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UNIFIED FACILITIES CRITERIA (UFC)

DoD MINIMUM ANTITERRORISM STANDARDS FOR BUILDINGS

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UNIFIED FACILITIES CRITERIA (UFC)

DoD MINIMUM ANTITERRORISM STANDARDS FOR BUILDINGS

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

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	**Date**	**Location**
1	08/19/2020	Corrected metric conversions, references and terminology. Updated: multiple paragraphs to incorporate criteria change requests and to provide clarification. Updated Fig 3-1 and 3-2. Deleted paragraph A-8
2	07/30/2022	Updated Forward, deleted Summary Sheet, added paragraph 1-3, revised paragraphs: 3-3.6, 3-11.2, 3-19, 4-3.1, 4-3.2, 4-4, B-1. Updated definition of expeditionary structures.
3	05/24/2024	Corrected the progressive collapse criteria conflict between this UFC and UFC 4-023-03; updated threshold for temporary and relocatable buildings to be consistent with DoDI 4165.56; and incorporated all current CCRs from the field.

This UFC supersedes UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*, dated 9 February 2012.

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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 ***/2/* its territories, and possessions** /2/ 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 Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), **\2** Naval Facilities Engineering Systems Command (NAVFAC) ***/2/***, and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. **\2** Technical content of UFC is the responsibility of the cognizant DoD working group. Defense agencies should contact the preparing service for document interpretation and improvements.***/2/*** 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 web site http://www.wbdg.org/ffc/dod.

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

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

One of the findings in the 1996 Downing Commission report on the Khobar Towers bombing in Dhahran, Saudi Arabia was that there were no standards for force protection in fixed DoD facilities. In partial response to that finding, the initial version of this document was published as an interim standard in December 1999. It applied to Military Construction (MILCON) funded new construction and major renovations of DoD buildings beginning with the Fiscal Year 2002 program. It was transmitted by a memorandum dated 20 September 2002 from the Undersecretary of Defense for Acquisition, Technology and Logistics (USD (AT&L)) and was referenced as a requirement by DoD Instruction 2000.16.

1-2 PURPOSE AND SCOPE.

The purpose of this standard is to establish minimum engineering standards that incorporate antiterrorism (AT) based mitigating measures where no identified threat or level of protection has been determined in accordance with UFC 4-020-01. **\2**

1-3 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 4-010-01, Change 1, dated August 2020. **/2/**

1-4 INTENT.

The intent of these standards is to reduce collateral damage and the scope and severity of mass casualties in the event of a terrorist attack. These standards provide cost effective, implementable, and enforceable construction standards to protect personnel against terrorist attacks. While complete protection against all potential threats for every inhabited building is cost prohibitive, the intent of these standards can be achieved through prudent master planning, real estate acquisition, and design and construction practices.

1-5 IMPLEMENTATION.

Implement in accordance with the Implementation, Administration, and Enforcement paragraph in UFC 1-200-01. These standards apply to projects funded under host-nation agreements after the implementation date of these standards or as soon as negotiations with the foreign governments can be completed.

Due to major changes between these standards and previous editions, projects currently under design and beyond 35% completion may consider complying with these standards where possible.

1-6 APPLICABILITY.

These standards apply to all DoD Components, to all DoD inhabited buildings and high occupancy family housing, to all inhabited tenant buildings on DoD installations, and to all DoD expeditionary structures.

1-6.1 New Construction.

Implementation of these standards is mandatory for all new construction regardless of funding source.

1-6.2 Existing Buildings.

Implementation of these standards is mandatory to existing buildings when triggered as specified below, regardless of funding source.

1-6.2.1 Major Investments.

Implementation of these standards to bring entire inhabited buildings into compliance is mandatory for all DoD building renovations, modifications, repairs, revitalizations, and restorations where project costs exceed 50% of the replacement cost of the existing building in accordance with UFC 3-701-01 except as otherwise stated in these standards. The **\1** project costs used to compare against the 50% threshold are exclusive of the additional **/1/** costs identified to meet these standards.

Where **\1** project **/1/** costs do not exceed the 50% threshold, compliance with these standards is recommended, but not required.

1-6.2.2 Change of Occupancy Level.

Implementation of these standards is mandatory when any building or portion of a building is converted from low occupancy to inhabited occupancy. Examples would include a warehouse (low occupancy) being converted to administrative (inhabited) use.

1-6.2.3 Window, Skylight, Glazing, and Door Replacement Projects.

Because of the significance of glazing hazards in a blast environment, implementation of all provisions of Standard 10 is mandatory for existing inhabited buildings any time a window, skylight, or glazing is being replaced. This also applies to installation of supplemental windows behind existing windows (inside face) and to installation of windows in new openings.

Because of the significance of door hazards in a blast environment, implementation of all provisions of Standard 12 is mandatory for existing inhabited buildings any time doors are being replaced.

1-6.2.4 Heating, Ventilating, and Air Conditioning (HVAC) Systems and Associated Controls.

Whenever HVAC systems featuring outside air intakes or control systems associated with HVAC systems including outside air intakes are being replaced or modified, apply provisions of Standards **\1** 16 and 18. **/1/** Modifications include, but are not limited to modifications such as complete air handling unit replacement, outside air control damper replacement, major ductwork reconfiguration, control system replacement, and control system reprogramming. Modifications do not include replacement of or repair of components such as coils and fans and do not include control system software updates or reprogramming in support of additional equipment added to an existing control system.

1-6.3 Building Additions.

Inhabited additions to existing buildings must comply with the minimum standards for new buildings. If the addition is 50% or more of the gross area of the existing building, the existing building will comply with the minimum standards for existing buildings in Chapter 3. Cost of building additions will not be included in calculating the 50% trigger for major investments.

Throughout these standards references to new construction will be considered to be inclusive of additions to existing buildings.

1-6.4 Leased Buildings.

\1 In accordance with DoD Instruction 2000.12, all leased facility space or space in buildings owned or operated by the U.S. General Services Administration (GSA) not located on DoD property must comply with the security standards established by the Interagency Security Committee (ISC) in The Risk Management Process for Federal Facilities: An Interagency Security Committee Standard. The ISC standard must additionally be applied to leased space not on DoD property in foreign countries. Facility space leased prior to 7 December 2012 must comply with the ISC standards to the extent practicable in accordance with existing lease agreements. **/1/**

1-6.5 Privatized Buildings.

Privatized inhabited buildings and high occupancy family housing that meet the applicability provisions above, will comply with these standards.

1-6.6 DoD Purchases of Existing Buildings.

Existing inhabited buildings purchased for use by DoD will comply with the minimum standards for existing buildings. Those buildings will meet the requirements before they can be occupied by DoD personnel.

1-6.7 Non-DoD Tenant Buildings on DoD Installations.

Tenant buildings on DoD installations other than those that meet one of the exemptions below are required to comply with these standards because it is assumed that the tenant buildings are likely to be turned over to DoD sometime during their design life and that they will then be occupied by DoD personnel. For the purposes of these standards, occupancy levels for non-DoD tenant-built building will be calculated assuming that building occupants are DoD personnel.

1-6.8 National Guard Buildings.

National Guard buildings that use Federal funding for new construction, renovations, modifications, repairs, or restorations that meet the applicability provisions above, will comply with these standards.

1-6.9 Expeditionary Structures.

Implementation of these minimum standards is mandatory for all expeditionary structures that meet the occupancy criteria for inhabited buildings. See Chapter 4 for structure types that meet the expeditionary structures criteria. Many expeditionary structures are in forward operating locations where there is a conventional and/or terrorist threat more severe than those addressed in these standards. In those situations, more detailed planning and additional measures are needed for providing protection. Refer to the GTA 90-01-011 **\1\/1/**.

1-6.9.1 New Structures.

These standards apply to all new expeditionary structures effective as of the implementation date of these standards.

1-6.9.2 Existing Structures.

These standards will apply to all existing expeditionary structures as they undergo major modifications or renovations as of the implementation date of these standards.

\3

1-6.10 Transitional, Temporary, and Relocatable Structures and Spaces in a Non-Expeditionary Environment.

Buildings, structures, and spaces that are required to maintain operations for limited durations during construction, for other temporary mission requirements, or for administering construction contracts, are required to comply with standards 1 through 5 only of this UFC. They are exempt from the remaining standards 7 through 21. Transitional, temporary, and relocatable structure provisions of this section are limited to those facilities intended for limited use not to exceed seven years. Those facilities initially planned for longer than seven years must comply with all of the provision of this UFC.

Lightweight buildings or trailers are frequently provided for these structures. These types of structures are commonly not commercially available with construction such as laminated glass windows that will meet these standards. Enforcing the standards on these structures would be of questionable economic feasibility for the short duration for which they are anticipated to be used.

1-6.10.1 Transitional Building Structures and Spaces.

Buildings and structures, including buildings and structures leased to provide transitional spaces during the life of the construction or renovation contract for which the transitional buildings and structures are being provided, must comply with standards 1 through 5 of this UFC.

1-6.10.2 Temporary and Relocatable Buildings.

Temporary and relocatable buildings in non-expeditionary environments, regardless of the procurement or funding source, must comply with standards 1 through 5 of this UFC.

1-6.10.3 Converting Transitional, Temporary, and Relocatable Structures to Real Property.

As prescribed by DODI 4165.56, *Relocatable Facilities*, existing temporary or relocatable buildings must be upgraded to comply with antiterrorism (AT) standards for existing buildings before they may be converted to permanent real property. Conversion to real property requires evaluation in accordance with UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual*, to validate design basis threats and level of protection requirements. ***/3/***

1-7 EXCEPTIONS.

The following buildings are exempt from all provisions of these standards. Compliance with these standards for those buildings is recommended where possible. In addition, there are some exemptions to individual standards that are included in the text of those standards in CHAPTER 3.

1-7.1 Low Occupancy Buildings.

Buildings whose occupancies do not meet the occupancy levels of inhabited buildings.

1-7.2 Low Occupancy Family Housing.

Family housing with 12 units or fewer per building.

The exemption of family housing with 12 units or fewer in a single building acknowledges that the density of such units is generally low, reducing the likelihood of mass casualties. It also acknowledges the fact that low-density housing has rarely been directly targeted by terrorists.

1-7.3 Fisher Houses.

Fisher houses with 24 units or fewer

1-7.4 Town Centers.

Town Center buildings that include retail, health, or community services space on the first floor and not more than 12 units of family housing above that space

This exception does not apply where the buildings contain any occupancy other than retail, health, community services, and family housing or where the retail space is more than half of the total area of the family housing.

1-7.5 Enhanced Use Leases.

Facilities associated with enhanced use leases on DoD installations, unless a facility warrants additional force protection due to its specific purpose and/or location per title 10 U.S.C. section 2667(b)(8). Application of these standards must be justified on a case-by-case basis.

1-7.6 Military Protective Construction.

Facilities designed to the North Atlantic Treaty Organization (NATO) (or equivalent) standards for collaterally protected, semi-hardened, protected, and hardened facilities are exempt from all provisions of these standards. (Refer to Supreme Headquarters Allied Power Europe (SHAPE) document 6160/SHLOFA-059-82.)

These facilities are exempted because the military conventional and nuclear weapons threats to which they are designed are much more stringent than those included in these standards due to their purpose of protecting critical military functions. Facilities designed to protective construction standards will provide higher levels of protection for facility occupants than those required by these standards.

1-7.7 Parking Structures.

Parking structures are exempt from these standards except where there are areas built into the structures that meet the definition of inhabited buildings. People accessing their vehicles do not need to be included in any calculation of population or population density.

1-8 OCCUPANCY CALCULATION.

The starting point for applying the Standards is based on buildings or portions of buildings being routinely occupied by 11 or more DoD personnel and with a population density of greater than one person per 430 gross square feet (40 gross square meters). The determination of occupancy is usually straightforward but in some cases there are questions on how to calculate occupancies. The following are examples of how to determine occupancy.

1-8.1 Gas Stations and Car Care Centers.

Where DoD or non-DoD visitors to Gas Stations and Car Care Centers routinely increase the occupancy of those buildings to levels meeting the definition of inhabited buildings, those buildings will comply with these standards.

1-8.2 Visitor Centers and Museums.

Where DoD or non-DoD visitors to visitor centers, museums, and similar buildings on DoD property routinely increase the occupancy of those buildings to levels meeting the definition of inhabited buildings, those buildings will comply with these standards.

1-8.3 Visitor Control Centers at Entry Control Facilities / Access Control Points.

Where DoD personnel and the average daily peak occupancy of visitors routinely increase the occupancy of those buildings to levels meeting the definition of inhabited buildings, those buildings will comply with these standards. See UFC 4-022-01 for average daily occupancy calculation.

1-9 REGULATORY AUTHORITIES.

The following regulatory authorities may establish antiterrorism related requirements in addition to the Standards in this UFC.

1-9.1 DoD and Heads of DoD Components.

DoD and heads of DoD Components may establish additional guidance or standards for facilities under their authority or to account for any component related special circumstances.

1-9.2 Geographic Combatant Commanders.

Geographic Combatant Commanders (GCC) may establish additional guidance or standards within their areas of operations. Such guidance is typically included in Antiterrorism Operations Orders (OPORD).

1-9.3 Installation Specific Requirements.

As required by DoD Instruction O-2000.16 and service directives, each installation must have an Antiterrorism Plan. The plan provides procedures and recommendations for reducing risk and vulnerability of DoD personnel, their family members, facilities, and assets from acts of terrorism. Installation Antiterrorism Plans may define a Design Basis Threat for the installation; however, UFC 4-020-01 must be used to establish the Design Basis Threat and level of protection for individual projects.

1-10 EXPLOSIVE SAFETY STANDARDS.

These antiterrorism standards establish criteria to minimize mass casualties and progressive collapse of buildings from terrorist attacks. DoD 6055.09-M, DoD Ammunition and Explosives Safety Standards as implemented by Service component explosive safety standards, establish acceptable levels of protection for accidental explosions of DoD-titled munitions. The explosive safety and antiterrorism standards address hazards associated with unique events; therefore, they specify different levels of protection. Compliance with both standards is required where applicable. Where conflicts arise, the more stringent criteria will govern.

1-11 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code* **\1\/1/**. 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.

It is assumed that the provisions of these standards will be coordinated with all other applicable DoD building and design criteria and policies. Nothing in these standards should be interpreted to supersede the provisions of any other applicable building or design criteria. Where other criteria mandate more stringent requirements, the most stringent is applicable.

1-12 PROJECT PLANNING AND DESIGN CRITERIA.

The standards contained within this document do not establish the Design Basis Threat or Level of Protection for DoD buildings. Use UFC 4-020-01 to establish the Design Basis Threat and Level of Protection for individual projects.

1-13 HISTORIC PRESERVATION COMPLIANCE.

1-13.1 Security and Stewardship.

The Department of Defense remains the lead federal agency in balancing security threats with the protection of historic properties. The Department of Defense abides by federal legislation on protecting cultural resources and issues its own complementary policies for stewardship.

1-13.2 Compliance with Laws.

Implementation of these standards will not supersede DoD’s obligation to comply with federal laws regarding cultural resources to include the National Historic Preservation Act (NHPA) and the Archaeological Resources Protection Act (ARPA). Installation personnel must determine possible adverse effects to historic structures and/or archaeological resources during project development and consult accordingly.

Personnel at installations outside the United States should coordinate with the applicable host nation regarding possible adverse effects to cultural resources.

1-13.3 Compliance with DoD Standards.

Conversely, historic preservation compliance does not negate the requirement to implement other Department of Defense policy. Federal agencies are always the decision-maker in the Section 106 process of the National Historic Preservation Act. An agency should seek to avoid prolonged consultations that conflict with the imminent need to implement security requirements. Preservation considerations and antiterrorism standards are not mutually exclusive, and any compliance conflicts should be quickly and effectively resolved in consultation with appropriate stakeholders.

1-14 GLOSSARY.

APPENDIX D contains acronyms, abbreviations, and definitions of terms.

1-15 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.

1-16 PLANNING AND INTEGRATION.

When the best procedures, proper training, and appropriate equipment fail to deter terrorist attacks, adherence to these standards goes toward mitigating the possibility of mass casualties from terrorist attacks against DoD personnel in the buildings in which they work and live. Although predicting the specific threat is not possible, proper planning and integration of those plans provide a solid foundation for preventing, and if necessary, reacting, when terrorist incidents or other emergencies unfold.

1-16.1 Threat-Specific Requirements.

Determining the Design Basis Threat is an installation function requiring programmers, antiterrorism officers, and members of the threat working group. Determining the facility specific Design Basis Threat is the first step in planning antiterrorism requirements. However, without a defined level of protection, only the minimum standards apply. The Design Basis Threat and level of protection are unique for each individual facility and are based on the threat likelihoods and the values of the assets in the building. Use UFC 4-020-01 to determine the Design Basis Threat and level of protection for individual projects. The process outlined in UFC 4-020-01 will determine if the minimum AT standards are adequate or if additional protective measures are required.

1-16.2 Effective Planning.

An effective planning process facilitates the necessary decision making, clarifies roles and responsibilities, and ensures support actions generally go as planned. A team consisting of the chain of command and key personnel from all appropriate functional areas who have an interest in the building and its operation executes this planning process. The team should include, as a minimum, antiterrorism/force protection, intelligence, security, and facility engineering personnel. This team is responsible for identifying requirements for the project, facilitating the development of supporting operational procedures, obtaining adequate resources, and properly supporting all other efforts needed to prudently enhance protection of the occupants of every inhabited DoD building. For further information on planning and integration, refer to UFC 4-020-01.

1-16.3 Critical Facilities.

\1 Buildings that must remain operational to maintain mission capability may warrant a level of protection higher than provided by these standards. When required, ensure the security design criteria is developed using UFC 4-020-01. **/1/**

1-17 MASTER PLANS.

Installation master plans must include roadmaps **\1** to accommodate present and future antiterrorism needs **/1/** for new and existing facilities. Master plans should consider threats and levels of protection for facilities. For site planning this may include standoff from parking, base perimeters, and entry control facilities / access control points, but it can also include utilities, vantage points, and the location of high value assets.

1-18 SECURITY ENGINEERING UFC SERIES.

This UFC is one of a series of security engineering unified facilities criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include the following:

1-18.1 DoD Minimum Antiterrorism Standards for Buildings.

This UFC establishes standards that provide minimum protection against terrorist attacks for the occupants of all DoD inhabited buildings. This UFC is intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings and inhabited tenant buildings on DoD installations. They also include recommendations that should be, but are not required to be incorporated into all such buildings.

1-18.2 Security Engineering Facilities Planning Manual.

UFC 4-020-01 presents processes for developing the design criteria necessary to incorporate security and antiterrorism into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards, or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also addresses the tradeoffs between cost and risk. The Security Engineering Facilities Planning Manual is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

1-18.3 Security Engineering Facilities Design Manual.

UFC 4-020-02FA provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02FA is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design. The primary audience for the Security Engineering Design Manual is the design team, but it can also be used by security and antiterrorism personnel.

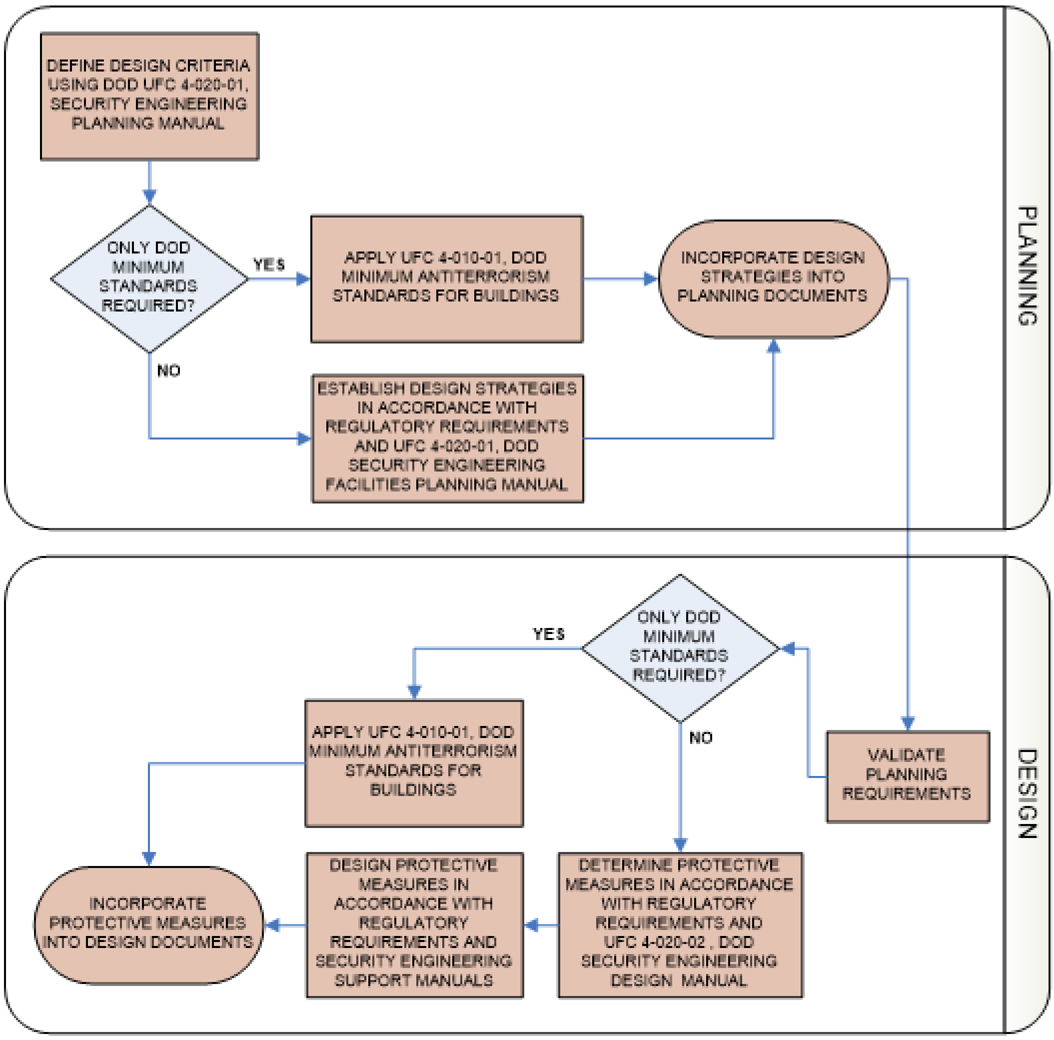
1-18.4 Security Engineering Support Manuals.

In addition to the standards, planning, and design UFCs mentioned above, there is a series of additional UFCs that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, forced entry, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mail rooms. Still others address details of designs for specific protective measures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

1-18.5 Security Engineering UFC Application.

The application of the security engineering series of UFCs is illustrated in Figure 1-1. UFC 4-020-01 is intended to be the starting point for any project that is likely to have security or antiterrorism requirements. By beginning with UFC 4-020-01, the design criteria will be developed that establishes which of the other UFCs in the series will need to be applied. The design criteria may indicate that only the minimum standards need to be incorporated, or it may include additional requirements, resulting in the need for application of additional UFCs. Applying this series of UFCs in the manner illustrated in Figure 1-1 will result in the most efficient use of resources for protecting assets against security and antiterrorism related threats.

Figure 1-1 Security Engineering UFC Applicability



1-19 STANDARDS AND RECOMMENDATIONS.

Mandatory DoD minimum antiterrorism standards for new and existing inhabited buildings are contained in Chapter 3. Mandatory DoD minimum antiterrorism standards for expeditionary structures are contained in Chapter 4. Where specific Design Basis Threat and level of protection are identified, additional guidance is included in APPENDIX B.

Additional recommended measures for new and existing inhabited buildings are included in APPENDIX A. The standards and recommendations in this document include a combination of performance and prescriptive requirements. In many cases where there are minimum prescriptive requirements, those requirements are based on performance standards and there are generally provisions to allow those performances to be provided through alternate means where those means will provide the required levels of protection.

CHAPTER 2 PHILOSOPHY, DESIGN STRATEGIES, AND ASSUMPTIONS

2-1 GENERAL.

The purpose of this chapter is to clarify the philosophies on which these standards are based, the design strategies that are their foundation, and the assumptions inherent in their provisions. The further purpose of this chapter is to provide background and rationale for the requirements in Chapter 1 and Chapter 3; therefore, nothing in this chapter should be construed to establish a requirement. Effective implementation of these standards depends on a reasonable understanding of the rationale for them. With this understanding, engineers and security and antiterrorism personnel can maximize the efficiency of their solutions for complying with these standards while considering site-specific threat and mission related issues and constraints that might dictate measures beyond these minimums.

2-2 PHILOSOPHY.

The overarching philosophy upon which this document is based is that comprehensive protection for every inhabited facility against the range of possible threats is cost prohibitive, but that appropriate protective measures can be provided for all DoD personnel at a reasonable cost. Those protective measures are engineering solutions intended to lessen the risk of mass casualties and collateral damage resulting from terrorist attacks. Implementation of these standards will provide some protection against a wide range of threats and will reduce injuries and fatalities. The costs associated with these standards are assumed to be less than the physical and intangible costs associated with incurring mass casualties.

Furthermore, all DoD decision makers must commit to making smarter investments with the scarce resources available and stop investing money in inadequate buildings that DoD personnel will have to occupy for decades, regardless of the threat environment. There are two key elements of this philosophy that influence the implementation of these standards.

2-2.1 Time.

Protective measures must be in place prior to the initiation of a terrorist attack. Incorporating those measures into DoD buildings and inhabited tenant buildings on DoD installations is least expensive at the time those buildings are being constructed, are undergoing major renovation, repair, restoration, or modernization, or when existing buildings are being purchased. Because of that investment strategy, it is recognized that it may take significant time before all DoD buildings and inhabited tenant buildings on DoD installations comply with these standards.

2-2.2 Design Practices.

The philosophy of these standards is to build a baseline level of resistance to terrorist attack into all DoD inhabited buildings. That philosophy affects the general practice of designing inhabited buildings. While these standards are not based on an identified threat or level of protection, they are engineering solutions intended to provide the easiest and most economical methods to minimize injuries and fatalities in the event of a terrorist attack. The primary methods to achieve this outcome are to construct superstructures to avoid progressive collapse, minimize hazardous flying debris, provide effective building layout, limit airborne contamination, and provide building mass notification. These and related design issues are intended to be incorporated into standard design practice.

2-3 DESIGN STRATEGIES.

There are several major design strategies that are applied throughout these standards. They do not account for all of the measures considered in these standards, but they are the most effective and economical in protecting DoD personnel from terrorist attacks. These strategies are summarized below.

2-3.1 Prevent Building Collapse.

Provisions for preventing building collapse are essential to minimizing mass casualties of building occupants. Those provisions apply regardless of standoff distance or the ability of buildings to resist blast effects since structural systems that provide greater continuity and redundancy among structural components will help limit collapse for any extreme loading events.

2-3.2 Minimize Hazardous Flying Debris.

In past explosive events where there was no building collapse, a high number of injuries resulted from flying glass fragments and debris from walls, ceilings, and fixtures (non-structural features). Flying debris can be minimized through building design and avoidance of certain building materials and construction techniques. The glass used in most windows breaks at very low blast pressures, resulting in hazardous, dagger-like fragments. Minimizing those hazards through reduction in window numbers and sizes and through enhanced glazing construction has a major effect on limiting mass casualties. Hazardous fragments may also include secondary debris from such sources as barriers and site furnishings.

2-3.3 Provide Effective Building Layout.

Effective design of building layout and orientation can significantly reduce opportunities for terrorists to target building occupants or injure large numbers of people.

2-3.4 Limit Airborne Contamination.

Effective design of heating, ventilation, and air conditioning (HVAC) systems can significantly reduce the potential for chemical, biological, and radiological agents being distributed throughout buildings.

2-3.5 Provide Building Mass Notification.

Providing a timely means to notify building occupants of threats and what should be done in response to those threats reduces the risk of mass casualties. Effective designs will include means for both local and remote origination of information.

2-4 ASSUMPTIONS.

This section includes assumptions that form the foundation of these standards and assumptions and philosophies behind some of the provisions of these standards.

2-4.1 Baseline Antiterrorism Protective Measures.

The location, severity, and nature of terrorist threats are unpredictable. It would be cost prohibitive to provide protection against the worst-case scenario in every building. These standards provide a reasonable baseline of antiterrorism protective measures for inhabited DoD buildings and inhabited tenant buildings on DoD installations. Designing to these standards will provide general collateral protection and will establish a foundation upon which to build additional measures **\1\/1/** in the future.

The terrorist threats addressed in these standards are further assumed to be directed against DoD personnel. Threats to other assets and critical infrastructure and specific threats to facilities are beyond the scope of these standards, but they are addressed in UFC 4-020-01. The following are the terrorist tactics upon which these standards are based:

2-4.1.1 External Explosive Threats.

These minimum standards are not based on a specific Design Basis Threat identified against the facility being designed. These minimum standards provide collateral damage protection for explosive threats directed against other nearby facilities.

2-4.1.2 Mail Bombs.

Explosives in packages delivered through the mail can cause significant localized damage, injuries, and fatalities if they detonate inside a building. No assumption as to the size of such explosives is made in these standards. Provisions for mail bombs are limited to specifying locations of mail rooms so that they can be more efficiently hardened if a specific threat of a mail bomb is identified in the future.

2-4.1.3 Chemical, Biological, and Radiological Weapons.

For the purposes of these standards, these weapons are assumed to be improvised weapons containing airborne agents employed by terrorists. These standards do not assume comprehensive protection against this threat. They provide means to reduce the potential for widespread dissemination of such agents throughout buildings in the event of an attack either outside buildings or in mail rooms.

2-4.2 Policies and Procedures.

It is assumed that policies and procedures will be developed to support these standards and other related issues and that those policies and procedures will be incorporated into antiterrorism plans, training, and exercises. It is assumed for the purposes of these standards that policies and procedures will be developed by physical security personnel at individual installations or buildings based on their local capabilities and situations.

2-4.3 Training.

It is assumed that key security and facility personnel will receive training in security engineering, antiterrorism, physical security, and related areas. It is further assumed that all DoD personnel have been trained in basic antiterrorism awareness in accordance with DoD Instruction O-2000.16, that they are able to recognize potential threats, and that they know the proper courses of action should they detect a potential threat.

CHAPTER 3 STANDARDS

3-1 INTRODUCTION.

The purpose of this chapter is to establish standards to provide appropriate protective measures for the protection of DoD personnel at a reasonable cost. These standards represent engineering solutions intended to lessen the risk of mass casualties and collateral damage resulting from terrorist attacks. Implementation of these standards will provide some protection against a wide range of threats and should reduce injuries and fatalities.

The standards in this chapter provide the minimum protective measures for DoD inhabited buildings. Engineers, security and antiterrorism personnel must consider site-specific threats, mission related issues and constraints that might dictate measures beyond these minimums. Use UFC 4-020-01 to establish project requirements and determine if these minimum standards are adequate or if additional mitigation measures are required. The engineering risk analysis conducted as part of UFC 4-020-01 should be consistent with the terrorism risk analysis conducted by the installation security/AT staff.

3-2 STANDARD 1. STANDOFF DISTANCE.

The previous version of Standard 1 established standoff distances to parking, roadways, and controlled perimeters that were based on building construction and occupancy. In this revision of Standard 1, standoff distances only apply to distances to installation perimeters for new construction and additions to existing buildings that are required to comply with these standards.

Exception: Existing buildings within an installation perimeter are exempt from this standard.

3-2.1 Minimum Standoff.

The minimum standoff distance for new construction and additions to existing buildings to the installation perimeter is 20 ft. (6 m) **\1** when there is 30 ft. (9m) of clear zone or greater outside the perimeter. Provide a minimum aggregate standoff of 50 feet (15 m) inclusive of the clear zones outside and inside the installation perimeter. For example, if an installation has an established inner clear zone of 20 ft. (6 m) but the outer clear zone is 20 ft. (6 m) wide, the standoff distance to the installation perimeter must be 30 ft. (9 m) wide. Where there is no clear zone outside the perimeter, the minimum standoff distance is 50 ft. (15 m).

For buildings that are outside an installation perimeter, use UFC 4-020-01 to establish project requirements. Where UFC 4-020-01 determines project specific Design Basis Threat and Level of Protection, design the project for the resulting standoff distance in accordance with APPENDIX B. **/1/**

3-2.1.1 Clear Zone.

\1 This standard does not establish the requirement for clear zones. Clear zones are defined by DoD and Service policy. Clear zones are established around the perimeters to provide unobstructed views to enhance detection and assessment. Typically, clear zones are free of all obstacles, topographical features, and vegetation exceeding 8 in. (200 mm) in height that could impede observation or provide cover and concealment of an aggressor. Some installations and high security areas may have higher clear zone requirements into which buildings or structures cannot encroach. Consult with local antiterrorism and security personnel to determine clear zone requirements. See Figure 3-1 and Figure 3-2. **/1/** **\1**

Figure 3-1 Installation Perimeter with Outer Clear Zone

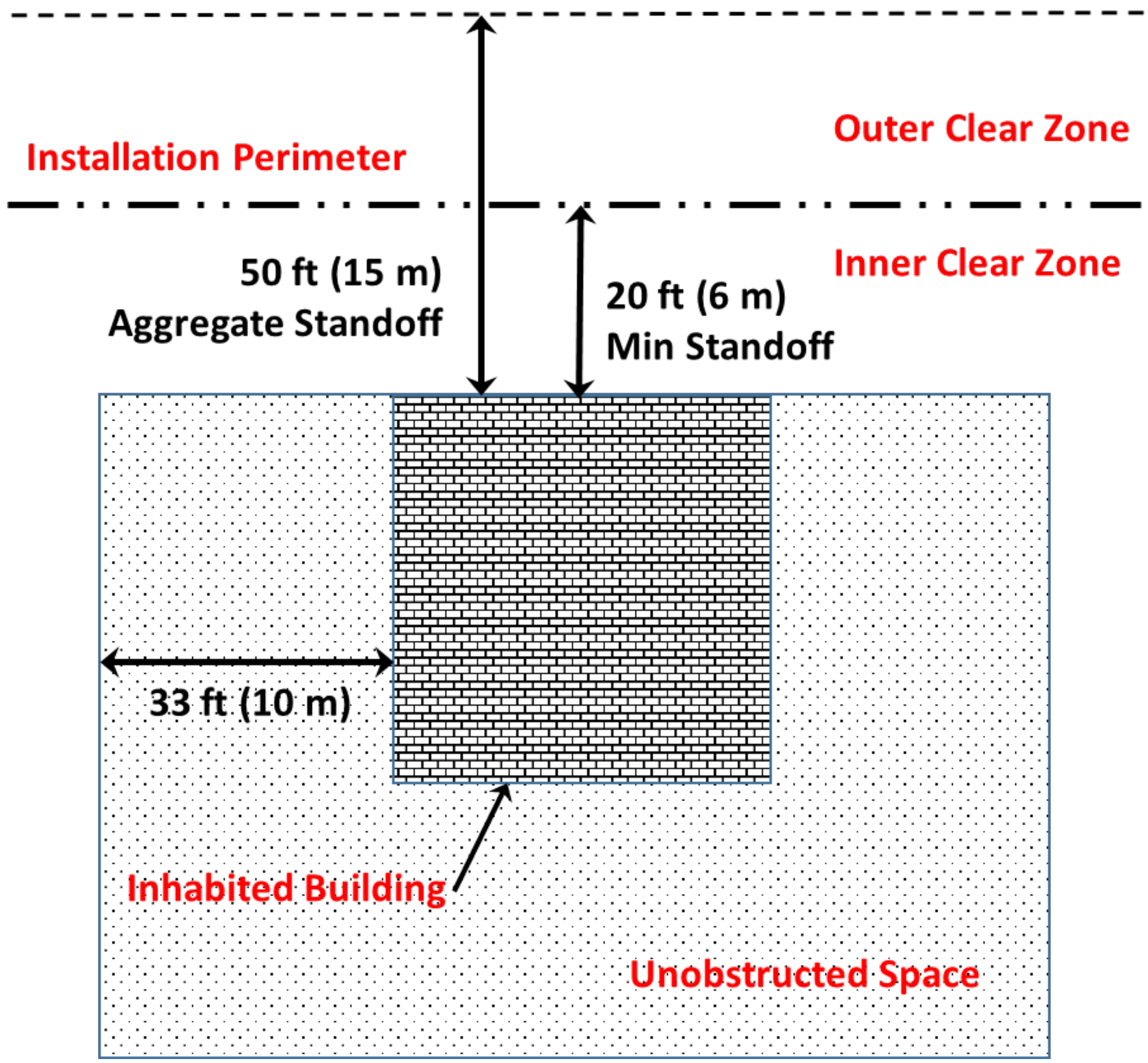
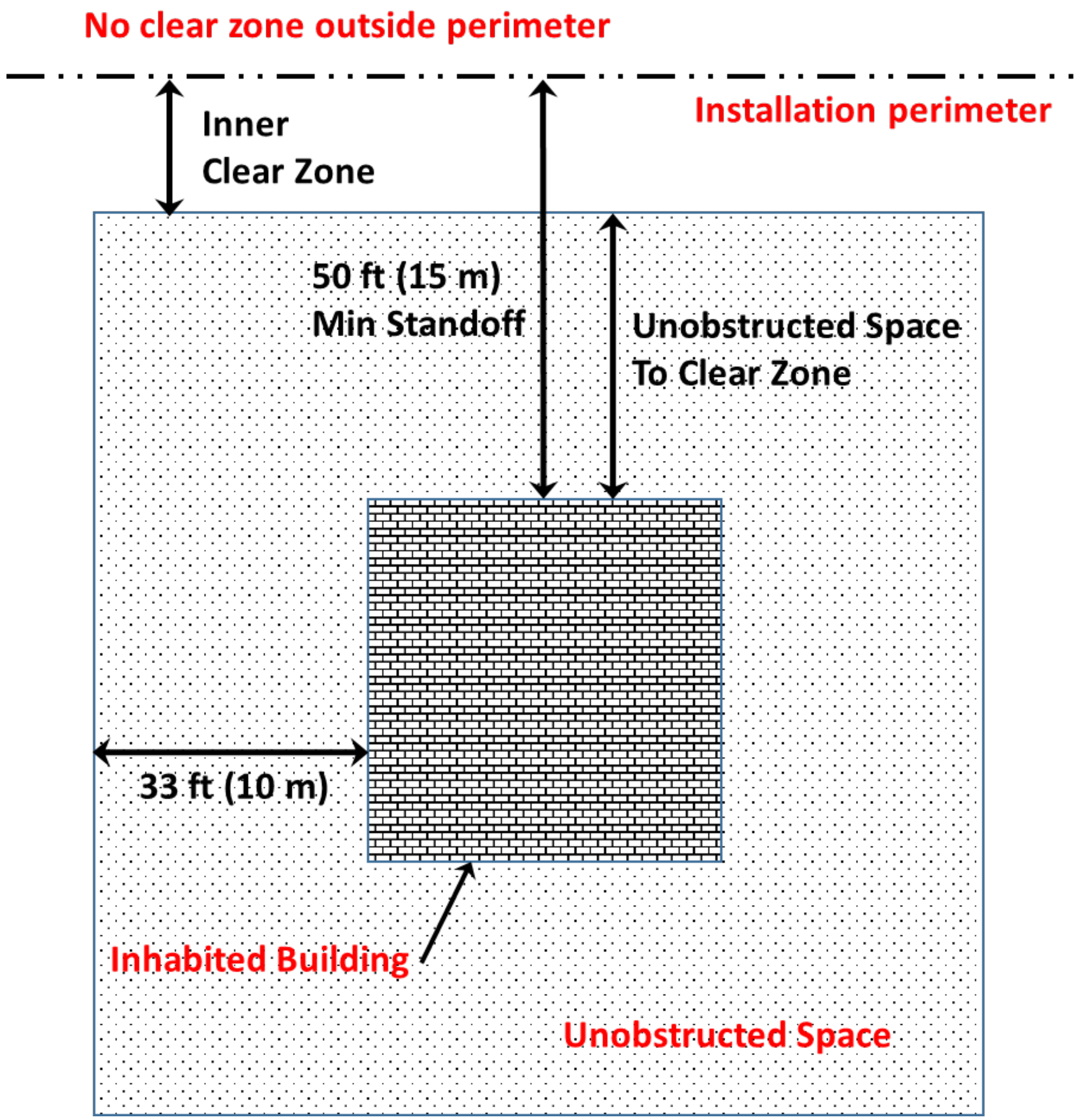


Figure 3-2 Installation Perimeter without Outer Clear Zone



/1/

3-3 STANDARD 2. UNOBSTRUCTED SPACE.

Where buildings are required to meet these standards, the unobstructed space must extend out from the building **\1** to the edge of the inner clear zone, or 33 ft. (10 m), whichever is less **/1/**.

It is assumed that aggressors will not attempt to place explosive devices in areas near buildings where those explosive devices could be visually detected by building occupants. Ensure there are unobstructed spaces in which there are no obstructions or building features that might allow for concealment from observation of explosive devices with dimensions of no less than a 6 in. (150 mm) cube around buildings and underneath building overhangs or breezeways. This does not preclude the placement of site furnishings or plantings around buildings. It only requires conditions such that any explosive devices placed in the unobstructed spaces would be observable by building occupants or passers by either from within the buildings or as they walk into or around it. For trees or shrubs ensure that no foliage extends lower than 3 ft. (1 m) above the grounds to improve observation of objects underneath them.

Exceptions:

- Stand-alone franchised fast food operations, commercial, bank, and pharmacy facilities.
- Stand Alone Shoppettes, Mini Marts, and Commissaries with areas of less than 15,000 square feet (1394 square meters).

3-3.1 Concealment.

The requirements for the unobstructed space are based on eliminating opportunities to conceal objects indicated above. The key to determining what may be located in unobstructed spaces is whether or not a person could see the objects. Obstructions such as mechanical equipment, electrical equipment, trash containers, or landscaping features may be permissible if the devices could be seen from at least one direction. Concealment establishes the basis for the requirement for above ground objects or obstructions. When applicable, evaluate indentations in landscapes such as ditches with respect to concealment.

Evaluate the capacity to conceal objects underneath and inside equipment. If there are voids into which explosives could be inserted or space underneath equipment large enough to conceal objects, that equipment will need to be secured if it is within the unobstructed space. The test should be whether or not something could be concealed behind the equipment or trash container. If walls or other screening devices are two sided it is assumed that people could see something out of place by observation from at least one direction.

3-3.2 Trash Containers.

Trash containers are not allowed within the unobstructed space unless the containers are secured to preclude concealment of explosives as described above or if they are enclosed in accordance with 3-3.6.

3-3.3 Electrical and Mechanical Equipment.

Electrical and mechanical equipment may be located within unobstructed spaces if they do not provide opportunities for concealment of explosives as described above or if they are enclosed in accordance with 3-3.6.

3-3.4 Fuel Tanks.

Fuel tanks may be located within unobstructed spaces if they do not provide opportunities for concealment of explosives as described above or if they are enclosed in accordance with 3-3.6. Distances between buildings and fuel tanks are based on flammability (not explosive equivalence); therefore, they should be determined using NFPA 30.

3-3.5 Walls and Screens.

If walls or other screening devices with more than two sides are placed around trash containers, fuel tanks or electrical or mechanical equipment within the unobstructed space, provide enclosure in accordance with 3-3.6.

3-3.6 Enclosures.

When trash containers, fuel tanks or electrical or mechanical equipment within the unobstructed space provide the opportunity for concealment, they must be enclosed. Enclosures must have four sides and a top. Openings in screening materials and gaps between the ground and screens or walls making up an enclosure **\2** must be less than 6 in (150 mm). ***/2/*** Secure any surfaces of the enclosures that can be opened so that unauthorized personnel cannot gain access. Where opaque top enclosures are provided, they will have a pitch of at least 1 vertical to 2 horizontal to increase visibility of objects thrown onto them and to increase the likelihood that the objects will slide off. Alternatively, if the vertical surfaces of the enclosures are transparent and at least 7 ft. (2.1 m) high, a top enclosure is not required.

3-3.7 Parking Within Unobstructed Spaces.

Parking is allowed within the unobstructed space. Parking may be temporarily eliminated within the unobstructed space at a higher Force Protection Condition (FPCON).

3-3.8 Adjacent Existing Buildings.

Where projects for new and existing buildings designed in accordance with these standards are located within 33 ft. (10 m) of existing inhabited buildings that are not required to meet these standards, ensure that the unobstructed spaces for buildings that must comply with the standards are maintained between those buildings and other existing buildings. If there are opportunities for concealment in the spaces around the other existing buildings those spaces should be modified to ensure fully compliant unobstructed spaces around the buildings that must comply.

3-4 STANDARD 3. DRIVE-UP/DROP-OFF AREAS.

This standard has been removed and no longer applies.

3-5 STANDARD 4. ACCESS ROADS.

This standard has been removed and no longer applies.

3-6 STANDARD 5. PARKING BENEATH BUILDINGS OR ON ROOFTOPS.

Avoid parking beneath buildings or on rooftops of buildings required to comply with these standards. Where very limited real estate makes such parking unavoidable, the following measures must be incorporated **\1\/1/**.

Ensure that access control measures are implemented to prohibit unauthorized **\1\/1/** vehicles from entering underground or rooftop parking areas. Because situations vary from location to location, the development of one standardized “one-size-fits-all” access control package (measures, procedures, and equipment) is not possible and is beyond the scope of these standards. Access control is the responsibility of installation security personnel.

3-7 STANDARD 6. PROGRESSIVE COLLAPSE RESISTANCE.

\3 This standard has been removed from this UFC. The requirement for progressive collapse is incorporated into UFC 4-023-03, *Design of Buildings to Resist Progressive Collapse*. **/3/**

3-8 STANDARD 7. STRUCTURAL ISOLATION.

Structural isolation minimizes the possibility that collapse of one part of a building will affect the stability of the remainder of the building.

3-8.1 Building Additions.

Design building additions that are required to comply with these standards to be structurally independent from the adjacent existing buildings. Alternatively, verify through analysis that collapse of either the addition or the existing building will not result in collapse of the remainder of the building. **\3** Structural isolation is not necessary if the existing building was designed in accordance with UFC 4-023-03. **/3/**

3-8.2 Portions of Buildings.

Design low occupancy portions of inhabited buildings required to comply with these standards to ensure their superstructures are structurally independent from the inhabited portions of the buildings. Alternatively, verify through analysis that collapse of low occupancy portions of buildings will not result in collapse of any portion of buildings covered by these standards. This standard is not mandatory for existing structures, but it should be implemented where possible.

3-9 STANDARD 8. BUILDING OVERHANGS AND BREEZEWAYS.

For new construction required to comply with these standards, avoid building overhangs and breezeways with inhabited spaces above them where people could gain access to the areas underneath the overhangs. Where such overhangs or breezeways must be used, incorporate the following measures

3-9.1 Building Elements.

Ensure the areas underneath the overhangs or breezeways comply with the provisions of the unobstructed space requirements of Standard 2. The areas underneath the overhangs or breezeways can be considered to be extensions of the surrounding unobstructed spaces.

3-10 STANDARD 9. EXTERIOR MASONRY WALLS.

Unreinforced masonry walls are prohibited for the exterior walls of new construction required to comply with these standards. Exterior masonry walls must have vertical and horizontal reinforcement distributed throughout the wall section. The vertical reinforcement ratio must be at least 0.05%, spaced no more than 4 ft. (1200 mm) on center with reinforcement within 1.3 ft. (410 mm) of the ends of walls. The horizontal reinforcement ratio must be at least 0.025%, consisting of either joint reinforcement spaced no more than 1.3 ft. (410 mm) on center, or bond beam reinforcement spaced no more than 4 ft. (1200 mm) on center, with reinforcement within 1.3 ft. (410 mm) of the top and bottom of the wall. For conventional **\1** concrete masonry **/1/** cavity wall construction reinforcement only needs to be in the inner wythe unless other reinforcement is required by other criteria.

\1 Exterior unreinforced clay, concrete or stone masonry veneers used in conjunction with wood or metal studs that meet the analysis assumptions of Table C-5 may be considered to meet the provisions of this standard **/1/**. European masonry walls that are within the range of parameters in Table C-5 and PDC Technical Report 10-01 may be considered to meet the requirements of this standard.

3-11 STANDARD 10. GLAZING.

Glazing that is in compliance with this standard is not required to be designed or constructed for blast resistance. It is only intended to minimize hazardous glazing fragments.

Apply the following prescriptive provisions for exterior glazing for new construction or existing buildings that are required to comply with these standards.

3-11.1 Glazing.

For glazing in exterior building elements such as storefronts, doors, windows, curtain walls, clerestories, and skylights provide no less than 1/4 in. (6 mm) nominal polycarbonate or laminated glass. The 1/4 in. (6 mm) laminated glass consists of two nominal 1/8 in. (3 mm) glass panes bonded together with a minimum of a 0.030 in. (0.75 mm) interlayer of a material **\1** that has typically been used in blast resistant window applications. For insulated glass units (IGU), use the polycarbonate or laminated glass for the innermost pane as a minimum.

For polycarbonate, provide a glazing frame bite of no less than 1.5 times the polycarbonate thickness. For laminated glass, the laminated pane shall be adhered to its supporting frame using structural silicone sealant or adhesive glazing tape. The structural silicone sealant bite shall be equal to the larger of 3/8-in. (10-mm) or the thickness of the laminated glass to which it adheres. The minimum thickness of the structural silicone bead shall be 3/16-in. (5-mm). The glazing tape bite shall be equal to two times the thickness of the laminated glass to which it adheres. The structural silicone bead or glazing tape shall be applied to both sides of single pane laminated glass but need only be applied to the inboard (protected) side of an IGU. **/1/**

Monolithic glass or monolithic acrylic used as a single pane or as the inner pane of a multi-pane system is not allowed for the purposes of complying with this standard. Spandrel glass when backed by a structural wall or spandrel beam, translucent fiberglass panels, other lightweight translucent plastics, and glass unit masonry are not required to comply with this standard. Spandrel glass that is open to occupied space must **\1** comply **/1/** with this standard.

3-11.2 Exterior Stairwells, Vestibules, and Covered or Enclosed Walkways.

Glazing in stairwells, vestibules, and covered or enclosed walkways that are exterior to buildings **\2\ /2/** must meet the provisions of this standard. In addition, any windows, inner doors, sidelights, and transoms that are interior to the exterior stairwells, vestibules, or covered or enclosed walkways must meet the requirements of this standard.

3-11.3 Replacement with Wall or Roof Systems.

When windows or skylights are being replaced by filling in the openings with wall or roof material fill in the openings with the same or similar construction as the adjacent wall or roof construction. Alternatively install lightweight translucent fiberglass or plastic panels in the openings.

3-11.4 Alternative Window Treatments.

Window retrofits incorporating alternative window treatments such as fragment retention films and blast curtains are not acceptable alternatives for new buildings or existing buildings that are required to comply with these standards.

The primary reason for that is the fact that such solutions commonly have much shorter design lives than laminated glazing, which requires their replacement multiple times as compared to laminated glazing. Laminated glazing, while more expensive initially, is less expensive over its life cycle. In the case of blast curtains, there needs to be operational procedures to ensure that they remain closed at all times for them to be effective. Fragment retention films and blast curtains are good interim solutions where compliance with these standards is not required.

3-12 STANDARD 11. BUILDING ENTRANCE LAYOUT.

The areas outside of installation perimeters are commonly not under the direct control of installations. Where the main entrances to buildings face installation perimeters, people entering and exiting the buildings are vulnerable to being fired upon from vantage points outside those perimeters. Obscuration or screening that minimizes targeting opportunities and mass notification are assumed to be the primary means of protecting DoD personnel from direct fire weapons. Hardening to resist direct fire effects represents a higher level of protection than required by these standards. To mitigate those vulnerabilities, apply the following measures for buildings required to comply with these standards:

3-12.1 New Construction.

For new construction, ensure that the main entrance to the building does not face uncontrolled vantage points with direct lines of sight or provide means to block the lines of sight using mitigation such as walls, privacy fencing, or vegetation.

3-12.2 Existing Buildings.

For existing buildings where the main entrance faces uncontrolled vantage points, either use a different entrance as the main entrance or screen that entrance to limit the ability of potential aggressors to target people entering and leaving the building using mitigation such as walls, privacy fencing, or vegetation.

3-13 STANDARD 12. EXTERIOR DOORS.

For all new and existing buildings covered by these standards, ensure that all exterior doors into inhabited areas open outwards. By doing so, the doors will seat into the door frames in response to an explosive blast, increasing the likelihood that the doors will not enter the buildings as hazardous debris. Alternatively, position doors such that they will not be propelled into inhabited spaces or provide other means to ensure they do not become hazards to building occupants.

3-13.1 Glazed Doors.

Glazing in and around doors must comply with Standard 10.

3-13.2 Sliding Glass doors and Revolving Doors.

Sliding glass doors and revolving doors do not have to open outwards.

3-13.3 Overhead Doors.

Because of the nature of overhead door failures due to blast loads there are no antiterrorism requirements for overhead doors.

3-14 STANDARD 13. MAIL ROOMS AND LOADING DOCKS.

The following measures address the location of rooms to which mail or supplies are delivered or in which mail or supplies are handled in new buildings required to comply with these standards. This standard is not required for existing buildings, but it is recommended to be applied when possible. These standards need not be applied to mail rooms or loading docks to which mail or supplies that were initially delivered to a central mail or supplies handling facility. These standards should be applied to such mail rooms or loading docks where possible to account for potential changes in mail or supplies handling procedures over the life of the building. The measures in this standard involve limiting collateral damage and injuries and facilitating future upgrades to enhance protection should it become necessary. This standard does not require the hardening of mail rooms or loading docks because the mail and supplies bomb threats are beyond the scope of these standards.

3-14.1 Location.

Where new construction is required to comply with these standards, locate the mail rooms or loading docks on the perimeter of the building. By locating the mail rooms or loading docks on the building perimeters there are opportunities to modify them in the future if a mail or supplies bomb threat is identified. Where mail rooms or loading docks are located in the interiors of buildings, few retrofit options are available for mitigating the mail and supplies bomb threats. Having mail rooms and loading docks on the building perimeter avoids situations where contaminated packages would be transported through the buildings.

3-14.1.1 Proximity.

Locate mail rooms and loading docks as far from heavily populated areas of buildings and from critical infrastructure as possible. This measure will minimize injuries and damage if a mail or supplies bombs detonate in mail rooms or loading docks. Further, it will reduce the potential for wider dissemination of hazardous debris. This applies where mail rooms or loading docks are not specifically designed to resist those threats.

3-15 STANDARD 14. ROOF ACCESS.

For buildings required to comply with these standards, control access to roofs to minimize the possibility of aggressors placing explosives or chemical, biological, or radiological agents there or otherwise threatening building occupants or critical infrastructure.

3-15.1 New Construction.

For new construction eliminate all external roof access by providing access from internal stairways or ladders, such as in mechanical rooms.

3-15.2 Existing Buildings.

For existing buildings, eliminate external access where possible or secure external ladders or stairways with locked cages or similar mechanisms.

3-16 STANDARD 15. OVERHEAD MOUNTED ARCHITECTURAL FEATURES.

For new construction and existing buildings required to comply with these standards, ensure that overhead mounted features weighing 31 pounds (14 kilograms) or more (excluding distributed systems such as suspended ceilings that collectively exceed that weight) are mounted using either rigid or flexible systems to minimize the likelihood that they will fall and injure building occupants. Mount all such systems so that they resist forces of 0.5 times the component weight in any horizontal direction and 1.5 times the component weight in the downward direction. This standard does not preclude the need to design architectural feature mountings for forces required by other criteria such as seismic standards.

3-17 STANDARD 16. AIR INTAKES.

Ground level air intakes to heating, ventilating, and air conditioning (HVAC) systems at that are designed to move air throughout a building provide an opportunity for aggressors to easily place contaminants where they could be drawn into buildings. The following measures will be applied to minimize those opportunities.

Exception: Air intakes within enclosures that meet the requirements of paragraph 3-3.6 and are a minimum of 10 ft. (3 m) horizontally from the enclosure perimeter.

3-17.1 New Construction.

For new construction required to comply with these standards locate all air intakes at least 10 ft. (3 m) above the ground.

3-17.2 Existing Buildings.

For existing buildings required to comply with these standards locate all air intakes at least 10 ft. (3 m) above the ground or provide means such as exterior chimneys to extend the elevations of air intakes to at least 10 ft. (3 m).

3-18 STANDARD 17. MAIL ROOM AND LOADING DOCK VENTILATION.

For new construction required to comply with these standards, provide separate, dedicated HVAC systems for mail rooms and loading docks whose purpose is to receive initial delivery of mail or supplies. This is to ensure airborne chemical, biological, and radiological agents introduced into mail rooms and loading docks do not migrate into other areas of buildings in which the mail rooms and loading docks are located,

3-18.1 Other Heating and Cooling Systems.

Building heating and cooling systems such as steam, hot water, chilled water, and refrigerant may serve mail rooms as long as the airflow systems for the mail rooms and loading docks and other areas of the buildings in which they are located remain separate.

3-18.2 Dedicated Exhaust Systems.

Provide dedicated exhaust systems within mail rooms and loading docks to maintain slight negative air pressures (minimum of 0.05 in. of water [12.5 Pa]) with respect to the remainder of the buildings in which the mail rooms and loading docks are located so that the flow of air is into and contained in the mail rooms and loading docks. Though the airflow into the mail rooms and loading docks will not eliminate the potential spread of contamination by personnel leaving the mail room or the loading dock, it will limit the migration of airborne contaminants through openings and open doorways.

3-18.3 Outside Intakes, Relief, and Exhausts.

Provide mail room and loading dock ventilation system outside air intakes, relief air, and exhausts with low leakage isolation dampers that can be automatically closed to isolate the mail rooms and loading docks. The low leakage dampers will have maximum leakage rates of 3 cfm/square foot (15 liters/second/square meter) with a differential pressure of one inch of water gage (250 Pa) across the damper.

3-18.4 Isolation Controls.

Provide separate switches or methods of control to isolate mail rooms **\1** and loading docks in the event of a suspected or actual chemical, biological, or radiological release in the mail room or loading dock **/1/**.

3-18.5 Walls and Sealing Joints and Doors.

Mail room and loading dock walls will extend from true floor to true ceiling and all joints will be sealed. Doors between mail rooms and loading docks and inhabited areas of buildings will have gaskets or weather stripping to minimize leakage around the doors.

3-19 STANDARD 18. EMERGENCY AIR DISTRIBUTION SHUTOFF.

\1 Provide an emergency shutoff switch in the HVAC control systems of new construction and existing buildings required to comply with these standards. The switch will initiate a response in HVAC systems and low leakage dampers leading to the outside regardless of hand/off/auto position within 30 seconds of switch activation subject to the guidance below.

- Switch activation may, but is not required to shut down HVAC systems that do not draw air from the outside **\2\ /2/**. **\3** One example is a stand-alone bathroom exhaust fan. **/3/**
- Switch activation will not shut down HVAC systems but will close dampers leading to the outside for systems whose continued operation assists in preventing the spread of airborne contaminants and that do not serve mail rooms. An example would be a collective protection system.

Provide a minimum of one shutoff switch per floor. Locate the shutoff switch (or switches) to be easily accessible by building occupants by locating them adjacent to such locations as fire alarm pull stations, interior stairwell entrance doors such that the travel distance to the nearest shutoff switch on the same floor will not exceed 200 ft. (61 m). **/1/**

Ensure that the shutoff switches are well labeled, and of a different color than fire alarm pull stations.

3-19.1 Outside Air Intakes, Relief Air, and Exhausts.

Provide outside air intakes, relief air, and exhaust openings with low leakage dampers that are automatically closed when the emergency air distribution shutoff switch is activated. The low leakage dampers will have maximum leakage rates of 3 cfm/square foot (15 liters/second/square meter) with a differential pressure of one inch of water gage (250 Pa) across the damper. Low leakage dampers will be located at the building envelope or as close as possible to the building envelope. If shutting down an exhaust system will violate building or fire codes or create an unsafe condition, then the exhaust system may continue to operate. For example, the installation of dampers in kitchen exhaust ductwork, where the dampers can become laden with grease, may be a violation of fire codes. In addition, kitchen hood exhaust fans may have to continue to operate to avoid potential fire hazards.

3-19.2 Critical Areas.

Switch activation will not shut down HVAC systems, but will close dampers leading to the outside for systems that serve critical areas where cooling, heating, and / or airflow requirements must be maintained to prevent mission failure, or loss of data, or unsafe conditions such as computer rooms.

Switch activation will not shut down HVAC systems and will not close dampers leading to the outside for critical systems whose continued operation is required by code or other safety protocols such as bio containment laboratories, radio isotope spaces, or other hazardous material or explosive hazard spaces.

3-19.3 Unoccupied Areas.

Switch activation may, but is not required to shutdown HVAC systems and may, but is not required to close dampers leading to the outside for systems that serve one or more normally unoccupied spaces whose access is directly to the outside such as electrical, mechanical, and fire pump rooms.

\3

3-19.4 Fan Coil Unit Heaters and Air Conditioners Through Exterior Surfaces.

For all new buildings required to comply with these standards, fan coil unit heaters and air conditioners that draw air through exterior surfaces must have a system that shuts them off in an emergency. Fan coil unit heaters and air conditioners do not require low leakage dampers. **/3/**

For existing inhabited buildings required to comply with these standards, emergency shutoffs for fan coil unit heaters and air conditioners are recommended.

\3

3-19.5 Laundry Dryers.

For all new buildings required to comply with these standards, automatic shutoff of power to all dryers upon activation of the building emergency shutoff switch is required. Dryer exhaust ducts do not require low leakage dampers.

For existing inhabited buildings required to comply with these standards, automatic shutoff of power to all dryers upon activation of the building emergency shutoff switch is recommended. **/3/**

3-20 STANDARD 19. EQUIPMENT BRACING.

For new construction and existing buildings required to comply with these standards mount all overhead utilities and other fixtures weighing 31 pounds (14 kilograms) or more (excluding distributed systems such as piping networks that collectively exceed that weight) using either rigid or flexible systems to minimize the likelihood that they will fall and injure building occupants. Design all equipment mountings to resist forces of 0.5 times the equipment weight in any horizontal direction and 1.5 times the equipment weight in the downward direction. This standard does not preclude the need to design equipment mountings for forces required by other criteria such as seismic standards.

3-21 STANDARD 20. UNDER BUILDING ACCESS.

To limit opportunities for aggressors placing explosives underneath buildings, ensure that access to crawl spaces, utility tunnels, and other means of under building access is controlled in all buildings required to comply with these standards.

3-22 STANDARD 21. MASS NOTIFICATION.

All buildings required to comply with these standards must have a timely means to notify occupants of threats and instruct them what to do in response to those threats.
\3 Buildings must provide real-time information to building occupants or personnel in

the immediate vicinity of the building during emergency situations. The information relayed must be specific enough to determine the appropriate response actions. Design building mass notification systems in accordance with UFC 4-021-01. **/3/**

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CHAPTER 4 STANDARDS FOR EXPEDITIONARY STRUCTURES

4-1 GENERAL.

Implementation of these minimum standards is mandatory for all expeditionary structures that meet the occupancy criteria for inhabited buildings. Many expeditionary structures are in forward operating locations where there is a conventional and/or terrorist threat more severe than those addressed in these standards. In those situations, more detailed planning and additional measures are needed for providing protection. Refer to GTA 90-01-011.

- New buildings built in expeditionary environments or existing buildings used by DoD in those environments will comply with all of the standards in Chapter 3.
- New expeditionary structures built in expeditionary environments will comply with the provisions of this chapter.

4-2 SITE PLANNING STANDARDS.

All the standards that are unique to expeditionary structures pertain to site planning. Integrate operational, logistic, and security requirements into the overall configuration of structures, equipment, landscaping, parking, roads, and other features during planning for expeditionary construction. The most cost-effective solution for mitigating explosive effects on expeditionary structures is to keep explosives as far away from them as possible. This is especially critical for these types of structures because hardening may not be possible or may be prohibitively expensive. Dispersed layouts reduce risks from a variety of threats by taking full advantage of terrain and site conditions; therefore, nothing in these standards is intended to discourage dispersal. Costs and requirements for expeditionary structure hardening are addressed in UFC 4-020-01.

4-2.1 Standard 1. Standoff Distances.

The previous version of Standard 1 established standoff distances to parking, roadways, and controlled perimeters that were based on building construction and occupancy. In this revision of Standard 1 standoff distances only apply to distances to installation perimeters for new construction and additions to existing buildings required to comply with these standards.

Exception: Existing buildings are exempt from this standard.

4-2.2 Minimum Standoff.

\1 The minimum standoff distance for new construction and additions to existing buildings to the installation perimeter is 20 ft. (6 m) **\1** when there is 30 ft. (9m) of clear zone or greater outside the perimeter. Provide a minimum aggregate standoff of 50 feet (15 m) inclusive of the clear zones outside and inside the installation perimeter. For example, if an installation has an established inner clear zone of 20 ft. (6 m) but the outer clear zone is 20 ft. (6 m) wide, the standoff distance to the installation perimeter must be 30 ft. (9 m) wide. **/1/** Where there is no clear zone outside the perimeter, the minimum standoff distance is 50 ft. (15 m).

For buildings that are outside an installation perimeter, use UFC 4-020-01 to establish project requirements. Where UFC 4-020-01 determines project specific Design Basis Threat and Level of Protection, design the project for the resulting standoff distance in accordance with Appendix B, Best Practices. **/1/**

4-2.2.1 Clear Zone.

\1 This standard does not establish the requirement for clear zones. Clear zones are defined by DoD and Service policy. Clear zones are established around the perimeters to provide unobstructed views to enhance detection and assessment. Typically, clear zones are free of all obstacles, topographical features, and vegetation exceeding 8 in. (200 mm) in height that could impede observation or provide cover and concealment of an aggressor. Some forward operating locations and high security areas may have higher clear zone requirements. Consult with local antiterrorism and security personnel to determine clear zone requirements. **/1/** See Figure 3-1 and Figure 3-2.

4-2.3 Standard 2. Structure Separation.

Structure separation requirements are established to minimize the possibility that an attack on one structure causes injuries or fatalities in adjacent structures. The separation distance is predicated on the potential use of indirect fire weapons. Structure separation also limits the ability of fire to spread from structure to structure, which is especially important in many of the types of construction used in expeditionary environments. Provide separation between structures in accordance with Figure 4-1.

4-2.4 Standard 3. Unobstructed Space.

Keep areas within 33 ft. (10 m) of all expeditionary structures free of items other than those that are part of the utilities and other supporting infrastructure. Do not allow roadways and trash containers within unobstructed spaces. Allowing parking within unobstructed spaces will be determined by security personnel.

4-3 ADDITIONAL STANDARDS.

In addition to the specific standards detailed in this chapter, apply the standards from Chapter 3 to expeditionary structures as follows:

4-3.1 Container Structures, \2\ Modular Structures, /2/ and Pre-engineered Buildings.

For these structures, all standards in Chapter 3 apply.

4-3.2 Fabric Covered, Trailers, \2\ /2/ and other Expeditionary Structures.

Apply the following standards from Chapter 3 to these structures:

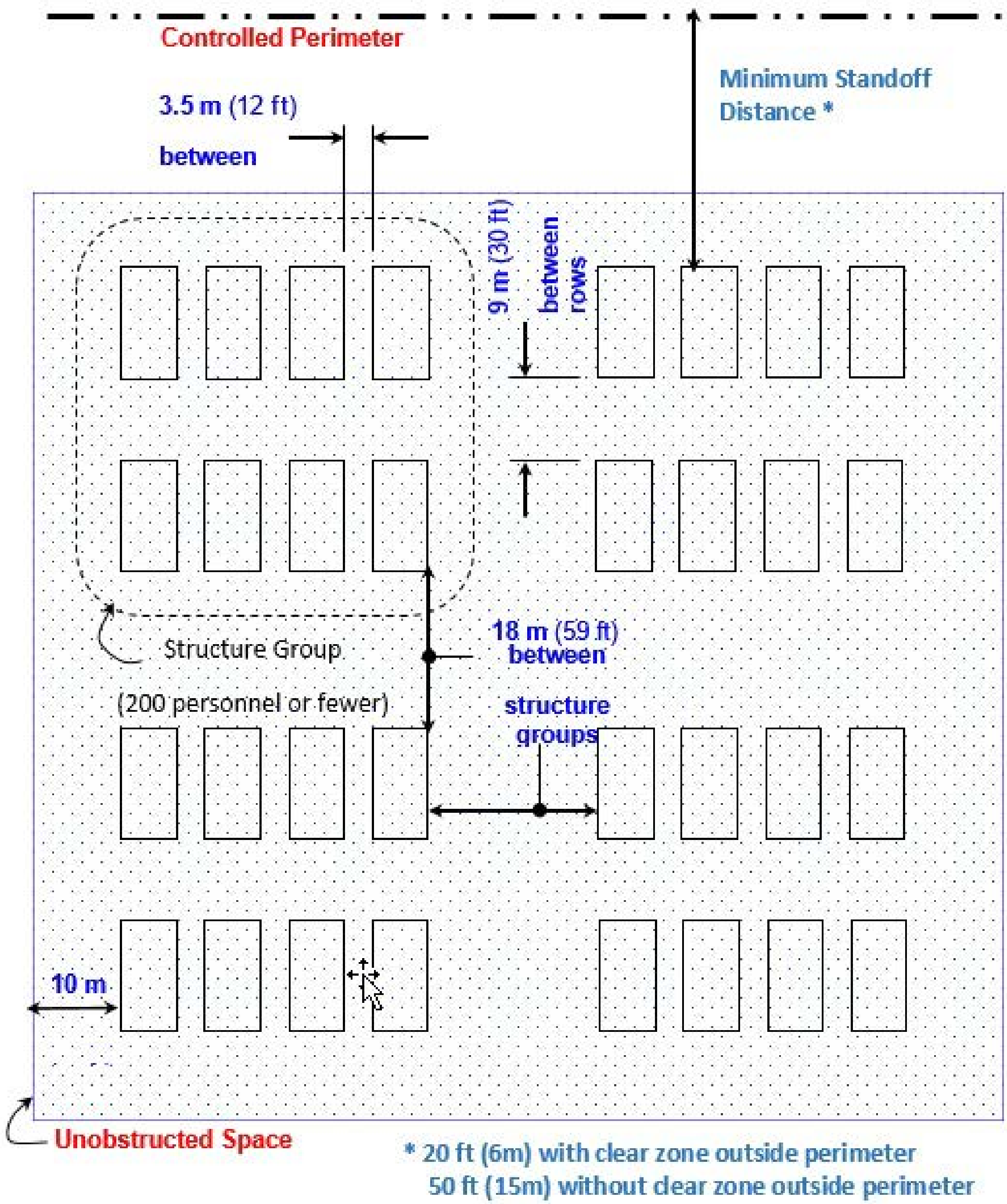
- Standard 10. Glazing
- Standard 11. Building Entrance Layout
- Standard 12. Exterior Doors
- Standard 15. Overhead Mounted Architectural Features
- Standard 19. Equipment Bracing
- Standard 21 Mass Notification

4-4 ANTITERRORISM RECOMMENDATIONS.

\2 Apply the following recommendations from Appendix A:

- Recommendation 1. Vehicle Access Points
- Recommendation 2. High-Speed Vehicle Approaches
- Recommendation 3. Drive-up/Drop-off Areas
- Recommendation 4. Building Location
- Recommendation 5. Railroad Location
- Recommendation 10. Asset Location
- Recommendation 11. Room Layout ***/2/***

Figure 4-1 Standoff and Separation Distances for Expeditionary Construction



APPENDIX A RECOMMENDED ANTITERRORISM MEASURES FOR NEW AND EXISTING BUILDINGS

A-1 INTRODUCTION.

The following additional measures, if implemented, will significantly enhance building occupants' safety and security with little increase in cost and should be considered for all new and existing buildings required to comply with these standards.

A-2 RECOMMENDATION 1. VEHICLE ACCESS POINTS.

The number of access points should be kept to the minimum necessary for security and operational purposes. This will limit the number of points at which access has to be controlled at increased Force Protection Conditions or if the threat increases in the future.

A-3 RECOMMENDATION 2. HIGH-SPEED VEHICLE APPROACHES.

The energy of a moving vehicle increases with the square of its velocity; therefore, minimizing a vehicle's speed enables the vehicle barriers used to be lighter and less expensive. To facilitate vehicle speed reduction, avoid unobstructed vehicle approaches that create direct paths to buildings.

A-4 RECOMMENDATION 3. DRIVE-UP/DROP-OFF AREAS.

Drive-up and drop-off areas should be located away from large glazed areas of buildings to minimize the potential for hazardous flying glass fragments in the event of an explosion. Consider locating the lanes at outside corners of buildings or otherwise away from main entrances or minimizing glazing in the proximity of drive-up and drop-off areas. Building geometries such as reentrant corners in the vicinity of drive-up and drop-off areas should be laid out to minimize the possibility that explosive blast forces could be increased due to being trapped or otherwise concentrated.

A-5 RECOMMENDATION 4. BUILDING LOCATION.

Activities with large visitor populations provide opportunities for potential aggressors to get near buildings with minimal controls and limit opportunities for early detection of aggressor activity. To limit opportunities for aggressors, separation distances should be maximized between buildings required to comply with these standards and areas with large visitor populations.

A-6 RECOMMENDATION 5. RAILROAD LOCATION.

For new construction avoid sites for buildings that are close to railroads. For existing buildings, procedures should be in place to prohibit trains from stopping in the vicinity of those buildings.

A-7 RECOMMENDATION 6. ACCESS CONTROL FOR FAMILY HOUSING.

For new family housing areas, allocate space at the perimeter of the housing area for an entry control facility/access control point designed in accordance with UFC 4-022-01 may be established if the need arises.

A-8 \1\/1/RECOMMENDATION 8. BUILDING SEPARATION.

For all new construction, buildings should be separated from adjacent buildings by at least 33 feet (10 meters).

This recommendation applies to new buildings and is established to minimize the possibility that an attack on one building causes injuries or fatalities in adjacent buildings.

A-9 RECOMMENDATION 9. VISITOR CONTROL.

Controlling visitor access maximizes the possibility of detecting potential threatening activities. Locations in buildings where visitor access is controlled should be kept away from sensitive or critical areas, areas where high-risk or mission-critical personnel are located, or other areas with large population densities of DoD personnel.

A-10 RECOMMENDATION 10. ASSET LOCATION.

To minimize exposure to direct blast effects and potential impacts from hazardous glass fragments and other potential debris, critical assets and mission-critical or high-risk personnel should be located away from the building exterior.

A-11 RECOMMENDATION 11. ROOM LAYOUT.

In rooms adjacent to the exterior of the building, personnel and critical equipment should be positioned to minimize exposure to direct blast effects and potential impacts from hazardous glass fragments and other potential debris.

A-12 RECOMMENDATION 12. EXTERNAL HALLWAYS.

Because doors can become hazardous debris during explosive blast events and designing them to resist blast effects is expensive, avoid building configurations that have large numbers of exterior doors leading into inhabited areas in buildings required to comply with these standards. A common example is a barracks/dormitory with exterior doors into each room or suite. Internal hallways with interior entrances to rooms or suites are preferable.

APPENDIX B BEST PRACTICES

B-1 INTRODUCTION.

\2 The contents in this appendix are not required to meet the minimum standards. This appendix presents a best practices strategy for site planning and designing facilities to protect against stationary vehicle bombs and hand delivered devices where a Design Basis Threat and Level of Protection are identified. **/2/**

The contents in this appendix are taken from the previous publication of this UFC to retain until publication of UFC 4-020-02. **\1** Use the information contained within based on Service, Agency, or Geographic Combatant Command guidance or when UFC 4-020-01 establishes a project specific Design Basis Threat and Level of Protection. **/1/**

B-2 SITE PLANNING FOR STATIONARY VEHICLE BOMBS AND HAND DELIVERED DEVICES.

Protective measures associated with site planning are established to address vehicle borne and hand placed explosive threats. The most cost-effective solution for mitigating explosive effects on buildings is to keep explosives as far as possible from them. Standoff distance should be coupled with appropriate building hardening to provide the necessary level of protection to DoD personnel as described in Table B-1.

Where conventional construction standoff distances cannot be achieved because land is unavailable, these best practices allow for building hardening to mitigate the blast effects. Planning level costs and requirements for building hardening are addressed in UFC 4-020-01. None of these best practices address physical barriers that are capable of stopping moving vehicles to prevent vehicles from accessing areas within the standoff distances established below. Measures using landscaping features, curbing, or pavement marking should meet the best practices for establishing standoff below. Those features address what is called the Stationary Vehicle Bomb Tactic in which the aggressor is assumed not to attempt to enter into areas where he or she would be noticed. Considerations for the Moving Vehicle Bomb Tactic where in the aggressor may be suicidal would include barriers that are capable of stopping the kinetic energy of the threat vehicle. For further discussion on both tactics, refer to UFC 4-020-01.

B-2.1 Standoff Distances.

Provide standoff distances between buildings and controlled perimeters, parking areas, roadways, and trash containers. The standoff distances are presented in Appendix C and illustrated in Figure B-1 and Figure B-2 for new buildings and Figure B-3 and Figure B-4 for existing buildings. For planning purposes, standoff distance is measured to the closest point on the building exterior. Vehicle barriers are not required to maintain these standoff distances unless threat analysis justifies them. **\1** Controlled perimeters can be utilized to limit the explosive weight that can get close to a building as illustrated in Figure B-1. **/1/**

B-2.1.1 Standoff Analysis.

Where the standoff distances in the “Conventional Construction Standoff Distance” (CCSD) columns of Table C-1 through Table C-4 can be met, conventional construction for the applicable building walls may be used for the buildings without a specific analysis of blast effects. Roofs do not need to be analyzed where the standoff distances for roofs in Table C-1 through Table C-4 are met and where they are within the ranges of one of the roof construction types in Table C-5. Types of construction not shown in Table C-5 may be permissible subject to validation by the designer of record. While the APPENDIX C tables address windows, the standoff distances shown should only be used for planning purposes as indicators of standoff distances at which conventionally constructed windows can be used. Standoff Distances for expeditionary structures are found in Table C-6.

Where conventional construction standoff distances are not available, lesser standoff distances may be validated through analysis that verifies the applicable level of protection is met, but none may be closer than the minimum standoff distance distances described in paragraph B-2.1.3 except as allowed for existing buildings. Allowable building damage and door and window hazards for the various levels of protection are described in Table B-1. Note that regardless of standoff distance, where buildings are three stories or more, the progressive collapse provisions of Standard 6 should be applied.

Figure B-1 Standoff Distances – With Controlled Perimeter

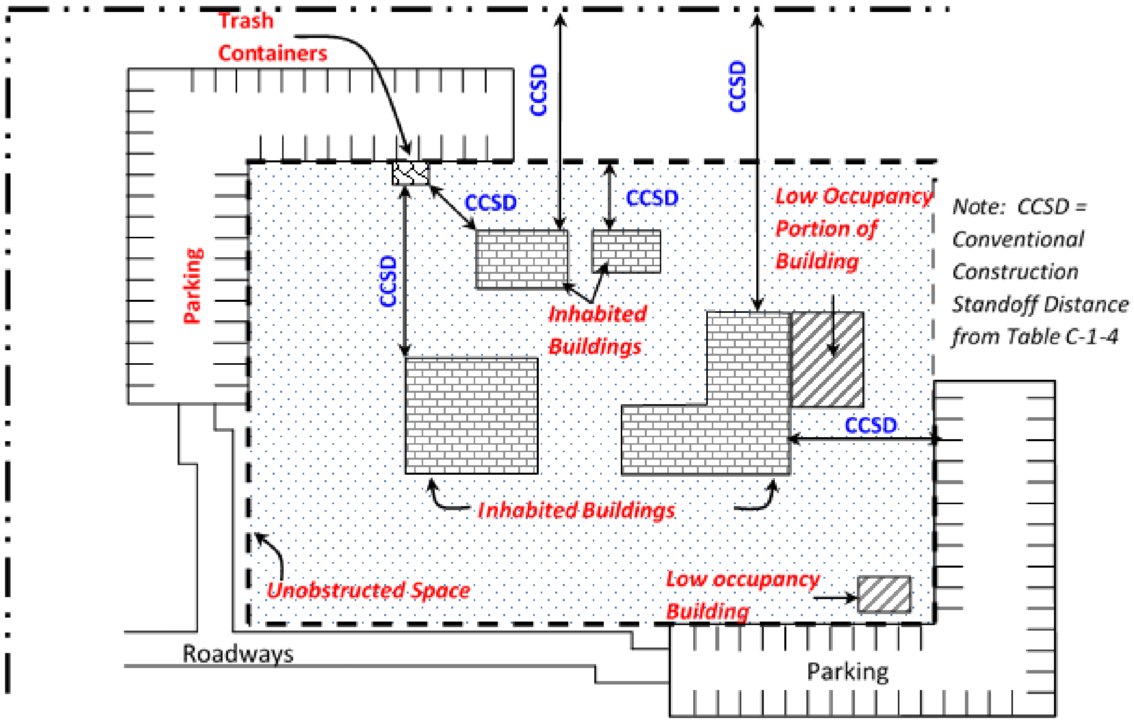


Figure B-2 Standoff Distances – No Controlled Perimeter

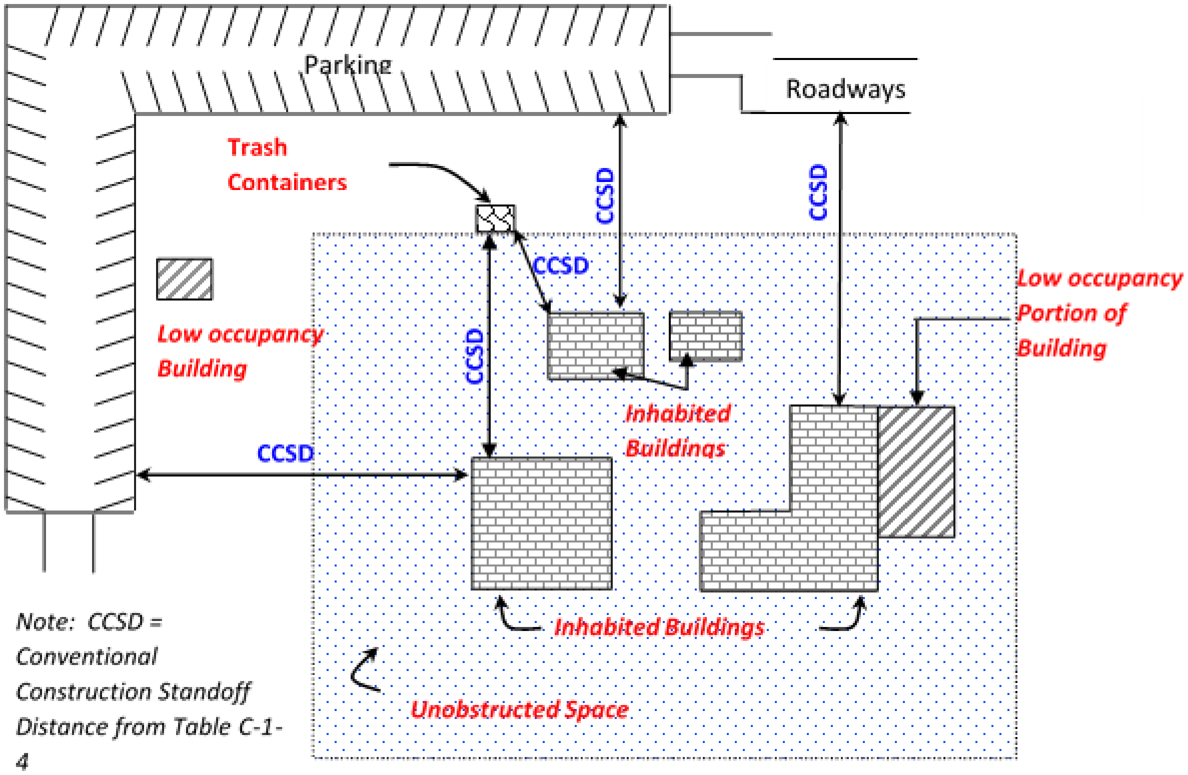


Figure B-3 Parking and Roadway Control for Existing Buildings – Controlled Perimeter

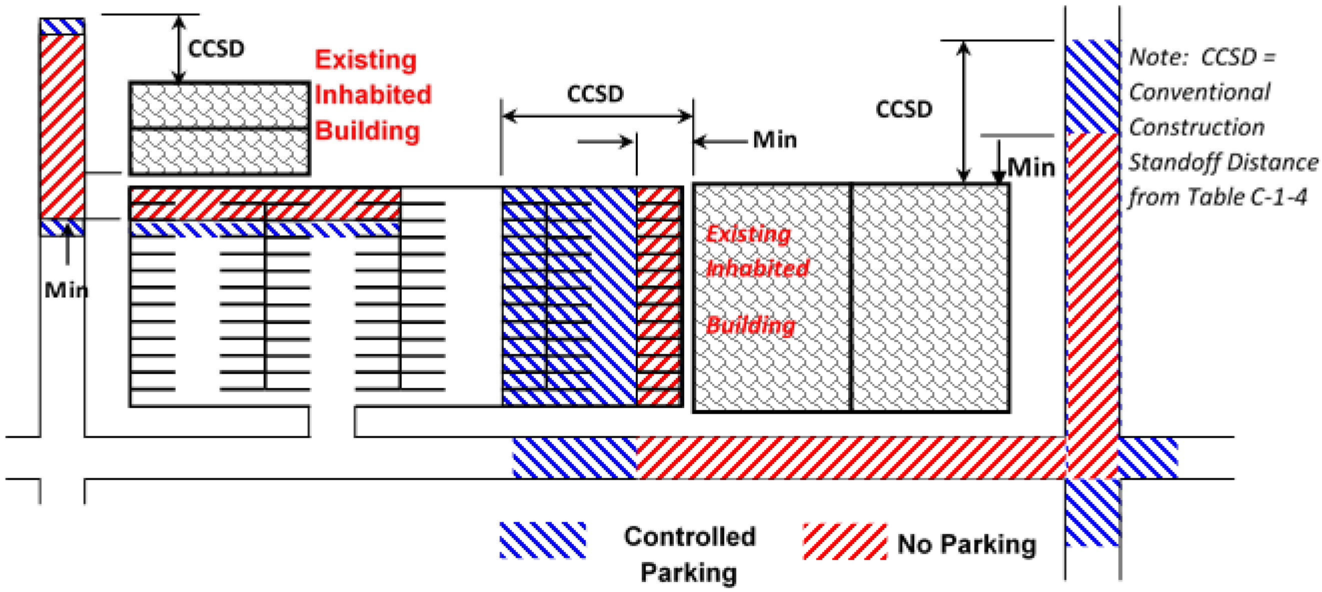
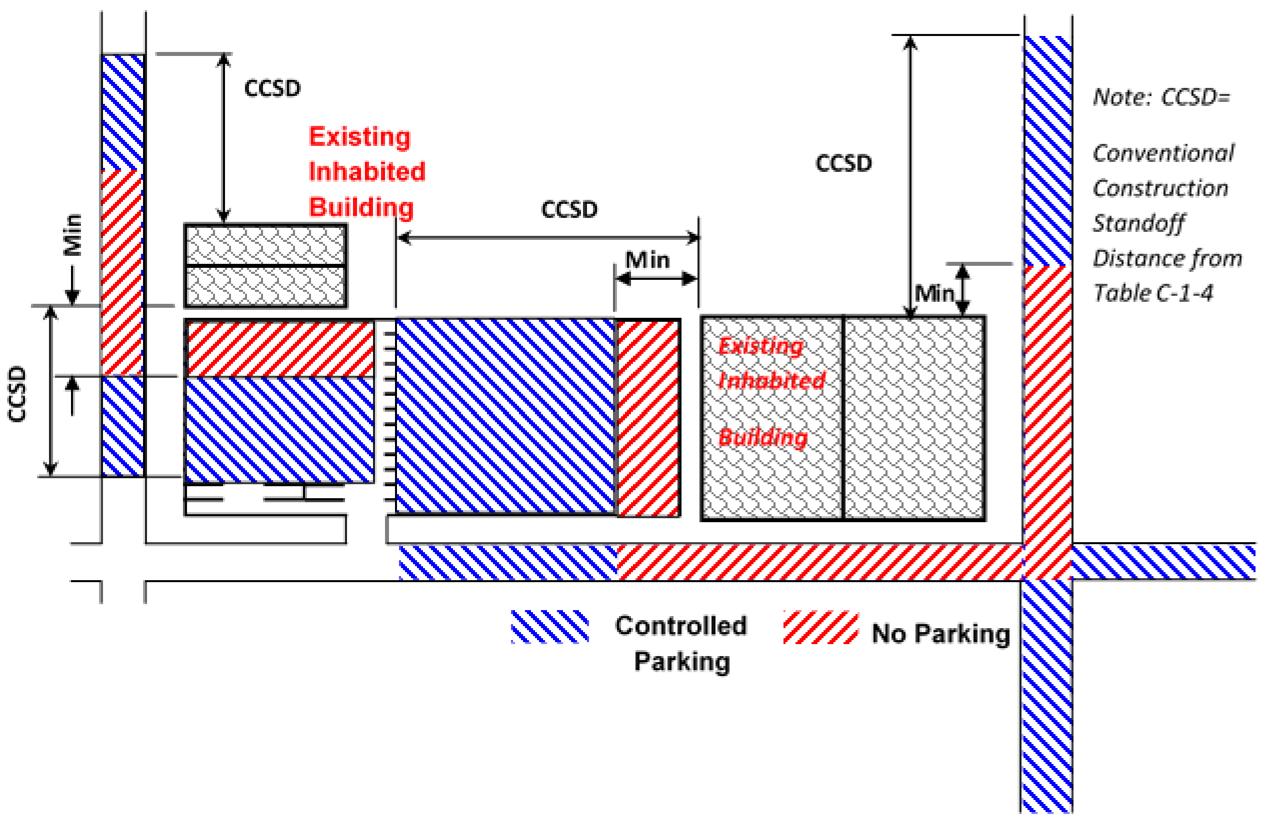


Figure B-4 Parking and Roadway Control for Existing Buildings – No Controlled Perimeter



B-2.1.2 Conventional Construction Standoff Distance.

Standoff distances for buildings vary based on the specific construction of the walls, on whether they are load bearing or non-load bearing, by level of protection, and by explosive weight. The specific construction types upon which the standoff distances are based are indicated in Table C-1 through Table C-4 and detailed descriptions of their design parameters are tabulated in Table C-5. The separate conventional construction standoff distances columns in Table C-1 through Table C-4 for load bearing and non-load bearing wall construction reflect the fact that the damage allowed to load bearing construction is less than that allowed to non-load bearing construction for the same level of protection as explained in PDC Technical Report 06-08. Specific standoff distances are tabulated for different construction types. Note that the conventional construction standoff distance columns in Table C-1 through Table C-4 are primarily related to walls because the walls in that table always controlled the conventional construction standoff distance over any of the roofs indicated in Table C-5. Walls and roofs of construction other than those included in Table C-5 should be designed to provide the applicable response described in Table B-1 and detailed in PDC Technical Report 06-08. Standoff distances for windows in Table C-1 through Table C-4 are for conventional windows. When standoff distances are closer than those standoff distances windows will commonly be much heavier and more expensive than conventional windows.

Conventional construction standoff distances do not apply to doors; refer to B-3.2. Planners and designers will have to analyze tradeoffs between wall standoff and window and door construction. Standoff distances for expeditionary structures are based on structure types as indicated in Table C-6.

B-2.1.3 Minimum Standoff Distance.

Minimum standoff distance is the smallest permissible standoff distance allowed for buildings regardless of any analysis results or hardening of buildings that would allow for closer standoff distances, except as established below for existing buildings. Note that achieving the minimum standoff distance generally requires a significant degree of building component hardening; therefore, where only the minimum standoff distance is provided there should be analysis results that show it can be achieved while still providing the applicable level of protection. Minimum standoff distance R_M is determined as a scaled range of 3 by the following equations:

$$\text{For Feet: } R_M = 3\sqrt[3]{W}$$

$$\text{For Meters: } R_M = 1.19\sqrt[3]{W}$$

Where:

W is the threat explosive weight in pounds for feet or kilograms for meters.
R_M is the minimum standoff distance in feet or meters.

Table B-1 Levels of Protection – New and Existing Buildings

Level of Protection	Potential Building Damage/Performance [2]	Potential Door and Glazing Hazards[3,4]	Potential Injury
Below AT standards[1]	Severe damage. Progressive collapse likely. Space in and around damaged area will be unusable.	* Windows will fail catastrophically and result in lethal hazards. *(High hazard rating)* * Doors will be thrown into rooms. *(Category V)*	Majority of personnel in collapse region suffer fatalities. Potential fatalities in areas outside of collapsed area likely.
Very Low	Heavy damage - Onset of structural collapse, but progressive collapse is unlikely. Space in and around damaged area will be unusable.	* Glazing will fracture, come out of the frame, and is likely to be propelled into the building, with potential to cause serious injuries. *(Low hazard rating)* * Doors will become dislodged from the structure but will not create a flying debris hazard. *(Category IV)*	Majority of personnel in damaged area suffer serious injuries with a potential for fatalities. Personnel in areas outside damaged area will experience minor to moderate injuries.
Low	Moderate damage – Building damage will not be economically repairable. Progressive collapse will not occur. Space in and around damaged area will be unusable.	* Glazing will fracture, potentially come out of the frame, but at reduced velocity, does not present a significant injury hazard. *(Very low hazard rating)* * Doors will experience non-catastrophic failure, but will have permanent deformation and may be inoperable. *(Category III)*	Majority of personnel in damaged area suffer minor to moderate injuries with the potential for a few serious injuries, but fatalities are unlikely. Personnel in areas outside damaged areas will potentially experience minor to moderate injuries.
Medium	Minor damage – Building damage will be economically repairable. Space in and around damaged area can be used and will be fully functional after cleanup and repairs.	* Glazing will fracture, remain in the frame and results in a minimal hazard consisting of glass dust and slivers. *(Minimal hazard and No Hazard ratings)* * Doors will be openable but will have permanent deformation. *(Category II)*	Personnel in damaged area potentially suffer minor to moderate injuries, but fatalities are unlikely. Personnel in areas outside damaged areas will potentially experience superficial injuries.
High	Minimal damage. No permanent deformations. The facility will be immediately operable.	* Innermost surface of glazing will not break. (No Break hazard rating) * Doors will be substantially unchanged and fully operable. *(Category I)*	Only superficial injuries are likely.

1. This is not a level of protection and should never be a design goal. It only defines a realm of more severe structural response and may provide useful information in some cases.
2. For damage / performance descriptions for primary, secondary, and non-structural members, refer to PDC Technical Report 06-08.
3. Glazing hazard ratings are from ASTM F 2912.
4. Door damage level categories are from ASTM F 2247 and F 2927.

For new buildings, standoff distances of less than a scaled range of 3 should not be allowed. For existing buildings, the minimum standoff distances should be provided except where doing so is not possible. In those cases, lesser standoff distances may be allowed where the applicable level of protection can be shown to be achieved through analysis or can be achieved through building hardening or other mitigating construction or retrofit as described in these standards

B-2.1.4 Distances Between Conventional and Minimum Standoff Distances

Where the conventional construction standoff distances are not available, an engineer experienced in blast-resistant design should analyze the building and apply building hardening as necessary to mitigate the effects of the applicable explosives at the achievable standoff distance to the appropriate level of protection. The appropriate levels of protection are described in Table B-1 and in UFC 4-020-01. Detailed design parameters for meeting the levels of protection are in PDC Technical Report 06-08. Buildings should be designed for fully reflected blast pressures except where it can be proven that a wall could never be exposed to reflected pressures.

B-2.1.5 Parking and Roadways Standoff Distances.

Measure the standoff distance from the closest edge of parking areas, driving lanes within parking areas, and roadways to the closest point on the building exterior or inhabited portion of the building or to specific building components. In addition, the following apply:

B-2.1.5.1 New Buildings.

The minimum standoff distance for all new buildings regardless of hardening or analysis is that associated with a scaled range of 3 for both parking areas and roadways, whether parking is allowed on the roadways or not.

B-2.1.5.2 Existing Buildings.

Where possible, move parking and roadways away from existing buildings in accordance with the standoff distances in Table C-1 through Table C-4 for the threat explosive weight and the applicable level of protection. It is recognized that moving existing parking areas and roadways or applying structural retrofits may be impractical in some cases; therefore, the following operational options are provided for existing buildings.

B-2.1.5.2. Controlled Parking Areas.

Controlled parking associated with existing buildings may be allowed to be as close as the minimum standoff distance without hardening or analysis if access control (see definition in glossary) to the parking area is established at the applicable conventional construction standoff distance for parking. In cases where the applicable level of protection can be provided (based on hardening or analysis) with a standoff distance between the conventional construction standoff distance and the minimum standoff distance, uncontrolled parking may be allowed at the standoff distance at which the level of protection can be achieved subject to the requirements below, but not closer than the minimum standoff distance.

To mitigate the introduction of hand delivered explosives into the controlled parking areas in violation of the unobstructed space standard (Standard 2), controlled parking areas should have some means to control pedestrian access as well as vehicular access, such as fencing or walls.

B-2.1.5.2. Driving Lanes within Parking Areas.

Where limited space necessitates, driving lanes within parking areas may be closer to existing buildings than parking spaces located at the applicable standoff distances, but vehicles should not be left unattended in those driving lanes. Standoff distance in these cases should be to the nearest parking space. This should not be allowed for new buildings.

B-2.1.5.2. Alternate Situations.

Parking may be closer to existing buildings than the minimum standoff distance where it is impractical to achieve that distance and where it can be shown through analysis that the applicable level of protection can be provided at the lesser standoff distance or if it can be provided through building hardening or other mitigating measures or retrofits designed for those standoff distances. Allowing any parking closer than the distances established in the paragraphs above should be avoided wherever possible.

B-2.1.5.3 Parking on Existing Roadways.

Parking along roadways is subject to similar standoff considerations as to other parking. Where there are existing roads adjacent to existing inhabited buildings, ensure there is no parking on those roadways closer than the conventional construction standoff distance unless the applicable level of protection can be provided (based on hardening or analysis) with a standoff distance between the conventional construction standoff distance and the minimum standoff distance. Parking along those roadways should not be closer than the minimum standoff distance under any circumstance. (Refer to Figure B-3 and Figure B-4). Where parking along existing roadways adjacent to existing buildings can be controlled, parking may be allowed to be as close as the minimum standoff distance without hardening or analysis.

B-2.1.5.4 Parking for Existing High Occupancy Family Housing.

For existing high occupancy family housing within a controlled perimeter or where there is access control to the parking area, parking within the required standoff distances may be allowed where designated parking spaces are assigned for specific residents or residences. Do not label assigned parking spaces with names or ranks of the residents. Where the existing standoff distances are less than the required standoff distances do not encroach upon those existing standoff distances with any additional parking. Avoid parking closer than the minimum standoff distance.

B-2.1.5.5 Adjacent Underground Parking.

Where underground parking is provided adjacent to (not underneath) buildings, parking may be allowed as close to the buildings as the construction of the building superstructure will allow based on the applicable level of protection and explosive weight. Analysis should show that the soil-structure interaction and any venting into the building will not cause progressive collapse of the building or damage to inhabited areas of the building beyond the applicable level of protection. Also, ensure there is no venting into inhabited areas of buildings that could result in occupant injuries.

B-2.1.5.6 Government Vehicle Parking.

Limitations on parking near buildings apply to all vehicles, including official and tactical vehicles, except for mobile ground tactical platforms, emergency vehicles, and operations support vehicles that are never driven out of restricted access areas, as established in these best practices. Government vehicles other than those vehicles are included in the parking limitations in these best practices because it is assumed that when they are out of restricted access areas they may be out of the immediate control of their operators, which could make them susceptible to having explosives placed on or inside of them.

B-2.1.5.7 Parking of Emergency, Command, and Operations Support Vehicles.

Emergency and command vehicles, as well as operations support vehicles may be parked closer to buildings than allowed in Table C-1 through Table C-4 without hardening or analysis if access to the vehicles is continuously controlled or as long as they are never removed from a restricted access area. Command and operations support vehicles should not be parked closer than the applicable minimum standoff distance. In addition, where standard operation of buildings includes parking emergency vehicles inside them, such as in fire stations, those emergency vehicles may be parked inside the buildings.

Emergency vehicles and command vehicles are exempted from parking restrictions because they are assumed to be under strict control while they are both in and away from their usual parking spaces. Operational support vehicles are exempted because they are assumed to always operate within restricted access areas such as airfields.

B-2.1.5.8 Parking of Vehicles Undergoing Maintenance.

Vehicles undergoing maintenance may be parked inside maintenance buildings close to inhabited areas of those buildings while they are undergoing repair without providing any hardening or analysis of the buildings. Vehicles stored outside awaiting maintenance are subject to the parking limitations in these best practices.

B-2.1.5.9 Parking of Mobile Ground Tactical Platforms.

Where operational requirements require parking mobile ground tactical platforms containing non-removable sensitive compartmented information systems adjacent to buildings, ensure those parking areas are surrounded by a 7 foot (2 meter) chain link security fence topped by a single outrigger with three-strands of barbed wire and that access to those parking areas is controlled so that the vehicles cannot be accessed without being detected.

Mobile ground tactical platforms are exempted because they are provided strict security and access control due the sensitive nature of their missions and because they must be parked adjacent to buildings to support their connectivity for electronic system updates.

B-2.1.5.10 Parking for Handicapped Personnel.

Parking for handicapped personnel should not be located closer than the standoff distances necessary to meet the applicable levels of protection. Handicapped parking is only required to be the closest parking available. There is no set distance associated with it.

B-2.1.5.11 Parking and Roadway Projects.

Where practical, all roadway and parking area projects not associated with a building renovation, modification, repair, or restoration should comply with the applicable conventional construction standoff distances from existing inhabited buildings. Where parking areas that are within the applicable standoff distances from such existing buildings are being constructed, expanded, or relocated, those parking areas should not encroach on the existing standoff distances of any existing inhabited building unless it can be shown that the building can provide the appropriate level of protection that would apply if the building were required to meet a standoff distance. Parking and roadway projects should not be located closer than the applicable minimum standoff distances.

If roadway projects include road widening or encroachment on existing standoff distances is otherwise unavoidable, ensure there are operational procedures in place to prohibit parking on the roadways within those standoff distances as described in paragraph B-2.1.5.2. Driving lanes within parking areas may be allowed to be closer to existing buildings than the closest parking spaces where limited space necessitates, but vehicles may not be left unattended in those driving lanes.

B-2.1.5.12 Standoff to Entry Control Facilities/Access Control Points.

For stationary vehicle bomb threats standoff distances from buildings to Entry Control Facilities/Access Control Points should be measured from the identification check area to the closest point on the building exterior or inhabited portion of the building or to specific building components. For moving vehicle bomb threats standoff distances should be measured to the nearest final denial active vehicle barrier.

B-2.1.5.13 Location of Trash Containers.

Provide standoff distances from the nearest points of trash containers or trash container enclosures to the closest points on building exteriors, inhabited portions of buildings, or to specific building components in accordance with the conventional construction standoff distance for the threat hand carried explosive. Where the applicable conventional construction standoff distance is not available, analyze the building and apply building hardening as necessary to mitigate the effects of the applicable explosives for trash containers at the achievable standoff distance to the appropriate level of protection.

Alternatively, harden trash enclosures to mitigate the direct blast effects and secondary fragment effects of the explosive on the building if the applicable level of protection can be proven by analysis or testing. As an additional alternative, if trash containers or enclosures are secured to preclude introduction of objects 6-in. (150 mm) or greater in height or width into them by unauthorized personnel, they may be located closer to the building as long as they do not violate the unobstructed space provisions of paragraph B-2.2. Openings in screening materials and gaps between the ground and screens or walls making up an enclosure should not be greater than 6 in. (150 mm).

B-2.1.5.14 Adjacent Existing Buildings.

Where projects for new and existing buildings include locating parking, roadways, or trash containers near existing inhabited buildings, the standoff distances from parking, roadways, and trash containers to those buildings should comply with the applicable standoff distances in Table C-1 through Table C-4.

Where those standoff distances are not available, do not allow parking and roadways to encroach on existing standoff distances to parking and roadways associated with those existing buildings unless it can be shown that the building can provide the appropriate level of protection that would apply if the building were required to comply with the minimum standards in this UFC. The encroachment provision above applies only to parking and roadways. Do not allow trash containers associated with new or existing buildings to be located closer to existing inhabited buildings than the applicable standoff distances in Table C-1 through Table C-4.

B-2.1.5.15 Parking Structures.

Standoff distances between parking structures and inhabited buildings should be measured to actual parking spaces within the parking structures, including spaces on all floors of the parking structures.

B-2.2 Unobstructed Space.

Standard 2 covers unobstructed space requirements to meet the minimum standards, however, fully mitigating the effects of a hand placed explosive requires determining a standoff distance based on the building construction, threat explosive weight, and applicable level of protection. To achieve that mitigation, do the following in addition to what is required by Standard 2. The unobstructed space should extend out to the applicable conventional construction standoff distance to walls for parking and roadways in accordance with Table C-1 through Table C-4, but not less than the minimum standoff distance. If the standoff distance required to provide the applicable performance of windows or doors is greater than the conventional construction standoff distance, the unobstructed space should extend to the applicable window or door distance. Unobstructed space for expeditionary structures should be determined using Table C-6.

Alternatively, for distances between the conventional construction standoff distance and the minimum standoff distance, standoff distances may be validated through analysis. That analysis verifies the applicable level of protection is met based on mitigating the effects of the threat hand carried explosive at the distance between the location of the explosive and the area of the building being protected. For existing buildings where the standoff distances for parking and roadways have been established at less than the minimum standoff distance, the unobstructed space may be reduced to be equivalent to those distances.

B-2.2.1 Controlled Parking.

Where controlled parking associated with existing buildings is allowed, the unobstructed space should be considered to extend to the limits of those parking areas where access is controlled. To mitigate the introduction of hand delivered explosives into the controlled parking areas, those areas should have some means to control pedestrian access as well as vehicular access, such as fencing or walls. Security fences or walls should be a minimum of 7 ft. (2 m) high. Specific fence, wall, and access control requirements should be coordinated with physical security and antiterrorism personnel.

B-2.2.2 Parking Within Unobstructed Spaces.

When an explosive threat has been identified, parking should not be allowed within unobstructed spaces except for parking of emergency, command, and operations support vehicles and mobile ground tactical platforms.

B-2.2.3 Adjacent Uncontrolled Public Space.

Where there is a defined explosive threat and there are spaces with uncontrolled public access below, above or beside building areas that are occupied by DoD, it should be considered that the threat explosives may be located in those spaces and the spaces occupied by DoD should be designed **\1** for blast resistance **/1/** to ensure that they meet the applicable level of protection.

B-2.3 Drive-Up/Drop-Off Areas.

Some facilities require access to areas within the required standoff distances for dropping off or picking up people or loading or unloading packages and other objects. Examples that may require drive-ups or drop-offs include, but are not limited to, medical facilities, exchanges and commissaries, schools, and child care centers. In these cases, standoff distances should be measured to the nearest legal parking spaces, not the drive-ups or drop-offs. No building hardening should be required to compensate for the closer standoff distances associated with the drive-ups or drop-offs. This also applies to drive-through lanes such as those at stand-alone franchised food operations.

B-2.3.1 Marking.

Where operational or safety considerations require drive-up or drop-off areas or drive-through lanes near, ensure those areas or lanes are clearly defined and marked in accordance with the Manual on Uniform Traffic Control Devices and that their intended use is clear to prevent parking of vehicles in those areas.

B-2.3.2 Unattended Vehicles.

Do not allow unattended vehicles in drive-up or drop-off areas or drive-through lanes. Prohibit unattended vehicles within conventional construction standoff distances in accordance with Table C-1 through Table C-4 or ensure through analysis that buildings can provide the appropriate level of protection at lesser standoff distances. Unattended vehicles should never be allowed closer than the minimum standoff distance.

B-2.3.3 Location.

Do not allow drive-through lanes or drive-up/drop-off areas to be located under any inhabited portion of any new building. For existing buildings that have drive-through lanes or drive-up areas, either eliminate them or design the buildings to provide the applicable level of protection for the applicable explosive weight located underneath the portion of the building accessed by the drive-through or drop-off.

B-2.4 Access Roads.

Where access roads are necessary for the operation of buildings (including those required for emergency access and/or security operations), ensure that access control measures are implemented to prohibit unauthorized vehicles from using access roads within the applicable standoff distances. Because situations at various buildings and installations are different, the development of specific access control measures and procedures is beyond the scope of these standards. That is left to local physical security personnel.

B-2.5 Parking Beneath Buildings or on Rooftops.

Standard 5 in Chapter 3 establishes the minimum measures required for addressing this situation. To mitigate the effects of an explosive event underneath or on top of a building, ensure that there is no general collapse of more than one single bay of floor beneath or floors/roof above inhabited areas and that all other adjacent supporting structural elements will not fail from the detonation in the parking area of the threat explosive. Unless it can be shown that a greater standoff distance can be justified, evaluate structural elements in parking areas at a standoff distance of 4 ft. (1.2 m) horizontally or 30 in. (76 cm) above the elements. Failure should be evaluated based on the applicable level of protection in accordance with PDC Technical Report 06-08. Also, ensure there is no venting into inhabited areas of buildings that could result in occupant injuries. In addition, see Standard 6 of the minimum standards for progressive collapse avoidance requirements.

B-3 ARCHITECTURAL AND STRUCTURAL DESIGN.

CHAPTER 3 establishes minimum requirements for glazing and doors. Those requirements do not address mitigation of blast effects on structures. Where an explosive threat has been identified to a facility, the following apply.

B-3.1 Windows and Skylights.

To minimize hazards from flying debris from windows and skylights, apply the following provisions for glazing, framing, connections, and supporting structural elements for all new and existing buildings for which there is an identified explosive threat. These provisions apply to window systems at all standoff distances, even those that meet or exceed the wall conventional construction standoff distances. The specific requirements below will result in window and skylight systems that provide for effective hazard mitigation. These provisions allow for design by dynamic analysis, testing, or the ASTM F 2248 design approach as described in the paragraphs below. Use strength design with load factors of 1.0 and strength reduction factors of 1.0 for all methods of analysis referenced herein for flexure and use typical strength reduction factors for other modes of failure. Windows will be inclusive of storefronts, clerestories, and similar glazed construction. For glazed doors refer to paragraph B-3.2.2.

Monolithic glass or monolithic acrylic used as a single pane or as the inner pane of a multi-pane system is not allowed as glazing when there is an identified explosive threat. Spandrel glass when backed by a structural wall or spandrel beam, translucent fiberglass panels, other lightweight translucent plastics, and glass unit masonry should meet the performance requirements of Table B-1. That performance needs to be proven through testing or analysis. Engineered glass block window systems and spandrel glass that is open to occupied space should be designed in accordance with the following guidance.

B-3.1.1 Dynamic Analysis.

Any of the glazing, framing members, connections, and supporting structural elements may be designed using dynamic analysis to prove the window or skylight systems will provide performance equivalent to or better than the hazard rating associated with the applicable level of protection established in the project requirements and described in Table B-1. Dynamic analysis guidance is presented in PDC TR 10-02. The design loadings for dynamic analyses should be the appropriate pressures and impulses from the applicable explosive weights at the actual standoff distances at which the windows are sited. The design loading should be applied over the areas tributary to the element being analyzed. The allowable response limits of structural elements for all of the levels of protection are provided in PDC-TR 06-08. Response limits for steel and aluminum window frame members are provided in PDC-TR-10-02. Window frames constructed from materials other than aluminum or steel should be tested in accordance with paragraph B-3.1.2 or proven by analysis to demonstrate performance equivalent to or better than the hazard rating associated with the applicable level of protection as indicated in Table B-1.

B-3.1.2 Testing.

Window and skylight systems may be dynamically tested to demonstrate performance equivalent to or better than the hazard rating associated with the applicable level of protection as indicated in Table B-1. Testing should include the entire window or skylight system, including connections, and should be in accordance with ASTM F 1642 with hazard ratings in accordance with ASTM F 2912.

The structural supporting material used in the test for fastener attachment should be representative of the fielded application. Any deviations in field application of the connections or the connected elements from the test should be demonstrated by calculation to provide the applicable level of protection for the specific application. The design loading for a dynamic test should be the appropriate pressure and impulse from the applicable explosive weight at the actual standoff distance at which the window is sited.

B-3.1.3 ASTM F 2248 Design Approach for Laminated Glass Glazing Systems.

Windows and skylights fabricated using laminated glass may be designed using ASTM F 2248 and ASTM E 1300 in accordance with the requirements below. The application of ASTM F 2248 and ASTM E 1300 results in a medium level of protection as reflected in Table B-1.

B-3.1.3.1 Glazing.

Provide laminated glass with a minimum interlayer thickness of 0.030 in. (0.75mm) and a load resistance determined from ASTM E 1300 greater than or equal to the 3-second duration equivalent design load determined from ASTM F 2248.

Note that ASTM F 2248 can be used for a limited range of charge weights and standoffs, including those covered by this standard. For charge weights and standoffs outside of the range of ASTM F 2248, for conditions outside the range of ASTM E 1300, and for glazing alternatives to laminated glass that provide equivalent levels of protection, refer to PDC Technical Report 10-02.

B-3.1.3.2 Frames.

Provide window and skylight frames, mullions and sashes of aluminum or steel designed in accordance with ASTM F 2248. Window frames constructed from materials other than aluminum or steel should be tested in accordance with paragraph B-3.1.2 or proven by analysis to demonstrate performance equivalent to or better than the hazard rating associated with the applicable level of protection as indicated in Table B-1.

In the case of a punched or ribbon window, the supported edge length should be taken as equal to the longest span of a single pane of glass, regardless of any intermediate support connections. For storefront and curtain wall systems, primary mullions that span between points of structural support should be considered supporting frame members and may be designed dynamically in accordance with paragraph B-3.1.1 or statically. If designed by the static method the moment and shear capacities of framing members should be designed to resist two (2) times the load resistance of the glazing applied to the framing members only from the tributary area of the window, and deflection should be limited to 1/60 of the members' span lengths between points of structural support. Intermediate mullions should be checked for deflection with the supported edge length taken as equal to the longest span of a single glass panel and the deflection should be calculated based on simple support conditions for that length.

B-3.1.3.3 Glazing Frame Bite.

Glazing frame bite requirements for structurally or non-structurally glazed windows or skylights should be in accordance with ASTM F 2248. Apply structural silicone bead or glazing tape to both sides of the glass panel for single pane glazing but only to the inboard side for insulating glass units.

B-3.1.3.4 Connection Design.

Connections of window and skylight frames to surrounding walls or roofs, of hardware and associated connections, of glazing stop connections, and of other elements in shear should be designed for the connection design load determined in accordance with ASTM F 2248 and should account for the geometry of the particular frame and the connection configuration being used when calculating bending, shear, bearing, and pull out loads for the connections.

B-3.1.4 Design of Supporting Structural Elements.

Supporting structural elements (i.e., those structural elements that frame the rough opening) for window and skylight systems of any glazing material can be designed statically to account for the increase in tributary areas to the adjacent supporting elements due to windows or skylights. Building elements that have only glazing framed into them, such as curtain walls and storefronts, should be designed as frame members in accordance with paragraph B-3.1.3.2. For window and skylight systems in buildings situated at less than the wall conventional construction standoff distance, the surrounding wall and roof elements should be designed dynamically in accordance with paragraph B-3.1.1.

B-3.1.4.1 Static Design of Wall and Roof Elements.

For window and skylight systems in buildings situated at or beyond the wall conventional construction standoff distance for the wall material to which it is attached, the surrounding wall and roof elements and their connections to the rest of the structure should be designed as described below. The supporting structural elements adjacent to windows or skylights should be designed to account for their increased tributary areas. These areas represent the tributary areas of windows or skylights, and the walls or roof area above and below them, whose loads should be laterally supported by those elements. Those increases in tributary areas should be accounted for by applying a tributary area increase factor (C) to the moment and shear capacities of the wall or roof elements. The tributary area increase factor is the ratio of the tributary area that accounts for the windows or skylights and the walls or roofs above and below them to the tributary area upon which typical conventional wall sections or elements are designed. See PDC Technical Report 10-02 for an illustration. The tributary area increase factor is shown in Equation 1 and should not be taken as less than 1.

$$C = \frac{a_{trib}}{a_{wall}} \geq 1$$ Equation 1

a wall = tributary area for typical conventional wall section or element

a trib = combined tributary area for supported window or skylight and wall or roof section or element

Design the supporting structural elements to have moment and shear capacities equal to or greater than the calculated conventional wall capacities multiplied by the applicable tributary area increase factor as shown in Equation 2 and Equation 3. Connection loads for the supporting structural element should be determined based on the increase in member shear capacity.

$$M_{SSE} \geq C \cdot M_{CW}$$ Equation 2

$$V_{SSE} \geq C \cdot V_{CW}$$ Equation 3

MSSE and VSSE are moment and shear capacities of supporting structural element.

MCW and VCW are moment and shear capacities of conventional wall section.

B-3.1.4.2 Reactions for Static Design.

The reactions from the supporting structural element analysis normally do not have to be carried through the horizontal and lateral bracing systems of buildings to the foundations. The main concern is that these loads are transferred into horizontal floor and roof systems without failing those connections or the attached elements, as the building mass dissipates those loads before they are transferred to the foundation. It is left to the structural engineer to assess the adequacy of these connections, the attaching elements, and the need for further analysis.

B-3.1.5 Skylights.

Because glazing fragment hazards are increased when glazing falls from the elevations of skylights, skylight glazing should be designed as a minimum to break, but remain in the frame, which is equivalent to the minimal hazard rating in ASTM F 2912 (medium level of protection in Table B-1). Use the appropriate blast load for the applicable angle of incidence to design or test the skylight.

B-3.1.6 Window and Skylight Replacement Projects.

Whenever windows and skylights are being replaced in existing buildings that have an identified explosive threat, design glazing, frames, connections, and supporting structural elements to meet all of the requirements of **\1** B-3.1 **/1/**. Base the window designs on either the standoff distances to existing parking and roadways or to the planned locations for future parking and roadways in accordance with the installation or facility master plan. These provisions also apply to new windows installed in new wall openings.

Provide no less than 1/4 in. (6 mm) nominal polycarbonate or laminated glass for exterior windows or skylights. The 1/4 in. (6 mm) laminated glass consists of two nominal 1/8 in. (3 mm) glass panes bonded together with a minimum of a 0.030 in. (0.75 mm) interlayer of a material designed and tested for bomb blast resistance. For insulating glass units (IGU), use the polycarbonate or laminated glass for the innermost pane as a minimum. For laminated glass provide a glazing frame bite in accordance with ASTM F 2248. For polycarbonate provide a glazing frame bite of no less than 1.5 times the polycarbonate thickness.

B-3.1.7 Replacement with Wall or Roof Systems.

When windows or skylights are being replaced by filling in the openings with wall or roof material the openings should be filled with the same or similar construction as the adjacent wall or roof construction. Lightweight translucent fiberglass or plastic panels or other construction dissimilar to the existing adjacent construction may also be used. Regardless of the infill construction used, it must **\1** be designed and constructed for blast resistance to **/1/** provide the applicable level of protection.

B-3.1.8 Alternative Window Treatments.

For existing buildings in which windows are not being replaced, window retrofits incorporating alternative window treatments are viable and economical solutions to mitigating the effects of explosive attacks but will be evaluated prior to installation so that reduction in glass hazards **\1** for the applicable level or protection **/1/** may be validated.

B-3.1.9 Exterior Stairwells and Covered or Enclosed Walkways.

\1 Because the glazing in stairwells and covered or enclosed walkways must comply with Standard 10 in Chapter 3 **/1/** building components behind the exterior stairwell glazing should be capable of mitigating any hazards resulting from the stairwell or enclosed walkway glazing failure in response to a blast event in accordance with the applicable levels of protection described in Table B-1. To provide that debris resistance, any windows, inner doors, sidelights, and transoms that are interior to the exterior stairwells or enclosed walkways should meet the windborne debris resistance requirements of ASTM E 1996 (missiles A and D in Table 2) All building components behind stairwells and covered or enclosed walkways should also be designed for blast resistance as if the stairwells or walkways were not present.

B-3.2 Exterior Doors.

For new and existing buildings for which there is an identified explosive threat provide exterior doors into inhabited areas in accordance with the provisions below

B-3.2.1 Unglazed Doors

Provide unglazed doors that are tested to achieve the applicable damage level category in Table B-1 in accordance with ASTM F 2247, with ASTM F 2927, or that meet the provisions of the “Alternative Designs” paragraph below.

- The fasteners and anchorage methods used to attach the tested door assembly should be representative of the actual door installation. Any deviations in actual installation of the connections or the connected elements from those tested should be demonstrated by calculation to provide the applicable level of protection for the specific application.
- The design air blast loading for the test should be the appropriate pressure and impulse from the applicable explosive weight at the actual standoff distance at which the door is sited.

B-3.2.2 Glazed Doors.

Provide glazed doors that are tested to achieve the applicable door damage level category and glazing hazard rating in Table B-1 in accordance with ASTM F 2927 that meet the provisions of the “Alternative Designs” paragraph below. Unless included as part of the tested assembly, glazed sidelights and transoms around doors should meet the window design requirements above.

- The fasteners and anchorage methods used to attach the tested door assembly should be representative of the actual door installation. Any deviations in actual installation of the connections or the connected elements from those tested should be demonstrated by calculation to provide the applicable level of protection for the specific application.

- The design air blast loading for the test should be the appropriate pressure and impulse from the applicable explosive weight at the actual standoff distance between the location of the doors and potential locations for explosives.

B-3.2.3 Alternative Designs.

As an alternative to the above testing provisions for glazed and unglazed doors, position doors such that they will not be propelled into inhabited areas if they fail in response to a blast or provide other means to ensure they are intercepted by a surface with sufficient strength to keep the doors from translating into inhabited areas if they fail or otherwise ensure they do not become hazards to building occupants. The glazing in glazed doors should still meet the glazing and frame bite provisions of Standard 10 if this alternative is exercised to reduce the glazing hazard. The framing, connection, and supporting structure provisions above do not have to be applied for this alternative. Where it is not possible to design surfaces to safely intercept doors, the doors should be designed to remain in the door frames.

B-3.2.4 Vestibules or Foyers.

In vestibules, foyers, or similar entry configurations into inhabited areas where there are inner and outer doors the vestibules, foyers, or similar entries the inner doors should meet the provisions of this appendix and any other glazing associated with inner door entries such as sidelights and transoms should meet the requirements above. The inner doors and glazing should be capable of mitigating any hazards resulting from the enclosed vestibule or foyer outer doors and glazing failure in response to the design blast event. This is to account for the fact that at the levels of protection associated with these best practices the outer doors and glazing may fail, which would subject the inner doors and glazing to significant blast loads. To provide that debris resistance, the inner doors, sidelights, and transoms should meet the windborne debris resistance requirements of ASTM E 1996 (missiles A and D in Table 2).

Alternatively, exterior doors and glazed surfaces of the exteriors of vestibules or foyers can be designed to a minimum of a medium level of protection. Designing to that level will ensure that blast effects do not breach outer layers of vestibules or foyers, protecting inner doors and associated glazing from blast effects. Those inner doors and glazed surfaces could then be designed of conventional construction.

B-3.2.5 Overhead Doors.

Because it is impractical to design conventional overhead doors to meet the required performance in Table B-1, ensure overhead doors do not open into inhabited spaces or ensure that if they fail that they are intercepted by walls or tether systems that are designed with sufficient strength to keep the overhead doors from translating into areas that meet the definition of inhabited spaces.

APPENDIX C REPRESENTATIVE STANDOFF DISTANCES FOR CONVENTIONAL CONSTRUCTION AND EXPEDITIONARY STRUCTURES

C-1 INTRODUCTION.

The purpose of this appendix is to provide representative standoff distances for a number of conventionally constructed walls, roofs, and windows that fall within the parameters of Table C-5. The materials that were selected are for systems that are commonly used in DoD construction. These standoff distances should only be used for project planning and not used as a basis for final design. Even if the final structural elements fall within the parameters of Table C-5 they should be validated during design. The contents in this appendix will be included in UFC 4-020-02 when published. The information contained within may be used when a specific threat has been identified for the location or project based on UFC 4-020-01 or Service, Agency, or Geographic Combatant Command guidance.

C-2 USING THIS APPENDIX.

Each of Table C-1 through Table C-4 corresponds to specific levels of protection from very low to high. Within those columns there are standoff distances for each of the construction types in the leftmost column. Instructions for walls, roofs, and windows follow.

C-3 WALLS.

For each wall type there are two entries for each threat severity level. There is one for load bearing walls (LB) and one for non-load bearing (NLB). Either select a wall material based on available standoff distance or select a standoff distance based on a desired wall material. Note that where wall types include multiple cladding systems such as brick half way up the wall and EIFS above that, use the greater of the two applicable standoff distances for the two wall materials. Note that the walls in Table C-5 have specific ranges of spans and material properties. Table C-1 through Table C-4 are only valid within those ranges of properties. Users must not extrapolate outside of the tables.

C-4 ROOFS.

Roofs seldom control the designs of buildings with respect to blast resistance, but standoff distances for common concrete and metal roofs are tabulated for reference. Other roof types will have to be analyzed separately.

C-5 WINDOWS.

The standoff distances for windows are for conventional laminated glass windows with glazing consistent with the minimum glazing in Paragraph B-3.1.3.1. These windows can be considered conventional windows. Any standoff distances less than those in Table C-1 through Table C-4 for windows will require heavier and more costly blast resistant window systems.

C-6 EXPEDITIONARY STRUCTURES.

Standoff distances to expeditionary structures are based on structure types as indicated in Table C-6. Standoffs are based on blast testing of actual structures of the types indicated. Note that there are some entries that have NDA instead of distances. Those entries reflect instances where there was no data available to make a determination of standoff distance. **\1** For container structures, use standoff distances for pre-engineered buildings in Tables C-1 through C-4. **/1/** Note that there are no entries for windows. If there are windows in expeditionary structures, use the window entries from Tables C-1 through C-4. For more information on standoff distances for expeditionary structures refer to **\1** GTA 90-01-011 **/1/**.

Table C-1 Representative Standoff Distances for Very Low Level of Protection [7]

Construction [1]	Explosive Weight (TNT)											
	55 lbs (25 kg)		220 lbs (100 kg)		550 lbs (250 kg)		1,100 lbs (500 kg)		4,400 lbs (2,000 kg)		19,800 lbs (9,000 kg)	
	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]
Metal Stud with Lightweight Sheathing [4]	150 ft (46 m)	67 ft (20 m)	376 ft (115 m)	162 ft (49 m)	661 ft (201 m)	290 ft (88 m)	971 ft (296 m)	445 ft (136 m)	1642 ft (500 m)	988 ft (301 m)	2656 ft (809 m)	2417 ft (737 m)
Metal Stud with Brick Veneer [4]	74 ft (22 m)	31 ft (9 m)	186 ft (57 m)	84 ft (26 m)	341 ft (104 m)	152 ft (46 m)	538 ft (164 m)	235 ft (72 m)	1303 ft (397 m)	571 ft (174 m)	2545 ft (776 m)	1416 ft (431 m)
Wood Stud with Lightweight Sheathing [4]	85 ft (26 m)	55 ft (17 m)	211 ft (64 m)	139 ft (42 m)	386 ft (118 m)	253 ft (77 m)	601 ft (183 m)	395 ft (120 m)	1441 ft (439 m)	958 ft (292 m)	2645 ft (806 m)	2304 ft (702 m)
Wood Stud with Brick Veneer [4]	36 ft (11 m)	17 ft (5 m)	103 ft (31 m)	64 ft (20 m)	193 ft (59 m)	127 ft (39 m)	303 ft (92 m)	203 ft (62 m)	761 ft (232 m)	498 ft (152 m)	2010 ft (613 m)	1307 ft (398 m)
Pre-engineered Building (Girt and Metal Panel) [4]	104 ft (32 m)	39 ft (12 m)	336 ft (102 m)	108 ft (33 m)	684 ft (209 m)	213 ft (65 m)	1132 ft (345 m)	345 ft (105 m)	1668 ft (508 m)	851 ft (259 m)	2780 ft (847 m)	2418 ft (737 m)
Unreinforced Concrete Masonry [4]	80 ft (24 m)	15 ft (4 m)	262 ft (80 m)	34 ft (10 m)	535 ft (163 m)	71 ft (22 m)	906 ft (276 m)	162 ft (49 m)	1893 ft (577 m)	538 ft (164 m)	2780 ft (847 m)	1651 ft (503 m)
Unreinforced European Clay Masonry [4]	38 ft (11 m)	15 ft (5 m)	163 ft (50 m)	29 ft (9 m)	398 ft (121 m)	51 ft (16 m)	748 ft (228 m)	84 ft (26 m)	1614 ft (492 m)	302 ft (92 m)	N/A	1304 ft (398 m)
Reinforced Masonry [4]	28 ft (9 m)	13 ft (4 m)	85 ft (26 m)	20 ft (6 m)	166 ft (51 m)	38 ft (12 m)	273 ft (83 m)	78 ft (24 m)	736 ft (224 m)	221 ft (67 m)	2212 ft (674 m)	644 ft (196 m)
Reinforced Concrete [4]	22 ft (7 m)	13 ft (4 m)	104 ft (32 m)	23 ft (7 m)	234 ft (71 m)	42 ft (13 m)	424 ft (129 m)	90 ft (27 m)	1255 ft (383 m)	341 ft (104 m)	2504 ft (763 m)	1231 ft (375 m)
Concrete roofs and Metal Roofs with concrete topping [5]	13 ft (4 m)		18 ft (5 m)		25 ft (8 m)		(47 ft (14 m)		155 ft (47 m)		560 ft (171 m)	
Windows [6]	40 ft (12 m)		93 ft (28 m)		155 ft (47 m)		230 ft (70 m)		504 ft (154 m)		1070 ft (326 m)	
Minimum Standoff Distance [8]	13 ft (4 m)		20 ft (6 m)		26 ft (8 m)		33 ft (10 m)		50 ft (15 m)		82 ft (25 m)	

1. Refer to **\1** Table C-5 **/1/** for details on the analysis assumptions and material properties for these wall and roof types.
2. Load bearing construction.
3. Non-load bearing construction.
4. Where wall types include multiple cladding systems, such as brick half way up the wall and EIFS above that, use the greater of the two applicable standoff distances. For additional information on Steel Studs see PDC TR 15-01, Minimum Standoff Distances for Non-Load Bearing Steel Stud In-Fill Walls.
5. Roof construction seldom controls standoff distances. Standoffs of at least those in this row will commonly be adequate for those roof types. Other roof types will have to be analyzed separately
6. At distances closer than these standoff distances windows will commonly be much heavier and more expensive than conventional windows.
7. Note that these standoff distances are for planning purposes only. All building components should be designed for blast loading and conventional loading.
8. See Paragraph B-2.1.3.

Table C-2 Representative Standoff Distances for Low Level of Protection [7]

Construction [1]	Explosive Weight (TNT)											
	55 lbs (25 kg)		220 lbs (100 kg)		550 lbs (250 kg)		1,100 lbs (500 kg)		4,400 lbs (2,000 kg)		19,800 lbs (9,000 kg)	
	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]
Metal Stud with Lightweight Sheathing [4]	150 ft (46 m)	84 ft (26 m)	376 ft (115 m)	206 ft (63 m)	661 ft (201 m)	372 ft (113 m)	971 ft (296 m)	566 ft (173 m)	1642 ft (500 m)	1279 ft (390 m)	2656 ft (809 m)	2910 ft (887 m)
Metal Stud with Brick Veneer [4]	74 ft (22 m)	42 ft (13 m)	186 ft (57 m)	107 ft (33 m)	341 ft (104 m)	191 ft (58 m)	538 ft (164 m)	300 ft (91 m)	1303 ft (397 m)	730 ft (223 m)	2545 ft (776 m)	1779 ft (542 m)
Wood Stud with Lightweight Sheathing [4]	85 ft (26 m)	65 ft (20 m)	211 ft (64 m)	163 ft (50 m)	386 ft (118 m)	299 ft (91 m)	601 ft (183 m)	465 ft (142 m)	1441 ft (439 m)	1134 ft (346 m)	2645 ft (806 m)	2625 ft (800 m)
Wood Stud with Brick Veneer [4]	36 ft (11 m)	22 ft (7 m)	103 ft (31 m)	78 ft (24 m)	193 ft (59 m)	150 ft (46 m)	303 ft (92 m)	238 ft (73 m)	761 ft (232 m)	589 ft (179 m)	2010 ft (613 m)	1546 ft (471 m)
Pre-engineered Building (Girt and Metal Panel [4])	104 ft (32 m)	54 ft (17 m)	336 ft (102 m)	151 ft (46 m)	684 ft (209 m)	287 ft (88 m)	1132 ft (345 m)	458 ft (140 m)	1668 ft (508 m)	1294 ft (394 m)	2780 ft (847 m)	2985 ft (910 m)
Unreinforced Concrete Masonry [4]	80 ft (24 m)	26 ft (8 m)	262 ft (80 m)	124 ft (38 m)	535 ft (163 m)	276 ft (84 m)	906 ft (276 m)	484 ft (148 m)	1893 ft (577 m)	1393 ft (425 m)	2780 ft (847 m)	2940 ft (896 m)
Unreinforced European Clay Masonry [4]	38 ft (11 m)	22 ft (7 m)	163 ft (50 m)	59 ft (18 m)	398 ft (121 m)	148 ft (45 m)	748 ft (228 m)	314 ft (96 m)	1614 ft (492 m)	1146 ft (349 m)	N/A	2688 ft (819 m)
Reinforced Masonry [4]	28 ft (9 m)	13 ft (4 m)	85 ft (26 m)	30 ft (9 m)	166 ft (51 m)	72 ft (22 m)	273 ft (83 m)	120 ft (37 m)	736 ft (224 m)	326 ft (99 m)	2212 ft (674 m)	945 ft (288 m)
Reinforced Concrete [4]	22 ft (7 m)	14 ft (4 m)	104 ft (32 m)	35 ft (11 m)	234 ft (71 m)	105 ft (32 m)	424 ft (129 m)	200 ft (61 m)	1255 ft (383 m)	663 ft (202 m)	2504 ft (763 m)	2122 ft (647 m)
Concrete roofs and Metal Roofs w/ concrete topping[5]	13 ft (4 m)		23 ft (7 m)		50 ft (15 m)		92 ft (28 m)		270 ft (82 m)		737 ft (225 m)	
Windows [6]	51 ft (15 m)		123 ft (37 m)		197 ft (60 m)		269 ft (82 m)		545 ft (166 m)		1092 ft (333 m)	
Minimum Standoff Distance [8]	13 ft (4 m)		20 ft (6 m)		26 ft (8 m)		33 ft (10 m)		50 ft (15 m)		82 ft (25 m)	

1. Refer to **\1** Table C-5 **/1/** for details on the analysis assumptions and material properties for these wall and roof types.
2. Load bearing construction.
3. Non-load bearing construction.
4. Where wall types include multiple cladding systems, such as brick half way up the wall and EIFS above that, use the greater of the two applicable standoff distances. For additional information on Steel Studs see PDC TR 15-01, Minimum Standoff Distances for Non-Load Bearing Steel Stud In-Fill Walls.
5. Roof construction seldom controls standoff distances. Standoffs of at least those in this row will commonly be adequate for those roof types. Other roof types will have to be analyzed separately
6. At distances closer than these standoff distances windows will commonly be much heavier and more expensive than conventional windows.
7. Note that these standoff distances are for planning purposes only. All building components should be designed for blast loading and conventional loading.
8. See Paragraph B-2.1.3.

Table C-3 Representative Standoff Distances for Medium Level of Protection [7]

Construction [1]	Explosive Weights (TNT)											
	55 lbs (25 kg)		220 lbs (100 kg)		550 lbs (250 kg)		1,100 lbs (500 kg)		4,400 lbs (2,000 kg)		19,800 lbs (9,000 kg)	
	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]
Metal Stud with Lightweight Sheathing [4]	311 ft (95 m)	150 ft (46 m)	701 ft (214 m)	376 ft (115 m)	844 ft (257 m)	661 ft (201 m)	1004 ft (306 m)	971 ft (296 m)	1504 ft (459 m)	1642 ft (500 m)	2567 ft (783 m)	2656 ft (809 m)
Metal Stud with Brick Veneer [4]	148 ft (45 m)	74 ft (22 m)	380 ft (116 m)	186 ft (57 m)	710 ft (216 m)	341 ft (104 m)	1145 ft (349 m)	538 ft (164 m)	1679 ft (512 m)	1303 ft (397 m)	2745 ft (837 m)	2545 ft (776 m)
Wood Stud with Lightweight Sheathing [4]	151 ft (46 m)	85 ft (26 m)	390 ft (119 m)	211 ft (64 m)	714 ft (218 m)	386 ft (118 m)	1076 ft (328 m)	601 ft (183 m)	1553 ft (473 m)	1441 ft (439 m)	2726 ft (831 m)	2645 ft (806 m)
Wood Stud with Brick Veneer [4]	67 ft (21 m)	36 ft (11 m)	186 ft (57 m)	103 ft (31 m)	345 ft (105 m)	193 ft (59 m)	554 ft (169 m)	303 ft (92 m)	1402 ft (427 m)	761 ft (232 m)	2642 ft (805 m)	2010 ft (613 m)
Pre-engineered Building (Girt and Metal Panel [4])	269 ft (82 m)	104 ft (32 m)	633 ft (193 m)	336 ft (102 m)	818 ft (249 m)	684 ft (209 m)	1096 ft (334 m)	1132 ft (345 m)	1682 ft (513 m)	1668 ft (508 m)	2505 ft (764 m)	2780 ft (847 m)
Unreinforced Concrete Masonry [4]	365 ft (111 m)	80 ft (24 m)	567 ft (173 m)	262 ft (80 m)	808 ft (246 m)	535 ft (163 m)	1033 ft (315 m)	906 ft (276 m)	1512 ft (461 m)	1893 ft (577 m)	2515 ft (767 m)	2780 ft (847 m)
Unreinforced European Clay Masonry [4]	N/A	38 ft (11 m)	N/A	163 ft (50 m)	N/A	398 ft (121 m)	N/A	748 ft (228 m)	N/A	1614 ft (492 m)	N/A	N/A
Reinforced Masonry [4]	224 ft (68 m)	28 ft (9 m)	563 ft (171 m)	85 ft (26 m)	768 ft (234 m)	166 ft (51 m)	1010 ft (308 m)	273 ft (83 m)	1598 ft (487 m)	736 ft (224 m)	2691 ft (820 m)	2212 ft (674 m)
Reinforced Concrete [4]	276 ft (84 m)	22 ft (7 m)	489 ft (149 m)	104 ft (32 m)	822 ft (251 m)	234 ft (71 m)	918 ft (280 m)	424 ft (129 m)	1433 ft (437 m)	1255 ft (383 m)	2672 ft (814 m)	2504 ft (763 m)
Concrete roofs and Metal Roofs w/ concrete topping[5]	15 ft (5 m)		43 ft (15 m)		101 ft (31 m)		171 ft (52 m)		443 ft (166 m)		1086 ft (333 m)	
Windows [6]	51 ft (15 m)		123 ft (37 m)		197 ft (60 m)		269 ft (82 m)		545 ft (166 m)		1092 ft (333 m)	
Minimum Standoff Distance [8]	13 ft (4 m)		20 ft (6 m)		26 ft (8 m)		33 ft (10 m)		50 ft (15 m)		82 ft (25 m)	

1. Refer to **\1** Table C-5 **/1/** for details on the analysis assumptions and material properties for these wall and roof types.
2. Load bearing construction.
3. Non-load bearing construction.
4. Where wall types include multiple cladding systems, such as brick half way up the wall and EIFS above that, use the greater of the two applicable standoff distances. For additional information on Steel Studs see PDC TR 15-01, Minimum Standoff Distances for Non-Load Bearing Steel Stud In-Fill Walls.
5. Roof construction seldom controls standoff distances. Standoffs of at least those in this row will commonly be adequate for those roof types. Other roof types will have to be analyzed separately
6. At distances closer than these standoff distances windows will commonly be much heavier and more expensive than conventional windows.
7. Note that these standoff distances are for planning purposes only. All building components should be designed for blast loading and conventional loading.
8. See Paragraph B-2.1.3.

Table C-4 Representative Standoff Distances for High Level of Protection [7]

Construction [1]	Explosive Weights (TNT)											
	55 lbs (25 kg)		220 lbs (100 kg)		550 lbs (250 kg)		1,100 lbs (500 kg)		4,400 lbs (2,000 kg)		19,800 lbs (9,000 kg)	
	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]	LB [2]	NLB [3]
Metal Stud with Lightweight Sheathing [4]	311 ft (95 m)	311 ft (95 m)	701 ft (214 m)	701 ft (214 m)	844 ft (257 m)	844 ft (257 m)	1004 ft (306 m)	1004 ft (306 m)	1504 ft (459 m)	1504 ft (459 m)	2567 ft (783 m)	2567 ft (783 m)
Metal Stud with Brick Veneer [4]	148 ft (45 m)	148 ft (45 m)	380 ft (116 m)	380 ft (116 m)	710 ft (216 m)	710 ft (216 m)	1145 ft (349 m)	1145 ft (349 m)	1679 ft (512 m)	1679 ft (512 m)	2745 ft (837 m)	2745 ft (837 m)
Wood Stud with Lightweight Sheathing [4]	151 ft (46 m)	151 ft (46 m)	390 ft (119 m)	390 ft (119 m)	714 ft (218 m)	714 ft (218 m)	1076 ft (328 m)	1076 ft (328 m)	1553 ft (473 m)	1553 ft (473 m)	2726 ft (831 m)	2726 ft (831 m)
Wood Stud with Brick Veneer [4]	67 ft (21 m)	67 ft (21 m)	186 ft (57 m)	186 ft (57 m)	345 ft (105 m)	345 ft (105 m)	554 ft (169 m)	554 ft (169 m)	1402 ft (427 m)	1402 ft (427 m)	2642 ft (805 m)	2642 ft (805 m)
Pre-engineered Building (Girt and Metal Panel) [4]	269 ft (82 m)	269 ft (82 m)	633 ft (193 m)	633 ft (193 m)	818 ft (249 m)	818 ft (249 m)	1096 ft (334 m)	1096 ft (334 m)	1682 ft (513 m)	1682 ft (513 m)	2505 ft (764 m)	2505 ft (764 m)
Unreinforced Concrete Masonry	365 ft (111 m)	365 ft (111 m)	567 ft (173 m)	567 ft (173 m)	808 ft (246 m)	808 ft (246 m)	1033 ft (315 m)	1033 ft (315 m)	1512 ft (461 m)	1512 ft (461 m)	2515 ft (767 m)	2515 ft (767 m)
Unreinforced European Clay Masonry [4]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Reinforced Masonry [4]	224 ft (68 m)	224 ft (68 m)	563 ft (171 m)	563 ft (171 m)	768 ft (234 m)	768 ft (234 m)	1010 ft (308 m)	1010 ft (308 m)	1598 ft (487 m)	1598 ft (487 m)	2691 ft (820 m)	2691 ft (820 m)
Reinforced Concrete [4]	276 ft (84 m)	276 ft (84 m)	489 ft (149 m)	489 ft (149 m)	822 ft (251 m)	822 ft (251 m)	918 ft (280 m)	918 ft (280 m)	1433 ft (437 m)	1433 ft (437 m)	2672 ft (814 m)	2672 ft (814 m)
Concrete roofs and Metal Roofs w/ concrete topping [5]	208 ft (63 m)		381 ft (116 m)		542 ft (184 m)		699 ft (213 m)		1137 ft (347 m)		2135 ft (651 m)	
Windows [6]	189 ft (58 m)		392 ft (119 m)		602 ft (184 m)		805 ft (245 m)		1412 ft (430 m)		2147 ft (654 m)	
Minimum Standoff Distance [8]	13 ft (4 m)		20 ft (6 m)		26 ft (8 m)		33 ft (10 m)		50 ft (15 m)		82 ft (25 m)	

1. Refer to **\1** Table C-5 **/1/** for details on the analysis assumptions and material properties for these wall and roof types.
2. Load bearing construction.
3. Non-load bearing construction.
4. Where wall types include multiple cladding systems, such as brick half way up the wall and EIFS above that, use the greater of the two applicable standoff distances. For additional information on Steel Studs see PDC TR 15-01, Minimum Standoff Distances for Non-Load Bearing Steel Stud In-Fill Walls.
5. Roof construction seldom controls standoff distances. Standoffs of at least those in this row will commonly be adequate for those roof types. Other roof types will have to be analyzed separately
6. At distances closer than these standoff distances windows will commonly be much heavier and more expensive than conventional windows.
7. Note that these standoff distances are for planning purposes only. All building components should be designed for blast loading and conventional loading.
8. See Paragraph B-2.1.3.

Table C-5 Conventional Construction Parameters

Wall or Roof Type[1]	Analysis Assumptions[2, 10]						
	Sections	Span	Spacing	Support Condition	Supported Weight[5]	Reinforcement Ratio	Min. Static Material Strength
Wood Studs – Brick Veneer	2x4 & 2x6 in (50x100 & 50x150 mm)	8 – 10 ft (2.4 - 3 m)	16 - 24 in (400 – 600 mm)	S-S	44 psf (215 kg/m^2)	N/A	875 psi (6 MPa)
Wood Studs – EIFS	2x4 & 2x6 in (50x100 & 50x150 mm)	8 – 10 ft (2.4 – 3 m)	16 -24 in (400 -600 mm)	S-S	10 psf (49 kg/m^2)	N/A	875 psi (6 MPa)
Steel Studs – Brick Veneer[3]	600S162-43 600S162-54 600S162-68	8 – 12 ft (2.4 – 3.7 m)	16 - 24 in (400 – 600 mm)	S-S	44 psf (215 kg/m^2)	N/A	50,000 psi (345 MPa)
Steel Studs – EIFS[3]	600S162-43 600S162-54 600S162-68	8 – 12 ft (2.4 – 3.7 m)	16 - 24 in (400 – 600 mm)	S-S	10 psf (49 kg/m^2)	N/A	50,000 psi (345 MPa)
Metal Panels[6] (in wall or roof construction)	1.5 – 3 in (38 - 76 mm) 22, 20, & 18 ga	4 – 8 ft (1.2 - 2.4 m)	N/A	S-S	10 psf (49 kg/m^2)	N/A	33,000 psi (228 MPa)
Girts[6] (in wall or roof construction)	8Z3 &10Z3 16, 14, & 12 ga	20 – 25 ft (6 – 7.6 m)	6 – 8 ft (1.8 – 2.4 m)	S-S	5 psf (24 kg/m^2)	N/A	50,000 psi (345 MPa)
Reinforced Concrete[7]	≥ 6 in (≥ 150 mm)	12 – 20 ft (3.7- 6 m)	N/A	S-S, One way flexure	10 psf (49 kg/m^2)	≥ 0.0015	3,000 psi (21 MPa)
Unreinforced Concrete Masonry [4, 8]	6 – 12 in (150 – 300 mm)	8 – 12 ft (2.4 – 3.7 m)	N/A	S-S, One way flexure	10 psf (49 kg/m^2)	0	1,500 psi (10 MPa)
Reinforced Concrete Masonry [7, 8]	8 – 12 in (200 - 300 mm)	10 – 14 ft (3 – 4.3 m)	N/A	S-S, One way flexure	10 psf (49 kg/m^2)	0.0005 - 0.0030	1,500 psi (10 MPa)

Wall or Roof Type[1]	**Analysis Assumptions**[2, 10]						
	Sections	**Span**	**Spacing**	**Support Condition**	**Supported Weight**[5]	**Reinforcement Ratio**	**Min. Static Material Strength**
European Clay Block Masonry[4, 9]	6 – 8 in (150 – 200 mm)	10 – 12 ft (3 – 3.7 m)	N/A	S-S, Brittle Flexure	10 psf (49 kg/m^2)	0	1,800 psi (12 MPa)
Concrete Roofs[7]	4 – 12 in (100 - 300 mm)	6 ft (1.8 m)	N/A	F-S	15 psf (73 kg/m^2)	0.0015 - 0.005	3,000 psi (21 MPa)
Metal Roofs	K and LH joists with Metal Deck and/or 3.5 - 5.5 in (90 - 140 mm) Concrete Topping	30 ft (9.1m)	4 – 8 ft (1.2 – 2.4 m)	S-S	15 – 90 psf (73 – 439 kg/m^2)	N/A	50,000 psi (345 MPa)

1. Other types of construction other than that shown in this table may be permissible subject to validation by the designer of record.
2. See PDC Technical Report 10-01 for details on the analysis assumptions and material properties.
3. Steel studs are assumed to be connected top and bottom for load bearing walls. For non-load bearing walls steel studs are assumed to have a slip-track connection at the top. For additional information on Steel Studs see PDC TR 15-01, Minimum Standoff Distances for Non-Load Bearing Steel Stud In-Fill Walls.
4. Unreinforced masonry must have adequate lateral support at the top and bottom.
5. Weight supported by the wall that moves through the same deflection as the wall, not including self-weight of the component.
6. For walls or roofs built using metal panels and girts; use the greater of the standoffs for the metal panel and the girt.
7. Reinforcing steel is 60,000 psi (414 MPa) tensile strength.
8. Concrete Masonry Units (excluding European block) are medium weight (120 pcf / 1922 kg/m^3)
9. European clay block masonry complies with DIN: 105 Teil 1 + 2/HLz B
10. Shear will need to be checked when using higher than minimum material strengths.

S-S = Simple - Simple Supports F-S = Fixed - Simple Supports

Table C-6 Standoff Distances for Expeditionary Structures

Explosive Weight	LOP	Expeditionary Structure Type			
		TEMPER and GP Tents	Small Shelter System	SEA Hut	Retrofitted SEA Hut
55 lbs (25 kg)	VL	33 ft (10 m)	33 ft (10 m)	75 ft (23 m)	NDA*
	L	46 ft (14 m)	46 ft (14 m)	105 ft (32 m)	45 ft (14m)
	M	67 ft (20 m)	59 ft (18 m)	135 ft (41 m)	65 ft (20 m)
	H	157 ft (48 m)	NDA	190 ft (58 m)	90 ft (27 m)
220 lbs (25 kg)	VL	79 ft (24 m)	79 ft (24 m)	154 ft (47 m)	NDA
	L	115 ft (35 m)	105 ft (32 m)	177 ft (54 m)	94 ft (29 m)
	M	145 ft (44 m)	145 ft (44 m)	256 ft (78 m)	123 ft (38 m)
	H	355 ft (108 m)	NDA	375 ft (114 m)	184 ft (56 m)
550 lbs (250 kg)	VL	NDA	NDA	NDA	NDA
	L	176 ft (54 m)	180 ft (55 m)	269 ft (82 m)	133 ft (41 m)
	M	220 ft (67 m)	249 ft (76 m)	387 ft (117 m)	178 ft (54 m)
	H	540 ft (165 m)	NDA	558 ft (170 m)	275 ft (84 m)
1100 lbs (550 kg)	VL	NDA	NDA	NDA	NDA
	L	243 ft (74 m)	262 ft (80 m)	355 ft (108 m)	174 ft (53 m)
	M	299 ft (91 m)	355 ft (108 m)	515 ft (157 m)	237 ft (72 m)
	H	705 ft (215 m)	NDA	760 ft (232 m)	355 ft (108 m)
4400 lbs (2000 kg)	VL	NDA	NDA	NDA	NDA
	L	447 ft (145 m)	490 ft (149 m)	576 ft (176 m)	288 ft (88 m)
	M	507 ft (155 m)	640 ft (195 m)	820 ft (250 m)	395 ft (120 m)
	H	1216 ft (371 m)	NDA	1285 ft (392 m)	593 ft (181 m)
19,800 lbs	VL	NDA	NDA	NDA	NDA
	L	755 ft (230 m)	924 ft (282 m)	NDA	NDA
	M	870 ft (265 m)	1285 ft (392 m)	1370 ft (418 m)	646 ft (197 m)
	H	2089 ft (637 m)	NDA	NDA	NDA
* NDA stands for No Data Available					

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APPENDIX D GLOSSARY

D-1 ABBREVIATIONS AND ACRONYMS.

ACHP Advisory Council on Historic Preservation

ANSI American National Standards Institute

ARPA Archaeological Resources Protection Act

ASTM Not an Abbreviation (Formerly American Society of Testing and Materials, now ASTM International)

AT Antiterrorism

BIA Bilateral Infrastructure Agreements

C Tributary width increase factor

CCSD Conventional Construction Standoff Distance

CFM Cubic Feet per Minute

cm Centimeter

CONEX Container Express

DIN Deutsches Institut fur Normung (German Institute for Standardization)

DBT Design Basis Threat

DoD Department of Defense

EIFS Exterior Insulation and Finish System

ESC Expandable Shelter Containers

FCU Fan Coil Unit

FPCON Force Protection Condition

FSTFS Frame-Supported Tensioned Fabric Structures

ft. Feet

GCC Geographic Combatant Commander

GP General Purpose

GSA General Services Administration (U.S.)

HNFA	Host Nation Funded Construction Agreement
HQUSACE	Headquarters, US Army Corps of Engineers
HVAC	Heating, Ventilating, and Air Conditioning
IGU	Insulating Glass Units
in.	Inches
ISC	Interagency Security Committee
JFOB	Joint Forward Operations Base
Kg/m^2	Kilograms per square meter
Kg/m^3	Kilograms per cubic meter
LB	Load Bearing
LOC	Local Operating Console
m	Meters
MILCON	Military Construction
mm	Millimeters
MPa	MegaPascals
MSS	Medium Shelter Systems
M_{CW}	Moment, conventional wall
M_{SSE}	Moment, Supporting Structural Element
NATO	North Atlantic Treaty Organization
NAVFAC	Naval Facilities Engineering Command
NCR	National Capital Region
NFPA	National Fire Protection Association
NHPA	National Historic Preservation Act
NLB	Non-Load Bearing

OPORD Operations Orders

OSD Office of the Secretary of Defense

Pa Pascals

PCF Pounds per cubic foot

PDC Protective Design Center

PSF Pounds per square foot

PSI Pounds per square inch

RFP Request for Proposal

R_M Minimum Standoff Distance

SHAPE Supreme Headquarters Allied Powers Europe

SOFA Status of Forces Agreement

SSS Small Shelter System

TEMPER Tent, Extendable, Modular, Personnel

TNT Trinitrotoluene

UFC Unified Facilities Criteria

USD (AT&L) Undersecretary of Defense for Acquisition, Technology, and Logistics

V_{CW} Shear, conventional wall

V_{SSE} Shear, Supporting Structural Element

D-2 DEFINITIONS OF TERMS.

Access control. For the purposes of these standards, any combination of barriers, gates, electronic security equipment, and/or guards that can limit entry or parking of unauthorized personnel or vehicles.

Access road. Any roadway such as a maintenance, delivery, service, emergency, or other special limited use road that is necessary for the operation of a building or structure.

Analysis. For the purposes of evaluating compliance with standoff distance and supporting structure requirements of these standards, evaluation of structural components using commonly accepted analysis methodologies such as single degree of freedom or finite element analysis.

Breezeway. A covered passage that passes between two buildings or portions of buildings or covered areas underneath or attached to buildings.

Building. A structure, usually enclosed by walls and a roof, constructed to provide support or shelter for an intended occupancy. Note that other structures, such as canopies or gazebos, are not considered buildings for the purposes of these standards.

Building hardening. Enhanced conventional construction that mitigates threat hazards where standoff distance is limited. Building hardening may also be considered to include the prohibition of certain building materials and construction techniques.

Building occupancy. For the purposes of these standards, the planned occupancy of a building or the allowable occupancy calculated in accordance with life safety codes where the occupancy is not known.

Building overhangs. Any structural configuration in which the outer walls or columns of the ground floor are set back from the outer walls or column lines of floors above.

Building separation. The distance between closest points on the exterior walls of adjacent buildings or structures.

Clear Zone. Areas commonly associated with perimeters that are free of all obstacles, topographical features, and vegetation exceeding 8 in. **\1** (200 mm) **/1/** in height that could impede observation or provide cover and concealment of an aggressor.

Collateral damage. Injury to personnel or damage to buildings that are not the primary targets of attacks.

Command vehicles. Government owned or leased vehicles operated by installation or senior mission commanders, exclusive of privately owned vehicles

Commercial facilities. Facilities that are not DoD owned or operated and that support commercial activities other than food service and retail activities such as banks.

Container structures. Structures built using shipping containers that are designed to withstand structural loadings associated with shipping, including Container Express (CONEX) and International Organization for Standardization (ISO) containers. Testing has shown that these structures behave similarly to buildings for the purposes of these standards.

Controlled parking. For the purposes of these standards, parking that is limited to authorized vehicles that is enforced through physical security measures such as card operated gates, identification or vehicle checks by personnel or similar measures that are acceptable to physical security personnel.

Controlled perimeter. For the purposes of these standards, a physical boundary at which vehicle access is controlled with sufficient means to channel vehicles to the access control points. At a minimum, access control at a controlled perimeter requires the demonstrated capability to search for and detect explosives. Where the controlled perimeter includes a shoreline and there is no defined perimeter beyond the shoreline, the boundary for measuring standoff distances will be at the mean high water mark or the elevation associated with top of bank (associated with a flood recurrence interval of 1.2 years).

Conventional construction. Building construction that is not specifically designed to resist weapons or explosives effects. Conventional construction is designed only to resist common loadings and environmental effects such as wind, seismic, and snow loads. Note that for the purposes of these standards, conventional construction may still require special windows, structural reinforcement around windows, and progressive collapse resistant construction.

Conventional construction standoff distance. The standoff distances at which conventional construction may be used for building components other than doors and windows without a specific analysis of blast effects, except as otherwise required in these standards.

Change of occupancy. Change of occupancy level as defined in these standards. It does not relate to conversions of facility category code. Examples include occupancy changing from low occupancy to inhabited.

Design basis threat. The threat (aggressors, tactics, and associated weapons, tools or explosives) against which assets within a building must be protected and upon which the security engineering design of the building is based.

DoD building. Any building or portion of a building (permanent, temporary, or expeditionary) owned, leased, privatized, or otherwise occupied, managed, or controlled by or for DoD. DoD buildings other than leased buildings are categorized within these standards as low occupancy, inhabited, and high occupancy family housing.

DoD components. The Office of the Secretary of Defense (OSD); the Military Departments (including their National Guard and Reserve Components); the Chairman, Joint Chiefs of Staff and Joint Staff; the Combatant Commands; the Office of the Inspector General of the Department of Defense; the Defense Agencies; the DoD Field Activities; and all other organizational entities within DoD.

DoD Installation. A base, camp, post, yard, center, homeport facility for any ship, or other activity under the jurisdiction of the Department of Defense

DoD personnel. Any U.S. military, DoD civilian or family member thereof, host-nation employees working for DoD, or contractors occupying DoD buildings. For the purposes of these standards, non-DoD visitors to DoD owned or controlled visitor centers, visitor control centers, museums, and similar facilities will be included in DoD personnel populations of those facilities. Visitor counts will be based on routine visitor levels.

Door. A building component for opening or closing an opening in a wall that allows normal access and passage.

Emergency vehicles. Vehicles such as fire trucks and ambulances and other vehicles that are critical to emergency response and for which close proximity to inhabited buildings or containment therein is essential.

Enhanced use lease. Out leases of non-excess DoD land or facilities to a public or private entities for development under the authority of 10 US Code Section 2667.

Equivalent level of protection. Performance of building components that results in building damage or door and glazing hazards similar to that required for the required level of protection as described in Table B-1 or as specified in PDC Technical Report 06-08.

Expeditionary structures. **\2** Non-permanent DoD facilities that are erected in support of military operations in accordance with UFC 1-201-01. **/2/** This group of structures typically includes but is not limited to tents, Small and Medium Shelter Systems, Expandable Shelter Containers (ESC), ISO and CONEX containers, General Purpose (GP) Medium tents and GP Large tents, trailers, and modular and light wood framed structures.

Fabric covered structures. A construction type that can be identified by wood or metal (usually aluminum) posts or load-bearing frames with some type of fabric (such as canvas) stretched or pulled over the posts or frames. Examples of the types of structures that should be considered under this classification of structures include Frame-Supported Tensioned Fabric Structures (FSTFS); Tent, Extendable, Modular, Personnel (TEMPER Tents); and Small and Medium Shelter Systems (SSS and MSS); General Purpose (GP) Medium tents and GP Large tents; and air supported fabric structures. Testing has shown that for these fabric structures, the posts and frames are what cause hazards.

Family housing. DoD buildings used as quarters for DoD personnel and their dependents. For the purposes of these standards, family housing will be considered to include Morale, Welfare, and Recreation housing (cottages) and temporary family lodging of similar occupancies.

Fan Coil Unit (FCU). A device consisting of a heating and / or cooling heat exchanger (coil) and a fan.

Final denial active vehicle barrier. Vehicle barriers that can be raised and lowered or otherwise moved to block traffic lanes to stop the motion of threat vehicles. In Entry Control Facilities / Access Control Points they are located at the end of the response zone (see UFC 4-022-01).

Fisher Houses. Houses constructed by the Fisher House Foundation at military medical centers for lodging families of military personnel while the military personnel are hospitalized.

Force Protection Condition (FPCON). A DoD-approved system that standardizes the Departments' identification and recommended preventive actions and responses to terrorist threats against U.S. personnel and facilities. This system is the principle means for a commander to apply an operational decision on how to protect against terrorism and facilitates inter-Service coordination and support for antiterrorism activities.

Glazing. The part of a window, skylight, or door assembly that is transparent or translucent and transmits light, but not air.

High occupancy family housing. Family housing with 13 or more units per building.

Identification check point. The location in an Entry Control Facility / Access Control Point at which driver identification is checked to control access into controlled perimeters

Inhabited building. Buildings or portions of buildings routinely occupied by 11 or more DoD personnel and with a population density of greater than one person per 430 gross square feet (40 gross square meters). This density generally excludes industrial, maintenance, and storage facilities, except for more densely populated portions of those buildings such as administrative areas. The inhabited building designation also applies to expeditionary structures with similar population densities. In a building that meets the criterion of having 11 or more personnel with low occupancy portions that do not have sufficient population densities to qualify as inhabited buildings, those portions that have sufficient population densities will be considered inhabited buildings while the remainder of the building may be considered low occupancy, subject to provisions of these standards. An example would be a hangar, warehouse, or maintenance facility with an administrative area within it. The administrative area would be treated as an inhabited building while the remainder of the facility could be treated as low occupancy. External stairwells and covered or enclosed walkways are not part of the inhabited space of a building. (Note: This definition differs significantly from the definition for inhabited building used by DoD 6055.09-M and is not to be construed as authorization to deviate from criteria of DoD 6055.09-M.)

Installation: For the purposes of these standards, the installation is an area or locality subject to the custody, jurisdiction, or administration of the Secretary of a Military Department or the Secretary of Defense, in the case of an activity in a foreign country, under the operational control of the Secretary of a Military Department or the Secretary of Defense. This term includes but not limited to, military reservations, bases, posts, camps, stations, or arsenals.

Installation Perimeter: For the purposes of these standards, the installation perimeter is defined as any demarcation identifying the limit of DoD property and directly or indirectly indicating that unauthorized access is prohibited. The landside perimeter may be established with fences, walls, signage, natural barriers or other means. The waterside perimeter will be at the mean high water mark or the elevation associated with top of bank (associated with a flood) recurrence interval of 1.2 years) or be established with channel markers, buoys, float lines, signage, or boat barriers.

Laminated glass. Multiple sheets of glass bonded together by a bonding interlayer.

Level of protection. The degree to which an asset (person, equipment, object, etc.) is protected against injury or damage from an attack.

Low occupancy building. Any building or portion of a building routinely occupied by fewer than 11 DoD personnel or with a population density of less than one person per 430 gross square feet (40 gross square meters).

Low occupancy family housing. Family housing with 12 or fewer units per building.

Mail room. A facility operated by or for the Department of Defense for the receipt and delivery of mail for military units or other authorized organizations and agencies by entities outside the DoD. This does not include mail rooms that receive mail distribution that was initially received at a central DoD mail handling facility.

Mass notification. Capability to provide real-time information to all building occupants or personnel in the immediate vicinity of a building during emergency situations.

Military protective construction. Military facilities designed to resist military conventional and nuclear weapons to the NATO (or equivalent) standards of hardened, protected, semi-hardened, collaterally protected, or splinter protected.

Minimum standoff distance. The smallest permissible standoff distance regardless of any analysis results or hardening of the building.

Mobile ground tactical platforms. Vehicle mounted tactical ground station for posting, processing, and distributing real-time intelligence, surveillance, and reconnaissance information.

Operations support vehicles. Vehicles such as airfield support equipment or material handling equipment whose purpose is direct support to operations, and which are operated only within a restricted access area.

Parking areas. Designated areas where vehicles may be left unattended, including parking lots, designated parking areas along roadways, and roadways within or accessing parking areas.

Progressive collapse. The spread of an initial local failure from building element to building element, eventually resulting in the collapse of an entire structure or a disproportionately large part of it.

Punched window. A window installed as a punched opening surrounded by cladding, as opposed to being arranged in vertical or horizontal strips.

Relocatable building. \3 A facility that is specially designed and constructed to be readily erected, disassembled, transported, stored, and re-used. Examples of relocatable facilities include, but are not limited to, trailers, CONEX boxes, sheds on skids, tension fabric structures, and air-supported domes. A relocatable facility is not constructed as a part of any other military vehicle, DoD tactical equipment (vehicle mounted or wheeled and towable), or equipment that is already accounted for in a designated accountable property system of record. **/3/**

Replacement Cost. The cost to design and construct a facility to current standards and building codes to replace an existing facility at the same location calculated in accordance with UFC 3-701-01.

Ribbon window. Windows installed in vertical or horizontal strips with no building wall elements between them but surrounded by cladding around the overall opening perimeter.

Roadways. Any surface intended for routine motorized vehicle traffic, including driving lanes of parking areas.

Routinely occupied. For the purposes of these standards, an established or predictable pattern of activity within a building that terrorists could recognize and exploit.

Scaled Range. A relationship based on cube-root scaling that allows comparisons to be made among blast wave properties created by detonations of different explosive quantities.

Security engineering. The process of identifying practical, risk managed short and long-term solutions to reduce and/or mitigate dynamic manmade hazards by integrating multiple factors, including construction, equipment, manpower, and procedures.

Skylight. Sloped or horizontal application of a fenestration product that allows for natural day lighting and that may be either fixed (non-operable) or venting (operable).

Spandrel Glass. Glass used in non-vision areas of building exteriors

Specific threat. Known or postulated aggressor activity focused on targeting a particular asset.

Standoff distance. A distance maintained between a building or portion thereof and the potential location for an explosive detonation.

Structural glazed window systems. Window systems in which glazing is bonded to both sides of the window frame using an adhesive such as a high-strength, high-performance structural silicone.

Superstructure. The supporting elements of a building above the foundation.

Supporting structural elements. Structural elements that support windows and that are not in direct contact with the glass, such as walls.

Temporary buildings. **\3** For the purposes of these standards, those buildings, other than expeditionary structures, that are real property facilities and are designed and constructed with a life expectancy of seven years or less. **/3/**

Testing. For the purposes of these standards, experiments performed in accordance with standardized procedures that prove that building components meet the performance required to meet a specific level of protection.

Town Centers. Mixed use small scale retail, health, or community services and family housing facilities in the same buildings.

TNT equivalent weight. The weight of TNT (trinitrotoluene) that has an equivalent energetic output to that of a different weight of another explosive compound.

Transitional structures and spaces. Structures or spaces within buildings that are used to temporarily relocate DoD occupants of buildings while those buildings or other buildings to which they will relocate undergo renovations, modifications, repairs, or restorations or are being constructed. (Also known as swing space.)

Uncontrolled Public Access. Spaces within and beneath buildings where there is insufficient positive access control to preclude unauthorized access. For the purposes of these standards, positive access control will be considered to include (but not be limited to) electronic access control on all exterior doors or providing personnel to control visitors.

Unobstructed space. Space around inhabited buildings in which there are no opportunities for concealment from observation of explosive devices of no less than a 6 in. (150 mm) cube.

Window or Skylight Replacement. The removal of an existing window or skylight assembly and replacement with a new window assembly. For the purposes of this definition a "window assembly" is considered to be the entire system of glazing, framing and anchorage components that fill in and fit within the opening in the wall or roof structure.

APPENDIX E REFERENCES

ADVISORY COUNCIL ON HISTORIC PRESERVATION

http://www.achp.gov/

36 CFR Part 800, *Protection of Historic Properties*

ASTM INTERNATIONAL

http://www.astm.org

ASTM E1300, *Standard Practice for Determining Load Resistance of Glass in Buildings*

ASTM E1996, *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes*

ASTM F1642, *Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings*

ASTM F2247, *Standard Test Method for Metal Doors Used in Blast Resistant Applications (Equivalent Static Method)*

ASTM F2248, *Standard Practice for Specifying an Equivalent 3-Second Duration Design Loading for Blast Resistant Glazing Fabricated with Laminated Glass*

ASTM F2912, *Standard Specification for Glazing and Glazing Systems Subject to Airblast Loadings*

ASTM F2927, *Standard Test Method for Door Systems Subject to Airblast Loadings*

DEPARTMENT OF DEFENSE

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

\3 DOD Instruction 4165.56, *Relocatable Facilities* **/3/**

DoD 6055.09-M, *DoD Ammunition and Explosive Safety Standards*

DoD Instruction 2000.12, *DoD Antiterrorism (AT) Program*

DoD Instruction O-2000.16, *DoD Antiterrorism (AT) Program Implementation (Volumes 1 and 2)*

GTA 90-01-011, **\1** *Deployed Forces Protection Handbook (JFOB Handbook)***/1/** *(For Official Use Only [FOUO])*

The Deputy Secretary of Defense, 7 December 2012, *Memorandum, Subject: Antiterrorism Building Standards for Leased Space*

DEPARTMENT OF DEFENSE, UNIFIED FACILITIES CRITERIA PROGRAM

http://dod.wbdg.org/

Military Standard (MIL-STD) 3007, *Department Of Defense Standard Practice Standard Practice For Unified Facilities Criteria and Unified Facilities Guide Specifications*

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

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

UFC 4-020-02FA, *DoD Security Engineering Facilities Design Manual*

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

UFC 4-022-01, *Security Engineering: Entry Control Facilities/Access Control Points*

UFC 4-023-03, *Design of Buildings to Resist Progressive Collapse*

UFC 4-023-07, *Design to Resist Direct Fire Weapons Effects*

UFC 3-701-01, *DoD Facilities Pricing Guide*

UFC 3-301-01, *Structural Engineering*

DEPARTMENT OF HOMELAND SECURITY

http://www.dhs.gov/interagency-security-committee

Interagency Security Committee Standards

FEDERAL HIGHWAY ADMINISTRATION

http://mutcd.fhwa.dot.gov/

Manual on Uniform Traffic Control Devices

NATIONAL FIRE PROTECTION ASSOCIATION

http://www.nfpa.org

NFPA 30, *Flammable and Combustible Liquids Code*

SUPREME HEADQUARTERS ALLIED POWERS EUROPE

SHAPE Document 6160/SHLOFA-059/82, *NATO Approved Criteria and Standards for Tactical and Transport Airfields (6th Addition) (NATO Restricted)*

UNITED STATES ARMY

https://pdc.usace.army.mil

PDC Technical Report 06-08, *Single Degree of Freedom Structural Response Limits for Antiterrorism Design*

PDC Technical Report 10-01, *Conventional Construction Standoff Distances for the Low and Very Low Levels of Protection*

PDC Technical Report 10-02, *Blast Resistant Design Methodologies for Window Systems Designed Statically and Dynamically*

PDC Technical Report 15-01, *Minimum Standoff Distances for Non-Load-Bearing Steel Stud In-Fill Walls*

UFC 4-010-05
26 May 2023

UNIFIED FACILITIES CRITERIA (UFC)

SCIF/SAPF PLANNING, DESIGN, AND CONSTRUCTION

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UNIFIED FACILITIES CRITERIA (UFC)

SCIF/SAPF
PLANNING, DESIGN, AND CONSTRUCTION

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

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location

This UFC supersedes UFC 4-010-05 Change 1, dated October 2013.

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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.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC is intended to provide unified criteria to make the planning, design and construction communities aware of the published regulatory requirements to ensure timely, consistent, and appropriate implementation.

1-2 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 4-010-05, Change 1, 1 October 2013.

1-3 APPLICABILITY.

This document applies to all construction, renovation, and repair projects for DoD Sensitive Compartmented Information Facility (SCIF) or Special Access Program Facility (SAPF). This UFC applies to each phase of a project, from planning through construction.

1-3.1 SCIF.

SCIF is an accredited area(s), room(s) or building(s) where Sensitive Compartmented Information (SCI) is stored, used, processed or discussed. SCIF is only required for SCI and not required for Confidential, Secret or Top Secret information.

1-3.2 SAPF.

A specific physical space that has been formally accredited in writing by the responsible program security officer (PSO) that satisfies the criteria for generating, safeguarding, handling, discussing, and storing classified or unclassified program information, hardware, and materials.

1-4 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and terms.

1-5 REFERENCES.

APPENDIX C 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 referenced publications applies.

1-6 POLICY.

There are multiple policy documents that establish the baseline requirements for planning, design, construction and accreditation of DoD facilities.

1-6.1 Office of the Director of National Intelligence.

Intelligence Community Directive (ICD) 705 was issued by the Director of National Intelligence (DNI) on May 26, 2010. Intelligence Community Standard (ICS) 705-1, ICS 705-02, and the Intelligence Community (IC) Tech Spec-for ICD/ICS 705 provides the physical and technical security standards for SCIFs, including existing, new construction, and renovations. Refer to ICS 705-1, ICS 705-02, and IC Tech Spec-for ICD/ICS 705 for additional information.

1-6.2 Department of Defense.

- DoDM 5105.21 (Volumes 1-3) are the primary documents associated with SCIFs for the DoD. The manuals are composed of several volumes, each having its own purpose. DoDM 5105.21 volume 2 concerns the physical security of a SCIF and it requires the implementation of Director of National Intelligence (DNI) policies for the protection of SCI and additional requirements.
- DoDM 5205.07 (Volumes 1-4) are the primary documents associated with SAPFs for the DoD. The manual is composed of several volumes, each having its own purpose. DoDM 5205.07 Vol 3 concerns the physical security of a SAPF and it establishes the construction of a SAPF will conform to the equivalent SCIF requirements, as defined in IC Tech Spec-for ICD/ICS 705.
- DoDM 5200.01 volumes 1-3 are the primary document associated with the protection of classified information for the DoD. The manual is composed of several volumes, each having its own purpose. DoDM 5200.01 volume 3 concerns the physical security of a classified information.
- DoDI 5200.48 is the primary document associated with the protection of Controlled Unclassified Information (CUI).

1-7 REGULATORY AUTHORITY.

1-7.1 DoD SCIF Authorities.

The DoDM 5105.21 manuals define the regulatory authorities for DoD SCIF.

1-7.2 Non-DoD SCIF Authorities.

In some cases, the DoD may build a SCIF for Non-DoD agencies. These projects will have an IC designated AO sponsor for each construction or renovation project for the Non-DoD agency.

1-7.3 DoD SAPF Authorities.

The DoDM 5205.07 manuals define the regulatory authorities for DoD SAPF. The special access program facility accrediting official (SAO) is defined as the AO for SAPF.

1-8 IMPLEMENTATION.

Note that this UFC was based on IC Tech Spec-for ICD/ICS 705 Version 1.5.1. When the National Counterintelligence and Security Center adopts a newer version, it will have precedence over the requirements contained in this UFC.

1-8.1 Department of Navy.

Refer to NAVFAC INST 4700.1 for additional policy for Department of Navy projects that include a SCIF. The NAVFAC instruction details various steps accomplished in the planning, design and construction phase of a SCIF including roles and responsibilities.

1-8.2 Department of the Army.

Department of the Army projects that include a SCIF, refer to *SCIF Security, Planning, Design, and Construction Tasks* downloadable at: https://www.wbdg.org/army/resource-library/scif-tasks. The task list details various steps accomplished in the planning, design, and construction of a SCIF, including the roles and responsibilities, Per USACE Engineering Regulation 1110-1-8158 Engineering and Design Centers of Expertise Program, for projects containing SCIFs completed by USACE, inclusion of representative(s) from the USACE Protective Design Center as part of the project delivery team is mandatory. For projects executed by any other services, inclusion of the USACE Protective Design Center is optional. Contact information can be found at: https://www.nwo.usace.army.mil/pdc/home/

1-8.3 Department of the Air Force.

Department of the Air Force projects that include a SCIF, the Construction Agency acting on behalf of the AF must utilize their respective task list for the planning, design, construction of SCIFs including the roles and responsibilities. In the rare case where the AF is acting as the DoD Construction Agent, either the NAVFAC or the USACE task list may be used.

1-9 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.

1-10 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.

1-10.1 Mission Critical Facility-Related Control Systems.

Determine facility-related control system categorization in coordination with supported command and mission owner. Incorporate cybersecurity into the mission critical facility-related control systems with a minimum Confidentiality/Integrity/Availability Categorization of Moderate/Moderate/Moderate as indicated in IC Standard 706-02.

1-11 FACILITY CLASSIFICATION.

SCIF and SAPF are classified based on operational requirements. There are various classifications.

1-11.1 Secure Working Area (SWA) or SAP Working Area (SAPWA).

Area where SCI or SAP is handled, discussed, and/or processed but not stored.

1-11.2 Temporary Secure Working Area (TSWA) or Temporary SAP Working Area (TSAPWA).

An accredited area used for the handling, discussing or processing of SCI or SAP information, when use is limited to less than 40 hours per month.

1-11.3 Temporary SCIF (T-SCIF) or Temporary SAPF (T-SAPF).

Established for a limited time to meet tactical, emergency, or immediate operational requirements.

1-11.4 Closed Storage.

An accredited facility where SCI or SAP material is required to be stored in GSA-approved storage containers when not in use. This includes all classified materials, equipment and information.

1-11.5 Open Storage.

An accredited facility in which SCI or SAP information may be openly stored or processed without using a GSA-approved storage container.

1-11.6 Continuous Operation.

An accredited facility staffed and operated 24/7.

1-12 SECURITY IN DEPTH.

Security in Depth (SID) is desired for all SCIF or SAPF and required for locations outside the United States, its possessions or territories. SID is a multilayered approach, which effectively employs human and other physical security measures throughout the installation or facility to create a layered defense against potential threats. The intent of SID is to increase the possibility of detection of potential aggressors prior to compromising the SCI or SAP materials. Per IC Tech Spec for ICD/ICS 705, the primary means to achieve SID include one of the following:

- Located on a Military installation, embassy compound, U.S. Government (USG) compound, or contractor compound with a dedicated response force of U.S. persons.
- Located within a controlled building with separate building access controls, alarms, elevator controls, stairwell controls required to gain access to the buildings or elevators.
- Controlled office areas adjacent to or surrounding the secure area that are protected by an Intrusion Detection System (IDS).
- Located within a fenced compound with access controlled vehicle gate and/or pedestrian gate.

1-13 SECURITY REQUIREMENTS.

ICS 705-1 and IC Tech Spec-for ICD/ICS 705 provide the security standards. Per IC Tech Spec-for ICD/ICS 705, exceeding or not meeting a standard, even when based upon risk, requires an approved waiver.

Waivers are processed and approved in accordance with DoDM 5105.21 Vol 2 for SCIF and DoDM 5205.07 Vol 3 for SAPF.

1-14 SITE SECURITY MANAGER (SSM).

The SSM is responsible for the security aspects of project planning, design and construction. The SSM is also responsible to ensure compliance of all regulatory requirements for the accreditation of the facility. Planners, Project Managers, Design Managers, Designers, and Construction Managers must work closely with the supported command and their designated SSM to determine the requirements for each project and ensure the implementation of the policy based requirements.

Projects with a SCIF and a SAPF may have two different SSMs reporting to two different AOs.

1-15 CONSTRUCTION SECURITY PLAN (CSP).

The CSP documents the security requirements from planning through construction for each project. Per IC Tech Spec-for ICD/ICS 705, a CSP is developed by the SSM and approved by the AO for each project.

Per IC Tech Spec – for ICD/ICS 705, do not award a construction contract without an approved CSP. See DoDM 5105.21 Vol 2 for SCIF and DoDM 5205.07 Vol 3 for SAPF for additional information and for Navy and Marine Corps projects, refer to NAVFAC INST 4700.01.

1-16 INFORMATION SECURITY.

Per ICS 705-1, construction plans and related documents are to be handled and protected in accordance with the CSP. Construction plans and related documents may be publicly releasable, CUI, or if Classification Guide dictates, plans and related documents may require classification. Refer to DoDM 5200.01 Vol 3 for the handling of classified information and DoDI 5200.48 for the handling of Controlled Unclassified Information (CUI).

1-16.1 SCIF Location and Identity.

DoDM 5105.21 Vol 2 states the facility's location (complete address) and identity of a SCIF must be protected at a minimum of CUI. Drawings or diagrams identified as a SCIF may not be posted on an UNCLASSIFIED website, transmitted over the Internet without some type of encryption or included on public releasable documents. Therefore, do not identify SCIF locations on planning or construction documents. With SSM's approval, areas may be identified as “Restricted Area”. “Controlled Space”, “Secure Area”, “Controlled Area” or some other non-identifiable name.

1-16.2 SAPF Location and Identity.

Similar to SCIF, coordinate with the SSM on how to identify SAPF locations on planning or construction documents. With the SSM's approval, areas may be identified as “Restricted Area”, “Controlled Space”, “Secure Area”, “Controlled Area” or some other non-identifiable name.

1-16.3 TEMPEST Vulnerabilities and Recommended Countermeasures.

TEMPEST vulnerabilities and recommended countermeasures are classified at a minimum of CONFIDENTIAL when associated with a physical location. A TEMPEST vulnerability or countermeasure associated with a SCIF ID number or in a manner that cannot be connected to the physical location is UNCLASSIFIED[1].

1-16.4 Security Environment Threat List (SETL) Information.

The SETL and its contents including a country's threat category is classified Secret.

1-17 DESIGN SECURITY.

Per IC Tech Spec – for ICD/ICS 705, design must be performed by U.S. companies using U.S. citizens or U.S. persons. AO must ensure mitigations are implemented when using non-U.S. citizens and these mitigations are documented in the CSP.

1-18 CONSTRUCTION SECURITY.

Depending on the location of the facility, the AO may impose procedures for the procurement, shipping, selection, and secure storage of construction materials. In

[1] DoDM 5105.21 Vol 2

addition, there may be site security and access control that may include vehicle and personnel inspections. The CSP documents the security requirements for each project. For reference, DoDM 5105.21-Volume 2 and DoD M5205.07 Volume 3 provide additional information on security requirements for DoD SCIF and SAPF construction projects.

1-18.1 Within the United States.

For facilities located within the U.S., its possessions or territories, general construction of the SCIF or SAPF must be performed by U.S. companies using U.S. citizens or U.S. persons. The AO must ensure mitigations are implemented when using non-U.S. citizens. These mitigations must be documented in the CSP.

Per IC Tech Spec – for ICD/ICS 705, Intrusion Detection System (IDS) installation and testing must be performed by U.S. companies using U.S. citizens. However, 5200.01, Volume 3 requires that the alarm installation and maintenance for IDS that protect classified information be accomplished by U.S. citizens who have been subjected to a trustworthiness determination.

1-18.2 Outside the United States.

For facilities located outside the U.S., its possessions or territories, general construction of the SCIF or SAPF must be performed using U.S. companies using U.S. citizens.

- On military facilities, the AO may authorize foreign national citizens or companies to perform general construction. In this situation, the SSM must prescribe, with AO approval, mitigating strategies. These mitigations must be documented in the CSP.
- U.S. Top Secret-cleared personnel must perform finish work in Category I and II countries. U.S. Secret-cleared personnel must perform finish work in Category III countries. Finish work includes activities such as closing up wall structures; installing, floating, taping and sealing wallboards; installing trim, chair rail, molding, flooring; acoustical ceiling tile, light fixtures, device plates, diffusers, registers, grilles, and painting.
- IDS installation and testing must be performed by personnel who are U.S. Top Secret-cleared or U.S. Secret-cleared and escorted by SCIF or SAPF personnel.

1-19 ACCREDITATION.

Accreditation is a formal process to ensure that a facility has been designed, constructed, inspected, and certified to operate in accordance with the provisions of ICD 705. Refer to DoDM 5105.21, Vol 2 and DoDM 5205.07 Vol 3 for the DoD policy on accreditation.

1-19.1 Accreditation Process.

Inspections and evaluations are typically performed by the SSM, or designee, prior to initial accreditation. The accreditation process includes, site inspections and a review of documents relating to design, construction, and testing. The SSM is responsible for assembling and submitting documents for AO approval. The forms for these documents are included in the IC Tech Spec – for ICD/ICS 705. These documents include, but are not limited to the following:

- Construction Security Plan
- Fixed Facility Checklist
- TEMPEST Addendum
- Pre-Construction Checklist

Planners, Designers of Record, Project Managers, and Construction Mangers must provide the SSM the project information needed to develop these documents to support the accreditation process. Information may include, site plans, floorplans, IDS plans, and information related to construction methods and materials.

1-19.2 Fixed Facility Checklist (FFC).

The FFC is a standardized form that documents the physical, technical, and procedural security information to obtain accreditation. This document may be CUI or Classified depending on contents.

1-19.3 TEMPEST Addendum.

The requesting command's Special Security Officer (SSO) or SSM will use the TEMPEST addendum to the FFC, sometimes referred to as the TEMPEST Checklist to request the TEMPEST Countermeasures Review (TCR) by the Certified Technical TEMPEST Authority (CTTA). For an initial TCR, the addendum will be submitted to AO during the planning phase[2]. While some specific information may not be known prior to construction, as much information as possible must be provided in order to minimize costly changes.

The CTTA will provide the TCR based on the TEMPEST addendum and recommend countermeasures to the AO as part of the accreditation process.

1-19.4 Pre-Construction Checklist.

The Pre-Checklist provides the AO with project information, points of contact and information required to assist in the determination of the security requirements for the project and final accreditation.

1-20 HISTORIC PRESERVATION COMPLIANCE.

[2] DoDM 5105.21 Vol 2

1-20.1 Security and Stewardship.

The Department of Defense remains the lead federal agency in balancing security threats with the protection of historic properties. The Department of Defense abides by federal legislation on protecting cultural resources, and issues its own complementary policies for stewardship.

1-20.2 Compliance with Laws.

Implementation of ICD 705 will not supersede DoD's obligation to comply with federal laws regarding cultural resources to include the National Historic Preservation Act (NHPA) and the Archaeological Resources Protection Act (ARPA). Installation personnel must determine possible adverse effects to historic structures and/or archaeological resources during project development and consult accordingly. Personnel at installations outside the United States should coordinate with the applicable host nation regarding possible adverse effects to cultural resources.

1-20.3 Compliance with DoD Standards.

Conversely, historic preservation compliance does not negate the requirement to implement other Department of Defense policy. Federal agencies are always the decision-maker in the Section 106 process of the National Historic Preservation Act. An agency should seek to avoid prolonged consultations that conflict with the imminent need to implement security requirements. Preservation considerations and security standards are not mutually exclusive, and any compliance conflicts should be quickly and effectively resolved in consultation with appropriate stakeholders.

1-21 SECURITY ENGINEERING UFC SERIES.

This UFC is one of a series of security engineering unified facilities criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include the following:

1-21.1 DoD Minimum Antiterrorism Standards for Buildings.

UFC 4-010-01 establishes standards that provide minimum protection against terrorist attacks for the occupants of all DoD inhabited buildings. This UFC is intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings and inhabited tenant buildings on DoD installations. They also include recommendations that should be, but are not required to be incorporated into all such buildings.

1-21.2 Security Engineering Facilities Planning Manual.

UFC 4-020-01 presents processes for developing the design criteria necessary to incorporate security and antiterrorism into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards, or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also addresses the tradeoffs between cost and risk. The Security Engineering Facilities Planning Manual is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

1-21.3 Security Engineering Facilities Design Manual.

UFC 4-020-02FA provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02FA is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design. The primary audience for the Security Engineering Design Manual is the design team, but it can also be used by security and antiterrorism personnel.

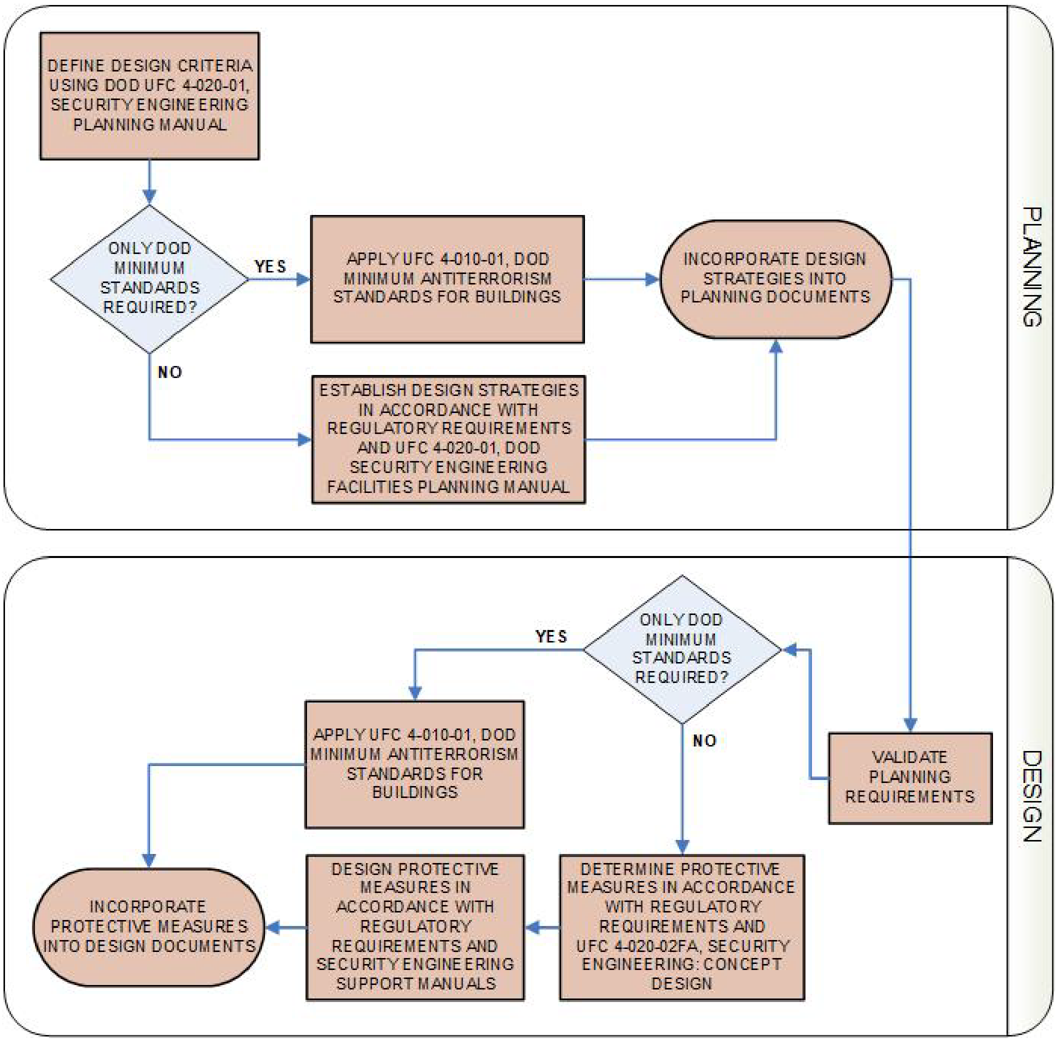
1-21.4 Security Engineering Support Manuals.

In addition to the standards, planning, and design UFCs mentioned above, there is a series of additional UFCs that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02FA. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, forced entry, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mail rooms. Still others address details of designs for specific protective measures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

1-21.5 Security Engineering UFC Application.

The application of the security engineering series of UFCs is illustrated in Figure 1-1. UFC 4-020-01 is intended to be the starting point for any project that is likely to have security or antiterrorism requirements. By beginning with UFC 4-020-01, the design criteria will be developed that establishes which of the other UFCs in the series will need to be applied. The design criteria may indicate that only the minimum standards need to be incorporated, or it may include additional requirements, resulting in the need for application of additional UFCs. Applying this series of UFCs in the manner illustrated in Figure 1-1 will result in the most efficient use of resources for protecting assets against security and antiterrorism related threats.

Figure 1-1 Security Engineering UFC Applicability



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CHAPTER 2 PLANNING

2-1 ESTABLISH PLANNING REQUIREMENTS.

This chapter is intended to make planners aware of requirements that may affect the facility scope and budget. It is not intended to document the standard planning processes related to project development.

2-2 CONCEPT APPROVAL.

SCIFs and SAPFs are established when there are clear operational requirements that are critical to the supported command's mission. All projects begin with an AO's sponsorship. This sponsorship is formalized for SCIF and some SAPFs with the Concept Approval.

2-2.1 SCIF Concept Approval.

Per DoDM 5105.21 Vol 2, to establish a SCIF, the supported command must have Concept Approval. The Concept Approval is the first critical element in the establishment of a SCIF. For approval, the commander must submit a request for SCI to the Service Cognizant Security Authority (CSA), their designee, or DoD Component senior intelligence official (SIO). This is referred to as the request for Concept Approval. Concept Approval certifies that a clear operational requirement exists for the SCIF and there is no existing SCIFs to support the requirement. Proof of sponsorship in the form of a SCIF number or written documentation of Concept Approval from the supported command is required to establish a SCIF.

2-2.2 SAPF Concept Approval.

DoDM 5205.07 Vol 3 does not require Concept Approval for SAPF. Sponsorship for most SAPFs is formalized at the program level.

2-2.2.1 Navy SAPF Concept Approval.

Per DONSAPCO/0779-22 Memo, Director, Department of the Navy Special Program Central Office requires Concept Approval for the establishment of a SAPF. The organization with the requirement for the SAPF submits a concept request endorsed by the leadership of the organization via the Program Security Officer (PSO) and the Government Program Manager (GPM). The concept request must clearly define the operational requirement and identify why existing SAPFs do not meet the need. In addition, the organization is required to identify a Site Security Manager (SSM) for the project.

2-3 MINIMUM AND ENHANCED SECURITY.

ICS 705-1 and IC Tech Spec-for ICD/ICS 705 provide the minimum security standards. The security requirements are based on classification, location, and risk assessment of the facility. APPENDIX A provides an overview of the minimum construction requirements. To implement security enhancements above the minimum, the AO will evaluate the threat, SID and balance the security enhancements with cost at acceptable risk.

2-4 PLANNING TEAM.

Establish an interdisciplinary planning team with local considerations. The interdisciplinary planning team must work together to determine classification of the space and establish the minimum/enhanced security requirements. The planning team may consider user constraints such as operations, manpower requirements or limitations, and sustainment costs when determining the requirements for the overall security solution. The planning team should include the following:

- Planning
- Supported Command
- SSM(s)
- Communications
- Security
- Engineering
- Cultural resources (if historical building)

Some teams may require more than one SSM if the facility includes a SCIF and SAPF.

2-5 PLANNING DOCUMENTATION.

The classification, operation, security requirements, TEMPEST countermeasures, and resulting facility related requirements must be scoped, documented, and budgeted during the planning process. Concept Approval, Preliminary CSP, FFC and TEMPEST Addendum are prepared by the SSM and submitted during the planning phase. These documents define the baseline requirements for the project. For Navy and Marine Corps projects, refer to NAVFAC INST 4700.01 for additional information.

2-6 CONSOLIDATION OF SPACES.

When a facility has more than one SCIF or SAPF, serious consideration must be given to consolidating the multiple spaces into one with Compartmented Areas within. Any consolidation of spaces will reduce initial infrastructure and electronic security systems, associated accreditation requirements, and sustainment. Coordinate consolidation with the supported command to ensure the configuration meets command’s operational (compartmented) requirements.

2-7 VISITOR CONTROL.

Some larger facilities may require additional space at the entrance for processing and visitor control. Program adequate space for processing un-indoctrinated personnel and visitors, issuing badges and space for personnel awaiting escorts.

2-8 PRIMARY ENTRANCE VESTIBULE.

Program space for a vestibule at the primary entrance. Vestibules enhance the security of the space by precluding visual observation into the space and enhancing acoustic protection.

2-9 TELECOMMUNICATION SPACES.

Per UFC 3-580-01, the minimum size for a Telecommunications Room (TR) is 10 feet x 8 feet (3m x 2.4m). This and the normal net to gross calculation may be inadequate if the TR contains equipment racks for multiple networks such as Secret Internet Protocol Router Network (SIPRNet), Joint Worldwide Intelligence Communications System (JWICS), Non-classified Internet Protocol Router Network (NIPRNet) and voice services. Depending on the number of workstations served, this could generate a larger space requirement when considering RED/BLACK separation requirements.

UFC 3-580-01 allows the use of Equipment Room in lieu of a TR for buildings that house substantial Information Technology (IT) electronics. A telecommunication space that contains equipment for multiple classified networks such as SIPRNet, JWICS and NIPRNet all requiring RED/BLACK separation is considered as substantial Information Technology (IT) electronics which would allow for the use of the larger Equipment Rooms.

2-9.1 Temperature and Humidity Control.

Substantial Information Technology (IT) equipment generate a significant amount of heat. In these environments, the heat densities can be up to five times higher than in a typical office load. Traditional HVAC systems cannot remove enough heat to protect this equipment. Instead, these areas require dedicated computer room air conditioner (CRAC) units with higher cooling capabilities. The smallest high-powered CRACs require a minimum 10 ft. x 3 ft. (3m×1m) footprint for equipment and clearances. This area must be included in the equipment room area calculation.

2-10 RESILIENCY.

Some critical operations or communication systems may require redundant utilities, standby power, and redundant systems to ensure continuous operation in the event of utility or equipment failure. Coordinate system and the associated resiliency requirements with the mission commander.

2-10.1 Redundant Utilities.

Critical operations or communication systems may require redundant utilities such as telecommunication system connectivity and utility power services. To be redundant, they must be two separate utilities that are not routed together.

2-10.2 Standby Power Systems (SPS).

Critical operations or Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance and Reconnaissance (C5ISR) systems may require an SPS designed to ensure continuity of electrical power to essential and uninterruptible loads upon loss of normal power sources.

2-10.2.1 Engine-Driven Generator.

When a SPS is required, provide a standby engine-driven generator sized for essential and uninterruptible loads to ensure continued operation upon loss of utility power.

2-10.2.2 Uninterruptible Power System (UPS).

When a SPS is required, provide UPS for the uninterruptible loads to filter commercial power and to support the uninterruptible loads during transitions to and from the standby generator.

2-10.3 Redundancy.

Some critical operations may require a minimum of N+1 redundancy to ensure system availability in the event of component failure. In this configuration, components (N) have at least one independent backup component (+1). An example would be chillers, CRACs, or generators.

2-11 HISTORIC PRESERVATION.

Preservation of Cultural Resources must be considered when converting a historical building into a secure facility or locating a secure space or room within a historic building. For instance, every effort should be made to minimize or eliminate windows, especially on the ground floor. Windows less than 18 feet above the ground or from the nearest platform affording access to the window (measured from the bottom of the window) and doors must be protected against forced entry and meet the standard for the perimeter, which may include acoustic and TEMPEST mitigation. State Historic Preservation Officers (SHPO) may consider window and door modifications to have an adverse effect but allow the modification if the impact is minimized and the effect mitigated. Planners need to explore options and consult with the State Historic Preservation Office (SHPO) to determine options that meet security requirements and are compatible with the Secretary of the Interior's Standards for Rehabilitation.

2-12 CONSTRUCTION SECURITY.

For locations outside the United States, its possessions or territories, the AO may impose procedures for the procurement, shipping, and storing of construction materials at the site. In addition, the AO may require access control to the construction materials and the construction area. These requirements and others are documented in the CSP. Since these additional security measures may have significant cost impacts on a project, they must be determined during project development and documented in the CSP, project planning documents, and the costs must be included in the project budget.

2-13 PROJECT DOCUMENTATION.

Work with the Supported Command, and the SSM to determine and document the classification, operation, and resulting facility requirements for the project. Projects in higher threat areas (outside the United States, its possessions or territories) may have additional security requirements. Determine and document the following during project development:

- Is the SCIF or SAPF the entire facility or an area within the facility?
- Will there be more than one SCIF or SAPF in the facility, if so how many?
  - If more than one, can they be consolidated?
- What is the classification of each space?
- Will the perimeter wall be standard, enhanced, or vault construction?
- What is the required Sound Transmission Class (STC) rating for the perimeter?
- Will there be Compartmented Areas? If so, how many?
  - Is there a STC requirement for the compartmented areas?
- Are there any Electronic Security System (ESS) requirements above that required by IC Tech Spec-for ICD/ICS 705?
- In addition to non-classified Internet Protocol Router Network (NIPRNet) and voice services, what networks such as Secret Internet Protocol Router Network (SIPRNet) or Joint Worldwide Intelligence Communications System (JWICS) that will be processing National Security Information (NSI) be required?
  - Multiple networks will require equipment rooms in lieu of standard telecommunication rooms.
  - Has area been allotted for multiple equipment racks with future expansion, RED/BLACK separation, and CRAC units within the telecommunication spaces?
    - The smallest high-powered CRACs require a minimum 10 ft. x 3 ft. (3m×1m) footprint for equipment and clearances.
- Will operations require redundant utilities such as utility power or telecommunications system connectivity?
- Will operations require standby generator and UPS for continuity of operations?
- Will operations require some level of resiliency such as N+1 chillers, CRACs or standby generators?

- Has the supported command provided the CTTA with a completed TEMPEST Addendum for the TCR?
    - If so, what will be the required TEMPEST countermeasures? RED/BLACK separation, shielding, or filters?
- Are there special procurement, shipping, and storage of construction materials required at the site? If so, what will be required?
- Are there access control requirements for the construction site?
- Are there access control and storage requirements for the construction materials?
- Will U.S. companies using U.S. citizens or U.S. persons be required for construction?
- For projects outside the United States, its possessions or territories:
    - Will U.S. Secret or U.S. Top Secret cleared personnel be required to perform finish work?
    - Will installation and testing of the ESS be performed by U.S. TOP SECRET-cleared personnel or escorted U.S. SECRET-cleared personnel?
- Will any mitigations or countermeasures above the minimum be required?
    - If so, is there an approved waiver?
- Some of these requirements are documented in the CSP. Therefore, it is very important to obtain the preliminary CSP during project development to ensure appropriate security requirements are documented and included in the project scope and budget.

CHAPTER 3 DESIGN

3-1 VALIDATE PLANNING REQUIREMENTS.

Work with the Supported Command and the SSM to validate the requirements established in the planning phase. Operation, classification, and threat classification may have changed since the project was planned. Validate and document the classification, operation, and resulting facility requirements documented in the CSP. Include requirements in the Design Build RFP, design documents, and construction contracts.

3-2 MINIMUM AND ENHANCED SECURITY.

ICS 705-1 and IC Tech Spec-for ICD/ICS 705 provide the minimum and enhanced security standards. APPENDIX A provides an overview of the minimum construction requirements. Per IC Tech Spec-for ICD/ICS 705, exceeding a standard, even when based upon risk, requires a waiver. Planners may have to provide the cost associated with exceeding a standard to include in the evaluation process.

Waivers are processed and approved in accordance with DoDM 5105.21 Vol 2 for SCIF and DoDM 5205.07 Vol 3 for SAPF.

3-3 GENERAL DESIGN STRATEGY.

The general design strategy for any tactic is the basic approach to developing a protective system to mitigate the effects of that tactic. It governs the general application of construction, building support systems, equipment, manpower, and procedures.

The design will vary depending on type, location, SID, risk assessment, and National Security Information (NSI) processing, storage and discussion requirements. Designers must take a six-sided approach when designing a secure space. Design the floor, ceiling, walls and any penetrations to meet the performance requirements for the perimeter.

3-3.1 Consolidation of Spaces.

When a facility has more than one SCIF or SAPF, serious consideration must be given to consolidate the multiple spaces into one. Any consolidation of spaces will reduce initial infrastructure, electronic security systems, associated accreditation requirements, and sustainment costs. Coordinate consolidation with the supported command to ensure the configuration meets command's operational and compartmented requirements.

3-3.2 Perimeter.

The perimeter includes perimeter walls, ceiling, floor, and all penetrations in the perimeter such as windows, doors, ducts and utilities. At a minimum, the perimeter provides:

- Resistance to forced entry
- Resistance to covert entry
- Visual evidence of surreptitious penetration
- Resistance to visual observation
- Sound Attenuation for acoustic eavesdropping
- Countermeasures for Electronic Emanations -TEMPEST (when required)

This includes above the false ceilings and below raised floors.

3-3.3 Building Layout.

To optimize the building layout for security and function, the designer must understand the various secure spaces in the facility, the security clearances of the occupants, visitor access, escort requirements, and the separations or adjacencies required. This takes an integrated design approach that balances the occupant's operational requirements, space requirements, visitor control, security-in-depth and the concept of zoning.

3-3.3.1 Zoning.

Zoning is the concept of grouping functional areas by security or access levels to enhance security. If configured correctly, having multiple zones within a facility can enhance the security of the higher security zones. This is accomplished by requiring personnel to transition through increasingly secure access control layers (zones) prior to accessing the highest security zone. Zones may include public access, controlled access, and restricted access, which can be related to public/visitor areas, service areas, controlled access areas, secret open storage, top secret open storage, SCIF or SAPF. See Figure 3-1 for access layers and Figure 3-2 for a bubble diagram example.

Figure 3-1 Access Layers

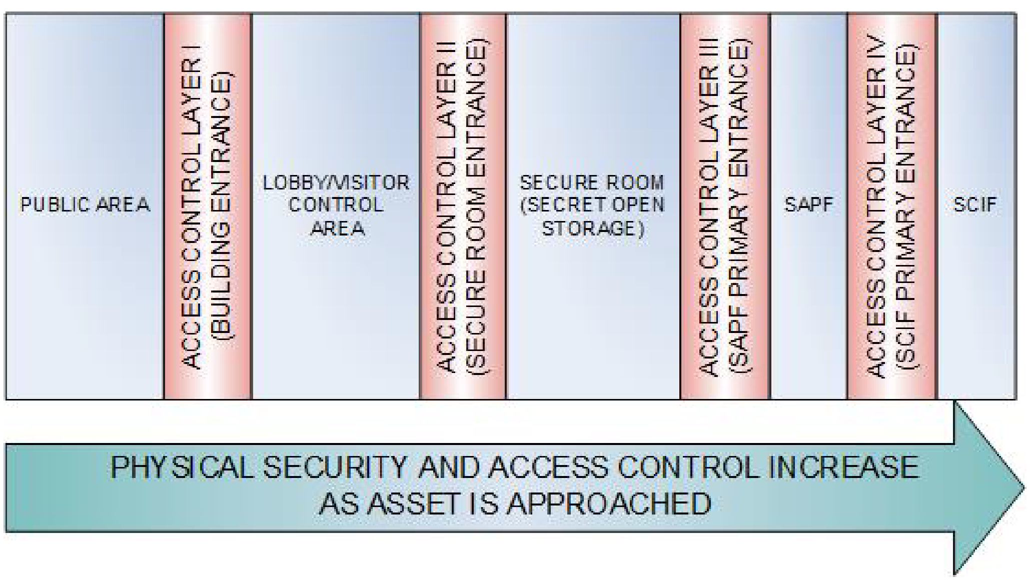
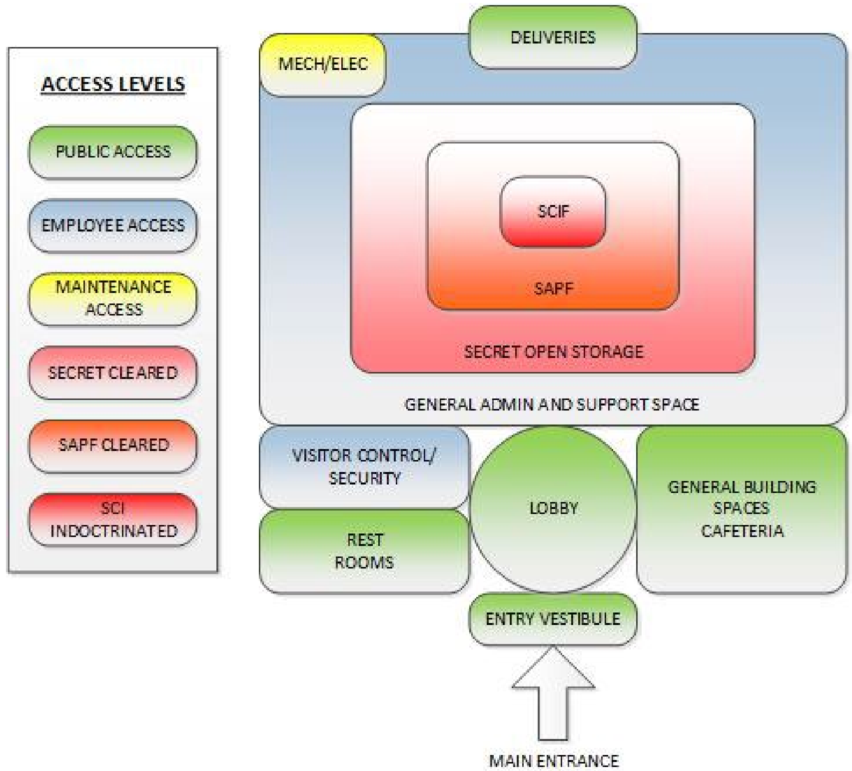


Figure 3-2 Security Zones



3-3.3.2 Layout Criteria.

In developing the building layout:

- Maximize the vertical and horizontal separation between the lowest and highest security areas.
- Maximize grouping of secure areas to enhance floor/ceiling security and to minimize locations of secure elements.
- In large facilities, the highest security area should be located in the building center, upper floor or basement.
- When a facility has multiple security levels, access to the highest security area should be through the area with the next lower security level. An example would be access to the SCIF through a SAPF or secret open storage area.
- Are foreign nationals allowed in the facility to work or participate in training given at the facility? If so, building layout should consolidate high security areas and provide the appropriate separation to minimize the technical threat and escort requirements.
- Utilities and general building support spaces should remain outside of the secure areas.

- Locate telecommunication spaces that contain the encryption equipment within or adjacent (shared wall) to the secure area to enhance security and minimize or eliminate Protected Distribution System (PDS) requirements.
- Entry into a lower security area cannot be through a higher security area. This would require escorts.
- Egress paths from the lower security areas must not pass through a higher security area.
  - Egress stairs intended for use as communicating stairs between secure areas must have appropriate access control at each floor level without compromising safe egress to grade from all floor levels.
  - Vertical circulation elements that are entirely within the secure area may not require additional controls at each landing.

3-3.3.3 Adjacent Space.

To increase SID, locate other areas that require access control adjacent to or surrounding the SCIF or SAPF.

3-3.3.4 Visitor Control.

Some larger facilities may require additional space at the entrance for processing and visitor control. For these facilities, provide adequate space for processing un-indoctrinated personnel and visitors, issuing badges and space for personnel awaiting escorts.

3-4 SPECIFIC DESIGN STRATEGY.

The specific design strategy for any tactic governs how the general design strategy varies for different levels of protection or threat severity. They may vary by the sophistication of the protective measures and the degree of protection provided. The specific design strategies reflect the degree to which assets will be left vulnerable after the protective system has been employed.

3-4.1 Perimeter Construction.

The secure area perimeters and the penetrations in those perimeters are the primary focus of the design and construction. IC Tech Spec-for ICD/ICS 705 provides the minimum and enhanced construction requirements for the perimeter with regard to forced entry, covert entry, visual evidence of surreptitious penetration, and sound attenuation. In addition, radio frequency (RF) shielding and other TEMPEST mitigation must be provided as documented in the TCR. Refer to Best Practices Guidelines for Architectural Radio Frequency Shielding for standard construction for RF shielding.

IC Tech Spec-for ICD/ICS 705 includes suggested construction details for acoustic wall construction and duct penetrations. Designers must ensure that details used from IC

Tech Spec-for ICD/ICS 705 comply with UFC 1-200-01. For example, IC Tech Spec-for ICD/ICS 705 has a suggested wall detail for Wall C - enhanced construction utilizing plywood. However, plywood used for construction of interior partitions must be Fire Retardant Treated (FRT) in buildings required to be of noncombustible construction.

3-4.1.1 Inspectable Perimeter.

Secure space perimeters, including the perimeter above the ceiling or below raised floors may need to be inspected for surreptitious penetration once a space becomes operational. The design should facilitate future inspections by minimizing the above ceiling obstructions on the controlled and uncontrolled side of the secure perimeter. Where hard ceilings are located adjacent to the perimeter, coordinate inspection methods with the SSM and SSO to ensure the capability of above ceiling or below raised floors inspections.

3-4.2 Compartmented Area.

A Compartmented Area may be an area, room, or a set of rooms within the accredited space that provides controlled separation between control systems, compartments, sub-compartments, or Controlled Access Programs. There are three types of compartmented areas. Type I is an area where discussion is not authorized so there is no sound rated construction required. Type II & III are a room, or set of rooms are constructed the same and require acoustic protection.

The design and layout of Type II & III Compartmented Areas is a critical element of the layout of the facility when acoustic protection is required for individual rooms within the space. Compartmented Areas, their type, and adjacencies must be identified early in the design process.

- Acoustic Z-Ducts can increase the above ceiling space requirement
- Sound baffles can significantly affect the HVAC system design due to the increase in backpressure.

3-4.3 Acoustic Protection.

The perimeter of the space must provide acoustic protection. The acoustic protection is intended to protect conversations from being inadvertently overheard outside the secure space, not to protect against deliberate interception of audio.[3]

3-4.3.1 Sound Transmission Class (STC).

The ability of an assembly to retain sound within the perimeter is rated using a descriptive value, the Sound Transmission Class (STC). Architectural Graphics Standards (AGS) established Sound Groups 1 through 4, of which Groups 3 and 4 are

[3] IC Tech Spec – for ICD/ICS 705

considered adequate for specific acoustical security requirements for construction. Per AGS:

- Sound Group 3 – (STC of 45) or better. Loud speech can be faintly heard but not understood. Normal speech is unintelligible.
- Sound Group 4 – (STC of 50) or better. Very loud sounds, such as loud singing, brass musical instruments or a radio at full volume, can be heard only faintly or not at all.

IC Tech Spec – for ICD/ICS 705 provides definitions for Sound Group 3 and 4 based on the above descriptions from AGS.

3-4.3.2 Sound Attenuation Descriptions.

The amount of sound energy reduction may vary according to individual facility requirements. However, Sound Group ratings will be used to describe the effectiveness of acoustical security measures afforded by various wall materials and other building components.

- A minimum of Sound Group 3 (STC 45 or better) for the perimeter unless additional protection is required for amplified sound[3]. This applies to the entire perimeter of the space to include walls, ceilings and floors and perimeter penetrations such as conduit, pipe, ducts, doors, and windows.
- Conference rooms or other areas where amplified audio is used such as video teleconference (VTC) equipment, audio visual systems, and speakerphones must meet Sound Group 4 (STC 50 or better)[3].

3-4.3.3 Minimum Perimeter STC Rating.

The SSM develops the CSP and recommends the STC rating for the perimeter with approval by the AO. The STC ratings for the perimeter should be either STC 45 or STC 50. When factory tested in accordance with ASTM E90, provide assemblies that are no less than STC 50 when STC 45 perimeter is required and no less than STC 55 when STC 50 perimeter is required. This will ensure the assemblies meet the minimum STC requirement when installed correctly. Most factory tests are conducted on assemblies with framing members spaced at 24” (607 mm) on center (o.c.). The spacing of the framing member may be reduced to 16” (406 mm) o.c. without compromising the STC rating[4].

3-4.3.4 Sound Masking.

When normal construction and baffling measures have been determined to be inadequate to meet the sound attenuation requirement, utilize sound masking. See IC Tech Spec for more information on the use of sound masking systems and devices.

[4] GA-600

3-4.4 Perimeter Walls.

SSM, with AO approval, will determine if the perimeter walls are Standard (Wall A), Enhanced (Wall B or C) or vault construction. Walls must go from floor slab (true floor) to underside of floor or roof deck (true ceiling). Perimeter walls, floor and ceiling must be permanently and solidly constructed and attached to each other. Seal partition continuously with acoustical sealant (both sides) and finished to match wall wherever it abuts another element such as the floor, ceiling, wall, or column.

Exception: When an existing wall is constructed with substantial material such as brick, concrete, masonry, the existing wall may be utilized to satisfy the specification[5].

3-4.4.1 Perimeter Wall Variations.

The IC Tech Spec-for ICD/ICS 705 included suggested wall drawings for Standard (Wall A), Enhanced (Wall B or C) and construction criteria for STC 45 and 50 walls. These are suggested and allow variations in wall construction techniques to meet the security standards.

There are criteria beyond the scope of the IC Tech Spec-for ICD/ICS 705 that require walls that may exceed the IC Tech Spec-for ICD/ICS 705. For example, the size of stud and gauge of the metal stud will vary depending on if this is a load bearing, non-load bearing or exterior wall. In some cases, walls may have to span heights greater than normal. For these cases, the stud size or gauge may be increased to reduce wall deflection. For exterior walls, the stud thickness is typically a minimum of 6” (152mm) depending on the thermal insulation requirements of the building envelope. These designs will exceed the IC Tech Spec-for ICD/ICS 705 required STC rating but should not require a waiver since the design exceeds the standard based on other criteria.

3-4.4.2 Gypsum Board.

IC Tech Spec-for ICD/ICS 705 indicates Standard STC 45 wall has three layers of 5/8 inch (15.9 mm) gypsum wallboard (GWB). One layer on the uncontrolled side (outside) of the protected area and two layers on the controlled side (interior) of the protected area to meet STC 45, see Figure 3-3. The STC 50 wall in IC Tech Spec-for ICD/ICS 705 indicates four layers. Two layers on the outside and two layers on the inside, see Figure 3-4.

- Stagger joints on the opposite sides of a partition so they are not on the same stud.
- Install the GWB so that the joints of the face layer are offset from the joints of the base layer.
- Joints in the face layer that are parallel to the framing members must fall over the framing members and offset from the base layer.

[5] IC Tech Spec – for ICD/ICS 705

Exception: When using adhesive between the layers, joints in the face layer do not have to occur over the framing member

3-4.4.3 Factory-Laminated GWB.

To enhance the sound attenuation of the assembly, one layer of factory laminated GWB meeting ASTM C1766 may be used. GWB meeting ASTM C1766 is designed for sound control systems and is composed of two layers of gypsum panels factory-laminated into a composite panel.

Figure 3-3 STC 45 Assembly

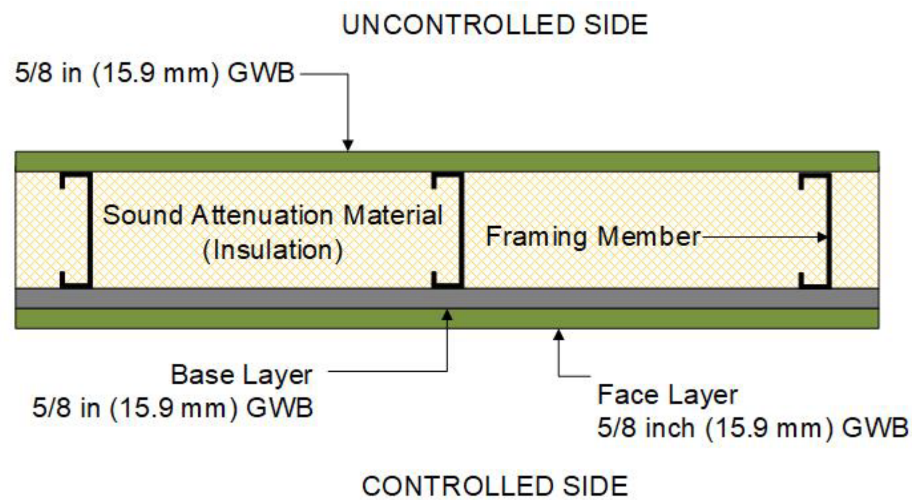
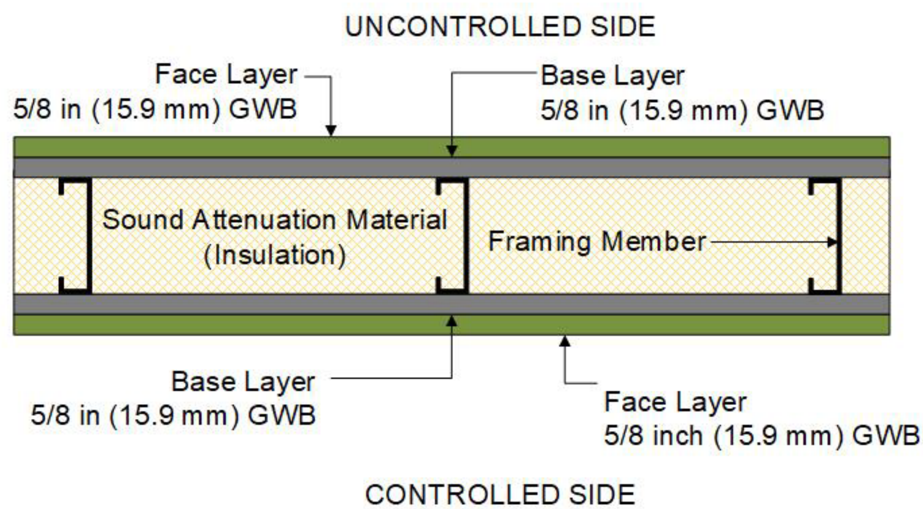


Figure 3-4 STC 50 Assembly



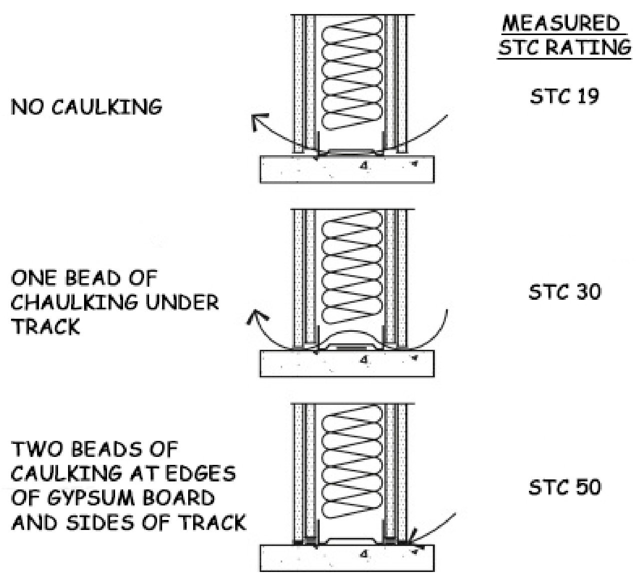
3-4.4.4 Insulation.

Use fibrous insulation to improve the sound isolating performance of the system. Over-packing the cavity may decrease the performance. In addition, the use of spray foam or other hardening insulations may decrease the sound performance.

3-4.4.5 Sealing Gaps.

Gypsum board panels are lifted into place during construction using a spacer under their bottom edge, so there is a 1/8 inch to 1/4 inch (3 mm to 6 mm) gap at the bottom. Sealing openings in partitions is critical to acoustical performance. Seal gaps on both sides with a non-hardening caulk so the acoustical rating of the wall is maintained. Figure 3-5 shows how sealing the gaps effect the STC ratings of the connection.

Figure 3-5 Sealing Tracks



3-4.4.6 Wall Finish.

Walls must be uniformly finished and painted from floor slab (true floor) to underside of floor or roof deck (true ceiling). See Figure 3-6.

3-4.4.7 Utilities on Perimeter Wall.

Utilities such as power, telecommunications, signal, and plumbing on the perimeter or compartmented wall treated for acoustic or RF must be surface mounted or construct a furred out wall for routing of utilities. This include recessed outlet boxes, recessed panels for power, telecommunications, ESS, fire alarm and other systems. Do not mount utilities in a manner that will affect the acoustic or RF shielding performance.

If a furred out wall is used, provide a minimum 3/8 inch (10 mm) gypsum board. The gypsum board only needs to go above the false ceiling. Figure 3-7 shows an example of a furred out wall prior to the installation of the 3/8 inch (10 mm) gypsum board.

Figure 3-6 Wall Finish

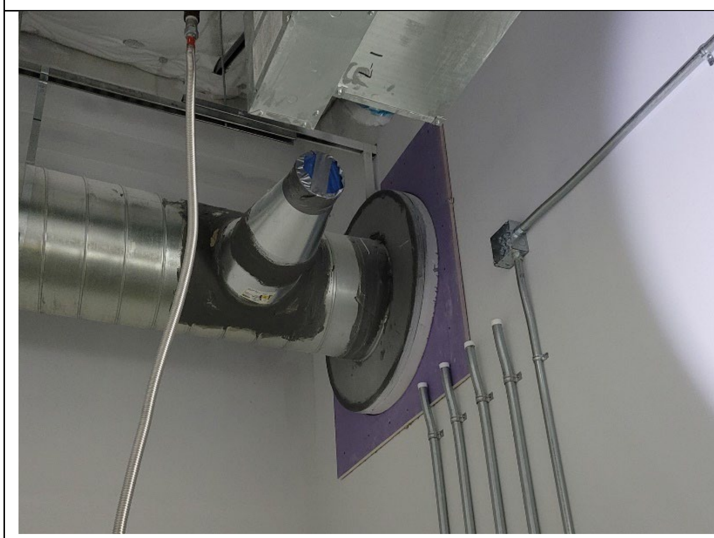
<table>
<tr><td></td><td><u>UNACCEPTABLE</u>
• Wall not uniformly finished and painted.
• Wall assembly does not meet acoustic rating
  - Wall not continuous and sealed where wall abuts floor pan.
• Wall penetrations not sealed.</td></tr>
<tr><td></td><td><u>UNACCEPTABLE</u>
• Not uniformly finished and painted.
• Gap between finished and unfinished GWB
• Gap between unfinished GWB and duct penetration
• Not finished and painted and the penetrations are not sealed and finished.</td></tr>
<tr><td></td><td><u>ACCEPTABLE</u>
• Wall is true floor to true ceiling
• Wall is sealed where wall abuts floor pan.
• Wall is uniformly finished and painted from true floor to true ceiling
• Wall penetrations are sealed.</td></tr>
</table>

Figure 3-7 Furred Out Wall for Utilities

3-4.4.8 Recessed Fire Extinguisher Cabinets.

Recessed fire extinguisher cabinets are prohibited on perimeter or sound rated compartmented area walls.

3-4.5 Ceilings and Floors.

Ceilings and floors must meet the same requirements as walls with regard to forced entry, covert entry, visual evidence of surreptitious penetration, and sound attenuation. In addition, ceilings, floors and all penetrations must meet TEMPEST requirements when recommended by the TCR

3-4.6 Perimeter Doors.

Perimeter doors and frame assembles must meet acoustic requirements unless declared a non-discussion area and protected by IDS. Provide dead bolts for perimeter doors with day access controls for occupants. In addition, perimeter doors must meet TEMPEST requirements when recommended by the TCR. All perimeter doors must be solid with no lites or sidelites.

3-4.6.1 Acoustic Rated Doors.

Use UFGS 08 34 73 to specify acoustical rated door assemblies to include door, seals, hinges, door closer, frame and threshold. Provide door assemblies that are factory tested in accordance with ASTM E90 to no less than STC 50 when a STC 45 perimeter is required and no less than STC 55 when STC 50 perimeter is required. This will help ensure the door assemblies meet the minimum STC requirement when installed correctly.

Acoustical rated door assemblies are much heavier than typical doors and require heavy-duty hardware and structurally adequate support. For acoustics, utilize structural C or U channel in lieu of tubing. Coordinate design of structural support with a Structural Engineer and install in door assembly in accordance with UFGS 08 34 73 and manufacturer's instructions.

3-4.6.2 Wood doors.

When used, wood doors must meet following minimum specifications:

- 1 ¾ inch (45 mm) thick solid wood core (wood stave, structural composite lumber).
- Lock area predrilled.

3-4.6.3 Steel Doors.

At a minimum, steel doors must meet following specifications:

- 1 ¾ inch (45 mm) thick face steel equal to 18 gauge.
- Lock area predrilled and reinforced to 10 gauge.

3-4.6.4 Door Closers.

Equip perimeter doors with a heavy-duty automatic non-hold door-closer installed internal to the perimeter the installation area reinforced to a minimum of 12 gauge for a steel door and at the top rail for a wood door.

3-4.6.5 Electric Locks.

Electric door strikes or electrified mortise locks installed with an access control system (ACS) must have a positive engagement, fail secure, and approved under UL 1034 for burglar resistance.

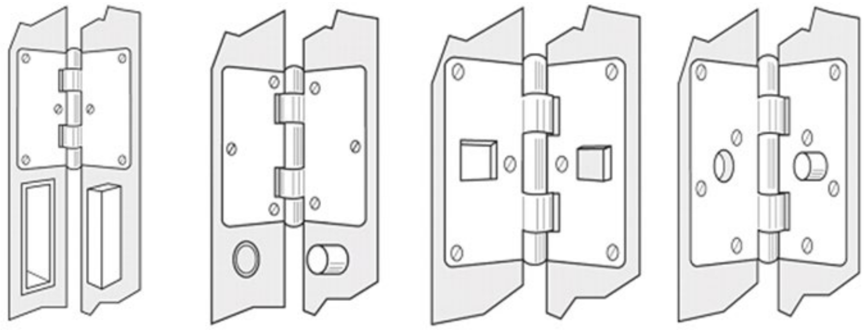
3-4.6.6 Hinges.

Hinges must be reinforced to a minimum of 7 gauge, and be cam-lift for acoustical door assemblies.

3-4.6.6.1 Hinge Pins.

Hinge pins on perimeter doors must be tamper resistant unless mounted on the protected side of the door. Tamper resistant hinges must have non-removable pins, security pins, set screws, welded, or equipped with a safety stud. See Figure 3-8.

Figure 3-8 Tamper Resistant Hinges



3-4.6.7 Primary Entrance.

Unless approved by the AO, provide one primary entrance where visitor control is conducted. Primary entrance must be:

- Equipped with an approved automated access control device.
- Equipped with a GSA-approved pedestrian door deadbolt meeting Federal Specification FF-L-2890.
- Equipped with combination lock meeting Federal Specification FF-L-2740.
- Equipped with a key override in the event of a malfunction or loss of power to the ACS.

3-4.6.8 Secondary Entrance.

In addition to the primary entrance, a secondary entrance may be allowed with AO approval. As with the primary entrance, the secondary entrance should incorporate a vestibule to preclude visual observation and enhance the acoustic protection. Secondary entrance must be:

- Equipped with an approved automated access control device.
- Equipped with a GSA-approved pedestrian door deadbolt meeting Federal Specification FF-L-2890. Additional standalone and flush mounted deadbolts are prohibited.

3-4.6.9 Primary and Secondary Entrance Vestibule.

When practical, the primary and secondary entrance should incorporate a vestibule to preclude visual observation and enhance acoustic protection. Primary entrance vestibule may have to accommodate space for visitor check-in and badging. In most applications, the interior door of the vestibule will be sound rated and the secure perimeter. To improve acoustic protection, provide acoustic treatments in vestibules to help absorb and diffuse sound.

3-4.6.10 Emergency Exit Doors.

Emergency exit doors must meet perimeter door requirements and:

- Have no exterior hardware; see Figure 3-9.
- Equipped with a GSA-approved pedestrian door deadbolt meeting Federal Specification FF-L-2890. Additional standalone flush-mounted deadbolts are prohibited.
- Alarmed 24/7 and equipped with a local annunciation.
- Delayed-egress is recommended with NFPA 101 compliance.

Figure 3-9 Emergency Exit Doors

3-4.6.11 Vault Doors.

General Services Administration (GSA)-approved Class 5 vault door equipped to meet Architectural Barriers Act (ABA) Standards. General Services Administration (GSA) has authorized the use of federal specification AA-D-600D for vault doors.

3-4.6.12 Roll-up Doors.

Roll-up doors can only be located in an area of non- discussion due to the inability to treat for acoustics. Roll-up doors must be 18 gauge or greater and secured with dead bolts on each side of the door.

3-4.6.13 Double Doors.

Double doors should not be used on the perimeter. If double doors are used:

- Secure one side with deadbolts at the top and bottom.
- Provide an astragal strip attached to either door to prevent observation into the space through the opening between the doors.
- Provide an independent high security switch (HSS) level 2 on each door.

3-4.7 Personal Electronic Device (PED) Cabinets.

Provide lockable metal cabinets outside the primary entrance for the storage of PEDs, see Figure 3-10. PED cabinets cannot be located within 10 ft. (3 m)[6] of equipment processing unencrypted NSI. Recessed PED cabinets are prohibited on perimeter walls.

Figure 3-10 PED Cabinets

3-4.8 Windows.

Every effort should be made to minimize windows, especially on the ground floor. When used, windows must be non-opening, be provide visual and acoustic protection and include TEMPEST requirements when recommended by the TCR.

3-4.8.1 Windows less than 18 feet (5.5 meters).

Windows less than 18 feet (5.5 meters) (measured from the bottom of the window) above the ground or from the nearest platform; such as lower roof, canopy or mechanical equipment, which affords access to the window must:

- Meet the standards of the perimeter
- Monitored by IDS

Large glazing panels may require noise generator transducers to achieve acoustic protection.

3-4.9 Daylighting.

Secure facilities are not exempt from the high performance building requirements of UFC 1-200-02. Promote access to daylight in breakrooms and other common spaces.

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[6] DoDM 5105.21-V2 and CNSSAM TEMPEST/1-13

When provided, daylighting design must be coordinated with the SSM. Design daylighting fenestration to be non-opening, provide visual and acoustic protection and include TEMPEST countermeasures when recommended by the TCR.

3-4.9.1 Daylighting Penetrations less than 18 feet (5.5 meters).

Daylighting penetrations that are less than 18 feet (5.5 meters) (measured from the bottom of the fenestration) above the ground or from the nearest platform; such as lower roof, canopy or mechanical equipment, which affords access to the fenestration or accessible from the roof must:

- Meet the standards of the perimeter
- Monitored by IDS

3-4.10 Visual Protection of Windows and Daylighting Fenestration.

Provide visual protection by methods such as full surface acid etching, sand blasting, or an obscure polyvinyl butyral interlayer. Method must obscure vision into the protected area while providing light transmission. Specify a maximum of 75% diffuse transmittance and a minimum haze of 90% when tested in accordance with ASTM D1003.

For existing windows, blinds, drapes or other coverings may be used with SSM/SSO approval.

3-4.11 Perimeter Penetrations.

Keep penetrations of the perimeter to a minimum. Ducts, conduits, pipes, or anything that penetrates the perimeter presents a vulnerability that must be addressed. All penetration must meet the acoustic requirements of the perimeter. In addition, perimeter penetrations may require TEMPEST countermeasures when recommended by TEMPEST Countermeasure Review.

Ducts, conduits or pipes servicing other areas cannot penetrate the perimeter unless mitigated with AO approval.

3-4.11.1 Utility Penetrations.

Utilities (power and signal) should enter at a single point. Seal all utility penetrations to mitigate acoustic emanations and covert entry. Spare conduits are allowed for future expansion provided the expansion conduit is filled with acoustic fill and capped or a Fire Stop System may be required for fire rated assemblies.

3-4.11.2 Metallic Penetrations.

All metallic penetrations through the perimeter are considered carriers of compromising emanations (CE) and pose TEMPEST hazards that must be addressed. Unless directed otherwise by the TEMPEST Countermeasure Review:

- Metal conduit or pipe: provide a nonconductive union inside the perimeter adjacent to the penetration, or ground the conduit within 6 inch (150 mm) of the perimeter penetration using a no. 4 wire (0.2043-diameter copper wire) to the building grounding system.
- Metallic sprinkler (fire suppression) pipe: ground the pipe within 6 inch (150 mm) of the perimeter penetration using a no. 4 wire (0.2043-diameter copper wire) to the building grounding system.
- Mechanical system refrigerant lines: ground the line within 6 inch (150 mm) of the perimeter penetration using a no. 4 wire (0.2043-diameter copper wire) to the building grounding system. Maintain integrity of refrigerant line insulation.
- HVAC ducts: provide a nonconductive break (flex connection) using material appropriate for the climate, for a 2- to 6-inch (50 to 150 mm) section of the duct inside the perimeter adjacent to the penetration, see Figure 3-11. When a waveguide is recommended by TEMPEST Countermeasure Review, provide between the perimeter and the nonconductive break.

In addition, the TEMPEST Countermeasure Review may require additional countermeasures.

Figure 3-11 Duct Penetrations

3-4.11.3 Penetration Seals.

Seal both sides of perimeter penetrations with an acoustical foam or sealant finished to match adjacent wall, floor, or ceiling see Figure 3-12. Fire Stop System may be required for fire rated assemblies. In addition, penetration seals must meet TEMPEST requirements when recommended by the TEMPEST Countermeasure Review.

Figure 3-12 Sealing Penetrations

3-4.12 Vents and Ducts.

Protect all vents or duct openings exceeding 96 square inches (619 cm2) that penetrate the perimeter with permanently affixed bars, grills, diamond mesh, welded wire fabric, metal sound baffles or waveguides. If one dimension of the penetration measures less than 6 inch (150 mm), protection is not required. One of the following can be used to secure openings 6-inches (150 mm) or more in any dimension.

- A minimum of ½ inch (13 mm) diameter steel bars welded vertically and horizontally 6 inch (150 mm) on center. A deviation of ½ inch (13 mm) in vertical and/or horizontal spacing is permissible, see Figure 3-13.
- ¾ inch (20 mm) #9 (10 gauge) case hardened expanded metal grills.
- Carbon steel standard expanded metal diamond mesh, 1-1/2” (38 mm) #10 (13 gauge). With a maximum design size of 1-3/8” by 3” (35 mm x 76 mm), strand size thickness of 0.093” (2.36 mm), with at least 80% open design).
- Welded wire fabric (WWF) 4x4-W2.9xW2.9 (6 gauge) smooth steel wire welded vertically and horizontally four inches on center.
- Metal sound baffles or waveguide permanently installed and set no farther apart than 6 inch (150 mm) in one dimension.

Coordinate material selection with Mechanical Engineer to ensure proper airflow and fan sizing.

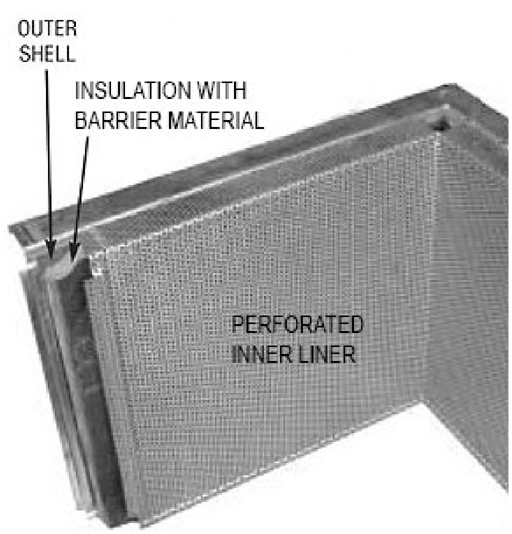
Figure 3-13 Bars on Penetration

3-4.13 Acoustic Protection for Ducts.

To ensure acoustic performance of the perimeter is not compromised, provide sound baffles (duct silencers) or (Z) Duct Penetrations. IC Tech Spec – for ICD/ICS 705 provides an example of a (Z) Duct Penetration. Coordinate selection with the mechanical engineer. Backpressures created by the baffles may significantly impact the HVAC system design.

Be aware, (Z) Duct Penetration in IC Tech Spec – for ICD/ICS 705 indicates acoustically lined duct. Per UFC 3-410-01, acoustical duct liner is not allowed. In lieu of acoustical duct liner, provide double wall acoustic duct, see Figure 3-14. For contamination protection, include a barrier material between the perforated liner and the insulation designed to prevent air quality issues caused by bacteria and other contaminates that can embed in the insulation.

Figure 3-14 Double Wall Acoustic Duct

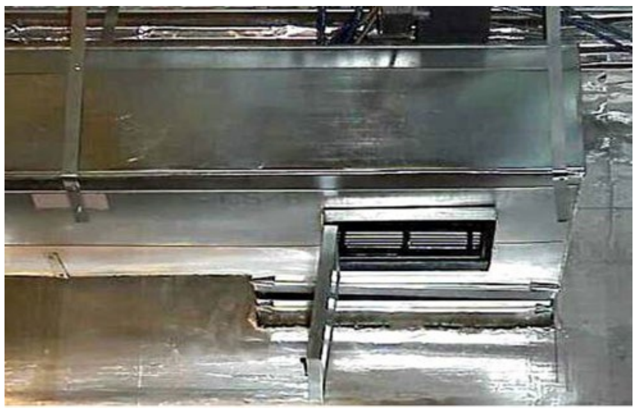


3-4.14 Access Port.

For vents or ducts that require bars or grill, provide an accessible access panel in the bottom within the perimeter to allow visual inspection of the bars, grill, or waveguide, see Figure 3-15.

If the area outside the perimeter is controlled (SECRET or equivalent proprietary space), the inspection port may be installed outside the perimeter, and be secured with an AO approved high-security lock such as a GSA combination padlock meeting Federal Specification FF-P-110.

Figure 3-15 Access Port



3-4.15 Flashing or Rotating Light.

Per DoDM 5105.21 Vol 2 and DoDM 5205.07 Vol 2, personnel must be informed when non-indoctrinated personnel have entered and departed the space. Per IC Tech Spec, Lights, signs, or other alerting mechanisms or procedures must be used to alert occupants of the presence of uncleared personnel. This may be accomplished either verbally or through visual notification methods. A flashing or rotating light is an approved method to indicate the presence of non-indoctrinated personnel in the area. This can be hand held or installed.

Coordinate use of flashing or rotating notification lights with mission requirements. There may be light-sensitive or simulation equipment that preclude use of such light during ongoing operations. When installed, place lights to ensure visual observation by the occupants of the space. At a minimum, provide controls within the perimeter at each entrance into the space or compartmented area.

3-4.16 Duress Alarm.

When a duress alarm is required, duress alarm must initiate an alarm condition at the central monitoring station and no audible or visual signal in the protected area.

3-4.17 Electronic Security System (ESS).

An ESS is comprised of three primary subsystems; intrusion detection system (IDS), access control system (ACS), and video system along with a supporting data transmission network and electrical power system.

ESS systems must meet the requirements of ICS 705-1 and IC Tech Spec-for ICD/ICS 705 and be designed in accordance with UFC 4-021-02. UFC 4-021-02 provides notional layouts for typical ESS systems.

3-4.17.1 Access Control System (ACS).

At a minimum, provide card reader with keypad at the primary entrance and when provided, the secondary entrance. Unless otherwise directed, the default ACS identifier credential is the Common Access Card (CAC)[7].

- Locate equipment containing access-control software programs within the perimeter or a SECRET controlled area.
- Protect system data that is carried on transmission lines (e.g., access authorizations, personal identification, or verification data) to and from equipment located outside the perimeter using FIPS AES certified encrypted lines. If this communication technology is not feasible, provide transmission lines as approved by the AO.
- Provide electric locks with positive engagement, fail secure, and approved under UL 1034 for burglar resistance.

3-4.17.2 Video System.

Cameras are not allowed within the perimeter or enable observation within the perimeter. A camera may be provided on the exterior to supplement the monitoring of a primary entrance for remote control of the door from within the space. A Video Intercom System may provide this capability. The system must provide a clear view of the primary entrance that is monitored and operated by indoctrinated personnel.

3-4.17.3 Intrusion Detection System (IDS).

Protect the space with IDS when not occupied. Protect all Interior areas through which reasonable access to the asset could be gained with IDS.

- The IDS must be independent of systems safeguarding other facilities and compatible with Installation’s central monitoring system.
- Provide point sensors on perimeter doors and man-passable openings such as roof hatches.
- Provide motion sensors within the perimeter to protect perimeter windows, doors, daylight fenestrations, and man-passable openings.

[7] Per DoD 5200.08-R

- Strategically place motion sensors within the space to detect movement where assets are stored or where assets are stored or in pathways leading to the asset. One hundred percent coverage is not required.
- Motion sensors are not normally required above false ceilings or below false floors; however, these detectors may be required by the AO for critical and high threat facilities outside the U.S.
- Monitor emergency exit doors 24 hours a day. Provide local annunciation to alert occupants when the door opened with identification of the appropriate door when there is an alarm indication.

3-4.17.3.1 Intrusion Detection Installation and Components.

Per IC Tech Spec – for ICD/ICS 705, IDS installation, related components, and monitoring stations must comply with Underwriters Laboratories (UL) 2050 Extent 3 standards. Systems developed and used exclusively by the U.S. Government do not require UL certification but must comply with UL 2050 Extent 3 standards for installation. UL 2050 materials are restricted and only distributed to those demonstrating relevant national industrial security involvement. However, UL 2050 implements UL 681, Installation and Classification of Burglar and Holdup Alarm Systems for alarm system installation. See UFC 4-021-02 for additional information and a notional ESS layout.

3-4.17.3.2 Motion Detection Sensors.

UL 639 Listed. Dual-technology sensors may be used when authorized and when each technology transmits alarm conditions independent of the other technology (“or” configuration).

3-4.17.3.3 Point Sensors.

UL 634 HSS level 2. Level 2 rated switches only include Balanced Magnetic Switches that pass additional performance testing.

3-4.17.3.4 Sensor Cabling.

Cabling between sensors and the PCU must be dedicated to the system, contained within the perimeter, and comply with Committee for National Security Systems (CNSS) standards. If the wiring cannot be contained within the perimeter, meet the requirements for External Transmission Line Security.

3-4.17.3.5 Premise Control Unit (PCU).

Locate PCU within the Perimeter. Configure system to only allow cleared personnel located within the secure/protected area to initiate changes in access modes or alarm conditions.

PCUs certified under UL 1610 must meet FIPS 197 or FIPS 140-2 encryption certification and methods. For PCUs certified under UL1076, only FIPS 140-2 is the acceptable encryption certification and method.

3-4.17.3.6 External Transmission Line Security.

IDS transmission lines to the central monitoring station, must meet National Institute of Standards and Technology, Federal Information Processing Standards (FIPS) certified encrypted lines.

All lines employing line supervision require certification of the algorithm by the National Institute of Standards and Technology (NIST) (a NIST certificate). An alternate form of line supervision may be approved on a case-by-case basis.

3-4.17.3.7 Standby Power.

Provide twenty-four hours of uninterruptible standby power. This may be provided by batteries, uninterruptible power supply (UPS), or engine-generators, or any combination. Standby power for IDS should not generate the requirement for a UPS or engine-generator. When an engine-generator is available for standby power, provide batteries for IDS that provide a minimum of four hours of standby power to allow uninterrupted power during transitions to and from standby generator power.

In the event of primary power failure, the IDS must:

- Automatically transfer to the backup power source without causing alarm activation.
- Initiate an audible or visual indicator at the PCU to provide an indication of the primary or backup power source in use.
- Initiate an audible or visual indicator at the monitoring station indicating a failure in a power source or a change in power source.

3-4.17.3.8 IDS Approval.

The AO must approve IDS proposals and plans prior to installation as part of the pre-construction approval process.

3-4.18 Telecommunications Space.

Per UFC 3-580-01, the minimum size for Telecommunications Room (TR) is 10 feet x 8 feet (3m x 2.4m). This will be inadequate if the telecommunications space contains equipment racks for multiple networks such as Secret Internet Protocol Router Network (SIPRNet), Joint Worldwide Intelligence Communications System (JWICS), Non-classified Internet Protocol Router Network (NIPRNet), voice services, and other equipment or services. Depending on the number of workstations served, this could generate a larger space requirement when considering the equipment racks and RED/BLACK separation requirements.

UFC 3-580-01 allows the use of an Equipment Room in lieu of a TR for buildings that house substantial Information Technology (IT) electronics. A telecommunication space that contains equipment for multiple networks such as SIPRNet, JWICS and NIPRNet all requiring RED/BLACK separation is considered as substantial Information Technology (IT) electronics which would allow for the use of a larger Equipment Room.

3-4.18.1 Telecommunications Expansion.

Design the telecommunication spaces to accommodate future equipment expansion. At a minimum, UFC 3-580-01 requires one spare rack for every four utilized racks with the minimum of one spare rack. Future operational capability for these types of facilities may require additional expansion space. Coordinate future expansion capabilities with mission commander and the C5ISR equipment provider. Provide additional power, environmental support, and floor space for the future expansion.

3-4.18.2 Temperature and Humidity Control.

Substantial Information Technology (IT) equipment generate a significant amount of heat. In these environments, the heat densities can be up to five times higher than in a typical office load. Traditional HVAC systems cannot remove enough heat to protect IT equipment. Instead, these areas require systems with higher cooling capabilities such as a computer room air conditioner (CRAC). The smallest high-powered CRACs require a minimum 10 ft. x 3 ft. (3m×1m) footprint for equipment and clearances.

Design air-conditioning systems for year-round cooling with very high cooling intensity. The high sensitivity of electronic components in such facilities requires that temperature, humidity, air movement and air cleanliness must be kept consistent and within specific limits to prevent premature equipment failures and costly downtime.

3-4.19 Telecommunication Cabling System.

Cabling, patch panels, connector blocks, work area outlets, and cable connectors must be color coded[8] to distinguish their classification level. If color-coding is not possible, cabling must be clearly marked to indicate their classification level. Cabling must enter the protected area from a single location and must be identified and labeled with its purpose and destination at the point of entry. Backbone and horizontal cabling may differ depending on network classification, service provider, and TEMPEST requirements. Coordinate requirements with SSM and service provider. See TEMPEST Countermeasures.

3-4.20 Protected Distribution Systems (PDS).

Protect signal distribution systems containing unencrypted NSI that enters an area of lesser classification, unclassified area, or uncontrolled (public) area with a PDS in accordance with CNSSI No 7003.

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[8] Per DoDM 5105.21 Vol 1

Avoid the use of PDS whenever possible due to inspection requirements. To avoid PDS, keep cabling transmitting unencrypted NSI within the protected perimeter.

3-4.21 RESILIENCE.

Some facilities must continue to operate effectively or recover rapidly to support the mission in the event of severe weather, earthquake, loss of utility, or equipment failure. Defining the appropriate International Building Code (IBC) Risk Category is critical in determining the earthquake, flood, snow and wind load requirements that will apply to the building. Some critical operations or C5ISR systems require redundant utilities, standby power systems, and redundant support systems to ensure continuous operation in the event of utility or equipment failure.

Coordinate resiliency requirements with the mission commander.

3-4.21.1 Redundant Utilities.

Critical operations or C5ISR systems may require redundant utilities such as telecommunication system connectivity or utility power service. To be redundant, the utilities providing connectivity or power to the facility must be two separate utilities that are not routed together.

3-4.21.2 Standby Power System (SPS).

Critical operations or C5ISR systems may require an SPS designed to ensure continuity of electrical power to essential and uninterruptible loads upon loss of normal power sources. Design SPS in accordance with NFPA 70 and NFPA 110. The SPS must have the capacity and rating to meet the maximum demand likely to be produced by the essential and uninterruptible loads and be consistent with the facilities emergency operations plan.

3-4.21.2.1 Engine-Driven Generator.

When a SPS is required, provide a standby engine-driven generator for essential and uninterruptible loads to ensure continued operation upon loss of utility power. Design the standby generator in accordance with UFC 3-540-01.

3-4.21.2.2 UPS Systems.

When a SPS is required, provide UPS for the uninterruptible loads to filter commercial power and to support the uninterruptible loads during transitions to and from the standby generator.

3-4.21.3 Redundant Support Systems.

Some critical operations may require support systems with a minimum of N+1 redundancy to ensure continuous operation in the event of component failure. In this configuration, components (N) have at least one independent backup component (+1). For a critical communication system, the N+1 redundancy would be applied to support systems such as the air-conditioning systems and SPS required to support continuous operation. For example, if the essential and uninterruptible loads required two 250 kW generators, N+1 would result in three 250 kW generators.

3-4.22 TEMPEST.

TEMPEST is a short name referring to investigation, study and control of compromising emanations from telecommunications and automated information systems equipment. In general, TEMPEST countermeasures apply when there is equipment that will be processing national security information (NSI). The intent is to minimize the likelihood that these emanations will be intercepted.

3-4.22.1 TEMPEST Countermeasures Review (TCR).

Each project requires a TEMPEST countermeasures review (TCR), performed or verified by the Certified TEMPEST Technical Authority (CTTA). The SSO or SSM will request a TCR by submitting a TEMPEST addendum to the FFC. For an initial TCR, the TEMPEST addendum will be submitted to AO during the preliminary design phase. While some specific information may not be known prior to construction, as much information as possible must be provided in order to minimize costly changes. Based on the results of the TCR, the CTTA will determine the most cost-effective countermeasures and will document these requirements in writing[9].

3-4.22.2 TEMPEST Countermeasures.

TEMPEST-suppressed equipment, radio frequency (RF) shielded enclosures, filters (power, signal, telephone, etc.), nonconductive conduit or duct sections, or other potentially expensive TEMPEST countermeasures must not be applied without AO approval. Normally, facilities located on military installations within the United States do not require additional countermeasures beyond implementing RED/BLACK separation guidance depending on threat and mission requirements. However, facilities that are located outside the U.S., off a military installation, in close proximity with a foreign entity; or facilities that share a common wall, floor, or ceiling with a non-government element may require additional measures beyond implementing RED/BLACK separation[9]. These additional measures are determined through the TCR process and approved by the AO.

3-4.22.3 RED/BLACK Telecommunication Systems.

All equipment, wirelines, components, and systems that process National Security Information (NSI) are considered RED. Equipment, wirelines, components, and systems that process encrypted NSI and non-NSI are considered BLACK. BLACK lines and other electrically conductive materials that egress the inspectable space are potential carriers of Compromising Emanations (CE) that can inadvertently couple to the RED lines. Various signal line isolation techniques such as separation and filtering are

[9] DoDM 5105.21 Vol 2 and DoDM 5205.07 Vol 3

used to protect the signal line, the distribution system or other fortuitous conductors from conducting compromising signals beyond secure areas.

Apply fundamental RED/BLACK mitigations in accordance with CNSSAM TEMPEST/01-13 to prevent the inadvertent transmission of classified data over telephone lines, power lines, signal lines, and electrical components, circuits, and communication media. The application of RED/BLACK separation establishes areas where equipment processing classified information (RED) are isolated from areas where equipment processing unclassified (BLACK) are located.

3-4.22.4 Radio Frequency (RF) Mitigation.

As documented in the TCR, protect the space from compromising emanations. When directed, provide RF mitigation for perimeter walls, ceilings, floors, doors, windows, skylights and penetrations with RF shielding, non-conductive breaks, and grounding. RF mitigations for penetrations may include waveguides.

When required, place foil layer on the secure side of the perimeter wall between the first and second layer of gypsum board. When required, place RF shielding material on floor and ceiling. Doors must be steel with RF gasket, and door frame must be electrically bonded continuously to RF shield. Entire window or skylight assembly must be RF shielded and widow or skylight frame and must be electrically bonded continuously to RF shield. Shielding must be electrically bonded continuously, with no gaps or discontinuities at any point, at interfaces between, walls, floors, ceilings, doors, windows, and skylights and penetrations. Power and low voltage systems may include power line and telecommunication line filters. Refer to *Best Practices Guidelines for Architectural Radio Frequency Shielding* for standard construction for RF shielding.

- Do not connect mounting apparatus to the RF shielding material in a manner that affects RF shielding performance.
- Consider providing furred out walls to protect RF shielding from future compromise.

3-4.22.5 RF Door ABA Compliance.

RF doors that utilize a knife-edge may not meet ABA Standards without modification due to accessibility requirements at the sill, see Figure 3-16. The use of temporary ramps will not meet ABA Standards.

3-4.22.6 Paging, Intercom, and Public Address Systems.

Systems should be totally contained within the perimeter. Refer to the TCR to determine TEMPEST countermeasures. Possible countermeasures may include:

- Separation of equipment and signal lines from RED telecommunication lines and processors.
- Provide a local buffer amplifier to prevent speakers or earphones from functioning as microphone. For most systems, this is a simple amplifier

within the perimeter that takes the incoming audio signal and amplifies/distributes the signal to the speakers within the perimeter.

- Provide electronic isolation for systems that require two-way communication. The system must alert occupants when the system is activated.
- Provide voice frequency, bandpass filters if they are not totally contained within the inspectable space. This protects against TEMPEST signals on the cables but does not protect against voice modulation of the speakers.
- Provide a subpanel within the perimeter with optical fiber backbone to the building system or convert the electrical signal to an optical signal before penetration of the perimeter. Provide optical fiber with no metallic shielding, cladding, or strength members.
- When required, provide electronic isolation components within the perimeter as near to the point of penetration as possible.

Figure 3-16 ABA Non-Compliant RF Door

3-4.22.7 Fire Alarm and Mass Notification System (MNS).

The introduction of electronic systems that have components outside the perimeter should be avoided. TEMPEST concerns may require electronic isolation. Speakers or other transducers, which are part of a system that is not wholly contained within the perimeter, may require mitigation. Refer to the TCR to determine TEMPEST countermeasures. Possible countermeasures may include:

- Separation of equipment and signal lines from RED telecommunication lines and processors.
- For eavesdropping (using the speakers as microphones), a simple buffer amplifier is the standard mitigation. For most systems, this is a simple amplifier within the perimeter that takes the incoming audio signal and amplifies/distributes the signal to the speakers within the space. However, equipment such as pre-amplifiers, amplifiers and products translating or converting live voice signals for use in mass notification systems must comply with the applicable requirements in UL 864, the Standard for Amplifiers for Fire-Protective Signaling Systems. Therefore, any amplifier used in a MNS must meet UL 864.
- Provide a MNS/Fire alarm subpanel within the perimeter with optical fiber backbone to the building system or convert the electrical signal to an optical signal before penetration of the perimeter. Provide optical fiber with no metallic shielding, cladding, or strength members.
- Provide electronic isolation for systems that require two-way communication. The system must alert the occupants when the system is activated.
- When required, provide electronic isolation components within the perimeter as near to the point of penetration as possible.

3-4.22.8 Power Systems.

The power requirements are divided into two groups -- power for the mission equipment (technical) and power for the supporting services (nontechnical). Supporting services include lighting, heating, ventilating, air conditioning, etc. Provide a separate service feeder dedicated to the sensitive equipment and control its distribution reducing the opportunity for unauthorized detection of compromising signals on those lines. Power line conduction occurs when data is transferred onto the power line by RED equipment, or radiated through free space and coupled onto the power lines. If a facility is processing NSI, power is sometimes divided into RED and BLACK power. RED power provides isolation for those non-TEMPEST approved equipment processing NSI. BLACK power is provided for equipment processing non-NSI because power isolation is not required. This separation prevents conducted emissions from RED equipment being coupled through BLACK equipment to BLACK lines that might egress the inspectable space. Refer to the TCR to determine TEMPEST countermeasures. Possible countermeasures may include:

- Separation of BLACK power lines from RED telecommunication lines and processors.
- Power line Filters. UPS within the perimeter may eliminate power line filters.

3-4.22.9 RF Communications Systems.

Facilities that require large RF communications systems (combat net radios, microwave systems, air to ground, or ship to shore) should be designed to place RF communications systems as far away from RED processors as possible.[10]

[10] DoDM 5105.21 Vol 2

CHAPTER 4 CONSTRUCTION

4-1 CONSTRUCTION AWARD.

Per IC Tech Spec – for ICD/ICS 705, prior to awarding a construction contract, a CSP for each project must be approved by the AO. The CSP documents the security requirements for the project. For Navy and Marine Corps projects, refer to NAVFAC INST 4700.01 for additional information.

4-2 CONSTRUCTION PLANS SECURITY.

Per ICS 705-1, protect and handle construction plans and related documents in accordance with the CSP. If classification guides dictate, plans and related documents may require classification. Under no circumstances should plans, diagrams, etc. that are identified for a SCIF or SAPF be sent or posted on unprotected information technology systems, networks or Internet venue without encryption.

4-3 CONSTRUCTION SITE SECURITY.

The SSM is the single point of contact regarding security and the individual responsible for the security aspects of the construction. The SSM will have 24-hour unrestricted access to the site to conduct periodic security inspections for the duration of the project. DoDM 5105.21 Vol 2 defines the minimum security requirements for the SCIF construction site. DoDM 5205.07 does not identify minimum security requirements for the SAPF construction site.

Refer to the CSP for the project specific security requirements.

4-4 ACCREDITATION PROCESS.

In support of the accreditation process and the updating of the FFC, and other required documentation, Project/Construction mangers will provide the SSM site plans, building floorplans, IDS plans, and information related to the perimeter's construction, penetrations, doors, locks, deadbolts, IDS, telecommunication systems, acoustical protection, low voltage systems, electrical power systems, and TEMPEST countermeasures. For SCIFs, refer to DoDM 5105.21 Vol 2, and for SAPFs, refer to DoDM 5205.07 Vol 3.

4-5 INSPECTIONS.

Coordinate preliminary walkthrough with the SSM prior to substantial completion of the space. SSM conducts periodic inspections of the area to validate and document elements for accreditation. Inspection elements may include:

- Perimeter construction
  - Wall goes from floor slab (true floor) to underside of floor or roof deck (true ceiling)
  - Wall uniformly finished and painted from true floor to true ceiling

- Top and bottom of walls are sealed (both sides) with acoustical foam or sealant
- Acoustic insulation is securely fastened
- Gypsum Wallboard installation
- Floor and Ceiling construction

- Perimeter Penetrations
  - Sealed (both sides) with acoustical foam or sealant
  - Finished to match wall
- Perimeter Doors
  - Door assemblies sealed with acoustical foam or sealant (both sides) and finished to match wall
  - Door hardware (locks, closers, sweeps and hinges)
  - ASTM E90 laboratory Test Report
  - ASTM E336 field Test Report
- HVAC Systems
  - Man-bar installation
  - Inspection Ports
  - Nonconductive break
  - Acoustic mitigation
    - Z-duct installation or sound baffle installation
- ESS installation
- TEMPEST Countermeasures (as applicable)
  - RED/BLACK LAN separation
  - Metallic penetrations at perimeter (non-conductive break or grounded at the interior perimeter
  - RF shielding including penetrations
  - Waveguides
  - Doors including RF gaskets
  - Power Line Filters
  - Signal Line Isolators and Filters

4-6 CONSTRUCTION DRAWINGS AND SUBMITTALS.

Prior to walk through; assemble required documents in support of the accreditation process. Requirements vary depending on project but in general assemble the following documents:

- Drawings:
  - Civil Site Plan
  - Architectural
    - Floor and Reflective Ceiling Plans
    - Perimeter wall sections (floor to ceiling)
    - Floor and Ceiling section
    - Door Schedule
    - Perimeter Door head, jamb, and threshold details
    - Window schedule and details
  - Fire Protection
    - Sprinkler piping grounding and penetration details
    - Low voltage cabling penetrations
    - Fire Alarm system
    - Mass Notification System
  - Mechanical
    - HVAC plans, sections and details of perimeter penetrations, ductwork details sheets
    - Plumbing floor plans, detail for perimeter penetrations
  - Electrical
    - Site plan
    - Lighting, Power, Telecommunications, Grounding, and ESS plans. Plans must indicate device and panel locations and when provided, include strobe lights and controls
    - One-line diagrams for Power, Telecommunications including RED/BLACK separation, and ESS
    - ESS door wiring details
    - Perimeter penetration details
- Submittals
  - Doors
  - Door Hardware (locks, closers, and hinges)
  - Acoustical rated assemblies
    - ASTM E90 Test Reports
  - Electronic Security Systems
  - TEMPEST Countermeasures (as applicable)

        - Non-metallic breaks
        - RF shielding
        - RF sealant
        - Waveguides
        - RF Shielded Doors including RF gaskets
        - RF Shielded Windows
        - Power Line Filters
        - Signal Line Isolators and Filters
    - RF Shielding Test Reports (as applicable)
- As-Built drawings

4-7 PHOTOGRAPHIC CONSTRUCTION SURVEILLANCE RECORD.

Photographic Construction Surveillance Record may be accomplished by the SSM or approved personnel to expedite the accreditation process. It is important to capture areas which will be covered up during construction. Pictures should capture:

- Wall construction
    - Stud walls
    - Acoustic insulation
    - Enhanced wall layer (when applicable)
    - Initial GWB layer installation
    - RF shielding installation
    - Wall penetrations
    - Wall finishes (true floor to true ceiling)
- Duct construction including inspection ports, Z-Ducts, Sound baffles and man-bars.

APPENDIX A MINIMUM CONSTRUCTION

A-1 MINIMUM CONSTRUCTION.

Table A-1 is provided as a synopsis of the construction and alarm requirements based on the IC Tech Spec-for ICD/ICS 705. Construction is determined on a project-by-project basis by the Commander or their designated SSM working with the AO.

Table A-1 Minimum Construction and Alarm

	CLASSIFICATION	TYPE OF CONSTRUCTION[1]	IDS[3]	ACS[4]	DURESS
INSIDE UNITED STATES, ITS POSSESSIONS OR TERRITORIES	Open Storage without SID[5]	Wall B - Enhanced Wall (Expanded Metal)[2] Wall C - Enhanced Wall (Plywood)[2]	YES	YES	NO
	Open Storage with SID[5]	Wall A - Standard Wall[2]	YES	YES	NO
	Closed Storage	Wall A - Standard Wall[2]	YES	YES	NO
	Continuous Operations	Wall A - Standard Wall[2]	YES	YES	NO
	Secure Working Area (SWA)	Wall A - Standard Wall[2]	YES	YES	NO
OUTSIDE UNITED STATES, ITS POSSESSIONS OR TERRITORIES	SETL Cat I[6]				
	Open Storage	Vault [2]	YES	YES	RECOMMENDED
	Closed Storage	Wall B - Enhanced Wall (Expanded Metal)[2] Wall C - Enhanced Wall (Plywood)[2]	YES	YES	NO
	Continuous Operation	Wall B - Enhanced Wall (expanded Metal)[2] Wall C - Enhanced Wall (Plywood)[2]	YES	YES	YES
	SETL Cat II & III[6]				
	Open Storage	Wall B - Enhanced Wall (expanded Metal)[2] Wall C - Enhanced Wall (Plywood)[2]	YES	YES	RECOMMENDED
	Closed Storage	Wall B - Enhanced Wall (Expanded Metal)[2] Wall C - Enhanced Wall (Plywood)[2]	YES	YES	NO
	Continuous Operation	Wall A - Standard Wall[2]	YES	YES	RECOMMENDED
	Secure Working Area (SWA)	Wall A - Standard Wall[2]	YES	YES	RECOMMENDED

Notes:

1. Table indicates the minimum construction from IC Tech Spec-for ICD/ICS 705.
2. Refer to IC Tech Spec-for ICD/ICS 705 for construction definitions and suggested details. Include Radio Frequency (shielding) protection, enhanced construction and sound attenuation as required.
3. IDS - Intrusion Detection System
4. ACS - Access Control System at Primary and secondary (if provided) entrance.
5. SID - Security in Depth
6. Security Environment Threat List (SETL). SETL Categories are classified.

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APPENDIX B GLOSSARY

B-1 ACRONYMS.

ACS Access Control System

AO Accrediting Official

BIA Bilateral Infrastructure Agreements

C5ISR Command, Control, Computers, Communications, Cyber, Intelligence, Surveillance and Reconnaissance

CA Compartmented Area

CSA Cognizant Security Authority

CSP Construction Security Plan

CTTA Certified TEMPEST Technical Authority

DNI Director of National Intelligence

ER Equipment Room

ESS Electronic Security System

FFC Fixed Facility Checklist

HNFA Host Nation Funded Construction Agreements

HSS High Security Switch

IC Intelligence Community

IDS Intrusion Detection System

JWICS Joint Worldwide Intelligence Communications System

MNS Mass Notification System

NIPRNET Non-classified Internet Protocol Router Network

NSI National Security Information

PDS Protected Distribution System

PCU Premise Control Unit

RF Radio frequency

SAO Special Access Program Facility Accrediting Official

SAP Special Access Program

SAPF Special Access Program Facility

SCI Sensitive Compartmented Information

SCIF Sensitive Compartmented Information Facilities

SETL Security Environment Threat List

SID Security-in-depth

SIO Senior intelligence Official

SIPRNET Secret Internet Protocol Router Network

SOFA Status of Forces Agreements

SPS Standby Power System

SSM Site Security Manager

SSO Special Security Officer

STC Sound Transmission Class

SWA Secure Working Area

TCR TEMPEST Countermeasure Review

TR Telecommunications Room

TSWA Temporary Secure Working Areas

UFGS Unified Facilities Guide Specification

VTC Video teleconference

B-2 DEFINITION OF TERMS.

Accrediting Official (AO): Person designated by the Cognizant Security Authority (CSA) that is responsible for all aspects of SCIF management and operations to include security policy implementation and oversight.

BLACK Equipment: A term applied to equipment that processes only unclassified and/or encrypted information. (CNSSAM TEMPEST/1-13)

BLACK LAN: A term applied to equipment, cables, or fiber that processes or carries only unclassified and/or encrypted information. (CNSSAM TEMPEST/1-13)

Certified TEMPEST Technical Authority (CTTA): U.S. Government employee who has met established certification requirements in accordance with NSTISSC-approved criteria and has been appointed by a U.S. Government department or agency.

Classification Guide: A documentary form of classification guidance issued by an Original Classification Authority (OCA) that identifies the elements of information regarding a specific subject that must be classified and establishes the level and duration of classification for each such element. (ODNI 80.16)

Cleared American Guard: A U.S. Secret cleared guard that performs access control functions to screen all non-cleared workers, vehicles, and equipment entering or exiting the site and conducts random inspections of site areas. (IC Tech Spec – for ICD/ICS 705)

Closed Storage: The storage of sensitive material in properly secured GSA approved security containers within an accredited space.

Cognizant Security Authority (CSA): The single Principal designated to serve as the responsible official for all aspects of security program management with respect to the protection of intelligence sources and methods.

Compartmented Area (CA): An area, room, or a set of rooms within the accredited space that provides controlled separation between control systems, compartments, sub-compartments, or Controlled Access Programs. (IC Tech Spec – for ICD/ICS 705)

DoD Construction Agent. The U.S. Army Corps of Engineers, the Naval Facilities Engineering Systems Command, or such other approved DoD activity assigned the design or construction execution responsibilities associated with the military construction program. (DoDD 4270.5)

Construction Security Plan (CSP): The plan developed by the SSM and approved by the AO, which outlines security protective measures that will be applied to each phase of the construction project. (IC Tech Spec – for ICD/ICS 705)

Construction Security Technician (CST): A U.S. Top Secret cleared person specially trained in surveillance and the construction trade to deter technical penetrations and thwart implanted technical collection devices. (IC Tech Spec – for ICD/ICS 705)

Continuous Operation: This condition exists when the secure space is staffed 24 hours every day.

Duress Alarm: A silent alarm signal generated by the manual activation of a device requiring a security force response.

Equipment Room (ER): An environmentally controlled, centralized space for telecommunications equipment that usually houses a main or intermediate cross-connect. (UFC 3-580-01)

Essential Loads: Loads that require standby power, but can be de-energized until they can be supplied from an engine generator system. Loads in this category usually include HVAC loads to vital facilities or other load types that can be de-energized for short periods without severe consequence. (UFC 3-540-01)

Fixed Facility Checklist (FFC): Checklist used by CSAs to determine whether construction requirements have been met.

Inspectable Space. The three-dimensional space surrounding equipment that processes classified or sensitive information within which TEMPEST exploitation is not considered practical or where legal authority to identify and remove a potential TEMPEST exploitation exists. Inspectable space may include parking areas around the facility which are owned or randomly inspected daily by the organization, public roads along which parking is not allowed, heavily wooded or other undeveloped areas with restricted vehicular access, and any areas where U.S. security personnel have unannounced 24-hour access. (DoD 5105.21-M Vol 2)

Open Storage: Storage of classified information within an approved facility where securing classified information in GSA approved storage containers while the facility is not occupied by authorized personnel is not required. (DoD 5105.21-M Vol 2)

Protected Distribution System (PDS): Wire line or fiber optic system that includes adequate safeguards and/or countermeasures (e.g., acoustic, electric, electromagnetic, and physical) to permit its use for the transmission of unencrypted information through an area of lesser classification or control. (CNSSAM TEMPEST/01-13)

RED Equipment: A term applied to equipment that processes unencrypted NSI that requires protection during electrical/electronic processing. (CNSSAM TEMPEST/1-13)

RED LAN: A term applied to equipment, cables, or fiber that processes or carries unencrypted National Security Information (NSI) that requires protection during electrical/electronic processing. (CNSSAM TEMPEST/1-13)

Secure Working Area (SWA): An accredited SCIF used for handling, discussing and/or processing of SCI, but where SCI will not be stored.

Security Environment Threat List (SETL): Classified list managed by the Office of Intelligence and Threat Analysis (ITA). The SETL reflects four categories of security threat, including political violence and crime for U.S. missions overseas.

Site Security Manager (SSM): Person designated for the construction project that is responsible for all aspects of security to include security policy implementation and oversight.

Sensitive Compartmented Information (SCI): Classified information concerning or derived from intelligence sources, methods, or analytical processes, which is required to be handled within formal access control systems established by the Director of National Intelligence.

Sensitive Compartmented Information Facility (SCIF): Accredited area, room, group of rooms, buildings, or installation where SCI may be stored, used, discussed, and/or processed.

Sound Transmission Class (STC): An integer rating of how well a building partition attenuates airborne sound.

Special Access Program Facility (SAPF): An accredited area, room, group of rooms, building, or installation where SAP materials may be stored, used, discussed, manufactured, or electronically processed. (DoDM 5205.07, Volume 3)

Special access program facility accrediting official (SAO): A properly trained SAP facility accrediting official designated by the CA SAPCO to physically inspect and review and approve or disapprove physical security preconstruction plans for a SAPF, T-SAPF, SAPCA, and SAPWA or SAPTSWA before accreditation. (DoDM 5205.07, Volume 3)

Special Security Officer (SSO): The SSO designated by the Senior Intelligence Official for any activity that is accredited for and authorized to receive, use, and store SCI. The activity SSO is responsible, IAW DoDM 5105.21, Volumes 1-3 and ICD 703 for the day-to-day security management, operations, implementation, use and dissemination of SCI within the activity. (DoDM 5200.01, Vol 1)

STC Rating: STC is a single number rating used to determine the sound barrier performance of walls, ceilings, floors, windows, and doors.

TEMPEST: A name referring to the investigation, study, and control of unintentional compromising emanations from telecommunications and automated information systems equipment. (CNSSI No. 4009)

TEMPEST Addendum: An addendum to the FFC that provides information to the CTTA to aid in the determination of what TEMPEST countermeasures, if any, need to be applied. (DoD 5105.21-M Vol 2)

TEMPEST Counter Measure Review (TCR): The review conducted or validated by the Certified TEMPEST Technical Authority to document the recommended TEMPEST countermeasures for the project.

Telecommunications Room (TR): An architectural space designed to contain telecommunications equipment, cable terminations, and cross connect cabling. (UFC 3-580-01)

Telecommunications System: Any system that transmits an analog or digital signal over a physical (cable or wire) or non-physical (wireless) connection. This includes systems such as information technology, control, cable television, electronic security, fire alarm, paging, intercom, public address, and mass notification.

Temporary Secure Working Areas (TSWAs): An accredited facility where handling, discussing, and/or processing of SCI is limited to less than 40-hours per month and the accreditation is limited to 12 months or less.

United States and its territories: The 50 states, the District of Columbia, Puerto Rico, Guam, American Samoa, the United States Virgin Islands, Wake Island, Johnston Atoll, Kingman Reef, Palmyra Atoll, Baker Island, Howland Island, Jarvis Island, Midway Islands, Navassa Island, and Northern Mariana Islands. (DoDM 5200.01, Volume 3)

Uninterruptible Load: Loads that require continuous power and cannot experience even momentary power disruptions. Loads in this category usually involve life safety or include hazardous or industrial process equipment, command, control, computer, data center, and communications systems. (UFC 3-540-01)

U.S. Person: An individual who has been lawfully admitted for permanent residence as defined in 8U.S.C. § 1101(a)(20) or who is a protected individual as defined by Title 8 U.S.C. §1324b (a)(3)). (IC Tech Spec – for ICD/ICS 705)

Vault: A room(s) used for the storing, handling, discussing, and/or processing of SCI and constructed to afford maximum protection against unauthorized entry. (IC Tech Spec – for ICD/ICS 705)

Waveguide: Devices installed at perimeter penetrations that are formed by metal tubing or ducting intended to attenuate wave energy.

APPENDIX C REFERENCES

C-1 GOVERNMENT.

COMMITTEE ON NATIONAL SECURITY SYSTEMS

https://www.cnss.gov/cnss/

Committee on National Security Systems Advisory Memorandum (CNSSAM) TEMPEST/01-13, *RED/BLACK Installation Guidance* (For Official Use Only)

Committee on National Security Systems Instruction (CNSSI) No.4009, *Committee on National Security Systems (CNSS) Glossary*

Committee on National Security Systems Instruction (CNSSI) No.7003, *Protective Distribution Systems (PDS)*

DEPARTMENT OF DEFENSE

https://www.esd.whs.mil/dd/dod-issuances/

Manuals:

DoDM 5105.21-Volume 1, *Sensitive Compartmented Information (SCI) Administrative Security Manual: Administration of Information and Information Systems Security*

DoDM 5105.21-Volume 2, *Sensitive Compartmented Information (SCI) Administrative Security Manual: Administration of Physical Security, Visitor Control, and Technical Security*

DoDM 5105.21-Volume 3, *Sensitive Compartmented Information (SCI) Administrative Security Manual: Administration of Personnel Security, Industrial Security, and Special Activities*

DoDM 5200.01 Volume 1, *DoD Information Security Program: Overview, Classification, and Declassification*

DoDM 5200.01 Volume 2, *DoD Information Security Program: Marking of Information*

DoDM 5200.01 Volume 3, *DoD Information Security Program: Protection of Classified Information*

DoDM 5205.07 Volume 1, *DoD Special Access Program (SAP) Security Manual: General Procedures*

DoDM 5205.07 Volume 2, *DoD Special Access Program (SAP) Security Manual: Personnel Security*

DoDM 5205.07 Volume 3, *DoD Special Access Program (SAP) Security Manual: Physical Security*

DoDM 5205.07 Volume 4, *DoD Special Access Program (SAP) Security Manual: Marking*

Directives:

DoD 5200.08-R (DTM) 08-004, *Physical Security Program*

DoDD 4270.5, *Military Construction*

Instructions:

DoDI 5200.48, Controlled Unclassified Information (CUI)

DEPARTMENT OF THE NAVY

DONSAPCO/0779-22, *Department of Navy Special Access Program Facilities Way Ahead*

DEPARTMENT OF STATE

Best Practices Guidelines for Architectural Radio Frequency Shielding (FOUO)

DIRECTOR OF NATIONAL INTELLIGENCE

https://www.dni.gov/index.php/ncsc-how-we-work/ncsc-ci-security-governance-regulations

Office of the Director of National Intelligence Instruction 80.16, Category 80 - *Information and Records Management*

Intelligence Community Directive (ICD) 703, *Protection of Classified National Intelligence, Including Sensitive Compartmented Information*

Intelligence Community Directive (ICD) 705, *Sensitive Compartment Information Facilities*

Intelligence Community Standard Number 705-1 (ICS 705-1), *Physical and Technical Security Standards for Sensitive Compartmented Information Facilities*

Intelligence Community Standard Number 705-02, *Standards for the Accreditation and Reciprocal Use of Sensitive Compartmented Information Facilities*

Intelligence Community Standard Number 706-02, *Protecting Mission Critical-Facility Related Control Systems (MC-FRCS) in Mission Critical Facilities (MCF)*

IC Tech Spec-for ICD/ICS 705, *Technical Specifications for Construction and Management of Sensitive Compartmented Information Facilities*

FEDERAL SPECIFICATIONS

https://quicksearch.dla.mil/qsSearch.aspx

AA-D-600D, *Federal Specification Door, Vault, Security*

FF-L-2740, *Locks, Combination*

FF-L-2890, *Lock Extension (Pedestrian Door, Deadbolt)*

FF-P-110, *Padlock, Changeable Combination (Resistant to Opening by Manipulation and Surreptitious Attack)*

NATIONAL INSTITUTE FOR STANDARDS AND TECHNOLOGY

Federal Information Processing Standard (FIPS) 140-2, *Security Requirements for Cryptographic Modules*

Federal Information Processing Standard (FIPS) 197, *Advanced Encryption Standard* (AES)

NAVAL FACILITES ENGINEERING COMMAND

NAVFAC INSTRUCTION 4700.01, *Planning, Design, and Construction of Navy Sensitive Compartmented Information 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*

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

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

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

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

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

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

UFC 4-020-02FA, *Security Engineering: Concept Design* (FOUO)

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

UNIFIED FACILITIES GUIDE SPECIFICATIONS

https://www.wbdg.org/dod/ufgs

UFGS 08 34 73, *Sound Control Door Assemblies*

UNITED STATES ACCESS BOARD

https://www.access-board.gov/aba/

Architectural Barriers Act (ABA) Standards

C-2 NON-GOVERNMENT.

THE AMERICAN INSTITUTE OF ARCHITECTS

Architectural Graphics Standards

ASTM INTERNATIONAL (ASTM)

ASTM C1766, Factory-Laminated Gypsum Board

ASTM D1003, Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics

ASTM E336, Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings

ASTM E90, Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements

GYPSUM ASSOCIATION

GA-600, *Fire Resistance and Sound Control Design Manual*

INTERNATIONAL CODE COUNCIL

https://www.iccsafe.org/

International Building Code (IBC)

NATIONAL FIRE PROTECTION ASSOCIATION

http://www.nfpa.org

NPFA 70, *National Electric Code*

NFPA 101, *Life Safety Code*

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

UNDERWRITER'S LABORATORIES, INC. (UL)

https://www.ul.com/

UL 634, *Standard for Connectors and Switches for Use with Burglar-Alarm Systems*

UL 639, *Standard for Intrusion-Detection Units*

UL 681, *Installation and Classification of Burglar and Holdup Alarm Systems for Alarm System Installation*

UL 864, *Standard for Control Units and Accessories for Fire Alarm Systems*

UL 1034, *Standard for Safety for Burglary-Resistant Electric Locking Mechanisms*

UL 1076, *Standard for Safety Proprietary Burglar Alarm Units and Systems*

UL 1610, *Standard for Safety Central-Station Burglar-Alarm Units*

UL 2050, *National Industrial Security Systems;* UL 2050 materials are restricted and only distributed to those demonstrating relevant national industrial security involvement

UNIFIED FACILITIES CRITERIA (UFC)

CYBERSECURITY OF FACILITY-RELATED CONTROL SYSTEMS (FRCS)

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UNIFIED FACILITIES CRITERIA (UFC)

CYBERSECURITY OF FACILITY-RELATED CONTROL SYSTEMS (FRCS)

Indicate the Military Department Preparing Activity responsible for the document.

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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/ffc/dod.

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

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

1-1.1 Control System Definition

Control systems are a combination of special purpose controlling devices (controllers), control components (e.g. electrical, mechanical or pneumatic sensors and actuators), and generally (but not always) network infrastructure (which may contain standard IT components) that act together upon underlying mechanical and/or electrical equipment to achieve an objective. A control system (CS) typically consists of sensors and actuators connected to networked digital controllers, includes a user interface, and is used to control and monitor equipment.

Some control systems are “monitor only” (they do not exercise control) but are still considered control systems.

1-1.2 Facility-Related Control Systems

There are many types of control systems ranging from building control systems to manufacturing control systems to weapon control systems, all with different names and terminology. Facility-Related Control Systems (FRCS) are a subset of control systems that are used to monitor and control equipment and systems related to DoD real property facilities (for example, building control systems, utility control systems, electronic security systems, and fire and life safety systems).

1-1.3 Risk Management Framework (RMF)

The Risk Management Framework (RMF) is the DoD process for applying cybersecurity to information technology (IT), including control systems. The RMF categorizes systems by the impact the system can have on organizational mission using HIGH, MODERATE, and LOW impact levels. The RMF is further described in CHAPTER 2 and APPENDIX A.

1-2 PURPOSE AND SCOPE.

This UFC describes requirements for incorporating cybersecurity in the design of all facility-related control systems which include a network. This UFC covers the cybersecurity aspects of control system design, and the requirements of this UFC must be coordinated with the control system design and the criteria relevant to the control system. This UFC only covers aspects specific to control system design. Many projects have IT-specific components (such as IP network design security) which are not covered by this UFC; in those cases, the controls designer will need to coordinate with other disciplines. This UFC defines a process for identification of cybersecurity requirements based on the Risk Management Framework suitable for control systems of any impact rating and provides specific guidance suitable for control systems assigned LOW or MODERATE impact level.

This UFC covers the incorporation of cybersecurity concepts and requirements in support of the Risk Management Framework. This UFC does not implement the RMF and does not address anything beyond the design of the system. Use of this UFC does not result in an ATO under the RMF process but will provide a system that is more capable of receiving an ATO than a system not designed in accordance with this UFC.

1-3 APPLICABILITY.

This UFC applies to all planning, design and construction, renovation, and repair of new and existing facilities (both permanent and non-permanent) and installations that result in DoD real property assets which include a control system with a network, regardless of funding source (and regardless of network type). Restated another way, this UFC applies to any project with any control system that includes architecture levels, as defined in this UFC, of 1 or higher. While this UFC can assist with the design of any system, portions of it are applicable only to the design of LOW and MODERATE impact systems and HIGH Impact system will typically require additional customized requirements to achieve appropriate levels of cybersecurity. Design of such systems should be coordinated with the points of contact provided in Paragraph 1-6.

In defining specific requirements for LOW or MODERATE systems, this UFC assumes the control system is being implemented on a DoD Installation or other DoD site, which allows inheritance of some cybersecurity controls. Systems not being implemented on a DoD Installation may require additional requirements not included in this UFC.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, DoD Building Code (General Building Requirements). 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 ORGANIZATION.

CHAPTER 2 provides an overview of the RMF as it applies to control systems, control system architecture and the cybersecurity approach to control systems. CHAPTER 3 defines a 5-step approach to incorporating cybersecurity into the design of control systems. CHAPTER 4 defines minimum design requirements for control systems to be implemented in addition to the specific requirements identified through the 5-step process described in CHAPTER 3. CHAPTER 5 defines the submittal requirements for documenting cybersecurity aspects of control system design.

APPENDIX A provides an overview of the Risk Management Framework as it pertains to control systems. APPENDIX B provides additional detail on the Platform Enclave concept. APPENDIX C describes the 5-Level architecture for control systems. APPENDIX D describes considerations in determination of control system impact ratings. APPENDIX E discusses considerations in the integration of critical building systems into a non-critical UMCS. APPENDIX F provides guidance for security control families, and individual security controls. APPENDIX G categorizes CCIs by impact and responsibility.

1-6 CYBERSECURITY POINTS OF CONTACT BY SERVICE.

Cybersecurity policies and approaches are evolving, and projects may have unique requirements. Assistance for control system cybersecurity design is available from the following Service organizations:

- Army, other than Civil Works: Control System Cybersecurity Mandatory Center of Expertise (CSC-MCX), Huntsville Engineering and Support Center (CSC-MCX@usace.army.mil)
- Army, Civil Works: HQUSACE Engineering and Construction Control System Community of Practice Leader (controlsystemcopleader@usace.army.mil).
- Navy (and Marine Corps): Naval Facilities Engineering Command, Command Information Office (CIO).
- Air Force (and Space Force): Air Force Civil Engineering Center (AFCEC) Operations Directorate, Tyndall Air Force Base. Support can be obtained via the reach-back center at AFCEC.RBC@us.af.mil. Note: All requests for support must be initiated by the Contracting Officer's Representative (COR) or, for government-designed projects, by the Project Lead.

1-7 GLOSSARY.

APPENDIX H contains acronyms, abbreviations, and definitions.

1-8 REFERENCES.

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

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CHAPTER 2 CONTROL SYSTEM CYBERSECURITY OVERVIEW

2-1 RISK MANAGEMENT FRAMEWORK OVERVIEW.

The risk assessment process, or Risk Management Framework (RMF), inventories the system components, identifies the System Owner (SO) and Authorizing Official (AO), and implements risk reduction measures. The Authorizing Official then evaluates the risk and either accepts the risk and issues an Authority to Operate (ATO) or denies the ATO. At this point, the system is allowed to operate and (if necessary) connect to DoD network infrastructure. Risk reduction measures include removal of network and wireless capabilities, documenting the system, and altering the system to limit capabilities.

APPENDIX A contains a more extensive summary of the RMF as it relates to this UFC. It is highly recommended that readers unfamiliar with the RMF review APPENDIX A before incorporating cybersecurity requirements into control system design.

2-1.1 Security Controls.

The RMF relies on the implementation of security controls, where a control is a specific action taken to secure a system. Note that this usage of the word ‘control’ is different from control engineering or control systems engineering, which is the engineering discipline that applies control theory to design systems with desired behaviors. To provide clarity of usage, this UFC will use the term “security control” to refer to cybersecurity controls.

2-1.2 RMF Goal.

For FRCS, the goal of the RMF is to reduce and mitigate vulnerabilities until the risk to the mission supported by the FRCS is deemed acceptable by the System Owner (SO) and Authorizing Official (AO). Under the RMF, risk reduction is not "all or nothing", rather the security solution must reduce risk while considering the constraints of resources and mission requirements. For application of the RMF to control systems, the determination of cybersecurity risk reduction must also account for any additional risks to system functionality due to application of the security controls. The final decision of whether a level of risk is acceptable is made by the assigned government AO.

2-1.3 RMF Roles of the Designer and Control System Installer.

2-1.3.1 RMF Role of the Designer

The designer has one primary role and one secondary role in the RMF process. Their primary role is to identify security controls which can be addressed by the design (during project planning and design) and implement those security controls in the design. As a secondary role, the designer provides input into the risk analysis process by advising on the impact, or lack thereof, of applying security controls to the control system and by advising on how the control system does or does not impact supported missions.

For an example of the need for designer input, consider the mechanical design of an HVAC system. These systems are designed to specific criteria - design day environmental conditions - and those criteria are a compromise between a system that is oversized for most of its operation, and a system that is sometimes under-sized. The criteria are well-established, and the tradeoffs are understood and accepted. Cybersecurity involves similar trade-offs but, unlike for HVAC design, the criteria are not well-established, and the AO must determine the balance point between an over-secure system (which will likely be more expensive, and harder to install, commission, and maintain) and a system that still has some residual risk. Evaluating this risk requires a detailed understanding of the control system functioning which the AO may not possess, necessitating input from the designer.

2-1.3.2 RMF Role of Control System Installer

The construction installer is – as with any other aspect of a construction project – responsible for meeting the specifications and requirements of the contract. They are not directly responsible for Cybersecurity. Given a proper design, meeting the specifications will provide for a proper implementation of Cybersecurity.

2-1.4 Platform Information Technology.

DoD Instructions 8500.01 and 8510.01 define the Risk Management Framework (RMF) for the DoD and establish a category for “special purpose” systems that are not traditional information technology or information systems, called Platform Information Technology (PIT) systems. These PIT systems, including control systems, use specifically tailored security controls sets and require the AO to have expertise in the system.

As further discussed in CHAPTER 3, the designer provides input into the determination of the control system impact rating by advising on the relationship between the control system and the mission supported and provides input on the security control selection by advising on the feasibility and potential impacts of applying a security control.

2-1.5 Inherited Security Controls.

An inherited security control is a security control that a system meets by virtue of someone else addressing it in such a way that it applies to the system. A control system will generally inherit security controls one of three ways: by existing within a physical security boundary, by being covered by policies and procedures already in place, or by connection to another system which addresses the security controls.

Since inheritance often requires the SO to coordinate with others, it’s critical to document all security controls the control system expects to inherit. During control system design, the designer must identify and document any security controls which are expected to be inherited.

2-1.5.1 Physical Security Inheritance Example.

DoD installations implement physical security to manage risk to an acceptable level. For a control system on a DoD Installation, a security control requiring that members of the public not be allowed unrestricted physical access to components of a control system will be met by virtue of the control system existing within that physical security boundary. Although military installations are on occasion opened to the public for events such as boot camp graduations, the access is not unrestricted, and the level of access has been accepted by installation security. Since control systems are innately tied to and co-located with the physical systems they control, in most cases a control system will be able to inherit physical security from the installation or separately secured facilities.

2-1.5.2 Policy and Procedures Inheritance Example.

The DoD has policies in place governing many aspects of cybersecurity. A control system can therefore inherit a security control such as “the organization defines the frequency to review and update the current security planning policy”.

2-1.5.3 Connection to another System Inheritance Example.

When a control system connects to another system, such as an Installation-wide network, inheritance may not be automatic but may require an agreement between the SOs of the systems. Such an agreement would cover acceptable behavior of the control system and explicitly define the security controls that will be inherited from the other system.

2-1.6 Applicability of RMF Security Controls to Design.

Security controls cover a wide range of requirements, many of which must be addressed by someone outside the control system design process. For example, a security control[1] that states “The organization protects the control system from unauthorized modification by members of the organization” is normally not addressed by the designer; but rather is addressed through policies and procedures put in place by the organization that owns and operates the control system.

2-1.6.1 Applicability of RMF Security Controls to Design of Critical Systems.

The determination of whether a security control should be applied at design can become particularly complex for more critical (higher impact) systems. While it may be sufficient for a LOW impact system to assume a particular security control is addressed by another entity, the designer of a HIGH impact system may need to explicitly address

[1] This is not an actual security control, but rather an illustrative example using a fictitious control.

a security control to ensure it is being implemented properly, to apply it at a higher standard, or to provide tools to the responsible parties to assist their implementation of the security control. For example, while a security control stating[2] "The organization protects the control system from unauthorized modification by members of the organization" might be addressed through policies and procedures for a LOW impact system, a higher impact system may require the designer to explicitly design in additional barriers to unauthorized modification, or to provide guidance to the organization concerning the importance of properly securing the control system against modification. In this case, however, it's vital to consider the impact these restrictions may have on the ability to make necessary authorized changes. For this reason, designers of systems with HIGH mission impact should likely seek the assistance of a dedicated cybersecurity engineer. MODERATE systems may also require specialized attention depending on the circumstances of the design.

2-1.6.2 Applicability to Control Systems as Compared to IT Systems

Another issue to be considered in the design of critical systems is the potential gap between the strict requirements of the (IT-centric) RMF and what is practical in control system design. Consider, for example, a fire alarm system and the level of support a fire alarm panel will have for Personal Identity Verification (PIV, such as the DoD CAC) compared to the RMF requirements at the MODERATE level. As a practical matter, it's likely impossible to install a fire alarm system that meets the PIV requirements of a MODERATE impact system.

In this case, insisting on RMF requirements "as written" is particularly problematic as it would prevent the procurement and installation of the system until the manufacturer develops a custom system and then obtains UL certification. In other cases, the designer could insist on the RMF-required functionality, driving the installing contractor to create custom solutions using specialized equipment, but this is rarely the best approach as it greatly increases the overall risk that the system will not function properly. The unique solutions required to meet these requirements will likely require controllers that are not designed for the purpose in which they are used, and the system will likely be installed by contractors with experience in securing systems but not in the specific functionality of the control system. Because of its non-standard nature the system is likely to be significantly more expensive and more difficult to install, test, operate and maintain, all of which reduce the overall reliability of the system.

2-1.6.3 Other Applicability Input

In addition to providing input on the impact the control system will have on the supported mission, designers may be required to provide input on the ability (or inability) of the control system to meet cybersecurity requirements. This assists the AO in defining and accepting requirements that address cybersecurity risks without introducing functional risks.

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[2] This is not an actual security control, but rather an illustrative example using a fictitious control.

2-2 5-LEVEL CONTROL SYSTEM ARCHITECTURE.

Even though control systems are becoming more like standard IT systems, there remain major differences that must be recognized. The 5-Level control system architecture shown in Figure 2-1 is a framework for describing the system architecture of any control system. This architecture allows distinctions to be made between portions of the control system that look like standard IT, and portions that do not look like standard IT. This is important as many security controls can be applied in the normal fashion to the portion of the control system that looks like a standard IT system but cannot be applied without modification (or sometimes cannot be applied at all) to the portion that does not look like a standard IT system.

APPENDIX C provides a more in-depth description of the 5-Level control system architecture.

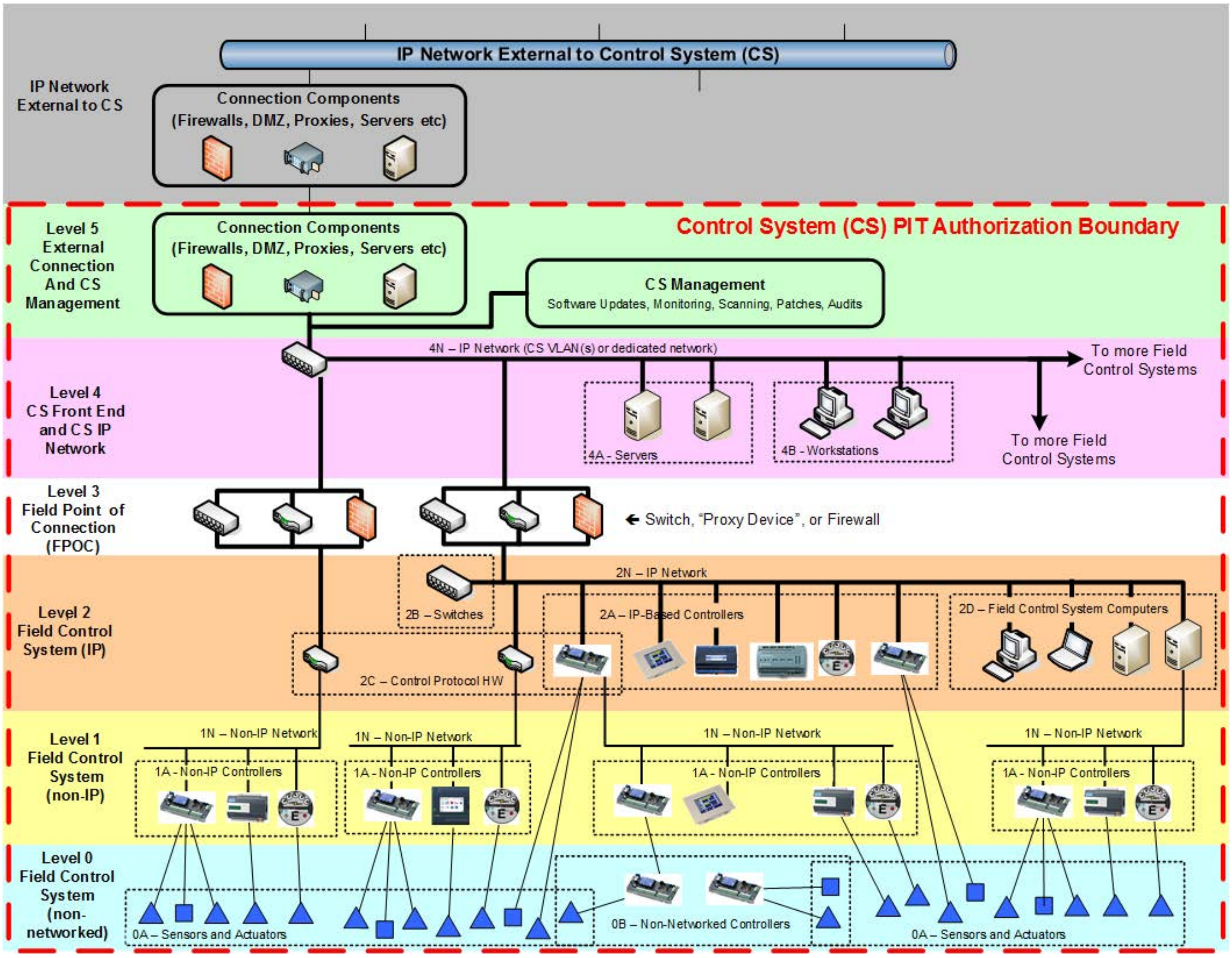
2-2.1 Architecture Is a General Architecture

This architecture is designed to highlight Cybersecurity aspects of the control system; it is not intended to be an exact depiction of a control system. A single control system may have multiple authorizations and the boundaries of these authorizations may not be easily depicted by the architecture itself. Other control systems with a single authorization might lack a system-wide network and – from an IT perspective – appear to be several distinct systems; these might not be easily depicted by a single architecture drawing. For example, an installation-wide fire protection system generally does not have a system-wide network; each building has a separate network, and the buildings are connected to a central monitoring station by radios and relay panels[3].

A single system may be described by the architecture in multiple ways – a multi-building control system with a dedicated IP network connecting the buildings may be described as a single FCS consisting only of levels 0-2 with the entire IP network residing at level 2, or it could be described as using levels 0-4 with multiple Level 2 networks connecting to a Level 4 IP network through multiple FPOCs. Depending on the system functionality as well as the cybersecurity approach, either or both may be valid, and which is the more appropriate depiction of the system depends on the details of the system itself and must be determined on a case-by-case basis. Both fit within and can be described by the 5-level architecture, and the intent of the architecture is to provide a common lexicon for defining systems and not to confine systems to a set definition.

[3] The use of relay panels breaks the system into a base-wide radio network and a collection of buildings, each with an ***independent*** network in it.

Figure 2-1 5-Level Control System Architecture



2-2.2 "Standard IT" Parts of the Control System.

The parts of the control system that most resemble a standard or traditional IT system are referred to as the "Standard IT" parts:

- The IP Network portion of Level 4 (Level 4N).
- The IP Network portion of Level 2 (Levels 2N and 2B).
- The field point of connection (FPOC) at Level 3.
- The computer hardware for both servers and workstations (Levels 2D, 4A, 4B)
- The computer OS and other standard packages (such as antivirus) for both servers and workstations (desktops and laptops) (Levels 2D, 4A, 4B). Note that this does not include control system software such as front-end packages or engineering tools, but it might include things like web servers and database engines used by the front end. While front end packages and engineering tools likely run on standard desktop operating systems and have many characteristics

in common with standard IT applications, they may have unique features and applying cybersecurity to them may require special expertise.

- External connections and control system management at Level 5.

The cybersecurity for the "standard IT" parts of the control system are largely addressed using standard cybersecurity practices and are generally outside the scope of control system design and are not addressed by this UFC. The designer should coordinate with IT experts for cybersecurity of those portions of the control system. The designer must address the IP Network at Level 2N, which is generally procured and installed by the control system contractor, and the control system specific software used by the front end, which is generally not adequately covered by standard IT approaches.

2-2.3 "Non-Standard IT" Parts of the Control System.

What makes cybersecurity for a control system challenging are the parts of the control system that do not generally resemble a standard IT system: Level 0, Level 1, Level 2A, Level 2C and the control system applications at Level 2D, Level 4A and Level 4B. These parts of the control system are referred to as the "non-standard IT" parts in order to differentiate them from the "standard IT" parts. Traditional cybersecurity tools and requirements such as vulnerability management alerts, bulletins, Secure Technical Implementation Guides (STIGs), Security Requirements Guides (SRGs), and DoD IT Policies are seldom applicable to these non-standard IT components, particularly to devices at Levels 0, 1 or 2. For example, a security control[4] requiring the screen to be locked when the user leaves the computer is not applicable to devices that do not have a screen or support user login. Different levels of the architecture have different issues related to the application of standard cybersecurity tools and requirements.

Cybersecurity for these portions of the control system must be addressed by the control system designer.

2-2.3.1 Computers at Level 2

If front end computers are on the same dedicated IP network as the control system (generally within the same building as the control system) they are considered to be at Level 2 rather than Level 4. This is a common scenario in legacy systems, and is sometimes found in new installations, particularly for systems that are not interfaced to a base-wide front end or where (typically to meet availability requirements) the front end servers (Level 4A) must be placed on that building's Level 2 network. However, when installing new computers as part of a project, the cybersecurity requirements are largely the same regardless of whether the computers are at Level 2 or Level 4.

2-2.3.2 Level 0 Components vs Systems

A common question that arises is: "How complex can a 'thing' be and still be considered a Level 0 device?" For example, consider a packaged backup power unit, with diesel engine, generator, and Automatic Transfer Switch (ATS). This unit has dozens of

[4] For reference – security control AC-11 deals with session lock requirements.

sensors and actuators, multiple controllers, and an internal network connecting them all together. Since it is a ***packaged unit*** and procured as a single component, if the unit ***does not*** have a network interface to the rest of the system it ***could*** be considered a single Level 0 device, even if procured independently of any other control system. Alternatively, the unit could be considered its own mini field control system.

Ultimately the decision on how best to address such units must be made in coordination with the SO and AO, but a general guideline is to consider packaged units with hardware interfaces to be Level 0 devices, and to consider built-up units connected with hardware interfaces to be separate FCS. Note that any device, no matter how "dumb," is not a Level 0 component if it is connected to a network (has a network interface as opposed to simple binary and analog connections), so even a simple networked temperature sensor is not a Level 0 device.

2-2.3.2.1 As a Level 0 Component

A Level 0 device with an internal network - particularly if procured independently of any other control system -, might need to go through the RMF process – as a FRCS consisting of a single Level 0 device with a greatly reduced set of cybersecurity requirements. Or the AO could greatly simplify the process and accept the risk up front for a Level 0 device (albeit an expensive and complex Level 0 device).

2-2.3.2.2 As a Mini Field Control System

The unit could be considered its own mini field control system, which requires the internal components of the packaged unit be defined as well as the hardware (non-networked) interface between the backup power unit and the building system. This adds a lot of effort and documentation for very little benefit, and is almost never the right choice. Note that this may also cause a separate ATO for the unit to be required, significantly increasing the burden even further.

2-2.3.3 Describing Systems Using the 5-Level Architecture.

As stated previously, the 5-level architecture provides a common lexicon for defining systems and is not intended to confine systems to a set definition. The basic architecture drawings presented in this UFC generally describe a single system with a single authorization, or with two authorizations where one of them is a Platform Enclave. Other control systems may require architecture drawings which depict systems using the 5-level architecture in various other ways. In some cases, the architecture may need to indicate additional authorization boundaries, and in others the architecture levels may be connected in ways not shown on the basic drawings in this UFC. For example:

- A base-wide fire reporting system where a system in a building is connected via radio to a base-wide central monitoring system at the main fire station. In this case, the building level system exists at Levels 0 – 2 and there is a Level 0 interface (relay panel) between it and a sitewide radio network. The radio network is (typically) a Level 1 (dedicated non-IP network) interface to a central front end and other Level 0 – 2 building level fire systems.

- A fire protection system where some subsystem (such as the releasing panel controlling a pre-action fire sprinkler system in a datacenter) has a higher cyber impact rating (say MODERATE) than the rest of the system (presumed to be LOW). In this case, the system may be authorized in two different ways:
    - A single authorization covering the entire building fire protection system. Because the releasing panel has a MODERATE impact, the entire system would need to meet MODERATE requirements.
    - Two separate authorizations: a) A small MODERATE authorization for the releasing panel, and b) A large LOW authorization for the remainder of the building. In this case, the two systems would need to have a cyber-secure separation between them; the easiest (but not only) way to achieve this this would be via an interposing relay panel.
- A MODERATE building control system needing integration into a base-wide LOW system. Again, there is a choice between either treating the base-wide system as a MODERATE system (a potentially very expensive solution) or having two authorizations – a MODERATE for the building and a LOW for the base-wide system. The tradeoff in this case is that the integration will need a high level of isolation and will likely be more expensive and provide much less functionality than the normal integration of a building into the base-wide system. This specific case is covered in more detail in APPENDIX E.

The key point here is that all FRCS can be described in terms of components at one or more of the 5 levels of this architecture.

2-2.4 Wireless Networks

Although not explicitly shown in the architecture, wireless networks may exist at Level 1, Level 2 or Level 4 of the architecture. Wireless networks require additional cybersecurity measures, and unless furnished by the project site must be carefully coordinated to ensure the use of wireless is approved and meets all the additional requirements.

2-2.5 Platform Enclave.

Many control systems are hosted within a network that is segmented from the general day-to-day business application (such as email, file servers) network either physically or virtually. This separate IT infrastructure environment dedicated to the delivery of common level services (for example, Active Directory Services, Assured Compliance Assessment Solution (ACAS) Services, Host Base Security System (HBSS) Services) to the FRCS is referred to as the Platform Enclave. In some cases, this Platform

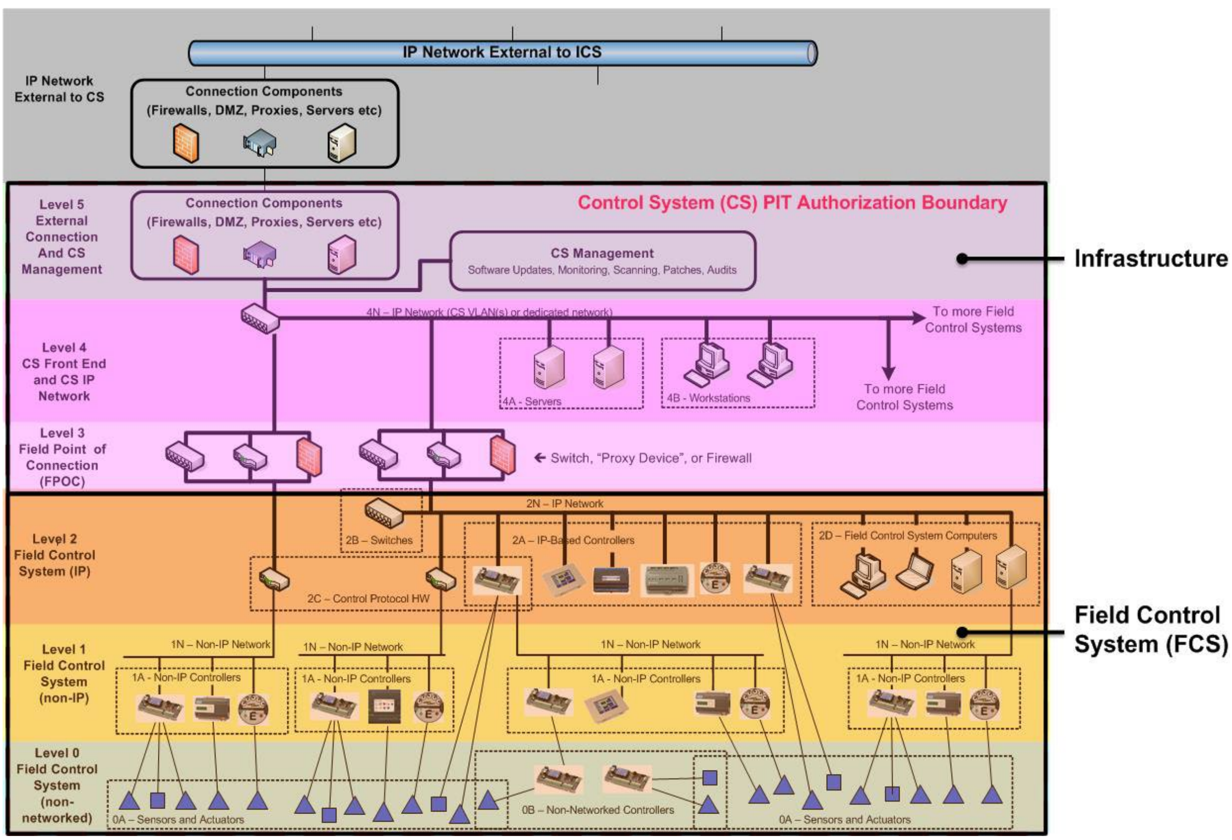
Enclave will have a separate authorization from the control systems within the enclave. The control systems will have their own authorization for their Operational Architecture which primarily covers the “non-standard IT” components of the system. In other cases, it is possible that a single authorization will be used for the entire system, both the enclave and the control system. Even in cases where a single authorization is used, however, it’s helpful to identify and categorize the “standard IT” portions of the control system. More information on the Platform Enclave approach is in APPENDIX B.

2-3 CONTROL SYSTEM PROCUREMENT OVERVIEW.

The DoD does not procure most installation-wide control systems as an entire 5-Level system as depicted in Figure 2-1. Typically, some Field Control Systems (FCS; architecture Levels 0 - 2 as shown in Figure 2-2) are procured along with a front end for those systems. Over time additional FCS are procured; these new FCS are integrated with the existing front end and added to the authorization (ATO) for the existing system to expand the installation-wide system. When designing an FCS that will be added to an existing system, there may be cybersecurity requirements that are specific to the authorization of the existing system which must be incorporated into the FCS design. Also note that the Level 3 FPOC and Level 4 IT infrastructure are usually provided by the site-wide IT support organization; they are not procured for (and are often not dedicated to) the control system. This UFC cannot address site-specific requirements; when designing systems which will be added to an existing system authorization coordinate with the project site to obtain relevant requirements from the existing system.

Some control systems are procured to operate independently, with no integration to a larger system and without further significant expansion. Depending on the circumstances and architecture, treat these systems either as complete systems, containing all 4 or 5 Levels, or as a FCS (Level 0-2) with its own user interface at Levels 1 or 2. See Table C-3 in APPENDIX C for more information on the Level 2D computers.

Figure 2-2 Control System Architecture



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CHAPTER 3 APPLYING CYBERSECURITY IN DESIGN

3-1 OVERVIEW.

The design of cybersecurity for facility-related control systems is a five-step process. In some cases, a specific step may be performed by someone other than the designer but may still require input from the designer. Documentation of cybersecurity-related design decisions and input to others is described in CHAPTER 5.

In addition to requirements specific to Control Correlation Identifier (CCIs), design all control systems according to the minimum cybersecurity design requirements in CHAPTER 4 and cybersecurity requirements otherwise standard for the type of control system being designed.

3-1.1 Five Steps for Cybersecurity Design.

The five steps for cybersecurity design are:

Step 1: Identify the Confidentiality, Integrity, and Availability (C-I-A) impact levels (LOW, MODERATE, or HIGH) to use for the control system design.

Step 2A: Use the impact levels to select the proper list of controls from NIST SP 800-82.

Step 2B: Using the DoD master Control Correlation Identifier (CCI) list, create a list of relevant CCIs based on the controls selected in Step 2A.

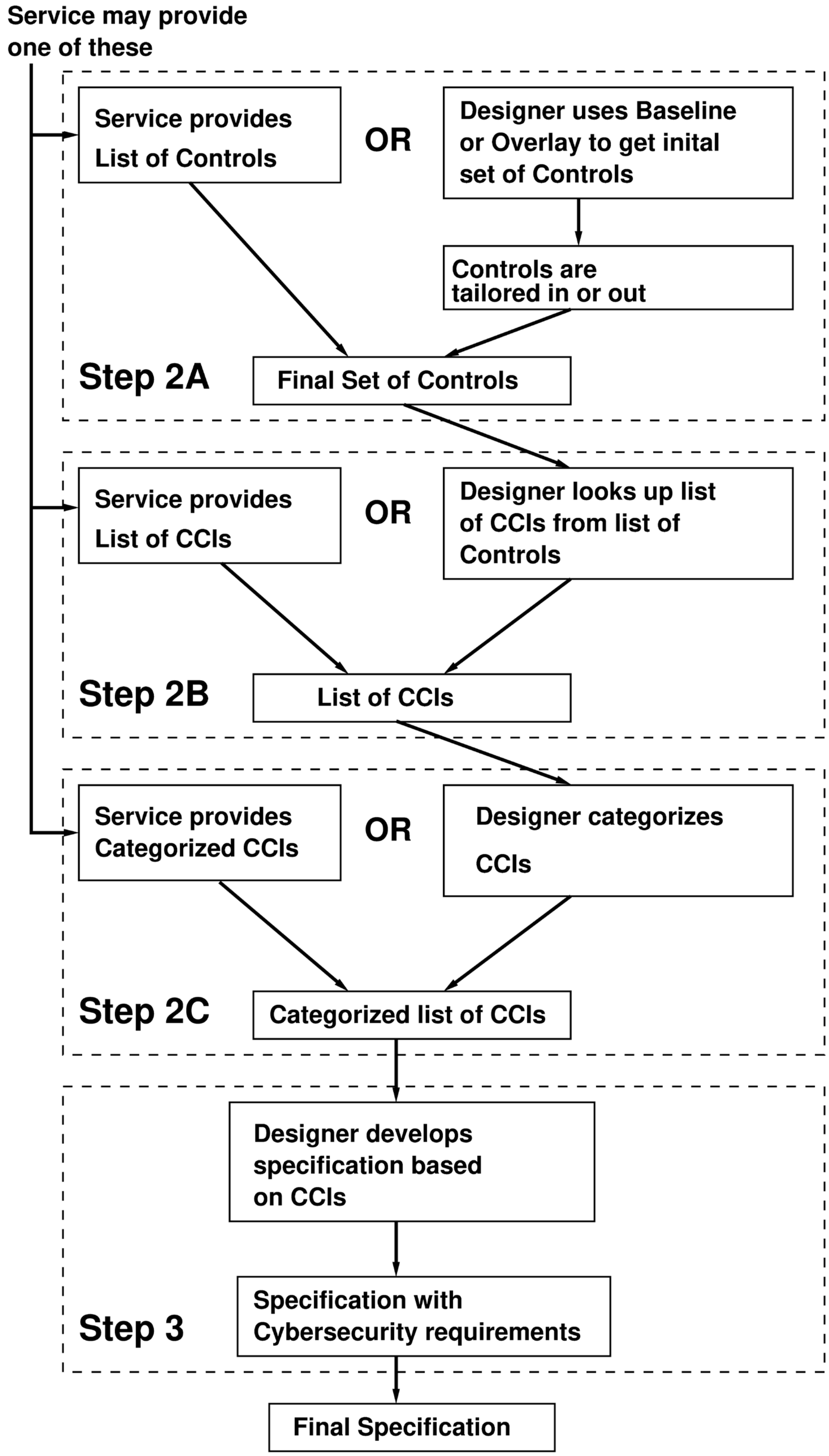
Step 2C: Categorize CCIs and identify CCIs that require input from the designer or are the designer's responsibility.

Step 3: Include cybersecurity requirements in the project specifications and provide input to others as required.

These steps are numbered in this way to align with the corresponding steps of the 7-step[5] RMF Process. For example, Steps 2A, 2B, and 2C all occur at Step 2 of the RMF process, "Select Security Controls". APPENDIX G contains tables covering Steps 2A, 2B and 2C for LOW and MODERATE systems, assuming the existence of a Platform Enclave. These tables, with additional information in a filterable format, are also available in Excel format on the RMF Knowledge Service (https://rmfks.osd.mil) and the use of that spreadsheet is highly recommended. This website is CAC-enabled; designers without a CAC must request assistance from the Service if tables and information were not provided. Figure 3-1 below provides an overview of steps 2A through 3, and APPENDIX F provides additional guidance on the implementation of specific controls.

[5] Formerly a six step process, the RMF has introduced a seventh step as "Step 0: Prepare"

Figure 3-1 Overview of Steps 2A through 3



3-1.1.1 Beginning Mid-Process

These five steps fully define the Cybersecurity portion of the design process when starting with a “blank page”. Strictly speaking, Step 1 should be completed by the AO or SO, and in some cases, the asset owner or Service may also have defined the list of cybersecurity controls (they have completed Step 2A), or the list of CCIs (they have completed step 2B), or even the specific CCIs to be addressed by the designer (they have completed step 2C). In these cases, (as shown in Figure 3-1 above) begin the design process at the appropriate step using the information provided.

3-1.2 Definition of “Organization”.

Security controls often refer to the “organization” in identifying responsibilities and risk, making proper determination of “organization” critical to proper evaluation of impact. For example, loss of heating, ventilating, and air-conditioning (HVAC) at the Houston franchise of a national hotel chain in August might be catastrophic to the local facility manager, but it is hardly a significant blow to the United States, or even to the hotel chain. Unless otherwise indicated, for the purposes of implementation of the RMF to control systems:

- For determining the impact level of a system, treat the “organization” as the relevant Service (Army, Navy, Air Force).
- For determining implementation requirements for specific controls, treat the “organization” as the Installation (garrison, post or base) or Region (for regional systems). Note that this doesn’t conflict with the above statement regarding the organization for determining impact, but rather indicates the portion of the Service that will have responsibility for implementation of the control.

3-1.3 Designer Coordination

- Meeting cybersecurity requirements may require substantial coordination between different design disciplines. Many systems will be unable to meet identification and authentication requirements for user interfaces and physical security is recommended as a compensating control. These requirements (such as “install controllers in locked enclosures”) will need to be coordinated with the physical security designer. Similarly, the use of insecure network protocols may require physical security to prevent unauthorized access to the network.

- In almost all cases, the control system is only as important as the controlled equipment. For example, an air handler controller is of no relevance if the air handler has failed for some simple mechanical reason. Some cyber requirements may suggest additional requirements on underlying equipment and coordination with those designers may be required.

- In many cases, good cybersecurity design is best accomplished via good control system design. In the case where the designer following this UFC is other than the controls designer, some requirements needed to address cybersecurity controls must be included in the control system specification by the control system designer and documented in the design submittals defined in this UFC.

- Requirements in the cybersecurity specification have potential to conflict with those in the control system design or may pose functional issues for the control system. Close coordination is required to ensure requirements are implementable.

3-2 STEP 1: DETERMINE CONTROL SYSTEM IMPACT RATING TO USE FOR DESIGN.

The first step of the design process is to determine an impact rating for the control system design. Ideally this impact rating will be the actual impact rating for the control system, but, in some cases, it will be an impact rating determined or assumed for the purposes of the design only.

3-2.1 Obtaining Actual Impact Ratings

The SO, with concurrence from the AO, determines the impact levels of the control system. The SO may seek assistance from the designer in defining the functionality of the control system, the information the control system contains, and the ***impact of failure of the control system***. While the SO and AO are uniquely qualified to determine the criticality of the mission in the facility, they will likely require assistance from the designer to determine the impact of the control system on the mission. For example, a critical mission of processing real-time DoD intelligence data may not depend at all on the lighting control system in the data center. For the DoD, impact levels are determined based on the mission of the relevant Service and in many cases can use the mission criticality rating of the facility (mission support, mission essential, mission critical) as a starting point to determining control system impact. It's also important to note that while a traditional information system generally prioritizes Confidentiality, then Integrity and lastly Availability, control systems usually prioritize Availability and Integrity over Confidentiality.

Note this discussion assumes that the SO and AO have been identified for the system. In many cases, this may be difficult – at this stage of the project the SO may not yet identified. In many cases the impact of the control system is driven by the impact of the control system on the mission supported by the control system (such as a data center supported by mechanical and electrical systems) so, while the local O&M staff may "own" the control system, the impact of the control system is driven by the underlying mission supported by the control system so that the "effective" SO is a facility tenant. Ultimately, while identification of an SO and AO is not the designer's responsibility, lack of identification can present a roadblock to successful project implementation.

3-2.2 When Impact Ratings Aren't Provided

If impact ratings aren't provided, request them from the Service. If the Service is unable to provide impact ratings, then request direction from the Service and follow one of the following three courses of action as directed:

1. Use one of the categorization methods discussed in APPENDIX D to categorize the system for purposes of design and document how the categorization was determined.
2. Design the system to a L-L-L impact rating.
3. Do not proceed with the design until C-I-A Impact ratings are provided.

Note that these options are presented in preference order, with course of action 1 being the preferred solution. When the Service provides direction on which course of action to follow, follow that course of action. Should the Service not provide direction, use the first course of action.

3-2.3 Considerations for Reduction of Control System Impact

Whether assisting the SO and AO in determining the control system impact rating, or determining a design impact rating, it's vital to remember that the impact rating of the control system may be less than (but not greater than) the impact rating of the mission served, and a MODERATE impact mission does not necessarily imply a MODERATE impact control system. Only when loss of the control system necessarily results in loss of mission is the control system impact the same as the mission's impact rating. Several options (suggested in a flowchart in APPENDIX D) are available to the designer to potentially reduce the impact rating of the control system, such as:

- Can manual controls be added to compensate for a compromised control system?

- Some critical facilities may be staffed 24/7. In this case, a local controls front end might be installed inside the facility and facility staff provided sufficient training to make basic adjustments to the system. Another option is to add local display panels (limited operator interfaces within the control system) in mechanical rooms, again with the intent of allowing onsite staff the ability to maintain system operation (perhaps in a degraded state, but sufficient to maintain basic mission capabilities).

- Can simple standalone backup systems be added to compensate for a failed (base-wide) control system? For example, for a data center, can a standalone air conditioning unit be added that would start based on a local thermostat and run independently of the base-wide system? Particularly in the case of a critical facility (which likely has redundant HVAC equipment), can the "normal" or "primary" unit be connected to the base-wide UMCS, while the "backup" or "secondary" unit operates in a standalone configuration with purely local controls? Again, note that control system operation in a degraded state may be acceptable, provided it continues to support the mission.

- Some buildings may overall be non-critical but have a small critical room or facility inside the larger building. Again, can a small standalone unit, such as a small backup generator unit be added specifically to support the critical room or facility?

Critical facilities often require redundant mechanical / electrical equipment, and in these cases, the question is: “Can the control system design take advantage of this equipment to reduce the dependency of the mission on the control system to the point that the impact rating of the control system is LOW?” By use of redundancy and following general principals of design simplicity, the effect of a compromised control system can be minimized. The additional hurdles required to secure a MODERATE impact system will often make reduction of control system impact rating a worthwhile approach.

3-3 STEP 2A: DETERMINATION OF SECURITY CONTROLS.

When the list of relevant controls is not provided by the Service, determine a starting list of controls based on the Confidentiality (C), Integrity (I) and Availability (A) impact ratings (or C-I-A ratings) provided by the Service (or using the design CIA rating if the actual rating was not provided) and the appropriate control system overlay or baseline. Using the resultant initial control set, review the security controls to recommend security controls that should be considered for tailoring out by the SO and AO.

3-3.1 Overlay versus Baseline

In the RMF process, a baseline is a complete set of security controls, and an overlay is a defined set of changes (additions or subtractions). So, in the example table (Table 3-1) below we have 2 baseline sets of controls, Base 1 and Base 2, along with a single overlay that is applied to both. The baselines define controls to apply (“Do control A”, “Do control B”, etc.) and the overlay can be applied to either Baseline, with the results shown in B1 + Overlay and B2 + Overlay.

Table 3-1 Overlay versus Baseline

Base 1	**Overlay**	**B1 + Overlay**		**Base 2**	**Overlay**	**B2 + Overlay**
Do A	Add A	Do A			Add A	Do A
Do B		Do B		Do B		Do B
Do C	Skip C				Skip C	
Do D		Do D		Do D		Do D
	Skip E			Do E	Skip E	
				Do F		Do F

While this is technically the definition of overlays and how they work, as a practical matter, overlays are rarely presented as a "bare" overlay, but as the result of an overlay applied to a specific baseline – effectively becoming a baseline. The initial set of security controls will come from a baseline or an overlay and the fact that one may be called a "baseline" and the other an "overlay" is of no practical significance to the designer.

3-3.2 Determining Initial Control Set Using an Overlay

3-3.2.1 High Water Mark Versus Individual C-I-A Values

The DoD implements RMF for control systems using CNSSI 1253, which identifies applicability of security controls using individual C-I-A values - so a L-L-M system may have different controls than a M-L-L system. Other processes (including those based on NIST SP 800-53 and NIST SP 800-82), and many overlays, employ a "high water mark" which assigns a single overall impact rating equal to the highest impact rating, so a L-L-M and M-L-L system are both essentially treated as M-M-M. CNSSI 1253 provides a table defining, for each control, whether that control affects C, I, or A, so it is possible to take a table prepared using a "high water mark" and back out a table appropriate to individual C-I-A values[6], but for control system design purposes this is often not worthwhile and the high water mark can generally be used as a "conservative" approach (since the high water mark will at least have all the controls as the individual impact approach)

3-3.2.2 Identifying An Appropriate Overlay

Based on the Service, project site and control system type there are several different overlays that may apply, including:

- NIST SP 800-82
- The Control System Overlay for Moderate Impact Systems published by the Risk Management Framework Technical Advisory Group (RMF TAG Overlay)
- (NAVY) The Navy Assess-Only Overlay
- (AIR FORCE) The Air Force Control System Overlay

When the Service does not provide a specific overlay, use NIST SP 800-82 or the RMF TAG Overlay (or a combination) to define the control set for design based on the C-I-A Impact Ratings:

- For a system with L-L-L Impact ratings: Use NIST SP 800-82.
- For a system with M-M-M Impact ratings: Use the RMF Tag Overlay

[6] Imagine a L-M-M system using a M-M-M table that includes a control that states "Sensor values must be protected against unauthorized disclosure". CNSSI 1253 indicates that this control is for C. Consult the corresponding L-L-L table and see if the control is required, if not, it may be removed from consideration.

- For a system with a mix of Impact Levels (such as L-M-M), use CNSSI 1253 to determine – for each control – which element of the CIA triad (the Confidentiality, Integrity or Availability) that control applies to. Then determine applicability of the control based on the assigned impact levels using the appropriate overlay:
  - For Low impact elements, use NIST 800-82
  - For Moderate impact elements, use the RMF TAG Overlay
  - For High impact elements, use both NIST 800-82 and the RMF TAG Overlay and include controls in the baseline if they are included by either overlay.

As described in the next paragraph, there are tables in the UFC that use these overlays with a high-water mark, and an Excel tool that can be used for systems with a mix of Impact Levels.

3-3.2.3 UFC Control Set and Control Set Tool

The control lists in APPENDIX G of this UFC have been generated as described above using the NIST 800-82 Revision 2 overlay for LOW impact systems and the RMF TAG Overlay for MODERATE Impact Systems. Both of these overlays are based on NIST 800-53 Revision 4. An Excel spreadsheet is posted to the document page for this UFC[7] which will generate control sets based on these two overlays for any combination of C, I and A impacts, where those overlays have been converted from the high-water mark employed by the overlay to the individual C-I-A value approach used by CNSSI 1253.

3-3.3 Recommend Security Controls to Tailor Out (or In).

Review the starting controls baseline obtained by applying the overlay(s) and provide recommendations for controls to be tailored out from (or added to) the security control set as part of the cybersecurity documentation required by CHAPTER 5.The standard security control baselines were developed for standard information systems and contain security controls that are inapplicable to control systems (or other Platform Information Technology), or are impractical to implement due to technical or resource constraints. The RMF process allows these baselines to be tailored for the project by the removal or addition of specific controls (with the constraint that the final set must be approved by the AO). While not likely to impact the final design (controls recommended to be tailored out won't apply to the system and will not result in design requirements), this step allows the AO to consider additional tailoring based on subject matter input from the designer.

Note this tailoring can either be applied at the security control level during Step 2A, at the CCI level during Step 2B, or at both Steps 2A and 2B of the design process.

[7] UFC Document Page is at https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-4-010-06

Tailoring at the security control level is often easier, but the CCI level offers a more precise level of control over which requirements to include.

3-3.4 Additional Resources and Information for Step 2A

Additional resources and information related to this step can be found as listed here. The use of these resources is optional, and the designer remains responsible for ensuring all design requirements are met whether or not these resources are used.

- There is a spreadsheet which automates the application of the NIST 800-82 and RMF Tag Overlays as described above located on the document page of this UFC at the Whole Building Design Guide Website (WBDG.org). This spreadsheet provides a list of controls and CCIs identifiers for given impact levels.
- There is a spreadsheet which provides a table of control information (control text, etc.) based on a list of control identifiers located on the document page of this UFC at the Whole Building Design Guide Website (WBDG.org).
- APPENDIX G of this UFC contains tables showing the control sets obtained from applying the NIST 800-82 and RMF Tag Overlay to LOW and MODERATE Impact systems.
- For LOW and MODERATE Impact systems, APPENDIX G lists recommended Controls to be tailored out.

3-4 STEP 2B: IDENTIFICATION OF CONTROL CORRELATION IDENTIFIERS.

Using the list of security controls provided by the Service or derived from Step 2A, generate the list of corresponding control correlation identifiers (CCIs). Note that generating CCIs from control lists is a purely mechanical process, a given control (perhaps SI-4) always maps to a specific list of CCIs. This list of CCIs provides the starting point for identifying cybersecurity requirements to be included in control system design. The complete CCI list (covering all controls) is available at the RMF Knowledge Service website via the “Export All Assessment Procedures to Spreadsheet" link at: https://rmfks.osd.mil/rmf/General/SecurityControls/Pages/ControlsExplorer.aspx. From the URL, select "All Control Families" from the "Choose Control Family" pull-down. After the page re-populates with the controls, click on “Export Implementation Guidance and Assessment Procedures” to download the CCIs into Excel. Note: This website is CAC-enabled; designers without a CAC must request the CCI list from the Service if it was not provided.

Additional resources are listed here. The use of these resources is optional, and the designer remains responsible for ensuring all design requirements are met whether or not these resources are used.

- There is a spreadsheet which provides a table of CCI information based on a list of CCIs located on the document page of this UFC at the Whole Building Design Guide Website (WBDG.org).

- APPENDIX G includes tables of all CCIs for LOW and MODERATE impact systems based on the initial control sets determined by the application of the NIST 800-82 and RMF TAG Overlays as described above.

3-5 STEP 2C: CATEGORIZATION OF CONTROL CORRELATION IDENTIFIERS BY RESPONSIBILITY.

3-5.1 Identifiers by Responsibility

Categorize each CCI provided by the Service or identified in Step 2B as ***one or more of*** the following categories:

- ***DoD-Defined:*** Either the DoD has provided a value for the "organization selected" values, or the DoD implementation guidance states that the CCI is already met by existing policy or regulation. These values are defined in the CCI list obtained from the RMF Knowledge Service. Note that definition or guidance provided may not be relevant for a control system – the organization definitions were determined from the perspective of a traditional information system, not for a control system.
- ***Designer:*** The designer has a role to address for this CCI. The designer must do one of the following:
    - provide design specifications to cover a requirement for the control system itself, or
    - provide input to others regarding the implementation of the CCI, or
    - provide input to others regarding lack of feasibility of the CCI (typically because the CCI was written with an IT system, rather than a control system, in mind).
- ***Non-Designer:*** The CCI is not the responsibility of the designer, and is the responsibility of someone else – typically the SO. This does not diminish the importance of these CCIs, but, as these CCIs are not the responsibility of the designer, they are beyond the scope of this UFC.
- ***Platform Enclave:*** The CCI contains a requirement which is expected to be implemented at the Platform Enclave and inherited by the control system or is mostly implemented at the Platform Enclave but also needed within the field control system (in which case the CCI is also in the "Designer" category). For example, passwords are implemented at the Platform Enclave, but are also necessary at the control system user interface itself, local display panels and some controllers (those which support passwords). While implementation of the Platform Enclave is not the designer's responsibility (a key point of the Platform Enclave is that it

is a standard approach that can be implemented across multiple control systems), it's important to document CCIs the control system expects to inherit from the Platform Enclave, should there be one.

In cases where there is a Platform Enclave, some non-designer CCIs should be addressed by the Enclave and these CCIs are identified as such. For projects or sites that do not have a Platform Enclave, all "Platform Enclave" CCIs (not also listed as "Designer") can be considered Non-Designer.

- ***Impractical:*** The CCI is impractical to fully implement in a control system but may be applied in a limited manner to at least some part of the control system. In most cases, these are CCIs that can be implemented at Level 4 of the architecture but would be prohibitively difficult to implement at Levels 0, 1, or 2. Note that these CCIs are generally also categorized as "Designer", and the designer must indicate what was done and what wasn't.

Many CCIs will be assigned multiple categories. For example, a security control related to passwords would be categorized in both "Platform Enclave" and "Designer" categories as it must be addressed at the Level 4 computers as well as at Level 1 and Level 2. If the DoD has selected a minimum password length for use with this control which cannot be met by all devices, it would also be categorized as "Impractical", and the designer must document how the security control was implemented for devices unable to meet the DoD selected value.

3-5.2 Additional Resources and Information For Step 2C

Additional resources and information related to this step can be found as listed here. The use of these resources is optional, and the designer remains responsible for ensuring all design requirements are met whether or not these resources are used.

- APPENDIX G includes tables with example categorization for LOW and MODERATE Impact Systems.
- There is a spreadsheet which provides a table of CCI information based on a list of CCIs located on the document page of this UFC at the Whole Building Design Guide Website (WBDG.org). This spreadsheet includes example categorization for LOW and MODERATE Impact systems

3-6 STEP 3: INCORPORATE CYBERSECURITY REQUIREMENTS.

In addition to requirements specific to CCIs, design all control systems according to the minimum cybersecurity design requirements in CHAPTER 4 and cybersecurity requirements otherwise standard for the type of control system being designed.

For each CCI identified as "designer" during Step 2C (see APPENDIX G for example tables resulting from Step 2C), address the CCI in one or more of the following three ways (summarized here, with details provided in following paragraphs):

- First, select or identify required changes to standard CCI requirements which affect CCI implementation, such as the value of a specific parameter. Note that approval or rejection of these values by the Service (the AO or their designated representative) will impact control system design.
- Based on requirements and CCIs (including potential changes identified above), incorporate cybersecurity requirements appropriate to the control system in a dedicated Cybersecurity specification for the system based on UFGS 25 05 11 "Cybersecurity for Facility-Related Control Systems". Some requirements may instead be covered in the project control system specifications.
- For the remaining "designer" CCIs (those that do not directly translate to a control system requirement), provide information about the design to others so they can implement a CCI. In particular, document CCIs that the system is expected to be inherited from another system or the Platform Enclave.

3-6.1 Addressing DoD Selected Values in CCIs.

Many CCIs have DoD standard values and are indicated in the Master CCI List as being automatically met or inherited based on the standard value. These CCIs have been derived from the general security controls in NIST SP 800-53, without regard to special consideration which might apply to a control system, such as the tailoring and supplemental guidance in NIST SP 800-82. Many of these CCIs cannot be applied to control systems using the approach identified by the DoD. In these cases, implement the CCI to the greatest extent practical, and document the incompatibilities.

3-6.2 Other "Organization Defined Values" in CCIs.

For CCIs which refer to "organization defined values" where the DoD has not defined a value and one has not been provided, request appropriate values from the Service. If the Service is unable to provide values, propose reasonable values and document the proposed value with rationale.

3-6.3 Requirement Definition and Implementation CCIs.

Often, one CCI defines a requirement, and a second requires the implementation of that requirement. A hypothetical example[8] is:

- CCI #1 says "organization defines which components collect audit records". The implementation guidance for this CCI says "this is automatically met because the DoD has defined the components as 'all components'".

[8] This example uses simplified fictitious CCIs for illustrative purposes. The AU family of security controls deals with audit logs.

- CCI #2 says “the information system collects audit records at the defined components”.

Together, these create an impossible requirement: if one accepts the definition in #1 (and that it’s “automatically met”), then the system fails to meet #2 because, for example, Level 0 sensors can’t collect audit records. In this case, both CCIs are “Designer” category; propose reasonable values for CCI #1, implement CCI #2 using these values and document the proposed values for CCI #1.

3-6.4 Additional Resources and Information for Step 3

Additional resources and information related to this step can be found as listed here. The use of these resources is optional, and the designer remains responsible for ensuring all design requirements are met whether or not these resources are used.

- APPENDIX G includes tables which indicate where specific CCIs are referenced in (an unedited/untailored) UFGS 25 05 11.
- There is a spreadsheet located on the document page of this UFC at the Whole Building Design Guide Website (WBDG.org) which provides a table of CCI information based on a list of CCIs. This spreadsheet includes UFGS references for LOW and MODERATE Impact systems.
- There is a spreadsheet which parses a SpecsIntact file to identify the location of CCI References (provided specific formatting rules are followed for the CCI references) on the document page of this UFC at the Whole Building Design Guide Website (WBDG.org).

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CHAPTER 4 MINIMUM CYBERSECURITY DESIGN REQUIREMENTS

4-1 DESIGN TO MINIMIZE FAILURE.

4-1.1 Reduce Dependency on the Network.

Avoid dependence on the network for the execution of control strategies. For example, a backup generator should always start based on a local measurement of utility availability, and not require a network "START" command. When dependence on the network is unavoidable, isolate that portion of the network as much as possible so that non-local network outages do not affect the required portions of the network. When operator input is absolutely required for the functioning of a control strategy, consider a local interface (local display panel) or a dedicated front end (Level 2 front end) physically co-located with the equipment.

In some cases, it may be necessary to take additional steps to protect critical functions from modification over the network, for example a controller where critical parameters are exposed to network manipulation based on the controller design. In these cases, design barriers to manipulation into the control network architecture itself. See APPENDIX E for one possible approach.

4-1.2 Reduce Extraneous Functionality

Since additional capabilities often result in additional vulnerabilities, a key cybersecurity concept is “least functionality”, which means not adding capabilities which are not specifically needed. Design control systems to minimize additional functionality which may create vulnerabilities in the control system, including but not limited to:

- Consider mission requirements before implementing remote adjustment of system parameters which are not expected or required to change. For example, a critical air conditioner serving a data center, a critical command and control building, or a UPS room which needs to maintain space temperature at 65 degrees Fahrenheit, 24 hours a day, 365 days a year should not have a network configurable operating schedule or set point.
- Advanced or complex control strategies often require increased sensor inputs and a greater level of maintenance. Use care when requiring these strategies as the increased complexity results in increased probability of failure if the system is not properly maintained or if any specific parameter is compromised.

4-2 DESIGN TO MANAGE FAILURE.

4-2.1 Design for Graceful Failure.

4-2.1.1 Unitary Control Systems.

For control systems controlling a single process or piece of equipment, coordinate with the equipment designer to determine any additional redundancy and failure requirements, and design the control system to match the requirements for the underlying equipment. In all cases design these systems to fail "safe" as defined by the criteria for the controlled system. For example, in cold climates, outside air intake dampers must fail closed based on the requirements of the heating, ventilation, and air conditioning UFC. Similarly, zones that are dominated by interior loads should consider failing to full cooling.

4-2.1.2 Control Systems with Independent Subsystems.

Many control systems are described as a single system but are actually composed of many (hundreds, even thousands) of essentially independent systems. A common example of this would be an installation-wide UMCS, where the air handler (AHU) controllers in one building have no dependence on the AHU in another building, and often no dependence on AHUs in the same building.

For control systems with independent subsystems, design each subsystem as required in paragraph 4-2.1.1, Unitary Control Systems, and design the overall system such that loss of a single subsystem does not affect the operation of the rest of the system. Reduce information required to be shared between subsystems and minimize dependence on the network. For subsystems which must rely on other subsystems define default ("fall back") behavior should the other subsystem fail.

4-2.2 Degraded Operation.

After a system fails to a safe state, it may need continue or resume operation in a degraded capacity using some automated or manual method, recognizing there may be risk in this operation, but that the risk is manageable and outweighed by mission requirements.

Based on mission requirements, consider requiring means for manual operation including both monitoring instrumentation (thermometers, pressure gauges, meters), and manual control devices (such as "hand-off-auto" switches and actuators with manual actuation capability). Consider if a local controls front end might be installed inside the facility and facility staff might be provided sufficient training to make basic adjustments to the system. Another option to consider is the addition of local display panels (limited operator interfaces within the control system) in mechanical rooms, again with the intent of allowing on-site staff the ability to maintain system operation (perhaps in a degraded state, but sufficient to maintain basic mission capabilities).

4-2.3 Redundancy.

If the criticality of the mission requires redundancy in the design of the control system, then the system must be designed to provide that redundancy without external intervention, and especially without human intervention. Design control strategies such that spare units start automatically when running units shut down, or have all units run and share load. Care must be taken when load-sharing to ensure that operators are notified when one unit of a redundant set fails since the remaining units will automatically pick up the load with no disruption in the load. Do not rely on an operator to start any backup unit; the odds of the operator not being available, or taking an incorrect action are too great. Provide alarms to alert operators of failures.

Note that the control system is often more reliable than the underlying controlled equipment. For example, a backup electrical source powered by a diesel generator is most likely to fail due to a mechanical fault. If installing a redundant control system do not neglect to install redundant mechanical and electrical controlled equipment as well.

4-2.4 Redundancy with independent control systems.

Where backup systems are required to meet mechanical or electrical needs consider installing simple, standalone backup systems with a simple, but completely independent control system. For example, for a data center, perhaps a standalone computer room air conditioner (CRAC) unit could be added that would start based on a local thermostat and run independently of the base wide system. Particularly in the case of a critical facility (which likely has redundant HVAC equipment), consider if the primary unit could possibly be connected to the base wide UMCS while the secondary unit might operate in a standalone configuration with purely local controls

Another example might be a non-critical buildings containing a small critical room or facility inside the larger building. Consider if it is possible to add a small independent standalone unit, such as a small Direct Expansion (DX) unit or dedicated backup generator.

4-3 DO NOT IMPLEMENT STANDARD IT FUNCTIONS.

As a type of Platform IT, control systems are special purpose systems and must not be used as general computing resources. In particular:

- Do not share control system resources with other systems, particularly with any system that is not a control system. Some exceptions such as separate virtual servers running on common hardware or shared Ethernet media with separate VLANs, may be permitted, but the overlap between control systems and other systems must be minimized.
- Do not allow control systems to provide, or share resources with, other applications that provide standard IT services. For example, do not use control system components as Domain Name System (DNS) servers. (DNS servers may be implemented within the “Platform Enclave” at Level 5, but that is beyond the scope of the control system designer’s responsibility and not addressed by this UFC.)
- Do not allow control systems to be publicly accessible over the Internet (if this capability is required, it must be restricted access and carefully implemented by IT professionals).
- Ensure that user interfaces with the ability to manipulate the system are secured with some combination of authentication (passwords, etc.) and physical security (in controlled space or locked enclosures).

- Prohibit the use of mobile code, except mobile code may be allowed at Level 4. Note that control systems may use mobile code technologies, Java in particular, within the control system, but must not download code without direct user approval.
- Do not use control system computers as standard computers for general applications.
- Do not implement Voice over Internet Protocol (VoIP) within the control system.
- Do not implement collaborative computing devices, technologies or protocols within the control system.
- Unless specifically authorized by the Service and required by the project site, do not allow control system components to access non-military IP addresses. Do not allow control system components to access social media. (Note that access to non-military IP address space is generally not needed, and when needed will generally be a function of the front end, not the field control system.)
- Do not allow control systems to receive email (note that at Level 4 they may need a method of sending email for notifications).

4-4 DO NOT PROVIDE REMOTE ACCESS.

Do not provide remote (off site) access to the control system. If required, remote access to the Level 4 network should be provided by the Platform Enclave or the site IT organization. Coordinate remote access requirements with the project site IT organization and with the POCs listed in 0.

4-5 AVOID PROBLEMATIC NETWORKS

While wireless networks are of great value in IT systems, their value in FRCS is very limited and they should - for the most part – be avoided. Most FRCS are fixed, they do not move, and there is no requirement for a wireless network. While wireless may apparently have a lower first cost, the frequent necessity to provide power to the control system devices or controlled equipment itself means that wires will be installed to provide power and there are multiple technologies that allow both power and network over the same wires (such as Power over Ethernet (PoE) and Powerline Networking).

- Be careful when designing for or allowing the use of wireless networks. Coordinate all use of wireless with the project site and where it is allowed require FIPS 140-2 validated radios wherever possible. Where using wireless IP (such as Wi-Fi) coordinate closely with the site IT group to ensure that the network meets current IT security standards.

- Where radios cannot be avoided – for example, in fire protection systems where buildings use radios to communicate with a base fire department – provide hardware isolation panels (relays) to isolate the control system from the radio.

- While many control systems run over IP networks, others instead use protocols that were designed specifically for the control system – protocols that are inherently more limited and have fewer vulnerabilities. Before selecting IP as a network protocol, carefully consider the pros and cons and consider implementing the control system using a less vulnerable non-IP protocol.

4-6 PROTECT THE CONTROL SYSTEM WITH PHYSICAL SECURITY

Ensure that access to the control system – controllers and network – is at least as difficult to obtain as access to the controlled equipment (mechanical and electrical) itself. Controllers should be co-located with the controlled equipment. Consider the potential for an aggressor with access to one controller to affect equipment controlled by another controller. Protect the network media itself from physical access. Depending on the situation, this may involve keeping controllers in locked controlled spaces, providing separate locked enclosures for controllers, and installing network media in metallic conduit.

4-7 PROTECT PRIVILEGED USER INTERFACES

By analogy with privileged users in the IT world, a Privileged UI is a UI that has sufficient capabilities or functionality that it requires specific cybersecurity measured to be put in place to limit its unauthorized use. Typically, this requires one or more of the following:

- Use of physical security to block access to the interface. Note that this will not work with interfaces that can be accessed over the network.

- Use of strong access controls, including hard passwords and/or PIV (smart cards)

- Use of strong network encryption for interfaces with network access.

4-8 EMPLOY PRINCIPALS OF DESIGN SIMPLICITY

Often there exist performance requirements that will push a control system towards increased complexity, and operational requirements that will drive a system towards simplicity. The more complex a system is, the more difficult the maintenance and operation of that system tends to be. More complex systems often have more vulnerabilities as well. For control systems, typically (historically), this complexity is in terms of number of components or the complexity of the sequence of operation of the system.

RMF requirements are geared toward IT systems and drive control systems to resemble IT, introducing new complexities. Simple controllers typically found in many BCS, for example, cannot begin to meet the access control and auditing requirements that a computer so easily meets. Left unchecked, this will lead to incredibly complex and unique systems which meet cybersecurity requirements at the cost of control functionality, maintainability, or operational capability.

4-8.1 Example: Using PLCs for HVAC Control

For example, Programmable Logic Controllers (PLCs) will generally more readily meet cybersecurity requirements than the direct digital controllers used for HVAC control systems. However, because PLCs are not generally used for HVAC, using PLCs to control the HVAC systems introduces significant risks:

- The standard and well-tested HVAC control routines developed by the HVAC controls industry won't be available to the system, and custom PLC programming will be required.
- The controls installer of the PLC system is unlikely to know HVAC well, so is more likely to miss operational requirements or pitfalls – including basic system physics such as thermodynamics of air-to-water heat exchangers.
- The HVAC maintenance staff is unlikely to be familiar with PLCs, resulting in an increased training burden or a reliance on contracted maintenance.

4-8.2 Consideration of Overall System Risk

It's vital that the cybersecurity requirements for the control system be balanced with the complexity of the system and the risk involved with an overly complex system. There is a point for every system where the application of an additional cybersecurity requirement will result in an overall increase in risk. This is an especially important consideration for more critical (higher impact) systems where the control system must operate properly to support the mission.

4-9 CYBERSECURITY DURING CONSTRUCTION

Do not neglect the potential for an aggressor to introduce malware into the control system during the construction process. While the government does not own the system during construction, it is naive to assume that there are no bad actors targeting government systems during the construction process[9] and that any cyber exploits during construction will be uncovered during the commissioning process. Require basic "cyber hygiene" of contractor systems touching the control system.

4-10 ADDITIONAL REQUIREMENTS FOR MODERATE SYSTEMS

For MODERATE impact systems, also include the following requirements:

- Do not allow devices with user interfaces capable of being accessed remotely, or capable of accessing other devices unless one is specifically required for the system. Do not allow devices with full remote user interfaces to execute sequences of operation.

[9] Consider the case of listening devices designed into overseas embassies during construction by foreign adversaries.

- Do not allow networked sensors or actuators unless one is specifically required for the system. (A networked sensor or actuator is a sensor or actuator that has an integral network interface where the device does not execute a sequence of operation; the sole purpose of the network interface is to communicate the sensor/actuator data over the network.) Note that this requirement does not prohibit networked I/O where the network is required to support high reliability/redundant I/O – such as PROFIBUS or CHARMS networked I/O busses.

- Do not rely on the network for execution of a sequence; to the greatest extent possible homerun I/O via analog/binary signals to a single controller executing the sequence of operation.

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CHAPTER 5 CYBERSECURITY DOCUMENTATION

This chapter describes cybersecurity documentation that is required as part of the control system design package. This documentation is in addition to the documentation required by the relevant control system design criteria.

5-1 OVERVIEW.

Cybersecurity documentation for control system design documents the security controls and CCIs applied to the control system along with assumptions made regarding CCI selection, implementation, and information required by others.

5-2 USE OF GUIDE SPECIFICATION.

The design specifications for control system cybersecurity developed in accordance with this UFC must derive from UFGS 25 05 11.

For projects designed by or for USACE, develop separate cybersecurity specifications for each system type and for each impact level. This prevents misinterpretation of specification requirements. Use fourth level numbering of the specification to differentiate the specification by system. Different fourth level numbering schemes are possible; the scheme that is clearest for the project should be used and should be used across the entire project. Two example schemes are using sequential numbering (such as Section 25 05 11.01: Low Impact HVAC, Section 25 05 11.02: Low Impact Lighting Controls, Section 25 05 11.03: Moderate Impact HVAC Controls, etc.) or using numbering that aligns with the division that the control specification is in (such as Section 25 01 11.23: HVAC, Section 25 05 11.26: Lighting). Note that the second scheme becomes unusable when multiple different systems have the same division number, or there are multiple systems of the same type but with different impact levels.

5-3 COORDINATION WITH OTHER DISCIPLINES

As discussed in CHAPTER 3, in order to develop a specification properly aligned with site choices, several design steps must be coordinated with other disciplines. To facilitate this coordination, an optional reference Cybersecurity Design Coordination Worksheet is posted on the Whole Building Design Guide document page for this UFC (https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-4-010-06).

5-3.1 Determination of Points of Contact

For this document, the primary points of contact are the System Owner (SO) and the Authorizing Official (AO) for the determination of the C-I-A Impact ratings. In addition there may be coordination with the controls designer, if this individual is separate from the cybersecurity designer, and possibly the SO and AO for the discussion of cybersecurity controls that are not feasible for the FRCS.

5-3.2 UFGS Coordination Issues

- For UFGS 25 05 11, there are many designer options that require input from the control's designer, SO, AO, and site personnel. Major consideration includes the following:

- Whether wireless will be allowed. If so, where? How will it be secured? How will it be tested?

- User Interfaces. Where will they be located? Which, if any, will be privileged? How will they be secured?

- User Interface behavior such as session termination and unsuccessful login handling

- Specific requirements for Fire Protection systems

- Submittal review. Specific details about documentation, level of inventory reporting, and other submittal requirements

- Specific hardware or software requirements: Ethernet switches, web and database servers, and device and equipment power.

- Auditing: front-ends, software, storage capacity, and information system monitoring

- User Authentication: PKI, passwords, and setting of passwords

- Cybersecurity testing and training: Field QC, PVT, level of training

5-4 REQUIREMENTS BY DESIGN PHASE.

Cybersecurity documentation requirements are indicated here by typical Design-Build or Design-Bid-Build design submittals. Some of these will require new design documents while others add requirements to design documents that are already required by other criteria or project requirements. The percentage design levels provided here are notional only to demonstrate the order and extent of information needed by each submittal. If the design is using a different submittal schedule, adjust accordingly. The documentation requirements here apply per system and impact level – if the project includes multiple systems or impact levels, a copy of the required documentation for each is required. Submittal templates are posted to the document page for this UFC.

The requirements here reference the five-step cybersecurity design process defined in CHAPTER 3.

5-4.1 Basis of Design (10-15%).

At the Basis of Design (10-15% design) submittal, or the equivalent submittal step for projects not incorporating a Basis of Design submittal, provide the following items:

- **System Description:** A brief functional description of the system
- **CIA Impact Level:** The C-I-A impact level for the control system and whether it was provided by the Service, or was determined using one of the courses of action described in CHAPTER 3 for when impact ratings aren't provided. If using the methods discussed in APPENDIX D provide a narrative documenting how the impact rating was determined.
- **Starting Security Control Set and Tailoring Recommendation:** A list of the security controls generated during Step 2A along with recommendations and justifications for further tailoring of the security control set
- **Network Connectivity Description:** A general description of expected network connectivity type, such as stand-alone, closed restricted network, dedicated transport, or shared transport.
- **System Connections:** Planned, expected, or required connections to other systems (if any).

5-4.2 Concept Design (30-35%).

At the Concept Design (30-35% design) submittal, or the equivalent submittal step for projects not incorporating a Concept Design submittal, provide a list of the CCIs resulting from the approved tailored security control list (Step 2B) or provided by the Service, and an initial classification for each CCI (Step 2C).

5-4.3 Interim Design (50-65%).

At the Interim Design (50-65% design) submittal, or the equivalent submittal step for projects not incorporating an Interim Design submittal, provide the following items:

- **CCI List:** The recommended format for this list is to use the format of the tables in APPENDIX G with the addition of a column to document the required information. In addition to any other required formats, provide the CCI list in a format compatible with Microsoft Excel. The list must include the following items.
    - The final classification (Designer, etc..) of each CCI (Step 2C).
    - For each CCI categorized as designer and addressed in the design, include:

    - ◊ Identification where and why the standard CCI requirements cannot be incorporated into the design (identified in Step 3), description of what requirements will be incorporated instead, and an explanation of the changes.
    - ◊ Documentation of how the CCI has been incorporated into the control system design (Step 3), including specification or drawing references. If there are specific changes from standard requirements, or multiple options available, document these changes or options..
  - For each CCI categorized as designer due to requiring information be provided (Step 3), provide the relevant information for use by others.
- **Redlined Specifications and Drawings:** Draft specifications based on UFGS 25 05 11 with appropriate tailoring for system type and impact rating and edited for project requirements, and any relevant drawings or other attachments when requirements have been incorporated into drawings or other attachments.
- **Riser Diagrams:** One-line/riser diagram showing concept architecture and major components.
- **System Connections:** A document either indicating no network connections to other systems will exist or describing the network connections to other systems. For system connections include a description of the other system, the nature and purpose of the connection, and all protocols used by the communication interface.

5-4.4 Final Design (Unreviewed 100%).

At the Final Design (Unreviewed 100% design) submittal, or the equivalent submittal step for projects not incorporating a Final Design submittal, provide all items from the Interim Design (50-65%) with updated Final Design information.

5-4.5 Issued for Construction (Reviewed 100%).

At the Issued for Construction (Reviewed 100% design) submittal, or the equivalent submittal step for projects not incorporating an Issued for Construction submittal, provide all items from the Final Design (Unreviewed 100%) with updated Issued for Construction information.

APPENDIX A RISK MANAGEMENT FRAMEWORK (RMF) OVERVIEW

A-1 RMF OVERVIEW

As defined by the National Institute of Standards and Technology (NIST), the RMF is "The process of managing risks to organizational operations (including mission, functions, image, reputation), organizational assets, individuals, other organizations, and the Nation, resulting from the operation of an information system, and includes: (i) the conduct of a risk assessment; (ii) the implementation of a risk mitigation strategy; and (iii) employment of techniques and procedures for the continuous monitoring of the security state of the information system.". The RMF details how Risk Management is applied to Department of Defense (DoD) information technology in accordance with DoDI 8510.01.

A-2 RMF PROCESS

As shown in Figure A-1, the RMF is a seven-step process:

0. Prepare: Carry out essential activities to help prepare all levels of the organization to manage its security and privacy risks using the RMF

1. Categorize the System: Categorization of the control system by Confidentiality, Integrity and Availability (C-I-A) Impact levels, taking into consideration both the importance of the mission and the importance of the control system to the mission. Determination of the C-I-A Impact levels will be made by the System Owner (SO) and is outside the scope of this UFC. The dashed box around Step 1 in the figure indicates that the designer needs information from this step when executing design in accordance with this UFC. When this information is not provided, the designer may need to determine a "design C-I-A" rating to use for the design.

2. Select Security Controls: Based on the C-I-A level, a set of controls and an overlay to be implemented will be selected from CNSSI No. 1253 and NIST SP 800-82. In many cases, these controls will be further tailored based on the requirements of the Control System prior to implementation. While this UFC includes guidance concerning applicability of specific controls, the process of selecting security controls is generally outside the domain of the designer. The solid box around Step 2 in the figure indicates that the designer must select controls for the design using the provided C-I-A value, and must provide information on the controls that are applicable (or not) to the control system.

3. Implement Security Controls: Implementation of many security controls will be outside the scope of designer responsibilities. This UFC focuses on security controls which the designer must somehow address in design, generally through the incorporation of requirements into the plans and drawings, and on security controls which others may ask the designer to

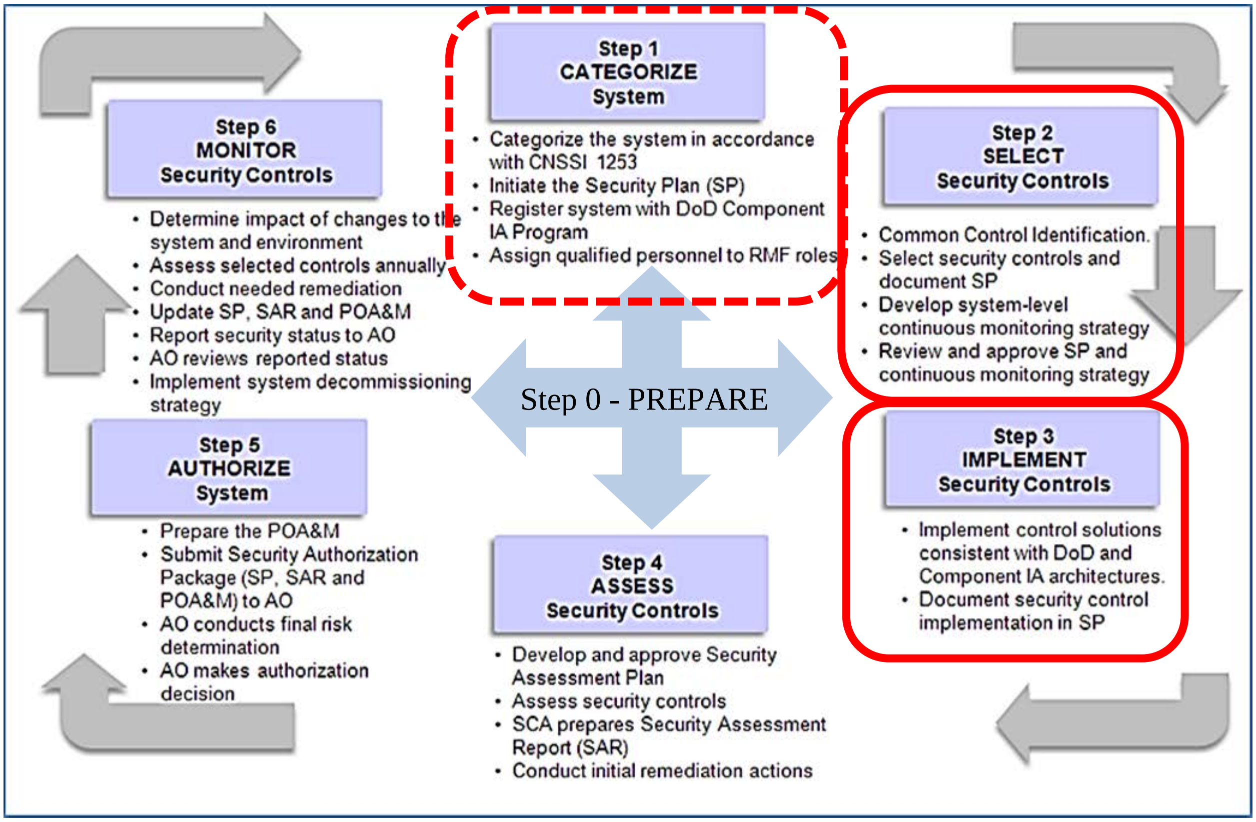
provide input on. The solid box around Step 3 in the figure indicates that the designer must develop specifications and designs that implement cybersecurity protections based on the controls identified in Step 2.

4. Assess Security Controls: After implementation, the effectiveness of the implementation is evaluated.

5. Authorize the System: Assuming a satisfactory evaluation, the Authorizing Official (AO) formally accepts the residual risk from the control system and authorizes operation of the system by issuing an authorization to operate.

6. Monitor Security Controls: The RMF enters a monitoring and evaluation phase, where the control system is monitored and periodically re-evaluated.

Figure A-1 NIST Risk Management Framework Steps



A-3 DEFINITION OF CONTROLS FROM NIST AND DODI 8510

A-3.1 Control Families

Since it is difficult to evaluate a performance requirement (“reduce risk below a specific level”), NIST provides a catalog of prescriptive requirements where meeting a particular requirement reduces the overall risk to the system. These requirements are broadly categorized into the following groupings (which are often referred to as "control families"):

- AC – Access Control
- AT – Awareness and Training
- AU – Audit and Accountability
- CA – Security Assessment and Authorization
- CM – Configuration Management
- CP – Contingency Planning
- IA – Identification and Authorization
- IR – Incident Response
- MA – Maintenance
- MP – Media Protection
- PE – Physical and Environmental Protection
- PL – Planning
- PM – Program Management
- PS – Personnel Security
- RA – Risk Assessment
- SA – System and Services Acquisition
- SC – System and Communications Protection
- SI – System and Information Integrity

A-3.2 Control Elements and Enhancements

Within each control family, there are numerous controls; most having multiple sub-elements. Many controls also have enhancements, additional actions that can be taken to enhance the effectiveness of the control. Individual controls are assigned a number within the control family, enhancements are sub-numbered, and elements of controls or enhancements are lettered. Enhancements and elements are written in parenthesis after the control number. An example of the AC-2 control from NIST SP 800-53 (Revision 4) is shown in Figure C-4.

Figure A-2 NIST SP 800-53 Control AC-2

AC-2 ACCOUNT MANAGEMENT

Control: The organization manages information system accounts, including:
Identifying account types (i.e., individual, group, system, application, guest/anonymous, and temporary);

a. Identifies and selects the following types of information system accounts to support organizational missions/business functions: [*Assignment: organization-defined information system account types*];
b. Assigns account managers for information system accounts;
c. Establishing conditions for group and role membership;
d. Specifies authorized users of the information system, group and role membership, and access authorizations (i.e., privileges) and other attributes (as required) for each account;
e. Requires approvals by [*Assignment: organization-defined personnel or roles*] for requests to create information system accounts;
f. Creates, enables, modifies, disables, and removes information system accounts in accordance with [*Assignment: organization-defined procedures or conditions*];
g. Monitors the use of information system accounts;
h. Notifying account managers:
   1. When accounts are no longer required;
   2. When users are terminated or transferred; and
   3. When individual information system usage or need-to-know changes;
i. Authorizes access to the information system based on:
   1. A valid access authorization;
   2. Intended system usage; and
   3. Other attributes as required by the organization or associated missions/business functions;
j. Reviews accounts for compliance with account management requirements [*Assignment: organization-defined frequency*]; and
k. Establishes a process for reissuing shared/group account credentials (if deployed) when individuals are removed from the group.

Supplemental Guidance: Information system account types include, for example, individual, shared…[10]
Related controls: AC-3, AC-4, AC-5, AC-6, AC-10, AC-17, AC-19, AC-20, AU-9, IA-2, IA-4, IA-5, IA-8, CM-5, CM-6, CM-11, MA-3, MA-4, PL-4, SC-13.

Control Enhancements:

(1) ACCOUNT MANAGEMENT | AUTOMATED SYSTEM ACCOUNT MANAGEMENT[10]
The organization employs automated mechanisms to support the management of information system accounts.

(2) ACCOUNT MANAGEMENT | REMOVAL OF TEMPORARY / EMERGENCY ACCOUNTS[10]
The information system automatically [*Selection: removes; disables*] terminates temporary and emergency accounts after [*Assignment: organization-defined time period for each type of account*].

(3) ACCOUNT MANAGEMENT | DISABLE INACTIVE ACCOUNTS
The information system automatically disables inactive accounts after [*Assignment: organization defined time period*].

(4) ACCOUNT MANAGEMENT | AUTOMATED AUDIT ACTIONS[10]
The information system automatically audits account creation, modification, enabling, disabling, and removal actions and notifies [*Assignment: organization-defined personnel or roles*].

(5) ACCOUNT MANAGEMENT | INACTIVITY LOGOUT[10]

[10] For sake of brevity, complete 'Supplemental Guidance' text is not shown for AC-2 ACCOUNT MANAGEMENT.

The organization requires that users log out when [Assignment: organization-defined time-period of expected inactivity or description of when to log out].

(6) ACCOUNT MANAGEMENT | DYNAMIC PRIVILEGE MANAGEMENT[10]
The information system implements the following dynamic privilege management capabilities: [*Assignment: organization-defined list of dynamic privilege management capabilities*].

(7) ACCOUNT MANAGEMENT | ROLE-BASED SCHEMES[10]
The organization:
(a) Establishes and administers privileged user accounts in accordance with a role-based access scheme that organizes allowed information system access and privileges into roles;
(b) Monitors privileged role assignments; and
(c) Takes [*Assignment: organization-defined actions*] when privileged role assignments are no longer appropriate.

(8) ACCOUNT MANAGEMENT | DYNAMIC ACCOUNT CREATION[10]
The information system creates [*Assignment: organization-defined information system accounts*] dynamically.

(9) [10]ACCOUNT MANAGEMENT | RESTRICTIONS ON USE OF SHARED / GROUP ACCOUNTS
The organization only permits the use of shared/group accounts that meet [*Assignment: organization-defined conditions for establishing shared/group accounts*].

(10) ACCOUNT MANAGEMENT | SHARED / GROUP ACCOUNT CREDENTIAL TERMINATION
The information system terminates shared/group account credentials when members leave the group.

(11) ACCOUNT MANAGEMENT | USAGE CONDITIONS[10]
The information system enforces [*Assignment: organization-defined circumstances and/or usage conditions*] for [*Assignment: organization-defined information system accounts*].

(12) ACCOUNT MANAGEMENT | ACCOUNT MONITORING / ATYPICAL USAGE[10]
The organization:
- **(a) Monitors information system accounts for [*Assignment: organization-defined atypical usage*]; and**
- **(b) Reports atypical usage of information system accounts to [*Assignment: organization-defined personnel or roles*].**

(13) ACCOUNT MANAGEMENT | DISABLE ACCOUNTS FOR HIGH-RISK INDIVIDUALS[10]
The organization disables accounts of users posing a significant risk within [*Assignment: organization-defined time period*] of discovery of the risk.

In this notation, AC-2 (5) is enhancement 5: “The organization requires that users log out when….”.

A-3.3 Control Correlation Identifiers

The DoD implementation of the NIST controls for control systems is DoDI 8500. The DoD took the additional step of breaking down each control and control element into specific actions; each action is identified by a unique Control Correlation Identifier (CCI). For example, the above control, AC-2, is broken down into 61 separate CCIs, with 11 distinct CCIs for AC-2 (4) alone.

While this leads to a very fine level of implementation (the control system could audit account creation, but not audit account modification), it also leads to many dependencies between CCIs. For example, two of the CCIs associated with security control AC-2(4) found on the RMF Knowledge Service (Security Control Explorer) are:

- CCI-000018: “The information system automatically audits account creation actions.”
- CCI-001683: “The information system notifies organization-defined personnel or roles for account creation actions.”

Note: The RMF Knowledge Service website is https://rmfks.osd.mil.

While these are written as independent CCIs, they are clearly closely related, and it is difficult to imagine a notification system that did not include an auditing capability.

A-4 REQUIREMENT DEFINITION VS IMPLEMENTATION

Broadly speaking, CCIs can be categorized into requirement definition and requirement implementation.

1. A CCI defines a requirement when the CCI is of the form “<someone> defines a <requirement>”. Examples of CCIs that define a requirement include those that state “The organization defines ….”

    a. “…a minimum level of detail for documentation”,

    b. “…a minimum frequency to review some criteria”,

    c. “…a list of events that raise a red flag for security”, or

    d. “…a policy or procedure for modifications to the control system”

2. A CCI implements a requirement when the CCI is of the form “<someone/something> meets a <requirement>”, where the requirement is typically defined in a related CCI. Examples of CCIs which implement a requirement defined in the previous example include CCIs that state “The organization ….”

    a. …obtains the required level of documentation”,

    b. …reviews a security plan annually”,

    c. …responds to breaches of physical security”, or

    d. …approves changes to the control system via a configuration management board”

A-4.1 CCIs Defining a Requirement

CCIs which define a requirement may be addressed by the designer but are often addressed by the organization or already defined DoD-wide. In some cases, the final statement of the requirement may be by the organization, but with input from the designer based on knowledge of the control system and the specific vulnerability to be addressed. For example, the designer needs to provide input on password complexity since not all control system components will support passwords, and those that do may support different complexities. In many cases, DoD-defined requirements are completely inappropriate for control systems and the designer must document deviations from the DoD definitions for these requirements in the design.

A-4.2 CCIs Requiring Implementing a Requirement

Implementation CCIs may further be classified by who/what does the implementation: the organization (or inherited from some other element), or the control system. "The organization conducts background checks" is an example of the former while "the control system logs users off after a period of inactivity" belongs to the latter. In some cases, this is not clear – a CCI that states "The organization enforces a minimum password length"[11] appears to create a requirement on the organization, but a moments consideration will make clear that this action must be implemented by the control system (since the control system either accepts or rejects a password entry), not the organization. CCIs that are implemented by the organization are not addressed by the designer and are outside the scope of this UFC. On the other hand, CCIs that are implemented by the control system must typically be addressed by the designer since implementing a CCI becomes a performance requirement in the specification of the control system.

A-5 PLATFORM INFORMATION TECHNOLOGY

The DoD implementation of the RMF defines Platform Information Technology (PIT) as "IT, both hardware and software, which is physically part of, dedicated to, or essential in real time to the mission performance of special purpose systems", and differentiates PIT systems from standard information systems. Most specifically, DoDI 8500.01 indicates that PIT Systems "require uniquely tailored security control sets and control validation procedures and require security control assessors and AOs with specialized qualifications"

The Cybersecurity of PIT systems, such as control systems, requires not only the use of customized control baselines, but also further tailoring of controls as appropriate for the specific control system.

[11] This is not the text of an actual CCI, but rather a simple fictitious example used for illustrative purposes.

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APPENDIX B PLATFORM ENCLAVE

B-1 PLATFORM ENCLAVE CONCEPT OVERVIEW

The fact that a significant portion of the control system resembles a standard IT system which can be implemented for different control systems regardless of the details of the control system itself has led to the creation of the Platform Enclave concept. This concept groups the standard IT portions of the control system into an entity which can be handled separately from the rest of the control system. In some cases, this Platform Enclave will be separately authorized, and the overall control system will have two authorizations, while in other cases a single authorization will be used for the entire system. Even in cases where a single authorization is used, however, it's helpful to identify and categorize the standard IT portions of the control system.

B-2 PLATFORM ENCLAVE USING TWO AUTHORIZATIONS

A primary reason to define to a Platform Enclave is to enable the approach where a control system is implemented using ***two*** Risk Management Framework authorizations, one for the Platform Enclave and one for the non-Platform Enclave portions of the control system, sometimes referred to as the "non-standard IT" portions. While this may seem to lead to a duplication of effort, in practice this generally isn't the case:

- While many controls, such as policies and procedures, will need to be done at both the Platform Enclave and "non-standard IT" portions, these policies and procedures can often be inherited by both from another Authorization, or implemented the same way in both the Platform Enclave and the "non-standard IT".
- Some controls can be applied at the Platform Enclave and then inherited by the "non-standard IT". For example, controls related to remote access can be defined independently of the "non-standard IT" by the Platform Enclave, and then inherited by the "non-standard IT" if necessary.
- While some controls will need to be addressed by both the Platform Enclave and the "non-standard IT", they will need to be addressed differently, and often to a different extent, in each.

B-3 PLATFORM ENCLAVE BENEFITS

The primary benefit of the Platform Enclave approach is that it allows for separation of the "standard IT" and "non-standard IT" components of the control system and allows for a single authorization for the IT portion to cover multiple control system types. This approach is most beneficial when there is an existing network and cybersecurity infrastructure on which to establish the Platform Enclave, such as those that exist on most DoD installations. Ideally, the Platform Enclave will be a standard established and authorized by each Service for implementation at every installation, in contrast to the authorization for the "non-standard IT" portion of the control system (the "Operational Architecture"), where factors such as control system type, vendor and protocol are more likely to make each authorization unique and non-standard.

B-4 ARMY PLATFORM ENCLAVE APPROACH

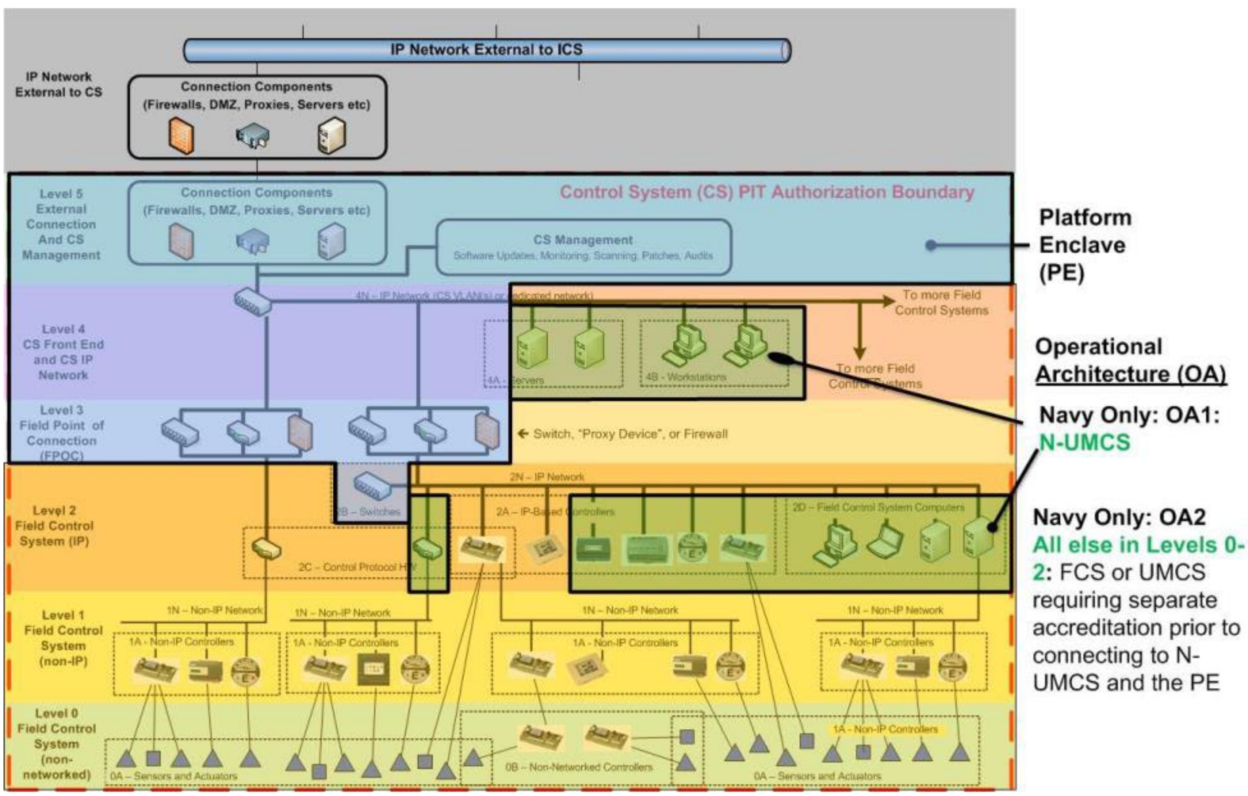
The Army has not formalized a Platform Enclave approach.

B-5 NAVY PLATFORM ENCLAVE APPROACH FOR BCS AND UCS

Figure B-1 shows which components of the 5-Level control system architecture are included in the Navy's Platform Enclave (PE) called the Control System Platform Enclave (CS-PE). The Navy's CS-PE is implemented at and has a presence today at Navy installations. The Navy is deploying an operational architecture (OA) called the Navy Utilities Monitoring and Control System (NUMCS), which is also shown in Figure B-1.

All Control Systems must connect to the Platform Enclave and must either be separately authorized or fall under the type accreditation of the CS-PE and NUMCS.

Figure B-1 Navy Platform Enclave and Operational Architecture



B-6 AIR FORCE PLATFORM ENCLAVE APPROACH

The Air Force currently does not have a formal Platform Enclave approach. The AF has deployed the Civil Engineering Community of Interest Network (COIN) at most locations. COIN has its own type accreditation and individual control systems for the most part have their own individual accreditations. CE control systems can use COIN for connectivity, but are not covered under the COIN authorization in a Platform Enclave approach at this time. As a prototype, the AF is deploying the Installation Resilience

Operations Center (IROC) network concept at selected locations, which will include selected control systems within the IROC type accreditation.

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APPENDIX C 5-LEVEL CONTROL SYSTEM ARCHITECTURE

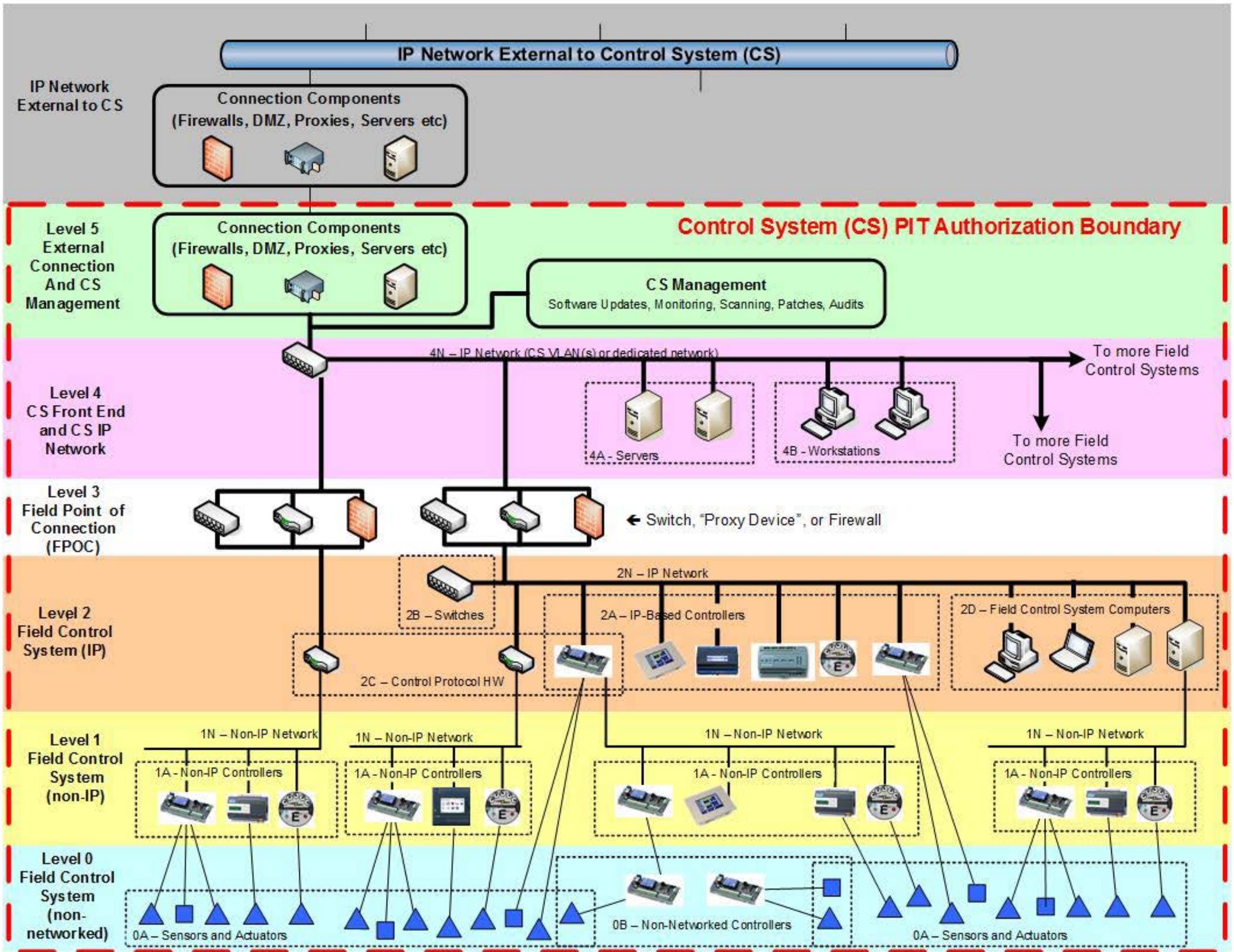
C-1 INTRODUCTION

As shown in Figure C-1, control systems are represented as a 5-Level architecture, where each level represents a collection of components that are logically grouped together by function, and which generally share a cybersecurity approach. This architecture is defined as a general architecture suitable for a wide range of control systems, thus there are some key considerations when using it to describe a specific control system:

- Not every implementation of a control system will make use of every level, or every type of component shown at a level.
- The same device may reside in different levels, depending on its configuration and its network interface. Some controllers even support different networks based on onboard switches, and thus the same device could reside in either Level 1 or Level 2 (but not both simultaneously – though a single system could have the same type of controller shown at both levels).
- In many cases, a device will fit multiple sub-levels within the same principal level, usually within Level 2. For example, a Level 2A controller may act as a Level 2C router to a Level 1 network beneath it.

This Appendix describes the 5-Level architecture for control systems and presents cybersecurity considerations for each level. Note that although there are more than five levels in the architecture shown in Figure C-1, it is commonly referred to as the “5-Level Control System Architecture”. This architecture applies to all control system types; while many of the example components or technologies included in this Appendix are based on building or utility control systems this is not meant to imply that this architecture is specific to these types of control systems.

Figure C-1 5-Level Control System Architecture



C-2 5-LEVEL ARCHITECTURE OVERVIEW

A brief description of each Level (from simple to complex devices) is:

Level 0. Non-networked devices which communicate using analog and binary signals. These include ("dumb") sensors and actuators as well as non-networked controllers (including their dedicated sensors and actuators). These communicate with Level 1 via hardware I/O (analog and binary signals).

Level 1. Networked controllers not on an IP network (such as BACnet MS/TP, RS-485 (DNP, Modbus), LonWorks TP/FT-10).

Level 2. Networked controllers on an IP network.

Level 3. The Field Point of Connection (FPOC), which is a connection between the field control system IP network at Level 2 and the Level 4 IP network.

Level 4. The site-wide IP network used for the control system, along with front end servers and workstations (desktops and laptops).

Level 5. Interfaces to “external” networks (IP networks other than the control system network). In many cases this level will not be a requirement of the project and will be provided by others. When it is part of the project it must be specified separately than the control system using IT specifications and standards.

Note that some levels contain sub-levels as indicated in Figure E-1.

C-3 LEVEL 0: SENSORS AND ACTUATORS

Level 0 consists of non-networked devices which communicate using analog and binary signals. These include (“dumb”) sensors and actuators, as well as non-networked controllers. These communicate with Level 1 or Level 2 via hardware I/O (analog and binary signals). Details for Level 0 are shown in Table C-1.

Table C-1 Level 0

LEVEL 0: Sensors and Actuators	
Definition	Level 0 devices lack a network and therefore cannot be attacked over a network. Level 0 devices, if they communicate at all, use only simple analog and binary signals, they do not use any form of digital protocol for communication. A sensor or actuator that uses a communications protocol (such as Zigbee, Bluetooth) is a Level 1 (non-IP) or Level 2 (IP) device.
Functional Description	The interface between the control system and the underlying controlled process / equipment where electrical signals in the control system get converted to/from physical values and actions in the underlying controlled system. Level 0A consists of Sensors and actuators Level 0B consists of non-networked controllers and their integral sensors and actuators. Level 0B devices may have some intelligence and may even have an internal network, but the device does not expose any internal network to other devices. These devices are typically packaged units with factory-installed integral controllers. Note that a “stand-alone” built-up unit with multiple field installed controllers which communicate over a network specific to that unit is NOT a Level 0 component, but rather a stand-alone field control system of its own.

<table>
<tr><th colspan="2">LEVEL 0: Sensors and Actuators</th></tr>
<tr><td>Implemented Via</td><td>Devices which:
Convert physical properties (temperature, pressure, etc.) to a binary or analog electrical signal
Take a binary or analog electrical signal and produce a physical action (open / close a valve or damper, etc.)
These electrical signals are purely binary or analog – there are no exposed digital signals or networks at this level. Also note that "smart" sensors or “smart” actuators which include a controller and network connection are considered to be Level1 or Level 2 devices.</td></tr>
<tr><td>Installed By</td><td>Controls contractor during installation or renovation of underlying mechanical or electrical system.</td></tr>
</table>

<table>
<tr><th colspan="2">LEVEL 0: Sensors and Actuators</th></tr>
<tr><td>Example Components</td><td>The vast majority of these devices are very simple (“dumb”) sensors or actuators, but more complex equipment may be at level 0 – as long as it lacks a network connection. Some examples are:
• A thermistor temperature sensor which simply provides a changing resistance as an indication of temperature is a Level 0A device.
• An electric actuator which takes a 4-20 mA signal and produces a proportional physical response is a Level 0A device.
• An occupancy sensor which uses BACnet to communicate occupancy values is a Level 1 (or Level 2) device, not a Level 0 device.
• A variable frequency drive controlling an air handler fan and using only binary and analog signals to communicate with the air handler controller is a Level 0B device.
• A flow sensor using HART over an analog wire is using a digital protocol (HART) and is a Level 1 device, not a Level 0 device.
• A packaged diesel generator operating in a stand-alone configuration – again with no network connection to other devices - is a Level 0B device, even if it has binary or analog connections to other devices.
• A relay panel acting as a Level 0 hardware interface between a building fire protection system and a sitewide radio network to a sitewide fire department.
The last three examples illustrate that the defining characteristic for Level 0 is not the complexity of the device, but rather whether the device communicates with other devices using a network.</td></tr>
</table>

LEVEL 0: Sensors and Actuators	
Security Control Considerations	In general, management and operational controls such as physical security and access control may still apply to this level. These devices are physically attached to the mechanical/electrical system and physical security is dictated and implemented based on the physical access to the equipment. Utility vaults, Mechanical, Electrical, Plumbing rooms, Pump Stations, etc. should be secure and only authorized personnel should have access. These devices, while they do not have network communication, can cause physical damage, for example a valve left in the “Open” position.

C-4 LEVEL 1: FIELD CONTROL SYSTEM (NON-IP)

Level 1 contains networked controllers not on an IP network (such as BACnet MS/TP, RS-485 (DNP, Modbus), LonWorks TP/FT-10). Details for Level 1 are shown in Table C-2.

Table C-2 Level 1

LEVEL 1: Field Control System (non-IP)	
Definition	That portion of the controls network which does not use the IP protocol. This includes both the controllers themselves (Level 1A) and the network (Level 1N).
Functional Description	(Level 1A) This is where the control logic resides and gets converted to or from binary and analog electrical signals, as well as the portion of the control system where: • Analog and binary electrical signals (from sensors) get converted to digital signals via analog-to-digital (A-D) converters. • Digital information is converted to analog and binary electrical signals (to actuators) via digital-to-analog (D-A) converters. • Digital information is transmitted and received over a network. • Digital information is processed according to a user-defined sequence to generate new digital information.

LEVEL 1: Field Control System (non-IP)	
	• Devices may incorporate integral Level 0 sensors and actuators, for example, many variable air volume (VAV) box controllers incorporate an electric actuator. Not all controllers will have hardware inputs. While there is exchange of data over the network, good design practice dictates that most of the data processing occurs using local (integral or via analog or binary signals) sensor data and local actuator outputs; the system is designed to minimize dependence on networked data. (Level 1N) The Level 1 network (media and hardware) does not use IP. It uses a variety of media at OSI Layers 1 and 2 (some standard, some not) and it uses Layer 3 protocols other than IP. Some examples are: • BACnet over MS/TP, or BACnet over ARCnet • LonTalk over TP/FT-10 or LonTalk over TP/XF-1250 • Modbus over RS-485 For this reason, it is generally very specific to the control application and cannot be used for "standard" IT protocols and applications.
Implemented Via	(Level 1A) Controllers, typically equipped with multiple analog and binary inputs and outputs and corresponding A-D and D-A converters. These devices are driven by cost to have the minimal functionality for the application and are very constrained in random access memory (RAM), processing power, and network input/output (I/O). In addition, these devices come in a vast variety of architectures, processors, vendors, and firmware. (Level 1N) The network media and hardware are similarly dedicated to that specific control protocol and are made by a variety of vendors.
Installed By	Controls contractor during installation or renovation of underlying mechanical or electrical system. Generally during new building construction or major renovation.
Example Components	VAV box controllers Networked (non-IP) electric meter Intelligent (networked) thermostat

LEVEL 1: Field Control System (non-IP)	
	LonWorks TP/XF-1250 (media) to TP/FT-10 (media) router. (This is not an IP router but routes the control system protocol at Open Systems Interconnection layer 3.)
Security Control Considerations	Since devices (controllers) in this tier tend to be simpler devices, often few security controls can be applied, particularly after the system has been designed and installed. Since they do not use IP, network attacks must be very protocol-specific. Some basic controls/measures that can be applied at this tier include: • Disabling (or at a minimum prohibiting) secondary network connections (connections other than to the Level 1 network) • The use of passwords on devices such as displays (to the capability supported by the device – many of which do not permit 14 character passwords, for example) • The application of physical security measures – which will be dictated and implemented by the underlying equipment

C-5 LEVEL 2: FIELD CONTROL SYSTEM (IP)

Level 2 consists of networked controllers on an IP network. Details for Level 2 are shown in Table C-3.

Table C-3 Level 2

LEVEL 2: Field Control System (IP)		
Definition		The portion of the control system which uses IP but is not shared with any other system. “Shared” in this context primarily refers to physical equipment and media. Note the Level 2 IP network is typically contained within a single building but may span multiple buildings in support of a control system for a single (linear) facility.
Functional Description	2A	This Level (along with Level 1) is where the control logic resides and where it gets converted to/and from electrical signals and can have the first IP connections. This is the portion of the control system where: • Analog and binary electrical signals (from sensors) get converted to digital signals via A-D converters

LEVEL 2: Field Control System (IP)		
		(although not all controllers will have hardware inputs). • Digital information is converted to analog and binary electrical signals (to actuators) via D-A converters (although not all controllers will have hardware outputs). • Digital information is transmitted and received over a network. • Digital information is processed according to a user-defined sequence to generate new digital information. • These devices may incorporate integral Level 0 sensors and actuators, for example, many Variable Air Volume (VAV) box controllers incorporate an electric actuator. Note this functional description is identical to that of Level 1. From a controls perspective, there is little difference between Level 1 and Level 2.
	2N/2B	The IP network (media and hardware) dedicated to the control network and carrying the control protocol (such as Distributed Network Protocol (DNP), IEC-61850, BACnet/IP or Lon/IP)). Generally, IP over Ethernet.
	2C	Control Protocol Routers and Gateways. Control Protocol Routers route the control protocol – that is, they selectively forward control protocol packets based on destination address. They are not IP routers. Control Protocol Gateways translate between Control Protocols.
	2D	Where the local control system has an elevated C-I-A requirement (due for example to a reliability requirement, an operator response time, or a need for local operators which cannot be met by the remote site-wide front end), the facility control system may contain a local operator interface similar to what is normally found at Level 4 but dedicated to this specific control system. In other cases, for either legacy or stand-alone systems (not necessarily isolated but stand alone in that they do not rely on another system such as a control system), the front-end operator interface may be physically local to that system. In this case, the operator interface is considered

LEVEL 2: Field Control System (IP)		
		to be part of Level 2 since it is dedicated to that building or facility and traffic between it and the Level 1 and Level 2 devices does not pass through the Level 3 FPOC.
Implemented Via	2A	Controllers, typically equipped with multiple analog inputs and outputs and corresponding A-D and D-A converters. These devices are driven by cost to have the minimal functionality for the application and are very constrained in RAM, processing power, and network I/O. In addition, these devices come in a vast variety of architectures, processors, vendors, and firmware. Aside from the fact that they use IP and are generally more powerful than Level 1A devices, they are otherwise identical to Level 1A devices. Many devices are available as either Level 1A or 2A devices, where the hardware is identical except for the transceiver; some can even be field configured for one or the other
	2N/2B	The Level 2N IP network is generally Ethernet, and the Level 2B network hardware is standard IT network hardware, though sometimes with reduced functionality. For example, there may not be any requirement for remotely managed switches. Similarly, there is seldom a need for an IP router, since field control systems generally reside within a single (private) IP subnet.
	2C	Controllers very similar in hardware characteristics to Level 2A devices except that these devices typically have multiple network interfaces.
	2D	Computers (as for Level 4) Computers for legacy systems Custom or modified computers with a touch screen interface
Installed By		Controls contractor during installation or renovation of underlying mechanical or electrical system. Generally during new building construction or major renovation
Example Components	2A	Air Handler Controller Chiller Controller

<table>
<tr><th colspan="3">LEVEL 2: Field Control System (IP)</th></tr>
<tr><td rowspan="4"></td><td></td><td>Boiler Controller
Terminal Unit Controller
Hydronic System Controller
Supervisory Controller
System Scheduler
Electric Meter
Local Display Panels
Electrical Protective Relay
Voltage Regulator Controller</td></tr>
<tr><td>2B</td><td>Ethernet Switch</td></tr>
<tr><td>2C</td><td>BACnet MS/TP to BACnet/IP Router
LonWorks TP/FT-10 to LonWorks IP Router</td></tr>
<tr><td>2D</td><td>Control system at a central plant where the nature and criticality of the system requires a local operator interface.</td></tr>
<tr><td>Security Control Considerations</td><td>2A</td><td>Controllers residing on the dedicated IP network vary greatly from devices residing on a typical IP network.
• They use a single fixed protocol (or a small number of fixed protocols)
• They often do not support “log in” functionality
• There is often no “session” capability
• They usually do not include a user interface, and if they do it’s generally extremely limited.
• They have very limited hardware capabilities (RAM, CPU, storage, etc.)
• They generally do not use Windows, and seldom use Linux. They are generally some version of a real time operating system (RTOS).
Many of the controllers will have the same limitations as the controllers in Level 1, where most security controls cannot/or will not apply to them. Some controllers will have significantly more capability, however, and additional controls will be applicable. In either case, the controllers</td></tr>
</table>

LEVEL 2: Field Control System (IP)		
		should disable any network connections or services not required for operation of the control system.
	2N/2B	This network is dedicated to the control system and is generally installed by the control system contractor, not the IT organization. This doesn't reduce the need for securing this network, but does affect the way in which this network is secured, and the risks and vulnerabilities that need to be addressed Some key differentiators between the Level 2 network and a standard IP network are: • The network structure and connected devices remain more static throughout the life of the system. Generally components are not added and removed on a regular bases. • The protocol(s) used are fixed, and in many cases only a single protocol is used. The protocols also differ from "regular" IP networks in that they are control system protocols rather than standard IT protocols. This allows for the implementation of very simple (a few very broad rules) firewalls to limit traffic. • Bandwidth usage is lower. Because the network configuration is more static, the bandwidth usage is also more fixed. • The devices residing on the network have fewer capabilities, and generally don't support network security standards such as IEEE 802.1X. • The control system does not require the level of functionality that Approved Product List (APL) network infrastructure devices provide. The Navy, however, does require APL products for all IP Network Hardware.. • Standard IT devices typically do not meet the UL Listing requirements for fire and life safety systems, so specialized network hardware may be required to meet the control system needs.
	2C	These devices are not manufactured by traditional IT companies and do not run standard IT software. Their functionality is often included as part of a Level 2A device. They do not route IP.

LEVEL 2: Field Control System (IP)		
	2D	While functionally, Level 2D components act similarly to computers at Level 4, the fact that they are local to (and dedicated to) a specific control system means that from a security controls perspective, they are better addressed as Level 2 components. There are two main reasons for computers at Level 2D: • Legacy systems that cannot be patched. The computers at Level 2D may be running an older operating system and may not support some of the security controls. In this case, the controls which can be applied without negatively affecting the availability of the system should be applied, and mitigating controls and measures should be taken when otherwise needed. Systems containing these computers should not be connected to other systems (i.e., should be operated stand-alone) until they can be properly addressed, with the computers replaced or otherwise upgraded to Level 4 standards. • Where a new system requires a local front end that, for whatever reason, cannot be installed on the base-wide shared IP network (Level 4). This is typically due to a C-I-A requirement. When installing a new system with a Level 2 front end, it's important to note that the Level 2 front end should be subject to the same controls as a Level 4 front end. While implementation and inheritance of security controls at this level may differ from the Level 4 front end, computers at this Level should be subject to the same controls as a "normal" Level 4 front end of equivalent criticality.

C-6 LEVEL 3: FIELD POINT OF CONNECTION (FPOC)

Level 3 is the Field Point of Connection (FPOC), which is a connection between the field control system IP network at Level 2 and the Level 4 IP network. Details for Level 3 are shown in Table C-4.

Note that there may be devices which resemble an FPOC in the sense that they are a security device providing a managed interface between different networks but are not located between a dedicated IP network and a base-wide shared IP network. While these devices (discussed in Chapter 2, and under the Level 0 description above) act as a security barrier, the term FPOC is reserved for a security device between Level 2 and Level 4.

Table C-4 Level 3

LEVEL 3: Field Point of Connection (FPOC)	
Definition	The device which connects the dedicated Level 2 IP network with the Level 4 IP network.
Functional Description	For each field control system, the FPOC is the specific single demarcation point in the control system between that field control system and the front-end system. The FPOC is a standard IT device, usually an Ethernet Switch. The FPOC generally has security controls in that it restricts access (by user, protocol, or specific commands) between levels above and levels below. Note that a large system (consisting of hundreds of FCSes) will have hundreds of these FPOC devices, one at each connection of a field control system to the local network.
Implemented Via	Almost always an Ethernet switch or IP router
Installed By	Generally installed by installation network staff or by the control system contractor with oversight by the network staff.
Example Components	Standard IT managed Ethernet switch or IP router
Security Control Considerations	This device is critical from a security controls perspective as it is where the dedicated local field control network connects to the installation-wide IP network. Normally, securing this device protects the installation-wide network from the local field systems (which often have a difficult time meeting security controls). Occasionally, where there is a critical field control system, this device can protect the more critical field control system from the less-secure local system (i.e., where there are 99 non-critical systems and 1 critical one, isolate the 1 from the 99 rather than try and secure the 99). This device should, in effect, have a "deny all / permit by exception" policy applied. The FPOC should be set up with the most restrictive set of access control list (ACL) possible.

C-7 LEVEL 4: CONTROL SYSTEM FRONT END AND CONTROL SYSTEM IP NETWORK

Level 4 is the IP network used to connect multiple Level 2 networks, along with front end servers and workstations (desktops and laptops). Details for Level 4 are shown in Table C-5.

Table C-5 Level 4

LEVEL 4: Control System Front End and Control System IP Network	
Definition	Front End computers and the IP network which connects multiple Level 2 Field Control Networks and is (generally) not dedicated to a specific FCS. The IP network may be shared with other applications, a dedicated physical network, or a Virtual Local Area Network (VLAN) or a Virtual Private Network (VPN) riding on top of another network.
Functional Description	(Level 4A and 4B) The multi-facility operator interface for the system. This is typically a web-based client-server system with the servers (Level 4A) running vendor-specific software on standard server PCs and the clients (Level 4B) accessing the servers via standard web browser software. Some functions of the control system are: • Providing graphical screens for monitoring and control of the system • Allowing operators to schedule systems, set up historical trends, and respond to alarm conditions • Provide for and support global control and optimization strategies that are impractical to implement within the control systems • Perform real-time analytical analysis and take appropriate real-time actions through supervisory commands to devices at levels 1 or 2. This level usually also includes Engineering Tool Software which provides tools for creating and modifying the control system. The Level 4N network is the network that connects multiple facility networks into a common base-wide network. (Note that generally this network is referred to as base-wide as that’s the normal use case, but it could be entirely contained within a single building)

LEVEL 4: Control System Front End and Control System IP Network	
Implemented Via	Either a dedicated physical network, or a Virtual Local Area Network (VLAN) or a Virtual Private Network (VPN) riding on top of another network, or some combination of these options. Personal Computers, servers and network devices.
Installed By	The network (Level 4N) is typically government furnished. The computers (servers and workstations in Levels 4A and 4B) are often government furnished. The software application is typically provided, installed and configured by the controls vendor.
Example Components	Servers and racks, computers, Laptops, operator interfaces, and network devices. The control system racks, hardware and software will likely be located in an Energy Operations Center, Campus Wide Operations Center, Facility Operations Center, Facility and Energy Operations Center, Security Operations Center, or Regional Operations Center.
Security Control Considerations	Level 4 is where the CSs most closely resemble a “standard” information system, and most security controls can be applied at this layer. It’s critical to remember that control system is NOT a standard IS, however, and that controls must be applied in such a way as to not hamper the availability of the system. For example, some control systems require software updates from the manufacturer prior to the implementation of a Java patch, and controls relating to the application of patches must not be implemented in a manner that requires automatic or immediate patching without ensuring that this won’t cause the system to go offline. Unlike standard IT applications (such as virus software or office automation tools), control system applications are generally a niche product and while standard guidance may cover some aspects of securing these applications, it will likely be insufficient to fully secure them.

C-8 LEVEL 5: EXTERNAL CONNECTION AND CONTROL SYSTEM MANAGEMENT

Level 5 contains interfaces to “external” networks (IP networks other than the control system network). Details for Level 5 are shown in Table C-6.

Table C-6 Level 5

<table>
<tr><th colspan="2">LEVEL 5: External Connection and Control System Management</th></tr>
<tr><td>Definition</td><td>Additional hardware, software, and networking used to manage the control system, provide security functionality, user management, and external access. These are IT management and IT security functions, and don’t provide control system functionality.</td></tr>
<tr><td>Functional Description</td><td>In many architectures, this level provides the enclave boundary defense between the control system (at Level 4 and below) and IP networks external to the control system. (In other architectures, this boundary defense occurs in the external network). In many cases, there is a component within the control system which would reside in Level 5.

This level may be absent for a variety of reasons: there may not be an external connection, or the connection may be handled in the external network.

Additional functionality allowed through external connections may include:
• Sending alarm notification using outbound access to a SMTP email server.
• Upload of historical data and meter data to an enterprise server using outbound HTTP/HTTPS access for uploading.

In some cases, inbound HTTP/HTTPS may be allowed from web clients on the external network to the Level 4A server, but this is not required and is often prohibited for security reasons. The Navy prohibits this functionality.</td></tr>
<tr><td>Implemented Via</td><td>Firewalls
DMZ/Perimeter Networking
Proxy Servers
Domain Controller, etc.</td></tr>
<tr><td>Installed By</td><td>IT and communications staff and contractors.</td></tr>
<tr><td>Example Components</td><td>Wide Area Networks
Metropolitan Area Networks
Local Area Networks</td></tr>
</table>

	Campus Area Networks Virtual Private Networks Point of Presence Demarcation Point or Main Point of Presence
Security Control Considerations	Generally speaking, if the control system can function in a completely isolated configuration, it should, and external connection should be absent. This Level should implement a "deny all / permit exception" policy to protect the control system from the external network and the external network from the control system.

C-9 ARCHITECTURE FREQUENTLY ASKED QUESTIONS (FAQ)

- ***Can there be controllers at Level 4?*** No, all networked controllers must be at Level 2 or Level 1. Non-networked controllers may also exist at Level 0.
- ***Can one Field Control System have multiple Level 2 networks?*** Yes. One case is multiple Level 2 networks with no IP connection between. In this case there may still be a Level 1 or Level 0 connection between them.

  Another possibility is that instead of having a single Level 2 network, you may architect the system to have multiple Level 2 networks which are connected by a Level 4 network.
- ***Can one Level 2 network support multiple field control systems?*** Yes, but they would have to share a cybersecurity authorization.
- ***I have a control system supporting a linear facility that operates across a wide geographic area using a network that no other system used. Is that a Level 4 or Level 2 network?*** It could be either – it can be defined using the architecture as a single Level 2 network, or as multiple Level 2 networks connected by a Level 4 network. Which is more accurate will depend on the details of the specific installation. Factors affecting how this system is best described include authorization boundaries, procurement and operation responsibilities for the network, and preference of the Authorizing Official. In a broad sense, the more tightly the network is tied to the control system (maintained by the same people for example) the more it resembles Level 2.

APPENDIX D CONSIDERATIONS IN DETERMINATION OF CONTROL SYSTEM IMPACT RATINGS

D-1 BACKGROUND

This appendix discusses methods for determining the cybersecurity impact rating for a building control system. A system is categorized based on an evaluation of the impact associated with the loss of confidentiality (C), integrity (I), or availability (A) (generally written as CIA) in organizational operations, organizational assets, or individuals. The system impact is categorized as high, moderate, or low. This is sometimes referred to as either the CIA level, CIA value, impact level, or security category. Where this categorization is not provided by the system owner (SO) or authorizing official (AO), the procedures in this appendix may be used to determine interim categorization values to allow the design process to move forward. These values cannot be assumed to be the values that will be used for authorization.

Before defining the system categorization, it is important to understand what is meant by a loss of confidentiality, integrity, or availability, and what is meant by a high, moderate and low impact.

D-1.1 Types of Security Breach

The RMF considers three types of security breaches:

- Loss of Confidentiality. Information within the system is leaked to the outside.
- Loss of Integrity. Information in the system is subject to unauthorized modification.
- Loss of Availability. The system (or information in the system) is unavailable.

D-1.2 Impact Ratings

The RMF categorizes systems as LOW, MODERATE, or HIGH based on the potential impact of a security breach. The DoD definitions for LOW, MODERATE, and HIGH impact are given in FIPS-199 (Federal Information Processing Standards) as modified in CNSSI-1253. (CNSSI adds the phrase “exceeding mission expectations” to each definition):

D-1.2.1 LOW Impact Definition

The potential impact is LOW if the loss of confidentiality, integrity, or availability could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals.

AMPLIFICATION: A limited adverse effect means that, for example, the loss of confidentiality, integrity, or availability might (i) cause a degradation in mission capability to an extent and duration that the organization is able to perform its primary functions, but the effectiveness of the functions is noticeably reduced; (ii) result in minor damage to organizational assets; (iii) result in mi-nor financial loss; or (iv) result in minor harm to individuals [exceeding mission expectations].

D-1.2.2 MODERATE Impact Definition

The potential impact is MODERATE if the loss of confidentiality, integrity, or availability could be expected to have a serious adverse effect on organizational operations, organizational assets, or individuals.

AMPLIFICATION: A serious adverse effect means that, for example, the loss of confidentiality, integrity, or availability might (i) cause a significant degradation in mission capability to an extent and duration that the organization is able to perform its primary functions, but the effectiveness of the functions is significantly reduced; (ii) result in significant damage to organizational assets; (iii) result in significant financial loss; or (iv) result in significant harm to individuals that does not involve loss of life or serious life-threatening injuries [exceeding mission expectations].

D-1.2.3 HIGH Impact Definition

The potential impact is HIGH if the loss of confidentiality, integrity, or availability could be expected to have a severe or catastrophic adverse effect on organizational operations, organizational assets, or individuals.

AMPLIFICATION: A severe or catastrophic adverse effect means that, for example, the loss of confidentiality, integrity, or availability might (i) cause a severe degradation in or loss of mission capability to an extent and duration that the organization is not able to perform one or more of its primary functions; (ii) result in major damage to organizational assets; (iii) result in major financial loss; or (iv) result in severe or catastrophic harm to individuals involving loss of life or serious life-threatening injuries [exceeding mission expectations.]

D-2 SYSTEM CATEGORIZATION AND DETERMINATION OF IMPACT RATING

Step 1 of the RMF requires categorizing the system in accordance with Committee on National Security Systems Instruction (CNSSI) 1253. This instruction describes how the CIA impact level is determined by the type of information on the system and mission criticality of the system. Rationales for system categorization will be required and may be supported by four approaches (listed in order of preference):

1. Compare to Similar Systems. This is probably the most defensible and easiest approach; is the project similar to an existing project with established categorization values?
2. Methodical System Review. This is a “common sense” approach to determining impact ratings based on the mission and the relationship the control system has to the mission.

3. Office of the Assistant Secretary of Defense for Sustainment (Energy, Installations and Environment) FRCS Master List (https://www.acq.osd.mil/eie/IE/FEP_CSC.html).This list includes “starting point” CIA impact ratings by control system type for three mission criticalities. The values here have generally (and more specifically for Utility Monitoring and Control System (UMCS), BCS, and UCS) been determined through an application of the “common sense” methodical process defined here.
4. National Institute of Standards and Technology (NIST) Guidance. This is the “proper formal way” to determine impact ratings but is not easily applicable to control systems. In practice, the approach used is to determine CIA using another approach first and then to confirm/document that impact rating determination using the NIST guidance.

D-2.1 Compare to Similar to Systems

At many sites, the project will be similar to existing control systems in similar mission space. It may be possible to simply determine what categorization values were used in the other project and assume those same values in the current project. Note that “similar” in this context must include the following elements (in order from most to least important):

- The other project should have the same organizational AO. Since acceptance of risk is subjective, it is vital to have the same organization accepting the risk.
- The other project must have a control system supporting a mission with a similar impact of the mission itself. Note: this has nothing to do with the control system, it is the criticality of the mission itself. Even if the mechanical systems were identical, a project supporting a mission of “processing real-time battlefield intelligence” cannot be compared to a project supporting a mission of “providing recreational facilities to soldiers.”
- The other project must have a similar dependency between the control system and mission. The key question here is “if the control system fails, how much impact is there on the mission?”

If there is a similar project that can be referenced, then a reasonable assumption is that “similar projects will have similar C-I-A impact categorization values”.

D-2.2 Methodical System Review

In almost all cases, loss of confidentiality of the information in the control system is of little or no consequence (even when it is, it is generally much less important than integrity or availability) and the impact of the control system is primarily due to loss of integrity or availability. Loss of integrity or availability relates to how these losses may impact the mission supported by the specific facility-related control system (FRCS). Determination of impact for the control system is typically a two-step process:

- What is the impact of the mission? Will loss of the mission result in a LOW, MODERATE, or HIGH impact?
- How much will a loss of (integrity or availability of) HVAC controls impact the mission?

This process will provide a rational (“common sense”) starting point for determining criticality of an FRCS to use during design but is not official policy. Ultimately, system criticality is determined by the AO (in coordination with the SO and based on input from the designer of the control system).

D-2.2.1 Impact of the HVAC Control System

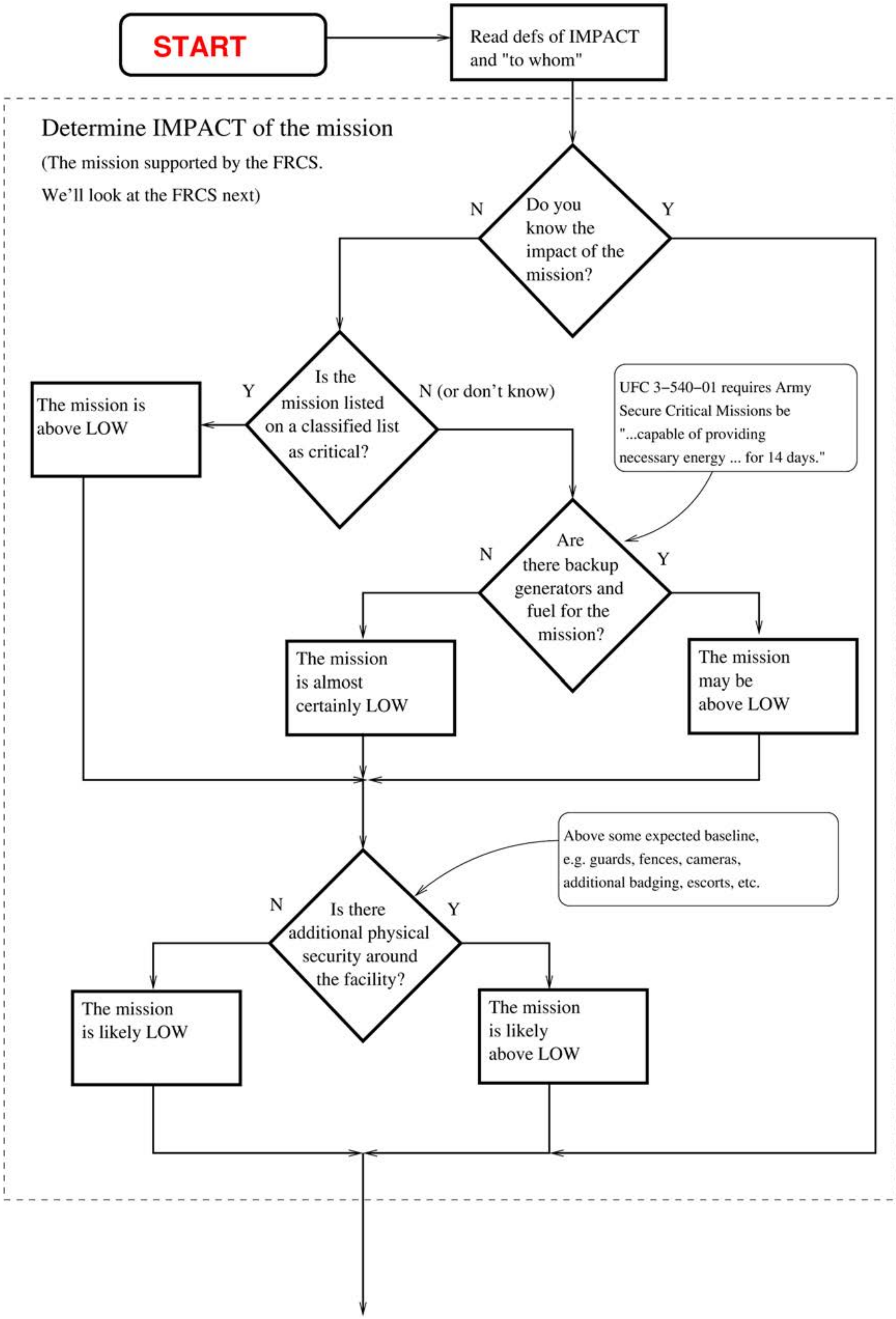
D-2.2.1.1 Mission Impact

Ideally, the AO, SO, or mission tenant will identify the mission impact, but this is often not feasible (mission tenants may not in fact know and frequently overstate their own importance). In cases where the mission impact is not known, or when the claimed mission impact seems exaggerated and confirmation is desired, the flow chart in Figure D-1, Figure D-2, and Figure D-3 may be helpful. The flowchart assumes that availability and integrity have the same impact rating and disregards confidentiality. (Although this is a single flowchart, it has been broken out across three figures to facilitate discussion of the flowchart).

The first part of the flowchart, Figure D-1, deals with the determination of the impact of the mission itself. This chart relies on three observations:

1. Critical mission facilities are often on a (classified) list of critical facilities.
2. Critical mission facilities generally have a requirement for local backup generators. UFC 3-540-01, Engine-Driven Generator Systems for Prime and Standby Power Applications requires that “For Army Secure Critical Missions, the Army will reduce the risk by being capable of providing necessary energy and water for 14 days.”
3. Critical mission facilities generally have a requirement for physical security above and beyond what is typical on the installation. Note that this is not definitive: child development centers typically have additional security but might not be considered mission critical. These security measures might include such things as additional fencing, cameras, security guards, additional badging, or requirements for escorts inside the facility. When electrical and mechanical infrastructure is outside the facility (for example, a diesel generator), there is typically a security fence surrounding the facility and the electrical and mechanical infrastructure.

**Figure D-1 - FRCS Impact Determination Flowchart Part 1
Determining Mission Impact**



D-2.2.1.2 Impact of Control System on Mission

Once the impact of the mission is known, the impact of the FRCS on the mission is evaluated. The flowchart continues in Figure D-2 and Figure D-3 and considers the relationship between the FRCS, the underlying equipment, and the mission itself:

- A key consideration is whether the mission depends on the equipment controlled by the FRCS. A computer server room is clearly dependent on continuous cooling for operation, while an outdoor training area is clearly not. Other related considerations are:
    - How long the mission can function before a loss of the controlled equipment will cause a mission failure. For example, a computer server room might fail completely if it loses cooling for 30 minutes, while an office environment (even one performing a critical function) might continue to function for hours before their mission was impacted and may be able to carry on indefinitely (with some reduced efficiency) without completely failing at their mission.
    - The extent that the controlled equipment relies on the FRCS for operation. For example, a lighting system controlled by an occupancy sensor that also has a manual ON/OFF switch relies very little on the occupancy sensor for meeting mission goals.

The next several considerations address the equipment controlled by the FRCS and the ability of site personnel to operate the underlying equipment after a control's failure.

- If the equipment controlled by the FRCS is critical, it likely requires the same level of backup power as the supported mission, which normally means local backup power generation.
- If the equipment controlled by the FRCS is critical, there will likely be redundant equipment to allow for failure (such as mechanical failure) of a piece of equipment (such as a broken belt or burned out bearing).
- If local controls are available that will allow staff (either installation operations and maintenance [O&M] staff or adequately trained mission staff) to restore operation of the equipment before the mission fails. Note that these manual controls might lead to reduced energy efficiency, but the key point is that the mission can continue with minimal disruption.
- The ability of O&M staff to repair or restore system operation before the mission fails due to the loss of the systems must be considered, as this ability to repair before failure is a mitigation that would lower the FRCS Impact level.
- The Integrity and Availability impact of the FRCS controls cannot exceed the supported mission impact. However, in cases where confidentiality is important, the Confidentiality impact rating of the FRCS impact may exceed the mission impact.

**Figure D-2 - FRCS Impact Determination Flowchart Part 2a
Determining FRCS Impact Based on Mission Impact**

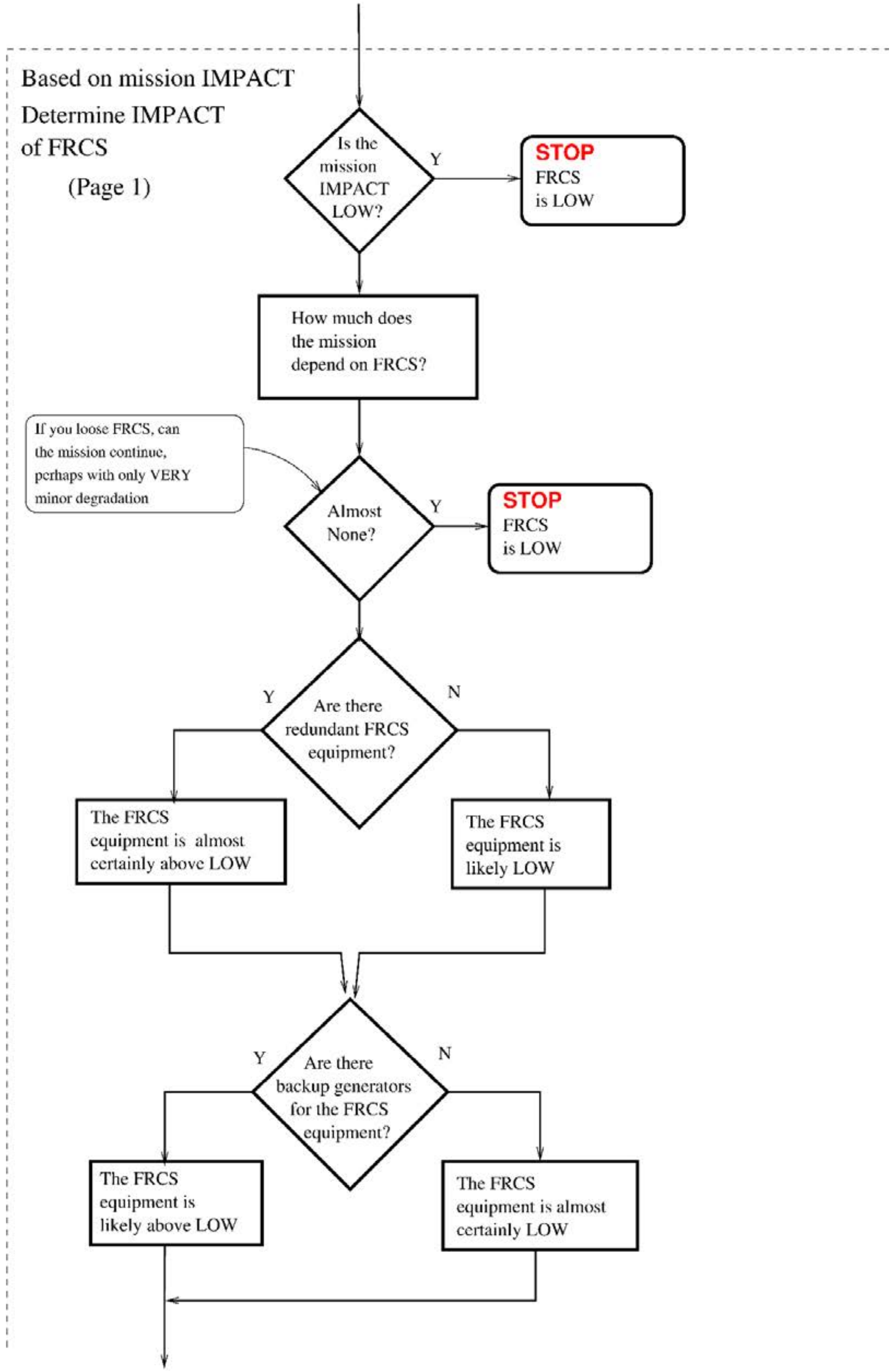
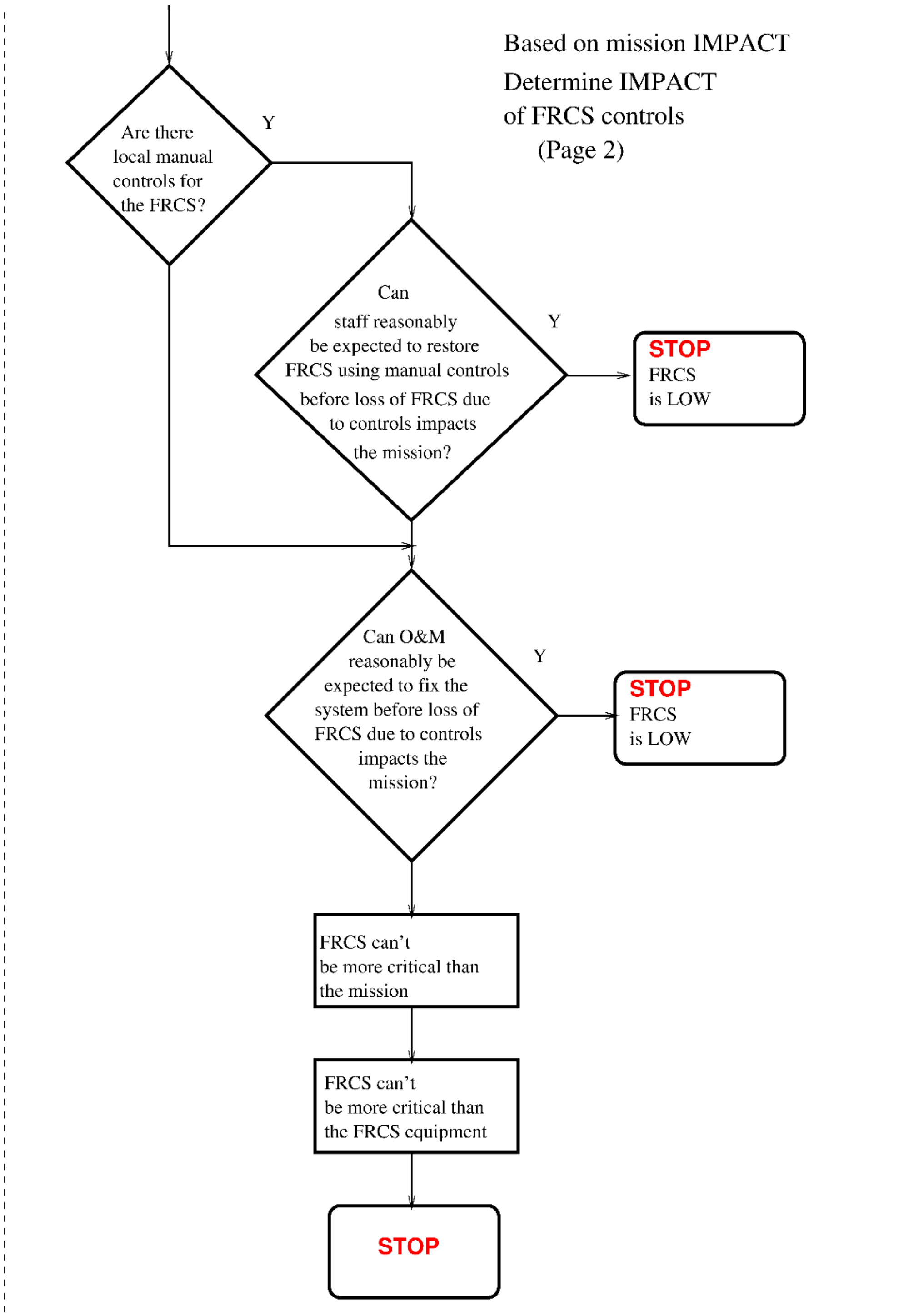


Figure D-3 - FRCS Impact Determination Flowchart Part 2b Determining FRCS Impact Based on Mission Impact.



D-2.2.2 Addressing the critical control system and reducing system criticality

Several options for addressing a critical FRCS (and possibly reducing its criticality) are suggested by the above drawing and are described in CHAPTER 4, such as the addition of manual controls, the use of local front ends or local display panels, and redundant equipment with independent control systems.

If the standalone system approach is used, this might mean that the standalone system cannot be monitored by the primary systems. Multiple strategies are discussed in APPENDIX E to allow for a lower-impact system to monitor a higher-impact system.

D-2.3 System categorization based on Facility-Related Control Systems (FRCS) Master List

The Facility-Related Control Systems (FRCS) Master List available on the Office of the Assistant Secretary of Defense for Sustainment FRCS Cybersecurity Website (https://www.acq.osd.mil/eie/IE/FEP_CSC.html), provides preliminary impacts dependent on supported mission criticality.

D-2.3.1 Supported Facility Criticality

The Master List uses three categories of mission criticality into which the facility or mission the system supports will fall. The DoDI 5000.02 defines them as:

- Mission Support. Not designated as mission essential or critical
- Mission Essential. “is basic and necessary for the accomplishment of the organizational mission. (designated by the DoD Component head)”
- Mission Critical. “the loss of which would cause the stoppage of warfighter operations or direct mission support of warfighter operations. (designated by the DoD Component head)”

Assuming that the mission is heavily dependent on the FRCS, then the CIA values under the mission criticality for the facility or mission can be used as preliminary CIA values for the FRCS. Figure D-4 shows an excerpt of the Master List for UMCS.

**Figure D-4 – Example FRCS Master List Entry
UMCS Categorization Based on Mission Criticality**

FRCS Type and Description	Preliminary Baseline C-I-A								
	Mission Support			Mission Essential			Mission Critical		
System Name	C	I	A	C	I	A	C	I	A
Utility Monitoring and Control System (UMCS)	L	L	L	L	L	L	L	M	M

* C=confidentiality, I = integrity, A=availability** L=low, M=medium, H-high

Note that the CIA values for mission essential or mission critical facilities should be lower than shown on the "Master List" if the mission does not depend heavily on the FRCS.

Note also that the Baseline C-I-A values from the Master List are not policy, rather they are guidance in helping one determine categorization. The focus on determining categorization is in the following instructions on the National Institute of Standards and Technology (NIST) Special Publication (SP) 800-60 (NIST 2008). For example, one may have a physical access control system that does not rise to the suggested CIA impact categorization of MMH (for moderate confidentiality, moderate integrity, and high availability impact) as depicted in the "Master List." Follow the next section and provide a clear concise categorization rationalization.

D-2.4 NIST SP 800-60, Vol. II -Rev. 1, Information Types

NIST SP 800-60, Vol. II, Appendices to Guide for Mapping Types of Information and Information System to Security Categories (NIST 2008) is the authoritative document to help SOs determine the CIA values for the information processing types of their systems.

NIST SP 800-60, Table D-1, "Mission-Based Information Types and Delivery Mechanisms Mission Areas and Information Types" lists information type. (NIST 2008).

While many system types are not an ideal match to the systems listed in Table D-1, UMCSs (and HVAC, electrical, and lighting systems) will most likely fall into information systems described in Section D.7, "Energy." The information types in D.7 are

- Energy Supply
- Energy Conservation and Preparedness (common information type for an Army UMCS)
- Energy Resource Management
- Energy Production

NIST SP 800-60, Table D-2 (shown in Figure D-5) lists the anticipated CIA categorization for each of the above types. Note that UMCSs fall in the energy conservation and preparedness information type and have a baseline CIA level of low-low-low.

Figure D-5 – Example FRCS Master List Entry
UMCS Categorization Based on Mission Criticality

Information Type	Confidentiality	Integrity	Availability
Energy Supply	Low	Moderate	Moderate
Energy Conservation and Preparedness (includes UMCS)	Low	Low	Low
Energy Resource Management (does not include UMCS)	Moderate	Low	Low
Energy Production	Low	Low	Low

This is still not enough information for you to appropriately justify your CIA categorization. Go to NIST SP 800-60 section D.7 “Energy” and review the definitions of the four types of energy (as listed above) and determine what best fits the system. Select all information types that are applicable to your system. Make sure you look at the definitions of confidentiality, integrity, and availability and any special factors that could elevate the baseline CIA.

D-2.5 Summary and required categorization rationale

Where applicable, the best approach is likely “compare to similar systems.” If that is not an option, the best approach may be to use the “methodical system review” approach to determine impact level, then select (if there is a plausible fit) the system type from NIST SP 800-60 to defend the decision.

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APPENDIX E CYBERSECURITY CONSIDERATIONS FOR INTEGRATING CRITICAL UTILITY OR BUILDING CONTROL SYSTEMS WITH NON-CRITICAL UMCS

NOTE: This appendix applies to Utility Control Systems (UCS) and Building Control Systems (BCS). For the purpose of this Appendix, the term Field Control Systems (FCS) is used to refer to both UCS and BCS, but not necessarily to other Field Control System (FCS) types.

E-1 INTRODUCTION

In those cases where a Building Control System (BCS) or Utility Control System (UCS) contains classified information, controls critical infrastructure, or otherwise supports critical missions or life safety, the FCS is a critical system. While some of the requirements for securing the FCS are covered in the list of CCIs to be applied to a MODERATE or HIGH system, there are issues specifically related to critical systems on a typical installation where the preponderance of systems is non-critical.

There are three main approaches to address the connection of a critical FCS to a UMCS:

1. **Secure the UMCS at the same Impact level as the FCS**. Conceptually, this is the most straightforward approach, but it requires the UMCS Front End to be addressed at the higher Impact level and requires special consideration all other connected FCS which are not at the higher impact level (and are therefore connecting to a higher impact system). A typical DoD installation will have many more non-critical FCS than critical FCS, so this approach will often prove to be impractical, particularly when connecting a lower impact FCS to a higher impact UMCS Front End is difficult. This approach is the preferred solution for the Navy, and the Navy has identified an approach to connect the lower impact systems without requiring them to be assessed at the higher impact level.

2. **Implement a stand-alone UMCS for the FCS.** In this case, the FCS is part of a dedicated local critical UMCS which is not connected to the UMCS serving the larger installation. This approach eliminates the risk of connection to a less critical system, but requires that the critical UMCS function independently, with its own dedicated UMCS operators. It also removes the ability to remotely monitor the critical system.

   In many cases this approach is logistically infeasible to sustain and must be carefully considered before implementing. Facility operation and maintenance staff must be willing and able to operate the stand-alone facility for this approach to work.

3. **Provide a secure connection between the critical FCS and a non-critical UMCS**. This approach connects the critical FCS to the installation-wide UMCS in a way that does not increase the impact level of the UMCS. While this connection requires a great deal of planning and

care, it can provide a more practical means of connecting the critical FCS than either implementing a stand-alone UMCS or raising the Impact level of the installation-wide UMCS.

This approach provides a security separation between the FCS and UMCS and is the preferred approach for the Army.

This Appendix presents design considerations specifically for connecting critical building control systems to a non-critical UMCS as described in approach 3. Considerations for the implementation of approach 1 or 2 are NOT addressed herein. While the considerations in this Appendix may be applicable to other control systems, particularly other building control systems or utility control systems, they are discussed here within the context of a Heating, Ventilation and Air Conditioning (HVAC) Building Control System.

E-2 LIMIT OUTSIDE FUNCTIONALITY

The key concept in connecting a critical FCS to a non-critical UMCS is limiting the ability of the UMCS to affect the FCS. The interactions between the FCS and UMCS should be specific and well-defined, and restricted to those required for system operation. In general, this will entail information from the FCS being sent to the UMCS for monitoring while greatly restricting or even eliminating information from the UMCS being sent to the FCS for control purposes. For example, a critical FCS may send status and alarm information to the non-critical UMCS but should not be receiving start/stop commands from the UMCS as this introduces vulnerabilities to the critical system. Operator changes to the critical FCS should always be carefully considered – by an operator in the zone, with ***full awareness of their actions and understanding of the impact of their actions***.

E-3 FCS-UMCS CONNECTION METHODS

Limiting ***possible*** actions is a very difficult requirement for networked controllers; in many cases the aggressor can connect their laptop to the UMCS network and download a new program to a device in the critical FCS. This is not to trivialize the significant barriers preventing this action, but by assumption, the UMCS is not sufficiently secured to protect the FCS, so it must be assumed that this action is possible and guard against it. This is similar to the additional physical security usually protecting a critical facility. Even though there are barriers limiting access to the installation in general, the assumption is that an aggressor can get access to the installation and critical facilities have additional physical security to further limit access.

There are three primary methods which can be employed to provide a secure connection between a critical FCS and a non-critical UMCS: a Hardware I/O interface, Hardware Gateway, and Network Firewall. Of these three, the recommended approach for critical FCS is the use of the Hardware I/O interface.

E-3.1 Hardware I/O Interface

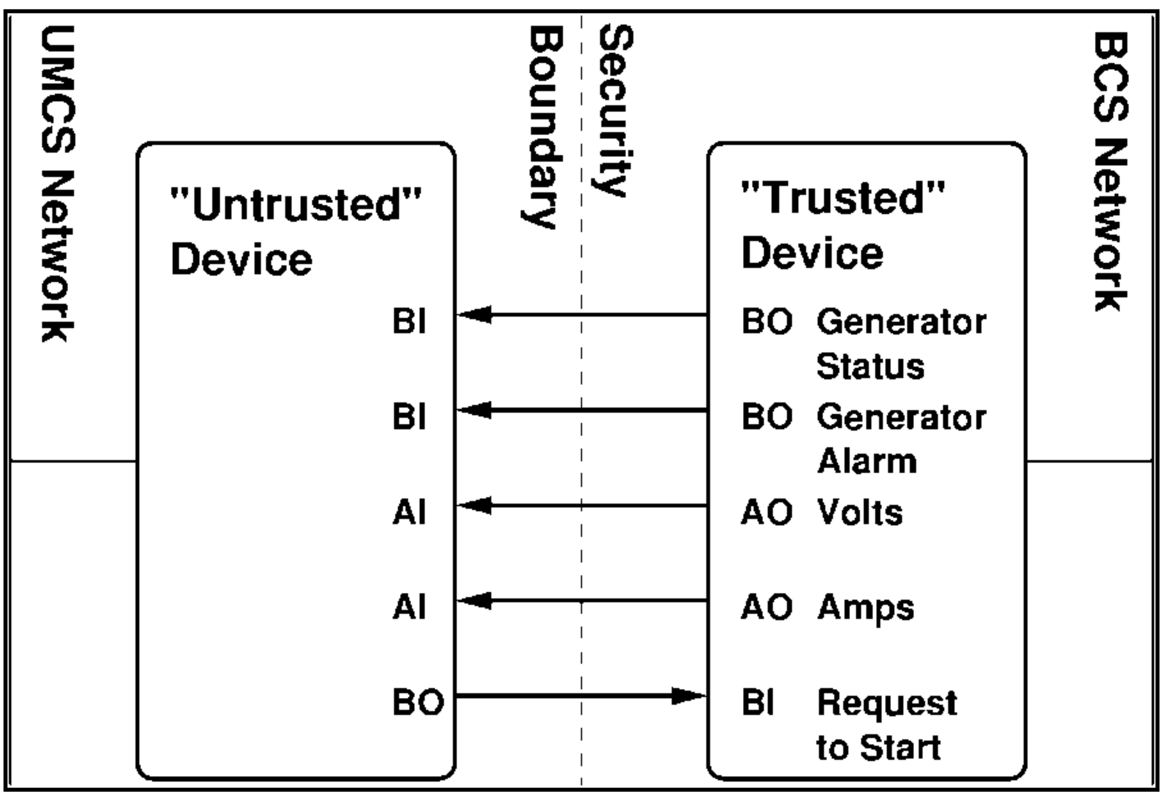
The most secure method to connect an FCS to a UMCS is to share data across the boundary using only analog and binary signals. Do ***not*** connect the FCS to the UMCS via a network. Using hardware I/O prevents an aggressor from “piggybacking” an unwanted command onto the interface as the information exchange is defined and restricted by the hardware connections. Even if an aggressor controls the untrusted device, the trusted device can only receive the commands that it has been designed and constructed to receive.

E-3.1.1 Hardware I/O Interface Overview

A Hardware I/O Interface consists of two controllers which share information between systems via binary or analog I/O, typically using dry contacts, 4-20mA signals or 0-10V signals.

Figure E-1 illustrates a Hardware I/O Interface where a generator serving a critical facility provides a few key monitoring points to a UMCS, and receives a control point, "Request to Start" from the UMCS. It’s important that this point is only a ***Request*** for the system to start, and that the actual decision of whether the generator will start or stop ***must*** be made by the critical FCS.

Figure E-1 Hardware I/O Interface Example



E-3.1.2 Hardware I/O Interface Implementation

Implementing a Hardware I/O Interface requires controllers on the FCS and UMCS with matching hardware points. An aggressor could apply excessive voltages to the I/O lines and physically damage the controller on the FCS side. To mitigate this vulnerability, either:

- Use a controller dedicated to the communication interface and performing no other functions on the FCS side so that damage to it doesn’t impact the control system.

  or

- Provide optical isolation of the analog and binary signals between the devices.

The controller on the UMCS side of the connection may be on a controller which performs other functions as the concern is exposing the more critical FCS to risk from the UMCS, and not the other direction. While the controller on the UMCS side is logically part of the UMCS (a "hardware I/O gateway"), procurement and installation may be simpler if it is furnished and installed by the FCS contractor.

E-3.1.3 Hardware I/O Interface Advantages and Disadvantages

This method is by far the most secure method of communication between the FCS and UMCS, as there is nothing an aggressor can do to the untrusted device that impairs the critical system. The potential disadvantage of this approach is the additional cost in the procurement and installation of two additional hardware I/O points each monitoring and/or control point. Depending on the amount and complexity of data being shared this may or may not be more costly than other approaches.

This approach is also conceptually the easiest to implement and requires no particular cybersecurity expertise skill, other than careful attention to limiting control points.

E-3.2 Hardware Gateway Interface

A Hardware Gateway is another means of connecting a critical FCS to a non-critical UMCS. While not as secure as a Hardware I/O Interface, it will be much more cost-effective if there is a large amount of data to exchange between the FCS and UMCS.

E-3.2.1 Hardware Gateway Overview

In this context, a gateway is a device with a connection to the UMCS network and a ***separate*** connection to the FCS network that does not pass network traffic between the two connections (i.e., it does not route packets between the two networks). Instead, information from one network is received by the gateway, processed by the gateway and then identical information is transmitted on the other network. While in theory the UMCS and FCS could both use the same protocol (like BACnet), in practice it may be difficult to find a gateway using the same protocol on “both sides” that is sufficiently secure, as typical designs would use the same connection for matching protocols.

E-3.2.2 Hardware Gateway Implementation

The key requirements for implementing a secure gateway are:

- The gateway must provide complete isolation / separation between the UMCS network and FCS network. This requires 2 separate network connections and may be difficult to meet if the FCS and UMCS protocols are the same.
- The gateway must not be able to be programmed, configured, or otherwise modified from the UMCS network. Since the gateway can likely be configured over the “primary” network, this requirement may be difficult to achieve if the UMCS and FCS protocols are the same. If both use the same protocol, the gateway is more likely to be configurable from both the UMCS and FCS. The configuration capability depends on the actual implementation of the gateway, so care must be taken to specify that the Gateway is not configurable from the UMCS network.
- The gateway must be configured to only expose those points absolutely necessary for the UMCS.

The gateway is part of the FCS and should be installed by the FCS contractor.

E-3.2.3 Hardware Gateway Advantages and Disadvantages

The main security concern with the gateway (assuming the above requirements are met) is security flaws in the gateway implementation. Just as a web server may have a flaw which allows an aggressor to take control of the server, a gateway may have an implementation flaw which would allow control of the gateway; once in control of the gateway, the aggressor could reconfigure the gateway to attack the FCS itself.

The gateway may provide a cost-effective alternative to the use of Hardware I/O points for systems with a requirement to share many points, and the cost of the gateway is not as dependent on the number of points as the Hardware I/O Interface.

E-3.3 Firewall Interface

The third option for securing a network connection between the UMCS and FCS is to allow a network connection but use a firewall to selectively block traffic between the two networks. The firewall requires a network connection and is therefore only applicable when the UMCS and FCS use the same protocol.

E-3.3.1 Firewall Interface Overview

Unlike a gateway where there is no network connection between the two networks and the gateway explicitly transmits information from one to the other, with the firewall the two networks are connected, and the firewall selectively limits the traffic allowed between the two. This inherently makes the firewall less secure than the gateway.

E-3.3.2 Firewall Interface Implementation

The key requirements for a secure firewall are:

- The firewall can only be programmed from within the critical facility. This is usually not a difficult requirement to meet because as security appliances, firewalls are designed with a "secure" side and an "insecure" side.
- Unlike traditional IT firewalls, the firewall must be able to filter traffic based on the detailed information in the packet. While a standard firewall can limit traffic based on IP address and TCP/UDP port and might block all traffic except that going to or from the UMCS server, the control system firewall must also be able to block all but specific commands. In addition to blocking all traffic except to/from the UMCS front end server, it might also block all traffic except for very specific messages – such as a BACnet ReadProperty requests for specific point values. This requires a firewall that understands the specific control protocol (BACnet in this case) and can selectively block traffic based on the specific message.

E-3.3.3 Firewall Interface Pros and Cons

The main implementation problem with a firewall is the lack of availability of a firewall that can decode control protocol packets and selectively filter based on the message. One advantage of the firewall over the gateway is that the firewall is designed for security and is less likely to have an implementation flaw than the gateway, which is typically not designed as a security device.

E-3.4 Data Diodes

Data diodes provide a physically-enforced, one-way data flow which can be used for the monitoring of control systems. This technology was until recently very expensive and geared more toward IT applications, but data diodes by multiple providers are coming down in price and some even have legacy RS-485 (screw terminal) connections to bring older equipment into a modern, connected architecture.

E-3.4.1 Methods of Isolation

Most data diodes provide isolation by (both of) the following two methods:

- Optical isolation. While inputs and outputs are via electrical signals, information is passed between the inputs and outputs via light (usually an LED and a photodetector). This isolation prevents electrical surges coming in from outside from causing damage to the inside network.

- Uni-directional transmission: Signals and information can only pass from inside to outside, there is no capability for information to come in from outside.

E-3.4.2 Data Diode Protocol Challenges

Uni-directional transmission can create problems for many protocols which use acknowledged transmissions. Consider the difference between regular email and email with acknowledgement or read receipt. In many cases, it's important to know that the information was received by the recipient, but that requires the ability to send a response message back to the sender; by definition the data diode blocks any sort of return message. For some protocols, this can be a showstopper; the protocol itself uses acknowledged transmissions. While all data diodes have hardware to copy the input to the output, data diodes supporting these protocols must "understand" these protocols and incorporate additional hardware to support them.

Consider a case where device A, an "inside" device, wants to send data to device B, an "outside" device, using an acknowledged send.

- Initially, device A sends the data to the data diode. The "inside" side of the data diode does two things:
    - Send the information across the optical isolator to the "outside" side of the diode
    - Uses additional hardware to generate an acknowledgement message to send back to device A.
- The "outside" side of the data diode then forwards the data on to device B and (if the message is received) gets an acknowledgement back from device B.

While this process can support protocols that use acknowledged transmissions, note that the overall message is not acknowledged – device A device received an acknowledgement from the data diode, but there's no knowledge of whether device B ever received the message. (While device B sends an acknowledgement back to the data diode, there's no capability to do anything based on the receipt, or lack thereof. The data diode cannot tell device A whether or not device B ever got the message.)

E-3.4.3 Data Diode Pros and Cons

Some pros and cons of data diodes are:

- If used with protocols that use acknowledged transmissions, the data diode must understand the protocol well enough to be able to reproduce the acknowledgements.
- There is no actual indication of end-to-end success of the transmission, and it may be desirable to send the information multiple times to ensure success.
- Unlike the simple hardware I/O interface, the data diode can easily move large amounts of data rapidly across the security boundary.
- Unlike the hardware I/O interface, the data diode cannot send any information in from outside. If there is a need to send in carefully

proscribed information (e.g., “Request Generator Start”), then the hardware I/O interface is likely the only viable solution.

E-4 OTHER CONSIDERATIONS

E-4.1 Local User Interfaces

Critical systems should be provided with additional local User Interfaces to allow maintenance personnel inside the secure area access to control data to allow for troubleshooting. Liberal use of local display panels is strongly recommended. For larger critical systems, it might be desirable to provide a more functional interface than normally obtainable via LDPs, such as an independent UMCS front end or a web interface appliance. For the largest or most critical systems, consideration should be given to installing a full-featured UMCS as specified in UFGS 25 10 10. This UMCS should be dedicated to the FCS (such as a Level 2D front end) and should reside fully within the physical security footprint of the critical systems.

E-4.2 Management of Risk

It must always be remembered that there is no perfect solution for cybersecurity for control systems. Cybersecurity experts often say, “there is no such thing as an air gap”. While it may be more accurate to say, “there are always ways to go around the air gap”, the intent remains – a determined aggressor will always find a way around, over, or through the protections put in place. The goal in the design of cybersecurity of control systems, and critical control systems in particular, is to do whatever is practical to make this as hard as possible.

APPENDIX F IMPLEMENTATION GUIDANCE FOR SECURITY CONTROLS

F-1 INTRODUCTION

This Appendix contains guidance on the implementation of security controls for control systems. The focus of this guidance is on LOW and MODERATE impact systems (L-L-L or M-M-M C-I-A Impact rating) which are being fielded on a DoD installation, particularly building control systems and utility monitoring and control systems. The CCI tables in APPENDIX G provide specific breakout of responsibilities by security control and CCI. The notes in this appendix supplement those CCI tables. Where these notes refer to the UFGS, it is UFGS 25 05 11, Cybersecurity for Facility-Related Control Systems.

F-2 GENERAL GUIDANCE

F-2.1 Control System versus Standard IT System Terminology

Security controls and CCIs were written for traditional IT systems, and many contain terminology and requirements that are confusing and conflicting when applied to a control system. For example, “incident” as used in the IR family of security controls includes all incidents – a broken fan belt is an “incident”, but “flaw” as used in security control SI-2 only covers security flaws, not operational flaws – an inaccurate sensor is not a “flaw”.

In most cases, the notes below will help make the application of the security control to a control system clear. In other cases NIST SP 800-53 should be consulted as it contains the best definition of the security controls as well as “Supplemental Guidance” that can assist in the interpretation and application of the CCI to a control system. NIST SP 800-82 (section 6.2 of revision 2) also has general information on the security control families, as well as guidance on the application of the security controls to Industrial Control Systems, which are a subset of control systems and have similar characteristics to facility-related control systems.

F-2.2 DoD-Defined Values

Many CCIs have DoD defined values of “all employees”, and many CCIs have DoD defined values of “all components” or similar where this level of detail is not appropriate for a LOW impact control system. It will be necessary to re-define (and document) values for CCIs when the DoD-defined values do not make sense for control systems.

F-2.3 Security Controls Which are “Automatically Met”

Some security controls may be “automatic” in the sense that they have already been implemented for another information system or control system. A security control that states “the organization does <something>…” may have already been met as a requirement for a different authorization for a different system.

F-2.4 Security Controls Applicability by Architecture Level

Many security controls may be difficult or impossible to apply below Level 3 for most control systems. Note, however, that some system, Electronic Security Systems (ESS) in particular, may be able to meet many of these security controls below Level 3. For example, an air handler controller (with a user interface) may have only a 4-character password, or no password support at all. A door lock on an ESS may have a CAC reader.

F-2.5 Impact Level Applicability

Only security controls for systems categorized with L-L-L (“LOW impact level”) and M-M-M (“MODERATE impact level”) are addressed by this Appendix and the CCI tables in APPENDIX G. The guidance provided for the baseline security controls is determined by the C-I-A impact level value for the control system:

- L-L-L Baseline Security Controls: Guidance is provided for a system categorized with a LOW impact value. These same security controls are also required for a system determined to have a MODERATE (or HIGH) impact level value, but additional security enhancements and implementation guidance may be required. When applying this guidance to MODERATE (or HIGH) impact systems, evaluate the guidance to determine if it applies or must be modified for the system.
- M-M-M Baseline Security Controls: Guidance is provided for a system categorized with a MODERATE impact value. These security controls aren’t used for LOW impact value systems. The guidance may not be the same for HIGH impact systems (using the same security controls).

The guidance in this Appendix and in the CCI tables in APPENDIX G is primarily targeted to LOW impact systems which are most capable of being addressed in a standard fashion. Care must be taken when extrapolating this guidance to systems with MODERATE or HIGH impact values.

F-3 GUIDANCE FOR INDIVIDUAL SECURITY CONTROLS

F-3.1 Access Control (AC) Control Family

Design guidance for the Access Control (AC) control family is shown in Table F-1

Table F-1 Access Control (AC) Control Family

Security Control ID	Security Control Name and Design Guidance
AC-2	**Account Management**: One significant issue is that many control system field devices cannot support accounts at the level of granularity required by the RMF. The UFGS defines three levels of support: NONE, MINIMAL, and FULL and then provides specific requirements for which devices must provide what level of support for accounts. Specify what account types provide which permissions in the control system (e.g. “view only”, “acknowledge alarms”, “change set-points”, etc.). Note that designer may need to explain these roles to the ISSM / ISSO so they can perform their DoD-defined duties under this control. Note that “accounts” (and particularly “temporary” or “emergency” accounts) likely exist at Level 4 and may or may not exist at Levels 1 or 2, depending on the control system type. (For example, many building control systems won’t have user accounts at these levels, but many utility control systems do). Designer may need to explain lack of “accounts” at Levels 1 and 2. Specifications should require that account activities be audited (logged), but auditing may be limited to software applications, and require notification be supported. Note that notification (e.g. email, rollup to another system) will generally require Platform Enclave or other Level 4 and Level 5 support for actual execution.
AC-3	**Access Enforcement:** AC-3 is met by requiring the contractor to configure any control system component which has a STIG or SRG in accordance with that STIG or SRG”. The UFGS has additional specific requirements for computers and web servers.
AC-4	**Information Flow Enforcement:** Information flow can be regulated by the IT organization at the FPOC. Level 2N devices exist that could be used at Level 2 to regulate flow (but they are not required in the UFGS). Similar Level 1N devices may exist. Include requirements in the specification that the installing contractor document necessary communications (to be used for “whitelisting”). If information flow enforcement at Level 2N is a requirement, include implementation requirements in the specification.

Security Control ID	Security Control Name and Design Guidance
AC-6	**Least Privilege:** Within the control system (as opposed to the Platform Enclave) least privilege should be met by specifications that limit functionality at the front end by user and roles (e.g., some users can only viewpoints, others can change values, etc.). Note the DoD definition of what requires explicit authorization includes (for a control system) everything – up to and including hardware. This may not be practical. Designer would need to ensure implementation via project specification requirements including physical security. Note also that AC-6 (2) requires that control system operators with access to privileged functions (via login to a privileged account) have a separate account when accessing non-privileged functions. This is probably not practical, or desirable for control system applications when considering the role that operators play (where it's impractical to expect an operator to log out and then back in to override a point, for example).
AC-7	**Unsuccessful Logon Attempts**: Note that a requirement for a HIGH availability at the front end may preclude locking out an account for failed login attempts. This control may be impractical below Level 3 and, even at Level 4, may only be implemented by login to the OS as a prerequisite for access to the control system. Designer needs to identify where this can be supported and include requirements in the specification where this is needed. The UFGS groups interfaces by level of account support, then provides different requirements for each group.
AC-8	**System Use Notification:** Login banners must be implemented at user login to government computers – e.g. at the Platform Enclave, Level 4 and Level 2 computers. User interfaces at Levels 0, 1 and 2 (e.g. Local Display Panels (LDP)) generally won't support a login banner. Require login banners where practical according to best industry practice and indicate where implementation is not practical. The UFGS allows for a permanently affixed label.
AC-11 and AC-12	**Session Lock and Session Termination:** The whole notion of a "session" generally only makes sense at a computer (i.e., Level 4) and for the computer these controls should be implemented by the operating system and inherited from the Platform Enclave. At Level 1 and Level 2, devices generally lack user interfaces. Designers should require that devices with user interfaces (e.g. LDPs) be password protected and automatically log out a user after a certain period of inactivity.

Security Control ID	Security Control Name and Design Guidance
AC-14	**Permitted Actions Without Identification or Authentication:** At Level 4, all actions should require authentication to the (Windows) Operating System. User interfaces at Level 1 or 2 should be password protected. Note that this security control is specifically about user actions, not "processes acting for a user". In most cases, this is met by virtue of the user having logged into a computer. Physical security may be required to deny access to devices and equipment and can be implemented at multiple levels through means such as lockable enclosures, tamper switches, room access control, people trap, and paper access logs. Some user interfaces may not sufficiently support authentication and necessary physical security should be considered. When considering physical security of such devices, it is generally not beneficial to secure an interface which is co-located with the controlled equipment without also securing the controlled equipment, as the equipment would remain vulnerable.
AC-17	**Remote Access:** Remote access should be covered by the Platform Enclave (see general notes for AC control family).
AC-18	**Wireless Access:** Wireless at Level 4 should be provided by the appropriate IT organization. Avoid wireless to the greatest extent possible at Levels 1 and 2. Wireless may be considered for retrofits where running wires would be prohibitive, but other technologies (such as powerline carrier) should be considered first. When permitting wireless, require extremely limited range such that signals are not available beyond the necessary ranges. In many cases Authentication and Encryption support will be marginal at Levels 1 and 2.
AC-19	**Access Control for Mobile Devices:** Mobile devices refer to tablets, phones, etc. These are addressed at the Platform Enclave. When permitted they may be used as workstations for browser-based clients or may be restricted to receiving alerts/notifications from the control system.
AC-20	**Use Of External Information Systems:** Connections from External systems, and portable storage, should all be handled at the Platform Enclave.
AC-21	**Collaboration And Information Sharing:** Control systems typically shouldn't share information. Any sharing is handled at the Platform Enclave.
AC-22	**Publicly Accessible Content:** Control systems should not be publicly accessible.

F-3.2 Audit and Accountability (AU) Control Family

Auditing (in the cybersecurity sense) can typically only be performed at Level 4, although some Level 1 or 2 devices may provide limited auditing capability. Designer needs to require auditing where possible and be prepared to justify not auditing where it is simply impractical. Designer may provide input into what can be audited, where it can be audited, and what types of information may be gathered. It might make sense for these controls to be inherited from the Platform Enclave.

Design guidance for controls in the Audit and Accountability (AU) control family is shown in Table F-2.

Table F-2 Audit and Accountability (AU) Control Family

Security Control ID	Security Control Name and Design Guidance
AU-2	**Audit Events:** No additional control-specific guidance. Use general control family guidance preceding this table for this control. The UFGS has extensive discussion of this, but not particularly definitive guidance.
AU-3	**Content Of Audit Records:** Note that this – particularly the “user” portion - may only be possible at Level 4
AU-4	**Audit Storage Capacity:** Long term audit storage will be at a computer at Level 4. Transfer from the control system to long term storage is likely a manual process, or perhaps scripted via by the computer operating system, but it is likely not an inherent feature of the control system. Designer needs to require that control system auditing can be accessed by operating system tools (e.g. control system supports or exports to standard file formats). The UFGS considers the possibility that there may be a separate computer specifically for audit storage and processing (review, analysis, reporting).
AU-5	**Response To Audit Processing Failures:** Notifications and specific actions may only be possible at Level 4.
AU-6	**Audit Review, Analysis, And Reporting:** No additional control-specific guidance. Use general control family guidance preceding this table for this control.
AU-7	**Audit Reduction and Report Generation:** Post-processing of audit logs can typically only be done by external tools at Level 4, but since the tools are specific to the control system audit log format, this will likely need to be met within the control system, not the Platform Enclave.

Security Control ID	Security Control Name and Design Guidance
AU-8	**Time Stamps:** Typically, the timing requirement inherent in the control system will be sufficient.
AU-9	**Protection Of Audit Information:** Can only be done at the Level 4 front end server or another computer. Audit logs must be stored (and protected) there.
AU-11	**Audit Record Retention:** No additional control-specific guidance. Use general control family guidance preceding this table for this control.
AU-12	**Audit Generation:** No additional control-specific guidance. Use general control family guidance preceding this table for this control. For UFGS content, see note on AU-2.

F-3.3 Security Assessment and Authorization (CA) Control Family

Design guidance for controls in the Security Assessment and Authorization (CA) control family is shown in Table F-3.

Table F-3 Security Assessment and Authorization (CA) Control Family

Security Control ID	Security Control Name and Design Guidance
CA-3	**System Interconnections:** Note this is about connections to other systems. These should be documented at the Platform Enclave. Specifications should define a specific protocol. The UFGS has an Interconnection Submittal.
CA-6	**Security Authorization:** The Authorizing Official is a senior-level executive or manager.
CA-9	**Internal System Connections:** The control system is a special purpose system. By design, only necessary connections should be allowed; typically this means use of a single specific protocol with limited capabilities. The specifications, points schedules, and network design document these controls. The UFGS has a submittal requirement if the standard controls submittals are insufficient.

F-3.4 Configuration Management (CM) Control Family

Design guidance for controls in the Configuration Management (CM) control family is shown in Table F-4.

Table F-4 Configuration Management (CM) Control Family

Security Control ID	Security Control Name and Design Guidance
CM-2	**Baseline Configuration:** This control is for a type accredited system. Typical control system contract submittals (drawings, software licenses, programmable controller "source code" etc.) should meet this CCI. Designer should assist in determining which devices are in areas of significant risk, and what additional configurations should be applied to those devices. Note that control systems (supporting fixed facilities) are not mobile.
CM-5	**Access Restrictions for Change:** Much of the control system may be in space outside the organization's control. May only apply at Level 4. See comments on PE Controls.
CM-6	**Configuration Settings:** For the designer, this is largely ensuring that other security design requirements are included in the control system requirements document and that these requirements are verified during control system commissioning. Designer should ensure specifications disable unnecessary ports, protocols, and services. Note that the assumption that the control system is "automatically" compliant because of existing STIGs etc. is completely false below Level 3 and designer may need to provide justification for the control system not meeting the standard checklists. As a control system is designed to have regularly configurable parameters, documentation and approval for all changes to controllers at Levels 1 and 2 is not practical. Significant architectural configuration changes should still be documented and approved. See UFGS comment on CA-9.
CM-7	**Least Functionality:** The control system has a specific purpose (not a general one), and its functions (and limitations) are specified by the control system architecture and protocols. Specifications should require disabling any ports/protocols/services not specifically needed by the control system. Required software should be covered by specification; all other software should be prohibited.

Security Control ID	Security Control Name and Design Guidance
CM-8	**Information System Component Inventory:** Initial configuration is specified by as-built documentation. In most cases automated tools for component inventory below Level 3 do not currently exist for many systems, although new tools may be available for systems in the future and should be implemented once available. See UFGS comment on CA-9.
CM-9 and CM-10	**Configuration Management Plan and Software Usage Restrictions:** Contract documents must require that the software licenses grant the Government the Rights in Technical Data to operate and maintain the systems and use the software as required.

F-3.5 Contingency Planning (CP) Control Family

Design guidance for controls in the Contingency Planning (CP) control family is shown in Table F-5.

Table F-5 Contingency Planning (CP) Control Control Family

Security Control ID	Security Control Name and Design Guidance
CP-2	**Contingency Plan:** Designer should assist in identifying critical control system assets supporting essential missions.
CP-6	**Alternate Storage Site:** For a control system, alternate storage only makes sense for backups and is at the Platform Enclave.
CP-7 and CP-8	**Alternate Processing Site and Telecommunications Services:** A PIT system can have an alternate front end (Level 4) and/or alternate connections from the front end to the lower levels, but you can’t separate the control system from the controlled equipment – whatever site-wide incident disables the AHU controller will also disable the AHU. These controls only apply at the Platform Enclave (Level 4), and, when determining whether to apply them, note that the front end (Level 4) will typically have lower availability requirements than the field controls (Levels 1 and 2). If the requirements are for a redundant control system at the field control system, then redundant controlled equipment and/or redundant tenant spaces should be considered as well.
CP-9	**Information System Backup:** Backups at Level 4 / Platform Enclave only

Security Control ID	Security Control Name and Design Guidance
CP-10	**Information System Recovery and Reconstitution:** Designer should require submittals containing data, documentation and software sufficient to restore the system to its final accepted as-built state. This must include custom programming and configuration for controllers or workstations. The UFGS has a specific submittal requirement.
CP-12	**Safe Mode:** The designer should determine, based on the criticality of the controlled equipment, what conditions to consider and which actions, if any, the control system should take when these conditions are true. This should all be specified in the control logic (e.g. sequence of operations), in particular by addressing normal/failed positions of output devices, and in the overall system design. Where high reliability is required, the analysis should consider the addition of redundant equipment to the design. See also SC-24 and SI-17, and CHAPTER 4.

F-3.6 Identification and Authorization (IA) Control Family

Note that authenticators might be either physical authenticators (CAC cards, tokens, etc.), non-physical ones (such as passwords), or biometrics. While Level 4 (Platform Enclave) may use any of these, most control systems will not support anything other than passwords at Level 2 and below – and even password support may only allow for "weak" passwords (much of IA-5 will not be supported except at Level 4). Therefore, DoD defined requirements may not be appropriate at Level 2 or below. Note that ESS is an exception, ESS will likely support CAC or biometrics - for example a door swipe. Designer should specify where possible to standard/best industry practice and be prepared to defend that decision when it does not meet DoD IT-centric standards.

Design guidance for controls in the Identification and Authorization (IA) control family is shown in Table F-6.

Table F-6 Identification and Authorization (IA) Control Control Family

Security Control ID	Security Control Name and Design Guidance
IA-2	**Identification And Authentication (Organizational Users):** Much of this can only be met at Level 4, and much of it depends on the computer operating system. Designer should provide specifications where possible and be prepared to justify non-implementation in the control system. Whenever possible, require that the control system (for access via a computer) support CAC (or similar) logins. Note that remote access is covered at the Platform Enclave. The UFGS defines these requirements by level of account support.
IA-3	**Device Identification and Authentication:** Much of this can only be met at Level 4, and much of it depends on the computer operating system. Typically, authentication between devices can be implemented between computers (Level 2 and 4) or between network hardware (Level 2, 3 or 4). Authentication may be supported between controllers, where not all controllers will support this capability and it will be more often supported at Level 4 than at Level 2. In general, device authentication between controllers will not be required, for LOW impact system. Even in MODERATE or HIGH, ensure that it can be met before requiring it. Exercise care before requiring non-standard control hardware and software in order to meet this requirement. Designer should provide specifications requiring authentication where possible and be prepared to justify non-implementation in the control system. The UFGS requires (in some cases) use of HTTPS. It also calls for use of 802.1x in some cases, but strongly cautions against it in most cases.
IA-5	**Authenticator Management:** The DoD-defined password complexity values may be impractical for control system components to meet. Specify password complexity at DoD-defined values where practical. The UFGS discusses this and provides some guidance. Require that default passwords be changed from defaults, and that passwords are submitted in a secure manner. For PKI systems, certificate paths should be provided by the Platform Enclave.
IA-6 and IA-7	**Authenticator Feedback and Cryptographic Module Authentication:** Almost certainly Platform Enclave only and not supported below that level. Designer may need to provide input/justification for this. The UFGS discusses the use of feedback and provides guidance in the unlikely case that Cryptographic Modules are required.

Security Control ID	Security Control Name and Design Guidance
IA-8	**Identification And Authentication (Non-Organizational Users):** As this deals with non-organizational users, this control generally doesn't apply to control systems other than some ESS. This may be addressed by the Platform Enclave (via computer login requirements).

F-3.7 Incident Response (IR) Control Family

Note that the definition of "incident" includes non-security related failures. A broken fan belt is an incident, as is a sticking valve, or an out-of-calibration sensor. The designer may need to provide input to the incident response plan to address any control system-specific actions. For example, the response to a successful attack on the front end might be to place equipment in Manual / Hand operation.

F-3.8 Maintenance (MA) Control Family

Design guidance for controls in the Maintenance (MA) control family is shown in Table F-7.

Table F-7 Maintenance (MA) Control Control Family

Security Control ID	Security Control Name and Design Guidance
MA-3	**Maintenance Tools:** Require that control system maintenance tools (software or hardware required to maintain the control system – most commonly engineering tool software) be provided. The UFGS requires this for MODERATE impact systems.
MA-4	**Nonlocal Maintenance:** This is met through operating system login for the use of the engineering tool maintenance software.

F-3.9 Media Protection (MP) Control Family

Media Protection is addressed only at the Platform Enclave.

Design guidance for controls in the Media Protection (MP) control family is shown in Table F-8.

Table F-8 Media Protection (MP) Control Family

Security Control ID	Security Control Name and Design Guidance
MP-5	**Media Transport:** CCI-001027 (MP-5 (4)) places a requirement on the control system, but only when the control system is outside a "controlled area" where "controlled area" is defined in CCI-001016 as areas approved for processing the information. By definition, an area must be approved for processing the information necessary for the control systems in that area. For transportation outside that area, the data would have to be encrypted by tools provided by the Platform Enclave.

F-3.10 Physical and Environmental Protection (PE) Control Family

Note that control systems are often distributed, with large portions of the system being in spaces outside the control of the organization. This impacts many of the PE controls, in particular PE-16 can only be met for spaces controlled by the organization. In general, these are met at the Platform Enclave, but implementation may be spotty below that. Designer should require locked rooms where possible. Level 4, 3, and 2N equipment should either be in locked rooms or locked enclosures. Level 2, Level 1 and Level 0 equipment will frequently be located in tenant spaces and outside the control of the organization. For some systems, it may be necessary to require lockable enclosures for some controllers at Level 2 and Level 1, but this must be weighed against the need for maintenance personnel to access the equipment. In general, there is little benefit in requiring lockable enclosures for controllers when the underlying equipment is readily accessible from the controller location.

Most of the control system is not in "normal" server spaces. For the normal server spaces, PE requirements will be met at the Platform Enclave. For the remainder of the control system, PE requirements (such as PE-14's temperature and humidity requirements) are either N/A or are covered by design specifications. Note that NIST guidance states that several PEs (PE-10, PE-12, PE-13, PE-14, and PE-15) only apply at major server rooms, not individual components. These are covered by the Platform Enclave and are N/A in the control system. Design guidance for controls in the Physical and Environmental Protection (PE) control family is shown in Table F-9.

Table F-9 Physical and Environmental Protection (PE) Control Family

Security Control ID	Security Control Name and Design Guidance
PE-4	**Access Control for Transmission Medium:** Designer should require physical security for network media and may need to coordinate with electrical designer for conduit requirements. Note that physical security may be required outside spaces controlled by the organization as well. See SC-8.
PE-5	**Access Control for Output Devices:** Note that “physical outputs” for a control system correspond to the location of the controlled equipment, which must also be secured so there are unlikely to be additional requirements for the control system components
PE-9	**Power Equipment and Cabling:** For systems requiring redundant power, designer should coordinate with electrical designer. Note that the weak link in reliability will often be the controlled equipment. For example, if a single backup generator is needed, a system with 2 generators - each with a single controller - will be more reliable than a single generator with redundant controllers. Note that, for a control system, redundant power to controllers is pointless without redundant power to the controlled system. In many cases, redundant controlled equipment (N+1 equipment design) may be required. The UFGS has an extensive designer note on this topic.
PE-11	**Emergency Power:** Within the control system, require an uninterruptible power supply (UPS), either in the control system specification or by coordination with electrical specification, when backup power is required. At the front end, this could either be met by the Platform Enclave, or by control system specification requirements also. For the majority of LOW impact systems, this control will not be implemented. See UFGS comment for PE-9.
PE-16	**Delivery And Removal:** No additional control-specific guidance. Use general control family guidance preceding this table for this control.
PE-17	**Alternate Work Site:** PE-17 can’t be applied except at Level 4 – there is no possible “alternate work site” for PIT. This is all at the Platform Enclave.

F-3.11 Planning (PL) Control Family

Design guidance for controls in the Planning (PL) control family is shown in Table F-10.

Table F-10 Planning (PL) Control Family

Security Control ID	Security Control Name and Design Guidance
PL-2	**System Security Plan:** While the designer is not directly responsible for the system security plan itself, the design must provide information to be used in this plan. For example, the system architecture drawing is part of the definition of the authorization boundary. The designer may also provide input for the security categorization since they have the specific knowledge of the underlying mechanical/electrical systems and can help assess the impact of those systems on control system tenants. The UFGS covers this with a Cybersecurity Riser Diagram submittal.
PL-4	**Rules Of Behavior:** As indicated in CHAPTER 4, social media should be completely inaccessible from the control system.
PL-7	**Security Concept of Operations:** Designer needs to provide input to a security concept of operations since the range of possible operations is defined by the underlying equipment, sequences of operation, selection of controllers, and front-end capabilities.
PL-8	**Information Security Architecture:** System architecture submittals are necessary inputs to the security architecture. Dependencies on external services should be minimal, if any.

F-3.12 Program Management (PM) Control Family

Generally, the designer does not get involved in project planning; therefore the PM controls are not a primary designer responsibility, but designer may need to provide input to support others.

Design guidance for controls in the Program Management (PM) control family is shown in Table F-11.

Table F-11 Program Management (PM) Control Family

Security Control ID	Security Control Name and Design Guidance
PM-3	**Information Security Resources:** See General Guidance for PM Control Family and SA-2.
PM-5	**Information System Inventory:** Initial inventory is provided by as-built bill of materials.
PM-11	**Mission/Business Process Definition:** Calls for "…an achievable set of protection needs are obtained" and may require designer input.

F-3.13 Personnel Security (PS) Control Family

None of the Personnel Security controls are the responsibility of the designer.

F-3.14 Risk Assessment (RA) Control Family

By and large, the implementation of the RA controls is outside the responsibility of the designer.

Design guidance for controls in the Risk Assessment (RA) control family is shown in Table F-12.

Table F-12 Risk Assessment (RA) Control Family

Security Control ID	Security Control Name and Design Guidance
RA-3	**Risk Assessment:** The designer is well versed in the control system and the underlying mechanical / electrical system and may therefore need to assist in identifying risks to the tenants served by the control system.
RA-5	**Vulnerability Scanning:** Scanning can be performed at Levels 3 and 4 and scanning of the control system at this level should be performed by the Platform Enclave. Scanning below this level – and particularly at Level 1 - is not supported by standard IT-centric tools but is supported by standard control system tools. Most control system software provides a tool which can probe the control system network and generate a map of the control system; this process corresponds to Vulnerability Scanning. Note that scanning tools should be within the Platform Enclave, scanning from outside the Platform Enclave just opens up a hole for an attacker. Designer may need to provide input to organizations attempting to meet RA-5. See SC-7, SI-3

F-3.15 System and Services Acquisition (SA) Control Family

The NIST description of “External information services” (SA-9) makes it clear that it’s an “external information system” not “external services (e.g. contractor) on this information system”

Design guidance for controls in the System and Services Acquisition (SA) control family is shown in Table F-13.

Table F-13 System and Services Acquisition (SA) Control Family

Security Control ID	Security Control Name and Design Guidance
SA-2	**Allocation Of Resources:** Designer may need to provide input to this process. See PM-3
SA-4	**Acquisition Process:** SA-4 is at least partially met by the designer incorporating security-specific requirements in the design, including acceptance testing. Requirements for FIPS PUB 201-2 may only apply at the Platform Enclave and designer may need to provide rationale for not meeting those requirements in the control system. Similarly, many of the requirements on the developer probably cannot be enforced on a COTS system. ESS systems may need to meet FIPS PUB 201-2 at Levels 1 and 2. The UFGS has extensive requirements for Cybersecurity during construction to prevent vulnerabilities from being exploited during construction to create exploits after acceptance.
SA-5	**Information System Documentation**: Designer should require submittals providing the documentation which is required by these CCIs. Note that some of the required documentation may not be obtainable, particularly for a COTS system. The UFGS has a submittal that covers this, but the requirements are limited by what is practical.
SA-9	**External Information System Services:** In general, control systems should not use external IS, so this control should not apply. Where it does, it should be addressed at the Platform Enclave.
SA-10 and SA-11	**Developer Configuration Management and Developer Security Testing and Evaluation:** SA-10, SA-11 are likely impossible for COTS systems. Designer needs to specify what can be specified (which will often require additional submittals) and explain what can't be specified. Note that the control assumes the developer has a role during implementation and/or operation – this is often not true.

F-3.16 System and Communications Protection (SC) Control Family

Design guidance for controls in the System and Services Acquisition (SA) control family is shown in Table F-14.

Table F-14 System and Communications Protection (SC) Control Family

Security Control ID	Security Control Name and Design Guidance
SC-2	**Application Partitioning:** This is met by separating out computer administration and by design specifications that require different user permissions within the control system (e.g. "view data" vs "modify data").
SC-4	**Information In Shared Resources:** Typically the control system will all be dedicated hardware and software, so there are no shared resources. This control might have some applicability at Level 4 if computer resources are shared.
SC-5	**Denial Of Service Protection:** Within the control system, denial of service attacks are mitigated by designing the system to not depend on the network or on computers. Otherwise, this is a Platform Enclave control. The UFGS has specific requirements for this (though they are sometimes caveated with "… whenever possible…"). The UFGS combines these requirements with SC-7 and SC-39 under "System and Communication Protection".
SC-7	**Boundary Protection:** Implementation at the external boundary should be the responsibility of the Platform Enclave. The Platform Enclave can perform monitoring/traffic control at Level 3, and perhaps key points near Level 4 assets. Aside from those locations, this control may be difficult to meet within the control system. Designer may need to provide justification for not monitoring or controlling traffic below Level 3. It may not be prudent for the control system to fail to a "secure" state after loss of a boundary protection device since this allows an attack vector to disable controlled equipment by taking out the boundary device. Control systems must continue to run independently when boundary devices are lost. See CP-12 comments and RA-5, SI-3, SC-24. The UFGS combines these requirements with SC-5.
SC-8	**Transmission Confidentiality and Integrity:** Note that NIST guidance suggests this only applies to information outside a secure physical boundary, and that, when this control cannot be met, alternate physical security safeguards such as a protected distribution system can be employed.
SC-10	**Network Disconnect:** Data within a control system is often communicated without setting up a "session". Most control systems will not use sessions other than for communications within Level 4.

Security Control ID	Security Control Name and Design Guidance
SC-12	**Cryptographic Key Establishment and Management:** Below Level 4, control systems support for cryptographic keys is extremely limited and it is impractical to implement many of these controls. The UFGS discusses use of HTTPS but suggests that other cryptography is seldom required.
SC-13	**Cryptographic Protection:** Note that NIST states this control does not require cryptography, it merely provides requirements for the implementation of cryptography where it is required. The vast majority of control systems should not have any information requiring the use of cryptography (and in the few cases where it is even possible, the designer should review whether it is really necessary for the control system to have this information). For UFGS comments, see SC-12.
SC-15	**Collaborative Computing Devices:** In general, control systems shouldn't use collaborative computing devices.
SC-18	**Mobile Code:** This control can and should be fully applied at Level 4. Below that, there's an important distinction between "mobile code" and "mobile code technologies": Java is a "mobile code technology" used by many control systems at Level 2 (and possibly other Levels), but Java should not be used as "mobile code" – which is code that is downloaded and executed without explicit user action. So, while mobile code technologies may be permissible below Level 4, mobile code should not be. Mobile code restrictions within the control system should be covered by design specifications. For example, common building control system products use Java, and serve web pages to clients. These pages do not constitute mobile code. Downloading a Java application, however, would be an example of mobile code.
SC-21 and SC-22	**Secure Name /Address Resolution Service (Recursive or Caching Resolver) and Architecture and Provisioning for Name / Address Resolution Service:** These controls apply only at the Platform Enclave.
SC-23	**Session Authenticity:** See comments on SC-10.
SC-24	**Fail In Known State:** What is key here is the status of controlled equipment after a control system failure. Designer should specify this where necessary. Note that the DoD requirement of a "secure state" may not be applicable and would be superseded by a "safe state", or by a "support the mission" state. Data preserved through a failure may be limited by the nature of the control system and designer should specify what is reasonable. See CP-12.

Security Control ID	Security Control Name and Design Guidance
SC-28	**Protection Of Information at Rest:** Note that many (if not most) control systems will not have any data requiring protection at rest since they will not have PII or classified data. Note, however, that Electronic Security Systems will often require protection of data at rest.
SC-39	**Process Isolation:** For control systems controlling multiple systems, a distributed control system meets this. See comment on SC-5.
SC-41	**Port And I/O Device Access:** See comments on CM-7. The UFGS has a Network Communication Report submittal which covers this, as well as requirements under "Least Functionality"

F-3.17 System and Information Integrity (SI) Control Family

Design guidance for controls in the System and Information Integrity (SI) control family is shown in Table F-.

Table F-15 System and Information Integrity (SI) Control Family

Security Control ID	Security Control Name and Design Guidance
SI-2	**Flaw Remediation:** SI-2 is about security updates and patches for software and firmware. While this can (and should) be applied at Level 3 and Level 4, this control may be largely "not applicable" or "impractical" below Level 3, due to both the relative infrequency of available updates and also the difficulty of patching controllers at Level 1 and 2. This is also largely irrelevant at Level 1 and 2, since it completely ignores flaws in the underlying equipment, which are likely to be much more common and much more significant. The UFGS requires security related software updates and patches.
SI-3	**Malicious Code Protection:** Should be implemented by the Platform Enclave at entry/exit points. Periodic scans within the control system may be difficult and the designer may need to justify their non-implementation. See RA-5, SC-7. The UFGS requires that computers meet the STIGS.

Security Control ID	Security Control Name and Design Guidance
SI-4	**Information System Monitoring:** Data collected can only be preserved at the Platform Enclave. Designer should provide input to monitoring objectives and methods based on the control system, the underlying mechanical/electrical system, and the impact on tenants. Note that this is not about operational monitoring of the control system (e.g. viewing graphics, receiving alarms), but about monitoring for security. The UFGS has a placeholder for this, but no default requirements.
SI-7	**Software, Firmware, And Information Integrity:** Integrity verification tools may only be possible at Level 4. Designer should provide input on what is reasonable based on the control system capabilities, and where this control is not feasible.
SI-10	**Information Input Validation:** This could cover network data, sensor input, or input from a user. Designer could require additional sanity checks on sensor input, or redundant sensors. User input validation would likely need to be addressed by policy. Network validation may not be possible except at Level 4.
SI-11	**Error Handling:** Designer should require alarm messages and other control system feedback to meet this. Note that the DoD definition of recipients is not applicable for a control system.
SI-16	**Memory Protection:** Memory Protection only makes sense at Level 4.
SI-17	**Fail-Safe Procedures:** See SC-24 and CP-12 comments, where failure is one of the conditions to consider.

APPENDIX G CONTROL CORRELATION IDENTIFIER (CCI) TABLES

G-1 INTRODUCTION

This appendix provides a number of tables which help classify the CCIs for a LOW or MODERATE system on a DoD installation where there is a separate authorization for the Platform Enclave and the minimum cybersecurity design requirements have been followed.

G-2 TABLE STRUCTURE AND CONTENT

Within each table, the following columns are defined. Note that not all tables use all columns:

- **CCI**: The CCI number.
- **NIST SP 800-53 Control Text Indicator**: NIST SP 800-53 breaks individual controls (i.e., single Control IDs) down into multiple elements and enhancements, where an enhancement is a more stringent requirement than the base control. The Control Text Indicator uniquely identifies each of these elements and enhancements. A letter indicates an element within a control, a number is an enhancement. For example, "AC-17 (4)(b)" is the second element of the fourth enhancement to AC-17.
- **CCI Definition**: The definition of the CCI.
- **Applies At or Above Impact**: This CCI should be applied if the control system impact is this or above.
- **Table Reference:** Indicated which other table(s) in this Appendix the CCI is found in.
- **Applicable to a Control System:** Is this CCI applicable to a control system?
- **Rational for non-inclusion:** Reason the CCI is not applicable to control systems
- **Rational for Removal from a LOW Baseline:** Reason the CCI should be removed from the baseline for a LOW impact control system.
- **Responsibility:** Indicates who has responsibility for implementing the control. One or more of:
    - ***DoD-Defined:*** Either the DoD has provided a value for the "organization selected" values, or the DoD implementation guidance states that the CCI is already met by existing policy or regulation. ***Note that definition or guidance provided may not be relevant for a control system – the organization definitions were determined from the perspective of a traditional information system, not for a control system.***
    - ***Designer:*** The designer has a role to address for this CCI. Either the designer needs to provide design specifications to cover a

requirement on the control system itself, or the designer must provide input to others regarding the implementation or lack of feasibility of the CCI (typically because the CCI was written with an IT system, not a control system, in mind).

- ***Non-Designer:*** The CCI is beyond the responsibility of the designer and is the responsibility of someone else – typically the System Owner (SO). This does not diminish the importance of these CCIs, but as these CCIs are not the responsibility of the designer they are beyond the scope of this UFC.
- ***Platform Enclave:*** The CCI contains a requirement which is assumed to be implemented at the Platform Enclave and inherited by the control system or is mostly implemented at the Platform Enclave but also needed within the field control system. Note that if there is no Platform Enclave, then CCIs listed in the "Platform Enclave" category are instead in the "Non-Designer" category.
- ***Impractical:*** The CCI is impractical to fully implement in a control system but may be applied in a limited manner to at least some part of the control system. Most often CCIs that can be applied to only part of the control system can be implemented at Level 4 of the architecture but would be prohibitively difficult to implement at Levels 1 or 2. Note that "prohibitively" is a judgment based on a typical LOW control system – for a MODERATE or HIGH system, it may be worthwhile to implement these controls at all possible levels even if this adds significant cost and complexity.

G-3 CCI TABLE NOTES

G-3.1 Controls Inherited from Platform Enclave

Note that not all controls that can be inherited from the Platform Enclave have ***necessarily*** been identified as such -- some controls labeled "Non-Designer" may in fact be implemented at the Platform Enclave and the control system inherits from that.

G-3.2 CCIs in Multiple Tables

Note that some CCIs will appear in multiple tables, typically "Designer and Platform Enclave" or "Platform Enclave and Other". For example, scanning (RA-5) should happen at the Platform Enclave level and not in the control system. But the designer may need to provide input to the selection of scanning tools appropriate for the control system. The purpose of these tables is to break down the responsibilities for each control such that a specific individual/role would not be required to look at all the tables to determine what needs to be done.

G-4 CCI TABLE DESCRIPTIONS

Multiple CCI tables are included in this Appendix, each including CCIs that meet certain characteristics as described. An electronic version of the CCI tables in Excel format is available at the RMF Knowledge Service website.

- **Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems** summarizes all the CCIs that can be applied to a MODERATE or lower control system, based on NIST 800-82. This table also indicates which other tables each CCI can be found in.

- **Table G-2 CCIs Not Applicable to Control Systems (CS)** lists CCIs that (assuming the minimum cybersecurity requirements in CHAPTER 4 have been met) never apply to a control system and provides a rationale for not using them.

- **Table G-3 CCIs Removed from LOW Impact Control Systems Baseline** lists CCIs that NIST 800-82 includes in the LOW baseline, but do not apply to a LOW control system, and provides a rationale. Note that CCIs here are listed as LOW but aren't used at LOW.

- **Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems** lists CCIs that should be addressed in design for both LOW and MODERATE Impact Systems. In many cases, guidance on addressing specific security controls in design is provided in APPENDIX F.

- **Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems** lists CCIs (in addition to those shown in **Table G-4**) that should be addressed in design of MODERATE Impact Systems. In many cases, guidance on addressing specific security controls in design is provided in APPENDIX F.

- Similar to Designer CCIs in **Table G-4** and **Table G-5**, **Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems** and **Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems** list CCIs in the "Platform Enclave" category. While implementation of the Platform Enclave is not the designer's responsibility (a key point of the Platform Enclave is that it is a standard approach that can be implemented across multiple control systems), those responsible for the Platform Enclave need to be aware of CCIs that the control system expects to inherit from the Platform Enclave

G-5 CCI TABLES

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems

CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-002107	AC-1(a)	LOW	None (Non-Designer)	TRUE
CCI-002108	AC-1(a)	LOW	None (Non-Designer)	TRUE
CCI-000001	AC-1(a)(1)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-000002	AC-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000004	AC-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000005	AC-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-001545	AC-1(b)(1)	LOW		TRUE
CCI-000003	AC-1(b)(1)	LOW	None (Non-Designer)	TRUE
CCI-001546	AC-1(b)(2)	LOW		TRUE
CCI-000006	AC-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-002110	AC-2(a)	LOW	Table G-4 (Designer)	TRUE
CCI-002111	AC-2(a)	LOW	None (Non-Designer)	TRUE
CCI-002112	AC-2(b)	LOW	None (Non-Designer)	TRUE
CCI-000008	AC-2(c)	LOW	None (Non-Designer)	TRUE
CCI-002113	AC-2(c)	LOW	None (Non-Designer)	TRUE
CCI-002115	AC-2(d)	LOW	None (Non-Designer)	TRUE
CCI-002116	AC-2(d)	LOW	None (Non-Designer)	TRUE
CCI-002117	AC-2(d)	LOW	None (Non-Designer)	TRUE
CCI-002118	AC-2(d)	LOW	None (Non-Designer)	TRUE
CCI-002119	AC-2(d)	LOW	None (Non-Designer)	TRUE
CCI-002120	AC-2(e)	LOW	None (Non-Designer)	TRUE
CCI-000010	AC-2(e)	LOW	None (Non-Designer)	TRUE
CCI-002121	AC-2(f)	LOW	None (Non-Designer)	TRUE
CCI-000011	AC-2(f)	LOW	None (Non-Designer)	TRUE
CCI-002122	AC-2(g)	LOW	None (Non-Designer)	TRUE
CCI-002123	AC-2(h)(1)	LOW	None (Non-Designer)	TRUE
CCI-002124	AC-2(h)(2)	LOW	None (Non-Designer)	TRUE
CCI-002125	AC-2(h)(3)	LOW	None (Non-Designer)	TRUE
CCI-002126	AC-2(i)(1)	LOW	None (Non-Designer)	TRUE
CCI-002127	AC-2(i)(2)	LOW	None (Non-Designer)	TRUE
CCI-002128	AC-2(i)(3)	LOW	None (Non-Designer)	TRUE
CCI-000012	AC-2(j)	LOW	None (Non-Designer)	TRUE
CCI-001547	AC-2(j)	LOW		TRUE
CCI-002129	AC-2(k)	LOW	None (Non-Designer)	TRUE
CCI-000015	AC-2(1)	MOD	Table G-7 (Enclave)	TRUE
CCI-001361	AC-2(2)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001365	AC-2(2)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001682	AC-2(2)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000016	AC-2(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-000017	AC-2(3)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000217	AC-2(3)	MOD	Table G-5 (Designer)	TRUE
CCI-000018	AC-2(4)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001403	AC-2(4)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002130	AC-2(4)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001404	AC-2(4)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001405	AC-2(4)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001683	AC-2(4)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001684	AC-2(4)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002132	AC-2(4)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001685	AC-2(4)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001686	AC-2(4)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002131	AC-2(4)	MOD	None (Non-Designer)	TRUE
CCI-002133	AC-2(5)	MOD	None (Non-Designer)	YES
CCI-000019	AC-2(5)(a)	MOD	None (Non-Designer)	YES
CCI-001406	AC-2(5)(a)	MOD	None (Non-Designer)	YES
CCI-001358	AC-2(7)(a)	MOD	None (Non-Designer)	YES
CCI-001407	AC-2(7)(a)	MOD	None (Non-Designer)	YES
CCI-001360	AC-2(7)(b)	MOD	None (Non-Designer)	YES
CCI-002136	AC-2(7)(c)	MOD	None (Non-Designer)	YES
CCI-002137	AC-2(7)(c)	MOD	None (Non-Designer)	YES
CCI-002140	AC-2(9)	MOD	None (Non-Designer)	YES
CCI-002141	AC-2(9)	MOD	None (Non-Designer)	YES
CCI-002142	AC-2(10)	MOD	None (Non-Designer)	YES
CCI-002146	AC-2(12)(a)	MOD	Table G-5 (Designer)	YES
CCI-002147	AC-2(12)(a)	MOD	None (Non-Designer)	YES
CCI-002148	AC-2(12)(b)	MOD	None (Non-Designer)	YES
CCI-002149	AC-2(12)(b)	MOD	None (Non-Designer)	YES
CCI-002150	AC-2(13)	MOD	None (Non-Designer)	YES
CCI-002151	AC-2(13)	MOD	None (Non-Designer)	YES
CCI-000213	AC-3	LOW	Table G-4 (Designer)	TRUE
CCI-002163	AC-3(4)	MOD	None (Non-Designer)	YES
CCI-002164	AC-3(4)	MOD	None (Non-Designer)	YES
CCI-002165	AC-3(4)	MOD	None (Non-Designer)	YES
CCI-001368	AC-4	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001414	AC-4	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001548	AC-4	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001549	AC-4	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001550	AC-4	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-001551	AC-4	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002219	AC-5(a)	MOD	None (Non-Designer)	TRUE
CCI-000036	AC-5(a)	MOD	None (Non-Designer)	TRUE
CCI-001380	AC-5(b)	MOD	None (Non-Designer)	TRUE
CCI-002220	AC-5(c)	MOD	Table G-7 (Enclave)	TRUE
CCI-000225	AC-6	MOD	Table G-7 (Enclave)	TRUE
CCI-001558	AC-6(1)	MOD	Table G-5 (Designer)	TRUE
CCI-002221	AC-6(1)	MOD	Table G-5 (Designer)	TRUE
CCI-002222	AC-6(1)	MOD	Table G-5 (Designer)	TRUE
CCI-002223	AC-6(1)	MOD	Table G-5 (Designer)	TRUE
CCI-000039	AC-6(2)	MOD	Table G-5 (Designer)	TRUE
CCI-001419	AC-6(2)	MOD	Table G-5 (Designer)	TRUE
CCI-002226	AC-6(5)	MOD	None (Non-Designer)	TRUE
CCI-002227	AC-6(5)	MOD	None (Non-Designer)	TRUE
CCI-002228	AC-6(7)(a)	MOD	None (Non-Designer)	YES
CCI-002229	AC-6(7)(a)	MOD	None (Non-Designer)	YES
CCI-002230	AC-6(7)(a)	MOD	None (Non-Designer)	YES
CCI-002231	AC-6(7)(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-002232	AC-6(8)	MOD	None (Non-Designer)	YES
CCI-002233	AC-6(8)	MOD	None (Non-Designer)	YES
CCI-002234	AC-6(9)	MOD	Table G-5 (Designer)	TRUE
CCI-002235	AC-6(10)	MOD	Table G-5 (Designer)	TRUE
CCI-000043	AC-7(a)	LOW	Table G-4 (Designer)	TRUE
CCI-000044	AC-7(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001423	AC-7(a)	LOW	Table G-4 (Designer)	TRUE
CCI-002236	AC-7(b)	LOW	Table G-4 (Designer)	TRUE
CCI-002237	AC-7(b)	LOW	Table G-4 (Designer)	TRUE
CCI-002238	AC-7(b)	LOW	Table G-4 (Designer)	TRUE
CCI-002247	AC-8(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000048	AC-8(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002243	AC-8(a)(1)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002244	AC-8(a)(2)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002245	AC-8(a)(3)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002246	AC-8(a)(4)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000050	AC-8(b)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002248	AC-8(c)(1)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001384	AC-8(c)(1)	LOW	Table G-2 (Not Applicable)	FALSE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-001385	AC-8(c)(2)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001386	AC-8(c)(2)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001387	AC-8(c)(2)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001388	AC-8(c)(3)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-000054	AC-10	MOD	Table G-5 (Designer)	YES
CCI-000055	AC-10	MOD	Table G-5 (Designer)	YES
CCI-002252	AC-10	MOD	Table G-5 (Designer)	YES
CCI-000059	AC-11(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000058	AC-11(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000057	AC-11(a)	MOD	None (Not Categorized)	
CCI-000056	AC-11(b)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000060	AC-11(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002360	AC-12	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002361	AC-12	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000061	AC-14(a)	LOW	Table G-4 (Designer)	TRUE
CCI-000232	AC-14(b)	LOW	Table G-4 (Designer)	TRUE
CCI-002256	AC-16(a)	MOD	None (Non-Designer)	YES
CCI-002257	AC-16(a)	MOD	None (Non-Designer)	YES
CCI-002258	AC-16(a)	MOD	None (Non-Designer)	YES
CCI-002259	AC-16(a)	MOD	None (Non-Designer)	YES
CCI-002260	AC-16(a)	MOD	None (Non-Designer)	YES
CCI-002261	AC-16(a)	MOD	None (Non-Designer)	YES
CCI-002262	AC-16(a)	MOD	None (Non-Designer)	YES
CCI-002263	AC-16(a)	MOD	None (Non-Designer)	YES
CCI-002264	AC-16(a)	MOD	None (Non-Designer)	YES
CCI-002265	AC-16(b)	MOD	None (Non-Designer)	YES
CCI-002266	AC-16(b)	MOD	None (Non-Designer)	YES
CCI-002267	AC-16(c)	MOD	None (Non-Designer)	YES
CCI-002268	AC-16(c)	MOD	None (Non-Designer)	YES
CCI-002269	AC-16(c)	MOD	None (Non-Designer)	YES
CCI-002270	AC-16(d)	MOD	None (Non-Designer)	YES
CCI-002271	AC-16(d)	MOD	None (Non-Designer)	YES
CCI-002291	AC-16(6)	MOD	None (Non-Designer)	YES
CCI-002292	AC-16(6)	MOD	None (Non-Designer)	YES
CCI-002293	AC-16(6)	MOD	None (Non-Designer)	YES
CCI-002294	AC-16(6)	MOD	None (Non-Designer)	YES
CCI-002295	AC-16(6)	MOD	None (Non-Designer)	YES

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002296	AC-16(6)	MOD	None (Non-Designer)	YES
CCI-002297	AC-16(6)	MOD	None (Non-Designer)	YES
CCI-002298	AC-16(6)	MOD	None (Non-Designer)	YES
CCI-000063	AC-17(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002310	AC-17(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002311	AC-17(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002312	AC-17(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000065	AC-17(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-000067	AC-17(1)	MOD	Table G-7 (Enclave)	TRUE
CCI-002314	AC-17(1)	MOD	Table G-7 (Enclave)	TRUE
CCI-000068	AC-17(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-001453	AC-17(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-001561	AC-17(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-002315	AC-17(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-000069	AC-17(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-000070	AC-17(4)(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-002316	AC-17(4)(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-002317	AC-17(4)(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-002318	AC-17(4)(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-002319	AC-17(4)(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-002320	AC-17(4)(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-000072	AC-17(6)	MOD	None (Non-Designer)	YES
CCI-002321	AC-17(9)	MOD	Table G-7 (Enclave)	YES
CCI-002322	AC-17(9)	MOD	Table G-7 (Enclave)	YES
CCI-001438	AC-18(a)	LOW	Table G-4 (Designer)	TRUE
CCI-002323	AC-18(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001439	AC-18(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001441	AC-18(b)	LOW	Table G-4 (Designer)	TRUE
CCI-001443	AC-18(1)	MOD	Table G-5 (Designer)	TRUE
CCI-001444	AC-18(1)	MOD	Table G-5 (Designer)	TRUE
CCI-001449	AC-18(3)	MOD	Table G-5 (Designer)	YES
CCI-002324	AC-18(4)	MOD	None (Non-Designer)	YES
CCI-000082	AC-19(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002325	AC-19(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002326	AC-19(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000083	AC-19(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000084	AC-19(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-002329	AC-19(5)	MOD	Table G-7 (Enclave)	TRUE
CCI-002331	AC-19(5)	MOD	None (Not Categorized)	
CCI-002330	AC-19(5)	MOD	Table G-7 (Enclave)	TRUE
CCI-002332	AC-10(b)	LOW	None (Non-Designer)	TRUE
CCI-000093	AC-20(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002333	AC-20(1)(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-002334	AC-20(1)(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-002335	AC-20(1)(a)	MOD	Table G-7 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-002336	AC-20(1)(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-002337	AC-20(1)(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-000097	AC-20(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-002338	AC-20(3)	MOD	Table G-5 (Designer)	???
CCI-000098	AC-21(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-001470	AC-21(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-001471	AC-21(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-001472	AC-21(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-001473	AC-22(a)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001474	AC-22(b)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001475	AC-22(c)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001476	AC-22(d)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001477	AC-22(d)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001478	AC-22(e)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-002048	AT-1(a)	LOW	None (Non-Designer)	TRUE
CCI-002049	AT-1(a)	LOW	None (Non-Designer)	TRUE
CCI-000100	AT-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000101	AT-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000103	AT-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000104	AT-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000102	AT-1(b)(1)	LOW		TRUE
CCI-001564	AT-1(b)(1)	LOW		TRUE
CCI-000105	AT-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-001565	AT-1(b)(2)	LOW		TRUE
CCI-001480	AT-2	LOW		TRUE
CCI-000106	AT-2(a)	LOW	None (Non-Designer)	TRUE
CCI-000112	AT-2(b)	LOW		TRUE
CCI-001479	AT-2(c)	LOW		TRUE
CCI-002055	AT-2(2)	MOD	None (Non-Designer)	TRUE
CCI-000108	AT-3(a)	LOW		TRUE
CCI-000109	AT-3(b)	LOW	None (Non-Designer)	TRUE
CCI-000110	AT-3(c)	LOW	None (Non-Designer)	TRUE
CCI-000111	AT-3(c)	LOW		TRUE
CCI-001568	AT-3(2)	MOD	None (Non-Designer)	YES
CCI-002051	AT-3(2)	MOD	None (Non-Designer)	YES
CCI-001566	AT-3(2)	MOD	None (Non-Designer)	YES
CCI-001567	AT-3(2)	MOD	None (Non-Designer)	YES
CCI-002054	AT-3(4)	MOD	Table G-5 (Designer)	YES
CCI-002053	AT-3(4)	MOD	None (Non-Designer)	YES
CCI-000113	AT-4(a)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-000114	AT-4(a)	LOW	None (Non-Designer)	TRUE
CCI-001336	AT-4(b)	LOW	None (Non-Designer)	TRUE
CCI-001337	AT-4(b)	LOW		TRUE
CCI-001930	AU-1(a)	LOW		TRUE
CCI-001931	AU-1(a)	LOW		TRUE
CCI-000117	AU-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-001832	AU-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000120	AU-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-001834	AU-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000119	AU-1(b)(1)	LOW	None (Non-Designer)	TRUE
CCI-001569	AU-1(b)(1)	LOW		TRUE
CCI-000122	AU-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-001570	AU-1(b)(2)	LOW		TRUE
CCI-000123	AU-2(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001571	AU-2(a)	LOW	Table G-4 (Designer)	TRUE
CCI-000124	AU-2(b)	LOW	None (Non-Designer)	TRUE
CCI-000125	AU-2(c)	LOW	Table G-4 (Designer)	TRUE
CCI-001485	AU-2(d)	LOW	Table G-4 (Designer)	TRUE
CCI-001484	AU-2(d)	LOW		TRUE
CCI-000126	AU-2(d)	LOW	None (Non-Designer)	TRUE
CCI-000127	AU-2(3)	MOD	None (Non-Designer)	TRUE
CCI-001486	AU-2(3)	MOD		TRUE
CCI-000130	AU-3	LOW	Table G-4 (Designer)	TRUE
CCI-000131	AU-3	LOW	Table G-4 (Designer)	TRUE
CCI-000132	AU-3	LOW	Table G-4 (Designer)	TRUE
CCI-000133	AU-3	LOW	Table G-4 (Designer)	TRUE
CCI-000134	AU-3	LOW	Table G-4 (Designer)	TRUE
CCI-001487	AU-3	LOW	Table G-4 (Designer)	TRUE
CCI-001488	AU-3(1)	MOD	Table G-5 (Designer)	TRUE
CCI-000135	AU-3(1)	MOD	Table G-5 (Designer)	TRUE
CCI-001848	AU-4	LOW	Table G-4 (Designer)	TRUE
CCI-001849	AU-4	LOW	Table G-4 (Designer)	TRUE
CCI-001851	AU-4(1)	LOW	None (Non-Designer)	TRUE
CCI-001850	AU-4(1)	LOW	None (Non-Designer)	TRUE
CCI-000139	AU-5(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001572	AU-5(a)	LOW	None (Non-Designer)	TRUE
CCI-000140	AU-5(b)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001490	AU-5(b)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001855	AU-5(1)	MOD	Table G-5 (Designer)	YES
CCI-001852	AU-5(1)	MOD	Table G-5 (Designer)	YES
CCI-001853	AU-5(1)	MOD	None (Non-Designer)	YES
CCI-001854	AU-5(1)	MOD	None (Non-Designer)	YES
CCI-000148	AU-6(a)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-000151	AU-6(a)	LOW		TRUE
CCI-001862	AU-6(a)	LOW	None (Non-Designer)	TRUE
CCI-000149	AU-6(b)	LOW	None (Non-Designer)	TRUE
CCI-001863	AU-6(b)	LOW		TRUE
CCI-001864	AU-6(1)	MOD	None (Non-Designer)	TRUE
CCI-001865	AU-6(1)	MOD	None (Non-Designer)	TRUE
CCI-000153	AU-6(3)	MOD	None (Non-Designer)	TRUE
CCI-000154	AU-6(4)	MOD	Table G-5 (Designer)	YES
CCI-001872	AU-6(10)	MOD	None (Non-Designer)	YES
CCI-001874	AU-6(10)	MOD	None (Non-Designer)	YES
CCI-001875	AU-7(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001876	AU-7(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001877	AU-7(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001878	AU-7(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001879	AU-7(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001880	AU-7(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001881	AU-7(b)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001882	AU-7(b)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000158	AU-7(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001883	AU-7(1)	MOD	None (Non-Designer)	TRUE
CCI-000159	AU-8(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001889	AU-8(b)	LOW	Table G-4 (Designer)	TRUE
CCI-001890	AU-8(b)	LOW	Table G-4 (Designer)	TRUE
CCI-001888	AU-8(b)	LOW		TRUE
CCI-001891	AU-8(1)	MOD	Table G-5 (Designer)	TRUE
CCI-001892	AU-8(1)	MOD	Table G-5 (Designer)	TRUE
CCI-002046	AU-8(1)	MOD	Table G-5 (Designer)	TRUE
CCI-000161	AU-8(1)	MOD	None (Non-Designer)	TRUE
CCI-001492	AU-8(1)	MOD	None (Non-Designer)	TRUE
CCI-000162	AU-9	LOW	Table G-6 (Enclave)	TRUE
CCI-000163	AU-9	LOW	Table G-6 (Enclave)	TRUE
CCI-000164	AU-9	LOW	Table G-6 (Enclave)	TRUE
CCI-001493	AU-9	LOW	Table G-6 (Enclave)	TRUE
CCI-001494	AU-9	LOW	Table G-6 (Enclave)	TRUE
CCI-001495	AU-9	LOW	Table G-6 (Enclave)	TRUE
CCI-001894	AU-9(4)	MOD	None (Non-Designer)	TRUE
CCI-001351	AU-9(4)(a)	MOD	None (Non-Designer)	TRUE
CCI-001899	AU-10	MOD	Table G-5 (Designer)	YES

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-000166	AU-10	MOD	Table G-5 (Designer)	YES
CCI-000167	AU-11	LOW	None (Non-Designer)	TRUE
CCI-000168	AU-11	LOW		TRUE
CCI-002044	AU-11(1)	MOD	None (Non-Designer)	YES
CCI-002045	AU-11(1)	MOD	None (Non-Designer)	YES
CCI-000169	AU-12(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001459	AU-12(a)	LOW	Table G-4 (Designer)	TRUE
CCI-000171	AU-12(b)	LOW	Table G-4 (Designer)	TRUE
CCI-001910	AU-12(b)	LOW	Table G-4 (Designer)	TRUE
CCI-000172	AU-12(c)	LOW	Table G-4 (Designer)	TRUE
CCI-001577	AU-12(1)	MOD	Table G-5 (Designer)	YES
CCI-000174	AU-12(1)	MOD	Table G-5 (Designer)	YES
CCI-000173	AU-12(1)	MOD	Table G-5 (Designer)	YES
CCI-001914	AU-12(3)	MOD	Table G-5 (Designer)	YES
CCI-002047	AU-12(3)	MOD	Table G-5 (Designer)	YES
CCI-001913	AU-12(3)	MOD	None (Non-Designer)	YES
CCI-001911	AU-12(3)	MOD	None (Non-Designer)	YES
CCI-001912	AU-12(3)	MOD	None (Non-Designer)	YES
CCI-001919	AU-14(b)	MOD	Table G-5 (Designer)	YES
CCI-001464	AU-14(1)	MOD	Table G-5 (Designer)	YES
CCI-001462	AU-14(2)	MOD	Table G-5 (Designer)	YES
CCI-001920	AU-14(3)	MOD	Table G-5 (Designer)	YES
CCI-002061	CA-1(a)	LOW	None (Non-Designer)	TRUE
CCI-002062	CA-1(a)	LOW	None (Non-Designer)	TRUE
CCI-000239	CA-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000240	CA-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000242	CA-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000243	CA-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000238	CA-1(b)(1)	LOW		TRUE
CCI-000241	CA-1(b)(1)	LOW		TRUE
CCI-000244	CA-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-001578	CA-1(b)(2)	LOW		TRUE
CCI-000245	CA-2(a)	LOW	None (Non-Designer)	TRUE
CCI-000246	CA-2(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000247	CA-2(a)(2)	LOW		TRUE
CCI-000248	CA-2(a)(3)	LOW	None (Non-Designer)	TRUE
CCI-002070	CA-2(a)(3)	LOW	None (Non-Designer)	TRUE
CCI-000251	CA-2(b)	LOW	None (Non-Designer)	TRUE
CCI-000252	CA-2(b)	LOW		TRUE
CCI-000253	CA-2(c)	LOW	None (Non-Designer)	TRUE
CCI-000254	CA-2(d)	LOW	None (Non-Designer)	TRUE
CCI-002071	CA-2(d)	LOW		TRUE
CCI-000255	CA-2(1)	MOD	None (Non-Designer)	TRUE
CCI-002063	CA-2(1)	MOD	None (Non-Designer)	TRUE
CCI-000257	CA-3(a)	LOW	Table G-6 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-000259	CA-3(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-000260	CA-3(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-002083	CA-3(c)	LOW	None (Non-Designer)	TRUE
CCI-002084	CA-3(c)	LOW		TRUE
CCI-000258	CA-3(b)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002072	CA-3(1)	MOD	None (Non-Designer)	YES
CCI-002073	CA-3(1)	MOD	None (Non-Designer)	YES
CCI-000262	CA-3(1)	MOD	None (Non-Designer)	YES
CCI-002081	CA-3(5)	MOD	Table G-7 (Enclave)	TRUE
CCI-002082	CA-3(5)	MOD	Table G-7 (Enclave)	TRUE
CCI-002080	CA-3(5)	MOD	Table G-7 (Enclave)	TRUE
CCI-000264	CA-5(a)	LOW	None (Non-Designer)	TRUE
CCI-000265	CA-5(b)	LOW		TRUE
CCI-000266	CA-5(b)	LOW	None (Non-Designer)	TRUE
CCI-000270	CA-6(a)	LOW	None (Non-Designer)	TRUE
CCI-000271	CA-6(b)	LOW	None (Non-Designer)	TRUE
CCI-000273	CA-6(c)	LOW		TRUE
CCI-000272	CA-6(c)	LOW	None (Non-Designer)	TRUE
CCI-000274	CA-7	LOW	None (Non-Designer)	TRUE
CCI-002087	CA-7(a)	LOW	None (Non-Designer)	TRUE
CCI-002088	CA-7(b)	LOW	None (Non-Designer)	TRUE
CCI-002089	CA-7(b)	LOW	None (Non-Designer)	TRUE
CCI-000279	CA-7(c)	LOW	None (Non-Designer)	TRUE
CCI-002090	CA-7(d)	LOW	None (Non-Designer)	TRUE
CCI-002091	CA-7(e)	LOW	None (Non-Designer)	TRUE
CCI-002092	CA-7(f)	LOW	None (Non-Designer)	TRUE
CCI-000281	CA-7(g)	LOW	None (Non-Designer)	TRUE
CCI-001581	CA-7(g)	LOW	None (Non-Designer)	TRUE
CCI-000280	CA-7(g)	LOW	None (Non-Designer)	TRUE
CCI-000282	CA-7(1)	MOD	None (Non-Designer)	TRUE
CCI-002085	CA-7(1)	MOD	None (Non-Designer)	TRUE
CCI-002101	CA-9(a)	LOW	None (Non-Designer)	TRUE
CCI-002103	CA-9(b)	LOW	Table G-4 (Designer)	TRUE
CCI-002104	CA-9(b)	LOW	Table G-4 (Designer)	TRUE
CCI-002105	CA-9(b)	LOW	Table G-4 (Designer)	TRUE
CCI-002102	CA-9(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001821	CM-1(a)	LOW	None (Non-Designer)	TRUE
CCI-001824	CM-1(a)	LOW	None (Non-Designer)	TRUE
CCI-000287	CM-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-001822	CM-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000290	CM-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-001825	CM-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000289	CM-1(b)(1)	LOW	None (Non-Designer)	TRUE
CCI-000286	CM-1(b)(1)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-000292	CM-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-001584	CM-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-000293	CM-2	LOW	Table G-4 (Designer)	TRUE
CCI-000295	CM-2	LOW	None (Non-Designer)	TRUE
CCI-000296	CM-2(1)(a)	MOD	None (Non-Designer)	TRUE
CCI-001497	CM-2(1)(a)	MOD		TRUE
CCI-000297	CM-2(1)(b)	MOD	None (Non-Designer)	TRUE
CCI-001585	CM-2(1)(b)	MOD		TRUE
CCI-000298	CM-2(1)(c)	MOD	Table G-5 (Designer)	TRUE
CCI-000299	CM-2(1)(c)	MOD	None (Non-Designer)	TRUE
CCI-000304	CM-2(3)	MOD	None (Non-Designer)	TRUE
CCI-001736	CM-2(3)	MOD	None (Non-Designer)	TRUE
CCI-001737	CM-2(7)a	MOD	Table G-5 (Designer)	TRUE
CCI-001738	CM-2(7)a	MOD	Table G-5 (Designer)	TRUE
CCI-001739	CM-2(7)a	MOD	Table G-2 (Not Applicable)	FALSE
CCI-001815	CM-2(7)b	MOD	Table G-2 (Not Applicable)	FALSE
CCI-001816	CM-2(7)b	MOD	Table G-2 (Not Applicable)	FALSE
CCI-000313	CM-3(a)	MOD	None (Non-Designer)	TRUE
CCI-001740	CM-3(b)	MOD	None (Non-Designer)	TRUE
CCI-000314	CM-3(b)	MOD	None (Non-Designer)	TRUE
CCI-001741	CM-3(c)	MOD	None (Non-Designer)	TRUE
CCI-001819	CM-3(d)	MOD	None (Non-Designer)	TRUE
CCI-000316	CM-3(e)	MOD	None (Non-Designer)	TRUE
CCI-002056	CM-3(e)	MOD	None (Non-Designer)	TRUE
CCI-000318	CM-3(f)	MOD	None (Non-Designer)	TRUE
CCI-000319	CM-3(g)	MOD	None (Non-Designer)	TRUE
CCI-000320	CM-3(g)	MOD	None (Non-Designer)	TRUE
CCI-000321	CM-3(g)	MOD	None (Non-Designer)	TRUE
CCI-001586	CM-3(g)	MOD	None (Non-Designer)	TRUE
CCI-000327	CM-3(2)	MOD	None (Non-Designer)	TRUE
CCI-000328	CM-3(2)	MOD	None (Non-Designer)	TRUE
CCI-000329	CM-3(2)	MOD	None (Non-Designer)	TRUE
CCI-000332	CM-3(4)	MOD	None (Non-Designer)	YES
CCI-001745	CM-3(6)	MOD	None (Non-Designer)	YES
CCI-001746	CM-3(6)	MOD	None (Non-Designer)	YES
CCI-000333	CM-4	LOW	None (Non-Designer)	TRUE
CCI-001817	CM-4(1)	MOD	None (Non-Designer)	YES
CCI-001818	CM-4(1)	MOD	None (Non-Designer)	YES
CCI-000338	CM-5	MOD	Table G-7 (Enclave)	TRUE
CCI-000339	CM-5	MOD	Table G-7 (Enclave)	TRUE
CCI-000340	CM-5	MOD	Table G-7 (Enclave)	TRUE
CCI-000341	CM-5	MOD	Table G-7 (Enclave)	TRUE
CCI-000342	CM-5	MOD	Table G-7 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-000343	CM-5	MOD	Table G-7 (Enclave)	TRUE
CCI-000344	CM-5	MOD	Table G-7 (Enclave)	TRUE
CCI-000345	CM-5	MOD	Table G-7 (Enclave)	TRUE
CCI-001813	CM-5(1)	MOD	Table G-5 (Designer)	YES
CCI-001814	CM-5(1)	MOD	Table G-5 (Designer)	YES
CCI-000349	CM-5(2)	MOD	Table G-5 (Designer)	YES
CCI-000348	CM-5(2)	MOD	None (Non-Designer)	YES
CCI-000350	CM-5(2)	MOD	None (Non-Designer)	YES
CCI-001826	CM-5(2)	MOD	None (Non-Designer)	YES
CCI-001753	CM-5(5)(a)	MOD	None (Non-Designer)	YES
CCI-001754	CM-5(5)(a)	MOD	None (Non-Designer)	YES
CCI-001827	CM-5(5)(b)	MOD	None (Non-Designer)	YES
CCI-001828	CM-5(5)(b)	MOD	None (Non-Designer)	YES
CCI-001829	CM-5(5)(b)	MOD	None (Non-Designer)	YES
CCI-001830	CM-5(5)(b)	MOD	None (Non-Designer)	YES
CCI-001499	CM-5(6)	MOD	None (Non-Designer)	YES
CCI-000363	CM-6(a)	LOW	Table G-4 (Designer)	TRUE
CCI-000364	CM-6(a)	LOW	Table G-4 (Designer)	TRUE
CCI-000365	CM-6(a)	LOW	Table G-4 (Designer)	TRUE
CCI-000366	CM-6(b)	LOW	None (Non-Designer)	TRUE
CCI-001755	CM-6(c)	LOW	Table G-4 (Designer)	TRUE
CCI-001756	CM-6(c)	LOW	None (Non-Designer)	TRUE
CCI-000367	CM-6(c)	LOW	None (Non-Designer)	TRUE
CCI-000368	CM-6(c)	LOW	None (Non-Designer)	TRUE
CCI-000369	CM-6(c)	LOW	None (Non-Designer)	TRUE
CCI-001502	CM-6(d)	LOW	None (Non-Designer)	TRUE
CCI-001503	CM-6(d)	LOW	None (Non-Designer)	TRUE
CCI-001588	CM-6(a)	LOW	Table G-4 (Designer)	TRUE
CCI-002059	CM-6(1)	MOD	Table G-5 (Designer)	YES
CCI-000370	CM-6(1)	MOD	None (Non-Designer)	YES
CCI-000371	CM-6(1)	MOD	None (Non-Designer)	YES
CCI-000372	CM-6(1)	MOD	None (Non-Designer)	YES
CCI-000382	CM-7(b)	LOW	Table G-4 (Designer)	TRUE
CCI-000380	CM-7(b)	LOW	Table G-4 (Designer)	TRUE
CCI-000381	CM-7(a)	LOW	Table G-4 (Designer)	TRUE
CCI-000384	CM-7(1)(a)	LOW	None (Non-Designer)	TRUE
CCI-001760	CM-7(1)(a)	LOW		TRUE
CCI-001761	CM-7(1)(b)	LOW	Table G-4 (Designer)	TRUE
CCI-001762	CM-7(1)(b)	LOW	Table G-4 (Designer)	TRUE
CCI-001592	CM-7(2)	MOD	Table G-5 (Designer)	TRUE
CCI-001763	CM-7(2)	MOD	Table G-5 (Designer)	TRUE
CCI-001764	CM-7(2)	MOD	Table G-5 (Designer)	TRUE
CCI-000388	CM-7(3)	MOD	Table G-5 (Designer)	YES
CCI-000387	CM-7(3)	MOD	None (Non-Designer)	YES
CCI-001772	CM-7(5)a	MOD	Table G-5 (Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-001773	CM-7(5)a	MOD	Table G-5 (Designer)	TRUE
CCI-001774	CM-7(5)b	MOD	Table G-5 (Designer)	TRUE
CCI-001775	CM-7(5)c	MOD	None (Non-Designer)	TRUE
CCI-001777	CM-7(5)c	MOD	None (Non-Designer)	TRUE
CCI-000395	CM-8(a)(3)	LOW	None (Non-Designer)	TRUE
CCI-000399	CM-8(a)(4)	LOW	None (Non-Designer)	TRUE
CCI-001779	CM-8(b)	LOW	None (Non-Designer)	TRUE
CCI-001780	CM-8(b)	LOW	None (Non-Designer)	TRUE
CCI-000389	CM-8(a)(1)	LOW	Table G-4 (Designer)	TRUE
CCI-000392	CM-8(a)(2)	LOW	Table G-4 (Designer)	TRUE
CCI-000398	CM-8(a)(4)	LOW	Table G-4 (Designer)	TRUE
CCI-000408	CM-8(1)	MOD	None (Non-Designer)	TRUE
CCI-000409	CM-8(1)	MOD	None (Non-Designer)	TRUE
CCI-000410	CM-8(1)	MOD	None (Non-Designer)	TRUE
CCI-000411	CM-8(2)	MOD	Table G-5 (Designer)	YES
CCI-000412	CM-8(2)	MOD	Table G-5 (Designer)	YES
CCI-000413	CM-8(2)	MOD	None (Non-Designer)	YES
CCI-000414	CM-8(2)	MOD	None (Non-Designer)	YES
CCI-000415	CM-8(3)(a)	MOD	None (Non-Designer)	TRUE
CCI-000416	CM-8(3)(a)	MOD	None (Non-Designer)	TRUE
CCI-001783	CM-8(3)(b)	MOD		TRUE
CCI-001784	CM-8(3)(b)	MOD	None (Non-Designer)	TRUE
CCI-000419	CM-8(5)	MOD	Table G-7 (Enclave)	TRUE
CCI-000421	CM-9(a)	MOD	None (Non-Designer)	TRUE
CCI-000423	CM-9(a)	MOD	None (Non-Designer)	TRUE
CCI-001790	CM-9(b)	MOD	None (Non-Designer)	TRUE
CCI-001792	CM-9(b)	MOD	None (Non-Designer)	TRUE
CCI-001793	CM-9(b)	MOD	None (Non-Designer)	TRUE
CCI-001795	CM-9(b)	MOD	None (Non-Designer)	TRUE
CCI-000426	CM-9(c)	MOD	None (Non-Designer)	TRUE
CCI-001796	CM-9(c)	MOD	None (Non-Designer)	TRUE
CCI-001798	CM-9(c)	MOD	None (Non-Designer)	TRUE
CCI-001799	CM-9(d)	MOD	None (Non-Designer)	TRUE
CCI-001801	CM-9(d)	MOD	None (Non-Designer)	TRUE
CCI-000424	CM-9(c)	MOD	None (Non-Designer)	TRUE
CCI-001726	CM-10(a)	LOW	None (Non-Designer)	TRUE
CCI-001727	CM-10(a)	LOW	None (Non-Designer)	TRUE
CCI-001728	CM-10(a)	LOW	None (Non-Designer)	TRUE
CCI-001729	CM-10(a)	LOW	None (Non-Designer)	TRUE
CCI-001730	CM-10(b)	LOW	None (Non-Designer)	TRUE
CCI-001802	CM-10(b)	LOW	None (Non-Designer)	TRUE
CCI-001803	CM-10(b)	LOW	None (Non-Designer)	TRUE
CCI-001731	CM-10(b)	LOW	None (Non-Designer)	TRUE
CCI-001732	CM-10(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-001733	CM-10(c)	LOW	Table G-6 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-001734	CM-10(1)	MOD	None (Non-Designer)	YES
CCI-001735	CM-10(1)	MOD	None (Non-Designer)	YES
CCI-001804	CM-11(a)	LOW	None (Non-Designer)	TRUE
CCI-001805	CM-11(a)	LOW	None (Non-Designer)	TRUE
CCI-001806	CM-11(b)	LOW	None (Non-Designer)	TRUE
CCI-001807	CM-11(b)	LOW	None (Non-Designer)	TRUE
CCI-001808	CM-11(c)	LOW		TRUE
CCI-001809	CM-11(c)	LOW	None (Non-Designer)	TRUE
CCI-001812	CM-11(2)	MOD	Table G-5 (Designer)	YES
CCI-002825	CP-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000438	CP-1(a)(1)	LOW		TRUE
CCI-000439	CP-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-002826	CP-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000441	CP-1(a)(2)	LOW		TRUE
CCI-001597	CP-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000437	CP-1(b)(1)	LOW		TRUE
CCI-000440	CP-1(b)(1)	LOW	None (Non-Designer)	TRUE
CCI-001596	CP-1(b)(2)	LOW		TRUE
CCI-001598	CP-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-000443	CP-2(a)(1)	LOW	Table G-3 (Removed from Low)	TRUE
CCI-000444	CP-2(a)(1)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-000445	CP-2(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000446	CP-2(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000447	CP-2(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000448	CP-2(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000449	CP-2(a)(3)	LOW	None (Non-Designer)	TRUE
CCI-000450	CP-2(a)(4)	LOW	Table G-3 (Removed from Low)	TRUE
CCI-000451	CP-2(a)(4)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-000452	CP-2(a)(4)	LOW	Table G-3 (Removed from Low)	TRUE
CCI-000453	CP-2(a)(4)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-000454	CP-2(a)(4)	LOW	Table G-3 (Removed from Low)	TRUE
CCI-000455	CP-2(a)(4)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-000456	CP-2(a)(5)	LOW	None (Non-Designer)	TRUE
CCI-000457	CP-2(a)(6)	LOW	None (Non-Designer)	TRUE
CCI-002830	CP-2(a)(6)	LOW		TRUE
CCI-000458	CP-2(b)	LOW	None (Non-Designer)	TRUE
CCI-000459	CP-2(b)	LOW	None (Non-Designer)	TRUE
CCI-000460	CP-2(c)	LOW	None (Non-Designer)	TRUE
CCI-000461	CP-2(d)	LOW		TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-000462	CP-2(d)	LOW	None (Non-Designer)	TRUE
CCI-000463	CP-2(e)	LOW	None (Non-Designer)	TRUE
CCI-000464	CP-2(e)	LOW	None (Non-Designer)	TRUE
CCI-000465	CP-2(e)	LOW	None (Non-Designer)	TRUE
CCI-000466	CP-2(e)	LOW	None (Non-Designer)	TRUE
CCI-000468	CP-2(f)	LOW	None (Non-Designer)	TRUE
CCI-002831	CP-2(f)	LOW	None (Non-Designer)	TRUE
CCI-002832	CP-2(g)	LOW	None (Non-Designer)	TRUE
CCI-000469	CP-2(1)	MOD	None (Non-Designer)	TRUE
CCI-000473	CP-2(3)	MOD		TRUE
CCI-000474	CP-2(3)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-000475	CP-2(3)	MOD	None (Non-Designer)	TRUE
CCI-000476	CP-2(3)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-002828	CP-2(8)	MOD	Table G-5 (Designer)	TRUE
CCI-002829	CP-2(8)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-002833	CP-3(a)	LOW		TRUE
CCI-000486	CP-3(a)	LOW	None (Non-Designer)	TRUE
CCI-002834	CP-3(b)	LOW	None (Non-Designer)	TRUE
CCI-000485	CP-3(c)	LOW		TRUE
CCI-000487	CP-3(c)	LOW	None (Non-Designer)	TRUE
CCI-000490	CP-4(a)	LOW		TRUE
CCI-000492	CP-4(a)	LOW	None (Non-Designer)	TRUE
CCI-000494	CP-4(a)	LOW	None (Non-Designer)	TRUE
CCI-000496	CP-4(b)	LOW	None (Non-Designer)	TRUE
CCI-000497	CP-4(c)	LOW	None (Non-Designer)	TRUE
CCI-000498	CP-4(1)	MOD	None (Non-Designer)	TRUE
CCI-000505	CP-6(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-002836	CP-6(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-000507	CP-6(1)	MOD	Table G-7 (Enclave)	TRUE
CCI-000509	CP-6(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-001604	CP-6(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-000510	CP-7(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-000513	CP-7(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-000514	CP-7(a)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-002839	CP-7(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-000515	CP-7(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-000521	CP-7(c)	MOD	Table G-7 (Enclave)	TRUE
CCI-000516	CP-7(1)	MOD	Table G-7 (Enclave)	TRUE
CCI-000517	CP-7(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-001606	CP-7(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-000518	CP-7(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-000522	CP-8	MOD	Table G-7 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-000523	CP-8	MOD	Table G-2 (Not Applicable)	FALSE
CCI-000524	CP-8	MOD	Table G-7 (Enclave)	TRUE
CCI-000525	CP-8	MOD	Table G-2 (Not Applicable)	FALSE
CCI-002840	CP-8	MOD	Table G-7 (Enclave)	TRUE
CCI-002841	CP-8	MOD	Table G-2 (Not Applicable)	FALSE
CCI-000526	CP-8(1)(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-000527	CP-8(1)(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-000528	CP-8(1)(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-000529	CP-8(1)(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-000530	CP-8(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-000534	CP-9(a)	LOW		TRUE
CCI-000535	CP-9(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000536	CP-9(b)	LOW	None (Non-Designer)	TRUE
CCI-000537	CP-9(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-000538	CP-9(c)	LOW	None (Non-Designer)	TRUE
CCI-000539	CP-9(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-000540	CP-9(d)	LOW	Table G-6 (Enclave)	TRUE
CCI-000541	CP-9(1)	MOD	Table G-7 (Enclave)	TRUE
CCI-000542	CP-9(1)	MOD	Table G-7 (Enclave)	TRUE
CCI-000547	CP-9(5)	MOD	None (Non-Designer)	YES
CCI-000548	CP-9(5)	MOD	None (Non-Designer)	YES
CCI-000550	CP-10	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000551	CP-10	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000552	CP-10	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000553	CP-10(2)	MOD	Table G-5 (Designer)	TRUE
CCI-002855	CP-12	LOW	Table G-4 (Designer)	TRUE
CCI-002856	CP-12	LOW	Table G-4 (Designer)	TRUE
CCI-002857	CP-12	LOW	Table G-4 (Designer)	TRUE
CCI-001933	IA-1(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-001934	IA-1(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000756	IA-1(a)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-000757	IA-1(a)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-001932	IA-1(a)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-000760	IA-1(a)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-000761	IA-1(a)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-000758	IA-1(b)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-000759	IA-1(b)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-000762	IA-1(b)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-000763	IA-1(b)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-000764	IA-2	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-000765	IA-2(1)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000766	IA-2(2)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000767	IA-2(3)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000768	IA-2(4)	MOD	Table G-5 (Designer)	YES
CCI-000770	IA-2(5)	MOD	None (Non-Designer)	YES
CCI-001941	IA-2(8)	MOD	None (Not Categorized)	
CCI-001942	IA-2(9)	MOD	Table G-5 (Designer)	YES
CCI-001947	IA-2(11)	MOD	Table G-7 (Enclave)	TRUE
CCI-001950	IA-2(11)	MOD	Table G-7 (Enclave)	TRUE
CCI-001948	IA-2(11)	MOD	Table G-7 (Enclave)	TRUE
CCI-001952	IA-2(11)	MOD	Table G-7 (Enclave)	TRUE
CCI-001951	IA-2(11)	MOD	Table G-7 (Enclave)	TRUE
CCI-001949	IA-2(11)	MOD	Table G-7 (Enclave)	TRUE
CCI-001953	IA-2(12)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001954	IA-2(12)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000777	IA-3	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000778	IA-3	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001958	IA-3	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001967	IA-3(1)	MOD	Table G-5 (Designer)	TRUE
CCI-001959	IA-3(1)	MOD	Table G-5 (Designer)	TRUE
CCI-001965	IA-3(4)	MOD	None (Non-Designer)	TRUE
CCI-001968	IA-3(4)	MOD	None (Non-Designer)	TRUE
CCI-001966	IA-3(4)	MOD	None (Non-Designer)	TRUE
CCI-001969	IA-3(4)	MOD	None (Non-Designer)	TRUE
CCI-001970	IA-4(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-001971	IA-4(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-001972	IA-4(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-001973	IA-4(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-001974	IA-4(d)	LOW	Table G-6 (Enclave)	TRUE
CCI-001975	IA-4(d)	LOW	Table G-6 (Enclave)	TRUE
CCI-000794	IA-4(e)	LOW	Table G-6 (Enclave)	TRUE
CCI-000795	IA-4(e)	LOW	Table G-6 (Enclave)	TRUE
CCI-000800	IA-4(4)	MOD	None (Non-Designer)	YES
CCI-000801	IA-4(4)	MOD	None (Non-Designer)	YES
CCI-001988	IA-5	LOW	None (Not Categorized)	
CCI-001980	IA-5(a)	LOW	None (Non-Designer)	TRUE
CCI-000176	IA-5(b)	LOW	Table G-4 (Designer)	TRUE
CCI-001544	IA-5(c)	LOW	Table G-4 (Designer)	TRUE
CCI-001984	IA-5(d)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-001985	IA-5(d)	LOW	None (Non-Designer)	TRUE
CCI-001986	IA-5(d)	LOW	None (Non-Designer)	TRUE
CCI-001987	IA-5(d)	LOW	None (Non-Designer)	TRUE
CCI-001982	IA-5(d)	LOW	None (Non-Designer)	TRUE
CCI-001981	IA-5(d)	LOW	None (Non-Designer)	TRUE
CCI-001983	IA-5(d)	LOW	None (Non-Designer)	TRUE
CCI-001989	IA-5(e)	LOW	Table G-4 (Designer)	TRUE
CCI-000180	IA-5(f)	LOW	None (Non-Designer)	TRUE
CCI-000181	IA-5(f)	LOW	None (Non-Designer)	TRUE
CCI-000179	IA-5(f)	LOW	None (Non-Designer)	TRUE
CCI-000182	IA-5(g)	LOW	Table G-4 (Designer)	TRUE
CCI-001610	IA-5(g)	LOW	Table G-4 (Designer)	TRUE
CCI-000183	IA-5(h)	LOW	None (Non-Designer)	TRUE
CCI-002042	IA-5(h)	LOW	None (Non-Designer)	TRUE
CCI-002366	IA-5(i)	LOW	None (Non-Designer)	TRUE
CCI-002365	IA-5(i)	LOW	None (Non-Designer)	TRUE
CCI-001990	IA-5(j)	LOW	Table G-6 (Enclave)	TRUE
CCI-000192	IA-5(1)(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000193	IA-5(1)(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000194	IA-5(1)(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000205	IA-5(1)(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001619	IA-5(1)(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001611	IA-5(1)(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001612	IA-5(1)(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001613	IA-5(1)(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001614	IA-5(1)(a)	LOW	Table G-4 (Designer)	TRUE
CCI-000195	IA-5(1)(b)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001615	IA-5(1)(b)	LOW	Table G-4 (Designer)	TRUE
CCI-000196	IA-5(1)(c)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000197	IA-5(1)(c)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000198	IA-5(1)(d)	LOW	Table G-4 (Designer)	TRUE
CCI-000199	IA-5(1)(d)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001616	IA-5(1)(d)	LOW	Table G-4 (Designer)	TRUE
CCI-001617	IA-5(1)(d)	LOW	Table G-4 (Designer)	TRUE
CCI-001618	IA-5(1)(e)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000200	IA-5(1)(e)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002041	IA-5(1)(f)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000185	IA-5(2)(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000186	IA-5(2)(b)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000187	IA-5(2)(c)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001991	IA-5(2)(d)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001992	IA-5(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-001993	IA-5(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-001994	IA-5(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-001995	IA-5(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-001996	IA-5(4)	MOD	Table G-5 (Designer)	YES
CCI-001997	IA-5(4)	MOD	Table G-5 (Designer)	YES
CCI-000202	IA-5(7)	MOD	None (Non-Designer)	YES
CCI-000203	IA-5(7)	MOD	None (Non-Designer)	YES
CCI-002367	IA-5(7)	MOD	None (Non-Designer)	YES
CCI-000204	IA-5(8)	MOD	None (Non-Designer)	YES
CCI-001621	IA-5(8)	MOD	None (Non-Designer)	YES
CCI-002002	IA-5(11)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002003	IA-5(11)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002007	IA-5(13)	MOD	Table G-5 (Designer)	YES
CCI-002006	IA-5(13)	MOD	None (Non-Designer)	YES
CCI-002008	IA-5(14)	MOD	None (Non-Designer)	YES
CCI-000206	IA-6	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000803	IA-7	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000804	IA-8	LOW	Table G-6 (Enclave)	TRUE
CCI-002009	IA-8(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-002010	IA-8(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-002011	IA-8(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-002012	IA-8(3)	LOW	None (Non-Designer)	TRUE
CCI-002013	IA-8(3)	LOW	Table G-6 (Enclave)	TRUE
CCI-002014	IA-8(4)	LOW	Table G-6 (Enclave)	TRUE
CCI-002776	IR-1(a)	LOW	None (Non-Designer)	TRUE
CCI-002777	IR-1(a)	LOW		TRUE
CCI-000805	IR-1(a)(1)	LOW		TRUE
CCI-000806	IR-1(a)(1)	LOW		TRUE
CCI-000809	IR-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000810	IR-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000808	IR-1(b)(1)	LOW		TRUE
CCI-000807	IR-1(b)(1)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-000812	IR-1(b)(2)	LOW		TRUE
CCI-000811	IR-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-002778	IR-2(a)	LOW		TRUE
CCI-000813	IR-2(a)	LOW	None (Non-Designer)	TRUE
CCI-002779	IR-2(b)	LOW	None (Non-Designer)	TRUE
CCI-000814	IR-2(c)	LOW	None (Non-Designer)	TRUE
CCI-000815	IR-2(c)	LOW		TRUE
CCI-000818	IR-3	MOD	None (Non-Designer)	TRUE
CCI-000819	IR-3	MOD		TRUE
CCI-000820	IR-3	MOD		TRUE
CCI-001624	IR-3	MOD	None (Non-Designer)	TRUE
CCI-002780	IR-3(2)	MOD	None (Non-Designer)	TRUE
CCI-000822	IR-4(a)	LOW	None (Non-Designer)	TRUE
CCI-000823	IR-4(b)	LOW	None (Non-Designer)	TRUE
CCI-000824	IR-4(c)	LOW	None (Non-Designer)	TRUE
CCI-001625	IR-4(c)	LOW	None (Non-Designer)	TRUE
CCI-000825	IR-4(1)	MOD	None (Non-Designer)	TRUE
CCI-000827	IR-4(3)	MOD	None (Non-Designer)	YES
CCI-000828	IR-4(3)	MOD	None (Non-Designer)	YES
CCI-000829	IR-4(4)	MOD	None (Non-Designer)	YES
CCI-002782	IR-4(6)	MOD	None (Non-Designer)	YES
CCI-002783	IR-4(7)	MOD	None (Non-Designer)	YES
CCI-002784	IR-4(7)	MOD	None (Non-Designer)	YES
CCI-002785	IR-4(8)	MOD	None (Non-Designer)	YES
CCI-002786	IR-4(8)	MOD	None (Non-Designer)	YES
CCI-002787	IR-4(8)	MOD	None (Non-Designer)	YES
CCI-000832	IR-5	LOW	None (Non-Designer)	TRUE
CCI-000834	IR-6(a)	LOW	None (Non-Designer)	TRUE
CCI-000835	IR-6(a)	LOW	None (Non-Designer)	TRUE
CCI-000836	IR-6(b)	LOW	None (Non-Designer)	TRUE
CCI-002791	IR-6(b)	LOW		TRUE
CCI-000837	IR-6(1)	MOD	None (Non-Designer)	TRUE
CCI-000838	IR-6(2)	MOD	None (Non-Designer)	YES
CCI-002792	IR-6(2)	MOD	None (Non-Designer)	YES
CCI-000839	IR-7	LOW	None (Non-Designer)	TRUE
CCI-000840	IR-7(1)	MOD	None (Non-Designer)	TRUE
CCI-000841	IR-7(2)(a)	MOD	None (Non-Designer)	YES
CCI-000842	IR-7(2)(b)	MOD	None (Non-Designer)	YES
CCI-002794	IR-8(a)	LOW	None (Non-Designer)	TRUE
CCI-002795	IR-8(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-002796	IR-8(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-002797	IR-8(a)(3)	LOW	None (Non-Designer)	TRUE
CCI-002798	IR-8(a)(4)	LOW	None (Non-Designer)	TRUE
CCI-002799	IR-8(a)(5)	LOW	None (Non-Designer)	TRUE
CCI-002800	IR-8(a)(6)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-002801	IR-8(a)(7)	LOW	None (Non-Designer)	TRUE
CCI-002802	IR-8(a)(8)	LOW		TRUE
CCI-000844	IR-8(a)(8)	LOW	None (Non-Designer)	TRUE
CCI-000845	IR-8(b)	LOW		TRUE
CCI-000846	IR-8(b)	LOW	None (Non-Designer)	TRUE
CCI-000847	IR-8(c)	LOW		TRUE
CCI-000848	IR-8(c)	LOW		TRUE
CCI-000849	IR-8(d)	LOW	None (Non-Designer)	TRUE
CCI-002803	IR-8(e)	LOW		TRUE
CCI-000850	IR-8(e)	LOW	None (Non-Designer)	TRUE
CCI-002804	IR-8(f)	LOW	None (Non-Designer)	TRUE
CCI-002805	IR-9(a)	MOD	None (Non-Designer)	YES
CCI-002806	IR-9(b)	MOD	None (Non-Designer)	YES
CCI-002807	IR-9(b)	MOD	None (Non-Designer)	YES
CCI-002808	IR-9(c)	MOD	None (Non-Designer)	YES
CCI-002809	IR-9(d)	MOD	None (Non-Designer)	YES
CCI-002810	IR-9(e)	MOD	None (Non-Designer)	YES
CCI-002811	IR-9(f)	MOD	None (Non-Designer)	YES
CCI-002812	IR-9(f)	MOD	None (Non-Designer)	YES
CCI-002813	IR-9(1)	MOD	None (Non-Designer)	YES
CCI-002815	IR-9(1)	MOD	None (Non-Designer)	YES
CCI-002816	IR-9(2)	MOD	None (Non-Designer)	YES
CCI-002817	IR-9(2)	MOD	None (Non-Designer)	YES
CCI-002818	IR-9(3)	MOD	None (Non-Designer)	YES
CCI-002819	IR-9(3)	MOD	None (Non-Designer)	YES
CCI-002820	IR-9(4)	MOD	None (Non-Designer)	YES
CCI-002821	IR-9(4)	MOD	None (Non-Designer)	YES
CCI-002822	IR-10	MOD	None (Non-Designer)	YES
CCI-002861	MA-1(a)	LOW		TRUE
CCI-002862	MA-1(a)	LOW		TRUE
CCI-000852	MA-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000853	MA-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000855	MA-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000856	MA-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000851	MA-1(b)(1)	LOW		TRUE
CCI-000854	MA-1(b)(1)	LOW	None (Non-Designer)	TRUE
CCI-001628	MA-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-000857	MA-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-002870	MA-2(a)	LOW	None (Non-Designer)	TRUE
CCI-002866	MA-2(a)	LOW	None (Non-Designer)	TRUE
CCI-002872	MA-2(a)	LOW	None (Non-Designer)	TRUE
CCI-002868	MA-2(a)	LOW	None (Non-Designer)	TRUE
CCI-002873	MA-2(a)	LOW	None (Non-Designer)	TRUE
CCI-002869	MA-2(a)	LOW	None (Non-Designer)	TRUE
CCI-002871	MA-2(a)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002867	MA-2(a)	LOW	None (Non-Designer)	TRUE
CCI-000859	MA-2(b)	LOW	None (Non-Designer)	TRUE
CCI-002874	MA-2(c)	LOW	None (Non-Designer)	TRUE
CCI-000860	MA-2(c)	LOW	None (Non-Designer)	TRUE
CCI-000861	MA-2(d)	LOW	None (Non-Designer)	TRUE
CCI-000862	MA-2(e)	LOW	None (Non-Designer)	TRUE
CCI-002876	MA-2(f)	LOW	None (Non-Designer)	TRUE
CCI-002875	MA-2(f)	LOW	None (Non-Designer)	TRUE
CCI-000865	MA-3	MOD	Table G-5 (Designer)	TRUE
CCI-000866	MA-3	MOD	None (Non-Designer)	TRUE
CCI-000867	MA-3	MOD	None (Non-Designer)	TRUE
CCI-000869	MA-3(1)	MOD	None (Non-Designer)	TRUE
CCI-000870	MA-3(2)	MOD	None (Non-Designer)	TRUE
CCI-000871	MA-3(3)(a)	MOD	None (Non-Designer)	YES
CCI-002882	MA-3(3)(d)	MOD	None (Non-Designer)	YES
CCI-000873	MA-4(a)	LOW	None (Non-Designer)	TRUE
CCI-000874	MA-4(a)	LOW	None (Non-Designer)	TRUE
CCI-000876	MA-4(b)	LOW	None (Non-Designer)	TRUE
CCI-000877	MA-4(c)	LOW	None (Non-Designer)	TRUE
CCI-000878	MA-4(d)	LOW	None (Non-Designer)	TRUE
CCI-000879	MA-4(e)	LOW	None (Non-Designer)	TRUE
CCI-002884	MA-4(1)(a)	MOD	None (Non-Designer)	YES
CCI-002885	MA-4(1)(a)	MOD	None (Non-Designer)	YES
CCI-002886	MA-4(1)(b)	MOD	None (Non-Designer)	YES
CCI-000881	MA-4(2)	MOD	None (Non-Designer)	TRUE
CCI-000882	MA-4(3)(a)	MOD	None (Non-Designer)	YES
CCI-000883	MA-4(3)(b)	MOD	None (Non-Designer)	YES
CCI-001631	MA-4(3)(b)	MOD	None (Non-Designer)	YES
CCI-002890	MA-4(6)	MOD	Table G-7 (Enclave)	YES
CCI-003123	MA-4(6)	MOD	Table G-7 (Enclave)	YES
CCI-002891	MA-4(7)	MOD	Table G-7 (Enclave)	YES
CCI-000890	MA-5(a)	LOW	None (Non-Designer)	TRUE
CCI-000891	MA-5(a)	LOW	None (Non-Designer)	TRUE
CCI-002894	MA-5(b)	LOW	None (Non-Designer)	TRUE
CCI-002895	MA-5(c)	LOW	None (Non-Designer)	TRUE
CCI-000903	MA-6	MOD	None (Non-Designer)	TRUE
CCI-002896	MA-6	MOD	None (Non-Designer)	TRUE
CCI-002897	MA-6	MOD		TRUE
CCI-002566	MP-1(a)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-000995	MP-1(a)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-000996	MP-1(a)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-000999	MP-1(a)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-001000	MP-1(a)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-000998	MP-1(b)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-000997	MP-1(b)(1)	LOW	Table G-6 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-001002	MP-1(b)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-001001	MP-1(b)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-001003	MP-2	LOW	Table G-6 (Enclave)	TRUE
CCI-001004	MP-2	LOW	Table G-6 (Enclave)	TRUE
CCI-001005	MP-2	LOW	Table G-6 (Enclave)	TRUE
CCI-001010	MP-3(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-001011	MP-3(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-001012	MP-3(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-001013	MP-3(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-001014	MP-4(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-001015	MP-4(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-001016	MP-4(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-001018	MP-4(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-001020	MP-5(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-001021	MP-5(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-001022	MP-5(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-001023	MP-5(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-001025	MP-5(c)	MOD	Table G-7 (Enclave)	TRUE
CCI-001024	MP-5(d)	MOD	Table G-7 (Enclave)	TRUE
CCI-001027	MP-5(4)	MOD	Table G-7 (Enclave)	TRUE
CCI-001028	MP-6(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002578	MP-6(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002579	MP-6(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002580	MP-6(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-002581	MP-7	LOW	Table G-6 (Enclave)	TRUE
CCI-002582	MP-7	LOW	Table G-6 (Enclave)	TRUE
CCI-002583	MP-7	LOW	Table G-6 (Enclave)	TRUE
CCI-002584	MP-7	LOW	Table G-6 (Enclave)	TRUE
CCI-002585	MP-7(1)	MOD	Table G-7 (Enclave)	TRUE
CCI-002908	PE-1(a)	LOW	None (Non-Designer)	TRUE
CCI-002909	PE-1(a)	LOW	None (Non-Designer)	TRUE
CCI-000904	PE-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000905	PE-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000908	PE-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000909	PE-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000907	PE-1(b)(1)	LOW		TRUE
CCI-000906	PE-1(b)(1)	LOW	None (Non-Designer)	TRUE
CCI-000911	PE-1(b)(2)	LOW		TRUE
CCI-000910	PE-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-000912	PE-2(a)	LOW	None (Non-Designer)	TRUE
CCI-002910	PE-2(a)	LOW	None (Non-Designer)	TRUE
CCI-002911	PE-2(a)	LOW	None (Non-Designer)	TRUE
CCI-000913	PE-2(b)	LOW	None (Non-Designer)	TRUE
CCI-000914	PE-2(c)	LOW	None (Non-Designer)	TRUE
CCI-000915	PE-2(c)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-001635	PE-2(c)	LOW	None (Non-Designer)	TRUE
CCI-002915	PE-3(a)	LOW	None (Non-Designer)	TRUE
CCI-000919	PE-3(a)	LOW	None (Non-Designer)	TRUE
CCI-000920	PE-3(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-002916	PE-3(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-000921	PE-3(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-002918	PE-3(b)	LOW	None (Non-Designer)	TRUE
CCI-002917	PE-3(b)	LOW	None (Non-Designer)	TRUE
CCI-002920	PE-3(c)	LOW	None (Non-Designer)	TRUE
CCI-002919	PE-3(c)	LOW	None (Non-Designer)	TRUE
CCI-002922	PE-3(d)	LOW	None (Non-Designer)	TRUE
CCI-002921	PE-3(d)	LOW	None (Non-Designer)	TRUE
CCI-002924	PE-3(d)	LOW	None (Non-Designer)	TRUE
CCI-002923	PE-3(d)	LOW	None (Non-Designer)	TRUE
CCI-000923	PE-3(e)	LOW	None (Non-Designer)	TRUE
CCI-002925	PE-3(f)	LOW		TRUE
CCI-000925	PE-3(f)	LOW		TRUE
CCI-000924	PE-3(f)	LOW	None (Non-Designer)	TRUE
CCI-000927	PE-3(g)	LOW		TRUE
CCI-000926	PE-3(g)	LOW	None (Non-Designer)	TRUE
CCI-000928	PE-3(1)	MOD	Table G-5 (Designer)	YES
CCI-002926	PE-3(1)	MOD	Table G-5 (Designer)	YES
CCI-000936	PE-4	MOD	Table G-5 (Designer)	TRUE
CCI-002930	PE-4	MOD	Table G-5 (Designer)	TRUE
CCI-002931	PE-4	MOD	Table G-5 (Designer)	TRUE
CCI-000937	PE-5	MOD	Table G-5 (Designer)	TRUE
CCI-002939	PE-6(a)	LOW	None (Non-Designer)	TRUE
CCI-000940	PE-6(b)	LOW		TRUE
CCI-000939	PE-6(b)	LOW	None (Non-Designer)	TRUE
CCI-002941	PE-6(b)	LOW	None (Non-Designer)	TRUE
CCI-002940	PE-6(b)	LOW	None (Non-Designer)	TRUE
CCI-000941	PE-6(c)	LOW	None (Non-Designer)	TRUE
CCI-000942	PE-6(1)	MOD	None (Non-Designer)	TRUE
CCI-002950	PE-6(4)	MOD	None (Non-Designer)	TRUE
CCI-002951	PE-6(4)	MOD	None (Non-Designer)	TRUE
CCI-002952	PE-8(a)	LOW		TRUE
CCI-000947	PE-8(a)	LOW	None (Non-Designer)	TRUE
CCI-000949	PE-8(b)	LOW		TRUE
CCI-000948	PE-8(b)	LOW	None (Non-Designer)	TRUE
CCI-000952	PE-9	MOD	Table G-5 (Designer)	TRUE
CCI-000956	PE-10(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-000957	PE-10(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-000958	PE-10(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-000959	PE-10(c)	MOD	Table G-7 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002955	PE-11	LOW	Table G-3 (Removed from Low) Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000961	PE-11(1)	LOW	Table G-3 (Removed from Low) Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-000963	PE-12	LOW	Table G-2 (Not Applicable)	FALSE
CCI-000965	PE-13	LOW	Table G-6 (Enclave)	TRUE
CCI-000971	PE-14(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000972	PE-14(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000973	PE-14(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-000974	PE-14(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-000977	PE-15	LOW	Table G-6 (Enclave)	TRUE
CCI-000978	PE-15	LOW	Table G-6 (Enclave)	TRUE
CCI-000979	PE-15	LOW	Table G-6 (Enclave)	TRUE
CCI-000981	PE-16	LOW	Table G-6 (Enclave)	TRUE
CCI-000982	PE-16	LOW	Table G-6 (Enclave)	TRUE
CCI-000983	PE-16	LOW	Table G-6 (Enclave)	TRUE
CCI-000984	PE-16	LOW	Table G-6 (Enclave)	TRUE
CCI-002974	PE-16	LOW	Table G-6 (Enclave)	TRUE
CCI-003047	PL-1(a)	LOW	None (Non-Designer)	TRUE
CCI-003048	PL-1(a)	LOW	None (Non-Designer)	TRUE
CCI-000563	PL-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000564	PL-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-000566	PL-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-001636	PL-1(b)(1)	LOW		TRUE
CCI-001637	PL-1(b)(1)	LOW	None (Non-Designer)	TRUE
CCI-001638	PL-1(b)(2)	LOW		TRUE
CCI-000568	PL-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-000567	PL-1(b)(2)	LOW	None (Non-Designer)	TRUE
CCI-003049	PL-2(a)	LOW	None (Non-Designer)	TRUE
CCI-003050	PL-2(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-003052	PL-2(a)(3)	LOW	None (Non-Designer)	TRUE
CCI-003054	PL-2(a)(5)	LOW	None (Non-Designer)	TRUE
CCI-003055	PL-2(a)(6)	LOW	None (Non-Designer)	TRUE
CCI-003056	PL-2(a)(7)	LOW	None (Non-Designer)	TRUE
CCI-003057	PL-2(a)(8)	LOW	None (Non-Designer)	TRUE
CCI-000571	PL-2(a)(9)	LOW	None (Non-Designer)	TRUE
CCI-003059	PL-2(b)	LOW	None (Non-Designer)	TRUE
CCI-003060	PL-2(b)	LOW		TRUE
CCI-003061	PL-2(b)	LOW	None (Non-Designer)	TRUE
CCI-003062	PL-2(b)	LOW		TRUE
CCI-000572	PL-2(c)	LOW		TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-000573	PL-2(c)	LOW	None (Non-Designer)	TRUE
CCI-000574	PL-2(d)	LOW	None (Non-Designer)	TRUE
CCI-003063	PL-2(e)	LOW	None (Non-Designer)	TRUE
CCI-003064	PL-2(e)	LOW	None (Non-Designer)	TRUE
CCI-003051	PL-2(a)(2)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-003053	PL-2(a)(4)	LOW	Table G-4 (Designer)	TRUE
CCI-003065	PL-2(3)	LOW	None (Non-Designer)	TRUE
CCI-003067	PL-2(3)	LOW	None (Non-Designer)	TRUE
CCI-000592	PL-4(a)	LOW	None (Non-Designer)	TRUE
CCI-001639	PL-4(a)	LOW	None (Non-Designer)	TRUE
CCI-000593	PL-4(b)	LOW	None (Non-Designer)	TRUE
CCI-003069	PL-4(c)	LOW		TRUE
CCI-003068	PL-4(c)	LOW	None (Non-Designer)	TRUE
CCI-003070	PL-4(d)	LOW	None (Non-Designer)	TRUE
CCI-003074	PL-8(a)(2)	MOD	None (Non-Designer)	TRUE
CCI-003076	PL-8(b)	MOD	None (Non-Designer)	TRUE
CCI-003077	PL-8(b)	MOD		TRUE
CCI-003078	PL-8(c)	MOD	None (Non-Designer)	TRUE
CCI-003079	PL-8(c)	MOD	None (Non-Designer)	TRUE
CCI-003080	PL-8(c)	MOD	None (Non-Designer)	TRUE
CCI-003075	PL-8(a)(3)	MOD	Table G-5 (Designer)	TRUE
CCI-003072	PL-8(a)	MOD	Table G-5 (Designer)	TRUE
CCI-003073	PL-8(a)(1)	MOD	Table G-5 (Designer)	TRUE
CCI-003081	PL-8(1)(a)	MOD	Table G-5 (Designer)	YES
CCI-003082	PL-8(1)(a)	MOD	Table G-5 (Designer)	YES
CCI-003083	PL-8(1)(a)	MOD	Table G-5 (Designer)	YES
CCI-003084	PL-8(1)(a)	MOD	Table G-5 (Designer)	YES
CCI-003085	PL-8(1)(a)	MOD	Table G-5 (Designer)	YES
CCI-003086	PL-8(1)(a)	MOD	Table G-5 (Designer)	YES
CCI-003087	PL-8(1)(b)	MOD	Table G-5 (Designer)	YES
CCI-003017	PS-1(a)	LOW	None (Non-Designer)	TRUE
CCI-003018	PS-1(a)	LOW	None (Non-Designer)	TRUE
CCI-001504	PS-1(a)(1)	LOW		TRUE
CCI-001505	PS-1(a)(1)	LOW		TRUE
CCI-001509	PS-1(a)(2)	LOW		TRUE
CCI-001510	PS-1(a)(2)	LOW		TRUE
CCI-001507	PS-1(b)(1)	LOW		TRUE
CCI-001506	PS-1(b)(1)	LOW		TRUE
CCI-001508	PS-1(b)(2)	LOW		TRUE
CCI-001511	PS-1(b)(2)	LOW		TRUE
CCI-001512	PS-2(a)	LOW	None (Non-Designer)	TRUE
CCI-001513	PS-2(b)	LOW		TRUE
CCI-001514	PS-2(c)	LOW	None (Non-Designer)	TRUE
CCI-001515	PS-2(c)	LOW		TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-001516	PS-3(a)	LOW	None (Non-Designer)	TRUE
CCI-001517	PS-3(b)	LOW	None (Non-Designer)	TRUE
CCI-001518	PS-3(b)	LOW	None (Non-Designer)	TRUE
CCI-001519	PS-3(b)	LOW	None (Non-Designer)	TRUE
CCI-003022	PS-4(a)	LOW		TRUE
CCI-001522	PS-4(a)	LOW	None (Non-Designer)	TRUE
CCI-003023	PS-4(b)	LOW	None (Non-Designer)	TRUE
CCI-003024	PS-4(c)	LOW	None (Non-Designer)	TRUE
CCI-001523	PS-4(c)	LOW	None (Non-Designer)	TRUE
CCI-001524	PS-4(d)	LOW	None (Non-Designer)	TRUE
CCI-001525	PS-4(e)	LOW	None (Non-Designer)	TRUE
CCI-001526	PS-4(e)	LOW	None (Non-Designer)	TRUE
CCI-003025	PS-4(f)	LOW		TRUE
CCI-003026	PS-4(f)	LOW		TRUE
CCI-003016	PS-4(f)	LOW		TRUE
CCI-003027	PS-4(1)(a)	MOD	None (Non-Designer)	YES
CCI-003028	PS-4(1)(b)	MOD	None (Non-Designer)	YES
CCI-001527	PS-5(a)	LOW	None (Non-Designer)	TRUE
CCI-001528	PS-5(b)	LOW	None (Non-Designer)	TRUE
CCI-001529	PS-5(b)	LOW		TRUE
CCI-001530	PS-5(b)	LOW		TRUE
CCI-003031	PS-5(c)	LOW	None (Non-Designer)	TRUE
CCI-003032	PS-5(d)	LOW	None (Non-Designer)	TRUE
CCI-003033	PS-5(d)	LOW		TRUE
CCI-003034	PS-5(d)	LOW		TRUE
CCI-003035	PS-6(a)	LOW	None (Non-Designer)	TRUE
CCI-001533	PS-6(b)	LOW		TRUE
CCI-001532	PS-6(b)	LOW	None (Non-Designer)	TRUE
CCI-001531	PS-6(c)(1)	LOW	None (Non-Designer)	TRUE
CCI-003037	PS-6(c)(2)	LOW		TRUE
CCI-003036	PS-6(c)(2)	LOW	None (Non-Designer)	TRUE
CCI-003038	PS-6(3)(a)	MOD	None (Non-Designer)	YES
CCI-003039	PS-6(3)(b)	MOD	None (Non-Designer)	YES
CCI-001539	PS-7(a)	LOW		TRUE
CCI-003040	PS-7(b)	LOW	None (Non-Designer)	TRUE
CCI-001540	PS-7(c)	LOW	None (Non-Designer)	TRUE
CCI-003042	PS-7(d)	LOW		TRUE
CCI-003043	PS-7(d)	LOW		TRUE
CCI-003041	PS-7(d)	LOW	None (Non-Designer)	TRUE
CCI-001541	PS-7(e)	LOW	None (Non-Designer)	TRUE
CCI-001542	PS-8(a)	LOW	None (Non-Designer)	TRUE
CCI-003046	PS-8(b)	LOW		TRUE
CCI-003044	PS-8(b)	LOW	None (Non-Designer)	TRUE
CCI-003045	PS-8(b)	LOW		TRUE
CCI-002368	RA-1(a)	LOW		TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002369	RA-1(a)	LOW		TRUE
CCI-001037	RA-1(a)(1)	LOW		TRUE
CCI-001038	RA-1(a)(1)	LOW		TRUE
CCI-001041	RA-1(a)(2)	LOW		TRUE
CCI-001042	RA-1(a)(2)	LOW		TRUE
CCI-001039	RA-1(b)(1)	LOW		TRUE
CCI-001040	RA-1(b)(1)	LOW		TRUE
CCI-001043	RA-1(b)(2)	LOW		TRUE
CCI-001044	RA-1(b)(2)	LOW		TRUE
CCI-001045	RA-2(a)	LOW	None (Non-Designer)	TRUE
CCI-001046	RA-2(b)	LOW	None (Non-Designer)	TRUE
CCI-001047	RA-2(c)	LOW	None (Non-Designer)	TRUE
CCI-001048	RA-3(a)	LOW	Table G-4 (Designer)	TRUE
CCI-001642	RA-3(b)	LOW		TRUE
CCI-001049	RA-3(b)	LOW	None (Non-Designer)	TRUE
CCI-001050	RA-3(c)	LOW	None (Non-Designer)	TRUE
CCI-001051	RA-3(c)	LOW		TRUE
CCI-002371	RA-3(d)	LOW		TRUE
CCI-002370	RA-3(d)	LOW	None (Non-Designer)	TRUE
CCI-001052	RA-3(e)	LOW	None (Non-Designer)	TRUE
CCI-001053	RA-3(e)	LOW		TRUE
CCI-001055	RA-5(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001054	RA-5(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001056	RA-5(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001641	RA-5(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001643	RA-5(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001057	RA-5(b)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001058	RA-5(c)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001059	RA-5(d)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001060	RA-5(d)	LOW		TRUE
CCI-002376	RA-5(e)	LOW		TRUE
CCI-001061	RA-5(e)	LOW	None (Non-Designer)	TRUE
CCI-001062	RA-5(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001063	RA-5(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-001064	RA-5(2)	MOD		TRUE
CCI-001067	RA-5(5)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001645	RA-5(5)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002906	RA-5(5)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-003089	SA-1(a)	LOW	None (Non-Designer)	TRUE
CCI-003090	SA-1(a)	LOW	None (Non-Designer)	TRUE
CCI-000602	SA-1(a)(1)	LOW		TRUE
CCI-000603	SA-1(a)(1)	LOW		TRUE
CCI-000605	SA-1(a)(2)	LOW		TRUE
CCI-000606	SA-1(a)(2)	LOW		TRUE
CCI-000601	SA-1(b)(1)	LOW		TRUE
CCI-000604	SA-1(b)(1)	LOW		TRUE
CCI-001646	SA-1(b)(2)	LOW		TRUE
CCI-000607	SA-1(b)(2)	LOW		TRUE
CCI-003091	SA-2(a)	LOW	None (Non-Designer)	TRUE
CCI-000610	SA-2(b)	LOW	None (Non-Designer)	TRUE
CCI-000611	SA-2(b)	LOW	None (Non-Designer)	TRUE
CCI-000612	SA-2(b)	LOW	None (Non-Designer)	TRUE
CCI-000613	SA-2(c)	LOW	None (Non-Designer)	TRUE
CCI-000614	SA-2(c)	LOW	None (Non-Designer)	TRUE
CCI-003092	SA-3(a)	LOW	None (Non-Designer)	TRUE
CCI-000615	SA-3(a)	LOW	None (Non-Designer)	TRUE
CCI-000616	SA-3(b)	LOW	None (Non-Designer)	TRUE
CCI-000618	SA-3(c)	LOW	None (Non-Designer)	TRUE
CCI-003093	SA-3(d)	LOW	None (Non-Designer)	TRUE
CCI-003094	SA-4(a)	LOW	None (Non-Designer)	TRUE
CCI-003095	SA-4(b)	LOW	None (Non-Designer)	TRUE
CCI-003096	SA-4(c)	LOW	None (Non-Designer)	TRUE
CCI-003097	SA-4(d)	LOW	None (Non-Designer)	TRUE
CCI-003098	SA-4(e)	LOW	None (Non-Designer)	TRUE
CCI-003099	SA-4(f)	LOW	None (Non-Designer)	TRUE
CCI-003100	SA-4(g)	LOW	None (Non-Designer)	TRUE
CCI-000623	SA-4(1)	MOD	Table G-5 (Designer)	TRUE
CCI-003101	SA-4(2)	MOD	Table G-5 (Designer)	TRUE
CCI-003102	SA-4(2)	MOD	Table G-5 (Designer)	TRUE
CCI-003103	SA-4(2)	MOD	Table G-5 (Designer)	TRUE
CCI-003104	SA-4(2)	MOD	Table G-5 (Designer)	TRUE
CCI-003105	SA-4(2)	MOD	Table G-5 (Designer)	TRUE
CCI-003106	SA-4(2)	MOD	Table G-5 (Designer)	TRUE
CCI-000634	SA-4(7)(a)	MOD	Table G-7 (Enclave)	YES
CCI-000635	SA-4(7)(b)	MOD	Table G-7 (Enclave)	YES
CCI-003114	SA-4(9)	MOD	Table G-5 (Designer)	TRUE
CCI-003116	SA-4(10)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-000642	SA-5(c)	LOW	None (Non-Designer)	TRUE
CCI-003132	SA-5(c)	LOW	None (Non-Designer)	TRUE
CCI-003133	SA-5(c)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-003134	SA-5(d)	LOW	None (Non-Designer)	TRUE
CCI-003135	SA-5(e)	LOW	None (Non-Designer)	TRUE
CCI-003136	SA-5(e)	LOW		TRUE
CCI-003126	SA-5(a)(1)	LOW	Table G-4 (Designer)	TRUE
CCI-003124	SA-5(a)(1)	LOW	Table G-4 (Designer)	TRUE
CCI-003128	SA-5(a)(3)	LOW	Table G-4 (Designer)	TRUE
CCI-003130	SA-5(b)(2)	LOW	Table G-4 (Designer)	TRUE
CCI-003125	SA-5(a)(1)	LOW	Table G-4 (Designer)	TRUE
CCI-003129	SA-5(b)(1)	LOW	Table G-4 (Designer)	TRUE
CCI-003131	SA-5(b)(3)	LOW	Table G-4 (Designer)	TRUE
CCI-003127	SA-5(a)(2)	LOW	Table G-4 (Designer)	TRUE
CCI-000664	SA-8	MOD	None (Non-Designer)	TRUE
CCI-000665	SA-8	MOD	None (Non-Designer)	TRUE
CCI-000666	SA-8	MOD	None (Non-Designer)	TRUE
CCI-000667	SA-8	MOD	None (Non-Designer)	TRUE
CCI-000668	SA-8	MOD	None (Non-Designer)	TRUE
CCI-003137	SA-9(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000669	SA-9(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000670	SA-9(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000671	SA-9(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-000672	SA-9(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-000673	SA-9(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-000674	SA-9(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-003138	SA-9(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-003139	SA-9(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-003140	SA-9(1)(a)	MOD	None (Non-Designer)	YES
CCI-003141	SA-9(1)(b)	MOD	None (Non-Designer)	YES
CCI-003142	SA-9(1)(b)	MOD	None (Non-Designer)	YES
CCI-003143	SA-9(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-003144	SA-9(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-003155	SA-10(a)	MOD	Table G-5 (Designer)	TRUE
CCI-003156	SA-10(b)	MOD	Table G-5 (Designer)	TRUE
CCI-003157	SA-10(b)	MOD	Table G-5 (Designer)	TRUE
CCI-003158	SA-10(b)	MOD	Table G-5 (Designer)	TRUE
CCI-003159	SA-10(b)	MOD	Table G-5 (Designer)	TRUE
CCI-000692	SA-10(c)	MOD	Table G-5 (Designer)	TRUE
CCI-000694	SA-10(d)	MOD	Table G-5 (Designer)	TRUE
CCI-003160	SA-10(d)	MOD	Table G-5 (Designer)	TRUE
CCI-003161	SA-10(e)	MOD	Table G-5 (Designer)	TRUE
CCI-003162	SA-10(e)	MOD	Table G-5 (Designer)	TRUE
CCI-003163	SA-10(e)	MOD	Table G-5 (Designer)	TRUE
CCI-003164	SA-10(e)	MOD	None (Non-Designer)	TRUE
CCI-000698	SA-10(1)	MOD	None (Non-Designer)	YES
CCI-003171	SA-11(a)	MOD	Table G-5 (Designer)	TRUE
CCI-003172	SA-11(a)	MOD	Table G-5 (Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-003173	SA-11(b)	MOD	Table G-5 (Designer)	TRUE
CCI-003174	SA-11(b)	MOD	Table G-5 (Designer)	TRUE
CCI-003175	SA-11(c)	MOD	Table G-5 (Designer)	TRUE
CCI-003176	SA-11(c)	MOD	Table G-5 (Designer)	TRUE
CCI-003177	SA-11(d)	MOD	Table G-5 (Designer)	TRUE
CCI-003178	SA-11(e)	MOD	Table G-5 (Designer)	TRUE
CCI-000723	SA-12	MOD	None (Non-Designer)	YES
CCI-000722	SA-12	MOD	None (Non-Designer)	YES
CCI-003233	SA-15	MOD	Table G-5 (Designer)	YES
CCI-003234	SA-15(a)(1)	MOD	Table G-5 (Designer)	YES
CCI-003235	SA-15(a)(2)	MOD	Table G-5 (Designer)	YES
CCI-003236	SA-15(a)(2)	MOD	Table G-5 (Designer)	YES
CCI-003237	SA-15(a)(3)	MOD	Table G-5 (Designer)	YES
CCI-003238	SA-15(a)(4)	MOD	Table G-5 (Designer)	YES
CCI-003239	SA-15(a)(4)	MOD	Table G-5 (Designer)	YES
CCI-003240	SA-15(a)(4)	MOD	Table G-5 (Designer)	YES
CCI-003241	SA-15(b)	MOD	None (Non-Designer)	YES
CCI-003242	SA-15(b)	MOD	None (Non-Designer)	YES
CCI-003243	SA-15(b)	MOD	None (Non-Designer)	YES
CCI-003244	SA-15(b)	MOD	None (Non-Designer)	YES
CCI-003245	SA-15(b)	MOD	None (Non-Designer)	YES
CCI-003246	SA-15(b)	MOD	None (Non-Designer)	YES
CCI-003356	SA-19(a)	MOD	None (Non-Designer)	YES
CCI-003357	SA-19(a)	MOD	None (Non-Designer)	YES
CCI-003358	SA-19(a)	MOD	None (Non-Designer)	YES
CCI-003359	SA-19(a)	MOD	None (Non-Designer)	YES
CCI-003360	SA-19(a)	MOD	None (Non-Designer)	YES
CCI-003361	SA-19(a)	MOD	None (Non-Designer)	YES
CCI-003362	SA-19(a)	MOD	None (Non-Designer)	YES
CCI-003363	SA-19(a)	MOD	None (Non-Designer)	YES
CCI-003364	SA-19(b)	MOD	None (Non-Designer)	YES
CCI-003365	SA-19(b)	MOD	None (Non-Designer)	YES
CCI-003366	SA-19(b)	MOD	None (Non-Designer)	YES
CCI-002380	SC-1(a)	LOW	None (Non-Designer)	TRUE
CCI-002378	SC-1(a)	LOW		TRUE
CCI-001074	SC-1(a)(1)	LOW		TRUE
CCI-001075	SC-1(a)(1)	LOW		TRUE
CCI-001078	SC-1(a)(2)	LOW		TRUE
CCI-001079	SC-1(a)(2)	LOW		TRUE
CCI-001077	SC-1(b)(1)	LOW		TRUE
CCI-001076	SC-1(b)(1)	LOW		TRUE
CCI-001081	SC-1(b)(2)	LOW		TRUE
CCI-001080	SC-1(b)(2)	LOW		TRUE
CCI-001082	SC-2	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-001090	SC-4	MOD	Table G-7 (Enclave)	TRUE
CCI-001093	SC-5	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002386	SC-5	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002385	SC-5	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-001094	SC-5(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-002387	SC-5(1)	MOD	None (Non-Designer)	YES
CCI-001095	SC-5(2)	MOD	Table G-5 (Designer)	YES
CCI-002388	SC-5(3)(a)	MOD	Table G-5 (Designer)	YES
CCI-002389	SC-5(3)(a)	MOD	None (Non-Designer)	YES
CCI-002390	SC-5(3)(b)	MOD	Table G-5 (Designer)	YES
CCI-002391	SC-5(3)(b)	MOD	None (Non-Designer)	YES
CCI-001097	SC-7(a)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002395	SC-7(b)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001098	SC-7(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-001101	SC-7(3)	MOD	Table G-7 (Enclave)	TRUE
CCI-001102	SC-7(4)(a)	MOD	Table G-7 (Enclave)	TRUE
CCI-001103	SC-7(4)(b)	MOD	Table G-7 (Enclave)	TRUE
CCI-002396	SC-7(4)(c)	MOD	Table G-7 (Enclave)	TRUE
CCI-001105	SC-7(4)(d)	MOD	Table G-7 (Enclave)	TRUE
CCI-001108	SC-7(4)(e)	MOD	Table G-7 (Enclave)	TRUE
CCI-001107	SC-7(4)(e)	MOD		TRUE
CCI-001106	SC-7(4)(e)	MOD	Table G-7 (Enclave)	TRUE
CCI-001109	SC-7(5)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002397	SC-7(7)	MOD	Table G-7 (Enclave)	TRUE
CCI-001113	SC-7(8)	MOD	Table G-7 (Enclave)	YES
CCI-001114	SC-7(8)	MOD	Table G-7 (Enclave)	YES
CCI-001112	SC-7(8)	MOD	Table G-7 (Enclave)	YES
CCI-002400	SC-7(9)(b)	MOD	Table G-5 (Designer)	YES
CCI-002398	SC-7(9)(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-002399	SC-7(9)(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-001116	SC-7(10)	MOD	None (Non-Designer)	YES
CCI-002403	SC-7(11)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-002401	SC-7(11)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-002402	SC-7(11)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-002404	SC-7(12)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002405	SC-7(12)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-002406	SC-7(12)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-001120	SC-7(13)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-001119	SC-7(13)	MOD	Table G-7 (Enclave)	YES
CCI-001121	SC-7(14)	MOD	Table G-7 (Enclave)	YES
CCI-001122	SC-7(14)	MOD	Table G-7 (Enclave)	YES
CCI-002407	SC-7(14)	MOD	Table G-7 (Enclave)	YES
CCI-001126	SC-7(18)	MOD	Table G-5 (Designer)	TRUE
CCI-002418	SC-8	MOD	Table G-5 (Designer)	TRUE
CCI-002419	SC-8(1)	MOD	Table G-5 (Designer)	TRUE
CCI-002421	SC-8(1)	MOD	Table G-5 (Designer)	TRUE
CCI-002420	SC-8(2)	MOD	Table G-5 (Designer)	YES
CCI-002422	SC-8(2)	MOD	Table G-5 (Designer)	YES
CCI-001133	SC-10	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001134	SC-10	MOD	Table G-5 (Designer)	TRUE
CCI-002428	SC-12	LOW	Table G-6 (Enclave)	TRUE
CCI-002429	SC-12	LOW	Table G-6 (Enclave)	TRUE
CCI-002430	SC-12	LOW	Table G-6 (Enclave)	TRUE
CCI-002431	SC-12	LOW	Table G-6 (Enclave)	TRUE
CCI-002432	SC-12	LOW	Table G-6 (Enclave)	TRUE
CCI-002433	SC-12	LOW	None (Non-Designer)	TRUE
CCI-002434	SC-12	LOW	None (Non-Designer)	TRUE
CCI-002435	SC-12	LOW	None (Non-Designer)	TRUE
CCI-002436	SC-12	LOW	None (Non-Designer)	TRUE
CCI-002437	SC-12	LOW	None (Non-Designer)	TRUE
CCI-002438	SC-12	LOW	None (Non-Designer)	TRUE
CCI-002439	SC-12	LOW	None (Non-Designer)	TRUE
CCI-002440	SC-12	LOW	None (Non-Designer)	TRUE
CCI-002441	SC-12	LOW	None (Non-Designer)	TRUE
CCI-002442	SC-12	LOW	None (Non-Designer)	TRUE
CCI-002449	SC-13	LOW	Table G-3 (Removed from Low) Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002450	SC-13	LOW	Table G-3 (Removed from Low) Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001150	SC-15(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-001151	SC-15(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-001152	SC-15(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-001159	SC-17	MOD	Table G-7 (Enclave)	TRUE
CCI-002456	SC-17	MOD	Table G-7 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-001160	SC-18(a)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001161	SC-18(b)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001162	SC-18(b)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001163	SC-18(c)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001164	SC-18(c)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001165	SC-18(c)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001166	SC-18(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-001662	SC-18(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-002457	SC-18(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-002458	SC-18(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	YES
CCI-001687	SC-18(2)	MOD	None (Non-Designer)	YES
CCI-001688	SC-18(2)	MOD	None (Non-Designer)	YES
CCI-001167	SC-18(2)	MOD	None (Non-Designer)	YES
CCI-001168	SC-18(2)	MOD	None (Non-Designer)	YES
CCI-001169	SC-18(3)	MOD	Table G-5 (Designer)	YES
CCI-001695	SC-18(3)	MOD	Table G-5 (Designer)	YES
CCI-002459	SC-18(3)	MOD	None (Non-Designer)	YES
CCI-001170	SC-18(4)	MOD	Table G-5 (Designer)	YES
CCI-002460	SC-18(4)	MOD	Table G-5 (Designer)	YES
CCI-001171	SC-18(4)	MOD	None (Non-Designer)	YES
CCI-001172	SC-18(4)	MOD	None (Non-Designer)	YES
CCI-001173	SC-19(a)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-001174	SC-19(a)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-001175	SC-19(b)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-001176	SC-19(b)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-001177	SC-19(b)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-001178	SC-20(a)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-002462	SC-20(a)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001179	SC-20(b)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001663	SC-20(b)	LOW	Table G-2 (Not Applicable)	FALSE
CCI-002465	SC-21	LOW	Table G-6 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002466	SC-21	LOW	Table G-6 (Enclave)	TRUE
CCI-002467	SC-21	LOW	Table G-6 (Enclave)	TRUE
CCI-002468	SC-21	LOW	Table G-6 (Enclave)	TRUE
CCI-001182	SC-22	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001183	SC-22	LOW	Table G-2 (Not Applicable)	FALSE
CCI-001184	SC-23	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-001185	SC-23(1)	MOD	Table G-5 (Designer)	YES
CCI-001188	SC-23(3)	MOD	Table G-5 (Designer)	YES
CCI-001664	SC-23(3)	MOD	Table G-5 (Designer)	YES
CCI-001189	SC-23(3)	MOD	None (Non-Designer)	YES
CCI-002470	SC-23(5)	MOD	Table G-5 (Designer)	YES
CCI-002469	SC-23(5)	MOD	None (Non-Designer)	YES
CCI-001190	SC-24	MOD	Table G-5 (Designer)	TRUE
CCI-001191	SC-24	MOD	Table G-5 (Designer)	TRUE
CCI-001192	SC-24	MOD	Table G-5 (Designer)	TRUE
CCI-001193	SC-24	MOD	Table G-5 (Designer)	TRUE
CCI-001665	SC-24	MOD	Table G-5 (Designer)	TRUE
CCI-001199	SC-28	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002472	SC-28	MOD	Table G-5 (Designer)	TRUE
CCI-002475	SC-28(1)	MOD	Table G-5 (Designer)	YES
CCI-002476	SC-28(1)	MOD	Table G-5 (Designer)	YES
CCI-002473	SC-28(1)	MOD	None (Non-Designer)	YES
CCI-002474	SC-28(1)	MOD	None (Non-Designer)	YES
CCI-002528	SC-38	MOD	None (Non-Designer)	YES
CCI-002529	SC-38	MOD	None (Non-Designer)	YES
CCI-002530	SC-39	LOW	Table G-4 (Designer)	TRUE
CCI-002544	SC-41	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002545	SC-41	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002546	SC-41	LOW	Table G-4 (Designer)	TRUE
CCI-002601	SI-1(a)	LOW		TRUE
CCI-001217	SI-1(a)(1)	LOW		TRUE
CCI-001218	SI-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-001220	SI-1(a)(2)	LOW		TRUE
CCI-001221	SI-1(a)(2)	LOW		TRUE
CCI-001223	SI-1(b)(1)	LOW		TRUE
CCI-001219	SI-1(b)(1)	LOW		TRUE
CCI-001224	SI-1(b)(2)	LOW		TRUE
CCI-001222	SI-1(b)(2)	LOW		TRUE
CCI-001225	SI-2(a)	LOW	None (Non-Designer)	TRUE
CCI-001226	SI-2(a)	LOW	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	800-53 Control Text Indicator	Applies At Or Above Impact	Table Reference	Applicable to a Control System?
CCI-001228	SI-2(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-001229	SI-2(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-002602	SI-2(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-002603	SI-2(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-002604	SI-2(c)	LOW		TRUE
CCI-002606	SI-2(c)	LOW		TRUE
CCI-002607	SI-2(c)	LOW	None (Non-Designer)	TRUE
CCI-001230	SI-2(d)	LOW	None (Non-Designer)	TRUE
CCI-001227	SI-2(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002605	SI-2(c)	LOW	None (Non-Designer)	TRUE
CCI-001231	SI-2(1)	MOD	None (Non-Designer)	YES
CCI-001234	SI-2(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-001233	SI-2(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-002615	SI-2(6)	MOD	None (Non-Designer)	YES
CCI-002616	SI-2(6)	MOD	None (Non-Designer)	YES
CCI-002617	SI-2(6)	MOD	None (Non-Designer)	YES
CCI-002618	SI-2(6)	MOD	None (Non-Designer)	YES
CCI-002619	SI-3(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002621	SI-3(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002620	SI-3(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-002622	SI-3(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-001240	SI-3(b)	LOW	None (Non-Designer)	TRUE
CCI-002623	SI-3(c)(1)	LOW	Table G-4 (Designer)	TRUE
CCI-001241	SI-3(c)(1)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002624	SI-3(c)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-001242	SI-3(c)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-001244	SI-3(c)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-001243	SI-3(c)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-001245	SI-3(d)	LOW	None (Non-Designer)	TRUE
CCI-001246	SI-3(1)	MOD	Table G-7 (Enclave)	TRUE
CCI-001247	SI-3(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-002634	SI-3(10)(a)	MOD	None (Non-Designer)	YES
CCI-002635	SI-3(10)(a)	MOD	None (Non-Designer)	YES
CCI-002636	SI-3(10)(a)	MOD	None (Non-Designer)	YES
CCI-002638	SI-3(10)(a)	MOD	None (Non-Designer)	YES
CCI-002639	SI-3(10)(b)	MOD	None (Non-Designer)	YES
CCI-002640	SI-3(10)(b)	MOD	None (Non-Designer)	YES
CCI-001253	SI-4(a)(1)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002641	SI-4(a)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-002642	SI-4(a)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-002643	SI-4(a)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-002644	SI-4(a)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-002645	SI-4(b)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002646	SI-4(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-001255	SI-4(c)	LOW	None (Non-Designer)	TRUE
CCI-001256	SI-4(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-002647	SI-4(d)	LOW	Table G-6 (Enclave)	TRUE
CCI-002648	SI-4(d)	LOW	Table G-6 (Enclave)	TRUE
CCI-002649	SI-4(d)	LOW	Table G-6 (Enclave)	TRUE
CCI-001257	SI-4(e)	LOW	Table G-6 (Enclave)	TRUE
CCI-001258	SI-4(f)	LOW	Table G-6 (Enclave)	TRUE
CCI-002650	SI-4(g)	LOW	Table G-6 (Enclave)	TRUE
CCI-002651	SI-4(g)	LOW	Table G-6 (Enclave)	TRUE
CCI-002652	SI-4(g)	LOW	Table G-6 (Enclave)	TRUE
CCI-002654	SI-4(g)	LOW	Table G-6 (Enclave)	TRUE
CCI-002655	SI-4(1)	MOD	Table G-7 (Enclave)	YES
CCI-002656	SI-4(1)	MOD	Table G-7 (Enclave)	YES
CCI-001260	SI-4(2)	MOD	Table G-7 (Enclave)	TRUE
CCI-002659	SI-4(4)	MOD	Table G-7 (Enclave)	TRUE
CCI-002660	SI-4(4)	MOD	Table G-7 (Enclave)	TRUE
CCI-002661	SI-4(4)	MOD	Table G-7 (Enclave)	TRUE
CCI-002662	SI-4(4)	MOD	Table G-7 (Enclave)	TRUE
CCI-001264	SI-4(5)	MOD	Table G-7 (Enclave)	TRUE
CCI-002663	SI-4(5)	MOD	Table G-7 (Enclave)	TRUE
CCI-002664	SI-4(5)	MOD	Table G-7 (Enclave)	TRUE
CCI-002665	SI-4(10)	MOD	None (Non-Designer)	YES
CCI-002666	SI-4(10)	MOD	None (Non-Designer)	YES
CCI-002667	SI-4(10)	MOD	None (Non-Designer)	YES
CCI-002668	SI-4(11)	MOD	None (Non-Designer)	YES
CCI-001273	SI-4(11)	MOD	Table G-7 (Enclave)	YES
CCI-001671	SI-4(11)	MOD	Table G-7 (Enclave)	YES
CCI-001275	SI-4(12)	MOD	None (Non-Designer)	YES
CCI-001274	SI-4(12)	MOD	None (Non-Designer)	YES
CCI-001673	SI-4(14)	MOD	Table G-7 (Enclave)	YES
CCI-001282	SI-4(15)	MOD	Table G-7 (Enclave)	YES
CCI-001283	SI-4(16)	MOD	None (Non-Designer)	YES
CCI-002673	SI-4(19)	MOD	None (Non-Designer)	YES
CCI-002674	SI-4(19)	MOD	None (Non-Designer)	YES
CCI-002675	SI-4(19)	MOD	None (Non-Designer)	YES
CCI-002676	SI-4(20)	MOD	None (Non-Designer)	YES
CCI-002677	SI-4(20)	MOD	None (Non-Designer)	YES
CCI-002681	SI-4(22)	MOD	None (Non-Designer)	YES
CCI-002682	SI-4(22)	MOD	None (Non-Designer)	YES
CCI-002683	SI-4(22)	MOD	Table G-7 (Enclave)	YES
CCI-002684	SI-4(22)	MOD	Table G-7 (Enclave)	YES
CCI-002686	SI-4(23)	MOD	Table G-5 (Designer)	YES
CCI-002685	SI-4(23)	MOD	Table G-7 (Enclave)	YES
CCI-002687	SI-4(23)	MOD	Table G-7 (Enclave)	YES

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-002692	SI-5(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-001285	SI-5(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-001286	SI-5(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-002693	SI-5(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-002694	SI-5(c)	LOW		TRUE
CCI-001288	SI-5(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-001287	SI-5(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-001289	SI-5(d)	LOW	Table G-6 (Enclave)	TRUE
CCI-002703	SI-7	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002704	SI-7	MOD	Table G-7 (Enclave)	TRUE
CCI-002705	SI-7(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002706	SI-7(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002707	SI-7(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002710	SI-7(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002711	SI-7(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002712	SI-7(1)	MOD	Table G-5 (Designer) Table G-7 (Enclave)	TRUE
CCI-002708	SI-7(1)	MOD	Table G-7 (Enclave)	TRUE
CCI-002709	SI-7(1)	MOD		TRUE
CCI-002719	SI-7(7)	MOD	Table G-7 (Enclave)	TRUE
CCI-002720	SI-7(7)	MOD	Table G-7 (Enclave)	TRUE
CCI-002723	SI-7(8)	MOD	Table G-5 (Designer)	YES
CCI-002724	SI-7(8)	MOD	Table G-5 (Designer)	YES
CCI-002722	SI-7(8)	MOD	None (Non-Designer)	YES
CCI-002721	SI-7(8)	MOD	None (Non-Designer)	YES
CCI-002738	SI-7(14)(b)	MOD	None (Non-Designer)	YES
CCI-002737	SI-7(14)(a)	MOD	Table G-5 (Designer)	YES
CCI-002741	SI-8(a)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-002742	SI-8(a)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-001306	SI-8(b)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-001307	SI-8(1)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-001308	SI-8(2)	MOD	Table G-2 (Not Applicable)	FALSE
CCI-002744	SI-10	MOD	Table G-5 (Designer)	TRUE
CCI-001310	SI-10	MOD	Table G-5 (Designer)	TRUE
CCI-002754	SI-10(3)	MOD	Table G-5 (Designer)	YES
CCI-001312	SI-11(a)	MOD	Table G-5 (Designer)	TRUE
CCI-002759	SI-11(b)	MOD	None (Non-Designer)	TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-001314	SI-11(b)	MOD	None (Non-Designer)	TRUE
CCI-001315	SI-12	LOW	None (Non-Designer)	TRUE
CCI-001678	SI-12	LOW	None (Non-Designer)	TRUE
CCI-002823	SI-16	MOD	Table G-7 (Enclave)	TRUE
CCI-002824	SI-16	MOD	Table G-7 (Enclave)	TRUE
CCI-002773	SI-17	LOW	Table G-4 (Designer)	TRUE
CCI-002774	SI-17	LOW	Table G-4 (Designer)	TRUE
CCI-002775	SI-17	LOW	Table G-4 (Designer)	TRUE
CCI-000073	PM-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-002985	PM-1(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-001680	PM-1(a)(2)	LOW		TRUE
CCI-002986	PM-1(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-002984	PM-1(a)(3)	LOW		TRUE
CCI-002987	PM-1(a)(3)	LOW	None (Non-Designer)	TRUE
CCI-000074	PM-1(a)(4)	LOW		TRUE
CCI-002988	PM-1(a)(4)	LOW	None (Non-Designer)	TRUE
CCI-000076	PM-1(b)	LOW		TRUE
CCI-000075	PM-1(b)	LOW	None (Non-Designer)	TRUE
CCI-000077	PM-1(c)	LOW	None (Non-Designer)	TRUE
CCI-002989	PM-1(d)	LOW	None (Non-Designer)	TRUE
CCI-002990	PM-1(d)	LOW	None (Non-Designer)	TRUE
CCI-000078	PM-2	LOW		TRUE
CCI-000080	PM-3(a)	LOW	Table G-6 (Enclave)	TRUE
CCI-000081	PM-3(b)	LOW	Table G-6 (Enclave)	TRUE
CCI-000141	PM-3(c)	LOW	Table G-6 (Enclave)	TRUE
CCI-002991	PM-4(a)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-000142	PM-4(a)(1)	LOW	Table G-6 (Enclave)	TRUE
CCI-000170	PM-4(a)(2)	LOW	Table G-6 (Enclave)	TRUE
CCI-002992	PM-4(a)(3)	LOW	Table G-6 (Enclave)	TRUE
CCI-002993	PM-4(b)	LOW	None (Non-Designer)	TRUE
CCI-000207	PM-5	LOW	Table G-4 (Designer)	TRUE
CCI-000209	PM-6	LOW		TRUE
CCI-000210	PM-6	LOW		TRUE
CCI-000211	PM-6	LOW	None (Non-Designer)	TRUE
CCI-000212	PM-7	LOW	None (Non-Designer)	TRUE
CCI-000216	PM-8	LOW	Table G-3 (Removed from Low)	TRUE
CCI-001640	PM-8	LOW	Table G-3 (Removed from Low)	TRUE
CCI-000227	PM-9(a)	LOW		TRUE
CCI-000228	PM-9(b)	LOW		TRUE
CCI-002994	PM-9(c)	LOW		TRUE
CCI-002995	PM-9(c)	LOW		TRUE
CCI-000229	PM-10(a)	LOW		TRUE
CCI-000230	PM-10(a)	LOW		TRUE

Table G-1 Summary of CCIs for LOW and MODERATE Impact Systems				
CCI #	**800-53 Control Text Indicator**	**Applies At Or Above Impact**	**Table Reference**	**Applicable to a Control System?**
CCI-000231	PM-10(a)	LOW		TRUE
CCI-000233	PM-10(b)	LOW		TRUE
CCI-000234	PM-10(c)	LOW		TRUE
CCI-000235	PM-11(a)	LOW		TRUE
CCI-000236	PM-11(b)	LOW	Table G-4 (Designer) Table G-6 (Enclave)	TRUE
CCI-002996	PM-12	LOW	None (Non-Designer)	TRUE
CCI-002997	PM-13	LOW		TRUE
CCI-002998	PM-14(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-002999	PM-14(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-003000	PM-14(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-003001	PM-14(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-003002	PM-14(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-003003	PM-14(a)(1)	LOW	None (Non-Designer)	TRUE
CCI-003004	PM-14(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-003005	PM-14(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-003006	PM-14(a)(2)	LOW	None (Non-Designer)	TRUE
CCI-003007	PM-14(b)	LOW	None (Non-Designer)	TRUE
CCI-003008	PM-14(b)	LOW	None (Non-Designer)	TRUE
CCI-003009	PM-14(b)	LOW	None (Non-Designer)	TRUE
CCI-003010	PM-15(a)	LOW	None (Non-Designer)	TRUE
CCI-003011	PM-15(b)	LOW	None (Non-Designer)	TRUE
CCI-003012	PM-15(c)	LOW	None (Non-Designer)	TRUE
CCI-003013	PM-16	LOW	None (Non-Designer)	TRUE

Table G-2 CCIs Not Applicable to Control Systems (CS)			
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Rationale for non- inclusion**
CCI-001384	AC-8(c)(1)	The information system, for publicly accessible systems, displays system use information organization-defined conditions before granting further access.	CS is not publically accessible
CCI-001385	AC-8(c)(2)	The information system, for publicly accessible systems, displays references, if any, to monitoring that are consistent with privacy accommodations for such systems that generally prohibit those activities.	CS is not publically accessible
CCI-001386	AC-8(c)(2)	The information system for publicly accessible systems displays references, if any, to recording that are consistent with privacy accommodations for such systems that generally prohibit those activities.	CS is not publically accessible
CCI-001387	AC-8(c)(2)	The information system for publicly accessible systems displays references, if any, to auditing that are consistent with privacy accommodations for such systems that generally prohibit those activities.	CS is not publically accessible
CCI-001388	AC-8(c)(3)	The information system, for publicly accessible systems, includes a description of the authorized uses of the system.	CS is not publically accessible
CCI-001473	AC-22(a)	The organization designates individuals authorized to post information onto a publicly accessible information system.	CS is not publically accessible
CCI-001474	AC-22(b)	The organization trains authorized individuals to ensure that publicly accessible information does not contain nonpublic information.	CS is not publically accessible
CCI-001475	AC-22(c)	The organization reviews the proposed content of information prior to posting onto the publicly accessible information system to ensure that nonpublic information is not included.	CS is not publically accessible
CCI-001476	AC-22(d)	The organization reviews the content on the publicly accessible information system for nonpublic information on an organization-defined frequency.	CS is not publically accessible
CCI-001477	AC-22(d)	The organization defines a frequency for reviewing the content on the publicly accessible information system for nonpublic information.	CS is not publically accessible
CCI-001478	AC-22(e)	The organization removes nonpublic information from the publicly accessible information system, if discovered.	CS is not publically accessible

Table G-2 CCIs Not Applicable to Control Systems (CS)			
CCI #	800-53 Control Text Indicator	CCI Definition	Rationale for non- inclusion
CCI-001739	CM-2(7)a	The organization issues organization-defined information systems, system components, or devices with organization-defined configurations to individuals traveling to locations the organization deems to be of significant risk.	CS aren't mobile.
CCI-001815	CM-2(7)b	The organization defines the security safeguards to be applied to devices when they return from areas of significant risk.	CS aren't mobile.
CCI-001816	CM-2(7)b	The organization applies organization-defined security safeguards to devices when individuals return from areas of significant risk.	CS aren't mobile.
CCI-000444	CP-2(a)(1)	The organization develops a contingency plan for the information system that identifies essential business functions.	CS are not business systems
CCI-000451	CP-2(a)(4)	The organization develops a contingency plan for the information system that addresses maintaining essential business functions despite an information system disruption.	CS are not business systems
CCI-000453	CP-2(a)(4)	The organization develops a contingency plan for the information system that addresses maintaining essential business functions despite an information system compromise.	CS are not business systems
CCI-000455	CP-2(a)(4)	The organization develops a contingency plan for the information system that addresses maintaining essential business functions despite an information system failure.	CS are not business systems
CCI-000474	CP-2(3)	The organization defines the time period for planning the resumption of essential business functions as a result of contingency plan activation.	CS are not business systems
CCI-000476	CP-2(3)	The organization plans for the resumption of essential business functions within the organization-defined time period of contingency plan activation.	CS are not business systems
CCI-002829	CP-2(8)	The organization identifies critical information system assets supporting essential business functions.	CS are not business systems
CCI-000514	CP-7(a)	The organization establishes an alternate processing site including necessary agreements to permit the transfer and resumption of organization-defined information system operations for essential business functions within organization-defined time period consistent with recovery time and recovery point objectives when the primary processing capabilities are unavailable.	CS are not business systems

Table G-2 CCIs Not Applicable to Control Systems (CS)			
CCI #	800-53 Control Text Indicator	CCI Definition	Rationale for non- inclusion
CCI-000523	CP-8	The organization defines the time period to permit the resumption of organization-defined information system operations for essential business functions when the primary telecommunications capabilities are unavailable at either the primary or alternate processing or storage sites.	CS are not business systems
CCI-000525	CP-8	The organization establishes alternate telecommunication services including necessary agreements to permit the resumption of organization-defined information system operations for essential business functions within organization-defined time period when the primary telecommunications capabilities are unavailable at either the primary or alternate processing or storage sites.	CS are not business systems
CCI-002841	CP-8	The organization defines the information system operations to be resumed for essential business functions within the organization-defined time period when the primary telecommunications capabilities are unavailable at either the primary or alternate processing or storage sites.	CS are not business systems
CCI-000963	PE-12	The organization employs and maintains automatic emergency lighting for the information system that activates in the event of a power outage or disruption and that covers emergency exits and evacuation routes within the facility.	CS does not need lighting, it functions perfectly well in the dark
CCI-002395	SC-7(b)	The information system implements subnetworks for publicly accessible system components that are physically and/or logically separated from internal organizational networks.	CS is not publically accessible
CCI-001173	SC-19(a)	The organization establishes usage restrictions for Voice over Internet Protocol (VoIP) technologies based on the potential to cause damage to the information system if used maliciously.	CS does not use VoIP
CCI-001174	SC-19(a)	The organization establishes implementation guidance for Voice over Internet Protocol (VoIP) technologies based on the potential to cause damage to the information system if used maliciously.	CS does not use VoIP
CCI-001175	SC-19(b)	The organization authorizes the use of VoIP within the information system.	CS does not use VoIP
CCI-001176	SC-19(b)	The organization monitors the use of VoIP within the information system.	CS does not use VoIP

Table G-2 CCIs Not Applicable to Control Systems (CS)			
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Rationale for non- inclusion**
CCI-001177	SC-19(b)	The organization controls the use of VoIP within the information system.	CS does not use VoIP
CCI-001178	SC-20(a)	The information system provides additional data origin authentication artifacts along with the authoritative name resolution data the system returns in response to external name/address resolution queries.	CS does not act as external DNS server
CCI-002462	SC-20(a)	The information system provides additional integrity verification artifacts along with the authoritative name resolution data the system returns in response to external name/address resolution queries.	CS does not act as external DNS server
CCI-001179	SC-20(b)	The information system, when operating as part of a distributed, hierarchical namespace, provides the means to indicate the security status of child zones.	CS does not act as external DNS server
CCI-001663	SC-20(b)	The information system, when operating as part of a distributed, hierarchical namespace, provides the means to enable verification of a chain of trust among parent and child domains (if the child supports secure resolution services).	CS does not act as external DNS server
CCI-001182	SC-22	The information systems that collectively provide name/address resolution service for an organization are fault-tolerant.	CS does not act as external DNS server
CCI-001183	SC-22	The information systems that collectively provide name/address resolution service for an organization implement internal/external role separation.	CS does not act as external DNS server
CCI-002741	SI-8(a)	The organization employs spam protection mechanisms at information system entry points to detect and take action on unsolicited messages.	While control systems may have outbound email for alarm, event and audit reporting, control systems don't use inbound email.
CCI-002742	SI-8(a)	The organization employs spam protection mechanisms at information system exit points to detect and take action on unsolicited messages.	While control systems may have outbound email for alarm, event and audit reporting, control systems don't use inbound email.
CCI-001306	SI-8(b)	The organization updates spam protection mechanisms when new releases are available in accordance with organizational configuration management policy and procedures.	While control systems may have outbound email for alarm, event and audit reporting, control systems don't use inbound email.
CCI-001307	SI-8(1)	The organization centrally manages spam protection mechanisms.	While control systems may have outbound email for alarm, event and audit reporting, control systems don't use inbound email.

Table G-2 CCIs Not Applicable to Control Systems (CS)			
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Rationale for non- inclusion**
CCI-001308	SI-8(2)	The information system automatically updates spam protection mechanisms .	While control systems may have outbound email for alarm, event and audit reporting, control systems don't use inbound email.

Table G-3 CCIs Removed from LOW Impact Control Systems Baseline			
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Rationale for non-inclusion**
CCI-000443	CP-2(a)(1)	The organization develops a contingency plan for the information system that identifies essential missions.	A LOW CS doesn't have any "essential" mission
CCI-000450	CP-2(a)(4)	The organization develops a contingency plan for the information system that addresses maintaining essential missions despite an information system disruption.	A LOW CS doesn't have any "essential" mission
CCI-000452	CP-2(a)(4)	The organization develops a contingency plan for the information system that addresses maintaining essential missions despite an information system compromise.	A LOW CS doesn't have any "essential" mission
CCI-000454	CP-2(a)(4)	The organization develops a contingency plan for the information system that addresses maintaining essential missions despite an information system failure.	A LOW CS doesn't have any "essential" mission
CCI-002955	PE-11	The organization provides a short-term uninterruptible power supply to facilitate an orderly shutdown of the information system and/or transition of the information system to long-term alternate power in the event of a primary power source loss.	NIST 800-53 does not have this in a LOW baseline. NIST 800-82 included it with the rationale "ICS may support critical activities....". By definition, a CS supporting "critical activities" is not a LOW system.
CCI-000961	PE-11(1)	The organization provides a long-term alternate power supply for the information system that is capable of maintaining minimally required operational capability in the event of an extended loss of the primary power source.	NIST 800-53 does not have this in a LOW baseline. NIST 800-82 included it with the rationale "ICS may support critical activities....". By definition, a CS supporting "critical activities" is not a LOW system.
CCI-002449	SC-13	The organization defines the cryptographic uses, and type of cryptography required for each use, to be implemented by the information system.	A LOW CS doesn't have any classified information
CCI-002450	SC-13	The information system implements organization-defined cryptographic uses and type of cryptography required for each use in accordance with applicable federal laws, Executive Orders, directives, policies, regulations, and standards.	A LOW CS doesn't have any classified information
CCI-000216	PM-8	The organization develops and documents a critical infrastructure and key resource protection plan that addresses information security issues.	A LOW Control System doesn't deal with critical infrastructure.
CCI-001640	PM-8	The organization updates the critical infrastructure and key resources protection plan that addresses information security issues.	A LOW Control System doesn't deal with critical infrastructure.

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002110	AC-2(a)	The organization defines the information system account types that support the organizational missions/business functions.	Designer	3.3.1 User Accounts
CCI-000213	AC-3	The information system enforces approved authorizations for logical access to information and system resources in accordance with applicable access control policies.	Designer	3.3.1 User Accounts
CCI-000043	AC-7(a)	The organization defines the maximum number of consecutive invalid logon attempts to the information system by a user during an organization-defined time period.	DoD-Defined Designer Impractical	3.3.2 Unsuccessful Logon Attempts
CCI-000044	AC-7(a)	The information system enforces the organization-defined limit of consecutive invalid logon attempts by a user during the organization-defined time period.	Designer	3.3.2 Unsuccessful Logon Attempts
CCI-001423	AC-7(a)	The organization defines the time period in which the organization-defined maximum number of consecutive invalid logon attempts occur.	DoD-Defined Designer Impractical	3.3.2 Unsuccessful Logon Attempts
CCI-002236	AC-7(b)	The organization defines the time period the information system will automatically lock the account or node when the maximum number of unsuccessful attempts is exceeded.	DoD-Defined Designer Impractical	3.3.2 Unsuccessful Logon Attempts
CCI-002237	AC-7(b)	The organization defines the delay algorithm to be employed by the information system to delay the next login prompt when the maximum number of unsuccessful attempts is exceeded.	DoD-Defined Designer Impractical	3.3.2 Unsuccessful Logon Attempts
CCI-002238	AC-7(b)	The information system automatically locks the account or node for either an organization-defined time period, until the locked account or node is released by an administrator, or delays the next login prompt according to the organization-defined delay algorithm when the maximum number of unsuccessful attempts is exceeded.	Designer Impractical	3.3.2 Unsuccessful Logon Attempts
CCI-002247	AC-8(a)	The organization defines the use notification message or banner the information system displays to users before granting access to the system.	DoD-Defined Enclave Designer Impractical	3.3.3 System Use Notification

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-000048	AC-8(a)	The information system displays an organization-defined system use notification message or banner before granting access to the system that provides privacy and security notices consistent with applicable federal laws, Executive Orders, directives, policies, regulations, standards, and guidance.	Enclave Designer Impractical	3.3.3 System Use Notification
CCI-002243	AC-8(a)(1)	The organization-defined information system use notification message or banner is to state that users are accessing a U.S. Government information system.	DoD-Defined Enclave Designer Impractical	3.3.3 System Use Notification
CCI-002244	AC-8(a)(2)	The organization-defined information system use notification message or banner is to state that information system usage may be monitored, recorded, and subject to audit.	DoD-Defined Enclave Designer Impractical	3.3.3 System Use Notification
CCI-002245	AC-8(a)(3)	The organization-defined information system use notification message or banner is to state that unauthorized use of the information system is prohibited and subject to criminal and civil penalties.	DoD-Defined Enclave Designer Impractical	3.3.3 System Use Notification
CCI-002246	AC-8(a)(4)	The organization-defined information system use notification message or banner is to state that use of the information system indicates consent to monitoring and recording.	DoD-Defined Enclave Designer Impractical	3.3.3 System Use Notification
CCI-000050	AC-8(b)	The information system retains the notification message or banner on the screen until users acknowledge the usage conditions and take explicit actions to log on to or further access.	Enclave Designer	3.3.3 System Use Notification
CCI-002248	AC-8(c)(1)	The organization defines the conditions of use which are to be displayed to users of the information system before granting further access.	DoD-Defined Enclave Designer Impractical	3.3.3 System Use Notification
CCI-000061	AC-14(a)	The organization identifies and defines organization-defined user actions that can be performed on the information system without identification or authentication consistent with organizational missions/business functions.	Designer	3.3.5 Permitted Actions Without Identific...
CCI-000232	AC-14(b)	The organization documents and provides supporting rationale in the security plan for the information	Designer	3.3.5 Permitted Actions Without Identific...

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
		system, user actions not requiring identification and authentication.		
CCI-001438	AC-18(a)	The organization establishes usage restrictions for wireless access.	Designer Non-Designer	3.2.3 Wireless and Wired Broadcast Commun...
CCI-002323	AC-18(a)	The organization establishes configuration/connection requirements for wireless access.	Designer Non-Designer	3.2.3 Wireless and Wired Broadcast Commun...
CCI-001439	AC-18(a)	The organization establishes implementation guidance for wireless access.	Designer Non-Designer	3.2.3 Wireless and Wired Broadcast Commun...
CCI-001441	AC-18(b)	The organization authorizes wireless access to the information system prior to allowing such connections.	Designer Non-Designer	3.2.3 Wireless and Wired Broadcast Commun...
CCI-000123	AU-2(a)	The organization determines the information system must be capable of auditing an organization-defined list of auditable events.	Designer Non-Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-001571	AU-2(a)	The organization defines the information system auditable events.	DoD-Defined Designer Impractical	3.5.1 Audit Events, Content of Audit Reco...
CCI-000125	AU-2(c)	The organization provides a rationale for why the list of auditable events is deemed to be adequate to support after-the-fact investigations of security incidents.	Designer Non-Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-001485	AU-2(d)	The organization defines the events which are to be audited on the information system on an organization-defined frequency of (or situation requiring) auditing for each identified event.	Designer Non-Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-000130	AU-3	The information system generates audit records containing information that establishes what type of event occurred.	Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-000131	AU-3	The information system generates audit records containing information that establishes when an event occurred.	Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-000132	AU-3	The information system generates audit records containing information that establishes where the event occurred.	Designer	3.5.1 Audit Events, Content of Audit Reco...

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-000133	AU-3	The information system generates audit records containing information that establishes the source of the event.	Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-000134	AU-3	The information system generates audit records containing information that establishes the outcome of the event.	Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-001487	AU-3	The information system generates audit records containing information that establishes the identity of any individuals or subjects associated with the event.	Designer Impractical	3.5.1 Audit Events, Content of Audit Reco...
CCI-001848	AU-4	The organization defines the audit record storage requirements.	Designer Non-Designer	3.5.4 Audit Storage Capacity and Audit Up...
CCI-001849	AU-4	The organization allocates audit record storage capacity in accordance with organization-defined audit record storage requirements.	Designer Non-Designer	3.5.4 Audit Storage Capacity and Audit Up...
CCI-000139	AU-5(a)	The information system alerts designated organization-defined personnel or roles in the event of an audit processing failure.	Enclave Designer Impractical	3.5.5 Response to Audit Processing Failur...
CCI-000140	AU-5(b)	The information system takes organization defined actions upon audit failure (e.g., shut down information system, overwrite oldest audit records, stop generating audit records).	Enclave Designer Impractical	3.5.5 Response to Audit Processing Failur...
CCI-001490	AU-5(b)	The organization defines actions to be taken by the information system upon audit failure (e.g., shut down information system, overwrite oldest audit records, stop generating audit records).	Enclave Designer Non-Designer Impractical	3.5.5 Response to Audit Processing Failur...
CCI-000159	AU-8(a)	The information system uses internal system clocks to generate time stamps for audit records.	Designer	3.5.2 Audit Time Stamps
CCI-001889	AU-8(b)	The information system records time stamps for audit records that meets organization-defined granularity of time measurement.	Designer	3.5.2 Audit Time Stamps
CCI-001890	AU-8(b)	The information system records time stamps for audit records that can be mapped to Coordinated Universal Time (UTC) or Greenwich Mean Time (GMT).	Designer	3.5.2 Audit Time Stamps

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-000169	AU-12(a)	The information system provides audit record generation capability for the auditable events defined in AU-2 a at organization defined information system components.	Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-001459	AU-12(a)	The organization defines information system components that provide audit record generation capability.	DoD-Defined Designer Impractical	3.5.1 Audit Events, Content of Audit Reco...
CCI-000171	AU-12(b)	The information system allows organization-defined personnel or roles to select which auditable events are to be audited by specific components of the information system.	Designer Impractical	3.5.1 Audit Events, Content of Audit Reco...
CCI-001910	AU-12(b)	The organization defines the personnel or roles allowed select which auditable events are to be audited by specific components of the information system.	DoD-Defined Designer Impractical	3.5.1 Audit Events, Content of Audit Reco...
CCI-000172	AU-12(c)	The information system generates audit records for the events defined in AU-2 d with the content defined in AU-3.	Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-000258	CA-3(b)	The organization documents, for each interconnection, the interface characteristics.	Enclave Designer Non-Designer	1.9.2 Cybersecurity Interconnection Sched... 1.11 CYBERSECURITY DURING CONSTRUCTION
CCI-002103	CA-9(b)	The organization documents, for each internal connection, the interface characteristics.	Designer	1.9.3 Network Communication Report
CCI-002104	CA-9(b)	The organization documents, for each internal connection, the security requirements.	Designer	1.9.3 Network Communication Report
CCI-002105	CA-9(b)	The organization documents, for each internal connection, the nature of the information communicated.	Designer	1.9.3 Network Communication Report
CCI-002102	CA-9(a)	The organization defines the information system components or classes of components that that are authorized internal connections to the information system.	Designer	1.9.3 Network Communication Report
CCI-000293	CM-2	The organization develops and documents a current baseline configuration of the information system.	Designer	---

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-000363	CM-6(a)	The organization defines security configuration checklists to be used to establish and document configuration settings for the information system technology products employed.	Designer	3.6 REQUIREMENTS FOR LEAST FUNCTIONALIT ...
CCI-000364	CM-6(a)	The organization establishes configuration settings for information technology products employed within the information system using organization-defined security configuration checklists.	Designer	3.6 REQUIREMENTS FOR LEAST FUNCTIONALIT ...
CCI-000365	CM-6(a)	The organization documents configuration settings for information technology products employed within the information system using organization-defined security configuration checklists that reflect the most restrictive mode consistent with operational requirements.	DoD-Defined Designer Non-Designer Impractical	3.6 REQUIREMENTS FOR LEAST FUNCTIONALIT ...
CCI-001755	CM-6(c)	The organization defines the information system components for which any deviation from the established configuration settings are to be identified, documented and approved.	DoD-Defined Designer Non-Designer Impractical	3.6 REQUIREMENTS FOR LEAST FUNCTIONALIT ...
CCI-001588	CM-6(a)	The organization-defined security configuration checklists reflect the most restrictive mode consistent with operational requirements.	DoD-Defined Designer Non-Designer Impractical	3.2.5 IP Control Networks 3.6 REQUIREMENTS FOR LEAST FUNCTIONALIT ...
CCI-000382	CM-7(b)	The organization configures the information system to prohibit or restrict the use of organization-defined functions, ports, protocols, and/or services.	Designer	3.2.5 IP Control Networks 3.6 REQUIREMENTS FOR LEAST FUNCTIONALIT ...
CCI-000380	CM-7(b)	The organization defines for the information system prohibited or restricted functions, ports, protocols, and/or services.	Designer	3.2.5 IP Control Networks 3.6 REQUIREMENTS FOR LEAST FUNCTIONALIT ...
CCI-000381	CM-7(a)	The organization configures the information system to provide only essential capabilities.	Designer	3.2.5 IP Control Networks 3.6 REQUIREMENTS FOR LEAST

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
				FUNCTIONALIT ...
CCI-001761	CM-7(1)(b)	The organization defines the functions, ports, protocols and services within the information system that are to be disabled when deemed unnecessary and/or nonsecure.	Designer	3.2.5 IP Control Networks 3.6 REQUIREMENT S FOR LEAST FUNCTIONALIT ...
CCI-001762	CM-7(1)(b)	The organization disables organization-defined functions, ports, protocols, and services within the information system deemed to be unnecessary and/or nonsecure.	Designer Impractical	3.2.5 IP Control Networks 3.6 REQUIREMENT S FOR LEAST FUNCTIONALIT ...
CCI-000389	CM-8(a)(1)	The organization develops and documents an inventory of information system components that accurately reflects the current information system.	Designer	1.9.4 Control System Inventory Report
CCI-000392	CM-8(a)(2)	The organization develops and documents an inventory of information system components that includes all components within the authorization boundary of the information system.	Designer	1.9.4 Control System Inventory Report
CCI-000398	CM-8(a)(4)	The organization defines information deemed necessary to achieve effective information system component accountability.	DoD-Defined Designer Non-Designer Impractical	1.9.4 Control System Inventory Report
CCI-000550	CP-10	The organization provides for the recovery and reconstitution of the information system to a known state after a disruption.	Enclave Designer Non-Designer	1.9.5 Software and Configuration Backups
CCI-000551	CP-10	The organization provides for the recovery and reconstitution of the information system to a known state after a compromise.	Enclave Designer Non-Designer	1.9.5 Software and Configuration Backups
CCI-000552	CP-10	The organization provides for the recovery and reconstitution of the information system to a known state after a failure.	Enclave Designer Non-Designer	1.9.5 Software and Configuration Backups
CCI-002855	CP-12	The information system, when organization-defined conditions are detected, enters a safe mode of operation with organization-defined restrictions of safe mode of operation.	Designer	3.8 SAFE MODE AND FAIL SAFE OPERATION

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002856	CP-12	The organization defines the conditions, that when detected, the information system enters a safe mode of operation with organization-defined restrictions of safe mode of operation.	Designer	3.8 SAFE MODE AND FAIL SAFE OPERATION
CCI-002857	CP-12	The organization defines the restrictions of safe mode of operation that the information system will enter when organization-defined conditions are detected.	Designer	3.8 SAFE MODE AND FAIL SAFE OPERATION
CCI-000764	IA-2	The information system uniquely identifies and authenticates organizational users (or processes acting on behalf of organizational users).	Enclave Designer Impractical	3.3.1 User Accounts 3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000765	IA-2(1)	The information system implements multifactor authentication for network access to privileged accounts.	Enclave Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-001953	IA-2(12)	The information system accepts Personal Identity Verification (PIV) credentials.	Enclave Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-001954	IA-2(12)	The information system electronically verifies Personal Identity Verification (PIV) credentials.	Enclave Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000777	IA-3	The organization defines a list of specific and/or types of devices for which identification and authentication is required before establishing a connection to the information system.	DoD-Defined Enclave Designer Impractical	1.9.4 Control System Inventory Report 3.2.7 Device Identification and Authentic...
CCI-000778	IA-3	The information system uniquely identifies an organization defined list of specific and/or types of devices before establishing a local, remote, or network connection.	Enclave Designer Impractical	1.9.4 Control System Inventory Report 3.2.7 Device Identification and Authentic...
CCI-001958	IA-3	The information system authenticates an organization defined list of specific and/or types of devices before establishing a local, remote, or network connection.	Enclave Designer Impractical	1.9.4 Control System Inventory Report 3.2.7 Device Identification and Authentic...

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-000176	IA-5(b)	The organization manages information system authenticators by establishing initial authenticator content for authenticators defined by the organization.	Designer Non-Designer	---
CCI-001544	IA-5(c)	The organization manages information system authenticators by ensuring that authenticators have sufficient strength of mechanism for their intended use.	Designer Non-Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-001989	IA-5(e)	The organization manages information system authenticators by changing default content of authenticators prior to information system installation.	Designer	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000182	IA-5(g)	The organization manages information system authenticators by changing/refreshing authenticators in accordance with the organization defined time period by authenticator type.	DoD-Defined Designer Non-Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-001610	IA-5(g)	The organization defines the time period (by authenticator type) for changing/refreshing authenticators.	DoD-Defined Designer Non-Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000192	IA-5(1)(a)	The information system enforces password complexity by the minimum number of upper case characters used.	Enclave Designer	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000193	IA-5(1)(a)	The information system enforces password complexity by the minimum number of lower case characters used.	Enclave Designer	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000194	IA-5(1)(a)	The information system enforces password complexity by the minimum number of numeric characters used.	Enclave Designer	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000205	IA-5(1)(a)	The information system enforces minimum password length.	Enclave Designer	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-001619	IA-5(1)(a)	The information system enforces password complexity by the minimum number of special characters used.	Enclave Designer	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-001611	IA-5(1)(a)	The organization defines the minimum number of special characters for password complexity enforcement.	DoD-Defined Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-001612	IA-5(1)(a)	The organization defines the minimum number of upper case characters for password complexity enforcement.	DoD-Defined Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-001613	IA-5(1)(a)	The organization defines the minimum number of lower case characters for password complexity enforcement.	DoD-Defined Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-001614	IA-5(1)(a)	The organization defines the minimum number of numeric characters for password complexity enforcement.	DoD-Defined Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000195	IA-5(1)(b)	The information system, for password-based authentication, when new passwords are created, enforces that at least an organization-defined number of characters are changed.	Enclave Designer	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-001615	IA-5(1)(b)	The organization defines the minimum number of characters that are changed when new passwords are created.	DoD-Defined Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000196	IA-5(1)(c)	The information system, for password-based authentication, stores only cryptographically-protected passwords.	Enclave Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000197	IA-5(1)(c)	The information system, for password-based authentication, transmits only cryptographically-protected passwords.	Enclave Designer	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000198	IA-5(1)(d)	The information system enforces minimum password lifetime restrictions.	Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...
CCI-000199	IA-5(1)(d)	The information system enforces maximum password lifetime restrictions.	Enclave Designer	3.4 USER IDENTIFICATIO N AND AUTHENTICAT...

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-001616	IA-5(1)(d)	The organization defines minimum password lifetime restrictions.	DoD-Defined Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT. ..
CCI-001617	IA-5(1)(d)	The organization defines maximum password lifetime restrictions.	DoD-Defined Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT. ..
CCI-001618	IA-5(1)(e)	The organization defines the number of generations for which password reuse is prohibited.	DoD-Defined Enclave Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT. ..
CCI-000200	IA-5(1)(e)	The information system prohibits password reuse for the organization defined number of generations.	Enclave Designer Non-Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT. ..
CCI-002041	IA-5(1)(f)	The information system allows the use of a temporary password for system logons with an immediate change to a permanent password.	Enclave Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT. ..
CCI-002002	IA-5(11)	The organization defines the token quality requirements to be employed by the information system mechanisms for token-based authentication.	DoD-Defined Enclave Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT. ..
CCI-002003	IA-5(11)	The information system, for token-based authentication, employs mechanisms that satisfy organization-defined token quality requirements.	Enclave Designer Impractical	3.4 USER IDENTIFICATIO N AND AUTHENTICAT. ..
CCI-000206	IA-6	The information system obscures feedback of authentication information during the authentication process to protect the information from possible exploitation/use by unauthorized individuals.	Enclave Designer Impractical	3.4.6 Authenticator Feedback
CCI-000803	IA-7	The information system implements mechanisms for authentication to a cryptographic module that meet the requirements of applicable federal laws, Executive Orders, directives, policies, regulations, standards, and guidance for such authentication.	Enclave Designer Impractical	3.2.8 Cryptographic Module Authentication

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-003051	PL-2(a)(2)	The organization's security plan for the information system explicitly defines the authorization boundary for the system.	Enclave Designer Non-Designer	1.9.6 Cybersecurity Riser Diagram
CCI-003053	PL-2(a)(4)	The organization's security plan for the information system provides the security categorization of the information system including supporting rationale.	Designer Non-Designer	1.9.6 Cybersecurity Riser Diagram
CCI-001048	RA-3(a)	The organization conducts an assessment of risk of the information system and the information it processes, stores, or transmits that includes the likelihood and magnitude of harm from the unauthorized access, use, disclosure, disruption, modification, or destruction.	Designer Non-Designer	---
CCI-001055	RA-5(a)	The organization defines a frequency for scanning for vulnerabilities in the information system and hosted applications.	DoD-Defined Enclave Designer Impractical	3.11 VULNERABILITY SCANNING
CCI-001054	RA-5(a)	The organization scans for vulnerabilities in the information system and hosted applications on an organization-defined frequency.	Enclave Designer Non-Designer	3.11 VULNERABILITY SCANNING
CCI-001056	RA-5(a)	The organization scans for vulnerabilities in the information system and hosted applications when new vulnerabilities potentially affecting the system/applications are identified and reported.	Enclave Designer Non-Designer	3.11 VULNERABILITY SCANNING
CCI-001641	RA-5(a)	The organization defines the process for conducting random vulnerability scans on the information system and hosted applications.	Enclave Designer Non-Designer Impractical	3.11 VULNERABILITY SCANNING
CCI-001643	RA-5(a)	The organization scans for vulnerabilities in the information system and hosted applications in accordance with the organization-defined process for random scans.	Enclave Designer Non-Designer	3.11 VULNERABILITY SCANNING
CCI-001057	RA-5(b)	The organization employs vulnerability scanning tools and techniques that facilitate interoperability among tools and automate parts of the vulnerability management process by using standards for: enumerating platforms, software flaws, and improper configurations; formatting checklists	Enclave Designer Non-Designer Impractical	3.11 VULNERABILITY SCANNING

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
		and test procedures; and measuring vulnerability impact.		
CCI-001058	RA-5(c)	The organization analyzes vulnerability scan reports and results from security control assessments.	Enclave Designer Non-Designer	3.11 VULNERABILIT Y SCANNING
CCI-001059	RA-5(d)	The organization remediates legitimate vulnerabilities in organization-defined response times in accordance with an organizational assessment risk.	Enclave Designer Non-Designer Impractical	3.11 VULNERABILIT Y SCANNING
CCI-003116	SA-4(10)	The organization employs only information technology products on the FIPS 201-approved products list for Personal Identity Verification (PIV) capability implemented within organizational information systems.	Enclave Designer Impractical	3.12 FIPS 201-2 REQUIREMENT
CCI-003126	SA-5(a)(1)	The organization obtains administrator documentation for the information system, system component, or information system services that describes secure operation of the system, component, or service.	Designer Non-Designer	1.9.8 Control System Cybersecurity Docume...
CCI-003124	SA-5(a)(1)	The organization obtains administrator documentation for the information system, system component, or information system services that describes secure configuration of the system, component, or service.	Designer Non-Designer	1.9.8 Control System Cybersecurity Docume... 1.9.8.2.1 HVAC Control System Devices FULLY S... 1.9.8.2.2 All Other HVAC Control System Devic... 1.9.8.3.1 Lighting Control System Devices FUL... 1.9.8.3.2 All Other Lighting Control System D... 1.9.8.5 Default Requirements for Control Sy...

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-003128	SA-5(a)(3)	The organization obtains administrator documentation for the information system, system component, or information system services that describes known vulnerabilities regarding configuration and use of administrative (i.e. privileged) functions.	Designer Non-Designer	1.9.8 Control System Cybersecurity Docume... 1.9.8.1 Software Applications 1.9.8.2.1 HVAC Control System Devices FULLY S... 1.9.8.3.1 Lighting Control System Devices FUL... 1.9.8.5 Default Requirements for Control Sy...
CCI-003130	SA-5(b)(2)	The organization obtains user documentation for the information system, system component or information system service that describes methods for user interaction which enables individuals to use the system, component, or service in a more secure manner.	Designer Non-Designer	1.9.8 Control System Cybersecurity Docume... 1.9.8.1 Software Applications 1.9.8.2.1 HVAC Control System Devices FULLY S... 1.9.8.2.2 All Other HVAC Control System Devic... 1.9.8.3.1 Lighting Control System Devices FUL... 1.9.8.3.2 All Other Lighting Control System D... 1.9.8.5 Default Requirements for Control Sy...
CCI-003125	SA-5(a)(1)	The organization obtains administrator documentation for the information system, system component, or information system services that describes secure installation of the system, component, or service.	Designer Non-Designer	1.9.8 Control System Cybersecurity Docume... 1.9.8.5 Default Requirements for Control Sy...

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-003129	SA-5(b)(1)	The organization obtains user documentation for the information system, system component, or information system service that describes user-accessible security functions/mechanisms and how to effectively use those security functions/mechanisms.	Designer Non-Designer	1.9.8 Control System Cybersecurity Docume... 1.9.8.1 Software Applications 1.9.8.2.1 HVAC Control System Devices FULLY S... 1.9.8.3.1 Lighting Control System Devices FUL... 1.9.8.5 Default Requirements for Control Sy...
CCI-003131	SA-5(b)(3)	The organization obtains user documentation for the information system, system component or information system service that describes user responsibilities in maintaining the security of the system, component, or service.	Designer Non-Designer	1.9.8 Control System Cybersecurity Docume... 1.9.8.1 Software Applications
CCI-003127	SA-5(a)(2)	The organization obtains administrator documentation for the information system, system component, or information system services that describes effective use and maintenance of security functions/mechanisms.	Designer Non-Designer	1.9.8 Control System Cybersecurity Docume... 1.9.8.1 Software Applications 1.9.8.2.1 HVAC Control System Devices FULLY S... 1.9.8.2.2 All Other HVAC Control System Devic... 1.9.8.3.1 Lighting Control System Devices FUL... 1.9.8.3.2 All Other Lighting Control System D... 1.9.8.5 Default Requirements for Control Sy...

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-001093	SC-5	The organization defines the types of denial of service attacks (or provides references to sources of current denial of service attacks) that can be addressed by the information system.	Enclave Designer	3.7.2 Denial of Service Protection<TAI OP...
CCI-002386	SC-5	The organization defines the security safeguards to be employed to protect the information system against, or limit the effects of, denial of service attacks.	Enclave Designer Non-Designer	3.7.2 Denial of Service Protection<TAI OP...
CCI-002385	SC-5	The information system protects against or limits the effects of organization-defined types of denial of service attacks by employing organization-defined security safeguards.	Enclave Designer	3.7.2 Denial of Service Protection<TAI OP...
CCI-001097	SC-7(a)	The information system monitors and controls communications at the external boundary of the system and at key internal boundaries within the system.	DoD-Defined Enclave Designer Impractical	3.3.6 Pysical Security in MODERATE Impact... 3.7.2 Denial of Service Protection<TAI OP... 3.7.5 Process Isolation and Boundary Prot...
CCI-002530	SC-39	The information system maintains a separate execution domain for each executing process.	Designer	---
CCI-002544	SC-41	The organization defines the information systems or information system components on which organization-defined connection ports or input/output devices are to be physically disabled or removed.	Enclave Designer Non-Designer	3.2.5 IP Control Networks 3.6 REQUIREMENTS FOR LEAST FUNCTIONALIT...
CCI-002545	SC-41	The organization defines the connection ports or input/output devices that are to be physically disabled or removed from organization-defined information systems or information system components.	Enclave Designer Non-Designer	3.2.5 IP Control Networks 3.6 REQUIREMENTS FOR LEAST FUNCTIONALIT...
CCI-002546	SC-41	The organization physically disables or removes organization-defined connection ports or input/output devices on organization-defined information systems or information system components.	Designer Impractical	3.2.5 IP Control Networks 3.6 REQUIREMENTS FOR LEAST FUNCTIONALIT...

Table G-4 Designer CCIs for LOW and MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002623	SI-3(c)(1)	The organization defines the frequency for performing periodic scans of the information system for malicious code.	DoD-Defined Designer Impractical	3.13.1 Malicious Code Protection
CCI-001241	SI-3(c)(1)	The organization configures malicious code protection mechanisms to perform periodic scans of the information system on an organization-defined frequency.	Enclave Designer Non-Designer	3.13.1 Malicious Code Protection
CCI-001253	SI-4(a)(1)	The organization defines the objectives of monitoring for attacks and indicators of potential attacks on the information system.	DoD-Defined Enclave Designer Impractical	3.13.3 Information System Monitoring
CCI-002645	SI-4(b)	The organization defines the techniques and methods to be used to identify unauthorized use of the information system.	Enclave Designer Non-Designer	3.13.3 Information System Monitoring
CCI-002773	SI-17	The organization defines the fail-safe procedures to be implemented by the information system when organization-defined failure conditions occur.	Designer	1.9.4 Control System Inventory Report 3.8 SAFE MODE AND FAIL SAFE OPERATION
CCI-002774	SI-17	The organization defines the failure conditions which, when they occur, will result in the information system implementing organization-defined fail-safe procedures.	Designer	1.9.4 Control System Inventory Report 3.8 SAFE MODE AND FAIL SAFE OPERATION
CCI-002775	SI-17	The information system implements organization-defined fail-safe procedures when organization-defined failure conditions occur.	Designer	1.9.4 Control System Inventory Report 3.8 SAFE MODE AND FAIL SAFE OPERATION
CCI-000207	PM-5	The organization develops and maintains an inventory of its information systems.	Designer Non-Designer Impractical	---
CCI-000236	PM-11(b)	The organization determines information protection needs arising from the defined mission/business processes and revises the processes as necessary, until an achievable set of protection needs are obtained.	Enclave Designer Non-Designer	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-001361	AC-2(2)	The organization defines a time period after which temporary accounts are automatically terminated.	DoD-Defined Enclave Designer Non-Designer Impractical	3.3.1 User Accounts
CCI-001365	AC-2(2)	The organization defines a time period after which emergency accounts are automatically terminated.	DoD-Defined Enclave Designer Non-Designer Impractical	---
CCI-001682	AC-2(2)	The information system automatically removes or disables emergency accounts after an organization-defined time period for each type of account.	DoD-Defined Enclave Designer Non-Designer Impractical	---
CCI-000017	AC-2(3)	The information system automatically disables inactive accounts after an organization-defined time period.	DoD-Defined Enclave Designer Non-Designer Impractical	3.3.1 User Accounts
CCI-000217	AC-2(3)	The organization defines a time period after which inactive accounts are automatically disabled.	DoD-Defined Designer Impractical	3.3.1 User Accounts
CCI-000018	AC-2(4)	The information system automatically audits account creation actions.	Enclave Designer Impractical	3.3.1 User Accounts
CCI-001403	AC-2(4)	The information system automatically audits account modification actions.	Enclave Designer Impractical	3.3.1 User Accounts
CCI-002130	AC-2(4)	The information system automatically audits account enabling actions.	Enclave Designer Impractical	3.3.1 User Accounts
CCI-001404	AC-2(4)	The information system automatically audits account disabling actions.	Enclave Designer Impractical	3.3.1 User Accounts
CCI-001405	AC-2(4)	The information system automatically audits account removal actions.	Enclave Designer Impractical	3.3.1 User Accounts
CCI-001683	AC-2(4)	The information system notifies organization-defined personnel or roles for account creation actions.	Enclave Designer	3.3.1 User Accounts
CCI-001684	AC-2(4)	The information system notifies organization-defined personnel or roles for account modification actions.	Enclave Designer	3.3.1 User Accounts

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002132	AC-2(4)	The information system notifies organization-defined personnel or roles for account enabling actions.	Enclave Designer	3.3.1 User Accounts
CCI-001685	AC-2(4)	The information system notifies organization-defined personnel or roles for account disabling actions.	Enclave Designer	3.3.1 User Accounts
CCI-001686	AC-2(4)	The information system notifies organization-defined personnel or roles for account removal actions.	Enclave Designer	3.3.1 User Accounts
CCI-002146	AC-2(12)(a)	The organization defines atypical usage for which the information system accounts are to be monitored.	Designer Non-Designer	---
CCI-001368	AC-4	The information system enforces approved authorizations for controlling the flow of information within the system based on organization-defined information flow control policies.	Enclave Designer Impractical	3.2.1 Information Flow Enforcement In MOD...
CCI-001414	AC-4	The information system enforces approved authorizations for controlling the flow of information between interconnected systems based on organization-defined information flow control policies.	Enclave Designer Impractical	3.2.1 Information Flow Enforcement In MOD...
CCI-001548	AC-4	The organization defines the information flow control policies for controlling the flow of information within the system.	Enclave Designer Non-Designer Impractical	3.2.1 Information Flow Enforcement In MOD...
CCI-001549	AC-4	The organization defines the information flow control policies for controlling the flow of information between interconnected systems.	Enclave Designer Non-Designer Impractical	3.2.1 Information Flow Enforcement In MOD...
CCI-001550	AC-4	The organization defines approved authorizations for controlling the flow of information within the system.	Enclave Designer Non-Designer Impractical	3.2.1 Information Flow Enforcement In MOD...
CCI-001551	AC-4	The organization defines approved authorizations for controlling the flow of information between interconnected systems.	Enclave Designer Non-Designer Impractical	3.2.1 Information Flow Enforcement In MOD...
CCI-001558	AC-6(1)	The organization defines the security functions (deployed in hardware, software, and firmware) for which access must be explicitly authorized.	DoD-Defined Designer Impractical	3.3.1 User Accounts 3.4 USER IDENTIFICATION AND AUTHENTICAT...

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002221	AC-6(1)	The organization defines the security-relevant information for which access must be explicitly authorized.	DoD-Defined Designer Impractical	3.3.1 User Accounts 3.4 USER IDENTIFICATION AND AUTHENTICAT...
CCI-002222	AC-6(1)	The organization explicitly authorizes access to organization-defined security functions.	DoD-Defined Designer Impractical	3.3.1 User Accounts 3.4 USER IDENTIFICATION AND AUTHENTICAT...
CCI-002223	AC-6(1)	The organization explicitly authorizes access to organization-defined security-relevant information.	DoD-Defined Designer Impractical	3.3.1 User Accounts 3.4 USER IDENTIFICATION AND AUTHENTICAT...
CCI-000039	AC-6(2)	The organization requires that users of information system accounts or roles, with access to organization-defined security functions or security-relevant information, use non-privileged accounts, or roles, when accessing nonsecurity functions.	DoD-Defined Designer Impractical	3.3.1 User Accounts 3.4 USER IDENTIFICATION AND AUTHENTICAT...
CCI-001419	AC-6(2)	The organization defines the security functions or security-relevant information to which users of information system accounts, or roles, have access.	DoD-Defined Designer Impractical	3.3.1 User Accounts 3.4 USER IDENTIFICATION AND AUTHENTICAT...
CCI-002234	AC-6(9)	The information system audits the execution of privileged functions.	Designer Impractical	3.3.1 User Accounts 3.4 USER IDENTIFICATION AND AUTHENTICAT...
CCI-002235	AC-6(10)	The information system prevents non-privileged users from executing privileged functions to include disabling, circumventing, or altering implemented security safeguards/countermeasures.	Designer Impractical	3.3.1 User Accounts 3.4 USER IDENTIFICATION AND AUTHENTICAT...
CCI-000054	AC-10	The information system limits the number of concurrent sessions for each organization-defined account and/or account type to an organization-defined number of sessions.	DoD-Defined Designer	3.3.4 Session Lock and Session Terminatio...

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-000055	AC-10	The organization defines the maximum number of concurrent sessions to be allowed for each organization-defined account and/or account type.	Designer Non-Designer	3.3.4 Session Lock and Session Terminatio...
CCI-002252	AC-10	The organization defines the accounts for which the information system will limit the number of concurrent sessions.	DoD-Defined Designer Non-Designer	3.2.3 Wireless and Wired Broadcast Commun... 3.3.4 Session Lock and Session Terminatio...
CCI-000059	AC-11(a)	The organization defines the time period of inactivity after which the information system initiates a session lock.	DoD-Defined Enclave Designer Impractical	3.3.4 Session Lock and Session Terminatio...
CCI-000058	AC-11(a)	The information system provides the capability for users to directly initiate session lock mechanisms.	Enclave Designer Impractical	3.3.4 Session Lock and Session Terminatio...
CCI-000056	AC-11(b)	The information system retains the session lock until the user reestablishes access using established identification and authentication procedures.	Enclave Designer Impractical	3.3.4 Session Lock and Session Terminatio...
CCI-000060	AC-11(1)	The information system conceals, via the session lock, information previously visible on the display with a publicly viewable image.	Enclave Designer Impractical	3.3.4 Session Lock and Session Terminatio...
CCI-002360	AC-12	The organization defines the conditions or trigger events requiring session disconnect to be employed by the information system when automatically terminating a user session.	Enclave Designer Impractical	3.3.4 Session Lock and Session Terminatio...
CCI-002361	AC-12	The information system automatically terminates a user session after organization-defined conditions or trigger events requiring session disconnect.	Enclave Designer Impractical	3.3.4 Session Lock and Session Terminatio...
CCI-001443	AC-18(1)	The information system protects wireless access to the system using authentication of users and/or devices.	Designer Impractical	---
CCI-001444	AC-18(1)	The information system protects wireless access to the system using encryption.	Designer Impractical	---
CCI-001449	AC-18(3)	The organization disables, when not intended for use, wireless networking capabilities internally embedded within information system	Designer	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
		components prior to issuance and deployment.		
CCI-002338	AC-20(3)	The organization restricts or prohibits the use of non-organizationally owned information systems, system components, or devices to process, store, or transmit organizational information.	Designer Non-Designer	---
CCI-002054	AT-3(4)	The organization defines indicators of malicious code to recognize suspicious communications and anomalous behavior in organizational information systems.	Designer Non-Designer	---
CCI-001488	AU-3(1)	The organization defines additional, more detailed information to be included in the audit records.	Designer Non-Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-000135	AU-3(1)	The information system generates audit records containing the organization-defined additional, more detailed information that is to be included in the audit records.	Designer Impractical	3.5.1 Audit Events, Content of Audit Reco...
CCI-001855	AU-5(1)	The information system provides a warning to organization-defined personnel, roles, and/or locations within organization-defined time period when allocated audit record storage volume reaches organization-defined percentage of repository maximum audit record storage capacity.	Designer	3.5.4.1 Audit Log Storage Notification In M...
CCI-001852	AU-5(1)	The organization defines the personnel, roles and/or locations to receive a warning when allocated audit record storage volume reaches a defined percentage of maximum audit records storage capacity.	DoD-Defined Designer Non-Designer	---
CCI-000154	AU-6(4)	The information system provides the capability to centrally review and analyze audit records from multiple components within the system.	Designer	3.5.3.4 Audit Reduction and Report Generati...
CCI-001875	AU-7(a)	The information system provides an audit reduction capability that supports on-demand audit review and analysis.	Enclave Designer Impractical	3.5.3.4 Audit Reduction and Report Generati...
CCI-001876	AU-7(a)	The information system provides an audit reduction capability that supports on-demand reporting requirements.	Enclave Designer Impractical	3.5.3.4 Audit Reduction and Report Generati...

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-001877	AU-7(a)	The information system provides an audit reduction capability that supports after-the-fact investigations of security incidents.	Enclave Designer Impractical	3.5.3.4 Audit Reduction and Report Generati...
CCI-001878	AU-7(a)	The information system provides a report generation capability that supports on-demand audit review and analysis.	Enclave Designer Impractical	3.5.3.4 Audit Reduction and Report Generati...
CCI-001879	AU-7(a)	The information system provides a report generation capability that supports on-demand reporting requirements.	Enclave Designer Impractical	3.5.3.4 Audit Reduction and Report Generati...
CCI-001880	AU-7(a)	The information system provides a report generation capability that supports after-the-fact investigations of security incidents.	Enclave Designer Impractical	3.5.3.4 Audit Reduction and Report Generati...
CCI-001881	AU-7(b)	The information system provides an audit reduction capability that does not alter original content or time ordering of audit records.	Enclave Designer Impractical	3.5.3.4 Audit Reduction and Report Generati...
CCI-001882	AU-7(b)	The information system provides a report generation capability that does not alter original content or time ordering of audit records.	Enclave Designer Impractical	3.5.3.4 Audit Reduction and Report Generati...
CCI-000158	AU-7(1)	The information system provides the capability to process audit records for events of interest based on organization-defined audit fields within audit records.	Enclave Designer Impractical	3.5.3.4 Audit Reduction and Report Generati...
CCI-001891	AU-8(1)	The information system compares internal information system clocks on an organization-defined frequency with an organization-defined authoritative time source.	Designer	3.5.2 Audit Time Stamps
CCI-001892	AU-8(1)	The organization defines the time difference which, when exceeded, will require the information system to synchronize the internal information system clocks to the organization-defined authoritative time source.	Designer Non-Designer	3.5.2 Audit Time Stamps
CCI-002046	AU-8(1)	The information system synchronizes the internal system clocks to the authoritative time source when the time difference is greater than the organization-defined time period.	Designer	3.5.2 Audit Time Stamps
CCI-001899	AU-10	The organization defines the action to be covered by non-repudiation.	DoD-Defined Designer Non-Designer	3.5.1 Audit Events, Content of Audit Reco...

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-000166	AU-10	The information system protects against an individual (or process acting on behalf of an individual) falsely denying having performed organization-defined actions to be covered by non-repudiation.	Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-001577	AU-12(1)	The organization defines the information system components from which audit records are to be compiled into the system-wide audit trail.	Designer Non-Designer	3.5.3.4 Audit Reduction and Report Generati...
CCI-000174	AU-12(1)	The information system compiles audit records from organization-defined information system components into a system-wide (logical or physical) audit trail that is time-correlated to within organization defined level of tolerance for relationship between time stamps of individual records in the audit trail.	Designer	3.5.3.4 Audit Reduction and Report Generati...
CCI-000173	AU-12(1)	The organization defines the level of tolerance for relationship between time stamps of individual records in the audit trail that will be used for correlation.	Designer Non-Designer	3.5.3.4 Audit Reduction and Report Generati...
CCI-001914	AU-12(3)	The information system provides the capability for organization-defined individuals or roles to change the auditing to be performed on organization-defined information system components based on organization-defined selectable event criteria within organization-defined time thresholds.	Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-002047	AU-12(3)	The organization defines the information system components on which the auditing that is to be performed can be changed by organization-defined individuals or roles.	Designer Non-Designer	---
CCI-001919	AU-14(b)	The information system provides the capability for authorized users to select a user session to capture/record or view/hear.	Designer Non-Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-001464	AU-14(1)	The information system initiates session audits at system start-up.	Designer Non-Designer	3.5.1 Audit Events, Content of Audit Reco...

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-001462	AU-14(2)	The information system provides the capability for authorized users to capture/record and log content related to a user session.	Designer Non-Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-001920	AU-14(3)	The information system provides the capability for authorized users to remotely view/hear all content related to an established user session in real time.	Designer Non-Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-000298	CM-2(1)(c)	The organization reviews and updates the baseline configuration of the information system as an integral part of information system component installations.	Designer Non-Designer	---
CCI-001737	CM-2(7)a	The organization defines the information systems, system components, or devices that are to have organization-defined configurations applied when located in areas of significant risk.	Designer Non-Designer	---
CCI-001738	CM-2(7)a	The organization defines the security configurations to be implemented on information systems, system components, or devices when they are located in areas of significant risk.	Designer Non-Designer	---
CCI-001813	CM-5(1)	The information system enforces access restrictions.	Designer Non-Designer	3.3.1 User Accounts
CCI-001814	CM-5(1)	The Information system supports auditing of the enforcement actions.	Designer Non-Designer	3.5.1 Audit Events, Content of Audit Reco...
CCI-000349	CM-5(2)	The organization reviews information system changes per organization defined frequency to determine whether unauthorized changes have occurred.	Designer Non-Designer	---
CCI-002059	CM-6(1)	The organization defines the information system components for which the organization will employ automated mechanisms to centrally manage, apply, and verify configuration settings.	Designer Non-Designer	---
CCI-001592	CM-7(2)	The organization defines the rules authorizing the terms and conditions of software program usage on the information system.	Designer	---
CCI-001763	CM-7(2)	The organization defines the policies regarding software program usage and restrictions.	Designer Non-Designer	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-001764	CM-7(2)	The information system prevents program execution in accordance with organization-defined policies regarding software program usage and restrictions, and/or rules authorizing the terms and conditions of software program usage.	Designer	---
CCI-000388	CM-7(3)	The organization ensures compliance with organization-defined registration requirements for functions, ports, protocols, and services.	Designer Non-Designer	1.9.3 Network Communication Report
CCI-001772	CM-7(5)a	The organization defines the software programs authorized to execute on the information system.	Designer	---
CCI-001773	CM-7(5)a	The organization identifies the organization-defined software programs authorized to execute on the information system.	Designer	---
CCI-001774	CM-7(5)b	The organization employs an deny-all, permit-by-exception policy to allow the execution of authorized software programs on the information system.	Designer	---
CCI-000411	CM-8(2)	The organization employs automated mechanisms to help maintain an up-to-date inventory of information system components.	Designer Non-Designer	---
CCI-000412	CM-8(2)	The organization employs automated mechanisms to help maintain a complete inventory of information system components.	Designer Non-Designer	---
CCI-001812	CM-11(2)	The information system prohibits user installation of software without explicit privileged status.	Designer Non-Designer	3.3.1 User Accounts
CCI-002828	CP-2(8)	The organization identifies critical information system assets supporting essential missions.	Designer	---
CCI-000553	CP-10(2)	The information system implements transaction recovery for systems that are transaction-based.	Designer	---
CCI-000766	IA-2(2)	The information system implements multifactor authentication for network access to non-privileged accounts.	Enclave Designer Impractical	---
CCI-000767	IA-2(3)	The information system implements multifactor authentication for local access to privileged accounts.	Enclave Designer Impractical	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-000768	IA-2(4)	The information system implements multifactor authentication for local access to non-privileged accounts.	Designer Impractical	3.4 USER IDENTIFICATION AND AUTHENTICAT...
CCI-001942	IA-2(9)	The information system implements replay-resistant authentication mechanisms for network access to non-privileged accounts.	Designer Impractical	3.2.6 Cryptographic Protection
CCI-001967	IA-3(1)	The information system authenticates organization-defined devices and/or types of devices before establishing a local, remote and/or network connection using bidirectional authentication that is cryptographically based.	Designer Impractical	3.2.6 Cryptographic Protection
CCI-001959	IA-3(1)	The organization defines the specific devices and/or type of devices the information system is to authenticate before establishing a connection.	DoD-Defined Designer Impractical	3.2.6 Cryptographic Protection
CCI-000185	IA-5(2)(a)	The information system, for PKI-based authentication validates certifications by constructing and verifying a certification path to an accepted trust anchor including checking certificate status information.	Enclave Designer Impractical	---
CCI-000186	IA-5(2)(b)	The information system, for PKI-based authentication enforces authorized access to the corresponding private key.	Enclave Designer	---
CCI-000187	IA-5(2)(c)	The information system, for PKI-based authentication, maps the authenticated identity to the account of the individual or group.	Enclave Designer	---
CCI-001991	IA-5(2)(d)	The information system, for PKI-based authentication, implements a local cache of revocation data to support path discovery and validation in case of inability to access revocation information via the network.	Enclave Designer	---
CCI-001996	IA-5(4)	The organization defines the requirements required by the automated tools to determine if password authenticators are sufficiently strong.	DoD-Defined Designer Non-Designer	---
CCI-001997	IA-5(4)	The organization employs automated tools to determine if password authenticators are sufficiently strong to satisfy organization-defined requirements.	Designer Non-Designer Impractical	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002007	IA-5(13)	The information system prohibits the use of cached authenticators after an organization defined time period.	Designer Non-Designer	3.4 USER IDENTIFICATION AND AUTHENTICAT...
CCI-000865	MA-3	The organization approves information system maintenance tools.	Designer Non-Designer	3.9 SYSTEM MAINTENANCE TOOL SOFTWARE
CCI-000928	PE-3(1)	The organization enforces physical access authorizations to the information system in addition to the physical access controls for the facility at organization-defined physical spaces containing one or more components of the information system.	Designer Non-Designer	3.3.6 Pysical Security in MODERATE Impact...
CCI-002926	PE-3(1)	The organization defines the physical spaces containing one or more components of the information system that require physical access authorizations and controls at the facility.	Designer Non-Designer	3.3.6 Pysical Security in MODERATE Impact...
CCI-000936	PE-4	The organization controls physical access to organization-defined information system distribution and transmission lines within organizational facilities using organization-defined security safeguards.	Designer Non-Designer	3.3.6 Pysical Security in MODERATE Impact...
CCI-002930	PE-4	The organization defines information system distribution and transmission lines within organizational facilities to control physical access using organization-defined security safeguards.	Designer Non-Designer	3.3.6 Pysical Security in MODERATE Impact...
CCI-002931	PE-4	The organization defines security safeguards to control physical access to organization-defined information system distribution and transmission lines within organizational facilities.	Designer Non-Designer	3.3.6 Pysical Security in MODERATE Impact...
CCI-000937	PE-5	The organization controls physical access to information system output devices to prevent unauthorized individuals from obtaining the output.	Designer Non-Designer	3.3.6 Pysical Security in MODERATE Impact...
CCI-000952	PE-9	The organization protects power equipment and power cabling for the information system from damage and destruction.	Designer Non-Designer	3.10 DEVICE POWER

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002955	PE-11	The organization provides a short-term uninterruptible power supply to facilitate an orderly shutdown of the information system and/or transition of the information system to long-term alternate power in the event of a primary power source loss.	Enclave Designer Impractical	3.10 DEVICE POWER
CCI-000961	PE-11(1)	The organization provides a long-term alternate power supply for the information system that is capable of maintaining minimally required operational capability in the event of an extended loss of the primary power source.	Enclave Designer	3.10 DEVICE POWER
CCI-003075	PL-8(a)(3)	The organization's information security architecture for the information system describes any information security assumptions about, and dependencies on, external services.	Designer Non-Designer	1.9.2 Cybersecurity Interconnection Sched... 1.9.3 Network Communication Report 1.9.6 Cybersecurity Riser Diagram
CCI-003072	PL-8(a)	The organization develops an information security architecture for the information system.	Designer Non-Designer	1.9.2 Cybersecurity Interconnection Sched... 1.9.3 Network Communication Report 1.9.6 Cybersecurity Riser Diagram
CCI-003073	PL-8(a)(1)	The organization's information security architecture for the information system describes the overall philosophy, requirements, and approach to be taken with regard to protecting the confidentiality, integrity, and availability of organizational information.	Designer Non-Designer	1.9.2 Cybersecurity Interconnection Sched... 1.9.3 Network Communication Report 1.9.6 Cybersecurity Riser Diagram
CCI-003081	PL-8(1)(a)	The organization designs its security architecture using a defense-in-depth approach that allocates organization-defined security safeguards to organization-defined locations.	Designer Non-Designer	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-003082	PL-8(1)(a)	The organization designs its security architecture using a defense-in-depth approach that allocates organization-defined security safeguards to organization-defined architectural layers.	Designer Non-Designer	---
CCI-003083	PL-8(1)(a)	The organization defines the security safeguards to be allocated to organization-defined locations.	Designer Non-Designer	---
CCI-003084	PL-8(1)(a)	The organization defines the security safeguards to be allocated to organization-defined architectural layers.	Designer Non-Designer	---
CCI-003085	PL-8(1)(a)	The organization defines the locations to which it allocates organization-defined security safeguards in the security architecture.	Designer Non-Designer	---
CCI-003086	PL-8(1)(a)	The organization defines the architectural layers to which it allocates organization-defined security safeguards in the security architecture.	Designer Non-Designer	---
CCI-003087	PL-8(1)(b)	The organization designs its security architecture using a defense-in-depth approach that ensures that the allocated security safeguards operate in a coordinated and mutually reinforcing manner.	Designer Non-Designer	---
CCI-001062	RA-5(1)	The organization employs vulnerability scanning tools that include the capability to readily update the information system vulnerabilities to be scanned.	Enclave Designer	2.3 DATABASE AND WEB SERVER SOFTWARE FO... 3.11 VULNERABILITY SCANNING
CCI-001067	RA-5(5)	The information system implements privileged access authorization to organization-identified information system components for selected organization-defined vulnerability scanning activities.	Enclave Designer	2.3 DATABASE AND WEB SERVER SOFTWARE FO... 3.11 VULNERABILITY SCANNING
CCI-001645	RA-5(5)	The organization identifies the information system components to which privileged access is authorized for selected organization-defined vulnerability scanning activities.	DoD-Defined Enclave Designer Impractical	2.3 DATABASE AND WEB SERVER SOFTWARE FO... 3.11 VULNERABILITY SCANNING

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002906	RA-5(5)	The organization defines the vulnerability scanning activities in which the information system implements privileged access authorization to organization-identified information system components.	Enclave Designer	2.3 DATABASE AND WEB SERVER SOFTWARE FO... 3.11 VULNERABILITY SCANNING
CCI-000623	SA-4(1)	The organization requires the developer of the information system, system component, or information system service to provide a description of the functional properties of the security controls to be employed.	Designer Non-Designer Impractical	---
CCI-003101	SA-4(2)	The organization requires the developer of the information system, system component, or information system service to provide design information for the security controls to be employed that includes security-relevant external system interfaces, high-level design, low-level design, source code, hardware schematics and/or organization-defined design/information at organization-defined level of detail.	Designer Non-Designer Impractical	---
CCI-003102	SA-4(2)	The organization requires the developer of the information system, system component, or information system service to provide implementation information for the security controls to be employed that includes security-relevant external system interfaces, high-level design, low-level design, source code and/or hardware schematics organization-defined implementation information at organization-defined level of detail.	Designer Non-Designer Impractical	---
CCI-003103	SA-4(2)	The organization defines the design information that the developer of the information system, system component, or information system service is required to provide for the security controls to be employed.	Designer Non-Designer Impractical	---
CCI-003104	SA-4(2)	The organization defines the implementation information that the developer of the information system, system component, or information system service is required to provide	Designer Non-Designer Impractical	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
		for the security controls to be employed.		
CCI-003105	SA-4(2)	The organization defines the level of detail the design information of the security controls is required to be provided by the developer of the information system, system component, or information system services.	Designer Non-Designer Impractical	---
CCI-003106	SA-4(2)	The organization defines the level of detail the implementation information of the security controls is required to be provided by the developer of the information system, system component, or information system services.	Designer Non-Designer Impractical	---
CCI-003114	SA-4(9)	The organization requires the developer of the information system, system component, or information system service to identify early in the system development life cycle, the functions, ports, protocols, and services intended for organizational use.	Designer Non-Designer Impractical	---
CCI-003155	SA-10(a)	The organization requires the developer of the information system, system component, or information system service to perform configuration management during system, component or service design, development, implementation and/or operation.	Designer Non-Designer Impractical	---
CCI-003156	SA-10(b)	The organization requires the developer of the information system, system component, or information system service to document the integrity of changes to organization-defined configuration items under configuration management.	Designer Non-Designer Impractical	---
CCI-003157	SA-10(b)	The organization requires the developer of the information system, system component, or information system service to manage the integrity of changes to organization-defined configuration items under configuration management.	Designer Non-Designer Impractical	---
CCI-003158	SA-10(b)	The organization requires the developer of the information system, system component, or information system service to control the	Designer Non-Designer Impractical	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
		integrity of changes to organization-defined configuration items under configuration management.		
CCI-003159	SA-10(b)	The organization defines the configuration items under configuration management that require the integrity of changes to be documented, managed and controlled.	Designer Non-Designer Impractical	---
CCI-000692	SA-10(c)	The organization requires the developer of the information system, system component, or information system service to implement only organization-approved changes to the system, component, or service.	Designer Non-Designer Impractical	---
CCI-000694	SA-10(d)	The organization requires the developer of the information system, system component, or information system service to document approved changes to the system, component, or service.	Designer Non-Designer Impractical	---
CCI-003160	SA-10(d)	The organization requires the developer of the information system, system component, or information system service to document the potential security impacts of approved changes to the system, component, or service.	Designer Non-Designer Impractical	---
CCI-003161	SA-10(e)	The organization requires the developer of the information system, system component, or information system service to track security flaws within the system, component, or service.	Designer Non-Designer Impractical	---
CCI-003162	SA-10(e)	The organization requires the developer of the information system, system component, or information system service to track flaw resolution within the system, component, or service.	Designer Non-Designer Impractical	---
CCI-003163	SA-10(e)	The organization requires the developer of the information system, system component, or information system service to report security flaws and flaw resolution within the system, component, or service findings to organization-defined personnel.	Designer Non-Designer Impractical	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-003171	SA-11(a)	The organization requires the developer of the information system, system component, or information system service to create a security assessment plan.	Designer Non-Designer Impractical	3.14 CONTROL SYSTEM CYBERSECURITY TESTIN...
CCI-003172	SA-11(a)	The organization requires the developer of the information system, system component, or information system service to implement a security assessment plan.	Designer Non-Designer Impractical	3.14 CONTROL SYSTEM CYBERSECURITY TESTIN...
CCI-003173	SA-11(b)	The organization requires the developer of the information system, system component, or information system service to perform unit, integration, system, and/or regression testing/evaluation at organization-defined depth and coverage.	Designer Non-Designer Impractical	3.14 CONTROL SYSTEM CYBERSECURITY TESTIN...
CCI-003174	SA-11(b)	The organization defines the depth and coverage to perform unit, integration, system, and/or regression testing/evaluation.	Designer Non-Designer Impractical	3.14 CONTROL SYSTEM CYBERSECURITY TESTIN...
CCI-003175	SA-11(c)	The organization requires the developer of the information system, system component, or information system service to produce evidence of the execution of the security assessment plan.	Designer Non-Designer Impractical	3.14 CONTROL SYSTEM CYBERSECURITY TESTIN...
CCI-003176	SA-11(c)	The organization requires the developer of the information system, system component, or information system service to produce the results of the security testing/evaluation.	Designer Non-Designer Impractical	3.14 CONTROL SYSTEM CYBERSECURITY TESTIN...
CCI-003177	SA-11(d)	The organization requires the developer of the information system, system component, or information system service to implement a verifiable flaw remediation process.	Designer Non-Designer Impractical	3.14 CONTROL SYSTEM CYBERSECURITY TESTIN...
CCI-003178	SA-11(e)	The organization requires the developer of the information system, system component, or information system service to correct flaws identified during security testing/evaluation.	Designer Non-Designer Impractical	3.14 CONTROL SYSTEM CYBERSECURITY TESTIN...
CCI-003233	SA-15	The organization requires the developer of the information system, system component, or information system service to follow a documented development process.	Designer Impractical	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-003234	SA-15(a)(1)	The documented information system, system component, or information system service development process explicitly addresses security requirements.	Designer Impractical	---
CCI-003235	SA-15(a)(2)	The documented information system, system component, or information system service development process identifies the standards used in the development process.	Designer Impractical	---
CCI-003236	SA-15(a)(2)	The documented information system, system component, or information system service development process identifies the tools used in the development process.	Designer Impractical	---
CCI-003237	SA-15(a)(3)	The documented information system, system component, or information system service development process documents the specific tool options and tool configurations used in the development process.	Designer Impractical	---
CCI-003238	SA-15(a)(4)	The documented information system, system component, or information system service development process documents changes to the process and/or tools used in development.	Designer Impractical	---
CCI-003239	SA-15(a)(4)	The documented information system, system component, or information system service development process manages changes to the process and/or tools used in development.	Designer Impractical	---
CCI-003240	SA-15(a)(4)	The documented information system, system component, or information system service development process ensures the integrity of changes to the process and/or tools used in development.	Designer Impractical	---
CCI-001082	SC-2	The information system separates user functionality (including user interface services) from information system management functionality.	Enclave Designer Non-Designer	3.7.2 Denial of Service Protection<TAI OP...
CCI-001094	SC-5(1)	The information system restricts the ability of individuals to launch organization-defined denial of service attacks against other information systems.	Enclave Designer	3.2.5 IP Control Networks

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-001095	SC-5(2)	The information system manages excess capacity, bandwidth, or other redundancy to limit the effects of information flooding types of denial of service attacks.	Designer	3.2.5 IP Control Networks
CCI-002388	SC-5(3)(a)	The organization defines a list of monitoring tools to be employed to detect indicators of denial of service attacks against the information system.	Designer Non-Designer	---
CCI-002390	SC-5(3)(b)	The organization defines the information system resources to be monitored to determine if sufficient resources exist to prevent effective denial of service attacks.	Designer Non-Designer	---
CCI-001109	SC-7(5)	The information system at managed interfaces denies network communications traffic by default and allows network communications traffic by exception (i.e., deny all, permit by exception).	Enclave Designer	1.9.2 Cybersecurity Interconnection Sched... 3.3.6 Pysical Security in MODERATE Impact... 3.7.5 Process Isolation and Boundary Prot...
CCI-002400	SC-7(9)(b)	The information system audits the identity of internal users associated with denied outgoing communications traffic posing a threat to external information systems.	Designer Impractical	3.5.1 Audit Events, Content of Audit Reco...
CCI-002398	SC-7(9)(a)	The information system detects outgoing communications traffic posing a threat to external information systems.	Enclave Designer Non-Designer	1.9.2 Cybersecurity Interconnection Sched... 3.7.5 Process Isolation and Boundary Prot...
CCI-002399	SC-7(9)(a)	The information system denies outgoing communications traffic posing a threat to external information systems.	Enclave Designer Non-Designer	1.9.2 Cybersecurity Interconnection Sched... 3.7.5 Process Isolation and Boundary Prot...
CCI-002403	SC-7(11)	The information system only allows incoming communications from organization-defined authorized sources routed to organization-defined authorized destinations.	Enclave Designer Non-Designer	1.9.2 Cybersecurity Interconnection Sched... 3.7.5 Process

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
				Isolation and Boundary Prot...
CCI-002401	SC-7(11)	The organization defines the authorized sources from which the information system will allow incoming communications.	Enclave Designer Non-Designer	1.9.2 Cybersecurity Interconnection Sched...
CCI-002402	SC-7(11)	The organization defines the authorized destinations for routing inbound communications.	Enclave Designer Non-Designer	1.9.2 Cybersecurity Interconnection Sched...
CCI-002404	SC-7(12)	The organization defines the host-based boundary protection mechanisms that are to be implemented at organization-defined information system components.	Enclave Designer Non-Designer	---
CCI-002405	SC-7(12)	The organization defines the information system components at which organization-defined host-based boundary protection mechanisms will be implemented.	Enclave Designer Non-Designer	---
CCI-002406	SC-7(12)	The organization implements organization-defined host-based boundary protection mechanisms at organization-defined information system components.	Enclave Designer Non-Designer	---
CCI-001120	SC-7(13)	The organization defines key information security tools, mechanisms, and support components to be isolated.	Enclave Designer Non-Designer	3.7.5 Process Isolation and Boundary Prot...
CCI-001126	SC-7(18)	The information system fails securely in the event of an operational failure of a boundary protection device.	Designer Impractical	1.9.2 Cybersecurity Interconnection Sched... 3.7.5 Process Isolation and Boundary Prot...
CCI-002418	SC-8	The information system protects the confidentiality and/or integrity of transmitted information.	Designer	3.2.6 Cryptographic Protection 3.3.6 Pysical Security in MODERATE Impact...
CCI-002419	SC-8(1)	The organization defines the alternative physical safeguards to be employed when cryptographic mechanisms are not implemented to protect information during transmission.	DoD-Defined Designer	3.3.6 Pysical Security in MODERATE Impact...

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002421	SC-8(1)	The information system implements cryptographic mechanisms to prevent unauthorized disclosure of information and/or detect changes to information during transmission unless otherwise protected by organization-defined alternative physical safeguards.	Designer	3.3.6 Pysical Security in MODERATE Impact...
CCI-002420	SC-8(2)	The information system maintains the confidentiality and/or integrity of information during preparation for transmission.	Designer	---
CCI-002422	SC-8(2)	The information system maintains the confidentiality and/or integrity of information during reception.	Designer	---
CCI-001133	SC-10	The information system terminates the network connection associated with a communications session at the end of the session or after an organization-defined time period of inactivity.	Enclave Designer Impractical	3.3.4 Session Lock and Session Terminatio...
CCI-001134	SC-10	The organization defines the time period of inactivity after which the information system terminates a network connection associated with a communications session.	DoD-Defined Designer Impractical	3.3.4 Session Lock and Session Terminatio...
CCI-002449	SC-13	The organization defines the cryptographic uses, and type of cryptography required for each use, to be implemented by the information system.	DoD-Defined Enclave Designer Impractical	3.2.6 Cryptographic Protection
CCI-002450	SC-13	The information system implements organization-defined cryptographic uses and type of cryptography required for each use in accordance with applicable federal laws, Executive Orders, directives, policies, regulations, and standards.	Enclave Designer Impractical	3.2.6 Cryptographic Protection
CCI-001160	SC-18(a)	The organization defines acceptable and unacceptable mobile code and mobile code technologies.	Enclave Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-001161	SC-18(b)	The organization establishes usage restrictions for acceptable mobile code and mobile code technologies.	Enclave Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-001162	SC-18(b)	The organization establishes implementation guidance for acceptable mobile code and mobile code technologies.	Enclave Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-001163	SC-18(c)	The organizations authorizes the use of mobile code within the information system.	Enclave Designer	3.7.3 Mobile Code In MODERATE Impact Syst...

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-001164	SC-18(c)	The organization monitors the use of mobile code within the information system.	Enclave Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-001165	SC-18(c)	The organization controls the use of mobile code within the information system.	Enclave Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-001166	SC-18(1)	The information system identifies organization-defined unacceptable mobile code.	Enclave Designer Non-Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-001662	SC-18(1)	The information system takes organization-defined corrective action when organization-defined unacceptable mobile code is identified.	Enclave Designer Non-Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-002457	SC-18(1)	The organization defines the corrective actions to be taken when organization-defined unacceptable mobile code is identified.	Enclave Designer Non-Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-002458	SC-18(1)	The organization defines what constitutes unacceptable mobile code for its information systems.	Enclave Designer Non-Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-001169	SC-18(3)	The information system prevents the download of organization-defined unacceptable mobile code.	Designer Non-Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-001695	SC-18(3)	The information system prevents the execution of organization-defined unacceptable mobile code.	Designer Non-Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-001170	SC-18(4)	The information system prevents the automatic execution of mobile code in organization-defined software applications.	Designer	3.7.3 Mobile Code In MODERATE Impact Syst...
CCI-002460	SC-18(4)	The information system enforces organization-defined actions prior to executing the code.	Designer	---
CCI-001184	SC-23	The information system protects the authenticity of communications sessions.	Enclave Designer Impractical	3.2.7 Device Identification and Authentic...
CCI-001185	SC-23(1)	The information system invalidates session identifiers upon user logout or other session termination.	Designer	3.2.6 Cryptographic Protection
CCI-001188	SC-23(3)	The information system generates unique session identifiers for each session with organization-defined randomness requirements.	Designer	3.2.6 Cryptographic Protection
CCI-001664	SC-23(3)	The information system recognizes only session identifiers that are system-generated.	Designer	3.2.6 Cryptographic Protection

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002470	SC-23(5)	The information system only allows the use of organization-defined certificate authorities for verification of the establishment of protected sessions.	Designer	3.2.7 Device Identification and Authentic...
CCI-001190	SC-24	The information system fails to an organization-defined known-state for organization-defined types of failures.	Designer	---
CCI-001191	SC-24	The organization defines the known states the information system should fail to in the event of a organization-defined system failure.	DoD-Defined Designer Impractical	---
CCI-001192	SC-24	The organization defines types of failures for which the information system should fail to an organization-defined known state.	DoD-Defined Designer Impractical	---
CCI-001193	SC-24	The organization defines system state information that should be preserved in the event of a system failure.	DoD-Defined Designer Impractical	---
CCI-001665	SC-24	The information system preserves organization-defined system state information in the event of a system failure.	Designer Impractical	---
CCI-001199	SC-28	The information system protects the confidentiality and/or integrity of organization-defined information at rest.	Enclave Designer Impractical	3.7.4 Protection of Information at Rest I...
CCI-002472	SC-28	The organization defines the information at rest that is to be protected by the information system.	Designer Non-Designer Impractical	3.7.4 Protection of Information at Rest I...
CCI-002475	SC-28(1)	The information system implements cryptographic mechanisms to prevent unauthorized modification of organization-defined information at rest on organization-defined information system components.	DoD-Defined Designer Impractical	3.7.4 Protection of Information at Rest I...
CCI-002476	SC-28(1)	The information system implements cryptographic mechanisms to prevent unauthorized disclosure of organization-defined information at rest on organization-defined information system components.	DoD-Defined Designer Impractical	3.7.4 Protection of Information at Rest I...
CCI-002686	SI-4(23)	The organization defines the information system components at which organization-defined host-based monitoring mechanisms are to be implemented.	DoD-Defined Designer Non-Designer	---

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002703	SI-7	The organization defines the software, firmware, and information which will be subjected to integrity verification tools to detect unauthorized changes.	Enclave Designer	---
CCI-002705	SI-7(1)	The organization defines the software on which integrity checks will be performed.	Enclave Designer	---
CCI-002706	SI-7(1)	The organization defines the firmware on which integrity checks will be performed.	Enclave Designer	---
CCI-002707	SI-7(1)	The organization defines the information on which integrity checks will be performed.	Enclave Designer	---
CCI-002710	SI-7(1)	The information system performs an integrity check of organization-defined software at startup, at organization-defined transitional states or security-relevant events, or on organization-defined frequency.	Enclave Designer	---
CCI-002711	SI-7(1)	The information system performs an integrity check of organization-defined firmware at startup, at organization-defined transitional states or security-relevant events, or on organization-defined frequency.	Enclave Designer	---
CCI-002712	SI-7(1)	The information system performs an integrity check of organization-defined information at startup, at organization-defined transitional states or security-relevant events, or on organization-defined frequency.	Enclave Designer	---
CCI-002723	SI-7(8)	The information system, upon detection of a potential integrity violation, provides the capability to audit the event.	Designer Non-Designer Impractical	---
CCI-002724	SI-7(8)	The information system, upon detection of a potential integrity violation, initiates one or more of following actions: generates an audit record; alerts current user; alerts organization-defined personnel or roles; and/or organization-defined other actions.	Designer Non-Designer Impractical	---
CCI-002737	SI-7(14)(a)	The organization prohibits the use of binary or machine-executable code from sources with limited or no warranty and without the provision of source code.	Designer Non-Designer Impractical	1.10 SOFTWARE LICENSING

Table G-5 Additional Designer CCIs for MODERATE Impact Control Systems				
CCI #	**800-53 Control Text Indicator**	**CCI Definition**	**Responsibility**	**UFGS Reference**
CCI-002744	SI-10	The organization defines the inputs the information system is to conduct validity checks.	DoD-Defined Designer	---
CCI-001310	SI-10	The information system checks the validity of organization-defined inputs.	Designer Non-Designer	---
CCI-002754	SI-10(3)	The information system behaves in a predictable and documented manner that reflects organizational and system objectives when invalid inputs are received.	Designer Impractical	3.8 SAFE MODE AND FAIL SAFE OPERATION
CCI-001312	SI-11(a)	The information system generates error messages that provide information necessary for corrective actions without revealing information that could be exploited by adversaries.	Designer	---

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-002247	AC-8(a)	The organization defines the use notification message or banner the information system displays to users before granting access to the system.
CCI-000048	AC-8(a)	The information system displays an organization-defined system use notification message or banner before granting access to the system that provides privacy and security notices consistent with applicable federal laws, Executive Orders, directives, policies, regulations, standards, and guidance.
CCI-002243	AC-8(a)(1)	The organization-defined information system use notification message or banner is to state that users are accessing a U.S. Government information system.
CCI-002244	AC-8(a)(2)	The organization-defined information system use notification message or banner is to state that information system usage may be monitored, recorded, and subject to audit.
CCI-002245	AC-8(a)(3)	The organization-defined information system use notification message or banner is to state that unauthorized use of the information system is prohibited and subject to criminal and civil penalties.
CCI-002246	AC-8(a)(4)	The organization-defined information system use notification message or banner is to state that use of the information system indicates consent to monitoring and recording.
CCI-000050	AC-8(b)	The information system retains the notification message or banner on the screen until users acknowledge the usage conditions and take explicit actions to log on to or further access.
CCI-002248	AC-8(c)(1)	The organization defines the conditions of use which are to be displayed to users of the information system before granting further access.
CCI-000063	AC-17(a)	The organization defines allowed methods of remote access to the information system.
CCI-002310	AC-17(a)	The organization establishes and documents usage restrictions for each type of remote access allowed.
CCI-002311	AC-17(a)	The organization establishes and documents configuration/connection requirements for each type of remote access allowed.
CCI-002312	AC-17(a)	The organization establishes and documents implementation guidance for each type of remote access allowed.
CCI-000065	AC-17(b)	The organization authorizes remote access to the information system prior to allowing such connections
CCI-000082	AC-19(a)	The organization establishes usage restrictions for organization controlled mobile devices.
CCI-002325	AC-19(a)	The organization establishes configuration requirements for organization controlled mobile devices.
CCI-002326	AC-19(a)	The organization establishes connection requirements for organization controlled mobile devices.
CCI-000083	AC-19(a)	The organization establishes implementation guidance for organization controlled mobile devices.
CCI-000084	AC-19(b)	The organization authorizes connection of mobile devices to organizational information systems.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-000093	AC-20(a)	The organization establishes terms and conditions, consistent with any trust relationships established with other organizations owning, operating, and/or maintaining external information systems, allowing authorized individuals to access the information system from the external information systems.
CCI-000098	AC-21(a)	The organization facilitates information sharing by enabling authorized users to determine whether access authorizations assigned to the sharing partner match the access restrictions on the information for organization-defined information circumstances where user discretion is required.
CCI-001470	AC-21(a)	The organization defines information sharing circumstances where user discretion is required.
CCI-001471	AC-21(b)	The organization employs organization-defined automated mechanisms or manual processes required to assist users in making information sharing/collaboration decisions.
CCI-001472	AC-21(b)	The organization defines the automated mechanisms or manual processes required to assist users in making information sharing/collaboration decisions.
CCI-000139	AU-5(a)	The information system alerts designated organization-defined personnel or roles in the event of an audit processing failure.
CCI-000140	AU-5(b)	The information system takes organization defined actions upon audit failure (e.g., shut down information system, overwrite oldest audit records, stop generating audit records).
CCI-001490	AU-5(b)	The organization defines actions to be taken by the information system upon audit failure (e.g., shut down information system, overwrite oldest audit records, stop generating audit records).
CCI-000162	AU-9	The information system protects audit information from unauthorized access.
CCI-000163	AU-9	The information system protects audit information from unauthorized modification.
CCI-000164	AU-9	The information system protects audit information from unauthorized deletion.
CCI-001493	AU-9	The information system protects audit tools from unauthorized access.
CCI-001494	AU-9	The information system protects audit tools from unauthorized modification.
CCI-001495	AU-9	The information system protects audit tools from unauthorized deletion.
CCI-000257	CA-3(a)	The organization authorizes connections from the information system to other information systems through the use of Interconnection Security Agreements.
CCI-000259	CA-3(b)	The organization documents, for each interconnection, the security requirements.
CCI-000260	CA-3(b)	The organization documents, for each interconnection, the nature of the information communicated.
CCI-000258	CA-3(b)	The organization documents, for each interconnection, the interface characteristics.
CCI-001732	CM-10(c)	The organization controls the use of peer-to-peer file sharing technology to ensure that this capability is not used for the unauthorized distribution, display, performance, or reproduction of copyrighted work.
CCI-001733	CM-10(c)	The organization documents the use of peer-to-peer file sharing technology to ensure that this capability is not used for the unauthorized distribution, display, performance, or reproduction of copyrighted work.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-000535	CP-9(a)	The organization conducts backups of user-level information contained in the information system per organization-defined frequency that is consistent with recovery time and recovery point objectives.
CCI-000537	CP-9(b)	The organization conducts backups of system-level information contained in the information system per organization-defined frequency that is consistent with recovery time and recovery point objectives.
CCI-000539	CP-9(c)	The organization conducts backups of information system documentation including security-related documentation per organization-defined frequency that is consistent with recovery time and recovery point objectives.
CCI-000540	CP-9(d)	The organization protects the confidentiality, integrity, and availability of backup information at storage locations.
CCI-000550	CP-10	The organization provides for the recovery and reconstitution of the information system to a known state after a disruption.
CCI-000551	CP-10	The organization provides for the recovery and reconstitution of the information system to a known state after a compromise.
CCI-000552	CP-10	The organization provides for the recovery and reconstitution of the information system to a known state after a failure.
CCI-001933	IA-1(a)	The organization defines the personnel or roles to be recipients of the identification and authentication policy and the procedures to facilitate the implementation of the identification and authentication policy and associated identification and authentication controls.
CCI-001934	IA-1(a)	The organization documents procedures to facilitate the implementation of the identification and authentication policy and associated identification and authentication controls.
CCI-000756	IA-1(a)(1)	The organization develops and documents an identification and authentication policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance.
CCI-000757	IA-1(a)(1)	The organization disseminates to organization defined personnel or roles an identification and authentication policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance.
CCI-001932	IA-1(a)(1)	The organization documents an identification and authentication policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance.
CCI-000760	IA-1(a)(2)	The organization develops and documents procedures to facilitate the implementation of the identification and authentication policy and associated identification and authentication controls.
CCI-000761	IA-1(a)(2)	The organization disseminates to organization-defined personnel or roles procedures to facilitate the implementation of the identification and authentication policy and associated identification and authentication controls.
CCI-000758	IA-1(b)(1)	The organization reviews and updates identification and authentication policy in accordance with the organization defined frequency.
CCI-000759	IA-1(b)(1)	The organization defines a frequency for reviewing and updating the identification and authentication policy.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-000762	IA-1(b)(2)	The organization reviews and updates identification and authentication procedures in accordance with the organization defined frequency.
CCI-000763	IA-1(b)(2)	The organization defines a frequency for reviewing and updating the identification and authentication procedures.
CCI-000764	IA-2	The information system uniquely identifies and authenticates organizational users (or processes acting on behalf of organizational users).
CCI-000765	IA-2(1)	The information system implements multifactor authentication for network access to privileged accounts.
CCI-001953	IA-2(12)	The information system accepts Personal Identity Verification (PIV) credentials.
CCI-001954	IA-2(12)	The information system electronically verifies Personal Identity Verification (PIV) credentials.
CCI-000777	IA-3	The organization defines a list of specific and/or types of devices for which identification and authentication is required before establishing a connection to the information system.
CCI-000778	IA-3	The information system uniquely identifies an organization defined list of specific and/or types of devices before establishing a local, remote, or network connection.
CCI-001958	IA-3	The information system authenticates an organization defined list of specific and/or types of devices before establishing a local, remote, or network connection.
CCI-001970	IA-4(a)	The organization defines the personnel or roles that authorize the assignment of individual, group, role, and device identifiers.
CCI-001971	IA-4(a)	The organization manages information system identifiers by receiving authorization from organization-defined personnel or roles to assign an individual, group, role or device identifier.
CCI-001972	IA-4(b)	The organization manages information system identifiers by selecting an identifier that identifies an individual, group, role, or device.
CCI-001973	IA-4(c)	The organization manages information system identifiers by assigning the identifier to the intended individual, group, role, or device.
CCI-001974	IA-4(d)	The organization defines the time period for which the reuse of identifiers is prohibited.
CCI-001975	IA-4(d)	The organization manages information system identifiers by preventing reuse of identifiers for an organization-defined time period.
CCI-000794	IA-4(e)	The organization defines a time period of inactivity after which the identifier is disabled.
CCI-000795	IA-4(e)	The organization manages information system identifiers by disabling the identifier after an organization defined time period of inactivity.
CCI-001990	IA-5(j)	The organization manages information system authenticators by changing authenticators for group/role accounts when membership to those accounts changes.
CCI-000192	IA-5(1)(a)	The information system enforces password complexity by the minimum number of upper case characters used.
CCI-000193	IA-5(1)(a)	The information system enforces password complexity by the minimum number of lower case characters used.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-000194	IA-5(1)(a)	The information system enforces password complexity by the minimum number of numeric characters used.
CCI-000205	IA-5(1)(a)	The information system enforces minimum password length.
CCI-001619	IA-5(1)(a)	The information system enforces password complexity by the minimum number of special characters used.
CCI-000195	IA-5(1)(b)	The information system, for password-based authentication, when new passwords are created, enforces that at least an organization-defined number of characters are changed.
CCI-000196	IA-5(1)(c)	The information system, for password-based authentication, stores only cryptographically-protected passwords.
CCI-000197	IA-5(1)(c)	The information system, for password-based authentication, transmits only cryptographically-protected passwords.
CCI-000199	IA-5(1)(d)	The information system enforces maximum password lifetime restrictions.
CCI-001618	IA-5(1)(e)	The organization defines the number of generations for which password reuse is prohibited.
CCI-000200	IA-5(1)(e)	The information system prohibits password reuse for the organization defined number of generations.
CCI-002041	IA-5(1)(f)	The information system allows the use of a temporary password for system logons with an immediate change to a permanent password.
CCI-002002	IA-5(11)	The organization defines the token quality requirements to be employed by the information system mechanisms for token-based authentication.
CCI-002003	IA-5(11)	The information system, for token-based authentication, employs mechanisms that satisfy organization-defined token quality requirements.
CCI-000206	IA-6	The information system obscures feedback of authentication information during the authentication process to protect the information from possible exploitation/use by unauthorized individuals.
CCI-000803	IA-7	The information system implements mechanisms for authentication to a cryptographic module that meet the requirements of applicable federal laws, Executive Orders, directives, policies, regulations, standards, and guidance for such authentication.
CCI-000804	IA-8	The information system uniquely identifies and authenticates non-organizational users (or processes acting on behalf of non-organizational users).
CCI-002009	IA-8(1)	The information system accepts Personal Identity Verification (PIV) credentials from other federal agencies.
CCI-002010	IA-8(1)	The information system electronically verifies Personal Identity Verification (PIV) credentials from other federal agencies.
CCI-002011	IA-8(2)	The information system accepts FICAM-approved third-party credentials.
CCI-002013	IA-8(3)	The organization employs only FICAM-approved information system components in organization-defined information systems to accept third-party credentials.
CCI-002014	IA-8(4)	The information system conforms to FICAM-issued profiles.
CCI-002566	MP-1(a)(1)	The organization defines personnel or roles to whom a documented media protection policy and procedures will be disseminated.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-000995	MP-1(a)(1)	The organization develops and documents a media protection policy that addresses purpose, scope, roles, responsibilities, management commitment, coordination among organizational entities, and compliance.
CCI-000996	MP-1(a)(1)	The organization disseminates to organization-defined personnel or roles a media protection policy.
CCI-000999	MP-1(a)(2)	The organization develops and documents procedures to facilitate the implementation of the media protection policy and associated media protection controls.
CCI-001000	MP-1(a)(2)	The organization disseminates to organization-defined personnel or roles procedures to facilitate the implementation of the media protection policy and associated media protection controls.
CCI-000998	MP-1(b)(1)	The organization defines a frequency for reviewing and updating the current media protection policy.
CCI-000997	MP-1(b)(1)	The organization reviews and updates the current media protection policy in accordance with organization-defined frequency.
CCI-001002	MP-1(b)(2)	The organization defines a frequency for reviewing and updating the current media protection procedures.
CCI-001001	MP-1(b)(2)	The organization reviews and updates the current media protection procedures in accordance with organization-defined frequency.
CCI-001003	MP-2	The organization restricts access to organization-defined types of digital and/or non-digital media to organization-defined personnel or roles.
CCI-001004	MP-2	The organization defines types of digital and/or non-digital media for which the organization restricts access.
CCI-001005	MP-2	The organization defines personnel or roles to restrict access to organization-defined types of digital and/or non-digital media.
CCI-001028	MP-6(a)	The organization sanitizes organization-defined information system media prior to disposal, release out of organizational control, or release for reuse using organization-defined sanitization techniques and procedures in accordance with applicable federal and organizational standards and policies.
CCI-002578	MP-6(a)	The organization defines information system media to sanitize prior to disposal, release out of organizational control, or release for reuse using organization-defined sanitization techniques and procedures in accordance with applicable federal and organizational standards and policies.
CCI-002579	MP-6(a)	The organization defines the sanitization techniques and procedures in accordance with applicable federal and organization standards and policies to be used to sanitize organization-defined information system media prior to disposal, release out of organizational control, or release for reuse.
CCI-002580	MP-6(b)	The organization employs sanitization mechanisms with the strength and integrity commensurate with the security category or classification of the information.
CCI-002581	MP-7	The organization defines the types of information system media to restrict or prohibit on organization-defined information systems or system components using organization-defined security safeguards.
CCI-002582	MP-7	The organization defines the information systems or system components to restrict or prohibit the use of organization-defined types of information system media using organization-defined security safeguards.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-002583	MP-7	The organization defines the security safeguards to use for restricting or prohibiting the use of organization-defined types of information system media on organization-defined information systems or system components.
CCI-002584	MP-7	The organization restricts or prohibits the use of organization-defined types of information system media on organization-defined information systems or system components using organization-defined security safeguards.
CCI-000965	PE-13	The organization employs and maintains fire suppression and detection devices/systems for the information system that are supported by an independent energy source.
CCI-000971	PE-14(a)	The organization maintains temperature and humidity levels within the facility where the information system resides at organization-defined acceptable levels.
CCI-000972	PE-14(a)	The organization defines acceptable temperature and humidity levels to be maintained within the facility where the information system resides.
CCI-000973	PE-14(b)	The organization monitors temperature and humidity levels in accordance with organization-defined frequency.
CCI-000974	PE-14(b)	The organization defines a frequency for monitoring temperature and humidity levels.
CCI-000977	PE-15	The organization protects the information system from damage resulting from water leakage by providing master shutoff or isolation valves that are accessible.
CCI-000978	PE-15	The organization protects the information system from damage resulting from water leakage by providing master shutoff or isolation valves that are working properly.
CCI-000979	PE-15	Key personnel have knowledge of the master water shutoff or isolation valves.
CCI-000981	PE-16	The organization authorizes organization-defined types of information system components entering and exiting the facility.
CCI-000982	PE-16	The organization monitors organization-defined types of information system components entering and exiting the facility.
CCI-000983	PE-16	The organization controls organization-defined types of information system components entering and exiting the facility.
CCI-000984	PE-16	The organization maintains records of information system components entering and exiting the facility.
CCI-002974	PE-16	The organization defines types of information system components to authorize, monitor, and control entering and exiting the facility and to maintain records.
CCI-003051	PL-2(a)(2)	The organization's security plan for the information system explicitly defines the authorization boundary for the system.
CCI-001055	RA-5(a)	The organization defines a frequency for scanning for vulnerabilities in the information system and hosted applications.
CCI-001054	RA-5(a)	The organization scans for vulnerabilities in the information system and hosted applications on an organization-defined frequency.
CCI-001056	RA-5(a)	The organization scans for vulnerabilities in the information system and hosted applications when new vulnerabilities potentially affecting the system/applications are identified and reported.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-001641	RA-5(a)	The organization defines the process for conducting random vulnerability scans on the information system and hosted applications.
CCI-001643	RA-5(a)	The organization scans for vulnerabilities in the information system and hosted applications in accordance with the organization-defined process for random scans.
CCI-001057	RA-5(b)	The organization employs vulnerability scanning tools and techniques that facilitate interoperability among tools and automate parts of the vulnerability management process by using standards for: enumerating platforms, software flaws, and improper configurations; formatting checklists and test procedures; and measuring vulnerability impact.
CCI-001058	RA-5(c)	The organization analyzes vulnerability scan reports and results from security control assessments.
CCI-001059	RA-5(d)	The organization remediates legitimate vulnerabilities in organization-defined response times in accordance with an organizational assessment risk.
CCI-003116	SA-4(10)	The organization employs only information technology products on the FIPS 201-approved products list for Personal Identity Verification (PIV) capability implemented within organizational information systems.
CCI-003137	SA-9(a)	The organization defines security controls that providers of external information system services employ in accordance with applicable federal laws, Executive Orders, directives, policies, regulations, standards, and guidance.
CCI-000669	SA-9(a)	The organization requires that providers of external information system services comply with organizational information security requirements.
CCI-000670	SA-9(a)	The organization requires that providers of external information system services employ organization-defined security controls in accordance with applicable federal laws, Executive Orders, directives, policies, regulations, standards, and guidance.
CCI-000671	SA-9(b)	The organization defines government oversight with regard to external information system services.
CCI-000672	SA-9(b)	The organization documents government oversight with regard to external information system services.
CCI-000673	SA-9(b)	The organization defines user roles and responsibilities with regard to external information system services.
CCI-000674	SA-9(b)	The organization documents user roles and responsibilities with regard to external information system services.
CCI-003138	SA-9(c)	The organization employs organization-defined processes, methods, and techniques to monitor security control compliance by external service providers on an ongoing basis.
CCI-003139	SA-9(c)	The organization defines processes, methods, and techniques to employ to monitor security control compliance by external service providers on an ongoing basis.
CCI-001093	SC-5	The organization defines the types of denial of service attacks (or provides references to sources of current denial of service attacks) that can be addressed by the information system.
CCI-002386	SC-5	The organization defines the security safeguards to be employed to protect the information system against, or limit the effects of, denial of service attacks.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-002385	SC-5	The information system protects against or limits the effects of organization-defined types of denial of service attacks by employing organization-defined security safeguards.
CCI-001097	SC-7(a)	The information system monitors and controls communications at the external boundary of the system and at key internal boundaries within the system.
CCI-001098	SC-7(c)	The information system connects to external networks or information systems only through managed interfaces consisting of boundary protection devices arranged in accordance with an organizational security architecture.
CCI-002428	SC-12	The organization defines the requirements for cryptographic key generation to be employed within the information system.
CCI-002429	SC-12	The organization defines the requirements for cryptographic key distribution to be employed within the information system.
CCI-002430	SC-12	The organization defines the requirements for cryptographic key storage to be employed within the information system.
CCI-002431	SC-12	The organization defines the requirements for cryptographic key access to be employed within the information system.
CCI-002432	SC-12	The organization defines the requirements for cryptographic key destruction to be employed within the information system.
CCI-001150	SC-15(a)	The information system prohibits remote activation of collaborative computing devices excluding the organization-defined exceptions where remote activation is to be allowed.
CCI-001151	SC-15(a)	The organization defines exceptions to the prohibiting of collaborative computing devices where remote activation is to be allowed.
CCI-001152	SC-15(b)	The information system provides an explicit indication of use to users physically present at collaborative computing devices.
CCI-002465	SC-21	The information system requests data origin authentication verification on the name/address resolution responses the system receives from authoritative sources.
CCI-002466	SC-21	The information system requests data integrity verification on the name/address resolution responses the system receives from authoritative sources.
CCI-002467	SC-21	The information system performs data integrity verification on the name/address resolution responses the system receives from authoritative sources.
CCI-002468	SC-21	The information system performs data origin verification authentication on the name/address resolution responses the system receives from authoritative sources.
CCI-002544	SC-41	The organization defines the information systems or information system components on which organization-defined connection ports or input/output devices are to be physically disabled or removed.
CCI-002545	SC-41	The organization defines the connection ports or input/output devices that are to be physically disabled or removed from organization-defined information systems or information system components.
CCI-001228	SI-2(b)	The organization tests software updates related to flaw remediation for effectiveness before installation.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-001229	SI-2(b)	The organization tests software updates related to flaw remediation for potential side effects before installation.
CCI-002602	SI-2(b)	The organization tests firmware updates related to flaw remediation for effectiveness before installation.
CCI-002603	SI-2(b)	The organization tests firmware updates related to flaw remediation for potential side effects before installation.
CCI-001227	SI-2(a)	The organization corrects information system flaws.
CCI-002619	SI-3(a)	The organization employs malicious code protection mechanisms at information system entry points to detect malicious code.
CCI-002621	SI-3(a)	The organization employs malicious code protection mechanisms at information system entry points to eradicate malicious code.
CCI-002620	SI-3(a)	The organization employs malicious code protection mechanisms at information system exit points to detect malicious code.
CCI-002622	SI-3(a)	The organization employs malicious code protection mechanisms at information system exit points to eradicate malicious code.
CCI-001241	SI-3(c)(1)	The organization configures malicious code protection mechanisms to perform periodic scans of the information system on an organization-defined frequency.
CCI-002624	SI-3(c)(1)	The organization configures malicious code protection mechanisms to perform real-time scans of files from external sources at network entry/exit points as the files are downloaded, opened, or executed in accordance with organizational security policy.
CCI-001242	SI-3(c)(1)	The organization configures malicious code protection mechanisms to perform real-time scans of files from external sources at endpoints as the files are downloaded, opened, or executed in accordance with organizational security policy.
CCI-001244	SI-3(c)(2)	The organization defines one or more actions to perform in response to malicious code detection, such as blocking malicious code, quarantining malicious code, or sending alert to administrator.
CCI-001243	SI-3(c)(2)	The organization configures malicious code protection mechanisms to perform organization-defined action(s) in response to malicious code detection.
CCI-001253	SI-4(a)(1)	The organization defines the objectives of monitoring for attacks and indicators of potential attacks on the information system.
CCI-002641	SI-4(a)(1)	The organization monitors the information system to detect attacks and indicators of potential attacks in accordance with organization-defined monitoring objectives.
CCI-002642	SI-4(a)(2)	The organization monitors the information system to detect unauthorized local connections.
CCI-002643	SI-4(a)(2)	The organization monitors the information system to detect unauthorized network connections.
CCI-002644	SI-4(a)(2)	The organization monitors the information system to detect unauthorized remote connections.
CCI-002645	SI-4(b)	The organization defines the techniques and methods to be used to identify unauthorized use of the information system.
CCI-002646	SI-4(b)	The organization identifies unauthorized use of the information system through organization-defined techniques and methods.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-001256	SI-4(c)	The organization deploys monitoring devices at ad hoc locations within the system to track specific types of transactions of interest to the organization.
CCI-002647	SI-4(d)	The organization protects information obtained from intrusion-monitoring tools from unauthorized access.
CCI-002648	SI-4(d)	The organization protects information obtained from intrusion-monitoring tools from unauthorized modification.
CCI-002649	SI-4(d)	The organization protects information obtained from intrusion-monitoring tools from unauthorized deletion.
CCI-001257	SI-4(e)	The organization heightens the level of information system monitoring activity whenever there is an indication of increased risk to organizational operations and assets, individuals, other organizations, or the Nation based on law enforcement information, intelligence information, or other credible sources of information.
CCI-001258	SI-4(f)	The organization obtains legal opinion with regard to information system monitoring activities in accordance with applicable federal laws, Executive Orders, directives, policies, or regulations.
CCI-002650	SI-4(g)	The organization defines the information system monitoring information that is to be provided the organization-defined personnel or roles.
CCI-002651	SI-4(g)	The organization defines the personnel or roles that are to be provided organization-defined information system monitoring information.
CCI-002652	SI-4(g)	The organization defines the frequency at which the organization will provide the organization-defined information system monitoring information to organization-defined personnel or roles
CCI-002654	SI-4(g)	The organization provides organization-defined information system monitoring information to organization-defined personnel or roles as needed or per organization-defined frequency.
CCI-002692	SI-5(a)	The organization defines the external organizations from which it receives information system security alerts, advisories and directives.
CCI-001285	SI-5(a)	The organization receives information system security alerts, advisories, and directives from organization-defined external organizations on an ongoing basis.
CCI-001286	SI-5(b)	The organization generates internal security alerts, advisories, and directives as deemed necessary.
CCI-002693	SI-5(c)	The organization defines the elements within the organization to whom the organization will disseminate security alerts, advisories and directives.
CCI-001288	SI-5(c)	The organization defines the personnel or roles to whom the organization will disseminate security alerts, advisories and directives.
CCI-001287	SI-5(c)	The organization disseminates security alerts, advisories, and directives to organization-defined personnel or roles, organization-defined elements within the organization, and/or organization-defined external organizations.
CCI-001289	SI-5(d)	The organization implements security directives in accordance with established time frames, or notifies the issuing organization of the degree of noncompliance.
CCI-000080	PM-3(a)	The organization ensures that all capital planning and investment requests include the resources needed to implement the information security program and documents all exceptions to this requirement.

Table G-6 Platform Enclave CCIs for LOW and MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-000081	PM-3(b)	The organization employs a business case/Exhibit 300/Exhibit 53 to record the resources required.
CCI-000141	PM-3(c)	The organization ensures that information security resources are available for expenditure as planned.
CCI-002991	PM-4(a)(1)	The organization implements a process for ensuring that plans of action and milestones for the security program and associated organizational information systems are developed.
CCI-000142	PM-4(a)(1)	The organization implements a process for ensuring that plans of action and milestones for the security program and the associated organizational information systems are maintained.
CCI-000170	PM-4(a)(2)	The organization implements a process for ensuring that plans of action and milestones for the security program and associated organizational information systems document the remedial information security actions to adequately respond to risk to organizational operations and assets, individuals, other organizations, and the Nation.
CCI-002992	PM-4(a)(3)	The organization implements a process for ensuring that plans of action and milestones for the security program and associated organizational information systems are reported in accordance with OMB FISMA reporting requirements.
CCI-000236	PM-11(b)	The organization determines information protection needs arising from the defined mission/business processes and revises the processes as necessary, until an achievable set of protection needs are obtained.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-000015	AC-2(1)	The organization employs automated mechanisms to support the information system account management functions.
CCI-001361	AC-2(2)	The organization defines a time period after which temporary accounts are automatically terminated.
CCI-001365	AC-2(2)	The organization defines a time period after which emergency accounts are automatically terminated.
CCI-001682	AC-2(2)	The information system automatically removes or disables emergency accounts after an organization-defined time period for each type of account.
CCI-000016	AC-2(2)	The information system automatically removes or disables temporary accounts after an organization-defined time period for each type of account.
CCI-000017	AC-2(3)	The information system automatically disables inactive accounts after an organization-defined time period.
CCI-000018	AC-2(4)	The information system automatically audits account creation actions.
CCI-001403	AC-2(4)	The information system automatically audits account modification actions.
CCI-002130	AC-2(4)	The information system automatically audits account enabling actions.
CCI-001404	AC-2(4)	The information system automatically audits account disabling actions.
CCI-001405	AC-2(4)	The information system automatically audits account removal actions.
CCI-001683	AC-2(4)	The information system notifies organization-defined personnel or roles for account creation actions.
CCI-001684	AC-2(4)	The information system notifies organization-defined personnel or roles for account modification actions.
CCI-002132	AC-2(4)	The information system notifies organization-defined personnel or roles for account enabling actions.
CCI-001685	AC-2(4)	The information system notifies organization-defined personnel or roles for account disabling actions.
CCI-001686	AC-2(4)	The information system notifies organization-defined personnel or roles for account removal actions.
CCI-001368	AC-4	The information system enforces approved authorizations for controlling the flow of information within the system based on organization-defined information flow control policies.
CCI-001414	AC-4	The information system enforces approved authorizations for controlling the flow of information between interconnected systems based on organization-defined information flow control policies.
CCI-001548	AC-4	The organization defines the information flow control policies for controlling the flow of information within the system.
CCI-001549	AC-4	The organization defines the information flow control policies for controlling the flow of information between interconnected systems.
CCI-001550	AC-4	The organization defines approved authorizations for controlling the flow of information within the system.
CCI-001551	AC-4	The organization defines approved authorizations for controlling the flow of information between interconnected systems.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-002220	AC-5(c)	The organization defines information system access authorizations to support separation of duties.
CCI-000225	AC-6	The organization employs the concept of least privilege, allowing only authorized accesses for users (and processes acting on behalf of users) which are necessary to accomplish assigned tasks in accordance with organizational missions and business functions.
CCI-002231	AC-6(7)(b)	The organization reassigns or removes privileges, if necessary, to correctly reflect organizational mission/business needs.
CCI-000059	AC-11(a)	The organization defines the time period of inactivity after which the information system initiates a session lock.
CCI-000058	AC-11(a)	The information system provides the capability for users to directly initiate session lock mechanisms.
CCI-000056	AC-11(b)	The information system retains the session lock until the user reestablishes access using established identification and authentication procedures.
CCI-000060	AC-11(1)	The information system conceals, via the session lock, information previously visible on the display with a publicly viewable image.
CCI-002360	AC-12	The organization defines the conditions or trigger events requiring session disconnect to be employed by the information system when automatically terminating a user session.
CCI-002361	AC-12	The information system automatically terminates a user session after organization-defined conditions or trigger events requiring session disconnect.
CCI-000067	AC-17(1)	The information system monitors remote access methods.
CCI-002314	AC-17(1)	The information system controls remote access methods.
CCI-000068	AC-17(2)	The information system implements cryptographic mechanisms to protect the confidentiality of remote access sessions.
CCI-001453	AC-17(2)	The information system implements cryptographic mechanisms to protect the integrity of remote access sessions.
CCI-001561	AC-17(3)	The organization defines managed access control points for remote access to the information system.
CCI-002315	AC-17(3)	The organization defines the number of managed network access control points through which the information system routes all remote access.
CCI-000069	AC-17(3)	The information system routes all remote accesses through organization-defined number managed network access control points.
CCI-000070	AC-17(4)(a)	The organization authorizes the execution of privileged commands via remote access only for organization-defined needs.
CCI-002316	AC-17(4)(a)	The organization authorizes the access to security-relevant information via remote access only for organization-defined needs.
CCI-002317	AC-17(4)(a)	The organization defines the operational needs when the execution of privileged commands via remote access is to be authorized.
CCI-002318	AC-17(4)(a)	The organization defines the operational needs when access to security-relevant information via remote access is to be authorized.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	800-53 Control Text Indicator	CCI Definition
CCI-002319	AC-17(4)(b)	The organization documents in the security plan for the information system the rationale for authorization of the execution of privilege commands via remote access.
CCI-002320	AC-17(4)(b)	The organization documents in the security plan for the information system the rationale for authorization of access to security-relevant information via remote access.
CCI-002321	AC-17(9)	The organization defines the time period within which it disconnects or disables remote access to the information system.
CCI-002322	AC-17(9)	The organization provides the capability to expeditiously disconnect or disable remote access to the information system within the organization-defined time period.
CCI-002329	AC-19(5)	The organization defines the mobile devices that are to employ full-device or container encryption to protect the confidentiality and integrity of the information on device.
CCI-002330	AC-19(5)	The organization employs full-device encryption or container encryption to protect the confidentiality of information on organization-defined mobile devices.
CCI-002333	AC-20(1)(a)	The organization permits authorized individuals to use an external information system to access the information system only when the organization verifies the implementation of required security controls on the external system as specified in the organization’s information security policy and security plan.
CCI-002334	AC-20(1)(a)	The organization permits authorized individuals to use an external information system to process organization-controlled information only when the organization verifies the implementation of required security controls on the external system as specified in the organization’s information security policy and security plan.
CCI-002335	AC-20(1)(a)	The organization permits authorized individuals to use an external information system to store organization-controlled information only when the organization verifies the implementation of required security controls on the external system as specified in the organization’s information security policy and security plan.
CCI-002336	AC-20(1)(a)	The organization permits authorized individuals to use an external information system to transmit organization-controlled information only when the organization verifies the implementation of required security controls on the external system as specified in the organization’s information security policy and security plan.
CCI-002337	AC-20(1)(b)	The organization permits authorized individuals to use an external information system to access the information system or to process, store, or transmit organization-controlled information only when the organization retains approved information system connection or processing agreements with the organizational entity hosting the external information system.
CCI-000097	AC-20(2)	The organization restricts or prohibits the use of organization-controlled portable storage devices by authorized individuals on external information systems.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-001875	AU-7(a)	The information system provides an audit reduction capability that supports on-demand audit review and analysis.
CCI-001876	AU-7(a)	The information system provides an audit reduction capability that supports on-demand reporting requirements.
CCI-001877	AU-7(a)	The information system provides an audit reduction capability that supports after-the-fact investigations of security incidents.
CCI-001878	AU-7(a)	The information system provides a report generation capability that supports on-demand audit review and analysis.
CCI-001879	AU-7(a)	The information system provides a report generation capability that supports on-demand reporting requirements.
CCI-001880	AU-7(a)	The information system provides a report generation capability that supports after-the-fact investigations of security incidents.
CCI-001881	AU-7(b)	The information system provides an audit reduction capability that does not alter original content or time ordering of audit records.
CCI-001882	AU-7(b)	The information system provides a report generation capability that does not alter original content or time ordering of audit records.
CCI-000158	AU-7(1)	The information system provides the capability to process audit records for events of interest based on organization-defined audit fields within audit records.
CCI-002081	CA-3(5)	The organization defines the information systems that employ either allow-all, deny-by-exception or deny-all, permit by exception policy for allowing connection to external information systems.
CCI-002082	CA-3(5)	The organization selects either allow-all, deny-by exception or deny-all, permit by exception policy for allowing organization-defined information systems to connect to external information systems.
CCI-002080	CA-3(5)	The organization employs either an allow-all, deny-by exception or deny-all, permit by exception policy for allowing organization-defined information systems to connect to external information systems.
CCI-000338	CM-5	The organization defines physical access restrictions associated with changes to the information system.
CCI-000339	CM-5	The organization documents physical access restrictions associated with changes to the information system.
CCI-000340	CM-5	The organization approves physical access restrictions associated with changes to the information system.
CCI-000341	CM-5	The organization enforces physical access restrictions associated with changes to the information system.
CCI-000342	CM-5	The organization defines logical access restrictions associated with changes to the information system.
CCI-000343	CM-5	The organization documents logical access restrictions associated with changes to the information system.
CCI-000344	CM-5	The organization approves logical access restrictions associated with changes to the information system.
CCI-000345	CM-5	The organization enforces logical access restrictions associated with changes to the information system.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-000419	CM-8(5)	The organization verifies that all components within the authorization boundary of the information system are not duplicated in other information system inventories.
CCI-000505	CP-6(a)	The organization establishes an alternate storage site including necessary agreements to permit the storage and retrieval of information system backup information.
CCI-002836	CP-6(b)	The organization ensures that the alternate storage site provides information security safeguards equivalent to that of the primary site.
CCI-000507	CP-6(1)	The organization identifies an alternate storage site that is separated from the primary storage site to reduce susceptibility to the same threats.
CCI-000509	CP-6(3)	The organization identifies potential accessibility problems to the alternate storage site in the event of an area-wide disruption or disaster.
CCI-001604	CP-6(3)	The organization outlines explicit mitigation actions for organization identified accessibility problems to the alternate storage site in the event of an area-wide disruption or disaster.
CCI-000510	CP-7(a)	The organization defines the time period consistent with recovery time and recovery point objectives for essential missions/business functions to permit the transfer and resumption of organization-defined information system operations at an alternate processing site when the primary processing capabilities are unavailable.
CCI-000513	CP-7(a)	The organization establishes an alternate processing site including necessary agreements to permit the transfer and resumption of organization-defined information system operations for essential missions within organization-defined time period consistent with recovery time and recovery point objectives when the primary processing capabilities are unavailable.
CCI-002839	CP-7(a)	The organization defines information system operations that are permitted to transfer and resume at an alternate processing sites for essential missions/business functions when the primary processing capabilities are unavailable.
CCI-000515	CP-7(b)	The organization ensures that equipment and supplies required to transfer and resume operations are available at the alternate processing site or contracts are in place to support delivery to the site within the organization-defined time period for transfer/resumption.
CCI-000521	CP-7(c)	The organization ensures that the alternate processing site provides information security safeguards equivalent to that of the primary site.
CCI-000516	CP-7(1)	The organization identifies an alternate processing site that is separated from the primary processing site to reduce susceptibility to the same threats.
CCI-000517	CP-7(2)	The organization identifies potential accessibility problems to the alternate processing site in the event of an area-wide disruption or disaster.
CCI-001606	CP-7(2)	The organization outlines explicit mitigation actions for organization identified potential accessibility problems to the alternate processing site in the event of an area-wide disruption or disaster.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-000518	CP-7(3)	The organization develops alternate processing site agreements that contain priority-of-service provisions in accordance with the organizational availability requirements (including recovery time objectives).
CCI-000522	CP-8	The organization defines the time period to permit the resumption of organization-defined information system operations for essential missions when the primary telecommunications capabilities are unavailable at either the primary or alternate processing or storage sites.
CCI-000524	CP-8	The organization establishes alternate telecommunication services including necessary agreements to permit the resumption of organization-defined information system operations for essential missions within organization-defined time period when the primary telecommunications capabilities are unavailable at either the primary or alternate processing or storage sites.
CCI-002840	CP-8	The organization defines the information system operations to be resumed for essential missions within the organization-defined time period when the primary telecommunications capabilities are unavailable at either the primary or alternate processing or storage sites.
CCI-000526	CP-8(1)(a)	The organization develops primary telecommunications service agreements that contain priority-of-service provisions in accordance with the organizations availability requirements (including recovery time objectives).
CCI-000527	CP-8(1)(a)	The organization develops alternate telecommunications service agreements that contain priority-of-service provisions in accordance with the organizations availability requirements (including recovery time objectives).
CCI-000528	CP-8(1)(b)	The organization requests Telecommunications Service Priority for all telecommunications services used for national security emergency preparedness in the event that the primary telecommunications services are provided by a common carrier.
CCI-000529	CP-8(1)(b)	The organization requests Telecommunications Service Priority for all telecommunications services used for national security emergency preparedness in the event that the alternate telecommunications services are provided by a common carrier.
CCI-000530	CP-8(2)	The organization obtains alternate telecommunications services to reduce the likelihood of sharing a single point of failure with primary telecommunications services.
CCI-000541	CP-9(1)	The organization defines the frequency to test backup information to verify media reliability and information integrity.
CCI-000542	CP-9(1)	The organization tests backup information per organization-defined frequency to verify media reliability and information integrity.
CCI-000766	IA-2(2)	The information system implements multifactor authentication for network access to non-privileged accounts.
CCI-000767	IA-2(3)	The information system implements multifactor authentication for local access to privileged accounts.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-001947	IA-2(11)	The organization defines the strength of mechanism requirements for the device that is separate from the system gaining access and is to provide one factor of a multifactor authentication for remote access to privileged accounts.
CCI-001950	IA-2(11)	The organization defines the strength of mechanism requirements for the device that is separate from the system gaining access and is to provide one factor of a multifactor authentication for remote access to non-privileged accounts.
CCI-001948	IA-2(11)	The information system implements multifactor authentication for remote access to privileged accounts such that one of the factors is provided by a device separate from the system gaining access.
CCI-001952	IA-2(11)	The device used in the information system implementation of multifactor authentication for remote access to non-privileged accounts meets organization-defined strength of mechanism requirements.
CCI-001951	IA-2(11)	The information system implements multifactor authentication for remote access to non-privileged accounts such that one of the factors is provided by a device separate from the system gaining access.
CCI-001949	IA-2(11)	The device used in the information system implementation of multifactor authentication for remote access to privileged accounts meets organization-defined strength of mechanism requirements.
CCI-000185	IA-5(2)(a)	The information system, for PKI-based authentication validates certifications by constructing and verifying a certification path to an accepted trust anchor including checking certificate status information.
CCI-000186	IA-5(2)(b)	The information system, for PKI-based authentication enforces authorized access to the corresponding private key.
CCI-000187	IA-5(2)(c)	The information system, for PKI-based authentication, maps the authenticated identity to the account of the individual or group.
CCI-001991	IA-5(2)(d)	The information system, for PKI-based authentication, implements a local cache of revocation data to support path discovery and validation in case of inability to access revocation information via the network.
CCI-001992	IA-5(3)	The organization defines the personnel or roles responsible for authorizing the organization's registration authority accountable for the authenticator registration process.
CCI-001993	IA-5(3)	The organization defines the registration authority accountable for the authenticator registration process.
CCI-001994	IA-5(3)	The organization defines the types of and/or specific authenticators that are subject to the authenticator registration process.
CCI-001995	IA-5(3)	The organization requires that the registration process, to receive organization-defined types of and/or specific authenticators, be conducted in person, or by a trusted third-party, before organization-defined registration authority with authorization by organization-defined personnel or roles.
CCI-002890	MA-4(6)	The information system implements cryptographic mechanisms to protect the integrity of nonlocal maintenance and diagnostic communications.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-003123	MA-4(6)	The information system implements cryptographic mechanisms to protect the confidentiality of nonlocal maintenance and diagnostic communications.
CCI-002891	MA-4(7)	The information system implements remote disconnect verification at the termination of nonlocal maintenance and diagnostic sessions.
CCI-001010	MP-3(a)	The organization marks information system media indicating the distribution limitations, handling caveats, and applicable security markings (if any) of the information.
CCI-001011	MP-3(b)	The organization exempts organization-defined types of information system media from marking as long as the media remain within organization-defined controlled areas.
CCI-001012	MP-3(b)	The organization defines types of information system media to exempt from marking as long as the media remain within organization-defined controlled areas.
CCI-001013	MP-3(b)	The organization defines controlled areas where organization-defined types of information system media are exempt from being marked.
CCI-001014	MP-4(a)	The organization physically controls and securely stores organization-defined types of digital and/or non-digital media within organization-defined controlled areas.
CCI-001015	MP-4(a)	The organization defines types of digital and/or non-digital media to physically control and securely store within organization-defined controlled areas.
CCI-001016	MP-4(a)	The organization defines controlled areas where organization-defined types of digital and/or non-digital media are physically controlled and securely stored.
CCI-001018	MP-4(b)	The organization protects information system media until the media are destroyed or sanitized using approved equipment, techniques, and procedures.
CCI-001020	MP-5(a)	The organization protects and controls organization-defined types of information system media during transport outside of controlled areas using organization-defined security safeguards.
CCI-001021	MP-5(a)	The organization defines types of information system media protected and controlled during transport outside of controlled areas.
CCI-001022	MP-5(a)	The organization defines security safeguards to be used to protect and control organization-defined types of information system media during transport outside of controlled areas.
CCI-001023	MP-5(b)	The organization maintains accountability for information system media during transport outside of controlled areas.
CCI-001025	MP-5(c)	The organization documents activities associated with the transport of information system media.
CCI-001024	MP-5(d)	The organization restricts the activities associated with the transport of information system media to authorized personnel.
CCI-001027	MP-5(4)	The information system implements cryptographic mechanisms to protect the confidentiality and integrity of information stored on digital media during transport outside of controlled areas.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-002585	MP-7(1)	The organization prohibits the use of portable storage devices in organization information systems when such devices have no identifiable owner.
CCI-000956	PE-10(a)	The organization provides the capability of shutting off power to the information system or individual system components in emergency situations.
CCI-000957	PE-10(b)	The organization places emergency shutoff switches or devices in an organization-defined location by information system or system component to facilitate safe and easy access for personnel.
CCI-000958	PE-10(b)	The organization defines a location for emergency shutoff switches or devices by information system or system component.
CCI-000959	PE-10(c)	The organization protects emergency power shutoff capability from unauthorized activation.
CCI-002955	PE-11	The organization provides a short-term uninterruptible power supply to facilitate an orderly shutdown of the information system and/or transition of the information system to long-term alternate power in the event of a primary power source loss.
CCI-000961	PE-11(1)	The organization provides a long-term alternate power supply for the information system that is capable of maintaining minimally required operational capability in the event of an extended loss of the primary power source.
CCI-001062	RA-5(1)	The organization employs vulnerability scanning tools that include the capability to readily update the information system vulnerabilities to be scanned.
CCI-001063	RA-5(2)	The organization updates the information system vulnerabilities scanned on an organization-defined frequency, prior to a new scan and/or when new vulnerabilities are identified and reported.
CCI-001067	RA-5(5)	The information system implements privileged access authorization to organization-identified information system components for selected organization-defined vulnerability scanning activities.
CCI-001645	RA-5(5)	The organization identifies the information system components to which privileged access is authorized for selected organization-defined vulnerability scanning activities.
CCI-002906	RA-5(5)	The organization defines the vulnerability scanning activities in which the information system implements privileged access authorization to organization-identified information system components.
CCI-000634	SA-4(7)(a)	The organization limits the use of commercially provided information assurance (IA) and IA-enabled information technology products to those products that have been successfully evaluated against a National Information Assurance partnership (NIAP)-approved Protection Profile for a specific technology type, if such a profile exists.
CCI-000635	SA-4(7)(b)	The organization requires, if no NIAP-approved Protection Profile exists for a specific technology type but a commercially provided information technology product relies on cryptographic functionality to enforce its security policy, that the cryptographic module is FIPS-validated.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-003143	SA-9(2)	The organization requires providers of organization-defined external information system services to identify the functions, ports, protocols, and other services required for the use of such services.
CCI-003144	SA-9(2)	The organization defines the external information system services for which the providers are required to identify the functions, ports, protocols, and other services required for the use of such services.
CCI-001082	SC-2	The information system separates user functionality (including user interface services) from information system management functionality.
CCI-001090	SC-4	The information system prevents unauthorized and unintended information transfer via shared system resources.
CCI-001094	SC-5(1)	The information system restricts the ability of individuals to launch organization-defined denial of service attacks against other information systems.
CCI-001101	SC-7(3)	The organization limits the number of external network connections to the information system.
CCI-001102	SC-7(4)(a)	The organization implements a managed interface for each external telecommunication service.
CCI-001103	SC-7(4)(b)	The organization establishes a traffic flow policy for each managed interface for each external telecommunication service.
CCI-002396	SC-7(4)(c)	The organization protects the confidentiality and integrity of the information being transmitted across each interface for each external telecommunication service.
CCI-001105	SC-7(4)(d)	The organization documents each exception to the traffic flow policy with a supporting mission/business need and duration of that need for each external telecommunication service.
CCI-001108	SC-7(4)(e)	The organization removes traffic flow policy exceptions that are no longer supported by an explicit mission/business need for each external telecommunication service.
CCI-001106	SC-7(4)(e)	The organization reviews exceptions to the traffic flow policy on an organization-defined frequency for each external telecommunication service.
CCI-001109	SC-7(5)	The information system at managed interfaces denies network communications traffic by default and allows network communications traffic by exception (i.e., deny all, permit by exception).
CCI-002397	SC-7(7)	The information system, in conjunction with a remote device, prevents the device from simultaneously establishing non-remote connections with the system and communicating via some other connection to resources in external networks.
CCI-001113	SC-7(8)	The organization defines the internal communications traffic to be routed to external networks.
CCI-001114	SC-7(8)	The organization defines the external networks to which the organization-defined internal communications traffic should be routed.
CCI-001112	SC-7(8)	The information system routes organization-defined internal communications traffic to organization-defined external networks through authenticated proxy servers at managed interfaces.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	800-53 Control Text Indicator	CCI Definition
CCI-002398	SC-7(9)(a)	The information system detects outgoing communications traffic posing a threat to external information systems.
CCI-002399	SC-7(9)(a)	The information system denies outgoing communications traffic posing a threat to external information systems.
CCI-002403	SC-7(11)	The information system only allows incoming communications from organization-defined authorized sources routed to organization-defined authorized destinations.
CCI-002401	SC-7(11)	The organization defines the authorized sources from which the information system will allow incoming communications.
CCI-002402	SC-7(11)	The organization defines the authorized destinations for routing inbound communications.
CCI-002404	SC-7(12)	The organization defines the host-based boundary protection mechanisms that are to be implemented at organization-defined information system components.
CCI-002405	SC-7(12)	The organization defines the information system components at which organization-defined host-based boundary protection mechanisms will be implemented.
CCI-002406	SC-7(12)	The organization implements organization-defined host-based boundary protection mechanisms at organization-defined information system components.
CCI-001120	SC-7(13)	The organization defines key information security tools, mechanisms, and support components to be isolated.
CCI-001119	SC-7(13)	The organization isolates organization-defined information security tools, mechanisms, and support components from other internal information system components by implementing physically separate subnetworks with managed interfaces to other components of the system.
CCI-001121	SC-7(14)	The organization protects against unauthorized physical connections at organization-defined managed interfaces.
CCI-001122	SC-7(14)	The organization defines the managed interfaces where boundary protections against unauthorized physical connections are to be implemented.
CCI-002407	SC-7(14)	The organization defines the managed interfaces at which the organization protects against unauthorized physical connections.
CCI-001133	SC-10	The information system terminates the network connection associated with a communications session at the end of the session or after an organization-defined time period of inactivity.
CCI-002449	SC-13	The organization defines the cryptographic uses, and type of cryptography required for each use, to be implemented by the information system.
CCI-002450	SC-13	The information system implements organization-defined cryptographic uses and type of cryptography required for each use in accordance with applicable federal laws, Executive Orders, directives, policies, regulations, and standards.
CCI-001159	SC-17	The organization issues public key certificates under an organization-defined certificate policy or obtains public key certificates from an approved service provider.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-002456	SC-17	The organization defines the certificate policy employed to issue public key certificates.
CCI-001160	SC-18(a)	The organization defines acceptable and unacceptable mobile code and mobile code technologies.
CCI-001161	SC-18(b)	The organization establishes usage restrictions for acceptable mobile code and mobile code technologies.
CCI-001162	SC-18(b)	The organization establishes implementation guidance for acceptable mobile code and mobile code technologies.
CCI-001163	SC-18(c)	The organizations authorizes the use of mobile code within the information system.
CCI-001164	SC-18(c)	The organization monitors the use of mobile code within the information system.
CCI-001165	SC-18(c)	The organization controls the use of mobile code within the information system.
CCI-001166	SC-18(1)	The information system identifies organization-defined unacceptable mobile code.
CCI-001662	SC-18(1)	The information system takes organization-defined corrective action when organization-defined unacceptable mobile code is identified.
CCI-002457	SC-18(1)	The organization defines the corrective actions to be taken when organization-defined unacceptable mobile code is identified.
CCI-002458	SC-18(1)	The organization defines what constitutes unacceptable mobile code for its information systems.
CCI-001184	SC-23	The information system protects the authenticity of communications sessions.
CCI-001199	SC-28	The information system protects the confidentiality and/or integrity of organization-defined information at rest.
CCI-001234	SI-2(2)	The organization defines a frequency for employing automated mechanisms to determine the state of information system components with regard to flaw remediation.
CCI-001233	SI-2(2)	The organization employs automated mechanisms on an organization-defined frequency to determine the state of information system components with regard to flaw remediation.
CCI-001246	SI-3(1)	The organization centrally manages malicious code protection mechanisms.
CCI-001247	SI-3(2)	The information system automatically updates malicious code protection mechanisms.
CCI-002655	SI-4(1)	The organization connects individual intrusion detection tools into an information system-wide intrusion detection system.
CCI-002656	SI-4(1)	The organization configures individual intrusion detection tools into an information system-wide intrusion detection system.
CCI-001260	SI-4(2)	The organization employs automated tools to support near real-time analysis of events.
CCI-002659	SI-4(4)	The organization defines the frequency on which it will monitor inbound communications for unusual or unauthorized activities or conditions.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-002660	SI-4(4)	The organization defines the frequency on which it will monitor outbound communications for unusual or unauthorized activities or conditions.
CCI-002661	SI-4(4)	The information system monitors inbound communications traffic per organization-defined frequency for unusual or unauthorized activities or conditions.
CCI-002662	SI-4(4)	The information system monitors outbound communications traffic per organization-defined frequency for unusual or unauthorized activities or conditions.
CCI-001264	SI-4(5)	The organization defines indicators of compromise or potential compromise to the security of the information system which will result in information system alerts being provided to organization-defined personnel or roles.
CCI-002663	SI-4(5)	The organization defines the personnel or roles to receive information system alerts when organization-defined indicators of compromise or potential compromise occur.
CCI-002664	SI-4(5)	The information system alerts organization-defined personnel or roles when organization-defined compromise indicators reflect the occurrence of a compromise or a potential compromise.
CCI-001273	SI-4(11)	The organization analyzes outbound communications traffic at the external boundary of the information system to discover anomalies.
CCI-001671	SI-4(11)	The organization analyzes outbound communications traffic at selected organization-defined interior points within the system (e.g., subnetworks, subsystems) to discover anomalies.
CCI-001673	SI-4(14)	The organization employs a wireless intrusion detection system to identify rogue wireless devices and to detect attack attempts and potential compromises/breaches to the information system.
CCI-001282	SI-4(15)	The organization employs an intrusion detection system to monitor wireless communications traffic as the traffic passes from wireless to wireline networks.
CCI-002683	SI-4(22)	The information system detects network services that have not been authorized or approved by the organization-defined authorization or approval processes.
CCI-002684	SI-4(22)	The information system audits and/or alerts organization-defined personnel when unauthorized network services are detected.
CCI-002685	SI-4(23)	The organization defines the host-based monitoring mechanisms to be implemented at organization-defined information system components.
CCI-002687	SI-4(23)	The organization implements organization-defined host-based monitoring mechanisms at organization-defined information system components.
CCI-002703	SI-7	The organization defines the software, firmware, and information which will be subjected to integrity verification tools to detect unauthorized changes.
CCI-002704	SI-7	The organization employs integrity verification tools to detect unauthorized changes to organization-defined software, firmware, and information.
CCI-002705	SI-7(1)	The organization defines the software on which integrity checks will be performed.

Table G-7 Additional Platform Enclave CCIs for MODERATE Impact Control Systems		
CCI #	**800-53 Control Text Indicator**	**CCI Definition**
CCI-002706	SI-7(1)	The organization defines the firmware on which integrity checks will be performed.
CCI-002707	SI-7(1)	The organization defines the information on which integrity checks will be performed.
CCI-002710	SI-7(1)	The information system performs an integrity check of organization-defined software at startup, at organization-defined transitional states or security-relevant events, or on organization-defined frequency.
CCI-002711	SI-7(1)	The information system performs an integrity check of organization-defined firmware at startup, at organization-defined transitional states or security-relevant events, or on organization-defined frequency.
CCI-002712	SI-7(1)	The information system performs an integrity check of organization-defined information at startup, at organization-defined transitional states or security-relevant events, or on organization-defined frequency.
CCI-002708	SI-7(1)	The organization defines the transitional state or security-relevant events when the information system will perform integrity checks on software, firmware and information.
CCI-002719	SI-7(7)	The organization defines the unauthorized security-relevant changes to the information system that are to be incorporated into the organizational incident response capability.
CCI-002720	SI-7(7)	The organization incorporates the detection of unauthorized organization-defined security-relevant changes to the information system into the organizational incident response capability.
CCI-002823	SI-16	The organization defines the security safeguards to be implemented to protect the information system's memory from unauthorized code execution.
CCI-002824	SI-16	The information system implements organization-defined security safeguards to protect its memory from unauthorized code execution.

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APPENDIX H GLOSSARY

H-1 ACRONYMS

H-1.1 General Acronyms

Acronym	**Term**
ACL	Access Control List
AO	Authorizing Official
BAS	Building Automation System
BCS	Building Control System
CCTV	Closed Circuit Television
CNSSI	Committee on National Security Systems Instruction
CCI	Control Correlation Identifier
COTS	Commercial Off The Shelf
CS	Control System
DoD	Department of Defense
ESS	Electronic Security System
FCN	Field Control Network
FCS	Field Control System
FIPS	Federal Information Processing Standards
FISMA	Federal Information Security Management Act
FPOC	Field Point of Connection
GFE	Government Furnished Equipment
ICS	Industrial Control System
IDS	Intrusion Detection System
ISSM	Information System Security Manager
ISSO	Information System Security Officer
IP	Internet Protocol
IT	Information Technology
MOA	Memorandum Of Agreement
MOU	Memorandum Of Understanding
NIST	National Institute of Standards and Technology
OS	Operating System

Acronym	**Term**
PIT	Platform Information Technology
PKI	Public Key Infrastructure
SO	System Owner
UCS	Utility Control System
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UMCS	Utility Monitoring and Control System
UPS	Uninterruptible Power Supply
USACE	U.S. Army Corps of Engineers

H-1.2 Security Control Family Acronyms

Acronym	**Term**
AC	Access Control
AT	Awareness and Training
AU	Audit and Accountability
CA	Security Assessment and Authorization
CM	Configuration Management
CP	Contingency Planning
IA	Identification and Authorization
IR	Incident Response
MA	Maintenance
MP	Media Protection
PE	Physical and Environmental Protection
PL	Planning
PM	Program Management
PS	Personnel Security
RA	Risk Assessment
SA	System and Services Acquisition
SC	System and Communications Protection
SI	System and Information Integrity

H-2 DEFINITION OF TERMS

Note that UFGS 25 05 11, “Cybersecurity for Facility-Related Control Systems” also has definitions that complement those provided here.

Term	Definition
Authorizing Official (CNSSI No. 4009)	A senior (federal) official or executive with the authority to formally assume responsibility for operating an information system at an acceptable level of risk to organizational operations (including mission, functions, image, or reputation), organizational assets, individuals, other organizations, and the Nation. Within the DoD, they are presumed to be SES or flag-level officers.
Building Automation System (BAS)	The system consisting of a UMCS Front End, connected Building Control Systems which control building electrical and mechanical systems, and user interfaces for building control supervision. The BAS is a subsystem of the Utility Monitoring and Control System. This term is being phased out in favor of UMCS.
Building Control System (BCS)	A system that controls building electrical and mechanical systems such as HVAC (including central plants), lighting, vertical transport systems, and irrigation systems. Building Control Systems generally do not have a full-featured user interface; they may have “local display panels” but typically rely on the UMCS front end for full user interface functionality. BCS is a subsystem of the Utility Monitoring and Control System and is a class of Field Control System.
Closed Circuit Television System (CCTV)	An ESS that allows video assessment of alarm conditions via remote monitoring and recording of video events. Video monitoring may also be incorporated into other systems which are not CCTV.
Control Correlation Identifier (CCI)	The Control Correlation Identifier (CCI) provides a standard identifier and description for each of the singular, actionable statements that comprise a security control.

Term	Definition
Control System (CS)	Control systems are a combination of special purpose controlling devices (controllers), control components (e.g. electrical, mechanical or pneumatic sensors and actuators), and generally (but not always) network infrastructure (which may contain standard IT components) that act together upon underlying mechanical and/or electrical equipment to achieve an objective. A control system (CS) typically consists of sensors and actuators connected to networked digital controllers, includes a user interface, and is used to control and monitor equipment. Some control systems are "monitor only" (they do not exercise control) but are still considered control systems.
Controller	An electronic device – usually having internal programming logic and digital and analog input/output capability – which performs control functions.
Distributed Control System	This term describes a system architecture (not system functionality) and appears in some reference material (such as a NIST publications) but is not used by this UFC. (It's included here due to use in some reference material.)
Electronic Security System (ESS)	The integrated electronic system that encompasses interior and exterior (physical) intrusion detection systems (IDS), CCTV systems for assessment of alarm conditions, access control systems, data transmission media, and alarm reporting systems for monitoring, control, and display.
Engineering Tool Software	Software that is used to perform device or network management for a control system, including network configuration, controller configuration and controller programming.
Facility-Related Control System	A control system which controls equipment and infrastructure that is part of a DoD building, structure, or linear structure.
Field Control System (FCS)	A Building Control System, Utility Control System, Electronic Security System, etc. within the Facility and "downstream" of the FPOC.
Field Control Network (FCN)	The network used by the Building Control System, Utility Control System, etc., within a facility "downstream" of the FPOC. This includes IP, Ethernet, RS-485, TP/FT-10 and other network infrastructure that support control system(s) in a given facility.

Term	Definition
Field Point of Connection (FPOC)	The FPOC is the point of connection between the Level 4 control system IP network and the Level 2 field control IP network. Note the Level 2 IP network here may consist entirely of a single patch cable from the FPOC to a Level 1-to-Level 2 device. The hardware which provides the connection at this location is an IT device such as a switch, IP router, or firewall.
[UMCS, ESS, etc.] Front End	The portion of the control system consisting primarily of IT equipment, such as computers and related equipment, intended to perform operational functions and run monitoring and control/engineering tool application software. The front end does not directly control physical systems; it interacts with them only through field control systems (FCS). The front end is a component of the [UMCS, ESS, etc.] infrastructure (see definition).
Impact	The effect on organizational operations, organizational assets, or individuals due to a loss of Confidentiality, Integrity, or Availability in the control system. Impact is categorized as one of three levels: • LOW: limited adverse effect • MODERATE: serious adverse effect • HIGH: severe or catastrophic adverse effect The impact level of a system is generally written in ALL CAPS for clarity. Further discussion of Impact level is in APPENDIX D
Incident (FIPS PUB 200)	An occurrence that actually or potentially jeopardizes the confidentiality, integrity, or availability of an information system or the information the system processes, stores, or transmits or that constitutes a violation or imminent threat of violation of security policies, security procedures, or acceptable use policies
Industrial Control System (ICS)	One type of control system. Most specifically a control system which controls an industrial (manufacturing) process. Sometimes also used to refer to other types of control systems, particularly utility control systems such as electrical, gas, or water distribution systems.

Term	**Definition**
Information System (CNSSI No. 4009)	A discrete set of information resources organized for the collection, processing, maintenance, use, sharing, dissemination, or disposition of information. Note: Information systems also include specialized systems such as industrial/process controls systems, telephone switching and private branch exchange (PBX) systems, and environmental control systems.
Information Technology (IT)	Any equipment or interconnected system or subsystem of equipment that is used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information by the executive agency.
[UMCS, ESS, ...] Infrastructure	The portion of a control system (such as a UMCS or ESS) which includes all components that are not part of a field control system. These components include the FPOC, the Platform Enclave, and the front end (i.e., its architecture Levels 3, 4 and 5)
Intrusion Detection System (IDS) [Physical/ESS]	A system consisting of interior and exterior sensors, surveillance devices, and associated communication subsystems that collectively detect an intrusion of a specified site, facility, or perimeter and annunciate an alarm.
Intrusion Detection System (IDS) [Cyber]	A device or software application that monitors network or system activities for malicious activities or policy violations and produces reports to management.
Least Privilege (CNSSI No. 4009)	The principle that a security architecture should be designed so that each entity is granted the minimum system resources and authorizations that the entity needs to perform its function.
Mobile Code (NIST SP 800-53r4)	Software programs or parts of programs obtained from remote information systems, transmitted across a network, and executed on a local information system without explicit installation or execution by the recipient.
Mobile Code Technology (NIST SP 800-53r4)	Software technologies that provide the mechanisms for the production and use of mobile code (e.g., Java, JavaScript, ActiveX, VBScript). Note that use of Mobile Code Technology does not necessarily imply the use of Mobile Code.

Term	Definition
Network	A network is a group of two or more devices that can communicate using a network protocol. Network protocols must provide a method for addressing devices on the network; a communication method that does not provide an addressing scheme is not a networked form of communication. Devices that communicate using a method of communication that does not support device addressing are not using a network.
Non-Local Maintenance (NIST SP 800-53)	Maintenance activities conducted by individuals communicating through a network; either an external network (e.g., the Internet) or an internal network.
Operational Architecture (OA)	Those components of a control system that represent the purely operational components of the system such as controllers, Front End software, and other devices which support operational functions. When the “Platform Enclave” approach to authorizing a control system is used, the “non-standard IT” portions of the control system are authorized as the Operational Architecture and the overall system has two authorizations: Platform Enclave and Operational Architecture.
[UMCS, ESS, ...] Platform Enclave	Those components of the control system that are standard IT components and can be secured in a standard manner independent of the type of control system. These components serve only the control system and include the IP network, network management and security devices (e.g., switches, routers), software, computers and/or other devices which provide management and security of the network.
Platform IT (PIT)	IT, both hardware and software, which is physically part of, dedicated to, or essential in real time to the mission performance of special purpose systems.
Remote Access (NIST SP 800-53)	Remote access is access to organizational information systems by users (or processes acting on behalf of users) communicating through external networks (e.g., the Internet). See definition of “User Interface, Remote” for critical distinction in use of terminology

Term	**Definition**
Risk (NIST SP 800-53)	A measure of the extent to which an entity is threatened by a potential circumstance or event, and typically a function of: (i) the adverse impacts that would arise if the circumstance or event occurs; and (ii) the likelihood of occurrence. Information system-related security risks are those risks that arise from the loss of confidentiality, integrity, or availability of information or information systems and reflect the potential adverse impacts to organizational operations (including mission, functions, image, or reputation), organizational assets, individuals, other organizations, and the Nation.
Risk Management (NIST SP 800-53)	The process of managing risks to organizational operations (including mission, functions, image, reputation), organizational assets, individuals, other organizations, and the Nation, resulting from the operation of an information system, and includes: (i) the conduct of a risk assessment; (ii) the implementation of a risk mitigation strategy; and (iii) employment of techniques and procedures for the continuous monitoring of the security state of the information system.
Supervisory Control and Data Acquisition (SCADA)	This term has a variety of meanings depending on context and is therefore not used in this UFC.
System Owner (SO) (CNSSI No. 4009)	Person or organization having responsibility for the development, procurement, integration, modification, operation and maintenance, and/or final disposition of an information system.
User Interface	A User Interface is something that allows a person to interact with the control system. For purposes of cybersecurity, a User Interface does not include simple analog and/or binary inputs such as HOA switches, dials, etc. (“Manual Local Input” in UFGS 25 05 11) or simple Card Readers. Proper addressing of User Interfaces is critical for cybersecurity. Note that User Interfaces are defined in a more exhaustive and prescriptive manner in UFGS 25 05 11 to enable specification of user interface requirements.

Term	**Definition**
User Interface, Remote or Local	A Remote User Interface implements a Client/Server model where the physical hardware the user interacts with (Client) is physically distinct from the device being affected (Server). Most or all of the security and functionality characteristics of the user interface are defined by the Server, not the Client. A common example of a remote user interface is a web-based interface where the browser (client) is generally on different hardware than the web server (server). A Remote UI remains a Remote UI even if the user happens to be at a Client on the same hardware as the Server. What is important is that a) the Client may be on different hardware than the Server and b) the majority of the security and functional characteristics of the interface are defined at the Server. A Local User Interface is a user interface where the physical hardware the user interacts with (keyboard, buttons, display, etc.) is physically part of the device being affected. All of the relevant characteristics of the user interface are embodied within a single device. Note that this definition of "remote" is consistent with that generally used in the control industry but is not aligned with the NIST 800-53 definition of "Remote" or “Remote Access”, which refers to "outside the system". The term "Remote" here better aligns with the NIST 800-53 definition of "Network" (remote from within the system) Access.
User Interface, Limited or Full	A Limited User Interface is a user interface that - by design - can only alter information local to the user interface. Note that the determination of "alter" includes only direct interactions, it explicitly excludes interactions that might occur as secondary effects. For example, an interface changing the flow setpoint in a pump controller is a direct interaction, the subsequent change in flow (as well as any subsequent downstream changes in valve position) are not direct interactions. For example, a variable speed drive has a Limited Local User Interface which allows the user to change properties within the drive but does not allow affecting things outside the drive. A Full User Interface can alter information in devices outside the device with the user interface. For example, a typical Local Display Panel is a Full Local User Interface while a browser-based front end is a Full Remote User Interface.

Term	**Definition**
User Interface, Privileged	A Privileged UI is a UI that has sufficient capabilities or functionality that it requires specific cybersecurity measures to be put in place to limit its unauthorized use. Ultimately, whether a specific user interface is considered a Privileged User Interface must be determined by usage. In general however, user interfaces that do not offer significant capabilities above and beyond those available at that location via other means (e.g., a disconnect switch, breaker, hand-off-auto switch, or direct physical attack) are not privileged. Note that UFGS 25 05 11 contains additional information and requirements on identifying when a UI is a Privileged UI to enable specification of UI requirements.
Utility Control System (UCS)	A type of field control system used for control of utility systems such as electrical distribution and generation, sanitary sewer collection and treatment, water generation and pumping, etc. Building controls are excluded from a UCS, however it is possible to have a Utility Control System and a Building Control System in the same facility, and for those systems to share components such as the FPOC. A UCS is a subsystem of a Utility Monitoring and Control System (UMCS) and is a class of Field Control System (FCS).
Utility Monitoring and Control System (UMCS)	The system consisting of one or more building control systems and/or utility control systems and the associated UMCS Infrastructure. In other words, it is the complete utility monitoring system – from the front end to the controllers. At the highest level the UMCS is composed of a UMCS Platform Enclave and UMCS Front End (jointly referred to as UMCS Infrastructure) and connected Field Control System(s). There are many different names for a UMCS – Energy Monitoring and Control System being a common one – but regardless of the name systems that perform this function are a type of UMCS.
Vulnerability (NIST SP 800-53)	Weakness in an information system, system security procedures, internal controls, or implementation that could be exploited or triggered by a threat source.

APPENDIX I REFERENCES

COMMITTEE ON NATIONAL SECURITY SYSTEMS

https://www.cnss.gov/CNSS/issuances/Instructions.cfm

CNSSI No. 1253, *Security Categorization and Control Selection for National Security Systems*

CNSSI No. 4009, *Committee on National Security Systems (CNSS) Glossary*

UNITED STATES DEPARTMENT OF DEFENSE

https://www.dtic.mil

Department of Defense Instruction 8500.01, *Cybersecurity*, March 2014

Department of Defense Instruction 8510.01, *Risk Management Framework (RMF) for DoD Information Technology (IT)*, March 2014

FEDERAL INFORMATION PROCESSING STANDARDS

https://csrc.nist.gov/publications/fips

FIPS PUB 200, *Minimum Security Requirements for Federal Information and Information Systems*

FIPS PUB 201-2, *Personal Identity Verification (PIV) of Federal Employees and Contractors*

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

https://standards.ieee.org/ieee/802.1X/7345/

IEEE 802.1X, *Port Based Network Access Control*

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

https://www.nist.gov/

NIST SP 800-53 Revision 4, *Security and Privacy Controls for Federal Information Systems and Organizations*, April 2013

NIST SP 800-60, Vol. II, *Appendices to Guide for Mapping Types of Information and Information System to Security Categories*, August, 2008

NIST SP 800-82 Revision 2, *Guide to Industrial Control Systems (ICS) Security*, May 2015

UNIFIED FACILITIES CRITERIA (UFC)

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

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

UNIFIED FACILITIES GUIDE SPECIFICATIONS (UFGS)

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

UFGS 25 05 11, *Cybersecurity for Facility-Related Control Systems*

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

UFC 4-020-01
11 September 2008

UNIFIED FACILITIES CRITERIA (UFC)

DoD Security Engineering Facilities Planning Manual

UNIFIED FACILITIES CRITERIA (UFC)

DoD Security Engineering Facilities Planning Manual

DEPUTY UNDER SECRETARY OF DEFENSE (INSTALLATIONS AND ENVIRONMENT)

J3, DEPUTY DIRECTORATE FOR ANTITERRORISM AND FORCE PROTECTION, JOINT CHIEFS OF STAFF

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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

Change No.	Date	Location

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

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

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

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

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Unified Facilities Criteria (UFC)
New Document Summary Sheet

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

Cancels: UFC 4-020-01 FA, Security Engineering Project Development

Document Description and Need:

- **Purpose:** This UFC supports the planning of DoD facilities that include requirements for security and antiterrorism. It will be used in conjunction with UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*, to establish the security and antiterrorism design criteria that will be the basis for DoD facility designs. Those criteria include the assets to be protected, the threats to those assets, the levels to which those assets are to be protected against those threats, and any design constraints imposed by facility users. This document also provides a means for identifying the costs for providing the applicable levels of protection and a risk management process for evaluating those costs and the protection options.
- **Application and Use:** Commanders, security and antiterrorism personnel, planners, and other members of project planning teams will use this UFC to establish project specific design criteria for DoD facilities, estimate the costs for implementing those criteria, and evaluating both the design criteria and the options for implementing it. The design criteria and costs will be incorporated into project programming documents. This UFC also provides guidance for incorporation of security and antiterrorism principles into installation master planning.
- **Need:** This UFC is one in a series of security engineering Unified Facilities Criteria that address minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. This UFC provides the starting point for application of all of the manuals within the security engineering series. Without this UFC, there would be no standardized DoD-wide process for identifying and justifying design criteria for security and antiterrorism and no basis for applying the other manuals in the series.

Impact. The following direct benefits will result from publication of UFC 4-020-01:

- Creates a standardized approach for identifying and justifying security and antiterrorism design criteria for DoD facilities
- Creates standardized nomenclature and criteria for asset, threat, and level of protection definition.
- Creates a standardized procedure for identifying costs for DoD facilities with security and antiterrorism requirements to a planning level of detail.
- Creates a standardized process for evaluating design criteria and protection options based on cost and risk management.
- Provides guidance for incorporating security and antiterrorism principles into installation master planning.
- Does not have any adverse impacts on environmental, sustainability, or constructability policies or practices.

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CHAPTER 1

INTRODUCTION

1-1 **BACKGROUND.** In December 1999 DoD published the *Interim Department of Defense Antiterrorism / Force Protection Construction Standards,* which was the first attempt by DoD to ensure that antiterrorism standards were incorporated into the planning, programming, and budgeting for the design and construction of military facilities. Those standards were replaced by UFC 4-010-01, the *DoD Minimum Antiterrorism Standards for Buildings*. The development of minimum standards for protecting DoD personnel against terrorist acts was required by Title 10 U.S. Code, Subtitle A, PART IV, CHAPTER 169, SUBCHAPTER III, §2859 and implemented by DoD Instruction 2000.16.

The minimum standards provide baseline minimum levels of protection with which all DoD inhabited buildings must comply as long as they meet specific "triggers". Those levels of protection can be achieved using conventional construction if certain minimum standoff distances are provided. There needed to be guidance for how to design buildings where the minimum standoff distances were not available. In addition, there needed to be guidance for providing higher levels of protection where users could justify them, for addressing threats other than terrorist threats, and for addressing protection of assets other than people.

Up until the development of the security engineering series of UFC, there was no DoD-wide standardized process for identifying and justifying design criteria beyond the minimum standards, which resulted in a wide range of solutions. Some of those solutions provided unjustifiably high levels of protection or protection to unrealistic threats. Some resulted in unreasonably low levels of protection. Design and planning guidance was spread among multiple service specific documents that were neither coordinated nor uniform. This UFC is intended to provide the uniformity and consistency in planning for security and antiterrorism that were not previously available.

1-2 **PURPOSE.** The purpose of this UFC is to support planning of projects that include requirements for security and antiterrorism. Those requirements come from the *DoD Minimum Antiterrorism Standards for Buildings*, combatant command standards, standards from other DoD components or commands, regulations, or installation or user requirements. Projects include new construction, existing construction or expeditionary and temporary construction. The intended users of this UFC are engineering planners responsible for project development and planning teams responsible for developing design criteria for projects. The ultimate purpose of this guidance is to develop appropriate, effective, unobtrusive, and economical protective designs to a level appropriate for project programming and to provide commanders with the information they need to allocate resources.

1-3 **SCOPE.** The scope of this UFC includes the following:

1-3.1 **Design Criteria Development.** This UFC includes a process for defining the design criteria for a protective system that protects important assets associated with a permanent facility or one in an expeditionary environment. The design criteria will consist of the assets to be protected, the threats to those assets, the degree to which those assets will be protected against the threat, and any constraints that might be imposed on a design. The design criteria may be limited to that defined in minimum standards or it may go beyond those requirements.

1-3.2 **Cost Increase Identification.** This UFC includes a process for identifying the increases in cost associated with protecting the identified assets to the applicable threat and to the appropriate level of protection over that of conventional construction.

1-3.3 **Cost Increase Justification.** The processes in this UFC provide a basis for justifying increased project costs related to security and antiterrorism in programming documents using relative risk to ensure the added costs are not deleted in the budgetary process.

1-4 **APPLICABILITY.** This UFC applies to all DoD components and to all DoD assets and facilities that are owned, leased, privatized, or otherwise occupied, managed, or controlled by or for DoD.

1-5 **REFERENCES**

- Interim Department of Defense Antiterrorism / Force Protection Construction Standards, December 16, 1999 (cancelled by UFC 4-010-01)
- DoD Instruction 2000.16, DoD Antiterrorism Standards, 14 June 2001.
- DoD O-2000.12-H, DoD Antiterrorism Handbook, 9 February 2004
- DoD Manual 5100.76-M, Physical Security of Sensitive Conventional Arms, Ammunition, and Explosives, 12 August 2000
- Unified Facilities Criteria (UFC) 3-701-05, DoD Facilities Pricing Guide, March 2005
- Unified Facilities Criteria (UFC) 4-010-01, DoD Minimum Antiterrorism Standards for Buildings, 8 October 2003
- Unified Facilities Criteria (UFC) 4-010-02, DoD Minimum Antiterrorism Standoff Distances for Buildings; (For Official Use Only (FOUO)) 8 October 2003
- Unified Facilities Criteria (UFC) 4-020-02, DoD Security Engineering Facilities Design Manual, (Draft)
- DoD 6055.9-STD, DoD Ammunition and Explosive Safety Standards, 5 October 2004

- United States European Command (USEUCOM) Antiterrorism Operations Order 08-01, January, 2008 (For Official Use Only (FOUO))
- United States Central Command (USCENTCOM) Operations Order 05-01, *Antiterrorism,* 10 August 2005
- Army Field Manual 3-9, Navy Publication P-467, Air Force Manual 355-7, Potential Military Chemical/Biological Agents and Compounds, 12 December 1990
- Army Field Manual 3-6, Air Force Manual 105-7, Fleet Marine Field Manual 7-11-H, Field Behavior of NBC Agents (Including Smoke and Incendiaries), 3 November 1986

1-6 **THE PLANNING TEAM.** Establishing the design criteria for security and antiterrorism is not something that can be done effectively by any one person. It requires a team of people to ensure that the varied interests relating to a project are considered appropriately. The specific membership of a planning team will be based on local considerations, but in general, the following functions should be represented.

1-6.1 **Facility User.** The ultimate users of the planned facility identify the assets within the facility that will require protection and establish their relative value. The users also identify any special operational or logistical design constraints for the facility.

1-6.2 **Antiterrorism.** DoD Instruction 2000.16 requires every installation or base to have an antiterrorism officer. The role of the antiterrorism officer is to orchestrate the development of comprehensive antiterrorism plans and to coordinate the efforts of all organizations on the installations with respect to antiterrorism preparation and response. As such, the antiterrorism officer is a critical member of the planning team.

1-6.3 **Intelligence.** Representatives of this function are responsible for providing input for the identification of threats to identified assets including information on potential aggressors, their likely targets, and their likely tactics. Because the scope of security engineering potentially includes criminals, terrorists, subversives, and foreign intelligence agents, the intelligence role might not be represented by one person or organization. Criminal intelligence and terrorist intelligence may be in different organizations, for example. This varies by DoD component and location.

1-6.4 **Operations.** Representatives of this function may be considered to serve as installation level user representatives or representatives of the senior tactical commander on an installation. The installation antiterrorism office and the responsibility for antiterrorism commonly reside in operations.

1-6.5 **Security.** Representatives of the security and law enforcement function are responsible for detecting and defeating acts of aggression against assets. Therefore, these representatives supply information about the response capabilities of military police, contract or security guards, local police, or other applicable security forces. They may also provide information on general security requirements and on criminal threats.

1-6.6 **Logistics.** Representatives of this function are commonly responsible for maintenance of installed equipment in facilities. They provide input on equipment maintenance and on integrating with existing systems.

1-6.7 **Engineering.** Representatives of this function are responsible for facility planning, design, construction, maintenance, and repair. The Director of Public Works (DPW) or Base Civil Engineer (BCE) (or equivalent) organizations commonly include the master planner or project programmer. The programmer organizes and leads the planning team; consolidates all facility requirements, design criteria, and project cost information into the appropriate programming documents; and establishes the project cost estimate or budget.

1-6.8 **Resource Management.** The resource manager will be responsible for obtaining the funds necessary to implement whatever projects are formulated as part of this process. They are also familiar with what funds sources are available and with the requirements for programming those funds.

1-6.9 **Others.** Based on local considerations, there may be others who should be consulted for input into the design criteria. They might include Fire Marshals, communications people, environmental people, and historic preservation officers.

1-7 **INTEGRATING WITH OTHER REQUIREMENTS.** Security and antiterrorism requirements will never be the only requirements associated with a project. Even where a project is specifically for security and antiterrorism upgrades, there will still be other requirements that must be considered. There will be times where one criterion is more stringent than another, in which case the more stringent one must be applied. In some cases, criteria may conflict. In those cases, those conflicts must be resolved, which may require compromise or adjustment to one or the other criteria. The following are examples of common criteria that must be integrated with security and antiterrorism requirements.

1-7.1 **Security Regulations.** Many security regulations specify protective measures, policies, and operations related to security. This UFC is intended to complement those existing regulations, not to contradict or supersede them. Regulatory requirements must be accommodated and coordinated.

1-7.2 **Explosive Safety.** Antiterrorism standards establish criteria to minimize the potential for mass casualties and progressive collapse from a terrorist attack. In addition, based on application of this UFC, planning teams may identify higher levels of protection against explosives threats than are mandated by the minimum standards. DoD 6055.9-STD, *DoD Ammunition and Explosive Safety Standards* as implemented by Service component explosive safety standards, establish acceptable levels of protection for accidental explosions of DoD-titled munitions. The explosive safety and antiterrorism standards address hazards associated with unique events; therefore, they may specify different levels of protection. Compliance with both standards is required. Where conflicts arise, the more stringent criteria will govern.

1-7.3 **Other DoD Component Standards.** DoD components and Combatant Commanders are allowed to supplement the *DoD Minimum Antiterrorism Standards for Buildings,* but those supplemental requirements may not be less stringent. Examples of such supplemental requirements include USEUCOM Operations Order 08-01 and USCENTCOM Operations Order 05-01. Those operations orders establish additional construction standards for projects constructed in the European and Central Command areas of operations. In addition, DoD components may establish implementing instructions for applying the *DoD Minimum Antiterrorism Standards for Buildings,* which need to be taken into account in project planning.

1-7.4 **Historic Preservation.** Implementation of security and antiterrorism requirements cannot supersede the DoD obligation to comply with federal laws regarding cultural resources to include the National Historic Preservation Act and the Archaeological Resources Protection Act. The planning team needs to determine possible adverse effects upon an historic structure and/or archaeological resource in conjunction with establishing antiterrorism and security requirements to the greatest extent possible and to consult accordingly. Personnel at installations abroad should coordinate with the host nation regarding possible adverse effects to cultural resources. Conversely, historic preservation compliance does not negate the requirement to implement security and antiterrorism standards and requirements. Federal agencies are always the decision-maker in the Section 106 process of the National Historic Preservation Act. An agency should not allow for prolonged consultations that conflict with the eminent need to implement security and antiterrorism standards and requirements. Preservation issues need to be quickly and effectively resolved to avoid obstructing security and antiterrorism efforts.

1-7.5 **Sustainable Design.** Sustainable design seeks to reduce negative impacts on the environment and on the health and comfort of building occupants, thereby improving building performance. The basic objectives of sustainability are to reduce consumption of non-renewable resources, minimize waste, and create healthy, productive environments. Requirements for security and antiterrorism may pose challenges for sustainable design, but the two goals are not mutually exclusive. Two of the most significant areas of conflict are in providing plantings close to buildings for shading and water conservation and in maximizing natural lighting. Issues such as those require careful coordination among design disciplines and may require tradeoffs.

1-7.6 **Other Facility Requirements.** Project programmers and designers also must consider issues such as life safety and fire protection, functional issues, energy conservation, seismic criteria, barrier-free handicapped access, and aesthetics. Protective measures may enhance energy conservation or seismic survivability, but the objectives of life safety requirements or barrier-free access may conflict with the objectives of the protective system. The programmer and the planning team need to recognize conflicts and establish priorities in the programming phase to guide designers to appropriate and optimal solutions.

1-8 **SECURITY ENGINEERING UFC SERIES.** This UFC is one of a series of security engineering Unified Facilities Criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include the following:

1-8.1 **DoD Minimum Antiterrorism Standards for Buildings.** UFC 4-010-01 and 4-010-02 establish standards that provide minimum levels of protection against terrorist attacks for the occupants of all DoD inhabited buildings. Those UFC are intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings. They also include recommendations that should be, but are not required to be incorporated into all such buildings.

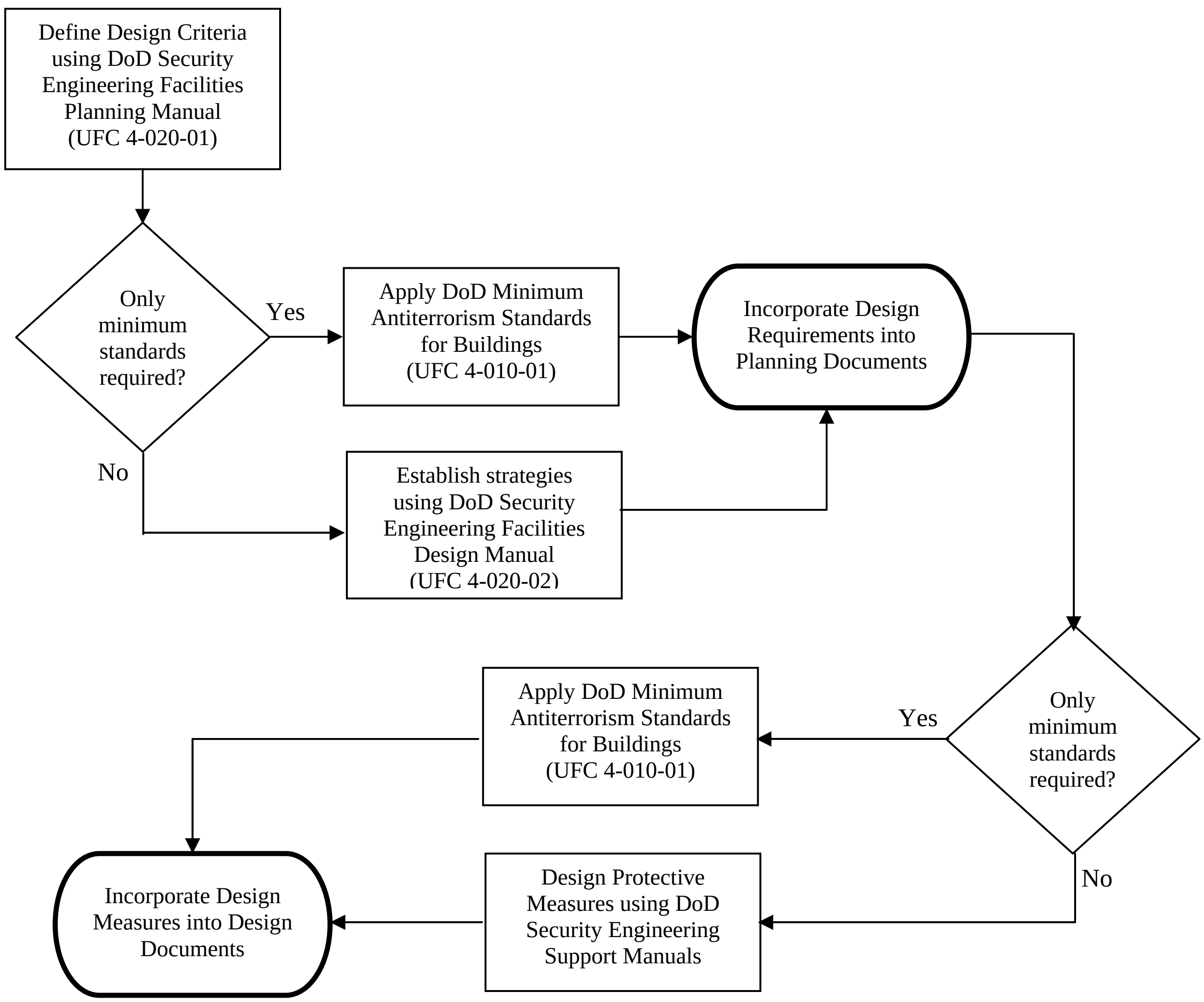
1-8.2 **Security Engineering Facilities Planning Manual.** This manual presents processes for developing the design criteria necessary to incorporate security and antiterrorism into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards, or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also addresses the tradeoffs between cost and risk. The Security Engineering Facilities Planning Manual is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

1-8.3 **Security Engineering Facilities Design Manual.** UFC 4-020-02 provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02 is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design. The manual also provides a process for assessing the impact of protective measures on risk. The primary audience for the Security Engineering Design Manual is the design team, but it can also be used by security and antiterrorism personnel.

1-8.4 **Security Engineering Support Manuals.** In addition to the standards, planning, and design UFCs mentioned above, there is a series of additional UFCs that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, forced entry, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mail rooms. Still others address details of designs for specific protective measures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

1-9 Security Engineering UFC Application. The application of the security engineering series of UFCs is illustrated in Figure 1-1. This manual is intended to be the starting point for any project that is likely to have security or antiterrorism requirements. By beginning with this UFC, the design criteria will be developed that establishes which of the other UFCs in the series will need to be applied. The design criteria may indicate that only the minimum standards need to be incorporated, or it may include additional requirements, resulting in the need for application of additional UFCs. Even if only the minimum standards are required other UFCs may need to be applied if sufficient standoff distances are unavailable. Applying this series of UFCs in the manner illustrated in Figure 1-1 will result in the most efficient use of resources for protecting assets against security and antiterrorism related threats.

Figure 1-1. Security Engineering UFC Application



CHAPTER 2

AGGRESSOR THREATS AND TACTICS

2-1 **INTRODUCTION.** Historical patterns and trends in aggressor activity indicate general categories of aggressors and the common tactics that they can be predicted to use against DoD assets. These aggressor tactics and their associated tools, weapons, explosives, and agents are the basis for the threat to assets. Understanding the basis for the threat and the aggressors' objectives is essential to effective protective system design. This chapter describes aggressors, tactics, tools, weapons, explosives, and agents that are referred to throughout the security engineering series of UFC.

For the purposes of designing a protective system, the perpetrators of terrorist or criminal acts or acts of espionage are not important. To designers the important issue is how an aggressor attacks the asset and with what. Within this UFC aggressors will only be considered in determining the tactics that will be used against assets and the tools, weapons, explosives, and agents associated with those tactics. The aggressors will not be carried into the design criteria.

This is by no means a comprehensive treatment of threat. The purpose of this chapter is to provide a common basis for defining threat for the purposes of facility design. Planning teams may add additional threat parameters as they find it necessary.

2-2 **AGGRESSORS.** Aggressors are people who perform hostile acts against assets such as equipment, personnel, and operations. The aggressor objectives and aggressor categories considered in this UFC are described below.

2-2.1 **Aggressor Objectives.** There are four major aggressor objectives that describe aggressor behavior. An explanation of how these objectives apply to each aggressor category is presented in subsequent paragraphs. Aggressors may use the first three objectives to accomplish the fourth. The four aggressor objectives include:

- Inflicting injury or death on people
- Destroying or damaging facilities, property, equipment, or resources
- Stealing equipment, materiel, or information
- Creating adverse publicity

2-2.2 **Aggressor Categories.** The four broad categories of aggressors considered in this manual are criminals, protesters, terrorists, and subversives. Hostile acts performed by these aggressors range from crimes such as burglary to low-intensity conflict such as unconventional warfare. Each of these aggressor categories describes predictable aggressors that pose threats to DoD assets and who share common objectives and tactics. This manual does not address the commonly referenced aggressor category of disaffected persons, which includes disoriented persons and disgruntled employees. Those aggressors are not covered separately in this manual because they may exhibit similar characteristics to any of the four categories included or they generally do not present a predictable threat.

2-2.2.1 **Criminals.** Criminals are divided into one of three possible groups based on their degree of sophistication. These three groups are defined as unsophisticated criminals, sophisticated criminals, and organized criminal groups. The common objective for all three criminal groups is assumed to be theft of assets.

2-2.2.1.1 **Unsophisticated Criminals.** Unsophisticated criminals are unskilled in the use of tools and weapons and have no formal organization. Their targets are those that meet their immediate needs such as drugs, money, and pilferable items. Unsophisticated criminals are interested in opportune targets that present little or no risk. Breaking and entering or smash-and-grab techniques are common. Theft by insiders is also common.

2-2.2.1.2 **Sophisticated Criminals.** Sophisticated criminals are skilled in the use of certain tools and weapons and are efficient and organized. They plan their attacks and have sophisticated equipment and the technical capability to employ it. Sophisticated criminals are often assisted by insiders. They target high value assets, frequently steal in large quantities, yet target assets with relatively low risk in handling and disposal. Commonly targeted facilities include controlled substance (drug) storage, warehouses, post exchanges, and Class VI (liquor) stores.

2-2.2.1.3 **Organized Criminal Groups.** Organized criminal groups are highly sophisticated, are able to draw on specialists, and are able to obtain the equipment needed to achieve their goals efficiently. These groups form efficient, hierarchical organizations which can employ highly paid insiders. Examples include drug cartels, organized crime "families," the Yakuza, and MS-13. Targets of organized criminal groups may involve a high degree of risk in handling and disposal such as large quantities of money; equipment; and arms, ammunition, and explosives. In addition, some such organizations have exhibited the will to inflict death or injury to support their activities or intimidate law enforcement personnel.

2-2.2.2 **Protesters**. For the purposes of this manual, only violent protesters are considered to be a threat. Protesters include the two general groups of vandals/activists and extremist protesters. Both groups are politically or issue oriented and act out of frustration, discontent, or anger against the actions of other social or political groups. The primary objectives of both groups commonly include destruction and publicity.

2-2.2.2.1 **Vandals/Activists.** Vandals/activists are commonly unsophisticated and superficially destructive. They generally do not intend to injure people or cause extensive damage to their targets. Their actions may be covert or overt. Typically, they choose symbolic targets that pose little risk to them. For the purposes of risk analysis in this document, vandals/activists are grouped with criminals.

2-2.2.2.2 **Extremist Protest Groups.** Extremist protest groups are moderately sophisticated and are usually more destructive than vandals. Their actions are frequently overt and may involve the additional objective or consequence of injuring people. They attack symbolic targets, including authority figures such as high-ranking officials and police, weapon systems, and things they consider to be environmentally unsound. For the purposes of risk analysis in this document, extremist protest groups are grouped with terrorists.

2-2.2.3 **Terrorists.** Terrorists are ideologically, politically, or issue oriented. They commonly work in small, well-organized groups or cells. They are sophisticated, skilled with tools and weapons, and possess an efficient planning capability. Terrorist objectives usually include death, destruction, theft, and publicity. Three types of terrorist groups are identified in this manual based on their areas of operation and their sophistication. The three types are domestic terrorists, international terrorists, and state sponsored terrorists.

2-2.2.3.1 **Domestic Terrorists.** Domestic terrorists for the purposes of this UFC are terrorists indigenous to the United States, Puerto Rico, and the US territories who are not directed by foreign interests. Domestic terrorists in the United States have typically been political extremists operating in distinct areas of the country. They have primarily consisted of ethnic and white supremacy groups, many with ties to groups that originated during the 1960's and 1970's. Historically, most acts of terrorism in the United States by domestic terrorists have been less severe than those outside the United States, and operations have been somewhat limited. One noted exception to that trend was the bombing of the Alfred P. Murrah Building in Oklahoma City.

2-2.2.3.2 **International Terrorists.** International terrorists are either connected to a foreign power or their activities transcend national boundaries. International terrorists have typically been better organized and better equipped than their domestic counterparts. They have included political extremists and ethnically or religiously oriented groups. Their attacks have also been more severe and more frequent than those by domestic terrorists in the United States. Examples of foreign terrorist groups designated by the U.S. Department of State include the Revolutionary Group 17 November, the Aum Shinrikyo Group, Basque Fatherland and Liberty (ETA), Sendero Luminoso (Shining Path), and the al-Aqsa Martyrs Brigade.

2-2.2.3.3 **State Sponsored Terrorists.** State sponsored terrorist groups generally operate independently, but receive foreign government support, to include intelligence and even operational support. They have exhibited military capabilities and have used a broad range of military and improvised weapons. They have historically staged the most serious terrorist attacks, including suicidal attacks. They are predominantly ethnically or religiously oriented. Some of these groups have legitimate political wings in addition to their terrorist wings. Examples of state sponsored terrorist groups designated by the U.S. Department of State include al Qaida, the Palestinian Islamic Jihad, Hizballah, and the Revolutionary Armed Forces of Columbia (FARC).

2-2.2.4 **Subversives.** Subversives include aggressors from foreign governments or from groups trying to overthrow the government by force. They include saboteurs and foreign intelligence agents.

2-2.2.4.1 **Saboteurs.** Saboteurs include guerrillas and unconventional warfare forces. They are paramilitary or actual military personnel who are very sophisticated, highly skilled, and employ meticulous planning. They commonly act in small groups, have an unlimited arsenal of weapons, and are well-trained in the use of those weapons. The objectives of saboteurs usually include destruction of property and death and their targets include mission-critical personnel, equipment, and operations. The scope of this manual is limited to sabotage in a low intensity conflict; therefore, full-scale attacks by guerrillas or commandos during wartime are not addressed.

2-2.2.4.2 **Foreign Intelligence Agents.** Foreign intelligence agents are highly skilled and very sophisticated. They are generally foreign agents, but they frequently employ insiders for assistance. These agents commonly operate covertly to avoid detection before, during, or after an action. Their objective is usually assumed to be theft of sensitive information.

2-3 **AGGRESSOR TACTICS.** Aggressors have historically employed a wide range of offensive strategies reflecting their capabilities and objectives. This UFC and subsequent UFCs in the security engineering series categorize these offensive strategies into 13 tactics that are specific methods of achieving aggressor goals. Separating these tactics into categories allows facility planners to define threats in common terms that can be used by facility designers.

2-3.1 **Moving Vehicle Bomb Tactic.** In this tactic aggressors drive an explosives-laden car or truck into a facility and detonate the explosives. The aggressors' goals are to damage or destroy the facility and/or to kill people. This is a suicide attack.

2-3.2 **Stationary Vehicle Bomb Tactic.** In this tactic aggressors covertly park an explosives-laden car or truck near a facility. It is assumed that the aggressors park the vehicle in a legal location to avoid being noticed. The aggressors then detonate the explosives either by time delay or remote control. The aggressors' goals in this tactic are the same as for the moving vehicle bomb tactic with the additional goal of destroying assets within the blast area.

2-3.3 **Hand Delivered Device Tactic.** In this tactic aggressors attempt to enter a facility or get close to the exterior of a facility or to assets not located within a facility with either placed or thrown explosives or incendiary devices. This tactic also includes explosive or incendiary devices delivered through the mail or to supply and materiel handling points such as loading docks. The aggressors' goals are to damage the facility, to injure or kill its occupants, or to damage or destroy assets.

2-3.4 **Indirect Fire Weapons Tactic.** In this tactic aggressors fire military or improvised indirect fire weapons at a facility from a significant distance. Indirect fire weapons (commonly mortars or rockets) do not require a clear line of sight to the target. They can be fired over obstacles. The aggressors' goals are to damage the facility, to injure or kill its occupants, or to damage or destroy assets.

2-3.5 **Direct Fire Weapons Tactic.** In this tactic aggressors fire weapons that require direct lines of sight to targets. These attacks may be from a significant distance or may be close-up as in a drive-by shooting. Direct fire weapons include antitank weapons and various small arms, such as pistols, submachine guns, shotguns, and rifles. The aggressors' goals are to injure or kill facility occupants or to damage or destroy assets.

2-3.6 **Forced Entry Tactic.** In this tactic aggressors forcibly enter a facility using forced entry tools, explosives, and small arms. The aggressor uses the tools and explosives to create a man-passable opening or to operate an operable assembly in the facility's walls, doors, roof, windows, or utility openings. The aggressor may also use explosives or small arms to overpower guards as part of this tactic. The aggressors' goals are to steal or destroy assets, compromise information, injure or kill facility occupants, or disrupt operations.

2-3.7 **Covert Entry Tactic.** In this tactic aggressors attempt to enter a facility or portion of a facility to which they do not have authorized access by using false credentials, by stealth, and by surreptitious entry. Covert entry can either be by people not associated with a facility or insiders who try to access areas in which they are not authorized. The aggressors' goals are to steal assets, to compromise information, to disrupt operations, or to injure or kill building occupants.

2-3.8 **Visual Surveillance Tactic.** In this tactic aggressors employ ocular and photographic devices such as binoculars and cameras with telephoto lenses to monitor facility or installation operations or to see assets. The aggressors' goal is to compromise information. Aggressors may also use this tactic as a precursor to other tactics to determine information about an asset of interest or about security measures.

2-3.9 **Acoustic Eavesdropping Tactic.** In this tactic aggressors employ listening devices from outside a facility or restricted area of a facility to monitor voice communication or other audibly transmitted information. This tactic does not include the use of listening devices "planted" inside facilities. Those devices are in the realm of technical security and are beyond the scope of this manual. The aggressors' goal in this tactic is to compromise information.

2-3.10 **Electronic Emanations Eavesdropping Tactic.** In this tactic aggressors employ electronic emanation surveillance equipment from outside a facility or restricted area of a facility to intercept electronic emanations from computers, communications, and related equipment. This tactic is commonly treated in the context of TEMPEST protection, most of the details of which are classified. There are, however, unclassified facility design related issues that will be described in the security engineering series of UFCs. The aggressors' goal in this tactic is to compromise information.

2-3.11 **Airborne Contamination Tactic.** In this tactic aggressors contaminate the air supply of a facility by introducing chemical, biological, or radiological agents into it. These agents can be delivered to facilities either by external or internal release. External release can be from directed plumes spread from a standoff distance, from a point or line source, from general aerial release, or by directly inserting them into outside air intakes. Internal release can be through the mail, by supplies delivery, direct release within the building area, or insertion into the building ventilation system. The aggressors' goal is to kill or injure people.

2-3.12 **Waterborne Contamination Tactic.** In this tactic aggressors contaminate the water supply to a facility by introducing chemical, biological, or radiological agents into it. These agents can be introduced into the system at any location with varying effectiveness depending on the quantity of water and the contaminant involved. The aggressors' goal is to kill or injure people.

2-3.13 **Waterfront Attacks.** In this tactic aggressors attack people or other waterfront assets from the water either by swimming or on watercraft. Attacks on waterfront assets from the land are covered by other tactics. The aggressors' goal is to kill or injure people or to damage or destroy equipment or other assets.

2-3.14 **Tactics Not Addressed.** This UFC and the security engineering series of UFCs address the typical threats to fixed facilities for which designers can provide protective measures. Some common terrorist tactics are beyond the protection facility designers can provide. Kidnappings, hijackings, and assassinations that take place away from facilities or during travel between facilities are beyond the designers' control. Protection against those threats is provided through operational security and other means not associated with facility design. This UFC does not address such tactics or postulated tactics that have minimal historical or intelligence basis among the aggressors addressed in this UFC such as airborne bombings or airborne attacks using light or remote-controlled aircraft. While attacks like the aircraft attack on the World Trade Center have precedent, they are not addressed in this UFC because it is impractical to design conventional facilities to resist them. The use of nuclear devices is not addressed for the same reason.

2-4 **TOOLS, WEAPONS, EXPLOSIVES, AND AGENTS.** Aggressors use various tools, weapons, explosives, and agents to attain their objectives. The tools, weapons, explosives, and agents included in this UFC and discussed throughout the security engineering series of UFCs represent those used currently and historically or those that can be reasonably expected in the near future. Specific tools, weapons, explosives, and agents associated with each tactic are identified in chapter 3 of this UFC. General descriptions of these tools, weapons, explosives, and agents are provided below.

2-4.1 **Tools.** Tools used to breach protective construction components or barriers include forced entry tools, vehicles, and surveillance tools. Credentials used to gain access to an asset can also be considered tools.

2-4.1.1 **Forced Entry Tools.** These tools include hand, power, and thermal tools and explosives that can be carried by two people. In this manual, forced entry tools are divided into the following categories based on increasing levels of sophistication, skill required to use the tools, and risk of detection associated with use of the tools (referred to as observability).

2-4.1.1.1 **Limited Hand Tools.** Limited hand tools are those hand tools that have low observability. They include claw tools, carpenter's saws, hacksaws, Kelly tools, bolt cutters, pliers, spanner wrenches, tin snips, wrecking and pry bars, and wire cutters. These kinds of tools can be found in homes and small workshops and require little skill or sophistication to use.

2-4.1.1.2 **Unlimited Hand Tools.** These tools include the limited hand tools listed above plus high observable tools such as hammers, sledgehammers, cutting mauls, shovels, pry axes, pick head axes, and fire axes. These include tools that are not as commonly available such as those that are used by firefighters.

2-4.1.1.3 **Power Tools.** Power tools are categorized a limited or unlimited. Unlimited power tools include electric (with external power), gasoline, or air-powered circular saws, reciprocating saws; chain saws; saber saws; roto-hammers (rotating jackhammers) and drills. Limited power tools can be the same as unlimited (circular and reciprocating saws, etc.), but the power source is self-contained (batteries). Hydraulic bolt cutters and rescue tools are also included in the limited tool category.

2-4.1.1.4 **Thermal Tools.** Thermal tools include oxyacetylene, electric arc, or oxygen fed cutting torches, burn bars, and rocket torches. Burn bars are pipes containing steel rods and an oxygen supply tube. They emit a stream of extremely hot flame capable of burning through thick steel plate and concrete.

2-4.1.1.5 **Explosives.** Explosives used as forced entry tools include bulk or equivalent tamped explosive breaching charges and linear shape charges. Breaching charges are quantities of explosives placed directly against an object the aggressor intends to breach or destroy. Such charges can be backed up with a mass such as a steel plate or soil to direct their explosive effects. This practice is referred to as tamping the charge. Linear shape charges are explosives that are manufactured in strips and formed into shapes that direct the force of the explosives into a narrow area directly underneath the strip. They are used to cut man-passable openings through materials.

2-4.1.2 **Vehicles.** Used as tools, vehicles breach layers of defense or barriers and may carry explosives. The vehicles considered in this UFC include cargo trucks ranging from 7000 to 18000 kilograms (approximately 15,000 to 40,000 pounds) gross vehicle weight, small trucks up to 2500 kilograms (approximately 5,500 pounds) gross vehicle weight, and cars up to 1800 kilograms (approximately 4,000 pounds) gross vehicle weight.

2-4.1.3 **Watercraft.** Used as tools, watercraft can breach defined perimeters associated with waterfronts. Watercraft considered in this UFC include small powerboats, Combat Rubber Raiding Craft, Rigid Hulled Inflatable Boats, jet skis, swimmer delivery vehicles, and torpedoes.

2-4.1.4 **Surveillance Tools.** Surveillance tools enable aggressors to gather information from a distance. The various types of these tools are described below.

2-4.1.4.1 **Ocular Devices.** These enhance vision for visual surveillance. Ocular devices include binoculars, telescopes, cameras, and night vision devices.

2-4.1.4.2 **Listening Devices.** These include devices that amplify audible communication signals such as speech. They include directional microphones and laser operated listening devices. For the purposes of this UFC, they do not include electronic microphones (bugs) hidden in a facility. Those devices are covered in the area of technical security, which is beyond the scope of this UFC and generally beyond the scope of facility design.

2-4.1.4.3 **Electronic Emanations Eavesdropping Equipment.** This equipment includes devices that intercept and translate emanations from electronic equipment. This equipment is generally described in the context of the TEMPEST threat, most of the details of which are classified.

2-4.1.5 **False Credentials.** False credentials include any form of authorization or identification credential that can be falsified or counterfeited and used by unauthorized personnel or otherwise misused. These include, but are not limited to, keys, key cards, badges, and identification or authorization documents. False credentials are used in the covert entry tactic.

2-4.2 **Weapons.** Aggressors kill or injure people or damage or destroy facilities or assets using weapons that range from incendiary devices to mortars. Categories of weapons and their uses are described below.

2-4.2.1 **Incendiary Devices.** These devices include a wide range of devices that can be used to spread fire, most of which are improvised. A prime example of an improvised incendiary device (IID) is a Molotov cocktail, which is a bottle of flammable liquid with a rag in the top. After the rag is lit, the bottle is thrown, it breaks on the surface it hits, the flammable liquid catches fire, and the fire spreads over whatever it hits. Incendiary devices may be used to attack the exterior of a facility or to sabotage an asset.

2-4.2.2 **Direct Fire Weapons.** Direct fire weapons must be aimed directly at a target and the line of sight to the target must be clear to successfully hit it. There is a broad range of indirect fire weapons, but for the purposes of this UFC, they will be limited to small arms and anti-tank weapons.

2-4.2.2.1 **Small Arms.** Small arms include pistols, rifles, shotguns, and submachine guns that can be either military issue or civilian weapons. The weapons are described in this UFC in terms of ballistics standards developed for testing the resistance of building elements or assemblies to the weapons' effects. These standards generally indicate the weapon to be used in the test, the ammunition, the muzzle velocity, and the number of rounds to be fired. Aggressors use small arms to attack assets from a distance and may also use them to overpower guards. They are not used to shoot off locks or similarly breach construction components.

2-4.2.2.2 **Antitank Weapons.** Antitank weapons are fired from a distance and may be directed against facilities, vehicles, or other assets that could be targeted from a distance. The antitank weapons considered in this manual are shoulder-fired, rocket propelled grenade (RPG) launchers. Examples of weapons that have been used by terrorists include the Russian RPG-7, RPG 18, and RPG 22 and the U.S. M-72 Light Antitank Weapon (LAW). While there are more effective antitank weapons and missiles, only the class of such weapons stated above will be considered due to their wide availability and the history of their use. In addition, building conventional buildings to resist more effective weapons is impractical.

2-4.2.3 **Indirect Fire Weapons.** Indirect fire weapons are those that can be fired over obstacles to hit targets. They do not require a clear line of sight as direct fire weapons do, but they do require a clear line of flight. For the purposes of this UFC, indirect fire weapons will be considered to include mortars and small rockets. The small rockets considered here are improvised or military rockets with small explosive or incendiary charges on them, which are representative of historical terrorist attacks. The mortars considered in this UFC include both military and improvised mortars. Historically, the improvised versions of mortars have carried larger quantities of explosives than the military versions used by terrorists.

2-4.3 **Explosives.** Aggressors commonly use explosives to damage or destroy facilities or assets or to kill or injure people. Explosives used to force entry are described in the discussion on tools above. Explosives are particularly attractive to terrorists because bombs are inexpensive to build and provide a significant psychological and destructive impact. Explosives are measured according to their equivalence to a particular weight of TNT, which is referred to as TNT equivalence. The types of explosives covered in this UFC are described below.

2-4.3.1 **Improvised Explosive Devices (IED).** These are homemade bombs built of explosives such as plastic explosives or TNT. Plastic explosives are the explosive of choice for terrorists and extremist protesters because they are readily formable, stable, and difficult to detect.

2-4.3.2 **Hand Grenades.** These include common military issue antipersonnel and fragmentation hand grenades that consist of casings filled with explosives that may or may not include a fragmenting material.

2-4.3.3 **Vehicle Bombs.** These bombs contain large quantities of explosives delivered in various sizes of both land vehicles and watercraft. The explosives weight categories chosen for use in this manual are based on historical precedent and concealability and vary with vehicle size. One of the more common explosives used in these large bombs is ammonium nitrate fuel oil (ANFO), which can be made easily from fertilizer and fuel oil.

2-4.4 **Chemical, Biological, and Radiological Agents.** Chemical, biological, and radiological agents and industrial chemical and radiological agents can be categorized by physical state as liquids, solids (or particulates), and gases (or vapors). In addition, for the purposes of waterborne contaminants, they can be further categorized based on the duration of their stability in water and the ease with which they can be disinfected with chlorine or chloramine.

2-4.4.1 **Toxic Industrial Chemicals.** These are liquids and gases produced for commercial and industrial applications. They are generally of lower toxicity than the military nerve agents but are available throughout the world. An industrial task force identified a list of 98 of these chemicals as presenting particular threat because of their toxicity and availability. in the Final Report of Task Force 25, Hazard from Industrial Chemicals, Facilities may be vulnerable to an accidental or terrorist caused release of toxic industrial chemicals from nearby manufacturing or storage facilities. Industrial chemicals can also be released from accidents or sabotage involving trucks or train cars carrying toxic industrial chemicals traveling near the facility.

2-4.4.2 **Military Chemical Agents.** Military chemical agents are described in U.S. Army Field Manual 3-9, Navy Publication P-467, and Air Force Manual 355-7. They can be liquid, gas, or aerosol at standard conditions. Most of the toxic military agents are liquids, which evaporate at differing rates to produce vapor. Chemical agents produce casualties through inhalation or contact with the skin or eyes.

2-4.4.3 **Biological Agents.** Biological agents are small particles of biological material, generally in the size range of 1 to 5 microns if they are to be delivered effectively as aerosols. Toxins, which are agents of biological origin, may be in liquid or crystalline form. Many of these agents can be cultured in unsophisticated laboratories using commercially available equipment. For descriptions of biological agents, refer to Army Field Manual 3-6, Marine Corps Publication FMFM 7-11-H, or Air Force Manual 105-7.

2-4.4.4 **Radiological Agents.** Terrorists could possibly build and detonate a nuclear weapon, but the intentional spread of radioactive isotopes or radioactive waste is much more likely. A potential means to spread radioactive materials is by incorporating radiological materials into a bomb made with a conventional explosive and letting the explosion disperse the radiological material. That kind of device is commonly referred to as a “dirty bomb.” Radioactivity can persist for years. Radioactivity is unaffected by chemical reactions, so it cannot be neutralized. Radioactive waste is typically disposed of by dilution of concentration. Concentration and storage at a disposal site is necessary for high-level (very radioactive) waste. For descriptions of radiological agents, refer to Army Field Manual 3-6, Marine Corps Publication FMFM 7-11-H, or Air Force Manual 105-7.

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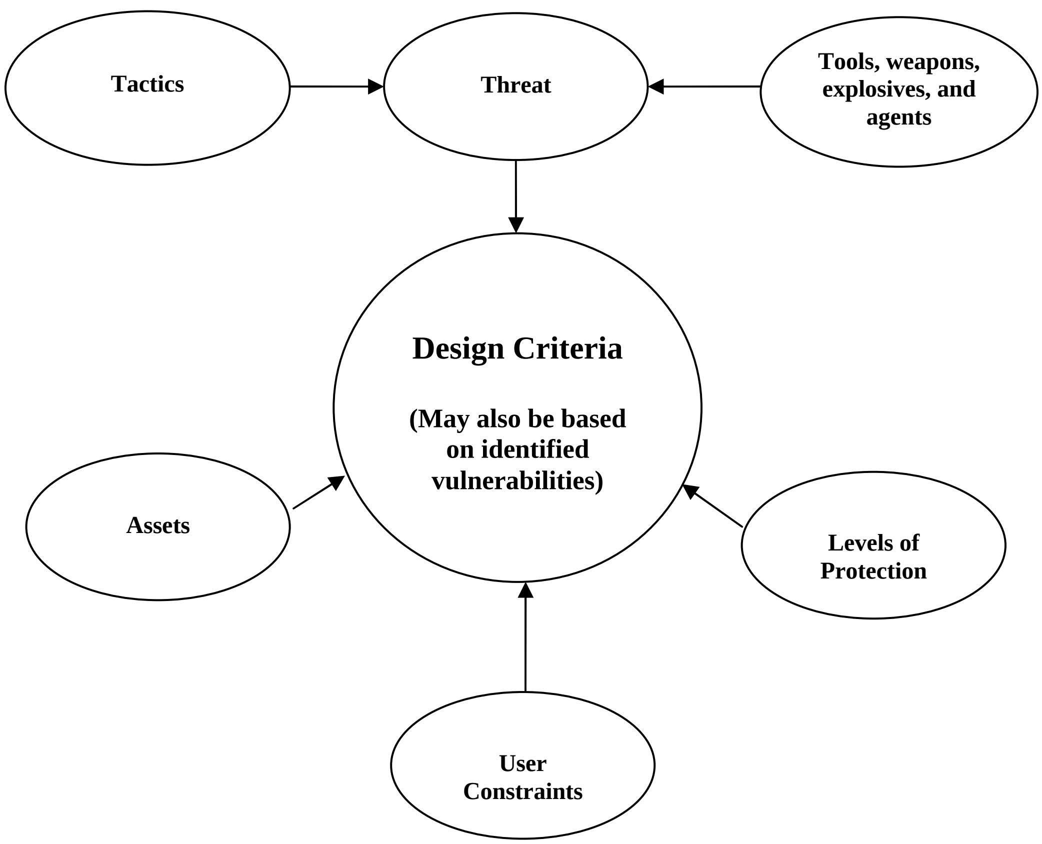
CHAPTER 3

DESIGN CRITERIA DEVELOPMENT

3-1 **INTRODUCTION.** This chapter presents a procedure for developing design criteria for a facility as illustrated in Figure 3-1 below. The procedure is designed to capture and apply the inputs of the diverse members of a Planning Team as described in Chapter 1. The procedure includes the development of preliminary design criteria based on consideration of the assets associated with a facility in terms of their value to their users and the likelihoods that different aggressors will target them. The preliminary design criteria are then evaluated using a preliminary risk analysis. The Planning Team may then adjust the preliminary design criteria to reflect the risk analysis or the cost necessary to implement the design criteria. The Planning Team may also adjust the criteria as necessary according to the professional judgments of the members of the team based on local and regional considerations. The resulting design criteria will be the basis for planning and preliminary design. It may be further adjusted during the design process based on the more detailed risk analysis process in UFC 4-020-02.

Figure 3-1. Design Criteria



3-1.1 **Design Criteria.** Design criteria are the basis for defining a protective system that mitigates vulnerabilities to assets. The criteria describe the assets associated with a facility, the threat to those assets, the level to which those assets are to be protected against the threat, and any constraints to the protective system design that may be imposed by the Planning Team. For existing facilities, vulnerabilities are additional factors in establishing the design criteria. Those vulnerabilities will be based on evaluating how existing conditions affect the protection of the identified assets against the identified threats to the applicable levels of protection. Figure 3-1 shows the components of the protective system criteria. Including security requirements with project criteria allows security to be addressed at the start of the project and to be integrated into the total design efficiently and cost-effectively. In the absence of any other standards, the process in this chapter should be used to establish facility design criteria for security and antiterrorism related issues.

3-1.2 **Other Standards.** This UFC is designed to provide guidance for determining if design criteria beyond those established in various minimum standards, such as the DoD Minimum Antiterrorism Standards for Buildings, are necessary or justifiable. In addition, where design criteria are established as part of minimum standards or Operations Orders issued by various Combatant Commanders, those threats should be considered to override threats established through the procedure in this manual where there is any conflict or where the Combatant Command standards are more stringent. In addition, any applicable regulations or other Service guidance needs to be incorporated into designs.

3-1.3 **Priority.** Security requirements comprise only one component of a project criteria package and receive different emphasis depending upon their priority in a project. For example, if a facility is intended to provide maximum protection for an asset, security may receive top priority. This may necessitate modifications to other previously established criteria. The Planning Team must consider how security fits into the total project design and give it appropriate emphasis.

3-1.4 **Risk Management.** Risk management can be defined for the purposes of security engineering as evaluating alternative countermeasures and design requirements and selecting among them based on their effectiveness in mitigating threats and on their costs. This involves consideration of political, social, economic, and engineering information in conjunction with risk-related information to develop, analyze, and compare acceptable options and to select the appropriate response to a potential threat. The selection process requires placing values on such issues as the acceptability of risk, the reduction in risk due to applied countermeasures, and the reasonableness of the costs of the countermeasures.

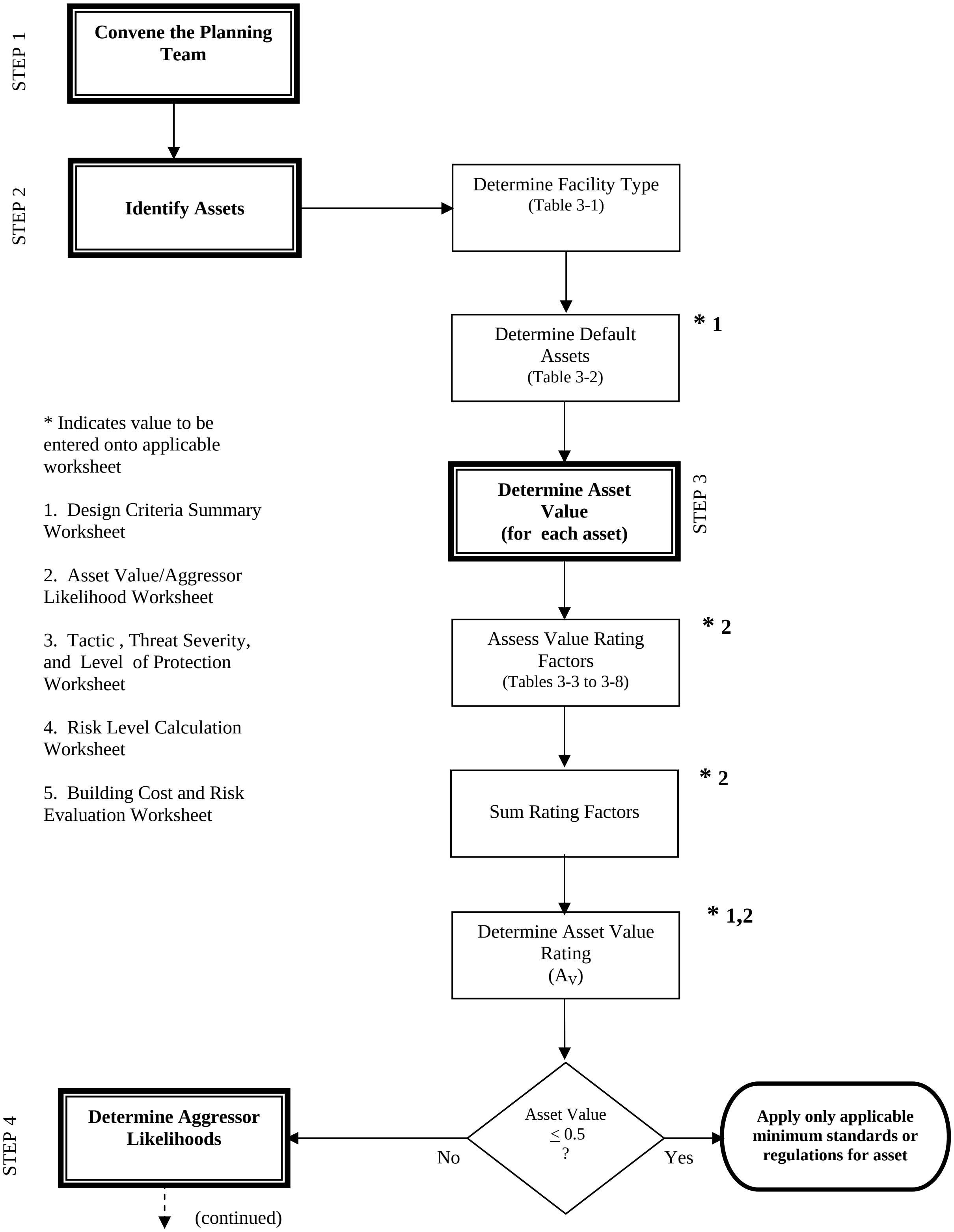
3-1.4.1 **Risk Analysis.** There are many ways to evaluate risk. Most are very rigorous and require a definitive database of frequency of events as well as detailed information on consequences and vulnerabilities. There is not yet a good enough database of terrorist, criminal, and other aggressors’ acts against DoD or Government assets to provide the basis for a realistic statistical distribution to predict such events. Aggressor acts against DoD and Government assets are so uncommon as to be statistically insignificant. That does not, however, mean we should be complacent because we know that such acts can occur at any time in any place. Evaluating risk, therefore, is necessary, but it requires a “relative” approach. The procedure in this chapter represents such an approach.

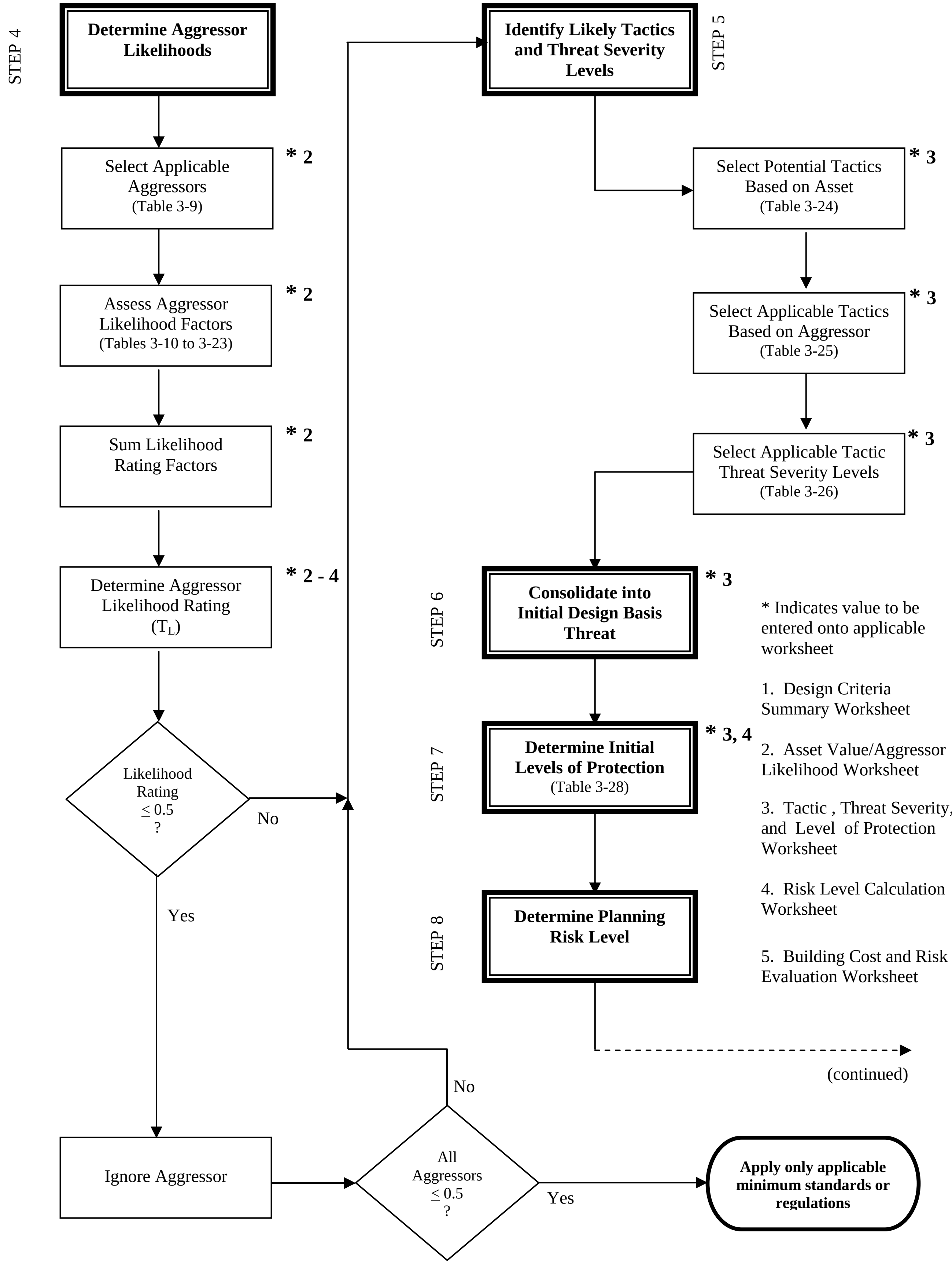
3-1.4.2 **Risk Analysis Procedure.** The procedure in this UFC evaluates risk based on likelihood of attack, the consequences of that attack, and the effectiveness of applied countermeasures in mitigating any attack. The latter is inversely related to vulnerability. Highly effective countermeasures commonly reflect lower vulnerability. The procedure is based on a subjective approach to determining design criteria and on a relative approach to evaluating vulnerabilities. The procedure also allows for quantification of risk acceptance by comparing the costs associated with changes in relative risk. The basic risk equation used in this procedure is the product of asset value, threat likelihood, and a measure of the effectiveness of protection. It will be described in detail later in the chapter. Risk analysis for the purposes of design criteria development and planning is predicated on simplifying assumptions regarding countermeasures. More detailed treatment of the contributions of individual countermeasures to risk is covered in UFC 4-020-02.

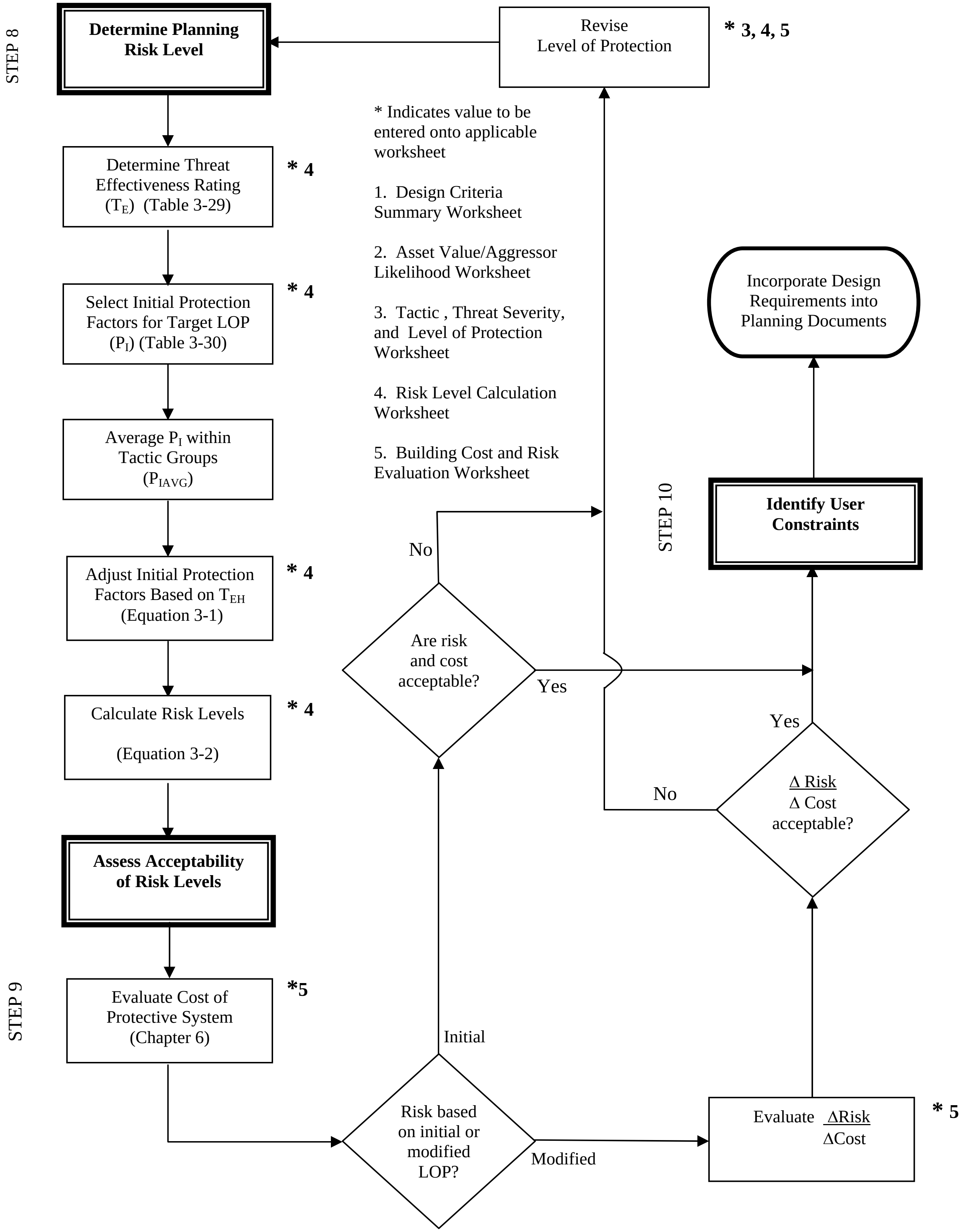
3-1.4.3 **Background.** In developing this procedure several other established procedures were considered. They included the procedure in the Joint Antiterrorism Guide, the procedure in Army Technical Manual 5-853-1/Air Force Manual AFMAN 32-1071, Volume 1 and Department of the Army Pamphlet 190-51, the CARVER process, the DSHARPP process, the MSHARPP process, and the Naval Facilities Engineering Service Center’s Risk Analysis Vulnerability Assessment (RAVA) process. In addition, processes in use by other agencies of the U.S. Government and private sector processes were evaluated. None of those processes were found to address all the needs of this UFC; therefore, the process in this document was developed. There were many elements of the other processes that were very useful, however. Those elements were incorporated into this process to the greatest extent possible. Detailed discussions on MSHARPP and CARVER can be found in DoD O-2000.12-H.

3-2 **USING THIS PROCEDURE.** The design criteria development procedure in this chapter comprises ten steps. The ten steps address the identification of the elements of design criteria and the adjustment of them through preliminary risk analysis. The procedure is summarized in the flow chart in Figure 3-2. The procedure uses worksheets to guide the Planning Team through the series of decisions necessary to identify the applicable assets, threats, and levels of protection. The decisions are based on a series of subjective questions that may lead the Planning Team to an objective answer in a manner that is reproducible among different Planning Teams and over time. The preliminary design criteria thereby developed may be adjusted through a common means of risk analysis. The ten steps in the design criteria development procedure are described separately below. In addition to the basic principles associated with each step, each of the applicable tables associated with that step is described and guidance is provided on their application.

Figure 3-2. The Design Criteria Development Procedure




STEP 4
Determine Aggressor Likelihoods
Select Applicable Aggressors (Table 3-9)
* 2
Assess Aggressor Likelihood Factors (Tables 3-10 to 3-23)
* 2
Sum Likelihood Rating Factors
* 2
Determine Aggressor Likelihood Rating (T_L)
* 2 - 4
Likelihood Rating ≤ 0.5 ?
No
Yes
Ignore Aggressor
All Aggressors ≤ 0.5 ?
No
Yes
Apply only applicable minimum standards or regulations
STEP 5
Identify Likely Tactics and Threat Severity Levels
Select Potential Tactics Based on Asset (Table 3-24)
* 3
Select Applicable Tactics Based on Aggressor (Table 3-25)
* 3
Select Applicable Tactic Threat Severity Levels (Table 3-26)
* 3
STEP 6
Consolidate into Initial Design Basis Threat
* 3
STEP 7
Determine Initial Levels of Protection (Table 3-28)
* 3, 4
STEP 8
Determine Planning Risk Level
(continued)
* Indicates value to be entered onto applicable worksheet
1. Design Criteria Summary Worksheet
2. Asset Value/Aggressor Likelihood Worksheet
3. Tactic , Threat Severity, and Level of Protection Worksheet
4. Risk Level Calculation Worksheet
5. Building Cost and Risk Evaluation Worksheet


STEP 8
Determine Planning Risk Level
Revise Level of Protection
* 3, 4, 5
Determine Threat Effectiveness Rating (T_E) (Table 3-29)
* 4
Select Initial Protection Factors for Target LOP (P_I) (Table 3-30)
* 4
Average P_I within Tactic Groups (P_{IAVG})
Adjust Initial Protection Factors Based on T_{EH} (Equation 3-1)
* 4
Calculate Risk Levels (Equation 3-2)
* 4
Assess Acceptability of Risk Levels
STEP 9
Evaluate Cost of Protective System (Chapter 6)
*5
* Indicates value to be entered onto applicable worksheet
1. Design Criteria Summary Worksheet
2. Asset Value/Aggressor Likelihood Worksheet
3. Tactic , Threat Severity, and Level of Protection Worksheet
4. Risk Level Calculation Worksheet
5. Building Cost and Risk Evaluation Worksheet
Incorporate Design Requirements into Planning Documents
STEP 10
Identify User Constraints
No
Are risk and cost acceptable?
Yes
Yes
No
Δ Risk
Δ Cost
acceptable?
Initial
Risk based on initial or modified LOP?
Modified
Evaluate ΔRisk
ΔCost
* 5

3-3 **STEP 1: CONVENE THE PLANNING TEAM.** The first step of the process of developing design criteria is to convene the Planning Team as described in Chapter 1. It is essential to the effectiveness of the design criteria development to have an interdisciplinary team involved in the process. All the members of that team have unique perspectives that need to be reflected in the effort. The team should be convened at the inception of project planning and should provide review and oversight at all stages of project development. It should also be consulted during the design process as described in UFC 4-020-02.

3-4 **STEP 2: IDENTIFY ASSETS.** The design criteria developed in this chapter relate primarily to assets associated with facilities as opposed to the facilities themselves. Protecting individual assets is generally more cost effective than protecting an entire facility. Buildings should only be considered assets if they are the likely direct target of aggression, as in vandalism or where the buildings have some special significance such as a highly symbolic or historic structure. Determining the assets to be protected is the first step in establishing any protective system. The following two steps are provided to facilitate a degree of consistency in identifying DoD assets.

3-4.1 **Determine Facility Types.** There are many types of facilities on military installations or used by the military off installations. For the purposes of easily identifying assets in a consistent manner, those facilities have been divided into 22 broad categories. Those categories are tabulated in Table 3-1, which also includes common examples of each of those facility types. Table 3-1 also includes the baseline building categories that are referred to in Chapter 4 and that are used in determining costs for the protective systems necessary to implement the design criteria developed using this process. Determine which of the facility types from the center column of Table 3-1 applies to the facility being analyzed.

3-4.2 **Determine Default Assets.** There are an almost unlimited number of different kinds of assets likely to be found in DoD facilities. Those assets may be grouped into categories to effectively deal with them. Table 3-2 includes a list of generic asset categories into which assets can be grouped. These categories include the assets that are commonly targeted by aggressors and which are frequently of significant value to their users. These categories also include assets that are required to be protected by regulation. They do not, however, include nuclear weapons or materials or chemical weapons because those assets have very strict regulations for their protection that are well established and generally more stringent than the countermeasures reflected in this manual.

The asset categories in Table 3-2 are assigned letters for ease of use. Those letters should not be interpreted to represent priorities. The assets that are likely to be present in various facility types are predictable, and can therefore be tabulated on a default basis. Table 3-2 provides a default list of asset types that may be expected to be found in the common facility types listed in Table 3-1.

Use Table 3-2 to identify default assets associated with the applicable facility type, and then adjust that list based on which of those assets are actually present in the facility. Also identify any other assets within a facility or associated with a project that are of value to the user based on their importance to the user's mission or on some other measure of value such as monetary worth. In addition, identify any additional assets that are to be protected based on policies, command directives, or regulations, and identify people who will be considered assets based on one or more of the above considerations. In the case of people, the Planning Team will have to determine whether they are mission critical people or the general population. The assets established in this step are the assets that the Planning Team should consider in the remainder of this procedure. Enter the identified assets and their applicable asset categories into the appropriate columns of the Design Criteria Summary Worksheet as illustrated in Figure 3-3.

Table 3-1. Common Facility Types

Baseline Building Category	Facility Type	Examples
Administrative and Community Support Buildings *	Headquarters and Operations Facilities and Other Administrative Facilities	Brigade, Battalion, Company Headquarters
		Airfield Operations Facility
		Aviation Unit Operations Facility
		Field Operations Facility
		Ship Operations Facility
		Emergency Operations Facility
		Fire / Police Station
		National Guard / Reserve Centers
		Cargo Handling Office
		Dispatch Building
		Courtroom
		General Administrative Facility
	Schools and Education Facilities	Education Center
		Dependent School
		Religious Education Center
	Community Facilities	Community Service Center
		Child Development Center
		Drug / Alcohol Abuse Center
		Red Cross Building
		Craft Centers
	Small Retail Facilities	Shoppette
		Golf Clubhouse
		Laundry
		Video Rental Store
Unaccompanied Personnel Housing *	Unaccompanied Personnel Housing	Enlisted Barracks / Dormitories
		Trainee Barracks / Dormitories
		Transient Unaccompanied Personnel Housing
		Unaccompanied Officers / Enlisted Personnel Housing
Family Housing	Family Housing	Family Housing Units
Dining Facilities *	Dining Facilities	Dining Facilities
		EM Club

(Table 3-1 continued)

Medical Facilities *	Medical Facilities	Hospital
		Medical Clinic
		Dental Clinic
		Pharmacy
		Veterinary Clinic
		Laboratory
Special Structures *	Religious Facilities	Chapel
	Recreation Facilities	Auditorium
		Gymnasium
		Bowling Alley
		Theater
	Commissaries and Exchanges	Commissary
		Exchange
	Alert Systems, Forces, and Facilities	Alert Systems, Forces, and Facilities
Maintenance Facilities (other than weapons)	Equipment Maintenance Facilities	Equipment Maintenance Facilities
	Aviation Maintenance Facilities	Aviation Maintenance Facilities
	Motor Pools	Motor Pools
	Aircraft Parking Areas - hangars	Aircraft Parking Areas
	Ship or Boat Berths	Ship or Boat Berths
	Arms, Ammunition, and Explosives Storage Facilities	Magazines
		Arms Rooms
		Weapons Maintenance Facilities
	Petroleum, Oils, and Lubricants Storage Facilities	Petroleum, Oils, and Lubricants Storage Facilities
	Research and Development Facilities	Research and Development Facilities
	Warehouses	Warehouses
	Utilities and Substations	Utilities and Substations
* Building types included in cost tables in Appendices A - C		

3-5 **STEP 3: DETERMINE ASSET VALUE.** Asset value refers to the value of an asset to its user. It is a reflection of the consequence of having the asset compromised by an aggressor. The asset value helps the Planning Team to determine the level of protection that is warranted for the asset.

3-5.1 **Value Rating Factors.** The value of an asset to its user is determined by evaluating up to five value rating factors, depending on the asset category. Those factors include mission criticality to the asset's user, impact on the national defense, replaceability, political sensitivity, and relative value. Not all factors are evaluated for general population, critical infrastructure, operations and activities, and sensitive information. Table 3-3 shows which factors are applicable to each asset category. The applicability of value rating factors is also indicated on the Asset Value/Aggressor Likelihood Worksheet. The factors are evaluated using tables in this chapter. These tables include statements that describe the value rating factors qualitatively. Select the statement from each table that most closely reflects the asset's value. Each statement has a numerical value associated with it that is used in determining the asset value rating. Where there is any question about the meaning of a specific statement in a table, consider all the statements in terms of "on a scale of 0 to 5." For each asset, enter the appropriate numerical value from each applicable value rating table in the spaces provided on the Asset Value/Aggressor Likelihood Worksheet. These will also

Table 3-2. Default Assets

Facility Type	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	Asset Category																	
	People (mission critical and general population)	Aircraft and components at aviation facilities	Ships, boats, and other watercraft	Vehicles and carriage mounted or towed weapons systems & components	Petroleum, oils, and lubricants (POL)	Arms, ammunition, and explosives (AA&E)	Controlled medical substances	Communications/electronics test, measurement, & diagnostic equipment and tool kits and night vision devices	Organizational clothing and individual equipment	Subsistence items at commissaries, warehouses, & troop Issue facilities	Repair parts at installation supply and direct support units	Facilities engineering supplies and construction material	Audiovisual equipment, training devices, & subcaliber devices	Miscellaneous pilferable assets and currency or negotiable instruments	Critical infrastructure & industrial equipment	Controlled cryptographic items	Sensitive information	Activities and operations
Headquarters and Operations Facilities	✓					✓		✓					✓	✓	✓	✓	✓	✓
Other Administrative Facilities	✓					✓		✓					✓	✓	✓	✓	✓	✓
Unaccompanied Personnel Housing	✓					✓								✓	✓			
Dining Facilities	✓													✓	✓			
Family Housing	✓													✓	✓			
Hospitals	✓						✓							✓	✓			
Medical Clinics	✓						✓							✓	✓			
Schools and Education Facilities	✓												✓	✓	✓			
Religious Facilities	✓												✓	✓	✓			
Community Facilities	✓													✓	✓			
Commissaries and Exchanges	✓									✓				✓	✓			
Other Retail Facilities	✓													✓	✓			
Recreational Facilities	✓													✓	✓			
Alert Systems, Forces, and Facilities	✓	✓	✓	✓	✓	✓		✓							✓	✓	✓	✓
Maintenance Facilities	✓	✓	✓	✓	✓	✓		✓			✓			✓	✓			✓
Motor Pools		✓	✓	✓	✓	✓		✓						✓	✓			✓
Aircraft Parking Areas		✓	✓	✓	✓	✓		✓							✓			✓
Ship or Boat Berths		✓	✓	✓	✓	✓		✓							✓			✓
Arms, Ammunition, and Explosives Storage		✓	✓	✓	✓	✓									✓			✓
Petroleum, Oils, and Lubricants Storage		✓	✓	✓	✓	✓									✓			✓
Research and Development Facilities	✓							✓							✓		✓	✓
Warehouses		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		
Utilities and Substations															✓			

Figure 3-3. Sample Design Criteria Summary Worksheet

DESIGN CRITERIA SUMMARY WORKSHEET

Project or Building	Analyst	Date
A Motor Pool	***Jane Q. Planner***	***4 August 2008***

			Tactics																									
			Explosive and Incendiary Devices						Standoff Weapons				Entry Tactics				Surveillance and Eavesdropping						Contamination Tactics					
Assets	Asset Category	Asset Value Rating	Moving Vehicle Devices		Stationary Vehicle Devices		Hand Delivered Devices		Indirect Fire Weapons		Direct fire weapons		Forced Entry		Covert Entry		Visual Surveillance		Acoustic Eavesdropping		Electronic Emanations Eavesdropping		Airborne Contamination		Waterborne Contamination		Waterfront Attack	
			DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP
Tactical vehicles	***D***	***.76***			***L***	***L***	***M***	***L***	***L***	***L***	***L***	***L***	***M***	***L***	***L***	***L***												

DBT = Design Basis Threat severity level LOP = Level of Protection

be entered on other worksheets for use in future steps of this process. The value rating factor tables and explanations for their application follow.

Table 3-3. Value Rating Factor Applicability

Asset Category	Value Rating Factor				
	Criticality to User / Population Type	Impact on National Defense	Replaceability	Political Sensitivity	Relative Value to User
General Population	✓			✓	✓
Critical Infrastructure and Operations and Activities	✓	✓	✓	✓	
Sensitive Information					✓
All Other Assets (including Mission Critical Personnel)	✓	✓	✓	✓	✓

3-5.1.1 **Criticality to User's Mission / Population Type.** This factor addresses the criticality of the asset in its support of its user's mission and, in the case of the general population, whether they are military, DoD civilians, or dependents and other civilians. Criticality of mission critical personnel and property is measured in terms of the impact the person's or asset's loss would have on the user's operations, output, production, or service. In the case of operations and activities, consider the impact of the activity's or operation's compromise. For the general population, because they are not mission critical, they are evaluated according to their status. The assumption therein is that the loss of military people is more readily accepted than the other types of personnel and the loss of DoD civilians is more accepted than dependents or other civilians. This factor is not evaluated for sensitive information. Evaluate this factor using Table 3-4.

Table 3-4. Criticality to User / Mission Impact/ Population Type

Asset Category	Population Type, Degradation Installation Mission, or Impact of Asset's Loss or Activity's Compromise on User's Mission	Value Rating Factor
General Population	Population is primarily military personnel	1
	Population is primarily DoD civilians and contractors	3
	Population is primarily dependents and other civilians	5
Critical Infrastructure	Loss would degrade or cause failure of specific functions, but have no effect on the installation-wide mission or missions of DoD facilities off installations	1
	Loss would cause failure of specific functions and minimally degrade the installation-wide mission or missions of DoD facilities off installations	2
	Loss would cause failure of specific functions and moderately degrade the installation-wide mission or missions of DoD facilities off installations	4
	Loss would cause installation-wide mission failure or failure of missions of DoD facilities off installations	5
All Other Assets (except for sensitive information) (including mission critical personnel, operations and activities, and critical industrial equipment)	Asset's loss or operation's /activity's compromise would have no significant effect on operations, output, production, or service	0
	Asset's loss or operation's /activity's compromise would result in halting operations within 1 month or would result in a 10% curtailment in output, production, or service	1
	Asset's loss or operation's /activity's compromise would result in halting operations within 2 weeks or would result in a 25% curtailment in output, production, or service	2
	Asset's loss or operation's /activity's compromise would result in halting operations within 1 week or would result in a 50% curtailment in output, production, or service	3
	Asset's loss or operation's /activity's compromise would result in halting operations within 1 day or would result in a 75% curtailment in output, production, or service	4
	Asset's loss or operation's /activity's compromise would immediately halt operations, output, production, or service. The user cannot function without it.	5

3-5.1.2 **Impact on the National Defense.** This factor addresses the criticality of the asset in its support of the defense of the United States and its interests. It accounts for the fact that some assets may be critical to their user's mission, but not to the broader national defense mission. An example of such an asset might be kitchen equipment in a community club. The equipment may be critical to the club's mission, but is unlikely to be critical to the war-fighting mission of the installation's tenant units. Considering this factor ensures that assets that are critical to military readiness receive a higher priority than those that are not. This factor is not evaluated for the general population or sensitive information. Evaluate this factor using Table 3-5.

Table 3-5. Impact on the National Defense

Impact of Asset’s Loss on the National Defense	Value Rating Factor
The loss, theft, destruction, or misuse of the asset or operation’s /activity’s compromise could have insignificant impact on the United States or a region.	0
The loss, theft, destruction, or misuse of the asset or operation’s /activity’s compromise could have significant mission impact on a regional level.	1
The loss, theft, destruction, or misuse of the asset or operation’s /activity’s compromise could compromise the defense infrastructure of the United States.	2
The loss, theft, destruction, or misuse of the asset or operation’s /activity’s compromise could impact the tactical capability of the United States.	3
The loss, theft, destruction, or misuse of the asset or operation’s /activity’s compromise could be expected to harm the operational capability of the United States.	4
The loss, theft, destruction, or misuse of the asset or operation’s /activity’s compromise could result in great harm to the strategic capability of the United States.	5

3-5.1.3 **Asset Replacement.** This factor addresses the ease with which assets can be replaced. There are separate entries for people and assets other than people. This factor is not evaluated for the general population or sensitive information. Evaluate this factor using Table 3-6.

3-5.1.3.1 **Mission Critical Personnel.** This table reflects the difficulty of finding replacements for personnel who are injured based on the skills and training necessary for replacement personnel. Note that this factor is only applied to people who are considered mission critical. It is not applied to the general population.

3-5.1.3.2 **Assets Other Than People.** This table is based on the amount of time required to replace assets or reestablish operations and activities that have been compromised, either in-kind or with substitutes that are acceptable to the user or the Planning Team. The replacement assets or operations or activities can also be either temporary or permanent depending on the Planning Team’s judgment. This factor accounts for the impact of delay in replacement of assets on the user's mission.

Table 3-6. Asset Replacement

Asset Category	Availability of Replacement Personnel or Time to Asset Replacement, Repair, or Substitution	Value Rating Factor
Mission critical personnel	Personnel would be immediately available to resume the functions of casualties	1
	Personnel would have to be transferred from other units on the installation to resume the function of the casualties	2
	Personnel would have to be transferred from other units at other installations to resume the function of the casualties	3
	Personnel would have to be trained over an extended period to resume the functions of the casualties	4
	Personnel of such a critical nature that “replacement” would not be realistic	5
All assets other than people and sensitive information (including operations and activities)	Asset can be replaced or operation / activity could be reestablished in less than 24 hours	0
	Asset can be replaced or operation / activity could be reestablished in 24 to 72 hours	1
	Asset can be replaced or operation / activity could be reestablished in 72 hours to 1 week	2
	Asset can be replaced or operation / activity could be reestablished in 1 week to 1 month	3
	Asset can be replaced or operation / activity could be reestablished in one to six months	4
	Asset will require more than a 6 months to replace or operation / activity will require more than 6 months to reestablish	5

3-5.1.4 **Political Sensitivity.** This factor accounts for the Planning Team’s perception of the political repercussions associated with the asset’s loss, destruction, or death or the operation’s or activity’s compromise. Considerations could include adverse publicity, erosion of confidence, and the perception of poor security. Note that political sensitivity is somewhat dependent on media attention; therefore, what asset is compromised and where may be significant factors. For example, a person being killed will be a much more politically sensitive issue than a computer being stolen. In addition, regarding people, killing a person in the Continental U.S. may be far more politically sensitive than killing somebody in a forward deployed location or a war zone. This factor is not evaluated for sensitive information. Evaluate this factor using Table 3-7.

Table 3-7. Perceived Political Sensitivity

User’s Perceived Political Sensitivity of Loss of Asset	Asset Value Rating
Negligible: Media attention would be unlikely	0
Minimal: Media attention would likely be limited to local media	1
Moderate: Media attention would likely extend to national media	3
High: Media attention would likely extend to international media.	5

3-5.1.5 **Relative Asset Value.** This factor provides a measure of the relative value of an asset based on measures of value appropriate for particular asset categories. The relative values of the different asset categories are measured in different ways. The most appropriate ways of measuring cost for various asset categories are reflected in Table 3-8. This factor is not evaluated for critical infrastructure or operations and activities. Evaluate this factor using Table 3-8.

3-5.1.5.1 **Personnel.** The relative value for personnel is based on the number of such personnel routinely inhabiting a facility. For mission critical personnel, this factor also considers the percentage of people required for mission execution that are routinely present in the facility. Assigning monetary costs to people is difficult, so value of personnel is based on numbers of people. That assumes that injuring or killing many people is inherently worse than injuring or killing only a few. There are separate entries for the general population and for mission critical personnel. Those for mission critical personnel are lower than those for the general population to reflect the increased importance to mission execution of those people. Where people are an asset and there are both mission critical personnel and general population in a building, either the higher value rating for the two categories of personnel can be applied for the entire facility or the facility can be broken onto mission critical personnel and general population areas. In the latter case, the different areas could have separate asset value ratings.

3-5.1.5.2 **Aircraft.** Relative values for aircraft are based on the types of aircraft commonly parked at an aviation facility (trainers; cargo, refueling, or utility aircraft; tactical or attack aircraft; and strategic aircraft.) They are also based on the size of the unit that operates the aircraft, either smaller or larger than squadron or company strength. This reflects the fact that a large number of aircraft is relatively more valuable than a small number.

3-5.1.5.3 **Ships, Boats, and Watercraft.** Relative value of watercraft is based on the categories of ships moored at a location, regardless of number. The relative values of those categories of ships reflect their relative importance. Ships moored near higher category vessels should be assigned the same value rating as the higher category ships.

3-5.1.5.4 **Vehicles.** Relative value for vehicles is based on similar assumptions to those for aircraft. The relative values of vehicles is based on whether they are or are not tactical vehicles or critical maintenance or support vehicles or whether they include carriage mounted or towed weapons systems. The breaks between numbers of vehicles are based on the number of vehicles in a company-sized element. The assumption is that these vehicles are in a motor pool , that the number of vehicles associated with a company-sized element constitutes a significant number, and that the loss of many vehicles is worse than the loss of a few.

3-5.1.5.5 **Petroleum, Oils, and Lubricants (POL).** The relative value of POL is based on the quantities of POL stored at the location in question. The quantities in the tables reflect the quantities handled by the various sizes of Army tactical units from battalion up to Theater Army. They are also representative of quantities handled by increasingly larger Air Force, Navy, and Marine Corps elements.

3-5.1.5.6 **Arms, Ammunition, and Explosives (AA&E).** The relative value of AA&E is based on its risk level as defined in DoD 5100.76-M. The categories of I through IV (highest to lowest risk, respectively) reflect the relative utility, attractiveness, and availability to criminal elements of the AA&E. As a general rule, only arms, missiles, rockets, explosive rounds, mines, and projectiles that have an unpacked unit weight of 100 pounds or less are categorized as sensitive for purposes of DoD 5100.76-M. In addition, any single container that contains a sufficient amount of spare parts that, when assembled, will perform the basic function of the end item will be categorized the same as the end item. Nuclear and chemical weapons are not to be addressed using this UFC. The requirements established in DoD instructions for protecting them are much more stringent than anything that would be established using the security engineering series of UFCs.

3-5.1.5.7 **Controlled Substances and Medically Sensitive Items.** Relative values for these assets are measured by their designation as sensitive items as established by the Drug Enforcement Agency and by the type of facility in which they are stored. Contact medical or pharmacy personnel to determine which of these designations apply. Quantity is accounted for in considering mission criticality. Substances that are protected under protocols for biosafety in microbiological laboratories are not within the scope of this UFC.

3-5.1.5.8 **Assets with Identifiable Monetary Value.** These are assets for which costs are readily definable. Their value, therefore, is based only on their value in U.S. dollars. In general, use this measure of relative value for assets that are not specifically covered by one of the asset types in this table. There are two entries for assets that are measured by their monetary value. One is to be used where only a single asset is being considered. The other is to be used where the assets are stored in quantities that are more appropriately measured as inventories.

3-5.1.5.9 **Controlled Cryptographic Items.** These are devices that process sensitive information. Their relative value is based on the level of sensitivity of the information they are accredited to process.

3-5.1.5.10 **Sensitive Information.** This is sensitive classified or unclassified information. Unlike other assets, the relative value of sensitive information is based only on this single factor. That is because many of the issues that are addressed in the criticality and replaceability factors are reflected in decisions on the classification of sensitive information.

Table 3-8. Relative Value to User

Asset Type		Measure of Relative Value	Relative Value	Value Rating Factor
People	Mission Critical Personnel	Number of people present in facility	Number of mission critical personnel in the facility is less than 5 or 10% of people needed for mission execution are routinely present in the facility	1
			Number of mission critical personnel in the facility is 6 to 10 or 25% of people needed for mission execution are routinely present in the facility	2
			Number of mission critical personnel in the facility is 11 to 49 or 50% of people needed for mission execution are routinely present in the facility	3
			Number of mission critical personnel in the facility is 50 to 100 or 75% of people needed for mission a execution re routinely present in the facility	4
			Number of mission critical personnel in the facility is greater than 100 or 90% of people needed for mission execution are routinely present in the facility	5
	General Population	Number of people present in facility	Number of people in the facility is less than 11	0
			Number of people in the facility is 11 to 49	1
			Number of people in the facility is 50 to 100	2
			Number of people in the facility is 101 to 500	3
			Number of people in the facility is 501 to 1000	4
			Number of people in the facility is greater than 1000	5
Aircraft		Organizational unit and aircraft type	Aircraft limited to trainers	1
			Aircraft include cargo, refueling, or utility type aircraft in units of less than company or squadron strength	2
			Aircraft include cargo, refueling, or utility type aircraft in units of greater than company or squadron strength	3
			Aircraft include tactical or attack type aircraft in units of less than company or squadron strength	3
			Aircraft include tactical or attack type aircraft in units of greater than company or squadron strength	4
			Aircraft include strategic aircraft	5
Watercraft		Number and type of watercraft	All other watercraft	1
			Patrol Coastal, MSC strategic sealift ships (reduced operational status)	2
			Surface combatants, other amphibious, auxiliary, MSC, strategic sealift ships, ammunition ships, and mine warfare	3
			Aircraft carriers or large deck amphibious (LHA,LHD, etc.) and other submarines	4
			SSBN and Sea Based X-Band Radar (SBX)	5

(Table 3-8 continued)

Vehicles	Number and type of vehicles	Fewer than 20 vehicles are parked in the vehicle parking area or motor pool. Vehicles do not include tactical vehicles, carriage mounted or towed weapons systems, or critical maintenance or support vehicles	1
		Fewer than 20 vehicles are parked in the vehicle parking area or motor pool. Vehicles include tactical vehicles and critical maintenance or support vehicles, but do not include carriage mounted or towed weapons systems	2
		Fewer than 20 vehicles are parked in the vehicle parking area or motor pool. Vehicles include carriage mounted or towed weapons systems	3
		20 or more vehicles are parked in the vehicle parking area or motor pool. Vehicles do not include tactical vehicles, carriage mounted or towed weapons systems, or critical maintenance or support vehicles	3
		20 or more vehicles are parked in the vehicle parking area or motor pool. Vehicles include tactical vehicles and critical maintenance or support vehicles, but do not include carriage mounted or towed weapons systems	4
		20 or more vehicles are parked in the vehicle parking area or motor pool. Vehicles include carriage mounted or towed weapons systems	5
Petroleum, Oils, and Lubricants	Quantity stored	Quantity of fuel stored is less than 190,000 liters (50,000 gallons)	1
		Quantity of fuel stored is greater than or equal to 190,000 liters (50,000 gallons) and less than 570,000 liters (150,000 gallons)	2
		Quantity of fuel stored is greater than or equal to 570,000 liters (150,000 gallons) and less than 1,900,000 liters (500,000 gallons)	3
		Quantity of fuel stored is greater than or equal to 1,900,000 liters (500,000 gallons) and less than 3, 800,000 liters (1,000,000 gallons)	4
		Quantity of fuel stored is greater than or equal to 3,800,000 liters (1,000,000 gallons)	5
Arms, Ammunition, and Explosives	Risk category (DoD 5200.76M)	Uncategorized	1
		Category IV	2
		Category III	3
		Category II	4
		Category I	5

(Table 3-8 continued)

Controlled Substances and Medically Sensitive Items	Sensitivity and storage location	Non-sensitive pharmaceuticals and other non-sensitive medical items	1
		Medically sensitive items in pharmacies, wards, clinics, or RDT&E facilities	2
		Medically sensitive items in bulk storage facilities	3
		Items identified as Note R in the Federal Supply Catalog, non-standard DEA Schedule II controlled substances , or standard drug items identified as Note Q in the Federal Supply Catalog , non-standard DEA Schedule III, IV, and V controlled substances in pharmacies, wards, clinics, or RDT&E facilities	4
		Items identified as Note R in the Federal Supply Catalog, non-standard DEA Schedule II controlled substances , or standard drug items identified as Note Q in the Federal Supply Catalog , non-standard DEA Schedule III, IV, and V in bulk storage facilities	5
Individual Assets with Monetary Value	Replacement cost	Asset value is less than $2500	0
		Asset value is greater than or equal to $2500 and less than $10,000	1
		Asset value is greater than or equal to $10,000 and less than $25,000	2
		Asset value is greater than or equal to $25,000 and less than $50,000	3
		Asset value is greater than or equal to $50,000 and less than $100,000	4
		Asset value is greater than $100,000	5
Inventories of Assets with Monetary Value	Replacement cost	Asset inventory value is less than $100,000	0
		Asset inventory value is greater than or equal to $100,000 and less than $250,000	1
		Asset inventory value is greater than or equal to $250,000 and less than $500,000	2
		Asset inventory value is greater than or equal to $500,000 and less than $1,000,000	3
		Asset inventory value is greater than or equal to $1,000,000 and less than $2,000,000	4
		Asset inventory value is greater than $2,000,000	5
Controlled Cryptographic Items (CCI)	Sensitivity of information processed	CCI processes unclassified and non-sensitive information	0
		CCI processes unclassified, but sensitive information (i.e. For Official Use Only)	1
		CCI processes Confidential information	2
		CCI processes Secret information	3
		CCI processes Top Secret information	4
		CCI processes Secure Compartmented information	5
Sensitive Information	Sensitivity or classification level	Unclassified sensitive (i.e. For Official Use Only)	5
		Confidential	7.5
		Secret	8.5
		Top Secret	9.5
		Secure Compartmented Information	10

3-5.2 **Determine Asset Value Rating.** Asset value ratings (except for sensitive information) are determined based on the sums of the applicable value rating factors and the percentages of the possible points those sums represent. Sum the applicable value rating factors for each asset and enter the sum in the appropriate box on the Asset Value/Aggressor Likelihood Worksheet. Then divide the sums by the applicable number of points possible for that asset category. Those total numbers of points will be 10 for sensitive information, 15 for general population, 20 for critical infrastructure and activities and operations, and 25 for all other assets. The resulting percentage is the asset value rating. Enter it in the appropriate boxes on the Asset Value/Aggressor Likelihood Worksheet as illustrated in Figure 3-4. Also enter it on the Design Criteria Summary Worksheet, the Tactic, Threat Severity, and Level of Protection Worksheet, and the Risk Level Calculation Worksheet.

3-5.3 **Eliminate Assets with "Very Low" Value Ratings.** Assets whose value ratings are less than or equal to 0.5 may be considered to be of minimal value and do not warrant further analysis. Eliminate those assets from further consideration. For those assets only countermeasures required by regulation or measures required by one or more of the minimum construction standards (either DoD or Combatant Command) should be applied. For other assets continue on to the next step of the procedure.

3-6 **STEP 4: IDENTIFY AGGRESSOR LIKELIHOODS.** The next step in the procedure after identifying the assets and their values is to look at those assets from the perspective of potential aggressors. This step includes identifying potential aggressors and determining the likelihoods that they will attempt to compromise the assets.

3-6.1 **Select Applicable Aggressors.** Table 3-9 indicates which of the 10 aggressor types defined in chapter 2 are likely to attempt to compromise assets in each of the 18 established asset categories. These aggressor selections represent default potential aggressors and were established based on assessment of the common goals and characteristics historically exhibited by those aggressor types. Further evaluation by the Planning Team relative to a specific asset's locality is required to make a final determination of the applicable aggressors. Indicate on the Asset Value/Aggressor Likelihood Worksheet the aggressor types applicable to an asset by placing "X's" or check marks in the spaces adjacent to them. Note that Table 3-9 also includes default aggressor goals, which are used later in the chapter.

3-6.2 **Assess Aggressor Likelihood Ratings.** The likelihood that a given aggressor will attempt to compromise an asset is evaluated using 14 likelihood rating factors for terrorists and 11 likelihood rating factors for all other aggressors. Each of those factors is described below. The factors measure likelihood by considering issues that reflect how likely an aggressor is to know that an asset exists, how common the asset is, where it is located, history of attacks on those assets, the state of law enforcement support, how it is stored, and the threat level. There are also asset specific considerations of the relative value of the asset to the aggressors. In evaluating the individual likelihood rating tables, select the entry from each applicable table that most closely applies to the aggressor and the asset. The rating factors are evaluated on scales of 0 to 5, 0 to10, 0 to 15, 0 to 20, or 0 to 30. In the higher range cases, the rating factors are rated higher to reflect increased importance of the issues reflected in

Figure 3-4. Sample Asset Value / Aggressor Likelihood Worksheet

ASSET VALUE/AGGRESSOR LIKELIHOOD WORKSHEET

Project or Building	Asset	Analyst
A Motor Pool	*Tactical vehicles*	*Jane Q. Planner*
	Asset Category: *D*	Date: *4 August 2008*

Value Rating Factors

	Criticality to User / Population Type [1]	Impact on National Defense	Replaceability	Political Sensitivity	Relative Value to User	Sum of Value Factors	Value Rating [2]
General Population							
Critical Infrastructure and Operations and Activities							
Sensitive Information							
All Other Assets							
	4	*4*	*4*	3	*4*	*19*	*.76*

Notes:

Likelihood Rating Factors

Potential Aggressors	Aggressor Goal [3]	Aggressors	Installation Location [4]	Publicity Profile [4]	Accessibility [4]	Availability [4]	Dynamics [4]	Recognizability	Relative Value to Aggressor	Law Enforcement [4]	Aggressors' Perception of Success	Threat Level	History [5] / Intentions [6]	Operational Capability [6]	Operating Environment [6]	Activity [6]	Sum of Likelihood Factors	Likelihood Ratings [7]
✓	*M*	Unsophisticated Criminals	2	4	2	2	3	12	15	18	24	6	6				94	.52
✓	*M*	Sophisticated Criminals	2	4	2	2	3	12	12	18	24	6	6				91	.51
✓	*M*	Organized Criminal Groups	2	4	2	2	3	15	9	18	30	6	6				97	.54
✓	G	Vandals	2	4	2	2	3	12	6	18	24	6	6				85	.47
✓	G	Extremist Protesters	2	4	2	2	3	15	6	18	24	6	6				88	.49
✓	G	Domestic Terrorists	2	4	2	2	3	15	9	18	24	5	4	4	6	4	102	.57
✓	G	International Terrorists	2	4	2	2	3	15	9	18	30	5	8	6	10	2	116	.64
✓	G	State Sponsored Terrorists	2	4	2	2	3	15	9	18	30	5	10	10	10	10	130	.72
✓	G	Saboteurs	2	4	2	2	3	15	3	18	30	6	6				91	.51
		Foreign Intelligence Services																

1. Population Type applies to General Population only
2. Sum of Value Ratings ÷ 10 for Sensitive Information 15 for General Population; 20 for Critical Infrastructure and Operations and Activities; 25 for all other assets
3. G for mission related goal, P for publicity related goal, M for monetary related goal.
4. Factors that should be same for all aggressors for given asset
5. Applies to all aggressors other than terrorists
6. Applies to Terrorists only
7. Sum of Likelihood Ratings ÷ 180

those factors. The likelihood rating factors can be subdivided into three main areas: factors relating to the assets themselves (the first 7), factors relating to asset protection (law enforcement and perception of success), and factors relating to history, threat level, and characteristics of terrorist groups (all others). The sums of all the factors within each of those areas are 1/3 of the total (180). Where the differences in meaning between descriptions in the tables are difficult to determine, think of them in terms of "on a scale of 0 to 5" or whatever the applicable range may be. Record the numerical values for the applicable likelihood rating factors in the appropriate spaces on the Asset Value/Aggressor Likelihood Worksheet.

Table 3-9. Potential Aggressors and Default Goals

		Default Aggressor Types									
	Asset Categories	Unsophisticated Criminals	Sophisticated Criminals	Organized Criminal Groups	Vandals	Extremist Protest Groups	Domestic Terrorists	International Terrorists	State Sponsored Terrorists	Saboteurs	Foreign Intelligence Services
A	People			G	P	P	P	P	P	G	
B	Aircraft and Components at Aviation Facilities	M	M	M	P	P	P	P	P	G	
C	Ships, Boats, and Other Watercraft	M	M	M	P	P	P	P	P	G	
D	Vehicles and carriage mounted or towed weapons systems	M	M	M	P	P	P	P	P	G	
E	Petroleum, Oils, and Lubricants	M	M	M	P	P	P	P	P	G	
F	Arms, Ammunition, and Explosives	M	M	M	P	1	1	1	1	G	
G	Controlled Medical Substances and Medically Sensitive Items	M	M	M							
H	Communications / Electronics Equip. and Night Vision Devices	M	M	M							
I	Organizational Clothing and Individual Equipment	M	M	M							
J	Subsistence Items at Commissaries, Warehouses, & Troop Issue Facilities	M	M	M							
K	Repair Parts at Installation Supply and Direct Support Units	M	M	M							
L	Facilities Engineering Supplies and Construction Material	M	M	M							
M	Audiovisual Equipment, Training Devices, and Subcaliber Devices	M	M	M							
N	Miscellaneous Pilferable Assets (other than above) and Money	M	M	M							
O	Critical Infrastructure and Industrial Equipment				P	P	P	P	P	G	
P	Controlled Cryptographic Items		M	M						G	G
Q	Sensitive Information			G						G	G
R	Activities and Operations			G		G	P	P	P	G	G
	1. May be mission, publicity, or monetary related goal (see Table 3-16) G = Mission related goal P = Publicity related goal M = Monetary related goal										

3-6.2.1 **Installation Location.** This factor reflects the assumption that installations that are outside the Continental United States are more likely targets of attack than those in the Continental United States and that the threat is higher near major population centers. Use Table 3-10 to evaluate this factor.

Table 3-10. Asset Location

Installation or facility Location	Likelihood Rating Factor
Located within the Continental United States away from major metropolitan areas	1
Located within the Continental United States near a major metropolitan area	2
Located outside the Continental United States away from major metropolitan areas	4
Located outside the Continental United States near a major metropolitan area	5

3-6.2.2 **Publicity Profile.** This factor addresses the level of publicity associated with an installation or facility. It accounts for the fact that some installations are very controversial and well known throughout a region while others are rather obscure. This factor is based on the assumption that installations or facilities that have a high publicity profile are more likely targets than those that are relatively unknown. Use Table 3-11 to evaluate this factor.

Table 3-11. Installation or Facility Publicity Profile

Level of Publicity Associated with Installation or Facility	Likelihood Rating Factor
Installation or facility is relatively unknown both locally and regionally.	1
Installation or facility is well known locally but is relatively unknown regionally.	2
Installation or facility is well known locally and regionally, but it relatively un known nationally.	3
Installation or facility is well known locally, regionally, and nationally, but is relatively unknown internationally	4
Installation or facility is well known locally, regionally, nationally and internationally	5

3.6.2.3 **Accessibility.** This factor addresses the assumption that assets are more vulnerable when the facilities in which or at which they are stored are readily accessible. This factor is evaluated using Table 3-12, which addresses whether or not the facility is on an “open” or access controlled installation and the proximity of the facility to the installation perimeter.

Table 3.12 Asset Accessibility

Asset Location and Access Controls	Likelihood Rating Factor
The facility in which or at which the asset is located is on a closed military installation or government compound to which access is controlled, the facility is in a separate access controlled compound interior of the installation, and there are no direct lines of sight to the facility from outside the installation	0
The facility in which or at which the asset is located is on a closed military installation or government compound to which access is controlled and the facility is in the interior of the installation	2
The facility in which or at which the asset is located is on a closed military installation or government compound to which access is controlled and the facility is within 100 meters of the installation perimeter	4
The facility in which or at which the asset is located is on an open military installation or government compound to which access is not controlled and the facility is in the interior of the installation	6
The facility in which or at which the asset is located is on an open military installation or government compound to which access is not controlled and the facility is within 100 meters of the installation perimeter	8
The facility in which or at which the asset is located is not on a military installation or government compound	10

3-6.2.4 **Asset Availability.** This factor assesses how common the asset is in the general area where it is located. The rating table addresses availability both on military installations or at other sites where military assets are housed and in their immediate vicinities. It reflects the assumption that the likelihood that an aggressor will attempt to compromise an asset in one particular location is less if it is widely available, assuming all locations are equally likely. Conversely, the likelihood increases if the location in question is the only place the asset can be found and it assumed the aggressor wants that specific asset. Use Table 3-13 to evaluate this factor.

Table 3-13. Asset Availability

Asset Availability	Likelihood Rating Factor
Similar assets are widely available both on and in the immediate vicinity off the installation or site	0
Similar assets have limited availability in the immediate vicinity off the installation, but are widely available on the installation or site	1
Similar assets are not available in the immediate vicinity off the installation, but are widely available on the installation or site	2
Similar assets have limited availability on the installation and are not available in the immediate vicinity off the installation or site	3
Similar assets are available at fewer than 3 other locations on the installation and are not available in the immediate vicinity off the installation or site	4
There are no similar assets on or off the installation except at this location or site	5

3-6.2.5 **Asset Dynamics.** This factor accounts for the assumption that an aggressor is less likely to attempt to attack an asset that is moved frequently or randomly because of the uncertainty of its location at any given time and the uncertainties in planning inherent in that condition. Use Table 3-14 to evaluate this factor.

Table 3-14. Asset Dynamics

Frequency of Asset Relocating or Moving	Likelihood Rating Factor
Asset is moved frequently on a random basis	1
Asset is moved frequently on a predictable basis	2
Asset is moved periodically on a random basis	3
Asset is moved periodically on a predictable basis	4
Asset is not moved.	5

3-6.2.6 **Recognizability.** This rating factor assesses how likely an aggressor is to know that an asset exists in the location where it is located. That likelihood should be evaluated based on assumptions about the sophistication of the aggressor and the amount of training or intelligence support the aggressor would need to be aware of the asset. Use Table 3-15 to evaluate this factor for all assets. Select the likelihood rating factor from the column that corresponds to the applicable aggressor. Different ratings factors apply to different aggressors to reflect their assumed intelligence capabilities.

Table 3-15. Recognizability

Recognizability	Likelihood Rating Factor		
	Unsophisticated Criminals Sophisticated Criminals Vandals	Organized Criminal Groups Extremist Protest Groups Domestic Terrorists	International Terrorists State Sponsored Terrorists Saboteurs Foreign Intelligence Services
The asset's existence can be recognized only by aggressors who are experts or who have expert intelligence support	3	6	9
The asset's existence can be recognized only by aggressors with a significant amount of training or intelligence support	6	9	12
The asset's existence can be recognized only by aggressors with a moderate amount of training or intelligence support	9	12	15
The asset's existence can be recognized only by aggressors with a minor amount of training or intelligence support	12	15	15
The asset's existence is obvious to the aggressor. It can be recognized by aggressors with little or no training or intelligence support	15	15	15

3-6.2.7 **Relative Value to Aggressor.** This factor assesses how likely aggressors are to attempt to target assets based on the value of those assets to those aggressors. Relative value is addressed differently for different aggressors and asset categories. Relative value is measured on the basis of an asset's value to the aggressors in achieving future or mission goals, the resultant publicity associated with destroying an asset, or the monetary value of an asset. Use Table 3-16 in evaluating this factor subject to the guidance below and the notes in the table. Enter the assumed goal of the aggressor into the appropriate space in the Asset Value/Aggressor Likelihood Worksheet for each aggressor using the abbreviations below. The aggressor goals will be used to select among options in Table 3-16. Default aggressor goals are tabulated in Table 3-9. They can be evaluated by the Planning Team for applicability.

- **G** where targeting the asset meets a specific mission related goal of an aggressor or where it can be used in future attacks
- **P** where the goal of targeting the asset would be to gain publicity
- **M** where the goal for targeting the asset would be related to its monetary value such as to sell it

3-6.2.7.1 **Value to Mission or Future Goals.** Use this portion of Table 3-16 to assess the value for assets where targeting them would satisfy a particular mission goal of the aggressor. This principally applies to saboteurs and foreign intelligence services because their primary interest in assets is likely to be associated with their mission to compromise them. This also applies to terrorists and extremist protest groups who might steal arms, ammunition, and explosives for the purposes of using them in a future attack. For organized criminal groups, use this portion of the table only where it is likely that they will target assets or officials for the purpose of deterring law enforcement officials from targeting them or for some similar purpose.

3-6.2.7.2 **Publicity Value.** Use this portion of Table 3-16 where the value of assets to users is likely to be based on the amount of publicity the aggressors could expect if they targeted the asset.

3-6.2.7.3 **Relative Value Based on Asset Cost.** Use these portions of Table 3-16 to assess value for assets for which a monetary cost can be identified and is the best measure of asset value to potential aggressors. The cost ranges in this table are the same as those previously used to assess asset value to the user, except for assets whose values to their users were not based on their costs (vehicles, POL, AA&E, and controlled cryptographic items.) For those assets, for the purposes of this table, estimate their monetary value. Use the upper portion where only one or a small number of assets are being considered and use the lower portion where asset inventories are more applicable in describing the asset quantities, as in assets stored in bulk. Note also that the points associated with cost ranges vary by aggressor. That reflects the assumption that sophisticated aggressors will not target low value assets and that unsophisticated criminals do not have the capability to effectively dispose of high value assets.

Table 3-16. Relative Value to Aggressors

Asset Category	Aggressor	Aggressor Goal[1]	Relative Value	Likelihood Rating Factor	
A B C D E F[2] O P Q R	Saboteurs and Foreign Intelligence Agents, or Organized Criminal Groups[3]	Target asset for value to mission or support to future goals	Compromising assets would have negligible utility to accomplishment of aggressor's mission or future goals.	0	
			Compromising assets would have minor utility to accomplishment of aggressor's mission or future goals.	3	
			Compromising assets would have moderate utility to accomplishment of aggressor's mission or future goals.	6	
			Compromising assets would have significant utility to accomplishment of aggressor's mission or future goals.	8	
			Compromising assets would have major utility to accomplishment of aggressor's mission or future goals.	12	
			Compromising assets would likely be critical to accomplishment of aggressor's mission or success of future goals.	15	
A B C D E F[2] O P R	Terrorist / Extremist Protest Group, Vandals	Target asset for Publicity value	Aggressor is likely to believe asset's compromise would result in insignificant publicity	0	
			Aggressor is likely to believe asset's compromise would result in publicity limited to local media	3	
			Aggressor is likely to believe asset's compromise would result in publicity that would likely extend to national media	9	
			Aggressor is likely to believe asset's compromise would result in publicity that would likely extend to international media	15	

Table 3-16 (continued)

Asset Category	Aggressors ⇨	Aggressor Goal[1]	Relative Value	Likelihood Rating Factors: Unsophisticated Criminals	Sophisticated criminals	Organized criminal groups	Others[5]
B C D E F[2] G H I J K L M N P	Individual assets[4]	Target asset for Monetary value	Asset value is less than $2500	9	3	0	3
			Asset value is greater than or equal to $2500 and less than $10,000	12	6	3	6
			Asset value is greater than or equal to $10,000 and less than $25,000	15	9	6	9
			Asset value is greater than or equal to $25,000 and less than $50,000	15	12	9	12
			Asset value is greater than or equal to $50,000 and less than $100,000	12	15	12	15
			Asset value is greater than $100,000	9	15	15	15
B E F[2] G H I J K L M N P	Asset inventories[4]	Target asset for Monetary value	Asset inventory value is less than $100,000	9	3	0	3
			Asset inventory value is greater than or equal to $100,000 and less than $250,000	12	6	3	6
			Asset inventory value is greater than or equal to $250,000 and less than $500,000	15	9	6	9
			Asset inventory value is greater than or equal to $500,000 and less than $1,000,000	15	12	9	12
			Asset inventory value is greater than or equal to $1,000,000 and less than $2,000,000	12	15	12	15
			Asset inventory value is greater than $2,000,000	9	15	15	15

Notes:

1. Select applicable measure of asset value to aggressors (defaults at Table 3-9).
2. For arms, ammunition, and explosives (AA&E) subject to action by terrorists or extremist protest groups, select the upper factor if the goal is to steal the AA&E for use in future attacks, select the second if the goal is to destroy it, and among the lower two if the goal is to steal and sell it.
3. Only use this factor for organized criminal groups where it is likely they would kill people to further their goals. See paragraph 3-6.2.7.1.
4. Select between factors based on whether analyzing individual assets or inventory of assets.
5. Use only where non-criminal aggressors are likely to steal assets to sell them.

3-6.2.8 **Law Enforcement Personnel Visibility.** This factor should be addressed in conjunction with installation law enforcement personnel. It addresses the visibility of law enforcement personnel or guards at an installation perimeter or in the vicinity of a facility and reflects the assumption that a strong law enforcement or guard presence can limit the likelihood that an aggressor will attempt to compromise assets there. It can be evaluated with respect to DoD or military police, contract or unit guards, and local or host nation law enforcement personnel as applicable. Use Table 3-17 in evaluating it. Enter the matrix on the left with the frequency of law enforcement or guard presence at the installation perimeter and enter it at the top with frequency of presence in the immediate vicinity of the facility housing the asset. Read the value rating factor at the intersection of the two frequencies. Note that the range of likelihood rating factors is higher for this factor because of its added significance to likelihood.

Table 3-17. Law Enforcement Personnel Visibility

		Frequency of Presence in Vicinity of Facility			
		Infrequent	Occasional	Frequent	Continuous
Frequency at Installation Perimeter	Occasional	30	24	18	12
	Scheduled	24	18	12	6
	Continuous	18	12	6	0

3-6.2.9 **Aggressors' Perception of Success.** This factor assesses aggressors' likely perception of the possibility that they will successfully compromise an asset and escape (where escape is a goal). It should be evaluated considering visible countermeasures that exist, are planned, or are otherwise likely to be present, in the context of how they would likely deter aggressors or otherwise affect their perception of their chances for success. At this point, countermeasures should only be considered in a very general sense. Specific countermeasures and their contribution to mitigation of vulnerabilities will be assessed in more detail in the design phase of this process using UFC 4-020-02. Use Table 3-18 to evaluate aggressor perceptions as described below. Note that more sophisticated aggressors are likely to be less easily deterred than less sophisticated ones. Where the differences in meaning between entries in the table are difficult to determine, think of them in terms of "on a scale of 6 to 30" with respect to the likely affect on aggressor perception.

3-6.2.9.1 **Exterior Assets.** This assesses deterrence due to visible countermeasures common to security of assets stored in exterior areas assuming the aggressor will try to gain access to the assets. Consider measures such as fences, lighting, intrusion detection systems (IDS), and closed circuit television (CCTV).

3-6.2.9.2 **Interior Assets.** This assesses the deterrence from visible security measures applied to assets stored inside structures assuming the aggressor will try to gain access to the assets. Consider the effect of building construction (walls, roofs, windows, and doors) and how it may provide resistance to forced entry. For example, reinforced concrete or masonry construction, heavy doors, and window barriers are commonly more resistant than lighter weight construction. Also consider perimeter security such as fences or walls, interior locations of assets, and measures such as IDS and CCTV.

3-6.2.9.3 **Interior Assets Subject to Destruction.** This is assessed for assets that are stored inside structures and are subject to being damaged or, in the case of people, killed. Consider how the building construction might be or might appear to be resistant to weapons and explosives effects. Again, reinforced concrete or masonry construction is generally more resistant than lightweight construction.

Table 3-18. Aggressors' Perception of Success

Aggressor's Likely Perception of Possibility of Success Based on Likely Presence of Visible Countermeasures	Likelihood Rating Factor
Based on the visible countermeasures that are likely to be present or are present at the facility where the asset is or will be located, aggressor would likely perceive a very low possibility of successfully compromising or destroying the asset and escaping.	6
Based on the visible countermeasures that are likely to be present or are present at the facility where the asset is or will be located, aggressor would likely perceive a low possibility of successfully compromising or destroying the asset and escaping.	12
Based on the visible countermeasures that are likely to be present or are present at the facility where the asset is or will be located, aggressor would likely perceive a moderate possibility of successfully compromising or destroying the asset and escaping.	18
Based on the visible countermeasures that are likely to be present or are present at the facility where the asset is or will be located, aggressor would likely perceive a high possibility of successfully compromising or destroying the asset and escaping.	24
Based on the visible countermeasures that are likely to be present or are present at the facility where the asset is or will be located, aggressor would likely perceive a very high possibility of successfully compromising or destroying the asset and escaping.	30

3-6.2.10 **Threat Level.** This factor addresses the general level of threat activity for a country, region, or locale. It will be evaluated differently for terrorists than for all other aggressors. In the case of terrorists, use the applicable DoD or Combatant Command terrorist threat level established for the locality or region. Those levels will be low, moderate, significant, or high as established in DoD O-2000.12-H. Established terrorist threat level methodologies commonly include considerations of the presence of a threat, operational capability, intentions, activity, and the operating environment. Those are the basis for the DoD and Combatant Command threat level determinations.

Terrorist threat levels can commonly be obtained from intelligence sources or from antiterrorism officers, who should be part of the Planning Team. Criminal, protester, foreign intelligence, and saboteur threat levels can be assigned similar descriptors to reflect the activity of those aggressors in an area. While the same considerations can be taken into account for threat levels for aggressors other than terrorists, the programs for doing so are far less formal than for terrorists. The information for those assessments may be established locally or by regional or national level entities. It should be available to local intelligence or law enforcement personnel, who should be part of the Planning Team.

Use Table 3-19 to assess likelihood ratings for this factor. Note that the range for aggressors other than terrorists is higher than for terrorists. The reason for that is that for terrorists the specific threat methodology factors of intention, operational capability, operational environment, and activity are addressed separately on a local basis, while they are all effectively incorporated into one factor for the other aggressors. By using different ranges for the factors, the overall weighting for the similar "groups" of factors is maintained at 1/3 of the total.

Table 3-19. Threat Level

Terrorist, Criminal, Vandal, Protestor, Foreign Intelligence, or Saboteur Threat Level	Likelihood Rating Factor	
	Terrorists	All Other Aggressors
Low	5	6
Moderate	10	14
Significant	15	22
High	20	30

3-6.2.11 **History / Intentions.** These are actually two closely related factors. History applies to all aggressors except for terrorists. It addresses the fact that previous attempts to compromise assets are potentially good indicators of future attempts to do so. It also reflects the fact that such attempts locally or regionally are better indicators than attempts elsewhere in the world and that more recent attempts are also potentially better indicators. Evaluate this factor in the contexts of each applicable aggressor's history.

Use intentions as a consideration in evaluating the local terrorist threat. Intentions reflect the stated and/or actual history of particular terrorist groups attacking U.S. Interests. For more information on intentions, refer to DoD 0-2000.12-H.

Use Table 3-20 to evaluate both history and intentions. The ranges of the factors for terrorists and for other aggressors are the same as for the threat level factor described above.

Table 3-20. History of Acts Against Like Assets / Terrorist Intention

Aggressor / Factor	History or Intention	Likelihood Rating Factor
Aggressor: All except terrorists Factor: History	There is no history of attacking or otherwise compromising assets of this type.	6
	There is little or no history of attacking or otherwise compromising assets of this type.	12
	There is history of attacking or otherwise compromising assets of this type, but not locally or regionally.	18
	There is local or regional history of attacking or otherwise compromising assets of this type in the past 10 years.	24
	There is a strong history of attacking or otherwise compromising assets of this type locally and regionally in the past 3 years.	30
Aggressor: Terrorists Factor: Intentions	No history of attacks	2
	Anti-U.S. ideology, but no direct attacks	4
	Anti-U.S. ideology, with a history of attacks outside region	6
	Recent attacks against U.S. interests regionally	8
	Recent attacks against U.S. interests locally	10

3-6.2.12 **Operational Capability.** This factor should be used to assess the local terrorist threat. It should not be applied for any other aggressors. Operational capability is the acquired, assessed, or demonstrated level of operational capability to conduct terrorist attacks. For more information on this factor, refer to DoD 0-2000.12-H. Use Table 3-21 to evaluate this factor.

Table 3-21. Terrorist Operational Capability

Capability to Conduct Terrorist Attack	Likelihood Rating Factor
Insignificantly capable	2
Minimally capable	4
Capable	6
Very capable	8
Extremely capable	10

3-6-2.13 **Operating Environment.** This factor considers how the overall environment, to include political and security considerations, influences a terrorist group's ability and motivation to conduct an attack. It should not be applied for any other aggressors. For more information on this factor, refer to DoD 0-2000.12-H. Use Table 3-22 to evaluate this factor.

Table 3-22. Terrorist Operating Environment

Environment for Terrorists Operating	Likelihood Rating Factor
Favors U.S. or host nation	2
Neutral	6
Favors terrorist	10

3-6.2.14 **Activity.** This factor considers the fact that a terrorist group's activity in a country may not always be related to operational planning or present a threat to U.S. / Host Nation interests. Many groups use countries as support bases and may not want to jeopardize their status by conducting terrorist acts there. For more information on this factor, refer to DoD 0-2000.12-H. Use Table 3-23 to evaluate this factor.

Table 3-23. Terrorist Activity

Terrorist Activities in the Applicable Country or Region	Likelihood Rating Factor
Present but inactive	2
Recruiting, fund-raising or non-directed activity	4
Suspected surveillance, threats, and suspicious incidents	6
Identified cell activity (operational or support)	8
Credible indications of targeting U.S. assets	10

3-6.3 **Determine Likelihood Ratings.** Likelihood ratings are determined based on the sums of the 11 or 14 applicable likelihood rating factors, depending on whether the applicable aggressor is a terrorist or any of the other aggressor categories. Sum the likelihood rating factors for each asset and enter their sums in the appropriate boxes on the Asset Value/Aggressor Likelihood Worksheet. Then divide the sums by the total number of points possible (180). The resulting percentages are the aggressor likelihood ratings. Enter them in the appropriate boxes on the Asset Value/Aggressor Likelihood Worksheet as well as on the Tactic, Threat Severity, and Level of Protection Worksheet and the Risk Level Calculation Worksheets.

3-6.4 **Aggressors with "Very Low" Likelihood Ratings.** Aggressors who have likelihood ratings of less than or equal to 0.5 need not be considered for further evaluation. Because of their very low assessed likelihood it is unlikely that they will be a threat to the assets under consideration and the risk of ignoring them should be acceptable. Any aggressors who have a likelihood rating of higher than 0.5 should be further evaluated in the next step. Enter the likelihood ratings for those aggressors on the Tactic, Threat Severity, and Level of Protection Worksheet in the applicable locations, using one worksheet for each asset. If all aggressors have received likelihood ratings of 0.5 or less, there will be no threat postulated for the asset and only minimum measures required by regulation and measures required by minimum construction standards (DoD or Combatant Command) should be applied.

3-7 **STEP 5. IDENTIFY TACTICS AND THREAT SEVERITY LEVELS.** The tactics aggressors are likely to use in attempting to compromise assets can be selected on a default basis considering the likely objectives of the aggressors toward the assets and the asset categories. The threat severity levels will indicate the initial tools, weapons, explosives, or agents that will be associated with those tactics for the purposes of the planning level risk analysis. These form the basis for a preliminary protective system for an asset that can be used to develop a planning level cost estimate. These threat severity levels may be adjusted based on the risk analysis results with the adjusted levels becoming part of the design criteria for the project. Selecting the likely tactics is a two-step process. The first step is to identify the tactics based only on the assets and the second is to consider the aggressors. Selecting the initial threat severity levels is a third step.

3-7.1 **Select Applicable Tactics Based on Assets.** Use Table 3-24 to determine which of the 13 tactics defined in Chapter 2 may apply against the identified assets based on the asset categories. These are default tactics based only on the asset category and do not include considerations of which aggressors are likely to carry out those tactics or if the specific goals of aggressors toward an asset would lead them to use that tactic against it. Those considerations will be addressed in the next step. Table 3-24 includes all the tactics that any aggressor might use against the asset.

3-7.2 **Select Applicable Tactics Based on Aggressors.** The previous step excluded aggressor considerations. In this step those considerations are taken into account. Use Table 3-25 to do the final selection of applicable tactics. That table reflects considerations relating to tactics specific aggressors may use based on their likely goals toward the asset. Select tactics for each applicable aggressor for which there are entries under a tactic. As an illustration of the additional filtering associated with this step, Table 3-25 indicates that hand delivered devices may be used against arms, ammunition, and explosives. In evaluating criminals with respect to that asset, Table 3-25 would not attribute that tactic to the criminals, who are limited to theft-oriented tactics. Enter "X's" or check marks in the appropriate locations for the applicable tactics on the Tactic, Threat Severity, and Level of Protection Worksheet as illustrated in Figure 3-5. These are the initial default tactics. If in the judgment of the Planning Team any of the default tactics do not apply, do not enter them on the worksheet. Similarly, if the Planning Team thinks tactics that were not included in the default tactics should be included, add them.

3-7.3 **Identify Threat Severity Levels.** A range of tools, weapons, explosives, or agents may apply to each tactic. A tactic's threat severity level defines which tools, weapons, explosives, or agents within that range apply for a given threat. Threat severity levels may be designated as very low, low, medium, high, or very high. Different tactics may have different numbers of possible threat severity levels. In some cases, a tactic only has one possible threat severity level. In those cases, the severity level is indicated by a "yes." In addition, some of those levels are not postulated to apply to all aggressors. The threat severity levels are selected based upon the likelihood ratings for the applicable aggressors. Selecting threat severity levels considering likelihood of aggression is based on the principles of risk acceptance. If the likelihood of aggression for an aggressor is low, the protective system can be designed for a threat severity level lower than the maximum threat severity level for that aggressor. That is based on the user assuming that the aggressors will expend less effort

Figure 3-5. Sample Tactic, Threat Severity, and Level of Protection Worksheet

TACTIC, THREAT SEVERITY, AND LEVEL OF PROTECTION WORKSHEET

Project or Building	Asset		Analyst
A Motor Pool	*Tactical Vehicles*		*Jane Q. Planner*
	Asset Category: *D*	Asset Value: *0.76*	Date: *4 August 2008*

Aggressors \ Tactics	Aggressor Likelihood	Explosives and Incendiary Devices			Standoff Weapons		Entry		Surveillance and Eavesdropping			Contamination		
		Moving Vehicle Devices	Stationary Vehicle Devices	Hand Delivered Devices	Indirect Fire Weapons	Direct fire weapons	Forced Entry	Covert Entry	Visual Surveillance	Acoustic Eavesdropping	Electronic Emanations Eavesdropping	Airborne Contamination	Waterborne Contamination	Waterfront Attack
Applicable Tactics			✓	✓	✓	✓	✓	✓						
Unsophisticated Criminals	*.52*						*L*	*L*						
Sophisticated Criminals	*.51*						*L*	*L*						
Organized Criminal Groups	*.54*			*L*		*L*	*L*	*L*						
Vandals	*< .5*													
Extremist Protesters	*< .5*													
Domestic Terrorists	*.57*		*L*	*M*	*L*	*L*	*L*	*L*						
International Terrorists	*.64*		*L*	*M*	*L*	*L*	*L*	*L*						
State Sponsored Terrorists	*.72*		*L*	*M*	*L*	*L*	*M*	*L*						
Saboteurs	*.51*			*M*	*L*	*L*	*M*	*L*						
Foreign Intelligence Services														
Initial Design Basis Threat (highest Threat Severity Level for each tactic)			*L*	*M*	*L*	*L*	*M*	*L*						
Initial Level of Protection for Applicable Tactic (Table 3-28)			*M*	*M*	*M*	*L*	*M*	*M*						

Table 3-24. Applicable Asset / Tactic Selection

Asset Categories		Applicable Tactics: Moving Vehicle Bomb Tactic	Stationary Vehicle Bomb Tactic	Hand Delivered Devices	Indirect Fire Weapons	Direct Fire Weapons	Forced Entry	Covert Entry	Visual Surveillance	Acoustic Eavesdropping	Electronic Emanations Eavesdropping	Airborne Contamination	Waterborne Contamination	Waterfront Attack
A	People	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓
B	Aircraft and Components at Aviation Facilities		✓	✓	✓	✓	✓	✓						
C	Ships, Boats, and Other Watercraft		✓	✓	✓	✓	✓	✓						✓
D	Vehicles and carriage mounted or towed weapons systems		✓	✓	✓	✓	✓	✓						✓
E	Petroleum, Oils, and Lubricants			✓	✓	✓	✓	✓						✓
F	Arms, Ammunition, and Explosives			✓	✓	✓	✓	✓						✓
G	Controlled Medical Substances and Medically Sensitive Items						✓	✓						
H	Communications / Electronics Equipment and Night Vision Devices			✓	✓	✓	✓	✓						
I	Organizational Clothing and Individual Equipment						✓	✓						
J	Subsistence Items at Commissaries, Warehouses, & Troop Issue Facilities						✓	✓						
K	Repair Parts at Installation Supply and Direct Support Units						✓	✓						
L	Facilities Engineering Supplies and Construction Material						✓	✓						
M	Audiovisual Equipment, Training Devices, and Subcaliber Devices						✓	✓						
N	Miscellaneous Pilferable Assets (other than above) and Money						✓	✓						
O	Critical Infrastructure and Utility Equipment		✓	✓	✓	✓	✓	✓						✓
P	Controlled Cryptographic Items						✓	✓						
Q	Sensitive Information						✓	✓	✓	✓	✓			
R	Activities and Operations	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 3-25. Applicable Aggressor / Tactic Selection

Aggressors	Applicable Tactics: Explosives Tactics – Moving Vehicle Devices Tactic	Explosives Tactics – Stationary Vehicle Devices Tactic	Explosives Tactics – Hand Delivered Devices	Standoff Weapons – Indirect Fire Weapons	Standoff Weapons – Direct Fire Weapons	Entry Tactics – Forced Entry	Entry Tactics – Covert Entry	Surveillance and Eavesdropping – Visual Surveillance	Surveillance and Eavesdropping – Acoustic Eavesdropping	Surveillance and Eavesdropping – Electronic Emanations Eavesdropping	Contamination Tactics – Airborne Contamination	Contamination Tactics – Waterborne Contamination	Waterfront Attack
Unsophisticated Criminals						L	L						
Sophisticated Criminals						L M H	L						
Organized Criminal Groups			L M		L M H	L M H VH	L						
Vandals			L		L	L	L						
Extremist Protesters			L M	L	L M H	L M	L M						L
Domestic Terrorists		L M	M H	L M	L M H	L M	L M H	H			L	L	L
International Terrorists	L M H	L M H	M H	L M H	L M H	L M H	L M H	H			L M	L M	L M
State Sponsored Terrorists	L M H VH	L M H VH	M H	L M H VH	L M H VH	M H VH	L M H VH	H			L M H	L M H	L M H
Saboteurs			M H	L M H VH	L M H VH	M H VH	L M H VH	H			L M H	L M H	L M H
Foreign Intelligence Services						L	H VH	H	H	H			

and fewer resources on assets that are less attractive to them. The Planning Team accepts the risk that this assumption is correct and that the aggressor does not attack at a higher threat severity level. If the Planning Team does not wish to accept the risk inherent in that assumption, they may choose to specify higher threat severity levels.

3-7.3.1 **Select Applicable Threat Severity Levels.** Table 3-25 indicates multiple threat severity levels for some aggressors for some tactics. Table 3-26 is used to determine which applies based on the aggressor likelihood ratings. To use Table 3-26, note how many possible threat severity levels apply for a specific aggressor in Table 3-25. Enter Table 3-26 on the left side with the number of possible threat severity levels (1, 2, 3, or 4,) and enter along the top of the table with the likelihood rating for the applicable aggressor. At the intersection of the two, read the number of the threat severity level that should be applied. Where only a "yes" is indicated in the table, there is only one threat severity level for that tactic, and any likelihood rating greater than 0.5 will mean that tactic and its single threat severity level apply. Enter the applicable threat severity level associated with the selection in the appropriate location on the Tactic, Threat Severity, and Level of Protection Worksheet as illustrated in Figure 3-5. Note that in Table 3-26 "minimum" is entered for likelihood ratings of less than or equal to 0.5. That indicates that minimum measures required by regulations or DoD or Combatant Command construction standards apply as described previously.

3-7.3.2 **Example.** As an example, assume the likelihood rating for international terrorists is 0.92. For the indirect weapons attack Table 3-25 indicates three possible choices for international terrorists, "low", "medium", and "high". Entering Table 3-26 with 3 choices and a likelihood rating of 0.92 indicates that the "3rd" choice should be used. Therefore, the applicable threat severity level for that aggressor is "high."

Table 3-26. Threat Severity Selection

Number of Threat Severity Level Choices *	Likelihood Rating				
	≤ 0.5	0.51 – 0.74	0.75 – 0.89	0.90 – 0.94	0.95 – 1
4	Minimum	1st	2nd	3rd	4th
3	Minimum	1st	2nd	3rd	3rd
2	Minimum	1st	1st	2nd	2nd
1	Minimum	1st	1st	1st	1st
* See Table 3-25					

3-8 **STEP 6: CONSOLIDATE INTO INITIAL DESIGN BASIS THREAT.** The initial design basis threat is the threat upon which the preliminary protective system will be based. It represents the worst-cases of the applicable threat severity levels for each applicable tactic for a given asset. The initial design basis threat may be changed during the design process based on detailed risk analysis as described in UFC 4-020-02. It will also be used to assess vulnerabilities in the case of existing facilities.

3-8.1 **Initial Design Basis Threat.** Determine the initial design basis threat by identifying the highest applicable threat severity level for each tactic across all aggressor types as entered on the Tactic Threat Severity, and Level of Protection Worksheet. Enter the initial design basis threat severity level for each tactic in the spaces provided at the bottom of the Tactic Threat Severity, and Level of Protection Worksheet. Refer to Table 3-27 to determine the design parameters (tools, weapons, explosives, and agents) associated with each of the threat severity levels for each tactic. In tactics with multiple threat severity levels, each threat severity level also includes the tools, weapons, explosives, and agents from lower threat severity levels. The threat severity levels will also be entered onto the Building Cost and Risk Evaluation Worksheet if that worksheet is used.

3-8.2 **Modifying the Initial Design Basis Threat.** The threat severity levels indicated are for generic aggressors in unspecified locations. If intelligence, experience, or the judgment of the Planning Team indicates that a different threat severity level applies based on known aggressor characteristics or site or asset specific considerations, those threat severity levels may be modified. In addition, if such considerations indicate that a specified tactic is inapplicable to threats against the asset under consideration, that tactic may be deleted from the threat. Also, if a Combatant Command standard indicates a specific threat, ensure that the initial design basis threat severity level is at least that which has design parameters equivalent to the threat associated with the Combatant Command threat. Ensure that the reasons for any change in the default threat severity levels are recorded for future reference.

Table 3-27 Threat Parameters

Aggressor Tactic	Design Basis Threat	Weapons	Tools Or Delivery Method
Moving and Stationary Vehicle Devices	Special Case [1]	9000 kg (19,800 lbs) TNT	18,000 kg / ~ 40,000 lbs truck
	Very High	2000 kg (4400 lbs) TNT, Fuel	7000 kg / ~ 15,000 lbs truck
	High	500 kg (100 lbs) TNT, Fuel	2500 kg / ~ 5500 lbs truck
	Medium	250 kg (550 lbs) TNT, Fuel	1800 kg / ~ 4000 lbs car
	Low	100 kg (220 lbs) TNT	1800 kg /~ 4000 lbs car
	Very Low	25 kg (55 lbs) TNT	1800 kg / ~ 4000 lbs car
Hand Delivered Devices	High	IID, IED (up to 25 kg/55 lbs TNT) &hand grenades (Mail bomb limited to 1 kg/2.2 lbs TNT)	None
	Medium	IID, IED (up to 1 kg/2.2 lbs TNT) & hand grenades	
	Low	IID	
Indirect Fire Weapons Attack	Very High	Improvised mortar (up to 20 kg/44 lbs TNT)	None
	High	122 mm rocket	
	Medium	82 mm mortar	
	Low	Incendiary devices	
Direct Fire Weapons Attack	Very High	Light antitank weapons, and UL 752 Level 10 (12.7 mm (0.50 caliber), 1 shot)	None
	High	UL 752 Level 9 (7.62mm NATO AP, 1 shot)	
	Medium	UL 752 Level 5 (7.62mm NATO ball)	
	Low	UL 752 Level 3 (.44 magnum)	
Forced Entry	Very High	Handguns and sub-machine guns (up to UL 752 Level 3 to overpower guards)	Bulk explosives (up to 25 kg / 55 lbs TNT), linear shaped charges (up to 10,500grains per foot), unlimited hand, power, thermal tools
	High		Unlimited hand, power, and thermal tools
	Medium	None	Unlimited hand tools - limited battery powered tools
	Low		Limited hand tools - low observables
Covert Entry	Very High	Handgun	Electronic Neutralization Equipment Drill & Specialized Tools Robotic Dialer Manipulation Enhancer
	High	Handgun	Mechanical & Electronic Lock Decoder Drill, simple tools & camouflage Specialized bypass tools
	Medium	None	Lock Picks Bypass techniques High Quality False Credentials Observation tools
	Low	None	Easily Duplicated False Credentials

(Table 3-27 continued)

Visual Surveillance	High	None	Ocular devices
Acoustic Eavesdropping	High		Sound amplification or laser "listening" devices
Electronic Emanations Eavesdropping	High		Electronic emanations interception equipment
Airborne Contamination	High	Internal and external release of all agents listed below	Limited hand tools +1 kg/2.2 lbs explosive (dirty bomb)
	Medium	Agents associated with Low plus external release of toxic military chemical agents	Limited hand tools
	Low	Agents associated with Very Low plus external release of biological and radiological particulates	
	Very Low	External and internal release of Toxic Industrial Chemicals or Toxic Industrial Materials (TIC and TIM)	
Waterborne Contamination	High	Liquid or particulate agent stable in water greater than 30 days and not easily mitigated by chlorine	Limited hand tools
	Medium	Liquid or particulate agent stable in water between 2 hours and 30 days and not easily mitigated by chlorine	
	Low	Liquid or particulate agent stable in water less than 2 hours or easily mitigated by chlorine	
Waterfront Attack Surface and/or Submerged Attack	High	500 kg (1100 lbs) TNT (surface or submerged) Anti-Tank Weapons UL 752 Level 10 (12.7 x 99 mm (0.50 caliber))	Powerboat Multiple small craft Swimmer delivery vehicle Torpedo
	Medium	250 kg (550 lbs) TNT (surface) 25 kg (55 lbs) TNT (submerged) UL 752 Level 10 (12.7 x 99 mm (0.50 caliber))	Combat Rubber Raiding Craft Rigid Hulled Inflatable Boat Torpedo Swimmer / diver
	Low	100 kg (220 lbs) TNT (surface) 25 kg (55 lbs) TNT (submerged) UL 752 Level - 5	Jet Ski Swimmer / diver
1. Note that the process in this UFC does not lead to the Special Case. Applicability is known by those to whom it applies.			

3-9 **STEP 7: DETERMINE INITIAL LEVEL OF PROTECTION.** Levels of protection reflect the degree to which an asset is protected against the threat based on its value to its user. A level of protection of “very high” corresponds to a low possibility that an asset will be compromised if attacked. For some tactics, level of protection refers to the amount of damage a facility or asset would be allowed to sustain in the event of an attack. A low amount of allowed damage equates to a high level of protection. For other tactics, level of protection refers to the probability that an aggressor will be defeated before the asset is compromised. A high probability of defeat equates to a high level of protection. There are one or more levels of protection (“very high”, ”high”, ”medium”, “low”, or “very low”) for each of the 12 tactics, as shown in Table 3-28. The levels of protection are described for each tactic in Chapter 4. Levels of protection apply to all threat severity levels for each tactic. The initial level of protection may be changed during the design process based on detailed risk analysis as described in UFC 4-020-02.

3-9.1 **Initial Level of Protection.** For each asset, determine the initial level of protection for each applicable tactic with a design basis threat entry. Use Table 3-28 and the asset's value rating listed to select appropriate levels of protection. Enter the initial levels of protection in the appropriate spaces on the Tactic, Threat Severity, and Level of Protection Worksheet. Also enter them into the appropriate spaces on the Risk Level Calculation Worksheet and the Building Cost and Risk Evaluation Worksheet.

3-9.2 **Example.** For example, for the indirect fire weapons tactic for an asset with a value rating of 0.81, select the medium level of protection. Enter the level of protection for each applicable tactic on the Tactic, Threat Severity, and Level of Protection Summary Worksheet in the appropriate cell associated with each applicable tactic as illustrated in Figure 3-3. Also enter the levels of protection on the Risk Level Calculation Worksheet as illustrated in Figure 3-6 and on the Building Cost and Risk Evaluation Worksheet as illustrated in Figure 3-7.

3-9.3 **Modifying the Initial Level of Protection.** The level of protection determined using Table 3-28 is a default level. If the Planning Team determines that the level of protection selected for a tactic is too high or too low, they may modify it. However, lowering the level of protection may result in the asset being protected less than its value warrants with a higher risk of asset compromise. Conversely, raising the level of protection may result in greater protection than the asset value warrants, resulting in a greater cost for the protective system. The best basis for considering changes in levels of protection is to evaluate them based on cost and risk levels. That process is described in the next step of this process. Ensure that the reasons for any change in the default levels of protection are recorded for future reference.

3-10 **STEP 8: DETERMINE PLANNING RISK LEVELS.** Risk levels are used as a basis for comparing alternatives among levels of protection or countermeasures. Risk levels are based on asset values, aggressor likelihoods, and protection factors that reflect levels of protection provided to the assets. The risk analysis process in this UFC is for developing design criteria. A more detailed treatment of risk that considers the contribution of specific countermeasures is in UFC 4-020-02. Follow the steps below to determine risk levels. Risk levels will be determined from groups of tactics as described below and indicated on the Risk Level Calculation Worksheet illustrated in Figure 3-6. Note that risk in this UFC is a relative risk level that is intended to be used as an aid in decision making. Specific risk levels should not be used as goals or targets.

3-10.1 **Determine Threat Effectiveness Ratings.** The capabilities of aggressors to find weaknesses in security measures and to exploit them have a significant impact on risk, and it varies widely for different aggressors. Some of the questions used in determining aggressor likelihood ratings included considerations that were specific to aggressor types, but those considerations did not reflect how effective countermeasures were likely to be against the aggressors. They dealt with the likelihood that those aggressors would target an asset. Applying an effectiveness factor to adjust protection effectiveness accounts for how the sophistication, motivation, and risk acceptance of the aggressors affects the risk levels for the assets those aggressors

Table 3-28. Applicable Levels of Protection

Tactic	Threat Severity Level	Asset Value ≤ 0.5	Asset Value 0.51 – 0.74	Asset Value 0.75 – 0.85	Asset Value 0.86 – 0.95	Asset Value 0.96 - 1
Moving Vehicle Bomb	All	Very Low[1]	Low[2]	Medium	High	
Stationary Vehicle Bomb		Very Low[1]	Low[2]	Medium	High	
Hand Delivered Devices		Very Low[1]	Low[2]	Medium	High	
Indirect Fire Weapons		Very Low[1]	Low	Medium	High	
Direct Fire Weapons	VH	Very Low[1]	Low	Medium[3]	High	
	L, M, H	Very Low[1]	Low		High	
Forced Entry	All	Very Low[1]	Low	Medium	High	Very High
Covert Entry			Low	Medium	High	Very High
Visual Surveillance			High			
Acoustic Eavesdropping			Low	Medium	High	Very High
Electronic Emanations Eavesdropping			High			
Airborne Contaminants		Very Low[1]	Low	Medium	High	
Waterborne Contaminants		Very Low[1]	Low	Medium	High	
Waterfront Attack		Very Low[1]	Low	Medium [3]	High	Very High

1. The very low level of protection includes only measures required by UFC 4-010-01 minimum standards or other applicable standards, operations orders, or regulations.
2. The low level of protection is the minimum for those tactics that are addressed in UFC 4-010-01 for primary gathering buildings. Note also that while the moving vehicle bomb tactic is not expressly addressed in UFC 4-010-01, if it applies it should also be given the same minimum level of protection as the stationary vehicle bomb tactic for primary gathering buildings.
3. The medium level of protection commonly does not apply to ballistics below 12.7 mm (.50 caliber), which are the weapons in the low through high threat severity levels. For those threat severity levels, apply the low level of protection for this range of asset value ratings.

might target. Establishing threat effectiveness ratings is a complex task that requires significant intelligence resources. To expedite this procedure, the threat effectiveness ratings have been established as defaults for specific aggressor types.

3-10.1.1 **Select Threat Effectiveness Ratings.** Use Table 3-29 to determine the appropriate threat effectiveness ratings for the applicable aggressors. Enter the effectiveness ratings in the appropriate spaces in the Risk Level Calculation Worksheet as illustrated in Figure 3-6. The threat effectiveness ratings will be used in the risk equation to adjust the previously determined protection factors to reflect that a protective system that is highly effective against an unsophisticated aggressor may not be as effective against a highly sophisticated one.

Table 3-29. Threat Effectiveness Ratings

Aggressor Type	Effectiveness Rating (T_E)
Unsophisticated criminals	1.0
Sophisticated criminals	0.98
Organized criminal groups	0.95
Vandals	1.0
Extremist protest groups	0.96
Domestic terrorists	0.95
International terrorists	0.93
State sponsored terrorists	0.90
Saboteurs	0.90
Foreign intelligence services	0.91

3-10.1.2 **Select Applicable Effectiveness Ratings for Aggressor Categories.** The threat effectiveness ratings will be used to adjust protection factors that are associated with each applicable tactic. For the purposes of the risk analysis the aggressors will be grouped into criminals, terrorists, saboteurs, and foreign intelligence services as indicated on the Risk Level Calculation Worksheet. Identify the threat effectiveness ratings associated with the aggressors with the highest likelihood rating for each of the applicable aggressor categories and enter them into the appropriate spaces on the Risk Level Calculation Worksheet. This entry is designated as T_{EH}.

3-10.2 **Select Initial Protection Factors.** Select the appropriate protection factor for each tactic based on the applicable level of protection using Table 3-30. These factors do not include any consideration of aggressor effectiveness. They only reflect the initial level of protection. These factors also do not reflect individual countermeasures. Instead, they are predicated on applying all of the countermeasures necessary to achieve a particular level of protection as tabulated in UFC 4-020-02. This assumption is appropriate for planning purposes. Consideration of individual countermeasures is left to the design process. Enter these factors in the appropriate spaces on the Risk Level Calculation Worksheet.

Table 3-30. Initial Protection Factors

Level of Protection	Protection Factor (P_I)
Very Low	0.1
Low	0.3
Medium	0.7
High	0.9
Very High	0.95

Figure 3-6. Sample Risk Level Calculation Worksheet

RISK LEVEL CALCULATION WORKSHEET

Project or Building:	Asset:	Analyst:
A Motor Pool	***Tactical vehicles***	***Jane Q. Planner***
	Asset Value (A_V): ***0.76***	Date: ***4 August 2008***

Aggressor group	Aggressor	T_L[1]	T_E (Table 3-29)	Highest[2] T_L (T_{LH})	T_{EH}[3]
Criminals (C)	Unsophisticated Criminals	***.52***	***1.0***	***.54***	***.95***
	Sophisticated Criminals	***.51***	***.98***		
	Organized Criminal Groups	***.54***	***.95***		
	Vandals	***< .5***			
Terrorists (T)	Extremist Protesters	***< .5***		***.72***	***.90***
	Domestic Terrorists	***.57***	***.95***		
	International Terrorists	***.64***	***.93***		
	State Sponsored Terrorists	***.72***	***.90***		
	Saboteurs (S)	***.51***	***.90***	***.51***	***.90***
	Foreign Intelligence Services (F)				

Tactic group	Tactic	LOP[1]	P_I[4] (Table 3-30)	Avg.[5] P_I (P_{IAVG})	P_E[6] Aggressor Category C	T	S	F	Risk Level[7] Aggressor Category C	T	S	F
Explosives and Incendiaries	Moving Vehicle Bomb			***.7***	***.67***	***.63***	***.63***		***.14***	***.20***	***.14***	
	Stationary Vehicle Bomb	***M***	***.7***									
	Hand Delivered Devices	***M***	***.7***									
Standoff Weapons	Indirect Fire Weapons	***M***	***.7***	***.5***	***.48***	***.45***	***.45***		***.22***	***.30***	***.21***	
	Direct Fire Weapons	***L***	***.3***									
Entry Tactics	Forced Entry	***M***	***.7***	***.7***	***.67***	***.63***	***.63***		***.14***	***.20***	***.14***	
	Covert Entry	***M***	***.7***									
Surveillance and Eavesdropping	Visual Surveillance											
	Acoustic Eavesdropping											
	Electronic Emanations Eavesdropping											
Contamination Tactics	Airborne Contamination											
	Waterborne Contamination											
Waterfront Attack												

1. From Tactic, Threat Severity, and LOP Worksheet.
2. Highest likelihood rating for each aggressor group.
3. Effectiveness rating for aggressor with highest likelihood.
4. From Table 3-30.
5. Average for P_I for all tactics within tactic group.
6. $P_E = T_{EH} \times P_{IAVG}$ for each aggressor & tactic group combination.
7. $R = A_V \times T_{LH} \times (1-P_E)$ for each aggressor & tactic group.

3-10.3 **Calculate Average Initial Protection Factors.** Risk levels are calculated for tactic groups instead of individual tactics to minimize the number of risk levels to be evaluated. An initial protection factor must, therefore, be determined for each tactic group. Use the average of the initial protection factors for each tactic group. Enter the average for each group into the applicable space on the Risk Level Calculation Worksheet. This entry is designated as P_{IAVG}.

3-10.4 **Adjust Initial Protection Factors.** Adjust the average initial protection factors to reflect threat effectiveness ratings. Determine effective protection factors for each applicable tactic. Enter the applicable threat effectiveness ratings (T_{EH}) for each of the applicable aggressor categories associated with the applicable average initial protection factors (P_{IAVG}) into Equation 3-1. The applicable aggressor categories for each tactic are those to whom those tactics apply as identified on the Tactic and Threat Severity Level Worksheet. For example, if the indirect fire weapons tactic was determined to be part of the initial design basis threat based on consideration of terrorists, use the applicable threat effectiveness rating for terrorists to determine the effective protection factor for that tactic using Equation 3-1. Where multiple aggressor categories are applicable to a given tactic, calculate a separate effective protection factor for each aggressor group. Enter the effective protection factors (P_E) in the appropriate spaces in the Risk Level Calculation Worksheet.

Equation 3-1. $$\mathbf{P_E = T_{EH} \times P_{IAVG}}$$

3-10.5 **Determine Risk Level.** Calculate risk levels for each asset and for each applicable tactic group and aggressor group as indicated on the Risk Level Calculation Worksheet. Risk levels are established by entering the likelihood and asset value ratings and the protection effectiveness factors into Equation 3-2. By subtracting P_E from 1, the risk equation reflects the fact that increases in protection effectiveness reduce risk. The 1- P_E term reflects "vulnerability".

Equation 3-2. $$\mathbf{R = A_V \times T_{LH} \times (1-P_E)}$$

3-10.5.1 **Asset Value Ratings.** Enter the asset value ratings (A_V) for each asset into the risk equation for each applicable tactic group.

3-10.5.2 **Likelihood Ratings.** Enter the highest likelihood ratings (T_{LH}) for each applicable aggressor group associated with each applicable tactic group as identified on the Tactic and Threat Severity Worksheet. Use the likelihood rating for the aggressor group that includes the aggressors who were used to establish the applicability and threat severity levels for that tactic group. For example, terrorists would commonly be the aggressors upon whom the applicability and threat severity levels for explosives tactics are based. Therefore, to determine the risk level for the explosives tactics, enter the highest likelihood rating for the terrorist aggressor group. Where there are multiple aggressor categories that were used to establish applicability and threat severities for a particular tactic group, calculate a separate risk level for each group.

3-10.5.3 **Protection Effectiveness factors.** Enter the protection effectiveness factor for each applicable tactic group and for each applicable aggressor group.

3-10.5.4 **Risk Level.** Enter the risk levels calculated using Equation 3-2 in the appropriate spaces on the Risk Level Calculation Worksheet.

3-11 **STEP 9: ASSESS ACCEPTABILITY OF RISK LEVELS.** There are no specific criteria for determining whether or not a given risk level is acceptable. In some cases the Planning Team may have a goal for a risk level, although that is not recommended. In other cases the costs for achieving a level of protection associated with a risk may be the basis for a risk being acceptable. Because the risk levels in this UFC are relative, their best use is as an aid in decision making. The risk level means relatively little in itself, but when the reduction in risk can be evaluated with respect to the cost of a protective system, that provides a rough means of evaluating benefit versus cost. The benefit is the reduction in risk. For example, if a large expenditure for countermeasures results in a very small reduction in risk, that may not be a good investment. On the other hand, when a small expenditure for countermeasures results in a large reduction in risk, that may be a good investment. Evaluating risk versus cost in that manner provides a basis for evaluating various alternatives.

3-11.1 **Cost and Risk Evaluation.** The Building Cost and Risk Evaluation Worksheet is provided to assist in evaluating changes in risk levels due to changes in threat severity levels or levels of protection. It has spaces for initial and revised conditions for threat severity levels, levels of protection or protection factors, risk levels, and cost increases. It also has spaces that support analysis of the differences between the initial and revised conditions. Those spaces include change in cost, change in risk, and the ratio of the two. Note that changes to threat severity levels will intuitively impact risk due to changes in the design basis threat, but those impacts are not captured in the risk calculation. Use one worksheet for each asset and for each option evaluated to ensure there is a “paper trail” for each option. Use the Risk Level Calculation Worksheet to evaluate the effects of changes in levels of protection or protection factors on risk levels.

3-11.1.1 **Risk Levels.** Enter risk levels for each tactic group on the Building Cost and Risk Evaluation Worksheet. In cases where there are multiple aggressors to whom tactics within a tactic group apply, use the risk level for the aggressor whose threat severity level is the basis for the design basis threat on the Tactic, Threat Severity, and Level of Protection Worksheet.

For example, in Figure 3-5, the forced and covert entry tactics apply to criminals, terrorists, and saboteurs, but the threat severity level for the terrorists is the basis for the design basis threat. In that case, the risk level for terrorists from the Risk Level Calculation Worksheet would be entered for the entry tactics on the Building Cost and Risk Evaluation Worksheet.

3-11.1.2 **Cost Increases.** To determine the costs of initial protective systems for planning purposes refer to Chapter 6 and Appendices A through C. Note that those costs are based on applying all the applicable countermeasures to achieve a particular level of protection. A more detailed treatment of cost and risk that considers the contribution of individual countermeasures is presented in UFC 4-020-02.

Enter the cost increases for each applicable tactic. In cases such as the hand delivered devices tactic, there are separate entries for different applications of that tactic (building exterior, mail rooms, loading docks, and entry areas). In those cases, enter cost increases for each applicable application.

Sum the costs for all applicable tactics and applications within each tactic group with the following exception. Because the construction to mitigate the effects of the vehicle bomb tactics and exterior application of the hand delivered devices tactic is similar, where more than one of those tactics applies, use the cost of the most expensive to represent all three rather than adding them together. All other tactics and applications should be additive. Note that the construction necessary to provide protection against some tactics is very similar to that for other tactics, which means that summing all the applicable costs as described above may be conservative due to potentially accounting for similar upgrades more than once. For example, walls to resist vehicle bombs may be adequate for resisting indirect fire weapons effects and windows to resist small arms may be effective for blast resistance. Accounting for such redundancy is very complex; therefore, it is beyond the scope of this UFC. It can be dealt with during design.

3-11.2 **Cost and Risk Analysis.** Use the analysis columns of the Building Cost and Risk Evaluation Worksheet to evaluate risk and cost changes. Enter the difference between the cost increases for the initial and revised conditions in the appropriate spaces on the Building Cost and Risk Evaluation Worksheet. Do the same for the changes in risk levels. Finally, enter the ratio of change in risk to change in cost. Note that the entries in the analysis columns are by tactic groups.

3-11.2.1 **Unacceptable Cost and Risk.** If the cost and risk are determined by the Planning Team to be unacceptable, for the purposes of planning, revise the level of protection, rerun the risk level calculation, and re-evaluate the acceptability of the risk. Alternatively, the team may modify threat severity levels for individual tactics and make similar adjustments.

3-11.2,2 **Acceptable Cost and Risk.** If the cost and risk are determined by the Planning Team to be acceptable, incorporate the design criteria developed using this procedure into the planning documents as requirements for the project design. Use the Design Criteria Summary Worksheet to record the design criteria, which will include the assets to be protected, the threats to those assets (tactics with associated threat severity levels), and the levels of protection to which those assets are to be protected, Recall that the design criteria also includes design constraints that might be imposed by the Planning Team, which is the subject of the next and final step of this process.

Figure 3-7. Sample Building Cost and Risk Evaluation Worksheet

BUILDING COST AND RISK EVALUATION WORKSHEET

Project or Building	Asset	Analyst
A Motor Pool	*Tactical Vehicles*	*Jane Q. Planner*
	Baseline Building Category *(Table 3-1)*	Date
	Special Structure	*4 August 2008*

Tactic		Initial: Design Basis Threat[2]	Initial: LOP[3,4] or P_I	Initial: Risk[4-7] Level	Initial: Standoff, Rm. Size, Stories, %	Initial: Cost[8] Increase (%)	Initial: Cost Incr. Sum	Revised: Threat Severity Level	Revised: LOP[3,4] or P_I	Revised: Risk[4-7] Level	Revised: Standoff, Rm. Size, Stories,%	Revised: Cost[8] Increase (%)	Revised: Cost Incr. Sum	Analysis: Change[11] in Cost (%)	Analysis: Change[12] in Risk (%)	Analysis: Ratio[13]
Explosives and Incendiaries	Moving Vehicle Bomb [1]			*(T)*			*17.1*			*(T)*			*6.5*	*-62*	*+40*	*-.64*
	Stationary Vehicle Bomb [1]	*L*	*M*	*.20*	*25 m*	*17.1*		*M*	*L*	*.28*	*25 m*	*6.5*				
	Hand Delivered Devices															
	• Exterior [1]	*M*	*M*		*10 m*	*1.7*		*H*	*L*		*10 m*	*1.7*				
	• Mail Room[9]															
	• Loading Dock[9]															
	• Entry Area[9]															
Standoff Weapons	Indirect Fire Weapons	*L*	*M*	*(T)*		*1.8*	*2.17*	*M*	*L*	*(T)*		*1.8*	*2.17*	*0*	*+40*	
	Direct Fire Weapons	*L*	*L*	*.30*		*0.37*		*M*	*L*	*.28*		*0.37*				
Entry Tactics	Forced Entry			*(T)*			*1.8*			*(T)*			*1.1*	*-39*	*+40*	*-1.02*
	• Exterior															
	• Interior[9]	*M*	*M*	*.20*	*large*	*0.35*		*H*	*L*	*.28*	*large*	*0.12*				
	Covert Entry	*L*	*M*			*0.5*		*M*	*L*			*0.1*				
Surveillance and Eavesdropping	Visual Surveillance															
	Acoustic Eavesdropping															
	• Exterior															
	• Interior[9]															
	Electronic Emanations Eavesdropping															
	• Exterior															
	• Interior[9]															
Contam-ination	Airborne Contamination															
	Waterborne Contamination															
Waterfront Attack																
						Sum[14] (%)	*21.07*					Sum[14] (%)	*9.77*			

1. Use highest cost among these tactics
2. From Tactic, Threat Severity and LOP Worksheet
3. Level of Protection or Initial Protection Level
4. From Risk Level Calculation Worksheet
5. One risk level for each tactic group
6. Risk level for aggressor whose threat severity level controls DBT(from Tactic, Threat Severity , and LOP Wksht)
7. Indicate which aggressor controls
8. From Appendix A or B or from other cost estimate
9. Enter small, medium, or large room
10. Enter percentage of building perimeter protected
11. (Revised cost sum– initial cost sum) ÷ initial cost sum
12. (Revised risk level – initial risk level) ÷ initial risk level
13. Change in risk ÷ change in cost
14. Total building cost increase (w/o progressive collapse)

3-12 **STEP 10: IDENTIFY USER CONSTRAINTS**. User constraints include physical characteristics and qualities or operational considerations that restrict or dictate the design of a protective system. During design criteria development the Planning Team considers non-technical constraints relating to user requirements. As part of the design of the protective system the designers may identify more technical design constraints related to specific countermeasures. User constraints are specific to an asset, a facility, a site, an entire installation, or a city. Installation master planning requirements and facility design criteria unrelated to security often constrain protective system design. Consider the following categories of constraints to the extent that they apply to the individual project. List the user constraints and describe them in a narrative to be included with the design criteria documents.

3-12.1 **Political Considerations.** The relationship between the military and the public, including personnel on or off the installation, may influence design. Evaluate the following:

3-12.1.1 **Adjacent Landowners or Other Tenant Organizations.** Assess potential problems such as the impact of high-intensity security lighting or traffic restrictions. Identify any neighbors requiring special consideration.

3-12.1.2 **Appearance.** Consider public perception of the appearance of a proposed secure facility, site, or area. For example, public perception of a “fortress” may be either desirable or undesirable depending on the intent of the Planning Team. Such facilities may provide deterrence. They may also be perceived negatively.

3-12.1.3 **Public Access.** Identify restrictions on limiting public access to a facility, a site, or an area of an installation.

3-12.1.4 **Political Climate.** Consider how the local political situation influences facility design or land use decisions. Politically unpopular decisions may attract acts of aggression to completed facilities.

3-12.2 **Financial Considerations.** Identify funding limitations for security based on such criteria as policy, available funds, asset value, or the Planning Team's judgment of a reasonable limit for security costs. Describe limitations in terms of actual cost or percentage of facility cost. In defining an acceptable cost, consider all costs of replacing the asset and costs of operating without it.

3-12.3 **Regulations.** Ensure that all pertinent regulations are cited to ensure that the designers consider them. Also consider requirements imposed by the installation's physical security and antiterrorism plans.

3-12.4 **Procedural or Operational Considerations.** Installation or facility user requirements related to operations in either normal or heightened Force Protection Conditions (FPCON) may constrain design. If there are specific user constraints related to procedures and operations, ensure they are communicated to the designers so they do not make conflicting recommendations as part of their protective system design. A protective system must comprise an integration of construction, building support systems, equipment, manpower, and procedures. Examples of applicable procedures and operations include the following:

3-12.4.1 **Deliveries.** Identify specific existing or planned requirements for how deliveries or pickups are to be made. Consider mail, supplies, materiel, and trash. Include limitations on where deliveries or pickups may be made. Also consider service or construction vehicles.

3-12.4.2 **Restricted Areas.** Identify areas within facilities or within the installation that require restricted access and state the scope of the restriction. Consider also how existing access limitations may impact design or construction.

3-12.4.3 **Access Controls.** Identify who or what is to be controlled, to what degree, and where and when the controls apply. Include personnel identity and weapons checks, vehicle checks, and checks of packages for such items as explosives or classified information.

3-12.4.4 **Functional Requirements.** Determine how the user will operate the facility and identify constraints related to operation. Include functional relationships between organizations or components of organizations, work schedules, types of operations to be performed, and special requirements for facility layout or construction.

3-12.5 **Facility and Site Constraints.** Examine the installation's master plan, existing facilities, and any plans or sketches for the proposed project. Identify requirements related to site or facility layout or construction. Potential constraints include the following:

3-12.5.1 **Occupancy Requirements.** Identify any special space requirements, window ratios, and other occupancy-related design constraints.

3-12.5.2 **Barrier-Free Accessibility.** Public facilities and facilities which may shelter or be used by military dependents or civilians must conform to the guidelines found in the *Uniform Federal Accessibility Standards* which may constrain security-related design.

3-12.5.3 **Parking Lots and Roads.** Identify specific requirements for parking lots and roads that could impact security. Consider, for example, how close to the protected building vehicles must be allowed to approach or park (with and without entry control) for operational purposes.

3-12.5.4 **Fences and Lighting.** Identify specific requirements or restrictions for installation of fences or security lighting.

3-12.5.5 **Electronic Security Systems.** Identify specific requirements for electronic security systems including CCTV, electronic entry control equipment unrelated to the threats identified in this process.

3-12.5.6 **Architectural Theme.** Identify requirements or restrictions on the construction materials or architectural style to be used for the building. Some installations provide architectural guidelines that define appropriate styles and limit construction materials.

3-12.5.7 **Existing Facilities.** Determine whether layout, proximity, construction, or operations of existing facilities constrain new projects.

3-12.5.8 **Miscellaneous.** Determine design constraints imposed by landmark status of buildings or areas, floodplain restrictions, endangered wildlife or plant species, or any other design considerations that can be addressed at this stage of project development.

3-12.6 **Response Force.** Identify the response forces that would respond to an act of aggression. The design of a protective system assumes the response force is capable of neutralizing the threat. Consider the following with respect to whether or not such forces are available for integration into the protective system:

3-12.6.1 **Armed Force.** Department of Defense civilian police or security guards, military or security police, troops, and special reaction teams may respond to detected attacks.

3-12.6.2 **Explosive Ordnance Disposal (EOD) Team.** When acts of aggression involve explosives, an EOD team may attempt to dispose of the explosives before detonation.

3-12.6.3 **Fire Department.** The fire department responds to support the EOD team, responds after a successful attack to contain fire damage and rescue victims, and may constitute the first responders to a chemical, biological, or radiological attack.

3-12.7 **Response Time.** The time required for a force to detect and assess an act of aggression and to reach a facility in response to the act is the response time. Response time has direct design implications only in the forced entry tactic, for which it is important because it determines the length of time building elements must delay an aggressor to allow an adequate response. . For certain assets, regulations specify maximum response times.

3-12.8 **Manpower Allocation.** Identify available security personnel that can be integrated into the protective system or positions to be eliminated. Consider the personnel listed below.

- Command and control center personnel or IDS operators.
- Entry/access control guards.
- Fixed post guards.
- Roving guards.

3-13 **INFORMATION SENSITIVITY.** Information generated by the Planning Team as output from the planning procedure indicates the assets the user considers important and the threats against which the protective system is designed. This is sensitive information and will be treated as "For Official Use Only" as a minimum. This applies to completed forms and to other documentation that reflects the sensitive information on the forms. The information will be considered for classification at an appropriate level when either of the following criteria exists:

3-13.1 **Derivative Classification.** If classified information is used in generating the output of this procedure, the resulting information may need the derivative classification of the material from which it was derived.

3-13.2 **Classification Guides.** For some situations, there may be a classification guide that governs the classification of information relating to that situation. Where there are such guides, they may govern classification of elements if the design criteria.

3-13.3 **Original Classification.** Capabilities or design parameters must be protected for operational security reasons. Operational security is especially relevant for overseas projects constructed in high-threat areas and for mission-essential facilities. The installation commander or a designated representative with original classification authority should determine the appropriate classification level to protect the facility design information.

CHAPTER 4

DESIGN STRATEGIES – WEAPONS AND EXPLOSIVES TACTICS

4-1 **INTRODUCTION.** The approaches to mitigating the effects on assets from any of the tactics described in this UFC are referred to as design strategies. It is not intended for planners to apply these design strategies in a detailed manner, but planners should understand how the design strategies affect the designs of facilities. With that understanding, planners can explain the basis for the costs associated with protecting against a given tactic as reflected in the cost increase appendices in this UFC. This chapter, therefore, describes the design strategies as well as summarizes the likely impacts on construction that will result from the application of those strategies. There are two levels of design strategies associated with each tactic, the general design strategy and the specific design strategy. Both levels of design strategies will be described for each tactic.

4-1.1 **General Design Strategy.** The general design strategy for any tactic is the basic approach to developing a protective system to mitigate the effects of that tactic. It governs the general application of construction, building support systems, equipment, manpower, and procedures.

4-1.2 **Specific Design Strategy.** The specific design strategy for any tactic governs how the general design strategy varies for different levels of protection. The specific design strategies and their nature vary with each tactic. They may vary by the sophistication of the protective measures, the degree of protection provided, or the degree of damage a building will be allowed to sustain, among others. The specific design strategies reflect the degree to which assets will be left vulnerable after the protective system has been employed.

4-1.3 **Project Scope Implications.** Because this UFC is intended to support project planning, it does not include detailed discussions on protective measures. Planners must have a basic understanding of the implications on project scopes of application of the design strategies for various levels of protection and tactics, however. To support that understanding, brief summaries of the types of protective measures that can be expected are provided for each tactic. Those summaries are only intended to aid in understanding the basis for the cost increases in the cost appendices. More detailed discussions of protective measures are included in the *DoD Security Engineering Facilities Design Manual (UFC-4-020-02).* The protective measures are divided into the categories below. Not all categories apply to all tactics.

4-1.3.1 **Sitework Elements.** These include all protective measures that are associated with areas surrounding buildings beyond 1.5 m (5 ft) from the building, excluding measures that are included under equipment. Commonly these will include such measures as fences, barriers, and landscaping.

4-1.3.2 **Building Elements.** These include all protective measures directly associated with buildings such as walls, doors, windows, roofs, superstructure, and building layout.

4-1.3.3 **Building Support Systems.** For the purposes of this UFC, building support systems will include those systems that are necessary to make the building operate on a day-to-day basis. The heating, ventilating, and air conditioning (HVAC) system is the primary such system addressed in this UFC.

4-1.3.4 **Equipment.** For the purposes of this UFC, equipment will include protective measures such as intrusion detection systems, electronic entry control systems, closed circuit television systems, and other electronic systems that support functions such as access control and detection of aggressors or tools, weapons, explosives, and agents.

4-1.3.5 **Manpower and Procedures.** While these are not engineering or architectural issues, they may have impact on the overall engineering and architecture of projects. The availability of manpower and the procedures that are in place may also affect the form of the protective system and, therefore, its cost. Manpower includes the guards or operators needed to operate whatever systems are provided or to provide functions such as access control and the response forces that are needed to respond to an act of aggression.

4-1.3.6 **Expeditionary and Temporary Construction Considerations.** The general and specific design strategies that apply to permanent construction also apply to expeditionary and temporary construction, but the forms of the protective measures may be somewhat different. For each tactic, the expeditionary and temporary construction considerations will address those differences.

4-2 **VEHICLE BOMB TACTICS.** Both the general and specific design strategies for the moving and stationary vehicle bomb tactics are the same. Only the details of the application of the countermeasures change.

4-2.1 **General Design Strategy.** The general design strategy for these tactics comprises four elements, standoff distance, building hardening, barriers, and manpower and procedures.

4-2.1.1 **Standoff Distance.** The pressures resulting from explosive blasts can be very high, but they decrease rapidly with distance (proportional to the cube root of the distance.) That suggests that where land is available the least expensive way to provide protection against explosives is to maximize the standoff distance. The general design strategy, therefore, is to provide as much standoff distance between protected facilities and potential locations for vehicles, such as parking areas, roadways, and other locations that could be accessible by vehicles. The only difference in the application of this strategy for moving vehicle bombs versus stationary vehicle bombs with respect to standoff distance is that the locations to be considered for the stationary vehicle bomb can be limited to those where parking or other vehicle access is common.

The reason for that is the assumption that the aggressors who would employ the stationary vehicle bomb seek to be covert as described in chapter 2. In the case of the moving vehicle bomb, that assumption is invalid because the aggressors are assumed to be suicidal. Detection is assumed not to be a deterrent to them.

4-2.1.2 **Building Hardening.** Where the standoff distance from a vehicle bomb to a protected facility is sufficient, the facility can be of conventional construction, which means that it can be built without any hardening of building elements. One major exception to that is windows, which would have to be constructed to minimize fragmentation as reflected in the windows required by the *DoD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01).* Where the sufficient standoff distances cannot be provided, building elements such as walls, doors, windows, roofs, and, potentially, building superstructures may have to be hardened to resist the explosive effects to the applicable level of protection. The cost tables in Appendices A and B account for building hardening where appropriate.

4-2.1.3 **Vehicle Barriers.** The general design strategy for both of these tactics includes the application of some form of vehicle barriers to establish and maintain the standoff distance between vehicles and facilities. Those barriers will commonly include passive perimeter barriers that define the standoff distance and active barriers that allow entry through the perimeter. For the stationary vehicle bomb tactic, both the passive perimeter and active barriers only need to define the perimeter and provide an obstacle whose breaching would draw attention. For the moving vehicle bomb tactic those barriers must actually stop the kinetic energy of the moving vehicle because the driver is assumed to be suicidal.

4-2.1.4 **Manpower and Procedures.** The general design strategy also depends on manpower and procedures. While those are not an engineering issue, because they are an integral part of the protective system necessary for mitigating these tactics, they must be incorporated in the design. That will require coordination with the operations or security people associated with each project, who ultimately will establish manpower requirements and define the procedures based on local considerations. The manpower and procedures support the general design strategy in controlling access closer to the facility than the standoff distance.

4-2.2 **Specific Design Strategies.** The specific design strategies for these tactics reflect differences in how protective measures are applied for different levels of protection. Those differences may manifest themselves in differing standoff distances or differences in the construction of building elements for different levels of protection. The general goals for manpower and procedures also vary with levels of protection. Barrier requirements commonly do not, however. The design goals associated with the various level of protection are reflected in Tables 4-1 and 4-2 for new and existing construction and expeditionary and temporary construction, respectively. Table 4-3 summarizes the manpower and procedures goals that are associated with each level of protection for new and existing buildings and for expeditionary and temporary construction.

Table 4-1 Levels of Protection – New and Existing Buildings

Level of Protection	Potential Building Damage / Performance [2]	Potential Door and Glazing Hazards[3]	Potential Injuries
Below Very Low [1]	Severe damage. Progressive collapse likely. Space in and around damaged area will be unusable.	Doors windows will fail catastrophically and result in lethal hazards. (High hazard rating)	Majority of personnel in collapse region suffer fatalities. Potential fatalities in areas outside of collapsed area likely.
Very Low	Heavy damage - Onset of structural collapse, but progressive collapse is unlikely. Space in and around damaged area will be unusable.	Glazing will fracture, come out of the frame, and is likely to be propelled into the building, with the potential to cause serious injuries. (Low hazard rating) Doors may be propelled into rooms, presenting serious hazards.	Majority of personnel in damaged area suffer serious injuries with a potential for fatalities. Personnel in areas outside damaged area will experience minor to moderate injuries.
Low	Moderate damage – Building damage will not be economically repairable. Progressive collapse will not occur. Space in and around damaged area will be unusable.	Glazing will fracture, potentially come out of the frame, but at a reduced velocity, does not present a significant injury hazard. (Very low hazard rating) Doors may fail, but they will rebound out of their frames, presenting minimal hazards.	Majority of personnel in damaged area suffer minor to moderate injuries with the potential for a few serious injuries, but fatalities are unlikely. Personnel in areas outside damaged areas will potentially experience a minor to moderate injuries.
Medium	Minor damage – Building damage will be economically repairable. Space in and around damaged area can be used and will be fully functional after cleanup and repairs.	Glazing will fracture, remain in the frame and results in a minimal hazard consisting of glass dust and slivers. (Minimal hazard rating) Doors will stay in frames, but will not be reusable.	Personnel in damaged area potentially suffer minor to moderate injuries, but fatalities are unlikely. Personnel in areas outside damaged areas will potentially experience superficial injuries.
High	Minimal damage. No permanent deformations. The facility will be immediately operable.	Glazing will not break. (No hazard rating) Doors will be reusable.	Only superficial injuries are likely.

Notes:
1. This is not a level of protection, and should never be a design goal. It only defines a realm of more severe structural response, and may provide useful information in some cases.
2. For damage / performance descriptions for primary, secondary, and non-structural members, refer to UFC 4-020-02.
3. Glazing hazard levels are from ASTM F 1642.

Table 4-2 Levels of Protection – Expeditionary and Temporary Structures

Level of Protection	Potential Structural Damage	Potential Injuries
Below Very Low	Severe damage. Frame collapse/massive destruction. Little left standing.	Majority of personnel in collapse region suffer fatalities. Potential fatalities in areas outside of collapsed area likely.
Very Low	Heavy damage. A majority of the structure will collapse and a majority of secondary structural members will collapse.	Majority of personnel in damaged area suffer serious injuries with a potential for fatalities. Personnel in areas outside damaged area will experience minor to moderate injuries.
Low	Moderate damage. Damage will be unrepairable Some sections of the structure may collapse or lose structural capacity.	Majority of personnel in damaged area suffer minor to moderate injuries with the potential for a few serious injuries, but fatalities are unlikely. Personnel in areas outside damaged areas will potentially experience a minor to moderate injuries.
Medium	Minor damage. Damage will be repairable. Minor to major deformations of both structural members and non-structural elements. Some secondary debris will be likely, but the structure remains intact with collapse unlikely.	Personnel in damaged area potentially suffer minor to moderate injuries, but fatalities are unlikely. Personnel in areas outside damaged areas will potentially experience superficial injuries.
High	Minimal damage. No permanent deformation of primary and secondary structural members or non-structural elements.	Only superficial injuries are likely.

Table 4-3. Manpower and Procedures Goals for Vehicle Bomb Tactics

Level of Protection	Manpower and Procedures Goals
Below Very Low	None
Very Low	Driver and vehicle authorization checked and visible areas of vehicles checked visually
Low	Driver and vehicle authorization and visual check of visible areas of all vehicles plus visual check of cargo areas or trunks for random number of vehicles
Medium	Driver and vehicle authorization and visual check of visible areas of all vehicles plus comprehensive search of random number of vehicles.
High	Driver and vehicle authorization plus comprehensive search of all vehicles.

4-2.3 **Project Scope Implications.**

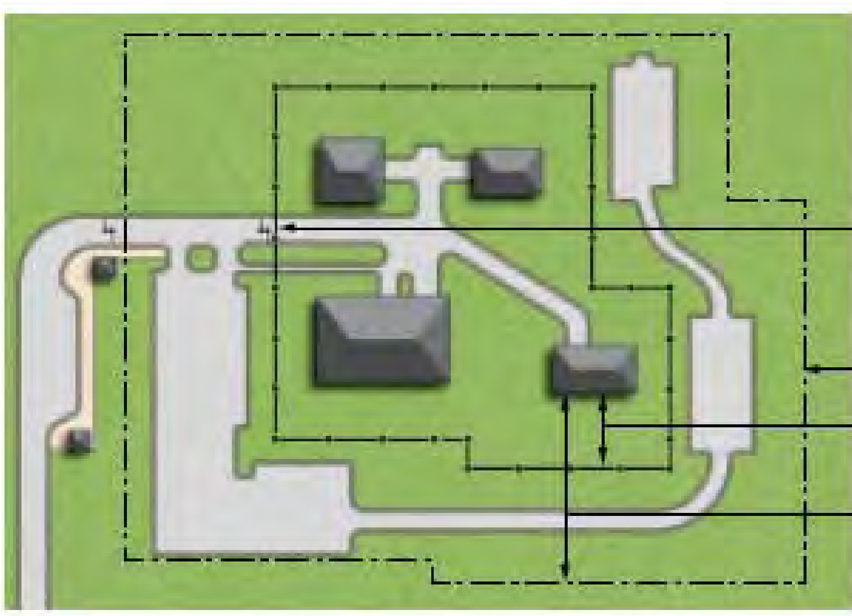
4-2.3.1 **Sitework Elements.** The impacts on project planning for sitework elements include standoff distance and barriers to establish and maintain that standoff distance.

4-2.3.1.1 **Standoff Distance.** The primary impact on project scope for sitework will be the establishment and maintenance of standoff distance. That standoff will have to be provided to any location that is accessible to vehicles. For the stationary vehicle bomb tactic those locations may be limited to those that have legitimate vehicle access such as parking areas and roadways. For the moving vehicle bomb tactic those locations will need to go beyond the areas that are legitimately accessible to vehicles and include those that are physically accessible.

The key to understanding the planning implications of the standoff distance is in knowing the type of vehicle and the explosive weight associated with the threat and determining where access of those vehicles will be controlled. Refer to Table 3-27 for the vehicles and explosive weights associated with the various threat severity levels. In addition, planners need to recognize that where a higher threat severity level applies, all those below it also apply. One approach, therefore, is to establish a standoff distance based on the largest applicable explosive weight based on the applicable threat severity level and require access procedures for entry past that perimeter to be applied to all vehicles at that standoff distance. In cases where the threat severity level is equal to or greater than "high" (where the threat vehicles are trucks), all vehicles would be required to be searched at that standoff distance. The operational implications of that requirement may be impractical in most locations.

Those operational challenges suggest another option for application at higher threat severity levels. That option capitalizes on the fact that trucks are assumed to carry more explosives than cars and recognizes that there are usually more cars than trucks that require access near facilities. The approach of this second option is to create a two tiered system of standoff distances where trucks are controlled at the standoff distance associated with the highest applicable threat severity level and a second tier of standoff distances is established within that outer perimeter at a distance associated with the largest explosive weight cars are assumed to carry, which is 100 kg (220 lbs). Note that where threats larger than 100 kg (220 lbs) apply, all threats smaller than them also apply. With the option of establishing two separate perimeters, trucks can be searched at the greater standoff distance and cars can be allowed to go up to the closer standoff distance before they have to be controlled and searched. This approach minimizes the operational challenges of searching all vehicles at the standoff distance associated with trucks. The perimeter associated with the higher explosive weight could be a controlled perimeter as described in UFC 4-010-01. It can be anywhere the installation operations and security personnel wanted to establish access control, including the installation perimeter. The option described above is illustrated in Figure 4-1. Note that in Figure 4-1, either of the perimeters can be anywhere as long as they provide the appropriate standoff distance for the building construction.

Figure 4-1. Standoff Zones



4-2.3.1.2 **Vehicle Barriers.** Vehicle barriers are part of the design strategy for both vehicle bomb tactics and for all levels of protection. Vehicle barriers will include both passive perimeter barriers and active vehicle barriers that are applied at entries through the passive perimeter barriers. Their application differs significantly for the moving and stationary vehicle bomb tactics, however. Note also that to be effective barriers need to span the entire perimeter and all entries though it. They do not need to all be the same, but they do need to meet the same requirements as described below.

Active and passive perimeter barriers for the stationary vehicle bomb tactic only need to present an obstacle that would draw attention to the drivers of vehicles as they breached them. Examples of passive perimeter barriers that would satisfy the design strategy are high curbs, shrubbery, and unreinforced fences as shown in Figure 4-2. Examples of satisfactory active barriers would be chains draped between poles and drop arm barriers such as those found commonly in commercial parking lots as shown in Figure 4-4.

Active and passive perimeter barriers for the moving vehicle bomb tactic need to be able to stop the full kinetic energy of the threat vehicle. The construction of those barriers will vary significantly based on the weight of the loaded threat vehicles and the speed they can attain. Passive perimeter barriers range from reinforced fences to heavily reinforced retaining walls such as those shown in Figure 4-3. There is a wide range of possible solutions that engineers and landscape architects can develop for passive perimeter barriers. Active barriers will commonly include retractable bollards, pop-up plate or drum barriers, and reinforced sliding gates such as those shown in Figure 4.5. They all need to have been tested to resist the threat vehicle.

Figure 4-2. Passive Perimeter Barriers for Stationary Vehicle Bombs

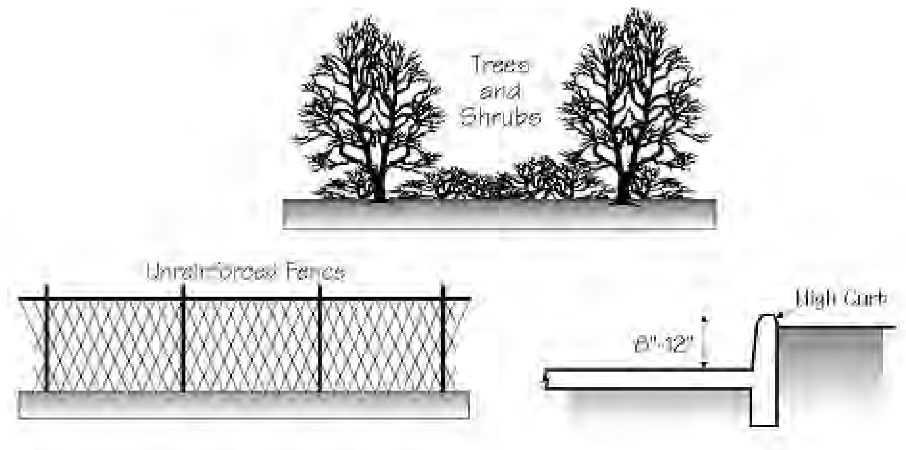


Figure 4-3. Passive Perimeter Barriers for Moving Vehicle Bombs

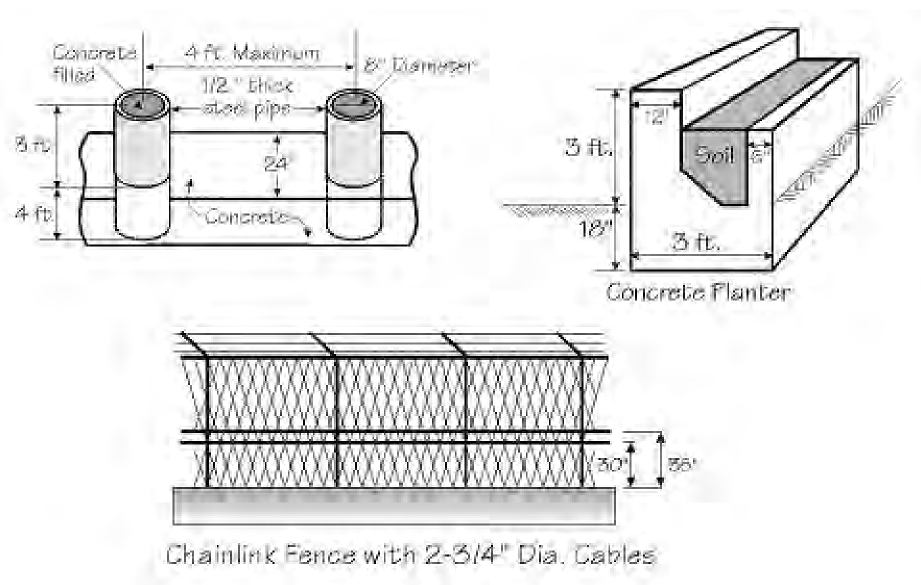


Figure 4-4. Active Vehicle Barriers for Stationary Vehicle Tactic

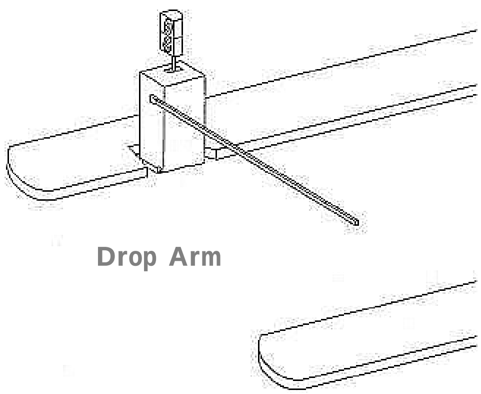
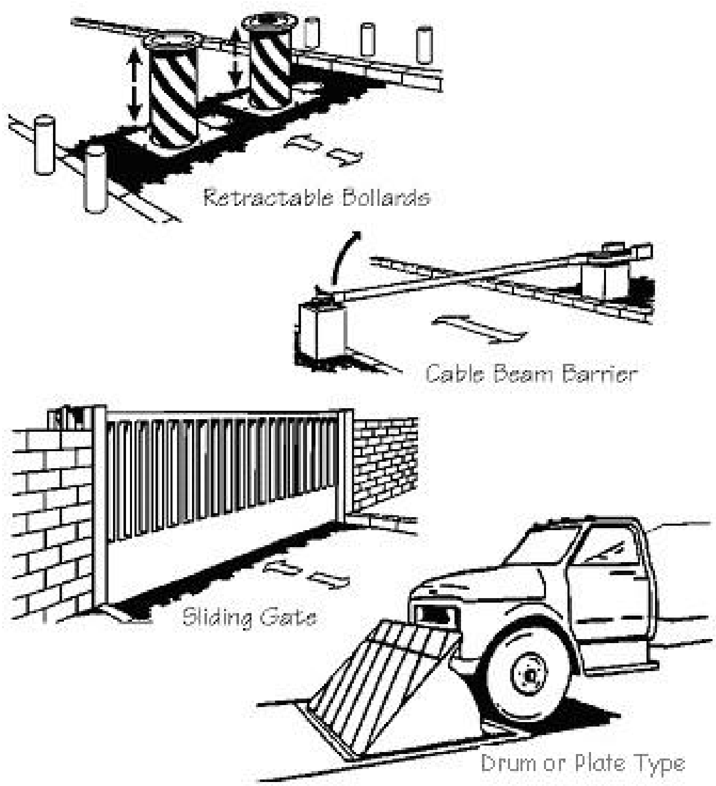


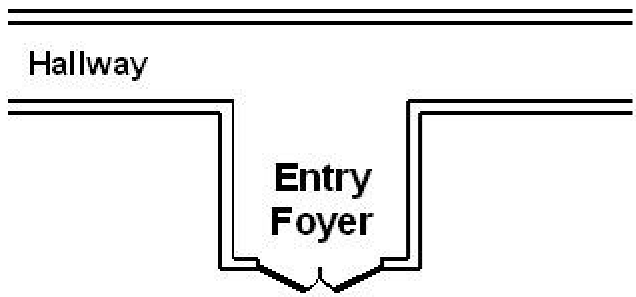
Figure 4-5. Active Vehicle Barriers for Moving Vehicle Tactic



4-2.3.2 **Building Elements.**

4-2.3.2.1 **New Construction.** Where standoff distances for conventional construction can be met, the impact on building construction will be limited. If the building is less than 3 stories, the only building elements that will have requirements beyond conventional construction are the doors and windows. Windows will have to be made with laminated glass and heavier frames than are common in conventional construction as required by the *DoD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01)*. Glazed doors will require laminated glass as well, and unglazed doors should be hollow steel to minimize fragmentation in the event of an explosion. They should also open outward, which may have some impact on elevated walkway widths. Finally, to minimize hazards from doors flying onto rooms, they should be backed up with walls that could intercept them as illustrated in Figure 4-6. For inhabited buildings that have three or more stories, the progressive collapse provisions of UFC 4-010-01 will have to be incorporated into the design.

Figure 4-6. Entry Foyer to Reduce Door Hazards



Where conventional construction standoff distances are not available, most of the major components of buildings are likely to be impacted. Walls and roofs may be thicker and heavier, windows may be heavier and constructed out of more expensive materials, and doors may be of heavy steel construction. In addition, building frames and other superstructure elements may also have to be heavier. The cost increases associated with those modifications to conventional construction are reflected in the cost appendices in this UFC.

4-2.3.2.2 **Existing Buildings.** Where conventional construction standoff distances can be met, the only impact on the existing construction is likely to be in windows and doors. The same considerations apply for windows and doors as described in the previous paragraph, but in the case of existing buildings, the existing windows and doors will probably have to be removed and replaced with the windows and doors described above. Where an existing building is not required to meet the requirements of the *DoD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01)*, window retrofits using materials such as fragment retention film or drapes may be used. There may also be cases in which the walls around the windows and doors have to be strengthened to handle the loads associated with the new windows and doors resisting the explosives effects.

Where conventional construction standoff distances are not available, the buildings' walls and roofs may have to be retrofitted to resist the applicable blast loads. In the case of the walls, there are retrofits that can be applied to the inner faces of the existing walls. In the case of roofs, removing the existing roof and replacing it with a new roof is the most economical way to provide the required protection.

4-2.3.3 **Equipment.** Equipment such as electronic entry control devices like card readers may be incorporated into protective systems to reduce requirements for permanent manpower. Those systems may also be augmented with closed circuit television systems or such systems may be employed in support of access control with equipment such as intercoms instead of electronic entry control systems. In general, these kinds of equipment will be installed in support of access control at entry control points through perimeters.

4-2.3.4. **Manpower and Procedures.** As stated above in the context of the design strategy for these tactics, manpower and procedures are a critical element of protective systems for these tactics. Their impacts on project scope mostly relate to the potential for increased equipment requirements where there are inadequate manpower resources available. Procedures may also increase requirements because they may increase the time required to allow vehicles through entry control points, which may lead to needing either more lanes at the entry control points or additional entry points. Manpower considerations may also drive the need for shelters for guards and other such appurtenances that may add to sitework costs.

4-2.3.5 **Expeditionary and Temporary Construction Considerations.** Most of the protective measures that will be applied in the expeditionary environment are sitework measures. Because it is generally impractical to harden or retrofit expeditionary and temporary construction significantly, increased standoff distance is the primary approach to providing protection in that environment. That will commonly drive the need for larger sites. In addition, barrier construction will generally include more temporary or improvised barriers than would commonly be provided for permanent construction.

4-3 **HAND DELIVERED DEVICES.** Because this tactic includes delivery of explosives and incendiary devices either to the exterior of buildings or attempts to deliver them into buildings, the design strategies will be discussed in the context of the exteriors of facilities and building entry points, mail rooms, and supplies handling areas.

4-3.1 **General Design Strategy.** The general design strategy for this tactic, regardless of the location of the explosive or incendiary device, is to attempt to detect the device and to ensure that assets inside buildings are protected in accordance with the applicable level of protection in the event a device detonates. For devices assumed to be placed exterior to a building, that generally requires an unobstructed space within which placed explosives or incendiary devices can be visually detected and building elements that are designed to resist the explosive effects of a detonation outside the distance associated with that unobstructed space. For devices at entry and delivery points into buildings, the general design strategy includes providing for detection of the device at those points and designing those areas to minimize damage to assets inside the building from a detonation inside those entry or delivery points.

4-3.2 **Specific Design Strategies.** Specific design strategies generally follow the same goals for protection of assets as the vehicle bomb tactic, but with additional emphasis on detection.

4.3.2.1 **Sitework Elements.** Sitework elements are only an issue for this tactic in the context of explosives or incendiary devices being placed at the exteriors of buildings. The only variance among levels of protection is that the high level of protection requires perimeter barriers to control access to the unobstructed spaces around the buildings and to reduce vulnerabilities associated with thrown devices.

4-3.2.2 **Building Elements.** The design goals associated with the different levels of protection are summarized in Tables 4-2 and 4-3. For exterior explosions those design goals are focused on the exterior building elements. For explosions at entry points, mail rooms, and supplies handling areas, those goals are focused on the building elements directly associated with the entry point areas and with the building elements in the immediate vicinity of those areas elsewhere in the buildings.

4-3.2.3 **Detection.** Detection is a critical component of the design strategy for this tactic. How detection is applied is significantly different whether the explosive or incendiary device is at the exterior of a building or at an entry point, mail room, or supplies handling area.

4-3.2.3.1 **Exterior Attacks.** For exterior attack considerations, detection at the low and medium levels of protection is based on visual observation of the unobstructed space. The high level of protection adds the requirement for perimeter detection outside the unobstructed space using some form of exterior intrusion detection system or guards.

4-3.2.3.2 **Attacks at Entry and Delivery Points.** At entry and delivery points it is necessary to detect explosives or incendiary devices either being carried into buildings or delivered to them. Detection is provided using either operational procedures or electronic equipment, depending on the level of protection. For the low level of protection, detection is provided only through operational procedures. For the medium level of protection, X-ray equipment and metal detectors are applied. The high level of protection includes the addition of explosive detectors. These measures will be applied at mail rooms and supplies handling areas as applicable for delivered devices and at either building or site entry points for devices that are being carried into buildings.

4-3.3 **Project Scope Implications.**

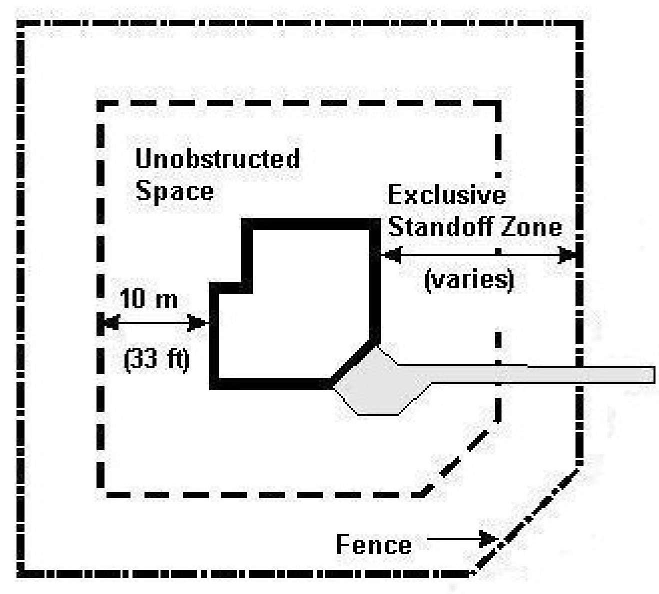
4-3.3.1 **Sitework Elements.** Sitework elements are only a consideration for explosive or incendiary devices being placed outside buildings or thrown at them. At the low and medium levels of protection, sitework considerations are limited to establishing unobstructed spaces as required in the *DoD Minimum Antiterrorism standards for Buildings (UFC 4-010-01.)* The extent of that unobstructed space can vary with threat severity level (explosive weight) and level of protection.

4-3.3.1.1 **Low and Medium Threat Severity Levels.** The 10 meter (33 feet) unobstructed space required by the minimum standards will generally be adequate for the low and medium threat severity levels at all levels of protection. The assumption in that is that explosives placed in that unobstructed space will be seen by passers by and that they are relatively small, so their detonation would result in minimal damage to people inside the buildings anyway.

4-3.3.1.2 **High Threat Severity Level.** For the high threat severity level at the low and medium levels of protection, the unobstructed space may need to be extended farther from the building. The reason for that goes back to the assumption that explosives placed in the unobstructed space will be visually detected; therefore, it is further assumed that the explosive will generally not be placed in that space. The unobstructed space may need to be extended because the standoff distance it provides will have to be based on the larger explosive associated with the high threat severity level. That standoff distance will be based on both available land and building construction. Where there is adequate standoff distance, conventional construction may be adequate to provide the required level of protection. Where there is insufficient standoff, building hardening may be necessary. The cost tables in Appendices A and B account for building hardening where appropriate.

4-3.3.1.3 **High Level of Protection.** For the high level of protection for all threat severity levels, there are additional sitework requirements to the unobstructed space. That level of protection requires establishment of an exclusive standoff zone to ensure aggressors cannot get close enough to the building to place an explosive. That exclusive standoff zone is located at whatever standoff distance is necessary to provide the required level of protection against the threat explosive based on the building construction. That standoff zone should be fenced to provide an effective barrier to access. In addition, to minimize vulnerabilities associated with thrown explosives, trees may be placed around that perimeter to assist in intercepting those thrown explosives. The unobstructed space, therefore, is not as significant a consideration, but the minimum unobstructed space should be retained in accordance with the *DoD Minimum Antiterrorism standards for Buildings (UFC 4-010-01.)* Figure 4-7 illustrates a site design that would meet the requirements for the high level of protection.

Figure 4-7. Site design example for high level of protection



4-3.3.2 **Building Elements.** Building elements have the most significant implications for project scope for this tactic. The implications are for the exterior of the building as well as at and in the vicinities of entry and delivery points. Variances among levels of protection are limited to how much damage will be allowed in response to an explosion as reflected in Tables 4-2 and 4-3.

4-3.3.2.1 **New Construction.**

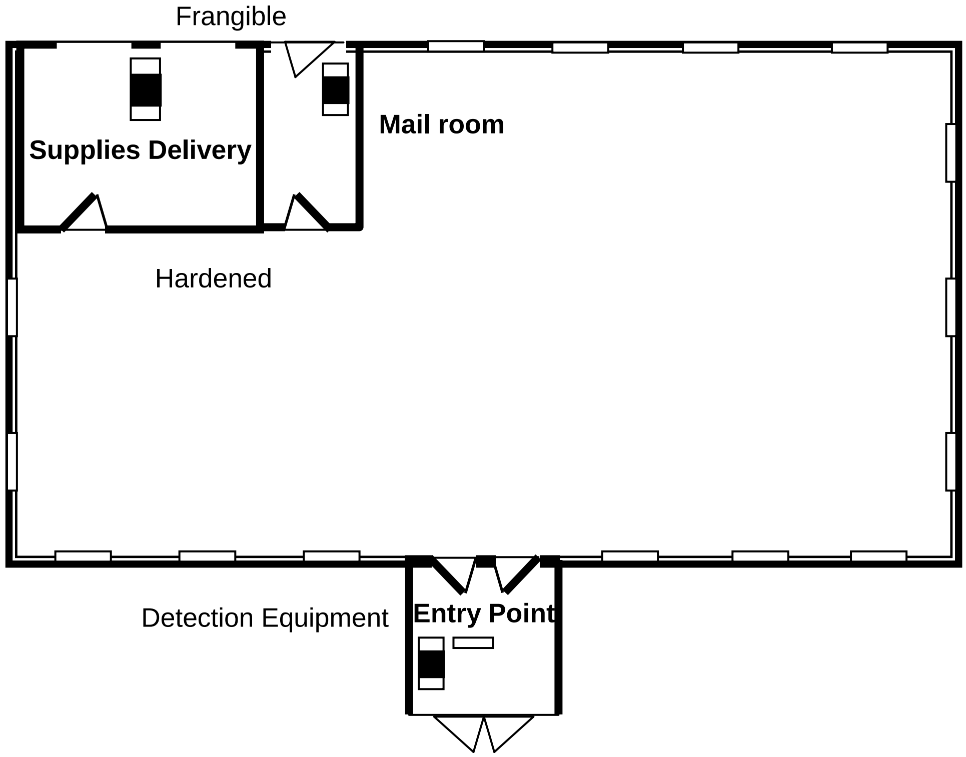
4-3.3.2.1.1 **Building Exterior.** The building exterior should be designed to provide the applicable level of protection to the bulk explosive at the edge of either the unobstructed space or the exclusive standoff zone. It should also be designed for smaller thrown explosives and incendiary devices well within those standoff distances.

For the low threat severity level, the only exterior requirements are that the building exterior be fire resistant, which is consistent with common building practice, and that windows be resistant to thrown objects. The DoD minimum window required by UFC 4-010-01 is generally adequate for that. For the medium threat severity level, the building exterior must further provide resistance to the small explosive and fragments associated with the explosives at that threat severity level. Because of the small size of the explosives, significant hardening is only considered at the high level of protection.

For the high threat severity level, where the unobstructed space or exclusive standoff zones are set at a standoff distance in accordance with Table 4-1, the only building elements for which there are any implications above those of conventional construction are doors and windows, which will have to meet the minimum standards in UFC 4-010-01. Where those conventional construction standoff distances cannot be provided, the implications for the exterior building elements will commonly be thicker and more heavily reinforced walls, blast resistant windows, heavier doors, and thicker and more heavily reinforced roofs. Those enhanced building elements will need to be applied over the entire building perimeter except in areas that are not inhabited.

4-3.3.2.1.2 **Entry and Delivery Points.** Because the general design strategy for this tactic assumes that no explosives or incendiary devices will be allowed into buildings, the entry and delivery points must be built such that there are opportunities to detect those devices and designed such that damage in the event of an explosion will be minimized outside the immediate vicinity of the entry or delivery points. One implication of implementing that assumption is that the entry and delivery points may have to be larger to accommodate detection equipment and search areas. The other implications are that the entry and delivery point areas will have hardened construction consisting of heavily reinforced interior walls and ceilings and blast resistant doors between those areas and the rest of the building. At least one exterior wall for the entry and delivery points will be designed to fail in response to an explosion so they can vent the explosive effects. The latter issue may result in additional requirements for the exterior of the building in the vicinities of the entry and delivery points as well. If possible, configurations of mail rooms and delivery areas should avoid doors directly into the buildings. Figure 4-8 illustrates these principles.

Figure 4-8. Entry and Delivery Points



4-3.3.2.2 **Existing Buildings.** Building retrofit considerations are similar to those for new construction, but they may involve modifying the existing construction. For the exterior of the building, there should be no issues other than the replacement of the windows as described above for the low threat severity level. Similarly, there should be minimal impacts for the medium threat severity level except for at the high level of protection.

For the high level of protection at the medium threat severity level and for all levels of protection at the high threat severity level, the building exterior may have to be retrofitted, including replacing windows and doors and adding wall retrofits to the interior of the buildings' exterior walls. Regarding roofs, in most cases the existing roofs will have to be removed and replaced with new ones.

For entry and delivery points, because of their limited size, the most economical solution is to remove the existing building components and replace them with construction similar to that for new construction.

4-3.3.3 **Equipment.** Equipment has minimal project implications for this tactic, except at the medium level of protection and higher. The equipment will generally include access control, metal detection, X-ray screening, or explosive detection equipment installed at the entry and delivery points. That equipment will commonly not be able to be provided as part of the Military Construction funding because it will not be installed equipment that is affixed to or built into the facility. Such equipment will commonly have to be funded through other appropriations in accordance with DoD component guidance. At the high level of protection, an additional equipment implication is the installation of perimeter intrusion detection systems at the exclusive standoff zone. That intrusion detection equipment may or may not be augmented with closed circuit television equipment for assessing intrusion alarms depending on user preference and operational considerations. The intrusion detection equipment also commonly will not be able to be funded as part of Military Construction.

4-3.3.4 **Manpower and Procedures.** Manpower and procedures implications on construction are limited, but they need to be incorporated into the overall project planning and operation. For the design strategy for this tactic to be effective, there need to be trained people capable of detecting explosives and incendiary devices available. For those devices placed outside of buildings, that detection may be provided through increased occupant awareness and procedures for what to do in the event that an explosive or incendiary device is observed outside the building. For detection of devices at entry and delivery points there need to be trained people dedicated to detecting those devices either through operational procedures or through the operation of detection equipment. In either case, there also need to be qualified people who will respond to detection of an explosive or incendiary device, such as an explosive ordnance disposal team.

4-3.3.5 **Expeditionary and Temporary Construction.** Generally, considerations such as hardening building elements are not realistic for expeditionary and temporary construction.

4-4 **INDIRECT FIRE WEAPONS.** Because this tactic involves weapons fired from a distance and over any practical obstacles that could be erected to block them, the design strategies for this tactic are all based on hardening of buildings to resist the effects of the weapons impacting on or near buildings.

4-4.1 **General Design Strategy.** The general design strategy for this tactic is to design a targeted building to protect assets inside it from the detonation of the threat weapon at locations that vary by level of protection. That design will generally require building hardening, which will vary with threat severity because the weapons range from simple incendiary devices to large improvised high explosive warheads.

4-4.2 **Specific Design Strategies.** Specific design strategies vary based on the distance from the impact of the threat weapon to the target building, the response of the building elements to the detonation of the weapon, and the fragment penetration through the building elements.

4-4.2.1 **Impact Distance.** Because the low level of protection commonly involves acceptance of significant risk, the impact distance for that level of protection is assumed to be a “near miss” at 5 meters (approximately 16 feet). Note that 5 meters is half of the recommended separation distance between buildings in the *DoD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01)*, which suggests that in the case of adjacent buildings, the impact point will be midway between the buildings where that recommendation is followed. The impact distance for the medium level of protection is a near miss of 2 meters (approximately 6 feet). The impact distance for the high level of protection is based on a “near contact” condition equal to the warhead diameter of the weapon. Impact distance is only an issue for walls, doors, and windows. Because it is as likely that a round would land on a roof as it is to land nearby, the roofs are designed for direct impact.

4-4.2.2 **Building Element Response.** Building element responses will vary significantly with the kind of building element (wall, roof, window, door) and the materials used. In general, building element response will be evaluated based on the overall member response and on the degree of “breach.” The overall building element response is governed by Tables 4-2 and 4-3.

Breach refers to the degree to which the building materials are locally damaged and their resulting dispersal into the protected building. Breach is where the material fails and there is a hole through the wall, roof, or other element. The material from that element may disperse into the protected building, potentially injuring people or damaging other assets. Spalling is a phenomenon exhibited by many materials wherein the building element is not breached in response to an explosion effect or an impact, but a portion of the interior face of the element “pops off” and disperses into the building. Spall is commonly less dangerous than breaching. Spall and breach are governed by the criteria below:

- Low level of protection: Onset of breach (spall)
- Medium level of protection: Medium spall (no breach)
- High level of protection: Onset of spall

Application of building element response and spall or breach is covered in more detail in the *DoD Security Engineering Facilities Design Manual (UFC 4-020-02.)*

4-4.2.3 **Fragment Penetration.** Most indirect fire weapons involve what are referred to as primary fragments, which are pieces of the casing for the explosive that are propelled at high velocity in response to the detonation of the warhead. Those primary fragments result in a specific loading on building elements, and they also may penetrate them. The following summarizes the criteria for considering fragment penetration (where applicable):

- Low level of protection: Perforation by 10 fragments
- Medium level of protection: Perforation by 3 fragments
- High level of protection: Perforation by 1/2 fragment

4-4.3 **Project Scope Implications.**

4-4.3.1 **Sitework Elements.** Because indirect fire weapons fire over obstacles, there are no practical sitework elements that can be applied to mitigate this tactic. The only sitework issue would be building separation to minimize the possibility of causing damage to multiple facilities from one weapon.

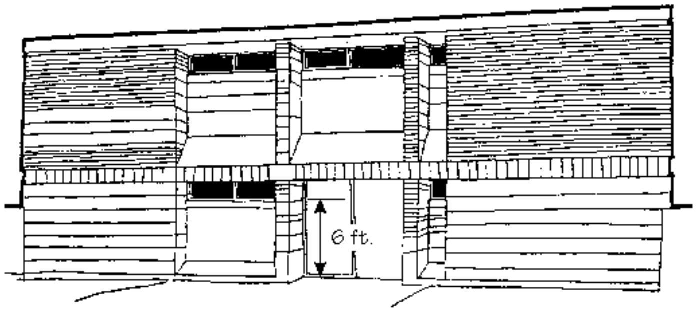
4-4.3.2. **Building Elements.** Effectively, all of the impacts on project scope will be in building elements, which will be affected by whatever hardening is applied to meet the applicable level of protection.

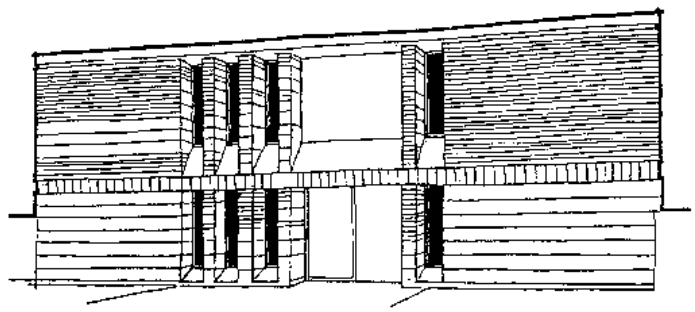
4-4.3.2.1 **New Construction.** For the low threat severity level (incendiary devices) the only implications to building element design are in flame resistance and the ability to keep the incoming warhead from penetrating the building and igniting inside. For the higher threat severity levels, however, the building elements will have to resist the effects of exploding warheads. Those effects will result in thicker walls, which will most commonly be constructed of reinforced masonry or concrete. They could also be built or retrofitted with steel plate, but that is generally more expensive.

4-4.3.2.1.1 **Windows.** Windows that are designed to resist the resulting explosive and fragment effects will generally need to be quite thick and would require the use of special materials such as polycarbonate. Because of that, the recommended solution is to use narrow, elevated windows that do not resist fragments, but only allow fragments to pass over the heads of building occupants. Where windows need to be able to be used for emergency egress, narrow, vertical windows can be used instead. In those cases, room layout would have to be adjusted to minimize exposure to occupants behind those windows. Those windows are illustrated in Figure 4-9. In either of the previous cases, the windows will still need to be designed to resist the blast load to the appropriate level of protection to minimize exposure of occupants to hazardous window fragments. Windows are not practical for the high level of protection.

4-4.3.2.1.2 **Doors.** Doors designed to resist the explosive and fragment effects would require the use of heavy steel plates. Such doors would be very heavy and expensive. For those reasons, the approach taken in this UFC is to build a foyer outside the building’s doors and allow the foyer to take the explosive and fragmentation effects of an exploding round, the foyers need to have walls constructed the same as the building’s walls. Doors into the foyers need to be offset from the doors into the building. The roofs of the foyers need to be designed the same as for the rest of the building to ensure incoming rounds do not penetrate them and explode within the foyer. Figure 4-10 shows foyers on the outside of a building.

Figure 4-9. Narrow Windows

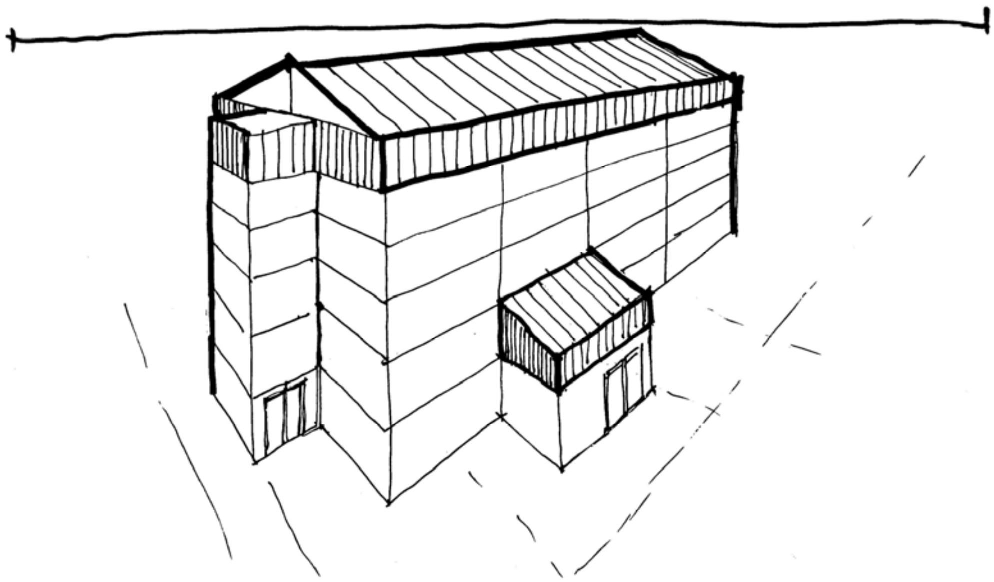




4-4.3.2.1.3 **Roofs.** Roofs designed to resist the direct impact of an incoming round will generally require thick heavily reinforced concrete. A more economical approach to the problem is to construct a sacrificial roof above the building's primary roof and to construct the primary roof to resist the effects of the round exploding at that standoff distance. That is the approach taken in developing the costs in Appendices A and B. The building's walls have to be extended to hold up the sacrificial roof and ensure rounds don't enter underneath it.

The sacrificial roof can be of conventional construction, although some lightweight roofs may need to be hardened slightly using such construction as rigid insulation and steel deck underneath to ensure incoming rounds detonate on the roof instead of beneath it. The insulation is used because some common mortar and rocket rounds have fuses that are inset from the nose of the round. Such rounds may not detonate on some solid conventionally constructed roofs, but they detonate as they pass through the rigid insulation because the insulation pushes into the recess in the nose cone. The hardened roof beneath the sacrificial roof will be reinforced concrete. For the purposes of developing costs in Appendices A and B, the standoff distances to the sacrificial roofs are at 2 meters (6 feet) and 4 meters (12 feet), representing half story and full story height, respectively. The space between the sacrificial roof and the hardened roof should not be occupied. Figure 4-10 shows sacrificial roofs on the building and on foyers.

Figure 4-10. Sacrificial Roof and Exterior Foyers



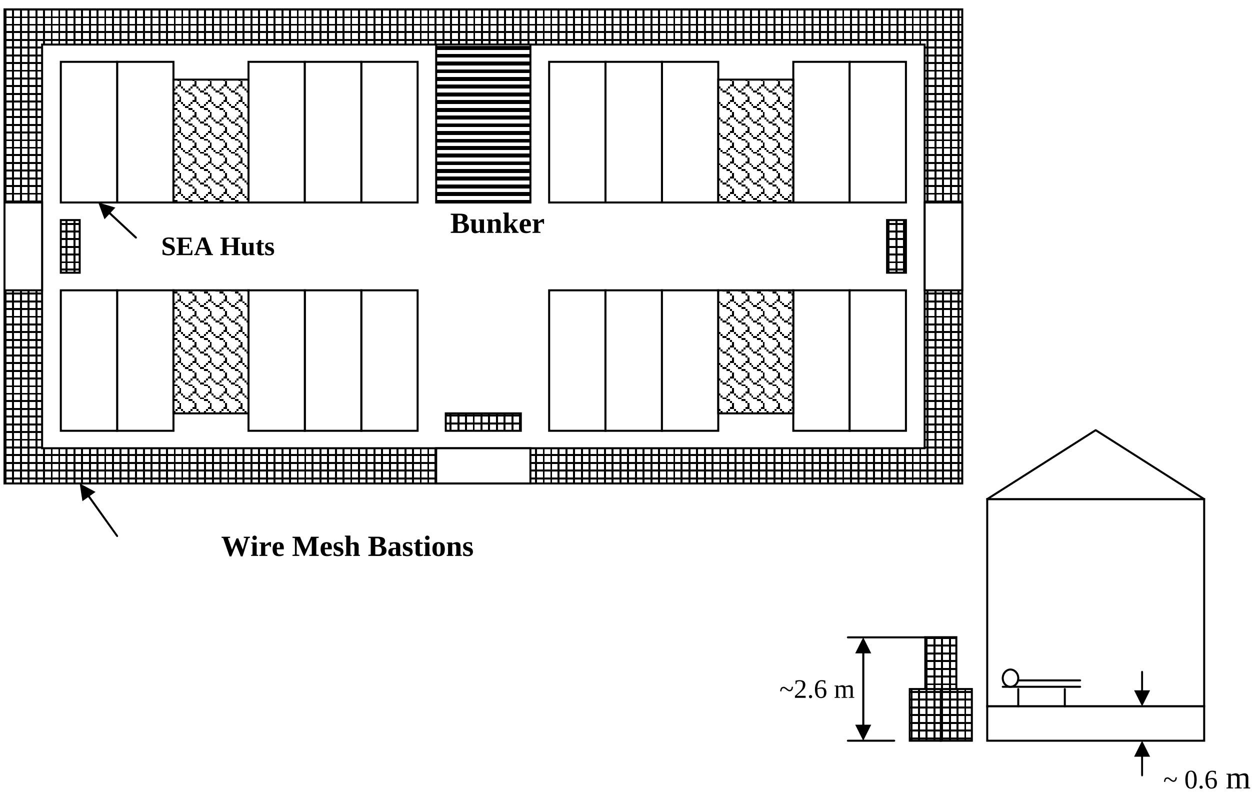
4-4.3.2.2 **Existing Buildings.** At the low threat severity level, which only requires fire resistant construction sufficient to keep the incendiary device from penetrating the building shell, retrofits should be minimal. At the higher threat severity levels, however, retrofitting existing buildings to resist the indirect fire weapons effects may be impractical in most cases. Walls require retrofits that resist the blast effects based on the explosive weight in the round, and they must provide sufficient thickness of concrete, masonry, or steel to resist the weapons' fragments. Such retrofits are only practical for the low and medium levels of protection for the medium and high threat severity levels. There are no practical retrofits for the very high threat severity level. Windows have to be replaced and the surrounding walls modified to create narrow window configurations such as those shown in Figure 4-9. In those cases, room layout has to be adjusted to minimize exposure to occupants behind those windows. Doors have to be replaced to provide door configurations similar to those described for new construction. Roofs would have to be removed and replaced with roofs similar to those described for new construction, including sacrificial roofs.

4-4.3.3 **Equipment.** The application of equipment to detect incoming indirect fire is impractical, so there are no equipment implications to project scope.

4-4.3.4 **Manpower and Procedures.** Because of the nature of the indirect fire weapon threat, there are no effective procedures that can be directly associated with an individual building to mitigate the attacks other than in response after an attack. At that point there should be emergency response procedures (fire and rescue) and building occupants should know to duck under whatever furniture they can.

4-4.3.5 **Expeditionary and Temporary Construction.** In general, hardening expeditionary and temporary construction to mitigate indirect fire weapons attack is impractical. The solutions, therefore, are commonly in dispersal of facilities so that one weapon does not damage multiple facilities and in construction of collective bunkers to which people can evacuate in anticipation of additional attacks. In addition, barriers such as wire mesh bastions or shielding walls can be erected to shield structures from fragments and to mitigate propagation of weapons effects to adjacent structures. These approaches are illustrated in Figure 4-11 below, which shows a cluster of SEA huts surrounded by wire mesh bastions.

Figure 4-11. Shielded SEA Hut Cluster



4-5 **DIRECT FIRE WEAPONS.** Because there are generally no opportunities to detect and prevent direct fire weapons attacks, the design strategies for this tactic are based on shielding and hardening.

4-5.1 **General Design Strategy.** The general design strategy involves identifying vantage points from which direct fire weapons can be launched and, depending on the level of protection, either blocking sightlines to assets and building occupants or hardening the building elements to resist the direct fire weapons effects.

4-5.2 **Specific Design Strategies.** Because this tactic includes both small arms and antitank weapons, and because the effects of those weapons vary significantly, the specific design strategies will not apply equally to all threat severity levels. Specifically, the medium level of protection only applies to the high threat severity level, which includes antitank weapons and high caliber small arms (12.7 mm or .50 caliber). For the threat severity levels that are limited to small arms of less than 12.7 mm (.50 caliber), apply the low level of protection design strategy for the medium level of protection.

4-5.2.1 **Low Level of Protection.** For all threat severity levels (involving both small arms and antitank weapons), the design strategy for this level of protection is to block sightlines to building occupants or assets. The assumption in that is that aggressors will not shoot at what they cannot see. Blocking sightlines may include applying both building and sitework elements.

4-5.2.2 **Medium Level of Protection.** The medium level of protection may apply to all threat severity levels, but is only practical in the case of large caliber small arms (like the 12.7 mm or .50 caliber) and antitank weapons. It includes the installation of predetonation screens that detonate antitank rounds at a specific distance from a target, and allow the effects of the antitank rounds to dissipate prior to impacting a building. The combination of that standoff distance and building element construction will prevent the small arms and antitank rounds from breaching the building envelope. An energy absorption screen can be installed in the case of large caliber small arms to reduce the energy of the small arms rounds before they impact the building.

4-5.2.3 **High Level of Protection.** For all threat severity levels (involving both small arms and antitank weapons), the design strategy for this level of protection is to harden building elements such that they resist the direct effects of the threat weapon.

4-5.3 **Project Scope Implications.**

4-5.3.1 **Sitework Elements.** Sitework elements only apply at the low and medium levels of protection. At the low level of protection, various landscaping elements or opaque barriers can be applied to block sightlines to occupied portions of buildings. The medium level of protection includes an energy absorption screen or a predetonation screen. The predetonation screen can be a solid fence or wall that will be sufficient to detonate an antitank round on impact. Commonly, that requires a surface of concrete, concrete masonry, steel, or at least 20-millimeter (approximately ¾ inch) thick wood. The predetonation screen should be placed to shield the occupied portions of buildings and will have to be between 3 and 12 meters (approximately 10 and 40 feet) away from the building depending on building construction. To serve as both a predetonation and energy absorption screen requires reinforced concrete or masonry because it requires much more mass to reduce the energy of a large caliber bullet than to predetonate an antitank round.

4-5.3.2 **Building Elements.** Implications to building elements are dependent on the level of protection.

4-5.3.2.1 **New Construction.**

4-5.3.2.1.1 **Low Level of Protection.** Because the design strategy for the low level of protection for all threat severity levels is concealment, there are limited implications to building elements. Since walls and roofs are generally opaque, there are no considerations for them. The only considerations, therefore, are for openings such as windows, skylights, and doors. The implications to windows and doors are either to configure them so that occupants and other assets are not visible through them or to provide treatments such as reflective coatings, shades, or drapes that make them difficult to see through. Skylights would have similar implications, but only if there were vantage points nearby from which those could be targeted.

4-5.3.2.1.2 **Medium and High Levels of Protection.** At the medium and high levels of protection the exterior building elements will have to resist the weapons effects for the threat weapons. For the small arms threats the implication to that is the use of bullet resisting construction. Generally, reinforced masonry or concrete walls will provide such resistance with 200-millimeter (8-inch) thick reinforced masonry or 150-millimeter (7-inch) reinforced concrete providing resistance up to the 7.62-millimeter rounds. For the higher caliber bullets and antitank rounds in the high threat severity level, the walls are likely to be thicker.

Doors and windows are commercially available to resist the small arms threats of 7.62 millimeters and smaller, but those assemblies will be thicker and heavier than conventional windows and doors. Windows and doors are also available that can stop higher caliber bullets, but they are not as commonly available. Windows and doors that would resist either predetonated antitank rounds or direct hits from those rounds are not practical. The implications for that are that those windows and doors will have to be shielded, configured to preclude lines of sight to occupants or assets, or eliminated.

Roofs and skylights are only an issue where there are sightlines to them from nearby vantage points. Where there are such sightlines, roofs and skylights will have to be treated similarly to walls and windows.

4-5.3.2.2 **Existing Buildings.** Retrofit considerations for the low level of protection are similar those for new construction. Windows and doors would need to have means to limit vision through them as described above. For the medium and high levels of protection, windows and doors will have to be replaced with bullet resistant window and door assemblies. Walls may have to have additional thickness of concrete or masonry added or steel plate added to the backs of the walls.

4-5.3.3 **Equipment.** Because of the fact that these attacks are commonly launched from a distance without warning, there is no practical opportunity to apply equipment to mitigate vulnerabilities to this tactic.

4-5.3.4 **Manpower and Procedures.** As with equipment, there are no practical applications of manpower and procedures in mitigating these attacks other than ensuring that people know to take cover immediately after detecting an incoming round and in some environments, firing back at the aggressors.

4-5.3.5 **Expeditionary and Temporary Construction.** It is generally not difficult to provide the low level of protection for expeditionary and temporary construction, but it is generally not practical to provide higher levels of protection through hardening of the structures themselves. The approach, therefore, is to provide shielding such as that illustrated in Figure 4-11.

4-6 **AIRBORNE CONTAMINATION TACTIC.** One of the critical assumptions inherent in the design strategies for this tactic is that airborne contaminants will be delivered into buildings from either outside the building or at entry or delivery points. Contaminants cannot be allowed to enter into buildings further than those points.

4-6.1 **General Design Strategy.** Based on the above assumption, the general design strategy for this tactic is to provide access control and screening to ensure that agents are not introduced into buildings and to design the building elements and building support systems to ensure that agents introduced from outside the buildings or at entry and delivery points are kept out of the buildings. This is commonly referred to as collective protection.

That generally means that building envelopes will be designed to minimize air infiltration and exfiltration and that at other than the very low level of protection the buildings will be pressurized to keep airborne agents out. That pressurization requires filtration to retain the purity of the makeup air necessary to retain overpressurization. In addition, ventilation systems for entry and delivery points will be isolated from the remainder of the buildings.

Note that the design strategy does not include detection of agents. Theoretically, automatic detectors can be used to initiate protective actions such as shutdown of ventilation systems, closing outside air intakes, or turning on filtration systems. Detection of radiological agents can be performed quickly with off-the-shelf equipment; however, current biological detection technology requires a minimum delay of approximately 15 minutes to detect the presence of biological agents, although there is high-end research and development equipment capable of detecting within a few minutes. Practical application of chemical detection is limited by shortcomings in response time, false alarms, broad-spectrum capability, maintenance requirements, cost, and the quantity of sensors needed for the various chemical agents at air intake locations. Therefore, the design strategy will be dependent on intelligence or operational detection of events rather than automated detection.

4-6.2 **Specific Design Strategies.** The specific design strategies associated with the levels of protection vary in the type of filtration provided, the air that is filtered, and the continuity of operation. The application of higher levels of protection includes the applications of all measures in lower levels of protection. Collective protection is also described by overpressurization class, which refers to the duration that the asset must be protected against the threat based on emergency operational procedures and the overpressurization that must be provided to resist particular wind speeds within the collective protection area.

4-6.2.1 **Very Low Level of Protection.** The strategy at this level of protection can be referred to as sheltering in place. It includes application of passive building element features to minimize air infiltration and the means to shut down the ventilation systems to limit dispersal of any agents that might infiltrate the building envelope.

4-6.2.2 **Low Level of Protection.** The strategy at this level of protection adds to that of the previous level of protection the application of high efficiency particulate air (HEPA) filters at air intakes. As a practical matter, however, the HEPA filters are generally installed in the central air-handling unit and they filter both the outside and recirculated air. A slight positive overpressurization of the building, referred to as Class II overpressure, should be added. The HEPA filtration should be run continuously and will remove biological and radiological agents.

4-6.2.3 **Medium Level of Protection.** The strategy at this level of protection also includes HEPA filtration and adds vapor adsorber systems with carbon filters to the outside air intakes to filter out chemical agents. It also provides either Class II or Class I overpressurization depending on operational considerations (see UFC 4-020-02). The filter system should be run continuously or in response to a threat or a heightened force protection condition.

4-6.2.4 **High Level of Protection.** The strategy at this level of protection includes HEPA filtration and vapor adsorber systems with carbon filters for both outside and recirculated air. It also includes Class II or Class I overpressurization, depending on operational considerations (see UFC 4-020-02). The filter system should be run continuously.

4-6.3 **Project Scope Implications.** The project scope implications for this tactic include building support systems, which were not included for the previous tactics.

4-6.3.1 **Sitework Elements.** Because the focus of this tactic is on keeping agents out of buildings, there are very limited sitework element implications. The only issues are in maintaining unobstructed space around buildings and avoiding locating buildings in depressions where air could stagnate.

4-6.3.2 **Building Elements.** The only implications to building element design are in designing building elements to minimize air infiltration and exfiltration. Modern energy efficiency design considerations go a long way toward achieving this design goal. In addition, windows should be inoperable and access to mechanical rooms and exterior ventilation system components should be secured. The considerations are the same for new construction and for existing buildings.

4-6.3.3 **Building Support Systems.** The most significant implications to project scope are in the heating, ventilating, and air conditioning (HVAC) systems. Fresh air intakes will need to be elevated to at least 3 meters (10 feet) as required by the *DoD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01).* In addition, UFC 4-010-01 requires that the ventilation system be capable of being shut off from multiple locations throughout buildings in response to a threat. Other implications to the HVAC systems include isolating entry and delivery points from the remainder of the protected buildings and providing the filtration systems required to meet the applicable levels of protection. Those filtration systems as well as the overpressurization requirements may necessitate larger air handling units and will necessitate larger mechanical rooms. The considerations are the same for new construction and for existing buildings.

4-6.3.4 **Equipment.** Equipment is generally assumed for the purposes of this manual to be associated with detection and access control, both of which are applicable to the design strategies for this tactic. The equipment implications, therefore, are oriented to electronic entry control equipment and other equipment such as X-ray devices and metal detectors to support detection of contraband that might include chemical, biological, and radiological agents. This equipment would be located at entry and delivery points. At this time, equipment will not be considered to include chemical or biological agent detectors but may include radiological material detectors. The state of the art of chemical and biological agent detectors is not sufficiently advanced to incorporate such detectors into protective systems for buildings.

4-6.3.5 **Manpower and Procedures.** Manpower implications are limited to the people necessary to operate the equipment at the entry and delivery points. Procedures will have to be developed for such issues as how and when to shut down the HVAC systems in response to attacks and how to operate within the protected areas in terms of such things as opening and closing doors and entering and leaving buildings. In addition, there will be additional periodic maintenance requirements associated with the HVAC and filtration systems and with maintenance of other building elements to ensure minimal air infiltration and exfiltration.

4-6.3.6 **Expeditionary and Temporary Construction.** Generally the construction of expeditionary and temporary structures or the condition of buildings the DoD may occupy will limit opportunities for providing the kind of protection envisioned for this tactic directly into those projects. There are expedient shelters and transportable collective protection equipment that can be used, however. Those include self-contained shelters and liners that can be installed in tents or rooms, both of which include the necessary HVAC equipment to operate in a contaminated environment. Refer to UFC 4-024-01 for additional information on these systems.

4-7 **WATERBORNE CONTAMINATION TACTIC.** The assumption inherent in the design strategy for this tactic is that it takes large amounts of contaminants to contaminate a water supply. Of 38 likely chemical contaminants that could be entered into a small reservoir (on the order of 38,000 cubic meters or 10,000,000 gallons), 3 would require a tank car load, 19 would require a dump truck load, and 16 would require a station wagon load to create a dangerous concentration. To put that quantity of water into perspective, it represents the average daily consumption for a city of 100,000 people. In addition, most chemical and biological agents are removed by water treatment processes. Because of those facts, the focus of the design strategy for this tactic is on components of the treated potable water supply system. Another possible approach, which would require lesser amounts of contaminants, would be to introduce contaminants into the system by overpressurizing the system at water discharge points such as faucets and hydrants. That approach is also dealt with by protecting elements of the water distribution system and through physical security.

4-7.1 **General Design Strategy.** The general design strategy for this tactic is to protect treated potable water supply and distribution system components from the introduction of large quantities of contaminants at likely access points and from small quantities introduction into the system closer to or inside buildings through physical security. The general design strategy also includes providing alternate drinking water sources in the event that the water gets contaminated. It involves both contamination avoidance and treatment. The locations to which this design strategy is should be applied include the following:

- Water sources
- Treatment plants
- Treated water storage
- Water distribution system
- Building water distribution system (plumbing)

4-7.2 **Specific Design Strategies.** There are three levels of protection associated with this tactic. The specific design strategies associated with those levels of protection vary with the sophistication of the security of the water supply and distribution system components and the frequency of use of alternate drinking water sources. All three levels of protection include protecting against the equivalent of a low threat severity level forced entry attack to the applicable level of protection and the application of access controls.

4-7.2.1 **Low Level of Protection.** This level of protection provides access control to treated potable water supply and distribution system components based on operational and procedural measures only and protection against forced and covert entry using elements of the low level of protection for those tactics (described later in this chapter.) It does not include the application of intrusion detection systems. There are no additional treatment or alternate source requirements for this level of protection.

4-7.2.2 **Medium Level of Protection.** This level of protection provides access control to treated potable water supply and distribution components to the equivalent of the medium level of protection for the covert entry tactic and to the equivalent of the low level of protection for the forced entry tactic (both described later in this chapter.) It also includes backflow prevention devices to be installed on treated potable water distribution elements and for the provision of a standby point of use treatment system to be applied either for an individually targeted building or a cluster of buildings.

4-7.2.3 **High Level of Protection.** This level of protection provides access control to water supply and distribution components to the equivalent of the high level of protection for the covert entry tactic and to the equivalent of the medium level of protection for the forced entry tactic (both described later in this chapter.) It also includes backflow prevention devices as for the medium level of protection and adds the capability to detect contaminants at the targeted facility. Water treatment is handled through continuously operated point of use treatment systems, internal potable water production (as from a well) or from redundant water storage tanks.

4-7.3 **Project Scope Implications.** The project scope implications for this tactic are relatively limited with most resulting from consideration to forced or covert entry to water system components. This tactic also has protective systems for water distribution system elements and water storage that are not present for other tactics.

4-7.3.1 **Sitework Elements.** The project scope implications for sitework elements are limited to controlling access to the areas around water treatment plants. Because most such facilities are fenced for safety purposes, the additional project implications should be minimal. They would be limited to providing means to control access through gates. There should only be limited differences among the three levels of protection. Those differences will be in the sophistication of access control measures.

4-7.3.2 **Building Elements.**

4-7.3.2.1 **New Construction.** The implications to building elements are focused on access control and resistance to forced entry. The additional requirements will primarily be at buildings associated with water treatment and distribution or at locations in targeted buildings where the building water system could be accessed. The access control requirements may change building entry configurations and the forced entry resistance may change the construction of building components such as walls, doors, windows, and roofs.

4-7.3.2.2 **Existing Buildings.** For existing buildings, windows and doors may need to be replaced with forced entry resistant window and door assemblies or, in the case of windows, they may have forced entry resistant barriers added. Walls and roofs may have retrofits added to increase their forced entry resistance as described in the forced entry section below.

4-7.3.3 **Water Distribution System Elements.** Because there is a possibility of contaminants being introduced through discharge points such as faucets and hydrants through overpressurization, water distribution system components may be required to be fitted with backflow prevention devices. In addition, any other water distribution system components at which contaminants could be introduced will need to be secured against forced and covert entry. In most cases, the additional requirements will be limited to locks except as described in the paragraph on equipment below. The considerations are the same for new construction and for existing buildings.

4-7.3.4 **Water Treatment Elements.** The medium and high levels of protection potentially include the provision of point of use treatment systems. The implications to project scope include both providing and installing that equipment and making space for it.

4-7.3.5 **Water Storage.** Because the high level of protection may include drinking water storage, designers will have to determine appropriate water storage requirements. Those requirements will vary based on the climate and other factors. For example, water requirements will be higher in desert regions than in temperate regions. While estimation of water demand is beyond the scope of this UFC, an approximate quantity for planning purposes could be 8 liters per person per day (approximately 2 gallons per person per day). Those quantities could be provided based on the expected full time occupants of a building plus a percentage of that for the expected number of visitors per day. The percentage for visitors would vary based on how long visitors would be expected to stay. It might be larger for a building where visitors are likely to attend all day events as opposed to a building where visitors only stop briefly.

While overall water demand depends on other considerations such as toilet flushing, washing, industrial uses, and irrigation, for the purposes of addressing this threat, the focus should be limited to drinking water based on the assumption that most people could be evacuated from the building in response to a contamination event instead of staying there and operating. Where there is an operational need to provide water for washing, limited additional demand could increase storage quantities to 20 liters per person per day (approximately 5-1/4 gallons) or more.

The water storage requirements for the high level of protection are further complicated by the need for redundant storage. With that, one storage source can be used while the other is filled, allowing for testing immediately after filling and prior to use. The implications to project scope include both providing and installing the storage tanks with the appropriate contaminant sensors and making space for them.

4-7.3.6 **Equipment.** Project scope considerations for security equipment are limited to the medium and high levels of protection. Those levels of protection will add requirements for access control equipment and for intrusion detection equipment to detect aggressors as they attempt to access water distribution system elements and the water treatment site.

4-7.3.7 **Manpower and Procedures.**

4-7.3.7.1 **Manpower.** The implications for manpower are potentially to add guards at treatment plant entrances if they are not there already. Where the high level of protection applies, there may also be requirements for additional people to monitor intrusion detection systems if there are none monitoring such systems already or if the additional equipment associated with these requirements overwhelms existing personnel capabilities.

4-7.3.7.2 **Procedures.** Additional procedural measures will primarily be associated with access control to water distribution system elements. In addition, at times when building occupants are to be consuming water from the alternate sources provided, there will need to be procedures to inform building occupants of that requirement. There should also be procedures to shut off drinking fountains and other water sources that could be used for drinking water. Additional procedures may be necessary to replace consumed water and monitor its quality.

4-7.3.7 **Expeditionary and Temporary Construction.** Water distribution in expeditionary environments often does not involve the level of infrastructure that is present in fixed installations. Often drinking water requirements are met completely with bottled water. Where there is a distribution infrastructure, however, much of the guidance above may apply to water distribution in expeditionary environments, but it will have to be tailored to the specific situation. In general, the same strategies of securing water sources and distribution and potentially providing alternate drinking water sources apply.

4-8 **WATERFRONT ATTACK.** For the purposes of this UFC, waterfront attacks are considered to come from the water. Landside attacks are covered by the other tactics in this UFC. Because this tactic involves attacks from the water, the design strategies will be based on detection and delay of and response to intruding watercraft. Requirements relating to waterfront security will also be significantly affected by Force Protection Conditions.

4-8.1 **General Design Strategy.** The general design strategy for the waterfront attack is to lay out and maintain defense in depth through the application of barriers, electronic security systems, and operational procedures. The defense in depth involves the following "zones."

4-8.1.1 **Assessment Zone.** The Assessment Zone is an area well beyond the government's property line. Vessels approaching the waterfront can be detected and patrol craft can be vectored to intercept them.

4-8.1.2 **Warning Zone.** The Warning Zone is an area just outside the government's property line. It is delineated by floating signage, signs on pilings, or other lines of demarcation at the property line. Watercraft in the warning area are often paralleled by patrol craft.

4-8.1.3 **Threat Zone.** The Threat Zone is the waterside area between the government's property boundary and the floating barrier. The inner boundary of the Threat Zone is marked with floating barriers.

4-8.1.4 **Engagement Zone.** The Engagement Zone is the area between a line of floating barriers and an asset. Watercraft entering this area are engaged and stopped using active defense measures.

4-8.2 **Specific Design Strategies.** Specific design strategies for this tactic involve increasing application of countermeasures.

4-8.2.1 **Low Level of Protection.** At the low level of protection, there are no special requirements on waterways, but restricted areas will be established with buoys and signs.

4-8.2.2 **Medium Level of Protection.** At the medium level of protection, a security zone will be established around the asset. Where possible that should be coordinated with the Coast Guard or its equivalent. This level of protection will also include harbor patrol boats and may include water barriers able to stop most small boats.

4-8.2.3 **High Level of Protection.** The high level of protection will include both waterside electronic security systems and water barriers designed to stop most powerful small boats and provide at least 5 minutes of delay.

4-8.2.4 **Very High Level of Protection.** The very high level of protection will incorporate the same measures as the high level of protection, but the water barriers will be able to stop all but the most powerful small boats.

4-8.3 **Project Scope Implications.**

4-8.3.1 **Sitework Elements.** For this tactic, the sitework elements are water barriers as described above and exterior electronic security systems as described below.

4-8.3.2 **Building Elements.** Because the focus of this tactic is on waterside approaches, building elements are only issues to the extent that an explosive laden watercraft could get near a building or that the applicable direct fire weapons effects would impact the building construction. In those cases, refer to the sections on vehicle bombs and direct fire weapons.

4-8.2.3 **Equipment.** Equipment for this tactic includes waterside electronic security system equipment such as closed circuit television (CCTV), surface or swimmer detection, and underwater detection.

4-8.2.4 **Manpower and Procedures.** There are few facility related issues related to manpower and procedures, but there do need to be qualified people to respond to watercraft incursions, and their response time may affect the distances associated with the various zones associated with the defense in depth. There may also be facility issues relating to supporting the patrol personnel and their patrol craft.

4-8.3.5 **Expeditionary and Temporary Construction.** The same principles apply in the expeditionary environment, but the nature of the barriers and the boundary demarcation may be different in that it is likely to be of a temporary nature.

4-9 **FORCED ENTRY TACTIC.** In this tactic aggressors are assumed to force their way through building elements or barriers. Attempts to gain entry through stealth are covered under the covert entry tactic.

4-9.1 **General Design Strategy.** Based on the above assumption, the general design strategy for this tactic is to detect aggressors either prior to their reaching barriers or as they attempt to breach them and then to provide sufficient delay to forced entry in the construction of those barriers to allow responding forces to arrive and defeat the aggressors before they can compromise the asset. Inherent in this strategy, therefore, is that there is an intrusion detection system that provides an alarm to a monitoring station in response to intrusion and that there is a response force that can respond to an alarm and reach its location before aggressors are able to breach the barriers between that point and the assets being protected.

4-9.2 **Specific Design Strategies.** The specific design strategies associated with the different levels of protection vary by the amount of delay provided and the sophistication of the intrusion detection. Note that the levels of protection have specific delay times associated with them. Those delay times are generalized goals, but if the planning team is confident that response times are either more or less than those associated with the applicable levels of protection, the applicable delay times may have to be adjusted. All building elements in the protective envelope that provides the delay time must provide at least the minimum delay time associated with the applicable level of protection based on the assumption that aggressors will always be able to identify the weakest element in the envelope. That protective envelope may be all in one layer, such as the shell of a room or the exterior of a building, or it may encompass multiple layers such as the building exterior and multiple rooms arrayed in rings around the asset. The detection element of the protective system may also include closed circuit television to assess the validity of alarms.

4-9.2.1 **Low Level of Protection.** The specific design strategy associated with this level of protection incorporates an envelope of building elements (walls, doors, windows, roofs, etc.) surrounding an asset that provides a delay time to the specified threat tools of at least 1 minute. In addition, the protective system incorporates intrusion detection sensors at all operable openings. Entry though other building elements would be detected through operational procedures, such as roving patrols.

4-9.2.2 **Medium Level of Protection.** The specific design strategy associated with this level of protection incorporates an envelope of building elements (walls, doors, windows, roofs, etc.) surrounding an asset that provides a delay time to the specified threat tools of at least 5 minutes. It also incorporates a complete ring of detection covering all possible approaches through the protective envelope.

4-9.2.3 **High Level of Protection.** The specific design strategy associated with this level of protection incorporates an envelope of building elements (walls, doors, windows, roofs, etc.) surrounding an asset that provides a delay time to the specified threat tools of at least 15 minutes. It also incorporates a complete ring of detection covering all possible approaches to the asset. That ring must include two different sensor phenomenologies covering each approach.

4-9.2.4 **Very High Level of Protection.** The specific design strategy associated with this level of protection incorporates the same delay and detection elements as the high level of protection, but the delay time is at least 30 minutes.

4-9.3 **Project Scope Implications.**

4-9.3.1 **Sitework Elements.** There will commonly be few sitework considerations that have any significant cost implications. The most significant issue is establishing unobstructed spaces around buildings or other enclosures housing assets, which in the case of inhabited buildings is required by the minimum standards in UFC 4-010-01. In general, sitework elements such as fences and walls, which may be considered barriers to forced entry, provide minimal delay. Therefore, they are not commonly used as part of a forced entry resistant protective system when the asset is stored within a building.

4-9-3.2 **Building Elements.** Building elements are a critical part of the protective system for protecting against forced entry, and the implications on their construction may be significant depending on the level of protection and the tools associated with the threat.

4-9.3.2.1 **New Construction.** In general, the walls and roofs will have to be more substantial than common lightweight conventional construction. In addition, the doors will be stronger and will have more robust locksets and hardware than conventional doors and windows will either be heavier and tougher or they will have external barriers. There may also have to be barriers installed over other potential man-passable openings (greater than 620 square centimeters or 96 square inches) such as air vents and utility openings.

4-9.3.2.2 **Existing Buildings.** Similar to new construction, walls and roofs will have to be more substantial than conventional construction, but in the case of existing construction, obtaining that will require retrofits of additional building materials. Windows and doors will either be replaced with forced entry resistant window and door assemblies or, in the case of windows, they may be fitted with forced entry resistant window barriers.

4-9.3.3 **Equipment.** Equipment, in the context of the design strategy for this tactic, is predominantly intrusion detection equipment. Intrusion detection systems include sensors, alarm monitoring systems, and data transmission media to get the signals from the sensors to the alarm monitoring system. The scope of the sensor application depends on the level of protection, how much space is monitored, and the kinds of sensors used. The important goal to keep in mind is that detection must occur prior to any forced entry resistant barriers for the system to work effectively.

Some locations may already have central monitoring stations; in which case, there may be opportunities to add to an existing monitoring system. In others, new monitoring stations may have to be established. Such considerations, in addition to the distance from the protected building to the monitoring station, make it difficult to easily estimate the cost implications of an intrusion detection system.

In addition to the intrusion detection system, equipment may include closed circuit television cameras to assess the alarms. In those cases, there will have to be enough cameras to view every alarm point or zone. Another alternative is to respond to every alarm with a response force of some kind. The cameras may allow for avoidance of responses to false alarms and may provide additional information to response forces if the alarm is valid, such as how many aggressors there are and whether or not they're armed. Lastly, in many cases there may be electronic entry control systems within the scope of the project or existing in a building. That will be particularly true where the convert entry tactic applies. In those cases, the intrusion detection system may have coordinated or integrated with the entry control system. Access control does not need to be very sophisticated if only the forced entry tactic is a concern.

4-9.3.4 **Manpower and Procedures.** Manpower and procedures are critical elements of any protective system designed to protect against forced entry. The design of the protective system should optimally be coordinated with available manpower and local procedures, for both response and alarm monitoring. Where there are no such capabilities or where what exists is inadequate, the designers will have to work with the applicable law enforcement authorities to coordinate the system design and the procedures.

4-9.3.5 **Expeditionary and Temporary Considerations.** The nature of the expeditionary and temporary environment and the facilities commonly available does not commonly lend itself to sophisticated intrusion detection systems and forced entry resistant construction. There are forced entry resistant containers available, and valuable assets may be stored in other common containers, but hardening of buildings or structures is generally economically infeasible. Because of those considerations, protection against forced entry in the expeditionary and temporary environment is commonly manpower intensive, involving the use of guards. Those guards may be supplemented by intrusion detection systems such as perimeter systems or alarms on containers; however, successfully protecting assets is likely to depend on a rapid response.

4-10 **COVERT ENTRY TACTIC.** The underlying assumption for the covert entry tactic is that aggressors will not force entry because their goal is to employ stealth to access assets without anybody knowing they have done so. Those aggressors may be outsiders or they may be people who legitimately have access to facilities, such as employees. The latter are commonly referred to as insiders, and they provide additional challenges to designers. Covert entry and forced entry are often both included in threats to assets, in which case the designers need to coordinate the protective measures for both tactics.

4-10.1 **General Design Strategy.** Because the assumption inherent in protecting against this tactic is that aggressors will not attempt to force entry, the general design strategy is limited to providing construction that presents a barrier between potential aggressors and assets and then providing access control through those barriers. Where only outsiders are a concern, that approach can be applied to entire buildings or large areas of buildings. Where insiders are a concern, there may have to be compartmentalization within the building.

4-10.2 **Specific Design Strategies.** The levels of protection vary in the sophistication of the access control measures associated with them. All four level of protection involve using access control measures and construction that allows assets to be segregated from unauthorized personnel.

4-10.2.1 **Low Level of Protection.** The design strategy for the low level of protection is to prevent the use of easily duplicated identification badges as a method of covert entry.

4-10.2.2 **Medium Level of Protection.** The design strategy for the medium level of protection is to prevent the use of easily duplicated identification badges or stolen electronic access control badges as a method of covert entry. It also involves provision of protection for mechanical locking systems to prevent bypassing.

4-10.2.3 **High Level of Protection.** The design strategy for the high level of protection is to prevent the use of electronic access control cards duplicated using sophisticated electronic methods through the use of primary and secondary credential systems (i.e., card and personal identification number (PIN) or retina, signature, or voice recognition, etc.). It also involves initiating tailgating policies or installing prevention equipment and providing protection for mechanical locking systems to prevent bypassing.

4-10.2.4 **Very High Level of Protection.** The design strategy for the very high level of protection is the same as the high level of protection with the addition of providing equipment that will detect the presence of weapons or material that could be used to carry out terrorist or criminal acts.

4-10.3 **Project Scope Implications.** The project scope implications for this tactic are predominantly in access control, but there are considerations in the other common areas as well.

4-10.3.1 **Sitework Elements.** Sitework issues for the covert entry tactic where assets are stored in buildings are limited to minimizing opportunities around buildings for aggressors to hide. That goal is effectively solved for inhabited buildings by applying the unobstructed space requirements from UFC 4-010-01. The only other area where sitework considerations are an issue is where assets to which access must be controlled are stored in other than buildings. In those cases, the assets will need to be surrounded with a barrier such as a fence such that potential aggressors cannot access the assets without breaching the barriers. The assumption therein is that they will not breach barriers because it would subject them to potential detection.

4-10.3.2 **Building Elements.** The implications on project scope on building construction are limited. Because of the assumption that aggressors will not force entry through barriers, walls, floors, ceilings, and roofs surrounding asset need only be sufficiently constructed such that breaching them leaves evidence of the act. Therefore, common lightweight construction is adequate. Windows must either be capable of being locked or be inoperable. Doors must also be lockable with door hardware that cannot be defeated without leaving evidence of the act. The only other building oriented issue is in building layout. The architectural layout of buildings will have to support separating assets into areas to which access can be controlled. This may be complicated where insider considerations must be taken into account, in which case the building layout may need to support compartmentalization. The considerations are the same for new construction and for existing buildings.

4-10.3.3 **Equipment.** This is the area where the project scope will be most affected. The primary implications in this are access control equipment, the requirements for which are summarized below. Where the threat is limited to outsiders, equipment can be provided at the building exterior or at a particular area. Where insiders are a concern, there may be access control requirements at multiple points interior to the building to support compartmentalization.

4-10.3.3.1 **Low Level of Protection.** The low level of protection requires installation of single-door mechanical or electronic access control at primary entrances and locks or internal emergency exit devices on all other doors.

4-10.3.3.2 **Medium Level of Protection.** The medium level of protection requires installation of a centralized electronic access control system capable of restricting access times for registrants and immediately removing stolen card credentials from the system. Those systems would be applied at primary entrances to controlled areas, It also requires installation of an internal intrusion detection system to detect after-hours entry and entry through access-controlled doors, emergency exit doors, and windows at all times.

4-10.3.3.3 **High Level of Protection.** The high level of protection requires installation of electronic access control with biometric recognition or a personal identification number (PIN) as a secondary credential, in conjunction with tailgating prevention measures. Tailgating is where one person enters with another person without the second person's access authority being checked, such as an unauthorized person forcing an authorized person to help him or her get access. In addition, closed circuit television may be provided to assess entry authority. The high level of protection also includes the same intrusion detection requirements as the medium level of protection.

4-10.3.3.4 **Very High Level of Protection.** The very high level of protection has the same requirements as the high level of protection with the addition of positive tailgating prevention hardware, such as turnstiles or mantraps. Is also includes the application of CCTV to assess entry authority, installation of metal and explosive detectors to prevent introduction of weapons into secured areas, and the same intrusion detection requirements as the medium level of protection.

4-10.3.4 **Manpower and Procedures.** Manpower and procedures are a critical part of protection against covert entry. Designers must incorporate manpower and procedures into the system design, which involves coordination with building users and supporting law enforcement personnel. In some cases, assigning guards to control access may eliminate the need for an access control system. For the low and medium levels of protection guards checking identification that includes photographs of authorized personnel may be adequate. In the case of the medium level of protection, however, a badge exchange procedure would have to be implemented. That procedure involves two distinct badges for each authorized person. A person entering a controlled area must surrender his or her identification to a guard who trades it for a badge that is under the guard's control. That system requires aggressors to forge both identification under their control and badges under the control of guards.

Where guards are not used to directly control access, there are still manpower requirements in that there must be procedures to respond to unauthorized entry attempts. In addition, where screening equipment is used, there will have to be personnel to operate it and procedures developed on how to operate it.

In addition, the application of the two-person rule may prevent insiders from breaching security. In the two-person rule, one person can never be alone in the vicinity of a protected asset. That way two employees would have to be co-opted to allow compromising an asset. The two-person rule can be a strictly procedural measure or it can be enforced through application of access control equipment that requires two people to provide the required credentials before access is granted.

4-10.3.5 **Expeditionary and Temporary Construction.** There are commonly limited opportunities to provide complex access control systems in the expeditionary and temporary environment, so the approach tends to be manpower intensive. There are opportunities to store assets in safes or containers when they are not in use. In those cases the containers need to be able to be locked with locks that cannot be defeated without leaving evidence.

4-11 **VISUAL SURVEILLANCE TACTIC.** The design strategy for mitigating this tactic involves preventing unauthorized people from seeing assets that users do not want to be seen.

4-11.1 **General Design Strategy.** The general design strategy for this tactic is simply to prevent aggressors from seeing assets.

4-11.2 **Specific Design Strategy.** There is only one level of protection associated with this tactic, so the specific design strategy is the same as the general design strategy. Because there is only one level of protection, either protection is provided or it is not.

4-11.3 **Project Scope Implications.** Project scope implications are minimal. They involve blocking sightlines to assets from areas outside of the control of the facility occupants. Identifying potential vantage points from which aggressors might observe assets is a key to the design strategy for this tactic. Once those points are identified, measures can be implemented to block those sightlines.

4-11.3.1 **Sitework Elements.** Sightlines may be blocked using such measures as walls or fences with obscuration screening. Also, vegetation such as trees can be used to block sightlines. Note that where vegetation is used, it should be a variety that maintains its foliage year-round.

4-11.3.2 **Building Elements.** Employing building elements to block sightlines to assets is the most effective means of providing protection against this tactic. One approach is to lay out buildings such that no assets subject to observation from outside the building are in exterior rooms or that windows are laid out and assets are located such that the assets cannot be viewed through the windows. Where that opportunity does not exist, it will be necessary to avoid transparent building elements (windows, doors, and skylights) or provide means to obscure vision through them. Common means to obscure vision through windows are to install reflective or tinted window treatments such as reflective fragment retention film or to use figured or translucent glazing. Another solution is to use drapes or blinds, but they require operational discipline to ensure they are closed when sensitive assets are in view. Note that where reflective films or glazings are used, they will be ineffective at night, so drapes or blinds will still have to be incorporated into the project scope. The considerations are the same for new construction and for existing buildings.

4-11.3.3 **Equipment.** There are no equipment implications associated with this tactic.

4-11.3.4 **Manpower and Procedures.** The only issue with respect to procedures for this tactic is that there will need to be procedures in place to ensure that drapes or blinds are closed when they need to be or that sensitive assets are kept away from locations where unauthorized personnel can view them.

4-11.3.5 **Expeditionary and Temporary Construction.** There are no special considerations for expeditionary and temporary construction. The same principles apply as to fixed facilities but the options for providing obscuration may be more limited.

4-12 **ACOUSTIC EAVESDROPPING.** The design strategy for mitigating this tactic involves keeping aggressors from hearing audible information from outside of controlled areas. This UFC does not address the use of covert electronic listening devices placed within buildings. That is within the scope of technical security, which is dealt with by others and is outside the scope of facility design.

4-12.1 **General Design Strategy.** The general design strategy for this tactic is to design building exteriors or rooms within buildings that have construction that attenuates sound transmission so that secure conversations can be held in the building.

4-12.2 **Specific Design Strategies.** The design strategies associated with the various levels of protection all involve providing walls, doors, window, ceiling, floor, and roof construction that provides the required sound attenuation. The only difference between levels of protection is the level of sound attenuation provided. Sound attenuation is categorized by Sound Transmission Class (STC). The STC ratings for each level of protection and the level of sound attenuation they provide are summarized in Table 4-5.

4-12.3 **Project Scope Implications.** The scope of project changes is mostly limited to building construction, and then only in those areas where the building user needs to be able to have secure conversations.

4-12.3.1 **Sitework Elements.** The only implications to sitework design are in keeping aggressors from getting near enough to areas of buildings where secure conversations might be held. That requirement will generally be met by providing the unobstructed space required for inhabited buildings by UFC 4-010-01.

4-12.3.2 **Building Elements.**

4-12.3.2.1 **New Construction.** The scope of additional construction requirements is dependent on how much of the building needs to meet the required STC rating. Beyond that, in general, construction to meet the required STC ratings is within the scope of conventional construction. The higher STC ratings may require the use of masonry or concrete for walls and roofs for exterior construction, but they can commonly be provided through additional insulation and special construction details for interior construction. Doors and windows meeting other than the lowest STC rating in Table 4-4 will commonly have to be purchased as tested STC rated assemblies.

4-12.3.2.2 **Existing Buildings.** Considerations for existing buildings are similar to new construction, but retrofits to existing construction may require adding building materials to the existing walls, roofs, ceilings, and floors to achieve the applicable STC ratings. Doors and windows will have to be replaced with STC rated assemblies.

Table 4-4. STC Ratings for Levels of Protection

Level of Protection	STC Rating	Sound Attenuation
Low	30	Loud speech can be understood fairly well. Normal speech cannot be easily understood.
Medium	40	Loud speech can be heard, but is barely intelligible. Normal speech can be heard only faintly, if at all.
High	45	Loud speech can be heard only faintly, but cannot be understood. Normal speech is inaudible.
Very high	50	Very loud sounds on the order of brass musical instruments can be heard only faintly or not at all.

4-12.3.3 **Equipment.** There are generally no equipment requirements associated with this tactic.

4-12.3.4 **Manpower and Procedures.** There are limited requirements for manpower and procedures associated with this tactic, and there are none that have to be coordinated into designs. The extent of these measures is to ensure that no unauthorized personnel are allowed to get close enough to the perimeters of secure conference rooms to listen to the secure conversations.

4-13 **ELECTRONIC EMANATIONS EAVESDROPPING.** The design strategy for mitigating this tactic involves preventing sensitive electronic emanations from being intercepted by aggressors from outside of controlled areas. Much of the specific guidance associated with mitigating this tactic involves what is known as TEMPEST protection. The requirements for TEMPEST protection are established based on TEMPEST assessments, which are performed by the applicable elements of the intelligence community. Those assessments, the criteria on which they are based, and much of the criteria on which mitigation measures are based are classified. The scope of this UFC will be to reflect the implications to construction if certain measures are specified as a result of the TEMPEST assessment.

4-13.1 **General Design Strategy.** The general design strategy for this tactic will follow one or more of the following depending on the TEMPEST assessment.

- Follow applicable information system security policy, which means no specific TEMPEST measures are required.
- Provide controlled space outside the area where sensitive information is being processed. This reflects the fact that emanations attenuate with distance.
- Provide TEMPEST shielded equipment.
- Provide separation between electrical and electronic circuits, components, and equipment that process classified and unclassified information.
- Provide TEMPEST shielded enclosures.

4-13.2 **Specific Design Strategy.** There is only one level of protection associated with this tactic for the purposes of this UFC. That reflects the fact that no requirements established within the scope of this UFC will govern which of the design strategies above are applicable. The requirements will be established through the TEMPEST assessment.

4-13.3 **Project Scope Implications.** Only two of the design strategies above have significant project scope implications. Those are described below.

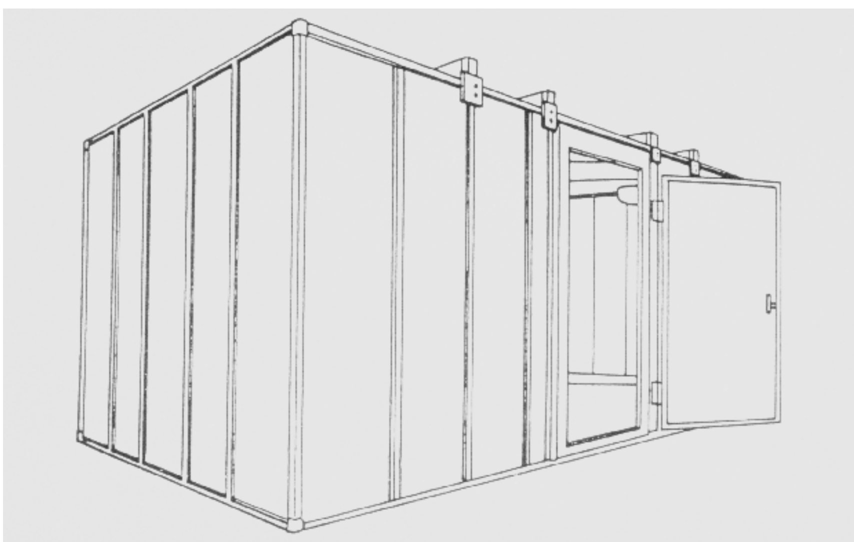
4-13.3.1 **Sitework Elements.** There are generally no significant project scope implications associated with this tactic. The only one that may have implications is the establishment of controlled space. The TEMPEST assessment may result in a requirement to establish a controlled area outside a protected building, which could require additional unobstructed space beyond that required for inhabited buildings by UFC 4-010-01. It could also require that the controlled space be fenced.

4-13.3.2 **Building Elements.** Requirements established as the result of TEMPEST assessments will have the most impact on building elements.

4-13.3.2.1 **New Construction.** To a minor extent the results of TEMPEST assessments could affect building layout by establishing a need to create controlled space around an area in which classified information is processed. Generally, however, the significant implications to building elements will be where a TEMPEST shielded enclosure is required. In those cases the entire building envelope of the area in which classified information is processed will need to be constructed using specialized TEMPEST shielding. That shielding is very expensive. In addition, special doors and windows are required and any penetrations of the envelope such as utility penetrations need to have emanations filters. Another option would be to provide a modular TEMPEST shielded enclosure such as the one shown in Figure 4-12 if the area requiring shielding is small enough. Cost information in the cost appendices does not include modular enclosures.

4-13.3.2.2 **Existing Buildings.** Considerations for existing buildings are similar to new construction, but retrofits to existing construction may require adding TEMPEST shielding to the existing walls, roofs, ceilings, and floors. Doors and windows will have to be replaced with TEMPEST shielded assemblies. Alternatively, as for new construction, where the areas requiring shielding are small enough, modular TEMPEST shielded enclosures can be provided.

Figure 4-12. Modular TEMPEST Enclosure



4-13.3.3 **Equipment.** Where TEMPEST shielded equipment is required as a result of the TEMPEST assessment, that equipment generally will be outside the scope of construction funding. It will commonly be installed by the users after construction is complete. The only area that has significant implications to equipment that falls within the scope of construction funding is in separation of between classified and unclassified circuits. That requirement may require additional conduit and conductor.

4-13.3.4 **Manpower and Procedures.** There may be many procedural requirements that need to be implemented as a result of the TEMPEST assessment, but they are beyond the scope of this UFC to describe and most will have limited implications to the scope of the project.

CHAPTER 5

MASTER PLANNING CONSIDERATIONS

5-1 **INTRODUCTION.** Master planning is also referred to as comprehensive planning, regional planning, land use planning, and facilities planning. For the purposes of this UFC it refers to a process by which an entity (government, base, installation etc) is concerned with documentation, planning and implementation of the long term goals, policies, and action strategies for a specific physical area. Its focus is usually long term (10-20 years) but may include near and mid-term strategies. The result is usually a "blueprint" for the physical development of a particular geographic area. Among DoD components, the master planning process is intended to provide a commander with a broad, long-term picture of facility needs and land use for an installation or base. In many ways the process is similar to the municipal planning process employed by cities in their attempts to anticipate growth and program improvements, which is appropriate because installations are effectively small cities. Each of the services has its own approach to "master planning" that is unique in terms of details, nomenclature and process, yet each attempts to provide the service with a long term policy guide for the physical development of installations. The Army and Marine Corps use the term Master Plan, and the Air Force refers to it as the General Plan. A number of land/facility planning processes are used by the Navy; however, the Regional Shore Infrastructure Planning process is the method that corresponds most closely with the recognizable master planning process.

Many security and antiterrorism objectives can be achieved through the master planning process. The least costly and often the most effective protection measures are those incorporated during this process. Implementing appropriate security and antiterrorism measures as part of master planning can preclude the need for piecemeal and costly security enhancements later on. That is particularly the case for issues relating to antiterrorism because of issues such as vehicular control and standoff distance.

It is also important to remember that the nature of the threat is ever changing. Some degree of security should be provided during master planning, with consideration given to increased or enhanced protection at times of increased threat. Security and antiterrorism objectives must be balanced with other planning objectives, such as the efficient use of land and resources, area development planning, and vehicular access and circulation, and they must take into account existing physical, programmatic, and fiscal constraints.

5-2 **SECURITY AND ANTITERRORISM PLANNING.** Security and antiterrorism planning is a parallel, but separate discipline that has its own DoD and service regulations and instructions. Security and antiterrorism requirements, responsibilities, and management controls are well defined by directives, instructions, regulations, and guides at all levels; however, those documents do not acknowledge their existence in broader based land and facility planning. Because of that, security and antiterrorism planning and land/facilities planning are generally accomplished independently using distinctly separate processes.

DoD protective design guides, standards, criteria, and vulnerability assessment programs stand as models, and are used by agencies and organizations throughout the world to implement needed security upgrades and to improve capabilities to mitigate vulnerabilities associated with terrorist attacks and criminal acts. While security and antiterrorism requirements are being addressed in Military Construction, minor construction, and other short-term projects, there is a general lack of security and antiterrorism guidance, coordination, and communication on long term planning issues such as land use, space management, and area development. Part of the problem might be attributed to the fact that security and antiterrorism tend to be more focused on the near term and directed at individual facility planning and design. Mitigation options to patch or fix vulnerabilities are typically short-term remedies or are incorporated into new construction or major renovations, modifications, repairs, and restorations of individual facilities.

There is abundant experience that demonstrates that the incorporation of improved security, protective, and response and recovery elements into new construction and at times of major rehabilitation of facilities are factors of two to ten times less expensive than upgrading security and protective systems in operating facilities. This cost differential can be even larger when life cycle costing is analyzed because quick reaction responses typically employ larger numbers of people. Well designed solutions, incorporating new and innovative uses of appropriate technology, Crime Protection Through Environmental Design (CPTED) concepts, and other architectural elements, can maximize security while minimizing operating costs.

5-3 **ISSUES IN MASTER PLANNING.** The master planning process provides a suitable framework for long-term security and antiterrorism planning and programming. Security and antiterrorism and land/facility planning converge at several component levels of master plan development, to include the following.

5-3.1 **Land Use Planning.** In most cases, integration of antiterrorism measures at the master planning level will increase the land area needed for individual facilities. Accordingly, future land use plans must take proposed antiterrorism measures into account when calculating land area requirements. Open circulation and common spaces on an installation, which are desirable from a conventional design perspective, may be undesirable from an antiterrorism perspective. Security considerations can be integrated into planning in such a way as to complement, rather than compete with other planning elements. For example, open space provides a number of mutual benefits. If the space is impassible for vehicles such as the case of a wetland or densely vegetated area, it provides not only environmental and aesthetic amenities, but helps to prevent vehicle intrusion as well. Permeable open space allows storm water to percolate into the ground, while enhancing surveillance and standoff distances and reducing the need for culverts, drainage pipes, and other site access or concealment opportunities. Plans must also consider high risk land uses with high concentrations of personnel, as well as off-base adjacent land use and zoning plans for potential development that may impact security of the installation. For example, planners must take into account adjacent land uses (internal and external) that could facilitate attacks or may be potential targets themselves, such as off-site roads, concealment areas for sniper attacks, or internal or external fuel storage or distribution points. Consider the following:

- When preparing land use plans, locate high-risk land uses in the interior of the installation. High-risk land uses contain high concentrations of personnel, such as administrative, community, and housing areas.

- Consolidate high-risk land uses to take advantage of opportunities for security efficiency such as minimized entry control points.

- Assess off-base adjacent land use and zoning plans for potential development that might impact security within the installation.

- When selecting a site for a facility, consider its location relative to the installation perimeter. Maximize the distance between the perimeter fence and developed areas, providing as much open space as possible inside the fence along the installation perimeter.

- When selecting a site for a facility, consider the facility design tradeoffs between the fact that elevated sites generally enhance surveillance of the surrounding area and the fact that adjacent high terrain or structures outside the base boundary may allow observation of on-base areas by outsiders.

- Recognize that dense vegetation in proximity to a facility can screen covert activity and should be avoided. Either avoid such areas or plan to remove some of the vegetation.

- Avoid low-lying topographic areas when siting facilities because airborne chemical, biological, and radiological agents, which are commonly heavier than air, can be trapped in those low-lying areas.

5-3.2 **Site Planning and Space Management.** Defensible space, access control, and standoff distance are key drivers in all aspects of development planning and site selection. The placement of buildings offers some challenges to security and antiterrorism and installation master planning. For example, clustering buildings or concentrating people, property, and operations in a single location increases opportunities for collateral impacts and single point vulnerabilities. On the other hand, grouping high-risk activities and concentrating personnel and critical functions in a cluster can provide opportunities for maximizing standoff distance and for creating defensible space. While the dispersal of buildings, people, and operations across an installation reduces the risk that an attack on any one location will impact others, such dispersal could have an isolating effect that reduces the effectiveness of existing security provisions, increases the complexity of emergency response, and creates less defensible space. Tradeoffs need to be carefully considered by planners; however, as illustrated in Figure 5-1, consolidating facilities that are functionally compatible and have similar threat levels reduces the perimeter area to be protected, limits access points, and results in defensible space that can be protected more efficiently. Other development or space management considerations include:

- Consider placement, orientation, and proximity of facilities with common functional uses (operations, administrative, support, logistics, housing etc) or similar threat levels to maximize opportunities for more efficient security.

- Avoid collocating high risk operations with low risk operations.

- Avoid locating facilities considered to be high risk in areas near uncontrolled public areas.

- Consider siting facilities to maximize opportunities for observation from nearby facilities as illustrated in Figure 5-2.

- Where possible, provide separation distances of at least 10 meters (33 feet) to minimize collateral damage in an explosive or indirect fire event.

- Consider locating safe havens or collective protection facilities with appropriate protection where large numbers of people could congregate in the event of an attack such as a chemical attack.

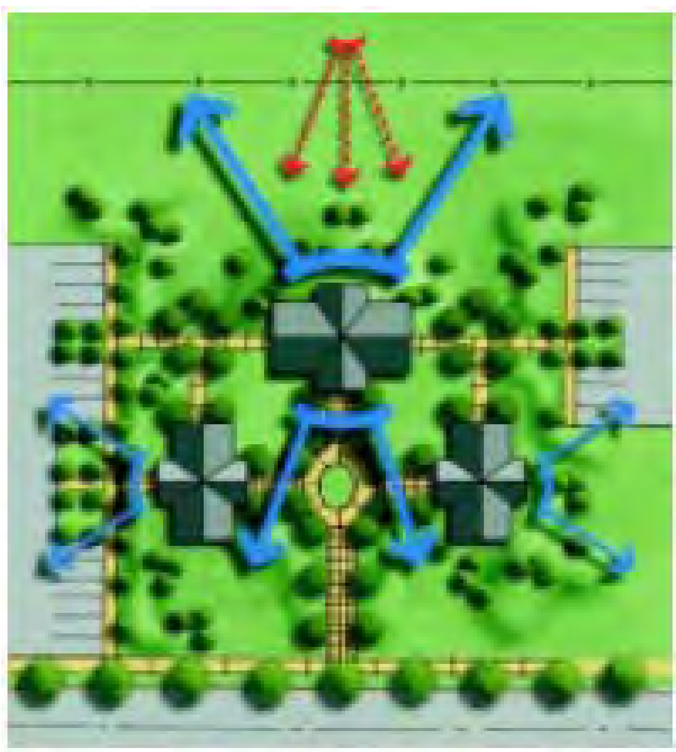
- Where possible, isolate loading docks and mail rooms to minimize the effects of explosives detonate within them on surrounding areas and other areas within the buildings. Where possible separate loading docks from other service areas and utility mains by at least 15 meters (approximately 50 feet.) Likewise, locate mail rooms on exterior walls of buildings away from main entrances or areas containing critical utility services.

5-3.3 **Vehicle Access and Circulation.** Vehicle bomb threats are among the most severe terrorist threats that might be expected on an installation. Most of the mitigating measures for such attacks are applied either at entry control points or at individual buildings. There are, however, some master planning oriented considerations that can reduce requirements for countermeasures to resist these attacks.

5-3.3.1 **Entry Control.** Controlling which vehicles gain access through controlled perimeters and controlling what those vehicles carry is a central factor in protecting against vehicle bombs. While design of entry control points is both beyond the scope of this UFC and not specifically a master planning issue, there are significant master planning considerations in establishing entry control points. The most significant such issue is establishing the appropriate number of entry control points. That number will be based on the number of vehicles that must enter the installation or interior controlled

Figure 5-1. Consolidated vs. Separated Facilities

Figure 5-2. Opportunities for Observation from Adjacent Facilities



perimeter and the number of personnel available to operate them. Also, because entry control point design to accommodate large trucks is more demanding than design to support personal and similar vehicles, master planners should consider establishing separate entry control points for trucks. The remaining significant master planning issue for entry control points is to ensure that the necessary space for them is figured into the master plan.

5-3.3.2. **Vehicle Circulation.** There are a number of goals relating to controlling potential threat vehicles that have master planning implications. The primary ones are keeping vehicles as far from buildings to which they might be a threat as possible, controlling their speed, and controlling their approaches. Keeping vehicles away from buildings can be addressed during site design for individual buildings, but it can also be addressed through measures such as road routings, road closures, and road restrictions, all of which have potential master planning issues. Vehicle speed can be addressed through such measures as creating curves in roads through road design, application of barriers, traffic calming devices, and traffic circles. Controlling approaches to buildings generally is done through road and parking lot configuration and closures. While parking lot entrance and layout is predominantly a facility planning issue, they can have an impact on master planning in that they may affect adjacent roads and traffic patterns. Figures 5-3 and 5-4 illustrate some of these principles of vehicle circulation through master planning. Consider the following:

- Where possible, designate centralized delivery points for commercial vehicles and limit the routes those vehicles use to access those points.

- Route roads away from buildings to which vehicle bomb threats may apply.

- Limit road access near buildings to which vehicle bomb threats may apply through road removal, road closures, and road restrictions. Figure 5-5 illustrates road closures to establish standoff distance to a building.

- Control vehicle speed by designing sharp curves into roadways through road design or placing barriers to create “serpentines,” employing traffic calming devices, or building traffic circles.

- Provide centralized parking to multiple buildings to the extent possible to maximize opportunities to provide standoff between parking and buildings.

- Eliminate straight-line approaches to buildings by rerouting or closing nearby roads and relocating parking lot entrances. See figure 5-6.

- Design parking lots to limit speed through parking layout and application of planted areas as shown in Figure 5-7.

Figure 5-3. Road Modifications to Reduce Speed

Figure 5-4. Installation Vehicle Circulation Modifications

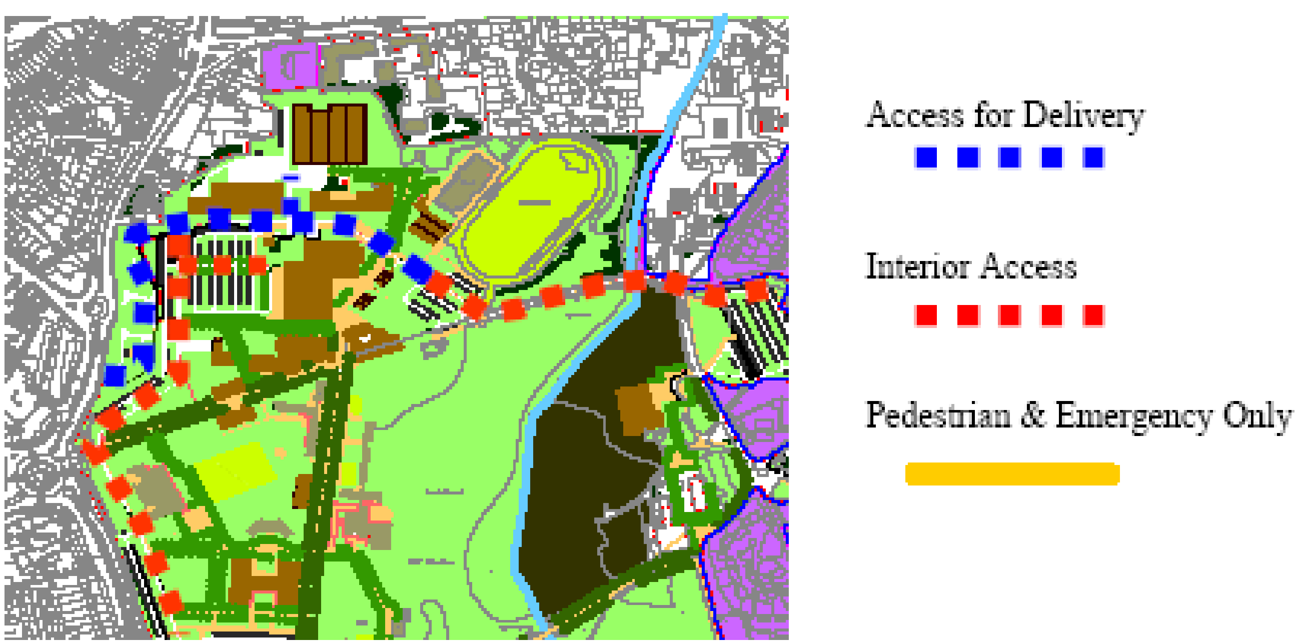


Figure 5-5. Road Closure to Create Standoff

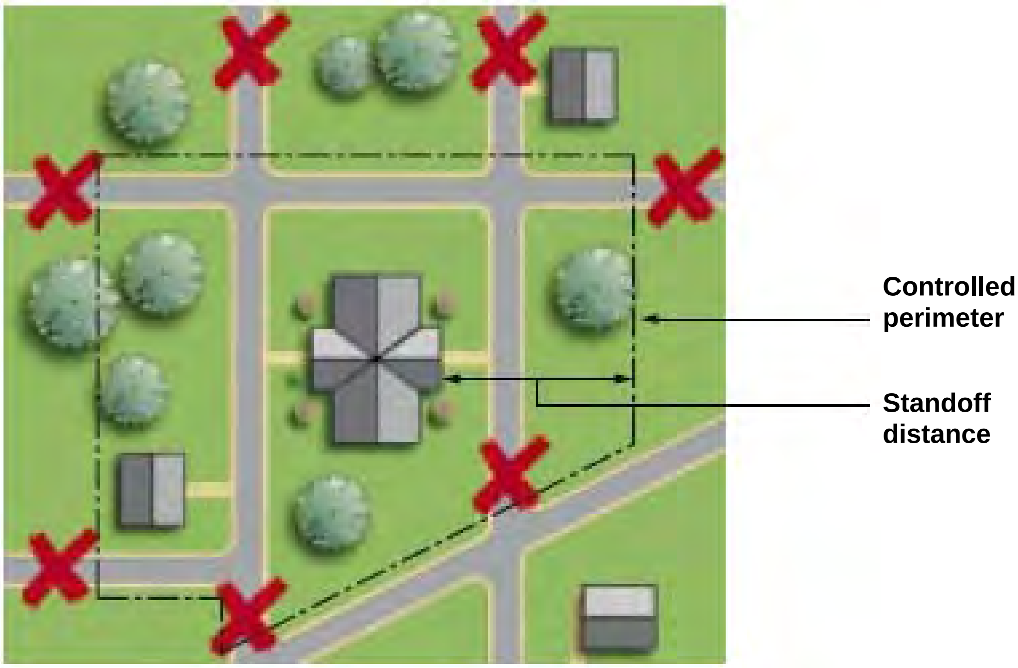
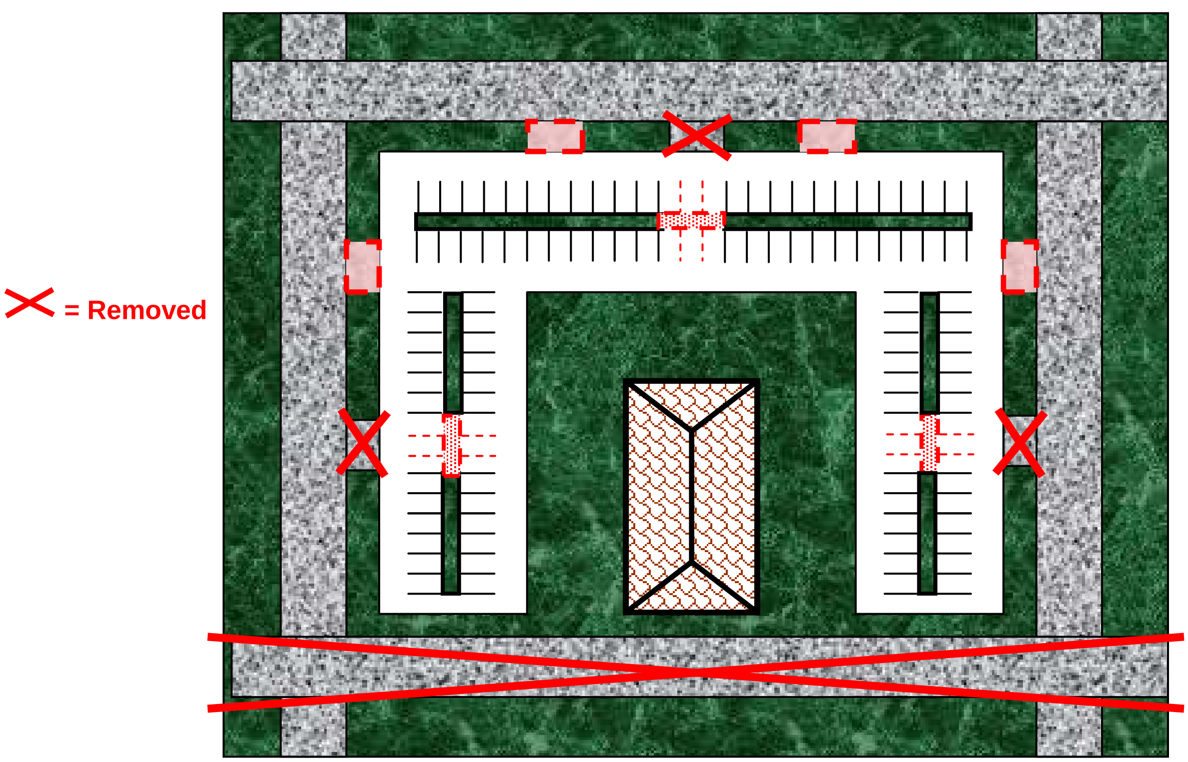


Figure 5-6. Parking and Roadway Modifications



CHAPTER 6

PROJECT COST DEVELOPMENT

6-1 **INTRODUCTION.** This UFC can be used to develop programming level cost estimates for new construction and major renovations (retrofit construction) where protection against the threats identified in this UFC is required. The costs are presented as increases (in percentages) over conventional new construction. By tabulating costs as percentage increases over common new construction, this UFC can avoid providing actual costs, which would be out of date shortly after publication. The general relationships among cost escalations of the various building components are such that the increased percentages approach is valid over time. The cost increases are currently tabulated for only the limited number of building types described below. The costs in this UFC include all labor, material, and markup costs.

6-2 **BUILDING TYPES.** The six building types addressed in the cost tables in this UFC are representative of the construction of a significant majority of the buildings built by DoD. They are selected based on their construction rather than their function. Table 3-1 lists examples of facility types that are represented by those six building types. The six building types are:

- Administrative buildings
- Medical facilities
- Dining facilities
- Barracks with internal entrances to rooms
- Barracks with external entrances to rooms
- Special structures (high bay, long span)

6-3 **BASELINE COSTS.** The baseline costs for the six building types were established by studying a significant number of buildings constructed similarly to buildings of the six types above, including buildings indicated in Table 3-1. Those baseline costs represent the common conventional construction cost for those buildings where there is an area cost factor of one. That means that construction in some areas of the United States or overseas will have to be adjusted according to the applicable area cost factors for those locations.

6-4 **NEW BUILDING CONSTRUCTION.** Use Appendix A to determine cost increases for new construction. Appendix A presents cost increases above the costs of the common conventional construction for the six building types in percentages above the baseline costs. Those increased percentages include the costs of walls, windows, doors, and roofs that are enhanced to mitigate the effects of the various threats to the applicable levels of protection. Refer to Appendix A for a description of the formulation of the cost tables for new construction. Those cost tables are for specific tactics, threat severity levels, and levels of protection. There is also guidance in Appendix A for estimating the additional costs for constructing to avoid progressive collapse.

6-5 **EXISTING BUILDING CONSTRUCTION.** Use Appendix B to determine costs for retrofits to existing construction. The costs in Appendix B are tabulated as increases over the costs of new construction. The reason for basing retrofit costs on increases over new construction costs is that the new construction costs are readily identifiable. The costs for the retrofit construction necessary to mitigate the effects of various threats to the applicable levels of protection were determined and tabulated as percentages above the cost for new construction. It is those percentages that are tabulated in Appendix B. Planning level costs, therefore, can be estimated by applying the percentages in Appendix B to costs in UFC 3-701-XX, *DoD Facilities Pricing Guide*. Refer to Appendix B for a description of the formulation of the cost tables for retrofit construction. Those cost tables are for specific tactics, threat severity levels, and levels of protection.

6-6 **SITEWORK COSTS.** The countermeasures required to mitigate the effects of some tactics require barriers at some locations on the site. Those barriers can be either passive perimeter barriers or active barriers, and they can also include screens. Tables A-52 and B-52 include cost multipliers for such barriers above the cost of baseline barriers for application for new and existing construction, respectively. Those baseline barriers are 8-foot chain-link fence and a 12 foot wide (1 traffic lane) motorized 8-foot chain link gate for passive perimeter and active barriers, respectively. The baseline barriers are very common, and their costs are easy to determine using various cost estimating guides. Representing the costs as multipliers above those of the baseline barriers avoids those costs being out of date shortly after the publishing of this UFC. Experience has shown that the costs of all of the barriers in Tables A-52 and B-52 escalate at approximately the same rate, so the cost multipliers should be adequate for planning purposes indefinitely.

6-7 **DETERMINING NEW CONSTRUCTION COST INCREASES.** Use the following steps to determine the cost increases for new construction for buildings that are built similarly to one of the six building types above as reflected in Table 3-1.

6-7.1 **Determine Representative Building Type.** Determine if one of the six baseline building types above is similar in construction to the building whose cost increase needs to be determined. Refer to Table 3-1 for common facility types that fall within the six baseline building types. Also refer to Table C-2 to determine if the baseline construction of the planned building is likely to be like that for the baseline construction in the cost model in Appendix A. If the baseline is not representative, the cost model in Appendix A may be inaccurate. For example, if the planned building is in a high seismicity or hurricane zone where buildings are commonly built with reinforced concrete walls, and the baseline construction in Table C-2 is brick veneer over metal studs, the cost model in Appendix A may be unreasonably conservative. In that case, it may be possible to use Appendices A and C together to interpolate a valid cost increase. The percentages of total building costs represented by the walls, doors, windows, and roofs are tabulated in Table C-2 to assist in those interpolations.

6-7.2 **Determine Facility Baseline Cost.** For the facility being considered, determine the common cost per unit area using UFC 3-701-05 or other master planning guidance. Initially use the cost for an area cost factor of one.

6-7.3 **Find Applicable Cost Tables.** Use Table A-1 to determine which of the cost tables apply to the facility being planned based on the applicable threats and levels of protection.

6-7.4 **Find the Cost Increase.** Find the applicable cost increase (a percentage) for each applicable tactic, threat severity level, and level of protection. Where multiple tactics apply, record all increases separately for later resolution, except that where the vehicle bomb tactics and the exterior application of the hand delivered device tactic apply, use only the highest cost increase of those three tactics.

6-7.5 **Resolve Construction Components.** Use Appendix C to determine the construction represented by the cost increases tabulated in Appendix A. In some cases, the construction indicted by one tactic will be adequate to provide protection against another. There are no convenient relationships between tactics to model that generically, so the construction components will have to be examined by the user to determine if there is likely to be any redundancy. For example, if the enhancements of building components for indirect fire weapons require heavier components than for hand delivered devices or for direct fire weapons, increases for all three tactics would not be required and the larger of the increases could be used. The percentages of total building costs represented by the walls, doors, windows, and roofs are tabulated in Table C-2 for use in resolving cost increase redundancies.

6-7.6 **Determine Facility Cost Increase.** Multiply the sum of the cost increases for the applicable tactics and multiply that by the facility's unit cost. That cost will be the cost increase for the building.

6-7.7 **Record the Cost Increase.** If the cost estimate is for the purposes of preparing a DD Form 1391, enter the cost increase under Primary Facility as a lump sum under the Antiterrorism/Force Protection line item. If the cost estimate is for another purpose, document the cost increase as is appropriate for that purpose.

6-8 **DETERMINING RETROFIT CONSTRUCTION COST INCREASES.** Use the following steps to determine the cost increases for modifications to existing construction for buildings that are built similarly to one of the six building types above as reflected in Table 3-1.

6-8.1 **Determine Representative Building Type.** Determine if one of the six baseline building types above is similar in construction to the building whose cost increase needs to be determined. Refer to Table 3-1 for common facility types that fall within the six baseline building types. Also refer to Table C-2 to determine if the existing construction of the building being modified is similar to that for the baseline construction in the cost model in Appendix B. If the existing construction is not similar, the cost model in Appendix B may be inaccurate. For example, if the existing building is built with heavy unreinforced masonry walls, and the baseline construction in Table C-2 is brick veneer over metal studs, the cost model in Appendix B may be unreasonably conservative. In that case, it may be possible to use Appendices B and C together to interpolate a valid cost increase. The percentages of total building costs represented by the walls, doors, windows, and roofs are tabulated in Table C-2 to assist in those interpolations.

6-8.2 **Determine Facility Baseline Cost.** For the facility being considered, determine the common cost per unit area for new construction using UFC 3-701-05 or other master planning guidance. Initially use the cost for an area cost factor of one.

6-8.3 **Find Applicable Cost Tables.** Use Table B-1 to determine which of the cost tables apply to the facility being planned based on the applicable threats and levels of protection.

6-8.4 **Find the Cost Increase.** Find the applicable cost increase (a percentage) for each applicable tactic, threat severity level, and level of protection. Where multiple tactics apply, record all increases separately for later resolution, , except that where the vehicle bomb tactics and the exterior application of the hand delivered device tactic apply, use only the highest cost increase of those three tactics..

6-8.5 **Resolve Construction Components.** Use Appendix C to determine the construction represented by the cost increases tabulated in Appendix B. In some cases, the construction indicted by one tactic will be adequate to provide protection against another. There are no convenient relationships between tactics to model that generically, so the construction components will have to be examined by the user to determine if there is likely to be any redundancy. For example, if the enhancements of building components for indirect fire weapons require heavier components than hand delivered devices or for direct fire weapons, increases for all three tactics would not be required and the larger of the increases could be used. The percentages of total building costs represented by the walls, doors, windows, and roofs are tabulated in Table C-2 for use in resolving cost increase redundancies.

6-8.6 **Determine Facility Cost Increase.** Multiply the sum of the cost increases for the applicable tactics and multiply that by the facility unit area cost for new construction. That cost will be the cost for the building modifications.

6-8.7 **Record the Cost Increase.** If the cost estimate is for the purposes of preparing a DD Form 1391, enter the cost increase under Primary Facility as a lump sum under the Antiterrorism/Force Protection line item. If the cost estimate is for another purpose, document the cost increase as is appropriate for that purpose.

6-9 **DETERMINING SITEWORK COSTS.** Where barriers are needed to mitigate the effects one or more tactics, follow the steps below to determine the costs of those barriers. Barrier costs are the same for new construction and for additions to existing facilities because it is assumed that such sitework elements will always be added to a project as opposed to modifying existing barrier construction.

6-9.1 **Identify Applicable Tactic and Threat Severity Level.** Determine whether the barriers needed are for the moving or stationary vehicle bomb tactic or if they are screening to mitigate direct fire weapons. In addition, if the moving vehicle tactic applies, identify the applicable threat severity level. The threat severity level will establish which vehicle must be stopped. For planning purposes, all vehicles are assumed to able to achieve a speed of 50 miles per hour. That assumption will result in a conservative cost estimate that may be adjusted during the design process through effective site design.

6-9.2 **Identify Costs of Baseline Barriers.** Identify the costs of the 8-foot high chain link fence or 12-foot wide, 8-foot high motorized chain link gate for passive or active barriers, respectively. Those costs can be found in cost estimating guides or local costs for those components may be well known. In the latter case, if the local costs are greater than costs for an area cost factor of one, ensure the area cost factor is not added again in the planning documents or adjust the baseline cost by the area cost factor.

6-9.3 **Find Applicable Barrier Multiplier.** Use Table A-52 or B-39 to determine the appropriate cost multipliers for passive perimeter barriers based on the applicable tactic and level of protection. Do the same for active barriers if they are to be used.

6-9.4 **Identify the Applicable Quantities.** Identify the applicable perimeter along which perimeter barriers are required and identify the number of traffic lanes for which active barriers will be needed.

6-9.5 **Determine Barrier Costs.** Multiply the appropriate cost multipliers by the costs of the applicable baseline barriers and multiply that product by the length of the perimeter or the number of traffic lanes that will require barriers, as applicable.

6-9.6 **Record Barrier Costs.** If the cost estimate is for the purposes of preparing a DD Form 1391, enter the barrier costs under Supporting Facilities as a lump sum under the Antiterrorism/Force Protection line item. If the cost estimate is for another purpose, document the cost increase as is appropriate for that purpose

6-10 **EXAMPLE PROBLEM.** The following is an example problem demonstrating how the cost tables are applied for a new construction project. The facility that is being programmed is an 8000 square foot Field Operations Facility whose baseline cost is $162 per square foot. The standoff distance from the building is 100 feet, resulting in a perimeter of 1160 feet, and there will need to be 2 one-lane entries through the perimeter. There is an unobstructed space around the facility of 10 meters. There is a loading dock (10 ft. x 22 ft.) and an entry lobby (15 ft. x 30 ft.) for the building, but no mail room. There is an 18 ft. x 24 ft. internal room that houses assets to which there is a forced entry threat. The design criteria include the following threats:

- Moving vehicle bomb threat at high threat severity level and medium level of protection

- Stationary vehicle bomb tactic at high threat severity level and medium level of protection.

- Hand delivered device tactic at high threat severity level and medium level of protection.

- Direct fire weapon tactic at high threat severity level and high level of protection.

- Forced entry tactic at high threat severity level and medium level of protection. The target asset for this tactic is limited to a single interior room.

6-10.1 **Building Cost Increase.**

6-10.1.1 **Determine Representative Building Type**. By referring to Table 3-1, the field operations facility can be seen to fall under the general category of an administrative building based on its construction.

6-10.1.2 **Determine Facility baseline Cost.** The baseline cost was given in the problem statement as $162 per square foot. Assume the baseline construction given in Appendix C is applicable to this building, so the tables in Appendix A can be used. Assume the baseline interior construction to cost $60 per square foot.

6-10.1.3 **Find Applicable Cost Tables.** The following are the applicable tables for the various tactics (Table A-1):

- For both the moving vehicle and stationary vehicle tactics, use Table A-15.

- For the hand delivered devices tactic, use Table A-3 for the exterior of the building, Table A-29 for the loading dock, and Table A-31 for the entry lobby.

- For the direct fire weapons tactic, use Table A-38.

- For the forced entry tactic, use Table A-48 (interior room).

6-10.1.4 **Find the Cost Increases.** The following are the applicable cost increases for the various tactics.

- For the moving and stationary vehicle tactics, the increase is 30.6% for the administrative facility Construction Type for 100 foot standoff (30.5 m).

- For the hand delivered devices tactic, assume the standoff distance to the building is the limit of the unobstructed space, 10 meters. In that case, the increased building cost will be 28.5%.

- For the hand delivered device at the loading dock, the cost increase to enhance the construction of the small loading dock is 1.5% of the cost of the whole building (medium LOP).

- For the hand delivered device in the entry lobby, the cost increase to enhance construction of the entry lobby is 1.7% of the cost of the whole building (medium LOP).

- For the direct fire weapons tactic, the cost is 37.7% (high LOP).

- For the forced entry tactic, the cost increase is 1.4%.

6-10.1.5 **Resolve Construction Components.** Looking at the construction component identifiers in the applicable tables in Appendix A and using the appropriate tables in Appendix C results in the enhanced construction indicated in Table 6-1. The vehicle bomb tactics and the external hand delivered devices tactic both will affect the exterior of the building. Note that the cost increase for the vehicle bombs is higher than that for the hand delivered device. In comparing the walls, those required for the hand delivered device are thicker than those for the vehicle bombs, but they are reinforced CMU instead of reinforced concrete and they have moderate instead of heavy reinforcement, so they will be less expensive. That can be verified by noting that in table C-3 the 200 mm heavily reinforced concrete wall is above the 300 mm moderately reinforced CMU wall. The construction in that table is arranged from most expensive at the top to least expensive at the bottom. Also note that the other components for the vehicle bomb tactics are heavier than those for the hand delivered device tactic, so the vehicle bomb tactic can be validated to control between those two tactics. Further comparison between the vehicle bomb tactics and the direct fire weapon tactic shows the direct fire weapon cost increase being higher, but in examining the building components, only the windows seem to be heavier for the direct fire weapon tactic. Because there is no easy way using these tables to determine the relative contribution of individual building components to the total cost increase, use the higher of the two cost increases (37.7%), which will ensure that all the necessary costs are covered. The other tactics do not need to be resolved because they relate to separate internal spaces.

6-10.1.6 **Determine Facility Cost Increase.** The following calculations show the total cost increase necessary to accommodate the requirements for mitigating the effects of all tactics (rounded to the nearest $1000):

- Building Exterior: 37.7% x ($162 per square foot X 8000 square feet) = $489,000

- Loading Dock: 1.5% x ($162 per square foot X 8000 square feet) = $19,000

- Entry Lobby: 1.7% x ($162 per square foot X 8000 square feet) = $22,000
- Secure Room: 1.4% x ($162 per square foot X 8000 square feet) = $18,000

Total: $548,000

6-10.1.7 **Record the Cost Increase.** The total cost increase for the building ($548,000) would be entered as a lump sum on a separate line item for Antiterrorism Measures under the Primary Facility if a DD Form 1391 was being prepared.

Table 6-1. Example Problem Building Components

Tactic	Wall	Window	Door	Roof/Ceiling
Vehicle Bombs (From Table C-3)	200 mm heavily reinforced concrete	1/4" + 4 x 5/32" glass + 3 x 0.045 in PVB	25 psi blast door	20K10 L=30', B=6'
Hand Delivered Devices (external) (From Table C-3)	300 mm moderately reinforced CMU	1/4" + 2 x 5/32" glass + 0.060 in PVB	Hollow metal with backer wall	20K10 L=30', B=6'
Hand Delivered Devices (Loading Dock) * (From Table C-7)	24-inch moderately reinforced concrete	None	-	27-inch heavily reinforced concrete
Hand Delivered Devices (Lobby)* (From Table C-7)	14-inch moderately reinforced concrete	None	-	14-inch heavily reinforced concrete
Direct Fire Weapons (From Table C-10)	8-inch fully grouted CMU	1-5/8 inch laminated glass with 1/4 inch polycarbonate	Industrial door with 11/16 inch armor plate	No special construction
Forced Entry * (From Table C-12)	8-inch grout filled CMU with #6 bars at 4 inches vertically and at 8 inches horizontally	None	12 gage hollow metal filled with lightweight fireproofing	7-inch re3inforced concrete with 6x6 welded wire mesh, 10 gage steel deck
* Note: Internal construction not affecting other components				

6-10.2 **Barrier Costs.** Only the vehicle bomb tactics have any barrier requirements in this example.

6-10.2.1 **Identify Applicable Tactic and Threat Severity Level.** Both the moving and stationary vehicle bomb tactics apply, but the threat severity level is only an issue for the moving vehicle bomb, for which the threat severity level is high.

6-10.2.2 **Identify Costs of Baseline Barriers.** The baseline barrier costs are for 8-foot chain link fence and motorized gates. Those costs can be found in common cost engineering guides. Assume for the purpose of this problem that the cost of the chain link fence is $15 per linear foot (lf) and the cost of the gates is $5000 per traffic lane.

6-10.2.3 **Find Applicable Barrier Multiplier.** From Table A-52, the cost multipliers for perimeter barriers and active barriers for the high threat severity level of the moving vehicle bomb tactic are 5.0 and 7.4, respectively. Note that the costs for the stationary vehicle bomb tactic are less, so the requirements to mitigate the effects of the moving vehicle bomb will control the barrier costs.

6-10.2.4 **Identify the Applicable Quantities.** The problem statement says that the site perimeter is 1160 feet and there need to be two one-lane entries, which would require active barriers.

6-10.2.5 **Determine Barrier Costs.** The following calculations show the total costs for barriers for this problem:

- Perimeter Barriers: 5.0 x $15 per lf x 1160 lf = $87,000
- Active Barriers: 7.4 x $5000 per lane * 2 lanes = <u>$74,000</u>

Total: $161,000

6-10.2.6 **Record Barrier Costs.** The total cost for barriers would be entered as a lump sum on a separate line item for Antiterrorism Measures under the Supporting Facilities if a DD Form 1391 was being prepared. Information as it would be entered onto the front page of a DD Form 1391 is illustrated in Table 6-2.

Table 6-2. Illustrative DD Form 1391 Front Page Cost Presentation

ARMY		2013		3 DEC 2007
FORT ANYWHERE USA		CIDC Field Operations Facility		
PRIMARY FACILITY				1,787
Field Operations Facility	SF	8000	142	1,136
Special Foundations	SF	8000	12.55	101
EMCS Preparation / Install	SF	8000	0.73	6
IDS Preparation / Install – Arms Room	SF	600	1.19	2
Building Information Systems	LS	--	--	62
Antiterrorism / Force Protection	LS	--	--	548
SUPPORTING FACILITIES				1,435
Electric Service	LS	--	--	85
Water, Sewer, Gas	LS	--	--	58
Steam and/or Chilled Water Distribution	LS	--	--	44
Paving, Walks, Curbs and Gutters	LS	--	--	425
Storm Drainage	LS	--	--	62
Site Improvements (200) Demo (376)	LS	--	--	576
Information Systems	LS	--	--	24
Antiterrorism / Force Protection	LS	--	--	161
ESTIMATED CONTRACT COST				3,290
CONTINGENCY PERCENT (5.00%)				165
SUBTOTAL				3,455
SUPERVISION, INSPECTION, AND OVERHEAD (5.7%)				197
TOTAL REQUEST				3,652
TOTAL REQUEST ROUNDED				3,700
INSTALLED EQUIPMENT – OTHER APPROPRIATIONS				22

GLOSSARY

ACRONYMS:

A_V	Asset Value
AA&E	Arms, Ammunition, and Explosives
AFCESA	Air Force Civil Engineering Support Agency
ANSI	American National Standards Institute
BCE	Base Civil Engineer
CARVER	Criticality, Accessibility, Recuperability, Vulnerability, Effect, and Recognizability
CCB	Construction Criteria Base
CCI	Controlled Cryptographic Items
CCTV	Closed Circuit Television
CMU	Concrete Masonry Unit
DBT	Design Basis Threat
DEA	Drug Enforcement Agency
DoD	Department of Defense
DPW	Directorate of Public Works
DSHARPP	Demography, Symbolism, History, Accessibility, Recognizability, Population, Proximity
EOD	Explosive Ordnance Disposal
FPCON	Force Protection Condition
HEPA	High Efficiency Particulate Air
HVAC	Heating, Ventilating, and Air Conditioning
IDS	Intrusion Detection System

IED	Improvised Explosive Device
IID	Improvised Incendiary Device
Kg	Kilogram
kPa	Kilopascal
Lbs	Pounds
LHA	Amphibious Helicopter Assault
LHD	Amphibious Helicopter Dock
LOP	Level of Protection
mm	millimeter
MS-13	Mara Salvatruche
MSC	Military Sealift Command
MSHARPP	Mission, Symbolism, History, Accessibility, Recognizability, Population, and Proximity
NAVFAC	Naval Facilities Engineering Command
P_E	Protection Effectiveness Factor
P_I	Initial Protection Factor
P_{IAVG}	Average Initial Protection Factor
PIN	Personal Identification Factor
POL	Petroleum, Oil, and Lubricants
PVB	Polyvinyl-Butyral
PSI	Pounds per square inch
R	Risk Level
RAVA	Risk Analysis Vulnerability Assessment
RDT&E	Research, Development, Test, and Evaluation

SBX	Sea Based X-Band Radar
SEA	Southeast Asia
SSBN	Subsurface Ballistic Nuclear
STC	Sound Transmission Class
T_E	Threat Effectiveness Factor
T_L	Threat Likelihood Factor
T_{LH}	Highest Threat Likelihood Factor (for aggressor group)
TIC	Toxic Industrial Chemical
TIM	Toxic Industrial Materials
TNT	Tri-nitro Toluene
UFC	Unified Facilities Criteria
UL	Underwriters Laboratories
USACE	United States Army Corps of Engineers
USEUCOM	United States European Command
USCENTCOM	United States Central Command

TERMS:

Area Cost Factor. A multiplier by which facility costs can be multiplied to account for increases in local construction costs based on labor, materials, and equipment costs for specific localities.

Access control. For the purposes of this document, any combination of barriers, gates, electronic security equipment, and/or guards that can deny entry to unauthorized personnel or vehicles.

Active vehicle barrier. A vehicle barrier that must be manually or automatically deployed in response to detection of a threat.

Aggressor. Any person seeking to compromise an asset. Aggressor categories include protesters, criminals, terrorists, and subversives.

Aggressor group. For the purposes of calculating risk, broad groupings of aggressors who exhibit similar threat characteristics.

Antitank weapons. For the purposes of this document, shoulder fired, direct fire weapons consisting of a rocket propelled projectile with a conical shaped charge warhead that are designed to perforate the armor of armored vehicles.

Antiterrorism. Defensive measures used to reduce the vulnerability of individuals and property to terrorist acts, to include limited response and containment by local military and civilian forces.

Assessment. Visual verification of the validity of an alarm from an electronic security system.

Assessment zone. In waterfront security, the area well beyond the government's property line.

Asset. A resource requiring protection.

Asset value rating. A measurement of the importance of an asset to its user.

Baseline cost. The common conventional construction cost of an element or a building.

Biological agents. Pathogens and toxins that can be used to contaminate air or water.

Breaching. Making a hole completely through a building surface through the use of tools or explosives.

Building elements. Components of buildings and countermeasures associated directly with building interiors and exterior surface features.

Building hardening. Enhanced conventional construction that mitigates threat hazards where standoff distance is limited. Building hardening may also be considered to include the prohibition of certain building materials and construction techniques.

Chemical Agents. Chemicals, including toxic industrial chemicals, toxic industrial materials, and military chemical agents that can be used to contaminate air or water.

Collective protection. Establishment of an area of a building where personnel can work or shelter during release of a chemical, biological, or radiological agent.

Combatant command. A unified or specified command with a broad continuing mission under a single commander established and so designated by the President, through the Secretary of Defense and with the advice and assistance of the Chairman of the Joint Chiefs of Staff. Combatant commands typically have geographic or functional responsibilities. See also specified command; unified command.

Controlled perimeter. A physical boundary at which vehicle access is controlled at the perimeter of an installation, an area within an installation, or another area with restricted access. A physical boundary will be considered as a sufficient means to channel vehicles to the access control points. At a minimum, access control at a controlled perimeter requires the demonstrated capability to search for and detect explosives. Where the controlled perimeter includes a shoreline and there is no defined perimeter beyond the shoreline, the boundary will be at the mean high water mark.

Critical Asset. Any facility, equipment, service or resource considered essential to DoD operations in peace, crisis, and war and warranting measures and precautions to ensure its continued efficient operation, protection from disruption, degradation, or destruction, and timely restoration. Critical assets may be DoD assets or other government or private assets, DoD O-2000.12-H. (e.g. industrial or infrastructure critical assets), domestic or foreign, whose disruption or loss would render DoD critical assets ineffective or otherwise seriously disrupt DoD operations. Critical assets include traditional “physical” facilities and equipment, non-physical assets (such as software systems), or “assets” that are distributed in nature (such as command and control networks, wide area networks or similar computer-based networks).

Critical Infrastructure. Infrastructure deemed essential to DoD operations or the functioning of a Critical Asset.

Design Basis Threat. The threat upon which a system of countermeasures protecting assets is based. The design basis threat includes the aggressor tactics and the associated weapons, explosives, tools, and agents.

Direct fire weapons. A weapon that is fired from a distance directly at a target and which requires an unobstructed line of sight from the weapon to the target.

Design criteria. For the purposes of this document, the basis for defining a protective system that mitigates vulnerabilities to assets. Design criteria include assets, threats, levels of protection, and design constraints.

Dirty bomb. A bomb that combines conventional explosives with radioactive materials in the form of powder or pellets that are dispersed by the explosion to contaminate a wide area. (Also known as a Radiological Dispersal Device.)

Energy absorption screen. A vertical or horizontal surface place at a standoff distance from a target that reduces the energy of a projectile to limit its effect on the target.

Engagement zone. In waterfront security, the area between a line of floating barriers and an asset.

Entry Control Point. A continuously or intermittently manned station at which entry through a perimeter is controlled.

Equipment. As part of a protective system, countermeasures such an electronic security system elements and other devices used by personnel for detection and assessment of threats or weapons, tools, explosives, or chemical, biological, or radiological agents.

Exclusive standoff zones. A controlled area surrounding a facility into which only service and delivery vehicles and other vehicles that must be allowed access within the perimeter are allowed. The perimeter of this area is defined by perimeter barriers and is set at a standoff distance sufficient to reduce the blast effects of vehicle bomb detonations on the protected facility.

Expeditionary construction. Construction that commonly built in forward areas and that is intended to be used for no more than 1 year after it is erected. Common structures typically include tents, Small and Medium Shelter Systems, Expandable Shelter Containers (ESC), ISO and CONEX containers, and General Purpose (GP) Medium tents and GP Large tents, etc.

Explosive safety. The practice of providing the maximum possible protection to personnel and property, both inside and outside the installation, from the damaging effects of potential accidents involving DoD ammunition and explosives.

Force Protection Conditions (FPCONs). A DoD-approved system that standardizes the Departments' identification and recommended preventive actions and responses to terrorist threats against U.S. personnel and facilities. This system is the principle means for a commander to apply an operational decision on how to protect against terrorism and facilitates inter-Service coordination and support for antiterrorism activities.

Fragment. For the purposes of developing protective systems, pieces of the materials surrounding an explosive that may be propelled at high velocity toward a building or other target as a result of an explosion of a bomb or a warhead.

General design strategy. The basic approach to developing a protective system to mitigate the effects of a given tactic. It governs the general application of construction, building support systems, equipment, manpower, and procedures.

Historic preservation. Protection afforded to districts, sites, buildings, structures, or objects listed on or eligible for inclusion on the National Register of Historic Places in accordance with the National Historic Preservation Act (Public Law 89-665 as amended; 16 USC 470 et seq)

Incendiary devices. Devices designed to spread fire.

Indirect fire weapons. Weapons that are designed to propel projectiles over obstacles, potentially over long distances, to effectively target assets where there are no clear lines of sight.

Inhabited facilities. Buildings or portions of buildings routinely occupied by 11 or more DoD personnel and with a population density of greater than one person per 40 gross square meters (430 gross square feet). This density generally excludes industrial, maintenance, and storage facilities, except for more densely populated portions of those buildings such as administrative areas. The inhabited building designation also applies to expeditionary and temporary structures with similar population densities. In a building that meets the criterion of having 11 or more personnel, with portions that do not have sufficient population densities to qualify as inhabited buildings, those portions that have sufficient population densities will be considered inhabited buildings while the remainder of the building may be considered uninhabited, subject to provisions of these standards. An example would be a hangar with an administrative area within it. The administrative area would be treated as an inhabited building while the remainder of the hangar could be treated as uninhabited. (Note: This definition differs significantly from the definition for inhabited building used by DoD 6055.9-STD and is not construed to be authorization to deviate from criteria of DoD 6055.9-STD.)

Level of protection. The degree to which an asset (e.g., a person, a piece of equipment, or an object, etc.) is protected against injury or damage from an attack.

Likelihood rating. A number between 0 and 1 that measures how likely an aggressor is to attempt to compromise a given asset.

Manpower. Countermeasures that relate to the use of guards or other personnel necessary to implement or operate elements of the protective system.

Military chemical agents. Liquid, gaseous, or aerosolized chemical agents designed for use in military weapons.

Minimum standoff distance. A standoff distance less than the Conventional Construction Standoff Distance at which the required level of protection can be shown to be achieved through analysis or can be achieved through building hardening or other mitigating construction or retrofit.

Overpressurization class. A measure of collective protection capability based on event duration and wind speed.

Passive Perimeter barriers. Vehicle barriers that are permanently deployed and do not require a response to be effective and fences, walls, screens, landforms, and lines of vegetation applied along an exterior perimeter used to obscure vision, hinder personnel access, or hinder or prevent vehicle access.

Penetration. Relating to bullets or fragments, entry into a material without passing all the way through.

Perforation. Relating to bullets and fragments, passing all the way through a material.

Planning team. A team of people with responsibilities relating to a project that is formed to develop design criteria and review material from all phases of the design process.

Predetonation screen. A fence, wall, or screen that causes an antitank round to detonate before it reaches its target. When placed at the proper distance for the facility construction, the screen will prevent penetration of the facility exterior by the antitank round.

Protective system. An integrated system of countermeasures designed to protect assets against threats to specific levels of protection. Protective systems include building elements, sitework elements, equipment, and manpower and procedures.

Protection Effectiveness factor. A number between 0 and 1 that reflects the effectiveness of countermeasures in mitigating the vulnerabilities associated with a given threat.

Procedures. Countermeasures that relate to actions taken by people, including guards and building occupants, to implement or operate elements of the protective system.

Risk. A means to quantify the combined issues of the value of an asset or the impact of its loss, the likelihood of the asset being attacked, and the effectiveness of the protection afforded the asset that can be used as a tool in making decisions about asset protection.

Risk analysis. The process of determining risk levels for assets.

Risk management. The process of evaluating how changes in countermeasures application affect risk levels and costs for the purpose of decision making.

Risk level. A number between 0 and 1 that reflects the product of asset value, aggressor likelihood, and protection effectiveness.

Shielding walls. Walls designed to intercept and resist fragment penetration and possibly to attenuate blast effects.

Sitework elements. Countermeasures that are applied beyond 1.5 meters (5 feet) from a building, excluding countermeasures categorized under equipment.

Sound Transmission Class. A numerical evaluation of an assembly’s effectiveness in isolating airborne sound transmission.

Spall. The condition in which pieces of a material are broken loose from the inner surface of a wall, roof, or similar element by tensile forces that are created when a compression shock wave travels through the body and reflects from the surface.

Specific design strategy. The approach to applying general design strategies based on the applicable levels of protection.

Standoff distance. A distance maintained between a building or portion thereof and the potential location for a weapon or explosive detonation.

Surreptitious entry. A method of entry, such as lock manipulation or radiological attack on a combination lock, which would not be detectable during normal use or during inspection by a qualified person.

Sustainable design. The design, construction, operation, and reuse/removal of the built environment (infrastructure and buildings) in an environmentally and energy efficient manner. (Synonymous with Sustainable Design is "Green Building.")

Tactics. The specific methods of achieving the aggressor's goals to injure personnel, destroy assets, or steal materiel or information.

Terrorist Threat Level. An intelligence threat assessment of the level of terrorist threat faced by U.S. personnel and interests. The assessment is based on a continuous intelligence analysis of a minimum of four elements: terrorist group operational capability, intentions, activity, and operational environment. There are four threat levels: LOW, MODERATE, SIGNIFICANT, and HIGH. Threat levels should not be confused with FPCONs. Threat level assessments are provided to senior leaders to assist them determine the appropriate local FPCON.

TEMPEST. An unclassified short name referring to investigations and studies of compromising emanations. It is sometimes used synonymously for the term "compromising emanations"; e.g., TEMPEST tests, TEMPEST inspections.

TEMPEST Shielding. Shielding (commonly metallic) that attenuates compromising emanations.

Temporary construction. Construction with an expected occupancy of 3 years or less. Common structures typically includes wood frame and rigid wall construction, and such things as Southeast Asia (SEA) Huts, hardback tents, ISO and CONEX containers, pre-engineered buildings, trailers, stress tensioned shelters, Expandable Shelter Containers (ESC), and Aircraft Hangars (ACH).

Threat Effectiveness rating. A number between 0 and 1 that reflects the capabilities of aggressors to find weaknesses in security measures and to exploit them considering their sophistication, motivation, and risk acceptance.

Threat zone. In waterfront security, the area between the government's property line and the line of floating barriers.

TNT equivalent weight. The weight of TNT (trinitrotoluene) that has an equivalent energetic output to that of a different weight of another explosive compound.

Toxic Industrial chemicals. Liquid, particulate, and gaseous chemicals used in commercial and industrial applications.

Toxic Industrial materials. Liquid, particulate, and gaseous materials used in commercial and industrial applications.

Unobstructed space. Space within 10 meters (33 feet) of an inhabited building that does not allow for concealment from observation of explosive devices 150 mm (6 inches) or greater in height.

Vulnerability. Any weakness in the design or operation of a protective system for an asset that can be exploited by an aggressor to disrupt, damage, destroy, injure, or otherwise compromise the asset.

Warning zone. In waterfront security, the area just outside the government's property line.

APPENDIX A

NEW CONSTRUCTION COST TABLES

A-1 **INTRODUCTION.** The purpose of the tables in this appendix is to provide planning level estimates of cost increases for new construction of buildings representative of those commonly built by the Department of Defense. The costs tabulated are increases (in percentage of baseline cost) over the common conventional construction for those building types or rooms within buildings of those types.

A-2 **NAVIGATING THE TABLES.** Table A-1 provides a guide to locating the cost tables for various threats. It is organized by tactic, threat severity level, and level of protection for all but the hand delivered devices and forced entry tactics. For the hand delivered devices tactic, the costs are tabulated by external attack, attacks on interior spaces for improvised incendiary devices, and attacks on mail rooms, loading docks, and entrance areas using different explosive weights.

A-3 **BUILDING COMPONENT COST FORMULATION.** The cost tables were formulated by arraying a number of components that would meet the requirements of mitigating the effects of particular tactics to the applicable threat severity levels and levels of protection. Those components were then sorted based on cost, and the least cost components were entered into a building cost model. That building cost model included the baseline costs of the building components that were found to be commonly used for those buildings and that were representative of the building components that are in military construction pricing guidance. The costs in these tables are for an area cost factor of one.

The additional costs for the enhanced construction components over the conventional component costs were determined as a percentage increase over conventional costs. The percentages of the building cost represented by each of the components were built into the model; therefore, the percentage increase in the total building costs represented by the enhanced building components could be determined. It is those cost increases that are tabulated.

Note that in the case of administrative buildings the cost increases are often very high. That is due to the fact that those buildings commonly have a high percentage of windows. Replacement windows to provide levels of protection against many of the threats covered by this UFC are very costly. Reducing window areas in those buildings may be an effective way to reduce costs; however, this appendix does not directly support determining those cost reductions.

A-4 **PROGRESSIVE COLLAPSE COSTS.** UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings,* requires that all inhabited buildings three stories or greater in height must be designed to resist progressive collapse. The following costs should be added to buildings of three of more stories in addition to any other costs arising out of this appendix. Because detailed guidance for application of those costs have not been developed, use the highest costs in the applicable ranges below:

- Framed structures
  - Very Low and Low Levels of Protection: 0.13 – 0.74%
  - Medium and High Levels of Protection: 0.32 – 2.74%
- Shear wall type construction
  - Masonry wall / reinforced concrete slab floor construction: 1.29% to 2.80%
  - Timber construction: 5.01% to 6.11%

A-5 **SITEWORK COST MULTIPLIERS.** Sitework costs are tabulated in Table A-57 as multiples of a baseline barrier. The baseline barrier is either an 8-foot chain link fence (7-foot fabric with outrigger) or an 8-foot high, 12-foot wide (one traffic lane) motorized chain link gate. The costs of those two barriers are easily located in commercial cost estimating guides or in military construction cost databases. The cost multipliers for other barriers were determined by comparing the costs of those barriers to the costs of the baseline barriers. The barriers in Table A-57 are identified by threat severity level for perimeter and active barriers. The barriers associated with those threat severity levels are identified in Appendix C. Boat barrier costs are not included because the costs vary widely and the design guidance is still being developed.

Table A-1. Guide to Cost Tables

Tactic		Threat Severity Level	Explosive Weight or other Information	Level of Protection	Table	Page
Vehicle Bombs		VL	25 kg (55 lbs)	VL	A-2	A-6
				L	A-2	A-6
				M	A-3	A-7
				H	A-4	A-8
		L	100 kg (220 lbs)	VL	A-5	A-9
				L	A-6	A-10
				M	A-7	A-11
				H	A-8	A-12
		M	250 kg (550 lbs)	VL	A-9	A-14
				L	A-10	A-15
				M	A-11	A-16
				H	A-12	A-18
		H	500 kg (1100 lbs)	VL	A-13	A-20
				L	A-14	A-21
				M	A-15	A-22
				H	A-16	A-24
		VH	2000 kg (4400 lbs)	VL	A-17	A-26
				L	A-18	A-27
				M	A-19	A-29
				H	A-20	A-31
		Special Case	9000 kg (19,800 lbs)	VL	A-21	A-33
				L	A-22	A-34
				M	A-23	A-36
				H	A-24	A-38
Hand Delivered Devices	**Exterior**	L	IID Only	All	A-25	A-40
		M	1 kg (2.2 lbs)	All	A-26	A-40
		H	25 kg (55 lbs)	VL	A-2	A-6
				L	A-2	A-6
				M	A-3	A-7
				H	A-4	A-8
	All Interior Spaces	L	IID Only	No cost increase[1]		
	Mail rooms	M & H	1 kg (2.2 lbs)	All	A-27	A-41
	Loading Docks	M	1 kg (2.2 lbs)	All	A-28	A-42
		H	25 kg (55 lbs)	All	A-29	A-43
	Entry Areas	M	1 kg (2.2 lbs)	All	A-30	A-44
		H	25 kg (55 lbs)	All	A-31	A-45

Table A-1 (continued)

Tactic		Threat Severity Level	Explosive Weight or other Information	Level of Protection	Table	Page
Indirect Fire Weapons		L	IID	All	A-32	A-46
		M	82 mm Mortar	All	A-33	A-47
		H	Rocket	All	A-34	A-48
		VH	Imp. Mortar	All	A-35	A-49
Direct Fire Weapons		L	UL Level 3	All	A-36	A-50
		M	UL Level 5	All	A-37	A-51
		H	UL Level 8	All	A-38	A-52
		VH	Antitank weapon & 0.50 caliber	All	A-39	A-53
Airborne Contamination		All	Chemical, biological, and radiological agents	All	A-40	A-54
Waterborne Contamination		All	Chemical, biological, and radiological agents	All	A-41	A-54
Waterfront Attack	**Surface or Submerged Attack**	L	100 kg (surf) explosives 25 kg (sub) explosives UL Level 5	All[2]	A-5 to A-8 A-2 to A-4 A-37	A-9 to A-13 A-6 to A-8 A-51
		M	250 kg (surf) explosives 25 kg (sub) explosives UL Level 10	All[2]	A-9 to A-12 A-2 to A-4 A-39	A-14 to A-19 A-6 to A-8 A-53
		H	500 kg explosives (surf & sub) AT weapons & UL Lev 10	All[2]	A-13 to A-16 A-39	A-20 to A-25 A-53

Table A-1 (continued)

Forced Entry	**Exterior** [4]	L	Various Forced Entry Tools	All	A-42	A-55
		M		All	A-43	A-56
		H		All	A-44	A-57
		VH		All	A-45	A-58
	Interior [4]	L	Various Forced Entry Tools	All	A-46	A-59
		M		All	A-47	A-61
		H		All	A-48	A-63
		VH		All	A-48[3]	A-63
Covert Entry		L	None	All	A-49	A-65
		M		All	A-50	A-65
		H		All	A-51	A-66
		VH		All	A-52	A-66
Visual Surveillance		H	Ocular devices	H	A-53	A-67
Acoustics Eavesdropping	**Exterior** [4]	H	Sound amplification or laser "listening" devises	All	A-54	A-68
	Interior [4]				A-55	A-69
Electronic Emanations Eavesdropping	**Exterior** [4]	H	Electronic emanations interception equipment	All	A-56	A-70
	Interior [4]					
Sitework Costs		All	None	All	A-57	A-71

Notes:

1. No cost increases over conventional construction because interior construction commonly fire resistant and it is assumed there are no windows.
2. Apply applicable table based on level of protection
3. Do not use very high threat severity level for interior case because it includes explosives, which are considered unlikely due to collateral damage. Apply cost for High threat severity level.
4. Use the exterior tables where entire buildings or large portions of them are to be protected. In the latter case, use percentages of the costs shown in the table based on the percentage of building perimeter area that will be protected. Use interior tables where protection will be focused on interior rooms within buildings. Combinations of interior and exterior costs can also be used where applicable.

Table A-2. 25 kg- TNT Very Low and Low Level of Protection

STANDOFF DISTANCE (meters)	% Increase				Construction Type				STANDOFF DISTANCE (meters)	%Δ	Construction Type				STANDOFF DISTANCE (meters)	%Δ	Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs		DINING FACILITY	Walls	Windows	Doors	Roofs		SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
Very Low LOP																				
≥10	9.5	1.7	1.7	1.7	-	A	-	-	≥10	1.2	-	A	-	-	≥10	1.7	-	A	-	-
Low LOP																				
10.0- 13.3	16.8	7.0	7.5	3.2	B	B	B	6	10.0-10.8	6.8	B	B	B	31	10.0-10.2	6.5	C	B	B	50
13.4-14.4	16.3	6.3	7.2	2.9	B	B	B	5	10.9-12.1	5.6	B	B	B	30	10.3-14.5	6.3	B	B	B	50
14.5	16.0	6.1	7.2	2.7	A	B	B	5	12.2-13.2	5.0	B	B	B	26	14.6-16.4	6.2	B	A	B	50
14.6-15.7	15.5	6.0	7.0	2.6	A	A	B	5	13.3-14.4	5.0	B	B	B	25	16.5-20.9	6.0	A	A	B	50
15.8-16.0	15.4	5.8	6.9	2.5	A	A	B	5	14.5	4.7	A	B	B	25	21.0-24.9	5.0	A	A	A	50
16.1-20.9	15.3	5.6	6.8	2.4	A	A	B	3	14.6-20.9	4.7	A	A	B	25	25.0-	1.7	-	A	-	-
21.0-24.9	14.5	4.5	6.7	2.1	A	A	A	1	21.0-24.9	3.9	A	A	A	25						
25.0-	9.5	1.7	1.7	1.7	-	A	-	-	25.0-	1.2	-	A	-	-						

Table A-3. 25 kg- TNT Medium Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0 - 10.4	28.5	20.7	63.1	9.2	L	B	B	7
10.5 – 10.7	27.5	20.2	62.5	8.5	E	B	B	7
10.8 – 12.4	26.2	18.6	55.1	7.9	E	B	B	7
12.5 – 12.9	25.9	18.4	54.8	7.7	C	B	B	7
13.0 – 14.5	25.2	17.4	54.4	7.2	C	B	B	6
14.6 – 15.6	24.8	17.3	54.3	7.2	C	A	A	6
15.7 – 17.0	22.3	14.1	39.5	6.0	C	A	A	6
17.1 – 17.3	21.7	13.8	39.1	5.6	B	A	A	6
17.4 – 18.7	21.1	13.0	35.4	5.3	B	A	A	6
18.8 – 20.9	20.6	12.3	35.1	5.1	B	A	A	5
21.0 – 21.7	15.1	5.2	2.5	2.5	B	A	A	5
21.8 – 22.6	15.0	5.0	2.4	2.4	B	A	A	3
22.7 – 27.1	14.8	4.7	2.3	2.3	B	A	A	1
27.2 –	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ: DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0 – 10.4	16.7	L	B	H	31
10.5 – 10.7	16.1	E	B	H	31
10.8 – 12.4	14.9	E	B	G	31
12.5 – 14.5	14.6	C	B	G	31
14.6 – 15.6	14.5	C	A	G	31
15.7 – 15.8	12.2	C	A	F	31
15.9 – 17.0	11.0	C	A	F	30
17.1 – 17.3	10.7	B	A	F	30
17.4 – 17.8	10.1	B	A	E	30
17.8 – 18.9	9.5	B	A	E	26
19.0 – 20.9	9.4	B	A	E	25
21.0 – 27.1	4.2	B	A	A	25
27.2 -	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ: SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0 – 10.3	21.9	L	B	H	58
10.4 – 10.7	19.7	L	B	H	54
10.8 – 12.4	18.0	L	B	G	54
12.5	17.3	L	B	G	51
12.6 – 13.4	16.9	E	B	G	51
13.5 – 14.4	16.9	E	B	G	50
14.5	16.7	C	B	G	50
14.6 – 15.6	16.6	C	A	G	50
15.7 – 17.3	13.4	C	A	F	50
17.4 – 20.4	12.6	C	A	E	50
20.5 – 20.9	12.3	B	A	E	50
21.0 – 31.5	5.2	B	A	A	50
31.6 -	5.0	A	A	A	50

Table A-4. 25 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
10.0-11.9	52.2	26.0	69.2	15.1	T	G	H	7
12.0-12.3	49.6	24.8	67.4	13.4	Q	G	H	7
12.4-13.1	48.4	23.2	60.0	12.9	Q	G	G	7
13.2-14.6	47.7	22.8	59.6	12.4	P	G	G	7
14.7-16.7	47.4	22.7	59.4	12.2	O	G	G	7
16.8-17.8	33.9	20.4	57.1	9.9	O	F	G	7
17.9-19.8	31.4	17.2	42.3	8.8	O	F	F	7
19.9-20.9	30.8	16.3	38.6	8.5	O	F	E	7
21.0-22.5	30.3	16.1	38.3	8.2	L	F	E	7
22.6-23.1	28.7	15.8	38.0	7.9	L	E	E	7
23.2-24.8	26.7	15.5	37.7	7.6	L	D	E	7
24.9-26.0	26.3	15.0	35.6	7.4	L	D	D	7
26.1-26.6	25.3	14.6	35.0	6.7	E	D	D	7
26.7-26.9	24.7	13.5	34.5	6.3	E	D	D	6
27.0-32.2	24.3	13.3	34.3	6.1	D	D	D	6
32.3-35.9	21.8	12.9	33.8	5.6	D	C	D	6
36.0-36.5	21.7	12.9	33.8	5.6	D	B	D	6
36.6-37.6	21.4	12.4	31.7	5.5	D	B	C	6
37.7-39.2	20.9	11.7	31.4	5.2	D	B	C	5
39.3-42.9	20.5	11.7	31.3	5.1	D	A	C	5
43.0-43.3	15.7	5.4	2.8	2.9	D	A	A	5
43.4-46.3	15.6	5.3	2.8	2.8	D	A	A	3
46.4-47.6	15.4	5.0	2.6	2.7	D	A	A	1
47.7-	14.8	4.7	2.3	2.3	B	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
10.0-11.9	22.5	T	G	H	31
12.0-12.3	20.8	Q	G	H	31
12.4-13.1	19.6	Q	G	G	31
13.2-14.6	19.2	P	G	G	31
14.7-16.7	18.9	O	G	G	31
16.8-17.8	16.8	O	F	G	31
17.9-19.8	14.5	O	F	F	31
19.9-20.9	13.9	O	F	E	31
21.0-22.5	13.5	L	F	E	31
22.6-23.1	13.3	L	E	E	31
23.2-24.8	13.0	L	D	E	31
24.9-26.0	12.6	L	D	D	31
26.1-26.9	12.0	E	D	D	31
27.0-32.2	11.7	D	D	D	31
32.3-33.2	11.3	D	C	D	31
33.3-35.9	10.2	D	C	D	30
36.0-36.5	10.2	D	B	D	30
36.6-36.7	9.8	D	B	C	30
36.8-38.7	9.2	D	B	C	26
38.8-39.2	9.2	D	B	C	25
39.3-42.9	9.1	D	A	C	25
43.0-47.6	4.5	D	A	A	25
47.7-	4.2	B	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
10.0-12.1	27.2	T	G	H	58
12.2-12.3	26.0	Q	G	H	58
12.4-13.7	24.4	Q	G	G	58
13.8-14.9	24.1	P	G	G	58
15.0-16.7	23.9	O	G	G	58
16.8-17.8	21.6	O	F	G	58
17.9-19.8	18.4	O	F	F	58
19.9-21.7	17.6	O	F	E	58
21.8-22.4	17.3	L	F	E	58
22.5-22.5	15.1	L	F	E	54
22.6-23.1	14.8	L	E	E	54
23.2-24.8	14.4	L	D	E	54
24.9-26.3	14.0	L	D	D	54
26.4-26.8	13.3	L	D	D	51
26.9-27.4	12.8	E	D	D	51
27.5-28.8	12.7	D	D	D	51
28.9-32.2	12.6	D	D	D	50
32.3-35.9	12.2	D	C	D	50
36.0-36.5	12.2	D	B	D	50
36.6-39.2	11.7	D	B	C	50
39.3-42.9	11.6	D	A	C	50
43.0-49.1	5.4	D	A	A	50
49.2-	5.2	B	A	A	50

Table A-5. 100 kg- TNT Very Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
10.0-10.4	20.9	8.9	9.1	4.7	E	D	B	7
10.5-14.1	20.6	8.7	8.8	4.5	C	D	B	7
14.2-19.4	20.0	8.5	8.4	4.1	B	D	B	7
19.5-20.2	17.5	8.0	8.0	3.7	B	C	B	7
20.3-20.3	16.8	7.0	7.5	3.2	B	C	B	6
20.4-23.0	16.8	7.0	7.5	3.2	B	B	B	6
23.1-27.9	16.4	6.8	7.3	3.0	A	B	B	6
28.0-28.6	16.0	6.7	7.2	2.9	A	A	B	6
28.7-33.4	15.5	6.0	6.9	2.6	A	A	B	5
33.5-33.6	15.4	5.8	6.8	2.5	A	A	B	3
33.7-38.9	15.3	5.6	6.7	2.4	A	A	B	1
39.0-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
10.0-10.4	7.8	E	D	B	31
10.5-14.1	7.6	C	D	B	31
14.2-19.4	7.2	B	D	B	31
19.5-20.3	6.8	B	C	B	31
20.4-22.9	6.8	B	B	B	31
23.0-23.0	5.6	B	B	B	30
23.1-25.7	5.4	A	B	B	30
25.8-27.9	4.8	A	B	B	26
28.0-28.4	4.7	A	A	B	26
28.5-38.9	4.7	A	A	B	25
39.0-44.9	3.9	A	A	A	25
45 -	1.2				

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
10.0-11.8	27.2	E	D	B	58
11.9-15.3	26.0	C	D	B	58
15.4-16.1	24.4	C	D	B	54
16.2-18.6	24.1	B	D	B	54
18.7-19.4	23.9	C	D	B	51
19.5-19.5	21.6	C	C	B	51
19.6-20.3	18.4	C	C	B	50
20.4-26.2	17.6	C	B	B	50
26.3-38.9	17.3	A	A	B	50
39.0-	15.1	A	A	A	50

Table A-6. 100 kg- TNT Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
10.0	24.8	10.1	10.6	6.2	P	E	B	7
10.1	22.7	9.8	10.2	5.9	P	D	B	7
10.2	22.4	9.6	10.0	5.7	O	D	B	7
10.3-13.2	21.9	9.4	9.7	5.4	L	D	B	7
13.3-16.5	20.9	8.9	9.1	4.7	E	D	B	7
16.6-20.3	20.6	8.7	8.8	4.5	C	D	B	7
20.4-20.9	18.0	8.3	8.4	4.0	C	C	B	7
21.0-21.5	18.0	8.3	8.4	4.0	C	B	B	7
21.6-24.2	17.4	8.0	8.0	3.7	B	B	B	7
24.3-29.2	16.8	7.0	7.5	3.2	B	B	B	6
29.3-34.4	16.3	6.9	7.5	3.1	B	A	B	6
34.5-35.5	15.9	6.2	7.2	2.9	B	A	B	5
35.6-39.8	15.5	6.0	6.9	2.6	A	A	B	5
39.9-40.4	15.4	5.8	6.8	2.5	A	A	B	3
40.5-48.9	15.3	5.6	6.7	2.4	A	A	B	1
49.0-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
10.0	9.3	P	E	B	31
10.1	9.0	P	D	B	31
10.2	8.8	O	D	B	31
10.3-13.2	8.5	L	D	B	31
13.3-16.5	7.8	E	D	B	31
16.6-20.3	7.6	C	D	B	31
20.4-20.9	7.2	C	C	B	31
21.0-21.5	7.2	C	B	B	31
21.6-28.6	6.8	B	B	B	31
28.7-29.2	5.6	B	B	B	30
29.3-31.9	5.6	B	A	B	30
32.0-34.6	5.0	B	A	B	26
34.7-35.5	4.9	B	A	B	25
35.6-48.9	4.7	A	A	B	25
49.0-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
10.0	11.3	P	E	B	58
10.1-11.7	11.0	P	D	B	58
11.8-15.1	10.6	L	D	B	58
15.2-18.8	10.1	E	D	B	58
18.9-19.0	9.9	C	D	B	58
19.1-20.3	7.7	C	D	B	54
20.4-20.9	7.2	C	C	B	54
21.0-23.2	7.2	C	B	B	54
23.3-24.5	6.5	C	B	B	51
24.6-24.8	6.5	C	B	B	50
24.9-29.2	6.3	B	B	B	50
29.3-40.7	6.2	B	A	B	50
40.8-48.9	6.0	A	A	B	50
49.0-	5.0	A	A	A	50

Table A-7. 100 kg- TNT Medium Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0-	37.8	24.8	74.0	12.8	S	E	I	7
10.1-10.9	35.8	24.5	73.6	12.5	S	D	I	7
11.0-11.8	35.4	24.3	73.4	12.2	R	D	I	7
11.9-12.8	33.2	23.2	71.9	10.7	P	D	I	7
12.9-15.5	31.8	21.5	64.1	10.1	P	D	H	7
15.6-17.1	31.5	21.3	63.8	9.9	N	D	H	7
17.2-18.6	30.2	19.7	56.5	9.3	N	D	G	7
18.7-20.3	29.8	19.5	56.2	9.0	L	D	G	7
20.4-20.9	27.3	19.1	55.7	8.6	L	C	G	7
21.0-24.6	27.2	19.1	55.7	8.6	L	B	G	7
24.7-24.9	26.2	18.6	55.1	7.9	E	B	G	7
25.0-27.6	23.7	15.4	40.3	6.8	E	B	F	7
27.7-29.2	23.1	14.6	36.6	6.5	E	B	E	7
29.3-29.8	22.7	14.5	36.5	6.4	E	A	E	7
29.9-33.0	22.3	14.3	36.3	6.2	C	A	E	7
33.1-34.5	21.6	13.3	35.8	5.7	C	A	E	6
34.6-40.8	21.3	12.8	33.7	5.6	C	A	D	6
40.9-46.3	20.7	12.5	33.4	5.2	B	A	D	6
46.4-48.9	20.3	11.9	33.1	4.9	B	A	D	5
49.0-53.5	15.1	5.2	2.5	2.5	B	A	A	5
53.6-56.0	15.0	5.0	2.4	2.4	B	A	A	3
56.1-66.4	14.8	4.7	2.3	2.3	B	A	A	1
66.5-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0	21.0	S	E	I	31
10.1-10.9	20.7	S	D	I	31
11.0-11.8	20.4	R	D	I	31
11.9-12.8	18.9	P	D	I	31
12.9-15.5	17.7	P	D	H	31
15.6-17.1	17.4	N	D	H	31
17.2-18.6	16.2	N	D	G	31
18.7-20.3	15.9	L	D	G	31
20.4-20.9	15.5	L	C	G	31
21.0-24.6	15.5	L	B	G	31
24.7	14.9	E	B	G	31
25.0-27.6	12.5	E	B	F	31
27.7-29.2	11.9	E	B	E	31
29.3-29.8	11.8	E	A	E	31
29.9-34.5	11.6	C	A	E	31
34.6-40.3	11.2	C	A	D	31
40.4-40.8	10.1	C	A	D	30
40.9-44.7	9.7	B	A	D	30
44.8-47.7	9.1	B	A	D	26
47.8-48.9	9.1	B	A	D	25
49.0-66.4	4.2	B	A	A	25
66.5-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0	26.0	S	E	I	58
10.1-11.3	25.7	S	D	I	58
11.3-12.4	25.5	R	D	I	58
12.4-12.9	24.4	P	D	I	58
12.9-16.1	22.7	P	D	H	58
16.1-17.2	22.6	N	D	H	58
17.2-20.0	20.9	N	D	G	58
20.0-20.4	20.8	M	D	G	58
20.4-21.0	20.4	M	C	G	58
21.0-22.5	20.4	M	B	G	58
22.5-25.0	20.3	L	B	G	58
25.0-27.6	17.1	L	B	F	58
27.6-27.7	14.8	L	B	F	54
27.7-29.3	14.0	L	B	E	54
29.3-30.1	13.9	L	A	E	54
30.1-33.0	13.5	E	A	E	54
33.0-34.6	12.8	E	A	E	51
34.6-35.2	12.3	E	A	D	51
35.2-35.4	12.1	C	A	D	51
35.4-49.0	12.1	C	A	D	50
49.0-49.6	5.4	C	A	A	50
49.6-78.4	5.2	B	A	A	50
78.4-	5.0	A	A	A	50

Table A-8. 100 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs	STANDOFF DISTANCE IN METERS	%Δ DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs	STANDOFF DISTANCE IN METERS	%Δ SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
12.0-12.4	57.4	29.7	78.7	17.5	W	H	I	12	12.0-12.5	29.6	W	H	I	45	12.7-12.8	30.2	W	G	I	60
12.5-14.6	55.8	29.4	78.5	17.2	W	G	I	12	12.5-13.5	29.3	W	G	I	45	12.9-14.0	29.9	W	G	I	59
14.7-17.1	54.5	27.7	70.7	16.6	W	G	H	12	13.5-14.7	25.5	W	G	I	36	14.1-14.6	29.7	W	G	I	58
17.2-17.5	53.9	26.8	70.3	16.2	W	G	H	7	14.7-17.6	24.2	W	G	H	36	14.7-18.9	28.0	W	G	H	58
17.6-19.6	52.2	26.0	69.2	15.1	T	G	H	7	17.6-17.8	23.1	T	G	H	36	19.0-19.6	27.2	T	G	H	58
19.7-26.6	51.0	24.4	61.8	14.6	T	G	G	7	17.8-19.7	23.0	T	G	H	35	19.7-28.5	25.6	T	G	G	58
26.7-28.2	48.4	23.2	60.0	12.9	Q	G	G	7	19.7-20.2	21.8	T	G	G	35	28.6-28.6	22.4	T	G	F	58
28.3-28.5	47.7	22.8	59.6	12.4	P	G	G	7	20.2-21.6	21.7	T	G	G	34	28.7-28.7	20.1	T	F	F	58
28.6-28.6	45.2	19.6	44.8	11.3	P	G	F	7	21.6-26.7	21.3	T	G	G	31	28.8-30.7	18.8	Q	F	F	58
28.7-31.5	31.8	17.3	42.5	9.0	P	F	F	7	26.7-28.3	19.6	Q	G	G	31	30.8-31.5	18.5	P	F	F	58
31.6-33.2	31.1	16.5	38.9	8.7	P	F	E	7	28.3-28.6	19.2	P	G	G	31	31.6-35.5	17.7	P	F	E	58
33.3-38.3	30.8	16.3	38.6	8.5	O	F	E	7	28.6-28.7	16.8	P	G	F	31	35.6-38.3	17.6	O	F	E	58
38.4-39.4	29.2	16.1	38.4	8.2	O	E	E	7	28.7-31.6	14.7	P	F	F	31	38.4-39.5	17.3	O	E	E	58
39.5-39.5	28.8	15.6	36.3	8.1	O	E	D	7	31.6-33.3	14.1	P	F	E	31	39.6-39.4	16.9	O	D	E	58
39.6-45.7	26.8	15.3	35.9	7.7	O	D	D	7	33.3-38.4	13.9	O	F	E	31	39.5-51.4	16.5	O	D	D	58
45.8-56.9	26.3	15.0	35.6	7.4	L	D	D	7	38.4-39.5	13.6	O	E	E	31	51.5-56.6	16.3	L	D	D	58
57.0-58.2	23.8	14.6	35.2	7.0	L	C	D	7	39.5-39.6	13.3	O	E	D	31	56.7-56.9	14.0	L	D	D	54
58.3-62.2	22.4	13.7	32.4	6.1	E	C	C	7	39.6-45.8	13.0	O	D	D	31	57.0-58.2	13.6	L	C	D	54
62.3-63.9	22.1	13.5	32.1	5.9	D	C	C	7	45.8-57.0	12.6	L	D	D	31	58.3-64.3	13.1	L	C	C	54
64.0-64.8	21.4	12.4	31.7	5.5	D	C	C	6	57.0-58.3	12.2	L	C	D	31	64.4-64.8	12.6	E	C	C	54
64.9-74.6	21.4	12.4	31.7	5.5	D	B	C	6	58.3-62.3	11.2	E	C	C	31	64.9-66.4	12.6	E	B	C	54
74.7-90.1	20.9	12.3	31.6	5.4	D	A	C	6	62.3-64.9	11.0	D	C	C	31	66.5-66.9	12.4	D	B	C	54
90.2-97.9	20.5	11.7	31.3	5.1	D	A	C	5	64.9-74.7	11.0	D	B	C	31	67.0-72.6	11.7	D	B	C	51
98.0-104.4	15.7	5.4	2.8	2.9	D	A	A	5	74.7-82.6	10.9	D	A	C	31	72.7-74.6	11.7	D	B	C	50

Table A-8 (continued). 100 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
104.5-108.4	15.6	5.3	2.8	2.8	D	A	A	3
108.5-111.9	15.0	5.0	2.4	2.4	B	A	A	3
112.0-	14.8	4.7	2.3	2.3	B	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
82.6-91.2	9.8	D	A	C	30
91.2-96.1	9.2	D	A	C	26
96.1-98.0	9.1	D	A	C	25
98.0-108.5	4.5	D	A	A	25
108.5-	4.2	B	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
74.7-97.9	11.6	D	A	C	50
98.0-118.4	5.4	D	A	A	50
118.5-	5.2	B	A	A	50

Table A-9. 250 kg- TNT Very Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
10.0-10.3	61.3	16.6	17.1	12.7	Q	J	B	7
10.4-10.9	51.3	14.8	15.4	11.0	Q	I	B	7
11.0-11.2	27.0	10.7	11.3	6.9	Q	F	B	7
11.3-11.5	26.1	10.2	10.6	6.3	O	F	B	7
11.6-14.8	25.6	10.0	10.3	6.0	L	F	B	7
14.9-15.0	24.0	9.7	10.1	5.7	L	E	B	7
15.1-17.0	23.0	9.3	9.4	5.0	E	E	B	7
17.1-18.7	20.9	8.9	9.1	4.7	E	D	B	7
18.8-25.2	20.6	8.7	8.8	4.5	C	D	B	7
25.3-30.7	20.0	8.5	8.4	4.1	B	D	B	7
30.8-31.3	17.5	8.0	8.0	3.7	B	C	B	7
31.4-36.9	17.4	8.0	8.0	3.7	B	B	B	7
37.0-41.4	16.8	7.0	7.5	3.2	B	B	B	6
41.5-44.1	16.4	6.8	7.3	3.0	A	B	B	6
44.2-51.5	16.0	6.7	7.2	2.9	A	A	B	6
51.6-60.1	15.5	6.0	6.9	2.6	A	A	B	5
60.2-60.5	15.4	5.8	6.8	2.5	A	A	B	3
60.6-64.9	15.3	5.6	6.7	2.4	A	A	B	1
65.0-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
10.0-10.2	15.7	Q	J	B	34
10.3	15.4	Q	J	B	31
10.4-10.9	13.8	Q	I	B	31
11.0-11.2	10.0	Q	F	B	31
11.3-11.5	9.4	O	F	B	31
11.6-14.8	9.0	L	F	B	31
14.9-15.0	8.8	L	E	B	31
15.1-17.0	8.1	E	E	B	31
17.1-18.7	7.8	E	D	B	31
18.8-25.2	7.6	C	D	B	31
25.3-30.7	7.2	B	D	B	31
30.8-31.3	6.8	B	C	B	31
31.4-41.4	6.8	B	B	B	31
41.5-43.3	6.5	A	B	B	31
43.4-44.1	5.4	A	B	B	30
44.2-47.9	5.3	A	A	B	30
48.0-52.2	4.7	A	A	B	26
52.3-64.9	4.7	A	A	B	25
65.0-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
10.0-10.3	17.8	Q	J	B	58
10.4-10.9	16.1	Q	I	B	58
11.0-12.7	11.9	Q	F	B	58
12.8-12.9	11.4	O	F	B	58
13.0-14.8	11.2	L	F	B	58
14.9-16.9	10.9	L	E	B	58
17.0-17.0	10.5	E	E	B	58
17.1-21.2	10.1	E	D	B	58
21.3-29.0	9.9	C	D	B	58
29.1-29.1	9.7	B	D	B	58
29.2-30.7	7.4	B	D	B	54
30.8-31.3	7.0	B	C	B	54
31.4-35.7	7.0	B	B	B	54
35.8-37.3	6.3	B	B	B	51
37.4-44.1	6.3	B	B	B	50
44.2-47.4	6.2	B	A	B	50
47.5-64.9	6.0	A	A	B	50
65.0-	5.0	A	A	A	50

Table A-10. 250 kg- TNT Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0-10.6	64.5	18.7	19.2	14.8	T	J	B	12
10.7-11.3	54.5	17.0	17.5	13.1	T	I	B	12
11.4-11.5	53.9	16.1	17.1	12.7	T	I	B	7
11.6-11.7	29.6	11.9	13.0	8.6	T	F	B	7
11.8-14.5	29.0	11.6	12.6	8.2	S	F	B	7
14.6-15.3	28.6	11.4	12.4	8.0	R	F	B	7
15.4-15.4	26.4	10.4	10.9	6.5	P	F	B	7
15.5-17.9	24.8	10.1	10.6	6.2	P	E	B	7
18.0-18.0	22.7	9.8	10.2	5.9	P	D	B	7
18.1-23.3	21.9	9.4	9.7	5.4	L	D	B	7
23.4-29.2	20.9	8.9	9.1	4.7	E	D	B	7
29.3-31.0	20.6	8.7	8.8	4.5	C	D	B	7
31.1-31.3	18.0	8.3	8.4	4.0	C	C	B	7
31.4-38.4	18.0	8.3	8.4	4.0	C	B	B	7
38.5-44.0	17.4	8.0	8.0	3.7	B	B	B	7
44.1-44.1	17.0	7.9	7.9	3.6	B	A	B	7
44.2-64.1	17.0	7.9	7.9	3.6	B	A	B	7
64.2-61.0	16.6	7.8	7.7	3.3	A	A	B	7
61.1-71.5	15.5	6.0	6.9	2.6	A	A	B	5
71.6-72.8	15.4	5.8	6.8	2.5	A	A	B	3
72.9-83.9	15.3	5.6	6.7	2.4	A	A	B	1
84.0-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0-10.4	17.7	T	J	B	36
10.5-10.6	17.6	T	J	B	35
10.7-11.5	16.0	T	I	B	35
11.6-11.7	12.2	T	F	B	35
11.8-12.0	11.8	S	F	B	35
12.1-12.6	11.7	S	F	B	34
12.7-14.5	11.3	S	F	B	31
14.6-15.3	11.1	R	F	B	31
15.4-15.4	9.6	P	F	B	31
15.5-17.9	9.3	P	E	B	31
18.0-18.0	9.0	P	D	B	31
18.1-23.3	8.5	L	D	B	31
23.4-29.2	7.8	E	D	B	31
29.3-31.0	7.6	C	D	B	31
31.1-31.3	7.2	C	C	B	31
31.4-38.4	7.2	C	B	B	31
38.5-44.1	6.8	B	B	B	31
44.2-52.3	6.7	B	A	B	31
52.4-57.7	5.6	B	A	B	30
57.8-63.3	5.0	B	A	B	26
63.4-64.1	4.9	B	A	B	25
64.2-83.9	4.7	A	A	B	25
84.0-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0-10.6	19.0	T	J	B	58
10.7-11.5	17.3	T	I	B	58
11.6-12.0	13.1	T	F	B	58
12.1-14.9	12.9	S	F	B	58
15.0-15.4	12.7	R	F	B	58
15.5-15.8	12.4	R	E	B	58
15.9-17.9	11.3	P	E	B	58
18.0-20.7	11.0	P	D	B	58
20.8-27.0	10.6	L	D	B	58
27.1-31.0	10.1	E	D	B	58
31.1-31.3	9.7	E	C	B	58
31.4-33.9	9.7	E	B	B	58
34.0-36.2	9.5	C	B	B	58
36.3-43.8	7.2	C	B	B	54
43.9-44.1	6.5	C	B	B	51
44.2-44.7	6.5	C	A	B	51
44.8-46.1	6.2	B	A	B	51
46.2-74.3	6.2	B	A	B	50
74.4-83.9	6.0	A	A	B	50
84.0-	5.0	A	A	A	50

Table A-11. 250 kg- TNT Medium Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.6-15.3	40.6	26.4	75.1	13.9	T	F	I	12
15.4-15.4	40.1	26.1	74.7	13.5	S	F	I	12
15.5-15.6	38.4	25.8	74.4	13.2	S	E	I	12
15.7-17.4	37.8	24.8	74.0	12.8	S	E	I	7
17.5-17.9	36.5	23.1	66.2	12.2	S	E	H	7
18.0-18.9	34.5	22.8	65.9	11.9	S	D	H	7
19.0-20.2	34.1	22.6	65.6	11.6	R	D	H	7
20.3-23.2	31.8	21.5	64.1	10.1	P	D	H	7
23.3-26.5	30.6	19.9	56.7	9.5	P	D	G	7
26.6-31.0	30.2	19.7	56.5	9.3	N	D	G	7
31.1-31.3	27.7	19.3	56.0	8.9	N	C	G	7
31.4-31.9	27.6	19.3	56.0	8.8	N	B	G	7
32.0-33.7	27.2	19.1	55.7	8.6	L	B	G	7
33.8-37.5	24.7	15.9	41.0	7.4	L	B	F	7
37.6-42.4	24.1	15.0	37.3	7.1	L	B	E	7
42.5-44.1	23.1	14.6	36.6	6.5	E	B	E	7
44.2-46.7	22.7	14.5	36.5	6.4	E	A	E	7
46.8-51.9	22.3	14.1	34.5	6.2	E	A	D	7
52.0-57.1	21.9	13.9	34.2	6.0	C	A	D	7
57.2-69.0	21.3	12.8	33.7	5.6	C	A	D	6
69.1-71.4	20.9	12.3	31.6	5.4	C	A	C	6
71.5-74.9	20.3	12.1	31.2	5.0	B	A	C	6
75.0-80.2	20.3	12.1	31.2	5.0	B	A	C	6
80.3-83.9	19.9	11.4	30.9	4.7	B	A	C	5

STANDOFF DISTANCE IN METERS	%Δ DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.6-15.3	22.3	T	F	I	36
15.4-15.4	21.7	S	F	I	35
15.5-17.2	21.5	S	E	I	35
17.3-17.4	21.3	S	E	I	34
17.5-17.9	20.1	S	E	H	34
18.0-18.5	19.8	S	D	H	34
18.6-18.9	19.4	S	D	H	31
19.0-20.2	19.2	R	D	H	31
20.3-23.2	17.7	P	D	H	31
23.3-26.5	16.5	P	D	G	31
26.6-31.0	16.2	N	D	G	31
31.1-31.3	15.8	N	C	G	31
31.4-31.9	15.8	N	B	G	31
32.0-33.7	15.5	L	B	G	31
33.8-37.5	13.1	L	B	F	31
37.6-42.4	12.6	L	B	E	31
42.5-44.1	11.9	E	B	E	31
44.2-46.7	11.8	E	A	E	31
46.8-51.9	11.5	E	A	D	31
52.0-69.0	11.2	C	A	D	31
69.1-71.4	10.9	C	A	C	31
71.5-72.8	10.5	B	A	C	31
72.9-80.2	9.4	B	A	C	30
80.3-83.9	8.8	B	A	C	26

STANDOFF DISTANCE IN METERS	%Δ SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.6-15.4	26.6	T	F	I	58
15.5-15.8	26.3	T	E	I	58
15.9-17.4	26.0	S	E	I	58
17.5-17.9	24.3	S	E	H	58
18.0-19.6	24.0	S	D	H	58
19.7-21.2	23.8	R	D	H	58
21.3-23.2	22.7	P	D	H	58
23.3-28.0	21.1	P	D	G	58
28.1-31.0	20.9	N	D	G	58
31.1-31.3	20.5	N	C	G	58
31.4-33.7	20.5	N	B	G	58
33.8-35.2	17.3	N	B	F	58
35.3-37.5	17.1	M	B	F	58
37.6-39.5	16.3	M	B	E	58
39.6-44.1	16.3	L	B	E	58
44.2-46.7	16.2	L	A	E	58
46.8-50.7	15.7	L	A	D	58
50.8-53.0	13.5	L	A	D	54
53.1-60.0	13.0	E	A	D	54
60.1-63.0	12.3	E	A	D	51
63.1-64.9	12.1	C	A	D	51
65.0-69.0	12.1	C	A	D	50
69.1-83.9	11.6	C	A	C	50
84.0-88.7	5.4	C	A	A	50

Table A-11 (continued). 250 kg- TNT Medium Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
84.0-94.0	**15.1**	**5.2**	**2.5**	**2.5**	**B**	**A**	**A**	**5**
94.1-98.6	**15.0**	**5.0**	**2.4**	**2.4**	**B**	**A**	**A**	**3**
98.7-117.9	**14.8**	**4.7**	**2.3**	**2.3**	**B**	**A**	**A**	**1**
118.0-	**14.5**	**4.5**	**2.0**	**2.1**	**A**	**A**	**A**	**1**

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
84.0-85.6	**4.2**	**B**	**A**	**A**	**26**
85.7-117.9	**4.2**	**B**	**A**	**A**	**25**
118.0-	**3.9**	**A**	**A**	**A**	**25**

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
88.8-141.9	**5.2**	**B**	**A**	**A**	**50**
142.0-	**5.0**	**A**	**A**	**A**	**50**

Table A-12. 250 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs		DINING FACILITY	Walls	Windows	Doors	Roofs		SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
18.1-19.8	62.0	37.2	82.0	20.6	W	H	I	24	18.1-19.8	30.9	W	H	I	48	19.7-19.8	37.2	W	H	I	72
19.9-19.9	57.4	29.7	78.7	17.5	W	H	I	12	19.9-19.9	29.6	W	H	I	45	19.9-19.9	30.5	W	H	I	60
20.0-20.9	56.1	28.0	70.9	16.9	W	H	H	12	20.0-20.9	28.3	W	H	H	45	20.0-20.9	28.8	W	H	H	60
21.0-26.6	54.5	27.7	70.7	16.6	W	G	H	12	21.0-26.0	28.1	W	G	H	45	21.0-25.0	28.5	W	G	H	60
26.7-26.8	53.2	26.1	63.3	16.1	W	G	G	12	26.1-26.6	24.2	W	G	H	36	25.1-26.6	28.2	W	G	H	59
26.9-32.8	51.6	25.3	62.2	15.0	T	G	G	12	26.7-26.8	23.0	W	G	G	36	26.7-27.0	26.5	W	G	G	59
32.9-38.5	51.0	24.4	61.8	14.6	T	G	G	7	26.9-34.1	21.9	T	G	G	36	27.1-29.7	26.4	W	G	G	58
38.6-39.8	48.4	21.1	47.0	13.4	T	G	F	7	34.2-38.5	21.8	T	G	G	35	29.8-38.5	25.6	T	G	G	58
39.9-42.4	35.0	18.8	44.7	11.1	T	F	F	7	38.6-38.7	19.4	T	G	F	35	38.6-39.8	22.4	T	G	F	58
42.5-42.8	34.4	18.6	44.3	10.7	S	F	F	7	38.8-39.8	19.3	T	G	F	34	39.9-42.8	20.1	T	F	F	58
42.9-42.9	33.7	17.7	40.6	10.4	S	F	E	7	39.9-41.3	17.2	T	F	F	34	42.9-48.8	19.3	T	F	E	58
43.0-44.2	31.8	16.8	39.3	9.1	Q	F	E	7	41.4-42.4	16.8	T	F	F	31	48.9-49.6	19.0	S	F	E	58
44.3-53.4	31.1	16.5	38.9	8.7	P	F	E	7	42.5-42.8	16.4	S	F	F	31	49.7-49.7	18.0	Q	F	E	58
53.5-53.8	30.8	16.0	36.8	8.5	P	F	D	7	42.9-42.9	15.8	S	F	E	31	49.8-53.4	17.7	P	F	E	58
53.9-54.5	29.2	15.8	36.5	8.3	P	E	D	7	43.0-44.2	14.5	Q	F	E	31	53.5-53.8	17.3	P	F	D	58
54.6-55.4	28.8	15.6	36.3	8.1	O	E	D	7	44.3-53.4	14.1	P	F	E	31	53.9-55.4	17.0	P	E	D	58
55.5-72.3	26.8	15.3	35.9	7.7	O	D	D	7	53.5-53.8	13.7	P	F	D	31	55.5-62.1	16.6	P	D	D	58
72.4-78.9	26.3	15.0	35.6	7.4	L	D	D	7	53.9-54.5	13.5	P	E	D	31	62.2-78.9	16.5	O	D	D	58
79.0-82.2	25.9	14.6	33.5	7.2	L	D	C	7	54.6-55.4	13.3	O	E	D	31	79.0-82.2	16.0	O	D	C	58
82.3-93.7	23.4	14.1	33.0	6.8	L	C	C	7	55.5-72.3	13.0	O	D	D	31	82.3-87.0	15.6	O	C	C	58
93.8-95.6	22.4	13.7	32.4	6.1	E	C	C	7	72.4-78.9	12.6	L	D	D	31	87.1-88.1	15.5	N	C	C	58
95.7-103.2	22.4	13.7	32.4	6.1	E	B	C	7	79.0-82.2	12.3	L	D	C	31	88.2-95.6	15.4	L	C	C	58
103.3-107.0	22.0	13.5	32.1	5.9	D	B	C	7	82.3-93.7	11.9	L	C	C	31	95.7-102.8	15.3	L	B	C	58
107.1-109.9	21.4	12.4	31.7	5.5	D	B	C	6	93.8-95.6	11.2	E	C	C	31	102.9-109.9	13.1	L	B	C	54

Table A-12 (continued). 250 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
110.0-150.3	20.9	12.3	31.6	5.4	D	A	C	6
150.4-164.9	20.5	11.7	31.3	5.1	D	A	C	5
165.0-175.9	16.1	6.1	3.1	3.1	D	A	A	6
176.0-176.3	15.6	5.3	2.8	2.8	D	A	A	3
176.4-189.5	15.0	5.0	2.4	2.4	B	A	A	3
189.6-	14.8	4.7	2.3	2.3	B	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
95.7-103.2	11.2	E	B	C	31
103.3-109.9	11.0	D	B	C	31
110.0-145.3	10.9	D	A	C	31
145.4-159.3	9.8	D	A	C	30
159.4-164.9	9.2	D	A	C	26
165.0-168.1	4.6	D	A	A	26
168.2-176.3	4.5	D	A	A	25
176.4-	4.2	B	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
110.0-111.7	13.0	L	A	C	54
111.8-117.3	12.5	E	A	C	54
117.4-121.4	12.4	D	A	C	54
121.5-131.8	11.7	D	A	C	51
131.9-164.9	11.6	D	A	C	50
165.0-206.5	5.4	D	A	A	50
206.6-	5.2	B	A	A	50

Table A-13. 500 kg- TNT Very Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.3-15.1	61.9	17.5	17.5	13.1	Q	J	B	12
15.2-15.4	61.3	16.6	17.1	12.7	Q	J	B	7
15.5-16.7	51.3	14.8	15.4	11.0	Q	I	B	7
16.8-17.2	27.0	10.7	11.3	6.9	Q	F	B	7
17.3-17.6	26.1	10.2	10.6	6.3	O	F	B	7
17.7-21.8	25.6	10.0	10.3	6.0	L	F	B	7
21.9-23.2	24.0	9.7	10.1	5.7	L	E	B	7
23.3-25.5	23.0	9.3	9.4	5.0	E	E	B	7
25.6-28.7	20.9	8.9	9.1	4.7	E	D	B	7
28.8-39.2	20.6	8.7	8.8	4.5	C	D	B	7
39.3-41.4	20.0	8.5	8.4	4.1	B	D	B	7
41.5-41.7	17.5	8.0	8.0	3.7	B	C	B	7
41.8-56.6	17.4	8.0	8.0	3.7	B	B	B	7
56.7-59.3	16.8	7.0	7.5	3.2	B	B	B	6
59.4-64.4	16.3	6.9	7.5	3.1	B	A	B	6
64.5-78.4	16.0	6.7	7.2	2.9	A	A	B	6
78.5-92.1	15.5	6.0	6.9	2.6	A	A	B	5
92.2-92.9	15.4	5.8	6.8	2.5	A	A	B	3
93.0-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.7-15.4	15.9	Q	J	B	35
15.5-15.7	14.3	Q	I	B	35
15.8-16.5	14.2	Q	I	B	34
16.6-16.7	13.8	Q	I	B	31
16.8-17.2	10.0	Q	F	B	31
17.3-17.6	9.4	O	F	B	31
17.7-21.8	9.0	L	F	B	31
21.9-23.2	8.8	L	E	B	31
23.3-25.5	8.1	E	E	B	31
25.6-28.7	7.8	E	D	B	31
28.8-39.2	7.6	C	D	B	31
39.3-41.4	7.2	B	D	B	31
41.5-41.7	6.8	B	C	B	31
41.8-59.3	6.8	B	B	B	31
59.4-64.4	6.7	B	A	B	31
64.5-67.2	6.5	A	A	B	31
67.3-74.1	5.3	A	A	B	30
74.2-81.9	4.7	A	A	B	26
82.0-92.9	4.7	A	A	B	25
93.0-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.7-15.0	19.0	T	J	B	58
15.1-15.4	17.8	Q	J	B	58
15.5-16.7	16.1	Q	I	B	58
16.8-19.6	11.9	Q	F	B	58
19.7-20.1	11.4	O	F	B	58
20.2-21.8	11.2	L	F	B	58
21.9-25.5	10.9	L	E	B	58
25.6-26.4	10.6	L	D	B	58
26.5-32.9	10.1	E	D	B	58
33.0-41.4	9.9	C	D	B	58
41.5-41.7	9.5	C	C	B	58
41.8-45.3	9.5	C	B	B	58
45.4-47.4	9.2	B	B	B	58
47.5-57.3	7.0	B	B	B	54
57.4-59.3	6.3	B	B	B	51
59.4-59.7	6.2	B	A	B	51
59.8-74.7	6.2	B	A	B	50
74.8-92.9	6.0	A	A	B	50
93.0-	5.0	A	A	A	50

Table A-14. 500 kg- TNT Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.5-15.5	64.5	18.7	19.2	14.8	T	J	B	12
15.5-17.1	54.5	17.0	17.5	13.1	T	I	B	12
17.1-17.8	30.2	12.9	13.4	9.0	T	F	B	12
17.8-18.6	29.6	12.6	13.0	8.6	S	F	B	12
18.6-21.9	29.0	11.6	12.6	8.2	S	F	B	7
21.9-23.0	27.0	11.2	12.1	7.7	R	E	B	7
23.0-25.6	24.8	10.1	10.6	6.2	P	E	B	7
25.6-27.0	22.7	9.8	10.2	5.9	P	D	B	7
27.0-27.5	22.4	9.6	10.0	5.7	O	D	B	7
27.5-35.6	21.9	9.4	9.7	5.4	L	D	B	7
35.6-41.5	20.9	8.9	9.1	4.7	E	D	B	7
41.5-41.8	18.4	8.5	8.6	4.3	E	C	B	7
41.8-45.0	18.4	8.5	8.6	4.3	E	B	B	7
45.0-59.2	18.0	8.3	8.4	4.0	C	B	B	7
59.2-59.4	17.4	8.0	8.0	3.7	B	B	B	7
59.4-65.9	17.0	7.9	7.9	3.6	B	A	B	7
65.9-91.5	16.3	6.9	7.5	3.1	B	A	B	6
91.5-99.5	15.9	6.2	7.2	2.9	B	A	B	5
99.5-75.5	15.5	6.0	6.9	2.6	A	A	B	5
75.5-108.1	15.5	6.0	6.9	2.6	A	A	B	5
108.1-110.3	15.4	5.8	6.8	2.5	A	A	B	3
110.3-123.0	15.3	5.6	6.7	2.4	A	A	B	1
123.0-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ: DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.7-13.9	20.9	T	J	B	44
14.0-15.4	17.7	T	J	B	36
15.5-16.9	16.2	T	I	B	36
17.0-17.0	16.0	T	I	B	35
17.1-17.7	12.2	T	F	B	35
17.8-19.6	11.8	S	F	B	35
19.7-20.6	11.7	S	F	B	34
20.7-21.8	11.3	S	F	B	31
21.9-22.9	10.8	R	E	B	31
23.0-25.5	9.3	P	E	B	31
25.6-26.9	9.0	P	D	B	31
27.0-27.4	8.8	O	D	B	31
27.5-35.5	8.5	L	D	B	31
35.6-41.4	7.8	E	D	B	31
41.5-41.7	7.4	E	C	B	31
41.8-44.9	7.4	E	B	B	31
45.0-59.1	7.2	C	B	B	31
59.2-59.3	6.8	B	B	B	31
59.4-81.5	6.7	B	A	B	31
81.6-89.5	5.6	B	A	B	30
89.6-97.5	5.0	B	A	B	26
97.6-99.4	4.9	B	A	B	25
99.5-122.9	4.7	A	A	B	25
123.0-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ: SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.7-13.8	19.3	U	J	B	59
13.9-14.2	19.2	T	J	B	59
14.3-15.4	19.0	T	J	B	58
15.5-17.0	17.3	T	I	B	58
17.1-18.2	13.1	T	F	B	58
18.3-21.8	12.9	S	F	B	58
21.9-22.6	12.6	S	E	B	58
22.7-23.9	12.4	R	E	B	58
24.0-25.5	11.3	P	E	B	58
25.6-31.6	11.0	P	D	B	58
31.7-32.0	10.8	O	D	B	58
32.1-41.4	10.6	L	D	B	58
41.5-41.7	10.2	L	C	B	58
41.8-41.9	10.2	L	B	B	58
42.0-52.7	9.7	E	B	B	58
52.8-57.8	9.5	C	B	B	58
57.9-59.3	7.2	C	B	B	54
59.4-68.7	7.2	C	A	B	54
68.8-69.9	6.5	C	A	B	51
70.0-72.1	6.2	B	A	B	51
72.2-117.1	6.2	B	A	B	50
117.2-122.9	6.0	A	A	B	50
123.0-	5.0	A	A	A	50

Table A-15. 500 kg- TNT Medium Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs		DINING FACILITY	Walls	Windows	Doors	Roofs		SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
16.9-17.4	43.8	31.1	77.3	15.9	U	F	I	20	17.1-17.4	25.6	U	F	I	44	17.1-17.4	27.5	V	F	I	60
17.5-19.0	43.6	31.1	77.1	15.8	T	F	I	20	17.5-19.5	25.5	T	F	I	44	17.5-18.1	27.2	U	F	I	60
19.1-21.8	43.3	30.7	77.0	15.7	T	F	I	19	19.6-21.8	22.3	T	F	I	36	18.2-18.6	27.1	T	F	I	60
21.9-21.9	41.7	30.4	76.7	15.4	T	E	I	19	21.9-21.9	22.0	T	E	I	36	18.7-20.1	26.8	T	F	I	59
22.0-22.6	40.4	28.7	68.9	14.8	T	E	H	19	22.0-22.6	20.8	T	E	H	36	20.2-21.8	26.6	T	F	I	58
22.7-25.4	39.8	28.4	68.5	14.4	S	E	H	19	22.7-25.1	20.4	S	E	H	36	21.9-21.9	26.3	T	E	I	58
25.5-25.5	36.5	23.1	66.2	12.2	S	E	H	7	25.2-25.5	20.2	S	E	H	35	22.0-23.7	24.6	T	E	H	58
25.6-28.0	34.5	22.8	65.9	11.9	S	D	H	7	25.6-28.0	19.9	S	D	H	35	23.8-25.5	24.3	S	E	H	58
28.1-29.2	34.1	22.6	65.6	11.6	R	D	H	7	28.1-28.5	19.6	R	D	H	35	25.6-29.2	24.0	S	D	H	58
29.3-29.6	32.8	21.0	58.2	11.0	R	D	G	7	28.6-29.2	19.5	R	D	H	34	29.3-29.5	22.4	S	D	G	58
29.7-39.3	30.6	19.9	56.7	9.5	P	D	G	7	29.3-29.6	18.3	R	D	G	34	29.6-31.7	22.2	R	D	G	58
39.4-41.4	30.2	19.7	56.5	9.3	N	D	G	7	29.7-30.3	16.8	P	D	G	34	31.8-41.4	21.1	P	D	G	58
41.5-41.7	27.7	19.3	56.0	8.9	N	C	G	7	30.4-39.3	16.5	P	D	G	31	41.5-41.7	20.7	P	C	G	58
41.8-42.4	27.6	19.3	56.0	8.8	N	B	G	7	39.4-41.4	16.2	N	D	G	31	41.8-42.2	20.7	P	B	G	58
42.5-46.9	25.1	16.1	41.2	7.7	N	B	F	7	41.5-41.7	15.8	N	C	G	31	42.3-42.4	20.5	N	B	G	58
47.0-47.1	24.7	15.9	41.0	7.4	L	B	F	7	41.8-42.4	15.8	N	B	G	31	42.5-47.1	17.3	N	B	F	58
47.2-59.0	24.1	15.0	37.3	7.1	L	B	E	7	42.5-46.9	13.4	N	B	F	31	47.2-53.4	16.5	N	B	E	58
59.1-59.3	23.7	14.6	35.2	7.0	L	B	D	7	47.0-47.1	13.1	L	B	F	31	53.5-59.0	16.3	M	B	E	58
59.4-62.6	23.3	14.5	35.1	6.9	L	A	D	7	47.2-59.0	12.6	L	B	E	31	59.1-59.3	15.9	M	B	D	58
62.7-77.8	22.3	14.1	34.5	6.2	E	A	D	7	59.1-59.3	12.2	L	B	D	31	59.4-60.0	15.8	M	A	D	58
77.9-87.2	21.9	13.9	34.2	6.0	C	A	D	7	59.4-62.6	12.2	L	A	D	31	60.1-79.5	15.7	L	A	D	58
87.3-107.0	21.6	13.4	32.0	5.8	C	A	C	7	62.7-77.8	11.5	E	A	D	31	79.6-81.2	13.5	L	A	D	54
107.1-117.1	21.0	13.1	31.7	5.4	B	A	C	7	77.9-87.2	11.2	C	A	D	31	81.3-87.2	13.0	E	A	D	54
117.2-122.9	19.9	11.4	30.9	4.7	B	A	C	5	87.3-107.0	10.9	C	A	C	31	87.3-93.9	12.5	E	A	C	54

Table A-15 (continued). 500 kg- TNT Medium Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
123.0-139.0	15.1	5.2	2.5	2.5	B	A	A	5
139.1-146.1	15.0	5.0	2.4	2.4	B	A	A	3
146.2-179.4	14.8	4.7	2.3	2.3	B	A	A	1
179.5-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
107.1-111.1	10.5	B	A	C	31
111.2-122.0	9.4	B	A	C	30
122.1-122.9	8.8	B	A	C	26
123.0-130.7	4.2	B	A	A	26
130.8-179.4	4.2	B	A	A	25
179.5-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
94.0-96.7	11.8	E	A	C	51
96.8-101.2	11.7	C	A	C	51
101.3-122.9	11.6	C	A	C	50
123.0-137.0	5.4	C	A	A	50
137.1-219.9	5.2	B	A	A	50
220.0-	5.0	A	A	A	50

Table A-16. 500 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs		DINING FACILITY	Walls	Windows	Doors	Roofs		SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
24.4-25.1	62.0	37.2	82.0	20.6	W	H	I	24	24.4-25.1	30.9	W	H	I	48	26.8-27.9	35.5	W	H	H	72
25.2-28.0	60.7	35.5	74.2	20.0	W	H	H	24	25.2-27.9	29.6	W	H	H	48	28.0-28.9	33.6	W	H	H	69
28.0-29.0	59.5	33.6	73.4	19.2	W	H	H	21	28.0-28.9	28.3	W	H	H	45	29.0-32.4	33.4	W	G	H	69
29.0-32.5	58.0	33.4	73.1	18.9	W	G	H	21	29.0-33.4	28.1	W	G	H	45	32.5-33.4	28.5	W	G	H	60
32.5-33.5	54.5	27.7	70.7	16.6	W	G	H	12	33.5-35.0	26.9	W	G	G	45	33.5-39.9	26.9	W	G	G	60
33.5-35.1	53.2	26.1	63.3	16.1	W	G	G	12	35.1-36.2	26.3	V	G	G	45	40.0-40.8	26.5	V	G	G	60
35.1-36.3	52.3	25.7	62.7	15.5	V	G	G	12	36.3-42.6	25.8	T	G	G	45	40.9-41.1	26.1	T	G	G	60
36.3-48.6	51.6	25.3	62.2	15.0	T	G	G	12	42.7-48.5	21.9	T	G	G	36	41.2-44.3	25.8	T	G	G	59
48.6-51.2	49.0	22.1	47.4	13.8	T	G	F	12	48.6-51.1	19.6	T	G	F	36	44.4-48.5	25.6	T	G	G	58
51.2-53.3	35.6	19.8	45.1	11.5	T	F	F	12	51.2-53.8	17.4	T	F	F	36	48.6-51.1	22.4	T	G	F	58
53.3-53.9	35.0	18.8	44.7	11.1	T	F	F	7	53.9-55.4	16.9	T	F	E	36	51.2-53.8	20.1	T	F	F	58
53.9-56.7	34.3	18.0	41.0	10.8	T	F	E	7	55.5-56.6	16.7	T	F	E	35	53.9-66.2	19.3	T	F	E	58
56.7-60.7	33.7	17.7	40.6	10.4	S	F	E	7	56.7-60.6	16.3	S	F	E	35	66.3-67.4	19.0	S	F	E	58
60.7-67.5	31.1	16.5	38.9	8.7	P	F	E	7	60.7-61.9	14.6	P	F	E	35	67.5-69.1	18.5	S	F	D	58
67.5-69.2	30.8	16.0	36.8	8.5	P	F	D	7	62.0-65.6	14.4	P	F	E	34	69.2-69.7	18.2	S	E	D	58
69.2-71.3	29.2	15.8	36.5	8.3	P	E	D	7	65.7-67.4	14.1	P	F	E	31	69.8-71.2	17.0	P	E	D	58
71.3-76.9	27.1	15.4	36.2	7.9	P	D	D	7	67.5-69.1	13.7	P	F	D	31	71.3-93.1	16.6	P	D	D	58
76.9-99.8	26.8	15.3	35.9	7.7	O	D	D	7	69.2-71.2	13.5	P	E	D	31	93.2-99.7	16.5	O	D	D	58
99.8-108.5	25.9	14.6	33.5	7.2	L	D	C	7	71.3-76.8	13.2	P	D	D	31	99.8-108.4	16.0	O	D	C	58
108.5-126.5	23.4	14.1	33.0	6.8	L	C	C	7	76.9-99.7	13.0	O	D	D	31	108.5-120.5	15.6	O	C	C	58
126.5-130.7	23.4	14.1	33.0	6.8	L	B	C	7	99.8-108.4	12.3	L	D	C	31	120.6-126.4	15.5	N	C	C	58
130.7-145.1	22.4	13.7	32.4	6.1	E	B	C	7	108.5-126.4	11.9	L	C	C	31	126.5-128.7	15.5	N	B	C	58
145.1-146.8	21.9	13.6	32.3	6.1	E	A	C	7	126.5-130.6	11.9	L	B	C	31	128.8-145.0	15.3	L	B	C	58
146.8-151.8	21.6	13.4	32.0	5.8	D	A	C	7	130.7-145.0	11.2	E	B	C	31	145.1-158.3	15.3	L	A	C	58

Table A-16 (continued). 500 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
151.8-212.5	20.9	12.3	31.6	5.4	D	A	C	6
212.5-238.0	20.5	11.7	31.3	5.1	D	A	C	5
238.0-247.1	15.7	5.4	2.8	2.9	D	A	A	5
247.1-250.3	15.1	5.2	2.5	2.5	B	A	A	5
250.3-270.6	15.0	5.0	2.4	2.4	B	A	A	3
270.6-	14.8	4.7	2.3	2.3	B	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
145.1-146.7	11.1	E	A	C	31
146.8-215.3	10.9	D	A	C	31
215.4-234.2	9.8	D	A	C	30
234.3-237.9	9.2	D	A	C	26
238.0-247.0	4.6	D	A	A	26
247.1-247.8	4.2	B	A	A	26
247.9-	4.2	B	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
158.4-165.2	13.0	L	A	C	54
165.3-176.9	12.5	E	A	C	54
177.0-186.5	12.4	D	A	C	54
186.6-202.5	11.7	D	A	C	51
202.6-237.9	11.6	D	A	C	50
238.0-	5.2	B	A	A	50

Table A-17. 2000 kg- TNT Very Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
25.8-26.1	64.6	18.8	19.4	14.9	U	J	B	12
26.2-29.2	64.5	18.7	19.2	14.8	T	J	B	12
29.3-30.7	54.5	17.0	17.5	13.1	T	I	B	12
30.8-32.2	51.9	15.8	15.8	11.4	Q	I	B	12
32.3-39.9	27.6	11.7	11.7	7.3	Q	F	B	12
40.0-40.1	26.7	11.2	11.1	6.7	O	F	B	12
40.2-40.4	26.1	10.2	10.6	6.3	O	F	B	7
40.5-41.1	24.4	9.9	10.4	6.0	O	E	B	7
41.2-47.1	24.0	9.7	10.1	5.7	L	E	B	7
47.2-53.7	21.9	9.4	9.7	5.4	L	D	B	7
53.8-67.5	20.9	8.9	9.1	4.7	E	D	B	7
67.6-71.8	20.6	8.7	8.8	4.5	C	D	B	7
71.9-72.4	18.0	8.3	8.4	4.0	C	C	B	7
72.5-92.3	18.0	8.3	8.4	4.0	C	B	B	7
92.4-103.5	17.4	8.0	8.0	3.7	B	B	B	7
103.6-118.6	17.0	7.9	7.9	3.6	B	A	B	7
118.7-154.9	16.3	6.9	7.5	3.1	B	A	B	6
155.0-164.1	16.0	6.7	7.2	2.9	A	A	B	6
164.2-172.9	15.5	6.0	6.9	2.6	A	A	B	5
173.0-197.5	14.7	5.0	2.2	2.2	A	A	A	5
197.6-199.3	14.6	4.8	2.1	2.2	A	A	A	3
199.4-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
25.9-26.1	21.1	U	J	B	44
26.2-29.2	20.9	T	J	B	44
29.3-29.9	19.4	T	I	B	44
30.0-30.7	16.2	T	I	B	36
30.8-32.2	14.4	Q	I	B	36
32.3-35.9	10.6	Q	F	B	36
36.0-39.9	10.5	Q	F	B	35
40.0-40.4	9.8	O	F	B	35
40.5-41.1	9.6	O	E	B	35
41.2-41.9	9.3	L	E	B	35
42.0-44.2	9.1	L	E	B	34
44.3-47.1	8.8	L	E	B	31
47.2-53.7	8.5	L	D	B	31
53.8-67.5	7.8	E	D	B	31
67.6-71.8	7.6	C	D	B	31
71.9-72.4	7.2	C	C	B	31
72.5-92.3	7.2	C	B	B	31
92.4-94.3	6.8	B	B	B	31
94.4-99.1	5.2	B	B	B	28
99.2-103.5	5.0	B	B	B	25
103.6-154.9	4.9	B	A	B	25
155.0-172.9	4.7	A	A	B	25
173.0-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
25.9-26.5	19.9	V	J	B	60
26.6-27.2	19.6	U	J	B	60
27.3-28.0	19.5	T	J	B	60
28.1-29.2	19.2	T	J	B	59
29.3-30.5	17.5	T	I	B	59
30.6-32.2	17.3	T	I	B	58
32.3-35.2	13.1	T	F	B	58
35.3-40.4	11.9	Q	F	B	58
40.5-46.4	11.6	Q	E	B	58
46.5-47.1	11.2	O	E	B	58
47.2-47.6	10.8	O	D	B	58
47.7-63.2	10.6	L	D	B	58
63.3-71.8	10.1	E	D	B	58
71.9-72.4	9.7	E	C	B	58
72.5-79.4	9.7	E	B	B	58
79.5-103.5	9.5	C	B	B	58
103.6-109.7	9.4	C	A	B	58
109.8-114.3	9.2	B	A	B	58
114.4-138.2	9.2	B	A	B	58
138.3-144.1	6.2	B	A	B	51
144.2-172.9	6.2	B	A	B	50
173.0-183.9	5.2	B	A	A	50
184.0-	5.0	A	A	A	50

Table A-18. 2000 kg- TNT Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs		DINING FACILITY	Walls	Windows	Doors	Roofs		SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
25.9-28.7	68.1	23.8	21.8	17.2	V	J	B	20	25.9-28.9	21.5	V	J	B	44	25.9-28.7	23.8	V	J	B	68
28.8-28.9	65.2	19.1	19.7	15.3	V	J	B	12	29.0-29.2	21.1	U	J	B	44	28.8-29.2	19.9	V	J	B	60
29.0-29.2	64.6	18.8	19.4	14.9	U	J	B	12	29.3-32.2	19.4	T	I	B	44	29.3-30.3	18.2	V	I	B	60
29.3-38.3	54.5	17.0	17.5	13.1	T	I	B	12	32.3-33.4	15.6	T	F	B	44	30.4-30.9	17.9	U	I	B	60
38.4-32.2	53.9	16.8	17.2	12.7	S	I	B	12	33.5-36.7	15.3	T	F	B	43	31.0-32.2	17.8	T	I	B	60
32.3-40.4	29.6	12.6	13.0	8.6	S	F	B	12	36.8-38.3	12.4	T	F	B	36	32.3-34.6	13.7	T	F	B	60
40.5-47.1	28.0	12.3	12.8	8.4	S	E	B	12	38.4-40.4	12.0	S	F	B	36	34.7-37.7	13.3	T	F	B	59
47.2-47.5	25.9	12.0	12.4	8.0	S	D	B	12	40.5-45.2	11.7	S	E	B	36	37.8-40.4	13.1	T	F	B	58
47.6-48.6	25.5	11.8	12.2	7.8	R	D	B	12	45.3-47.1	11.6	S	E	B	35	40.5-40.7	12.9	T	E	B	58
48.7-48.8	23.3	10.7	10.7	6.3	P	D	B	12	47.2-47.5	11.2	S	D	B	35	40.8-47.1	12.6	S	E	B	58
48.9-66.0	22.7	9.8	10.2	5.9	P	D	B	7	47.6-48.6	11.0	R	D	B	35	47.2-50.8	12.2	S	D	B	58
66.1-60.9	22.3	9.6	10.0	5.6	N	D	B	7	48.7-51.9	9.5	P	D	B	35	50.9-52.8	12.0	R	D	B	58
61.0-71.8	21.9	9.4	9.7	5.4	L	D	B	7	52.0-55.0	9.4	P	D	B	34	52.9-71.8	11.0	P	D	B	58
71.9-72.4	19.4	8.9	9.3	4.9	L	C	B	7	55.1-60.9	9.0	P	D	B	31	71.9-72.0	10.5	P	C	B	58
72.5-79.7	19.3	8.9	9.3	4.9	L	B	B	7	61.0-71.8	8.5	L	D	B	31	72.1-72.4	10.4	N	C	B	58
79.8-99.7	18.4	8.5	8.6	4.3	E	B	B	7	71.9-72.4	8.1	L	C	B	31	72.5-74.6	10.3	N	B	B	58
99.8-102.7	18.0	8.3	8.4	4.0	D	B	B	7	72.5-79.7	8.1	L	B	B	31	74.7-98.4	10.2	L	B	B	58
102.8-103.5	18.0	8.3	8.4	4.0	C	B	B	7	79.8-99.7	7.4	E	B	B	31	98.5-103.5	9.7	E	B	B	58
103.6-119.8	17.5	8.2	8.3	3.9	C	A	B	7	99.8-102.7	7.2	D	B	B	31	103.6-124.6	9.6	E	A	B	58
119.9-134.1	17.5	8.2	8.3	3.9	C	A	B	7	102.8-103.5	7.2	C	B	B	31	124.7-125.6	9.4	D	A	B	58
134.2-135.7	16.9	7.1	7.8	3.5	C	A	B	6	103.6-135.7	7.1	C	A	B	31	125.7-136.6	9.4	C	A	B	58
135.8-185.5	16.3	6.9	7.5	3.1	B	A	B	6	135.8-179.0	6.7	B	A	B	31	136.7-163.6	7.2	C	A	B	54
185.6-224.0	15.9	6.2	7.2	2.9	B	A	B	5	179.1-194.9	5.6	B	A	B	30	163.7-167.6	6.5	C	A	B	51
224.1-228.6	15.8	6.0	7.1	2.8	B	A	B	3	195.0-214.6	5.0	B	A	B	26	167.7-172.2	6.2	B	A	B	51

Table A-18 (continued). 2000 kg- TNT Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase					Construction Type					STANDOFF DISTANCE IN METERS	%Δ	Construction Type					STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)		Walls	Windows	Doors	Roofs			DINING FACILITY	Walls	Windows	Doors	Roofs			SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
228.7-234.3	15.6	5.7	7.0	2.7		B	A	B	1		214.7-234.3	4.9	B	A	B	25		172.3-250.9	6.2	B	A	B	50
234.4-250.9	15.3	5.6	6.7	2.4		A	A	B	1		234.4-250.9	4.7	A	A	B	25		251.0-284.2	5.2	B	A	A	50
251.0-	14.5	4.5	2.0	2.1		A	A	A	1		251.0-	3.9	A	A	A	25		284.3-	5.0	A	A	A	50

Table A-19. 2000 kg- TNT Medium Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs		DINING FACILITY	Walls	Windows	Doors	Roofs		SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
22.6-28.9	80.1	38.6	84.4	23.1	W	J	I	21	27.2-28.9	32.6	W	J	I	45	23.8-29.2	38.6	W	J	I	69
29.0-29.2	79.2	38.2	83.9	22.5	V	J	I	21	29.0-29.2	32.0	V	J	I	45	29.3-30.8	36.9	W	I	I	69
29.3-32.2	69.2	36.5	82.2	20.8	V	I	I	21	29.3-32.2	30.4	V	I	I	45	30.9-32.2	36.5	V	I	I	69
32.3-33.8	44.9	32.3	78.1	16.7	V	F	I	21	32.3-33.8	26.6	V	F	I	45	32.3-33.8	32.3	V	F	I	69
33.9-34.9	44.3	31.4	77.7	16.3	V	F	I	20	33.9-34.9	26.0	V	F	I	44	33.9-34.9	31.4	V	F	I	68
35.0-35.2	43.0	29.7	69.9	15.7	V	F	H	20	35.0-35.2	24.7	V	F	H	44	35.0-37.7	29.7	V	F	H	68
35.3-35.4	42.4	29.4	69.5	15.3	U	F	H	20	35.3-35.4	24.3	U	F	H	44	37.8-38.4	29.4	U	F	H	68
35.5-40.2	42.3	29.4	69.4	15.2	T	F	H	20	35.5-40.4	24.2	T	F	H	44	38.5-40.2	29.4	T	F	H	68
40.3-40.4	39.3	24.7	67.3	13.3	T	F	H	12	40.5-44.2	24.0	T	E	H	44	40.3-40.4	25.4	T	F	H	60
40.5-46.1	37.7	24.4	67.0	13.0	T	E	H	12	44.3-46.1	23.7	T	E	H	43	40.5-46.5	25.2	T	E	H	60
46.2-46.5	37.1	24.1	66.6	12.6	S	E	H	12	46.2-46.5	23.3	S	E	H	43	46.6-47.1	23.6	T	E	G	60
46.6-47.1	35.9	22.5	59.2	12.0	S	E	G	12	46.6-47.1	22.1	S	E	G	43	47.2-49.7	23.2	T	D	G	60
47.2-57.7	33.8	22.1	58.9	11.7	S	D	G	12	47.2-51.8	21.8	S	D	G	43	49.8-50.5	22.8	T	D	G	59
57.8-59.1	33.4	21.9	58.6	11.4	R	D	G	12	51.9-57.7	18.8	S	D	G	36	50.6-53.5	22.5	S	D	G	59
59.2-66.6	31.2	20.9	57.1	9.9	P	D	G	12	57.8-59.1	18.6	R	D	G	36	53.6-63.7	22.4	S	D	G	58
66.7-67.4	30.6	19.9	56.7	9.5	P	D	G	7	59.2-66.6	17.1	P	D	G	36	63.8-66.8	22.2	R	D	G	58
67.5-71.8	28.1	16.7	41.9	8.4	P	D	F	7	66.7-67.4	16.9	P	D	G	35	66.9-67.4	21.1	P	D	G	58
71.9-72.4	25.6	16.2	41.5	8.0	P	C	F	7	67.5-71.8	14.6	P	D	F	35	67.5-71.8	17.9	P	D	F	58
72.5-74.9	25.5	16.2	41.5	7.9	P	B	F	7	71.9-72.4	14.2	P	C	F	35	71.9-72.4	17.5	P	C	F	58
75.0-80.9	24.9	15.4	37.8	7.7	P	B	E	7	72.5-74.9	14.2	P	B	F	35	72.5-74.9	17.5	P	B	F	58
81.0-93.7	24.5	15.2	37.5	7.4	N	B	E	7	75.0-75.3	13.6	P	B	E	35	75.0-91.4	16.7	P	B	E	58
93.8-94.2	24.1	14.8	35.5	7.2	N	B	D	7	75.4-80.3	13.4	P	B	E	34	91.5-93.7	16.5	N	B	E	58
94.3-103.5	23.7	14.6	35.2	7.0	L	B	D	7	80.4-80.9	13.1	P	B	E	31	93.8-103.5	16.0	N	B	D	58
103.6-127.1	23.3	14.5	35.1	6.9	L	A	D	7	81.0-93.7	12.8	N	B	E	31	103.6-118.1	15.9	N	A	D	58

Table A-19 (continued). 2000 kg- TNT Medium Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
127.2-138.0	22.3	14.1	34.5	6.2	E	A	D	7
138.1-163.3	21.9	13.6	32.3	6.1	E	A	C	7
163.4-165.2	21.3	12.5	31.8	5.6	E	A	C	6
165.3-224.4	20.9	12.3	31.6	5.4	C	A	C	6
224.5-228.4	20.3	12.1	31.2	5.0	B	A	C	6
228.5-250.9	19.9	11.4	30.9	4.7	B	A	C	5
251.0-275.3	15.1	5.2	2.5	2.5	B	A	A	5
275.4-289.3	15.0	5.0	2.4	2.4	B	A	A	3
289.4-393.2	14.8	4.7	2.3	2.3	B	A	A	1
393.3-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
93.8-94.2	12.5	N	B	D	31
94.3-103.5	12.2	L	B	D	31
103.6-127.1	12.2	L	A	D	31
127.2-138.0	11.5	E	A	D	31
138.1-165.2	11.1	E	A	C	31
165.3-224.4	10.9	C	A	C	31
224.5-234.1	10.5	B	A	C	31
234.2-250.9	9.4	B	A	C	30
251.0-253.8	4.8	B	A	A	30
253.9-273.9	4.2	B	A	A	26
274.0-393.2	4.2	B	A	A	25
393.3-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
118.2-131.1	15.8	M	A	D	58
131.2-138.0	15.7	L	A	D	58
138.1-179.1	15.3	L	A	C	58
179.2-181.0	14.8	E	A	C	58
181.1-216.0	12.5	E	A	C	54
216.1-220.1	11.8	E	A	C	51
220.2-233.1	11.7	C	A	C	51
233.2-250.9	11.6	C	A	C	50
251.0-310.6	5.4	C	A	A	50
310.7-508.7	5.2	B	A	A	50
508.8-	5.0	A	A	A	50

Table A-20. 2000 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs	STANDOFF DISTANCE IN METERS	%Δ DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs	STANDOFF DISTANCE IN METERS	%Δ SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
42.2-51.4	60.7	35.5	74.2	20.0	W	H	H	24	42.2-51.4	29.6	W	H	H	48	47.2-51.4	35.5	W	H	H	72
51.5-51.5	59.1	35.2	74.0	19.7	W	G	H	24	51.5-51.5	29.4	W	G	H	48	51.5-51.5	35.2	W	G	H	72
51.6-53.2	58.0	33.4	73.1	18.9	W	G	H	21	51.6-53.2	28.1	W	G	H	45	51.6-53.2	33.4	W	G	H	69
53.3-59.6	56.7	31.8	65.8	18.4	W	G	G	21	53.3-59.6	26.9	W	G	G	45	53.3-69.0	31.8	W	G	G	69
59.7-63.5	55.8	31.3	65.2	17.8	V	G	G	21	59.7-63.5	26.3	V	G	G	45	69.1-73.3	31.3	V	G	G	69
63.6-77.0	55.1	31.0	64.7	17.3	T	G	G	21	63.6-77.0	25.8	T	G	G	45	73.4-77.0	31.0	T	G	G	69
77.1-83.1	52.5	27.7	49.9	16.1	T	G	F	21	77.1-83.1	23.4	T	G	F	45	77.1-83.1	27.7	T	G	F	69
83.2-83.5	39.1	25.4	47.6	13.8	T	F	F	21	83.2-83.5	21.3	T	F	F	45	83.2-83.5	25.4	T	F	F	69
83.6-85.6	38.5	24.5	47.2	13.5	T	F	F	20	83.6-85.6	20.6	T	F	F	44	83.6-85.6	24.5	T	F	F	68
85.7-85.9	37.9	23.7	43.5	13.2	T	F	E	20	85.7-97.8	20.1	T	F	E	44	85.7-85.9	23.7	T	F	E	68
86.0-97.8	34.9	19.0	41.4	11.2	T	F	E	12	97.9-107.1	19.7	S	F	E	44	86.0-105.7	19.8	T	F	E	60
97.9-107.1	34.3	18.7	41.0	10.8	S	F	E	12	107.2-108.3	19.3	S	F	D	44	105.8-107.1	19.4	T	F	E	59
107.2-108.6	34.0	18.3	39.0	10.7	S	F	D	12	108.4-108.6	16.1	S	F	D	36	107.2-112.3	19.0	T	F	D	59
108.7-113.0	31.4	17.0	37.2	8.9	P	F	D	12	108.7-113.0	14.4	P	F	D	36	112.4-113.0	18.8	T	F	D	58
113.1-116.0	29.8	16.7	36.9	8.7	P	E	D	12	113.1-116.0	14.1	P	E	D	36	113.1-116.0	18.5	T	E	D	58
116.1-131.0	27.7	16.4	36.6	8.3	P	D	D	12	116.1-138.9	13.8	P	D	D	36	116.1-117.1	18.2	T	D	D	58
131.1-143.6	27.1	15.4	36.2	7.9	P	D	D	7	139.0-143.6	13.6	P	D	D	35	117.2-129.1	17.9	S	D	D	58
143.7-157.8	26.8	15.3	35.9	7.7	O	D	D	7	143.7-153.9	13.4	O	D	D	35	129.2-157.8	16.6	P	D	D	58
157.9-181.2	26.4	14.8	33.8	7.5	O	D	C	7	154.0-157.8	13.3	O	D	D	34	157.9-184.3	16.2	P	D	C	58
181.3-180.6	26.4	14.8	33.7	7.5	N	D	C	7	157.9-163.7	12.9	O	D	C	34	184.4-192.9	15.7	P	C	C	58
180.7-184.3	25.9	14.6	33.5	7.2	L	D	C	7	163.8-180.6	12.6	O	D	C	31	193.0-214.8	15.6	O	C	C	58
184.4-214.8	23.4	14.1	33.0	6.8	L	C	C	7	180.7-184.3	12.3	L	D	C	31	214.9-220.1	15.6	O	B	C	58
214.9-240.8	23.4	14.1	33.0	6.8	L	B	C	7	184.4-214.8	11.9	L	C	C	31	220.2-245.3	15.5	N	B	C	58
240.9-245.3	22.4	13.7	32.4	6.1	E	B	C	7	214.9-240.8	11.9	L	B	C	31	245.4-253.8	15.5	N	A	C	58

Table A-20 (continued). 2000 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
245.4-278.5	21.9	13.6	32.3	6.1	E	A	C	7
283.7-393.3	21.3	12.5	31.8	5.6	E	A	C	6
393.4-458.9	20.9	11.8	31.5	5.3	E	A	C	5
459.0-465.5	16.0	5.6	3.1	3.1	E	A	A	5
465.6-503.6	15.9	5.4	3.0	3.0	E	A	A	3
503.7-	15.8	5.2	2.9	2.9	E	A	A	1

STANDOFF DISTANCE IN METERS	%Δ DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
240.9-245.3	11.2	E	B	C	31
245.4-278.4	11.1	E	A	C	31
278.5-425.5	10.9	D	A	C	31
425.6-457.1	9.8	D	A	C	30
457.2-458.9	9.2	D	A	C	26
459.0-483.7	4.6	D	A	A	26
483.8-	4.5	D	A	A	25

STANDOFF DISTANCE IN METERS	%Δ SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
253.9-333.0	15.3	L	A	C	58
333.1-340.3	14.8	E	A	C	58
340.4-371.7	12.5	E	A	C	54
371.8-400.4	12.4	D	A	C	54
400.5-437.0	11.7	D	A	C	51
437.1-458.9	11.6	D	A	C	50
459.0-	5.2	D	A	A	49

Table A-21. 9000 kg- TNT Very Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
47.2-53.2	68.7	24.7	22.2	17.6	V	J	B	21
53.3-56.4	58.7	23.0	20.5	15.9	V	I	B	21
56.5-59.3	58.0	22.7	20.0	15.4	T	I	B	21
59.4-67.2	33.7	18.5	15.9	11.3	T	F	B	21
67.3-71.9	30.2	12.9	13.4	9.0	T	F	B	12
72.0-73.4	27.6	11.7	11.7	7.3	Q	F	B	12
73.5-83.7	26.0	11.4	11.4	7.0	Q	E	B	12
83.8-93.4	24.0	11.0	11.1	6.7	Q	D	B	12
93.5-97.1	23.0	10.6	10.5	6.1	O	D	B	12
97.2-112.3	22.5	10.3	10.1	5.7	L	D	B	12
112.4-126.4	21.9	9.4	9.7	5.4	L	D	B	7
126.5-127.0	19.4	8.9	9.3	4.9	L	C	B	7
127.1-128.5	19.3	8.9	9.3	4.9	L	B	B	7
128.6-165.2	18.4	8.5	8.6	4.3	E	B	B	7
165.3-183.7	18.0	8.3	8.4	4.0	C	B	B	7
183.8-225.9	17.5	8.2	8.3	3.9	C	A	B	7
226.0-236.6	17.0	7.9	7.9	3.6	B	A	B	7
236.7-307.9	16.3	6.9	7.5	3.1	B	A	B	6
308.0-327.0	15.5	5.8	2.8	2.8	B	A	A	6
327.1-399.5	15.1	5.2	2.5	2.5	B	A	A	5
399.6-399.8	15.0	5.0	2.4	2.4	B	A	A	3
399.9-403.0	14.6	4.8	2.1	2.2	A	A	A	3
403.1-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
47.2-53.2	22.1	V	J	B	45
53.3-54.7	20.5	V	I	B	45
54.8-56.4	19.9	V	I	B	44
56.5-59.3	19.4	T	I	B	44
59.4-71.8	15.6	T	F	B	44
71.9-71.9	15.3	T	F	B	43
72.0-73.4	13.6	Q	F	B	43
73.5-83.7	13.3	Q	E	B	43
83.8-85.1	13.0	Q	D	B	43
85.2-93.4	10.1	Q	D	B	36
93.5-97.1	9.4	O	D	B	36
97.2-102.7	9.1	L	D	B	36
102.8-118.6	8.9	L	D	B	35
118.7-125.0	8.8	L	D	B	34
125.1-126.4	8.5	L	D	B	31
126.5-127.0	8.1	L	C	B	31
127.1-128.5	8.1	L	B	B	31
128.6-165.2	7.4	E	B	B	31
165.3-183.7	7.2	C	B	B	31
183.8-209.6	7.1	C	A	B	31
209.7-225.9	5.4	C	A	B	26
226.0-242.3	5.0	B	A	B	26
242.4-307.9	4.9	B	A	B	25
308.0-399.8	4.2	B	A	A	25
399.9-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
47.2-49.7	25.2	W	J	B	69
49.8-53.2	24.7	V	J	B	69
53.3-54.7	23.0	V	I	B	69
54.8-59.3	22.1	V	I	B	68
59.4-61.1	18.0	V	F	B	68
61.2-67.2	17.6	T	F	B	68
67.3-73.4	13.7	T	F	B	60
73.5-80.7	13.4	T	E	B	60
80.8-81.4	13.0	T	E	B	59
81.5-83.7	12.7	S	E	B	59
83.8-86.3	12.4	S	D	B	59
86.4-87.0	11.4	Q	D	B	59
87.1-105.3	11.3	Q	D	B	58
105.4-114.5	11.0	P	D	B	58
114.6-118.1	10.8	O	D	B	58
118.2-126.4	10.6	L	D	B	58
126.5-127.0	10.2	L	C	B	58
127.1-157.9	10.2	L	B	B	58
158.0-176.4	9.7	E	B	B	58
176.5-183.7	6.7	E	B	B	50
183.8-201.7	6.6	E	A	B	50
201.8-279.5	6.4	C	A	B	50
279.6-307.9	6.2	B	A	B	50
308.0-476.1	5.2	B	A	A	50
476.2-	5.0	A	A	A	50

Table A-22. 9000 kg- TNT Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type				STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs		DINING FACILITY	Walls	Windows	Doors	Roofs		SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
47.2-51.0	69.6	25.2	22.8	18.2	W	J	B	21	47.2-51.0	22.7	W	J	B	45	47.2-53.2	25.2	W	J	B	69
51.1-53.2	68.7	24.7	22.2	17.6	V	J	B	21	51.1-53.3	22.1	V	J	B	45	53.3-54.9	23.5	W	I	B	69
53.3-59.3	58.7	23.0	20.5	15.9	V	I	B	21	53.3-59.4	20.5	V	I	B	45	55.0-59.3	23.0	V	I	B	69
59.4-60.7	34.5	18.9	16.4	11.8	V	F	B	21	59.4-60.7	16.7	V	F	B	45	59.4-60.6	18.9	V	F	B	69
60.8-73.4	33.7	18.5	15.9	11.3	T	F	B	21	60.7-60.8	16.1	V	F	B	44	60.7-66.7	18.0	V	F	B	68
73.5-80.0	32.1	18.2	15.6	11.1	T	E	B	21	60.8-73.5	15.6	T	F	B	44	66.8-73.4	17.6	T	F	B	68
80.1-82.2	31.5	17.9	15.2	10.7	S	E	B	21	73.5-79.5	15.3	T	E	B	44	73.5-79.4	17.3	T	E	B	68
82.3-83.7	28.0	12.3	12.8	8.4	S	E	B	12	79.5-80.1	15.0	T	E	B	43	79.5-82.2	16.9	T	E	B	67
83.8-99.6	25.9	12.0	12.4	8.0	S	D	B	12	80.1-83.8	14.6	S	E	B	43	82.3-83.7	13.4	T	E	B	60
99.7-126.4	23.3	10.7	10.7	6.3	P	D	B	12	83.8-99.7	14.3	S	D	B	43	83.8-89.0	13.0	T	D	B	60
126.5-127.0	20.8	10.3	10.2	5.8	P	C	B	12	99.7-104.2	12.6	P	D	B	43	89.1-99.4	12.8	S	D	B	60
127.1-133.3	20.7	10.3	10.2	5.8	P	B	B	12	104.2-126.5	9.6	P	D	B	36	99.5-106.9	12.4	S	D	B	59
133.4-134.1	19.9	9.9	9.7	5.3	L	B	B	12	126.5-127.1	9.2	P	C	B	36	107.0-113.5	12.2	S	D	B	58
134.2-176.1	19.3	8.9	9.3	4.9	L	B	B	7	127.1-127.5	9.2	P	B	B	36	113.6-114.1	12.0	R	D	B	58
176.2-183.7	18.4	8.5	8.6	4.3	E	B	B	7	127.5-133.4	9.1	P	B	B	35	114.2-126.4	11.0	P	D	B	58
183.8-220.6	17.9	8.4	8.5	4.2	E	A	B	7	133.4-144.7	8.5	L	B	B	35	126.5-127.0	10.5	P	C	B	58
220.7-237.7	17.6	8.2	8.3	4.0	D	A	B	7	144.7-152.4	8.4	L	B	B	34	127.1-160.6	10.5	P	B	B	58
237.8-260.0	17.5	8.2	8.3	3.9	C	A	B	7	152.4-176.2	8.1	L	B	B	31	160.7-175.6	10.3	N	B	B	58
260.1-310.5	16.9	7.1	7.8	3.5	C	A	B	6	176.2-183.8	7.4	E	B	B	31	175.7-183.7	10.2	L	B	B	58
310.6-361.2	16.3	6.9	7.5	3.1	B	A	B	6	183.8-220.7	7.3	E	A	B	31	183.8-234.9	10.1	L	A	B	58
361.3-441.3	15.9	6.2	7.2	2.9	B	A	B	5	220.7-237.8	7.1	D	A	B	31	235.0-298.8	9.6	E	A	B	58
441.4-449.9	15.8	6.0	7.1	2.8	B	A	B	3	237.8-310.6	7.1	C	A	B	31	298.9-302.1	9.4	D	A	B	58
450.0-480.9	15.6	5.7	7.0	2.7	B	A	B	1	310.6-368.0	6.7	B	A	B	31	302.2-307.7	7.2	D	A	B	54
481.0-560.1	14.8	4.7	2.3	2.3	B	A	A	1	368.0-397.4	5.6	B	A	B	30	307.8-365.2	7.2	C	A	B	54

Table A-22 (continued). 9000 kg- TNT Low Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
560.2-	14.5	4.5	2.0	2.1	A	A	A	1

STANDOFF DISTANCE IN METERS	%Δ DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
397.4-440.7	5.0	B	A	B	26
440.7-481.0	4.9	B	A	B	25
481.0-560.2	4.2	B	A	A	25
560.2-	3.9	A	A	A	25

STANDOFF DISTANCE IN METERS	%Δ SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
365.3-385.1	6.5	C	A	B	51
385.2-411.0	6.4	C	A	B	50
411.1-480.9	6.2	B	A	B	50
481.0-712.2	5.2	B	A	A	50
712.3-	5.0	A	A	A	50

Table A-23. 9000 kg- TNT Medium Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Windows	Doors	Roofs
45.6-48.6	81.2	40.5	85.2	23.8	W	J	I	24
48.7-53.1	80.3	39.1	84.6	23.2	W	J	I	23
53.2-53.2	80.1	38.6	84.4	23.1	W	J	I	21
53.3-58.0	70.1	36.9	82.8	21.4	W	I	I	21
58.1-59.3	67.9	34.8	74.4	20.2	V	I	H	21
59.4-69.1	43.6	30.6	70.3	16.1	V	F	H	21
69.2-73.4	42.8	30.3	69.8	15.6	T	F	H	21
73.5-77.2	41.2	30.0	69.5	15.3	T	E	H	21
77.3-83.7	39.9	28.4	62.1	14.7	T	E	G	21
83.8-91.1	37.9	28.0	61.8	14.4	T	D	G	21
91.2-95.4	37.3	27.8	61.4	14.0	S	D	G	21
95.5-101.1	36.5	26.5	60.8	13.5	S	D	G	19
101.2-111.5	36.1	26.3	60.5	13.2	R	D	G	19
111.6-113.9	33.6	23.1	45.7	12.0	R	D	F	19
114.0-115.0	30.9	18.7	43.8	10.2	R	D	F	12
115.1-124.1	28.7	17.6	42.4	8.8	P	D	F	12
124.2-126.4	28.1	16.8	38.7	8.5	P	D	E	12
126.5-127.0	25.5	16.4	38.2	8.1	P	C	E	12
127.1-155.3	25.5	16.4	38.2	8.0	P	B	E	12
155.4-161.3	25.1	15.9	36.2	7.9	P	B	D	12
161.4-172.6	24.7	15.8	35.9	7.6	N	B	D	12
172.7-183.7	24.1	14.8	35.5	7.2	N	B	D	7
183.8-184.1	23.7	14.7	35.4	7.2	N	A	D	7
184.2-228.9	23.3	14.5	35.1	6.9	L	A	D	7

STANDOFF DISTANCE IN METERS	%Δ DINING FACILITY	Construction Type: Walls	Windows	Doors	Roofs
47.2-48.6	33.9	W	J	I	48
48.7-53.1	32.9	W	J	I	47
53.2-53.2	32.6	W	J	I	45
53.3-58.0	31.0	W	I	I	45
58.1-59.3	29.2	V	I	H	45
59.4-69.1	25.4	V	F	H	45
69.2-72.8	24.9	T	F	H	45
72.9-73.4	24.2	T	F	H	44
73.5-77.2	24.0	T	E	H	44
77.3-83.7	22.8	T	E	G	44
83.8-91.1	22.4	T	D	G	44
91.2-95.4	22.0	S	D	G	44
95.5-101.1	21.8	S	D	G	43
101.2-111.5	21.5	R	D	G	43
111.6-115.0	19.1	R	D	F	43
115.1-124.1	17.6	P	D	F	43
124.2-126.4	17.1	P	D	E	43
126.5-127.0	16.7	P	C	E	43
127.1-143.4	16.6	P	B	E	43
143.5-155.3	13.7	P	B	E	36
155.4-161.3	13.4	P	B	D	36
161.4-178.0	13.1	N	B	D	36
178.1-183.7	13.0	N	B	D	35
183.8-184.1	12.9	N	A	D	35

STANDOFF DISTANCE IN METERS	%Δ SPECIAL STRUCTURE	Construction Type: Walls	Windows	Doors	Roofs
49.8-53.1	39.1	W	J	I	71
53.2-53.2	38.6	W	J	I	69
53.3-58.0	36.9	W	I	I	69
58.1-59.3	35.2	W	I	H	69
59.4-64.0	31.1	W	F	H	69
64.1-72.8	30.6	V	F	H	69
72.9-73.4	29.7	V	F	H	68
73.5-77.2	29.4	V	E	H	68
77.3-77.6	27.8	V	E	G	68
77.7-83.7	27.5	T	E	G	68
83.8-95.4	27.1	T	D	G	68
95.5-104.2	26.8	T	D	G	67
104.3-111.5	26.5	S	D	G	67
111.6-113.5	23.2	S	D	F	67
113.6-113.9	23.1	R	D	F	67
114.0-124.1	19.5	R	D	F	60
124.2-126.4	18.7	R	D	E	60
126.5-127.0	18.3	R	C	E	60
127.1-135.6	18.3	R	B	E	60
135.7-140.0	17.2	P	B	E	60
140.1-148.5	16.8	P	B	E	59
148.6-155.3	16.7	P	B	E	58
155.4-183.7	16.2	P	B	D	58
183.8-192.2	16.1	P	A	D	58

Table A-23 (continued). 9000 kg- TNT Medium Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
229.0-249.7	22.9	14.0	32.9	6.7	L	A	C	7
249.8-309.0	21.9	13.6	32.3	6.1	E	A	C	7
309.1-340.2	21.3	12.5	31.8	5.6	E	A	C	6
340.3-432.0	20.9	12.3	31.6	5.4	C	A	C	6
432.1-454.7	20.5	11.7	31.3	5.1	C	A	C	5
454.8-480.9	19.9	11.4	30.9	4.7	B	A	C	5
481.0-524.3	15.1	5.2	2.5	2.5	B	A	A	5
524.4-550.9	15.0	5.0	2.4	2.4	B	A	A	3
551.0-	14.8	4.7	2.3	2.3	B	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
184.2-196.1	12.6	L	A	D	35
196.2-210.1	12.5	L	A	D	34
210.2-228.9	12.2	L	A	D	31
229.0-249.7	11.8	L	A	C	31
249.8-340.2	11.1	E	A	C	31
340.3-454.7	10.9	C	A	C	31
454.8-463.6	10.5	B	A	C	31
463.7-480.9	9.4	B	A	C	30
481.0-498.6	4.8	B	A	A	30
498.7-539.8	4.2	B	A	A	26
539.9-	4.2	B	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
192.3-228.9	15.9	N	A	D	58
229.0-255.3	15.5	N	A	C	58
255.4-273.7	15.3	M	A	C	58
273.8-378.6	15.3	L	A	C	58
378.7-382.7	14.8	E	A	C	58
382.8-458.2	12.5	E	A	C	54
458.3-480.9	11.8	E	A	C	51
481.0-489.1	5.6	E	A	A	51
489.2-494.5	5.4	C	A	A	51
494.6-674.5	5.4	C	A	A	50
674.6-	5.2	B	A	A	50

Table A-24. 9000 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase: ADMIN FACILITY	% Increase: MEDICAL CLINIC	% Increase: BARRACKS (EXT ENT)	% Increase: BARRACKS (INT ENT)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
73.9-88.3	60.7	35.5	74.2	20.0	W	H	H	24
88.4-90.7	59.4	33.9	66.8	19.4	W	H	G	24
90.8-93.6	57.8	33.6	66.6	19.1	W	G	G	24
93.7-103.1	56.7	31.8	65.8	18.4	W	G	G	21
103.2-112.0	55.8	31.3	65.2	17.8	V	G	G	21
112.1-127.5	55.1	31.0	64.7	17.3	T	G	G	21
127.6-139.8	52.5	27.7	49.9	16.1	T	G	F	21
139.9-141.8	39.1	25.4	47.6	13.8	T	F	F	21
141.9-171.1	38.4	24.6	43.9	13.5	T	F	E	21
171.2-177.5	37.8	24.3	43.5	13.1	S	F	E	21
177.6-190.7	37.5	23.9	41.4	13.0	S	F	D	21
190.8-194.8	35.9	23.6	41.2	12.7	S	E	D	21
194.9-195.9	33.2	22.4	39.4	11.0	P	E	D	21
196.0-213.8	31.2	22.0	39.1	10.6	P	D	D	21
213.9-227.3	30.4	20.7	38.5	10.1	P	D	D	19
227.4-261.6	27.7	16.4	36.6	8.3	P	D	D	12
261.7-265.3	27.3	15.9	34.4	8.1	P	D	C	12
265.4-314.2	27.0	15.8	34.2	7.9	O	D	C	12
314.3-319.9	26.4	14.8	33.8	7.5	O	D	C	7
320.0-323.0	23.9	14.4	33.3	7.1	O	C	C	7
323.1-327.1	23.8	14.3	33.3	7.1	N	C	C	7
327.2-372.7	23.4	14.1	33.0	6.8	L	C	C	7
372.8-424.8	23.4	14.1	33.0	6.8	L	B	C	7
424.9-441.6	22.9	14.0	32.9	6.7	L	A	C	7

STANDOFF DISTANCE IN METERS	%Δ DINING FACILITY	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
73.9-88.3	29.6	W	H	H	48
88.4-90.7	28.5	W	H	G	48
90.8-93.6	28.2	W	G	G	48
93.7-103.1	26.9	W	G	G	45
103.2-112.0	26.3	V	G	G	45
112.1-127.5	25.8	T	G	G	45
127.6-139.8	23.4	T	G	F	45
139.9-141.8	21.3	T	F	F	45
141.9-147.7	20.7	T	F	E	45
147.8-171.1	20.1	T	F	E	44
171.2-177.5	19.7	S	F	E	44
177.6-190.7	19.3	S	F	D	44
190.8-194.8	19.1	S	E	D	44
194.9-195.9	17.3	P	E	D	44
196.0-213.8	17.0	P	D	D	44
213.9-261.6	16.7	P	D	D	43
261.7-265.3	16.4	P	D	C	43
265.4-279.1	16.2	O	D	C	43
279.2-319.9	13.2	O	D	C	36
320.0-323.0	12.8	O	C	C	36
323.1-327.1	12.8	N	C	C	36
327.2-356.1	12.5	L	C	C	36
356.2-372.7	12.4	L	C	C	35
372.8-386.0	12.4	L	B	C	35

STANDOFF DISTANCE IN METERS	%Δ SPECIAL STRUCTURE	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
83.6-88.3	35.5	W	H	H	72
88.4-90.7	33.9	W	H	G	72
90.8-93.6	33.6	W	G	G	72
93.7-120.7	31.8	W	G	G	69
120.8-127.5	31.3	V	G	G	69
127.6-131.5	28.1	V	G	F	69
131.6-139.8	27.7	T	G	F	69
139.9-141.8	25.4	T	F	F	69
141.9-147.7	24.6	T	F	E	69
147.8-177.5	23.7	T	F	E	68
177.6-190.7	23.3	T	F	D	68
190.8-195.9	23.0	T	E	D	68
196.0-208.2	22.6	T	D	D	68
208.3-213.8	22.3	S	D	D	68
213.9-227.3	22.0	S	D	D	67
227.4-237.0	18.4	S	D	D	60
237.1-261.6	17.2	P	D	D	60
261.7-279.5	16.7	P	D	C	60
279.6-292.7	16.3	P	D	C	59
292.8-319.9	16.2	P	D	C	58
320.0-372.7	15.7	P	C	C	58
372.8-384.6	15.7	P	B	C	58
384.7-401.3	15.6	O	B	C	58
401.4-424.8	15.5	N	B	C	58

Table A-24 (continued). 9000 kg- TNT High Level of Protection

STANDOFF DISTANCE IN METERS	% Increase				Construction Type			
	ADMIN FACILITY	MEDICAL CLINIC	BARRACKS (EXT ENT)	BARRACKS (INT ENT)	Walls	Windows	Doors	Roofs
441.7-520.2	21.9	13.6	32.3	6.1	E	A	C	7
520.3-520.6	21.3	12.5	31.8	5.6	E	A	C	6
520.7-713.3	20.9	12.3	31.6	5.4	D	A	C	6
713.4-844.3	20.5	11.7	31.3	5.1	D	A	C	5
844.4-914.6	20.4	11.5	31.2	5.0	D	A	C	3
914.7-1024.9	20.2	11.2	31.1	4.9	D	A	C	1
1025.0-	15.4	5.0	2.6	2.7	D	A	A	1

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	DINING FACILITY	Walls	Windows	Doors	Roofs
386.1-412.8	12.2	L	B	C	34
412.9-424.8	11.9	L	B	C	31
424.9-441.6	11.8	L	A	C	31
441.7-520.6	11.1	E	A	C	31
520.7-799.7	10.9	D	A	C	31
799.8-851.0	9.8	D	A	C	30
851.1-899.5	9.2	D	A	C	26
899.6-1024.9	9.1	D	A	C	25
1025.0-	4.5	D	A	A	25

STANDOFF DISTANCE IN METERS	%Δ	Construction Type			
	SPECIAL STRUCTURE	Walls	Windows	Doors	Roofs
424.9-488.6	15.5	N	A	C	58
488.7-647.3	15.3	L	A	C	58
647.4-679.0	14.8	E	A	C	58
679.1-742.7	12.5	E	A	C	54
742.8-794.1	12.4	D	A	C	54
794.2-864.7	11.7	D	A	C	51
864.8-1024.9	11.6	D	A	C	50
1025.0-	5.4	D	A	A	50

**Table A-25. Building Cost Increases Hand Delivered Devices
Low Threat Severity Level
(IID only)**

Building Type	Very Low & Low LOP					Medium LOP					High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility	9.5					9.5					9.5				
Medical Clinic	1.7					1.7					1.7				
Barracks with Exterior Entries	1.7	A	A	A	A	1.7	A	A	A	A	1.7	A	A	A	A
Barracks with Interior Entries	1.7					1.7					1.7				
Dining Facility	1.2					1.2					1.2				
Special Structure	1.7					1.7					1.7				

**Table A-26. Building Cost Increases Hand Delivered Devices
Medium Threat Severity Level
(Hand grenades and 1 kg IED only)**

Building Type	Very Low and Low LOP					Medium LOP					High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility	9.5					9.5					41.7				
Medical Clinic	1.7					1.7					17.0				
Barracks with Exterior Entries	1.7	A	A	A	A	1.7	A	A	A	A	14.4	C	B	A	B
Barracks with Interior Entries	1.7					1.7					10.0				
Dining Facility	1.2					1.2					14.1				
Special Structure	1.7					1.7					17.0				

Table A-27. Cost Increases for Mail rooms 1 kg TNT Explosive						
Building Type	**Low Level of Protection**		**Medium Level of Protection**		**High Level of Protection**	
	% Cost Increase	**Construc-tion**	**% Cost Increase**	**Construc-tion**	**% Cost Increase**	**Construc-tion**
Dining Facility • Small [1] • Medium [2] • Large [3]	0.8 1.0 1.3	See Table C-6	0.9 1.0 1.3	See Table C-6	0.9 1.1 1.4	See Table C-6
Administration Building • Small [1] • Medium [2] • Large [3]	0.8 1.0 1.3		0.8 1.0 1.3		0.9 1.1 1.4	
Medical Clinic • Small [1] • Medium [2] • Large [3]	0.5 0.6 0.7		0.5 0.6 0.7		0.5 0.6 0.8	
Barracks with Exterior Entrances • Small [1] • Medium [2] • Large [3]	0.2 0.2 0.3		0.2 0.2 0.3		0.2 0.3 0.3	
Barracks with Interior Entrances • Small [1] • Medium [2] • Large [3]	0.2 0.3 0.3		0.2 0.3 0.3		0.2 0.3 0.3	
Special Structures • Small [1] • Medium [2] • Large [3]	0.6 0.7 0.9		0.6 0.7 0.9		0.6 0.7 1.0	
1. 10 ft. x 20 ft. x 10 ft. 2. 16 ft. x 25 ft. x 10 ft. 3. 22 ft. x 32 ft. x 10 ft.						

Table A-28. Cost Increases for Loading Docks 1 kg TNT Explosive						
Building Type	**Low Level of Protection**		**Medium Level of Protection**		**High Level of Protection**	
	% Cost Increase	**Construc-tion**	**% Cost Increase**	**Construc-tion**	**% Cost Increase**	**Construc-tion**
Dining Facility • Small [1] • Medium [2] • Large [3]	0.8 1.1 1.4	See Table C-6	0.9 1.1 1.4	See Table C-6	0.9 1.2 1.6	See Table C-6
Administration Building • Small [1] • Medium [2] • Large [3]	0.8 1.1 1.4		0.9 1.1 1.4		0.9 1.2 1.6	
Medical Clinic • Small [1] • Medium [2] • Large [3]	0.5 0.6 0.8		0.5 0.6 0.8		0.5 0.6 0.9	
Barracks with Exterior Entrances • Small [1] • Medium [2] • Large [3]	0.2 0.3 0.3		0.2 0.3 0.3		0.2 0.3 0.4	
Barracks with Interior Entrances • Small [1] • Medium [2] • Large [3]	0.2 0.3 0.3		0.2 0.3 0.3		0.2 0.3 0.4	
Special Structures • Small [1] • Medium [2] • Large [3]	0.6 0.7 0.9		0.6 0.8 1.0		0.6 0.8 1.1	
1. 10 ft. x 22 ft. x 10 ft. 2. 16 ft. x 34 ft. x 10 ft. 3. 22 ft. x 46 ft. x 10 ft.						

Table A-29. Cost Increases for Loading Docks
25 kg TNT Explosive

Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection	
	% Cost Increase	Construction	% Cost Increase	Construction	% Cost Increase	Construction
Dining Facility • Small [1] • Medium [2] • Large [3]	1.4 2.0 2.9	See Table C-7	1.5 2.1 3.0	See Table C-7	1.6 2.3 3.3	See Table C-7
Administration Building • Small [1] • Medium [2] • Large [3]	1.4 2.0 2.8		1.5 2.1 3.0		1.6 2.3 3.3	
Medical Clinic • Small [1] • Medium [2] • Large [3]	0.8 1.1 1.5		0.8 1.2 1.6		0.9 1.2 1.8	
Barracks with Exterior Entrances • Small [1] • Medium [2] • Large [3]	0.3 0.5 0.7		0.4 0.5 0.7		0.4 0.5 0.8	
Barracks with Interior Entrances • Small [1] • Medium [2] • Large [3]	0.4 0.5 0.7		0.4 0.5 0.7		0.4 0.6 0.8	
Special Structures • Small [1] • Medium [2] • Large [3]	1.0 1.4 1.9		1.1 1.5 2.1		1.1 1.6 2.3	

1. 10 ft. x 22 ft. x 10 ft.
2. 16 ft. x 34 ft. x 10 ft.
3. 22 ft. x 46 ft. x 10 ft.

Table A-30. Cost Increases for Entry Areas 1 kg TNT Explosive						
Building Type	**Low Level of Protection**		**Medium Level of Protection**		**High Level of Protection**	
	% Cost Increase	**Construction**	**% Cost Increase**	**Construction**	**% Cost Increase**	**Construction**
Dining Facility • Small [1] • Medium [2] • Large [3]	1.0 1.3 2.0	See Table C-6	1.0 1.3 2.0	See Table C-6	1.1 1.4 2.0	See Table C-6
Administration Building • Small [1] • Medium [2] • Large [3]	1.0 1.2 2.0		1.0 1.3 2.0		1.1 1.4 2.0	
Medical Clinic • Small [1] • Medium [2] • Large [3]	0.6 0.7 1.1		0.6 0.7 1.1		0.6 0.7 1.1	
Barracks with Exterior Entrances • Small [1] • Medium [2] • Large [3]	0.2 0.3 0.5		0.2 0.3 0.5		0.3 0.3 0.5	
Barracks with Interior Entrances • Small [1] • Medium [2] • Large [3]	0.3 0.3 0.5		0.3 0.3 0.5		0.3 0.3 0.5	
Special Structures • Small [1] • Medium [2] • Large [3]	0.7 0.9 1.4		0.7 0.9 1.4		0.7 0.9 1.4	
1. 15 ft. x 30 ft. x 10 ft. 2. 20 ft. x 40 ft. x 10 ft. 3. 40 ft. x 50 ft. x 10 ft.						

Table A-31. Cost Increases for Entry Areas 25 kg TNT Explosive						
Building Type	**Low Level of Protection**		**Medium Level of Protection**		**High Level of Protection**	
	% Cost Increase	**Construc-tion**	**% Cost Increase**	**Construc-tion**	**% Cost Increase**	**Construc-tion**
Dining Facility • Small [1] • Medium [2] • Large [3]	1.6 2.2 4.1	See Table C-6	1.7 2.4 4.5	See Table C-6	1.9 2.5 4.9	See Table C-6
Administration Building • Small [1] • Medium [2] • Large [3]	1.6 2.2 4.0		1.7 2.3 4.5		1.8 2.5 4.8	
Medical Clinic • Small [1] • Medium [2] • Large [3]	0.9 1.2 2.2		0.9 1.3 2.5		1.0 1.4 2.6	
Barracks with Exterior Entrances • Small [1] • Medium [2] • Large [3]	0.4 0.5 1.0		0.4 0.6 1.1		0.4 0.6 1.1	
Barracks with Interior Entrances • Small [1] • Medium [2] • Large [3]	0.4 0.5 1.0		0.4 0.6 1.1		0.5 0.6 1.2	
Special Structures • Small [1] • Medium [2] • Large [3]	1.1 1.5 2.8		1.2 1.6 3.1		1.3 1.7 3.3	
1. 15 ft. x 30 ft. x 10 ft. 2. 20 ft. x 40 ft. x 10 ft. 3. 40 ft. x 50 ft. x 10 ft.						

Table A-32. Building Cost Increases for Indirect Fire Weapons Low Threat Severity Level															
Building Type	**Low LOP**					**Medium LOP**					**High LOP**				
	% Increase	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase**	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase**	**Walls**	**Windows**	**Doors**	**Roof**
Dining Facility	1.2	cc	A	cc	cc	1.2	cc	A	cc	cc	1.2	cc	A	cc	cc
Administrative Facility	9.5					9.5					9.5				
Medical Clinic	1.8					1.8					1.8				
Barracks with Exterior Entrances	1.7					1.7					1.7				
Barracks with Interior Entrances	1.7					1.7					1.7				
Special Structure	1.8					1.8					1.8				
cc = conventional construction. The baseline construction for those components is adequate															

Table A-33. Building Cost Increases for Indirect Fire Weapons
Medium Threat Severity Level

Building Type	Low LOP							Medium LOP							High LOP						
	% Increase	Walls	Wall Extensions	Windows	Doors	Hardened Roof	Sacrificial Roof	% Increase	Walls	Wall Extensions	Windows	Doors	Hardened Roof	Sacrificial Roof	% Increase	Walls	Wall Extensions	Windows*	Doors	Hardened Roof	Sacrificial Roof
Dining Facility	8.2	A	A	A	A	2	3	16.5	B	B	A	A	3	3	22.3	F	C	C	A	8	3
Administrative Facility	15.5	A	A	A	A	2	3	25.4	B	B	A	A	3	3	24.6	F	C	C	A	8	3
Medical Clinic	10.2	A	A	A	A	2	1	17.6	B	B	A	A	3	1	22.4	F	C	C	A	8	1
Barracks with Exterior Entrances	14.3	B	B	A	A	2	3	14.6	B	B	A	A	3	3	25.2	F	C	C	A	8	3
Barracks with Interior Entrances	7.6	B	B	A	A	2	3	7.9	B	B	A	A	3	3	12.2	F	C	C	A	8	3
Special Structure	18.3	B	B	A	A	2	3	19.0	B	B	A	A	3		22.9	F	C	C	A	8	3

*Note: Windows are not feasible at this LOP due to weapon casing fragments

Table A-34. Building Cost Increases for Indirect Fire Weapons High Threat Severity Level																					
Building Type	**Low LOP**							**Medium LOP**							**High LOP**						
	% Increase	**Walls**	**Wall Extensions**	**Windows**	**Doors**	**Hardened Roof**	**Sacrificial Roof**	**% Increase**	**Walls**	**Wall Extensions**	**Windows**	**Doors**	**Hardened Roof**	**Sacrificial Roof**	**% Increase**	**Walls**	**Wall Extensions**	**Windows***	**Doors**	**Hardened Roof**	**Sacrificial Roof**
Dining Facility	16.7	B	B	A	A	7	3	22.0	E	C	A	A	8	3	37.2	H	C	C	A	9	4
Administrative Facility	25.6	B	B	A	A	7	3	32.6	E	C	A	A	8	3	44.4	H	C	C	A	9	4
Medical Clinic	18.0	B	B	A	A	7	1	22.5	E	C	A	A	8	1	35.7	H	C	C	A	9	2
Barracks with Exterior Entrances	14.8	B	B	A	A	7	3	23.4	E	C	A	A	8	3	46.5	H	C	C	A	9	4
Barracks with Interior Entrances	8.0	B	B	A	A	7	3	12.3	E	C	A	A	8	3	23.0	H	C	C	A	9	4
Special Structure	19.3	B	B	A	A	7	3	23.2	E	C	A	A	8	3	34.1	H	C	C	A	9	4
*Note: Windows are not feasible at this LOP due to weapon casing fragments																					

Table A-35. Building Cost Increases for Indirect Fire Weapons
Very High Threat Severity Level

Building Type	Low LOP							Medium LOP							High LOP						
	% Increase	Walls	Wall Extensions	Windows	Doors	Hardened Roof	Sacrificial Roof	% Increase	Walls	Wall Extensions	Windows*	Doors	Hardened Roof	Sacrificial Roof	% Increase	Walls	Wall Extensions	Windows	Doors	Hardened Roof	Sacrificial Roof
Dining Facility	25.7	E	C	B	A	5	4	28.2	G	C	C	A	11	4							
Administrative Facility	37.2	E	C	B	A	5	4	28.6	G	C	C	A	11	4							
Medical Clinic	25.7	E	C	B	A	5	2	28.6	G	C	C	A	11	2		*Designing to meet this level of protection for this threat is not practical for conventional buildings*					
Barracks with Exterior Entrances	25.8	E	C	B	A	5	4	29.1	G	C	C	A	11	4							
Barracks with Interior Entrances	13.6	E	C	B	A	5	4	14.6	G	C	C	A	11	4							
Special Structure	25.3	E	C	B	A	5	4	28.0	G	C	C	A	11	4							

*Note: Windows are not feasible at this LOP due to weapon casing fragments

Table A-36. Building Cost Increases for Direct Fire Weapons Low Threat Severity Level

Building Type	Low LOP: % Increase	Low LOP: Walls	Low LOP: Windows	Low LOP: Doors	Low LOP: Roof	High LOP: % Increase[1]	High LOP: Walls	High LOP: Windows	High LOP: Doors	High LOP: Roof[2]
Dining Facility	0.22					4.0				A
						5.0				C
Administration Building	1.43					23.2				A
						23.9				B
Medical Clinic	0.23					4.4				A
		A	A	A	A	7.2	B	C	B	B
Barracks with Exterior Entrances	0.24					9.9				A
						10.4				B
Barracks with Interior Entrances	0.24					4.3				A
						4.8				B
Special Structures	0.37					7.5				A
						10.8				D

Note: Costs are for entire building exterior. For smaller portions of buildings use a straight percentage of protected perimeter ÷ total perimeter

1. For roofs to which there is no sightline, use top number in each pair of values for % cost increase. Where there is a sightline to a roof, use bottom number in each pair of values for % cost increase.
2. For roofs to which there is no sightline, the top roof designation in each pair indicates the roof construction on which the cost increase is based. The bottom roof designation in each pair indicates the roof construction on which the cost increase is based where there is a sightline to the roof.

Table A-37. Building Cost Increases for Direct Fire Weapons Medium Threat Severity Level

Building Type	Low LOP % Increase	Low LOP Walls	Low LOP Windows	Low LOP Doors	Low LOP Roof	High LOP % Increase[1]	High LOP Walls	High LOP Windows	High LOP Doors	High LOP Roof [2]
Dining Facility	0.22	A	A	A	A	7.8	C	D	C	A
						8.8				C
Administration Building	1.43					29.2				A
						29.7				B
Medical Clinic	0.23					7.2				A
						10.0				B
Barracks with Exterior Entrances	0.24					12.3				A
						12.8				B
Barracks with Interior Entrances	0.24					4.8				A
						5.3				B
Special Structures	0.37					8.2				A
						11.5				D

Note: Costs are for entire building exterior. For smaller portions of buildings use a straight percentage of protected perimeter ÷ total perimeter

1. For roofs to which there is no sightline, use top number in each pair of values for % cost increase. Where there is a sightline to a roof, use bottom number in each pair of values for % cost increase.
2. For roofs to which there is no sightline, the top roof designation in each pair indicates the roof construction on which the cost increase is based. The bottom roof designation in each pair indicates the roof construction on which the cost increase is based where there is a sightline to the roof.

Table A-38. Building Cost Increases for Direct Fire Weapons High Threat Severity Level

Building Type	Low LOP					High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase[1]	Walls	Windows	Doors	Roof [2]
Dining Facility	0.22	A	A	A	A	9.7	D	E	D	A
						15.3				E
Administration Building	1.43					37.7				A
						41.1				E
Medical Clinic	0.23					9.1				A
						17.2				E
Barracks with Exterior Entrances	0.24					15.3				A
						18.0				E
Barracks with Interior Entrances	0.24					6.8				A
						9.7				E
Special Structures	0.37					10.4				A
						18.5				E

Note: Costs are for entire building exterior. For smaller portions of buildings use a straight percentage of protected perimeter ÷ total perimeter

1. For roofs to which there is no sightline, use top number in each pair of values for % cost increase. Where there is a sightline to a roof, use bottom number in each pair of values for % cost increase.
2. For roofs to which there is no sightline, the top roof designation in each pair indicates the roof construction on which the cost increase is based. The bottom roof designation in each pair indicates the roof construction on which the cost increase is based where there is a sightline to the roof.

Table A-39. Building Cost Increases for Direct Fire Weapons
Very High Threat Severity Level

Building Type	Low LOP					Medium and High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase[1]	Walls	Windows	Doors	Roof [2]
Dining Facility	0.22	A	A	A	A	13.0 19.6	E	None	E	A F
Administration Building	1.43					19.0 24.8				A F
Medical Clinic	0.23					12.5 24.2				A F
Barracks with Exterior Entrances	0.24					33.5 37.4				A F
Barracks with Interior Entrances	0.24					15.0 19.3				A F
Special Structures	0.37					14.6 26.3				A F

Note: Costs are for entire building exterior. For smaller portions of buildings use a straight percentage of protected perimeter ÷ total perimeter

1. For roofs to which there is no sightline, use top number in each pair of values for % cost increase. Where there is a sightline to a roof, use bottom number in each pair of values for % cost increase.
2. For roofs to which there is no sightline, the top roof designation in each pair indicates the roof construction on which the cost increase is based. The bottom roof designation in each pair indicates the roof construction on which the cost increase is based where there is a sightline to the roof.

Table A-40. Building Cost Increases for Airborne Contamination Mitigation (All Threat Severity Levels and Levels of Protection)						
Building Type	**Low LOP**		**Medium LOP**		**High LOP**	
	% Increase	**HVAC Requirements**	**% Increase**	**HVAC Requirements**	**% Increase**	**HVAC Requirements**
Dining Facility	1.0	See Table C-12	17.2	See Table C-12	27.9	See Table C-12
Administrative Facility	0.4		6.3		13.9	
Medical Clinic	0.7		11.8		18.5	
Barracks with Exterior Entrances	0.4		11.1		13.9	
Barracks with Interior Entrances	0.1		6.7		7.8	
Special Structure	1.0		33.0		46.4	

Table A-41. Costs to Mitigate Waterborne Contamination (All Building Types, Threat Severity Levels and Levels of Protection)						
	Level of Protection					
Building Type	**Low LOP**		**Medium LOP**		**High LOP**	
	%	O & M / year	%	O & M / year	%	O & M / year
Administrative Facility	0.4	0	6.1	$30,000	10.5	$30,000
Medical Clinic	0.1	0	2.5	$30,000	4.3	$30,000
Barracks with Exterior Entries	0.1	0	1.6	$30,000	2.8	$30,000
Barracks with Interior Entries	0.1	0	1.4	$30,000	2.5	$30,000
Dining Facility	0.5	0	7.9	$30,000	13.6	$30,000
Special Structure	0.3	0	5.7	$30,000	9.9	$30,000

<table>
<tr><th colspan="21">Table A-42. Building Cost Increases for Forced Entry Tactic
Low Threat Severity Level</th></tr>
<tr><th rowspan="2">Building Type</th><th colspan="5">Low LOP</th><th colspan="5">Medium LOP</th><th colspan="5">High LOP</th><th colspan="5">Very High LOP</th></tr>
<tr><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th></tr>
<tr><td>Administrative Facility</td><td>8.2</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td>10.6</td><td rowspan="6">B</td><td rowspan="6">B</td><td rowspan="6">A</td><td rowspan="6">A</td><td>19.1</td><td rowspan="6">D</td><td rowspan="6">B</td><td rowspan="6">D</td><td rowspan="6">D</td><td>5.6</td><td rowspan="6">F</td><td rowspan="6">No*</td><td rowspan="6">E</td><td rowspan="6">F</td></tr>
<tr><td>Medical Clinic</td><td>0.0</td><td>0.3</td><td>12.7</td><td>12.5</td></tr>
<tr><td>Barracks with Exterior Entries</td><td>1.3</td><td>2.8</td><td>10.2</td><td>9.9</td></tr>
<tr><td>Barracks with Interior Entries</td><td>0.9</td><td>2.4</td><td>8.0</td><td>7.1</td></tr>
<tr><td>Dining Facility</td><td>0.0</td><td>0.0</td><td>8.1</td><td>7.9</td></tr>
<tr><td>Special Structure</td><td>0.0</td><td>4.4</td><td>17.6</td><td>18.8</td></tr>
<tr><td colspan="21">* Note: Windows are not available to meet this requirement. Eliminate or limit openings to 96 square inches.</td></tr>
</table>

<table>
<tr><th colspan="21">Table A-43. Building Cost Increases for Forced Entry Tactic
Medium Threat Severity Level</th></tr>
<tr><th rowspan="2">Building Type</th><th colspan="5">Low LOP</th><th colspan="5">Medium LOP</th><th colspan="5">High LOP</th><th colspan="5">Very High LOP</th></tr>
<tr><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th></tr>
<tr><td>Administrative Facility</td><td>11.6</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td>19.6</td><td rowspan="6">C</td><td rowspan="6">B</td><td rowspan="6">B</td><td rowspan="6">G</td><td>4.7</td><td rowspan="6">E</td><td rowspan="6">No*</td><td rowspan="6">H</td><td rowspan="6">E</td><td>11.3</td><td rowspan="6">L</td><td rowspan="6">No*</td><td rowspan="6">F</td><td rowspan="6">J</td></tr>
<tr><td>Medical Clinic</td><td>4.8</td><td>14.0</td><td>11.6</td><td>17.6</td></tr>
<tr><td>Barracks with Exterior Entries</td><td>3.8</td><td>9.1</td><td>13.4</td><td>17.1</td></tr>
<tr><td>Barracks with Interior Entries</td><td>3.2</td><td>8.3</td><td>6.4</td><td>10.4</td></tr>
<tr><td>Dining Facility</td><td>1.4</td><td>8.8</td><td>7.4</td><td>12.6</td></tr>
<tr><td>Special Structure</td><td>4.3</td><td>17.6</td><td>17.4</td><td>28.5</td></tr>
<tr><td colspan="21">* Note: Windows are not available to meet this requirement. Eliminate or limit openings to 96 square inches.</td></tr>
</table>

**Table A-44. Building Cost Increases for Forced Entry Tactic
High Threat Severity Level**

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility	11.6	A	A	A	A	22.2	G	B	C	H	7.7	H	No*	I	I	17.2	J	No*	J	J
Medical Clinic	4.8					15.7					14.3					23.2				
Barracks with Exterior Entries	3.8					12.4					15.5					22.6				
Barracks with Interior Entries	3.2					10.1					8.2					13.9				
Dining Facility	1.4					10.8					9.8					17.5				
Special Structure	4.3					23.4					22.4					38.4				

* Note: Windows are not available to meet this requirement. Eliminate or limit openings to 96 square inches.

Table A-45. Building Cost Increases for Forced Entry Tactic
Very High Threat Severity Level

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility	12.8	C	No*	A	C	24.9	K	No*	G	K	28.9	L	No*	J	M	50.4	M	No*	K	N
Medical Clinic	5.3					25.3					31.7					46.9				
Barracks with Exterior Entries	3.8					25.0					29.7					47.9				
Barracks with Interior Entries	3.2					18.2					20.1					33.2				
Dining Facility	2.1					21.1					25.7					40.9				
Special Structure	8.3					53.3					59.0					97.0				

* Note: Windows are not available to meet this requirement. Eliminate or limit openings to 96 square inches.

Table A-46. Interior Area Cost Increases for Forced Entry Tactic Low Threat Severity Level																				
Building Type	**Low LOP**					**Medium LOP**					**High LOP**					**Very High LOP**				
	% Increase	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase**	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase**	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase**	**Walls**	**Windows**	**Doors**	**Roof**
Administrative Facility • Small [1] • Medium [2] • Large [3]	 0.04 0.06 0.07	A	None [4]	A	A	 0.12 0.18 0.21	C	None [4]	A	D	 0.25 0.41 0.52	D	None [4]	H	G	 0.32 0.51 0.65	E	None [4]	E	F
Medical Clinic • Small [1] • Medium [2] • Large [3]	 0.02 0.03 0.04					 0.06 0.10 0.11					 0.14 0.22 0.29					 0.18 0.28 0.36				
Barracks with Exterior Entries • Small [1] • Medium [2] • Large [3]	 0.01 0.01 0.02					 0.03 0.04 0.05					 0.06 0.10 0.12					 0.08 0.12 0.15				

Table A-46 - continued

Barracks with Interior Entries • Small [1] • Medium [2] • Large [3]	0.01 0.02 0.02					0.03 0.05 0.05					0.06 0.10 0.13					0.08 0.13 0.17				
Dining Facility • Small [1] • Medium [2] • Large [3]	0.04 0.06 0.07	A	None [4]	A	A	0.12 0.18 0.21	C	None [4]	A	D	0.26 0.41 0.53	D	None [4]	H	G	0.33 0.52 0.66	E	None [4]	E	F
Special Structure • Small [1] • Medium [2] • Large [3]	0.03 0.04 0.05					0.08 0.12 0.14					0.18 0.28 0.36					0.22 0.35 0.45				

Notes:
1. Room size: 12 ft. x 12 ft. x 10 ft. high
2. Room size: 12 ft. x 24 ft. x 10 ft. high
3. Room size: 18 ft. x 24 ft. x 10 ft. high
4. Windows are not included because areas are interior spaces.

Table A-47. Interior Area Cost Increases for Forced Entry Tactic
Medium Threat Severity Level

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility																				
• **Small** [1]	0.08					0.23					0.36					0.48				
• **Medium** [2]	0.13					0.39					0.53					0.73				
• **Large** [3]	0.18					0.51					0.65					0.90				
Medical Clinic																				
• **Small** [1]	0.04					0.13					0.20					0.26				
• **Medium** [2]	0.07	A	None [4]	A	A	0.21	C	None [4]	B	G	0.29	E	None [4]	H	E	0.40	L	None [4]	F	J
• **Large** [3]	0.10					0.28					0.36					0.49				
Barracks with Exterior Entries																				
• **Small** [1]	0.02					0.05					0.08					0.11				
• **Medium** [2]	0.03					0.09					0.12					0.17				
• **Large** [3]	0.04					0.12					0.15					0.21				

Table A-47 - continued

Barracks with Interior Entries		A	None [4]	A	A		C	None [4]	B	G		E	None [4]	H	E		L	None [4]	F	J
• **Small** [1]	0.02					0.06					0.09					0.12				
• **Medium** [2]	0.03					0.10					0.13					0.19				
• **Large** [3]	0.05					0.13					0.17					0.23				
Dining Facility																				
• **Small** [1]	0.08					0.23					0.36					0.48				
• **Medium** [2]	0.14					0.39					0.54					0.73				
• **Large** [3]	0.18					0.51					0.66					0.91				
Special Structure																				
• **Small** [1]	0.05					0.16					0.25					0.33				
• **Medium** [2]	0.09					0.27					0.37					0.50				
• **Large** [3]	0.12					0.35					0.45					0.62				

Notes:
1. Room size: 12 ft. x 12 ft. x 10 ft. high
2. Room size: 12 ft. x 24 ft. x 10 ft. high
3. Room size: 18 ft. x 24 ft. x 10 ft. high
4. Windows are not included because areas are interior spaces.

Table A-48. Interior Area Cost Increases for Forced Entry Tactic
High Threat Severity Level

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility • **Small** [1] • **Medium** [2] • **Large** [3]	0.2 0.4 0.6					0.6 1.0 1.4					0.9 1.4 1.9					1.1 1.8 2.3				
Medical Clinic • **Small** [1] • **Medium** [2] • **Large** [3]	0.1 0.2 0.3	A	None [4]	A	A	0.3 0.6 0.7	G	None [4]	C	H	0.5 0.8 1.0	H	None [4]	I	I	0.6 1.0 1.3	H	None [4]	J	J
Barracks with Exterior Entries • **Small** [1] • **Medium** [2] • **Large** [3]	0.1 0.1 0.1					0.1 0.2 0.3					0.2 0.3 0.4					0.3 0.4 0.5				

Table A-48 - continued

Barracks with Interior Entries • **Small** [1] • **Medium** [2] • **Large** [3]	0.1 0.1 0.2					0.2 0.3 0.3					0.2 0.4 0.5					0.3 0.5 0.6				
Dining Facility • **Small** [1] • **Medium** [2] • **Large** [3]	0.2 0.4 0.6	A	None [4]	A	A	0.6 1.0 1.4	G	None [4]	C	H	0.9 4.5 1.9	H	None [4]	I	I	1.1 1.8 2.3	H	None [4]	J	J
Special Structure • **Small** [1] • **Medium** [2] • **Large** [3]	0.2 0.3 0.4					0.4 0.7 0.9					0.6 1.0 1.3					0.8 1.2 1.6				

Notes:
1. Room size: 12 ft. x 12 ft. x 10 ft. high
2. Room size: 12 ft. x 24 ft. x 10 ft. high
3. Room size: 18 ft. x 24 ft. x 10 ft. high
4. Windows are not included because areas are interior spaces.

Table A-49. Building Cost Increases for Covert Entry Tactic *Low Threat Severity Level*								
Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection		Very High Level of Protection	
	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set
Dining Facility	0.11	B	0.74	C	1.25	D	1.95	E
Admin. Building	0.08	B	0.15	C	0.97	D	1.51	E
Medical Clinic	0.03	B	0.23	C	0.39	D	0.61	E
Barracks with Exterior Entrances	.02	B and A	.015	C and A	.026	D and A	0.40	E and A
Barracks with Interior Entrances	0.02	B and A	0.14	C and A	0.23	D and A	0.36	E and A
Special Structures	0.08	B	0.54	C	0.91	D	1.42	E

Table A-50 Building Cost Increases for Covert Entry Tactic Medium Threat Severity Level								
Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection		Very High Level of Protection	
	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set
Dining Facility	0.67	F	0.83	G	1.33	H	1.95	I
Admin. Building	0.52	F	0.64	G	1.03	H	1.51	I
Medical Clinic	0.21	F	0.26	G	0.42	H	0.61	I
Barracks with Exterior Entrances	0.14	F and A	0.17	G and A	0.28	H and A	0.40	I and A
Barracks with Interior Entrances	0.12	F and A	0.15	G and A	0.24	H and A	0.36	I and A
Special Structures	0.46	F	0.61	G	0.97	H	1.42	I

Table A-51 Building Cost Increases for Covert Entry Tactic High Threat Severity Level								
Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection		Very High Level of Protection	
	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set
Dining Facility	1.0	J	1.16	K	5.08	L	5.85	M
Admin. Building	0.77	J	0.9	K	3.93	L	4.52	M
Medical Clinic	0.31	J	0.36	K	1.59	L	1.83	M
Barracks with Exterior Entrances	0.21	J and A	0.24	K and A	1.05	L and A	1.21	M and A
Barracks with Interior Entrances	0.18	J and A	0.21	K and A	0.93	L and A	1.07	M and A
Special Structures	0.73	J	0.85	K	3.70	L	4.27	M

Table A-52 Building Cost Increases for Covert Entry Tactic Very High Threat Severity Level								
Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection		Very High Level of Protection	
	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set
Dining Facility	1.0	J	1.16	K	5.08	L	5.85	M
Admin. Building	0.77	J	0.9	K	3.93	L	4.52	M
Medical Clinic	0.31	J	0.36	K	1.59	L	1.83	M
Barracks with Exterior Entrances	0.21	J and A	0.24	K and A	1.05	L and A	1.21	M and A
Barracks with Interior Entrances	0.18	J and A	0.21	K and A	0.93	L and A	1.07	M and A
Special Structures	0.73	J	0.85	K	3.70	L	4.27	M

Table A-53. Surveillance Tactic Cost Increases

Building Type	% Cost Increase	Construction
Dining Facility	0.3%	0.10 mm (4-mil) reflective fragment retention film on windows
Administration Building	1.4%	
Medical Clinic	0.2%	
Barracks with Exterior Entrances	0.2%	
Barracks with Interior Entrances	0.2%	
Special Structures	0.3%	

Table A-54. Building Cost increases for Acoustics Eavesdropping Tactic

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Dining Facility	0	A	A	A	A	0.8	A	B	B	A	1.3	A	C	C	A	2.5	A	D	D	A
Administrative Facility	0					2.5					3.8					7.3				
Medical Clinic	0					0.9					1.5					2.6				
Barracks with Exterior Entries	0					5.8					7.9					11.4				
Barracks with Interior Entries	0					0.6					1.0					1.7				
Special Structure	0					0.9					1.5					2.6				

Table A-55. Interior Area Cost Increases for Acoustics Eavesdropping Tactic

Building Type	Low LOP (STC 30)					Medium LOP (STC 40)					High LOP (STC 45)					Very High LOP (STC 50)				
	% Increase	Walls	Windows	Doors	Ceiling	% Increase	Walls	Windows	Doors	Ceiling	% Increase	Walls	Windows	Doors	Ceiling	% Increase	Walls	Windows	Doors	Ceiling
1 story building • **Small [1]** • **Medium [2]** • **Large [3]**	 0.04 0.08 0.11	A	None	A	B	 0.25 0.28 0.32	A	None	B	C	 0.33 0.38 0.42	B	None	C	D	 0.44 0.51 0.57	C	None	D	E
Multi-story building • **Small [1]** • **Medium [2]** • **Large [3]**	 0.01 0.01 0.01				A	 0.21 0.21 0.21				A	 0.28 0.29 0.29				A	 0.39 0.40 0.41				A

Notes:
1. Room size: 12 ft. x 12 ft. x 10 ft. high
2. Room size: 12 ft. x 24 ft. x 10 ft. high
3. Room size: 18 ft. x 24 ft. x 10 ft. high
4. Windows are not included because areas are interior spaces.

Table A-56. Building Cost Increases for Electronic Emanations Eavesdropping Tactic

Building Type		% Increase	Walls	Windows	Doors	Ceiling / Roof
Building Exterior Shielded	Dining Facility	27.3	TEMPEST shielding in walls	Specially manufactured TEMPEST windows	Specially manufactured TEMPEST doors	TEMPEST shielding in roof or ceiling
	Administrative Facility	53.1				
	Medical Clinic	34.1				
	Barracks with Exterior Entries	46.7				
	Barracks with Interior Entries	17.8				
	Special Structure	34.1				
Interior Room Shielded	1 story building • Small [1] • Medium [2] • Large [3]	 1.44 1.69 1.85		None		
	Multi-story building • Small [1] • Medium [2] • Large [3]	 1.35 1.55 1.69				

1. Room size: 12 ft. x 12 ft. x 10 ft. high
2. Room size: 12 ft. x 24 ft. x 10 ft. high
3. Room size: 18 ft. x 24 ft. x 10 ft. high

Table A-57. Sitework Cost Multipliers

Tactic	Barrier Type	Threat Severity Level	Cost Multiplier [1]	Construction
Moving Vehicle Bomb	Passive Perimeter	Minimum	1.2	B
		Low	1.3	C
		Medium	1.4	D
		High	5.0	E
		Very High	7.5	F
		Special Case	8.5	G
	Active	Minimum	1.0	I
		Low	5.6	J
		Medium	7.4	K
		High	7.4	L
		Very High	11.1	M
		Special Case	16.7	N
Stationary Vehicle Bomb	Passive Perimeter	All	1.0	A
	Active	All	1.0	H
Direct Fire Weapons	Screen	Very High [2]	2.3	O

1. Cost multipliers based on Standard 8-foot chain link fence (7-foot fabric with outrigger) for passive perimeter barriers and a motorized 8-foot high x 12 feet wide chain link gate for active barriers.
2. Predetonation screen only. Directly hardening building for ballistics element of this tactic is less expensive than employing energy absorption screen.

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APPENDIX B

RETROFIT CONSTRUCTION COST TABLES

B-1 **INTRODUCTION.** The purpose of the tables in this appendix is to provide planning level estimates of cost increases for retrofit construction for buildings representative of those commonly built by the Department of Defense. The costs tabulated represent the costs to meet the design criteria as percentages of new construction costs for the common existing conventional construction for those building types or rooms within buildings of those types. Presenting retrofit costs as increases over new construction costs was done because new construction costs for common military construction can be easily identified.

B-2 **NAVIGATING THE TABLES.** Table B-1 provides a guide to locating the cost tables for various threats. It is organized by tactic, threat severity level, and level of protection for all but the hand delivered devices and forced entry tactics. For the hand delivered devices tactic, the costs are tabulated by external attack, attacks on interior spaces for improvised incendiary devices, and attacks on mail rooms, loading docks, and entrance areas using different explosive weights.

B-3 **BUILDING COMPONENT COST FORMULATION.** The cost tables were formulated by arraying a number of components that would meet the requirements of mitigating the effects of particular tactics to the applicable threat severity levels and levels of protection. Those components were then sorted based on cost, and the least cost components were entered into a building cost model. That building cost model included the new construction baseline costs of the building components that were found to be commonly used for those buildings and that were representative of the building components that are in military construction pricing guidance. The costs in these tables are for an area cost factor of one.

The additional costs for the enhanced construction components over the conventional component costs were determined as a percentage increase over new conventional construction costs. The percentages of the building cost represented by each of the components were built into the model; therefore, the percentage increase in the total building costs represented by the enhanced building components could be determined. It is those cost increases that are tabulated. Note that in some retrofit tables there are not multiple levels of protection for all building components. In those cases there is insufficient development in the retrofit technologies to support different performances for different levels of protection, so one solution applies to multiple levels of protection.

Note that in the case of administrative buildings the cost increases are often very high. That is due to the fact that those buildings commonly have a high percentage of windows. Replacement windows to provide levels of protection against many of the threats covered by this UFC are very costly. Reducing window areas in those buildings may be an effective way to reduce costs; however, this appendix does not directly support determining those cost reductions. In addition, note that Special

Structures are excluded from the cost increase tables for explosive related tactics (Tables B-2 – B-7). That is because for those structure types, existing construction is too variable to develop common cost models. For those structures, special cost studies will need to be performed.

B-4 **PROGRESSIVE COLLAPSE COSTS.** UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings,* requires that all inhabited buildings three stories or greater in height must be designed to resist progressive collapse. For existing buildings, that requirement applies when a building is undergoing renovations, modifications, repairs, and restorations whose costs exceed 50% of the replacement cost of the building. While Appendix A contains cost guidance for new construction, there are no such convenient relationships for existing construction, and those buildings must be evaluated for progressive collapse on a case by case basis; therefore, those costs are no included on this appendix.

B-4. **SITEWORK COST MULTIPLIERS.** Sitework costs are tabulated in Table B-39 as multiples of a baseline barrier. The baseline barrier is either an 8-foot chain link fence (7-foot fabric with outrigger) or an 8-foot high, 12-foot wide (one traffic lane) motorized chain link gate. The costs of those two barriers are easily located in commercial cost estimating guides or in military construction cost databases. The cost multipliers for other barriers were determined by comparing the costs of those barriers to the costs of the baseline barriers. The barriers in Table B-39 are identified by threat severity level for perimeter and active barriers. The barriers associated with those threat severity levels are identified in Appendix C. Boat barrier costs are not included because the costs vary widely and the design guidance is still being developed.

Table B-1. Guide to Retrofit Cost Tables

Tactic		Threat Severity Level	Explosive Weight or other Information	Level of Protection	Table	Page
Vehicle Bombs[1]		VL	25 kg (55 lbs)	All	B-2	B-5
		L	100 kg (220 lbs)	All	B-3	B-6
		M	250 kg (550 lbs)	All	B-4	B-8
		H	500 kg (1100 lbs)	All	B-5	B-10
		VH	2000 kg (4400 lbs)	All	B-6	B-12
		Special Case	9000 kg (19,800 lbs)	All	B-7	B-14
Hand Delivered Devices	**Exterior[1]**	L	IID Only	All	B-8	B-16
		M	1 kg (2.2 lbs)	All	B-9	B-16
		H	25 kg (55 lbs)	VL	Not Applicable [2]	
				L	B-2	B-5
				M		
				H		
	All Interior Spaces	L	IID Only	No cost increases[3]		
	Mail rooms	M & H	1 kg (2.2 lbs)	All	B-10	B-17
	Loading Docks	M	1 kg (2.2 lbs)	All	B-11	B-18
		H	25 kg (55 lbs)	All	B-12	B-19
	Entry Areas	M	1 kg (2.2 lbs)	All	B-13	B-20
		H	25 kg (55 lbs)	All	B-14	B-21
Indirect Fire Weapons		L	IID	All	B-15	B-22
		M	82 mm Mortar	All	B-16	B-23
		H	Rocket	All	B-17	B-24
		VH	Imp. Mortar	Not Provided[4]		
Direct Fire Weapons		L	UL Level 3	All	B-18	B-25
		M	UL Level 5	All	B-19	B-26
		H	UL Level 8	All	B-20	B-27
		VH	Antitank & .50 caliber	All	B-21	B-28

Table B-1 (continued)

Waterfront Attacks (surface / submerged)		L	100 / 25 kg UL Level 5	All	B-3/B-2 B-19	B-6/B-5 B-26
		M	250 / 25 kg UL Level 10.	All	B-4/B-2 B-21	B-8/B-5 B-28
		H	500 kg expl. AT & Level 10	All	B-5/B-2 B-21	B-10/B-5 B-28
Forced Entry	**Exterior** [6]	L	Various Forced Entry Tools	All	B-22	B-29
		M		All	B-23	B-30
		H		All	B-24	B-31
		VH		All	B-25	B-32
	Interior [6]	L	Various Forced Entry Tools	All	B-26	B-33
		M		All	B-27	B-35
		H		All	B-28	B-37
		VH		All	B-28[5]	B-37
Covert Entry		L	None	All	B-29	B-39
		M		All	B-30	B-39
		H		All	B-31	B-40
		VH		All	B-32	B-40
Acoustics Eaves-dropping	**Exterior** [6]	H	Sound amplification devices	All	B-33	B-41
	Interior [6]				B-34	B-42
Elect. Eman. Eaves	**Exterior** [6]	H	Emanations. interception equipment	All	B-35	B-43
	Interior [6]					
Visual Surveillance		H	Ocular Devices	H	B-36	B-44
Airborne Contamination		All	Chem, Bio and Rad. Agents	All	B-37	B-44
Waterborne Contamination		All	Chem, Bio and Rad. Agents	All	B-38	B-45
Sitework Costs		All		All	B-39	B-45

1. Special structures not included. See paragraph B-3.
2. Very low level of protection is not tabulated because baseline construction for all six building types will provide the very low level of protection as close as 10 meters, and no standoff distances less than 10 meters were included in this manual due to requirements in UFC 4-010-01.
3. No cost increases over conventional construction because interior construction is commonly fire resistant already and it is assumed there are no windows.
4. There are no practical retrofits for the improvised mortar.
5. Very high threat severity level not tabulated because it includes explosives, which are considered unlikely for interior use due to collateral damage. Use cost for High threat severity level.
6. Use the exterior tables where entire buildings or large portions of them are to be protected. In the latter case, use percentages of the costs shown in the table based on the percentage of building perimeter area that will be protected. Use interior tables where protection will be focused on interior rooms within buildings. Combinations of interior and exterior costs can also be used where applicable.

Table B-2. 25 kg TNT – All Levels of Protection

Standoff Distance In Meters	% Increase		Construction Type				Standoff Distance In Meters	% Increase		Construction Type				Standoff Distance In Meters	%Δ	Construction Type			
	Admin Facility	Medical Clinic	Walls[2]	Windows	Doors	Roofs		Barracks (Ext. Ent.)	Barracks (Int. Ent.)	Walls[2]	Windows	Doors	Roofs		Dining Facility	Walls[2]	Windows	Doors	Roofs
10.0 – 13.3	25.7	11.4	D	B	B	4	10.0 – 13.3	14.4	8.3	A	B	B	4	10.0 – 10.8	11.7	D	B	B	12
	31.9	14.3	K					15.3	9.1	E					15.9	K			
13.4 – 14.5	25.2	10.7	D	B	B	3	13.4 – 14.5	14.2	8.1	A	B	B	3	10.9 – 12.1	10.6	D	B	B	11
	31.5	13.7	K					15.0	8.9	E					14.8	K			
14.6 – 15.7	24.8	10.6	D	A	B	3	14.6 – 15.7	14.1	8.0	A	B	B	3	12.2 – 13.2	10.0	D	B	B	10
	31.0	13.6	K					14.9	8.8	E					14.2	K			
15.8 – 16.0	24.7	10.4	D	A	B	2	15.8 – 16.0	14.0	7.9	A	A	B	3	13.3 – 14.5	7.6	D	B	B	9
	30.9	13.4	K					14.9	8.7	E					11.8	K			
16.1 – 20.9	22.5	7.0	D	A	B	1	16.1 – 20.9	12.8	6.6	A	A	B	1	14.6 – 20.9	7.5	D	A	B	9
	28.8	10.0	K					13.6	7.4	E					11.7	K			
21.0 – 24.9	21.4	5.5	D	A	A	1	21.0 – 24.9	6.1	6.0	A	A	A	1	21.0 – 24.9	6.5	D	A	A	9
	27.6	8.5	K					6.9	6.9	E					10.7	K			
≥ 25.0	15.3	2.6	cc	A	A	1	≥ 25.0	2.6	2.6	cc	A	A	1	≥ 25.0	2.4	cc	A	A	9
	15.3	2.6	cc					2.6	2.6	cc					2.4	cc			

Notes:

1. For percentage cost increases, upper percentage is for non-load bearing wall construction and lower percentage is for load bearing wall construction
2. For walls, upper letter applies to retrofits for non-load bearing walls and lower letter applies to retrofits for load bearing walls.
3. cc = conventional construction. No retrofits required.
4. Percentages of cost increases are over new construction costs for the applicable building types

Table B-3. 100 kg TNT – All Levels of Protection

Standoff Distance In Meters	% Increase: Admin Facility	% Increase: Medical Clinic	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0 – 10.1	30.9	13.2	D	E	B	5
	-	-	-			
10.1 – 14.9	28.9	12.9	D	D	B	5
	-	-	-			
15.0 – 20.3	28.9	12.9	D	D	B	5
	35.1	15.9	K			
20.4 – 20.9	26.4	12.5	D	C	B	5
	32.6	15.4	K			
21.0 – 24.2	26.3	12.4	D	B	B	5
	32.6	15.4	K			
24.3 – 29.2	25.7	11.4	D	B	B	4
	31.9	14.3	K			
29.3 – 34.3	25.2	11.3	D	A	B	4
	31.5	14.3	K			
34.5 – 39.8	24.8	10.6	D	A	B	3
	31.0	13.6	K			
39.9 – 40.4	24.7	10.4	D	A	B	2
	30.9	13.4	K			
40.5 – 44.9	22.5	7.0	D	A	B	1
	16.4	4.1	K			
45.0 – 48.9	15.3	4.1	cc	A	A	1
	15.3	4.1	cc			
≥ 49.0	15.3	2.6	cc	A	A	1
	15.3	2.6	cc			

Standoff Distance In Meters	% Increase: Barracks (Ext. Ent.)	% Increase: Barracks (Int. Ent.)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0 -10.1	16.2	10.1	D	E	B	5
	-	-	-			
10.1 – 10.4	15.8	9.7	D	D	B	5
	-	-	-			
10.5 – 11.2	15.5	9.4	C	D	B	5
	-	-	-			
11.3 – 12.4	15.5	9.4	C	D	B	5
	18.1	11.9	J			
12.5 – 15.7	15.3	9.2	B	D	B	5
	17.3	11.2	I			
15.8 – 17.6	15.3	9.2	B	D	B	5
	16.8	10.7	G			
17.7 – 20.3	15.3	9.2	A	D	B	5
	16.5	10.4	F			
20.4 – 22.5	14.8	8.7	A	C	B	5
	16.1	10.0	F			
22.6 – 24.2	14.8	8.7	A	C	B	5
	15.7	9.6	E			
24.3 – 29.2	14.4	8.3	A	B	B	4
	15.3	9.1	E			
29.3 – 34.4	14.3	8.2	A	A	B	4
	15.2	9.1	E			
34.5 – 39.8	14.1	8.0	A	A	B	3
	14.9	8.8	E			
39.9 – 40.4	14.0	7.9	A	A	B	2
	14.9	8.7	E			

Standoff Distance In Meters	%Δ: Dining Facility	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0 – 10.1	12.4	D	E	B	12
	-	-			
10.1 – 14.9	12.1	D	D	B	12
	-	-			
15.0 – 20.3	12.1	D	D	B	12
	16.3	K			
20.4 – 28.6	11.7	D	C	B	12
	15.9	K			
28.7 – 29.2	10.6	D	B	B	11
	14.8	K			
29.3 – 31.9	10.5	D	A	B	11
	14.7	K			
32.0 – 34.6	9.9	D	A	B	10
	14.1	K			
34.7 – 44.9	7.5	D	A	B	9
	11.7	K			
45.0 – 48.9	3.4	cc	A	B	9
	3.4	cc			
≥ 49.0	2.4	cc	A	A	9
	2.4	cc			

Table B-3 (continued)

	40.5 – 44.9	**12.8**	**6.0**	**A**	**A**	**B**	**1**	
		13.6	**6.9**	**E**				
	45.0 – 48.9	**9.3**	**2.6**	**cc**	**A**	**A**	**1**	
		9.3	**2.6**	**cc**				
	≥ 49.0	**2.6**	**2.6**	**cc**	**A**	**a**	**1**	
		2.6	**2.6**	**cc**				

Notes:

1. For walls, upper letter applies to retrofits for non-load bearing walls and lower letter applies to retrofits for load bearing walls.
2. For load bearing walls, a “-“ entry means that no economical retrofit is available at that standoff distance
3. cc = conventional construction. No retrofits required.
4. Percentages of cost increases are over new construction costs for the applicable building types

Table B-4. 250 kg TNT – All Levels of Protection

Standoff Distance In Meters	% Increase: Admin Facility	% Increase: Medical Clinic	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0 – 10.6	67.4	20.3	D	H	B	6
	-	-	-			
10.7 – 11.3	57.4	18.6	D	G	B	6
	-	-	-			
11.4 – 11.5	56.8	17.7	D	G	B	5
	-	-	-			
11.6 – 15.4	32.6	13.5	D	F	B	5
	-	-	-			
15.5 – 17.9	30.9	13.2	D	E	B	5
	-	-	-			
18.0 – 22.9	28.9	12.9	D	D	B	5
	-	-	-			
23.0 – 31.0	28.9	12.9	D	D	B	5
	35.1	15.9	K			
31.1 – 31.3	26.4	12.5	D	C	B	5
	32.6	15.4	K			
31.4 – 44.0	26.3	12.4	D	B	B	5
	32.6	15.4	K			
44.1 – 57.9	25.9	12.4	D	A	B	5
	32.1	15.3	K			
58.0 – 61.0	19.8	9.5	cc	A	B	5
	19.8	9.5	cc			

Standoff Distance In Meters	% Increase: Barracks (Ext. Ent.)	% Increase: Barracks (Int. Ent.)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0 – 10.6	22.6	16.5	D	H	B	6
	-	-	-			
10.7 – 11.3	20.9	14.8	D	G	B	6
	-	-	-			
11.4 – 11.5	20.6	14.5	D	G	B	5
	-	-	-			
11.6 – 15.4	16.5	10.4	D	F	B	5
	-	-	-			
15.5 – 17.9	16.1	10.1	D	E	B	5
	-	-	-			
18.0 – 19.9	15.8	9.7	D	D	B	5
	18.1	11.9	J			
20.0 – 21.9	15.5	9.4	C	D	B	5
	18.1	11.9	J			
22.0 – 23.9	15.5	9.4	C	D	B	5
	17.3	11.2	I			
24.0 – 27.9	15.3	9.2	B	D	B	5
	17.3	11.2	I			
28.0 – 29.9	15.3	9.2	B	D	B	5
	16.8	10.7	G			
30.0 – 31.0	15.3	9.2	A	D	B	5
	16.5	10.4	F			

Standoff Distance In Meters	%Δ: Dining Facility	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
10.0 – 10.4	18.7	D	H	B	15
	-	-			
10.5 – 10.6	18.5	D	H	B	14
	-	-			
10.7 – 11.5	17.0	D	G	B	14
	-	-			
11.6 – 12.0	13.1	D	F	B	14
	-	-			
12.1 – 12.6	13.0	D	F	B	13
	-	-			
12.7 – 15.4	12.7	D	F	B	12
	-	-			
15.5 – 17.9	12.4	D	E	B	12
	-	-			
18.0 – 22.9	12.1	D	D	B	12
	-	-			
23.0 – 31.0	12.1	D	D	B	12
	16.3	K			
31.1 – 44.2	11.7	D	C	B	12
	15.9	K			
44.2 – 52.3	11.6	D	A	B	12
	15.8	K			

Table B-4 (continued)

61.1 – 71.5	**18.7**	**7.7**	**cc**	**A**	**B**	**3**	**31.1 – 42.9**	**14.8**	**8.7**	**A**	**C**	**B**	**5**	**52.4 – 57.7**	**10.5**	**D**	**A**	**B**	**11**
	18.7	**7.7**	**cc**					**16.1**	**10.0**	**F**					**14.7**	**K**			
71.6 – 72.8	**18.6**	**7.5**	**cc**	**A**	**B**	**2**	**43.0 – 44.0**	**14.8**	**8.7**	**A**	**B**	**B**	**5**	**57.8 – 57.9**	**9.9**	**D**	**A**	**B**	**10**
	18.6	**7.5**	**cc**					**15.7**	**9.6**	**E**					**14.1**	**K**			
72.9 – 83.9	**16.4**	**4.1**	**cc**	**A**	**B**	**1**	**44.1 – 57.9**	**14.7**	**8.6**	**A**	**A**	**B**	**5**	**58.0 – 63.3**	**5.8**	**cc**	**A**	**B**	**10**
	16.4	**4.1**	**cc**					**15.6**	**9.5**	**E**					**5.8**	**cc**			
≥ 84.0	**15.3**	**2.6**	**cc**	**A**	**A**	**1**	**58.0 – 61.0**	**11.2**	**5.2**	**cc**	**A**	**B**	**5**	**63.4 – 79.9**	**3.4**	**cc**	**A**	**B**	**9**
	15.3	**2.6**	**cc**					**11.2**	**5.2**	**cc**					**3.4**	**cc**			
							61.1 – 71.5	**10.6**	**4.5**	**cc**	**A**	**B**	**3**	**≥ 84.0**	**2.4**	**cc**	**A**	**A**	**9**
								10.6	**4.5**	**cc**					**2.4**	**cc**			
							71.6 – 72.8	**10.5**	**4.4**	**cc**	**A**	**B**	**2**						
								10.5	**4.4**	**cc**									
							72.9 – 83.9	**9.3**	**3.1**	**cc**	**A**	**B**	**1**						
								9.3	**3.1**	**cc**									
							≥ 84.0	**2.6**	**2.6**	**cc**	**A**	**A**	**1**						
								2.6	**2.6**	**cc**									

Notes:

1. For walls, upper letter applies to retrofits for non-load bearing walls and lower letter applies to retrofits for load bearing walls.
2. For load bearing walls, a "-" entry means that no economical retrofit is available at that standoff distance
3. cc = conventional construction. No retrofits required.
4. Percentages of cost increases are over new construction costs for the applicable building types.

Table B-5. 500 kg TNT – All Levels of Protection

Standoff Distance In Meters	% Increase: Admin Facility	% Increase: Medical Clinic	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.5 – 15.4	67.4	20.3	D	H	B	6
	-	-	-			
15.5 – 17.0	57.4	18.6	D	G	B	6
	-	-	-			
17.1 – 18.5	33.2	14.5	D	F	B	6
	-	-	-			
18.6 – 21.8	32.6	13.5	D	F	B	5
	-	-	-			
21.9 – 25.5	30.9	13.2	D	E	B	5
	-	-	-			
25.6 – 26.9	28.9	12.9	D	D	B	5
	-	-	-			
27.0 – 41.4	28.9	12.9	D	D	B	5
	35.1	15.9	K			
41.5 – 41.7	26.4	12.5	D	C	B	5
	32.6	12.5	K			
41.8 – 59.3	26.3	12.4	D	B	B	5
	32.6	12.4	K			
59.4 – 65.8	25.9	12.4	D	A	B	5
	32.1	12.4	K			

Standoff Distance In Meters	% Increase: Barracks (Ext. Ent.)	% Increase: Barracks (Int. Ent.)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.5 – 15.4	22.6	16.5	D	H	B	6
	-	-	-			
15.5 – 17.0	20.9	14.8	D	G	B	6
	-	-	-			
17.1 – 18.5	16.8	10.7	D	F	B	6
	-	-	-			
18.6 – 21.8	16.5	10.4	D	F	B	5
	-	-	-			
21.9 – 25.5	16.2	10.1	D	E	B	5
	-	-	-			
25.6 – 26.9	15.8	9.7	D	D	B	5
	-	-	-			
27.0 – 27.4	15.8	9.7	D	D	B	5
	20.0	13.9	K			
27.5 – 29.9	15.8	9.7	D	D	B	5
	18.1	11.9	J			
30.0 – 30.9	15.5	9.4	C	D	B	5
	18.1	11.9	J			
31.0 – 36.9	15.5	9.4	C	D	B	5
	17.3	11.2	I			

Standoff Distance In Meters	%Δ: Dining Facility	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
13.7 – 19.9	21.9	D	H	B	17
	-	-			
14.0 – 15.4	18.7	D	H	B	15
	-	-			
15.5 – 16.9	17.1	D	G	B	15
	-	-			
17.0 – 17.1	17.0	D	G	B	14
	-	-			
17.1 – 19.6	13.1	D	F	B	14
	-	-			
19.7 – 20.6	13.0	D	F	B	13
	-	-			
20.7 – 21.8	12.7	D	F	B	12
	-	-			
21.9 – 25.5	12.4	D	E	B	12
	-	-			
25.6 – 26.9	12.1	D	D	B	12
	-	-			
27.0 – 41.4	12.1	D	D	B	12
	16.3	K			

Table B-5 (continued)

65.9 – 72.9	**25.2**	**11.3**	**D**	**A**	**B**	**4**
	31.5	**11.3**	**K**			
73.0 – 75.4	**19.1**	**8.4**	**cc**	**A**	**B**	**4**
	19.1	**8.4**	**cc**			
75.5 – 108.0	**18.7**	**7.7**	**cc**	**A**	**B**	**3**
	18.7	**7.7**	**cc**			
108.1 – 110.2	**18.6**	**6.0**	**cc**	**A**	**B**	**2**
	18.6	**6.0**	**cc**			
110.3 – 122.9	**16.4**	**4.1**	**cc**	**A**	**B**	**1**
	16.4	**4.1**	**cc**			
≥ 123.0	**15.3**	**2.6**	**cc**	**A**	**A**	**1**
	15.3	**2.6**	**cc**			

37.0 – 40.9	**15.3**	**9.2**	**B**	**D**	**B**	**5**
	17.3	**11.2**	**I**			
41.0 – 41.4	**15.3**	**9.2**	**B**	**D**	**B**	**5**
	16.8	**10.7**	**G**			
41.5 – 45.9	**14.9**	**8.8**	**B**	**C**	**B**	**5**
	16.4	**10.3**	**G**			
46.0 – 47.9	**14.9**	**8.8**	**B**	**B**	**B**	**5**
	16.1	**10.0**	**F**			
48.0 – 59.3	**14.8**	**8.7**	**A**	**B**	**B**	**5**
	16.1	**10.0**	**F**			
59.4 – 60.9	**14.7**	**8.6**	**A**	**A**	**B**	**5**
	16.0	**9.9**	**F**			
61.0 – 65.8	**14.7**	**8.6**	**A**	**A**	**B**	**5**
	15.6	**9.5**	**E**			
65.9 – 72.9	**14.3**	**8.2**	**A**	**A**	**B**	**4**
	15.2	**9.1**	**E**			
73.0 – 91.4	**10.8**	**4.8**	**cc**	**A**	**B**	**4**
	10.8	**4.8**	**cc**			
91.5 – 108.0	**10.6**	**4.5**	**cc**	**A**	**B**	**3**
	10.6	**4.5**	**cc**			
108.1 – 110.2	**10.5**	**4.4**	**cc**	**A**	**B**	**2**
	10.5	**4.4**	**cc**			
110.3 – 122.9	**9.3**	**3.1**	**cc**	**A**	**B**	**1**
	9.3	**3.1**	**cc**			
≥ 123.0	**2.6**	**2.6**	**cc**	**A**	**A**	**1**
	2.6	**2.6**	**cc**			

41.5 – 59.3	**11.7**	**D**	**C**	**B**	**12**
	15.9	**K**			
59.4 – 72.9	**11.6**	**D**	**A**	**B**	**12**
	15.8	**K**			
73.0 – 81.5	**7.5**	**cc**	**A**	**B**	**12**
	7.5	**cc**			
81.6 – 89.5	**6.4**	**cc**	**A**	**B**	**11**
	6.4	**cc**			
89.6 – 97.5	**5.8**	**cc**	**A**	**B**	**10**
	5.8	**cc**			
97.6 – 122.9	**3.4**	**cc**	**A**	**B**	**9**
	3.4	**cc**			
≥ 123.0	**2.4**	**cc**	**A**	**A**	**9**
	2.4	**cc**			

Notes:

1. For walls, upper letter applies to retrofits for non-load bearing walls and lower letter applies to retrofits for load bearing walls.
2. For load bearing walls, a "-" entry means that no economical retrofit is available at that standoff distance
3. cc = conventional construction. No retrofits required.
4. Percentages of cost increases are over new construction costs for the applicable building types.

Table B-6. 2000 kg TNT – All Levels of Protection

Standoff Distance In Meters	% Increase: Admin Facility	% Increase: Medical Clinic	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
25.9 – 28.7	70.4	25.1	D	H	B	7
	-	-	-			
28.8 – 29.2	67.4	20.3	D	H	B	6
	-	-	-			
29.3 – 32.2	57.4	18.6	D	G	B	6
	-	-	-			
32.3 – 40.4	33.2	14.5	D	F	B	6
	-	-	-			
40.5 – 47.1	31.5	14.2	D	E	B	6
	-	-	-			
47.2 – 48.8	29.5	13.9	D	D	B	6
	-	-	-			
48.9 – 52.9	28.9	12.9	D	D	B	5
	-	-	-			
53.0 – 71.8	28.9	12.9	D	D	B	5
	35.1	15.9	K			
71.9 – 72.4	26.4	12.5	D	C	B	5
	32.6	15.4	K			
72.5 – 103.5	26.3	12.4	D	B	B	5
	32.6	15.4	K			
103.6 – 115.9	25.9	12.4	D	A	B	5
	32.1	15.3	K			

Standoff Distance In Meters	% Increase: Barracks (Ext. Ent.)	% Increase: Barracks (Int. Ent.)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
25.9 – 28.7	24.3	18.3	D	H	B	7
	-	-	-			
28.8 – 29.2	22.6	16.5	D	H	B	6
	-	-	-			
29.3 – 32.2	20.9	14.8	D	G	B	6
	-	-	-			
32.3 – 40.4	16.8	10.7	D	F	B	6
	-	-	-			
40.5 – 47.1	16.5	10.4	D	E	B	6
	-	-	-			
47.2 – 48.8	16.2	10.1	D	D	B	6
	-	-	-			
48.9 – 52.9	15.8	9.7	D	D	B	5
	-	-	-			
53.0 – 59.7	15.8	9.7	D	D	B	5
	20.0	13.9	K			
59.8 – 65.9	15.8	9.7	D	D	B	5
	18.1	11.9	J			
66.0 – 68.9	15.8	9.7	D	D	B	5
	17.3	10.2	I			
69.0 – 71.8	15.5	89.4	C	D	B	5
	17.3	11.2	I			

Standoff Distance In Meters	%Δ: Dining Facility	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
25.9 – 29.2	21.9	D	H	B	17
	-	-			
29.3 – 32.2	20.3	D	G	B	17
	-	-			
32.3 – 33.4	16.5	D	F	B	17
	-	-			
33.5 – 36.7	16.2	D	F	B	16
	-	-			
36.8 – 40.4	13.3	D	F	B	15
	-	-			
40.5 – 45.2	13.0	D	E	B	15
	-	-			
45.3 – 47.1	12.9	D	E	B	14
	-	-			
47.2 – 51.9	12.6	D	D	B	14
	-	-			
52.0 – 52.9	12.4	D	D	B	13
	-	-			
53.0 – 55.0	12.4	D	D	B	13
	16.6	K			
55.1 – 71.8	12.1	D	D	B	12
	16.3	K			

Table B-6 (continued)

116.0 – 134.1	**19.8**	**9.5**	**cc**	**A**	**B**	**5**
	19.8	**9.5**	**cc**			
134.2 – 185.5	**19.1**	**8.4**	**cc**	**A**	**B**	**4**
	19.1	**8.4**	**cc**			
185.6 – 224.0	**18.7**	**7.7**	**cc**	**A**	**B**	**3**
	18.7	**7.7**	**cc**			
224.1 – 287.6	**18.6**	**7.5**	**cc**	**A**	**B**	**2**
	18.6	**7.5**	**cc**			
228.7 – 250.9	**16.4**	**4.1**	**cc**	**A**	**B**	**1**
	16.4	**4.1**	**cc**			
≥ 251.0	**15.3**	**2.6**	**cc**	**A**	**A**	**1**
	15.3	**2.6**	**cc**			

71.9 – 72.4	**15.1**	**9.0**	**C**	**C**	**B**	**5**
	16.9	**10.8**	**I**			
72.5 – 85.9	**15.0**	**9.0**	**C**	**B**	**B**	**5**
	16.9	**10.8**	**I**			
86.0 – 86.1	**14.9**	**8.8**	**B**	**B**	**B**	**5**
	16.9	**10.8**	**I**			
86.2 – 100.9	**14.9**	**8.8**	**B**	**B**	**B**	**5**
	16.4	**10.3**	**G**			
101.0 – 103.5	**14.9**	**8.8**	**B**	**B**	**B**	**5**
	16.1	**10.0**	**F**			
103.6 – 108.9	**14.8**	**8.7**	**B**	**A**	**B**	**5**
	16.0	**9.9**	**F**			
109.0 – 115.9	**14.7**	**8.6**	**A**	**A**	**B**	**5**
	16.0	**9.9**	**F**			
116.0 – 134.1	**11.2**	**5.2**	**cc**	**A**	**B**	**5**
	11.2	**5.2**	**cc**			
134.2 – 185.5	**10.8**	**4.8**	**cc**	**A**	**B**	**4**
	10.8	**4.8**	**cc**			
185.6 – 224.0	**10.6**	**4.5**	**cc**	**A**	**B**	**3**
	10.6	**4.5**	**cc**			
224.1 – 228.6	**10.5**	**4.4**	**cc**	**A**	**B**	**2**
	10.5	**4.4**	**cc**			
228.7 – 250.9	**9.3**	**3.1**	**cc**	**A**	**B**	**1**
	9.3	**3.1**	**cc**			
≥ 251.0	**2.6**	**2.6**	**cc**	**A**	**A**	**1**
	2.6	**2.6**	**cc**			

71.9 – 103.5	**11.7**	**D**	**C**	**B**	**12**
	15.9	**K**			
103.6 – 115.9	**11.6**	**D**	**A**	**B**	**12**
	15.8	**K**			
116.0 – 179.0	**7.5**	**cc**	**A**	**B**	**12**
	7.5	**cc**			
179.1 – 194.9	**6.4**	**cc**	**A**	**B**	**11**
	6.4	**cc**			
195.0 – 214.6	**5.8**	**cc**	**A**	**B**	**10**
	5.8	**cc**			
214.7 – 250.9	**3.4**	**cc**	**A**	**B**	**9**
	3.4	**cc**			
≥ 251.0	**2.4**	**cc**	**A**	**A**	**9**
	2.4	**cc**			

Notes:

1. For walls, upper letter applies to retrofits for non-load bearing walls and lower letter applies to retrofits for load bearing walls.
2. For load bearing walls, a “-“ entry means that no economical retrofit is available at that standoff distance
3. cc = conventional construction. No retrofits required.
4. Percentages of cost increases are over new construction costs for the applicable building types.

Table B-7. 9000 kg TNT – All Levels of Protection

Standoff Distance In Meters	% Increase: Admin Facility	% Increase: Medical Clinic	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
47.2 – 53.2	70.9 -	26.0 -	D -	H	B	8
53.3 – 59.3	60.9 -	24.3 -	D -	G	B	8
59.4 – 73.4	36.7 -	20.1 -	D -	F	B	8
73.5 – 82.2	35.0 -	19.8 -	D -	E	B	8
82.3 – 83.7	31.5 -	14.2 -	D -	E	B	6
83.8 – 124.9	29.5 -	13.9 -	D -	D	B	6
125.0 – 126.4	29.5 35.7	13.9 16.8	D K	D	B	6
126.5 – 127.0	27.0 33.2	13.4 16.4	D K	C	B	6
127.1 – 134.1	26.9 33.2	13.4 16.4	D K	B	B	6
134.2 – 183.7	26.3 32.6	12.4 15.4	D K	B	B	5
183.8 – 197.9	25.9 32.1	12.4 15.3	D K	A	B	5

Standoff Distance In Meters	% Increase: Barracks (Ext. Ent.)	% Increase: Barracks (Int. Ent.)	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
47.2 – 53.2	24.7 -	18.7 -	D -	H	B	8
53.3 – 59.3	23.0 -	17.0 -	D -	G	B	8
59.4 – 73.4	18.9 -	12.9 -	D -	F	B	8
73.5 – 82.2	18.6 -	12.6 -	D -	E	B	8
82.3 – 83.7	16.5 -	10.4 -	D -	E	B	6
83.8 – 110.9	16.2 -	10.1 -	D -	D	B	6
111.0 – 119.9	16.2 18.4	10.1 12.3	D J	D	B	6
120.0 – 126.4	16.2 17.7	10.1 11.6	D I	D	B	6
126.5 – 127.0	15.8 17.3	9.7 11.2	D I	C	B	6
127.1 – 134.1	15.7 17.3	9.7 11.2	D I	B	B	6
134.2 – 160.9	15.4 16.9	9.3 10.8	D I	B	B	5

Standoff Distance In Meters	%Δ: Dining Facility	Construction Type: Walls	Construction Type: Windows	Construction Type: Doors	Construction Type: Roofs
47.2 – 53.2	22.5 -	D -	H	B	18
53.3 – 59.3	20.9 -	D -	G	B	18
59.4 – 60.6	17.1 -	D -	F	B	18
60.7 – 73.4	16.5 -	D -	F	B	17
73.5 – 79.4	16.2 -	D -	E	B	17
79.5 – 83.7	16.0 -	D -	E	B	16
83.8 – 104.1	15.6 -	D -	D	B	16
104.2 – 124.9	12.7 -	D -	D	B	15
125.0 – 126.4	12.7 16.9	D K	D	B	15
126.5 – 127.4	12.3 16.5	D K	C	B	15
127.5 – 144.6	12.2 16.4	D K	B	B	14

Table B-7 (continued)

198.0 – 260.0	**19.8**	**9.5**	**cc**	**A**	**B**	**5**
	19.8	**9.5**	**cc**			
260.1 – 361.2	**19.1**	**8.4**	**cc**	**A**	**B**	**4**
	19.1	**8.4**	**cc**			
361.3 – 441.3	**18.7**	**7.7**	**cc**	**A**	**B**	**3**
	18.7	**7.7**	**cc**			
441.4 – 449.9	**18.6**	**7.5**	**cc**	**A**	**B**	**2**
	18.6	**7.5**	**cc**			
450.0 – 480.9	**16.4**	**4.1**	**cc**	**A**	**B**	**1**
	16.4	**4.1**	**cc**			
≥ 481.0	**15.3**	**2.6**	**cc**	**A**	**A**	**1**
	15.3	**2.6**	**cc**			

161.0 – 164.9	**15.0**	**9.0**	**C**	**B**	**B**	**5**
	16.9	**10.8**	**I**			
165.0 – 183.7	**15.0**	**9.0**	**C**	**B**	**B**	**5**
	16.4	**10.3**	**G**			
183.8 – 196.9	**15.0**	**8.9**	**C**	**A**	**B**	**5**
	16.3	**10.2**	**G**			
197.0 – 197.9	**14.8**	**8.7**	**B**	**A**	**B**	**5**
	16.3	**10.2**	**G**			
198.0 – 260.0	**11.2**	**5.2**	**cc**	**A**	**B**	**5**
	11.2	**5.2**	**cc**			
260.1 – 361.2	**10.8**	**4.8**	**cc**	**A**	**B**	**4**
	10.8	**4.8**	**cc**			
361.3 – 441.3	**10.6**	**4.5**	**cc**	**A**	**B**	**3**
	10.6	**4.5**	**cc**			
441.4 – 449.9	**10.5**	**4.4**	**cc**	**A**	**B**	**2**
	10.5	**4.4**	**cc**			
450.0 – 480.9	**9.3**	**3.1**	**cc**	**A**	**B**	**1**
	9.3	**3.1**	**cc**			
≥ 481.0	**2.6**	**2.6**	**cc**	**A**	**A**	**1**
	2.6	**2.6**	**cc**			

144.7 – 152.3	**12.0**	**D**	**B**	**B**	**13**
	16.2	**K**			
152.4 – 183.7	**11.7**	**D**	**B**	**B**	**12**
	15.9	**K**			
183.8 – 220.6	**11.6**	**D**	**A**	**B**	**12**
	15.8	**K**			
220.7 – 367.9	**7.5**	**cc**	**A**	**B**	**12**
	7.5	**cc**			
368.0 – 397.3	**6.4**	**cc**	**A**	**B**	**11**
	6.4	**cc**			
397.4 – 440.6	**5.8**	**cc**	**A**	**B**	**10**
	5.8	**cc**			
440.7 – 480.9	**3.4**	**cc**	**A**	**B**	**9**
	3.4	**cc**			
≥ 481.0	**2.4**	**cc**	**A**	**A**	**9**
	2.4	**cc**			

Notes:

1. For walls, upper letter applies to retrofits for non-load bearing walls and lower letter applies to retrofits for load bearing walls.
2. For load bearing walls, a "-" entry means that no economical retrofit is available at that standoff distance
3. cc = conventional construction. No retrofits required.
4. Percentages of cost increases are over new construction costs for the applicable building types.

<table>
<tr><th colspan="16">Table B-8. Building Retrofit Cost Increases Hand Delivered Devices
Low Threat Severity Level
(IID only)</th></tr>
<tr><th rowspan="2">Building Type</th><th colspan="5">Low LOP</th><th colspan="5">Medium LOP</th><th colspan="5">High LOP</th></tr>
<tr><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th></tr>
<tr><td>Administrative Facility</td><td>10.1</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td>10.1</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td>10.1</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td></tr>
<tr><td>Medical Clinic</td><td>1.9</td><td>1.9</td><td>1.9</td></tr>
<tr><td>Barracks with Exterior Entries</td><td>1.8</td><td>1.8</td><td>1.8</td></tr>
<tr><td>Barracks with Interior Entries</td><td>1.8</td><td>1.8</td><td>1.8</td></tr>
<tr><td>Dining Facility</td><td>1.2</td><td>1.2</td><td>1.2</td></tr>
<tr><td>Special Structure</td><td>1.9</td><td>1.9</td><td>1.9</td></tr>
</table>

<table>
<tr><th colspan="16">Table B-9. Building Retrofit Cost Increases Hand Delivered Devices
Medium Threat Severity Level
(Hand grenades and 1 kg IED only)</th></tr>
<tr><th rowspan="2">Building Type</th><th colspan="5">Low LOP</th><th colspan="5">Medium LOP</th><th colspan="5">High LOP</th></tr>
<tr><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th></tr>
<tr><td>Administrative Facility</td><td>10.1</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td>10.1</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td rowspan="6">A</td><td>41.3</td><td>B</td><td rowspan="6">B</td><td rowspan="6">A</td><td rowspan="6">B</td></tr>
<tr><td>Medical Clinic</td><td>1.9</td><td>1.9</td><td>18.0</td><td>B</td></tr>
<tr><td>Barracks with Exterior Entries</td><td>1.8</td><td>1.8</td><td>20.1</td><td>D</td></tr>
<tr><td>Barracks with Interior Entries</td><td>1.8</td><td>1.8</td><td>9.5</td><td>D</td></tr>
<tr><td>Dining Facility</td><td>1.2</td><td>1.2</td><td>14.0</td><td>B</td></tr>
<tr><td>Special Structure</td><td>1.9</td><td>1.9</td><td>18.0</td><td>D</td></tr>
</table>

Table B-10. Retrofit Cost Increases for Mail rooms 1 kg TNT Explosive						
Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection	
	% Cost Increase	Construc-tion	% Cost Increase	Construc-tion	% Cost Increase	Construc-tion
Dining Facility • Small [1] • Medium [2] • Large [3]	1.1 1.6 2.3	See Table C-6	1.1 1.6 2.3	See Table C-6	1.1 1.6 2.4	See Table C-6
Administration Building • Small [1] • Medium [2] • Large [3]	1.1 1.6 2.3		1.1 1.6 2.3		1.1 1.6 2.3	
Medical Clinic • Small [1] • Medium [2] • Large [3]	0.6 0.9 1.2		0.6 0.9 1.3		0.6 0.9 1.3	
Barracks with Exterior Entrances • Small [1] • Medium [2] • Large [3]	0.3 0.4 0.5		0.3 0.4 0.5		0.3 0.4 0.6	
Barracks with Interior Entrances • Small [1] • Medium [2] • Large [3]	0.3 0.4 0.6		0.3 0.4 0.6		0.3 0.4 0.6	
Special Structures • Small [1] • Medium [2] • Large [3]	0.8 1.1 1.6		0.8 1.1 1.6		0.8 1.1 1.6	
1. 10 ft. x 20 ft. x 10 ft. 2. 16 ft. x 25 ft. x 10 ft. 3. 22 ft. x 32 ft. x 10 ft						

Table B-11. Retrofit Cost Increases for Loading Docks 1 kg TNT Explosive						
Building Type	**Low Level of Protection**		**Medium Level of Protection**		**High Level of Protection**	
	% Cost Increase	**Construc-tion**	**% Cost Increase**	**Construc-tion**	**% Cost Increase**	**Construc-tion**
Dining Facility • Small [1] • Medium [2] • Large [3]	1.1 1.8 2.8	See Table C-6	1.2 1.9 2.8	See Table C-6	1.2 1.9 3.0	See Table C-6
Administration Building • Small [1] • Medium [2] • Large [3]	1.1 1.8 2.8		1.2 1.8 2.8		1.2 1.9 3.0	
Medical Clinic • Small [1] • Medium [2] • Large [3]	0.6 1.0 1.5		0.6 1.0 1.5		0.7 1.1 1.6	
Barracks with Exterior Entrances • Small [1] • Medium [2] • Large [3]	0.3 0.4 0.6		0.3 0.4 0.7		0.3 0.5 0.7	
Barracks with Interior Entrances • Small [1] • Medium [2] • Large [3]	0.3 0.5 0.7		0.3 0.5 0.7		0.3 0.5 0.7	
Special Structures • Small [1] • Medium [2] • Large [3]	0.8 1.3 1.9		0.8 1.3 1.9		0.8 1.3 2.0	
1. 10 ft. x 22 ft. x 10 ft. 2. 10 ft. x 34 ft. x 10 ft. 3. 22 ft. x 46 ft. x 10 ft.						

Table B-12. Retrofit Cost Increases for Loading Docks 25 kg TNT Explosive						
Building Type	**Low Level of Protection**		**Medium Level of Protection**		**High Level of Protection**	
	% Cost Increase	**Construc-tion**	**% Cost Increase**	**Construc-tion**	**% Cost Increase**	**Construc-tion**
Dining Facility • Small [1] • Medium [2] • Large [3]	1.7 2.8 4.2	See Table C-7	1.8 2.9 4.4	See Table C-7	1.9 3.0 4.7	See Table C-7
Administration Building • Small [1] • Medium [2] • Large [3]	1.7 2.7 4.2		1.8 2.9 4.4		1.9 3.0 4.7	
Medical Clinic • Small [1] • Medium [2] • Large [3]	0.9 1.5 2.3		1.0 1.6 2.4		1.0 1.6 2.6	
Barracks with Exterior Entrances • Small [1] • Medium [2] • Large [3]	0.4 0.6 1.0		0.4 0.7 1.0		0.5 0.7 1.1	
Barracks with Interior Entrances • Small [1] • Medium [2] • Large [3]	0.4 0.7 1.0		0.5 0.7 1.1		0.5 0.7 1.2	
Special Structures • Small [1] • Medium [2] • Large [3]	1.2 1.9 2.9		1.3 2.0 3.0		1.3 2.1 3.2	
1. 10 ft. x 22 ft. x 10 ft. 2. 10 ft. x 34 ft. x 10 ft. 3. 22 ft. x 46 ft. x 10 ft.						

Table B-13. Retrofit Cost Increases for Entry Areas 1 kg TNT Explosive						
Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection	
	% Cost Increase	Construc-tion	% Cost Increase	Construc-tion	% Cost Increase	Construc-tion
Dining Facility • Small [1] • Medium [2] • Large [3]	1.6 2.4 4.7	See Table C-6	1.7 2.4 4.7	See Table C-6	1.7 2.5 4.8	See Table C-6
Administration Building • Small [1] • Medium [2] • Large [3]	1.6 2.3 4.7		1.6 2.4 4.7		1.7 2.4 4.7	
Medical Clinic • Small [1] • Medium [2] • Large [3]	0.9 1.3 2.6		0.9 1.3 2.6		0.9 1.3 2.6	
Barracks with Exterior Entrances • Small [1] • Medium [2] • Large [3]	0.4 0.6 1.1		0.4 0.6 1.1		0.4 0.6 1.1	
Barracks with Interior Entrances • Small [1] • Medium [2] • Large [3]	0.4 0.6 1.2		0.4 0.6 1.2		0.4 0.6 1.2	
Special Structures • Small [1] • Medium [2] • Large [3]	1.1 1.6 3.2		1.1 1.6 3.2		1.2 1.7 3.2	

1. 15 ft. x 30 ft. x 10 ft.
2. 20 ft. x 40 ft. x 10 ft.
3. 40 ft. x 50 ft. x 10 ft.

**Table B-14. Retrofit Cost Increases for Entry Areas
25 kg TNT Explosive**

Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection	
	% Cost Increase	Construction	% Cost Increase	Construction	% Cost Increase	Construction
Dining Facility		See Table C-7		See Table C-7		See Table C-7
• Small [1]	2.3		2.3		2.5	
• Medium [2]	3.3		3.5		3.6	
• Large [3]	6.8		7.3		7.6	
Administration Building						
• Small [1]	2.2		2.3		2.5	
• Medium [2]	3.2		3.4		3.6	
• Large [3]	6.8		7.2		7.6	
Medical Clinic						
• Small [1]	1.2		1.3		1.3	
• Medium [2]	1.8		1.9		2.0	
• Large [3]	3.7		4.0		4.1	
Barracks with Exterior Entrances						
• Small [1]	0.5		0.5		0.6	
• Medium [2]	0.8		0.8		0.8	
• Large [3]	1.6		1.7		1.8	
Barracks with Interior Entrances						
• Small [1]	0.6		0.6		0.6	
• Medium [2]	0.8		0.9		0.9	
• Large [3]	1.7		1.8		1.9	
Special Structures						
• Small [1]	1.5		1.6		1.7	
• Medium [2]	2.2		2.4		2.5	
• Large [3]	4.7		5.0		5.2	

1. 15 ft. x 30 ft. x 10 ft.
2. 20 ft. x 40 ft. x 10 ft.
3. 40 ft. x 50 ft. x 10 ft.

Table B-15. Retrofit Cost Increases for Indirect Fire Weapons Low Threat Severity Level															
Building Type	**Low LOP**					**Medium LOP**					**High LOP**				
	% Increase	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase**	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase**	**Walls**	**Windows**	**Doors**	**Roof**
Dining Facility	1.3	cc	A	cc	cc	1.3	cc	A	cc	cc	1.3	cc	A	cc	cc
Administrative Facility	10.1					10.1					10.1				
Medical Clinic	1.8					1.8					1.8				
Barracks with Exterior Entrances	1.8					1.8					1.8				
Barracks with Interior Entrances	1.8					1.8					1.8				
Special Structure	1.8					1.8					1.8				
cc = conventional construction. The baseline construction for those components is adequate															

Table B-16. Retrofit Cost Increases for Indirect Fire Weapons Medium Threat Severity Level																					
Building Type	**Low LOP**							**Medium LOP**							**High LOP**						
	% Increase	**Walls**	**Wall Extensions**	**Windows**	**Doors**	**Hardened Roof**	**Sacrificial Roof**	**% Increase**	**Walls**	**Wall Extensions**	**Windows**	**Doors**	**Hardened Roof**	**Sacrificial Roof**	**% Increase**	**Walls**	**Wall Extensions**	**Windows***	**Doors**	**Hardened Roof**	**Sacrificial Roof**
Dining Facility	14.0	A	A	A	A	2	2	22.2	E	A	A	A	3	2	*Designing retrofits to meet this level of protection for this threat is not practical for conventional buildings*						
Administrative Facility	22.3	A	A	A	A	2	2	33.4	E	A	A	A	3	2							
Medical Clinic	14.1	A	A	A	A	2	1	21.4	E	A	A	A	3	1							
Barracks with Exterior Entrances	16.3	B	B	A	A	2	2	16.6	B	B	A	A	3	2							
Barracks with Interior Entrances	9.4	B	B	A	A	2	2	9.7	B	B	A	A	3	2							
Special Structure	21.1	B	B	A	A	2	2	21.8	B	B	A	A	3	2							

<table>
<tr><th colspan="22">Table B-17. Retrofit Cost Increases for Indirect Fire Weapons
High Threat Severity Level</th></tr>
<tr><th rowspan="2">Building Type</th><th colspan="7">Low LOP</th><th colspan="7">Medium LOP</th><th colspan="7">High LOP</th></tr>
<tr><th>% Increase</th><th>Walls</th><th>Wall Extensions</th><th>Windows</th><th>Doors</th><th>Hardened Roof</th><th>Sacrificial Roof</th><th>% Increase</th><th>Walls</th><th>Wall Extensions</th><th>Windows</th><th>Doors</th><th>Hardened Roof</th><th>Sacrificial Roof</th><th>% Increase</th><th>Walls</th><th>Wall Extensions</th><th>Windows*</th><th>Doors</th><th>Hardened Roof</th><th>Sacrificial Roof</th></tr>
<tr><td>Dining Facility</td><td>31.6</td><td>F</td><td>A</td><td>A</td><td>A</td><td>7</td><td>2</td><td colspan="7" rowspan="6">Designing retrofits to meet this level of protection for this threat is not practical for conventional buildings</td><td colspan="7" rowspan="6">Designing retrofits to meet this level of protection for this threat is not practical for conventional buildings</td></tr>
<tr><td>Administrative Facility</td><td>46.2</td><td>F</td><td>A</td><td>A</td><td>A</td><td>7</td><td>2</td></tr>
<tr><td>Medical Clinic</td><td>29.5</td><td>F</td><td>A</td><td>A</td><td>A</td><td>7</td><td>1</td></tr>
<tr><td>Barracks with Exterior Entrances</td><td>19.6</td><td>D</td><td>B</td><td>A</td><td>A</td><td>7</td><td>2</td></tr>
<tr><td>Barracks with Interior Entrances</td><td>11.2</td><td>D</td><td>B</td><td>A</td><td>A</td><td>7</td><td>2</td></tr>
<tr><td>Special Structure</td><td>23.4</td><td>D</td><td>B</td><td>A</td><td>A</td><td>7</td><td>2</td></tr>
</table>

**Table B-18. Retrofit Cost Increases for Direct Fire Weapons
Low Threat Severity Level
(Retrofit Construction)**

Building Type	Low LOP % Increase	Low LOP Walls	Low LOP Windows	Low LOP Doors	Low LOP Roof	High LOP % Increase[1]	High LOP Walls	High LOP Windows	High LOP Doors	High LOP Roof[2]
Dining Facility	0.3	A	A	A	A	5.8	B	B	B	A
						14.1				B
Administration Building	2.0					28.7				A
						34.7				B
Medical Clinic	0.4					6.1				A
						13.6				B
Barracks with Exterior Entrances	0.3					19.4				A
						23.6				B
Barracks with Interior Entrances	0.3					12.0				A
						16.2				B
Special Structures	0.5					9.3				A
						26.7				B

Note: Costs are for entire building exterior. For smaller portions of buildings use a straight percentage of protected perimeter ÷ total perimeter

1. For roofs to which there is no sightline, use top number in each pair of values for % cost increase. Where there is a sightline to a roof, use bottom number in each pair of values for % cost increase.
2. For roofs to which there is no sightline, the top roof designation in each pair indicates the roof construction on which the cost increase is based. The bottom roof designation in each pair indicates the roof construction on which the cost increase is based where there is a sightline to the roof.

**Table B-19. Retrofit Cost Increases for Direct Fire Weapons
Medium Threat Severity Level
(Retrofit Construction)**

Building Type	Low LOP					High LOP				
	% Increase	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase[1]**	**Walls**	**Windows**	**Doors**	**Roof [2]**
Dining Facility	0.3	A	A	A	A	17.4	C	C	C	A
						32.4				C
Administration Building	2.0					46.4				A
						57.2				C
Medical Clinic	0.4					14.6				A
						28.0				C
Barracks with Exterior Entrances	0.3					26.6				A
						34.1				C
Barracks with Interior Entrances	0.3					16.6				A
						24.1				C
Special Structures	0.5					10.3				A
						41.6				C

Note: Costs are for entire building exterior. For smaller portions of buildings use a straight percentage of protected perimeter ÷ total perimeter

1. For roofs to which there is no sightline, use top number in each pair of values for % cost increase. Where there is a sightline to a roof, use bottom number in each pair of values for % cost increase.
2. For roofs to which there is no sightline, the top roof designation in each pair indicates the roof construction on which the cost increase is based. The bottom roof designation in each pair indicates the roof construction on which the cost increase is based where there is a sightline to the roof.

Table B-20. Retrofit Cost Increases for Direct Fire Weapons High Threat Severity Level (Retrofit Construction)

Building Type	Low LOP					High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof *
Dining Facility	0.3	A	A	A	A	22.7	C	C	C	A
Administration Building	2.0					60.1				
Medical Clinic	0.4					19.0				
Barracks with Exterior Entrances	0.3					32.2				
Barracks with Interior Entrances	0.3					22.1				
Special Structures	0.5					12.2				

Note: Costs are for entire building exterior. For smaller portions of buildings use a straight percentage of protected perimeter ÷ total perimeter

* Designing retrofits to a conventionally constructed roof to meet the high level of threat is not practical in cases where there are sightlines to roofs.

**Table B-21. Retrofit Cost Increases for Direct Fire Weapons
Very High Threat Severity Level
(Retrofit Construction)**

Building Type	Low LOP					Medium LOP					High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Dining Facility	0.3	A	A	A	A	Designing retrofits to meet this level of protection for this threat is not practical for conventional buildings					Designing retrofits to meet this level of protection for this threat is not practical for conventional buildings				
Administrative Facility	2.0														
Medical Clinic	0.4														
Barracks with Exterior Entrances	0.3														
Barracks with Interior Entrances	0.3														
Special Structure	0.5														

Table B-22. Retrofit Cost Increases for Forced Entry Tactic
Low Threat Severity Level

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility	22.6					26.4					29.4					37.1				
Medical Clinic	5.3					10.9					13.2					19.9				
Barracks with Exterior Entrances	7.8					10.3					13.9					21.5				
Barracks with Interior Entrances	5.6	A	A	A	A	8.0	C	B	A	D	10.0	D	B	C	G	14.2	E	C	E	F
Dining Facility	5.6					9.2					12.0					17.9				
Special Structure	13.5					19.1					24.9					37.0				

Note: Retrofitting existing windows to meet this requirement is impractical. Replace windows with wall construction with maximum openings of 96 square-inches

Table B-23. Retrofit Cost Increases for Forced Entry Tactic
Medium Threat Severity Level

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility	22.6					26.4					25.0					35.3				
Medical Clinic	5.3					10.1					22.4					32.1				
Barracks with Exterior Entrances	7.8					10.3					23.6					30.0				
Barracks with Interior Entrances	5.6	A	A	A	A	8.0	D	B	C	D	14.8	F	No*	H	G	21.2	G	No*	F	I
Dining Facility	5.6					9.2					20.0					28.5				
Special Structure	13.5					19.1					42.6					60.6				

Note: Retrofitting existing windows to meet this requirement is impractical. Replace windows with wall construction with maximum openings of 96 square-inches

Table B-24. Retrofit Cost Increases for Forced Entry Tactic
High Threat Severity Level

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility	22.1	A	A	A	B	40.1	F	B	D	G	36.1	G	No*	I	I	45.8	H	No*	J	J
Medical Clinic	5.2					24.2					34.1					42.4				
Barracks with Exterior Entrances	7.7					21.2					21.4					38.6				
Barracks with Interior Entrances	5.6					17.1					22.0					27.9				
Dining Facility	5.6					21.5					29.9					37.4				
Special Structure	13.4					45.2					62.3					79.4				

Note: Retrofitting existing windows to meet this requirement is impractical. Replace windows with wall construction with maximum openings of 96 square-inches

<table>
<tr><th colspan="21">Table B-25. Retrofit Cost Increases for Forced Entry Tactic
Very High Threat Severity Level</th></tr>
<tr><th rowspan="2">Building Type</th><th colspan="5">Low LOP</th><th colspan="5">Medium LOP</th><th colspan="5">High LOP</th><th colspan="5">Very High LOP</th></tr>
<tr><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th><th>% Increase</th><th>Walls</th><th>Windows</th><th>Doors</th><th>Roof</th></tr>
<tr><td>Administrative Facility</td><td>8.1</td><td rowspan="6">B</td><td rowspan="6">No</td><td rowspan="6">B</td><td rowspan="6">C</td><td>27.8</td><td rowspan="6">F</td><td rowspan="6">No*</td><td rowspan="6">F</td><td rowspan="6">H</td><td colspan="10" rowspan="6">Retrofit for these levels of protection is impractical at this threat severity level. Retrofit cost would exceed the cost of building replacement.</td></tr>
<tr><td>Medical Clinic</td><td>4.8</td><td>22.1</td></tr>
<tr><td>Barracks with Exterior Entrances</td><td>9.4</td><td>19.1</td></tr>
<tr><td>Barracks with Interior Entrances</td><td>3.8</td><td>15.0</td></tr>
<tr><td>Dining Facility</td><td>4.9</td><td>19.6</td></tr>
<tr><td>Special Structure</td><td>11.6</td><td>42.0</td></tr>
<tr><td colspan="21">Note: Retrofitting existing windows to meet this requirement is impractical. Replace windows with wall construction with maximum openings of 96 square-inches</td></tr>
</table>

Table B-26. Interior Area Retrofit Cost Increases for Forced Entry Tactic Low Threat Severity Level																				
Building Type	**Low LOP**					**Medium LOP**					**High LOP**					**Very High LOP**				
	% Increase	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase**	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase**	**Walls**	**Windows**	**Doors**	**Roof**	**% Increase**	**Walls**	**Windows**	**Doors**	**Roof**
Administrative Facility • **Small** [1] • **Medium** [2] • **Large** [3]	0.2 0.4 0.6					0.3 0.5 0.7					0.4 0.6 0.9					0.5 0.9 1.2				
Medical Clinic • **Small** [1] • **Medium** [2] • **Large** [3]	0.1 0.2 0.3	A	None [4]	A	A	0.2 0.3 0.4	C	None [4]	A	D	0.2 0.3 0.5	D	None [4]	H	G	0.3 0.5 0.6	E	None[4]	E	F
Barracks with Exterior Entries • **Small** [1] • **Medium** [2] • **Large** [3]	0.1 0.1 0.1					0.1 0.1 0.2					0.1 0.2 0.2					0.1 0.2 0.3				

Table B-26 - continued

Barracks with Interior Entries • **Small** [1] • **Medium** [2] • **Large** [3]	0.1 0.1 0.2					0.1 0.1 0.2					0.1 0.2 0.2					0.1 0.2 0.3				
Dining Facility • **Small** [1] • **Medium** [2] • **Large** [3]	0.2 0.4 0.6	A	None [4]	A	A	0.3 0.5 0.7	C	None [4]	A	D	0.4 0.6 0.9	D	None [4]	H	G	0.5 0.9 1.2	E	None [4]	E	F
Special Structure • **Small** [1] • **Medium** [2] • **Large** [3]	0.2 0.3 0.4					0.2 0.4 0.5					0.2 0.4 0.6					0.4 0.6 0.8				

Notes:
1. Room size: 12 ft. x 12 ft. x 10 ft. high
2. Room size: 12 ft. x 24 ft. x 10 ft. high
3. Room size: 18 ft. x 24 ft. x 10 ft. high
4. Windows are not included because areas are interior spaces.

Table B-27. Interior Area Retrofit Cost Increases for Forced Entry Tactic
Medium Threat Severity Level

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility																				
• **Small** [1]	0.2					0.3					0.7					0.9				
• **Medium** [2]	0.4					0.5					1.1					1.4				
• **Large** [3]	0.6					0.7					1.4					1.8				
Medical Clinic																				
• **Small** [1]	0.1					0.2					0.4					0.5				
• **Medium** [2]	0.2	A	None [4]	A	A	0.3	D	None [4]	C	D	0.6	F	None [4]	H	G	0.8	G	None [4]	F	I
• **Large** [3]	0.3					0.4					0.8					1.0				
Barracks with Exterior Entries																				
• **Small** [1]	0.1					0.1					0.2					0.2				
• **Medium** [2]	0.1					0.1					0.3					0.3				
• **Large** [3]	0.1					0.2					0.3					0.4				

Table B-27 - continued

Barracks with Interior Entries • **Small** [1] • **Medium** [2] • **Large** [3]	0.1 0.1 0.2					0.1 0.1 0.2					0.2 0.3 0.4					0.2 0.4 0.5				
Dining Facility • **Small** [1] • **Medium** [2] • **Large** [3]	0.2 0.4 0.6	A	None [4]	A	A	0.3 0.5 0.7	D	None [4]	C	D	0.7 1.1 1.4	F	None [4]	H	G	0.9 1.4 1.9	G	None [4]	F	I
Special Structure • **Small** [1] • **Medium** [2] • **Large** [3]	0.2 0.3 0.4					0.6 1.0 1.4					0.5 0.7 1.0					0.6 1.0 1.3				

Notes:

1. Room size: 12 ft. x 12 ft. x 10 ft. high
2. Room size: 12 ft. x 24 ft. x 10 ft. high
3. Room size: 18 ft. x 24 ft. x 10 ft. high
4. Windows are not included because areas are interior spaces.

Table B-28. Interior Area Retrofit Cost Increases for Forced Entry Tactic
High Threat Severity Level

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Administrative Facility																				
• **Small [1]**	0.2					0.6					0.9					1.1				
• **Medium [2]**	0.4					1.0					1.4					1.8				
• **Large [3]**	0.6					1.4					1.9					2.3				
Medical Clinic																				
• **Small [1]**	0.1					0.3					0.5					0.6				
• **Medium [2]**	0.2	A	None [4]	A	A	0.6	F	None [4]	D	G	0.8	G	None [4]	I	I	1.0	H	None [4]	J	J
• **Large [3]**	0.3					0.7					1.0					1.3				
Barracks with Exterior Entries																				
• **Small [1]**	0.1					0.1					0.2					0.3				
• **Medium [2]**	0.1					0.2					0.3					0.4				
• **Large [3]**	0.1					0.3					0.4					0.5				

Table B-28 - continued

Barracks with Interior Entries • **Small** [1] • **Medium** [2] • **Large** [3]	0.1 0.1 0.2					0.2 0.3 0.3					0.2 0.4 0.5					0.3 0.5 0.6				
Dining Facility • **Small** [1] • **Medium** [2] • **Large** [3]	0.2 0.4 0.6	A	None [4]	A	A	0.6 1.0 1.4	F	None [4]	D	G	0.9 1.5 1.9	G	None [4]	I	I	1.1 1.8 2.3	H	None [4]	J	J
Special Structure • **Small** [1] • **Medium** [2] • **Large** [3]	0.2 0.3 0.4					0.4 0.7 0.9					0.6 1.0 1.3					0.8 1.2 1.6				

Notes:
1. Room size: 12 ft. x 12 ft. x 10 ft. high
2. Room size: 12 ft. x 24 ft. x 10 ft. high
3. Room size: 18 ft. x 24 ft. x 10 ft. high
4. Windows are not included because areas are interior spaces.

Table B-29. Retrofit Cost Increases for Covert Entry Tactic *Low Threat Severity Level*								
Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection		Very High Level of Protection	
	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set
Dining Facility	0.11	B	0.74	C	1.25	D	1.95	E
Admin. Building	0.08	B	0.15	C	0.97	D	1.51	E
Medical Clinic	0.03	B	0.23	C	0.39	D	0.61	E
Barracks with Exterior Entrances	.02	B and A	.015	C and A	.026	D and A	0.40	E and A
Barracks with Interior Entrances	0.02	B and A	0.14	C and A	0.23	D and A	0.36	E and A
Special Structures	0.08	B	0.54	C	0.91	D	1.42	E

Table B-30 Retrofit Cost Increases for Covert Entry Tactic Medium Threat Severity Level								
Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection		Very High Level of Protection	
	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set
Dining Facility	0.67	F	0.83	G	1.33	H	1.95	I
Admin. Building	0.52	F	0.64	G	1.03	H	1.51	I
Medical Clinic	0.21	F	0.26	G	0.42	H	0.61	I
Barracks with Exterior Entrances	0.14	F and A	0.17	G and A	0.28	H and A	0.40	I and A
Barracks with Interior Entrances	0.12	F and A	0.15	G and A	0.24	H and A	0.36	I and A
Special Structures	0.46	F	0.61	G	0.97	H	1.42	I

Table B-31 Retrofit Cost Increases for Covert Entry Tactic High Threat Severity Level								
Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection		Very High Level of Protection	
	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set
Dining Facility	1.0	J	1.16	K	5.08	L	5.85	M
Admin. Building	0.77	J	0.9	K	3.93	L	4.52	M
Medical Clinic	0.31	J	0.36	K	1.59	L	1.83	M
Barracks with Exterior Entrances	0.21	J and A	0.24	K and A	1.05	L and A	1.21	M and A
Barracks with Interior Entrances	0.18	J and A	0.21	K and A	0.93	L and A	1.07	M and A
Special Structures	0.73	J	0.85	K	3.70	L	4.27	M

Table B-32 Retrofit Cost Increases for Covert Entry Tactic Very High Threat Severity Level								
Building Type	Low Level of Protection		Medium Level of Protection		High Level of Protection		Very High Level of Protection	
	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set	% Cost Increase	Equip. Set
Dining Facility	1.0	J	1.16	K	5.08	L	5.85	M
Admin. Building	0.77	J	0.9	K	3.93	L	4.52	M
Medical Clinic	0.31	J	0.36	K	1.59	L	1.83	M
Barracks with Exterior Entrances	0.21	J and A	0.24	K and A	1.05	L and A	1.21	M and A
Barracks with Interior Entrances	0.18	J and A	0.21	K and A	0.93	L and A	1.07	M and A
Special Structures	0.73	J	0.85	K	3.70	L	4.27	M

Table B-33. Building Retrofit Cost Multipliers for Acoustics Eavesdropping Tactic

Building Type	Low LOP					Medium LOP					High LOP					Very High LOP				
	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof	% Increase	Walls	Windows	Doors	Roof
Dining Facility	0	A	A	A	A	0.9	A	B	B	A	1.5	A	C	C	A	2.6	A	D	D	A
Administrative Facility	0.9					3.1					4.4					8.0				
Medical Clinic	0.3					1.0					1.6					2.7				
Barracks with Exterior Entries	0.4					6.2					8.3					11.8				
Barracks with Interior Entrances	0.2					0.8					1.1					1.8				
Special Structure	0.3					1.0					1.6					2.7				

Table B-34. Interior Area Retrofit Cost Increases for Acoustics Eavesdropping Tactic

Building Type	Low LOP (STC 30)					Medium LOP (STC 40)					High LOP (STC 45)					Very High LOP (STC 50)				
	% Increase	Walls	Windows	Doors	Ceiling	% Increase	Walls	Windows	Doors	Ceiling	% Increase	Walls	Windows	Doors	Ceiling	% Increase	Walls	Windows	Doors	Ceiling
1 story building • **Small** [1] • **Medium** [2] • **Large** [3]	0.05 0.09 0.13	A	None	A	B	0.25 0.30 0.34	A	None	B	F	0.35 0.41 0.46	B	None	C	D	0.46 0.54 0.61	C	None	D	G
Multi-story building • **Small** [1] • **Medium** [2] • **Large** [3]	0.01 0.01 0.01				A	0.21 0.21 0.21				A	0.30 0.32 0.29				A	0.41 0.43 0.44				A

Notes:
1. Room size: 12 ft. x 12 ft. x 10 ft. high
2. Room size: 12 ft. x 24 ft. x 10 ft. high
3. Room size: 18 ft. x 24 ft. x 10 ft. high
4. Windows are not included because areas are interior spaces.

Table B-35. Building Retrofit Cost Increases for Electronic Emanations Eavesdropping Tactic

Building Type		% Increase	Walls	Windows	Doors	Ceiling / Roof
Building Exterior Shielded	Dining Facility	32.4	TEMPEST shielding in walls	Specially manufactured TEMPEST windows	Specially manufactured TEMPEST doors	TEMPEST shielding in rook or ceiling
	Administrative Facility	58.8				
	Medical Clinic	40.3				
	Barracks with Exterior Entries	50.6				
	Barracks with Interior Entries	21.3				
	Special Structure	40.3				
Interior Room Shielded	1 story building • Small [1] • Medium [2] • Large [3]	 1.53 1.85 2.05		None		
	Multi-story building • Small [1] • Medium [2] • Large [3]	 1.42 1.67 1.83				

1. Room size: 12 ft. x 12 ft. x 10 ft. high
2. Room size: 12 ft. x 24 ft. x 10 ft. high
3. Room size: 18 ft. x 24 ft. x 10 ft. high

Table B-36. Surveillance Tactic Cost Increases

Building Type	% Cost Increase	Construction
Dining Facility	0.3%	0.10 mm (4-mil) reflective fragment retention film on windows
Administration Building	1.4%	
Medical Clinic	0.2%	
Barracks with Exterior Entrances	0.2%	
Barracks with Interior Entrances	0.2%	
Special Structures	0.3%	

Table B-37. Building Cost Increases for Airborne Contamination Mitigation (All Threat Severity Levels and Levels of Protection)

Building Type	Low LOP		Medium LOP		High LOP	
	% Increase	**HVAC Requirements**	**% Increase**	**HVAC Requirements**	**% Increase**	**HVAC Requirements**
Dining Facility	1.6	See Table C-12	27.5	See Table C-12	44.7	See Table C-12
Administrative Facility	0.6		10.1		22.2	
Medical Clinic	1.1		18.9		29.6	
Barracks with Exterior Entrances	0.6		17.8		22.2	
Barracks with Interior Entrances	0.2		10.7		12.5	
Special Structure	1.6		52.8		74.2	

Table B-38. Costs to Mitigate Waterborne Contamination (All Building Types, Threat Severity Levels and Levels of Protection)						
	Level of Protection					
Building Type	**Low LOP**		**Medium LOP**		**High LOP**	
	%	O & M / year	%	O & M / year	%	O & M / year
Administrative Facility	0.4	0	6.1	$30,000	10.5	$30,000
Medical Clinic	0.1	0	2.5	$30,000	4.3	$30,000
Barracks with Exterior Entries	0.1	0	1.6	$30,000	2.8	$30,000
Barracks with Interior Entries	0.1	0	1.4	$30,000	2.5	$30,000
Dining Facility	0.5	0	7.9	$30,000	13.6	$30,000
Special Structure	0.3	0	5.7	$30,000	9.9	$30,000

Table B-39. Sitework Retrofit Cost Multipliers				
Tactic	**Barrier Type**	**Threat Severity Level**	**Cost Multiplier [1]**	**Construction**
Moving Vehicle Bomb	Passive Perimeter	Minimum	1.2	B
		Low	1.3	C
		Medium	1.4	D
		High	5.0	E
		Very High	7.5	F
		Special Case	8.5	G
	Active	Minimum	1.0	I
		Low	5.6	J
		Medium	7.4	K
		High	7.4	L
		Very High	11.1	M
		Special Case	16.7	N
Stationary Vehicle Bomb	Passive Perimeter	All	1.0	A
	Active	All	1.0	H
Direct Fire Weapons	Screen	Very High [2]	2.3	O
		Very High [3]	10	P

1. Cost multipliers based on Standard 8-foot chain link fence with outrigger for perimeter barriers and motorized 8-foot high x 12 feet wide chain link gate
2. Predetonation screen only (anti-tank weapon only).
3. Energy absorption screen (anti-tank weapon and 12.7 mm ballistics).

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APPENDIX C

CONSOLIDATED CONSTRUCTION COMPONENT TABLES

C-1 **INTRODUCTION.** The purpose of this appendix is to identify the construction components that were the basis for the cost tables in Appendices A and B. The baseline construction for the six common building types is also identified in this appendix. Table C-1 provides a guide to the construction component tables organized by tactic for all tactics except the hand delivered device tactic. For that tactic, the entries are organized by explosive weight and whether the threat is applied to the exterior or the interior of buildings.

C-2 **BASELINE CONSTRUCTION.** Table C-2 contains the baseline construction for the six common building types identified in Chapters 3 and 6 and for which the cost tables are tabulated in Appendices A and B. The building elements in Table C-2 are common to the building types identified in the tables and are representative of the construction upon which the baseline costs in the *DoD Facilities Pricing Guide (UFC 4-701-05)* are based. They may not be representative of how such buildings are built in all parts of the country or the world, but they represent very common construction. If common construction in your area is significantly different from a cost standpoint than that in Table C-2, the cost tables in Appendices A and B may not work for you or you may have to do some interpolating or extrapolating. Table C-2 also includes the percentages of the entire building cost represented by the major building components that are affected by security and antiterrorism (walls, doors, windows, and roofs). Those percentages may also be used to evaluate costs where local construction practices are different than the baseline construction in Table C-2.

C-3 **ENHANCED BUILDING CONSTRUCTION.** The building construction identified in tables C-3 through C-17 in this appendix is representative of construction that will mitigate the effects of the various threats identified. They do not represent the only possible selections. They only represent selections that reflect a representative minimum cost for providing the required protection using common construction practice. Issues specific to each of the tables in this appendix follow. They include both new construction and retrofit construction. For retrofit construction, all retrofit costs include the costs of removing existing building materials and providing new finished surfaces where applicable.

C-3.1 **Blast Resistant Exterior Construction.** Blast resistant exterior construction is described separately for new construction and retrofits to existing construction.

C3.1.1 **New Construction.** Table C-3 contains the walls, windows, doors, and roofs that were used in establishing the cost factors in Appendix A for vehicle bombs and hand delivered devices of 25 kg (55 lbs) or more. Additional costs for other building components are not included because necessary modifications to them generally do not have a significant impact on cost.

C-3.1.1.1 **Walls.** The walls are either reinforced concrete masonry using US standard concrete blocks or reinforced concrete. Reinforcement is based on the following ratios:

- Reinforced concrete
  - Heavy reinforcement: 0.50%
  - Moderate reinforcement: 0.25%
  - Light reinforcement: 0.15% (generally minimum reinforcement)

- Reinforced masonry
  - Heavy reinforcement: 0.30%
  - Moderate reinforcement: 0.15%
  - Light reinforcement: 0.05% (generally minimum reinforcement)

C-3.1.1.2 **Windows.** Windows are either laminated annealed glass or polycarbonate. The minimum window glazing in the table is the window required by the *DoD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01)***.**

C-3.1.1.3 **Doors.** Doors are either conventional hollow metal doors in steel frames or blast resistant doors designed to resist specific blast pressures (in pounds per square inch). The table also includes an option for providing backing walls constructed behind a conventional hollow metal door to intercept the door if it flies into the building in response to a blast or for providing conventional doors in foyers to serve a similar function.

C-3.1.1.4 **Roofs.** Roof construction includes both reinforced concrete flat slabs and steel deck on top of bar joists. The bar joists are built to US standards, so foreign made joists may not directly match.

C-3.1.2 **Retrofit Construction.** Table C-4 contains the walls, windows, doors, and roofs that were used in establishing the cost factors in Appendix B for vehicle bombs and hand delivered devices of 25 kg (55 lbs) or more. Additional costs for other building components are not included because necessary modifications to them generally do not have a significant impact on cost.

C-3.1.2.1 **Walls.** Wall retrofits are of two major types; those that may be used on masonry walls and those that can be used on lightweight construction. They also differ in that some may be used for load-bearing walls and others can only be used for non-load-bearing walls. The following retrofits are included:

C-3.1.2.1.1 **Steel Stud Retrofit.** This is a retrofit that can be applied to steel stud walls. It involves adding an additional steel stud wall in the interior of the building. That wall has back-to-back steel studs with special connections to steel channels. It also has light gage sheet steel on one side and polycarbonate reinforced gypsum wall board with sheet metal reinforcing strips on the other.

C-3.1.2.1.2 **Reinforced Concrete Backer Walls.** This retrofit can be applied behind masonry walls to minimize the debris from the masonry wall when it fails. They can be either bonded to the masonry or unbonded.

C-3.1.2.1.3. **High Capacity Wall Catcher System.** This retrofit uses foam block behind the existing wall and light gage sheet steel behind the foam blocks. The system is bolted to the floor and ceiling. It is designed to catch hazardous debris.

C-3.1.2.1.4 **Geotextile Fabric Retrofits.** This retrofit uses common geotextiles fastened to floors and ceilings behind existing masonry walls to minimize debris from the masonry wall when it fails.

C-3.1.2.2 **Windows.** Because retrofits applied in this UFC are assumed to be used as elements of major renovations, all window retrofits involve removing the existing windows and replacing them with new, blast resistant window assemblies.

C-3.1.2.3 **Doors.** Door retrofits in this UFC are limited to building foyers incorporating the existing doors to ensure that when they fail in response to a blast they will be caught by the foyer wall and not become hazardous flying debris.

C-3.1.2.4 **Roofs.** The most economical roof retrofits involve removing the old roofs and replacing them with the roofs specified for new construction.

C-3.2 **Construction Resistant to Hand Delivered Devices.** Table C-5 includes the walls, doors, windows, and roofs that are necessary to meet the requirements for small hand delivered devices delivered external to buildings. Tables C-6 and C-7 include construction to resist internal explosions in mail rooms, loading docks, and entry areas of multiple sizes.

C-3.2.1 **Walls.** Walls to resist externally delivered hand delivered devices of 1 kg (2.2 lbs) or less are either conventional construction of any sort, conventional masonry construction that is reinforced to the minimum requirements of the *DoD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01),* or lightly reinforced concrete. Walls to resist internal explosions are reinforced concrete with reinforcement ratios as discussed above. They are tabulated according to the purpose of the interior space (mail rooms, loading dock, or entry area), the size of the space, the explosive weight, and the level of protection. Exterior retrofits are similar to those described for other blast resistant construction. Interior retrofits assume it is more economical to remove existing interior walls and replace them with the same construction that would be used for new construction.

C-3.2.2 **Windows.** Windows to resist externally delivered devices of 1 kg (2.2 lbs) or less either have the minimum laminated glass required by the *DoD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01)* or polycarbonate glazing. The latter is sized to resist fragments. There are no windows provided for internal explosions except those on the exterior walls of those areas. The exterior windows are laminated glass intended to fail quickly to allow the blast pressures to vent out of the internal areas. As for other blast resistant construction, all window retrofits involve replacing the existing windows with appropriate new window assemblies.

C-3.2.3 **Doors.** Doors to resist externally delivered devices of 1 kg (2.2 lbs) or less are conventional hollow steel for all cases, except they are incorporated into entry foyers for higher levels of protection as described in Chapter 4. Doors for internal explosions are blast resistant doors, but their costs are not currently included in the tables in this appendix. Retrofitted doors similarly use foyers to back them up.

C-3.2.4 **Roofs.** Roofs to resist externally delivered devices of 1 kg (2.2 lbs) or less are either conventional construction or lightly reinforced concrete. Ceilings of rooms subject to internal explosions will be reinforced concrete reinforced according the reinforcement ratios described above. The basis for tabulating ceilings is the same as for walls. Retrofits to existing construction involve removing existing roofs and ceilings where necessary and replacing them with the same construction as is specified for new buildings.

C-3.3 **Construction to Resist Indirect Fire Weapons.** Construction to resist indirect fire weapons is in Table C-8 for new construction and Table C-9 for existing construction. In both cases construction must resist both the effects of blast pressures from the exploding rounds and the effects of the fragmentation of the warhead. It depends, therefore, significantly on mass. Considerations are similar for new construction and retrofits, but they will still be described separately here.

C-3.3.1 **New Construction.**

C-3.3.1.1 **Walls.** Walls must provide blast resistance similar to those described for blast resistant exterior construction, but they must also have sufficient mass to stop or significantly reduce the effects of the warhead fragments. For the lower threat severity level weapons and lower levels of protection, that can be done by slightly enhancing the baseline construction such as by spacing studs closer together for lightweight construction or lightly reinforcing masonry walls for the masonry construction. For all building types the exterior is assumed to have at least a clay brick face, which is sufficient to stop the fragments at those levels. At higher threat severity levels and levels of protection, walls become increasingly heavier reinforced concrete and reinforced concrete masonry.

C-3.3.1.2 **Windows.** While windows can be designed to resist the blast pressure effects of the exploding rounds, they cannot be economically designed to resist the fragment effects as well. Because of that, the approach in this UFC is to replace windows with window assemblies that are resistant to the blast pressure effects, and that are narrow so they minimize exposure to fragments instead of resisting them. Windows cannot be made economically to provide a high level of protection to any but the low threat severity level. In those cases, for the purposes of this UFC, the windows are eliminated and replaced by the same material as is used for the buildings’ walls.

C-3.3.1.3 **Doors.** Building doors to resist both blast and fragments is very expensive and the resulting doors would not be easy to operate. Because of that, all doors for this tactic are backed up by foyers to both catch the failing door and to intercept the fragments. The foyer walls and roofs are of the same construction as the rest of the building.

C-3.3.1.4 **Roofs.** Conventional roofs are sufficient to resist the indirect fire weapons effects for only the low threat severity level. For all other threat severity levels, roof construction is based on a sacrificial roof of conventional construction at either 2 meters (6 feet) or 4 meters (12 feet) above reinforced concrete slab construction of increasing thickness. The sacrificial roof in each case uses the roof construction in the baseline construction as tabulated in Table C-2. Where the baseline construction is standing seam metal roof, the sacrificial roof needs to be hardened slightly using rigid foam insulation and corrugated steel deck.

C-3.3.1.5 **Wall Extensions.** The sacrificial roofs are held up by extended walls to ensure that rounds do not detonate beneath the sacrificial roofs. The wall extensions are of construction similar to that used for the hardened construction, but they are not as heavily reinforced and they may not be as thick.

C-3.3.2 **Existing Construction.**

C-3.3.2.1 **Walls.** Designing wall retrofits to resist the blast pressure and fragmentation effects is only economical at the lower levels of protection and lower threat severity levels. In those cases, walls retrofits are mostly those that were described above for blast resistant exterior construction. They also include adding steel plate to stop the fragment, however. Retrofits to higher threat severity levels and levels of protection are not included at all due to their impracticality.

C-3.3.2.2 **Windows.** Window retrofits involve replacing existing windows with new window assemblies. As for new construction, they only resist the blast pressure effects from the exploding rounds, and not the fragmentation. For buildings with masonry or concrete exteriors, the retrofits include concrete in-fill to minimize the size of the window opening so narrow windows can be installed.

C-3.3.2.3 **Doors.** Doors for retrofits use the same foyers as those for new construction.

C-3.3.2.4 **Roofs.** Roofs for retrofits involve removing the existing roofs and installing new roofs like those for new construction.

C-3.3.2.5 **Wall Extensions.** The wall extensions that support the sacrificial roofs use similar construction to that used for the hardened wall construction, but the wall extensions are not as heavily reinforced, may not be as thick, or may not include the retrofit that is applied to the hardened walls. The wall extensions only need to keep rounds from penetrating and detonating under the sacrificial roof.

C-3.4 **Construction to Resist Direct Fire Weapons.** Construction to mitigate the effects of direct fire weapons is in Table C-10 (new construction) and C-11 (retrofit construction). In both cases, the construction either obscures sightlines to assets (low level of protection) or provides resistance to the effects of the weapons (other levels of protection).

C-3.4.1 **Walls.** Other than the conventional construction to provide obscuration, the walls required to resist the weapons effects are either masonry or reinforced concrete for new construction. For retrofit construction, the walls have steel plate of varying thicknesses added.

C-3.4.2 **Windows.** Windows will be reflective (using fragment retention film or factory applied coatings) for the low level of protection. For the higher levels of protection they are provided only for bullet resistance and include varying thicknesses of laminated glass. The same windows are used for new and retrofit construction, assuming that windows will be replaced during major renovations. There will not be windows at the higher levels of protection for antitank weapons.

C-3.4.3 **Doors.** Doors at the low level of protection will be opaque to obscure sightlines. For the high level of protection for the threat severity levels that are limited to small arms, the doors will be bullet resistant assemblies for new construction and they will be retrofitted with steel plate for retrofit construction. For the higher levels of protection for the larger caliber bullets and the anti-tank weapons, doors are impractical, so conventional doors will be installed in shielded entry foyers.

C-3.4.4 **Roofs.** Roofs in this table are conventional construction based on the assumption that there are no direct fire sightlines to roofs. If there are such sightlines, additional cost will need to be added to account for using reinforced concrete for new construction or adding steel for retrofit construction.

C-3.5 **Construction to Mitigate Airborne Contamination.** The building elements associated with construction to mitigate airborne contamination are limited to enhancements to heating, ventilating, and air conditioning systems. They include increases in system air handling capacity and the addition of filters. Those elements are shown in Table C-12

C-3.6 **Construction to Mitigate Waterborne Contaminants.** Enhancements for waterborne contaminants are limited to water treatment and distribution system elements that are reflected in Table C-13.

C-3.7 **Construction to Mitigate Waterfront Attacks.** The construction enhancements for this tactic are addressed under blast resistant exterior construction and construction to resist direct fire weapons as applicable.

C-3.8 **Forced Entry Resistant Construction.** Construction to resist forced entry is tabulated in Tables C-14 and C-15. The construction includes materials and assemblies that have been tested to provide forced entry resistance for specific time periods against a range of tools.

C-3.8.1 **Walls.** For new construction, walls are reinforced masonry or concrete with varying amounts of reinforcing steel or with the addition of expanded metal mesh. In the case of the varying reinforcement, the reinforcement is both vertical and horizontal and often consists of staggered meshes. For retrofitted walls, various combinations of steel and plywood are added to the existing walls.

C-3.8.2 **Windows.** Windows to resist forced entry, where possible, are laminated glass of varying thicknesses. The same windows are used for new and retrofit construction, assuming that windows will be replaced during major renovations.

C-3.8.3 **Doors.** Doors to resist forced entry have thick steel plate and may be filled with concrete or may include expanded metal meshes. Retrofit doors are similar, assuming doors can be replaced relatively easily during major retrofits.

C-3.8.4 **Roofs.** For new construction, roofs are reinforced concrete with varying levels of reinforcement and expanded metal as described for walls. For retrofit construction, similar additions are made to the roofs as are made to the walls.

C-3.9 **Covert Entry Construction.** There are no significant requirements for construction for mitigating covert entry. The requirements are limited to employing access control equipment and procedures with varying levels of sophistication. The specific equipment reflected in Table C-16 is described in detail in the *DoD Security Engineering Design Manual (UFC 4-011-02).*

C-3.10 **Construction for Mitigating Acoustics Eavesdropping.** Construction to mitigate acoustics eavesdropping is tabulated in Table C-17. It includes considerations for the four major building components as follows:

C-3.10.1 **Walls.** Generally, conventionally constructed interior walls provide adequate attenuation of sound transmission to meet the requirements of all levels of protection. Common interior construction may require the installation of additional layers of gypsum wall board and emplacing insulation in the voids between studs. Retrofit construction effectively is only a consideration for interior walls. It involves removing gypsum wall board from one side of the existing wall, emplacing insulation inside the wall, and replacing the gypsum wall board.

C-3.10.2 **Doors.** Doors to provide sound transmission attenuation can either be conventional solid core wood doors with gaskets around them, which only apply to the low level of protection, or specially manufactured door assemblies designed to provide the applicable STC rating. For retrofits, the existing doors will have to be replaced with the same doors as are used for new construction.

C-3.10.3 **Windows.** Windows used in this manual for attenuating sound transmission are laminated glass of varying thicknesses and configurations insulating glass with differing air space dimensions. For retrofit construction, the existing windows are removed and replaced with windows like those specified for new construction.

C-3.10.4 **Roofs.** Roofs are commonly adequate to attenuate sound transmission without modification. Ceilings are either varying thicknesses of reinforced concrete slab or combinations of gypsum wall board and insulation. One of the tabulated ceilings refers to channels on which the gypsum wall board is mounted. Those channels are light gage steel channels that are common to sound attenuating construction.

C-2.11 **Construction to Mitigate Electronic Emanations Eavesdropping.** Construction to attenuate electronic emanations is very specialized. It involves installing steel sheets in walls, roofs, and ceilings and providing specially manufactured TEMPEST rated doors and windows. For retrofit construction, the doors and windows must be replaced with doors and windows like those used for new construction. Walls, roofs, and ceilings can have the steel sheets added to them, but the interior finish may have to be removed and replaced. There is no table in this appendix for building components associated with this tactic because the costs are too complex and site specific.

C-3.6 **Sitework Element Construction.** Barriers in Table C-18 are perimeter barriers, active barriers, or screens to either provide predetonation of antitank rounds or to shield assets from those weapons. The passive perimeter barriers are either chain link fence or concrete filled pipe bollards. In the case of the chain link fence, it is reinforced with cable except for in the case of the stationary vehicle bomb tactic where the only requirement is to ensure there is an obstacle to easy passage through the perimeter. In that case, the basic chain link fence is adequate for cost estimating purposes. For the active barriers the chain link gate is for the stationary vehicle bomb tactic. The others are tested to resist moving vehicle penetration. Specific models of active barriers were included in the table. They were chosen because they were representative of what is available on the market, and the selections include products from multiple manufacturers. Most manufacturers can provide a model of barrier to meet each requirement, and procurement should be through guide specifications. In the case of the screens, both are free standing and constructed adequately to withstand wind loads. The wood slat fence has posts in concrete footings and the wall has a foundation that extends to frost depth (at least 1 meter for cost estimating purposes.)

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</table>

Table C-2. Baseline Construction for Common Building Types

Building Category	Building Component Construction			
	Walls	**Doors**	**Windows**	**Roofs**
288 Person Barracks (exterior entrances) (3 stories) (102,000 gross sf)	Concrete masonry unit (3.41%)*	3' X 7' Hollow metal and 6' X 7' glazed pairs (0.26%)*	Aluminum frame / sliding (0.86%)*	Standing seam metal (1.11%)*
288 Person Barracks (interior entrances) (3 stories) (115,000 gross sf)	Concrete masonry unit (3.44%)*	3' X 7' Hollow metal and 6' X 7' glazed pairs (2.12%)*	Aluminum frame / sliding (0.86%)*	Standing seam metal (1.19%)*
Dining Facility (1 story) (14,000 gross sf)	Brick veneer / metal stud (0.36%)*	Hollow metal and glazed, 3' X 7' & 6' X 7' pairs (0.84%)*	Aluminum frame / fixed (1.19%)*	Standing seam metal (2.00%)*
Administrative Facility (2 stories) (26,000 gross sf)	Brick veneer / metal stud (0.53%)*	Hollow metal and glazed, 3' X 7' & 6' X 7' pairs (0.74%)*	Aluminum frame / fixed, projected, & storefront (5.40%)*	Standing seam metal (1.73%)*
Medical Clinic (1 story) (40,000 gross sf)	Brick veneer / metal stud (0.25%)*	Hollow metal and glazed, 3' X 7' & 6' X 7' pairs (1.08%)*	Aluminum frame / fixed (0.81%)*	Built-up roofing (1.11%)*
Special Structures	Concrete masonry unit (0.25%)*	Hollow metal and glazed, 6' X 7' pairs (1.08%)*	Aluminum frame / fixed (0.81%)*	Standing seam metal (1.11%)*
* Note: Percentages shown are the percentages of baseline total building cost represented by each of the building components for conventional construction				

Table C-3. Blast Resistant Building New Construction (for 25 kg TNT explosives and higher)		
Building Component	**Construction Description**	**Construction Type**
Walls	450 mm (18 in) heavily reinforced concrete	W
	450 mm (18 in) moderately reinforced concrete	V
	450 mm (18 in) lightly reinforced concrete	U
	300 mm (12 in) heavily reinforced concrete	T
	300 mm (12 in) moderately reinforced concrete	S
	300 mm (12 in) lightly reinforced concrete	R
	300 (12 in) mm heavily reinforced CMU	Q
	200 mm (8 in) heavily reinforced concrete	P
	250 mm (10 in) heavily reinforced CMU	O
	200 mm (8 in) moderately reinforced concrete	N
	200 mm (8 in) lightly reinforced concrete	M
	300 mm (12 in) moderately reinforced CMU	L
	150 mm (6 in) heavily reinforced concrete	K
	150 mm (6 in) moderately reinforced concrete	J
	150 mm (6 in) lightly reinforced concrete	I
	100 mm (4 in) heavily reinforced concrete	H
	100 mm (4 in) moderately reinforced concrete	G
	100 mm (4 in) lightly reinforced concrete	F
	250 mm (10 in) moderately reinforced CMU	E
	200 mm (8 in) heavily reinforced CMU	D
	300 mm (12 in) lightly reinforced CMU	C
	200 mm (8 in) moderately reinforced CMU	B
	200 mm (8 in) lightly reinforced CMU	A
	Conventional construction	-
Windows	2” (50 mm) Polycarbonate	J
	1.5” (38 mm) Polycarbonate	I
	1” (25 mm) Polycarbonate	H
	¾” (19 mm) Polycarbonate	G
	¼” (6 mm) + 7 x 1/8 in (3 mm) glass + 6 x 0.045 in (1mm) PVB	F
	¼” (6 mm) + 5 x 1/8 in (3 mm) glass + 4 x 0.045 in (1mm) PVB	E
	¼” (6 mm) + 4 x 5/32 in (4 mm) glass + 3 x 0.045 in (1mm) PVB	D
	¼” (6 mm) + 2 x 3/16 in (5 mm) glass + 0.060 in (1.5 mm) PVB	C
	¼” (6 mm) + 2 x 5/32 in (4 mm) glass + 0.060 in (1.5 mm) PVB	B
	¼” (6 mm) + 2 x 1/8 in (3 mm) glass + 0.030 in (0.75 mm) PVB	A
Doors	100 PSI (690 kPa) blast door	I
	50 PSI (345 kPa) blast door	H
	25 PSI (172kPa) blast door	G
	12 PSI (83 kPa) blast door	F
	10 PSI (69 kPa) blast door	E
	7 PSI (48 kPa)blast door	D
	4 PSI (28 kPa) blast door	C
	Hollow metal door with backing wall	B
	Hollow metal door	A

Table C-3 (continued)

Roofs	300 mm (12 in) heavily reinforced concrete	72
	300 mm (12 in) moderately reinforced concrete	71
	300 mm (12 in) lightly reinforced concrete	70
	225 mm (9 in) heavily reinforced concrete	69
	225 mm (9 in) moderately reinforced concrete	68
	225 mm (9 in) lightly reinforced concrete	67
	150 mm (6 in) heavily reinforced concrete	66
	150 mm (6 in) moderately reinforced concrete	65
	150 mm (6 in) lightly reinforced concrete	64
	100 mm (4 in) heavily reinforced concrete	63
	100 mm (4 in) heavily reinforced concrete	62
	100 mm (4 in) heavily reinforced concrete	61
	36LH15 L=60’ (18.2 m) ;B=8’ (2.4 m) with metal deck and 5.5” (150 mm) concrete	60
	32LH12 L=60’ (18.2 m) ;B=6’ (1.8 m) with metal deck and 4.5” (115 mm) concrete	59
	32LH09 L=60’ (18.2 m) ;B=4’ (1.2 m) with metal deck and 3.5” concrete	58
	30K12 L=60’ (18.2 m);B=4’ (1.2 m) with metal deck and 3.5” concrete	57
	30K12 L=60’ (18.2 m);B=8’ (2.4 m) with metal deck and 5.5” (150 mm) concrete	56
	30K12 L=60’ (18.2 m);B=6’ (1.8 m) with metal deck and 4.5” (115 mm) concrete	55
	32LH06 L=60’ (18.2 m);B=4’ (1.2 m) with metal deck	54
	30K9 L=60’ (18.2 m);B=4’ (1.2 m) with metal deck	53
	32LH07 L=60’ (18.2 m);B=6’ (1.8 m) with metal deck	52
	32LH09 L=60’ (18.2 m);B=8’ (2.4 m) with metal deck	51
	30K12 L=60’ (18.2 m);B=6’ (1.8 m) with metal deck	50
	30K12 L=60’ (18.2 m);B=8’ (2.4 m) with metal deck	49
	300 mm (12 in) heavily reinforced concrete	48
	300 mm (12 in) moderately reinforced concrete	47
	300 mm (12 in) lightly reinforced concrete	46
	225 mm (9 in) heavily reinforced concrete	45
	225 mm (9 in) moderately reinforced concrete	44
	225 mm (9 in) lightly reinforced concrete	43
	150 mm (6 in) heavily reinforced concrete	42
	150 mm (6 in) moderately reinforced concrete	41
	150 mm (6 in) lightly reinforced concrete	40
	100 mm (4 in) heavily reinforced concrete	39
	100 mm (4 in) moderately reinforced concrete	38
	100 mm (4 in) lightly reinforced concrete	37
	24LH11 L=40’ (12.2 m);B=8’ (2.4 m) with metal deck and 5.5” (150 mm) concrete	36
	20LH09 L=40’ (12.2 m);B=6’ (1.8 m) with metal deck and 4.5” (115 mm) concrete	35
	20LH05 L=40’ (12.2 m);B=4’ (1.2 m) with metal deck and 3.5” (90 mm) concrete	34
	30K12 L=40’ (12.2 m);B=8’ (2.4 m) with metal deck and 5.5” (150 mm) concrete	33
	30K12 L=40’ (12.2 m);B=6’ (1.8 m) with metal deck and 4.5” (115 mm) concrete	32

Table C-3 (continued)

Roofs (continued)	20K10 L=40' (12.2 m);B=4' (1.2 m) with metal deck and 3.5" (90 mm) concrete	31
	20LH02 L=40' (12.2 m);B=4' (1.2 m) with metal deck	30
	20LH04 L=40' (12.2 m);B=6' (1.8 m) with metal deck	29
	20K5 L=40' (12.2 m);B=4' (1.2 m) with metal deck	28
	20LH06 L=40' (12.2 m);B=8' (2.4 m) with metal deck	27
	20K10 L=40' (12.2 m);B=6' (1.8 m) with metal deck	26
	22K10 L=40' (12.2 m);B=8' (2.4 m) with metal deck	25
	300 mm (12 in) heavily reinforced concrete	24
	300 mm (12 in) moderately reinforced concrete	23
	300 mm (12 in) lightly reinforced concrete	22
	225 mm (9 in) heavily reinforced concrete	21
	225 mm (9 in) moderately reinforced concrete	20
	225 mm (9in) lightly reinforced concrete	19
	150 mm (6 in) heavily reinforced concrete	18
	150 mm (6 in) moderately reinforced concrete	17
	150 mm (6 in) lightly reinforced concrete	16
	100 mm (4 in) heavily reinforced concrete	15
	100 mm (4 in) heavily reinforced concrete	14
	100 mm (4 in) heavily reinforced concrete	13
	18LH08 L=30' (9.1 m);B=8' (2.4 m) with metal deck and 5.5" (150 mm) concrete	12
	18LH05 L=30' (9.1 m);B=6' (1.8 m) with metal deck and 4.5" (115 mm) concrete	11
	18LH02 L=30' (9.1 m);B=4' (1.2 m) with metal deck and 3.5" (90 mm) concrete	10
	30K12 L=30' (9.1 m);B=8' (2.4 m) with metal deck and 5.5" (150 mm) concrete	9
	16K7 L=30' (9.1 m);B=4' (1.2 m) with metal deck and 3.5" (90 mm) concrete	8
	20K10 L=30' (9.1 m);B=6' (1.8 m) with metal deck and 4.5" (115 mm) concrete	7
	18LH02 L=30' (9.1 m);B=4' (1.2 m) with metal deck	6
	18LH02 L=30' (9.1 m);B=6' (1.8 m) with metal deck	5
	16K2 L=30' (9.1 m);B=4' (1.2 m) with metal deck	4
	18LH02 L=30' (9.1 m);B=8' (2.4 m) with metal deck	3
	16K5 L=30' (9.1 m);B=6' (1.8 m) with metal deck	2
	16K9 L=30' (9.1 m);B=8' (2.4 m) with metal deck	1
	Conventional Construction	-

Table C-4. Blast Resistant Building Retrofit Construction (for 25 kg TNT explosives and higher)

Building Component	Construction Description	Construction Type
Walls	Steel Stud Wall Retrofit	K
	150 mm (6 in) Bonded Reinforced Concrete Backer Wall (#3 reinforcing bars @ 150 mm (6 in))	J
	150 mm (6 in) Bonded Reinforced Concrete Backer Wall (#3 reinforcing bars @ 250 mm (10 in))	I
	150 mm (6 in) Unbonded Reinforced Concrete Backer Wall (#3 reinforcing bars @ 150 mm (6 in))	H
	100 mm (4 in) Bonded Reinforced Concrete Backer Wall (#3 reinforcing bars @ 300 mm (12 in))	G
	150 mm (6 in) Unbonded Reinforced Concrete Backer Wall (#3 reinforcing bars @ 250 mm (10 in))	F
	100 mm (4in) Unbonded Reinforced Concrete Backer Wall (#3 reinforcing bars @ 300 mm (12 in))	E
	High Capacity Wall Catcher System	D
	Geotextile fabric catcher system (Comtrac R 500)	C
	Geotextile fabric catcher system (HS 1715)	B
	Geotextile fabric catcher system (HS 800)	A
	Conventional construction	-
Windows	2” (50 mm) Polycarbonate	H
	1.5” (38 mm) Polycarbonate	G
	¼” (6 mm) + 7 x 1/8 in (3 mm) glass + 6 x 0.045 in (1mm) PVB	F
	¼” (6 mm) + 5 x 1/8 in (3 mm) glass + 4 x 0.045 in (1mm) PVB	E
	¼” (6 mm) + 4 x 5/32 in (4 mm) glass + 3 x 0.045 in (1mm) PVB	D
	¼” (6 mm) + 2 x 3/16 in (5 mm) glass + 0.060 in (1.5 mm) PVB	C
	¼” (6 mm) + 2 x 5/32 in (4 mm) glass + 0.060 in (1.5 mm) PVB	B
	¼” (6 mm) + 2 x 1/8 in (3 mm) glass + 0.030 in (0.75 mm) PVB	A
Doors	Metal Door Retrofit	B
	Hollow Metal Door	A
Roofs	225 mm (9 in) heavily reinforced concrete slab	18
	225 mm (9 in) moderately reinforced concrete slab	17
	225 mm (9 in) lightly reinforced concrete slab	16
	24LH11 L=40’ (12.2 m); B=8’ (2.4 m) **with metal deck and 5.5” (140 mm) concrete**	15
	20LH09 L=40’ (12.2 m); B=6’ (1.8 m) **with metal deck and 4.5” (115 mm) concrete**	14
	20LH05 L=40’ (12.2 m); B=4’ (1.2 m) **with metal deck and 3.5” (90 mm) concrete**	13
	20K10 L=40’ (12.2 m); B=4’ (1.2 m) **with metal deck and 3.5” (90 mm) concrete**	12
	20LH02 L=40’ (12.2 m); B=4’ (1.2 m) **with metal deck**	11
	20K10 L=40’ (12.2 m); B=6’ (1.8 m) **with metal deck**	10
	22K10 L=40’ (12.2 m); B=8’ (2.4 m) **with metal deck**	9
	225 mm (9 in) heavily reinforced concrete slab	8
	225 mm (9 in) moderately reinforced concrete slab	7

Table C-4 (continued)

Roofs (continued)	18LH08 L=30’ (9.1 m); B=8’ (2.4 m) **with metal deck and 5.5” (140 mm) concrete**	6
	20K10 L=30’ (9.1 m); B=6’ (1.8 m) **with metal deck and 4.5” (115 mm) concrete**	5
	18LH02 L=30’ (9.1 m); B=4’ (1.2 m) **with metal deck**	4
	18LH02 L=30’ (9.1 m); B=6’ (1.8 m)	3
	18LH02 L=30’ (9.1 m); B=8’ (2.4 m)	2
	16K9 L=30’ (9.1 m); B=8’ (2.4 m)	1
	Conventional Construction	-

Table C-5. Hand Delivered Device Resistant Building Exterior Construction (for IID, hand grenades, and 1 kg TNT IID)
New and Existing Construction

Building Component	Construction Description	Construction Type
Walls	Conventional construction (no special requirements)	A
	High capacity wall catcher system retrofit	B
	100 mm (6-inch) lightly reinforced concrete	C
	100 mm (6-inch) concrete backing wall retrofit (#3 @ 300 mm (12 in))	D
Windows	¼ –inch (6 mm) laminated glass in accordance with minimum standards	A
	¾–inch (19 mm) polycarbonate glazing	B
Doors	Conventional hollow metal doors	A
	Conventional hollow steel doors in 6-inch (150 mm) reinforced concrete entry foyers	B
Roofs	Conventional roof	A
	100 mm (6 – inch) lightly reinforced concrete	B

Table C-6. Construction for Interior Spaces Subject to Explosions
Medium Threat Severity Level (1 kg)
New and Existing Construction

Type of Space	Low LOP						Medium LOP						High LOP					
	Walls			Ceilings			Walls			Ceilings			Walls			Ceilings		
	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement
Small Mail Rooms (10' x 20' x 10' High)	6	H	H	8	H	H	8	M	H	9	H	H	10	M	H	12	H	H
Medium Mail Rooms (16' x 25' x 10' High)	6	M	M	8	H	H	6	M	M	10	H	H	8	M	M	14	H	H
Large Mail Room (22' x 32' x 10' High)	6	M	M	8	H	H	6	M	H	10	H	H	6	H	H	14	H	M
Small Loading Dock (10' x 22' x 10' High)	6	M	M	8	H	H	6	M	H	8	H	H	8	H	H	12	M	M
Medium Loading Dock (10' x 34' x 10' High)	6	M	M	6	H	H	6	M	H	8	H	H	6	H	H	12	M	M
Large Loading Dock (22' x 46' x 10' High)	6	M	M	6	M	M	6	M	M	8	M	M	6	H	H	10	H	H
Small Entry Area (15' x 30' x 10' High)	6	M	M	6	H	H	6	M	M	8	H	H	6	M	H	12	M	M
Medium Entry Area (20' x 40' x 10' High)	6	M	M	6	M	M	6	M	M	8	H	H	6	M	H	12	H	H
Large Entry Area (40' x 50' x 10' High)	6	M	M	6	M	M	6	M	M	6	M	M	6	M	M	6	M	M

M = Moderate reinforcement ratio (0.25%)
H = Heavy reinforcement ratio (0.5%)

Table C-7. Construction for Interior Spaces Subject to Explosions
High Threat Severity Level (25kg)
New and Existing Construction

Type of Space	Low LOP						Medium LOP						High LOP					
	Walls			Ceilings			Walls			Ceilings			Walls			Ceilings		
	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement	Thickness (inches)	Horizontal Reinforcement	Vertical Reinforcement
Small Mail Room (10' x 20' x 10' High)	Maximum explosive applied to mail rooms is 1 kg. See Table C-6																	
Medium Mail Room (16' x 25' x 10' High)																		
Large Mail Room (22' x 32' x 10' High)																		
Small Loading Dock (10' x 22' x 10' High)	24	M	M	26	H	H	28	M	M	32	H	H	32	M	M	39	H	H
Medium Loading Dock (10' x 34' x 10' High)	20	M	H	22	H	H	24	M	H	27	H	H	30	M	M	36	H	H
Large Loading Dock (22' x 46' x 10' High)	16	H	H	20	H	H	20	M	H	26	H	H	24	M	H	36	H	H
Small Entry Area (15' x 30' x 10' High)	14	M	M	14	H	H	16	M	H	20	H	H	22	M	M	26	H	H
Medium Entry Area (20' x 40' x 10' High)	14	M	H	18	H	H	16	H	H	22	H	H	22	M	H	32	H	H
Large Entry Area (40' x 50' x 10' High)	10	H	H	20	H	H	12	H	H	26	H	H	15	M	H	36	H	H

M = Moderate reinforcement ratio (0.25%)
H = Heavy reinforcement ratio (0.5%)

Table C-8. Indirect Fire Weapons Resistant Building Construction (New Construction)		
Building Component	**Construction Description**	**Construction Type**
Walls	150 mm (6 in) steel stud wall at 300 mm (12 in.) o.c. with brick veneer	A
	200 mm (8 in) lightly reinforced CMU	B
	200 mm (8 in) moderately reinforced CMU	C
	100 mm (4 in) lightly reinforced concrete	D
	300 mm (12 in) lightly reinforced concrete	E
	600 mm (24 in) lightly reinforced concrete	F
	450 mm (18 in) heavily reinforced concrete	G
	1400 mm (56 in) moderately reinforced concrete	H
Wall Extensions	150 mm (6 in) steel stud wall at 300 mm (12 in.) o.c. with brick veneer	A
	200 mm (8 in) lightly reinforced CMU	B
	100 mm (4 in) lightly reinforced concrete	C
Windows	6 mm (1/4 in) + 2 x 3 mm (1/8 in) glass with 0.75 mm (0.030 in) PVB in narrow window	A
	6 mm (1/4 in) + 4 x 3 mm (1/8 in) glass with 3 x 1 mm (0.045 in) PVB in narrow window	B
	No window – use wall material as in fill	C
Doors	Doors in entry foyer using same construction as rest of building (walls, wall extensions, hardened roof, sacrificial roof)	A
Hardened Roofs	Standing seam metal roof + 50 mm (2 in) extruded polystyrene insulation + 50 mm (2 in) corrugated steel deck	1
	150 mm (6 in) moderately reinforced concrete (1.5 m / 5 ft span – 2 m / 6 ft high)	2
	225 mm (9 in) lightly reinforced concrete (1.5 m / 5 ft. span)	3
	225 mm (9 in) lightly reinforced concrete (3.8 m / 12.5 ft. span)	4
	225 mm (9 in) lightly reinforced concrete (6 m / 20 ft. span)	5
	225 mm (9 in) moderately reinforced concrete (1.5 m / 5 ft. span)	6
	225 mm (9 in) moderately reinforced concrete (3.8 m / 12.5 ft. span)	7
	225 mm (9 in) moderately reinforced concrete (6 m / 20 ft. span)	8

Table C-8 (continued)

Hardened Roofs (continued)	225 mm (9 in) heavily reinforced concrete (6 m / 20 ft. span)	9
	300 mm (12 in) moderately reinforced concrete (6 m / 20 ft. span)	10
	300 mm (12 in) heavily reinforced concrete (6 m / 20 ft. span)	11
Sacrificial Roofs	Conventional built up roofing at 2 m (6 ft)	1
	Conventional built up roofing at 4 m (12 ft)	2
	Standing seam metal roof + 50 mm (2 in) extruded polystyrene insulation + 50 mm (2 in) corrugated steel deck at 2 m (6 ft)	3
	Standing seam metal roof + 50 mm (2 in) extruded polystyrene insulation + 50 mm (2 in) corrugated steel deck at 4 m (12 ft)	4

Table C-9. Indirect Fire Weapons Resistant Building Construction (Existing Construction)

Building Component	Construction Description	Construction Type
Walls	Add steel studs between existing studs in existing steel stud wall (with brick veneer)	A
	100 mm (4 in) unbonded lightly reinforced concrete backing wall	B
	150 mm (6 in) unbonded lightly reinforced concrete backing wall	C
	150 mm (6 in) unbonded moderately reinforced concrete backing wall	D
	Steel stud wall retrofit	E
	Steel stud wall retrofit with 50 mm (2 in) steel plate	F
Wall Extensions	150 mm (6 in) steel stud wall at 300 mm (12 in.) o.c. with brick veneer	A
	200 mm (8 in) lightly reinforced CMU	B
Windows	1/4" (6 mm) + 2 x 1/8 in (3 mm) glass + 0.030 in (0.75 mm) PVB narrow window with wall in fill	A
Doors	Doors in entry foyer using same construction as rest of building (walls, wall extensions, hardened roof, sacrificial roof)	A
Hardened Roofs	Standing seam metal roof + 50 mm (2 in) extruded polystyrene insulation + 50 mm (2 in) corrugated steel deck	1
	150 mm (6 in) moderately reinforced concrete (1.5 m / 5 ft span - 2 m / 6 ft high)	2
	225 mm (9 in) lightly reinforced concrete (1.5 m / 5 ft. span)	3
	225 mm (9 in) lightly reinforced concrete (3.8 m / 12.5 ft. span)	4
	225 mm (9 in) lightly reinforced concrete (6 m / 20 ft. span)	5
	225 mm (9 in) moderately reinforced concrete (1.5 m / 5 ft. span)	6
	225 mm (9 in) moderately reinforced concrete (3.8 m / 12.5 ft. span)	7
	225 mm (9 in) moderately reinforced concrete (6 m / 20 ft. span)	8
	225 mm (9 in) heavily reinforced concrete (6 m / 20 ft. span)	9
	300 mm (12 in) moderately reinforced concrete (6 m / 20 ft. span)	10

Table C-9 (continued)

Hardened Roofs (continued)	300 mm (12 in) heavily reinforced concrete (6 m / 20 ft. span)	11
Sacrificial Roofs	Conventional built up roofing at 2 m (6 ft)	1
	Standing seam metal roof + 50 mm (2 in) extruded polystyrene insulation + 50 mm (2 in) corrugated steel deck at 2 m (6 ft)	2

Table C-10. Direct Fire Weapons Resistant Building Construction (New Construction)		
Building Component	**Construction Description**	**Construction Type**
Walls	No special construction (opaque)	A
	4-inch fully grouted concrete masonry unit or 4-inch clay brick	B
	6-inch fully grouted concrete masonry unit	C
	8-inch fully grouted concrete masonry unit	D
	24-inch thick reinforced concrete	E
Windows	4-mil reflective fragment retention film	A
	1/4 inch laminated glass in accordance with DoD minimum antiterrorism standards	B
	1/2 inch laminated tempered glass, 1/4 inch air gap and 3/4 inch glass clad polycarbonate (1/2 inch polycarbonate with 1/4 inch tempered glass on inside face)	C
	3/4 inch laminated tempered glass, 1/4 inch air gap and 1-3/16 inch glass clad polycarbonate (15/16 inch polycarbonate with 1/4 inch tempered glass on inside face)	D
	1-5/8 inch laminated annealed glass and 1/4 inch polycarbonate (1/4 inch polycarbonate with 1/4 inch tempered glass on inside face)	E
Doors	Standard hollow metal door	A
	Industrial door (3 foot by 7 foot) with interior 1/4 inch thick steel armor plate	B
	Industrial door (3 foot by 7 foot) with interior 7/16 inch thick steel armor plate	C
	Industrial door (3 foot by 7 foot) with interior 11/16 inch thick steel armor plate	D
	Doors shielded with 24-inch reinforced concrete walls	E
Roofs	No special roof construction (opaque)	A
	20K10 L=30’ (9.1 m);B=6’ (1.8 m) with metal deck and 4.5” (115 mm) concrete	B
	30K12 L=40’ (12.2 m);B=6’ (1.8 m) with metal deck and 4.5” (115 mm) concrete	C
	30K12 L=60’ (18.2 m);B=6’ (1.8 m) with metal deck and 4.5” (115 mm) concrete	D
	225 mm (9in) lightly reinforced concrete	E
	600 mm (24 in) lightly reinforced concrete	F

Table C-11. Direct Fire Weapons Resistant Building Construction (Retrofit Construction)		
Building Component	**Construction Description**	**Construction Type**
Walls	No special construction (opaque)	A
	5/16 mild steel plate	B
	9/16 mild steel plate	C
	13/16 mild steel plate	D
Windows	4-mil reflective fragment retention film	A
	1/2 inch laminated tempered glass, 1/4 inch air gap and 3/4 inch glass clad polycarbonate (1/2 inch polycarbonate with 1/4 inch tempered glass on inside face)	B
	3/4 inch laminated tempered glass, 1/4 inch air gap and 1-3/16 inch glass clad polycarbonate (15/16 inch polycarbonate with 1/4 inch tempered glass on inside face)	C
	1-5/8 inch laminated annealed glass and 1/4 inch polycarbonate (1/4 inch polycarbonate with 1/4 inch tempered glass on inside face)	D
Doors	Standard hollow metal door	A
	Industrial door (3 foot by 7 foot) with interior 1/4 inch thick steel armor plate	B
	Industrial door (3 foot by 7 foot) with interior 7/16 inch thick steel armor plate	C
	Industrial door (3 foot by 7 foot) with interior 11/16 inch thick steel armor plate	D
Roofs	No special roof construction (opaque)	A
	UL Level 3 ballistics rated fiberglass	B
	UL Level 5 ballistics rated fiberglass	C

Table C-12. HVAC Requirements for Airborne Contamination

Level of Protection	HEPA filtration	HEPA and carbon filtration for outside air	HEPA and carbon filtration for all supply air	Overpressurization
Low	X			
Medium		X		X
High			X	X
Note: Overpressurization based on 0.25 cfm /ft^2 plus exhaust				

Table C-13. Water Treatment Requirements for Waterborne Contamination

Level of Protection	Superchlorination	Micro-filtration	Carbon filtration	Chlorination	Reverse Osmosis
Low	X				
Medium		X	X	X	
High		X	X	X	X

Table C-14. Forced Entry Resistant Building Construction (New Construction)		
Building Component	**Construction Description**	**Construction Type**
Walls	4-inch, solid-core, filled and reinforced masonry construction with interior wall system	A
	8-inch, solid-core, filled concrete masonry with #3 bars at 8 inches on center each way	B
	8-inch, solid-core, filled concrete masonry with #5 bars at 8 inches on center each way	C
	8-inch, mortar-filled concrete block with #6 bars at 8 inches on center each way	D
	8-inch, reinforced concrete with # 4 bars at 6 inches on center each way	E
	12-inch, mortar-filled, concrete block with #6 bars at 8 inches on center each way	F
	8-inch, solid-core, filled concrete masonry with #6 bars at 4 inches on center vertically and 8 inches on center horizontally	G
	12-inch, reinforced concrete with # 5 bars at 6 inches on center each way	H
	12-inch, reinforced concrete with 2 layers of #5 bars at 6 inches on center each way	I
	12-inch, reinforced concrete with 2 layers of # 7 bars at 4 inches on center each way	J
	12-inch, reinforced concrete with 5/16 expanded metal 2½ inches on center (4 layers)	K
	12-inch, reinforced concrete with 5/16-inch, expanded, metal mesh at 2½ inches on center and a ¼-inch backing plate	L
	18-inch-thick reinforced concrete with 5/16-inch expanded metal at 2½ inches on center and a ¼-inch backing plate	M
Windows	11/16-inch, glass-clad with 3/8-inch polycarbonate core	A
	13/16-inch, glass-clad with ½-inch polycarbonate core	B
	15/16-inch, glass-clad with 3/4-inch polycarbonate core	C

Table C-14 (continued)

Doors	Standard 16-gage, hollow, metal door (3 feet by 7 feet) with hinge-side protection, anti-pry strip, and drill-resistant dead bolt lock	A
	12-gage, hollow, metal door (3 feet by 7 feet) with hinge-side protection, anti-pry strip, and drill-resistant dead bolt lock	B
	12-gage, hollow, metal door with hinge-side protection, anti-pry strip, drill-resistant dead bolt lock, and filled with lightweight fireproofing	C
	12-gage, hollow, metal door filled with lightweight concrete (3 feet by 7 feet) with hinge-side protection, anti-pry strip, and drill-resistant dead bolt lock	D
	12-gage, hollow, metal door (3 feet by 7 feet) with hinge-side protection, anti-pry strip, drill-resistant dead bolt lock, and multipoint (3) locking	E
	Swinging door (6 inches thick) with ½-inch plate inside and out, lightweight concrete fill, and an internal locking system	F
	Sliding door (6 inches thick) filled with lightweight concrete that has been reinforced with expanded metal mesh with a 3/4-inch steel front plate, 1/4–inch back plate, and an internal locking system	G
	Swinging door (10 inches thick) with ½-inch plate inside and out	H
	Swinging door (10 inches thick) with ½-inch plate inside and out, lightweight concrete fill, and an internal locking system	I
	Swinging door (10 inches thick) with ½-inch plate inside and out, lightweight concrete fill reinforced with expanded metal mesh, and an internal locking system	J
	Swinging door (10 inches thick) with ½-inch plate inside and out, lightweight concrete fill reinforced with expanded metal mesh, and an internal locking system with a welded C-steel grating vestibule around the door for standoff protection	K

Table C-14 (continued)

Roofs	Built-up roof with gravel and rigid insulation on steel decking	A
	Built-up roof with gravel and rigid insulation and 2.5-inch lightweight concrete on steel decking	B
	Built-up roof with gravel and rigid insulation and 4-inch lightweight concrete with #5 bars at 8 inches on center each way on steel decking	C
	6-inch, reinforced concrete with #4 bars at 8 inches on center each way on steel decking and with built-up roofing	D
	6-inch, reinforced concrete with # 4 bars at 6 inches on center each way on steel decking and with a built-up roofing system	E
	8-inch, reinforced concrete with #4 bars at 8 inches on center each way on steel decking and with built-up roofing	F
	4-inch, reinforced concrete with 6 by 6 welded wire mesh, 10-gage reinforcing on steel decking and a built-up roofing system	G
	6-inch, reinforced concrete with 6 by 6 welded wire mesh, 10-gage reinforcing on steel decking and a built-up roofing system	H
	10-inch, reinforced concrete with # 5 bars at 6 inches on center each way on steel decking and with a built-up roof	I
	10-inch, reinforced concrete with 2 layers of #5 bars at 6 inches on center each way on steel decking and with a built-up roofing system	J
	10-inch, reinforced concrete with 5/16 expanded metal 2½ inches on center on steel decking with a built-up roofing system	K
	12-inch, reinforced concrete with 2 layers of # 7 bars at 4 inches on center each way on steel decking and built-up roofing	L
	10-inch, reinforced concrete with 5/16-inch, expanded, metal mesh at 2½ inches on center with ¼-inch decking and a built up roofing system	M
	12-inch-thick, reinforced concrete with 5/16-inch expanded metal at 2½ inches on center, ¼-inch steel decking, and built-up roofing	N

Table C-15. Forced Entry Resistant Building Construction (Retrofit Construction)		
Building Component	**Construction Description**	**Construction Type**
Walls	Add ¾-inch plywood to the inside face	A
	Add #5 bars at 8 inches on center reinforcing or grating to the inside face between exterior and interior walls.	B
	Add 9-gage, expanded, metal mesh between existing exterior and interior wall systems	C
	Add 9-gage sheet metal between existing exterior and interior wall systems	D
	Add ¼-inch steel plate between existing exterior and interior wall systems	E
	Add 3-layer (10-gage steel/ ¾-inch plywood/10-gage steel), steel-plywood system between existing exterior and interior wall systems	F
	Add 5-layer (10-gage steel/ ¾-inch plywood/10-gage steel/ ¾-inch plywood/10-gage steel) steel-plywood system between existing interior and exterior wall systems.	G
	Add 7-layer (10-gage steel/ ¾-inch plywood/10-gage steel/ ¾-inch plywood/10-gage steel/ ¾-inch plywood/10-gage steel) steel-plywood system between existing interior and exterior wall systems	H
Windows	11/16-inch, glass-clad with 3/8-inch polycarbonate core	A
	13/16-inch, glass-clad with ½-inch polycarbonate core	B
	15/16-inch, glass-clad with ¾-inch polycarbonate core	C
Doors	Standard 16-gage, hollow, metal door (3 feet by 7 feet) with hinge-side protection, anti-pry strip, and drill-resistant dead bolt lock	A
	A vestibule outside entrance door, designed to resist explosive effects, must be provided to force two explosive attempts	B
	12-gage, hollow, metal door (3 feet by 7 feet) with hinge-side protection, anti-pry strip, and drill-resistant dead bolt lock	C

Table C-15 (continued)

Doors (continued)	12-gage, hollow, metal door (3 feet by 7 feet) with hinge-side protection, anti-pry strip, and drill-resistant dead bolt lock and filled with lightweight fireproofing	D
	Steel door with ¼-inch inner and outer face (3 feet x 7 feet) with hinge-side protection, anti-pry strip, drill-resistant dead bolt lock, and multipoint (3) locking	E
	Sliding door (6 inches thick) filled with lightweight concrete that has been reinforced with expanded metal mesh with a 3/4-inch steel front plate, 1/4–inch back plate, and an internal locking system	F
	Swinging door (6 inches thick) with ½-inch plate inside and out, lightweight concrete fill, and an internal locking system	G
	Swinging door (10 inches thick) with ½-inch plate inside and out	H
	Swinging door (10 inches thick) with ½-inch plate inside and out, lightweight concrete fill, and an internal locking system	I
	Swinging door (10 inches thick) with ½-inch plate inside and out, lightweight concrete fill reinforced with expanded metal mesh, and an internal locking system	J
Roofs	Built-up roof with gravel and rigid insulation on steel decking	A
	Add ¾-inch plywood and built-up roofing on top of existing metal seam construction	B
	Install #5 bar 8 inches on center square grid under existing roof construction.	C
	Add 9-gage, expanded, metal mesh on top of existing roof system, then resurface	D
	Add 9-gage, steel sheet on top of existing roofing system, then resurface	E
	Install ¼-inch steel plate on top of existing roofing system, and then resurface.	F
	Add 3-layer (10-gage steel/ 3/4-inch plywood/10-gage steel), steel-plywood system under the existing roof system	G
	Add 3-layer (10-gage steel/ 3/4-inch plywood/10-gage steel), steel-plywood system on top of existing roof system, then resurface	H

Table C-15 (continued)

Roofs (continued)	Add 5-layer (10-gage steel/ 3/4-inch plywood/10-gage steel/ 3/4-inch plywood/10-gage steel), steel-plywood system on top of existing roof, and then resurface.	I
	Add 7-layer (10-gage steel/ 3/4-inch plywood/10-gage steel/ 3/4-inch plywood/10-gage steel/ 3/4-inch plywood/10-gage steel) steel-plywood system on top of existing roof, and then resurface	J

Table C-16. Access Control Equipment for Covert Entry Tactic

Threat Severity Level	Equipment Set	Level of Protection	Equipment												
			Electric Strike Lock	Mag. Lock	Card Reader	PIN Reader	Shielded PIN Reader	Biometric Device	Portal Counter	Turnstile	Person-trap	IDS on Operable Openings	Motion Sensor in Information	CCTV	Metal Detector
Very High	P	Very High						X			X	X	X	X	X
	O	High					X			X		X	X	X	X
	N	Medium		X			X		X			X			
	M	Low		X			X		X						
High	L	Very High						X			X	X	X	X	X
	K	High					X			X		X	X	X	X
	J	Medium		X			X		X			X			
	I	Low		X			X		X						
Medium	H	Very High		X				X				X	X	X	
	G	High		X			X					X	X	X	
	F	Medium		X			X					X			
	E	Low		X			X								
Low	D	Very High		X	X	X		X				X	X	X	
	C	High		X	X							X	X	X	
	B	Medium		X		X						X			
	A	Low	X												

Note: No special construction is required for this tactic
NR = Not required

Table C-17. Construction for Acoustics Eavesdropping Tactic (New and Existing Construction)

Building Component	Construction Description	Construction Type
Walls	Conventional construction	A
	Steel studs with gypsum wallboard both sides and insulation in cavity	B
	Steel studs with 2 layers of gypsum wallboard on one side and one on the other with insulation in cavity	C
Windows	6 mm (1/4 inch) laminated glass	A
	Insulated glass window with 10 mm (3/8 inch) laminated glass inside, 6 mm (1/4 inch) laminated glass outside, 12 mm (1/2 inch) airspace	B
	Insulated glass window with 6 mm (1/4 inch) laminated glass inside, 6 mm (1/4 inch) laminated glass outside, 50 mm (2 inch) airspace	C
	Insulated glass window with 12 mm (1/2 inch) laminated glass inside, 5 mm (3/16 inch) laminated glass outside, 100 mm (4 inch) airspace	D
Doors	Conventional solid core wood or insulated steel door with gaskets	A
	Specially manufactured STC 40 rated door	B
	Specially manufactured STC 45 rated door	C
	Specially manufactured STC 50 rated door	D
Ceilings / Roofs	Conventional construction	A
	Wood joists with 2 layers of plywood subfloor gypsum wallboard underneath	B
	100 mm (4 inch) reinforced concrete	C
	Wood joists with 2 layers of plywood subfloor gypsum wallboard suspended on channels underneath	D
	150 mm (6 in) (6 inch) reinforced concrete	E
	Wood or steel joists with gypsum wall board and insulation in cavities	F
	Wood or steel joists with 2 layers of gypsum wallboard and insulation in cavities	G

Table C-18. Sitework Element Construction		
Barrier Category	**Barrier Construction**	**Construction Type**
Passive Perimeter	Standard 8-foot high, (7-foot fabric) 9 gage steel chain link fence with outrigger	A
	Standard chain link fence with a single ¾-inch cable anchored every 200 feet; allows 20- to 40-foot penetration into site	B
	Standard chain link fence with two ¾-inch cables anchored every 200 feet; allows 20- to 40-foot penetration into site	C
	Standard chain link fence with three ¾-inch cables anchored every 200 feet; allows 20- to 40-foot penetration into site	D
	8-inch diameter, concrete-filled bollards at 3 feet on center; penetration into site 0 to 3 feet	E
	8-inch diameter, concrete-filled bollards at 2 feet on center; penetration into site 0 to 3 feet	F
	8-inch diameter, concrete-filled bollards at 2 feet on center with 12-inch channel rail; penetration into site 3 to 20 feet	G
Active	Standard chain link gate	H
	Barriers similar to the ARMR Model 712 cable crash beam barrier or the Delta Scientific Model TT212 crash tested and shown to stop 40 K foot-pounds of kinetic energy	I
	Barriers similar to the Nasatka Model XI or the Delta Scientific Model TT203 crash tested and shown to stop 350 K foot-pounds of kinetic energy	J
	Barriers similar to the Nasatka Model VII or the Delta Scientific Model TT210 have been crash tested and shown to stop 450 K foot-pounds of kinetic energy	K
	Barriers similar to the Nasatka Model IIIb or the Delta Scientific Model TT207 crash tested and shown to stop 1.2 M foot-pounds of kinetic energy	L
	Barriers similar to the Nasatka Model V or Delta Scientific Model TT207 (S) have been crash tested and shown to stop 1.2 M foot-pounds of kinetic energy	M
	No commercial active barriers available that have been tested at this level of impact; however, basic construction of standard vehicles makes them vulnerable to barrier systems recommended for the very high threat severity level. Penetration of the disabled vehicle into the site could exceed requirements at this level	N
Screen	¾ -inch wood slat fence predetonation screen x 8 feet high	O
	2-foot thick reinforced concrete shielding wall x 8 feet high	P
Note: All active vehicle barriers may allow vehicle penetration of 3 to 20 feet.		

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APPENDIX D

EXPEDITIONARY CONSTRUCTION COSTS

D-1 **INTRODUCTION.** The purpose of the table in this appendix is to provide planning level estimates of costs to incorporate countermeasures for security and antiterrorism into expeditionary and temporary construction.

D-2 **FORMULATION.** While the tables in Appendices A and B tabulate cost increases over the cost of new construction, that approach is not realistic for expeditionary construction due to the fact that there is no DoD-wide data base of expeditionary construction the way there is for permanent new construction. Expeditionary construction is not done as commonly as permanent new construction and the nature of expeditionary construction is that its cost varies significantly depending on who is building it and where it is being built. Because of the wide variability of this construction, the costs are tabulated here as actual costs of labor, materials, and equipment. In addition, the number of man-hours necessary to do the construction is tabulated. These costs can be used on a relative basis by comparing them to known costs of labor, materials, and equipment in the location where cost is being estimated or by using area cost factors as tabulated in the *DoD Facilities Pricing Guide (UFC 4-701-05)* .

D-3 **USING THE TABLE.** To use Table D-1, determine the countermeasure that is needed to mitigate a threat and the quantity of that component that is required. The costs shown for materials, labor, and equipment are in dollars per man-hour of installation time. The installation time is shown in man-hours per unit of measure. To determine the total cost of installing a given countermeasure, sum the applicable material, labor, and equipment costs per unit of measure and multiply that sum by the quantity of units required. The costs tabulated are for an area cost factor of one. They will need to be adjusted to reflect differences in costs of construction in other areas using either the area cost factors in the *DoD Facilities Pricing Guide (UFC 4-701-05)* or known costs for materials, labor, and equipment in the area. The installation time requirements are in man-hours per unit. To calculate the amount of time required for installation in terms of man-hours, multiply the number of units required by the installation number.

The cost and installation time would be calculated as follows:

- Cost = Units x (Materials +Labor + Equipment)
- Installation Time = Units x Installation

D-4 **EXAMPLE.** A base camp needs to be surrounded by one mile (5280 feet) of triple standard concertina fence and a countermobility berm. There also need to be four entry lanes with motorized gates. The costs and installation times would be as follow:

- Triple Standard Concertina Fence:
  Cost = 5280 lf x ($9.00/lf + $0.95/lf + $0.00/lf) = $52,536
  Installation Time = 5280 lf x 0.03 mh/lf = 158.4 man-hours

- Freestanding Soil Berm (6 ft High):
  Cost = 5280 lf x ($0.00/lf + $11.00/lf + $17.60/lf) = $151,008
  Installation Time = 5280 lf x 0.3 mh/lf = 1584 man-hours

- Fence Gate (12 ft, One Lane):
  Cost = 4 lanes x ($530.00/lane + $630.00/lane + $310.00/lane) = $5,880
  Installation Time = 4 lanes x 20.4 mh/lane = 81.6 man-hours

- Mechanical Fence Gate Operator (12 ft, One Lane):
  Cost = 4 lanes x ($1,560.00/lane + $520.00/lane + $240.00/lane) = $9,280
  Installation Time = 4 lanes x 17 mh/lane = 68 man-hours

- Total Cost: $ 218,704

D-5 **RECORDING THE COST.** How costs are recorded for expeditionary construction is widely variable depending on the operation and the funds source. Follow guidance established for the applicable operation.

Table D-1. Expeditionary Costs

Expedient Passive Defense Measure	Unit	Installation (M.H/Unit)	Materials ($/Unit)	Labor ($/Unit)	Equipment ($/Unit)
Signage					
Warning Signs	Ea	0.20 mh	$26.00	$6.00	$5.00
Physical Barriers					
Traffic Barricades	Ea	0.10 mh	$87.00	$4.00	$0.00
Plastic Safety Fence	Lf	0.03 mh/lf	$1.44	$0.40	$0.00
Ornamental Steel Fence	Lf	0.16 mh/lf	$24.00	$5.00	$2.30
Ornamental Wood Fence	Lf	0.15 mh/lf	$13.10	$4.60	$0.00
Triple Standard Concertina Fence	Lf	0.03 mh/lf	$9.00	$0.95	$0.00
Barbed Tape Concertina Double Coil	Lf	0.05 mh/lf	$3.40	$0.95	$0.00
Barbed Wire Fence	Lf	0.025 mh/lf	$0.40	$0.75	$0.00
Chain Link Fence	Lf	0.17 mh/lf	$9.10	$5.25	$2.70
Chain Link Fence (Sensor Ready)	Lf	0.18 mh/lf	$8.75	$5.55	$2.70
Fence Gate (Personnel)	Ea	3.7 mh	$145.00	$110.00	$75.00
Fence Gate (12-Ft One Lane)	Ea	20.4 mh	$530.00	$630.00	$310.00
Fence Gate (20-Ft Two Lane)	Ea	25.6 mh	$675.00	$790.00	$385.00
Mechanical Fence Gate Operator (12-Ft One Lane)	Ea	17mh	$1,560.00	$520.00	$240.00
Mechanical Fence Gate Operator (20-Ft Two Lane)	Ea	17mh	$2,800.00	$520.00	$240.00
Obscuration And Predetonation Screens					
Fence Obscuration	Lf	0.18 mh/lf	$3.40	$4.60	$0.00
Camouflage Netting	Lf				
Plywood Obscuration Panel (12 Ft Tall)	Lf	0.4 mh/lf	$17.60/lf	$13.15/lf	0.80/lf
Wood Pole And Plank Wall (20 Ft Tall)	Lf	1 mh/lf	$50.00	$31.00	$3.25
10-In CMU Wall (14 Ft Tall)	Lf	2.5 mh/lf	$99.00	$82.00	$27.50
10-In Cast-In-Place Concrete Wall (16-Ft Tall)	Lf	3.4 mh/lf	$54.30	$133.50	$6.80
Precast Concrete Panels With Steel Columns (15 Ft Tall)	Lf	2.25 mh/lf	$209.00	$99.00	$32.00
Shipping Containers (20 Ft By 8 Ft By 8 Ft)	Ea	0.5 mh	$0.00	$15.40	$154/mo
Parked Semi-Trailers With Plywood Skirt	Ea	1.4 mh	$360.00	$43.20	$1980/mo
Revetments					
Sandbag Wall (4 Ft High)	Lf	1.5 mh/lf	$39.00	$45.30	$1.00
Plywood Predetonation Screen (12 Ft Tall)	Lf	0.4 mh/lf	$17.60/lf	$13.15/lf	$0.80/lf
Freestanding Soil Berm (6 Ft High)	Lf	0.3 mh/lf	$0.00	$11/lf	$17.60/lf
Fabric-Reinforced Soil Berm (6 Ft High)	Lf	0.32 mh/lf	$4.60/lf	$11.60/lf	$17.60/lf
Sand Grid Wall (6 Ft High)	Lf	0.4 mh/lf	$56.50/lf	$13.85/lf	$4.90/lf
Hesco-Bastion Concertainer Wall					
Plywood Parallel Walls Soil-Bin Revetment (11 Ft High)	Lf	1.53 mh/lf	$299.90/lf	$55.80/lf	$14.75/lf
Countermobility Measures					
Triangular Ditch (5 Ft Deep)	Lf	0.049 mh/lf	$0.00	$1.43/lf	$2.28/lf
Sidehilll Cut Ditch (7.5 Ft Deep)	Lf	0.0208 mh/lf	$0.00	$0.56/lf	$1.73/lf
Trapezoidal Ditch (6 Ft Deep)	Lf	0.102 mh/lf	$0.00	$3.00/lf	$4.80/lf
Precast Concrete Median Barrier	Lf	0.66 mh	$275.00	$21.00	$21.00
Cable Reinforced Existing Chain Link (200 Ft Segment)	Ea	12 mh	$1,646.00	$381.00	$134.00
Post And Cable Barrier (200 Ft Segment)	Ea	32 mh	$2,000.00	$1.10	$360.00
Cable And Drum Vehicle Barrier (200 Ft Segment)	Ea	15 mh	$2,090.00	$580.00	$165.00

Table D-1 (continued)

Concrete Filled Pipe Bollard	Ea	2 mh	$165.00	$63.80	$22.60
Removable Pipe Bollard	Ea	4 mh	$288.00	$127.55	$45.25
Precast Concrete Pipe	Ea	1.5 mh	$113.00	$49.40	$66.90
Earth-Filled Barrier	Ea	0.15 mh	$41.00	$475.00	$7.00
Water Filled Barrier:	Ea	0.25 mh	$300.00	$3.50	$0.00
Steel Hedgehog	Ea	3 mh	$130.00	$134.00	$36.00
Log Hurdles (Set Of Four 8-Ft Long Hurdles)	Ea	4 mh	$453.00	$128.00	$224.00
Post And Cable Gate	Ea	4 mh	$445.00	$128.00	$44.00
Guardrail (Corrugated Steel)	Ea	0.038 mh	$11.00	$0.95	$0.55
Guardrail (Cable Guide)	Ea	0.033 mh	$8.25	$0.75	$0.50
Guardrail (Corrugated Steel)	Ea	0.036 mh	$10.30	$0.80	$0.50
Cantilevered Crash Gate (12 Foot One Lane)	Ea	32 mh	$15,600.00	$1,120.00	$740.00
Cantilevered Crash Gate (20 Foot Two Lane)	Ea	32 mh	$23,900.00	$1,120.00	$740.00

APPENDIX E

BLANK WORKSHEETS

DESIGN CRITERIA SUMMARY WORKSHEET

Project or Building	Analyst	Date

Assets	Asset Category	Asset Value Rating	Tactics																									
			Explosive and Incendiary Devices						Standoff Weapons				Entry Tactics				Surveillance and Eavesdropping						Contamination Tactics					
			Moving Vehicle Devices		Stationary Vehicle Devices		Hand Delivered Devices		Indirect Fire Weapons		Direct fire weapons		Forced Entry		Covert Entry		Visual Surveillance		Acoustic Eavesdropping		Electronic Emanations Eavesdropping		Airborne Contamination		Waterborne Contamination		Waterfront Attack	
			DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP

DBT = Design Basis Threat severity level LOP = Level of Protection

ASSET VALUE/AGGRESSOR LIKELIHOOD WORKSHEET

Project or Building	Asset	Analyst
	Asset Category	Date

Value Rating Factors						
Criticality to User / Population Type [1]	Impact on National Defense	Replaceability	Political Sensitivity	Relative Value to User	Sum of Value Factors	Value Rating [2]
General Population						
Critical Infrastructure and Operations and Activities						
Sensitive Information						
All Other Assets						

Notes:

Potential Aggressors	Aggressor Goal [3]	Aggressors	Installation Location [4]	Publicity Profile [4]	Accessibility [4]	Availability [4]	Dynamics [4]	Recognizability	Relative Value to Aggressor	Law Enforcement [4]	Aggressors' Perception of Success	Threat Level	History [5] / Intentions [6]	Operational Capability [6]	Operating Environment [6]	Activity [6]	Sum of Likelihood Factors	Likelihood Ratings [7]
		Unsophisticated Criminals																
		Sophisticated Criminals																
		Organized Criminal Groups																
		Vandals																
		Extremist Protesters																
		Domestic Terrorists																
		International Terrorists																
		State Sponsored Terrorists																
		Saboteurs																
		Foreign Intelligence Services																

1. Population Type applies to General Population only
2. Sum of Value Ratings ÷ 10 for Sensitive Information 15 for General Population; 20 for Critical Infrastructure and Operations and Activities; 25 for all other assets
3. G for mission related goal, P for publicity related goal, M for monetary related goal
4. Factors that should be same for all aggressors for given asset
5. Applies to all aggressors other than terrorists
6. Applies to Terrorists only
7. Sum of Likelihood Ratings ÷ 180

TACTIC, THREAT SEVERITY, AND LEVEL OF PROTECTION WORKSHEET

Project or Building	Asset		Analyst
	Asset Category	Asset Value	Date

Tactics / Aggressors	Aggressor Likelihood	Explosives and Incendiary Devices			Standoff Weapons		Entry		Surveillance and Eavesdropping			Contamination		Waterfront Attack
		Moving Vehicle Devices	Stationary Vehicle Devices	Hand Delivered Devices	Indirect Fire Weapons	Direct fire weapons	Forced Entry	Covert Entry	Visual Surveillance	Acoustic Eavesdropping	Electronic Emanations Eavesdropping	Airborne Contamination	Waterborne Contamination	
Applicable Tactics														
Unsophisticated Criminals														
Sophisticated Criminals														
Organized Criminal Groups														
Vandals														
Extremist Protesters														
Domestic Terrorists														
International Terrorists														
State Sponsored Terrorists														
Saboteurs														
Foreign Intelligence Services														
Initial Design Basis Threat (highest Threat Severity Level for each tactic)														
Initial Level of Protection for Applicable Tactic (Table 3-28)														

RISK LEVEL CALCULATION WORKSHEET

Project or Building:	Asset:	Analyst:
	Asset Value (A_V):	Date:

Aggressor		T_L[1]	T_E (Table 3-29)	Highest[2] T_L (T_{LH})	T_{EH}[3]
Criminals (C)	Unsophisticated Criminals				
	Sophisticated Criminals				
	Organized Criminal Groups				
	Vandals				
Terrorists (T)	Extremist Protesters				
	Domestic Terrorists				
	International Terrorists				
	State Sponsored Terrorists				
	Saboteurs (S)				
	Foreign Intelligence Services (F)				

Tactic		LOP[1]	P_I[4] (Table 3-30)	Avg.[5] P_I (P_{IAVG})	P_E[6] Aggressor Category C	T	S	F	Risk Level[7] Aggressor Category C	T	S	F
Explosives and Incendiaries	Moving Vehicle Bomb											
	Stationary Vehicle Bomb											
	Hand Delivered Devices											
Standoff Weapons	Indirect Fire Weapons											
	Direct Fire Weapons											
Entry Tactics	Forced Entry											
	Covert Entry											
Surveillance and Eavesdropping	Visual Surveillance											
	Acoustic Eavesdropping											
	Electronic Emanations Eavesdropping											
Contamination Tactics	Airborne Contamination											
	Waterborne Contamination											
Waterfront Attack												

1. From Tactic, Threat Severity, and LOP Worksheet
2. Highest likelihood rating for each aggressor group.
3. Effectiveness rating for aggressor with highest likelihood.
4. From Table 3-30.
5. Average for P_I for all tactics within tactic group.
6. $P_E = T_{EH} \times P_{IAVG}$ for each aggressor & tactic group combination.
7. $R = A_V \times T_{LH} \times (1-P_E)$ for each aggressor & tactic group.

BUILDING COST AND RISK EVALUATION WORKSHEET

Project or Building	Asset	Analyst
	Baseline Building Category *(Table 3-1)*	Date

Tactic		Initial						Revised						Analysis		
		Design Basis Threat [2]	LOP[3,4] or P_I	Risk[4-7] Level	Standoff, Rm. Size, Stories, %	Cost[8] Increase (%)	Cost Incr. Sum	Threat Severity Level	LOP[3,4] or P_I	Risk[4-7] Level	Standoff, Rm. Size, Stories, %	Cost[8] Increase (%)	Cost Incr. Sum	Change[11] in Cost (%)	Change[12] in Risk (%)	Ratio[13]
Explosives and Incendiaries	Moving Vehicle Bomb [1]															
	Stationary Vehicle Bomb [1]															
	Hand Delivered Devices															
	• Exterior [1]															
	• Mail Room[9]															
	• Loading Dock[9]															
	• Entry Area[9]															
Standoff Weapons	Indirect Fire Weapons															
	Direct Fire Weapons[10]															
Entry Tactics	Forced Entry															
	• Exterior															
	• Interior[9]															
	Covert Entry															
Surveillance and Eavesdropping	Visual Surveillance															
	Acoustic Eavesdropping															
	• Exterior															
	• Interior[9]															
	Electronic Emanations Eavesdropping															
	• Exterior															
	• Interior[9]															
Contam -ination	Airborne Contamination															
	Waterborne Contamination															
Waterfront Attack																
						Sum[14](%)						Sum[14] (%)				

1. Use highest cost among these tactics 2. From Tactic, Threat Severity and LOP Worksheet
3. Level of Protection or Initial Protection Level
4. From Risk Level Calculation Worksheet
5. One risk level for each tactic group
6. Risk level for aggressor whose threat severity level controls DBT (Tactic, Threat Severity, and LOP Wksht)
7. Indicate which aggressor controls8. From Appendix A or B or from other cost estimate
9. Enter small, medium, or large room
10. Enter percentage of building perimeter protected
11. (Revised cost sum– initial cost sum) ÷ initial cost sum
12. (Revised risk level – initial risk level) ÷ initial risk level
13. Change in risk ÷ change in cost
14. Total building cost increase (w/o progressive collapse)

UFC 4-021-01
9 April 2008
Change 1, January 2010

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN AND O&M:
MASS NOTIFICATION SYSTEMS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UFC 4-021-01
9 April 2008
Change 1, January 2010

UNIFIED FACILITIES CRITERIA (UFC)

MASS NOTIFICATION SYSTEMS

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

U.S. ARMY CORPS OF ENGINEERS

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

Change No.	**Date**	**Location**
1	January 2010	Revised paragraph 1-3.3; revised paragraph 2-4; revised Chapter 4; revised Chapter 5; revised glossary; revised Appendix A; revised paragraph B-1; and revised paragraph C-2.3

This UFC supersedes UFC 4-021-01, dated 18 December 2002.

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

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

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

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

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 4-021-01
Superseding: UFC 4-021-01, dated 18 December 2002

Description of Changes: This revision to UFC 4-021-01 incorporates new mass notification system (MNS) design requirements for the Air Force, Army, Marine Corps, and Navy. Design figures were changed accordingly. Criteria was added approving the use of combined MNS and fire alarm systems in some facilities. Chapters were added on wide area MNS, operational characteristics, and special considerations. Sample pre-recorded MNS messages were added in Appendix B. Progress towards incorporation of Internet capability into DOD mass notification is discussed in Appendix C.

Reasons for Changes:

- Incorporate lessons learned from field experience since the initial revision of this UFC in 2002.
- Achieve consistency with new national consensus standards for MNS.
- Incorporate Marine Corps MNS requirements into one consolidated manual.
- Comply with the new format for Security Engineering UFC series documents.

Impact: There are negligible cost impacts; however, these benefits should be realized:

- Simplify construction and avoid installation costs in many new and renovated facilities by permitting combined MNS and fire alarm systems.
- Simplify procurement of MNS equipment by requiring consistency with national consensus standards for MNS.
- Ensure future MNS will coordinate with the new national “public alert and warning system” required by Executive Order 13407 of 28 June 2006.

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CHAPTER 1

INTRODUCTION

1-1 **BACKGROUND.** Mass notification provides real-time information and instructions to people in a building, area, site, or installation using intelligible voice communications along with visible signals, text, and graphics, and possibly including tactile or other communication methods. The purpose of mass notification is to protect life by indicating the existence of an emergency situation and instructing people of the necessary and appropriate response and action.

This Unified Facilities Criteria (UFC) was developed by collecting and refining criteria from Department of Defense (DOD) antiterrorism guidance, examining previous mass notification system (MNS) evaluation reports, and reviewing the capabilities of representative, commercially available MNS and products.

1-2 **PURPOSE.** This UFC provides technical criteria for systems that will:

- Implement mass notification in compliance with the DOD antiterrorism requirements as specified in UFC 4-010-01

- Implement national design standards and recommendations for mass notification systems as provided in National Fire Protection Association (NFPA) Standard 72 (including Annex E)

- Achieve coordination of DOD mass notification capabilities with national systems as required by Executive Order 13407

1-3 **SCOPE.** This UFC provides the design, operation, and maintenance requirements of MNS for DOD facilities. The requirement for a MNS is established by UFC 04-010-01. This document is intended to assist in the design of systems that meet the requirement established by UFC 04-010-01 and to give guidance to commanders, architects, engineers, and end users on design, operation, and maintenance of MNS.

1-3.1 **Applicability**. This UFC applies to new construction, major renovations, and leased buildings and must be used in accordance with the applicability requirements of UFC 4-010-01 or as directed by service guidance. See UFC 4-010-01 for more information on the applicability requirements.

1-3.2 **Service Exception.** Where one or more service's criteria vary from the other services' criteria, it is noted in the text with the SE (Service Exception) symbol.

1-3.3 **Compliance with Technical Criteria.** Do not deviate from the technical criteria of this UFC without prior approval from the component office of responsibility:

- U.S. Air Force: Air Force Civil Engineer Support Agency, \1\ Operations and

Programs Support Division /1/ (HQ AFCESA/CEO)

- U.S. Army: U.S. Army Corps of Engineers, Directorate of Civil Works, Engineering and Construction (HQ USACE/CECW-CE)
- U.S. Navy: Naval Facilities Engineering Command, Headquarters Chief Engineer's Office (NAVFACENGCOM HQ Code CHE)
- U.S. Marine Corps (HQMC), Code PS and Code LFF-1
- Defense Logistics Agency Director (HQ DLA-D) through Support Services (DLA-DES-SE)
- National Geospatial-Intelligence Agency (NGA), Security and Installations
- Other DOD components: the Office of the Deputy Under Secretary of Defense (Installations & Environment) (DUSD [I&E]) via the DOD Committee on Fire Protection Engineering

1-3.4 **Authority having Jurisdiction (AHJ).** The component office of responsibility listed in paragraph 1-3.3 is also referred to in this UFC as the AHJ.

1-3.5 **Waivers and Exemptions.** The AHJ may approve waivers and exemptions to the technical criteria of this UFC only. Waivers and exemptions shall comply with the requirements of MIL-STD-3007, *Department of Defense Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications*.

1-3.6 **Implementation.** Implementation of an effective MNS will require the coordinated efforts of engineering, communications, and security personnel. Fire protection engineering personnel are needed for the successful implementation of this UFC because they bring a special expertise in life safety evaluations, building evacuation systems, and the design of public notification systems. Coordination with communications personnel is required when the MNS is connected to the DOD installation's communications infrastructure. The designated first responders of the DOD installation are ultimately responsible for the protection of building occupants, and will be the primary users of an individual building MNS. Designated security or command personnel will be the primary users of a wide area MNS and should recommend installation projects, oversee access control, update central control system mapping and, as necessary, develop associated local recipient groups for targeted notification.

1-3.7 **Responsibilities.** DOD does not mandate which organizations are responsible for funding, operation, or maintenance of MNS installed in accordance with UFC 4-010-01; each DOD component must assign those responsibilities.

1-3.8 **Retroactivity.** Existing MNS installed in compliance with an earlier version of this UFC do not have to be modified to meet the requirements of the current edition of this UFC; however, any alteration or any installation of new equipment shall meet, as nearly as practicable, the requirements for new MNS.

1-4 **REFERENCES.** See Appendix A.

1-5 **QUALIFICATIONS OF SUPPLIERS AND CONTRACTORS**

1-5.1 **System Integrators and Contractors.** Use system integrators and contractors that are able to demonstrate a full knowledge and understanding of systems used for mass notification, and that have factory-trained personnel to perform system design, installation, testing, training, and maintenance.

1-5.2 **MNS Component Products and Manufacturers.** Only accept products from manufacturers that can meet the design criteria of this UFC and can demonstrate 5 years of experience in producing products similar to those required for mass notification. Utilize products of current manufacture with replacement parts and components available for a minimum of ten years.

1-5.3 **Performance and Acceptance Testing**

1-5.3.1 Upon completion of the installation, the contractor must complete performance testing of the MNS for compliance with this UFC. Verification of performance testing will be checked by local representatives of the AHJ. Performance results, including the required sound pressure levels and intelligibility values, shall be documented and submitted to the AHJ with notation of any deficiencies and corrective actions.

Note: The AHJ are those component offices of responsibility listed in paragraph 1-3.3 (see paragraph 1-3.4).

1-5.3.2 Upon successful completion of performance testing, the contractor must complete a witnessed acceptance test. Acceptance testing will be witnessed by local representatives of the AHJ. (See paragraph 1-3.4 for more information on the AHJ.)

1-5.4 **Installation Records.** The contractor must provide a complete set of record drawings and operations and maintenance manuals for the MNS. Record drawings and operations and maintenance manuals must provide information for troubleshooting, preventive maintenance, and corrective maintenance.

1-6 **SECURITY ENGINEERING UFC SERIES.** This UFC is one of a series of security engineering UFC documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include:

1-6.1 **DOD Minimum Antiterrorism Standards for Buildings.** UFC 4-010-01 and 4-010-02 establish standards that provide minimum levels of protection against terrorist attacks for the occupants of all inhabited DOD buildings. These UFC are intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DOD buildings. These UFC also include recommendations for designs that should be, but are not required to be, incorporated into all such buildings.

1-6.2 **Security Engineering Facilities Planning Manual.** UFC 4-020-01FA presents processes for developing the design criteria necessary to incorporate security and antiterrorism measures into DOD facilities and for identifying the cost implications of applying those design criteria. These design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards, or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also addresses the tradeoffs between cost and risk. UFC 4-020-01FA is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

1-6.3 **Security Engineering Facilities Design Manual.** UFC 4-020-02FA provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established in UFC 4-020-01FA. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them work as a system. The information in UFC 4-020-02FA is in sufficient detail to support concept-level project development, and as such can provide a good basis for a more detailed design. The manual also provides a process for assessing the impact of protective measures on risk. The primary audience for UFC 4-020-02FA is the design team, but the UFC can also be used by security and antiterrorism personnel.

1-6.4 **Security Engineering Support Manuals.** In addition to the standards, planning, and design UFC discussed in paragraphs 1-6.1 through 1-6.3, a series of additional UFC documents is planned that will provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02FA. These support manuals will provide specialized, discipline-specific design guidance. Some will address specific tactics such as direct-fire weapons, forced entry, or airborne contamination. Others will address limited aspects of design such as resistance to progressive collapse or the design of portions of buildings such as mailrooms. Still others will address details of designs for specific protective measures such as vehicle barriers or fences. The security engineering support manuals are intended to be used by the design team during the development of final design packages.

CHAPTER 2

OVERVIEW OF SYSTEMS

2-1 **SCOPE.** This chapter includes important definitions and provides an overview of MNS.

2-2 **CAPABILITY.** Mass notification provides real-time information and instructions to people in a building, area, site, or DOD installation using intelligible voice communications along with visible signals, text, and graphics, and possibly including tactile or other communication methods. MNS are intended to protect life by indicating the existence of an emergency situation and instructing people of the necessary and appropriate response and action.

2-3 **LIFE SAFETY SYSTEMS.** MNS are designated as life safety systems in a manner similar to DOD-required fire protection systems.

2-4 **ACCESSIBILITY.** Compliance with \1\ Architectural Barriers Act Accessibility Guidelines (ABAAG) /1/ for MNS is required. Visual alarm notification appliances shall be provided inside of buildings for hearing impaired persons when new MNS are installed. Providing visual alarm notification appliances is required for DOD compliance with Executive Order 13347*.*

2-5 **PUBLIC ALERT AND WARNING SYSTEM.** Coordination of MNS with national alert and warning systems is required for DOD compliance with Executive Order 13407*.*

2-6 SYSTEM TYPES

Note: See Appendix C for a discussion of Internet-based alerting systems.

2-6.1 **Wide Area MNS.** Wide area MNS are installed to provide real-time information to outdoor areas of a DOD installation. These systems are normally provided with and operated from two or more central control stations. Communications between central control stations and individual building MNS is provided. Communications between the central control stations and regional or national command systems may also be provided. The requirements to install wide area MNS are specific to each DOD component. A general DOD requirement to install these systems on all DOD installations has not yet been established.

2-6.1.1 **Interconnection with Individual Building MNS.** The wide area MNS manufacturer shall provide a standard interface method (such as an audio line-level output and multiple relay contacts) or supply the necessary digital communication protocols to permit the DOD installation to select more than one manufacturer of individual building MNS. Depending on system architecture, the manufacturer may be required to provide a system Internet Protocol (IP) interface capable of allowing data transfer from an outside source to internal mass notification functions via a common data communications protocol.

2-6.1.2 **Army Installations.** Wide area MNS shall be installed on Army installations in accordance with Army Chief of Staff antiterrorism guidance.

2-6.1.3 **Air Force Installations.** A wide area MNS shall be a component of and connected to the Installation Notification and Warning System (INWS) as defined by Air Force instruction (AFI) 10-2501. The INWS typically includes a "giant voice" system for outdoor notification of personnel.

2-6.1.4 **Marine Corps Installations.** Wide area MNS shall be installed on Marine Corps installations in accordance with the most current edition of Marine Corps Order (MCO) 5530.14 and MCO 3302.1.

Note: Marine Corps designs use central control stations shared by both the wide area MNS and the individual building MNS.

2-6.1.5 **Navy Installations.** Wide area MNS shall be installed on Navy installations in accordance with Chief of Naval Operations (CNO) antiterrorism guidance.

2-6.2 **Individual Building MNS.** Individual building MNS are installed to provide real-time information to all building occupants or personnel in the immediate vicinity of a building, including exterior egress and gathering areas. These systems are designed to operate from one or more locations in the building, and operate with or without connection to a wide area MNS—but must be connected to with the wide area MNS if one is provided on the DOD installation. All DOD components are required to provide individual building mass notification capability.

SE Marine Corps individual building MNS are not required to provide the capability to initiate messages from any location within the individual building.

Note: Marine Corps designs use central control stations shared by both the wide area MNS and the individual building MNS.

2-6.2.1 **DOD Requirements.** The DOD must provide mass notification for new and existing buildings when required by UFC 4-010-01. Mass notification is required in all new inhabited buildings, including new primary gathering buildings and new billeting. Mass notification is required in existing primary gathering buildings and existing billeting when implementing a project exceeding the replacement cost threshold specified in UFC 4-010-01 or when prioritized by local command personnel. Mass notification is recommended in other existing inhabited buildings when implementing a project not exceeding the replacement cost threshold. Mass notification is required for leased buildings, building additions, and expeditionary and temporary structures.

Note: UFC 4-010-01 provides specific definitions of inhabited buildings, primary gathering buildings, and billeting for application of antiterrorism requirements.

CHAPTER 3

WIDE AREA MNS

3-1 **SCOPE.** Wide area MNS are intended to provide real-time information to outdoor areas of a DOD installation. Small facilities that are exempted by UFC 4-010-01 from providing individual building MNS could be covered by a wide area MNS. These facilities could include buildings such as single-family and duplex military family housing, individual lodging buildings housing 10 occupants or less, shopettes, automobile service stations, storage buildings with very low density of occupancy, and military family campgrounds. The requirements to install wide area MNS are specific to each DOD component. A general DOD requirement to install these systems on all DOD installations has not been established.

3-2 REQUIREMENTS FOR SYSTEM DESIGNERS

3-2.1 **Designer Qualifications.** The wide area MNS shall be designed under the supervision of a registered professional engineer with a minimum of 4 years' current work experience in fire protection, electrical, and communication-electronics engineering areas specific to wide area MNS. Alternately, the wide area MNS may be designed by an engineering technologist verified by the National Institute for Certification in Engineering Technologies (NICET) as certified at Level IV in low voltage electronic-communications systems or Level IV in fire alarm systems, plus this engineering technologist shall possess a minimum of 4 years' current work experience specific to wide area MNS communications-electronics. Alternately, the wide area MNS may be designed by an engineering technologist that possesses a minimum of 10 years' documented current work experience specific to wide area MNS communications-electronics. The speaker array supporting structure shall be designed by a registered professional structural engineer to resist all environmental loads, including site-specific wind and seismic forces. The individual's name, signature, and professional engineer number or NICET certification number (when applicable) shall be included on all final design documents.

3-2.2 **System Integrators and Contractors.** Use system integrators and contractors that can demonstrate a full knowledge and understanding of systems used for mass notification, and that have factory-trained personnel to perform system design, installation, testing, training, and maintenance.

Note: The MNS designer should have demonstrated expertise in audio system design, sound pressure and intelligibility measurement and evaluation, radio communications systems, audible and visual notification appliances, and central control station designs.

3-3 **SYSTEM SIGNALS.** Wide area MNS shall include an outdoor speaker and siren system providing voice signals, music, and alarm tones.

3-3.1 **Voice Signals.** Wide area MNS shall be capable of providing intelligible live and pre-recorded voice signals.

3-3.2 **Music.** Wide area MNS shall be capable of providing music such as the national anthem and other musical signals such as Attention to Colors, Reveille, and Taps.

3-3.3 **Tones.** Wide area MNS shall be provided with standard Federal Emergency Management Agency (FEMA) weather warning tones. Military-specific warning tones shall be provided as specified by the DOD installation, and should include tones for conventional attack warning, non-conventional attack warning, all clear, and a system test tone. Such tones should be similar to Civil Defense tones originally developed during World War II and the Cold War era.

3-4 **SUBSYSTEMS.** Wide area MNS includes several subsystems: central control stations; high power speaker arrays (HPSA); communication links; and ancillary equipment.

3-4.1 **Central Control Stations.** These stations operate and control the system.

3-4.2 **HPSA.** The speakers are used to provide the sound signals to the outdoor locations on the DOD installation.

3-4.3 **Communications Links.** Communications links are used for sending signals between the central control stations and the HPSA, and between the central control stations and regional or national command centers. A redundant (backup) means of communication shall be provided unless the primary means of communication is highly reliable, well protected, and constantly monitored by the central control station for operational status.

Note: See Appendix C for a discussion of requirements for Internet-based communication systems (under development).

3-4.4 **Ancillary Equipment.** This equipment includes items such as aircraft obstruction lights, anti-nesting spikes, and meters to meet local DOD installation requirements.

3-5 **CENTRAL CONTROL STATIONS.** The wide area MNS shall be provided with at least one primary and one redundant central control station.

3-5.1 **Locations.** The locations of the central control stations shall be coordinated with the first responders on each DOD installation. The primary central control station should be located at the installation control center (ICC), command post, emergency operations center (EOC), or similar location. The redundant central control center should be located at a physically separate location such as a security forces building, military police station, fire station, or director of emergency services office.

Marine Corps primary central control stations should be located at a security forces or military police dispatch center, and the redundant central control center should be located at the ICC, EOC, operations center, or similar location.

3-5.2 **On-Installation Control.** The central control stations shall control the operation of outdoor speakers on the DOD installation. Communications shall be provided between the central control stations and individual building MNS. The wide area MNS shall have the capability to communicate with other notification systems on the DOD installation such as the telephone alerting system, paging system, commander's channel on public access television stations, and highway advisory radio and sign control system (used for dynamic control of radio information and traffic signs for emergency information and traffic management).

Communication with other notification systems is not required for Marine Corps systems.

3-5.3 **Off-Installation Interfaces.** Communications between the central control stations and regional or national command systems shall be provided. This shall include the receipt, recording, and distributing of voice messages and alert signals received from the Commander in Chief through the national public alert and warning system.

3-5.4 **Central Control Station Requirements.** The central control unit shall consist of these components and features:

3-5.4.1 **Graphical User Interface (GUI).** This should be a computer interface with sufficient capability to operate the system with easy point and click operations.

3-5.4.2 **Backup Power.** Each central control station shall be equipped with batteries to supply power for a minimum of 4 hours of full-load operation when the central control station is provided with a permanently installed backup electrical power generator. This electrical power generator need not be dedicated solely to the central control station but may be intended to supply other important electrical loads in addition to the central control station. If not provided with a permanently installed backup electrical power generator, a portable backup electrical power generator may be used if procedures are established that ensure that the central control station is provided with electrical power within 4 hours.

3-5.4.3 **Inputs.** The central control station must provide capability for at least these features:

3-5.4.3.1 Total, zone, and single voice activations

3-5.4.3.2 Total, zone, and single tone activations

3-5.4.3.3 Total, zone, and single music activations

3-5.4.3.4 Total, zone, and single tests

3-5.4.3.5 Total, zone, and single signal cancellations

3-5.4.3.6 Automatic status reporting for each HPSA and for all activations and the status of the activations

3-5.4.3.7 Alarm summary report that provides a historical report for, at least, all changes of status, including all troubles, equipment failure, power system trouble (including normal and emergency power), unsolicited messages, tamper/supervision of the enclosure for the HPSA electronics, amplifier status, last activation and synchronization error, operator log on and log off, and configurable reports for time-based events such as “report all troubles from 1/01/04 to 6/30/04.”

3-5.4.3.8 Communications logs in tabular format

3-5.4.3.9 Screen displays of the customized DOD installation maps showing the general status of the speakers or remote equipment. This GUI shall provide for easy uploading of DOD installation-specific plan changes and for interactive operation.

Note: The DOD installation should specify the source of maps used by the GUI.

Note: Automatic recognition and display of new speakers, new remote equipment, and newly connected individual building MNS is available for some digital control systems. This feature, if provided, can significantly reduce system maintenance costs for the DOD installation.

3-5.4.3.10 Global Positioning System (GPS) coordinates of HPSA and facilities provided with an individual building MNS

3-5.4.3.11 Multiple levels of password protection, including levels for system operators, maintainers, supervisors, and military commanders, at a minimum

3-5.4.3.12 The ability to record and send digital messages to the HPSA via the primary (and redundant, if provided) communication link and to receive confirmation that the messages were received and stored at the HPSA. Alternately, the DOD installation may authorize use of fixed, pre-recorded emergency messages that are physically installed in each HPSA (typically by installing an erasable programmable read-only memory (EPROM) or flash memory device).

3-5.4.3.13 The capability to connect to and control message signs to direct vehicular traffic on roadways

SE Not required for Marine Corps systems

3-5.4.3.14 The capability to deliver at least two essentially concurrent voice messages: one for threatened areas or buildings and one for adjacent areas or buildings. This includes the capability for two pre-recorded voice messages, or one live and one pre-recorded voice message.

Marine Corps systems may deliver sequential voice messages (at least 2) instead of at least 2 concurrent voice messages.

3-5.4.3.15 The capability to target specific messages to any individual HPSA, zone of HPSAs, or to all areas on the DOD installation

3-5.4.3.16 Means for dynamic or "on-the-fly" configuration of zoning, with a minimum of 8 zones available

3-5.4.3.17 Secure method for easily creating or modifying recorded messages

3-5.4.3.18 The capability to store at least 60 minutes of pre-recorded messages

3-5.4.3.19 The capability to deliver text pager messages to pager stations

Not required for Marine Corps systems

3-5.4.3.20 The capability to deliver faxes

Not required for Marine Corps systems

3-5.4.3.21 The capability to connect to Reverse 911® systems and other telephone dialing/notification systems

Not required for Marine Corps systems

3-5.4.3.22 Microphone for live voice announcements

3-5.4.3.23 The capability to perform silent tests, including a test of the amplifiers, controllers, and sound drivers, and tests to verify that communications are operational

3-5.4.3.24 The capability to control individual speaker zones of those HPSAs designated by the DOD installation

Not required for Marine Corps systems

3-5.4.3.25 The capability to receive, record, and broadcast throughout the DOD installation all voice messages and alert signals received from the Commander-in-Chief through the national public alert and warning system. This will include the capability to immediately broadcast the messages and signals without a noticeable time delay, and the capability to delay the broadcast so not to interfere with operational requirements when so authorized by the DOD installation commander.

3-6 HPSA

3-6.1 **Arrangement in Zones.** HPSAs shall be arranged into zones so that each zone can be individually controlled by the control station.

3-6.2 **Directional Characteristics.** HPSAs shall be designed with directional characteristics that will minimize the distortion of voice signals by interface from other zones, and will minimize the transmission of voice, siren, or other sound signals into environmentally sensitive areas or off the DOD installation.

Note: HPSAs with omnidirectional (i.e., approximately spherical shape) sound transmission characteristics may be considered for specific areas of the installation but should be used only for isolated areas having minimal concern for mutual interference between HPSA zones, when local operation of the HPSA is not required by the DOD installation, when Occupational Safety and Health Administration (OSHA) noise exposure levels will not be exceeded beneath the HPSA, and when omnidirectional speakers can be shown to be the most cost effective design.

SE Marine Corps systems will primarily use omnidirectional, 360-degree coverage HPSAs and speaker towers to maximize the alerting coverage area; however, directional speaker towers may be used as needed to minimize off-base or host nation disturbances.

3-6.3 **Outdoor Areas.** HPSAs shall be designed to maintain the intelligibility of voice signals within the zone at a level no less than 0.7 on the Common Intelligibility Scale (CIS) or 0.5 on the Speech Transmission Index (STI) measure in outdoor areas during normal weather conditions. Intelligibility may be less than 0.7 CIS in areas of the zone if personnel can determine that a voice signal is being broadcast and they could walk less than 50 meters (m) (164 feet (ft)) to find a location in the zone with at least 0.7 CIS.

Note: Values of 0.65 through 0.74 will be rounded to 0.7.

Note: Physical limitations in outdoor sound propagation normally limit the maximum distance of personnel from the sound system speaker to the range of about 550 to 610 m (1800 to 2000 ft) for the receipt of an intelligible voice message. Increases in speaker output power may extend the sound wave propagation distance but often cause excessive distortion of the voice message and decrease intelligibility to unacceptably low levels.

Note: Commercially available test instrumentation should be used to measure intelligibility using the CIS as specified by International Electrotechnical Commission (IEC) 60849 and IEC 60268-16. Alternately, trained human speakers and listeners may be used to measure intelligibility using the STI as specified in American National

Standards Institute (ANSI) 3.2. The mean value of at least 3 readings is required to compute the intelligibility score at each test location when using the test instrumentation method.

Note: Normal weather conditions should be specified by the DOD installation as appropriate for its geographic location. Intelligibility meters with internal compensation should be used to adjust CIS measurements for other than normal weather conditions. Weather data for the DOD is maintained by the Air Force Combat Climatology Center and may be accessed for all DOD locations at https://www2.afccc.af.mil/. This site contains a database of engineering weather data that may be searched by installation or city name. Use of the average wind speed and direction data from the “Dry Bulb Temperature” section of the “Design Criteria Data” table is recommended.

3-6.4 **Special Outdoor Areas (Army and Air Force Projects).** HPSAs shall be designed to maintain the intelligibility of voice signals within the zone at a level no less than 0.8 CIS or 0.7 STI during normal weather conditions in special outdoor areas such as those with a high concentration of multi-story buildings in close proximity. Parade grounds, training fields, and similar outdoor areas should also be provided with this higher intelligibility. Many DOD installations contain one or more special outdoor areas. The boundaries of special outdoor areas shall be established by the DOD installation. Intelligibility may be less than 0.8 CIS in areas of the zone if personnel can determine that a voice signal is being broadcast and could walk less than 25 m (82 ft) to find a location in the zone with a CIS score of at least 0.8.

Note: Values of 0.75 through 0.84 will be rounded to 0.8.

Note: In special outdoor areas (such as in industrial areas with many multi-story buildings), the maximum distance of personnel from an outdoor speaker often has to be significantly reduced to retain acceptable intelligibility of the voice message. Speakers that provide directional capability should be used. These may be mounted on building exteriors if the speakers do not radiate unacceptable levels of sound into the building on which they are mounted.

Note: Physical limitations in outdoor sound propagation normally limit the maximum distance of personnel from the sound system speaker to the range of about 550 to 610 m (1800 to 2000 ft) for the receipt of an intelligible voice message. Increases in speaker output power may extend the sound wave propagation distance but often cause excessive distortion of the voice message and decrease intelligibility to unacceptably low levels.

Note: Commercially available test instrumentation should be used to measure intelligibility using the CIS as specified by IEC 60849 and IEC 60268-16. Alternately, trained human speakers and listeners may be used to measure intelligibility using the STI as specified in ANSI 3.2. The mean value of at least three readings is required to compute the intelligibility score at each test location when using the test instrumentation method.

Note: Normal weather conditions should be specified by the DOD installation as appropriate for its geographic location. Intelligibility meters with internal compensation should be used to adjust CIS measurements for other than normal weather conditions. Weather data for the DOD is maintained by the Air Force Combat Climatology Center and may be accessed for all DOD locations at https://www2.afccc.af.mil/. This site contains a database of engineering weather data that may be searched by installation or city name. Use of the average wind speed and direction data from the "Dry Bulb Temperature" section of the "Design Criteria Data" table is recommended.

3-6.5 **Occupational Noise Exposure.** It is necessary to control the occupational noise exposure to personnel from the HPSA to comply with Federal regulations (Title 29, Code of Federal Regulations, Parts 1910.95 and 1926.52). Sound levels at any location where personnel may be located, including directly underneath the HPSA, shall not exceed 120 decibels (adjusted) (dBA) when measured on the A-scale of a standard sound level meter at slow response. Do not exceed 85 dBA at the location of the individual HPSA equipment cabinet for those HPSAs designated by the DOD installation to be furnished with a local microphone.

Note: The 120-dBA maximum is based on the assumption that the wide area MNS will expose personnel on the ground to a sound level of 120 dBA for no more than a total of 7.5 minutes out of any 24-hour period. This noise exposure limit should accommodate most anticipated daily messages and the occasional antiterrorism exercise without exceeding OSHA limits. DOD installations that anticipate that personnel will receive a longer time of noise exposure at this sound level must establish a lower maximum value (e.g., 90 dBA will permit up to an 8-hour noise exposure, 100 dBA for 2 hours' exposure, 110 dBA for 30 minutes' exposure) or provide hearing protection.

3-6.6 **Noise Pollution.** At some DOD installations, it is necessary to control the amount of sound that propagates in undesirable directions, such as into civilian communities adjacent to the DOD installation boundaries or into wildlife areas with protected or endangered animal species. Additionally, in some areas it might be necessary to mount wide area MNS speakers on the side of a building while simultaneously preventing an unacceptable increase in that building's interior noise levels.

3-6.6.1 **Design Goals.** Use speakers designed to minimize back-plane emissions for HPSA zones where the speakers will be mounted directly to an occupiable building, or where noise pollution is a concern for off-installation populated areas or sensitive wildlife areas.

3-6.6.2 **Speakers Attached to Buildings.** Speakers attached to occupiable buildings shall be capable of using phase shifting and filtering to help eliminate unwanted "spillover" emissions and back-plane noise.

3-6.6.3 **Measuring Noise in Buildings.** Back-plane noise transmitted inside of occupiable buildings shall be no more than 15 dBA above ambient noise.

3-6.7 **HPSA inside of Buildings.** HPSA zones shall not be used to provide mass notification inside any structures when UFC 4-010-01 would require an individual building MNS if the structure were built new or renovated.

3-6.8 **HPSA Speaker Sites.** Each HPSA site for each zone shall include a field-mounted local control unit, microprocessor, amplifier, standby batteries, charger, power supply, radio, mounting brackets and loudspeaker assembly for pole or building mounting. Those HPSA sites designated by the DOD installation shall be capable of microphone input and shall be provided with a microphone designed to prevent feedback at that particular microphone location.

3-6.8.1 **Locations of Sites.** Locations of the HPSA sites shall be verified and recorded with GPS coordinates. These locations shall be established prior to the installation of speaker array supporting structures as part of a site survey conducted jointly by the installing contractor and the DOD installation.

3-6.8.2 **Equipment Cabinets.** All equipment for each HPSA speaker site shall be housed in modular, mountable cabinets suitable for the local environmental conditions, including space heaters and ventilation fans, as appropriate.

Note: Enclosures qualified to the requirements of National Electrical Manufacturers Association (NEMA) 3R (rain tight), NEMA 4 (wash-down areas), or NEMA 4X (harsh environments) should be used for all outdoor applications.

3-6.8.3 **Surge Suppression.** All external conductors (conductors passing outside of the HPSA equipment cabinet) shall be provided with surge suppression tested to Underwriters Laboratories, Inc. (UL) standards as specified by UFC 3-520-01.

3-6.9 **HPSA Performance.** The HPSA control units shall provide at least these components and features:

3-6.9.1 A digitally addressable controller

3-6.9.2 The ability to receive and store messages via the primary (and redundant, if required) communication link with a confirmation signal sent back to the primary and redundant central control stations. Alternately, the DOD installation may authorize use of fixed, pre-recorded emergency messages that are physically installed in each HPSA (typically by installing an EPROM or flash memory device).

3-6.9.3 A charger/ power supply that will accept alternating current (AC) input, backup electrical power generator input, battery input, or solar power cell input

3-6.9.4 The capability of storing at least 60 minutes of pre-recorded messages

3-6.9.5 The capability of providing a minimum of 7 standard tones. In addition, the systems shall have the capability to provide custom tones.

Marine Corps systems require a minimum of 6 standard tones.

3-6.9.6 The ability to accept and play an auxiliary input from a digital recording device such as a compact disk (CD) player or Moving Picture Experts Group (MPEG) Layer 3 player

3-6.9.7 An amplifier efficiency of not less than 90 percent. The amplifier shall have not more than 0.1 percent total harmonic distortion (THD). The amplifier frequency response shall be at least 200 hertz (Hz) to 10,000 Hz. There shall be no more than 2 percent THD at the speaker at 1000 Hz.

Note: Some outdoor warning systems use amplifiers that are rated for as little as 30 minutes of continuous operation. These amplifiers are often of low efficiency and may be damaged by heat buildup. Such amplifiers may be adequate for many non-emergency applications; however, higher efficiency amplifiers with improved cooling capabilities should be used to provide the capability needed for antiterrorism operations.

3-6.9.8 The capability for local control at those HPSAs designated by the DOD installation. Designated HPSAs shall be able to function independently of the central control station. Designated HPSAs shall be furnished complete with a local microphone and local controls. The local microphone shall be designed to prevent feedback at that particular microphone location.

Note: Local control capability should be designated for all HPSAs where an on-scene commander is expected to be located during emergencies. This capability should also be designated for areas used for troop formations, parade fields, parks and sports fields, areas opened to the public for air shows or fireworks displays, and any other areas where an individual HPSA could be used by the DOD installation in lieu of providing a temporary public address (PA) system.

3-6.9.9 A headphone output port to permit private listening of the system broadcast at each HPSA designated by the DOD installation for testing purposes

Not required for Marine Corps systems

3-6.9.10 An input port for connecting a laptop computer or digital device to make field changes. Alternately, the DOD installation may authorize use of fixed, pre-recorded emergency messages that are created elsewhere and physically installed in the HPSA (typically by installing an EPROM or flash memory device).

Not required for Marine Corps systems

3-6.9.11 A tamper switch that will signal the central control station that the HPSA enclosure door is open

3-6.10 **Temperature Rating.** Speakers shall be able to operate between temperatures of -40 degrees Celsius (C) (-40 degrees Fahrenheit (F)) to +60 degrees C (+140 degrees F). Enclosures shall protect the HPSA control unit from external temperatures ranging from -40 degrees C (-40 degrees F) to +60 degrees C (+140 degrees F). The DOD installation should specify an upper external temperature limit of +80 degrees C (+175 degrees F) in those geographic locations subject to extreme heat.

3-6.11 **Battery Backup Power.** Each HPSA site shall be equipped with backup batteries to supply power for a minimum of 72 hours of electrical supervision following the loss of normal charging power, followed by a total of 60 minutes of full load operation at the end of the supervisory period.

Note: The DOD installation should specify the temperature to be used to size the backup batteries for the HPSA. Weather data for the DOD is maintained by the Air Force Combat Climatology Center and may be accessed for all DOD locations at https://www2.afccc.af.mil/. This site contains a database of engineering weather data that may be searched by installation or city name. Use of the lowest mean minimum temperature from the "Annual Summary of Temperatures" graph is recommended. Alternately, use the minimum design temperature of the HPSA control unit enclosure if internal heating is provided within the enclosure.

3-6.12 **Connection to Portable Electrical Power Generator.** Each HPSA site so designated by the DOD installation shall be capable of direct connection to a commercially available portable electrical power generator or a military-approved mobile electrical power (MEP) generator.

3-6.13 **Elevated Supporting Structure**

3-6.13.1 **Required.** An elevated supporting structure (e.g., pole, tower) shall be provided at each HPSA site other than those attached directly to a building.

3-6.13.2 **Structural Loads, Wind and Seismic Design.** The supporting structure shall be designed for the structural loads listed in UFC 3-310-01, except that the design wind speed shall be not less than 100 miles per hour (mph) (161 kilometers per hour (km/h), 86.8 knots). The supporting structure shall be sized to accommodate the static and dynamic loads produced by the sound systems and all attachments.

3-6.13.3 **Mounting Height**. The HPSA shall be attached to the elevated supporting structure. The minimum mounting height of the speakers shall be based on the rated output of the speakers and shall prevent hearing damage to anyone directly below the speakers. Do not exceed noise exposure limits as specified in paragraph 3-6.5. The height shall not be less than 9 m (30 ft) or greater than 18 m (60 ft) above ground level.

Ensure that the location and height of HPSA supporting structures do not interfere with aircraft flight operations.

3-6.13.4 **Mounting of Cabinets.** HPSA equipment cabinets shall be mounted on the elevated supporting structure with the top of the enclosure no more than 3 m (10 ft) above ground level. The equipment cabinet and power boxes must be capable of being locked shut.

3-6.14 **HPSA attached to Buildings**

3-6.14.1 **Mounting Height.** The HPSA shall be mounted at a minimum mounting height that is based on the rated output of the HPSA and shall prevent hearing damage to anyone directly below the speakers. Do not exceed noise exposure limits as specified in paragraph 3-6.5.

3-6.14.2 **Structural Loads, Wind and Seismic Design.** The mounting of the HPSA shall be designed for the structural loads listed in UFC 3-310-01, except that the design wind speed shall be not less than 100 mph (161 km/h, 86.8 knots). The mounting shall be sized to accommodate the static and dynamic loads produced by the sound systems and all attachments.

3-6.14.3 **Sound into Building.** If attached to an occupiable building, the HPSA shall not permit unacceptable levels of sound into the building. (See paragraph 3-6.6.3.)

3-6.14.4 **Noise Exposure under HPSA.** Do not exceed the OSHA occupational noise exposure limits specified in paragraph 3-6.5.

3-7 **COMMUNICATIONS LINKS**

3-7.1 **Primary Communications Link.** Primary communications shall use radio frequency-type systems that comply with National Telecommunications and Information Administration (NTIA) requirements. The systems shall be designed to minimize the potential for interference, jamming, eavesdropping, and spoofing.

Note: See Appendix C for a discussion of requirements for Internet-based communication systems (under development).

3-7.1.1 **Licensed Radio Frequency Systems**. An approved DD Form 1494 for the system is required prior to operation. When available, use systems designed for secure digital communication standards such as the Association of Public-Safety Communications Officials (APCO) Standard 25.

Note: APCO 25 is an industry-wide effort to set the recommended voluntary standards of uniform digital two-way radio technology for public safety organizations.

Note: Receiving a new radio frequency assignment often takes a relatively long time. Be sure to request the frequency assignment early in the design process.

3-7.1.2 **Non-licensed Radio Frequency Systems.** When authorized by the DOD installation commander, the NTIA permits the use in the continental United States (CONUS) of non-licensed radio frequency-type devices that conform to Federal Communications Commission (FCC) rules and regulations (47 CFR 15); however, all transmitting devices on a military installation require an approved DD Form 1494 prior to installation. In locations outside of the continental United States (OCONUS), confirm that the devices conform to host-country regulations and obtain the approval from the DOD installation commander prior to using non-licensed radio frequency-type devices. In all cases, request permission from the spectrum manager for the local area. Provide GPS coordinates of installed transmitters when required by the spectrum manager.

Note: Non-licensed devices operate at very low power levels, have no vested or recognized right to any part of the radio frequency spectrum, and are not <u>required</u> to provide any immunity to interference. If a non-licensed system is selected, be sure the system compensates for these limitations by providing suitable radio signal modulation features (e.g., spread spectrum and frequency hopping) and that propagation distance parameters for the radio signals are not exceeded.

3-7.2 **Redundant Communications Link.** Redundant communication means (when required) should be established using several alternate wireless radio frequency paths to the radios. In some cases, the redundant communication means might be accomplished by using the DOD installation's communications backbone network (e.g., optical fiber cable). In this case, the central control units should accomplish this by being directly connected to the backbone network.

Note: All software and hardware to be installed on DOD Ethernet or Internet systems must first successfully complete an accreditation process. Accreditation often takes a relatively long time.

Note: See Appendix C for a discussion of requirements for Internet-based communication systems (under development).

3-7.3 **Off-the-Shelf Equipment.** Communications equipment furnished as part of the wide area MNS shall be commercial off-the-shelf (COTS). All programming codes or passwords required to access, update, modify, and maintain the communications equipment shall be provided to the DOD installation no later than the date of final system acceptance.

Note: Receiving authorization to operate any communications equipment often takes a relatively long time. Be sure to request approval early in the design process. At some DOD installations, a Certificate to Operate (CTO) or Certificate of Networthiness (CON) is required.

3-7.4 **Supervision.** Full system supervision shall be provided. Notification of system alarm, supervisory, and trouble signals shall be provided to the central control stations within a time period not to exceed 200 seconds.

3-7.5 **Diagnostics.** The communications systems shall provide self-test and diagnostics capabilities. Local diagnostics information shall be transmitted to the central control stations.

3-7.6 **Interfaces with Other Systems.** The communications systems shall be capable of interfacing with existing fire alarm systems, existing PA systems, and existing telephone dialing systems on the DOD installation. The communications systems shall be designed with an established protocol that is provided to the DOD installation to allow existing and future individual building MNS from other manufacturers to interface with the wide area MNS. The wide area MNS manufacturer shall provide a standard interface method (such as an audio line-level output and multiple relay contacts) or supply the necessary digital communication protocols to permit the DOD installation to select more than one manufacturer of individual building MNS.

SE Marine Corps systems will interface with the telephone dialer system that has been approved by the AHJ. (See paragraph 1-3.4 for more information on the AHJ).

CHAPTER 4

INDIVIDUAL BUILDING MNS FOR NEW CONSTRUCTION PROJECTS

4-1 **SCOPE.** Individual building MNS are intended to provide real-time information to personnel within and in the immediate vicinity of buildings on a DOD installation. These systems are required by UFC 4-010-01 for new construction and renovation of existing buildings. This chapter provides the design criteria for new construction projects. It discusses the requirements of the individual building MNS that is installed in new construction as part of a combined MNS/fire alarm system.

Note: In most cases, the simplest and most economical approach for new construction will be to install a combined system that performs both as an individual building MNS and as the building fire alarm/voice evacuation system.

4-2 **REQUIREMENTS FOR SYSTEM DESIGNERS.** The individual building MNS shall be designed under the supervision of a registered fire protection engineer, by a registered professional engineer having at least four years of current experience in the design of fire protection and detection systems, or by an engineering technologist qualified at NICET Level IV in fire alarm systems. The individual's name, signature, and professional engineer number or NICET certification number shall be included on all final design documents.

SE Navy systems shall be designed only by a registered fire protection engineer who has passed the fire protection engineering written examination administered by the National Council of Examiners for Engineering and Surveys (NCEES).

4-3 **SYSTEM OVERVIEW.** A combined system is required by the Navy and is highly recommended by the Army and Air Force. The combined system design may be used by the Marine Corps when specifically approved by the AHJ based on the class and size of the building requiring the MNS. Otherwise, Marine Corps projects will use the technical criteria of Chapter 5. If an Army or Air Force installation approves use of a separate MNS and separate building fire alarm system in a new construction project, use the technical criteria of Chapter 5.

SE A separate MNS may be installed in Navy projects for a building not provided with a fire alarm system. See Chapter 5.

Note: See paragraph 6-5 for MNS requirements for special occupancies such as medical facilities and facilities intended for occupancy by persons not capable of self-preservation.

4-3.1 **Subsystems.** An individual building MNS for new construction projects includes several subsystems: autonomous control unit (ACU); local operating consoles (LOC); notification appliance network; and interface with the wide area MNS on the DOD installation. System design and wiring is designed to meet NFPA 72 requirements for MNS and fire alarm systems.

4-3.2 **ACU**

4-3.2.1 **Functions.** The ACU is used to monitor and control the notification appliance network. At the ACU, personnel in the building can initiate delivery of pre-recorded voice messages, provide live voice messages and instructions, and initiate visual strobe and alphanumeric message notification appliances. Actions taken at the ACU take precedence over actions taken at any other location, including the LOC, or inputs from the wide area MNS on the DOD installation.

4-3.2.2 **Combined System.** For new construction, the ACU shall be integrated with the building fire alarm control panel (FACP) to form one combined system that performs both functions. The building PA system for smaller buildings may be integrated with the combined system so that all three functions—mass notification, fire alarm, and PA—are provided by one building system. In large buildings, however, combining the PA system will typically require the design of very complex speaker switching matrices and is not recommended. Combined systems shall meet the requirements of NFPA 72.

Note: A combined system may include an ACU and FACP supplied from different manufacturers or placed in separate equipment enclosures; however, the ACU and FACP must be integrated in their controls and performance to meet the requirements of NFPA 72 and this UFC.

Note: The Army and Air Force permit the MNS and fire alarm system to be installed as separate systems if mandated by the DOD installation. The Marine Corps normally requires the MNS and fire alarm system to be installed as separate systems unless specifically permitted by the AHJ. See Chapter 5 for technical criteria for this design approach.

4-3.3 **LOC.** A LOC is a unit designed to allow emergency response forces and building occupants to operate the individual building MNS, including initiating delivery of pre-recorded voice messages, providing live voice messages and instructions, initiating visual strobe and alphanumeric message notification appliances, overriding external voice announcements, and terminating mass notification functions. A LOC is usually contained in a small, wall-mounted enclosure. Not all functions that could be performed at the ACU are necessarily available at a LOC.

4-3.4 **Notification Appliance Network.** A notification appliance network consists of a set of audio speakers, strobes, and text signs (when required) that are located to alert occupants and provide intelligible voice and visual instructions.

4-3.4.1 **Audio Appliance Network.** Speakers are provided at all locations in the building and also around the building at entrances/exits and other outdoor areas (such as courtyards) commonly used by the building occupants. Important design considerations for the audio speakers include intelligibility and audio intensity.

Note: Outside notification more than 5 m (16 ft) from the building should be provided by the wide area MNS.

4-3.4.1.1 Intelligibility is defined in NFPA 72. Commercially available test instrumentation shall be used to verify intelligibility.

4-3.4.1.2 Effective voice communication within buildings occurs by using a system design of many speakers, each with low audio intensity.

4-3.4.2 **Visual Appliance Network.** Strobes are provided at all locations inside the building to meet the accessibility requirements of \1\ ABAAG /1/ for persons with hearing disabilities. Strobes are provided at the same locations in a building that would be required for a fire alarm system notification appliance. Combined MNS/FACP systems may use either one strobe (clear) or two strobes (clear for fire and amber for MNS) as specified by the AHJ.

4-3.4.2.1 Navy installations shall use one clear strobe and also shall provide text signs. Text signs are required over the door to each egress stairwell and over (or adjacent to) the substantial means of egress from the level of discharge. Exterior exit doors from a single room (e.g., mechanical or electrical rooms) do not require a text sign.

4-3.4.2.2 Army and Air Force installations shall use a clear strobe for fire and an amber strobe for MNS. Use of text signs is optional and at the discretion of the DOD installation. If provided, text signs shall be located over the door to each egress stairwell and over (or adjacent to) the substantial means of egress from the level of discharge. Exterior exit doors from a single room (e.g., mechanical or electrical rooms) do not require a text sign.

4-3.4.2.3 Marine Corps installations shall contact the AHJ for guidance on visual notification appliances.

4-3.5 **Interfaces with the Wide Area MNS**. If a wide area MNS is provided on the DOD installation, the individual building MNS communicates with the central control units of the wide area MNS to provide status information, receive commands, activate pre-recorded messages, and originate live voice messages. If no wide area MNS is provided on the DOD installation, at a minimum, the individual building MNS shall be able to receive an audio line-level input.

4-3.6 **Logical Block Diagrams.** Figures 4-1 and 4-2 show the logical block diagrams for acceptable configurations of the individual building MNS for new construction.

Note: These diagrams are intended to show only the functional relationships of the major components. They are not intended to serve as wiring diagrams. Many essential design features for an operational system, such as end-of-line resistors, are not shown.

Figure 4-1. Individual Building Mass Notification System: Combination Fire Alarm System and MNS (Navy)

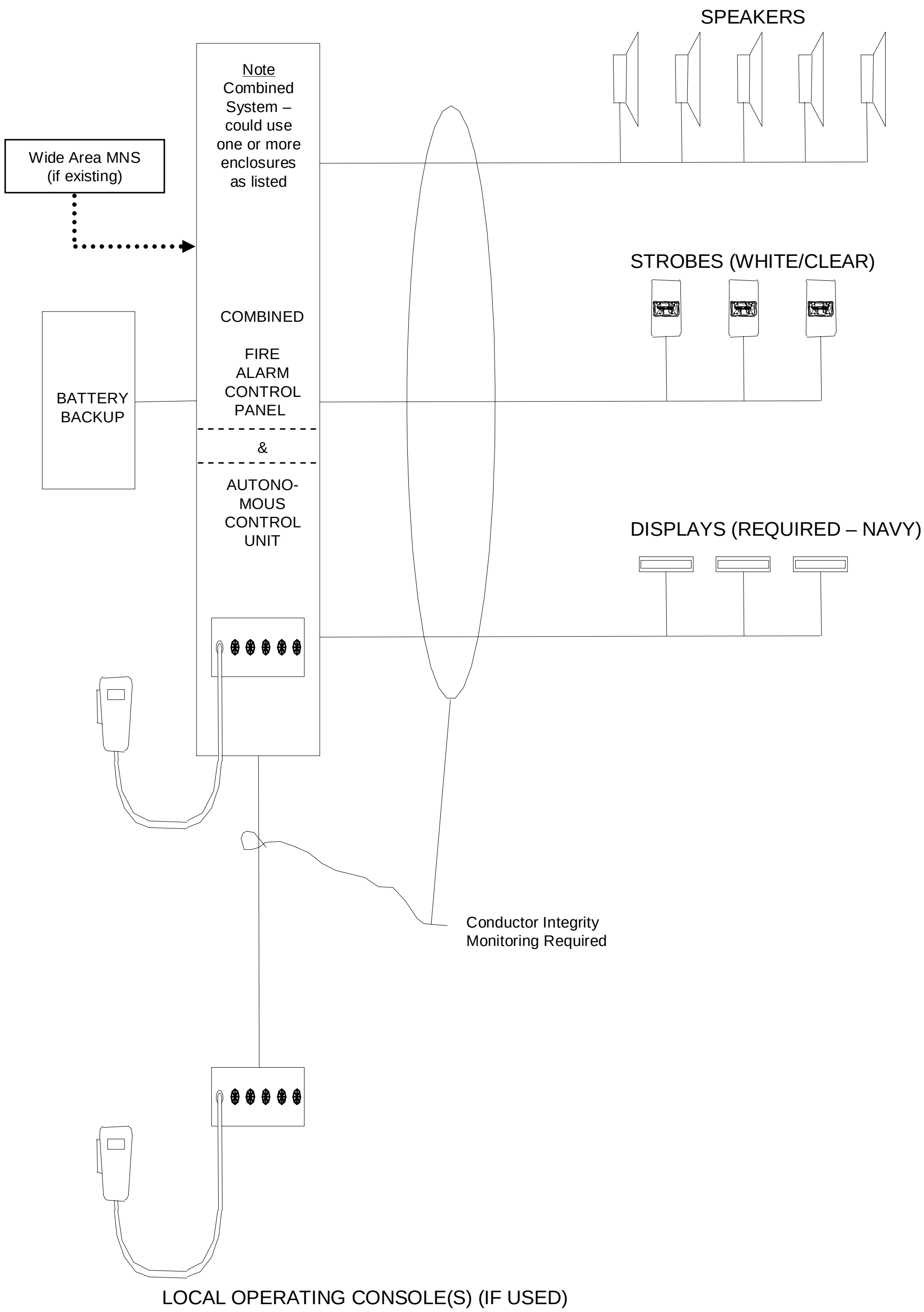
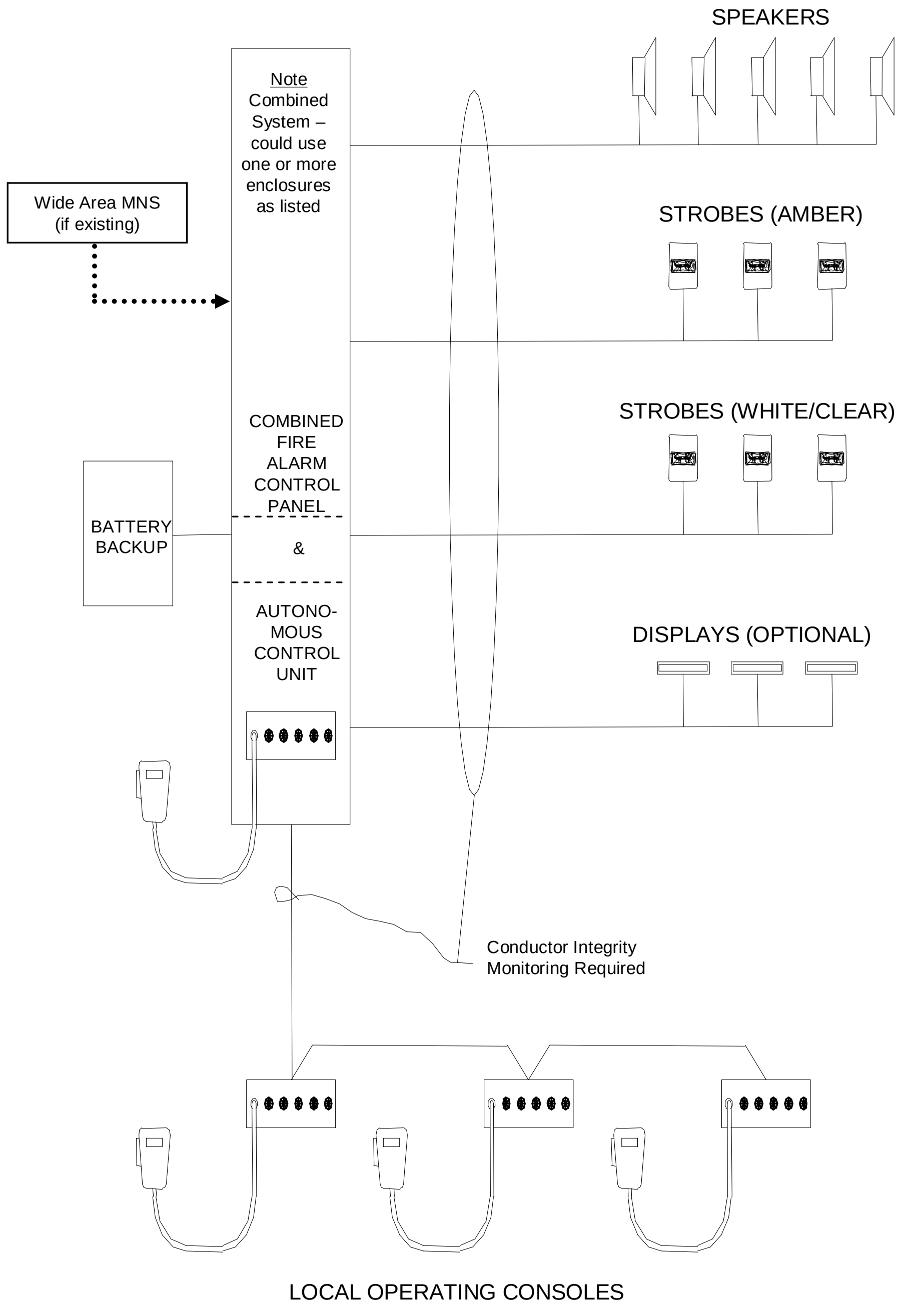


Figure 4-2. Individual Building Mass Notification System: Combination Fire Alarm System and MNS (Army and Air Force)



4-4 ACU

4-4.1 **Locations.** The ACU shall form a combined system with the FACP. These control panels may be co-located in the same enclosure or may be physically separated. If they are located in the same enclosure, install the enclosure at the location normally specified by the DOD component AHJ for a stand-alone FACP.

4-4.2 **Design Features.** The ACU shall:

- Be able to function independently upon failure of the wide area MNS (if provided on the DOD installation).
- Be a listed combination system with the fire alarm system as described in NFPA 72 and meeting UL Standard 864 and the specific requirements of this UFC. The listing evaluation shall be accomplished by UL, Factory Mutual Research Corporation (FM), or another nationally recognized testing laboratory (NRTL).

Note: Systems designed to UL 2017 instead of UL 864 may not be used for a combination system. Systems designed to UL 2017 are permitted for a MNS separate from the fire alarm system (see Chapter 5).

- Be able to activate strobes and text signs:
  - Navy: Energize clear strobe lights marked “ALERT” along with light-emitting diode (LED)-type text signs. Text signs are required over the door to each egress stairwell and over (or adjacent to) the substantial means of egress from the level of discharge. Exterior exit doors from a single room (e.g., mechanical or electrical rooms) do not require a text sign. Strobes shall meet all UL listing requirements for fire alarm system strobes except for the marking “ALERT.”
  - Marine Corps: Contact the AHJ for guidance on visual notification appliances.
  - Army and Air Force: Energize either one set of clear strobe lights marked “FIRE” for the fire alarm system or a separate set of amber strobe lights marked “ALERT” for the MNS as appropriate for the emergency. Energize LED-type text signs if required by the DOD installation.
- Make general paging or other non-emergency messages available without the activation of strobes. A separate microphone must be provided for this purpose.
- Have the ability to interrupt PA system announcements and to silence building background music while delivering voice messages.

- Be able to accept voice messages from the DOD installation telephone system

- Have conductor connections that comply with NFPA 72.

Note: Ethernet or IP connections for initiating and indicating circuits are not currently available that will meet NFPA 72 requirements and, therefore, may not be used. Additionally, all software and hardware to be installed on DOD Ethernet or Internet systems must first successfully complete an accreditation process. Accreditation often takes a relatively long time.

- Have conductor integrity monitoring for strobes, speaker wiring, power supplies, and connections to the LOC.

- Be able to switch between MNS and fire alarm notification functions without generating trouble alarms in either system.

- Have the capacity for multiple pre-recorded messages (at least eight, but more if required by the DOD installation). Pre-recorded messages shall be passed in the English language and, for OCONUS locations, also in the predominant language(s) used by the host nation. Pre-recorded messages, if used, should address at least these subjects:

    - Bomb threat or actual bomb within/around the building

    - Intruder/hostile person sighted within/around the building

    - Directions to occupants to take cover within the building

    - Evacuation of the building using exits other than the normal main entrance/exit (since the front entrance/exit is often a location targeted by terrorists)

    - Emergency weather conditions appropriate for the local area

    - “All Clear” message

    - A test message intended for verifying functionality of the system.

    The Marine Corps AHJ will determine the number and content of pre-recorded messages.

- \1\ Provide an alerting sound prior to playing pre-recorded messages. The alerting sound for fire alarm messages shall be different than that used for other pre-recorded messages. The fire alarm alerting sound for buildings other than child development centers shall be either the temporal three-tone or the slow whoop for fire alarm messages, unless otherwise approved by the approving authority (i.e., the AHJ for the Navy and Marine Corps; the DOD installation in conjunction with the contracting officer for the Army and Air Force). The fire alarm alerting sound for child development centers shall be a chime sound. /1/

- Be able to deliver messages quickly.
- Be able to automatically repeat pre-recorded messages until they are terminated.
- Have a microphone for delivering live voice messages.
- Have adequate discrete outputs to initiate text signs and initiate strobes.
- Interface to the LOC for initiating recorded messages and delivering live voice messages from locations in the building other than at the ACU.
- Establish priority for passing messages to prevent interference between the ACU, LOC, and the wide area MNS on the DOD installation.
- Allow the MNS to temporarily override fire alarm audible messages and visual signals, and to provide intelligible voice commands during simultaneous fire and terrorist events. All other features of the fire alarm system, including the transmission of signals to the fire department, shall function properly. MNS messages shall take priority and continue to override fire alarm audible messages until the MNS message is either manually or automatically ended. If not manually ended, the MNS message will automatically end after 10 minutes.
- Provide a supervisory signal if the MNS is used to override fire alarm audible messages and visible signals during simultaneous fire and terrorist events. The supervisory signal shall be annunciated at the FACP and any remote fire alarm annunciators and be transmitted to the fire department. The visual annunciation of the separate supervisory signal shall be distinctly labeled or otherwise clearly identified.

SE The Army requires that this supervisory signal be separate from other fire alarm system supervisory signals.

- Remote monitoring of trouble, supervisory, and alarm functions to a constantly occupied location meeting the requirements of NFPA 72
- Have a single switch or operating mechanism capable of shutting down all heating, ventilating, and air conditioning (HVAC) equipment in the facility in accordance with the requirements of UFC 4-010-01. If permitted by the DOD installation, this shutdown capability may be provided at a LOC or be deleted entirely if the capability is otherwise provided at a location readily accessible

to building occupants.

- Provide a complete set of self-diagnostics for the controller and appliance network.
- Have a local diagnostic information display.
- Provide a local system event log file.

4-4.3 **Off-the-Shelf Equipment.** ACU equipment furnished as part of the individual building MNS shall be COTS and shall be tested to the standards of UL or FM by a NRTL.

4-4.4 **Programming Codes.** All programming codes or passwords required to access, update, modify, and maintain the ACU shall be provided to the DOD installation no later than the date of final system acceptance.

4-4.5 **Power Supply Features.** The power supply shall:

- Be capable of accepting 120/240 VAC, 50/60 Hz.
- Be appropriate for a MNS/FACP system that meets at least the minimum NFPA 72 requirements for standby power capacity. In addition, secondary (standby) power should be provided as follows: immediately upon loss of normal AC power, the standby source of power shall provide a minimum of 60 minutes of mass notification at the maximum connected load.
- Disable use of any microphones intended solely for general paging or other non-emergency messages upon loss of normal AC power.
- Conform to applicable sections of NFPA 72.
- Use only COTS components.
- Provide surge protection in accordance with UFC 3-520-01.

4-5 LOC

4-5.1 **Locations.** Provide a LOC to allow emergency response forces and building occupants to access the MNS and originate messages in emergency situations from locations in the building other than from the ACU. Follow these requirements:

- Provide a separate LOC for use by the fire department near the building FACP (or fire command center) unless this is also the location of the ACU.
- Do not place a LOC inside a locked room or closet (with the possible exception of the LOC intended for use by the fire department near the FACP).

- Install a LOC at those facility entrances/exits that will be used when building access is limited because of elevated terrorism threat levels.

Note: This LOC is intended to enable immediate notification of building occupants when unauthorized building access is threatened or has occurred at this location.

- Army and Air Force: Provide a LOC so that occupants do not need to travel more than 61 m (200 ft) horizontally or to travel to other floors to access a LOC.

- Army and Air Force: Make a LOC available for use by visitors in those facilities open to unescorted visitors or to the public.

- Navy: Provide no more than one LOC (if necessary) in addition to the ACU. Locate the LOC as directed by the responsible fire protection engineer.

- Marine Corps: Provide no more than one LOC (if necessary) in addition to the ACU. Locate the LOC as directed by the AHJ.

4-5.2 **Design Features.** The LOC shall:

- Have a remote microphone station that emulates operation of the MNS from the ACU.

- Have an easy method (such as individual manual activation push buttons) of activating the MNS pre-recorded messages. Signage shall be provided to allow rapid recognition of the means of initiating the pre-recorded messages.

Activation of MNS pre-recorded messages is not required for Marine Corps LOC.

- Provide a single switch or operating mechanism capable of shutting down all HVAC equipment in the facility in accordance with the requirements of UFC 4-010-01. If permitted by the DOD installation, this shutdown capability may be provided at only one LOC when multiple LOCs are installed, or be deleted from all LOCs if the capability is otherwise provided at a location readily accessible to building occupants.

- Be protected in a small, wall-mounted enclosure.

- Have supplemental heating and ventilation for those enclosures located outdoors or in areas where the LOC will be exposed to temperatures or humidity outside of the manufacturer’s design limits.

- Be protected from tampering by use of a break-glass, thumb-lock, tamper wire, tamper alarm, or equivalent protection. This is not required in those facilities with limited access so that unauthorized use would not reasonably be expected to occur. Enclosures that can be opened only by a key shall not be used.

Marine Corps LOC may use key-operated locks when emergency response forces are provided with immediate access (e.g., master key, Knox-box®)

- Have signage on the outside of the enclosure similar to “Mass Notification” and “HVAC Emergency Shutdown” (if applicable).

4-6 NOTIFICATION APPLIANCE NETWORK

Note: Also see paragraph 6-5 for notification appliance requirements in special occupancies.

4-6.1 **Audible Appliance Network.** These are the requirements of the audible appliance network:

- Provide appliances capable of satisfying \1\ ABAAG. /1/
- Use speakers suitable for the intended climatic and environmental conditions.
- Use speakers suitable for installation in commercial/industrial applications with consideration of electrically hazardous (classified) locations.
- Provide speakers and installation methods compliant with Director of Central Intelligence Directive (DCID) 6/9 for areas classified as sensitive, compartmented information facilities (SCIF).
- Speakers shall meet the listing requirements of UL Standard 1480.
- System design shall comply with NFPA 72.
- Provide speakers at all locations inside a building where the building fire alarm must be audible.
- \1\Ensure speakers in the vicinity of the ACU and LOC will not create acoustical feedback or otherwise interfere with the ability to deliver live voice messages./1/
- Provide speakers mounted on the exterior of the building to provide notification of any areas commonly used by building occupants. These include courtyards, covered break areas, designated smoking areas, and sidewalks leading from the building’s exit doors to a public street or from parking areas for a distance up to 5 m (16 ft) from the building. Use speakers with directional characteristics that transmit minimal backplane noise when mounted on the sides of the building. Generally, the speakers should be

located near entrance/exit doors.

- Provide an effective voice communication within buildings using a design including many speakers, each with low audio intensity.

- Install speakers with field-adjustable tap settings to allow adjustment after installation to meet audibility and intelligibility requirements.

- Do not use speakers exceeding 15 watts (W) for indoor applications without prior approval of the AHJ.

- Wiring methods shall comply with NFPA 72. Class B wiring is permitted unless Class A wiring is required for fire alarms systems on the DOD installation.

4-6.1.1 **Speaker Design Recommendations**

- Speakers rated at 2 W or less and with multiple tap settings to adjust the output power can often provide acceptable sound quality in most occupied areas.

- Speakers rated at 8 W or less and with multiple tap settings can often provide acceptable sound quality for most large or very noisy areas.

- Speakers rated at 8 to 10 W for interior distribution should be used when the speakers are also intended to meet the better sound quality normally expected from PA systems. These speakers should be capable of a frequency response over the range at least 200 Hz to 10,000 Hz.

  Note: Such speakers are often adjusted to operate at a tap setting of 2 W or less, but are used because their sound quality is greatly superior to the small speakers typically used in fire alarm systems.

4-6.1.2 \1\ **Intelligibility** /1/ **Requirements**

- Verify intelligibility by measurement after installation.

- \1\ Ensure that a CIS value greater than the required minimum value is provided in each area where building occupants typically could be found. The minimum required value for Navy and Marine Corps is 0.7 CIS. The minimum required value for Army and Air Force is 0.8 CIS, although rounding is permitted such that a value of 0.75 may be rounded to 0.8. /1/

- Areas of the building provided with hard wall and ceiling surfaces (such as metal or concrete) that are found to cause excessive sound reflections may be permitted to have a CIS score less than \1\ the minimum required value /1/ if approved by the DOD installation, and if building occupants in these areas can determine that a voice signal is being broadcast and they must walk no more than 10 m (33 ft) to find a location with at least \1\ the minimum required CIS value within the same area. /1/

- Areas of the building where occupants are not expected to be normally present are permitted to have a CIS score less than \1\ the minimum required value /1/ if personnel can determine that a voice signal is being broadcast and they must walk no more than 15 m (50 ft) to a location with at least \1\ the minimum required CIS value within the same area. /1/

- Measurements should be taken near the head level applicable for most personnel in the space under normal conditions (e.g., standing, sitting, sleeping, as appropriate).

- \1\ The distance the occupant must walk to the location meeting the minimum required CIS value shall be measured on the floor or other walking surface as follows:

    - Along the centerline of the natural path of travel, starting from any point subject to occupancy with less than the minimum required CIS value.

    - Curving around any corners or obstructions, with a 300-mm (12 in.) clearance therefrom.

    - Terminating directly below the location where the minimum required CIS value has been obtained. /1/

- Commercially available test instrumentation shall be used to measure intelligibility as specified by IEC 60849 and IEC 60268-16. The mean value of at least three readings shall be used to compute the intelligibility score at each test location.

- \1\ Occasionally, large DOD buildings are designed to provide cavernous-type open areas to meet unique operational requirements. Such areas are typically designed with hard wall and ceiling surfaces (such as metal or concrete) without acoustical treatments, and this has been found to cause excessive sound reflections that prevent obtaining the normal, minimum required CIS value. In such facilities, the cavernous-type open area is permitted to have locations with a CIS value lower than the normal, minimum required CIS value when the following conditions are met:

    - The requirement for a deviation from the normal, minimum CIS criteria is identified in the design phase.

    - Justification for the deviation from the normal, minimum CIS criteria is provided to the approving authority (i.e., the AHJ for the Navy and Marine Corps; the DOD installation in conjunction with the contracting officer for the Army and Air Force). The justification shall address all factors relevant to the request for deviation from normal, minimum CIS criteria, including, but not limited to: the operational requirements that restrict the installation of acoustical wall and ceiling treatments; the potential use of special speaker technologies such as directional speakers or stacked speaker systems; and, the availability of physically larger or higher-fidelity speakers even though such speakers might not be listed for fire alarm use.

Note: Deviation from normal, minimum CIS criteria should not be requested for the design of normal, large, open areas that are typically found in permanent DOD buildings, such as dining halls, theaters, and gymnasiums. The potential for deviation from normal criteria is intended to address the rare exception to normal criteria that is sometimes needed for DOD buildings with unique operational requirements.

- o Building occupants located in the large, cavernous area can adequately understand the message content in the voice signal being broadcast. Whether the voice message is adequately understood shall be determined by the approving authority (i.e., the AHJ for the Navy and Marine Corps; the DOD installation in conjunction with the contracting officer for the Army and Air Force).

- o The CIS value is not less than 0.6 at any location within the large, cavernous area.

- o The building occupants in the large, cavernous area must walk no more than 30 m (98 ft) to find another location within the large, cavernous area having at least the normal, minimum required CIS value. /1/

Note: An STI score of 0.5 is considered equivalent to a CIS score of 0.7. \1\ An STI value of 0.7 is considered equivalent to a CIS value of 0.8. /1/

4-6.1.3 \1\ DELETED /1/

4-6.2 **Visual Appliance Network.** These are the requirements for the visual appliance network:

- Provide visual appliances capable of satisfying \1\ ABAAG. /1/
- Use visual appliances suitable for the intended climatic and environmental conditions.
- Use visual appliances suitable for installation in commercial/industrial applications with consideration of electrically hazardous (classified) locations.
- Strobes shall meet the listing requirements of UL Standards 1638 and 1971.

Text signs shall comply with UL Standard 48.

- Strobes are not required outside the building.
- Where more than two visible notification appliances are in any field of view, they shall flash in synchronization.
- Wiring methods shall comply with NFPA 72. Class B wiring is permitted unless required otherwise by the local AHJ.

4-6.2.1 **Navy-Specific Requirements**

- Provide clear strobes marked with the word “ALERT” for shared use by the building’s combination MNS/FACP.
- Provide LED text signs. Text signs are required over the door to each egress stairwell and over (or adjacent to) the substantial means of egress from the level of discharge. Exterior exit doors from a single room (e.g., mechanical or electrical rooms) do not require a text sign. (See Chapter 7 for operational requirements and information on message content.)

4-6.2.2 **Marine Corps-Specific Requirements**

- Contact the AHJ for guidance on visual notification appliances.

4-6.2.3 **Army- and Air Force-Specific Requirements**

- Provide amber-colored strobes marked with the word “ALERT” to alert the hearing impaired. Provide these strobes in addition to existing clear strobes provided for the building fire alarm system.
- Amber strobes activated in conjunction with the delivery of a pre-recorded voice message shall operate continuously until message termination. Amber strobes activated in conjunction with the delivery of a live voice message shall operate during the message and for not less than 15 seconds after the message ends.
- Clear/white strobes activated by the fire alarm system shall not operate during those periods when the amber strobes are in operation, but otherwise shall operate continuously until the fire alarm system is reset.

4-7 **INTERFACES WITH WIDE AREA MNS.** The individual building MNS shall be capable of being interoperable with an existing wide area MNS. If a wide area MNS is not presently provided on the DOD installation, the individual building MNS shall be designed to allow future interface with a wide area MNS procured from another manufacturer. The electrical requirements, computer codes, or other protocols that are needed to interface the systems shall be provided to the DOD installation.

Note: When a wide area MNS is provided on the DOD installation, the system manufacturer should provide a standard method (such as an audio line-level output and multiple relay contacts) or supply the necessary digital communication protocols to permit the DOD installation to select more than one manufacturer of individual building MNS. Depending on system architecture, the manufacturer may be required to provide a system IP interface capable of allowing data transfer from an outside source to internal mass notification functions via a common data communications protocol.

CHAPTER 5

INDIVIDUAL BUILDING MNS FOR RENOVATION PROJECTS

5-1 **SCOPE.** Individual building MNS are intended to provide real-time information to personnel within and in the immediate vicinity of buildings on a DOD installation. These systems are required by UFC 4-010-01 for new construction and renovation of existing building. This chapter provides the design criteria for renovation projects, including the installation of MNS in existing buildings. This chapter should be used for new Marine Corps projects unless combination systems (see Chapter 4) are specifically approved by the AHJ. This chapter should also be used when an Army or Air Force installation approves the use of a separate MNS and separate building fire alarm system in a new construction project.

Note: See paragraph 6-5 for MNS requirements for special occupancies such as medical facilities and facilities intended for occupancy by persons not capable of self-preservation.

5-2 **REQUIREMENTS FOR SYSTEM DESIGNERS.** The individual building MNS shall be designed under the supervision of a registered professional engineer with a minimum of 4 years of current work experience in fire protection, electrical, and communication-electronics engineering areas specific to individual building MNS. Alternately, the individual building MNS may be designed by an engineering technologist verified by NICET as certified at Level IV in low voltage electronic-communications systems or at Level IV in fire alarm systems, plus this engineering technologist shall possess a minimum of 4 years current work experience specific to individual building MNS communications-electronics. Alternately, the individual building MNS may be designed by an engineering technologist that possesses a minimum of 10 years of documented current work experience specific to individual building MNS communications-electronics. The individual's name, signature, and professional engineer number or NICET certification number (when applicable) shall be included on all final design documents.

5-3 USE OF NEW CONSTRUCTION CRITERIA

5-3.1 **FACP Replacement: No Existing MNS in Building.** When replacing a FACP in a building without an existing MNS, provide a combination mass notification and fire alarm system meeting the requirements for new construction projects (see Chapter 4).

5-3.2 FACP Replacement: Existing MNS in Building

5-3.2.1 When replacing a FACP in a building with an existing separate MNS, removal of both systems and installation of a combination system meeting new construction criteria is recommended but not required. Consider the age and condition of the MNS and the life-cycle costs of keeping the existing MNS when determining whether to install a new combined system or remain with separate systems.

5-3.3 MNS Installation Projects

5-3.3.1 When installing a MNS in a building with an existing separate FACP, removal of both systems and installation of a combination system meeting new construction criteria is recommended but not required. Consider the age and condition of the FACP and the life-cycle costs of keeping the existing FACP when determining whether to install a new combined system or remain with separate systems.

Separate systems are required for Marine Corps projects unless a combination system is specifically permitted by the AHJ.

5-4 SYSTEM OVERVIEW

5-4.1 **Subsystems.** An individual building MNS for renovation projects includes several subsystems: ACU; LOC; notification appliance network; interface with facility FACP; interface with facility PA system; and interface with the wide area MNS on the DOD installation. System design and wiring must meet NFPA 72 requirements for MNS and fire alarm systems.

Individual building MNS for Marine Corps projects shall serve as a subsystem of the wide area MNS.

5-4.2 **ACU.** The ACU is used to monitor and control the notification appliance network. At the ACU, personnel in the building can initiate delivery of pre-recorded voice messages, provide live voice messages and instructions, initiate visual strobe and alphanumeric message notification appliances, and temporarily silence fire alarm system visual and audible notification appliances.

Marine Corps MNS designs are not required to use an ACU.

5-4.3 **LOC.** A LOC is a unit designed to allow emergency response forces and building occupants to operate the individual building MNS, including initiating delivery of pre-recorded voice messages, providing live voice messages and instructions, initiating visual strobe and alphanumeric message notification appliances, temporarily silencing fire alarm system visual and audible notification appliances, overriding external voice announcements, and terminating mass notification functions. A LOC is usually contained in a small, wall-mounted enclosure. Not all functions that could be performed at the ACU are necessarily available at a LOC.

Marine Corps MNS designs are not required to use a LOC.

5-4.4 **Notification Appliance Network.** A notification appliance network consists of a set of audio speakers, strobes, and text signs (when required by the AHJ) located to alert occupants and provide intelligible voice and written instructions. When required, text signs are installed over the door to each egress stairwell and over (or adjacent to) the substantial means of egress from the level of discharge. Exterior exit doors from a single room (e.g., mechanical or electrical rooms) do not require a text sign.

Text signs are not authorized in Marine Corps MNS designs unless specifically permitted by the AHJ.

5-4.4.1 **Audio Appliance Network.** Speakers are provided at all locations in the building and are provided around the building at entrances/exits and other outdoor areas (such as courtyards) commonly used by the building occupants. Important design considerations for the audio speakers include intelligibility and audio intensity.

Note: Outside notification more than 5 m (16 ft) from the building should be provided by the wide area MNS.

5-4.4.1.1 Intelligibility is defined in NFPA 72. Commercially available test instrumentation shall be used to verify intelligibility.

5-4.4.1.2 Effective voice communication within buildings occurs by using a system design of many speakers, each with low audio intensity.

5-4.4.2 **Visual Appliance Network.** Strobes are provided at all locations inside the building to meet \1\ ABAAG /1/ for persons with hearing disabilities. Strobes are provided at the same locations in a building that would be required for a fire alarm \1\ visual /1/ notification appliance. Separate MNS and FACP systems may use either one strobe (clear) or two strobes (clear for fire and amber for MNS) as specified by the AHJ. Text signs may be required by the AHJ over the door to each egress stairwell and over (or adjacent to) the substantial means of egress from the level of discharge. Exterior exit doors from a single room (e.g., mechanical or electrical rooms) do not require a text sign.

5-4.4.2.1 Army and Air Force installations shall use existing clear/white strobes for fire and install amber strobes for MNS. New amber strobes will be marked with word "ALERT." Installation of text signs is optional and at the discretion of the DOD installation.

\1\ 5-4.4.2.2 Navy installations shall use clear/white strobes marked with the word "ALERT." Text signs shall be located over the door to each egress stairwell and over (or adjacent to) the substantial means of egress from the level of discharge. Exterior doors from a single room (e.g., mechanical or electrical rooms) do not require a text sign. /1/

\1\ 5-4.4.2.3 /1/ Marine Corps installations shall contact the AHJ for guidance on visual notification appliances.

5-4.5 **Interfaces with Facility FACP.** The MNS shall provide the capability (either internally as a design feature, or with an approved or listed external controller) to temporarily deactivate the facility's fire alarm system audible and visual notification appliances. This is intended to allow the MNS to provide intelligible voice commands inside an individual building during simultaneous fire and terrorist events. System features are provided to compensate for the increased risk from fire in these cases.

Marine Corps MNS designs may interface with the facility FACP. Contact the AHJ for guidance.

5-4.6 **Interfaces with Facility PA System.** The use of the speakers and other components in the existing PA system may be appropriate in smaller size buildings in which the installation of a new speaker system is not cost effective and the existing PA system is new or relatively new, in excellent condition, and of relatively simple design. If this implementation approach is taken, an ACU must be interfaced with the existing PA system. The existing PA system must be tested to demonstrate acceptable intelligibility of the voice messages, and additional speakers must be added as required. These features must be provided in or added to the PA system:

- Emergency messages must have priority over non-emergency messages.
- All individual or zone speaker volume controls must default to the emergency sound level when used for an MNS message.
- Provide a supervisory signal when the PA system has been placed in the “OFF” condition.
- When monitoring of circuit integrity is provided by the PA system, continue monitoring even if local speaker volume controls are placed in the “OFF” position.
- Provide the required visual notification appliance network (i.e., strobes and text signs).

Marine Corps MNS designs are not required to provide an interface with the facility PA system.

Note: The term “public address system” (or “PA system”) is used in this UFC to mean both PA and intercommunication systems.

5-4.7 **Interfaces with the Wide Area MNS**. If a wide area MNS is provided on the DOD installation, the individual building MNS communicates with the central control units of the wide area MNS to provide status information, receive commands, activate pre-recorded messages, and originate live voice messages. Depending on system architecture, the manufacturer may be required to provide a system IP interface capable of allowing data transfer from an outside source to internal mass notification functions via a common data communications protocol.

Marine Corps MNS designs shall interconnect the wide area MNS with the individual building MNS through the use of common control systems.

Note: When a wide area MNS is provided on the DOD installation, the system manufacturer should provide a standard method (such as an audio line-level output and multiple relay contacts) or supply the necessary digital communication protocols to permit the DOD installation to select more than one manufacturer of individual building MNS.

5-4.8 **Logical Block Diagrams.** Figures 5-1 through 5-7 show the logical block diagrams for acceptable configurations of the individual building MNS for renovation projects, including the installation of MNS in existing buildings.

Note: These diagrams are intended to show only the functional relationships of major components. The diagrams are not intended to serve as wiring diagrams. Many essential design features for an operational system, such as end-of-line resistors, are not shown.

Figure 5-1. Individual Building Mass Notification System: Separate Fire Alarm System and MNS (Navy)

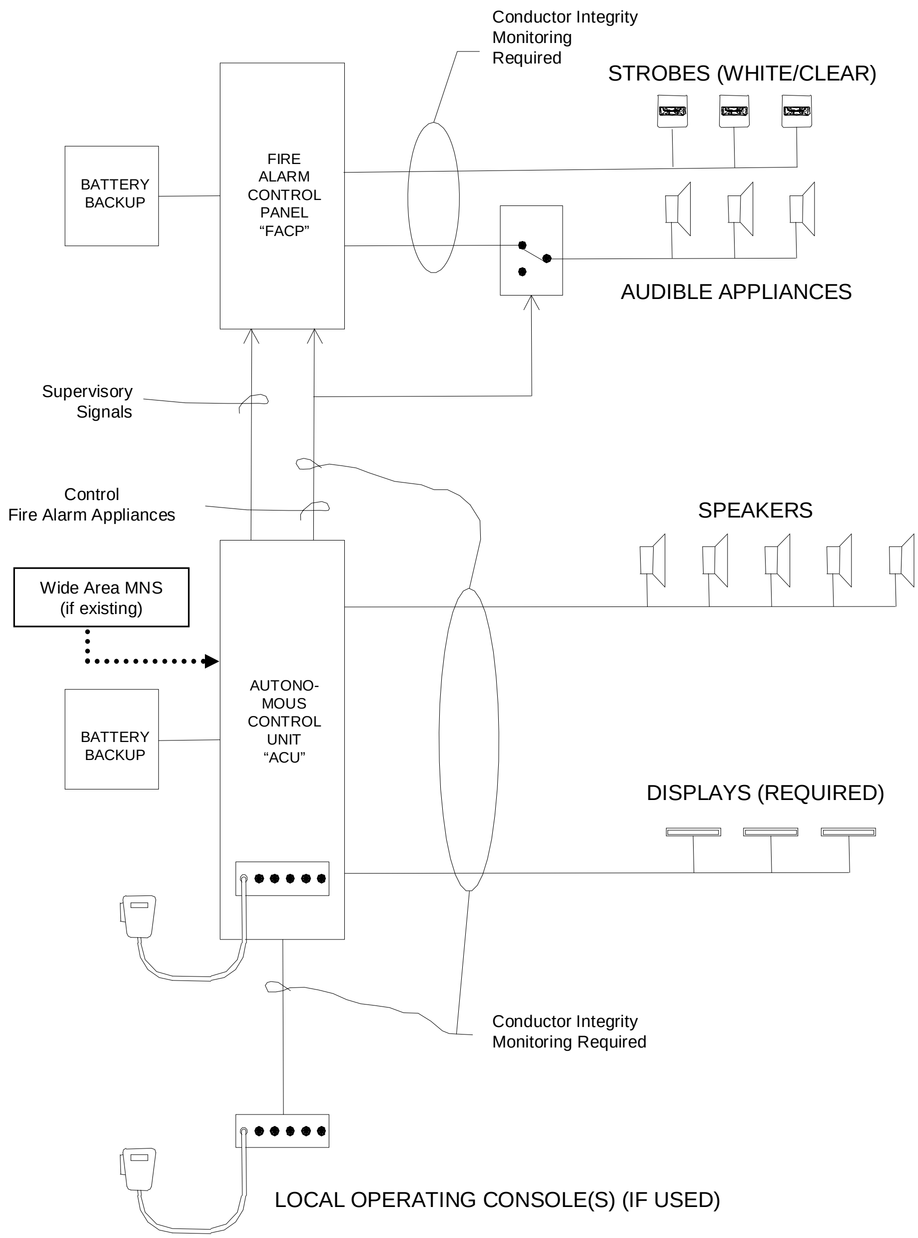


Figure 5-2. Individual Building Mass Notification System: Separate Fire Alarm System and MNS (Army and Air Force)

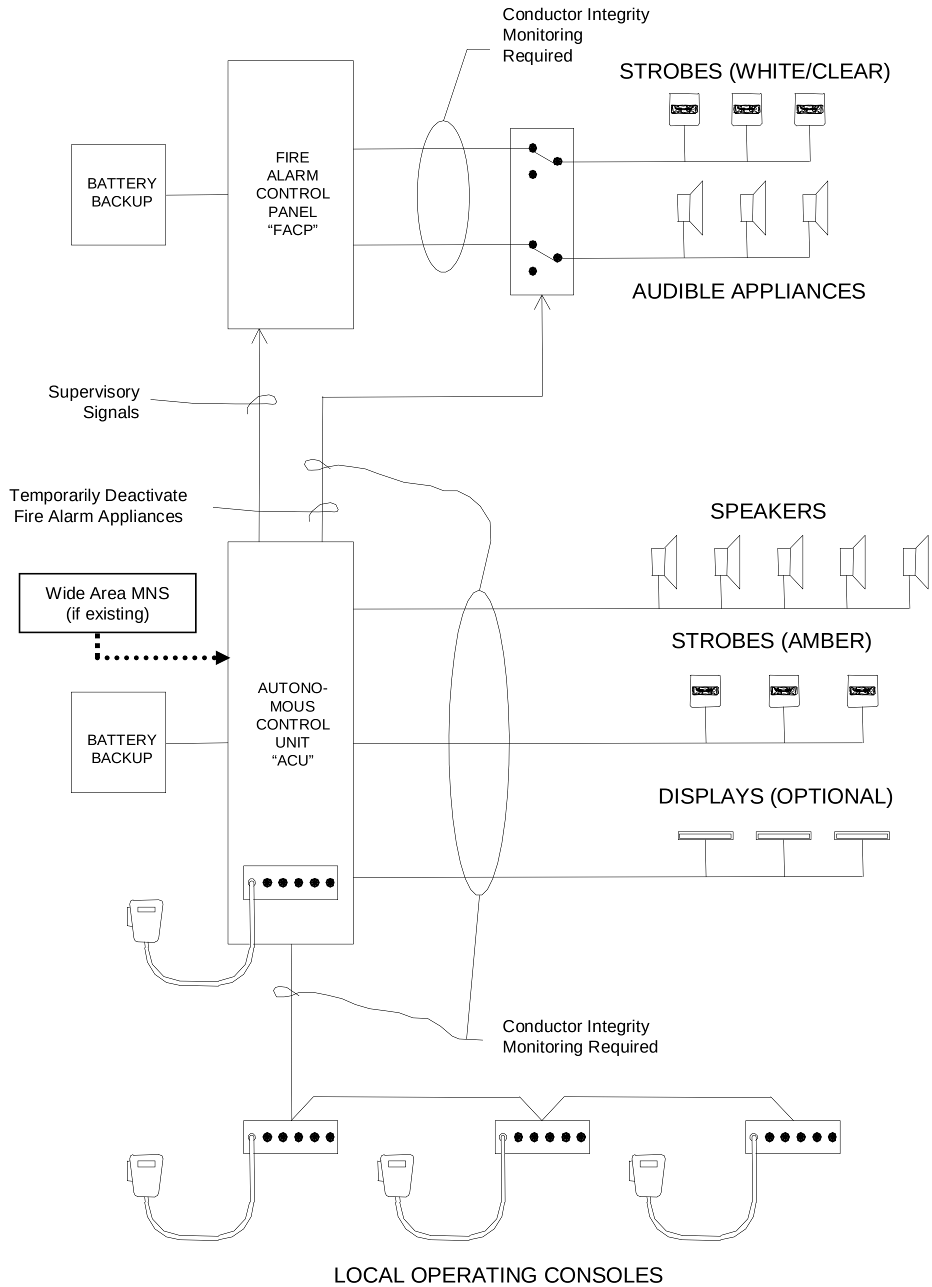


Figure 5-3. Individual Building Mass Notification System: Separate Fire Alarm System and MNS (Marine Corps)

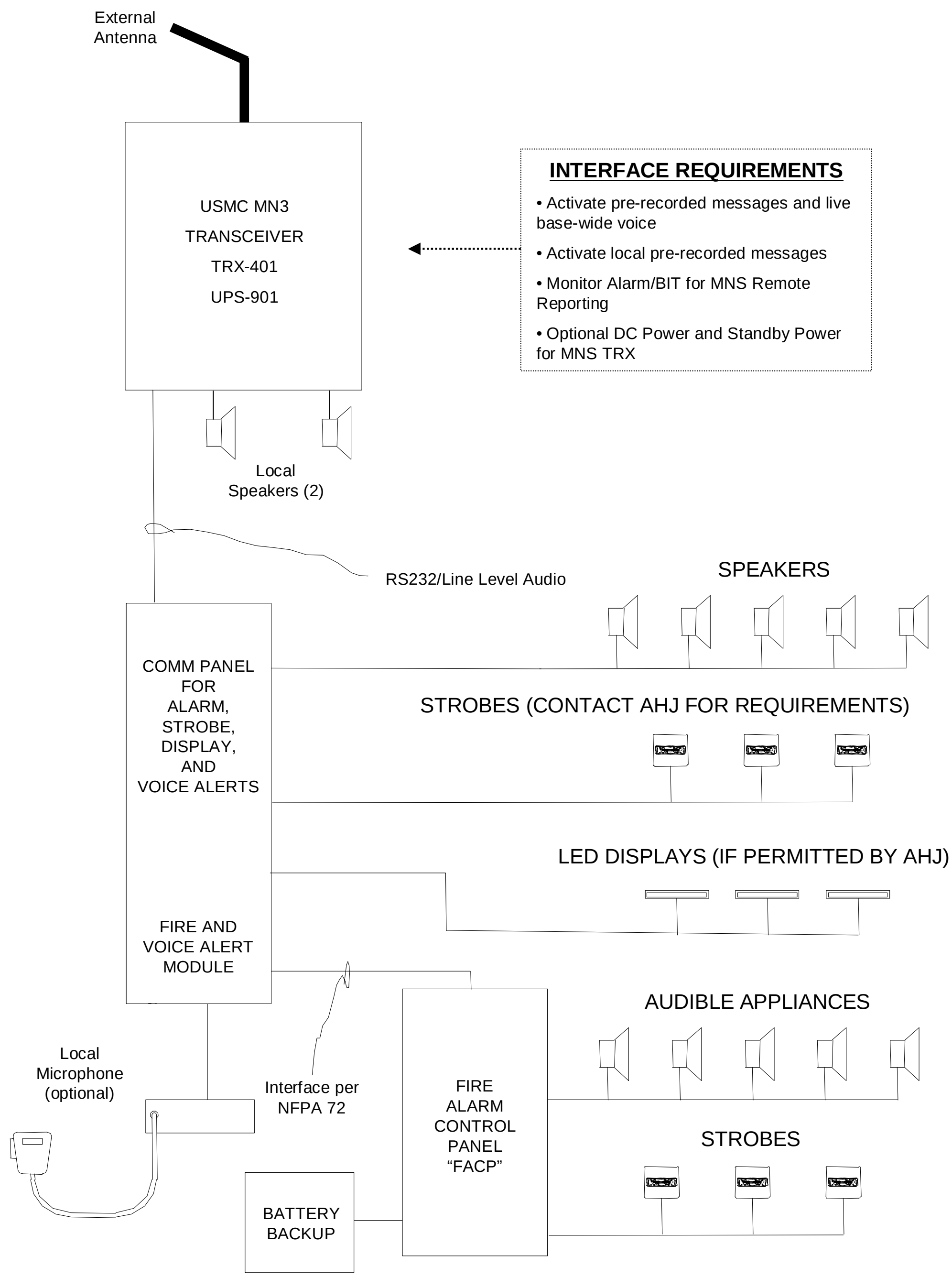


Figure 5-4. Individual Building Mass Notification System: Speakers Shared by Fire Alarm System and MNS (Navy)

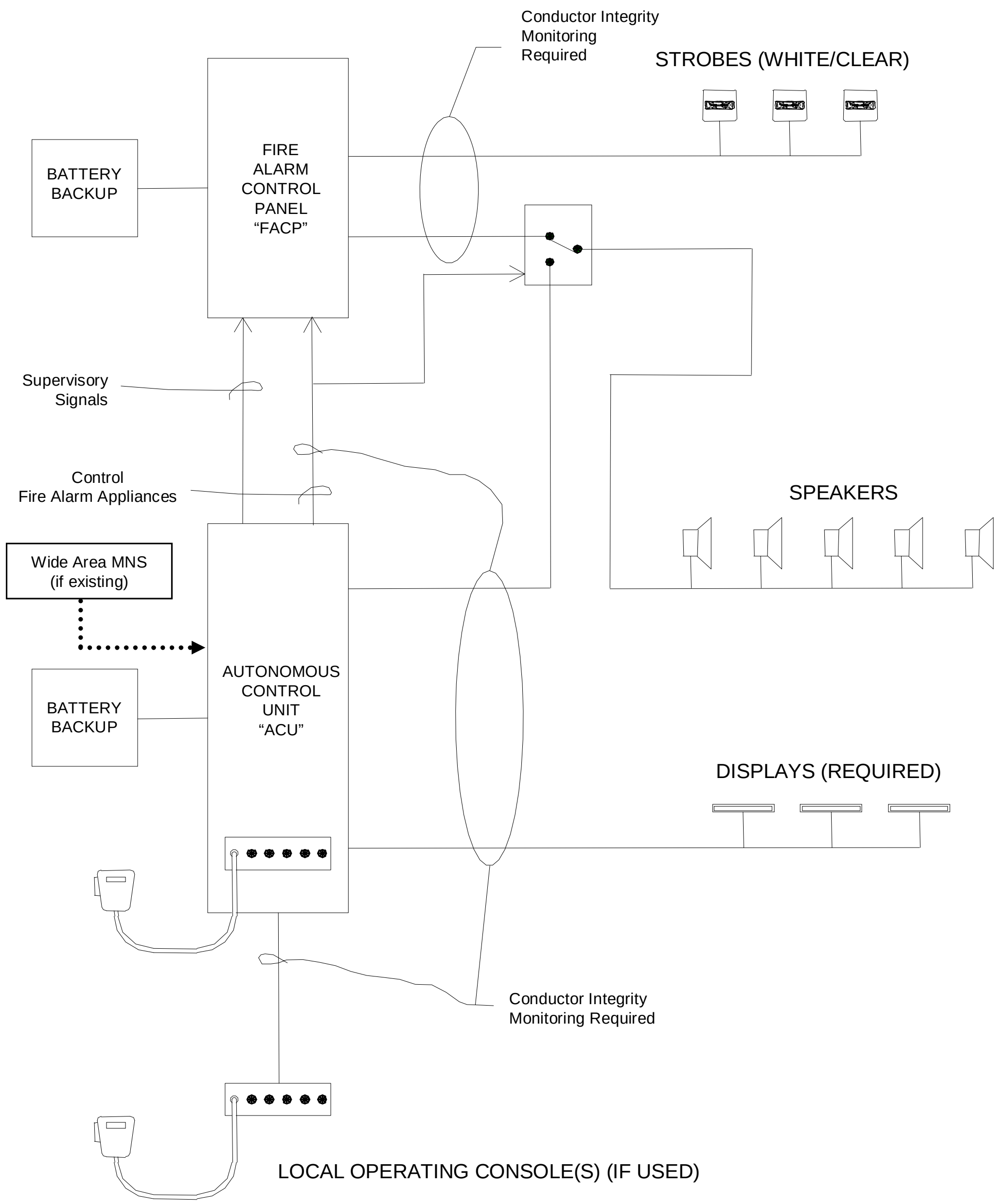


Figure 5-5. Individual Building Mass Notification System: Speakers Shared by Fire Alarm System and MNS (Army and Air Force)

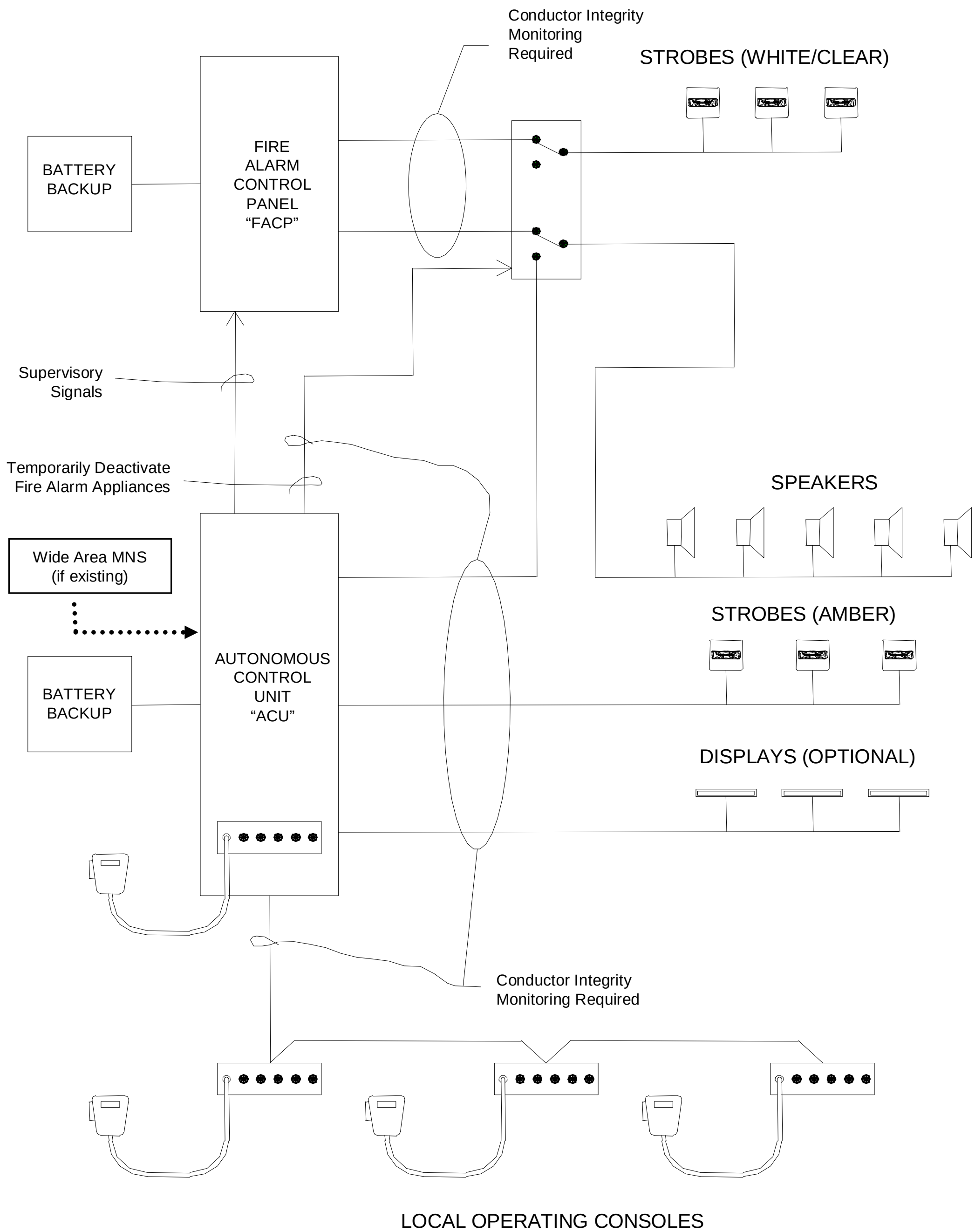


Figure 5-6. Use of Existing Public Address System: Navy

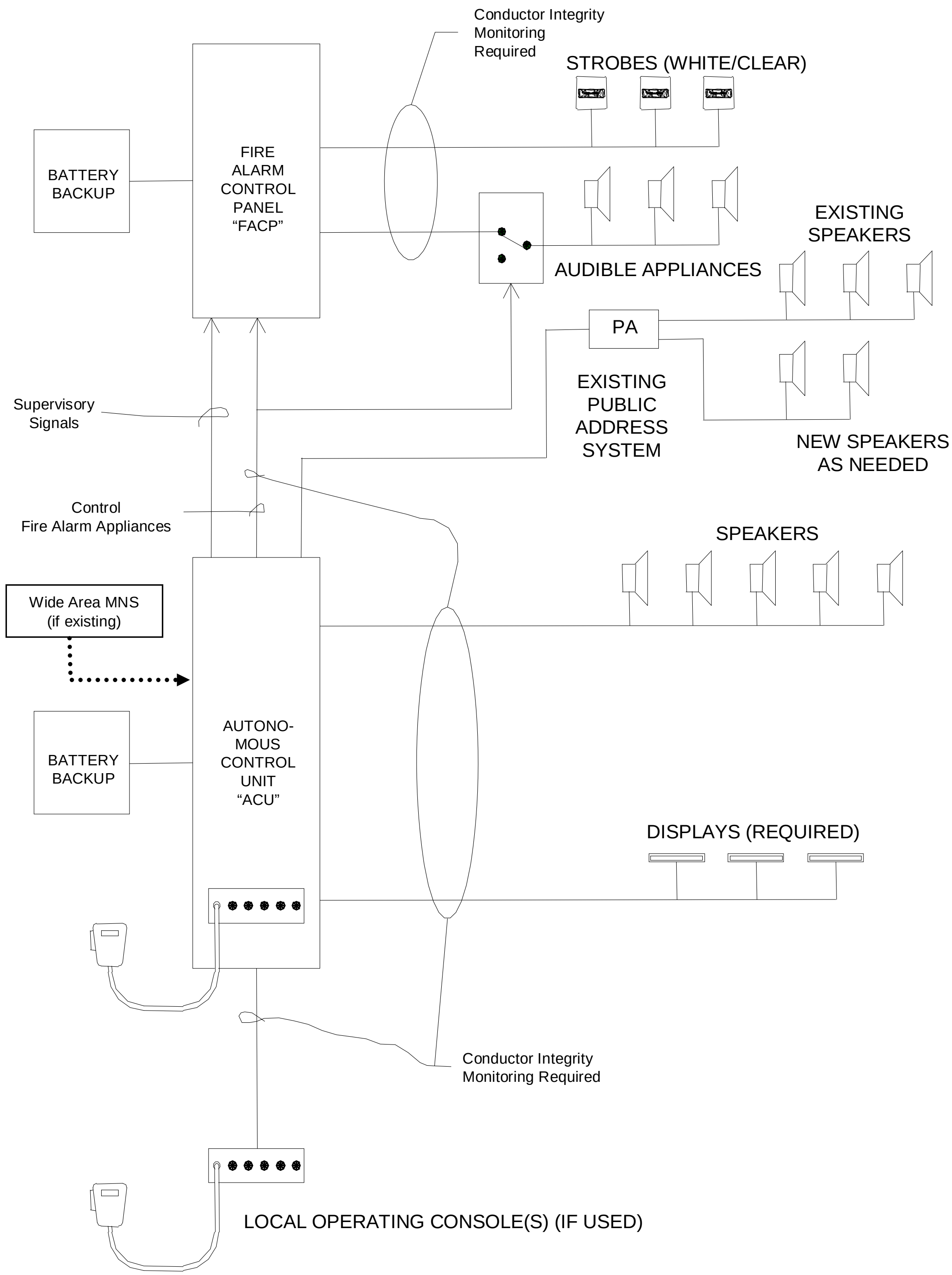
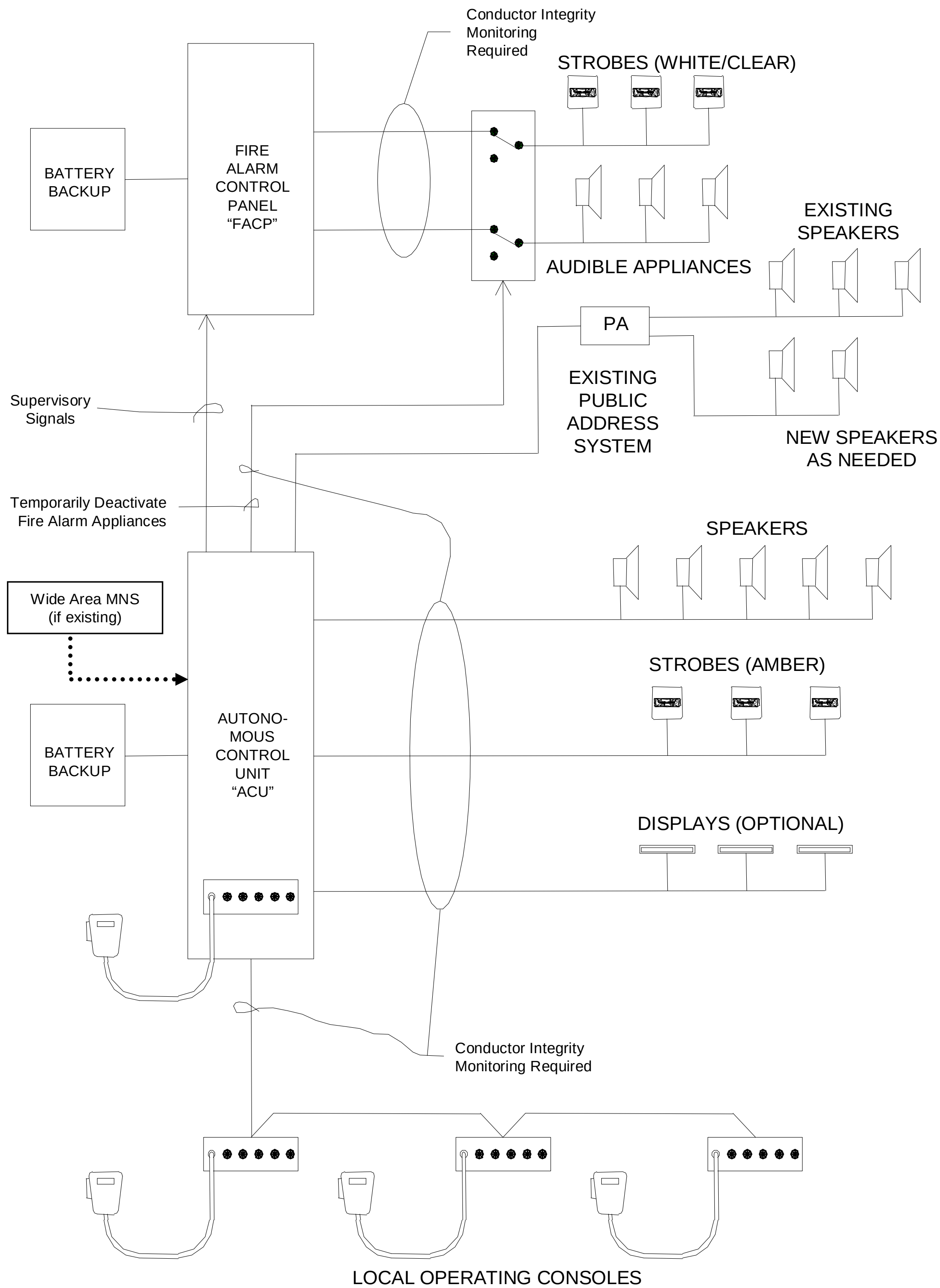


Figure 5-7. Use of Existing Public Address System: Army and Air Force



5-5 **ACU**

5-5.1 **Location.** Install the ACU at the location normally specified by the DOD component AHJ for a stand-alone FACP.

5-5.2 **Design Features.** The ACU shall:

- Be able to function independently upon failure of the wide area MNS (if provided on the DOD installation).

- Meet UL Standard 864 or UL Standard 2017, and meet the MNS requirements in NFPA 72 and the specific requirements of this UFC. The listing evaluation shall be accomplished by UL, FM, or another NRTL.

- Be able to activate strobes and text signs:

  - Navy: Energize LED-type text signs. Text signs are required over the door to each egress stairwell and over (or adjacent to) the substantial means of egress from the level of discharge. Exterior exit doors from a single room (e.g., mechanical or electrical rooms) do not require a text sign.

  - Marine Corps: Contact the AHJ for guidance on visual notification appliances.

  - Army and Air Force: Energize a set of amber strobe lights marked “ALERT” for the MNS. Simultaneously de-energize clear/white strobe lights used by the fire alarm system. Energize LED-type text signs if required by the DOD installation.

- Make general paging or other non-emergency messages available without the activation of strobes. A separate microphone must be provided for this purpose.

- Be able to interrupt PA system announcements and to silence building background music while delivering voice messages.

- Be able to accept voice messages from the DOD installation telephone system.

- Have conductor connections that comply with NFPA 72.

- **Note:** Ethernet or IP connections for initiating and indicating circuits are not currently available that will meet NFPA 72 requirements and, therefore, may not be used. Additionally, all software and hardware to be installed on DOD Ethernet or Internet systems must first successfully complete an accreditation process. Accreditation often takes a relatively long time.

- Have conductor integrity monitoring for strobes, speaker wiring, power supplies, and connections to LOC.

- Be able to switch between MNS and fire alarm notification functions without generating trouble alarms in either system.

- Have the capacity for multiple pre-recorded messages (at least eight, but more if required by the DOD installation). Pre-recorded messages shall be passed in the English language and, for OCONUS locations, also in the predominant language(s) used by the host nation. Pre-recorded messages, if used, should address at least these subjects:

  - Bomb threat or actual bomb within/around the building

  - Intruder/hostile person sighted within/around the building

  - Directions to occupants to take cover within the building

  - Evacuation of the building using exits other than the normal main entrance/exit (since the front entrance/exit is often a location targeted by terrorists)

  - Emergency weather conditions appropriate for the local area

  - “All Clear” message

  - A test message intended for verifying functionality of the system

  Marine Corps AHJ will determine the number and content of pre-recorded messages.

- \1\ Provide an alerting sound prior to playing pre-recorded messages. The alerting sound for fire alarm messages shall be different than that used for other pre-recorded messages. The fire alarm alerting sound for buildings other than child development centers shall be either the temporal three-tone or the slow whoop for fire alarm messages, unless otherwise approved by the approving authority (i.e., the AHJ for the Navy and Marine Corps; the DOD installation in conjunction with the contracting officer for the Army and Air Force). The fire alarm alerting sound for child development centers shall be a chime sound. /1/

- Be able to deliver messages quickly.

- Be able to automatically repeat pre-recorded messages until they are terminated.

- Have a microphone for delivering live voice messages.

- Provide adequate discrete outputs to initiate text signs and MNS strobes, and de-energize fire alarm strobes.

- Interface to the LOC for initiating recorded messages and delivering live voice messages from locations in the building other than at the ACU.

- Establish priority for passing messages to prevent interference between the ACU, LOC, and the wide area MNS on the DOD installation.

- Interface with the FACP to override fire alarm audible and visual notification appliances. The FACP shall provide supervised circuit integrity of interconnecting wiring between the MNS and FACP.

- Allow the MNS to temporarily override fire alarm audible messages and visual signals, and to provide intelligible voice commands during simultaneous fire and terrorist events. All other features of the fire alarm system, including the transmission of signals to the fire department, shall function properly. MNS messages shall take priority and continue to override fire alarm audible messages until the MNS message is either manually or automatically ended. If not manually ended, the MNS message will automatically end after 10 minutes.

- Provide a supervisory signal if the MNS is used to override fire alarm audible messages and visible signals during simultaneous fire and terrorist events. The supervisory signal shall be annunciated at the FACP and any remote fire alarm annunciators, and be transmitted to the fire department. The visual annunciation of the separate supervisory signal shall be distinctly labeled or otherwise clearly identified.

SE The Army requires that this supervisory signal be separate from other fire alarm system supervisory signals.

- Provide remote monitoring of trouble, supervisory, and alarm functions to a constantly occupied location. This may be the same location that receives fire alarm system signals or to the central control units of the wide area MNS on the DOD installation.

- Provide a single switch or operating mechanism capable of shutting down all HVAC equipment in the facility in accordance with the requirements of UFC 4-010-01. If permitted by the DOD installation, this shutdown capability may be provided at a LOC or be deleted entirely if the capability is otherwise provided at a location readily accessible to building occupants.

- Provide a complete set of self-diagnostics for the controller and appliance network.

- Have a local diagnostic information display.

- Have a local system event log file.

5-5.3 **Off-the-Shelf Equipment.** ACU equipment furnished as part of the individual building MNS shall be COTS and shall be tested to the standards of UL or FM by a NRTL.

5-5.4 **Programming Codes.** All programming codes or passwords required to access, update, modify, and maintain the ACU shall be provided to the DOD installation no later than the date of final system acceptance.

5-5.5 **Power Supply Features.** The power supply shall:

- Be capable of accepting 120/240 VAC, 50/60 Hz.

- Be appropriate for a MNS that meets at least the minimum NFPA 72 requirements for standby power capacity. In addition, secondary (standby) power should be provided as follows: immediately upon loss of normal AC power, the standby source of power shall provide a minimum of 60 minutes of mass notification at the maximum connected load.

- Disable use of any microphones intended solely for general paging or other non-emergency messages upon loss of normal AC power.

- Conform to applicable sections of NFPA 72.

- Use only COTS components.

- Provide surge protection in accordance with UFC 3-520-01.

5-6 **LOC**

5-6.1 **Locations.** Provide LOC to allow emergency response forces and building occupants to access the MNS and originate messages in emergency situations from locations in the building other than from the ACU. Follow these requirements:

- Provide a separate LOC for use by the fire department near the building FACP (or fire command center) unless this is also the location of the ACU.

- Do not place a LOC inside of locked rooms or closets (with the possible exception of the LOC intended for use by the fire department near the FACP).

- Install LOC at those facility entrances/exits that will be used when building access is limited because of elevated terrorism threat levels.

Note: This LOC is intended to enable immediate notification of building occupants when unauthorized building access is threatened or has occurred at this location.

- Army and Air Force: Provide a LOC so that occupants do not need to travel a distance in excess of 61 m (200 ft) horizontally or to travel to other floors to access a LOC.

- Army and Air Force: Make LOC available for use by visitors in those facilities open to unescorted visitors or to the public.

- Navy: Provide no more than one LOC (if necessary) in addition to the ACU. Locate the LOC as directed by the responsible fire protection engineer.

- Marine Corps: Provide no more than one LOC (if necessary) in addition to the ACU. Locate the LOC as directed by the AHJ.

5-6.2 **Design Features.** The LOC shall:

- Have a remote microphone station that emulates operation of the MNS from the ACU.

- Have an easy method (such as individual manual activation push buttons) of activating the MNS pre-recorded messages. Signage shall be provided to allow rapid recognition of the means of initiating the pre-recorded messages.

SE Activation of MNS pre-recorded messages is not required for Marine Corps LOC.

- Provide a single switch or operating mechanism capable of shutting down all HVAC equipment in the facility in accordance with the requirements of UFC 4-010-01. If permitted by the DOD installation, this shutdown capability may be provided at only one LOC when multiple LOCs are installed, or be deleted from all LOCs if the capability is otherwise provided at a location readily accessible to building occupants.

- Be protected in a small, wall-mounted enclosure.

- Have supplemental heating and ventilation for those enclosures located outdoors or in areas where the LOC will be exposed to temperatures or humidity outside of the manufacturer's design limits.

- Be protected from tampering by use of a break-glass, thumb-lock, tamper wire, tamper alarm, or equivalent protection. This is not required in those facilities with limited access so that unauthorized use would not reasonably be expected to occur. Enclosures that can be opened only by a key shall not be used.

SE Marine Corps LOC may use key-operated locks when emergency response forces are provided with immediate access (e.g., master key, Knox-box®)

- Have signage on the outside of the enclosure similar to “Mass Notification” and “HVAC Emergency Shutdown” (if applicable).

5-7 NOTIFICATION APPLIANCE NETWORK

Note: Also see paragraph 6-5 for notification appliance requirements in special occupancies.

5-7.1 **Audible Appliance Network.** These are the requirements for the audible appliance network:

- Provide appliances capable of satisfying \1\ ABAAG /1/.

- Use speakers suitable for the intended climatic and environmental conditions.

- Use speakers suitable for installation in commercial/industrial applications with consideration of electrically hazardous (classified) locations.

- Provide speakers and installation methods compliant with DCID 6/9 for areas classified as SCIF.

- Network design shall comply with NFPA 72.

- Speakers shall meet the listing requirements of UL Standard 1480.

- Provide speakers at all locations inside a building where the building fire alarm must be audible.

- \1\ Ensure speakers in the vicinity of the ACU and LOC will not create acoustical feedback or otherwise interfere with the ability to deliver live voice messages. /1/

- Provide speakers mounted on the exterior of the building to provide notification of any areas commonly used by building occupants. These include courtyards, covered break areas, designated smoking areas, and sidewalks leading from the building’s exit doors to a public street or from parking areas for a distance up to 5 m (16 ft) from the building. Use speakers with directional characteristics that transmit minimal backplane noise when mounted on the sides of the building. Generally, the speakers should be located near entrance/exit doors.

- Provide an effective voice communication within buildings using a design including many speakers, each with low audio intensity.

- Install speakers with field-adjustable tap settings to allow adjustment after installation to meet audibility and intelligibility requirements.

- Do not use speakers exceeding 15 W for indoor applications without prior approval of the AHJ.

5-7.1.1 **Speaker Design Recommendations**

- Speakers rated at 2 W or less and provided with multiple tap settings to adjust the output power can often provide acceptable sound quality in most occupied areas.

- Speakers rated at 8 W or less and provided with multiple tap settings can often provide acceptable sound quality for most large or very noisy areas.

- Speakers rated at 8 to 10 W for interior distribution should be used when the speakers are also intended to meet the better sound quality normally expected from PA systems. These speakers should be capable of a frequency response over the range of at least 200 to 10,000 Hz.

Note: Such speakers are often adjusted to operate at a tap setting of 2 W or less, but are used because their sound quality is greatly superior to the small speakers typically used in fire alarm systems.

- Wiring methods shall comply with NFPA 72. Class B wiring is permitted unless Class A wiring is required for fire alarms systems on the DOD installation.

5-7.1.2 \1\ **Intelligibility** /1/ **Requirements**

- Verify intelligibility by measurement after installation.

- \1\ Ensure that a CIS value greater than the required minimum value is provided in each area where building occupants typically could be found. The minimum required value for Navy and Marine Corps is 0.7 CIS. The minimum required value for Army and Air Force is 0.8 CIS, although rounding is permitted such that a value of 0.75 may be rounded to 0.8. /1/

- Areas of the building provided with hard wall and ceiling surfaces (such as metal or concrete) that are found to cause excessive sound reflections may be permitted to have a CIS score less than \1\ the minimum required value /1/ if approved by the DOD installation, and if building occupants in these areas can determine that a voice signal is being broadcast and they must walk no more than 10 m (33 ft) to find a location with at least \1\ the minimum required CIS value within the same area. /1/

- Areas of the building where occupants are not expected to be normally present are permitted to have a CIS score less than \1\ the minimum required value /1/ if personnel can determine that a voice signal is being broadcast and they must walk no more than 15 m (50 ft) to a location with at least \1\ the minimum required CIS value within the same area. /1/

- Measurements should be taken near the head level applicable for most personnel in the space under normal conditions (e.g., standing, sitting, sleeping, as appropriate).

- \1\ The distance the occupant must walk to the location meeting the minimum required CIS value shall be measured on the floor or other walking surface as follows:

    - Along the centerline of the natural path of travel, starting from any point subject to occupancy with less than the minimum required CIS value.

    - Curving around any corners or obstructions, with a 300-mm (12 in.) clearance therefrom.

    - Terminating directly below the location where the minimum required CIS value has been obtained. /1/

- Commercially available test instrumentation shall be used to measure intelligibility as specified by IEC 60849 and IEC 60268-16. The mean value of at least three readings shall be used to compute the intelligibility score at each test location.

- \1\ Occasionally, large DOD buildings are designed to provide cavernous-type open areas to meet unique operational requirements. Such areas are typically designed with hard wall and ceiling surfaces (such as metal or concrete) without acoustical treatments, and this has been found to cause excessive sound reflections that prevent obtaining the normal, minimum required CIS value. In such facilities, the cavernous-type open area is permitted to have locations with a CIS value lower than the normal, minimum required CIS value when the following conditions are met:

    - The requirement for a deviation from the normal, minimum CIS criteria is identified in the design phase.

    - Justification for the deviation from the normal, minimum CIS criteria is provided to the approving authority (i.e., the AHJ for the Navy and Marine Corps; the DOD installation in conjunction with the contracting officer for the Army and Air Force). The justification shall address all factors relevant to the request for deviation from normal, minimum CIS criteria, including, but not limited to: the operational requirements that restrict the installation of acoustical wall and ceiling treatments; the potential use of special speaker technologies such as directional speakers or stacked speaker systems; and the availability of physically larger or higher-fidelity speakers even though such speakers might not be listed for fire alarm use.

Note: Deviation from normal, minimum CIS criteria should not be requested for the design of normal, large, open areas that are typically found in permanent DOD buildings, such as dining halls, theaters, and gymnasiums. The potential for deviation from normal criteria is intended to address the rare exception to normal criteria that is sometimes needed for DOD buildings with unique operational requirements.

- o Building occupants located in the large, cavernous area can adequately understand the message content in the voice signal being broadcast. Whether the voice message is adequately understood shall be determined by the approving authority (i.e., the AHJ for the Navy and Marine Corps; the DOD installation in conjunction with the contracting officer for the Army and Air Force).
- o The CIS value is not less than 0.6 at any location within the large, cavernous area.
- o The building occupants in the large, cavernous area must walk no more than 30 m (98 ft) to find another location within the large, cavernous area having at least the normal, minimum required CIS value. /1/

Note: An STI score of 0.5 is considered equivalent to a CIS score of 0.7. \1\ An STI value of 0.7 is considered equivalent to a CIS value of 0.8. /1/

5-7.1.3 \1\ DELETED /1/

5-7.2 **Visual Appliance Network.** These are the requirements for the visual appliance network:

- Provide visual appliances capable of satisfying all \1\ ABAAG. /1/
- Use visual appliances suitable for the intended climatic and environmental conditions.
- Use visual appliances suitable for installation in commercial/industrial applications with consideration of electrically hazardous (classified) locations.
- Strobes shall meet the listing requirements of UL Standards 1638 and 1971. Text signs shall comply with UL Standard 48.
- Strobes are not required outside the building.
- Where more than two visible notification appliances are in any field of view, they shall flash in synchronization.
- Wiring methods shall comply with NFPA 72. Class B wiring is permitted unless required otherwise by the local AHJ.

5-7.2.1 **Navy-Specific Requirements**

- Provide clear strobes marked with the word "ALERT" for shared use by the facility's MNS and FACP.

- Provide LED text signs. Text signs are required over the door to each egress stairwell and over (or adjacent to) the substantial means of egress from the level of discharge. Exterior exit doors from a single room (e.g., mechanical or electrical rooms) do not require a text sign. (See Chapter 7 for operational requirements and information on message content.)

5-7.2.2 **Marine Corps-Specific Requirements**

- Contact the AHJ for guidance on visual notification appliances.

5-7.2.3 **Army- and Air Force-Specific Requirements**

- Provide amber-colored strobes marked with the word "ALERT" to alert the hearing impaired. Provide these strobes in addition to existing clear strobes provided for the building fire alarm system.

- Amber strobes activated in conjunction with the delivery of a pre-recorded voice message shall operate continuously until message termination. Amber strobes activated in conjunction with the delivery of a live voice message shall operate during the message and for not less than 15 seconds after the message ends.

- Clear/white strobes activated by the fire alarm system shall not operate during those periods when the amber strobes are in operation, but otherwise shall operate continuously until the fire alarm system is reset.

5-8 **INTERFACES WITH WIDE AREA MNS.** The individual building MNS shall be capable of interfacing with an existing wide area MNS. If a wide area MNS is not presently provided on the DOD installation, the individual building MNS shall be designed to allow future interface with a wide area MNS procured from another manufacturer. The electrical requirements, computer codes, or other protocols that are needed to interface the systems shall be provided to the DOD installation. At a minimum, the wide area MNS shall be able to provide and the individual building MNS shall be able to receive an audio line-level input. The individual building MNS shall not be activated or controlled by a giant voice system unless the giant voice system also meets the design and performance requirements of a wide area MNS.

CHAPTER 6

SPECIAL CONSIDERATIONS

6-1 **OVERVIEW.** DOD requirements for antiterrorism mandate the installation of individual building MNS during new construction and renovation projects. These systems are presently being installed on most DOD installations. Although not required by the DOD, use of a wide area MNS may be an important part of the antiterrorism strategy established by DOD installations.

6-2 **IMPLEMENTATION PLAN.** Each DOD installation should establish an implementation plan that establishes a comprehensive approach to MNS that is acceptable to security, communications, and fire protection engineering personnel. Elements of an implementation plan should include a needs assessment, requirements definition, alternatives evaluation, system selection, and implementation schedule. Some DOD installations may choose to first select and install a wide area MNS and subsequently install an individual building MNS that is compatible with the wide area MNS. This is not required by the DOD but will immediately increase the readiness of the DOD installation to respond to terrorist and other threats. Other DOD installations may choose to install individual building MNS in new construction and renovation projects, and also in their most significant and important facilities. This approach will spread the cost of installation over a longer time. The completed implementation plan will serve as a roadmap to address the specific needs and unique circumstances associated with each particular DOD installation.

6-3 **GIANT VOICE SYSTEM.** Some DOD installations are currently provided with a giant voice system for outdoor notification. Many of these systems were designed in the Cold War era and were intended to transmit tones signals, not voice signals. These systems may not adequately provide intelligible voice signals over much of the DOD installation. Closer spaced and less powerful speaker arrays are often required to achieve adequate intelligibility. Existing giant voice systems often have proved unsatisfactory in providing intelligible messages between multi-story buildings in high population density areas (such as industrial areas). Newer speaker technologies are available and should be considered for installation in these areas. Additionally, this UFC does not permit the use of giant voice systems inside of buildings because of the difficulty in achieving acceptable intelligibility of voice messages, the need to monitor circuit integrity, and the requirement to provide visual notification appliances for persons with hearing disabilities. This UFC does not permit an existing giant voice system to activate or control an individual building MNS unless the giant voice system fully complies with the requirements for a wide area MNS.

6-4 **TELEPHONE ALERTING SYSTEM.** A telephone alerting system may be useful in supplementing a wide area MNS and providing notification to building occupants where mass notification would not be required by UFC 4-010-01, such as in small facilities with only a few occupants and single-family and duplex military family housing. Telephone alerting system services are sometimes outsourced to reduce the operation and maintenance burden on the base; however, outsourcing increases reliance on systems not under direct control of the facility being serviced and could impact the reliability or vulnerability of the telephone system capability.

6-5 SPECIAL OCCUPANCIES

6-5.1 **No Self-Preservation Capability.** This UFC does not require the installation of mass notification capability for those persons who are unable to protect themselves and could not take action without the assistance of others. Examples include prisoners in correctional facilities that are physically prevented from taking action or patients in a hospital that require assistance from the medical staff to take action. Mass notification capability is still required for the staff of these facilities so they may know to take action to protect themselves and those in their care. The appropriate approach for these facilities is to emulate the design solution that would be applied in that building for the installation of a new fire alarm system.

Individual building MNS for Marine Corps projects shall serve as a subsystem of the wide area MNS as described in chapters 3 and 5.

6-5.2 **Not Occupied by Hearing Impaired Persons.** This UFC does not require the installation of visual notification signals in areas not subject to occupancy by persons who are hearing impaired, except that visual notification signals shall be provided in areas where hearing protection is worn due to high ambient noise levels.

Note: Visual notification signals must be provided even if the area is only accessed occasionally by personnel who are hearing impaired and granted unaccompanied access, such as maintenance or cleaning personnel, except for those areas listed in section 6-5.3.

6-5.3 **Housing and Lodging Facilities.** When MNS is required for personnel housing (such as barracks, dormitories, lodges, temporary or transient living facilities, and other sleeping quarters with 11 or more unaccompanied persons) or for military family housing (such as 13 or more family units in one building), audible and visible MNS appliances shall be provided.

6-5.3.1 Audible appliances, including in sleeping areas, shall provide a sound level of at least 15 dBA above the average ambient sound level and at least 5 dBA above the maximum sound level having a duration of at least 60 seconds, and they shall provide a CIS score equal to or greater than 0.7 (Navy and Marine Corps) or 0.8 (Army and Air Force). Sleeping areas shall also be provided with a minimum sound level of 75 dBA unless a CIS score equal to or greater than 0.7 (Navy and Marine Corps) or 0.8 (Army and Air Force) is provided.

6-5.3.2 Visual appliances are not required within private living and sleeping rooms except those that are specifically designated by the DOD installation for the accommodation of hearing-impaired individuals. Visual notification appliances shall be provided in other general usage areas such as common rooms, day rooms, meeting rooms, hallways, corridors, lobbies, and public restrooms.

CHAPTER 7

OPERATIONAL CHARACTERISTICS

7-1 **INTRODUCTION.** This chapter provides a description of the most significant operating characteristics of wide area MNS and individual building MNS.

7-2 WIDE AREA MNS

7-2.1 **Central Control Stations.** A primary and backup central control station are provided. At each central control station, a computer with a GUI is provided. With the GUI, the system operator can send live voice signals using a microphone and can send or activate pre-recorded voice signals, tones, and music signals. The signals can be sent to individual buildings, zones of buildings, individual outdoor speaker arrays, zones of outdoor speaker arrays, or to the entire DOD installation. Different signals can be sent to different locations. The central control station can receive voice signals by telephone or radio and patch those signals through to desired locations on the DOD installation. Music, such as Reveille and the national anthem, can be transmitted throughout the DOD installation. The central control station automatically or manually assigns priorities to all transmitted signals.

7-2.2 **Regional or National Command Centers.** When required by the DOD component, those signals transmitted on the DOD installation that meet a screening criteria for priority are automatically relayed to a regional or national command center, or to nearby DOD installations that have a need to know of the emergency.

7-2.3 **Public Alert and Warning System.** This national system is under development by the Department of Homeland Security as directed by Executive Order 13407. DOD systems are required by this same Executive Order to coordinate with the national system. The wide area MNS will be designed with the capability to receive, record, and distribute voice messages and alert signals received from the Commander-in-Chief through the national public alert and warning system. This will permit the central control station to immediately distribute the voice messages or alert signals, or to delay the distribution as necessary to meet operational requirements as approved by the DOD installation commander.

7-2.4 **HPSA.** Designated HPSAs are provided with a microphone to enable an on-scene commander, security forces, or others (such as a drill instructor) to use the HPSA for local announcements and instructions. In some cases, individual speakers or all speakers of these arrays may be locally selected and energized. The speakers for these arrays will be highly directional when designed to permit operation from a location directly below the speakers without feedback or harmful sound pressure levels.

7-2.5 **Supplemental Mass Notification Delivery Systems.** The wide area MNS can also interface with and control other notification systems such as telephone dialers, tone alert systems, computer network alerting systems, pagers, facsimile machines, and vehicular traffic directional control signs. Text notification via wireless devices and desktop computer notification are effective means for delivering mass notification messages to multiple recipient groups. Wireless text messaging is effective in reaching off-base personnel. This is especially useful for OCONUS locations. Desktop notification is particularly effective when more complex information must be conveyed, and can be a cost-effective interim solution prior to installing an individual building MNS.

Note: See Appendix C for a discussion of requirements for Internet-based communication systems (under development).

7-3 INDIVIDUAL BUILDING MNS

7-3.1 **Combined Systems.** In new construction, mass notification and fire alarm functions are combined into one system. PA may also be combined into this system. In renovation projects, combined systems are preferred, but separate systems may be permitted in some applications. The mass notification functions can temporarily disable the fire alarm notification appliances to allow intelligible voice announcements when needed in the case of simultaneous terrorist and fire events. This is necessary because arson and unauthorized fire system activation are methods of attack that have been used previously by terrorists.

SE Individual building MNS for Marine Corps projects shall serve as a subsystem of the wide area MNS as described in Chapters 3 and 5, and might not interface with the fire alarm system.

7-3.2 **LOC.** These consoles are provided to allow building occupants and emergency response forces to operate the system and provide live voice or pre-recorded messages to personnel in the building. They also enable the building occupants to completely shut down the heating, ventilating, and air conditioning system as needed to respond to a terrorist event or external natural disaster. Army and Air Force systems permit most building occupants to access the LOC, and use tamper-resistant features to minimize unauthorized use. The Navy limits access to the LOC to emergency response forces and a few of the building occupants, such as the building manager, security staff, or the commanding officer’s staff. The Marine Corps does not provide a LOC but does provide a remote microphone.

7-3.3 **ACU.** The ACU has the same capabilities to operate the system as a LOC, plus the ability to override or disable the mass notification capability. Access to the ACU is limited to emergency response personnel.

7-3.4 **Notification Appliances.** Speakers are used to provide intelligible voice signals for mass notification. Strobes are used to meet the accessibility requirements for those persons with hearing disabilities. The Army and Air Force use amber-colored strobes to alert those with hearing disabilities. The Navy uses one set of clear strobes for both fire and mass notification. These strobes are marked “ALERT” instead of “FIRE”. The Navy also uses text signs to assist persons with hearing disabilities. These signs read “EVACUATE” when the fire alarm system is in alarm. The signs read “ANNOUNCEMENT” when a mass notification message is being transmitted, and the text sign will continue for 10 seconds after the end of the announcement. Text signs are required over the door to each egress stairwell and over (or adjacent to) the substantial means of egress from the level of discharge. Exterior exit doors from a single room (e.g., mechanical or electrical rooms) do not require a text sign.

Note: The Marine Corps uses notification appliances as specified by the AHJ.

CHAPTER 8

MAINTENANCE

8-1 **INTRODUCTION.** This chapter was developed on the basis of recommendations from MNS manufacturers, as well as experience with similar computer-based systems. Maintenance requirements established for each MNS must consider the manufacturer's maintenance recommendations and the applicable DOD maintenance requirements. MNS shall be maintained so that they comply with the minimum operating parameters recommended by the manufacturer.

8-2 **MAINTENANCE RESPONSIBILITIES.** DOD components that have assigned maintenance responsibilities include:

8-2.1 **Air Force.** Air Force communications squadrons are responsible for maintaining giant voice systems in accordance with AFI 21-116 on Air Force installations. Civil engineering squadrons are usually responsible for maintaining individual building MNS on Air Force installations that are designed and installed in accordance with this UFC.

8-2.2 **Marine Corps.** Headquarters Marine Corps (HQMC) Technical Service Agency is responsible for maintaining the MNS across the Marine Corps.

8-3 QUALIFICATIONS OF MAINTENANCE PERSONNEL

8-3.1 **Inspection, Testing, and Maintenance Tasks.** Only personnel trained and qualified in maintaining and repairing MNS will perform inspection, testing, and maintenance tasks. Most types of MNS use technology commonly found in fire alarm systems, giant voice, or other outdoor voice and siren warning systems, and similar maintenance skills are needed. If specific manufacturer training is available, maintenance personnel must satisfactorily complete the training to be considered qualified. If specific manufacturer training is not available for a MNS, personnel shall be considered qualified if they have achieved a NICET Level III in fire alarm systems or in low-voltage electronic communication systems, or have achieved the UL certification level for fire alarm systems. Tasks must be performed according to the manufacturer's instructions. Certain jurisdictions may require varying levels of continuing education to maintain recognized qualifications. Overseas locations should contact their command fire protection engineering office for guidance on appropriate qualifications. Military personnel who have satisfactorily completed the required schools in their career field in fire detection and alarm system maintenance or communications electronics are considered qualified.

8-3.2 **Other Inspections.** This UFC lists inspection tasks that must be performed during regularly scheduled facility inspections. Fire prevention, safety, and maintenance personnel, as well as other individuals familiar with MNS operations, shall perform these inspection tasks.

8-3.3 **Maintenance Records.** Each DOD installation must maintain a permanent record of completed inspection, testing, and maintenance tasks in accordance with each agency's program for record keeping of recurring facility maintenance. Records may be hard copy or electronic. Where no DOD component-wide programs exist, records should be developed locally. Records must be maintained for every facility and must include, as a minimum, each task, the date scheduled, the date completed, and the name of the person completing the task.

8-4 **INDIVIDUAL BUILDING MNS.** See UFC 3-600-02, paragraph 2-2.2, "Fire Detection and Alarm Systems," for applicable guidance on inspecting, testing, and maintaining engineered protection features in DOD facilities.

8-5 **WIDE AREA MNS.** Tables 8-1 and 8-2 provide maintenance information for the central control unit and communications network for a wide area MNS.

Table 8-1. Central Control Unit Maintenance

Frequency	Component	Tasks
Weekly	Central control unit, diagnostic log files	• Review the event log file; verify that the correct events were logged. • Review the system diagnostic log file; correct deficiencies noted in the file.
	Central control unit, hard drive	• Delete unneeded log files. • Delete unneeded error files. • Verify that sufficient free disk space is available.
	System – Functional test	Send out an alert to a small set of pre-designated receiving devices and confirm receipt.
	System – Security	If remote control software is loaded onto the system, verify that it is disabled to prevent unauthorized system access.

Frequency	Component	Tasks
Monthly	System – Functional test	Send out an alert to a diverse set of pre-designated receiving devices and confirm receipt. Include at least one of each type of receiving device.
	Central control unit, reset	Power down the central control unit computer and restart it.
Quarterly	System – Software backups	Make a full system software backup. Rotate backups based on the accepted practice at the site.
	Central control unit, computer	• Verify proper operation of the computer. • Defragment the hard drive. • Verify unobstructed flow of cooling air. Clean filters. Remove dust buildup on cooling fans, cooling fins, and air intake vents.
	Central control unit, uninterruptible power supply (UPS)	• Verify that the system will operate in the absence of line power; discontinue line power to the system and verify functionality. • Test the UPS. See NFPA 70B.
Yearly	System – Software backups	Test the current software backup system by installing the system backup.
	Central control unit, operation	• Verify the content of pre-recorded messages. • Verify activation of the correct pre-recorded message based on a selected event. • Verify activation of the correct pre-recorded message based on a targeted area. • Verify that the central control unit security mechanism is functional.

Table 8-2. Communications Network Maintenance

Frequency	Component	Tasks
Weekly	Central control console	Verify that no diagnostic failures are indicated.
Monthly	HPSA/Wireless transceivers	Perform silent activation and/or health monitoring of all components.
	Total system functionality	• Perform a test system activation for a particular zone/building/area. • Verify that field components perform as expected.
Quarterly	Central control unit, UPS	• Verify that the system will operate in the absence of line power; discontinue line power to the system and verify functionality. • Test the UPS. See NFPA 70B.
Every 6 months	Field components	• Perform a visual inspection of all components. Verify that enclosure integrity is not compromised. • Perform a visual inspection of the antenna. Verify a solid connection and no corrosion. • Perform a visual inspection of the transceivers. Verify proper operation. • Generate a conductor integrity monitor alarm. Verify the alarm status on the central console. • Disconnect AC power. Verify the AC power failure alarm status on the central console. • Disconnect AC power. Verify the battery voltage under load.
Every 6 months	Wireless signals	Check forward/reflected radio power.

GLOSSARY

Acronyms and Abbreviations

\1\ **ABAAG**—Architectural Barriers Act Accessibility Guidelines /1/

AC—alternating current

ACU—Autonomous Control Unit

AFB—Air Force base

AFI—Air Force instruction

AHJ—authority having jurisdiction

ANSI—American National Standards Institute

APCO—Association of Public-Safety Communications Officials

C—Celsius

CAC—Common Access Card

CAP—common \1\ alert /1/ protocol

CD—compact disk

CIS—Common Intelligibility Scale

CNO—Chief of Naval Operations

CON—Certificate of Networthiness

CONOPS—concept of operations

CONUS—continental United States

COTS—commercial off-the-shelf

CSC-STD—DOD Computer Security Center Standard

CTO—Certificate to Operate

dBA—sound/noise power, adjusted, in decibels

DCID—Director of Central Intelligence Directive

DD—Department of Defense (as used on forms)

DIACAP—DOD Information Assurance Certification and Accreditation Process

DITSCAP—DOD Information Technology Security Certification and Accreditation Process

DOD—Department of Defense

EM—emergency management

EMWIN—Emergency Managers Weather Information Network

EOC—Emergency Operations Center

EPROM—erasable programmable read-only memory

F—Fahrenheit

FACP—fire alarm control panel

FCC—Federal Communications Commission

FEMA—Federal Emergency Management Agency

FM—Factory Mutual Research Corporation

FPCON—force protection condition

ft—feet

GPS—Global Positioning System

GUI—Graphical User Interface

HAZMAT—hazardous materials

HPSA—high power speaker array

HQ AFCESA/CEO—Air Force Civil Engineer Support Agency, \1\ Operations and Programs Support Division /1/

HQ DLA-D—Defense Logistics Agency Director

HQ DLA-DES-SE—Defense Logistics Agency, Support Services

HQ USACE/CECW-CE—U.S. Army Corps of Engineers, Directorate of Civil Works, Engineering and Construction

HQMC CODE PS—U.S. Marine Corps, Critical Infrastructure Assurance Branch

HVAC—heating, ventilation, air conditioning

Hz—hertz

ICC—Installation Control Center

IEC—International Electrotechnical Commission

INWS—Installation Notification and Warning System

IP—Internet Protocol

kHZ—kilohertz

km/h—kilometers per hour

LDAP—Lightweight Directory Access Protocol

LED—light-emitting diode

LOC—Local Operating Console

m—meter

MCO—Marine Corps Order

MEP—mobile electrical power

METOC—meteorology and oceanography

MIL-STD—military standard

MNS—mass notification system

MPEG—Moving Picture Experts Group

mph—miles per hour

NAVFACENGCOM HQ Code CHE—Naval Facilities Engineering Command, Headquarters Chief Engineer's Office

NCAS—Net-Centric Alerting System

NCEES—National Council of Examiners for Engineering and Surveys

NEMA—National Electrical Manufacturers Association

NFPA—National Fire Protection Association

NGA—National Geospatial-Intelligence Agency

NICET—National Institute for Certification in Engineering Technologies

NRTL—Nationally Recognized Testing Laboratory

NTIA—National Telecommunications and Information Administration

OCONUS—outside of the continental United States

OSHA—Occupational Safety and Health Administration

PA—public address

PC—personal computer

PDA—personal data assistant

ROC—regional operations center

SCIF—Sensitive, Compartmented Information Facilities

SE—Service Exception

STI—Speech Transmission Index

THD—total harmonic distortion

UFC—Unified Facilities Criteria

UL—Underwriters Laboratories, Inc.

UPS—uninterruptible power supply

VAC—volts of alternating current

VoIP—voice over IP

XML—Extensible Markup Language

Terms

Contractor—An entity that executes work in accordance with a contract.

Giant Voice—A nickname for the wide area outdoor siren and voice signaling system often found on military bases. An earlier name for this system was “Big Voice.”

Mass Notification System—A system that provides real-time information to all building occupants or personnel in the immediate vicinity of the building during emergency situations.

System Integrator—A contractor that designs, fabricates, installs, starts up, tests, and documents electrical and electronic systems using COTS components manufactured by others. Qualified manufacturers can act as system integrators.

APPENDIX A

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APPENDIX B

SAMPLE PRE-RECORDED MNS MESSAGES

B-1 **OVERVIEW.** Pre-recorded messages are not required, but can prove beneficial in emergency situations. This appendix contains the sample text for pre-recorded MNS messages based on actual messages in use at several DOD installations. These sample messages are provided for information only to assist DOD installations in defining the content of their pre-recorded MNS messages. Each DOD installation should create MNS messages appropriate for its particular locale.

\1\ **Note:** DOD has implemented a requirement for a standardized alerting sound to be played prior to playing pre-recorded messages for new and replacement MNS. (Refer to paragraphs 4-4.2 and 5-5.2). The following messages were fielded prior to establishment of the requirement and some do not include the currently required alerting sound. /1/

B-2 **SAMPLE PRE-RECORDED MESSAGES**

B-2.1 **ARMY: FORT XXX.** All messages were recorded in a female voice.

B-2.1.1 **Red-Fire.** Five seconds of siren are played, followed by the message:

"Attention, attention. A fire emergency has been reported. Please leave the building using the nearest exit."

B-2.1.2 **Blue-Weather.** Five seconds of 100-kHz steady tone are played, followed by the message:

"The National Weather Service has issued a weather alert for this area; further information will be broadcast as it becomes available."

B-2.1.3 **Orange-Force Protection Antiterrorism Threat.** Five seconds of fast whoop sound are played, followed by the message:

"Attention. A force protection antiterrorism threat has been issued for this area. Effective immediately, we are operating, 'secure and lockdown procedures.' All personnel should remain calm and stay where you are. Please wait for further instructions."

B-2.1.4 **Green-All Clear.** Five seconds of chime sound are played, followed by the message:

"The emergency has now ended. Please resume normal operations. Thank you for your cooperation."

B-2.2 **AIR FORCE: XXY Air Force Base**

B-2.2.1 **MESSAGE #1.** A 1-kHz tone is sounded for 5 seconds, followed by the message:

"May I have your attention, please. This is the command post with a test of the ____ Air Force Base mass notification system. Repeat, this is only a test."

B-2.2.2 **MESSAGE #2.** Five seconds of wail are played, followed by the message:

"Attention, attention. ____ Air Force Base is in Force Protection Condition Charlie. All personnel immediately implement FPCON Charlie actions."

B-2.2.3 **MESSAGE #3.** Five seconds of wail are played, followed by the message:

"Attention, attention. ____ Air Force Base is in Force Protection Condition Delta. All personnel immediately implement FPCON Delta actions."

B-2.2.4 **MESSAGE #4.** No alerting tone is used. The message played is:

"May I have your attention, please. All clear. The emergency has ended."

B-2.2.5 **MESSAGE #5.** One round of code 3 horn is played, followed by the message:

"Your attention, please. ____ Air Force Base has issued a severe weather warning. Take required actions and tune into local radio or television for the latest update."

B-2.2.6 **MESSAGE #6.** One round of code 3 temporal is played, followed by the message:

"Attention. A fire emergency has been reported. Please evacuate the building."

B-2.3 **Air Force: XXZ Air Force Base.** Messages were pre-programmed for the MNS ACU and recorded in a male voice. All messages are repeated twice.

B-2.3.1 **Force Protection Condition Alert.** This message is labeled "FPCON ALERT." A siren is played for 5 seconds (sound clip from manufacturer), followed by the message:

"Attention, attention. The Force Protection Condition for ____ AFB has been elevated. All personnel are to immediately implement prescribed actions. Tune your television to the Commander's access channel or access the base intranet for further information."

B-2.3.2 **Peacetime Emergency Warning.** This message is labeled “Peacetime emergency.” A horn sound is played for 5 seconds (sound clip from the manufacturer), followed by the message:

“Your attention, please. An emergency has been reported on ____ AFB. Immediately take shelter inside a facility. Remain in place and await further instructions.”

B-2.3.3 **Severe Weather Warning.** This message is labeled “Severe Weather.” A horn sound is played for 5 seconds (sound clip from the manufacturer), followed by the message:

“Your attention, please. A severe weather warning has been issued for ____ AFB. Take appropriate action and tune in to the local radio or television stations for the latest updates.”

B-2.3.4 **Natural Disaster Warning.** This message is labeled “Natural Disaster.” A horn sound is played for 5 seconds (sound clip from the manufacturer), followed by the message:

“Your attention, please. A natural disaster has either occurred or is expected shortly that will impact ____ AFB. Take appropriate action and tune in to the local radio or television stations for the latest updates.”

B-2.4 **AIR FORCE: XYX Air Force Base.** Messages were recorded in a male voice. The language used was English.

B-2.4.1 Three 1-kilohertz (kHz) tones (one second each) are played, followed by the message:

“Attention, attention. Implement Force Protection Condition Delta. Refer to ____ AFB intranet for current Battle Staff Directive.”

B-2.4.2 Three 1-kHz tones (one second each) are played, followed by the message:

“Attention, attention. Disaster control group recall. Report to primary rally point.”

B-2.4.3 Three 1-kHz tones (one second each) are played, followed by the message:

“Attention, attention. All personnel shelter in place.”

B-2.4.4 Three 1-kHz tones (one second each) are played, followed by the message:

“Attention, attention. Battle-staff recall. Key personnel report to command post.”

B-2.4.5 Three 1-kHz tones (one second each) are played, followed by the message:

"Attention, attention. Implement Force Protection Condition Charlie. Refer to ____ AFB intranet for current Battle Staff Directive."

B-2.4.6 Three 1-kHz tones (one second each) are played, followed by the message:

"Attention, attention. Implement Force Protection Condition Bravo. Refer to ____ AFB intranet for current Battle Staff Directive."

B-2.4.7 Three 1-kHz tones (one second each) are played, followed by the message:

"Attention, attention. Implement Force Protection Condition Alpha. Refer to ____ AFB intranet for current Battle Staff Directive."

B-2.4.8 No alerting tone is used. Message played is:

"May I have your attention, please. The National Weather Service has issued a severe weather warning for our area."

B-2.5 **AIR FORCE: XYY Air Force Base.** Messages were pre-programmed for the MNS ACU and recorded in a male voice. All messages were repeated twice.

B-2.5.1 **Force Protection Condition Alert.** This message is labeled "FPCON." The button color used was red. A siren is played for 5 seconds (sound clip from manufacturer), followed by the message:

"Attention, attention. The Force Protection Condition for ____ AFB has been changed. All personnel are to immediately implement prescribed actions. Tune your television to the Commander's access channel or access the base intranet for further information."

B-2.5.2 **Bomb Threat Warning.** This message is labeled "BOMB." The button color used was red. A horn sound is played for 5 seconds (sound clip from the manufacturer), followed by the message;

"Attention, attention. A bomb threat alert has been issued for this building. All personnel are to evacuate immediately using the nearest exit. Further instructions will be issued outside the building by emergency response teams."

B-2.5.3 **Terrorist Threat Warning.** This message is labeled "TERRORIST." The button color used was red. A horn sound is played for 5 seconds (sound clip from the manufacturer), followed by the message:

"May I have your attention, please. A terrorist threat has been received. Effective immediately, we are operating 'secure and lockdown procedures.' All personnel should remain calm and stay where you are. Please await further instructions."

B-2.5.4 **All Clear.** This message is labeled "ALL CLEAR." The button color used was blue. A horn sound is played for 5 seconds (sound clip from manufacturer), followed by the message:

"The building emergency has now ended. Please resume your normal duties. Thank you for your cooperation."

APPENDIX C

NET-CENTRIC ALERTING SYSTEMS (NCAS)

C-1 **OVERVIEW.** This appendix provides information on on-going development of system requirements for alerting systems that will be based on IP technologies. This appendix is not mandatory but is provided to stimulate development of suitable requirements and standards for DOD installations. Consequently, user suggestions and feedback on this appendix are highly encouraged and requested. Methods to ensure reliability and robustness in off-normal or emergency conditions are of particular concern. The required amount of and method for isolating alerting functions from normal, non-alerting system functions needs development. The need for listing or approval by NRTLs is also an area of investigation.

C-2 SUGGESTED CAPABILITIES OF A NCAS

C-2.1 **Overview.** NCAS are enterprise-class systems for the management of and mass distribution of emergency notification messages within buildings, throughout installations, across entire geographical regions, or throughout a worldwide military command. Net-centric alerting may not be used in lieu of required audible alerting MNS but should be integrated with MNS whenever possible. Using NCAS, designated system operators would be able to rapidly and reliably inform appropriate personnel about anti-terrorism/force protection conditions (FPCON) (including chemical, biological, radiological, and nuclear threats), hazardous weather conditions, and many other critical events—possibly with near real-time response capability. NCAS leverages the IP network infrastructure to instantly reach those personnel who have access to nearly any IP-connected devices (such as pop-up alerts on personal computers (PC), text messages to personal data assistants (PDA) and cellular telephones, electronic mail to IP-capable cellular telephones, and recorded voice messages to voice-over-IP (VoIP) telephones and PCs). Additionally, NCAS could be used to activate, through a single interface, non-IP alerting systems such as giant voice outdoor warning systems and traditional dial-up telephone alerting systems.

NCAS would also enable the central management of the entire notification flow, including users' management, groups targeting, operators' permissions, access policies, pre-defined emergency scenarios, and response tracking and reporting. This capability would provide NCAS with the flexibility to comply with existing concept of operations (CONOPS) for emergency management (EM) and personnel notifications. NCAS could also monitor external sensors and third-party sources of emergency events, such as government-supplied weather information, and could be used to automatically initiate alerts based on pre-defined alerting scenarios.

C-2.2 **Installed Independently in each Facility or centrally in a 24/7 Regional Operations Center (ROC).** NCAS would be installed independently in each installation/facility (such as in the base network control center) or centrally in a 24/7 ROC that covers multiple geographically separated facilities and installations.

In a centrally managed NCAS configuration, personnel and facilities in the ROC's particular area of coverage could be alerted instantly by events either from any individual installation or centrally from the ROC. Using management tools, designated operators from each installation in the region could log in via a Web browser and have complete access to their own portion of the NCAS. The ROC would retain the ability to centrally monitor and manage all portions of the system.

C-2.3 **Network Security Compliance.** The NCAS would be installed behind the appropriate Internet system firewalls. It would be provided with net-centric architecture that fully supports DOD networking standards and security requirements. More specifically, the NCAS would use a Web-based user interface, support DOD standard network ports and protocols, and provide open interfaces to support interoperability such as Extensible Markup Language (XML)- and common \1\ alert /1/ protocol (CAP)-based emergency messages. The system would include provisions for secure communications, authentication, and encryption using DOD and industry-standard encryption technologies. The system would be DOD Information Technology Security Certification and Accreditation Process/DOD Information Assurance Certification and Accreditation Process (DITSCAP/DIACAP) approved/certified, comply with DOD Computer Security Center Standard (CSC-STD) 002-85, and have a proven support for DOD Common Access Card (CAC) authentication.

C-2.4 **General NCAS Functionality.** The NCAS would be a COTS software product and use industry standards. The NCAS would have server-based architecture, allowing central alert activation, control, and management; such server(s) would be connected to the local network and integrated with the local user directory (i.e., support for Lightweight Directory Access Protocol (LDAP) and Active Directory integration is required).

C-2.4.1 **Delivery Methods.** The NCAS would be capable of sending alert messages to end-users (recipients) via multiple delivery methods, including:

- Audio-visual network alerts to desktops and laptops via desktop pop-up
- Text alerts to mobile phones and pagers
- Text alerts to electronic mail (e-mail) clients
- Audio alerts to phones
- Audio alerts to existing outdoor PA/giant voice systems
- Network alerts to any other IP-connected devices via standard XML and CAP protocols

The system would be extendable to support additional delivery methods in the future as this technology develops.

C-2.4.2 **Targeted Recipients.** The NCAS would be capable of sending alert messages to target recipients according to:

- Hierarchical organizational structure (as would be imported from an LDAP or Active Directory)
- Organizational roles
- Specific distribution lists (e.g., hazardous materials (HAZMAT) response teams)
- Dynamic groups created through on-the-fly queries of the user directory
- Geographical locations (e.g., entire bases, zones within bases)
- IP addresses (required for targeting devices in specific physical locations)

C-2.4.3 **Tracking and Reporting Functions.** The NCAS would be able to centrally track, in real-time, all alerting activities for each individual recipient, including sending, receiving, and responding to alerts, and be able to generate reports based on tracked information.

C-2.4.4 **Signal and Message Library.** The NCAS would incorporate a pre-defined library of signals and messaging appropriate to:

- FPCONs
- Terrorism threats, watches, or warnings
- Evacuation routes
- Battle staff directives
- Personnel recall requirements
- Federal, DOD, or installation-specific warning and notification requirements

The NCAS would provide means for monitoring and integrating with external event sources, and activating alerts automatically based on identifying a match with pre-defined conditions.

C-2.4.5 **Web-based Management.** The NCAS would incorporate a Web-based management and alert activation application through which all operators and administrators could gain access to the system's capabilities based on the users' permissions and the defined access policy. Such a management application would incorporate management of the alert activation flow through all delivery methods, as well as end-user management, operators' permission and access, tracking and reporting, and all administrative aspects of the system.

C-2.5 **Interoperability.** The NCAS would be able to interface and interoperate with UFC 4-021-01-compliant mass notification capabilities, including wide area MNS, individual building MNS, giant voice outdoor warning systems, and telephony alerting systems. During emergencies, systems operators should not need to send notifications using multiple alerting systems. The NCAS would provide the capability to integrate user interfaces and consolidate access to multiple mass notification and alerting systems.

C-2.6 **Monitoring and Automating Emergency Alerts Flow.** The NCAS would be capable of monitoring emergency notifications from multiple data sources (National Weather Service, Emergency Managers Weather Information Network (EMWIN), meteorology and oceanography (METOC), and others) and automatically sending out notifications to designated facilities and personnel based on pre-defined rules.

C-2.7 **Back-up NCAS Systems.** The NCAS would support multiple server configurations to achieve a “hot standby” failover configuration (i.e., no down time in case of failure in a single server) as well as to support higher load scenarios (e.g., more users).

UFC 4-021-02
1 October 2013
Change 1, 11 September 2019

UNIFIED FACILITIES CRITERIA (UFC)

ELECTRONIC SECURITY SYSTEMS

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UNIFIED FACILITIES CRITERIA (UFC)

ELECTRONIC SECURITY SYSTEMS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	**Date**	**Location**
1	09/11/2019	3.4.6 Deleted unsupported Card technologies Appendix C: Updated Notional drawings and text for SCIF, Secure Rooms and Magazines

This UFC supersedes UFC 4-021-02, dated 1 October 2013

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

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

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

Refer to UFC 1-200-01, General Building Requirements, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
DOCUMENT SUMMARY SHEET

Document: UFC 4-021-02, *Electronic Security Systems Change 1*

Superseding: UFC 4-012-02, dated 01 October 2013.

Description: This UFC (Unified Facilities Criteria) document provides design requirements and guidance on how to design electronic security systems required by the current antiterrorism/force-protection and physical security environment. Electronic security systems consist of access control systems (card reader systems), closed-circuit television (CCTV) system, intrusion detection systems, data transmission media systems (a means to communicate information internally and externally to DoD sites), and provision of local or regional dispatch centers (also known as security command centers). Electronic security systems are one part of an overall physical security plan. This document provides guidance to commanders, architects and engineers on how to design electronic security systems for projects to include new construction, additions, renovations, expeditionary, or temporary construction.

Reasons for Document:

- The design of physical security measures is a specialized technical area that does not fall in the normal skill record and resume of commanders, architects, engineers, and project managers. This document provides guidance to those parties tasked with implementing existing and emerging physical protection system requirements for the protection of DoD assets.

Impact:

- Reduced project costs are achieved by a better understanding of baseline requirements in the specialized technical area of electronic security systems.

Unification Issues

There are no unification issues.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE.

The purpose of this UFC is to provide guidance for designing Electronic Security Systems (ESS) in support of the Department of Defense (DoD) physical security program requirements. An ESS is one of many physical security measures that must be considered when addressing the physical security posture of a facility. This UFC is intended to provide uniformity and consistency in the design of an ESS.

1-2 SCOPE.

This UFC provides design requirements and guidance for the design of ESS. It is not intended to create the requirement for an ESS, but rather to assist in designing systems that meet an established requirement and to give guidance to commanders, architects, and engineers on designing an ESS for new projects. Headquarters, Major Command, and installation physical security personnel should be consulted for DoD and Service directives outlining ESS requirements for asset protection. The ESS requirement may come from DoD policy, service policy, installation requirements, or user requirements. Projects may include new construction, additions, renovations, expeditionary, or temporary construction.

1-3 VULNERABILITY AND RISK ASSESSMENT.

In accordance with DOD O-2000.12H Antiterrorism handbook, a vulnerability and risk assessment must be conducted prior to beginning any security project. Upon identifying facility or asset vulnerabilities to threats, physical security measures such as ESS may be deployed to reduce vulnerabilities. In summary, this document assumes the pre-design phases, including the risk analysis, are complete prior to beginning design. For information on Security Engineering Planning and Design process, refer to UFC 4-020-01 and UFC 4-020-02 (described in the section “Security Engineering UFC Series” in this chapter). The engineering risk analysis conducted as part of UFC 4-020-01 should be consistent with the terrorism risk analysis conducted by the installation security/AT staff.

1-4 APPLICABILITY.

This UFC provides planning and design criteria for DoD components and participating organizations. This UFC applies to all construction, renovation, or repair projects that include an Electronic Security System.

1-5 GENERAL BUILDING REQUIREMENTS.

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

1-6 REFERENCES.

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

1-7 GLOSSARY.

Appendix B contains acronyms, abbreviations, and terms.

1-8 SECURITY ENGINEERING UFC SERIES.

This UFC is one of a series of security engineering unified facilities criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed for a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include: the following:

1-8.1 DoD Minimum Antiterrorism Standards for Buildings.

UFC 4-010-01 and UFC 4-010-02 establish standards that provide minimum levels of protection against terrorist attacks for the occupants of all DoD inhabited buildings. These UFCs are intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings. They also include recommendations that should be, but are not required to be incorporated into all such buildings.

1-8.2 DoD Security Engineering Facilities Planning Manual.

UFC 4-020-01 presents processes for developing the design criteria necessary to incorporate security and antiterrorism into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also addresses the tradeoffs between cost and risk. The Security Engineering Facilities Planning Manual is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

1-8.3 DoD Security Engineering Facilities Design Manual.

UFC 4-020-02 provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02 is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design. The manual also provides a process for assessing the impact of protective measures on risk. The primary audience for the Security Engineering Design Manual is the design team, but it can also be used by security and antiterrorism personnel.

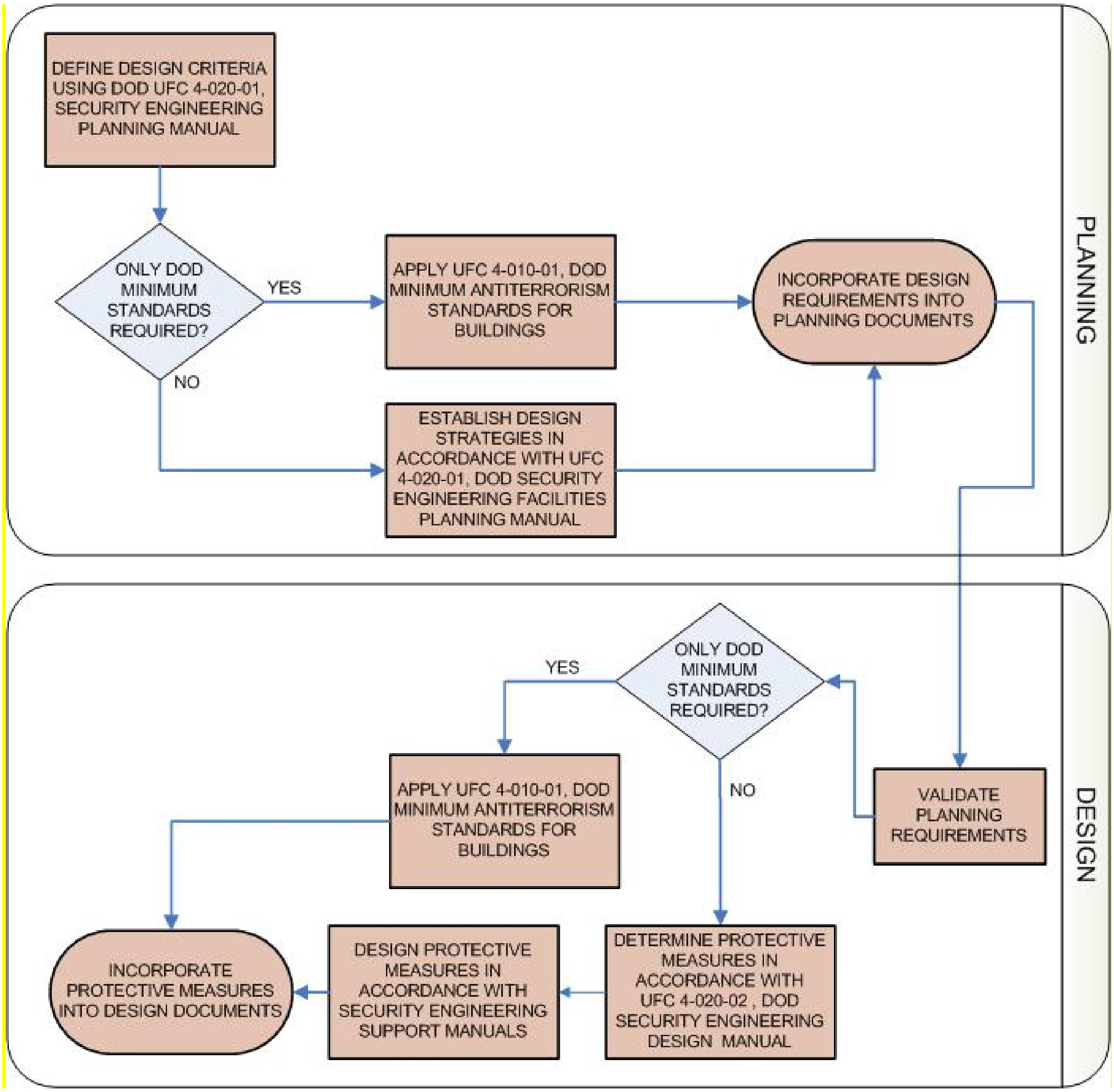
1-8.4 Security Engineering Support Manuals.

In addition to the standards, planning, and design UFCs mentioned above, there is a series of additional UFCs that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, forced entry, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mail rooms. Still others address details of designs for specific protective measures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

1-8.5 Security Engineering UFC Application.

The application of the security engineering series of UFCs is illustrated in Figure 1-1. UFC 4-020-01 is intended to be the starting point for any project that is likely to have security or antiterrorism requirements. By beginning with UFC 4-020-01, the design criteria will be developed that establishes which of the other UFCs in the series will need to be applied. The design criteria may indicate that only the minimum standards need to be incorporated, or it may include additional requirements, resulting in the need for application of additional UFCs. Even if only the minimum standards are required other UFCs may need to be applied if sufficient standoff distances are unavailable. Applying this series of UFCs in the manner illustrated in Figure 1-1 will result in the most efficient use of resources for protecting assets against security and antiterrorism related threats.

Figure 1-1 Security Engineering UFC Application.



CHAPTER 2 ELECTRONIC SECURITY SYSTEM OVERVIEW

2-1 OVERVIEW.

ESS is the integrated electronic system that encompasses the ACS, interior and exterior IDS, CCTV systems for assessment of alarm conditions, the DTM, alarm reporting systems for monitor, control, and display, and the policies, procedures, and response times that ensure that all elements of the ESS work effectively. It is part of an overall physical protection system. As shown in Figure 2-1, the overall physical protection system consists of civil engineering features of fences, gates, entry points, clear zones, and standoff distances; architectural issues of construction materials, barriers, doors, windows, and door hardware; structural issues of blast resistant protection; mechanical issues of HVAC protection and redundancy, electrical engineering issues of power redundancy and lighting systems, ESS, and operational considerations such as policy, procedures, and response times. In summary, the ESS is one component of a bigger physical protection scheme. This chapter describes the ESS in general as a lead-in to subsequent detailed chapters on each of the ESS subsystems.

Service Exception, Marine Corps: Aboard Marine Corps Installations, Mass Notification Systems (MNS) are considered a component of the ESS. Design of Mass Notification Systems is not within the scope of this UFC. Refer to UFC 4-021-01 for Mass Notification System design guidance.

2-2 DETECT, DELAY, AND RESPOND.

For effective intrusion intervention, the ESS should operate on the Detect, Delay, and Respond principle that ensures the time between detection of an intrusion and response by security forces is less than the time it takes for damage or compromise of assets to occur. Refer to Figure 2-2. (Note: Some documents consider the additional specific steps of Annunciate, Classify, and Assess as part of the intrusion intervention process. These additional steps are part of the process, but for this document are intrinsically included as part of the Detect step.)

2-2.1 Detect, Delay and Respond Example.

Table 2-1 provides an example of the times related to each detect and delay option in Figure 2-2. The cumulative delay times shown in this example are estimated at slightly over eight and a half minutes. Assuming a security forces response time of eleven minutes, the sequence of events shown in Table 2-1 allows sufficient time for an adversary to compromise and/or damage the targeted asset. Conversely, assuming a security forces response time of five minutes, the sequence of events shown in Table 2-1 allows sufficient time to intervene on the intrusion efforts. Depending on the nature of the asset, there are some dictated response times. The ESS designer should work with the facility/base security officer to identify the response forces and reaction times. Security and planning personnel should refer to DoD, agency, and service directives to identify response requirements.

Detect, Delay, and Respond Factors Samples. The above example is provided to illustrate the general principles of Detect, Delay, and Respond. Table 2-2 provides additional samples of Detect, Delay, and Respond factors. For additional information on delay times, refer to the book, *The Design and Evaluation of Physical Protection Systems.*

Figure 2-1. ESS as a Part of a Physical Security System.

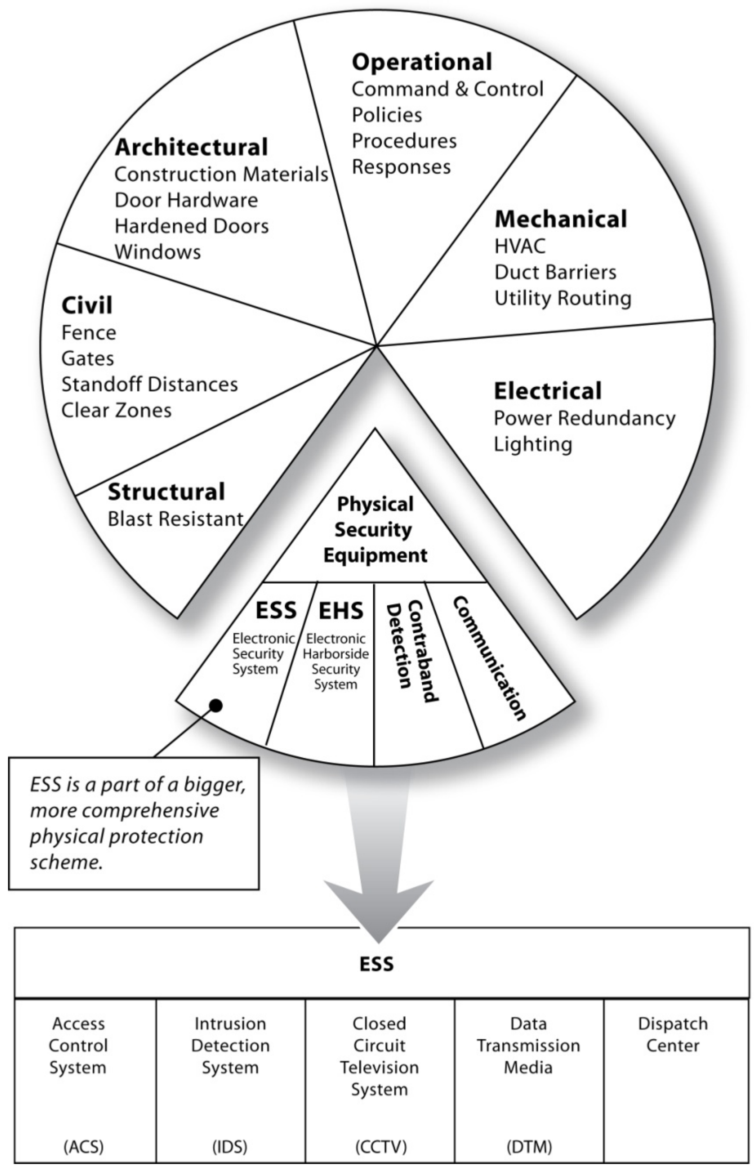


Figure 2-2. Example Detect and Delay Options.

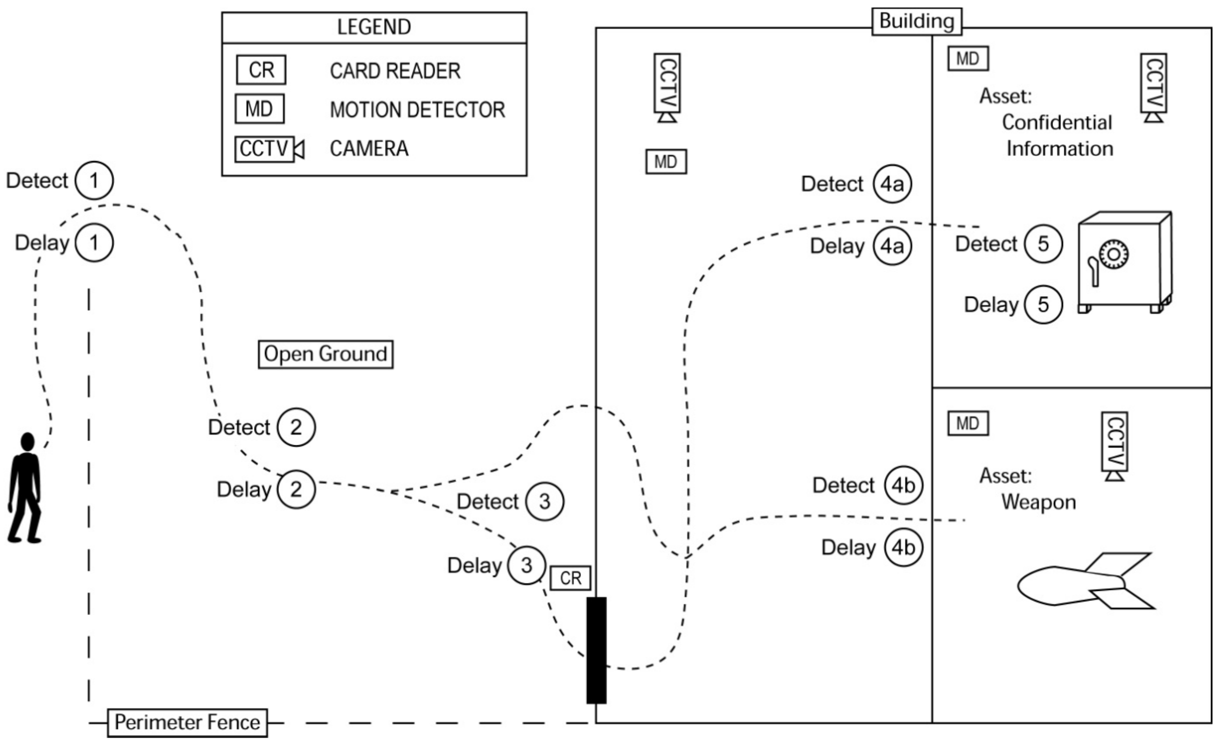


Table 2-1. Example Breach Events and Delay Time.

	Delay Options	Delay Time	Detection Options
1	Climb fence	8-10 sec.	Perimeter fence detection system
2	Cross open ground (for example 600 feet)	10 feet/sec.	Microwave sensors
3	Breach building door or window or wall	1-2 min.	Door contacts or glass breakage sensor
4	Breach interior hardened door	2-4 min.	Door contacts
5	Work time in breached space	3 min.	Motion sensor
TOTAL DELAY TIME		**8 min 39 sec nominal for this example**	

Table 2-2. Sample Detect, Delay, and Respond Measures.

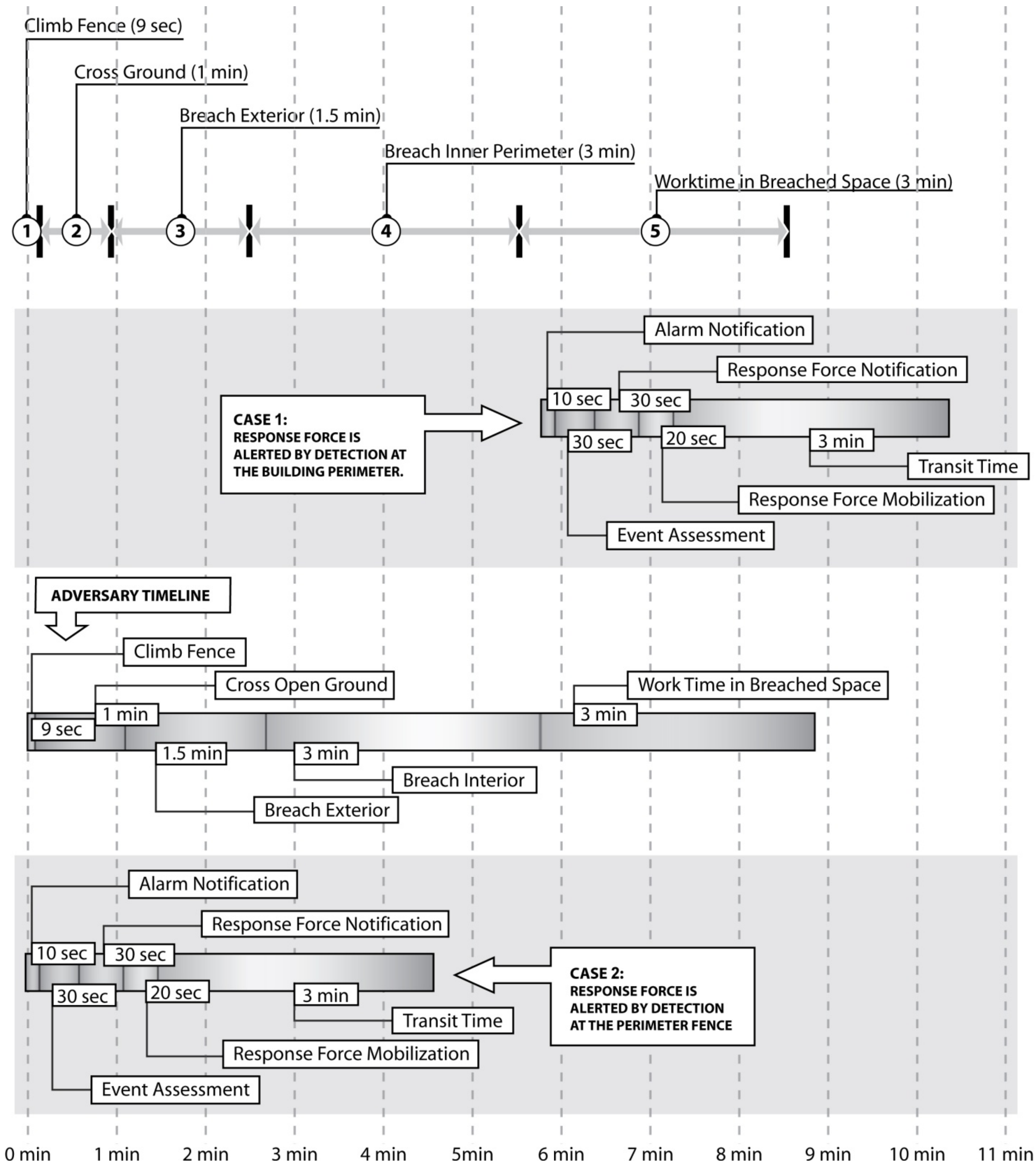
Detect Measures	Delay Measures	Respond Measures
Intrusion detection devices	Fences	Response force alerted
Alarm notification	Walls	Response force travel
Visual displays	Doors	Neutralization

2-2.2 Alerting a Response Force.

Figure 2-3 shows two cases of alerting a response force. In the first case, initial detection is not made until the interior wall of the critical asset has been breached. With initial detection nearly six minutes after the adversary climbs the perimeter fence, response forces do not arrive on the scene until after some compromise of the critical asset has been achieved. In the second case, initial detection is made at the fence line, thus allowing response forces to arrive and intervene before the asset is compromised.

The timeline in figure 2-3 illustrates two different security strategies - containment and denial. A containment strategy concedes that the adversary may gain physical access to the protected asset, but it ensures that the response force arrives soon thereafter, thus containing the degree to which the asset is compromised. However, the asset may be damaged or destroyed, depending on the objective and capabilities of the adversary. A denial strategy, on the other hand, ensures that the protected asset is in no way compromised by the adversary. Denial generally requires early detection, long delay, and rapid response to ensure that the adversary is unable to gain physical access to the protected asset.

Figure 2-3. Timeline Showing Two Cases of Breach and Detection.



2-3 ESTABLISH REQUIREMENTS.

2-3.1 Planning Process.

Establish the requirement for ESS early in the planning process. Establishing the requirement necessitates an interdisciplinary planning team to ensure all interests related to a project are considered appropriately and to determine how security fits into the total project design. The specific membership of the planning team will be based on local considerations, but, in general, the following functions should be represented: facility user, antiterrorism officer, operations officer, security, logistics, engineering, life safety, information assurance, and others as required. The interdisciplinary planning team will use the process in UFC 4-020-01 to identify the design criteria, which includes the assets to be protected, the threats to those assets (the Design Basis Threat), and the levels of protection to be provided for the assets against the identified threats. In addition to the above-listed criteria elements, the planning team may also identify user constraints such as appearance, operational considerations, manpower requirements or limitations, and sustaining costs. That design criteria will be the basis for establishing the requirements of the ESS and other elements of the overall security solution.

2-3.2 Existing Facilities.

For existing facilities, the design criteria are used to perform a vulnerability assessment, the results of which are used to establish the requirements for the ESS. For new facilities, the design criteria are used to establish the requirements directly. The levels of protection will be the most important criteria element in establishing the ESS requirements. The process outlined in UFC 4-020-01 establishes the planning requirements. It also provides a risk management process that can be used to evaluate the resulting requirement. Figure 2-4 depicts the life cycle of an ESS.

2-4 SYSTEM COMPLEXITY.

2-4.1 General.

ESS can range from simple to complex systems. While there may be some different views or definitions of what constitutes a simple or a complex system, this guide will use the criteria described in this section. The definitions used are an academic basis for presenting different system configurations and integration needs rather than standardized industry terminology, which does not exist for defining system complexity.

2-4.2 Simple System.

The simplest ESS consists of a single ESS subsystem. For example, an IDS at a low value asset is a simple system. Other examples are an IDS with door contact, motion sensors, break-glass sensors and other digital input type sensors that do not require integration with another ESS subsystem. Another example of a simple system would be a basic CCTV system of two cameras going to a Digital Video Recorder (DVR).

2-4.3 Intermediate System.

An intermediate system contains elements of at least two ESS subsystems requiring integration. One example would be an ESS system requiring both an ACS and an IDS. Virtually all ACS can accommodate digital input signals. Quite often it is possible to combine ACS and IDS when the IDS inputs are limited to simple digital input devices that do not require separate IDS controllers. Examples of these types of digital input IDS devices are door contacts, glass-break sensors, and motion sensors. A basic block diagram for this type of system reporting to a common Dispatch Center is shown in Figure 2-5.

Figure 2-4. Project Process.

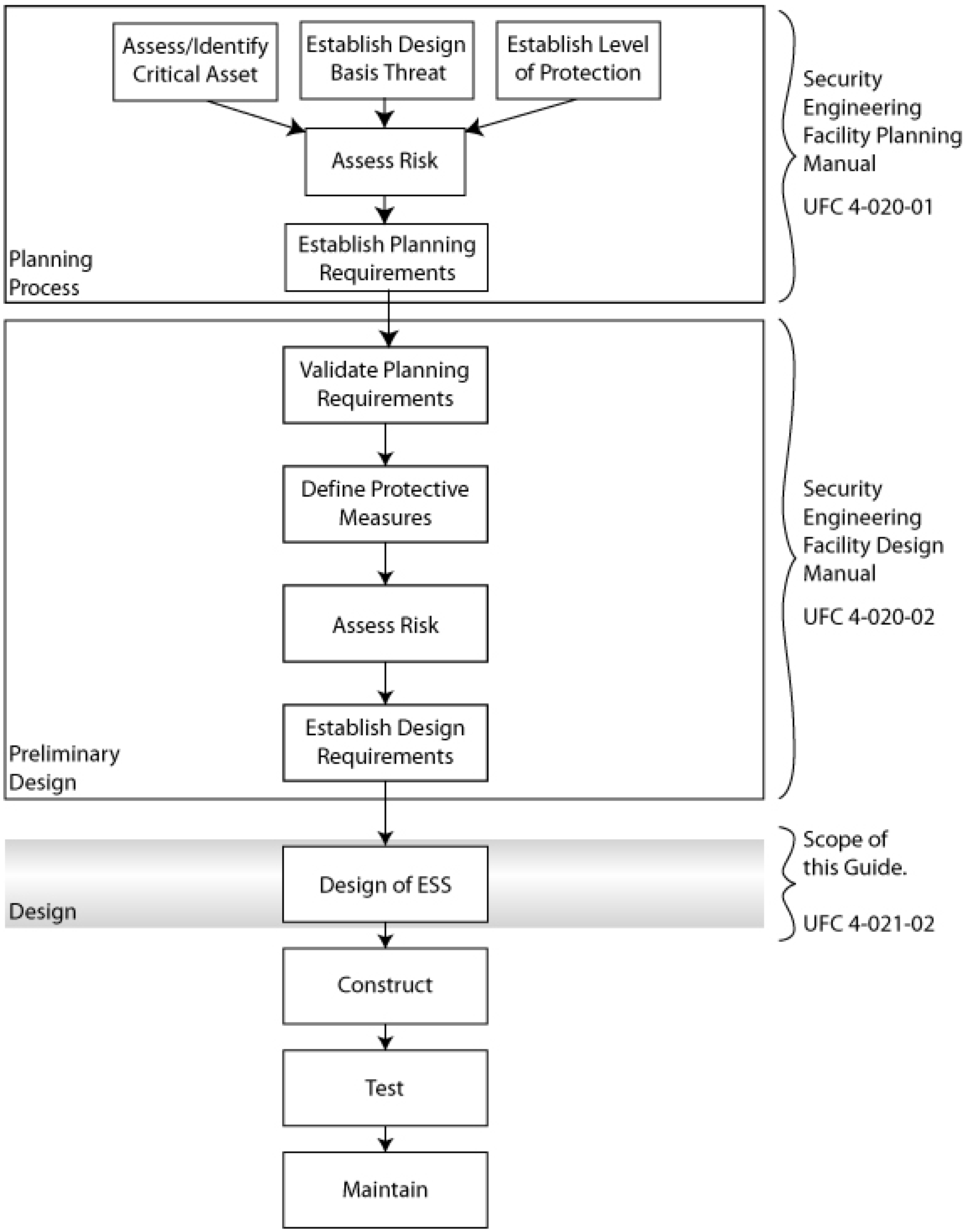
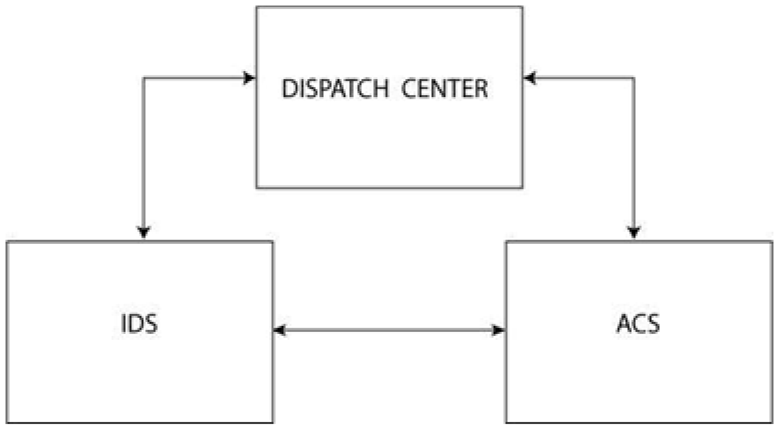


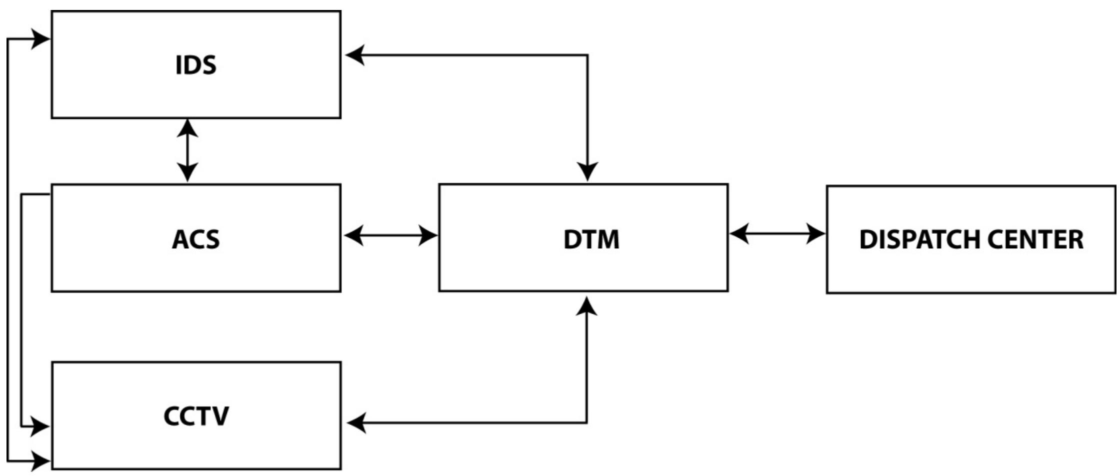
Figure 2-5. Intermediate System with Separate ACS and IDS.



2-4.4 Complex System.

A complex system has a separate ACS and IDS system as well as a CCTV system communicating to a Dispatch Center through a DTM as shown in Figure 2-6.

Figure 2-6. Complex System With Separate ACS, IDS, and CCTV Subsystems.

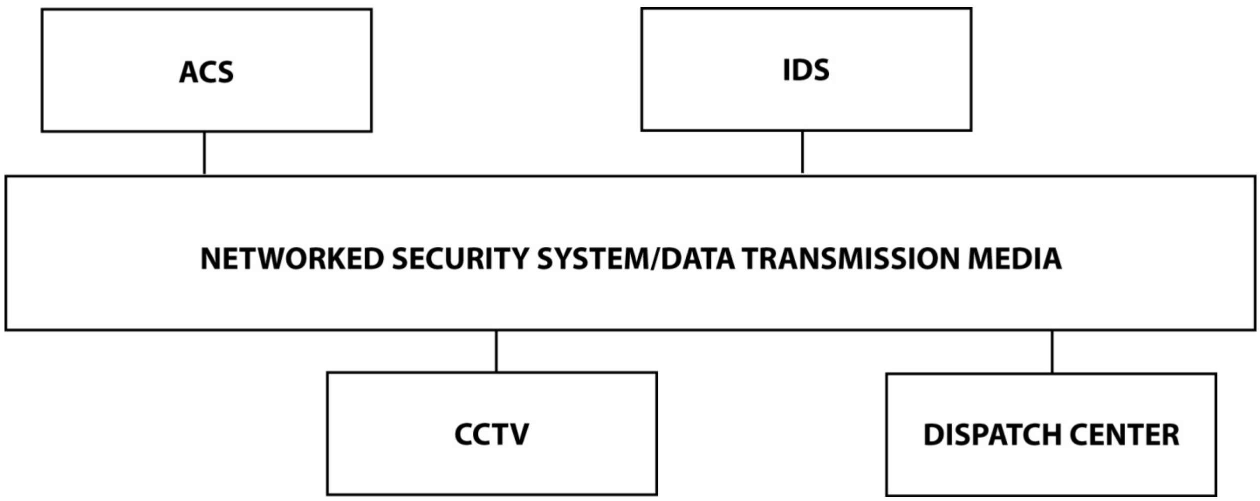


In Figure 2-6, the lines from the ACS/IDS to the CCTV system represent the integration required to automatically display a user-specified camera scene when triggered by a corresponding intrusion or access control alarm. The integration can vary from hardwired contacts to intelligent data communications. System interfaces and integration are described further in Chapter 8, “ESS Subsystem Integration.”

2-4.5 Networked System.

The networked security system, illustrated in Figure 2-7, operates on a single network with drivers to the different discrete components of the subsystems. Responding to the proliferation of networks supporting Ethernet and Internet protocols, the security industry now offers many network-ready components such as local processors for ACS and IDS, intrusion panels, cameras, biometric devices, intercom stations, video recorders, central station receivers, file servers, and workstations. Application software and device drivers are also widely available to allow integration and management of all subsystems across the network. Refer to Chapter 8, "ESS Subsystem Integration" for more information.

Figure 2-7. Networked System.



Networked security systems are typically a Proprietary Security Network. A Proprietary Security network is a completely self-contained dedicated local area network (LAN) with security system software installed and run on a host server (computer). Proprietary Security Networks are dedicated to the ESS with no outside (Internet, LAN, or WAN) connections. All networks must meet the applicable DoD and service component information assurance policies and procedures. For example, the DoD Information Assurance Certification and Accreditation Process (DIACAP) is described in DoDI 8510.01. A unique user ID and password is required for each individual granted access to the host computer. Public Key Infrastructure (PKI) certificates may be used in lieu of User ID and password for positive authentication. Positive authentication methods must be in accordance with published DoD policy and procedures. The system must monitor and log all network and ESS component access attempts and all changes to ESS applications using auditing and network intrusion detection software or similar enhancements. If connection to an outside LAN/WAN is a system requirement, the system would not be considered a Proprietary Security Network and the following additional requirements would apply:

- Encrypt all host server communications to the LAN/WAN using a NIST-approved algorithm with a minimum of 128-bit encryption.
- Protect the system from compromise with firewalls, or similar enhancements that are configured to only allow data transfers between ESS components and authorized monitoring components.

2-5 MONITORING METHODS.

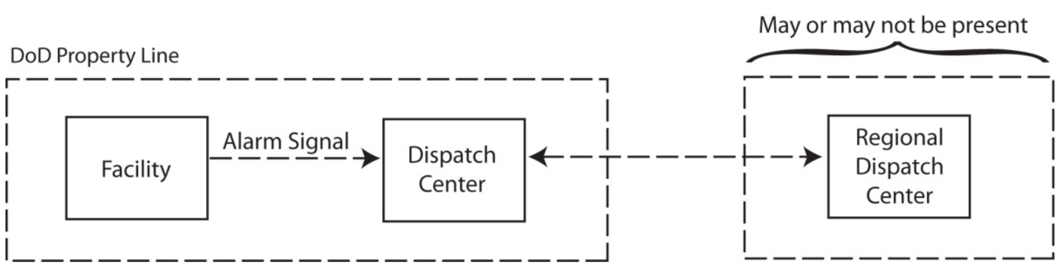
2-5.1 General.

The ESS designer must determine the alarm monitoring method early in the project planning process. This will ensure that issues related to alarm monitoring such as equipment compatibility, data transmission, space allocation, manpower, and standard operating procedures can be adequately addressed in the design phase. Four alarm monitoring methods are defined in DoD 0-2000.12-H - proprietary station, local alarm, central station, and police connection. These methods are described in the following paragraphs.

2-5.2 Proprietary Station.

A proprietary station is a method in which a property owner provides all facilities, equipment, and staffing necessary to monitor alarms. This is the preferred and most common method for a DoD installation where a Dispatch Center functions as a proprietary station and the installation security force responds to all ESS alarms. As a basic configuration, the Dispatch Center may be centrally located at an installation. Two possible configurations of a Proprietary Station Dispatch Center are shown in Figure 2-8: a Dispatch Center centrally located at a base or a detached Regional Dispatch Center (RDC).

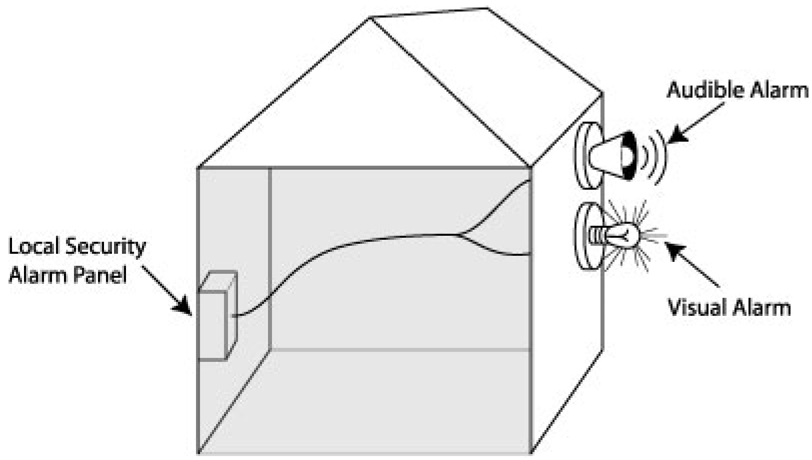
Figure 2-8. Proprietary Station Monitoring.



2-5.3 Local Alarm.

Local alarms actuate a visible and/or audible signal, usually located on the exterior of the facility. Refer to Figure 2-9. Alarm transmission lines do not leave the facility. Response is generated from security forces located in the immediate area. Without security forces in the area, response may only be generated upon report from a person(s) passing through the area or during security checks. Local alarms may offer some deterrence value, but they cannot be relied upon to initiate the Detect, Delay, Respond sequence. Because of this limitation, a local audible/visible alarm should not be used as the sole means of annunciation. In some cases, however, it may be beneficial to provide a local alarm in addition to annunciation at a qualified monitoring station.

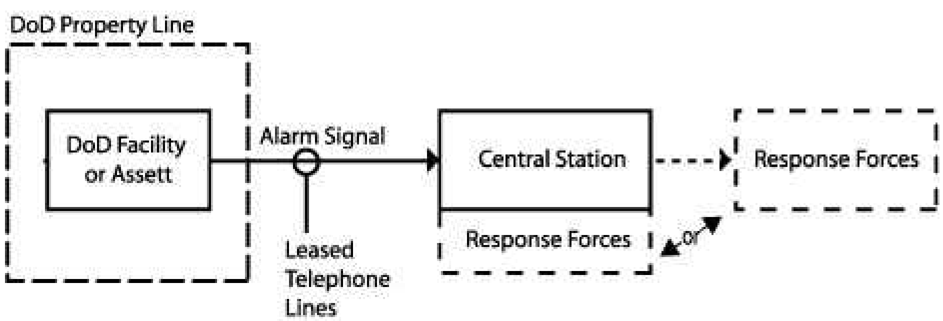
Figure 2-9. Local Alarm Monitoring.



2-5.4 Central Station.

Devices and circuits are automatically signaled to, recorded, maintained, and supervised from a central station owned and managed by a commercial firm with operators in attendance at all times. The Central Station personnel monitor the signals and provide the response force to any unauthorized entry into the protected area. Connection of alarm equipment to the central station is usually over leased telephone company lines for systems of significance. Other connection options are dial-up modems with cellular backup and the Internet. Refer to Figure 2-10.

Figure 2-10. Central Station Monitoring.



2-5.5 Police Connection.

Police connection systems are transmitted to and annunciated at a local police agency dispatch center that records alarm annunciation. Connection to the police is primarily over leased telephone lines. Police personnel respond to alarms. A formal agreement with the police department is required to ensure monitoring and response requirements. Often police departments impose a penalty after some quota of false alarms, thus the sensitivity is often turned down to minimize nuisance alarms and may result in missed indications. Police responders may be attending to other emergencies and unavailable to respond when needed. Police connection configurations may be used for highly valued assets not located on a DoD base or installation. Refer to Figure 2-11 for a diagram of a police station connection.

Figure 2-11. Police Connection Monitoring.

2-5.6 Summary.

Table 2-3 provides a summary of the pros and cons of each type of monitoring method.

Table 2-3 Pros and Cons of Monitoring Methods.

	Pros	Cons
Proprietary Station	Not reliant on outside sources. Can be equipped with CCTV monitoring capability for alarm assessment, video analytics, and general surveillance.	Requires 24/7 trained personnel; possibly increased staffing. Requires real estate space and fit-out hardware. Increased recurring labor cost of Dispatch Center operators.
Local Alarm	Easy to implement Cost effective Simple	No guaranteed response, relies on support forces being in audible/visual range
Central Station	Does not require any additional space or building Probably does not require any additional staffing	Requires an existing Central Station Some complexity in establishing connection May rely on non-DoD forces CCTV capability may be limited or non-existent
Police Connection	Direct communication with law enforcement/response forces without delay.	Requires a cooperating law enforcement station with space and equipment. Must consider separate archiving resource Probably does not have CCTV assessment capability. Ongoing fee may be required for monitoring Interface connection is required. Systems often operate with reduced sensitivity to minimize the number of nuisance alarms.

CHAPTER 3 ACCESS CONTROL SYSTEMS

3-1 OVERVIEW.

The primary function of an ACS is to ensure that only authorized personnel are permitted ingress to a controlled area. The ACS should log and archive all transactions and alert authorities of unauthorized entry attempts. ACS can be interfaced with the CCTV system to assist security personnel in the assessment of unauthorized entry attempts.

3-1.1 Elements.

An ACS can have many elements, including electric locks, card readers, biometric readers, door contacts, and request-to-exit devices, all monitored and controlled by a distributed processing system and one or more workstations. ACS workstations allow security personnel to enroll authorized users in the system, set user access permissions, monitor events and alarms, and run reports on past system activity. Figure 3-1 shows an example ACS configuration, and detailed descriptions of the various elements of an ACS are provided later in this chapter.

3-1.2 Methodology.

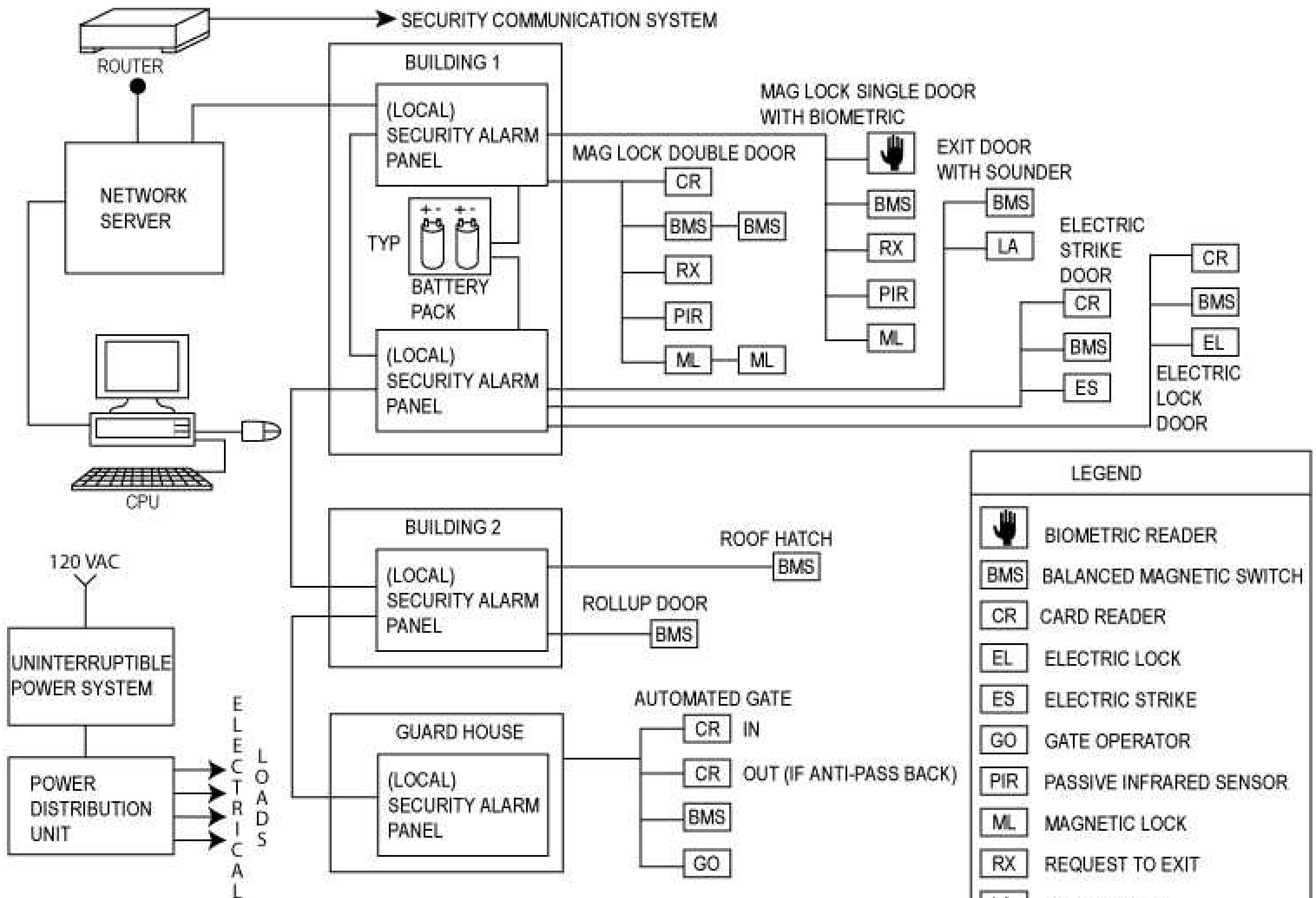
In general, an ACS compares an individual’s entry authorization identifier against a verified database. If an individual's identity is verified, the ACS sends output signals to allow that authorized individual entry through controlled portals such as gates or doors. The system has the capability of logging entry attempts (authorized and unauthorized) that are archived. (Event and tracking logs are discussed in more detail in Paragraph 3-3.4 Event Tracking/Event Logs.) Typically the ACS interfaces with the IDS for input of digital alarm signals at access portals controlled by the ACS. An example of this would be “door forced” alarms at a card reader controlled door. Similarly, the ACS interfaces with the CCTV system in that cameras could be placed at remote gates to verify identity of entrants before manually actuating the remote gate. Signals from the ACS are communicated to the Dispatch Center through the transmission lines of the DTM. Further information on the specifics of how the ACS interfaces with the rest of the ESS is provided in Chapter 8, “ESS Subsystem Integration.”

3-2 ACS ENTRY-AUTHORIZATION IDENTIFIERS.

ACS entry-authorization identifiers are grouped into three categories:

- Credential devices
- Coded devices
- Biometric devices

Figure 3-1. Example Access Control System (ACS).



These devices operate on three basic techniques:

- Something a person has, such as a Common Access Card (CAC) **\1\/1/**
- Something a person knows, such as a personal identification number (PIN)
- Something a person is or does, such as a biometric identifier

3-2.1 Credential Devices.

Credential devices allow a person possessing a recognized credential to enter a controlled area. A coded credential (such as a plastic card or key) contains a prerecorded, machine-readable code. When the card or key is read, an electric signal unlocks the door if the code stored on the credential matches the code stored in the system. A credential device only authenticates the credential; it assumes a user with a recognized credential is authorized to enter. Various technologies are used to store the code within a card or key. The most common types of cards are described in more detail in the section Card Types.

Advantages and disadvantages of using credential devices are shown in Figure 3-2.

Figure 3-2. Advantages and Disadvantages of Using Credential Devices.

Advantages

- Cards and card readers are reliable.

Disadvantages

- Cards can be lost or stolen.
- Some types of cards can easily be duplicated.

Each type of card and card reader has its own advantages and disadvantages. Refer to the subsections *Card Readers* and *Card Types* in the section *ACS Equipment* in this chapter for more on the advantages and disadvantages of each.

3-2.2 Coded Devices.

Coded devices such as keypads operate on the principle that a person has been issued a code or PIN to enter into the device that will verify the authenticity of the code entered. Any person entering a correct code is authorized to enter the controlled area.

Advantages and disadvantages of using coded devices are shown in Figure 3-3. For information about the different types of coded devices see the section Keypads and PIN Codes, later in this chapter.

Figure 3-3. Advantages and Disadvantages of Using Coded Devices.

Advantages

- Keypads are compact and easily understood.
- Different codes may be used to give access to different points and doors.
- Maintenance is easy.
- Keypads are not expensive. They are reliable and easily replaced or repaired. Little complex hardware is needed.
- No cards or tokens need be carried so there is nothing to lose.
- A duress code, known only to the user, can be input covertly if a legitimate person is forced to enter under duress.

Disadvantages

- Codes are easily passed on to other unintended or unwelcome visitors.
- The code can possibly be viewed by others and thus used for unapproved entry.
- Hands-free operation is not an option.
- The number of allowable unique codes can be limited. For example, a four-digit PIN only provides 10,000 different possible codes.

3-2.3 Biometric Devices.

Biometric devices rely on the comparison of a specific biological characteristic to a stored template. Fingerprint, facial patterning, hand geometry and iris scanning are the predominant biometric modalities used within DoD. Selected individual characteristics are stored in a device’s memory or on a card, from which stored reference data can be analyzed and compared with the presented template. A one-to-many (identification) or a one-to-one (verification) comparison of the presented template with the stored template can be made, and access granted if a match is found (depending on the authorized security level). The verification mode generally provides faster transaction times but does require a user to present a credential or enter a code to cue a specific stored template for the one-to-one comparison. Verification is the preferred mode of operation for ACS biometric applications in DoD.

3-2.3.1 Biological Measurements.

Because of the potential differences in biological measurements made over time, the comparison of the current biological measurement with the stored template is not likely to result in a perfect match. Therefore, the algorithm allows for a small percentage of variation. While the allowed variation is small, it does raise the possibility of the two types of errors associated with ACS. The first is false reject (commonly referred to as a Type I error) where the difference between the current biological measurement and the stored template is beyond the level of acceptable variation. The second is false accept (commonly referred to as a Type II error) where an individual's biological characteristic is sufficiently close to that of another individual that access is incorrectly granted. While biometrics can introduce both types of errors, the most likely impact will be on the overall false reject rate of an ACS. All ACS have some percentage of false positive (accept) alarm signals, and ESS system designers must understand the issues and work to minimize the number of false positive (accept) events. From a logistics perspective, missions cannot be accomplished if false reject rates are high and authorized personnel are regularly unable to enter their workspace or facility.

3-2.3.2 Advantages and Disadvantages.

Advantages and disadvantages of using biometric devices to grant or deny access are shown in Figure 3-4. For information about the different types of biometric technologies, see the subsection Biometric Readers in the section ACS Equipment in this chapter.

Figure 3-4. Advantages and Disadvantages of Using Biometric Devices.

Advantages

- They provide automated verification that the person attempting to gain access is authentic.
- Biometric credentials are extremely difficult to duplicate.

Disadvantages

- The cost is slightly higher.
- Longer verification time.
- Require special housings.
- Some devices are not well-suited to outdoor use.

3-2.4 Combining Entry Authorization Identifiers.

A site's security can be significantly enhanced by combining two or more entry authorization identifiers such as a biometric characteristic with a smart card **\1\/1/** with a PIN code. However, combining identifiers results in increased verification time and will decrease throughput rate. Throughput time must be considered when making decisions about whether or not to use multiple identifiers. Another consideration in combining two identifiers is that a system can be required to use one identifier during lower risk times (such as during normally staffed times) and two identifiers during higher risk periods (such as nights and weekends). The same philosophy can be applied for access control enhancement during times of heightened force protection threat levels.

3-2.5 Selecting Entry Authorization Identifiers.

The type of identifier (credential, code, biometric attribute or a combination thereof) that will be used needs to be selected early in the project. This selection will drive the specifications for card readers, keypads, and biometric devices, and it will influence the layout of access control equipment at doors and other portals. The ESS designer must solicit user input concerning previously-issued credentials, such as the CAC, that may be appropriate for the ACS.

3-3 OTHER ACS FEATURES.

Other features to consider implementing as part of an ACS include anti-passback, anti-tailgating, two-man rule, and event tracking. These are described in the following sections.

3-3.1 Anti-Passback.

Anti-passback is a functional characteristic employed within ACS. It is used to eliminate/mitigate the risk of someone giving their credential (passing it back) to another person after that credential is used to access a secure area. Anti-passback requires that a person present a credential to enter an area or facility, and then again use the credential to “badge out.” This makes it possible to know how long a person is in an area, and to know who is in the area at any given time. This requirement also has the advantage of instant personnel accountability during an emergency or hazardous event. In a rigid anti-passback configuration, a credential is used to enter an area and that same credential must be used to exit. If a credential holder fails to properly “badge-out”, entrance into the secured area can be denied. Anti-passback is a standard software feature for Commercial-Off-The-Shelf (COTS) access control systems, but enabling this feature requires that every portal be equipped with two credential readers, one on the entry side and the other on the exit side.

An alternative approach to “badging out,” which is not as rigid as the process described above, is use of a time delay on entrance readers. In this design, the credential (card or PIN) cannot be reused within a prescribed minimum time period. This time delay feature can be programmed and set for a time period such as a half-hour. During the half-hour time period, the same card or PIN cannot be used for a second entry. While affording some increased security, this process is not as rigid or secure as a ‘badge-out” process.

3-3.2 Anti-Tailgating.

While not commonly required, a project security requirement may be to deter tailgating. Tailgating is the act of a person following another authorized person closely in order to gain ingress through the same portal when the authorized person’s credential grants access. An example of a simple anti-tailgating requirement would be a pedestrian turnstile for access control. Since turnstiles are easily defeated, when significant, anti-tailgating measures are required, high-security vestibules or guard-controlled entrances can be a solution. Such application may slow down access.

3-3.3 Two-Man Rule.

The two-man rule is a strategy where two people must be in an area together, thus mitigating insider threats to certain critical areas. Two-man rule programming is optional with many identification systems. It prevents an individual cardholder from entering a selected empty security area unless accompanied by at least one other person. Once two card holders are logged into the area, other card holders can come and go individually as long as at least two people are in the area. Conversely, when exiting, the last two occupants of the security area must leave together using their cards. Most ACS software will enable the assignment of a specific second person that can be established (such as clearance escort requirement).

3-3.4 Event Tracking/Event Logs.

Event tracking/event logs are lists or logs of security events recorded by the access control system that indicate the actions performed and monitored by the system. Each event log entry contains the time, date, and any other information specific to the event. This feature allows security personnel to query the ACS database based on specific portals, persons, or time periods of interest.

3-4 ACS EQUIPMENT.

Once the type of identifier and other implementation strategies are determined, the ESS designer must identify the type of equipment necessary to implement all required system features. Various types of ACS equipment are available, as described in the following sections.

3-4.1 Badging Equipment.

When access credentials have an associated identification badge function, ancillary badging equipment is needed. Note that besides the CAC issued to all DoD personnel, supplemental badging may be required for certain restricted access facilities. The Activity must provide justification to support the requirement for any badging equipment. Badging equipment includes:

- Camera for capturing photographs
- Software for creating badge images
- Signature capture tablet
- Biometric template capture device (where applicable)
- Badge printer capable of printing a color ID template on the front and back of the badge. There are new technology printers that are capable of printing pseudo holograms on the clear protective laminate, which may be considered for higher security applications.
- Computer for retention and programming of the security credential database. This computer may be a stand-alone or client workstation that is connected to the ACS server database in client/server architecture.

If there is no existing badging location and equipment, the design must include the badging infrastructure described above as well as space allocation for equipment and storage requirements. If there is an existing system, an interface to an existing personnel database where the necessary information is stored and maintained will be required. If so, requirements for this database interface and security must be established.

3-4.2 ACS Central Computer.

The central computer is where the ACS application software and database reside and where all system activity is archived. For a small ACS, a single personal computer may be sufficient, but a large ACS may require one or more servers. A multi-server "cluster" configuration provides failover redundancy and ensures high-availability for the ACS application software and database. The central computer, together with all distributed local processors, can be thought of as the "brain" of the ACS.

3-4.3 ACS Workstation.

An ACS workstation allows personnel to view and interact with the ACS hardware and software. The central computer can function as a workstation for small systems, but a large system will likely require multiple client workstations connected to the ACS server(s) via network. The location of all ACS workstations must be identified early in the design process, recognizing that any computer with the appropriate network access and ACS software can function as a workstation.

3-4.4 ACS Local Processor.

Local processors collect inputs from card readers, keypads, biometric devices, door sensors, and request-to-exit devices, and provide output signals to electronic door locks, electric door strikes, turnstiles or gate operators. With its onboard microprocessor and memory, a local processor is able to process portal transactions even during periods when its connection to the central computer is down. This continuity is a major benefit of the distributed intelligence architecture employed by an ACS.

Local processors may employ multiple connection methods such as dial-up modem, serial (RS-232), multi-drop (RS-485), and network TCP/IP.

3-4.5 Card Readers.

The most common form of credential verification is a security card reader, and there are a number of different types. Insertion readers require that you insert the card into a slot that is just large enough to accommodate the card and then remove it. \1\/1/ Contactless readers require that you hold the card in front of the blank face of the reader.

3-4.5.1 Insertion Readers.

\1 Insertion readers, while functional, are generally considered less convenient for users when compared to 13.56 MHz contactless readers. This inconvenience factor, coupled with the mechanical wear associated with inserting cards favors the selection of contactless readers over insertion readers. **/1/**

3-4.5.2 Door Configuration.

Figure 3-5 displays a sample configuration for a single door equipped with a card reader and electric lock. Refer to the subsections on Doors and Door Locks in Chapter 9, General Requirements and Cross-Discipline Requirements for additional information on door hardware types and interface considerations.

3-4.6 Card Types.

Card readers use a number of different card types, the most common of which are described in the following subsections.

\1\/1/

3-4.6.1 Smart Cards.

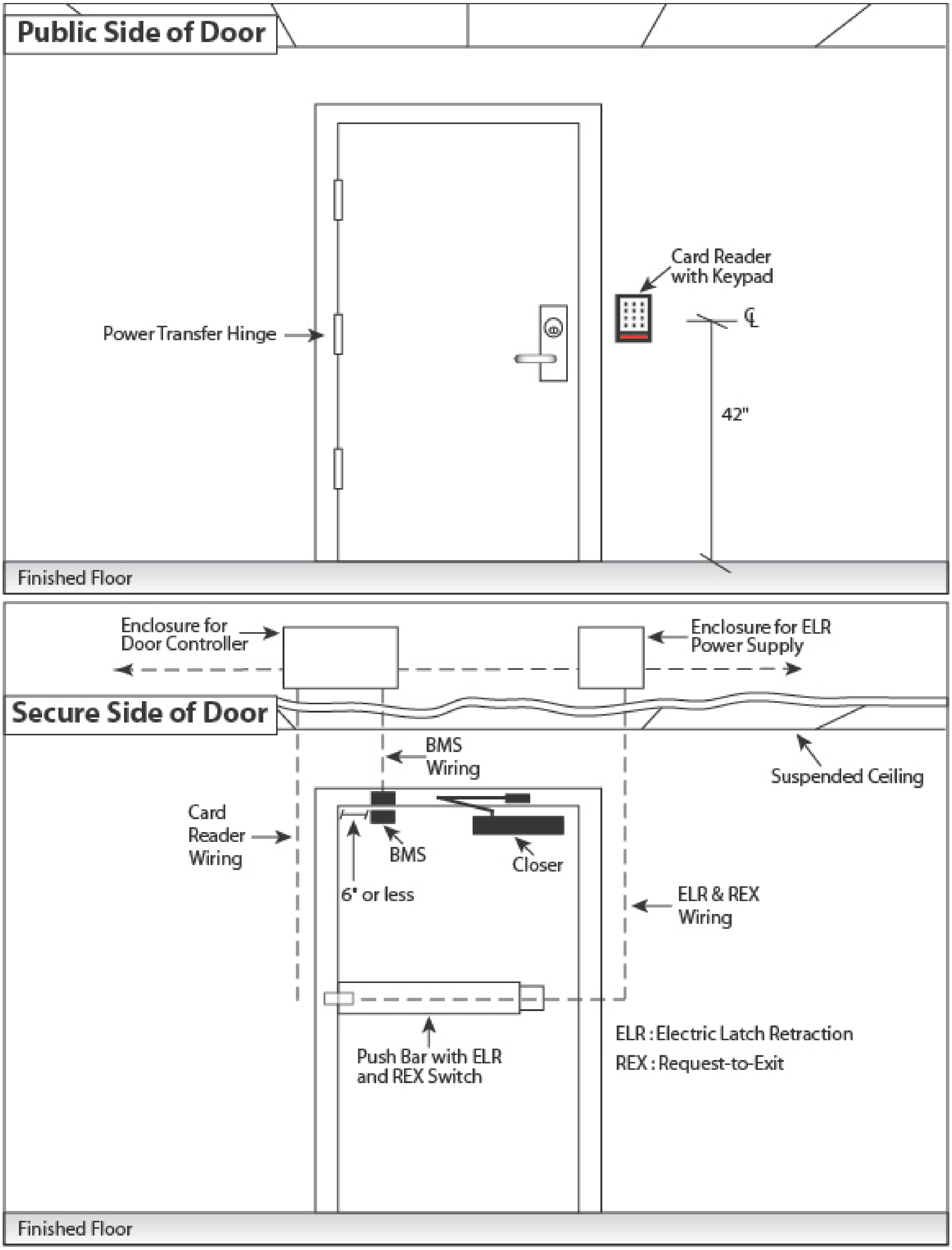
Smart cards are credential cards with a microchip embedded in them. The term “smart card” can define cards that simply carry data, but more commonly is used to describe cards with integral microprocessing and read/write data storage capability. Smart cards are available as a “Contact” type or as a “Contactless” (and wireless) type. An example of a “Contact” smart card is one which can interface to a computer through the embedded contact. The contactless, wireless smart card operates at 13.56 MHz, which is more than a hundred times faster than the data exchange rate of 125kHz proximity cards. There are also hybrid cards available, which have both types of smart card chips in one plastic body or have both contact and contactless interfaces to one microprocessor in the plastic body. Smart cards can store enormous amounts of data such as access transactions, licenses held by individuals, qualifications, safety training, security access levels, and biometric templates. One principal security advantage of smart cards is that cryptographic capabilities can be used to send card information to legitimate readers and encrypts that transmission such that the system remains immune from replay attacks. It is difficult to copy security credential information onto a forged card. For more information on the federal standard for electronic smart cards, refer to National Institute of Standards and Technology Federal Information Processing Standards (NIST FIPS) 201.

3-4.6.2 Common Access Card (CAC).

The CAC is a credential used by the DoD to allow access to DoD computers and physical locations worldwide. For each individual, one card works for all access to computers and physical locations. The CAC is a JAVA-based smart card. It can store a number of personal demographic data elements. It supports multiple bar codes **\1\/1/** for legacy applications, making the card extremely versatile.

Per DoD 5200.08-R, “the CAC must be the principal identity credential for supporting interoperable access to installations, facilities, buildings, and controlled spaces.” For physical access control, the contactless smart chip is the preferred feature of the CAC. However, a dual-technology smart card reader allows the contact interface to be used (via insertion) as a fallback should the contactless antenna in a card become damaged.

Figure 3-5. Sample Card Reader Door Configuration.



3-4.6.3 Operational Strategies.

Operational strategies for badge policy such as where the badge is worn, the type of photograph (if required), backgrounds for area authorization, rules of challenge, penalties for not wearing, and losing are important but are not within the scope of this design guide.

3-4.7 Keypads and PIN Codes.

Coded devices use a series of assigned numbers commonly referred to as a PIN. This series of numbers is entered into a keypad and is matched to the numbers stored in the ACS. By itself, this technology does not offer a high level of security since a PIN can be stolen by even casual observation. However, coded devices can be effective when used in combination with a credential or biometric technology. For an ACS that uses keypads as the sole entry authorization identifier, microprocessor-controlled keypads are preferred. Unlike a standard keypad, a microprocessor-controlled keypad alters the arrangement of numbers each time it is used, thereby making it more difficult for an onlooker to determine a PIN by observing which keys are pressed. Numbers are displayed on LEDs with a narrow viewing angle so that only the person directly in front of the keypad can clearly see the numbers.

3-4.8 Biometric Readers.

Biometric readers verify personal biological metrics (biometrics) of an individual. Biometric readers may be used in addition to credential devices or with a PIN code.

3-4.8.1 Biometric Devices.

Biometric devices are well suited for very high security areas, but may not be appropriate for portals where high throughput is a primary design objective. Designers have to evaluate the tradeoff between added security and decreased throughput.

There are several types of biometric characteristics that can be used. The most common are described in the following sections.

3-4.8.1.1 Fingerprint.

Fingerprint technology scans the loops, whorls, and other characteristics of a fingerprint and compares it with stored templates. When a match is found, access is granted (depending on the authorized security level). This technology is mature and well understood but performance can be degraded if cuts or sores appear on fingers or if grease or other medium contaminates the fingers and the scanning plates. Some systems create two templates for two different fingers, in the event that one finger is altered by injury or other means. Fingerprint technology is not convenient in environments where workers wear gloves. Early fingerprint readers were compromised by picking up a valid fingerprint from a reader with a manufactured “finger”. To combat this shortcoming of the technology, sensors were equipped with the ability to sense a pulse and temperature. Fingerprint technology is the first choice biometric method per FIPS 201.

3-4.8.1.2 Facial Image.

This technology measures the geometric properties of the subject's face relative to an archived image. Specifically, the centers of the subject's eyes must be located and placed at precise (within several pixels) locations. Facial imaging is the backup technology for biometric authentication per FIPS 201.

3-4.8.1.3 Hand Geometry.

This technology assesses the hand's geometry: height, width, and distance between knuckle joints and finger length. Advantages of hand geometry are that the systems are durable and easily understood. The speed of hand recognition tends to be more rapid than fingerprint recognition. Hand recognition is reasonably accurate since the shape of each hand is unique. A disadvantage is that they tend to give higher false accept rates than fingerprint recognition. As with fingerprint technology, hand geometry is not convenient in environments where workers wear gloves.

3-4.8.1.4 Handwriting.

Handwriting recognition analyzes the pressure and form of a signature. This technology is only used in an ACS without heavy traffic because the procedure of verification is slow. A PIN is typically entered into the system first so that the computer can more quickly find a template against which to identify the person seeking entry. Handwriting systems are not widely used.

3-4.8.1.5 Voice Recognition.

Voice recognition identifies the voice characteristics of a given phrase to that of one held in a template. Voice recognition is generally not performed as one function, and is typically part of a system where a valid PIN must be entered before the voice analyzer is activated. An advantage of voice recognition is that the technology is less expensive than other biometric technologies. Additionally, it can be operated hands-free. A disadvantage is that the voice synthesizer must be placed in an area where the voice is not disturbed by background sounds. Often a booth has to be installed to house the sensor in order to provide the system an acceptable quiet background. Voice recognition systems are not widely used.

3-4.8.1.6 Iris Patterns.

Iris recognition technology scans the surface of the eye and compares the iris pattern with stored iris templates. Iris scanning is the most accurate and secure biometric. After DNA, irises are the most individualized feature of the human body. Even identical twins have different irises, and each person's two irises differ from each other. The unique pattern of the human iris is fully formed by ten months of age and remains unchanged through a person's lifetime. A benefit of iris recognition is that it is not susceptible to theft, loss, or compromise, and irises are less susceptible to wear and injury than many other parts of the body. Iris scanners allow scanning to occur from up to sixteen inches away. A disadvantage of iris scanning is that some people are timid about having their eye scanned. Throughput time for this technology must be considered. Typical transaction time is two seconds. If a number of people need to be processed through an entrance in a short period of time, this can be problematic.

3-4.8.1.7 Retinal Scanning.

Retinal scanning is an older, comparable technology that reads the blood vessel pattern on the retina in the back of the eye, but it is not readily available in the marketplace. Whereas iris scanners can work up to sixteen inches from the reader, retinal scanners require individuals to look into a device that shines a harmless infrared light into the eye. Hesitance to look directly into such a reader has curtailed the acceptance of retinal scanners in most applications.

3-4.9 Request-to-Exit (REX) Devices.

Doors and other portals secured with an ACS must provide a means of authorized egress for personnel inside the controlled space. A REX device performs this function by initiating a temporary shunt of the door sensor alarm, thus allowing the ACS to distinguish between an authorized exit and an unauthorized (forced) entry. For some door configurations the REX device also releases the door locking/latching mechanism.

An ACS designer must work with the project architect to analyze each controlled door and portal to determine the appropriate REX device, taking into account security, life safety, Americans with Disabilities Act (ADA), aesthetics, ergonomics, and wiring. An overview of the four categories of REX devices is as follows:

3-4.9.1 Door Hardware.

Practically any type of door hardware can be equipped with an internal REX switch. This approach eliminates the need for an external REX device but requires that wiring be extended to the door either through an electrified hinge or exposed armored flex conduit.

3-4.9.2 Buttons.

A button labeled "PUSH TO EXIT" can be mounted on the door frame or an adjacent wall.

3-4.9.3 Motion Sensors.

A motion sensor can be mounted above the door to detect a person approaching from the secure side. This is generally considered to be the least secure REX device due to the potential for false activations.

3-4.9.4 Card Readers, Keypads, and Biometric Devices.

Using a card reader, keypad, or biometric device as a REX device offers the potential for "who's in and who's out" accountability. Refer to section 3-3 for further discussion of ACS features that require exit readers.

3-5 ACS DESIGN CONSIDERATIONS.

a. Specify a card reader with an integrated keypad for portals where the added security of credential plus code access is required.

b. All card readers must be UL 294 listed.

c. Contactless card readers must conform to ISO/IEC 14443 Parts 1 through 4 and NISTIR 6887, The Government Smart Card Interoperability specification (GS-IS).

d. For facilities requiring a higher degree of security, provide biometric capability in addition to the minimum.

e. Per FIPS 201, fingerprint reading is the biometric technology of choice. Facial imaging is listed as a secondary biometric credential.

f. Outside hand-geometry readers require special exterior housings. Check with manufacturer's specifications for external applications on other biometric readers.

g. A common cable type for card readers is a twisted, shielded cable (typically, six conductor). One pair is used for low voltage dc power, one pair is used for data transmission, and one pair is normally used for LED or signal illumination. Verify the cable requirements with the equipment manufacturer.

h. In general, the ESS designer must balance security requirements with life safety, fire-alarm interface, and normal operational convenience factors.

i. Work with the project architect to clearly define controlled access boundaries and portals early in the design process. Specify the entry and exit function of each door on a controlled access boundary, and identify any special portal equipment such as turnstiles and security booths. Ensure that the Life Safety Plan addresses any egress restrictions associated with the ACS.

j. Avoid using a life safety emergency exit as a high security entry portal.

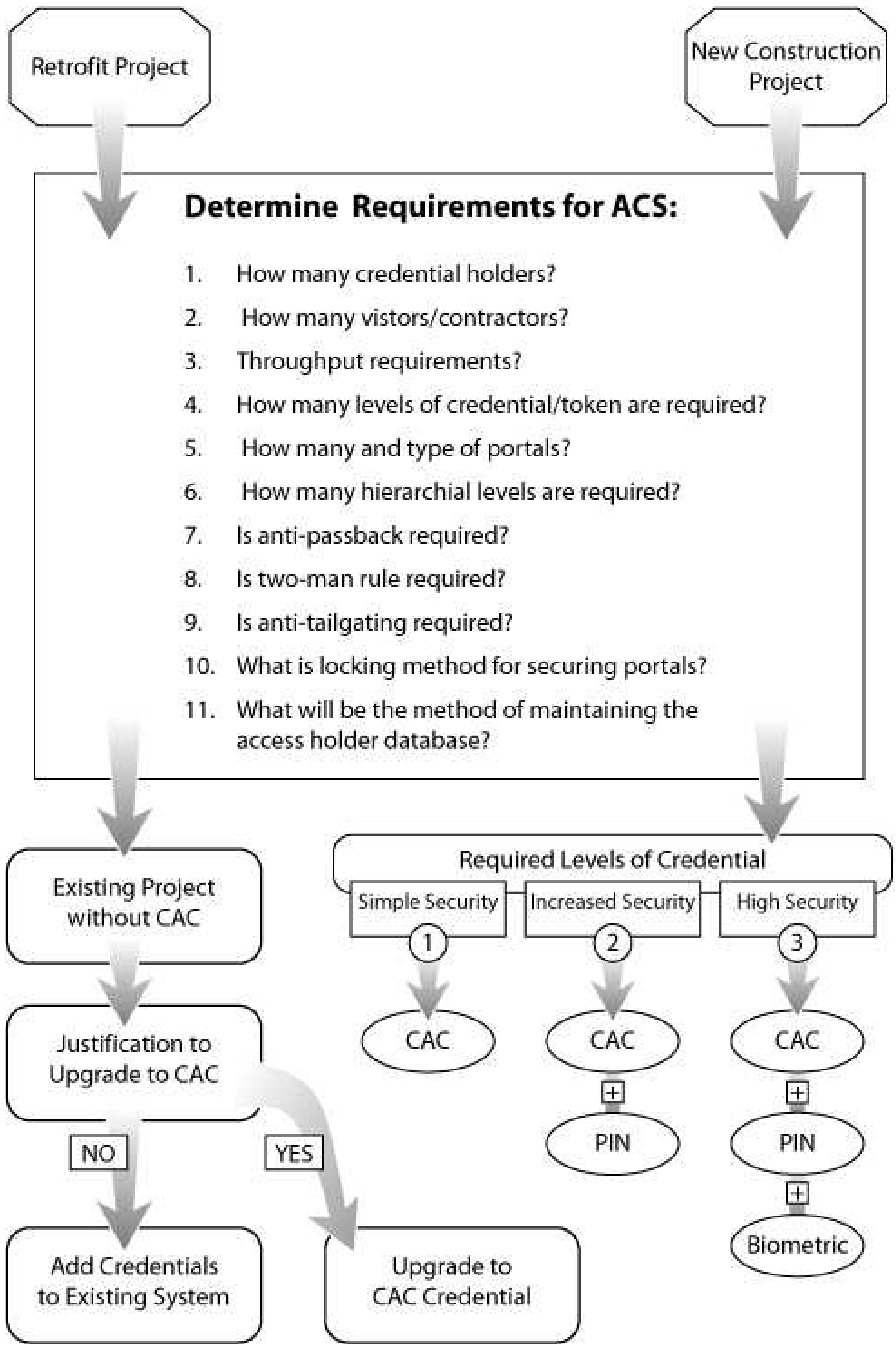
k. Limit entrances into the controlled area. SCIFs are limited to one primary entrance.

l. Coordinate with the Architect to ensure proper doors, door frames, and door hardware are provided. For example, when an electric door strike is specified, the door frame and hardware must be checked or specified such that they are compatible with the strike in terms of wiring and latching.

m. Consider throughput and traffic flow of normal operational traffic and emergency exiting requirements. Ensure that entry throughput at controlled portals will be adequate for the morning surge period.

n. Additional design guidance for ACS is provided in Figure 3-6.

Figure 3-6. ACS Design Process.



CHAPTER 4 CLOSED CIRCUIT TELEVISION SYSTEMS

4-1 OVERVIEW.

The CCTV system is another core subsystem of an overall ESS. It is the collection of cameras, recorders, switches, keyboards, and monitors that allow viewing and recording of security events. The CCTV system can be integrated with ACS and IDS and may be centrally monitored at the Dispatch Center or locally monitored by security personnel at an individual facility. Uses of CCTV systems for security services include several different functions as described below.

4-1.1 Alarm Assessment.

When alerted by an alarm notification, CCTV cameras allow security personnel to visually assess the situation and make a determination as to what type of response may or may not be required. An example would be an intrusion alarm at a remote facility. Visual assessment and other confirmation may indicate an unannounced maintenance crew at work. Symptoms of intrusion would lead to a response.

4-1.2 Access Control.

Cameras can be used by security personnel to visually identify persons and vehicles requesting entry prior to releasing a controlled portal (door, turnstile, gate, vehicle barrier, etc.).

4-1.3 Surveillance.

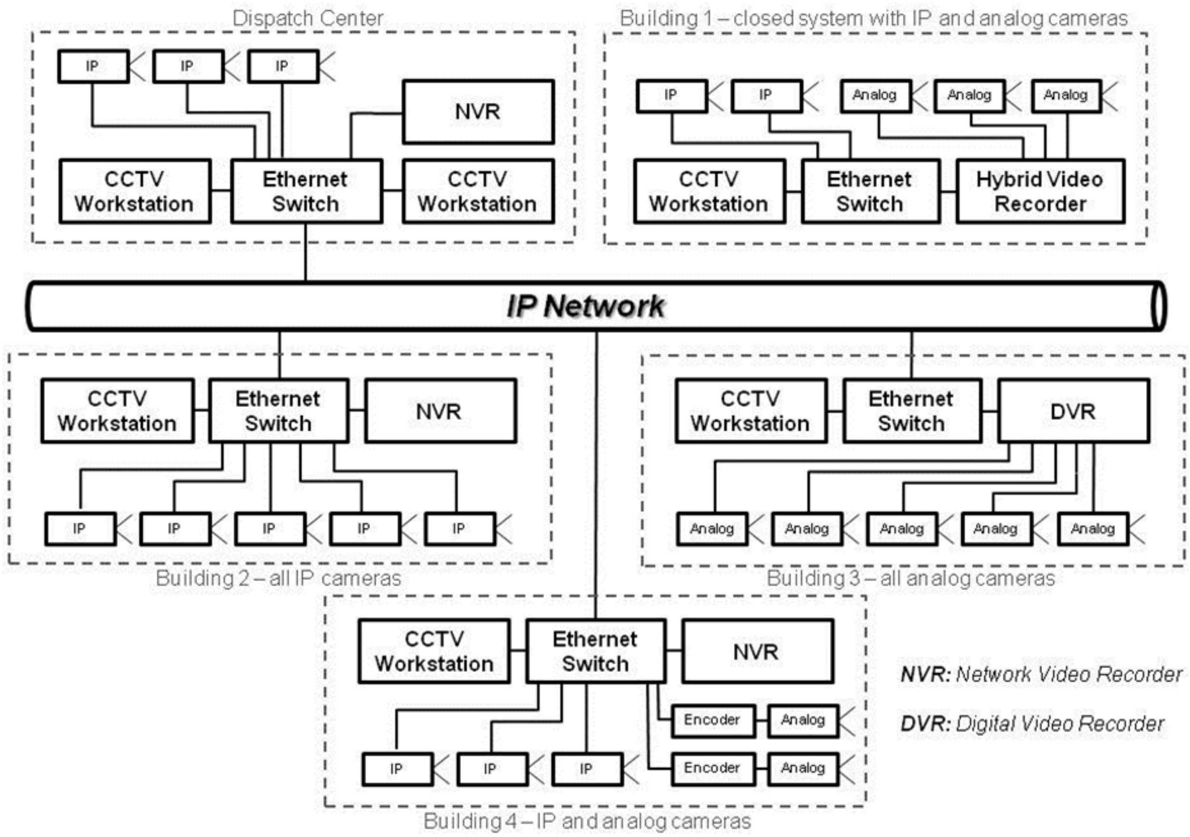
CCTV cameras can be used to give security personnel the capability to be made aware of or view visual events at multiple locations from a centralized remote viewing area. CCTV camera technology makes visual information available that would normally only be available through multiple (possibly roving) human resources. Video analytics can significantly enhance surveillance effectiveness by cuing scenes of interest and highlighting areas within scenes for priority viewing by an operator.

4-1.4 Evidentiary Archives.

Retrieval of archived images may be helpful in identification or prosecution of trespassers, vandals, or other intruders.

As shown in Figure 4-1, a large networked CCTV system may encompass several buildings and can include multiple workstations where live and recorded video can be viewed. Both analog and Internet Protocol (IP) cameras can be used to gather video images which are then stored in a digital format. Building 1 represents a closed system with no connection to an outside network, in which case all video recording, viewing and management is done within the building.

Figure 4-1. Example Block Diagram for a Networked CCTV System.



4-2 CAMERAS.

Selecting the appropriate cameras is critical to a CCTV design. The following paragraphs provide guidance regarding basic camera types and features.

4-2.1 Color Versus Black and White.

Color cameras offer more information such as color of a vehicle or subject's clothing. Some ultra-low light color cameras are able to automatically sense the ambient light conditions and switch from color to black and white in low light conditions. Cameras must have auto-white balance to adjust for the changing color temperature of daylight and artificial lighting needed for night-time viewing. Black and white cameras are more sensitive than color cameras under low-light conditions and are best used when IR illuminators are required. These cameras are further described in the Viewing in Low-Light Conditions Section of this chapter.

Color cameras require a higher illumination level than black and white cameras to be effective. Typically, a high-quality color camera will work well down to 1 foot-candle (fc) (10 lux) of scene illumination, whereas a black and white camera might only require 0.1

fc (1 lux). These lighting level requirements vary with the camera model and manufacturer, so be sure to specify the appropriate illumination level for the scene of interest.

4-2.2 Indoor Cameras.

Indoor camera installations reduce the complexity of the system, but care must be taken to correctly specify the lens, field-of-view and camera hardware. Indoor cameras need:

- Sturdy, secure mounting.
- Auto-iris for lighting control.
- Auto-white balance to ensure proper color correction to accommodate changes in color temperature of lighting if it is dimmed or lighting is changed due to a light outage.
- To be mounted in a position to prevent glare from overhead lighting.

4-2.3 Outdoor Cameras.

Outdoor camera installations cost more than indoor cameras due to the need to environmentally house, heat, and ventilate the outside camera. When mounting a camera outdoors, the lighting requirement changes depending on the time of day and the weather. Because of this, consider the following for outdoor cameras:

a. Shrubs, trees, and other vegetation in a camera’s line of sight may cause obstructed views. Designers need to be aware of this when determining where to place cameras. Also, video motion detection systems can register a false positive when plants in the field-of-view move in windy conditions.

b. Provide heaters in cold weather applications.

c. Always use auto-iris lenses with outdoor cameras. The iris automatically adjusts the amount of light reaching the camera and thereby optimizes its performance. The iris also protects the image sensor from getting damaged by strong sunlight. Always set the focus in low light with an auto-iris lens. If the adjustment is made in sunlight, it is very easy to focus, but at night the iris diameter increases and the image is not in focus anymore. Special dark focus filters called “neutral density” filters or ND filters help reduce lighting by one or more stops of exposure. These filters do not affect the color of the image.

d. Use caution when mounting a camera behind glass. If you mount a camera behind glass, such as in housing, make sure that the lens is close to the glass. If the lens is too far away from the glass, reflections from the camera and the background will appear in the image.

e. Always try to avoid direct sunlight in an image. Direct sunlight blinds the camera and may permanently bleach the small color filters on the sensor chip, causing stripes in the image.

f. When using a camera outdoors, avoid viewing too much sky. Due to the large contrast, the camera will adjust to achieve a good light level for the sky, and the landscape and objects that must be assessed might appear too dark. One way to avoid these problems is to mount the camera high above ground. Use a pole if needed. Given mounting choices, mount cameras facing away from rising or setting sun, realizing that this varies by season.

g. Always use sturdy mounting equipment to avoid vibrations caused by strong wind. This is especially important with a long focal length lens. These lenses amplify even the smallest movement of the mount. Building mounts are generally more stable than pole mounts. When in extremely windy conditions for a critical camera, consider using a gyro-stabilized mount lens to avoid vibration caused by wind. The gyro-stabilized lens has a cost premium and is not appropriate for general applications.

4-2.4 Fixed Position Cameras.

After being mounted, aimed, and focused by an installer, a fixed position camera provides a field of view that cannot be changed via remote control. When used for visually assessing intrusion or access control alarms, fixed cameras are good for review of pre-alarm conditions because there is a constant view of the scene in which the alarm was triggered. Pre-alarm allows the review of video information for the time period (typically ten to fifteen seconds) immediately before the alarm occurred. Pre-alarm video is often the most useful video content for determining the actual cause of the alarm. Because of their static field of view, fixed cameras are well suited for video motion detection, but are not able to track a target of interest after it leaves the camera scene. The installation and cost of fixed cameras is lower because there is no associated motor and control wiring.

4-2.5 Pan/Tilt/Zoom (PTZ) Cameras.

A PTZ camera contains a motorized mechanism for adjusting camera aim point and lens focal length, thus allowing an operator to dynamically change the field of view via remote control. This gives the operator a much better view of the overall area compared to a fixed camera. PTZ cameras are often used for both alarm assessment and video surveillance applications; however, they are not well-suited for pre-alarm assessment because they may not be focused on the alarm area at all times. Because of the drive motor, housing, and wiring for controls, PTZ cameras are typically three to four times more expensive than fixed cameras. Table 4-1 compares other salient parameters of fixed and PTZ cameras.

A PTZ camera can be controlled by an operator or it can be programmed to perform a guard tour during which it moves sequentially through a series of user-defined preset views. When not under operator or guard tour control, a PTZ can be set to return to a home position preset corresponding to the most important scene of interest. Preset views for alarm conditions can be programmed to override operator control, guard tour, and home position.

Table 4-1. Fixed versus PTZ Cameras.

	Applications	Cost	Pre-alarm Review	Video Motion Detection	Intruder Tracking Capability
Fixed	Alarm assessment for doors, gates and fence lines	Lower	Recommended	Recommended	None
PTZ	Surveillance for large open areas such as ports and airfields	Three times more expensive than a fixed camera	Poor application	Only for fixed, preset scenes	Good

4-2.6 Dome Cameras.

A dome camera is mounted in a hardened plastic lower-dome, which is commonly smoked-colored to conceal the camera. The use of smoke-colored domes provides covert lens positioning, while the use of clear domes provides for better low-light performance. Dome cameras are a good design solution for applications where the camera needs to be protected from the environment (such as dust) or it is desired to conceal the camera’s aim point. The variety of dome cameras is extensive, giving the designer a dome option for nearly any security application: fixed or PTZ, indoor or outdoor, full-size or mini-dome, analog or IP. A common application of dome cameras is in office buildings with suspended ceilings where aesthetics and ease of installation are important factors. PTZ dome cameras can move quickly from a home position to any preset, typically in less than two seconds.

4-2.7 IP and Analog Cameras.

A CCTV camera can be specified as either IP or analog, depending on the required video output format. As illustrated previously in Figure 4-1, an IP camera connects directly to an Ethernet switch from which the camera signal can be transmitted to any network node for viewing or recording. An analog camera typically connects to a digital video recorder from which live or recorded video can be transmitted to one or more CCTV workstations on the network. To ensure reliable video storage and viewing, IP cameras generally require a network with high bandwidth, high availability, and low latency.

4-3 ILLUMINATION.

4-3.1 Illuminance.

The CCTV designer must coordinate with the project's lighting engineer, landscape architect and interior designer to ensure that illuminance within scenes of interest is sufficient for cameras to render full video. Meeting this objective involves analyzing two parameters - faceplate illuminance and scene illuminance - which are illustrated in Figure 4-2 and related by the following equation:

$$\mathbf{C} = \mathbf{BR}\left(\frac{\mathbf{T}}{\mathbf{4N^2}}\right)$$

where

C = faceplate illuminance (units are foot-candles or lux)

B = scene illuminance (units are foot-candles or lux)

R = scene reflectivity factor (dimensionless number between 0 and 1)

T = lens transmittance efficiency (dimensionless number, typical value is 0.8)

N = lens f-number (ratio of lens focal length to aperture diameter)

To illustrate the use of this equation, consider the following example:

A specific outdoor fixed camera has been proposed for use at an aircraft parking area. Examining the manufacturer's data reveals that the camera requires 0.0007 foot-candle of illuminance at the faceplate to generate useable video. To achieve the desired field of view, a 5-mm lens with an f-number of 1.6 and transmittance efficiency of 0.8 is proposed. During a nighttime lighting survey it is determined that the scene of interest includes dark-colored rotary wing aircraft parked on asphalt concrete. The reflectivity factor for this scene is estimated to be 0.07. Noting that existing light fixtures are in place, light meter readings are taken at several locations within the scene and the average illuminance value is calculated to be 1.2 foot-candle. Using this average scene illuminance, faceplate illuminance is calculated as follows:

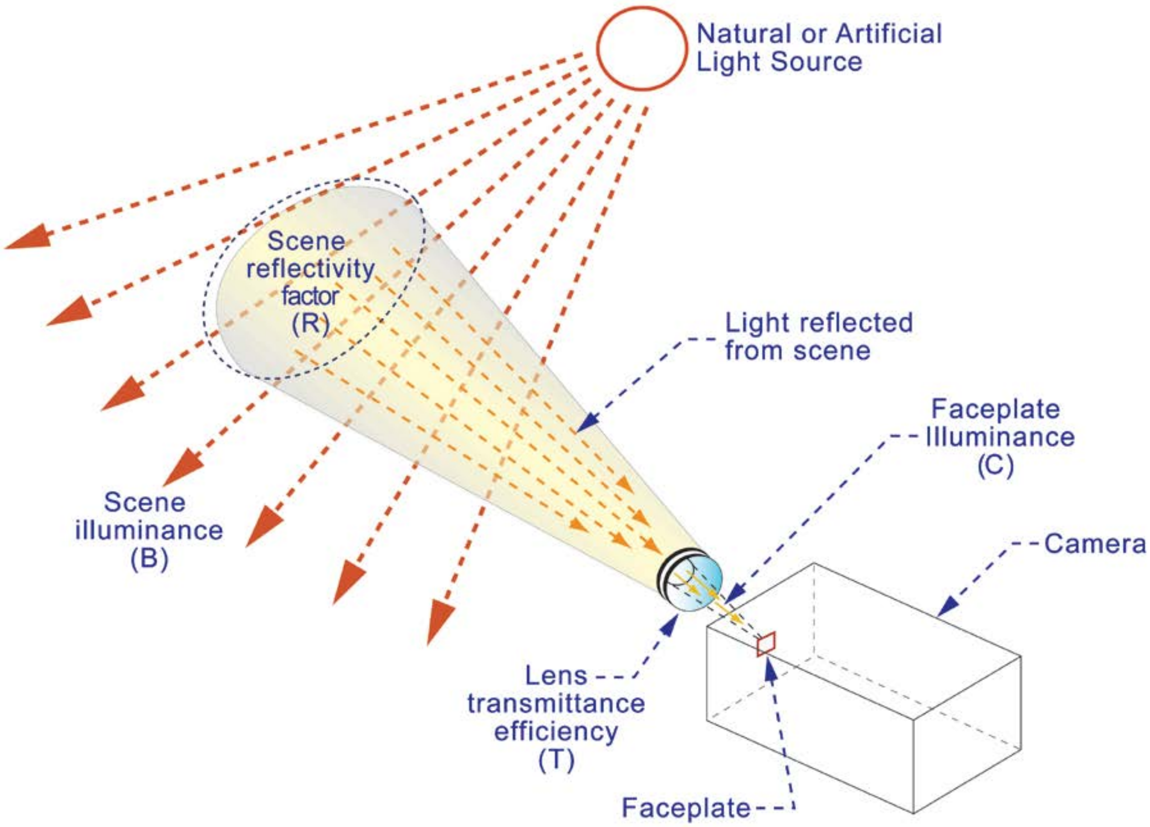
$$C = (1.2)(0.07)\left[\frac{0.8}{(4)(1.6)^2}\right] = 0.007\ footcandles$$

Comparing this calculated value with the manufacturer's specification (0.0007 foot-candle) indicates that existing nighttime illumination at the aircraft parking area is more than adequate to support full video capture by the proposed camera.

4-3.2 Uniformity.

Uniform illuminance within a camera scene yields the highest video quality. While not always achievable, the designer should strive for an average-to-minimum uniformity ratio of 4:1 within a scene of interest. Video quality degrades noticeably when the uniformity ratio exceeds 8:1. For additional guidance on uniformity and other CCTV illumination parameters, refer to UFC 3-530-01.

Figure 4-2. Scene Illuminance and Faceplate Illuminance.



Reflectivity factors for a range of surface conditions are presented in Table 4-2, and these values can be used to estimate reflectivity for actual scenes of interest.

Table 4-2. Reflectivity Factors for Various Surface Conditions.

Scene Description	Reflectivity Factor
Asphalt concrete	0.07
Grass and trees	0.2
Red brick	0.35
Portland cement concrete	0.4
White matte painted surface	0.6
Glass window or wall	0.7
Snow-covered surface	0.85

4-3.3 Glare Reduction.

Glare is very detrimental to CCTV camera performance as illustrated in Figure 4-3. Glare reduction can be achieved by specifying full cut-off luminaires and insuring that luminaires are not in a camera's field of view. In general, the source of illumination is best located above the level of the camera. The CCTV designer must coordinate with the lighting designer to ensure that these glare-reduction objectives are met.

Figure 4-3. Effect of Glare on CCTV Camera Image Quality.

4-3.4 Interior Lighting.

Interior lighting for CCTV presents special issues that need to be considered by the designer. For example, after-hours lighting may be significantly lower than normal operation lighting. Two solutions help minimize this impact.

a. The first technique is the use of cameras with automatic backlight compensation. Backlight compensation is a camera feature that enables the camera to automatically adjust picture brightness depending on lighting conditions, which compensates for bright backgrounds so foreground objects are not silhouetted. Frequently, CCTV cameras near windows are affected by backlighting, causing shadows and silhouettes, so the use of appropriate cameras with backlight compensation is effective.

b. The second technique is the use of cameras with automatic gain control, a feature that amplifies existing video to help a camera create an enhanced video signal at low light levels.

Both of these techniques enable cameras to function more effectively in interior low-light conditions and are useful for outdoor cameras as well. In some cases, the integration of CCTV cameras with night-lights and intrusion sensors can be very effective. The sequence of events might be as follows: an intruder activates an interior presence sensor which, in turn, activates instant-on lighting for CCTV camera assessment.

4-4 VIEWING IN LOW-LIGHT CONDITIONS.

In addition to increasing the illumination level of the surrounding area, several technology solutions are available to permit viewing under low-light conditions. These include black/white switching cameras, infrared illuminators, or thermal imagers. These technologies are often used where visible light either brings undesired attention to a critical facility, or surrounding property owners object to visible light adequate for good visual camera operation.

4-4.1 Black/White Switching.

Many cameras will automatically switch from color during daytime to black/white at night, which permits viewing under low light conditions. This can be an effective solution in situations where the existing illumination levels are too low during night conditions to permit color camera use, but color camera use is desired during daytime conditions. Numerous CCTV camera manufacturers offer auto-switching black/white cameras.

4-4.2 Infrared Illuminators.

The human eye cannot see infrared light. Most monochrome CCTV (black/white) cameras, however, can. Thus, invisible infrared light from either an LED or laser source can be used to illuminate a scene, which allows night surveillance without the need for additional artificial lighting. IR illumination patterns can be matched to camera field of view. A variety of patterns are available ranging from narrow- to wide-angle and short- to long-range coverage. LED IR illuminators are a good choice for short-range flood coverage and medium-range spot coverage. Approximate coverage ranges for a 26-watt LED illuminator are 65 feet (20 m) for a 120-degree flood pattern and 310 feet (95 m) for a 10-degree spot pattern. Laser IR illuminators should be considered when the desired coverage range exceeds the capabilities of LED illuminators. For example, a 60-watt laser IR illuminator can project a 10-degree pattern to a maximum effective distance of approximately 2300 feet (700 m). Infrared provides the following benefits over conventional lighting:

- Extended service life - up to 10 years.
- Lower running costs (but higher installation costs).
- Covert surveillance - no visible lighting to alert or annoy neighbors.

It is important to design illumination specifically for the CCTV camera being used. For example, infrared illuminators require black/white cameras and do not work on color cameras, unless the color camera has an automatic black-and-white switching feature. Cameras will not render color images when used under infrared illumination. The range that the camera will see in the dark depends on sensitivity and spectral response of the camera and lens combination. Many black and white cameras use infrared filters to intentionally filter out non-visible light. Therefore, black and white cameras which are designed to be used in conjunction with infrared lighting must not have an infrared filter. Dual mode cameras that can switch from color to monochrome operation in low light conditions must not have an infrared filter for the reason cited above.

4-4.3 Thermal Imagers.

Thermal imagers use a special technology that senses heat signatures rather than visual information. These cameras operate under complete darkness. Thermal imagers are best used in long-range detection and surveillance applications. Thermal imagers detect and display images based on infrared energy emitted from objects rather than visible light reflected off objects. The most common technology is Forward Looking Infrared (FLIR). Thermal cameras work on a temperature differential between the object and the background. In desert environments, the background is white and people are black. In cooler environments, the background is black and people are shown as white images. A key advantage of long-range thermal imagers is that they are less susceptible to environmental influences from rain and fog in comparison to visible light cameras. The disadvantage of thermal-imagers is the high cost and the inability to discern facial features and other fine details in the scene.

Typically thermal imagers are classified as medium or long wavelength as illustrated in Table 4-3. For security applications in which the object of interest is a man-size target within a few hundred meters of the camera, uncooled long-wavelength imagers are preferred because of their lower cost, both in terms of initial purchase and lifecycle maintenance. Cooled medium-wavelength imagers, though more costly, can resolve very small thermal gradients and, equipped with the appropriate lens, can capture images of man-size targets at ranges out to a few thousand meters.

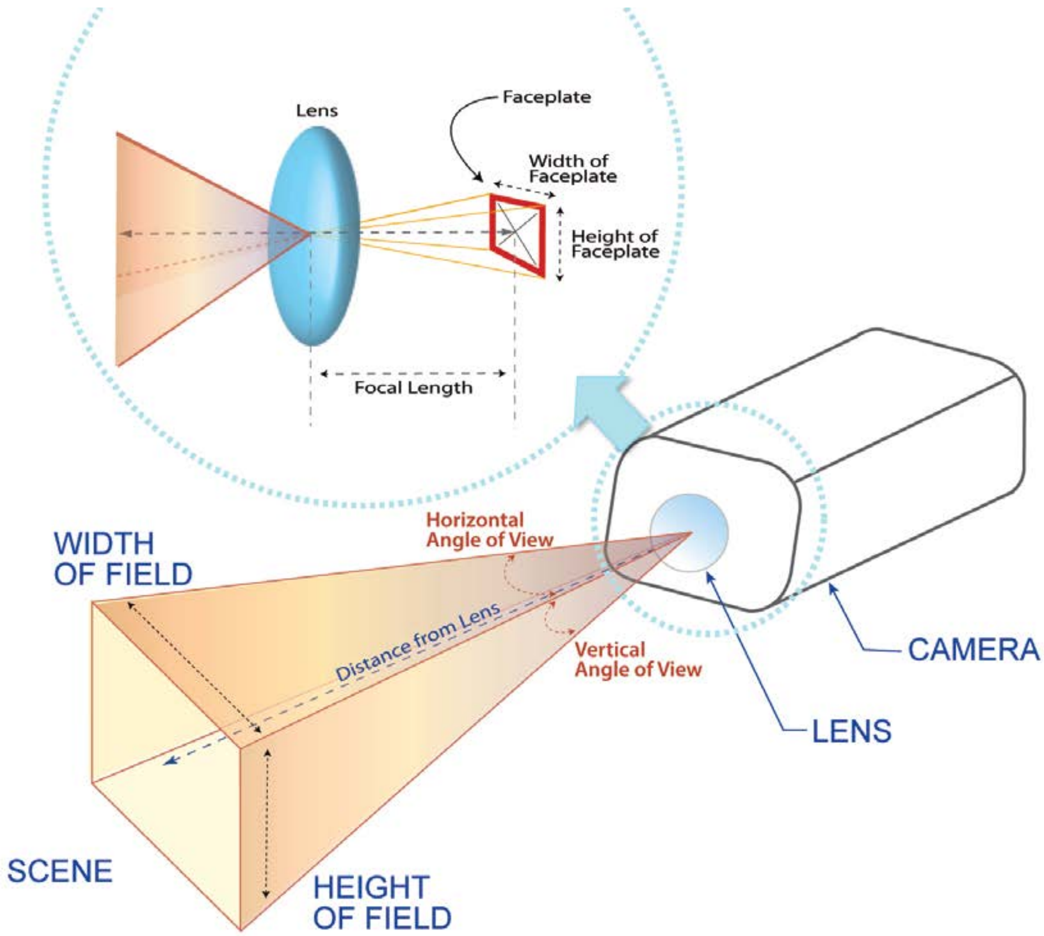
Table 4-3. Characteristics of Thermal Imagers.

Classification	Wavelength	Cooling	Cost	Recommended Service Period
Medium Wavelength	3- 5 microns	Cryogenically cooled	$50K - $150K	7,500 hours
Long Wavelength	7-14 microns	Uncooled	$5K - $50K	30,000 hours

4-5 ANGLE OF VIEW AND FIELD OF VIEW.

An important consideration when designing a CCTV system is determining the desired field of view for each camera. Field of view and angle of view are illustrated in Figure 4-4. Based on the desired field of view, the designer must specify the appropriate camera mounting location, aim point, format, and lens focal length to capture the required image.

Figure 4-4. Angle of View and Field of View.



Camera format refers to the nominal diagonal measure of the image sensor (also called the faceplate), and typical sizes are shown in Table 4-4. Given the faceplate dimensions and the lens focal length, the angle of view for any camera-lens combination can be calculated as follows:

$$\boldsymbol{\alpha} = 2\,\boldsymbol{tan}^{-1}\frac{\boldsymbol{l}}{2\mathrm{f}}$$

where

α = angle of view (horizontal or vertical)

l = length of image sensor (width or height, refer to Table 4-4)

f = focal length of lens

A relatively narrow angle of view would be provided by a 2/3-inch format camera equipped with 50-mm lens. In this example, the angles of view would be as follows:

$$\alpha_{horizontal} = 2tan^{-1}\left[\frac{8.8}{(2)(50)}\right] = 10.1°$$

$$\alpha_{vertical} = 2tan^{-1}\left[\frac{6.6}{(2)(50)}\right] = 7.6°$$

A relatively wide angle of view would be provided by a 1/3-inch format camera equipped with 5-mm lens. In this example, the angles of view would be as follows:

$$\alpha_{horizontal} = 2tan^{-1}\left[\frac{4.8}{(2)(5)}\right] = 51.3°$$

$$\alpha_{vertical} = 2tan^{-1}\left[\frac{3.6}{(2)(5)}\right] = 39.6°$$

The following simple ratios can be used to perform several types of field of view calculations:

$$\frac{l_{width}}{W} = \frac{l_{height}}{H} = \frac{f}{D}$$

where
l_{width} = width of image sensor
W = width of field
l_{height} = height of image sensor
H = height of field
f = focal length of lens
D = distance from lens
To show the application of these field-of-view ratios, consider this example. A ½-inch format camera will be mounted on a pole located 30 feet (10 m) from a pedestrian turnstile on the perimeter of an outdoor restricted area. If the desired vertical field of view is a full-height image of each person entering the restricted area, what lens focal length is needed? Assuming a 7-foot (2,134 mm) height of field at a distance of 30 feet (9,144 mm), lens focal length can be calculated as follows:

$$f = \frac{Dl_{height}}{H} = \frac{(9144)(4.8)}{2134} = 20.6\ mm$$

In this example, the designer could specify a varifocal lens to allow some fine tuning of the field of view during the installation process or later adjustment to meet a new field-of-view requirement. A 10-40 mm varifocal lens set at 20.6 mm would meet the stated objective of providing a full-height image of a person at the turnstile, but the same varifocal lens could be set to 40 mm to provide better facial detail or to 10 mm to cover an adjacent vehicle gate. Supporting calculations for these focal lengths are as follows:

$$H = \frac{Dl_{height}}{f} = \frac{(9144)(4.8)}{40} = 1,097\ mm = \text{ 3.6 feet (Better Facial Detail)}$$

$$W = \frac{Dl_{width}}{f} = \frac{(9144)(6.4)}{10} = 5,852\ mm = 19 \text{ feet (Cover Vehicle Gate)}$$

Table 4-4. Typical Faceplate Sizes.

Nominal Diagonal Measure	Actual Width	Actual Height
1/4 inch	3.2 mm	2.4 mm
1/3 inch	4.8 mm	3.6 mm
1/2 inch	6.4 mm	4.8 mm
2/3 inch	8.8 mm	6.6 mm
1 inch	12.8 mm	9.6 mm

4-6 CAMERA RESOLUTION.

Camera resolution refers to the “graininess” of images captured and transmitted by a camera and is expressed in terms of televisions lines (TVL) for analog cameras and picture elements (pixels) for IP cameras. Table 4-5 correlates qualitative resolution descriptions to equivalent camera specifications for both analog and IP cameras. For each scene of interest, the CCTV designer must determine the camera resolution required to achieve the desired discrimination level for objects in the scene. Visual target discrimination criteria developed by John Johnson in the 1950’s, commonly referred to as the Johnson criteria and summarized in Table 4-6, can be used to analyze the impact of camera resolution on object discrimination for any given angle of view. These criteria are based on a 50% probability of accurate discrimination by a person viewing the camera image. The following example applies the Johnson criteria to illustrate the difference in object discrimination performance between a high-resolution camera and a megapixel camera.

Table 4-5. Typical Camera Resolution Specifications.

	Equivalent Camera Resolution Specification	
Qualitative Description	Analog Camera	IP Camera
Very Low Resolution - Quarter VGA	N/A	320 X 240 pixels
Low Resolution - VHS	330 TVL	N/A
High Resolution - DVD	540 TVL	720 X 480 pixels
Megapixel Resolution	N/A	1280 X 1024 pixels (and higher)
HD 1080p Resolution	N/A	1920 x 1080 pixels

Table 4-6. Object Discrimination Levels Based on Johnson Criteria.

Discrimination Level	Meaning	Pixels required across minimum dimension	Example
Detection	An object of a specified size is present.	2	An object with minimum dimension of 60 inches in the vertical orientation is present in the scene.
Recognition	The class to which the object belongs can be determined.	8	The object is a vehicle, not people or animals.
Identification	The type of object within the class can be determined.	16	The vehicle is a sedan, not a truck, SUV or van.

A 2/3-inch format camera with a 25-mm lens will be used to visually assess outdoor perimeter intrusion alarms along a restricted area. The camera will be aimed parallel to the fence line to view objects in the clear zone. The objective is for the camera to provide recognition level discrimination for a person crawling through the clear zone. This level of discrimination will allow a human crawler to be distinguished from objects of similar size such as animals and wind-blown debris. The minimum dimension for a human crawler is 12 vertical inches (0.3 m), and applying the Johnson criteria suggests that this 12-inch (0.3 m) vertical profile must be “painted” by 8 vertical pixels on the image collected by the camera. Given the properties of the camera, lens, and object to be viewed, the following equation can be used to calculate the maximum range for “recognizing” the human crawler:

$$\boldsymbol{D = \frac{hfR_{vertical}}{p_{vertical}l_{height}}}$$

where

D = distance from lens to object

h = height of object

f = focal length of lens

$R_{vertical}$ = vertical resolution of the camera in pixels

$p_{vertical}$ = vertical pixels required on object

l_{height} = height of image sensor

Converting the height of the human crawler from 12 inches to 305 mm and solving this equation yields the following result for a high-resolution (720 X 480 pixels) camera:

$$\boldsymbol{D = \frac{(305)(25)(480)}{(8)(6.6)} = 69,318\ mm = 227\ feet}$$

A megapixel camera (1,280 X 1,024 pixels), by comparison, provides a maximum “recognition” range of:

$$\boldsymbol{D = \frac{(305)(25)(1,024)}{(8)(6.6)} = 147,879\ mm = 485\ feet}$$

In this illustration, even though the angles of view are the same for both cameras (20° horizontal & 15° vertical), the megapixel camera has two times the effective range of the high-resolution camera.

For objects having a minimum dimension equal to their width (such as a person walking), the following equation can be used in conjunction with the Johnson criteria to calculate maximum effective range:

$$\boldsymbol{D = \frac{wfR_{horizontal}}{p_{horizontal} l_{width}}}$$

where

D = distance from lens to object

w = width of object

f = focal length of lens

$R_{\text{horizontal}}$ = horizontal resolution of the camera in pixels

$p_{\text{horizontal}}$ = horizontal pixels required on object

l_{width} = width of image sensor

4-7 VIDEO FRAME RATE.

Video frame rate is an important CCTV design parameter that affects video transmission, storage, and display. A frame rate of 30 frames per second (fps) is generally considered to be “full motion video” based on the National Television Standards Committee (NTSC) analog video standard. However, the transmission and recording frame rates for digital video can be set for a range of values between 1 and 30 fps, and some IP cameras and network video recorders support frame rates up to 60 fps. For most security applications, including alarm assessment and evidentiary archives, frame rates between 4 and 10 fps are fully adequate. Higher frame rates are appropriate for surveillance applications in which a smooth video stream is beneficial to the operator, especially when using a PTZ camera. Frame rates of 24 fps and higher will be perceived as “smooth” when viewed by an operator for extended periods of time. In most digital video systems, transmission and recording frame rates can be programmed to automatically change in response to an external event such as an intrusion alarm or an internal video motion detection trigger.

4-8 DIGITAL VIDEO BANDWIDTH.

The CCTV designer must coordinate closely with the appropriate network designer or administrator to ensure that network bandwidth will support digital video transmission. Estimating bandwidth requirements using the equation below will aid in this coordination.

$$\boldsymbol{b = krz}$$

where

$\boldsymbol{b}$ = bandwidth required for a single video stream

$\boldsymbol{k}$ = network overhead factor, typical value is 1.4

$\boldsymbol{r}$ = video frame rate

$\boldsymbol{z}$ = average compressed file size of a single video frame

The average file size for a single frame is dictated by the video resolution and compression, and typical values are given in Table 4-7. The following example illustrates the use of this table and the equation above.

Four IP cameras will be installed in an administrative building as part of an access control upgrade. One fixed camera will be installed at the main entry door and the other three fixed cameras will be installed at doors designated for emergency exit only. Each camera has megapixel (1280 X1024) resolution and H.264 video compression. Video from the administrative building will be transmitted via network at 5 fps to a headquarters building for recording and viewing. How much network bandwidth is required to support these four cameras?

Assuming that the main entry camera will have high scene activity, a single video frame will have an average compressed file size of 72 kB. The other three cameras will each have low scene activity and a corresponding file size of 36 kB. Using these file size values from Table 4-7, along with the specified frame rate of 5 fps, the following bandwidth estimates can be made, with the results expressed in units of Megabits per second (Mbps):

ENTRY DOOR CAMERA: $\mathbf{b_{entry} = (1.4)(5)(72) = 504\ kBps = 4.03\ Mbps}$

EXIT DOOR CAMERA: $\mathbf{b_{exit} = (1.4)(5)(36) = 252\ kBps = 2.02\ Mbps}$

TOTAL FOR ALL CAMERAS: $\mathbf{b_{total} = b_{entry} + 3b_{exit} = 10.09\ Mbps}$

(Note: 1 Mbps = 125 kBps)

Based on this calculation, the four IP cameras will require approximately 10 Mbps of network bandwidth to transmit video from the administrative building to the headquarters building.

Table 4-7. Single-frame File Size for Various Resolution Values and Compression Schemes

Resolution (H x V pixels)	Average Compressed File Size (kB) for a Single Video Frame		
	H.264 - Low Scene Activity	H.264 - High Scene Activity	MJPEG - High Quality
320 X 240	4	8	20
720 X 480	12	24	60
1280 X 1024	36	72	180
1920 X 1080	50	100	250

4-9 DIGITAL VIDEO RECORDING.

The CCTV designer must plan for digitally recording video from all cameras, and several technology options are available. The following paragraphs provide a brief overview of four of the most common video recording methods followed by an explanation of how to estimate video storage requirements.

4-9.1 Memory Card.

Several camera models have a built-in memory card which allows video to be recorded at the edge of the CCTV system. This ensures uninterrupted recording even when the connection between the camera and the central system is lost, but storage capacity is very limited. An SD card, for example, has a capacity of 2 GB.

4-9.2 Digital Video Recorder (DVR).

A DVR digitizes analog camera inputs and stores the video on one or more internal hard drives. The number of camera inputs ranges from 4 to 32, depending on the model selected. Recording resolution up to 720 X 480 at 30 fps is available on many models. Access to live and recorded video from remote workstations is enabled by a network interface card in the DVR, but video will continue to be recorded even if network connectivity is lost. A DVR can provide several terabytes of video storage capacity.

4-9.3 Network Video Recorder (NVR).

An NVR records digital video from multiple IP cameras and video encoders to one or more internal hard drives. The capacity and sophistication varies greatly within this category of video recording technology. A low-end NVR can typically record up to 16 cameras at 30 fps, with recording resolution no greater than 720 X 480. A high-end NVR can accommodate 50 or more cameras, recording each camera at 24 fps with HD 1080p resolution. All NVRs have an internal network interface card to receive and distribute IP video streams, and high-end units have two or more Gigabit Ethernet ports. A CCTV designer must ensure that each network path connecting an IP camera with its associated recording node is adequate in terms of both availability and bandwidth. NVR storage capacity ranges from 1 TB at the low end of the category to greater than 10 TB for high-end units.

4-9.4 Hybrid Video Recorder (HVR).

Combining the functionality of a DVR and an NVR into a single unit, an HVR can digitize and record multiple analog camera inputs while simultaneously recording multiple IP video streams. Many HVRs provide up to HD 1080p recording resolution for IP cameras, and HVR video storage capacities generally range from 2 to 10 TB.

4-9.5 Required Storage Capacity.

Once all cameras have been specified for a project, the CCTV designer should use the following equation to estimate the required storage capacity for each video storage device:

$$\mathbf{s = trz}$$

where

s = required video storage capacity for a single camera

t = required video storage duration

r = video frame rate

z = average compressed file size of a single video frame

The following example illustrates the methodology and calculations needed to estimate required video storage capacity for a single storage device.

The CCTV system for an access control point will be upgraded. All existing components, with the exception of two analog PTZ cameras, will be removed and replaced with 5 new megapixel IP cameras, all fixed, and an NVR. Video encoders will be used to convert the analog camera signals to IP video streams which will be recorded to the NVR along with the 5 IP camera feeds. The security manager has stated that the fixed cameras will be recorded at 4 fps with a resolution of 1280 X 1024, and the PTZ cameras will be recorded at 10 fps with a resolution of 720 X 480. The security manager also stated that there is a 7-day video storage requirement for all access control point cameras. The IP cameras and the encoders for the PTZ cameras will all use MJPEG compression. How much video storage is required for the NVR?

Converting 7 days to 604,800 seconds, the storage required for a single fixed IP camera can be calculated as follows:

$$\mathbf{s_{fixed} = (604,800\ s)(4\ fps)(180\ kB) = 435,456,000\ kB \cong 415\ GB}$$

The storage required for a single PTZ camera can be calculated in a similar manner:

$$\mathbf{s_{ptz} = (604,800\ s)(10\ fps)(60\ kB) = 362,880,000\ kB \cong 346\ GB}$$

Taking into account the quantity of fixed and PTZ cameras, the total storage required for all cameras can be calculated as follows:

$$\mathbf{s_{total}} = (\mathbf{5})(\mathbf{415\ GB}) + (\mathbf{2})(\mathbf{346\ GB}) = \mathbf{2,767\ GB} \cong \mathbf{2.7\ TB}$$

(Note: 1 TB = 1024 GB = 1,073,740,000 kB)

4-10 CCTV WORKSTATION.

To allow viewing of live and recorded video, the designer must specify at least one workstation for each CCTV system, and multiple workstations may be required for a large distributed system. Because of the computational demands associated with processing and displaying digital video streams, a “gaming” computer is a good choice for a CCTV workstation. These computers generally have high-speed processors, large amounts of RAM, fast graphics cards with high-resolution output, and network interface cards supporting Gigabit Ethernet speed. For a single-operator workstation, a graphics card feeding one or two monitors will usually be sufficient for CCTV viewing and management. If three or four monitors are needed for a workstation, two dual output graphics cards or a single quad output graphics card must be specified for the workstation. The graphics card and monitor must provide display resolution equal to or greater than the highest resolution camera in the system. Any workstation that will be used to control PTZ cameras must be equipped with a joystick. Video management software that is compatible with all cameras, encoders, and recording devices must be installed on each workstation.

4-11 VIDEO ANALYTICS.

If surveillance is an important security objective for a CCTV system, the designer must consider including video analytics as part of the system specification. Video analytics software allows the user to input a specific set of rules for each scene of interest, which, if violated, generate visual cues on the monitor, thus drawing the operator’s attention to suspicious objects or behaviors. This capability to automatically prioritize scenes and highlight suspicious areas for the operator maximizes the effectiveness of surveillance activities. Video analytics can be especially beneficial when a single operator is required to perform surveillance with a large number of cameras. Video analytics algorithms can be embedded in IP cameras, encoders, and recording devices or they can run on dedicated file servers. Common rule violations programmed to alert the operator include crossing a virtual tripwire, loitering in a prohibited area, moving in the wrong direction, leaving an unattended object, and removing an object.

4-12 CCTV DESIGN PROCESS SUMMARY.

4-12.1 Define Security Objectives for the CCTV System.

Begin by evaluating specific project requirements in light of the four most common CCTV functions: 1) alarm assessment, 2) access control, 3) surveillance, and 4) evidentiary archives. Concisely state objectives with enough detail to facilitate camera selection and layout. Example objectives are as follows:

- Visually assess perimeter intrusion alarms for seven bistatic microwave sensor zones around the satellite communications facility.
- Visually identify the driver and vehicle prior to opening the gate at the test area.
- Perform surveillance of four exhibit areas in the museum and maintain a 30-day video archive for evidentiary purposes.

4-12.2 Develop a Camera Layout to Meet the Security Objectives.

Indicate camera locations on site plans and building floor plans, identifying each camera as fixed or PTZ. Specify the mounting configuration (wall, ceiling, pole, roof, etc.) for each camera, and select the appropriate camera and lens for the intended field of view.

4-12.3 Verify That Illumination Is Sufficient For Each Scene Of Interest.

Ensure that camera specifications for faceplate illumination are met and that uniformity ratios are within acceptable limits. Specify lighting upgrades as needed.

4-12.4 Specify Workstation Locations.

Indicate workstation locations on building floor plans, and describe the basic configuration of each workstation including quantity and size of monitors. Identify any special furniture or console requirements.

4-12.5 Specify Recording Locations and Capacity.

Indicate recording locations on building floor plans, and describe the type and quantity of recording devices required at each location. Calculate the required video storage capacity for each recording device.

4-12.6 Define Network Architecture.

Develop a block diagram to illustrate connectivity for all cameras, recorders, workstations, and networking devices. Specify cables required for equipment interconnection, and calculate bandwidth requirements for all network connections.

4-12.7 Define Power Requirements.

Determine the power requirements for each component. Specify all power circuits and the location of all power supplies.

4-12.8 Describe Software and Integration Requirements.

Specify features and functions required for camera control, video management, and analytics. State alarm assessment requirements for integration with intrusion detection and access control software.

CHAPTER 5 INTRUSION DETECTION SYSTEM

5-1 OVERVIEW.

The function of an IDS is to detect intruders. The detection of an intruder starts the “clock” on the Detect, Delay, Respond timeline addressed in Chapter Two, Electronic Security Systems Overview. The principal elements of an IDS include sensors, local processors, arm/disarm devices, workstations, and the central system along with the supporting data transmission infrastructure. These elements are shown in Figure 5-1. An IDS requires integration with a process and mechanisms for assessing and responding to intrusion alarms.

5-2 SYSTEM CONFIGURATION.

The designer must determine the appropriate IDS configuration early in the planning stage of a project. The four most important configuration issues that must be resolved are policy compliance, alarm monitoring location(s), zone definition, and IDS/ACS integration. These four issues are discussed in the following paragraphs.

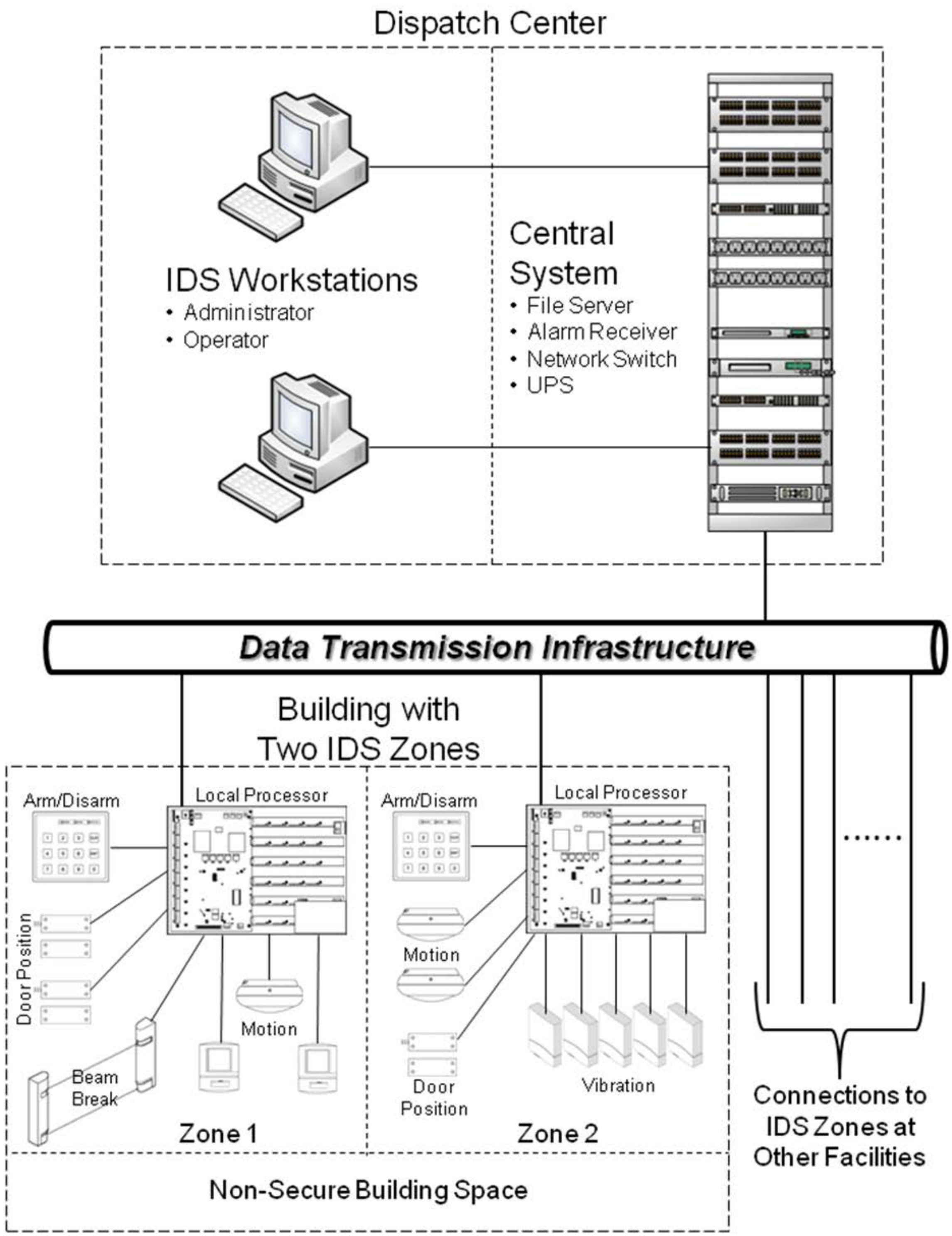
5-2.1 Policy Compliance.

Determining which assets require IDS coverage is an essential first step in the IDS design process. The designer must work closely with the facility owner/user to understand what assets are present and then determine whether or not IDS is required based on applicable security policy. The goal of this activity is to focus IDS coverage where it is required at a facility (arms room, SCIF, etc.) while avoiding frivolous investment to cover low-security areas (office suite, conference room, etc.) This activity is also beneficial in defining IDS zones as described in greater detail later in this section. Notional interior IDS configurations for a variety of assets are provided in Appendix C along with policy references for each. Examples of assets that generally require exterior perimeter IDS are special weapons (nuclear, chemical) storage facilities, high-value aircraft parking areas, and ballistic missile defense sites.

5-2.2 Alarm Monitoring Location(s).

Since most IDS requirements are focused on protecting unattended high-value assets, the designer must identify the best method for continuous alarm monitoring during periods when the secure area is not occupied. For IDS zones located in a facility that has a continuously-manned security desk, local monitoring may be the best option. Most buildings on military installations, however, do not have around-the-clock security staffing. This is especially true of smaller buildings that may have only one or two IDS zones such as an arms room or SECRET open storage area. The best option for these facilities is connecting the IDS zone(s) to a base-wide IDS with continuous alarm monitoring at the Dispatch Center. This configuration is illustrated in Figure 5-1. For some projects, it may be appropriate to provide the capability to monitor IDS alarms locally (at the security desk during duty hours, for example) and also at the Dispatch Center (primarily after duty hours).

Figure 5-1. Example Intrusion Detection System (IDS).



5-2.3 Zone Definition.

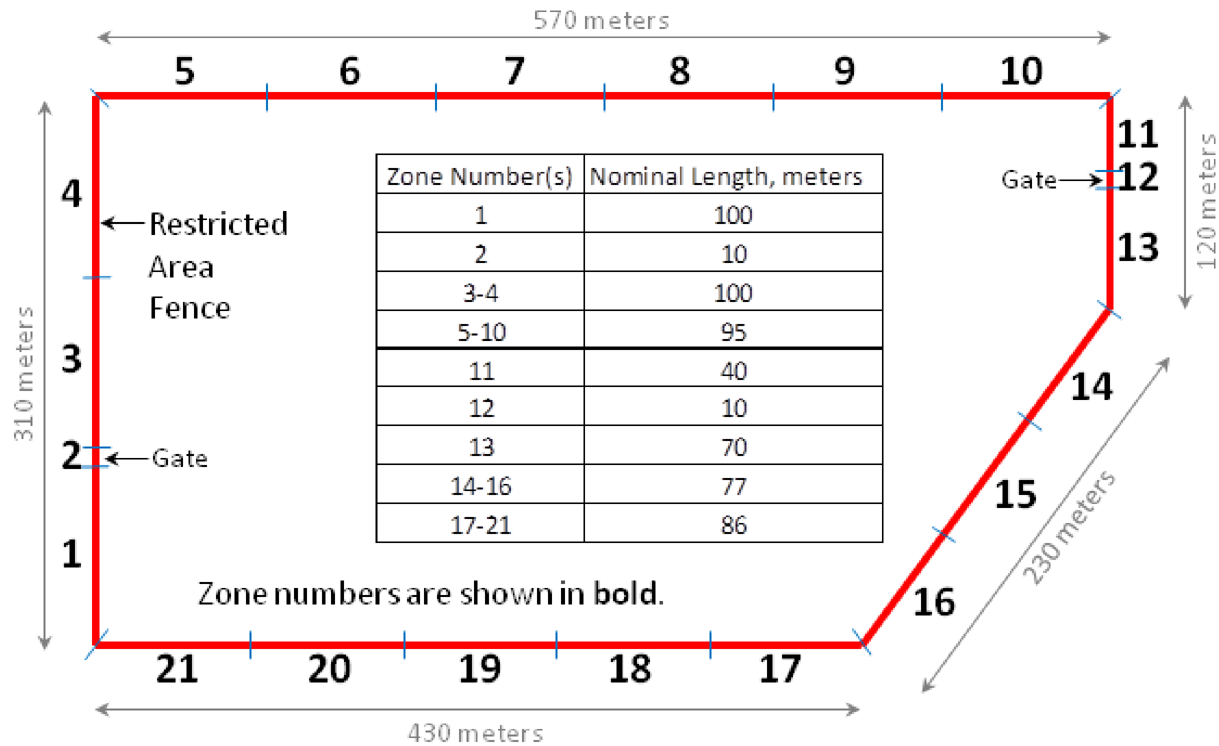
The designer must define zones for both interior and exterior IDS. In general terms, an interior IDS zone is a room or space within a building that can be armed and disarmed independently from all other zones. The simplest interior zone is a single room with a specialized function protected by a few sensors connected to a local processor. A good example of a simple interior zone is an arms room. A large zone may encompass several adjacent rooms (to include an entire floor, wing or office suite in some buildings) or a large open area, and it may have twenty or more sensors connected to the local processor. Regardless of the size or complexity of a given interior zone, the designer should specify that each sensor annunciate as a discrete, identifiable alarm point in the IDS. Examples of interior IDS zones are provided in Appendix C. An exterior IDS zone is a continuous section of perimeter for which alarms are annunciated independently from all other alarm zones.

Like its interior counterpart, an exterior IDS zone can also be independently armed and disarmed. The designer must determine the appropriate perimeter zone layout based on the shape of the perimeter, length of each side or fence segment, location of access roads and gates, and the range capability of the candidate sensor technology. As a general rule, shorter zones enhance alarm assessment and response, but longer zones are more economical. Best practice dictates that a standard zone length of approximately 330 feet (100 m) achieves a good balance between system cost and system effectiveness and is well within the range capabilities of most sensor technologies. Another advantage of a 330 feet 100 m) zone is that alarms can be visually assessed anywhere in the zone with a single fixed camera (assuming that the appropriate lens focal length and faceplate resolution are specified). An example of an exterior IDS zone layout is shown in Figure 5-2.

5-2.4 IDS/ACS Integration.

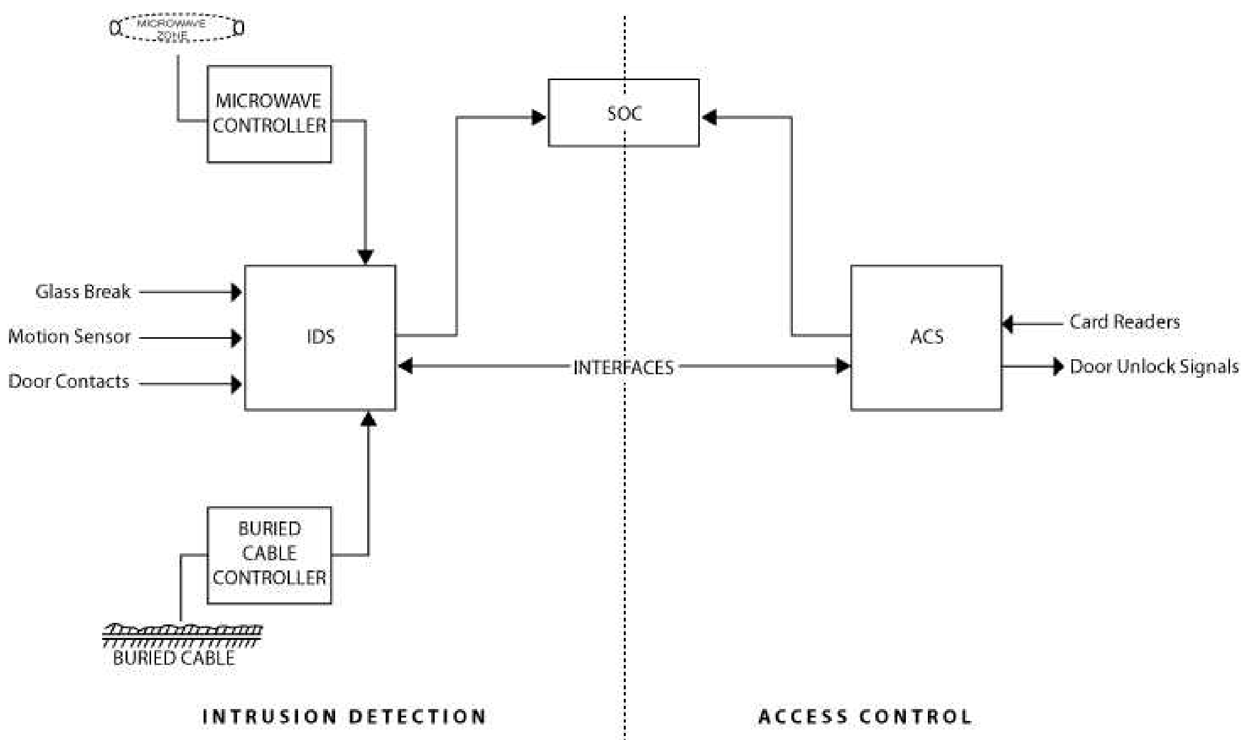
For each ESS project, the designer must determine whether IDS and ACS functions would be best provided through a single unified IDS/ACS or through two separate systems. Even if it is appropriate to field separate systems as shown in Figure 5-3, some degree of IDS/ACS integration is often desirable. In general, any output from one system can be incorporated as an input to another system through a simple relay-to-relay integration. As an example, door held open violations from an ACS can be annunciated as alarms in a separate IDS by wiring ACS outputs to IDS inputs at the local processor level. Additional information on IDS/ACS integration is provided in Chapter 8.

Figure 5-2. Example Exterior IDS Zone Layout.



Zone Number(s)	Nominal Length, meters
1	100
2	10
3-4	100
5-10	95
11	40
12	10
13	70
14-16	77
17-21	86

Figure 5-3. Separate ACS and IDS.



5-3 INTERIOR SENSORS.

This section covers both interior point sensors and interior volumetric sensors. For additional information on interior IDS sensors to include types, purposes, principles of operation, common causes of false alarms, and appropriate applications refer to DoD O-2000.12-H. Table 5-1 provides application notes for interior IDS sensors.

5-3.1 Interior Point Sensors.

5-3.1.1 Balanced Magnetic Switch(s) (BMS).

BMS use a magnetic field or mechanical contact to determine if an alarm signal is initiated (for example, if an access portal such as a door, window, or roof hatch has been opened). BMS differ from standard magnetic status switches in that BMS incorporate two aligned magnets with an associated reed switch. If an external magnet is applied to the switch area, it upsets the balanced magnetic field such that an alarm signal is received. Standard magnetic switches can be defeated by holding a magnet near the switch. Mechanical contacts can be defeated by holding the contact in the closed position with a piece of metal or taping them closed. Balanced magnetic switches are not susceptible to external magnetic fields and will generate an alarm if tampering occurs. Therefore, only specify balanced magnetic switches for access portal sensors. Figures 5-4, 5-5, and 5-6 show some typical applications of BMS.

Figure 5-4. Sample Door Configuration.

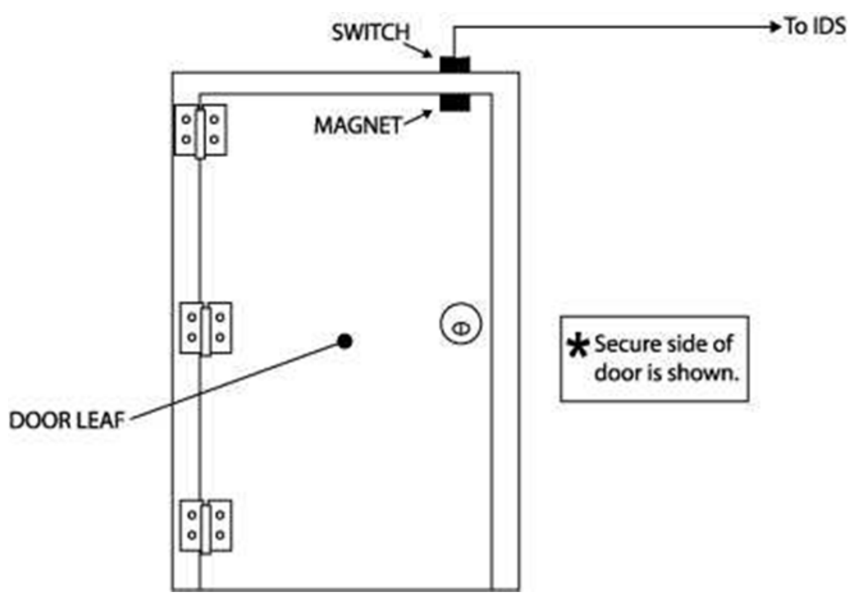


Figure 5-5. Sample Window Configuration.

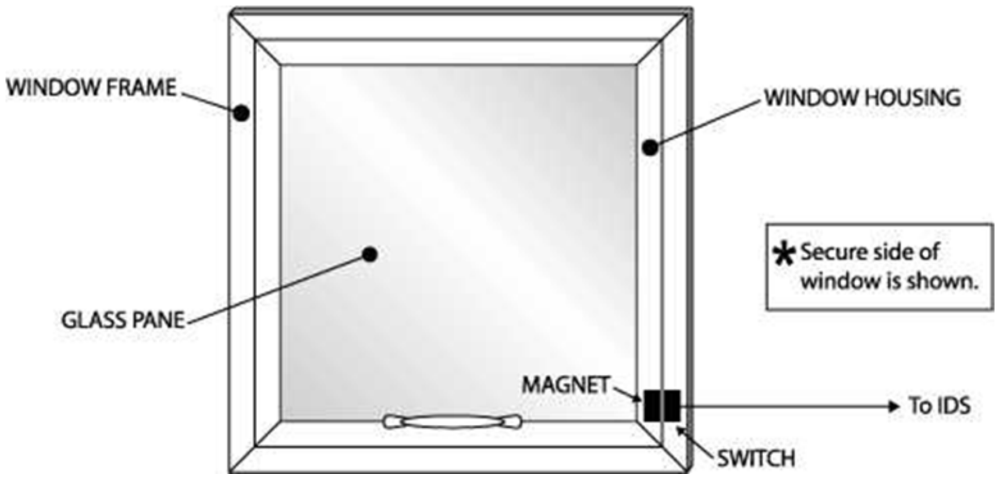
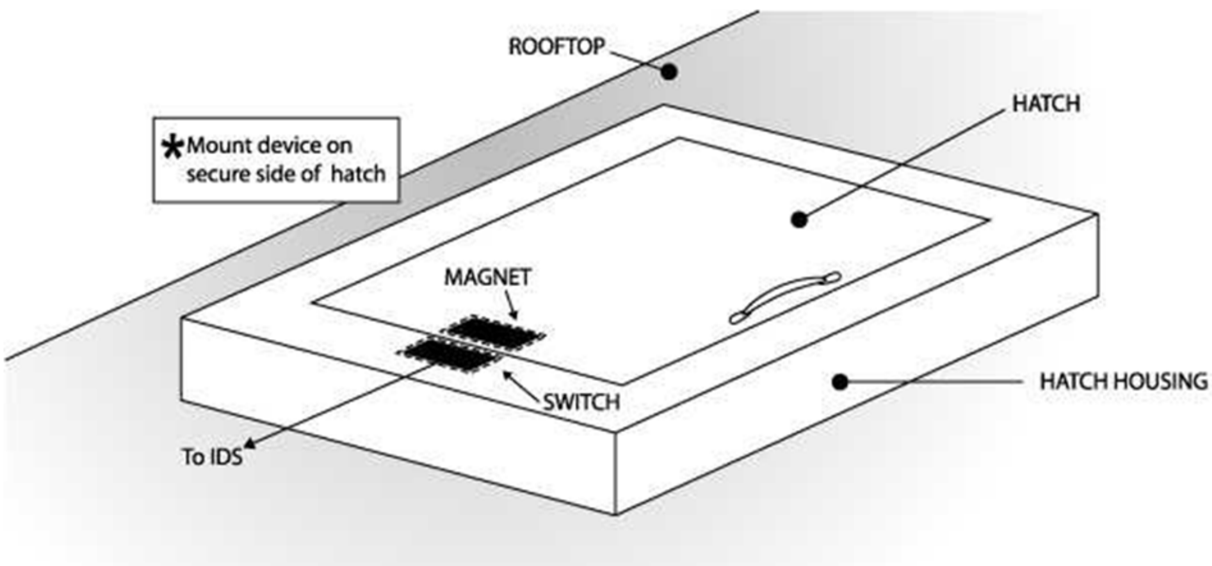


Figure 5-6. Sample Roof Hatch Configuration.



5-3.1.2 Glass Break.

Glass break sensors are a good intrusion detection device for buildings with a lot of glass (windows, doors with glass panes). Glass as an exterior protection barrier is easily defeated. Windows can be quickly and easily broken. Consider the case of installing a card reader on an administrative exterior door. The determined intruder will not let the door lock deter the intrusion effort, but can take the option of breaking nearby accessible windows. Glass break sensors can be used to cover multiple windows.

There are three basic types of glass-break sensors: acoustic sensors (listens for an acoustic sound wave that matches the frequency of broken glass), shock sensors (feels the shock wave when glass is broken), and dual technology sensors (senses acoustic and shock vibrations). Glass-break sensors must be used in conjunction with other methods (such as volumetric sensors) because they do not sense motion or intrusion from entering a door or hatch.

5-3.1.2.1 Glass Types.

There are a variety of glass types: plate, tempered, laminated, and wired. For inhabited facilities, UFC 4-010-01 requires laminated glass for windows. Most glass break sensors work with all glass types to include laminated glass.

5-3.1.3 Glass Break Sensor Guidance.

a. Do not use window mounted glass break sensors.

b. Glass break sensors should only be used in protected areas with windows on the ground floor or that are easily accessible.

c. Use volumetric sensors in conjunction with glass break sensors in protected areas.

d. Use dual-technology glass break sensors (acoustic and shock wave). There is not a significant price difference between a simple acoustic sensor and a combination sensors (acoustic and shock). For the nominal component price increase, which is a fraction of the total installed cost, the increased capability justifies the higher cost.

e. Check glass break sensor specifications to ensure they are rated for the type of glass used, typically laminated glass.

5-3.2 Interior Volumetric Sensors.

Volumetric sensors monitor an internal area to detect the presence of an intruder. There are several types of volumetric sensors including acoustic, infrared linear beam sensors, passive infrared (PIR), ultrasonic and dual-technology (microwave and PIR).

5-3.3 Acoustic Sensors.

Acoustic sensors use passive listening devices to monitor building spaces. An application is an administrative building that is normally only occupied in daylight working hours. Typically, the acoustic sensing system is tied into a password protected building entry control system, which is monitored by an off-site Central Station. When someone has logged into the building with a proper password, the acoustic sensors are disabled. When the building is secured and unoccupied, the acoustic sensors are activated. After hours intruders make noise which is picked up by the acoustic array and an alarm signal is generated.

Acoustic sensors act as a detection means for stay-behind covert intruders.

5-3.4 Passive Infrared (PIR) Sensors.

Passive Infrared (PIR) Sensors are one of the most common interior volumetric intrusion detection sensors. PIRs pickup heat signatures (infrared emissions) from intruders by comparing infrared receptions to typical background infrared levels. Typically, activation differentials are 3 degrees Fahrenheit. These devices work best in a stable environmentally-controlled space.

5-3.4.1 PIR Coverage.

Different lenses can be placed on the PIR to focus or spread-out the coverage of the detection window. In other words, standard supplied covers for lens can be made to provide a narrower or wider sensor coverage area.

5-3.4.2 PIR Sensor Guidance.

a. Use caution when specifying this sensor for areas that can be exposed to sudden changes in background environmental temperature.

b. Best use is in interior climate-controlled spaces.

c. PIRs can receive false alarms from other heat radiating objects such as heat-system registers, rodents, pets, or other warm objects (in one case a mop bucket with hot water in it).

d. PIRs can also be defeated by a trained, slow-moving intruder. (Very hard to achieve.)

e. PIRs are much more sensitive to travel crossing its sensing area as opposed to travel toward the sensor.

5-3.5 Ultrasonic Sensors.

Ultrasonic Sensors use active transmission of sound waves to pick up intruders much like a radar transmitter and receiver. To get an alarm signal, a signal must be transmitted, bounced off an intruder and receipt signal received. Ultrasonic sensors are rarely used.

5-3.6 Dual-Technology Sensors.

Dual-technology sensors use both microwave and PIR sensor circuitry within a single housing. An alarm condition is generated if either the microwave or PIR sensor detects an intruder. In some dual-technology sensors, alarm settings may be adjusted to require that both the microwave and the PIR unit detect an intruder presence before an alarm condition is generated. Since two independent means of detection are involved, false alarm rates are reduced when configured in the “AND” condition (both microwave and PIR sense an intruder). Dual-technology sensors can only be used in a SCIF, vault, or secure room if the technologies operate in an “OR” configuration (either the microwave or PIR sense an intruder). Therefore dual technology sensors are not recommended for this application.

Table 5-1. Application Notes – Interior IDS Sensors.

Application	Sensor Type	Notes
Doors	Balance magnetic switch (BMS).	Proper alignment and properly installed doors minimize false alarms. Used in conjunction with volumetric sensors.
Windows	BMS Break Glass Sensor Acoustic Shock Dual Technology	Use combination acoustic/shock wave sensor. Used in conjunction with volumetric sensors.
Roof Hatches	BMS	Proper alignment and proper installation minimize false alarms. Used in conjunction with volumetric sensors.
Room/Hallways	Volumetric Sensors: Passive Infrared Microwave Dual Tech (PIR & MW) Ultrasonic	Do not use dual-tech devices in SCIFs.
Walls	Vibration Sensors Fiber Optic Sensors.	Design to detect a compromise of a wall to a secure area.

5-4 EXTERIOR SENSORS.

This section covers exterior sensors for intrusion detection in the following categories: (1) open terrain sensors such as infrared and microwave sensors, (2) property/fence-line sensors such as electro-mechanical systems and fiber-optic sensing systems, and finally (3) other sensor technologies such as buried cable and wide area sensors.

5-4.1 Open Terrain.

Open terrain sensors include infrared, microwave systems, combination (dual technology), and vibration sensors. In general, open terrain sensors work best on flat, cleared areas. Heavily or irregular contoured areas are not conducive to open terrain sensing systems.

5-4.1.1 Infrared Sensors.

5-4.1.1.1 Passive.

Passive sensors can work well in exterior environments, but outside interference issues of reflected light or radiated light have to be considered.

5-4.1.1.2 Active.

Active infrared sensors transmit an infrared signal via a transmitter. The location for reception is at a receiver. Interruption of the normal IR signal indicates an intruder or object has blocked the path. The beam can be narrow in focus, but should be projected over a cleared path. Refer to Figure 5-7 for a conceptual diagram of how an active infrared IDS works.

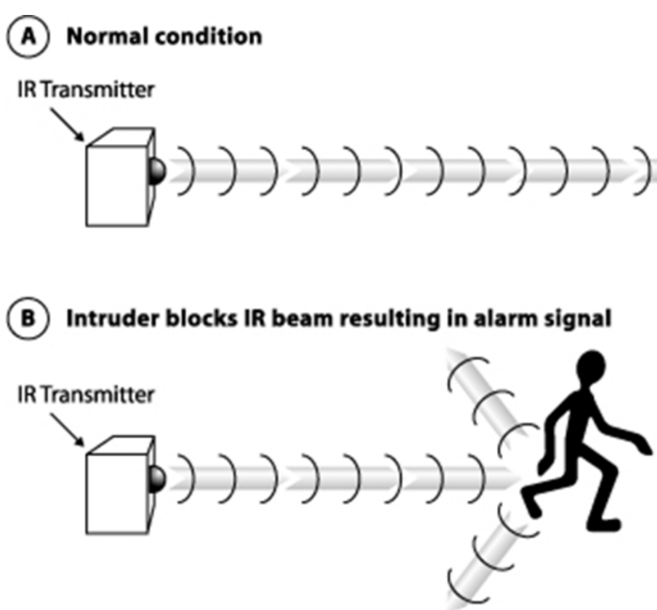
5-4.1.1.3 Infrared Sensors Guidance.

a. Check that the terrain is suitable for clear signal transmission.

b. Infrared arrays do not work well in areas with heavy snowfall because drifts or snow mounds cover sensors and or block transmission and reception paths.

c. Shield receiver from direct sunlight.

Figure 5-7. Active Infrared IDS.



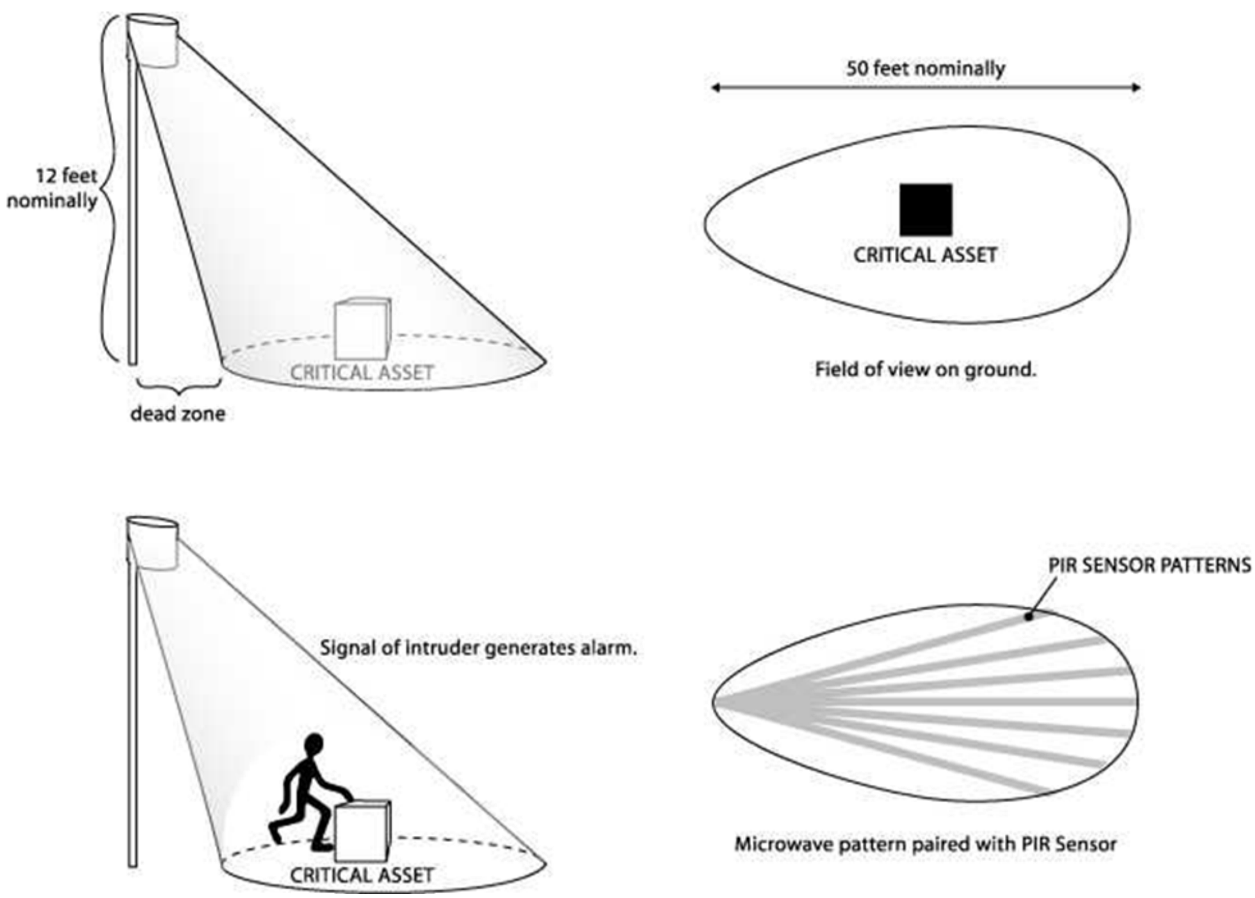
5-4.1.2 Microwave Sensors.

Microwave sensors come in two configurations: bistatic and monostatic. With both bistatic and monostatic sensors, the sensors operate by radiating a controlled pattern of microwave energy into the protected area. The transmitted microwave signal is received, and a base level "no intrusion" signal level is established. Motion by an intruder causes the received signal to be altered, setting off an alarm. Microwave signals pass through concrete and steel and must be applied with care if roadways or adjacent buildings are near the area of coverage. Otherwise nuisance alarms may occur due to reflected microwave patterns.

5-4.1.2.1 Monostatic.

Monostatic microwave sensors use a single sensing unit that incorporates both transmitting and receiving functions. Many monostatic microwave sensors feature a cut-off circuit, which allows the sensor to be tuned to only cover within a selected region. This helps to reduce nuisance alarms. Refer to Figure 5-8 for illustrations of a monostatic microwave sensor and associated footprints.

Figure 5-8. Monostatic Microwave Sensor and Associated Footprints.



5-4.1.2.2 Bistatic.

Bistatic microwave sensors are more commonly used than monostatic sensors for wide-area surveillance. Bistatic microwave sensors use a transmitter and receiver pair. Bistatic sensors work over longer distances than mono-static sensors. Typical distances for transmitter-receiver pairs are 10 - 600 feet (3 – 182 m) for X-band frequencies and

100 - 1500 feet (30 – 457 m) for K-band frequencies. The bistatic transmitter typically sends out a high frequency open-band radio frequency in a 3-8 degree pattern. (Common microwave frequencies are X-band 10 GHz or K-band 24 GHz.) Refer to Figure 5-9 and Figure 5-10 for illustrations of bistatic microwave sensor operation.

Figure 5-9. Bistatic Microwave Sensor Operation.

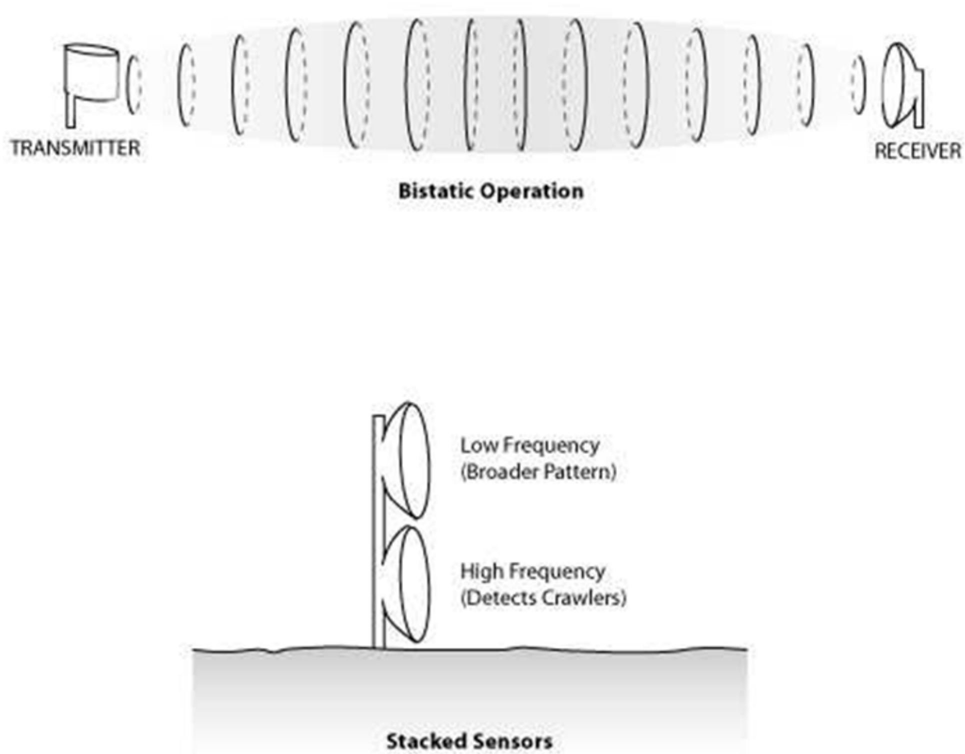
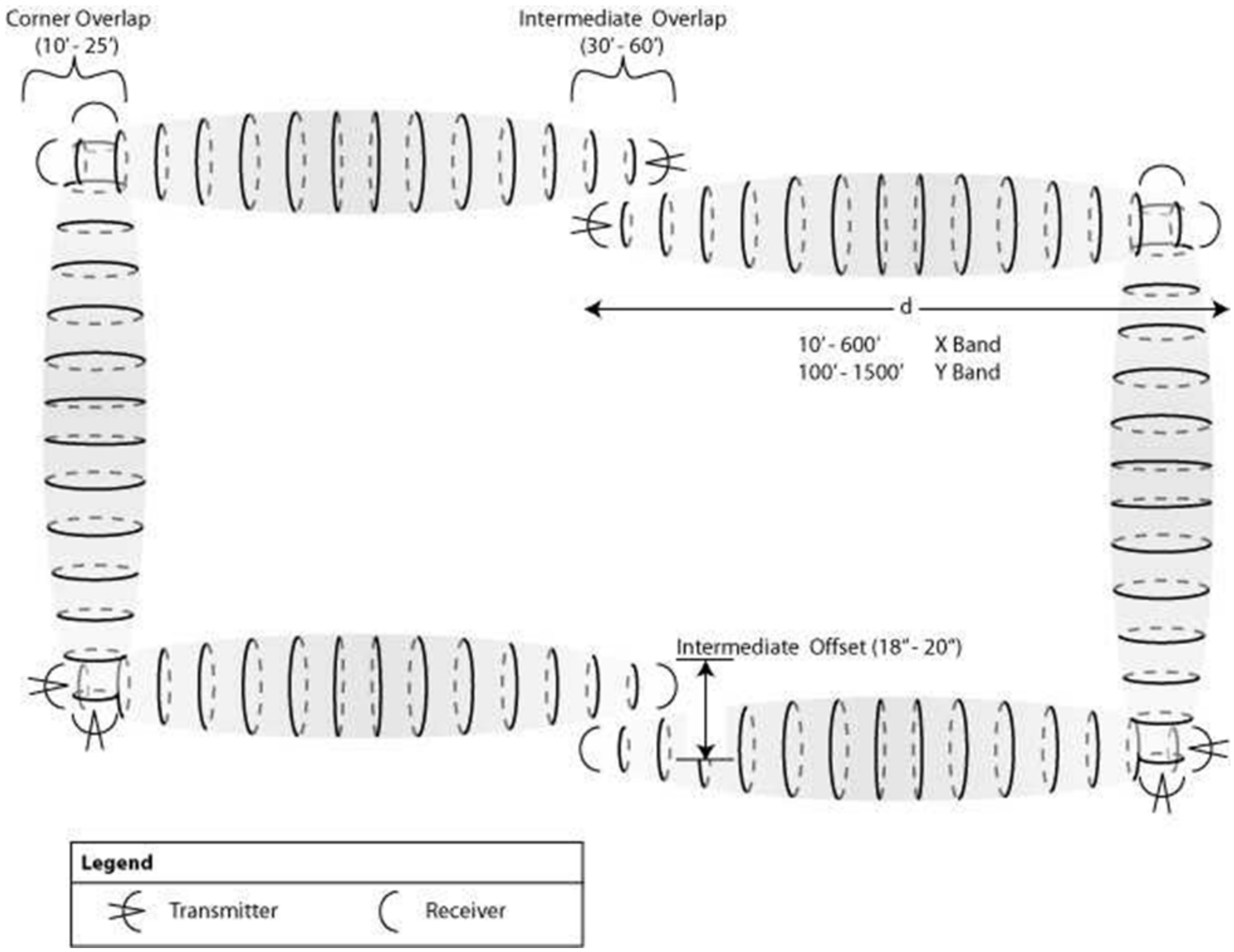


Figure 5-10. Typical Bistatic Microwave Layout and Guidance.



5-4.1.2.3 Microwave Design Guidance and Recommendations.

a. The detection zone should be free of bushes and obstructions.

b. The detection zone should be graded to within three inches to detect crawling intruders.

c. Grass should be kept cut to less than three inches. A gravel surface prepared for water drainage is better than a grass surface. Since a typical microwave pattern is 10 feet (3 m) by 10 feet (3 m), a 20 foot (6 m) wide gravel bed works well.

d. Avoid water puddles. The wave action of wind on water can cause nuisance alarms.

e. For high security applications, consider use of stacked sensors (one sensor on top of another), with the lower frequency (wider/broader pattern) on top and the higher frequency (more focused pattern) to detect crawling intruders on the bottom.

f. Do not place sensors too close to perimeter fences. Wind action on the fence fabric can cause false alarms.

5-4.1.3 Dual-Technology.

As discussed previously, dual-technology sensors use a combination of PIR and microwave technology. Techniques of “ANDing” or “ORing” the microwave signal and the PIR signal are reviewed in Paragraph 5-6 “AND/OR” CONFIGURATION OPTIONS.

5-4.1.4 Vibration Sensors.

Vibration sensors sense intrusion through vibrations caused by personnel or vehicular movement. These sensors are not well employed near railroad tracks, roadways, rock quarries, or runways. Many of these systems use wireless battery-powered sensors to send alarm signals to a notification station.

5-4.2 Property/Fence Line Detection.

Several types of fence-mounted perimeter IDS exist. With all fence-mounted systems it is critical that the fence construction be of high quality, with no loose fabric, flexing, or sagging material. The fence must have solid foundations for posts and gates. Otherwise nuisance alarms may occur. Five types of exterior fence-sensing systems will be discussed: (1) electro-mechanical systems, (2) taut-wire systems, (3) coaxial strain-sensitive cable, (4) Time Domain Reflectometry (TDR) systems, and (5) fiber-optic strain-sensitive cable systems.

5-4.2.1 Electro-Mechanical Systems.

According to the “Perimeter Security Sensor Technologies Handbook,” electro-mechanical fence-sensing systems use either mechanical inertia switches or mercury switches to detect a fence climbing or cutting incident. An electronic controller looks for momentary contact openings of the inertia or mercury switches. For more information on electro-mechanical fence-sensing systems refer to the “Perimeter Security Sensor Technologies Handbook.” Due to advances with other (better) technologies, electro-mechanical systems are not recommended for DoD use.

5-4.2.2 Taut Wire Systems.

Taut-wire fence-sensing systems use a series of parallel wires under tension with numerous micro-switches attached to it. The system is very sensitive, but requires frequent maintenance. For more information on taut-wire systems refer to The Design and Evaluation of Physical Protection Systems.

5-4.2.3 Coaxial Strain-Sensitive Cable Systems.

Coaxial strain-sensitive cable systems use a coaxial cable woven through the fabric of the fence. The coaxial cable transmits an electric field. As the cable moves due to strain on the fence fabric caused by climbing or cutting, changes in the electric field are detected within the cable, and an alarm condition occurs.

Coaxial strain-sensing systems are readily available and are highly tunable to adjust for field conditions due to weather and climate characteristics. Some coaxial cable systems are susceptible to electromagnetic interference and radio frequency interference.

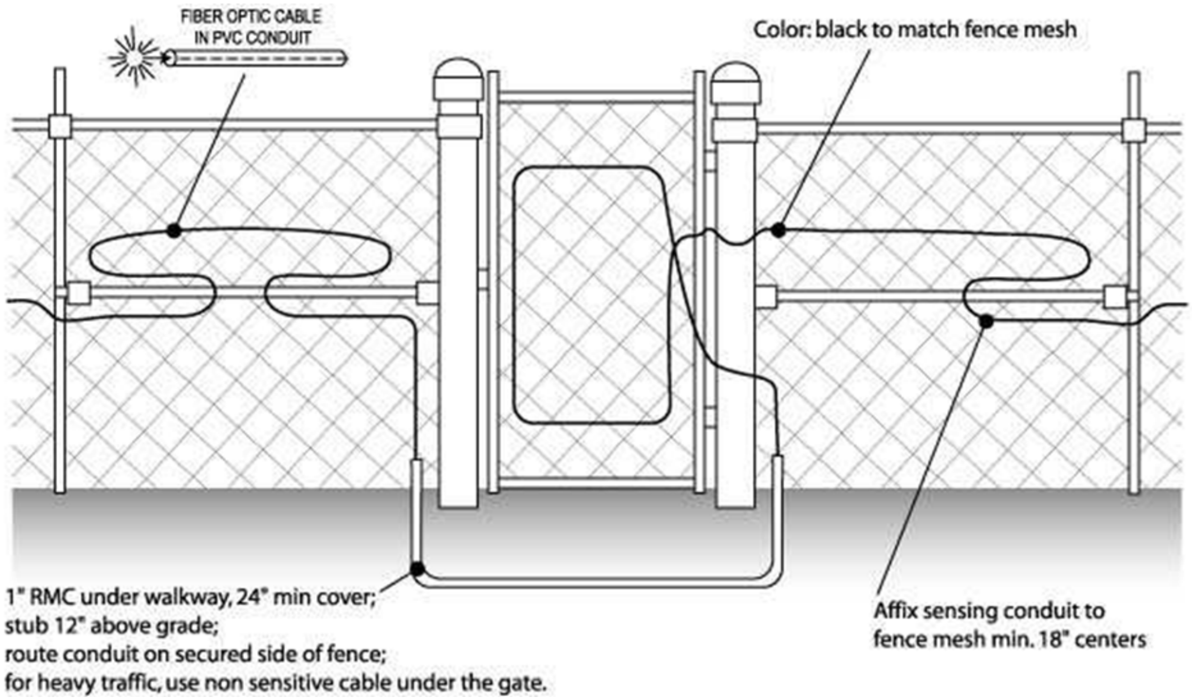
5-4.2.4 TDR Systems.

Time Domain Reflectometry systems send an induced radio-frequency (RF) signal down a cable attached to the fence fabric. Intruders climbing or flexing a fence create a signal path flaw that can be converted to an alarm signal. When the conductor cable is bent or flexed, a part of the signal returns to the origination point. This reflected signal can be converted to an intrusion point by computing the time it takes for the signal to travel to the intrusion point and return. The cable can be provided in armored cable, which requires more than a bolt cutter to sever the sensing cable. These systems require their own processor unit and can be configured in a closed loop, such that if the cable is cut, a detection can be detected by the other return path.

5-4.2.5 Fiber-Optic Strain-Sensitive Cable Systems.

Fiber-optic strain-sensitive cable systems are similar to the coaxial strain-sensitive cable systems. The fiber-optic system uses a fiber-optic cable, rather than a coaxial cable, woven through the fence fabric. Strain on the fence fabric causes micro-bending of the fiber cable, which is monitored by the control panel and generates an alarm condition. Figure 5-11 shows a typical fiber-optic fence detection illustration. Fiber-optic strain-sensing systems are relatively newer detection systems but have a strong following. The systems are readily available and are highly tunable to adjust for field conditions due to weather and climate characteristics. The systems are impervious to lightning, electromagnetic interference, radio frequency interference, or other electronic signals and can be used over long distances.

Figure 5-11. Typical Fiber Optic Fence Detection System.



5-4.2.6 Defeat Measures and False Positives.

Possible defeat measures include tunneling, jumping, or bridging across the fence system. Careful climbing at corner posts may not generate sufficient vibration to generate an alarm condition.

Possible false positives can occur from debris, animals, and plants.

5-4.3 Other Exterior Sensors.

5-4.3.1 Buried Cable.

Two common types: buried ported cable and buried fiber-optic cable. The two principle advantages of buried cable are that (a) it is covert, and (b) it follows the terrain. A limitation is buried cable systems do not work well with shrubbery or trees on it and require landscaping and maintenance. It is important that the cable be buried to a uniform depth. Changes in soil conductivity can affect the sensor readings.

5-4.3.2 Ported Cable.

Ported cable comes in two principal configurations, Single cable and paired cable. A single cable system uses one cable to create a sensing field approximately 6 feet (1.8 m) in diameter around the cable. Paired cable systems use two cables routed in parallel approximately five feet (1.5 m) apart. One cable transmits and the other receives a signal to create the sensing field.

5-4.3.3 Fiber Optic.

Fiber optic lines can be used to monitor pipelines or manholes.

5-4.3.4 Wide Area Sensors.

Wide area sensors such as radar can be employed on logical approach paths for large terrain or water territories/boundaries. Wide area sensors can assist response forces with early alerting or tracking of intruders. This technology approach has the advantage of being able to detect intruders beyond the defined perimeter. In other words, the system can detect intruders before they have crossed the protected area's perimeter.

5-4.4 Double Fence Concept.

When fence detection sensors are used, the best application is to use the double-fence concept. The typical configuration is outer clear zone, outer fence, isolation zone, inner fence, and inner clear zone, see Figure 5-12. Outer fence line defines the protected or restricted area boundary and is intended to keep animals, people, vehicles, and windblown debris out of the isolation zone to reduce nuisance alarms. No sensors should be placed on the outer fence of a double fence line system. Refer to MIL-HDBK-1013/10 (scheduled to be replaced by UFC 4-022-03, Security Engineering: Fences and Gates) for fence requirements.

Figure 5-12. Double Fence Example.

5-4.5 False Alarm Causes for Exterior Sensors.

Table 5-2 displays typical false alarm causes for exterior IDS sensors. Snowfall, removal of snow, winds, temperature change, and rain drainage are some factors to consider in exterior sensor selection. Refer to the "Perimeter Security Sensor Technologies Handbook" for more information on exterior IDS sensors.

Table 5-2. False Alarm Causes—Exterior IDS Sensors.

Sensor Type	False Alarm Cause	Notes
Active Infrared	Animals Wind-blown debris	Fencing mitigates animal false alarms
Passive Infrared (PIR)	Reflected light Radiated heat	Not recommended
Microwave	Nearby movement outside IDS area	Use of dual-technology PIR minimizes false alarms
Dual Technology	Same as PIR and microwave	Good choice. Uses both microwave and PIR
Vibration	Railroads—trains Roadways—vehicles Runways—airplanes Rock quarries—explosions Seismic event	Only works well in low background vibration areas
Coaxial Strain-Sensitive	Wind flexing fence EMI	Temperamental
Fiber-Optic	Improper noise level adjustment Animal activity	Recommended technology, provided suitable fence-mount is provided and animals are excluded from the area
Buried Cable	Ground shifting due to standing or puddling water, or erosion.	Varying terrain or material composition (asphalt pavement to grass to gravel) requires adjusting sensitivity to match each material
Ported Cable	EMI Movement of nearby vehicles or medium to large animals Congregation of small animals.	Very susceptible to EMI from large electrical equipment or substations and should not be used near these installations

5-5 VIDEO ANALYTICS FOR IDS.

Although video analytics can be very effective as a surveillance tool (see Chapter 4, paragraph VIDEO ANALYTICS), it should not be considered a primary IDS technology on par with the proven interior and exterior sensors described previously in this chapter. For most common IDS applications, traditional IDS sensors are generally superior to video analytics in terms of probability of detection, nuisance alarm rate, integration with alarm monitoring systems, and cost. The designer may consider specifying video analytics as an IDS sensor for projects where unusual site conditions bring into question the viability of all other sensor technology options.

5-6 “AND/OR” CONFIGURATION OPTIONS.

Subcomponents of an IDS can be configured in an “AND” or “OR” configuration. In the “AND” configuration, two or more sensors must detect intrusion for an alarm notification to occur. In the “OR” configuration, only a single sensor need go into alarm for a notification to occur. The “AND” configuration is used when a concern about nuisance alarms exists. The “OR” configuration is more secure and is used to increase the probability of detection. An example is pairing two microwave sensor fields. In the “AND” configuration, both Field A and Field B have to be in alarm to cause alarm notification. In the “OR” configuration, if either Field A or Field B go into alarm, then an alarm signal is sent to the Dispatch Center. Addressable sensors allow the capability to switch the “AND/OR” configuration from the Dispatch Center. However for some facilities, such as SCIFs, this feature must be disabled. Table 5-3 displays the advantages and disadvantages of each configuration.

Table 5-3. Advantages and Disadvantages of “AND” and “OR” Configurations.

	Pros	Cons
AND	Decreased nuisance alarms	Decreased probability of detection
OR	Increased probability of detection	Increased nuisance alarms

5-7 IDS DESIGN GUIDANCE.

The IDS Designer must first determine the design objectives for the project, usually expressed as a Probability of Detection (Pd). Some sample requirements are a Pd of 95% for most assets and a Pd of 99% for critical assets. Understanding the requirement, the designer can then go about laying out the ESS and strategy.

5-7.1 Critical Asset Case Study.

Consider a case study of having to provide a Pd of 99% for a critical asset. Some sample vendor-specifications for three types of IDS sensors are shown in Table 5-4.

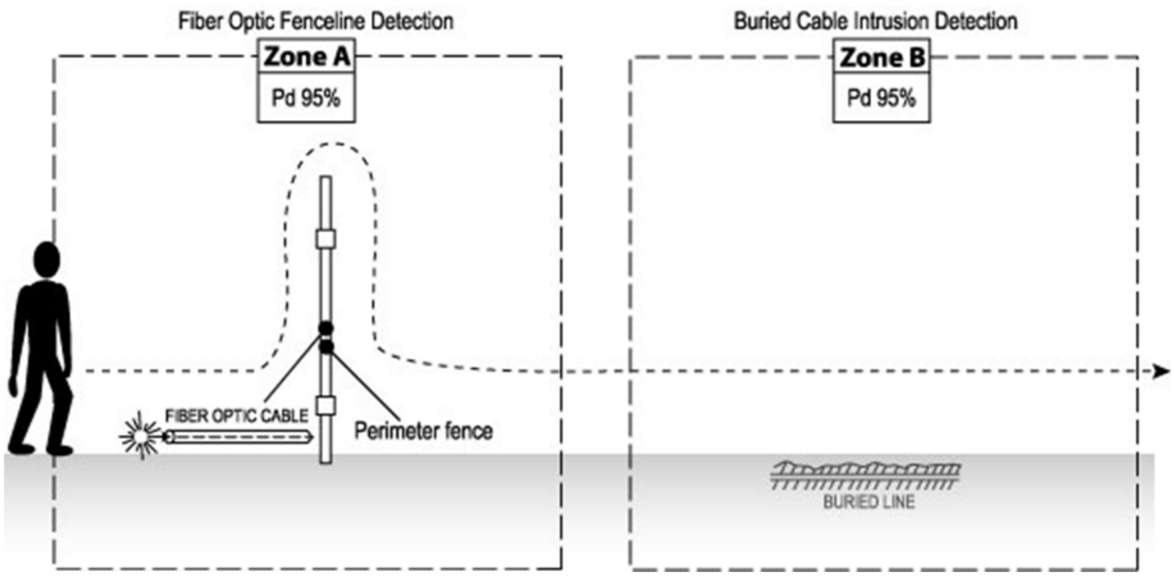
Table 5-4. Sample Probability of Detection Factors.

Product	Probability of Detection
Buried Cable	95%
Fence-Mounted Fiber Optic	95%
Microwave	99%

For the purpose of demonstrating the application of different approaches, two alternatives for meeting the project requirement are presented. While an individual component probability of detection may not meet a more demanding specification, layering or combining components can result in a higher overall system probability of detection as illustrated below:

- Option A: Use a microwave perimeter system with a Pd of 99%. The equipment and system meets the project objectives and no other IDS methods are technically required to meet the specified intrusion detection range.
- Option B: If the scenario is such that terrain contour makes microwave technology unfeasible, the IDS designer could consider a zoned approach of combining a fence mounted fiber-optic detection system with a buried cable detection system as shown in Figure 5-13.

Figure 5-13. Zoned Detection System.



5-7.1.2 Probability of Detection (Pd) Calculation.

If the two detection systems shown in Figure 5-13 are integrated in an electrical "OR" logic, an alarm from either system results in an IDS alarm. The resultant net Pd can be calculated as follows:

(Pd)A = 95%; therefore the probability of not being detected is (1-Pd) = 1-0.95= 5%

The probability of not being detected in Zone B is similarly calculated as 5% as well.

The net probability of not being detected by either Zone A or Zone B can be calculated by multiplying the chances of not being detected in either A or B together as follows:

= (1-Pd) A * (1-Pd) B
=5% * 5%
=0.25%
=0.0025.

Thus the probability of not being detected by either intrusion system A or B is 0.25%, which is another way of saying the probability of being detected is 99.75% or nominally 99%.

In the above example, two solutions of meeting a requirement to meet the Pd of 99% were analyzed. There are other options than the two discussed. The example presented is an academic case study to demonstrate different values of Pd for and methods of layered protection. It is based on convenient Pd factors for two common intrusion detection technologies based (fiber optic fence line and buried cable). For each project, the IDS designer will have to design a solution taking into account project requirements, available technology, site-specific information, and possible causes of false alarms.

5-7.2 Additional IDS Design Guidance.

Additional IDS design guidance is provided in Tables 5-5 and 5-6.

Table 5-5. IDS Design Guidance.

Issue	Recommendations
Door Status Monitoring	Restricted area perimeter monitoring should be included at all building entrance and exit points, to include perimeter doors, roof hatch openings, and doors used for emergency egress. Doors for emergency egress should include an audible device (door screamer) on the secured side. All door monitoring should be via balance magnetic switches. The status switch contacts must be closed when the door is closed.
Redundant Path for Alarms	In large critical systems, plan an alternate path for alarms. One method of achieving this is to route IDS alarms into the ACS and out to the Dispatch Center as an alternate path to a normal primary route of having the IDS inputs report directly to the Dispatch Centers.

Table 5-6. Exterior IDS Applications Table.

Application	Sensor Type	Notes
Fence Line	Taut wire	Very sensitive, high maintenance.
	Coaxial strain-sensitive	Works, susceptible to EMI.
	TDR	When fence is not in good condition.
	Fiber Optic	More expensive, but better filtering.
Gates	BMS	Simplest device, provide lightning protection.
	Fence detection systems	Will detect a fence intruder that climbs the gate.
	Magnetic loop sensor	Will detect vehicles only.
Open areas	Microwave	Works well in desert environments, does not work well around trees and un-cleared line-of-sight areas.

	Ported Coaxial	Does not work well near electrical substations, certain geographic areas with unusual magnetic influences. Can be effective, when used as part of a double-fence system.
Note: Table is not all inclusive of all exterior sensor options. Refer to text above for more detail.		

5-8 SUMMARY.

In general, intrusion detection is challenging. There is no one single sensor system that works in all applications. Realistically, the best Pd that can be achieved by a single system is 95 percent. Given enough time and resources, all intrusion detection systems can be defeated. For simple installations with lower security needs, a fiber-optic fence-perimeter detection-system works well. For higher security applications, double fences/intermediate, gravel bed and microwave sensors offer improved security.

CHAPTER 6 DATA TRANSMISSION MEDIA (DTM)

6-1 INTRODUCTION.

A critical element in an integrated ESS is the data transmission media (DTM) that transmits information from sensors, access control devices, and video components to display and assessment equipment. A DTM link is a path for transmission of data between two or more components, and back to the Dispatch Center. An effective DTM link ensures rapid and reliable transmission of data, is resistant to compromise, has redundancy, and is conducive to rapid fault detection and repair. A number of technology issues are relevant to implementing the DTM, such as bandwidth analysis, secure communications, network topology, communication redundancy, transmission modes or protocols, and transmission media. These issues are discussed in the following sections.

6-2 BANDWIDTH ANALYSIS.

With any data-intensive transmission network, such as an electronic security system network, it is important to determine the amount of bandwidth consumed by the system under normal and high-traffic conditions. This can affect network cost, reliability, and transmission speed. Of the three ESS subsystems, CCTV generally requires the most bandwidth and IDS requires the least. ACS bandwidth requirements are generally low, but bandwidth usage will spike during database synchronization cycles. For the DTM, design a system capable of handling the total bandwidth (plus contingency) for each link required in the system. Table 6-1 presents bandwidth usage values for some common ESS components.

6-3 SECURE COMMUNICATIONS.

No matter what transmission mode or media is selected, it is important that a method for securing communications be included. This includes physical protection, such as providing conduit for all conductors, as well as electronic protection, such as encrypting communication transmissions and supervising alarm circuits. Refer to Chapter 9 for the subsection on Tamper Protection, which includes a discussion on physical protection of conductors as well as more general information on encryption requirements.

6-4 NETWORK TOPOLOGY.

One of the initial steps in designing and evaluating a security DTM is to identify the topology to be used. Additionally, the designer must coordinate network requirements with installation security and the communications office. Typically, networked security systems are a Proprietary Security Network. Refer to Chapter 8, “ESS Subsystem Integration” for more information.

Table 6-1. Bandwidth Usage Values.

Component	Bandwidth Usage Range (kilobits per second)		
	Low	High	High bandwidth usage results from:
IDS Local Processor	1	3	high alarm rate, encryption
ACS Local Processor	5	50	high-volume portal traffic, large database synchronizations
IP Camera	100	70,000	high frame rate and resolution, low compression ratio
ESS Workstation	100	100,000	large number of simultaneous video streams

6-4.1 General Network Topologies.

Three general network topologies are possible: star, ring, and fully meshed. These concepts apply to intra-site system architectures as well as inter-site regional configurations. A brief description of each topology follows.

6-4.1.1 Star.

The star, or “hub and spoke” network involves a central Dispatch Station (or head-end) and single communication lines out to individual sites (or field panels). The disadvantage to a star topology is that if one of the links is disabled or severed then communication is lost to that node. The unconnected node may still operate through distributed intelligence, but will be unable to receive updates from and transmit alarms to the rest of the system. For example, if a new credential holder were added to the access list, this information could be downloaded to a remote site or panel from a central location. With a severed link, these updates are not available unless the information was uploaded at the local site/panel. Conversely, if a credential holder were deleted from the access database, a “severed” site/panel would continue to allow access until communications were re-established or a local upload made. Figure 6-1 shows a star topology for both an inter-site architecture and an intra-site architecture.

6-4.1.2 Ring.

The ring topology communicates through a loop. This topology is slightly more robust than a star topology in that if a link fails, communications can still be maintained through the “backside” direction on the loop. Communications may be slower in this backup mode of operation but would be sustainable. Figure 6-2 shows a ring topology for both the inter-site and intra-site scenario.

6-4.1.3 Fully Meshed.

The most robust topology is a fully meshed topology depicted in Figure 6-3. This topology has backup means of communication, such that if any one link is disabled or severed, data has an alternate path to communicate directly between nodes. This is the preferred ESS network topology.

Figure 6-1 Star Topologies.

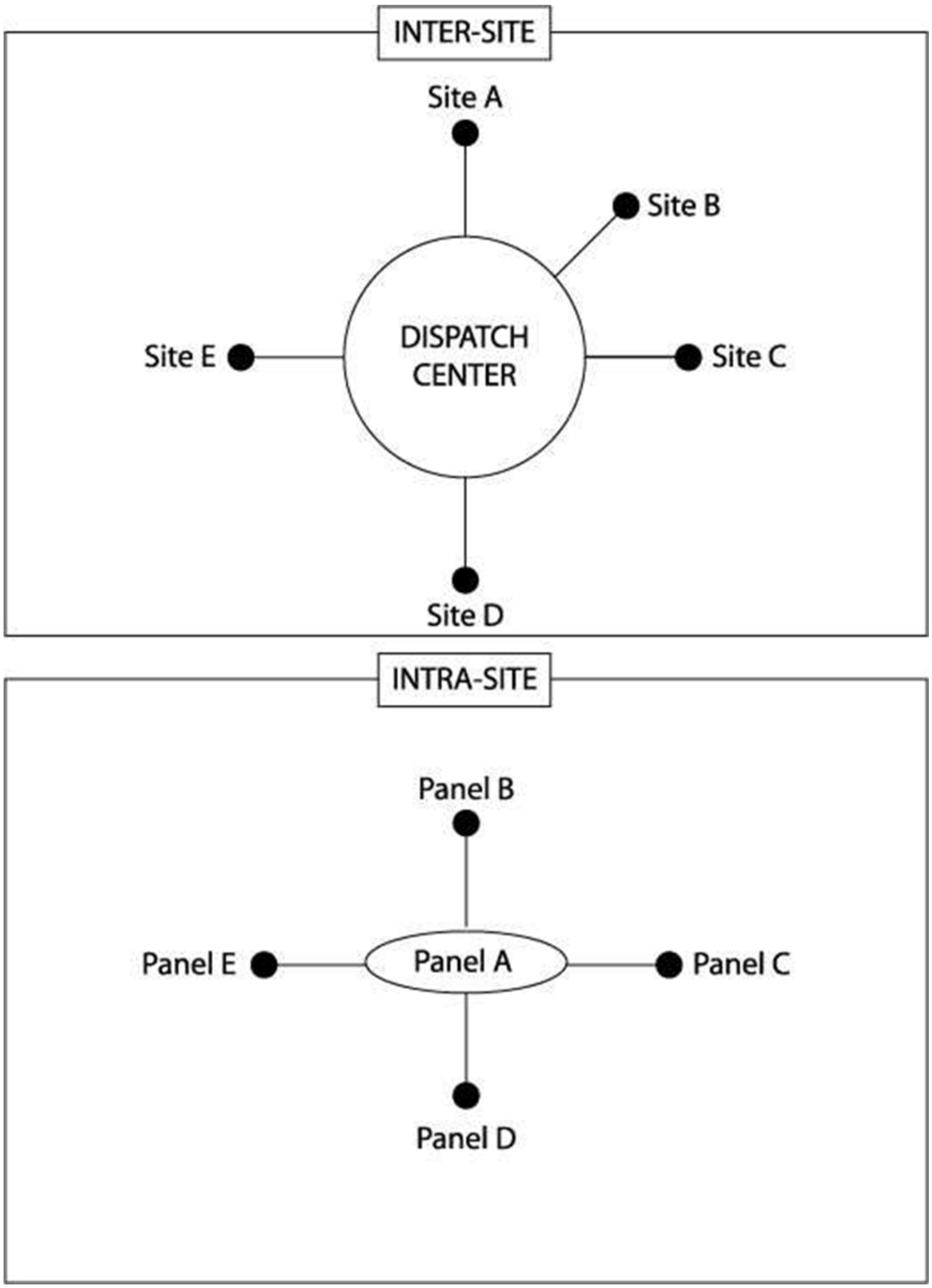


Figure 6-2. Ring Topologies.

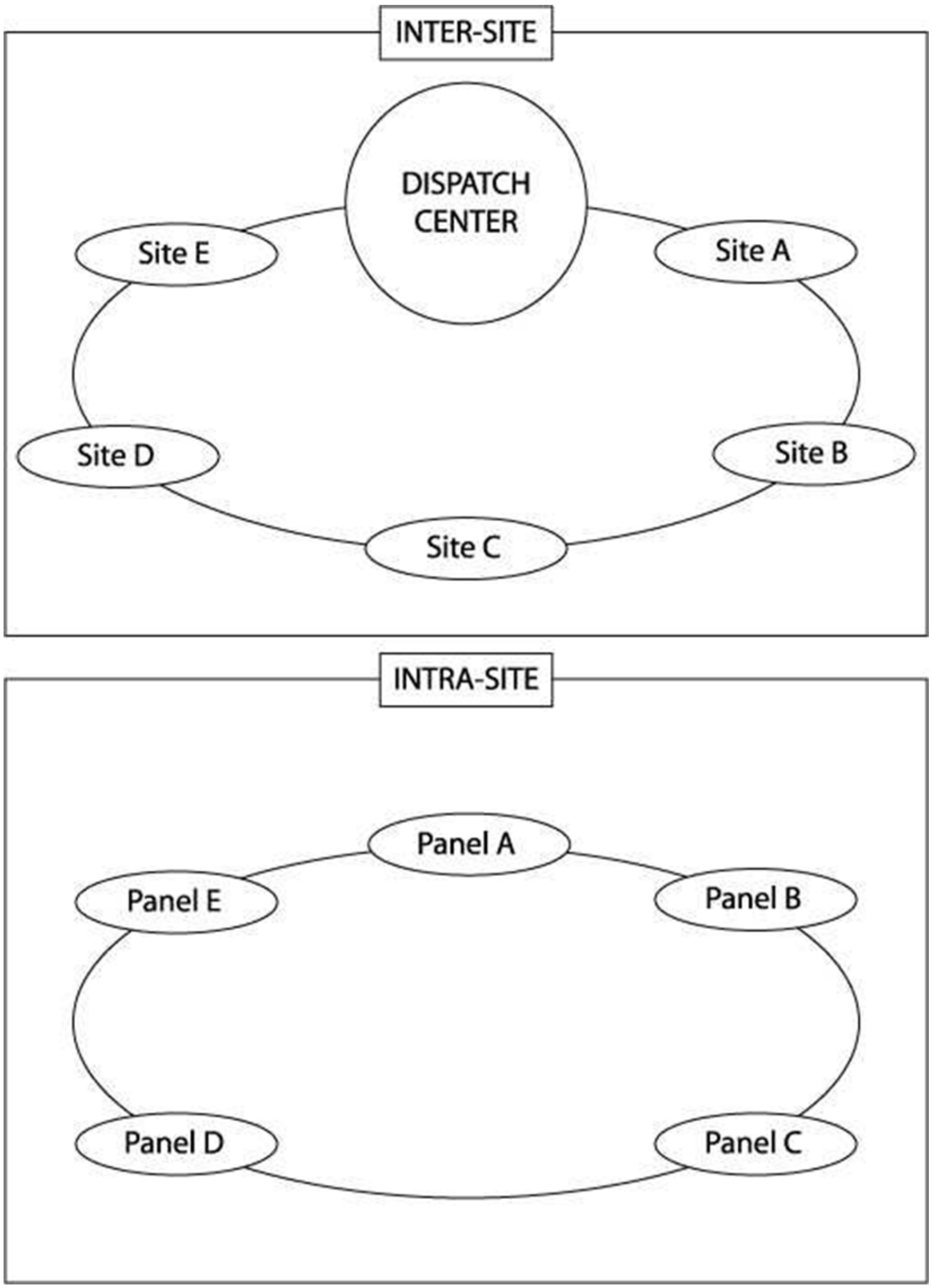
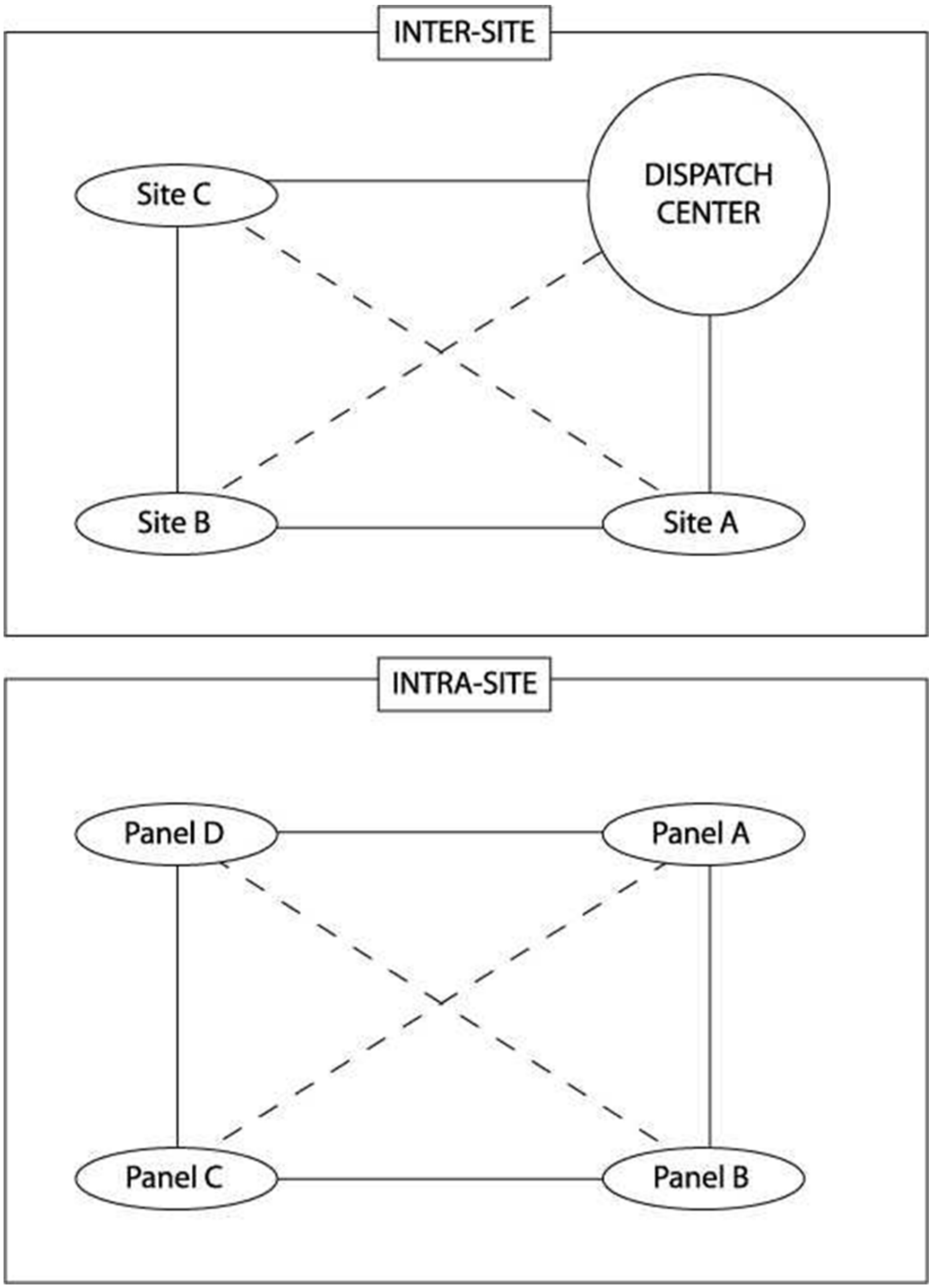


Figure 6-3. Fully-Meshed Topologies.



6-5 COMMUNICATION REDUNDANCY.

Typically the only communication redundancy made is between subsystem field panels and the system head-end. Redundancy between field panels and devices is cost prohibitive. A common method of achieving communication redundancy is running primary as well as backup RS-485 lines. If this is done, it is best to use different raceway routing schemes.

New product developments and improved design configurations increasingly harden communication system redundancy. This concept is generally more applicable to network backbones as opposed to vendor-specific ESS subsystems, such as ACS, CCTV, and IDS. Redundant communication paths are established such that if a component or link goes down, communication is maintained through an alternate communication path. While some people refer to these designs as “self-healing”, the term is really a misnomer because the failed component is still a failed component. Alternate communication paths are employed until the fault can be corrected.

6-6 TRANSMISSION MODES/PROTOCOLS.

Several modes and protocols exist for electronic security data transmission including serial communication (RS-485, RS-232), network communication using Ethernet protocol, modem, and wireless. The designer must consider protocol compatibility as well as data rate and distance requirements when selecting the appropriate data transmission methods for a project. The information presented in Table 6-2 will aid in this selection process. This information is discussed in the following section as part of an overview of the data transmission media commonly specified for ESS projects.

6-7 TRANSMISSION MEDIA.

6-7.1 Hardwired.

Hardwired refers to using dedicated proprietary (DoD-owned) circuits to transmit data/video between DTM nodes. Dedicated circuits can be copper or fiber-optic, both of which are discussed below.

6-7.1.1 Copper Circuits.

Copper circuits can meet most ESS data transmission needs from alarm circuits transmitting a simple state change to network links operating at speeds up to 1 Gb/s. As shown in Table 6-2, copper circuits are capable of supporting lower data rates out to distances of 1,000 feet (305 m) and greater, but copper Ethernet links can be no longer than 330 feet (100 m). Single-pair high-speed digital subscriber line (SHDSL) technology is a good option for achieving moderately high data rates at fairly long distances over a single copper pair. Disadvantages of copper circuits include susceptibility to electromagnetic interference, radio-frequency interference and damage from lightning strikes.

6-7.1.2 Fiber Optic Cable.

Fiber optic allows transmission over longer distances by using light, which does not have the higher resistance loss over distance of copper circuits. Furthermore, fiber optic is not affected by electromagnetic interference or lightning. As seen in Table 6-2, fiber optic cable, when compared to copper, allows high data rate links to be established over much greater distances. For example, a Gigabit Ethernet link of 6.2 miles (10,000 m) is possible with fiber, compared to only 330 feet (100 m) with copper. Since the cost of a data transmission system can be a significant component of overall ESS cost, the designer must evaluate the advantages of fiber links in light of their higher cost compared to copper circuits. Of the two varieties of fiber optic cable, single-mode fiber offers greater distance capabilities than multi-mode fiber but is more expensive to implement.

6-7.2 Direct Subscriber Lines (T 1 Lines).

Direct subscriber lines, also called T-1 lines, are commonly used in data transmission media systems for connecting remote sites. T-1/DS1 lines are permanent point-to-point links through public networks. The bandwidth capacity of a T-1 line is 1.544 Mbps. The cost of the leased line is dependent on distance and existing capacity or infrastructure. T-1 lines are uniquely assigned to a customer, such that only the DoD information would be transmitted over the assigned point-to-point link.

6-7.3 Wireless.

For security reasons, only use wireless if other media cannot be used. Wireless broadband networks make use of radio frequency transmission between towers. Wireless systems have high data transmission rates and do not require installation of cable, nor rely on existing copper infrastructure. Wireless communications are affected by line-of-sight topography and extreme weather conditions (such as rain, snow, or fog). Some radio modem units can provide data transmission rates of several megabits per second - at ranges up to ten or more miles between modems. One disadvantage of wireless systems is the systems are susceptible to jamming.

6-7.3.1 Wireless Security

Security can be achieved by vendor encryption and decryption at each node. The design and cost estimate must consider equipment and software for equipment and software for authentication servers and encryption systems.

6-7.3.2 Frequency Allocation.

Frequency allocation or radio frequency spectrum planning is a critical issue and must be an early project design consideration. Frequency allocation is a long lead-time item. Employment of radio frequency transmitting equipment outside of the continental United States may require approval by the Host nation. Refer to service policies for frequency allocation.

6-7.4 Free-Space Optics (FSO).

FSO, also called free-space photonics (FSPO), refers to the transmission of modulated visible or infrared (IR) beams through the atmosphere to obtain broadband communications. Most frequently, laser beams are used. FSO operates similar to fiber optic transmission, except that information is transmitted through space rather than a fiber optic cable. FSO systems can function over distances of several kilometers, but each link requires a clear line-of-sight unless mirrors are used to reflect the light energy. FSO systems offer advantages of reduced construction cost in that fiber optic lines do not have to be installed, but there are limitations. Rain, dust, snow, fog, or smog can block the transmission path and shutdown the network.

Table 6-2. Data Transmission.

Protocol / Media	Data Rate @ Distance
Supervised alarm circuit / copper, single pair	state change @ 1,000 feet (305 m)
RS232 / copper	19.2 kb/s @ 50 feet (15 m)
	9.6 kb/s @ 500 feet (150 m)
	4.8 kb/s @ 1,000 feet (300 m)
	2.4 kb/s @ 3,000 feet (900 m)
V.35 / copper	1.5 Mb/s @ 50 feet (15 m)
	56 kb/s @ 102 feet (31 m)
	19.2 kb/s @ 513 feet (156 m)
	9.6 kb/s @ 1,025 feet (312 m)
	4.8 kb/s @ 2,050 feet (625 m)
	2.4 kb/s @ 4,100 feet (1250 m)
RS422 / copper	10 Mb/s @ 40 feet (12 m)
	1 Mb/s @ 200 feet (61m)
	100 kb/s @ 4,000 feet (1220 m)
RS485 / copper	10 Mb/s @ 40 feet (12 m)
	1 Mb/s @ 200 feet (61m)
	100 kb/s @ 4,000 feet (1220 m)
SHDSL / copper, single pair	256 kb/s @ 21,980 feet (6,700 m)
	1.5 Mb/s @ 16,404 feet (5,000 m)
	2.3 Mb/s @ 13,780 feet (4,200 m)
10BASE-T Ethernet / copper, two pairs	10 Mb/s @ 328 feet (100 m)
Fast Ethernet / copper, two pairs	100 Mb/s @ 328 feet (100 m)
Fast Ethernet / multi-mode fiber, two fibers	100 Mb/s @ 1,804 feet (550 m)
Fast Ethernet / single-mode fiber, two fibers	100 Mb/s @ 32,808 feet (10,000 m)

Gigabit Ethernet / copper, four pairs	1 Gb/s @ 328 feet (100 m)
Gigabit Ethernet / multi-mode fiber, two fibers	1 Gb/s @ 1,804 feet (550 m)
Gigabit Ethernet / single-mode fiber, two fibers	1 Gb/s @ 32,808 feet (10,000 m)

6-8 TECHNOLOGY COMPARISION.

Table 6-3 provides a comparison matrix of different DTM technologies for ESS.

Dedicated conductors are highlighted for on-base applications and T-1 lines are highlighted for interbase applications as a general guide. Whichever method is used, initial calculations have to be made on the data rate and distance requirements.

6-9 ENCRYPTION.

An ESS designer is responsible for reviewing applicable security policies and consulting with information assurance (IA) personnel to determine data transmission encryption requirements and methods on a project-by-project basis. Two details must be addressed when making this determination - the types of data being transmitted and the data transmission techniques being used. As a general guideline, ESS data associated with very high security assets (such as SCIFs) or containing personally identifiable information (such as biometrics) must be encrypted. Encryption will generally be required when any ESS data is transmitted using techniques such as wireless links and shared or public networks that are inherently more susceptible to interception than hardwired circuits and closed, restricted ESS networks.

Refer to Chapter 9 for additional information on tamper protection and encryption requirements.

Table 6-3. DTM Technologies for ESS.

	Hardwired	Leased T-1 Lines	Wireless	Free Space Optics
Suitability On Base	Recommended application.	Does not make sense when base level information infrastructure can be used.	Generally requires line of sight.	May make sense, can be used when there is line of sight.
Suitability Inter Base	Rarely achievable, because of property line boundaries.	Recommended application. Can cross property lines.	A workable application	May make sense.
Initial Cost	Dependent on distance. Principle cost is per linear foot of trenching/ conductors.	Low, which is good. Must provide interface to site's demarcation point for supplier.	Construction costs of towers and tie-ins have to be computed.	Reduced initial cost because conductors are not used. Need transmit/ receive equipment.
Recurring Cost	Low, which is good. Minimal maintenance cost of installed conductors.	One T-1 line at 1.544 Mbps can be estimated at $500/month. Obtain vendor quote.	Relatively low, which is good if DoD-owned. Otherwise obtain vendor quote.	Low if DoD equipment. Leased equipment requires vendor quote.
Considerations	Best technology. Not affected by line of sight.	Reasonable alternative to "hardwired." Not affected by line of sight.	Generally requires line-of-sight. Approved frequencies must be used.	Requires line of sight or mirrors.
Security	Very good, especially if totally contained on DoD property and encrypted.	Second or third best choice. Usually dedicated conductors are used from one provider.	Not recommended by CIA studies, but may make sense on DoD property if there is little chance of interception.	Signals can be blocked. Hard to transmit forged signals.
Weather Effects	Not affected. Best technology from weather consideration.	Not affected. As good as "hardwired."	Not as bad as free space optics, but can be affected by heavy rain and snow.	Rain, dust, snow, fog, or smog can block transmission and shutdown network.

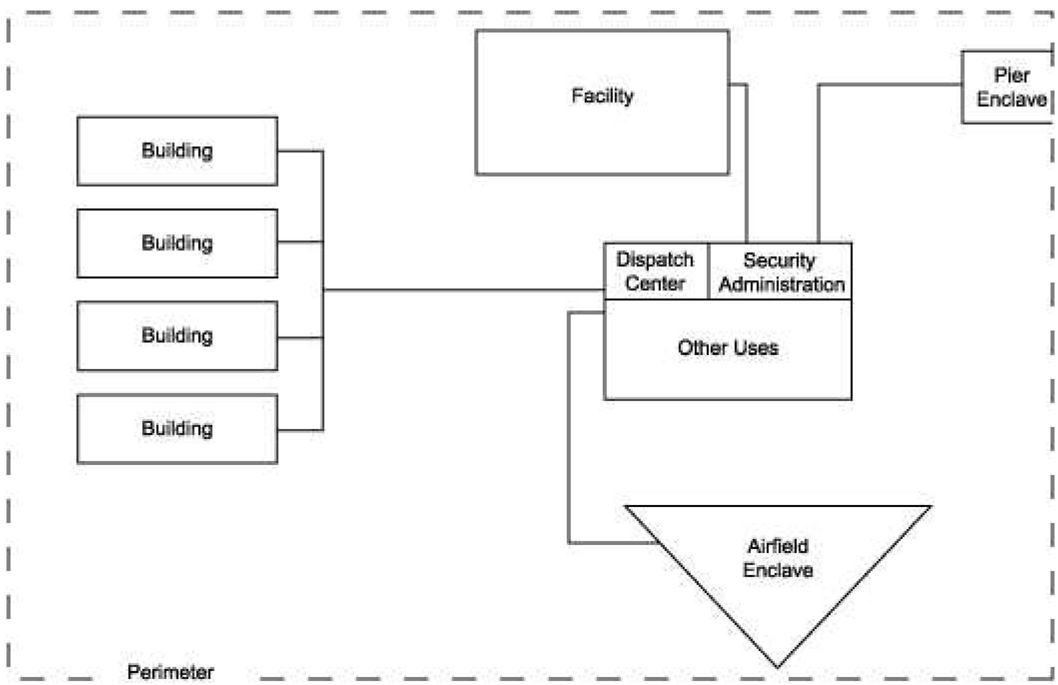
CHAPTER 7 DISPATCH CENTER

7-1 INTRODUCTION.

7-1.1 Dispatch Center.

The Dispatch Center, also known as the Security Operations Center (SOC), Security Control Center (SCC), or Central Monitoring Station is an area that serves as a central monitoring and assessment space for the ACS, CCTV, and IDS systems. The Dispatch Center must meet the applicable requirements of NFPA 1221. In this space, operators assess alarm conditions and determine the appropriate response, which may entail dispatching of security forces. Normally, the Dispatch Center is staffed by trained personnel 24 hours a day, seven days a week. The Dispatch Center may be co-located with other installation functions. Refer to Figure 7-1.

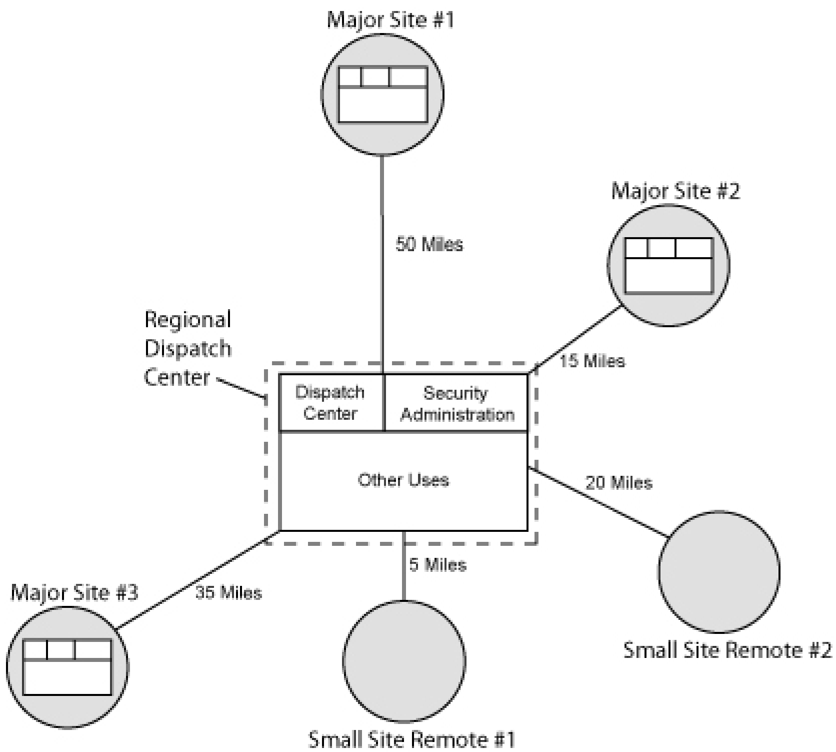
Figure 7-1. Dispatch Center Centrally Located.



7-1.2 Regional Dispatch Center (RDC).

When several regional installations or sites interface and report to a centralized dispatch center, that space or building may be known as a Regional Dispatch Center (RDC). Refer to Figure 7-2.

Figure 7-2. Example RDC.



7-1.3 Small Facility Options.

Small facilities not located on a DoD installation such as Reserve Centers, medical clinics, or pharmacies may be connected to a Central Station or Police Station.

7-2 SPACE.

7-2.1 Space Programming.

Space programming for a Dispatch Center must consider the following:

a. Equipment wall space

b. Provide a minimum 36 inches (900 mm) space both in front and in back of equipment racks and a minimum side clearance of 24 inches (600 mm) on end equipment racks.

c. Counter space for consoles

d. Personnel space for each operator

e. Space for UPS equipment

f. Access requirements for maintenance or repair.

g. Conduit space requirements for future system wiring or enhancements.

H. Future growth or expansion space

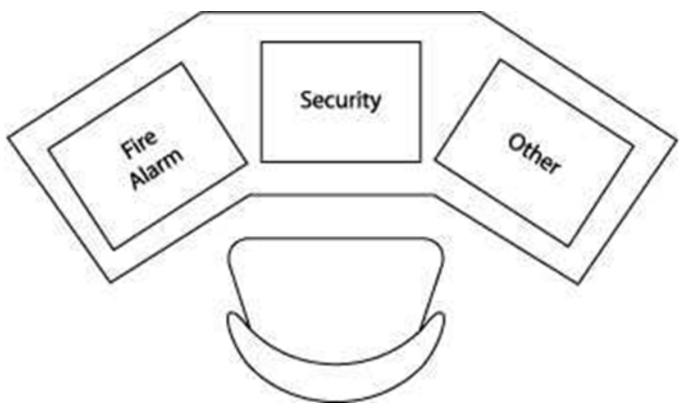
7-3 LIGHTING.

The Dispatch Center space should be designed for normal interior lighting levels according to the classification of the space: equipment room or Dispatch Center. Consideration must be given to selectable lighting or dimmers that allow reducing the lighting behind or near system displays. Use of dimmers or task lighting must be considered at operator's areas. Indirect lighting should be a consideration. The design should strive for no glare on monitor screens.

7-4 CONSOLES.

A determination should be made early as to how many consoles are required. The layout for a simple Dispatch Center console is displayed in Figure 7-3. Although security system monitors may be co-located with other functions such as a 911 call center and fire alarm monitoring personnel, most commands find a separate administrative personal computer and printer is required in the Dispatch Center. A conceptual layout for a small to medium sized Dispatch Center is displayed in Figure 7-4.

Figure 7-3. Sample Simple Dispatch Center Console Layout.

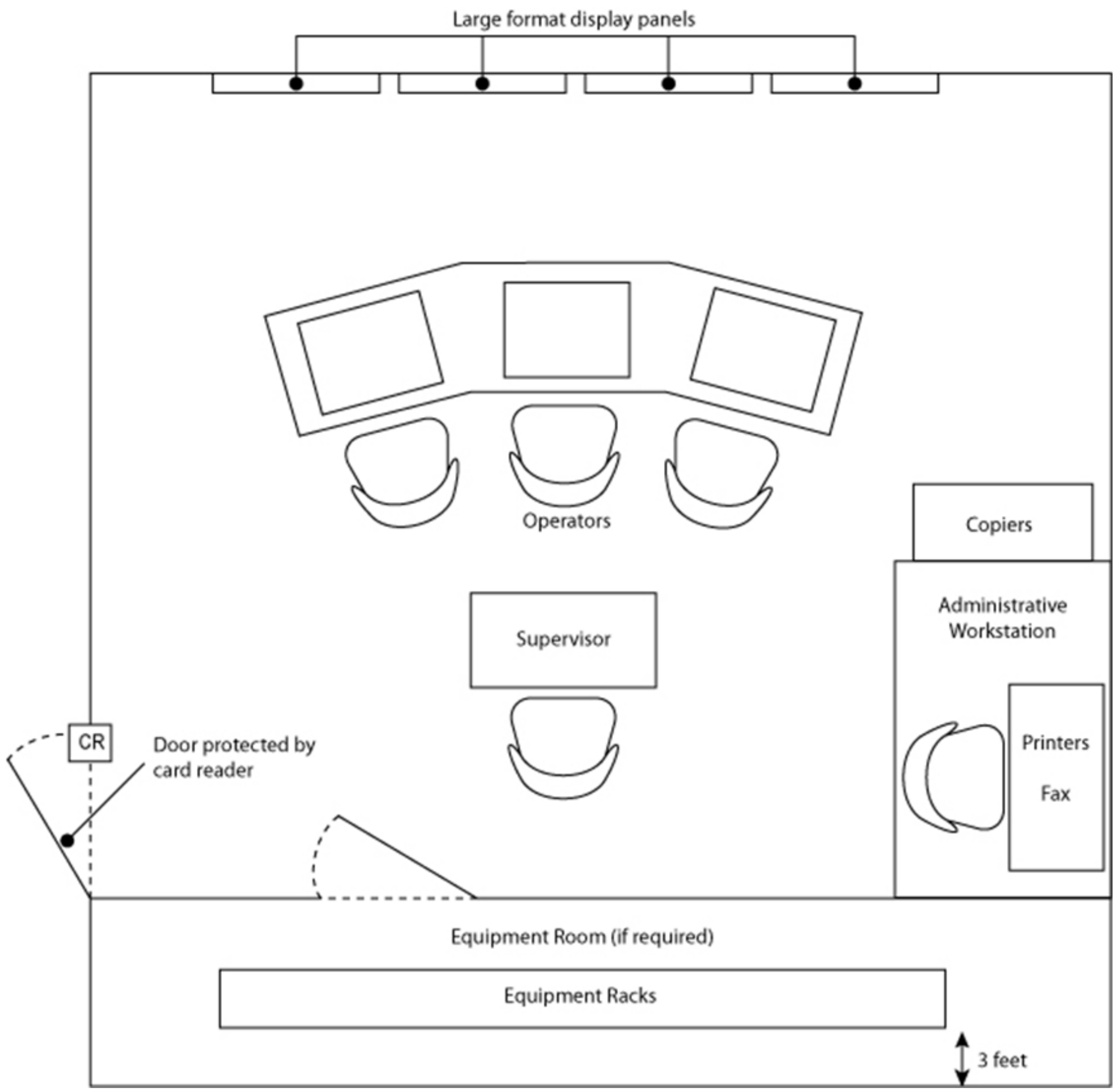


7-5 MONITORS.

Monitors must be ergonomically mounted. Current products allow wall-mounted flat-screen displays and smaller, hinged, flat-panel monitors that can be swiveled out and adjusted for individual operators.

The quantity, size, and resolution of monitors are all important design considerations, with the primary goal being to maximize the effectiveness of operators in performing their duties. For a single-operator workstation, two to four monitors is generally adequate, recognizing that more is not necessarily better. Monitors in the 20 - 24-inch (500 – 600 mm) display range providing HD 1080p resolution are a good, economical option for most ESS applications.

Figure 7-4. Sample Small-Medium Dispatch Center Space Layout.



7-6 GROUNDING/POWER CONDITIONING.

It is a good practice to provide a dedicated ground bus bar in the Dispatch Center for grounding the ESS panels. Refer to NFPA 70 and ANSI/TIA-J-STD-607 for additional guidance on grounding, surge protection, and power conditioning.

7-7 HEATING, VENTILATION AND AIR CONDITIONING.

Dispatch Centers lend themselves to “packaged HVAC equipment systems” because of the relatively low heat load, as opposed to centralized systems for bigger, more complex building types.

7-7.1 Environmental Considerations.

Typical environmental conditions for a Dispatch Center are as follows:

- 72 degrees Fahrenheit plus/minus five degrees.
- 50% Relative Humidity (RH) plus/minus 10%. If the relative humidity drops below 30%, there can be equipment problems due to abnormally high level of static electricity. Conversely, too high a humidity can result in condensation, which may cause electrical shorting or corrosion problems.

7-7.2 Load Calculation Considerations.

HVAC heat/cooling loads can be calculated by considering these heat loads:

a. Personnel and Equipment. The average staffing count of personnel in conjunction with the kilowatt (kw) load of associated electrical equipment such as DVRs and ESS servers as well as internal lighting loads must all be considered when calculating this heat load component. For personnel, ASHRAE 62.1 recommends 20 cfm (9.4 l/s) flow rate per occupant. Refer to UFC 3-501-01 and utilize equipment loads based on the room configuration.

b. Shell Load. Shell load considers the perimeter walls, ceilings, windows, and associated solar gains of the external surfaces.

c. Outside Air. This load component varies according to the climatic conditions of the Dispatch Center location.

7-7.3 Components Considerations.

Components to consider are air handlers, ductwork, inlets and outlets (diffusers and grills), as well as heating and cooling sources.

7-8 SUPPORT ROOMS.

A good practice is to plan for space in a room near the Dispatch Center to house support equipment. This room can be used to house local ESS equipment such as digital recording equipment (DVRs), local security panels, and termination cabinets. Additional HVAC capability may be required in dedicated equipment spaces due to the heat generated by equipment.

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CHAPTER 8 ESS SUBSYSTEM INTEGRATION

8-1 OVERVIEW.

Since the different subsystems of a facility's total ESS are drawn on a number of different technologies (i.e. camera technology, biometric technology, microwave intrusion technology, and information transfer technology), the manufacturers of subsystems tend to be uniquely different. As a result, system integration or making the subsystems and components "talk to each other" reliably and consistently is a major portion of an ESS design. The purpose of this chapter is to briefly consider some of the system integration issues associated with an ESS.

8-2 COMMUNICATION FROM THE IDS TO THE ACS.

As covered in Chapter Two, "Electronic Security System (ESS) Overview," for an intermediate system, the IDS may already be an integral part of the ACS. In these systems (depicted in Figure 2-7), basic intrusion detection devices are brought into a combined ACS/IDS system as digital inputs on local security panels. All that is required is to allocate digital input points in the closest security panels and program the ACS to provide an alarm on event.

For some facilities, however, the IDS and ACS will be separate. This is a fairly common scenario in which each IDS zone within a facility is equipped with an IDS local processor connected to the Dispatch Center for the sole purpose of IDS alarm monitoring, and doors/portals within the facility are controlled by a local ACS administered and monitored by the owner/tenant. In facilities where the two systems are separate, the IDS and ACS often share a common need to monitor the position of certain doors. Rather than having two position sensors on a door (one for IDS and the other for ACS), the designer should specify a single door sensor that has two independent outputs. This allows one output to be wired to the IDS local processor and the other to the ACS local processor. This approach reduces the cost and eliminates the clutter associated with having two sensors on a single door.

8-3 COMMUNICATION FROM THE IDS[1] TO THE CCTV SYSTEM.

Once an intrusion is detected (i.e. door forced open or perimeter fence or microwave intercept), it is generally the practice to make sure the event is being viewed and recorded. Interface of the IDS to the CCTV system can occur through several different means: hardwired conductors, serial communications, and networked connections as discussed below. Activation of an intrusion detection alarm results in an audible alarm that gets the operator's attention.

8-3.1 Hardwired Conductors.

This is older technology, but it is still effective for simple installations. In this case, copper wiring is taken as digital outputs from the IDS or combined ACS/IDS and

[1] or combined ACS/IDS

connected as inputs to the CCTV system to initiate camera recording, and if required, panning to a pre-set location. In the most basic approach, this design requires a pair of wires for each alarm notification output signal.

8-3.2 Serial Communications.

In theory, this is the same principle of operation as the hardwired method with an improvement in that a single serial data link can handle several camera control signals. It is most easily done when the CCTV and IDS (or combined ACS/IDS) are made by the same vendor, but can be done with different vendors if appropriate software drivers are available. While slightly more complicated than the hardwired approach, this method has the advantage of reduced wiring costs.

8-3.3 Software-Based Integration for Networked ESS.

This approach provides flexibility in the initial system setup and allows the user to make configuration changes via software with no additional hardware or wiring investment. For this reason, software-based integration is preferred for most projects, but it requires a networked ESS in which all subsystems are connected to a common IP network. In this approach, all file servers, workstations, video recording devices, cameras, and local processors are connected to the same network via Ethernet cables and switches. This network configuration allows communication between the remote equipment and a server or desktop personal computer (PC), usually located in the Dispatch Center. The desktop PC will have a security program that accesses remote equipment through IP addresses provided during setup. The security program allows the user to access CCTV and IDS/ACS information. When using this approach, having adequate bandwidth is important due to the large amount required for video information. As mentioned, network security is also of paramount importance, and for DoD projects a dedicated security network is recommended. Cost savings of reduced point-to-point wiring have to be compared to possible new costs of installing a dedicated network. A drawback to this approach is that typically the manufacturer of both the CCTV and IDS/ACS has to be the same vendor unless compatible software drivers for allowing both systems to talk to each other are available.

8-4 COMMUNICATION FROM THE CCTV SYSTEM TO THE ACS.

Cameras may be used to visually assess access control alarms in the same way they are used to assess intrusion alarms. Cameras may also be used to visually confirm the identity of a person requesting entry into a secure area before releasing the portal (referred to as video verification by some ACS vendors). The IDS/CCTV integration techniques described above also apply to ACS/CCTV integration.

8-5 COMMUNICATION FROM THE ACS TO THE DISPATCH CENTER.

ACS alarms may be transmitted from a facility to the Dispatch Center. The designer must determine for each project whether a facility owner/tenant will monitor ACS alarms locally or will rely on the Dispatch Center to provide ACS monitoring services. If the

Dispatch Center will monitor ACS alarms, the monitored facility must be equipped with a local processor that is compatible with the existing central monitoring system.

8-6 DESIGN GUIDANCE ON IT SYSTEM COORDINATION.

Fiber optic cables typically come in multiples of twelve strands, with 12-strand and 24-strand fiber optic cable being very common. While there are no technical limitations on combining ESS with other base systems, such as IT or Instrumentation and Control, it is preferable to keep ESS fibers dedicated for security purposes only from a security standpoint. If other unrelated systems are on a common fiber, other vendors or organizations will have closer access to the security communications. Plan for future expansion (provide a minimum of 20%) spare capacity (fibers).

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CHAPTER 9 GENERAL CONSIDERATIONS AND CROSS-DISCIPLINE COORDINATION

9-1 GENERAL CONSIDERATIONS.

9-1.1 General.

The highest security should be applied close to the critical asset. Avoid burdening the entire general population with the highest level of security. Other considerations include:

- All local processors should be located within the secure area.
- Annunciators, controls and displays subsystems should be located in areas closed off from public access or view.
- Certifications and Listings.

9-1.1.2 Equipment and Systems.

Equipment and systems should be proven with a demonstrated history of reliability. One way of achieving this criterion is to specify listed or certified products/systems such as:

- United States: Underwriter's Laboratory (UL) or similar nationally recognized testing and listing agency. Refer to UL 294 for a standard on ACS.
- European Union: CE listing. CE certifications, referred to as "CE Marking" may be required by the Host Nation for systems provided in Europe. The letters "CE" are an abbreviation of a French phrase "Conformite Europeene". The marking indicates that the manufacturer has conformed with all the obligations required by the European Union (EU) marketplace.

9-1.1.3 Spare Capacity.

An ESS must have the capability to be easily expanded or modified for simple changes, such as adding a card reader or camera, over the near-term life of the system. Accordingly, the ESS designer should plan for a nominal 20% expansion capacity when designing a new system.

9-1.2 System Acceptance Testing.

The ESS technical specifications or scope of work must include requirements for the ESS installation contractor to conduct comprehensive testing of every component and feature in order to demonstrate acceptable system performance to the Government. This section discusses system testing and ownership acceptance procedures.

9-1.2.1 Labeling.

Major equipment must have labels to identify the system and device. Cables must be labeled at origination, termination, and within enclosures using permanent labels.

9-1.2.2 Test Documentation and Acceptance Forms.

The ESS installation contractor must prepare a test plan along with detailed test procedures and submit these to the Government for approval prior to testing. The ESS designer must include this requirement in the technical specifications or the Scope of Work.

9-1.2.3 Pre-Test Walkthrough.

A pre-test walkthrough should be performed just prior to the start of the final acceptance testing. This allows the final acceptance test to go smoothly and prevents mishaps and additional testing. The walkthrough also provides a good opportunity to check installation workmanship and validate equipment types and quantities against the design requirements. The designer should participate in the walkthrough along with the installation contractor and the Government representative.

9-1.2.4 Training.

Include administrator and operator training and add the number of hours required to the system specifications. Typically, several training sessions with a minimum of one per work shift should be considered. It is a good practice to define some performance criteria such as "upon training completion, the tenant command must be able to unilaterally make additions or deletions to the ACS database."

9-1.3 Operation and Maintenance.

In specifying ESS, the designer must consider maintenance, service, repair, and sustainability of systems and the associated components. Systems with arduous requirements should be reconsidered.

9-2 GENERAL COORDINATION.

Throughout the planning and design process the designer must coordinate closely with security (Physical Security Officer) and anti-terrorism personnel (Antiterrorism Officer), end-users, base communications officer (information technology and information assurance), fire and safety personnel, and the installation facilities engineering office.

9-3 CIVIL COORDINATION.

9-3.1 Gate Control (Vehicle Gates and Sally Ports).

A sally port is a secure controlled entry and exit portal, utilized for inspections and to prevent tailgating. Sally ports may require control hardware for interlocking gates. Refer to UFC 4-022-01 Security Engineering: Entry Control Facilities/Access Control Points for more information on sally ports and entry control points.

9-3.2 Underground Site Work.

Inter-building DTM communications are often made by buried direct conductors. Underground site work needs to coordinate with existing civil drawings and buried utilities.

9-3.3 Outdoor Perimeter Security Features.

Perimeter security projects often involve clearing, grading, drainage improvement, erosion control and paving, and these design elements must be coordinated with local site development and environmental representatives. Civil Engineering input must be solicited when designing above-ground perimeter security features such as fences, passive vehicle barriers, towers, and poles.

9-4 ARCHITECTURAL COORDINATION.

Past experience shows that the biggest disconnect in project design and a construction cost is due to lack of coordination between commands, security, engineers, and ESS installation personnel. It is imperative that planned ESS component locations be identified early in initial design and planning stages in order to coordinate conduit installation and electronic module interface requirements for security locks and equipment. Additionally, coordination in the project programming stage will give persons responsible for collateral equipment the time necessary to plan for the facility's necessary equipment.

Detailed door-by-door coordination reviews must be conducted during design development and creation of construction documents.

9-4.1 Balance of Security with Convenience.

Other architectural issues that need to be considered include balancing security with convenience, entries and exits, life safety code considerations, space planning, doors, and door locks. These are discussed in the following sections.

There is a natural conflict between making a facility as convenient as possible for operation and maintaining a secure facility. Convenience should be considered during the different phases of the design review; however, the requirement for security must not be sacrificed for convenience. Proper security controls will reduce the flow rate and ease of ingress and egress for a facility. These issues must be addressed in initial planning to facilitate additional entry points or administrative requirements.

9-4.1.1 Entries and Exits.

In general, provide separate entries and exits. Establish the number of entry/exit points consistent with security and Life Safety requirements.

9-4.1.2 Space Planning.

Early in the project, architectural issues for Dispatch Center space, wall space for security panels and floor space for ESS equipment racks and consoles need to be discussed. Normally, security panels will go in telecommunication rooms. The ESS designer must coordinate with the telecommunications system designer and local Information Technology personnel for space requirements in the telecommunications room.

DoD criteria require that telecommunication rooms are separate from electrical equipment rooms. These spaces will be climate controlled separately from adjacent spaces.

9-4.1.3 Doors.

Access control is achieved through locking an opening such as a door or gate. Using the example of card reader controlled doors, the door is controlled through a door locking mechanism. When deciding which locking mechanism to use, a decision must be made as to whether the door is “fail-safe” or “fail-secure.” While most facilities will make all egress doors able to be opened from the “secure-side” in the egress path during a fire emergency, there are options as to whether the controlled door is able to be opened from the “public-side.”

9-4.1.3.1 Fail-Safe.

Fail-safe doors fail unlocked on loss of electrical power. This means that if power is lost the door hardware is configured such that the door can be opened by anyone from the “public-side.” While affording great convenience, this configuration is vulnerable to intrusion during a power-loss event.

9-4.1.3.2 Fail-Secure.

Fail-secure refers to entry from the public-side. Fail-secure doors fail locked on loss of electrical power. This means that if power is lost the door hardware is configured such that the door cannot be opened from the public-side. These doors need to be keyed such that they can be manually unlocked by appropriate response personnel until the security alarm panel and electrical power can be reset. Emergency doors are required to be able to be opened for exiting during a fire-emergency except for certain restricted institutional facilities (prisons and high-security hospitals).

Recommendation: Unless there is a compelling convenience reason for making a door fail-safe, most ESS projects are designed such that the door hardware is Fail-Secure.

9-4.1.4 Door Coordination.

Door control impacts (door hardware needs or changes) are sometimes overlooked in project construction cost estimates. Inventory of doors and assessment of door and hardware suitability must be an early design consideration for assessing project door interface requirements. Door coordination is one of the most frequent (and costly) problem areas on security projects. It is important that the ESS designer coordinate with the project architect to ensure that the proper door hardware is specified and installed.

9-4.1.5 Door Locks.

9-4.1.5.1 Electric Locks.

The electric lock is a very secure method to control a door. An electric lock actuates the door bolt. For very secure applications dual locks can be used (for example, a retractable bolt on the top of the door and an additional retractable bolt on the side). In some cases, power is applied to engage the handle, so the user can retract the bolt vice the electric operator actually retracting the bolt. Most electric locks can have built-in position switches and request-to-exit hardware. While offering a high security level, electric locks carry a cost premium. In addition to the lock itself, a special door hinge and internal are required. For retrofit applications, electric locks usually require purchase of a new door.

9-4.1.5.2 Electric Strikes.

The difference between an electric strike and an electric lock is the mechanism that is activated at the door. In an electric-lock door the bolt is moved. In an electric-strike door the bolt remains stationary and the strike (or cover latch) is retracted. As in electric locks, electric strikes can be configured for fail-safe or fail-secure operation. The logic is the same. In fail-safe configuration the strike retracts when de-energized on loss of power. This allows the door to be opened from the public side. In fail-secure configuration the strike remains in place causing the door to be locked from the public side and requires manual key entry to unlock the door from the public side. Again, as with electric locks, unimpeded access is allowed in the direction of egress by manual activation of the door handle/lever when exiting from the secure side. For retrofit situations electric strikes rarely require door replacement and can often be done without replacing the doorframe.

Electric strikes should be protected with a cover guard. Exposed electric strikes can be over-ridden (pried open) by an intruder with a pocket knife or screwdriver.

9-4.1.5.3 Magnetic Locks.

The magnetic lock is popular because it can be easily retrofitted to existing doors. The magnetic lock is surface-mounted to the door and doorframe. Power is applied to magnets continuously to hold the door closed. Magnetic locks are normally fail-safe, which may be a problem for unstaffed facilities in that a power disruption that will leave the site unsecured until security personnel arrive or power is restored. Magnetic locks should be the designer's last choice for door locking mechanisms and should only be considered on a retrofit project.

Magnetic locks do have a security disadvantage. In the United States, life safety requirements generally favor the use of a passive infrared (PIR) sensor as the primary request-to-exit (REX) device for doors equipped with magnetic locks. While enhancing overall building safety, this configuration in which a REX PIR sensor is mounted above the secure side of the door allows possible compromise of the magnetic door lock in the following scenario:

- Person A is on the secure side and walks past the door with no intent to exit
- The magnetic lock is released by the activation of the REX PIR sensor. This activation generates a "click" sound.
- Person B is on the public side of the door and, upon hearing the "click", opens the unlocked door and enters the secure area.

9-5 LIFE SAFETY CODE COORDINATION.

Applicable life safety and existing codes/standards must be met. In the event of an emergency, building occupants must be able to follow emergency procedures quickly and safely. The ESS designer must coordinate with the fire protection engineer (for items such as exit plan considerations and fire alarm system integration) to implement security without comprising life safety code standards. Physical security system designs need to be coordinated with and comply with NFPA 101 and the *ABA Accessibility Standard for Department of Defense*.

9-6 ELECTRICAL COORDINATION.

Electrical issues that need to be considered include power, backup power, grounding, bonding, lightning protection, cable type, electromagnetic interference, tamper protection, voltage drop considerations, power reliability, harmonics, raceway, labeling, shielding, fire alarm system interface, and lighting. These are discussed in the following sections.

9-6.1 Power.

ESS loads should be fed from distribution panels within the protected area. A good practice is to use distribution panels with dedicated security system breakers that can be locked.

9-6.2 Backup Power.

9-6.2.1 Battery Backup.

The minimum requirement for battery backup for an IDS and its monitoring station is eight hours[2]. This may be provided by batteries integral to the IDS, uninterruptible power supply (UPS), or generators, or any combination. Emergency backup power for IDS will not generate the requirement for a UPS or generator. If a generator or UPS is not available for backup, provide backup with batteries.

[2] Based on DoD O-2000.12-H, Antiterrorism Handbook

In the event of primary power failure, the IDS must:

- Automatically transfer to an emergency electrical power source without causing alarm activation.
- Initiate an audible or visual indicator at the PCU to provide an indication of the primary or backup electrical power source in use.
- Initiate an audible or visual indicator at the monitoring station indicating a failure in a power source or a change in power source.

9-6.2.2 Backup Power for CCTV.

Depending on criticality of an asset and the availability of security forces to assess alarms, consideration should be given for providing backup power for CCTV systems used for assessing alarm conditions. Backup power must be provided for CCTV systems that employ video analytics as the primary means of intrusion detection and considered when used for surveillance around critical assets.

9-6.3 Grounding, Bonding, and Lightning Protection.

Refer to UFC 3-520-01 Interior Electrical Systems, UFC 3-575-01, ANSI/TIA J-STD-607, NFPA 70, and NFPA 780 as applicable.

9-6.4 Cable Type.

Data communication signals are sensitive to changes in capacitance and resistance associated with different cable types. Digital “1s” and “0s” trigger on sharp LRC (inductance, resistance, and capacitance) time constants. The ESS designer should specify low capacitance cable and sufficient twists per foot that meet manufacturers’ specifications.

9-6.5 Surge Protection.

Provide surge protective devices for all systems identified in NFPA 780. Refer to UFC 3-520-01 for the requirements.

9-6.6 Electromagnetic Interference (EMI).

Interference can be introduced to unprotected communication lines that are in close proximity to electrical power wiring, radio frequency sources, large electric motors, generators, induction heaters, power transformers, welding equipment, and electronic ballasts. Protection from EMI includes avoiding the sources of the interference by physical separation or shielding wire lines by means of specialty wiring (coaxial, twisted shielded (foil) pairs, and metal sheathed cables), and metallic conduit systems.

9-6.7 Tamper Protection.

Tamper protection for ESS can be physical protection, line supervision, encryption, and/or tamper alarming of enclosures and components. \1\ /1/ All tamper alarm signals must be monitored continuously whether the system is in the access or secure mode of operation.

9-6.7.1 Cable Routing.

All conduit and cabling associated with the ESS should be installed within the perimeter of the protected area to the greatest extent possible. A communications link from a protected area to a central monitoring system is an obvious exception to this guideline.

9-6.7.2 Signal and DTM Supervision.

Line supervision is a term used to describe the various techniques that are designed to detect or inhibit manipulation of communication networks. All signal and DTM lines must incorporate some level of line supervision. Line supervision for ESS must detect and annunciate communication interruptions or compromised communications between field devices, workstations, and the associated central system. Field device signals must be supervised by monitoring the circuit and initiate an alarm in response to opening, closing, shorting, or grounding of the signal. DTM supervision must initiate an alarm upon any manipulation or disruption of the signal.

9-6.7.3 Encryption.

Encryption provides a level of protection against interception and malicious use of ESS data associated with high-security facilities and personally identifiable information. In general, encryption must comply with NIST FIPS standards. Refer to specific service policy for the asset being protected.

9-6.7.4 Physical Protection of Exterior ESS.

Physically protect exterior ESS. All exterior intrusion detection sensors and access control readers must have tamper resistant enclosures and integral tamper protection switches. All enclosures, cabinets, housings, boxes, and fittings having hinged doors or removable covers that are protected by employed sensors must be locked, welded, brazed, or secured with tamper resistant security fasteners and be tamper-alarmed. Route exterior ESS sensor communication and power cables that are not directly protected by sensors by the following methods:

- In rigid or intermediate metal conduit as defined by NFPA 70.
- In concrete encased duct.
- In conduit buried a minimum of twenty-four inches (0.6 meters) below finished grade.
- Suspended at a minimum of 15.5 feet (4.5 meters) above the finished grade.

9-6.7.5 Physical Protection of Interior ESS.

All intrusion detection sensors, access control readers, and assessment equipment located outside controlled areas must have tamper resistant enclosures. All interior intrusion detection sensors and access control readers must have integral tamper protection switches. All ESS cabling should be routed within the protected area to the greatest extent possible. Additionally, the following design criteria must be applied:

a. All enclosures, cabinets, housings, boxes, and fittings having hinged doors or removable covers must be locked, welded, brazed, or secured with tamper resistant security fasteners and be tamper-alarmed.

b. Any metallic conduit that leaves an area that processes classified information such as a SCIF must be decoupled (insert of nonmetallic conduit) when exiting the area.

c. For ordnance facilities, metallic conduit must be run underground for at least 50 feet (15 m) from the structure. Refer to UFC 3-575-01 for additional requirements.

d. Comply with applicable security policy requirements for installing IDS communications wiring in conduit. Apply security policy for the specific asset being protected. For example, security policy for SCIFs requires: "IDS-associated cabling that extends beyond the SCIF perimeter must be installed in rigid conduit or must employ line security". There is no universal requirement for IDS wiring to be installed in conduit.

9-6.8 Radio Frequencies.

RF systems must employ some form of tamper protection such as:

- The security system must use dedicated frequencies to transmit ESS alarm data.
- The system must detect and report intentional and unintentional jamming attempts.

9-6.9 Voltage Drop Considerations.

Standard voltage drop calculations need to be made by the designer for calculating ESS conductor size. This is especially important for CCTV cameras, which may be located some distance from interior termination cabinets and will probably be outside. The system designer must strive for a voltage drop of 10% or less.

9-6.10 Harmonics

Harmonics in a power system are typically the odd multiples of 60 Hz such as 180 Hz and 300 Hz and are generated by switching power supplies such as in a computer, by adjustable frequency motor drives, by lighting ballasts, by UPS systems, by electric welders, and by other rectifier type equipment. Harmonics in a system are measured in total harmonic distortion (THD).

9-6.10.1 In a Power System

Harmonics in a power system can cause overheating of cables and equipment along with false operations. NFPA 70 requires designs to consider harmonics and IEEE 519 is a reference standard. When a neutral of a multiphase feed has significant harmonics, it is to be oversized. UL and the IEEE both have methods for de-rating standard transformers for harmonics.

9-6.10.2 Mitigation

Mitigation of harmonics involves either isolating the harmonic source from the rest of the power system or in isolating sensitive equipment from the harmonics. Methods of mitigation involve use of oversized/de-rated standard transformers or harmonic K-rated transformers (K4 or K13 being common), use of oversized neutrals in distribution systems (full size is adequate for feeds to individual equipment), use of input line reactors or output filters (usually on motor drives), and use of surge suppressors at panelboards, in wall receptacles, in power bars, or built into the input of ends loads, such as a security panel.

9-6.10.3 Electrical Noise Reduction

To further reduce electrical noise, a copper equipment ground sized per NFPA 70 (unless the cable is already shielded) and copper grounding electrode conductors sized per NFPA 70 should be run in raceways in addition to bonding metallic raceways and enclosures together.

9-6.11 Raceway.

All conduit, wireway, and raceway must meet the requirements of NFPA 70.

Conduit runs must have a maximum of three 90-degree bends or any combination of bends not-to-exceed 270 degrees.

9-6.12 Labeling.

Cables must be labeled at origination, termination, entry into and exit from enclosures with permanent labels.

9-6.13 Shielding.

When required, shielded cable must only be grounded at one end, typically back at the local security panel to prevent open loop grounds.

9-6.14 Fire Alarm System.

In the United States most egress doors are required to unlock (in the path of emergency egress) in the event of a fire emergency. (Note: certain institutional facilities are exempt from this automatic door-unlock requirement, for example, prisons, hospitals, and other high security facilities.) Methods vary on how this may be accomplished. Meet requirements of NFPA 101. If free egress hardware is supplied (which is possible when electric locks or electric strikes are used), then that is all that is required. If magnetic locks are supplied, this life safety function has to be achieved by interfacing the ACS with the fire alarm system. The ESS design needs to include the elements identified in Figure 9-1 for system interface.

Figure 9-1. Elements of a Fire Alarm System.

- Wire and conduit from the fire alarm system to the security system. It is required that the power and communication lines not be placed in the same conduit.
- Assignment of fire alarm input/output addresses. The fire alarm system sends a signal (fire alarm system output) to each individual door controller in the event of a fire alarm signal.
- Assignment of security system input/output addresses.
- Termination of the fire alarm/security system interface on the fire alarm system.
- Termination of the fire alarm/security system interface on the security system.
- Programming of the fire alarm system to achieve door unlock signals in the event of a fire alarm signal.
- Programming of the security system to achieve door unlock signals in the event of a fire alarm signal.
- Door access control hardware all needs to be “home run” to a local junction box for ease of troubleshooting and repair.

9-6.15 Intercom System.

While not a requirement, site-specific factors may require provision of an intercom or similar auxiliary communication system at entry portals (such as motorized gates) to communicate with entering personnel from the Dispatch Center or other location.

9-6.16 Lighting.

While not an official part of ESS, lighting is an effective part of the overall physical protection design, see UFC 3-530-01. Lighting may be considered as a countermeasure for protection of each critical asset. Coordination with the electrical/lighting engineer needs to occur for placement of lighting to enhance viewing of CCTV systems, as discussed in Chapter Four.

Lighting at guard check-points must be sufficient to clearly allow a guard to verify the picture ID on access badges. Some installations may provide a fixed camera at an automatically operated gate for both surveillance and verification of a visual credential for access. In these cases, lighting must similarly be sufficient to allow accurate verification of the picture ID.

9-7 MATERIAL ENTRY CONTROL.

Other mandates will dictate specific requirements, but the following are typical considerations for material entry control as it relates to ESS and physical security:

- Material entry control circulation should be separated from general facility traffic.
- Loading docks are typically monitored by fixed cameras.
- Rollup doors are normally monitored by an interior point sensor such as a BMS.
- Shipping and receiving areas are normally caged or secured with a restricted access scheme, such as a higher card access hierarchy level.

CHAPTER 10 MODEL DESIGN APPROACH

10-1 INTRODUCTION.

Other documents provide guidance or directives on design and construction of DoD facilities. This chapter presents a model approach on how to design an ESS. The intent of this chapter is not to set new directives, but rather to communicate a process that works well.

Two principle project approaches are design-bid-build and design-build. The model design process outlined in this chapter is applicable to both approaches.

10-2 PROJECT PLANNING.

As discussed in Chapter 2, ESS is a portion of the overall physical security scheme for a facility and must be integrated into the overall physical protection plan.

10-2.1 Balance Project Funding and Project Scope.

Heightened levels of a security system provide increased resistance to intrusion and attack. Increased security brings increased construction costs and complexity. The more complex the system, the more the cost of operation and maintenance will increase. The level of security elements and security requirements need to be identified and reconciled with project funds early in a project. The design team's challenge is to balance security requirements with life safety, convenience, maintenance, and operational costs.

10-2.2 Existing Site and Building Plans.

Locating and obtaining site plans and building plans for associated buildings should be accomplished during the planning stage. CAD drawings are preferred. Early in the design process, the ESS designer should conduct site surveys to verify the accuracy of the existing plans with regard to current site conditions.

10-2.3 Site Surveys.

Site surveys include a capacity assessment of existing systems to include the following issues:

a. ACS: How many spare card reader slots are available at what panels?

b. What type of credential is used?

c. Is there badging (issuing new badges) capability?

d. CCTV: How many spare camera ports back at central server?

e. Is archiving capability present?

f. IDS: any expansion capability?

g. Transmission system bandwidth availability.

h. Approval of radio frequency emitters by local jurisdiction or host nations

i. Coordination of DTM transmission Lines

For existing and new DTM transmission lines, coordinate with the base communications officer (information technology).

10-2.4 Dispatch Center.

Identification of the location of the central monitoring facility (space) for the ESS must be made. If sufficient space does not exist for the current project, the Dispatch Center needs to be identified and a scheme for central monitoring made (i.e. a new command center space is required). A determination of Dispatch Center connectivity (DTM) requirements needs to be made. Connectivity requirements refer to bandwidth and pathway considerations. Additionally, distance issues and availability of points of connection needs to be reviewed. There will be additional project cost if new pathways and connections are required.

10-2.5 Multi-Organizational Interfaces.

Meetings with end users and facility security specialists need to be held. Additionally, determine facility and security forces operational requirements.

10-2.6 Space Planning.

The ESS designer must interact early to reserve space requirements in a new building (square footage area) for ESS components such as equipment racks, consoles, operator stations, and administrative stations.

10-3 INITIAL DRAWING PREPARATION.

A good start for drawing production is to begin with security plan drawings and a system block diagram.

10-3.1 Cable Schedule.

For identifying different cable types required for a project, a good approach is to use a cable schedule and show the conductor count and cable legend on riser diagrams. This approach is illustrated in Figures 10-1 and 10-2.

Figure 10-1 Cable Counts on Riser Diagrams.

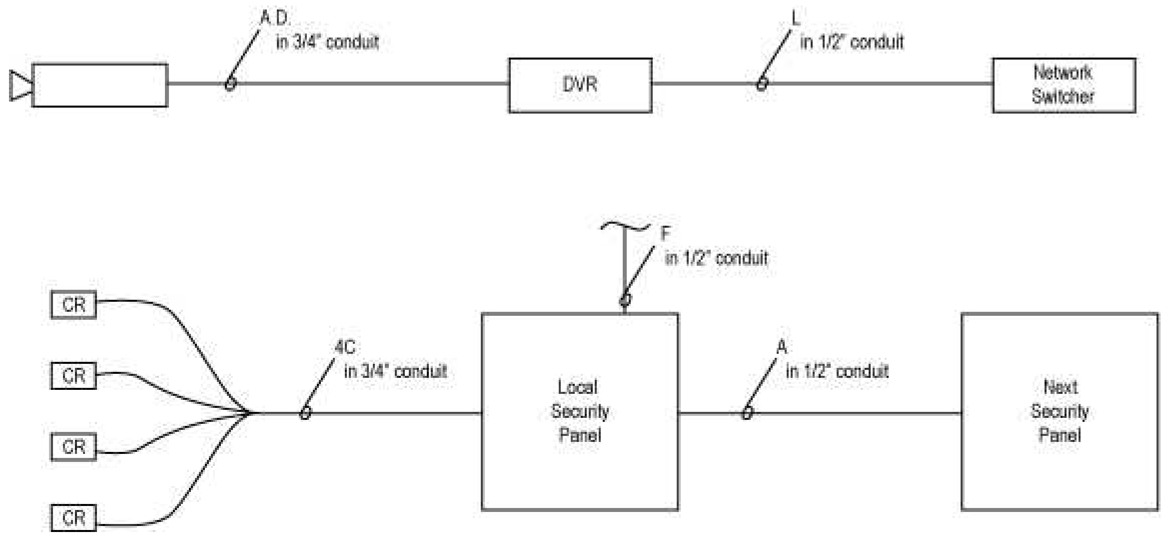

Figure 10-2. Sample Cable Schedule.

Cable Legend	Style	Type	Use
A	#16/1 TSP	Communication Cable Plenum Rated (CMP)	RS-485
C	#20 AWG/ 3 TSP	Communications Cable Riser Rated (CMR)	Card reader cable
D	#20 Coaxial	RG-59U	CCTV Video
E	#18 Solid /shield	RG-6U	CCTV Video
F	2 #12 w/1 #12 ground	THHN	120 VAC Wiring
G	#18/1 TP	Communications Cable General Purpose (CMG)	CCTV Video
L	8-C	CAT6	Ethernet cable
U	24-strand	50 micron	Fiber optic cable
W	-----------	50 FT VGA	Workstation to display

10-3.2 Functional Matrix.

A document defining the functionality to the system is a useful tool similar to the one, and an example shown in Figure 10-3.

10-4 BASIS OF DESIGN.

Some projects require a Basis of Design. Typically a Basis of Design is done as a report and includes: a functional description of systems, a narrative of systems requirements, some base drawings such as the functional matrix, and documentation of factors effecting the ultimate design and functionality of a system.

Figure 10-3. Functional Matrix.

	ACTION	A: Signal sent to security system @ Dispatch Center	B: DVR records camera image	C: Guard verifies alarm with camera	D: UPS system or batteries engage	E: Local door sounder to alarm	F: PTZ camera "moves" to preset location	G: Door unlocks until fire alarm panel is reset	H: Door unlocks	I: Motorized gate opens	J: Response force mobilized
1	Valid card reader attempt	●							●		
2	"Lost card" attempt	●	●	●							
3	Outdoor microwave sensor alarm	●	●	●			●				
4	Local security panel power loss	●			●						
5	Door held open alarm	●	●	●		●	●				
6	Door forced entry alarm	●	●	●		●	●				
7	Tamper switch activated on local security panel	●									
8	Fixed camera video motion detection activated	●	●	●							
9	Interior motion sensor alarm	●									
10	Tamper notification activated on security device	●									
11	Glass break sensor alarm	●									
12	Fence sensor alarm	●	●	●			●				
13	Fire panel alarm	●						●			
14	Remote door access activated	●							●		
15	Remote gate access activated	●	●							●	
16	Emergency exit door opened	●				●					

10-5 SCHEMATIC DESIGN PHASE.

During schematic design, system solutions for the project issues (problems) identified during programming will be generated. The key product for this phase will be outlined technical specifications and one-line riser diagrams. The schematic design documents can be used to provide the first cost estimate not based on concepts.

Initial panel board schedules should be started to indicate power sources for ESS equipment. Any new needs for power panels should be identified by electrical power one-line diagrams.

10-6 DESIGN DEVELOPMENT PHASE.

During the design development phase, project plans and specifications will be completed. Drawings should include the following:

- Legends and abbreviations
- Site plans
- Floor plans
- Riser diagrams
- Mounting details
- Door hardware schedule (may be on architectural plans)
- Sequence of construction when applicable
- Site and floor plans will include power panel locations, security panels, consoles, sensors, cameras, card readers, power circuits, and other related equipment. Riser diagrams should include all devices (including location and zoning requirements), cabling, power connections, grounding, and required system interfaces.

The system designer should have owner feedback on any changes to devices upon completion of the design development review meeting.

10-7 BIDDING.

Installers and integrators must be experienced in the installation, tuning, and programming of ESS. Require a minimum of three years of documented experience for the types of systems the project includes.

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UFC 3-501-01, *Electrical Engineering*

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

UFC 3-530-01, *Design: Interior and Exterior Lighting and Controls*

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

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

UFC 4-010-02, *Minimum Antiterrorism Standoff Distances for Buildings* (FOUO)

UFC 4-010-05, *Sensitive Compartmented Information Facilities Planning, Design, and Construction*

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

UFC 4-020-02, *Security Engineering Facilities Design Manual*, currently in Draft and unavailable

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

UFC 4-022-01, *Security Engineering: Entry Control Facilities/Access Control Points*

UFC 4-022-03, *Security Engineering: Fences and Gates*; scheduled to replace MIL-HDBK-1013/10, Design Guidance for Security Fencing, Gates, Barriers, and Guard Facilities

U.S. MARINE CORPS

MCO 5530.14A *Marine Corps Physical Security Program Manual*

U.S. NAVY

MIL-HDBK-1013/10, *Design Guidance for Security Fencing, Gates, Barriers, and Guard Facilities*, (scheduled to be replaced by UFC 4-022-03, *Security Engineering: Fences and Gates*), http://www.wbdg.org/ccb/browse_cat.php?c=80

OPNAV INSTRUCTION 5530.13C *Department of the Navy Physical Security Instruction for Conventional Arms, Ammunition, and Explosives*

SECNAV M-5510.36, *Information Security Program*

APPENDIX B GLOSSARY

B-1 ACRONYMS AND ABBREVIATIONS

ACS—Access Control System

AA&E—Arms, Ammunition, and Explosives.

BMS—Balanced Magnetic Switch

BOC—Base Operations Center

CCD—Charge-Coupled Device

CAC—Common Access Card

CCTV—Closed Circuit Television System

COTS—Commercial Off-the-Shelf Equipment

CPU—Central Processing Unit

CSA—Cognizant Security Authority

DBT—Design Basis Threat

DTM—Data Transmission Media

DVR—Digital Video Recorder

EMI—Electro Magnetic Interference

ESS—Electronic Security System

ESSC—Electronic Security System Console

FAR—False Acceptance Rate

FIPS—Federal Information Processing Standards

FRR—False Rejection Rate

FOUO—For Official Use Only

HD—High Definition

HVAC—Heating, Ventilation, and Air Conditioning

HVR—Hybrid Video Recorder

IDE—Intrusion Detection Equipment

IDS—Intrusion Detection System

IP—Internet protocol

IR—Infrared

IVS—Intelligent Video Surveillance

LAN—Local Area Network

LCD—Liquid Crystal Display

MNS—Mass Notification System

NAR—Nuisance Alarm Rate

NIST—National Institute of Standards and Technology

NMCI—Navy/Marine Corps Intranet

NVR—Network Video Recorder

PCU—Premise Control Unit

PIN—Personal Identification Number

PIR—Passive Infrared

Pd—Probability of Detection

PVC-Poly-Vinyl Chloride

PTZ—Pan/Tilt/Zoom

RDTS—Radar Detection System

RFID—Radio Frequency Identification

RDC—Regional Dispatch Center

SCI—Sensitive Compartmented Information

SCIF—Sensitive Compartmented Information Facility

SEIWG—Security Equipment Integration Working Group

SOC—Security Operations Center

TDR—Time Domain Reflectometry

UPS—Uninterruptable Power Supply

VMD—Video Motion Detection

WAN— Wide Area Network

B-2 DEFINITION OF TERMS

Access Control System (ACS). An automated system that interfaces with locking mechanisms that momentarily permit access (for example, by unlocking doors or gates) after verifying entry credentials (i.e. using a card reader). Other DoD documents may refer to the ACS as an Automated Access Control System or an Electronic Entry Control system. The ACS may also be referred to as an Automated Access Control System (AACS), Electronic Access Control System, and Electronic Entry Control.

Balanced Magnetic Switch (BMS). A door position switch using a switch held in a balanced or center position by interacting magnetic fields when not in an alarm condition.

Base Level Information Infrastructure, That information technology (IT) infrastructure which exists on DoD proprietary or leased property.

Base Operations Center (BOC). An operations center for a DoD base that has equipment and personnel for operational responses. Typically, the BOC is the receiving point for emergency alarms from fire alarm, ESS and 911 calls. This location is typically staffed by trained staff twenty-hour hours a day. The BOC may have a law enforcement desk of handling domestic dispute or interface with local and federal authorities. The BOC typically will house the Dispatch Center, which is the centralized location for receiving and assessing ESS alarms.

Charge-coupled device (CCD). A semiconductor technology used to build light-sensitive electronic devices such as cameras and image scanners. Such devices may detect either color or black and white.

Closed Circuit Television (CCTV) System. The system that allows video assessment of alarm conditions via remote monitoring and recording of video events.

Common Access Card (CAC). The CAC, a "smart" card about the size of a credit card, is the standard identification for active-duty military personnel, Selected Reserve, DoD civilian employees, and eligible contractor personnel. It is also the principal card used to enable physical access to buildings and controlled spaces, and it provides access to defense computer networks and systems.

Central Processing Unit (CPU). In a computer-based system, the component such as a microprocessor, programmable logic controller (PLC), or similar device that functions as the overall system coordinator, performing automated alarm functions, control of peripheral devices, operator interface, alarm reporting, and event logging. CPU is synonymous with the “head-end” of a system and is conceptually the “brains” of the associated system. Contemporary systems use distributed intelligence such that PC functions are downloaded to each local panel, which improves system reliability in the event a communications line is severed.

Data Transmission Media (DTM). The system that allows for Electronic Security Systems (ESS) data transmission and communication between system nodes and also back to the Dispatch Center. In other words, the DTM is the security communications system and can consist of dedicated conductors, wireless networks, leased T-1 lines, or virtual private networks. DTM includes both Base Level Information Infrastructure (BLII: on-base) as well as Defense Information Infrastructure (DII: inter-base).

Defense Information Infrastructure. That Information Technology (IT) infrastructure that is not on DoD proprietary or leased property and requires transmission of information across property boundary lines, for example, inter-base communications.

Dispatch Center. The space that serves as a central monitoring and assessment facility for the ACS, CCTV, and IDS systems. The key components of a Dispatch Center include consoles, monitors, and printers. Normally, the Dispatch Center is staffed 24 hours a day, seven days a week by trained personnel. Other names for the Dispatch Center include Security Operations Center (SOC), Security Command Center and Security Control Center (SCC), Central Monitoring Station, Data Transmission Center (DTC), and Alarm Control Center (ACC).

Electronic Security System (ESS). The integrated electronic system that encompasses interior and exterior Intrusion Detection Systems (IDS), Closed Circuit Television (CCTV) systems for assessment of alarm conditions, Access Control Systems (ACS), Data Transmission Media (DTM), and alarm reporting systems for monitoring, control, and display.

Electronic Security System Console (ESSC). While not always specifically referred to as the ESSC, most security systems end up with a console that houses monitoring and server interface equipment. Generally, this console is located in the Dispatch Center.

Electromagnetic Interference (EMI). A naturally occurring phenomenon when the electromagnetic field of one device disrupts, impedes, or degrades the electromagnetic field of another device by coming into proximity with it. With ESS, devices are susceptible to EMI because electromagnetic fields are a byproduct of the passing electricity through a wire. Data lines that have not been properly shielded are susceptible to EMI. A good example of an ESS application is using shielded wiring from a field card reader back to the local ACS panel.

False Acceptance Rate – (FAR). The rate or percentage at which a false credential is inaccurately accepted as being valid by an ACS. A sample FAR for a product could be 0.1%.

False Alarm. An alarm when there is no alarm stimulus.

False Rejection Rate (FRR). The rate or percentage at which an ACS product or system rejects an authorized credential holder.

Frame Rate Per Second (FPS). When referring to CCTV video image, this term refers to how often the visual still image is being updated. Most movies at the cinema operate at thirty fps. Recommended values for alarm and non-alarm CCTV video fps are provided in the CCTV technical section of the document.

Intrusion Detection System (IDS). A system consisting of interior and exterior sensors, surveillance devices, and associated communication subsystems that collectively detect an intrusion of a specified site, facility, or perimeter and annunciate an alarm.

Local Area Network (LAN). A geographically limited data communication system for a specific user group consisting of a group of interconnected computers sharing applications, data and peripherals.

Liquid Crystal Display (LCD). A type of display used for ESS monitors and other applications. LCDs utilize two sheets of polarizing material with a liquid crystal solution between them. An electric current passes through the crystals to align so that light cannot pass through them. Each crystal, therefore, is like a shutter, either allowing light to pass through or blocking the light. LCD displays can be monochrome or color. Monochrome displays are typically blue or dark gray images on top of a grayish-white background.

Multiplexing (MUXing). Combining two or more information channels into a common transmission/storage medium. With old VHS tape systems, the term referred to the storage of four different CCTV camera recordings onto a single VHS tape. With current technology, it is sometimes used to refer to transmission media. For example, a bigger transmission line can be used to bring back six door contact signals from a remote site to a centralized facility on one line as opposed to six different lines. The end result of multiplexing on transmission media is construction cost savings of installing fewer conductors.

Nuisance Alarm. An alarm resulting from the detection of an appropriate alarm stimulus, or failure to use established entry control procedures, but which does not represent an attempt to intrude into the protected area. Examples of nuisance alarms would be an improper opening of a monitored exit door or activation of an exterior intrusion detection system by a DoD maintenance crew. Animal activation of detection systems is a potential cause of nuisance alarms. Another example would be a wind-generated alarm of a fence monitoring system caused by flexing of the fence. Numerous nuisance alarms can cause complacency.

Premise Control Unit (PCU). A PCU is an electronic device that continuously monitors the alarm status of local intrusion detection sensors and duress devices and transmits alarm conditions to a remote monitoring station. The PCU allows authorized personnel to place the alarm zone in an “armed” or “disarmed” state via a local keypad, credential reader or biometric device. The term “PCU” is generally synonymous with the terms “IDS local processor” and “intrusion panel”.

Personal Identification Number (PIN). An identification string used as a password to authenticate identity and gain access to a location or computer resource. Although there are alphanumeric product options, most hardware entry devices make use of a numeric keypad. Many computer resource programs require an alphanumeric string.

Physical Protection System, Physical Security System. Means of preventing unauthorized physical access to a system, such as fences, walls, locks, sensors, surveillance, and so on.

Probability of Detection (Pd). A measure of an intrusion detection sensor’s performance in detecting an intruder within its detection zone.

Proprietary Security Network. A completely self-contained dedicated local area network (LAN) with security system software installed and run on a host server (computer). Proprietary Security Networks are dedicated to the ESS with no outside (Internet, LAN, or WAN) connections.

Regional Dispatch Center (RDC). A centralized security command center for multiple bases and facilities within a geographic region. This location is typically staffed twenty-four hours a day by staff trained to assess and initiate response for ESS alarms. The RDC requires interface and communication systems to different bases and facilities. The RDC concept is a trend of economically consolidating different base ESS at one centralized location to save money and infrastructure of having different discrete base operations center.

Security Equipment Integration Working Group (SEIWG). A working group responsible for a standard (SEIWG-012) pertaining to information encoded on an access control card. This standard is generally referred to as "SEIWG," although there are other SEIWG specifications as well. Originally designed by the DoD, the standard's intent was to provide requirements for an access card that could store enough data to determine information such as the individual cardholder, from which branch of the military the card was issued, and from which base the card was issued, all within the available 40 digits of data storage. The DoD's specification for the CAC is based on the SEIWG standard. To meet the SEIWG standard, three important issues beyond the card and reader must also be addressed:

- The access control software must address the complete SEIWG specification.
- The field panel must handle the 40 digits information resident to the CAC.
- The communication between the card reader and the field panel must be secure.

Sensitive Compartmented Information (SCI). Classified information concerning or derived from intelligence sources, methods, or analytical processes that is required to be handled within formal access control systems established by the Director of National Intelligence.

Sensitive Compartmented Information Facility (SCIF). A facility capable of storing Sensitive Compartmented Information (SCI) material. Requirements for these facilities are defined in ICS 705-1.

Time Domain Reflectometry (TDR). Use of sending an electronic signal down a conductor (wiring or cabling) and measuring the time it takes for the signal or part of the signal to return to determine the location of a conductor flaw or disturbance. The signal's reflection begins at the flaw or disturbance point. Once the signal returns, time is converted to distance, then divided by the speed of light, multiplied by the proper velocity of propagation, and the result in divided by two. As used in Intrusion Detection Systems, it is a technology for a fence mounted system that detects intruders climbing or flexing the fence fabric (and thereby inducing a conductor flaw).

Uninterruptible Power Supply (UPS). A power supply system that includes a rectifier, battery, and inverter to maintain power in the event of a power outage. UPS systems are specified by hours of operation to sustain power during an outage (six hours, ten hours, or twenty-four hours). UPS systems can be standby power systems or on-line systems. Typically, a centralized UPS is not a mandated requirement for an ESS project.

Video Analytics/IVS. Video Analytics, also known as IVS (Intelligent Video Surveillance) is the practice of using computers to automatically identify things of interest without an operator having to view the video. IVS consists of algorithms that detect movement or changes in live and recorded video to see whether the movement or changes mean a possible threat is about to occur or occurring. These algorithms work by examining each pixel of the video and putting together all the pixel changes. If many pixels are changing in one area and that area is moving in a direction, the software considers this to be motion. Depending on the policies and alerts you have setup, you will be notified of this motion or other actions can be automatically taken by the software such as motion tracking which follows the motion until it is no longer detected.

Wide Area Network (WAN). An internetwork that uses telecommunication links to connect geographically distant networks.

Acknowledgement: A computer dictionary called “Webopedia” was used for some of the definitions used in this glossary. Webopedia is found at http://webopedia.com/.

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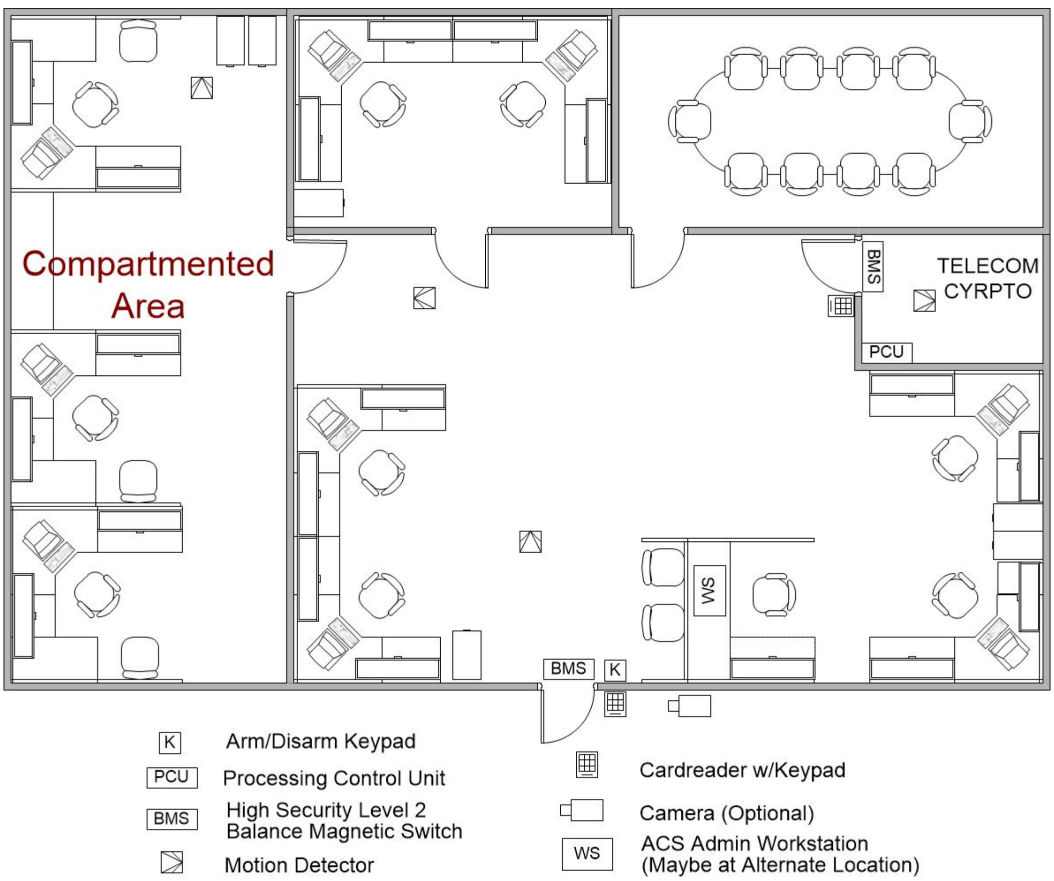
APPENDIX C NOTIONAL INTERIOR IDS CONFIGURATIONS

The information provided in this appendix is intended to aid the designer in understanding and applying policy-directed IDS requirements. It is not comprehensive as it addresses only a few high-security assets and summarizes only the most critical technical requirements. Using this information as a starting point, the designer must identify all security policies that pertain to each project and ensure that all IDS requirements are addressed in the design. **\1**

C-1 SENSITIVE COMPARTMENTED INFORMATION FACILITY (SCIF).



C-1.1 DoD Criteria Document.

UFC 4-010-05, Sensitive Compartmented Information Facilities Planning, Design, and Construction.

C-1.2 Policy Baseline.

- Director of National Intelligence, Intelligence Community Standard (ICS) 705-1 Physical and Technical Security Standards for Sensitive Compartmented Information Facilities.

- DoD Manual 5105.21, Sensitive Compartmented Information (SCI) Administrative Security Manual: Administration of Information and Information Systems Security.

C-1.3 Baseline Intrusion Detection System (IDS) Requirements.

- Must be protected by an IDS when not occupied.
- Provide point sensors on all doors, and man-passable openings. Provide motion sensors within SCIF to protect all windows, doors, and man-passable openings and detect movement within the SCIF to include compartmented areas.
- Emergency exit doors must be secured, alarmed, and monitored 24 hours per day.
- Interior areas of a SCIF through which reasonable access could be gained, including walls common to areas not protected at the SCI level, must be protected by IDS consisting of motion sensors and Level 2 high security switches (HSS).
- IDS must be installed in accordance with UL 681 and consist of:
  - Point Sensors that meet UL 634 Level 2 high security switches (HSS). Level 2 rated switches only include Balanced Magnetic Switches that pass additional performance testing.
  - Motion detection sensors must be UL 639 listed. Dual-technology sensors may be used when authorized and when each technology transmits alarm conditions independent of the other technology (“or” configuration).
- Premise Control Units (PCUs) must be located within perimeter of a SCIF.

C-1.4 Cameras.

Cameras are not allowed within the SCIF.

C-1.5 Tamper Protection.

- All IDS systems; including any access control system equipment, must be equipped with tamper detection devices that must be monitored continuously whether the system is in the access or secure mode of operation. Upon detection, an alarm (not fault) condition must be transmitted to the PCU or monitoring station.
- IDS-associated cabling that extends beyond the SCIF perimeter must be installed in rigid conduit or must employ line supervision.
- All system sensors should be located within the perimeter of the SCIF. Cabling between all sensors and the PCU must be dedicated to the system, contained within the SCIF. With Accrediting Official (AO)

approval, sensors external to the SCIF perimeter and any perimeter equipment used may be connected to the IDS provided the lines are installed on a separate zone and routed within grounded conduit.

C-1.6 External Transmission Line Security.

- Any system transmission line that leaves a SCIF must have line supervision and be encrypted to National Institute of Standards and Technology FIPS 140-2. Alternative methods must be approved by the AO.

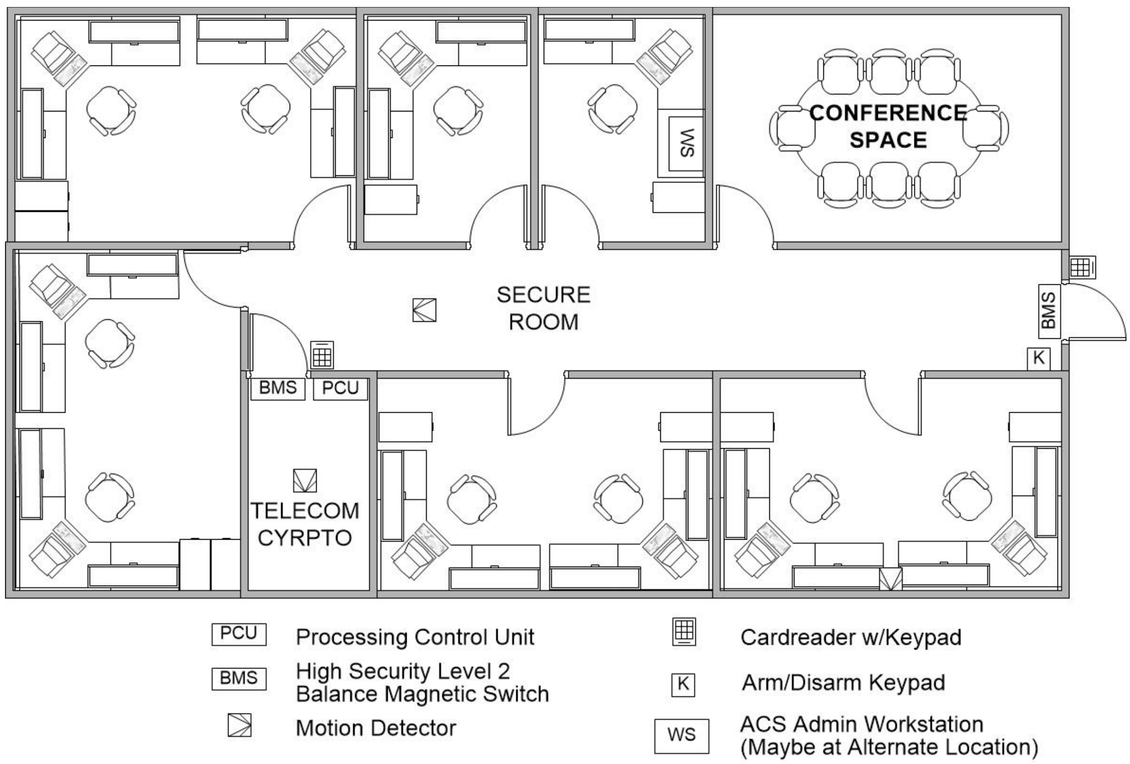
C-1.7 Emergency Backup Electrical Power.

- Twenty four hours of uninterruptible backup power is required. This may be provided by batteries integral to the ESS, uninterruptible power supply (UPS), generators, or any combination thereof. In the event of primary power failure, the system must automatically transfer to an emergency electrical power source without causing alarm activation.
- An audible or visual indicator at the PCU must provide an indication of the primary or backup electrical power source in use. Equipment at the monitoring station must visibly and audibly indicate a failure in a power source or a change in power source. The individual system that failed or changed must be indicated at the PCU or monitoring station as directed by the AO.

C-1.8 Optional Equipment.

- External CCTV Camera to monitor primary entrance.

C-2 SECURE ROOM (TOP SECRET OR SECRET OPEN STORAGE)



C-2.1 Policy Baseline.

- DoD Manual 5200.01, DoD Information Security Program: Protection of Classified Information
- SECNAV M-5510.36 Department of the Navy Information Security Program
- AFI 31-401 Department of the Air Force Information Security Program Management
- AR 380-5 Department of the Army Information Security Program

C-2.2 Baseline Intrusion Detection System (IDS) Requirements.

- Must be protected by an IDS when not continuously manned or under constant surveillance. If an IDS is not required, a continuously manned secure area should be equipped with an alerting system on all potential entrances into the secure area that cannot be observed by the occupants.
- All perimeter doors and man-passable openings into the secure area must be protected by High Security Switch (HSS) and a motion detection sensor.

- Keypad at Primary Entrance.
- Perimeter emergency exit doors must be secured, alarmed, and monitored 24 hours per day.
- IDS must be installed in accordance with UL 681 and consist of:
    - Level 2 high security switches (HSS) that meet UL 634, and/or other government approved sensors.
    - Motion detection sensors UL 639 listed. Dual-Technology Sensors are authorized when each technology transmits alarm conditions independent of the other technology.
- Premise Control Units (PCUs) must be located within a secure room.

C-2.3 Cameras.

Cameras are not allowed within spaces that contain classified materials.

C-2.4 Tamper Protection.

- All IDS systems, including any access control system connected must be equipped with tamper detection devices that must be monitored continuously whether the system is in the access or secure mode of operation. Upon detection, an alarm (not fault) condition must be transmitted to the PCU or monitoring station.
- System associated cabling that extends beyond the protected area perimeter must be installed in conduit and must employ electronic line supervision. Electronic line supervision will entail a polling or multiplexing system or equivalent. If line supervision is unavailable, two independent means of alarm signal transmission to the monitoring location must be provided.
- All system sensors must be located within the protected area.
- Cabling between all sensors and the PCU must be dedicated to the system, contained within the protected area.

C-2.5 External Transmission Line Security.

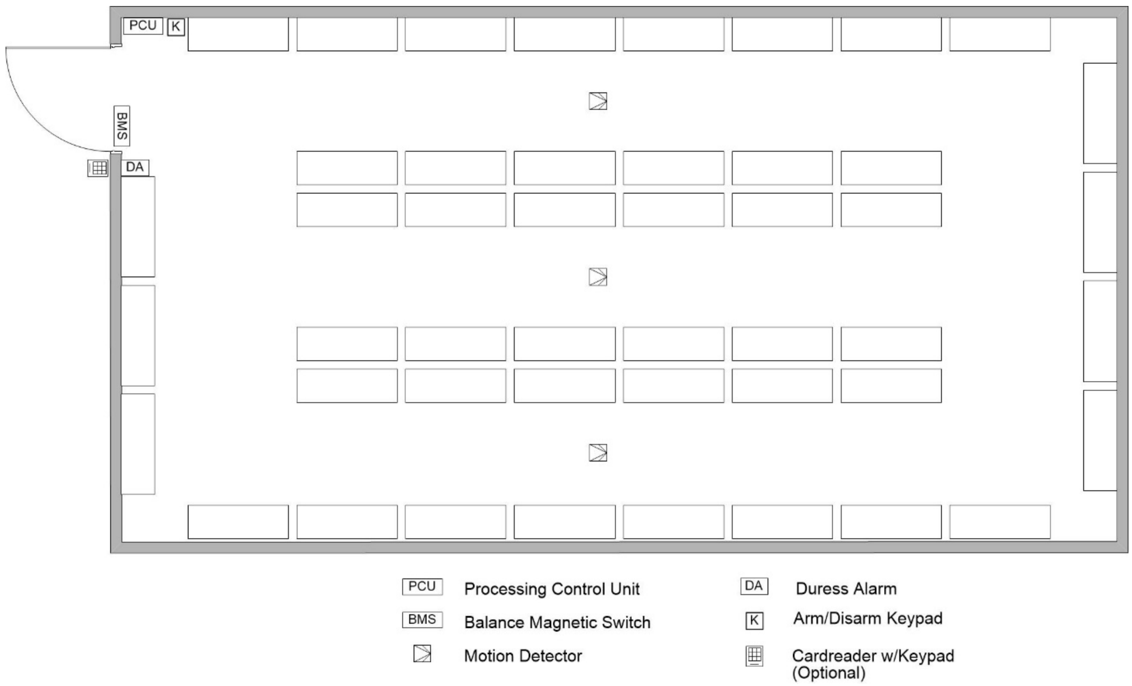
- Any system transmission line that leaves the protected area must be encrypted to National Institute of Standards and Technology FIPS 140-2.

C-2.6 Emergency Backup Electrical Power.

- Eight hours of uninterruptible backup power is required. This may be provided by an uninterruptible power supply (UPS), batteries integral to the ESS, generators, or any combination thereof. In the event of primary power failure, the system must automatically transfer to an emergency electrical power source without causing alarm activation.

- An audible or visual indicator at the PCU must provide an indication of the primary or backup electrical power source in use. Equipment at the monitoring station must visibly and audibly indicate a failure in a power source or a change in power source. **/1/**

C-3 ARMS STORAGE AREA (ARMORY, ARMS ROOM, READY ISSUE ROOM).



C-3.1 Policy Baseline.

- DoD Manual 5100.76, Physical Security of Sensitive Conventional Arms, Ammunition, and Explosives (AA&E),
- OPNAV INSTRUCTION 5530.13C Department of the Navy Physical Security Instruction for Conventional Arms, Ammunition, and Explosives.
- MCO 5530.14A Marine Corps Physical Security Program Manual
- AFI 31-101 Department of the Air Force Integrated Defense
- AR 190-11 Department of the Army Physical Security of Arms, Ammunition, and Explosives

C-3.2 Baseline Intrusion Detection System (IDS) Requirements.

- Must be protected by an IDS when not continuously manned or under constant surveillance.

- All perimeter doors and man-passable openings into the storage area must be protected by High Security Switch (HSS) and a motion detection sensor.
- Duress alarm at all issue ports.
- Keypad at entrance and for all separated (unit-based) interior storage areas that require an independent IDS capability.
- Perimeter emergency exit doors must be secured, alarmed, and monitored 24 hours per day.
- IDS must be installed in accordance with UL 681 and consist of:
    - Level 2 high security switches (HSS) that meet UL 634, and/or other government approved sensors.
    - Motion detection sensors UL 639 listed.
- Premise Control Units (PCUs) should be located within the protected area.

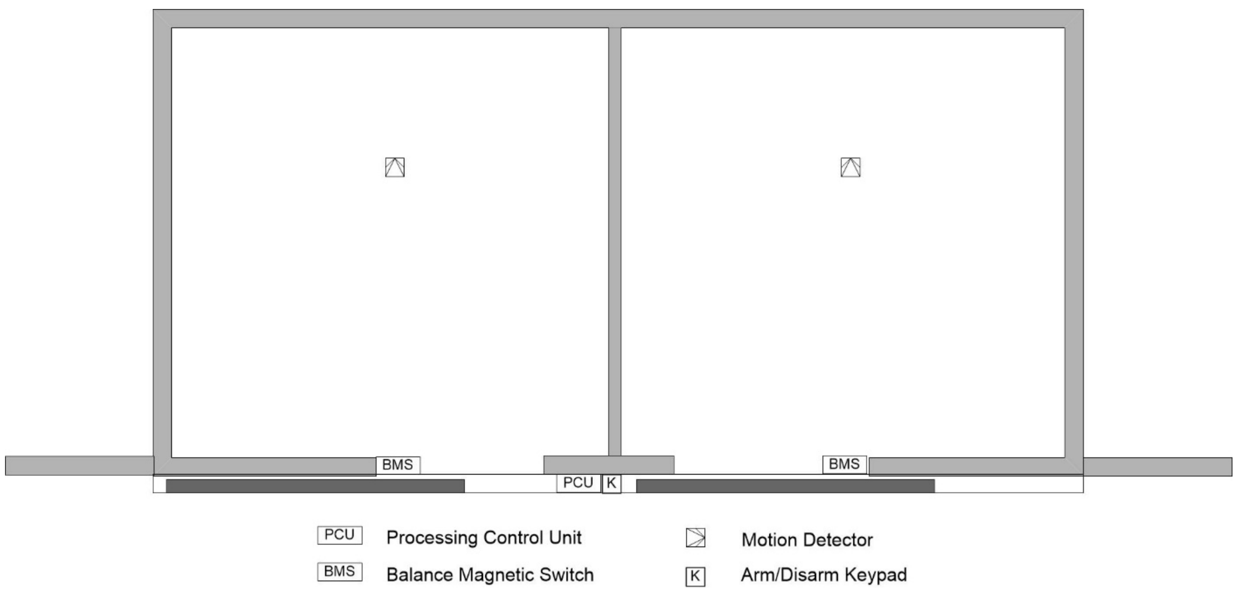
C-3.3 Tamper Protection.

- All IDS systems, including any access control system connected must be equipped with tamper detection devices that must be monitored continuously whether the system is in the access or secure mode of operation. Upon detection, an alarm (not fault) condition must be transmitted to the PCU or monitoring station.
- System associated cabling that extends beyond the protected area perimeter must be installed in conduit and must employ electronic line supervision. Electronic line supervision will entail a polling or multiplexing system or equivalent. If line supervision is unavailable, two independent means of alarm signal transmission to the monitoring location must be provided.
- All system sensors must be located within the protected area.
- Cabling between all sensors and the PCU must be dedicated to the system, contained within the protected area.

C-3.4 Emergency Backup Electrical Power.

- Eight hours of uninterruptible backup power is required[3]. This may be provided by an uninterruptible power supply (UPS), batteries integral to the ESS, generators, or any combination thereof. In the event of primary power failure, the system must automatically transfer to an emergency electrical power source without causing alarm activation.
- An audible or visual indicator at the PCU must provide an indication of the primary or backup electrical power source in use. Equipment at the monitoring station must visibly and audibly indicate a failure in a power source or a change in power source.

C-4 MAGAZINE



C-4.1 Policy Baseline.

- DoD Manual 5100.76, Physical Security of Sensitive Conventional Arms, Ammunition, and Explosives (AA&E),
- OPNAV INSTRUCTION 5530.13C Department of the Navy Physical Security Instruction for Conventional Arms, Ammunition, and Explosives.
- MCO 5530.14A Marine Corps Physical Security Program Manual
- AFI 31-101 Department of the Air Force Integrated Defense
- AR 190-11 Department of the Army Physical Security of Arms, Ammunition, and Explosives

C-4.2 Baseline Intrusion Detection System (IDS) Requirements.

[3] Based on DoD O-2000.12-H, Antiterrorism Handbook

- Must be protected by an IDS when not continuously manned or under constant surveillance.
- All perimeter doors and man-passable openings into the magazine must be protected by High Security Switch (HSS) and a motion detection sensor.
- Keypad at entrance of all separated (unit-based) storage areas that require an independent IDS capability.
- IDS must be installed in accordance with UL 681 and consist of:
  - Level 2 high security switches (HSS) that meet UL 634, and/or other government approved sensors.
  - Motion detection sensors UL 639 listed.
- Premise Control Units (PCUs) should be located within the protected area.

C-4.3 Tamper Protection.

- All IDS systems, including any access control system connected must be equipped with tamper detection devices that must be monitored continuously whether the system is in the access or secure mode of operation. Upon detection, an alarm (not fault) condition must be transmitted to the PCU or monitoring station.
- System associated cabling that extends beyond the protected area perimeter must be installed in conduit and must employ electronic line supervision. Electronic line supervision will entail a polling or multiplexing system or equivalent. If line supervision is unavailable, two independent means of alarm signal transmission to the monitoring location must be provided.
- All system sensors must be located within the protected area.
- Cabling between all sensors and the PCU must be dedicated to the system, contained within the magazine.

C-4.4 Emergency Backup Electrical Power.

- Eight hours of uninterruptible backup power is required[4]. This may be provided by an uninterruptible power supply (UPS), batteries integral to the ESS, generators, or any combination thereof. In the event of primary power failure, the system must automatically transfer to an emergency electrical power source without causing alarm activation.
- An audible or visual indicator at the PCU must provide an indication of the primary or backup electrical power source in use. Equipment at the

[4] Based on DoD O-2000.12-H, Antiterrorism Handbook

monitoring station must visibly and audibly indicate a failure in a power source or a change in power source.

UNIFIED FACILITIES CRITERIA (UFC)

ENTRY CONTROL FACILITIES
ACCESS CONTROL POINTS

UFC 4-022-01
27 July 2017

ENTRY CONTROL FACILITIES
ACCESS CONTROL POINTS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by ...)

Change No.	Date	Location

This UFC supersedes UFC 4-022-01, dated 25 May 2005.

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

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

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

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

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Subject: UFC 4-022-01, Entry Control Facilities / Access Control Points

Cancels: UFC 4-022-01, Security Engineering: Entry Control Facilities / Access Control Points, dated 25 May 2005

Reasons for Revision: UFC 4-022-01 was updated for the following reasons:

- To eliminate information that could be referenced from other references, especially tables, charts, figures, and diagrams.
- To improve consistency and uniformity of terminology.
- To remove ambiguous language and clarify between recommendations and requirements.
- To minimize the amount of service-specific items.
- To incorporate new and updated standards and requirements.
- To eliminate extraneous information so pertinent information is more accessible.
- To reduce misunderstandings of some of its provisions.
- To address situations not previously addressed by the standards.
- To improve consistency of interpretation.
- To reduce redundancy or inconsistency with other UFCs that were not available at the time of the previous version of this document.
- To eliminate standards or recommendations that were unnecessary or that had been superseded by other UFCs.
- To eliminate materials covered by other documents and to reference them where appropriate.
- To incorporate information based on new studies and research or new or revised national standards.

Impact. Most of the changes result in overall life cycle cost savings. Further impacts include the following:

- More consistent application of the provisions of the document due to clearer and more consistent guidance.
- Improved designs and reduced construction costs due to the changes of requirements versus recommendations.

Non Unified Issues. Document content is unified and consistent for all services and agencies of the Department of Defense.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE.

This document presents the required baseline approach to the design of Continental United States (CONUS) and Outside Continental United States (OCONUS) Entry Control Facilities (ECFs) and Access Control Points (ACPs) at Department of Defense (DoD) military installations. The term “Entry Control Facilities/Access Control Points” encompasses the overall layout, organization, infrastructure, and facilities at entrance locations onto United States military installations. ECF is synonymous with the term Access Control Point (ACP) used in some service publications. This UFC identifies design features necessary to ensure that infrastructure constructed today will have the flexibility to support current and future technologies, a changing threat environment, and changes in operations.

1-2 APPLICABILITY.

This UFC provides planning and design criteria and guidance for DoD components and participating organizations. This document applies to all construction, renovation, modernization, and repair projects for entry control facilities/access control points (ECF/ACP).

This UFC is not intended to guide the development of entry control points (ECPs). ECPs are defined as an internal access control portal to a building or building compound once one passes through an existing installation ECF/ACP or after one has already been vetted and permitted into and within a controlled perimeter. The definition of a controlled perimeter is included in other security engineering UFC documents.

1-3 SCOPE AND GUIDANCE.

Commanders, security personnel, planners, designers, architects, and engineers must use this UFC when evaluating existing and providing new ECFs/ACPs of an installation. Technical information considered generally known to professional designers, architects, or engineers or readily available in existing technical references (Unified Facilities Criteria - UFC, FHWA, AASHTO, SDDCTEA etc.) has not been included.

1-4 VULNERABILITY AND RISK ASSESSMENT.

In accordance with DoD security and antiterrorism (AT) policies, a vulnerability and risk assessment must be conducted prior to beginning any security project. Upon identifying facility or asset vulnerabilities to threats, physical security measures such as access control, fences, gates, vehicle barriers and Electronic Security Systems (ESS) may be deployed to reduce vulnerabilities. In summary, this document assumes the planning phases, including the risk analysis, are complete prior to beginning design. For information on Security Engineering Planning and Design process, refer to UFC 4-020-01 and UFC 4-020-02FA (described in the section “Security Engineering UFC Series” in this chapter). The engineering risk analysis conducted as part of UFC 4-020-01 should be consistent with the terrorism risk analysis conducted by the installation security/AT staff.

1-5 EXAMPLES AND APPLICATION.

The examples provided in this UFC are notional and will need to be site adapted using sound engineering and security practices as required by site constraints and the credentialing process of those professions. Consult with service guidelines and policies for specific facility related requirements. Consult with most recent source document for the most up to date information. This UFC is not intended to address procedural issues such as tactics and techniques; however, a well-designed ECF/ACP can enhance and improve operations. UFC 4-020-01, Security Engineering: Facilities Planning Manual contains information regarding the application and use of Security Engineering UFC documents and should be consulted prior to using this UFC in the project development process.

1-6 DOD BUILDING CODE.

Comply with UFC 1-200-01, DoD Building Code (General Building Requirements). 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.

1-7 ECF/ACP MISSION, PRIORITIES AND FUNCTIONS.

The objective of ECFs/ACPs is to secure the installation from unauthorized access and intercept contraband (weapons, explosives, drugs, classified material, etc.) while maximizing vehicular traffic flow by ensuring the proper level of access control and safety for all DoD personnel, visitors, and commercial traffic to an installation. ECF/ACP priorities include:

- Security
- Safety
- Capacity
- Sustainability

1-7.1 ECF/ACP Function.

An ECF/ACP and its facilities when required perform a variety of functions including visitor processing, vehicle registration, ID checks, privately owned vehicle (POV) inspections, and commercial/large vehicle inspections. An ECF/ACP when required should accommodate pedestrians and a variety of vehicles, including passenger vehicles, trucks, oversize vehicles, construction equipment, buses, recreational vehicles, motorcycles, and bicycles.

1-7.2 ECF/ACP Checklist.

Appendix D is a checklist for the development of ECF/ACP designs that is provided to assist in the planning and design stages to determine the requirements and major features for proposed ECF/ACP projects.

1-7.3 Security Concerns.

It is well established that installations must focus on threats that can be mitigated at the first line of defense–the installation perimeter. ECFs/ACPs and the access control they provide are extremely important to defense-in-depth and effective risk mitigation.

An ECF/ACP:

- Is a part of the installation perimeter and a legal line of demarcation and provides the first physical security boundary layer that restricts entry/access to DoD installations.
- Must accommodate Random Antiterrorism Measures (RAM), for sustained operations
- Must be able to operate at all Force Protection Conditions (FPCONs), including 100% vehicle inspections.
- Must have security features that protect against vehicle-borne threats and illegal entry.

1-7.4 Safety Concerns.

ECFs/ACPs must have a working environment that is both safe and comfortable for Security Forces personnel. Security Forces safety includes provisions for personal protection against attack and errant drivers; consider climate, location, and orientation.

Design the ECF/ACP so that persons and vehicles entering and leaving the facility do so in a safe and orderly manner to protect themselves, security personnel, and pedestrians from harm.

1-7.5 Capacity.

Design the ECF/ACP to maximize the flow of traffic without compromising safety, security, or causing undue delays that may affect installation operations or off-installation public highway users. A traffic engineering and safety study is recommended prior to the modification of an existing ECF/ACP and prior to the implementation of active vehicle barriers (AVB) and automated equipment. A traffic engineering and safety study is required prior to the major modification of an existing ECF/ACP and prior to the design of a new ECF/ACP.

1-7.6 **Sustainability.**

The ECF/ACP should reduce energy costs, facility maintenance and operations costs through sustainable design where appropriate. Refer to the DoD Building Code for additional guidance.

1-8 REFERENCES.

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

1-9 GLOSSARY.

Appendix E contains acronyms, abbreviations, and terms.

1-10 POLICY REQUIREMENTS.

The requirement to provide entry and access control comes from DoD Instruction/Directives, Geographic Combatant Commander (GCC) Instructions, Service Instruction/Directives, and Regional or Installation requirements. Consult Headquarters, Major Command, Regional, and Installation personnel to establish project requirements.

1-11 DOD REQUIREMENTS.

There are several instructions and publications within the Department of Defense (DoD) that establish required access control procedures for an installation, objectives of an ECF/ACP, and the responsibility for the operation of the facility. The most recent versions of these documents can be obtained from DoD, agency and service web sites. The intent of the references listed in Appendix A is to provide designers with the most relevant and specialized requirements for ECFs/ACPs. Other specific design requirements exist for various aspects of design such as buildings and roadways and are found in the DoD Building Code indicated above.

Specific to access control, Directive-Type Memorandum (DTM) 09-012, Interim Policy Guidance for DoD Physical Access Control establishes DoD access control policy and the minimum DoD security standards for controlling entry to DoD installations and stand-alone facilities.

1-12 NATIONAL REQUIREMENTS.

ECFs/ACPs must meet nationally accepted standards as applicable per Multi-Service Regulation (Army Regulation (AR) 55-80, Chief of Naval Operations Instruction (OPNAVINST) 11210.2, Air Force Manual (AFMAN) 32-1017, Marine Corps Order (MCO) 11210.2D and Defense Logistics Agency Regulation (DLAR) 4500.19) DoD Transportation Engineering Program and Code of Federal Regulations (CFR) – Title 23: Highways, Chapter I, Subchapter G, Part 655, subpart f: Traffic Control Devices on Federal-Aid and Other Streets and Highways. Title 32: National Defense, Subtitle A, Chapter V, Part 634, Subpart D: Traffic Supervision. These references and other nationally recognized documents are found in Appendix A under National Design Standards.

1-13 GEOGRAPHIC COMBATANT COMMANDER REQUIREMENTS.

Geographic Combatant Commanders (GCC) issue requirements for antiterrorism and physical security for installations within their area of responsibility. Ensure any such requirements are incorporated in addition to the requirements found in DoD and Service Directive/Instructions. Resolve any differences in the requirements by applying the most stringent requirement.

1-14 INSTALLATION SPECIFIC REQUIREMENTS.

The FPCON and RAM specified in an installation AT Plan impact the operation, capacity, and design of the ECF/ACP. Ensure any such requirements are incorporated in addition to the requirements found in this UFC. Resolve any differences in the requirements for the design of an ECF/ACP by applying the most stringent requirement.

1-15 OCONUS REQUIREMENTS.

Code of Federal Regulations Title 32, National Defense, Part 634, Subpart D-Traffic Supervision establishes that it is the Commander’s responsibility to develop traffic codes based on the Status of Forces Agreement (SOFA) with the host nation. For ECFs/ACPs developed at OCONUS installations, refer to the SOFA agreement for direction on which standard to apply. If the SOFA agreement is not explicit on which standard dictates, the most stringent requirement must be applied.

Specific service requirements may also apply.

1-16 DOD SECURITY ENGINEERING UFC SERIES

This UFC is one of a series of security engineering Unified Facilities Criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include the following, and the intended process for applying them is illustrated in Figure 1-1.

1-16.1 DoD Minimum Antiterrorism Standards for Buildings.

UFC 4-010-01 establishes standards that provide minimum levels of protection against terrorist attacks for the occupants of all DoD inhabited buildings. This UFC is intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings. They also include recommendations that should be, but are not required to be incorporated into all such buildings.

1-16.2 Security Engineering Facilities Planning Manual.

UFC 4-020-01 presents processes for developing the design criteria necessary to incorporate security and antiterrorism into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards or levels of protection beyond those required by the minimum standards.

The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also addresses the tradeoffs between cost and risk. The Security Engineering Facilities Planning Manual is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

1-16.3 Security Engineering Facilities Design Manual.

UFC 4-020-02FA provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02FA is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design. The manual also provides a process for assessing the impact of protective measures on risk. The primary audience for the Security Engineering Design Manual is the design team, but it can also be used by security and antiterrorism personnel.

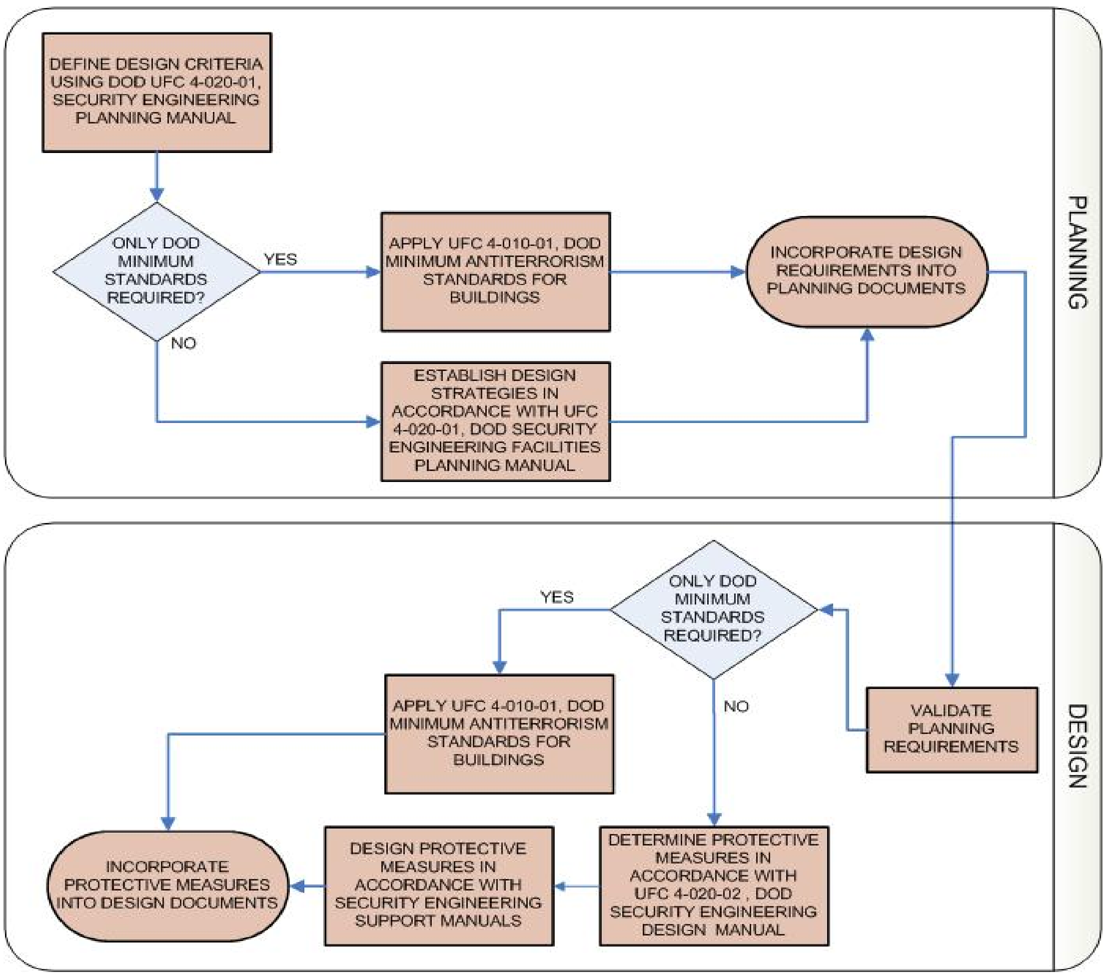
1-16.4 Security Engineering Support Manuals.

In addition to the standards, planning, and design UFCs mentioned above, there is a series of additional UFCs that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02FA. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, forced entry, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mail rooms. Still others address details of designs for specific protective measures such as vehicle barriers or electronic security systems. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

1-16.5 Security Engineering UFC Application.

The application of the security engineering series of UFCs is illustrated in Figure 1-1. UFC 4-020-01 is intended to be the starting point for any project that is likely to have security or antiterrorism requirements. By beginning with UFC 4-020-01, the design criteria will be developed that establishes which of the other UFCs in the series will need to be applied. The design criteria may indicate that only the minimum standards need to be incorporated, or it may include additional requirements, resulting in the need for application of additional UFCs. Even if only the minimum standards are required other UFCs may need to be applied if sufficient standoff distances are unavailable. Applying this series of UFCs in the manner illustrated in Figure 1-1 will result in the most efficient use of resources for protecting assets against security and antiterrorism related threats.

Figure 1-1 Security Engineering UFC Application



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CHAPTER 2 CLASSIFICATIONS AND FUNCTIONS

2-1 ECF/ACP USE CLASSIFICATIONS.

ECFs/ACPs are classified based on the intended function and anticipated usage of the ECF/ACP. The four "use" classifications are outlined in Table 2-1. The use classification is a function of the type of traffic, hours of operation, and FPCON considerations.

Table 2-1 ECF/ACP Use Major Classifications

Use Classification	Operational Hours	FPCON Considerations	Typical Operation
Primary	24/7, Open continuously	Open thru FPCON Delta	Vehicle registration/Visitor Pass capacity. Regular operations, visitors with authorization. Could also be designated as truck and delivery ECF/ACP.
Secondary	Regular hours, closed at times	Potentially closed at or above FPCON Charlie	Regular operations, visitors with authorization. Could also be designated as truck and delivery ECF/ACP.
Limited Use	Only opened for special purposes	Closed at most times	Tactical vehicles, Construction Equipment/Vehicles, HAZMAT, special events, emergency access... etc.
Pedestrian Access	Varies	Potentially closed at or above FPCON Charlie	Personnel only. Could be located near installation housing areas, near schools, or as part of a Primary or Secondary ECF/ACP.

The guidance contained in this UFC is intended for primary and secondary ECFs/ACPs. Primary and Secondary ECFs/ACPs must provide the means to defeat a vehicular and/or pedestrian threat through permanent measures. Limited-use ECFs/ACPs or internal/restricted area entry control points (ECP) may require significantly less infrastructure due to reduced operations. Limited Use ECFs/ACPs must provide means to defeat vehicular and/or pedestrian threats through temporary or permanent measures. Limited Use ECFs/ECPs/ACPs do not have routine hours of operation. A Pedestrian ECF/ACP may be part of an ECF/ACP that accommodates vehicles or it may stand alone.

2-2 ECF/ACP FUNCTION.

An ECF/ACP can have many functions. Not all functions are required at every ECF/ACP. Functions for each ECF/ACP are based on the installation's mission, AT Plan, ECF/ACP use classification, and land area. Functions may change to meet the demands of higher FPCON levels. The basic functions associated with an ECF/ACP are:

- Processing visitors
- Vehicle ID checks
- Personnel ID checks
- Privately Owned Vehicle (POV) Inspections
- Commercial/Large Vehicle Inspections

2-2.1 Site Functions.

ECF/ACP site functions include, but are not limited to, Approach Zone, Access Control Zone, Response Zone, Passive Vehicle Barriers, Active Vehicle Barriers (AVB), Command and Control, ID check area, Overwatch, Canopies, Turn Arounds, Search Areas, Lighting, and CCTV.

2-2.2 Building Functions.

Visitor Control Center (VCC), Guard Booths (Vehicle ID Check and Pedestrian ID Check), Search Area Building, Command and Control, Communications, Mechanical, Electrical, Latrine, Storage, and Overwatch are some building function components of the ECF/ACP.

2-2.3 Multi-Function ECFs/ACPs.

Where appropriate, ECF/ACP functional requirements should be consolidated or isolated to best maintain an installation's mission.

2-2.3.1 Mixed Vehicles.

An installation with limited access control space may combine all the above functions within a single ECF/ACP or an installation with high commercial vehicle demand may designate one isolated ECF/ACP for commercial vehicle inspections. When combining or isolating ECF/ACP functional requirements, designers must consider the destination of each user (visitors, commercial vehicles, etc.) and the real estate available to provide adequate facilities.

2-2.3.2 Commercial Vehicles.

Within a combined ECF/ACP, truck processing must be segregated from POV processing. Traffic lanes that require speed management to delay a high performance passenger vehicle should exclude truck traffic from these lanes. The effectiveness of most speed management techniques for passenger vehicles decreases when trucks must use the same lanes.

2-2.3.3 **Oversized Vehicles.**

When designating the functions for all ECFs/ACPs at an installation, give consideration to the requirements to support oversized, atypical vehicles such as those frequently encountered during construction operations or during mobilization of military vehicles and equipment. These atypical vehicles should be supported by at least one limited use or primary/secondary ECF/ACP, which may require modifications such as wider lanes, limiting the use of channelization islands, or limiting potential obstructions. It is recommended that canopies cover all inbound lanes and that random, infrequent oversized vehicles be directed to limited use ECFs/ACPs or be directed through outbound lanes with the appropriate traffic management.

2-3 **ECF/ACP FUNCTIONAL DIAGRAMS.**

The functional diagrams shown in Figure 2-1 through 2-4 illustrate general relationships and desired adjacencies for different types of ECFs/ACPs. These can be modified based on installation or site-specific requirements for an ECF/ACP. See SDDCTEA Pamphlet 55-15 *Traffic and Safety Engineering for Better Entry Control Facilities, Army Standard for Access Control Points' and 'Army Access Control Points Standard Design*, and Air Force Civil Engineer Center's *Facilities Dynamic Prototypes Design: Entry Control Facilities/Installation Access Control Points (ECF/IACP)* for additional layout options.

The UFC defines functional flow requirements for ECPs/ACPs including visitor processing, truck inspection, and random inspections. All ECFs/ACPs must have a mechanism to conduct select inspections after the ID check area. In some cases, security requirements may require that all vehicles be inspected prior to entry. Where and when random inspection activities occur, facilities and procedures must be developed to minimize the impact to traffic flow on the main approach.

Figure 2-1 Visitors/DoD Personnel ECF/ACP – Functional Relationships

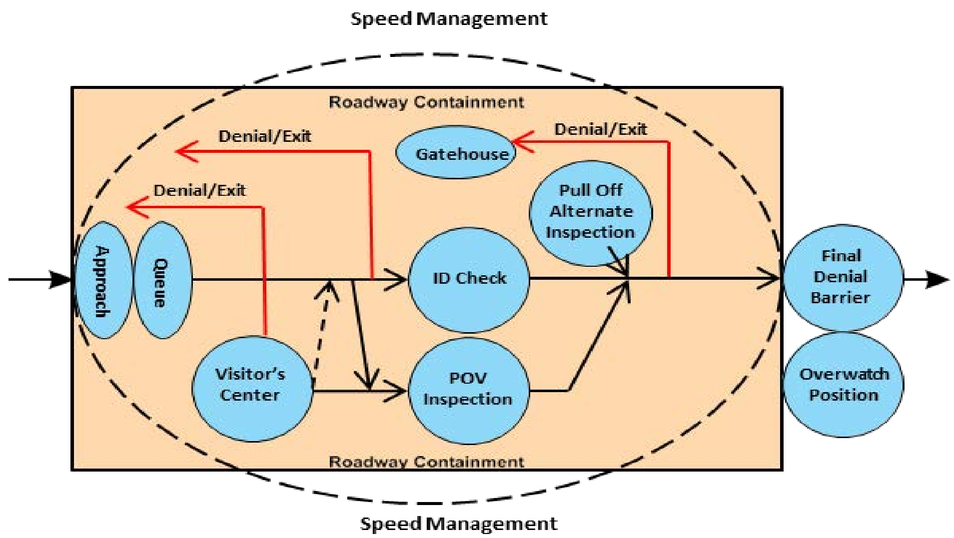

Figure 2-2 DoD/Authorized Personnel Only ECF/ACP – Functional Relationships

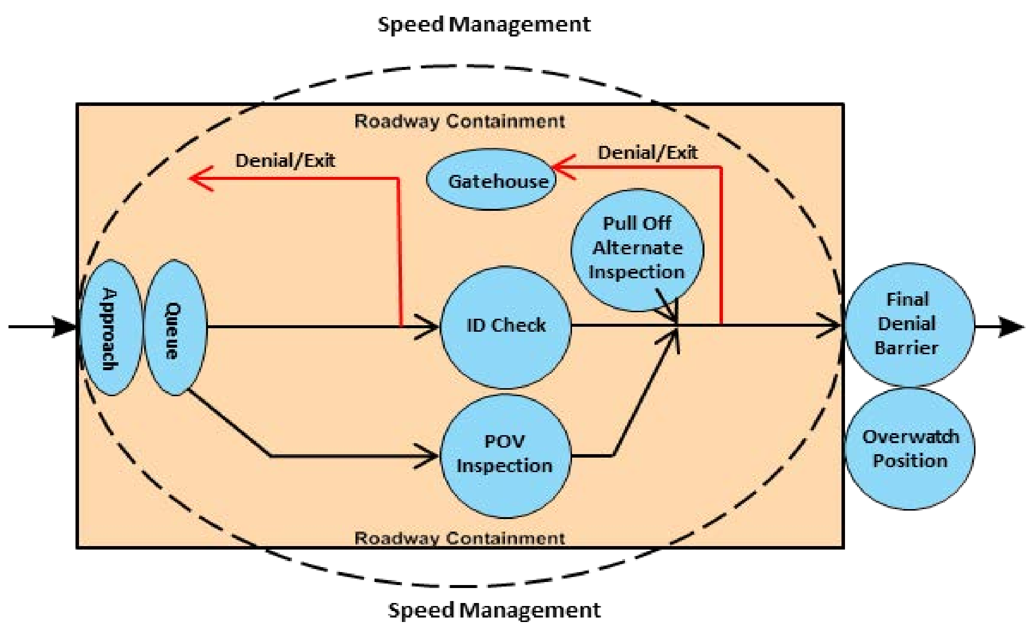

Figure 2-3 Commercial Vehicle ECF/ACP: Functional Relationships

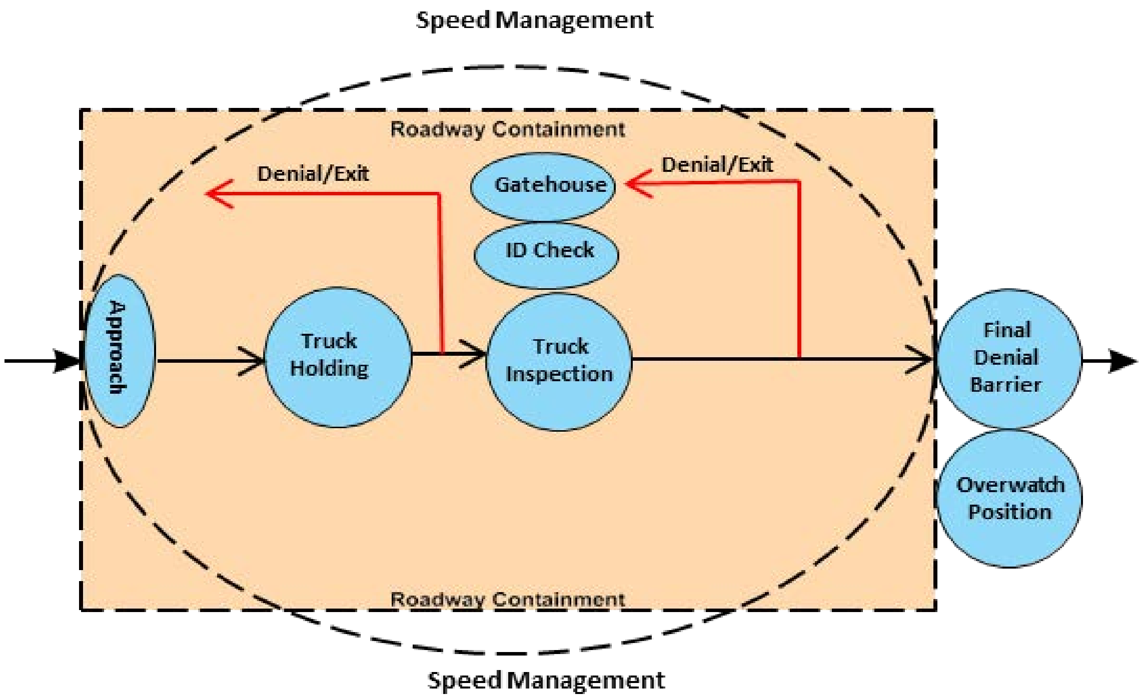

Figure 2-4 Primary ECF/ACP w/POV, Visitor, and Commercial Vehicle Processing

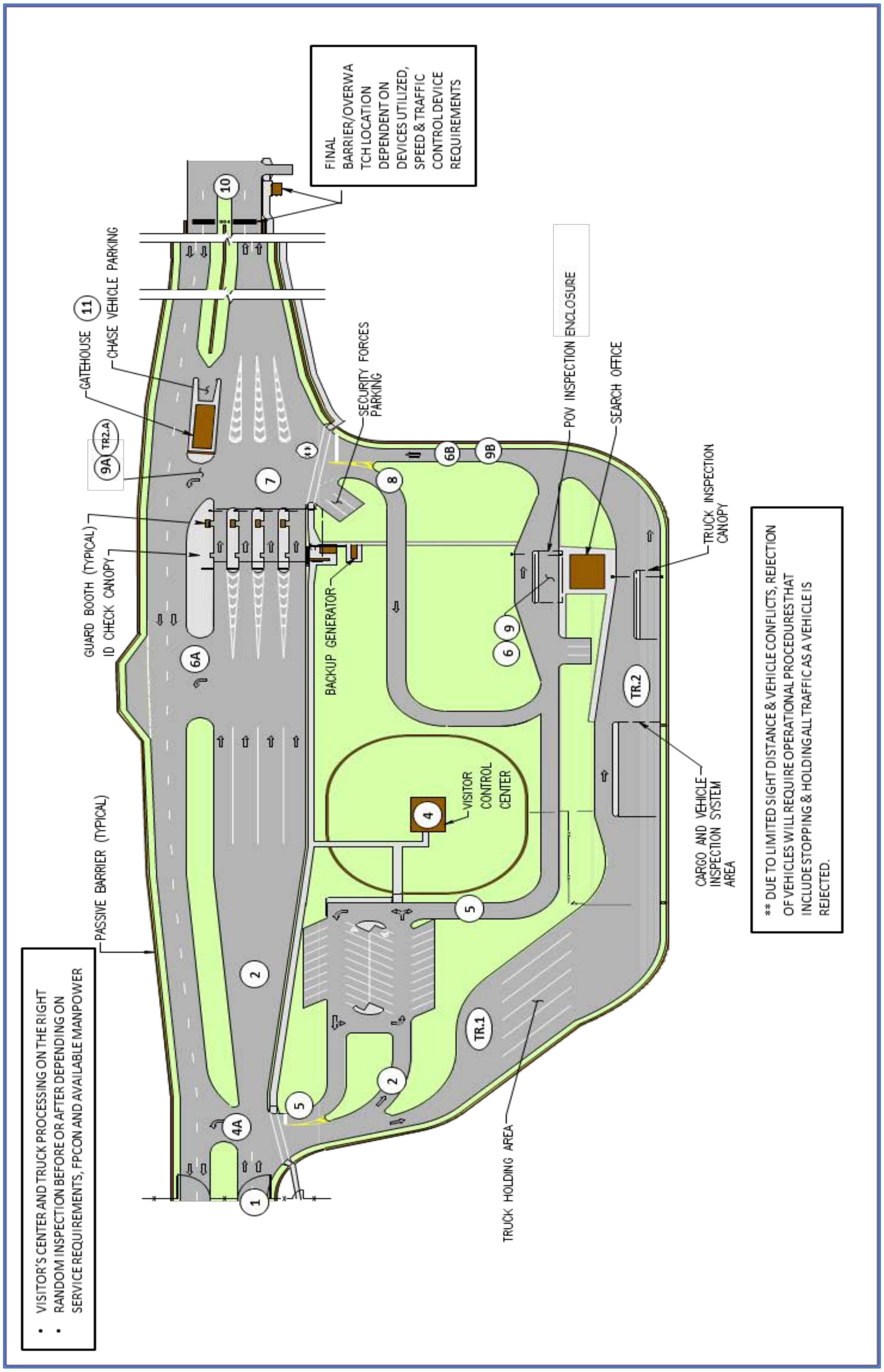

Table 2-2 ID #s for Figure 2-4

APPROACH ZONE	ACCESS CONTROL ZONE	RESPONSE ZONE
1 - Approach	**6/8/9** - ID Check Area POV and Truck including Search Office	**6B/9B** – Onto the Installation or Turnaround/Rejection Point at 9A/TR.2A
2 - Queue	**TR.2** – Truck Inspection	**10** - Final Denial Barrier and Overwatch Location
3/4/5 - Visitor Control	**7**- ID Check Area Guard Booth	
4A- Turnaround	**6A** – Turnaround/Rejection Point	
TR.1 - Truck Holding Area		

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CHAPTER 3 PLANNING AND SITE SELECTION CRITERIA

3-1 PLANNING.

Proper planning will help ensure that ECFs/ACPs meet an installation's needs, satisfy ECF/ACP priorities, satisfy ECF/ACP functions, and accommodate future development plans. Through proper ECF/ACP planning and design:

- Needed security can be achieved
- Safety of motorists can be provided
- Safety of guards can be enhanced
- Traffic and safety impacts can be mitigated
- Sustainable elements can be integrated
- Clear and intuitive transaction experience for entry candidate and gatekeeper can be achieved
- Facilities can provide an aesthetic sense of professionalism

The following stakeholders should be involved in the planning and design of an ECF/ACP:

Installation Stakeholders

- Antiterrorism Officer (ATO)/Security Forces
- Engineering and Public Works
- Community/Master Planning
- Safety Officers
- Communication Officers
- Installation Command
- Housing Contacts

Other Military Stakeholders

- Surface Deployment and Distribution Command Transportation Engineering Agency (SDDCTEA)
- ECF/ACP Service Branch Representative
- Command Groups
- Major/Tenant Commands

Other Stakeholders

- Local Police
- Emergency Services (Fire/Ambulance)
- Local Municipality/County
- State Department of Transportation (DOT)
- Federal Highway Administration (FHWA)

3-2 TRAFFIC ENGINEERING AND SAFETY STUDY.

A traffic engineering and safety study must be conducted or validated by SDDCTEA prior to initiating ECF/ACP planning and programming documentation. This engineering and safety study is recommended prior to the modification of an existing ECF/ACP and prior to the implementation of active vehicle barriers (AVB) and automated equipment. A traffic engineering and safety study is required prior to the major modification of an existing ECF/ACP and prior to the design of a new ECF/ACP. Traffic engineering and safety study guidance is defined in SDDCTEA Pamphlets 55-15 and 55-8. Traffic engineering and safety study must be performed in accordance with Institute of Transportation Engineers (ITE) or the host nation. As a minimum, the study must develop and identify demand requirements/volumes for vehicles, and also include pedestrians and multi-modal transportation. Recommend traffic engineering and safety study be included as part of the contracted engineering effort to develop the request for proposal (RFP) for a design build construction project.

The traffic engineering and safety study must, at a minimum, include the following:

- Current peak hour demand volume for both POVs and commercial vehicles.
- Current peak hour vehicle search demand volume for both POVs and commercial vehicles.
- Current peak hour pedestrian and bicycle demand volume.
- Reasonable development of proposed Design Hourly Volume (DHV).
- ECF/ACP capacity impacts caused by intersections or other roadway features prior to the approach zone and immediately after the response zone. Intersections and other roadway features that are located within the approach and response zones must also be analyzed for traffic volume impacts.
- Identify the required number of ID check lane.
- Identify visitor control center (VCC) processing and parking requirements.

SDDCTEA Pamphlets 55-15/55-8 provides additional study elements to be considered.

3-3 SITE SELECTION CRITERIA.

The ECF/ACP must be planned, designed, and so located as not to create un-safe off-Installation traffic queuing or any other un-safe traffic practices as defined by Surface Deployment and Distribution Command Transportation Engineering Agency (SDDCTEA) and all other applicable roadway standards/criteria.

When considering alternative locations for an ECF/ACP, a properly designed concept is needed. The concept must be drawn to a scale satisfying geometric design requirements, meeting service requirements and must include the appropriate number of lanes determined by the traffic engineering study and needed features. The concept can be used to determine if a site is a feasible location for an ECF/ACP. It is important to include the stakeholders in the alternative evaluation process as they may have considerations to be addressed.

3-3.1 Location and Master Plan Coordination.

Installation Master Plans and Future Development Plans must depict future ECF/ACP needs and locations when possible. When ECFs/ACPs are depicted on master plans and future development plans, they must be based on the results of a traffic engineering and safety study and must be scaled to meet design requirements.

Comply with the requirements of UFC 4-010-01. ECF/ACP selection is dependent on several considerations and it is beneficial to consider alternatives. Key considerations include:

- Antiterrorism Standards
- Master Plans and Future Development Plans
- Compatible Land Use
- Environmental Constraints
- Topography
- Utilities
- Proximity to Majority of Final Facility Destinations
- Other Restrictions

3-3.1.1 Compatible Land Use.

If possible, ECFs/ACPs should not be located near mission-critical areas, restricted areas or residential areas unless the ECF/ACP's purpose is to serve that area. Carefully evaluate master and future development plans for the installation and the surrounding community when selecting a site for a new ECF/ACP or modifying existing facilities. All ECF/ACP development plans must accommodate future modifications necessitated by increased demand or revised security measures.

3-3.1.2 Environmental Constraints.

Consider the impact to existing environmental systems as well as constraints that may prohibit development in certain areas, including wetlands, protected habitats and resources, and restoration sites.

3-3.2 Master Plans and Future Development Plans.

ECFs/ACPs are key nodes within installation circulation plans. Base circulation/transportation plans address the critical relationship between circulation and land use. The installation's future development, mission changes, population, facilities, and infrastructure must be synchronized with its circulation system. The ECF/ACP designer must consult with the installation planner regarding development scenarios, future facility projects, land use patterns, strategic vision, base capacity profile and other planning considerations impacting access to base cantonment area, military family housing, training and operating areas, and critical linkages with regional transportation systems.

The base planner can also facilitate coordination with Antiterrorism/Force Protection (AT/FP) experts to assist the designer's understanding of spatial separation requirements, controlling threats, and needed ECF/ACP levels of service. Growth and expansion must also be addressed during these conversations.

3-3.3 **Sustainability.**

Sustainability is a major factor in installation planning. Impacts on ECF/ACP design will include considerations for multi-modal (or intermodal) access to the installation. Emphasis on alternative transportation modes suggests future demand for pedestrian, bicycle, and van/car pool or bus lanes to expedite safe access to the installation. (Visitor Center projects must also be integrated into base transportation plans.) Intermodal suggests coordination with off-base circulation systems to consider connections to public transit, light rail, park & ride and pedestrian access points to emphasize sustainable transportation systems. Additionally, base planners will coordinate with local community planners for integrated circulation between the regional and installation networks.

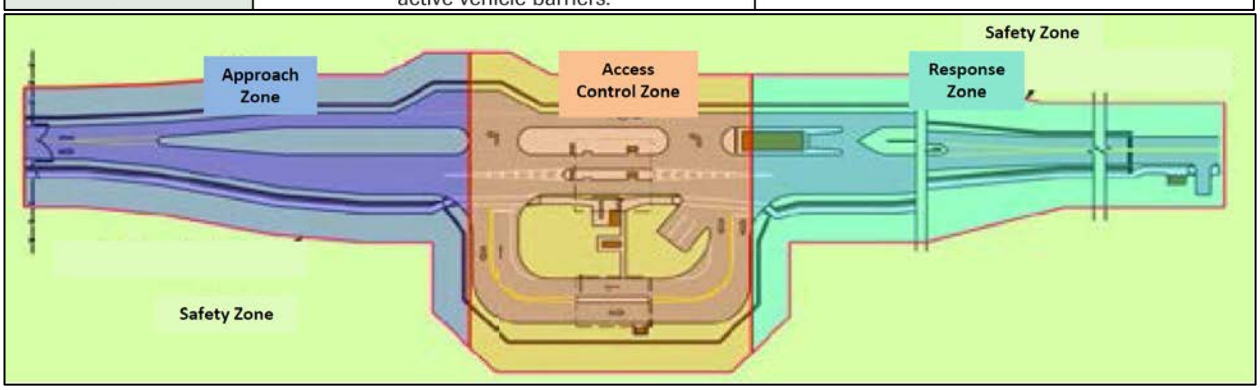
CHAPTER 4 ORGANIZATION AND OPERATION OF AN ECF/ACP

4-1 ECF/ACP ZONES.

An ECF/ACP is subdivided into four zones, each encompassing specific functions and operations. Beginning at the installation property boundary, the zones include the approach zone, access control zone, response zone, and the safety zone. Specific components are used within each zone to conduct the necessary operations. The location of each zone of the ECF/ACP is illustrated in Figure 4-1.

Figure 4-1 ECF/ACP Zones

Zone	Location	Goals
Safety	Extends in all directions beyond passive and active barriers.	Protect assets and personnel from explosions.
Approach	Installation boundary to a point just before the ID checkpoint.	Reduce speed, sort vehicles, provide stacking room, identify potential threats.
Access Control	A point just before and after the ID checkpoint.	Identify vehicles and personnel; provide surveillance, random inspection, visitor processing, and rejection capabilities.
Response	A point just after the ID checkpoint to the active vehicle barriers.	Provide measures to react to and resist a threat.



Source: SDDCTEA Pamphlet 55-15

4-1.1 Approach Zone.

The Approach Zone lies between the installation boundary/entrance and the beginning of the Access Control Zone. For the purpose of traffic and security analysis, it is appropriate to consider the approach beyond the installation boundary. The Approach Zone is the interface between the off-installation road network and the access control zone, and the area where all vehicles must traverse before reaching the ID checkpoint within the Access Control Zone. Refer to Section 5-3 for Approach Zone requirements and design methodology.

4-1.1.1 Design Elements.

The Approach Zone must include design elements to support the following functions and operations:

- Reduce the speed of incoming vehicles to, or below, the design speed of the ECF/ACP.
- Perform sorting of traffic by vehicle type (e.g., sorting commercial/large vehicles or visitors into the proper lane) before reaching the inspection area or checkpoint.
- Provide adequate stacking distance for vehicles waiting for entry, especially during times of peak demand, to ensure minimal impact on traffic approaching the installation and on traffic safety operations of adjacent public highways.
- Provide the first opportunity to identify potential threat vehicles, including those attempting entry through the outbound lanes of traffic.

4-1.1.2 **Size of the Approach Zone.**

The length of the Approach Zone is based on available land, distance required for queuing and performing traffic sorting, and the space required to create additional lanes of traffic without queuing excessively onto adjacent public highways, based on FPCON Bravo+ conditions. The design must also support measures that may be needed during higher FPCON levels, the use of RAMS at lower FPCON levels, and the temporary placement of traffic barriers as specified in the Installation AT Plan to constrain and slow traffic. Space may also be required to support speed management techniques to mitigate high-speed threats.

4-1.2 **Access Control Zone.**

The Access Control Zone is the central part of the ECF/ACP and includes guard facilities and traffic management equipment used by the security forces. The Access Control Zone begins at the turn around prior to the ID check and extends to the end of the turn around/rejection lane immediately after the ID check area. The design of the Access Control Zone must be flexible enough to ensure the infrastructure can support future inspection demands, access control equipment, and technologies. Refer to Section 5-4 for Access Control Zone requirements and design methodology.

When designing the Access Control Zone, evaluate impacts to process the following types of traffic depending on the intended functions of the ECF/ACP:

- Pedestrians
- Bicycles
- POV of authorized personnel
- Government vehicles
- Visitor vehicles
- Military convoys
- Delivery vans, commercial/large vehicles/trucks, and buses
- Construction Equipment/Oversized vehicles

4-1.2.1 Typical Operations in the Access Control Zone.

Access control zone procedures must include manual and automated actions to:

- Verify vehicle identity
- Verify personnel identity
- Conduct surveillance of the vehicle and its contents
- Conduct random or complete inspections of the vehicle and contents

Visitor and/or vehicle passes must be issued at a centralized visitor control center in the Approach Zone.

4-1.2.2 Inspection and Control of Vehicles.

The frequency of complete inspections is dependent of the FPCON level, the use of RAM, or the suspicions raised from general surveillance. Design inspection areas to accommodate one or more vehicles requiring detailed inspection. The number of inspection areas must be determined by the anticipated number of vehicles to be inspected during RAM or elevated FPCON levels. Generally, inspections take approximately 2 to 5 minutes. Consider monitoring and control of both inbound and outbound traffic. At high FPCONs, installations may conduct vehicle checks or check visitor passes as personnel are leaving the installation.

If a vehicle is denied entry during identification checks, the access control zone must have room for that vehicle to be re-directed to exit the installation. Traffic arms can be used to control traffic when a vehicle is being rejected from the ECF/ACP. Random and complete inspections must be done in the access control zone but not in the travel or ID Check lanes open for processing. Pull off alternate vehicle inspection area should be provided immediately after the ID check area to accommodate vehicles identified for search or other assistance.

4-1.2.3 Support for Automation.

In addition to supporting manual procedures, design of the Access Control Zone may need to accommodate automated identification equipment /entry (AIE) systems. To use automated systems, vehicles will need to be channeled to the proper locations. Design automated operations to mimic current procedures, which usually include identification of personnel and sometimes their vehicles.

Where the automated system is known, design the Access Control Zone to provide the required number of processing lanes and necessary infrastructure on the ID check islands to support the system. If the exact type of automated equipment and procedures used for vehicle or personnel identification is unknown, provide a flexible layout on the ID check islands where the electrical power, data and communications infrastructure is installed to support any existing or future installation of an automated system with limited disruption to operations of the ECF/ACP.

4-1.2.3.1 **Navy Automation.**

Appendix B provides information on the equipment, connectivity, and system schematic used for the Navy's Automated Vehicle Gate.

4-1.2.3.2 **Army Automation.**

Appendix C describes the Army's Automated Installation Entry program. Specific information must be acquired from the Product Manager for Force Protection Systems (PM-FPS).

4-1.3 **Response Zone.**

The Response Zone is the area extending from the end of the Access Control Zone to the final denial AVB. The Response Zone defines the end of the ECF/ACP. Design the Response Zone so that the security forces have time to react to a threat, operate the AVB, and close the ECF/ACP if necessary. When inbound and outbound travel is separated by a median, the response zone is measured from the trailing end of the last point of inspection or turn around/denial/exit roadways to the final denial AVB. When inbound and outbound travel is not separated by a median the Response Zone is measured from the trailing end of the inspection roadway (end of turn around/rejection lane immediately after ID check area) to the final denial AVB. Refer to Section 5-5 for Response Zone requirements and design methodology.

4-1.4 **Safety Zone.**

Consider the effects an explosion may have on nearby DoD personnel, buildings, or assets. The safety zone extends from the passive vehicle barriers in all directions to protect installation personnel from an explosion at the within the ECF/ACP corridor. Refer to UFC 4-010-01 for information on safety zone/stand-off distances at entry control facilities/access control points. The minimum explosive weights in UFC 4-010-01 apply to personal operating vehicle (POV) and Commercial vehicle ECF/ACP unless increased by other Service or COCOM policy. There is no required minimum antiterrorism standards for non-DoD personnel, buildings, or assets outside the installation and adjacent to the safety zone. Consider in the development of the safety zone any exclusion zones, which may be required to minimize radiation exposure for inspection systems. For explosive threats above the minimum antiterrorism standards see UFC 4-020-01.

CHAPTER 5 DESIGN GUIDELINES

5-1 INTRODUCTION.

The following design considerations are provided for primary and secondary ECFs/ACPs. For Commercial/Large Vehicle Inspection, follow the additional guidelines in Chapter 6.

5-2 GENERAL LAYOUT AND DESIGN GUIDELINES.

This section reviews the general layout and design guidelines for the various zones of an ECF/ACP. Further details concerning specific elements are provided in later sections.

5-2.1 Containment and Control of Vehicles.

The design of an ECF/ACP must ensure that vehicles are contained through an arrangement of passive and active vehicle barriers (AVB). AVBs require some action, either by personnel, equipment, or both, to prevent entry of a threat vehicle. Passive vehicle barriers are used to direct and channel the flow of traffic in the desired direction.

DoD approved passive and AVB systems are designed based on their capacity to stop two threat vehicles, a four door full size sedan and a 7.5 ton single unit truck. The characteristic of these two vehicles will be used to design the containment and control of threat vehicles within the ECF/ACP safety zone. However, the design basis threat may also be determined by a site-specific threat assessment or specified by the installation commander with respective service approval. In these cases the service or agency identified threat vehicle and/or barrier capacity must be considered baseline. Some services may establish minimum barrier capacities or specify threat vehicles for primary and secondary ECFs/ACPs. The velocity of the threat vehicle will be determined based on vehicle characteristics and the roadway layout. The allowable penetration following impact must be based on site considerations and the proximity of inhabited facilities or high value assets. Further information concerning design and specification of active and passive vehicle barrier systems is provided in UFC 4-022-02.

5-2.1.1 Perimeter Fence and Gate.

The ECF/ACP typically begins at the installation perimeter. In most cases, the perimeter is defined and secured with a fence. Each ECF/ACP must have a gate enabling the ECF/ACP to be closed at the installation perimeter when not in use. This gate must maintain an equivalent level of security as the adjacent fence/barriers. In addition, the gate must have signage and retroreflectivity as detailed in SDDCTEA Pamphlet 55-15 and Manual on Uniform Traffic Control Devices (MUTCD) and the Department of Defense (DoD) Supplement To The National Manual on Uniform Traffic Control Devices.

5-2.1.2 **Vehicle Containment Within the Roadway.**

Vehicle containment within the roadway is necessary to prevent inbound vehicles from unauthorized access and must extend from the installation perimeter to the final denial AVB to be effective. Passive vehicle barriers must encompass a contiguous perimeter around the ECF/ACP, with the final denial AVBs completing the containment. Arrange barrier to ensure that a vehicle will not circumvent the ECF/ACP once the vehicle has entered.

5-2.1.2.1 **Passive Vehicle Barriers.**

Passive vehicle barriers utilized must be tested products listed on the DoD Anti-Ram Vehicle Barrier List.

Consider the potential debris hazard produced by passive vehicle barrier systems exposed to a blast during an attack and the effect on any nearby buildings or assets. Further information concerning barrier debris minimization is provided in UFC 4-022-02. The aesthetics and design of the barrier system should be consistent with the installation's exterior architectural plan and the surrounding architectural and landscape features. Breaks in the passive vehicle barrier system of the ECF/ACP must not exceed 3 feet (0.9 m) in width for traffic having a 90-degree approach and 4 feet (1.2m) in width for traffic paralleling the barrier. The location and installation of passive vehicle barriers must conform to the requirements of the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide* for objects placed near roadways. All passive vehicle barriers installed within the clear zone must meet the requirements of AASHTO's Manual for Assessing Safety Hardware (MASH) approved for crash safety.

5-2.2 **Personnel Protection.**

Design the ECF/ACP to enhance safety of the security personnel operating in the access control zone. All ECF/ACP facilities, or other manned posts, must be afforded crash protection (from traffic in either direction). Passive vehicle barriers such as bollards, reinforced concrete walls or knee-walls, or crash cushions must be used to protect personnel standing on the traffic islands; however, these elements must meet clear zone requirements as detailed in SDDCTEA Pamphlet 55-15 and AASHTO Roadside Design Guide.

An example of a barrier system would be a short, concrete bull nose wall with impact attenuator at the appropriate location on the traffic island. Traffic islands separating directions of travel require protective devices on both sides of the island. Traffic islands separating similar directions of travel only require protective devices on the leading edge of the island. By elevating the personnel on an island, they are protected from accidental impact during identification checks. The bull nose with impact attenuator is designed to protect the personnel from potential injury caused by a vehicle leaving the roadway or lane. This type of system not only enhances the safety of security personnel, but it also offers the personnel cover in the event of an attack. See SDDCTEA Pamphlet 55-15 for further information concerning barriers and crash cushions. The height of crash protection barriers needs to be reviewed closely to assure there are no conflicts with traffic or guard sightlines.

5-2.3 **Capability to Reject Unauthorized Vehicles.**

Unauthorized vehicles may enter the ECF/ACP and the design must support rejecting these vehicles as follows:

- Provide turn around/denial/exit points as shown in Figure 2-1 through Figure 2-4; one located before the ID check area and one located immediately after the ID check area. See Access Control Zone Requirement and Guidelines for additional information.
- Implement operating procedures and consider the use of traffic arms to halt traffic such that rejected traffic can be safely directed to the turn around/denial/exit point.

Design turn around/denial/exit points in accordance with SDDCTEA Pamphlet 55-15 and with the following characteristics:

- Design turn around/denial/exit points for the largest vehicle identified in the traffic engineering and safety study that is expected to enter the installation on a regular basis, but not less than a single unit vehicle (SU).
- ECFs/ACPs designed for smaller vehicles (POV) must be capable of rejecting a commercial vehicle (AASHTO Wheel Base (WB)-67) before the post ID check area due to the likelihood of commercial vehicles attempting to enter the installation through POV ECPs/ACPs.
- If space is unavailable to support a single movement, consider the impact on the flow of traffic while a vehicle makes a three-point turn or similar movement. If the impact is infrequent or acceptable, or large vehicles are not expected at the ECF/ACP, then the required space can be minimized.
- Sign the turn around/denial/exit area per the Manual on Uniform Traffic Control Devices (MUTCD) and the DoD Supplement to the MUTCD.

5-2.4 **Traffic Considerations.**

The effect of an ECF/ACP design on the surrounding roadways and intersections is of paramount concern. If congestion occurs, and there is inadequate vehicle processing and stacking distance, the queues may extend into adjacent intersections or cause congestion on feeder roads. Find additional guidance in SDDCTEA Pamphlet 55-15.

5-2.4.1 **Design Capacity.**

The design capacity is based on the peak hour traffic demand volume that the ECF/ACP handles without unreasonable congestion and/or negatively impacting the surrounding local roadway system. Consider both current and future traffic demands. Since some disruption in the level of service is expected at high FPCON(s) (Charlie or Delta), design the ECF/ACP to minimize congestion at FPCON Bravo and below.

5-2.4.2 **Traffic Congestion.**

At FPCON Charlie and Delta, some congestion may occur but this is sometimes offset by the installation reducing the population seeking to enter the installation to mission essential personnel only. Where possible, minimize the congestion during FPCON Charlie or Delta. If the final capacity achieved at an ECF/ACP is below the expected peak hour traffic volume, congestion can be reduced by implementing staggered work hours, encouraging carpooling, adding lanes, and/or tandem processing (no more than two) guards per lane.

5-2.4.3 **Lane Requirements.**

The number of lanes planned for an ECF/ACP must be sufficient to handle the expected volume of traffic, especially during times of peak demand such as morning rush hour and must consider both manual and automated operations (handheld, structurally mounted). Additional guidance can be found in SDDCTEA Pamphlet 55-15.

Provide a number of ID Check lanes sufficient to process the traffic volume demand identified in the traffic engineering and safety study. Analysis must consider the length of the queue and the number of ID Check lanes required to preclude off-installation impacts to roadways.

5-2.4.4 **ECF/ACP Smart Decision Evaluator.**

The ACP/ECF SMART Decision Evaluator was developed to provide perspective on the issues associated with each approach to ECF/ACP vehicle processing so that when combined with practical knowledge, decisions are made with full awareness of the ramifications. The ACP/ECF SMART Decision Evaluator has been designed to require a minimal amount of data entry when determining lane requirements.

The SMART Decision Evaluator:

- Provides comprehensive perspective
- Provides awareness of ramifications through costs and associated risks
- Is derived from common engineering, security and economic principals

Recommend utilizing the ACP/ ECF SMART Decision Evaluator (or other methods to accomplish the same results) to evaluate the existing, short-term and long-term impact of security, manpower, automation, and roads and traffic for DoD developed ECF/ACP. For additional information visit the U.S. Army's Transportation Engineering Agency website:
https://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/Pages/default.aspx

5-2.5 **Geometric Design.**

Geometric design is dependent on design speed, roadway classification, and design vehicle. Also, the type of ECF/ACP, space available, and traffic volume may impact design. This section is intended to provide basic guidance on general design features.

Design criteria can be classified into the following areas: cross-section features; horizontal curvature and alignment; and vertical curvature and clearances.

5-2.5.1 **General Guidelines.**

In general, the design criteria for inbound and outbound travel lanes must be based on the design vehicle (identified from the traffic engineering and safety study) and the speed at which the design vehicle is expected to travel. For roadways leading to/from inspection areas, visitor centers, and other facilities within the ECF/ACP, the design vehicle dimensions and maneuverability considerations must dictate the design. An example of maneuverability of the design vehicle is the minimum inside turning radius of the vehicle.

Consult with AASHTO's *A Policy on Geometric Design of Highways and Streets, Roadside Design Guide*, SDDCTEA Pamphlets 55-15 and 55-17, and service guidance regarding geometric design to include the following elements. Use the more stringent criteria. See Appendix A for references.

- Design guidelines and criteria
  - Design speed
  - Roadway classification
  - Design vehicle
- Cross-sections
  - Travel Way and Lane Width
  - Curb and gutter
  - Shoulders
  - Clear zone
  - Medians and traffic islands
- Turning movements and turning radii
  - Turn around/denial/exit points
- Horizontal alignment
  - Horizontal curves
  - Lane widening
  - Horizontal Tangents and Transitions
  - Horizontal Sight Distance
- Vertical alignments
  - Vertical clearance
  - Vertical curvature
- Other geometric elements
  - Transition tapers
  - Drainage
  - Landscaping

5-2.6 **Speed Management.**

The control of vehicle speeds at ECFs/ACPs is a common concern. The roadway geometry and passive vehicle barrier alignment will contribute in limiting the maximum attainable speed of threat vehicles. Speed management for threat speed mitigation must include horizontal curvature designed in conformance to SDDCTEA Pamphlet 55-15 along with national and state roadway design criteria.

To control the speed of non-threat vehicles, other options, such as traffic calming and signing can be considered. The use of traffic calming devices must be evaluated by a traffic engineering and safety study.

5-2.6.1 **In-Roadway Barrier Guidance.**

Do not design for in-roadway barriers, bollards, and other fixed objects as speed management techniques for threat speed mitigation at new ECFs/ACPs. In-roadway barriers and bollards may be utilized at existing ECFs/ACPs to obtain additional response time if they are installed and delineated as prescribed in SDDCTEA Pamphlet 55-15 and if it is demonstrated that the lane reductions do not unduly delay traffic or cause back-up into the public throughway or create other unsafe situation.

5-2.6.2 **Speed Hump/Table Guidance.**

Speed humps and speed tables are not for threat speed mitigation. Speed humps and speed tables may be used for speed management and to gauge motorist intent in the approach zone only. If used, provide speed humps and speed tables in accordance with the applications and profiles detailed in SDDCTEA Pamphlet 55-15 and per FHWA and ITE guidelines.

5-2.7 **Traffic Control Devices.**

All traffic signals, signs, and pavement markings must be in conformance with the MUTCD/ DoD Supplement to the MUTCD, SDDCTEA Pamphlets 55-15 and Pamphlet 55-17 as well as applicable state, local, and OCONUS requirements.

The above indicated documents provide guidance on the following:

- Signs and Signals
    - Requirements
    - Types
    - Sizes and Legibility
    - Retroreflectivity requirements
- Speed Limit Signing
- Guide Signing
- Pavement Markings
    - Longitudinal

  - o Transverse
- Traffic cones
- Barrier delineation

5-2.8 **Multimodal and Alternative Transportation Considerations.**

The use of transit as well as pedestrian and bicycle activity must be considered while analyzing the conditions at an existing ECF/ACP or developing a new ECF/ACP. All modes must be accommodated to the appropriate level at ECFs/ACPs.

Accommodating alternate modes of transportation can help reduce the demand of vehicles seeking entry during peak periods.

5-2.8.1 **Pedestrian Access.**

When pedestrian access control is required, ensure that proper sidewalk and safety provisions direct pedestrian traffic to the Access Control Zone and separate it from vehicular traffic. Design pedestrian access to ensure security personnel can maintain visual contact with the pedestrians as they approach the ECF/ACP. Plan sidewalks to integrate into the existing site layout and accommodate new facilities. Breaks may be provided in the passive vehicle barriers surrounding the ECF/ACP to allow pedestrian access to the ECF/ACP. Provide sidewalks with a minimum width of 4 feet (1.2 m). Provide crosswalks with a minimum 6 feet (1.8 m) wide. Design elements for pedestrians must be compliant with Architectural Barrier Act (ABA) and AASHTO *A Policy on Geometric Design of Highways and Streets* requirements and to the requirements of Public Rights of Way Guidelines (PROWAG). PROWAG is endorsed by SDDCTEA and FHWA and provides additional guidance of the construction of ABA compliant facilities on or adjacent to roadways.

Where turnstiles or other pedestrian controls are utilized they must either be manned/controlled/metered by guard personnel or equipment that must be included to validate credentials. Other considerations in the selection of turnstiles or similar access control devices include the control of potential tailgating and the likelihood that personnel will have equipment or luggage, which may require additional space in the turnstile. Consider if pedestrian inspection areas will be required based on pedestrian demand and any requirement to inspect personnel and packages. See UFC 4-022-03, *Security Fences and Gates* for additional guidance on personnel gates including turnstiles.

5-2.9 **Parking Guidance.**

Incorporate parking in the design of the ECF/ACP to support security vehicles, visitors and vehicles associated with shift changes of security personnel. Where an ECF/ACP includes a visitor control center, sufficient parking will be necessary to support this facility. The number of parking spaces to provide should be based on the methodology outlined in SDDCTEA Pamphlet 55-15 and must meet ABA requirements.

Locate spaces to minimize the walking distance and potential interference with moving or parked vehicles. Implement UFC 4-010-01 as applicable.

5-2.10 Landscaping and Aesthetics.

ECPs/ACPs provide the first public impression of the installation. They should present the proper appearance for visitors, employees, and military personnel. The layout, landscaping, and architecture of the facilities are factors in this image. The architectural design of the facilities should comply with the installation or command's architectural design standards.

Include line-of-sight considerations in the landscape design. It is important that the line-of-sight of security personnel through the ECF/ACP not be impeded. This includes consideration of overwatch positions, which require an adequate and acceptable line-of-fire.

5-3 APPROACH ZONE REQUIREMENTS AND GUIDELINES.

Design the approach zone to accommodate design traffic demand without off-installation impacts per the direction previously indicated in the traffic engineering and safety study section of this document.

Base the layout of the approach zone on the following guidelines:

- Provide an entry gate that joins the installation perimeter that fully contains the ECF/ACP.
- Provide a passive vehicle barrier system that tie into the entry gate and the access control zone passive vehicle barrier system.
- Maximize the length of the approach zone to provide optimal stacking distance for the traffic queue.
- Reversible lanes can increase throughput and flexibility where space is unavailable for additional lanes.
- Sort traffic by vehicle type. For example, use the farthest right lane for truck traffic. Rejection of these vehicles requires additional space for their larger turning radii.
- Wrong way detection must be considered for all the outbound lanes.
- ECFs/ACPs must have the minimum ability for a wheel base (WB)-67 vehicles to be rejected prior to the identification (ID) check area for a POV only ECF/ACP. ECFs/ACPs that accept commercial vehicles (combined POV/truck gate or exclusive truck gate) must provide for a WB-67 vehicle to be rejected. OCONUS projects must have requirements similar to CONUS. OCONUS projects must provide a means to reject a WB-67 or OCONUS equivalent vehicle prior to the ID check area.

5-4 ACCESS CONTROL ZONE REQUIREMENTS AND GUIDELINES.

Design the access control zone to manage authorized vehicles and personnel, to reject unauthorized vehicles, and minimize the adverse impacts on traffic.

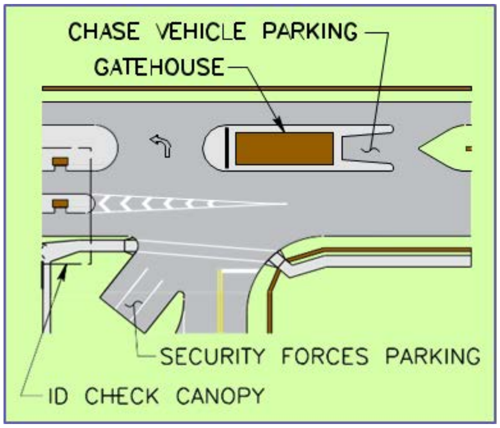
Base the layout of the access control zone on the following guidelines:

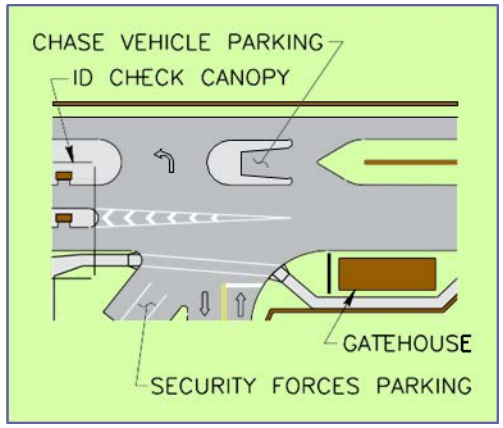
- Provide the capability to process visitors. Visitor processing must be conducted prior to entry into the installation.
- Provide an Identification (ID) check area where guards and/or automated equipment validate drivers and vehicle occupant's identifications. Provide infrastructure to support identification and search areas for the inbound lanes.
- Provide a passive vehicle barrier system that ties into the approach zone passive vehicle barrier system and the response zone passive vehicle barrier system that presents a fully contained ECF/ACP. If the site cannot accommodate an approach zone as described previously, provide a passive vehicle barrier system tied into the installation perimeter barrier system and the response zone passive vehicle barrier system that presents a fully contained ECF/ACP.
- Provide raised curbed islands between all inbound lanes or outbound lanes designed as reversible lanes in the ID check area. Islands must be 50 feet (15.25m) in length for single processing and 75 feet (23m) in length for tandem processing. Consider providing curb cuts or a step down area for security personnel at ID Check positions but make sure roadway drainage, equipment installation, and safety of the guard is not compromised. Cover all inbound lanes in the main ID check area and all search areas as required with an overhead canopy to protect against inclement weather, facilitate identification and inspection procedures, and provide a platform for lighting and Closed Circuit Television (CCTV). Maintain a minimum 3 feet (0.9m) setback from the face of curb to the guard facilities on the island. Must also include, as a minimum, a 1 foot (0.3 m) horizontal clearance between face of traffic island curb and guard facility roof, gutters or any other objects protruding from the guard facility. Maintain a minimum lateral clearance of 2 ft (610 mm) in the access control zone to allow security personnel to pass between fixed objects and obstructions and the roadway. See Figures 5-11 and 5-12 for additional details.
- As shown in Figures 2-1 through 2-4 and 5-1, it is recommended that two turn around/denial/exit points be provided. One occurring prior to the central ID check area guard booth and the other occurring after this point but prior to or within an area assessable from the gatehouse. Where only one turn around/denial/exit point is possible, the rejection should occur following the ID check area.
- Provide a gatehouse for each ECF/ACP. The gatehouse serves as the central control center for the ECF/ACP by providing shelter for security personnel and controls for the vehicle barriers, traffic control devices, access controls, lighting, and surveillance equipment. Where low numbers of visitors

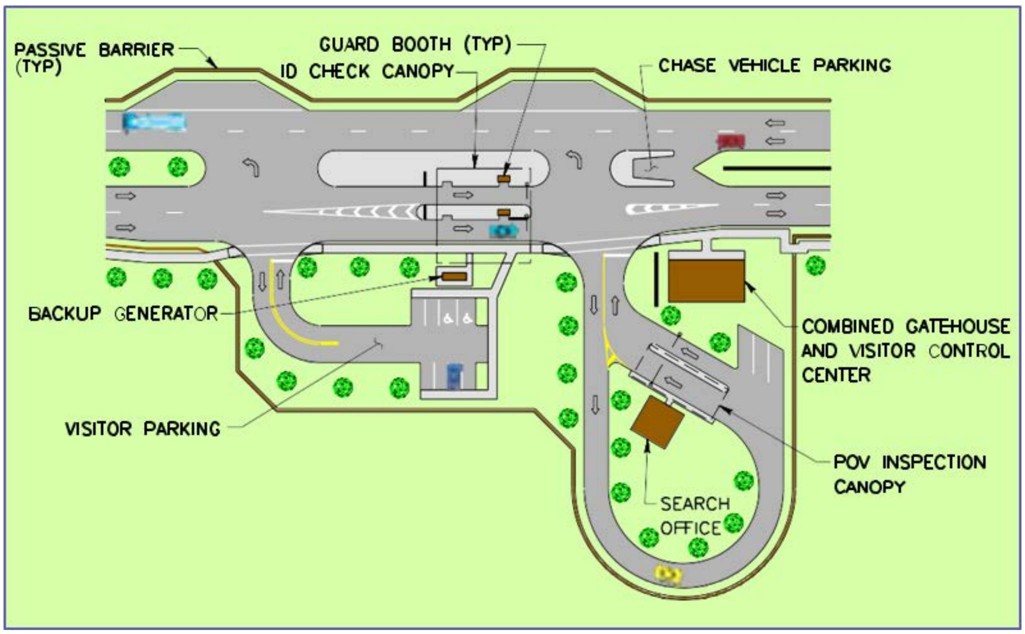
are expected, the visitor center may be combined with the gatehouse to reduce the ECF/ACP footprint and maximize manpower; however, there must be a ballistic rated separation between the guards and the portion of the building accessible to the public. The gatehouse can be centrally located on a median, or may be positioned to the side of the ECF/ACP. See Figure 5-1 for gatehouse location options.

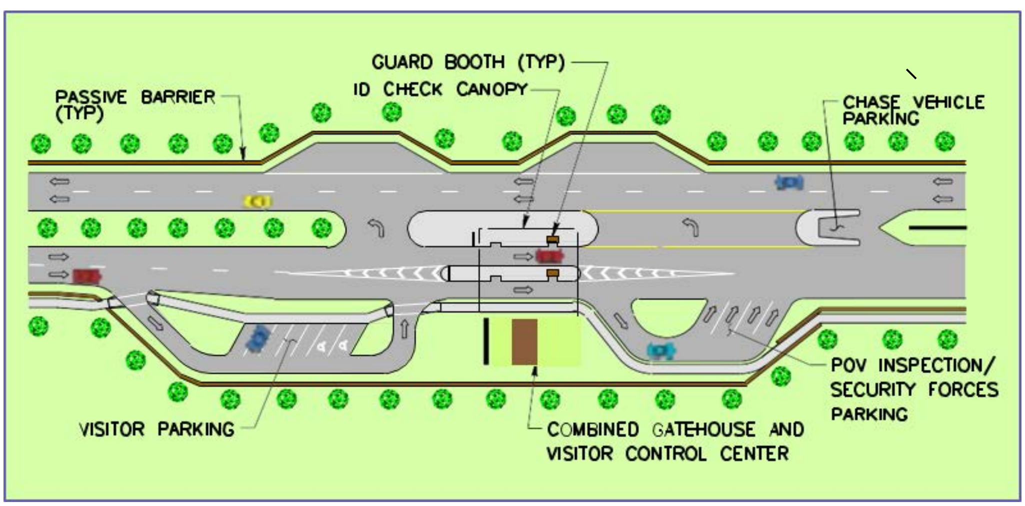
- Provide a vehicle search area(s) that is located with the access control zone, easily accessible from the ID check area, sized in accordance with the search volumes identified in the traffic engineering and safety study and provides an enclosed shelter for vehicle occupants removed from vehicles during search operations.
- Provide pull off alternate vehicle inspect area immediately after the ID check area to accommodate vehicles identified for search or other assistance. This alternate inspection area will not have the same requirements of a dedicated vehicle inspection facility.
- Provide guard booths for each entry lane within the ID check area.
- Where reversible lanes are utilized ensure that all MUTCD/DoD Supplement to MUTCD requirements are met.

Figure 5-1 Gatehouse Location Options









5-5 RESPONSE ZONE REQUIREMENTS AND GUIDELINES.

5-5.1 Layout Guidelines for the Response Zone.

Design the response zone with a sufficient length to provide adequate reaction time, safety time and deployment time in response to the applicable threat. Provide AVBs at the termination of the ECF/ACP to provide the capability to stop threat vehicles from gaining entry to the installation. The necessary length of the response zone and location of the final denial AVBs is based on the provision of adequate response time.

5-5.1.1 Determining Length of Response Zone.

The length of the response zone is calculated based on the velocity of the threat vehicle, the subsequent rate of acceleration, and the required response time. Response time is the time required for complete activation of the AVBs once a threat is detected. This implies the distance required to provide an adequate response time is measured from a starting position and velocity where threat can be assumed detected ,i.e., assessment of the threat, has already occurred. The location of the threat vehicle when first detected is based on the threat scenario and site plan. The rate of acceleration is dependent on the type of vehicle. Generally, the acceleration capabilities of threat vehicles are known.

The length of the response zone can be minimized, or the available response time maximized, by using speed management to control the velocity of vehicles as they travel through the approach and response zones. Also, by reducing the response zone length, there is reduction in the site area required for the ECF/ACP. Implementation of speed management measures are most effective when installed within the response zone because these measures are effective against all four threat scenarios indicated below.

5-5.1.2 Threat Scenarios.

The length of the response zone determines the placement of the final denial AVBs. AVBs must be installed on all inbound and outbound lanes in the response zone to defeat all threat scenarios.

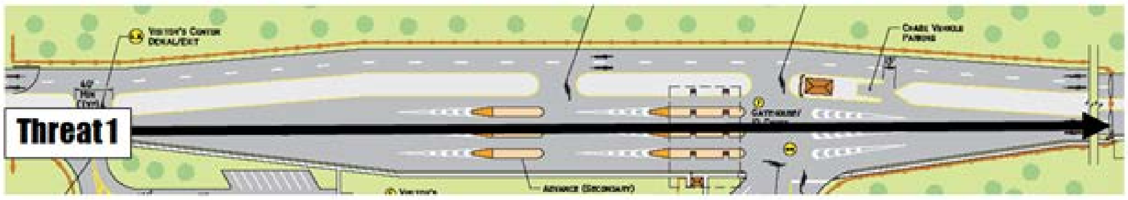
Consider all scenarios when designing the Response Zone, determine which scenario governs, and verify the adequacy of the response time and AVB selected. ECFs/ACPs must be designed to defeat the following four threat scenarios as a minimum.

5-5.1.2.1 Vehicle Threat Scenario #1.

Vehicle Threat Scenario #1 - Threat vehicle enters the ECF/ACP in the inbound or outbound lane(s) at the maximum speed attainable at the ECF/ACP entrance and then immediately accelerates at its maximum acceleration rate through the ECF/ACP. This scenario often includes either or both wrong way detection or over speed detection used to alert the ECF/ACP personnel of the threat and establishes the point within the

ECF/ACP in which the threat is detected. See Figure 5-2 for a graphic representation of this threat scenario.

Figure 5-2 Vehicle Threat Scenario #1 Diagram

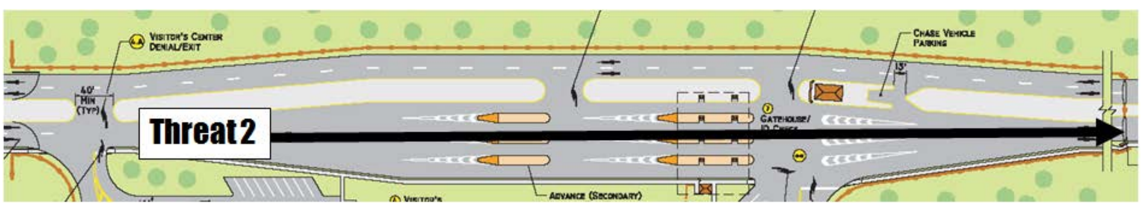


5-5.1.2.2 **Vehicle Threat Scenario #2.**

Vehicle Threat Scenario #2 - Threat vehicle enters the ECF/ACP in the inbound or outbound lane(s) at or under the posted speed limit and then, later at some point farther in the approach zone, accelerates at its maximum acceleration rate through the rest of the ECF/ACP. This scenario often includes overspeed detection to establish the starting point and the initial velocity of the threat vehicle. See Figure 5-3 for a graphic representation of this threat scenario.

Note that ‘some point’ must be interpreted as being the worst case threat delay time from point of detection to Active Vehicle Barrier (AVB) location(s) in the response zone. If multiple zones of overspeed detection are utilized the analysis will include the worst case situations for each overspeed zone.

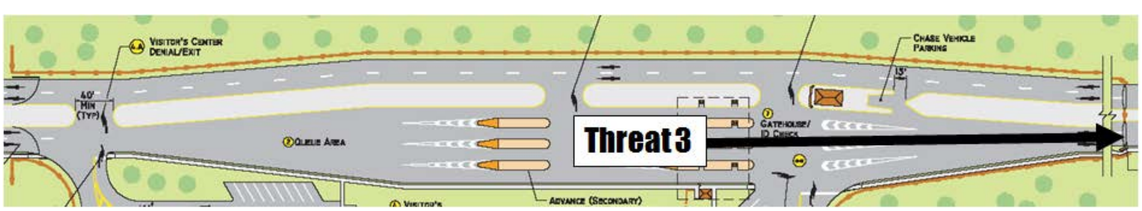
Figure 5-3 Vehicle Threat Scenario #2 Diagram



5-5.1.2.3 **Vehicle Threat Scenario #3**

Vehicle Threat Scenario #3 - Threat vehicle attempts to covertly enter the ECF/ACP, but is detected and denied entry by guards at the ID Check Area. Vehicle driver then defies guards and accelerates at its maximum acceleration rate through the rest of the ECF/ACP. The initial velocity of this threat must be 25 mph. See Figure 5-4 for a graphic representation of this threat scenario.

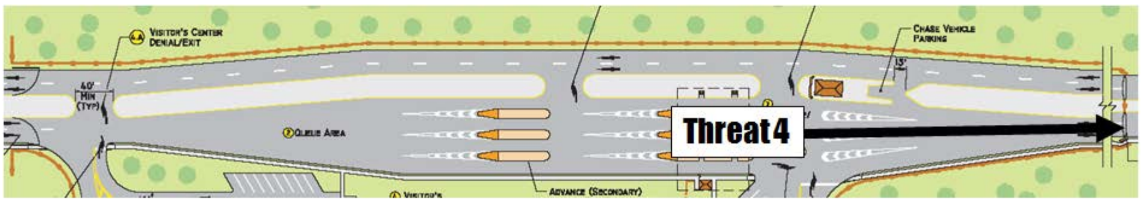
Figure 5-4 Vehicle Threat Scenario #3 Diagram



5-5.1.2.4 **Vehicle Threat Scenario #4.**

Vehicle Threat Scenario #4 - Similar to Threat Scenario 3 above, except the driver of the denied vehicle drives toward the turn around/denial/exit point or search area at the ECF/ACP speed limit of 10mph as if complying with guard instructions, but then fails to turn and instead accelerates through the rest of the ECF/ACP. The initial velocity of this threat is no less than 10 mph. See Figure 5-5 for a graphic representation of this threat scenario.

Figure 5-5 Vehicle Threat Scenario #4 Diagram



5-5.1.2.5 **Additional Threat Considerations.**

Additional threat scenarios and initial velocity conditions may be considered and analyzed if supported by a local vulnerability or threat assessment and/or variations in facilities located in atypical ECF/ACP configurations. Consult service subject matter experts for more guidance.

5-5.1.3 **Threat Vehicle Characteristics.**

- **Acceleration Rate -** Threat calculations must utilize the acceleration rate of 11.3 feet per second squared (feet/second/second - ft/s^2) ($3.4\ m/s^2$) when determining delay
  - Where applicable the lower acceleration rates associated with trucks/commercial vehicles can be utilized for calculating the required stopping capability of passive and active vehicle barrier systems; however, lower acceleration rates are not relevant to delay calculations.
- **Deceleration Rate -** Threat calculations must utilize a deceleration rate of 24.1 feet per second squared (feet/second/second - ft/s^2) ($7.3\ m/s^2$) when calculating delay.
- **Friction Factors -** Threat calculations must utilize a friction factor of 1.0. Calculations performed for threat purposes differ significantly from calculations typically performed for consideration of driver comfort. Lower friction factors associated with highway safety must not be used for threat calculations.
- **Maximum Velocity -** The maximum velocity of the 4,630 pounds (2100 kg) baseline threat vehicle utilized for delay calculations must be 130 mph (210

kph). This parameter must be utilized for calculation of delay unless a 'local' threat assessment and/or policy identifies a vehicle that is capable of a greater velocity. The addition of larger vehicles or trucks through mandatory incorporation of threats identified in 'local' threat assessments and/or policies must not be considered justification for use of a reduced velocity in delay calculations.

  - The maximum velocity of specific threat vehicles (where local threat analysis and/or policy identifies a specific vehicle) must be obtained from manufacturer specifications.

  - The maximum velocity of other vehicle classes (where a type of vehicle e.g. 'pickup truck' is identified in local threat analysis and/or policy) must be calculated through acquisition of information on at least five vehicles within the type and averaging the top speed of the lot. If significant outliers (atypical vehicles with unusual characteristics) exist they may be removed from the sample set.

- **Vehicle Mass -** The baseline threat vehicle must be a large passenger car as defined in ASTM F2656. The weight of the baseline threat vehicle is 4,630 pounds (2100 kg) and the mass is 143.8 slugs (2100 kg). This mass must be utilized for kinetic energy calculations unless a vehicle of larger mass is included due to the aforementioned incorporation of local threat analysis and/or policy.

  - **Modification of baseline vehicle threat -** The baseline threat vehicle must be adjusted in accordance with all applicable 'local' threat analysis and policy. All relevant 'local' threat analyses and policy must be reviewed and incorporated. Classification of such documentation is not justification for exclusion of baseline threat vehicle for barrier impact energy and/or delay calculations. Both the baseline vehicle and the additional vehicle(s) (identified by 'local' threat assessment and/or policy) must be analyzed and the more stringent of results must be applied.

5-5.1.4 **Threat Delay Calculation.**

Key considerations in evaluating threats include:

- The minimum acceleration rate of a threat vehicle must be no less than 11.3 ft/s^2 (3.4 m/s^2) indicated above . Initial velocities for Threats 1 and 2 will be established based on geometric constraints. The maximum velocity for unconstrained conditions (no geometric curvature or features that will limit maximum speed must be 130 mph (210 kph). 130 mph (210 kph) is also the maximum velocity for threat calculations unless a higher speed is identified by local threat assessment and/or service policy.

- On declines, the acceleration must be adjusted by the angle of the decline. An adjustment on inclines will be considered if response zone requirements cannot be satisfied.
- The threat calculations will not consider the use of speed humps, speed tables, removable bollards, etc., as a factor in reducing the velocity unless validated through an traffic engineering and safety study by the responsible service in coordination with SDDCTEA or as detailed in SDDCTEA Pamphlet 55-15.

The following equations are the primary equations used for calculating response time for an ECF/ACP. Additional instructions can be found in the UFC 4-022-02.

Formulas for Calculating Velocity

For Tangents: $V_F = \sqrt{V_O^2 + 2aL}$ For Curves: $V_S = \sqrt{(f + e)gR}$

Formulas for Calculating Time

For Tangents: $T = \dfrac{2L}{V_F + V_O}$ For Curves: $T = \dfrac{L}{V_S}$

V_F = Final Velocity
V_O= Initial Velocity
a = Acceleration
L = Distance
T= Time

V_S= Skidding Velocity
f = Coefficient of friction
e= Super elevation (%)
g= gravity coefficient (9.8)
R= radius of horizontal curvature

5-5.1.5 **Response Time.**

The response time begins the instant the threat is detected. The response time includes guard reaction time, time for barrier safety system, and barrier deployment time. The response time minimums are as follows:

- Guard reaction time must be no less than 3 seconds for Threat Scenarios #1 through #3 and a minimum of 1 second for Threat Scenario #4 based on the emergency operation controls being in the immediate vicinity of the guard personnel.
- Safety and signal sequence time must be no less than 4 seconds. Barriers collocated at neighboring intersections may require additional time as prescribed by SDDCTEA Pamphlet 55-15. Note: The four seconds is specific to the Signs and Signals safety scheme. Other approved SDDCTEA safety systems as well as other parameters (posted speed limit, barriers at an intersection, road geometry) may require a different time.
- Threat calculations must not assume less than 2 seconds for AVB deployment.

- The time for security personnel to react to a threat and initiate the response is dependent on the standard operating procedures and location of emergency operation controls.
- Barriers located on roadways with a posted speed limit in excess of 30mph may require additional safety time.
- The time assumed for the reaction of personnel must be determined based on the specific conditions and layout of the ECF/ACP; however, it must not be assumed to be less than 3 seconds as noted above. When evaluating the threat scenario associated with rejection, the reaction time for personnel may be reduced to 1 second only where the guard personnel have been notified of a specific action to be taken by an identified vehicle and guard personnel have had time to prepare for activation of AVBs.

If possible, maximize the response time by lengthening the Response Zone, which will increase the distance between the Access Control Zone and the final denial AVBs. In certain instances, there may not be enough space available to provide an acceptable response time. In those cases, it may be necessary to utilize a different barrier deployment and/or speed management strategy that must be approved by the appropriate service representative with consultation from SDDCTEA.

5-5.2 **Passive Vehicle Barriers.**

Provide passive vehicle barriers that tie into the access control zone passive vehicle barriers as well as the final denial AVBs presenting a fully contained ECF/ACP. The DoD anti-ram vehicle barrier list contains many tested commercial passive barriers systems. This list is available on the PDC Web site: https://pdc.usace.army.mil . Additional guidance is detailed in UFC 4-022-02.

5-5.3 **Active Vehicle Barriers.**

ECFs/ACPs must be provided with active vehicle barriers (AVB) to enable the ECF/ACP to be closed (fully contained) and to prevent a threat vehicle from breaching the security. Recommend either net or wedge-style AVBs for each lane as required. Drop arm/beams and bollards are not recommended as AVBs in an Emergency Fast Operation (EFO) system. Tire shredder and claw type systems are prohibited as AVBs. These devices are not capable of stopping a potential threat vehicle with any certainty or specified distance. At ECFs/ACPs, AVBs must be capable of deploying in less than 2 seconds or less. Additional considerations:

- The non-deployed AVB must not result in unsafe roadway obstruction.
- AVBs across multiple lanes (intersections or alone) must consider vehicle presence detection system vulnerabilities (i.e., a vehicle presence detection system in one lane will suppress entire system).
- Wedges are desirable for AVBs at intersections since they operate independently.

- Use separate AVBs on the inbound and outbound lanes, when there is more than one lane per given direction of travel.

5-5.3.1 **Barrier Certification.**

Selected active vehicle barriers (AVBs) must be included on the list of DoD Certified Anti-Ram Vehicle Barriers maintained by the U.S. Army Corps of Engineers (USACE) Protective Design Center (PDC). The DoD certified anti-ram vehicle barrier lists are available on the PDC Web site: https://pdc.usace.army.mil . Additional guidance is detailed in UFC 4-022-02.

5-5.4 **Design and Safety Considerations.**

The design and operation of the ECF/ACP must include provisions to protect innocent users of the ECF/ACP from operation of the AVB whether deployment is accidental, during a test, or during an actual response to a threat. AVBs must be programmed with the required response time necessary to allow the sequencing of the AVB safety system to warn motorists of the activation, and to allow non-threat vehicles within the vicinity of the AVBs to safety traverse or stop before the AVBs prior to their deployment.

AVBs must be designed, implemented, and operated in accordance with UFC 4-022-02, UFGS 34 71 13.19 *Active Vehicle Barriers,* and UFGS 34 41 26.00 10 *Access Control Point Control System.* AVB safety requirements include proper signage, signals and delineation as well as providing adequate sequencing and timing as defined in SDDCTEA Pamphlet 55-15. Specific safety elements include:

- Delineation of AVBs
- Approved Safety Schemes
- Vehicle Presence Detection

5-5.4.1 **Delineation of AVBs.**

AVBs must be delineated as prescribed in Department of Defense (DoD) Supplement To The National Manual on Uniform Traffic Control Devices (MUTCD) and detailed in UFGS-34 71 13.19 *Active Vehicle Barriers*. This includes:

- Red and white retroreflective markings/material that is visible on both sides of the barrier when deployed.
- Supplemental barrier lights for AVBs with limited deployable surfaces.
- Use of in-roadway lights where the previous alternatives are not suitable/feasible or additional delineation is warranted.

5-5.4.2 **Recommended Safety Scheme.**

A SDDCTEA Pamphlet 55-15 recommended safety scheme must be implemented. Deviations from these safety schemes must be approved by the appropriate service representative with consultation from SDDCTEA. The recommended safety schemes are:

- Conventional AVB Traffic and Safety Control System
- AVB System Collocated at an Intersection
- AVB System Staggered at an Intersection
- High Efficiency Presence Detection System
- Stop Control Safety Scheme
- Barrier Normally Closed/Platooning Safety Scheme
- Other systems approved by SDDCTEA that provide an equivalent level of safety

Refer to SDDCTEA Pamphlet 55-15 for additional guidance, updates, and example layouts for each of safety schemes.

5-5.4.2.1 **Conventional AVB Traffic and Safety Control System.**

Proper signing, signaling, and delineation are required on the approach to the AVBs for the inbound and outbound lanes. Refer to SDDCTEA Pamphlet 55-15 for additional guidance, updates, and example layout with appropriate signs and signals.

5-5.4.2.2 **AVB System Collocated at an Intersection.**

If necessary, AVBs should be collocated to downstream intersections if the inbound traffic queue from the intersection extends through the proposed AVB location or the proposed AVB location is too close to the intersection for outbound traffic to stop safely after traversing the intersection When an AVB system is collocated at an intersection, the intersection must be signalized on all approaches and should operate a normal phasing sequence unless preempted by barrier deployment.. Refer to SDDCTEA Pamphlet 55-15 for additional guidance, updates, and example layout with appropriate signs and signals.

5-5.4.2.3 **AVB System Staggered at an Intersection.**

An alternative AVB system can be incorporated at an intersection where the additional time required for an outbound vehicle to clear the intersection cannot be met. To eliminate the additional clearance time required, outbound AVB(s) can be moved a minimum of 200 feet (61 m) away from the intersection towards the identification check area. Both the inbound and outbound AVB(s) locations must meet the minimum response time of 9 seconds. When utilizing this strategy, the outbound threat will typically govern the design of the ECF. Designers should implement additional speed management strategies and technologies on the outbound lane(s) to mitigate a wrong way threat. Refer to SDDCTEA Pamphlet 55-15 for additional guidance, updates, and example layout with appropriate signs and signals.

5-5.4.2.4 **High Efficiency Presence Detection System.**

The high efficiency presence detection scheme is a modified version of vehicle presence detection system that is no longer an option. The system uses a conventional traffic signal with detection to improve traffic flow across the AVBs.

If there are no vehicles detected, the traffic arm is down and the traffic signal is red. When a vehicle approaches, it is detected, the traffic arm rises and the signal turns green allowing the vehicle to continue. If more vehicles are following, the signal remains green, the traffic arm stays up and vehicles continue on. Once the last vehicle exits and a new vehicle is not detected after a few seconds, the traffic signal turns yellow then red and the traffic arm lowers. The high efficiency presence detection system can also operate in a normally closed configuration. The operation is similar to the prior description, except the active vehicle barrier will open prior the traffic arm opening and the active vehicle barrier will close after the traffic arm closed. Refer to SDDCTEA Pamphlet 55-15 for additional guidance, updates, and example layout with appropriate signs and signals.

5-5.4.2.5 **Stop Control Safety Scheme.**

The Stop Control Scheme is an alternate AVB strategy to signalization. It utilizes stop signs instead of signalization at AVBs to reduce the required response time and distance. By utilizing stop signs, motorists are forced to stop at the barriers eliminating the required safety time with signalization (yellow and red time). This system is useful where there is limited real estate and vehicle volumes are below 800 veh/hr/ln. Refer to SDDCTEA Pamphlet 55-15 for additional guidance, updates, and example layout with appropriate signs and signals.

5-5.4.2.6 **Barrier Normally Closed/Platooning.**

Barrier Normally Closed/Platooning Safety System requires that two sets of barriers be installed to create an “entrapment area” in each inbound and outbound lane. One of the two barriers in each entrapment area must be closed to prevent unauthorized entry. This system can be utilized when real estate for the ECF is limited and vehicle volumes are low. The distance between the two sets of barriers must be large enough to accommodate the largest vehicle served by the ECF/ACP, or it could be made larger to provide space for platooning multiple vehicles to increase vehicular throughput. Refer to SDDCTEA Pamphlet 55-15 for additional guidance, updates, and example layout with appropriate signs and signals.

5-5.4.2.7 **Exit Only.**

The Exit Only safety scheme is used at locations that will operate with the traffic leaving the installation. The system operates in the same manner as described under High Efficiency Presence Detection System for normally closed operation.

5-5.4.3 **Vehicle Safety Detection.**

For all options (midblock or collocated at intersections) install AVB vehicle safety detection systems immediately before and after the AVBs to prevent deployment of barriers while a vehicle is crossing. The vehicle safety detection system must be able to detect all roadway vehicles including high clearance trucks, motorcycles, and bicycles. Refer to SDDCTEA Pamphlet 55-15 for additional guidance and updates. The vehicle safety detection system must be installed in conformance with UFGS 34 41 26.00 10 *Access Control Point Control System*. The vehicle safety detection system for each lane must be tied to the Emergency Fast Operation (EFO) sequence; however, they must be capable of operating independently of one another. During EFO activation, a barrier must not initially activate if the vehicle safety detection system indicates the presence of a vehicle.

To avoid tailgating to defeat the barriers, it may be necessary to deploy the barrier as soon as that first vehicle clears the vehicle safety detection system, regardless of whether a second vehicle enters into the vehicle safety detection system. This may add a requirement for additional equipment and programing. Refer to Traffic Detector Handbook (FHWA-HRT-06-139) for additional guidance on vehicle safety detection systems.

5-5.5 **Control Requirements.**

AVB controls must conform to UFGS 34 41 26.00 10 *Access Control Point Control System*.

Locate the main, multi-function control panel for the AVB systems in the Command and Control (Gatehouse) location.

- The control panel must require a key for normal operation and control all lanes.
- Provide a single separate emergency activation control on the panel to initiate the EFO mode of the AVBs in all entrance and exit lanes.
- A protected, emergency activation control for the AVBs must be located, as a minimum, at each guard facility or post (channelization island, gatehouse, ID Check Island and guard booth, search area(s) and overwatch position). Controls located in the overwatch position must be capable of being secured, deactivated or removed when the position is not manned.

5-5.6 **Detection Systems.**

Due to the dangers associated with EFO/emergency activation of AVBs and the potential for false alarms, in no case will emergency activation of the AVBs be triggered through automatic detection and response. All AVB deployments must be based on the actions of the security personnel manning the ECF/ACP (such as push button or hand operated switches).

Detection devices such as video, radar, Light Detection and Ranging (LIDAR) and inductive loops may be utilized for the following purpose:

- Wrong-Way Detection - Wrong-way sensors can be deployed in all outbound lanes at the ECF/ACP entrance and after each turn-around to monitor for illegal outbound entry. Wrong-way detectors are allowed to be several different types per UFGS 34 41 26.00 10.
- Overspeed Detection - Detection devices in the approach zone can be used to monitor vehicles approaching at a high rate of speed. In many cases, the system can be developed to distinguish between cars and trucks. Point overspeed monitors speed at a particular location, while, continuous overspeed detection provides overspeed for the entire approach zone and access control zone. Continuous overspeed detection may be more suitable for addressing the various threat scenarios. Overspeed detectors are allowed to be several different types per UFGS 34 41 26.00 10; however, local weather conditions and topology requirements must be taken into account.
- Vehicle Presence Detection and AVB Safety - Vehicle presence and AVB safety sensors must be deployed at all AVBs to detect a vehicle immediately over the barrier. Where practical and when the vehicle presence safety scheme is utilized, redundancy must be integrated into the design by deploying multiple technologies such as loops and break beams. This will provide protection should one technology fail and will increase the likelihood that motorcycles and bicycles are detected.
- Traffic Flow Monitoring - Detection devices can be used to monitor queuing traffic at an ECF/ACP or on a neighboring roadway.

Additional guidance on detection devices is contained in SDDCTEA Pamphlet 55-15.

5-6 VEHICLE INSPECTION CONSIDERATIONS.

All ECFs/ACPs must have a process in place to conduct select inspections. Vehicle inspections are dependent on local directives and RAM, but generally take two forms:

- Random inspection
- Select inspection based on guard concern or random anti-terrorism measures

Once vehicles have been inspected, they should not have to pass through the ID check area again. The inspection area exit lane may bypass the ID check area and merge with other inbound traffic in the response zone.

5-6.1 Location of Inspection Area.

Since vehicle content inspection can be time consuming, it is important to allow the inspection to occur without impeding the flow of traffic through the ECF/ACP. To the extent possible, the inspection area should not be immediately adjacent to inbound traffic lanes. While this separation is primarily for safety reasons, some screening of the inspection procedure from public view is also desired. Appropriate obscuration features must be in place to accomplish this. Also, the inspection area will be equipped with an inspection office that is ABA compliant. At ECFs/ACPs with a visitor's center, direct access from the visitor's center to the inspection area should be provided if practical.

The inspection area can occur prior or adjacent to, or after the ID check area in the access control zone.

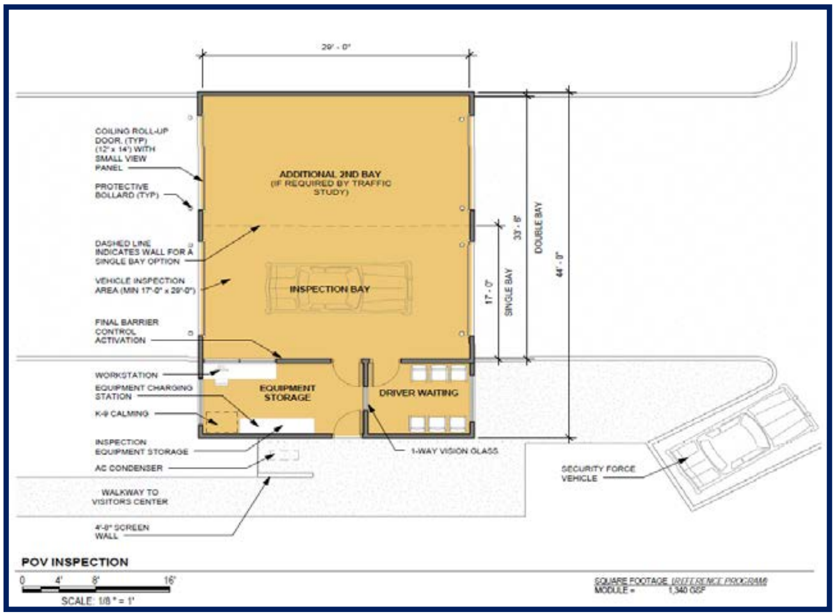
- Prior to ID Check - For advance random inspections, especially when there are numerous lanes, it is beneficial to provide advance islands for the guards to stand on as they select and direct motorists into random inspection areas and direct suspect vehicles to the inspection area. A pull-off/alternate inspection area will be provided if the typical inspection area layout cannot be provided. The pull-off area provides an area just after the ID check area where alternate inspections can be conducted, ID discrepancies addressed, or driver's questions answered. When required, include a pull-off area on the exit lane where vehicle inspections can be conducted.
- After ID Check - When inspections take place after the ID check area, the access to the inspection area needs to be as close as geometrically possible and must be within the line of sight of the guard.
- To facilitate both random and select/RAM inspections, access to the inspection area must be provided both before and after the ID check location.

If possible, design inspection facilities adjacent to the ID check area to allow bi-directional access. This permits advance random inspections as well as post ID inspections and maximizes operational flexibility.

5-6.2 Inspection Shelters.

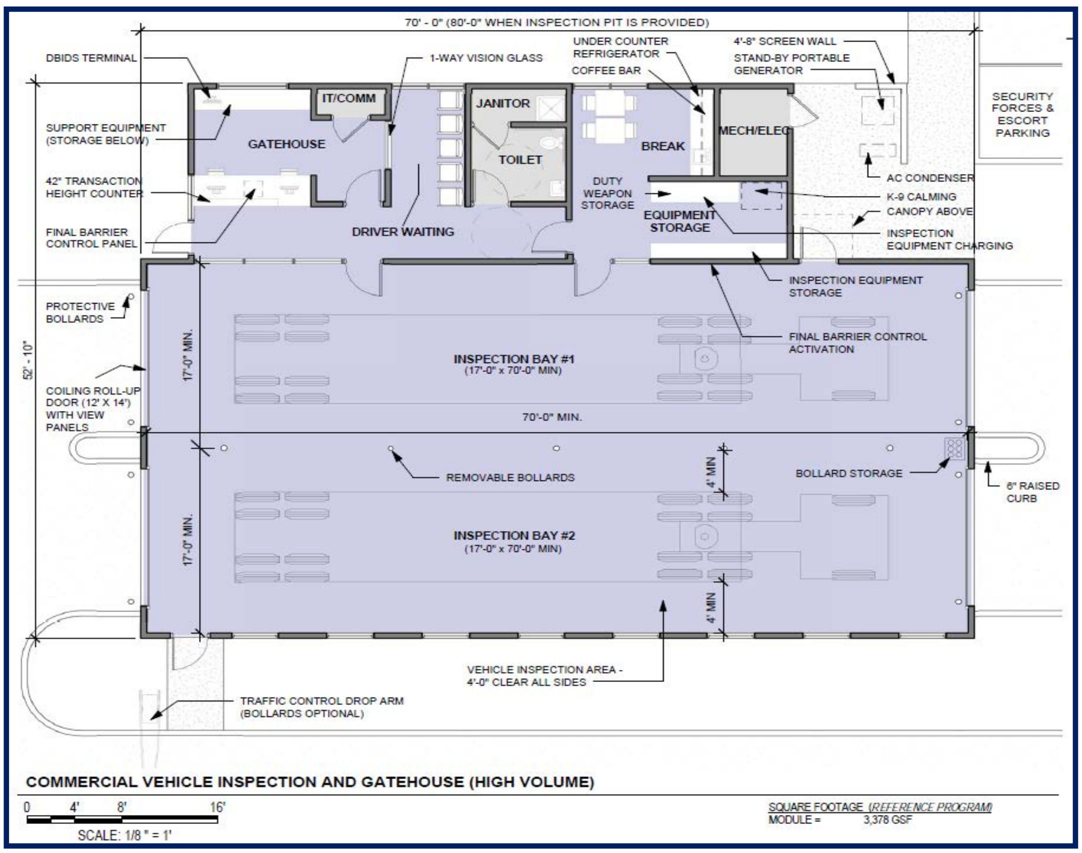
When required, include a covered inspection area. Provide sufficient seating for the number of expected occupants who will be undergoing or queuing up to undergo vehicle inspections. A small waiting area should be provided to protect vehicle occupants from inclement weather and moving vehicles. Figure 5-6 shows an example plan for a POV inspection area and shelter. For larger (commercial and large vehicle) ECFs/ACPs, an inspection office combined with a gatehouse may be considered. Figure 5-7 shows an example of a combined commercial vehicle inspection and inspection office.

Figure 5-6 Inspection Shelter and Inspection Office Example - POV



Source: Air Force Civil Engineer Center

Figure 5-7 Inspection Shelter and Inspection Office Example - Commercial



Source: Air Force Civil Engineer Center

5-6.3 Location and Support for Inspection Equipment.

Most vehicle inspections are conducted with manual procedures using tools or hand-held detectors. Provide space required to store this equipment and to conduct battery-charging operations. Other types of inspection equipment are of a more permanent nature, and require planning for their deployment.

5-7 FACILITY DESIGN GUIDELINES.

This section outlines design guidelines for the various facilities associated with an ECF/ACP. Facilities (visitor control center, gatehouse, guard booths, overwatch) at the ECF/ACP should provide a comfortable, safe working environment for security personnel. Consult with service guidelines for specific facility requirements. The basic considerations in determining the size of the facilities are:

- Number of personnel assigned during normal operations
- Usage
- Space required for electronic, electrical, and mechanical equipment, and counter or work space

5-7.1 Gatehouse, Guard Booth, and Overwatch.

Since gatehouse, guard booths and overwatch facilities are located in the immediate vicinity of the explosive threats they are trying to prevent from entering the installation; it is impractical and impossible to provide protection from the possible effects of an explosive device. In addition, the occupancy of the gatehouse, guard booths, and overwatch facilities are typically below the threshold for the requirements of UFC 4-010-01 *DOD Minimum Antiterrorism Standards for Buildings*. Therefore, typically no protective design elements are required for the gatehouse, guard booths and overwatch facilities to mitigate the effects of an explosive device. However, in some instances Service Secretary and/or Agency Head and/or Geographic Combatant Commander policy requires one or more of these building types to be hardened against a blast of a specific charge weight.

5-7.2 Visitor Control Center.

The visitor control center (VCC) occupancy may exceed the threshold for the requirements of UFC 04-010-01 and protective elements may be required.

5-7.3 Personnel Safety.

Where facilities are located near the roadway, provide a minimum platform width of 3 feet (0.9m) behind the curb. This width is the minimum necessary for security personnel to stand post adjacent to the facility, therefore additional platform width is recommended to provide additional safety through increased lateral clearance and space for security personnel carrying weapons or equipment.

5-7.4 General Requirements.

This section outlines the requirements that are common to all guard facilities.

5-7.4.1 Construction.

Design the facilities as required in UFC 1-200-01. Provide corrosion resistant materials for the guard facilities, especially pre-manufactured facilities, due to the perils of environmental exposure commonly encountered at some installations and the high visibility of these structures.

5-7.4.2 Physical Security and Protective Design.

Determine the required physical security design features in accordance with installation requirements and UFC 4-020-01*, Security Engineering Facilities Planning Manual.*

Threats that may commonly be considered include forced entry and ballistic attack. Provide ballistic protection equivalent to Underwriters Laboratories (UL) 752 Level III for all guard facilities as a minimum. Consult with COCOM/Service policy if protection from a higher threat is required. Provide this protection in the design and construction of the exterior envelope including windows, doors, walls, and other equipment. Table 5-1 provides examples of the wall thickness required for commonly encountered materials adequate for ballistic resistance against UL 752 Level III. Table 5-2 provides examples of the wall thickness required for commonly encountered materials adequate for ballistic resistance against UL 752 Level V. Additional information and guidance can be found in UFC 4-023-07, *Design to Resist Direct Fire Weapons.*

Table 5-1 Thickness of Common Materials for Resistance Against UL 752 Level III

UL 752 Level III (.44 Mag)	
Wall Material	**Wall Thickness**
Concrete Masonry (Fully Grouted)	4 in (102 mm)*
Brick	4 in (102 mm)*
Reinforced Concrete (3000 psi)	2.5 in (63.5 mm)
Steel Plate (mild)	5/16 in (8 mm)
Steel Plate (armor)	1/4 in (6 mm)

Table 5-2 Thickness of Common Materials for Resistance Against UL 753 Level V

UL 752 Level V (7.62 mm)	
Wall Material	**Wall Thickness**
Concrete Masonry (Fully Grouted)	6 in (152 mm)*
Brick	6 in (152 mm)*
Reinforced Concrete (3000 psi)	4 in (102 mm)
Steel Plate (mild)	9/16 in (14.3 mm)
Steel Plate (armor)	7/16 in (11.1 mm)

Some mechanical equipment installed in the exterior envelope of a guard facility may not be capable of providing sufficient ballistic resistance. Therefore, locate the equipment to minimize potential exposure to projectile penetration or provide ballistic hardened equipment and/or louvers. As an example, it may be prudent to install the heating, ventilating, and air conditioning (HVAC) equipment on the roof of the gatehouse or guard booth to reduce penetrations in the walls. Provide roof ballistic protection only where there are sightlines to the roof.

5-7.4.2.1 **Passive Vehicle Barrier Protection.**

Provide passive vehicle barrier protection for facilities located less than 3 feet (0.9 m) behind the face of curb when adjacent to a curbed roadway section.

Provide passive vehicle barrier protection for facilities located less than 7 feet (2.1 m) from the traveled lane when adjacent to a shouldered roadway section.

5-7.5 **Common Facility Requirements.**

5-7.5.1 **Windows and Glazing.**

Provide translucent or figured glazing per UFC 4-023-07. Glazing must limit viewing into the facility to the extent possible without restricting views out of the facility during day and night operations. The intent is to reduce the visible signature of security personnel, as seen from the outside of the gatehouse, without reducing the ability of security personnel to see out. The Illuminating Engineering Society of North America (IESNA) Handbook-10 suggests specular-reflecting, low transmission glazing at a tilted angle can be used in the windows to limit view into the guard facilities from the exterior.

Any windows provided in the overwatch positions must not interfere with the capability to respond to an attack. Therefore, any windows must be capable of being fully opened/removed quickly or have a substantial gun port to enable unobstructed line of fire from the position.

5-7.5.2 **Floors/Walkways.**

The finished floor elevation must be 6 inches (152 mm) or more above grade or the adjacent walkways, unless the facility is located on a raised island. If the facility is on an island, the minimum finished floor elevation will be the elevation of the island. Provide floors and walkways with anti-skid surfaces. Anti-fatigue mats should be provided at all security personnel posts to relieve fatigue and discomfort from standing for long periods of time.

5-7.5.3 **Environmental Control.**

Provide heating and cooling appropriate for personnel, the electronic and electrical systems or fixtures, and the security support equipment. The HVAC requirements must be based on existing service design guidance and installation requirements. Consider protection from chemical or biological agents used during an attack based on the anticipated threats. However, due to the small size of the facility, comprehensive protection is often not feasible. To limit airborne contamination and maximize the time for security personnel to shelter in place to initiate a response, utilize protective gear, and respond to an attack. When required, design of the HVAC system to include the minimum measures outlined in UFC 4-010-01. For guard booths and overwatch positions, provide adequate storage for all CBRN personnel protective equipment.

5-7.5.4 **Interior Lighting.**

Interior lighting must comply with UFC 3-530-01 “Design: Interior and Exterior Lighting and Controls “and with the sustainability requirements. The interior lighting must be diffused lighting and must be provided with dimmer controls to aid with night vision and reduce the ability of those outside the guard facility to see inside. The interior lighting must be connected to the backup power source. As discussed in the IESNA Handbook-10, the illuminance inside the guard facility must be limited to the minimum required for comfortable completion of the expected tasks and functions. As indicated in Figure 29-17 of the IESNA Handbook-10, the recommended average illuminance for the gatehouse is 30 foot-candles (323 lux) on the work plane in the gatehouse. Additional recommendations from the Hanbook-10, include providing well-shielded task luminaires to avoid reflections on monitors and windows. Consider providing magenta filters for interior lighting to lessen the impact of interior lighting on the night vision of security personnel.

5-7.6 **Visitor Control Center.**

Most installations require one visitor control center (VCC). The visitor occupancy number is calculated by dividing the peak hourly visitor demand by the number of processors, then divided by the number of visitors processed per hour. Then add the number of security processing personnel within the building to obtain the number of personnel routinely occupying the VCC. Example: Peak hourly visitor demand of 120 visitors, divided by 2 processors then divided by 12 to represent a 5 min processing time per visitor. This equals 5 visitors. Add the 2 security personnel processing the passes plus 1 security supervisor and the routine occupancy of the visitors center is 8. This calculation is used to determine in the VCC is required to comply with UFC 4-010-01. Where appropriate, future demands and accommodations for installations with special periodic demands will be considered and evaluated based on traffic engineering study. Figures 5-8 and 5-9 shows example plans for a visitor control center. Table 5-3 provides information on the areas/elements that are typical for a visitor center. Consult with the installation/service for specific requirements.

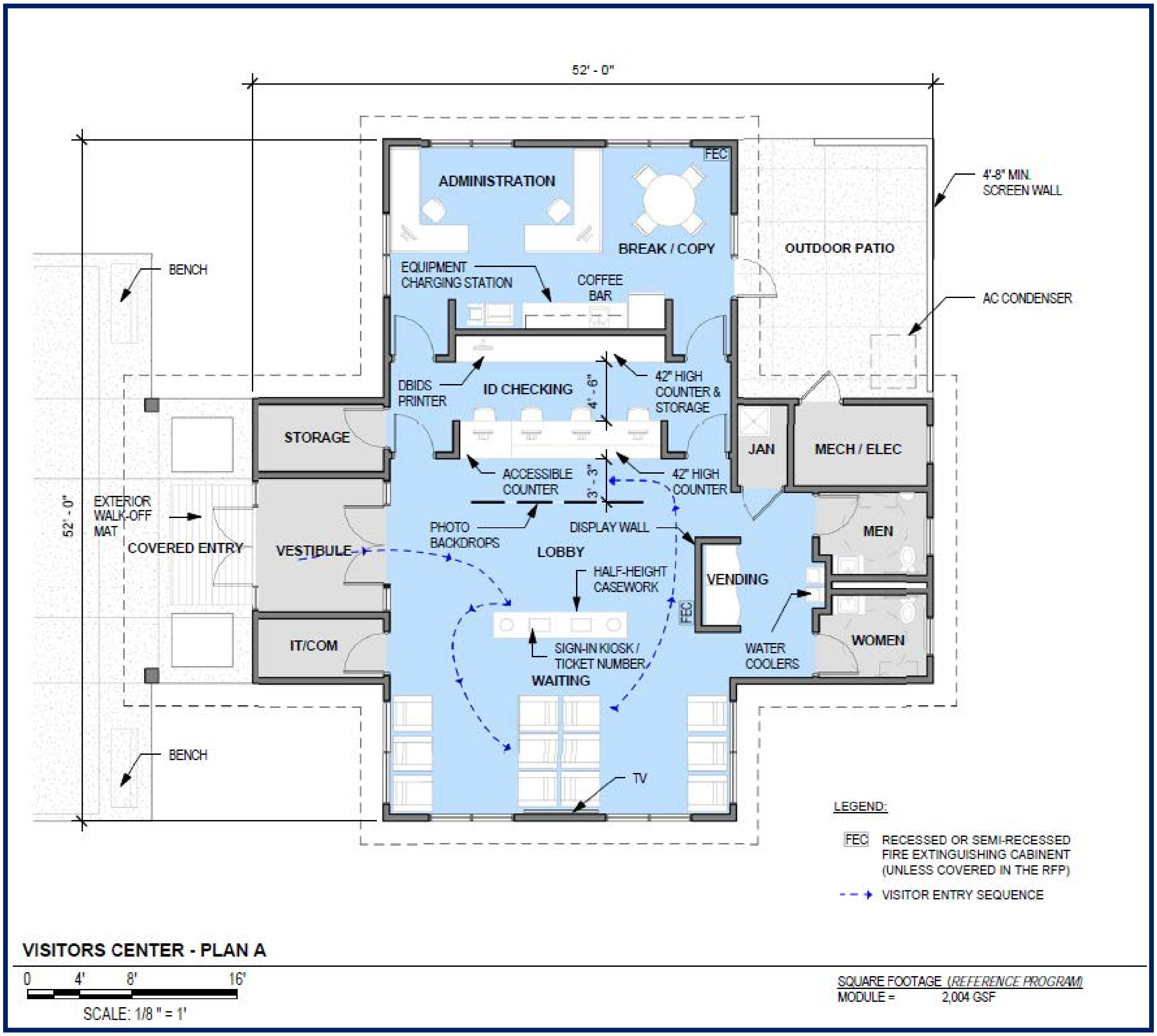
5-7.6.1 **VCC Parking.**

Adequate parking must be provided for all visitors and employees. Parking must be designed in accordance with SDDCTEA Pamphlet 55-15 and must include adequate parking based on typical peak volume. Provide employee parking based on normal operating conditions. . Refer to SDDCTEA Pamphlet 55-15 for additional guidance, updates, and example layouts.

5-7.6.2 **VCC Design and Location Considerations.**

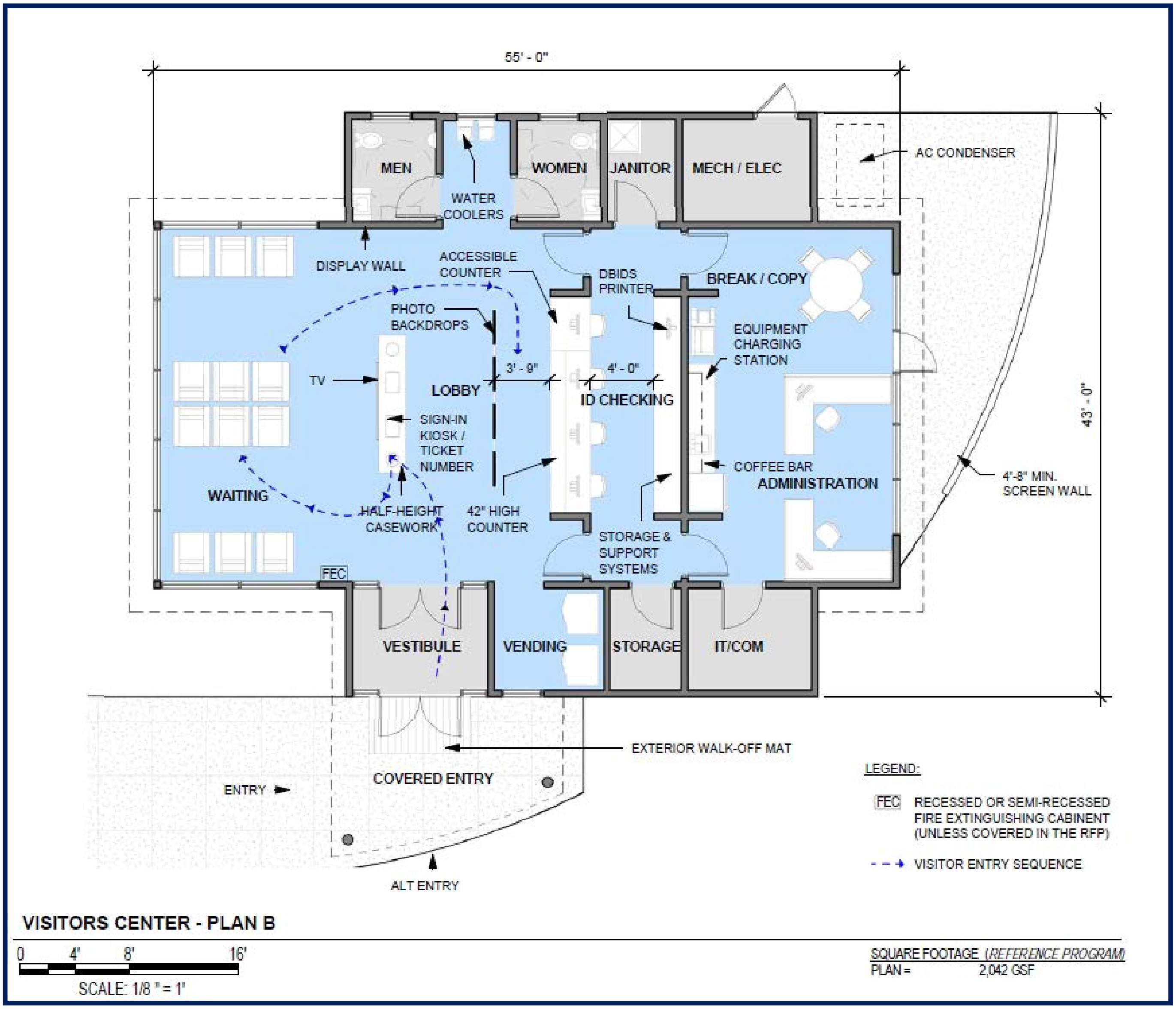
The Visitor Control Center (VCC), if present, must be placed such that the processing of visitors is done prior to entry into the installation. This means that the visitor vetting is conducted prior to inbound traffic (vehicular and pedestrian) reaching the ID check and search area. The building and surrounding site must be highly visible and must be understandable to visitors as a public facility. The building and site must be designed and constructed in accordance with the Architectural Barriers Act including required reserved accessible parking, curb ramps, and sidewalks. The visitor's center may need to meet the required stand-off distance if it is considered an "inhabited" facility (see UFC 4-010-01). If an "inhabited" Visitor's Center cannot meet the required distances, it may need to be hardened per UFC 4-010-01.

Figure 5-8 Model Visitors Center



Source: Air Force Civil Engineer Center

Figure 5-9 Model Visitors Center



Source: Air Force Civil Engineer Center

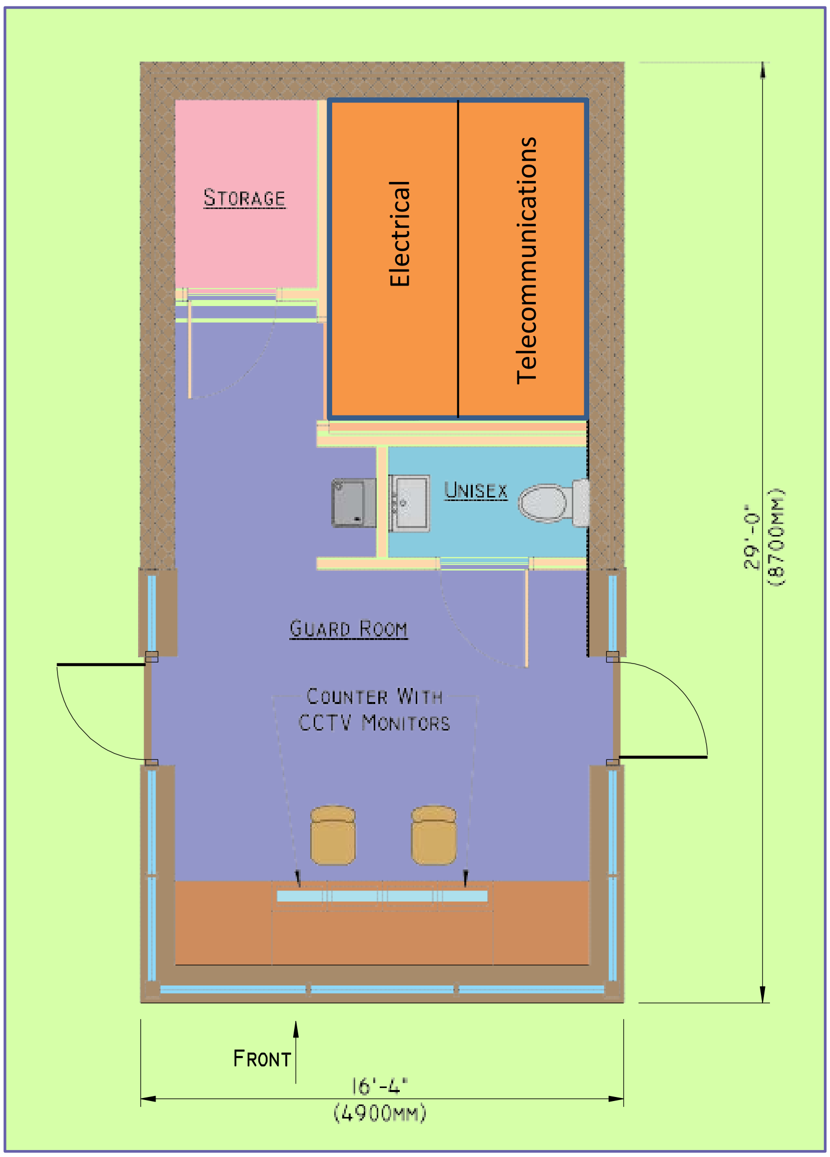
Table 5-3 Visitors Center Elements

Area	Element
Waiting Area	• Provide a comfortable environment with adequate seating for visitors. • Provide a water fountain. • Provide a vestibule with walk-off mat • Provide a designated area for a computer station to be used by visitors to enter registration information. This computer station must network from each processing station to the office area so that registration information can be accessed.
Service Counter	• Include sufficient desktop work surfaces and countertop space for required processing station based on anticipated usage. • Allow three to five minutes per person for processing. • Assume that approximately 12-20 people can be processed each hour on average per processing station. • Include a computer station with networking and Internet access for each processing station. • Provide photo ID capability at each processing station. Install a photo backdrop. • Provide wiring at each processing station for a duress alarm.
Administration Area	• Provide an enclosed office for two workstations and a filing cabinet. • Provide video surveillance equipment for the interior and exterior areas of the Visitors Center. • Provide Internet connectivity, telecommunications, a closed-circuit television system, and a radio battery recharging area.
Break Room	• Locate the break room so that it is out of the direct line of sight of the waiting/seating area. • Provide a refrigerator, microwave, and sink. • Provide seating for four staff.
Rest Rooms	• Provide men’s and women’s restrooms for public and security personnel use per ABA requirements. • Consider accommodations for baby-changing stations in each restroom if appropriate.
Environmental Controls	• Provide heating and cooling appropriate for personnel, the electronic and electrical systems or fixtures, and the security support equipment. The HVAC requirements must be based on existing service design guidance and installation requirements.

5-7.7 Gatehouse.

The gatehouse serves as the control center for the ECF/ACP and provides shelter for security personnel. Every Primary and Secondary ECF/ACP must have a gatehouse designed to support the desired number of security personnel. As the control center, the gatehouse controls the AVB and other ECF/ACP security systems. Do not locate controls for other aspects of an installation security system in the gatehouse or at other facilities associated with an ECF/ACP. Locate the installation security center or emergency control center within the controlled perimeter of the installation. The gatehouse must serve only as the control center for equipment associated with the ECF/ACP only.

Figure 5-10 Model Gatehouse Floor Plan



5-7.7.1 **Design Considerations.**

Base the design of the gatehouse (See Figure 5-10) on the following equipment and functions:

- Communications equipment
- Electronic control panels for all current or anticipated future equipment for automated entry
- Monitor stations for closed circuit television or computer monitors associated with automation controls
- An electrical room for the main electric panel boards
- Storage for traffic control devices, weapons, and personnel equipment including vehicle inspection kits and the storage of personal protective equipment for Chemical, Biological, and Radiological (CBR) exposure
- Computer servers for future AIE systems
- Counter or work space
- A unisex restroom

5-7.7.2 **Location Considerations.**

Typically, a gatehouse is centered in the ECF/ACP between the inbound and outbound lanes and adjacent to the ID check area (see Figures 5-11 and 5-12), or alternatively the gatehouse may be located to the side of the roadway. The gatehouse may also be located after the last turn around/denial/exit point to give security personnel in the gatehouse an overall view of the access control zone operations and vehicles directed to the turn around/denial/exit point or vehicle inspection area. If the gatehouse is located to the side of the roadway or after the last turn around/denial/exit point, consider providing a guard booth in the central island of the access control zone or in between entry lanes to provide easily accessible shelter and protection for the guards operating the ECF/ACP. See Figure 5-1 for additional gatehouse location options.

5-7.7.3 **Parking Considerations.**

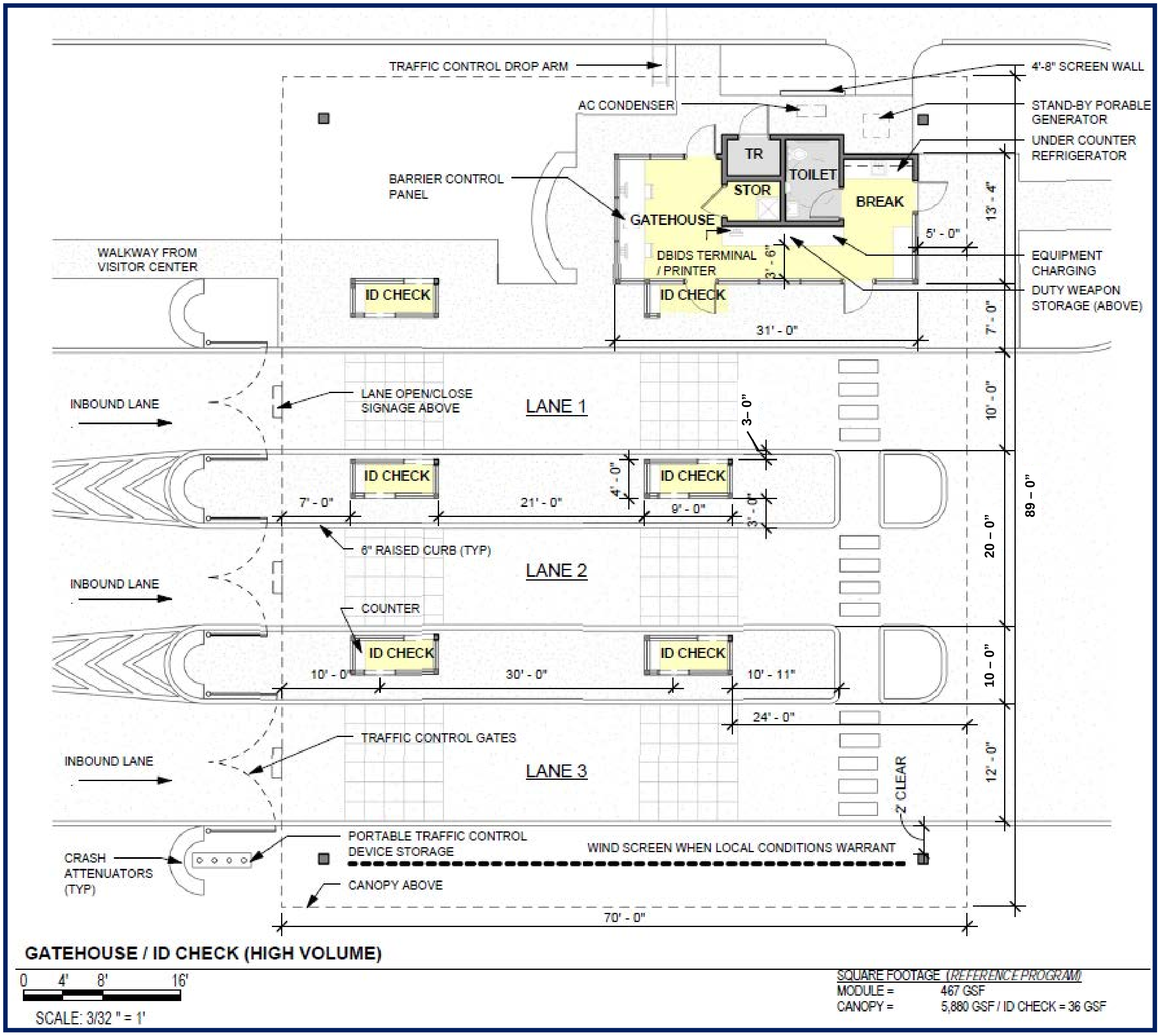
It is beneficial to provide parking for security forces staff in close proximity to the gatehouse. At a minimum, provide one space for a chase vehicle sited as close to the gatehouse as practical. The chase vehicle parking will be located for quick response and will be sized for the planned response vehicle.

5-7.8 ID Check Island and Guard Booth.

The ID check is located in a median island or channelization island between traffic lanes. The area must provide minimum of one guard with protection against the weather and potential threats. The island must have appropriate pavement markings identified in SDDCTEA Pamphlet 55-15. The guard booth must have space allotted for electronic control panels for ECF/ ACP automation equipment, EFO, duress alarm, intercom, workspace incorporating space for computer monitors, and an electrical panel board. There may be up to two guard booths per lane; however, at installations where the second processing area is not readily utilized, it may be more appropriate to not construct a second guard booth but to reserve an area for processing.

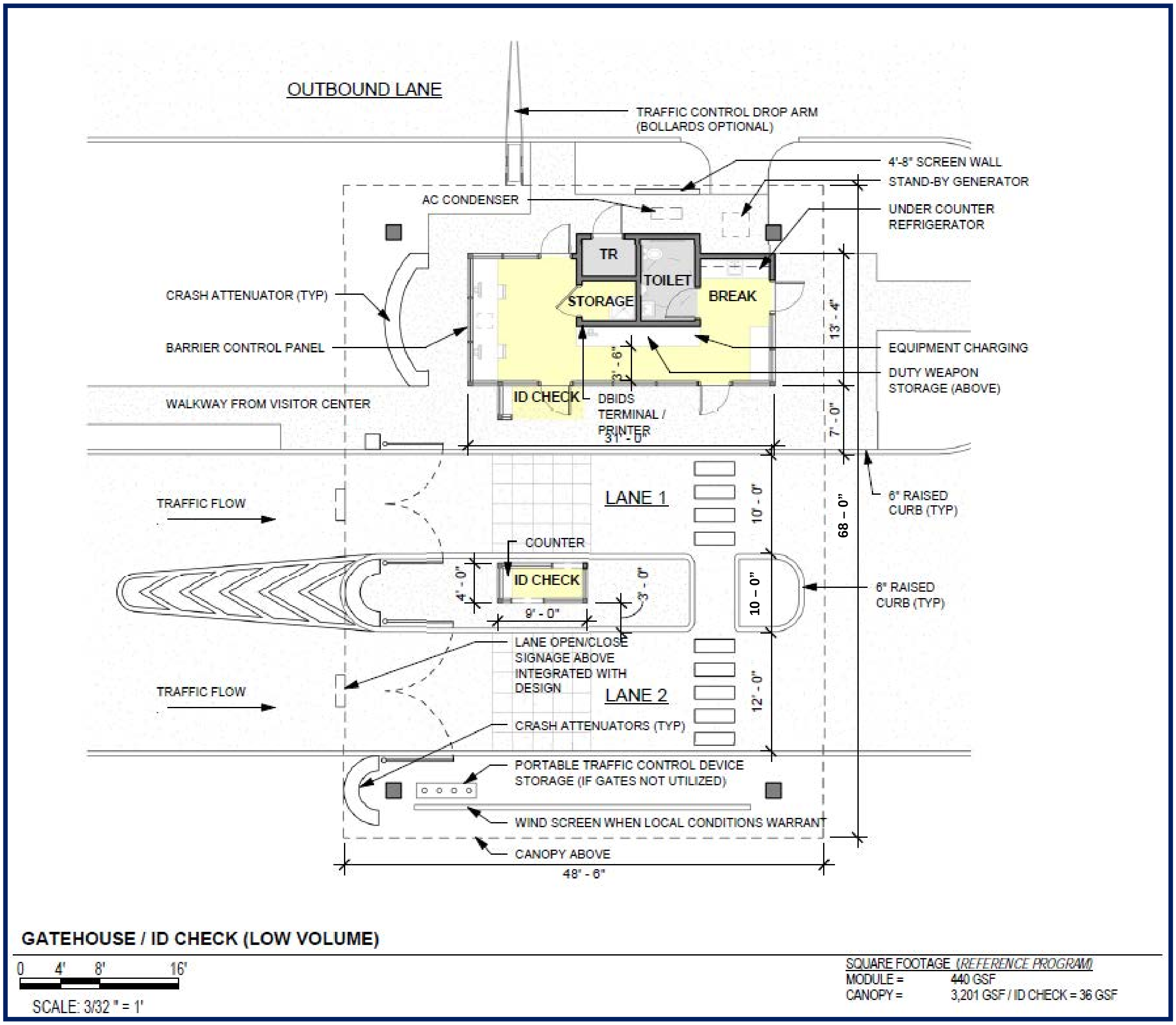
When guards need to stand between lanes of traffic, raised islands provide a measure of safety and separation. Consider designing the ID check area with a depressed step down area so that guards can process motorists at eye-level without having to bend over or step into traffic. The depressed area or sloped area must be designed to promote proper drainage so that it does not become an impediment to vehicular traffic. For all designs, items like guard safety, ponding water and automated equipment installation need to be reviewed in detail and impacts (both pro and con) identified and evaluated. Typically, ID check areas should be 50 (15.25 m) to 75 feet (23 m) long. Providing 75 feet (23 m) of length will allow tandem checking of vehicles, if required. Maintain a minimum 3 foot (0.9 m) setback from the face of curb to the guard facilities on the island. Must also include, as a minimum, a 1 foot (0.3 m) horizontal clearance between face of traffic island curb and guard facility roof, gutters or any other objects protruding from the guard facility. Maintain a minimum lateral clearance of 2 ft (610 mm) in the access control zone to allow security personnel to pass between fixed objects and obstructions and the roadway. See Figures 5-11 and 5-12 for additional details.

Figure 5-11 Model ID Check Island Details – High Volume



Source: Air Force Civil Engineer Center

Figure 5-12 Model ID Check Island Details – Low Volume



Source: Air Force Civil Engineer Center.

5-7.9 **Overwatch Position.**

Installations must consider additional position(s) for security personnel to facilitate a response to a threat. These positions known as overwatch are normally placed in the response zone to facilitate surveillance and armed response. This position may be fixed or temporary/portable. Manning of the overwatch position must be in accordance with the installation physical security plans. If an overwatch position is not being considered in the initial design, the site plan must provide a location and utility stub out or a future permanent/temporary one.

The overwatch (Figure 5-13) must be provided with an intercom, EFO controls to activate the AVBs and an enunciator to alert security personnel of the duress alarm being triggered at the other guard facilities. The overwatch must maximize visibility with 360-degree visibility. The overwatch position must have a direct line of sight to the access control zone of the ECF/ACP including identification and inspection areas.

5-7.9.1 **Permanent Facility.**

In most cases, the overwatch position will be located at or near the end of the response zone to provide sufficient distance for this response. In all designs, coordinate the location with security personnel to ensure proper line of fire and safety considerations. If required, elevate the facility to aid the observation of incoming traffic and reduce incidental/collateral damage by creating a plunging fire scenario.

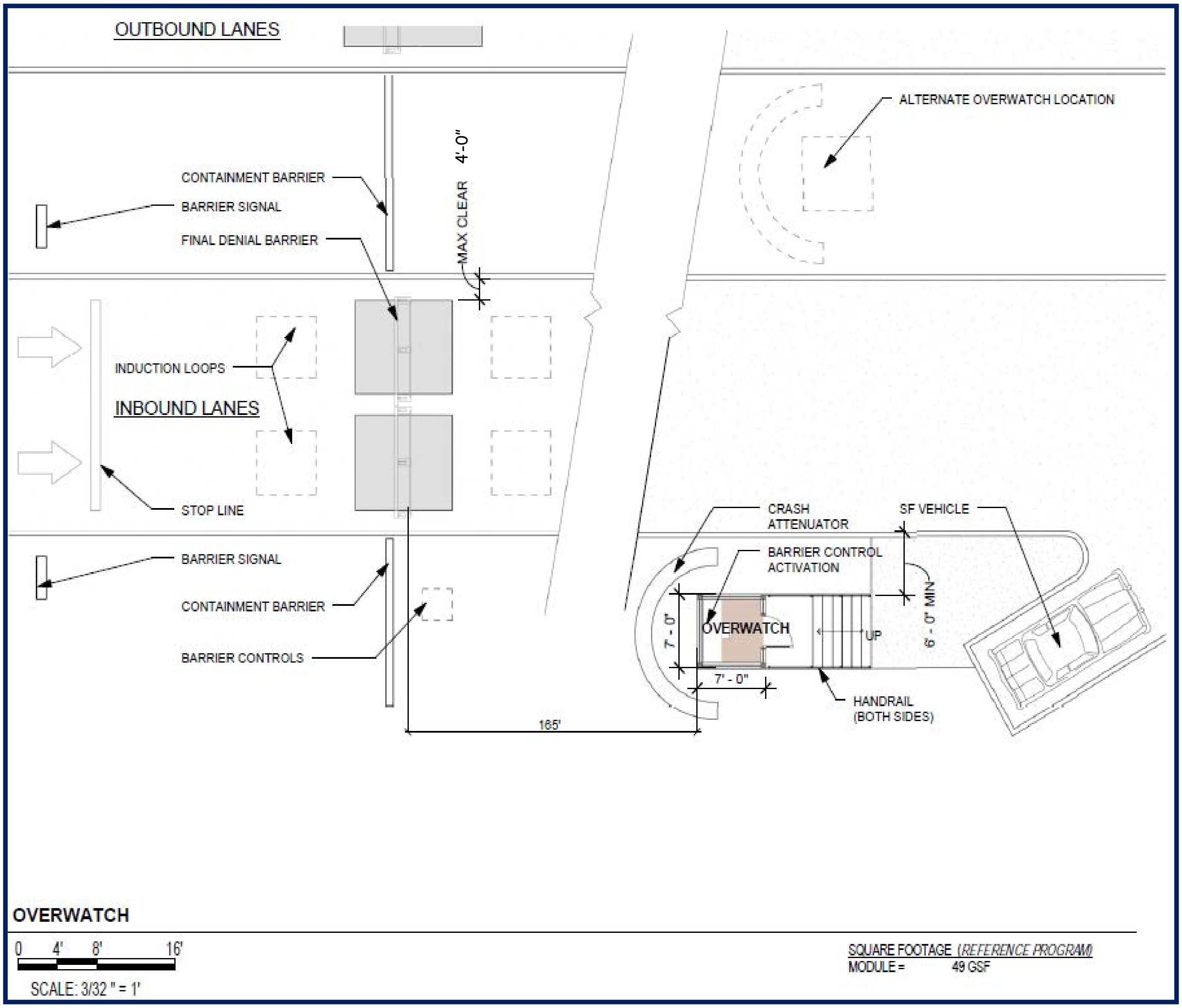
5-7.9.1.1 **Dimensions.**

Dimensions must be sufficient for movement of guard personnel within the structure. Design must provide adequate space for movement of a guard and use of both handgun and shoulder fired weapon with gunports. Gunports must be provided on each face of the overwatch. All gunports must be usable for both handgun and shoulder fired weapons. Gunport design must not require weapons to be oriented in an unusual way (e.g. gunport being placed immediately above counter and counter interfering with vertical orientation of pistol magazine).

5-7.9.2 **Temporary Facility.**

If the overwatch position is established as a temporary facility, an asphalt or otherwise paved pad must be provided at the overwatch location to accommodate a security forces vehicle or temporary facility during increased FPCONs. A communications stub must be provided for this facility as well as ruggedized and lockable EFO AVB controls.

Figure 5-13 Model Overwatch



Source: Air Force Civil Engineer Center

5-7.10 **Overhead Canopy.**

Provide canopies in the following areas:

- ID check area/access control zone (inbound lanes)

Provide an open/close visual indicator on canopy(s) over each lane that is controlled in accordance with the MUTCD/ DoD Supplement to the MUTCD. The preferred style of indicator is the red “X” and green “Arrow”, but the two head traffic signal (red/green) is allowed. If there is only one search lane, then it is up to the installation to determine if a visual indicator is desired.

5-7.10.1 **Benefits.**

Canopies provide the following benefits:

- Protection from weather (sun, rain, and snow) for ID check and inspection areas.
- Improved lighting since lighting can be installed under the canopy.
- Improved security since CCTV can be installed under the canopy.
- Improved security by allowing for more thorough processing during inclement weather.
- Support for automation systems.
- A structure to mount lane use signals and signs.
- A “gateway” for motorists which encourages lower speeds.

5-7.10.2 **Vertical Clearance Requirements.**

The minimum desirable clear height must be 17.5 feet (5.3 m) where commercial traffic at the ECF/ACP is allowed and facilitate use of the overhead canopy for signage, lighting or security equipment. Where the ECF/ACP use is limited to POVs the clear height must be 15 feet. This clear height is measured from the pavement to the lowest point on the overhead canopy, including light fixtures and other equipment.

5-7.10.3 **Design Considerations.**

The architectural appearance of the canopy should match surrounding features and meet the requirements of the installation exterior architectural plan. Avoid the use of structural elements that could obstruct visibility where individual canopy columns must limit field of view from ID check guard booth by no more than 11 degrees. Structural elements should be strategically located where possible behind attenuators or barrier walls and must be placed at least 3 feet (0.9 m) behind the face of curb.

5-8 ELECTRICAL AND COMMUNICATIONS REQUIREMENTS.

Electrical design must consider current power demands as well as the communication and power requirements for future traffic control devices, identification equipment, and other devices associated with potential automation of the ECF/ACP. Coordinate power requirements for security systems with the manufacturer. Some systems may require three-power configuration.

5-8.1 **General Guidance.**

Space must be reserved in the gatehouse for the controls and electric panel boards associated with the future control systems.

5-8.2 **Alternate Electrical Power Source.**

In the event of a loss of the primary electrical source, a reliable alternate power source is necessary to ensure continuous operation of the ECF/ACP. Follow service guidance for approval of backup power authorization and design.

The alternate power source status must be monitored at Command and Control (Gatehouse) to include alarms for loss of normal power, malfunction, and low fuel. It is recommended that generator be installed so that it is at least 30 feet from the service entrance transformer to allow for ease of maintenance. Ensure the alternate power source location allows access for maintenance of the unit as well as adding fuel.

5-8.2.1 **Standby Generator.**

Use a standby generator or other equivalent means as the alternate electrical power source. Provide an automatic means of starting the generator and load transfer depending on the permissible duration of the electrical power outage per UFC 3-550-01, UFC 3-520-01, and UFC 3-501-01. Recommend the generator be installed so that it is at least 30 feet (9 m) from the service entrance transformer to allow for ease of maintenance and adding fuel.

5-8.2.2 **System Considerations.**

Equipment on back-up power must include:

- Command and Control / Gatehouse interior and exterior lighting
- Canopy lighting
- Exterior lighting in the access control zone
- Roadway lighting within 100 ft (30.3m) of both sides of the access control zone
- ID check area and inspection area traffic arms
- Roadway lighting within 150 feet (47.5m) at the final denial vehicle barrier location(s)
- Exterior lighting in the inspection area(s) including 100 feet (30.3m) on both sides of the canopy
- Traffic control systems
- Automated systems
- Uninterruptible power supply (UPS).

Generator systems must include Command and Control / Gatehouse notification of the following

- Loss of primary power
- Standby generator malfunction
- Low fuel.

5-8.2.3 **Back-up Power and Auto-start Requirements.**

The generator must be provided with sufficient fuel to provide back-up power for a period of at least 12 hours or as required to support the installation's plan for refueling operations. For a fixed generator provide auto-start capability within 10 seconds of primary source failure. When natural gas generators are allowed they are not required to have a 12 hour tank.

5-8.2.4 **Portable Generators.**

In some cases, installations may specify the use of portable generators in addition to stationary auxiliary electrical power sources. Where portable units are utilized, provide a suitable location, power connection point, and access for trailer mounted portable generator.

5-8.3 **Uninterruptible Power Supply.**

To maintain security and barrier safety functions, provide a UPS for use during generator starting and load transfer. The UPS system supports computerized equipment to avoid power disruption. At a minimum, provide UPS for the following:

- Primary communications system
- Duress alarm system
- Computers
- CCTV systems
- Intrusion Detection Systems (IDS)
- Enunciator
- Access Control Equipment including AVB systems, traffic control devices and automated systems.
- AVB Systems include:
  - Active vehicle barrier controls.
  - Active barrier activation system for one complete operation cycle (opens to close and close to open). Hydraulic systems do not need to have the pump motor on UPS, if the system can maintain enough pressure for one complete cycle. The hydraulic pump motor then only needs to be on generator back-up power.
  - Traffic arms located at the active vehicle barriers.
  - Traffic sensors (wrong way, over speed, and presence detectors).
  - Traffic signals and warning lights.

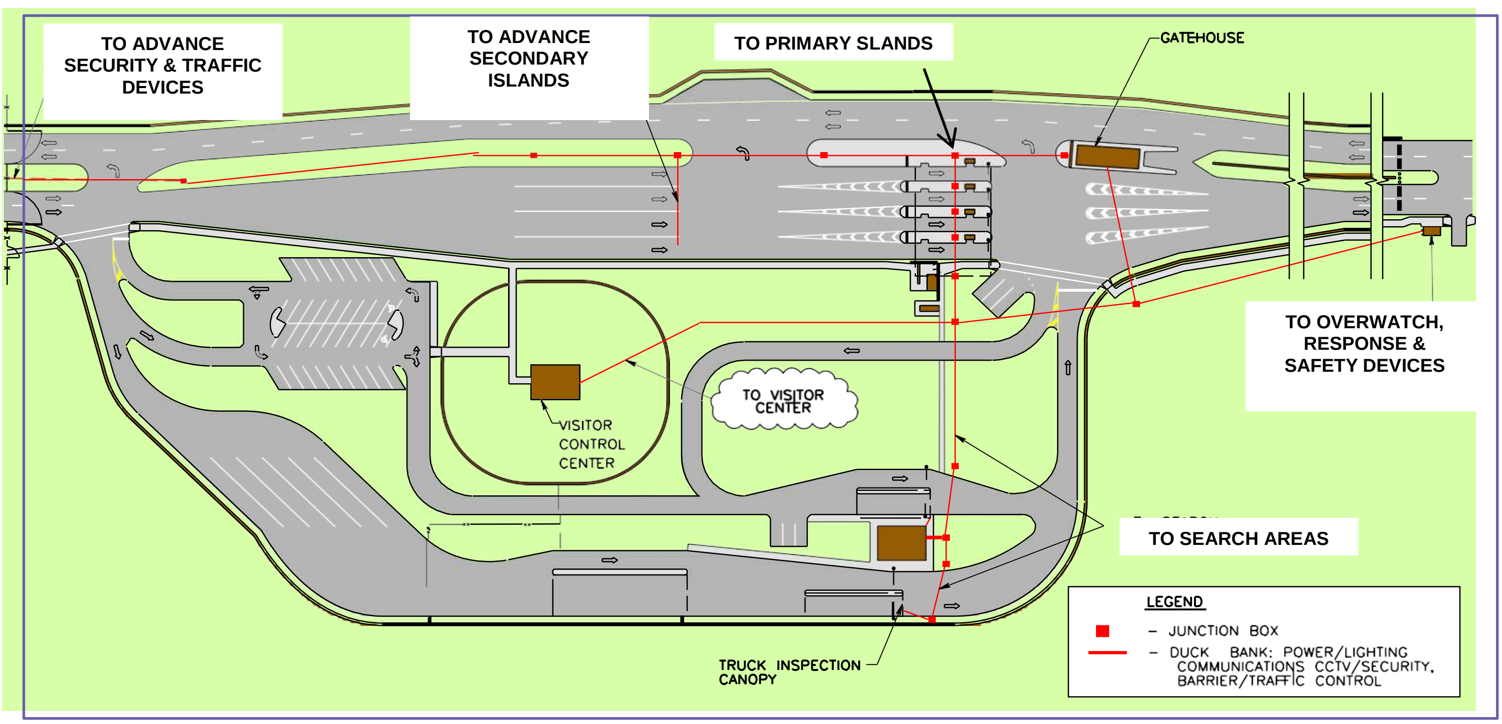
An UPS is not normally used for security lighting per UFC 3-530-01 due to the nonlinear nature of most luminaires. Provide limited lighting at the control consoles in the gatehouse (command and control) and inspection (search) office. Provide some luminaires at the ID check area (one per lane near the guard position) and at the active vehicle barrier location when required by other criteria or by the installation. The design should clearly identify the nonlinear nature and switching patterns of the load to be served by the UPS. It may be desirable to place limited lighting on the UPS to avoid restrike concerns.

5-8.4 Infrastructure.

In areas close to the gatehouse, physical interconnection is more feasible. In those cases, conduits and duct banks must be part of the overall design. Communication conduits are to be separated from power conduits and from signal/security system conduits. Provide spare conduits in all exterior pathways so that future devices can be added to the ECF/ACP. Conduits must connect all key features to the gatehouse including guard booths, inspection areas, AVBs, overwatch positions, and the visitor's center.

At a minimum, provide a system of underground duct banks and hand-holes for distribution of power, control, and communications/data wiring from the ECF/ACP gatehouse to each area as illustrated in Figure 5-14 Model Duct Bank Plan.

Figure 5-14 Model Duct Bank Plan



Source: SDDCTEA Pamphlet 55-15

5-8.5 **Information Technology.**

Each ECF/ACP must have at least two means of communication from the ECF/ACP to a central monitoring point. The type of communication is dependent on the devices being utilized and site conditions. CCTV systems require higher bandwidth. Coordinate the requirements for radio-based communication with the installation. Some installations may require an emergency ring down telephone, which provides a direct, hard-wired duress alarm to the installation emergency dispatch or control center.

Provide a central duress alarm, which signals the installation emergency control center, dispatch center, or similar designated location in each gatehouse, guard booth, inspection area, and overwatch position. The duress alarm must be silent in the ECF/ACP to avoid alerting aggressors of its activation.

5-8.5.1 **Installation-Wide Networks.**

The ECF/ACP must be capable of connecting to installation-wide, information technology systems. As services continue to enhance security at ECFs/ACPs, the need for reliable, high-speed data connectivity at installation perimeters becomes increasingly important. While many installations have been proactive in extending their fiber optic backbone to the perimeter, many ECF/ACP security upgrade projects continue to be hampered by the inability to transmit data from ECFs/ACPs back to security monitoring and administration facilities. Although a dedicated copper phone circuit is generally sufficient for transmitting basic ECF alarm messages (guard duress, door forced, enclosure tamper, etc.), ECF/ACP video and access control data demand a much faster connection that is best provided by fiber optic cable. To ensure adequate connectivity for an ECF/ACP security upgrade, the project team must first confirm the availability of fiber at each ECF/ACP and then design and build a network capable of transmitting all required data.

5-8.5.2 **Stand-Alone Networks.**

A stand-alone ECF/ACP network, physically separated from the information management network, is preferred due to the criticality and sensitivity of the data being transferred. This network must provide multiple connections at each ECF/ACP and at security administration, monitoring and dispatch facilities. For example, the network switch at a single ECF/ACP could require local ports/connections for a digital video recorder (DVR), video workstation computer, automated system servers and workstation computers. The port configuration of the ECF/ACP switch should include a fiber optic uplink to the backbone switch and enough local spares to accommodate new equipment in the future. The network must support Ethernet and Transmission Control Protocol/Internet Protocol (TCP/IP) protocols, and the data rate must be no less than 100 Mbps. A properly designed ECF/ACP network will support “plug-and-play” connectivity for a wide range of security equipment and ultimately enhance the force protection posture at the installation perimeter.

5-8.6 Closed Circuit Television (CCTV).

ECFs/ACPs must be equipped with a CCTV system. The system must be equipped with DVR capability for 24 hours and 7 days a week operation. Camera(s) must provide a perspective of ECF/ACP operations to include the following:

- ID check area
- Inspection areas
- Visitor’s center
- The approach zone
- Response zone to monitor traffic approaching from both directions unless not required by the individual service.
- Neighboring intersections and roadways that may be impacted by ECF/ACP operations.

Each inbound lane of traffic must be equipped with cameras capable of reading license plates and viewing drivers in the identification check areas and inspection areas.

The CCTV system must be monitored in the gatehouse, inspection office, and the Installation’s Central Security Monitoring Station (Military Police (MP) Desk, 911 Desk, Installation Emergency Operations Center (EOC), etc.).

5-8.7 Intrusion Detection System (IDS).

Coordinate with the installation and the service for these requirements. Provide balanced magnetic switches (BMS) on the exterior doors to the Command and Control/Gatehouse, Guard Booths, Overwatch, Search Office, and Visitors Control Center. Provide BMS on interior doors that go to rooms that contain communication, CCTV, or security equipment. Storage rooms that do not contain any security, CCTV or Communication equipment are not required to have BMS. See UFC 4-021-02, Electronic Security Systems (ESS) for additional information and guidance.

5-8.7.1 Tamper Switches.

Coordinate with the installation and the service for these requirements. The tamper switch can be part of the equipment itself and monitored by its system e.g. the active vehicle barrier control system can monitor the tampers on its system including the manholes/handholes. When the IDS panel is not monitoring the tamper switches, then the IDS panel must receive a general alarm from the other system when a tamper switch is activated.

Provide tamper switches on the following:

- Electronic control cabinets for Communications, AIE, CCTV, and security controls.

- Active vehicle barrier cabinets that contain controllers and power units. Operating control panels associated with the AVB controls (master, guard booth, local, etc.) are required to be equipped with tamper switches.
- The junction box at the Overwatch Position pad (if provided).
- Manholes and handholes that contain duress alarm, AIE, CCTV, intrusion detection or AVB control wiring and have splices present.
- Uninterruptible power supply (UPS) cabinets must be equipped with tamper switches.

5-8.8 **General Power Requirements.**

- Ensure power panel board are not be installed below a counter which includes pre-fabricated structures such as the guard booths, pedestrian check area booth and overwatch.
- Direct buried wiring is not allowed unless specifically requested by the installation or service in writing. Provide all 600V or less wiring in conduit. If the conduit is within eight (8) ft of a roadway, then concrete encased the conduit or use rigid steel conduit.
- Provide power receptacles per NFPA 70. The following are in addition to the general requirements.
    - Search Function/Bus Shelter is to have at least one duplex receptacle.
    - ID Check Guard Booth, Pedestrian ID Check, Overwatch Building. Provide one duplex receptacle at the counter that is either on a UPS circuit or provide a standalone UPS.
    - ID Check Guard Booth. Provide an exterior receptacle on each of the narrow ends. Provide at least one receptacle below the eave along each of the long sides.
    - Overwatch Pad. Provide a duplex receptacle at the pad.
    - ID Check Canopy. Provide at least one duplex receptacle per island.
    - Truck Search Area Canopy, Passenger Vehicle Search Area Canopy. Provide at least one duplex receptacle on a column on each side of the inspection space. Provide a dedicated circuit for each side of the inspection space receptacles.
    - ID Check Canopy, Truck Search Area Canopy, Passenger Vehicle Search Area Canopy. Provide one 20 amp circuit at either 208VAC, 240VAC, 277VAC or similar voltage depending on the country that can be used by heaters or other equipment. Provide an appropriate receptacle for the amperage and voltage configuration and have an adjacent disconnecting means.

5-9 **EXTERIOR LIGHTING.**

Lighting is required for guards to perform their security functions. ECF/ACP lighting is important so that motorists and guards can see each other. ECFs/ACPs must be designed with lighting features that support the operational requirements during dawn, dusk, or nighttime periods. Even if the ECF/ACP is intended to be used only during daytime hours, lighting must be considered in the event there is a change in usage.

Lighting must be complete and continuous. Specific areas of the ECF/ACP require their own lighting requirements. These requirements are governed by UFC 3-530-01 and criteria established by the individual services. The lighting plan for the ECF/ACP must transition from the existing roadway lighting so that it does not blind the driver or backlight signs. Proper design of the lighting system will increase safety and efficiency, aid security forces, enhance appearance, and reduce light pollution.

5-9.1 **General Requirements.**

Provide the ECF/ACP with multiple, redundant luminaries to ensure the loss of a single luminaire does not seriously degrade the total lighting available for security personnel. Transitional lighting is necessary on approaches (approach zone) and departures (response zone) to the ECF/ACP to minimize blinding effects as drivers travel into and out of a brightly illuminated access control zone of the ECF/ACP. Within the ECF/ACP, the lighting requirements vary depending on the zone of the ECF/ACP as noted UFC 3-530-01 Table 6-1, Minimum Lighting for Unaided Guard Visual Assessment.

The lighting at the ECF/ACP must be designed as controlled lighting, to reduce light pollution and increase traffic safety. Glare projection or glare lighting must be avoided where a safety hazard would be created. Use luminaires that are classified as cutoff or semi-cutoff.

5-9.1.1 **Placement of Luminaires.**

Light poles can be placed along the roadway or in the median. In some cases, light poles in the median may reduce the number of poles needed. However, at wider ECFs/ACPs with numerous lanes, the needed illumination may not be achievable with light poles only in the median. Therefore, light poles must be placed on both sides of the road. Provide exterior lighting poles and the electrical connections that are frangible when required by MUTCD/ DoD Supplement to the MUTCD. Poles can be no shorter than 15 feet.

When light poles are in uncurbed areas, the pole must be located outside of the roadway clear zone. In curbed areas, light poles must be located at least 2 feet (0.6 m) behind the face of the curb.

5-9.1.2 **Color Rendition Index.**

The ability to identify colors accurately and confidently is determined by the light source spectral power distribution and the illuminance level. This capability is commonly referred to as color rendition and is measured by the color rendition index (CRI). To ensure appropriate color rendition, use a light source with CRI greater than or equal to 65-in the ID check area, access control zone, and search areas, and use any nominally white light source (CRI greater than or equal to 50) at the illuminances typically encountered in the remaining areas of an ECF/ACP.

When CCTV is used as part of the security operations, it is important to coordinate the design of lighting and CCTV systems such that enough illumination and CRI is provided per CCTV equipment specifications.

5-9.1.3 **Restrike or Restart Capability.**

Another important consideration in the design of the site lighting, is the restart or restrike time for the selected lamps. Restart occurs when a lamp experiences a loss of power and there is a time delay before backup power restores power to the lamp and the subsequent restrike or restart of the lamp. Coordinate the restart capability with the user. As an example, high intensity discharge (HID) lamps are more energy conserving than incandescent lamps, however, they require several minutes to warm up and restart after power is interrupted. This period of time, which could be 15 to 20 minutes, is unsatisfactory for security operations. The installation should designate the maximum acceptable period for which loss of illumination can be tolerated, however, without specific data two minutes is considered the maximum outage period acceptable. The selection of light sources, especially in the Access Control Zone, must include an evaluation of restart or restrike time. It will be necessary to provide lamps and auxiliary equipment for rapid startup and restrike to provide minimal adequate lighting in the event of a power interruption.

5-9.2 **Approach and Response Zone Lighting.**

The approach and response zones require roadway lighting. The roadway lighting must provide enough intensity so that pedestrians, security personnel, islands, signage, and other hazards are visible. The lighting must not be directed in the driver's eyes and it must not backlight important signage. See UFC 3-530-01 and criteria established by the individual services.

Transitional lighting is necessary on approaches to the ECF/ACP so that drivers are not blinded during arrival and departure. See UFC 3-530-01, SDDCTEA Pamphlet 55-15, and criteria established by the individual services for transitional lighting guidance. Transition lighting goes from the lower light levels prior to the Approach Zone up to the required light level for the Approach Zone and then again up to the required level for the Access Control Zone. Then the lighting will transition from the Access Control Zone to the lower level for the Response Zone. After the active vehicle barriers the light level needs to transition down to the lower light level for the street. Roadway geometry may impact the ability to do the transition lighting per the criteria. Actual lighting locations must be determined on a case-by-case basis and depend on the height, light source, and lens distribution.

5-9.3 **Access Control Zone Lighting.**

In the Access Control Zone, area lighting is provided in the vicinity of the facilities. The lighting needs to illuminate the exterior and interior of a vehicle to facilitate identification of the occupants and the vehicle contents. Good vertical illuminance facilitates the identification and inspection procedures per UFC 3-530-01. Lighting levels above those indicated in UFC 3-530-01 Table 6-1 or those established by the individual services may be appropriate where practical and desired. However, careful consideration of the potential adaptation problems and the design of the lighting of surrounding areas are required for the safety of traffic and security personnel.

It may also be necessary to provide additional task lighting in the ID and inspection areas to support adequate identification of vehicle occupants and contents. Such lighting must be directed transverse to the roadway; it will then illuminate the roadway in front of the gatehouse, the driver, and the guard.

5-9.3.1 **Under-Vehicle Inspection Lighting.**

Per UFC 3-530-01, lighting may also be mounted at or below pavement level to facilitate under vehicle inspection. The system must eliminate shadows and create contrast.

5-10 **CONSTRUCTION PHASING.**

If the project involves the modification of an existing ECF/ACP, pay considerable attention to the phasing of construction. In most cases, it is desirable to minimize the interruption of the ECF/ACP operations especially during periods of peak demand.

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CHAPTER 6 LARGE COMMERCIAL VEHICLE AND TRUCK INSPECTION FACILITIES

6-1 INTRODUCTION.

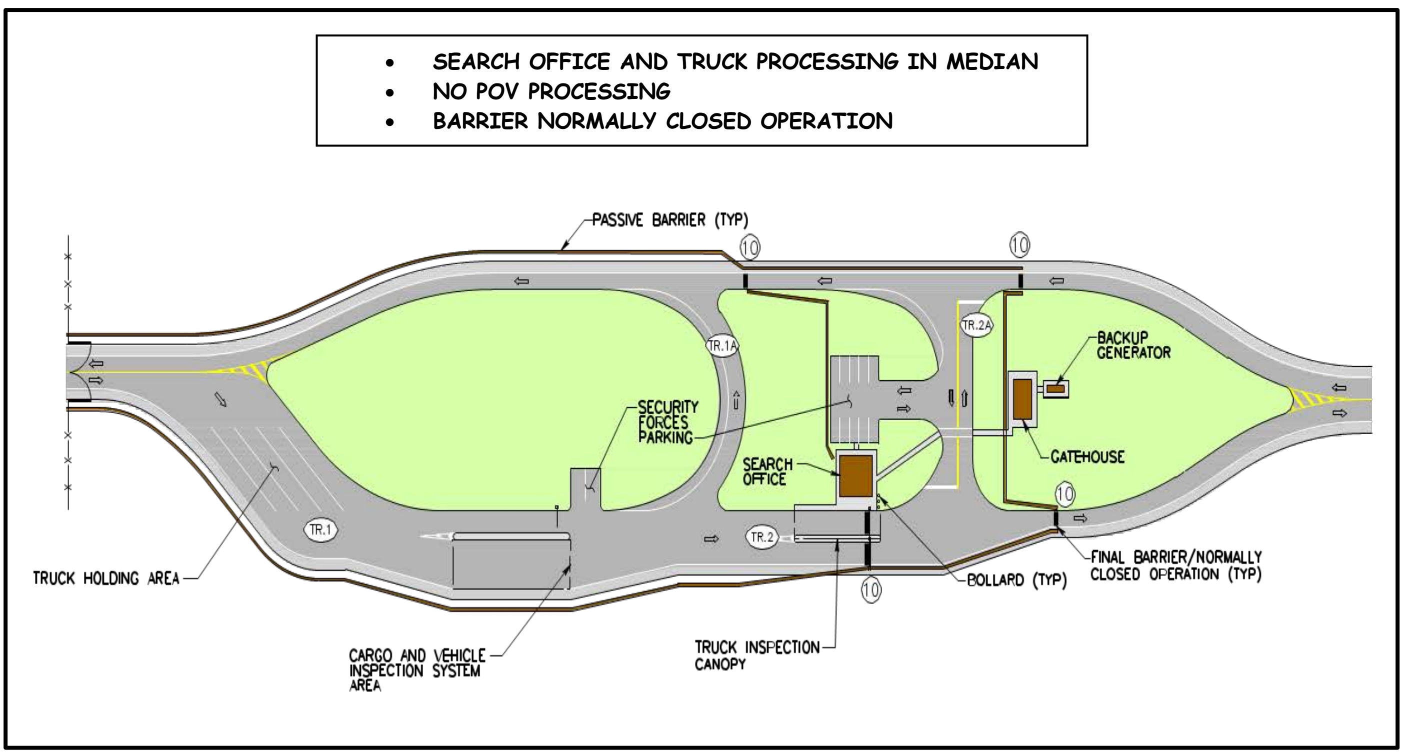
A large vehicle inspection facility may be a separate centralized facility or combined into the functions of a primary ECF/ACP as indicated in the function diagram in Figure 2-4. See Figure 5-7 for example layout of Commercial Vehicle Shelter and Inspection Office.

Key considerations in determining the need for segregated facilities include:

- Mission
- Location
- Population
- Truck traffic volume
- Security procedures
- Availability of land

The following criteria are intended to provide minimum requirements and general considerations in the design of such an inspection facility. The same ECF/ACP design features (i.e. IDS, duress system, and lighting) employed for POV only facilities are required for commercial vehicle/truck ECF/ACPs. See Chapter 5 Design Guidelines for design criteria/guidance on those features.

Figure 6-1 Example of Commercial Vehicle Only ECF/ACP



6-2 MISSION AND OPERATION.

An installation large vehicle inspection facility is intended to be the single point of inspection for all large commercial and truck traffic intending to enter the installation. It is envisioned that once a vehicle is inspected and authorized to access an installation, that the vehicle may be tracked and monitored until it enters the installation.

6-3 SIZING OF LARGE VEHICLE INSPECTION FACILITIES.

The capacity and truck holding requirements of a large vehicle inspection facility must be determined by a traffic engineering study as per SDDCTEA Pamphlet 55-15. The calculations must consider the longer processing times of trucks and the larger vehicle size. In some cases, where there is significant truck volume over several hours, the cumulative demands must be considered. All hours of the day when trucks are being accepted must be reviewed to determine the actual design truck demand.

Processing times vary based on security procedures, but often range from three to five minutes per vehicle, which equates to 12 to 20 trucks per hour processed. Where two inspection lanes are present, these rates are doubled. Once the number of vehicles not processed is known, that number represents the size of holding area needed.

6-4 INSPECTION EQUIPMENT.

Base the design of the large vehicle inspection station on the use of large vehicle inspection equipment. Some examples of these technologies are x-ray, ion mobility spectrometry, gamma ray imaging, and neutron analysis. An ever-increasing number of these devices are being installed. The design must include space for vehicle inspection equipment and utility conduits. The inspection equipment may be a mobile or fixed installation. It must be noted that some detection equipment is built-in to a large, drive-through structure. If this type of equipment is anticipated, then this must be coordinated and incorporated into the inspection office, drive through structure or overhead canopy facilities.

In addition, many installations desire CCTV inspection of the top and underside of vehicles. Mount these cameras on the overhead canopy and in the pavement below the vehicle. As a minimum, the inspection facility must possess the infrastructure to support the installation of CCTV inspection equipment, including adequate lighting to illuminate the underside of the vehicles during inspection. Some installations may also consider the use of vehicle inspection pits, although this type of facility is not recommended due to commonly encountered soil conditions and anticipated operational safety issues. The following sections contain information on various inspection-related devices to facilitate the layout of the truck inspection facility and the determination of the required infrastructure to support inspection equipment.

Follow service guidance for approval of inspection equipment authorization and design.

6-4.1 Under Vehicle Search Systems (UVSS).

If a CCTV UVSS is utilized, evaluate the following considerations and guidelines.

- Consider maintenance requirements.
- If installed below grade, the enclosure must be waterproof.
- Install the system within the ECF/ACP footprint so that the largest vehicle can pass over the equipment without entering the installation.
- Drainage must be established such that water drains away from the equipment.
- When providing drains from the equipment enclosure, provide backflow prevention valves to prevent water from entering the vault. Ensure any water that may be captured in the vault will not drain through control conduit to the control center.
- The electrical circuit serving the equipment must be a ground fault interrupt (GFI) circuit.
- Monitoring area must be free of glare.
- Vehicle speed must be kept below 15 mph (24.1 km/h) to ensure adequate performance.
- Where exposed to freezing temperatures, the equipment installation must include heaters.

6-4.2 Cargo and Vehicle Inspection Systems.

There are many types of automated inspection equipment for large vehicle or cargo inspection. Some of the types available, which provide an image of the contents of a vehicle or container, include X-ray and Gamma Ray inspection systems. There are other systems available, such as neutron or vapor/particle analysis, which aim to detect the common chemical elements associated with explosives or other contraband. Many installations are considering procuring mobile systems that afford the possibility of varying the location of the equipment amongst various ECFs/ACPs. Consider a fixed installation for Installations that plan centralized truck inspection facilities, which potentially have an increased throughput and a reduced space requirement. Due to the wide-ranging requirements for the different manufactured systems, it is not possible to provide detailed guidance that will support all types of this equipment. Consult with manufacturers of these systems during the design of an ECF/ACP to ensure data concerning operational considerations is both current and the best available, and to assure that the area where the system will be used is properly sized.

6-4.2.1 Safety and Regulatory Considerations.

Due to the use of gamma or x-ray radiation, there are safety and regulatory considerations in the use of these systems. The requirements vary depending on the system. Normally an exclusion zone, an area where personnel are not permitted during operation of the equipment, is established within and around the inspection equipment.

The region outside of the exclusion zone is considered safe for personnel during scanning operations. The size of the exclusion zone varies greatly depending on the type of equipment.

Nuclear Regulatory Commission regulations state that radiation dose limits in Public-Uncontrolled areas are 2 milli-Roentgens (mR) in any hour or 100 mR in any year. Therefore, depending on the characteristics of the source, the frequency of scans, and the expected occupancies, the exclusion zone can vary. Additionally, a shielding wall can be constructed to reduce the dose substantially. Some x-ray systems have qualified as a “cabinet x-ray system” in accordance with Food and Drug Administration (FDA) regulations or similar standards, meaning minimal shielding is required and the exclusion zone does not extend outside of the footprint of the inspection area. To qualify for this designation, FDA regulations require an emission limit of 0.5 mR per hour at 2 inches (5 cm) from the surface of the cabinet. Other regulatory considerations are that systems utilizing radioactive sources may require operation under a radiation materials license held and administered by the owner of the equipment (the installation) and a permit for operation may be required**.**

6-5 LAYOUT OF COMMERCIAL VEHICLE INPECTION FACILITY.

The layout of the large vehicle inspection facility is extremely important to ensure the facility will function properly. The civil design must consider the turning radius and other operating characteristics of the expected vehicle types. In addition, the facility should consider having multiple lanes of inspection to support different vehicle types, or varying inspection levels. The design must have adequate stacking distances for the anticipated queue and parking for vehicles to be inspected and security vehicles. Size parking areas for the range of expected vehicles and consider the anticipated volume of vehicles to be inspected.

6-5.1 Security Considerations.

Consider providing a “sally port” in the inspection area. A “sally port” configuration is created through the use of vehicle barricades or traffic gates. These barriers are intended to confine the vehicle during inspection until it is determined that the vehicle is authorized to proceed or if the vehicle is denied admission to the installation. The barriers can also be used to aid in positioning the vehicle relative to inspection equipment.

Some installations may require screening of the inspection operations from the remaining portions of the ECF/ACP. Screening may increase safety and shields the inspection procedures from public view to prevent visual surveillance from unauthorized personnel.

6-5.2 Inspection Equipment Considerations.

The inspection equipment can have a significant impact on the layout of a truck inspection facility. It is difficult to develop a layout that can support all potential types of automated inspection equipment. If the installation specifies the anticipated inspection systems, then the layout can be customized. If the specific system is not identified, but the use of imaging or related inspection equipment is anticipated, the layout must facilitate the future incorporation of this equipment.

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APPENDIX A REFERENCES

DoD REFERENCES	
Title	**Source**
Army Standard for Access Control Points' and 'Army Access Control Points Standard Design	https://mrsi.erdc.dren.mil/cos/army-standards/ https://mrsi.erdc.dren.mil/cos/standard-designs/
Air Force (AF) BIM Dynamic Prototype Entry Control Facility	http://www.wbdg.org/references/afbim_tools.php
DoDI 2000.16 *DoD Antiterrorism Standards*	http://www.dtic.mil/whs/directives/ (available for download)
Directive-Type Memorandum (DTM) 09-012, "Interim Policy Guidance for DoD Physical Access Control	http://www.dtic.mil/whs/directives/ (available for download)
Multi-Service Regulation AR 55-80/ OPNAVINST 11210.2/ AFMAN 32-1017/ MCO 11210.2D/ DLAR 4500.19 DoD Transportation Engineering Program	www.apd.army.mil/ (available for download)
Military Surface Deployment and Distribution Command – Transportation Engineering Agency (SDDCTEA) Pamphlet 55-8 *Traffic Engineering Studies Reference*	http://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/Pages/default.aspx (available for download)
SDDCTEA Pamphlet 55-15 *Traffic and Safety Engineering for Better Entry Control Facilities*	http://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/Pages/default.aspx (available for download)
SDDCTEA Pamphlet 55-17 *Better Military Traffic Engineering*	http://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/Pages/default.aspx (available for download)
UFC 1-200-01, *General Building Requirements*	wbdg.org (available for download
UFC 2-100-01: *Installation Master Planning*	wbdg.org (available for download)
UFC 3-201-01:*Civil Engineering*	wbdg.org (available for download)
UFC 3-210-10: *Low Impact Development*	wbdg.org (available for download)
UFC 3-250-18FA: *General Provisions and Geometric Design for Roads, Streets, Walks, and Open Storage Areas*	wbdg.org (available for download)
UFC 3-530-01: *Design: Interior and Exterior Lighting and Controls*	wbdg.org (available for download)
UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Buildings*	wbdg.org (available for download)
UFC 4-010-02 *DoD Minimum Standoff Distances for Buildings* (FOUO)	wbdg.org (available for download)
UFC 4-010-03 *Security Engineering: Physical Security Measures for High-Risk Personnel*	wbdg.org (available for download)
UFC 4-020-01 *Security Engineering Facilities Planning Manual*	wbdg.org (available for download)
UFC 4-020-02FA *Security Engineering: Concept Design* (FOUO)	wbdg.org (available for download)

DoD REFERENCES	
Title	**Source**
UFC 4-020-03FA *Security Engineering: Final Design (*FOUO)	wbdg.org (available for download)
UFC 4-021-02 *Electronic Security Systems:*	wbdg.org (available for download)
UFC 4-022-02 *Selection and Application of Vehicle Barriers,*	wbdg.org (available for download)
UFC 4-022-03 *Security Fences and Gates*	wbdg.org (available for download)
UFC 4-023-07 *Design to Resist Direct Fire Weapons Effects*	wbdg.org (available for download)
UFGS 34 71 13.19 *Active Vehicle Barriers*	wbdg.org (available for download)
UFGS 34 41 26.00 10 *Access Control Point Control System*	wbdg.org (available for download)

NATIONAL DESIGN STANDARDS	
Title	**Source**
American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets (Greenbook)*	Transportation.org (available for purchase)
AASHTO *Roadside Design Guide*	Transportation.org (available for purchase)
AASHTO *Manual for Assessing Safety Hardware (MASH)*	Transportation.org (available for purchase)
Architectural Barrier Act (ABA) Accessibility Standard For Department Of Defense Facilities	www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-aba-standards/aba-standards
Code of Federal Regulations	www.ecfr.gov.
Federal Highway Administration *Manual on Uniform Traffic Control Devices (MUTCD)*	mutcd.fhwa.dot.gov (available for download)
FHWA-HRT-06-139 *Traffic Detector Handbook*	https://www.fhwa.dot.gov/publications/research/operations/its/06139/06139.pdf (available for download)
Department of Defense Supplement To The National Manual on Uniform Traffic Control Devices	https://www.sddc.army.mil/sites/TEA/Functions/SpecialAssistant/TrafficEngineeringBranch/Documents/MUTCD_DOD_Supplement_Revision_20150601.pdf (available for download)
Federal Highway Administration *Standard Highway Signs*	mutcd.fhwa.dot.gov (available for download)

APPENDIX B NAVY GATE AUTOMATION

B-1 GATE AUTOMATION.

Entry control facilities ensure the proper level of access control to all DoD personnel, visitors, and commercial traffic entering an installation. Currently, security personnel visually inspect the vehicle and driver credentials as they enter DoD Installations. The DoD is moving to automate the vehicle and driver validation process to reduce manpower and improve access control for DoD Installations. An Installation's perimeter access control is the first line of defense in the concept of defense-in-depth. Access control measures such as guards, gates, passive vehicle barriers, and active barriers must perform as an integrated system to protect DoD installations from the terrorist threat.

The primary objectives of the Navy's Automated Vehicle Gate – Low Volume program are as follows:

- Protect personnel and operationally critical assets onboard Navy Installations.
- Standardize and integrate identification, authorization, authentication, credentialing, and access into an enterprise-wide system onboard Installations per Homeland Security Presidential Directive (HSPD-12) through the use of Navy Access Control Management System (NACMS) enabled Physical Access Control Systems (PACS).
- Limit access to Installations based on a Navy Physical Access Control System (NPACS) authorization and authentication process.
- Increase manpower efficiencies.

B-1.1 Major Equipment (Per Lane):

- Access Pedestal – Contains card reader, intercom, and driver's image capture.
- Vehicle Presence Sensor -Used to monitor vehicle transition through the ECF.
- Barrier Signal – Physically located on the drop arm, containment gate and final denial barrier. Red and flashing yellow lights.
- Drop Arm – Used to control vehicle movement at the access pedestal.
- Vehicle Trap – Used to control vehicle movement through the ECF during unmanned operations. Prevents tailgating and pass back of user credentials.
- Vehicle Trap Gate – Used to maintain a secure perimeter and forms the initial portion of the vehicle trap.
- Vehicle Trap Barrier – Not to be confused with AVBs. Used to form the final portion of the vehicle trap.

- Situational Awareness (SA) Closed circuit television (CCTV) cameras – Used to provide SA of the ECF as well as rear mounted vehicle license plate and vehicle operator.
- Dynamic Message Sign – used to notify vehicle operators of current gate status (Open / Closed).
- Fixed signage to indicate and direct traffic flow. Approach zone signage will become critical for traffic throughput. Provide signage to lane use and direct traffic into the appropriate lanes.
- Guard Interface Panel – NPACS enabled panel used by the Contact Guard to configure ECF automation.
- Wrong-way detection sensors (outbound lanes)
- Excessive speed detection sensors (inbound lanes)
- Gate automation hardware - Includes NEMA-4X rated enclosure, chassis/power supply, digital input modules and digital output modules used to control gate automation. The gate automation I/O modules interface the various input and output devices to include the following equipment:
    - Traffic Gate Arm
    - Vehicle Presence Sensors
    - Dynamic Message Sign
    - Guard Interface

B-1.2 Major Equipment (ABA Compliant Pedestrian Turnstiles).

- Access Pedestal – Contains card reader, intercom, and pedestrian image capture.
- Situational Awareness (SA) Closed circuit television (CCTV) cameras – Used to provide SA of the ECF as well as the card holder.

B-1.3 Major Equipment (Guard House):

- Storage for handheld credential scanners (2/inbound lane plus spares).
- Guard Interface– NPACS enabled panel used by the Contact Guard to configure ECF automation.

B-1.4 Major Equipment (Visitor’s Center):

- Card holder ID management system with enrollment workstations.

B-1.5 Major Equipment (Primary and Secondary Monitoring locations):

- Main Distribution Frame – Houses servers, LAN gear, UPS, and other required equipment.

- Physical Security Information Management (PSIM) client - Used to monitor system status, alarms, communications, SA, and perform system administration.

B-1.6 Connectivity (Guard House):

- In addition to standard Installation voice and data connectivity, a minimum of one 12 strand single mode optical fiber cable is required for gate automation systems. Coordinate point of service with installation. Typically, point of connection/service will be the Installation's dispatch Center.

B-1.7 Connectivity (Visitor's Center):

- Connectivity will be supported by the Navy's PSNet network.

Figure B-1 Example of Lane Layout for Gage Automation

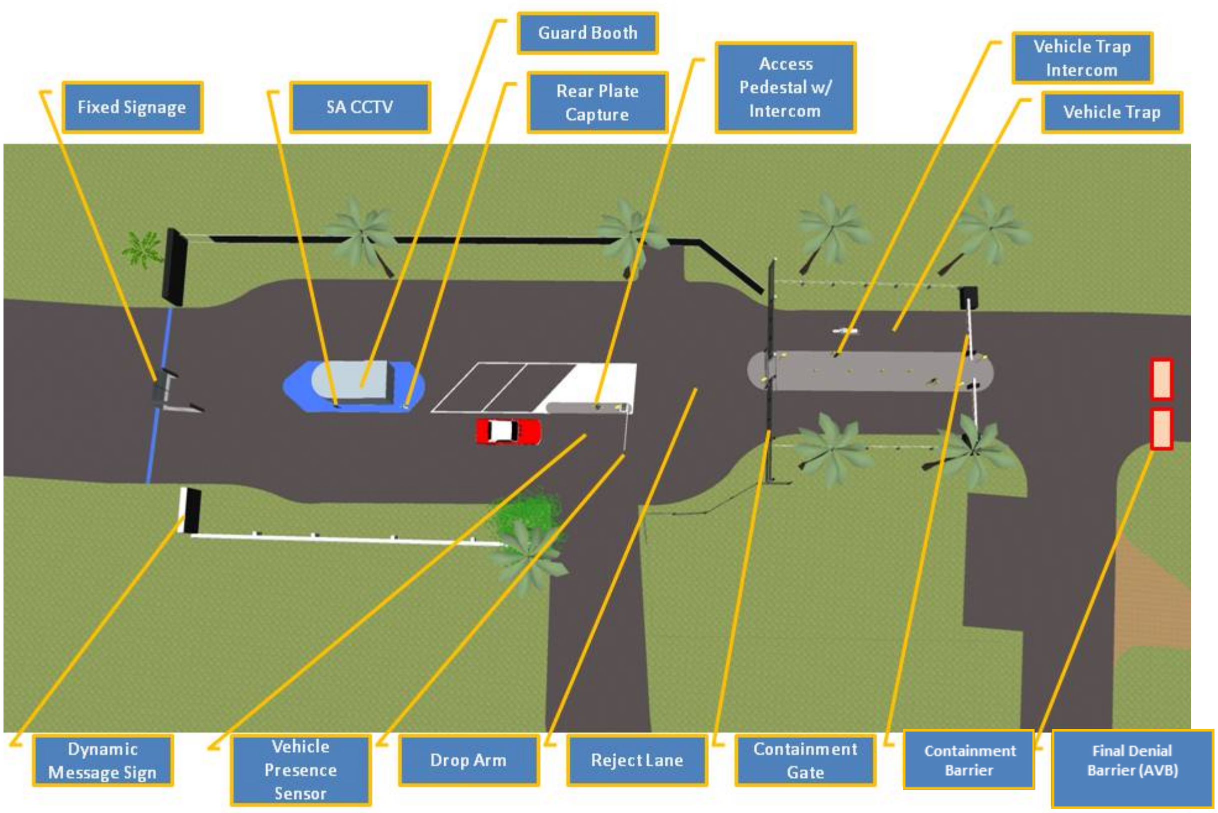
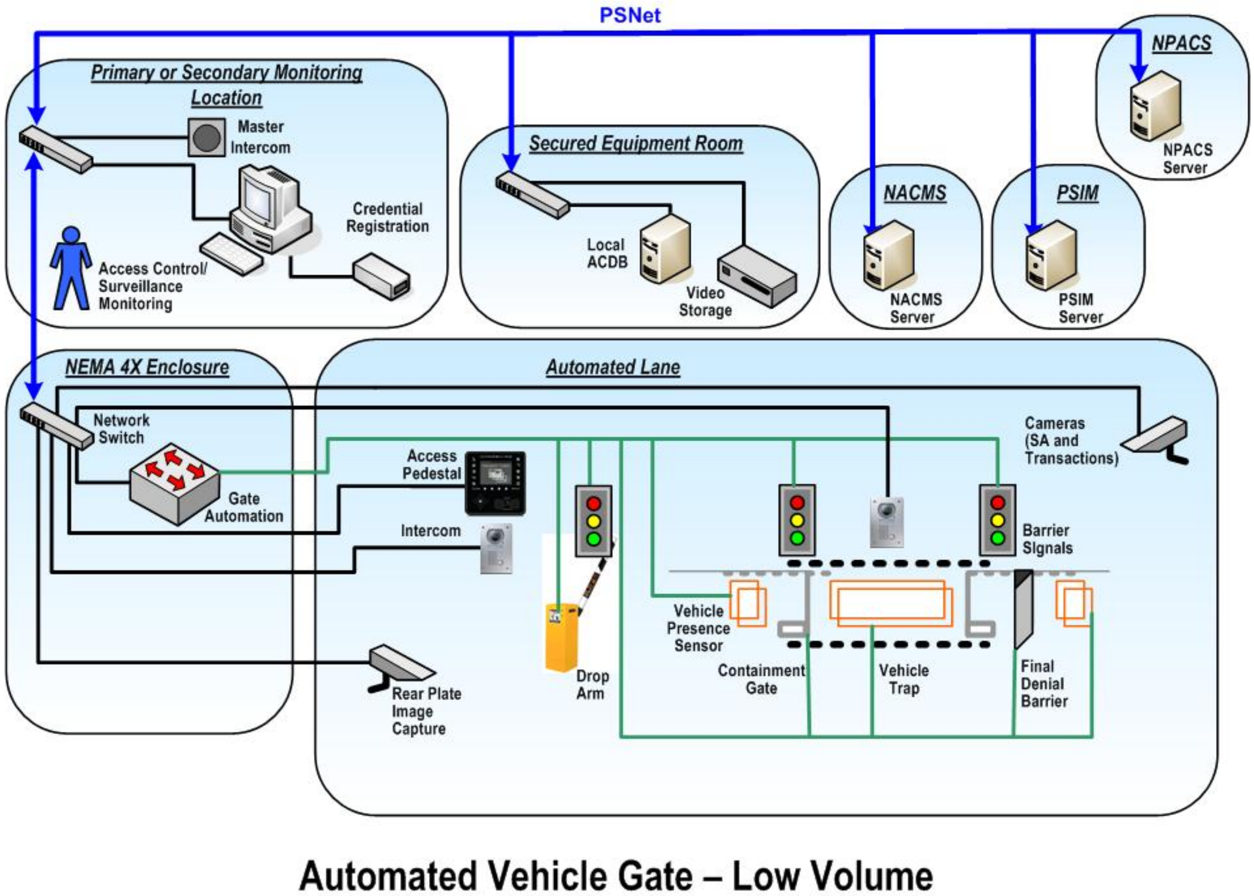


Figure B-2 Gate Automation System Schematic
(Does not include wrong way and speed detection)



APPENDIX C ARMY GATE AUTOMATION

C-1 GATE AUTOMATION.

The Automated Installation Entry (AIE) System provides a cost effective system that enhances security of Army Installation Access Control Points (ACPs), automates identity authentication and verification of authorized registered personnel entering the Installation, maintains or increases pedestrian and vehicle throughput with enhanced security, and allows for adaptation of increased authentication requirements at high threat levels.

The AIE System provides automated access control for vehicular traffic and pedestrians that have been enrolled in the system and are authorized access In Accordance With (IAW) the Department of Defense (DOD), Army and Installation Commander's policies. The System is modular and scalable to allow future extensions to other security, access control and force protection systems. The System is flexible and can support future upgrades and technical advancements. AIE consists of Fixed-Full and wireless Handheld configurations. The Handheld configuration provides AIE capabilities to Installations that do not require the full System.

C-1.1 Major Equipment (Per Lane).

Table C-1 Major Equipment Per Lane

Video Cameras	Cameras to capture font of vehicle, rear of vehicle (for vehicle lane), and person's face (vehicle and pedestrian gates).
Lane Control Workstation	Touch-enhanced workstation for use by Guard to monitor and control devices at the lane or multiple lanes.
ACP Monitoring Workstation	Touch-enhanced workstation for use by Guard to monitor and control devices at one or more lanes.
Remote Monitoring Workstation	Touch-enhanced workstation for use by Guard to monitor and control devices at one or more lanes.
Guard Booth Intercom Station	Intercom station that allows Guard to answer and initiate calls from/to the vehicle and pedestrian lanes.
ACP Intercom Station	Intercom station that allows Guard to answer and initiate calls from/to the vehicle and pedestrian lanes.
Remote Monitoring Intercom Station	Intercom station that allows Guard to answer and initiate calls from/to the vehicle and pedestrian lanes.
Rhino Reader Pedestal	Multi-credential reader with display, biometric verification, and PIN pad.
Handheld Device	Retrieves all data in real time from the ACP server and presents it to the operator for situational awareness
Traffic Light	The Traffic Light interface is the Human-Machine Interface (HMI) that informs the vehicle driver to proceed (green light) or not proceed (red light).

Drop Arm	Used to control vehicle movement at the access pedestal

C-1.1.1 Lane Controls.

Lane Controls is the physical interface between an access control card reader and the Physical Access Control System (PACS) that controls the gate arm and coordinates other activities such as situational awareness, common operating picture, and services management. The PACS responds with two signal lines generally intended to light a red (access denied) or green (access granted) indicator that are presented to the user (driver or pedestrian).

C-1.2 Major Equipment (Per ACP).

Table C-2 Major Equipment Per ACP

ACP Monitoring Workstation	Touch-enhanced workstation for use by Guard to monitor and control devices at one or more lanes.
ACP Intercom Station	Intercom station that allows Guard to answer and initiate calls from/to the vehicle and pedestrian lanes.

C-1.3 Registration Operations.

Registration Stations interface displays registration information for the registrar as it is collected. The registrar interacts with the Entry Point registration workstation through the touchscreen monitor or with keyboard and mouse to assist the registrant in presenting appropriate information in expected order. Registration of personnel can also be conducted at the vehicle lane using the pedestal scanner or handheld device.

C-1.4 Registration Equipment.

Registration Data Collection interface allows the registrant to provide the data needed to vet the individual for potential registration in the AIE System. The data collection includes driver’s license and passport scanner, fingerprint scanner, signature capture, and PIN entry pad.

C-1.5 Registration Data Package.

The Registration Data Package interface utilizes the IP network to send the collected and packaged PIR data from the Entry Point Client to the Entry Point Server.

C-1.6 Database Overview.

The AIE System makes use of several databases that are described below in Figures C-1 and C-2. The databases are all managed by Microsoft (MS) SQL Server, Enterprise Edition. The choice of Microsoft SQL Server was made by the manufacturers of the COTS software – this is the only database management system (DBMS) that is supported by all software component manufacturers.

Figure C-1 AIE Operational View

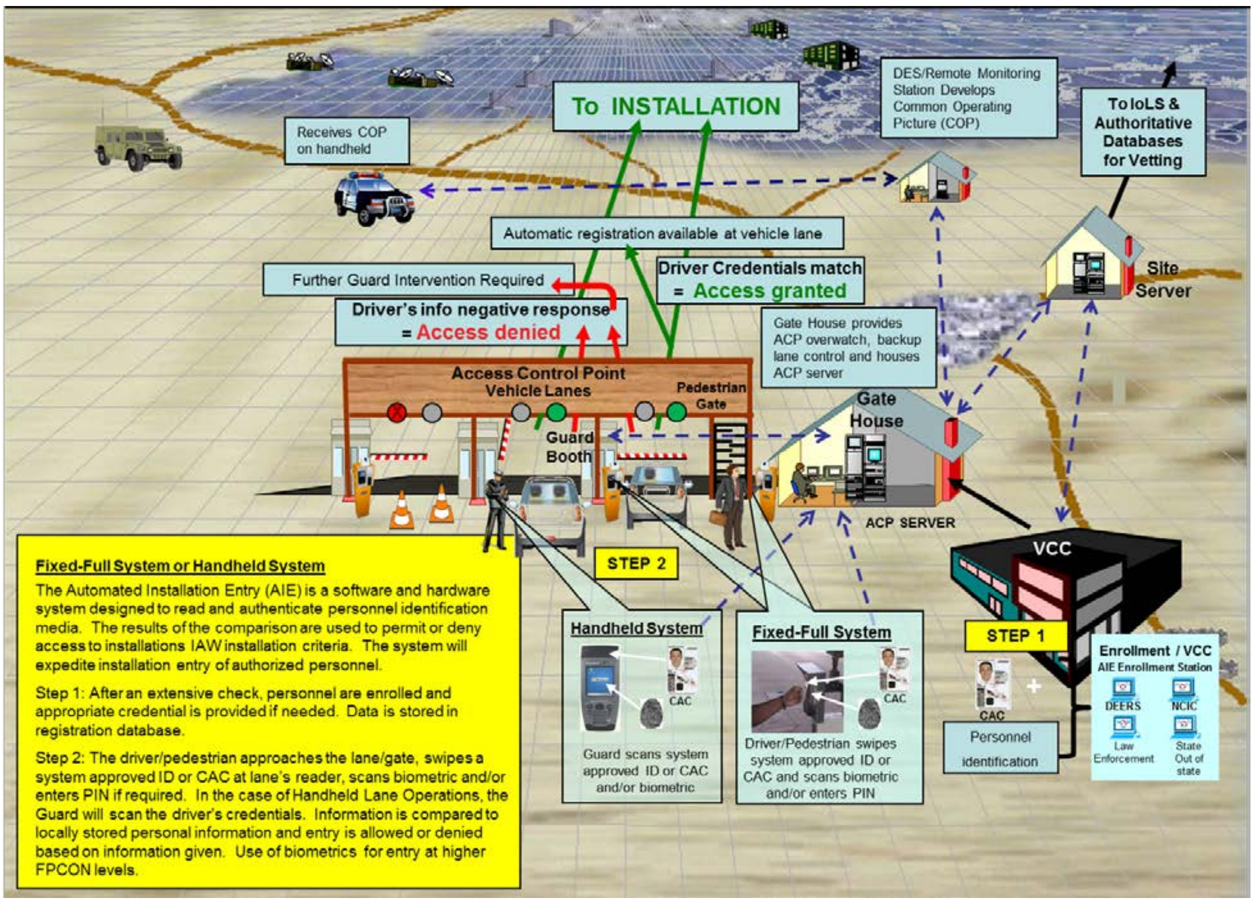
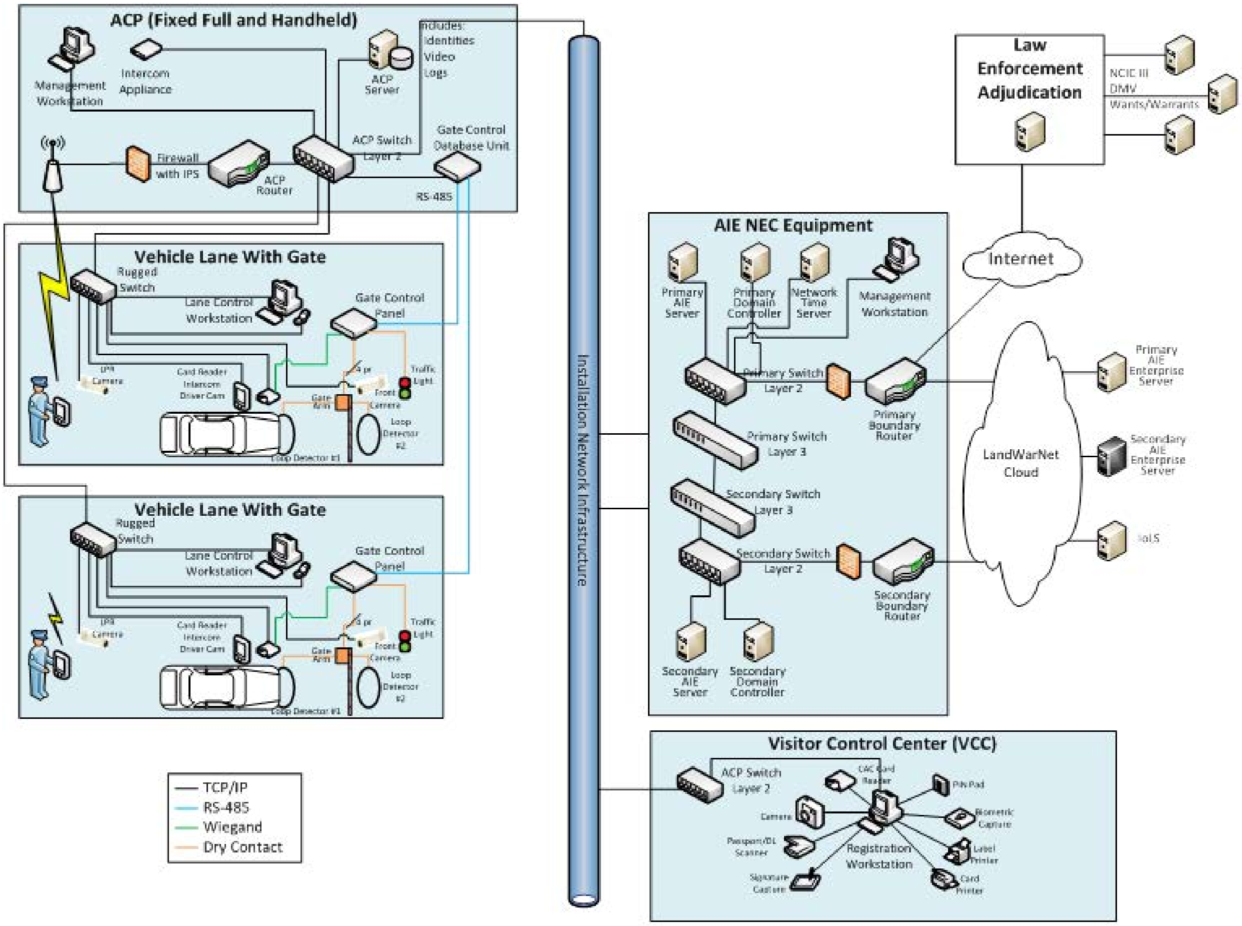


Figure C-2 System Connectivity and Interface Description



APPENDIX D ECF/ACP DEVELOPMENT CHECKLIST

This checklist is provided to assist the planning and design/RFP teams to determine the requirements and major features for an ECF/ACP project. This checklist should be utilized by the planning team, and validated by the RFP/Design team.

Arrange a stakeholder coordination meeting. If possible, include the following Base personnel and public representatives

Stakeholder	Representative Name	Organization	Title
Base Security			
Base Operations/Facilities			
Base Public Works/Utilties			
Base Enviromental			
Base Planning			
Base Antiterrorism Officer (ATO)			
Base Traffic Engineer			
Base Safety			
ECF EIC/Project Manager			
Local Municipality			
State/Local DOT			

Existing ECF/ACP:

1) What type of ECF/ACP? Primary / Secondary / Limited Use

2) What are the ECF/ACP hours of operation? ____________________

3) What are peak times and staffing levels at those times? ____________________

4) What are the staffing levels at off peak times? ____________________

5) How many inbound lanes? ____________________

6) How many outbound Lanes? ____________________

7) How are POVs processed? Single / Tandem

8) Are there traffic queuing issues? Yes / No

9) Does the ECF/ACP traffic affect the local community? Yes / No

10) Are current processing times unacceptable? Yes / No

11) Is the ECF/ACP a high crash area? Yes / No

Planning:

1) Was a traffic study done? *(if Yes, go to #6)* Yes / No

2) Will a traffic study be required to update/estimate traffic volumes necessary to validate scope and budget? Yes / No

3) Who will coordinate traffic study and when will it be performed?

__________________________/_______________

4) What are the queuing requirements? POV ________ Truck ________

5) How many vehicles/hour must the ECF/ACP process? __________________

6) Will future demand fluctuate due to mission changes, joint basing, or base closure? Yes / No

7) Will the ECF/ACP need to be designed for future demand? Yes / No

If Yes, please explain future demands:

____
____
____
____

8) Has a Conceptual Design Workshop been completed? Yes / No

If No, convene conceptual Design Workshop if necessary to establish conceptual design. Workshop may be necessary to confirm budget and scope of project.

9) Are there any site-specific challenges unique to the project such as Historical significance or Installation Appearance Plan (IAP), or current site/area availabilities that may affect budget or design? Yes / No

If Yes, explain site specific challenges:

____
____
____
____

10) Are there any environmental considerations such as wetlands, protected habitats, or cultural resources? Yes / No

If Yes, explain considerations:

____
____
____
____

11) May the current ECF/ACP be closed for the duration of construction? Yes / No

12) Will a secondary gate be opened? Yes / No

If Yes, which gate? ___________________________

13) Will a temporary ECF/ACP have to be constructed? Yes / No

14) During ECF construction, will traffic be rerouted? Yes / No

15) What are the contractor's responsibilities in regards to gate closure and traffic rerouting?

____
____

16) Will this ECF/ACP process Commercial/Large Vehicles? Yes / No

If NO, go to #22

17) Will Commercial/Large Vehicle Inspections be conducted at the ECF/ACP or at a remote site? Yes / No

18) What is the queuing requirement for the Commercial/Large Vehicle Inspection facilities?

19) Will Large Commercial Vehicle/Truck Inspection Facilities require a canopy?

Yes / No

20) Will Large Commercial Vehicle/Truck Inspection facilities require an inspection office?

Yes / No

21) How will Commercial/Large Vehicles be processed?

22) What commercial vehicle inspection equipment will be incorporated and are the specifications available?

23) Will this ECF/ACP process Buses/other Public Transportation vehicles? Yes / No

If Yes, how will uses be processed?

24) Are bus shelters required for this ECF/ACP? Yes / No

If Yes, list requirements for shelter:

____

____

25) Will the ECF/ACP process pedestrians? Yes / No

If Yes, how will pedestrians processed?

____

____

____

____

26) Will the ECF/ACP process bicycles? Yes / No

If Yes, how will bicycles processed?

____

____

____

____

27) Will the ECF/ACP process visitors? Yes / No

If Yes, will a visitor's center be required? Yes / No

28) Will the ECF/ACP process any unique vehicles? Yes / No
(Construction/Weight Handling/Wide Load Vehicles)

____

____

____

29) What is the design threat vehicle? _____ lb. / kg

30) Will a new Gatehouse be required for the ECF/ACP? Yes / No

31) Will new Guard Booths be required for the ECF? Yes / No

If Yes, how many Guard Booths are required? ________

32) Are prefabricated guard booths/houses acceptable? Yes / No

33) Will an Overwatch Position be required for the ECF/ACP? Yes / No

If Yes, will it be permanent structure or concrete pad? Structure / Pad

34) Will an Overhead Canopy be required for the ECF/ACP? Yes / No

35) Will signal light timing have to be coordinated with off installation systems?

Yes / No

36) Will public roadways or signal lights have to be modified to implement new ECF/ACP? Yes / No

If Yes, describe modifications.

____

____

____

____

37) Will active and passive vehicle barriers be required? Yes / No

If Yes, what type of active barrier does the base have or desire?

Net / Wedge / Bollards

38) What type of fencing will be required to match existing appearance?

Chain-Link / Ornamental / ____________

39) Locate utility connection points:

Water:

Connection Point _________________Size ________ Distance ________

Sewage:

Connection Point _________________Size ________ Distance ________

Storm water:

Connection Point _________________Size ________ Distance ________

Electric:

Connection Point _________________Size ________ Distance ________

Voice:

Connection Point _________________Size ________ Distance ________

Data:

Connection Point _________________Size ________ Distance ________

Security (duress, identity management, CCTV monitoring):

Connection Point _________________Size ________ Distance ________

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APPENDIX E GLOSSARY

ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ACP	Access Control Point
ABA	Architectural Barriers Act
AFMAN	Air Force Manual
AR	Army Regulation
AT	Antiterrorism
ATO	Antiterrorism Officer
AVB	Active Vehicle Barrier
BIA	Bilateral Infrastructure Agreements
CBR	Chemical, Biological and Radiological
CCR	Criteria Change Request
CCTV	Closed Circuit Television
CFR	Code of Federal Regulations
CONUS	Continental United States (Within the United States and its territories and possessions.)
CRI	Color Rendition Index
DLAR	Defense Logistics Agency Regulation
DoD	Department of Defense
DoS	Department of State
DOT	Department of Transportation
DVR	Digital Video Recorder
ECF	Entry Control Facility
EFO	Emergency Fast Operation

EOC	Emergency Operations Center
FDA	Food and Drug Administration
FHWA	Federal Highway Administration
FP	Force Protection
FPCON	Force Protection Condition
FOUO	For Official Use Only
GCC	Geographic Combatant Command
GFI	Ground Fault Interrupt
HAZMAT	Hazardous Material
HID	High intensity Discharge
HNFA	Host Nation Funded Construction Agreement
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	Heating Ventilating Air Conditioning
IAW	In Accordance With
ID	Identification
IDS	Intrusion Detection System
IEEE	Institute of Electrical and Electronics Engineers
IEQ	Indoor Environmental Quality
IESNA	Illuminating Engineering Society of North America
ITE	Institute of Transportation Engineers
LEED	Leadership in Energy and Environment Design
LIDAR	Light Detection and Ranging
MCO	Marine Corps Order
MIL-STD	Military Standard
MP	Military Police

mR	milli-Roentgens
MUTCD	Manual on Uniform Traffic Control Devices
NAVFAC	Naval Facilities Engineering Command
NFPA	National Fire Protection Association
OCONUS	Outside the Continental United States (Outside the United States and its territories and possessions.)
OPNAVINST	Chief of Naval Operations Instruction
PDC	Protective Design Center
POV	Privately Owned Vehicle
PROWAG	Public Rights of Way Guidelines
RAM	Random Antiterrorism Measures
SDDCTEA	Surface Deployment and Distribution Command –
SOFA	Status of Forces Agreement
SU	Single Unit (Vehicle)
TCP/IP	Transmission Control Protocol/ Internet Protocol
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UL	Underwriters Laboratories
UPS	Uninterruptible Power Supply
USACE	U.S. Army Corps of Engineers
USD (AT&L)	Under Secretary of Defense of Acquisition, Technology, and Logistics
UVSS	Under Vehicle Search Systems
WB	Wheel Base
WBDG	Whole Building Design Guide

UFC 4-022-02
8 June 2009
Change 1, 9 August 2010

UNIFIED FACILITIES CRITERIA (UFC)

SELECTION AND APPLICATION OF VEHICLE BARRIERS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

SELECTION AND APPLICATION OF VEHICLE BARRIERS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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

Change No.	**Date**	**Location**
1	August 9, 2010	Revisions throughout Document: Deleted Appendix B – List of Manufacturers; revised document text and appendices accordingly.

This UFC supersedes MIL-HDBK-1013/14, dated 1 February 1999.

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

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

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

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

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UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

Document: UFC 4-022-02, Selection and Application of Vehicle Barriers
Superseding: Military Handbook 1013/14, Selection and Application of Vehicle Barriers

Description: Provides a unified approach for the design, selection, and installation of active and passive vehicle barriers associated with Department of Defense (DoD) facilities. The examples provided in this UFC are for illustration only and shall be modified and adapted to satisfy installation specific constraints. This UFC is not intended to address procedural issues such as threat levels or to provide specific design criteria such as impact forces.

This UFC was developed by consolidating and refining criteria from USACE Protective Design Center, Security Engineering Working Group (SEWG); Naval Facilities Engineering Command (NAVFACENGCOM), Engineering Criteria Office, Engineering Service Center and available military, government, and commercial sources\1\ /1/.

Commanders, security and antiterrorism personnel, planners, designers, architects, and engineers should use this UFC when evaluating existing and providing new vehicle barriers. Technical information considered generally known to professional designers, architects, engineers, or readily available in technical references (UFC, Military Handbooks, Technical Manuals, etc.) has not been included.

Reasons for Document: Vehicle barriers are primarily used as one of many elements that define perimeters that require a final denial barrier to be provided for certain restricted areas. This UFC focuses of the design, selection, and application of active and passive vehicle barriers.

Impact: The following direct benefits will result:

- A standardized approach for identifying and justifying security and antiterrorism design criteria for DoD facilities;
- A standardized nomenclature and criteria for asset, threat, and level of protection definition;
- A standardized procedure for identifying costs for DoD facilities with security and antiterrorism requirements to a planning level of detail;
- A standardized process for evaluating design criteria and protection options based on cost and risk management;
- Guidance for incorporating security and antiterrorism principles into installation master planning; and
- There are no adverse impacts on environmental, sustainability, or constructability policies or practices.

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CHAPTER 1 - INTRODUCTION

1-1 PURPOSE.

This UFC provides the design requirements necessary to plan, design, construct, and maintain vehicle counter-mobility barriers used within Entry Control Facilities (ECF) or as perimeter protection. This UFC is to be used during the design of Department of Defense (DoD) facilities to ensure an optimal vehicle barrier system is selected by engineers and security personnel for a specific operation within an installation. Barrier performance, maintenance, and cost should all be optimized. It is intended to establish consistent requirements, standards, and design basis for barrier planning, design, construction, and maintenance for all military departments. This UFC identifies design features necessary to ensure that infrastructure constructed today will have the flexibility to support future technologies, a changing threat environment, and changes in operations.

1-2 INTRODUCTION.

A vehicle barrier selection and placement process is presented herein, along with criteria for the design, selection, installation, operation, and maintenance of security barrier systems. The selected barrier system must effectively stop and/or disable vehicles that pose a threat, including explosive laden vehicles, of breaching the perimeter of a protected area. Both passive (static or non-movable) perimeter barriers and active (operational for access control) barriers at facility entrances are included. The examples presented in this UFC are for illustration purposes only and should be modified and adapted to satisfy installation specific constraints. This UFC is not intended to address procedural issues such as tactics and techniques; however, an appropriately designed vehicle barrier system used within an ECF/ACP or along an installation perimeter can enhance and improve operations.

1-3 BACKGROUND.

Guidance and documentation regarding issues of vehicle barriers and vehicle counter-mobility design are provided within the joint military services. Each document presents useful information to engineers, planners, architects, and security personnel responsible for Entry Control Facilities (ECFs) and Access Control Points (ACPs), both existing and new facility construction involving vehicle barriers and counter-mobility techniques.

Until now, there has been no single DoD document that provides all the information required for vehicle barrier design. This UFC, in conjunction with UFC 4-022-01 for Entry Control Facilities/Access Control Points, establishes consistent standards and requirements for each military service branch. The UFC supplements and is referenced by the Security Engineering Facility Planning Manual (UFC 4-020-01) and the Security Engineering Facility Design Manual (UFC 4-020-02). The design of a vehicle barrier system should begin with planning as directed in UFC 4-020-01, then graduate to design guidance provided in UFC 4-020-02, then culminate with selection and installation of a barrier system using this UFC.

1-4 SCOPE AND USE OF GUIDANCE.

Commanders, security personnel, planners, designers, and engineers should use this UFC when designing vehicle barrier systems for ECFs or other perimeter locations. Technical information considered generally known to professional designers or engineers or readily available in existing technical references (Unified Facility Criteria, Military Handbooks, Technical Manuals, etc.) has not been included.

1-5 SECURITY ENGINEERING UFC SERIES.

This UFC is one of a series of security engineering Unified Facilities Criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include the following:

a. DoD Minimum Antiterrorism Standards for Buildings. UFC 4-010-01 DoD Minimum Antiterrorism Standards for Buildings and UFC 4-010-02 DoD Minimum Antiterrorism Standoff Distances for Buildings establish standards that provide minimum levels of protection against terrorist attacks for the occupants of all DoD inhabited buildings. Those UFC are intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new constructions and major renovations of inhabited DoD buildings. They also include recommendations that should be, but are not required to be, incorporated into all such buildings.

b. Security Engineering Facilities Planning Manual. UFC 4-020-01 *Security Engineering Facilities Planning Manual* presents processes for developing the design criteria necessary to incorporate security and antiterrorism into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also includes a means to assess the tradeoffs between cost and risk. The Security Engineering Planning Manual is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

c. Security Engineering Facilities Design Manual. UFC 4-020-02 *Security Engineering Facilities Design Manual* provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02 is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design. The manual also provides a process for assessing the impact of protective measures on risk. The primary audience for the Security Engineering Facility Design Manual is the design team, but it can also be used by security and antiterrorism personnel.

d. Security Engineering Support Manuals. In addition to the standards, planning, and design UFC mentioned above, there is a series of additional UFC that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, forced entry, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mailrooms. Still others address details of designs for specific protective measures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

CHAPTER 2 - EXISTING REQUIREMENTS AND TECHNICAL GUIDANCE

2-1 GENERAL.

This UFC should be used in conjunction and coordination with UFC 4-020-01 Security Engineering Facilities Planning Manual, UFC 4-020-02 Security Engineering Facilities Design Manual, UFC 4-022-01 Security Engineering: Entry Control Facilities/Access Control Points, and UFC 4-022-03 Security Engineering: Fences, Gates and Guard Facilities to guide the user through a selection process to establish a protective barrier system around a DoD installation and designated restricted areas within the installation (enclave areas). A systematic approach is used. The main issues to be considered during the selection and design of a vehicle barrier include:

a. *Threat Analysis* – to quantify the potential threat. For threat analysis, refer to UFC 4-020-01 Security Engineering Facilities Planning Manual and UFC 4-020-02 Security Engineering Facilities Design Manual. The procedures in these manuals will quantify and qualify all potential threats, including the "moving" vehicle bomb threat necessary for the determination of the appropriate vehicle barrier for a given location.

b. *Performance* – to determine the appropriate levels of protection (both to personnel and property). An acceptable level of protection must be defined by the installation commander.

c. *Access Control Measures* – physical controls, operating procedures, hardware and software features used in various combinations to allow, detect, or prevent access.

d. *Requirements* – appropriate standoff distance to maintain a level of protection compatible with operational needs; passive or active barrier systems to stop the threat vehicle; barrier reliability and maintainability, safety, sabotage and malfunction protection, and cost effectiveness.

e. *Response* – potential structural damage to the vehicle barrier from blast loads produced during an explosion.

f. *Liabilities* – potential liability effects on the decision to protect assets against the effects of a terrorist act.

g. *Cost* – security expenditures based on the value of the asset to be protected and the importance of the asset to national security and readiness. For protection against vehicle bombs, the potential loss of human life generally drives the cost of security, overriding the value of the property to be protected. The decision to use vehicle barriers and provide protection against terrorist vehicle bombs is primarily motivated by protection of personnel.

2-2 **DOD REQUIREMENTS**. There are several instructions and publications within the Department of Defense that establish access control, physical security, and antiterrorism requirements for the Department of Defense installations and restricted areas.

2-2.1 **DOD 5200.8-R Physical Security Program**.

This regulation requires DOD Components to determine the necessary access control based on the requirements of a developed physical security program. Emergency planning is specified to include establishment of a system for positive identification of personnel and equipment authorized to enter and exit the installation and maintenance of adequate physical barriers that will be deployed to control access to the installation. Planning will also include increasing vigilance and access restrictions during higher force protection conditions

2-2.2 **DOD 2000.12 DOD Antiterrorism (AT) Program**.

This directive provides DOD policies for ATFP and assigns responsibilities for implementing the procedures for the DOD ATFP Program. It authorized the publication of DOD O-2000.16 as the DOD standards for ATFP and DOD O-2000.12-H DOD Antiterrorism Handbook as guidance for the DOD standards. DOD O-2000.12H defines the DOD Force Protection Condition (FPCON) System, which describes the potential threat levels and the applicable FPCON measures to be enacted for each level. It also requires Commanders to develop and implement Random Antiterrorism Measures (RAM) as an integral part of their AT Program.

2-2.3 **DOD 2000.16 DOD Antiterrorism Standards**.

This instruction and service directives require the installation or activity Commanding Officer to define the access control measures at installations. Additionally DOD 2000.16 requires Commanders at all levels to develop and implement a comprehensive Antiterrorism (AT) Program, which should define the necessary action sets, including identification and inspection procedures, at each of the potential Force Protection Condition (FPCON) levels.

2-3 **COMBATANT COMMANDER REQUIREMENTS**

Combatant Commanders issue requirements for Antiterrorism and physical security for installations within their area of responsibility. Ensure any such requirements are incorporated in addition to the requirements found in this UFC

2-4 **ADDITIONAL REFERENCES**.

Other documents, drawings, and publications that could contribute to the guidance provided in this UFC are listed below.

PDC-TR90-2	Barrier Impact Response Model 3

	Dimension (BIRM 3D)
SD-STD-02.1, Revision A	Specification for Vehicle Crash Test of Perimeter Barriers and Gates
UFGS 34 71 13.19	Unified Facilities Guide Specification, Active Vehicle Barriers
UFGS 12 93 00	Unified Facilities Guide Specification, Site Furnishings
ASTM F 2656-07	Standard Test Method for Vehicle Crash Testing of Perimeter Barriers

Means, R.S., "Building Construction Cost Data", 61st Edition, 2003 (Copies can be ordered from the R.S. Means website: http://www.rsmeans.com)

2-5 **REFERENCE WEBSITES**.

Copies of many of the documents referenced in this chapter can be obtained from the following websites.

a. Whole Building Design Guide web site http://www.wbdg.org/references/pa_dod.php (See Service Specific information on the right hand side of the website.)

b. United States Army Corps of Engineers (USACE), Protective Design Center, Omaha District https:/pdc.usace.army.mil/library/drawings/acp

CHAPTER 3 - DEFINITIONS

3-1 **ACRONYMS**.

The acronyms used in this UFC are defined below.

a) BDAM - Blast Damage Assessment Model

b) CCTV - Closed-Circuit Television

b) DOD - Department of Defense

c) DODISS - DOD Index of Specifications and Standards

d) DOS - Department of State

e) ERASDAC - Explosive Risk and Structural Damage Assessment Code

f) FACEDAP - Facility and Component Explosive Damage Assessment Program

g) FRF - Fragment-Retention Film

h) MIL-HDBK - Military Handbook

i) NAVFAC - Naval Facilities Engineering Command

j) NFESC - Naval Facilities Engineering Service Center

k) PDC - Protective Design Center

CHAPTER 4 - VEHICLE BARRIER DESIGN PARAMETERS

4-1 GENERAL.

Vehicles loaded with explosives can detonate as a large bomb, inflicting severe damage on critical military facilities and potentially injuring DoD personnel. Such vehicle bombs are effective terrorist tools because they facilitate the transport of large quantities of explosives to any desired location. When planning and selecting vehicle barriers to be used for facility perimeter protection, the first step is to determine the Design Basis Threat (DBT) for any given location in the facility. Table B-1 provides active vehicle barrier kinetic energy rating and vehicle penetration based on the SD-STD-02.1 Revision A test standard. The DBT may vary within and around the installation. It can be affected by guidance instructions specific to the area and service specific guidance. UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Buildings*, as well as local and service specific guidance documents, should be consulted in defining Design Basis Threats at each location where barriers are required.

Several factors should be considered when setting up defense against the DBT: (1) the occupied structures in a particular area; (2) the barrier penetration capabilities of the DBT vehicle (based on the maximum vehicle velocity to the barrier location, the angle of impact, and the area around the barrier location); and (3) the structural response of and potential debris throw from the barrier, if the vehicle bomb detonates.

Both stationary and moving vehicle bombs need to be considered. To effectively prevent a moving vehicle from getting close to the intended target, the perimeter barrier must absorb the kinetic energy produced by the total weight of the vehicle bomb (vehicle weight plus the weight of explosives and any other cargo in the vehicle) and the vehicle's maximum attainable speed at the point of impact. Thus, kinetic energy is a primary factor used to establish performance requirements for moving vehicle barriers.

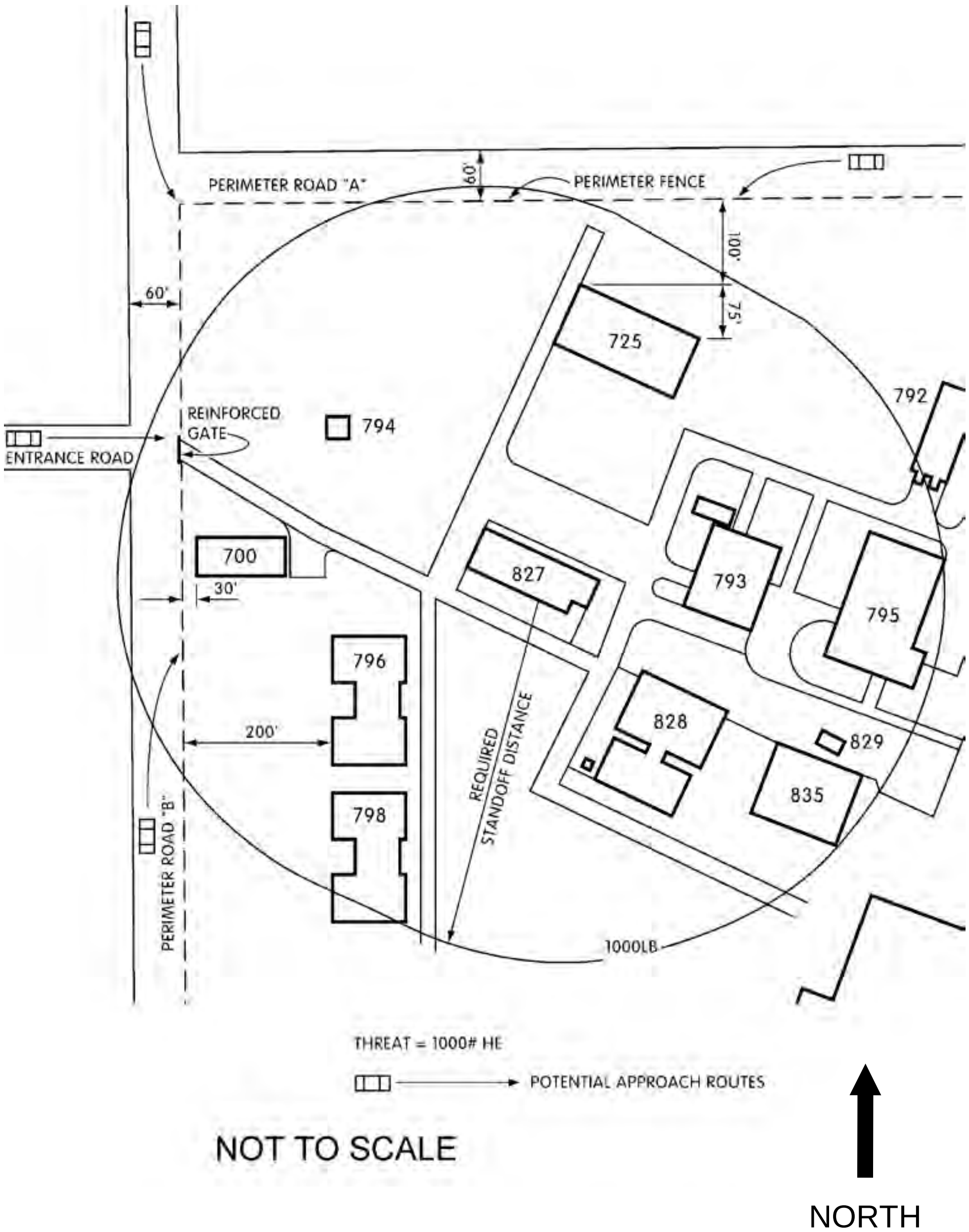
Another primary consideration for either stationary or moving vehicle bombs should be the barrier's response to the load produced by detonation of the explosives in the vehicle. The amount of debris produced and subsequent debris throw distance should also factor into the selection of appropriate barriers.

4-2 SITE SURVEY.

The process of selecting and designing a barrier system begins with determination of the Design Basis Threat (DBT) and required levels of protection. Reference UFC 4-020-01, *Security Engineering Facilities Planning Manual* and UFC 4-020-02, *Security Engineering Facilities Design Manual* for methods to determine the DBT and levels of protection. Next, preparations are made for a site survey. First, a scaled map of the protected area must be prepared from detailed plans of the facility that must include at least one block beyond the perimeter. This map should include the relative locations, major dimensions and descriptions of structures, roads, terrain and landscaping, existing security features, and property perimeter. Any features outside the perimeter (within one block or so) that could possibly be used to reduce vehicle speed, prevent access to the perimeter barrier, shield structures from damage in the event of an explosion, or affect an aggressor's progress in any other way should be shown on the site map as well. This map will permit careful analysis of distances and topographical features between the perimeter and the facility. The map identifies potential vulnerabilities. Due to the information included on any such site map, it may need to be a classified document. Figure 4-1 shows an example site map for a facility.

As shown in Figure 4-1, the individual segments of the perimeter can be attacked from a variety of paths. For example, for Building 827 with a controlled area on two sides of the perimeter, the two remaining sides (Perimeter Roads "A" and "B") are vulnerable to a vehicle attack. The Entrance Road and the extension of Perimeter Road "B" are perpendicular and lead directly to the compound boundary. Each of these roads is a potential attack path. Certain segments of the perimeter can be attacked from more than one street. In addition, for Perimeter Roads "A" and "B", running parallel to the perimeter, there are an infinite number of impact points and angles depending upon vehicle location and speed. As a result, a large number of potential impact conditions (the combination of vehicle speed and impact angle) can occur at any point along the perimeter boundary.

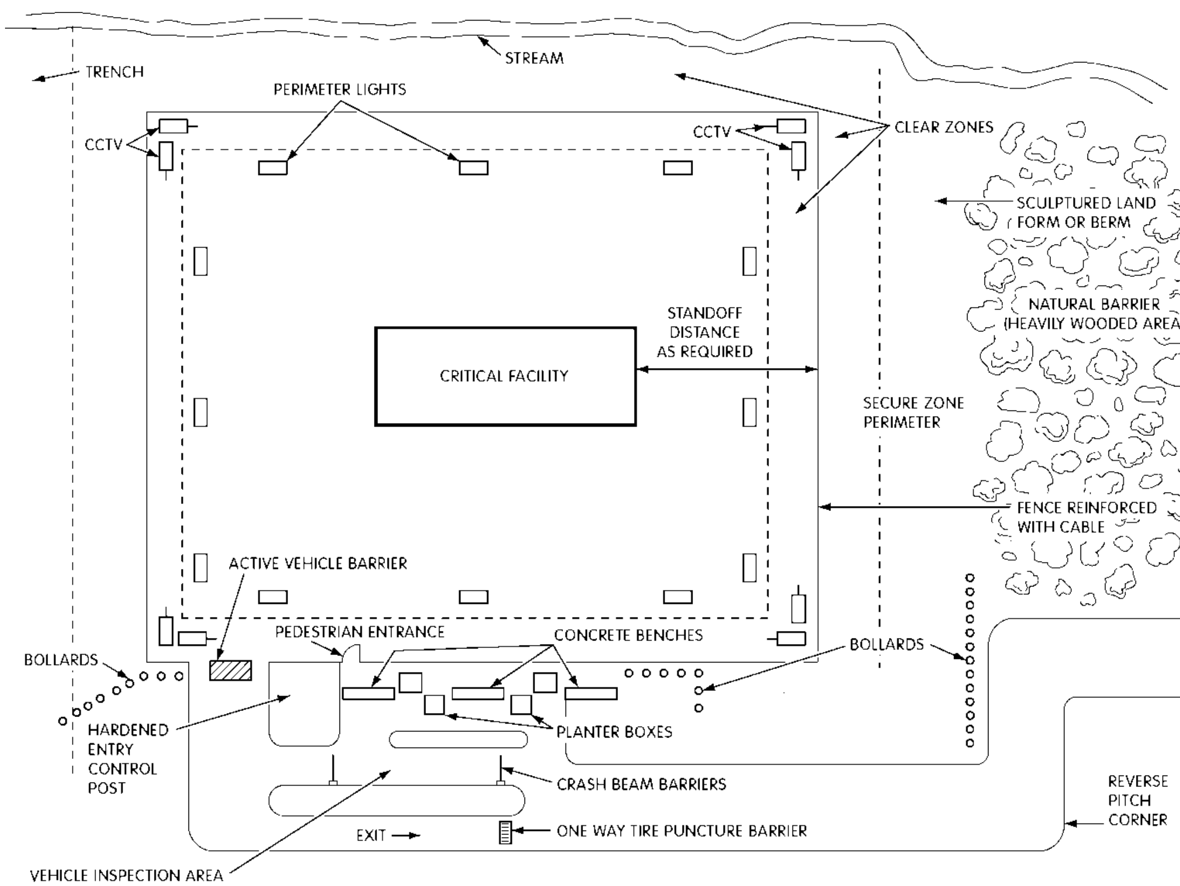
Figure 4-1 Example Site Layout



4-3 INTEGRATED PHYSICAL SECURITY SYSTEM.

Any vulnerabilities identified in the site survey should be addressed by developing an integrated physical security protection system. Design Basis Threats identified for the specific facility and current security requirements need to be considered. These threats are determined by assessment of site-specific threats or are specified by an installation. Comprehensive protection can be provided by coordinating physical barriers (such as fences, active barriers, and passive barriers) with other security components and options. For example, perimeter sensors, lights, and closed circuit television can be used to detect vehicles attempting to covertly penetrate the perimeter. Sallyports can be used to detect bombs hidden in vehicles entering a facility. Performance of the perimeter barrier can be enhanced with strategic placement of bollards, ditches, and planters. A wide range of potential threats can be detected early using clear zones as well. All barrier requirements should be coordinated with the ECF design guidance given in UFC 4-022-01 *Security Engineering: Entry Control Facilities/Access Control Points.* Figure 4-2 illustrates some examples of integrated physical security measures.

Figure 4-2 Integrated Physical Security System



4-4 ATTAINABLE VEHICLE SPEED.

The speed of a vehicle at the point of impact on a vehicle barrier is a major parameter in determining the required performance of the barrier. The impact is calculated from the initial speed, "**v**", the acceleration rate, "**a**", and the distance, "**s**", available for acceleration between the starting point and the point of impact. Additional factors that must be considered are the general terrain, the surface condition of the path, whether or not the path is straight, curved, or banked. Information presented in Figure 4-1 through Figure 4-7 allows calculation of maximum attainable vehicle speed, or suggests strategies for modifying possible attack paths to control vehicle speed.

The impact speed along the perimeter should be calculated for all possible driving paths identified on the site survey map. The strategy for barrier system design, selection, and installation can then be developed using this data.

The methods presented in this section for determining attainable vehicle speeds assume flat roadway surfaces. Most roadways are not flat, either due to super-elevation or to typical roadway crowning and constructed transverse slopes. If a driver can use a non-flat roadway surface to his advantage in attaining a higher speed, this needs to be taken into consideration. The use of any geometrics in the selection of barriers and design of an ECF should only be provided under the guidance of an engineer experienced in roadway/transportation engineering. Otherwise, some of the assumptions for the methods in this section may be highly conservative and may lead to designs that are treacherous for vehicles traveling at normal/design speeds, for vehicles traveling during wet conditions, or for large commercial and emergency vehicles.

Consult with the AASHTO Roadside Design Guide and AASHTO Geometric Design of Highways and Streets for roadway design and road geometry/geometric requirements.

4-4.1 Attainable Vehicle Speed on a Straight Path.

The highest attainable vehicle speed results from a long, straight path between the starting point and a vehicle barrier.

a) On a Horizontal Surface. On a horizontal, straight path, the speed attainable by an accelerating vehicle depends primarily on its initial speed, "$\mathbf{v_0}$", the acceleration, "**a**", and the distance, "**s**", traveled during acceleration. The relationship among these parameters is given in Equation (1).

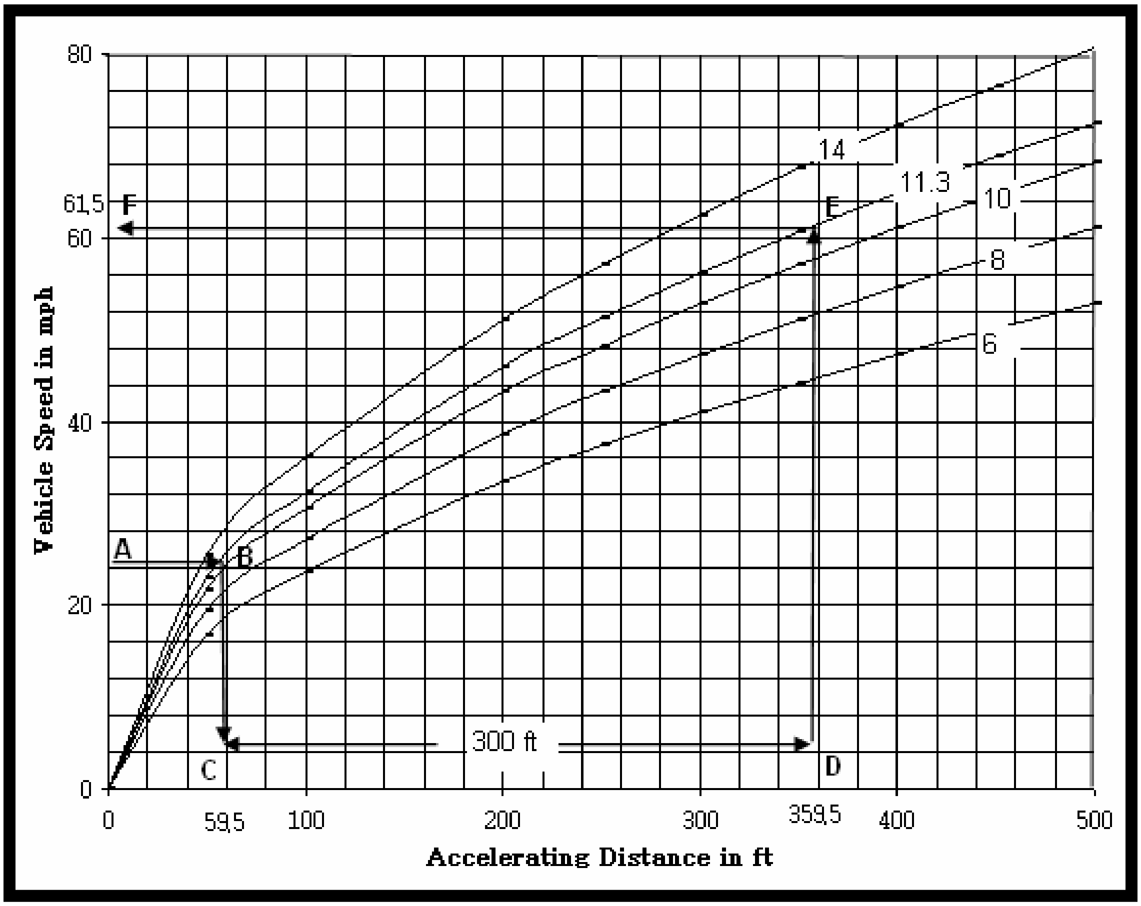
$$\mathbf{v = (v_0^2 + 2as)^{1/2}} \quad (1)$$

where:

- $\mathbf{v}$ = final vehicle speed (mph or kph)
- $\mathbf{v_0}$ = initial vehicle speed (mph or kph)
- $\mathbf{a}$ = acceleration (ft/sec^2 or m/sec^2)
- $\mathbf{s}$ = distance traveled (feet or meters)

For convenience, Equation (1) is plotted as Figure 4-3, using a conversion factor for values in ft/sec^2 and mph.

Figure 4-3 Vehicle Speed vs. Acceleration Distance



To illustrate its use, consider the case of a high performance car accelerating on a 300-ft (91.5 m), straight, horizontal path with initial speed, $\mathbf{v_0}$ = 25 mph (15.53 kph), and acceleration, **a** = 11.3 ft/sec^2 (3.4 m/sec^2). The speed at the end of the path will be determined as follows:

Locate $\mathbf{v_0}$ = 25 mph (15.53 kph) on the vertical axis (point A).

Draw a horizontal line from point A until it intersects the curve (at point B) for **a** = 11.3 feet per second^2 (3.4 m/sec^2).

Draw a vertical line down from point B until it intersects the horizontal axis (point C). This is the point from which velocity will be calculated.

Locate point D on the horizontal axis so that the distance between points C and D is the accelerating distance [300 feet (91.5 m) in this example].

Draw a vertical line up from point D until it intersects the curve (at point E) for **a** = 11.3 ft/sec^2 (3.4 m/sec^2).

Draw a horizontal line from point E until it intersects the vertical axis (point F).

The value of the speed, "**v**", at point F, 61.5 mph (98.97 kph), is the answer.

Note: If "$\mathbf{v_0}$" = 0, the graph can be used to determine velocity from a dead start.

b) On a Slope. Due to gravitational effect, to achieve the same final speed as that on a horizontal path, the required distance for acceleration on a slope will be shorter (longer) if the vehicle is traveling downhill (uphill). Let, "**s**", be the acceleration distance needed to also attain final speed, "**v**", on a horizontal path, and let, "**s'**", be the acceleration distance needed to attain, "**v**", on a sloped path. The following relationship shown in Equation (2) applies:

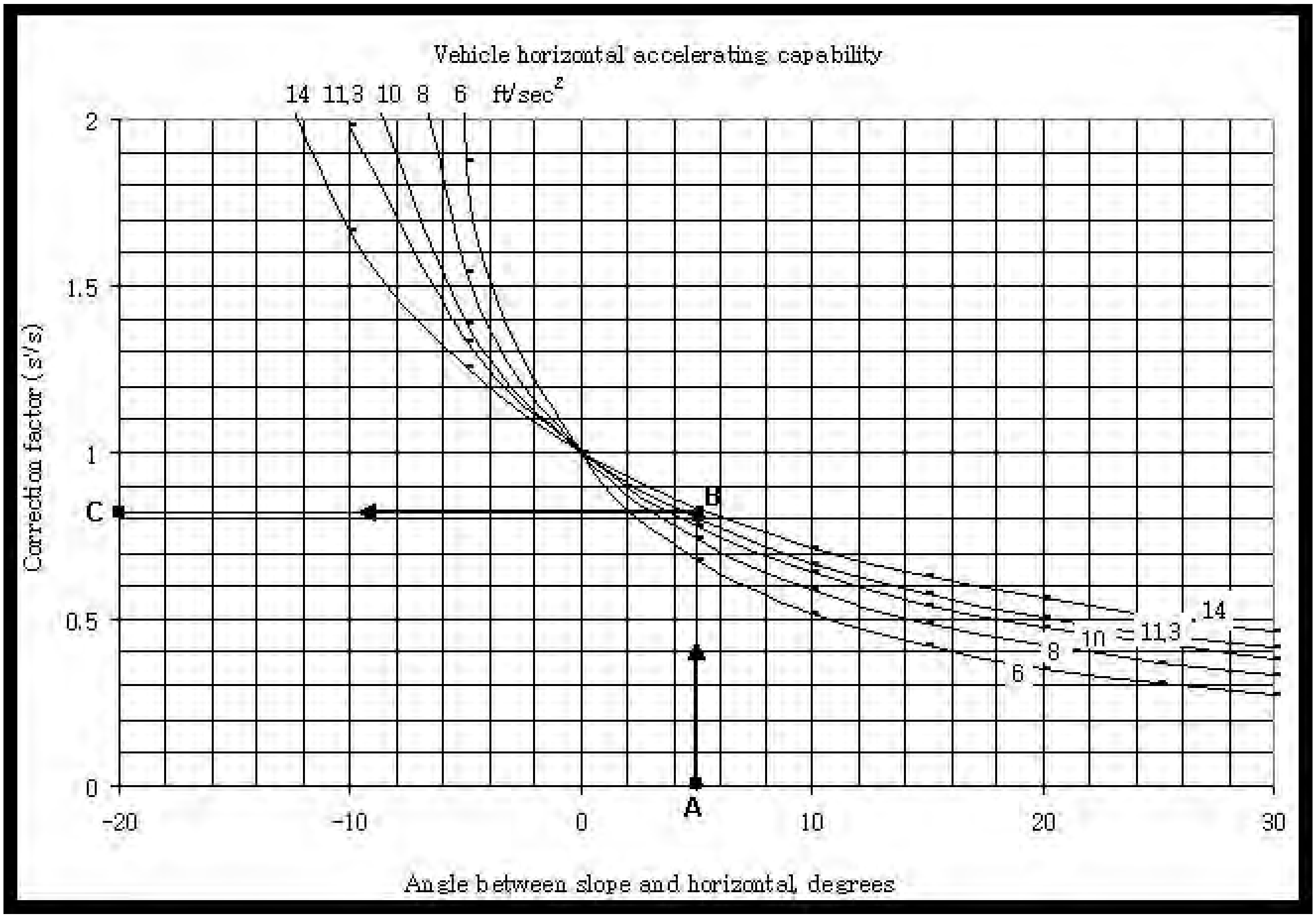
$$\mathbf{s'/s = 1/[1 + (g/a)\sin\theta]} \quad (2)$$

where:

- **s'** = acceleration distance needed to attain final speed on a sloped path
- **s** = acceleration distance needed to attain final speed on a horizontal path
- **g** = gravitational constant = 32.2 ft/sec2 (9.82 m/sec2)
- **a** = acceleration of the vehicle, ft/sec2
- θ = angle between the slope and the horizontal in degrees

This correction factor relationship is plotted as Figure 4-4.

Figure 4-4 Speed Correction Factor for Vehicles Driving on a Sloped Path



To illustrate the use of this figure, consider the example used in 4-4.1a, except the vehicle is traveling downhill on a 5-degree slope. The steps are:

Locate 5 degrees on the horizontal axis (point A).

Draw a vertical line up from point A until it intersects the curve (at point B) for **a** = 11.3 ft/sec^2 (3.4 m/sec^2).

Draw a horizontal line from point B toward the vertical axis and read off the "**s'/s**" value at the intersecting point C.

The value of **s'/s** is 0.8. Because **s' = s x (s'/s)** and **s** = 300 feet (91.5 m), therefore **s'** = 300 feet (91.5 m) x 0.8 = 240 feet (73.2 m).

This example shows that to accelerate the vehicle to the same 61.5 mph speed (98.97 kph), a 5-degree slope will help shorten the accelerating distance from 300 feet (91.5 m) to 240 feet (73.2 m). It clearly demonstrates the increased vulnerability caused by local terrain sloping down toward a protected area. Modifying the local terrain is an effective way to minimize vulnerability.

4-4.2 **Attainable Vehicle Speed on a Curved Path**.

Centrifugal force makes it difficult to drive fast on a curve unless the road surface is properly banked. The centrifugal force, "**CF**", of a vehicle moving on a curved path depends on its weight, "**w**", the radius of the curvature, "**r**", and the speed, "**v**", and **g** = gravitational constant = 32.2 ft/sec^2 (9.82 m/sec^2), as shown in Equation (3).

$$\mathbf{CF = wv^2 /(gr)} \qquad (3)$$

where:

CF = centrifugal force (lbs/kgs)
W = vehicle weight (lbs/kgs)
r = radius of curvature (feet/meters)
v = vehicle speed (mph/kph)
g = gravitational constant = 32.2 ft/sec2 (9.82 m/sec2)

When the "**CF**" is large enough, it will overcome the road friction and a vehicle will skid. The vehicle could also topple if its center of gravity is too high. Because skidding usually occurs first, only this condition will be considered here. Road friction force, "**FF**," equals the product of the vehicle weight, "**w**," and the friction coefficient, "**f**," between the tires and the road surface, as shown in Equation (4).

$$\mathbf{FF = fw} \qquad (4)$$

where:

FF = road friction force
f = friction coefficient
w = vehicle weight

NOTE: The value of friction coefficient, "f", is between 0 and 1 and is highly variable. It depends on the tire and its condition, the material and condition of the drive path, any oil or water on the drive surface, etc. On a roadway, under normal conditions, f = 0.6 is usually used. If unable to determine, use f = 1, which will provide a more conservative value.

a) On a Horizontal Surface. The skidding speed (the speed at which skidding occurs), "$\mathbf{v_S}$", is obtained by equating the centrifugal force and the road friction force, as shown in Equations (5) and (6).

$$\mathbf{fw = w\, v_S^2 /(gr)} \qquad (5)$$

where:

f = friction coefficient
w = vehicle weight
$\mathbf{v_S}$ = skidding speed
g = gravitational constant
r = radius of curvature

From which,

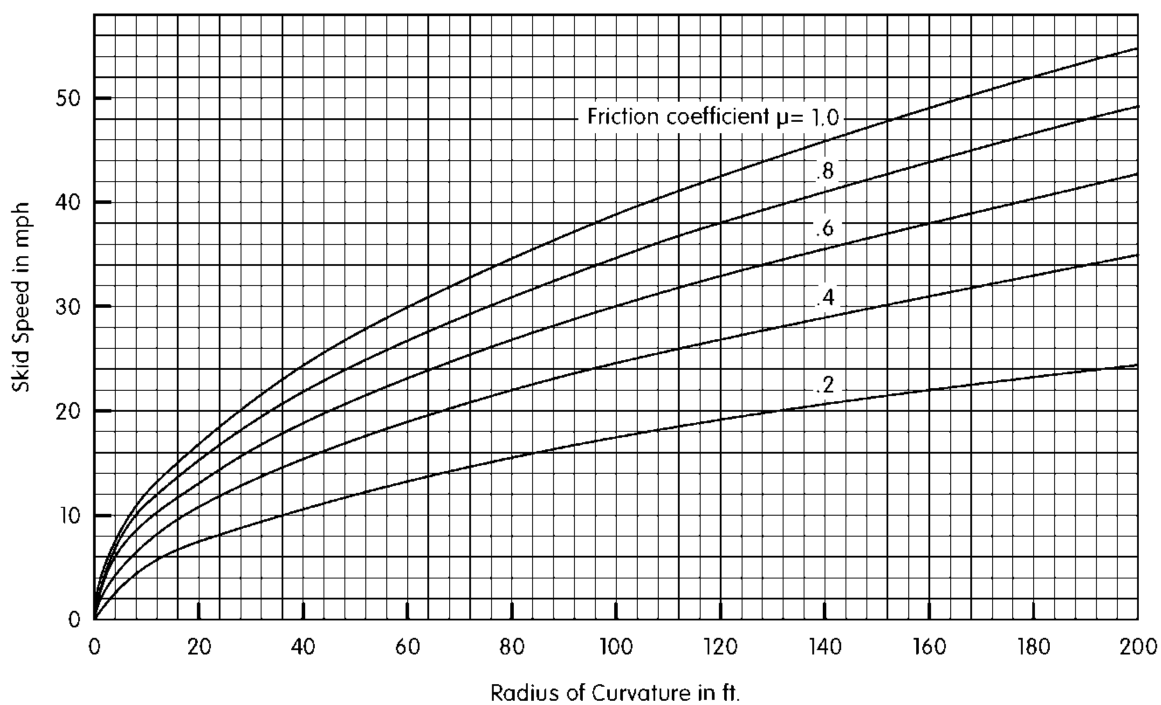
$$\mathbf{v_S} = \sqrt{fgr} \qquad (6)$$

where:

- $\mathbf{v_S}$ = skidding speed
- **f** = friction coefficient
- **g** = gravitational constant = 32.2 ft/sec^2 (9.82 m/sec^2)
- **r** = radius of curvature

Because "**v**" must be made as small as possible for the most cost-effective protection, this relationship suggests that options for the physical security planner include making the drive path slippery, with a small radius of curvature, or both. The above relationship is plotted as Figure 4-5, using "**f**" as a parameter using a conversion factor for values in ft and mph.

Figure 4-5 Skid Speed vs. Radius of Curvature



Using this figure, with a chosen value of "**f**" (see previous Note) and the tolerable vehicle impact speed of the selected barrier, a curved path can be designed to cause any vehicle driving above that velocity to skid.

b) On a Slope. Unlike a straight downhill path (see Paragraph 4-4.1), a curved downhill path is actually effective in deterring vehicle attacks. This is because the extra velocity gained from traveling downhill can easily cause the vehicle to skid or topple. Therefore, if a protected area has downhill approach paths, the local terrain can be modified so that a straight driving path is impossible. Caution should be exercised when designing roads to decrease velocity. Posting speed restrictions along the path is strongly recommended to reduce the possibility of accidental skidding.

To determine the final velocity at the end of a curved path, use the length of the curved path as the acceleration distance in Figure 4-3 and as the acceleration distance needed to attain final speed on a horizontal path (s) in Figure 4-3. Figure 4-4 can then be used to determine the velocity at which the vehicle will skid.

4-4.3 **Attack Routes Parallel to the Barrier**.

A reduction in energy transferred to a barrier can be accomplished by forcing a vehicle to make an abrupt (short radius) turn before impacting the barrier. Short radius turns effectively reduce vehicle speed by forcing the vehicle to slow down to avoid skidding, reducing the load transfer if the impact angle is less than 90 degrees to the barrier. Thus, the amount of energy that must be absorbed by a perimeter barrier depends on the impact angle, see Figure 4-1, perimeter roads A and B for a graphical representation of this angle of impact) and the final speed of the vehicle at impact. The load transferred to the barrier is determined by the perpendicular component of the velocity. By using Figure 4-6 and Figure 4-7, the impact angle directed toward the barrier, based on the offset distance (distance between restricting barriers, i.e., the distance between curbs or barriers that will limit the available turning radius), can be determined. These figures are based on the formulas provided in Paragraphs 4-4.2 and 4-4.3. Figure 4-6 and Figure 4-7 show the impact angle versus speed for a given offset distance for friction factors **f** = 0.5 and **f** = 0.9. The curves can be used to determine the angle of impact, "θ", knowing the values of the friction coefficient, "**f**", speed at the start of the turn, "**v**", and the offset distance available.

Once the angle of impact is determined from Figure 4-6 and Figure 4-7, the speed component perpendicular to the barrier, "**Vp**", can be calculated using Equation (7), where "**sinθ**" is the correction factor.

$$\mathbf{Vp = v \sin\theta} \qquad (7)$$

where:

Vp = speed component perpendicular to barrier
V = speed at start of turn
θ = angle of impact

Figure 4-6 Correction Factor for Vehicle Traveling Parallel to Barrier (Based on Coefficient of Friction, f = 0.5)

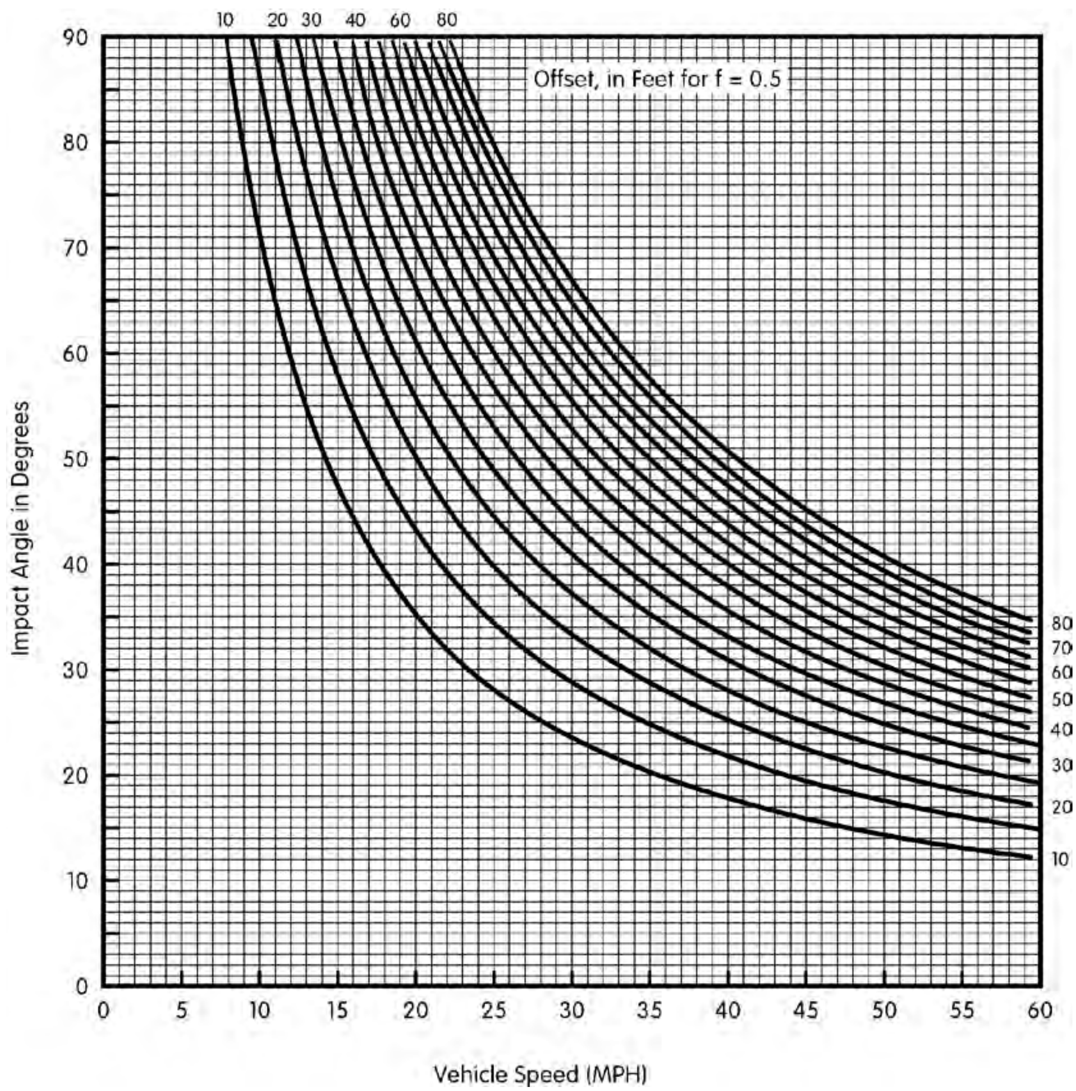
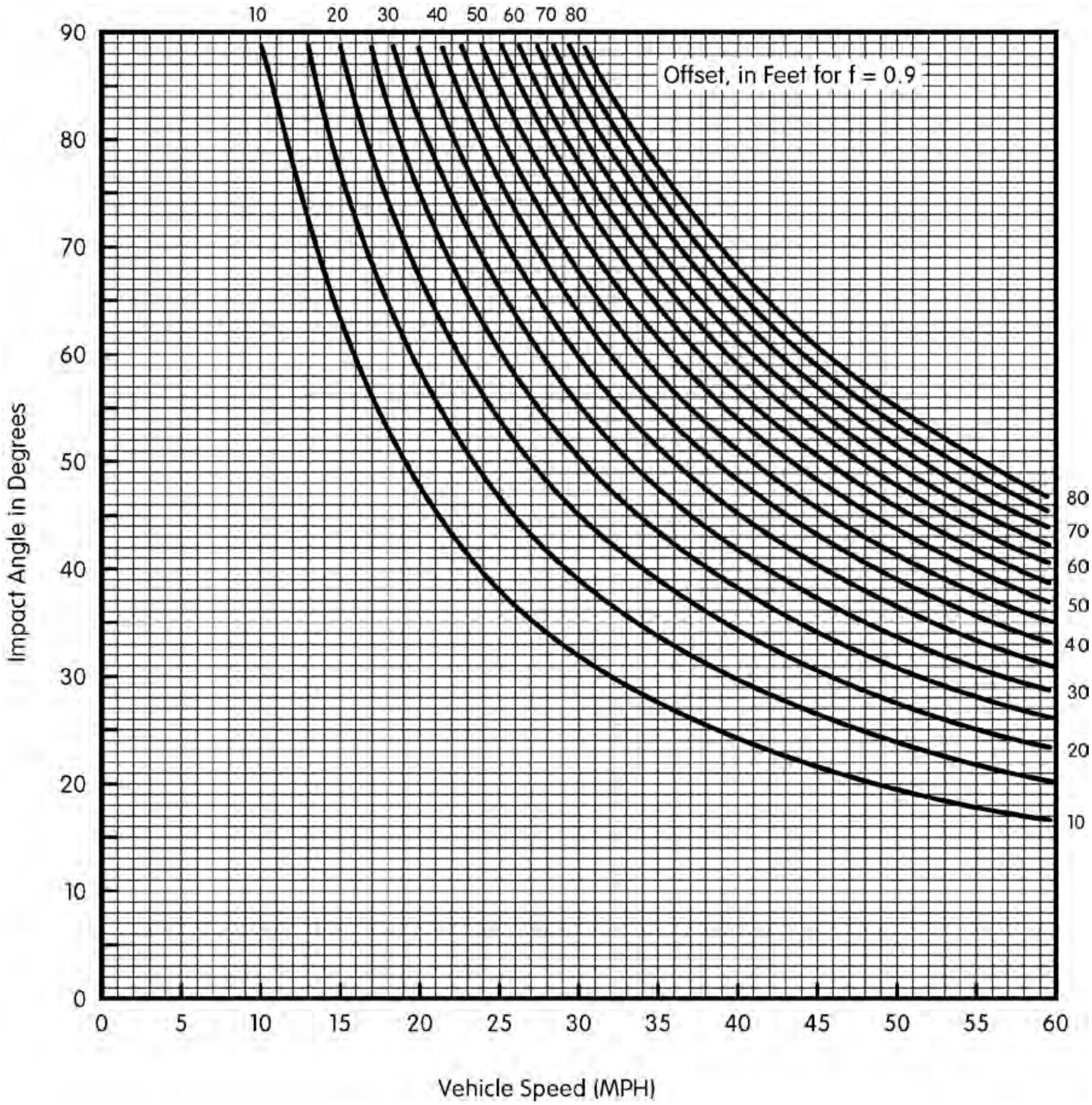


Figure 4-7 Correction Factor for Vehicle Traveling Parallel to Barrier (Based on Coefficient of Friction, f = 0.9)



For convenience, Table 4-1 provides a correction factor for "**Vp**" based on the speed of the vehicle at the beginning of the turn, the offset distance available for negotiating the turn, and a friction coefficient **f** = 1.0 (the most conservative value). Thus, "**Vp**" is calculated by multiplying the initial speed of the vehicle by the correction factor from Table 4-1.

Table 4-1 Speed Correction Factor for a Vehicle Traveling Parallel to Barrier (Based on Friction Coefficient = 1.0)

Speed of Vehicle in mph (kph)→	20 (32)	30 (48)	40 (64)	50 (80)	60 (97)	70 (113)	80 (129)
Max. Radius of Curve @ f=1.0 ft (m)→	27 (8)	60 (18)	107 (33)	167 (51)	240 (73)	327 (100)	427 (56)
Offset Distance in ft (m) ↓							
10 (3.1)	0.616	0.559	0.438	0.342	0.292	0.242	0.208
20 (6.2)	0.966	0.743	0.588	0.470	0.407	0.342	0.309
30 (9.3)	1.0	0.866	0.707	0.547	0.485	0.423	0.375
40 (12.4)	1.0	0.946	0.788	0.656	0.559	0.470	0.423
50 (15.3)	1.0	0.988	0.848	0.707	0.616	0.545	0.470
60 (18.3)	1.0	1.0	0.899	0.766	0.656	0.588	0.515
70 (21.4)	1.0	1.0	0.940	0.809	0.707	0.629	0.545
80 (24.4)	1.0	1.0	0.966	0.867	0.743	0.656	0.574

4-5 **VEHICLE KINETIC ENERGY**.

The kinetic energy of a moving vehicle is measured by its weight and speed, calculated as shown in Equation (8).

$$KE\ (ft\text{-}lbf) = 0.0334\ wv^2 \qquad (8)$$
$$KE\ (kgf\text{-}m) = 0.0039\ wv^2$$

where:

KE = kinetic energy in ft-lbs force (kgf-m)
W = vehicle total weight in lbs (kg)
V = vehicle speed in mph (kph)

A vehicle must have a certain amount of kinetic energy to penetrate perimeter security barriers. The vehicle must penetrate these barriers to inflict damage on a protected facility. Since kinetic energy is a function of vehicle weight and speed, a heavy vehicle moving slowly and a lighter vehicle moving fast could have the same kinetic energy.

Kinetic energy for 4,000-lb and 15,000-lb vehicles, traveling at various speeds, is shown in Table 4-2. Once the kinetic energy of the vehicle has been determined, active and passive barriers that are capable of stopping the vehicle can be selected from the information contained in Chapters 5 and 6.

In some cases (with dead men, bollards, cabled concrete tee walls or chained vehicles etc.) some of these being unique expeditionary uses based on available material there may be a requirement for the design of system of barriers other than those listed herein. Those cases may require the computation of an impact force to design that system. An impact force is a high force or shock applied over a short time period. Since force is the product of mass times acceleration for a mass *m* accelerating at an *acceleration*, then assuming an ideal system, we can set the impact force as, mass times the difference in velocity for a time interval *dt*. (F= mXdv/dt)

For example, a car that weighs 1 kg moving at 500 m/s and that hits a 'perfect' steel barrier where it uniformly decelerates from 500 m/s to 0 m/s in .02 seconds, has an approximate impact force of 25000 N. Thus, a body, which decelerates more quickly, has a greater effective impact force than one that decelerates more slowly.

Table 4-2 Kinetic Energy Developed by Vehicle, ft-lbf (kgf-m) x 1,000

	Speed of Vehicle in mph (kph)						
Vehicle Weight in lbs (kg) ↓	10 (16)	20 (32)	30 (48)	40 (64)	50 (80)	60 (97)	70 (113)
4,000-lb (1,818 kg) Vehicle	13 (2)	53 (7)	120 (17)	214 (29)	334 (46)	481 (66)	655 (90)
15,000-lb (6,818 kg) Vehicle	50 (7)	200 (28)	451 (62)	802 (111)	1,253 (173)	1,804 (249)	2,455 (339)

CHAPTER 5 - VEHICLE BARRIER SELECTION, DESIGN, AND INSTALLATION

5-1 **VEHICLE BARRIER TYPES**.

Vehicle barriers are categorized as either active or passive. Active and passive barriers can be fixed or movable, depending on how they are made, operated, or used. Some commercial barriers are dual-classified, when they meet the requirements for both categories (e.g., fixed-active, portable-passive, etc.) There is no industry-wide standard terminology for vehicle barriers. For this UFC, the following definitions will be used.

5-1.1 **Active Barrier Systems**.

An active barrier requires some action, either by personnel, equipment, or both, to permit or deny entry of a vehicle. The system has some form of moving parts. Active barrier systems include barricades, bollards, beams, gates, and active tire shredders.

5-1.2 **Passive Barrier Systems**.

A passive barrier has no moving parts. Passive barrier effectiveness relies on its ability to absorb energy and transmit the energy to its foundation. Highway medians (Jersey), bollards or posts, tires, guardrails, ditches, and reinforced fences are examples of passive barriers.

5-1.3 **Fixed Barrier Systems**.

A fixed barrier is permanently installed or requires heavy equipment to move or dismantle. Examples include hydraulically-operated rotation or retracting systems, pits, and concrete or steel barriers. Fixed barrier systems can be either active or passive.

5-1.4 **Portable/Movable Barrier Systems**.

A portable/movable barrier system can be relocated from place to place. It may require heavy equipment to assist in the transfer. Hydraulically operated, sled-type, barricade systems, highway medians, or filled 55-gallon drums that are not set in foundations are typical examples. Portable/movable barrier systems can be either active or passive.

5-2 **DESIGN CONSIDERATIONS**.

In addition to the calculation of the kinetic energy of a threat vehicle described in Chapter 4 many factors must be considered before selecting an appropriate barrier system. The Security Engineering: Entry Control Facilities/Access Control Points UFC 4-022-01 is a required document for planning vehicle barrier design and installation. An outline is presented below to serve as a checklist of key information that is important to the facility planner, security professional, designer, user, and maintainer in the design of barrier systems. Some of these issues are discussed in more detail following the outline.

- Design Basis Threat (s)
    - The Attack Vehicle(s)
        - Type
        - Weight
        - Maximum Velocity
        - Contents
        - Calculated Kinetic Energy
    - Points of Attack
    - Path of Attack(s)
    - Direction of Attack(s)
    - Type of Attack
        - Single
        - Multiple Vehicles
    - Country in Which Installation Resides

- Allowable Penetration Beyond the line of Barrier(s)

- Sufficient Standoff Distance Between Planned Barrier and Protected Structure

- Existing or Desired Traffic Patterns
    - Levels of Authorized Traffic
        - Peak Levels
        - Average Levels per Day
    - Types of Traffic
        - Staff
        - Freight
        - Visitors
    - Number of Available Traffic Lanes
        - One-Way Only
        - Reversible
        - Width and Separation
    - Minimization of Access Points

- Vehicle Barrier Operating Protocol(s).
    - Deploy and Inspect
        - Maximum Throughput Rate
            - Per Day
            - Per Hour (peak)
    - Threat Dependent, Local / Remote Option
    - Sally Port Interlock with other Visual Barriers

Automatic (Emergency Deployment)
    Deployment Signal Source
        Manual
        Velocity Sensors
        Direction Sensors
        Other
    Minimum Speed of Deployment
Automatic (Normal Authorized Traffic) Vehicle Identification Means
Parade
Lock down
Free Flow

- Site (Civil Engineering)
  - Roadway Layout
    - Number of Lanes
    - Width
    - Flat / Sloping/ Crowned
    - Islands, etc.
    - Lane Separator(s)
    - Boundary / Passive Barriers
  - Approaching or Crossroad Locations
  - Sub Surface Conditions
  - Berms
  - Landscaping
  - Buried Utilities
  - Drainage
  - Frost Line
  - Water Table Height

- Site (Facility Engineering)
  - Power Distribution Points
  - Communication Lines
    - Secure
    - Local
    - Existing Network Type
    - Required Network Type (Bus, Ring, Multiple Rings, Mesh, or Combination)
  - Drainage
  - Utility Cabinets/ Equipment Lockers
  - Lighting
  - Traffic Signals/ Controls
  - Buried Vehicle Sensors

- Site (General)
  - Environmental

        High/ Low Temperatures
        Rain Fall
        Snow
        Frost Line
        Other
    Power Sources
        Location
        Type
            Local
            Post-Emergency Backup
        Voltage/ Phase/ Frequency

- Barrier Selection
    DOS / DoD Crash Rating

    Note:

    Both the U. S. Department of State and the U. S. Department of Defense rate barriers based on full scale crash tests conducted by independent test laboratories or government-approved facilities. See United States Army Corps of Engineers (USACE) Protective Design Center website for latest DoS and DoD certified barriers: https://pdc.usace.army.mil/library/BarrierCertification/

    The 'K' in a rating refers to the Kinetic Energy (K.E.) of the test vehicle at the moment of impact.

    A rating of K12, for example, indicates K.E. of approximately 1,200,000 ft-lb (165,960 kg-m) of energy (15,000 lb @ 50 mph [6,818 kg @ 80 kph]). A rating of K8, 800,000 ft-lb (110,640 kg-m) of energy (15,000 lb @ 40 mph [6,818 kg @ 64 kph]) and K4, 400,000 ft-lb (55,320 kg-m) of energy, (15,000 lb @ 30 mph [6,818 kg @ 48 kph]).

    The 'L' rating refers to the penetration of the vehicle beyond the front line of the barrier. A rating of 'L3' indicates the truck penetrated less than 3.0 feet (0.9 m). A rating of 'L2' means penetration of less than 20.0 feet (6 m). And 'L1' means the penetration was less than 50.0 feet (15 m).

    Active or Passive
    Temporary or Permanent
    Style of Barrier(s)
        Wedge, Plate type (Phalanx) (In ground / surface / shallow mount)
        Bollard
        Rolling Gate

        - Drop Arm
        - Transportable
    - Required Aesthetics, if any
    - Flush Mount Barriers to Road Surface
    - Width of Lane(s) to be Protected
    - Number of Lanes
    - Barriers to be Operated
        - Independently
        - Sets
        - Sally Port(s)
    - Speed of Operation
        - Normal
        - Emergency
    - Number of Operating Cycles per Barrier
        - Per Day
        - Per Hour (peak)
    - Available Training from Manufacturer
    - Availability of Spare Parts
    - Crash Test Results
    - Computer Analysis Results Using BIRM 3D (PDC TR90-2)
    - Environmental Protection
        - Winterizing
        - Cooler (Hydraulic Power Unit)
        - Galvanizing
        - Stainless Steel
    - Barrier Road Surface
        - Special Texture
        - Excessive Load (over 50,000 lbs)
    - Cost Effectiveness

- Foundation/ Installation
    - Foundation Restrictions
        - Allowable Depth of Foundation
        - Extent of Foundation Allowable
        - Flush mount barrier system to road surface
    - Power Source
        - Distance from Barrier Line
        - Voltage/ Phase / Frequency
        - Power Available (watts)
        - Type of Source
    - Location of Enclosure for Hydraulic Power Unit
        - Existing Building
        - Vault
        - Stand Alone
        - Distance from Barrier Line

Drainage
Color
Special Markings
Mounted Lights
Equipment Required to Move Barriers

OPERATING SYSTEMS CONSIDERATIONS

- Control Circuits
  - Single Barrier
  - Multiple Barrier(s)
    - Local Control(s)
    - Local(s) with Remote Master(s)
    - Remote Empower and Override
    - Hand Held
  - Sally Port Interlock
  - Master to Slave Interconnect
    - Hard line
    - RF Link
    - Phone Line, Etc.
  - Remote / Local Status Signal(s)
    - Status Panel (Visual Indicators / Audible)
      - Barrier Position (Guard/ Open)
      - Cycling
      - Advance Warning
    - Open Beyond Time-out
    - Security Level
      - Is there constant surveillance?

- Power off Operation
    - Hydraulic Reserve/Number of Cycles
    - Control Circuit/Battery Backup
    - Emergency Standby Power
      - Dedicated
      - On Site
    - Hydraulic Hand Pump

- Power Failure Deployment
    - To Full Guard Position
    - To Full Open Position

- Warning / Safety Signs/ Signals
    - Barrier Closing/ Opening
      - Lights

Horns
Strobes, Etc.
Barrier in Guard Position
Lights
Horns
Red Traffic Signal (Steady/ Flashing)
Barrier Down and Clear (Yellow Traffic Signal)
Semaphore Gate Arms
Gate Arm Synchronized with Barriers Interlocked
Gate Down Before Barrier Deployment
Barrier Down Before Gate Opening

- Emergency Fast Operation (EFO)
    - Signal Source
        - Automatic Sensors
        - Master(s) / Slave Panels(s)
        - Deploy Barriers/Speed
    - Lock Out
        - Slave Panels
        - Sub Masters
        - Automatic Entrance Controls
    - Deactivate (EFO)
        - Signal Source
            - Local Panel Authority
                - Local Guard
                - Supervisor
                    - Key Switch
                    - PIN
            - Master Panel Authority / Level

Some of these design and operating considerations, as well as other key issues, are discussed in more detail in the following sections.

5-2.1 **Fencing**.

Fences should not be considered as protection against a moving vehicle attack. Most fences can be easily penetrated by a moving vehicle and will resist impact only if reinforcement is added. Fences are primarily used to:

a. Provide a legal boundary by defining the outermost limit of a facility

b. Assist in controlling and screening authorized vehicle entries into a secured area by deterring overt entry elsewhere along the boundary

c. Support detection, assessment, and other security functions by providing a "clear zone" for installing lighting, intrusion detection equipment and CCTV

d. Deter "casual" intruders from penetrating into a secured area by presenting a barrier that requires an overt action to penetrate

e. Cause an intruder to make an overt action that will demonstrate intent

f. Briefly delay penetration into a secured area or facility, thereby increasing the possibility of detection

In the field of security, perimeter barriers provide the first line of defense for a facility. The true value of a perimeter security fence comes in its association with other components of a security system. When perimeter security is required, the security fence forms the basic building block for the rest of the system. UFC 4-022-03, *Security Engineering: Fences, Gates and Guard Facilities* should be consulted for details on the use of fencing in barrier systems.

5-2.2 **Location**.

Active vehicle barriers can be located at facility entrances, enclave entry points (gates), or selected interior locations (e.g., entrances to restricted areas). Exact locations may vary among installations; however, in each case, the barrier should be located as far from the critical structure as practical to minimize damage due to possible explosion. Also, locate support equipment (e.g., hydraulic power, generator, batteries, etc.) on the secure side and away from guard posts to lower the threat of sabotage and injury to security personnel. Passive barriers can be used at entry points, if traffic flow is restricted or sporadic (i.e., gates that are rarely used). Passive barriers are normally used for perimeter protection. For more information regarding the location of vehicle barriers, consult UFC 4-022-01, *Security Engineering: Entry Control Facilities/Access Control Points.*

5-2.3 **Aesthetics**.

The overall appearance of a vehicle barrier plays an important role in its selection and acceptance. Many barriers are now made to blend in with the environment and be aesthetically pleasing, minimizing a “fortress look”.

5-2.4 **Safety**.

An active vehicle barrier system is capable of inflicting serious injury. Even when used for its intended purpose, it can kill or seriously injure individuals when activated inadvertently, either by operator error or equipment malfunction. Warning signs, lights, bells, and bright colors should be used to mark the presence of a barrier and make it visible to oncoming traffic. These safety features must always be provided to ensure personnel safety. The following issues should be addressed to manufacturers and users to identify potential safety issues affecting the selection of an active barrier system:

a. Backup power;

b. Emergency cutoff switch;

c. Adequate lighting;

d. Installation of safety options, such as alarms, strobes (or rotating beacons), and safety interlock detectors to prevent the barrier from being accidentally raised in front of or under an authorized vehicle;

e. Army exception – Installation of Traffic Safety Schemes; i.e., Vehicle Presence Detection, Vehicle Platooning, etc., as outlined in the "Standard Definitive Designs; Access Control Points for U.S. Army Installations".

Once installed, vehicle barriers should be well marked and pedestrian traffic channeled away from the barrier system. For high-flow conditions, vehicle barriers are normally open (allowing vehicles to pass) and used only when a threat has been detected. In this case, the barrier must be located far enough from the guard post to allow time to activate and close the barrier before the threat vehicle can reach it. For low-flow conditions, or where threat conditions are high, barriers are normally closed (stopping vehicle flow) and lowered only after authorization has been approved.

5-2.5 **Security**.

Vehicle barriers must be ready to function when needed. A potential for sabotage exists when barriers are left unattended or are located in remote or unsecured areas. For these installation conditions, tamper switches should be installed on all vehicle barrier access doors to controllers, emergency operation controls and hydraulic systems. Tamper switches should be connected directly to a central alarm station so that security of the barrier system can be monitored on a continuous basis. Provide tamper resistant screws at all controls and junction boxes.

5-2.6 **Reliability**.

Many barrier systems have been in production long enough to develop an operations history under a variety of installation conditions. Reliability data from manufacturers show less than a three-percent failure rate when these barriers are properly maintained. Some systems have been placed in environments not known to the manufacturer, while others have developed problems not anticipated by either the manufacturer or user. Most manufacturers will help resolve problems that arise in their systems. Backup generators or manual override provisions are needed to ensure continued operation of active vehicle barriers during power failure or equipment malfunction. Spare parts and supplies should also be on hand to ensure that barriers are quickly returned to full operation. If a high cycle rate is anticipated, or the environmental impact from hydraulic fluid contamination is a concern, the selection of a pneumatic operating system is recommended. Operate barrier system at least once every 24 hours to assure performance for security operations. Perform this operation at low traffic period or before opening to traffic. Maintain log of this operation.

5-2.7 **Maintainability**.

Many manufacturers provide wiring and hydraulic diagrams, maintenance schedules, and maintenance procedures for their systems. They should also have spare parts available to keep barriers in continuous operation. The manufacturer should provide barrier maintenance support in the form of training, operation manuals, and maintenance manuals. Maintenance contracts are available from most manufacturers and are recommended to ensure proper maintenance of the barrier and assurance that the barrier will function as intended. Reliability and maintainability data are available from most manufacturers. Yearly maintenance contracts are usually available from the manufacturer and should be included in the planning process and budgeted. Maintenance contracts should include inspection, adjustment, cleaning, pressure checks on hydraulic systems, and replacement of worn parts.

5-2.8 **Cost**.

Traffic in restricted or sensitive areas should be minimized and the number of access control points limited. Reducing traffic flow and the number of control points will increase security and lower the overall cost of the system. Installation and operational costs are a significant part of the overall cost of a barrier system and must be addressed during the barrier selection process. Complexity and lack of standardized components can result in high costs for maintenance and create long, costly downtime periods. Reliability, availability, and maintainability requirements on the system also affect costs. Annual maintenance needs to be included in the cost of the system.

5-2.9 **Barrier Operations**.

A barrier must be capable of operating continuously and with minimal maintenance and downtime to properly satisfy security requirements. System failure modes must be evaluated to ensure that the barrier will fail in a predetermined position (open or closed) based on security and operational considerations. Selecting a normally open (allowing access) or closed (preventing access) option should be evaluated based on traffic flow conditions at the site (either existing or expected) and the overall site security plan. Emergency operation systems (backup generators or manual override systems) should be in place to operate the barrier in case of breakdowns or power failure. Security personnel should be involved in the decision to deploy and use a vehicle barrier system. If a normally open (allows traffic through) operation is selected, there must be sufficient distance between the guard and the vehicle barrier to allow for guard reaction time to activate the barrier, barrier deployment time, and time required for selected safety regimes. Certain barriers use locking pins (most notably crash beam type barriers) to lock down barrier. There have been incidents when controls were activated to raise arm with locking pins inserted causing damage to beam portion of barrier. Determine if pin is required for full performance of barrier and inquire of manufacturer if a sensor system is available that detects presence of pin. Ensure training of personnel to verify pin status prior to operation of crash beam barriers.

5-2.10 **Unobstructed Space**.

Barriers installed in inner and outer security unobstructed space must be designed so they will not provide a protective shield or hiding place. Tall, continuous barriers, such as planters, Jersey Barriers, guardrails, and other similar passive vehicle barriers can be a violation of mandated requirements, if installed in a designated unobstructed space. Placement of any barriers near or within this unobstructed space must be coordinated with the activity security officer.

5-2.11 **Environment**.

The environment must be considered during the selection process. Hinges, hydraulics, or surfaces with critical tolerances may require heaters to resist freezing temperatures and ice buildup. They may also require protection from excessive heat, dirt, humidity, salt water, sand, high water table, and debris. If options for protection against environmental conditions are not available, the system may be unsuitable for a specific location. Maintenance should be increased and/or compensating options (i.e., sump pumps, heaters, hydraulic fluid coolers, etc.) selected for vehicle barriers subject to severe environmental conditions to ensure acceptable operation. In cold regions and during winter months, it is recommended to increase operation of the barrier system to cycle hydraulic fluids through lines. See Reliability paragraph above.

5-2.12 **Installation Requirements**.

The vehicle barrier selected must be compatible with the available power source and with other security equipment installed at the selected site, such as perimeter intrusion detection and CCTVs designed to detect and assess covert penetration of the perimeter. Power requirements can vary depending upon the manufacturer and location of the installation.

5-2.13 **Facility Compatibility**.

The chosen barrier system must be compatible with other security components in place at a site. For example, an active barrier system should not be installed adjacent to an unhardened, chain-link fence because the fence then becomes the weakest path. The cost and value of the active barrier as a preventive measure is then lost. Any decisions on facility compatibility should be coordinated with UFC 4-022-01, *Security Engineering: Entry Control Facilities/Access Control Points.*

5-2.14 **Operator Training**.

Most manufacturers recommend operator training for active barrier systems. Operator training prevents serious injury and legal liability, as well as equipment damage caused by improper operations. If a manufacturer does not provide a thorough program for operator training, the user should develop a checklist for normal and emergency operating procedures.

5-2.15 **Options**.

Manufacturers offer a number of optional features that can be added to the baseline systems. Some options enhance system performance, while others improve maintainability or safety. Options increase system cost and may also increase maintenance requirements. Selection of options depends on operational, safety, security, site, and environmental conditions. The manufacturers of certified DoS anti-ram vehicle barriers listed in can be contacted to determine available options for specific vehicle barrier systems. These manufacturers can provide guidance on available options and will make recommendations that will enhance barrier operations.

5-2.16 **Operational Cycle**.

The frequency of operation must be considered in the selection process. Where traffic flow is light, a manually operated or removable passive system may work well at considerable savings. However, for high-traffic conditions (especially during peak hours), an automatically controlled system designed for repeated and fast open and close operation (pneumatic or hydraulic) would be more desirable. The use of one or more barriers at an entry point can also improve throughput.

5-2.17 **Methods of Access Control**.

When selecting an active barrier, consider how vehicles will be allowed access. If a vehicle must be searched for explosives, a sally port design should be used, which will trap the vehicle between two active barriers while it is being searched.

This will prevent the vehicle from proceeding into the secured area before it has been searched and prevent escape (see Figure 4-2).

Access control can be accomplished with a staffed guard station or, remotely, using card or biometric access control devices that automatically activate the barrier (subject to random searches). The barrier can also be operated from a protected location other than the entry control point, using CCTV and remote controls. Access control systems are available as options from vehicle barrier manufacturers (see \1\manufacturer specific website for additional information/1/). Vehicle-sensing loops on the secure side of the vehicle barrier should always be included to prevent activation of the barrier until the vehicle has completely cleared the system. If card access control systems are used, procedures must be included to prevent tailgating (authorized vehicle must wait until the barrier has closed completely before proceeding).

5-2.18 **Cost Effectiveness**.

Tradeoffs on protective measures may include:

a. Locating the vehicle barrier to provide optimum separation distance

b. Slowing down vehicles approaching the barrier, using obstructions or redesign of the access route

c. Barrier open to permit access vs. closed to prevent access

d. Active vs. passive barriers

e. System-activating options: manual vs. automatic, local vs. remote, electrical vs. hydraulic

f. Safety, reliability, availability, and maintainability characteristics

5-2.19 **Liabilities**.

Possible legal issues resulting from accidents (i.e., deaths, injuries) and legal jurisdiction (i.e., state, local, foreign country) must be deliberated with the installation legal representatives when deciding to install an active vehicle barrier system.

5-3 **ADDITIONAL DESIGN CONSIDERATIONS**.

The following actions are also to be considered when selecting and installing barrier systems.

a. If the location of a vehicle barrier is in an area of high water table, consider using a surface mounted or shallow profile barrier system.

Below ground barriers can be installed if the required installation depth is above the water table. If the excavation cannot be drained, water collection could cause corrosion, and freezing weather may incapacitate the system.

b. When barriers are installed at entrance and exit gates, also consider installing passive barrier systems along the remaining accessible perimeter of the protected area.

c. Protection of individual buildings or zones within the perimeter is generally more cost-effective than extensive protection of a large facility perimeter. For example, passive barriers installed in areas where vehicles cannot reach, just to complete a perimeter barrier system, are not effective use of security funding

d. Since most types of active barriers can be easily sabotaged, consider installing active barriers only in areas where they can be under continuous observation.

e. Barriers should be used to divert traffic or prevent entry or exit. Installation of barriers immediately adjacent to guard posts is not desirable because the possibility of injury should be minimized. Consider keeping vehicle barriers as far from guard posts as possible.

f. Barriers should be installed on the exit side of an access control point, as well as the entrance.

g. Long, straight paths to a crash-resistant barrier can result in increased vehicle speed and greater kinetic energy upon possible impact. Where this cannot be avoided, installation of a passive-type barrier maze should be considered to slow the vehicle.

h. Design passive barrier systems to comply the requirements of the DEPSECDEF Memorandum, "Access for People with Disabilities" dated 31 October 2008. The memorandum updates the DoD standards for making facilities accessible to people with disabilities. The US Access Board issued an update of the accessibility guidelines which the DEPSECDEF Memorandum implements with military unique requirements specified in the memorandum attachment. The new DoD, "ABA (Architectural Barriers Act) Accessibility Standard" and the DEPSECDEF Memorandum are located at http://www.access-board.gov/ada%2daba/aba-standards-dod.cfm .

5-4 **BARRIER CAPABILITY**.

In general, vehicle-crash-resistant barriers should be considered at vehicle access points to sensitive areas and enclaves. Active and passive barriers should be tested against specific threats (vehicle weight and speed). Passive barrier only designs can be analyzed using finite element analysis or computer programs specifically developed to analyze performance of vehicle barriers. It is recommended that passive barriers be physically tested before being utilized. All active barriers concepts are required to be physically tested in accordance with DoS/ASTM standards prior to deployment. Supplemental gate and fencing reinforcements may also be needed to provide the same level of protection.

The acceptable penetration distance will vary among installations, depending upon the locations of the barriers relative to the assets to be protected. The appropriate penetration distance for a given facility should be determined by the threat and risk assessments and physical security survey results as indicated by the process outlined in UFC 4-020-01, *Security Engineering Facilities Planning Manual* and UFC 4-020-02, *Security Engineering Facilities Design Manual*. For an illustration, refer to Example 1 in Appendix \1\D/1/ of this document.

In the example, the barrier system selected as a candidate barrier must be capable of stopping the vehicle and allowing little or no penetration. Sufficient standoff distance is not available to protect Building 827 from the expected explosive-loading conditions. Possible options would include moving the barriers further away from the target, closing the perimeter roads to traffic, hardening building 827 against increased blast-loading conditions or accepting additional risk to the structure.

For static perimeter barriers, it is important to note that weight alone will not prevent penetration. As described in paragraph 6-2.2, concrete barriers used to protect against vehicle impact should be anchored to a concrete foundation, if the impact angle is expected to exceed 30 degrees.

5-5 **VEHICLE BARRIER CERTIFICATION**.

When the Department of State (DoS) published the standard SD-STD-02.01, Revision A, March 2003 “Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates”, the penetration distance of a vehicle into a barrier was limited to 1 m. The DoS list of certified barriers was developed under ‘Revision A’ and all barriers allowing penetration in excess of 1 m were removed from the list. Most DoD components have sufficient standoff and can utilize barriers which allow penetration distances in excess of 1m. Due to this and other needs the requirement for a national standard for crash testing of perimeter was established.

ASTM F 2656-07 Standard Test Method for Vehicle Crash Testing of Perimeter Barriers has been published and is being adopted by both DoD and DoS for certification/approval of vehicle barriers. This standard includes more vehicle types and differing penetration depths. The ASTM test vehicles, overall test protocol, instrumentation, measurements, and report requirements are standardized to provide consistent procedures and requirements for barrier manufacturers and accredited testing facilities.

Under ASTM F 2656-07 barrier manufacturers are required to utilize an accredited independent testing laboratory. Laboratory accreditation must be done in accordance with ISO/IEC 17025. Laboratories that are not ISO/IEC 1705 accredited but whose testing protocols are accepted by a federal agency may also conduct tests for a period of one year after performing the first test using ASTM F 2656-07. However, it is unlikely that this acceptance will be extended beyond those facilities which have previously been given permission to conduct tests in accordance with the current DoS anti-ram vehicle barrier testing criteria. Without the federal agency acceptance, the testing facilities will be required to complete accreditation prior to crash testing of vehicle barriers under this ASTM.

The PDC will continue to maintain a list of approved anti-ram vehicle barriers for DoD. Currently DoS is maintaining their list as well. Barriers on either the DoS list or DoD list are approved for use on DoD projects. If a time comes when the DoS list is no longer kept the PDC will take the information from the DoS list and incorporate it into the DoD list to make it a comprehensive list of barriers for DoD application. Note that not all DoD sites have standoff suitable for barriers which allow more than 1m of penetration. The list of DoD approved anti-ram vehicle barriers and the DoS list of certified anti-ram vehicle barriers are available on the PDC web site: https://pdc.usace.army.mil/library/BarrierCertification

Any barrier that is on the current DoS-certified anti-ram vehicle barrier list may be used by DoD, as well as any barriers listed on the current DoD approved anti-ram vehicle barrier list. The DoD list includes information on permissible barrier widths as well as information on penetration of the vehicle during the impact test. Barrier systems must be installed in the ‘as certified’ condition. Only those widths contained in the DoS and DoD approved anti-ram barrier lists are considered acceptable for DoD use.

CHAPTER 6 - ACTIVE AND PASSIVE BARRIERS

6-1 ACTIVE BARRIER SYSTEMS.

Commercially available active vehicle barrier systems are presented in this section as generic representations. Inclusion of any equipment in this section does not constitute an endorsement, nor is this a complete listing of vehicle barriers that are commercially available. The equipment shown here is for illustration purposes only. Selection of a specific barrier should be based on site conditions and results of the design, selection, and installation checklist provided in Chapter 5. Results of this checklist can be used to establish cost, operational, performance, and environmental requirements. The checklist results can also be used to select the optimum active and passive barriers from those presented in this section. Users are advised to consult with manufacturers on current and more detailed information regarding products and options available. \1\ /1/ See United States Army Corps of Engineers (USACE), Protective Design Center, Omaha District (https://pdc.usace.army.mil/library/BarrierCertification for latest versions of DoS and DoD certified anti-ram vehicle barriers. Currently barriers are being tested to be in conformance with ASTM F 2656-07. DoS and DoD are beginning to accept vehicle barriers systems tested in conformance with ASTM F 2656-07.

Barrier systems used must be listed in either the Department of State (DoS) certified or Department of Defense (DoD) approved anti-ram vehicle barrier lists. Barrier widths shall be 'as certified/approved' on these lists. Alternatively, if a barrier system's width is between the widths of two listed barrier systems that are identical except for their widths, then that barrier system is also acceptable. Exceptions and acceptable widths will only be taken from the DoD anti-ram vehicle barrier list. The design and structural materials of the vehicle barrier furnished shall be the same as those used in the crash tested barrier. Crash test must have be performed and data compiled by an approved independent testing agency in accordance with either ASTM F 2656 or SD-STD-02.01. Barriers tested and certified on the previous Department of State standard, SD-STD-02.01, April 1985, and listed on the DoD approved anti-ram vehicle barrier list are also acceptable.

6-1.1 Portable Vehicle Barriers.

6-1.1.1 Description.

The portable vehicle barrier shown in Figure 6-1 is a movable, self-contained, portable roadway barrier, referred to as the vehicle surface barrier system (Example 1). It can be controlled as a manned checkpoint. Example standard equipment for this sample portable vehicle barrier is a 50-ft (15.2-m) cord attached to a control box. For unmanned control, options include either an electric card reader or keypad. The self-contained hydraulic system is located in the curb panels and sealed to prevent fluid leaks. The unit can be placed on any roadway or other flat surface (with passive barriers installed to prevent bypass). Once the electricity is connected, the system is operational. This barrier is best used for temporary installations, where high water table is a concern, or where portability is a requirement. Contact the manufacturer for current cost information. Example performance data are shown in Table 6-1 as Example 1.

A second example of a portable barrier system is depicted in Figure 6-2. This portable high security anti-terrorist vehicle crash barrier can be towed into position by a medium-sized truck. The barrier can be deployed in 15 minutes and can be operated either locally or remotely. The wheels are stored on the side, and the vehicle ramps are folded out upon deployment. Its deployment, retrieval, and operation are all hydraulic and push-button controlled. The system can be equipped with a battery-operated power unit or a hydraulic power unit operated on a locally-supplied power or full manual system, or combination. Example performance data are provided in Table 6-1 as Example 2.

Another portable barrier system (Example 3) is shown in Figure 6-3. This barrier is designed to be rapidly deployed in an emergency situation and fully operational in 15 minutes. It can be towed to a site by a truck then lowered into position using built-in jacks. The barrier can be an instant road block and can be installed in areas where foundation work cannot be safely or quickly poured. Stabilizers on the back side of the unit serve as additional reinforcement. The electro-hydraulic version of this barrier uses standard relay logic to allow control of the barrier with the supplied push-button control station. Example performance data are provided in Table 6-1 as Example 3.

A fourth example of a portable barrier system is illustrated in Figure 6-4. This maximum security vehicle arrest barrier can be relocated and deployed in less than 20 minutes upon arriving at its intended setup destination. The barrier does not require excavation and will not mark or damage the road surface. Although it is normally operated manually, it can be supplied with a hydraulic operating system. Example performance data are provided in Table 6-1 as Example 4.

6-1.1.2 **Testing**.

The vehicle surface barrier (Example 1) was tested by the Naval Facilities Engineering Command (NAVFAC), Naval Facilities Engineering Service Center (NFESC) at a vehicle barrier test bed in China Lake, California. Upon impact, the cab of a 15,200-lb (6,909-kg) truck, moving at 50.5 mph (81 kph), was crushed. The portable vehicle barrier, with the truck on top, slid 9.2 ft (2.8 m).

Both the Example 2 and Example 3 portable barrier systems have been certified by DoS as Level K4/L1 barriers. They will stop and disable a 15,000-lb (6,818-kg) truck, moving at 30 mph (48 kph). The manufacturers can provide crash test data.

The Example 4 portable barrier system has several versions. The version depicted in Figure 6-4 has been crash-certified by DoS as K12/L2. It will stop a 15,000-lb (6,818-kg) truck, traveling at 50 mph (80 kph). Specific crash test data can be obtained from the manufacturer.

Figure 6-1 Vehicle Surface Barrier (Example 1)

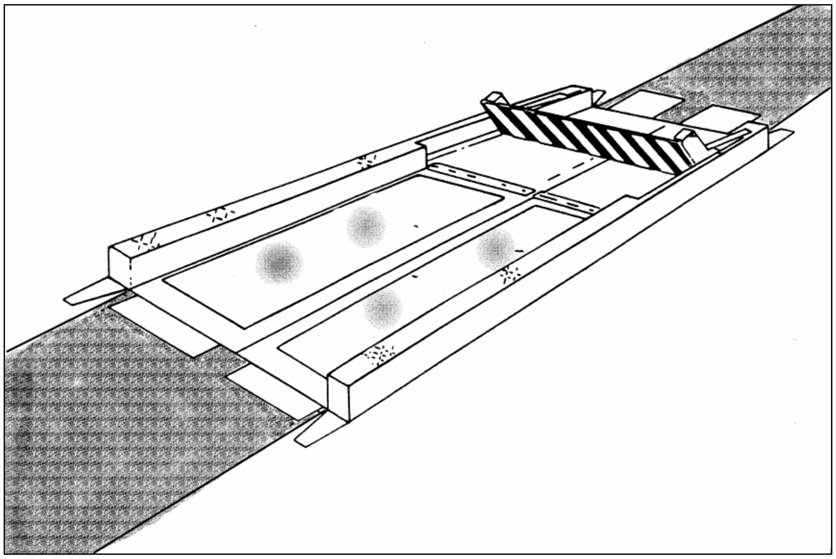


Table 6-1 Performance Data for Portable Vehicle Barriers

	Example 1*	Example 2*	Example 3*	Example 4*
Height, in. (cm)	30 (76)			31 (78.7)
Width, in. (cm)	96 (244)		144 (366)	144 (366)
Normal operating cycle (seconds)	3	10 - 15	15	3 - 5
Emergency operating cycle (seconds)	1			
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) x one million	1.2 (0.16)			1.2 (0.16)

*DoS certified

Figure 6-2 Portable High Security Anti-Terrorist Vehicle Crash Barrier (Example 2)

Figure 6-3 Portable Barrier (Example 3)

Figure 6-4 Maximum Security Vehicle Arrest Barrier (Example 4)

6-1.2 **High-Security Barricade System**.

6-1.2.1 **Description**.

The high-security barricade systems, shown in Figure 6-5 and Figure 6-6, are self-contained, hydraulically or pneumatically-operated units that, depending on the model, rise to various heights. These barriers are intended for high-speed impact conditions. Models are available for site conditions where shallow foundations are required. Performance data for an example system are shown in Table 6-2.

6-1.2.2 **Testing**.

Numerous manufacturers now produce DoS-certified high-security barriers which have been formally crash-tested\1\ /1/ The manufacturers should provide crash data for DoS-certified models. An example model was tested by Sandia National Laboratories with a 6,000-lb (2,727-kg) vehicle, traveling at 50 mph (80 kph), that penetrated the barrier 27 ft (8.2 m) and an 18,000-lb (8,182-kg) vehicle, traveling at 30 mph (48 kph), that penetrated 29 ft (8.8 m). Another model was tested by Southwest Research Institute for DoS using a 15,000-lb (6,818-kg) vehicle, traveling at 50 mph (80 kph), that penetrated less than 3 ft (0.9 m). A manufacturer tested a third model, using a 15,000-lb (6,818-kg) vehicle, traveling at 50 mph (80 kph), that penetrated less than 3 ft (0.9 m).

Figure 6-5 Example High-Security Barricade System (Wedge Type)

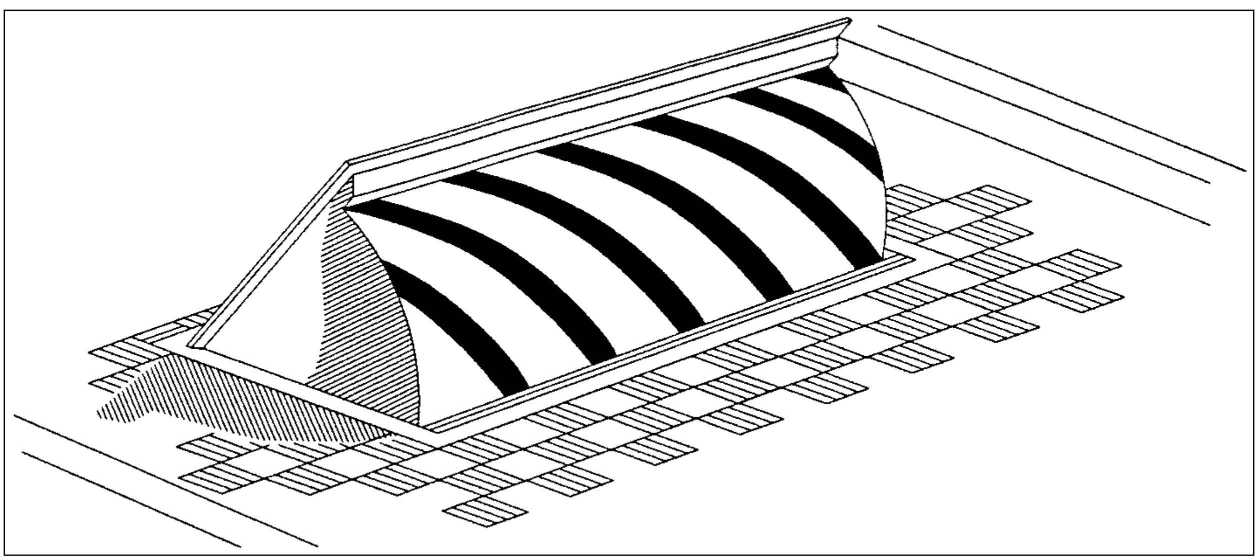


Figure 6-6 Example High-Security Barricade System (Flush-Mounted)

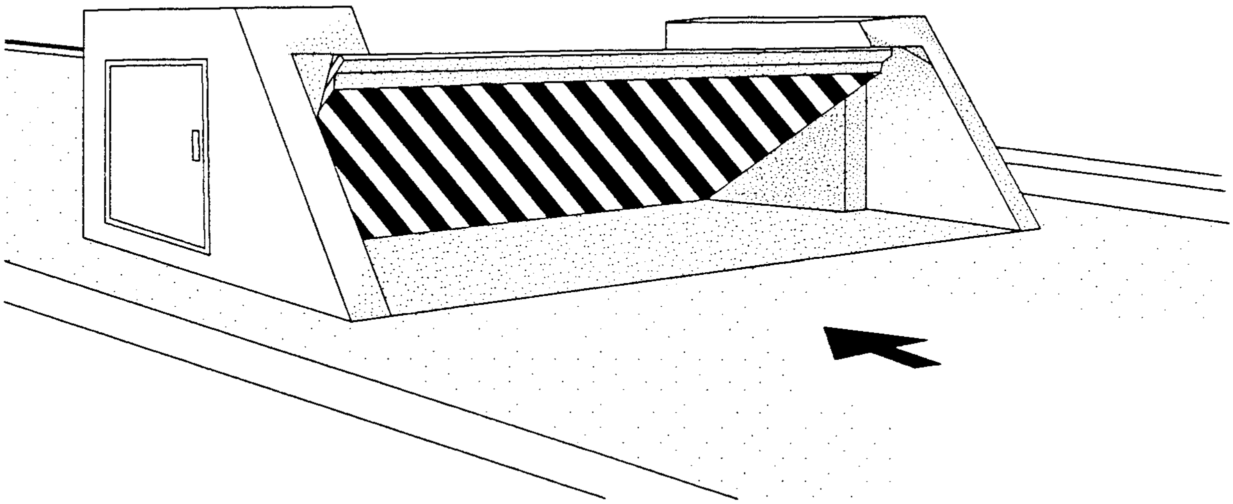


Table 6-2 Performance Data for Example High-Security Barricade System

	Example System*	Example Flush-Mounted System*
Height, in. (cm)	38 (96)	36 (91)
Width, in. (cm)	84 to 144 (213 to 366)	144 (366)
Normal operating cycle (seconds)	3 to 15	3 to 15
Emergency operating cycle (seconds)	<1.5	<1.5
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) x one million	.12 (0.16)	.12 (0.16)
Kinetic energy rating by engineering analysis, ft-lbf (kgf-m) x one million (destruction of vehicle with some damage to barrier)	.40 (0.55)	.32 (0.44)

*DoS certified

6-1.3 **Bollard System**.

6-1.3.1 **Description**.

Numerous manufacturers now produce DoS-certified bollard systems which have been formally crash-tested. \1\ /1/ The manufacturers should provide crash data for DoS-certified models. The example bollards shown in Figure 6-7 are 10-in (25.4-cm) diameter steel bollards that are 30 in. (0.76 m) high. They can be lifted into position either manually (60-lb (27-kg) pull) or hydraulically. The compact size and ease of operation make this system particularly well-suited as either a stand-alone or a backup to existing pedestrian gates in the single post configuration. They can also be used to secure wide entrances when the cost for installing larger systems becomes prohibitive. Flush mount top of bollard system to surrounding pavement is required.

Hydraulically-operated bollards can be operated individually or in sets, with up to 24 bollards controlled from a single hydraulic power unit. Typical performance data are shown in Table 6-3.

See paragraph 5.3 h Additional Design Considerations, for handicap accessibility requirements.

6-1.3.2 **Testing**.

Sandia National Laboratories tested an example model with a 15,180-lb (6,900-kg) vehicle at 32 mph (51 kph), penetrating the barrier 12.2 ft (3.7 m). An example model was tested by the NFESC and DoS with a 10,000-lb (4,545-kg) vehicle at 40 mph (64 kph) that failed to penetrate the barrier.

Figure 6-7 Example Bollard System

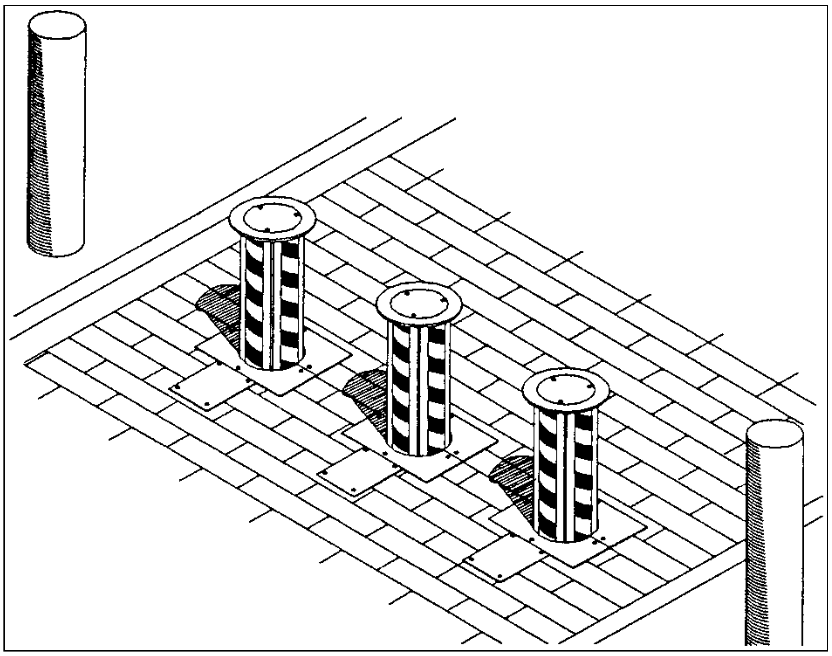


Table 6-3 Performance Data for Example Bollard System

	Example *
Height, in. (cm)	30 (76)
Width, in. (cm)	10 (25) @ 2 ft (0.6 m) on center
Normal operating cycle (seconds)	3 to 15
Emergency operating cycle (seconds)	<1.5
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) x one million	0.445 (0.06)
Kinetic energy rating by engineering analysis, ft-lbf (kgf-m) x one million (destruction of vehicle with some damage to barrier)	1.9 (0.26)

*DoS certified

6-1.4 **Crash Beam Barrier System**.

6-1.4.1 **Description**.

Numerous manufacturers now produce DoS-certified crash beam barrier systems which have been formally crash-tested\1\ /1/ The manufacturers should provide crash data for DoS-certified models. Crash beam barrier systems, such as the one shown in Figure 6-8, are cable-reinforced, manually or hydraulically-operated, bollard-mounted barriers. The beam is counterbalanced and lifts at one end to allow vehicle access. This system is frequently used for low impact conditions (when vehicle speed can be limited) and as the interior barrier (after a primary high impact barrier) for vehicle inspection areas or sally ports. Typical performance data for an example barrier are shown in Table 6-4. See “Barrier Operations” paragraph, 5.2.9, for specific operation requirements for crash beam systems.

Figure 6-8 Cable-Reinforced Crash Beams

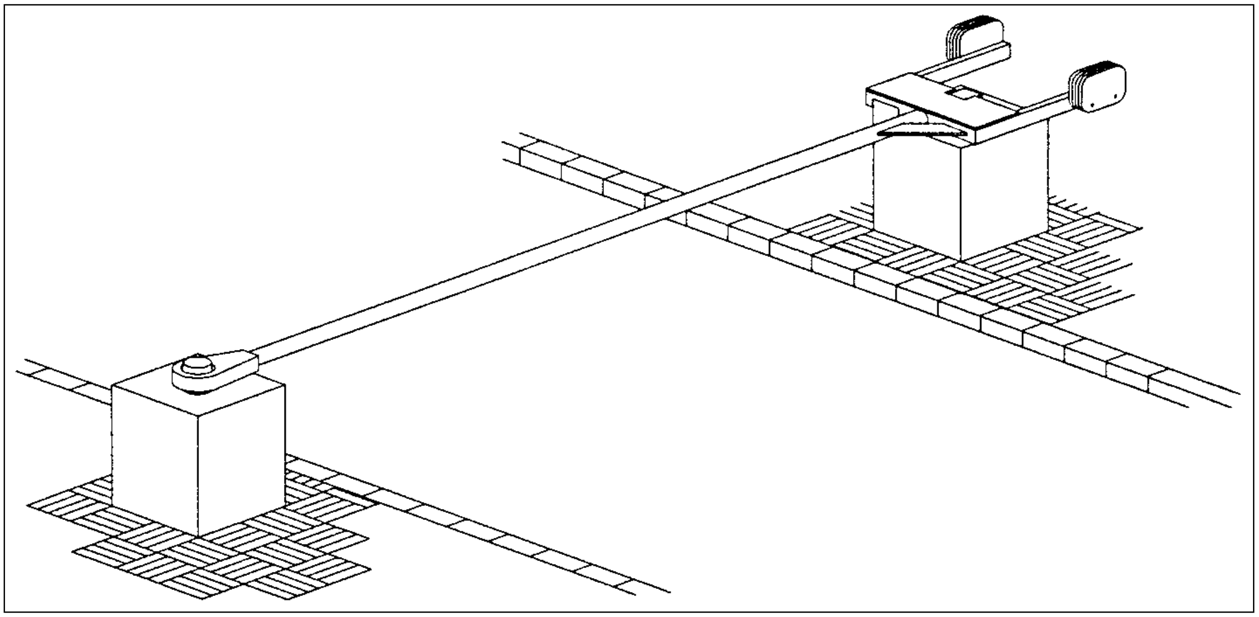


Table 6-4 Performance Data for Cable-Reinforced Crash Beams

	Example Model
Height, in. (cm)	30 (76) to 36 (91)
Length, in. (cm)	120 (305) to 240 (610) Note 1
Normal operating cycle (seconds)	8 to 15
Emergency operating cycle (seconds)	Not available
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) x one million	0.0965 (0.013)
1. Contact vendor to verify length and performance of barrier tested	

6-1.4.2 **Testing**.

The example crash beam barrier has been tested by the NFESC at the China Lake test facility. A 10,000-lb (4,545-kg) vehicle at 17 mph (27 kph) impacted the sample barrier and rebounded. There is now a K12 certified crash beam barrier system available as well.

6-1.5 **Crash Gate System**.

6-1.5.1 **Description**.

A crash gate system, such as the example system illustrated in Figure 6-9, is a sliding gate that offers pedestrian access and resistance to heavy vehicle impact. The example system is electromechanically operated with a 30 to 100 ft/min (9 to 30 m/min) sliding speed (instantly reversible). Safety infrared sensors and front edge obstacle sensors are standard features. A tested manual version of a crash gate is also available. Gate systems are normally used where aesthetics is an issue or where wide opening is required [up to 25-ft (7.6 m) clear opening]. Most systems can be used for both portable and permanent construction. Typical performance data are shown in Table 6-5.

Figure 6-9 Example Linear Crash Gate

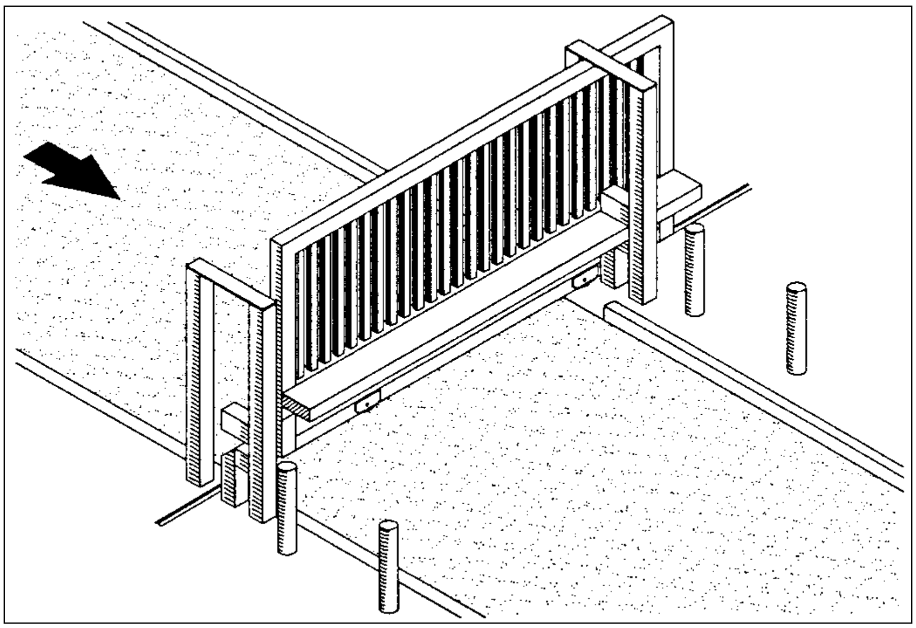


Table 6-5 Performance Data for Example Linear Crash Gate

	Example System*
Height, in. (cm)	108 (274)
Length, in. (cm)	144 (365) to 300 (762)
Normal operating cycle (Ft (m) per minute)	30 (9) to 100 (30)
Emergency operating cycle (seconds)	Not applicable
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) x one million	1.2 (0.16)

*DoS certified

6-1.5.2 **Testing**.

Three tests have been conducted on the example crash gate system by the NFESC, in conjunction with DoS, using vehicles weighing approximately 15,000 lbs (6,818 kg). At speeds of 34 and 40 mph (55 and 65 kph), the vehicle did not penetrate the sliding gate. At 55 mph (89 kph), the vehicle penetrated the sliding gate 5.5 ft (1.7 m).

6-1.6 **Ground Retractable Automobile Barrier (GRAB)**.

6-1.6.1 **Description**.

A ground retractable barrier is an attenuating device designed to span a roadway or traffic lane to bring an encroaching vehicle to a controlled stop and prevent its passage. An example system consists of a steel anchor post at each end, four hydraulic energy absorbers, and a cable/net assembly. The anchor posts are made from two sections of A36 steel pipe – a fixed 25-mm thick inner pipe with a 305-mm outer diameter and a 19-mm thick, 381-mm outer diameter outer pipe, free to rotate around the anchor post. Reusable hydraulic cylinders are set between the anchor posts and the net (two at each end). The net consists of upper and lower 19-mm diameter Extra High Strength (EHS) wire strands, with a 16-mm diameter wire rope in the center and 16-mm diameter wire rope woven up and down along the width of the net and attached to the top, middle, and bottom cables with clamps.

6-1.6.2 **Testing**.

The example GRAB was tested to the National Highway Research Program (NCHRP) Report 350 test level 2, with both the 1,800-lb (820-kg) car and the 4,400-lb (2000-kg) truck impacting at the third point of the net at a nominal speed of 45-mph (70 km/h). Both vehicles were stopped smoothly with no significant roll, pitch, or yaw. The maximum dynamic deflection of the example GRAB was 20.7 ft (6.3 m) with the car and 21.7 ft (6.6 m) with the truck.

6-1.7 **Maximum Security Barrier (MSB)**.

6-1.7.1 **Description**.

The MSB vehicle barrier (see example in Figure 6-10) is a hydraulically-operated barrier, 31 in. (79 cm) high by 14 ft (4.3 m) wide. It has a fully electronic, programmable controller that provides a range of functions. Multiple barriers can be controlled from a single hydraulic power system. Typical models can be moved without roadway rebuilding. Installation can be completed in 24 hours by bolting the barriers to the roadway. Some specific models are certified by DoS.

This type of barrier can also be an underground, flush-mounted barrier, as shown in Figure 6-11. Most MSB models are similar in construction and operation, varying only in the height of the barrier and surface foundation pad construction. Typical performance data are shown in Table 6-6.

The MSB also is available as a surface-mounted barrier with a gate arm. It has been crash-tested by the manufacturer, however they are not DoS certified. This system is frequently used for low impact conditions (when vehicle speed can be limited) and as the inside barrier (after a primary high impact barrier) for vehicle inspection areas or sally ports. Typical performance data are shown in Table 6-6.

Figure 6-10 Example MSB Vehicle Barrier (Lift Plate Barricade System)

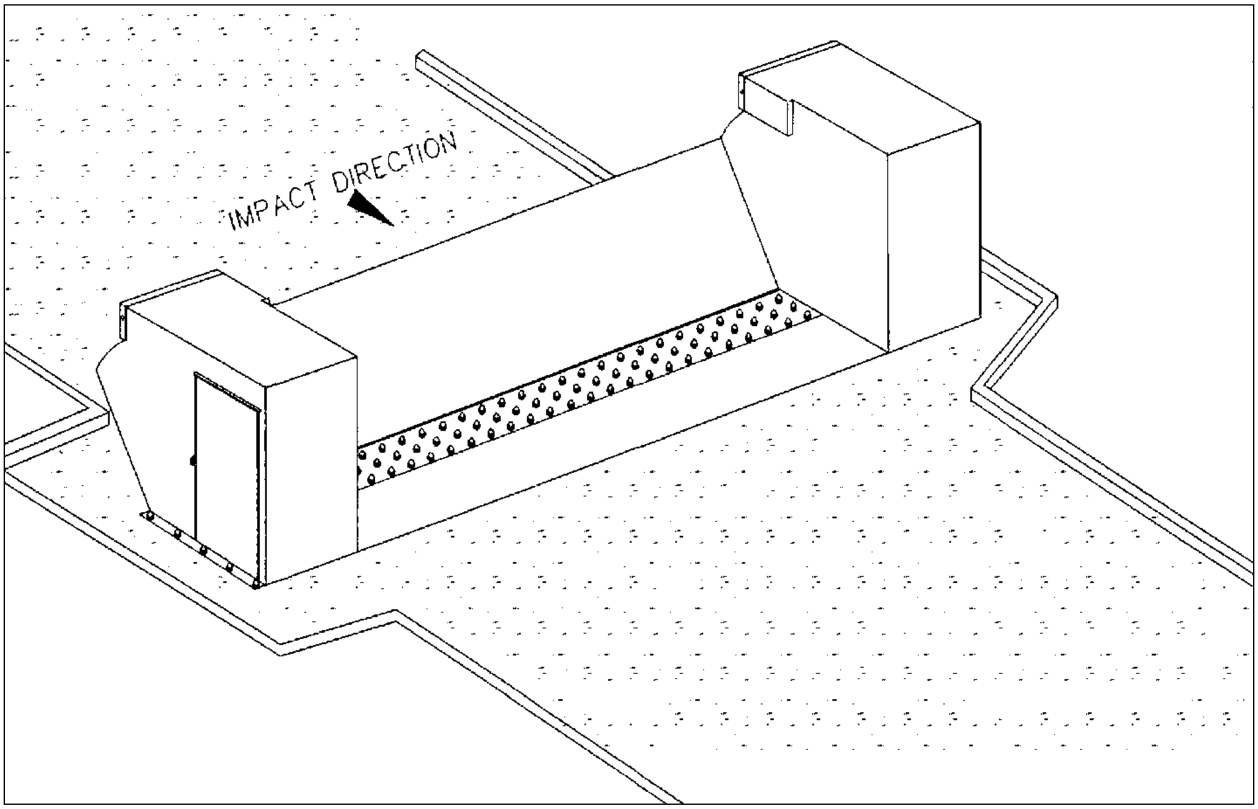


Figure 6-11 Second Example MSB Vehicle Barrier

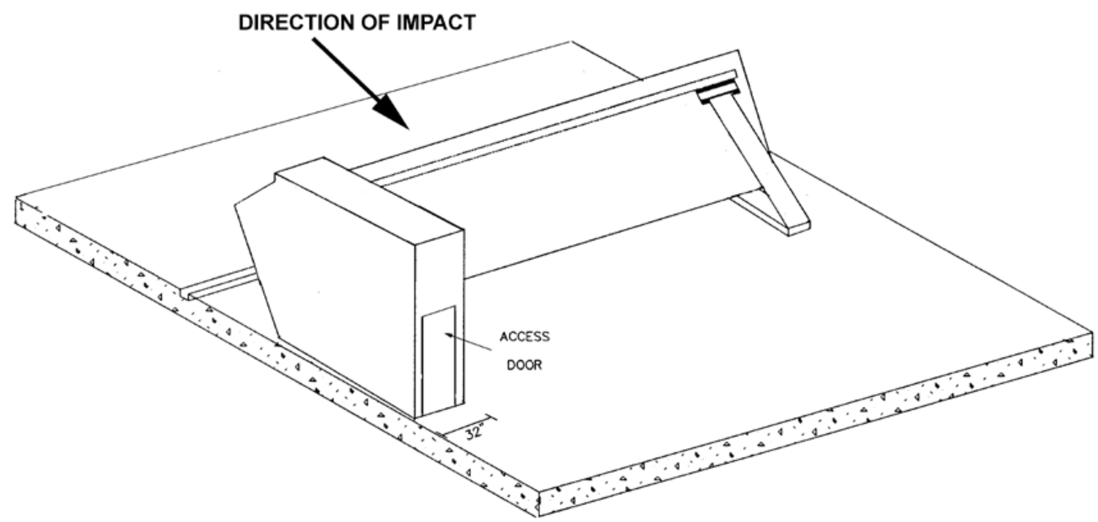


Table 6-6 Performance Data for MSB Vehicle Barriers

	Example 1*	Example 2*
Height, in. (cm)	31 (79)	33 (84)
Width, in. (cm)	168 (427) 10 ft (3m) clear	168 (427) 10 ft (3m) clear
Normal operating cycle (seconds)	3 to 5	3 to 5
Emergency operating cycle (seconds)	1	1
Kinetic energy absorbed in impact testing, ft-lbf (kgf-m) x one million	1.2 (0.16)	1.2 (0.16)

*Not DoS certified

6-1.7.2 **Testing**.

The Example 1 barrier was tested by NFESC in conjunction with DoS. A 14,980-lb (6,809-kg) vehicle at 50.3 mph (81 kph) failed to penetrate.

6-2 **PASSIVE BARRIER SYSTEMS**.

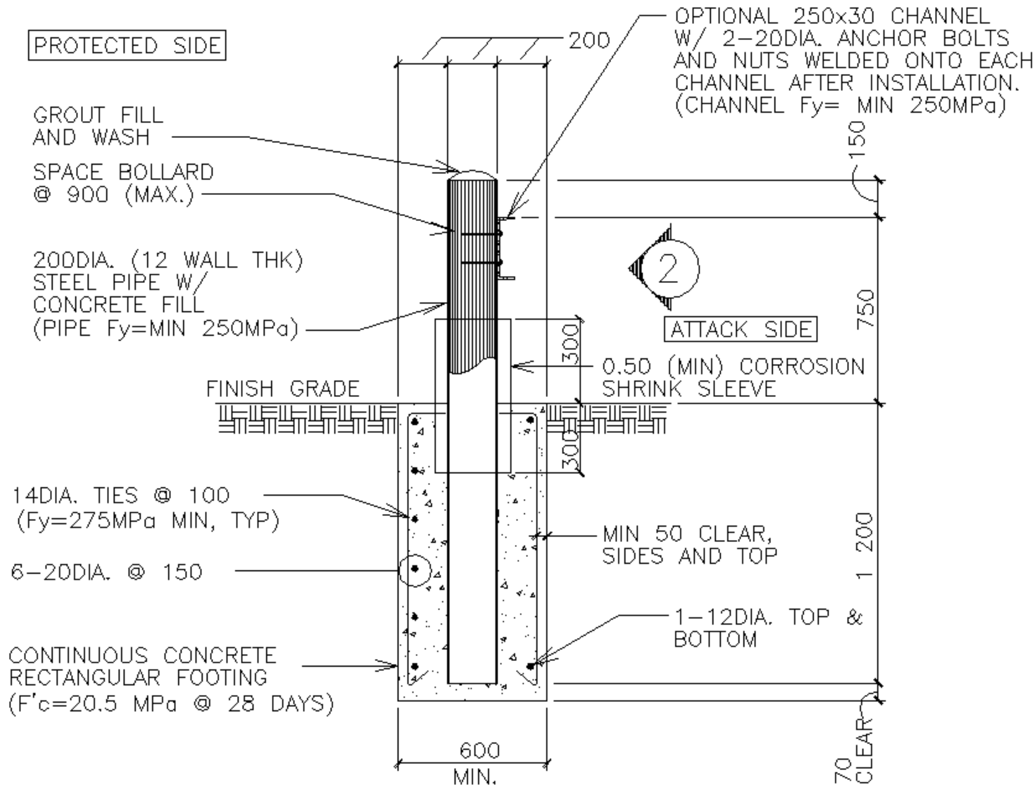
The following is a compilation of passive vehicle barrier systems used at DOD facilities. Included are generic systems that can be constructed with the aid of self-help manuals, using standard, and locally available materials. Some of the systems have not been formally tested, but should inflict substantial damage on a vehicle if impacted. A consolidated list of passive barriers, kinetic energy, and penetration data is provided in Appendix \1\ C /1/. See paragraph 5.3 h Additional Design Considerations, for handicap accessibility requirements.

6-2.1 **Concrete-Filled Bollard**.

6-2.1.1 **Description**.

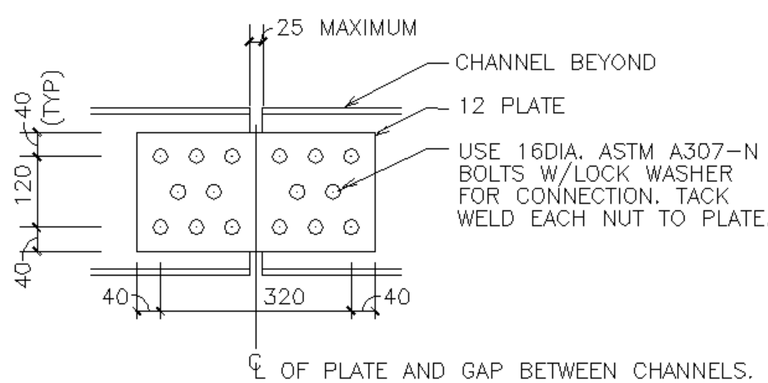
Passive steel bollards can be constructed locally and are an effective means of enhancing security against vehicular bomb attacks. Approved bollards are constructed of structural steel pipe filled with concrete. The steel pipe should have a minimum outside diameter of 8-in. (20-cm), 1/2-in. (1.2-cm) wall, and be a minimum of 7-ft (2.1-m) in length. The bollards should extend 3 ft (0.9 m) above the ground level from a continuous footing with minimum width of 2 ft (0.6 m), as shown in Figure 6-12 and Figure 6-13. The bollards should be positioned 3 ft (0.9 m) ft apart on center (see example layout in Figure 6-13 and Figure 6-14. Bollards should never be placed on the un-secure side (outside) of a fence where they can be used as a climbing aid.

Figure 6-12 DOS Passive Anti-Ram Bollard Example



1 BOLLARD SECTION
SCALE = 1:20

NOTE: ALL DIMENSIONS IN MILLIMETERS.



2 CHANNEL SPLICE DETAIL

NOTE: ALL DIMENSIONS IN MILLIMETERS.

Figure 6-13 Example Bollard Design Section

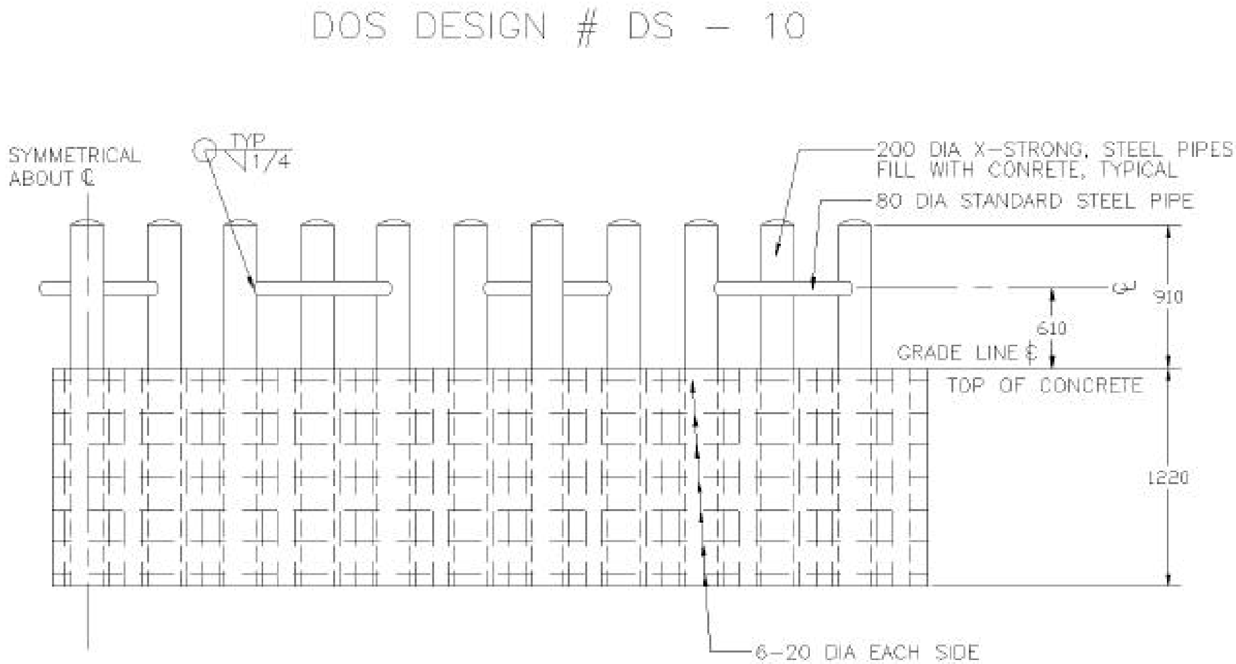
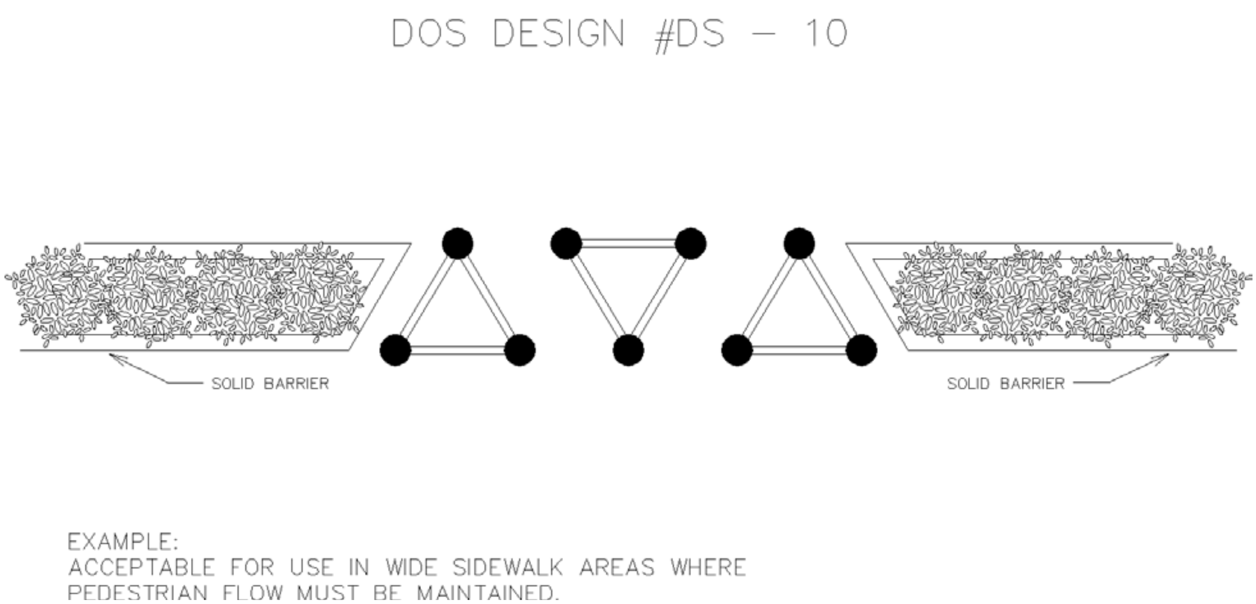


Figure 6-14 Bollard Design Example Layout in Plan View



6-2.2 **Concrete Median**.

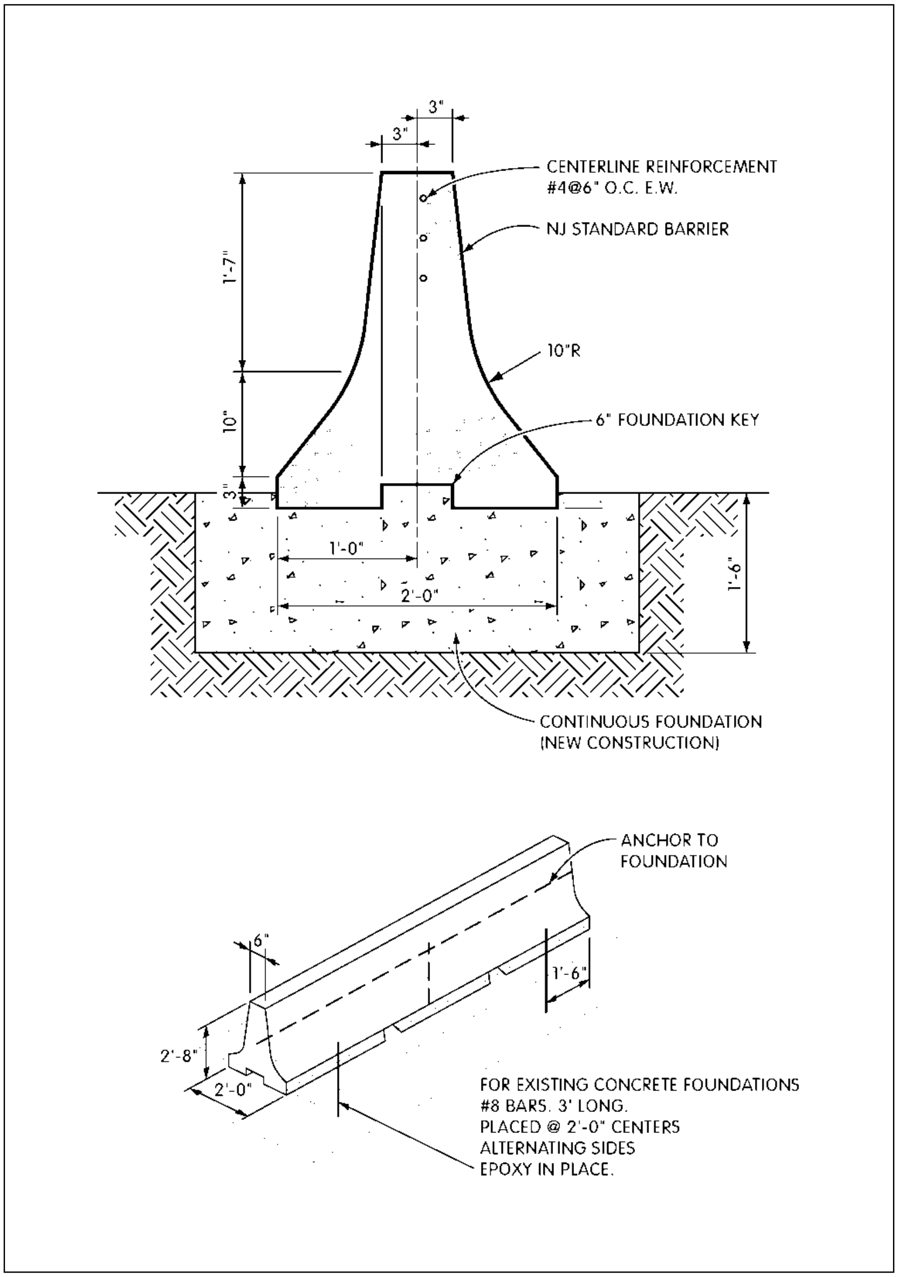
6-2.2.1 **Description**.

A concrete highway median (also known as a Jersey Bounce or Jersey Barrier) can be effectively used as a perimeter vehicle barrier, but only if the medians are securely fastened together. It can either be erected from pre-cast tongue-and-groove sections or cast in place with special concrete-forming equipment. It is especially effective for impact angles less than 30 degrees and is appropriate for locations where access roads are parallel to the barrier. Complete penetration is possible with light vehicles; however, damage to the vehicle will be extensive. If the potential impact angle from threat vehicle is expected to exceed 30 degrees, anchor barrier to foundation. These barriers should be set in a concrete foundation, as shown in Figure 6-15. Also barriers need to be securely connected with a minimum of one 3/4 inch steel cable tying them together to be effective.

6-2.2.2 **Testing**.

A non-reinforced, anchored, concrete median barrier was tested with a 4,000-lb (1,818-kg) vehicle at 50 mph (81 kph). The vehicle penetrated the barrier 20 ft (6 m). The vehicle had extensive front-end damage, and the occupants would have received serious to critical injuries. During the impact, a section of the barrier was broken and overturned. These barriers should be set in a concrete foundation, as shown in Figure 6-15, for applications where the impact angle exceeds 30 degrees. The barriers need to be securely tied together to be effective.

Figure 6-15 Precast Non-Reinforced Concrete Median



6-2.3 **King Tut Blocks**.

6-2.3.1 **Description**.

Non-reinforced concrete blocks can be used effectively as vehicle barriers or to slow the speed of oncoming vehicles, as shown in Figure 6-16. The placement of the blocks is shown in Table 6-7. These blocks can be cast in place and should be anchored to the ground so that movement or removal is difficult. Both Figure 6-16 and Table 6-7 are for passenger vehicles only. If trucks are considered, the ability to control POV speeds is lost. Thus, POV and truck traffic must be separated for optimum serpentine use.

Figure 6-16 Concrete Blocks

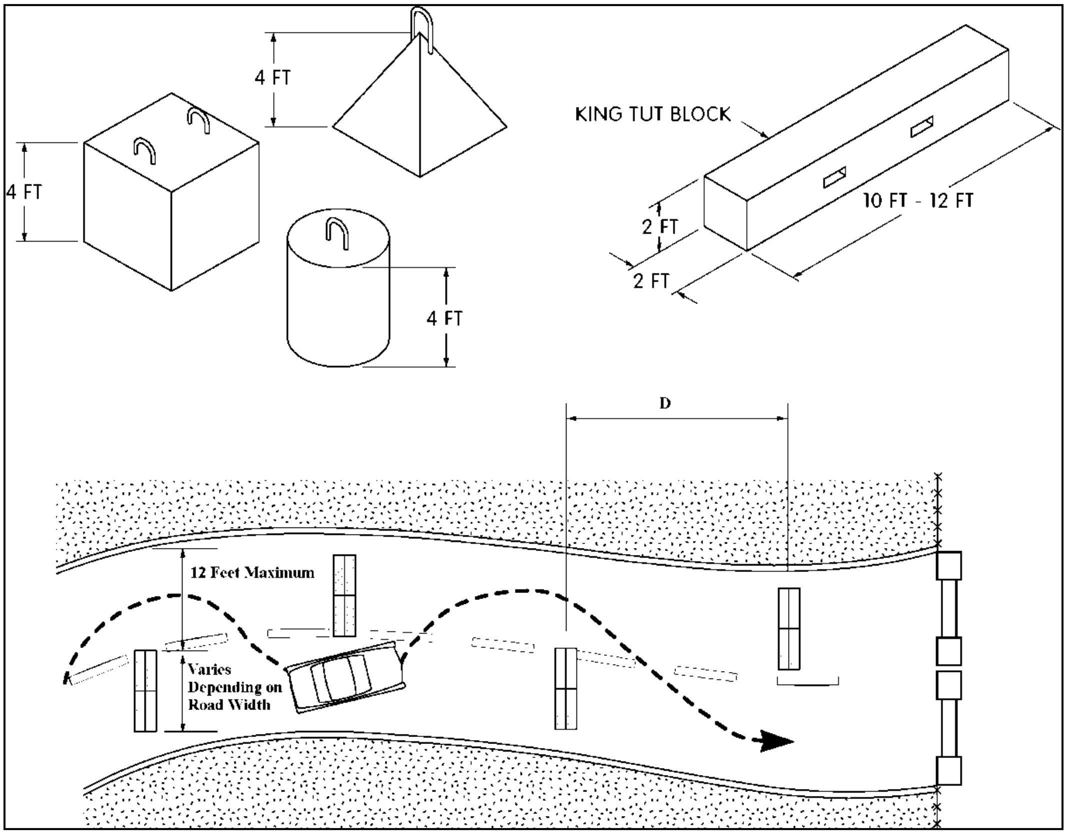


Table 6-7 Separation Distance (D)* for Barriers to Reduce Speed on a Straight Path in Ft (m)

Achievable Speed of Vehicle on a Curve in mph (kph)→ Road Width in ft (m) ↓	**20 (32)**	**30 (48)**	**40 (64)**	**50 (80)**	**60 (97)**
20 (6.1)	28 (8.5)	43 (13.1)	58 (17.7)	73 (22.2)	87 (26.5)
30 (9.1)	40 (12.2)	63 (19.2)	86 (26.2)	108 (32.9)	130 (39.6)
40 (12.2)	47 (14.3)	77 (23.5)	106 (32.3)	134 (40.8)	161 (49.1)
50 (15.2)	51 (15.5)	87 (26.5)	122 (37.2)	155 (47.2)	187 (57.0)
60 (18.3)	54 (16.5)	96 (29.3)	135 (41.1)	172 (52.4)	209 (63.7)

*Based on f=1.0

6-2.3.2 **Testing**.

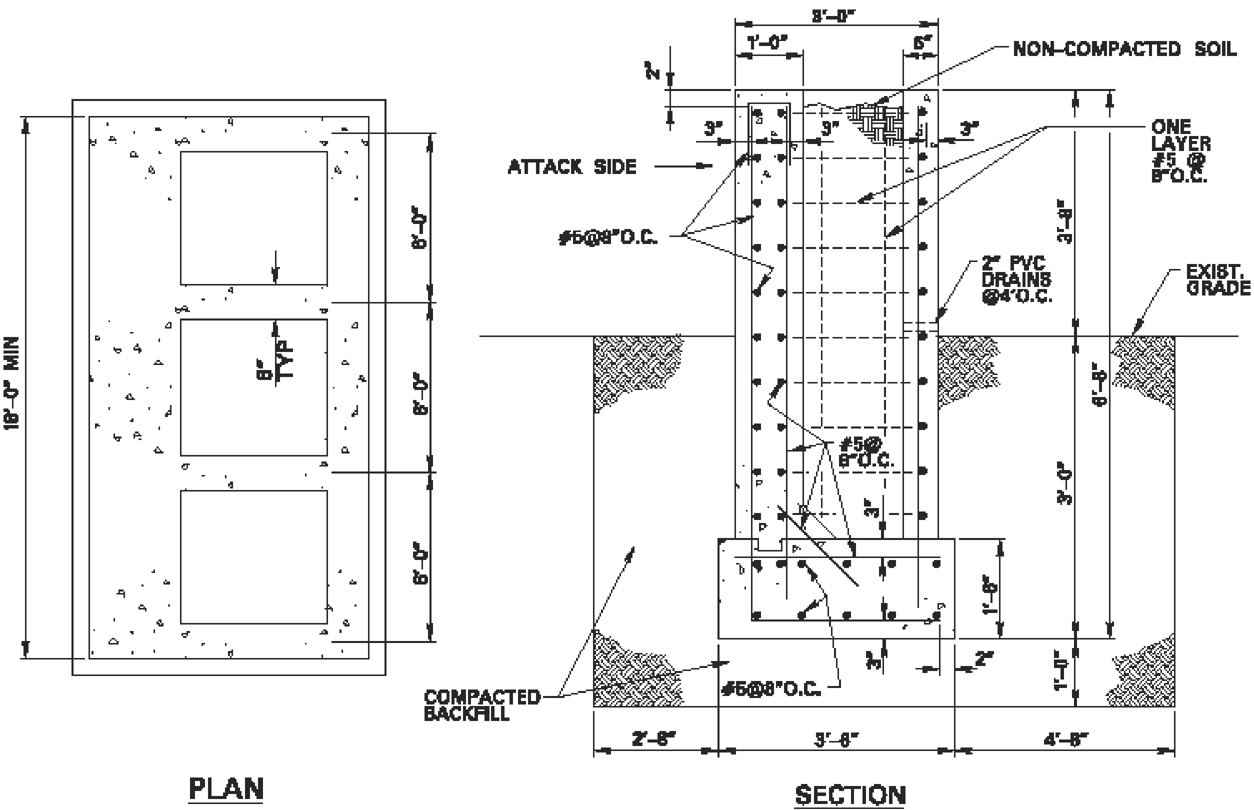
No formal crash testing has been conducted; however, the mass of this type of concrete construction should perform at least as well as a concrete median (Figure 6-15).

6-2.4 **Concrete Planter**.

6-2.4.1 **Description**.

A concrete planter barrier (Figure 6-17) offers permanent protection from vehicle penetration and can also be aesthetically pleasing.

Figure 6-17 Reinforced Concrete Planter



6-2.4.2 **Testing**.

This barrier was tested with a 15,000-lb (6,818-kg) vehicle traveling at 47 mph. The vehicle did not penetrate the barrier. The planter is DoS K12 certified.

6-2.5 **Excavations and Ditches**.

Ditches offer a simple method of rapidly securing a lengthy perimeter against a moving vehicle tactic. They can function as permanent anti-vehicle barriers if the required ditch profile is well maintained, or they can provide a temporary barrier before another permanent vehicle barrier system is installed. The ditch profile, including the approach slope, is critical to its ability to function as a vehicle barrier.

There are two vehicle attack methods against a ditch; 1) a slow covert attack where the vehicle attempts to cross the ditch by approaching at a oblique angle almost parallel to the ditch and going down and then up along the profile of the ditch, and 2) a fast attack where the vehicle approaches perpendicular to the ditch at high speed and attempts to jump the ditch. In the latter case, the flexibility in the vehicle suspension system and inertia of the vehicle can allow the front wheels to roll over the far edge of the ditch even if they do not fully clear the ditch. Also ditches are vulnerable to coordinated attacks, where the ditch profile is modified in the initial attack and then a moving vehicle attack is mounted across the ditch before it can be repaired.

Soil berms adjacent to the protected side of the ditch provide additional resistance to vehicle attack but they also can make the ditch a more effective hiding place for attackers on foot. This negative aspect of berms is less significant when there are elevated observation positions near the ditch. Soil berms and placement of spoil from ditch excavation on the attack side of the ditch should not be used because they provide a ramp effect, or launch angle over the ditch for a fast vehicle attack, increasing the capability of a vehicle to jump the ditch.

Numerous profiles for anti-vehicular ditches have been proposed in previous DoD documents, that were based on ditches used primarily to slow tank attacks. These profiles were not tested against simulated moving terrorist vehicle bombs until recently when similar ditches, tested in the United Kingdom. The following conclusions were determined from the United Kingdom tests:

a. Asymmetric V-shaped ditches with an inclined angle greater than 65 degrees and a total width and depth equal or greater than 5 m and 1.2 m, respectively, were able to stop the test vehicle.

b. The approach terrain on the attack side of the ditch should not have any incline or spoil and preferably should have a slight decline.

c. Ditches will stop a fast vehicle attack provided the vehicle drops more than 75% of its wheel diameter in the space provided.

d. Trapezoidal ditches should be avoided in general due to a concern that a vehicle can drive in and out of the ditch in a slow attack

The United Kingdom tests were not part of a comprehensive design project for anti-vehicular ditches that allowed the ditch profile to be optimized based on both resistance to moving vehicle attack and practical construction considerations. A study by NAVFAC was conducted to use observations from the United Kingdom tests, simple analyses of moving vehicle trajectories over various ditch profiles, and a survey of large commercial vehicle geometry information to design the three anti-vehicular ditches shown in Figures 6-18, 6-19 and 6-20. In all three figures, the protected side of the ditch is on the left.

Figure 6-18 Anti-Vehicular Ditch Profile with Incline Slope Requiring Stabilization

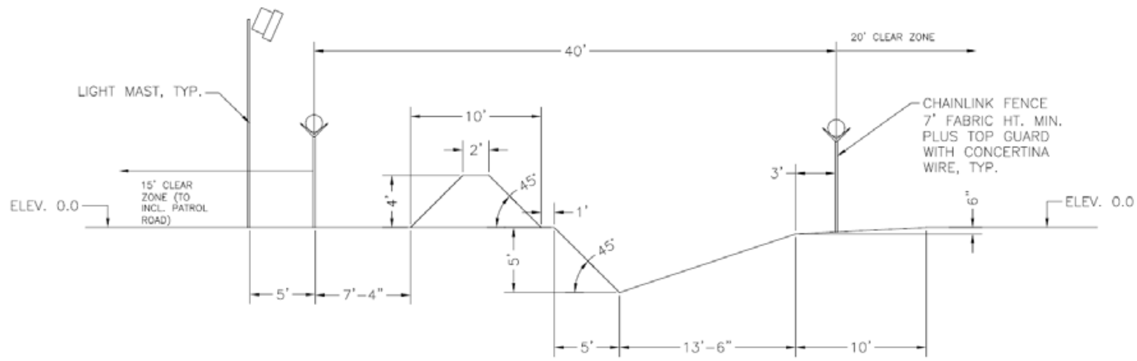


Figure 6-19 Anti-Vehicular Ditch Profile with Maximum Incline Slope Not Requiring Stabilization

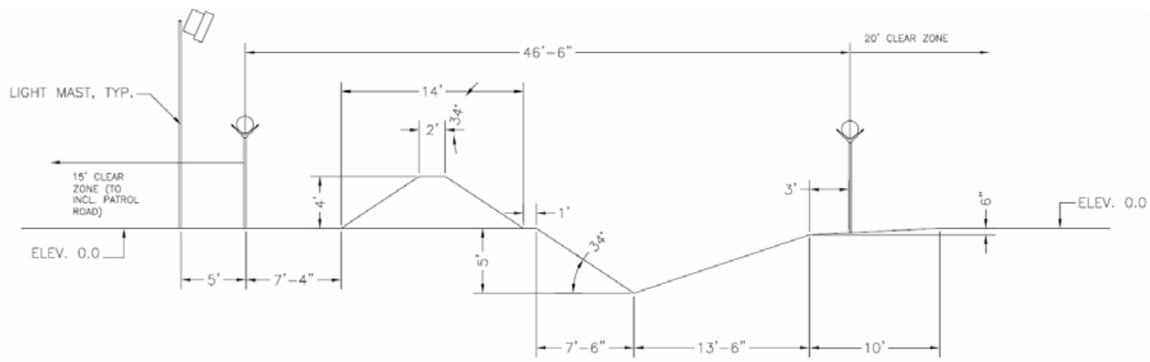
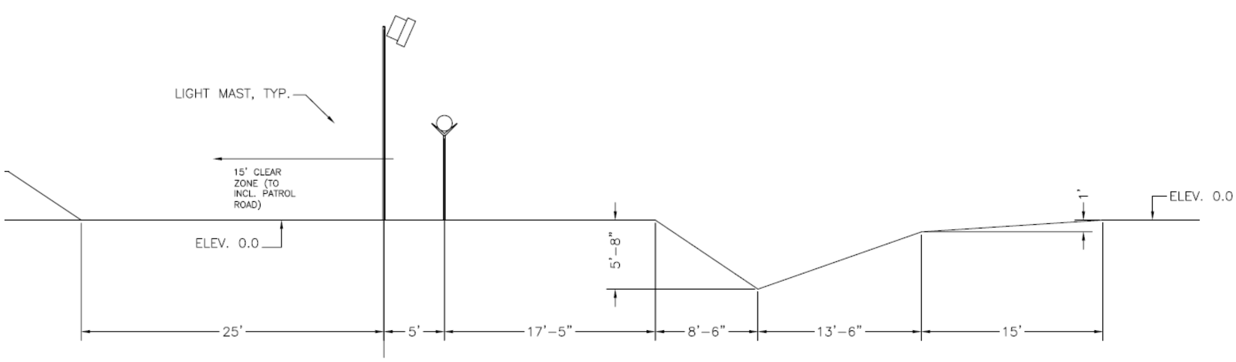


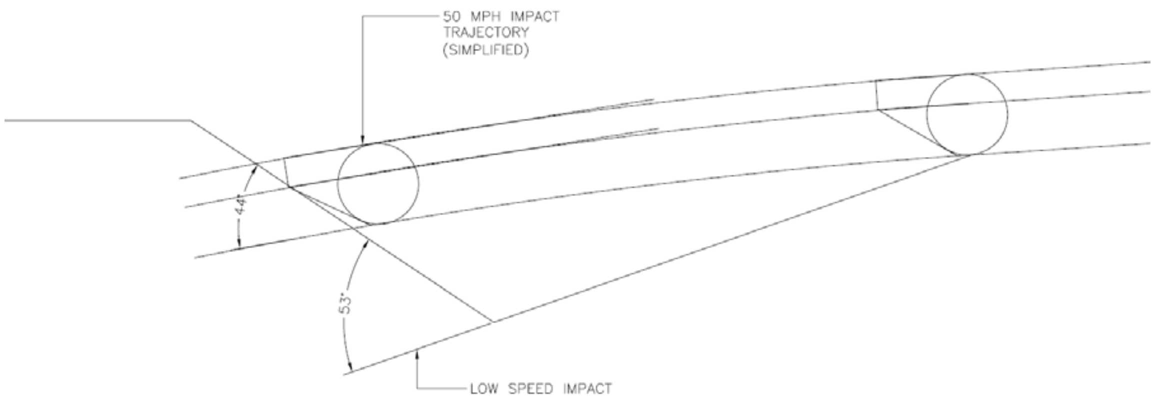
Figure 6-20 Anti-Vehicular Ditch Profile with Maximum Incline Slope Not Requiring Stabilization or Berm



Trajectory simulations of \1\ medium sized SUV's /1/ at velocities up to 50 mph showed that the vehicle impact angle relative to the inclined slope on the far side of the ditch was at least 43 degrees for all the ditch profiles in Figure 6-18 through

The trajectory simulations were based on a simple physics derivation that ignored air resistance and specific vehicle geometry characteristics. Figure 6-21 shows a trajectory analysis where the approach angle at impact for the vehicle at 50 mph is 43 degrees. This approach angle is sufficient to prevent the front bumper from clearing the top edge of ditch for a range of commercial utility vehicles including Jeeps, Land Rovers, SUV's, and Hummers (except a Hummer 1) based on a limited survey of the geometry of these vehicles by NAVFAC Atlantic. This survey also indicated that a 42 degree side slope or greater was sufficient to cause all the surveyed vehicles to tip if they were trying to make a cross the ditch at an oblique angle in a covert attack.

Figure 6-21 Simulated Trajectory Path and Impact Angle with Ditch Incline Slope for Vehicle at Two Speeds



The most vehicle survey focused on the lower bumper reference line height of the vehicles, which affects the maximum approach impact angle that could allow a vehicle to clear the ditch, and the maximum side slope angle. The approach angle and lower bumper reference line are illustrated in Figure 6-22 from the International Organization of Motor Vehicle Manufacturer's (OICA). Based on a limited survey of SUVs by the OICA, the lower bumper reference height ranged from 340 mm (13.4") to 500 mm (19.7"). This information was used with a survey of SUV vehicle specifications to determine maximum vehicle approach angles and side slope angles shown in Tables 6-18, 6-19 and 6-20. The side slope in Table 6-8 is the transverse angle the vehicle can be at without tipping over.

Figure 6-22 Lower Bumper Reference Line and Vehicle Approach Angle

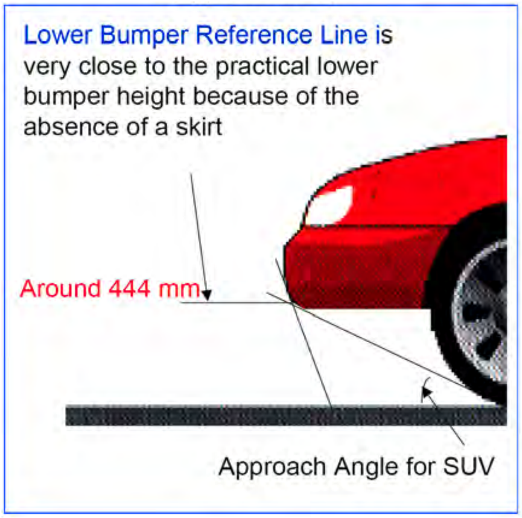


Table 6-8 Maximum Vehicle Approach Angles and Side Slope Angles

Vehicle	Maximum Approach Angle (degrees)	Maximum Side Slope Angle (degrees)
Jeep Liberty	38.1	
Jeep Commander	34	
Hummer H3	39.4	
Hummer H1	72	40
Hummer H2	41	40
Land Rover LR3	37	35
Toyota FJ Cruiser	34	41
Land Rover Range Rover	34	
Jeep Grand Cherokee	34	
Mercedes G-Class	36	28.4
Toyota 4 Runner	31	

The berms in Figure 6-18 and Figure 6-19 are essentially safety factors and they are recommended given the approximations in the analyses used to design the ditch profiles. The profile in Figure 6-18 provides the highest amount of resistance against a moving vehicle threat, but it requires a stabilized slope, such as concrete riprap or sand-bag cover, since natural soil cannot maintain a 45 degree slope. The profile in Figure 6-19 provides less resistance against a moving vehicle threat, but sandy soil can theoretically maintain a 34 degree slope. Finally, the profile in Figure 6-20 is similar to Figure 6-19 except that it does not have the additional safety factor of a berm for stopping a moving vehicle threat. As mentioned previously, the berm may be considered unacceptable because it may provide a potential hiding place for attackers on foot. The declined approach slope helps to some effect, to offset the reduced resistance to a moving vehicle threat caused by deletion of the berm.

6-2.6 **Guardrails**.

6-2.6.1 **Description**.

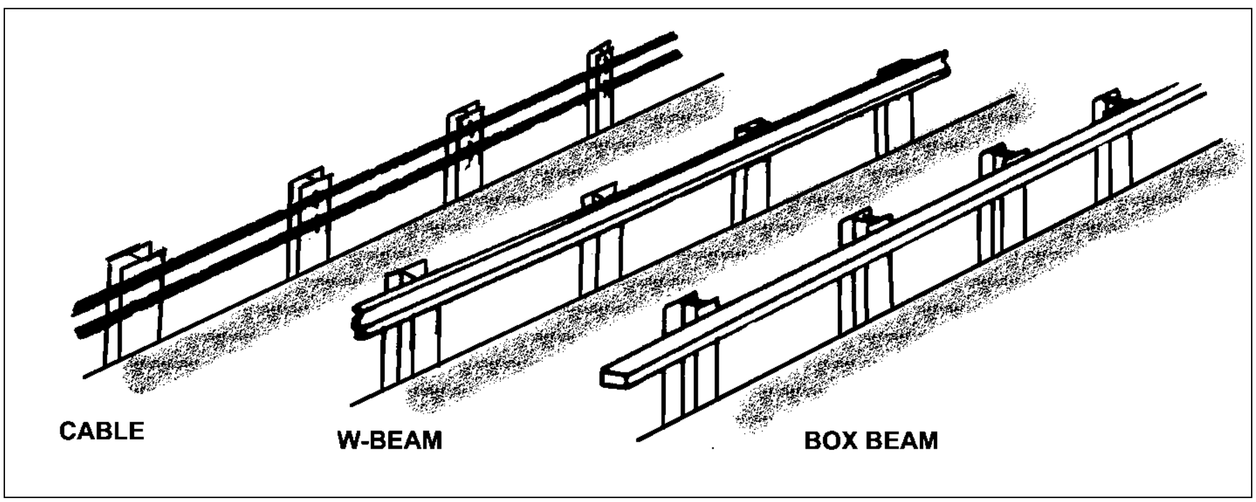
Standard highway guardrails or median barriers can be used as perimeter vehicle barriers (Figure 6-23). Guardrail design procedures can be found in the AASHTO Roadside Design Guide and AASHTO Geometric Design of Highways and Streets and in many state DOT standard drawings. Guardrails are normally designed to redirect vehicles approaching at angles less than or equal to 25 degrees and are not recommended as perimeter vehicle barrier for approach angles greater than 25 degrees..

A cable guardrail (AASHTO type G1) consists of three ¾-inch diameter steel cables, spaced 3 inches apart. The posts used are S3x5.7 steel, spaced at 16-ft intervals. The height, measured from the surface to the top rail, is 30 inches. From the end post, all three cables are turned down at a 45-degree angle and anchored to buried concrete deadmen.

A W-beam flexible guardrail (AASHTO type G2) consists of a 12 gauge "W" section bolted to S3x5.7 steel posts, spaced at 12 ft 6 in. intervals. A Blocked-Out W beam (AASHTO type G4) guardrail system uses a 12 gauge "W" section bolted to W6x8.5 posts, spaced at 6 ft 3 in. intervals. The AASHTO Guide for Selecting, Locating and Designing Traffic Barriers provides four post and blocking alternatives for this guardrail system. A thrie beam (AASHTO type G9) guardrail system consists of a steel thrie beam bolted to W6x8.5 steel posts at 6 ft 3 in. intervals.

A box-beam guardrail (AASHTO type G3) system consists of a 6 in. x 6 in. x 0.180 in. steel tube bolted to S3x5.7 steel posts, spaced at 6 ft 4 in. intervals.

Figure 6-23 Guardrails



6-2.6.2 **Testing**.

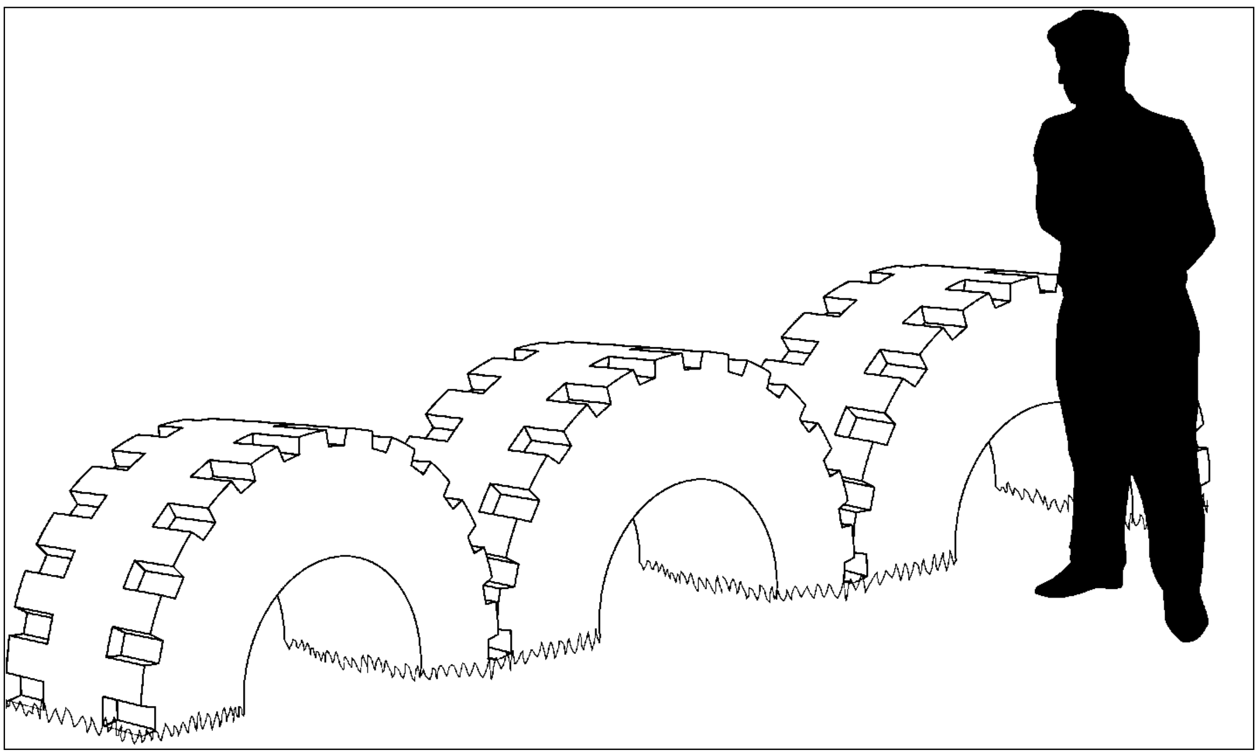
The cable guardrail system successfully redirected both low profile 3,500 lb (1,587 kg) vehicles and a 4,100 lb (1,850 kg) van, as well as other 4,000 lb (1,814 kg) vehicles, during testing for impact angles of 25 degrees or less. Tests of the W beam system resulted in redirection of a vehicle with an impact angle of 25 degrees, but the redirected vehicle was airborne for a distance of 50 ft. During testing of the Blocked-Out W beam system, the barrier successfully redirected low profile vehicles with impact angles of equal to or less than 25 degrees. This system caused several vans and other vehicles with high centers of gravity to overturn after impact. Tests of the thrie beam system provided a smooth redirection of vehicles when the impact angle was 25 degrees or less. The box beam guardrail system tested provided excellent redirection of the vehicle.

6-2.7 **Heavy Equipment Tires**.

6-2.7.1 **Description**.

Heavy equipment tires, half-buried in the ground and tamped to hold them rigid, can be effective vehicle barriers (Figure 6-24). Use tires that are 7 to 8 ft (2.1 to 2.4 m) in diameter. Heavy equipment tires can usually be obtained locally from salvage operations for the cost of hauling them away.

Figure 6-24 Heavy Equipment Tire Barrier



6-2.7.2 **Testing**.

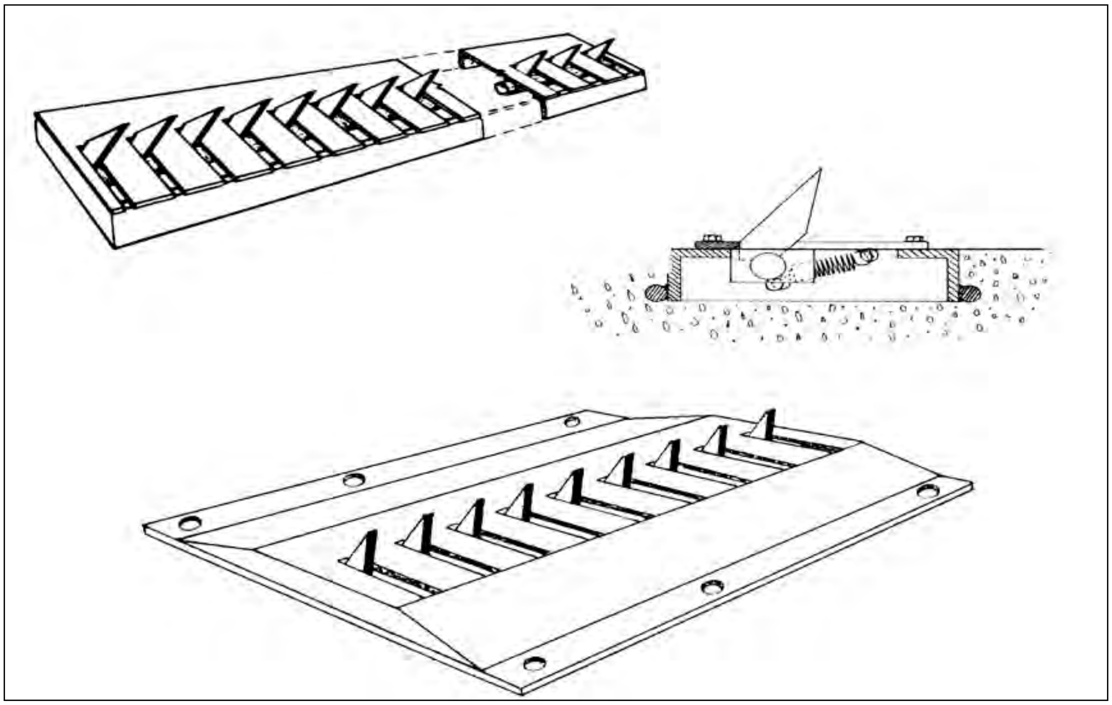
Buried equipment tires were tested using a 3,350-lb (1,523-kg) vehicle traveling at 51 mph (82 kph). The vehicle penetrated the barrier 1-ft (0.3-m). The tires used were 36 ply, 8 ft in diameter (2.4 m), and weighed 2,000 lbs (909 kg) each.

6-2.8 **Tire Shredders**.

6-2.8.1 **Description**.

Tire shredders can be either surface-mounted or imbedded, as shown in Figure 6-25. These devices are normally used for traffic control purposes and are designed to slow or stop a vehicle by deflating their pneumatic tires. These units are available from a number of commercial manufacturers. Delta Scientific Corporation manufactures the unit shown in Figure 6-25. When a vehicle drives over the mechanism in the wrong direction, the spikes penetrate the tire casing, which quickly deflates the tires, making the vehicle difficult to operate for extended periods. These systems should not be considered vehicle barriers. Tire shredders are not recommended where vehicle traffic drives over these devices at speeds exceeding 5 mph. These systems may also not be effective against modern "run flat" tires, heavy-duty truck tires, or extra-wide tires that can bridge over two or more spikes. Tire shredders have a very limited capability to stop a vehicle.

Figure 6-25 Tire Shredders



6-2.8.2 **Testing**.

These systems have not been formally tested, and as indicated above are not considered a vehicle barrier.

6-2.9 **Steel Cable Barriers**.

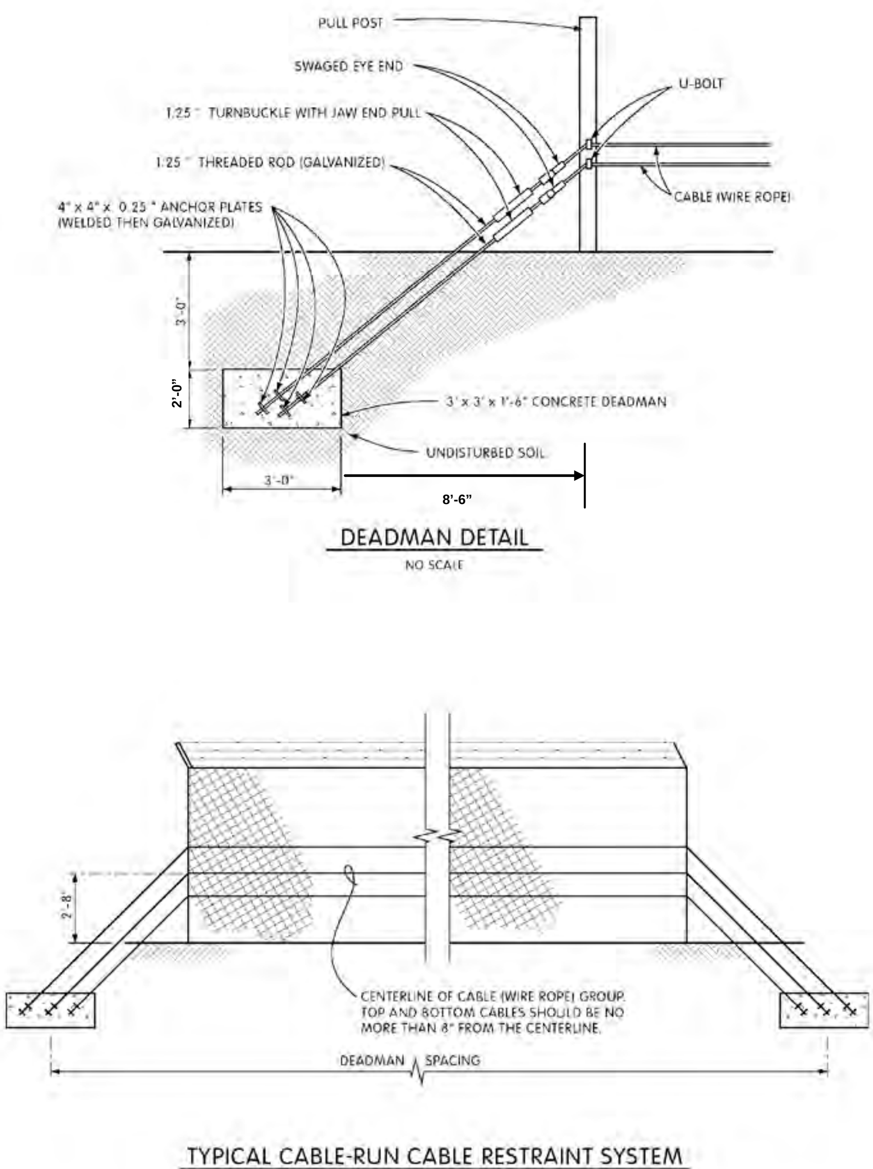
6-2.9.1 **Description**.

As shown in Figure 6-26, there are several configurations for steel cable barriers. Site requirements, configuration, and environment must be carefully considered prior to selecting a cable system for a particular application.

6-2.9.2 **Testing**.

Systems such as those shown in Figure 6-26 have not been formally tested. However, two 3/4-in. (1.9-cm) diameter cables attached to a 200-ft section of fence, minus fabric, with deadman anchors at both ends were tested with a 4,000-lb (1,818-kg) vehicle at 52 mph (84 kph). The vehicle was stopped within 13 ft (4 m) and then pushed back to the impact point. For additional considerations, details, and design guidance relating to the use of steel cables in fencing and gates, refer to UFC 4-022-03.

Figure 6-26 Steel Cable Barriers

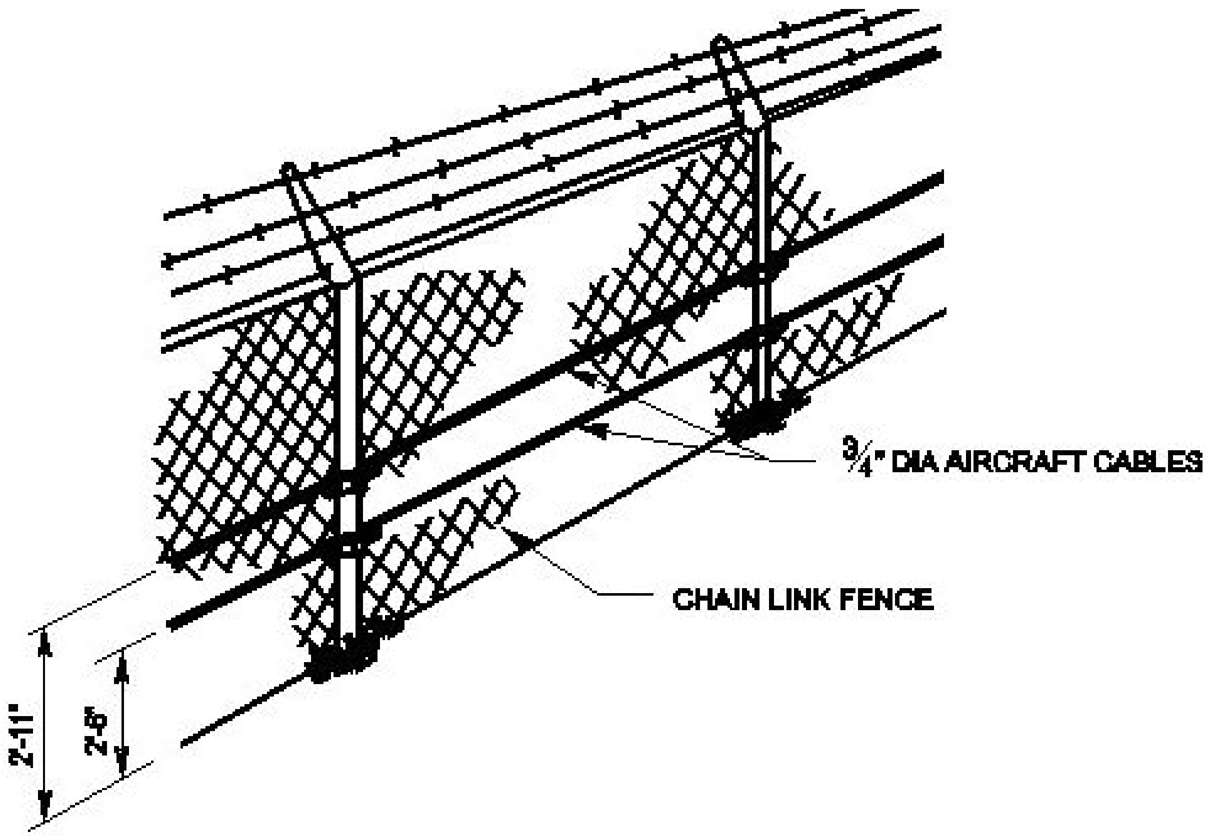


6-2.10 **Steel Cable-Reinforced Chain Link Fencing**.

6-2.10.1 **Description**.

Without some reinforcement, a standard chain-link fence can be penetrated easily by a light vehicle with little or no damage. However, standard fencing can be reinforced to provide a cost-effective method to protect against the threat of penetration by light vehicles, as in Figure 6-26 and Figure 6-27. Although no required pre-tension is specified for the cable, it is generally considered acceptable that it should be snug and not have significant sag. Routine (usually daily) perimeter inspection should include checking for visible sagging. At this time, there is no specific sag measurement benchmark, so checking for “visible” sag is a conservative approach. Regularly scheduled inspections should also check for corrosion of fittings, including the turnbuckles, anchor bolts, U-bolts, any swaged fittings, and cable clamps. Cable clamps should be inspected as well to insure no nuts have become loose. For additional considerations, details, and design guidance relating to the reinforcing of fencing and gates, refer to UFC 4-022-03.

Figure 6-27 Typical Steel Cable Reinforced Chain-Link Fencing



6-2.10.2 **Testing**.

Sandia National Laboratories tested a barrier consisting of a chain link fence reinforced with a 3/4-in. (1.9-cm) cable. In this test, a 3,350-lb (1,523-kg) vehicle traveling at 23.5 mph (38 kph) penetrated the barrier 7 ft (2.1 m). A 4,050-lb (1,841-kg) vehicle, traveling at 50.6 mph (82 kph), penetrated 26 ft (7.9 m), and the cable failed at the impact location. A test using two cables with no fabric was impacted by a 4,000-lb (1,814-kg) vehicle, traveling at 52 mph (84 kph), and the vehicle penetrated 13 ft (4 m) and then pushed back to the original fence line. Engineering analysis of various cable restraint configurations, using the BIRM computer model (PDC-TR90-2), is shown in Table 6-9.

Table 6-9 Performance of Cable Restraint Systems

Cable Barrier w/200-ft Anchorage Spacing	Kinetic Energy in ft-lbf x 1,000 (kgf-m)	Penetration in Ft (m)
1 Cable @ 3/4-in. dia.	100 (13.8)	40 (12.2)
2 Cables @ 3/4-in. dia.	200 (27.6)	40 (12.2)
3 Cables @ 3/4-in. dia.	338 (46.7)	40 (12.2)
4 Cables @ 3/4-in. dia.	418 (57.8)	40 (12.2)
1 Cable @ 1-in. dia.	150 (20.7)	40 (12.2)
2 Cables @ 1-in. dia.	340 (47.0)	40 (12.2)
3 Cables @ 1-in. dia.	506 (70.0)	40 (12.2)
4 Cables @ 1-in. dia.	706 (97.6)	40 (12.2)

6-2.11 **Reinforced Concrete Knee Walls**.

6-2.11.1 **Description**.

When a perimeter wall or fence line needs to also serve as a vehicle barrier, it must meet passive vehicle barrier standards. This can be achieved by using a reinforced concrete knee wall structure. A knee wall barrier is a wall resting on a footing. The entire footing and part of the wall are imbedded in the existing soil or in a crushed stone mix. Figures 6-28, 6-29 and 6-30 show representative cross sections of this type of barrier.

Figure 6-28 Anti-Ramming Foundation Wall

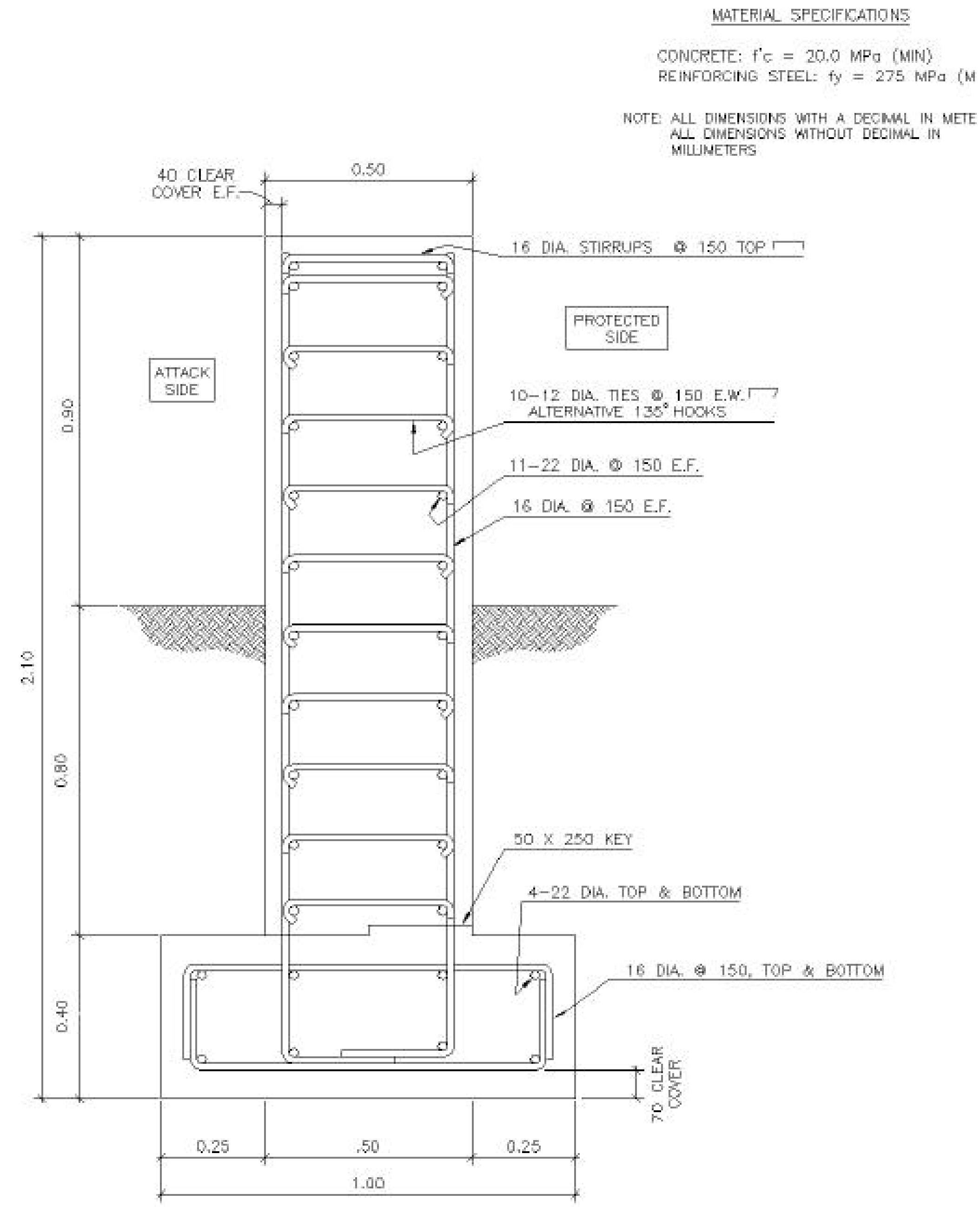


Figure 6-29 Anti-Ramming Knee Wall Section

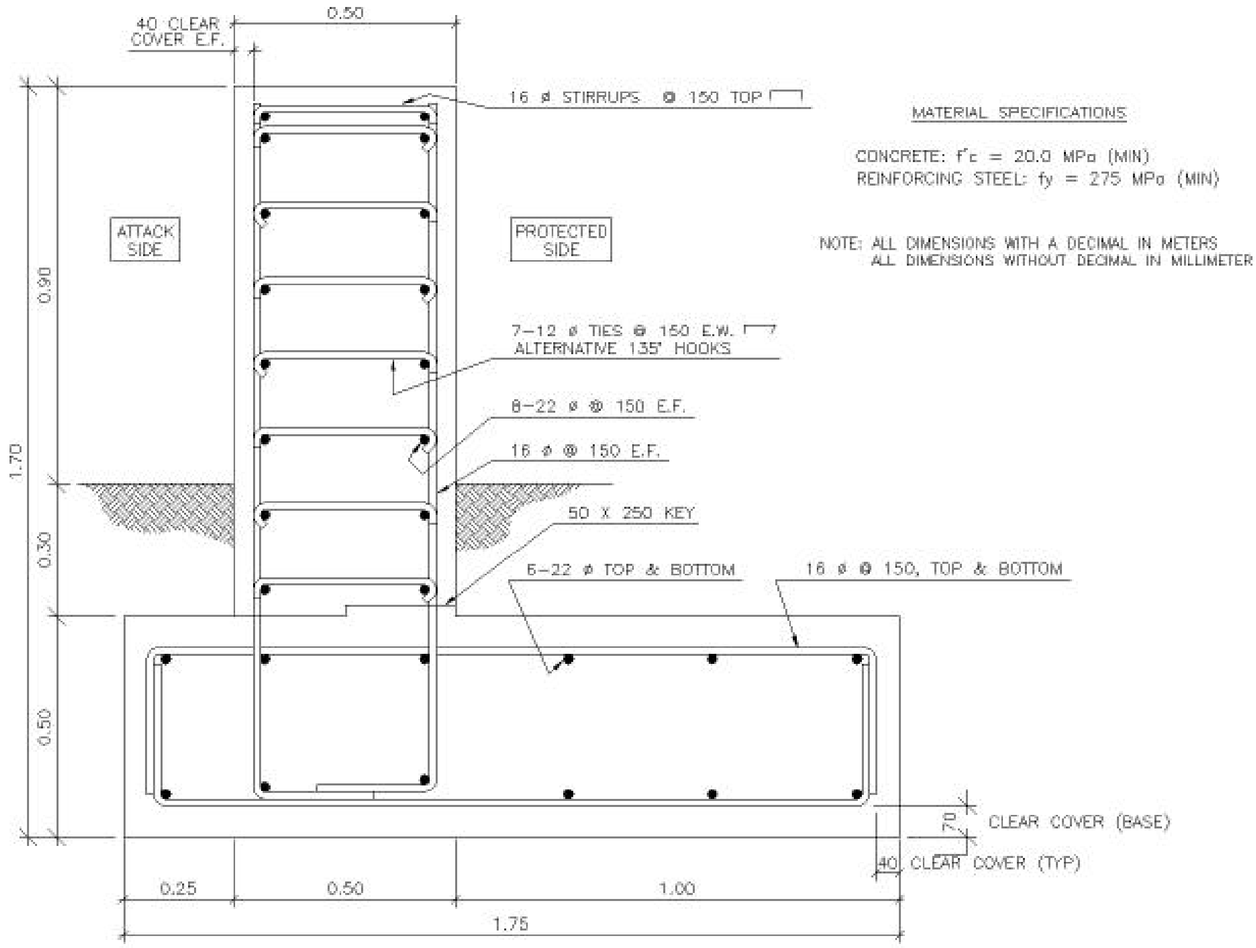
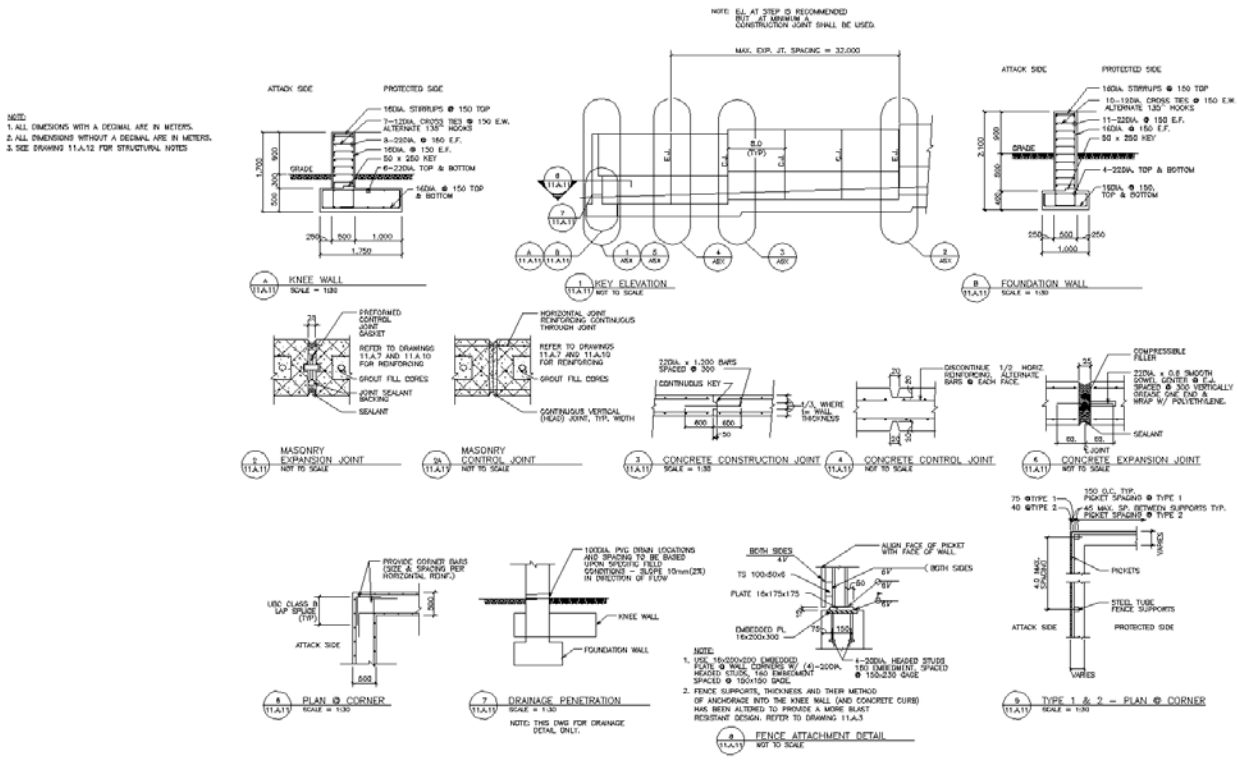


Figure 6-30 Reinforced Concrete Knee Wall Details



6-2.11.2 **Testing**.

Reinforced concrete knee walls have been formally tested. A configuration similar to Figure 6-28 was tested with a 15,000-lb (6,818-kg) vehicle traveling at 50 mph (80 kph). The wall effectively stopped the attack vehicle within 3.28 ft (1 m).

6-2.12 **Plastic Barrier Systems**.

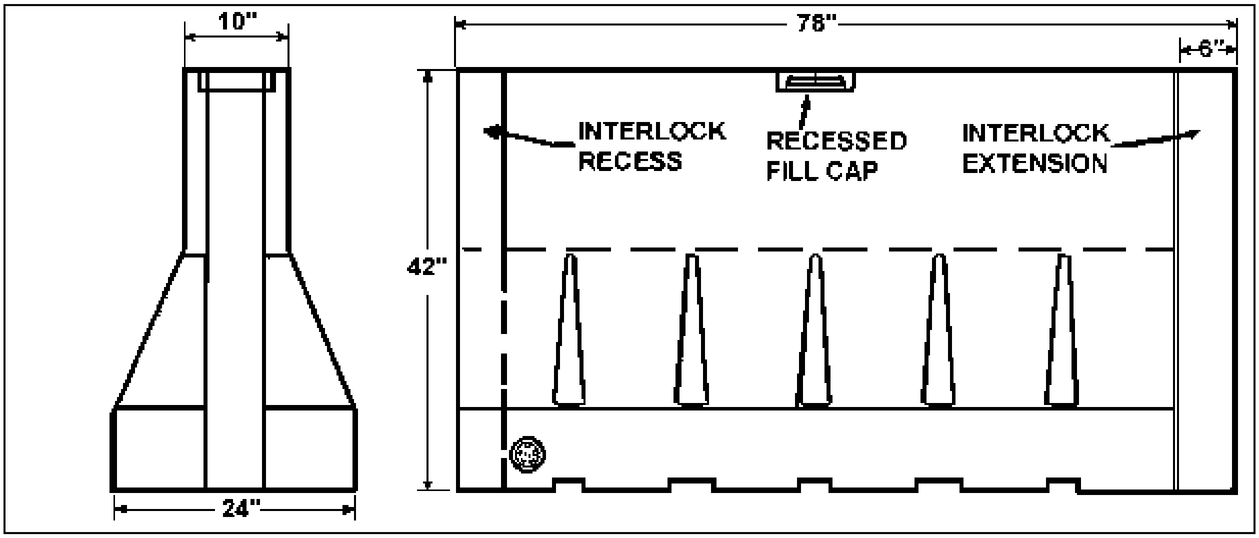
6-2.12.1 **Description**.

Plastic barrier systems (Figure 6-31) are available from several manufacturers.\1\ /1/ They are molded in a configuration similar to the Jersey Bounce or Barrier, shown in Figure 6-15. These barriers weigh approximately 130 lbs empty and 1,600 to 1,800 lbs when filled with water. The units are made from polyethylene plastic and come in six-ft sections that are easily transported. An interlocking section and steel pipe are used to link the sections together. Linking the sections is strongly recommended to provide added resistance to vehicle impact and reduce lateral movement. Surface mounting of these units limits their use as effective vehicle barriers, except for low-speed impacts (less than 15 mph) and angles less than 25 degrees.

6-2.12.2 **Testing**.

Example plastic barriers, filled with sand, have been crash tested, as described in Appendix \1\ C/1/, paragraph C-3.

Figure 6-31 Commercially Available Plastic Barrier System



6-2.13 **Expedient Barrier Systems**.

When barrier systems are required quickly with no time for ordering manufactured barriers, common construction items or available construction vehicles can be used as barriers. Materials such as large-diameter concrete and steel pipes can form makeshift barriers. Even large construction vehicles (e.g., dump trucks and earth moving equipment) that have heavy mass and size can be used, or modified for use, as expedient barrier systems. Some examples are:

a. Three-ft (0.9-m) sections of large-diameter, corrugated metal or reinforced concrete pipe can be placed on end and filled with sand or earth.

b. Steel pipe can be stacked and welded together in a pyramid.

c. Construction vehicles can be anchored together with cable or chain.

These expedient measures can provide effective protection against vehicle ramming attacks. Because no testing has been done on these systems, it is important that these barriers be stabilized and anchored to prevent displacement by a threat vehicle.

6-3 **VEHICLE BARRIER PERFORMANCE**.

Full-scale testing of vehicle barrier systems is only one way to obtain information on the performance capabilities of vehicle barriers. Testing provides evidence that the selected barrier will effectively absorb the impact of a threat vehicle. Tests may be conducted by independent testing laboratories, government agencies, or the manufacturer. Some tests are properly documented and/or witnessed by authorities, while others are not. Only tests conducted by independent laboratories or government agencies should be accepted.

It is important to correctly interpret the test results. For example, “full penetration” could mean that the vehicle passed through a barrier and was still capable of movement after penetration. Or, it could mean the vehicle payload penetrated through a barricade, but the vehicle was incapacitated. Whenever possible, carefully review the actual test report before selecting a barrier system. For commercially-available active barriers, these reports are usually accessible from the manufacturer. Such review may not always be possible

Selection of vehicle barriers can also be based on engineering analysis. Finite element analysis and computer models specifically designed to analyze barrier impact, such as the Barrier Impact Response Model 3 Dimension, have been successfully used and correlated to actual test results. Using this method is much more cost-effective than full-scale testing. Before accepting the results of an engineering analysis from a manufacturer, have the calculations carefully checked by a qualified structural engineer.

Appendix A - REFERENCES

AASHTO Guide for Selecting, Locating and Designing Traffic Barriers.

Army Regulation (AR) 190-13, *Army Physical Security Program.*

\1\ Construction Criteria Base (CCB) and the Whole Building Design Guide (WBDG) maintained by the National Institute of Building Sciences at Internet site http://www.wbdg.org/ccb./1/

DOD 2000.12 *DOD Antiterrorism (AT) Program*.

DOD 2000.16 *DOD Antiterrorism Standards.*

DOD 5200.8-R *Physical Security Program.*

MCO P5530.14A *Marine Corps Physical Security Program Manual.*

Means, R.S., "Building Construction Cost Data", 61st Edition, 2003, http://www.rsmeans.com.

PDC-TR90-2, *BIRM 3D – Barrier Impact Response Model 3 Dimension.*

SD-STD-02.1, *Specification for Vehicle Crash Test of Perimeter Barriers and Gates*.

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*, Tri-Service Engineering Senior Executive Panel, http://dod.wbdg.org/

UFC 4-010-02, *DoD Minimum Antiterrorism Standoff Distances for Buildings*, Tri-Service Engineering Senior Executive Panel, http://dod.wbdg.org/

UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual*, Tri-Service Engineering Senior Executive Panel, http://dod.wbdg.org/

\1\ UFC 4-020-02FA, *Security Engineering: Concept Design*, Tri-Service Engineering Senior Executive Panel, http://dod.wbdg.org/ /1/

UFC 4-022-01, *Security Engineering: Entry Control Facilities/Access Control Points*, Tri-Service Engineering Senior Executive Panel, http://dod.wbdg.org/

UFGS 34 71 13.19, *Unified Facilities Guide Specification, Active Vehicle Barriers,* http://dod.wbdg.org/.

UFGS 12 93 00, *Unified Facilities Guide Specification, Site Furnishings,* http://dod.wbdg.org/.

UG-2031-SHR *User's Guide: Protection Against Terrorist Vehicle Bombs.*

\1\ /1/

Appendix B - \1\ BARRIER /1/ COST DATA

B-1 **SCOPE.**

This appendix presents rating and cost data for commercial vehicle barriers, and cost data for passive barriers. The information contained herein is intended for informational purposes only.

B-2 **NON-GOVERNMENT PUBLICATIONS.**

Means, R.S., "Building Construction Cost Data", 65th Edition, 2007.

B-3 **DEFINITIONS.**

The definitions in Chapter 3 of this UFC apply to this appendix.

B-4 **ACTIVE BARRIERS.**

B-4.1 **DoS Ratings for Active Barriers.**

\1\See United States Army Corps of Engineers (USACE), Protective Design Center, Omaha District (https://pdc.usace.army.mil/library/BarrierCertification) for latest versions of DoS and DoD certified/rated anti-ram vehicle barriers./1/

\1\/1/

The ratings are explained in Table B-1.

Table B-1 DoS Ratings*

DoS Rating	Speed of Vehicle At Impact in mph (kph)	Kinetic Energy	Max. Allowable Penetration of Vehicle
K12	50 mph (81 kph)	1,250,000 ft-lbf (178,812 kgf-m)	
K8	40 mph (64 kph)	800,000 ft-lbf (110,600 kgf-m)	
K4	30 mph (48 kph)	450,000 ft-lbf (62,212 kgf-m)	
L3			3 ft (0.91 m)
L2			3 to 20 ft (0.91 to 6.1 m)
L1			20 to 50 ft (6.1 to 15.2 m)

* Based on 15,000-lb (6,818-kg) vehicle weight

B-4.2 **Cost Data for Active Barriers.**

\1\ Table B-2 contains cost data for active vehicle. /1/

\1\/1/

Table B-2 Manufacturer's Data and Cost for Certified Active Barriers

\1\

Characteristics Barrier Type (Active, Fixed, Portable, Barricade, Bollard, Gate)	DOS Rating	Equipment Cost* ($x1,000)	Installation Cost (% of Equip. Cost)	Width (ft)	Height (in.)	Operating Cycle (sec)	Emergency Cycle (sec)
SLIDING GATE Active, Fixed, Gate	K4 – K12	***	***	12	108	10 to 15	7 to 10
HYDRAULIC WEDGE Active, Fixed, Barricade	K12	35 to 45	125	#	36	2 to 15	1
SURFACE MOUNTED HYDRAULIC WEDGE Active, Fixed, Barricade	K12	35 to 45	125	#	39	4 to 5	1
SLIDING GATE Active, Fixed, Gate	K12	35 to 45	125	12	108	27 to 48 FPM	
SURFACE MOUNTED HYDRAULIC WEDGE Active, Fixed, Barricade	K12	35 to 45	125	#	39	3 to 15	2
RETRACTABLE BOLLARDS Active, Bollard	K8	27 to 37	125	1.06 dia.	39	3 to 15	1.5
RETRACTABLE BOLLARDS Active, Bollard	K12	29 to 39	118	1.06 dia.	35	3 to 15	1.5
RETRACTABLE BOLLARDS Active, Bollard	K4	25 to 35	133	0.55 dia.	30	3 to 15	1.5

Characteristics Barrier Type (Active, Fixed, Portable, Barricade, Bollard, Gate)	DOS Rating	Equipment Cost* ($x1,000)	Installation Cost (% of Equip. Cost)	Width (ft)	Height (in.)	Operating Cycle (sec)	Emergency Cycle (sec)
SHALLOW MOUNT HYDRAULIC WEDGE Active, Fixed, Barricade	K12	20 to 40	70	#	44	4 to 6	1
HYDRAULIC WEDGE Active, Fixed, Barricade	K12	20 to 40	75	#	32	4 to 6	1
RETRACTABLE BOLLARDS Active, Bollard	K4	15 to 20	75	#	30	4 to 6	1
SURFACE MOUNTED HYDRAULIC WEDGE Active, Fixed, Barricade	K12	13	60	14	31	3	1
SURFACE MOUNTED HYDRAULIC WEDGE SINGLE BUTTRESS Active, Fixed, Barricade	K12	24	35	14	33	3	1
HYDRAULIC WEDGE Active, Fixed, Barricade	K12	18	60	14	31	3	1
RETRACTABLE BOLLARD Active, Fixed, Bollard	K12	43.2	50-75	# (3 bollards)			
HYDRAULIC DROP ARM Active, Fixed, Barricade	K4	22.7	40	#	39	3	

Characteristics Barrier Type (Active, Fixed, Portable, Barricade, Bollard, Gate)	DOS Rating	Equipment Cost* ($x1,000)	Installation Cost (% of Equip. Cost)	Width (ft)	Height (in.)	Operating Cycle (sec)	Emergency Cycle (sec)
NET BASED NON-HYDRAULIC SINGLE LANE Active, Fixed, Barricade	K8	47.9	Included in cost	#	55-58	2	1.5
NET BASED NON-HYRAULIC MULTIPLE LANE Active, Fixed, Barricade	K8	59.4	Included in cost	36	55-58	2	1.5
NET BASED NON-HYRAULIC MULTIPLE LANE Active, Fixed, Barricade	K12	95.5	Included in cost	36	55-58	2	1.5
RETRACTABLE BOLLARDS Active, Fixed, Bollard	K12	~100	20 to 30	4 bollards			
DEEP FOUNDATION CRASH BEAM Active, Fixed, Barricade	K12	***	***	25	24 to 30	3 to 5	1
SHALLOW FOUNDATION CRASH BEAM Active, Fixed, Barricade	K4	***	***	25	24 to 30	3 to 5	1
WEDGE BARRIER Active, Fixed Barricade	K8	***	***			2 to 4	

* Cost figures are estimates from various manufacturers of vehicle barrier systems.
*** Cost information not publicly available
*# No data currently available
Various widths were tested. /1/

B-5 COST DATA FOR PASSIVE BARRIERS.

Table B-3 is a summary of cost data for selected passive vehicle barriers.

Table B-3 Cost for Passive Barriers

Barrier	Cost/Unit**
Anchored concrete Jersey barrier, non-reinforced (2007 Means double face, precast concrete median barrier; 34 71 13.26.2200)	$65/ft ($213.25/m)
Buried tires, 36-ply, 8-ft (2.4-m) diameter, weighing 2,000 lb (909 kg) each	$25.00/tire
Eight-in. (20.3-cm) diameter bollard system @ 3 ft (0.9 m) on center with 12-in. (30.5-cm) channel rail (2007 Means 8-in (0.2-m) bollard 34 71 13.17.2700, corrugated steel rail, 3 ft (0.9 m), 34 71 13.260012.)	$629/each
Standard chain link fence [7 ft (2.1 m), 9 ga w/ outrigger] and two 3/4-in. (1.9-cm) diameter cables (2007 Means 7-ft (2.1-m) chain link 32 31 13.53.0100 with cable guide rail assuming a ¾-in. (1.9-cm) cable 34 71 13.26.0600)	$61.30/ft ($201/m) (including fence)
Eight-in. (20.3-cm) diameter concrete-filled pipe (2007 Means 8-in. concrete-filled pipe bollards 34 71 13.17.2700)	$515.00/each
Concrete planter barrier (2007 Means for 48-in. (1.2-m) dia., 3-ft (0.9-m) high 34 71 13.17.0200)	$955/each
Cable barrier (2007 Means 34 71 13.26.0600 guide rail with steel posts; wire rope [6x19] adjusted per 05 15 16.50.0830 series rope costs)	
One cable @ 3/4-in. (1.9-cm) dia.	$12.90/ft ($42.32/m)
Two cables @ 3/4-in. (1.9-cm) dia.	$16.95/ft ($55.61/m)
Three cables @ 3/4-in. (1.9-cm) dia.	$21.05/ft ($69.06/m)
Four cables @ 3/4-in. (1.9-cm) dia.	$25.10/ft ($82.35/m)
One cable @ 1-in. (2.5-cm) dia.	$18.50/ft ($60.70/m)
Two cables @ 1-in. (2.5-cm) dia.	$26.75/ft ($87.76/m)
Three cables @ 1-in. (2.5-cm) dia.	$34.00/ft ($111.55/m)
Four cables @ 1-in. (2.5-cm) dia.	$43.25/ft ($141.90/m)
Reinforced concrete retaining or knee wall [2007 Means 03 30 53.40.6200 for cast-in-place concrete retaining walls, 4-ft (1.2-m) high]	$340/cu. yd ($445/cu. m)

** Based on "Building Construction Cost Data, 65th Annual Edition, 2007." Average cost for continental United States. All costs including overhead and profit.

Appendix C - PERFORMANCE DATA FOR \1\/1/ PASSIVE VEHICLE BARRIERS

C-1 **SCOPE**.

This appendix presents performance data for commercial vehicle barriers and passive barriers. The information contained herein is intended for guidance only.

C-2 **DEFINITIONS**.

The definitions in Chapter 3 of this handbook apply to this appendix.

\1\/1/

C-3 **PASSIVE BARRIERS**.

Table C-4 is a summary of performance data for selected passive barriers.

Table C-4 Performance for Passive Barriers

Barrier	Kinetic Energy ft-lbf (kgf-m) x 1,000,000	Penetration ft (m)
Anchored concrete Jersey barrier, non-reinforced	0.3 (0.04)	20 (6.1)
Buried tires, 36-ply, 8-ft (2.4-m) diameter, weighing 2,000 lb (909 kg) each	0.3 (0.04)	1 (3.05)
Eight-in. (20.3-cm) diameter bollard system @ 3 ft (0.9 m) on center with 12-in. (30.5-cm) channel rail	1.1 (0.15)	None
12.75-in. (32.4-cm) to 13.25-in. (33.7-cm) diameter bollard system @ 3 ft (0.9 m) on center	0.8 (0.11) 1.2 (0.17)	3 (0.9) 3 (0.9)
Standard chain link fence [7 ft (2.1 m), 9 ga w/ outrigger] and one 3/4-in. (1.9-cm) diameter cable	0.06 (0.008) 0.35 (0.048)	7 (2.1) 26 (7.9)
Eight-in. (20.3-cm) diameter concrete-filled pipe	0.135 (0.019)	1.5 (0.46)
Concrete planter barrier	1.08 (0.15)	31.2 (9.5)
Cable barrier [200-ft (60.9-m) anchorage spacing]*		
One cable @ 3/4-in. (1.9-cm) dia.	0.1 (0.014)	40 (12)
Two cables @ 3/4-in. (1.9-cm) dia.	0.2 (0.028)	40 (12)
Three cables @ 3/4-in. (1.9-cm) dia.	0.338 (0.047)	40 (12)
Four cables @ 3/4-in. (1.9-cm) dia.	0.418 (0.058)	40 (12)
One cable @ 1-in. (2.5-cm) dia.	0.15 (0.021)	40 (12)
Two cables @ 1-in. (2.5-cm) dia.	0.34 (0.047)	40 (12)
Three cables @ 1-in. (2.5-cm) dia.	0.506 (0.07)	40 (12)
Four cables @ 1-in. (2.5-cm) dia.	0.706 (0.098)	40 (12)
Reinforced-concrete retaining wall** 10 in. (25.4 cm) thick 21 in. (53.3 cm) thick 3.28 ft (1 m) wall	0.157 (0.022)	None
Cable barrier – two 3/4-in. (1.9-cm)	0.36 (0.05)	13 (3.96)

* Based on analytical modeling, using BIRM 3D (PDC-TR90-2) or other finite element analysis process
**Of the wall designs, the shorter and thinner section 1 meter wall is the most efficient, based on K rating. /1/

Appendix D - EXAMPLES FOR PROTECTION AGAINST TERRORIST VEHICLE BOMBS

D-1 **SCOPE**.

This appendix contains examples for determining the design of vehicle barrier systems. The information contained herein is intended for informational purposes only.

D-2 **NON-GOVERNMENT PUBLICATIONS**.

Means, R.S., "Building Construction Cost Data", 65th Edition, 2007.

D-3 **DEFINITIONS**.

The definitions in Chapter 3 of this UFC apply to this appendix.

D-4 **EXAMPLES**.

D-4.1 **Example 1**.

Administrative Building 827 (Figure D-2) must be protected against a terrorist vehicle bomb. The structure is a single-story, reinforced-concrete building. The following factors apply:

a. A high threat level is considered. The design basis threat has been established as a moving vehicle with a gross weight of 15,000 lbs (6,818 kg), including 1,100 lbs (500 kg) of explosives, traveling at 50 mph (80 kph). This combination of vehicle size and speed will develop 1,253 ft-lbf (173 kgf-m) of energy on impact (Table 4-2).

b. Assume an asset value of 0.8 for Building 827. For a moving vehicle bomb as described above, this corresponds to a medium level of protection, according to UFC 4-020-01. The damage to the building will be repairable. No permanent deformation will occur in primary structural members.

c. For a medium level of protection, some injury from debris is anticipated, but serious injury or death is unlikely.

Referring to Figure D-2, the lines of approach are perimeter roads on the north and west sides of the building. Perimeter passive barriers and an active barrier on the west entrance to the facility will be required. A candidate active vehicle barrier system might be one of the example systems described in Table 6-2. For the perimeter fence, a candidate passive barrier could be the bollard system shown in Figure 6-1.

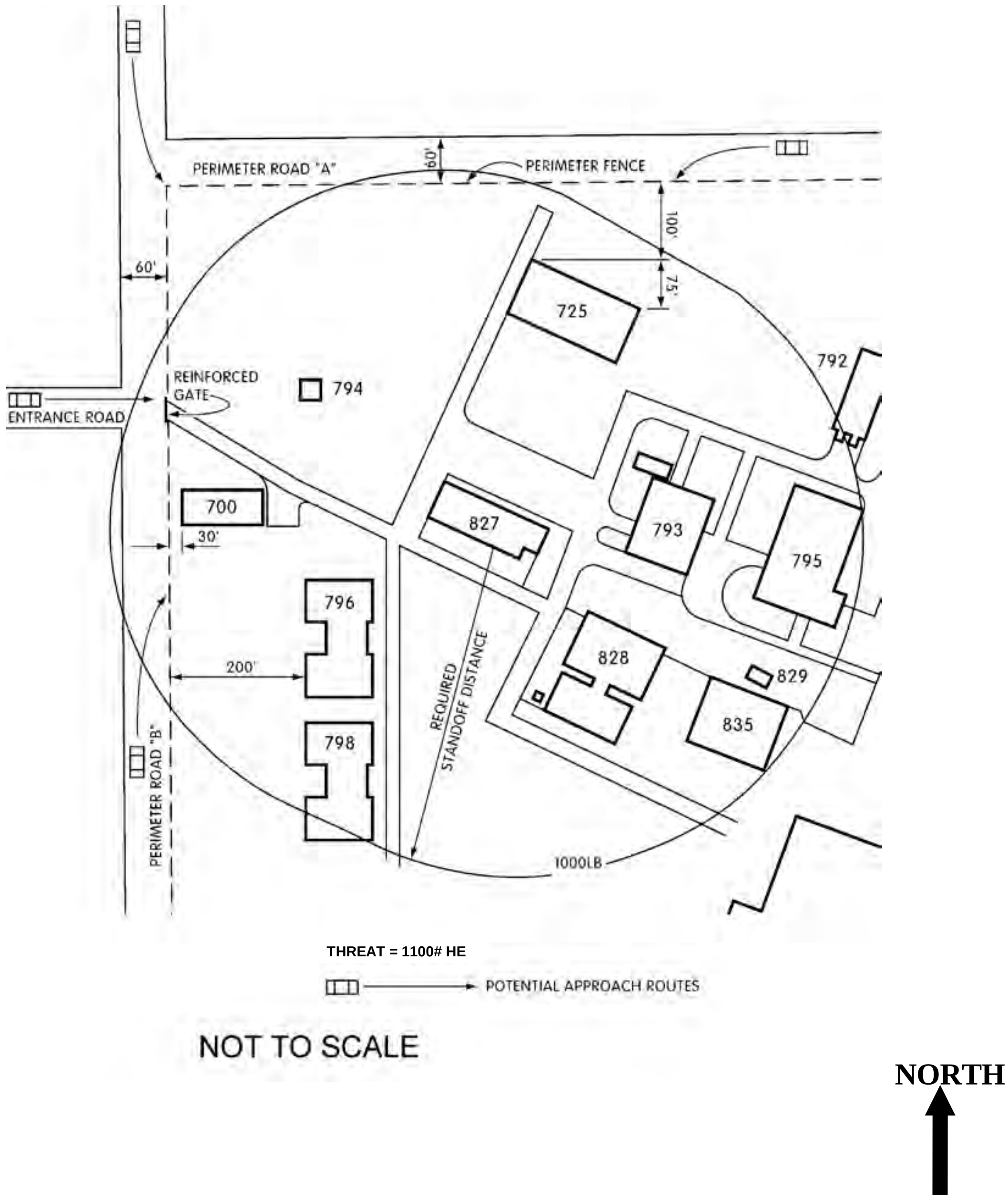
Using UFC 4-020-01, the required standoff distance for a minimal level of damage to the building from 1,100 lbs (500 kg) of explosives is 310 ft (95 m). Because there is about 320 ft (97 m) available for standoff at the location closest to the perimeter (at

Building 700), a medium level of protection can be secured. In this case, the asset value and high threat level indicate some injury is allowable, and minor damage to the structure is acceptable.

Based on the performance characteristics of the example barrier system, the penetration distance of the design threat vehicle is 27 ft (8 m). Adding this distance to the distance required for mitigating the explosive effects, the total standoff distance between the barrier and the building should be at least 337 ft (103 m). Because this standoff distance is not available for Building 827 under current site conditions, the next step would be facility hardening or the acceptance of more damage to the structure.

Passive barriers along the fence line should be designed to allow little or no penetration; the available standoff distance is already at the marginal level to protect personnel against death and injury. Selection of the concrete-filled bollard system (Figure 6-3) will provide adequate penetration resistance, because the approach is parallel to the barrier (77% of the impact load from Table 4-1).

Figure D-2 Site Plan for Examples



D-4.2 **Example 2**.

Referring to Figure D-2, the target buildings in this case are 796 and 798. Perimeter Road "B" has a 60-ft (18-m) offset (distance from the barrier to the restricting opposite curb). Using Table 4-1, a vehicle traveling at 50 mph (80 kph) can safely turn on a maximum 167-ft (51 m) radius curve without skidding. At this speed and angle of approach to the barrier, the vehicle will strike the barrier at an angle. Due to the angle of impact (Table 4-1), the speed directed at the barrier is 76.6 percent of the 50-mph (80-kph) speed, or 38 mph (61 m). Using Table 4-2 and rounding up to the next highest speed [40 mph (64 kph)], the kinetic energy transferred to the barrier will be 214,000 ft-lbf (29 kgf-m) if the design basis threat is a moving 4,000-lb (1,818-kg) vehicle, and 919,200 ft-lbf (111 kgf-m) if the design basis threat is a moving 15,000-lb (6,818-kg) vehicle.

> Note: Incorporate reduction due to angle of impact after calculation of kinetic energy.

Once the kinetic energy has been calculated, refer to Appendix\1\ C /1/ for a listing of passive barriers and penetration distances that can be used to select the most effective barrier. Anchored Jersey barriers could be used for the threat of a moving 4,000-lb (1,818-kg) vehicle, and a bollard system or concrete planter would be the only passive barriers that would be capable of stopping a 15,000-lb (6,818-kg) vehicle. For the larger threat, it would be appropriate to install concrete blocks as shown in Figure 6-16 and space them in accordance with the information from Table 6-7 to reduce the vehicle speed to 30 mph (48 kph) or less.

Appendix E - VEHICLE BARRIER DEBRIS MINIMIZATION AND EFFECTS ON COUNTER-MOBILITY

E-1 **GENERAL**.

Barriers are widely used in Entry Control Facilities/Access Control Points (ECF/ACP) and as perimeter boundaries to effectively control traffic. They can be successful in preventing entry of a suspected vehicle bomb into an installation; however, barriers may not prevent detonation of the bomb at the ECF/ACP. The barriers typically used in ECF/ACPs are designed to resist vehicle impact loads, not blast loads. The blast loading of a barrier wall can result in breakup of the barrier and subsequent throw of debris toward the facility being protected by the barrier. This debris has the potential of being thrown great distances, depending on the explosive quantity in the vehicle bomb. The debris can range in size from small, penetrating pieces to whole barrier sections, presenting a significant hazard to personnel, and possibly structures, near the detonation site. Control of this debris, as well as control of traffic, should be considered when selecting and installing a barrier system.

E-2 **BARRIER RESPONSE TO EXPLOSIVE LOAD TESTING**.

A large test program, Barrier Assessment for Safe Standoff (BASS), was conducted in 2001 for the USAF Force Protection Battlelab (FPB). Full-scale ECF/ACP vehicle barriers were subjected to detonations of bare explosives. The primary objectives of the effort were to analyze the secondary debris hazard for typical reinforced concrete ECF/ACP vehicle barriers and to identify barrier modifications that would minimize or eliminate this debris hazard.

Twelve barrier tests were conducted, with two barriers used per test. Various barrier, charge weight, and standoff distance configurations were tested. The tested barriers included:

- Jersey
- Jersey with soil revetment
- Bitburg
- Bitburg with soil revetment
- Jersey with polymer liner applied
- Cellular Jersey with polymer liner applied
- Jersey with rock/gravel fill revetment

- Back-to-back Bitburgs
- Texas
- Plastic, sand-filled barrier

Data collection included barrier debris pickup in designated areas behind each barrier, high-speed video of debris flight to aid in measuring debris velocities, documentation of the barrier response to the blast load, and free-field pressure measurements at specific locations in the debris fields.

Based on the barrier debris collected and analyzed in this study, some barrier systems are more effective than others at reducing the potential secondary debris hazard from a vehicle bomb detonating at an ECF/ACP. The addition of a soil revetment to common barrier configurations significantly reduces debris hazards. Depending on the amount of explosives and the standoff distance from the barrier to the charge, the barriers with a soil revetment either do not break up, or the debris are thrown considerably lesser distances than the same barrier configuration without soil revetment. A rock/gravel revetment presents only a slightly worse hazard than a soil revetment, if only the throw of the barrier debris is considered. Maximum debris distances measured from tests with Jersey reinforced concrete barriers backed by a rock/gravel revetment exceeded debris distances measured in tests of Jersey barriers backed by a soil revetment by less than 20%. It should be noted, however, that debris from the rock/gravel revetment could also be thrown and could cause damage (such as window breakage) to buildings within the installation.

The polymer liner applied to a Jersey barrier does not offer any improvement to the debris hazard from a Jersey barrier. Lightweight concrete and sand-filled plastic barriers produce significantly reduced debris hazards. This may seem attractive in selecting a barrier system to minimize barrier debris throw upon detonation of a vehicle bomb. However, subsequent counter-mobility testing of these barriers showed failure in stopping the vehicle and preventing access through an ECF/ACP, making them undesirable for use at an ECF/ACP.

The tests also showed that the vehicle-to-barrier standoff used at an ECF/ACP is equally important. Generally, using terminology from UFC 4-022-01, this standoff distance refers to the distance between the access control zone (inspection site) and the final debris barriers in the response zone. The larger 35-ft (10.7-m) standoff decreased debris hazards for all barrier systems tested. It was recommended that the standoff distances be increased from 10 ft (3.05 m) to 35 ft (10.7 m) at ECF/ACPs, where possible. It is recognized that a vehicle could potentially move through the access control zone without stopping and through the response zone to impact a barrier. If the vehicle bomb detonates while in direct contact with the barrier, the debris throw is obviously greater than if the bomb detonates 10 ft (3.05 m) or 35 ft (10.7 m) away from the barrier. The use of low-debris barriers in this case is even more attractive.

E-3 **LOW-DEBRIS BARRIER COUNTER-MOBILITY EVALUATION**.

Barriers qualified as low-debris producing barriers when exposed to detonations of typical vehicle bombs do not necessarily meet counter-mobility criteria. Barriers that have been proven to minimize, or eliminate, debris hazards from an explosive threat must still be validated for entry control capabilities. Both detonation response and counter-mobility issues should be addressed when selecting a barrier system for a particular base function, such as in an ECF/ACP.

For instance, the lightweight concrete and sand-filled plastic barriers proven to be low-debris barriers in the 2001 BASS tests did not perform well in subsequent crash tests. The Barriers for Reduced-debris and Counter-mobility Effects (BRACE) test program involved testing of these barrier types for counter-mobility. A baseline performance test was first conducted on a line of ten standard, reinforced concrete Jersey barriers tied together with steel cables. A 15,000-lb (6,820-kg) truck impacted the center of the line of barriers at 30 mph (48 kph). While the line of Jersey barriers successfully stopped the vehicle, neither the lightweight concrete nor the sand-filled plastic barrier was able to stop the vehicle. Two new low-debris vehicle barrier concepts were later devised and tested in another FPB-funded test series, Vehicle Impact Performance Evaluation of Reduced-debris, Counter-mobility Barriers (VIPER-CB).

The low-debris barriers tested in the later program were Hesco bastion concertainers (typically used as perimeter barriers and to provide ballistic and fragment protection) and a modification of the lightweight concrete Jersey barrier with polymer coating. The lightweight concrete, polymer-coated barriers and the steel gate successfully defeated the threat of a 15,000-lb (6,820-kg) truck traveling at 30 mph (48 kph). The depth of penetration of the truck was 16 ft (4.9 m) for the lightweight concrete, polymer-coated barriers. The Hesco bastion concertainers were tested with a 15,000-lb (6,820-kg) truck traveling at 50 mph (80 kph). The concertainers successfully stopped the truck in approximately 5 ft (1.5 m), with no penetration of the payload. Contact HESCO for proper configuration tested as indicated above.

The recommendations from the tests described in this section are to use both low-debris, counter-mobility barriers (Hesco bastion and lightweight concrete, polymer-coated barriers). The low-debris systems adequately protect against the standard threat of a 15,000-lb (6,820-kg) vehicle impacting at 30 mph (48 kph). The Hesco bastion barriers do not require any anchoring. They are simply stacked in layers. To defeat the standard threat above, two rows of barriers on the bottom with a staggered row of barriers on top are sufficient, as shown in Figure E-3. Concrete anchors to existing thick roadways or to specially placed foundations should be used with the polymer-coated, lightweight concrete barrier system.

Figure E-4 shows the cabling and anchor system used to test this system. For the test, the polymer-coated, lightweight concrete Jersey barriers were placed in a line and connected with three 1-in steel cables, as shown in Figure E-4. The cable was 1-in diameter, 6 x 36 extra improved plow steel, with independent wire rope center. A 4-ft long loop was created in the cables at the right end of the line of barriers. The purpose of this loop is to allow some slack in the cable; this reduces the peak tensile force but allows additional penetration of the truck Steel shackles were used to connect the cables to the anchor plate and 1-in cable clips at a 6-in spacing were used to tie the ends of the cables. For this example, the barrier anchoring system was designed to meet a load of 75,000 lb of force in each cable. Anchoring for a similar barrier system should at least meet the same anchoring requirement.

Figure E-3 Hesco Bastion Concertainer Barrier, Oblique View

Figure E-4 Polymer-Coated, Lightweight Concrete Barrier System

E-4 RESTORATION OF DAMAGED BARRIERS.

Another critical consideration in selection of vehicle barriers for use in an ECF/ACP or in other perimeter protection is the amount of time required to restore the barrier system to 100% capability after it has been damaged by exposure to a vehicle bomb detonation. Some barriers can be fully restored to their original protection capability within minutes after the removal of the vehicle debris. Other barrier types may take months to repair and restore to 100%.

Restoration time depends on the type of barrier, whether or not it has a revetment, the size of the vehicle bomb, and the standoff distance between the bomb and the barrier at the time of detonation. Concrete barriers exposed to low design basis threats will have minimal breakup and may just topple over or be slightly displaced. In such a case, the barriers could be reused and re-anchored back into the barrier system. Other barrier types may need to be completely replaced with new barriers. If a revetment was being used, it will have to be rebuilt when the barriers are replaced. Estimates of time required to restore the barrier system to 100% capability is critical information to consider in vehicle barrier selection.

UFC 4-022-03
1 October 2013

UNIFIED FACILITIES CRITERIA (UFC)

SECURITY FENCES AND GATES

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

SECURITY FENCES AND GATES

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location

This UFC supersedes NAVFAC Military Handbook 1013/10, *Design Guidelines for Security Fencing, Gates, Barriers, and Guard Facilities.*

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

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

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

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

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Unified Facilities Criteria (UFC)
New Document Summary Sheet

Document: UFC 4-022-03, *Security Fences and Gates.*

Superseding: NAVFAC Military Handbook 1013/10, *Design Guidelines for Security Fencing, Gates, Barriers, and Guard Facilities*.

Document Description and Need:

Purpose: This document is to provide a unified approach for the design, selection, and installation of security fences and gates. The examples provided in the UFC are for illustration only and must be modified and adapted to satisfy service and installation specific constraints. This document is not intended to address procedural issues such as threat level determination and security operations or to provide specific design criteria such as impact forces.

This UFC was developed by consolidating and refining criteria from USACE Protective Design Center, Naval Facilities Engineering Command (NAVFACENGCOM), and available military, government, and commercial sources that are listed in Appendix A of this document.

Application and Use: Commanders, security personnel, planners, designers, architects, and engineers must use this UFC when evaluating existing and providing new security fences and gates.

Need: Fences and gates are primarily used to define perimeters; however, Department of Defense (DoD) and Service regulations require fencing to be provided for certain protected/restricted areas. DoD and Service policies address certain fencing requirements. This UFC focuses on the requirements for security fences, however, the information and design details presented within may also be used for general or perimeter fencing. Modifications to existing fencing are not required to meet this new UFC.

Impact: The following direct benefits will result:

- This document does not set the requirement for security operations at the installation perimeter.
- No additional cost impacts are anticipated by the publication of this document.
- This document does not have any adverse impacts on environmental, sustainability, or constructability policies or practices.

Unification Issues

There are no unification issues.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE

This document provides a unified approach for the design, selection, and installation of security fences and gates for Department of Defense (DoD).

1-2 APPLICABILITY

This document applies to all construction, renovation, and repair projects including expeditionary or temporary construction that include security fencing and gates for DoD. Consult with current Service policies, location of facility, and threat level for specific requirements.

1-3 SECURITY FENCES AND GATES

Security fences and gates are installed and used primarily to define the perimeter of protected areas, such as restricted areas, controlled areas, entry control/access control points, installation perimeters, and to provide a physical and psychological deterrent to entry and preventing unauthorized personnel from entering a protected area.

1-4 SCOPE AND GUIDANCE

Commanders, security personnel, planners, designers, architects, and engineers must use this UFC when evaluating existing and providing new security fences and gates. Technical information considered generally known to security professionals and engineers, or readily available in technical references (Unified Facility Criteria, Military Handbooks, Technical Manuals, etc.) has not been included. This document is not intended to address procedural issues such as threat levels or to provide specific design criteria such as vehicle impact forces.

1-4.1 Drawings

The notional examples provided in the body of this UFC are for illustration and must be modified for the specific application, environmental conditions, and local constraints. The details and drawings identified in Appendix C provide the minimum mandatory requirements and must be modified for the specific application, environmental conditions, and local/project constraints. See paragraph titled ‘Integration With Other Requirements’ for additional direction.

1-5 GENERAL BUILDING REQUIREMENTS

Comply with UFC 1-200-01, *General Building Requirements*. 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.

This UFC is one of a series of unified facilities criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used by a diverse audience to facilitate development of projects throughout the design cycle.

1-5.1 UFC Application

The application of the security and antiterrorism UFCs is illustrated in Figure 1-1. UFC 4-020-01 is intended to be the starting point for any project that is likely to have security or antiterrorism requirements. By beginning with UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual*, the design criteria will be developed that establishes which of the other UFCs in the series will need to be applied. The design criteria may indicate that only the minimum standards need to be incorporated, or it may include additional requirements, resulting in the need for application of additional UFCs. Applying this series of UFCs in the manner illustrated in Figure 1-1 will result in the most efficient use of resources for protecting assets against security and antiterrorism related threats.

1-5.2 Requirements Determination

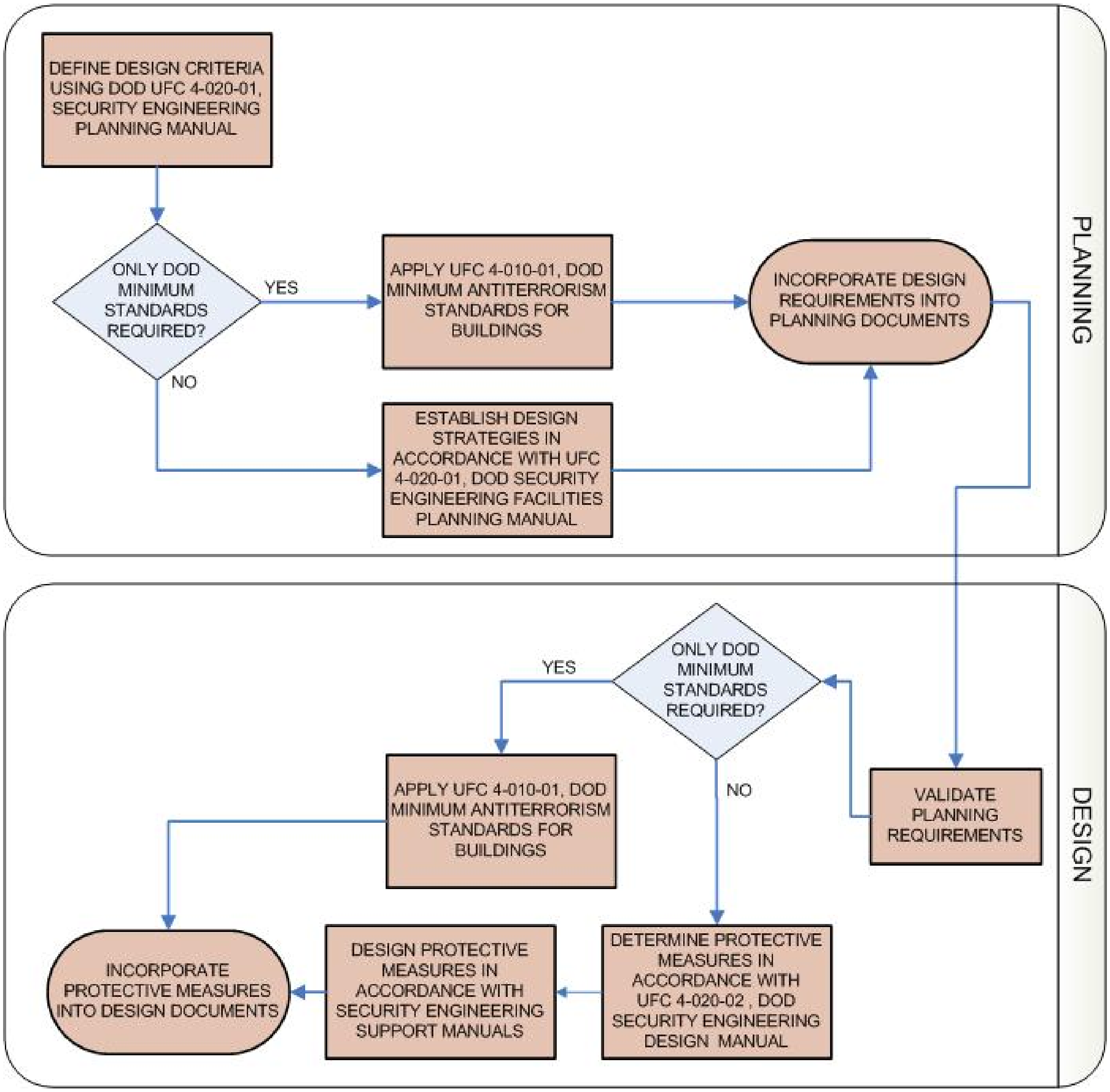
UFC 4-020-01 includes a process for defining the design criteria for a protective system that protects important assets associated with a permanent facility or one in an expeditionary environment. The design criteria will consist of the assets to be protected, the threats to those assets, the degree to which those assets will be protected against the threat, and any constraints that might be imposed on a design. The design criteria may be limited to that defined in minimum standards or it may go beyond those requirements.

Establishing the design criteria for security and antiterrorism is not something that can be done effectively by any one person. It requires a team of people to ensure that the varied interests relating to a project are considered appropriately. The specific membership of a planning team will be based on local considerations, but in general, the following functions should be represented - Facility User, Antiterrorism, Intelligence, Operations, Security, Logistics, Engineering, and Resource Management. Based on local considerations, there may be others who should be consulted for input into the design criteria. They might include Fire Marshals, communications people, environmental people, and historic preservation officers.

1-5.3 Integration With Other Requirements

Security and antiterrorism requirements will never be the only requirements associated with a project. Even where a project is specifically for security and antiterrorism upgrades, there will still be other requirements that must be considered. There will be times where one criterion is more stringent than another, in which case the more stringent one must be applied. In some cases, criteria may conflict. In those cases, those conflicts must be resolved, which may require compromise or adjustment to one or the other criteria. Many security regulations specify protective measures, policies, and operations related to security. This UFC is intended to complement those existing regulations, not to contradict or supersede them. Regulatory requirements must be accommodated and coordinated.

Figure 1-1 Security and Antiterrorism UFC Application



1-6 VULNERABILITY AND RISK ASSESSMENT

In accordance with DoD O-2000.12H Antiterrorism Handbook, a vulnerability and risk assessment must be conducted prior to beginning any security project. Upon identifying facility or asset vulnerabilities to threats, physical security measures such as security fences, gates, and Electronic Security Systems (ESS) may be deployed to reduce vulnerabilities. In summary, this UFC assumes the pre-design phases, including the risk analysis, are complete prior to beginning design. For information on Security

Engineering Planning and Design process, refer to UFC 4-020-01 and UFC 4-020-02. The engineering risk analysis conducted as part of UFC 4-020-01 must be consistent with the terrorism risk analysis conducted by the installation security/AT staff.

1-7 POLICY REQUIREMENTS

The requirement to protect installation assets comes from DoD Instruction/Directives, Geographic Combatant Commander (GCC) Instructions, Service Instruction/Directives, and Regional or Installation requirements. Consult Headquarters, Major Command, Regional, and Installation personnel to established installation asset protection requirements.

1-7.1 Department of Defense (DoD)

There are several instructions and publications within the Department of Defense that establish requirements for access control and physical security for installation perimeter, restricted access areas and other secure areas.

1-7.1.1 DoD Physical Security Program

DoD 5200.8-R: Requires DOD Components to determine the necessary access control based on the requirements of a developed physical security program. Emergency planning is specified to include establishment of a system for positive identification of personnel and equipment authorized to enter and exit the installation and maintenance of adequate physical barriers (i.e. security fences and gates) that will be employed to control access to the installation.

1-7.1.2 Physical Security of Sensitive Conventional Arms, Ammunition, and Explosives (AA&E)

DoD 5100.76-M prescribes minimum standards and criteria for the physical security of DoD sensitive conventional AA&E. This Manual establishes the requirements to protect sensitive AA&E including perimeters, openings, and security fences.

1-7.1.3 Nuclear Facilities

DoD S-5210.41-M Vols. 1-3, AFMAN 31-108, OPNAVINST 5210.16, and AR 190-54 prescribe policy, responsibilities, procedures, and minimum standards for the security and safeguarding of DoD nuclear reactors, special nuclear materials and weapons including perimeters, openings, and security fences.

1-7.1.4 DoD Antiterrorism Program

DoDI 2000.12: Provides DoD policies for ATFP and assigns responsibilities for implementing physical security systems as part of the DoD ATFP Program. It authorized the publication of DODI 2000.16 Antiterrorism Standards as the DoD standards for ATFP and DoD O-2000.12-H DoD Antiterrorism Handbook as guidance for the DoD standards.

1-7.1.5 DoD Antiterrorism Handbook

DoD O-2000.12H: Defines the DoD Force Protection Condition (FPCON) System, which describes the potential threat levels and the applicable FPCON measures to be enacted for each level. FPCON measures in the 12-H were modified in DoDI 2000.16, Change 2 of 08 Dec 2006. DoD O-2000.12H also requires Commanders to develop and implement Random Antiterrorism Measures (RAM) as an integral part of their AT Program. This handbook provides a detailed discussion on physical security functional requirements of which physical barriers (security fences and gates) are integral.

1-7.1.6 DoD Antiterrorism Standards

DoD I 2000.16: This instruction requires the installation or activity Commanding Officer to define the access control measures at installations. Additionally, DoDI 2000.16 requires Commanders at all levels to develop as part of the physical security program and implement a comprehensive Antiterrorism (AT) Program, which must define the necessary action sets, including identification and inspection procedures, barrier requirements at each of the potential Force Protection Condition (FPCON) levels and lists the most current approved FPCONS.

1-7.2 Geographic Combatant Commander (GCC) Requirements

GCC issue requirements for Antiterrorism and physical security for installations within their area of responsibility. Ensure any such requirements are incorporated in addition to the requirements found in DoD and Service Directives/Instructions. Resolve any differences in the requirements for the design of perimeter security by applying the most stringent requirement.

1-7.3 Service Requirements

1-7.3.1 Department of Air Force

1-7.3.1.1 AFI 31-101 – Integrated Defense (ID)(FOUO)

This Instruction provides the tools to plan and execute ID. It guides personnel through a familiar 7-step risk assessment process. Furthermore, working groups that are focused on mutually-supporting components of ID, such as the antiterrorism (AT) program and resource protection program (RPP), may be combined and streamlined. This Instruction provides flexible planning and execution opportunities that allow owners/users of various Air Force assets to become actively involved in the defense of their areas; however, some assets must remain secured in accordance with higher headquarters (HHQ) directives, such as nuclear weapons; arms, ammunition and explosives (AA&E); classified information and Defense Critical Infrastructure Program (DCIP) assets.

1-7.3.1.2 AFMAN 32-1084 Civil Engineering: Facility Requirements

This Manual is a tool to assist commanders, their management, and technical staff in programming the acquisition of facilities and in managing the inventory of real property facilities and provides additional guidance for fencing/barrier requirements.

1-7.3.2 Department of the Army

1-7.3.2.1 AR 190-13 The Army Physical Security Program

Implements DOD 5200.08–R. It prescribes policies, procedures, and guidance to plan and implement the Department of the Army Physical Security Program.

1-7.3.2.2 AR 190-16 Physical Security

Establishes standard policies on physical security systems planning, threat statements, control of access to installations, security of aircraft, bulk petroleum assets, and critical communications facilities.

1-7.3.2.3 AR 190-11 Physical Security of Arms, Ammunition and Explosives

Refer to AR 190-11 for physical security criteria for conventional arms, ammunition, and explosives (AA&E) for additional guidance on fencing requirements.

1-7.3.2.4 ATTP 3-39.32 Physical Security: Army Tactics, Techniques, and Procedures (ATTP)

Provides doctrinal guidance for personnel who are responsible for planning and executing physical security programs. It is the basic reference for training security personnel and is intended to be used in conjunction with the Army Regulation (AR) 190 series (Military Police), Security and Antiterrorism Unified Facilities Criteria (UFC) publications, Department of Defense (DOD) directives, and other Department of the Army (DA) publications.

1-7.3.3 Department of the Navy including Marine Corps

1-7.3.3.1 OPNAVINST 5530.14 Navy Physical Security and Law Enforcement

The intent of this instruction is to identify responsibilities and provide guidance for the protection of people and assets throughout the Navy.

1-7.3.3.2 Physical Security of Arms, Ammunition and Explosives

Refer to OPNAVINST 5530.13 for physical security criteria for conventional arms, ammunition, and explosives (AA&E) and additional fencing requirements.

1-7.3.3.3 NTTP 3-07.2.3 Law Enforcement and Physical Security

Provides guidance for the physical security for Naval Installations to include perimeter security and restricted areas.

1-7.3.3.4 MCO 5530.14 Marine Corps Physical Security Program Manual

Provides requirements for physical security for Marine Corps installations and organizations including additional barrier/security fence requirements.

1-7.4 Installation Specific Requirements

As required by DODI 2000.16 and service directives, each installation must have an Antiterrorism Plan. The plan provides procedures and recommendations for reducing risk and vulnerability of DOD personnel, their family members, facilities, and assets from acts of terrorism. As such, the installation AT plan reflects the foundation for requirements determination. Installation specific requirements need to be factored into all capital improvement initiatives.

1-7.5 Airfield Requirements

For Air National Guard (ANG) and Air Force Reserve Command (AFRC) units that are co-located with civilian airports, the airfield side of the restricted areas does not require fencing installation as it is prohibited by the Federal Aviation Agency (FAA) safety requirements. Fencing requirements for airports and heliports are provided in UFC 4-141-10N and UFC 3-260-01.

1-8 PHYSICAL SECURITY

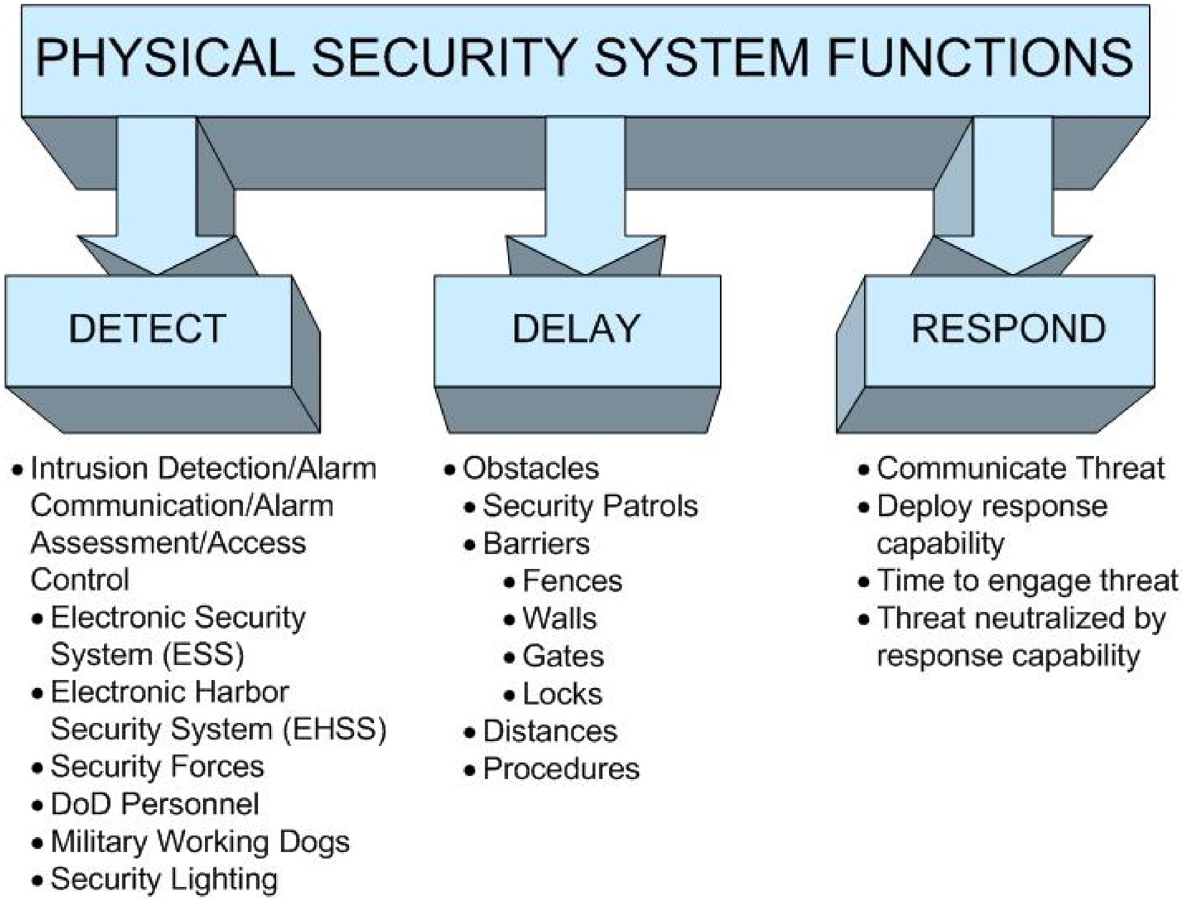
That part of security concerned with physical measures designed to safeguard personnel; to prevent or delay unauthorized access to equipment, installations, material, and documents; and to safeguard them against espionage, sabotage, damage, and theft.

1-8.1 Physical Security System

A system comprised of people, equipment, and operational procedures that control access to critical facilities or assets. Fences are but one of many elements that comprise the equipment component of a physical security system. Figure 1-2 diagrams some of the additional components of a physical security system.

From Figure 1-2, fencing is considered part of the delay function of the overall Physical Security System. However, standard chain-link fencing provides approximately 7- 15 seconds of delay.

Figure 1-2 Diagram of Physical Security System Functions



1-9 EMERGENCY ACCESS

Locate security fence as to not impede emergency vehicle or emergency personnel access to fire hydrants or other fire protection features. Coordinate with installation fire department regarding security fence location as it applies to fire hydrants and other fire protection features. See UFC 3-600-01, Fire Protection Engineering for Facilities for additional information.

1-10 CORROSION PREVENTION CONTROL

Design strategies for installation security structures and equipment must consider corrosion prevention and control (CPC) preservation techniques for long term maintainability throughout their life cycle. Trade-off decisions involving cost, useful service life, and effectiveness must address corrosion prevention and mitigation.

1-10.1 Material Selection and Coatings

Local environments must be considered during the selection of material for the fencing components as well as the required coatings to provide protection against corrosion. Color polymer and other coatings on fencing fabric, fittings, framework, and gates must be applied to enhance visibility and provide greater corrosion resistance, especially in corrosive or salt laden environment. Appendix B defines this environment.

Coating on any fasteners or ties must be electrolytically compatible with fencing fabric to inhibit corrosion. All security fence fittings must be electrolytically compatible with all fence components. Regarding drainage openings (ditches, culverts, vents, metal ducts/pipes, and other opening) consideration must be given to the materials used (smaller metal pipe, metal/steel grillage) in securing such openings. One of the most important corrosion issues is the chemical reaction between dissimilar metals. When dissimilar metals are in contact with one another in the presence of an electrolyte, galvanic action occurs, resulting in the deterioration. The electrolyte may be rain water running from one surface to another, or moisture from the air containing enough acid to cause it to act as an electrolyte. See Appendix A for material specifications.

1-11 REFERENCES

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

1-12 GLOSSARY

Appendix B contains definitions of terms.

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CHAPTER 2 FENCING

2-1 FUNCTION

The physical security barrier provided by a security fence provides one or more of the following functions:

- Gives notice of legal boundary of the outermost limits of the protected area.
- Assists in controlling and screening authorized entries into secured/protected areas by channeling vehicles and personnel to access control points.
- Supports surveillance, detection, assessment, and other security functions by providing a platform for installing intrusion detection equipment.
- Deters casual intruders from penetrating a secured/protected area by presenting a barrier that requires an overt action to enter.
- Causes a delay to obtain access to a installation/facility, thereby increasing the probability of detection.

2-2 CHAIN LINK FENCING

Chain link fence is a fencing material made from wire helically wound and interwoven in such a manner as to provide a continuous mesh without knots or ties. See Figure 2-1 below for standard chain link fence details identifying all of the components.

Chain link fences and gates must comply with specification requirements in UFGS 32 31 13, *Chain Link Fences and Gates* and UFGS 32 31 13.53, *High-Security Chain Link Fences and Gates*. Consult with ASTM F2611 and ASTM F1712 for additional guidance (fabric, post, framework, fittings, and other accessories) regarding chain link fencing. Refer also to the Chain Link Manufacturers Institute's Security Fencing Recommendations (CLF-SFR0111) and Product Manual (CLF0PM0610) for additional information.

2-2.1 Chain Link Fencing Fabric

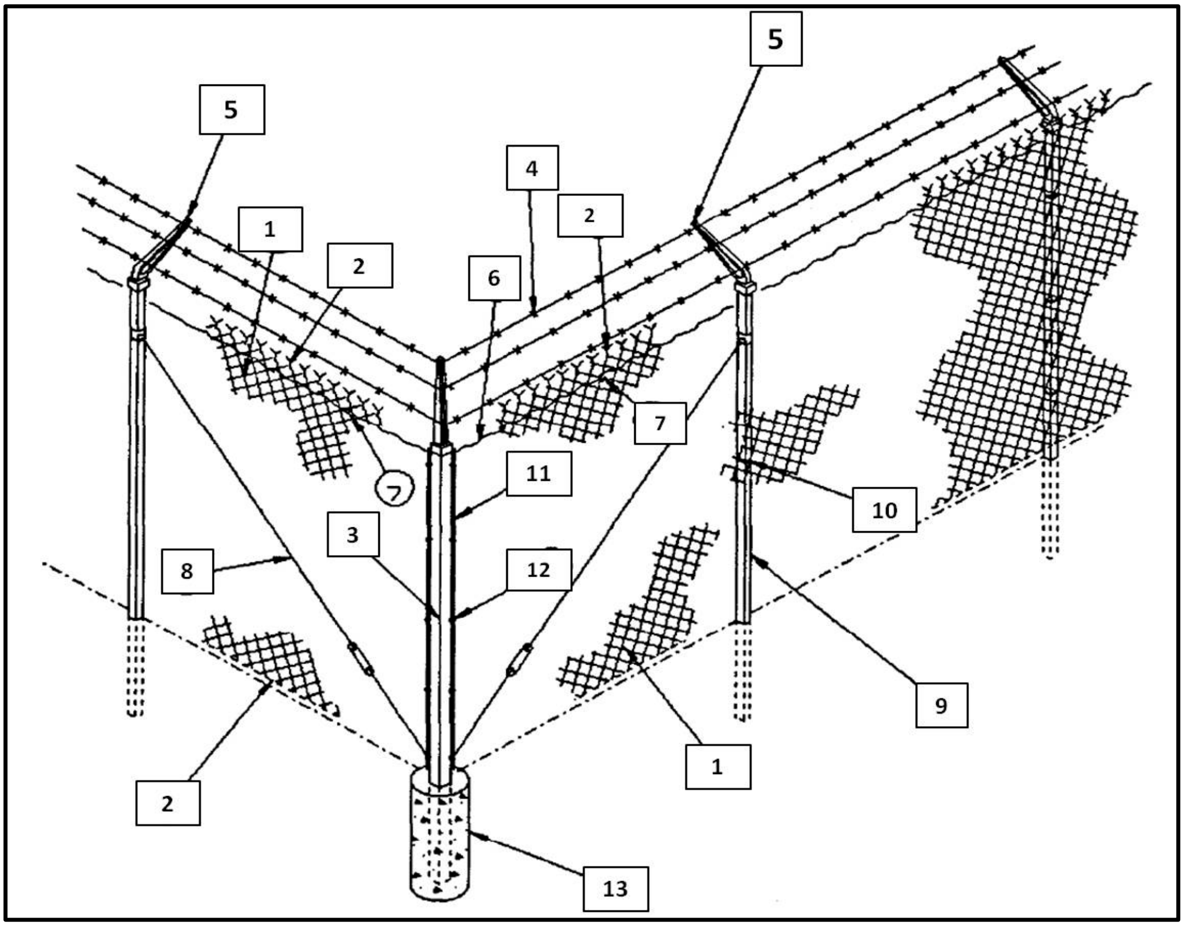
Fencing fabric must be minimum 9-gage wire mesh and mesh openings must be not be greater than 2-inches (51 mm) per side. Fence fabric material will be galvanized steel, PVC coated steel fabric (use PVC coated if located in corrosive environment or where aesthetics are of prime importance), or aluminum coated steel fabric (use aluminum coated if located in corrosive environment). See Corrosion Prevention Control for additional information regarding material selection.

2-2.1.1 Additional Fencing Fabric Requirements

The fencing fabric must be extended to within 2 inches (51 mm) of firm ground and anchored, if required by service requirements, using horizontal bottom rails, tension wires, concrete curbs, sills, sheet piling, piping, or other inexpensive materials. For additional security burying the fabric 12 inches (305 mm) may also be considered; however, corrosion of the buried fabric must be monitored. This anchoring will prevent the fencing fabric from being able to be lifted by hand more than 5 inches (125 mm) in height. Horizontal bottom rails, concrete curbs, or sills can assist in mitigating an intruder from lifting the fence fabric beyond the requirement above. Mesh openings in chain link fencing are intended to not be covered, blocked, or laced with material which would prevent a clear view of personnel, vehicles, or material in outer clear zones.

Locate all posts, rails, bracing and tension wires on the secure/protected side, i.e. inner side, of the fencing fabric. Select the framework components and material from ASTM F626, ASTM F1043, and ASTM F1083.

Figure 2-1: General Chain-Link Fence Components



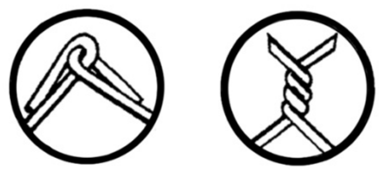
1	Fabric
2	Selvage
3	Corner Post
4	Barbed Wire/Barbed Tape
5	Outrigger/Barbed Wire Arm
6	Tension Wire (Top and Bottom)
7	Hog Ring
8	Truss Rod
9	Line Post
10	Tie Wire
11	Tension Bar
12	Tension Clip
13	Concrete Footing

2-2.1.2 Top and Bottom Selvages

Selvage is the edge finish on woven chain link fabric joining pairs of pickets. The selvage may be knuckled or twisted depending on application. Knuckled selvage is defined as the type of selvage obtained by interlocking adjacent pairs of wire ends and bending the wire back into a loop. Twisted is obtained by twisting adjacent pairs of wire ends together in a close helix of 1 1⁄2 machine turns, which is equivalent to three full twists. See Figure 2-2 for selvage examples.

Twisted selvage must be provided on the top of the fence fabric to deter climbing. Twisted selvage must be provided at the bottom of the fence fabric to deter borrowing unless the fence has a bottom rail, is buried, or encased in concrete. In these applications the selvage may be knuckled.

Figure 2-2 Selvage



2-2.1.3 Fence Posts

Fencing fabric must be mounted on steel posts that are set in concrete with additional bracing at corners and gate openings, as necessary. If steel posts are not available, reinforced concrete posts will be used. Posts, bracing, and all other structural members must be placed on the secure-side of the fencing fabric.

Posts must be vertical within plus or minus 2 degrees in each direction. Determine the embedment depth of the fence posts and associated footings considering wind load, local soil conditions, and the potential for wind and water erosion. Posts for security fencing must be embedded and encased in concrete according to the design details in Appendix C.

2-2.1.4 Fence Bracing

Steel truss rods used for bracing must have a minimum nominal diameter of 5/16 inch (8 mm) and provided with turnbuckles for tensioning. Provide bracing for each gate, terminal and end post. Install truss rods diagonally from near ground level of the gate, terminal or end post to within 6 inches (152 mm) from the top of the fabric at the adjacent line post. Fencing fabric can be securely fastened to tension wires on the top and bottom with 9 gage (3.76 mm) galvanized tie wires incorporating at least three full twists, 9 gage (3.76 mm) round wire galvanized hog rings, or in a manner that provides a tensile strength equal to or greater than the strength of the fencing fabric. Consider securing all fastening and hinge hardware by peening or welding to prevent disassembly of fencing and gate components where warranted by the required level of protection.

See Appendix C for design details of chain link fencing posts, rails, braces, and tension wires.

2-3 ORNAMENTAL FENCES

Ornamental (also known as tubular) fencing provides a greater resistance to climbing as well as providing aesthetic qualities in comparison to chain link fencing. Ornamental fencing systems are constructed of either steel or aluminum components. Install ornamental fence pickets plumb and provide a minimum of 2 inches (51 mm) or maximum of 6 inches (152 mm) between the fence and the ground. See ASTM F2408 for additional guidance for ornamental fence systems. See Appendix C for design details of ornamental fence.

2-4 WELDED WIRE MESH FABRIC FENCING

Welded wire mesh fabric fencing material is composed of a series of longitudinal and transverse steel wires arranged substantially at right angles to each other, and welded together. In comparison to chain link fencing has a greater deterrence to intrusion by climbing and cutting. Welded wire mesh fabric fence openings are relatively small to prevent toe or finger hold. Although the mesh sizes are small, visibility through the fence may be higher than chain link fencing even at sight angles near parallel to the fence line. See ASTM F2453/F2453M for material requirements. Maximum vertical/horizontal opening dimension must be 2 inches (51 mm). Minimum thickness – 9 gage (3.76 mm).

Welded wire mesh fabric fencing construction costs in non-urban environments may be approximately one half of ornamental security grade fencing. See Figure 2-3 for an example of a welded wire mesh fence.

2-4.1 Fence Components, Fittings, and Accessories

Provide welded wire mesh posts in accordance with ASTM F626, ASTM F1083, ASTM F1043, or ASTM A500/A500M. Posts and rails must be designed to resist specified loading and be spaced per manufacturer’s guidance. Connect fencing fabric with a minimum of 9 gage (3.76 mm) tie wires or other connection per manufacturer providing equal or greater capacity and resistance to tampering. If using welded wire mesh fence panels, attach to line and terminal posts and gate frames with post brackets.

Figure 2-3: Welded Wire Mesh Fence

2-5 EXPANDED METAL FENCING

Similar to welded wire mesh fabric fencing, expanded metal fencing is ideal for medium and high security applications. The diamond shaped mesh's small openings and wide strands deter climbing, cutting, and tunneling. Panels are constructed of steel sheets, simultaneously slit, and stretched into a rigid, open mesh design making continuous sheets that prohibit unraveling at the strands. Maximum vertical/horizontal opening dimension must be 2 inches (51 mm). Minimum strand width must be 0.150 inches (9 gage) (3.81 mm).

- In lieu of installing a fence topping, an expended metal fabric cap sheet can be installed at a 45-degree angle extending outside of the secured perimeter and terminating with a turned up vertical section. If additional protection measures are required, barbed tape can be applied to the back of the vertical portion of the cap sheet.

See ASTM F2548 and ASTM F2780 for design, construction, and application of expanded metal fencing systems. Available fence patterns can provide the architectural aesthetics of ornamental fencing. See Figure 2-4 for an example of an expanded metal fence.

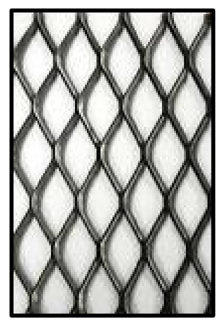
2-5.1 Retrofit Existing Fence

Expanded metal fencing can be applied as a retrofit to existing chain link fencing and gates to provide additional protection, strength, and durability. Expanded metal fencing should be installed directly to the existing fence utilizing the installed chain link fence fabric and framework.

2-5.2 Fence Components, Fittings, and Accessories

Line and terminal posts must be hot-dip galvanized in accordance with ASTM F626, ASTM F1043, and ASTM F1083. The manufacturer's recommendation must be considered when spacing line posts. Top, middle, and bottom rails must be hot-dip galvanized. Rails can be fastened to posts using clamps. Standard weight piping must be used for the posts and rails of expanded metal fencing. Fittings such as line rail clamps, post caps, tension bands, and panel clamps must be galvanized, heavy pressed steel or malleable iron.

Figure 2-4: Expanded Metal Fence



2-6 FARM STYLE FENCES

Farm style fences are constructed of wood and/or metal posts and wire. Farm style fences, barb wire, and woven wire must comply with specification requirements in UFGS 32 31 26, *Wire Fences and Gates* and the drawings in Appendix C. Pressure treat all wood posts and metal posts must be zinc coated and conform to ASTM A702. Steel post conforming to ASTM F1043 must be used in conjunction with T-section or U-section line post. The gates are constructed of 1 5/8 inch (41.3 mm) minimum diameter tubular steel, and secured with a chain and padlock.

See Appendix C for design details of farm-style fence.

2-7 EXPEDITIONARY PERIMETER FENCING

Refer to GTA 90-01-011, Joint Forward Operations Base (JFOB) Survivability and Protective Construction Handbook for perimeter security requirements.

2-8 FENCE FABRIC HEIGHT

Unless otherwise directed all security and perimeter fencing must have a minimum fence fabric height of 7 feet (2.13m), excluding the top guard. Fence height including outriggers must be a minimum of 8 feet (2.44m). Modifications to existing fences are not required to meet this new UFC.

Consult with current Service policies on specific requirements regarding fence height and assets that may require a higher level of protection.

2-9 TOP GUARDS

When required, install outriggers (support arms) at 45-degree angles in a single arm (towards the threat side) or “Y”/”V” configuration, constructed of a single or double outrigger consisting of 18-inch (457 mm) arm(s), each having three strands of barbed wire at regular intervals along the top of the fence.

The outriggers must provide a minimum of an additional 12 inches (305 mm) to the fence height. The top guard fencing adjoining gates may range from a vertical height of 18 inches (457 mm) to the normal 45 degree outward protection, but for a limited distance along the fence line to adequately open the gates. Outriggers must be permanently affixed to the fence posts with screws or by spot welding. Screws used to affix outriggers to posts must be made tamper-proof either by design, peening, or welding.

2-9.1 Outrigger/Barbed Wire Arm Material Specifications

Top guards must be constructed of the same material as the other fencing components in accordance to ASTM F626. See Appendix C for details.

2-9.2 Barbed Wire and Barbed Tape Concertina

Barbed wire is a fabricated wire product consisting of two line wires twisted to form a two-wire strand, into which 2–point or 4–point barbs are tightly wrapped and locked into place at specific intervals.

Barbed tape concertina is a strip of metal, machined to produce clusters of sharp points. Provide three strands of barbed wire, equally spaced, on outrigger/support arms where barbed tape/concertina is mounted.

2-9.2.1 Barbed Wire

Fences requiring barbed wire must use a minimum of 3 strands of barbed wire equally spaced. Additional strands may be added as required. Barbed wire must consist of two 12.5 -gage /0.099-inch (2.5 mm) (+0. 005- inch (.127 mm)) twisted line wires with 15-gage /0.080- inch (2 mm)(+0, 005-inch (.127 mm)) round barbs. Barbed wire must be zinc-coated steel, aluminum coated steel, aluminum alloy, or PVC over zinc-coated steel as specified. All barbs must consist of four points and spacing of barbs must be at 5- inch (127 mm) (+1- inch (25.4 mm)) centers.

2-9.2.1.1 Barbed Wire Material Specifications

Barbed wire must be in accordance to ASTM A121 and ASTM F1665. See Appendix C for barbed wire support configurations.

2-9.2.2 Barbed Tape/Concertina

Barbed-tape concertina is a commercially manufactured wire coil constructed of high-strength-steel barbed wire that is clipped together at intervals to form a single coil or double coil. The single coil must be a minimum of 2 feet (610 mm) in diameter and extend at least 50 feet (15.2 m) without permanent distortion. Double coil must be 24/30 inch (610 mm/762 mm) and extend at least 50 feet (15.2 m) without permanent distortion.

Barbed tape concertina may be added to the top and, in some cases, to the bottom to increase the level of protection. Barbed tape concertina must be secured at a minimum interval of 18 inches (457 mm) along the fence fabric to the top barbed wire strand and a maximum gap of 2 inches (51 mm) must be maintained between the bottom barbed wire and the top of the chain-link fabric. After use, barbed tape concertina may be recoiled and reused without distortion. For additional protection, barbed tape concertina may be installed between the “Y” configuration of the outriggers.

2-9.2.2.1 Barbed Tape/Concertina Material Specifications

Barbed tape concertina must be in accordance to ASTM F1911 and ASTM F1910. See Appendix C barbed tape configurations.

2-9.2.3 Specific Barb Requirements

2-9.2.3.1 Farm Style Fence

Any barbs used with farm fencing must be a minimum of 15.5 gage wire. Barbed clusters must have a minimum width of 1.2 inches (30.7 mm). The distance between these strands is intended not to exceed 6 inches (152 mm) and at least one wire must be interlaced vertically and midway between posts. The ends of the barbed wire strands may be staggered or fastened together, and the base wire may be picketed to the ground. See Appendix C for barbed wire details.

2-9.2.3.2 Barb Wire Fencing

3, 4, or 5-strand barbed wire fencing, 4 feet (1.2 m) high, should be used for extensions of flight-line area barriers, perimeter boundary for isolated portions of installations, livestock barrier, and area boundary for on-base bulk material storage areas. Barbed wire fastened on wooden posts may use a minimum of 1.5 inch (38 mm) staples made from the same metal as the wire for fastening. See Appendix C for barbed wire details.

2-9.2.3.3 Temporary Usage

When used for temporary purposes (not used as fence topper), concertina wire should be used in multiple stacked coils. Stacked concertina wire on perimeter barriers may be laid between poles with one roll on top of another or in a pyramid arrangement (minimum of 3 rolls). Concertina blades must have a minimum length of 1.2 inches (30.7 mm).

Barbed tape concertina as an expedient measure for short-term use, pending the erection of permanent fencing, can be non-reinforced. Reinforce all barbed tape concertina used for permanent security applications.

2-10 GROUNDING

Grounding and bonding of the perimeter systems must be in accordance with the National Electric Safety Code (NESC) - IEEE C2. Fences that are required to be grounded by NESC must be designed to limit touch, step, and transferred voltages in accordance with industry practices. IEEE Std 80™-2000 - IEEE Guide for Safety in AC Substation Grounding is one source that may be utilized to provide guidance in meeting these requirements.

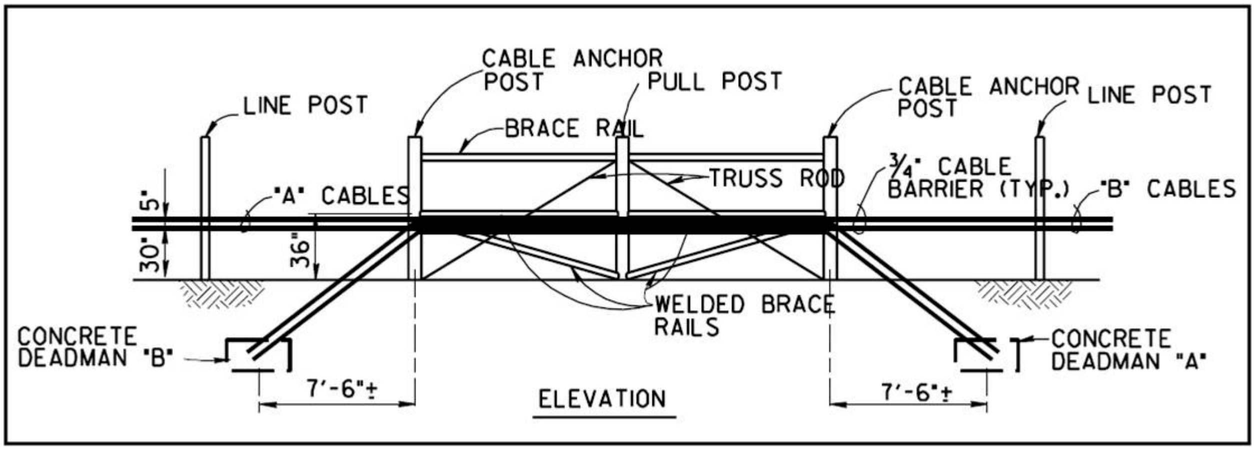
The grounding connections must be made either to the grounding system of the enclosed equipment or to a separate ground.

1. Fences must be grounded at each side of a gate or other opening.
2. Gates must be bonded to the grounding conductor, jumper, or fence.
3. A buried bonding jumper must be used to bond across a gate or other opening in the fence, unless a nonconducting fence section is used.
4. If barbed wire strands are used above the fence fabric, the barbed wire strands must be bonded to the grounding conductor, jumper, or fence.
5. When fence posts are of conducting material, the grounding conductor must be connected to the fence post or posts, as required, with suitable connecting means
6. When fence posts are of nonconducting material, suitable bonding connection must be made to the fence mesh strands and the barbed wire strands at each grounding conductor point.

2-11 REINFORCEMENT FOR FENCING

Refer to UFC 4-022-01 and 4-022-02 for additional guidance and requirements (number and size of cables) on fence reinforcement for identified moving vehicle threat. For fabric type fences install fence reinforcement between fence fabric and fence post. For both fabric type and ornamental fences reinforcement must be installed on exterior side of fence post. If located in a corrosive environment, coated or sheathed cable may be used; however, the sheathing must be removed at the connections. See Figures 2-5/2-6 and Appendix C for design details of fence reinforcement. See Appendix A for material specifications.

Figure 2-5 Steel Cable-Reinforced Chain Link Fence



2-11.1 Deadman Anchor

Reinforcing cables must be terminated to concrete deadman anchors. Anchors are to be placed at intervals of 200 feet (61 m) on the secure/protected side of the perimeter fencing. Offset deadman anchors from fence at the minimum distance required to avoid interference with post and to allow maintenance access to the turnbuckles, clamps, and other accessories.

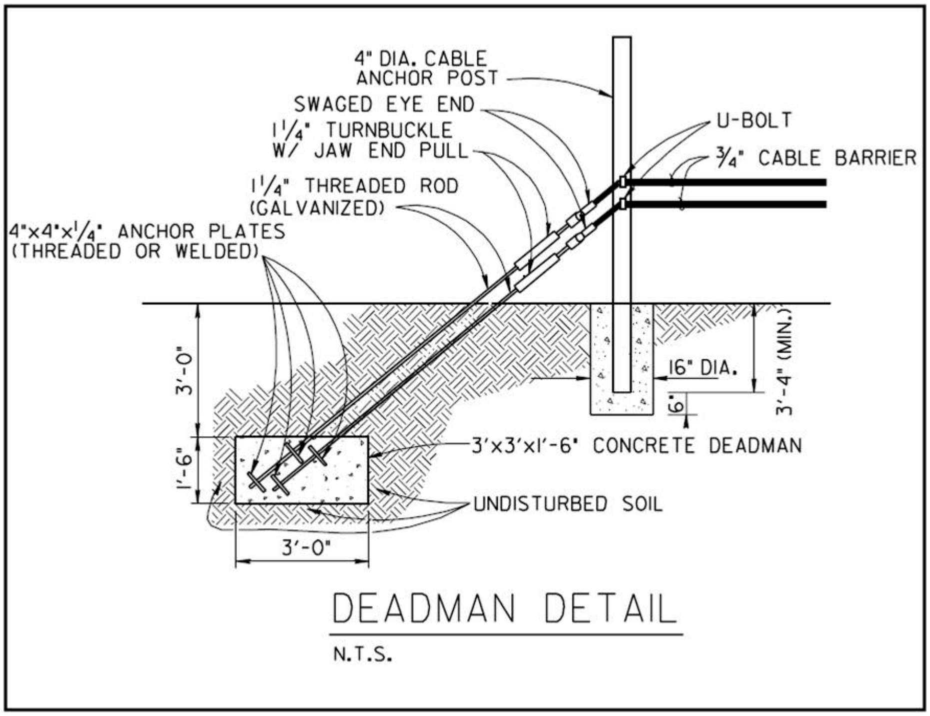
The anchoring system: deadman dimensions or other anchoring systems and burial depth, eyebolt embedment depth, etc. must be designed for local soil conditions and the anticipated impact force established by the threat parameters defined in UFC 4-022-02. See Appendix C for design details of deadman anchors.

2-11.1.1 Cable Connection

Eyebolts embedded in the concrete deadman anchors may have either a welded “T” or “L” end. The eyebolt can either be in-line with the attached cable or flush against the deadman surface. When used, eyebolts should be welded and galvanized to the anchor rods. The top side of the deadman can either be placed flush with or below the ground surface with the eye of the eyebolt above ground. Threaded rods may also be used as an alternative to the eye bolt when securing the cables to the deadman anchor. When using threaded rods, the threaded rod and wire rope connection must be visible above ground like the eyebolt previously described.

Figure 2-6 and details in Appendix C show the deadman position using a cable clamp and turnbuckle to secure the cable rather than a swaged on clamp. This turnbuckle adds the advantage of being able to adjust the tension of the cable.

Figure 2-6: Deadman Anchor Detail



2-12 SPECIAL SECURITY FEATURES

2-12.1 Clear Zones

Clear zones are areas established around the fence to provide and unobstructed view to enhance detection and assessment around fences. When required, dimensions of clears zones vary depending on asset being protected and level of protection. For example, outer clear zones may be 30 feet (9 m) wide and inner clear zones may be 20 feet (6 m) wide. Consult with Service policies for assets being protected to determine if clear zones are required and what dimensions are required.

2-12.2 Double Fence Lines

Assets that require Electronic Security Systems (ESS) for perimeter security may require a double fence line. Perimeter ESS and double fence lines typically associated with assets that require a high level of protection for the force or covert entry tactic. This system is intended to increase the probability of detection, decrease nuisance alarms, and prevent access to ESS. The typical configuration is outer clear zone, outer fence, isolation zone, inner fence, and inner clear zone. See Figure 2-7a/b below.

2-12.2.1 Outer Fence Line

Outer fence line acts to reduce the Nuisance Alarm Rate (NAR) by keeping animals, people, vehicles, and windblown debris out of the isolation zone. No sensors should be placed on the outer fence of a double fence line system. In some instances the outer fence line may define a protected or restricted area boundary. In the case where the outer fence line defines a protected or restricted area boundary, the outer fence must meet the minimum requirements as set forth in this UFC.

2-12.2.2 Isolation Zone

The isolation zone is the area between the inner and outer fence lines sometimes referred to as the detection zone and must meet clear zone requirements indicated above. The area must be free of all vegetation and above ground obstructions except for the ESS and its supporting infrastructure. The isolation zone is typically light colored gravel or crushed stone bed sloped to prevent standing water. This reduces maintenance, increases probability of detection, and enhances the assessment capability within the fence lines.

2-12.2.3 Inner Fence Line

The Inner fence line provides the inner boundary for the isolation zone and defines the protected or restricted area boundary. It may be used for mounting of fence line detection systems such as taut wire, Time Domain Reflectometry (TDR), or fiber-optic strain-sensitive cable systems, refer to UFC 4-021-02 for sensor types and applications. When used as a foundation for fence line detection systems, the fence meet the following minimum requirements.

2-12.2.3.1 Inner Fence Fabric

Fence fabric material must be in accordance with ASTM A491 and must comply with minimum requirements set forth in this UFC.

2-12.2.3.2 Inner Fence Components, Fittings, and Accessories

Select the framework components and material from ASTM F626, ASTM F1043, ASTM F1083, and ASTM F1712 in addition to the following:

1. End, corner, and pull posts will be concrete filled.
2. Gateposts must be minimum of 4-inch (102 mm) outside diameter (O.D.) and be sized according to Table 2-1.
3. Three (3) tension bands must be used. Top tension wire must be 7.5-inches (191 mm) below top of fabric with the other two (2) bands located approximately 31(787) and 56.5 (1435) inches (mm) down respectively from the top of fence fabric.

Table 2-1 Fence Type Components

PIPE	SIZE
Bottom or Brace Rails	1 5/8 in (41mm)
Line Posts	2 ½ in (63.5mm)
Corner, end and pull posts)	4 in (102mm)
Single Gate Posts – equal or less than 12ft (3.7m) Width	4 in (102mm)
Double Gate Posts – equal or less than 24ft (7.3m) Width	4 in (102mm)
Single Gate Posts – greater than 12ft (3.7m and less than 18ft (5.5m) Width	6 5/8 in (168 mm)
Double Gate Posts – greater than 24ft (7.3m) and less than 36ft (11m) Width	6 5/8 in (168 mm)
Single Gate Posts – over 18ft (5.5m) Width	8 5/8 in (219 mm)
Double Gate Posts – over 36ft (11m) Width	8 5/8 in (219 mm)

Figure 2-7a: Double Fence Line

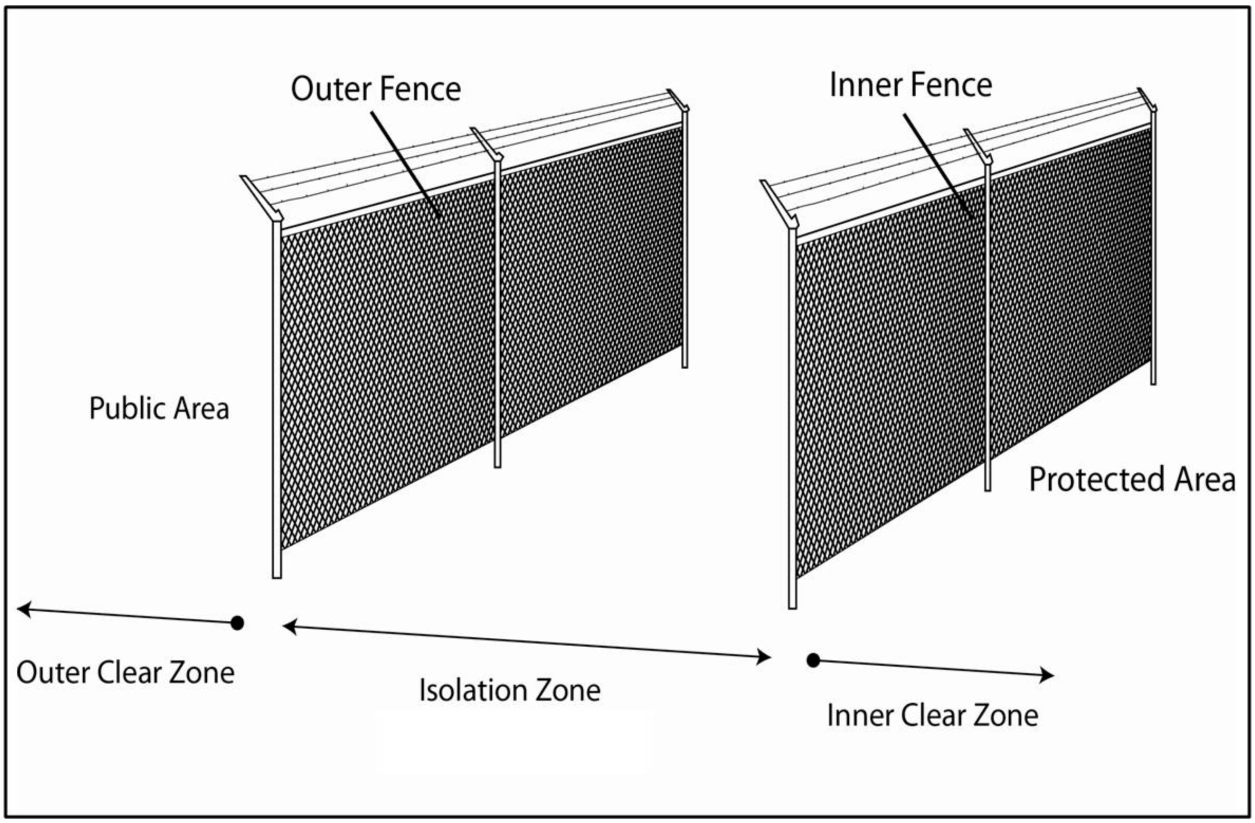


Figure 2-7b: Double Fence Line

2-12.3 Fence Line Electronic Security Systems

Electronic Security Systems (ESS) may be used to increase the probability of detection and the assessment of intruders attempting to enter restricted areas. ESS includes Intrusion Detection Systems (IDS), Access Control Systems (ACS), and Closed Circuit Television (CCTV) for assessment of alarm conditions. The design of fences and gates must support the site specific design of the ESS as required. Further information on Electronic Security Systems can be found in UFC 4-021-02.

2-12.4 Security Lighting

Security lighting or protective lighting provides illumination during periods of darkness or in areas of low visibility to aid in the detection, delay, and respond functions of a physical security system. Coordinate security lighting requirements with security personnel. Refer to UFC 3-530-01 for lighting design criteria.

2-12.5 Patrol Roads

When required provide an interior, all-weather perimeter road in all areas not affected by impassable terrain features for security-patrol vehicles. Drainage ditches parallel to patrol roads should be designed to utilize shallow or low angle side slopes to prevent obscuring the observation from a 4-foot (1.2 m) high line of sight above the road surface. Where patrol roads pass through clear zones, precautions must be taken in roadway design to preclude concealment for intruders.

2-12.6 Drainage Culverts and Utility Openings

Provide protective measures for culverts, storm drains, sewers, air intakes, exhaust tunnels, and utility openings, that have a cross-section area of 96 square inches (61,939 square mm) or greater, with the smallest dimension being more than 6 inches (152.4 mm) and :

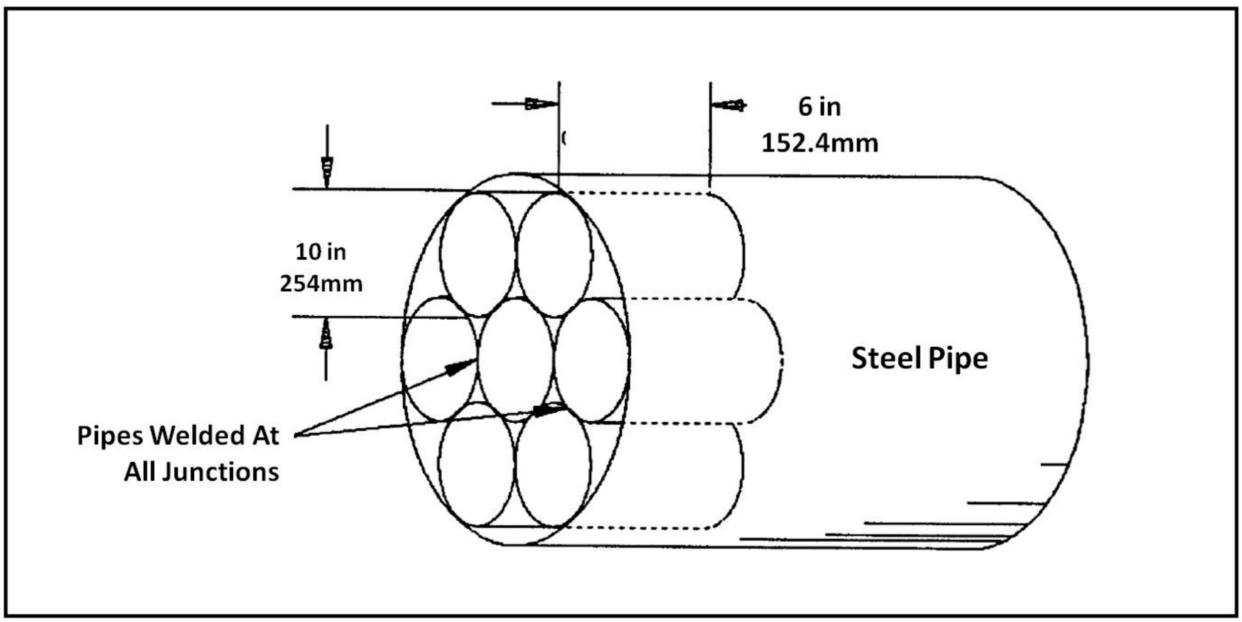
1. Pass through clear zones.
2. Traverse under or through security fences.

Such openings and barrier penetrations will be protected by securely fastened grills, locked manhole covers, or equivalent means to prevent entry or provide forced entry penetration resistance equal that of the fence. Regarding material selection for securing openings/penetrations see Material Selection and Coatings.

2-12.6.1 Large Diameter Pipes – Multiple Pipes

If drainage conditions require large diameter pipes, or if it is a more economical approach to provide security protection, drainage openings may be constructed of multiple pipes having individual diameters of 10 inches (250 mm) or less Extend multiple pipes through the entire conduit, secured to each other and to the large opening. As an economical alternative, reduce the pipe lengths to short segments approximately 6-inches (152 mm) long. Place the short segments at the attack side of the opening and secure them to the welded bar grill. See Figure 2-8.

Figure 2-8: Large Culvert with Short Pipes



2-12.6.2 Large Diameter Pipes – Grilled Configuration

Steel pipes that pass under fences must have grills welded to the pipe as shown in Figure 2-9. For concrete pipes that pass under fences, the grill ends must be welded to a steel rim that fits snugly over the concrete pipe. The rim and grillwork will be fastened over the concrete pipe and bolted or pinned to the rim of the concrete pipe as shown in Figure 2-10. Grill ends may be embedded in a concrete headwall that encapsulates the concrete pipe. Grills must be placed on attack side of the fence. Care must be taken during design to assure that bars and grills across culverts are not susceptible to clogging. All utility openings are intended to be designed with a debris catcher to permit either rapid clearing or removal of grating for cleaning when required. Steel used for grill must be in accordance with ASTM A529 and the corrosion prevention control section of this UFC.

Figure 2-9: Steel Culvert Grill

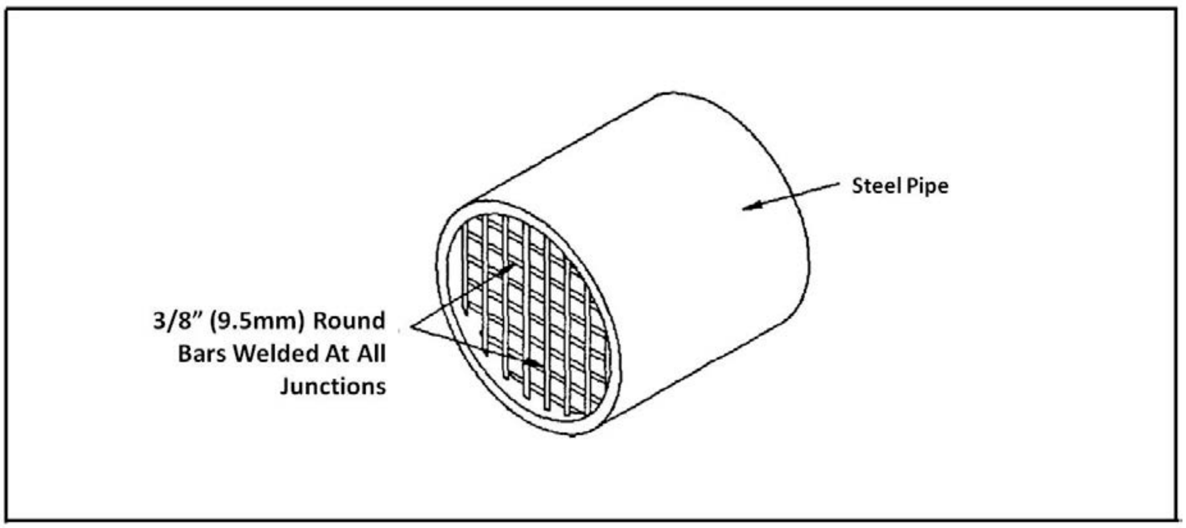
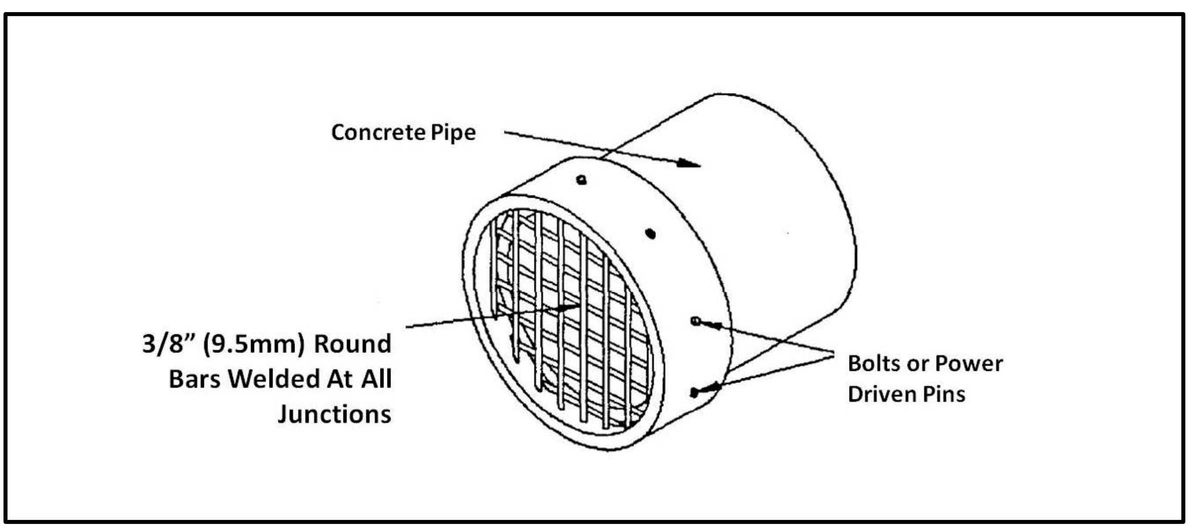


Figure 2-10: Concrete Culvert Grill



2-12.6.3 Utility Openings

Inlets for utility openings that are outside of the fence line must have a debris catcher with grating. As shown in Figure 2-11a/b below, inlets for utility openings that are outside of fence line must have a debris catcher (i.e. chain link fabric) with the grating on the inlet side. Caution must be taken when using debris catchers to ensure that plugging and flooding of the area surrounding the headwall do not occur.

2-12.6.4 Additional Considerations

In lieu of installing a grill in the utility pipe itself, provide manhole covers, 10 inches (254 mm) or more in diameter, covering a utility which passes through security perimeter fencing of a restricted access area and secure with locks and hasps or by welding them shut or by bolting them to their frame, or by using keyed bolts. Hasps, locks, and bolts must all be made of materials that resist corrosion.

Figure 2-11a: Utility Openings

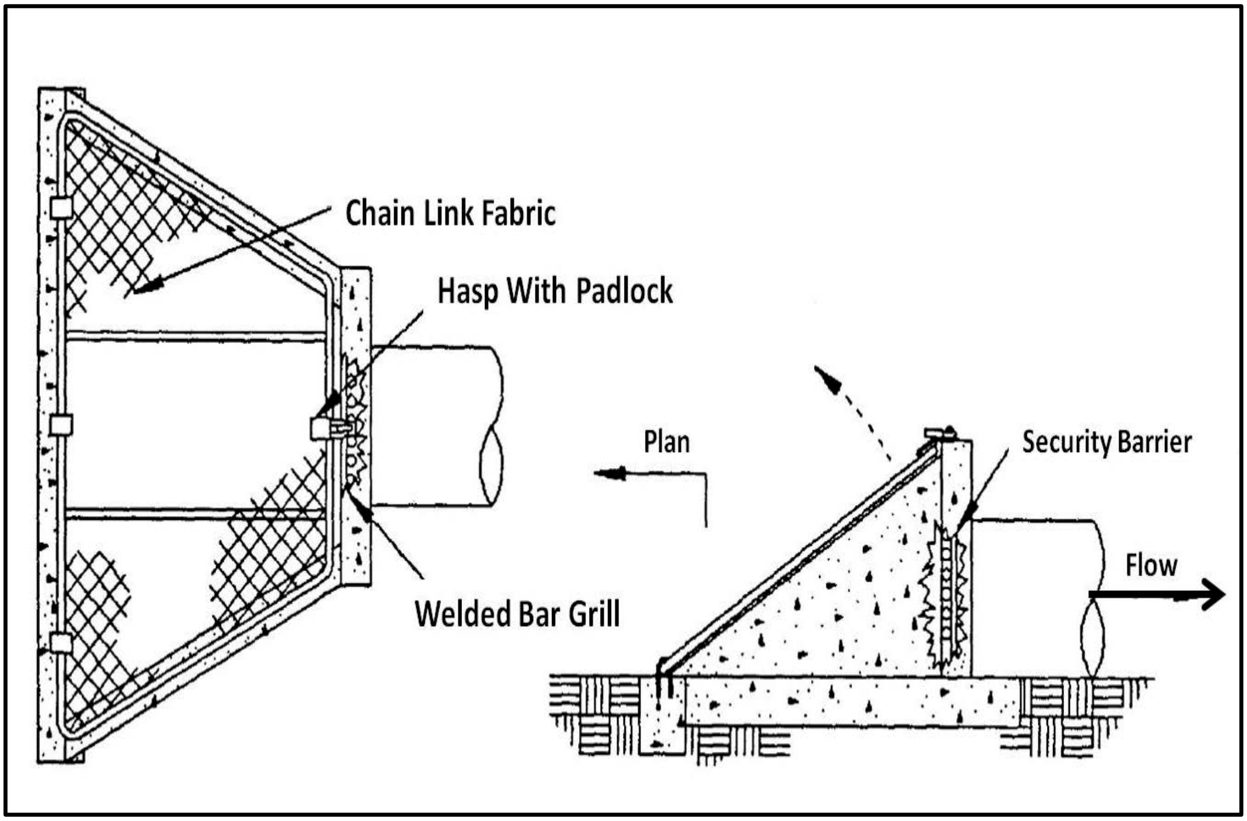
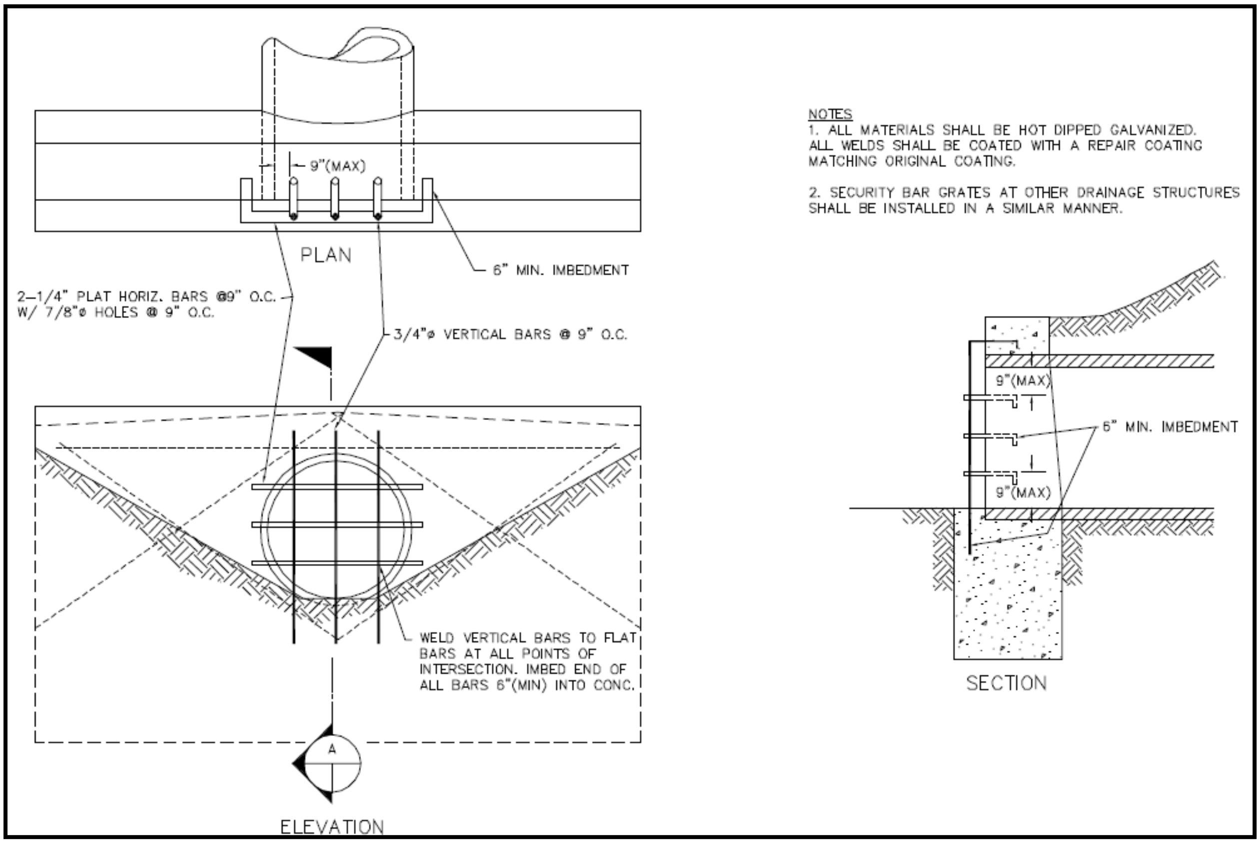


Figure 2-11b: Utility Openings



2-12.7 Drainage Crossing

Fencing passing over ditches or swales is intended to provide protection to prevent unauthorized entry. Ditches and swales that do not receive frequent water flow must provide additional fencing below, suspending from the lower rail of the main fence to the auxiliary frame and around the sides of the ditch. See Figure 2-15. The added fence must be attached every 2 inches (51 mm) along the intersection of the two fence sections and either attached to a series of ground stakes secured to the sides and bottom of the ditch, or embedded in a concrete sill in the ditch or swale as shown in Figures 2-12 and 2-13. Concrete curbing must be used to fill areas between fencing and ground surface.

Provide a screen arrangement below fencing using vertical and/or horizontal steel bars or pipes for ditches and swales receiving frequent water flow. Provide a maximum spacing of 9 inches (229 mm) between either vertical or horizontal bars. Possible debris must be considered when designing the spacing between bars. Crossing bars must be welded at each intersection, with bars embedded 6 inches (152 mm) into concrete and fastened to the bottom rail of the crossing fence. See Figures 2-14a/b/c/. Analyze the hydraulic capacity of ditches, swales, and culverts to verify the bar grills will not decrease the channel flow capacity below the maximum expected design flow.

Steel used for grill must be in accordance with ASTM A529 and the corrosion prevention control section of this UFC.

2-12.8 Tunneling Prevention

Soil under fence must provide a minimum of 15 seconds of tunneling resistance using hand tools. Tunneling prevention must be used in areas containing “soft” soils. UFC 3-220-10N describes “very soft” and “soft” soils as those that can be extruded between fingers when squeezed and/or molded by light finger pressure. Classification of soils must be in accordance with ASTM D2487, Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), and ASTM D2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Areas with a soil analysis indicating that “soft” soils are present must embed fencing in a continuous concrete curb. The recommended depth of the curb will be determined from the soil analysis and the frost depth at the facility. The frost depth for the subject areas must be considered to assure that heaving of posts and curb cannot occur during the winter. If the soil analysis does not indicate tunneling may occur quickly, continuous concrete curbing may still be considered as an added protective measure. Nuclear sites with very sandy terrain are directed to have a soils engineering analysis to determine the recommended depth of the concrete curb. Restricted access facilities with a risk of tunneling may provide IDS for tunneling protection. Welded wire mesh fence systems may incorporate additional fence panels for burial on the secure-side of the perimeter and tie-wired to the vertical panels to deter tunneling.

Figure 2-12: Swale Crossing with Ground Stakes

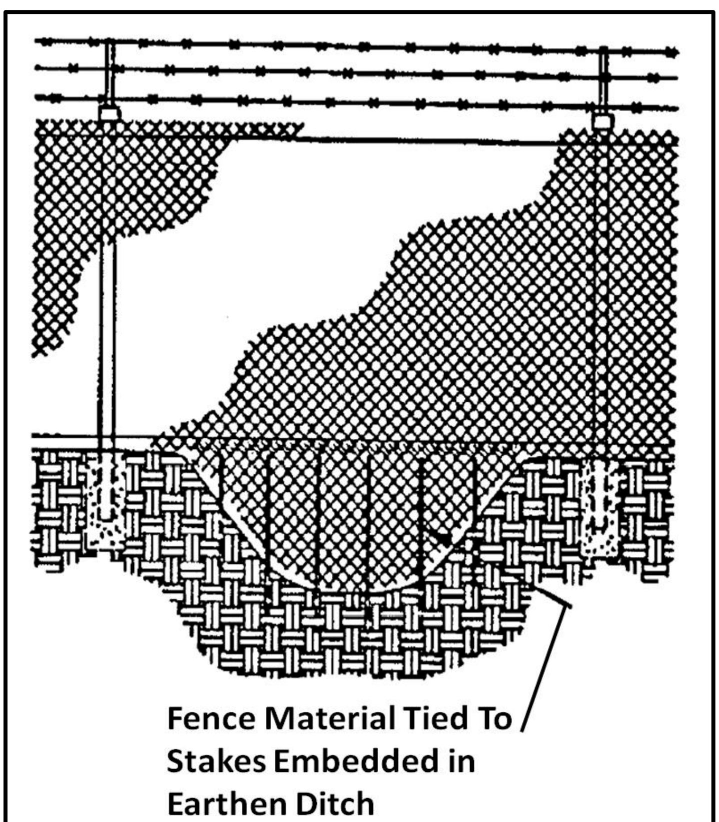


Figure 2-13: Swale Crossing Embedded in Concrete

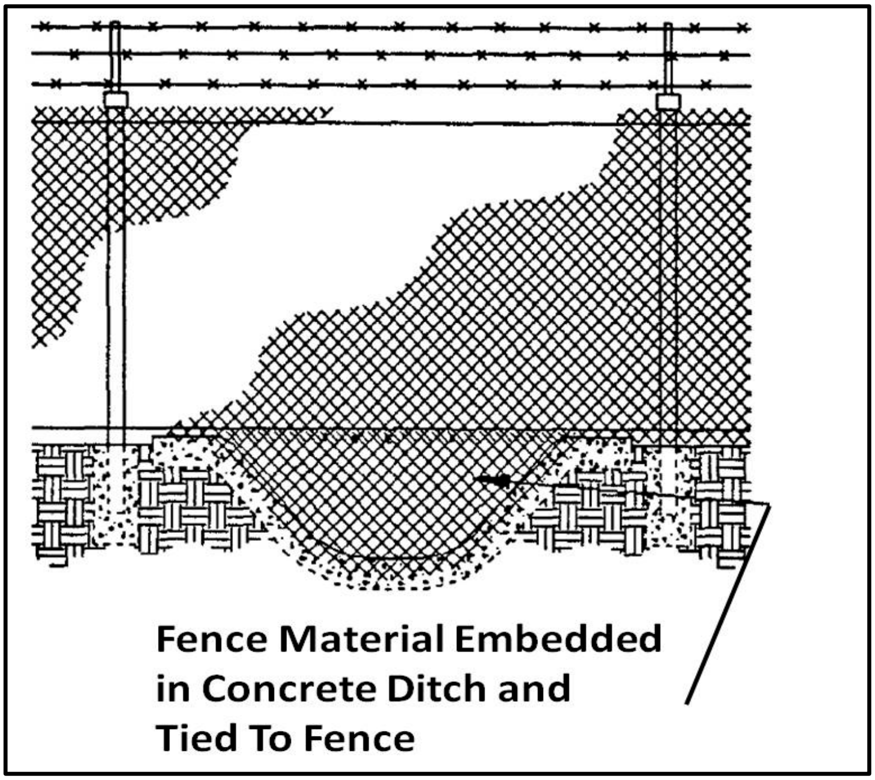


Figure 2-14a: Bar Grill Embedded in Concrete

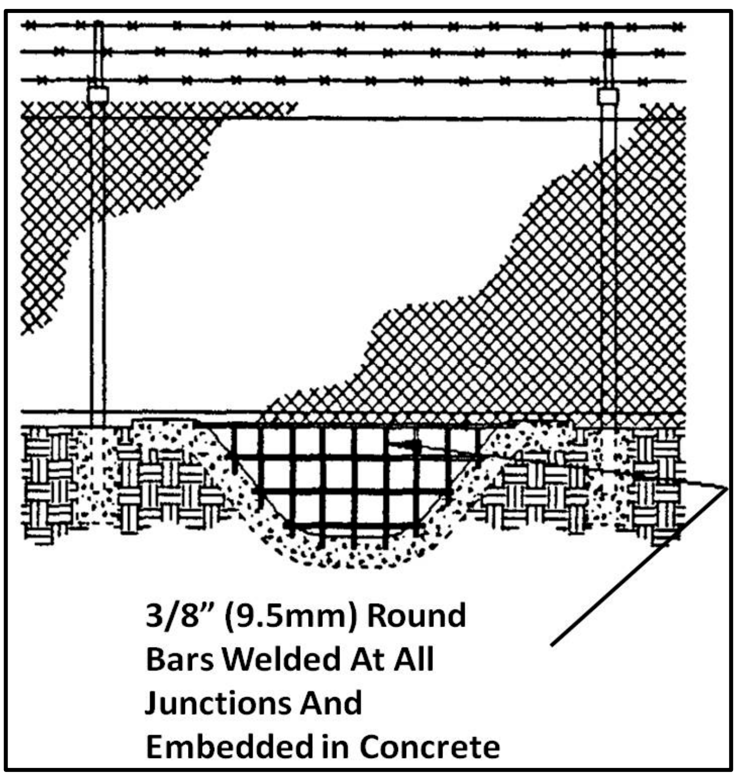


Figure 2-14b: Bar Grill Embedded in Concrete

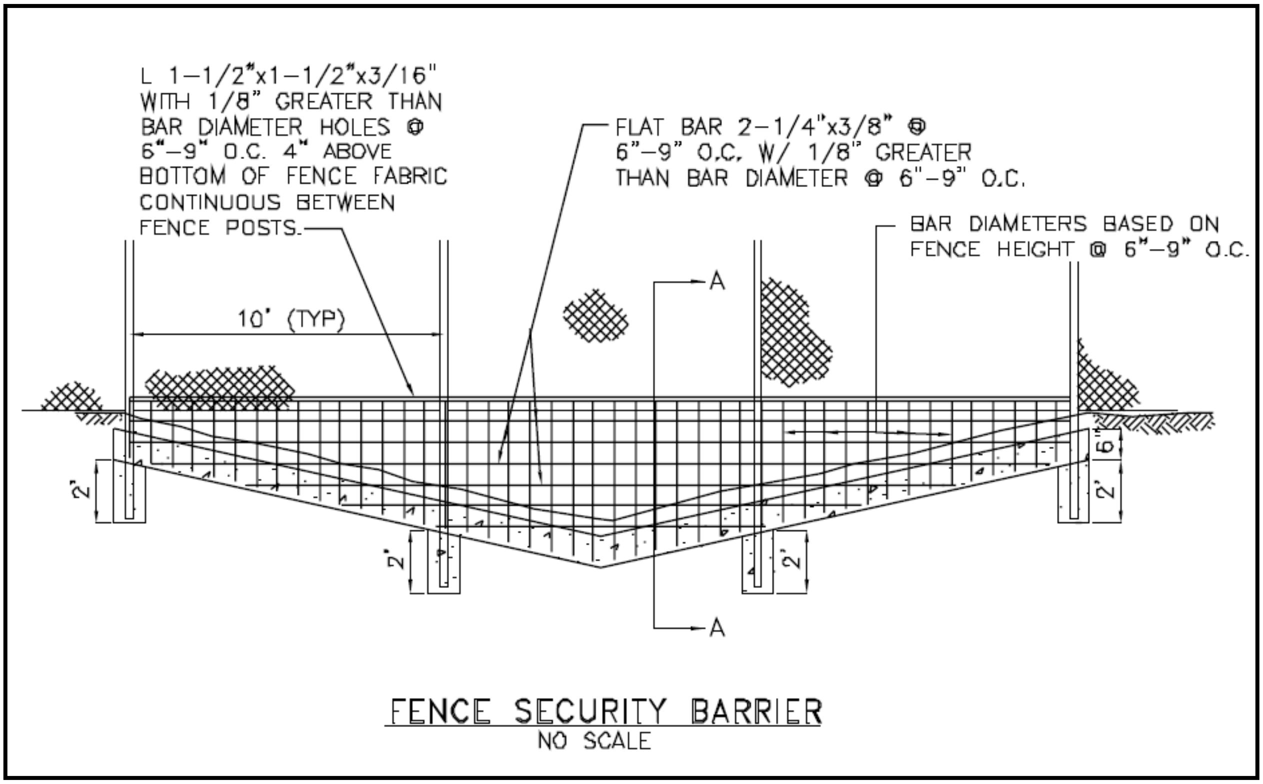


Figure 2-14c: Bar Grill Embedded in Concrete

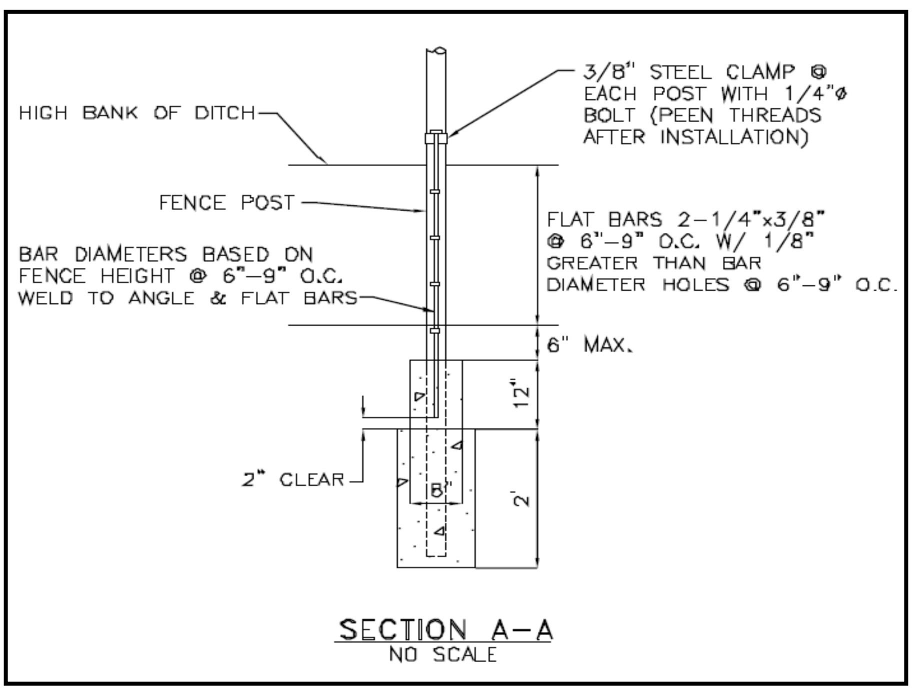


Figure 2-15- Chain Link Fence over Ditch

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CHAPTER 3 GATES

3-1 GATES OVERVIEW

3-1.1 Access Control

Access Control is a primary design consideration for gate systems. The design of gates must consider and address the following items to ensure proper specification of power-operator accessories and controls. See Appendix C for details of standard gates.

- Pedestrian traffic
- Reversing devices to keep gates from closing on vehicles
- Traffic flow
- Number of open and close cycles
- Type of vehicles
- Operational site security plan
- Provide lighting in accordance with UFC 3-530-01, *Design: Interior and Exterior Lighting and Controls.*

Gates, as part of perimeter fences, must be as effective as their associated fence to provide an equivalent deterrent. Gates will normally require additional hardening features due to their location across entrance roads and the inherent vulnerability of their hinges and latches. Gates are known to be the weakest point in the perimeter security fence and as such, attention must be paid to their requirements when designing security fencing. Materials used in fabricating and erecting chain-link gates must be the same as the materials used for the associated chain-link fence. A primary concern for gate design associated with security fences is to assure that the bottom of the gate fabric extends within 2 inches (51mm) of the roadbed or firm soil when closed. Where possible, pedestrian and vehicular gates should be clearly separated and defined.

3-2 PERSONNEL GATES

Personnel gates are intended to be designed to permit only one person to approach the guard at any time. Turnstile gates may be considered to control personnel entry.

Gates must conform to the Architectural Barrier Act (ABA) Accessibility Standard for Department of Defense Facilities as adopted by the Deputy Secretary of Defense memorandum dated October 31, 2008.

3-2.1 Single Swing Gates

Design single swing gates to match fence fabric height, with an additional 1 ft (305 mm) of three strand barbed wire added to the height if barb wire is part of the fence structure. The gate opening should not exceed a width of 14 ft (4.3 m). See ASTM F900 for additional gate requirements.

For pedestrian use, single swing gates may be considered as the second alternative to turnstile gates. See Figure 3-1 for a fixed and welded single swing gate example

3-2.2 Turnstile (Rotational) Gates

Turnstile gates are manufactured as single or tandem and are available for ABA access. Tandem turnstile gates should be considered where high volumes of pedestrian traffic are exchanged from both sides of the perimeter such as shift work. Only full height turnstile gates are permitted for access through security fencing. Automated access control systems such as card readers, push button, and wireless remote can be incorporated to access turnstile gates. Metal detectors and counters are also available as accessories. Movement of travel can be set for clockwise, counterclockwise, or bi-directional. Arms and barrier tubing are 1-3/4 in (44.5) diameter, 14 gage. Overall exterior height is 91 in (2.31 m) with a pedestrian walk through height of 84 in (2.13 m).

Provide canopy or barbed wire/barbed tape over top channel between adjacent fence posts. Provide Barbed wire/tape in accordance with Chapter 2. See Figure 3-2 for a turnstile gate example. See Appendix C for design details of turnstile (rotational) gates.

Figure 3-1: Single Swing Gate

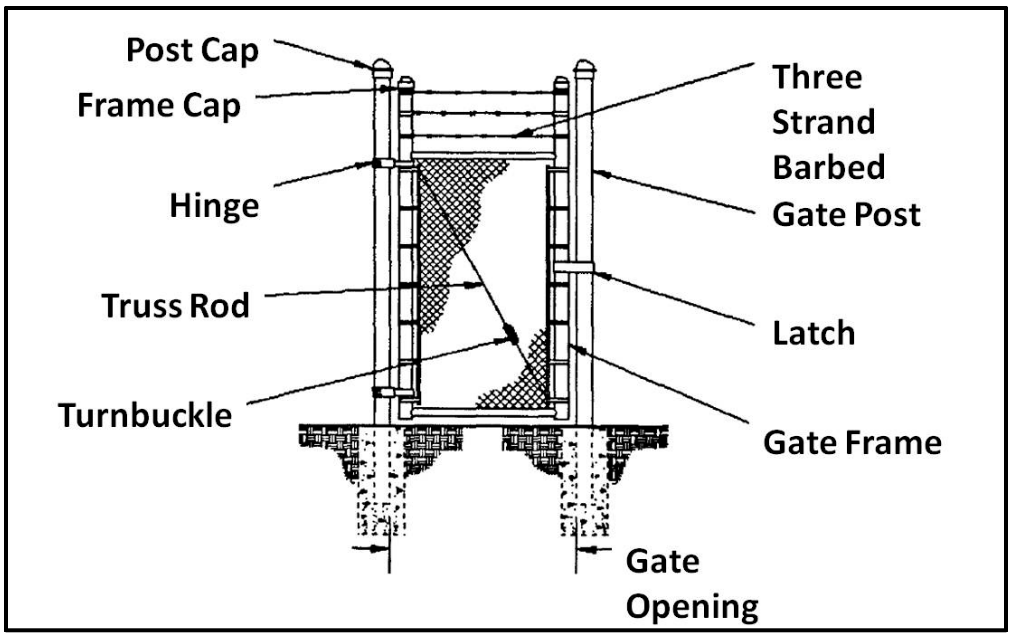
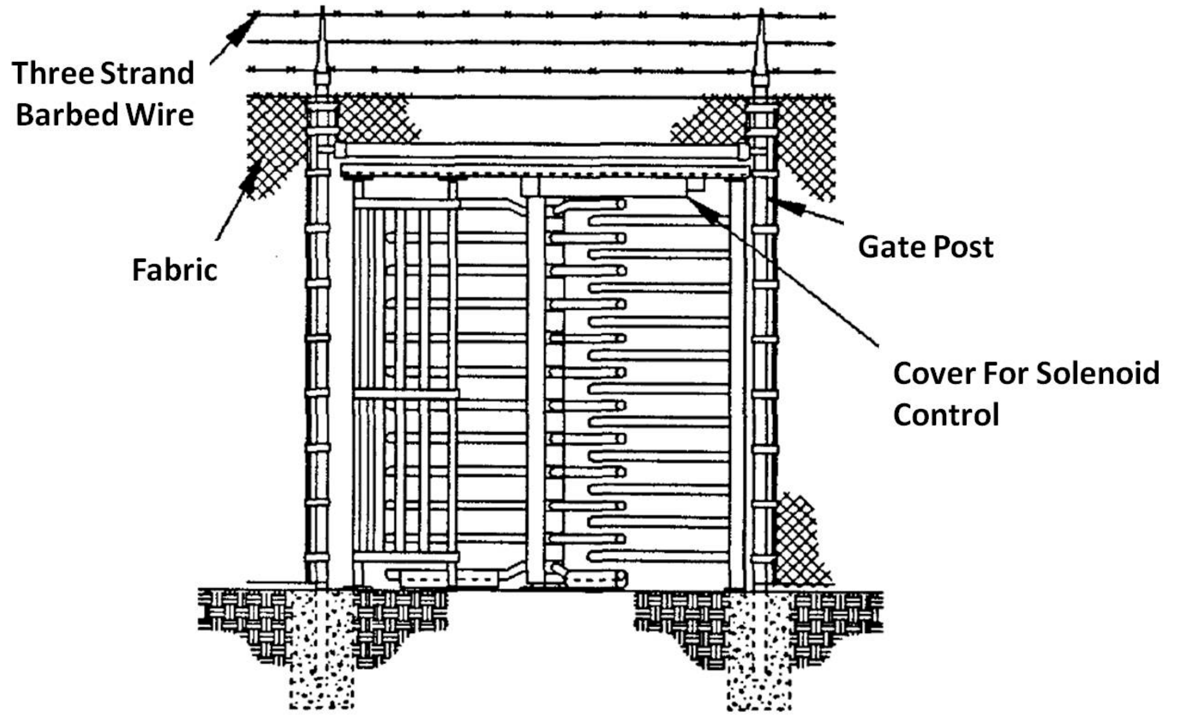


Figure 3-2: Turnstile/Turnstile with Barbed Wire



3-3 VEHICULAR GATES

Vehicular gates should limit opening sizes when possible to decrease open/close cycle time. There is no maximum height for vehicular gates. Coordinate gate height with surrounding/adjacent security fencing and the width will be at least as wide as the road entering the gate. The operational requirements for the gate must be evaluated to determine which gate type is most suitable. Analysis for all vehicular gates must consider daily peak of vehicular traffic and the operational access control requirements for the secured area to determine opening size, gate type, and whether an automatic operator is needed. Follow the requirements of ASTM F2200 for gates used for vehicular traffic that are to be automated. Cantilevered, sliding or wheel supported gates are considered the best selection for vehicle security gates followed by overhead sliding gates, swing gates, vertical tilt and overhead “guillotine” gates. Areas where snow and ice are prevalent may consider using cantilever or swing gates instead of tracked sliding gates. However, if sliding gates are used, consideration should be given to adding internal heating for gate mechanisms. Areas where real estate is tight vertical tilt gates are recommended.

3-3.1 Sliding Gates

Sliding gates must have all entry-exit points secured with a heavy duty sliding steel, iron, or heavily braced chain link gate equipped with a heavy locking device. The cross-slope of the road surface must be sloped at a constant grade for the full length of the gate path to permit proper drainage while maintaining smooth operation of the gate opening and closing. Where a sliding gate is installed at an existing paved entrance, the pavement may be filled or leveled where the gate will be installed. Follow the requirement of ASTM F1184 for sliding gates.

3-3.1.1 Single Wheel-Supported (V-groove) Sliding Gate

A guide rail or trough across the roadbed is utilized by this type of gate. The trough provides a smoother surface for vehicular traffic, but is not recommended due to debris buildup. Single wheel supported sliding gates do not have an opening distance restriction, but are limited by the power requirements of the gate operator. Wheel supported gates require 1/3 less straight level storage space along adjacent fence than cantilevered.

3-3.2 Cantilevered Gates

3-3.2.1 Single Cantilevered Gate

All single cantilevered gates should use full support and suspension of gate frame by four rollers secured to two posts inside the restricted area. Single cantilevered gates are not recommended for openings exceeding 24 ft (7.3 m). When an opened gate rests parallel to existing fence, a straight and level fence line 1.5 times the size of the opening should be made to accommodate when the gate is fully open. See Figure 3-3 and Appendix C for an example of single cantilevered gates.

3-3.2.2 Double Cantilevered Gate

Double cantilevered gates are not recommended for openings greater than 48 feet (14.6 m) and should be constructed in a similar manner as described for single cantilevered gates as shown in Figure 3-4.

3-3.3 Double Swing Gates

All double swing vehicular gates must be designed to swing inward, toward secured area. A 2 inch (51 mm) maximum clearance must be maintained between the bottom of fence and the road surface when gate is in closed position. The road surface may be leveled or sloped downward in the direction the gate opens. Recommend gate openings for double swing gates are not greater than 28 feet (8.5 m). Table 3-1 provides recommended concrete foundation diameters for swing gate posts. A minimum of 3 feet (915 mm) deep concrete foundation must be used for swing gate posts. Gate swings greater than 90 degrees must be designed with a large arc space for proper operation. See Figure 3-5 for double swing gates.

Table 3-1: Gate Post Foundations

Steel Post Diameter	Foundation Hole Diameter	Gate Leaf Length
2.875 in (73 mm)	18 in (450 mm)	0 - 6 ft (0 - 1.8 m)
4.000 in (101.6 mm)	24 in (609.6 mm)	6 - 12 ft (1.8 - 3.7 m)
6.625 in (168.3 mm)	36 in (914.4 mm)	12 - 18 ft (3.7 - 5.5 m)
8.625 in (219 mm)	40 in (1016 mm)	18 - 24 ft (5.5 - 7.3 m)

Figure 3-3: Single Cantilevered Gate

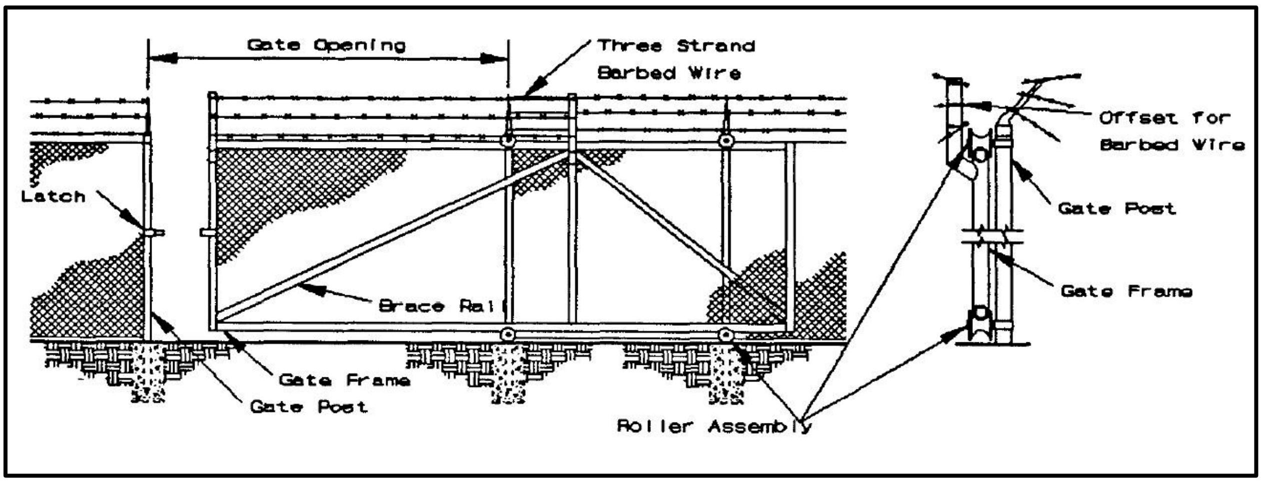


Figure 3-4: Double Cantilevered Gate

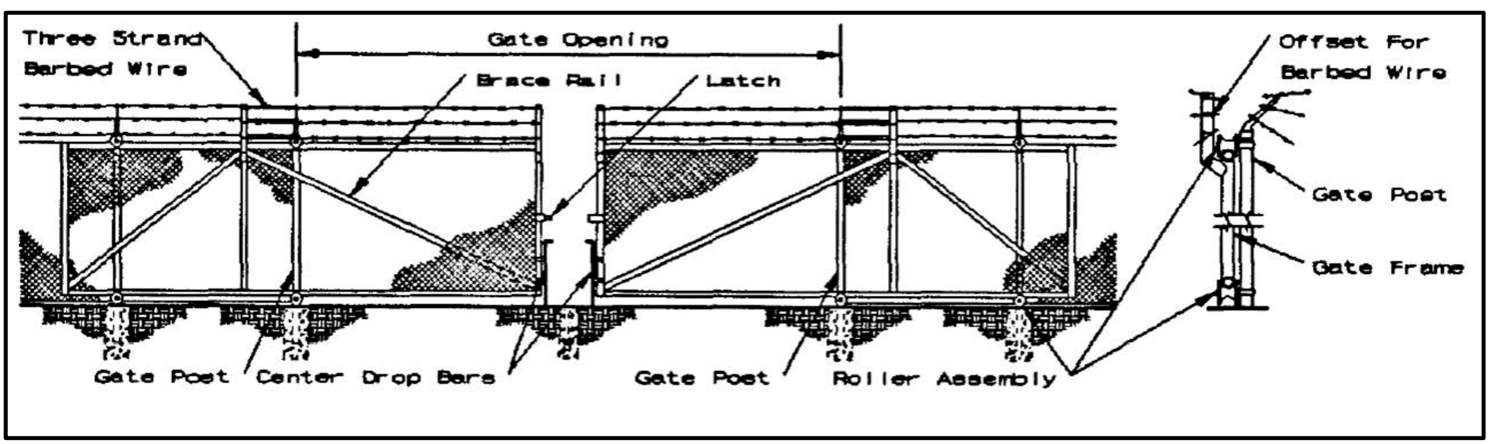
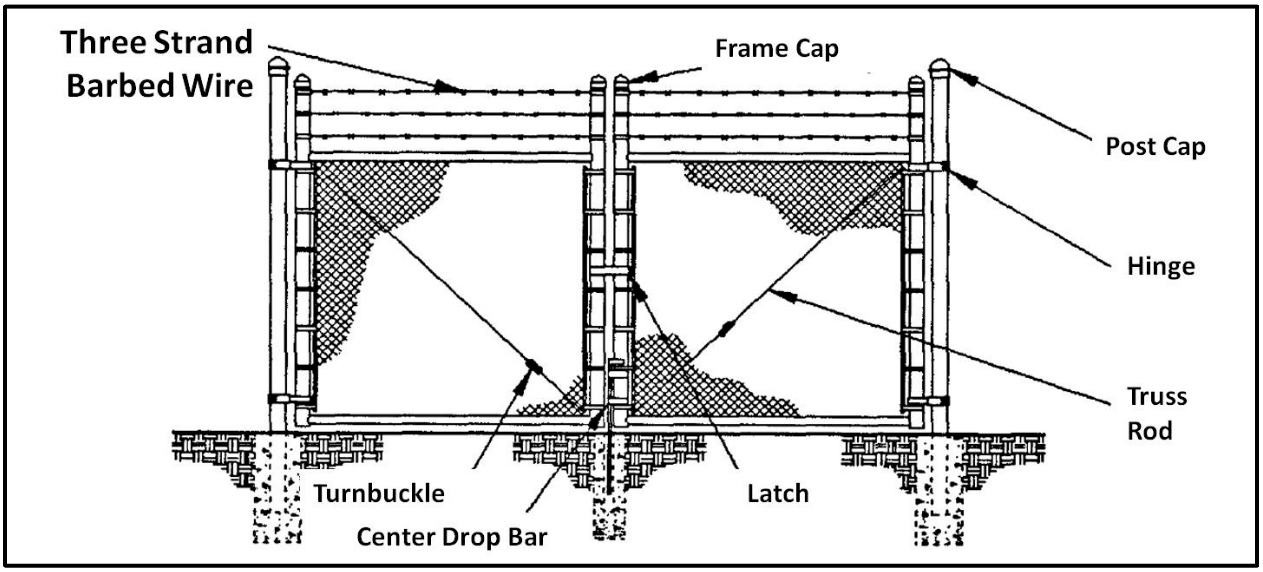


Figure 3-5: Double Swing Gate



3-3.4 Vertical Pivot Gate

Vertical pivot gates can be manufactured with chain link fabric, expanded metal, ornamental, or similar materials as indicated within this document. A 2 inch (51 mm) maximum clearance must be maintained between the bottom of fence and the road surface when gate is in closed position. Recommend gate openings are not greater than 24 feet (7.3 m). For openings greater than 24 feet (7.3 m), consult with the manufacturer. See specific manufacturer requirements for gate foundation.

3-3.5 Overhead (Sliding) Gates

An overhead gate is a horizontal slide gate supported by an I-beam or enclosed track that is suspended above the opening. The support must extend at least the full opening width on one side of the opening to support storing the gate parallel to the adjacent fence line when the gate is opened. The gate storage area must be in line with the gate opening and either be level or have a decreasing grade to accommodate the gate when it is fully opened. Gates may be suspended from the I-beam or enclosed track by rollers attached to posts extending upward from the leading and trailing edge of the gate. The overhead beam or track height is intended to allow room for the largest possible vehicle going through the gate. Gates should be suspended above ground from the overhead beam or track and supported laterally near the ground by vertical rollers. The I-beam may be applied to strengthen the gate for peak hour traffic, large opening sizes, and heavy gate construction. More posts extending upward from the center of the gate to the tracks may be added to carry heavier loads. Overhead gates must conform to ASTM F1184.

3-3.4.1 Single Overhead Supported Gate

See Appendix C for design details of single overhead supported gates.

3-3.4.2 Double Overhead Supported Gate (Biparting) Gate

See Appendix C for design details of double overhead supported gates.

3-3.6 Vertical Lift Gate

The vertical lift gate, or "guillotine" gate, should be used where the topography does not provide enough room to store the gate adjacent to the fence line. Vertical lift gates should have a counterweight with a continuous drive chain on each side.

3-4 GATE REINFORCEMENT

The gates discussed under the 'Vehicular Gates' paragraph above are non-reinforced gates and not considered to resist impact by vehicles. Standard non-reinforced gates can be fitted with cables, chains, and anchors to increase their resistance to penetration by vehicles. In addition, there are proprietary, rated active vehicle barrier gate systems that are designed to resist penetration by vehicles. See UFC 4-022-02 for additional information on active and passive vehicle barriers. Provide cables at a minimum 3/4 inch (19 mm) wire rope in accordance with ASTM A1023/A1023M. Welded alloy steel chains must be minimum 1/2 inch (13 mm) diameter. These wire ropes must then be chained together and fastened with padlocks to create a continuous barrier. Padlocks used with this system must be medium security padlocks. The wire ropes must be positioned as to not interfere with gate operations when the chain is removed. Figures 3-6 through 3-8 and details in the drawings of Appendix C provide illustrations for reinforced gates.

Application of deadman anchors must be in accordance with the provisions of Chapter 2. See Appendix C for additional reinforcement details for gates.

3-4.1 Swing Gates

For swing gates, the cable must be looped around the gatepost, the gate frame upright, and through the fence cable loop. Cable must be strung across the inside of the gate leaf and fastened around the vertical gate frame upright and fabric tension bar midway above the road surface. The cable must be terminated with a swaged loop or wire rope clamp around the gatepost to interconnect with the gate cable barrier system. All cable ends must be looped and terminated with either four wire rope clamps or hydraulically swaged wire rope fittings. Remove sheathing on covered cables at connections so that the connections can be properly made and rated.

Figure 3-6: Locking Assembly for Reinforced Swing Gate

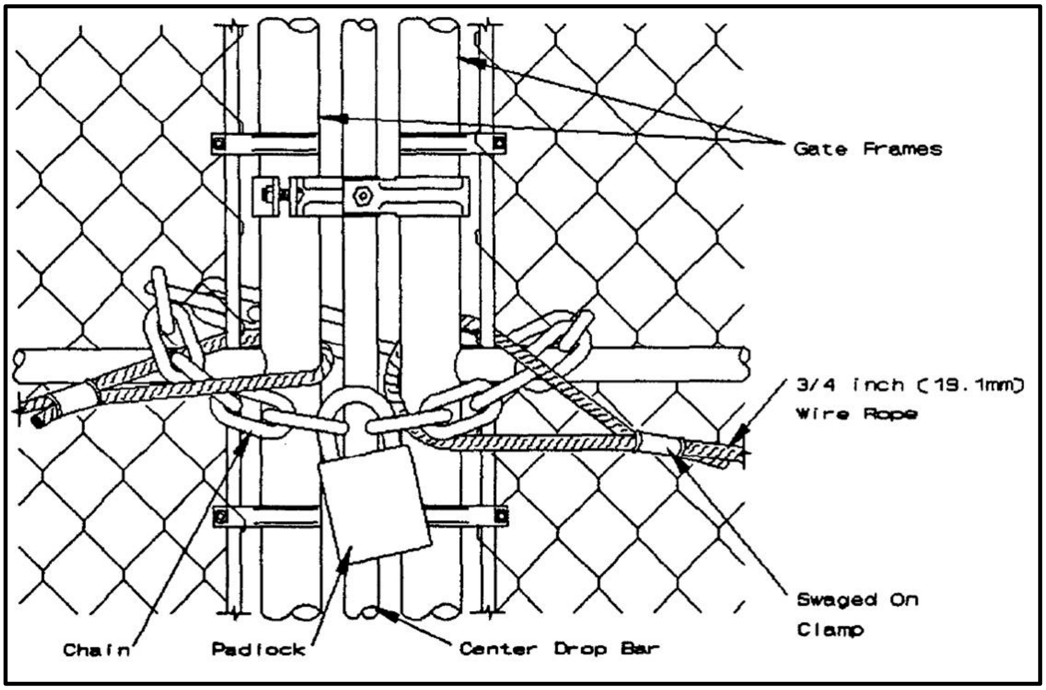


Figure 3-7: Locking Assembly for Reinforced Sliding Gate

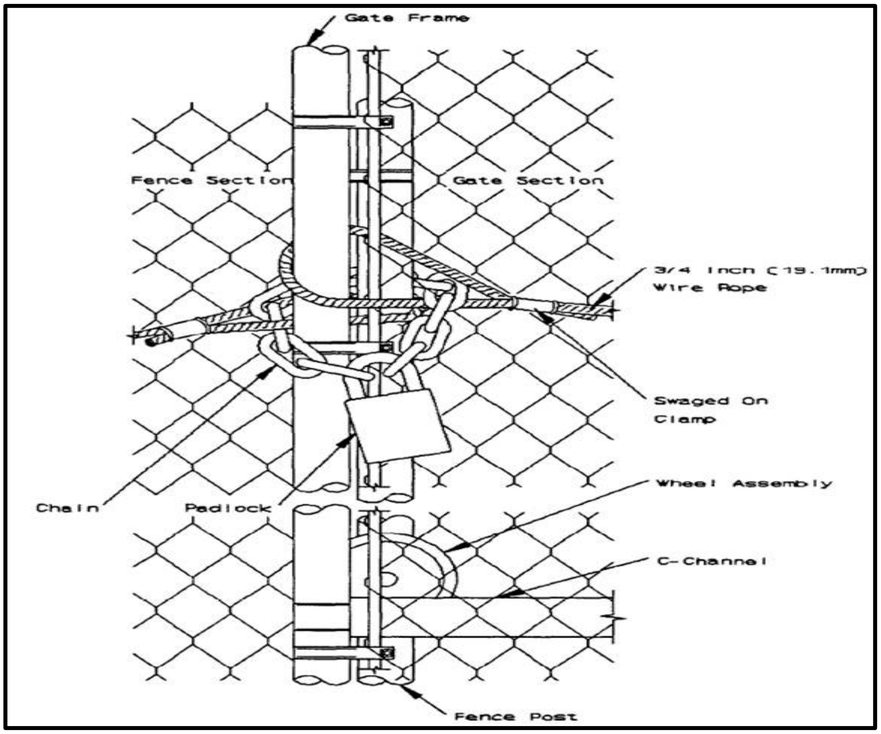
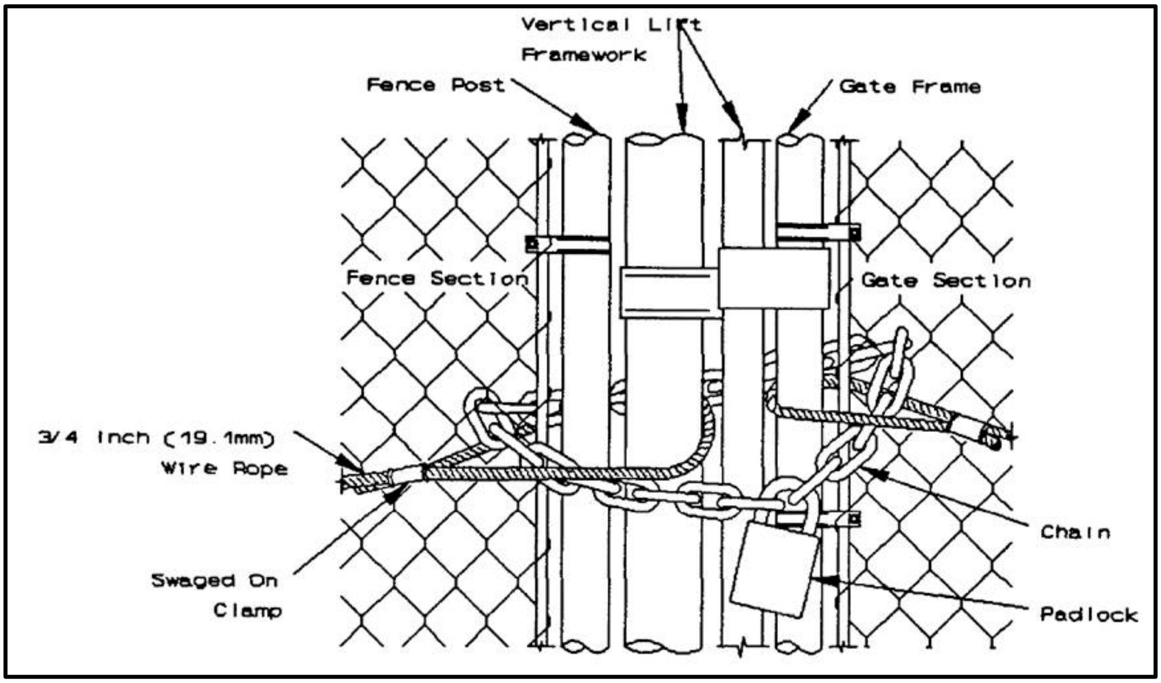


Figure 3-8: Locking Assembly for Reinforced Vertical Lift Gate



3-4.2 Sliding Gates

For sliding and vertical lift gates, the same materials must be used for reinforcement; however, the cable placement may vary. These gates must have the cable running along the length of the gate in the inside and looped around the frame in an appropriate place. The cable must be terminated and fastened as described previously in this section.

There are times when a gate reinforcement cable barrier system is desired but a cable reinforcement system for the adjoining fence is not necessary since terrain, natural barriers, structures, or other passive barrier features provide vehicle crash protection adjacent to the gate. In such cases, the gate cable system can be terminated directly on each side of the gate with the deadman anchors.

3-5 LATCHES AND HINGES

Hinge selection must consider size of the gate and frequency of use. Weld hinges to the gate post and gate frame if increased resistance against tampering is desirable. In addition, hinges may incorporate welded security top plates, reverse the direction of hinge pins, or have the hinge pins spot welded to provide increased tamper resistance and displacement during an incident.

3-6 LOCKING SYSTEM

As a minimum any locking system must provide penetration resistance equal to an approved general field service padlock. Where sally-port gates include automatic latches and the gate provides access for emergency vehicles or other special situations, the gatehouse must have an emergency override. The padlocked bolt or plunger arrangement must not be easily accessible from outside the barrier. Padlocks used must be medium security padlocks.

See Appendix C for design details of chain and wire rope locking systems.

3-7 GATE POWER OPERATORS

Locate all gate operators to prevent tampering from outside the fence. Coordinate design of gate operating systems with the Command Safety Officer to ensure consideration of site particular operating accessories, warning devices, and safety systems. Coordinate gate operation safety with guidance provided in UFC 4-022-01, *Security Engineering: Entry Control Facilities/Access Control Points.*

Provide powered gate operators for vertical lift gates unless use is infrequent and manual operation is reasonable. Powered gate operators with automatic latching systems must be provided at nuclear storage facilities.

3-7.1 Sliding Gate Power Operators

Automated sliding gates at restricted areas should use positive drive rail gate power-operators.

3-7.2 Swing Gate Power Operators

Swing gate power operators may be either positive drive or electromechanical swing.

3-7.3 Linear Induction Gate Operators

A linear induction gate operator incorporates electromagnetic Linear Induction Motor (LIM) technology, eliminating moving drive components, hydraulic fluids and lubricants and their environmental risks. This technology combines unprecedented speed and reliability and without moving drive components, making it efficient in operation and less costly to maintain. This technology is compatible with existing access control devices and can be specified for new construction or easily retro-fitted to accommodate existing gates. No requirement for any connecting mechanisms such as chains, gear boxes, or belts. Can work in the most rugged environment and has flexible settings that allow for variable and differentiate speeds for open and close mode. LIM technology can reach gate operating speeds of up to 8 feet (2.44m) per second – a significant improvement over existing designs that operate at approximately 1 foot (0.305 meter) per second.

APPENDIX A REFERENCES

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AR 190-11, *Physical Security of Arms, Ammunition, and Explosives*

AR 190-13, *The Army Physical Security Program*

AR 190-16, *Physical Security*

AR 190–54, *Security of Nuclear Reactors and Special Nuclear Materials*

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ASTM: SEE REFERENCE TABLE BELOW

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CLF-PM0610, *Product Manual*

DEPARTMENT OF DEFENSE

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DoD I 2000.12, *DoD Antiterrorism Program*

DoD I 2000.16, *DoD Antiterrorism Standards*

DoD O-2000.12H, *DoD Antiterrorism Handbook*

DoD 5100.76-M, *Physical Security of Sensitive Conventional Arms, Ammunition, and Explosives*

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UFGS 32 31 26, *Wire Fences and Gates*

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OPNAVINST 5530.14E, *Navy Physical Security and Law Enforcement Program*

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UNITED STATES ACCESS BOARD

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ASTM

http://www.astm.org/

ASTM FOR FENCING [1]		
DOCUMENT NUMBER	**TITLE**	**FENCE TYPE - COMPONENT**
ASTM F552	*Standard Terminology Relating to Chain Link Fencing*	Chain Link/All
ASTM F1553	*Standard Guide for Specifying Chain Link Fence*	Chain Link/All
***ASTM F2611**	***Standard Guide for Design and Construction of Chain Link Security Fencing***	**Chain Link/Design & Construction**
***ASTM F1712**	***Standard Specification for Steel Chain Link Fencing Materials Used for High Security Applications***	**Chain Link/All**
ASTM F567	*Standard Practice for Installation of Chain- Link Fence*	Chain Link/Installation of
ASTM A392	*Standard Specification for Zinc-Coated Steel Chain- Link Fence Fabric*	Chain Link/Fence Fabric
***ASTM A491**	***Standard Specification for Aluminum- Coated Steel Chain- Link Fence Fabric***	**Chain Link/Fence Fabric**

ASTM FOR FENCING [1]		
DOCUMENT NUMBER	**TITLE**	**FENCE TYPE - COMPONENT**
ASTM F668	*Standard Specification for Polyvinyl Chloride(PVC), Polyolefin and Other Polymer Coated Steel Chain Link Fence Fabric*	Chain Link/Fence Fabric
ASTM F1345	*Standard Specification for Zinc-5% Aluminum-Mischmetal Alloy-Coated Steel Chain- Link Fence Fabric*	Chain Link/Fence Fabric
ASTM F1183	*Standard Specification for Aluminum Alloy Chain Link Fence Fabric*	Chain Link/Fence Fabric
***ASTM F626**	***Standard Specification for Fence Fittings***	**Chain Link/Post & Line Caps; Rail & Brace ends; Tie wires; Tension bars; Barbed Wire arms**
ASTM F2814	*Standard Guide for Design and Construction of Ornamental Steel Picket Fence Systems for Security Purposes*	Ornamental/Design & Construction
***ASTM F2408**	***Standard Specification for Ornamental Fences Employing Galvanized Steel Tubular Pickets***	**Ornamental/Pickets**
ASTM F2589	*Standard Specification for Ornamental Fences Employing Steel Tubular Pickets*	Ornamental/Pickets
ASTM B221	*Standard Specification for Aluminum and Aluminum- Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes*	Ornamental/All
***ASTM A121**	***Standard Specification for Metallic- Coated Carbon Steel Barbed Wire***	**All/Barbed Wire**
ASTM F1379	*Standard Terminology Relating to Barbed Tape*	All/Barbed Tape a.k.a Concertina
***ASTM F1910**	***Standard Specification for Long Barbed Tape Obstacles***	**All/Barbed Tape a.k.a Concertina**
***ASTM F1911**	***Standard Practice for Installation of Barbed Tape***	**All/Barbed Tape a.k.a Concertina**

ASTM FOR FENCING [1]		
DOCUMENT NUMBER	**TITLE**	**FENCE TYPE - COMPONENT**
***ASTM F1665**	***Standard Specification for Poly(Vinyl Chloride) (PVC) and Other Conforming Organic Polymer- Coated Steel Barbed Wire Used with Chain-Link Fence***	**Chain Link/Barbed Wire**
***ASTM F1043**	***Standard Specification for Strength and Protective Coatings on Steel Industrial Fence Framework***	**Chain Link/Post; Rail**
***ASTM A702**	***Standard Specification for Steel Fence Posts and Assemblies, Hot Wrought***	**Taut Wire, Wood/Post**
***ASTM F1083**	***Standard Specification for Pipe, Steel, Hot Dipped Zinc-Coated (Galvanized) Welded, for Fence Structures***	**Chain Link/Post; Rail**
***ASTM A500/A500M**	***Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes***	**Chain Link; Ornamental/Post; Rail**
ASTM A501	*Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing*	Chain Link; Ornamental/Post; Rail
ASTM B429/B429M	*Standard Specification for Aluminum-Alloy Extruded Structural Pipe and Tube*	Chain Link; Ornamental/Post; Rail
***ASTM F2453/F2453M**	***Standard Specification for Welded Wire Mesh Fence Fabric (Metallic-Coated or Polymer Coated) for Meshes of 6 in^2 [3871mm^2] or Less, in Panels or Rolls, with Uniform Meshes***	**Welded Wire Mesh/Fabric**
ASTM F2919/F2919M	*Standard Specification for Welded Wire Mesh Fence Fabric (Metallic-Coated or Polymer Coated) with Variable Mesh Patterns or Meshes Greater than 6 in^2* ***[3871mm^2]*** *in Panels*	Welded Wire Mesh/Fabric
ASTM F1267	*Standard Specification for Metal, Expanded, Steel*	Expanded Metal/Design & Construction

ASTM FOR FENCING [1]		
DOCUMENT NUMBER	**TITLE**	**FENCE TYPE - COMPONENT**
***ASTM F2780**	***Standard Guide for Design and Construction of Expanded Metal Security Fences and Barriers***	**Expanded Metal/Design & Construction**
***ASTM F2548**	***Standard Specification for Expanded Metal Fence Systems for Security Purposes***	**Expanded Metal/All**
***ASTM F900**	***Standard Specification for Industrial and Commercial Steel Swing Gates***	**All/Gate**
***ASTM F1184**	***Standard Specification for Industrial and Commercial Horizontal Slide Gates***	**All/Gate**
***ASTM F2200**	***Standard Specification for Automated Vehicular Gate Construction***	**All/Gate**
ASTM F537	*Standard Specification for Design Fabrication, and Installation of Fences Constructed of Wood and Related Materials*	Wood/All
***ASTM A1023/A1023M**	***Standard Specification for Stranded Carbon Steel Wire Ropes for General Purpose***	**All/Reinforcing**
ASTM F1145	*Standard Specification for Turnbuckles, Swaged, Welded, Forged*	All/Reinforcing

NOTES:

1. This portion of the table, ASTM FOR FENCING, provides the ASTM Standard Specification/Standard Design and Construction specifications and requirements for the different fence systems indicated in this UFC. Not all are specifically referenced in this UFC. These specifications are provided for information and reference. Those specifically referenced in this UFC are indicated with an asterisk (*) and are in **bold** type.

MISCELLANEOUS ASTM		
DOCMENT NUMBER	TITLE	FENCE TYPE - COMPONENT
***ASTM A529**	***Standard Specification for High-Strength Carbon-Manganese Steel of Structural Quality***	**Steel, Grill**
***ASTM D2487**	***Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)***	**All/none**
***ASTM D2488**	***Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)***	**All/none**

Note: Those specifically referenced in this UFC are indicated with an asterisk (*) and are in **bold** type.

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APPENDIX B GLOSSARY

B-1 DEFINITION OF TERMS

Active Sensors: A sensor that can receive signals from either itself or other devices.

Attack Side: The outer side of the perimeter fence for a protected area. The side from which to expect attacks or forced entry.

Bollards: Reinforced concrete shapes or sleeves, or steel pipe filled with concrete, used to slow down vehicles and/or deny vehicle access.

Clear Zone: Area free of obstacles, topographical features and vegetation which reduce the effectiveness of the physical barrier, impede observation or provide cover and concealment of an intruder.

Color Polymer Coating: A coating on chain link fences to further protect and add color.

Concrete Sill or Curb: A concrete section to create a non-passable connection between a fence and the existing ground.

Corrosive or Salt Laden Environment/Atmosphere: Atmosphere which contains enough salt or corrosive elements to corrode a fence enough to decrease the intended strength. These areas are typically bordering oceans or other water bodies. For the application of coating requirements in this UFC, the corrosive atmosphere is considered 10 miles (16 kilometers) from coastal mean high water line.

Deadman Anchor : An anchor for fence or gate reinforcement cables which transfer the force from the fencing or gate fabric/surface to the ground. Deadman anchors are typically concrete blocks buried in the ground.

Electronic Security System (ESS): The integrated electronic system that encompasses interior and exterior Intrusion Detection Systems (IDS), Closed Circuit Television (CCTV) systems for assessment of alarm conditions, Automated Access Control Systems (ACS), Data Transmission Media (DTM) and alarm reporting systems for monitoring, control and display.

Eye Ends: Center space created when looping a wire for termination or reinforcement.

Fabric Diamonds: The opening formed by the woven wires in chain link fence fabric.

Fabric Tension Bar: A bar that the fencing fabric is attached to and it serves to hold the fabric tight to decrease ability to deform.

Fencing Accessories: Any fasteners, ties, wires or other objects used to attaching the fencing fabric, posts or top guards.

Fence Fabric: As used in this document means (chain link, ornamental, welded wire mesh, expanded metal).

Gate Leaf: A panel of a gate (There is one gate leaf for single fences and two for double fences).

Gates Openings: In the barrier system to allow authorized entry and exit.

Intrusion Detection System (IDS): A system consisting of interior and exterior sensors, surveillance devices, and associated communication subsystems that collectively detect an intrusion of a specified site, facility or perimeter and annunciate an alarm.

Line Posts: intermediate posts spaced a maximum of 10 feet (3 m) apart and considered the backbone of the fence line.

Mesh Openings: The opening formed by the woven wires.

Moving Vehicle Bomb Tactic: A forced entry tactic to place an explosive or other damaging terrorist device in a moving vehicle to create a mobile vehicular weapon.

Natural Boundaries: Natural formations such as bodies of water, rough terrain, or densely wooded areas that may act as a barrier to define and protect the restricted area's perimeter.

Outriggers: Metal top guards which are placed on the top of the barrier and may consist of at least one vertical arm, angled arm facing inside, angles arm facing outside or two angles arms facing both inside and outside. In addition, there may be more than one arm on each side if desired. The number and direction of arms depends on the nature of the barrier.

Passive Barriers: A passive barrier has no moving parts. Passive barrier effectiveness relies on its ability to absorb energy and transmit the energy to its foundation. Highway medians (Jersey), bollards or posts, tires, guardrails, ditches and reinforced fences are examples of passive barriers.

Passive Sensors: A sensor that receives signals through light or radio waves.

Protected Side: The inside of the fence that is being protected through various security measures.

Sally Ports: Sally ports are used to control entry into highly protected and restricted areas and used as part of an entry control facility/access control point for vehicle inspection.

Secure Side: The inside of the fence that is being protected through various security measures.

Special Nuclear Material (SNM): Nuclear material that requires extensive protection.

Swaged Loop: A loop created by looping a wire and fastening the loop with a swaged on clamp.

Swing Gates: Gates for entrance or exit that swing open either manually or automatically when controlled either electronically or manually.

Taut Wire: Wire that is continuously under tension through a series of spring connections.

Tension Bar: The bar that is threaded through the last vertical link of fabric. It attaches the fabric to the terminal post.

Top Guard: Additional protection of fences or other barriers that are placed on top of the barrier to prevent climbing or jumping. Possible top guards include, but are not limited to, outriggers with barbed wire, concertina wire, or barbed tape.

Truss Rods: A rod used in brace assemblies to draw and hold the line post firmly to the brace rail. The truss rod uses an adjustable turnbuckle to maintain proper tension. Truss rod details can be seen in the "Non Reinforced Chain-Link Fence" drawings in Appendix C.

Turnbuckles: A metal coupling device consisting of an oblong piece internally threaded at both ends into which the corresponding sections of two threaded rods are screwed in order to form a unit that can be adjusted for tension or length.

Turnstile Gates: Pedestrian gates which rotate around a central pole to allow only one entrance at a time.

Welded Bar Grill: A series of vertical and horizontal bars that are placed over an opening and welded at all bar crossing points.

Additional Terms relating to fences are found in:

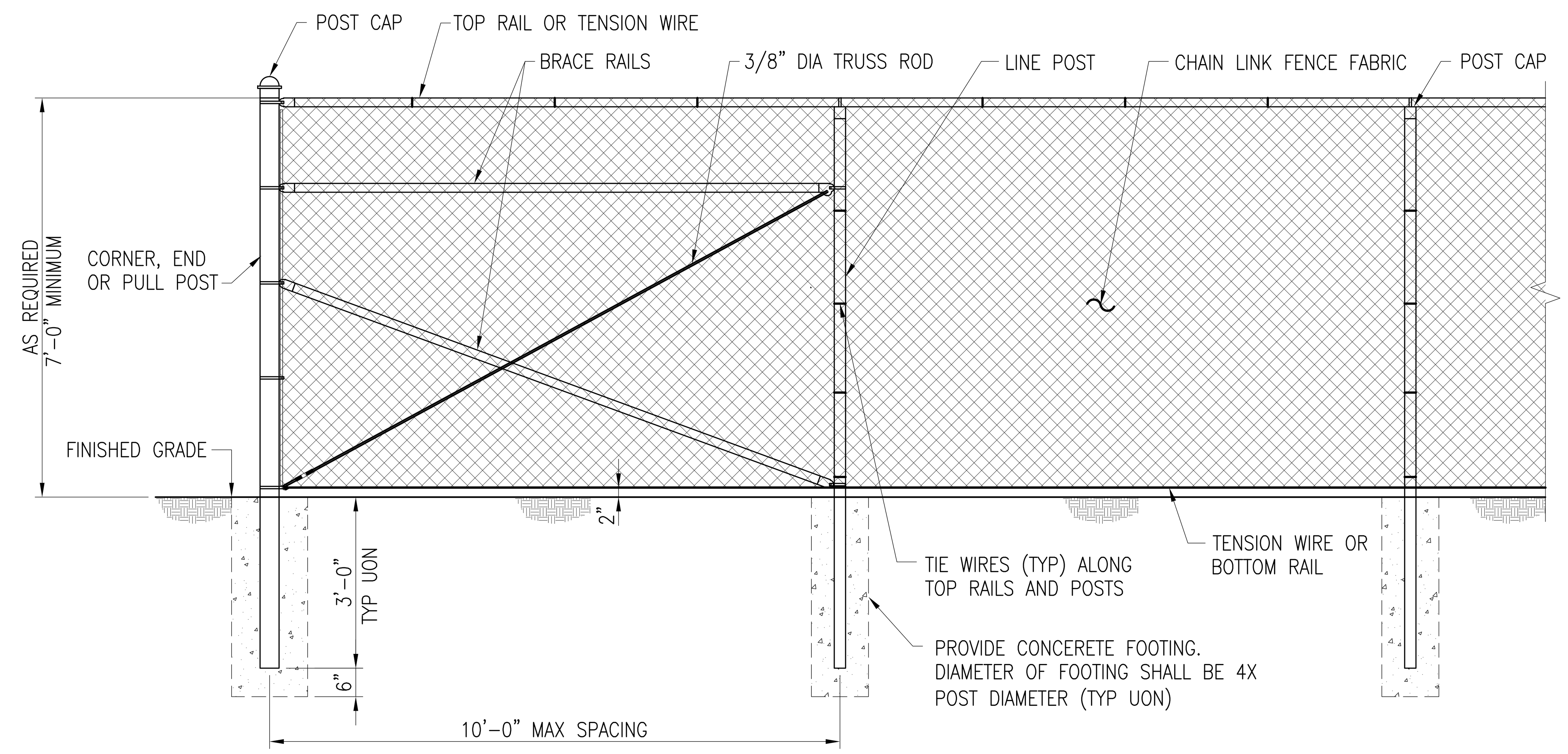
- ASTM F552 - Standard Terminology Relating to Chain Link Fencing
- ASTM F2814 - Standard Guide for Design and Construction of Ornamental Steel Picket Fence Systems for Security Purposes
- ASTM F2780 - Standard Guide for Design and Construction of Expanded Metal Security Fences and Barriers
- ASTM F1379 - Standard Terminology Relating to Barbed Tape

- ASTM F537 - Standard Specification for Design, Fabrication, and Installation of Fences Constructed of Wood and Related Materials

APPENDIX C FENCE AND GATE DESIGN DETAILS

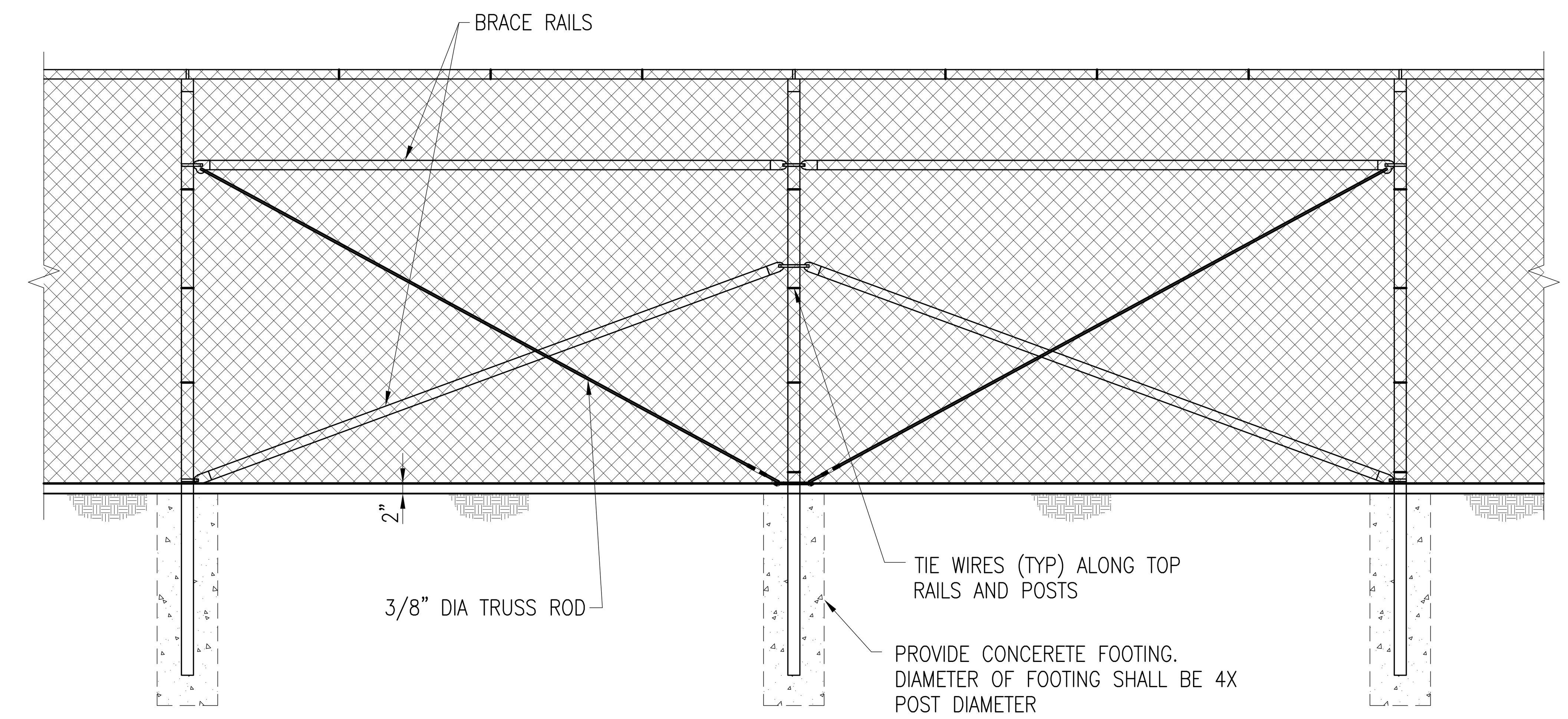
The details in this appendix illustrate general layouts for each type of fence or gate. These illustrations are not intended to depict the importance or size of each element. Sizes and dimensions indicated are the minimum requirement that must be modified per service policy and for the specific application, environmental conditions, and local constraints.

DRAWINGS FOR SECURITY FENCING, GATES AND CABLING	
DRAWING NUMBER	DRAWING TITLE
UFC-700	Chain Link Fencing and Details
UFC-701	Barbed Wire/Tape Arrangement Details
UFC-702	Chain Link Swing Gate and Details
UFC-703	Chain Link Cantilevered Gate Details
UFC-704	Chain Link Overhead Roller Gate
UFC-705	Typical Turnstile and Bollard Details
UFC-710	Typical Cable Reinforced Chain Link
UFC-711	Typical Cable Reinforced Chain Link Fence Deadman/Line Post
UFC-712	Typical Cable Reinforced Chain Link Fence – Gates
UFC-713	Cable Reinforcing Details
UFC-714	Cable Reinforcing Details (Cont’d)
UFC-720	Typical Cable Reinforced Ornamental Fence – End Post
UFC-721	Typical Cable Reinforced Ornamental Fence Deadman/Line Post
UFC-722	Ornamental Cantilevered and Swing Gates and Cabling Details
UFC-730	Farm Style Fences
UFC-731	Farm Style Gates
UFC-732	Farm Style Gate and Fence Details
UFC-733	Farm Style Fence Details



TYPICAL FENCE AND CORNER PANEL ELEVATION

SCALE: 1" = 1'-0"

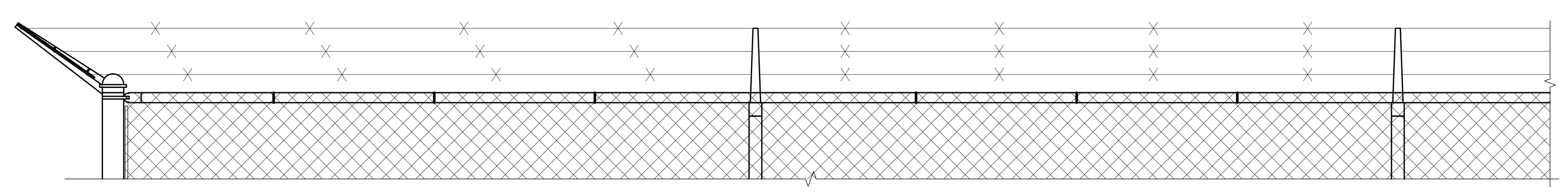


TYPICAL FENCE AND BRACED PANEL ELEVATION

SCALE: 1" = 1'-0"

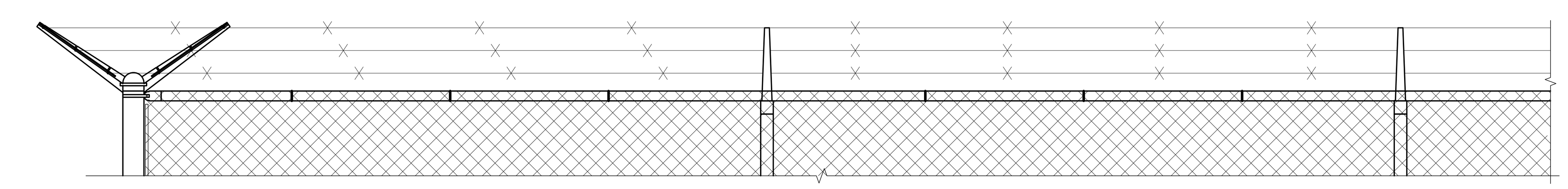
NOTE (1): A BOTTOM RAIL CAN BE ADDED FOR SECURITY, IT SHALL BE INSTALLED APPROX 3" ABOVE GRADE (A MINIMUM OF 2" AND A MAXIMUM OF 4"). HARDWARE SHALL BE WELDED OR SHOT NAILED TO POSTS AND RAILS IN ORDER TO SECURE IN PLACE. ATTACH FABRIC TO NEW BOTTOM RAIL TO ELIMINATE POSSIBILITY OF PEELING UP FABRIC.

NOTE (2): SOME LOCATIONS MAY REQUIRE 8' OF FABRIC.



TYPICAL 3 STRAND BARBED WIRE AND SINGLE EXTENSION ARM CONFIGURATION

SCALE: 1" = 1'-0"



TYPICAL 6 STRAND BARBED WIRE AND DOUBLE EXTENSION ARM CONFIGURATION

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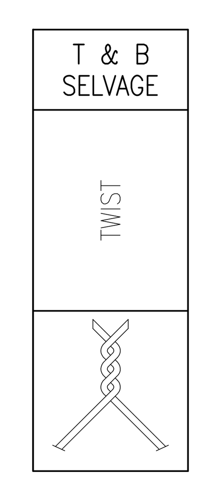
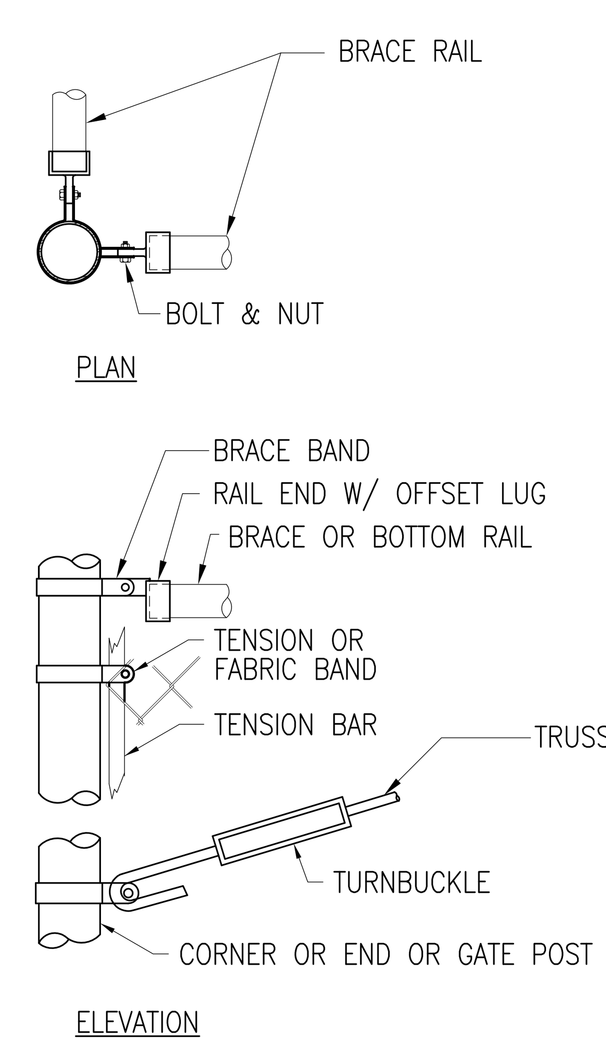
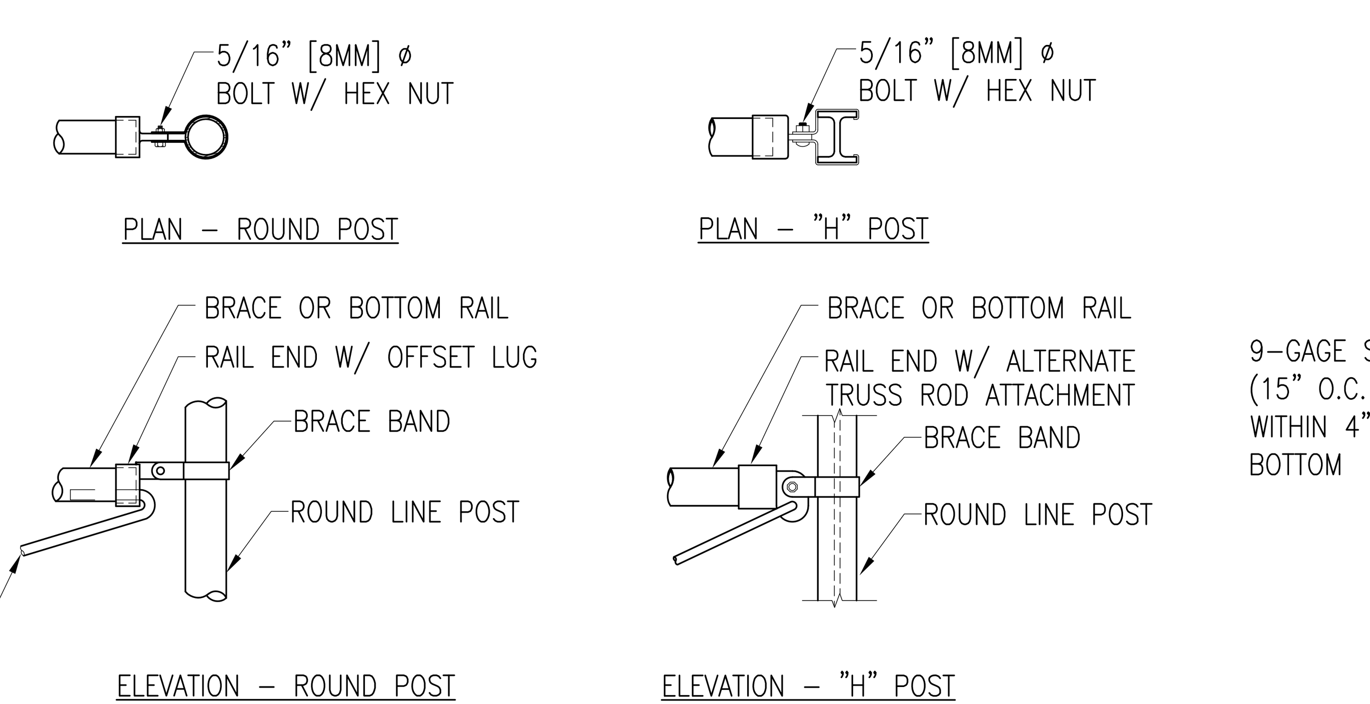
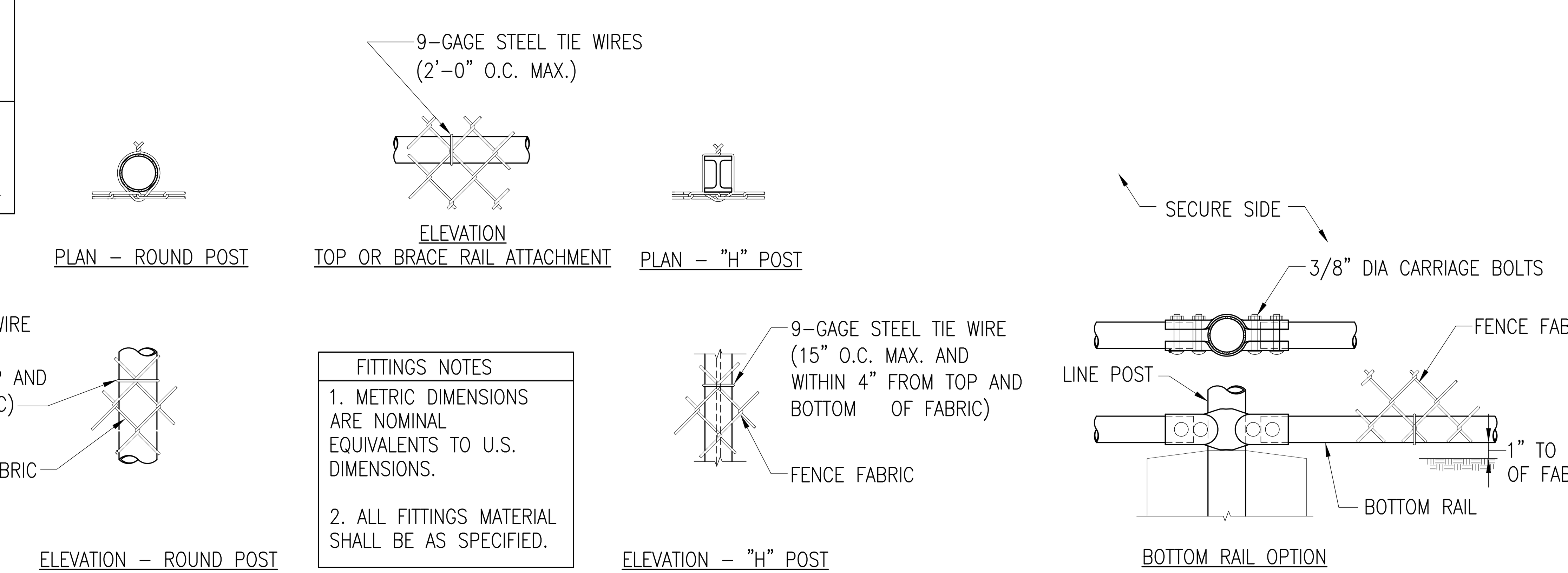




CORNER OR END POSTS

SCALE: 1 1/2" = 1'-0"





FITTINGS NOTES

1. METRIC DIMENSIONS ARE NOMINAL EQUIVALENTS TO U.S. DIMENSIONS.

2. ALL FITTINGS MATERIAL SHALL BE AS SPECIFIED.

LINE POST DETAILS

SCALE: 1 1/2" = 1'-0"

GRAPHIC SCALES

1" = 1'-0" (0, 6", 1', 2')

1 1/2" = 1'-0" (0, 4", 8", 1'-4")

UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

CHAIN LINK FENCE AND DETAILS

UFC-700

DRAWFORM REVISION: 24 AUGUST 2007

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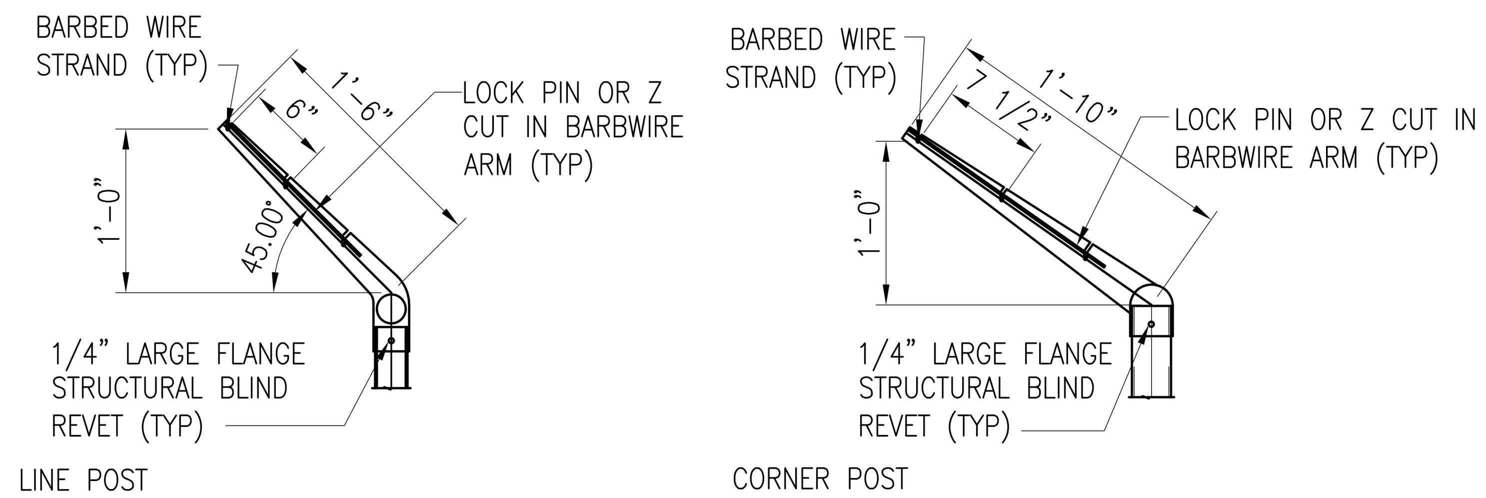
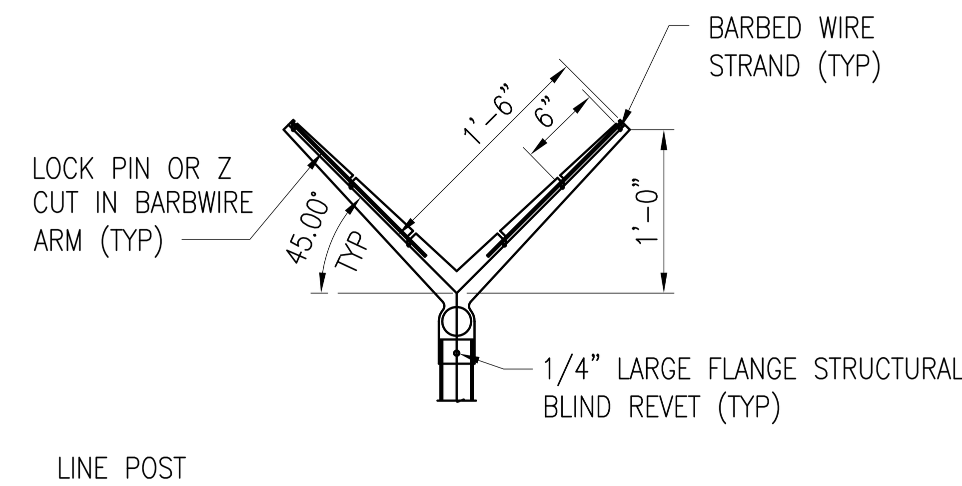


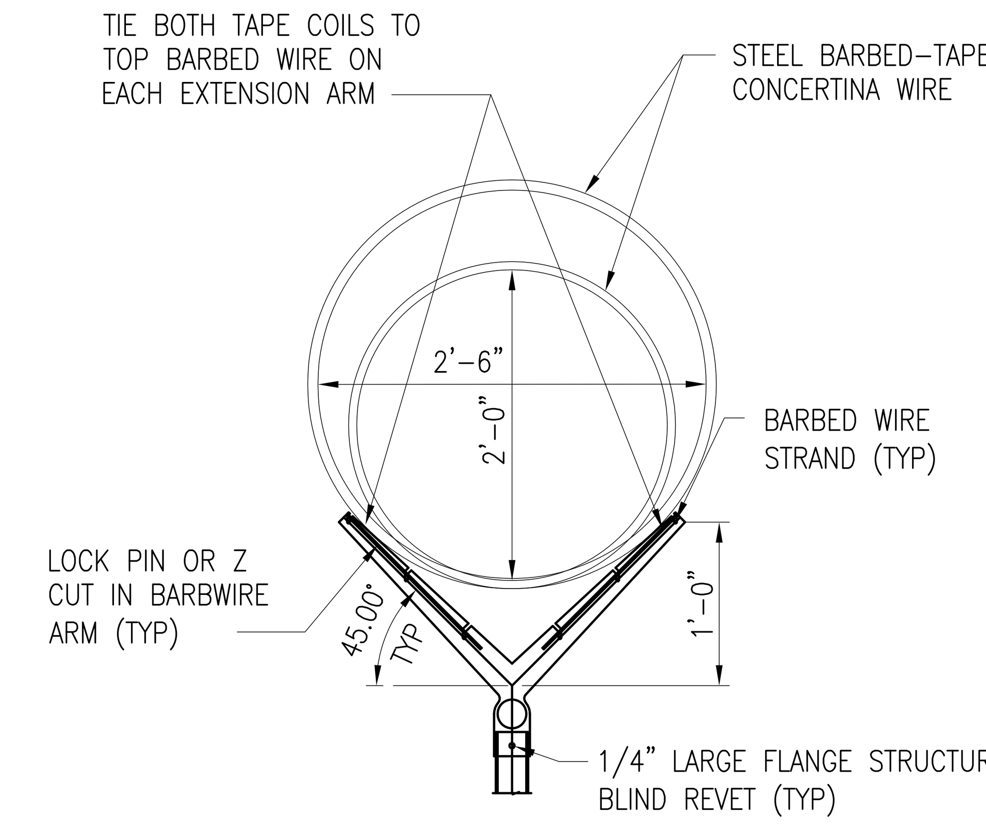
SINGLE EXTENSION ARM DETAILS

SCALE: 1" = 1'-0"



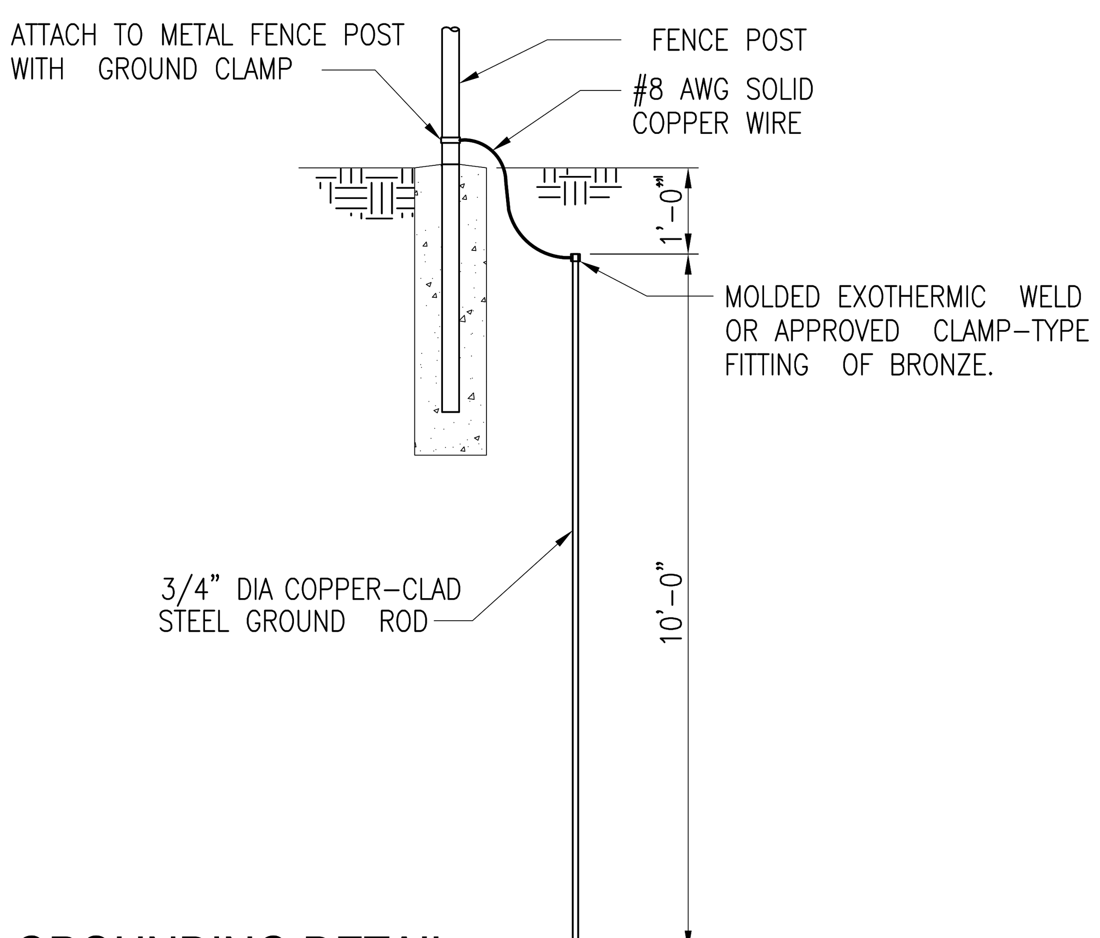
DOUBLE EXTENSION ARM DETAILS

SCALE: 1" = 1'-0"



CONCERTNA WIRE MOUNTING

SCALE: 1" = 1'-0"



GROUNDING DETAIL

NO SCALE

CHAIN LINK FENCING NOTES

1. FABRIC: THE STANDARD FENCE FABRIC SHALL BE VINYL, ZINC OR ALUMINUM-COATED STEEL WIRE CHAIN LINK WITH MESH OPENINGS NOT LARGER THAN TWO INCHES PER SIDE AND A TWISTED AND BARBED SELVAGE AT TOP AND BOTTOM IN ACCORDANCE WITH THE SPECIFICATIONS. UTILIZE 6-GAUGE FOR BASE PERIMETER OR HEIGHTENED SECURITY ZONES AND 9-GAUGE FOR BASE INTERIOR OR WHEN JOINING AN EXISTING FENCE WHICH IS ALREADY 9-GAUGE.

2. FABRIC TIES: ONLY 12-GAUGE STEEL TIES SHALL BE USED. COATING OR PLATING WILL BE ELECTROLYTICALLY COMPATIBLE WITH THE FENCE FABRIC TO INHIBIT CORROSION.

3. REINFORCEMENT: TENSION WIRES SHALL BE INSTALLED AND INTERWOVEN (OR AFFIXED WITH FABRIC TIES) ALONG THE TOP & BOTTOM OF THE FENCE FOR STABILIZATION OF THE FENCE FABRIC.

4. FENCE HEIGHT: CHAIN LINK FABRIC SHALL BE 7' HIGH WITH AN ADDITIONAL 1' IN HEIGHT COMPOSED OF 3 STRANDS OF BARBED WIRE AS REQUIRED. THE TOTAL FENCE HEIGHT SHALL BE 8'.

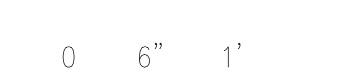
5. GROUND CLEARANCE: BOTTOM OF THE FENCE FABRIC SHALL BE WITHIN TWO INCHES OF FIRM SOIL.

6. TOP GUARDS: A TOP GUARD IS AN OVERHANG OF BARBED WIRED ALONG THE TOP OF A FENCE, FACING OUTWARD (AWAY FROM PROTECTED SITE) AND UPWARD AT APPROX. 45 ANGLE. TOP GUARD SUPPORTING ARMS WILL BE PERMANENTLY AFFIXED TO THE TOP OF FENCE POSTS TO INCREASE THE OVERALL HEIGHT OF THE FENCE AT LEAST 1 FOOT. THREE STRANDS OF 12-GAUGE BARBED WIRE, EQUALLY SPACED, SHALL BE INSTALLED ON THE SUPPORTING ARMS.

7. FENCE POSTS: SHALL BE ASTM F1043 OR F1083 ROUND PIPE OR SQUARE TUBE AND SHALL BE GALVANIZED IN ACCORDANCE WITH THE SPECIFICATIONS. FENCE POST SPACING AND SIZE (DIAMETER) SHALL BE DETERMINED IN ACCORDANCE WITH CHAIN LINK FENCE MANUFACTURERS' INSTITUTE (WLG 2445). SPACING SHALL NOT EXCEED 10'-0" OC. SIZE (DIAMETER) SHALL NOT BE LESS THAN THAT SPECIFIED.

GRAPHIC SCALES

1" = 1'-0"



UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

BARBED WIRE ARRANGEMENT DETAILS

UFC-701

DRAWFORM REVISION: 24 AUGUST 2007

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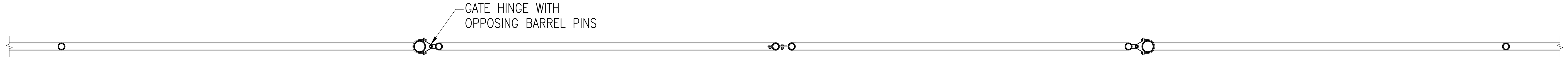
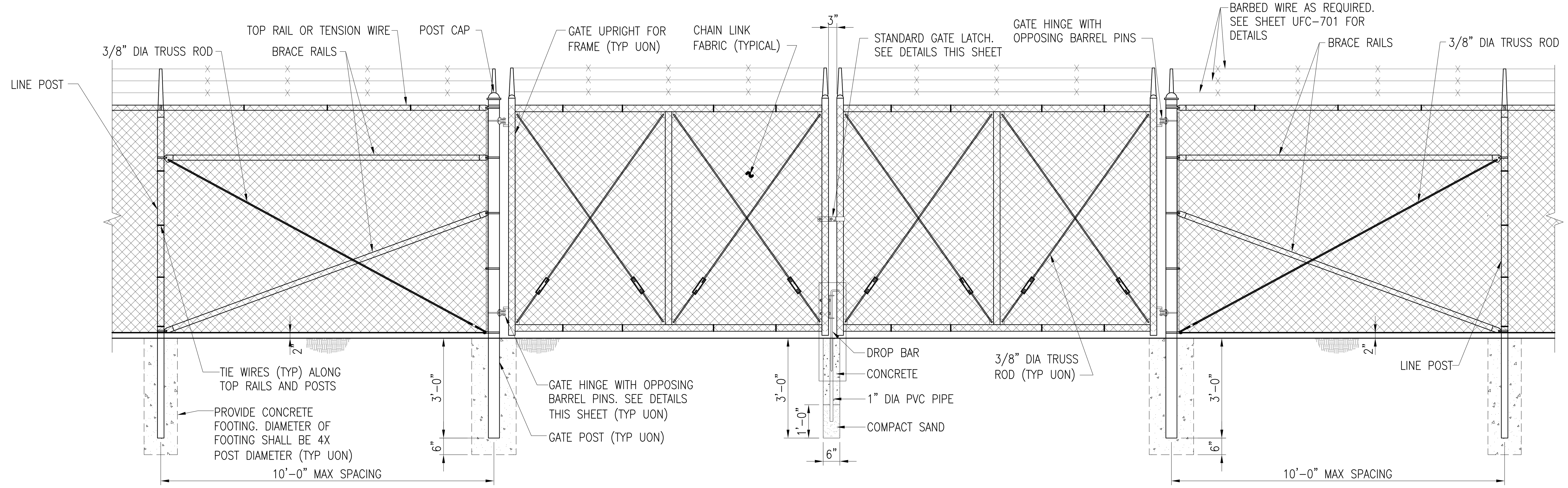


PLAN - DOUBLE SWING GATE

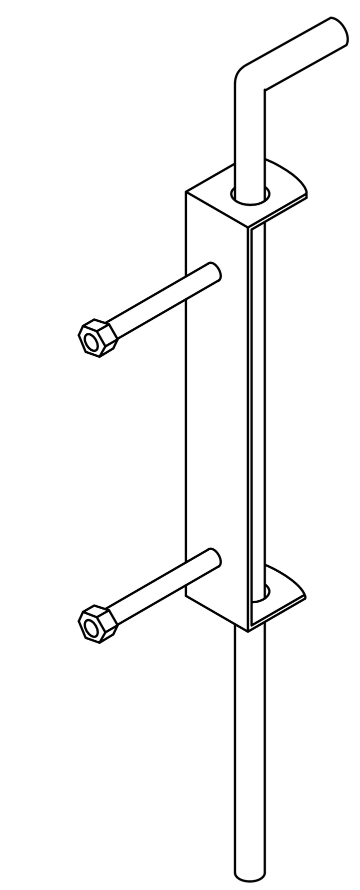
SCALE: 1" = 1'-0"



TYPICAL DOUBLE SWING GATE ELEVATION

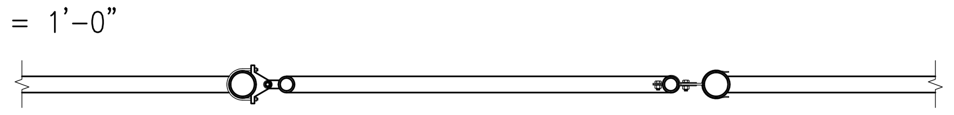
SCALE: 1/2" = 1'-0"

NOTE: PROVIDE ONE DROP BAR FOR EACH LEAF (TYP). ASSOCIATED GALV SLEEVES TO BE INSTALLED FLUSH WILL GRADE AT FULLY OPEN AND CLOSED POSITIONS. CONTRACTOR SHALL PROVIDE 6" LAYER OF #10 STONE BELOW BOTTOM OF SLEEVE TO ALLOW FOR DRAINAGE.



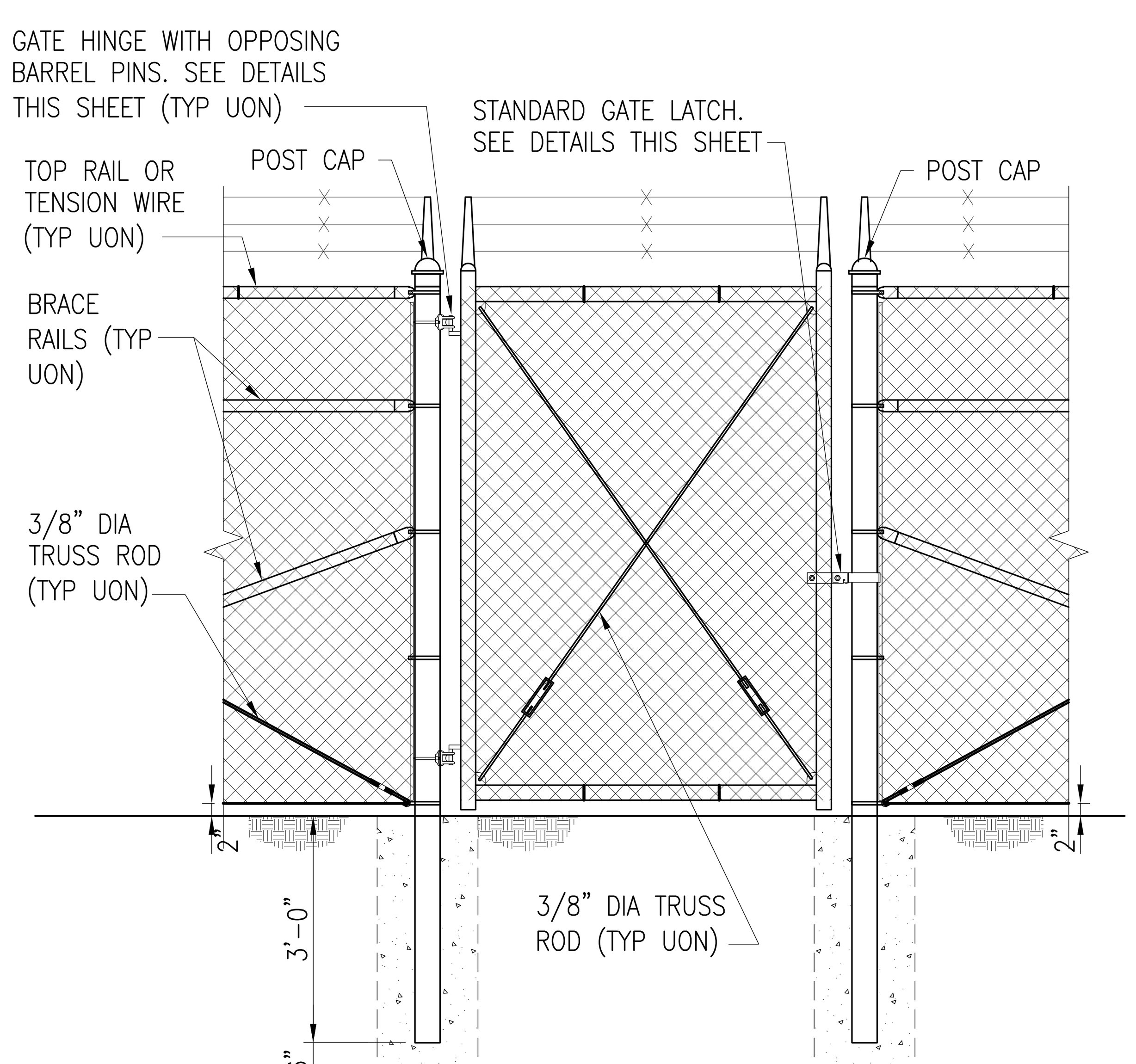
DETAIL: DROP BAR

NOT TO SCALE



PLAN SINGLE SWING GATE

SCALE: 1" = 1'-0"



TYPICAL FENCE SINGLE SWING GATE ELEVATION

SCALE: 1/2" = 1'-0"

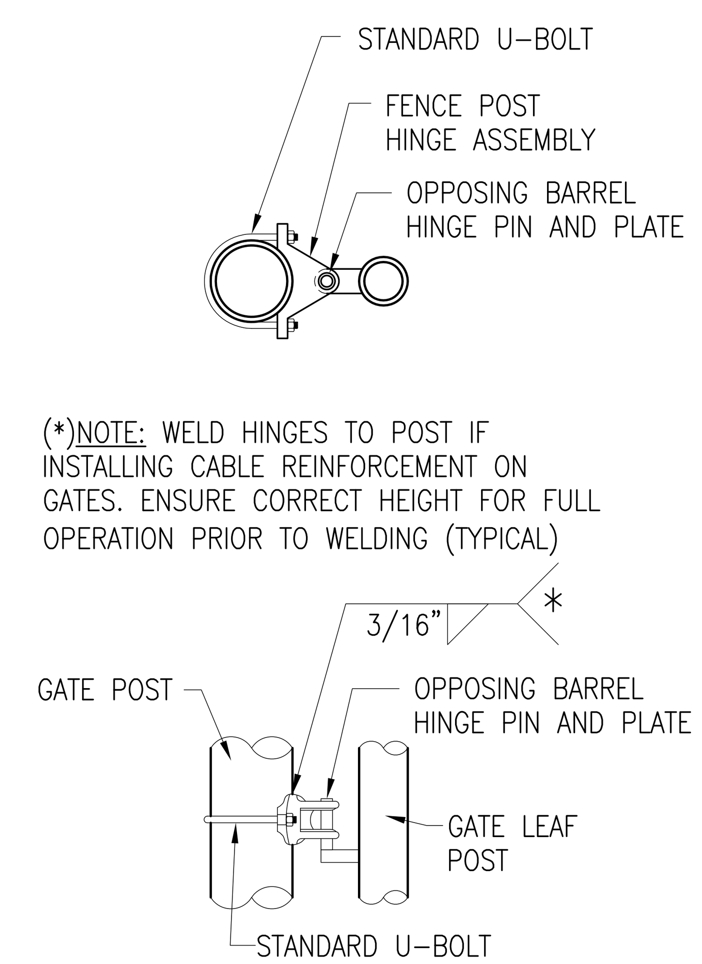
SINGLE OR DOUBLE LEAF GATES		
NOM HEIGHT (H)	UPRIGHT HT (U)	FRAME HT (F)
NOM HT INCLUDING BARBED WIRE	ACTUAL DIM	ACTUAL DIM
8'-0" [2438MM]	7'-10" [2388MM]	6'-8 1/2" [2045MM]

SINGLE LEAF GATES		
OPENING	GATE POSTS	HINGE SPACE (S)
FACE TO FACE	SQUARE & ROUND SIZES	POST TO UPRIGHT
3'-0" [914MM] THROUGH 6'-0" [1829MM]	2.5"[63.5MM]SQ x 3/16"TH OR 2.875" [73MM] OD	FOR SQUARE & ROUND GATE POSTS: 2 1/4" [57MM]
6'-0" [1829MM] THROUGH 12'-0" [3657MM]	4" [102MM] SQ x 3/16"TH OR 4" [102MM] OD	FOR SQUARE & ROUND GATE POSTS: 2 1/4" [57MM]
12'-0" [3657MM] THROUGH 19'-0" [5790MM]	6" [153MM] SQ x 3/16"TH OR 6.625" [168MM] OD	FOR SQUARE & ROUND GATE POSTS: 2 1/4" [57MM]
19'-0" [5790MM] THROUGH 23'-0" [7010MM]	8" [203MM] SQ x 1/4"TH OR 8.625" [219MM] OD	FOR SQUARE & ROUND GATE POSTS: 2 1/4" [57MM]

GATE POSTS & FOUNDATIONS: GATE POST SIZE AND ASSOCIATED FOOTING DIAMETER TO BE DETERMINED BY MANUFACTURER, BASED ON LEAF WEIGHT & DIMENSION, BUT NOT LESS THAN DIAMETER SHOWN ON THESE DRAWINGS. MINIMUM FOOTING DIAMETERS (TO BE FILLED W/4000 PSI CONC): 40" ø FOR 8" POST; 36" ø FOR 6" POST; 24" ø FOR 4" POST; OTHER SIZES TO BE DESIGNED BY MFR OR KTR. NO FOOTING WIDTH SHALL BE LESS THAN 4(X) THE POST WIDTH.

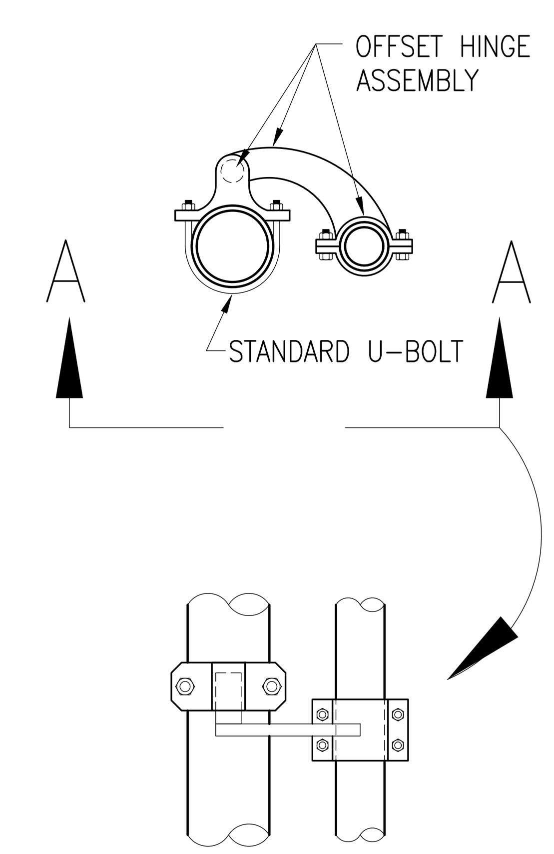
NOTE: IF GATE HINGES ARE NOT OPPOSING (AS SHOWN ABOVE) OR LEAF IS NOT LOCKED MECHANICALLY TO THE HINGES, WELD AN ANGLE, PLATE, OR BLOCK ABOVE HINGE TO RESTRICT LEAF FROM BEING REMOVED OR LIFTED OFF. RESTRICTION SHALL NOT HINDER OPERATION OF GATE.

(*)NOTE: WELD HINGES TO POST IF INSTALLING CABLE REINFORCEMENT ON GATES. ENSURE CORRECT HEIGHT FOR FULL OPERATION PRIOR TO WELDING (TYPICAL)



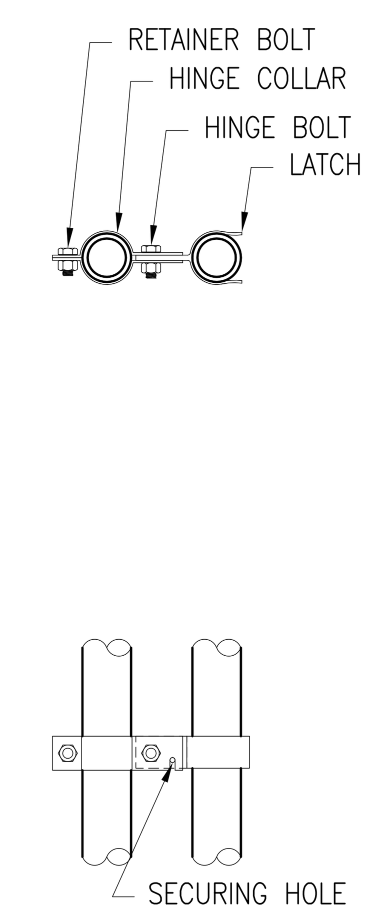
GATE HINGE DETAIL

SCALE: 1 1/2" = 1'-0"



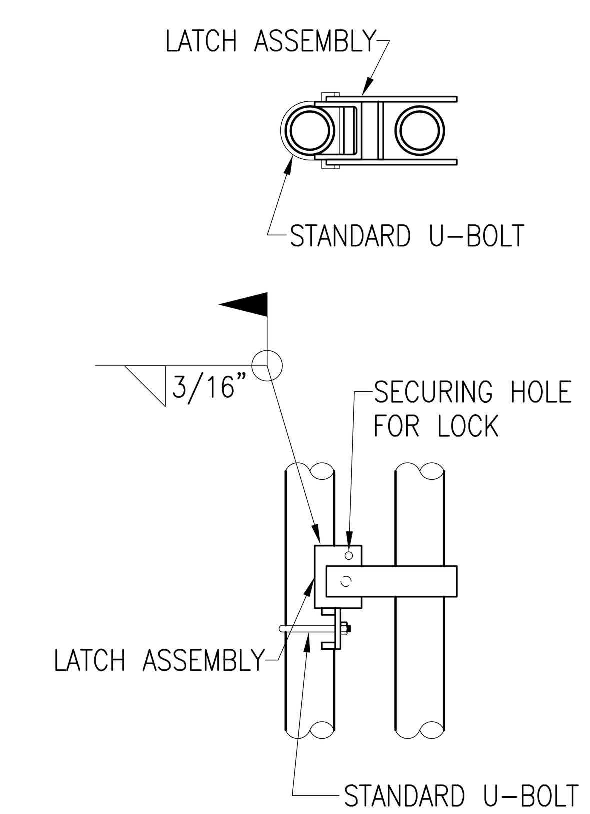
OFFSET HINGE DETAIL

SCALE: 1 1/2" = 1'-0"



GATE LATCH DETAIL

SCALE: 1 1/2" = 1'-0"



FULCRUM LATCH DETAIL

SCALE: 1 1/2" = 1'-0"

GRAPHIC SCALES

1/2" = 1'-0" (0, 1', 2', 4')

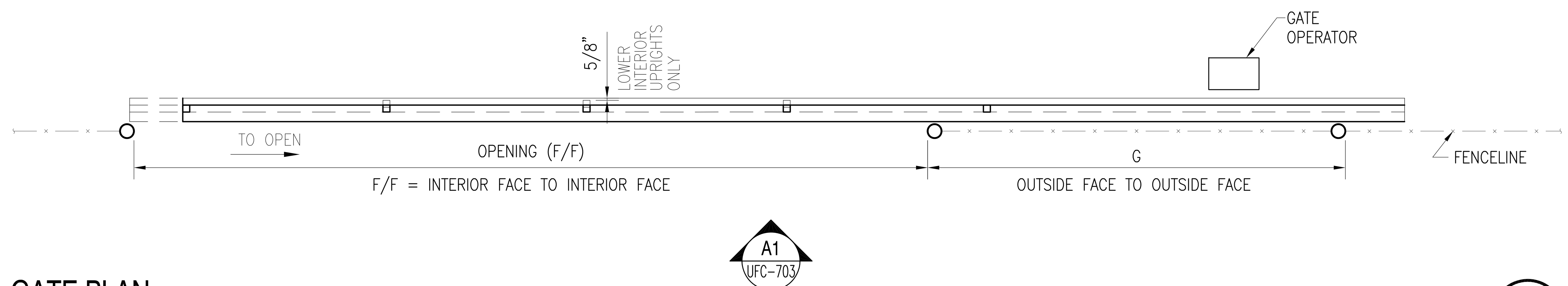
1 1/2" = 1'-0" (0, 4", 8", 1'-4")

UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES

DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

CHAIN LINK SWING GATE AND DETAILS

UFC-702



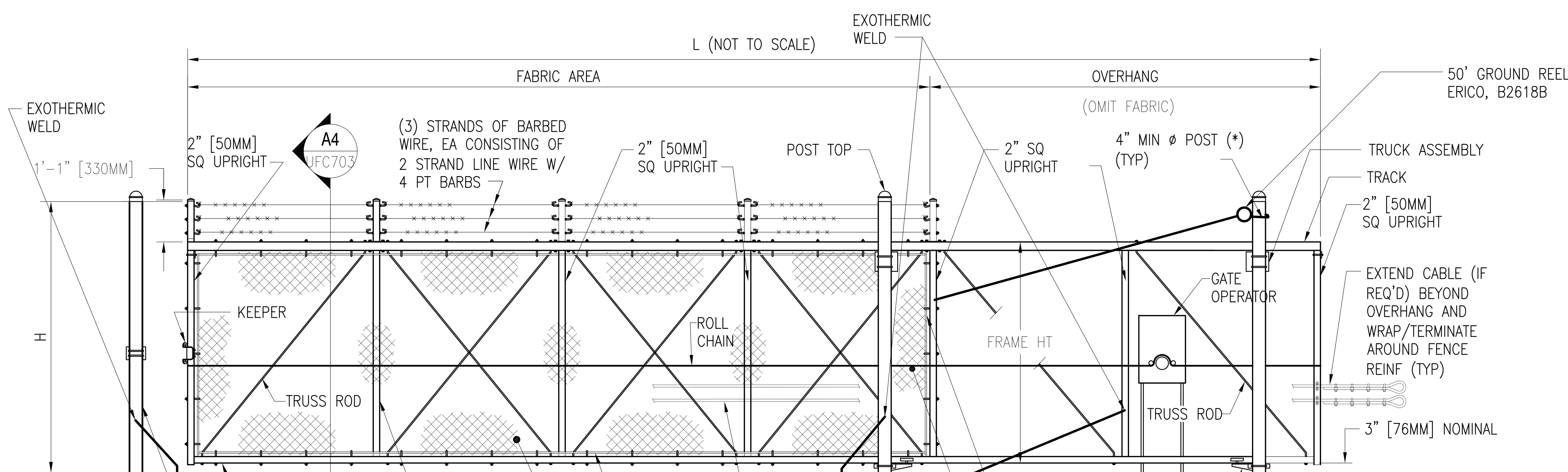
GATE PLAN

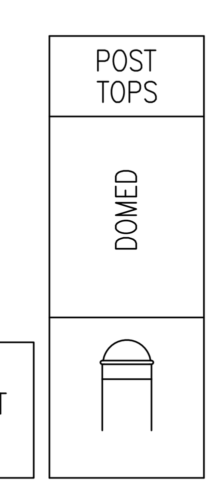
NOT TO SCALE

C1 — CIVIL DWGS | UFC-703

SAMPLING OF SIZES:

OPENING (F/F)	NOMINAL HEIGHT (H)	LENGTH (L)	GATE POSTS (G)	BAYS / OVERHANG
37'-0"	8'-0"	53'-3"	16'-0"	5 (FABRIC) / 2 (W/O)
30'-0"	8'-0"	42'-3"	12'-0"	4 (FABRIC) / 2 (W/O)
24'-0"	8'-0"	36'-3"	12'-0"	3 (FABRIC) / 2 (W/O)





(*) POST SIZE AND ASSOCIATED FOOTING DIAMETER TO BE DETERMINED BY MANUFACTURER, BASED ON LEAF WEIGHT & DIMENSION. MINIMUM FOOTING DIAMETERS (TO BE FILLED W/4000 PSI CONC): 40" ø FOR 8" POST; 36" ø FOR 6" POST; 24" ø FOR 4" POST; OTHER SIZES TO BE DESIGNED BY MFR OR KTR. NO FOOTING WIDTH SHALL BE LESS THAN 4(X) THE POST WIDTH.

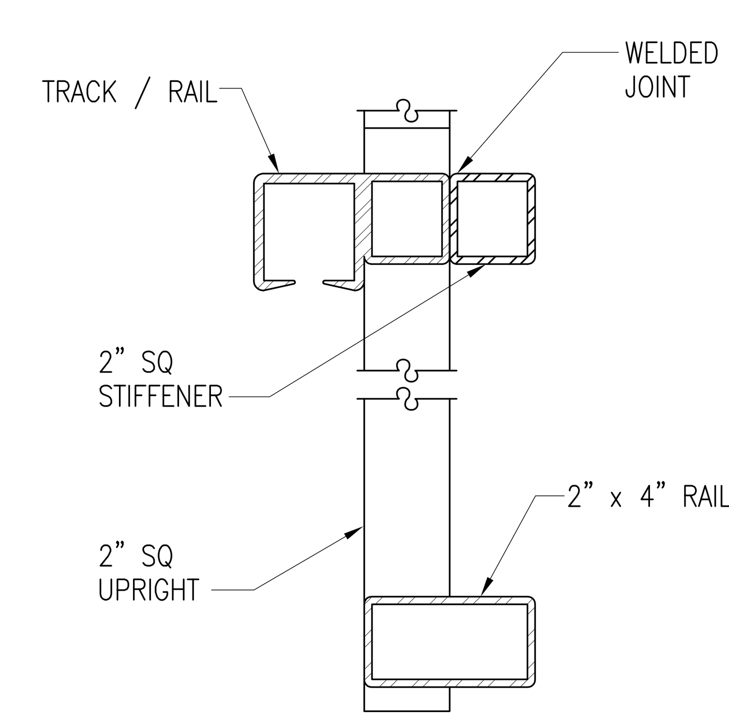
NOTE: BARBED WIRE NOT SHOWN ON FENCE PORTION FOR CLARITY. SEE SHEET UFC S-701 FOR BARBED WIRE TYPE.

TYPICAL SINGLE CANTILEVERED SLIDING GATE ELEVATION- (4) BAYS SHOWN

WITH ROUND POSTS & WITH BARBED WIRE

NOT TO SCALE

A1 — UFC-703 | UFC-703



SECTION (TYP)

NOT TO SCALE

A4 — UFC-703 | UFC-703

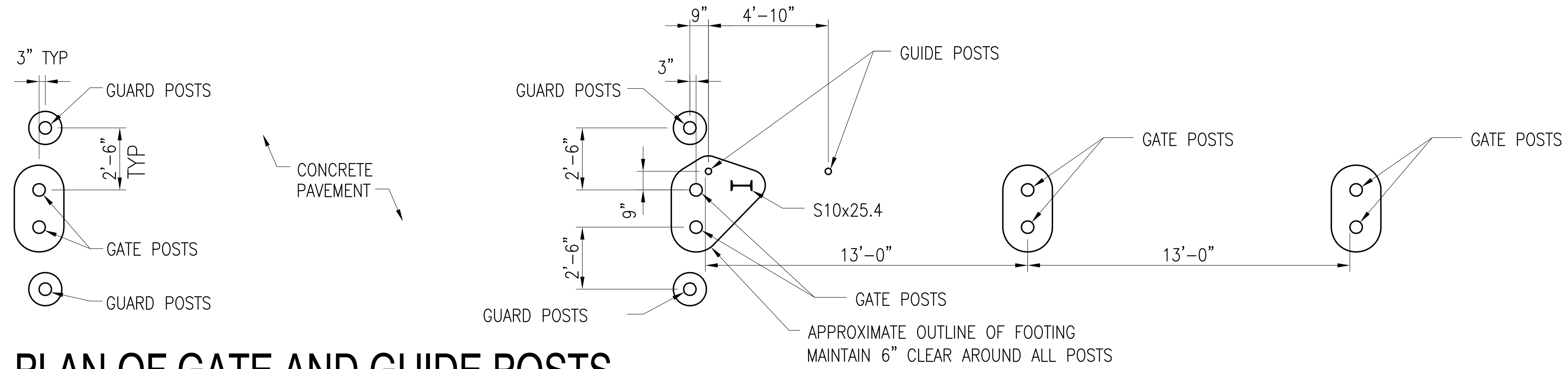
UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

CHAIN LINK CANTILEVERED GATE DETAILS

UFC-703

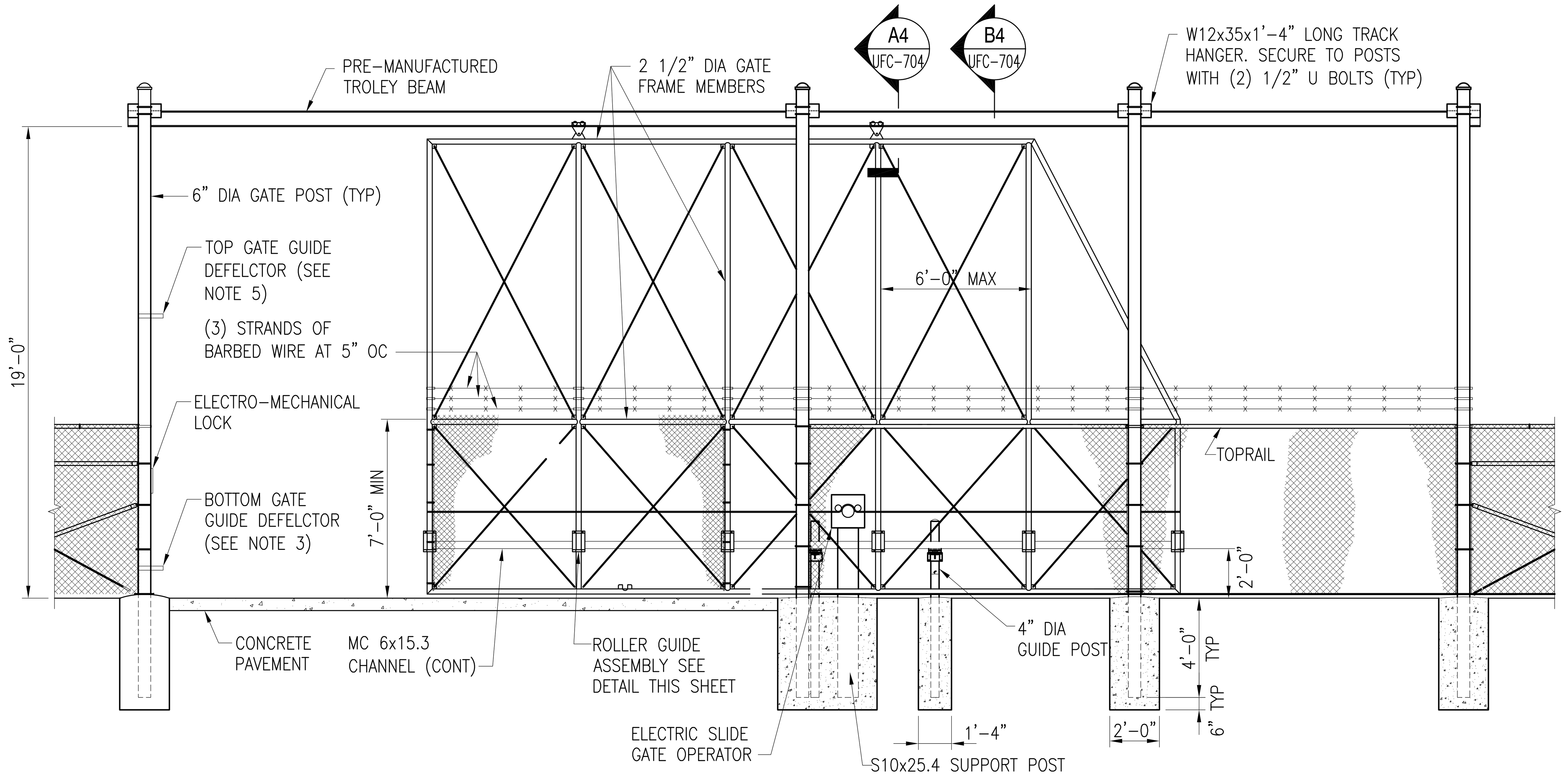
DRAWFORM REVISION: 24 AUGUST 2007

FILE NAME: J:\CICE\FENCE DRAWINGS\552005-UFC-703.dwg LAYOUT NAME: Layout1 PLOTTED: Monday, April 29, 2013 - 1:09pm



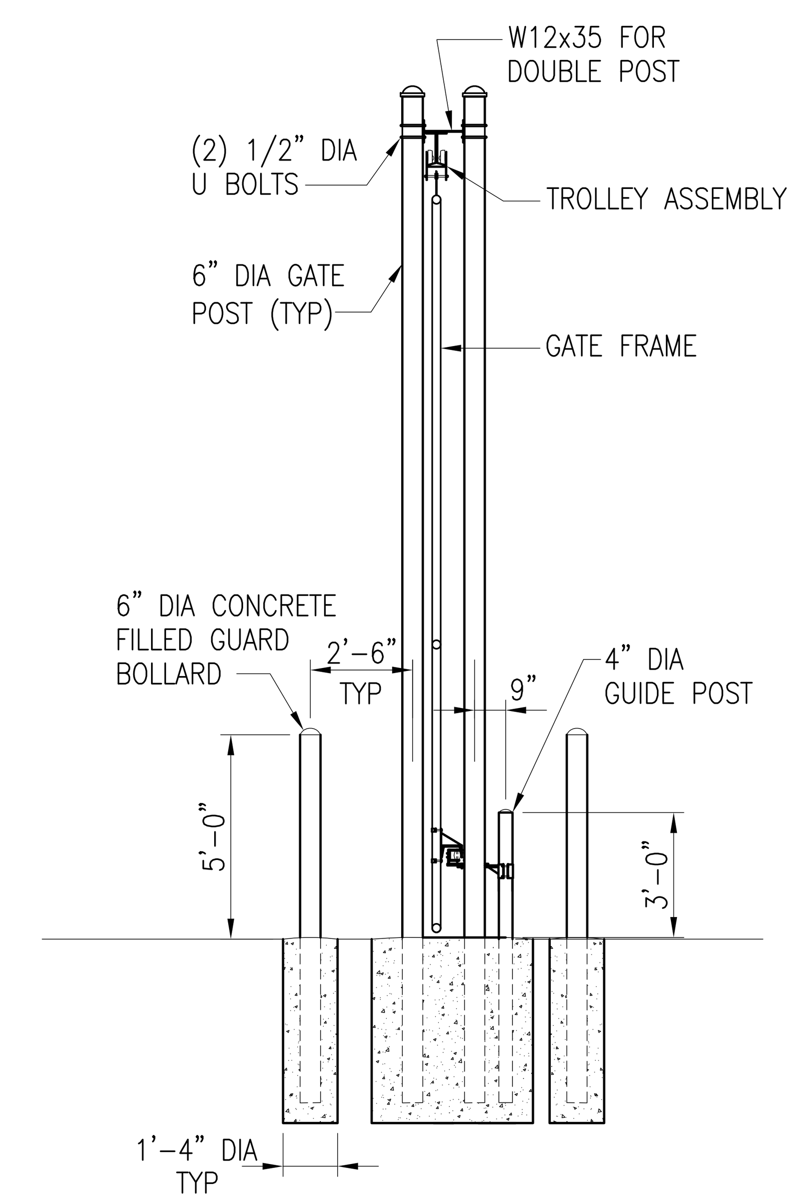
PLAN OF GATE AND GUIDE POSTS

SCALE: 3/16" = 1'-0"



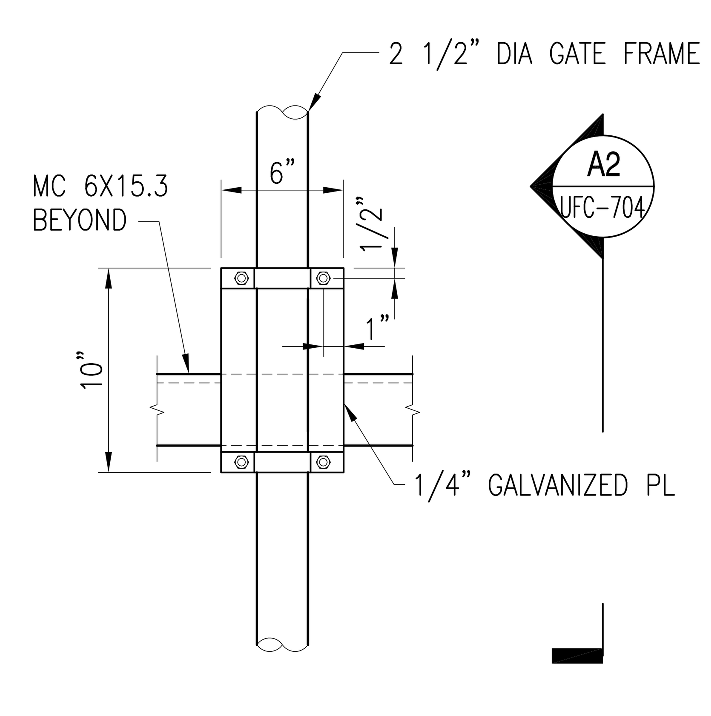
ELEVATION OF OVERHEAD ROLLER GATE

SCALE: 1/4" = 1'-0"



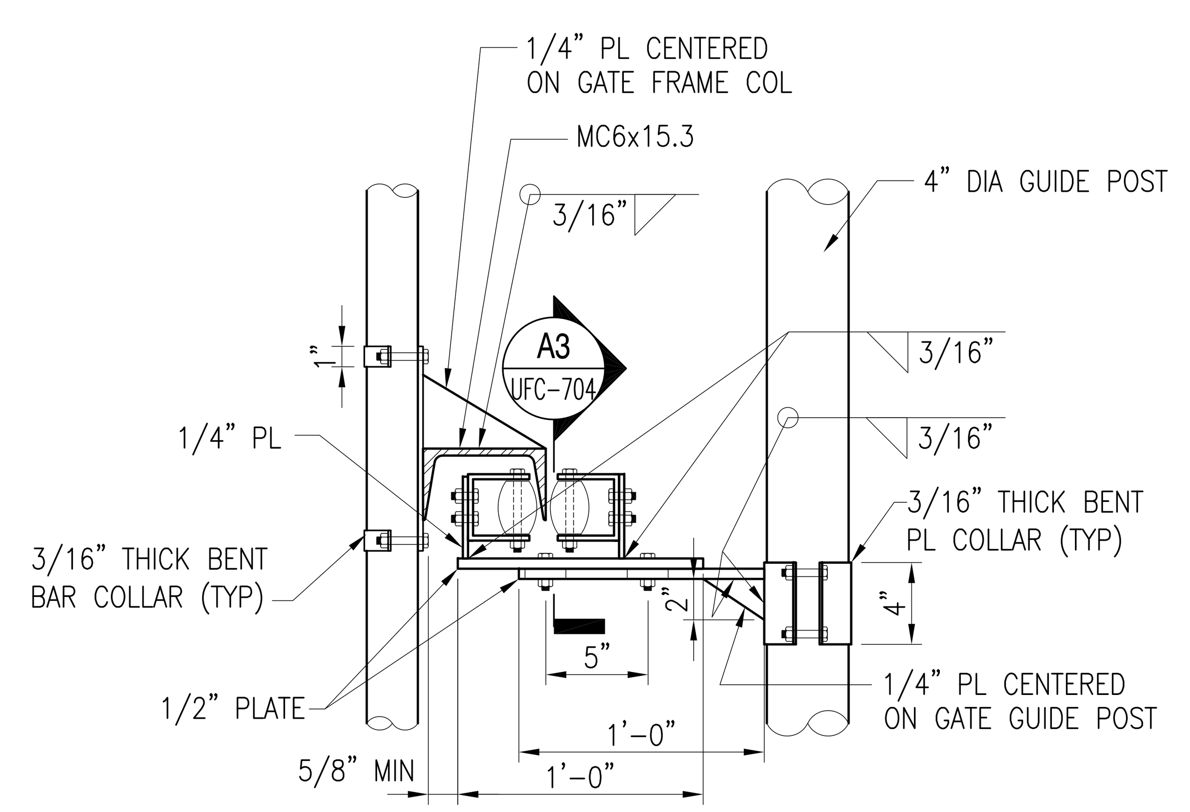
SECTION

SCALE: 1/4" = 1'-0" B4 UFC-704 UFC-704



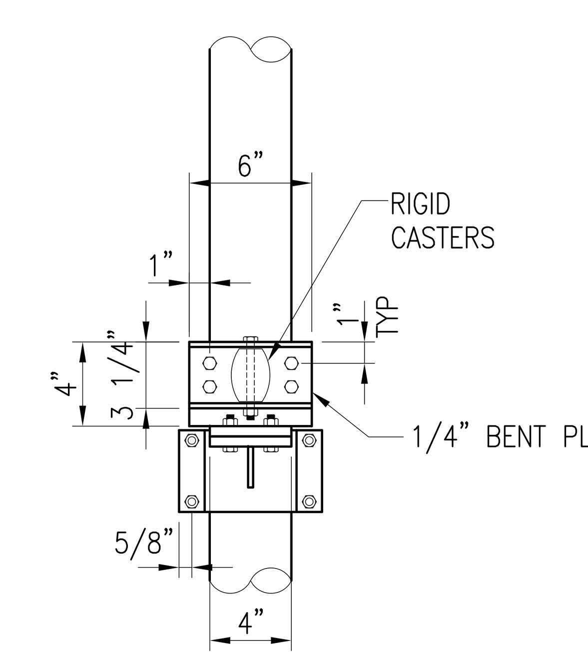
DETAIL - ROLLER GUIDE ASSEMBLY

SCALE: 1 1/2" = 1'-0" A1 UFC-704 UFC-704



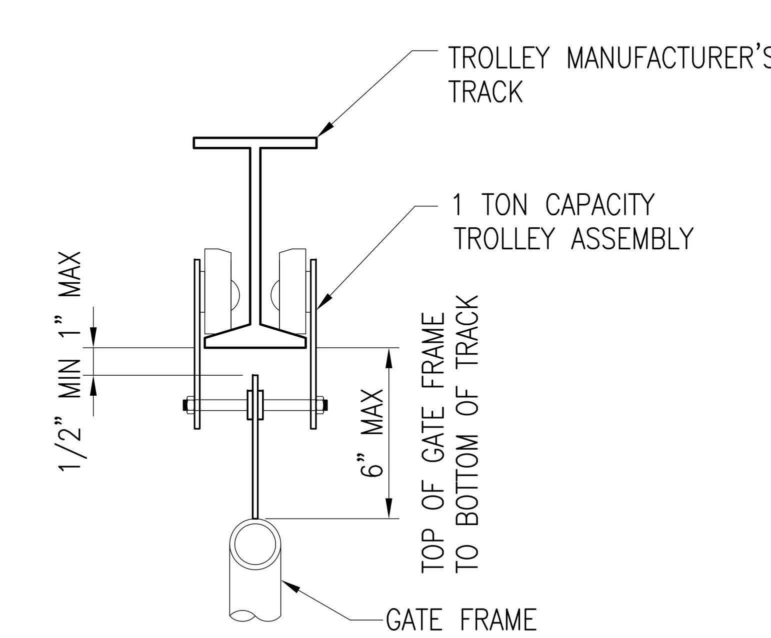
SECTION

SCALE: 1 1/2" = 1'-0" A2 UFC-704 UFC-704



SECTION

SCALE: 1 1/2" = 1'-0" A3 UFC-704 UFC-704



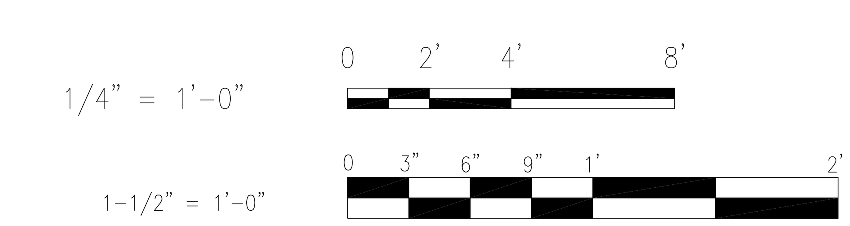
SECTION

SCALE: 1 1/2" = 1'-0" A4 UFC-704 UFC-704

GENERAL NOTES

1. THE GATE SHOWN IS TYPICAL. ANY STANDARD COMMERCIAL GATE THAT VARIES ONLY IN NON-ESSENTIAL DETAILS SHALL BE ACCEPTABLE SUBJECT TO APPROVAL.
2. GATE SHALL CONFORM TO ASTM F 1184, TYPE 1, EXCEPT AS EXCEEDED BY THIS DRAWING.
3. GATES SHALL SLIDE ON THE SECURE SIDE.
4. GATES SHALL BE CONSTRUCTED WIT A TROLLEY SYSTEM THAT WILL PREVENT THE GATE FROM BEING ELEVATED OVER 2 INCHES ABOVE THE PAVEMENT.
5. ALL GATE GLIDE DEFLECTORS SHALL BE COMPATIBLE WITH THE MANUFACTURED ELECTRO-MECHANICAL LOCK. THE GUIDE DEFLECTIOR SHALL BE DESIGNED FOR THE WIND CONDITIONS WITH 3/8" PLATE AND GALVANIZED.
6. GUARD POSTS SHALL BE NPS 6 STD WEIGHT, GRADE B, STEEL PIPE FILLED WITH CONCRTE. STEEL PIPE SHALL CONFORM TO ASTM A53/53M, TYPE E OR S, GALVANIZED, MINIMUM WALL THICKNESS .312 INCHES.
7. ALL STEEL PLATES, SHAPES AND ACCESSORIES SHLL BE GALVANIZED IN ACCORDANCE WITH ASTM A123.
8. ELECTRIC SLIDE GATE OPERATOR SHALL HAVE A MINIMUM 1 HP, PHASE MOTOR.
9. UNLESS OTHERWISE NOTED, ALL BOLTS SHALL BE 3/8" DIAMETER, ASTM A307, GALVANIZED BOLTS.

GRAPHIC SCALES



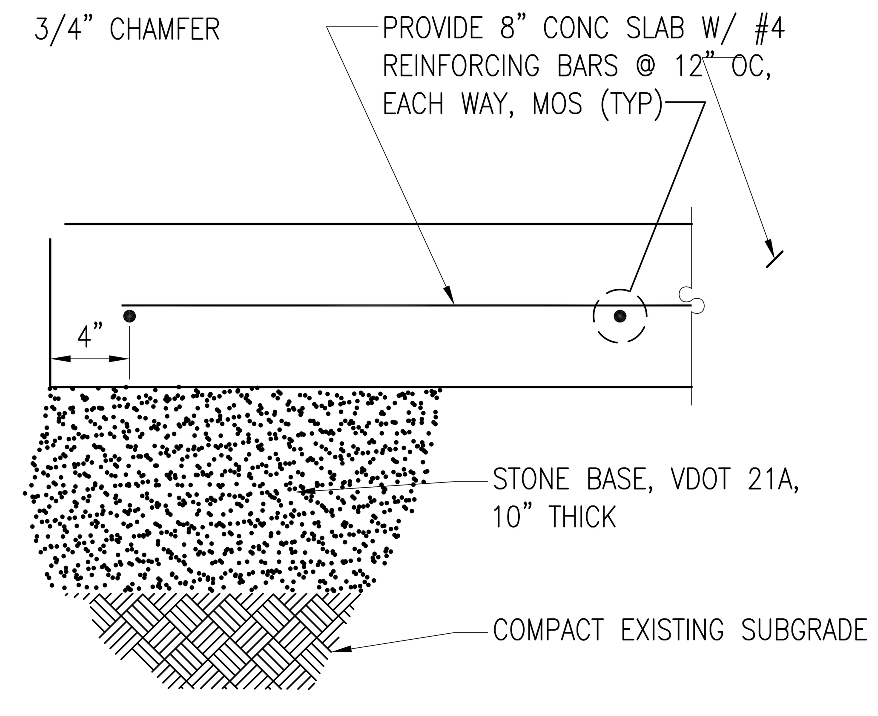
UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

CHAIN LINK OVERHEAD ROLLER GATE

UFC-704

DRAWFORM REVISION: 24 AUGUST 2007

FILE NAME: J:\CICE\FENCE DRAWINGS\552005-UFC-704.dwg LAYOUT NAME: Layout1 PLOTTED: Monday, April 29, 2013 - 1:11pm



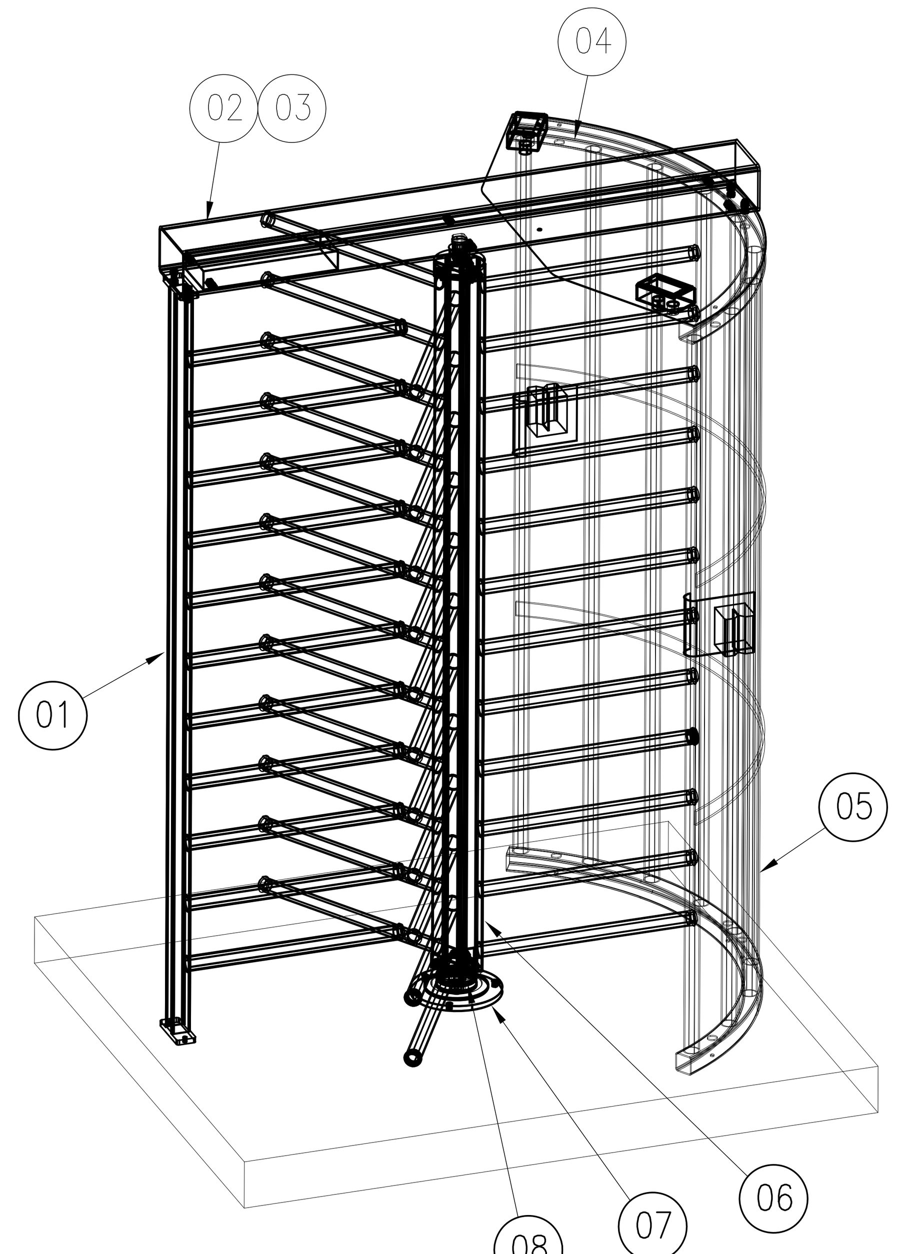
TURNSTILE MOUNTING SLAB
C2
SCALE: 1-1/2" = 1'-0" UFC-705 | UFC-705

1 1/2" = 1'-0" 0 4" 8" 1'-4"

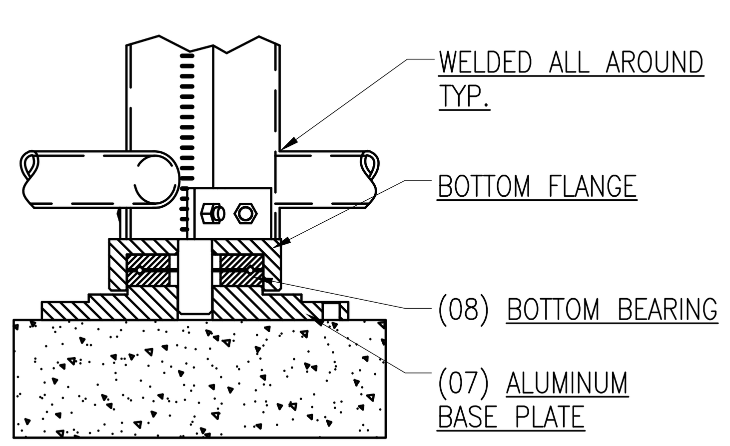
TURNSTILE NOTES:

1. TURNSTILE SHALL BE COMPOSED OF CARBON STEEL. ALL MATERIALS SHALL BE HOT-DIPPED GALVANIZED IN ACCORDANCE WITH ASTM A123.
2. TURNSTILE SHALL HAVE BI-DIRECTIONAL CONTROLS: IN THE CASE OF A POWER FAILURE, OUTBOUND TRAFFIC SHALL BE SET TO "FAIL SAFE"; THE INBOUND TRAFFIC WILL HAVE A "FAIL LOCK" MECHANISM (UNLESS OTHERWISE DIRECTED BY THE ACTIVITY VIA THE CONTRACTING OFFICER).
3. PROVIDE CARD READER MOUNTING PLATES FOR BOTH SIDES (INBOUND & OUTBOUND) OF TURNSTILE. CARD READER WILL BE INSTALLED BY THE ACTIVITY AT A LATER DATE.
4. BRACE BARRIER POST AT TOP TO ADJACENT VERTICAL SURFACE.
5. ALLOW 5 INCH CLEARANCE ABOVE TOP OF TURNSTILE TO REMOVE LIFT-OFF TYPE TOP COVER.
6. CONCRETE MOUNTING SLAB MUST BE LEVEL WITHIN 1/4". SEE DETAIL C2 THIS SHEET FOR CONC MOUNTING PAD.
7. CONTRACTOR SHALL PROVIDE AN ELECTRICAL 3-ROTOR FULL HEIGHT TURNSTILE AS MANUFACTURED BY TOMSED, MODEL THT-100ECP(3), OR APPROVED EQUAL.
8. TURNSTILE SHALL HAVE FINISH TO MATCH ADJACENT FENCEWORK: POWDER COATED BLACK FOR ORNAMENTAL FENCE AND GALVANIZED FOR CHAIN-LINK.
9. INSTALL 3 STRANDS BARBED WIRE OR CONCERTINA WIRE OVER TOP CHANNEL OF TURNSTILE (BETWEEN ADJACENT FENCE POSTS) TO HINDER SCALING UNIT.

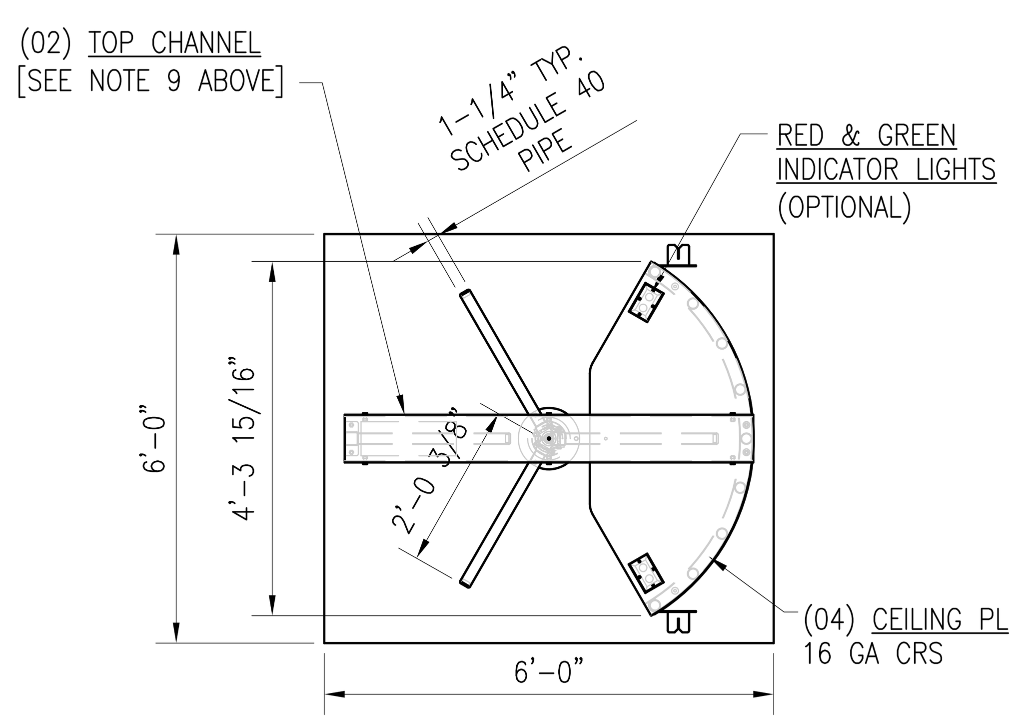
TURNSTILE SKETCHES:



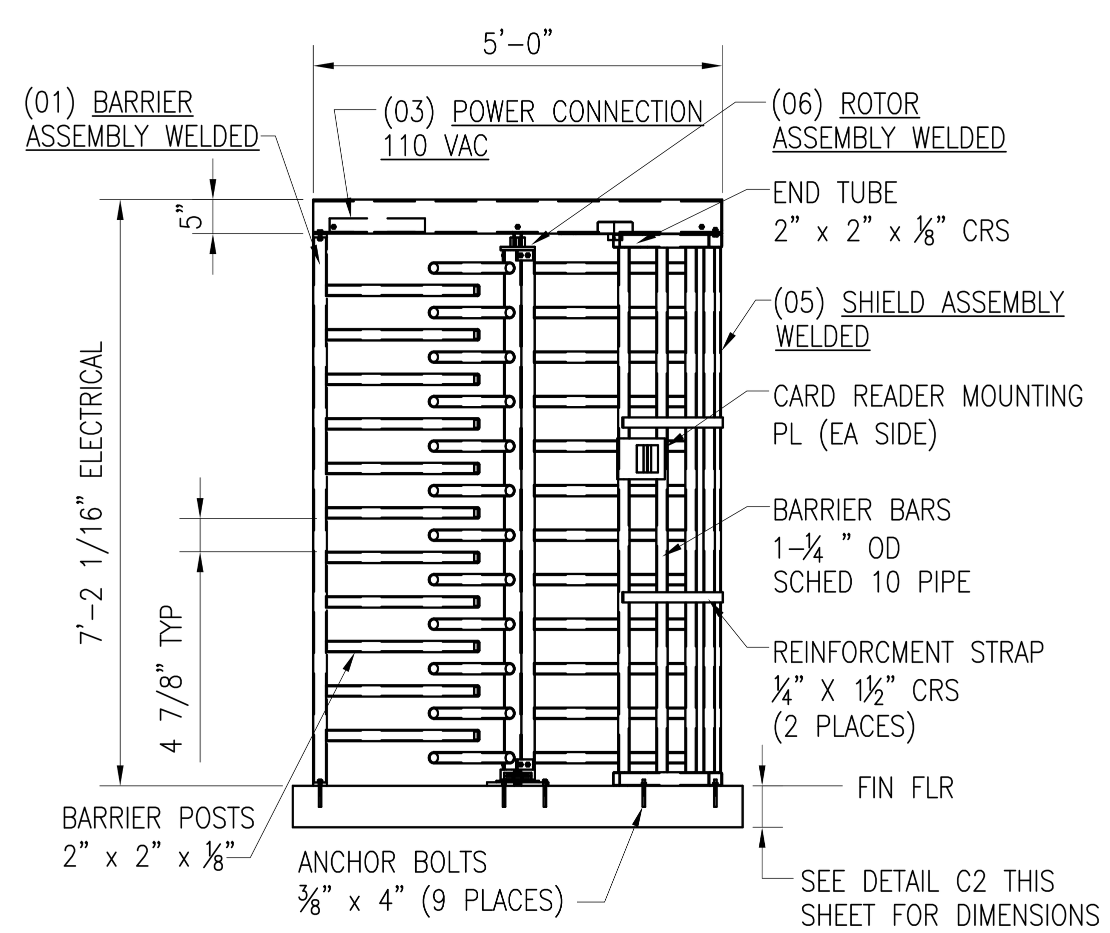
ISOMETRIC
NOT TO SCALE



BOTTOM BEARING DETAIL
NOT TO SCALE

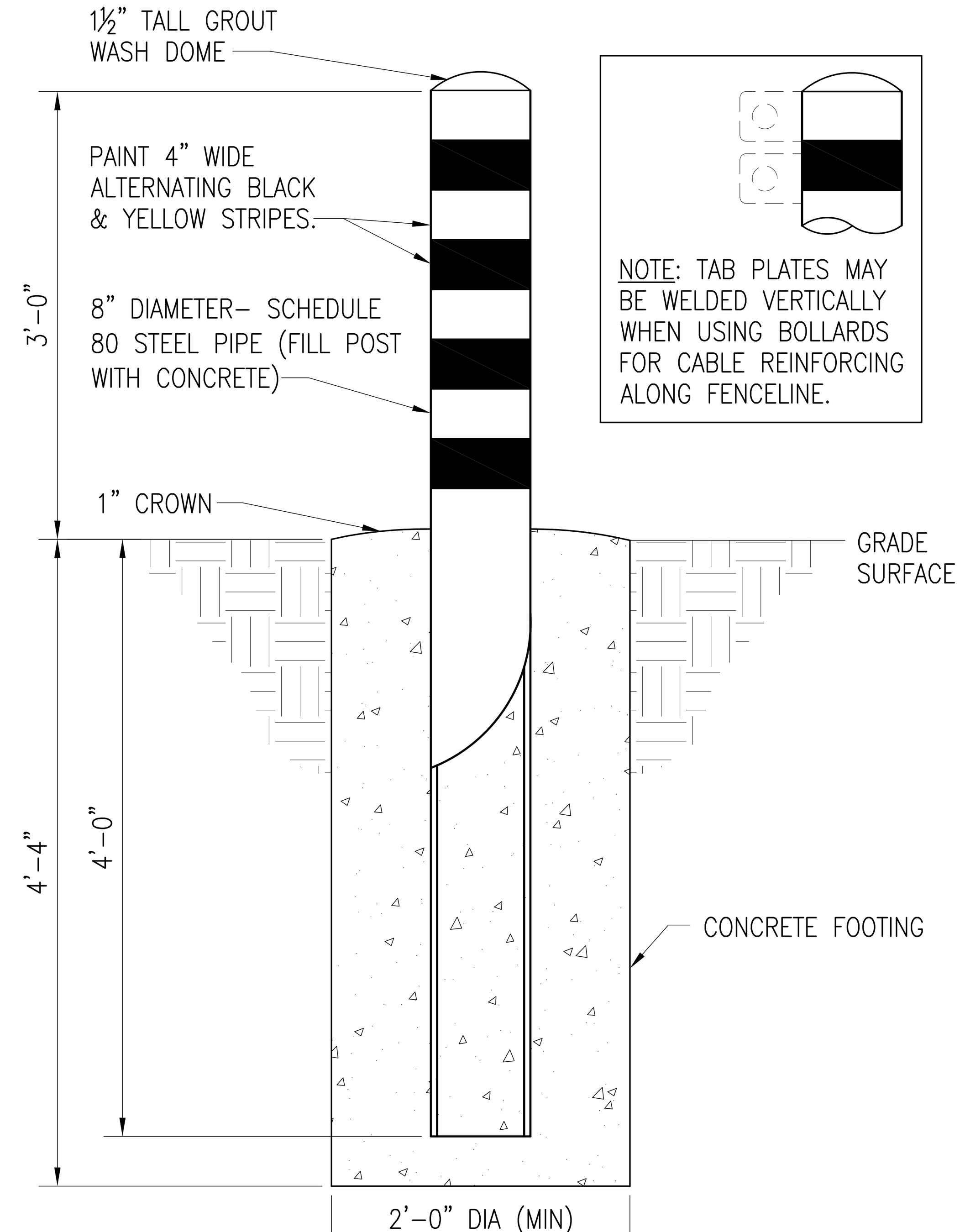


PLAN VIEW
NOT TO SCALE



ELEVATION VIEW
NOT TO SCALE

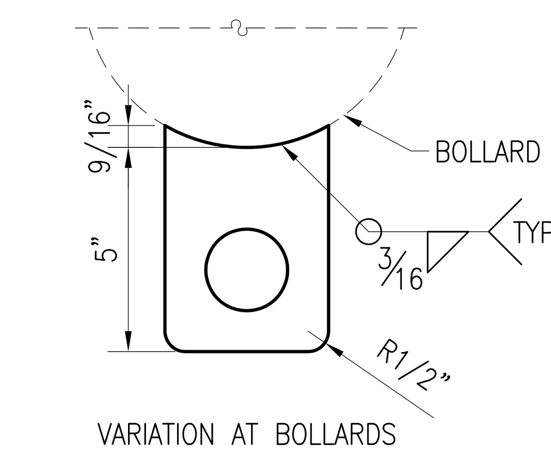
NOTE: STEEL PIPE FOR BOLLARDS SHALL CONFORM TO ASTM A53, TYPE E OR S, GALVANIZED.



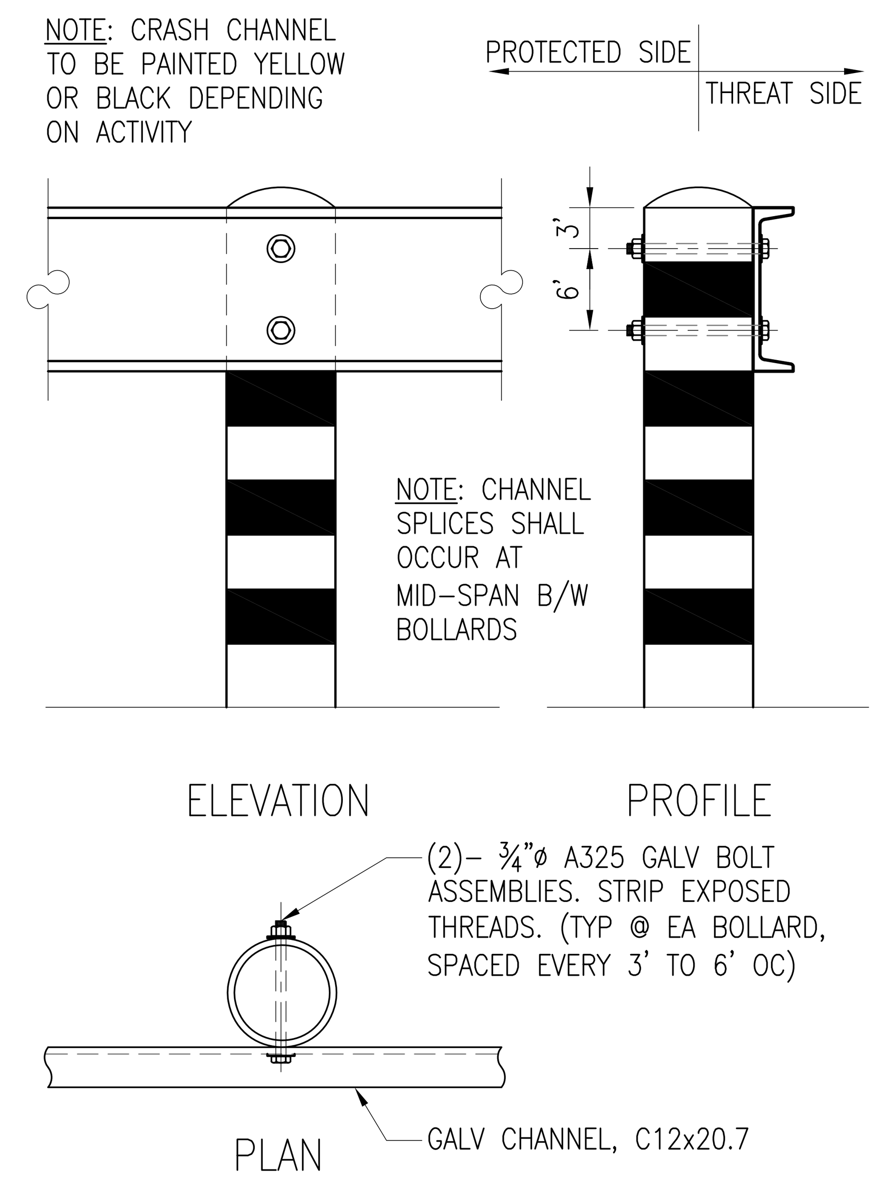
CONC FILLED BOLLARD ~ FOOTING
B3
SCALE: 1" = 1'-0" VARIOUS | UFC-705

GRAPHIC SCALES

1" = 1'-0"	0 6" 1' 2'
1 1/2" = 1'-0"	0 4" 8" 1'-4"
3" = 1'-0"	0 3" 6" 9"

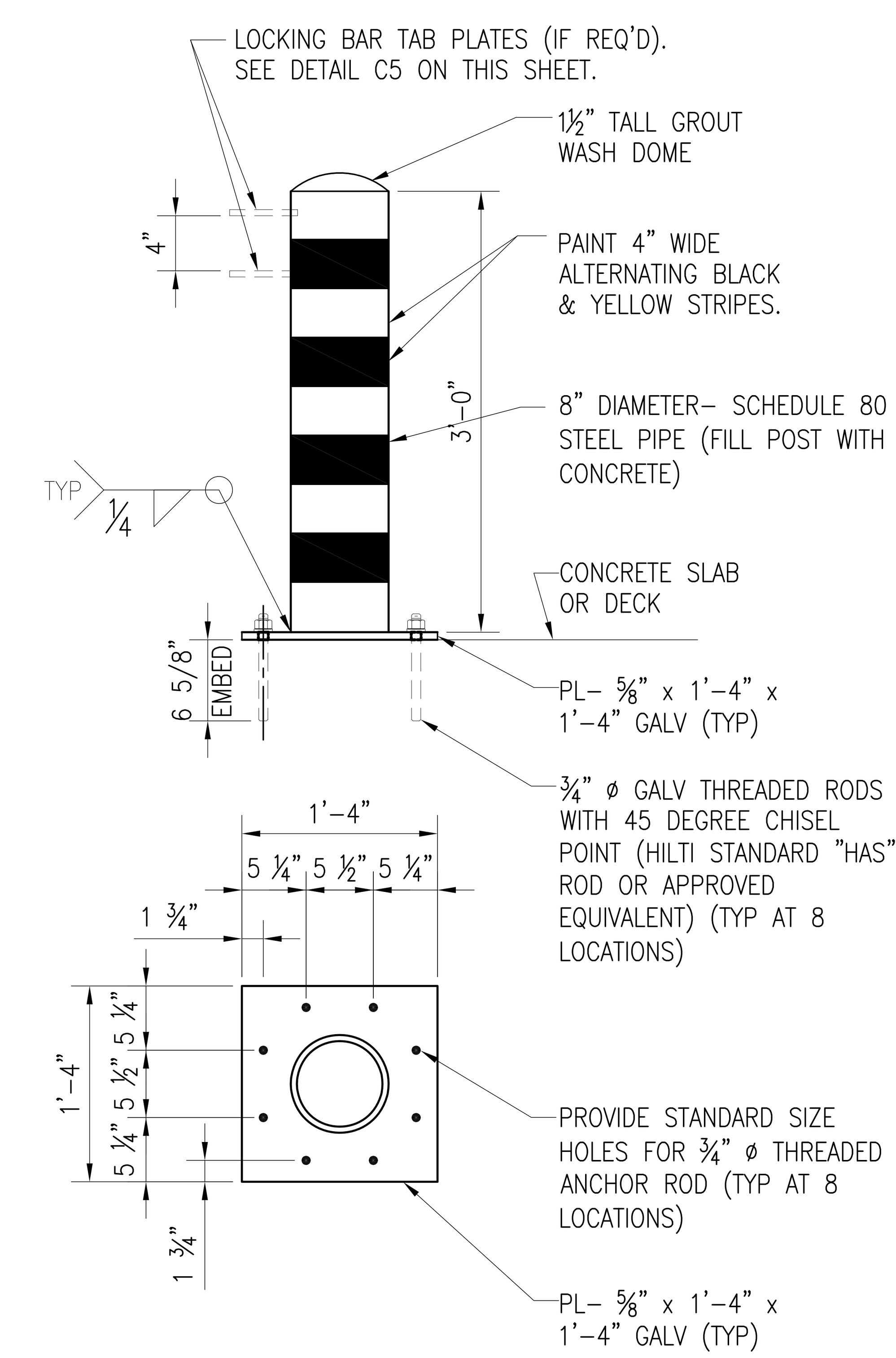


TAB PLATE DETAIL
C5
SCALE: 3" = 1'-0" UFC-705 | UFC-705



CHANNEL FOR BOLLARDS
A3
SCALE: 1" = 1'-0" CIVIL DWGS | UFC-705

NOTE: CONTRACTOR SHALL HAVE PLATED BOLLARD CONNECTION ANALYZED AND STAMPED BY A REGISTERED ENGINEER FOR IT BE USED FOR ATFP PURPOSES.



CONC FILLED BOLLARD ~ PLATE
A4
SCALE: 1" = 1'-0" CIVIL DWGS | UFC-705

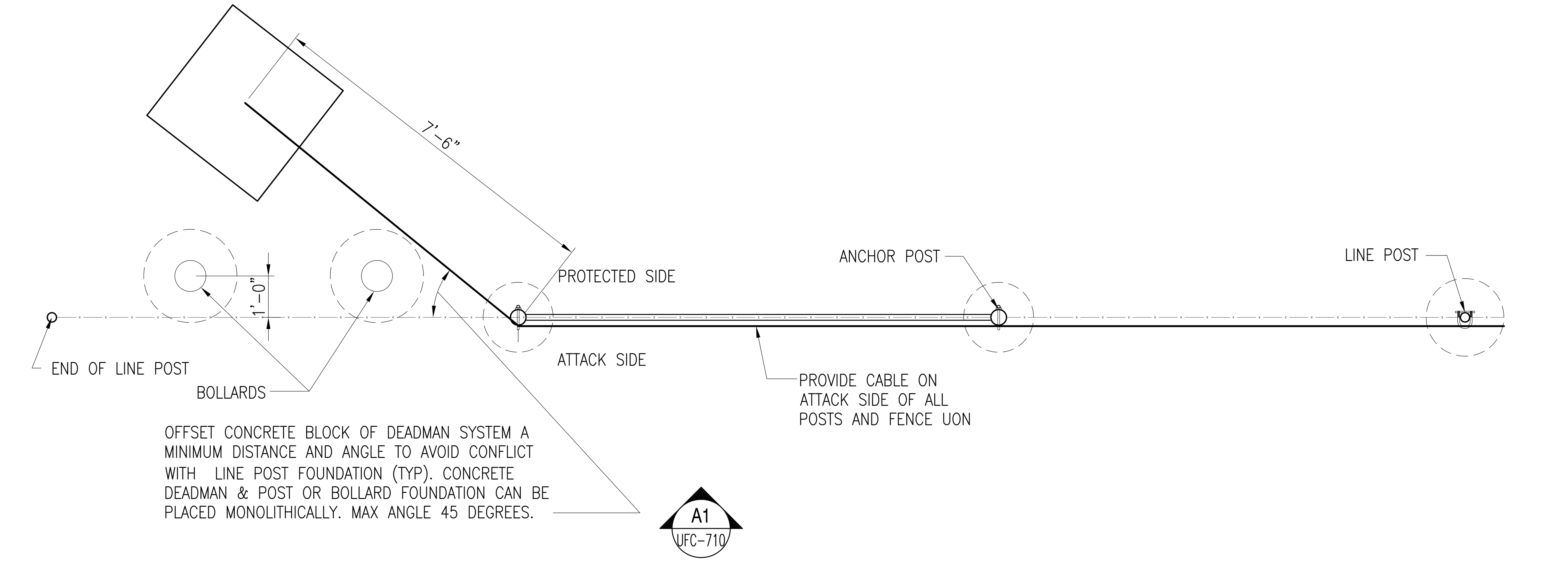
UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

TYPICAL TURNSTILE AND BOLLARD DETAILS

UFC-705

FILE NAME: J:\CICE\FENCE DRAWINGS\552005-UFC-705.dwg LAYOUT NAME: Layout1 PLOTTED: Monday, April 29, 2013 - 1:14pm

DRAWFORM REVISION: 24 AUGUST 2007

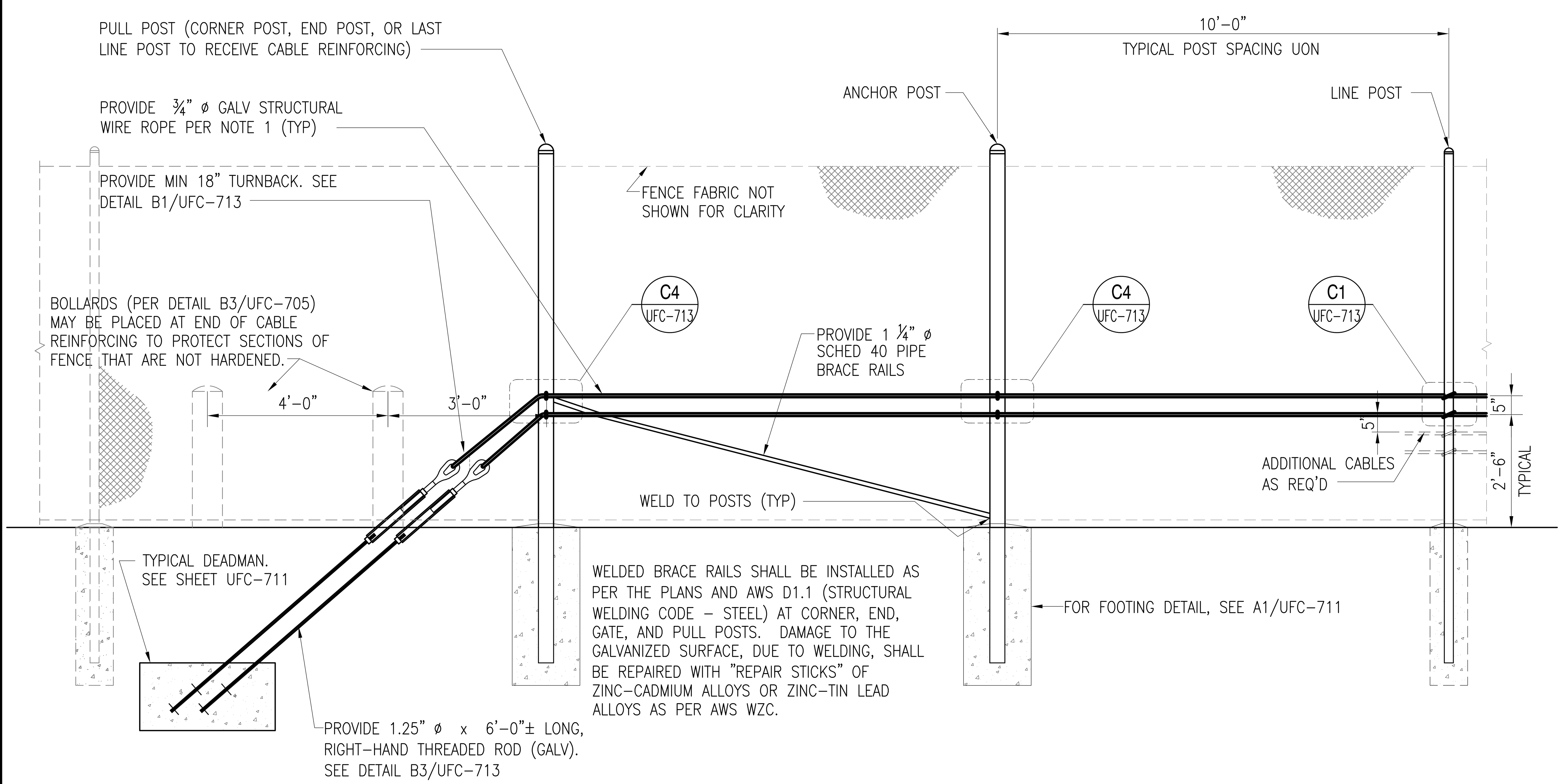


TYPICAL PLAN OF END POST DEADMAN AND LINE POST LAYOUT

SCALE: 1/2" = 1'-0"

C1 CIVIL DWGS | UFC-710

NOTE: FOR RETROFITTING OF EXIST CLF, CABLE CAN BE PLACED ON THE ATTACK SIDE OF THE FENCE FABRIC. FOR NEW CONSTRUCTION, CABLE SHALL BE INSTALLED ON ATTACK SIDE OF POST, BETWEEN POST AND FABRIC.



TYPICAL ELEVATION OF END POST DEADMAN AND LINE POST LAYOUT

SCALE: 1/2" = 1'-0"

A1 UFC-710 | UFC-710

LAYOUT OF REINFORCING

DESIGNER OF RECORD TO LOCATE DEADMEN ON SITE PLANS, SATISFYING SPACING CRITERIA, OVERLAPS, AND FENCE CORNERS / TURNING POINTS. AT GATES IT IS DESIRABLE TO HAVE TRAFFIC ON EITHER SIDE OF A MEDIAN TO OPERATE AND PROTECT INDEPENDENTLY (NOT UTILIZING THE SAME DEADMAN SYSTEMS). THEREFORE DEADMEN SHOULD BE PLACED IN THE MEDIAN TO ANCHOR THE GATE REINFORCING FOR EACH SIDE OF THE ROAD. IF THERE IS NO PHYSICAL MEDIAN (MERELY PAINTED LINES), LIMITED ROOM, OR UTILITY CONFLICTS THAT DO NOT ALLOW FOR DEADMEN PLACEMENT BETWEEN THE GATES, ENSURE THAT THE CABLING FOR BOTH GATES ARE CONNECTED-- EITHER DIRECTLY OR VIA AN INTERMEDIATE CABLE WHICH CREATES AN INTEGRAL CABLE SYSTEM ACROSS THE ENTIRE GATE AREA.

MODIFICATIONS TO TYPICAL DESIGN

NOTE FOR CONTRACTOR: IF LARGER DESIGN THREATS OR CUSTOMER REQUESTS INDICATE A NEED FOR GREATER SECURITY, MORE 3/4" ø CABLES CAN BE UTILIZED OR THE CABLES CAN BE UPGRADED TO 1" ø. BOTH SCENARIOS REQUIRE THE DEADMAN (WHICH WILL NEED TO BE LARGER) TO BE DESIGNED BY A PROFESSIONAL ENGINEER TO SATISFY THE CRITERIA OUTLINED IN REINF NOTE 18 ON THIS SHEET. FOR BIDDING PURPOSES, ESTABLISH A UNIT COST FOR ADDITIONAL EXCAVATION AND NEW CONCRETE PER CUBIC FOOT.

IF 1" ø CABLE IS USED, SPECIFICATIONS SHALL MATCH REINF NOTE 1 ON THIS SHEET, EXCEPT THE CABLE SHALL HAVE A MINIMUM BREAKING STRENGTH OF 70,000 POUNDS (35 TONS). OTHER COMPONENTS, SUCH AS EYEBOLTS, U-BOLTS, ROPE CLIPS, THIMBLES, AND OTHER ASSOCIATED HARDWARE SHALL BE SIZED ACCORDINGLY.

GRAPHIC SCALES

1/2" = 1'-0" — 0 1' 2' 4'

REINFORCING NOTES

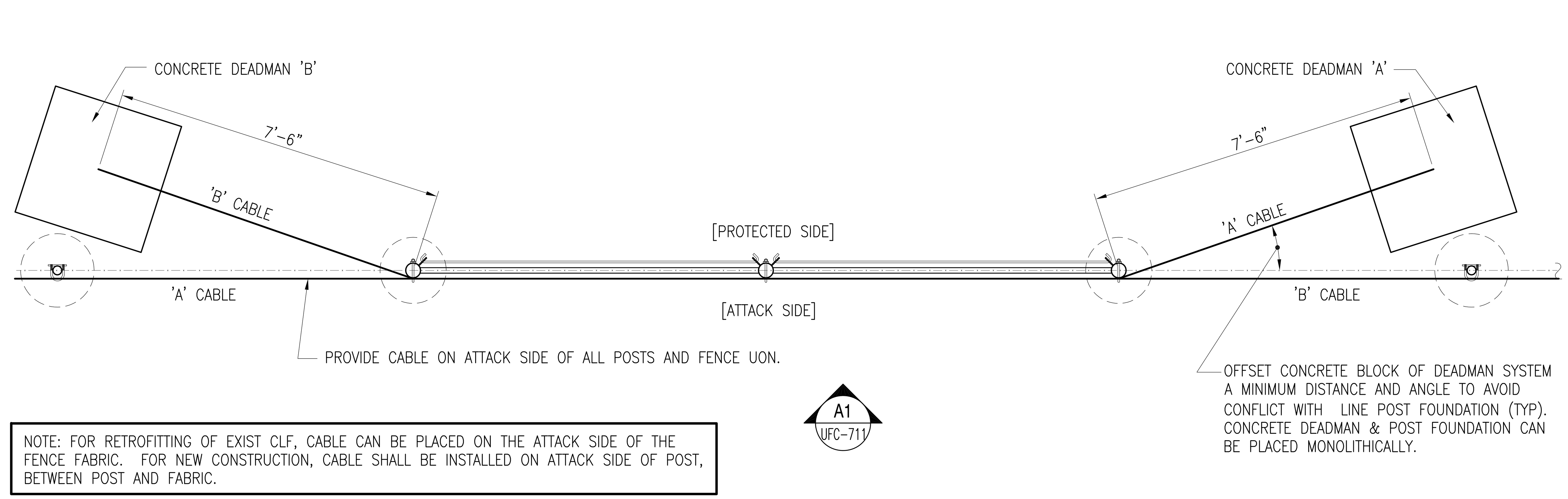
1. REINFORCING CABLES SHALL BE U.S. DOMESTIC MINIMUM 3/4" ø 6x19 CLASS WIRE ROPE, REGULAR LAY, EXTRA IMPROVED PLOW STEEL (EIP), INDEPENDENT WIRE ROPE CORE (IWRC), CONFORMING TO ASTM A1023 AND GALVANIZED IN ACCORDANCE WITH ASTM A475 CLASS A, & HAVE A MINIMUM BREAKING STRENGTH OF 40,000 POUNDS (20 TONS). CABLES WITH A BLACK VINYL COATING, SHALL NOT BE IMPREGNATED.
2. CABLES SHALL BE CONTINUOUS FROM DEADMAN TO DEADMAN. NO SPLICES IN CABLE SHALL BE ALLOWED. CABLE BARRIER SHALL BE INSTALLED BETWEEN FENCE POST AND FENCE FABRIC AS PER PLANS. U-BOLTS SHALL BE INSTALLED PERPENDICULAR TO THE LAY OF THE STRANDS OF THE WIRE ROPE AND SHALL BE TIGHTENED AFTER SAG IN CABLE BARRIER HAS BEEN REMOVED. UNLESS INDICATED OTHERWISE, CONCRETE DEADMAN SPACING SHALL BE AT MAXIMUM 200' INTERVALS & TURNING POINTS (EXTERNAL CORNERS).
3. WIRE ROPE ENDS SHALL TERMINATE AROUND TURNBUCKLES, GATE POSTS OR EXTRA HEAVY-DUTY WIRE ROPE THIMBLES (AT GATES). THESE TERMINATIONS REQUIRE 18" MINIMUM OF ROPE FOR TURN BACK AND A MINIMUM OF (4)- CLIPS EACH (EQUAL SPACING).
4. CONTRACTOR SHALL FIELD VERIFY ALL DIMENSIONS PRIOR TO ORDERING MATERIALS.
5. DEADMEN SHALL BE INSTALLED ON THE SECURED SIDE (INTERIOR) OF THE FENCE; WHILE CABLES SHALL BE INSTALLED ON THE EXTERIOR SIDE OF POST.
6. PROVIDE NECESSARY SLACK IN CABLES (GATES ONLY) TO ALLOW FOR FULL SWING OF ALL GATE LEAVES.
7. OFFSET DEADMAN SYSTEMS FROM FENCELINE (PLAN VIEW) TO AVOID CONFLICT WITH EXISTING FENCE POSTS.
8. ALLOW EPOXY ANCHOR BOLTS (MIN 2 DAYS) & CONCRETE DEADMEN (MIN 7 DAYS) TO CURE, PRIOR TO APPLYING LOADS (INSTALLING TURNBUCKLES & STRAIGHTENING CABLES).
9. ALL WELDING SHALL BE DONE IN ACCORDANCE WITH AWS D1.1. ALL WELD MATERIAL SHALL BE E70XX ELECTRODES.
10. STRUCTURAL STEEL CONSTRUCTION SHALL BE IN ACCORDANCE WITH THE NINTH EDITION OF THE AISC "MANUAL OF STEEL CONSTRUCTION FOR ALLOWABLE STRESS DESIGN.
11. STRUCTURAL STEEL SHALL CONFORM TO ASTM A36 AND SHALL HAVE A MINIMUM YIELD STRESS OF 36,000 PSI.
12. ALL STRUCTURAL STEEL MEMBERS AND HARDWARE USED IN CABLE ANCHORING SYSTEM SHALL BE HOT-DIPPED GALVANIZED. ANY AREAS WHERE COATING IS DAMAGED OR REMOVED SHALL BE COVERED WITH A ZINC RICH COMPOUND.
13. TURNBUCKLES SHALL BE 1¼"x18", TYPE I, GALVANIZED IN ACCORDANCE WITH ASTM F1145.
14. WIRE ROPE CLAMPS SHALL BE TYPE I, GALVANIZED, AND CONFORM TO FS FF-C-450.
15. ALL THREADED RODS, U-BOLTS, AND BOLTS SHALL CONFORM TO ASTM A307 AND SHALL BE INSTALLED WITH F844 WASHERS AND A563 NUTS. ENTIRE BOLT ASSEMBLY SHALL BE GALVANIZED IN ACCORDANCE WITH ASTM A153. INSTALL PER MANUFACTURER'S RECOMMENDATIONS.
16. ZINC RICH COMPOUND FOR REPAIRS SHALL BE 95% METALLIC ZINC, BY WEIGHT IN DRIED FILM; INSTALL AT LEAST TWO COATS, 4 MILS MIN TOTAL THICKNESS.
17. ALL CONCRETE WORK SHALL BE IN ACCORDANCE WITH THE LATEST EDITION OF ACI 318. CONCRETE SHALL HAVE A MINIMUM 28-DAY COMPRESSIVE STRENGTH OF 4000 PSI. THE MINIMUM CONCRETE COVER SHALL BE 3", UNLESS OTHERWISE NOTED.
18. DESIGN CRITERIA:
    UFC 4-022-03 "Security Engineering: Fences and Gates
    UFC 4-022-02 "SELECTION AND APPLICATION OF VEHICLE BARRIERS"
19. AT CABLE REINFORCING GATES, PROVIDE TWIST-OFF METAL TIES TO SECURE CABLE TO GATE FABRIC @ 24" OC & U-BOLTS TO SECURE TO GATE UPRIGHTS. MODIFY AS NEEDED TO FACILITATE OPERATION OF GATE.

UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES

DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

TYPICAL CABLE REINFORCED CHAIN LINK

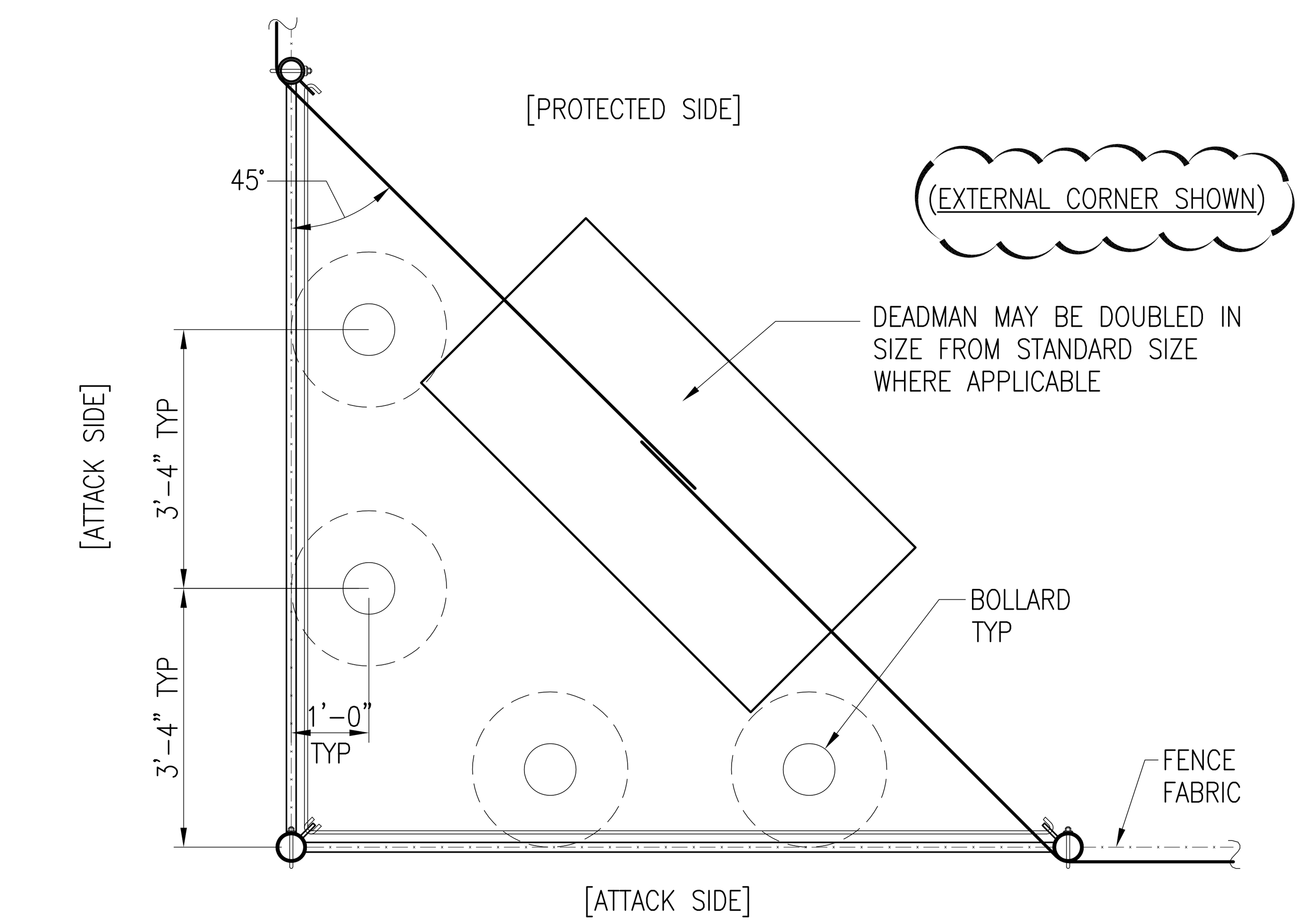
UFC-710



TYPICAL PLAN OF DEADMAN AND LINE POST LAYOUT

SCALE: 1/2" = 1'-0"

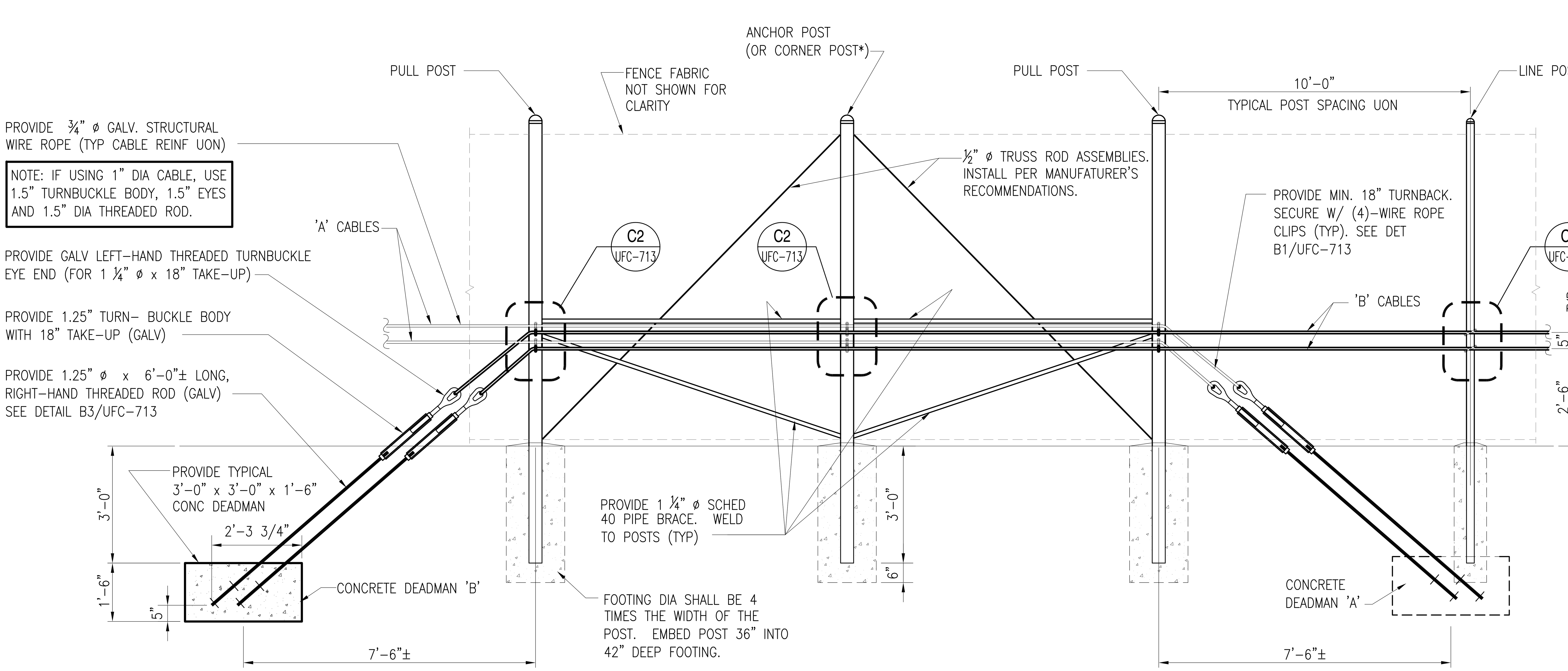
C1 — CIVIL DWGS | UFC-711



TYPICAL PLAN OF TURNING POINT POST LAYOUT

SCALE: 1/2" = 1'-0"

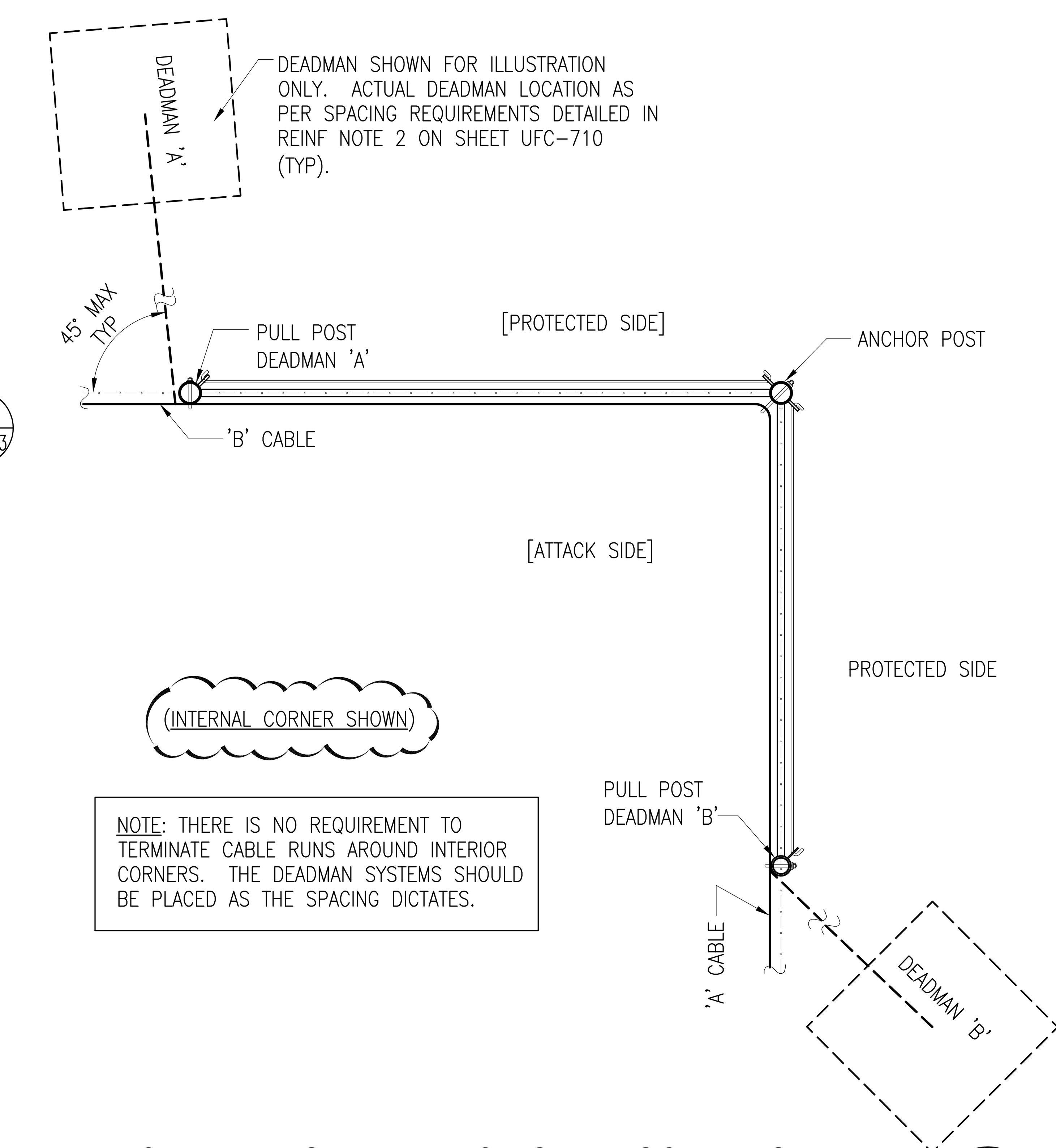
C4 — CIVIL DWGS | UFC-711



TYPICAL ELEVATION OF DEADMAN AND LINE POST LAYOUT

SCALE: 1/2" = 1'-0"

A1 — CIVIL DWGS | UFC-711



TYPICAL PLAN OF TURNING POINT POST LAYOUT

NOT TO SCALE

A4 — CIVIL DWGS | UFC-711

GRAPHIC SCALES

1/2" = 1'-0" — 0 1' 2' 4'

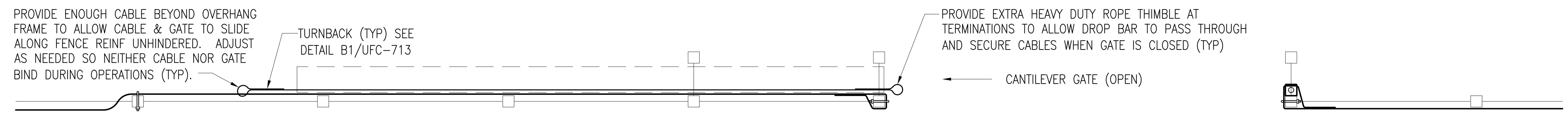
UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES

DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

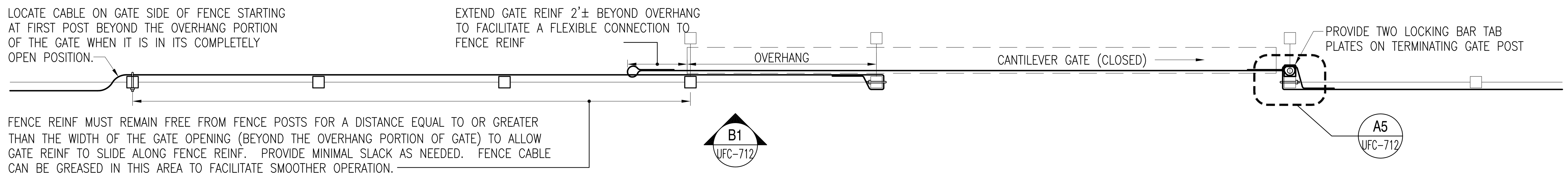
TYPICAL CABLE REINF CHAIN LINK FENCE-DEADMAN AND LINE POST

UFC-711

DRAWFORM REVISION: 24 AUGUST 2007
FILE NAME: J:\CICE\FENCE DRAWINGS\552005-UFC-711.dwg LAYOUT NAME: #-### PLOTTED: Monday, April 29, 2013 - 1:19pm



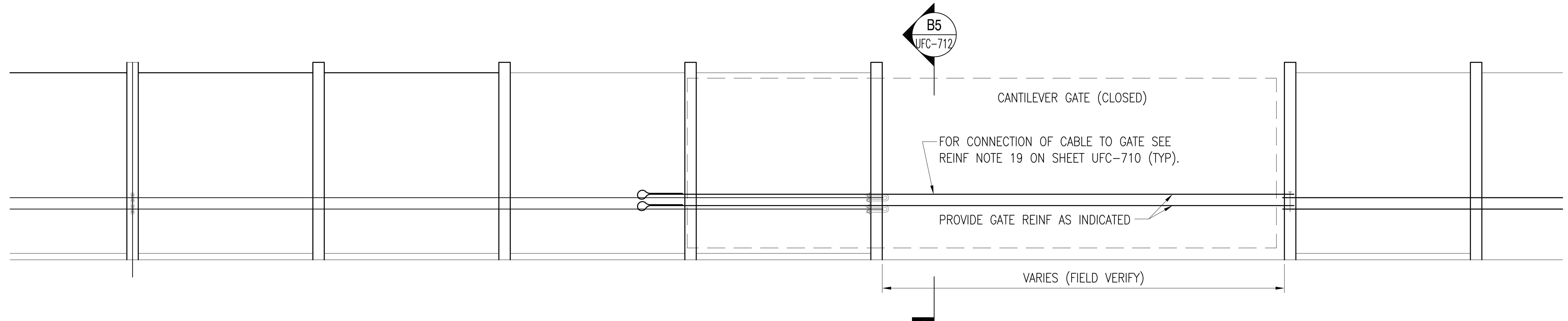
PLAN VIEW (GATE OPEN)



PLAN VIEW (GATE CLOSED)

SCALE: 1/2" = 1'-0"

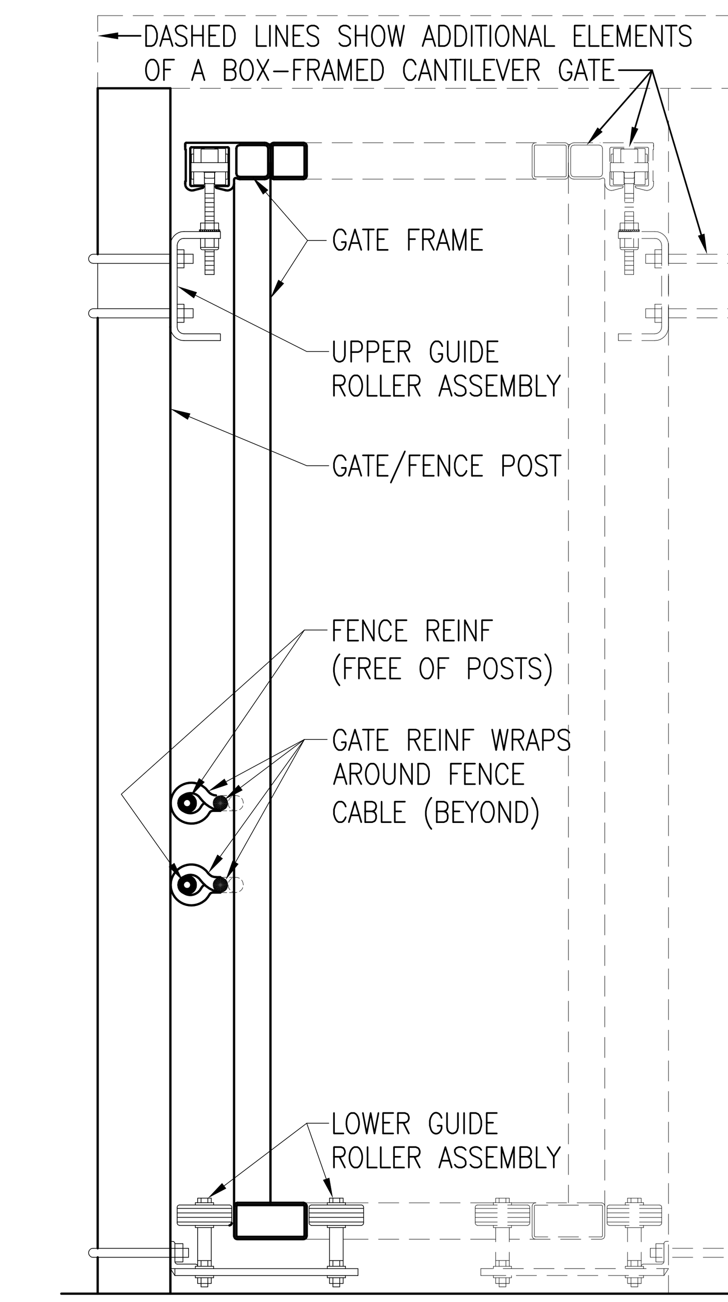
C1
CIVIL DWGS | UFC-712



ELEVATION - TYPICAL CABLE REINFORCING CANTILEVER SLIDE GATE

SCALE: 1/2" = 1'-0"

B1
UFC-712 | UFC-712

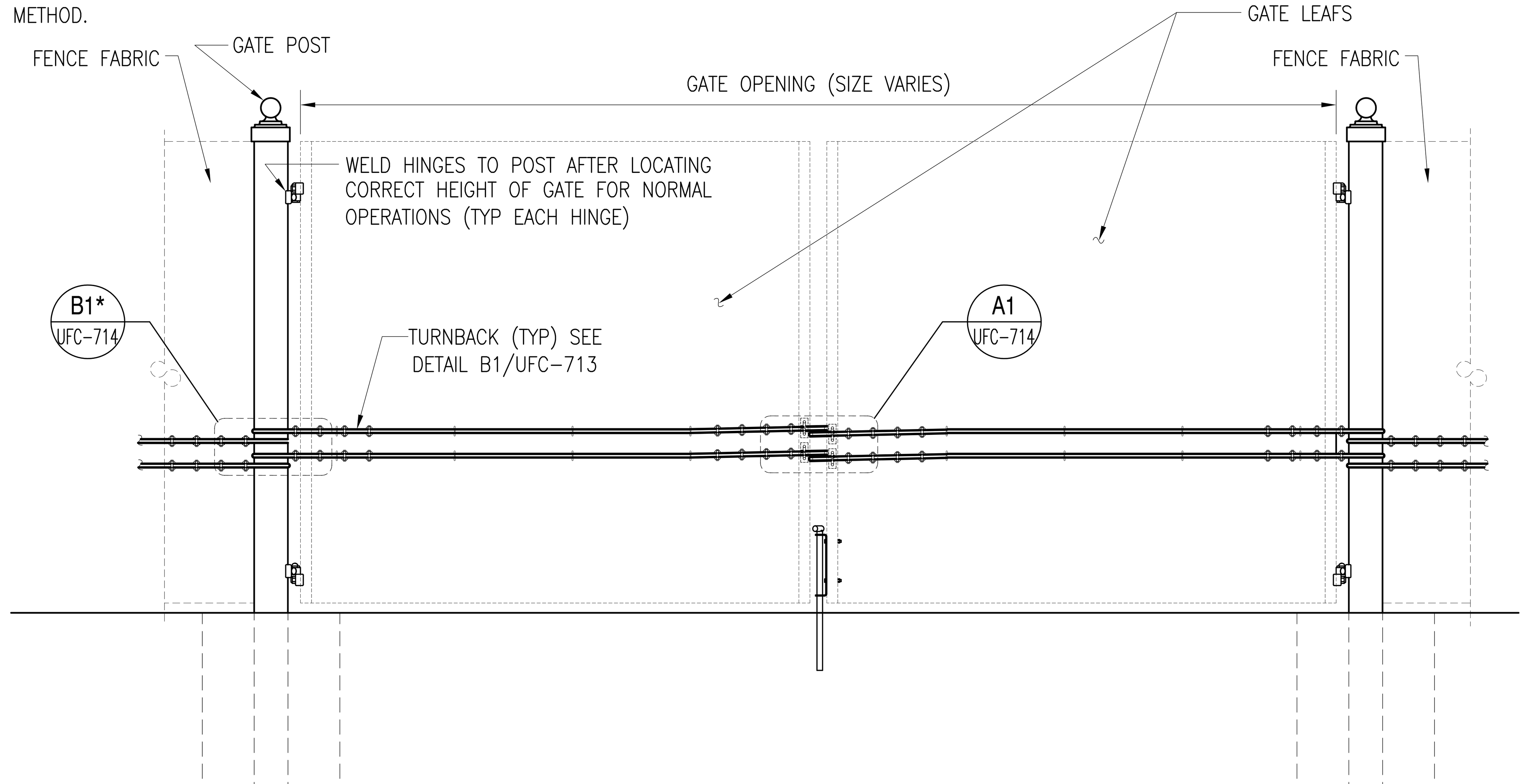


GATE SECTION

SCALE: 1/2" = 1'-0"

B5
UFC-712 | UFC-712

*NOTE: SEE DETAIL D1 ON SHEET UFC-714 FOR ALTERNATIVE METHOD.

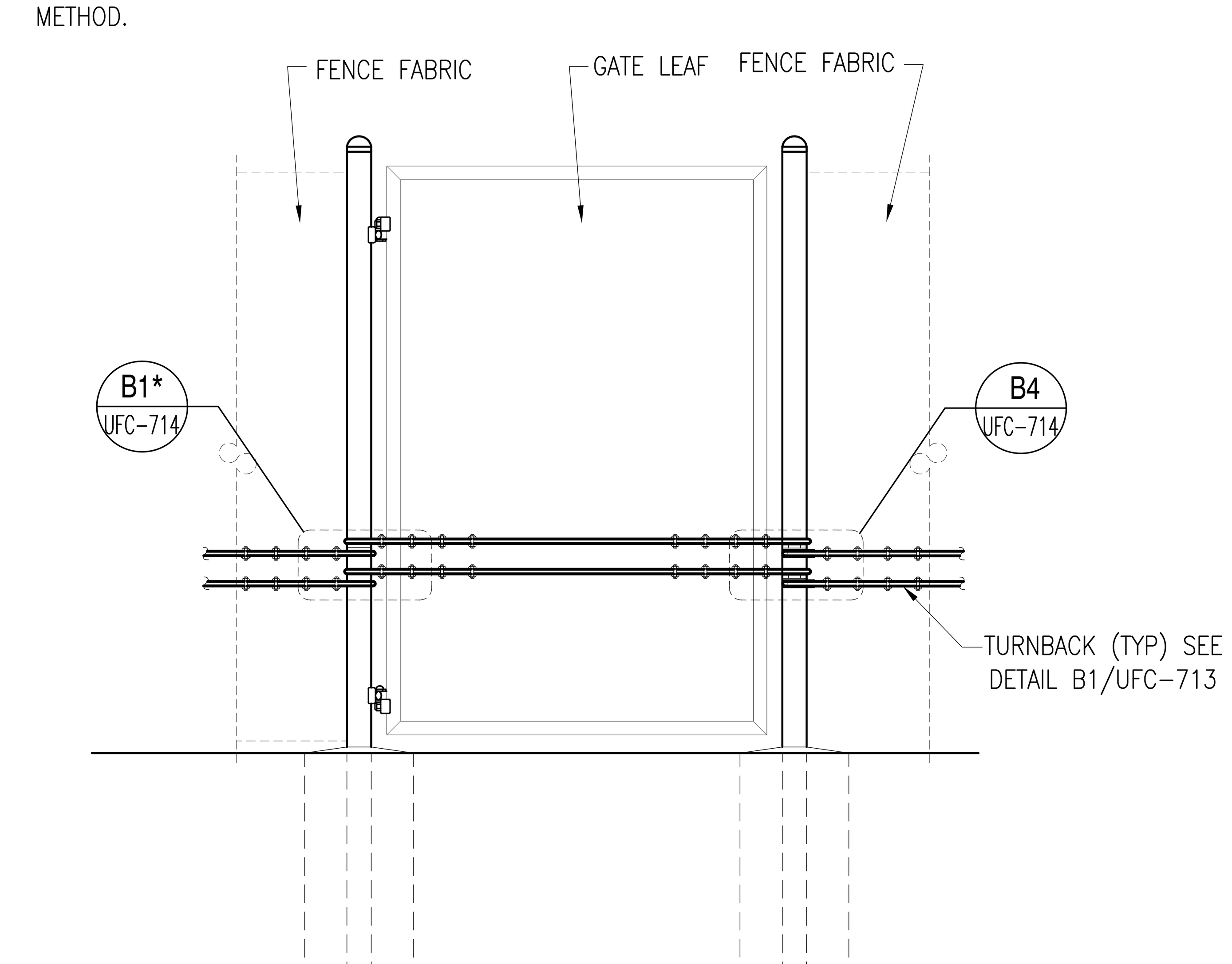


ELEVATION - TYP CABLE REINFORCING DOUBLE FOR SWING GATE

SCALE: 1/2" = 1'-0"

A1
CIVIL DWGS | UFC-712

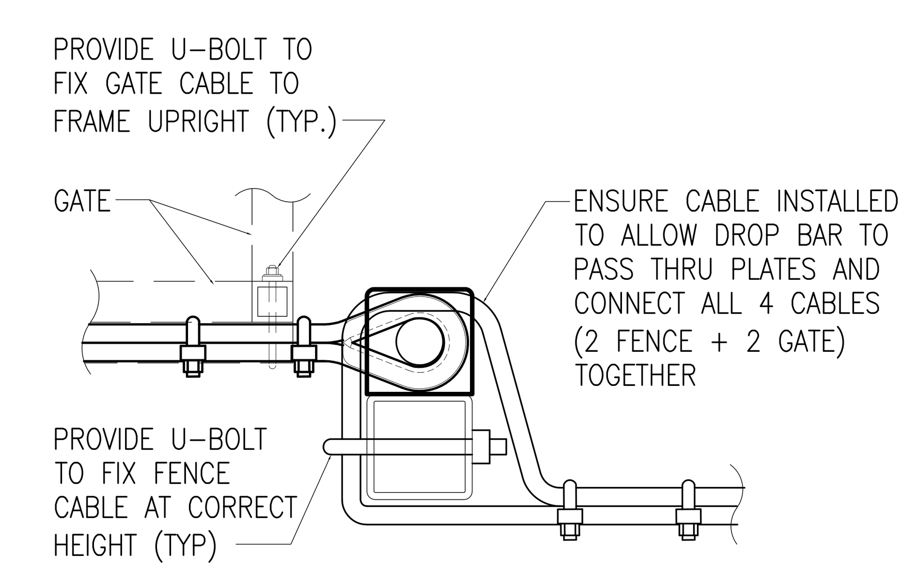
*NOTE: SEE DETAIL D1 ON SHEET UFC-714 FOR ALTERNATIVE METHOD.



ELEVATION - TYP CABLE REINF SINGLE SWING GATE

SCALE: 1/2" = 1'-0"

A3
CIVIL DWGS | UFC-712



GATE SECTION

NOT TO SCALE

A5
UFC-712 | UFC-712

GRAPHIC SCALES

1/2" = 1'-0" 0 1' 2' 4'

UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES

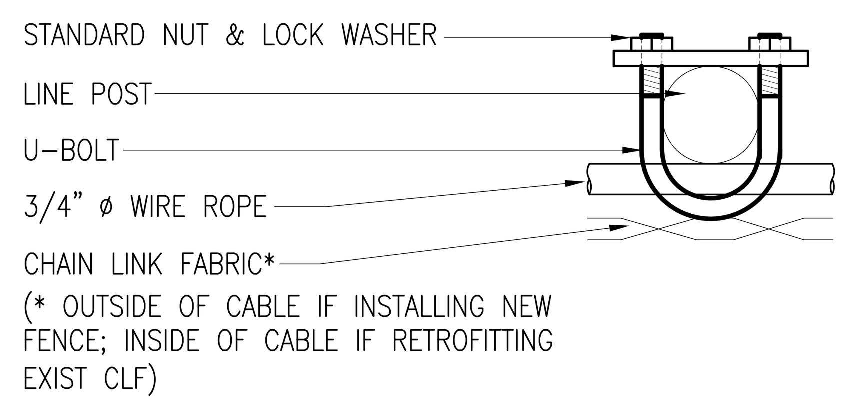
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

TYPICAL CABLE REINFORCED CHAIN LINK FENCE - GATES

UFC-712

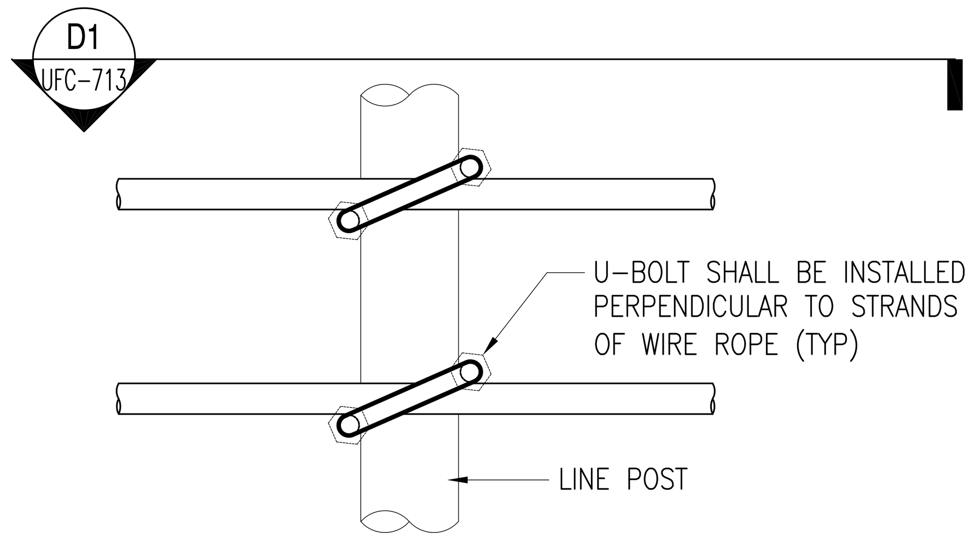
DRAWFORM REVISION: 24 AUGUST 2007

FILE NAME: J:\CICE\FENCE DRAWINGS\552005-UFC-712.dwg LAYOUT NAME: #-### PLOTTED: Monday, April 29, 2013 - 1:22pm



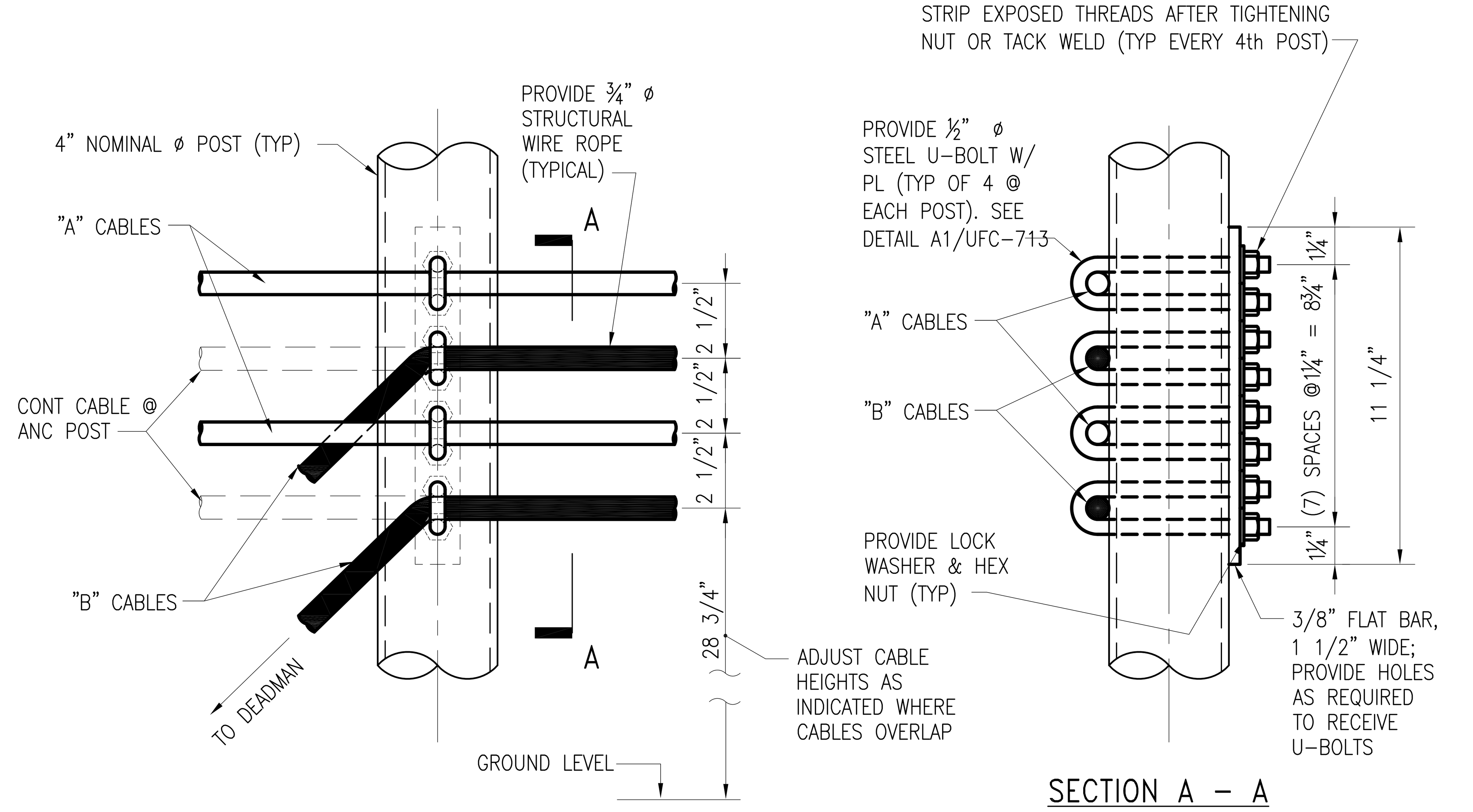
PLAN

SCALE: 3" = 1'-0" — D1 UFC-713 | UFC-713



LINE POST DETAIL (CLF ONLY)

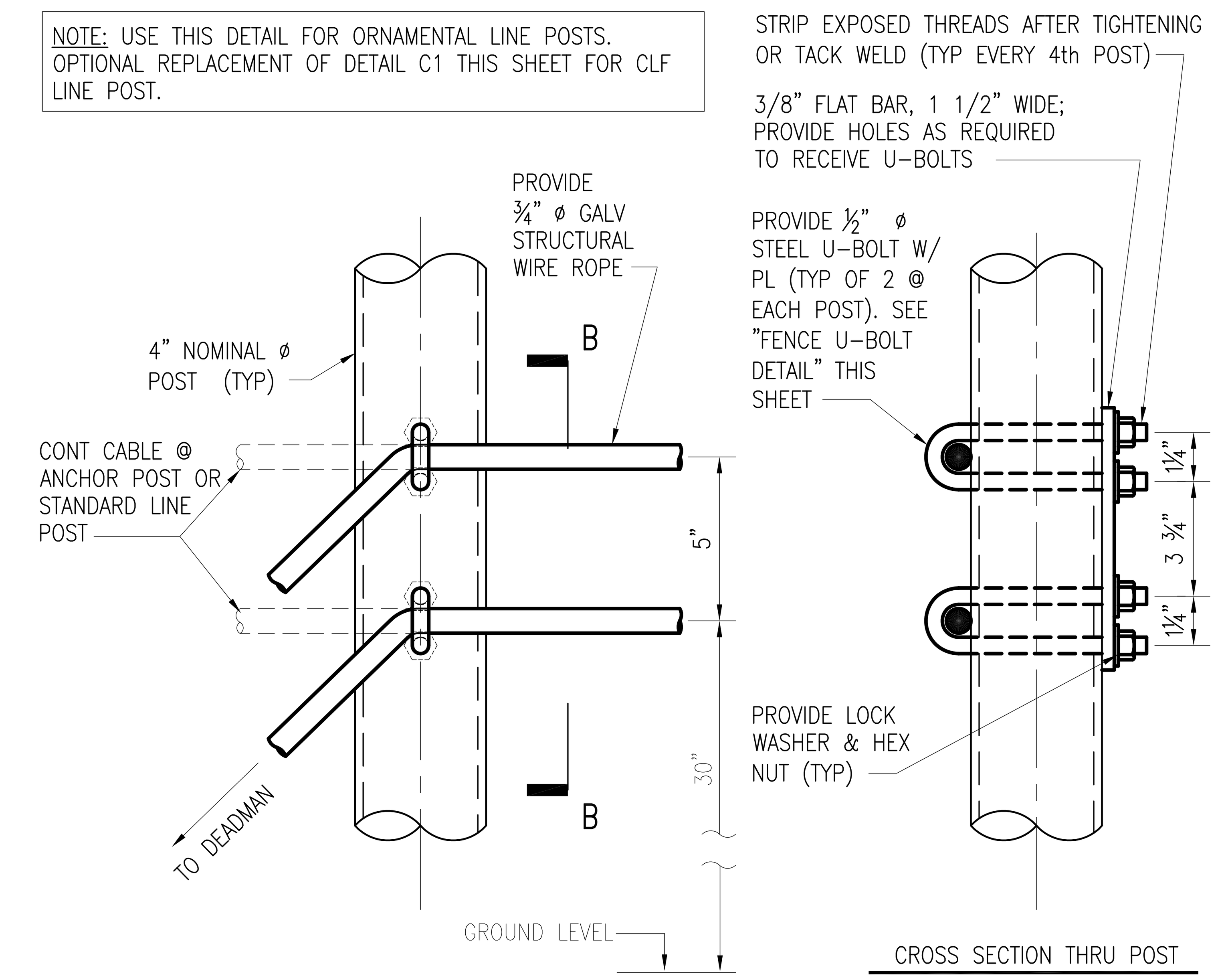
SCALE: 3" = 1'-0" — C1 UFC-711,UFC-710 | UFC-713



CABLE ANCHORAGE DETAIL @ PULL & ANCHOR POST W/ OVERLAPPING CABLES

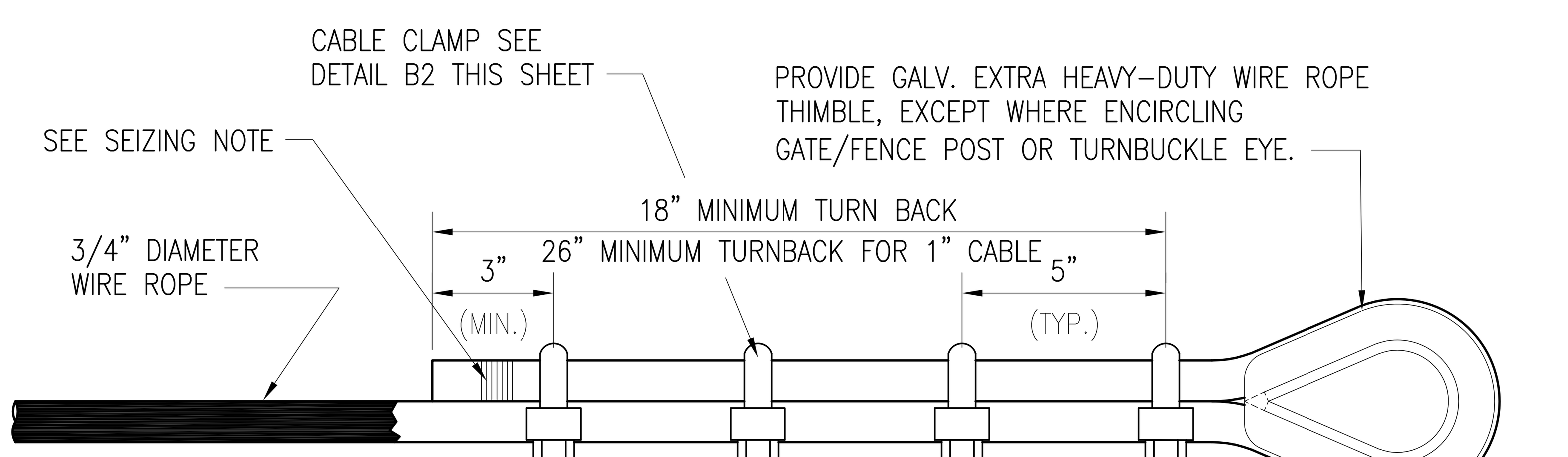
SCALE: 3"= 1'-0" — C2 UFC-710 | UFC-713

NOTE: USE THIS DETAIL FOR ORNAMENTAL LINE POSTS. OPTIONAL REPLACEMENT OF DETAIL C1 THIS SHEET FOR CLF LINE POST.



CABLE ANCHORAGE DETAIL @ PULL & ANCHOR POST

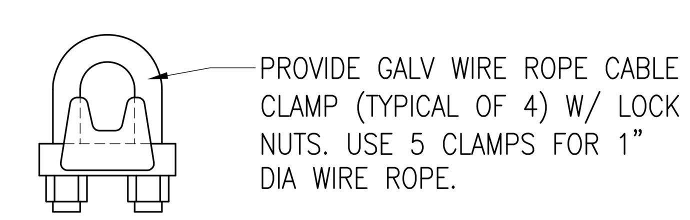
SCALE: 3" = 1'-0" — C4 UFC-711 | UFC-713



ORNAMENTAL FENCE NOTE: STRIP VINYL COATING OFF WIRE ROPE IN AREA OF CLIPS AND THIMBLE (APPROX. LAST 4'-6").	SEIZING NOTE: WIND SEIZING WIRE IN A TIGHT SPIRAL AROUND THE ROPE END TO A 1" LENGTH OF SEIZING. TWIST THE TWO ENDS OF THE SEIZING WIRE AT THE CENTER OF THE SEIZING LENGTH. USE ZINC COATED STEEL WIRE.
NOTE (ALL FENCE TYPES): INSTALL SADDLE OF CLIPS ON LIVE SIDE (AS SHOWN), SEIZE CUT END OF WIRE ROPE, AND TORQUE NUTS PER MANUFACTURER'S RECOMMENDATIONS (TYP).	

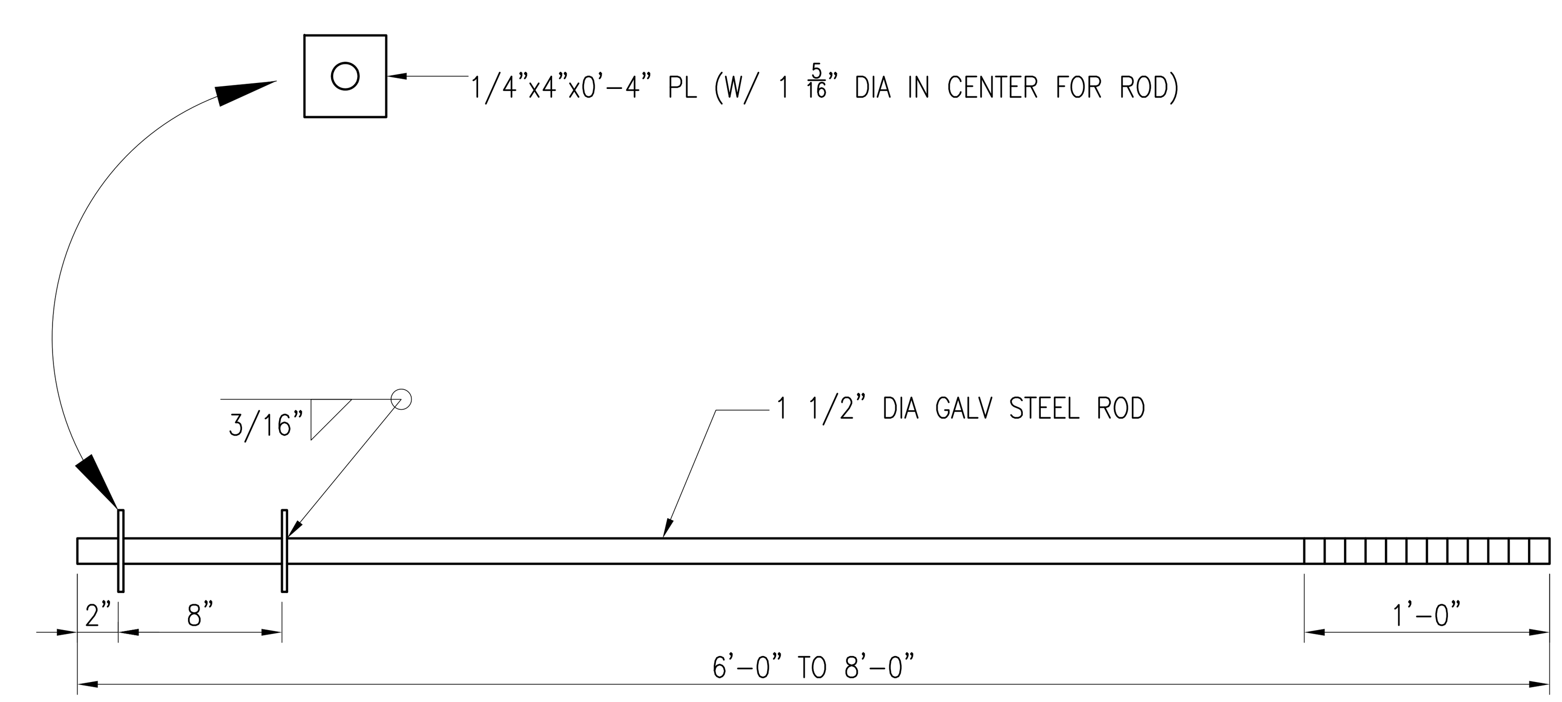
TYPICAL TURNBACK AND CLAMP DETAIL

SCALE: 3" = 1'-0" — B1 UFC-710, UFC-711, UFC-712, UFC-720, UFC-721, UFC-722 | UFC-713



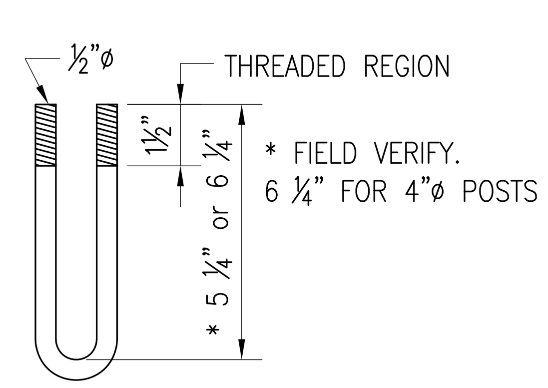
CLAMP DETAIL

NOT TO SCALE — B2 UFC-713 | UFC-713



DEADMAN ANCHOR ROD

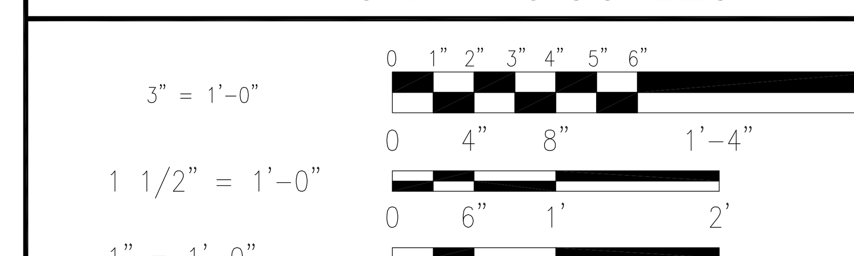
SCALE: 1 1/2" = 1'-0" — B3 UFC-710, UFC-711, UFC-720, UFC-721 | UFC-713



FENCE U-BOLT DETAIL

SCALE: 3" = 1'-0" — A1 UFC-713 | UFC-713

GRAPHIC SCALES



UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES

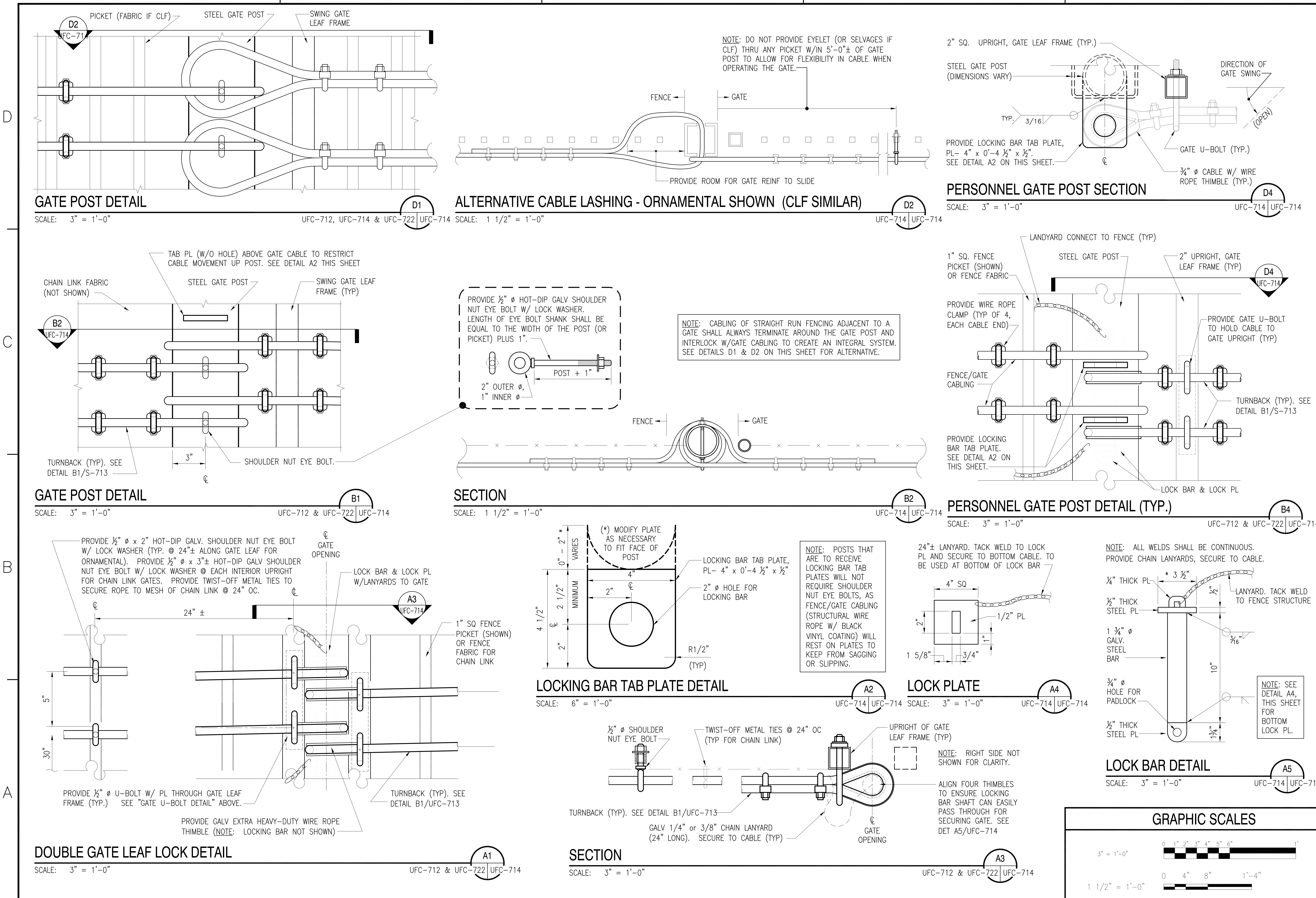
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

CABLE REINFORCING DETAILS

UFC-713

DRAWFORM REVISION: 24 AUGUST 2007

FILE NAME: J:\CICE\FENCE DRAWINGS\552005-UFC-713.dwg LAYOUT NAME: Layout1 PLOTTED: Monday, April 29, 2013 - 2:23pm



UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES

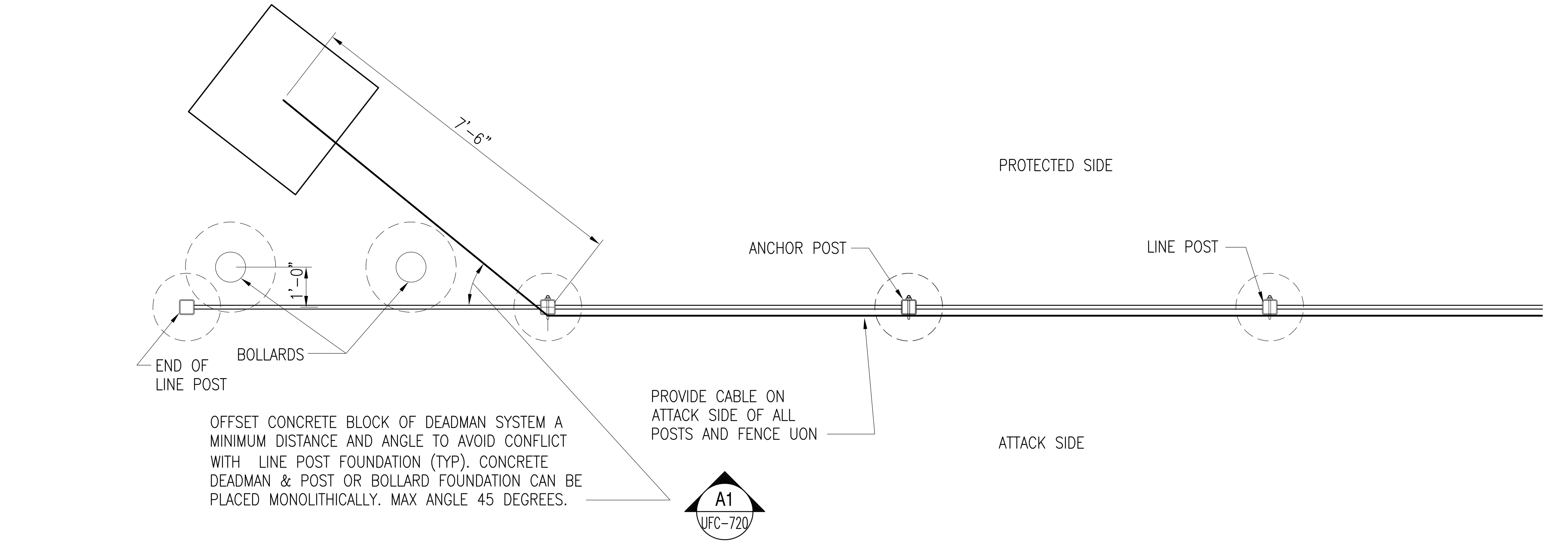
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

CABLE REINFORCING DETAILS (CONT'D)

UFC-714

DRAWFORM REVISION: 24 AUGUST 2007

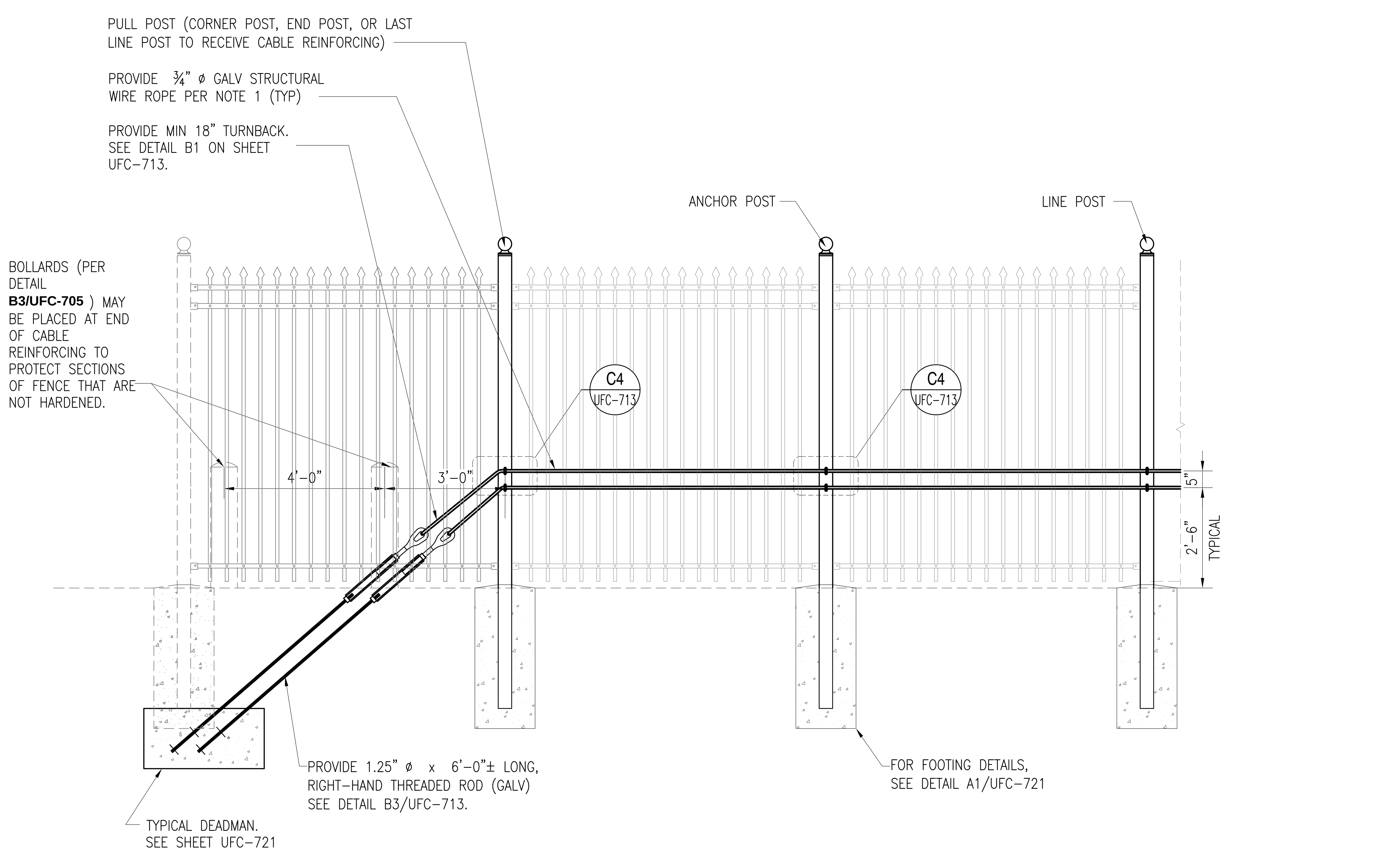
FILE NAME: J:\C\CE\FENCE DRAWINGS\552005-UFC-714.dwg LAYOUT NAME: Layout1 PLOTTED: Monday, April 29, 2013 - 2:27pm



TYPICAL PLAN OF END POST DEADMAN AND LINE POST LAYOUT

SCALE: 1/2" = 1'-0"

C1 CIVIL DWGS | UFC-720



TYPICAL ELEVATION OF END POST DEADMAN AND LINE POST LAYOUT

SCALE: 1/2" = 1'-0"

A1 UFC-720 | UFC-720

LAYOUT OF REINFORCING

DESIGNER OF RECORD TO LOCATE DEADMEN ON SITE PLANS, SATISFYING SPACING CRITERIA, OVERLAPS, AND FENCE CORNERS / TURNING POINTS. AT GATES IT IS DESIRABLE TO HAVE TRAFFIC ON EITHER SIDE OF A MEDIAN TO OPERATE AND PROTECT INDEPENDENTLY (NOT UTILIZING THE SAME DEADMAN SYSTEMS). THEREFORE DEADMEN SHOULD BE PLACED IN THE MEDIAN TO ANCHOR THE GATE REINFORCING FOR EACH SIDE OF THE ROAD. IF THERE IS NO PHYSICAL MEDIAN (MERELY PAINTED LINES), LIMITED ROOM, OR UTILITY CONFLICTS THAT DO NOT ALLOW FOR DEADMEN PLACEMENT BETWEEN THE GATES, ENSURE THAT THE CABLING FOR BOTH GATES ARE CONNECTED-- EITHER DIRECTLY OR VIA AN INTERMEDIATE CABLE WHICH CREATES AN INTEGRAL CABLE SYSTEM ACROSS THE ENTIRE GATE AREA.

MODIFICATIONS TO TYPICAL DESIGN

IF LARGER DESIGN THREATS OR CUSTOMER REQUESTS INDICATE A NEED FOR GREATER SECURITY, MORE 3/4" ø CABLES CAN BE UTILIZED OR THE CABLES CAN BE UPGRADED TO 1" ø. BOTH SCENARIOS REQUIRE THE DEADMAN (WHICH WILL NEED TO BE LARGER) TO BE DESIGNED BY A PROFESSIONAL ENGINEER TO SATISFY THE CRITERIA OUTLINED IN REINF NOTE 19 ON THIS SHEET. FOR BIDDING PURPOSES, ESTABLISH A UNIT COST FOR ADDITIONAL EXCAVATION AND NEW CONCRETE PER CUBIC FOOT.

IF 1" ø CABLE IS USED, SPECIFICATIONS SHALL MATCH REINF NOTE 1 ON THIS SHEET, EXCEPT THE CABLE SHALL HAVE A MINIMUM BREAKING STRENGTH OF 70,000 POUNDS (35 TONS). OTHER COMPONENTS, SUCH AS EYEBOLTS, U-BOLTS, ROPE CLIPS, THIMBLES, AND OTHER ASSOCIATED HARDWARE SHALL BE SIZED ACCORDINGLY.

GRAPHIC SCALES

1/2" = 1'-0" — 0, 1', 2', 4'

REINFORCING NOTES

1. REINFORCING CABLES SHALL BE U.S. DOMESTIC MINIMUM 3/4" ø 6x19 CLASS WIRE ROPE, REGULAR LAY, EXTRA IMPROVED PLOW STEEL (EIP), INDEPENDENT WIRE ROPE CORE (IWRC), CLASS A CONFORMING TO ASTM A1023 AND GALVANIZED IN ACCORDANCE WITH ASTM A475, & HAVE A MINIMUM BREAKING STRENGTH OF 40,000 POUNDS (20 TONS). CABLES SHALL HAVE A BLACK VINYL COATING, BUT SHALL NOT BE IMPREGNATED.
2. CABLES SHALL BE CONTINUOUS FROM DEADMAN TO DEADMAN. NO SPLICES IN CABLE SHALL BE ALLOWED. CABLE BARRIER SHALL BE INSTALLED BETWEEN FENCE POST AND FENCE FABRIC AS PER PLANS. U-BOLTS SHALL BE INSTALLED PERPENDICULAR TO THE LAY OR THE STRANDS OF THE WIRE ROPE AND SHALL BE TIGHTENED AFTER SAG IN CABLE BARRIER HAS BEEN REMOVED. CONCRETE DEADMAN SPACING SHALL BE AT MAXIMUM 200' INTERVALS & TURNING POINTS (EXTERNAL CORNERS).
3. WIRE ROPE ENDS SHALL TERMINATE AROUND TURNBUCKLES, GATE POSTS OR EXTRA HEAVY-DUTY WIRE ROPE THIMBLES (AT GATES). THESE TERMINATIONS REQUIRE 18" MINIMUM OF ROPE FOR TURN BACK AND A MINIMUM OF (4)- CLIPS EACH (EQUAL SPACING).
4. CONTRACTOR SHALL FIELD VERIFY ALL DIMENSIONS PRIOR TO ORDERING MATERIALS.
5. DEADMEN TO BE INSTALLED ON THE SECURED SIDE (INTERIOR) OF THE FENCE; WHILE CABLES SHOULD BE INSTALLED ON THE EXTERIOR SIDE OF POST.
6. PROVIDE NECESSARY SLACK IN CABLES (GATES ONLY) TO ALLOW FOR FULL SWING OF ALL GATE LEAVES.
7. OFFSET DEADMAN SYSTEMS FROM FENCELINE (PLAN VIEW) TO AVOID CONFLICT WITH EXISTING FENCE POSTS.
8. ALLOW EPOXY ANCHOR BOLTS (MIN 2 DAYS) & CONCRETE DEADMEN (MIN 7 DAYS) TO CURE, PRIOR TO APPLYING LOADS (INSTALLING TURNBUCKLES & STRAIGHTENING CABLES).
9. ALL WELDING SHALL BE DONE IN ACCORDANCE WITH AWS D1.1. ALL WELD MATERIAL SHALL BE E70XX ELECTRODES.
10. STRUCTURAL STEEL CONSTRUCTION SHALL BE IN ACCORDANCE WITH THE NINTH EDITION OF THE AISC "MANUAL OF STEEL CONSTRUCTION FOR ALLOWABLE STRESS DESIGN.
11. STRUCTURAL STEEL SHALL CONFORM TO ASTM A36 AND SHALL HAVE A MINIMUM YIELD STRESS OF 36000 PSI.
12. ALL STRUCTURAL STEEL MEMBERS AND HARDWARE USED IN CABLE ANCHORING SYSTEM SHALL BE HOT-DIPPED GALVANIZED. ANY AREAS WHERE COATING IS DAMAGED OR REMOVED SHALL BE COVERED WITH A ZINC RICH COMPOUND.
13. TURNBUCKLES SHALL BE 1¼"x18", TYPE I, GALVANIZED IN ACCORDANCE WITH ASTM F1145.
14. WIRE ROPE CLAMPS SHALL BE TYPE I, GALVANIZED, IN ACCORDANCE WITH FS FF-C-450.
15. ALL THREADED RODS, U-BOLTS, AND BOLTS SHALL CONFORM TO ASTM A307 AND SHALL BE INSTALLED WITH F844 WASHERS AND A563 NUTS. ENTIRE BOLT ASSEMBLY SHALL BE GALVANIZED. INSTALL PER MANUFACTURER'S RECOMMENDATIONS.
16. ZINC RICH COMPOUND FOR REPAIRS SHALL BE 95% METALLIC ZINC, BY WEIGHT IN DRIED FILM; CONFORMING TO FED SPEC DOD-P-21035A & MEETING MILITARY SPEC MIL-P-26915A. INSTALL AT LEAST TWO COATS, 4 MILS MIN TOTAL THICKNESS.
17. ALL CONCRETE WORK SHALL BE IN ACCORDANCE WITH THE LATEST EDITION OF ACI 318. CONCRETE SHALL HAVE A MINIMUM 28-DAY COMPRESSIVE STRENGTH OF 4000 PSI. THE MINIMUM CONCRETE COVER SHALL BE 3", UNLESS OTHERWISE NOTED.
18. ALL ITEMS NOT NOTED AS "EXIST" OR "EXISTING" SHALL BE PROVIDED AND INSTALLED UNDER THE REQUIREMENTS OF THIS CONTRACT.
19. DESIGN CRITERIA:
    UFC 4-022-03 "Security Engineering: Fences and Gates
    UFC 4-022-02 "SELECTION AND APPLICATIONS OF VEHICLE BARRIERS."
20. IF CABLE REINFORCING GATES, PROVIDE EYEBOLTS TO SECURE CABLE TO GATE PICKETS @ 24" OC & U-BOLTS TO SECURE TO GATE UPRIGHTS. MODIFY AS NEEDED FOR OPERATION.

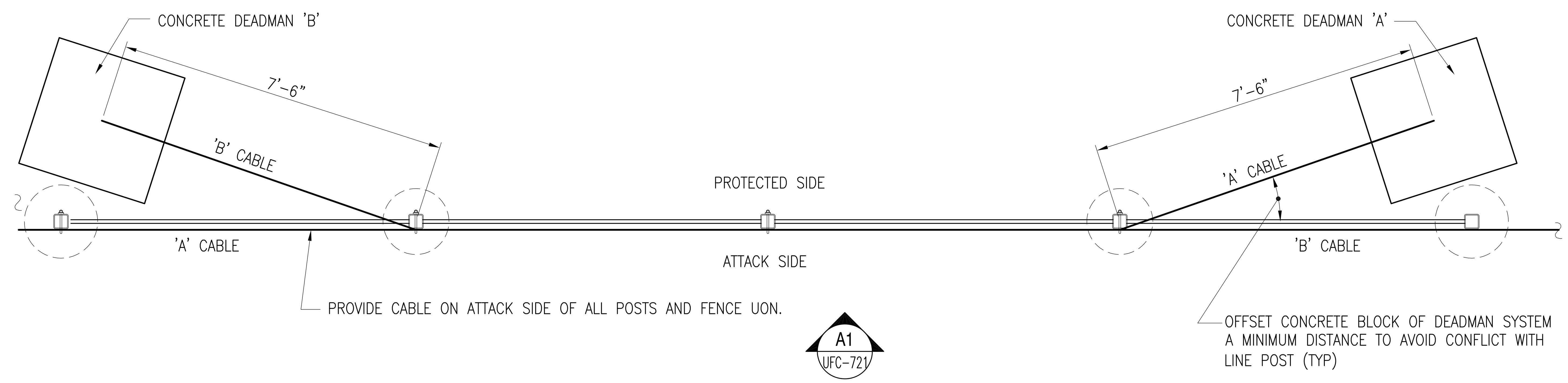
UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES

DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

TYPICAL CABLE REINFORCED ORNAMENTAL FENCE - END POST

UFC-720

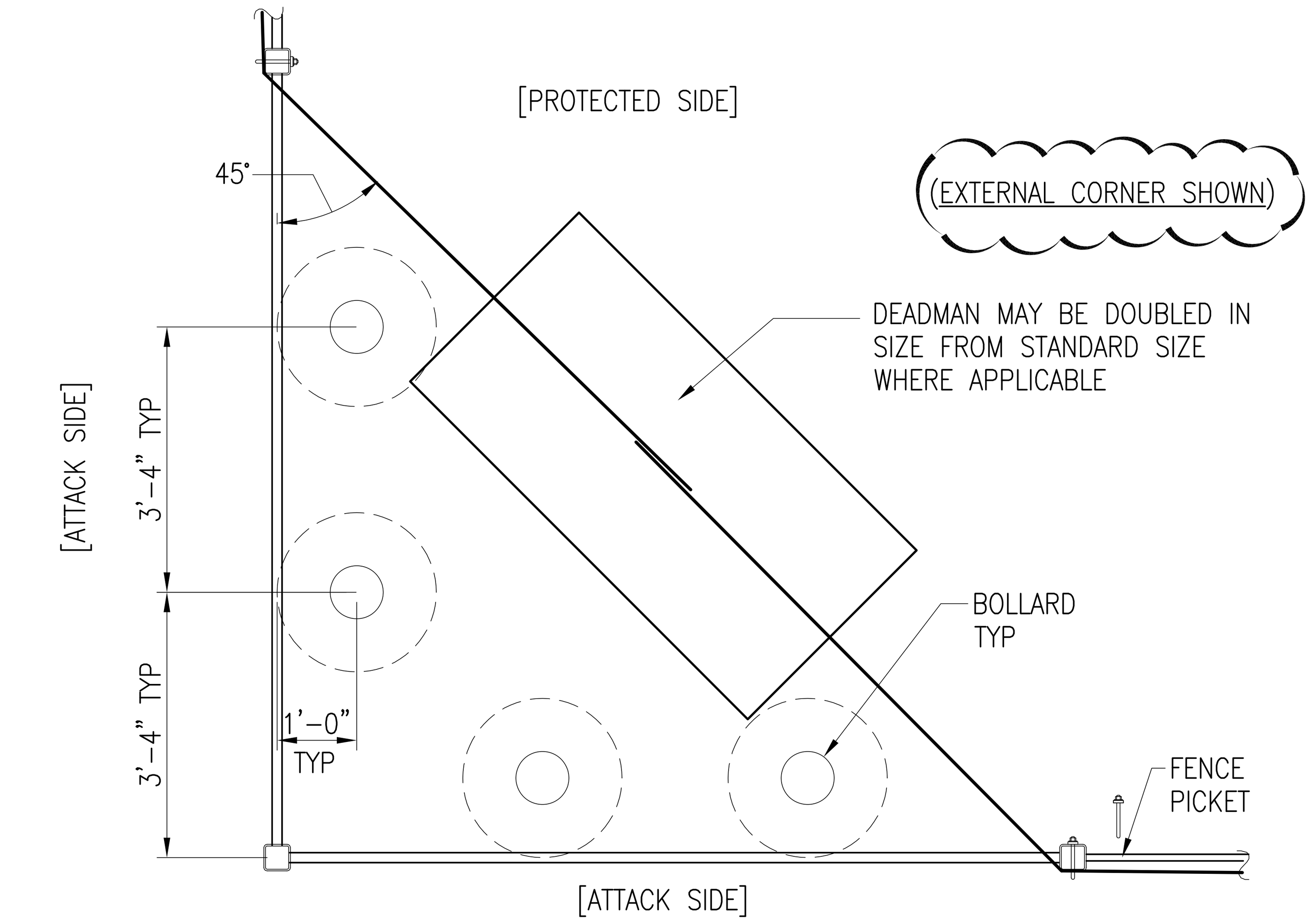
DRAWFORM REVISION: 24 AUGUST 2007



TYPICAL PLAN OF DEADMAN AND LINE POST LAYOUT

SCALE: 1/2" = 1'-0"

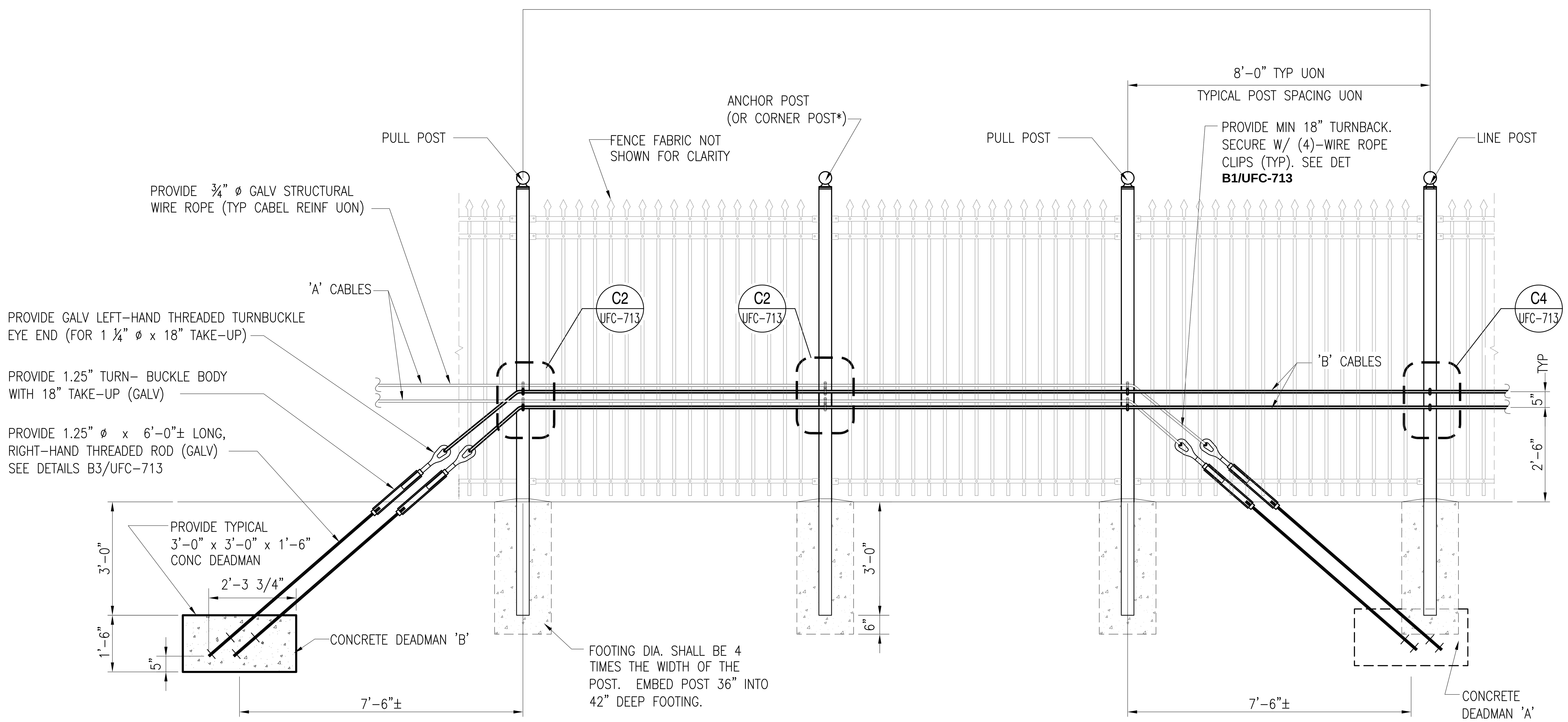
C1 CIVIL DWGS UFC-721



TYPICAL PLAN OF TURNING POINT POST LAYOUT

SCALE: 1/2" = 1'-0"

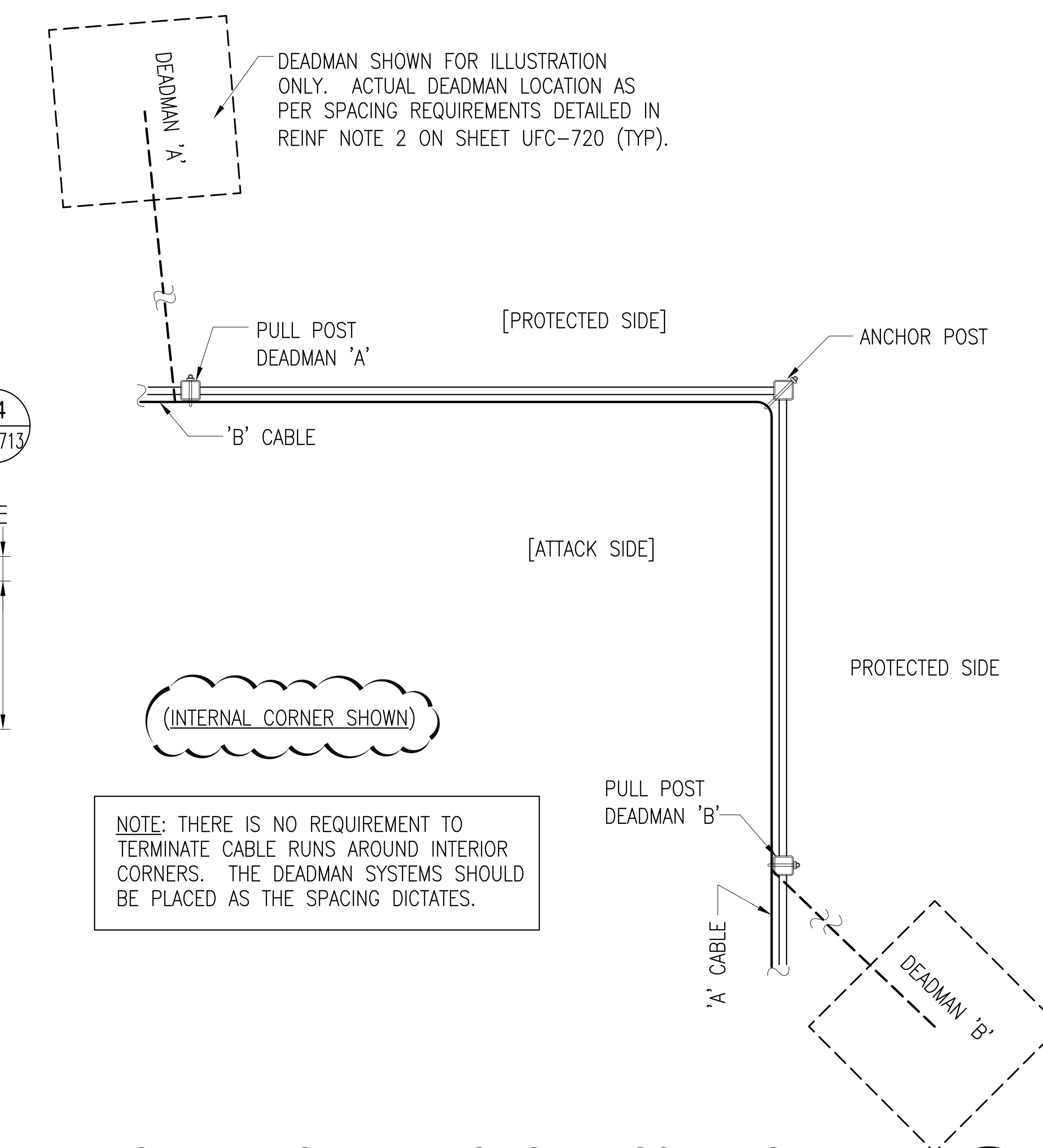
C4 CIVIL DWGS UFC-721



TYPICAL ELEVATION OF DEADMAN AND LINE POST LAYOUT

SCALE: 1/2" = 1'-0"

A1 CIVIL DWGS UFC-721



TYPICAL PLAN OF TURNING POINT POST LAYOUT

NOT TO SCALE

A4 CIVIL DWGS UFC-721

GRAPHIC SCALES

1/2" = 1'-0"   0 1' 2' 4'

UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES

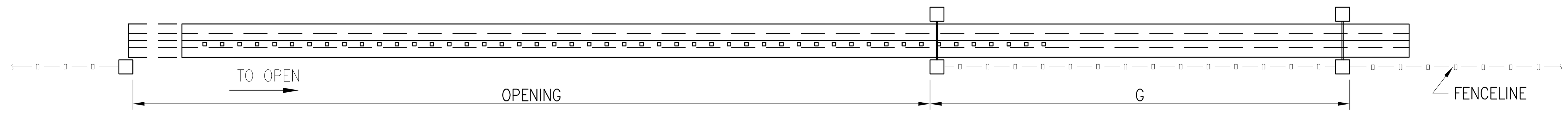
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

TYPICAL CABLE REINFORCED ORNAMENTAL FENCE - DEADMAND AND LINE POST

UFC-721

DRAWFORM REVISION: 24 AUGUST 2007

FILE NAME: J:\CICE\FENCE DRAWINGS\552005-UFC-721.dwg LAYOUT NAME: #-### PLOTTED: Monday, April 29, 2013 - 2:31pm

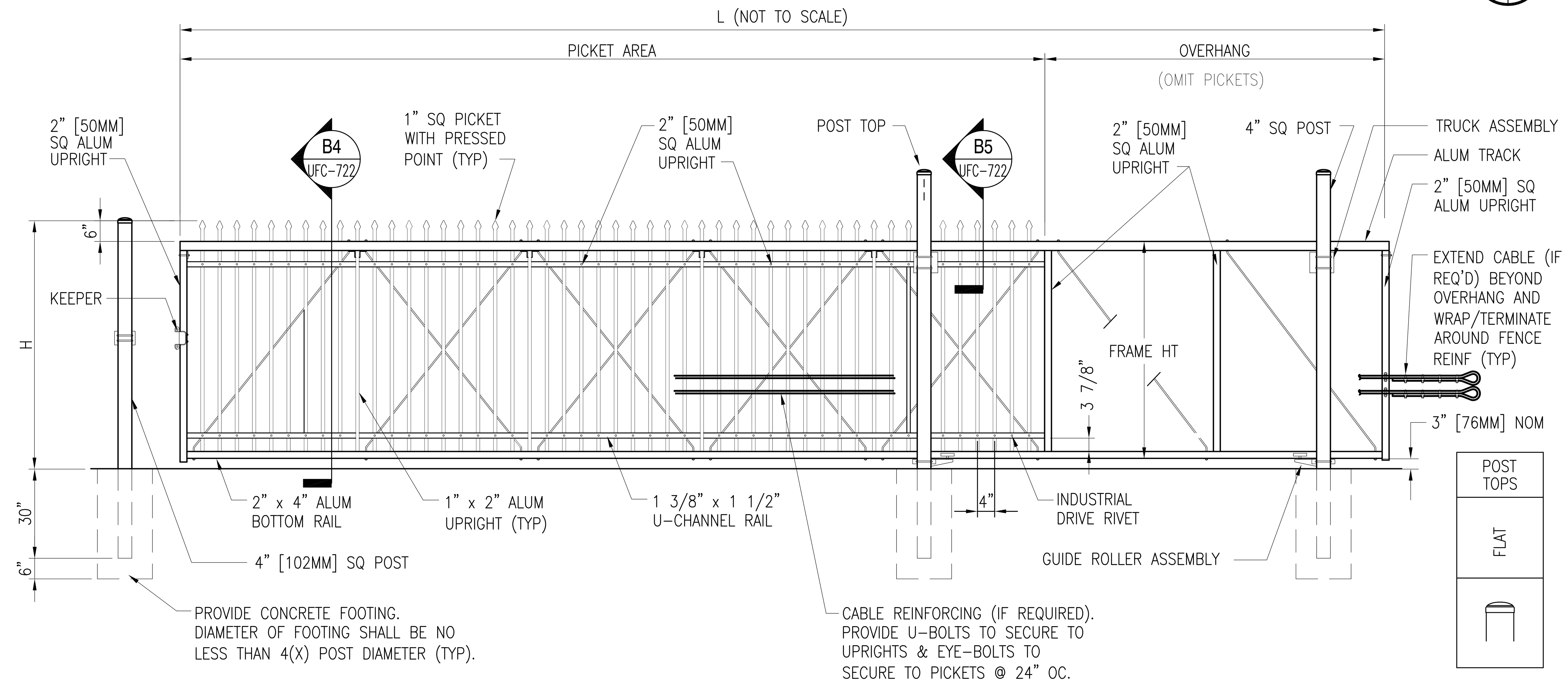


GATE PLAN
NOT TO SCALE

D1 CIVIL DWGS | UFC-722

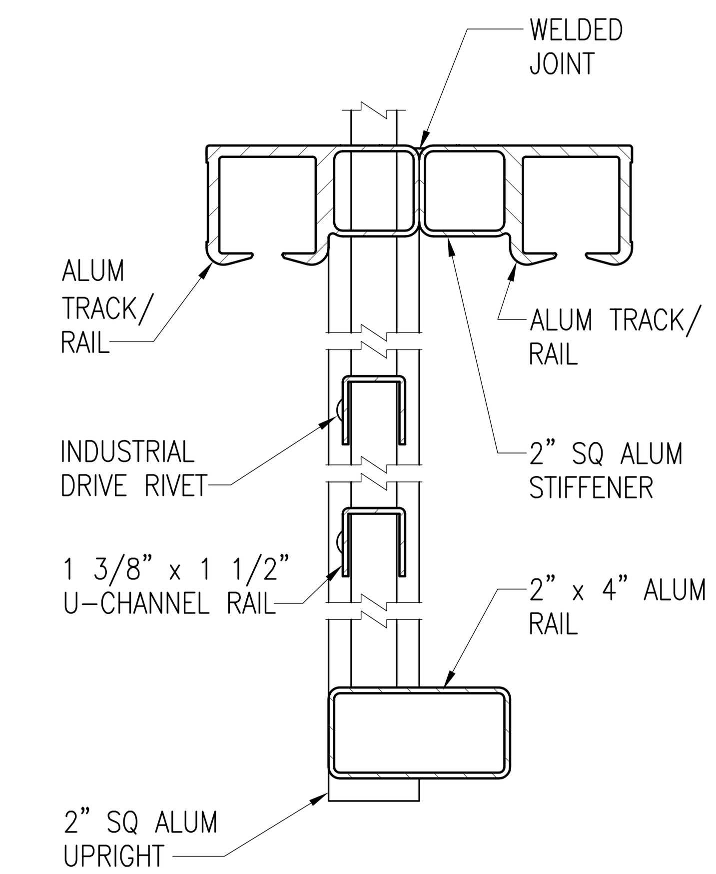
BAYS	OPENING (F/F)	NOM HEIGHT (H)	LENGTH (L)	GATE POSTS (G)	BAYS / OVERHANG
5	30'-0" [9144MM]	8'-0" [2438MM]	42'-3" [12878MM]	12'-0" [3658MM]	5(Pickets) / 2(w/o)

* NOTE: VERIFY SIZE OF OPENING WITH SITE PLANS. DIMENSIONS WILL VARY BASED ON OPENING. DIMENSIONS ABOVE PROVIDED FOR BASELINE PURPOSES.



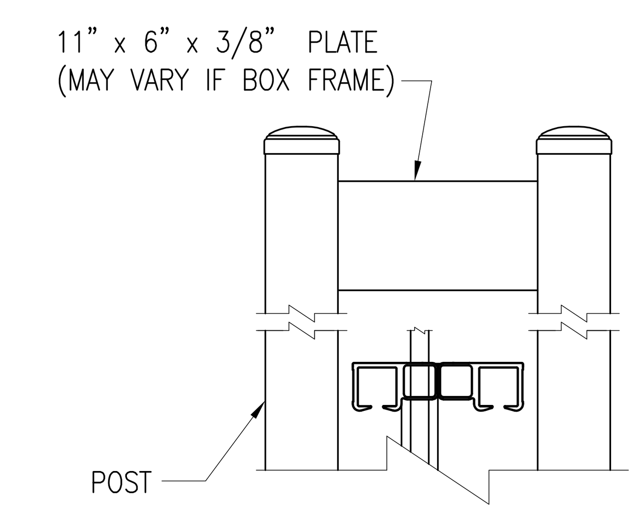
TYPICAL SINGLE CANTILEVERED SLIDING GATE ELEVATION- (5) BAYS SHOWN
NOT TO SCALE

B1 CIVIL DWGS | UFC-722



SECTION (TYP)
NOT TO SCALE

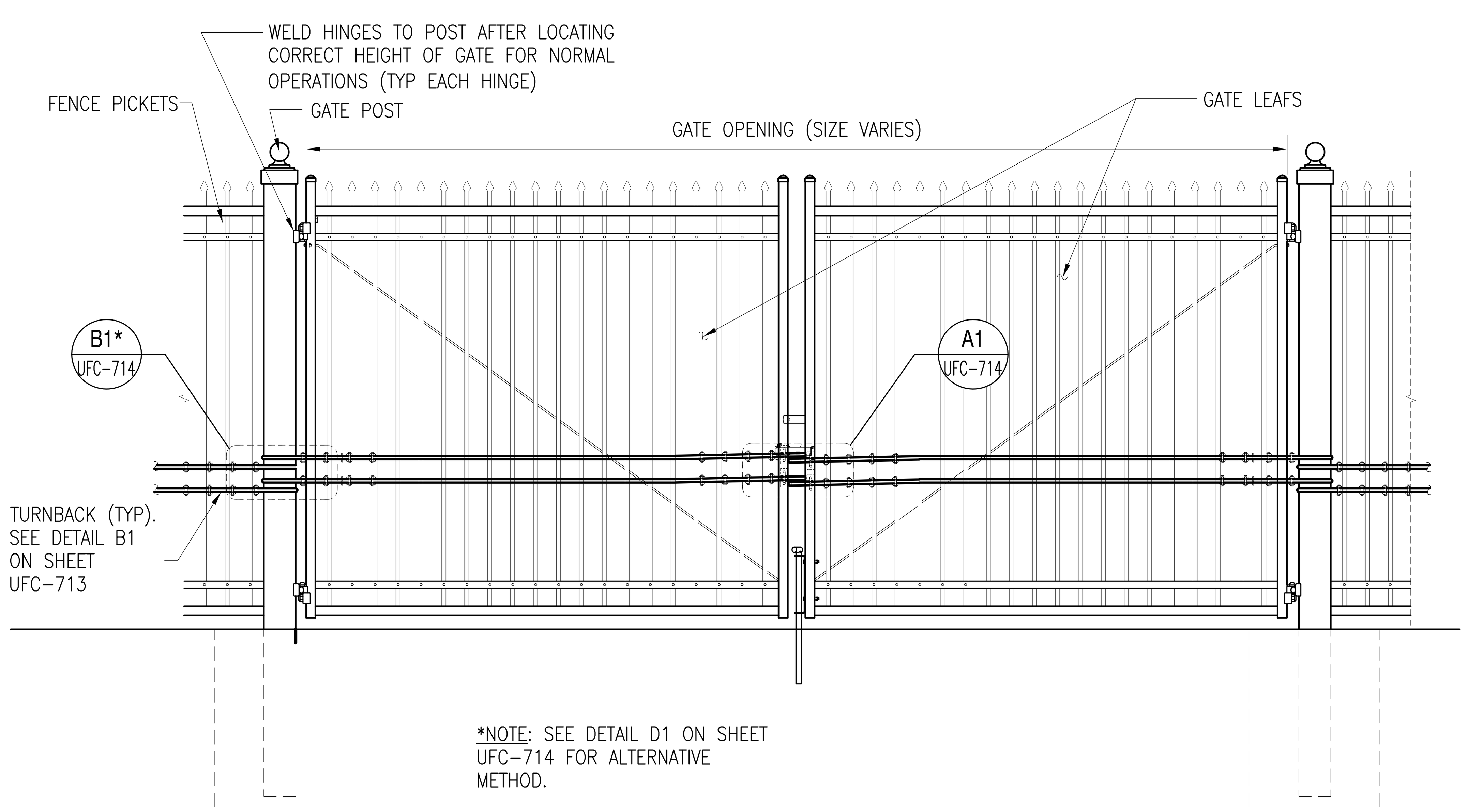
B4 UFC-722 | UFC-722



SECTION (TYP)
NOT TO SCALE

B5 UFC-722 | UFC-722

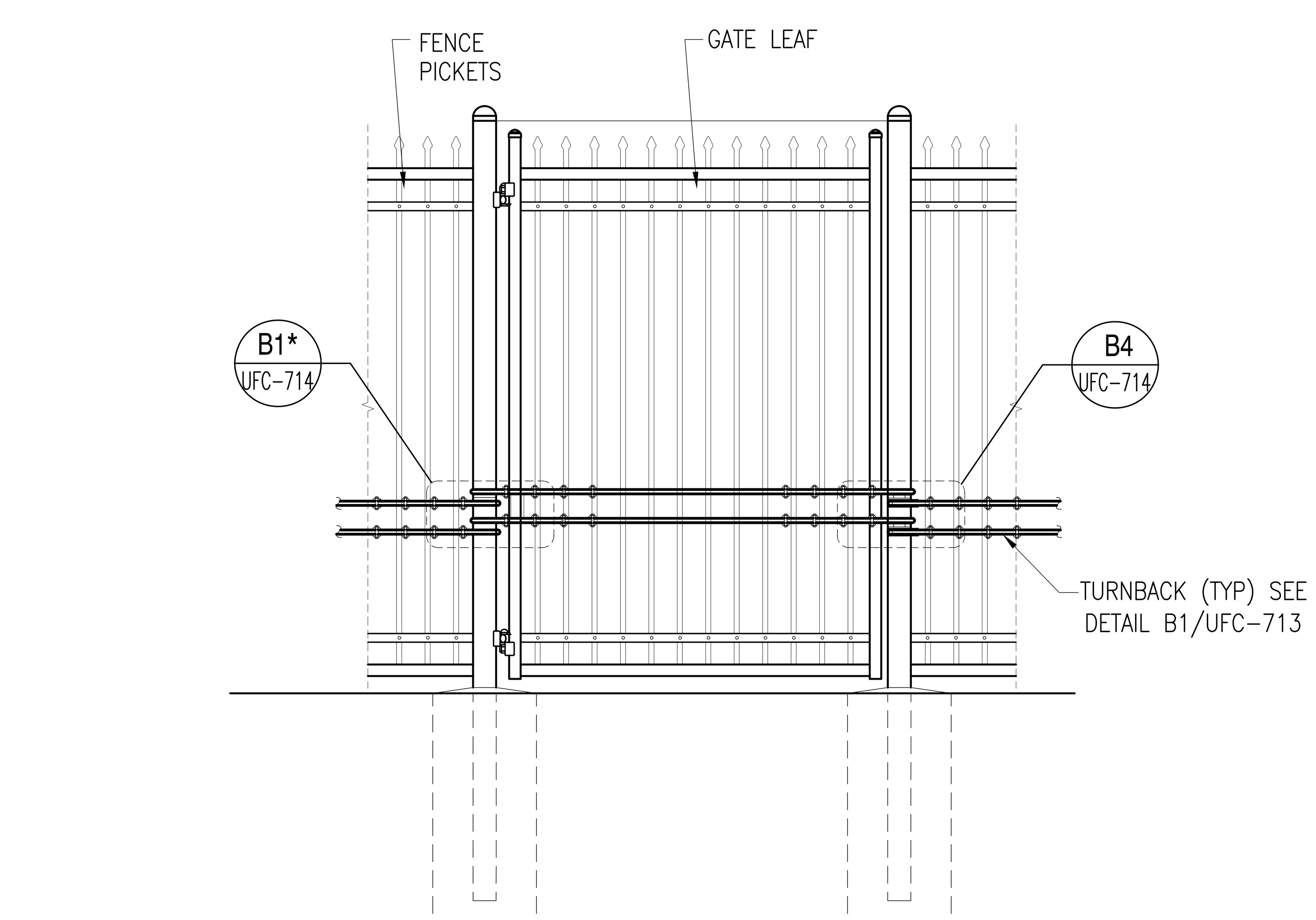
*NOTE: SEE DETAIL D1 ON SHEET UFC-714 FOR ALTERNATIVE METHOD.



*NOTE: SEE DETAIL D1 ON SHEET UFC-714 FOR ALTERNATIVE METHOD.

ELEVATION - TYP CABLE REINFORCING DOUBLE FOR SWING GATE
SCALE: 1/2" = 1'-0"

A1 CIVIL DWGS | UFC-722



ELEVATION - TYP CABLE REINFORCING SINGLE SWING GATE
SCALE: 1/2" = 1'-0"

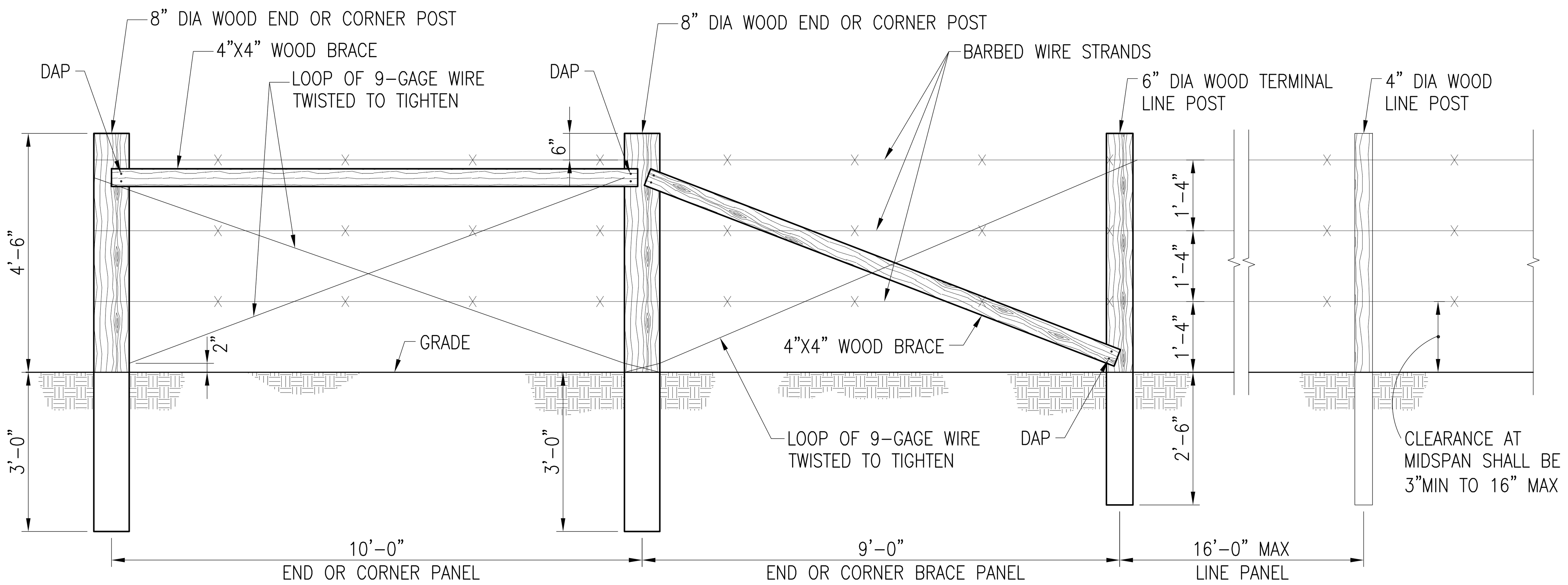
A3 CIVIL DWGS | UFC-722

GRAPHIC SCALES
1/2" = 1'-0" — 0 1' 2' 4'

UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

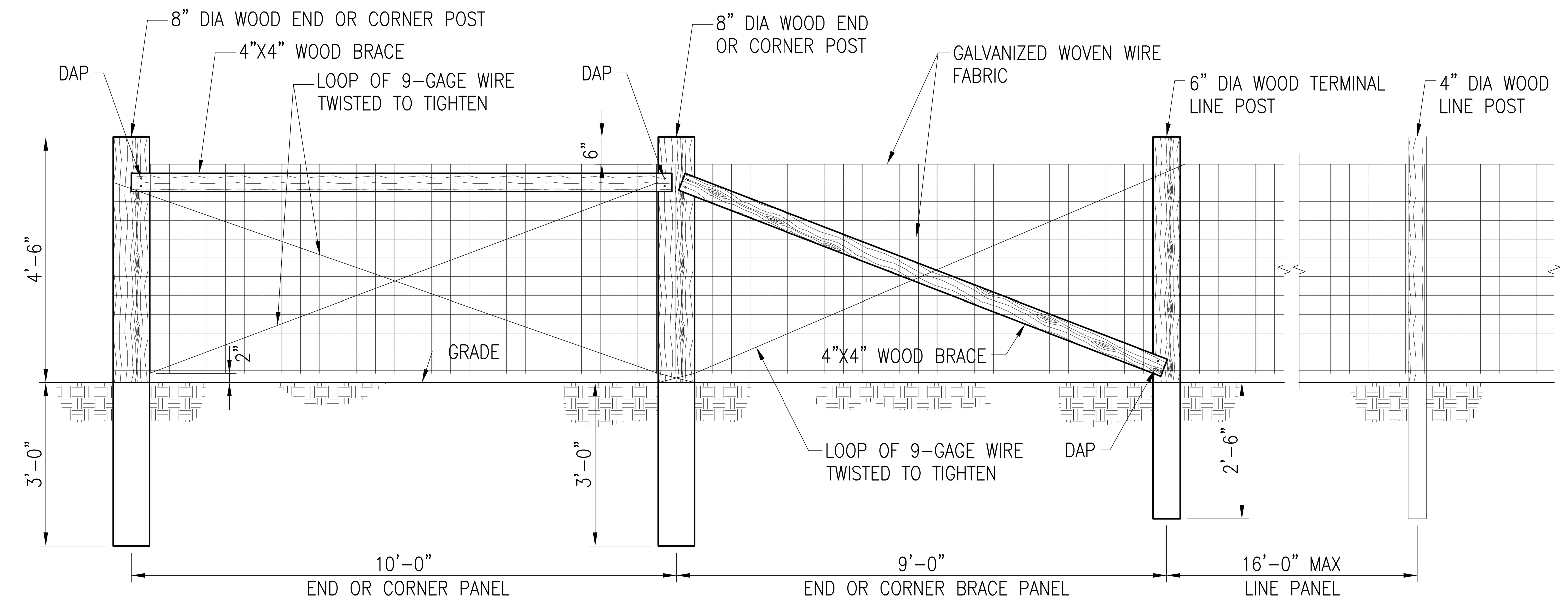
ORNAMENTAL CANTILEVERED AND SWING GATES AND CABLING DETAILS

UFC-722



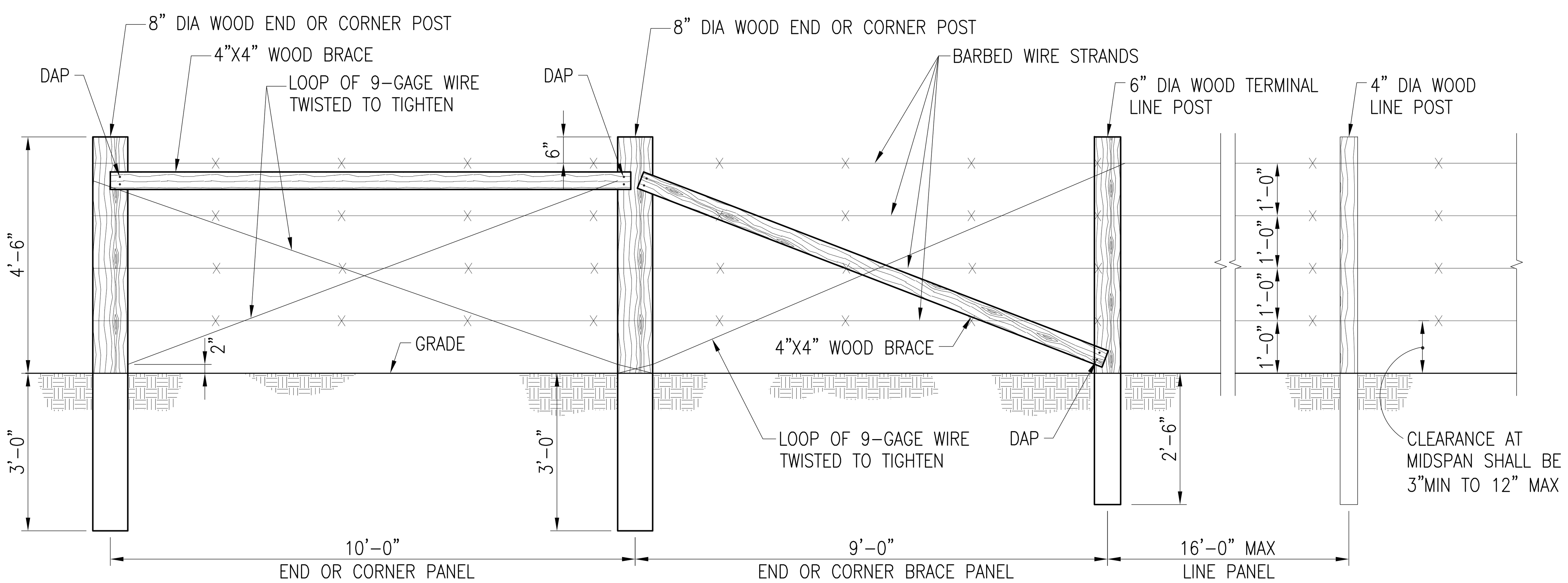
TYPICAL 3 STRAND BARBED WIRE FENCE

SCALE: 1/2" = 1'-0"



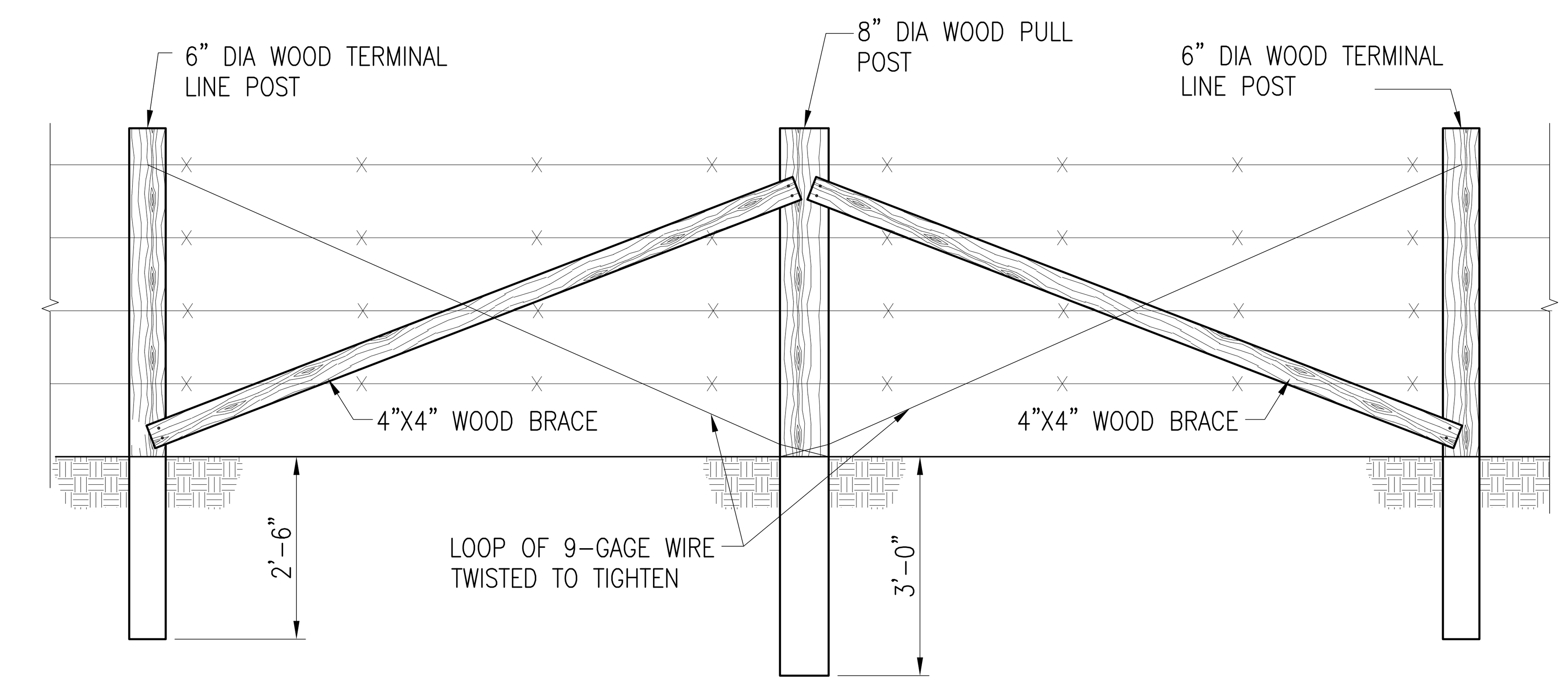
TYPICAL LAYOUT - WOVEN WIRE FENCE

SCALE: 1/2" = 1'-0"



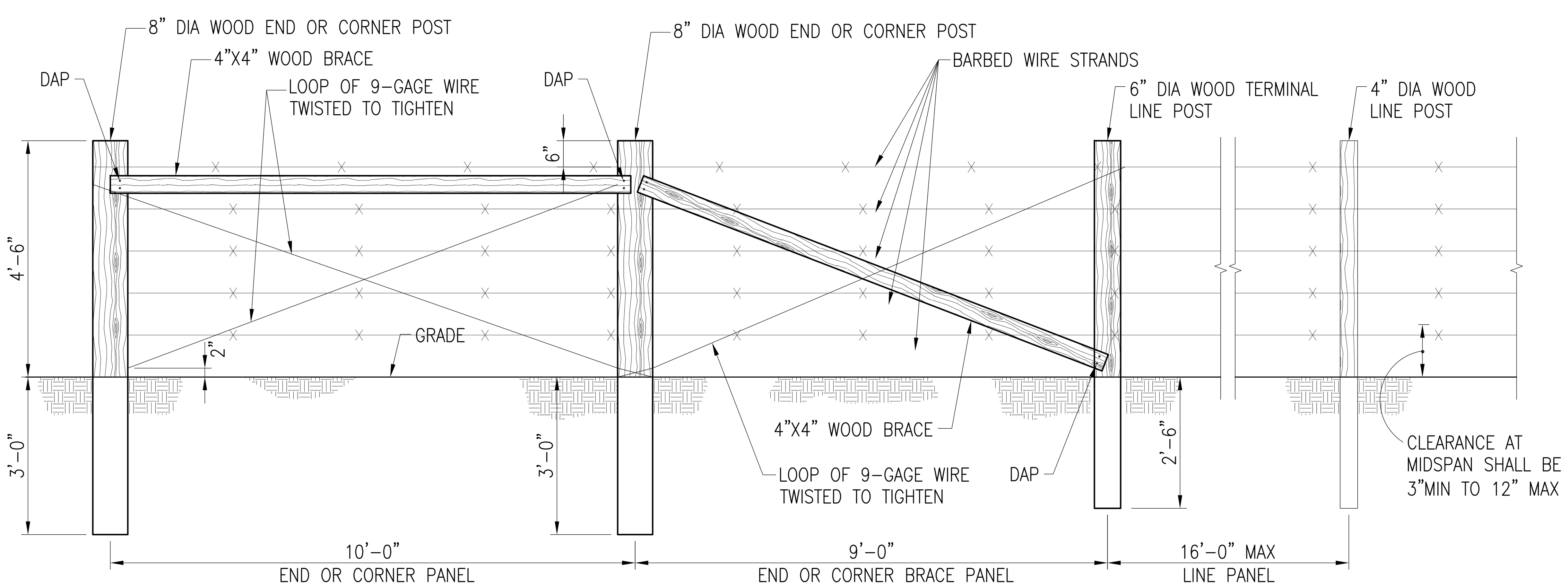
TYPICAL 4 STRAND BARBED WIRE FENCE

SCALE: 1/2" = 1'-0"



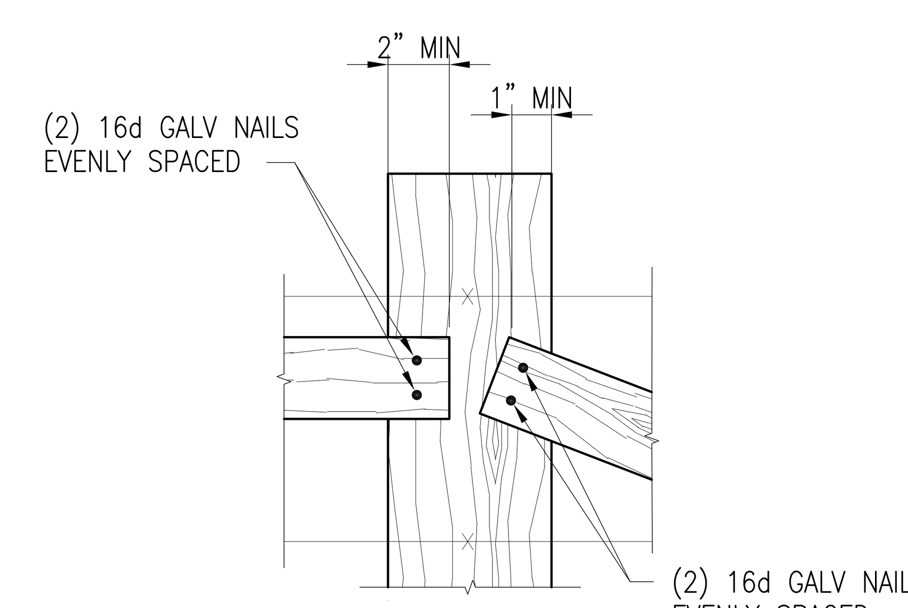
PULL POST BRACE PANEL DETAIL

SCALE: 1/2" = 1'-0"



TYPICAL 5 STRAND BARBED WIRE FENCE

SCALE: 1/2" = 1'-0"



DAP DETAIL

SCALE: 1 1/2" = 1'-0"

GENERAL NOTES

1. THE SPACING OF END OR CORNER PANEL AND BRACE PANEL OF 10'-0" AND 9'-0" IS MAXIMUM. WHEN CORNER OR END PANEL CONFLICTS WITH GATE OR CATTLE GUARD BRACE PANEL OR TWO CORNER PANELS CONFLICT, BRACING AND SPACING OF POSTS SHALL BE ALTERED TO PROVIDE ADEQUATE BRACING AS REQUIRED.
2. THE GATE SHOWN IS TYPICAL. ANY STANDARD COMMERCIAL GATE THAT VARIEW ONLY IN NON-ESSENTIAL DETAILS SHALL BE ACCEPTABLE, SUBJECT TO APPROVAL.
3. LATCH AND PIN FOR PANEL GATE REQUIRED, BUT NOT SHOWN.

GRAPHIC SCALES

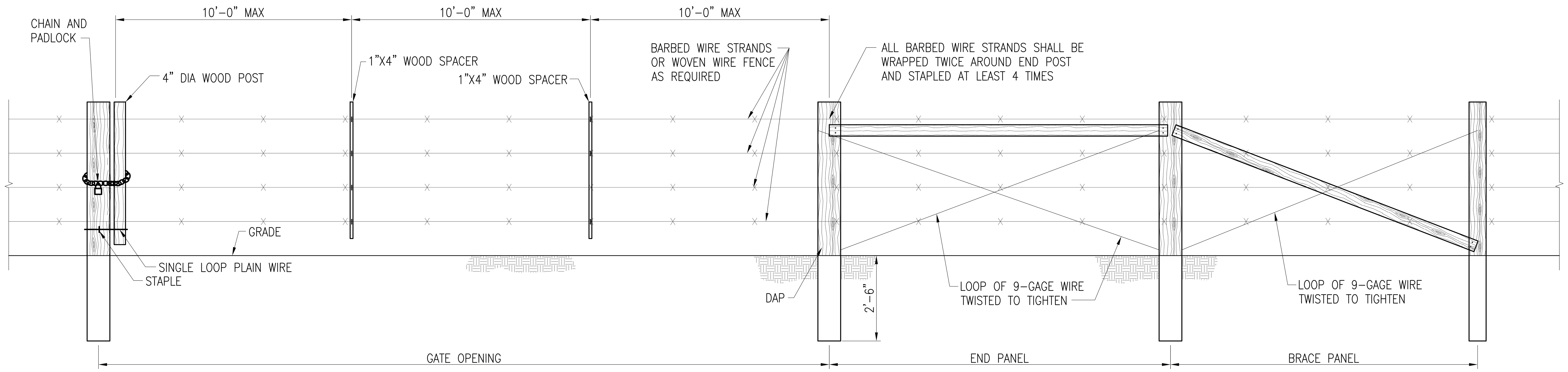
UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

FARM STYLE FENCES

UFC-730

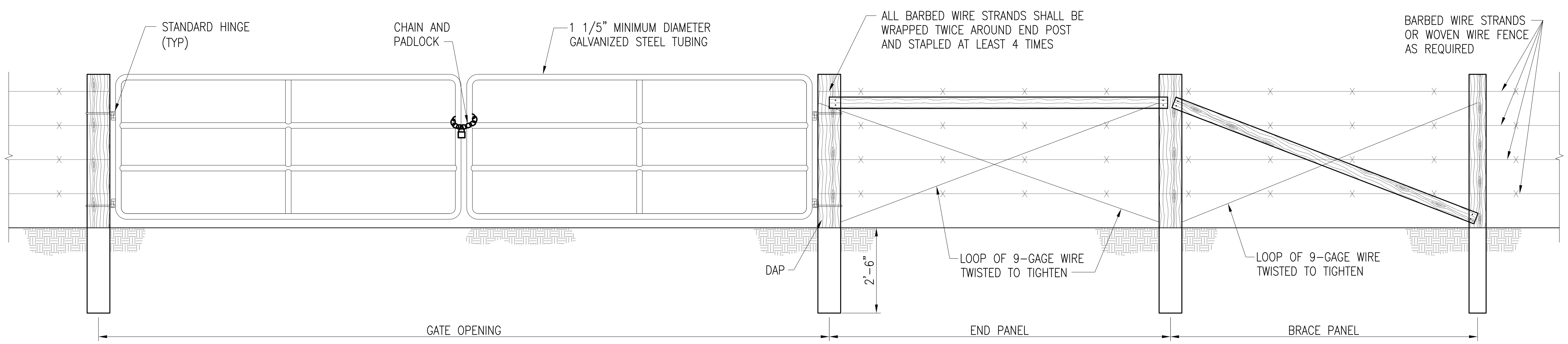
DRAWFORM REVISION: 24 AUGUST 2007

FILE NAME: J:\CICE\FENCE DRAWINGS\552005-UFC-730.dwg LAYOUT NAME: S-702 PLOTTED: Monday, April 29, 2013 - 2:35pm



TYPICAL BARBED WIRE DROP GATE ELEVATION

SCALE: 1/2" = 1'-0"



TYPICAL PANEL GATE ELEVATION

SCALE: 1/2" = 1'-0"

GRAPHIC SCALES

1/2" = 1'-0" 0 1' 2' 4'

UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

FARM STYLE GATES

UFC-731

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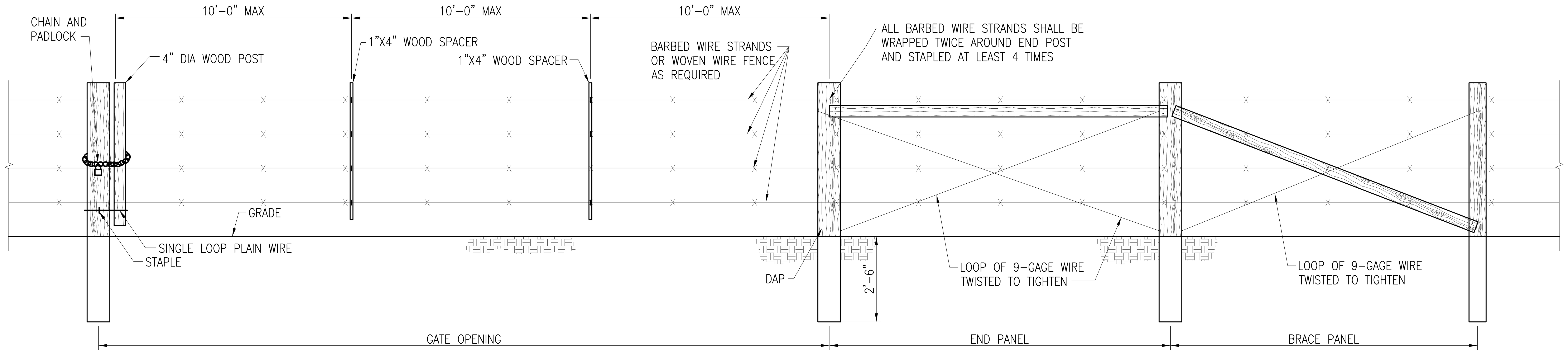
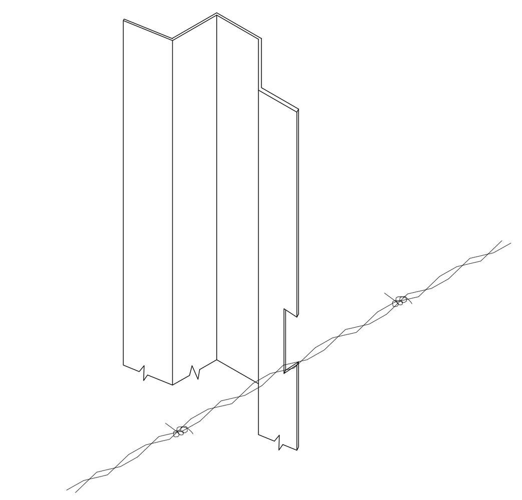


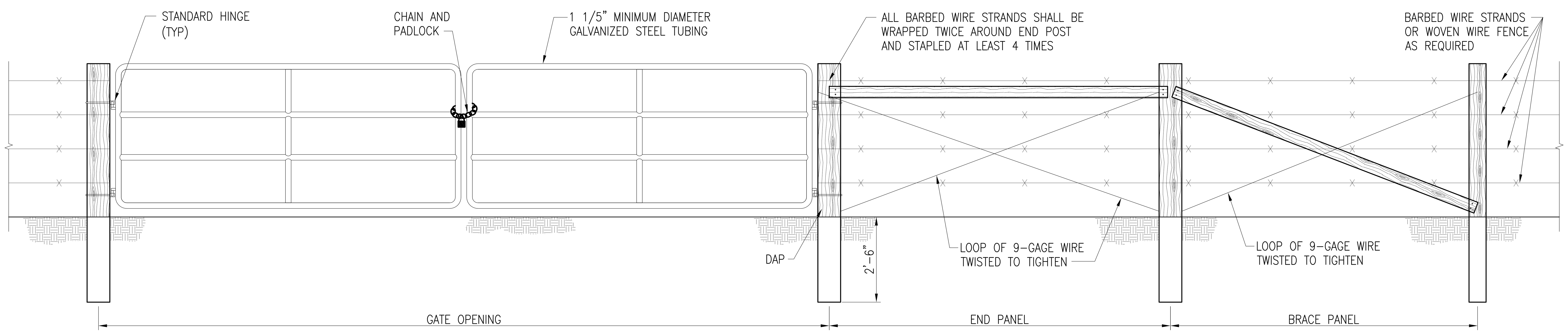
TYPICAL BARBED WIRE DROP GATE ELEVATION

SCALE: 1/2" = 1'-0"



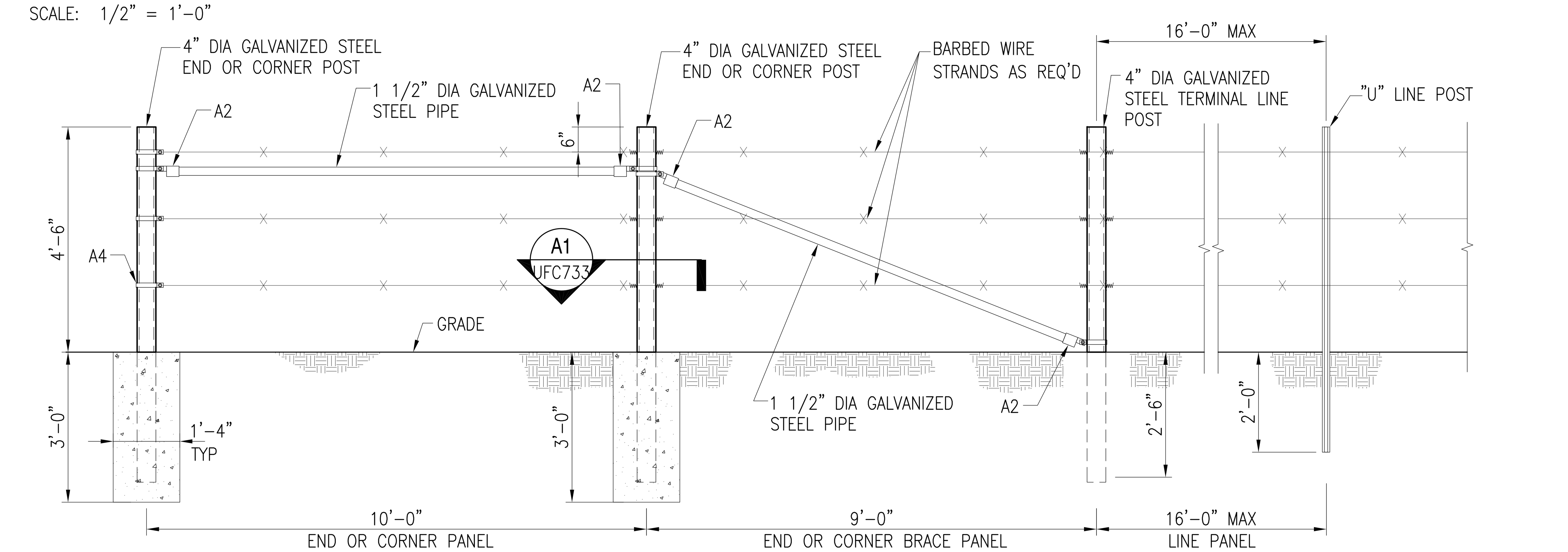
"U" LINE POST

NO SCALE



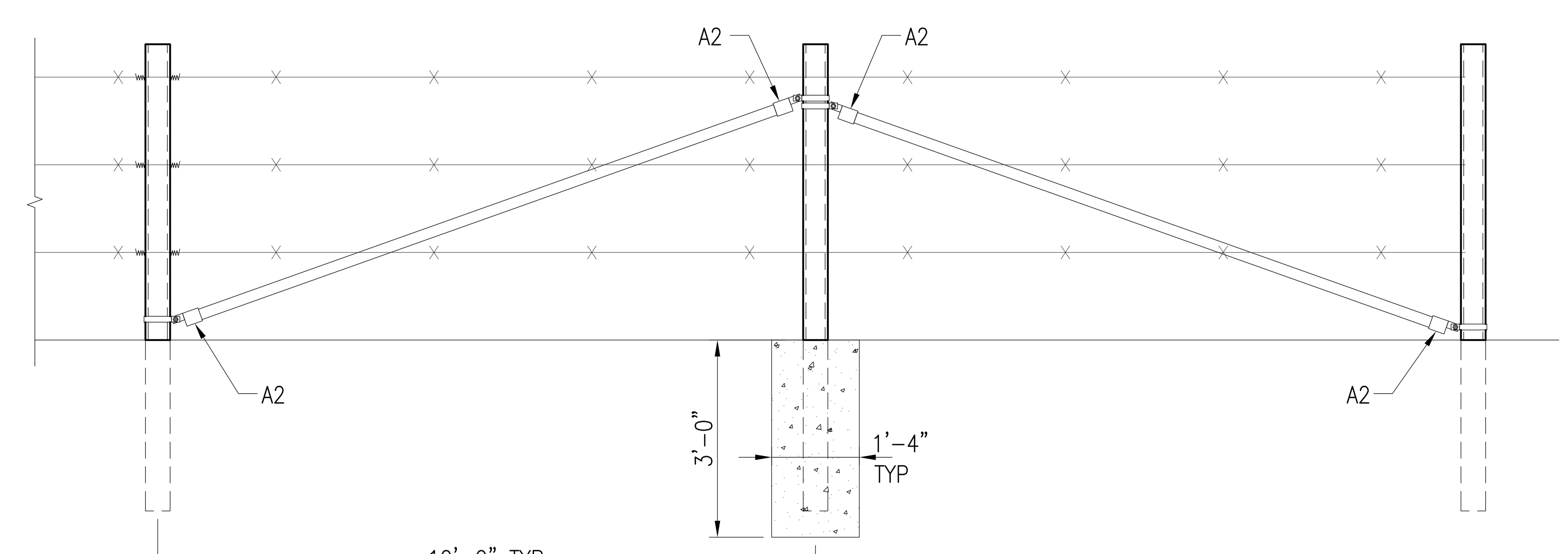
TYPICAL PANEL GATE ELEVATION

SCALE: 1/2" = 1'-0"



TYPICAL 3 STRAND BARBED WIRE FENCE WITH STEEL POSTS (FOR OTHER STRAND CONFIGURATIONS SEE SHEET 730)

SCALE: 1/2" = 1'-0"

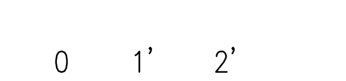


PULL POST PANEL - BARBED WIRE FENCE WITH STEEL POSTS

SCALE: 1/2" = 1'-0"

GRAPHIC SCALES

1/2" = 1'-0"



UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES
DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

FARM STYLE GATE AND FENCE DETAILS

UFC-732

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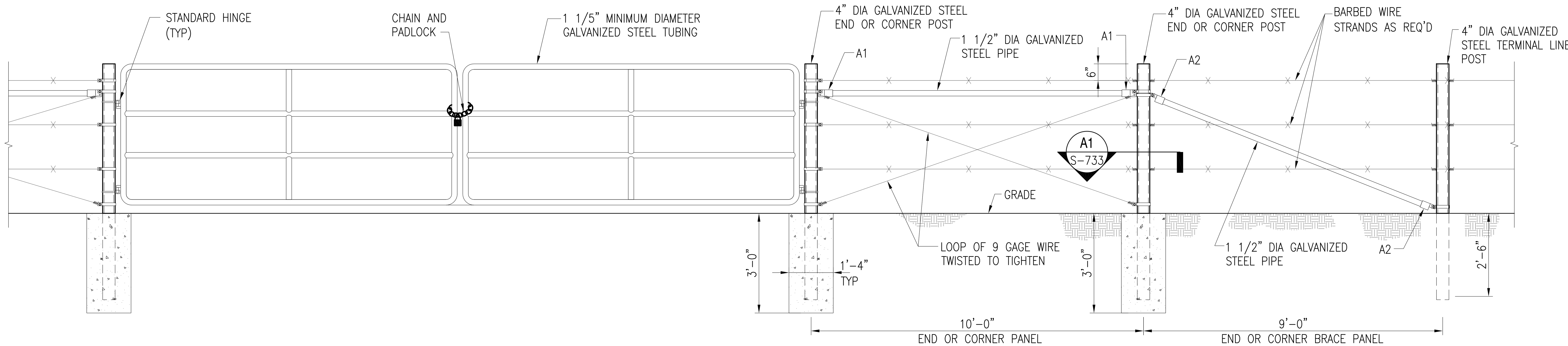
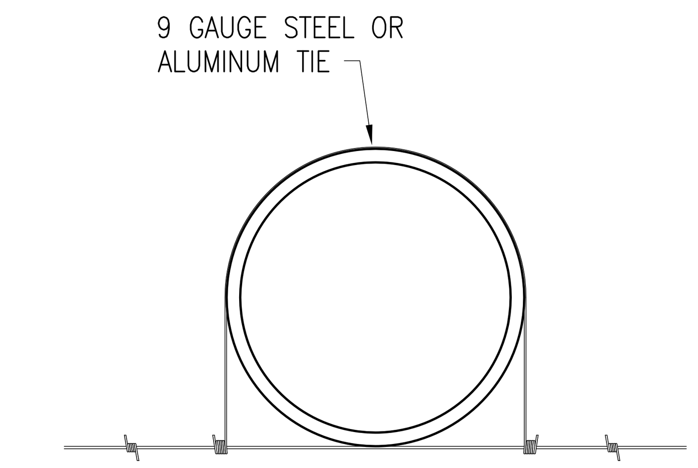


TYPICAL 3 STRAND BARBED WIRE FENCE WITH STEEL POSTS (FOR OTHER STRAND CONFIGURATIONS SEE SHEET 730)

SCALE: 1/2" = 1'-0"



SECTION A1

SCALE: 1/2" = 1'-0" UFC-732, UFC-733 UFC-733

GRAPHIC SCALES

1/2" = 1'-0" 0 1' 2' 4'

UNIFIED FACILITIES CRITERIA 4-022-03 SECURITY ENGINEERING: FENCES, GATES AND GUARD FACILITIES

DEFINITIVE DRAWINGS FOR SECURITY FENCING, GATES AND CABLING

FARM STYLE FENCES

UFC-733

DRAWFORM REVISION: 24 AUGUST 2007

FILE NAME: J:\CICE\FENCE DRAWINGS\552005-UFC-733.dwg LAYOUT NAME: S-702 PLOTTED: Monday, April 29, 2013 - 2:41pm

UFC 4-023-03
14 July 2009
Change 4, 10 June 2024

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN OF BUILDINGS TO RESIST PROGRESSIVE COLLAPSE

UFC 4-023-03
14 July 2009
Change 4, 10 June 2024

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN OF BUILDINGS TO RESIST PROGRESSIVE COLLAPSE

U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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

Change No.	**Date**	**Location**
1	27 January 2010	Changed all references from UFC 3-310-01 "Structural Load Data" to UFC 3-301-01 "Structural Engineering"
2	1 June 2013	Revised tie force equations; removed 0.9 factor and lateral loads from alternate path load combination; clarified definition of controlled public access; clarified live load reduction requirements; revised reinforced concrete and structural steel examples; added cold-formed steel example.
3	1 November 2016	Changed organization name to Air Force Civil Engineer Center (AFCEC), updated ASCE 41-13 references, changed all reference from “Occupancy Category” to “Risk Category”, added a footnote “A” for Risk Category IV & V in Table 2-2, added section 1-8 for Design Submittals and section 1-9 for Recommendations for Specification, updated Chapter 17 section numbering. Editorial changes throughout.
4	10 June 2024	Removed inconsistent language with UFC-4-010-01.

This UFC supersedes UFC 4-023-03, dated 25 January, 2005. The format of this document does not conform to UFC 1-300-01.

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 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 more 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 Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and, \3\Air Force Civil Engineer Center (AFCEC)/3/ are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request (CCR). The form is also accessible from the Internet sites listed below.

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

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

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Subject: UFC 4-023-03, Design of Structures to Resist Progressive Collapse

Cancels: UFC 4-023-03, Design of Structures to Resist Progressive Collapse, Dated 25 January 2005

Reasons for Change. UFC 4-023-03 was updated for the following reasons:

- Removed inconsistent language within UFC \4\ 4-010-01 /4/.

Description of Changes. This update to UFC 4-023-03 is a \4\ minor /4/ revision to the 25 January 2005 version. The \4\ /4/ changes include:

- \4\ Review use of modifiers “new” and “existing”
- Revise Section 1-2, APPLICABILITY to match information from the Security DWG
- Revised Section 1-2.1, Building Type and Story Height for clarity. /4/

Impact. The impact of this updated UFC 4-023-03 will vary depending upon the particular structure, structure type, location, and function. \4\ Retrofitting of existing buildings to resist progressive collapse is no longer mandatory, which aligns UFC 4-023-03 with UFC 4-010-01. /4/

Non-Unified Issues. Document content is unified and consistent for all services and agencies of the Department of Defense.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This Unified Facilities Criteria (UFC) provides the design requirements necessary to reduce the potential of progressive collapse for \4\ /4/ facilities that experience localized structural damage through normally unforeseeable events.

1-2 APPLICABILITY.

\4\ The requirements outlined in this UFC are mandatory for all new construction of buildings three or more stories. For existing buildings, these requirements may be applied as required by the project proponents or AHJ. /4/

1-2.1 Building Type and Story Height.

\4\ ~~/4/~~ For this UFC, penthouse structures and floors below grade (i.e., single and multiple level basements) will be considered a story if there is any space that is designed for human occupancy and that is equipped with means of egress as well as light and ventilation facilities that meet the local building code requirements. If any story will not be occupied, perhaps due to mechanical equipment or storage, that story will be omitted from the calculation of the number of stories.

At changes in building elevation from a one or two story section to a section with three or more stories, the appropriate progressive collapse design requirements from Section 2-2 shall be applied to the section with three or more stories. Special attention shall be given to potential deleterious effects associated with the attachment of the short building section to the building section with three or more stories.

1-2.2 Clarification for Partial Occupancy.

When DoD personnel occupy 25% or more of the net interior useable space, the requirements of this UFC are applicable to the entire structure, not just the portion of the building occupied by DoD personnel; this requirement supersedes that given in UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Buildings.*

\2\

1-2.3 Clarification for Controlled Public Access.

Per UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Buildings*, controlled public access will be considered to include (but not be limited to) electronic access control devices or mechanical locks on all exterior doors. Where visitor processing makes locking visitor entrances during building operating hours impractical, providing personnel to control visitor access can be considered positive control at those entrances.

/2/

1-2.4 Application by Other Organizations.

This UFC may be employed by other federal and state government agencies as well as organizations that create and implement building codes (e.g. International Building Code) and material specific design codes (e.g., American Institute of Steel Construction, American Concrete Institute, The Masonry Society, American Iron and Steel Institute, American Forest and Paper Association). The responsibility for determining applicability rests with the specifying agency.

The material contained herein is not intended as a warranty on the part of DoD that this information is suitable for any general or particular use. The user of this information assumes all liability arising from such use. This information should not be used or relied upon for any specific application without competent professional examination and verification.

1-3 GENERAL.

Progressive collapse is defined in the commentary of the American Society of Civil Engineers Standard 7 *Minimum Design Loads for Buildings and Other Structures* (ASCE 7) as "the spread of an initial local failure from element to element, eventually resulting in the collapse of an entire structure or a disproportionately large part of it." The standard further states that buildings should be designed "to sustain local damage with the structural system as a whole remaining stable and not being damaged to an extent disproportionate to the original local damage." As discussed in the commentary of ASCE 7, "except for specially designed protective systems, it is usually impractical for a structure to be designed to resist general collapse caused by severe abnormal loads acting directly on a large portion of it. However, structures can be designed to limit the effects of local collapse and to prevent or minimize progressive collapse." The structural design requirements presented herein were developed to ensure prudent precautions are taken when the event causing the initial local damage is undefined and the extent of the initial damage is unknown.

1-3.1 Significance of Progressive Collapse.

Progressive collapse is a relatively rare event, in the United States and other Western nations, as it requires both an abnormal loading to initiate the local damage and a structure that lacks adequate continuity, ductility, and redundancy to resist the spread of damage. However, significant casualties can result when collapse occurs. This is illustrated by the April 19, 1995 bombing of the Alfred P. Murrah building in Oklahoma City, in which the majority of the 168 fatalities were due to the partial collapse of the structure and not to direct blast effects. The recent escalation of the domestic and international terrorist threat has increased the probability that other US government structures will be attacked with explosives or other violent means.

1-3.2 Hardening of Structures to Resist Initial Damage.

As the initiating event is unknown, the requirements in this UFC are not intended to directly limit or eliminate the initial damage. This is consistent with UFC 4-010-01, which applies where there is a known risk of terrorist attack, but no specific terrorist threat is defined; in this case, the goal is to reduce the risk of mass casualties in the event of an attack. For cases where specific explosive threats against a building have been identified, the designer shall employ the appropriate design methodology for hardening the building. However, even though a structure is designed to resist an identified explosive threat, the progressive collapse design requirements herein shall still apply.

1-3.3 Risk Considerations.

Hazards and consequences are addressed in a typical risk assessment. Due to the limited database of progressive collapse events (from deliberate attack, vehicle impact, natural causes, etc), it is not possible to reasonably assess the probability of occurrence for a specific hazard or group of hazards. Therefore, the risk assessment reduces to a consideration of consequences. In general, consequences are measured in terms of human casualties and, therefore, the \3\ risk category /3/ of a building or structure is often the most critical issue. The progressive collapse design approaches in this UFC are primarily a function of the \3\ risk category /3/ of the building, although the structure's function is also considered. In Section 2-1, guidance is provided on choosing the \3\ Risk Category /3/ of a building, using the occupancy tables contained in UFC 3-301-01 *Structural Engineering*.

1-3.4 Design Approaches.

ASCE 7 defines two general approaches for reducing the possibility of progressive collapse: Direct Design and Indirect Design.

1-3.4.1 Direct Design Approaches.

Direct Design approaches include "explicit consideration of resistance to progressive collapse during the design process…" These include: 1) the Alternate Path (AP) method, which requires that the structure be capable of bridging over a missing structural element, with the resulting extent of damage being localized, and 2) the Specific Local Resistance (SLR) method, which requires that the building, or parts of the building, provide sufficient strength to resist a specific load or threat.

1-3.4.2 Indirect Design Approaches.

With Indirect Design, resistance to progressive collapse is considered implicitly "through the provision of minimum levels of strength, continuity and ductility". The commentary in ASCE 7 goes on to present general design guidelines and suggestions for improving structural integrity. These include: 1) good plan layout, 2) integrated system of ties, 3) returns on walls, 4) changing span directions of floor slabs, 5) load-bearing interior partitions, 6) catenary action of the floor slab, 7) beam action of the walls, 8) redundant structural systems, 9) ductile detailing, 10) additional reinforcement for blast and load reversal, if the designer must consider explosive loads, and 11) compartmentalized construction. However, no quantitative requirements for either direct or indirect design to resist progressive collapse are provided in ASCE 7.

In this UFC, Tie Forces (TF) are used to enhance continuity, ductility, and structural redundancy by specifying minimum tensile forces that must be used to tie the structure together. This approach is similar to that employed by the British after the Ronan Point apartment building collapse in 1968 and currently used in the Eurocode.

1-4 SUMMARY OF THE PROGRESSIVE COLLAPSE DESIGN PROCEDURE.

For \4\ /4/ the level of progressive collapse design for a structure is correlated to the \3\ risk category /3/ (RC). The RC will either be assessed per Section 2-1.

The design requirements in this UFC were developed such that varying levels of resistance to progressive collapse are specified, depending upon the RC as discussed in Chapter 2. These levels of progressive collapse design employ:

- Tie Forces, which prescribe a tensile force strength of the floor or roof system, to allow the transfer of load from the damaged portion of the structure to the undamaged portion,
- Alternate Path method, in which the building must bridge across a removed element, and
- Enhanced Local Resistance, in which the shear and flexural strength of the perimeter columns and walls are increased to provide additional protection by reducing the probability and extent of initial damage.

1-5 REFERENCES.

This UFC incorporates provisions from other publications by dated or undated reference. These references are cited at the appropriate places in the text and the citations for the publications are listed in Appendix A References. For dated references, subsequent amendments to, or revisions of, any of these publications apply to this UFC only when incorporated in it by amendment or revision. For undated references, the latest edition of the referenced publication applies (including amendments).

1-6 INSPECTION REQUIREMENTS.

Inspection requirements to verify conformance with this UFC are provided in Appendix H. These inspection requirements are modifications to the provisions of the International Building Code (IBC), which cover construction documents, structural tests and special inspections for buildings that have been designed to resist progressive collapse.

1-7 SECURITY ENGINEERING UFC SERIES.

This UFC is one of a series of security engineering Unified Facilities Criteria that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include the following:

DoD Minimum Antiterrorism Standards for Buildings. UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Buildings* and UFC 4-010-02 *DoD Minimum Standoff Distances for Buildings* establish standards that provide minimum levels of protection against terrorist attacks for the occupants of all DoD inhabited buildings. These UFC are intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings. They also include recommendations that should be, but are not required to be, incorporated into all such buildings.

Security Engineering Facility Planning Manual. UFC 4-020-01*Security Engineering Facility Planning Manual* presents processes for developing the design criteria necessary to incorporate security and antiterrorism features into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards, or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also includes a means to assess the tradeoffs between cost and risk. The Security Engineering Facility Planning Manual is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

Security Engineering Facility Design Manual. UFC 4-020-02 *Security Engineering Facility Design Manual* provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02 is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design. The manual also provides a process for assessing the impact of protective measures on risk. The primary audience for the Security Engineering Facility Design Manual is the design team, but security and antiterrorism personnel can also use it.

Security Engineering Support Manuals. In addition to the standards, planning, and design UFC mentioned above, there is a series of additional UFC that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, forced entry, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mailrooms. Still others address details of designs for specific protective measures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

\3\

1-8 DESIGN SUBMITTALS.

Design submittals for DoD projects requiring compliance with these criteria will include the following elements as a minimum;

- Narratives of the design includes the Risk Category, Design Approach (Tie Forces (TF) or Alternate Path (AP), and Design Method (Linear Static, Nonlinear Static or Nonlinear Dynamic),
- A list of the design software used to perform the progressive collapse mitigation, and
- The electronic input files for all phases of the design review.

1-9 RECOMMENDATIONS FOR SPECIFICATION.

Additional recommended specification language for new and existing buildings is included in Appendix C-11. The recommendations in this document include the sample paragraphs for the Request-For-Proposal (RFP) specification.

/3/

CHAPTER 2 PROGRESSIVE COLLAPSE DESIGN REQUIREMENTS FOR NEW AND EXISTING CONSTRUCTION

For both new and existing buildings, the level of progressive collapse design will be based on the \3\ risk category /3/ (RC) of the structure. The \3\ risk category /3/ will be determined per Section 2-1. The RC is used to define the corresponding level of progressive collapse design for new and existing construction as detailed in Section 2-2.

Chapter 3 Design Procedures provides the approaches and requirements for applying Tie Forces (TF), Alternate Path (AP), and Enhanced Local Resistance (ELR). The overall techniques for these three approaches are the same for each construction type, but the details may vary with material type. Chapters 4 through 8 provide the material specific design requirements. Finally, Appendix C provides insight into the development of these approaches.

2-1 \3\RISK CATEGORY/3/ DETERMINATION.

Determine the \3\Risk Category (RC) /3/ of a particular structure by using Table 2-1 for the situation that most closely matches the building. The Risk Category is taken from the risk category definitions in \1\ UFC 3-301-01 *Structural Engineering* /1/*;* the RC level can be considered as a measure of the consequences of a progressive collapse event and is based on two main factors: level of occupancy and building function or criticality.

Table 2-1. Risk Categories

Nature of Occupancy	\3\Risk Category/3/ [C]
• Buildings in Risk Category I in \1\ Table 2-2 of UFC 3-301-01. /1/ • Low Occupancy Buildings[A]	I
• Buildings in Risk Category II in \1\ Table 2-2 of UFC 3-301-01. /1/ • Inhabited buildings with less than 50 personnel, primary gathering buildings, billeting, and high occupancy family housing[A,B]	II
• Buildings in Risk Category III in \1\ Table 2-2 of UFC 3-301-01. /1/	III
• Buildings in Risk Category IV in \1\ Table 2-2 of UFC 3-301-01. /1/ • Buildings in Risk Category V in \1\ Table 2-2 of UFC 3-301-01. /1/	IV

[A] As defined by UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Buildings*
[B] Risk Category II is the minimum occupancy category for these buildings, as their population or function may require designation as Risk Category III, IV, or V.
\2\ [C] Section 1604.5.1 Multiple occupancies of the International Building Code (IBC) is applicable for determination of the Risk Category including the provisions for structurally separated structures. /2/

2-2 DESIGN REQUIREMENTS \4\./4/.

The design requirements for each \3\ risk category /3/ (RC) are shown in Table 2-2. The details are provided in the following sections.

Table 2-2. Risk Categories and Design Requirements

\3\ Risk Category /3/	Design Requirement
I	No specific requirements
II	Option 1: Tie Forces (TF) for the entire structure and Enhanced Local Resistance (ELR) for the corner and penultimate columns or walls at the first story. **OR** Option 2: Alternate Path (AP) for specified column and wall removal locations.
III	Alternate Path for specified column and wall removal locations and Enhanced Local Resistance (ELR) for all perimeter first story columns or walls.
IV[A]	Tie Forces and Alternate Path for specified column and wall removal locations and Enhanced Local Resistance for all perimeter first story columns or walls.

\3\ [A] For buildings in Risk Category IV in Table 2-2 of UFC 3-301-01, the minimum structural requirements for Tie Force application in Section 3-1.1 can be exempted. The minimum structural requirements shall remain for buildings in Risk Category V. /3/

2-2.1 \3\ Risk Category /3/ I Design Requirement.

Progressive collapse design is not required for these structures.

2-2.2 \3\ Risk Category /3/ II Design Requirement.

For RC II structures, one of two options may be chosen. In the first, the designer shall incorporate the Tie Force requirement for the entire structure and Enhanced Local Resistance for the first story corner and penultimate columns and walls (a penultimate column or wall is the closest column or wall to the corner). In the second option, the designer shall design or analyze the building with the Alternate Path method to show that the structure can bridge over the removal of columns, load-bearing walls, or beams supporting columns or walls at specified locations.

2-2.2.1 Option 1 for \3\ Risk Category /3/ II: Tie Force and Enhanced Local Resistance.

The requirements in 2-2.2.1.1 and 2-2.2.1.2 for Tie Forces and Enhanced Local Resistance shall be satisfied, if this option is chosen.

2-2.2.1.1 Tie Force Requirement for RC II Option 1.

The procedure and requirements for Tie Forces for framed and load-bearing wall structures are presented in Section 3-1.

If a vertical structural member cannot provide the required vertical tie force strength, either re-design the member or use the AP method to prove that the structure can bridge over the element when it is removed.

For elements with inadequate horizontal tie force strength, the designer shall re-design the element in the case of new construction or retrofit the element in the case of existing construction. The AP method cannot be used as an alternative for inadequate horizontal ties.

2-2.2.1.2 Enhanced Local Resistance Requirement for RC II Option 1.

The Enhanced Local Resistance requirement is applied to the first story corner and penultimate columns and walls only. For this requirement for RC II Option 1, the flexural demand of the column or wall is not increased; however, the design shear strength of the column or wall and the connections to the slabs, floor system or other lateral load resisting elements shall be greater than the shear demand associated with the flexural demand of the component. The procedure is presented in Section 3-3.

2-2.2.2 Option 2 for \3\ Risk Category /3/ II: Alternate Path.

If the Alternate Path requirement is chosen, then the structure shall be able to bridge over vertical load-bearing elements that are notionally removed one at a time from the structure at specific plan and elevation locations, as required in Section 3-2. The procedures and general requirements for the Alternate Path method are provided in Section 3-2 with specific requirements for each material given in Chapters 4 through 8. If bridging cannot be demonstrated for one of the removed load-bearing elements, the structure shall be re-designed or retrofitted to increase the bridging capacity.

If the results of the analyses are similar for multiple locations due to the redundancy of the building, a formal analysis is not required for every location, provided that one typical analysis is performed, and that this observation is annotated in the design documents.

Note: for load-bearing wall structures, the Alternate Path approach will often be the most practical choice.

2-2.3 \3\ Risk Category /3/ III Design Requirement.

For \3\ Risk Category /3/ III, two requirements shall be satisfied: Alternate Path and Enhanced Local Resistance as discussed in the following sections.

2-2.3.1 Alternate Path Requirement for \3\ Risk Category /3/ III.

The structure shall be able to bridge over vertical load-bearing elements that are notionally removed one at a time from the structure at specific plan and elevation locations, as required in Section 3-2. If bridging cannot be demonstrated for one of the removed load-bearing elements, the structure shall be re-designed or retrofitted to increase the bridging capacity. Note that the structural re-design or retrofit is not applied to just the deficient element, i.e., if a structure cannot be shown to bridge over a removed typical column at the center of the long side, the engineer shall develop suitable or similar re-designs or retrofits for that column and other similar columns.

The procedures and general requirements for the Alternate Path method are provided in Section 3-2 with specific requirements for each material given in Chapters 4 through 8.

2-2.3.2 Enhanced Local Resistance Requirement for \3\ Risk Category /3/ III.

The Enhanced Local Resistance requirement is applied to all first story perimeter columns and walls. For this requirement, for RC III, the flexural demand of the column or wall need not be increased; however, the design shear strength of the column or wall and the connections to the slabs, floor system or other lateral load resisting elements shall be greater than the shear demand associated with the flexural demand of the component. The procedure is presented in Section 3-3.

2-2.4 \3\ Risk Category /3/ IV Design Requirement.

The design requirements for \3\ Risk Category /3/ IV include Alternate Path, Tie Forces and Enhanced Local Resistance as discussed in the following paragraphs.

2-2.4.1 Tie Force Requirement for \3\ Risk Category /3/ IV.

For RC IV, the designer shall provide adequate internal, peripheral and vertical Tie Force strengths. The procedure and requirements for applying the Tie Force approach are provided in Section 3-1.

If a structural member cannot provide the required vertical tie force strength, the designer shall either re-design the member or use the Alternate Path method to prove that the structure can bridge over the element when it is removed. For elements with inadequate horizontal tie force strength, the Alternate Path method cannot be used. In this case, the designer shall re-design the element in the case of new construction or retrofit the element for existing construction.

The minimum structural requirements for Tie Force application in Section 3-1.1 can be exempted for \3\ Risk Category /3/ IV, however, for \3\ Risk Category /3/ V, the minimum structural requirements shall remain.

2-2.4.2 Alternate Path Requirement for \3\ Risk Category /3/ IV.

For RC IV, use the same AP requirement as for RC III; see Section 2-2.3.1.

2-2.4.3 Enhanced Local Resistance Requirement for \3\ Risk Category /3/ IV.

The Enhanced Local Resistance requirement is applied to all first story perimeter columns and walls. The flexural demand of the columns and walls for a design with only gravity loads meeting the AP requirements shall be increased respectively by a factor of 2 and a factor of 1.5 and compared to the flexural demands for the building as designed to meet the AP requirements and all other building code requirements; the larger of these two flexural demands is used to determine the shear demand. The design shear strength of the column or wall and the connections to the slabs, floor system or other lateral load resisting elements shall be greater than this shear demand. Procedures for Enhanced Local Resistance are given in Section 3-3.

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CHAPTER 3 DESIGN PROCEDURES

The progressive collapse design requirements employ three design/analysis approaches: Tie Forces (TF), Alternate Path (AP), and Enhanced Local Resistance (ELR). This chapter discusses the required procedures for these approaches.

3-1 TIE FORCES.

In the Tie Force approach, the building is mechanically tied together, enhancing continuity, ductility, and development of alternate load paths. Tie forces can be provided by the existing structural elements that have been designed using conventional design methods to carry the standard loads imposed upon the structure. There are three horizontal ties that must be provided: longitudinal, transverse, and peripheral. Vertical ties are required in columns and load-bearing walls. Figure 3-1 illustrates these ties for frame construction. Note that these “tie forces” are different from “reinforcement ties” as defined in ACI 318 *Building Code Requirements for Structural Concrete*.

Unless the structural members (beams, girders, spandrels) and their connections can be shown capable of carrying the required longitudinal, transverse, or peripheral tie force magnitudes while undergoing rotations of 0.20-rad (11.3-deg), the longitudinal, transverse, and peripheral tie forces are to be carried by the floor and roof system. Acceptable floor and roof systems include cast-in-place concrete, composite decks, and precast concrete floor planks with concrete topping, reinforcement, and mechanical anchorage that meet the requirements of Sections 3-1.4 through 3-1.6. Other floor or roof systems may be used, provided that the ability to carry the required tie strength while undergoing rotations of 0.20-rad (11.3-deg) is adequately demonstrated to and approved by an independent third-party engineer or by an authorized representative of the facility owner.

\2\ Note: The use of structural composites such as fiber reinforced polymer (FRP) to provide the tie forces is not acceptable unless the designer can prove that the FRP is capable of meeting the rotation requirement of 0.20-rad (11.3-deg) specified in the previous paragraph. Also, the tie force design must not allow portions of the structure to break free and fall to the floor above, i.e., positive mechanical anchorage or connection must be provided between the tie force members and the other structural elements (floors, beams, etc). /2/

\2\

3-1.1 Minimum Structural Requirements for Tie Force Application.

To apply the Tie Force method, the structure must meet the requirements listed in the following paragraphs.

For framed and two-way load-bearing wall structures, the number of bays in both directions must be four or greater. A bay is defined as the square or rectangular floor area with boundaries demarked by vertical load-bearing elements, such as columns at the corners or load-bearing walls along the edges.

For one-way load-bearing wall structures, the number of bays in the one-way span direction must be four or greater. The length of the load-bearing walls (or width of the building) must be at least $4\ h_w$ where h_w is the clear story height.

/2/

3-1.2 Load and Resistance Factor Design for Tie Forces.

Following the Load and Resistance Factor Design (LRFD) approach, the design tie strength is taken as the product of the strength reduction factor, Φ, and the nominal tie strength R_n calculated in accordance with the requirements and assumptions of applicable material specific codes. Include any over-strength factors provided in Chapters 9 to 11 of ASCE 41, where these over-strength factors are referred to as "factors to translate lower bound material properties to expected strength material properties" and are given in Tables 9-3 (structural steel), 10-4 (reinforced concrete), and 11-2 (masonry). For wood and cold-formed steel, Chapter 12 of ASCE 41 provides default expected strength values; note that for wood construction, a time effect factor λ is also included. Per the LRFD approach, the design tie strength must be greater than or equal to the required tie strength:

$$\Phi R_n \geq R_u \qquad \text{Equation (3-1)}$$

where
- ΦR_n = Design tie strength
- Φ = Strength reduction factor
- R_n = Nominal tie strength calculated with the appropriate material specific code, **including the over-strength factors from Chapters 5 to 8 of ASCE 41.**
- R_u = $\Sigma \gamma_i Q_i$ = Required tie strength
- γ_i = Load factor
- Q_i = Load effect

The required tie strengths are provided in the following sub-sections for framed and load-bearing wall structures.
\2\/2/

3-1.3 Floor Loads.

3-1.3.1 Uniform Floor Load.

Use the floor load in Equation 3-2 to determine the required tie strengths:

$$w_F = 1.2D + 0.5L \qquad \text{Equation (3-2)}$$

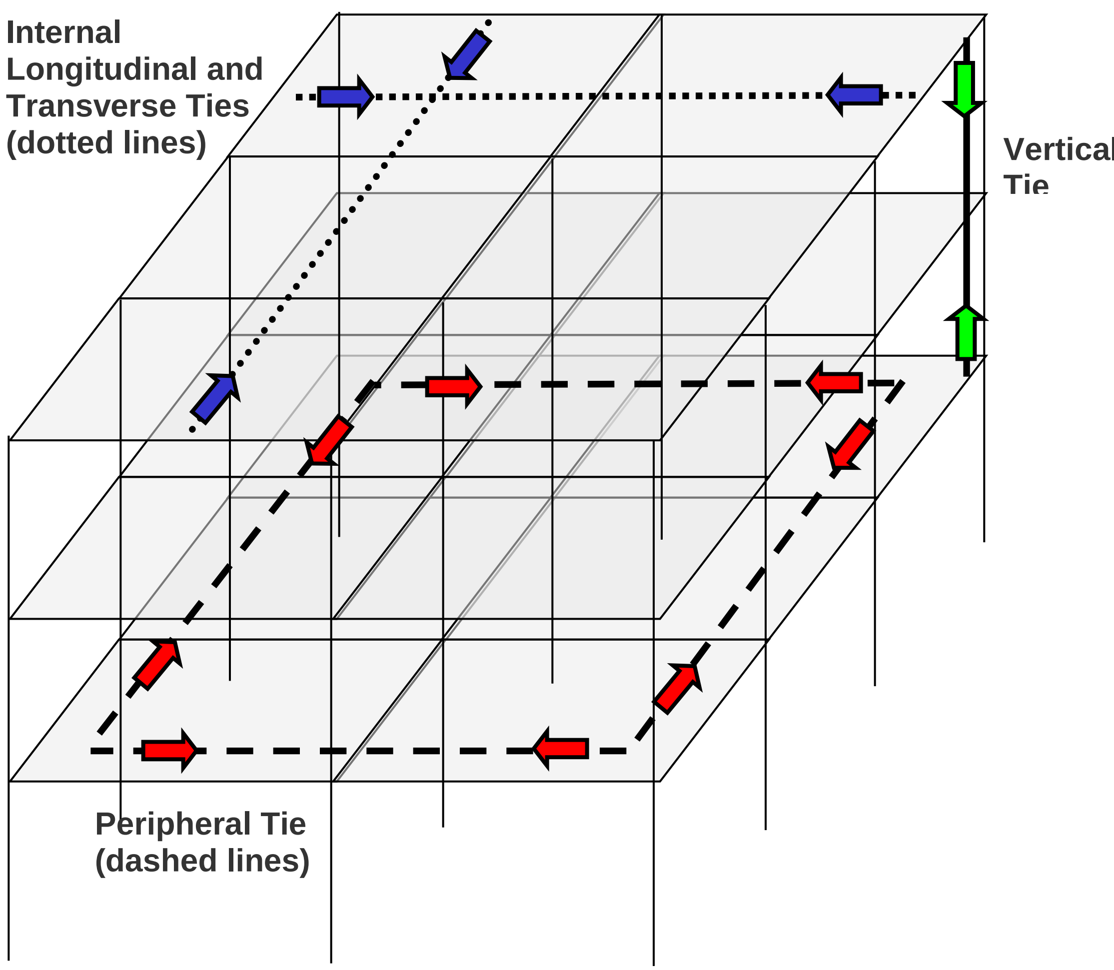
Where w_F = Floor Load (lb/ft^2 or kN/m^2)

D = Dead Load (lb/ft^2 or kN/m^2)
L = Live Load (lb/ft^2 or kN/m^2)

If the Dead Load or Live Load vary over the plan of the floor, use the procedure in Section 3-1.3.2 to determine the effective w_F.

\2

Figure 3-1. Tie Forces in a Frame Structure



NOTE: 1. Peripheral, longitudinal and transverse ties are not required in floors above crawlspaces if public access control is provided.
2. Vertical ties are not required to extend to the foundation and shall be straight. /2/

3-1.3.2 Consideration for Non-Uniform Load Over Floor Area.

3-1.3.2.1 Concentrated Loads.

If a concentrated load is located within a bay or one portion of the bay has a different loading than the rest of the bay, distribute the load evenly over the bay area and include in the dead or live load, as appropriate, in Equation 3-2.

3-1.3.2.2 Load Variations.

The load magnitude may vary significantly over the plan area of a given story, e.g. manufacturing activities may be located in one section of the floor and office space in another; see Figure 3-2. Calculate the floor load for each bay using Equation 3-2. Determine the effective floor load that will be used to determine the longitudinal, transverse, and peripheral Tie Forces, as follows:

1) If the difference between the minimum and maximum floor load in the bays on the floor plan is less than or equal to 25% of the minimum floor load and the area associated with the maximum floor load is

   a. Less than or equal to 25% of the total floor plan area, use an effective w_F, calculated by computing the total force acting on the floor and dividing by the total plan area.

   b. Greater than 25% of the floor plan, use the maximum floor load as the effective w_F.

2) If the difference between the minimum and maximum floor load in the bays on the floor plan is greater than 25% of the minimum floor load, either:

   a. Use the maximum floor load as the effective w_F, or,

   b. Divide the floor plan into sub-areas, where a sub-area is a region composed of contiguous or adjacent bays that have the same floor load. Each sub-area shall have its own longitudinal and transverse ties and peripheral ties. In addition, a peripheral tie will be placed in the boundary between the sub-areas, as shown in Figure 3-2. The required strength of the peripheral tie between the sub-areas shall be equal to the sum of the required peripheral tie force on the heavily loaded sub-area and the required peripheral tie force on the lightly loaded sub-area. In this case, the internal ties are not required to be continuous from one side of the structure to the other but may be interrupted at the sub-area peripheral tie, providing that the internal ties from both sub-areas are properly anchored with seismic hooks to the sub-area peripheral tie. If desired, the longitudinal and transverse internal ties on the lightly loaded sub-area may be continued across the heavily loaded sub-area as part of the longitudinal and transverse internal ties of the heavily loaded side. Note that sufficient embedment or anchoring must be provided to develop the strength of all peripheral ties, at the sub-area boundary and at the exterior of the building.

c. Note that the peripheral tie between the sub-areas may be omitted if the transverse and longitudinal ties from the heavily loaded sub-area continue across the lightly loaded sub-area and are anchored to the exterior peripheral ties. For instance, in Figure 3-2, the longitudinal ties from the heavily loaded sub-area could extend the full length of the floor plan, the transverse ties from the heavily loaded sub-area in the three left bays could extend the full width of the floor plan and transverse ties from the lightly loaded sub-area in the right two bays could extend the full width of the floor plan.

3-1.3.3 Cladding and Façade Loads.

Cladding and façade loads are used for the calculation of the peripheral and vertical tie forces and are omitted for the transverse and longitudinal tie calculations.

3-1.4 Required Tie Strength, Distribution, and Location.

The required tie strength, distribution, and location for longitudinal, transverse, peripheral, and vertical ties are defined in the following sub-sections for framed and load-bearing wall structures.

The design tie strengths are considered separately from the forces that are typically carried by each structural element due to live load, dead load, wind load, etc In other words, the design tie strength of a slab, beam, column, rebar, or connection **with no other loads acting** must be greater than or equal to the required tie strength. In addition, the tie member itself, its splices and its connections only resist the calculated tensile forces. There are no structural strength or stiffness requirements to be applied to the structural members that are anchoring these horizontal tie forces.
\2\ /2/

3-1.4.1 Longitudinal and Transverse Ties.

Use the floor and roof system to provide the required longitudinal and transverse tie resistance. The structural members (beams, girders, spandrels, etc) may be used to provide some or all of the required tie forces, if they and their connections can be shown capable of carrying the total internal tie force acting over the structural member spacing while undergoing a 0.20-rad (11.3-deg) rotation, i.e., if the required longitudinal tie force is 10-k/ft (146-kN/m) and the beams are located at 10-ft (3.05-m) on center, the designer must show that the beam can carry a tensile force of 100-k (445-kN) with rotations of 0.20-rad (11.3-deg).

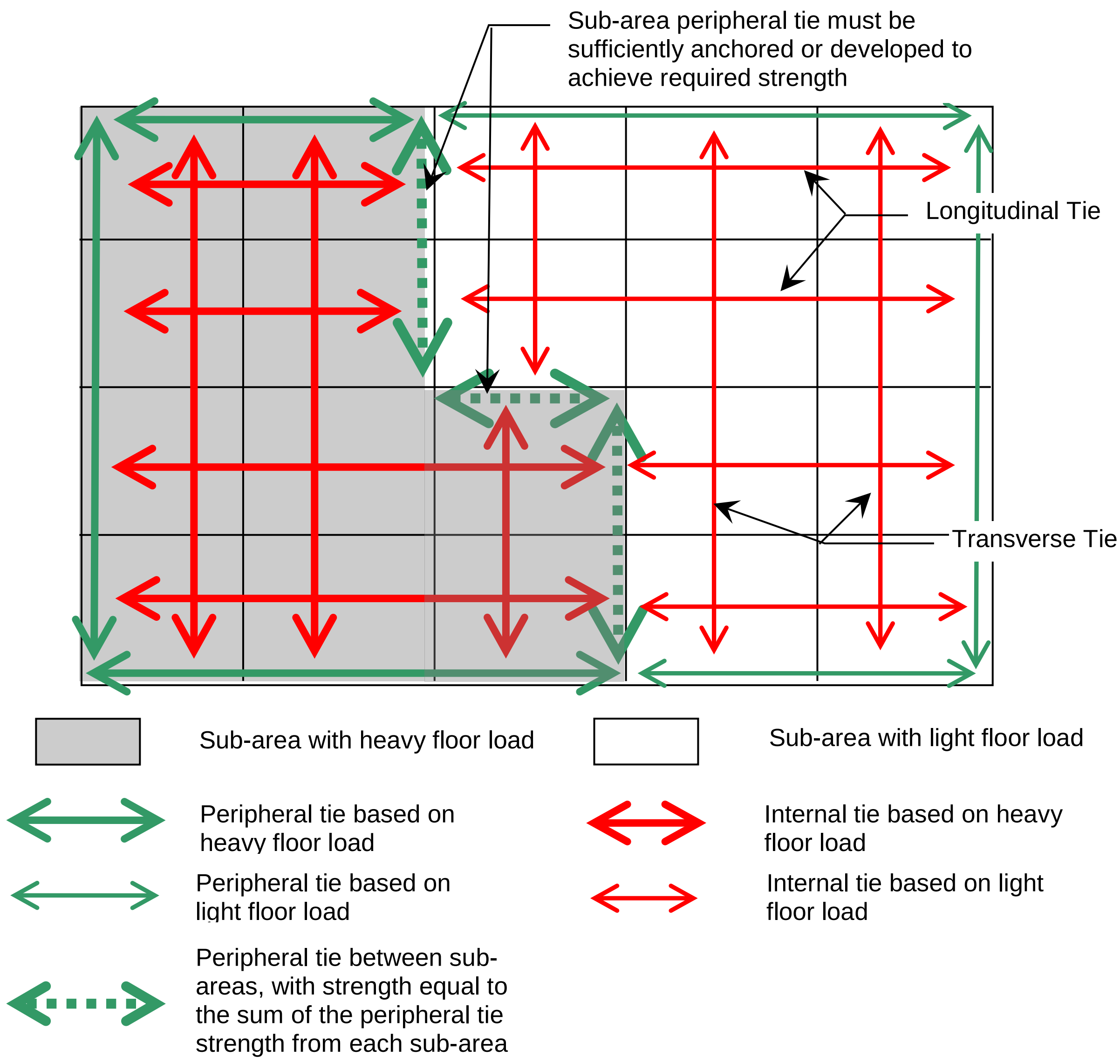
/2/ Note that longitudinal and transverse ties are not required in floors above crawlspaces if public access control is provided. See Section 1-2.3 for definition of public access control. /2/

3-1.4.1.1 Framed Structures, Including Flat Plate and Flat Slab.

Longitudinal and transverse tie forces shall be distributed orthogonally to each other throughout the floor and roof system. The longitudinal and transverse ties must be anchored to peripheral ties at each end. Spacing must not be greater than ***0.2*** L_T, or ***0.2*** L_L where L_T and L_L are the greater of the distances between the centers of the columns, frames, or walls supporting any two adjacent floor spaces in the transverse and longitudinal directions, respectively.

\2\

Figure 3-2. Sub-areas, Peripheral and Internal Ties for Non-uniform Floor Loads



/2/

For flat plate and flat slab structures without internal beams, girders, or spandrels, place no more than twice the required tie strength (force per unit length) in the column area, which is the column strip ***0.2 L_L*** or ***0.2 L_T*** wide that is centered on the column lines and runs in the direction of the tie under consideration, as shown in Figure 3-3. For instance, if the required longitudinal tie force ***F_L*** is 10-k/ft (146-kN/m), and ***L_T*** is 20-ft (6.1-m), then the width of the column area is ***0.2 L_T*** or 4-ft (1.22-m) and the maximum total tie force allowed in the column area is 2 x 10-k/ft x 0.2 x 20-ft or 80-k (356-kN). The remainder of the required total tie force is distributed in the floor or roof system.

For framed buildings with internal beams, girders, or spandrels, internal ties may cross over these elements, but are not to be placed parallel to these members and within the member or within the area directly above the member, unless the member can be shown capable of a 0.20-rad (11.3-deg) rotation. The internal ties that would fall within this area must be placed on either side of the beam, so that the total required tie strength for the adjacent bays is maintained. An illustration of this restriction is shown in Figure 3-4.

The required tie strength $\boldsymbol{F_i}$ (lb/ft or kN/m) in the longitudinal or transverse direction is:

$$F_i = 3\, w_F\, L_1 \qquad \text{Equation (3-3)}$$

Where w_F = Floor load, determined per Section 3-1.3, in (lb/ft^2 or kN/m^2)

L_1 = Greater of the distances between the centers of the columns, frames, or walls supporting any two adjacent floor spaces in the direction under consideration (ft or m)

\2\

Figure 3-3. Determination of L_1 and Column Area for Frame and Two-way Span Load-bearing Wall Construction

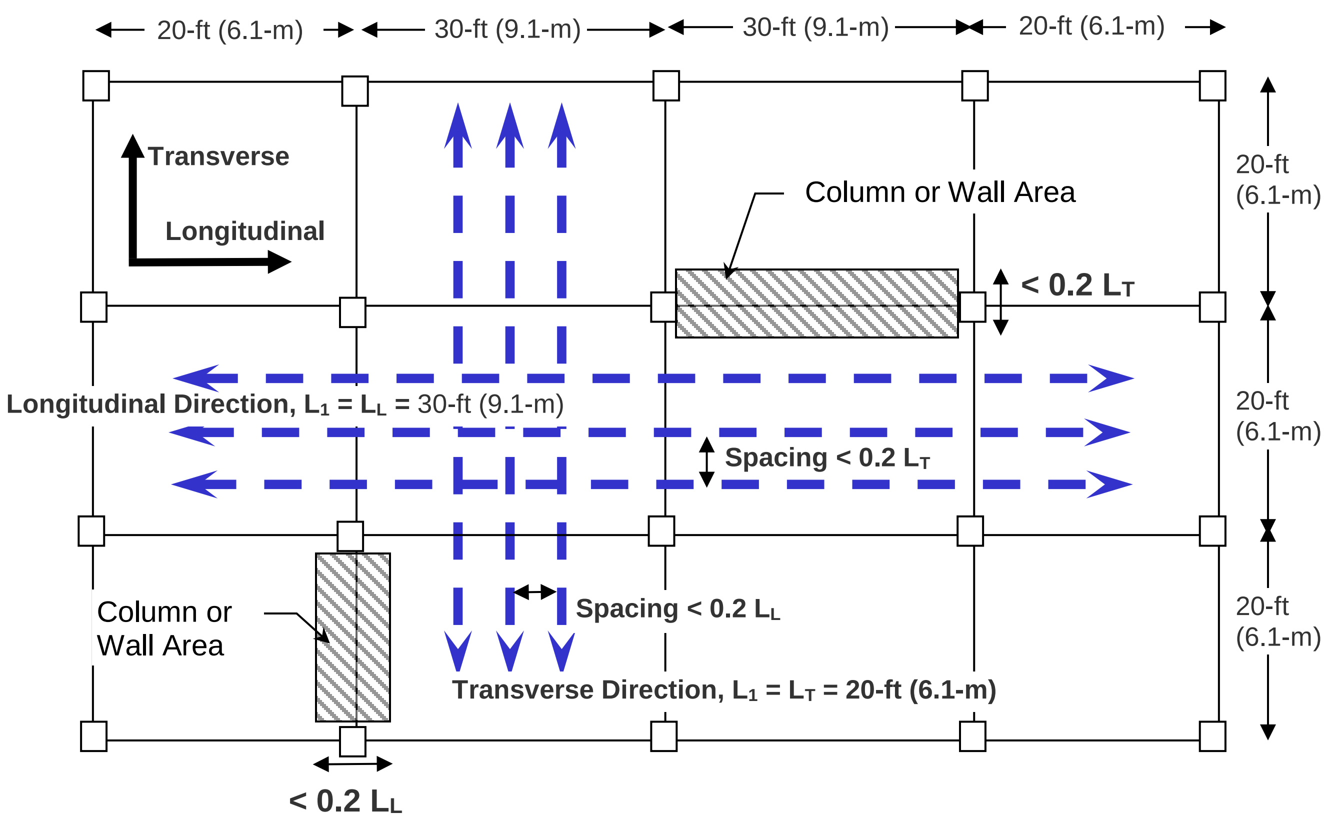
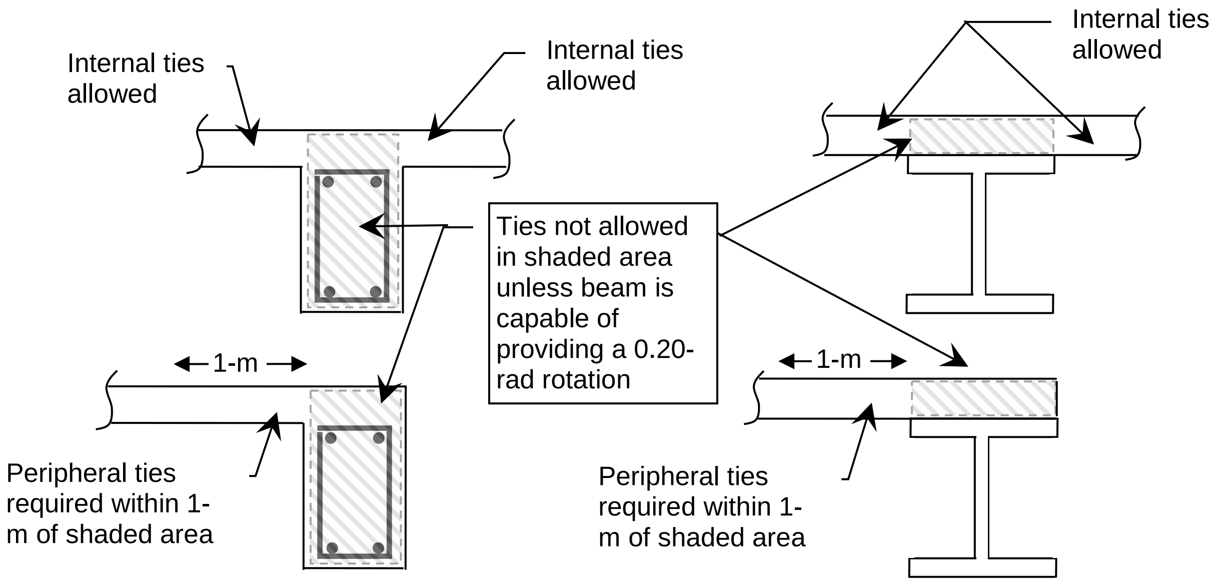


Figure 3-4. Location Restrictions for Internal and Peripheral Ties that are Parallel to the Long Axis of a Beam, Girder or Spandrel



/2/

3-1.4.1.2 Load-bearing Wall Structures.

A longitudinal and a transverse tie force shall be distributed orthogonally to each other throughout the floor and roof system. These ties must be anchored to peripheral ties at each end.

For two-way spans, spacing must not be greater than $0.2\ L_T$, or $0.2\ L_L$ where L_T and L_L are the greatest of the distances between the centers of the walls supporting any two adjacent floor spaces in the transverse and longitudinal directions, respectively; see Figure 3-3. No more than twice the required tie strength shall be placed in the wall area, which is defined as the area bounded by the centers of the columns, frames, or walls supporting any two adjacent floor spaces in the direction of the tie under consideration and within $0.1\ L_T$ or $0.1\ L_L$ of the wall line, as appropriate, as shown in Figure 3-3. For two-way spans, the required tie strength F_i (lb/ft or kN/m) in the longitudinal or transverse direction is:

$$F_i = 3\ w_F\ L_1 \qquad \text{Equation (3-4)}$$

Where w_F = Floor load, determined per Section 3-1.3, (lb/ft^2 or kN/m^2)

L_1 = Greater of the distances between the centers of the columns, frames, or walls supporting any two adjacent floor spaces in the direction under consideration (ft or m)

For one-way spans, spacing of the longitudinal and transverse ties must not be greater than $0.2\ L_L$, where L_L is the greatest of the distances between the centers of the walls supporting any two adjacent floor spaces in the longitudinal direction; see Figure 3-5. A maximum of twice the required tie strength shall be placed in the wall area, which is defined as the area within $0.1\ L_L$ of the wall line, as shown in Figure 3-5. For one-way spans, L_L is the greater of the distances between the centers of the wall in the one-way span direction, as shown in Figure 3-5. In the transverse direction L_T is $5\ h_w$, where h_w is the clear story height. The required tie strength F_i (lb/ft or kN/m) in the longitudinal or transverse direction is

$$F_i = 3\ w_F\ L_1 \qquad \text{Equation (3-5)}$$

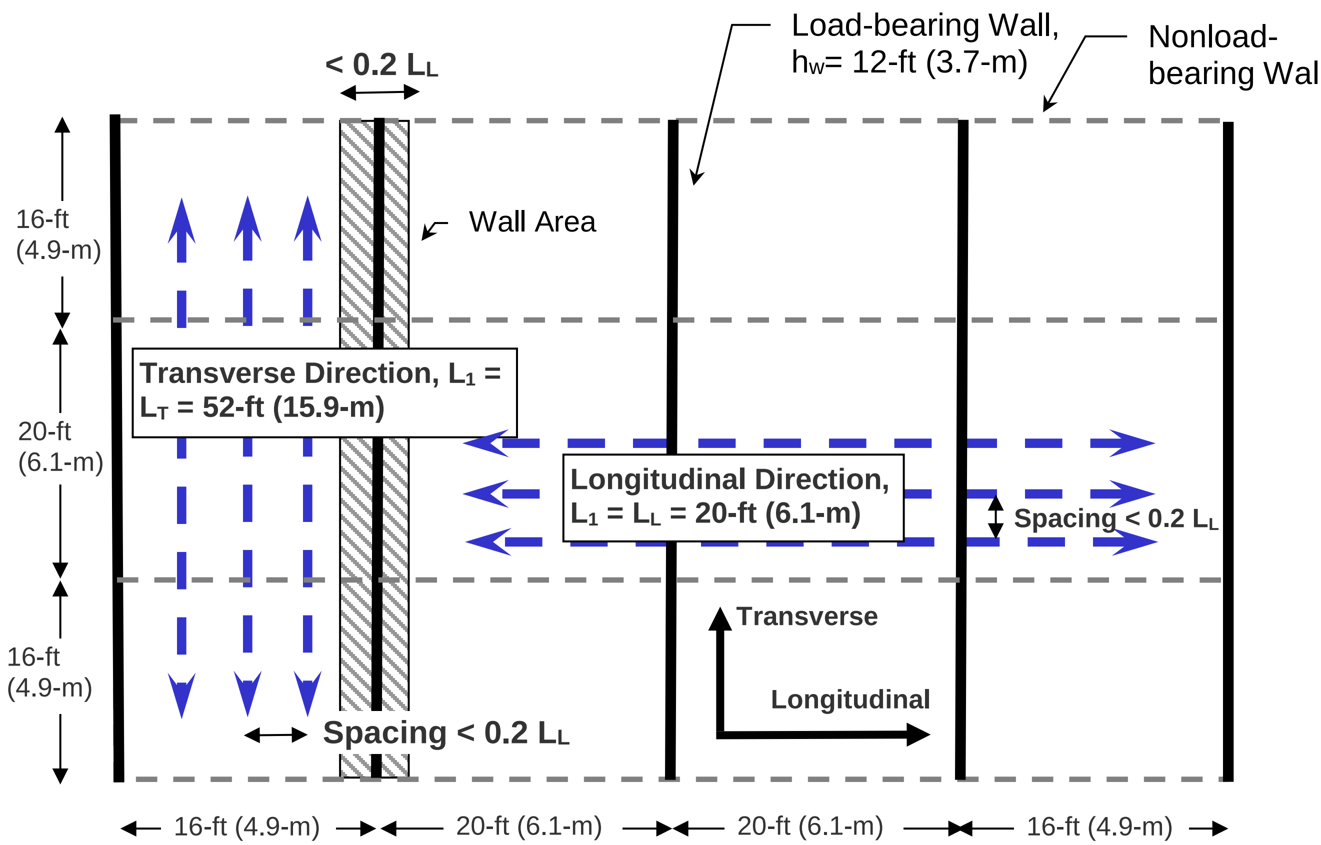
Where w_F = Floor load, determined per Section 3-1.3, ((lb/ft^2 or kN/m^2)

L_1 = Either L_L = the greater of the distances between the centers of the walls supporting any two adjacent floor spaces in the longitudinal direction or L_T = lesser of 5 h_w or the building width in the transverse direction (ft or m)

h_w = Clear story height (ft or m)

\2\ /2/

Figure 3-5. Determination of L_1 and Column Area for One-way Load-bearing Wall Construction with h_w = 12-ft (3.7-m)



3-1.4.2 Peripheral Ties.

Use the floor and roof system to carry the required peripheral tie strength. The structural members (beams, girders, spandrels, etc) may be used instead, if they can be proven capable of carrying the peripheral tie force while undergoing a 0.20-rad (11.3-deg) rotation.

\2\ Note that peripheral ties are not required in floors above crawlspaces if public access control is provided. See Sections 1-2.1 and 1-2.3 for definitions of occupied space and public access control, respectively.

For buildings with one- and two-story sections attached to a section with three or more stories, peripheral ties shall be placed in any contiguous floors at the boundary between the short and tall sections. /2/

Place peripheral ties within 3.3-ft (1.0-m) of the edge of a floor or roof and provide adequate development or anchors at corners, re-entrant corners or changes of construction. For framed buildings with perimeter beams, girders, or spandrels, peripheral ties may not be placed parallel to these members and within the member or

within the area directly above the member, unless the member can be shown capable of a 0.20-rad (11.3-deg) rotation. If perimeter beams, girders, or spandrels are present, the 3.3-ft (1.0-m) shall be measured from the interior edge of the beam, girder or spandrel. An illustration of this restriction is shown in Figure 3-4.
\2\

3-1.4.2.1 Framed and Two-way Load-Bearing Wall Buildings.

For framed and two-way load-bearing wall buildings, the required peripheral tie strength F_p (lb or kN) is

$$F_p = 6\, w_F\, L_1\, L_p + 3\, W_C \qquad \text{Equation (3-6)}$$

Where
- w_F = Floor load, determined per Section 3-1.3, (lb/ft^2 or kN/m^2)
- W_C = 1.2 x Dead load of cladding over the length of L_1, (lb or kN), where 1.2 is the LRFD dead load factor
- L_1 = For peripheral ties at the edge of the building: The greater of the distances between the centers of the columns, frames, or walls, at the perimeter of the building in the direction under consideration (ft or m).
  = For peripheral ties at openings (see Figure 3-6), the length of the bay in which the opening is located, in the direction under consideration.
- h_w = Clear story height (ft or m)
- L_p = 3.3-ft (1.0-m)

Note that the dead load includes the self-weight of the members and superimposed dead loads.

3-1.4.2.2 One-way Load-Bearing Wall Buildings.

For one-way load-bearing wall buildings, the required peripheral tie strength F_p (lb or kN) is

$$F_p = 6\, w_F\, L_1\, L_p + 3\, W_C + 3\, W_W \qquad \text{Equation (3-7)}$$

Where
- w_F = Floor load, determined per Section 3-1.3, (lb/ft^2 or kN/m^2)
- W_C = 1.2 x Dead load of cladding over the length of L_1, (lb or kN), where 1.2 is the LRFD dead load factor,
- W_W = 1.2 x Dead load of wall over the length of h_w, where 1.2 is the LRFD dead load factor,
- h_w = Clear story height (ft or m)

L_1 = For exterior peripheral ties perpendicular to the load-bearing walls (longitudinal direction in Figure 3-5), the greatest of the distances between the centers of the walls in the direction under consideration (m or ft).
= For exterior peripheral ties parallel to the load-bearing walls (transverse direction in Figure 3-5), 2 h_W (m or ft).
= For peripheral ties at openings (see Figure 3-6), the length of the bay in which the opening is located, in the direction under consideration (ft or m)
L_p = 3.3-ft (1.0-m)

Notes: 1) For the end load-bearing walls, only the wall load is acting, as the end wall is the façade, and W_C = 0.; 2) The dead load includes the self-weight of the members and superimposed dead loads; 3) See Commentary C-5.4.2 for additional information.
/2/

3-1.4.3 Vertical Ties.

\2\ Use the columns and load-bearing walls to carry the required vertical tie strength. Each column and load-bearing wall shall be tied continuously from the roof level down to the first column- or wall-supported floor above the foundation, i.e., the vertical ties are not required to extend to the foundation. Vertical ties shall be straight. /2/

The vertical tie must have a design strength in tension equal to the largest vertical load received by the column or wall from any one story, using the tributary area and the floor load w_F as determined in Section 3-1.3.

3-1.5 Continuity of Ties.

\2\ The load path for peripheral ties must be continuous between building corners and edge of openings. /2/ For internal longitudinal and transverse ties, the path must be continuous from one edge to the other. However, interruptions due to courtyards, mezzanines, elevator/stairwell cores, etc, are allowed, as shown in Figure 3-6, when a peripheral tie is placed at the interruption; \2\ note that peripheral ties around an opening are not required if the opening fits between the longitudinal and transverse ties that meet the spacing requirements of Sections 3-1.4.1.1 and 3-1.4.1.2./2/ Insure that sufficient embedment or anchoring is provided to develop the strength of the peripheral ties placed at the interruption; anchor the longitudinal and transverse ties to the peripheral ties with seismic hooks. Along a particular load path, different structural elements may be used to provide the required tie strength, providing that they are adequately connected.

\2\Each column and load-bearing wall shall be tied continuously from the roof level down to the first column- or wall-supported floor above the foundation, i.e., the vertical ties are not required to extend to the foundation. /2/

Re-entrant corners are allowed for all types of construction, providing that the transverse, longitudinal, and peripheral ties are adequately developed and anchored, per Section 3-1.6.
\2\/2/

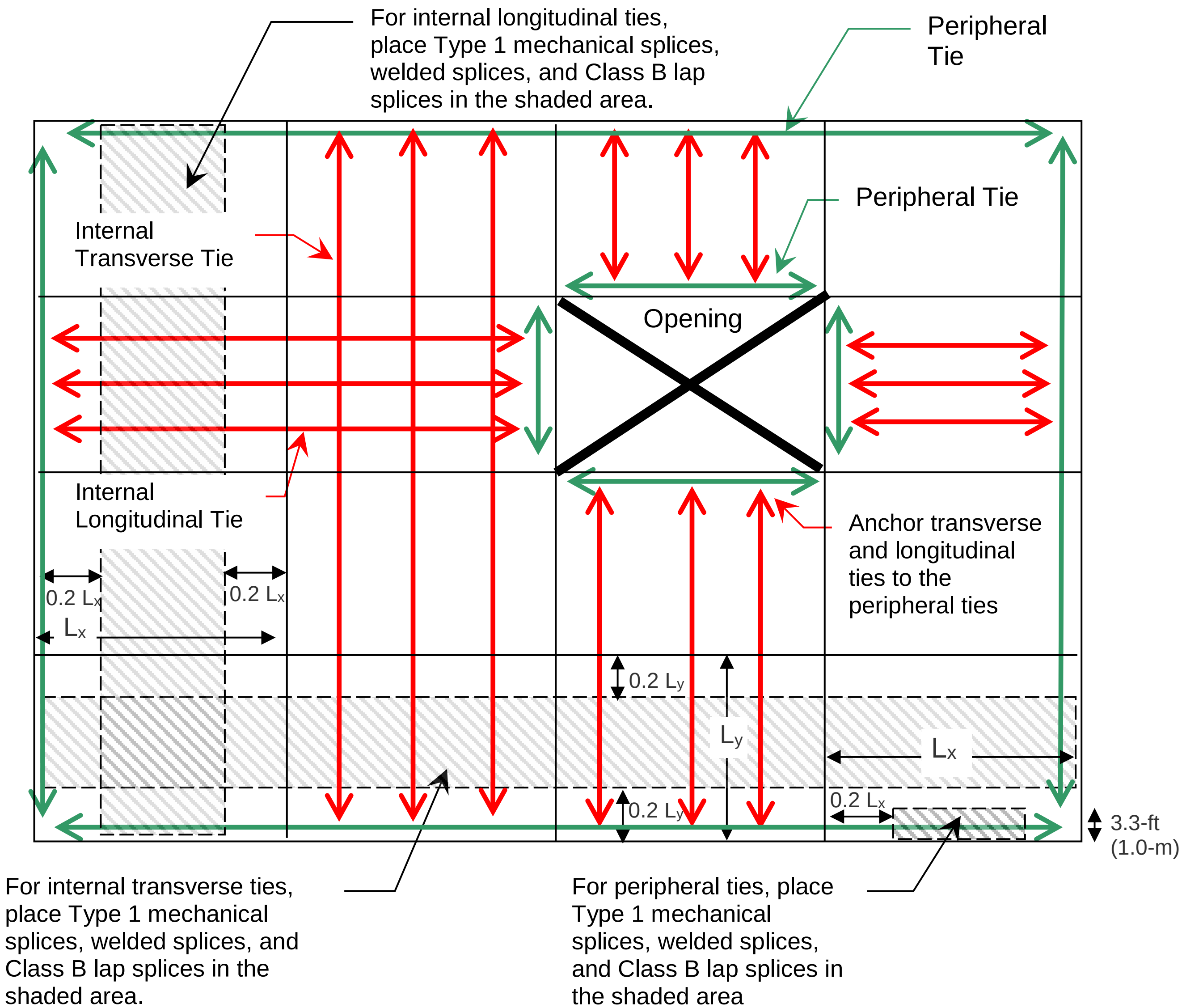
3-1.6 Splices, Anchorage, and Development of Ties.

3-1.6.1 Cast-in-Place Reinforced Concrete Floor and Roof Systems.

For cast-in-place construction, including composite construction with sheet metal decks and reinforced concrete topping, and, for precast floor systems with a concrete topping and reinforcement, splices in steel reinforcement used to provide the design tie strength shall be lapped with Class B lap splices, welded, or mechanically joined with Type 1 or Type 2 mechanical splices, per ACI 318. Splices shall be staggered within the allowable shaded areas shown in Figure 3-6.

Type 2 mechanical splices may be used at any location in the slab. For internal longitudinal and transverse ties, Type 1 mechanical splices, welded splices, and Class B lap splices shall be located no closer than 20% of the bay spacing in the direction of the tie to any vertical load carrying elements (i.e., these splices must be within the middle 60% of the slab or floor or roof system bay, in the direction of the tie); see Figure 3-6. For peripheral ties, Type 1 mechanical splices, welded splices, and Class B lap splices shall be placed no closer than 20% of the span distance in the peripheral tie direction; see Figure 3-6. Note that noncontact splices are not allowed.
\2\

Figure 3-6. Splice Locations and Interruptions in Internal Tie Forces



Use seismic hooks as defined in ACI 318 to anchor and connect internal longitudinal and transverse ties to the peripheral ties; when multiple rebar are used as the peripheral tie, the seismic hooks on the longitudinal and transverse ties shall engage the furthest peripheral tie rebar (the rebar closest to the edge of the structure). The strength of the peripheral ties shall be developed within the 3.3-ft (1.0-m) wide area at the edge of the floor or roof, using development lengths from Chapter 12 of ACI 318. At re-entrant corners or at substantial changes in construction, take care to insure that the transverse, longitudinal, and peripheral ties are adequately anchored and developed. /2/

3-1.6.2 Precast Concrete Floor and Roof Systems.

For precast concrete floor and roof systems, the rebar within the precast planks may be used to provide the internal tie forces, providing the rebar is continuous across the structure and properly anchored; this may be difficult to accomplish in the short direction of the plank. Also, the rebar may be placed within a concrete topping; in this case, provide positive mechanical engagement between the reinforcement and the precast floor system, with sufficient strength to insure that the precast units do not separate from the topping and fall to the space below. Do not rely on the bond strength between the topping and precast units, as the bond can be disrupted by the large deformations associated with catenary behavior. This attachment between the rebar in the concrete topping and the precast planks may be accomplished with hooks, loops or other mechanical attachments that are embedded in the precast floor units.

3-1.6.3 Composite Construction Floor and Roof Systems.

If composite construction with steel decks and concrete topping is employed, provide sufficient connection between the steel beam and the composite floor such that the beam will not fall to the space below.

3-1.6.4 Other Floor and Roof Systems and Structural Elements.

If other floor and roof systems and structural elements can be shown capable of carrying the tie forces required in Sections 3-1.4.1 and 3-1.4.2 while undergoing a rotation of 0.20-rad (11.3-deg) and while meeting the continuity requirement of Section 3-1.5, provide adequate splicing and anchorage that allows development of the transverse, longitudinal, and peripheral tie forces required in Section 3-1.6.

3-1.7 Structural Elements and Connections with Inadequate Tie Strength

If the vertical design tie strength of any structural element or connection is less than the vertical required tie strength, the designer must either: 1) revise the design to meet the tie force requirements or 2) use the Alternate Path method to prove that the structure is capable of bridging over this deficient element.

The AP method shall not be applied to structural elements or connections that cannot provide the required longitudinal, transverse, or peripheral tie strength; in this case, the designer must redesign or retrofit the element and connection such that a sufficient design tie strength is developed.

3-2 ALTERNATE PATH METHOD.

The Alternate Path method is used in two situations: 1) for Option 1 of \3\ Risk Category /3/ II and for \3\ Risk Category /3/ IV, when a vertical structural element cannot provide the required tie strength, the designer may use the AP method to determine if the structure can bridge over the deficient element after it has been notionally removed, and 2) for \3\ Risk Category /3/ II Option 2, \3\ Risk Category /3/ III, and \3\ Risk

Category /3/ IV, the AP method must be applied for the removal of specific vertical load-bearing elements which are prescribed in Section 3-2.9.

3-2.1 General.

This method follows the general LRFD philosophy by employing a modified version of the ASCE 7 load factor combination for extraordinary events and resistance factors to define design strengths. Three analysis procedures are employed: Linear Static (LSP), Nonlinear Static (NSP) and Nonlinear Dynamic (NDP). These procedures follow the general approach in ASCE 41 with modifications to accommodate the particular issues associated with progressive collapse. Much of the material-specific criteria from Chapters 9 to 12 of ASCE 41 are explicitly adopted in Chapters 4 to 8 of this document. The topics of each ASCE 41 Chapter are:

- Steel or cast iron, ASCE 41 Chapter 9,
- Reinforced concrete, ASCE 41 Chapter 10,
- Reinforced or un-reinforced masonry, ASCE 41 Chapter 11,
- Timber, light metal studs, gypsum, or plaster products, ASCE 41 Chapter 12.

Note that some of the deformation and strength criteria in ASCE 41 Chapters 9 to 12 have been superseded by requirements that are specified in the material specific Chapters 4 to 8 in this UFC.

3-2.2 Alternative Rational Analysis.

For the performance of the Alternate Path analysis and design, nothing in this document shall be interpreted as preventing the use of any alternative analysis procedure that is rational and based on fundamental principles of engineering mechanics and dynamics. For example, simplified analytical methods employing hand calculations or spreadsheets may be appropriate and more efficient for some types of buildings, such as load-bearing wall structures.

The results of any alternative rational analyses shall meet the acceptance criteria contained in Section 3-2.10 and in Chapters 4 through 8. The analyses shall include the specified locations for removal of columns and load-bearing walls in Section 3-2.9 and the ASCE 7 extreme event load combination, with the load increase factors in Sections 3-2.11.5 and 3-2.12.5 for linear static and nonlinear static analyses, respectively. The designer shall verify that these criteria are applicable to the alternative rational analyses. If a Linear Static approach is employed, the requirements of Section 3-2.11.1 must be met. All projects using alternative rational analysis procedures shall be reviewed and approved by an independent third-party engineer or by an authorized representative of the facility owner.

3-2.3 Load and Resistance Factor Design for Alternate Path Method.

\2\The Alternate Path method employed in this UFC follows the general philosophy of the standard LRFD approach but with modifications to facilitate the integration of the ASCE 41 procedures, which are not LRFD. /2/ For LRFD, the design strength is taken as the product of the strength reduction factor $\boldsymbol{\Phi}$ and the nominal strength $\boldsymbol{R_n}$ calculated in accordance with the requirements and assumptions of applicable material specific codes. The design strength must be greater than or equal to the required strength:

$$\Phi R_n \geq R_u \qquad \text{Equation (3-8)}$$

where
- ΦR_n = Design strength
- Φ = Strength reduction factor
- R_n = Nominal strength
- $R_u = \Sigma \gamma_i Q_i$ = Required strength
- γ_i = Load factor
- Q_i = Load effect

Items to note relative to the integration of the LRFD and the ASCE 41 approaches: /2/

- While ASCE 41 requires that all Φ factors be taken as unity, this UFC requires that strength reduction factors, Φ, be used as specified in the appropriate material specific code, for the action or limit state under consideration.

- \2\ASCE 41 uses the term “action” in the way LRFD defines “required strength”. ASCE 41 further differentiates actions into “deformation-controlled” and “force-controlled”. These terms are defined later.

- In this UFC, the LRFD “nominal strength” is defined as either the “expected strength” when deformation actions are being considered or the “lower-bound strength” for force-controlled actions; ASCE 41 sets all Φ factors to 1 and therefore, the expected and lower bound strengths are the nominal strengths in this document.

- This UFC and ASCE 41 both employ the same “over-strength factors” to translate lower bound material properties to expected strength material properties. The over-strength factors are provided in ASCE 41 Tables 9-3 (structural steel), 10-4 (reinforced concrete), and 11-2 (masonry). For wood and cold-formed steel, Chapter 12 of ASCE 41 provides default expected strength values; note that for wood construction, a time effect factor λ is also included.

Note that live load reductions (LLRs) per ASCE 7 are permitted for all live loads used in Alternate Path analysis and design. For framed structures, where the floor slab is supported by beams and girders, the analyst may use the LLR for each beam individually or may use the same LLR for the entire structure. In the latter case, the LLR shall be equal to the smallest LLR (greatest live load) for any beam in the bays above the column removal location. For flat-slab structures, load-bearing wall structures and other situations where the floor system transfers loads directly to the columns or walls, the LLR shall be computed for, and applied to, the floor in each bay. In all cases, the LLRs shall be based on the structural configuration before the column or load-bearing wall section is removed. /2/

3-2.4 Primary and Secondary Components.

Designate all structural elements and components as either primary or secondary. Classify structural elements and components that provide the capacity of the structure to resist collapse due to removal of a vertical load-bearing element as primary. Classify all other elements and components as secondary. For example, a steel gravity beam may be classified as secondary if it is assumed to be pinned at both ends to girders and the designer chooses to ignore any flexural strength at the connection; if the connection is modeled as partially restrained and thus contributes to the resistance of collapse, it is a primary member.

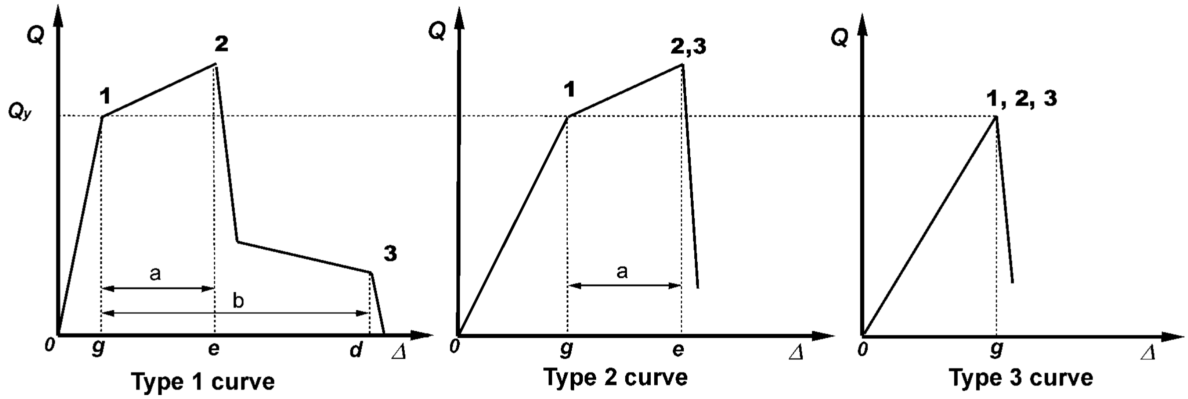
3-2.5 Force and Deformation Controlled Actions.

Classify all actions as either deformation controlled or force-controlled using the component force versus deformation curve shown in Figure 3-7. Examples of deformation and force controlled actions are listed in Table 3-1. Note that a component might have both force and deformation controlled actions. Further, classification as a force or deformation controlled action is not up to the discretion of the user and must follow the guidance presented here.

Define a primary component action as deformation controlled if it has a Type 1 curve and $e \geq 2g$, or, it has a Type 2 curve and $e \geq 2g$. Define a primary component action as force-controlled if it has a Type 1 or Type 2 curve and $e < 2g$, or, if it has a Type 3 curve.

Define a secondary component action as deformation controlled if it has a Type 1 curve for any e/g ratio or if it has a Type 2 curve and $e \geq 2g$. Define a secondary component action as force controlled if it has a Type 2 curve and $e < 2g$, or, if it has a Type 3 curve.

Figure 3-7. Definition of Force Controlled and Deformation Controlled Actions, from ASCE 41



3-2.6 Expected and Lower Bound Strength.

When evaluating the behavior of deformation controlled actions, use the expected strength, Q_{CE}. Q_{CE} is defined as the statistical mean value of the strength, Q (yield, tensile, compressive, etc, as appropriate), for a population of similar components, and includes consideration of the variability in material strengths as well as strain hardening and plastic section development. Note that Q_{CE} relates to any deformation-controlled action presented in Table 3-1, e.g., the expected strength for the moment in a deformation-controlled, laterally braced beam would be $Q_{CE} = M_{CE} = Z\,F_{YE}$, where Z is the plastic section modulus and F_{YE} is the expected yield strength. If a database to determine F_{YE} is not available, F_{YE} is obtained by multiplying the lower-bound strength F_{YL} (the nominal strength or strength specified in the construction documents) by the appropriate factor from Chapters 9 to 12 in ASCE 41, as discussed in Section 3-2.7.

When evaluating the behavior of force-controlled actions, use a lower bound estimate of the component strength, Q_{CL}. Q_{CL} is defined as the statistical mean minus one standard deviation of the strength, Q (yield, tensile, compressive, etc, as appropriate), for a population of similar components. Note that Q_{CL} relates to any force-controlled action presented in Table 3-1, e.g., the lower bound strength of a steel column under axial compression would be $Q_{CL} = P_{CL}$, where P_{CL} is based on the lowest value obtained for the limit states of column buckling, local flange buckling, or local web buckling, calculated with the lower bound strength, F_{YL}. Where data to determine the lower bound strength are not available, use the nominal strength or strength specified in the construction documents.

3-2.7 Material Properties.

Expected material properties such as yield strength, ultimate strength, weld strength, fracture toughness, elongation, etc, shall be based on mean values of tested material properties. Lower bound material properties shall be based on mean values of tested material properties minus one standard deviation.

If data to determine the lower bound and expected material properties do not exist, use nominal material properties, or properties specified in construction documents, as the lower bound material properties unless otherwise specified in Chapters 9 through 12 of ASCE 41. Calculate the corresponding expected material properties by multiplying lower bound values by appropriate factors specified in Chapters 9 through 12 of ASCE 41 to translate from lower bound material properties to expected material values. If factors for converting from a lower bound to expected material property are not specified, use the lower bound material property as the expected material property.

Table 3-1. Examples of Deformation Controlled and Force Controlled Actions, from ASCE 41

Component	Deformation Controlled Action	Force Controlled Action
Moment Frames • Beams • Columns • Joints	 Moment (M) M --	 Shear (V) Axial load (P), V V[1]
Shear Walls	M, V	P
Braced Frames • Braces • Beams • Columns • Shear Link	 P -- -- V	 -- P P P, M
Connections	P, V, M[2]	P, V, M

1. Shear may be a deformation controlled action in steel moment frame construction.
2. Axial, shear, and moment may be deformation controlled actions for certain steel and wood connections.

3-2.8 Component Force and Deformation Capacities.

\2\/2/Methods for calculation of individual component strengths and deformation capacities shall comply with the requirements in the individual ASCE 41 material chapters.

\2\As shown in the acceptance criteria given in Sections 3-2.11.7, 3-2.12.7 and 3-2.13.6, the expected and lower-bound strengths shall be multiplied by the strength reduction factors that are specified in the material specific design codes (i.e., the *Φ* factors in ACI 318, the AISC Steel Construction Manual, etc). Note that *Φ* factors are taken as 1.0 in ASCE 41. /2/

3-2.8.1 Component Capacities for Nonlinear Procedures.

For nonlinear procedures, component capacities for deformation controlled actions shall be taken as permissible inelastic deformation limits, and component capacities for force-controlled actions shall be taken as lower-bound strengths, Q_{CL}, multiplied by the appropriate strength reduction factor Φ, as summarized in Table 3-2.

Table 3-2. Calculation of Component Capacities for Nonlinear Static and Nonlinear Dynamic Procedures

Parameter	Deformation Controlled	Force Controlled
Deformation Capacity	Deformation limit	N/A
Strength Capacity	N/A	$\Phi\ Q_{CL}$

3-2.8.2 Component Capacities for the Linear Static Procedure.

For the linear static procedure, component capacities for deformation-controlled actions shall be defined as the product of ***m-factors*** and expected strengths, Q_{CE}, multiplied by the appropriate strength reduction factor Φ. Capacities for force-controlled actions shall be defined as lower-bound strengths, Q_{CL}, multiplied by the appropriate strength reduction factor Φ, as summarized in Table 3-3.

Table 3-3. Calculation of Component Capacities for the Linear Static Procedure

Parameter	Deformation Controlled	Force Controlled
Material Strength	Expected Material Strength	Lower Bound Strength
Strength Capacity	$\Phi\ m\ Q_{CE}$	$\Phi\ Q_{CL}$

3-2.9 Removal of Load-Bearing Elements for the Alternate Path Method.

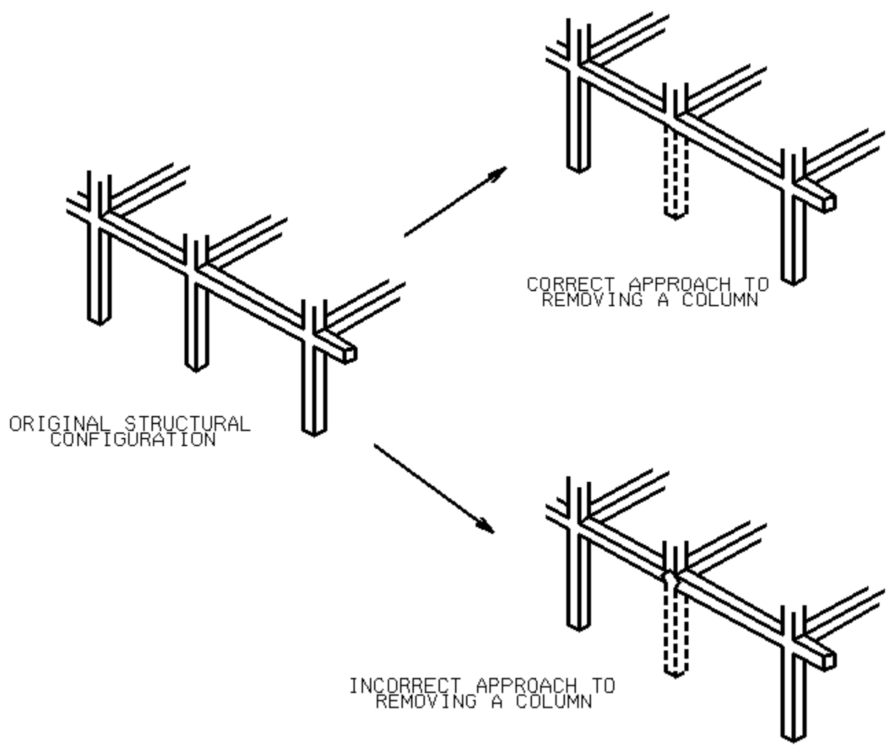
Load-bearing elements are removed for the following two cases:

1) For RC II Option 1 and RC IV structures, where an element cannot provide the required vertical tie strength,
2) For RC II Option 2, RC III, and RC IV structures, where AP is applied to elements for which the location and size are specified to verify that the structure has adequate flexural resistance to bridge over the missing element.

For both external and internal column removal, for the purposes of AP analysis, beam-to-beam continuity is assumed to be maintained across a removed column; see Figure 3-8.

The details of the size and location of the removed load-bearing elements are described in the following sub-paragraphs.

Figure 3-8. Removal of Column from Alternate Path Model



3-2.9.1 Extent of Removed Load-Bearing Elements.

3-2.9.1.1 RC II Option 1 (Deficient Vertical Tie Force).

For each column that cannot provide the required vertical tie force, remove the clear height between lateral restraints***.***

For each load-bearing wall that cannot provide the required vertical tie force, the length of the removed section of wall is twice the clear story height ***H***, if the length of the deficient wall is greater than ***2H***. If the length of the deficient wall is less than ***2H***, remove just that portion of deficient wall. In both instances, remove the clear height between lateral restraints. Note that discontinuities, such as joints, segmented walls, or openings for doors or windows, can be located within the ***2H*** length, providing that the loads above that discontinuity are carried by the remainder of the wall in the ***2H*** length.

3-2.9.1.2 RC II Option 2, RC III, and RC IV

For each column, remove the clear height between lateral restraints.

For each load-bearing wall, remove a length that is twice the clear story height ***H***. Remove the clear height between lateral restraints. Note that only planar sections of wall are removed, i.e., if a shear wall has a C-shaped cross-section in plan, only the flange or only the web are removed, but not both. However, for external corners, where one or both of the intersecting walls is load bearing, remove a length of wall equal to the clear story height ***H*** in each direction

3-2.9.2 Location of Removed Load-Bearing Elements.

3-2.9.2.1 RC II Option 1 (Deficient Vertical Tie Force).

Remove the column that cannot provide the required vertical tie force.

For a deficient load-bearing wall or section thereof that is longer than ***2H***, determine the location(s) for removal by using the guidance for wall removal locations provided in Sections 3-2.9.2.4 and 3-2.9.2.5. Additionally, use engineering judgment to shift the location of the removed ***2H*** section of wall within the length of deficient wall to evaluate worse case scenarios. If the length of the deficient load-bearing wall is less than ***2H***, remove just the section that is deficient.

3-2.9.2.2 RC II Option 2, RC III and IV External Columns.

For RC II Option 2, RC III and RC IV, as a minimum, remove external columns near the middle of the short side, near the middle of the long side, and at the corner of the building, as shown in Figure 3-9. Also remove columns at locations where the plan geometry of the structure changes significantly, such as abrupt decrease in bay size or re-entrant corners, or, at locations where adjacent columns are lightly loaded, the bays have different tributary sizes, and members frame in at different orientations or elevations. Use engineering judgment to identify these critical column locations.

\2\If any other column is within a distance of 30% of the largest dimension of the associated bay from the column removal location, it must be removed simultaneously. /2/

For each plan location defined for element removal, perform AP analyses for:

1. First story above grade
2. Story directly below roof
3. Story at mid-height
4. Story above the location of a column splice or change in column size

For example, if a corner column is specified as the removed element location in a ten story building with a column splice at the third story, one AP analysis is performed for removal of the ground story corner column; another AP analysis is performed for the removal of the corner column at the tenth story; another AP analysis is performed for the fifth story corner column (mid-height story) and one AP analysis is performed for the fourth story corner column (story above the column splice).

3-2.9.2.3 RC II Option 2, RC III and RC IV Internal Columns.

For RC II Option 2, RC III and RC IV structures with underground parking or areas of uncontrolled public access, remove internal columns near the middle of the short side, near the middle of the long side and at the corner of the uncontrolled space, as shown in Figure 3-10; see Section 1-2.3 for a definition of controlled public access. The removed column extends from the floor of the underground parking area or uncontrolled public floor area to the next floor (i.e., a one story height must be removed). Internal columns must also be removed at other critical locations within the uncontrolled public access area, as determined with engineering judgment. For each plan location, the AP analysis is only performed for the story with the parking or uncontrolled public area.

\2\If any other column is within a distance of 30% of the largest dimension of the associated bay from the column removal location, it must be simultaneously removed as well. /2/

3-2.9.2.4 RC II Option 2, RC III and RC IV External Load-Bearing Walls.

As a minimum, remove external load-bearing walls near the middle of the short side, near the middle of the long side and at the corner of the building, as shown in Figure 3-11. For external corners, where one or both of the intersecting walls is load bearing, remove a length of wall equal to the clear story height ***H*** in each direction. Also remove load-bearing walls at locations where the plan geometry of the structure changes significantly, such as at an abrupt decrease in bay size or at re-entrant corners, as well as at locations where adjacent walls are lightly loaded, the bays have different sizes, and members frame in at different orientations or elevations. Use engineering judgment to identify these critical locations. The length of the removed wall section is specified in Section 3-2.9.1. The designer must use engineering judgment to shift the location of the removed wall section by a maximum of the clear story height ***H*** if that creates a worst-case scenario.

For each plan location defined for element removal, perform AP analyses for the following stories:

1. First story above grade
2. Story directly below roof
3. Story at mid-height
4. Story above the location of a change in wall size

For example, if a wall section at the middle of the long side is specified as the removed element location in a six story wood building with a change in wall framing at the third story, one AP analysis is performed for removal of the ground story wall section; another AP analysis is performed for the removal of the wall section at the sixth story; another AP analysis is performed for the third story (mid-height story) and one AP analysis is performed for the fourth story (story above the change in wall framing).

If any other load-bearing element such as a column is within a distance of 30% of the clear story height (H) behind or in front of the wall removal location, it must be removed simultaneously.

Figure 3-9. Location of External Column Removal for RC II Option 2, RC III and IV Structures

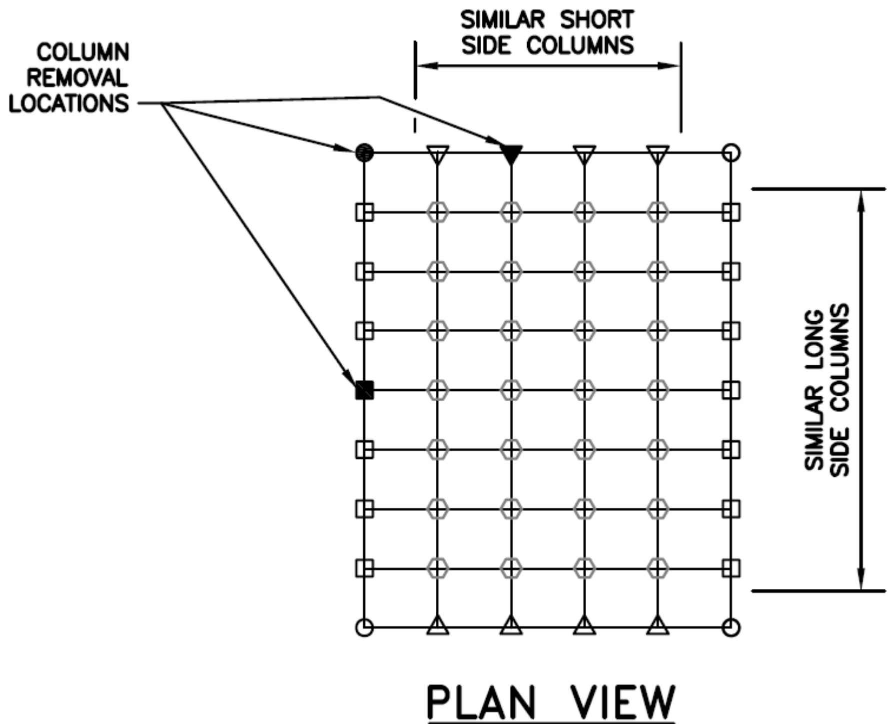


Figure 3-10. Location of Internal Column Removal for RC II Option 2, RC III and IV Structures

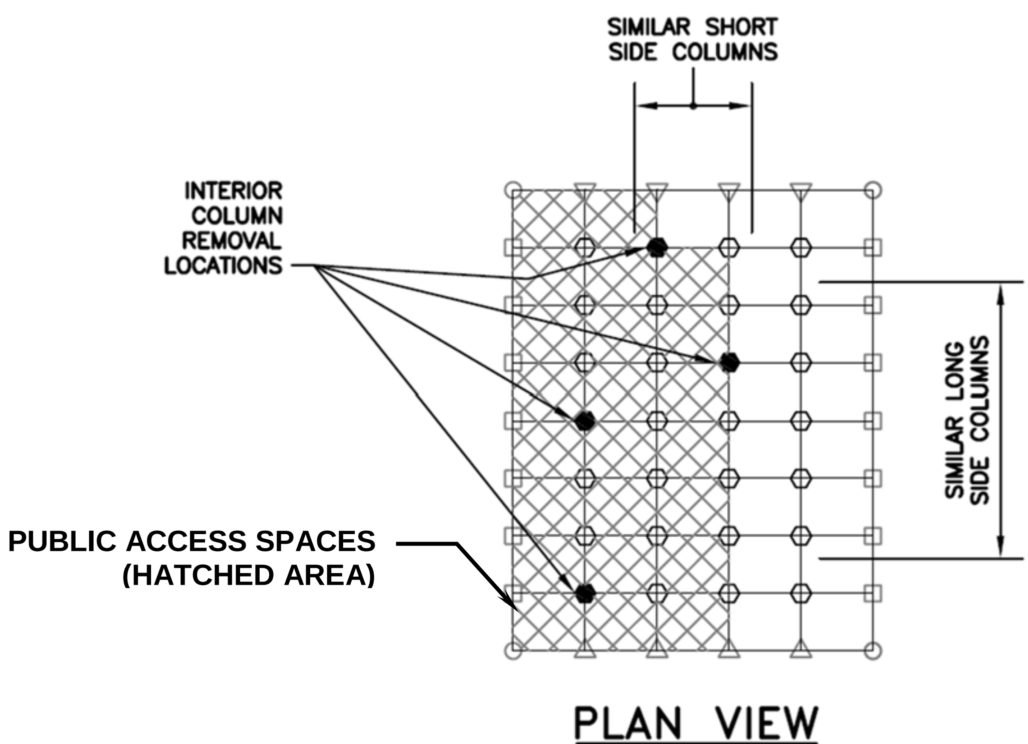


Figure 3-11. Location of External Load-Bearing Wall Removal for RC II Option 2, RC III and RC IV Structures

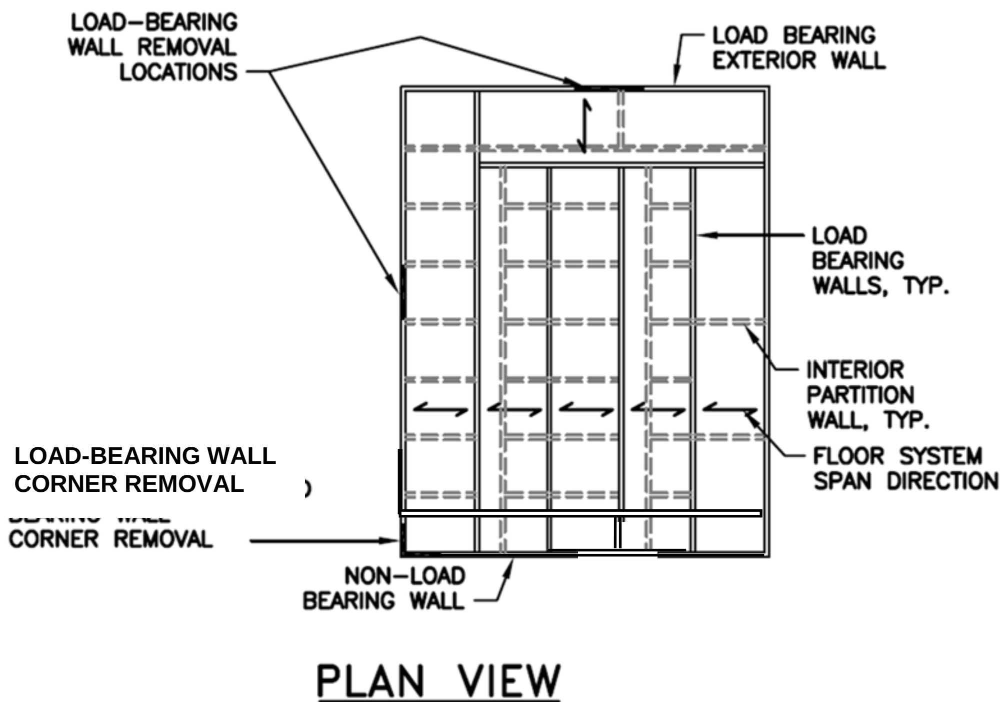
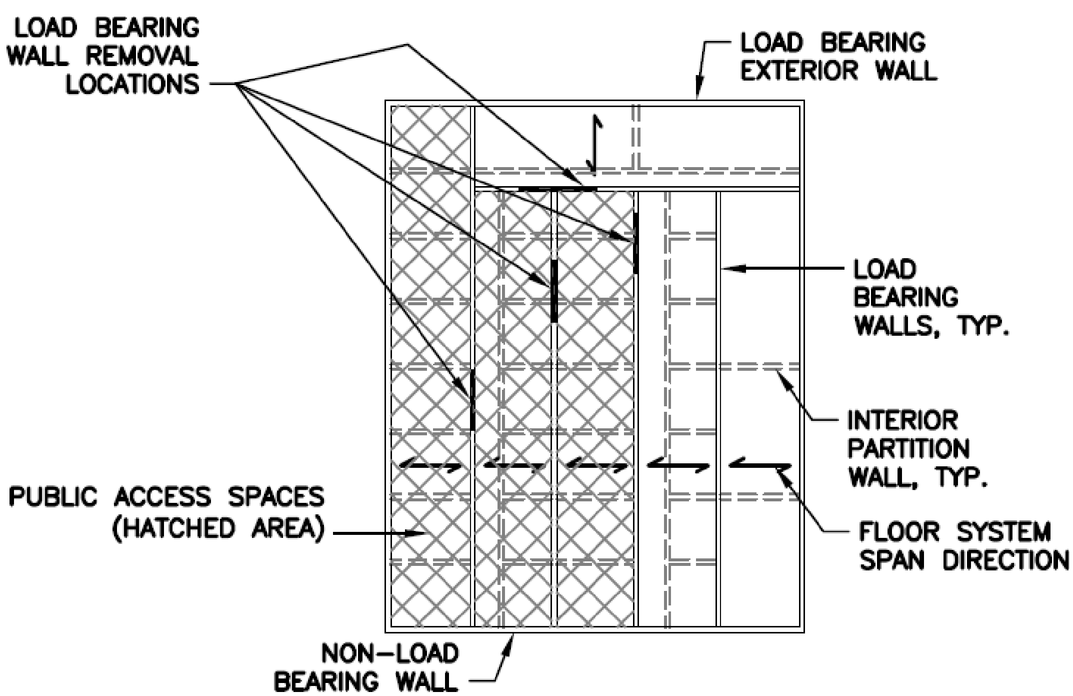


Figure 3-12. Location of Internal Load-Bearing Wall Removal for RC II Option 2, RC III and RC IV Structures



3-2.9.2.5 RC II Option 2, RC III and RC IV Internal Load-Bearing Walls.

For structures with underground parking or areas of uncontrolled public access, remove internal load-bearing walls near the middle of the short side, near the middle of the long side and at the corner of the uncontrolled space, as shown in Figure 3-12; see Section 1-2.3 for a definition of controlled public access. For internal corners, where one or both of the intersecting walls is load-bearing, remove a length of wall equal to the clear story height ***H*** in each direction. The removed wall extends from the floor of the underground parking area or uncontrolled public floor area to the next floor (i.e., a one story height must be removed). Also remove internal load-bearing walls at other critical locations within the uncontrolled public access area, as determined with engineering judgment. For each plan location, the AP analyses are only performed for the load-bearing walls at the story with parking area or uncontrolled public space, and not for all stories in the structure. The length of the removed wall section is specified in Section 3-2.9.1. The designer must use engineering judgment to shift the location of the removed wall section by a maximum of the wall height if that creates a worst-case scenario. If any other load-bearing element such as column is within a distance of 30% of the clear story height (H) behind or in front of the wall removal location, it must be removed simultaneously.

3-2.10 Structure Acceptance Criteria.

For all three analysis types (LS, NS, and ND), the building is structurally adequate if none of the primary and secondary elements, components, or connections exceeds the acceptance criteria, in Paragraphs 3-2.11.7, 3-2.12.7, and 3-2.13.6, as appropriate. If the analysis predicts that any element, component, or connection does not meet these acceptance criteria, the building does not satisfy the progressive collapse requirements and must be re-designed or retrofitted to eliminate the non-conforming element.

3-2.11 Linear Static Procedure.

The LSP and limitations to its use are provided in the following sub-sections.

3-2.11.1 Limitations on the Use of LSP.

The use of the LSP is limited to structures that meet the following requirements for irregularities and Demand-Capacity Ratios (DCRs).

If there are no structural irregularities as defined in Section 3-2.11.1.1, a linear static procedure may be performed and it is not necessary to calculate the DCRs defined in Section 3-2.11.1.2. If the structure is irregular, a linear static procedure may be performed if all of the component DCRs determined in the Section 3-2.11.1.1 are less than or equal to 2.0. If the structure is irregular and one or more of the DCRs exceed 2.0, then a linear static procedure cannot be used.

3-2.11.1.1 Irregularity Limitations.

A structure is considered irregular if any one of the following is true:

1. Significant discontinuities exist in the gravity-load carrying and lateral force-resisting systems of a building, including out-of-plane offsets of primary vertical elements, roof "belt-girders", and transfer girders (i.e., non-stacking primary columns or load-bearing elements). Stepped back stories are not considered an irregularity.
2. At any exterior column except at the corners, at each story in a framed structure, the ratios of bay stiffness and/or strength from one side of the column to the other are less than 50%. Three examples are; a) the lengths of adjacent bays vary significantly, b) the beams on either side of the column vary significantly in depth and/or strength, and c) connection strength and/or stiffness vary significantly on either side of the column (e.g., for a steel frame building, a shear tab connection on one side of a column and a fully rigid connection on the other side shall be considered irregular).
3. For all external load-bearing walls, except at the corners, and for each story in a load-bearing wall structure, the ratios of wall stiffness and/or strength from one side of an intersecting wall to the other are less than 50%.
4. The vertical lateral-load resisting elements are not parallel to the major orthogonal axes of the lateral force-resisting system, such as the case of skewed or curved moment frames and load-bearing walls.

3-2.11.1.2 DCR Limitation.

To calculate the DCRs for either framed or load-bearing structures, create a linear model of the building as described in Section 3-2.11.2.2. The model will have all primary components with the exception of the removed wall or column. The deformation-controlled load case in Section 3-2.11.4.1 shall be applied, with gravity dead and live loads increased by the load increase factor Ω_{LD} in Section 3-2.11.5. The resulting actions (internal forces and moments) are defined as Q_{UDLim}:

Use Q_{UDLim} to calculate the ***DCRs*** for the deformation controlled actions as:

$$DCR = Q_{UDLim}/Q_{CE} \qquad \text{Equation (3-9)}$$

where Q_{CE} = Expected strength of the component or element, as specified in Chapters 4 to 8.

3-2.11.2 Analytical Modeling.

To model, analyze, and evaluate a building, employ a three-dimensional assembly of elements and components. Two-dimensional models are not permitted. Note that hand or spreadsheet calculations can be used, as allowed in Section 3-2.2 Alternative Rational Analysis.

3-2.11.2.1 Loads.

Analyze the model with two separate load cases: 1) to calculate the deformation-controlled actions Q_{UD}, and 2) to calculate the force-controlled actions Q_{UF}. Apply the Gravity loads to the model using the load cases for deformation-controlled actions and force-controlled actions defined in Section 3-2.11.4.

3-2.11.2.2 Required Model Elements.

Include the stiffness and resistance of only the primary elements and components. Insure that the model includes a sufficient amount of structural detail to allow the correct transfer of vertical loads from the floor and roof system to the primary elements. Use the guidance of ASCE 41 Chapters 9 through 12 to create the model. Also, as discussed later, and after the analysis is performed, check the primary and secondary elements against the acceptance criteria for force-controlled and deformation-controlled actions. While secondary elements are not included in the model, their actions and deformations can either be estimated based on the deformations of the model with only primary elements or the model may be re-analyzed with the secondary components included. If the model is re-analyzed with the secondary components included, their stiffness and resistance must be set to zero, i.e., the advantage of including the secondary components is that the analyst may more easily check the secondary elements deformations rather than perform hand calculations of the original model.

If the building contains sections that are less than three stories and are attached to the sections with three or more stories, the designer shall perform an analysis to determine whether there is a possibility that the presence of the short section will affect the taller section in a negative manner; if so, then include the short section in the model.

3-2.11.2.3 Limitations on Connection Strength.

For models that incorporate connections between horizontal flexural elements (beams, slabs, girders, etc) and vertical load-bearing elements (columns and walls), the strength of the connection shall not be modeled as greater than the strength of the attached horizontal flexural element.

3-2.11.3 Stability/P-Δ Effects.

\2\Note that overall vertical and lateral stability as well as local stability (i.e., lateral torsional buckling) must be considered. However, a P-Δ analysis is not required for the Linear Static approach due to the small deformations. /2/

3-2.11.4 Loading.

Due to the different methods by which deformation-controlled and force-controlled actions are calculated, two load cases will be applied and analyzed: one for the deformation-controlled actions, and one for the force-controlled actions, as specified here.

Live load reduction is allowed, if the requirements in Section 3-2.3 are met.

3-2.11.4.1 Load Case for Deformation-Controlled Actions Q_{UD}.

To calculate the deformation-controlled actions, simultaneously apply the following combination of gravity loads:

Increased Gravity Loads for Floor Areas Above Removed Column or Wall. Apply the following increased gravity load combination to those bays immediately adjacent to the removed element and at all floors above the removed element; see Figures 3-13 and 3-14:

\2\ $G_{LD} = \Omega_{LD}\,[1.2\,D + (0.5\,L \text{ or } 0.2\,S)]$ /2/ Equation (3-10)

where

G_{LD} = Increased gravity loads for deformation-controlled actions for Linear Static Analysis
D = Dead load including façade loads (lb/ft^2 or kN/m^2)
L = Live load including live load reduction per Section 3-2.3 (lb/ft^2 or kN/m^2)
S = Snow load (lb/ft^2 or kN/m^2)
Ω_{LD} = Load increase factor for calculating deformation-controlled actions for Linear Static analysis; use appropriate value for framed or load-bearing wall structures; see Section 3-2.11.5

Gravity Loads for Floor Areas Away From Removed Column or Wall. Apply the following gravity load combination to those bays not loaded with G_{LD}; see Figures 3-13 and 3-14:

\2\ $G = 1.2\,D + (0.5\,L \text{ or } 0.2\,S)$ /2/ Equation (3-11)

where G = Gravity loads

\2\ /2/

3-2.11.4.2 Load Case for Force-Controlled Actions Q_{UF}.

To calculate the force-controlled actions, simultaneously apply the following combination of gravity loads.

Increased Gravity Loads for Floor Areas Above Removed Column or Wall. Apply the following increased gravity load combination to those bays immediately adjacent to the removed element and at all floors above the removed element; see Figures 3-13 and 3-14:

\2\ $G_{LF} = \Omega_{LF} [1.2 D + (0.5 L \text{ or } 0.2 S)]$ /2/ Equation (3-12)

where
- G_{LF} = Increased gravity loads for force-controlled actions for Linear Static analysis
- D = Dead load including façade loads (lb/ft^2 or kN/m^2)
- L = Live load including live load reduction per Section 3-2.3 (lb/ft^2 or kN/m^2)
- S = Snow load (lb/ft^2 or kN/m^2)
- Ω_{LF} = Load increase factor for calculating force-controlled actions for Linear Static analysis; use appropriate value for framed or load-bearing wall structures; see Section 3-2.11.5

Gravity Loads for Floor Areas Away From Removed Column or Wall. Use Equation 3-11 to determine the load ***G*** and apply as shown in Figures 3-13 and 3-14. \2\ /2/

3-2.11.5 Load Increase Factor.

The load increase factors for deformation-controlled and force-controlled actions for column and wall removal are provided in Table 3-4.

In Table 3-4, m_{LIF} is the smallest ***m*** of any primary beam, girder, spandrel or wall element that is directly connected to the columns or walls directly above the column or wall removal location. For each primary beam, girder, spandrel or wall element, ***m*** is the ***m***-factor defined in Chapters 4 to 8 of this UFC, where **m** is either explicitly provided in each chapter or reference is made to ASCE 41 and a corresponding performance level (Collapse Prevention or Life Safety). Columns are omitted from the determination of m_{LIF}. The method behind this procedure is explained in Appendix C.

Table 3-4. Load Increase Factors for Linear Static Analysis

Material	Structure Type	Ω_{LD}, Deformation controlled	Ω_{LF}, Force controlled
Steel	Framed	0.9 m_{LIF} + 1.1	2.0
Reinforced Concrete	Framed[A]	1.2 m_{LIF} + 0.80	2.0
	Load-bearing Wall	2.0 m_{LIF}	2.0
Masonry	Load-bearing Wall	2.0 m_{LIF}	2.0
Wood	Load-bearing Wall	2.0 m_{LIF}	2.0
Cold-formed Steel	Load-bearing Wall	2.0 m_{LIF}	2.0

[A] Note that, per ASCE 41, reinforced concrete beam-column joints are treated as force-controlled; however, the hinges that form in the beam near the column are deformation-controlled and the appropriate m-factor from Chapter 4 of this UFC shall be applied to the calculation of the deformation-controlled load increase factor Ω_{LD}.
\2\

Figure 3-13. Loads and Load Locations for External and Internal Column Removal for Linear and Nonlinear Static Models (Left Side Demonstrates External Column Removal; Right Side Shows Internal Column Removal)

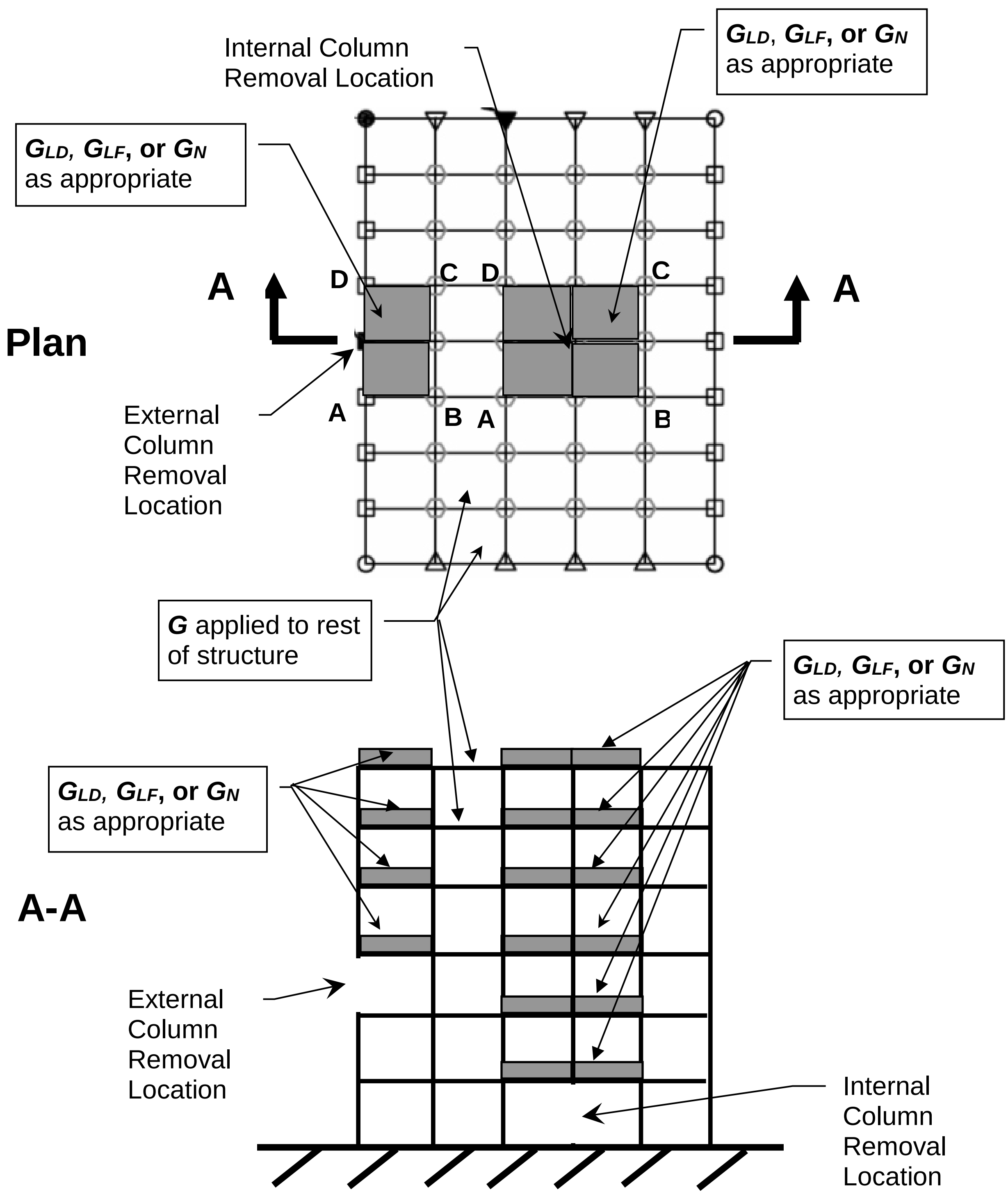
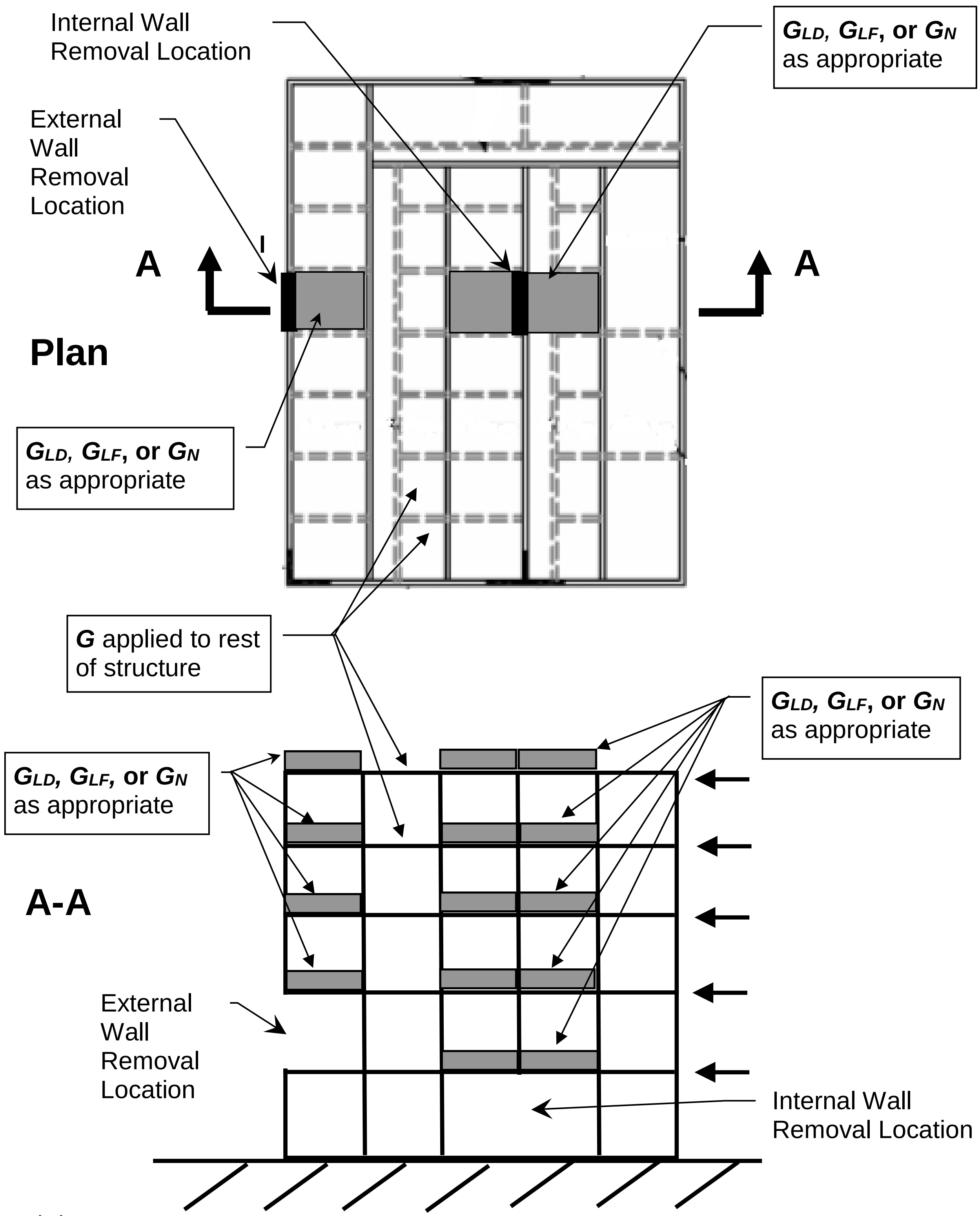


Figure 3-14. Loads and Load Locations for External and Internal Wall Removal for Linear and Nonlinear Static Models (Left Side Demonstrates External Wall Removal; Right Side Shows Internal Wall Removal)



/2/

3-2.11.6 Design Forces and Deformations.

Calculate the deformation-controlled actions Q_{UD}, and force-controlled actions Q_{UF}, accordance with the linear analysis procedures of Sections 3-2.11.2 to 3-2.11.5.

3-2.11.7 Component and Element Acceptance Criteria.

Components and elements analyzed using the linear procedures of Section 3-2.11.2 to 3-2.11.5 shall satisfy the requirements of this section. Prior to selecting component acceptance criteria, classify components as primary or secondary, and classify actions as deformation-controlled or force-controlled, as defined in Section 3-2.5.

3-2.11.7.1 Deformation Controlled Actions.

For deformation-controlled actions in all primary **and** secondary components, check that:

$$\Phi\, m\, Q_{CE} \geq Q_{UD} \qquad \text{Equation (3-13)}$$

where
- Q_{UD} = Deformation-controlled action, from Linear Static model
- m = Component or element demand modifier (m-factor) as defined in Chapters 4 to 8 of this document.
- Φ = Strength reduction factor from the appropriate material specific code.
- Q_{CE} = Expected strength of the component or element for deformation-controlled actions.

Q_{CE}, the expected strength, shall be determined by considering all coexisting actions on the component under the design loading condition by procedures specified in ASCE 41 Chapters 9 through 12. Note that this includes interaction equations for shear, axial force, and moment and that these equations include force- and deformation-controlled actions, as well as expected and lower bound strengths.

Use the appropriate resistance factor for each action, as specified in the material specific design codes (i.e., the Φ factors in ACI 318, the AISC Steel Construction Manual, etc).

3-2.11.7.2 Force-Controlled Actions.

For force-controlled actions in all primary **and** secondary components:

$$\Phi\, Q_{CL} \geq Q_{UF} \qquad \text{Equation (3-14)}$$

where
- Q_{UF} = Force-controlled action, from Linear Static model
- Q_{CL} = Lower-bound strength of a component or element

for force-controlled actions

$\boldsymbol{\Phi}$ = Strength reduction factor from the appropriate material specific code.

Q_{CL}, the lower-bound strength, shall be determined by considering all coexisting actions on the component under the design loading condition by procedures specified in ASCE 41 Chapters 9 through 12. Use the appropriate resistance factor for each action, as specified in the material specific design codes (i.e., the $\boldsymbol{\Phi}$ factors in ACI 318, the AISC Steel Construction Manual, etc).

3-2.11.7.3 Secondary Elements and Components.

All secondary components and elements must be checked to ensure that they meet the acceptance criteria. Deformation-controlled actions are checked according to Equation 3-13 and force-controlled actions are checked according to Equation 3-14.

3-2.12 Nonlinear Static Procedure.

The NSP and limitations to its use are provided in the following sub-sections.

3-2.12.1 Limitations on the Use of NSP.

There are no DCR or geometric irregularity limitations on the use of the NSP.

3-2.12.2 Analytical Modeling.

To model, analyze, and evaluate a building, employ a three-dimensional assembly of elements and components. Two-dimensional models are not permitted. Create one model, as shown in Figures 3-13 and 3-14 for either framed or load-bearing wall structures, respectively. Inclusion of secondary components in the model is optional. However, if the secondary components are omitted, they must be checked after the analysis, against the allowable deformation-controlled criteria (e.g., to check the connections of gravity beams in a steel structure, compute the chord rotation and compare against the allowable plastic rotation angle for that connection). Include the stiffness and resistance of primary components. Note that the strength reduction factors are applied to the nonlinear strength models of the deformation controlled components (e.g., the nominal flexural strength of a beam or connection is multiplied by the appropriate $\boldsymbol{\Phi}$ factor). Analyze the model for the Nonlinear Static load case defined in Section 3-2.12.4

Use the stiffness requirements of ASCE 41 Chapters 9 through 12 to create the model. Discretize the load-deformation response of each component along its length to identify locations of inelastic action. The force-displacement behavior of all components shall be explicitly modeled, including strength degradation and residual strength, if any. Model a connection explicitly if the connection is weaker or has less ductility than the connected components, or the flexibility of the connection results in a change in the connection forces or deformations greater than 10%.

If the building contains sections that are less than three stories and are attached to the sections with three or more stories, the designer shall use engineering judgment to include some or all of the shorter section if there is any possibility that the presence of the short section will affect the taller section in a negative manner.

3-2.12.3 \2\Stability/P-Δ Effects.

Note that overall vertical and lateral stability as well as local stability (i.e., lateral torsional buckling) must be considered. /2/

3-2.12.4 Loading

\2\Live load reduction is allowed, if the requirements in Section 3-2.3 are met. /2/

3-2.12.4.1 Loads.

To calculate the deformation-controlled and force-controlled actions, simultaneously apply the following combination of gravity loads:

Increased Gravity Loads for Floor Areas Above Removed Column or Wall. Apply the following increased gravity load combination to those bays immediately adjacent to the removed element and at all floors above the removed element; see Figures 3-13 and 3-14:

\2\ $G_N = \Omega_N [1.2 D + (0.5 L \text{ or } 0.2 S)]$ /2/ Equation (3-15)

where
- G_N = Increased gravity loads for Nonlinear Static Analysis
- D = Dead load including façade loads (lb/ft^2 or kN/m^2)
- L = Live load including live load reduction per Section 3-2.3 (lb/ft^2 or kN/m^2)
- S = Snow load (lb/ft^2 or kN/m^2)
- Ω_N = Dynamic increase factor for calculating deformation-controlled and force-controlled actions for Nonlinear Static analysis, use appropriate value for framed or load-bearing wall structures. see Section 3-2.12.5

Gravity Loads for Floor Areas Away From Removed Column or Wall. Apply the following gravity load combination to those bays not loaded with G_N; see Figures 3-13 and 3-14.

\2\ $G = 1.2 D + (0.5 L \text{ or } 0.2 S)$ /2/ Equation (3-16)

where G = Gravity loads

\2\ /2/

3-2.12.4.2 Loading Procedure.

Apply the loads using a load history that starts at zero and is increased to the final values. Apply at least 10 load steps to reach the total load. The software must be capable of incrementally increasing the load and iteratively reaching convergence before proceeding to the next load increment.

3-2.12.5 Dynamic Increase Factor for NSP.

The Nonlinear Static dynamic increase factors are provided in Table 3-5.

In Table 3-5, θ_{pra} is the plastic rotation angle given in the acceptance criteria tables in ASCE 41 and this UFC for the appropriate structural response level (Collapse Prevention or Life Safety, as specified in Chapters 4 to 8 of this UFC) for the particular element, component or connection; θ_y is the yield rotation. For steel, θ_y is given in Equation 9-1 in ASCE 41. For reinforced concrete, θ_y is determined with the effective stiffness values provided in Table 10-5 in ASCE 41. Note that for connections, θ_y is the yield rotation angle of the structural element that is being connected (beam, slab, etc) and θ_{pra} is for the connection (determined from ASCE 41 and this UFC). Columns are omitted from the determination of the DIF.

To determine the DIF for the analysis of the entire structure, choose the smallest ratio of θ_{pra}/θ_y for any primary element, component, or connection in the model within or touching the area that is loaded with the increased gravity load, as shown in Figures 3-13 and 3-14. In other words, the DIF for every primary connection, beam, girder, wall element, etc that falls within or touches the perimeter marked as A-B-C-D must be determined and the largest value is used for the analysis. The method behind this procedure is explained in Appendix C.

Table 3-5. Dynamic Increase Factors for Nonlinear Static Analysis

Material	Structure Type	Ω_N
Steel	Framed	$1.08 + 0.76/(\theta_{pra}/\theta_y + 0.83)$
Reinforced Concrete	Framed	$1.04 + 0.45/(\theta_{pra}/\theta_y + 0.48)$
	Load-Bearing Wall	2
Masonry	Load-bearing Wall	2
Wood	Load-bearing Wall	2
Cold-formed Steel	Load-bearing Wall	2

3-2.12.6 Design Forces and Deformations.

Calculate component design forces and deformations in accordance with the nonlinear analysis procedure of Sections 3-2.12.2 to 3-2.12.5.

3-2.12.7 Component and Element Acceptance Criteria.

Components and elements analyzed using the nonlinear procedures of Sections 3-2.12.2 to 3-2.12.5 shall satisfy the requirements of this section.

3-2.12.7.1 Deformation-Controlled Actions.

Primary and secondary elements and components shall have expected deformation capacities greater than the maximum calculated deformation demands. Expected deformation capacities shall be determined considering all coexisting forces and deformations in accordance with Chapters 4 to 8 of this document.

3-2.12.7.2 Force-Controlled Actions.

For force-controlled actions in all primary **and** secondary elements and components:

$$\Phi \, Q_{CL} \geq Q_{UF} \qquad \text{Equation (3-17)}$$

where

- Q_{UF} = Force-controlled action, from Nonlinear Static model
- Q_{CL} = Lower-bound strength of a component or element.
- Φ = Strength reduction factor from the appropriate material specific code.

Q_{CL}, the lower-bound strength, shall be determined by considering all coexisting actions on the component under the design loading condition by procedures specified in ASCE 41 Chapters 9 through 12. Use the appropriate resistance factor for each action, as specified in the material specific design codes (i.e., the Φ factors in ACI 318, the AISC Steel Construction Manual, etc).

3-2.13 Nonlinear Dynamic Procedure.

The NDP and limitations to its use are provided in the following sub-sections.

3-2.13.1 Limitations on the Use of NDP.

There are no DCR or geometric irregularity limitations on the use of the NDP.

3-2.13.2 Analytical Modeling.

To model, analyze, and evaluate a building, employ a three-dimensional assembly of elements and components. Two-dimensional models are not permitted. Create a model of the entire structure, including the wall section and column that are to be removed during the analysis. Include the stiffness and resistance of primary components. Note that the strength reduction factors are applied to the nonlinear strength models of the deformation controlled components (e.g., the nominal flexural strength of a beam or connection is multiplied by the appropriate $\boldsymbol{\Phi}$ factor). Inclusion of secondary components in the model is optional. However, if the secondary components are omitted, they must be checked after the analysis, against the allowable deformation-controlled criteria (e.g., to check the connections of gravity beams in a steel structure, compute the chord rotation and compare against the allowable plastic rotation angle for that connection). Apply the loads per the loading procedure in Section 3-2.13.4.

Use the stiffness requirements of ASCE 41 Chapters 9 through 12 to create the model. Discretize the load-deformation response of each component along its length to identify locations of inelastic action. The force-displacement behavior of all components shall be explicitly modeled, including strength degradation and residual strength, if any. Model a connection explicitly if the connection is weaker or has less ductility than the connected components, or the flexibility of the connection results in a change in the connection forces or deformations greater than 10%.

If the building contains sections that are less than three stories and are attached to the sections with three or more stories, the designer shall use engineering judgment to include some or all of the shorter section if there is any possibility that the presence of the short section will affect the taller section in a negative manner.

3-2.13.3 Lateral Stability and P- Δ Effects.

\2\Note that overall vertical and lateral stability as well as local stability (i.e., lateral torsional buckling) must be considered./2/

3-2.13.4 Loading

\2\Live load reduction is allowed if the requirements in Section 3-2.3 are met. /2/

3-2.13.4.1 Loads.

To calculate the deformation-controlled and force-controlled actions, apply the following gravity load per the loading procedure given in Section 3-2.13.4.2:

Gravity Loads for Entire Structure. Apply the following gravity load combination to the entire structure.

\2\ $G_{ND} = 1.2\,D + (0.5\,L \text{ or } 0.2\,S)$ /2/ Equation (3-18)

where
G_{ND} = Gravity loads for Nonlinear Dynamic Analysis
D = Dead load including façade loads (lb/ft^2 or kN/m^2)
L = Live load including live load reduction per Section 3-2.3 (lb/ft^2 or kN/m^2)
S = Snow load (lb/ft^2 or kN/m^2)

\2\/2/

3-2.13.4.2 Loading Procedure.

Starting at zero load, monotonically and proportionately increase the gravity loads to the entire model (i.e., the column or wall section have not been removed yet) until equilibrium is reached.

After equilibrium is reached for the framed and load-bearing wall structures, remove the column or wall section. While it is preferable to remove the column or wall section instantaneously, the duration for removal must be less than one tenth of the period associated with the structural response mode for the vertical motion of the bays above the removed column, as determined from the analytical model with the column or wall section removed. The analysis shall continue until the maximum displacement is reached or one cycle of vertical motion occurs at the column or wall section removal location.

3-2.13.5 Design Forces and Deformations.

Calculate component design forces and deformations in accordance with the nonlinear analysis procedure of Sections 3-2.13.2 to 3-2.13.4.

3-2.13.6 Component and Element Acceptance Criteria.

Components and elements analyzed using the nonlinear procedures of Sections 3-2.13.2 to 3-2.13.4 shall satisfy the requirements of this section.

3-2.13.6.1 Deformation-Controlled Actions.

Primary and secondary elements and components shall have expected deformation capacities greater than the maximum calculated deformation demands. Expected deformation capacities shall be determined considering all coexisting forces and deformations in accordance with Chapters 4 to 8 of this document.

3-2.13.6.2 Force-Controlled Actions.

For force-controlled actions in all primary **and** secondary components,

$$\Phi Q_{CL} \geq Q_{UF} \quad \text{Equation (3-19)}$$

where Q_{UF} = Force-controlled action, from Nonlinear Dynamic model
Q_{CL} = Lower-bound strength of a component or element.
Φ = Strength reduction factor from the appropriate material specific code.

Q_{CL}, the lower-bound strength, shall be determined by considering all coexisting actions on the component under the design loading condition by procedures specified in ASCE 41 Chapters 9 through 12. Use the appropriate resistance factor for each action, as specified in the material specific design codes (i.e., the Φ factors in ACI 318, the AISC Steel Construction Manual, etc).

\2\

3-3 ENHANCED LOCAL RESISTANCE

Enhanced Local Resistance (ELR) is required in three cases: RC II Option 1 (Tie Forces and ELR), RC III (Alternate Path and ELR), and RC IV (Tie Forces, Alternate Path and ELR). All three cases contain the same objective, which is to insure that a ductile failure mechanism can form when the column or wall is loaded laterally to failure. To meet this objective, the column or wall must not fail in shear prior to the development of the maximum flexural strength.

Two components must meet the ELR requirement: 1. The column or wall, and 2. The connections between the end of the column or wall and the lateral supports (floor slab, base plate, etc).

Note that design for ELR is not required if the wall or column has been designed for a specific design basis threat, providing that the design basis threat was developed with a risk assessment approach that was approved by the building owner, government agency or other responsible entity.

3-3.1 Load and Resistance Factor Design for Enhanced Local Resistance.

The LRFD approach is used for ELR design,

$$\Phi R_n \geq R_u \quad \text{Equation (3-20)}$$

where ΦR_n = Design strength
Φ = Strength reduction factor

R_n = Nominal strength, including over-strength factors
R_u = Required strength

The design strength provided by a component is taken as the product of the strength reduction factor Φ and the nominal strength R_n. For ELR, all strength reduction factors Φ shall be 1.0. In addition, the material strengths for shear, flexure and all other actions shall be the expected material strength (i.e., with the appropriate over-strength factor applied to the lower bound material strength).

3-3.1.1 Flexural Demand.

The flexural demand is the nominal flexural strength **(R_n)** of a column or wall under the conditions specified in Sections 3-3.3, 3-3.4, and 3-3.5.

3-3.1.2 Shear Demand.

The shear demand is the required shear strength **(R_u)** of the column or wall that is necessary to achieve the required flexural demand of the component, i.e. at the formation of a three-hinge mechanism or similar failure mode in the component. In calculating the shear demand, consider any effects (axial load, end conditions, etc) that may act to increase the nominal flexural strength; in no case shall the shear demand be less than that of the column or wall with zero axial load acting. Include any applicable material over-strength factors. The shear demand shall be determined for the horizontal out-of-plane direction (i.e., perpendicular to the building perimeter façade). Columns at building corners or re-entrant corners shall be evaluated in both directions normal to the building perimeter façade. Examples of this procedure are provided in Appendices D and E.

3-3.2 ELR Location and Extent Requirements.

3-3.2.1 RC II Option 1.

For RC II Option 1 and framed and two-way load-bearing wall buildings, ELR is applied to the perimeter corner and penultimate columns and load-bearing walls of the first story above grade. For one-way load-bearing wall buildings, ELR shall be applied to the entire length of the end wall and penultimate wall; it is recognized that the majority of the penultimate wall may be interior to the structure, but it must still be designed for ELR.

3-3.2.2 RC III.

For RC III and framed and two-way load-bearing wall buildings, ELR is applied to all perimeter columns and load-bearing walls of the first story above grade. For one-way load-bearing wall buildings, ELR shall be applied to the entire length of the end wall and penultimate wall; it is recognized that the majority of the penultimate wall may be interior to the structure, but it must still be designed for ELR.

3-3.2.3 RC IV.

For RC IV and framed and two-way load-bearing wall buildings, ELR is applied to all perimeter columns and load-bearing walls of the first story above grade. For one-way load-bearing wall buildings, ELR shall be applied to the entire length of the end wall and penultimate wall; it is recognized that the majority of the penultimate wall may be interior to the structure, but it must still be designed for ELR.

3-3.3 RC II Option 1 Shear and Flexural Requirements.

For RC II Option 1, the flexural demand for the columns and walls is the nominal flexural strength **(R_n)** of the existing or as-designed structure and, therefore, no design modification is needed to meet the flexural requirement.

The shear demand is based on the flexural demand of the component as described above. Apply the procedure in Section 3-3.1.2 to the columns and walls to determine the shear demand. If Equation 3-20 is not satisfied, modify the column or wall design such that adequate design shear strength **(ΦR_n)** is achieved. If the flexural demand is increased as a result of meeting the shear requirement, check that the design shear strength still exceeds the shear demand associated with this new flexural demand.

3-3.4 RC III Shear and Flexural Requirements.

\4\ An RC III building /4/ must first meet the Alternate Path requirement. The flexural demand for the columns and walls is the nominal flexural strength **(R_n)** of the design after the Alternate Path requirement is applied and therefore, no design modification is needed to meet the flexural requirement.

The shear demand is based on the flexural demand of the component as described above. Apply the procedure in Section 3-3.1.2 to the columns and walls to determine the shear demand. If Equation 3-20 is not satisfied, modify the column or wall design such that adequate design shear strength **(ΦR_n)** is achieved. If the flexural demand is increased as a result of meeting the shear requirement, check that the design shear strength still exceeds the shear demand associated with this new flexural demand.

3-3.5 RC IV Shear and Flexural Requirements.

3-3.5.1 RC IV Flexural Requirements.

For RC IV, two nominal flexural strengths must first be determined and used to define the flexural demand. First, the **baseline** nominal flexural strength is determined using the design of the structure when only gravity loads are considered and after the AP procedure is applied. If such a design or analysis was not performed during the initial design and analysis of the new or existing structure, it must be performed to determine the column and load-bearing wall design.

Second, the **existing** nominal flexural strength is determined using the column and load-bearing wall design defined after the Alternate Path procedure was applied to the structural design that incorporated all applied loads (wind, earthquake, gravity, etc).

For columns in RC IV structures, the flexural demand is equal to the larger of: 1) the baseline nominal flexural strength multiplied by 2.0 and 2) the \4\ /4/ nominal flexural strength. If the flexural demand is controlled by condition 1), then redesign the column as required to meet the flexural demand of this controlling condition.

For load-bearing walls in RC IV structures, the flexural demand is equal to the larger of 1) the baseline nominal flexural strength multiplied by 1.5, and 2) the \4\ /4/ nominal flexural strength. If the flexural demand is controlled by condition 1), then redesign the wall as required to meet the flexural demand of this controlling condition.

3-3.5.2 RC IV Shear Requirements.

The shear demand for columns and walls is based on the flexural demand as calculated in the above section. Apply the procedure in Section 3-3.1.2 to the columns and walls to determine the shear demand. If Equation 3-20 is not satisfied, modify the column or wall design such that adequate design shear strength **(ΦR_n)** is achieved. If the flexural demand is increased as a result of meeting the shear requirement, check that the design shear strength still exceeds the shear demand associated with this new flexural demand.

3-3.6 Connection Design for Rebound Reaction Forces.

In some dynamic loading scenarios, the column or wall will initially be pushed into the building and then rebound back; the connections must be designed to prevent failure during both phases of loading. Connections at the top and bottom of the columns and walls shall be designed for a rebound reaction force equal to 50% of the inbound value.

3-3.7 Conflicts Between ELR and Other Design Requirements.

The ELR requirements may be satisfied in a number of ways and as the designer desires, providing the ELR-modified design does not violate the standard building and material-specific design codes. If there is a conflict with the ELR modifications, the building or material-specific design code has precedence and the ELR design must be altered. /2/

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CHAPTER 4 REINFORCED CONCRETE

This chapter provides the specific requirements for designing a reinforced concrete building to resist progressive collapse. Appendix D demonstrates the application of the reinforced concrete design requirements for a 7-story building.

If composite construction with other materials is employed, use the design guidance from the appropriate material chapter in this UFC for those structural elements or portions of the structure.

Note that the combination of design requirements (TF, AP, and ELR) will depend upon the \3\ Risk Category /3/ of the buildings, as defined in Section 2-2.

4-1 MATERIAL PROPERTIES FOR REINFORCED CONCRETE.

Apply the appropriate over-strength factors to the calculation of the design strengths for both Tie Forces and the Alternate Path method. The over-strength factors are provided in ASCE 41 in Table 10-4 Factors to Translate Lower-Bound Material Properties to Expected Strength Material Properties.

4-2 STRENGTH REDUCTION FACTOR Φ FOR REINFORCED CONCRETE.

For the Alternate Path and Tie Force methods, use the appropriate strength reduction factor specified in ACI 318 *Building Code Requirements for Structural Concrete* for the component and behavior under consideration.

4-3 TIE FORCE REQUIREMENTS FOR REINFORCED CONCRETE.

Apply the Tie Force requirements in Section 3-1, when applicable, for concrete frame and load-bearing wall structural systems, mixed systems with concrete elements, and framed and load-bearing wall systems with precast concrete floors

The strength reduction factor Φ for properly anchored, embedded, or spliced steel reinforcement in tension shall be taken as 0.75 (based on ACI 318 for strut and tie models).

The structural integrity requirements of ACI 318 for cast-in-place and precast concrete construction must be satisfied, as well as the Tie Force requirements in this document. Use the largest or most stringent requirement when there is overlap between ACI 318 and this UFC.

4-4 ALTERNATE PATH REQUIREMENTS FOR REINFORCED CONCRETE.

4-4.1 General.

Use the Alternate Path method in Section 3-2 to verify that the structure can bridge over removed elements.

4-4.2 Flexural Members and Joints.

\4\ /4/The design strength and rotational capacities of the beams and beam-to-column joints shall be determined with the guidance found in ASCE 41, as modified with the acceptance criteria provided in Paragraph 4-4.3.

4-4.3 Modeling and Acceptance Criteria for Reinforced Concrete.

With the exception of Tables 10-7, 10-11, 10-14, and 10-15 in ASCE 41, use the modeling parameters, nonlinear acceptance criteria and linear m-factors for the Life Safety condition from Chapter 10 of ASCE 41 for primary and secondary components. Use the ASCE 41 modeling parameters and guidance, including definitions of stiffness, to create the analytical model.

Replace Table 10-7 of ASCE 41 with Table 4-1, which contains the nonlinear modeling parameters and acceptance criteria for reinforced concrete beams. Replace Table 10-11 of ASCE 41 with Table 4-2, which contains the acceptance criteria for linear modeling of reinforced concrete beams.

Replace Table 10-14 of ASCE 41 with Table 4-3, which contains the nonlinear modeling parameters and acceptance criteria for two-way slabs and slab-column connections. Replace Table 10-15 of ASCE 41 with Table 4-4, which contains the acceptance criteria for linear modeling of two-way slabs and slab-column connections.

4-5 ENHANCED LOCAL RESISTANCE REQUIREMENTS FOR REINFORCED CONCRETE.

Apply the Enhanced Local Resistance requirements in Section 3-3, where applicable, for framed and load-bearing wall reinforced concrete buildings.

Table 4-1. Nonlinear Modeling Parameters and Acceptance Criteria for Reinforced Concrete Beams (Replacement for Table 10-7 in ASCE 41)

			Modeling Parameters[1]			Acceptance Criteria[1,2]		
						Plastic Rotations Angle, radians		
			Plastic Rotations Angle, radians		Residual Strength Ratio		Component Type	
							Primary	Secondary
Conditions			a	b	c			
i. Beams controlled by flexure[3]								
$\frac{\rho-\rho'}{\rho_{bal}}$	Trans. Reinf.[4]	$\frac{V}{b_w d\sqrt{f'_c}}$						
≤ 0.0	C	≤ 3	0.063	0.10	0.2		0.063	0.10
≤ 0.0	C	≥ 6	0.05	0.08	0.2		0.05	0.08
≥ 0.5	C	≤ 3	0.05	0.06	0.2		0.05	0.06
≥ 0.5	C	≥ 6	0.038	0.04	0.2		0.038	0.04
≤ 0.0	NC	≤ 3	0.05	0.06	0.2		0.05	0.06
≤ 0.0	NC	≥ 6	0.025	0.03	0.2		0.025	0.03
≥ 0.5	NC	≤ 3	0.025	0.03	0.2		0.025	0.03
≥ 0.5	NC	≥ 6	0.013	0.02	0.2		0.013	0.02
ii. Beams controlled by shear[3]								
Stirrup spacing ≤ d /2			0.0030	0.02	0.2		0.002	0.01
Stirrup spacing > d /2			0.0030	0.01	0.2		0.002	0.005
iii. Beams controlled by inadequate development or splicing along the span[3]								
Stirrup spacing ≤ d /2			0.0030	0.02	0.0		0.002	0.01
Stirrup spacing > d /2			0.0030	0.01	0.0		0.002	0.005
iv. Beams controlled by inadequate embedment into beam-column joint[3]								
			0.015	0.03	0.2		0.01	0.02

1. Linear interpolation between values listed in the table shall be permitted. See Section 3-2.4 for definition of primary and secondary components and Figure 3-7 for definition of nonlinear modeling parameters *a, b,* and *c*
2. Primary and secondary component demands shall be within secondary component acceptance criteria where the full backbone curve is explicitly modeled including strength degradation and residual strength, in accordance with Section 7.4.3.2 of ASCE 41.
3. Where more than one of the conditions i, ii, iii, and iv occurs for a given component, use the minimum appropriate numerical value from the table.
4. "C" and "NC" are abbreviations for conforming and nonconforming transverse reinforcement. A component is conforming if, within the flexural plastic hinge region, hoops are spaced at ≤ *d/3*, and if, for components of moderate and high ductility demand, the strength provided by the hoops (V_s) is at least three-fourths of the design shear. Otherwise, the component is considered nonconforming.

Table 4-2. Acceptance Criteria for Linear Models of Reinforced Concrete Beams (Replacement for Table 10-11 in ASCE 41)

Conditions				*m*-factors[1]	
				Component Type	
				Primary	Secondary
i. Beams controlled by flexure[2]					
$\frac{\rho - \rho'}{\rho_{bal}}$	Trans. Reinf.[3]	$\frac{V}{b_w d \sqrt{f'_c}}$ [4]			
≤ 0.0	C	≤ 3		16	19
≤ 0.0	C	≥6		9	9
≥ 0.5	C	≤ 3		9	9
≥ 0.5	C	≥ 6		6	7
≤ 0.0	NC	≤ 3		9	9
≤ 0.0	NC	≥ 6		6	7
≥ 0.5	NC	≤ 3		6	7
≥ 0.5	NC	≥ 6		4	5
ii. Beams controlled by shear[2]					
Stirrup spacing ≤ d /2				1.5	3
Stirrup spacing > d /2				1.5	2
iii. Beams controlled by inadequate development or splicing along the span[2]					
Stirrup spacing ≤ d /2				1.5	3
Stirrup spacing > d /2				1.5	2
iv. Beams controlled by inadequate embedment into beam-column joint[2]					
				2	3

1. Linear interpolation between values listed in the table shall be permitted. See Section 3-2.4 for definition of primary and secondary components.
2. Where more than one of the conditions i, ii, iii, and iv occurs for a given component, use the minimum appropriate numerical value from the table.
3. "C" and "NC" are abbreviations for conforming and nonconforming transverse reinforcement. A component is conforming if, within the flexural plastic hinge region, hoops are spaced at ≤ *d/*3, and if, for components of moderate and high ductility demand, the strength provided by the hoops (V_s) is at least three-fourths of the design shear. Otherwise, the component is considered nonconforming.
4. V is the design shear force calculated using limit-state analysis procedures in accordance with Section 10.4.2.4.1 of ASCE 41.

Table 4-3. Modeling Parameters and Acceptance Criteria for Nonlinear Models of Two-Way Slabs and Slab-Column Connections (Replacement for Table 6-14 in ASCE 41)

		Modeling Parameters[1]			Acceptance Criteria[1,2]		
					Plastic Rotations Angle, radians		
						Component Type	
		Plastic Rotations Angle, radians		Residual Strength Ratio		Primary	Secondary
Conditions		a	b	c			
i. Slabs controlled by flexure, and slab-column connections[3]							
$\frac{V_g}{V_o}$ [2]	Continuity Reinforcement[3]						
≤ 0.2	Yes	0.05	0.10	0.2		0.05	0.10
≥ 0.4	Yes	0.0	0.04	0.2		0.0	0.08
≤ 0.2	No	0.02	0.02	-		0.015	0.015
≥ 0.4	No	0.0	0.0	-		0.0	0.0
ii. Slabs controlled by inadequate development or splicing along the span[3]							
		0.0	0.02	0.0		0.0	0.01
iii. Slabs controlled by inadequate embedment into slab-column joint[3]							
		0.015	0.03	0.2		0.01	0.02

1. Linear interpolation between values listed in the table shall be permitted. See Section 3-2.4 for definition of primary and secondary components and Figure 3-7 for definition of nonlinear modeling parameters *a*, *b*, and *c*.
2. Primary and secondary component demands shall be within secondary component acceptance criteria where the full backbone curve is explicitly modeled including strength degradation and residual strength, in accordance with Section 7.4.3.2 of ASCE 41.
3. Where more than one of the conditions i, ii, iii, and iv occurs for a given component, use the minimum appropriate numerical value from the table.
4. V_g = the gravity shear acting on the slab critical section as defined by ACI 318; V_o = the direct punching shear strength as defined by ACI 318.
5. Under the heading "Continuity Reinforcement," use "Yes" where at least one of the main bottom bars in each direction is effectively continuous through the column cage. Where the slab is post-tensioned, use "Yes" where at least one of the post-tensioning tendons in each direction passes through the column cage. Otherwise, use "No."

Table 4-4. Acceptance Criteria for Linear Models of Two-Way Slabs and Slab-Column Connections (Replacement for Table 6-15 in ASCE 41)

Conditions			*m*-factors[1]	
			Component Type	
			Primary	Secondary
i. Slabs controlled by flexure, and slab-column connections[2]				
$\frac{V_g}{V_o}$[3]	Continuity Reinforcement[4]			
≤ 0.2	Yes		6	7
≥ 0.4	Yes		1	5
≤ 0.2	No		2	2
≥ 0.4	No		1	1
ii. Slabs controlled by inadequate development or splicing along the span[2]				
			-	4
iii. Slabs controlled by inadequate embedment into slab-column joint[2]				
			3	4

1. Linear interpolation between values listed in the table shall be permitted. See Section 3-2.4 for definition of primary and secondary components.
2. Where more than one of the conditions i, ii, and iii occurs for a given component, use the minimum appropriate numerical value from the table.
3. V_g = the gravity shear acting on the slab critical section as defined by ACI 318; V_o = the direct punching shear strength as defined by ACI 318.
4. Under the heading "Continuity Reinforcement," use "Yes" where at least one of the main bottom bars in each direction is effectively continuous through the column cage. Where the slab is post-tensioned, use "Yes" where at least one of the post-tensioning tendons in each direction passes through the column cage. Otherwise, use "No."

CHAPTER 5 STRUCTURAL STEEL

This chapter provides the specific requirements for designing a structural steel building to resist progressive collapse. Appendix E demonstrates the application of the structural steel design requirements for a 4-story building.

If composite construction with other materials is employed, use the design guidance from the appropriate material chapter in this UFC for those structural elements or portions of the structure.

Note that the combination of design requirements (TF, AP, and ELR) will depend upon the \3\ Risk Category /3/ of the buildings, as defined in Section 2-2.

5-1 MATERIAL PROPERTIES FOR STRUCTURAL STEEL.

Apply the appropriate over-strength factors to the calculation of the design strengths for both Tie Forces and the Alternate Path method. The over-strength factors are provided in ASCE 41 in Table 5-3 Factors to Translate Lower-Bound Steel Properties to Expected Strength Steel Properties.

5-2 STRENGTH REDUCTION FACTOR *Φ* FOR STRUCTURAL STEEL.

For Alternate Path and Tie Force methods, use the appropriate strength reduction factor ***Φ*** specified in ANSI/AISC 360 *Specifications for Structural Steel Buildings* for the component and behavior under consideration. If steel components can be proven capable of carrying the required longitudinal, transverse, and peripheral tie strength while undergoing rotations of 0.20-rad (11.3-deg), use the appropriate strength reduction factor ***Φ*** for each limit state considered.

5-3 TIE FORCE REQUIREMENTS FOR STEEL.

Apply the Tie Force requirements in Section 3-1, where applicable, for framed steel buildings.

5-4 ALTERNATE PATH METHOD FOR STEEL.

5-4.1 General.

Use the Alternate Path method in Section 3-2, where applicable, to verify that the structure can bridge over removed elements.

5-4.2 Connection Rotational Capacity.

\4\-/4/ The design strength and rotational capacities of the beams and beam-to-column connections shall be determined with the guidance found in ASCE 41, as modified with the acceptance criteria provided in Paragraph 5-4.3.

5-4.3 Modeling and Acceptance Criteria for Structural Steel.

With the exception of the connections and elements discussed later in this section, use the modeling parameters, nonlinear acceptance criteria and linear ***m***-factors for the Life Safety condition from Chapter 9 of ASCE 41 for primary and secondary components. Use the modeling parameters and guidance, including definitions of stiffness, to create the analytical model.

Columns under high axial load (P/P_{CL} > 0.5) shall be considered force-controlled, with the considered loads (***P*** and ***M***) equal to the maximum loads from the analysis. The ***P-M*** interaction equation shall not exceed unity. For $P/P_{CL} \leq 0.5$, the interaction equation shall be used with the moment considered as deformation-controlled and the axial force as force-controlled.

Nonlinear and linear acceptance criteria for structural steel components shall meet the Life Safety condition for primary and secondary elements provided in Tables 9-5, 9-6 and 9-7 of ASCE 41, except as follows:

1. For beams subjected to flexure or flexure plus axial tension, use the Collapse Prevention values for primary and secondary elements.

2. For the Fully Restrained (FR) and Partially Restrained (PR) connections listed in Tables 5-1 and 5-2 in this UFC, use the specified plastic rotations, modeling parameters and m-factors, as given.

For the Double Angles PR connection, the expected flexural strength shall be determined for each of the three limit states listed in Tables 5-1 and 5-2, using accepted analytical procedures. For the Simple Shear Tab, the expected flexural strength will be taken as the smallest flexural strength determined with limit state analysis for bolt shear, weld failure, block shear, bearing, plate flexure or other limit states as appropriate.

5-5 ENHANCED LOCAL RESISTANCE REQUIREMENTS FOR STEEL.

Apply the Enhanced Local Resistance requirements in Section 3-3, where applicable, for framed and load-bearing wall steel buildings.

Table 5-1. Acceptance Criteria for Linear Static Modeling of Steel Frame Connections

Connection Type	Linear Acceptance Criteria	
	m-factors	
	Primary[(1)]	Secondary[(1)]
Fully Restrained Moment Connections		
Improved WUF with Bolted Web	2.3 – 0.021d	4.9 – 0.048d
Reduced Beam Section (RBS)	4.9 – 0.025d	6.5 – 0.025d
WUF	4.3 – 0.083d	4.3 -0.048d
SidePlate®	6.7 – 0.039d[(2)]	11.1 – 0.062d
Partially Restrained Moment Connections (Relatively Stiff)		
Double Split Tee		
a. Shear in Bolt	4	6
b. Tension in Bolt	1.5	4
c. Tension in Tee	1.5	4
d. Flexure in Tee	5	7
Partially Restrained Simple Connections (Flexible)		
Double Angles		
a. Shear in Bolt	$5.8 – 0.107d_{bg}$[(3)]	$8.7 – 0.161d_{bg}$
b. Tension in Bolt	1.5	4
c. Flexure in Angles	$8.9 – 0.193d_{bg}$	$13.0 – 0.290d_{bg}$
Simple Shear Tab	$5.8 – 0.107d_{bg}$	$8.7 – 0.161d_{bg}$

(1) Refer to Section 3-2.4 for determination of Primary and Secondary classification
(2) d = depth of beam, inch
(3) d_{bg} = depth of bolt group, inch

Table 5-2. Modeling Parameters and Acceptance Criteria for Nonlinear Modeling of Steel Frame Connections

Connection Type	Nonlinear Modeling Parameters(1)			Nonlinear Acceptance Criteria	
	Plastic Rotation Angle, radians		Residual Strength Ratio	Plastic Rotation Angle, radians	
	a	***b***	***c***	**Primary(2)**	**Secondary(2)**
Fully Restrained Moment Connections					
Improved WUF with Bolted Web	0.021 - 0.0003d	0.050 - 0.0006d	0.2	0.021 - 0.0003d	0.050 - 0.0006d
Reduced Beam Section (RBS)	0.050 - 0.0003d	0.070 - 0.0003d	0.2	0.050 - 0.0003d	0.070 - 0.0003d
WUF	0.0284 - 0.0004d	0.043 - 0.0006d	0.2	0.0284 - 0.0004d	0.043 - 0.0006d
SidePlate®	0.089 - 0.0005d(3)	0.169 - 0.0001d	0.6	0.089 - 0.0005d	0.169 - 0.0001d
Partially Restrained Moment Connections (Relatively Stiff)					
Double Split Tee					
a. Shear in Bolt	0.036	0.048	0.2	0.03	0.040
b. Tension in Bolt	0.016	0.024	0.8	0.013	0.020
c. Tension in Tee	0.012	0.018	0.8	0.010	0.015
d. Flexure in Tee	0.042	0.084	0.2	0.035	0.070
Partially Restrained Simple Connections (Flexible)					
Double Angles					
a. Shear in Bolt	$0.0502 - 0.0015d_{bg}$(4)	$0.072 - 0.0022d_{bg}$	0.2	$0.0502 - 0.0015d_{bg}$	$0.0503 - 0.0011d_{bg}$
b. Tension in Bolt	$0.0502 - 0.0015d_{bg}$	$0.072 - 0.0022d_{bg}$	0.2	$0.0502 - 0.0015d_{bg}$	$0.0503 - 0.0011d_{bg}$
c. Flexure in Angles	$0.1125 - 0.0027d_{bg}$	$0.150 - 0.0036d_{bg}$	0.4	$0.1125 - 0.0027d_{bg}$	$0.150 - 0.0036d_{bg}$
Simple Shear Tab	$0.0502 - 0.0015d_{bg}$	$0.1125 - 0.0027d_{bg}$	0.2	$0.0502 - 0.0015d_{bg}$	$0.1125 - 0.0027d_{bg}$

(1) Refer to Figure 3-7 for definition of nonlinear modeling parameters *a, b,* and *c*
(2) Refer to Section 3-2.4 for determination of Primary and Secondary classification
(3) d = depth of beam, inch
(4) d_{bg} = depth of bolt group, inch

CHAPTER 6 MASONRY

This chapter provides the specific requirements for designing a masonry building to resist progressive collapse.

If composite construction with other materials is employed, use the design guidance from the appropriate material chapter in this UFC for those structural elements or portions of the structure.

Note that the combination of design requirements (TF, AP, and ELR) will depend upon the \3\ Risk Category /3/ of the buildings, as defined in Section 2-2.

6-1 MATERIAL PROPERTIES FOR MASONRY.

Apply the appropriate over-strength factors to the calculation of the design strengths for both Tie Forces and the Alternate Path method. The over-strength factors are provided in ASCE 41 in Table 11-1 Factors to Translate Lower-Bound Masonry Properties to Expected Strength Masonry Properties.

6-2 STRENGTH REDUCTION FACTOR Φ FOR MASONRY.

For Tie Force and Alternate Path methods, use the appropriate strength reduction factor specified in ACI 530 *Building Code Requirements for Masonry Structures* for the component and behavior under consideration. If masonry components can be proven capable of carrying the required longitudinal, transverse, and peripheral tie strength while undergoing rotations of 0.20-rad (11.3-deg), use the appropriate strength reduction factor Φ for each limit state considered.

6-3 TIE FORCE REQUIREMENTS FOR MASONRY.

Apply the Tie Force requirements in Section 3-1, where applicable, for load-bearing masonry buildings.

6-4 ALTERNATE PATH METHOD FOR MASONRY.

6-4.1 General.

Use the Alternate Path method in Section 3-2, where applicable, to verify that the structure can bridge over removed elements.

6-4.2 Modeling and Acceptance Criteria for Masonry.

Use the modeling parameters, nonlinear acceptance criteria and linear m-factors for the Life Safety condition from Chapter 11 of ASCE 41 for primary and secondary components. Use the modeling parameters and guidance, including definitions of stiffness, to create the analytical model.

6-5 ENHANCED LOCAL RESISTANCE REQUIREMENTS FOR MASONRY.

Apply the Enhanced Local Resistance requirements in Section 3-3, where applicable, for framed and load-bearing wall masonry buildings.

CHAPTER 7 WOOD

This chapter provides the specific requirements for designing a wood building to resist progressive collapse. Appendix F demonstrates the application of the wood design requirements for a 3-story load-bearing wall building

Wood construction takes several forms in current practice. As described in the 1996 version of AF&PA/ASCE 16, *Load and Resistance Factor Design Manual for Engineered Wood Construction*, wood construction can be categorized as wood frame, noncombustible wall-wood joist, and heavy timber. As most wood construction used for DoD facilities falls under the wood frame category, this is the focus of these provisions. If composite construction with other materials is employed, use the design guidance from the appropriate material chapter in this UFC for those structural elements or portions of the structure.

Note that the combination of design requirements (TF, AP, and ELR) will depend upon the \3\ Risk Category /3/ of the buildings, as defined in Section 2-2.

7-1 MATERIAL PROPERTIES FOR WOOD.

Per ASCE 41, default expected strength values for wood materials shall be based on design resistance values from AF&PA/ASCE 16. In addition, ASCE 41 provides default expected strength values for shear walls and wood diaphragms. When default lower bound strength values are needed, multiply the expected strength values by 0.85.

7-2 STRENGTH REDUCTION FACTOR Φ FOR WOOD.

For Tie Force and Alternate Path methods, use the appropriate strength reduction factor specified in ANSI/AF&PA *National Design Specification for Wood Construction* for the component and behavior under consideration. If wood components can be proven capable of carrying the required longitudinal, transverse, and peripheral tie strength while undergoing rotations of 0.20-rad (11.3-deg), use the appropriate strength reduction factor Φ for each limit state considered.

7-3 TIME EFFECT FACTOR λ FOR WOOD.

The time effect factor λ for wood is 1.0.

7-4 TIE FORCE REQUIREMENTS FOR WOOD.

Apply the Tie Force requirements in Section 3-1, where applicable, for load-bearing wood buildings.

7-5 ALTERNATE PATH METHOD FOR WOOD.

7-5.1 General.

Use the Alternate Path method in Section 3-2, where applicable, to verify that the structure can bridge over removed elements.

7-5.2 Modeling and Acceptance Criteria for Wood.

Use the modeling parameters, nonlinear acceptance criteria and linear m-factors for the Life Safety condition from Chapter 12 of ASCE 41 for primary and secondary components. Use the modeling parameters and guidance, including definitions of stiffness, to create the analytical model.

7-6 ENHANCED LOCAL RESISTANCE REQUIREMENTS FOR WOOD.

Apply the Enhanced Local Resistance requirements in Section 3-3, where applicable, for framed and load-bearing wall wood buildings.

CHAPTER 8 COLD-FORMED STEEL

This chapter provides the specific requirements for designing a cold-formed steel building to resist progressive collapse.

If composite construction with other materials is employed, use the design guidance from the appropriate material chapter in this UFC for those structural elements or portions of the structure.

Note that the combination of design requirements (TF, AP, and ELR) will depend upon the \3\ Risk Category /3/ of the buildings, as defined in Section 2-2.

8-1 MATERIAL PROPERTIES FOR COLD-FORMED STEEL.

ASCE 41 provides default expected strength values for light metal framing shear walls. When default lower bound strength values are needed, multiply the expected strength values by 0.85.

8-2 STRENGTH REDUCTION FACTOR *Φ* FOR COLD-FORMED STEEL.

For Tie Force and Alternate Path methods, use the appropriate strength reduction factor specified in AISI/COS/NASPEC *AISI Standard North American Specification for the Design of Cold-Formed Steel Structural Members* for the component and behavior under consideration. If cold formed steel components can be proven capable of carrying the required longitudinal, transverse, and peripheral tie strength while undergoing rotations of 0.20-rad (11.3-deg), use the appropriate strength reduction factor ***Φ*** for each limit state considered.

8-3 TIE FORCE REQUIREMENTS FOR COLD-FORMED STEEL.

Apply the Tie Force requirements in Section 3-1, where applicable, for load-bearing cold-formed steel buildings.

8-4 ALTERNATE PATH METHOD FOR COLD-FORMED STEEL.

8-4.1 General.

Use the Alternate Path method in Section 3-2, where applicable, to verify that the structure can bridge over removed elements.

8-4.2 Modeling and Acceptance Criteria for Cold-Formed Steel.

Use the modeling parameters, nonlinear acceptance criteria and linear m-factors for the Life Safety condition from Chapter 12 of ASCE 41 for primary and secondary components. Use the modeling parameters and guidance, including definitions of stiffness, to create the analytical model.

8-5 ENHANCED LOCAL RESISTANCE REQUIREMENTS FOR COLD-FORMED STEEL.

Apply the Enhanced Local Resistance requirements in Section 3-3, where applicable, for framed and load-bearing wall cold-formed steel buildings.

APPENDIX A REFERENCES

GOVERNMENT PUBLICATIONS:

1. National Bureau of Standards Washington, DC 20234	Report Number NBS-GCR 75-48 The Avoidance of Progressive Collapse: Regulatory Approaches to the Problem 1975
2. Federal Emergency Management Agency 500 C Street, SW Washington, DC	FEMA 350 Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings 2000
	FEMA 355D State of the Art Report on Connection Performance 2000
3. General Services Administration Washington, DC	Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Projects 2003
	GSA Steel Frame Bomb Blast & Progressive Collapse Test Program Report (2004-2007) 2008
4. US Army Corps of Engineers Protective Design Center Omaha District 215 N. 17th St. Omaha, NE 68102-4978	Department of Defense Interim Antiterrorism/Force Protection Construction Standards, Guidance on Structural Requirements 2001
	Methodology Manual for the Single-Degree-of-Freedom Blast Effects Design Spreadsheets (SBEDS) PDC TR-06-01 Rev 1 2008
5. Department of Defense Washington, DC	UFC 3-301-01 Structural Engineering
	UFC 3-340-01 Design and Analysis of Hardened Structures to Conventional

	Weapons Effects
	UFC 4-010-01 DoD Minimum Antiterrorism Standards for Buildings
6. Interagency Security Committee Washington, DC	Facility Security Level Determinations for Federal Facilities An Interagency Security Committee Standard, February 21, 2008. For Official Use Only
7. National Institute of Standards and Technology Gaithersburg, MD	Best Practices for Reducing the Potential for Progressive Collapse in Buildings NISTIR 7396 2007

NON-GOVERNMENT PUBLICATIONS:

1. American Concrete Institute P.O. Box 9094 Farmington Hills, MI 48333-9094	ACI 318 Building Code Requirements for Structural Concrete ACI 530 Building Code Requirements for Masonry Structures
2. American Forest & Paper Association American Wood Council 1111 19th Street NW, Suite 800 Washington, DC 20036	National Design Specification for Wood Construction
3. American Institute of Steel Construction One E. Wacker Dr., Suite 3100 Chicago, IL 60601-2000	Manual of Steel Construction, Load and Resistance Factor Design AISC 341 Seismic Provisions for Structural Steel Buildings ANSI/AISC 360 Specification for Structural Steel Buildings
4. American Iron and Steel Institute 1101 Seventeenth Street NW Suite 1300 Washington, DC 20036-4700	AISI Standard North American Specification for the Design of Cold-Formed Steel Structural Members

5. American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, VA 20191-4400

ASCE 7 Minimum Design Loads for Buildings and Other Structures

ASCE 41 Seismic Rehabilitation of Existing Buildings

6. Building Research Establishment
Bucknalls Lane
Garston, Watford WD25 9XX
England

Multi-storey Timber Frame Buildings, A Design Guide
2003

7. International Code Council
500 New Jersey Avenue, NW
Washington, DC 20001-2070

International Building Code

8. National Institute of Building Sciences
Washington, DC

National Workshop on Prevention of Progressive Collapse

The UK and European Regulations for Accidental Actions, D. B. Moore 2002.

9. Myers, Houghton & Partners (MHP)
4500 East Pacific Coast Highway
Suite 100
Long Beach, CA 90804

Engineering Analysis and Guidance for Structural Steel Issues in Progressive Collapse, Tasks 5.7 and 5.19
J. Karns, D. Houghton
January 2008

10. Protection Engineering Consultants
4594 US Hwy 281 North, Suite 100
Spring Branch, TX 78070

Final Report for Assessment and Proposed Approach for Tie Forces in Framed and Load-bearing Wall Structures
D.J. Stevens
May 2008

A Proposed Enhanced Local Resistance Procedure for Perimeter Columns and Load-bearing Walls
K. Marchand, D. Stevens
February 2008

Dynamic Increase Factors (DIF) and Load Increase Factors (LIF) for Alternate Path Procedures
A. McKay, K. Marchand, and D. Stevens, January 2008

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APPENDIX B DEFINITIONS

B-1 INTRODUCTION.

Definitions for terminology and for structural analysis concepts are provided in this appendix. Many of the terms in this UFC are provided in other DoD UFCs, instructions, directives, standards, and manuals, as well as in typical non-government standards, such as ASCE 41, AISC Manual of Steel Construction, etc. Those terms of significance to this UFC are included in Section B-2. The definitions for structural analysis procedures are given in Section B-3.

B-2 TERMINOLOGY.

Deformation Controlled Action. A deformation controlled action provides a resistance that is proportional to the imposed deformation until the peak strength is reached, after which the resistance remains at a significant level, as the deformation increases. Classification as a deformation-controlled action is not based on engineering judgment and must follow the guidance presented in Section 3-2.5.

Expected Strength. The expected strength of a component is the statistical mean value of yield strengths for a population of similar components, and includes consideration of the variability in material strengths as well as strain hardening and plastic section development. If a statistically determined value for the expected strength is not available, the expected strength can be obtained by multiplying the lower bound strength (i.e., the nominal strength or strength specified in the construction documents) by the appropriate factor from Chapters 9 to 12 in ASCE 41.

Enhanced Local Resistance (ELR). ELR is an indirect design approach that provides a prescribed level of out-of-plane flexural and shear resistance of perimeter building columns (including their connections, splices and base plates) and load bearing wall elements, such that the shear resistance exceeds the shear associated with the required out-of-plane enhanced flexural resistance of the columns and wall elements. When the shear strength is reached before the flexural strength, the possibility exists of a sudden, non-ductile failure of the element, which may lead to progressive collapse.

Force Controlled Action. A force controlled action provides a resistance that is proportional to the imposed deformation until the peak strength is reached, after which the resistance drops to zero. Classification as a force-controlled action is not based on engineering judgment and must follow the guidance presented in Section 3-2.5.

Linear Static Procedure. In a linear static procedure, the structural analysis incorporates only linear elastic materials and small deformation theory; buckling phenomena are not included in the model but are assessed through examination of the output. Inertial forces are not considered. The analysis consists of a single step, in which the deformations and internal forces are solved based on the applied loads and geometry and materials.

Lower Bound Strength. The lower bound strength of a component is the statistical mean minus one standard deviation of the yield strengths for a population of similar components. If a statistically determined value for the lower bound strength is not available, the nominal strength or strength specified in the construction documents may be used.

Nonlinear Dynamic Procedure. In a nonlinear dynamic procedure, inertial effects and material and geometric nonlinearities are included. A time integration procedure is used to determine the structural response as a function of time.

Nonlinear Static Procedure. In a nonlinear static procedure, the structural model incorporates material and geometric nonlinearities. Inertial effects are not included. An incremental or iterative approach is typically used to solve for the structural response as a function of the applied loading.

Penultimate Column or Wall. The column or wall that is next to the corner column or corner wall on the exterior surface, i.e., the next-to-last wall or column along the exterior of the building.

Secondary Component. Any component that is not a primary component is classified as secondary.

Story. That portion of a building between the surface of any one floor and the surface of the floor above it or, if there is no floor above it, then that portion of the building included between the surface of any floor and the ceiling or roof above it.

Tie Forces. A tie force is the tensile resistance that is used to transfer the loads from the damaged region of the structure to the undamaged portion. Tie forces can be provided by the existing structural elements that have been designed using conventional design methods to carry the standard loads imposed upon the structure. If an existing structure or a new conventional structure design does not meet the tie force requirements, then new members must be added, or the structure must be redesigned.

B-3 DEFINITIONS FOR STRUCTURAL ANALYSIS PROCEDURES.

Joint and Joint Rotation. From ASCE 41, a joint is an area where ends, surfaces, or edges of two or more components are attached; categorized by type of fastener or weld used and method of force transfer. As shown in Figure B-1, a joint is the central region to which the structural members are attached. A joint possesses size, geometry, and material and, as such, the joint can rotate as a rigid body, as shown in Figure B-2. The joint in Figure B-2 is shown as a "+" shape, to facilitate visualization of the joint rotation, Γ.

Typically, deformations within the joint are ignored and only rigid body rotation is considered. However, shear deformations within the panel zone of structural steel and reinforced concrete joints can occur, as defined later.

Figure B-1. Joint and Connection Definition

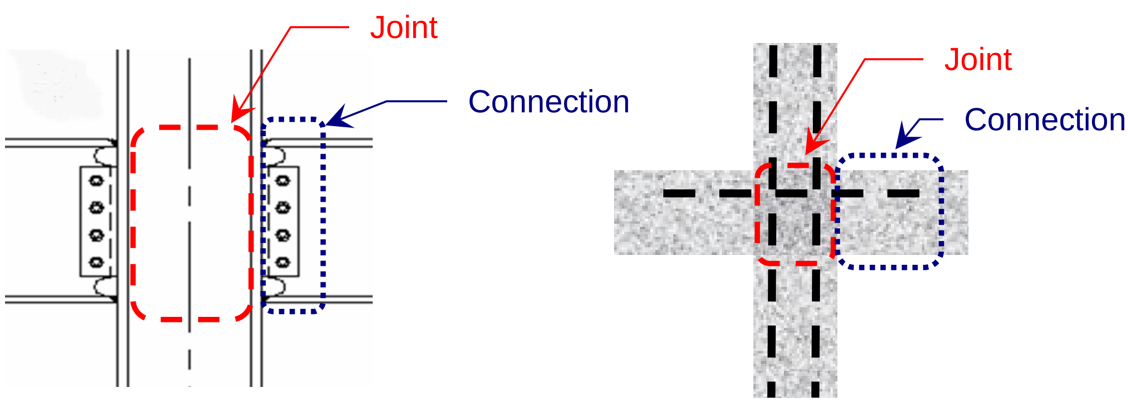
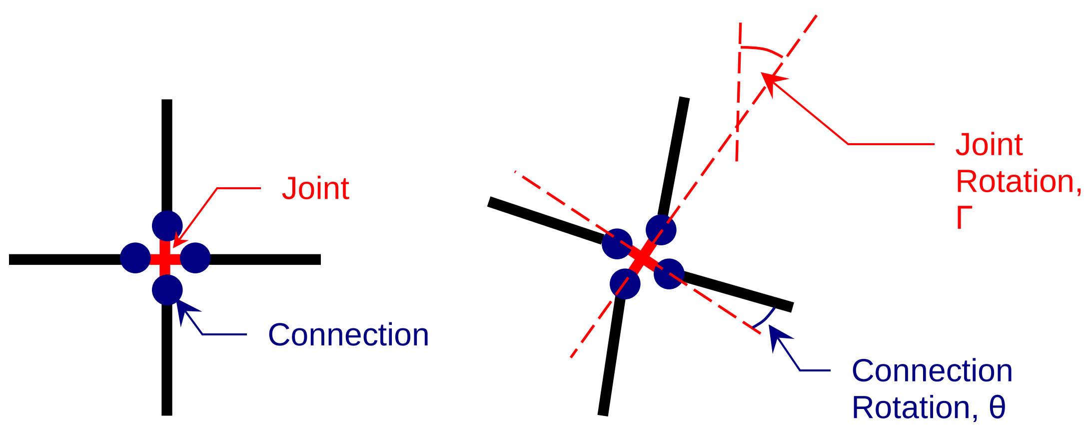


Figure B-2. Joint and Connection Rotations

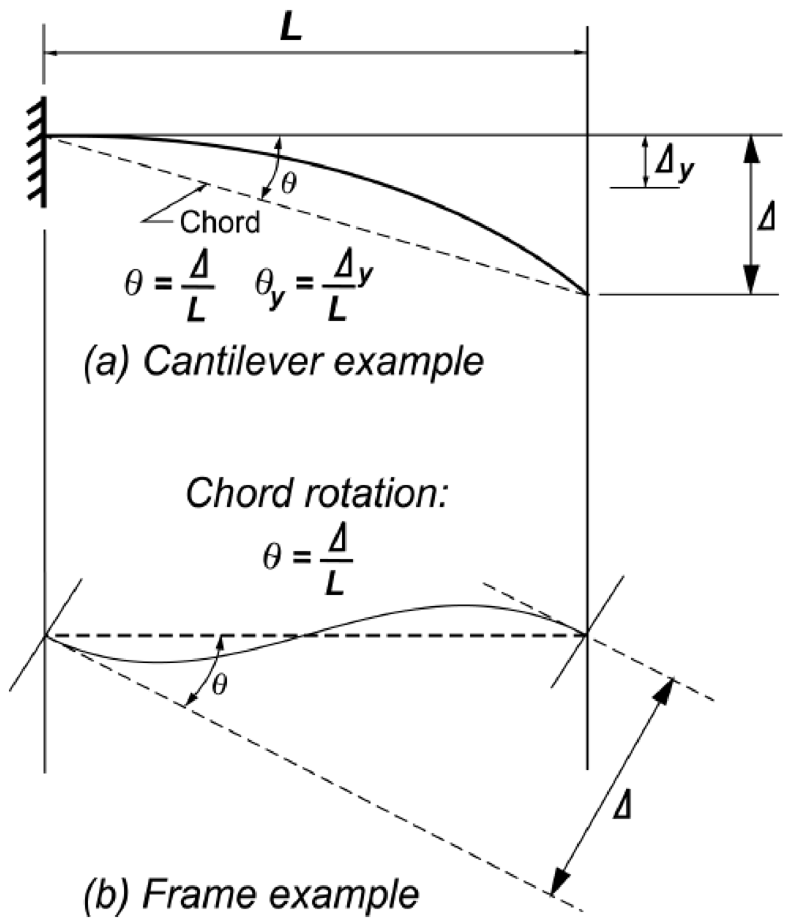


Connection and Connection Rotation. A connection is defined as a link that transmits actions from one component or element to another component or element, categorized by type of action (moment, shear, or axial) (ASCE 41). Steel moment and reinforced concrete connections are shown in Figure B-1. The rotation of the connection is shown in the sketches in Figure B-2. Rotation can occur through shear and flexural deformations in the connection and may be elastic (recoverable) or plastic (permanent). The connection rotation is measured relative to the rigid body rotation of the joint as shown in Figure B-2.

In a frame, calculation of the connection rotation is often determined via the chord rotation. In the case shown in Figure B-3, the chord rotation and connection rotation θ are identical; however, joint rotation must also be considered. The total connection rotation is the sum of the elastic and plastic rotations, defined later.

In numerical models and design software, connections are typically modeled with discrete “plastic hinges”, which exhibit a linear elastic behavior until the yield plateau is reached; in some models, the elastic rotations are ignored, due to their small value. In this case, the rotation of the discrete plastic hinge model is the connection rotation; care must be taken to insure that the rotation of the plastic hinge model only considers the connection rotation θ and does not also include the joint rotation Γ.

Figure B-3. Definition of Chord Rotation (from ASCE 41)



Yield Rotation. Many flexural elements will deform elastically until the extreme fibers of the element reach their yield capacity and the response becomes nonlinear. While the depth of the yielded material in the cross section will gradually increase as the moment is increased, this portion of the response is typically assumed as a finite change in the slope of the moment vs. rotation curve, as shown in Figure B-4. The yield rotation θ_y corresponds to the flexural rotation at which the extreme fibers of the structural elements reach their yield capacity f_y. This is also called the elastic rotation as it corresponds to the end of the elastic region.

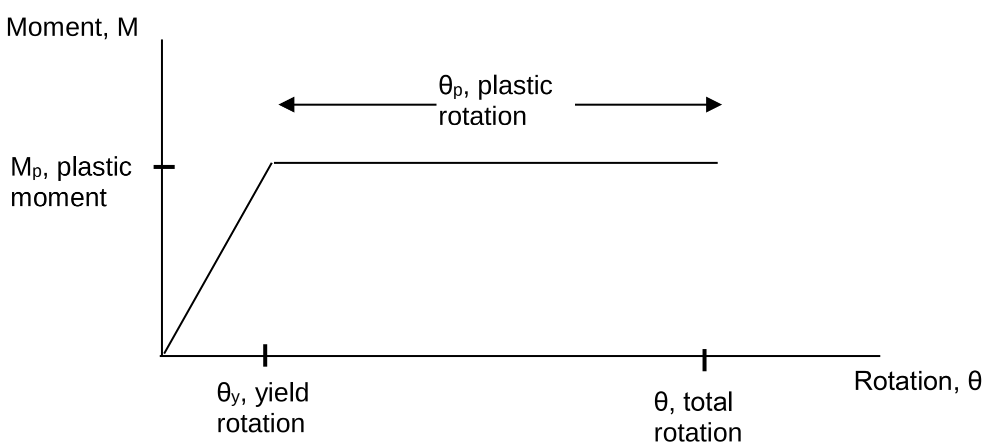
For steel beams and columns, ASCE 41 allows θ_y to be calculated as follows, where it has been assumed that the point of contraflexure occurs at the mid-length of the beam or column.

$$\text{Beams:} \quad \theta_y = \frac{ZF_{ye}l_b}{6EI_b}$$

$$\text{Columns:} \quad \theta_y = \frac{ZF_{ye}l_c}{6EI_c}\left(1 - \frac{P}{P_{ye}}\right)$$

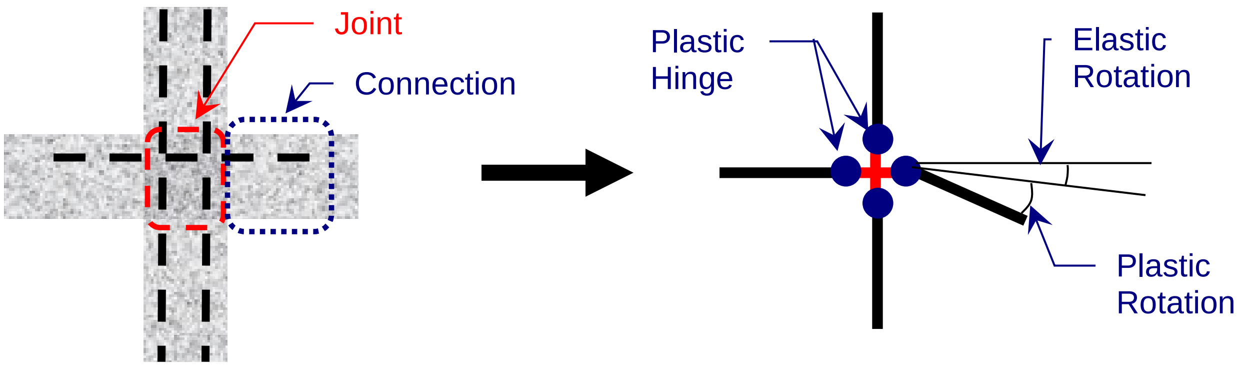
For steel structures, in ASCE 41, multiples of the yield rotation θ_y are used to define the acceptance criteria and modeling parameters in terms of plastic rotation for a number of elements (beams, columns, shear walls).

Figure B-4. Definition of Yield Rotation, Plastic Rotation, and Total Rotation



Plastic Rotation and Plastic Hinge. The plastic rotation θ_p is the inelastic or non-recoverable rotation that occurs after the yield rotation is reached and the entire cross section has yielded; see Figure B-4. The plastic rotation θ_p is typically associated with a discrete plastic hinge that is inserted into a numerical frame model, as shown in Figure B-5. The plastic hinge measures both elastic and plastic rotations, although for simplicity, the elastic portion is often ignored due to its small size.

Figure B-5. Plastic Hinge and Rotation



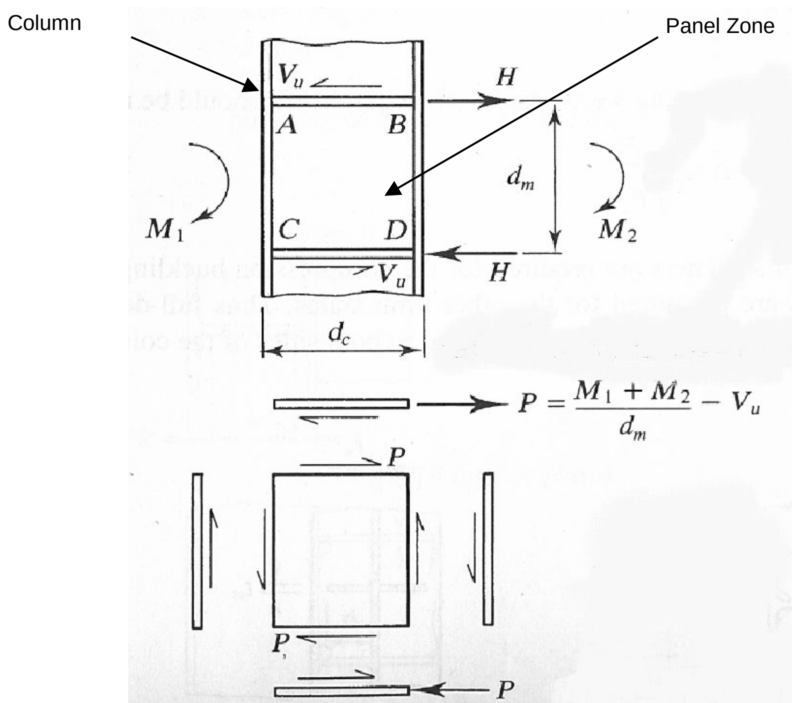
For both steel and concrete, ASCE 41 specifies the acceptance criteria and the modeling parameters in terms of plastic rotation. For some steel structural elements, the criteria parameters are given in terms of multiples of the yield rotation θ_y; for concrete and the remainder of the structural steel elements, a numerical value for the plastic rotation is given, in units of radians.

Total Rotation. The total rotation θ is the sum of the yield rotation θ_y and the plastic rotation θ_p.

Panel Zone. In steel frame structures, the panel zone is the region of high shear stress in the column web within the boundaries of the joint, which results from the large moment transferred to the column joint from a fully restrained connection; see Figure B-6. The panel zone is an integral part of the steel frame beam-to-column moment connection. The deformation measure is the plastic angular shear rotation. Guidance for including or excluding the panel zone in steel models is given in Sections 9.5.2.2.1 and 9.5.2.2.2 in ASCE 41.

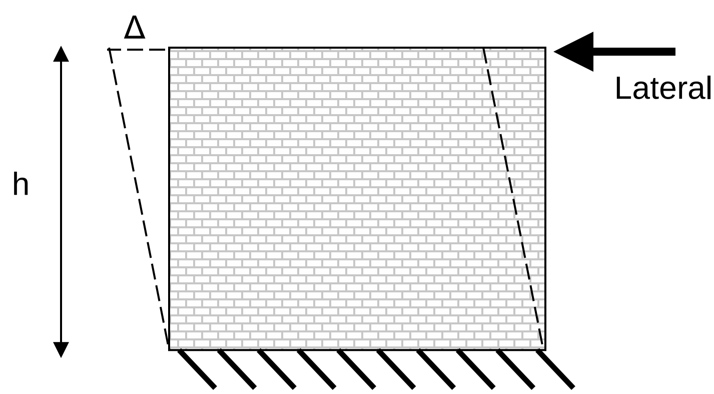
Similarly, for beam-column joints in reinforced concrete framed structures, the plastic shear rotation is the deformation parameter used in the acceptance criteria; in ASCE 41, only the secondary beam-column joints must be checked for shear rotation.

Figure B-6. Panel Zone



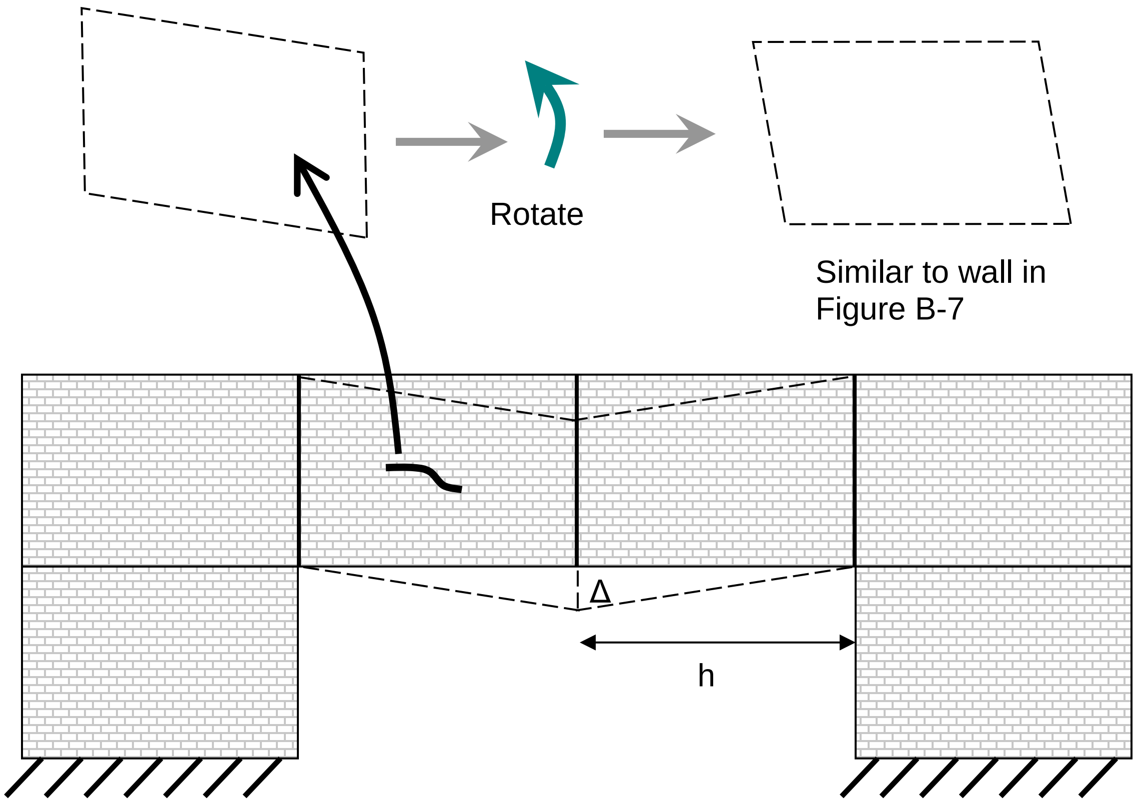
Story Drift (Wall Structures). In ASCE 41, story drift is used as the nonlinear deformation measure for load-bearing wall structures (masonry, wood, and cold formed steel). The story drift is defined as the ratio of the lateral deflection at the top of a wall segment Δ to the overall height of the wall segment, as shown in Figure B-7.

Figure B-7. Story Drift



While the story drift deformation criteria in ASCE 41 are applied to horizontal deformations due to lateral earthquake loads, this information can be used directly for progressive collapse analysis with vertical deformations due to removed wall sections, as shown in Figure B-8.

Figure B-8. Vertical Wall Deflection (Drift)



APPENDIX C COMMENTARY

C-1 INTRODUCTION.

The goal of these design requirements is to provide a rational and uniform level of resistance to progressive or disproportionate collapse. \4\ /4/ These requirements are threat-independent and are not intended to provide resistance to the local damage that may initiate the progressive collapse. Discussion and justification for the applicability requirements, design approaches, modeling techniques, and acceptance criteria are provided in this Appendix.

C-2 APPLICABILITY.

C-2.1 Three Story Requirement and Story Definition.

The required minimum height of 3 stories for progressive collapse design is taken from the original DoD guidance (DoD 2001). This requirement was based on a minimum threshold of 12 casualties in a progressive collapse event where it was assumed that the 2 bays on either side of a removed column or wall would collapse on each of 3 floors and that each bay/room would house 2 persons. Thus, the justification for setting the limit at 3 stories was determined by the level of casualties and not by the mechanics of progressive collapse as a function of structural characteristics.

As casualties are the key metric, a basement or penthouse structure is defined to be a story if it is occupied. The definition of "occupied" in the International Building Code (IBC) is: "A room or enclosed space designed for human occupancy in which individuals congregate for amusement, educational or similar purposes or in which occupants are engaged at labor, and which is equipped with means of egress and light and ventilation facilities." This definition was adopted in Section 1-2.1. Further, as noted in Section 1-2.1, any story that will not be occupied does not count towards the limit of 3 stories; this may include floors that house mechanical equipment or are used for storage.

Any portion of a building that is less than 3 stories is not required to meet the progressive collapse design requirements of this UFC. However, any deleterious effect from the attachment of a short section of the building to the 3 story or higher section must be considered. In particular, peripheral tie forces must be placed in the 3+ story section of the building, at the boundaries between the short section and 3+ story section. For Alternate Path, the structural elements of the short section must be considered in the analysis and design of the 3+ story section if there is any possibility that the presence of the short section will affect the 3+ story section in a negative manner.

C-2.2 Clarification for Partial Occupancy.

UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Buildings* requires that: "These standards only apply where DoD personnel occupy leased or assigned space constituting at least 25% of the net interior useable area or the area as defined in the lease, and they only apply to that portion of the building that is occupied by DoD personnel." This 25% space threshold might be met by lease of entire stories in a multi-story building, e.g., DoD might lease the 3rd and 4th story in a 7-story building. As it is impractical to design or retrofit a building to resist collapse on only certain stories, this requirement from UFC 4-010-01 has been superseded by the requirement in Section 1-2-2.

C-3 RISK CATEGORIES.

In the 2005 UFC4-023-03, the level of progressive collapse design was based on the level of protection (LOP), which, in turn, was based on the asset value of the building, as calculated with UFC 4-020-01 *DoD Security Engineering Facilities Planning Manual*. The asset value was a function of different asset categories, including General Population, Critical Infrastructure and Operations and Activities, Sensitive Information, and All Other Assets, including Mission Critical Personnel. Thus, there was a strong dependence upon the level of occupancy and the criticality to the user. In essence, this is a "consequence approach" in that probability of occurrence and the associated risk for progressive collapse cannot be explicitly considered due to the very small database of progressive collapse events. Thus, the level of casualties and the degradation of function are the key considerations.

Beginning with the 2009 UFC 4-023-03, different levels of design requirements are specified, depending upon the \3\ Risk Category /3/ (RC). The RC is based on the Risk categories defined in Table 2-2 \3\ Risk Category /3/ of Buildings and Other Structures in UFC 3-301-01 *Structural Engineering*. The descriptions for "Nature of Occupancy" in Table 2-2 are very similar to those in ASCE 7 Minimum Design Loads for Buildings and Other Structures, however, some modifications specific to DoD have been made.

It is noted that the RC is independent of threat or initiating event, and, as with the previous LOP approach, this is consequence-based where Risk level and function are key parameters in defining the level of progressive collapse design.

C-4 DESIGN REQUIREMENTS.

The design requirements for RC I through RC IV are listed in Table 2-2 and briefly summarized in the following sections.

C-4.1 RC I Design Requirement.

These buildings present little risk to human life and no progressive collapse design is required providing the buildings were designed to the extant building code.

C-4.2 RC II Design Requirement.

For RC II structures, one of two options must be chosen: Option 1, Internal, peripheral and vertical Tie Forces with Enhanced Local Resistance for the corner and penultimate columns or walls at the first story **OR** Option 2, Alternate Path applied to specific locations. For load-bearing wall structures, the AP method may be the best choice, as the designer can take advantage of the building's inherent redundancy as well as the ability to develop deep beam or arching action.

In the 2005 UFC 4-023-03, only tie forces were used for LLOP (i.e., RC II) buildings. Tie Forces can be very difficult to implement in existing buildings and even for some new types of load-bearing wall construction. Since many load-bearing wall buildings are very redundant and may meet the Alternate Path requirements while staying elastic, Option 2 (as suggested in the Eurocode) was added. Thus, this provides some relief for existing buildings. For many load-bearing buildings, the walls are identical and a single set of calculations for a typical wall may be sufficient.

C-4.2.1 RC II Option 1, Tie Forces and Enhanced Local Resistance.

The goal of the Tie Force requirement is to enhance the structural integrity evenly throughout the structure, by prescriptively defining the magnitude, location, and distribution of the Tie Forces and without requiring significant design or analysis effort. While the Tie Forces are distributed uniformly throughout the structure, the response and performance of the structure varies with the location at which the initial damage occurs. As discussed in Stevens 2008, the removal of a corner column or wall or a penultimate corner or wall can lead to local collapse of a portion of the bay since the lateral support to anchor the Tie Forces has been removed or reduced. This damage will extend to the height of the building, but is unlikely to progress horizontally. While this damage is spatially limited and does not threaten the rest of the building, it is a limitation of the Tie Force approach. Therefore, to reduce the possibility that the corner or penultimate column or wall will be damaged, the Enhanced Local Resistance approach is applied to these elements at the first story above grade, as discussed in Section 3-3.

C-4.2.2 RC II Option 2, Alternate Path.

While the Tie Force requirement can be easily implemented in new construction for some material types, it can be difficult to apply to existing buildings and to non-ductile floor systems. The option to use the Alternate Path method provides another approach by which to evaluate an existing structure. It also allows the designer to account for the inherent and often substantial collapse resistance due to the natural redundancy and available load paths, commonly found in load-bearing wall structures. Many of the structures in RC II will be short (5 stories or less) load-bearing wall buildings with a uniform or regular layout. Hand calculations can be used to demonstrate bridging by deep beam action or arching over removed wall sections for a typical wall and those results applied to the similar walls in the structure.

C-4.3 RC III Design Requirement.

For RC III, two requirements must be satisfied: Alternate Path and Enhanced Local Resistance. The consequence of collapse is greater for this \3\ Risk Category /3/, which also increases the (unknown and unquantifiable) probability of a deliberate attack. Thus, a specified level of resistance to loss of a column or wall is provided by the Alternate Path method. Additional protection is provided by minimizing the likelihood of a non-ductile failure of the columns and walls at the building perimeter, in the first story above grade, through the Enhanced Local Resistance requirement.

For RC III (and IV), the buildings will tend to be large, framed structures, and the specified locations for column or wall removal are only the minimal locations that must be considered; the engineer must also consider locations where the geometry of the structure changes significantly. Since the regular portion of the structure should be covered by the minimum cases and all unusual portions of the structure should be identified by the engineer, this requirement applied to all columns or load-bearing walls in the structure. However, note that for RC III (and RC IV) structures without underground parking or other areas of uncontrolled public access, internal column removal does not need to be considered.

C-4.4 RC IV Design Requirement.

For RC IV, three requirements must be satisfied: Alternate Path, Tie Forces, and Enhanced Local Resistance. The addition of the Tie Force requirement to those of RC III provides another layer of resistance to collapse and will supplement the flexural resistance developed through the AP method. In addition, the ELR requirement is applied to all perimeter walls and columns, over the first story above grade and the level of flexural resistance is increased, to minimize the possibility that two columns or walls at the same level will be removed in the same event.

C-5 TIE FORCES.

C-5.1 General.

The Tie Force requirement is designed to enhance the structural integrity of the building by prescriptively defining tensile force strength of the members and connections, in terms of strength, location, and distribution. This prescriptive method is simple in that detailed or complicated models and analyses are not required, yet it must also be based on mechanical principles, such as equilibrium and deformation compatibility, as applied to a damaged structure.

C-5.2 Previous Requirements.

The Tie Force requirements in the 2005 UFC 4-023-03 were based on the British Building Standards (before the Eurocodes were introduced) for reinforced concrete, structural steel, and masonry. The previous Tie Force requirements were

material-specific, with limited similarity across the different materials in terms of location, distribution, magnitude, and other details. As discussed in the 2005 UFC 4-023-03, the Tie Forces for Reinforced Concrete could be related to an assumed catenary behavior of the floor system, but similar justification could not be found for the other materials.

One common and justified criticism of the previous Tie Force approach was that the great majority of steel connections as well as some RC connections are not capable of providing the magnitudes of rotation that are needed to develop the typically small Tie Forces that were specified. Thus, the connections would fail before the beams, girders, and spandrels could develop axial force. This is also true for Tie Forces distributed in floor systems with limited ductility, such as plywood on engineered I-joists or precast planks with limited continuity across connections.

C-5.3 New Tie Force Approach.

Due to the inability of many connections to sustain large rotations, a new approach was proposed and employed beginning with the 2009 UFC 4-023-03. In this new approach, the floor system now provides and carries the internal Tie Forces, thus removing these Tie Forces from the beams, girders, and spandrels. In essence, the floor system will transfer the vertical loads from the damaged section, via catenary or membrane action, to the undamaged horizontal members, which, in turn, will transfer the load into the vertical load carrying elements, as shown in Figure C-1.

While the internal and peripheral ties are now placed in the floor system, a designer is allowed to use the members and connections for steel, reinforced concrete and other materials, if it can be shown that the connections can carry the tensile forces due to a removed column/wall without failure due to large deformations and rotations.

Additional modifications from the previous UFC include:

- Requirements are now material-independent,
- Explicit tying to external and corner walls and columns is removed,
- Provisions to address openings in the floor system (stairwells, elevators, atria) are included,
- Provisions are added to account for large variations in floor loads over the plan geometry of a single floor.

C-5.4 Justification for the Tie Force Approach.

In the development of the 2009 UFC 4-023-03, analytical and numerical methods were used to derive reasonable tie force requirements that can be used for different column and wall loss locations for braced frames, moment frames, and load-bearing wall structures, with floor systems that are capable of developing membrane or catenary response; the details can be found in Stevens 2008. These floor systems include reinforced concrete (RC) floors with integral slabs, composite construction with

steel decks and RC, and floor systems that incorporate a grid of rebar or welded wire fabric.

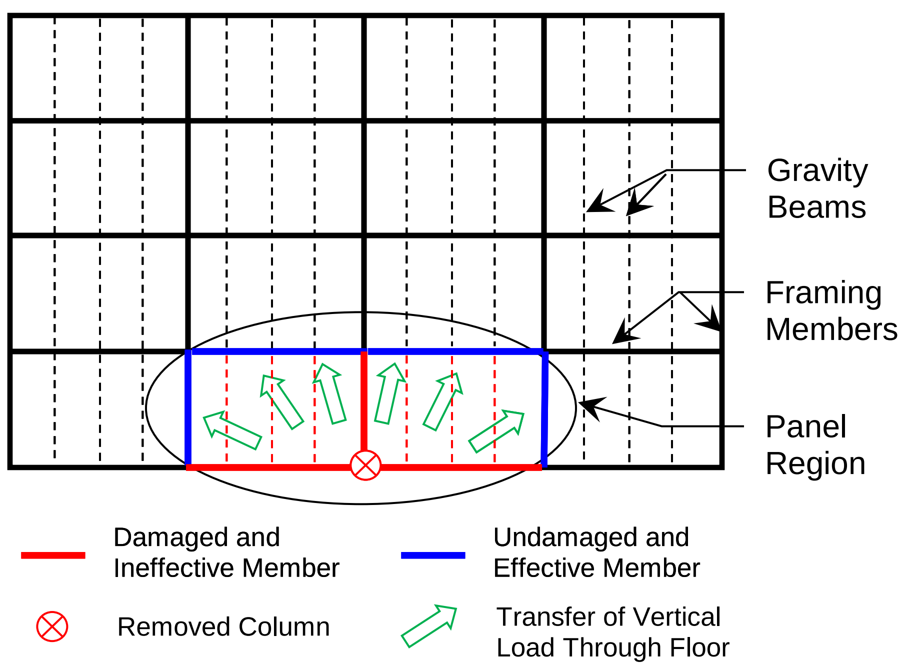


Figure C-1. Damaged and Undamaged Structural Elements

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C-5.4.1 Tie Forces for Framed and Two-way Load-bearing Wall Buildings.

To develop the internal and peripheral tie force requirements for framed structures, 6 different column scenario removals were assessed, using simple catenary theory, membrane theory, and finite element analysis; see Stevens 2008. The removal locations included the corner column, penultimate column, internal column, near penultimate column, edge column, and near edge column, as shown in Figure C-2. In addition to assessing the tie force magnitudes required to carry the loads in catenary or membrane action, the transfer of the vertical force from the damaged panel to the undamaged structures was assessed. Finite element analyses were also performed to determine the dynamic effects created by the sudden loss of column support; the results of these analyses were used to modify the Tie Force equations. Load-bearing wall structures were also considered. As the floor system is the critical element for developing and supplying the internal and peripheral tie forces, many of the findings from the framed structure assessment are directly applicable to load-bearing wall structures.

The application of peripheral ties around the perimeter of openings was also investigated with numerical methods and the loads were shown to be adequately transferred from the damaged area to the peripheral ties and to the undamaged elements. Care must be taken to develop, lap or anchor the peripheral ties at openings

in the floor system (stairways, elevators, atria, etc), such that the strength can be developed. This same approach was used to develop the sub-areas and peripheral ties at the boundary between sub-areas with different floor loads.

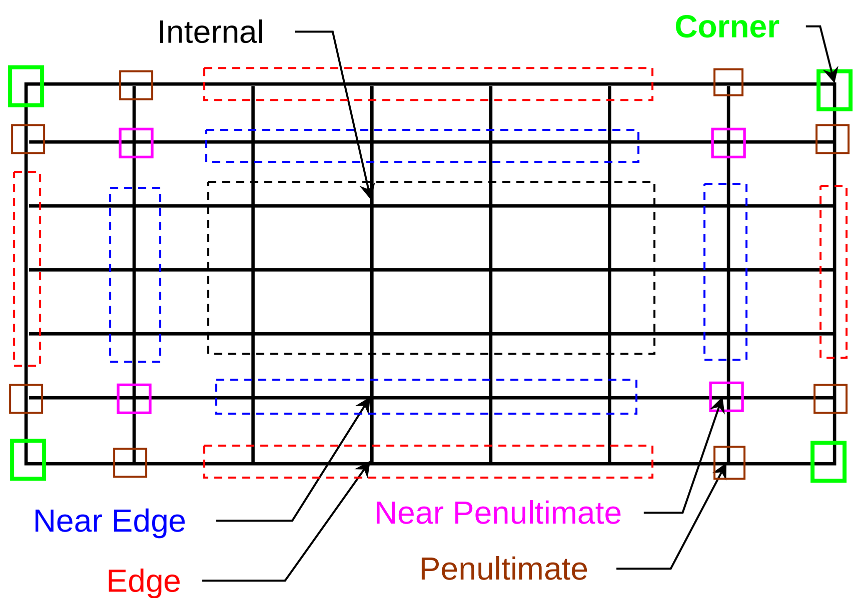

Figure C-2. Column Removal Locations

C-5.4.2 One-way Load-bearing Wall Buildings.

The internal tie force equations for one-way load-bearing wall structures in the 2009 version of UFC 4-023-03 were based on the Eurocode. A series of finite element analyses were subsequently performed to investigate 1) the use of 5h_w in determining the internal tie forces in the direction parallel to the load-bearing walls; and 2) the effect of loads from the removed section of the load-bearing wall on the internal and peripheral ties. As noted in Paragraph 2-2.2.2 design of this structural system to resist progressive collapse is often best addressed with the alternate path approach.

Figure C-3 shows the plan view of a one-way load-bearing wall building. To determine the required magnitude of the internal and peripheral tie forces, different wall removal locations must be analyzed; in all cases, the length of the removed wall is 2h_w

where ***h**_w_* is the clear story height. Four wall removal locations were considered, shown by the shaded boxes in Figure C-3: End wall--center; End wall--end; Interior wall--center; and, Interior wall--end. The results of the numerical simulations for the first two wall removal locations verified that tie forces are not an effective mechanism for resisting progressive collapse when the removed wall sections are at the end of the building. The end walls pull into the building and the wall and floor fail, as there is no means for resisting the lateral forces created by the tie force members; this fact was the motivation behind the requirement to apply Enhanced Local Resistance to the end and penultimate load-bearing walls for \3\ Risk Category /3/ 2 Option 1, in the 2009 version of UFC 4-023-03. A similar result will occur for the removal of the end and center wall sections for the penultimate load-bearing walls. Therefore, the numerical simulations were used to assess the second two cases: interior wall-center and interior wall-end.

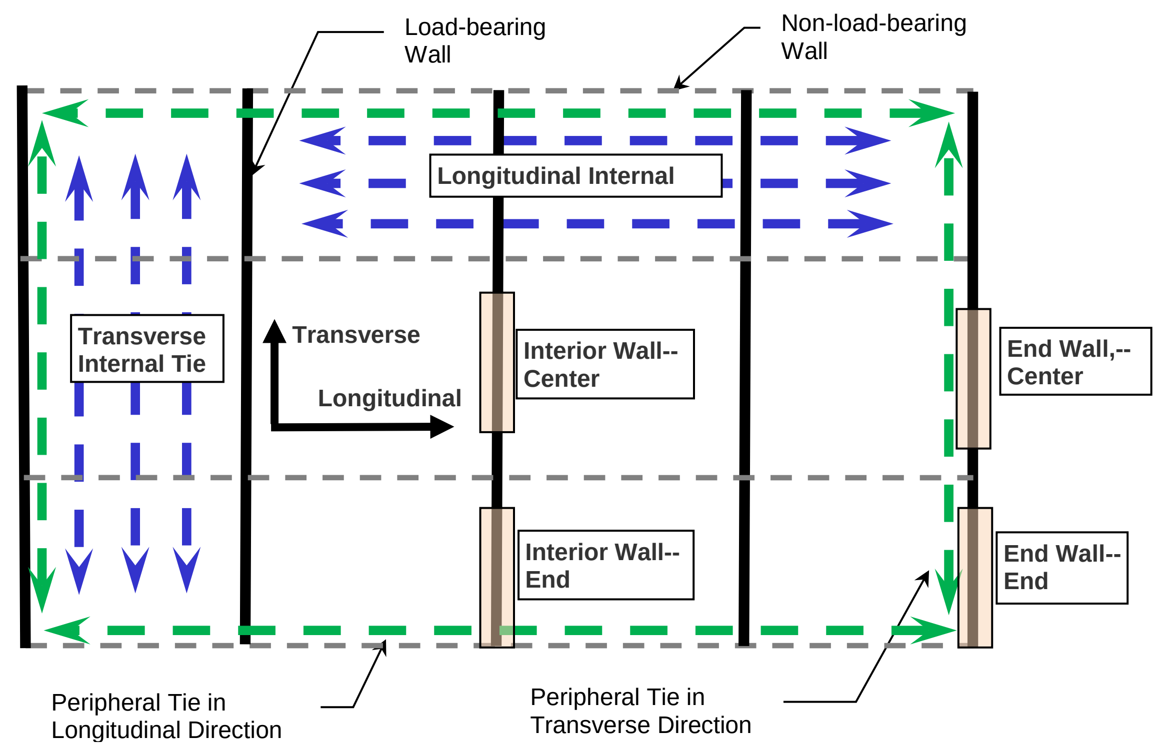

Figure C-3. Plan View of One-way Load-bearing Wall Structure

The purpose of the internal and peripheral tie forces is to transfer the loads of the floor section that is no longer vertically supported to the portions of the structure that are undamaged. For the case of framed structures, this means that each floor must carry its own dead and live load and, thus, each floor can be considered as a separate entity. This same approach holds for load-bearing wall structures, with the addition that the dead load must now include the weight of the walls above the removed wall sections as well as the façade load, if the façade is tied into the floor system. Thus, an idealized representation of the loads on a typical floor above the wall removal location is as shown in Figure C-4.

A series of finite element simulations were performed, using a similar approach as discussed for frame buildings. As reported in Stevens 2008, two levels of façade load (500-plf and 2000-plf) and two levels of wall loads (300-plf and 1500-plf) were considered. The deformation criteria were based on a 10% sag over a double span length; for these analyses, the double span length is in the longitudinal direction as shown in Figure C-4. The results of the analyses were used to create Equation (3-7); details can be found in Stevens 2008.

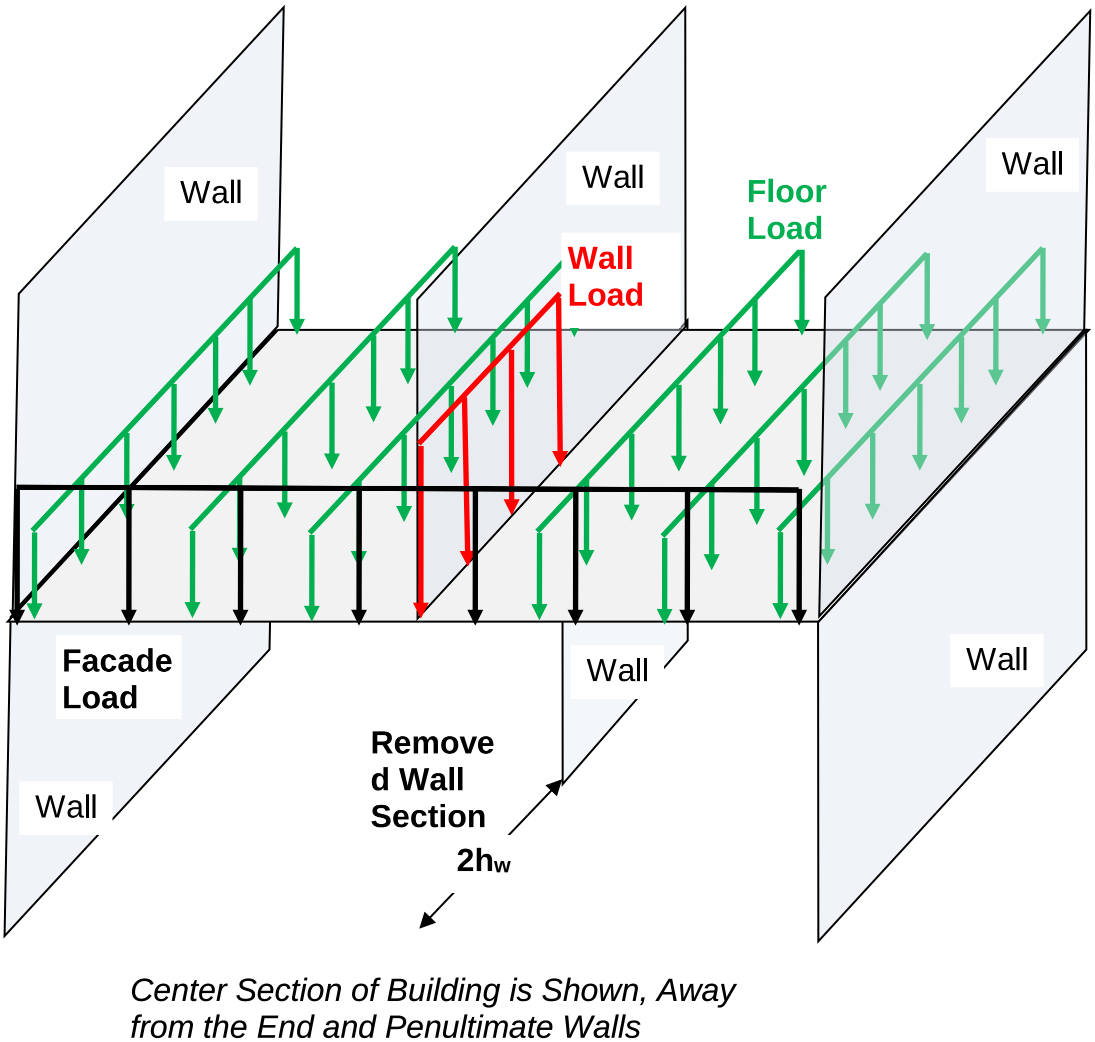

Figure C-4. Loads in a One-way Load-bearing Wall Structure

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C-5.5 Tie Forces in Roof Systems

The roof system must meet the Tie Force requirements in Section 3-1. As with floor systems, these requirements will be more easily met with some types of roof systems, such as reinforced concrete slabs and composite decks.

For lightweight systems such as steel deck and joist roof systems, sufficient strength and ductility should be available in the direction of the joist, providing that the bottom chord of the joist does not connect to the column or beam; see Figure C-5. If so, then the top chord of the joist can be used to supply the Tie Force, providing that the load path is continuous across each vertical support. Two approaches can be used in the transverse direction. In the first, steel shapes (rods, angles, bars, etc.) could be placed through the open webs. Attachments of these internal ties to the peripheral ties must be capable of developing the longitudinal and transverse tie forces. Second, a steel deck that spans in the transverse direction to the joist could be used to supply the internal Tie Force provided that the welds or other connections between the steel deck sections are sufficient to develop the Tie Force. While there may be crushing of the steel deck where it crosses the joist or other vertical support, the upper surface of the deck should remain intact and capable of supplying tension up to 0.20-rad; see Figure C-6.

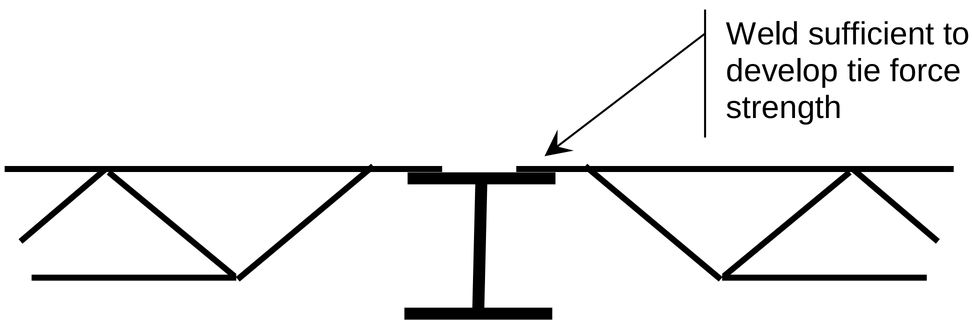

Figure C-5. Tie Force in Upper Chord of Roof Joist

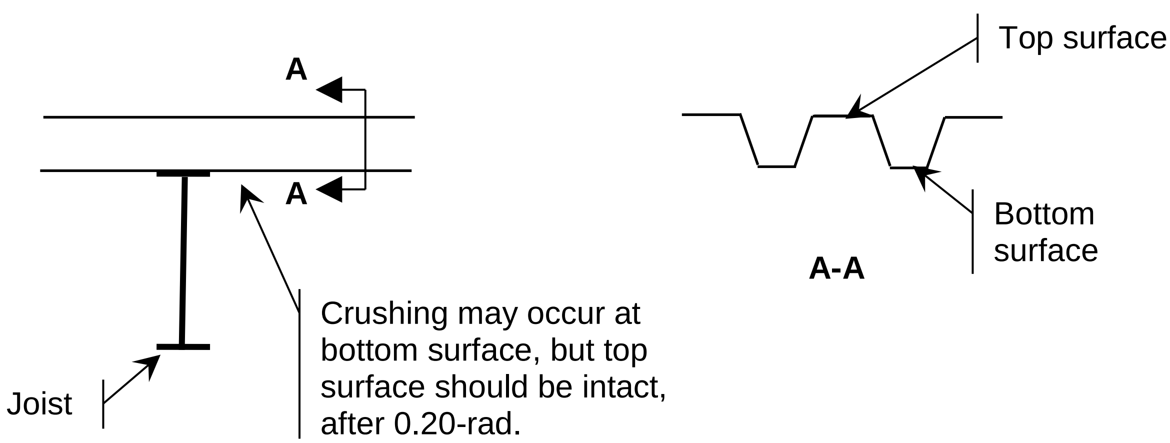

Figure C-6. Tie Force in Steel Deck

C-5.6 Location Restrictions on Internal and Peripheral Ties.

As mentioned, one goal of the revised Tie Force approach is to remove the Tie Forces from the flexural members, which typically are not capable of sustaining the large amount of deformation associated with catenary and diaphragm action. For example, if a peripheral tie was placed in a deep edge beam with limited ductility, the peripheral tie may be damaged or failed by the resulting motion of the edge beam after a column is removed. Within the floor plan, the internal ties can be shifted to either side of the beam, girder or spandrel for framed structures; for flat plate or flat slab structures without edge beams or internal beams, the tie forces can be placed on the column lines and pass through the columns. However, the peripheral ties also need to be close to the edge of the structure and therefore the peripheral ties are permitted to be close to the inner edge of the beam, girder or spandrel. While the portion of the slab/floor next to the beam may respond as a flange of the beam early in the deflection, at some point the beam and its action will be separated from the slab and the peripheral tie will function as intended.

C-5.7 Consideration for Non-Uniform Load Over Floor Area.

Since the load magnitude may vary significantly over the plan area of a given story, e.g. manufacturing activities may be located in one section of the floor and office space in another, the concept of sub-areas is used to accommodate the differences in longitudinal, transverse, and peripheral ties that result from the load variation.

The approach in Paragraph 3-1.3 is illustrated in Figure 3-2 for the case of two sub-areas. In principle, multiple sub-areas can be used across a floor system, but the designer is encouraged to minimize the number of sub-areas, to reduce the number of unique rebar layouts as well as the potential for errors in construction.

The peripheral ties between the sub-areas must be satisfactorily anchored or embedded such that the full tensile strength can be developed.

C-6 ALTERNATE PATH METHOD.

C-6.1 General.

In the Alternate Path (AP) method, the designer must show that the structure is capable of bridging over a removed column or section of wall and that the resulting deformations and internal actions do not exceed the acceptance criteria. Three analysis procedures are permitted: Linear Static, Nonlinear Static, and Nonlinear Dynamic.

These procedures were re-evaluated for the 2009 UFC 4-023-03. An assessment of analysis methods in the related field of seismic design revealed that the procedures specified in ASCE 41 *Seismic Rehabilitation of Existing Buildings* could be adopted and modified for application in the 2009 UFC 4-023-03. While progressive collapse design and seismic design are distinctly different, the general ASCE 41 approach was adopted for the following reasons:

- ASCE 41 and UFC 4-023-03 deal with extreme events that severely damage structures which must not collapse or otherwise imperil the occupants.
- The ASCE 41 methodology was developed and vetted by a panel of structural engineering experts over many years of effort and could be modified in a straightforward manner for progressive collapse design.
- Five materials are considered: steel, RC, masonry, wood, and cold formed steel, in ASCE 41 and UFC 4-023-03.
- Explicit requirements and guidance for analyzing and designing multiple building types for each material are provided in ASCE 41.
- Careful attention is given in ASCE 41 to deformation- and force-controlled actions, as well as primary and secondary components.
- The acceptance criteria and modeling parameters in ASCE 41 can be scaled for different structural performance levels.

The most significant differences between the physics, intent, and approaches underlying UFC 4-023-03 and ASCE 41 are:

- **Extent.** The seismic event involves the entire structure, whereas, for progressive collapse, the initial event is localized to the column/wall removal area.
- **Load Types**. Seismic loads are horizontal and temporary; for progressive collapse, the loads are vertical and permanent.
- **Damage Distribution**. For earthquake design, it is accepted that the damage will be distributed throughout the structure. For progressive collapse, the initial damage is localized and the goal is to keep the damage from progressing.
- **Connection and Member Response**. In typical tests to evaluate the seismic performance of connections and members, cyclic loads with increasing magnitude are applied, without axial loading, and the resulting curves are used to develop “backbone” curves. In progressive collapse, the connection and member experiences one half cycle of loading, often in conjunction with a significant axial load, due to large deformations and catenary response.

These differences have been accommodated in the adaptation of ASCE 41 procedures and criteria to Alternate Path modeling and design for progressive collapse. The significant elements of the Alternate Path method are presented in the following paragraphs.

C-6.2 Peer Review.

In the 2005 UFC 4-023-03, a peer review was required for Alternate Path design of medium and high level of protection buildings. In both the 2009 UFC 4-023-03 and in this UFC, a peer review is no longer required as this is a policy issue that is best addressed by the building owner. However, peer reviews are strongly recommended, for Alternate Path design in any \3\ Risk Category /3/.

C-6.3 Alternative Rational Analysis.

Any rational alternative analysis procedure that is based on fundamental principles of engineering mechanics and dynamics may be used. For load-bearing wall structures with uniform and regular wall layouts or simple frame structures, hand calculations or spreadsheet applications may be appropriate and more efficient. New software design and analysis tools, based on novel analytical formulations, may be used as well. However, any alternative rational analyses must incorporate or satisfy the following:

- the acceptance criteria contained in Section 3-2.10 and in Chapters 4 through 8.
- the specified locations and sizes of removed columns and load-bearing walls in Section 3-2.9.
- the ASCE 7 extreme event load combination.
- the load increase factors and dynamic increase factors in Sections 3-2.11.5 and 3-2.12.5 for linear static and nonlinear static analyses, respectively.
- the requirements of Section 3-2.11.1 must be met for a Linear Static analysis.

All projects using alternative rational analysis procedures shall be reviewed and approved by an independent third-party engineer or by an authorized representative of the facility owner.

C-6.4 Load and Resistance Factor Design.

Load and Resistance Factor Design (LRFD) continues to be used in this version of UFC 4-023-03 as well as the ASCE 7 extraordinary event load combination is employed. Also, unlike ASCE 41, strength reduction factors are employed in determining the design strength. The strength reduction factors account for deficient material strength, construction errors, design flaws and other uncertainties that can act to reduce the strength of the building; all of these uncertainties are “locked” into the building when it is constructed and will still be there when a progressive collapse event occurs. Therefore, the strength reduction factors, load factors, and the LRFD approach continue to be employed in this version of UFC 4-023-03.

C-6.5 Primary and Secondary Components.

The designation of elements, components and connections as primary or secondary is left to the judgment of the engineer; however, in all cases, the engineer must verify that the structure and its elements, components and connections are capable of meeting the structural acceptance criteria in Paragraph 3-2.10.

For evaluation of existing buildings, the engineer may wish to include elements that are typically considered secondary, i.e., gravity beams, slabs, infill walls, etc. If such elements are included as part of the system that resists the vertical loads and collapse, they become primary components by definition and must meet the primary component acceptance criteria.

C-6.5.1 Secondary Components.

While secondary components are designated by the engineer as not contributing to the resistance of gravity loads and progressive collapse, they are a critical part of the load path for the vertical loads and they pose a risk to the building occupants if they drop into the space below, potentially creating additional damage and collapse. As an example, the gravity beams in a bay supporting heavy mechanical equipment could be treated as secondary components; however, the shear tab connections with a deep bolt group could have reduced allowable rotations/m-factors such that the rotations from the column removal could be sufficient to fail the shear tab connections. Secondary components are not included as part of the models in the linear or nonlinear procedures but must be checked against the acceptance criteria given in this UFC and in ASCE 41.

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C-6.5.2 Linear Static Secondary Component Acceptance Criteria.

While secondary components such as gravity beams and simple shear tab connections are not included in the linear static model, these members may fail if subjected to large dynamic loads and/or significant deflections due to column/wall removal and may pose a hazard to occupants or lead to additional structural failure if they detach and impact the floor below. These members must be checked with the same level of attention as the primary members. For linear procedures, the secondary component must meet the force- and deformation-controlled criteria of Equations 3-13 and 3-14.

Before the column or wall is removed, the secondary component will be initially stressed and deformed due to the deformation-controlled or force-controlled load combinations given in Equations 3-10 and 3-12, respectively. When the column or wall is removed, additional stresses and deformations are created. As a linear static procedure is being used, these two sets of demands can be directly added. Two steps are required. First, for each secondary component or connection, the force- or deformation controlled load case is applied to the secondary component in the un-deformed configuration and the demand (internal shear, moment, axial force) due to this load is calculated. Second, the displacements and rotations from the linear static model with the removed column/wall are then applied to the secondary component (without the gravity load) and the resulting demand is calculated. The two demands (due to load and due to deformed structure) are added together to determine the total demand. This approach is used in the steel example in Appendix E.

As Appendix E shows, acceptance checks of gravity beams and simple shear tab connections (secondary components) in steel frame structures present a unique challenge. While force- and deformation-controlled actions can be checked in a straight-forward manner with nonlinear procedures, the linear static procedure and criteria are based on m-factors applied to the moments and other deformation-controlled actions and thus moments must be determined to perform the checks, even at the simple connections and the ends of gravity beams which are often considered to be pinned. While allowable plastic rotations are available for nonlinear static and nonlinear dynamic procedures, they cannot be used for checks in the linear static method, as the analysis procedures are different, in terms of load adjustment factors, explicit consideration of hinges, fidelity of the nonlinear models, etc. Thus, the linear static acceptance criteria must be based on moments, shears, and other forces. As simple shear tab connections can be considered partially restrained (PR) connections, their flexural strength can be calculated with an approximate rotational stiffness and the overall rotations, for comparison to the flexural demand, as shown in Appendix E. Similar approaches must be devised and used for reinforced concrete, masonry, wood, and cold-formed steel structures./2/

C-6.6 Analysis Procedures.

C-6.6.1 Linear Static.

The Linear Static approach in the 2005 UFC 4-023-03 had been replaced with an “m-factor” procedure, very similar to that defined in ASCE 41. The two significant departures from the ASCE 41 procedure are in the definition of the “Irregularity Limitations” in Paragraph 3-2.11.1.1 and the use of a load increase factor appropriate for progressive collapse loading. The irregularity limitations have been adjusted due to the inherent difference between lateral/seismic loading and vertical/progressive collapse loading and the related criticality of different building geometric and strength features. As discussed in Section C-6.8, a new load increase factor to account for nonlinearity and dynamic effects has been implemented.

C-6.6.2 Nonlinear Static.

The Nonlinear Static procedure is similar to that specified in the 2005 UFC 4-023-03 and in ASCE 41. Two exceptions are the modeling parameters and the acceptance criteria, which are now taken from ASCE 41, unless specifically modified in Chapters 4 to 8 of this UFC. One advantage of ASCE 41 is that guidance is provided for the development of analytical and numerical models for a number of distinct structural systems, including the determination of connection and member properties

One significant difference from ASCE 41 and the 2005 UFC 4-023-03 is the specification of a dynamic increase factor that is applied to the loads on the bays above the removed column or wall location to account for dynamic effects. In the 2005 UFC 4-023-03 and in the 2003 *GSA Progressive Collapse Analysis and Design Guidelines for New Federal Office Buildings and Major Modernization Projects* (“GSA Guidelines”), the load factor was set at 2, as for the Linear Static analysis, despite the explicit incorporation of nonlinear effects in the Nonlinear Static procedure. The dynamic increase factor is discussed in Section C-6.8.

C-6.6.3 Nonlinear Dynamic.

The Nonlinear Dynamic procedure is essentially unchanged from the 2005 UFC 4-023-03, with the exception of the incorporation of the modeling parameters and acceptance criteria from ASCE 41.

C-6.7 Loads.

\2\The ASCE 7 extraordinary event load combination is employed, with the exception that the lateral load has been removed. In alternate path analyses, the initial and primary damage is limited to the column or removal location, with the rest of the structure being intact and providing the majority of its original lateral load resistance; the original lateral load resistance would be based on peak wind forces much higher than 0.2W, 0.002ΣP or seismic loads if present. It is highly unlikely that the loss of a column or 2H wall section would destabilize the building laterally and cases where applying the lateral load uncovered any instability of the building and motivated any changes to the building design are unknown. Therefore, the lateral load requirement has been removed. /2/

C-6.8 Load and Dynamic Increase Factors.

Three analytical procedures may be employed: Linear Static, Nonlinear Static, and Nonlinear Dynamic. As progressive collapse is a dynamic and nonlinear event, the applied load cases for the static procedures require the use of load increase factors or dynamic increase factors, which approximately account for inertial and nonlinear effects. For both Linear Static and Nonlinear Static, the 2005 UFC 4-023-03 and the GSA Guidelines use a load multiplier of 2.0, applied directly to the progressive collapse load combination.

Three issues with the use of a fixed factor of 2 have been identified. First, the same load multiplier is used for Linear Static and Nonlinear Static analyses, although the Nonlinear Static analysis incorporates nonlinearity. Second, an increase factor of 2.0 is not appropriate for the majority of LS and NS cases. The maximum dynamic displacement of an instantaneously applied and sustained load in a linear analysis is twice the displacement achieved when the load is applied statically. If a structure is designed to remain elastic, a factor of 2.0 would be appropriate. However, in extreme loading events, it is typical to design structures to respond in the nonlinear range. Thus, the dynamic increase factor (DIF) that allows a Nonlinear Static solution to approximate a Nonlinear Dynamic solution, is typically less than 2. On the other hand, the load increase factor (LIF) for a Linear Static analysis must be greater than 2, since dynamic and nonlinear effects are present. Third, the load enhancement factor did not vary with the structural performance level, i.e., a structure is assigned a load enhancement factor of 2.0 regardless of whether the designer wants to allow significant structural damage or very little damage.

A study was undertaken to investigate the factors needed to better match the results of the LS and NS static procedures to the ND results; see McKay et al. 2008. As in ASCE 41, structural deformation was considered to be the best metric for approximating structural damage. To match the ND deformation levels, SAP2000 models of reinforced concrete and steel multi-story models were developed and analyzed with LS, NS, and ND procedures. For the LS and ND models, the loads were varied until agreement with the NS model was reached. The ASCE 7 extreme event load case was used for all analyses.

The range of nonlinear structural deformations used in this study was based primarily on the acceptance criteria in ASCE 41, with some modifications for reinforced concrete, for which the Life Safety values were increased by a factor of 3.5. For reinforced concrete, the allowable deformation criteria in ASCE 41 are much smaller than indicated by test data from blast- and impact-loaded RC structural members. In addition, the conservative ASCE 41 RC criteria are based on backbone curves derived from cyclic testing of members and joints, whereas only one-half cycle is applied in a progressive collapse event.

As an example, the results of this procedure for the Dynamic Increase Factor (DIF), used for Nonlinear Static analyses of steel structures, are shown in Figure C-7, where the DIF is shown as a function of the normalized rotation (allowable plastic rotation divided by the rotation at yield of the cross section). The data points in this plot were obtained by analyzing a range of buildings with various heights, bay dimensions and structural details. With this plot the DIF can be chosen as a function of the level of nonlinear behavior (i.e., structural performance level) that the designer wishes to employ or, else, the level of nonlinear behavior can be assigned, resulting in a specific DIF. In this UFC, the designer must find the smallest normalized rotation for any structural component or connection within the region of the structure affected by the column removal and will use this value to determine the DIF from the recommended equation in Figure C-7.

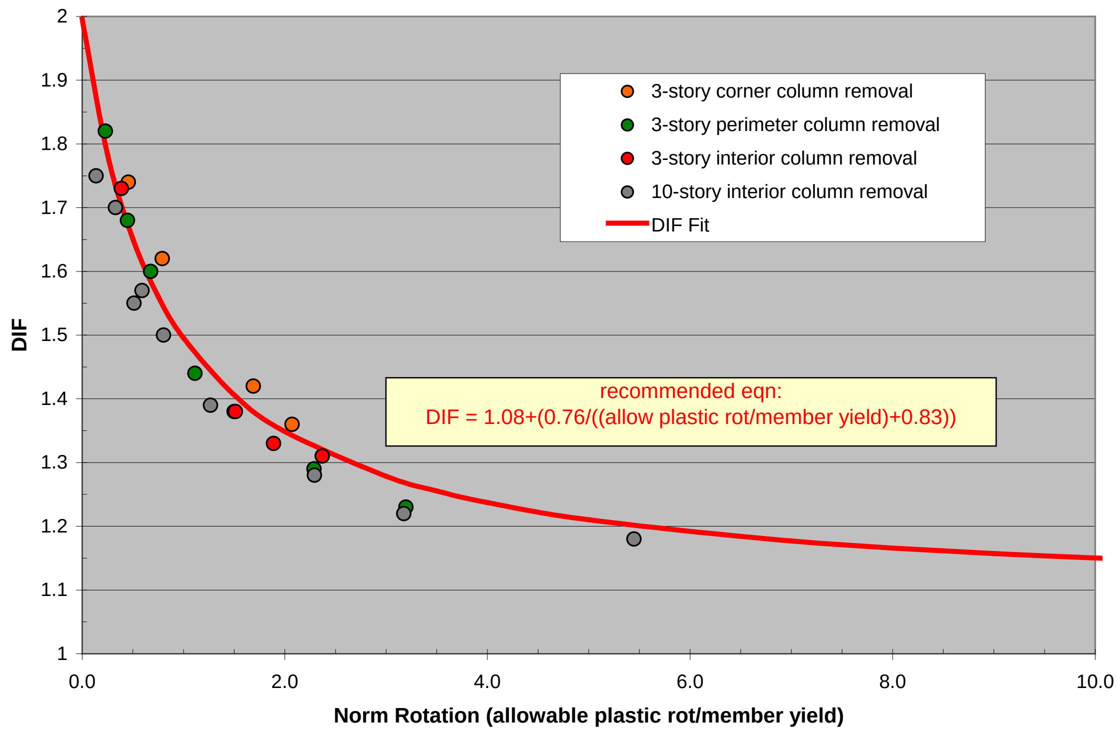


Figure C-7. Dynamic Increase Factor for Structural Steel

C-6.9 Structural Damage Limits.

In the previous UFC, the structural damage limits were set at 15% and 30% for the floor area above the removed column or wall at an external or internal column or wall, respectively. In this UFC, no damage to the floor is allowed and these criteria have been removed, as the floor system, beams, and girders in the bays directly above the removed column can be designed to not fail, as is done for the bays in the floors above the removed column location.

C-6.10 Modeling and Acceptance Criteria.

With a few notable exceptions, the acceptance criteria for linear and nonlinear approaches and the modeling criteria for nonlinear approaches from ASCE 41 are employed in the updated UFC 4-023-03. The ASCE 41 criteria are considered to be conservative when applied to progressive collapse design as they have been developed for repeated load cycles (i.e., backbone curves) whereas only one-half load cycle is applied in progressive collapse. As specified in each material specific chapter of this UFC, either the Collapse Prevention or Life Safety structural performance levels in ASCE 41 are used for many of the components; see Chapters 4 to 8.

The notable exceptions/modifications to the acceptance and modeling criteria include RC beams and slabs and a number of steel connections. These changes are motivated and justified by experimental data and numerical analysis results, as discussed later in this Appendix.

C-7 ENHANCED LOCAL RESISTANCE.

The second direct design approach is Specific Local Resistance (SLR) or structural hardening, in which key or critical elements of the structure are designed for a specific load, such as blast or vehicle impact. This approach reduces the likelihood or extent of the initial damage and can be effective, for those cases where the threat can be quantified through risk analysis or specified through prescriptive design requirements. SLR can be a cost-effective method for providing resistance to collapse prevention, particularly for existing structures. The main shortcoming to this method is the requirement to define the threat or design load, as this information could be used to plan a deliberate attack on the structure; because of this, the threat information may be considered classified, restricting its use by the general public. Also, philosophically, progressive collapse design is typically considered to be threat-independent and if a specific threat such as an explosive device is specified, separate design guidance for hardening buildings is available.

In the 2005 UFC 4-023-03, a version of SLR was implemented in the Additional Ductility Requirement (ADR), which specified that the shear strength of a ground story column or wall exceed the flexural strength. With this requirement, the columns or walls will fail in flexure, which provides a more ductile and controlled response than the sudden failure associated with shear. This requirement can be implemented cost-effectively in new construction and provides a significant benefit.

A modified or enhanced version of SLR is implemented in this UFC to provide a nominal level of protection for perimeter columns and walls. This procedure is also threat independent and is referred to as Enhanced Local Resistance (ELR) to differentiate it from SLR and ADR. As ELR is intended to provide resistance against severe dynamic loadings, the same philosophy as is used for blast resistant design is employed, wherein all strength reduction factors are set to 1.0 and the expected strength is employed for shear, flexure and all other actions. The development and design approach of this method is “tuned” to the inherent structural robustness of the system as discussed in Marchand and Stevens 2008. A charge weight that will destroy multiple columns or wall sections, depending upon standoff and location, was determined for a variety of representative structures. An analysis of the data resulted in required enhancement factors of 2 and 1.5 for the flexural and shear demands of columns and walls, respectively. The design shear strength of the column or wall and the connections to the lateral force resisting elements is also stipulated to be greater than the shear demand, which is based on the flexural demand, to provide a ductile and more controlled failure mode. \2\

C-7.1 ELR Design Requirements.

For RC II Option 1, the shear demand of the columns and walls is determined based on the existing or as-designed structure. For RC III, the shear demand is based on the structure design after the AP method has been applied.

A higher level of resistance is required for RC IV structures; in this case, two flexural demands are compared and used to determine the final shear demand. Because an RC IV building in a seismic region will have significantly larger columns than the same RC IV building in a non-seismic region, the seismic structure will also have significantly higher shear demand. However, both buildings should provide the same protection to the occupants. To accomplish this and to provide a reasonable shear demand, the design of the building based on only gravity loads and the AP requirements is used to define the baseline nominal flexural strength. If a gravity loads only design was not accomplished during the design effort, it must be performed. It is anticipated that mathematical models will be created for RC IV buildings and the effort to use them for a gravity loads only design and AP analysis should not be significant. After the baseline nominal flexural strength is determined with the column design from the gravity loads-only AP structural design, it is multiplied by 2.0 and compared to the existing nominal flexural strength. The existing nominal flexural strength is based on the column design after the Alternate Path method is applied to the final structure (i.e., the structural design based on wind, seismic, snow, and gravity loads). The larger of 2.0 times the baseline nominal flexural strength and the existing nominal flexural strength is defined as the flexural demand. If the flexural demand is greater than the existing nominal flexural strength, then the design of the column must be upgraded to match the flexural demand. The same procedure applies for load-bearing walls but in this case, the baseline flexural strength is multiplied by 1.5.

C-7.2 Connection Design for Rebound.

Rebound is most likely to occur for explosive loadings, not vehicle impact and the magnitude of the rebound reaction is a function of the column properties, end conditions, façade design, charge weight and standoff, etc Guidance for rebound forces can be found in Section 4-1.2.5 of PDC TR-06-01 *Methodology Manual for the Single-Degree-of-Freedom Blast Effects Design Spreadsheets (SBEDS)*, which states that “An equivalent static design load for rebound equal to one-half the inbound ultimate resistance is often used as a rule of thumb for blast design.” This is the basis for the requirement in Section 3-3.6 that the connection be designed for a rebound reaction equal to 50% of the inbound reaction force. It should be noted that this requirement is based on analytical modeling, engineering judgment, and qualitative observations. However, there is limited experimental evidence that neither supports nor discredits this requirement for the wide range of construction types and scenarios covered in this UFC. /2/

C-8 REINFORCED CONCRETE.

C-8.1 Reinforced Concrete Beams and Joints.

\4\ /4/ The design strength and rotational capacities of the beams and beam-to-column-to-beam joints shall be determined with the guidance found in ASCE 41, as modified with the acceptance criteria provided in Paragraph 4-4.3.

C-8.2 Structural Performance Levels.

To determine the appropriate structural performance level and the corresponding modeling and acceptance criteria from ASCE 41, the types of loading and resulting performance of reinforced concrete beams and beam-column joints were assessed. In seismic events, the structural elements and connections are subjected to primarily shear and bending with little axial tension. Under progressive collapse conditions, axial tension is developed in the beam, as they undergo large displacements in a double-span condition and the beam starts to behave as a catenary.

Conceptually, the damage states reflected in the Life Safety category make sense for progressive collapse. In seismic design, it is assumed that the primary components can sustain significant degradation to their lateral load resisting behavior as long as they can still support the gravity loads; for progressive collapse, the primary components must resist gravity loads during and after the event. As defined in ASCE 41, Collapse Prevention results in a damage state for which there is little additional deformation capacity and the stability of the system has been severely compromised. Life Safety provides a greater reserve in terms of nonlinear deformation and strength and thus is used for the majority of the steel acceptance criteria.

C-8.3 Modeling and Acceptance Criteria for Reinforced Concrete.

The majority of the modeling parameters, acceptance criteria and linear m-factors for reinforced concrete are chosen as the Life Safety values in Chapter 6 of ASCE 41 for primary and secondary components. Modifications to the modeling and acceptance criteria for beams and slabs were made based on data from blast- and impact-loaded beams and other flexural members. For RC beams and slabs controlled by flexure, the modeling and acceptance criteria values for Collapse Prevention were multiplied by a factor of 2.5 for primary members and 2.0 for secondary members. For all other conditions and cases of beams and slabs, the Life Safety values are used.

C-8.4 Best Practice Recommendation.

To insure ductile and energy absorbing response in new construction of reinforced concrete structures, it is recommended that the primary reinforced concrete beams and beam-to-column-to-beam joints comply with the provisions for special moment frames in ACI 318. These code provisions include ductile detailing requirements for longitudinal reinforcement, transverse reinforcement, required shear strength, and development length of bars in tension.

C-9 STRUCTURAL STEEL.

C-9.1 Structural Steel Connections.

A variety of steel frame connection types are listed in Table C-1 and illustrated in Figures C-8 through C-10. This list constitutes an inventory of connection types that have been used either in the past and/or present for standard building code design applications (gravity, wind, and earthquake loads).

Proprietary connections have been evaluated and found to be acceptable for specific projects and/or for general application. Inclusion of these connections in this UFC does not constitute an endorsement. The Kaiser Bolted Bracket®, SidePlate® and SlottedWeb™ are shown schematically in Figures C-11 through C-13, respectively. Details of the performance and geometry can be obtained from the vendors.

C-9.2 Steel Connection Requirements.

\4\/4/ The design strength and rotational capacities of the beams and beam-to-column connections shall be determined with the guidance found in ASCE 41, as modified with the acceptance criteria provided in Paragraph 5-4.3 in this UFC.

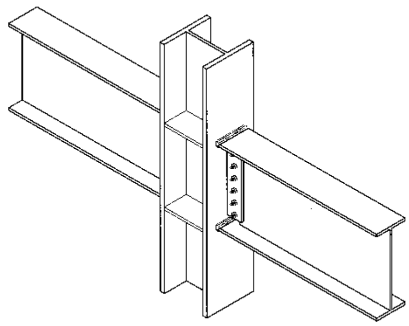
C-9.3 Structural Performance Levels.

To determine the appropriate structural performance level and the corresponding modeling and acceptance criteria from ASCE 41, the types of loading and resulting performance of structural steel connections were assessed as there is a fundamental difference between seismic and progressive collapse events. The seismic modeling and acceptance criteria in ASCE 41 are based upon cyclic tests in which the end of a cantilever beam is subjected to ever-increasing amplitudes; the beams and connections experience shear and bending moment with no axial tension. Under progressive collapse conditions, axial tension is developed as the beam experiences large displacements in a double-span condition and the beam starts to behave more like a cable than a beam.

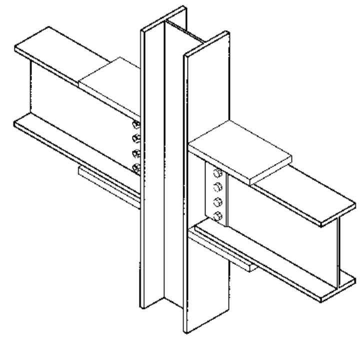
Table C-1. Steel Frame Beam-to-Column Connection Types

Connection	Description	Type	Figure
Welded Unreinforced Flange (WUF)	Full-penetration welds between beams and columns, flanges, bolted or welded web, designed prior to code changes following the Northridge earthquake.	FR	C-8(a)
Welded Flange Plates (WFP)	Flange plate with full-penetration weld at column and fillet welded to beam flange	FR	C-8(b)
Welded Cover-Plated Flanges	Beam flange and cover-plate are welded to column flange	FR	C-8(c)
Bolted Flange Plates (BFP)	Flange plate with full-penetration weld at column and field bolted to beam flange	FR or PR	C-8(d)
Improved WUF-Bolted Web[(1)]	Full-penetration welds between beam and column flanges, bolted web, developed after Northridge Earthquake	FR	C-8(a)
Improved WUF-Welded Web	Full-penetration welds between beam and column flanges, welded web developed after Northridge Earthquake	FR	C-8(a)
Free Flange	Web is coped at ends of beam to separate flanges, welded web tab resists shear and bending moment due to eccentricity due to coped web developed after Northridge Earthquake	FR	C-8(e)
Welded Top and Bottom Haunches	Haunched connection at top and bottom flanges developed after Northridge Earthquake	FR	C-8(f)
Reduced Beam Section (RBS) [(2)]	Connection in which net area of beam flange is reduced to force plastic hinging away from column face developed after Northridge Earthquake	FR	C 8(g)
Top and Bottom Clip Angles	Clip angle bolted or riveted to beam flange and column flange	PR	C-9(a)
Bolted Double Split Tee[(2)]	Split tees bolted or riveted to beam flange and column flange	PR	C-9(b)
Composite Top and Clip Angle Bottom	Clip angle bolted or riveted to column flange and beam bottom flange with composite slab	PR	C-9(a) similar
Bolted Flange Plates	Flange plate with full-penetration weld at column and bolted to beam flange	PR	C-8(d)
Bolted End Plate	Stiffened or unstiffened end plate welded to beam and bolted to column flange	PR	C-8(c)
Shear Tab Connection with or without[(2)] floor deck	Simple gravity connection with shear tab, may have composite floor deck	PR	C-8(d)
Kaiser Bolted Bracket®,	SMF moment connection with fastened cast steel haunch brackets that are bolted to the column flange and either fillet-welded or bolted to both beam flanges.	FR	C-11
SidePlate®	SMF moment connection with full-depth side plates and fillet welds, developed following the 1994 Northridge earthquake.	FR	C-12
SlottedWeb™	SMF moment connection similar to WUF with extended web slots at weld access holes to separating the beam flanges from the beam web in the region of the connection.	FR	C13

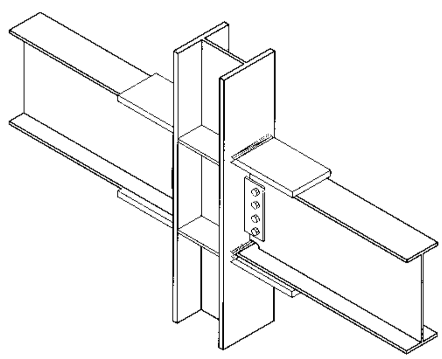
Note: PR = Partially Restrained Moment Connection or Shear Connection
FR = Fully Restrained Moment Connection
(1) Testing and predictive analysis information is provided in Karns and Houghton 2008.
(2) Predictive Analysis only information is provided in Karns and Houghton 2008.



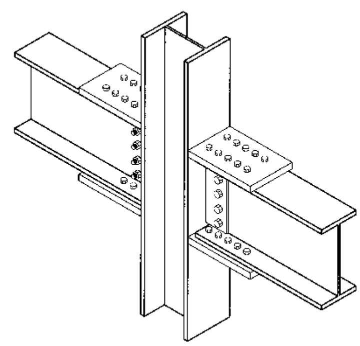
(a) WUF Connection



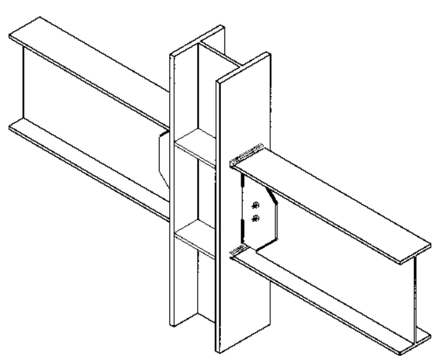
(b) Welded Flange Plate



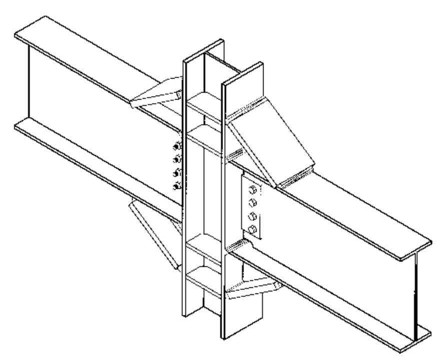
(c) Welded Cover Plated Flanges



(d) Bolted Flange Plate



(e) Free Flange



(f) Top and Bottom Haunch

Figure C-8. Fully Restrained Moment Connections

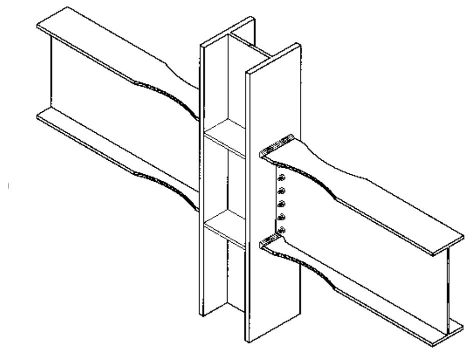
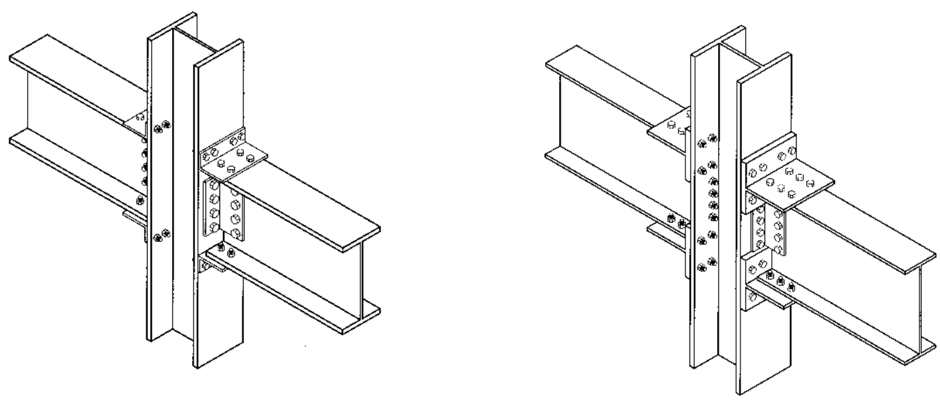
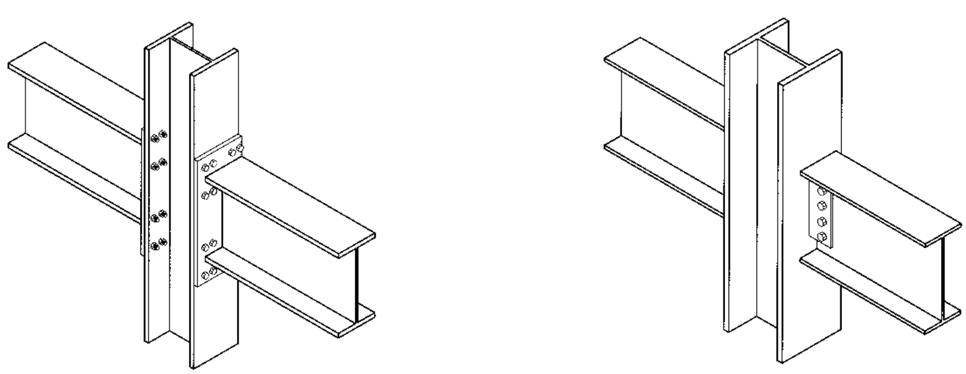


Figure C-8 (continued) Fully Restrained Moment Connections



(a) Bolted or Riveted Angle

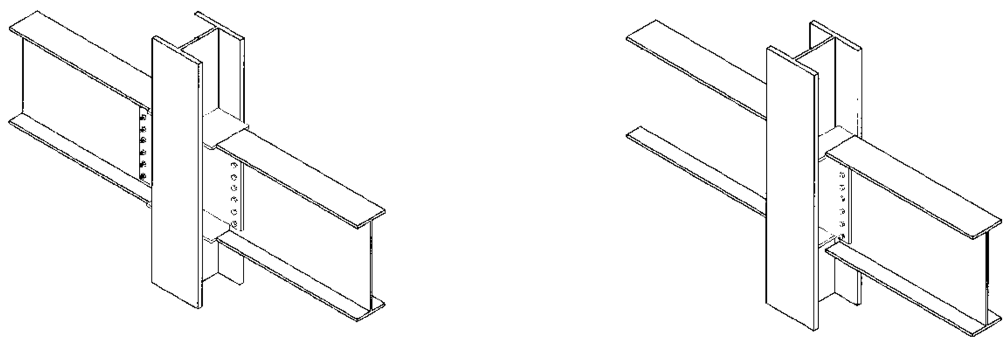
(b) Bolted Double Split Tee



(c) End Plate (Unstiffened)

(d) Simple Shear Tab Connection

Figure C-9. Partially Restrained Moment Connections or Shear Connections



(a) Fully Restrained Connection (b) Typical Shear Only Connection

Figure C-10. Weak Axis Moment Connection or Shear Connection

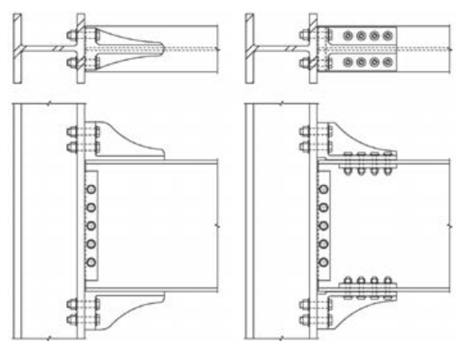


Figure C-11. Kaiser Bolted Bracket® Fully Restrained Connection

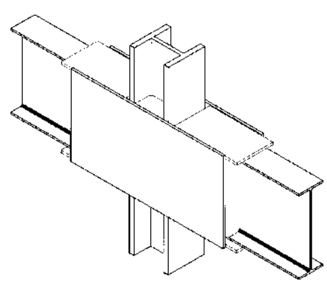


Figure C-12. SidePlate® Fully Restrained Moment Connection

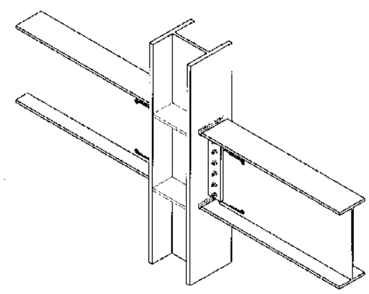


Figure C-13. SlottedWeb™ Fully Restrained Connection

The rotational capacity values for connections in the 2005 UFC 4-023-03 were based upon the 2003 GSA Guidelines, and reasonably agree with those in ASCE 41 for primary elements and the Life Safety structural response level. Conceptually, the damage states reflected in the Life Safety category make sense for progressive collapse. The governing assumption for seismic design is that the primary components can sustain significant degradation to their lateral load resisting behavior as long as reserve capacity is maintained to support the gravity loads. For progressive collapse, the primary components must resist gravity loads during and after the event. Since gravity loads are constant, damage can result in instabilities and failure. Per the definitions of structural performance levels in ASCE 41, Collapse Prevention results in a damage state for which there is little additional deformation capacity and the stability of the system has been severely compromised. Life Safety provides a greater reserve in terms of nonlinear deformation and strength and thus is used for the majority of the steel acceptance criteria.

C-9.4 Modeling Parameters and Acceptance Criteria.

In developing the modeling procedures and acceptance criteria, a comparison was made between the deformation limits contained in ASCE 41, the Eurocode, and the 2005 UFC 4-023-03. These limits were also compared to the rotational capacities reported in the *GSA Steel Frame Bomb Blast & Progressive Collapse Test Program Report (2004-2007)* ("GSA Test Program Report") as summarized in Karns and Houghton 2008. The progressive collapse test configurations in the GSA Test Program were designed to capture both bending and axial tension to determine the effect of their interaction on the rotational capacity of the connection investigated.

Models and acceptance criteria in ASCE 41 are based upon cyclic loadings with bending moment only and rotational capacities are often limited because of degradation and premature loss of strength due to low cycle fatigue. In contrast, recent progressive collapse research with monotonic loading conditions has demonstrated that rotational capacities are most often higher than for cyclic loading. However, with the addition of axial loads, the progressive collapse rotational capacities may be limited, as some connections are unable to develop significant axial tension load upon reaching the

ultimate moment capacity of the beam. Thus, the majority of the modeling and acceptance criteria in Chapter 5 are specified either as Life Safety justified by the behavioral differences associated with the effects of loading (monotonic vs. cyclic) and the ultimate state of strain (moment only vs. moment-axial tension interaction).

Where appropriate, some modifications to the modeling parameters and acceptance criteria have been applied. In some cases, little or no criteria were available and new acceptance criteria were created, using the existing literature and recent tests and numerical simulations, as detailed in Karns and Houghton 2008. The results were used to determine the modeling and acceptance criteria provided in Tables 5-1 and 5-2 of this document.

C-9.5 Best Practice Recommendation.

For new construction, it is recommended that all primary steel frame beam-to-column moment connections be one of the special moment frame (SMF) connections identified in FEMA 350 under Section 3.5 (welded), Section 3.6 (bolted) or Section 3.8 (proprietary), and/or ANSI/AISC 358 (including Supplements), and/or prequalified under ICC-ES AC129. The use of an SMF connection type should not be construed to include the SMF seismic detailing provisions specified in national building codes for higher seismic regions, except for the case where a particular building design is subject to those code provisions.

The additional cost for SMF connections should be minimal, as the use of notch-tough weld wire, continuity plates, and high strength bolts, etc, is common practice. The primary reason for using an SMF connection is to secure the connection characteristics that provide a minimum threshold of rotational capacity. It is important to note that the “seismic detailing” provisions of the IBC Building Code are not required for progressive collapse design applications, unless the seismic region for a particular building design is subject to those earthquake code provisions anyway.

Acceptable SMF-type connections include:

- Welded Unreinforced Flanges with Welded Web (WUF-W)
- Bolted Flange Plate (BFP)
- Bolted Unstiffened End Plate (BUEP)
- Bolted Stiffened End Plate (BSEP)
- Reduced Beam section (RBS)
- Kaiser Bolted Bracket®
- SidePlate®

- Slotted Web™

Two common connections that do not meet the SMF requirements are:

- Double Split Tee (DST)
- Welded Unreinforced Flanges with Bolted Web (WUF-B).

For the WUF-B connection, welding of its bolted web-to-shear tab connection is all that is required for it to become a WUF-W connection, for which there is a significant improvement in rotational performance, including increased reliability.

C-10 MASONRY, WOOD, AND COLD-FORMED STEEL.

As discussed for steel and reinforced concrete, the modeling parameters, nonlinear acceptance criteria and linear m-factors for the Life Safety performance level in ASCE 41 are appropriate for Alternate Path analysis and design of masonry, wood, and cold-formed steel structures.

C-10.1 Time Effect Factor λ for Wood.

Note that for wood construction, the time effect factor λ must be included in the determination of strength for the Tie Force and Alternate Path requirements. As discussed in AFPA/AWC "LRFD Manual for Engineering Wood Construction", the time effect factors, λ, were derived based on reliability analysis that considered variability in strength properties, stochastic load process modeling and cumulative damage effects. The time effect factors are applied to the reference strengths used in the code, which are based on short-term loading test values. Time effect factors range in value from 1.25 for a load combination controlled by impact loading to 0.6 for a load combination controlled by permanent dead load. Common building applications will likely be designed for time effect factors of 0.80 for gravity load design and 1.0 for lateral load design. Further ANSI/ASCE 16-95 indicates time effect factors of 0.7 when the live load in the basic gravity load design combination is for storage, 0.8 when the live load is from occupancy, and 1.25 when the live load is from impact. It is desirable that the structure is stable following local damage to allow for rescue operations and the installation of temporary shoring, however stability in the damaged state is not a permanent condition. Therefore a time effect factor greater than that associated with permanent occupancy and less than that associated with impact is warranted. For this reason and to avoid overly conservative values for such an extreme loading, a time effect factor of 1.0, consistent with the time effect factors used for gravity-lateral load combinations, is specified.

\3\

C-11 RECOMMENDED ADDITIONAL SPECIFICATION PARAGRAPHS.

C-11.1 Recommendation 1. Work Experience.

The resume of the licensed Professional Engineer (P.E.) with a minimum of 3 years of experience with the Alternate Path Analysis per UFC 4-023-03 shall be submitted.

Reference projects.

Provide the list of projects involving progressive collapse design. Each reference project should include the design method used such as Tie Force Method or Alternate Path Method. For Alternate Path Method, specify the design procedure such as linear static, non-linear static or non-linear dynamic.

C-11.2 Resume for ATPF and Progressive Collapse Design Experience.

Specify the engineer(s) responsible for the progressive collapse design and/or the ATFP, blast design analysis for the project.

/3/

APPENDIX D REINFORCED CONCRETE EXAMPLE

D-1 INTRODUCTION.

A typical reinforced concrete frame commercial building design and analysis example has been prepared to illustrate tie force calculations. The structure is assumed to have an occupancy less than 500 people and is classified as \3\ Risk Category /3/ II per UFC 3-301-01.

The example has been prepared using tools and techniques commonly applied by structural engineering firms in the US. Computer software that is typical of that used for structural design was employed for preliminary design. Per the option given in the UFC, as specified in Section 2-2, tie forces and enhanced local resistance are applied to provide resistance to progressive collapse.

D-2 BASELINE PRELIMINARY DESIGN.

The structure is a seven-story concrete moment frame. The intended function of the building is office use, with occupancy of less than 500 people. See Figures D-1 and D-2 for drawings of the building. The preliminary design, shown in Figures D-1 and D-2, and described below, has been sized to meet the requirements of IBC2006.

D-2.1 Modeling Assumptions.

Systems:
- Gravity:
  - Floor system: Pan formed beams
  - Vertical support: Columns
- Lateral:
  - Moment frames
- Foundation:
  - Shallow spread footings

Elevation:

Foundation to L1:	16’-0”
Typical:	13’-0”
Roof:	14’-0”
Parapet:	4’-0”

Plan:

E-W dimension:	227’-0”
N-W dimension:	97’-0”

Concrete:
All concrete shall be normal weight concrete and shall have specified 28-day compressive strength as shown below:

f'c columns: 5000 psi
f'c floor: 4000 psi
f'c foundation: 4000 psi

Rebar:
A615 grade 60 ksi.

Details of pan formed beams and slab:
Slab thickness = 5" (fire rating)
Per ACI table 9.5 (a) for beams spanning 37.5' (clear span approximately 34.5') the required depth ~ 34.5X12/18.5 = 22.3". 20" deep beams with 5" slab (overall depth of 25") are provided. Rib width of 6" and spacing of 6'-0" utilizes pan form system that is very common.

Pans have 1" to 12" side slope.
Therefore Eq. thickness = (6" + 9.33")/2 X 20" / (72") = 2.13" + 5" slab = 7.13"
Therefore Eq. uniform weight = 89 psf

Details of girders:
Width of the beam: 36"
Depth of beam: 25"
Since the slab and pan formed beam weight is considered for the entire floor area, there is common area of concrete between girders and pan formed beams.
Eq. beam depth = 25 – 7.13" = 17.87"
There are 7 girders over the width of 227' in N-S direction and therefore eq. weight = (36 x 17.87) /144 x 150 x 7 /227 = 20.66 psf

There are 2 girders over the width of 97' in E-W direction and therefore eq. weight = (36 x 17.87) /144 x 150 x 2 / 97 = 13.82 psf

Therefore total weight of beams other than pan formed beams = 20.66 + 13.82 = 34.48 psf. Say 35 psf

Details of columns:
Typical interior column:
Pu = 1.2 (89 + 35 + 10) + 1.6 (50 + 10 + 20) = 288 psf
Pu = 0.288 x 37.5' x 37.5/2 x 7 = 1421 kips.
Axial stress = 1421/(24x24) = 2.46 ksi
For f'c of 5 ksi use 24' square column.

There are 28 columns at each floor.
Weight of column at typical floor = (24"x24")/144 x 13' x 28 x 150 / (97' x 227') = 9.91 psf say 10 psf.

D-2.2 Loading Assumptions.

Dead loads (equivalent uniform loads) (D):
- Self weight:
- Slab and pan formed beams→ 89 psf
- Beams → 35 psf
- Columns → 10 psf

Super imposed dead load (SDL):
- Ceiling, MEP → 10 psf
- Roofing → 20 psf

Cladding (CL) → 60 psf (wall area)

Live loads:
- Office floor area (LL) → 50 psf + 20 psf allowance for partitions
- Storage/Mechanical floor area (LL) → 125 psf
- Corridors → (LL) 80 psf
- Roof (Lr) → 20 psf

Wind Load (W) was determined per IBC 2006 using 110 mph with exposure = B and importance factor = 1.0

Earthquake Load (E) is assumed not to control the design because the building is in a non-seismic region.

Other Loads: Snow Loads (S), Rain Loads (R) are assumed to not control the design.

D-2.3 Design Information.

Column reinforcement at first level above grade:

Corner columns:	8-#8, 3 each face
Long side columns:	14-#11, 4X-5Y
Short side columns:	8-#8, 3 each face
Interior columns:	12-#10, 4 each face

Slab reinforcement at first level above grade:

Each direction:	#3 at 12”

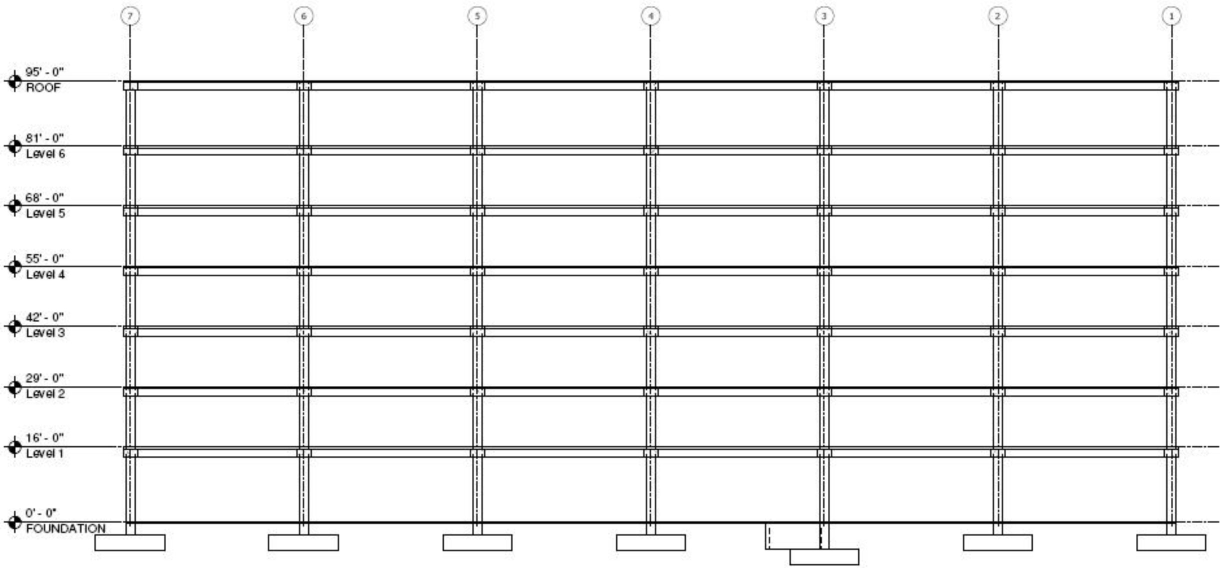


Figure D-1. Concrete Building Elevation

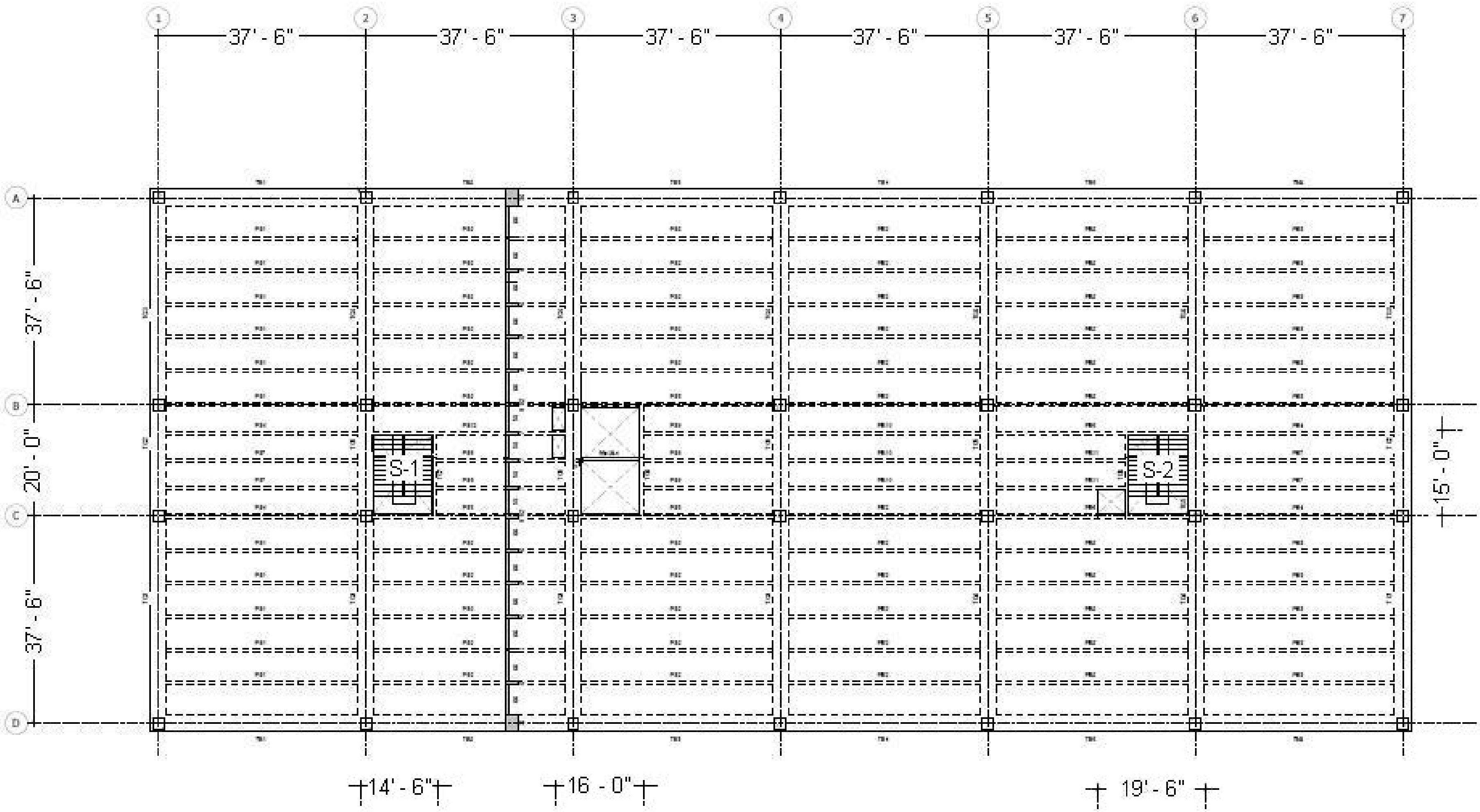


Figure D-2. Concrete Building Plan

D-3 \2\TIE FORCE DESIGN.

The procedure and requirements for Tie Forces for framed buildings are presented in Section 3-1. In the Tie Force approach, the building is mechanically tied together, enhancing continuity, ductility, and development of alternate load paths. There are three horizontal ties that must be provided: longitudinal, transverse, and peripheral. Vertical ties are required in columns. Figure 3-1 illustrates these ties for frame construction.

D-3.1 Calculating w_F.

Section 3-1.3 presents Equation 3-2 for determination of the floor load used in tie force calculations. The corridor load is applied over 25% of bay B-C and storage/mechanical load is provided over the 75% of bay B-C over the length of the building. Office live load is applied over the remainder of the floor. Based on these loads in combination with those presented in Section D-2.2, the effective w_F for transverse and longitudinal ties is 214.5-psf (from Section 3-1.3.2.2, with the difference between the minimum and maximum floor load in the bays on the floor plan being less than or equal to 25% of the minimum floor load and with the area associated with the maximum floor load less than or equal to 25% of the total floor plan area). The calculation is shown in Table D-1.

Table D-1. Load Calculations for w_F

Dead, psf	**Live, psf**			**w_F (1.2D+0.5L), psf**			
Slab and pan formed beams, beams, columns, ceiling, MEP	Office	Storage/ Mech	Corr.	Office		Storage/ Mech	Corr.
144	70	125	80	207.8		235.3	212.8
				Difference = 235.3-207.8 = 27.5 psf, less than 25% of smallest w_F			
Areas, sf	Office	Storage/ Mech	Corridor	Total			
	16875	3375	1125	21375			
	Storage/Mech area is less than 25% of total area						
Since max difference in w_F is less than 25% of smallest w_F and area of largest load is less than 25% of total area, use average w_F for the entire floor							
w_F, total load over total area, psf	= (16875 * 207.8 + 3375 * 235.3 + 1125 * 212.8)/(21375) = 214.5-psf						

The cladding load W_C is calculated as:

W_C = 1.2 * 60-psf * 13-ft height * 37.5-ft span = 35.1-kip

For vertical ties on the perimeter, the cladding load is averaged over the bays in which it is present and added to the floor distributed loading, to determine the effective w_F. For example, for column A1:

w_F = Floor distributed load + Cladding load/area
= 214.5-psf + 1.2 (18.75-ft + 18.75-ft) (13-ft) (60-psf)/(18.75-ft) ^2
= 314.3-psf

D-3.2 Tie Force Calculations.

The required tie forces and rebar area can be calculated with the loads from the previous section and the geometric properties of the building. As an example, the peripheral tie force in the transverse (N-S) direction is determined with Equation 3-6:

F_p = $6\ w_F\ L_1\ L_p + 3\ W_C$
= 6 (214.5-psf) 37.5-ft (3-ft) + 3 (35.1-kip)
= 250.1-kips

The required area is determined with Equation 3-1:

$\Phi\ R_n \geq \Sigma\ \gamma_i\ Q_i$
$0.75\ (1.25{*}60\text{-ksi})\ A_{s\ req'd} \geq 250.1\text{-kips}$
$A_{s\ req'd} = 4.45\text{-in}^2$

where 0.75 is the LRFD strength reduction factor per Section 4-3 of this document and 1.25 is the over-strength factor for rebar, per ASCE 41.

The data for tie force calculations and the resulting reinforcement are summarized in Table D-2.

Table D-2. Tie Force Calculations

Tie Type	Location	Length	w_F	W_C	F	$A_{s\ req'd}$	Reinfm't
		(ft)	(psf)	(kips)	(kips)	(sq in)[A]	
Peripheral	Transverse	37.5	214.5	35.1	250.1	4.45	8 - #7
Peripheral	Longitudinal	37.5	214.5	35.1	250.1	4.45	8 - #7
Peripheral	Stair 1 (S1) Transverse	15	214.5	0	57.9	1.03	6 - #4
Peripheral	Stair 1 (S1) Longitudinal	14.5	214.5	0	56.0	1.00	5 - #4
Peripheral	Stair 2 (S2) Transverse	15	214.5	0	57.9	1.03	6 - #4
Peripheral	Stair 2 (S2) Longitudinal	19.5	214.5	0	74.3	1.32	7 - #4
Peripheral	Elevator Transverse	21	214.5	0	81.08	1.44	8 - #4
Peripheral	Elevator Longitudinal	16	214.5	0	61.8	1.10	6 - #4
Tie Type	Location	Length	w_F		F	$A_{s\ req'd}$	Reinfm't
		(ft)	(psf)		(kips/ft)	(sq in/ ft)	
Transverse	Distributed	37.5	214.5		24.13	0.429	#5 @ 8" O.C.[B]
Longitudinal	Distributed	37.5	214.5		24.13	0.429	#5 @ 8" O.C.[B]
Tie Type	Location	Area	w_F		F	$A_{s\ req'd}$	Reinfm't
		(sq ft)	(psf)		(kips)	(sq in)	
Vertical	A1	351.6	314.3		110.5	1.96	No Additional
Vertical	A2	703.2	264.4		185.9	3.31	No Additional
Vertical	B1	539.1	264.4		142.5	2.53	No Additional
Vertical	B4	1078.2	214.5		231.3	4.11	No Additional

[A] The over-strength factor is 1.25, for rebar, per ASCE 41 and Φ is 0.75, per Section 4-3 of this UFC.
[B] Replace #3 at 12" O.C slab reinforcement with #5 at 8" O.C.

Reinforcement already present from the baseline design may be used to satisfy the tie force requirements in Table D-1 provided it is not within or directly above flexural members. Splices, development lengths and connections of reinforcement must be per Section 3-1.6. Note that the required tie forces at each of the stairs are different. This difference is to account for the additional MEP opening located immediately adjacent to Stair 2. In the case of Stair 2 and the adjacent MEP opening, these openings are separated by a flexural member. Since tie reinforcement cannot be located directly above a flexural member unless it can be shown to meet Section 3-1 rotation requirements, these openings were combined for the purposes of tie force calculation and placement of opening peripheral ties. A similar concept was used for the elevator and adjacent MEP openings. Note the dimension extents shown in Figure D-2.

Also note that the reinforcement shown in Table D-1 for internal longitudinal and transverse ties is to replace the preliminary #3 bars at 12”. A diagram of tie layout for an exterior bay is shown in Figure D-3. The internal ties may be connected to peripheral ties as shown in Figure D-4. Note that only the portion of the internal tie steel needed for the baseline design (the #3 bars at 12”) must extend to the beam top steel; the remainder of the internal ties may be directly connected to the peripheral tie (i.e., the supplemental hook is not needed for the internal ties that are directly connected to the peripheral tie).

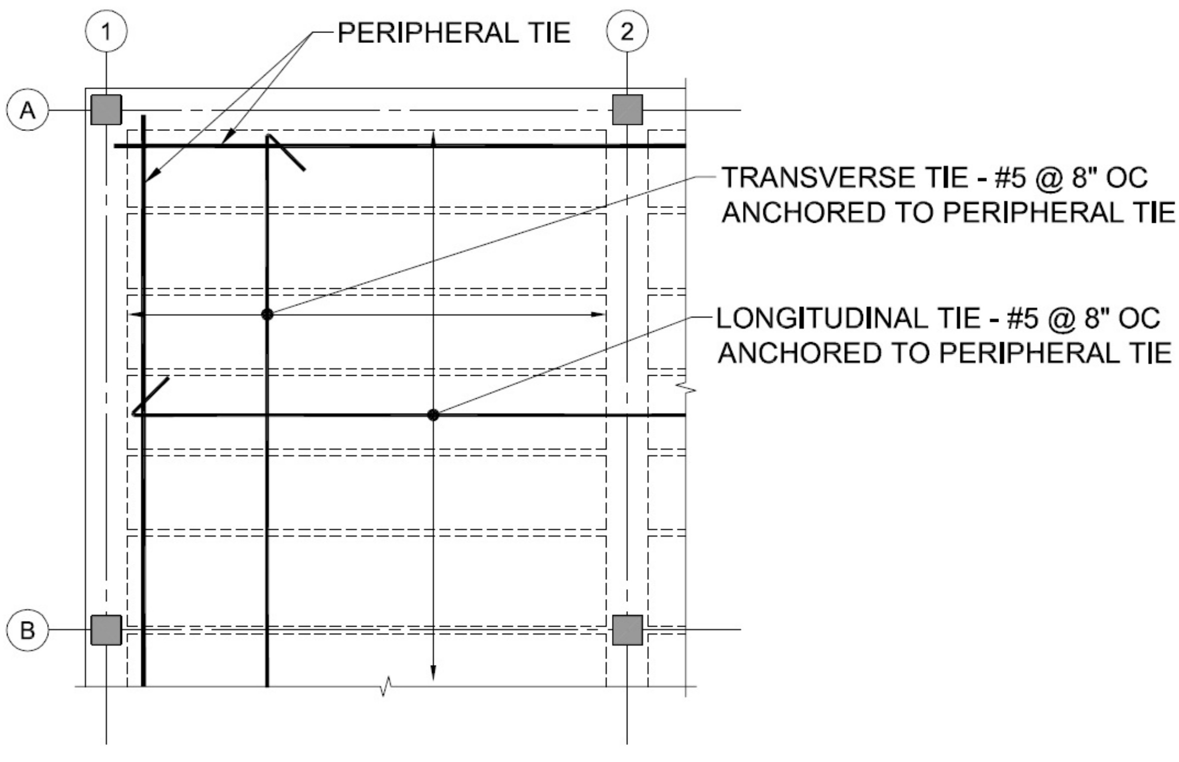


Figure D-3. Typical Layout of Internal Ties

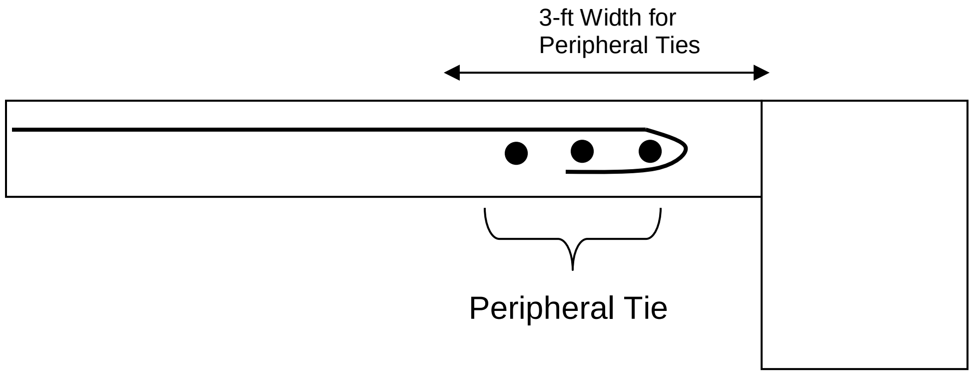


Figure D-4. Typical Anchorage of Internal Ties to Peripheral Ties

D-3.3 Enhanced Local Resistance.

ELR provisions for \3\ Risk Category /3/ II require that corner and penultimate perimeter columns at the first floor above grade achieve design shear strengths that exceed the shear demand associated with the flexural demands of the columns. For \3\ Risk Category /3/ II Option 1, the flexural demand is determined from the building design after it meets the TF requirements. For the purposes of ELR evaluation, the columns are considered fixed at the first level above grade due to continuity of the column above the first level and the rigid support provided by the floor diaphragm and pinned at the base. The flexural demand is based on the development of a three hinged mechanism in the column, with one hinge present as the pinned end of the column, a plastic hinge that develops at the fixed end at the first level above grade and a plastic hinge that develops within the column.

The required shear strength (i.e., the shear demand) can be found using methods in plastic structural design references or in Table 4-4 of PDC TR-06-01 *Methodology Manual for the Single-Degree-of-Freedom Blast Effects Design Spreadsheets (SBEDS)*. From PDC TR-06-01, the largest reaction/shear for a pinned-fixed, uniformly loaded beam is 5 r_u L/8, where r_u is the ultimate resistance and equal to 12 M_p/L^2. M_p is the plastic moment of the column cross-section and thus is the nominal flexural strength of the penultimate and corner columns, which incorporate vertical tie forces. Thus,

$V_u = 5\, r_u\, L/8$
$r_u = 12\, M_n/L^2$

and re-arranging yields

$$V_u = 7.5\, M_n / L \qquad \text{Equation (D-1)}$$

where V_u = Shear demand (maximum shear and reaction in the beam)
M_n = Nominal flexural strength, accounting for axial load

r_u = Ultimate resistance,
L = Column height

The corner column is considered in this example. The axial load on the corner column is based on the loads given in Section 3-2.2, bay sizes of 37.5-ft by 37.5-ft and the 7-story height.

P_{axial} = 7 [1.2D + 0.5L] 37.5-ft 37.5-ft/4
= 7 [1.2(89 + 35 + 10) + 0.5 (50 + 10 + 20)] 37.5-ft 37.5-ft/4
= 494-kip

With over-strength factors of 1.5 for concrete and 1.25 for steel (from ASCE 41), the concrete and steel strengths are 7500-psi and 75-ksi, respectively. For a 24-in x 24-in column with 8 #8s (3 each face) and an axial load of 494-kip, the interaction equation shows that M_n = 9,400-in-kip = 783-ft-kip.

V_u = 7.5 M_n/L = 7.5 (783-ft-kip)/16-ft
= 367-kip

The shear force carried by the concrete is

V_c = 2 (1 + N_u/2000A_g) $(f'_c)^{1/2}$ b_w d
= 2 [1 + 494,000-lb/2000(24-in x 24-in)] $(7500\text{-psi})^{1/2}$ 21.5-in 24-in
= 128-kip

The shear force carried by the steel is

$\Phi (V_n) = \Phi (V_c + V_s) \geq V_u$

V_s ≥ Vu/Φ - V_c
≥ 367-kip/1.0 – 128-kip
≥ 239-kip

Using s = 4 in, d = 21.5-in, fy = 75 ksi, the required area for shear steel is

V_s = A_v f_y d/s

A_v ≥ 0.59-in^2

Three #4 ties will work (0.2 in^2/tie) (3 ties) = 0.6 in^2

Note that Section 11.4.7.9 of ACI 318-11 states that "V_s shall not be taken greater than $8\,(f'_c)^{1/2}\,b_w\,d$".

$V_s = 8\,(f'_c)^{1/2}\,b_w\,d$
$= 8\,(5000)^{1/2}$ 21.5-in 24-in
= 291.8-kip > 239-kip. **OK**

/2/

D-3.4 Tie Force Evaluation Complete.

After provision of ties forces and additional stirrups as specified in D-3.2 and D-3.3, the tie force procedure is complete and the structure meets minimum requirements for progressive collapse resistance.

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APPENDIX E STRUCTURAL STEEL EXAMPLE

E-1 INTRODUCTION.

A typical steel frame health care facility design and analysis example has been prepared to illustrate alternate path calculations. The structure is assumed to be occupied by 50 or more resident patients; placing the structure in Risk category III per UFC 3-301-01. This RC requires the Alternate Path Method to be applied to select elements to demonstrate capacity to resist progressive collapse as specified in Section 2-2. The structure does not include underground parking. Enhanced local resistance for all perimeter first story columns will also be required for this building per Section 2-2.

The example was prepared using tools and techniques commonly applied by structural engineering firms in the US. Computer software that is typical of that used for structural design was employed for preliminary design and for the alternate path analysis. To illustrate the various options given in the UFC, the example is prepared using the linear static and nonlinear dynamic analysis procedures.

E-2 BASELINE PRELIMINARY DESIGN.

The structure is a four-story steel dual lateral system with a perimeter moment frame. The intended function of the building is health care, with occupancy of fifty or more resident patients. See Figures E-1 and E-2 for drawings of the building and the orientation of the members. The preliminary design, shown on the drawings below, has been sized to meet the requirements of IBC2006. In addition, the lateral drift of the frame has been evaluated for a performance limit of L/400 under a 10-year wind. Limited contribution of gravity framing due to partial restraint provided by simple connections was ignored for lateral load resistance (and stiffness).

E-2.1 Modeling Assumptions.

1) Members are represented by centerline elements (i.e. zero end offset to account for joint flexibility)
2) All moment connections are improved WUF.
3) Gravity framing connections are simple shear tabs, 3/8-in plate with 4 3/4-in A325N bolts and ¼” weld with a depth of bolt group = 9-in, assumed to be pinned except for secondary member checks when they are considered partially restrained (PR) moment connections
4) Column to foundation connections are considered pinned
5) Each floor was taken as a rigid diaphragm
6) Gravity framing was designed as composite sections
7) All steel shapes ASTM A992
8) Concrete 4000 psi NWC
9) Floor system: 3” composite steel deck + 4 ½” topping (total slab thickness = 7 ½”)
10) Roof system: metal deck only (no concrete fill)

E-2.2 Loading Assumptions.

Dead loads (D):
Self weight of members
Floor: 3 + 4½" normal weight composite slab with a weight of 75 psf + 3 psf allowance for deck
Roof: metal deck 5 psf (including secondary members not modeled)
Super imposed load (SDL):
15 psf for ceiling weight, and mechanical loads (including membrane/insulation at roof)
Cladding (CL):
15 psf x 14'- 8" → 220 plf on perimeter of the building
Live load:
Floor (LL): 80 psf + 20 psf allowance for partitions
Roof (Lr): 20 psf

Wind Load (W) was determined per IBC 2006 using 110 mph with exposure = B and importance factor = 1.15

Earthquake Load (E) is assumed not to control the design because the building is in a non-seismic region.

Other Loads: Snow Loads (S), Rain Loads (R) are assumed to not control the design.

E-2.3 Member Sizes.

Gravity floor design considers composite behavior and is identical for levels 2, 3 and 4. Roof gravity beams are non-composite with metal deck. Perimeter moment frames vary up the height of the building for drift control; see Figure E-1 for sizes.

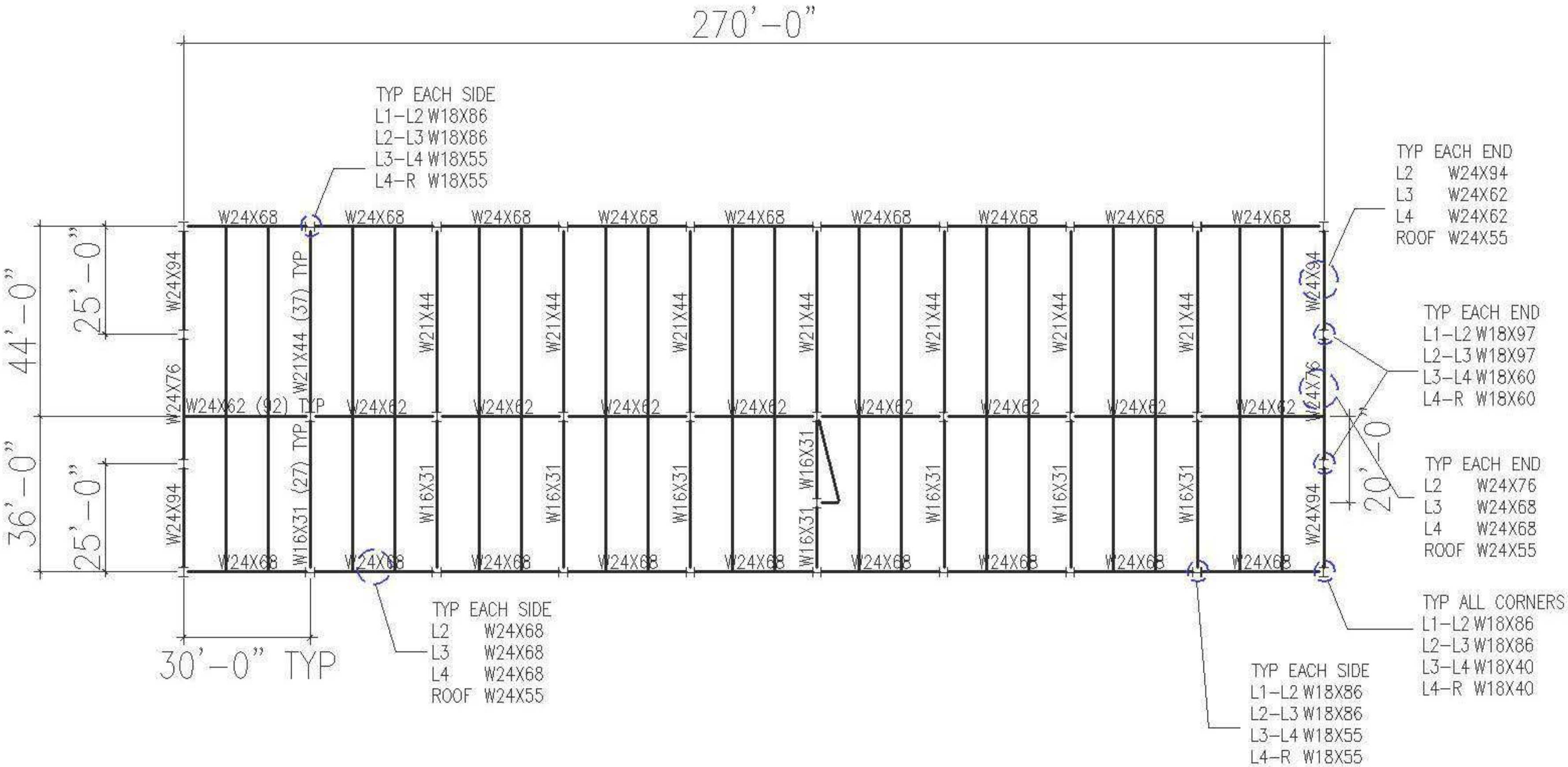


Figure E-1. Steel Building Plan

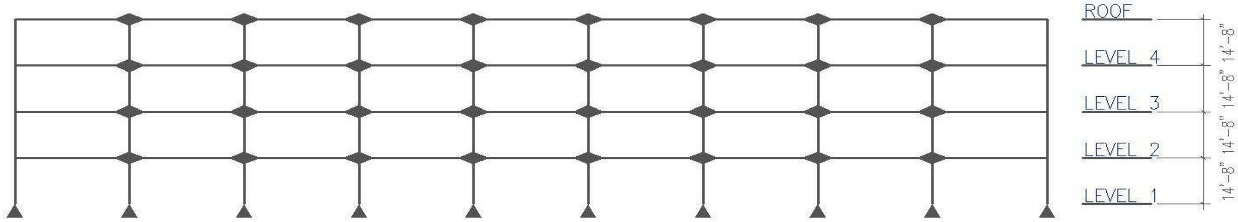


Figure E-2. Steel Building Elevation

E-3 LINEAR STATIC PROCEDURE.

Locations of required columns removals are illustrated in Figure E-3. Each removal is considered separately. For the purpose of this example, the column below level 2 is removed. Section 3-2 requires additional analyses for removals at other levels.

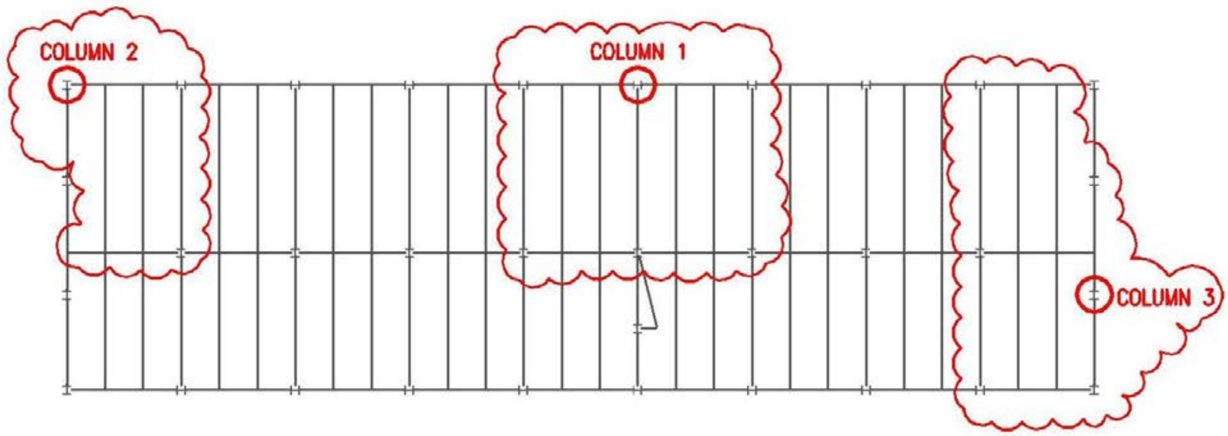


Figure E-3. Column Removal Locations

E-3.1 DCR and Irregularity Limitations.

The structure does not contain irregularities as defined by Section 3-2.11.1.1 and therefore DCR values are not limited for the use of the LSP.

E-3.2 Classification of Deformation Controlled and Force Controlled Actions.

Separate structural models are required to verify acceptability of components and actions which are deformation controlled and force controlled. Categorize these actions using the curves presented in Figure 3-7. A summary of classifications for this example is shown in Table E-1.

Table E-1. Deformation Controlled Column Calculations

Component	Deformation Controlled Action	Force Controlled Action
Moment Frames • Beams • Columns • Joints	 Moment (M) M, Axial Load (P)	 Shear (V) P, V V
Connections	M	V

E-3.3 Determination of m-Factors and Load Increase Factors.

Each component within the structure is assigned an **m** factor, or demand modifier which is determined from Table 5-1 and ASCE 41. Load increase factors (LIF) are applied to the area immediately affected by the removed column as required in Section 3-2.11. The LIF for the model to determine acceptability of force controlled actions is equal to 2. The LIF for the model to determine acceptability of deformation controlled actions is dependent on the lowest **m** factor for a component within the region of load increase. The **m** factors for each column removal location shown in Figure E-3 are summarized in Table E-2. The LIFs for deformation controlled actions based on these **m** factors are summarized in Table E-3.

Table E-2. Component m Factors for Primary Deformation Controlled Actions

Removed Column	Level	Beam/Girder	Beam/Girder **m** Factor	Simple Connection **m** Factor	Fixed Connection **m** Factor
1	2, 3, 4	W24x68	6.14	--	1.8
	2, 3, 4	W24x62	8	5.479	--
	2, 3	W24x146	8	--	1.79
	4	W24x117	6.52	--	1.79
	Roof	W24x55	8	--	1.8
	Roof	W24x62	8	5.479	--
	Roof	W24x76	8	5.479	1.8
2	2	W24x68	6.14	5.479	1.8
	2	W24x94	8	--	1.79
	2	W24x76	8	--	1.8
	2	W24x62	8	4.516	--
	2	W24x146	8	5.479	1.79
	3, 4	W24x68	6.14	5.479	1.8
	3, 4	W24x62	8	4.516	1.8
	3	W24x146	8	5.479	1.79
	4	W24x117	6.52	5.479	1.79
	Roof	W24x55	8	5.479	1.8
	Roof	W24x62	8	4.516	--
	Roof	W24x76	8	5.479	1.8
3	2	W24x68	6.14	5.479	1.8
	2	W24x94	8	--	1.79
	2	W24x76	8	--	1.8
	2	W24x62	8	4.516	--
	2	W24x146	8	5.479	1.79
	3, 4	W24x62	8	4.516	1.8
	3, 4	W24x68	6.14	5.479	1.8
	3	W24x146	8	5.479	1.79
	4	W24x117	6.52	5.479	1.79
	Roof	W24x55	8	5.479	1.8
	Roof	W24x62	8	5.479	--
	Roof	W24x76	8	5.479	1.8

Table E-3. Load Increase Factors

Removed Column	m_{LIF} (Smallest ***m-factor***)	Ω_{LD}, LIF for Deformation Controlled Actions	Ω_{LF}, LIF for Force Controlled Actions
1	1.8	2.72	2
2	1.79	2.71	2
3	1.79	2.71	2

E-3.4 Alternate Path Analysis.

The software used for this example was SAP 2000NL. The details of this example can be generally applied in any structural software capable of nonlinear static analysis. The “Staged Construction” option in SAP was used to ensure proper redistribution of loads upon member removal. Comparable software should also have the capability of load redistribution, or loads must be redistributed manually.

E-3.4.1 Develop Preliminary Model.

See Figure E-4 for a model developed in SAP2000. Gravity beams not on column lines are not modeled.

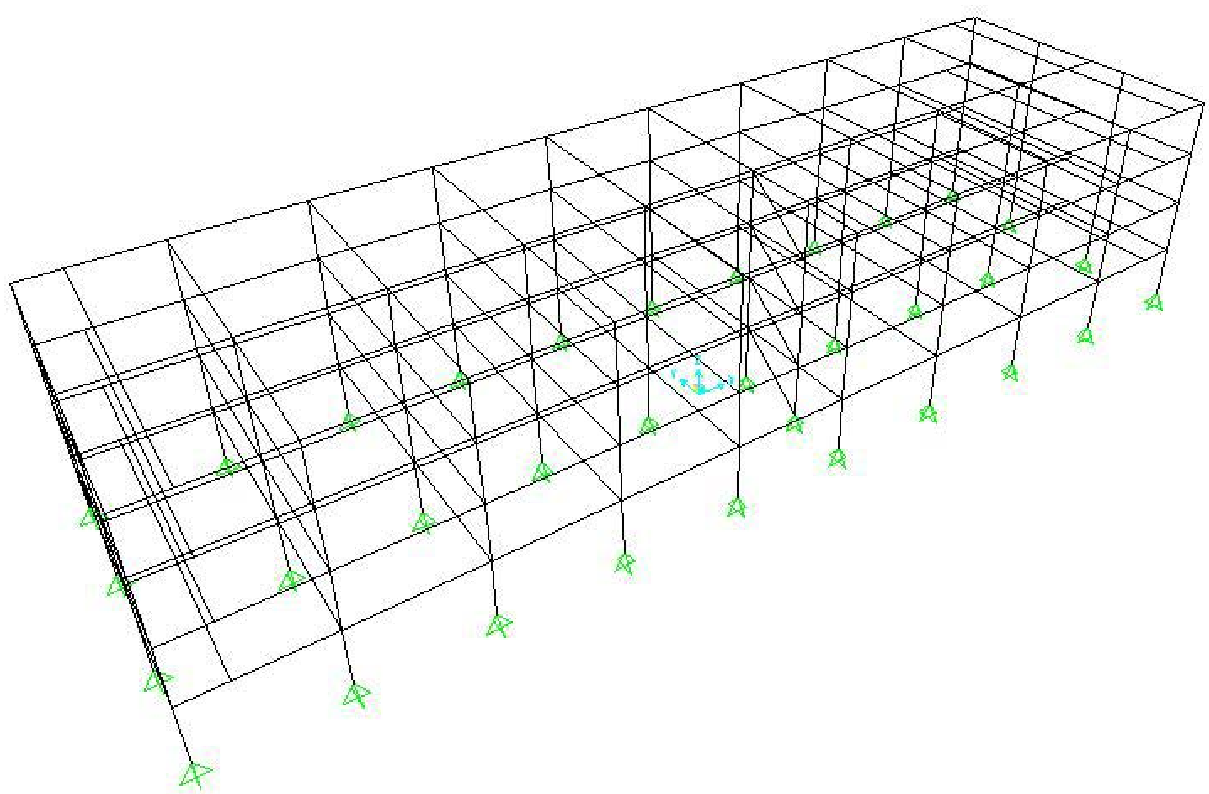


Figure E-4. Isometric View of SAP Model

E-3.4.2 Assign Groups.

Assign each column that is to be removed to a separate group. In this example, removal of three columns is demonstrated, each supporting the first elevated level. Columns are removed at three plan locations, one at a time.

E-3.4.3 Define Load Cases and Assign Loads.

Since increased loads are only applied over the location of the removed column, separate load cases are needed to assign the increased loading over each element to be removed. Separate models are needed to check force controlled actions and deformation controlled actions because of different LIFs.

E-3.4.4 Define Analysis Cases.

The "Staged Construction" option in SAP allows for the creation of separate analysis cases to automate the removal of columns. Create analysis cases which capture the stiffness for column removal. To do this, click Staged Construction button. In stage 1 add ALL, in stage 2 remove the column under investigation. Using these staged construction analysis cases as the initial stiffness, add a new analysis case for each column being removed. Within these analysis cases, assign all loads to be used in this analysis case per the load combinations in Equation 3-10 and 3-11. Click Nonlinear parameters button and choose P-delta option. It is possible to use P-delta + large displacements, but it is not necessarily needed for this analysis. Figure E-5 shows a screenshot of the interface for definition of analysis cases and their assigned loads.

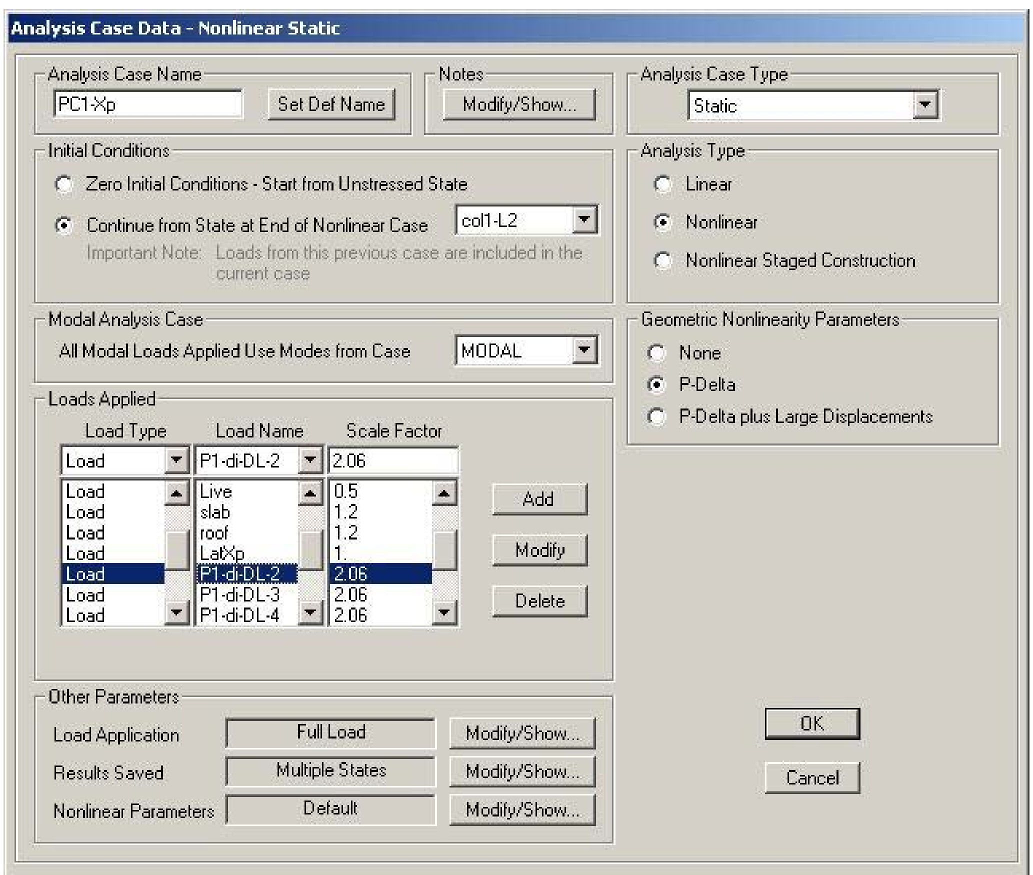


Figure E-5. Analysis Case Definition

E-3.4.5 Define Design Combinations.

In order to use the SAP design procedures to evaluate acceptance criteria design combinations must be defined. Create a design combination for each analysis case (12 total design cases created in this example, additional cases would be required for column removal at other elevations).

E-3.4.6 Run Analysis.

It is important to check that both stages of every analysis case converge. If the analysis does not converge, there is a problem with the model and it must be fixed.

E-3.4.7 Run Design and Compare to Acceptance Criteria.

After each analysis case converges, perform the SAP design. The design details allow for the comparison of each components **m** factor to the ratio of $Q_{UD}/\Phi Q_{CE}$ and comparison of $Q_{UF}/\Phi Q_{CL}$ to unity. In this example, the deformation controlled moment acceptance at beam ends is governed by the **m** factor for the improved WUF moment connections. By reviewing the moment diagrams of the design combinations for the progressive collapse cases it was determined that the moment at beam ends is greater than at other locations along its length. Based on this information the moment ratio provided by SAP within the deformation controlled model for the defined design load combinations can be compared directly to the connection **m** factor of 1.80. The design details can also be used to review the beam shear demand ratio within the force controlled model. Figure E-6 shows SAP screen captures of the moment ratios from the deformation controlled model for the removal of column 1 prior to any member upgrades. Figure E-7 and Figure E-8 show similar screen captures for removal of columns 2 and 3 respectively. Also pictured are the interaction ratios of columns in the vicinity of the removed members. Column upgrades are discussed below.

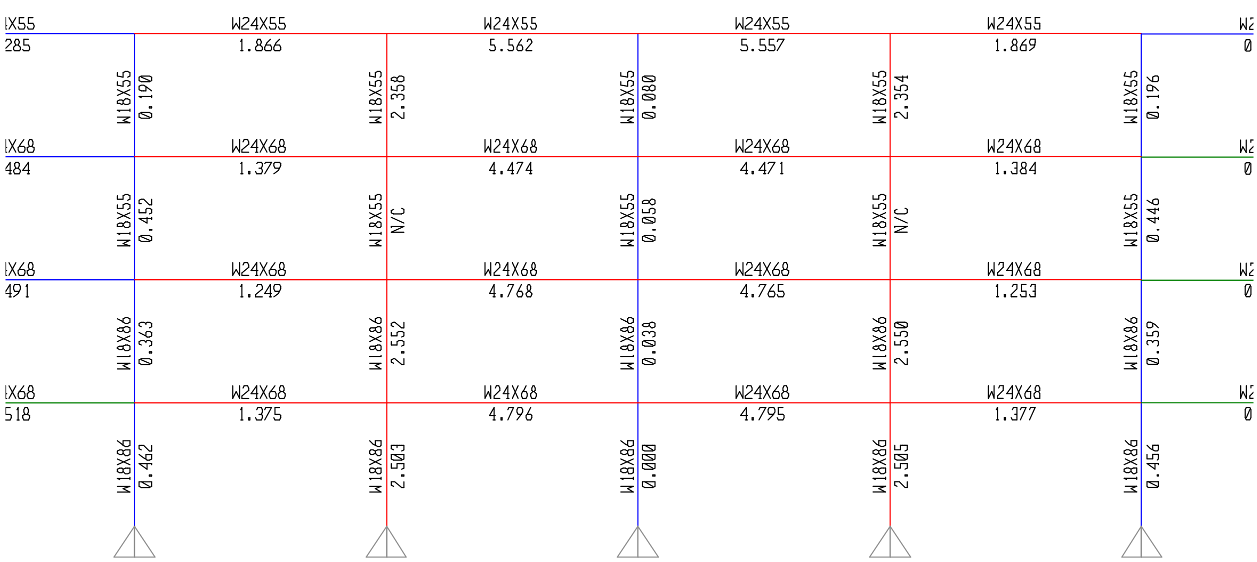


Figure E-6. Moment Ratios Due to Column 1 Removal with Original Design

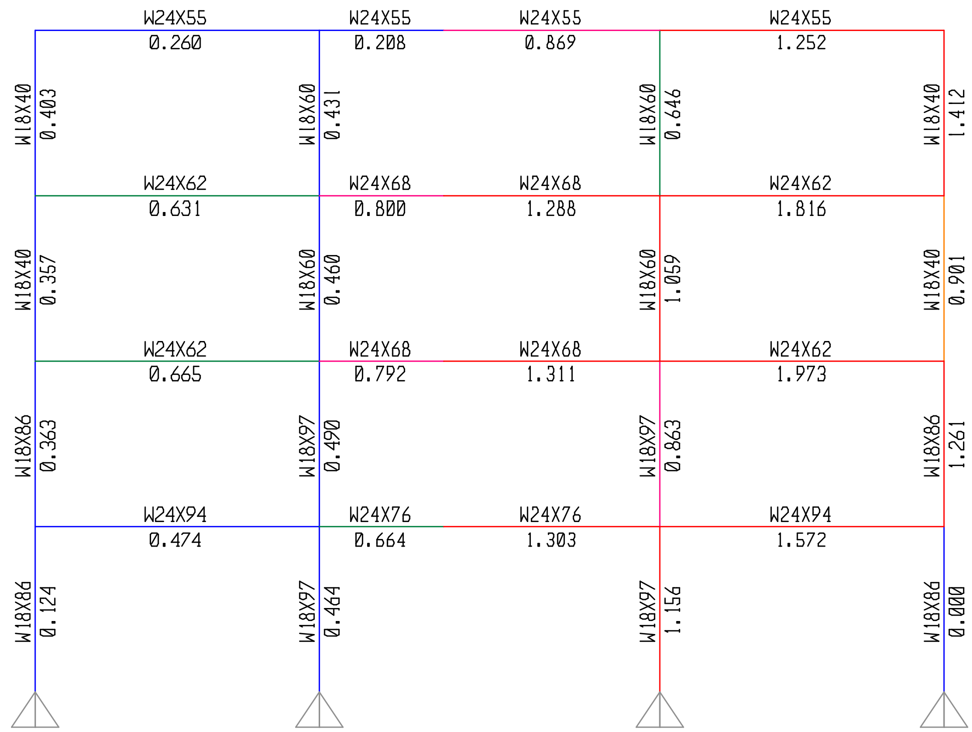


Figure E-7. Moment Ratios Due to Column 2 Removal with Original Design

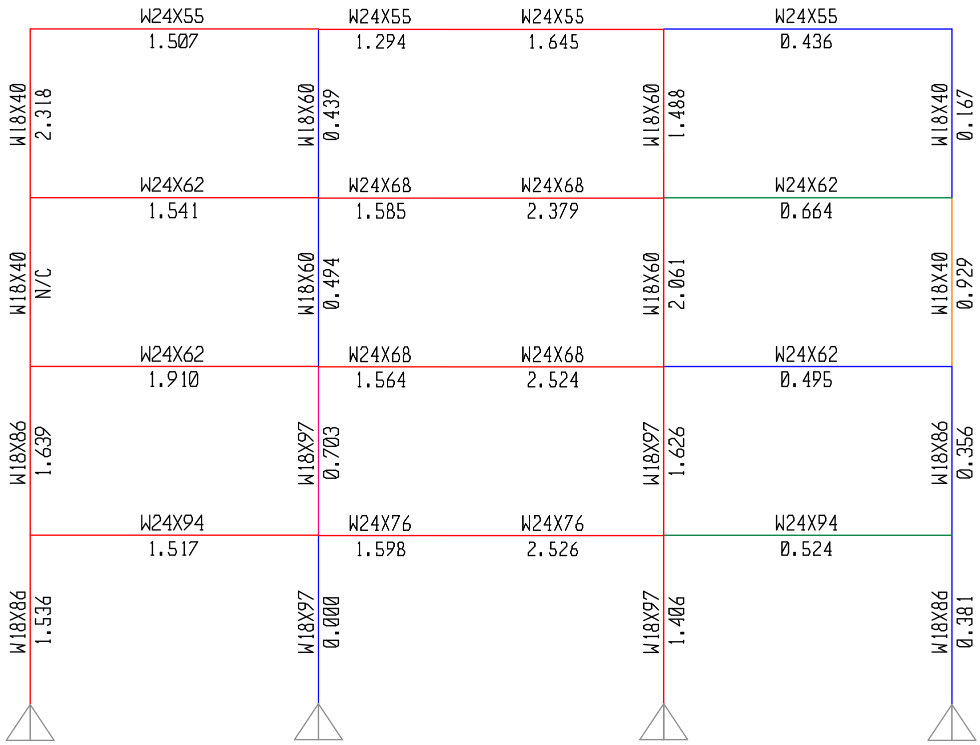


Figure E-8. Moment Ratios Due to Column 3 Removal with Original Design

Figures E-9 through E-11 show SAP screen captures of the moment ratios after member upgrade for the removal of columns 1 through 3 respectively.

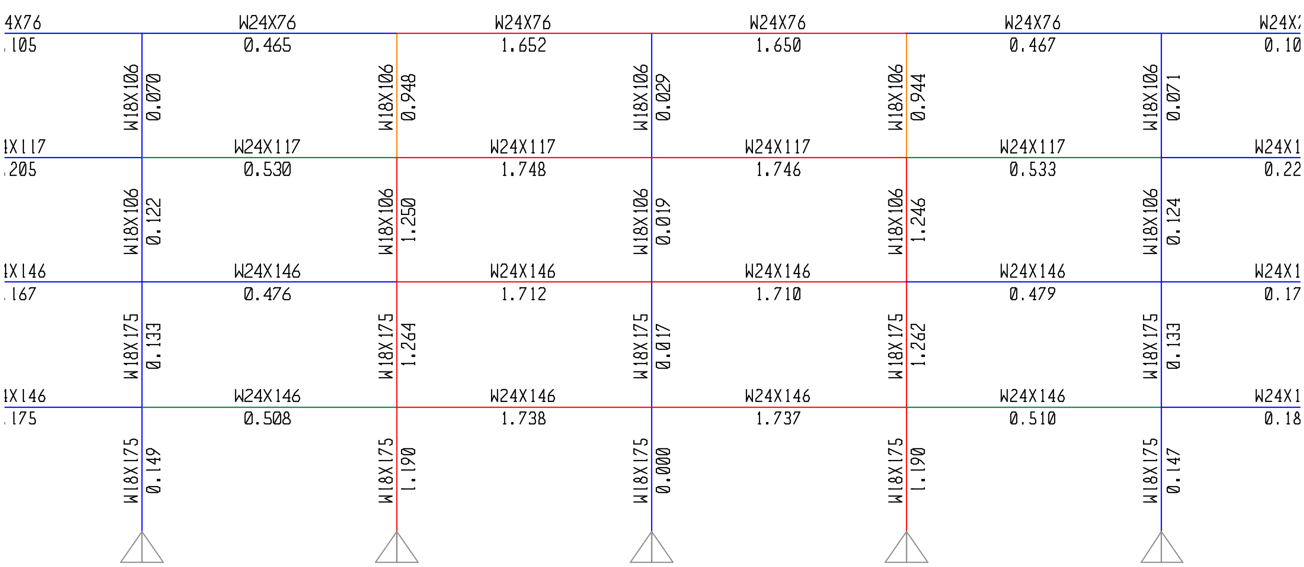


Figure E-9. Moment Ratios Due to Column 1 Removal with Redesign

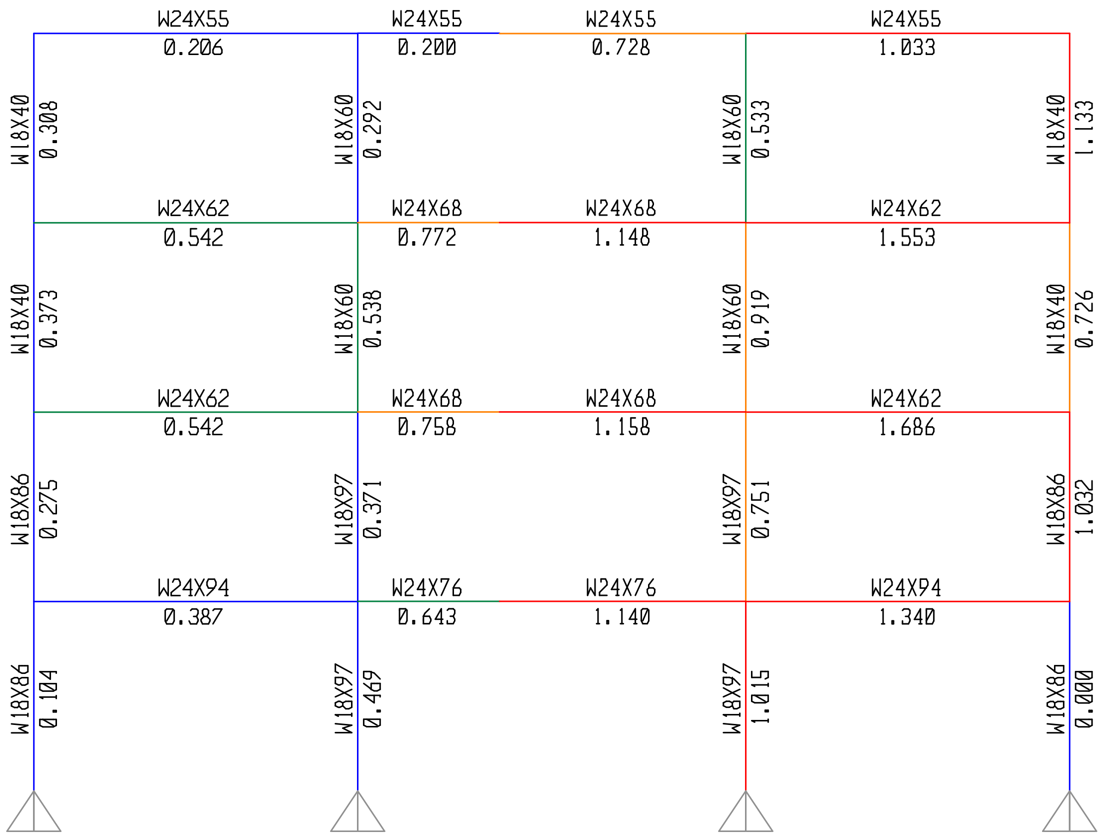


Figure E-10. Moment Ratios Due to Column 2 Removal with Redesign

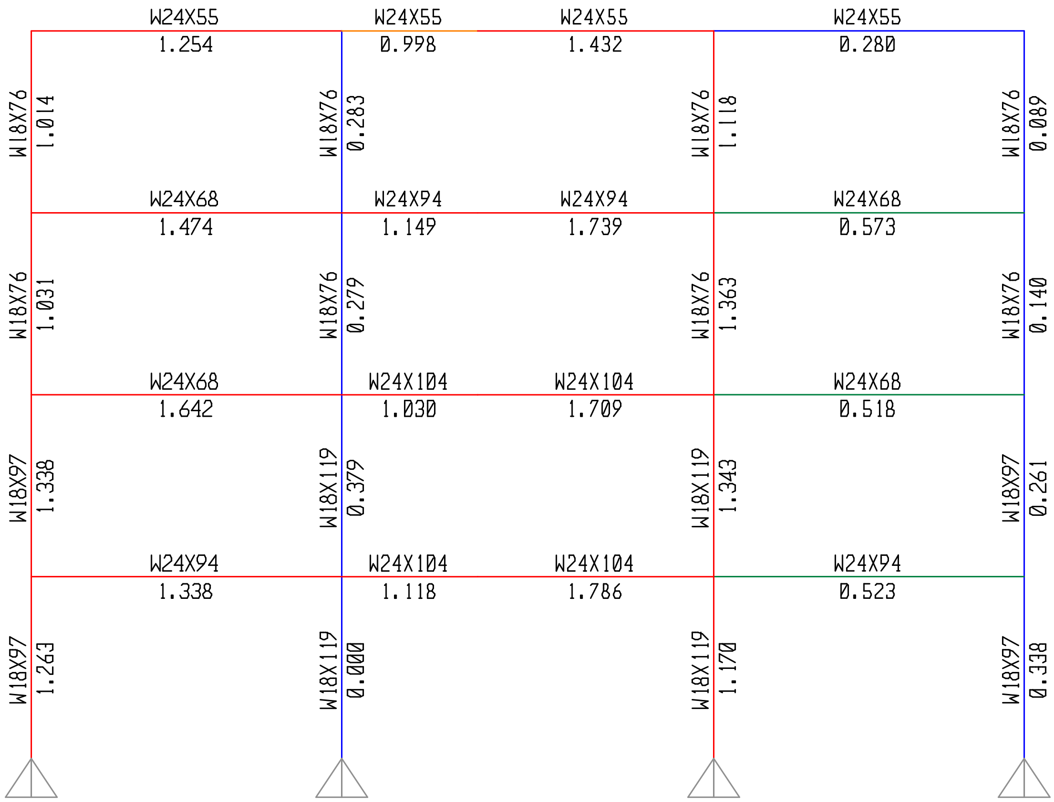


Figure E-11. Moment Ratios Due to Column 3 Removal with Redesign

To determine the acceptability of columns, the deformation-controlled model is reviewed to determine the level of axial load. In accordance with ASCE 41, any column with an axial load ratio of greater than or equal to 0.5 must be checked using the model for force controlled actions. These force controlled columns must have interaction values that do not exceed 1. Using the force controlled model, column sizes are increased to reduce interaction values less than unity or to reduce the axial demand in order to evaluate the column as deformation controlled.

Deformation controlled columns (axial load ratio less than 0.5) are checked using the acceptance criteria from ASCE 41. An example calculation for this verification of acceptance is shown in Table E-4.

Table E-4. Deformation Controlled Column Calculations

Removed Column	1
Column Size	W18x106
P/ΦPn	0.49
8/9 M/ΦMn	0.59
m = 9 (1-5/3 P/Pcl)	ASCE 41 Table 9-4
m = 9 (1-5/3 x 0.49 x 0.9)	2.385
Interaction = P/ΦPn + (8/9 M/ΦMn)/m	0.49 + 0.59/2.385 =0.73 **OK**

E-3.4.8 Secondary Component Checks.

\2\After verifying that all primary members satisfy the force- and deformation-controlled acceptance criteria, the secondary members must also be checked. The following calculations present the checks for the gravity beam and the interior connection of the gravity beam at removal location 1, where the closest secondary beam to the loss location is a W21x44 that spans 44-ft.

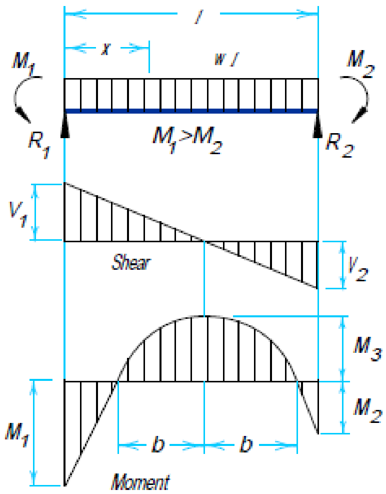
Acceptance checks of gravity beams in steel frame structures present a unique challenge within the framework of linear static analysis. Typically, gravity beams and simple shear tab connections are considered secondary members and not included in the linear static model. However, these members may fail if subjected to large dynamic loads and/or significant deflections due to column removal and may pose a hazard to occupants or lead to additional structural failure if they detach and impact the floor below. While force- and deformation-controlled actions can be checked in a straight-forward manner with nonlinear procedures, the linear static procedure and criteria are based on m-factors applied to the moments and other deformation-controlled actions and thus moments must be determined to perform the checks, even at the ends of gravity beams which are often considered to be pinned. While allowable plastic rotations are available for nonlinear static and nonlinear dynamic procedures, they cannot be used for checks in the linear static method, as the analysis procedures are different, in terms of load adjustment factors, explicit consideration of hinges, fidelity of the nonlinear models, etc. Thus, the linear static acceptance criteria must be based on moments, shears, and forces. As simple shear tab connections can be considered partially restrained (PR) connections, their flexural strength can be calculated with an approximate rotational stiffness and the overall rotations, for comparison to the flexural demand.

E-3.4-8.1 Deformation-Controlled Actions

For the gravity beam and the simple shear tab connection, the deformation controlled actions are the moments.

Gravity Beam

There are two contributions to the peak moment demand in the gravity beam. The first is due to the factored linear static load; while the gravity beam is not included in the linear static model, it will experience dynamic and nonlinear effects and the load must be increased accordingly. The second is the end moment created by the rotational stiffness of the simple shear tab connection and the displacements at the end of the beam, as determined from the linear static analysis for column removal at location 1, using the deformation-controlled load case. The combination of end moments and uniform load corresponds to the loading case shown in Figure E-12, which is taken from the AISC LRFD design manual.



$$R_1 = V_1 \quad \ldots\ldots\ldots\ldots \quad = \frac{wl}{2} + \frac{M_1 - M_2}{l}$$

$$R_2 = V_2 \quad \ldots\ldots\ldots\ldots \quad = \frac{wl}{2} - \frac{M_1 - M_2}{l}$$

$$V_x \quad \ldots\ldots\ldots\ldots\ldots \quad = w\left(\frac{l}{2} - x\right) + \frac{M_1 - M_2}{l}$$

$$M_3 \left(\text{at } x = \frac{l}{2} + \frac{M_1 - M_2}{wl}\right) \ldots = \frac{wl^2}{8} - \frac{M_1 + M_2}{2} + \frac{(M_1 - M_2)^2}{2wl^2}$$

$$M_x \quad \ldots\ldots\ldots\ldots\ldots \quad = \frac{wx}{2}(l - x) + \left(\frac{M_1 - M_2}{l}\right)x - M_1$$

$$b \quad \text{(to locate inflection points)} = \sqrt{\frac{l^2}{4} - \left(\frac{M_1 + M_2}{w}\right) + \left(\frac{M_1 - M_2}{wl}\right)^2}$$

$$\Delta_x = \frac{wx}{24EI}\left[x^3 - \left(2l + \frac{4M_1}{wl} - \frac{4M_2}{wl}\right)x^2 + \frac{12M_1}{w}x + l^2 - \frac{8M_1 l}{w} - \frac{4M_2 l}{w}\right]$$

Figure E-12. Shear and Moment in Simply Supported Beam with End Moments and Uniform Loading

The load w in Figure E-12 is the factored linear static load as calculated with Equation 3-10:

w $= G_{LD} = \Omega_{LD}$ [1.2 D + (0.5 L or 0.2 S)]

w $= G_{LD}$ = 2.7 [1.2 (SW + DL_{floor} + SDL) + 0.5 (LL_{floor})] = 4.5-kip/ft

where

Ω_{LD} = Load increase factor = 2.7 as discussed earlier for column removal location 1
SW = Self Weight = 44-lb/ft for W21/44
DL_{floor} = Dead Load of floor over tributary area of gravity beam = 78-psf * 10-ft
SDL = Superimposed Dead Load over tributary area = 15-psf * 10-ft
LL_{floor} = Live Load of floor over tributary area of gravity beam = 100-psf * 10-ft

The end moments in Figure E-12 are calculated from the rotations created by the relative displacement at the end of the beams, as calculated for the column removal at location 1 using the deformation-controlled load case. The rotation is calculated as:

θ = Δ/L = 4.09-in/528-in = 0.0077-rad

where

θ = Chord rotation
Δ = Relative displacement = 4.09-in
L = Beam length = 44-ft = 528-in

To determine the resulting end moments, the approximate stiffness for a partially restrained connection is calculated using Eq. 9-15 from ASCE 41:

K_o = M_{CE}/0.005

where

M_{CE} = Expected moment strength of the simple shear tab connection

The expected moment strength for the simple shear connection is based on the shear strength of the connection multiplied by the eccentricity of the bolt group, which is 3.5 inches in accordance with Figure 10-11 of the AISC Manual, 13th Edition. The shear strength from Table 10-9a of the AISC Manual is 63.6-k for 4 ¾-in A325N bolts. The expected moment strength and partially restrained connection stiffness are:

M_{CE} = 63.6-kip * 3.5-in = 22.6-in-kip
K_o = 222.6-in-kip/0.005 = 44.5 x 10^3-in-kip/rad

Thus, the end moment demands (M_1 and M_2 in Figure E-12) are

$M_1 = M_2 = K_o\,\theta$ = 44.5 x 10^3-in-kip/rad 0.0077-rad = 342.7.0-in-kip = 28.55-ft-kip

The maximum moment demand is found using the equation for M_3 in Figure E-12.

M_3 = $w\,L^2/8 – (M_1 + M_2)/2 + (M_1 – M_2)^2/2wL^2$
= 4.5-kip/ft [(44-ft) ^2]/ 8 - (28.55-ft-kip -28.55-ft-kip)/2 +
(28.55-ft-kip + 28.55-ft-kip)^2/ [2 (4.5-kip/ft) (44-ft)^2]
= 1089-ft-kip

This is the demand or Q_{UD} for the gravity beam. For a W21x44, the expected moment strength is

Q_{CE} = $\Omega\, F_y\, Z_x$ = 1.1*50-ksi*95.4-in^3 = 5247-in-kip = 437.3-ft-kip.

where

Ω = Overstrength factor = 1.1 from ASCE 41 Table 9-3
F_y = Yield strength = 50-ksi
Z_x = Plastic modulus, from AISC LRFD design manual = 95.4-in^3

Note that the unbraced length must be checked as part of the design.

Checking Equation 3-13 and with m = 12 for a secondary compact beam, per ASCE 41 Table 9.5,

$\Phi\ m\ Q_{CE} \geq Q_{UD}$
0.9 (12) (437.3-ft-kip) = 4723-ft-kip ≥ 1089-ft-kip **OK**

Simple Shear Tab Connection

A somewhat similar procedure is performed for the simple shear tab connection. In this case, there are two contributions to the moment demand at the connection. The first is the moment demand created by the shear reaction from the factored linear static load, multiplied by the eccentricity of 3.5-in. In this case, the factored linear static load is used to calculate the shear reaction and moment demand:

w = G_{LD} = 2.7 [1.2 (SW + DL_{floor} + SDL) + 0.5 (LL_{floor})] = 4.5-kip/ft
V = 0.5 w L + (M_1 - M_2)/L = 0.5 (4.5-kip/ft) 44-ft + (28.55-kip + 28.55-kip)/44-ft = 100.3-kip
M_{Dload} = V * 3.5-in = 351-in-kip

The second moment demand is generated by the relative displacements at the end of the gravity beam, as calculated from the linear static model for removal location 1 with the factored linear static load. The chord rotation is as before, θ = 0.0077-rad. The approximate stiffness for a partially restrained connection is calculated with Equation 9-15 of ASCE 41, or K_o = 44.5 x 10^3-in-kip/rad. This moment demand is

M_{Ddispl} = $K_o\ \theta$ = 44.5 x 10^3-in-kip/rad 0.0077-rad = 342.7-in-kip

The total demand is

M_{UD} = M_{Dload} + M_{Ddispl} = 351-in-kip + 342.7-in-kip = 693.7-in-kip

The strength of the simple shear tab connection was calculated earlier and is based on the design shear load for the connection times the eccentricity of the bolt group or

M_{CE} = 63.6-kip * 3.5-in = 222.6-in-kip

For the simple shear tab connection, Table 5-1 in Chapter 5 shows that the m-factor for secondary members is.

m = $8.7 - 0.161 d_{bg} = 7.25$

where

d_{bg} = Depth of bolt group or 9-in with 4 ¾-in A325N bolts.

Checking Equation 3-13 and with m = 7.25 for a simple shear tab connection, per Table 5.1,

$\Phi\ m\ Q_{CE} \geq Q_{UD}$

0.9 (7.725) (222.6-in-kip) = 1613.9-in-kip ≥ 693.7-in-kip **<u>OK</u>**

E-3.4-8.2 Force-Controlled Actions

For the gravity beam and the simple shear tab connection, the force-controlled action is the shear.

Gravity Beam

There are two contributions to the peak shear demand in the gravity beam. The first is due to the factored force-controlled linear static load; while the gravity beam is not included in the linear static model, it will experience dynamic and nonlinear effects and the load must be increased accordingly. The second is the end shear due to the end moments created by the displacements at the end of the beam (as determined from the linear static model with the force-controlled load case) and the rotational stiffness of the simple shear tab connection. The combination of end moments and uniform load corresponds to the loading case shown in Figure E-12.

The load w in Figure E-12 is the factored linear static load as calculated with Equation 3-12.

w = $G_{LF} = \Omega_{LF}$ [1.2 D + (0.5 L or 0.2 S)]

w = G_{LF} = 2.0 [1.2 (SW + DL_{floor} + SDL) + 0.5 (LL_{floor})] = 3.34-kip/ft

The end moments in Figure E-12 are calculated from the rotations created by the relative displacement at the end of the beams, as calculated for the column removal at location 1 using the force-controlled load case; this displacement is 3.03-in. The rotation is calculated as:

θ = Δ/L = 3.03-in/528-in = 0.0057-rad

To determine the resulting end moments, the approximate stiffness for a partially restrained connection is used, as calculated earlier.

K_o = $M_{CE}/0.005 = 44.5 \times 10^3$-in-kip/rad

Thus, the end moment demands (M_1 and M_2 in Figure E-12) are

$M_1 = M_2 = K_o\ \theta$ = 44.5 x 10^3-in-kip/rad 0.0057-rad = 253.7-in-kip = 21.1-ft-kip

The maximum shear demand is found using the equation for V_1 in Figure E-12.

V_1 = w L/2 + (M_1 - M_2)/L
= 3.34-kip/ft [(44-ft)]/2 + (21.1-ft-kip + 21.1-ft-kip)/44-ft+
= 74.4-kip

This is the demand or V_{UF} for the gravity beam. For a W21x44, the lower bound shear strength is

V_{CL} = 0.6 t_w d F_y = 0.6 (0.35-in) (20.66-in) (50-ksi) = 216.9-kip

where
t_w = Web thickness for W21x44 = 0.35-in
d = Depth of W21x44 = 20.66-in
F_y = Yield stress = 50-ksi

Checking Equation 3-13,

$\Phi\ Q_{CL} \geq Q_{UF}$
0.9 (216.9-kip) = 195.2-kip ≥ 74.4-kip **OK**

Simple Shear Tab Connection

A similar procedure is performed for the simple shear tab connection. In this case, there are two contributions to the shear demand at the connection. The first is the shear demand created by the shear reaction from the factored linear static load. In this case, the factored linear static load is used to calculate the shear demand:

w = G_{LD} = 2.0 [1.2 (SW + DL_{floor} + SDL) + 0.5 (LL_{floor})] = 3.338-kip/ft
V_{Dload} = 0.5 w L + (M_1 - M_2)/L = 0.5 (3.338-kip/ft) 44-ft + (21.1-ft-kip + 21.1-ft-kip)/44-ft
= 74.4-kip

The second shear demand is generated by the moment created by relative displacements at the end of the gravity beam, as calculated from the linear static model for removal location 1 with the factored force-controlled linear static load. The chord rotation and stiffness are as before, θ = 0.0057-rad and K_o = 44.5 x 10^3-in-kip/rad. This moment demand is

$M_{Ddispl} = K_o\ \theta$ = 44.5 x 10^3-in-kip/rad 0.0057-rad = 253.7-in-kip

From statics for a beam subjected to two end moments, the shear demand due to displacement is

V_{Ddispl} = 2 M_{Ddispl}/L = 2 (253.7-in-kip)/528-in = 0.96-kip

The total demand is

V_{UF} = V_{DLoad} + V_{Ddispl} = 74.4-kip + 0.96-kip = 75.4-kip

The shear strength of the simple shear tab connection is taken from Table 10-9a of the AISC Manual.

V_{CL} = 63.6-kip

Checking Equation 3-13,

$\Phi\ Q_{CL} \geq Q_{UF}$
0.9 (63.6-kip) = 57.2-kip ≥ 75.4-kip **NG**

Thus, the shear strength of the simple shear tab connection must be increased. Since the original design strength of the connection is based on the typical design load combination (1.2D + 1.6L) and the demand is based on the smaller load combination (1.2D + 0.5L) multiplied by the LIF of 2.0, this is not unexpected. Therefore, the strength of the simple shear tab must be increased to 75.4-kips and the deformation-controlled action (the moment) for the connection must be re-checked. For this example, the deformation controlled action is acceptable, by inspection.

Note that the axial force in these beams and connections are not checked, due to the small displacements at the ends of the beams. Similarly, the concrete slab is not checked, based on the small rotations and engineering judgment.

E-3.5 Enhanced Local Resistance.

ELR provisions for \3\ Risk Category /3/ III require that all perimeter columns at the first floor above grade achieve design shear strengths that exceed the shear demand associated with the flexural demand of the columns. For \3\ Risk Category /3/ III, the flexural demand is determined from the building design after it meets the AP requirements. For the purposes of ELR evaluation, the columns are considered fixed at the first level above grade due to continuity of the column above the first level and the rigid support provided by the floor diaphragm and pinned at the base. The flexural demand is based on the development of a 3-hinge mechanism in the column, with one hinge present as the pinned end of the column, a plastic hinge that develops at the fixed end at the first level above grade and a plastic hinge that develops within the column.

The required shear strength (i.e., the shear demand) can be found in plastic structural design references or in Table 4-4 of PDC TR-06-01 *Methodology Manual for the Single-Degree-of-Freedom Blast Effects Design Spreadsheets (SBEDS)*. From PDC

TR-06-01, the largest reaction/shear for a pinned-fixed, uniformly loaded beam is 5 r_u L/8, where r_u is the ultimate resistance and equal to 12 M_p/L^2. M_p is the plastic moment of the column cross-section and thus is the nominal flexural strength of the perimeter columns, which have been sized to meet the AP requirements as well as standard design requirements. Thus,

V_u = 5 r_u L/8
r_u = 12 M_p/L^2

and

V_u = 7.5 M_p / L   Equation (E-1)

where
- V_u = Shear demand (required shear strength)
- M_p = Nominal flexural strength, accounting for axial load; also, the plastic moment
- r_u = Ultimate resistance,
- L = Column height

In this example, the design shear strength for all columns other than corner columns exceeds the shear demand so no member size increases were required beyond those determined using the alternate path procedure. For corner columns, there is no W18 section that can provide adequate design shear strength to meet the shear demand. To satisfy these provisions, web doubler plates were added. At these corner locations the axial load is less than 10% of the column capacity and was ignored.

The corner column is a W18x97 with a strong axis plastic modulus of 211 in^3 per Figure E-11. The shear demand is calculated with Equation E-1 and using an over-strength factor of 1.1 (per Section 3-3.1) is

V_u = 7.5 M_p / L = 7.5 * 1.1 * 50-ksi * 211-in^3 / 174-in = 495-kips

The design shear strength (per AISC Chapter G) is:

ΦV_n = 1.0 * 0.6 * t_w * h * F_y= 0.6 * 0.535-in * 18.6-in * 50-ksi = 298-kips

The required additional design shear strength is achieved by adding a doubler plate to the web of the W18x97. The thickness is found by subtracting the design shear strength (298-kips) from the shear demand (495-kips) and using this difference to size a 14-in high plate. A 1/2" thick doubler plate is required for all corner columns. See Figure E-13 for a diagram of the doubler plate used to enhance strong axis shear strength.

/2/

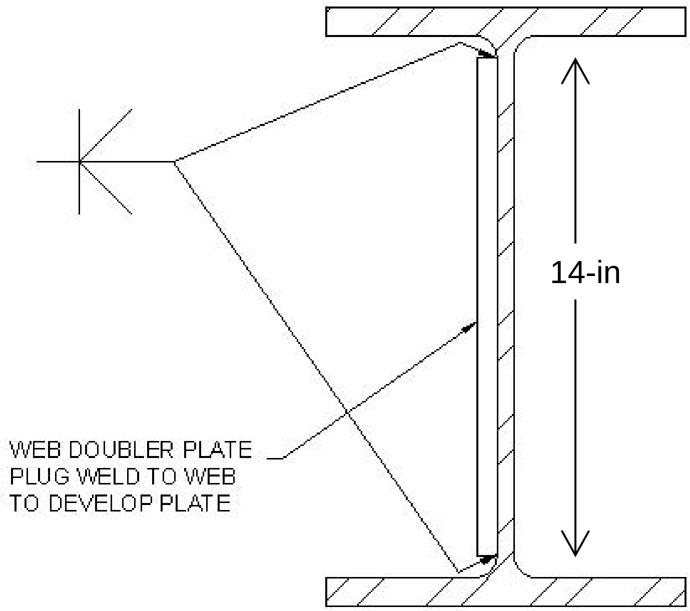


Figure E-13. Web Doubler Plate for ELR

E-3.6 Alternate Path Design Method Complete.

Once the model converges, all acceptance criteria have been met, and enhanced local resistance has been provided, the building has satisfied progressive collapse resistance requirements of this UFC.

E-4 NON LINEAR DYNAMIC PROCEDURE (NDP).

Locations of required columns removals are illustrated in Figure E-14. Each removal is considered separately. For the purpose of this example, the column below level 2 is removed, Section 3-2 requires additional analyses for removals at other levels.

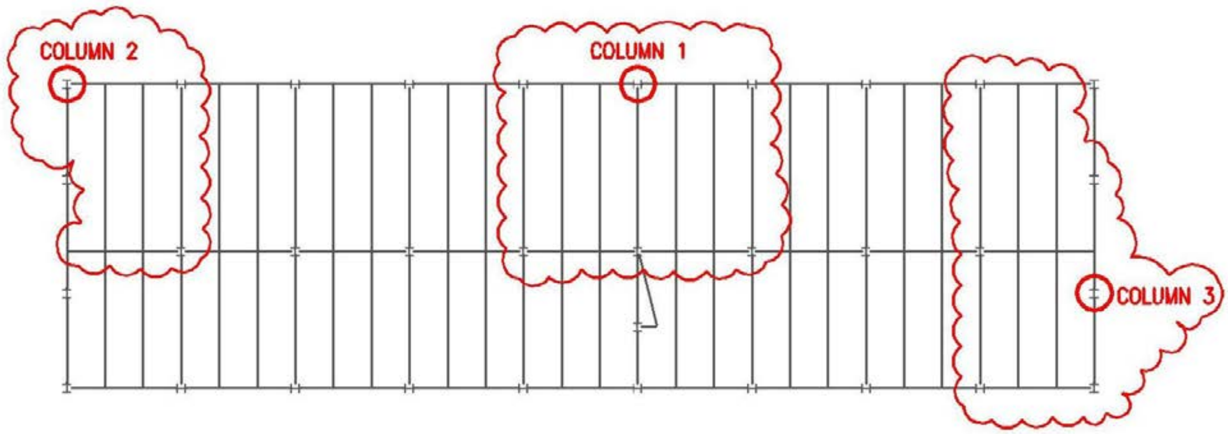


Figure E-14. Column Removal Locations

E-4.1 DCR and Irregularity Limitations.

There are no DCR or geometric irregularity limitations on the use of the NDP.

E-4.2 Alternate Path Analysis.

The software used and screen shots depicted for this example was SAP 2000NL. The details of this example can be generally applied in any structural software capable of nonlinear static analysis. The “Staged Construction” option in SAP was used to ensure proper redistribution of loads upon member removal. Comparable software should also have the capability of load redistribution, or loads must be redistributed manually.

E-4.2.1 Develop Preliminary Model.

See Figure E-15 for a model developed in SAP2000. All beams and columns are modeled including gravity beams.

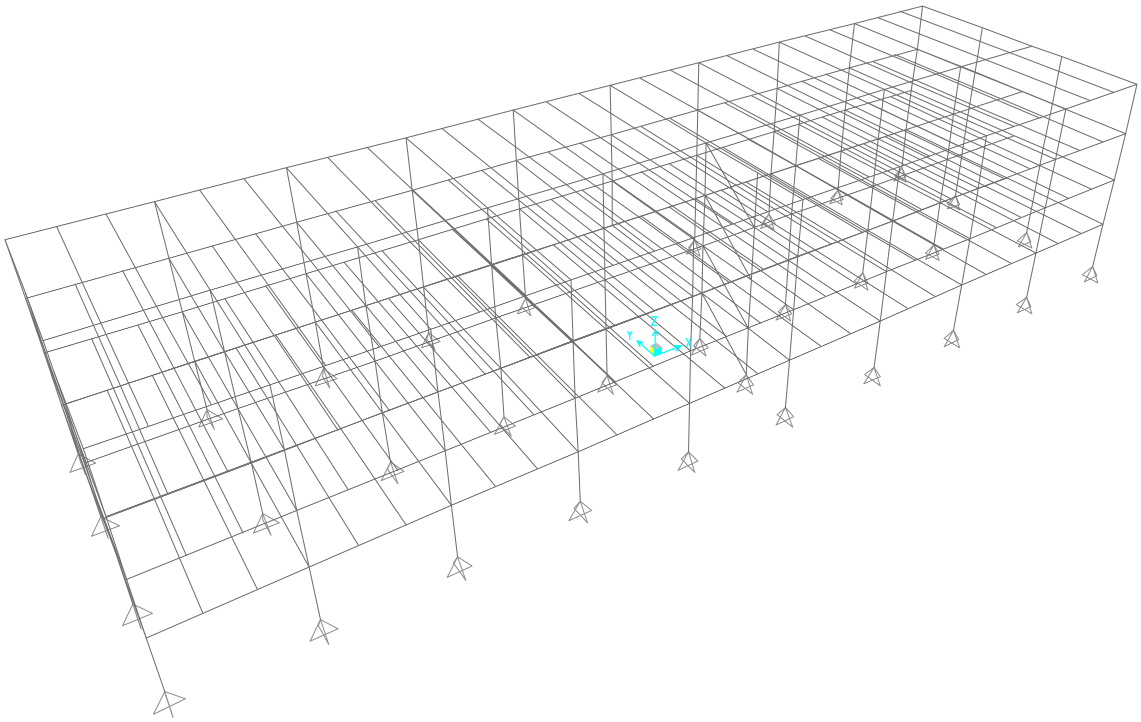


Figure E-15. Isometric View of SAP Model

E-4.2.2 Define Load Cases and Assign Loads.

The dynamic nature of this procedure does not require an increase factor to account for dynamic effects. No additional load cases are needed to account for dynamic load increase. For this reason, a single model may be used to verify acceptance of force controlled actions and deformation controlled actions.

E-4.2.3 Define Analysis Cases.

The nonlinear dynamic procedure requires one analysis case for each column removal. Analysis cases are created to determine the forces present at equilibrium in each column to be removed. For each column removal, the column member is deleted in the structural model and the internal forces determined from the equilibrium model are applied to the structure as a load case to the joint or joints at each column end. These static nonlinear analysis cases are used as the starting conditions for the column removals.

Within these analysis cases, assign all loads to be used in this analysis case per the load combination in Equation 3-18. Click Nonlinear parameters button and choose P-delta option. It is possible to use P-delta + large displacements, but it is not necessarily needed for this analysis. Figure E-16 shows a screenshot of the interface for definition of analysis cases and their assigned loads.

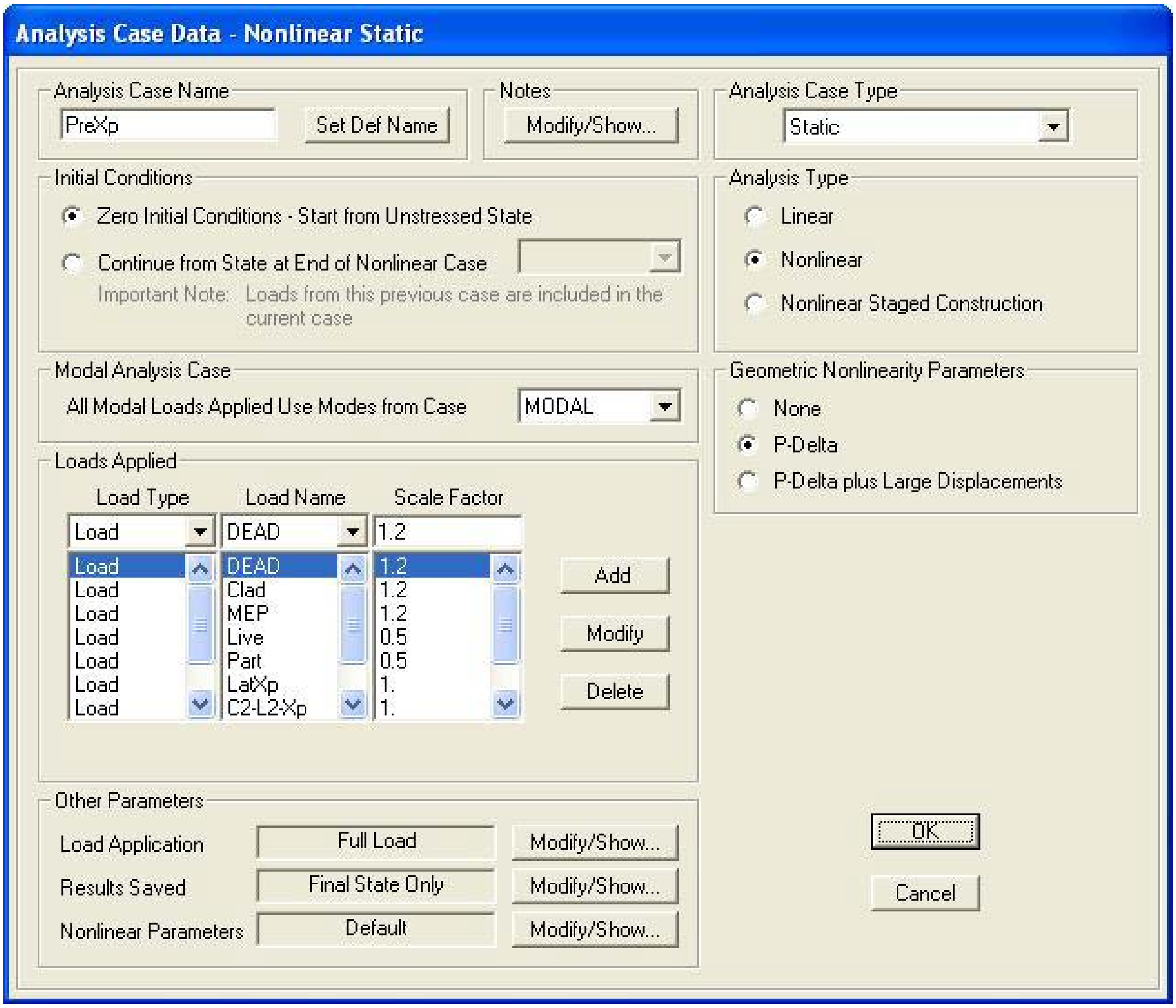


Figure E-16. Analysis Case Definition

After equilibrium is reached for the structure, remove the column by ramping down the column forces under a duration for removal of less than one tenth of the period associated with the structural response mode for the element removal. The analysis shall continue until the maximum displacement is reached or one cycle of vertical motion occurs at the column or wall section removal location. Figure E-17 shows a screen shot of the column removal analysis case definition.

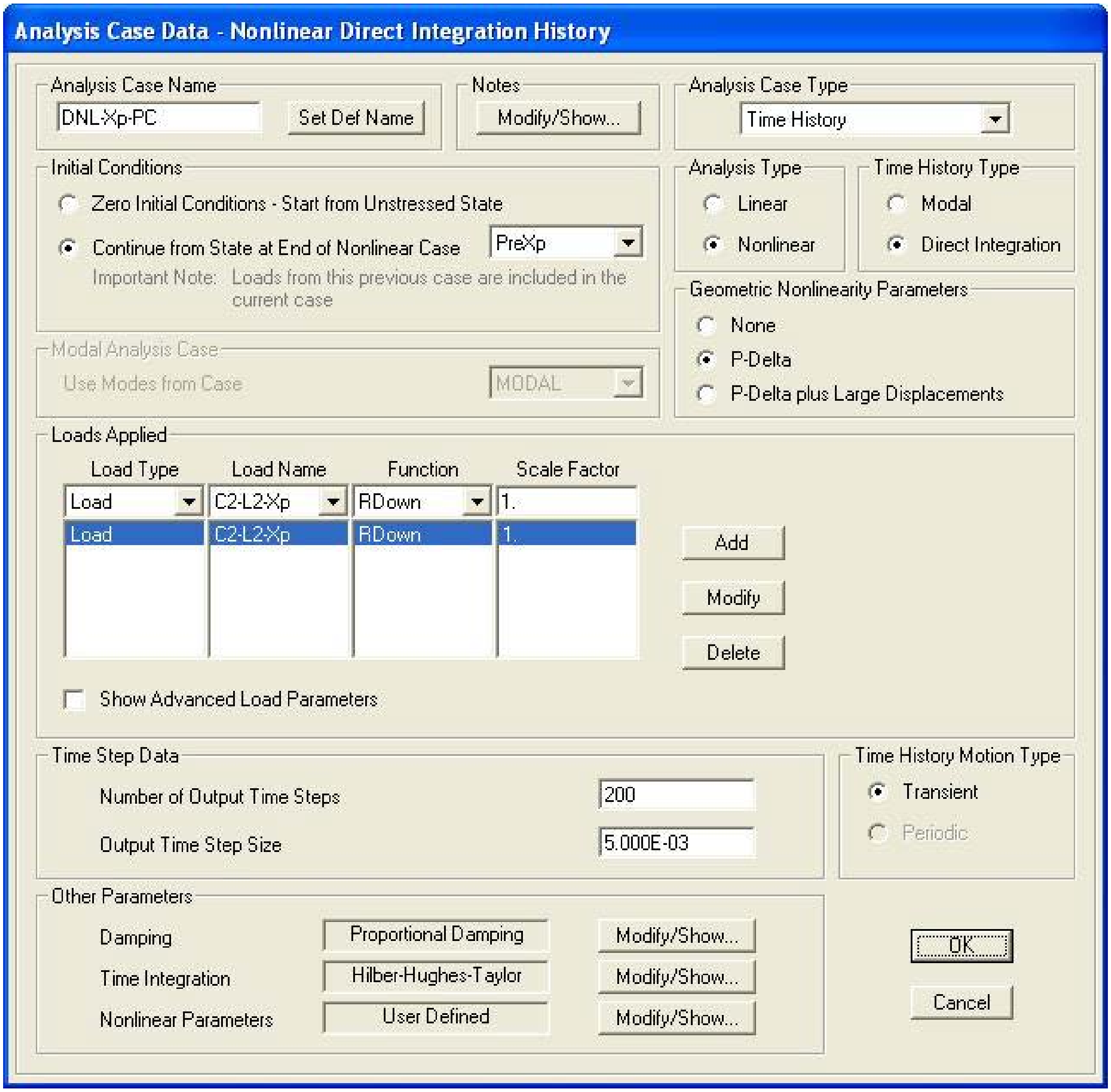


Figure E-17. Analysis Case Definition

E-4.2.4 Define Design Combinations.

SAP design procedures may be used to evaluate whether columns are deformation or force controlled. Design checks also aid in the definitions of column hinges by determining axial load demand and capacity. Create a design combination for each analysis case (12 total design cases created in this example, additional cases would be required for column removal at other elevations).

E-4.2.5 Run Dynamic Analysis.

It is important to check that both stages of every analysis case converge. If the analysis does not converge, there is a problem with the model and it must be fixed. The problem could be numerical with assumptions made in SAP, but the most likely reason is that the model has a plastic hinge that failed or a mechanism has formed. At this point, the model cannot support the load.

E-4.2.6 Plastic Hinges.

For the nonlinear alternate load path method, plastic hinges are allowed to form along the members. These hinges are based on maximum moment values calculated using phi factors and over-strength factors per the UFC. However, only flexural moments can cause a plastic hinge to form in beam members, and only the axial-moment interaction (PMM) can cause a plastic hinge to form in a column. Any shear or torsion values that would cause a hinge to form would result in an immediate failure.

E-4.2.7 Hinge Locations.

Theoretically hinges can occur anywhere along the beam. However, hinges are allowed to occur at the ends of each member and at the midspan of the flexural members. This simplifies the model by placing hinges in the most probable locations.

E-4.2.8 Hinge Properties.

Nonlinear acceptance criteria and component definitions are from Chapter 9 of ASCE 41 for the Life Safety condition for primary and secondary components. Use the modeling parameters and guidance, including definitions of stiffness, to create the analytical model. For beams subjected to flexure or flexure plus axial tension, use the Collapse Prevention values for primary and secondary elements. For the Fully Restrained (FR) and Partially Restrained (PR) connections listed in Tables 5-1 and 5-2 in this UFC, use the specified plastic rotations and modeling parameters as given. Figure E-18 shows the form of the plastic hinges for this model.

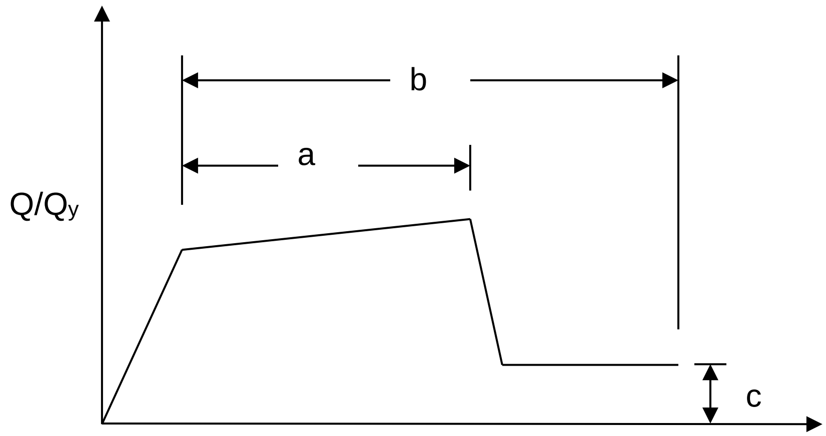


Figure E-18. Generalized Force-Deformation Hinge Definition

Beam and connection hinge properties are determined using ASCE 41 Table 9-6 and UFC Table 5-2. A summary of hinge properties and acceptance criteria for beams and connections corresponding to Figure E-18 are shown in Tables E-5, E-6 and E-7. When defining connection and beam hinges, be certain to include applicable strength reduction factors per AISC as required by this UFC.

Table E-5. Beam Hinge Properties

Beam	Plastic Rotation Angle		Residual Strength Ratio	Acceptance Criteria	
	a	b	c	Primary	Secondary
W24x55	$9\theta_y$	$11\theta_y$	0.6	$8\theta_y$	$11\theta_y$
W24x62	$9\theta_y$	$11\theta_y$	0.6	$8\theta_y$	$11\theta_y$
W24x76	$9\theta_y$	$11\theta_y$	0.6	$8\theta_y$	$11\theta_y$
W24x84	$9\theta_y$	$11\theta_y$	0.6	$8\theta_y$	$11\theta_y$
W24x94	$9\theta_y$	$11\theta_y$	0.6	$8\theta_y$	$11\theta_y$
W24x131	$9\theta_y$	$11\theta_y$	0.6	$8\theta_y$	$11\theta_y$
W24x68	$7.15\theta_y$	$9.15\theta_y$	0.452	$6.15\theta_y$	$8.41\theta_y$
W24x104	$4.76\theta_y$	$6.76\theta_y$	0.260	$3.76\theta_y$	$5.06\theta_y$
W24x117	$7.52\theta_y$	$9.52\theta_y$	0.482	$6.52\theta_y$	$8.93\theta_y$

Table E-6. Fully Restrained Connection Hinge Properties

Beam	Depth	Plastic Rotation Angle		Residual Strength Ratio	Acceptance Criteria
		a	b	c	Primary
	(in)	(rad)	(rad)		(rad)
		(0.021-0.0003D)	(0.05-0.0006D)		(0.021-0.0003D)
W24x55	23.6	0.01392	0.03584	0.2	0.01392
W24x62	23.7	0.01389	0.03578	0.2	0.01389
W24x68	23.7	0.01389	0.03578	0.2	0.01389
W24x76	23.9	0.01383	0.03566	0.2	0.01383
W24x84	24.1	0.01377	0.03554	0.2	0.01377
W24x94	24.3	0.01371	0.03542	0.2	0.01371
W24x104	24.1	0.01377	0.03554	0.2	0.01377
W24x117	24.3	0.01371	0.03542	0.2	0.01371
W24x131	24.5	0.01365	0.03530	0.2	0.01365

Table E-7. Shear Tab Partially Restrained Connection Hinge Properties

Beam	D_{bg}	V_{max}	$M_{capacity}$	Plastic Rotation Angle		Residual Strength Ratio	Acceptance Criteria	
				a	b	c	Primary	Secondary
	(in)	(kips)	(kip-in)	(rad)	(rad)		(rad)	(rad)
				(0.0502-0.0015D)	(0.072-0.0022D)		(0.0502-0.0015D)	(0.0503-0.0011D)
W16x31	6	56	168	0.0412	0.0588	0.2	0.0412	0.0437
W16x31 (R)	3	32	96	0.0457	0.0654	0.2	0.0457	0.0470
W21x44	6	67	201	0.0412	0.0588	0.2	0.0412	0.0437
W21x44 (R)	3	32	96	0.0457	0.0654	0.2	0.0457	0.0470
W24x55 (R)	3	32	96	0.0457	0.0654	0.2	0.0457	0.0470
W24x62	12	126	378	0.0322	0.0456	0.2	0.0322	0.0371
W24x62 (R)	3	32	96	0.0457	0.0654	0.2	0.0457	0.0470
W24x68	3	55	165	0.0457	0.0654	0.2	0.0457	0.0470
W24x84	3	32	96	0.0457	0.0654	0.2	0.0457	0.0470
W24x94	3	55	165	0.0457	0.0654	0.2	0.0457	0.0470
W24x104	3	55	165	0.0457	0.0654	0.2	0.0457	0.0470

Column hinge properties are determined using ASCE 41 Table 9-6. These hinge definitions are dependent on the level of axial load present in the member. Because the hinge properties are based on the level of force present, they must be updated when the force level changes significantly. The initial model run was used for preliminary definitions of column hinges. A summary of hinge properties and acceptance criteria for columns used in this example corresponding to Figure E-18 are shown in Tables E-8, E-9 and E-10.

Table E-8. Column Hinge Properties for Removal of Column 1

Column	P/Pcl	Plastic Rotation Angle		Residual Strength Ratio	Acceptance Criteria
		A	b	c	Primary
		(rad)	(rad)		(rad)
W18x40	0.12	0.0504	0.0623	0.557	0.0332
W18x40	0.42	0.0118	0.0189	0.2	0.0159
W18x76	0.09	0.0425	0.0554	0.406	0.0262
W18x76	0.12	0.0352	0.0471	0.349	0.0209
W18x76	0.19	0.0323	0.0433	0.349	0.0192
W18x76	0.21	0.0278	0.0423	0.2	0.0121
W18x76	0.38	0.0169	0.0257	0.2	0.0059
W18x86	0.17	0.0474	0.0586	0.557	0.0312
W18x106	0.24	0.0331	0.0511	0.2	0.0241
W18x106	0.27	0.0296	0.0458	0.2	0.0216
W18x106	0.35	0.0197	0.0305	0.2	0.0144
W18x106	0.39	0.0158	0.0244	0.2	0.0115

Table E-9. Column Hinge Properties for Removal of Column 2

Column	P/Pcl	Plastic Rotation Angle		Residual Strength Ratio	Acceptance Criteria
		A	b	c	Primary
		(rad)	(rad)		(rad)
W18x50	0.05	0.0530	0.0664	0.512	0.0470
W18x50	0.15	0.0471	0.0591	0.512	0.0418
W18x50	0.19	0.0451	0.0565	0.512	0.0400
W18x60	0.06	0.0590	0.0721	0.6	0.0393
W18x60	0.13	0.0545	0.0667	0.6	0.0364
W18x60	0.27	0.0252	0.0384	0.2	0.0117
W18x60	0.40	0.0160	0.0244	0.2	0.0063
W18x76	0.04	0.0384	0.0515	0.349	0.0229
W18x76	0.06	0.0376	0.0504	0.349	0.0224
W18x76	0.19	0.0323	0.0433	0.349	0.0192
W18x76	0.27	0.0236	0.0359	0.2	0.0097
W18x86	0.09	0.0521	0.0644	0.557	0.0343
W18x86	0.11	0.0509	0.0629	0.557	0.0335
W18x86	0.13	0.0500	0.0618	0.557	0.0329
W18x97	0.17	0.0499	0.0610	0.6	0.0333
W18x97	0.23	0.0345	0.0533	0.2	0.0251
W18x97	0.25	0.0322	0.0498	0.2	0.0234
W18x97	0.37	0.0182	0.0281	0.2	0.0132
W18x106	0.24	0.0333	0.0514	0.2	0.0242
W18x106	0.34	0.0208	0.0321	0.2	0.0151
W18x106	0.35	0.0198	0.0305	0.2	0.0144
W18x106	0.49	0.0067	0.0104	0.2	0.0049

Table E-10. Column Hinge Properties for Removal of Column 3

Column	P/Pcl	Plastic Rotation Angle		Residual Strength Ratio	Acceptance Criteria
		a	b	c	Primary
		(rad)	(rad)		(rad)
W18x50	0.05	0.0530	0.0664	0.512	0.0470
W18x50	0.14	0.0477	0.0598	0.512	0.0423
W18x50	0.19	0.0451	0.0566	0.512	0.0400
W18x50	0.41	0.0157	0.0239	0.2	0.0060
W18x60	0.06	0.0590	0.0722	0.6	0.0394
W18x60	0.14	0.0537	0.0657	0.6	0.0358
W18x60	0.27	0.0252	0.0384	0.2	0.0117
W18x60	0.40	0.0161	0.0245	0.2	0.0063
W18x86	0.11	0.0508	0.0628	0.557	0.0334
W18x86	0.16	0.0480	0.0593	0.557	0.0316
W18x86	0.23	0.0334	0.0515	0.2	0.0229
W18x86	0.35	0.0202	0.0311	0.2	0.0135
W18x97	0.18	0.0498	0.0608	0.6	0.0332
W18x97	0.24	0.0340	0.0526	0.2	0.0248
W18x97	0.35	0.0202	0.0312	0.2	0.0147

E-4.2.9 Iterate Dynamic Analysis.

It is important to check that both stages of every analysis case converge. If the analysis does not converge, there is a problem with the model and it must be fixed. The problem could be numerical with assumptions made in SAP, but the most likely reason is that the model has a plastic hinge that failed or a mechanism has formed. At this point, the model cannot support the load. If the analysis fails to converge,

1) Since the analysis did not converge, members must be redesigned. To determine which members must be redesigned, step through the incomplete progression of plastic hinge formations. The final steps saved by SAP will often give the best results on which beams or columns to redesign. See Figure E-18 for the final step in the hinge formations of an analysis that did not converge.

2) To view the plastic hinges, click Display – Deformed Shape. Choose an analysis case and click to the last step of that case. Any hinge that forms will "light up," and its color denotes the region the hinge has progressed (see Figure E-17). A hinge deformed in excess of the limit defined by its acceptance criteria, or is orange or red has failed.

3) Once members have been selected to be redesigned, re-run the analysis. Repeat this process until the structure converges. The engineer must check each analysis case to make sure that no hinge has failed. Once the analysis converges and no hinges fail, perform a shear check on each member. See Figures E-19 through E-21 for final deformed shapes and hinge formations and Figures E-22 through E-24 for final member sizes for each column removal location.

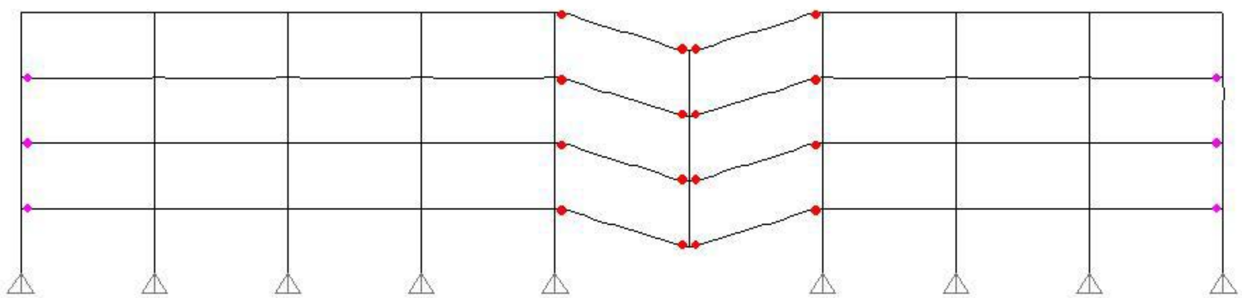


Figure E-19. Column 1 Removal Failed Convergence

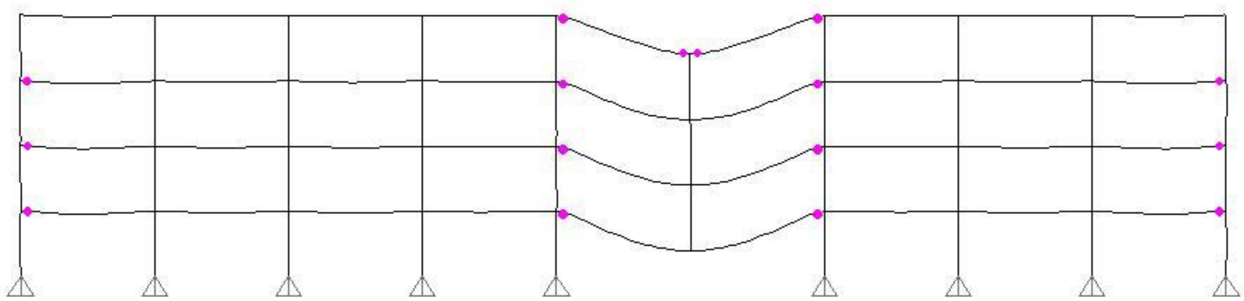


Figure E-20. Column 1 Removal Convergence After Redesign

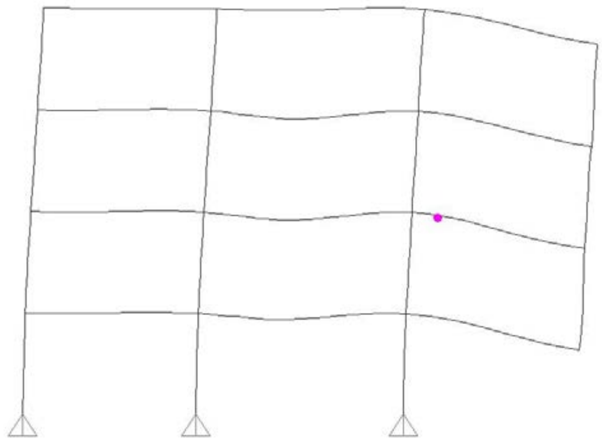


Figure E-21. Column 2 Removal Convergence After Redesign

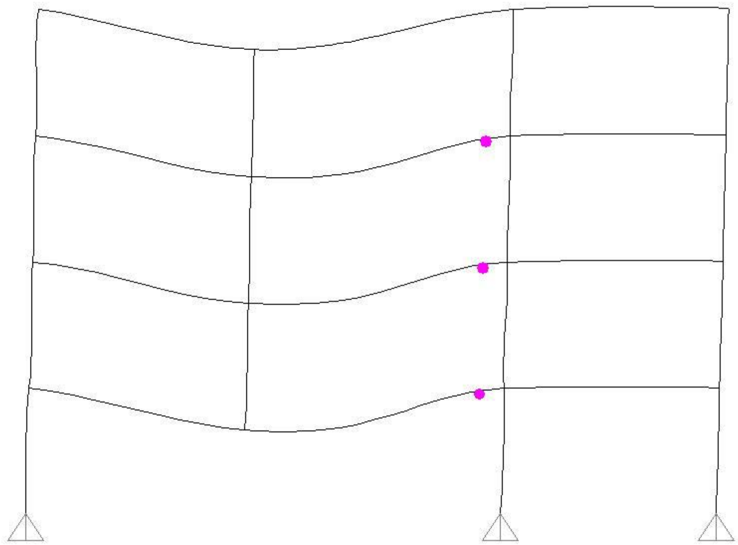


Figure E-22. Column 3 Removal Convergence After Redesign

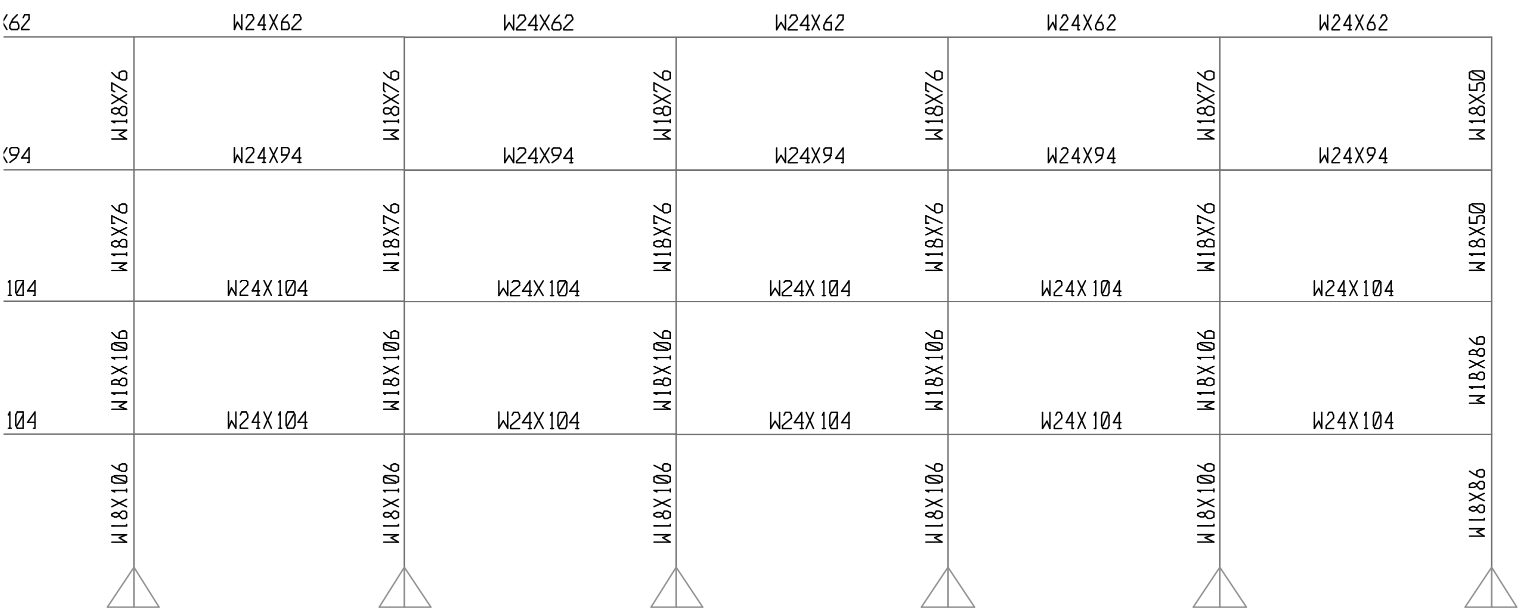


Figure E-23. Typical Member Sizes After Redesign for Column 1 Removal

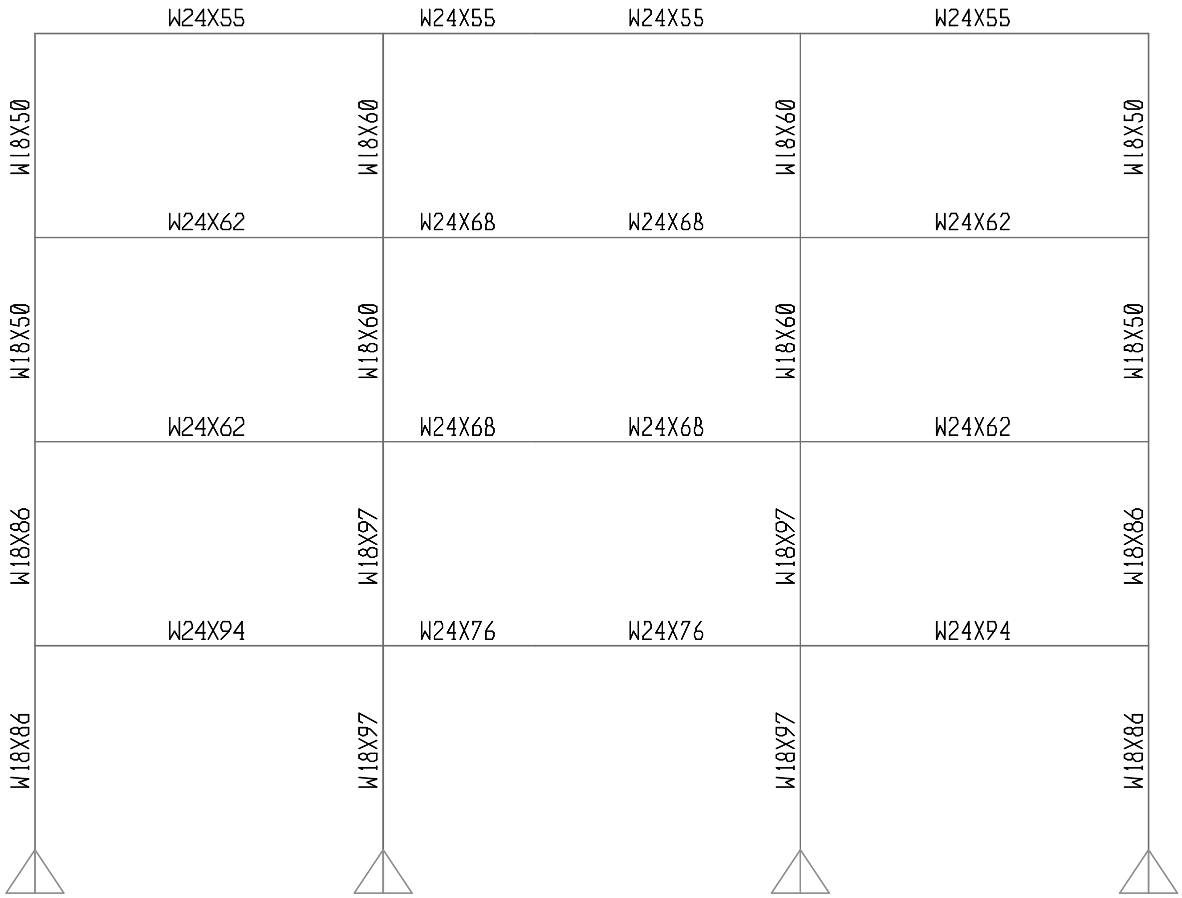


Figure E-24. Typical Member Sizes After Redesign for Column 2 or 3 Removal

E-4.2.10 Secondary Component Checks.

Because the gravity beams were explicitly included in the model, there are no secondary components to check. As with the Linear Static solution, the slab is adequate due to the small deformations and by engineering judgment.

E-4.3 Enhanced Local Resistance.

The provisions for \3\ Risk Category /3/ III require that all perimeter columns at the first floor above grade achieve design shear strengths that exceed the shear demand associated with the flexural demand of the columns. For \3\ Risk Category /3/ III, the nominal flexural strength is determined from the building design after it meets the AP requirements. The ELR design process for the Nonlinear Dynamic solution is similar to that used for the Linear Static solution in Section E-3.5.

In this example, the design shear strength for all columns other than corner columns exceeds the shear demand so no member size increases were required

beyond those determined using the alternate path procedure. For corner columns, there is no W18 section that can provide adequate design shear strength to meet the shear demand. In order to satisfy these provisions, web doubler plates were added. At these corner locations the axial load is less than 10% of the column capacity and was ignored.

The corner column is a W18x86 with a strong axis plastic modulus of 186 in^3. The shear demand is calculated with Equation E-1 and using an over-strength factor of 1.1 (per Section 3-3.1) is

V_u = 7.5 M_p / L = 7.5 * 1.1 * 50 ksi * 186 in^3 / 174 in = 441 kips

The design shear strength (per AISC Chapter G) is:

ΦV_n = 1.0 * 0.6 * t_w * h * F_y= 0.6 * 0.480 in * 18.4 in * 50 ksi = 265 kips

The required additional design shear strength is achieved by adding a doubler plate to the web of the W18x86. The thickness is found by subtracting the design shear strength (265-kips) from the shear demand (441-kips) and using this difference to size a 14-in high plate. A 7/16” thick doubler plate is required for all corner columns. See Figure E-13 for a diagram of the doubler plate used to enhance strong axis shear strength.

E-4.4 Alternate Path Design Method Complete.

Once the model converges, all acceptance criteria have been met, and enhanced local resistance has been provided, the building has satisfied progressive collapse resistance requirements of this UFC.

E-5 RESULTS COMPARISON.

Member size requirements determined from the linear static and nonlinear dynamic procedures are presented and compared to original size requirements in Tables E-11 and E-12.

Table E-11. Moment Frame Size Comparison

Location	Level	Original Size	LSP AP Size	NDP AP Size
Long Side	2	W24x68	W24x146	W24x104
Long Side	3	W24x68	W24x146	W24x104
Long Side	4	W24x68	W24x117	W24x94
Long Side	Roof	W24x55	W24x76	W24x62
Short Side – Exterior	2	W24x94	W24x94	W24x94
Short Side – Exterior	3	W24x62	W24x68	W24x62
Short Side – Exterior	4	W24x62	W24x68	W24x62
Short Side – Exterior	Roof	W24x55	W24x55	W24x55
Short Side – Central	2	W24x76	W24x104	W24x76
Short Side – Central	3	W24x68	W24x104	W24x68
Short Side – Central	4	W24x68	W24x94	W24x68
Short Side – Central	Roof	W24x55	W24x55	W24x55

Table E-12. Perimeter Column Size Comparison

Location	Level	Original Size	LSP AP Size	NDP AP Size
Long Side – Interior	1-3	W18x86	W18x175	W18x106
Long Side – Interior	3-Roof	W18x55	W18x106	W18x76
Short Side – Interior	1-3	W18x97	W18x119	W18x97
Short Side – Interior	3-Roof	W18x60	W18x76	W18x60
Corner	1-3	W18x86	W18x97	W18x86
Corner	3-Roof	W18x40	W18x76	W18x50

The frame size increases required for progressive collapse resistance are summarized by total weight in Table E-13. The weight of the exterior moment frames (girders and columns) are reported for the long side and short side for the baseline design, and after providing progressive collapse resistance using each of the linear static and nonlinear dynamic procedures.

Table E-13. Frame Weight Comparison

Frame	Original Weight	LSP AP Weight	NDP AP Weight
	(tons)	(tons)	(tons)
Long Side	58.2	108.7	78.2
Short Side	20.1	24.5	20.4

APPENDIX F WOOD EXAMPLE

F-1 INTRODUCTION

A wood load-bearing wall structure example has been prepared to illustrate Alternate Path analysis of a bearing wall type structure. The structure is assumed to have an occupancy of less than 100 people and is classified as \3\ Risk Category /3/ II per UFC 3-301-01.

The example has been prepared using tools and techniques commonly applied by structural engineering firms in the US. For wood design, this example relies primarily upon hand analysis supplemented with standard design tables published by various wood organizations. \3\ Risk Category /3/ II Option 2: Alternate Path has been selected from UFC Table 2-2 to evaluate resistance to progressive collapse.

F-2 BASELINE DESIGN

The example building is a 3-story wood structure, six bays long and two bays deep. The relevant design information is shown in Figures F-1 through F-4.

Platform construction is used. The internal shear walls are load bearing, with engineered I-joists (EIJ) running in the direction of the long length of the structure. One 4.5-foot x 6-foot window opening is present in each room. The footings are reinforced concrete with masonry. There are no internal partition walls.

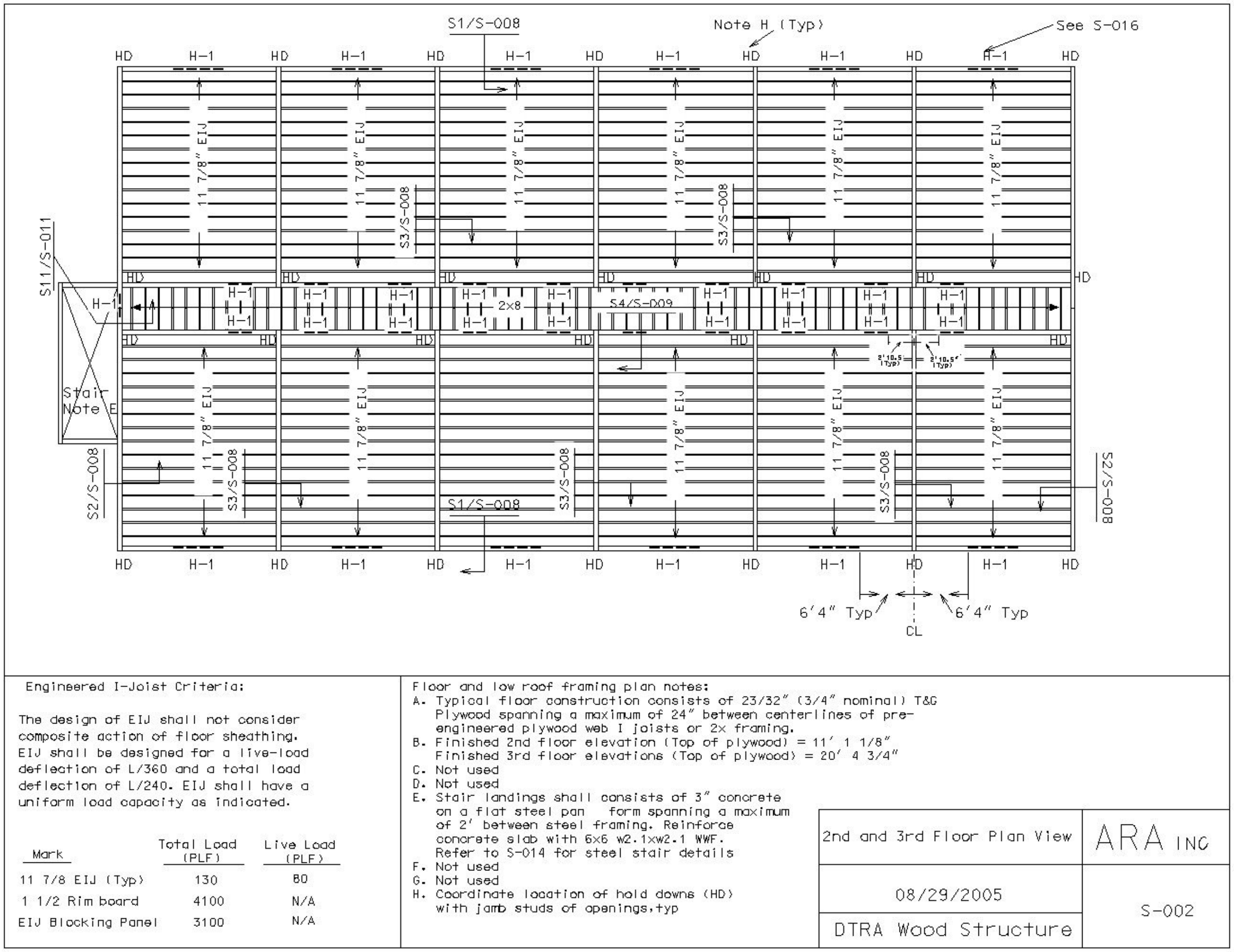


Figure F-1. Wood Frame Example Plan

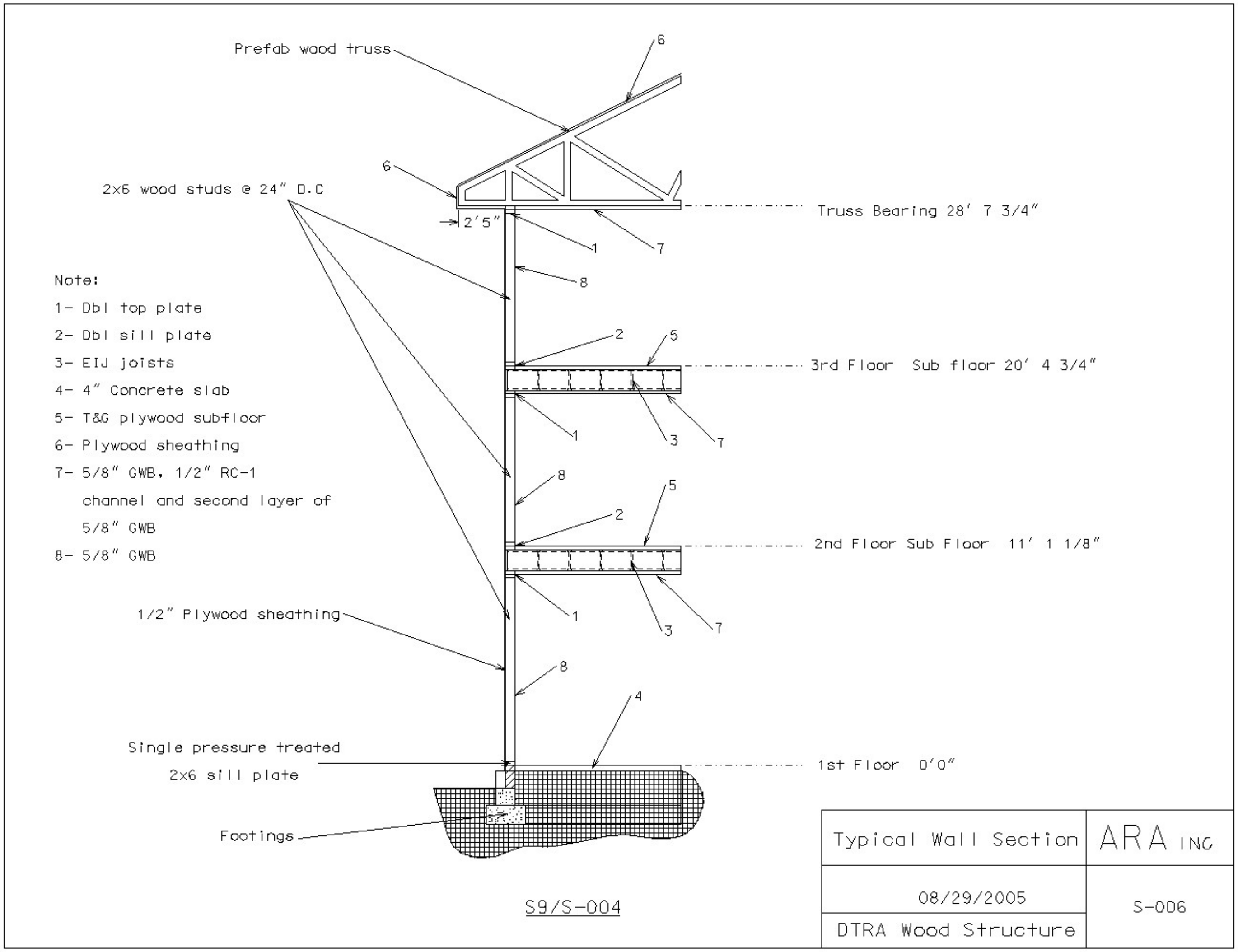


Figure F-2. Wood Frame Example Wall Section

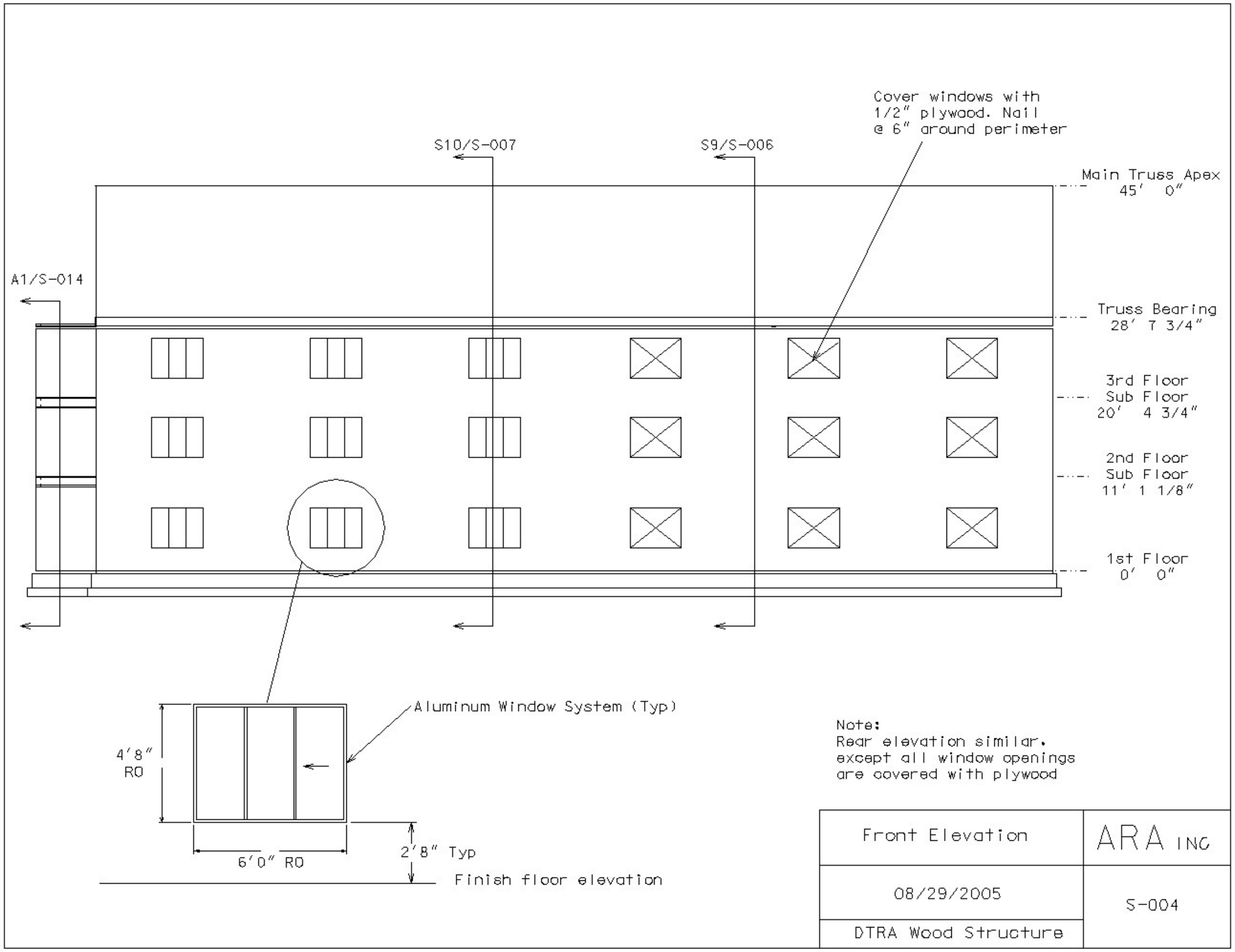


Figure F-3. Wood Frame Example Exterior Wall Elevation

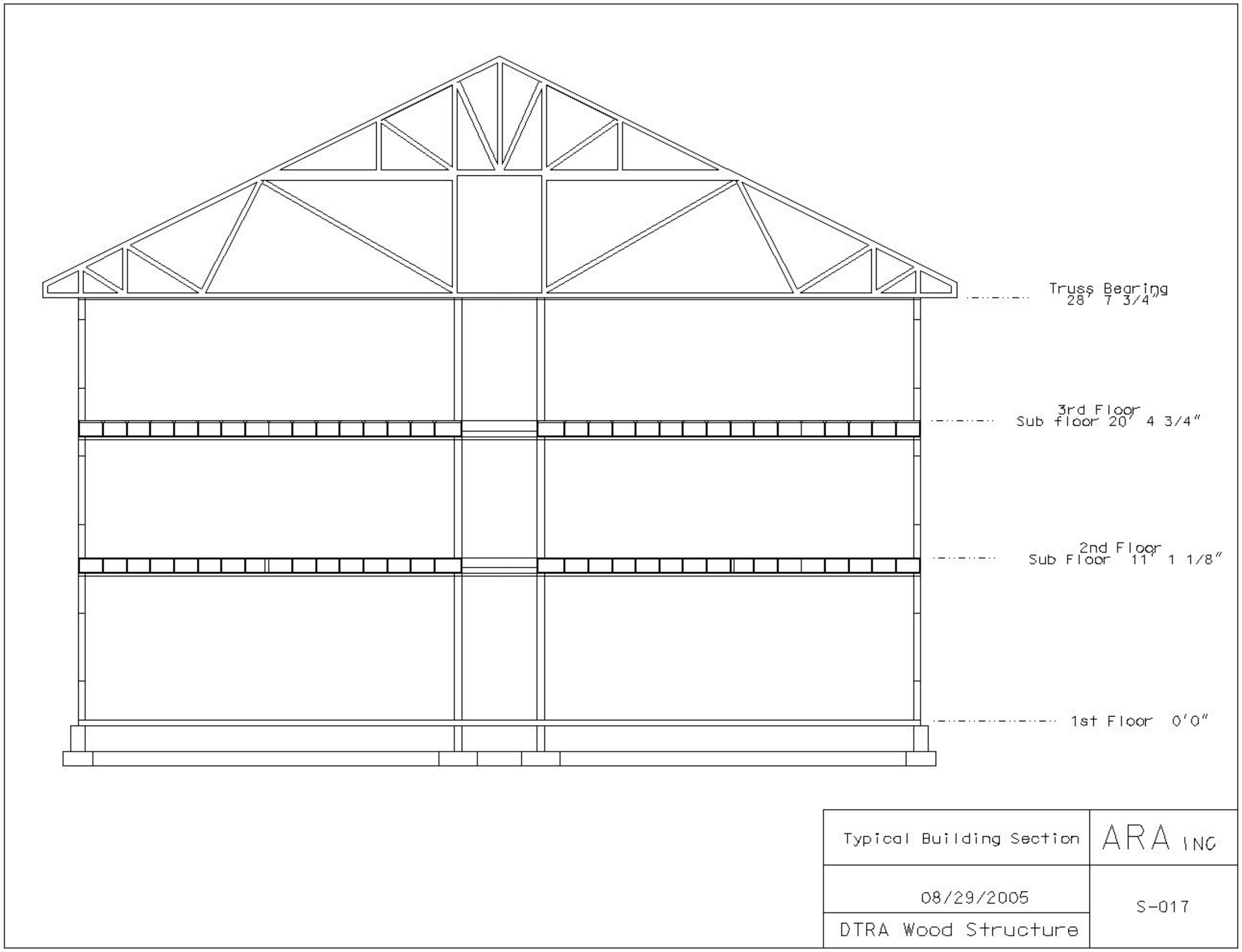


Figure F-4. Wood Frame Example Building Section

F-2.1 Construction and Materials

Wall Construction:
2x6 at 24 inches on center

Exterior Walls: 19/32” Plywood Sheathing Exterior Face, blocked; 5/8” Gypsum Wallboard, unblocked Interior Face

Interior Walls: 19/32” Plywood Sheathing both Faces, blocked

Floor Construction:
Engineered I-joists (EIJ) at 24 inches on center with 0.75-inch tongue and groove plywood sub-floor. Bottom surface 5/8” gypsum wallboard with a ½” channel separation for noise and fire suppression.

Roof Construction:
Engineered Trusses with ½” Plywood Sheathing

Material Grades:
Plywood: Voluntary Product Standard PS 1-07 Exposure 1; APA Rated

Wood Framing: Produced to American Softwood Lumber Standard Voluntary Product Standard PS 20.

- 19% maximum moisture content
- Grade 2 or better
- Southern Pine (SPIB)

F-2.2 Loading Assumptions

Typical loading relevant to AP Analysis:

Floors:
Dead Load: 25 psf including ceiling
Live Load: 40 psf

Roof:
Dead Load: 25 psf including roofing and bottom surface ceiling
Live Load: 20 psf
Snow Load: 7 psf (design, including all applicable ASCE 7-05 factors)

Walls:
Dead Load: 7 psf including sills and headers

Live loads reducible depending on tributary area considered.

F-2.3 Relevant Standards and Reference Documents

ANSI/AF&PA NDS-2005 National Design Specification for Wood Construction ASD/LRFD

ANSI/AF&PA SDPWS-2005 ASD/LRFD Special Design Provisions for Wind and Seismic With Commentary

International Building Code 2006

For design compatible with the UFC document LRFD is followed.

F-3 ALTERNATE PATH ANALYSIS

An alternate path (AP) analysis is conducted according to the requirements of Section 3-2. Removal scenarios are defined by 3-2.9.1 and 3-2.9.2. To bridge the wall removals, the remaining load bearing walls will be utilized as shear wall elements. The linear static AP analysis method will be followed.

F-3.1 Scope and Analysis Assumptions

Four scenarios of wall removal will be evaluated:

1. Removal of interior load-bearing wall (see Figure F-5) at first story
2. Removal of exterior long walls (see Figure F-6) at second story
3. Removal of exterior long walls (see Figure F-8) at second story (alternate location)
4. Removal of exterior long walls (see Figure F-9) at third story

General assumptions of the analysis are as follows:

- No wind or internal pressure acts on interior or exterior walls during wall removal scenario
- Contributions of EIJ and engineered roof trusses to the alternate path capacity are neglected due to uncertainty in specific properties during the design phase. At the designer's option, these elements could be included, provided that appropriate performance specifications including AP requirements are incorporated into the contract documents.

Per ASCE 41-13
C12.2.2.5:
"Actions associated with wood and light metal framing components generally are deformation controlled, and expected strength material properties will be used most often."

8.3.3:
"Demands on connectors, including nails, screws, lags, bolts, split rings, and shear plates used to link wood components to other wood or metal components shall be considered deformation controlled actions. Demands on bodies of connections, and bodies of connection hardware, shall be considered force-controlled actions."

For the AP analysis of this structure, wood shear wall assemblies and primary connections will be taken to be deformation controlled elements. Bodies of connectors will be checked as force controlled elements as required.

F-3.2 AP Analysis of Interior Load Bearing Wall Removal

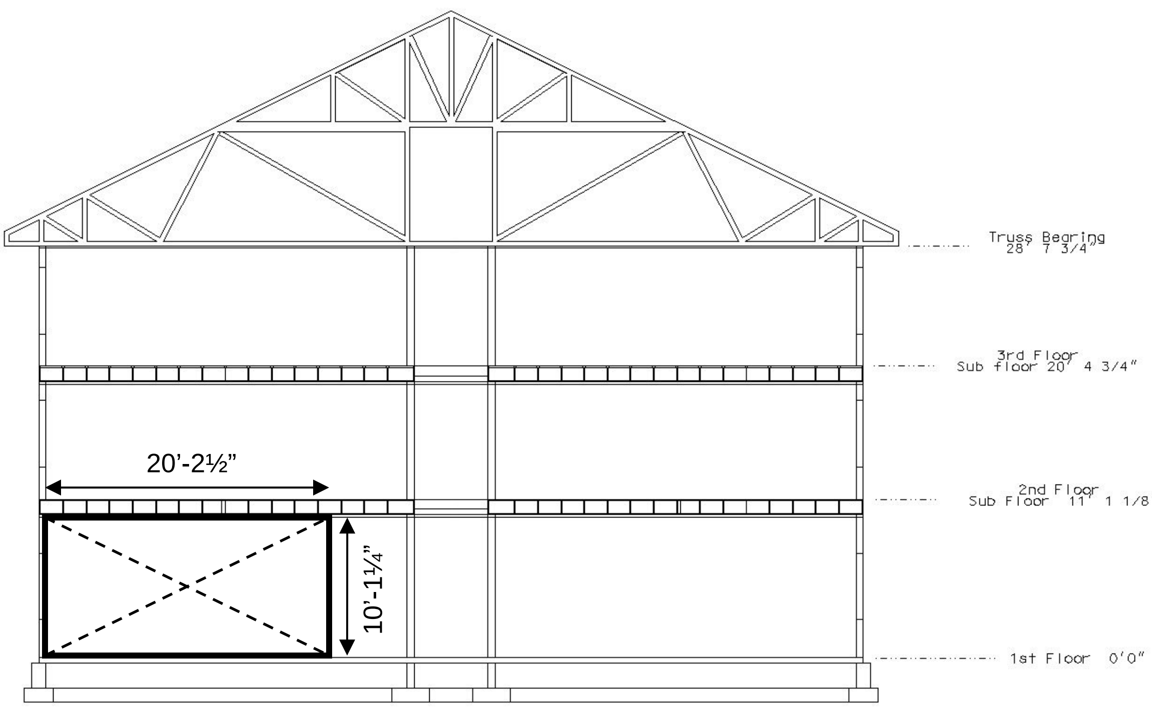


Figure F-5. Interior Load Bearing Wall Removal

As shown in Figure F-5, a segment of wall of length 2H is removed from the lower floor interior load bearing wall. H is taken as the distance between the 1st floor sub-floor elevation and the bottom of the 11-7/8" EIJ floor joists at the 2nd floor (=10'-1¼").

The remaining structure creates a shear wall element that must span the floor and wall loads from the 2nd and 3rd stories. The shear wall is taken to have an overall depth of 17'-6 5/8" (2nd floor to truss bearing). The boundary (chord) elements consist of (2) 2x6 plates provided at the top and bottom of each wall.

To bridge the removed section of wall, the shear wall panel must span from the exterior wall to a wall pier segment consisting of the remaining portion of the removed lower story interior wall. Note that no continuity action that might engage the right-hand wall panels in Figure F-5 is possible due to the corridor opening.

The structure contains no irregularities and therefore the linear static AP analysis is permitted per Section 3-2.11.1.1.

Loading:

Dead Load
Floors: 25 psf * 18'-8" * 2 floors = 934 plf
Wall: 7 psf * 18'-6 ½" = 130 plf

Live Load
40 psf * 18.67 * 2 floors = 1494 plf

Reduce live load in accordance with IBC 2006 1607.9.2:

A = 18.67'*20.21'*2 = 755 SF
R = 0.08 (A – 150) = 0.08 (755-150) = 48.4%
R_{max} = 60% or 23.1(1 + 25/40) = 37.5%

Live load used in AP check = 1494 plf (1-0.375) = 934 plf

Linear Static AP Load Case for Deformation Controlled Elements:

$\boldsymbol{G_{LD} = \Omega_{LD}\,[1.2D + 0.5\,L]}$

From ASCE 41-13 Table 12-3:

for "Wood Structural Panel Sheathing or Siding"
h/b = 17.55/20.21 = 0.87 < 2.0
m = 3.8 for Life Safety Primary Element

Assume all connections to be nailed:

m = 6.0 for "Nails – Wood to Wood"
m = 4.0 for "Nails – Wood to Metal"

m = 3.8 controls

Ω_{LD} = 2.0m = 7.6 (UFC Table 3-4)

G_{LD} = 7.6*(1.2*(934+130) + 0.5*(934)) = 7.6*(1744 plf) = 13,254 plf

Deformation controlled actions:

Shear: Q_{UD} = 13,254 plf * 20.21' / 2 / 17.55' = 7,631 plf in wall

Capacity checks of deformation controlled actions:

Shear in Wall:

Wall shear strength ϕQ_{CE} = 1.5 (ϕv_s)
where ϕv_s = LRFD shear strength of wall taken from ANSI/AFPA SDPWS-2005 and factor 1.5 for expected strength is taken from ASCE 41-13 12.4.9.2, but note that Section 3-2.11.7.1 requires inclusion of the material specific ϕ factor whereas ASCE 41-13 uses a ϕ of 1.0.

From ANSI/AFPA SDPWS-2005 Table 4.3A:

For "Wood Structural Panels – Sheathing", 19/32 with 10d nailing at 6" at edges:

v_{wc} = 950 plf (for one side of wall)
Note that value for wind is chosen rather than seismic per UFC Ch. 7.

Since the interior walls have plywood sheathing on both sides, strength of each individual side is additive per ANSI/AFPA SDPWS-2005 4.3.3.2.

ϕ = 0.8 for LRFD per ANSI/AFPA SDPWS-2005 4.3.3
ϕv_s = 0.8 (950) (2) = 1520 plf
ϕQ_{CE} = 1.5 (ϕv_s) = 1.5 (1520) = 2280 plf

Check UFC Equation 3-13:

$\phi m Q_{CE} \geq Q_{UD}$
2280 plf (3.8) = 8,664 plf > 7,631 plf **OK**

At the edge of the removed wall segment adjacent to the building exterior, the interior load bearing wall must transfer its reaction in shear to the exterior wall for distribution to an adequate length of exterior load bearing stud wall.

Exterior Wall Check:

Q_{UD} = 7,631 plf / 2 = 3,816 plf (half of reaction distributed each direction)

From ANSI/AFPA SDPWS-2005 Table 4.3A:

Exterior sheathing plywood 19/32 with 10d nailing at 6" at edges:

v_{WC} = 950 plf
ϕv_S = 0.8 (950) = 760 plf
ϕQ_{CE} = 1.5 (760) = 1140 plf

From ASCE 41-13 Table 12-3 m = 4.7 for Gypsum Wallboard with h/b ≤ 1.0. Assuming the shear reaction is spread over a length b less than 17.55', the m factor for wood structural panels controls.

Check UFC Equation 3-13:

$\phi m Q_{CE} \geq Q_{UD}$
1140 (3.8) = 4,322 plf > 3,816 plf **OK**

For force controlled actions:

$\boldsymbol{\Omega_{LD}}$ = 2.0 (UFC Table 3-4)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*(934+130) + 0.5*(934)) = 2.0*(1744 plf) = 3,488 plf

Force controlled actions:

Shear: Q_{UF} = 3,488 plf * 20.21' / 2 / 17.55' = 2,008 plf in wall
Chord Force: Q_{UF} = 3,488 plf * 20.21^2 / (8*17.55) = 10,147 pounds

Though ASCE 41 is somewhat ambiguous on the subject, consider the chord forces to be deformation controlled actions because ASCE 41 Table 12-3 designates "Frame Components Subject to Axial Compression" as force controlled. Treating both tension and compression chords as force controlled will be conservative.

From the NDS supplement for 2x6 #2 Southern Pine:

F_t = 825 psi
F_c = 1650 psi
$F_{c\perp}$ = 565 psi
E_{min} = 580,000 psi

Chord force limit will be governed by tension capacity since compression chord is fully braced in both directions:

Adjusted reference design value $F'_t = C_M C_t C_F C_i K_F \phi_t \lambda F_t$
All adjustment values are 1.0 except:
K_F = 2.16/ϕ_t
ϕ_t = 0.80

Note λ = 1.0 for short duration loading event
F'_t = 2.16*825 = 1782 psi

ϕQ_{CL} = 1782 psi (8.25 in^2) = 14,702 pounds for (1) 2x6 > Q_{UF} = 10,147 pounds

Note that by providing adequate strength for (1) 2x6 plate to act as a chord, the pair of 2x6's may be stagger spliced via nailing without the need for a direct metal plate splice of both plates. Nailing for splices should be sized for 10,147 pounds.

Check bearing transfer of bridged load to load bearing stud walls as force controlled action.

Q_{UF} = 3,488 plf * 20.21' / 2 = 35,246 pounds

\2\ 2x6 studs at 24" on center with in-plane bracing provided by sheathing. Check as columns for out-of-plane strength at lower story./2/

Adjusted reference design value $F'_c = C_M C_t C_F C_i C_P K_F \phi_c \lambda F_c$
All adjustment values are 1.0 except:

K_F = 2.16/ϕ_c
ϕ_c = 0.90
Note λ = 1.0 for short duration loading event

C_P calculation:
F_{c*} = $K_F \phi_c \lambda F_c$ = 2.16*1650 = 3564 psi
E'_{min} = $C_M C_t C_i C_T K_F \phi_s E_{min}$
All adjustment values are 1.0 except:
K_F = 1.5/ϕ_s
ϕ_c = 0.85
E'_{min} = 580,000*1.5 = 870,000 psi
l_e = 11'-1 1/8" – 4 ½" = 10'-8 5/8"
F_{cE} = 0.822*(870,000)/ (128.625/5.5)^2 = 1308 psi (NDS 3.7.1)
F_{cE}/ F_{c*} = 1308 / 3564 = 0.367
C_p = 0.334 per NDS Equation 3.7-1

ϕQ_{CL} = 0.334(3564 psi) (8.25 in^2) = 9820 pounds per stud

ϕQ_{CL} = 9820/2' = 4910 plf

Check bearing on plates:

Adjusted reference design value $F'_{c\perp} = C_M C_t C_i C_b K_F \phi_c \lambda\ F_{c\perp}$
All adjustment values are 1.0 except:
K_F = 1.875/ϕ_s

ϕ_c = 0.9
C_b = 1.25 for 1.5” wide member (NDS Table 3.10.4)
$F'_{c\perp}$ = 1.25*1.875*565 psi = 1324 psi

ϕQ_{CL} = (1324 psi)(8.25 in^2) = 10,923 pounds per stud

ϕQ_{CL} = 10,923/2’ = 5461 plf

ϕQ_{CL} = 4910 plf controls

Required width of wall = 35,246 pounds / 4910 plf = 7’-3”

Adequate width available at external wall

Available wall pier at interior wall = 25’-11” – 20’-2 ½” = 5’-8 ½” **NG**

Note that location of the removed section of wall could shift such that the situation on the interior side is similar to that considered in Figure F-5 for the exterior side. Therefore, the reaction must be transferred by shear into the interior corridor transverse load bearing walls. The wall construction is identical so shear capacity will be adequate.

Removal of a wall segment above the 2nd floor would produce a very similar analysis and results to those described above as the load resisted is roughly proportional to the available depth of remaining wall.

Similarly, removal of an exterior load bearing wall along the short side would produce results consistent with the interior removal as the tributary area of floor carried is roughly half that of an interior wall, and the provided capacity consists of one face plywood and one face drywall, giving larger than half the capacity of the interior wall.

/2/Secondary Component Check

EIJ joists span 18’-8” and are supported by the short direction load bearing walls. Removal of a load bearing wall will result in loss of support for EIJs.

Accordingly, all EIJs must be attached to the wall above to prevent collapse in the event of a bearing wall removal. The floor joists shall be hung from the wall above using a tension tie nailed to the 2x6 wall stud above which will include a threaded tension rod bolted through the top plate of the removed wall (See Figure F-6). The top plate of the removed wall shall be assumed to be held in place due by the tension rod.

Connection of each EIJ will consist of multiple connectors so it shall be considered force controlled:

Floor loadings:
DL = 25 psf * 18.67' * 2' = 934 lbs
LL = 40 psf * 18.67' * 2' = 1494 lbs (no live load reduction due to limited tributary area for each EIJ tension tie)

$\boldsymbol{\Omega_{LD}}$ = 2.0 (UFC Table 3-4)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*DL + 0.5*LL)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*(934 lbs) + 0.5*(1494)) = 3735 lbs

The tension tie capacity must be greater than 3735 lbs. Accordingly, provide one (1) Simpson HTT5 with 26-10dx1 ½" nails into the wall stud above with a capacity of 4350 lbs.

The head plate of the wall below consists of (2) 2x6 southern pine plates.

The shear in the 2x6 head plates will be a force controlled action.

For each 2x6 head plate:
$V' = 2/3\ F_V' * A$
$F_V' = 175$ psi
$A = 8.25\ in^2$

$F_V' = C_D C_M C_t C_i K_F \phi_v \lambda F_v$

All adjustment factors 1.0 except:
$K_F = 2.16/\phi_b$
$\phi_b = 0.75$
Note λ = 1.0 for short duration loading event

F_V'= 2.16/0.75 * 0.75* 175psi = 378psi

V' = 2/3 378psi * 8.25in^2 = 2079 lbs per head plate

ϕQ_{CL} = 2079 lbs * 2 = 4158 lbs > 3735 lbs **OK**

The flexure in the 2x6 head plates will be a deformation controlled action.

From ASCE 41-13 Table 12-3:
For "frame components subject to axial tension and/or bending":
m = 2.5 for Life Safety Secondary Element

$\boldsymbol{\Omega_{LD}}$ = 2.0m = 5.0 (UFC Table 3-4)

$\boldsymbol{G_{LD}}$ = 5.0*(1.2*(934 lbs) + 0.5*(1494 lbs)) = 5.0*(1868 lbs) = 9340 lbs

Since the head plate will be part of a continuous span the maximum moment will be:

Q_{UD} = $\boldsymbol{G_{LD}}$ * L / 8 = 9340 lb * 2 ft / 8 = 2335 lb-ft

Flexural capacity of each 2x6 head plate (weak axis bending):

$M' = F_b' * S$

S_y = 2.063 in^3
F_b = 1250 psi

$F_b' = C_D C_M C_t C_L C_F C_{fu} C_i C_r K_F \phi_b \lambda F_b$

All adjustment factors 1.0 except:
C_{fu} = 1.15
K_F = 2.16/ϕ_b
ϕ_b = 0.85
Note λ = 1.0 for short duration loading event

F_b' = 1.15*2.16/0.85 * 0.85 1250 psi = 3105 psi

M' = 3105 psi * 2.063 in^3 = 6406 lb-in = 534 lb-ft
$\phi m Q_{CE} \geq Q_{UD}$

$\phi m Q_{CE}$ = 2.5 * 534 lb-ft* 2 = 2670 lb-ft > 2335 lb-ft **OK**

Since the shear and flexural capacity of both 2x6 head plates is required to support secondary members, a 3rd 2x6 head plate must be provided in order to accommodate splicing. All splices shall be staggered. See Figure F-6 for a floor joist support detail.

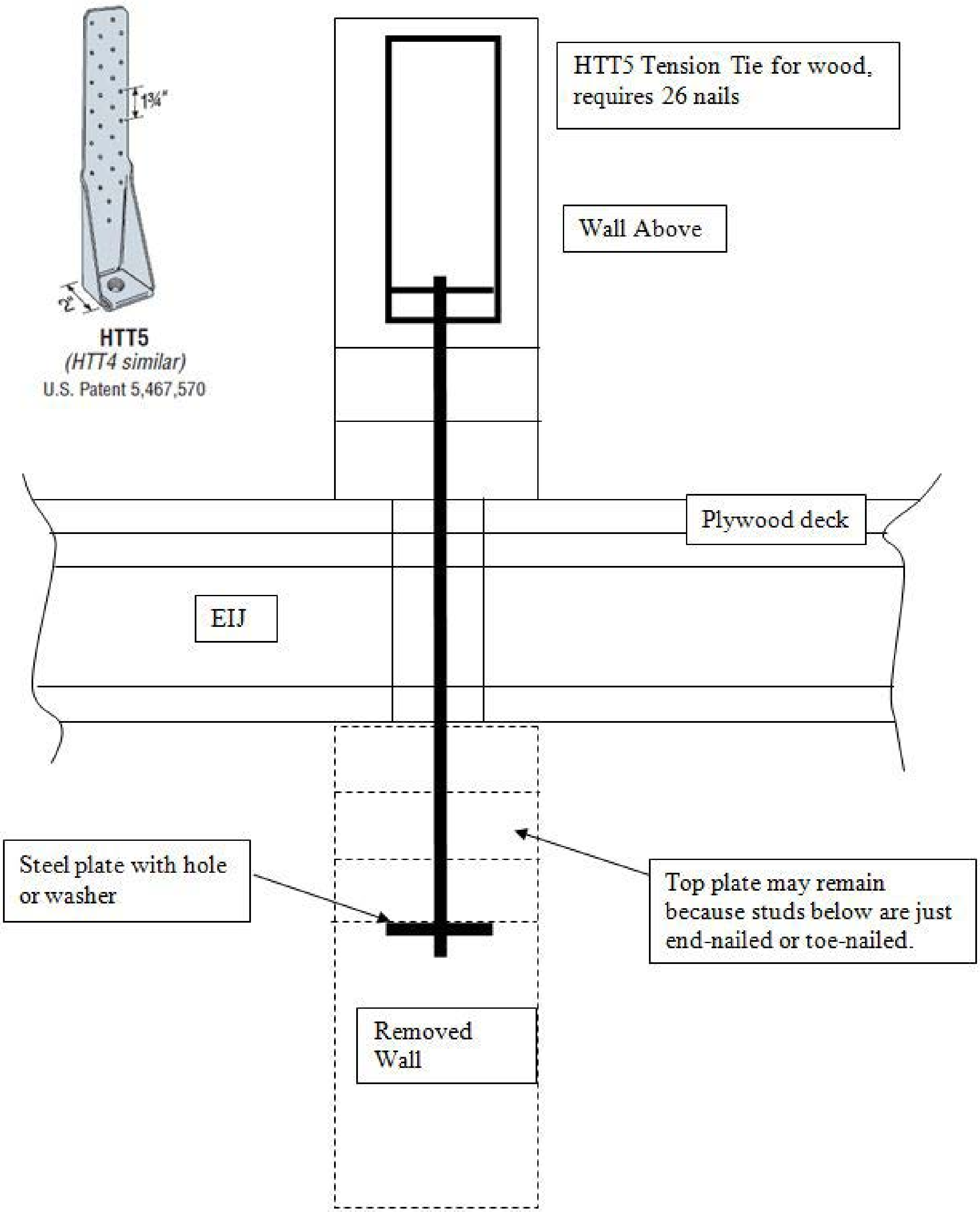


Figure F-6. Floor Joist Support Detail

/2/

F-3.3 AP Analysis of Removal of Exterior Load Bearing Walls (Long Direction)

As shown in Figure F-7, a segment of wall of length 2H is removed between the second and third floors. H is taken as the distance between the 2nd floor sub-floor elevation and the bottom of the 11-7/8" EIJ floor joists at the 3rd floor (=8'-3 1/8").

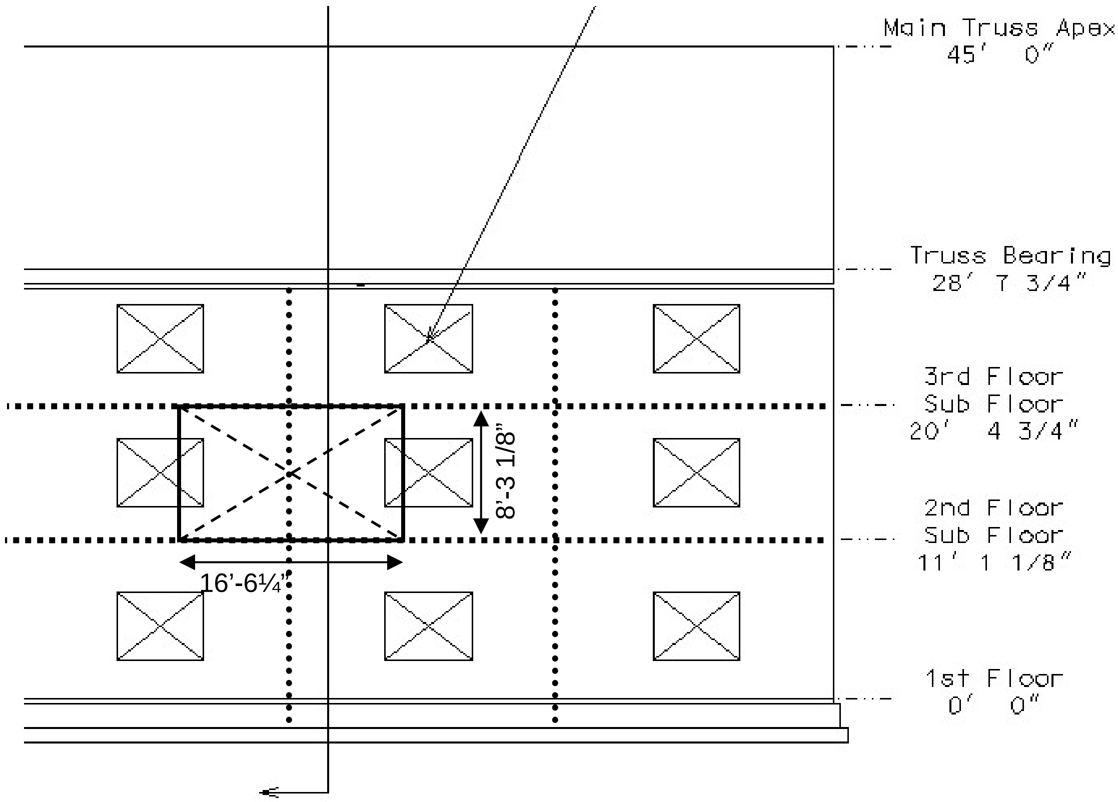


Figure F-7. Exterior Wall Removal

The chosen area of removal takes away the jamb and jack studs supporting the header of the window opening above the third floor. This header must now transfer its reaction via the remaining jack studs into the remaining wall above the 3rd floor. This remaining wall segment must then act as a cantilever from a vertical support provided by the crossing interior wall. Any unbalanced loads in the cantilever system must be resolved via drag forces in the 3rd floor and top of wall sill elements to adjacent intact wall segments. See Figure F-8.

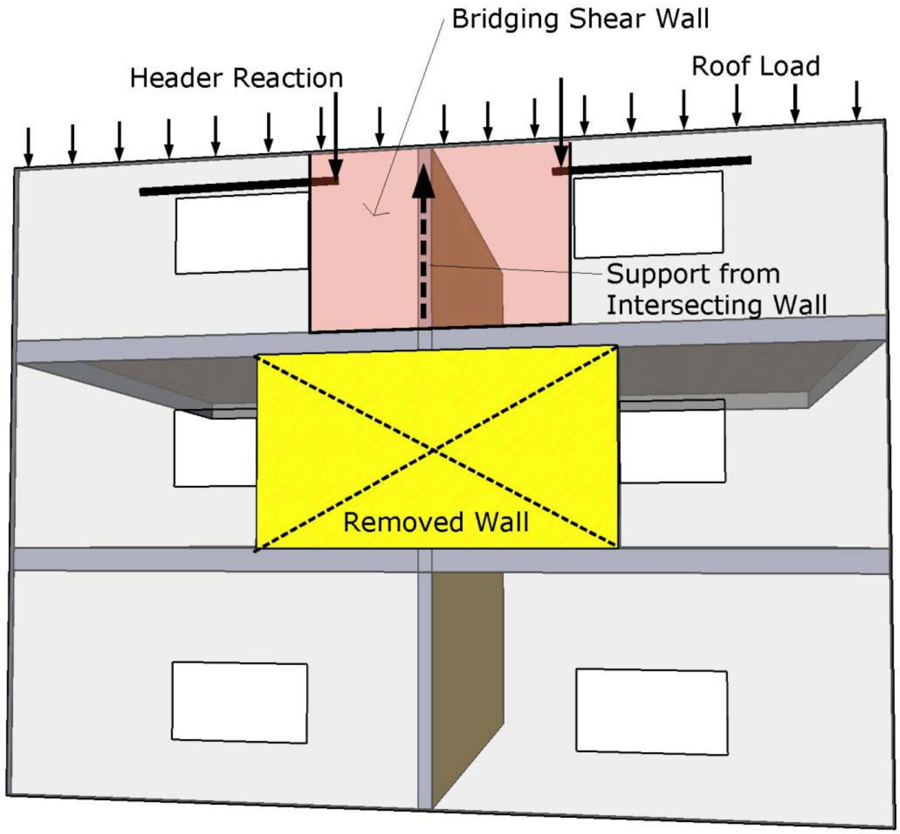


Figure F-8. Load Path for Exterior Wall Removal

The primary loading is that of the roof trusses:

Dead Load
Roof: 25 psf * 25'-11" / 2 = 324 plf
Wall: 7 psf * 8'-3" = 58 plf

Roof live load not applicable for UFC design combination

Snow Load
7 psf * 25'-11" / 2 = 91 plf

Linear Static AP Load Case for Deformation Controlled Elements:
$\boldsymbol{G_{LD} = \Omega_{LD}\ [1.2D + 0.2S]}$

From ASCE 41-13 Table 12-3:
for "Wood Structural Panel Sheathing or Siding"
h/b = 6.33/9.25 = 0.68 < 2.0
m = 3.8 for Life Safety Primary Element
m = 4.7 for Gypsum Wallboard with h/b ≤ 1.0 at interior face

Assume all connections to be nailed:
m = 6.0 for “Nails – Wood to Wood”
m = 4.0 for “Nails – Wood to Metal”

m = 3.8 controls

$\boldsymbol{\Omega_{LD}}$ = 2.0m = 7.6 (UFC Table 3-4)

$\boldsymbol{G_{LD}}$ = 7.6*(1.2*(324+58) + 0.2*(91)) = 7.6*(477 plf) = 3,622 plf

Header reaction = 3622 plf * 6’ / 2 = 10,866 pounds

Total shear in wall segment at intersection with interior wall
= 10,866 + 3622*(6’-4”) = 33,793 pounds

Unit shear = 33,793 / 8’-3” = 3528 plf

Wall strength ϕQ_{CE} = 1140 plf (established in wall analysis F-3.2)

Check UFC Equation 3-13:

$\phi m Q_{CE} \geq Q_{UD}$
1140 (3.8) = 4332 plf > 3,528 plf **OK**

For force controlled actions:

$\boldsymbol{\Omega_{LD}}$ = 2.0 (UFC Table 3-4)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*(324+58) + 0.2*(91)) = 2.0*(477 plf) = 954 plf

Header reaction = 954 plf * 6’ / 2 = 2,862 pounds

Chord force = [2862*6 + 954*$(6.33)^2$ / 2] / 8.25’ = 3,498 pounds = Q_{UF}

Chord tension ϕQ_{CL} = 14,702 pounds for (1) 2x6 (established in analysis F-3.2)

Total available strength = 14,702*2 = 29,404 pounds > 3,498 pounds OK

\2\The cantilever walls sections are to be supported by the interior load bearing wall that is perpendicular to cantilever wall sections.

Shear reaction from each side of the cantilever = 33,793 lbs
Total shear reaction from 2 cantilevers = 2*33793 lbs = 67,586 lbs

Interior load bearing shear walls with plywood at each side continue through the exterior wall to the exterior face of the building (see Figure F-1).

The exterior plywood sheathing of the long direction exterior walls must be nailed into the end 2x6's of the interior load bearing walls to allow for shear transfer. To carry the shear load from each side of the interior wall, two rows of 10d nails @6" will be required from the exterior sheathing into the end 2x6's.

Cantilever wall reaction then carried by shear in interior load bearing wall (between 3rd floor and truss bearing).

Interior load bearing wall has plywood sheathing on both sides.

ϕv_s = 0.8 * 2 * (950) = 1520 plf
ϕQ_{CE} = 1.5 (1520) = 2280 plf

8'-3" wall height for interior load bearing wall

Q_{UD} = 67,586 lbs / 8.25 ft = 8192 plf
$m\phi Q_{CE}$ = (3.8 * 2280 plf) = 8664 plf > 8192 plf **OK**

The interior wall below the 3rd floor supports the shear wall with compression in wall studs. Compression in studs is a force controlled action.

For force controlled actions:

$\boldsymbol{\Omega_{LD}}$ = 2.0 (UFC Table 3-4)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*(324+58) + 0.2*(91)) = 954 plf

Header reaction = 6 ft / 2 * 954 lb/ft = 2862 lbs

Reaction onto interior wall for each side:

954 plf * (6.33 ft) + 2862 lbs = 8900 lbs
Total reaction (from both sides) = 2 * 8900 lbs = 17,800 lbs (from exterior walls)

Bearing on interior wall studs (lowest level) will also include floor loading from 2 floors (18'-8" floor span)

DL = 25 psf each floor
Reduced LL = 40 psf (1-0.375) = 25 psf each floor

DL = 2 floors * 25 psf * 18.67 ft = 934 plf
LL = 2 floors * 25 psf * 18.67 ft = 934 plf

G_{LF} = 2.0*(1.2*(934) + 0.5*(934)) = 1587 plf

G_{LF} = 1587 plf * 2 ft stud spacing = 3174 lbs / stud

Bearing on interior wall (lower story) carried by 2x6 studs at 2’ on center with in-plane bracing provided by sheathing. Check as column for out-of-plane strength of lower story

Per F-3.2 Stud strength is 9820 lbs / stud

9820 lb / stud – 3174 lb / stud = 6646 lbs available per stud

17,800 lbs / 6646 lbs = 2.7 studs

3 studs available within 4 feet of interior wall **OK**

F-3.4 AP Analysis of Removal of Exterior Load Bearing Walls (Long Direction, Alternate Location)

As shown in Figure F-9, a segment of wall of length 2H is removed between the second and third floors. H is taken as the distance between the 2^{nd} floor sub-floor elevation and the bottom of the 11-7/8” EIJ floor joists at the 3^{rd} floor (=8’-3 1/8”).

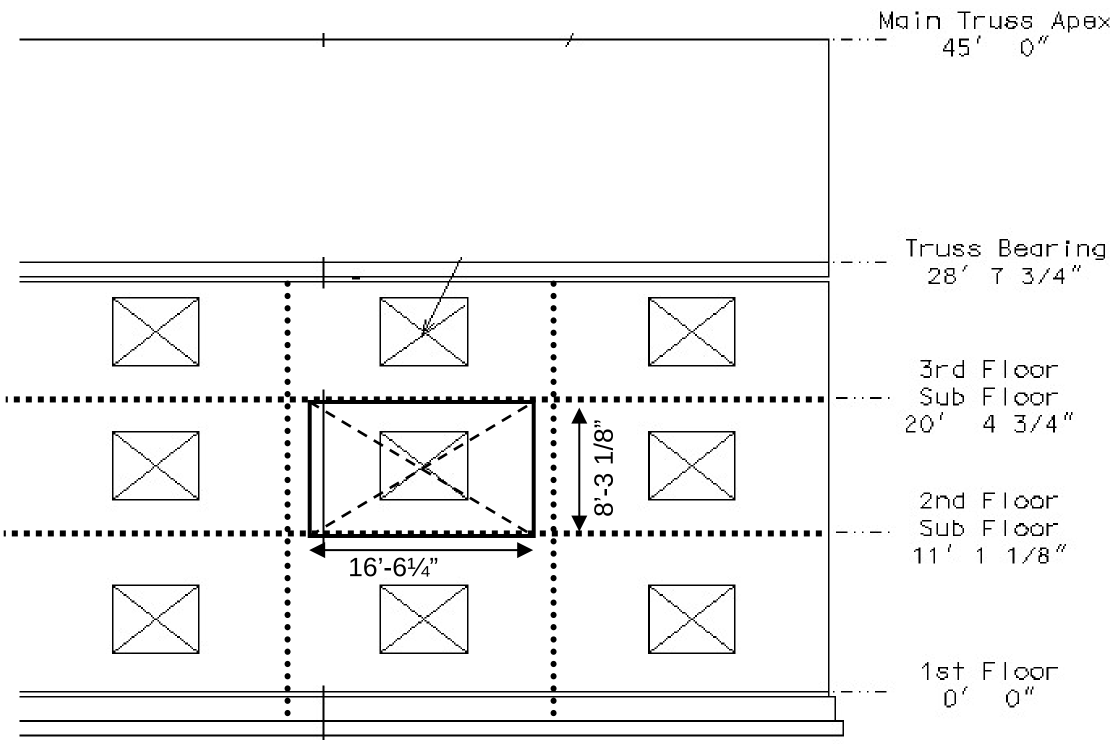


Figure F-9. Exterior Wall Removal

The chosen area of removal between the second and the third floor will allow for the shear wall above to span over and be supported on each side of the removed wall section. (Note, shifted removal locations could be addressed similar to F-3.3, however they will be less critical because additional cantilever shear wall sections could be engaged).

The primary loading is that of the roof trusses:

Dead Load
Roof: 25 psf * 25'-11" / 2 = 324 plf
Wall (including glazing): 7 psf * 8'-3" = 58 plf

Roof live load not applicable for UFC design combination

Snow Load
7 psf * 25'-11" / 2 = 91 plf

Linear Static AP Load Case for Deformation Controlled Elements:

$\boldsymbol{G_{LD} = \Omega_{LD} [1.2D + 0.2S]}$

From ASCE 41-13 Table 12-3:

for "Wood Structural Panel Sheathing or Siding"
h/b = 8.25/9.25 = 0.89 < 2.0
m = 3.8 for Life Safety Primary Element

m = 4.7 for Gypsum Wallboard with h/b ≤ 1.0 at interior face

Assume all connections to be nailed:
m = 6.0 for "Nails – Wood to Wood"
m = 4.0 for "Nails – Wood to Metal"

m = 3.8 controls

$\boldsymbol{\Omega_{LD}}$ = 2.0m = 7.6 (UFC Table 3-4)

$\boldsymbol{G_{LD}}$ = 7.6*(1.2*(324+58) + 0.2*(91)) = 7.6*(477 plf) = 3,622 plf

Total force onto the removed section
F = 3622 lb/ft * 16.5 ft = 59,763 lbs

Shear each side V = 59,763 lbs / 2 = 29,882 lbs

Unit shear = 29,882 lbs / 9.25' = 3230 plf

Wall strength ϕQ_{CE} = 1860 plf (established in wall analysis F-3.2)

Check UFC Equation 3-13:

$\phi m Q_{CE} \geq Q_{UD}$
1860 (3.8) = 7,068 plf > 3,230 plf **OK**

For force controlled actions:

$\boldsymbol{\Omega_{LD}}$ = 2.0 (UFC Table 3-4)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*(324+58) + 0.2*(91)) = 2.0*(477 plf) = 954 plf

Wall moment = $\boldsymbol{G_{LF}} * L^2 / 8$ = 954 plf * $(16.5')^2$ / 8 = 32,466 lb-ft

Chord force limit will be governed by tension strength since compression chord is fully braced in both directions

Chord force = M/d = [32,466 lb-ft] / 9.25' = 3,510 pounds = Q_{UF}

Chord tension ϕQ_{CL} = 14,702 pounds for (1) 2x6 (established in analysis F-3.2)

Total available capacity = 14,702*2 = 29,404 pounds > 3,923 pounds OK

End reactions of spanning wall will be carried by studs in compression between the 1st and 2nd floor. Compression of studs will be force controlled.

G_{LF} = 954 plf + additional wall load carried by each stud to the foundation

h = 28'-8" = 28.67' stud spacing = 2 ft wall DL = 7 psf

Additional wall load = 954 plf + 2.0 * (0.5* 7 psf * 28.67') = 201 lbs/ft

Q_{UD} = 954 lbs/ft * 0.5 * 16.5 feet + 201 lbs/ft * 2 ft = 8273 lbs/stud

Compression carried by 2x6 studs at 2' on center with in-plane bracing provided by sheathing and blocking. Check as column for out-of-plane capacity of lower story

Per F-3.2 Stud capacity is 9820 lbs / stud > 8273 lbs /stud **OK**

F-3.5 AP Analysis of Removal of Exterior Load Bearing Walls Below Third Floor (Long Direction)

As shown in Figure F-10, a segment of wall of length H is removed at exterior corners in each direction between the second and third floors. H is taken as the distance between the 3rd floor sub-floor elevation and the truss bearing location (=8'-3").

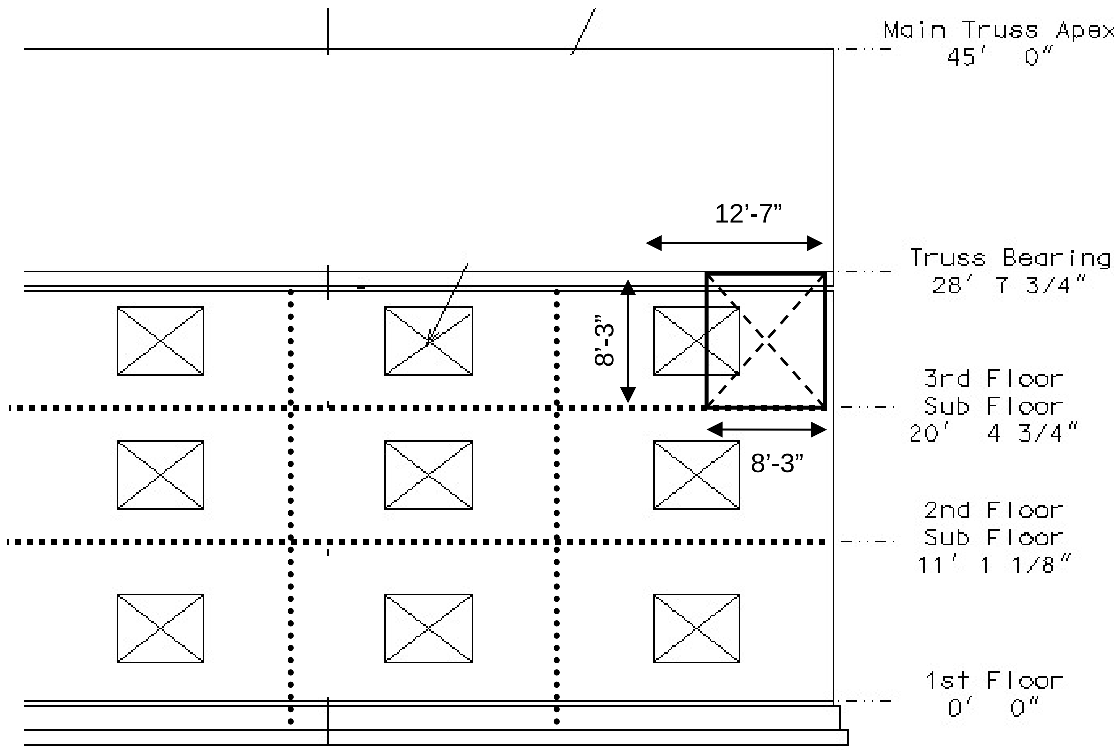


Figure F-10. Exterior Corner Wall Removal

The primary loading is that of the roof trusses:

Dead Load
Roof: 25 psf * 25'-11" / 2 = 324 plf

Roof live load not applicable for UFC design combination

Snow Load
7 psf * 25'-11" / 2 = 91 plf

Linear Static AP Load Case for Deformation Controlled Elements:
$\boldsymbol{G_{LD} = \Omega_{LD}\,[1.2D + 0.2S]}$

From ASCE 41-13 Table 12-3:
for "Frame Components Subjected to Axial Tension and/or Bending"
m = 2.5 for Life Safety Primary Element

Connections to include:
m = 6.0 for "Nails – Wood to Wood"

m = 2.8 for "Machine Bolts – Metal to Wood"

m = 2.5 controls

$\boldsymbol{\Omega_{LD}}$ = 2.0m = 5.0 (UFC Table 3-4)

$\boldsymbol{G_{LD}}$ = 5.0*(1.2*(324) + 0.2*(91)) = 5.0*(407 plf) = 2,035 plf

Provide new glulam beams at truss level, as shown in Figure F-11, to provide capacity for corner cantilever

Cantilever span = L = 12'-7"

Q_{UD} = $\boldsymbol{G_{LD}}$ * L^2 / 2 = 2,035 plf * $(12.6 \text{ ft})^2$ / 2 = 161,539 lb-ft

Try glulam 24F-V5 Southern Pine

ANSI/AFPA SDPWS-2005

Fb = 2400 psi

Volume factor Cv = $[(21 / L_o)^{(1/20)} * (12 / d)^{(1/20)} * (5.125 / b)^{(1/20)}] \leq 1$]
L_o = 2 * L for cantilever = 25.2 ft
Width = b = 3"
Depth = d = 12.375"

C_v = $[(21 / 12.6)^{(1/20)} * (12 / 12.375)^{(1/20)} * (5.125 / 3)^{(1/20)}] \leq 1]$
C_v = 1

S = $b*d^2/ 6 = 76.6 \text{ in}^3$

C_L = $(1 + Fbe/Fb) / 1.9 – \text{sqrt} (((1+ Fbe/Fb) / 1.9)^2 – (Fbe/Fb) / 0.95)$

Rb = $\text{sqrt} (Le * d / b^2)$

Beam supported against lateral and rotational displacement by nailing at each truss bearing post at 48" on center.

Lu = 48"
Le = 1.33 * Lu (uniformly distributed load on cantilever) = 63.8"

Rb = $\text{sqrt} (63.8 * 12.375 / 3^2)$

FbE = $1.2 \text{ Emin} / Rb^2 = 1.2 * 0.78 * 10^6 * (1.5/0.85) / 9.37 = 18817$
Fbe/Fb = 18817 / 2400 = 7.84

C_L = (1 + Fbe/Fb) / 1.9 – sqrt (((1+ Fbe/Fb) / 1.9)^2 – (Fbe/Fb) / 0.95)
C_L = (1 + 7.84) / 1.9 – sqrt (((1+ 7.84) / 1.9)^2 – (7.84) / 0.95) = 0.99

Lesser of C_L or C_v shall apply, C_L = 0.99

F'b = C_L C_{fu} K_f Φ_b λ Fb

All factors 1 except:
C_L = 0.99
Φ = 0.85
K_f = 2.16 / Φ
λ = 1 per UFC

ϕF'b = 0.99 * 2.16 * 2400 psi = 5146.7 psi

ϕQ_{CE} = M' = ϕF'b * S = 5146.7 psi * 76.6 in^3 = 394,084 lb-in = 32,840.3 lb-ft

$\phi m Q_{CE} \geq Q_{UD}$

$\phi m Q_{CE}$ = 32,840.3 lb-ft * 2.5 = 82,100.8 lb-ft
Q_{UD} = 161,539 lb-ft

Q_{UD} / $\phi m Q_{CE}$ = 1.97 therefore require two (2) 24F-V5 Southern Pine 12.375" x 3" beams

Provide one (1) 24F-V5 Southern Pine 12.375" x 3" beam at each side of roof truss vertical bearing post. Stagger the splice of these beams and provide a third identical beam between vertical truss posts at splice location.

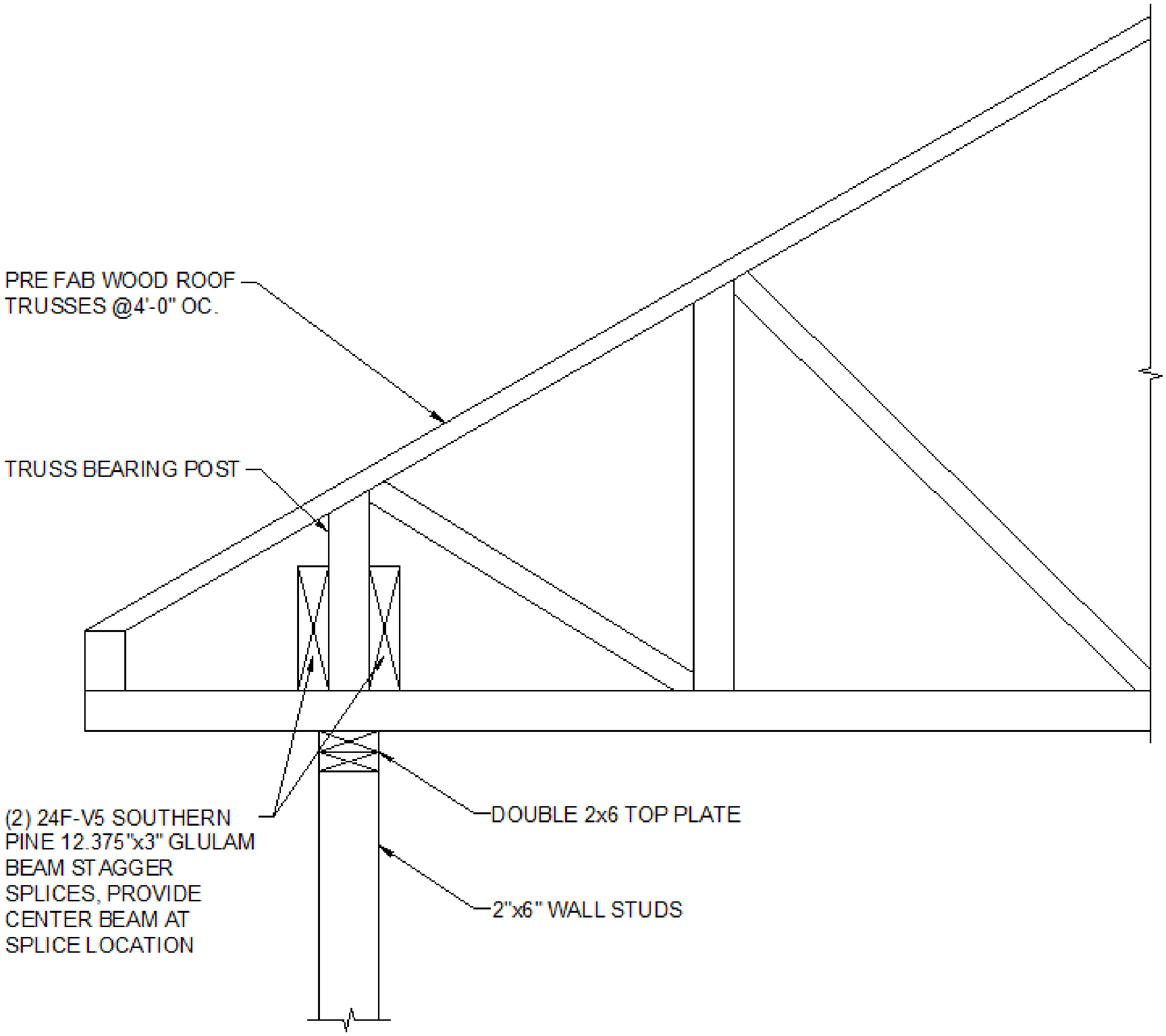


Figure F-11. Exterior Roof Beams

Anchorage of beams required to prevent uplift of the cantilever backspan. Nail Glulam to truss posts, and utilize hold-down anchors, such as Simpson HD9B at each side of truss post to resist uplift.

Two tie downs shall be used so in accordance with ASCE 41-13 section 12.3.3:
“demands on nails, screws, lags, bolts, split rings and shear plates used to link wood components to other wood or metal components shall be considered deformation controlled actions. Demands on bodies of connections and bodies of connection hardware shall be considered force controlled actions”

Accordingly, since 2 tie downs will be used, the action shall be considered force controlled.

$\boldsymbol{\Omega_{LD}}$ = 2.0 (UFC Table 3-4)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*(324) + 0.2*(91)) = 2.0*(407 plf) = 814 plf

Cantilever moment = $\boldsymbol{G_{LF}}$ * L^2 / 2 = 814 plf * $(12.6\text{ ft})^2$ / 2 = 64615.3 lb-ft
Backspan distance = 11'-5" = 11.4 ft
Uplift reaction = 64615.3 lb-ft / 11.4ft = 5668.8 lbs

Based on bolting into (2) 2x6 wall headers:
Capacity of Simpson HD9B = 7740 lbs

A single anchor would suffice; however provide 2 anchors to prevent connection eccentricity.

See Figure F-12 for tie down regions and Figure F-13 for anchorage configuration.

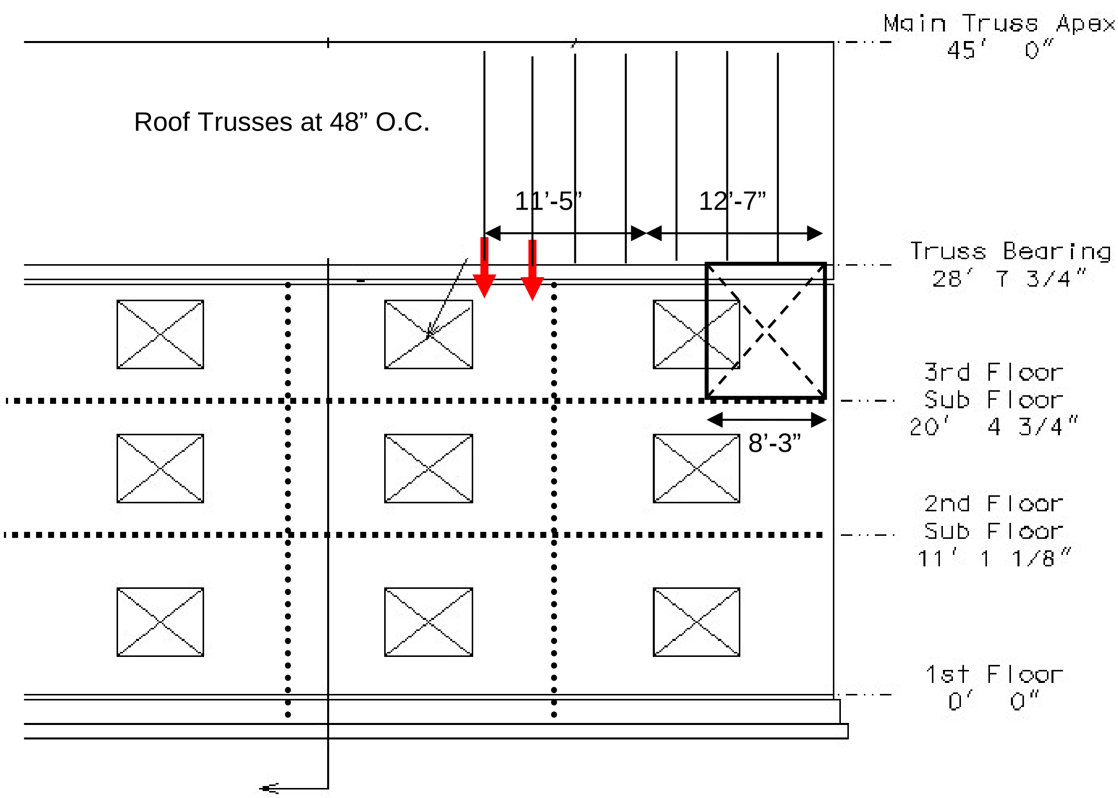


Figure F-12. Exterior Corner Wall Removal Tie Down Locations

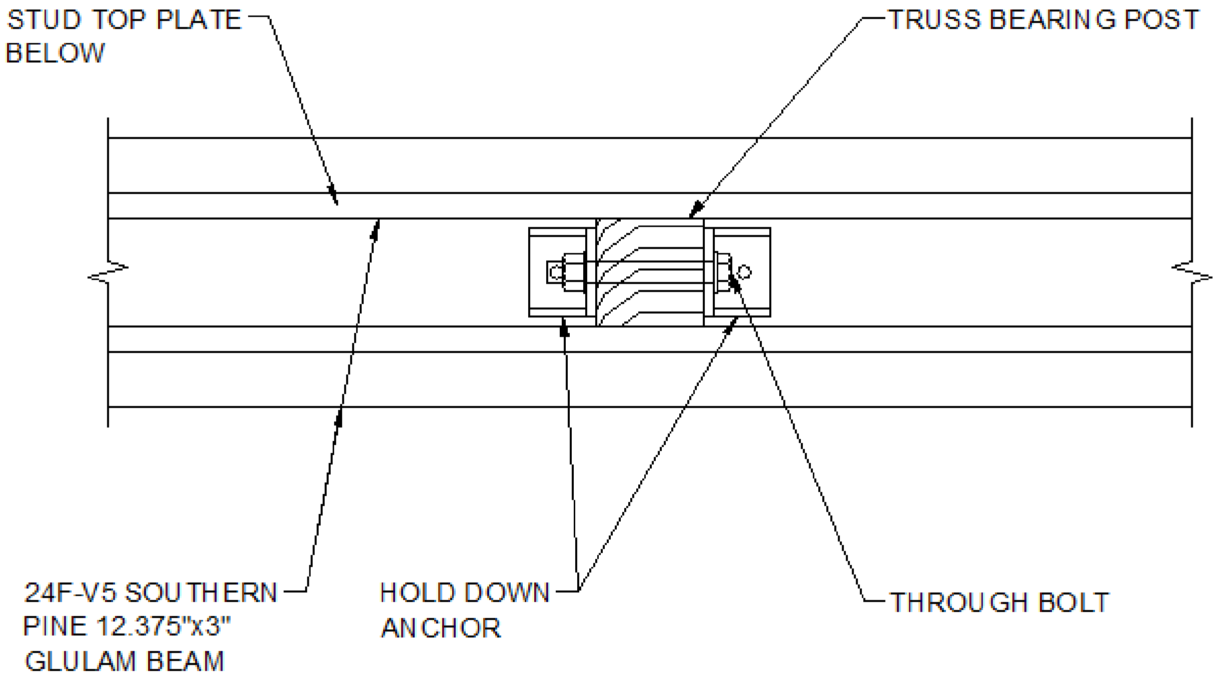


Figure F-13. Roof Beam Tie Down Anchorage, Plan View

For a stud bearing to support bridging, beam shall be force-controlled:

Stud compression in lowest level: QUF = G_{LF} * L + Uplift reaction + additional wall load

Additional wall load carried by each stud to the foundation

h = 28’-8” = 28.67’ stud spacing = 2 ft wall DL = 7 psf

Additional wall load = 2.0 * (0.5* 7 psf * 28.67’) = 201 lbs / ft * 2 ft = 402 lbs

Q_{UF} = 814 lb/ft * 12.6 ft + 5669 lbs + 402 lbs = 16,328 lbs

Compression carried by 2x6 studs at 2’ on center with in-plane bracing provided by sheathing and blocking. Check as column for out-of-plane strength of lower story

Per F-3.2 Stud strength is 9820 lbs / stud

16,328 lbs / 9,820 = 1.7 studs

2 studs available at each window jamb **OK**

/2/

Change 2
1 June 2013

APPENDIX G COLD FORMED STEEL EXAMPLE

G-1 INTRODUCTION

A cold formed steel load-bearing wall structure example has been prepared to illustrate Alternate Path analysis of a cold formed steel structure. The structure is assumed to have an occupancy of less than 100 people and is classified as \3\ Risk Category /3/ II per UFC 3-301-01.

The example has been prepared using tools and techniques commonly applied by structural engineering firms in the US. For cold formed design, this example relies primarily upon hand analysis supplemented with publically available AISIWIN software and standard design tables published in the International Building Code. \3\ Risk Category /3/ II Option 2: Alternate Path has been selected from UFC Table 2-2 to evaluate resistance to progressive collapse.

G-2 BASELINE DESIGN

The example building is a 3-story cold formed steel structure, six bays long and two bays deep similar to the building considered in the Appendix F wood example. The relevant design information is shown in Figures G-1 through G-4.

Platform construction is used. The internal and end shear walls are load bearing, with a composite deck running in the direction of the long length of the structure. One 4.5-foot x 6-foot window opening is present in each room. The footings are reinforced concrete with masonry. There are no internal partition walls.

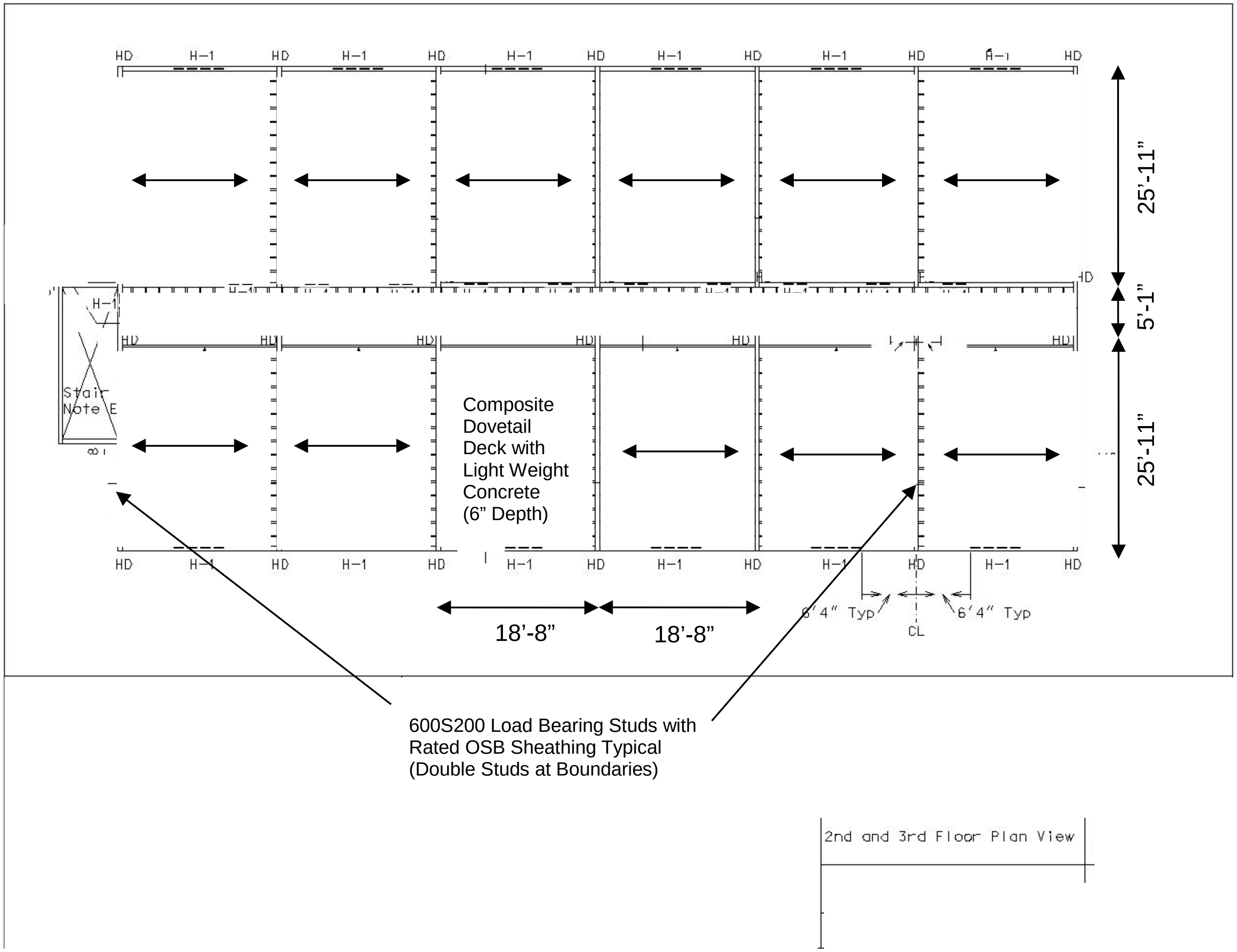


Figure G-1. Cold Formed Building Example Plan

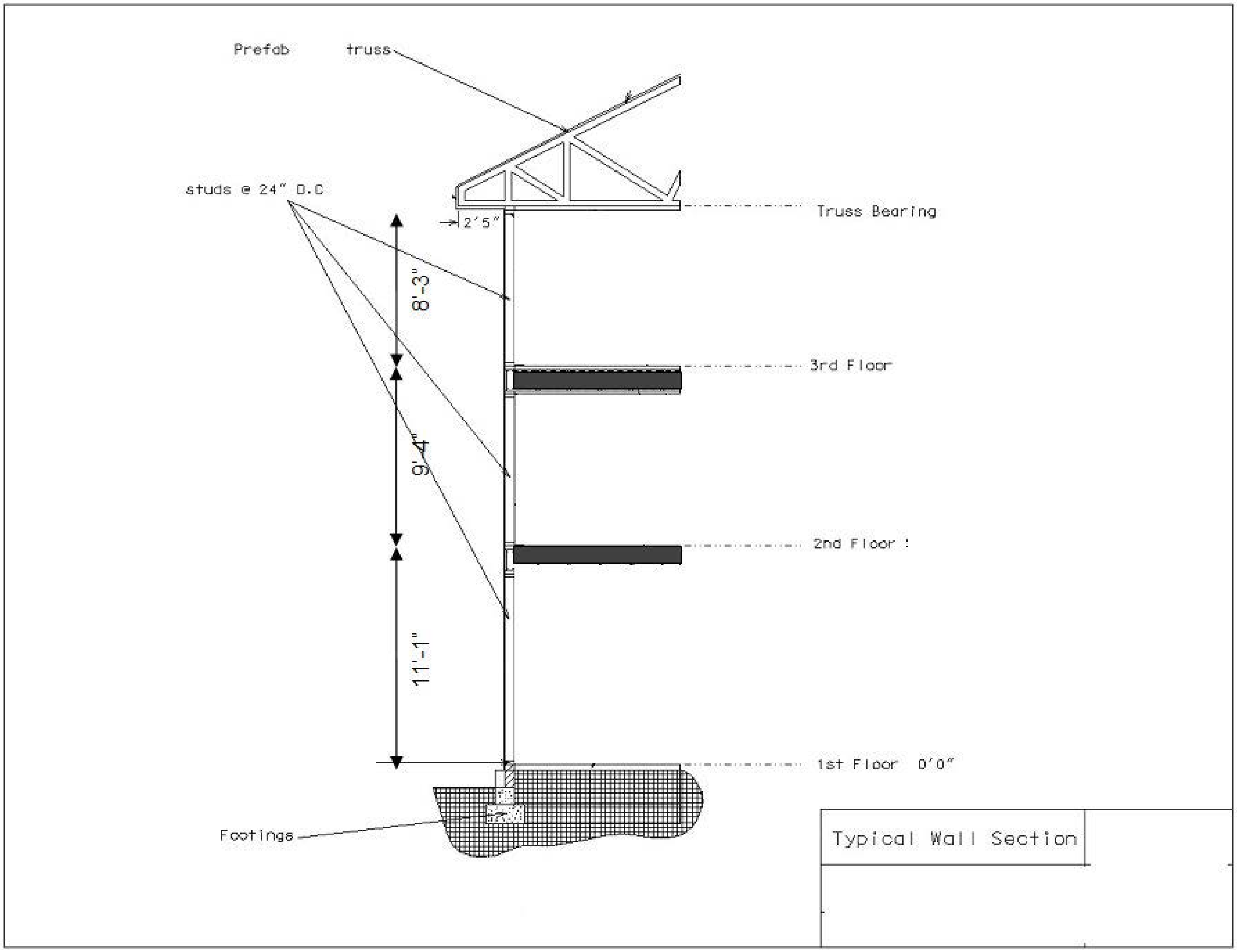


Figure G-2. Cold Formed Example Wall Section

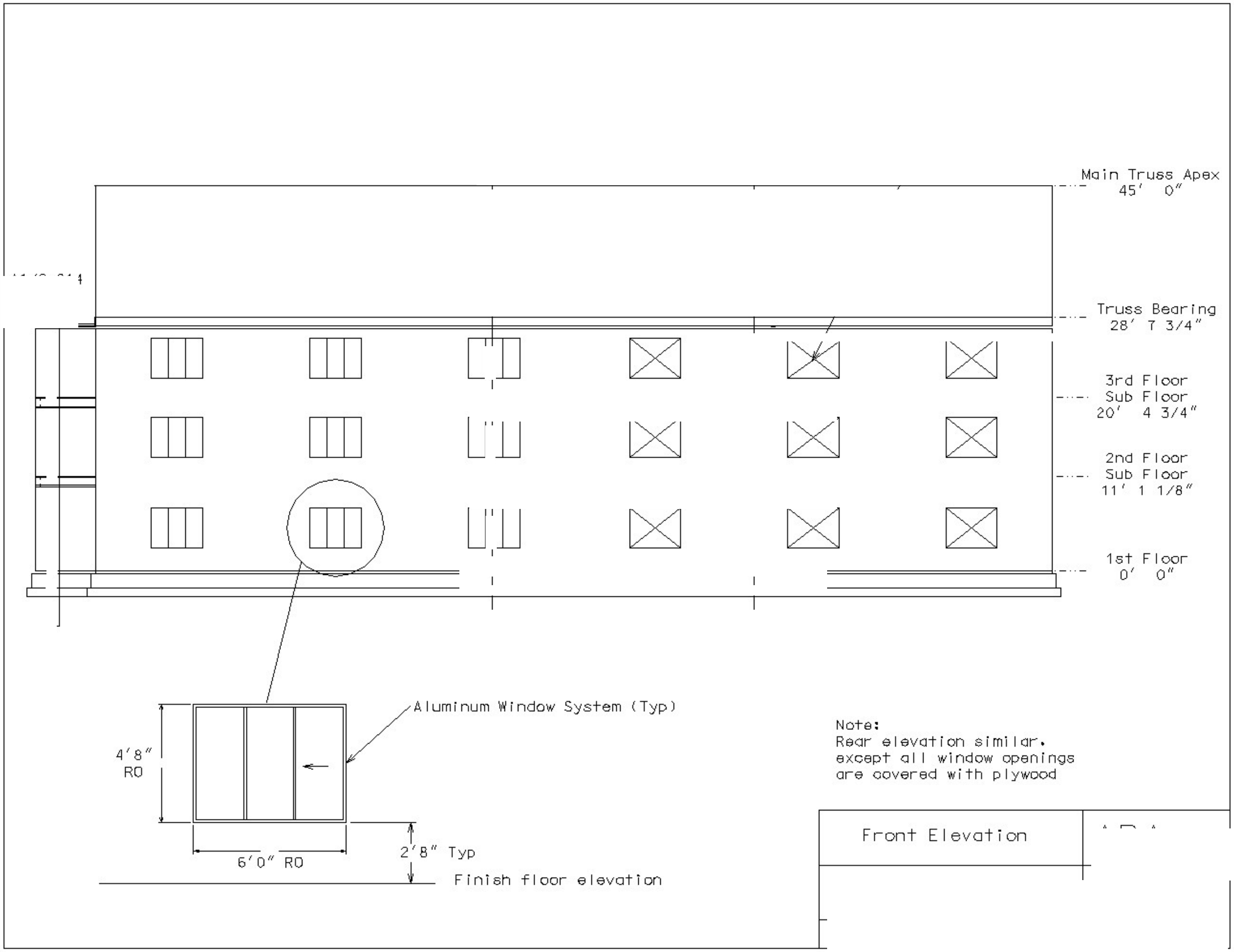


Figure G-3. Cold Formed Example Exterior Wall Elevation

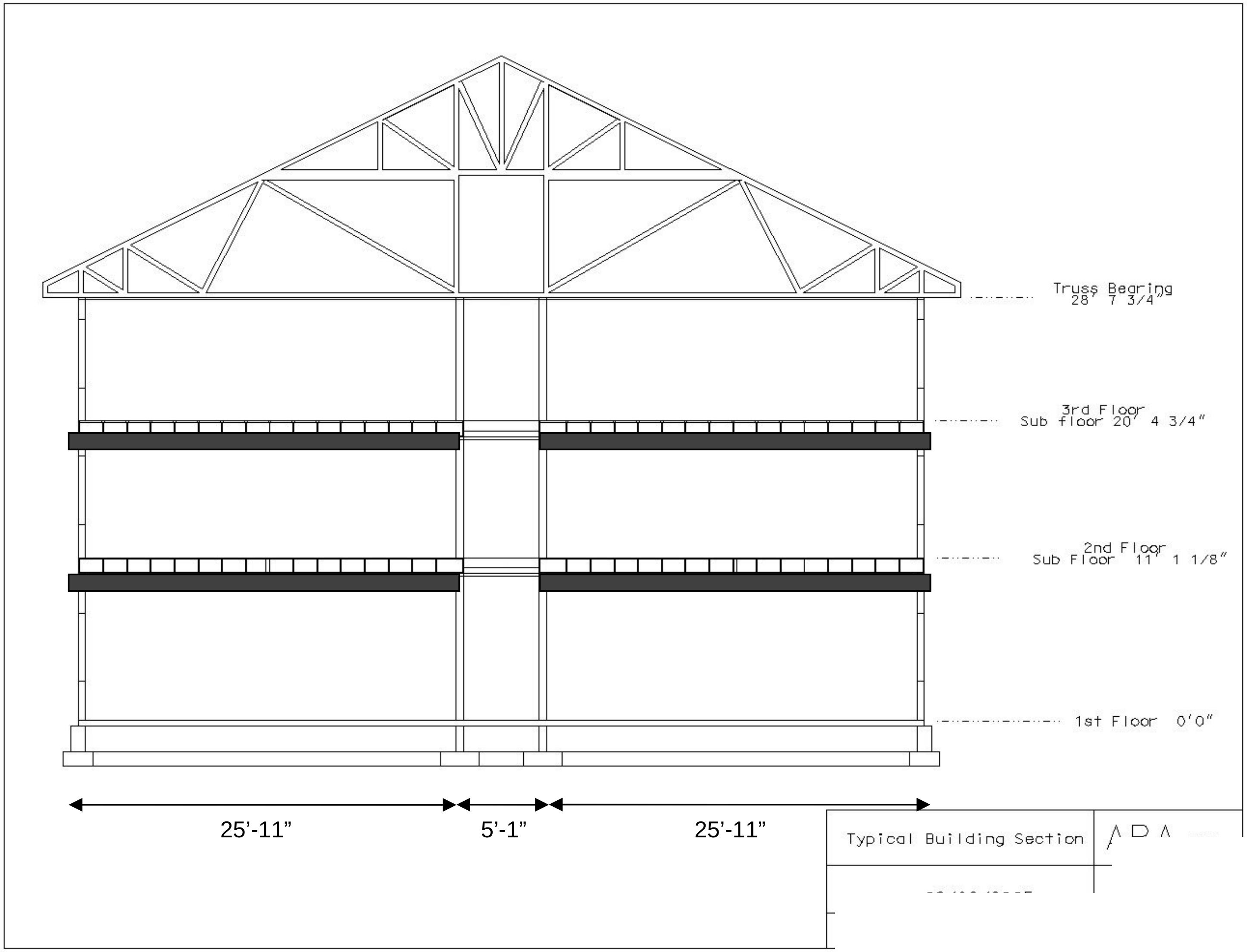


Figure G-4. Cold Formed Example Building Section

G-2.1 Construction and Materials

Wall Construction:
Interior Walls and Exterior End Walls: 7/16” rated OSB Sheathing both Faces, blocked
600S200-68 Gr50 studs at 24 inches on center
(2) 600S200-68 Gr50 studs stitched together at wall ends

Exterior Long Direction Walls: 7/16” rated OSB Sheathing exterior face, blocked
600S200-54 Gr50 studs at 24 inches on center
(2) 600S200-68 Gr50 studs stitched together at wall ends

Floor Construction:
Composite dovetail deck with light weight concrete (6” total depth) such as CSI Versa Deck or Vulcraft VLI.

Roof Construction:
Engineered Trusses with ½” Plywood Sheathing

Material Grades:
A653 Grade 50 cold formed steel

G-2.2 Loading Assumptions

Typical loading relevant to AP Analysis:

Floors:
Dead Load: 62 psf including concrete filled deck, MEP, ceiling
Live Load: 40 psf

Roof:
Dead Load: 25 psf including roofing and bottom surface ceiling
Live Load: 20 psf
Snow Load: 7 psf (design, including all applicable ASCE 7-05 factors)

Walls:
Dead Load: 7 psf including sills and headers

Live loads reducible depending on tributary area considered.

G-2.3 Relevant Standards and Reference Documents

American Iron and Steel Institute (AISI) North American Specification for Design of Cold-Formed Steel Structural Members

International Building Code 2006

For design compatibility with UFC 4-023-03, the LRFD approach is followed.

G-3 ALTERNATE PATH ANALYSIS

An alternate path (AP) analysis is conducted according to the requirements of Section 3-2. Removal scenarios are defined by 3-2.9. To bridge the wall removals, the remaining load bearing walls will be utilized as shear wall elements. The linear static AP analysis method will be followed.

G-3.1 Scope and Analysis Assumptions

Three scenarios of wall removal will be evaluated:

1. Removal of interior load-bearing wall (see Figure G-5) at first story
2. Removal of exterior long walls (see Figure G-6) at second story
3. Removal of exterior long walls (see Figure G-7) at third story

General assumptions of the analysis are as follows:

- No wind or internal pressure acts on interior or exterior walls during wall removal scenario
- Contributions of engineered roof trusses to the alternate path capacity are neglected due to uncertainty in specific properties during the design phase. At the designer's option, these elements could be included, provided that appropriate performance specifications including AP requirements are incorporated into the contract documents.

Per ASCE 41-13
C12.2.2.5:
"Actions associated with wood and light metal framing components generally are deformation controlled, and expected strength material properties will be used most often."

12.3.3:
"Demands on connectors, including nails, screws, lags, bolts, split rings, and shear plates used to link wood components to other wood or metal components shall be considered deformation controlled actions. Demands on bodies of connections, and bodies of connection hardware, shall be considered force-controlled actions."

For the AP analysis of this structure, wood shear wall assemblies and primary connections will be taken to be deformation controlled elements. Bodies of connectors will be checked as force controlled elements as required.

G-3.2 AP Analysis of Interior Load Bearing Wall Removal

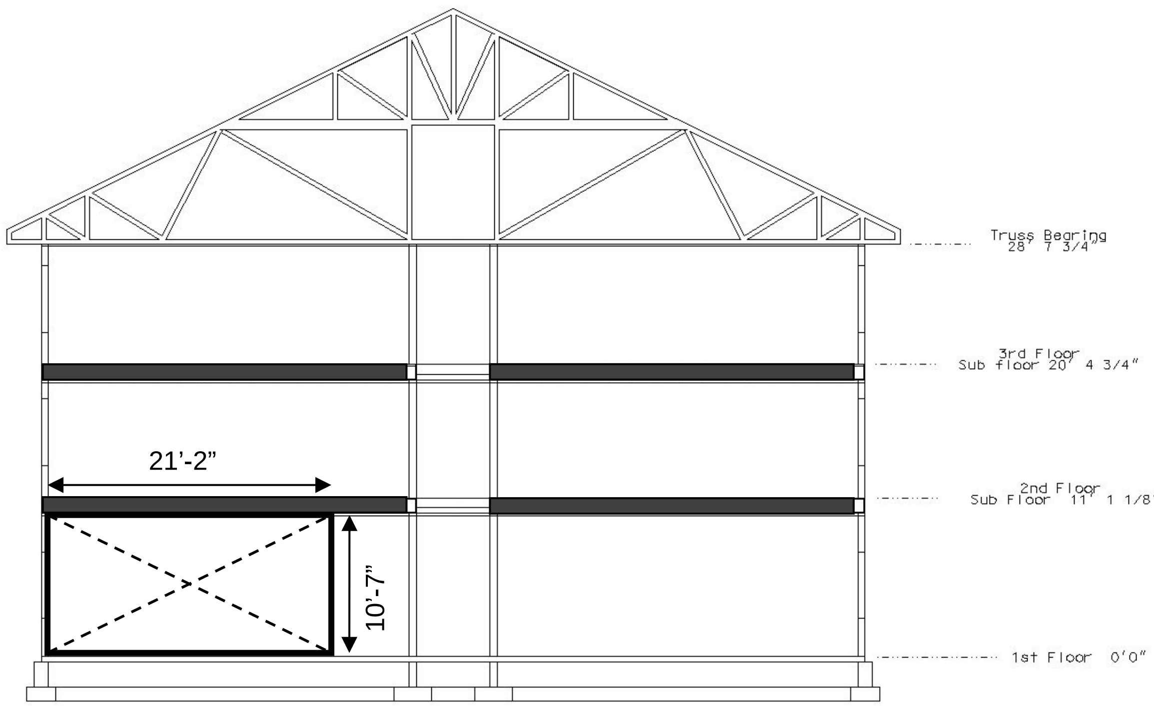


Figure G-5. Interior Load Bearing Wall Removal

As shown in Figure G-5, a segment of wall of length 2H is removed from the lower floor interior load bearing wall. H is taken as the distance between the 1st floor sub-floor elevation and the bottom of the 6-inch floor slab at the 2nd floor (=10'-7").

The remaining structure creates a shear wall element that must span the floor and wall loads from the 2nd and 3rd stories. The shear walls above will be divided by the floor slab at each level. The wall from level 2 to level 3 will have an overall depth of 8'-10" and the wall from level 3 to the roof level will have an overall depth of 8'-3". The boundary (chord) elements consist of 600T200 track provided at the top and bottom of each wall.

To bridge the removed section of wall, the shear wall panel must span from the exterior wall to a wall pier segment consisting of the remaining portion of the removed lower story interior wall. Note that no continuity action that might engage the right-hand wall panels in Figure G-5 is possible due to the corridor opening.

The structure contains no irregularities and therefore the linear static AP analysis is permitted per Section 3-2.11.1.1.

Loading:

Dead Load
Floors (each): 62 psf * 18'-8" = 1153 plf
Walls (each level): 7 psf * 9'-4" = 65 plf

Reduce live load in accordance with IBC 2006 1607.9.2:

A = 18.67'*25.91'*2 = 967.5 SF
R = 0.08 (A – 150) = 0.08 (967.5-150) = 65.4%
R_{max} = 60% or 23.1(1 + 62/40) = 58.9%

Live Load used in AP check (each level)
40 psf * 18.67' * (1-0.589) = 307 plf

Linear Static AP Load Case for Deformation Controlled Elements:

$G_{LD} = \Omega_{LD} [1.2D + 0.5 L]$

From ASCE 41-13 Table 12-3:
for "Wood Structural Panel Sheathing or Siding"
h = 21.17'/2 = 10.59'
b = 8.25'
h/b = 10.59'/8.25' = 1.28 < 2.0
m = 3.8 for Life Safety Primary Element

Connections to be screwed:
m = 1.8 for "Screws –Metal to Wood"

m = 1.8 controls

Ω_{LD} = 2.0m = 3.6 (UFC Table 3-4)

G_{LD} = 3.6*(1.2*(1153 +62) + 0.5*(307)) = 3.6*(1640 plf) = 5,802 plf (each level)

Deformation controlled actions:

Shear: Q_{UD} = 5,802 plf * 21.17' / 2 / 8.25' = 7,444 plf in wall

Capacity checks of deformation controlled actions:

Shear in Wall:

Wall shear strength $\phi Q_{CE} = 1.5 (\phi v_s)$
where ϕv_s = LRFD shear strength of wall taken from IBC

Factor 1.5 for expected strength is taken from ASCE 41-13 12.4.9.2 but note that Section 3-2.11.7.1 requires inclusion of the material specific ϕ factor whereas ASCE 41-13 uses a ϕ of 1.0.

From IBC Table 2306.2:

For "Wood Structural Panels – Sheathing", 7/16" rated OSB sheathing, fasteners at 4" O.C max at edges:
v_{WC} = 1410 plf (for one side of wall)
Note that value for wind is chosen rather than seismic per UFC Ch. 7.

Since the interior walls have identical plywood sheathing on both sides, capacity of each individual side is additive per IBC 2211.2.2.

ϕ = 0.55 for LRFD per IBC 2211.2.1
ϕv_S = 0.55 (1410 plf) (2) = 1551 plf
ϕQ_{CE} = 1.5 (ϕv_S) = 1.5 (1551) = 2327 plf

Check UFC Equation 3-13:

$\phi m Q_{CE} \geq Q_{UD}$
2327 plf (3.8) = 8,842.6 plf > 7,444 plf **OK**

For force controlled actions:

$\boldsymbol{\Omega_{LD}}$ = 2.0 (UFC Table 3-4)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*(1153 +62) + 0.5*(363)) = 2.0*(1640 plf) = 3,280 plf (each level)

Force controlled actions:

Moment in each wall above: Q_{UF} = 3,280 plf * 21.17' * 21.17' / 8 = 183,749 lb-ft
Chord Force: Q_{UF} = M/h = 183,749 lb-ft / 8.25 ft = 22,273 pounds

Though ASCE 41 is somewhat ambiguous on the subject, consider the chord forces to be forced controlled actions because ASCE 41 Table 12-3 designates "Frame Components Subject to Axial Compression" as force controlled. Treating both tension and compression chords as force controlled will be conservative.

Each chord and track element will be fully braced in both directions:

600T200-54
ASTM A653 Gr 50 Fy = 50ksi Fu = 65 ksi

Tension yield
ϕ_t = 0.9
T_n = A_g F_y
A_g = 0.5653 in^2
ϕ_t T_n = 0.9 * 0.5653 in^2 * 50,000 psi = 25,438 pounds

Tension fracture
ϕ_t = 0.75
T_n = A_n F_u
A_n = Ag – 3 * 3/16" * 0.054" = 0.535 in^2 (3 - #8 screws)
ϕ_t T_n = 0.75 * 0.535 in^2 * 65,000 psi = 26,078 pounds

Compression
ϕ_t = 0.85
P_n = A_g F_y
A_g = 0.5653
ϕ_t T_n = 0.85 * 0.5653 in^2 * 50,000 psi = 24,025 pounds

ϕQ_{CL} = 24,025 pounds for (1) 600T200-54 > Q_{UF} = 22,273 pounds

Track must be spliced with a minimum gross area of 0.56 in^2 or doubled across splice locations

At each edge of the removed wall segment, the shear present in the wall above must be transferred into the load bearing walls studs below. Compression in wall studs shall be considered force controlled.

$\boldsymbol{G_{LF}}$ = 3,280 plf (each level) 6,560 plf (2 levels) above

Wall shear: Q_{UF} = $\boldsymbol{G_{LF}}$ * L / 2

Q_{UF} = *6,560* * (21.17 ft) / 2 = 69,437 lbs each side of removal

Typical studs are 600S200-68 at 24" on center and are braced in-plane by rated sheathing and mid-height blocking and will be controlled by out-of-plane buckling.

Stud length at the lower level = (11' -1") – (0'-6") = 10' – 7" = 10.6 ft

Per American Iron and Steel Institute (AISI) North American Specification for Design of Cold-Formed Steel Structural Members

ϕ_c = 0.85
λ_c = $\sqrt{(Fy/Fe)}$
F_e = $\pi^2 E/(KL/r)^2$
F_y = 50 ksi

E = 29,000 ksi
KL_x = 127.2 in
r_x = 2.3162 in
A_e = 0.6574 in^2

KL/r_x = 127.2 in / 2.3162 in = 54.92
F_e = $\pi^2 E/(KL/r)^2 = \pi^2 * 29000 / (54.92)^2$ = 94.9 ksi
λ_c = $\sqrt{(50/94.9)}$ = 0.726

For λ_c =1.5 $\quad$ $Fn = (0.658^{(\lambda c)\,\wedge 2})\, F_y$

$F_n = 0.658^{0.726\wedge 2} * 50$ ksi = 27.23 ksi

$\phi_c P_n$ = $\phi_c * F_n * A_e$ = 0.85 * 27.23 ksi * 0.6574 in^2 = 15.2 kips per stud

Q_{UF} = 69.4 kips / 15.2 kips per stud = 4.6 studs

Studs at 24 in on center, therefore 5 studs available per 8 feet of wall

Removed wall section could be located at edge of exterior wall, or shifted toward the interior bearing walls, therefore 5 studs must be available at either exterior or interior long direction walls. A minimum of 6 studs will be available at the interior long direction walls, therefore the wall stud compression strength is adequate.

Bearing load will be transferred through concrete floor system to allow distribution to multiple studs.

Secondary Component Check

The composite floor deck consists of 4” light weight concrete over 2” dovetail deck and must span 18’-8” to be supported by the short direction load bearing walls. Removal of a load bearing wall will result in loss of support for deck. Accordingly, the deck shall be connected to the wall above to prevent collapse in the event of a bearing wall removal.

The floor joists shall be hung from the wall above using a tension tie screwed to the 600S200-68 wall stud above which will include a threaded tension rod through bolted to the deck (See Figure G-6) and including a plate washer to prevent the tension rod from pulling through the deck.

Connection of each floor slab will consist of multiple connectors so it shall be considered force controlled:

Floor loadings:
DL = 62 psf * 18.67’ * 2’ = 2315 lbs
LL = 40 psf * 18.67’ * 2’ = 1494 lbs (no live load reduction due to limited tributary area for each tension tie)

$\boldsymbol{\Omega_{LD}}$ = 2.0 (UFC Table 3-4)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*DL + 0.5*LL)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*(2315 lbs) + 0.5*(1494)) = 7050 lbs

The tension tie capacity must be greater than 7050 lbs. Accordingly, provide one (1) Simpson HTT5 with 26 #10 screws into the wall stud above with a capacity of 6505 lbs. Note that 6505 lbs is less than the required capacity, however the nominal tension capacity of the hanger is 11,585 lbs. This capacity, in conjunction with a phi factor of 0.6 will indicate sufficient strength. The 600S200-68 stud has sufficient strength and thickness to support this tension hanger. See Figure G-6 for a detail showing the floor system connection to the wall above.

In order to prevent the through bolt from tearing through the floor system, a plate washer shall be used. Grout packing will be needed at locations for which the washer must bear on the unfilled portion of the dovetail deck. Additionally, typical floor reinforcement in the direction of the deck span shall continue across load bearing wall supports and transverse reinforcement shall be provided above each interior load bearing wall to distribute forces horizontally between each tension hanger connection.

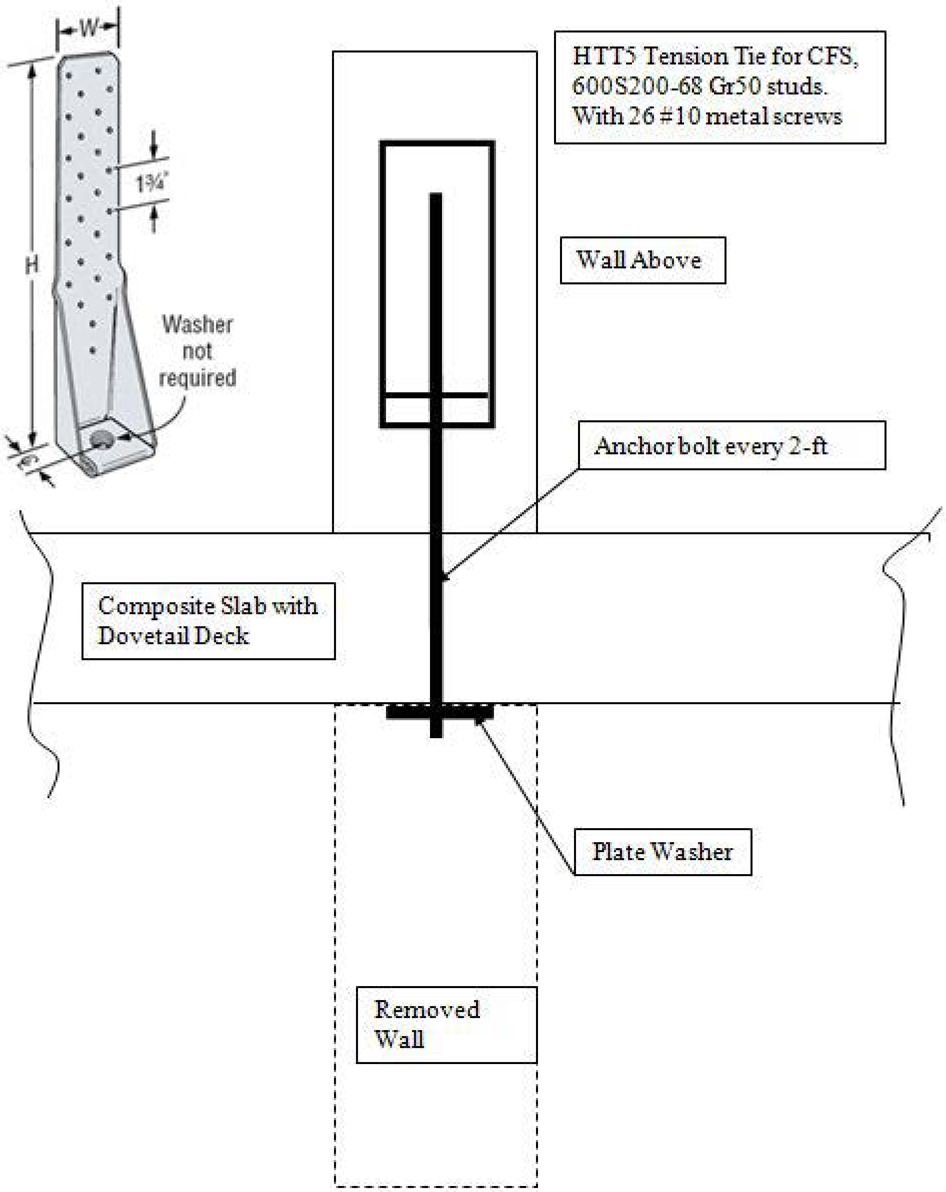


Figure G-6. Floor System Support Detail

Removal of a wall segment above the 2nd floor would produce similar analysis and results to those described above as the load resisted is roughly proportional to the available depth of remaining wall per level.

Similarly, removal of an exterior load bearing wall along the short side would produce results consistent with the interior removal as the tributary area of floor carried is roughly half that of an interior wall, and the provided capacity will be similar.

G-3.3 AP Analysis of Removal of Exterior Load Bearing Walls (Long Direction)

As shown in Figure G-7, a segment of wall of length 2H is removed between the second and third floors. H is taken as the distance between the 2nd floor sub-floor elevation and the bottom of the concrete deck at the 3rd floor (= 8'-10").

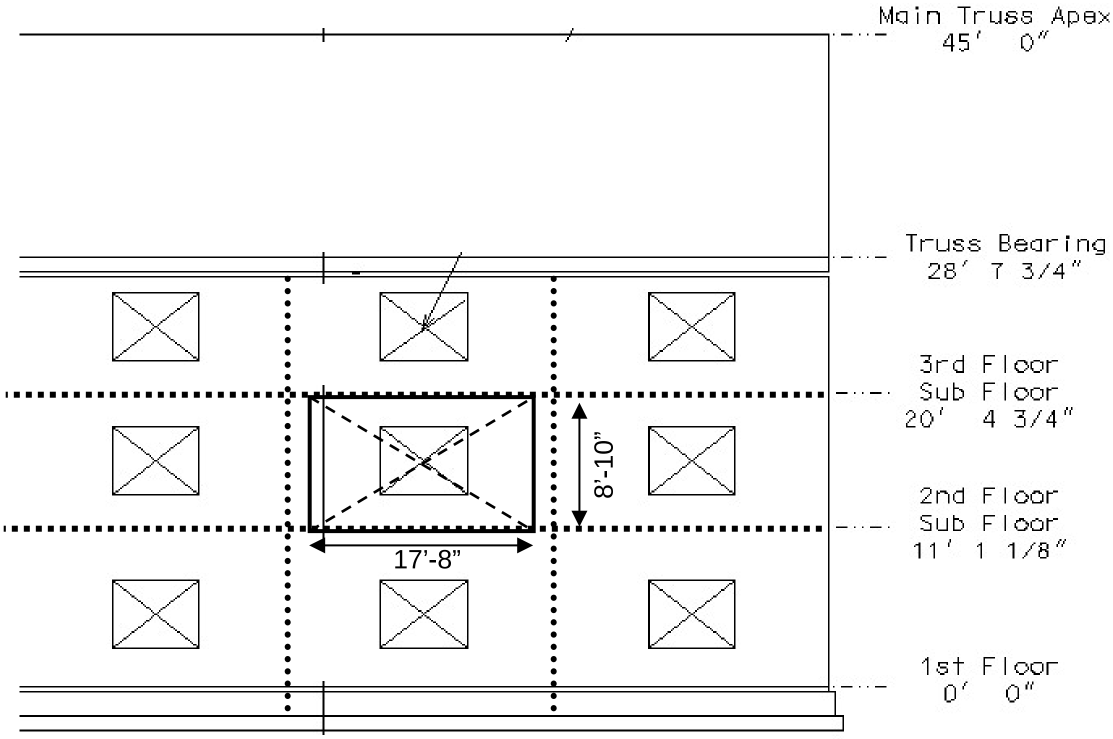


Figure G-7. Exterior Wall Removal

The chosen area of removal between the second and the third floor will allow for the shear wall above to span over and be supported on each side of the removed wall section. (Note: shifted removal locations could be addressed similar to the wood building examples of Appendix F).

The primary loading is that of the roof trusses:

Dead Load
Roof: 25 psf * 25'-11" / 2 = 324 plf
Wall: 7 psf * 8'-9" = 61 plf

Roof live load not applicable for UFC design combination

Snow Load
7 psf * 25'-11" / 2 = 91 plf

Linear Static AP Load Case for Deformation Controlled Elements:
G_{LD} = Ω_{LD} [1.2D + 0.2S]

From ASCE 41-13 Table 12-3:

for "Wood Structural Panel Sheathing or Siding"
h = 8'-10" b= 8'-9"
h/b = 8.83/8.75 = 1.0 < 2.0
m = 3.8 for Life Safety Primary Element

Connections to be screwed:
m = 1.8 for "Screws – Metal to Wood"

m = 1.8 controls

Ω_{LD} = 2.0m = 3.6 (UFC Table 3-4)

G_{LD} = 3.6*(1.2*(324+61) + 0.2*(91)) = 3.6*(480 plf) = 1,644 plf

Total force onto the removed section

F = 1644 lb/ft * 17.67 ft = 29,028 lbs

Shear each side V = 29,028 lbs / 2 = 14,514 lbs

Unit shear = 14,514 lbs / 8.83' = 1644 plf

For "Wood Structural Panels – Sheathing", 7/16" rated OSB sheathing, fasteners at 4" O.C max at edges:

v_{wc} = 1410 plf (for one side of wall)

Per IBC Table 2211.2, where gyp wall board is applied on opposite side of wall with fastener spacing less than 7" on center, shear strength may be increased by 30%.

ϕ = 0.55 for LRFD per IBC 2211.2.1
ϕv_s = 0.55 (1410 plf) (1.3) = 1008 plf
ϕQ_{CE} = 1.5 (ϕv_s) = 1.5 (1008) = 1512 plf

Check UFC Equation 3-13:

$\phi m Q_{CE} \geq Q_{UD}$
1512 plf (3.8) = 5746 plf > 1644 plf **OK**

For force controlled actions:

$\boldsymbol{\Omega_{LD}}$ = 2.0 (UFC Table 3-4)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*(324+61) + 0.2*(91)) = 2.0*(481 plf) = 961 plf

Wall moment = $\boldsymbol{G_{LF}}$ * L^2 / 8 = 961 plf * $(17.67')^2$ / 8 = 37,507 lb-ft

Chord force = M/d = 37,507 lbs / 8.25' = 4,546 pounds = Q_{UF}

ϕQ_{CL} = 24,025 pounds for (1) 600T200-54 as established in G-3.2 > 4,546 pounds OK

For stud bearing to support bridging walls:

Q_{UF} = $\boldsymbol{G_{LF}}$ * L / 2 = 961 lb/ft * 17.67 ft / 2 = 33,962 lbs at each side of removed wall

Similar to G-3.2, compression strength of bearing walls is adequate to support bridging wall.

G-3.4 AP Analysis of Removal of Exterior Load Bearing Walls Below Third Floor (Long Direction)

As shown in Figure G-8, a segment of wall of length H is removed at exterior corners in each direction between the second and third floors. H is taken as the distance between the 3rd floor sub-floor elevation and the truss bearing location (=8'-3").

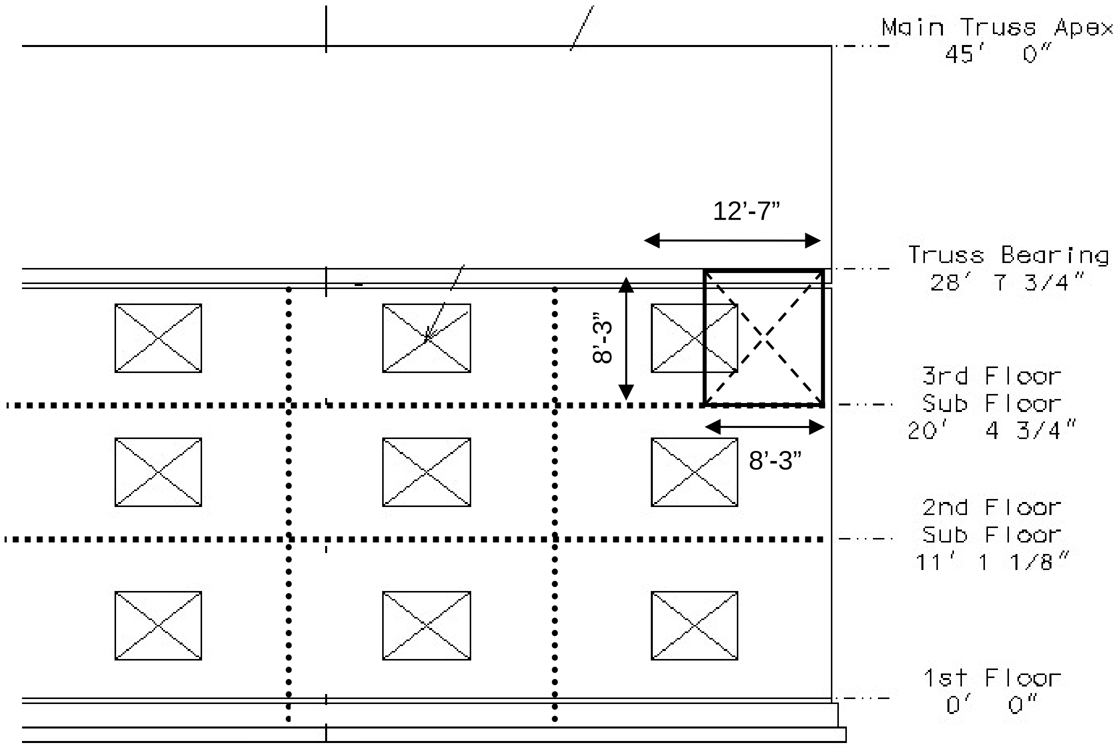


Figure G-8. Exterior Corner Wall Removal

The primary loading is that of the roof trusses:

Dead Load
Roof: 25 psf * 25'-11" / 2 = 324 plf

Roof live load not applicable for UFC design combination

Snow Load
7 psf * 25'-11" / 2 = 91 plf

Linear Static AP Load Case for Deformation Controlled Elements:
$G_{LD} = \Omega_{LD} [1.2D + 0.2S]$

Resistance will be provided by steel beam(s) at roof level braced at each roof truss at 4'-0" on center as shown in Figure G-9.

From ASCE 41-13 Table 9-5:

for "Frame Components Subjected to Axial Tension and/or Bending"
m = 8 for Collapse Prevention Primary Element

Connection for backspan to be similar to double angle shear tab
Per UFC Table 5-1
m = $5.8 - 0.107\ d_{bg}$ d_{bg} = 3”
m = 5.8 – 0.107 * 3 = 5.5

m = 5.5 controls

$\boldsymbol{\Omega_{LD}}$ = 0.9 m + 1.1 = 6.0 (UFC Table 3-4)

$\boldsymbol{G_{LD}}$ = 6.0*(1.2*(324) + 0.2*(91)) = 2,463 plf

Cantilever span = L = 12’-7”

Q_{UD} = $\boldsymbol{G_{LD}}$ * L^2 / 2 = 2,463 plf * $(12.6\ ft)^2$ / 2 = 195,513 lb-ft (2347 k-in)

Use Steel HSS beam Fye = 1.1 * 46ksi = 50.6 ksi

Beam supported against lateral and rotational displacement by bolting at each truss bearing post at 48” on center as shown in Figure G-9).

$\phi mQ_{CE} \geq Q_{UD}$
$\phi\ m\ F_{ye}\ Z$ = 0.9 * 8 * 50.6 ksi 8 Z ≥ 2347 k-in

$Z \geq 6.5\ in^3$ Use (2) HSS3x3x3/8” $Z_x = 3.25\ in^3$
Q_{UD} = 161,539 lb-ft

$Q_{UD} / \phi mQ_{CE}$ = 1.97 therefore require two (2) HSS3x3x3/8”

Provide (1) HSS3x3x3/8 beam at each side of roof truss vertical bearing post. Stagger the splice of these beams and provide a third identical beam between vertical truss posts at splice location or use a full moment splice at any splice locations.

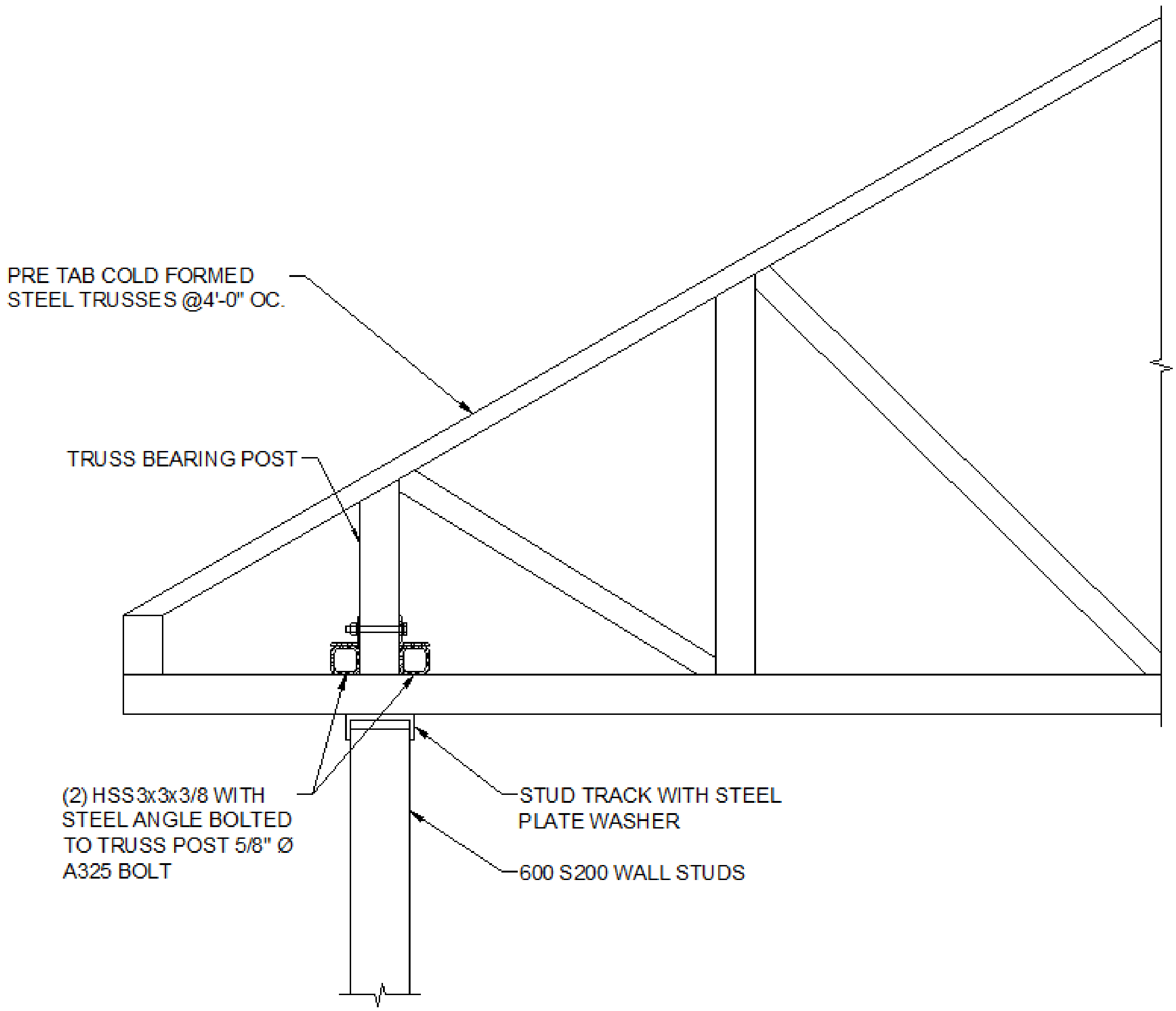


Figure G-9. Exterior Roof Beams

Anchorage of beams required to prevent uplift of the cantilever backspan at 11.4'. Attach beams using double angle connection to truss posts, and utilize hold-down anchors, such as Simpson HD7B at each side of truss post to resist uplift.

Double angle connection between HSS beams and truss shall be deformation controlled with m = 6

M_{LD} = 195,513 lb-ft
Vuplift = 195,513 lb-ft / 11.4' = 17,150 lbs
Bolt in double shear – 5/8" diameter A325 bolt
Per AISC table 7-1 ϕr_n = 11 kips
$m\phi r_n$ = 6 * 11 kips = 66 kips ≥ 17.15 kips

Two tie downs shall be used so in accordance with ASCE 41-13 section 12.3.3:
"demands on nails, screws, lags, bolts, split rings and shear plates used to link wood components to other wood or metal components shall be considered deformation controlled actions. Demands on bodies of connections and bodies of connection hardware shall be considered force controlled actions"

Accordingly, since 2 tie downs will be used, the action shall be considered force controlled.

$\boldsymbol{\Omega_{LD}}$ = 2.0 (UFC Table 3-4)

$\boldsymbol{G_{LF}}$ = 2.0*(1.2*(324) + 0.2*(91)) = 2.0*(407 plf) = 814 plf

Cantilever moment = $\boldsymbol{G_{LF}} * L^2 / 2$ = 814 plf * $(12.6\text{ ft})^2$ / 2 = 64615.3 lb-ft
Backspan distance = 11'-5" = 11.4 ft
Uplift reaction = 64615.3 lb-ft / 11.4ft = 5668.8 lbs

Capacity of Simpson HD7B = 6645 lbs

A single anchor would suffice; however provide 2 anchors to prevent connection eccentricity. Include a steel plate washer at wall header track to prevent anchor tension pullout.

See Figure G-10 for tie down regions and Figure G-11 for anchorage configuration.

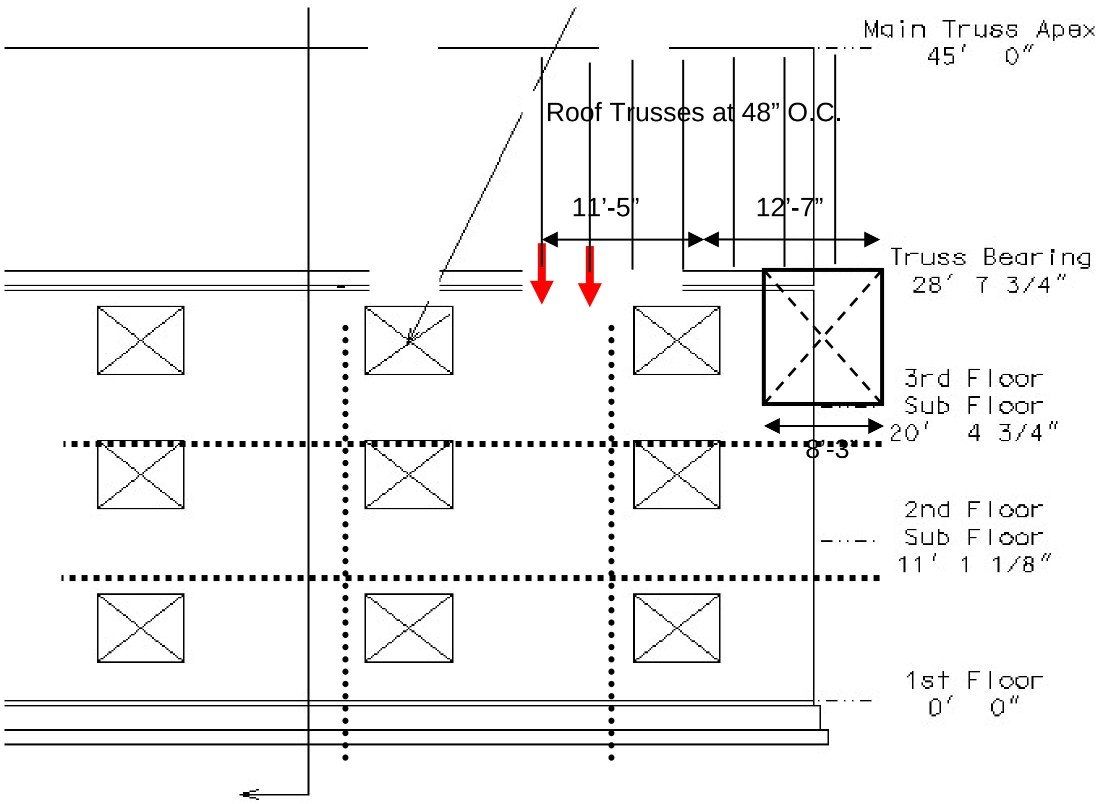


Figure G-10. Exterior Corner Wall Removal Tie Down Locations

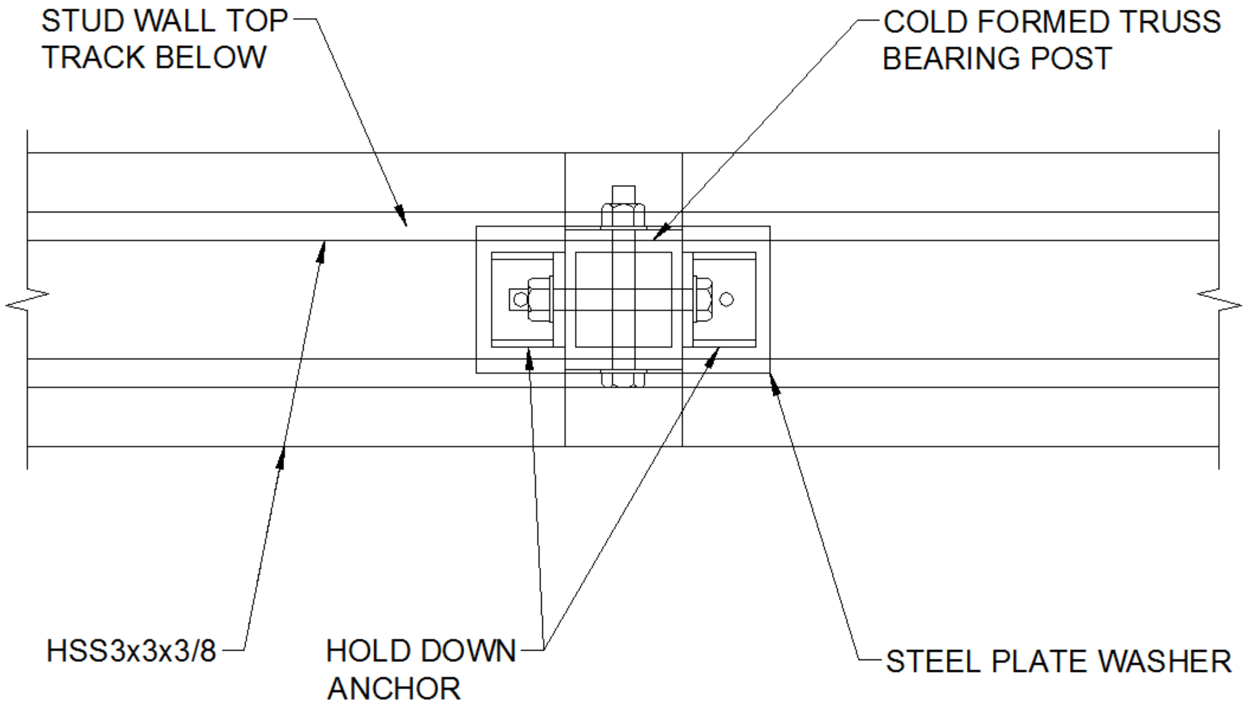


Figure G-11. Roof Beam Tie Down Anchorage, Plan View

Stud bearing to support bridging beam shall be force controlled:

Stud compression in lowest level:

Q_{UF} = $\boldsymbol{G_{LF}}$ * L + Uplift reaction + additional wall load

Additional wall load carried by each stud to the foundation

h = 28'-8" = 28.67' stud spacing = 2 ft wall DL = 7 psf

Additional wall load = 2.0 * (0.5* 7 psf * 28.67') = 201 lbs / ft * 2 ft = 402 lbs

Q_{UF} = 814 lb/ft * 12.6 ft + 5669 lbs + 402 lbs = 16,328 lbs

Compression carried by 600S200-68 studs at studs at 2' on center with in-plane bracing provided by sheathing and blocking. Check as column for out-of-plane strength of lower story

Per G-3.2 Stud strength is 15,200 lbs / stud

16,328 lbs / 15,200 = 1.1 studs

2 studs available at each window jamb **OK**

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APPENDIX H /2/INTERNATIONAL BUILDING CODE MODIFICATIONS FOR CONSTRUCTION OF BUILDINGS TO RESIST PROGRESSIVE COLLAPSE

The following narrative identifies required modifications to the provisions of the *International Building Code* (IBC 2015) addressing construction documents, structural tests and special inspections for buildings that have been designed to resist progressive collapse. The modifications reference specific sections in the IBC that require modification. Apply IBC requirements except as modified herein. The required IBC modifications are one of two actions, according to the following legend:

LEGEND FOR ACTIONS

[Addition] -- New section added, includes new section number not shown in IBC.

[Replacement] -- Delete referenced IBC section and replace it with the narrative shown.

Chapter 16 Structural Design

1603 Construction Documents

1603.1.9 [Addition] Progressive Collapse design data. The following information shall be indicated on the construction documents:

1. General note stating the follow:

    Design of the building is in accordance with UFC 4-023-03, DD/MM/YYYY. Future additions or alterations to this structure shall not jeopardize the requirements for progressive collapse resistance.

2. \3\ Risk Category /3/ II, III or IV.

3. Method of progressive collapse resistance (Tie Force, Alternate Path, Enhanced Local Resistance or combinations thereof).

1603.1.10 [Addition] Systems and components requiring special inspections for progressive collapse resistance. Construction documents or specifications shall be prepared for those systems and components requiring special inspection for progressive collapse resistance and shall be submitted for approval as specified in section 1705.11 by the registered design professional responsible for their design on 107.1.

Chapter 17 Structural Tests and Special Inspections

1701.1 [Replacement] Scope The provisions of this chapter shall govern the quality, workmanship and requirements for materials covered. Materials of construction and tests shall conform to the applicable standards listed in this code.

1710 [Addition] QUALITY ASSURANCE FOR PROGRESSIVE COLLAPSE REQUIREMENTS

1710.1 [Addition] Scope A quality assurance plan shall be provided in accordance with Section 1710.1.1.

1710.1.1 [Addition] When required. A quality assurance plan for progressive collapse requirements shall be provided for the following structures designed for various Risk categories as follows:

1. Structures designed for \3\ Risk Category /3/ II, where either 1) structural elements provide horizontal and vertical tie force capacity as well as additional ductility requirements in which the shear resistance of the corner and penultimate first story walls and columns is greater than the flexural resistance for lateral loads, or, 2) the alternate path method is used to provide bridging over the deficient elements.

2. Structures designed for \3\ Risk Category /3/ III, with horizontal and vertical tie forces, alternate path design, and enhanced local resistance where the columns or walls in the first two perimeter stories are designed for increased flexural and shear resistance.

3. Structures designed to \3\ Risk Category /3/ IV, which requires a design based on the results of a systematic risk assessment of the building.

1710.1.2 [Addition] Detailed requirements. When required by Section 1710.1.1, a quality assurance plan shall provide for the following:

1. Horizontal and vertical tie force connections as required based on material type.

2. Roof and floor diaphragm systems including transverse, longitudinal, and peripheral ties.

3. Vertical progressive collapse resisting systems including vertical ties and bridging connections.

4. Perimeter ground floor columns and walls with enhanced ductility requirements to ensure shear strength is greater than the flexural strength

1710.2 [Addition] Quality assurance plan preparation. The design of each designated progressive collapse resisting system shall include a quality assurance plan prepared by the registered design professional. The quality assurance plan shall identify the following:

1. The designated progressive collapse resisting systems and elements that are subject to quality assurance in accordance with 1710.1.

2. The special inspections and testing to be provided as required by sections 1704 and other applicable sections of this code, including the applicable standards reference by this code.

3. The type and frequency of testing required.

4. The type and frequency of special inspections required.

5. The required frequency and distribution of testing and special inspection reports.

6. The structural observations to be performed.

7. The required frequency and distribution of structural observation reports.

1710.3 [Addition] Contractor responsibility. Each contractor responsible for the construction of the progressive collapse resisting system or progressive collapse component listed in the quality assurance plan shall submit a written contractor's statement of responsibility to the contracting officer prior to the commencement of work on the system or component. The contractor's statement of responsibility shall contain the following.

1. Acknowledgement of awareness of the special requirements contained in the quality assurance plan;

2. Acknowledgement that control will be exercised to obtain conformance with the construction documents approved by the building official;

3. Procedures for exercising control within the contractors organization, the method and frequency of reporting the distribution of reports; and

4. Identification and qualification of the person(s) exercising such control and their position(s) in the organization.

1711 [Addition] SPECIAL INSPECTIONS FOR PROGRESSIVE COLLAPSE RESISTANCE

1711.1 [Addition] General. Special inspections for progressive collapse resistance shall follow the requirements of Section 1704.1. Special inspections itemized in Sections 1717.2 through 1717.4 are required for the following:

1. Structures designed for Occupancy Category II, where either 1) structural elements provide horizontal and vertical tie force strength as well as additional ductility requirements in which the shear resistance of the corner and penultimate ground floor walls and columns is greater than the flexural resistance for lateral loads, or, 2) the alternate path method is used to provide bridging over the deficient elements.

2. Structures designed for Occupancy Category III, with horizontal and vertical tie forces, alternate path design, and enhanced local resistance where the columns or walls in the first two perimeter stories are designed for increased flexural and shear resistance.

3. Structures designed to Occupancy Category IV, which requires a design based on the results of a systematic risk assessment of the building.

1711.2 [Addition] Structural steel. Continuous special inspection for structural welding in accordance with AWS D1.1, including floor and roof deck welding.

Exemptions:

1. Single pass fillet welds not exceeding 5/16” (7.9mm) in size.

1711.3 [Addition] Structural Wood. Periodic special inspections during nailing, bolting, anchoring and other fastening of components within the progressive collapse resisting system, including horizontal tie force elements, vertical tie force elements and bridging elements.

1711.4 [Addition] Cold–formed steel framing. Periodic special inspections during welding operations, screw attachment, bolting, anchoring and other fastening of components within the progressive collapse resisting system, including horizontal tie force elements, vertical tie force elements and bridging elements.

1711.5 [Addition] Cast-in-place concrete. Continuous special inspection for reinforcing steel placement with a particular emphasis on reinforcing steel anchorages, laps and other details within the progressive collapse resisting system, including horizontal tie force elements, vertical tie force elements and bridging elements.

1712 STRUCTURAL OBSERVATIONS

1712.1 [Addition] Structural observations. Structural observations shall be provided for the progressive collapse resisting systems as follows:

1. When the contracting officer requires such observation.

2. In structures designed to \3\ Risk Category /3/ IV

UFC 4-023-07
7 July 2008
Change 1, 1 February 2017

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN TO RESIST DIRECT FIRE WEAPONS EFFECTS

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UFC 4-023-07
7 July 2008
Change 1, 1 February 2017

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN TO RESIST DIRECT FIRE WEAPONS EFFECTS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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

Change No.	**Date**	**Location**
1	1 February 2017	Reformatted to Word Template. Modified paragraphs 1-4,1-5,1-6,1-7, 1-8, 1-9, 2-2.1, 4-4, 5-3.3.1,5-3.3.2, 5-4.4.1, B-2. New Fig 1-1. Updated Fig 4-1. Moved Appendix A to Appendix C

This UFC supersedes UFC 4-023-07, dated Jul 2008.

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

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

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

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

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UNIFIED FACILITIES CRITERIA (UFC)
REVISIONSUMMARY SHEET

Document: UFC 4-023-07, *Design to Resist Direct Fire Weapons Effects, Change 1*

Superseding: UFC 4-023-07, *Design to Resist Direct Fire Weapons Effects*

Description: This change updated the document’s format, incorporated multiple Criteria Change Requests and updated references.

Reasons for Document:

This UFC presents unified engineering guidance for designing facilities to protect assets within them from the effects of direct fire weapons, which include small arms and shoulder fired antitank weapons for the purposes of this UFC. It includes guidance to be applied to new construction and to apply in developing retrofits to existing buildings. This UFC is one in a series of security engineering Unified Facilities Criteria that address minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in the security engineering series include the following:

- UFC 4-010-01: DoD Minimum Antiterrorism Standards for Buildings
- UFC 4-020-01: DoD Security Engineering Facilities Planning Manual
- UFC 4-020-02: DoD Security Engineering Facilities Design Manual
- Security Engineering Support Manuals

This UFC is one of the security engineering support manuals, and as such is intended to be used to refine preliminary designs developed using UFC 4-020-02.

Impact:

The following will result from publication of this UFC:

- The approach to designing to resist direct fire weapons effects will be standardized among the Services.
- Use of this manual will not result in any adverse impacts on environmental, sustainability, or constructability policies or practices.

Unification Issues

No unification issues.

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CHAPTER 1 INTRODUCTION

1-1 INTRODUCTION.

Attacks against facilities and other assets using direct fire weapons have always been a threat to U.S. Government operations. A direct fire attack requires an unobstructed line-of-sight to the asset being attacked within the effective range of the weapon being used. Aggressors often fire these weapons from vantage points outside the controlled perimeter of an installation or facility, which makes these threats difficult to prevent or to detect before they occur. The aggressors' goals are to damage the facility, to injure or kill its occupants, or to damage or destroy assets.

1-2 PURPOSE.

The purpose of this UFC is to present engineering guidelines and cost effective solutions for protecting assets within fixed facilities against direct fire (antitank weapons and small arms) attacks. Those solutions will vary according to the applicable level of protection, which must be provided to designers as part of the design criteria. This UFC is intended to be used to refine preliminary countermeasures designs and protective strategies developed using UFC 4-020-02.

1-3 SCOPE.

This document provides guidance for design of new buildings and for retrofits of existing buildings against the effects of direct fire weapons. Direct fire weapons, for the purposes of this UFC, are limited to small arms and shoulder fired antitank weapons. Small arms include ballistic weapons such as pistols, rifles, shotguns, and submachine guns up to 12.7 mm (0.50 caliber). Anti-tank weapons are limited to shoulder fired rockets such as the Russian RPG-7, RPG-18, and RPG-22 and the U.S. M-72 Light Antitank Weapon (LAW). For guidance on protecting against weapons outside of this scope, refer to UFC 3-340-01.

The ballistic weapons in this UFC are described in terms of ballistic standards developed by Underwriter's Laboratories (UL) for testing the resistance of building elements or assemblies to the ballistics effects. Those standards indicate the weapon to be used in the test, the ammunition, the muzzle velocity, the number of rounds to be fired, and the acceptance criteria for the targets. Coverage of the ballistic threat in this UFC includes the penetration mechanics of the ammunition, threat mitigation measures, and the use of ballistic resistant materials that prevent penetration. Countermeasures vary with level of protection and include blocking sight lines to facilities or assets, facility siting strategies, obscuration techniques, and facility hardening to resist the weapons effects. While there are more effective anti-tank weapons and missiles than those listed above, only weapons of the class described above will be considered in this UFC due to their wide availability and their frequent use. In addition, constructing conventional buildings to resist more effective weapons is impractical. The countermeasures described in this document are based on protecting against single hits, not volleys, since protecting against multiple hits is also impractical and since the accuracy of these weapons is such that firing two rounds through the same hole is difficult. Protection against multiple stage and delayed fuse warheads is also not addressed in this UFC. Strategies to mitigate the effects of these antitank weapons include obscuring assets from lines-of-sight and hardening building components for either pre-detonated rounds or direct hits depending on the level of protection. **\1**

1-4 APPLICABILITY.

This document provides design criteria for DoD components and participating organizations. This document applies to all construction, renovation, and repair projects requiring mitigation for direct fire weapons effects.

1-5 VULNERABILITY AND RISK ASSESSMENT.

A vulnerability and risk assessment must be conducted prior to beginning any security project. Upon identifying facility or asset vulnerabilities to threats, protection measures such as mitigation for direct fire weapons effects may be deployed to reduce vulnerabilities. In summary, this document assumes the pre-design phases, including the risk analysis, are complete prior to beginning design. For information on Security Engineering Planning and Design process, refer to UFC 4-020-01 and UFC 4-020-02 (described in the section “Security Engineering UFC Series” in this chapter). The engineering risk analysis conducted as part of UFC 4-020-01 should be consistent with the terrorism risk analysis conducted by the installation security/antiterrorism (AT) staff.

1-6 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, General Building Requirements. 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.

1-7 REFERENCES.

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

1-8 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

1-9 SECURITY ENGINEERING UFC SERIES.

This UFC is one of a series of security engineering unified facilities criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include the following:

1-9.1 DoD Minimum Antiterrorism Standards for Buildings.

This UFC 4-010-01 and 4-010-02 establish standards that provide minimum levels of protection against terrorist attacks for the occupants of all DoD inhabited buildings. These UFCs are intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings. They also include recommendations that should be, but are not required to be incorporated into all such buildings.

1-9.2 Security Engineering Facilities Planning Manual.

UFC 4-020-01 presents processes for developing the design criteria necessary to incorporate security and antiterrorism into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also addresses the tradeoffs between cost and risk. The Security Engineering Facilities Planning Manual is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

1-9.3 DoD Security Engineering Facilities Design Manual.

UFC 4-020-02 provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02 is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design. The manual also provides a process for assessing the impact of protective measures on risk. The primary audience for the Security Engineering Design Manual is the design team, but it can also be used by security and antiterrorism personnel.

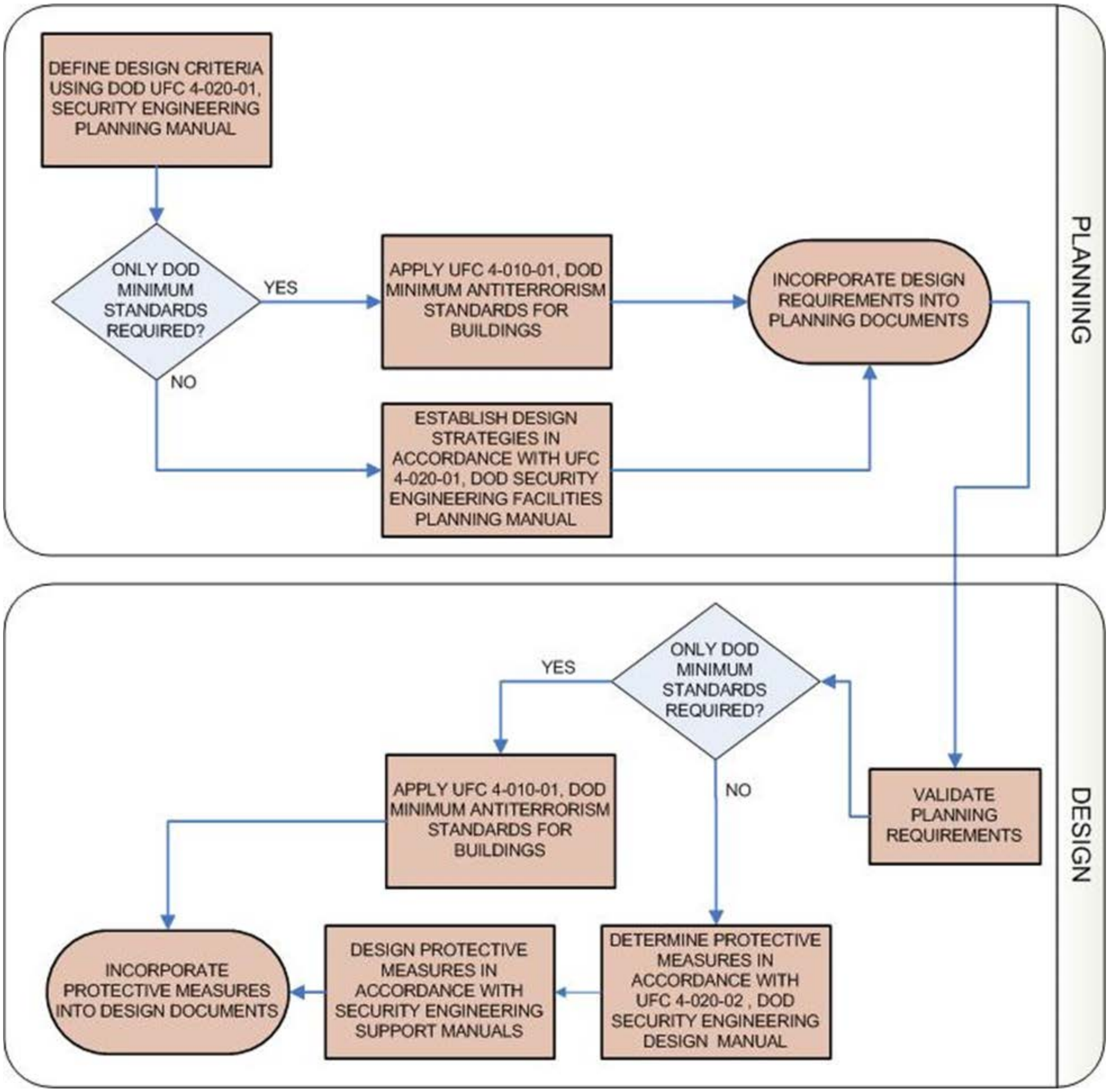
1-9.4 Security Engineering Support Manuals.

In addition to the standards, planning, and design UFCs mentioned above, there is a series of additional UFCs that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, forced entry, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mail rooms. Still others address details of designs for specific protective measures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

1-9.5 Security Engineering UFC Application.

The application of the security engineering series of UFCs is illustrated in Figure 1-1. UFC 4-020-01 is intended to be the starting point for any project that is likely to have security or antiterrorism requirements. By beginning with UFC 4-020-01, the design criteria will be developed that establishes which of the other UFCs in the series will need to be applied. The design criteria may indicate that only the minimum standards need to be incorporated, or it may include additional requirements, resulting in the need for application of additional UFCs. Even if only the minimum standards are required other UFCs may need to be applied if sufficient standoff distances are unavailable. Applying this series of UFCs in the manner illustrated in Figure 1-3 will result in the most efficient use of resources for protecting assets against security and antiterrorism related threats.

Figure 1-1 Security Engineering UFC Application



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CHAPTER 2 DIRECT FIRE WEAPONS PROPERTIES

2-1 INTRODUCTION.

Direct fire weapons threats involve weapons that require an unobstructed line-of-¬sight from the weapon to a target, for the shooter to acquire a target, and for the projectile to arrive at a target. Direct fire threat weapons include both ballistic and rocket propelled munitions. In a ballistic threat, the aggressor fires small arms such as pistols, submachine guns, shotguns, or rifles. Anti-tank (AT) weapons are military weapons or similar improvised weapons originally designed to penetrate the armor on armored vehicles. They can also be fired at facilities, which are the focus of this UFC.

2-2 THREAT LEVELS.

Table 2-1 shows the four threat severity levels associated with the direct fire weapons tactic in UFC 4-020-01. These threats provide representative weapons and munitions to the variety of direct fire weapons that can be expected to be used against people and facilities in criminal and terrorist attacks. There are more severe threats, but they are considered at this time to be less likely to be used by criminals and terrorists. The effective ranges of the weapons at which aggressors could be expected to accurately target person sized targets are entered for use in identifying relevant vantage points as described in Chapter 4.

2-2.1 Threat Severity.

Of the ballistic threats in Table 2-1, the weapon associated with the low threat severity level is a handgun. The weapons for **\1** medium, high and very high threat severity levels include rifles **/1/**. Rounds include ball type and armor piercing ammunition. Refer to **\1** Appendix C **/1/** for specific rounds.

The anti-tank weapon **\1** is associated with very high threat severity **/1/** and representative of a range of shoulder fired rocket propelled projectile weapons including the United States M-72 and the Russian RPG-7, RPG-18, and RPG-22.

Table 2-1 Threat Parameters

Design Basis Threat	Weapons / Standards	Effective Range
Very High	Anti-tank weapons ANSI/UL 752 Level 10 (12.7 mm / .50 caliber)	AT Weapon: 300 meters .50 Caliber: 2000 meters
High	ANSI/UL 752 Level 9 (.30 caliber Armor Piercing)	800 meters
Medium	ANSI/UL 752 Level 5 (7.62 mm / .30 caliber)	1000 meters
Low	ANSI/UL 752 Level 3 (.44 caliber Magnum)	100 meters

2-3 BALLISTIC THREATS.

Ballistic threats are described in terms of ballistic standards developed for testing the resistance of building components to ballistic threats. These standards provide criteria to evaluate the performance of materials or systems. Test standards specify caliber, weight, projectile composition, muzzle velocity of the round, number of impacts, and spacing of impacts. They also define what constitutes failure of the building component.

2-3.1 U.S Standards.

There are several recognized ballistic standards in the United States and other countries. There are many similarities among the standards, but their differences make them so they are not interchangeable. The most common commercial standards in the United States are American National Standards Institute (ANSI) / Underwriters Laboratories (UL) 752 and National Institute of Justice (NIJ) 0108.01. Additionally, there is the ASTM International F 1233 standard, although it is limited to security glazing materials and systems. The three standards are mostly based on the same weapons and rounds. The ballistic threats referenced in this UFC are from the ANSI/UL 752. Two additional U.S. standards are by the U.S. Department of State and H.P. White Laboratories. Those standards are not widely used commercially. **\1** Appendix C **/1/** lists all of the major national and international standards and their most common parameters. For a more detailed listing of the parameters of the standards in Table 2-1, refer to Table X1.1 in ASTM F 1233.

2-3.2 Non-U.S. Standards.

There are several standards available from other countries. They include Australian, British, European, and German standards. All are summarized in **\1** Appendix C **/1/** and are covered in more detail in Table X1.1 in ASTM F 1233.

2-4 ANTI-TANK WEAPONS AND MUNITIONS.

The anti-tank weapon threats addressed in this document are shoulder-fired weapons consisting of two components, the launcher and projectile. The projectile consists of an explosive warhead affixed to a solid fuel rocket motor. There are several types of warheads used in these weapons, but this document only addresses the armor penetrating warheads. They are the most common and represent the greatest challenge in designing countermeasures to mitigate this threat. This document also will not address multiple stage or delayed fuse warheads that are available for these weapons due to their limited availability. While the details of the specific projectiles and weapons differ, they all have similar operating mechanisms, which are summarized below.

2-4.1 Projectile.

The projectile (rocket motor and warhead) is fired from a light hand-held, shoulder fired launcher. When fired, the projectile leaves the launch tube and is propelled to the target by the rocket motor. When the projectile impacts the target, a fuse sends a signal to the detonator, which detonates the warhead.

2-4.2 Warhead.

The warhead incorporates a conical metal shaped charge (often copper lined) with high explosive packed behind it. See figure 2-1. On detonation, the material of the inner lining of the cone of the shaped charge collapses and forms a molten metallic "slug". The explosive gasses and the molten metallic slug together form a high velocity jet (on the order of 10,000 meters per second or 33,000 feet per second). As the gas and molten metallic jet begin to penetrate a target material, the pressure exerted by the jet tip pushes the material away in all directions, eventually driving through the target material. In addition, the force of the penetration of the jet causes the inside face of the target to fracture, and it is propelled into the protected space at high velocity. That effect is called "spall." The penetration effect of a conical shaped charge is illustrated in Figure 2-2. The kinetic energy of the warhead will allow it to penetrate 24 to 32 inches of reinforced concrete, depending on the weapon. Note that anti-tank weapons are designed to "poke" holes in armor, and they have similar narrowly focused effects on buildings as shown in Figure 2-3. Once the jet passes through a wall, it maintains its narrowly focused effects

Figure 2-1. Representative Anti-tank Round Cross-Section

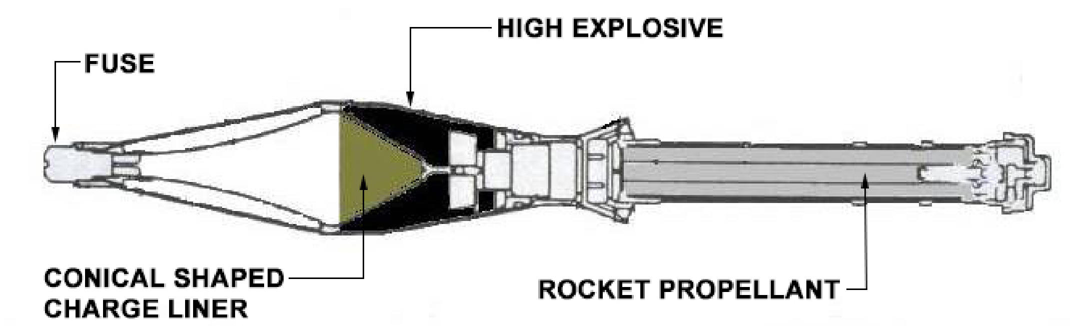

Figure 2-2. Shaped Charge Penetration

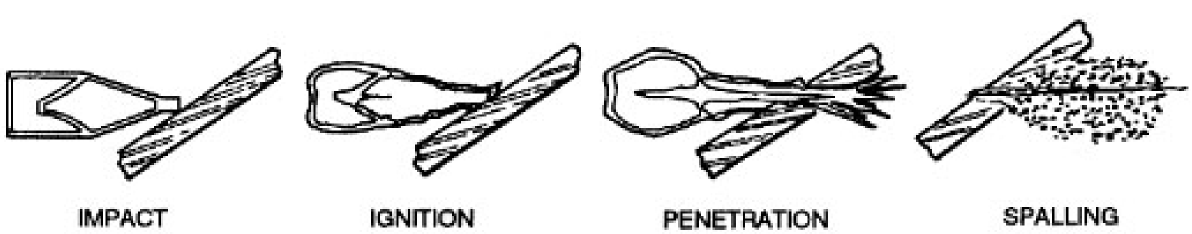

Figure 2-3. Shaped Charge Penetration of Masonry

2-4.3 Older Warheads.

Some older warheads for some of the commonly available shoulder fired anti-tank weapons had design configurations in which the wires extending from the fuses to the detonators could be severed when the warheads were forced through a wire mesh or a chain-link fence. That resulted in the warhead being rendered inert, which is often called “dudding.” Because there are available warheads that do not have that design vulnerability and because the process described above is not very reliable, the whole issue of dudding anti-tank rounds will not be addressed in this UFC.

CHAPTER 3 DESIGN APPROACH

3-1 INTRODUCTION.

This chapter describes the approach to developing systems of countermeasures to mitigate the effects of direct fire weapons attacks.

3-2 DESIGN STRATEGIES.

In approaching solutions to any security engineering related threat, there are two applicable strategies, the general design strategy and the specific design strategy. The general design strategy is the basic approach to developing a protective system to mitigate the effects a given tactic. It governs the general application of construction, building support systems, equipment, manpower, and procedures. The specific design strategy governs how the general design strategy is applied for different levels of protection. The specific design strategies address the different performances required by the levels of protection. The general design strategy and the specific design strategies for direct fire weapons will be described below.

3-2.1 General Design Strategy.

The general design strategy involves identifying vantage points from which direct fire weapons can be launched and, depending on the level of protection, either blocking sight lines to assets and building occupants or hardening the building elements to resist the direct fire weapons effects.

3-2.2 Specific Design Strategies.

Because this tactic includes both small arms and antitank weapons, and because the effects of those weapons vary significantly, the specific design strategies will not apply equally to all threat severity levels. Specifically, the medium level of protection applies only to the high threat severity level, which includes antitank weapons and high caliber small arms (12.7 mm or .50 caliber). When the medium level of protection applies for lower threat severity levels, use the design strategy for high level of protection.

3-2.2.1 Very Low Level of Protection.

The very low level of protection is limited to incorporating the standards of UFC 4-010-01, the DoD Minimum Antiterrorism Standards for Buildings. Those requirements will be described in this UFC, but detailed coverage will be left to UFC 4-010-01.

3-2.2.2 Low Level of Protection.

For all threat severity levels (involving both small arms and antitank weapons), the design strategy for this level of protection is to block sight lines to building occupants or assets. The assumption behind that strategy is that aggressors will not shoot at what they cannot see. Blocking sight lines may be accomplished by applying both building and sitework elements.

3-2.2.3 Medium Level of Protection.

The medium level of protection may be applied to all threat severity levels, but is only practical in the case of large caliber small arms (12.5 mm or .50 caliber) and antitank weapons. It includes the installation of predetonation screens that detonate antitank rounds at a specific distance from a target and/or energy absorption screens that reduce the energy of the small arms rounds before they impact the target. In both cases, the combination of screen material, standoff distance, and building element construction will prevent the small arms and antitank rounds from breaching the building envelope.

3-2.2.4 High Level of Protection.

For all threat severity levels (involving both small arms and antitank weapons), the design strategy for this level of protection is to harden building elements such that they resist the direct effects of the threat weapon.

3-3 THE PROTECTIVE SYSTEM.

The system of countermeasures that is provided to mitigate the effects of any tactic is referred to as the protective system. Develop the countermeasures that are parts of that system based on the general and specific design strategies associated with levels of protection and then evaluate them to ensure they are integrated so they act as part of a system. Countermeasures are divided into five major categories. Those categories are explained below.

3-3.1 Sitework Elements.

These include all countermeasures that are associated with areas surrounding buildings beyond 1.5 m (5 ft) from the building. They are addressed in Chapter 4.

3-3.2 Building Elements.

These include all countermeasures directly associated with buildings such as walls, doors, windows, roofs, and building layout. They are addressed in Chapter 5.

3-3.3 Building Support Systems.

Building support systems are systems such as utilities and heating, ventilating, and air conditioning (HVAC) systems. There are no significant issues relating to such systems in relation to mitigating the effects of direct fire weapons tactics, so they will not be addressed in this UFC.

3-3.4 Equipment.

Equipment as a category of countermeasures includes such things as electronic security systems and explosives detection equipment. Because there are no opportunities to detect direct fire weapons attacks and because they can be launched from a distance, equipment is not considered in protective system development for this tactic and will not be addressed in this UFC.

3-3.5 Manpower and Procedures.

Because there are no opportunities to detect direct fire weapons attacks prior to shots being fired and because they can be launched from a distance, manpower and procedures are only issues associated with response to attacks; therefore, they do not have facility implications, and they will not be addressed in this UFC. Similarly, activities such as patrolling areas from which attacks could be launched to deter or prevent attacks are also not addressed in this UFC.

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CHAPTER 4 SITE WORK ELEMENTS

4-1 INTRODUCTION.

Sitework elements commonly play a limited role in mitigating direct fire weapons attacks, including both ballistics and anti-tank weapons. The primary reason for that limited role is that it is generally less expensive to build protection into buildings than to shield buildings using sitework elements. That may not be the case, however, for some existing buildings of lightweight construction, where there are limited areas of buildings that require protection, or where assets are not located in buildings. Sitework elements are used either to obscure assets from lines-of-sight to assets or to shield assets from direct fire weapons. How they are used with respect to those two functions varies by level of protection, and they are therefore addressed in the contexts of the applicable specific design strategies. In addition, there are sitework related issues that drive site selection and facility location, which are covered separately.

4-2 FACILITY LOCATION.

Before determining the location of new facilities, site planners should evaluate the site to identify vantage points from which aggressors could launch direct fire attacks. Look for vantage points that will permit an unobstructed line-of-sight to the facility or to areas within the facility where assets that are potential targets may be located. Consider the following in site planning to avoid such vantage points:

4-2.1 Locating Away from Vantage Points.

Locate buildings in areas of installations that are beyond the maximum range of the applicable weapons from identified vantage points where possible. Those vantage points may be either inside or outside the perimeter of the installation. An example would be tall buildings outside the secured perimeter from which an aggressor could establish a direct line-of-sight to facilities within the secured perimeter. That leads to the general recommendation to locate buildings that require protection closer to the interiors of installations. The DoD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01) specifically address this issue in a recommendation.

4-2.2 Locating on High Points of Land.

Consider locating buildings on high points of land. If buildings are situated higher than the surrounding area there will be fewer potential vantage points from which to target the buildings. Locating the “castle on the hill” will also cause ballistic projectiles fired from a lower elevation to strike at an oblique angle, reducing their effectiveness slightly. That advantage is minimal for anti-tank weapons, however. One disadvantage of locating buildings on high points is that doing so may make the building more noticeable and easier to target.

4-2.3 Locating Near Existing Landforms.

Look for landforms that may block sight lines from vantage points. Consider locating buildings to take advantage of those landforms. Avoid locating near natural features that can be used as vantage points, however, unless they are within controlled areas. Also avoid locating buildings adjacent to drainage channels, ditches, ridges, or culverts that can provide concealment to aggressors and from which they could target buildings.

4-2.4 Locating Near Other Buildings.

Consider locating buildings near parking garages, warehouses, and other structures that may block sight lines from vantage points. Also take advantage of structures that house less critical assets and use those structures to block lines-of-sight. This could also be a strategy for placing multiple new buildings on a site. In that case, less critical buildings could be sited to block sightlines from vantage points to critical buildings.

4-3 COUNTERMEASURES FOR VERY LOW LEVEL OF PROTECTION.

The design strategy for the very low level of protection is limited to incorporating the minimum standards of UFC 4-010-01, the DoD Minimum Antiterrorism Standards for Buildings, into the protective system. There are no site work oriented requirements among those standards that are related to mitigating any effects of direct fire weapons.

4-4 COUNTERMEASURES FOR LOW LEVEL OF PROTECTION.

As stated in Chapter 3, the design strategy for the low level of protection is based on blocking lines-of-sight between vantage points and potential targets. This strategy assumes that aggressors will not fire at what they cannot see. Sitework elements that can be used effectively in implementing this strategy include vegetation, fences, land forms, and walls placed to interrupt sight lines. **\1**Consult a Landscape Architect to determine the appropriate site elements and plants for use in specific areas. **/1/** Recognize that vegetation used to block sight lines may not be effective until it matures, which may take years, and that plants that do not retain their foliage year-round will have periods when they are ineffective.

4-4.1 Planting and the Unobstructed Space.

The DOD Minimum Antiterrorism Standards for Buildings (UFC 4-010-01) require inhabited buildings to be surrounded by unobstructed spaces that extend **\1\/1/**outside of the buildings. Unobstructed spaces cannot have obstructions within them that would allow for concealment from observation of explosive devices 150 mm (6 inches) in height. Any **\1** shrubs or trees **/1/** planted to block sight lines, therefore, must either be planted outside the unobstructed space or should be kept trimmed to a height of 1.2 meters (4 feet) above the ground to preclude concealing explosives under them. Figure 4-1 illustrates the placement of trees in the vicinity of the unobstructed space. **\1**

4-4.2 Hedges.

/1/ Hedges can be effective at blocking sight lines, but their feasibility and the species available vary by region. **\1\/1/** Optimally select plants for hedges that retain their **\1** form and **/1/** foliage year-round and that are typically used for hedges. Where plants that are not evergreen varieties are used, alternative means to block sight lines will have to be provided during the periods of the year when the plants do not have leaves. Use caution when selecting shrubs or trees for planting in temperate or colder zones. Some shrubs or trees that are evergreen in warm climates may not be evergreen in cold climates. **\1**

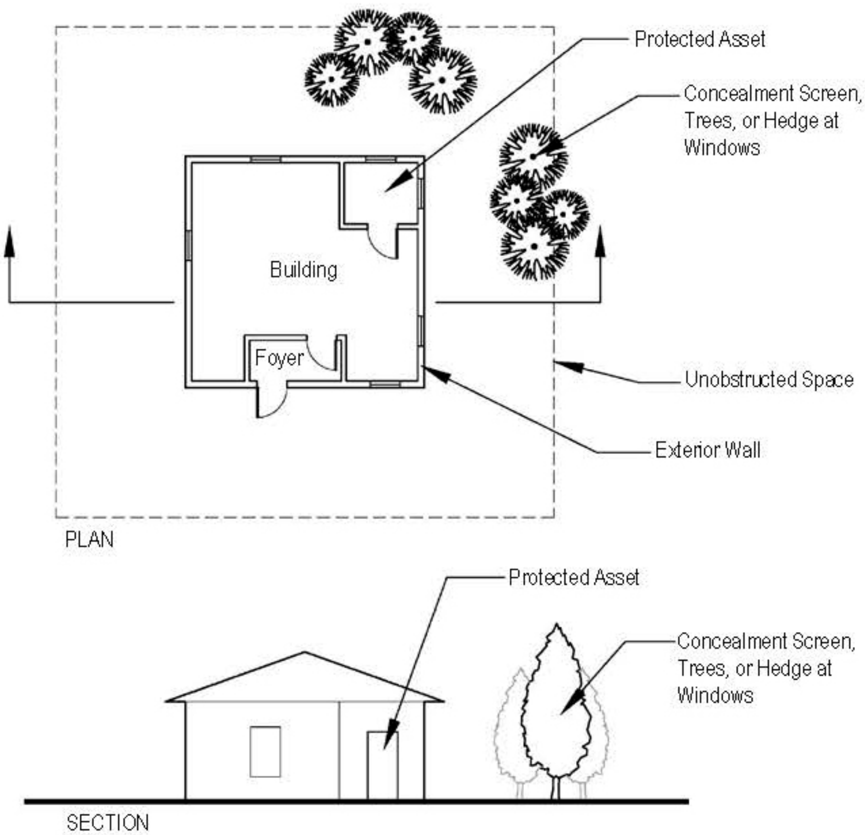
4-4.2.1 Shrubs for Hedges.

Utilize native and naturalized plants that are adapted to the local regional climate and natural aesthetic. Select plant species that are hardy, disease resistant, drought-tolerant, and low maintenance. Select plant species by ultimate size and form to maintain the natural shape and not require extensive maintenance or pruning. Place hedges a minimum of two-thirds of the radius of the ultimate growth of the shrub from hardscape, walls, fences, or buildings. Provide plant materials of sufficient size and spacing to achieve the desired screening effect. Confirm plant species with the appropriate Base Exterior Architecture Plan (BEAP), Installation Appearance Plan (IAP), Public Works Department or the reviewing Government Landscape Architect.

4-4.2.2 Shrubs to Avoid.

Avoid plants that are invasive, poisonous, or have excessive leaf, flower, seed or cone litter. Avoid plants that are short-lived or that have surface-rooting tendencies. Provide 100% native or naturalized plant materials on projects that are immediately adjacent to designated open space or sensitive environments. Provide plant materials that are fire-resistant on projects in regions prone to wild-fire. Refer to the appropriate Base Exterior Architecture Plan (BEAP), Installation Appearance Plan (IAP), Public Works Department or the reviewing Government Landscape Architect. **/1/ \1**

Figure 4-1. Trees and the Unobstructed Space



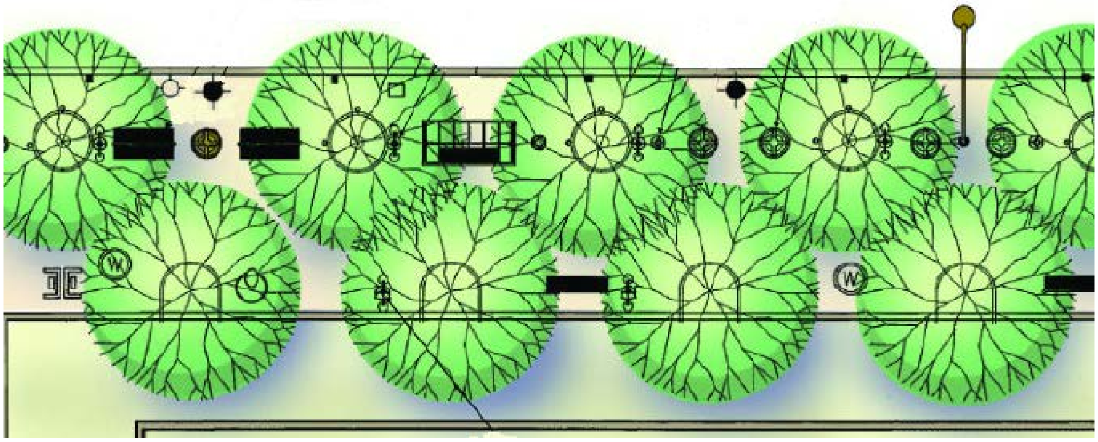
/1/ \1

4-4.3 Trees for Screening.

Select trees that retain their foliage year-round. Utilize native and naturalized trees that are adapted to the local regional climate and natural aesthetic. Select tree species that are hardy, disease resistant, drought-tolerant, and low maintenance. Select tree species by ultimate size and form to maintain the natural shape and not require extensive maintenance or pruning. In addition, ensure that trees overlap such that there are no visible gaps between them as shown in Figure 4-2. Note in the elevation view of Figure 4-2 that only the upper floors would be shielded, so only non-critical areas could be located on lower floors. Refer to the appropriate Base Exterior Architecture Plan (BEAP), Installation Appearance Plan (IAP), Public Works Department or the reviewing Government Landscape Architect. ***/1/***

Some varieties such as Douglas Fir can grow very tall and in areas with heavy snows will lose most of their lower branches. That may diminish their effectiveness for obscuration. Blue spruce will retain its branches even in heavy snows, but can be very slow growing. Magnolia trees will work well for warm climates and some of the new varieties will stay a nice medium height. Ficus is fast growing and will provide a good screen, but it can develop a massive root system, so it should be planted at least 3 meters (10 feet) away from paved areas.

Figure 4-2. Overlapping Trees for Obscuration



Plan

Elevation

\1 Utilize trees species that are "fanlike" (wide but not deep) for narrow areas such as between unobstructed spaces and paved areas where space for planting trees is limited. **/1/**

4-4.4 Fences and Walls.

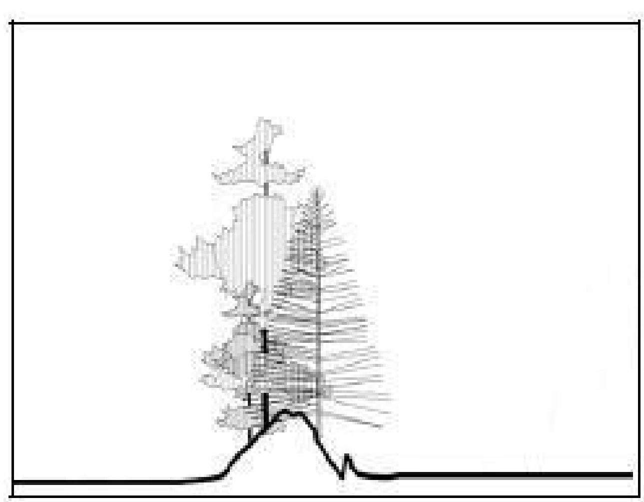
Perimeter barriers such as fences and walls can be used to block lines-of-sight. Walls, due to the fact that they are generally opaque and can be built to almost any height are very effective at blocking sight lines. Fences can be either solid, such as wood slat fences, or they can be transparent, such as chain-link or expanded metal. The solid fences are quite effective at blocking sightlines, but transparent fences require some form of obscuration material to be added to them for them to be effective at blocking sight lines. There are many such materials available for use with chain-link fencing. Some of the most common are wood, light gauge steel, or aluminum slats. The slats are woven in between the chain links. One significant issue in adding obscuration to fences is that they must be designed to resist the additional wind load that will result from adding the obscuration material. Figure 4-3 shows a chain link fence that failed due to the increased wind loading resulting from the addition of plastic obscuration material.

Figure 4-3. Failed Chain Link Fence with Obscuration Material Added

4-4.5 Using Landforms to Increase the Height.

Landforms can be built to raise fence-lines or to increase the height of newly planted trees or shrubs. Shrubbery can also be raised using individual or continuous planter boxes. Raising shrubs or tree lines for new plantings can obstruct lines-of-sight sooner than if the shrubs or trees are planted at ground level. Figure 4-4 shows a tree line elevated on a berm. The disadvantage to using landforms in this manner is that such landforms can create areas for intruder concealment or for the hiding of explosive devices. Due to such considerations, landforms should not be located within the **\1\/1/**unobstructed spaces required by UFC 4-010-01.

Figure 4-4. Tree Line Elevated on Berm



4-4.6 Berms and Landforms.

Berms and other such landforms can be used by themselves to block sightlines. Building them tall enough to be effective is generally impractical for all but the lowest of buildings, however. The berm in Figure 4-4, for example, would only potentially shield the lower floor of the building behind it. Berms can also provide opportunities for concealment, so they should be kept outside of unobstructed spaces.

4-5 COUNTERMEASURES FOR MEDIUM LEVEL OF PROTECTION.

The primary design strategy for the medium level of protection is to place a screen in front of portions of targeted buildings where there are assets identified as requiring protection against direct fire weapons. The screens intercept incoming direct fire rounds. In the case of ballistics, the screen will serve to absorb energy from the incoming round. In the case of anti-tank weapons, the screen will predetonate the incoming warhead. Both applications will be described below. Note that a screen can serve the purposes of both an energy absorption screen and a predetonation screen, but differences in construction will have to be evaluated to determine which controls.

4-5.1 Energy Absorption Screen.

The energy absorption screen serves to reduce the energy of incoming rounds, which allows for savings in the construction of building components behind them that are provided to resist penetration of the rounds. This strategy is only practical for the .50 caliber (12.7 mm) threat. For lesser threats it is more cost effective to build the full bullet resistance into the building construction. To be effective, the screen has to be solid and must have enough mass to reduce the velocity of the incoming round. That requires a minimum of 12 mm (1/2 inch) thick wood fence, reinforced concrete, or brick. The distance from the screen to the target is not a critical design parameter, but such screens should not be located within the 10 meter (33 feet) unobstructed space. Design guidance on screen thickness and material is provided in the wall design section of Chapter 5.

4-5.2 Predetonation Screen.

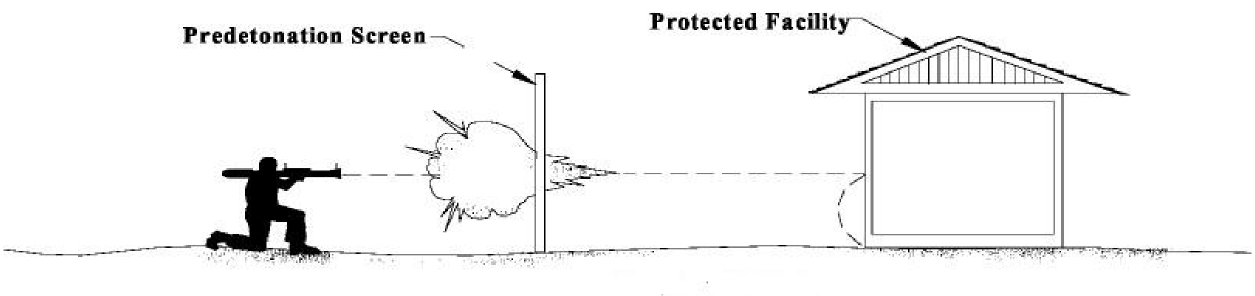
The effects of anti-tank warheads can be reduced by detonating the warheads at a distance from their targets. When the charges are detonated farther from the targets than their optimum standoffs (technically, the distance from the conical shaped charge to the tip of the warhead), the jets tend to break up and lose energy before striking the targets. This design strategy is called predetonation. It is accomplished by building a predetonation screen.

4-5.2.1 Predetonation Screen Location.

Predetonation screens generally will be located in front of portions of buildings that must provide protection against anti-tank weapons or areas that are vulnerable to an attack. In some cases a screen could surround an entire building. The standoff distance between the predetonation screen and the building is governed by the building construction. Those distances are discussed in the wall design section of Chapter 5.

For a range of common conventionally constructed walls the standoff distances range from 2 to 15 meters (7 to 49 feet), but the screens should not be located within the 10 meter (33 feet) unobstructed space. Figures 4-5 and 4-6 illustrate the placement and function of a predetonation screen.

Figure 4-5. Predetonation Screen



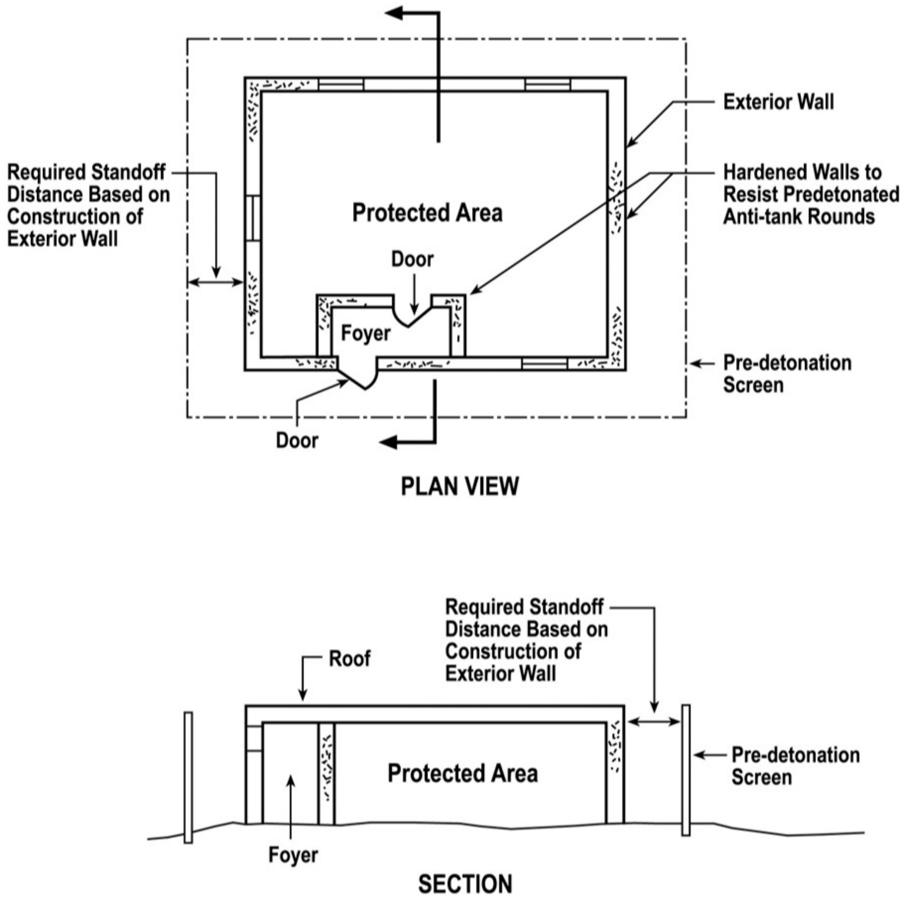
4-5.2.2 Predetonation Screen Height.

Predetonation screens need to be as high as the portions of buildings they are intended to protect. They may only be practical, therefore, for intercepting anti-tank rounds fired at the lower stories of buildings. Where building predetonation screens high enough to protect upper stories of buildings is not practical, design to a different level of protection for those portions of the building that are not shielded by the predetonation screen. Either use obscuration (low level protection) or harden the building to resist the direct impact of the anti-tank round. Note that in the case of designing for the low level of protection, building users are accepting the additional risk that goes along with that level of protection; therefore, the design team should not make that decision without consulting with the user or the planning team.

4-5.2.3 Building Exterior Envelope.

The exterior envelope of the building could be used as a predetonation screen if the assets that require protection are in interior rooms. In that case, the building exterior could be used as a predetonation screen and the interior walls would be designed to resist the predetonated round as described in Chapter 5.

Figure 4-6. Predetonation Screen Location



4-5.2.4 Predetonation Screen Material.

Predetonation screens can be constructed of concrete, masonry, or wood. If wood is used for the predetonation screen, construct it in sections so that if one section is damaged, it can easily be replaced. Wood predetonation screens thicknesses vary with wood species used. The minimum thicknesses required for some common wood species are listed below. The other requirement for the wood fences is that if wood slat fencing is used, the slats should be spaced no more than 6.4 mm (1/4 inch) apart.

- Cedar: 9 mm (3/8 inch)
- Douglas Fir or Pine: 25 mm (1 inch)
- Plywood: 18 mm (3/4 inch) (including Oriented Strand Board)

The thickness of concrete or masonry predetonation screens does not need to be greater than 25 mm (1 inch); therefore, they are limited only by what is required for structural stability. Another constraint is that a structural wall made of concrete or masonry could amplify the effects of a pressure wave created by a bomb blast by reflecting it back to the facility. If that is a concern blast resistance will have to be taken into account during the design of the predetonation screen. In addition, concrete or masonry predetonation screens could break up and produce hazardous flying debris in the event of an explosive detonation. The blast amplification and debris considerations are outside the scope of this UFC. See the DoD Security Engineering Facilities Design Manual (UFC 4-020-02).

4-6 COUNTERMEASURES FOR HIGH LEVEL OF PROTECTION.

The design strategy for the high level of protection depends on the shell of the building protecting the targeted assets to provide all of the resistance to the direct fire weapons. Because that strategy relies only on building components, sitework elements do not enter into the design strategy for this level of protection.

CHAPTER 5 BUILDING ELEMENTS

5-1 INTRODUCTION.

Building elements are the predominant components of protective systems to mitigate direct fire weapons effects. The exterior shells of buildings are commonly what provide the protection for assets within them, whether or not shielding has been provided using site work elements. This chapter will provide guidance for designing walls, windows, doors, vent covers, grilles, and roofs to implement the design strategies for the four applicable levels of protection. It will also address how building layout may be affected by the design strategies for mitigating direct fire weapons.

5-2 BUILDING LAYOUT.

Building layout can provide significant opportunities for mitigating the effects of direct fire weapons. How the design strategies for building layout vary for the different levels of protection is described below. Note, however, that applying the layout principles for the low and very low levels of protection can simplify protection at the higher levels of protection; therefore, always apply those principles where possible.

5-2.1 Very Low Level of Protection.

There is a requirement in UFC 4-010-01 that is predicated on consideration of direct fire weapons threats. Standard 11 requires main entrances to buildings not to face installation perimeters or other uncontrolled vantage points or to provide some means to block those lines-of-sight. The latter is addressed later in this chapter where the low level of protection for doors is discussed. For existing buildings, this requirement may lead to reorganization of building circulation to accommodate moving the main building entrance. Note, however, that the standards of UFC 4-010-01 are only triggered for existing buildings that are undergoing major modifications or conversions of use. Refer to UFC 4-010-01 for descriptions of those triggers. This main entrance requirement accounts for the facts that there is little control over what happens off installations and that building main entrances are especially vulnerable due to the level of traffic into and out of buildings at those locations.

5-2.2 Low level of protection.

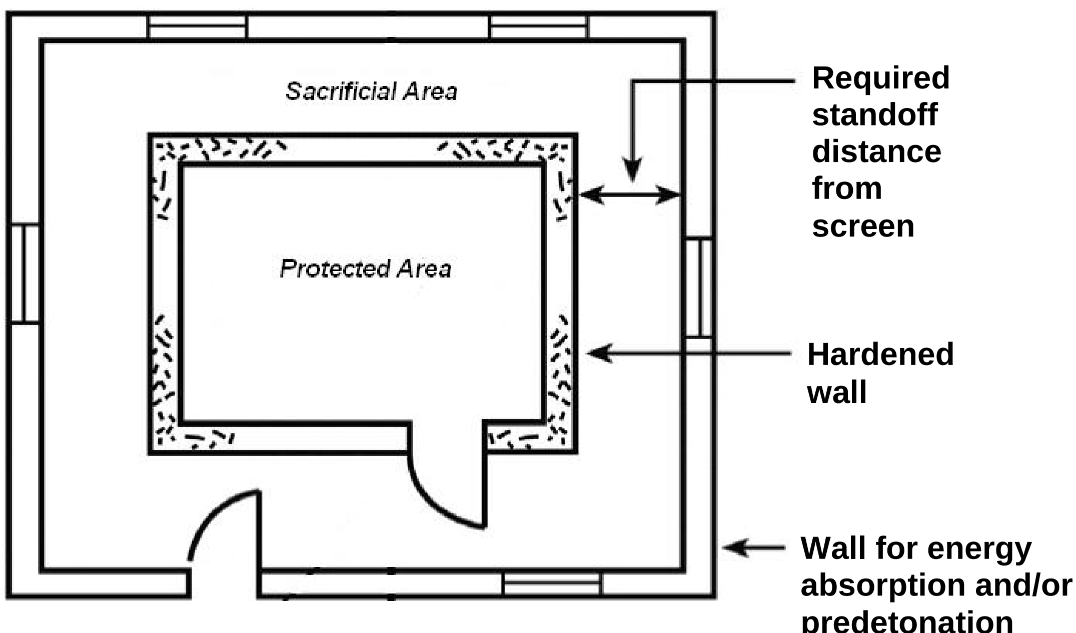
Building layout for the low level of protection is focused on minimizing lines-of-sight to targeted assets. Consider designing interior layouts of buildings to locate critical assets as far as possible into the interior of the building to make them easier to protect. Unoccupied areas or areas in which non-critical functions will be performed can be located along the exterior of the facility. Any such layout considerations must take into account whether or not issues such as building occupant operations will constrain where assets or functions are located. Interior room layout can also limit asset exposure. In designing room layouts locate furniture and activity areas to minimize visibility through windows and doors.

Building orientation can also be used to minimize asset exposure. Where possible, orient buildings so critical areas do not face known vantage points or installation perimeters. Storerooms or other uninhabited areas can be located on those sides of buildings.

5-2.3 Medium Level of Protection.

The design strategy for the medium level of protection includes employment of energy absorption and/or predetonation screens. Where targeted assets can be located in interior areas of buildings, the building shell can be used for energy absorption or predetonation. In those cases lay out interior walls between the building exterior and the assets and design the interior walls to resist the weapons effects remaining after energy dissipation and/or predetonation as described in the section in this chapter on walls. Figure 5-1 illustrates such a building layout. In addition, lay out buildings to minimize windows and doors leading to targeted assets. Refer to the section in this chapter on windows for more guidance on window layout.

Figure 5-1. Sacrificial Area Layout



5-2.4 High Level of Protection.

Because the design strategy for the high level of protection is based on building exteriors resisting the direct impacts of direct fire munitions, there are minimal layout issues to be considered. The only significant one relates to windows and doors. It is often not practical to design windows and doors to provide the high level of protection, especially for the higher threat severity levels, so a more practical approach for those cases is to avoid exposing targeted assets to windows and doors through effective building layout. Refer to the sections in this chapter on windows and doors for more guidance on window and door layout.

5-3 WALLS.

5-3.1 Very Low Level of Protection.

Because the design strategy for the very low level of protection is limited to incorporating the minimum standards of UFC 4-010-01, the DoD Minimum Antiterrorism Standards for Buildings, and since there are no minimum standards related to mitigating direct fire weapons effects against walls, there are no requirements for walls at this level of protection.

5-3.2 Low Level of Protection.

Because the design strategy for the low level of protection is limited to blocking lines-of-sight to targeted assets and because walls are commonly opaque, there are no additional requirements for walls at this level of protection. If, however, glass block are used for walls, ensure they are translucent or figured so assets cannot be targeted through them.

5-3.3 Medium Level of Protection.

The design strategy for the medium level of protection is predicated on either predetonating anti-tank rounds and/or reducing the energy of large caliber ballistics. Design of walls will differ based on whether they are designed for ballistics threats, anti-tank weapon threats, or both.

5-3.3.1 Ballistics Threats.

Table 5-1 covers wall design where an energy absorption screen is employed to mitigate the effects of high caliber ballistics (.50 caliber or 12.7 mm). Select a material and thickness for the energy absorption screen and find the reinforced concrete or masonry wall necessary to resist the residual velocity of the round after it impacts the screen. Masonry walls are either fully grouted concrete masonry units or solid clay brick masonry units. The distances from screens to targets are unimportant, but they cannot be located within the **\1\/1/** unobstructed space required by UFC 4-010-01.

For concrete and masonry materials, the design condition of the wall is for no spalling from the inside face. Spalling is a phenomenon in which the impact of a projectile propagates a shock wave through the material. That wave is reflected from the rear face of the wall as a tensile wave. When that tensile wave exceeds the limited tensile capacity of the material, the material is ejected from the spalled region, potentially at hazardous velocities. Spalling is illustrated in Figure 2-3. For more options, use the equations in the section on the high level of protection. Calculate the residual velocity of the round after it perforates the energy absorption screen and then design the target wall to resist that residual velocity.

5-3.3.2 Anti-tank Weapon Threats.

Table 5-2 covers wall design where a predetonation screen is employed to mitigate the effects of anti-tank weapons. The table includes 8 different common wall constructions, their total thicknesses, and the standoff distances from those walls at which predetonation screens must be located for the target wall to resist the predetonated round. The values in Table 5-2 were obtained through testing, and they represent walls that will resist the “family” of anti-tank weapons that were described in Chapter 2. Note that where Table 5-2 shows a predetonation screen standoff of less than the standoff associated with the unobstructed space, screens should not be located within the **\1\/1/** unobstructed space unobstructed space required by UFC 4-010-01.

Figures 5-2 and 5-3 illustrate techniques for retrofitting existing reinforced concrete walls to resist predetonated anti-tank rounds. Both techniques employ sand against the outside of the wall. The configuration in Figure 5-3 also includes the installation of steel plate on the interior face of the wall to prevent spall. There are many ways that sand in the thicknesses shown can be placed against walls, such as light retaining walls, sand bags, or sand grids. Aesthetics and maintainability issues are left up to designers.

Table 5-1 Wall Construction with Energy Absorption Screen [1]

Energy Absorption Screen Material and Thickness [2, 3]	Reinforced Concrete Wall Thickness [2]	Masonry Wall Thickness [2,3]
No screen	22 inch (560mm)	30 inch (760 mm)
½ inch (12 mm) wood	18 inch (460mm)	30 inch (760 mm)
¾ inch (19 mm) wood	18 inch (460mm)	28 inch (710 mm)
1 inch (25 mm) wood	18 inch (460mm)	28 inch (710 mm)
2 inch (50 mm) reinforced concrete	18 inch (460mm)	26 inch (660 mm)
4 inch (100 mm) reinforced concrete	16 inch (400mm)	26 inch (660mm)
6 inch (150 mm) reinforced concrete	15 inch (380 mm)	22 inch (560 mm)
8 inch (200 mm) reinforced concrete	14 inch (350 mm)	20 inch (500 mm)
12 inch (300 mm) reinforced concrete	10 inch (250 mm)	16 inch (400 mm)
Ungrouted CMU (1.5 inch or 40 mm total face shell thickness)	18 inch (460mm)	28 inch (710 mm)
4 inch (100 mm) masonry	16 inch (400mm)	26 inch (660 mm)
6 inch (150 mm) masonry	15 inch (380 mm)	22 inch (560 mm)
8 inch (200 mm) masonry	14 inch (350 mm)	20 inch (500 mm)
12 inch (300 mm) masonry	10 inch (250 mm)	16 inch (400 mm)

1. For .50 caliber (12.7 mm) round
2. All thicknesses are nominal thicknesses.
3. Masonry walls can either be fully grouted CMU or solid clay brick. Reinforcement ratio is not a significant factor in bullet resistance.

Table 5-2 Wall Construction with Anti-Tank Round Predetonation Screens

Material	Total Wall Thickness [1]	Standoff Distance to Predetonation Screen
4 inch (100 mm) brick / 2 inch (50 mm) air gap / 8 inch (200 mm) hollow CMU	14 inches (356 mm)	49 feet (15 meters)
8 inch (200 mm) grout filled CMU	8 inches (200 mm)	36 feet (11 meters)
8 inch (200 mm) solid brick	8 inches (200 mm)	36 feet (11 meters)
4 inch (100 mm) brick / 2 inch (50 mm) air gap / 4 inch (100 mm) brick	10 inches (254 mm)	36 feet (11 meters)
4 inch (100 mm) brick / 4 inch (100 mm) air gap / 4 inch (100 mm) brick	11.5 inches (292 mm)	36 feet (11 meters)
6 inch (150 mm) reinforced concrete	6 inch (150 mm)	25 feet (7.6 meters) [2]
8 inch (200 mm) reinforced concrete	8 inch (200 mm)	11 feet (3.4 meters) [2]
12 inch (300 mm) reinforced concrete	12 inch (300 mm)	7 feet (2.1 meters) [2]

1. Nominal thicknesses.

2. Do not locate closer than the edge of the unobstructed space where unobstructed space is required in accordance with UFC 4-010-01.

Figure 5-2. Anti-tank Weapon Wall Retrofit Using Sand

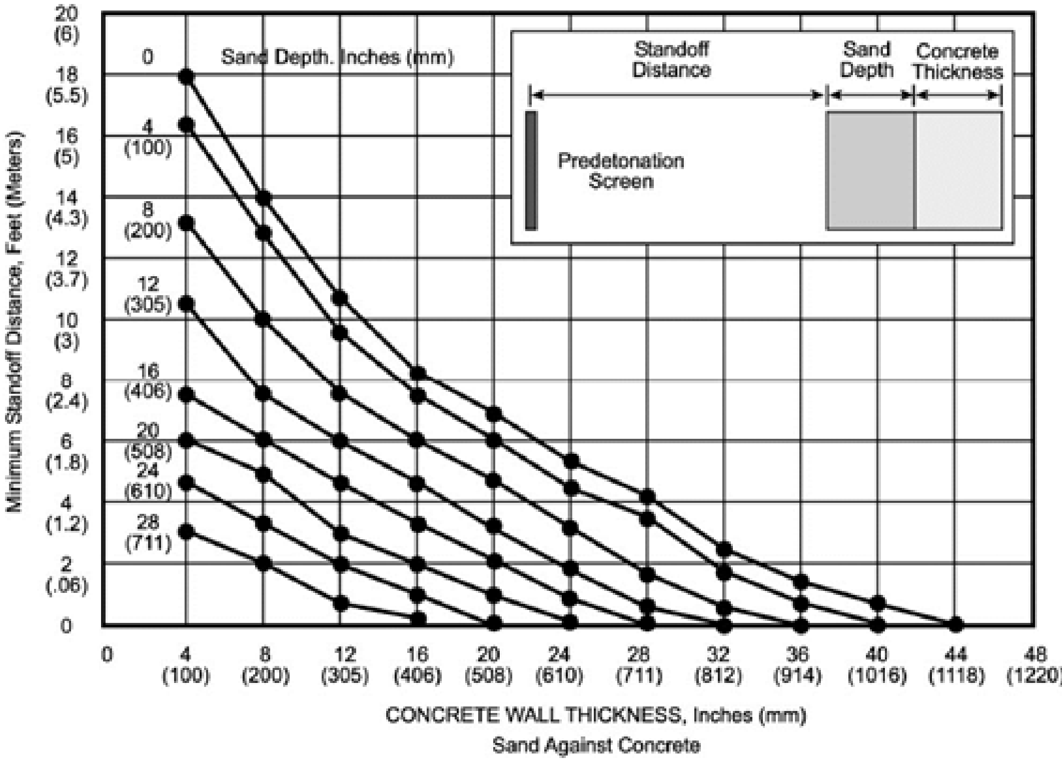
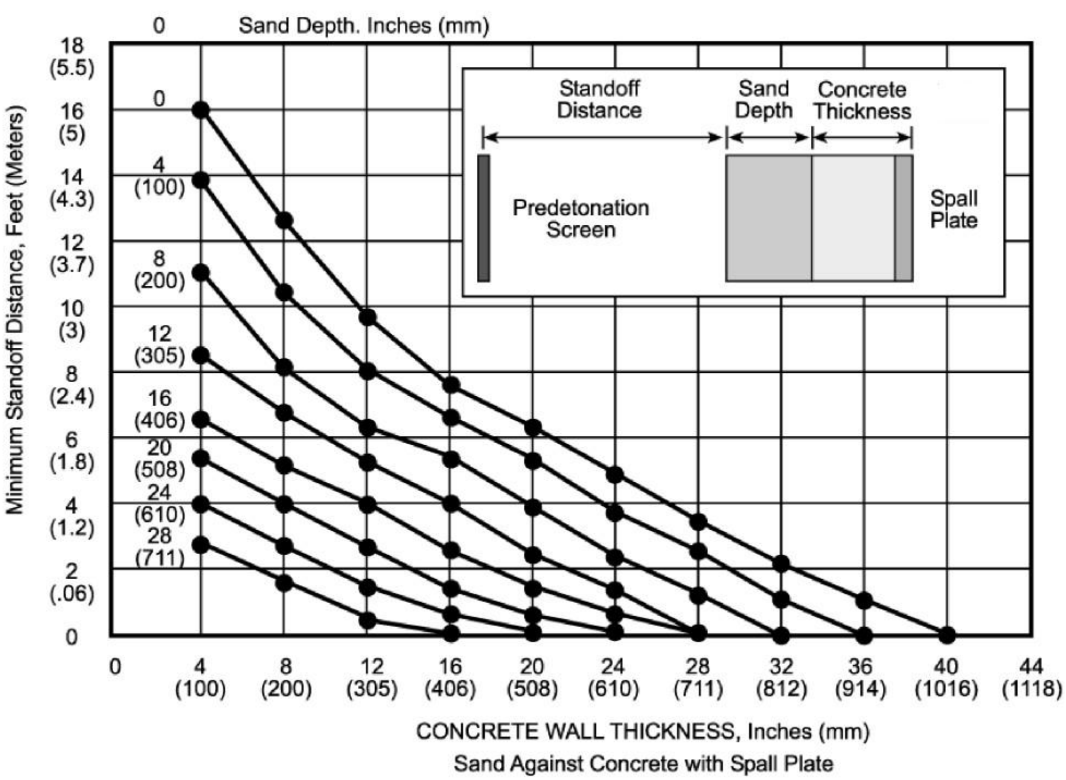


Figure 5-3. Anti-Tank Weapon Retrofit Using Sand and Spall Plate



5-3.3.3 Ballistic and Anti-tank Weapon Threats.

The very high threat severity level is shown in Table 2-1 to include both high caliber ballistics and anti-tank weapons. In designing against both of those threats, apply both Tables 5-1 and 5-2 and use whichever construction is heaviest.

5-3.4 High Level of Protection.

The design strategy for the high level of protection is predicated on resisting the full effects of the ballistic or anti-tank rounds without any energy reduction or predetonation. That strategy results in hardened construction for all building components to which there are lines-of-sight and behind or under which there are assets that require protection. It can result in an entire building envelope or portions thereof being hardened depending on building layout and asset location. Walls constructed to resist ballistics or antitank weapons will commonly need to be constructed of reinforced concrete or masonry. Steel plate can also be added to existing wall construction as a retrofit.

5-3.4.1 Design Using Tables.

5-3.4.1.1 Ballistics Threat.

Table 5-3 provides construction that will resist the effects of direct hits by ballistics for all four threat severity levels. Some of the entries are from tests; others are from calculations. It includes reinforced concrete and concrete and clay brick masonry. Note that where concrete masonry unit construction is used, all cells must be grouted full.

Table 5-3 also includes steel plate and bullet resisting fiberglass, both of which can be used to retrofit existing walls that do not provide the necessary ballistic resistance. The steel plate includes both mild steel, which is common structural steel plate, and rolled homogeneous armor. The Brinnell Hardness Numbers for the two steel plate types are specified in the notes to Table 5-3. The bullet resistant fiberglass thicknesses are commercially available thicknesses that are based on tests. To design for other threats or to explore other options use the computational procedures later in this section.

5-3.4.1.2 Anti-tank Weapon Threat.

Table 5-4 provides the necessary thicknesses for a variety of potential construction materials to resist direct hits by anti-tank warheads. While the practicality of some of them is questionable, the results tabulated are provided for reference and to allow designers as much flexibility as possible.

Table 5-3 Ballistics Resistant Construction

Threat Level	Reinforced Concrete [1]	CMU [2] or Brick [1]	Steel Plate [1]		Bullet Resistant Fiberglass [1]
			Mild [3]	Armor [4]	
Low	2-1/2 inches (64 mm)	4 inches (100 mm)	5/16 inches (8mm)	1/4 inches (6mm)	7/16 inches (14mm)
Medium	4 inches (100 mm)	8 inches (200 mm)	9/16 inches (14 mm)	7/16 inches (11 mm)	1-1/8 inches (28.4mm)
High	6-1/2 inches (165 mm)	8 inches (200 mm)	13/16 inches (21 mm)	11/16 inches (18 mm)	Note 5
Very High	22 inches[6] (560 mm) 12 inches[7] (305 mm)	30 inches (760 mm)	1-1/4 inches (32 mm)	1 in. (25 mm)	Note 5

1. All thicknesses are nominal thicknesses. Reinforcement ration is not a significant factor in bullet resistance
2. For concrete masonry unit construction, all cells must be grouted full.
3. Brinnell Hardness Number for mild steel is 110 to 160
4. Brinnell Hardness Number for rolled homogeneous armor is 220 to 350
5. Bullet resisting fiberglass is not commonly available for bullets of these calibers or compositions.
6. Minimum compressive strength of 3000 psi (21 MPa).
7. Minimum compressive strength of 5000 psi (35 MPa).

Table 5-4 Anti-Tank Weapon Resistant Construction

Material	Thickness
Rolled Homogeneous Armor	22 inches (560 mm)
Mild Steel	28 inches (710 mm)
Aluminum	39 inches (990 mm)
Lead	20 inches (280 mm)
Copper	21 inches (530 mm)
Concrete	40 inches (1016 mm)
Concrete Masonry	44 inches (1118 mm)
Clay Brick Masonry	46 inches (1168 mm)
Granite	38 inches (965 mm)
Rock	39 inches (990 mm)
Soil	55 inches (1400 mm)
Water	62 inches (1575 mm)
Green wood	66 inches (1676 mm)

5-3.4.2 Design Using Computations.

Where threats are different than those in Table 2-1, where designers wish to explore options not included in the tables, or where they want to explore multiple materials or layers, the design tables above will fall short and designers will need to apply computational methods. Examples of evaluating multiple layers or materials include determining the required thickness of an inner wythe of a cavity wall after a bullet passes through the outer wythe and determining the effect of a steel plate mounted on the interior surface of a masonry wall. Note in the latter case that application of those equations is conservative where the two materials are in contact. Computational methods are presented separately for various materials for the ballistics threats, but there is only one computational method for the anti-tank weapons threat.

5-3.4.2.1 Ballistics Threats.

There are multiple ways to apply computational methods for designing building components to resist penetration by ballistics rounds. Complex finite element models can be used, but they are very expensive and seldom warrant the effort. There are also equations. The equations in this UFC come from the penetration chapter of UFC 3-340-01. In some cases, they have been modified slightly to compute the desired quantity, which is commonly the thickness of the material needed to resist perforation by a particular round. Applying the equations requires detailed knowledge of both the round and the material. Material properties that are not commonly known are provided. Projectile properties, including mass, velocity, and ratios needed to evaluate nose performance coefficients can be found in **\1** Appendix C **/1/**. All velocities in **\1**Appendix C **/1/** are muzzle velocities. Using those velocities is conservative because bullets will lose some velocity over distance due to drag.

Note that some of the equations are in metric units and some are in English units. Because the equations are largely curve fits of actual data, they are left in their original form rather than attempting to convert them to metric or English units.

5-3.4.2.1.1 Wood.

Equation 5.1 gives the thickness of wood necessary to resist perforation. Values for density and hardness for various species of wood can be found in Table 5-5. Where the thickness of wood target is less than that given by Equation 5-1, use Equation 5-2 to determine the residual velocity that the round will have after passing through the wood. Note that the latter case is how energy absorption screens can be designed. That residual velocity could then be applied to another material layer. In doing so, it is commonly assumed (conservatively) that the bullet retains all of its mass.

Equation 5-1. Wood Thickness to Prevent Projectile Perforation

$$T_W = 9837\left(\frac{v^{0.4113}w^{1.4897}}{\rho\left(\frac{\pi D^2}{4}\right)^{1.3596} H^{0.5414}}\right)$$

Where:
T_W = thickness of wood necessary to prevent perforation (in)
v = projectile impact velocity (ft/s) (conservatively use muzzle velocity in Appendix C)
w = projectile weight (lbs) (see Appendix C)
D = projectile diameter (in2)
ρ= wood density (lbs/ft3) (see Table 5-5)
H = wood hardness (lbs) (see Table 5-5)

Table 5-5 Wood Properties

Species		Density (lbs./ft^3)	Hardness (pounds)
Pine	Dry	23.5	38.7
	Wet	30	51.1
Maple	Dry	35	76.9
	Wet	40	72
Green Oak	Dry	55	88.1
	Wet	55	72.1
Marine plywood	Dry	37	68.7
	Wet	37	58.8
Balsa	Dry	6	21
	Wet	6	61.5
Fir plywood	Dry	30	75
	Wet	30	68.9
Hickory	Dry	50	74.3
	Wet	55	63.5

Equation 5-2. Residual Velocity from Wood Target

$$v_r = v\left[1.0 - \left(\frac{t}{T_w}\right)^{0.5735}\right]$$

Where:
v_r = residual velocity (ft/s)
t = actual target thickness (in)

5-3.4.2.1.2 Steel Plate.

The projectile velocity at which a given type and thickness of steel plate can prevent perforation is commonly referred to as the limit velocity. Equation 5-3 is a manipulation of the limit velocity equation for steel to give plate thickness. Note that the thickness reported by Equation 5-3 is what is necessary to stop complete perforation (the projectile passing completely through the plate and emerging with zero velocity). That represents a safe condition for most applications, although there are times when ensuring that there is no rear face spalling is necessary. In those cases, add two bullet diameters to the plate thickness determined from Equation 5-3. Note that Equation 5-3 is only valid for calibers of 0.50 (12.7 mm) or less. For larger calibers, refer to UFC 3-340-01.

If the plate thickness is less than that given in Equation 5-3, the bullet will pass through the plate with a residual velocity, which can be predicted using Equation 5-4. That residual velocity could then be applied to another material layer. In doing so, it is commonly assumed (conservatively) that the bullet retains all of its mass. In that equation, impact velocity can initially (conservatively) be taken to be muzzle velocity. Where the equation is used to evaluate multiple protective layers, the residual velocity would be used as the impact velocity in equations 5-3 or 5-4 or in other similar equations for other materials.

Equation 5-3. Steel Thickness to Prevent Projectile Perforation

$$T_S = D\left(\frac{vm^{0.5}\cos^{0.8}\theta}{1.125D^{1.5}\log_{10}BHN}\right)^{1.25}$$

Where:
v = impact velocity (m/s) (initially use maximum muzzle velocity from Appendix C.)
D = projectile diameter (mm) (see Appendix C)
T_S = thickness of steel plate to prevent perforation (mm)
θ = angle of obliquity (degrees)(see glossary)
m = mass of projectile (kg) (see Appendix C)
BHN = Brinnell Hardness Number (see Table 5-3)

Equation 5-4. Residual Velocity from Steel Plate Target

$$v_r = \left\{v^2 - \left[\frac{1.1275\left(\frac{t}{D}\right)^{0.8} D^{1.5}\log_{10}BHN}{m^{0.5}\cos^{0.8}\theta}\right]^2\right\}^{0.5}$$

Where:
t = thickness of steel plate (mm)
v_r = residual velocity (m/s)
v = impact velocity (m/s)

5-3.4.2.1.3 Concrete.

Concrete is the most common construction material used to provide bullet resistance. Calculating the thickness of concrete needed to stop projectiles requires the application of two equations. Use Equation 5-5 to determine projectile penetration into concrete for an air backed slab. If the wall is soil backed rather than air backed, see UFC 3-340-01. Determine the minimum thickness of concrete to prevent perforation of the wall slab by entering the results of Equation 5-5 into Equation 5-7, which provides the thickness at which the nose of the projectile reaches the back face of the slab, but with zero velocity. That is sufficiently safe for most applications in that any concrete that "spalls" off the back face is likely to represent a minimal hazard. Where that is not considered acceptable, use Equation 5-8, which provides the thickness required to prevent spall. These equations can also reasonably be used to estimate behavior of masonry. To do so, enter the lower of the compressive strength of the grout, the mortar, and that of the blocks or bricks themselves in Equation 5-5 for $f_c^{'}$.

If the concrete thickness is less than that calculated in Equation 5-7, the bullet will pass through the wall with a residual velocity, which can be predicted using Equation 5-9. That residual velocity could then be applied to another material layer as the impact velocity. In doing so, it is commonly assumed (conservatively) that the bullet retains all of its mass.

Equation 5-5. Penetration into Concrete (air backed)

$$P_C = \frac{56.6\left(\frac{m}{D^3}\right)^{0.075} \overline{N} m v^{1.8}}{D^2 \sqrt{f_{C'}^{'}}} \left(\frac{D}{c}\right)^{0.15} f_{age} + D$$

Where:
P_C = Maximum penetration into concrete (mm)
D = projectile diameter (mm) (see Appendix C)
m = projectile mass (kg) (see Appendix C)
c = maximum gravel size in concrete (mm)
(assume to be 19 mm for most concrete and 4 mm for concrete masonry)
v = impact velocity (m/s) (conservatively use muzzle velocity in Appendix C)
$f_C^{'}$ *= concrete compression strength (MPa)*
$\overline{N}$ *= nose performance coefficient (see equation 5-6)*

- *= 0.91 for low threat severity level*
- *= 1.26 for medium threat severity level*
- *= 1.39 for high threat severity level*
- *= 1.31 for very high threat severity level*

f_{age}*= concrete age factor*

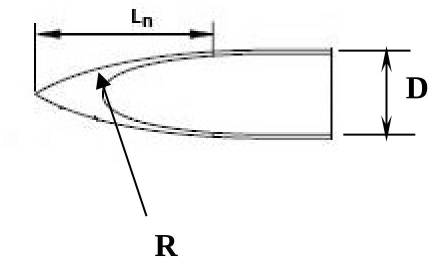
f_{age}	Concrete age (days)
1.0	≥ 360
1.01	180
1.02	66
1.05	≤ 28

Equation 5-6. Nose performance coefficient

$\overline{N} = 0.72 + 0.25\left(\frac{L_N}{D}\right)$ *(values for* $\overline{N}$ *are tabulated in Table C-1 for common bullets)*

$\frac{L_N}{D}$ *can also be calculated as* $\left(\frac{R}{D} - 0.25\right)^{0.5}$

$\frac{R}{D}$ *is tabulated in some publications as CRH (caliber radius head)*



Note: If the tangent ogive is truncated, use the actual L_N of the truncated nose in equation 5-6. If the nose shape does not conform to a tangent ogive, select an equivalent ogive with a similar length-to-diameter ratio using engineering judgment

L_N = nose length of projectile
R = tangent ogive radius

Equation 5-7. Perforation Limit Thickness for Air Backed Concrete Slabs

$$T_{BD} = D\left[1.375\left(\frac{P_C}{D}\right) + 2\right]$$

T_{BD} = thickness to prevent back face damage (mm)

Equation 5-9. Residual Velocity Equation from Concrete Slab Target

$$v_r = v\left(1 - \frac{\frac{t}{D}}{\frac{T_{PL}}{D}}\right)^{0.733}$$

Where:
v_r = residual velocity (m/s)
v = impact velocity (m/s)
t = slab thickness (mm)

5-3.4.2.2 Anti-tank Weapon Threat.

Anti-tank weapon penetration of building materials is not as well understood as ballistics penetration, but Equation 5-10 can be used to estimate common building material thicknesses necessary to resist perforation by anti-tank warheads for weapons within the family of antitank weapons covered by the UFC. The equation is a function of warhead diameter and is based on the required thicknesses of rolled homogeneous armor. The material multiplication factor "corrects" the thickness for armor to that for other materials. The following are common warhead diameters for the weapons discussed in Chapter 2 that can be used in applying Equation 5-9.

- Russian RPG 7 (and similar copies): 70 mm
- Russian RPG 18 (and similar copies): 64 mm
- Russian RPG 22 (and similar copies): 72.5 mm
- US M 72: 66 mm

Equation 5-10. Building Material Thickness to Resist Anti-tank Weapons

$$T = 7.79\ D\ M$$

Where:
T = thickness of the building material to resist perforation (in)
D = warhead diameter (in)
M = Material Multiplication Factor (see Table 5-6)

Table 5-6 Material Multiplication Factors for Antitank Weapon Resistance

Target Material	Material Multiplication Factor (M)	Material Density
Rolled Homogeneous Armor	1.00	7850 Kg/m^3 (490 $lb/ft^{3)}$
Mild steel	1.25	7850 Kg/m^3 (490 $lb/ft^{3)}$
Aluminum	1.75	2600 Kg/m^3 (160 $lb/ft^{3)}$
Lead	0.88	10,600 Kg/m^3 (660 $lb/ft^{3)}$
Copper	0.94	8900 Kg/m^3 (556 $lb/ft^{3)}$
Concrete	1.82	2400 Kg/m^3 (150 $lb/ft^{3)}$
Concrete Masonry	1.98	2000 Kg/m^3 125 lb/ft^3
Clay Brick Masonry	2.02	1920 Kg/m^3 120 lb/ft^3
Granite	1.68	2800 Kg/m^3 (170 $lb/ft^{3)}$
Rock	1.75	2600 Kg/m^3 (160 $lb/ft^{3)}$
Earth	2.47	1300 Kg/m^3 (80 $lb/ft^{3)}$
Water	2.80	1000 Kg/m^3 (60 $lb/ft^{3)}$
Green wood	2.97	900 Kg/m^3 (60 $lb/ft^{3)}$
Note: For other materials $M = \sqrt{\frac{\rho_s}{\rho_t}}$ ρ_s = density of steel; ρ_t = density of target material		

5-3.4.3 Design Based on Testing.

For ballistics threats there are a number of testing standards that can be used to test building components against a range of different ballistics rounds. Those test standards specify how the test specimens will be set up, the mass and velocity of the bullets to be used in the test, the number and positioning of the shots, and the criteria for “passing” the test. Testing can be used to test complex material interactions, to evaluate materials for which there are no computational methods and in cases where manufacturers wish to optimize designs. Refer to the test standards tabulated in **\1** Appendix C **/1/** for detailed information. There are no standardized tests for antitank weapons, but tests can be conducted using similar failure criteria to those of the ballistics tests.

5-4 WINDOWS.

5-4.1 Very Low Level of Protection.

Because the design strategy for the very low level of protection is limited to incorporating the minimum standards of UFC 4-010-01, the DoD Minimum Antiterrorism Standards for Buildings, and since there are no minimum standards related to mitigating direct fire weapons effects against windows, there are no requirements for windows at this level of protection.

5-4.2 Low Level of Protection.

Because the design strategy for the low level of protection is limited to blocking lines-of-sight to targeted assets, window requirements are focused on obscuration. This level of protection applies to all ballistics and anti-tank weapon threats. Obscuration can be accomplished by controlling sight lines to assets through window layout and placement, window design, window treatment application, or shielding. In addition, consider minimizing the number and size of windows to decrease visible window area and limit available targets. In addressing window layout and placement, consider layouts and placements that do not allow sight lines to assets from outside the building using window configurations such as those shown in Figures 5-4 and 5-5. Alternatively, arrange rooms to ensure that potentially targeted assets cannot be seen through the windows or block sight lines through windows using screening materials such as fences or vegetation as described in Chapter 4.

Figure 5-4. Narrow Obliquely Recessed Windows

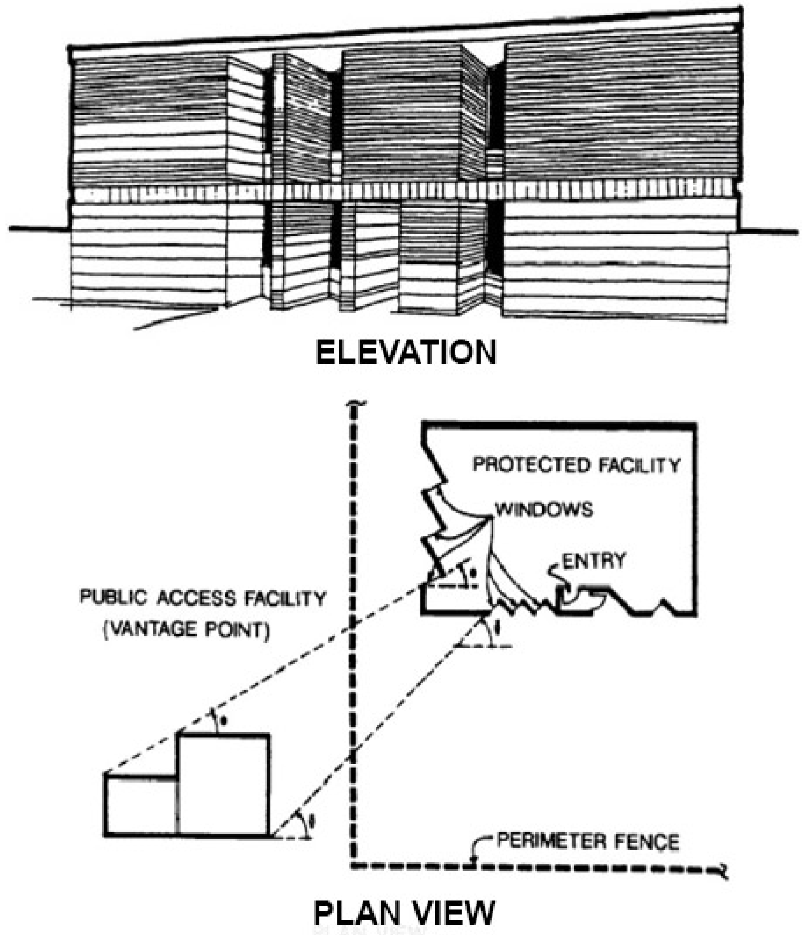


Figure 5-5. Elevated Windows

5-4.2.1 Low Level of Protection Alternatives.

An alternate approach is to design windows to limit sight lines through them by using translucent or figured glazing that allows light in but is not sufficiently transparent for people to be able to see anything through them.

Windows can also be treated with reflective films or glazing tints to limit views into buildings from outside. This is particularly useful for windows in existing buildings where there is little opportunity for reconfiguration. Reflective films are made by applying a thin metallic layer to a polyester or similar film to limit how much light passes through the film, a characteristic referred to as “visible transmittance”. When one side of the film is brighter than the other side, a relatively large amount of light is reflected off the bright side of the film. The reflection of that light results in an observer on the bright side seeing a mirror –like image while an observer on the darker side can see through the window. At night when the outside of the window becomes darker than the inside, more light is transmitted from the lit rooms inside of the building to the outside and an observer outside will see through the window while people inside the room will see a reflective surface. That suggests that drapes or blinds may need to be provided to obscure assets at night.

5-4.3 Medium Level of Protection.

The design strategy for this level of protection is to employ energy absorption or predetonation screens to limit the energy with which the projectiles impact the target and to provide hardened construction to prevent the projectiles from penetrating the protective envelope. In general, is not practical to apply that strategy to window designs to resist high caliber ballistics (12.7 mm or .50 caliber) and anti-tank weapons. Windows cannot be practically designed to resist predetonated anti-tank rounds, and while it may be feasible to design windows for reduced energy ballistics, most windows are designed and tested to meet particular ballistic standards, none of which address reduced energy ballistics. Developing window designs for that situation would therefore be impractical. One approach that can be used for both anti-tank weapons and high caliber ballistics is to use Tables 5-1 or 5-2 or Figures 5-2 or 5-3 to locate energy absorption or predetonation screens and to locate walls constructed to resist reduced energy or predetonated rounds a short distance in front of windows to shield them. Where such options are employed, ensure that the walls and screens do not provide opportunities for concealment with in the unobstructed space required by UFC 4-010-01. A more common approach to addressing this level of protection for the high caliber ballistics and antitank weapons is to minimize the number and size of windows to decrease visible window area and limit available targets. While that does not fully provide the medium level of protection to the same extent that it is provided for walls or other building components, doing anything else has limited practicality.

5-4.4 High Level of Protection.

The design strategy for the high level of protection applies similarly to all threat severity levels. It entails providing windows that resist the direct impact of the ballistic or anti-tank rounds. Designing windows to resist antitank rounds is impractical, however. The only practical approaches to addressing this level of protection against anti-tank weapons are to either eliminate windows or to take the reduced window area and layout approaches described in the low level of protection paragraph above. The latter will not fully mitigate the vulnerabilities associated with this tactic, which will require assumption of some risk on the part of the building occupants.

Ballistic resistant windows are commonly designed based on testing to standards such as those tabulated in Appendix C. It is important to note that window designs to meet those standards must include entire window assemblies including glazing, frames, and connections assembled as they would be in the field. Testing assemblies ensures that all potential impact points on a window provide ballistics resistance. Window designs will usually be proprietary and may use a variety of glazing and frame materials. Manufacturers certify their compliance with the standards, usually through independent testing laboratories. Window designs for non-armor piercing rounds of 7.62 mm (.30 caliber) and below are commonly available from most bullet resistant window manufacturers. Designs to resist armor piercing rounds are less common. That makes it important that designers review the actual test reports to ensure the tests follow procedures similar to those in national standards and that the results appear to be reasonable.

5-5 DOORS.

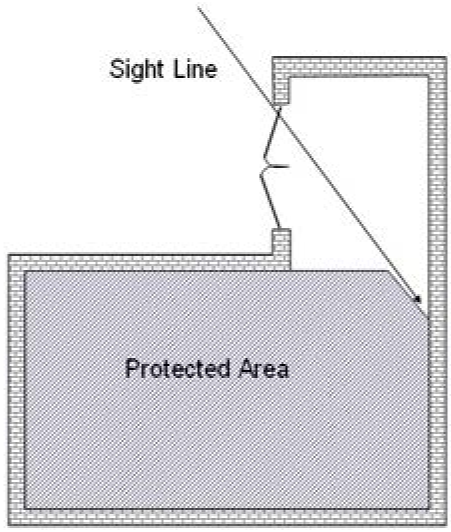
5-5.1 Very Low Level of Protection.

While the design strategy for the very low level of protection is limited to incorporating the minimum standards of UFC 4-010-01, the DoD Minimum Antiterrorism Standards for Buildings, there is a minimum standard that involves doors. It requires main entrances to inhabited buildings to be oriented such that they do not face installation perimeters or uncontrolled vantage points to minimize vulnerabilities to people entering or leaving buildings. Where such orientations are not an option, the standard allows for providing means to block lines of sight. Means to block lines of sight are described in the following paragraph. In existing buildings changing entrance orientation may require significant changes in building operations, such as using an alternate entrance as a main entrance. The option of blocking sight lines is often the most practical for existing buildings.

5-5.2 Low Level of Protection.

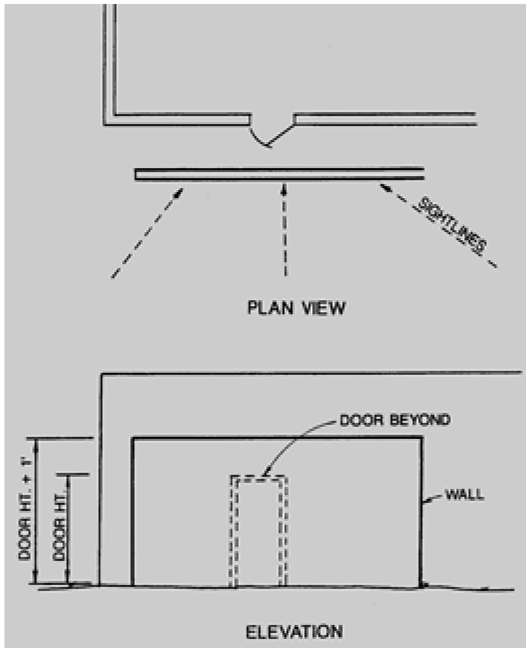
Because the design strategy for the low level of protection is limited to blocking lines-of-sight to targeted assets, door requirements are focused on obscuration. This level of protection applies to all ballistics and anti-tank weapon threats. Obscuration can be accomplished by controlling sight lines through door layout, door design, or shielding. In addressing door layout, consider door arrangements that do not allow sight lines to assets from outside the building such as the layout shown in Figure 5-6 or through the use of foyers in front of doors. Alternatively, arrange rooms to ensure that potentially targeted assets cannot be seen through the doors.

Figure 5-6. Entrance Layout to Limit Sight Lines



Doors can also be designed to limit sight lines through them by making them opaque (as wood or metal doors would be) or by using translucent or figured glazing for vision panels that allow light in but are not sufficiently transparent for people to be able to see anything through them. Vision panels in doors can also be treated with reflective films or glazing tints to limit views into buildings from outside as described above for windows. Note that drapes or blinds need to be provided to obscure assets at night as described previously. Drapes or blinds cannot be used for egress doors, however, unless they are built into the doors' vision panels or the doors will violate the requirements of NFPA 101, the Life Safety Code. Sight lines to doors can also be blocked by shielding the door from vantage points using walls or other screening materials as illustrated in Figure 5-7. This is a particularly useful option for limiting sightlines through existing doors. For the low level of protection, the screening material only needs to be sufficient to limit vision through it. Design the shield to be wider than the door by a distance established by extending a line from the door frame to the end of the wall at a 45^0 angle from the building on both sides of the door as shown in Figure 5-7. Design the shield to be higher than the door by at least the distance shown in Figure 5-7. Ensure the shield does not interfere with the requirements in NFPA 101 for egress and egress discharge. Doing so may require the shield to be moved away from the door, which may make it necessary to extend the wall.

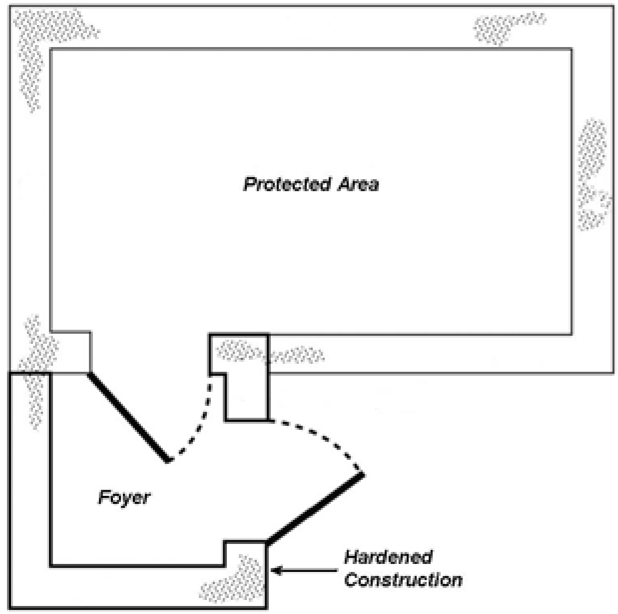
Figure 5-7. Door Shielding



5-5.3 Medium Level of Protection.

In general, the medium level of protection is only practical for high caliber ballistics (.50 caliber or 12.7 mm) or anti-tank weapons. The applicable design strategy is to employ energy absorption or predetonation screens to limit the energy with which the projectiles impact the target and to provide hardened construction to prevent the projectiles from penetrating the protective envelope. It is not practical to design doors to resist predetonated anti-tank rounds. While it may be possible to design doors for reduced energy ballistics, most doors are designed and tested to meet a particular ballistic standard and the reduced energy ballistics would not be reflected by any of those standards. Developing door designs for that situation would be impractical. The approach used, therefore, is to use Tables 5-1 or 5-2 or Figures 5-2 or 5-3 to locate energy absorption or predetonation screens and to select wall construction to resist reduced energy or predetonated rounds. Such walls should be configured in foyer arrangements as illustrated in Figure 5-8 or in shielding configurations as in Figure 5-7. In either case, the walls would provide all the necessary resistance to the threat and the doors could be of any material.

Figure 5-8. Hardened Foyer Configuration



5-5.4 High Level of Protection.

The design strategy for the high level of protection is to provide construction that resists the direct impact of ballistics or anti-tank rounds. Approaches to applying that strategy for doors are different for high caliber ballistics and anti-tank rounds and smaller caliber ballistics.

5-5.4.1 Small caliber ballistics.

For ballistics below 0.50 caliber (12.7 mm) the design approach is to use bullet resistant door assemblies. Those assemblies are tested in accordance with standards such as those in Appendix C. Note that, as for windows, tested door designs to meet those standards must include entire door assemblies including, frames, hardware, vision panels, and connections assembled as they would be in the field. Testing assemblies ensures that all potential impact points on a door provide ballistics resistance. Doors are available from multiple manufacturers to meet the various standards, although not all manufacturers provide doors to meet all the standards.

Door designs will commonly be proprietary and may use a variety of different door and frame materials. Manufacturers certify their compliance with the standards, usually through independent testing laboratories. Ballistics resistant doors will often be of the same approximate dimensions and outward appearance as conventional doors, but their cores may include other materials such as steel or bullet resistant fiberglass as shown in Figure 5-9. Note that bullet resistant doors may be significantly heavier than conventional doors, which may make them more difficult to operate and may require heavier duty door operators where they are necessary. Egress doors must meet the requirements of NFPA 101 for maximum allowable door operating force.

Figure 5-9. Bullet Resistant Fiberglass Door Core

5-5.4.2 High Caliber Ballistics and Anti-tank Weapons.

Doors designed to resist direct impacts from anti-tank rounds are not practical; therefore, the approach to providing the high level of protection for that threat for doors is to design foyers in front of the doors as shown in Figure 5-8. The exterior foyer wall would be designed to provide the full resistance to the anti-tank round. Door designs to resist .50 caliber (12.7 mm) rounds are available, but at the time this UFC is being written none were tested to any nationally approved standards because such a standard was only recently developed. That makes it important that designers review the actual test reports to ensure the tests follow procedures similar to those in national standards and that the results appear to be reasonable. Alternatively, application of hardened foyers as described above is a good option for protecting doors against high caliber ballistics.

5-6 VENT COVERS AND GRILLES.

Where there are potential sight lines to assets through vents or other building openings they should be protected similarly to windows and doors.

5-6.1 Very Low Level of Protection.

Because the design strategy for the very low level of protection is limited to incorporating the minimum standards of UFC 4-010-01, and since there are no minimum standards related to mitigating direct fire weapons effects against vent covers or grills, there are no requirements for vents or grills at this level of protection.

5-6.2 Low Level of Protection.

Because the design strategy for the low level of protection involves obscuration, ensure that any vent covers or grilles through which there are potential sight lines to assets are designed such that aggressors cannot see through them. Alternatively, shield them or block sightlines to them using opaque materials or vegetation or ensure through room arrangement that there is nothing that could be targeted through them. Any shielding using site furnishings or vegetation must avoid providing opportunities for concealment within the **\1\/1/** unobstructed space required by UFC 4-010-01.

5-6.3 Medium Level of Protection.

The design strategy for the medium level of protection is to employ energy absorption or predetonation screens to limit the energy with which the projectiles impact the target and to provide hardened construction to prevent the projectiles from penetrating the protective envelope. That approach is only practical for high caliber ballistics (.50 caliber or 12.7 mm) or anti-tank weapons. Designing vent covers or grilles to resist predetonated anti-tank rounds is not practical; therefore, the vents should be shielded by a wall designed to resist the predetonated round as described in the sections above on walls and doors. Vent covers or grilles could be designed to resist reduced energy ballistics or they could be shielded with walls designed to resist the reduced energy rounds. To design vent covers and grilles to resist the reduced energy rounds locate an energy absorption screen in accordance with the section above on walls and use Equations 5-3 and 5-4 to design steel louvers. Where shielding walls are used, ensure that their location and configuration are communicated to the mechanical engineers to ensure that their heating, ventilation, and air conditioning designs take the potential for reduced air flow into account.

5-6.4 High Level of Protection.

Because the design strategy for this level of protection requires protective elements to resist the direct impact of rounds and because resistance of vent and grill materials to anti-tank weapons and low and high caliber ballistics are so different, each of those applications will be discussed separately.

5-6.4.1 Low Caliber Ballistics.

Design vent covers or grilles with steel plate using equation 5-3 or use vent covers and grilles that have been tested for ballistics resistance to an appropriate standard.

5-6.4.2 High Caliber Ballistics and Antitank Weapons.

Designing vent covers and grilles to resist the direct impact of 12.7 mm (.50 caliber) bullets or anti-tank rounds would be impractical. Use shielding walls to resist the rounds or orient the openings so they cannot be targeted. Where shielding walls are provided, ensure that their location and configuration are communicated to the mechanical engineers to ensure that their heating, ventilation, and air conditioning designs take the potential for reduced air flow into account.

5-7 ROOFS.

Designing roofs to resist direct fire weapons is only an issue where there are sightlines to roofs. Where that is the case, design the roof similarly to walls.

5-7.1 Very Low Level of Protection.

Because the design strategy for the very low level of protection is limited to incorporating the minimum standards of UFC 4-010-01, and since there are no minimum standards related to mitigating direct fire weapons effects against roofs, there are no requirements for roofs at this level of protection.

5-7.2 Low Level of Protection.

Because the low level of protection is predicated on blocking sightlines to assets, ensure the roof is opaque or translucent and treat any skylights like windows using the guidance in the window section above.

5-7.3 Medium Level of Protection.

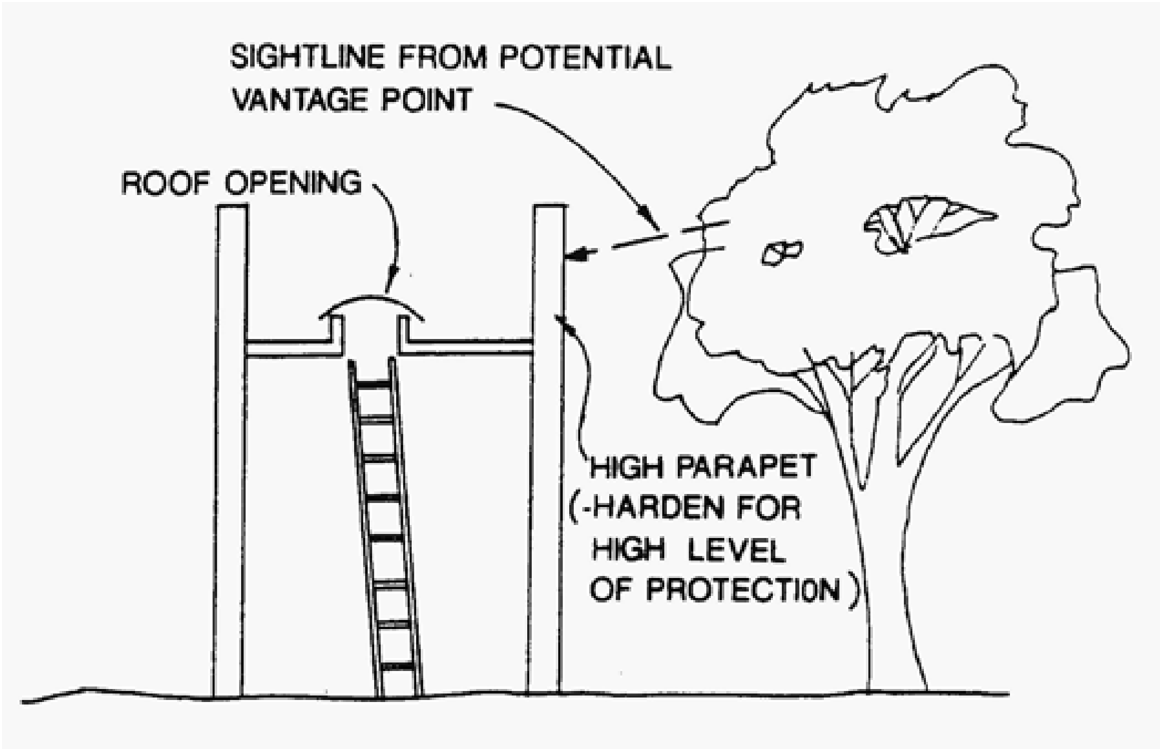
Because the design strategy for this level of protection involves erecting energy absorption or predetonation screens and designing to resist the reduced energy or predetonated rounds it is only practical for high caliber (12.7 mm or .50 caliber) or anti-tank rounds. Designing for this level of protection will require erecting an energy absorption or predetonation screen above the roof by the appropriate distance and of the appropriate material and designing the roof to resist the reduced energy or predetonated round. Follow the guidance in the wall section above in designing for this condition. That design will be conservative because it is predicated on perpendicular impacts and roof impacts will most likely be at oblique angles. The steel penetration equations for ballistics do take angle of obliquity into account, however.

5-7.4 High Level of Protection.

Because the design strategy for the high level of protection depends on building components resisting the direct impact of incoming rounds, where there are direct sight lines to roofs the roofs will have to be designed using materials such as reinforced concrete or steel to provide the necessary resistance.

Use the guidance in the wall section of this chapter to design roofs to resist either ballistics or anti-tank threats. Note that impacts on roofs will commonly be at oblique angles, so the tabulated material thicknesses in Tables 5-1 and 5-2 will be conservative as will most of the equations in this chapter. The exception to that is Equation 5-4 for steel, which includes angles of obliquity. Another option is to provide high parapets that block sightlines to the roof. For this level of protection those parapets would either be sufficiently constructed to provide all the penetration resistance necessary or the combination of the parapet and the roof material would have to provide the resistance. Refer to the wall section of this chapter to design the parapets. Figure 5-10 shows a raised parapet configuration.

Figure 5-10. Raised Parapets



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APPENDIX A REFERENCES

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) INTERNATIONAL

http://www.astm.org/Standard/standards-and-publications.html

ASTM F 1233-08, Standard Test Method for Security Glazing Materials and Systems, 2013

DEPARTMENT OF STATE (DOS)

SD-STD-01.01, *Certification Standard Forced Entry and Ballistic Resistance of Structural Systems Revision G April 30, 1993*

FOREIGN STANDARDS

Australia / New Zealand AS/NZ 243, *Bullet-Resistant Panels and Elements, 1997*

British Standards Institution Standard BS 5051, *Security Glazing, Part 1. Specification for Bullet Resistant Glazing for Interior Use, 1988*

Deutches Institut fur Normung (DIN) 52 290, Security Glazing, 1988

European Standard DIN EN 1063:2000: *Glass In Building - Security Glazing - Testing and Classification of Resistance Against Bullet Attack, 2000*

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 101, *Life Safety Code 2012*

NATIONAL INSTITUTE OF JUSTICE STANDARD (NIJ)

NIJ) 0108.01, *Ballistic Resistant Protective Materials, 1985*

UNDERWRITER'S LABORATORY

Underwriters Laboratories Standard 752, *Bullet-Resisting Equipment, 2005*

UNIFIED FACILITIES CRITERIA

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

UFC 1-200-01, *General Building Requirements*

UFC 3-340-01, *Design and Analysis of Hardened Structures to Conventional Weapons Effects (FOUO)*

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

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

UFC 4-020-02, *DoD Security Engineering Facilities Design Manual*, currently in Draft and unavailable

OTHER

- H.P. White Laboratory, Inc. HPW-TP 0500.03, Test procedure: Transparent Materials for Use in Forced Entry or Containment Barriers, 2003

APPENDIX B GLOSSARY

B-1 ACRONYMS

ANSI	American National Standards Institute
AP	Armor piercing
ASTM	Not an acronym. Formerly American Society for Testing and Materials
AT	Anti-tank
CNSC	Conical nosed soft core
CRH	Caliber Radius Head
DoD	Department of Defense
FCJ	Full copper jacket
FMCJ	Full metal copper jacket
FMJ	Full metal jacket
FSJ	Full steel jacket
ft/s	Feet per second
g	Grams
gr.	Grains
JSP	Jacketed soft point
lbs	Pounds
LAW	Light anti-tank weapon
mm	Millimeters
m/s	Meters per second
NATO	North Atlantic Treaty Organization
NIJ	National Institute of Justice
RN	Round nosed
RNL	Round nosed lead
RNSC	Round nosed soft core

RPG	Rocket propelled grenade
SHC	Steel hard core
SWC	Semi - wadcutter
UL	Underwriters Laboratories

B-2 DEFINITION OF TERMS:

Ammunition. One or more loaded cartridges consisting of a primed case, propellant and with or without one or more projectiles.

Angle of obliquity. The vertical angle from the perpendicular at which a projectile strikes a target.

Armor piercing. The characteristics of bullets that allow them to penetrate armor, relying on the design characteristics of the projectile, such as the shape of the tip and materials used in the bullet, rather than upon increased muzzle energy. The effects of armor piercing rounds differ from other rounds only in their ability to penetrate greater material thicknesses, especially of hardened or armored materials such as steel or composite assemblies including multiple layers of steel.

Ball. In ballistics, a general term used to describe military bullets which are entirely inert and intended for antipersonnel and general use. The term is used to distinguish them from specialized bullets such as tracers.

Ballistic Limit Velocity. That velocity for which there is a 50% probability of target perforation.

Buckshot. The coarse lead-alloy spherical pellets loaded in shotgun shells as projectiles. Buckshot is manufactured in sizes up to 1/3-inch diameter.

Building elements. Components of buildings and countermeasures associated directly with building interiors and exterior surface features.

Bullet resistant. A descriptive term for a material designed to prevent injury to persons or damage to objects positioned behind it when subjected to a ballistics attack.

Caliber. The caliber of a bullet refers to its diameter and is expressed either in decimals of an inch or in millimeters. Typical examples include the 9mm (.38 caliber), 5.56mm **\1** (.22 caliber) and 7.62mm (.30 caliber) **/1/** ammunition for military arms.

Controlled perimeter. For the purposes of this UFC, a physical boundary at which vehicle access is controlled with sufficient means to channel vehicles to the access control points. At a minimum, access control at a controlled perimeter requires the demonstrated capability to search for and detect explosives. Where the controlled perimeter includes a shoreline and there is no defined perimeter beyond the shoreline, the boundary for measuring standoff distances will be at the mean high water mark or the elevation associated with top of bank (associated with a flood recurrence interval of 1.2 years). (UFC 4-010-01)

Countermeasure. Any protective element put in place to mitigate the effects of a threat. Countermeasures may include building elements, sitework elements, building support systems, equipment, and manpower and procedures.

Design Strategy. The approach for developing a protective system to mitigate the effects of an attack. There are both general design strategies and specific design strategies (specific to levels of protection) associated with each tactic.

Dudding. Rendering a live round inert.

Effective range. The maximum distance at which a weapon may be expected to be accurate and achieve the desired effect.

Energy absorption screen. A solid surface that causes the energy of a projectile to be reduced as the projectile passes through the screen with a residual velocity.

Full metal jacketed. A bullet made of lead and completely covered, except for the base, with a copper alloy jacket (approximately 90 percent copper and 10 percent zinc). Most military bullets are full metal jacketed.

Gas checked. In ballistics, a method for preventing the lead buildup in high velocity handguns. A lead buildup occurs when an uncased soft lead bullet is propelled through a gun barrel by a column of gas, causing enough friction to melt the edges of the base of the lead bullet and subsequently causing a deposit of molten lead on the inner barrel of the gun. To prevent this, a shallow copper cup is placed on the base of the bullet to insulate it from the heat of the powder gases and to prevent lead buildup along the rifle bore.

Gauge. In ballistics, the size of a shotgun expressed as the number in a pound of round lead balls of a size to just fit into the barrel.

Grain. In ballistics, a measure of weight which is 1/7,000th of an English pound. Grains are used to express the weight of bullets used for all ballistics standards.

Jacketed soft point. A bullet made of lead and completely covered, except for the point, with copper alloy (approximately 90 percent copper and 10 percent zinc). The absence of jacketing at the point of the bullet enhances its deformation upon impact.

Level of Protection. The degree to which an asset (person, equipment, object, etc.) is protected against injury or damage from an attack. (UFC 4-010-01)

Lines of sight. Unobstructed direct views from vantage points to targets.

Magnum. A load or cartridge having greater power than other cartridges of the same caliber. A magnum case is generally longer than a common case. For example, a .44 Magnum is approximately 1/8 inch longer than the .44 Special. A .44 Magnum revolver will chamber either round, but a .44 Special revolver will chamber only the .44 Special cartridge. Another variation of the magnum is a cartridge with an exceptionally large propellant capacity in relation to the bore diameter, such as the .300 Winchester Magnum.

Muzzle velocity. The velocity of a projectile as it exits the muzzle of a firearm.

Obscuration. Blocking sightlines using any form of screening, vegetation, or building treatment.

Parabellum. Cartridges and pistols originating with Deutsche Waffen and Munitions Fabrik, Berlin; a term derived from their telegraphic address and trademark.

Penetration. Intrusion of a projectile beyond the strike face of a material without emerging from the protected face.

Perforation. Complete penetration through a material creating an opening in both the threat (target) face and the protected face.

Predetonation screen. A solid surface that causes an antitank round to detonate before it reaches its target. When placed at the proper distance for the facility construction, the screen will prevent penetration of the facility exterior by the antitank round.

Residual velocity. In ballistics, the velocity a projectile has after it has perforated a layer of material.

Round Nosed Lead. A lead bullet with a blunt, rounded tip.

Semi wadcutter. Intermediate bullet shape between round-nose and wadcutter (flat point).

Sitework elements. Countermeasures that are applied beyond 1.5 meters (5 feet) from a building, excluding countermeasures categorized under equipment.

Small arms. describes any number of smaller infantry weapons, such as firearms that an individual soldier can carry. It is usually limited to revolvers, pistols, submachine guns, shotguns, carbines, assault rifles, rifles, squad automatic weapons, light machine guns.

Spall. The condition in which pieces of a material are broken loose from the inner surface of a wall, roof, or similar element by tensile forces that are created when a compression shock wave travels through the body and reflects from the surface.

Temperate zone. Either of two middle latitude zones of the Earth; the Northern Temperate Zone and the Southern Temperate Zone, lying between 23-1/2 degrees and 66-1/2 degrees north and south.

Unobstructed space. Space around inhabited buildings in which there are no opportunities for concealment from observation of explosive devices 6 inches (150 mm) or greater in height or width. (UFC 4-010-01)

Witness panel. In ballistics, a material such as aluminum foil or corrugated cardboard that is positioned behind and parallel to a test target. Witness panels are used to provide evidence of penetration and spall created during impact of a test sample.

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APPENDIX C BALLISTIC STANDARDS

C-1 BALLISTIC STANDARDS

Organization	Standard or Rating	Ammunition	Weight	Diameter	$\bar{N}$	Velocity	Number of Shots
ASTM F 1233	9 mm Parabellum /Submachine Gun	9 mm Parabellum FMJ	124 gr. 8.04 g	.354 in 9 mm	0.94	1350 - 1450 ft/s 411 – 442 m/s	3
	.38 Super / Handgun	.38 Super FMJ	130 gr. 8.42 g	.357 in 9.07 mm	0.94	1230 - 1330 ft/s 375 – 436 m/s	
	.44 Magnum / Handgun	.44 Magnum JSP	240 gr. 15.55 g	.427 in 10.85 mm	0.91	1400 - 1500 ft/s 427 – 457 m/s	
	7.62 mm NATO / Rifle	7.62 mm (.30 caliber) M-80 NATO	147 gr. 9.53 g	.30 in 7.82 mm	1.26	2750 - 2850 ft/s 838 – 869 m/s	
	.30-’06 Armor Piercing / Rifle	.30-’06 M2 AP	165 gr. 10.69 g	.30 in 7.82 mm	1.39	2725 - 2825 ft/s 831 – 861 m/s	
	12 Gauge Shotshell, 3 inch Magnum / Shotgun	# 00 Buckshot 3 inch Magnum	808 gr. 52.36 g	n/a	n/a	1265 - 1365 ft/s 386 – 416 m/s	
Councils of Standards Australia / New Zealand AS/NZ 2343	G0, 9mm Parabellum	9 mm Parabellum FMJ	115 gr. 7.45 g	.355 in 9 mm	0.94	1294 – 1362 ft/s 394 – 415 m/s	3
	G1, .357 Magnum	.357 Magnum SWC	158 gr. 10.24 g	.357 in 9.07 mm	0.94	1467 – 1532 ft/s 447 – 467 m/s	
	G2, .44 Magnum	.44 Magnum SWC	240gr. 15.55 g	.427 in 11.18 mm	0.91	1568 – 1634 ft/s 478 – 498 m/s	
	R1, .223, 5.56 NATO	.223 caliber, 5.56 mm NATO M193	55 gr. 3.56 g	.223 in 5.66 mm	1.17	3182 – 3248 ft/s 970 – 990 m/s	
	R2, .30, 7.62 NATO	.30 caliber, 7.62 mm NATO M80	147 gr. 7.53 g	.30 in 7.82 mm	1.26	2766 – 2831 ft/s 843 – 863 m/s	
	S0, 12 Gauge, 2-3/4 “	12 Gauge, 2-3/4” Shot	493 gr. 31.95 g	n/a	n/a	1289 – 1355 ft/s 393 – 413 m/s	
	S1, 12 Gauge, 2-3/4”	12 Gauge, 2-3/4” Slug	382 gr. 24.75 g	n/a	n/a	1532 – 1598 gr. 467 – 487 g	2
British Standards Institution BS 5051	BSI, G0, 9 mm Parabellum	9 mm Parabellum FMJ	115 gr. 7.45 g	.355 in 9 mm	0.94	1280 – 1378 ft/s 390- 420 m/s	3
	BSI, G1, .357 Magnum	.357 Magnum JSP	158 gr. 10.24 g	.357 in 9.07 mm	0.94	1427 – 1526 ft/s 435 – 465 m/s	
	BSI, G2, .44 Magnum	.44 Magnum JSP	240gr. 15.55 g	.427 in 11.18 mm	0.91	1496 – 1594 ft/s 456 – 486 m/s	

Organization	Standard or Rating	Ammunition	Weight	Diameter	$\overline{N}$	Velocity	Number of Shots
British Standards Institution BS 5051 (continued)	BSI, R1, .223, 5.56 NATO	.223 caliber, 5.56 mm NATO M885/SS109	63 gr. 4.08 g	.223 in 5.66 mm	1.17	3015 – 3114 ft/s 919 – 949 m/s	3
	BSI, R2, .30, 7.62	.30 caliber, 7.62 mm NATO M80	147 gr. 9.53 g	.30 in 7.82 mm	1.26	2674 – 2772 ft/s 815 – 845 m/s	
	BSI, S86, 12 Gauge 2-3/4”	12 Gauge, 2-3/4” Slug	438 gr. 28.38 g	n/a	n/a	1332 – 1463 ft/s 406 – 446 m/s	1
European Standard DIN EN 1063	BR1, .22 LR	.22 LR RNL	40 gr. 2.59 g	.222 in 5.63 mm	0.95	1048 – 1214 ft/s 319 – 370 m/s	3
	BR2, 9 mm Parabellum	9 mm Luger FSJ-RNSC	124 gr. 8.04 g	.354 in 9 mm	0.94	1280 – 1345 ft/s 390 – 410 m/s	
	BR3, .357 Magnum	.357 Magnum FSJ-CNSC	158 gr. 10.24 g	.357 in 9.07 mm	0.94	1378 – 1444 ft/s 420 – 440 m/s	
	BR4, .44 Magnum	.44 Magnum FCJ-FNSC	240 gr. 15.55 g	.427 in 11.18 mm	0.91	1411 – 1476 ft/s 430 – 450 m/s	
	BR5, 5.56 x 45 NATO AP	5.56 x 45 NATO (.223 Remington) SS 109 steel penetrator	62 gr. 4.02 g	.223 in 5.66 mm	1.17	3084 – 3150 ft/s 940-0960 m/s	
	BR6, 7.62 x 51 NATO	7.62 x 51 NATO M80 FSJ	147 gr. 9.53 g	.30 in 7.82 mm	1.26	2690 – 2756 ft/s 820 – 840 m/s	
	BR7, 7.62 x 51 NATO AP	7.62 x 51 NATO AP SHC	150 gr. 9.72 g	.30 in 7.82 mm	1.26	2657 – 2723 ft/s 810 – 830 m/s	
	SG1, Shotgun	12 Gauge solid lead Brenneke slug	478 gr. 30.97 g	n/a	n/a	1312 – 1444 ft/s 400 – 440 m/s	1
	SG2, Shotgun	12 Gauge solid lead Brenneke slug	478 gr. 30.97 g	n/a	n/a	1312 – 1444 ft/s 400 – 440 m/s	3
German Deutche Institut fur Normung (DIN) 52-290	C1-SF and C1-SA, 9 mm Parabellum	9 mm Parabellum FMJ	124 gr. 8.04 g	.355 in 9 mm	0.94	1165 – 1198 ft/s 355 – 365 m/s	3
	C2-SF and C2-SA, .357 Magnum	.357 Magnum FMJ	158 gr. 10.24 g	.357 in 9.07 mm	0.94	1362 – 1394 ft/s 415 – 425 m/s	
	C3-SF and C3-SA, .44 Magnum	.44 Magnum FMJ	240 gr. 15.55 g	.427 in 11.18 mm	0.91	1427 – 1460 ft/s 435 – 445 m/s	
	C4-SF and C-4 SA, .30, 7.62 NATO	.30 caliber, 7.62 mm NATO M80	147 gr. 9.53 g	.30 in 7.82 mm	1.26	2575 – 2608 ft/s 785 – 795 m/s	
	C5-SF and C5-SA, .30, 7.62 NATO	.30 caliber , 7.62 mm NATO M61 AP	150 gr. 9.72 g	.30 in 7.82 mm	1.26	2625 – 2657 ft/s 800 – 810 m/s	

Organization	Standard or Rating		Ammunition	Weight	Diameter	$\bar{N}$	Velocity	Number of Shots
HP White Laboratories HPW-TP 0500.02	A, .38 Special		.38 Special RNL	158 gr. 10.24 g	.357 in 9.07 mm	0.94	700 – 800 ft/s 213 – 274 m/s	3
	B, 9 mm x 19		9 mm x 19 FMJ	124 gr. 8.04 g	.355 in 9 mm	0.94	1100 – 1180 ft/s 335 – 360 m/s	
	C, .44 Magnum		.44 Magnum	240gr. 15.55 g	.427 in 11.18 mm	0.91	1350 – 1450 ft/s 411 – 442 m/s	
	D, 7.62 x 51		7.62 x 51 NATO M80	147 gr. 9.53 g	.30 in 7.82 mm	1.26	2725 – 2825 ft/s 831 – 861 m/s	
	E, .30-06		.30-06 M2 AP	165 gr. 10.69 g	.30 in 7.82 mm	1.39	2725 – 2825 ft/s 831 – 861 m/s	
MIL-SAMIT (Military Small Arms Multiple Impact Test)	.30, 7.62 NATO Part 1		.30 caliber, 7.62 mm NATO M80	147 gr. 9.53 g	.30 in 7.82 mm	1.26	2750 - 2800 ft/s 838 - 853 m/s	
	.30, 7.62 NATO Part 2		.30 caliber, 7.62 mm NATO M61 AP	150 gr. 9.72 g	.30 in 7.82 mm	1.26	> 2800 ft/s > 853 m/s	25
National Institute of Justice (NIJ) 0108.01	Type I	.22 long rifle	.22 Long Rifle, High Velocity, Lead	40 gr. 2.6 g	.222 in 5.64 mm	0.95		5
		.38 Special	.38 Special RN	158 gr. 10.2 g	.357 in 9.07 mm	0.94	800 – 900 ft/s 244 – 274 m/s	
	Type IIA	Lower velocity .357 Magnum	.357 Magnum JSP	158 gr. 10.2 g	.357 in 9.07 mm	0.94	1200 – 1300 ft/s 366 – 396 m/s	
		Lower velocity 9 mm	9 mm FMJ	124 gr. 8.0 g	.355 in 9 mm	0.94	1050 – 1130 ft/s 320 – 344 m/s	
	Type II	Higher velocity .357 Magnum	.357 Magnum JSP	158 gr. 10.2 g	.30 in 7.82 mm	0.94	1345 – 1445 ft/s 410 – 440 m/s	
		Higher velocity 9 mm	9 mm FMJ	124 gr. 8.0 g	.355 in 9 mm	0.94	1135 – 1215 ft/s 346 – 370 m/s	
	Type IIIA	.44 Magnum	.44 Magnum Lead SWC Gas Checked	240 gr. 15.55 g	.427 in 11.08 mm	0.91	1350 – 1450 ft/s 411 – 442 m/s	
		Submachine gun – 9 mm	9 mm FMJ	124 gr. 8.0 g	.355 in 9 mm	0.94	1350 – 1450 ft/s 411 – 442 m/s	
	Type III (High Powered Rifle)		7.62 mm / .30 Winchester FMJ	150gr. 9.7 g	.30 in 7.82 mm	1.26	2700 – 2800 ft/s 823 – 853 m/s	
	Type IV (Armor Piercing Rifle)		30-06 AP	166 gr. 10.8 g	.30 in 7.82 mm	1.39	2800 – 2900 ft/s 853 – 884 m/s	1

Organization	Standard or Rating	Ammunition	Weight	Diameter	$\bar{N}$	Velocity	Number of Shots
State Department SD-STD-01.01	SD – Minimum, 9 mm Parabellum	9 mm Parabellum FSJ	115 gr. 7.45 g	.354 in 9 mm	0.94	1350 – 1450 ft/s 411 – 442 m/s	3
	SD - Minimum, 12 gauge, 2-3/4”	12 gauge, 2-3/4”, #4 Buck	556 gr. 36.03 g	n/a	n/a	1275 – 1375 ft/s 389 – 419 m/s	1
	SD - Rifle .30, 7.62 NATO (Part 1)	.30 caliber, 7.62 mm NATO M80	147 gr. 9.53 g	.30 in 7.82 mm	1.26	2700 – 2800 ft/s 823 – 853 m/s	
	SD - Rifle .223, 5.56 NATO (Part 2)	.223 caliber, 5.56 mm NATO M193	55 gr. 3.56 g	.223 in 5.66 mm	1.17	3135 – 3235 ft/s 956 – 986 m/s	
	SD - Rifle .223, 5.56 NATO (Part 3)	.223 caliber, 5.56 NATO M855	63 gr. 4.08 g	.223 in 5.66 mm	1.17	> 2950 ft/s > 899 m/s	
	SD – Rifle, 12 gauge, 2-3/4” (Part 4)	12 gauge, 2-3/4”, #4 Buck	556 gr. 36.03 g	n/a	n/a	1275 – 1375 ft/s 389 – 419 m/s	
	SD – Rifle AP, .30, 7.62 NATO (Part 1)	.30 caliber, 7.62 mm NATO M61 AP	150gr. 9.72 g	.30 in 7.82 mm	1.39	2700 – 2800 ft/s 823 – 853 m/s	3
	SD – Rifle AP, 12 gauge, 2-3/4” (Part 1)	12 gauge, 2-3/4”, #4 Buck	556 gr. 36.03 g	n/a	n/a	1275 – 1375 ft/s 389 – 419 m/s	1
	SD – Rifle AP, .30, 30-06 (Part 1)	.30-06 caliber M2AP	165 gr. 10.69 g	.30 in 7.82 mm	1.39	2800 – 2900 ft/s 853 – 884 m/s	3
	SD – Rifle AP, 12 gauge, 2-3/4” (Part 1)	12 gauge, 2-3/4”, #4 Buck	556 gr. 36.03 g	n/a	n/a	1275 – 1375 ft/s 389 – 419 m/s	1

Organization	Standard or Rating	Ammunition	Weight	Diameter	$\overline{N}$	Velocity	Number of Shots
Underwriters Laboratories (UL) 752	Level 1	9mm FMCJ w/ lead core	124 gr. 8.0 g	.354 in 9 mm	0.94	1175 – 1293 ft/s 358 – 394 m/s	3
	Level 2	.357 Magnum JSP	158 gr. 10.2 g	.357 in 9.07 mm	0.94	1250 – 1375 ft/s 381 – 419 m/s	
	Level 3	.44 Magnum lead SWC, gas checked	240 gr. 15.6 g	.427 in 11.18 mm	0.91	1350 – 1485 ft/s 411 – 453 m/s	
	Level 4	.30-06 caliber rifle lead core soft point	180 gr. 11.7 g	.30 in 7.82 mm	1.39	2540 – 2794 ft/s 774 – 852 m/s	1
	Level 5	7.62 mm (.30 caliber) rifle lead core FMCJ , Military Ball	150gr. 9.7 g	.30 in 7.82 mm	1.26	2750 – 3025 ft/s 838 – 922 m/s	
	Level 6	9 mm FMCJ with lead core	124 gr. 8.0 g	.354 in 9 mm	0.94	1400 – 1540 ft/s 427 – 469 m/s	5
	Level 7	5.56 rifle, FMCJ with lead core	55 gr. 3.56 g	.223 in 5.66 mm	1.17	3080 – 3388 ft/s 939 – 1033 m/s	
	Level 8	7.62 mm rifle lead core FMCJ, military ball	150 gr. 9.7 g	.30 in 7.82 mm	1.26	2750 – 3025 ft/s 838 – 922 m/s	
	Level 9	.30-06 caliber rifle, steel core lead point filler, FMJ (APM2)	166 gr. 10.8 g	.30 in 7.82 mm	1.39	2715 – 2987 ft/s 828 – 910 m/s	1
	Level 10	.50 caliber rifle lead core FMCJ Military Ball, M2	709.5 gr. 45.9 g	.51 in 12.95 mm	1.31	2810 – 3091 ft/s 856 – 942 m/s	
	Supplementary Shotgun	12-gauge rifled lead slug	437 gr. 28.3 g	n/a	n/a	1585 – 1744 ft/s 483 – 531 m/s	3
		12 gauge 00 buck shot	650 gr. 42 g	n/a	n/a	1200 – 1320 ft/s 366 – 402 m/s	

ABBREVIATIONS:

AP = armor piercing
CNSC = Conical Nosed Soft Core
FCJ = Full Copper Jacket
FMCJ = Full Metal Copper Jacket
FMJ = Full Metal Jacket
FSJ = Full Steel Jacket

JSP = Jacketed Soft Point
RN = Round Nosed
RNL = Round Nosed Lead
RNSC = Rounds Nosed Soft Core (lead)
SHC = Steel Hard Core
SWC = Semi Wad Cutter

$\overline{N}$ = Nose Shape Coefficient
n/a = not applicable
ft/s = feet per second
m/s = meters per second
gr. = grains
g = grams

in = inches
mm = millimeters

C-2 UL LEVELS

LEVEL 1: Protection against hand guns of medium power, such as the 9 mm, Super 38 Automatic, and the like, with muzzle energy of 380 – 460 foot-pounds (515 – 624 J).

LEVEL 2: Protection against hand guns of high power, such as the .357 Magnum, and the like, with muzzle energy of 548 – 663 foot-pounds (743 – 899 J).

LEVEL 3: Protection against hand guns of super power, such as the .44 Magnum, and the like, with muzzle energy of 971 – 1175 foot-pounds (1317 – 1593 J).

LEVEL 4: Protection against high-power hunting and sporting rifles, such as the 30-06, and the like, with muzzle energy of 2580 – 3120 foot-pounds (3498 – 4929 J).

LEVEL 5: Protection against military ball full metal copper jacket ammunition fired from a hunting rifle such as the 308 Winchester or a military rifle with muzzle energy of 2519 – 3048 foot-pounds (3416 – 4133 J).

LEVEL 6: Protection against multiple shots from a submachine-gun, such as a 9 mm Uzi, and the like, with muzzle energy of 540 – 653 foot-pounds (732 – 885 J).

LEVEL 7: Protection against multiple shots from a military assault rifle, such as an M-16, and the like, with muzzle energy of 1158 – 1402 foot-pounds (1570 – 1901 J).

LEVEL 8: Protection against multiple shots from a military assault rifle, such as an M-14, and the like, with muzzle energy of 2519 – 3048 foot-pounds (3416 – 4133 J).

LEVEL 9: Protection against armor piercing rounds fired from an M1 Garand rifle or the like, or high-power hunting and sporting rifles with muzzle energy of 2717 to 2777 foot-pounds (3683 – 4457 J). The bullet will be a .30-06 armor piercing round such as the US Military APM2.

LEVEL 10: Protect against one shot from a military sniper rifle, such as the Barrett M82 A1 (XM 107), with a muzzle energy of 12,439 – 12. 706 foot-pounds (16, 863 – 20,404 J). The bullet will be a .50 caliber round such as the US Military M2.

SUPPLEMENTARY SHOTGUN: A supplementary test using a rifled lead slug with a muzzle energy of 2438 – 2950 foot-pounds (3306 – 4000 J) and 00 lead buckshot with a muzzle energy of 2078 – 2415 foot-pounds (2818 – 3275 J), fired from a 12-gauge shotgun. Products shall be tested with both loads. Products complying with this test may have the suffix ²-SG² added to the rating designation.

UFC 4-023-10
1 June 2016

UNIFIED FACILITIES CRITERIA (UFC)

SAFE HAVENS

UNIFIED FACILITIES CRITERIA (UFC)

SAFE HAVENS

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location

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

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

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

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

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UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

Subject: UFC 4-023-10, Safe Havens

Supersedes: None

Document Description and Need:

- **Purpose:** In some DoD facilities, a safe haven may be required to provide additional protection to DoD personnel and their dependents for man-made and natural threats. This UFC specifies the development of design criteria for these threats and provides guidance for satisfying those criteria when designing a safe haven.

- **Application and Use:** This UFC applies to the design of a safe haven for all DoD buildings and facilities that require additional protection from man-made and natural threats. The safe haven may also be used as a fallback position for the destruction of classified information during an attack. This UFC will be employed when the project planning team (as defined in UFC 4-020-01) and/or the facility owner require that a safe haven be incorporated into the building or facility. The primary use of this UFC is to design the safe haven for man-made threats and that the guidance provided herein for natural threats is for information purposes and the planner/designer shall design the facility for the natural threats as necessary in accordance with UFC 1-200-01, General Building Requirements.

- **Need:** No guidance previously existed for the design of safe havens within the DoD or any of its components.

Impact: The following benefits will result from publication of UFC 4-023-10.

- Consistency in the planning and design of safe havens will be implemented across DoD.

- Safe haven design will be based on careful consideration, identification, and evaluation of man-made and natural threats.

- The design of a safe haven will employ the best existing design guidance for man-made and natural threats.

- The safety of DoD personnel and dependents will be increased, for both CONUS and OCONUS applications.

Unification Issues
There are no unification issues.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC provides planning and design requirements and guidance for a safe haven. It is not intended to create the requirement for a safe haven, but to assist in meeting the planning and design criteria requirements. The requirement for a safe haven may come from Department of Defense (DoD) policy, service policy, installation requirements, or user requirements when supported by policy.

1-2 APPLICABILITY.

This UFC provides planning and design criteria and guidance for DoD components and participating organizations. The primary use of this UFC is to design the safe haven for man-made threats and that the guidance provided herein for natural threats is for information purposes and the planner/designer shall design the facility for the natural threats as necessary in accordance with UFC 1-200-01, General Building Requirements. This document applies to all construction, renovation, and repair projects for safe havens.

For some applications, specific design or facility type criteria may be available, in those applications; the more stringent criteria will apply.

1-3 DEFINITION OF SAFE HAVEN.

A safe haven is a structure, or protected area within a structure, that provides protection from man-made threats, natural threats, or combination for short durations and infrequent intervals.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *General Building Requirements*. 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 VULNERABILITY AND RISK ASSESSMENT.

1-5.1 Man Made Threat.

Manmade threats range from focused attacks by trained aggressors using explosives, direct and indirect fire weapons, forced entry tools, and chemical or biological agents, to haphazard attempts to disrupt or occupy a facility by protestors with political or social motivations.

In accordance with DoD security and antiterrorism (AT) policies, a vulnerability and risk assessment must be conducted prior to beginning any security project. Upon identifying facility or asset vulnerabilities to threats, physical security measures such as a safe haven, a hardened and secure facility, fences, gates, and Electronic Security Systems (ESS) may be deployed to reduce vulnerabilities. In summary, this document assumes the planning phases, including the risk analysis, are complete prior to beginning design. For information on Security Engineering Planning and Design process, refer to UFC 4-020-01 and UFC 4-020-02FA (described in the section “Security Engineering UFC Series” in this chapter). The engineering risk analysis conducted as part of UFC 4-020-01 should be consistent with the terrorism risk analysis conducted by the installation security/AT staff.

1-5.2 Natural Threat.

For natural threats such as hurricanes, tornadoes, typhoons, earthquakes, and tsunamis, refer to UFC 3-301-01 *Structural Engineering,* and American Society of Civil Engineers (ASCE), Federal Emergency Management Agency (FEMA), and International Code Council (ICC) criteria referenced herein for guidance for assessing natural threats.

1-6 POLICY REQUIREMENTS.

The requirement to provide a safe haven comes from DoD Instruction/Directives, Geographic Combatant Commander (GCC) Instructions, Service Instruction/Directives, and Regional or Installation requirements. Consult Headquarters, Major Command, Regional, and Installation personnel to establish project requirements.

1-6.1 Department of Defense.

- DoD policy provides guidance to ensure individuals designated as High Risk Personnel (HRP) or serving in a designated High Risk Billet (HRB) are provided an appropriate level of protection.

- Department of Defense Instruction O-2000.22 *Designation and Physical Protection of DoD High-risk Personnel (HRP)*: The Protection-Providing Organization (PPO) will conduct a Personal Security Vulnerability Assessment (PSVA) for each HRP. The resulting PSVA will provide recommendations for the protection of the HRP which may include a safe haven. The PPO refers to the U.S. Army Criminal Investigative Command, the Naval Criminal Investigative Service, the U.S. Air Force Office of Special Investigations, the Defense Criminal Investigative Service, the Pentagon Force Protection Agency, and the National Security Agency. For additional information on HRP, refer to UFC 4-010-03, *Security Engineering: Physical Security Measures for High-Risk Personnel.*

1-6.2 Geographic Combatant Commander (GCC) Requirements.

GCCs issue requirements for antiterrorism and physical security for installations within their area of responsibility. Ensure any such requirements are incorporated in addition to the requirements found in DoD and Service Directive/Instructions. Resolve any differences in the requirements by applying the most stringent requirement.

1-7 REFERENCES.

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

1-8 DOD SECURITY ENGINEERING UFC SERIES.

This UFC is one of a series of security engineering Unified Facilities Criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include the following, and the intended process for applying them is illustrated in Figure 1-1.

1-8.1 DoD Minimum Antiterrorism (AT) Standards for Buildings.

UFC 4-010-01 establishes standards that provide minimum levels of protection against terrorist attacks for the occupants of all DoD inhabited buildings. UFC 4-010-01 is intended to be used by security and antiterrorism personnel and design teams to identify the minimum AT requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings. UFC 4-010-01 also includes recommendations that should be, but are not required to be incorporated into all such buildings.

1-8.2 Security Engineering Facilities Planning Manual.

UFC 4-020-01 outlines the processes for developing the design criteria necessary to incorporate security and antiterrorism design criteria into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum AT standards, or they may include protection of assets other than those addressed in the minimum AT standards (people), aggressor tactics that are not addressed in the minimum AT standards or levels of protection beyond those required by the minimum AT standards.

The cost implications for security and AT are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they only represent construction that will meet the requirements of the design criteria. The manual also addresses the tradeoffs between cost and risk. The Security Engineering Facilities Planning Manual is intended to be used by planners as well as security and AT personnel with support from planning team members.

1-8.3 Security Engineering Facilities Design Manual.

UFC 4-020-02FA provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02FA is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design. The manual also provides a process for assessing the impact of protective measures on risk. The primary audience for the Security Engineering Design Manual is the design team, but security and antiterrorism personnel can also use it.

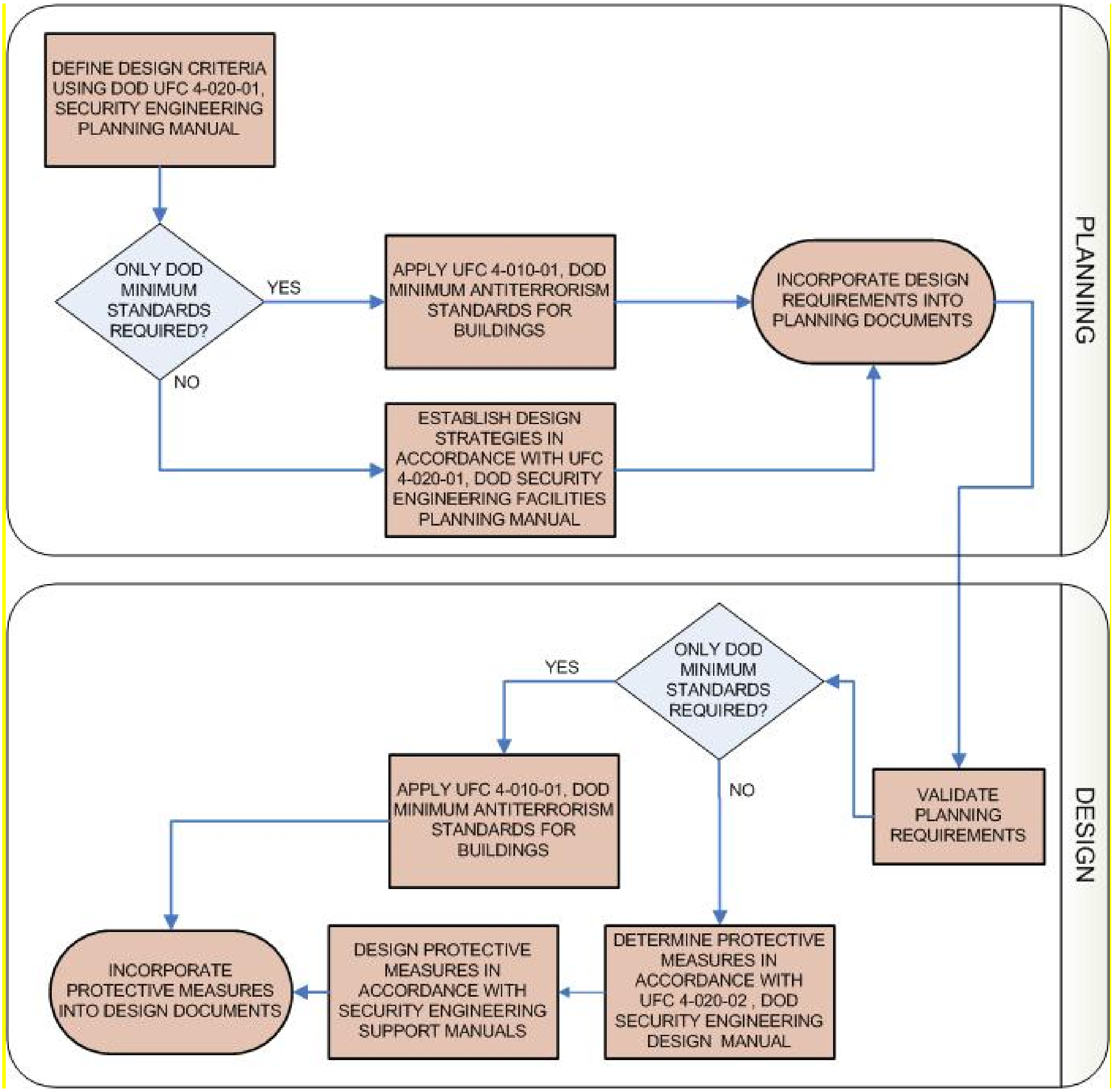
1-8.4 Security Engineering Support Manuals.

In addition to the standards, planning, and design UFC mentioned above, there is a series of additional UFCs that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02FA. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, forced entry, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mail rooms. Still others address details of designs for specific protective measures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

1-8.5 Security Engineering UFC Applications.

The application of the security engineering series of UFCs is illustrated in Figure 1-1. UFC 4-020-01 is intended to be the starting point for any project that is likely to have security or AT requirements. By beginning with UFC 4-020-01, the design criteria will be developed that establishes which of the other UFCs in the series will need to be applied. The design criteria may indicate that only the minimum AT standards need to be incorporated, or it may include additional requirements, resulting in the need for application of additional UFCs. Even if only the minimum AT standards are required, other UFCs may need to be applied if sufficient standoff distances are unavailable. Applying this series of UFCs in the manner illustrated in Figure 1-1 will result in the most efficient use of resources for protecting assets against security and AT related threats.

Figure 1-1 Application of UFC Documents for Planning and Design



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CHAPTER 2 DESIGN CRITERIA DEVELOPMENT

2-1 INTRODUCTION.

Each safe haven must be sized, configured, and outfitted based on the project requirements. This section is intended to make planners aware of safe haven requirements that may affect the facility scope and budget. It is not intended to document the standard planning processes related to project development.

2-2 OVERVIEW OF PLANNING AND DESIGN PROCESS.

Determining the requirements for a safe haven requires an interdisciplinary team knowledgeable of local considerations. The interdisciplinary team must work together to determine project requirements. The team must consider cost, user constraints such as operations, manpower requirements or limitations, and sustainment costs when determining the requirements for the overall solution. The planning team should include the following:

- Supported Command
- Protection Providing Organization (PPO) representative (If for HRP)
- Security
- Safety
- Logistics
- Engineering (Planning and Design)
- Cultural resources/historic preservation officers (if historical building)

The process for determining the requirements for man-made and natural threats is provided further in this chapter. Physical security and structural design requirements and procedures required to meet these criteria are provided in Chapter 3.

2-3 PLANNING CONSIDERATIONS.

To define the design criteria for the safe haven, a preliminary determination of some of the physical attributes of its facility must be known.

2-3.1 Time

The location of a safe haven is an important part of the planning and design process, especially for natural threats such as tornados and some man-made threats that are presented in a relatively short time after the threat is annunciated.

2-3.1.1 Transit Time.

The planner and designer shall consider the time required for all occupants of a building or facility to reach the safe haven. The National Weather Service (NWS) has made great strides in predicting tornadoes and hurricanes and providing warnings that allow time to seek shelter. For tornadoes, the time span is often short between the NWS warning and the onset of the tornado. It is recommended that a safe haven for a natural threat be designed and located in such a way that the following access criteria are met. All potential users of the safe haven should be able to reach it within 5 minutes per FEMA P-361 *Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms*. For hurricanes, these restrictions do not apply, because warnings are issued much earlier, allowing more time for preparation. Note that the typical walking speed is 3 to 4 ft/s (0.9 to 1.2 m/s) per Manual on Uniform Traffic Control Devices (MUTCD). For man-made threats, discuss transit time to the safe haven with the security professional based on the design basis threat.

Transit time may be especially important when safe haven users have disabilities that impair their mobility. Those with special needs may require assistance from others to reach the safe haven; wheelchair users may require a particular route that accommodates the wheelchair.

2-3.2 Travel Route.

The designer must consider the time factors above to provide the shortest possible access time and most accessible route for all potential safe haven occupants. To ensure that personnel are able to reach the safe haven within the required amount of time and that all personnel are provided a safe haven, it may be necessary to construct multiple safe havens at a given facility.

The route to the safe haven must be free from obstruction. If it is necessary for personnel to reach the safe haven by motorized conveyance, such as by automobile or shuttle, space around the safe haven must be provided for drop-off and parking.

2-3.3 Duration of Occupancy.

As specified in FEMA P-361, for short-duration natural events (tornadoes and earthquakes), the duration of occupancy is 2 hours. For the design of a safe haven that must protect against hurricanes, typhoons, and the airborne contamination tactic of a medium or high threat severity level, the duration of occupancy is a minimum of 24 hours. For all other man-made threats, the duration of occupancy is equal to the response time of the security forces. For instance, if 1 hour is required for security forces to respond and there are no natural threats or threat of airborne contamination, the duration of occupancy is 1 hour.

2-3.4 Occupancy Level.

The occupancy level for a safe haven is based on the maximum number of personnel required to occupy the safe haven. In the case of a HRP, the occupancy would be one. In the case of a Sensitive Compartmented Information Facility (SCIF), the occupancy would be the occupancy of the SCIF.

2-3.5 Floor Area.

2-3.5.1 Occupants.

The amount of required floor space depends upon the design threat, event duration, and the number and types of occupants. Natural events, such as hurricanes, or man-made threats, such as the air contamination tactic, may require longer occupancy times and therefore more floor area per person. For additional discussion on occupancy, means of egress, access, and accessibility see FEMA P-361.

If the building/facility in which the safe haven will reside must be designed for a hurricane or typhoon or if the threat severity level for the airborne contamination in accordance with UFC 4-020-01 is Medium or High, then use the floor area for long duration occupation in Table 2-1 to calculate the total required floor area. Otherwise, use the floor area for short duration occupation in Table 2-2.

Table 2-1 Floor Area for Long Duration (adapted from FEMA P-361)

Type of Person	Floor Area per Person, ft^2 (m^2)
Adult standing	20 (1.9)
Adult seated	20 (1.9)
Children under age 10	20 (1.9)
Wheelchair users	20 (1.9)
Bedridden persons	40 (3.8)

Table 2-2 Floor Area for Short Duration (adapted from FEMA P-361)

Type of Person	Floor Area per Person, ft^2 (m^2)
Adult standing	5 (0.46)
Adult seated	5 (0.46)
Children under age 10	5 (0.46)
Wheelchair users	10 (0.93)
Bedridden persons	30 (2.8)

2-3.5.2 Equipment for Destruction of Classified Materials.

If the safe haven will be used for destruction of classified materials, contact the responsible security office or the Facility Security Officer (FSO) to identify the equipment and procedure that is required to destroy or neutralize the classified materials and sensitive information. Determine the floor area and power requirements for this equipment. Check that the equipment can be safely used in a closed environment and that the generated waste can be accommodated within the space.

Note, for a SCIF or top secret open storage area that has been designated as a safe haven, the safe haven must be designed to provide sufficient space and delay time for the occupants to destroy documents. The occupants for such a safe haven must be limited to those personnel already occupying the space and those who are cleared and necessary for the destruction of the sensitive information. Additional safe havens may be required within the building to accommodate additional personnel.

2-3.5.3 Floor Area.

Calculate the required floor area by adding the floor area for occupants from the previous section on floor area to the floor area for the equipment used to destroy classified materials from Section on equipment for destruction of classified materials. The floor area must also include sufficient area for operational supplies for the safe haven, discussed in Chapter 4 on additional safe haven supplies.

2-3.6 Height.

For all safe havens, the minimum distance from the floor to ceiling is 7.5 feet (2.3 meters), as prescribed in NFPA 101 *Life Safety Code*.

2-3.7 Location, Type, and Number of Safe Havens.

Identify candidate safe haven locations with the guidance on site selection presented in siting section of Chapter 3, including maximum transit time to reach the safe haven as discussed previously. Note that a safe haven may serve multiple purposes, such as a conference room, cafeteria, gymnasium, restroom, classroom, or temporary lodging, and this possibility should be considered in the preliminary site selection.

After identification of the candidate safe haven types and locations, consider the issues of accessibility, power, ventilation (including special filtration for airborne contaminants, if necessary), water, communications, and waste storage. If the candidate safe haven location is still valid, proceed with the requirement determination of the design criteria in the following sections.

2-4 DESIGN CRITERIA FOR MAN-MADE THREATS.

To create the design criteria for man-made threats, employ the processes in UFC 4-020-01 to determine the level of protection (LOP) and the design basis threat (DBT). The man-made tactics relevant to safe haven design and discussed in UFC 4-020-01 include the following:

- Moving vehicle bomb
- Stationary vehicle bomb
- Hand delivered device
- Indirect fire weapons
- Direct fire weapons
- Forced entry
- Visual surveillance
- Airborne contamination
- Waterborne contamination
- Waterfront attack

The covert entry, acoustic eavesdropping, and electronic emanations eavesdropping tactics are not typically threats to a safe haven and need not be considered. In the event of retreat to a safe haven, personnel are alerted to the presence of a threat, and covert entry is unlikely to be employed by an aggressor. Per UFC 4-020-01, the acoustic eavesdropping and electronic emanations eavesdropping tactics are assumed to be employed by foreign intelligence services. As safe havens will only be used for destruction of classified material and not for creation or transmission, these two threats are removed from further consideration. In the event of a SCIF or classified conference room being designated as a multi-use safe haven, the creation and transmission of classified information will only be done during normal operations when the room is not being used as a safe haven. When such a room is being utilized as a safe haven, classified material will only be destroyed, not created or transmitted. Further, for the purposes of applying the UFC 4-020-01 procedures, the aggressors will not include unsophisticated criminals, sophisticated criminals, organized criminal groups, and vandals. For the Forced Entry tactic, specify the required protection time based on the response time of the security forces determined in security forces evaluation in addition to the DBT and the LOP.

2-5 DESIGN CRITERIA FOR NATURAL THREATS.

Natural threats include hurricanes, tornados, tsunamis, and earthquakes. Design to resist loads created by natural phenomena is discussed in design procedures for natural threats in Chapter 3.

2-5.1 Hurricane and Typhoon.

Hurricanes and typhoons are tropical cyclones in the western hemisphere and in the western North Pacific Ocean, respectively. In this UFC, the term hurricane also encompasses typhoons, for simplicity.

Hurricanes create three types of loads on a building. Wind-induced forces, high speed debris impact, and hydrodynamic forces from either flooding or storm surge. Ensure compliance with the most stringent of UFC 3-301-01 and FEMA P-361 for wind-speed data.

2-5.2 Tornado.

A tornado is a violently rotating column of air, in contact with the ground. According to FEMA P-361, tornados may load a structure in three ways: wind-induced forces, debris impact, and forces induced by change in atmospheric pressure. Forces induced by change in atmospheric pressure result from the large pressure gradient between the atmospheric pressure and the air pressure within the funnel of a tornado. As the tornado passes over a structure, it can cause outward pressures on a structure, due to the instantaneous pressure differences between the structure interior and exterior.

ICC 500-2014*ICC/National Storm Shelter Association (NSSA) Standard for the Design and Construction of Storm Shelters* provides design guidance for community shelters and residential safe rooms including wind speeds and other design criteria. Regarding wind speed and other structural design criteria ensure compliance with the most stringent of the UFC 3-301-01, FEMA P-361, and ICC 500-2014.

2-5.3 Earthquake.

Structures in earthquake regions are subjected to ground motions that generate inertial forces on the structure. Therefore, the ground motion is the critical parameter for seismic design. Use UFC 3-301-01 and 3-310-04 *Seismic Design for Buildings* to obtain data for ground motion data.

2-5.4 Tsunami.

A tsunami consists of waves generated by seismic activity, including sudden displacements of the seafloor or volcanic activity. When these waves reach shore, they can cause dramatic flooding in coastal areas. The result is that structures in affected areas can be subjected to hydrodynamic forces.

If tsunamis are a design threat, the building/facility in which the safe haven will reside must be designed in accordance with the guidance presented in UFC 3-310-04 and FEMA P-646 *Guidelines for Design of Structures for Vertical Evacuation from Tsunami.*

2-6 OTHER APPLICABLE DESIGN REQUIREMENTS.

Depending upon the location of the safe haven, additional design requirements may be imposed by the American Embassy Chief of Mission, the host nation’s military and police, and host nation agreements. Work with the Planning Team to identify these additional requirements.

Geographic combatant commanders may also establish additional guidance to ensure uniform and consistent application of these standards within their areas of operations or to account for any special circumstances.

2-7 FINAL DESIGN CRITERIA.

The design criteria developed in previous sections and the other applicable design requirements above must be combined such that the maximum criteria controls for all cases of overlap. Develop a final design criteria requirement that includes, as a minimum, the following items:

- Relevant man-made tactics, and corresponding DBT and LOP
- Required response time for Forced Entry tactic
- Identification of natural threats and all corresponding load criteria (such as maximum wind speed, earthquake load cases, debris impact, and hydrodynamic forces)
- Other applicable design requirements as described above

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CHAPTER 3 DESIGN PROCESS

3-1 INTRODUCTION.

The design of a safe haven must meet the criteria that were developed in Chapter 2. Note that design to resist a given threat may provide protection against some other threat. For example, walls designed to resist a forced entry tactic for a high LOP will be more than sufficient to resist a hand-delivered weapon tactic at a low LOP. After examining the DBTs and LOPs for all applicable tactics, the tactic requiring the most stringent design will govern. Different tactics may govern various components of the safe haven, and each component must be validated to handle all applicable tactics. In addition, there are often multiple ways by which to satisfy the design criteria. Any method that is rational, based on fundamental principles of engineering mechanics and dynamics, and/or validated with experimental data is permissible. Any design approach that is not specified or referenced in this document must be approved by the Planning Team or by an authorized representative of the facility owner.

3-2 INITIAL CONSIDERATIONS.

3-2.1 Siting.

3-2.1.1 General Conditions.

A safe haven can be defined as standalone, such as a buried shelter or the entire structure, or internal, such as a protected area within a building. Specific guidance for standalone and internal safe havens is discussed in the following section on structural integration. The location of the safe haven must permit personnel to reach the safe haven from their work areas within 5 minutes after annunciation of a threat. Personnel will follow signage to reach the appropriate safe haven. The safe haven must also provide sufficient space for the protected assets, such as personnel and associated supplies or classified material. Furthermore, the site must provide a sufficient number of entry points into the safe haven, with appropriate access control. Finally, to facilitate egress of occupants from the safe haven once the threat has passed, site elevation must not be greater than an elevation that can be accessed by ladders available to the local fire department.

It is recommended that a standalone safe haven, as described in this document not be located near multi-story buildings or other relatively large structures, if possible, since collapse of these structures could damage the safe haven.

3-2.1.2 Natural Threat.

To prevent flooding, see FEMA P-361 and ICC 500 for siting facility with regards to Special Flood Hazard Area (SFHA). FEMA P-361 notes that smaller structures, such as poles for light fixtures and power lines, antenna towers, and satellite dishes, and roof mounted mechanical equipment should not be located near a safe haven. Smaller structures, trees, and waste receptacles can become hazardous debris in extreme weather events.

3-2.1.3 Explosives Tactics.

For explosives tactics, it is recommended that smaller structures, trees, and waste receptacles not be located near an internal or standalone safe haven, to prevent hazardous debris. Also, positioning a safe haven below ground provides protection against explosives tactics. To impede delivery of a vehicle-borne explosive, it is recommended that the building/facility in which the safe haven will reside be located at an appropriate standoff distance from railways, roadways, and parking facilities based on the DBT and required LOP.

Finally, the structural design of the building/facility in which the safe haven will reside must provide the required LOP for the DBTs for the assets that will occupy the safe haven at the available standoff distances. If at a given location the LOP requirements cannot be satisfied, the safe haven may be moved to satisfy them, or the building/facility in which the safe haven will reside can be hardened to provide the required LOP. Vehicle barriers may also be installed to increase standoff distance. Note that the construction of vehicle barriers will vary significantly, depending on whether the DBT includes moving vehicle bombs or is limited to stationary vehicle bombs.

3-2.1.4 Standoff Weapons.

To impede aggressor use of direct fire weapon threats, a safe haven must be located to minimize the number of vantage points for attack, such that an aggressor is denied line of sight. This objective can be accomplished by placing obstructions between the vantage points and the safe haven, or by providing an internal safe haven with no external windows. As with the explosives tactics, below-grade placement of the safe haven provides protection against ballistic tactics. However, if the safe haven is at a high elevation, an aggressor must shoot upwards at the position, causing the projectile to strike the structure at less than 90 degrees, diminishing its penetration into the structure.

Indirect fire weapons, such as mortars and small rockets, can be fired over obstacles to reach a target. These weapons do not require a direct line of sight to a target, but they do need a clear line of flight. While a safe haven may be located to minimize clear flight lines from these weapons, the best way to protect the safe haven from indirect fire is to harden its structure. The building/facility in which the safe haven will reside must be designed to protect the assets inside it from the detonation of the threat weapon at standoff distances that vary by level of protection. Per UFC 4-020-01, the structure must be designed to provide protection from the blast pressure from the exploding rounds and from warhead casing fragment penetration.

3-2.1.5 Airborne Contamination Tactic.

Trees, shrubberies, and any other vegetation must not be located within 10 feet (3 meters) of a standalone or internal safe haven, as vegetation can retain airborne contaminant agents. In addition, a below-grade safe haven is more vulnerable to the air contamination tactic. UFC 4-020-01 notes that aerosolized materials used for the air contamination tactic are heavier than air and tend to settle in the low-lying areas.

3-2.2 Structural Integration.

Depending on the facility, a standalone or an internal safe haven may be more effective. A standalone safe haven is physically separate from any other building. An internal safe haven is physically connected to another building but may be structurally independent.

3-2.2.1 Standalone Safe Haven.

Although a standalone safe haven is unlikely to be suitable for multi-use, as described in this document, the standalone safe haven does have several advantages:

- The safe haven may be sited away from likely targets, which can serve as potential debris hazards.
- The construction process of the safe haven can be simplified since it need not be integrated with another structure.
- It may be easier to implement at an existing facility.
- It may be concealed or camouflaged.
- An attack on the primary facility will likely not compromise the structural integrity of the safe haven.
- Physical separation from other buildings may prevent damage by the possible collapse of those buildings.
- Its ventilation and power systems are separate from the main facility.

3-2.2.2 Internal Safe Haven.

An internal safe haven has a different set of advantages:

- The design may only need to satisfy man-made threats, if the surrounding structure has been adequately designed for natural threats.
- Because it is within another structure, it is partially shielded from debris caused by either a man-made or a natural threat.
- Personnel do not have to be exposed when accessing the safe haven.
- An internal safe haven can likely be reached more quickly by building occupants, since they need not exit the building to enter the safe haven.
- With adequate planning, an internal safe haven may more readily serve two or more purposes such as a conference room, cafeteria, gymnasium, restroom, classroom, or temporary lodging.
- A separate air handling system can be included in the design of the safe haven for new construction to protect occupants from airborne contamination, without the expense of providing a special air handling system for the entire building to withstand the airborne contamination tactic if required.

For internal safe havens, use the available structure as much as possible to meet the required LOPs and DBTs. Existing walls can provide protection from forced entry, direct and indirect weapons, explosive devices, and potentially the airborne contamination tactic, if adequately sealed. Note that there will be an added delay for an internal safe haven, since the aggressors would have to penetrate the building first to reach the safe haven. The available structure should also be used as part of the design for natural threats.

3-2.3 Use of Safe Haven.

3-2.3.1 Single Use Safe Haven.

A single-use safe haven is used only in emergencies to provide protection in the event of an attack or natural event, and it has two advantages:

- Its restricted use can also permit it to have simplified electrical and mechanical systems, which can reduce construction costs.
- In addition, a single-use safe haven is always ready for occupants and will not be cluttered with furnishings and storage items.

The primary disadvantage of a single-use shelter is that it remains unused most of its design life.

3-2.3.2 Multi-Use Safe Haven.

A multi-use safe haven is designed to provide protection in an emergency but is also used as for other purposes in the absence of an emergency, such as a conference room, cafeteria, gymnasium, restroom, classroom, or temporary lodging. As noted in FEMA P-361 and FEMA 453, *Design Guidance for Shelter and Safe Rooms*, in contrast to single-use shelters, multi-use shelters can provide an immediate return on the financial investment required to construct them, because they can be used for non-emergency events.

A Sensitive Compartmented Information Facility (SCIF) is one example of a multi-use area that could be designed as an internal safe haven. If a SCIF is also designed to be a safe haven, SCI documents would not have to be transferred outside the SCIF and could be destroyed in place. Consult with UFC 4-010-05 *Sensitive Compartmented Information Facilities Planning, Design, and Construction,* ICS 705-1 and the IC Tech Spec-for ICD/ICS 705 that provide the standards for the physical and technical security standards that apply to a SCIF.

3-2.3.2.1 Multi-Use Signage.

Both the routine maximum occupancy and safe haven maximum occupancy must be posted in a multi-use structure.

3-2.4 System Integration.

The safe haven is part of the overall physical security scheme for the facility and must be coordinated with other physical security elements. For instance, communication equipment in the safe haven must be compatible with the other facility communications. The power source, backup power, and communications should be shared, if these resources are sufficiently protected against the DBTs.

3-3 ADJUSTMENTS IN SAFE HAVEN DESIGN.

During the application of the design procedures laid out in the following sections, the designer may decide to modify key physical parameters, such as size, location, or type of safe haven. For every modification and for each iteration through the design process, the engineer must revisit Chapter 2 to determine if these changes affect any of the final design criteria defined in Chapter 2.

3-4 DESIGN PROCEDURE FOR MAN-MADE THREATS.

The following paragraphs contain specific design procedures and design resources to be employed for the selected tactics determined by UFC 4-020-01. The following paragraphs may not applicable. UFC 4-020-01 is a planning tool and as such contains general design strategies to address these tactics. Some of the approaches from UFC 4-020-01 are incorporated in the following paragraphs.

Specific DoD design approaches for the tactics are available in UFC 4-020-02FA and Security Engineering Support Manuals as applicable. Any conflicts between this UFC and UFC 4-020-02FA and support manuals must be resolved by the project Planning Team.

3-4.1 Moving Vehicle.

When required, the building/facility in which the safe haven will reside must be designed to resist the pressure and impulse from the explosive weight associated with the DBT, and associated standoff of the moving vehicle threat. Employ standard blast design methods for the analysis and design of the building/facility in which the safe haven will reside and its components, including doors and windows, to resist the pressure and impulse. Blast design and analysis methods can be found in UFC 3-340-01, *Design and Analysis of Hardened Structures to Conventional Weapons Effects* and ASCE 59-11, *Blast Protection of Buildings.* Use the structural response limits specified in PDC-TR 06-08 *Single Degree of Freedom Structural Response Limits for Antiterrorism Design*. Approved design tools such as the *Single-degree-of-freedom Blast Effects Design Spreadsheet* (SBEDS) and *Single degree of freedom Blast Effects Design Spreadsheet for Windows* (SBEDS-W) both available from the US Army Corps of Engineers Protective Design Center may be employed if approved by the project planning team.

3-4.2 Stationary Vehicle.

The DBT for stationary vehicle bombs will be used to establish the design explosive weight. The standoff will be the distance from the building/facility in which the safe haven will reside to possible vehicle locations, as determined by a review of the site layout and the presence of components such as vehicle barriers, parking lots, and roadways. Note that multiple locations and standoff distances may need to be required for the design, depending upon the shielding provided by the terrain, buildings, and other obstructions between the vehicle bomb and the safe haven.

Use the same approach and response criteria as specified in the previous section to design the building/facility in which the safe haven will reside for a stationary vehicle bomb threat.

3-4.3 Hand Delivered Devices.

The DBT for hand delivered devices as determined with UFC 4-020-01 will be used to establish the design incendiary device or explosive type and weight. The standoff will be the shortest possible distance from the building/facility in which the safe haven will reside to the likely placement locations for the hand-delivered device; this could include direct contact with the structure.

Use the same approach and response criteria as specified above in moving vehicle bomb threat to design the building/facility in which the safe haven will reside for a hand delivered device.

3-4.4 Indirect Fire Weapons.

Consult UFC 4-020-01 for the general design approach and employ UFC 4-020-02FA as required for specific guidance to design the safe haven for the DBT and LOP.

3-4.5 Direct Fire Weapons.

Employ UFC 4-023-07 *Design to Resist Direct Fire Weapon Effects* as required to design the safe haven for the DBT and LOP.

3-4.6 Forced Entry.

Consult UFC 4-020-01 for the general design approach to design the safe haven to resist the design basis threat for the period of time determined in security forces evaluation. Use the procedures and guidance in UFC 4-020-02FA and UFC 4-020-03FA, *DoD Security Engineering: Final Design* to design the physical components of the safe haven, including walls, floors, ceilings, windows, doors, and other components.

3-4.7 Visual Surveillance.

UFC 4-020-01 recommends the following in the design against the visual surveillance threat when required; the safe haven is positioned, concealed, or camouflaged such that an aggressor cannot see it. In particular, safe haven entrances must be placed in locations that are not easily seen. If windows are used, window blinds or curtains must be installed to prevent aggressors from being able to observe activity inside the safe haven.

This guidance may conflict with other design guidance, such as design for natural threats, for which signage will be needed to assist personnel in finding the safe haven. In this case, the Planning Team will resolve the conflicts.

3-4.8 Airborne Contamination.

Employ UFC 4-024-01 *Security Engineering: Procedures for Designing Airborne Chemical, Biological, and Radiological Protection for Buildings* to design the safe haven for the DBT and LOP.

3-4.9 Waterborne Contamination.

Employ the guidance in Chapter 4 of UFC 4-020-02FA to design the safe haven for the DBT and LOP.

3-4.10 Waterfront Attack.

When required employ the guidance in Chapter 4 of UFC 4-020-01 and UFC 4-025-01, *Security Engineering: Waterfront Security* to design the building/facility in which the safe haven will reside for the DBT and LOP appropriate for waterfront attacks. Use the same approach and response criteria as specified in the previous section on moving vehicles regarding blast design and analysis.

3-5 DESIGN PROCEDURE FOR NATURAL THREATS.

Natural threats, as discussed in Chapter 2, must be identified for both standalone and internal safe havens. If an internal safe haven is placed within a building which has the capacity to resist relevant natural threats, then only elements of the safe haven that are exposed to natural threats must be considered. In the case of standalone safe havens, all relevant natural threats must be considered. For both standalone and internal safe havens with exposed elements, employ the procedures in the following four sections. For regions where wind speeds and loads from hurricanes/typhoons and tornados overlap ensure the most stringent threat is used in design and construction of the required shelter.

3-5.1 Hurricane and Typhoon.

As discussed in Chapter 2, hurricanes and typhoons can apply wind-induced forces, debris impact, and hydrodynamic forces. To resist wind-induced forces and debris impact, the building/facility in which the safe haven will reside must be designed according to FEMA P-361, ICC 500 and UFC 3-301-01. Wind speed data for building sites outside the US must be obtained from Appendix E of UFC 3-301-01. Ensure compliance with the more stringent criteria in design and construction.

To resist hydrodynamic forces associated with flooding, the building/facility in which the safe haven will reside must be designed according to UFC 3-301-01 and Chapter 5 of ASCE 7-10. If the safe haven is built in a location that lacks a US Flood Hazard Map or the equivalent in the host nation, available flood data from local agencies must be used for design. See United States Geological Survey (USGS) website for additional flood information: http://water.usgs.gov/floods/

3-5.2 Tornado.

As discussed in Chapter 2, a tornado subjects a building to wind-induced forces, debris impact, and forces induced by change in atmospheric pressure. ICC 500-2014 provides minimum design and construction requirements for storm shelters that provide a safe refuge from storms that produce high winds, hurricanes, and tornadoes. Chapter C26 of ASCE 7-10 also provides references pertaining to tornadic design and these references should be consulted. Regarding wind speed and other structural design criteria ensure compliance with the most stringent of the UFC 3-301-01, FEMA P-361, and ICC 500-2014. Ensure compliance with the more stringent criteria in the design and construction of the shelter.

3-5.3 Earthquake.

The building/facility in which the safe haven will reside must be designed in accordance with the seismic provisions presented in UFC 3-301-01 and UFC 3-310-04. Seismic ground motion data for buildings/facilities built outside of the US must be obtained from UFC 3-301-01. See USGS Earthquake Hazard Program website for additional seismic information: http://earthquake.usgs.gov/hazards/

It should be noted that the objective in designing the building/facility in which the safe haven will reside to resist seismic loading is not for the building/facility to serve as an earthquake shelter, though it could serve as a shelter for aftershocks. Rather, the objective is to ensure that the building/facility survives likely seismic events. In this way, the safe haven as part of the overall building structure is designed, like any other building in a seismic zone, to continue functioning despite the occurrence of a seismic event.

3-5.4 Tsunami.

If required the building/facility in which the safe haven will reside must be designed to resist hydrodynamic forces caused by a tsunami according to UFC 3-310-04. If the building/facility in which the safe haven will reside is built in a location that lacks a US Flood Hazard Map or the equivalent in the host nation, available flood data from local agencies must be used for design. See United States Geologic Survey (USGS): http://walrus.wr.usgs.gov/tsunami and National Oceanic and Atmospheric Administration (NOAA): http://www.tsunami.noaa.gov/ websites for additional Tsunami information.

CHAPTER 4 OTHER DESIGN GUIDANCE

4-1 EMERGENCY ROUTE MARKING.

For natural threats, proper route marking is essential to personnel reaching the safe haven within the required time. Therefore, the facility must incorporate signage demarcating routes to the safe haven. The signage should also indicate the threats for which the safe haven was designed. Entry points to the safe haven must be clearly identified. Route marking may be accomplished by powered lighting, or more recently developed photo luminescent path marking. Maps illustrating routes to the safe haven must be posted in appropriate locations in the facility. Any written content on the maps must be in a language intelligible to all personnel in the facility. Signage must comply with ADA requirements, including those for the blind. If this guidance conflicts with other guidance, such as the need to camouflage the safe haven to prevent visual surveillance, the Planning Team will resolve the conflict. For additional guidance on route marking and signage see UFC 3-600-01, *Fire Protection Engineering for Facilities.*

Vehicle parking can be a problem, either from the standpoint of insufficient number of parking spaces or due to traffic congestion in reaching a safe haven. Thus, a sufficient number of safe havens must be provided so personnel can reach a safe haven on foot within the required 5 minutes timeframe.

4-2 EMERGENCY POWER.

4-2.1 Backup Power Source.

Follow Service guidance for approval of backup power authorization and design. When required, provide at least one independent backup power source that will be available to a safe haven such that loss of the primary power source does not cause the safe haven(s) to lose power. The backup power source of a safe haven must be protected from the identified threats and consequently must be independent of the conventional power grid. Potential backup power sources include the building's backup power supply, electric cells, and standalone internal-combustion generators. The type of power source and quantity of power required for a safe haven must be determined from its power use in emergency operating conditions. When multiple safe havens are provided within the same building, one backup power source can be shared by all the safe havens.

4-2.2 Duration.

Sufficient power must be available for a safe haven to operate for the duration of the controlling event, whether that controlling event is the moving vehicle bomb tactic, waterborne contamination tactic, tornado, hurricane, or some other threat. For example, if the controlling event is a tornado, a safe haven must be provided with sufficient energy to operate at its required power for 2 hours. If the controlling event is a hurricane, there must be sufficient power for 24 hours of operation.

4-2.3 Supported Systems.

The following systems must be supported by the power source for the duration of the controlling event, as a minimum:

- Lighting
- Ventilation
- Communication

Safe havens equipped to destroy classified information must have sufficient power to support the necessary equipment. Per UFC 4-020-01, power to these systems must be resistant to interruption due to a natural event or deliberate attack. The equipment required to destroy the classified material must be determined in conjunction with the responsible security office or the FSO.

4-2.4 Signage.

UFC 4-020-01 recommends that the possibility of sabotage be minimized by limiting signage identifying the location of the power source.

4-3 EMERGENCY LIGHTING.

4-3.1 Internal Lighting.

Primary lighting must be provided within the safe haven for personnel to perform essential tasks, such as tending to injured personnel and destroying classified materials. Reliable primary lighting can also serve to calm personnel within a safe haven. All lighting must conform to UFC 3-530-01 *Design: Interior and Exterior Lighting and Controls.*

Primary lighting must be supported by fixtures that are designed to resist the motions from the identified threats, such as earthquakes and blast. The motions that the fixtures must withstand must be determined from analysis of safe haven structural response to the threat. All safe havens must meet the minimum requirements for bracing, as discussed in UFC 4-010-01. Furthermore, the electrical wiring joining the primary lighting to the power source must be resistant to sabotage and attack.

4-3.2 Lighting of Entry Points.

To expedite ingress into the safe haven, all entry points must be illuminated. As a minimum, lighting at entry points must conform to UFC 3-530-01.

4-4 COMMUNICATION.

The following means of communication may be provided for a safe haven, depending on its particular requirements (FEMA P-361 and FEMA 453 *Design Guidance for Shelter and Safe Rooms*):

- Handheld or emergency radios connected to the security force, police, or fire and rescue
- Cellular or satellite telephones (may not operate during certain events and may require signal amplifier to function within the safe haven)
- Standard telephones
- Battery-powered radio transmitters or signal-emitting devices for signaling emergency personnel
- Duress alarm
- Audible sounding device (e.g. canned air horn) to signal rescue personnel
- Megaphone
- Public address system
- Portable computers with modem and internet capabilities
- Fax machine, copier, and scanner
- Signal flares
- National Oceanic Atmospheric Administration (NOAA) weather radios or receivers for commercial broadcast

4-5 ENTRY POINT MONITORING.

Depending on operational requirements, an audible cue may be required at the entry points of the safe haven for access control. The audible cue would sound any time that the doors at the entry point are opened. In addition, a guard may be stationed at each entry point. For multi-use safe havens having such operational requirements, the cue should be activated and guards should be posted once the threat exists.

4-6 FIRE SAFETY.

Safe havens must comply with all fire and life-safety code requirements per UFC 3-600-01 and the following minimum requirements. The fire and life safety system inside the safe haven must remain operational, if determined by the level of protection and design basis threat, and provide life-safety protection after an incident and allow for safe evacuation of the building when appropriate for the required occupancy level. See Chapter 2, Occupancy Level for discussion on occupancy level and square footage requirements of the safe haven.

4-6.1 Fire Suppression Systems.

Facilities that are multi-use safe havens or contain a multi-use safe haven must be protected with an automatic sprinkler system.

Any fire suppression systems specified for use within the safe haven must be appropriate for use in an enclosed environment with human occupancy.

Provide fire extinguishers for safe havens. Fire extinguishers must be flush mounted on the surface of the safe haven wall.

Based on the LOP and DBT, the fire protection water system for the safe haven must be protected from single-point failure in case of an event.

4-6.2 Additional Guidance.

In no case will a standpipe cabinet or fire extinguisher cabinet/enclosure be recessed into the interior face of the exterior wall of the safe haven. This requirement is necessary to ensure that the integrity of the safe haven wall is not compromised by the installation of standpipes and fire extinguishers.

Maintain a positive pressure in the safe haven. Duct openings must be protected by a Class A, 2-hr fire and smoke dampener.

The enclosure of the safe haven must have a 2-hour fire resistance rating.

4-7 PLUMBING.

If the plumbing system includes faucets that discharge into the safe haven, it must be protected against the waterborne contamination tactic, as discussed in Chapter 3. To eliminate vulnerability to the waterborne contamination tactic, it is recommended that bottled water be provided to the occupants.

4-8 SANITATION MANAGEMENT.

Normal design procedures and code requirements will prevail for management of sanitation within the safe haven. See FEMA P-361 and ICC 500 for guidance on the number and type of toilets and associated plumbing requirements.

4-9 ADDITIONAL SAFE HAVEN SUPPLIES.

The agency operating the safe haven will identify appropriate supplies based on items listed in Table 4-1 of FEMA 453 with additional discussion in P-361 and ICC 500, including food and water, if required. Any design requirements for storing these supplies must be considered in the safe haven design.

APPENDIX A REFERENCES

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

http://ascelibrary.org/

ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures*

ASCE 59-11, *B*last *Protection of Buildings*

DEPARTMENT OF DEFENSE

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

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DIRECTOR OF NATIONAL INTELLIGENCE

Intelligence Community Standard Number 705-1 (ICS 705-1), *Physical and Technical Security Standards for Sensitive Compartmented Information Facilities*

http://www.ncsc.gov/publications/policy/docs/ICS_7051_Physical_and_Technical_Security_Standards_for_Sensitive_Compartmented_Information_Facilities.pdf

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IC Tech Spec-for ICD/ICS 705, *Technical Specifications for Construction and Management of Sensitive Compartmented Information Facilities*

https://fas.org/irp/dni/icd/ics-705-ts.pdf

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

http://www.fema.gov/.

FEMA P-361, *Safe Rooms for Tornadoes and Hurricanes: Guidance for Community and Residential Safe Rooms*

FEMA 453, *Safe Rooms and Shelters: Protecting People Against Terrorist Attacks*

FEMA P-646, Guidelines *for Design of Structures for Vertical Evacuation from Tsunami*

FEDERAL HIGHWAY ADMINISTRATION

http://mutcd.fhwa.dot.gov/

Manual on Uniform Traffic Control Devices for Streets and Highways

INTERNATIONAL CODE COUNCIL (ICC)

www.iccsafe.org

ICC 500-2014, International Code Council (ICC) and National Storm Shelter Association (NSSA), *Standard for the Design and Construction of Storm Shelters*

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)

http://www.tsunami.noaa.gov/

National Oceanic and Atmospheric Administration - Tsunami

NATIONAL FIRE PROTECTION ASSOCIATION

http://www.nfpa.org/

NFPA 101 *Life Safety Code*

UNIFIED FACILITIES PROGRAM; DEPARTMENT OF DEFENSE,

http://DoD.wbdg.org/

UFC 1-200-01, *General Building Requirements*

UFC 3-301-01, *Structural Engineering*

UFC 3-310-04, *Seismic Design for Buildings*

UFC 3-340-01*, Design and Analysis of Hardened Structures to Conventional Weapons Effects*

UFC 3-530-01, *Design: Interior and Exterior Lighting and Controls*

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

UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Building*

UFC 4-010-03, *Security Engineering: Physical Security Measures for High Risk Personnel*

UFC 4-010-05 *Sensitive Compartmented Information Facilities Planning, Design, and Construction*

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

UFC 4-020-02FA, *DoD Security Engineering: Concept Design*

UFC 4-020-03FA, *DoD Security Engineering: Final Design*

UFC 4-023-07, *Design to Resist Direct Fire*

UFC 4-024-01, *Security Engineering: Procedures for Designing Airborne Chemical, Biological, and Radiological Protection for Buildings*

UFC 4-025-01, *Security Engineering: Waterfront Security*

UFC 3-530-01, *Design: Interior and Exterior Lighting and Controls*

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

UNITED STATES ARMY CORPS OF ENGINEERS – PROTECTIVE DESIGN CENTER

https://pdc.usace.army.mil/library

PDC-TR 06-08, *Single Degree of Freedom Structural Response Limits for Antiterrorism Design*

UNITED STATES GEOLOGIC SURVEY (USGS)

http://water.usgs.gov/floods/

United States Geologic Survey (USGS) Water Resources of the United States

http://earthquake.usgs.gov/hazards/

United States Geologic Survey (USGS) Earthquake Hazards Program

http://walrus.wr.usgs.gov/tsunami/

United States Geologic Survey (USGS) Tsunami and Earthquake Research

Additional Resource Publications

UNITED STATES ARMY CORPS OF ENGINEERS – PROTECTIVE DESIGN CENTER

https://pdc.usace.army.mil/library

PDC-TR 06-01, *Single Degree of Freedom Blast Design Spreadsheet (SBEDS) Methodology Manual*

PDC-TR 06-02, *Single Degree of Freedom Blast Design Spreadsheet (SBEDS) User's Guide*

PDC-TR 12-01, *Single Degree of Freedom Blast Design Spreadsheet for Windows (SBEDS-W) Methodology Manual*

PDC-TR 12-02, *Single Degree of Freedom Blast Design Spreadsheet for Windows (SBEDS-W) User's Guide*

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APPENDIX B EXAMPLE PROBLEM

B-1 SCENARIO.

- 7-story reinforced concrete Navy operations building in Casablanca, Morocco (Figure B-1 and Figure B-2)
- Design is 40% complete
- No controlled perimeter
- Primarily military occupants
- Heavy winds, seismic; no tornado or tsunami
- Top Secret information exists and must be destroyed
- Internal safe haven, so classified material does not have to be transported outside the facility

NOTE: The scenarios, requirements and mitigating measures presented in this example may not be typical for a safe haven and are used to navigate the reader through the process (occupancy, asset needing protection, design basis threat, level of protection required, mitigating measures employed) of planning and designing a safe haven. In reality, the threat may be minimal; requiring minimum mitigating measures for a minimum number of occupants i.e. the occupancy of a safe haven for high risk executive may require the protection of just one person. The primary use of this UFC is to design the safe haven for man-made threats and that the guidance provided herein for natural threats is for information purposes and the planner/designer shall design the facility for the natural threats as necessary in accordance with UFC 1-200-01, General Building Requirements.

Figure B-1 Overall Building Elevation

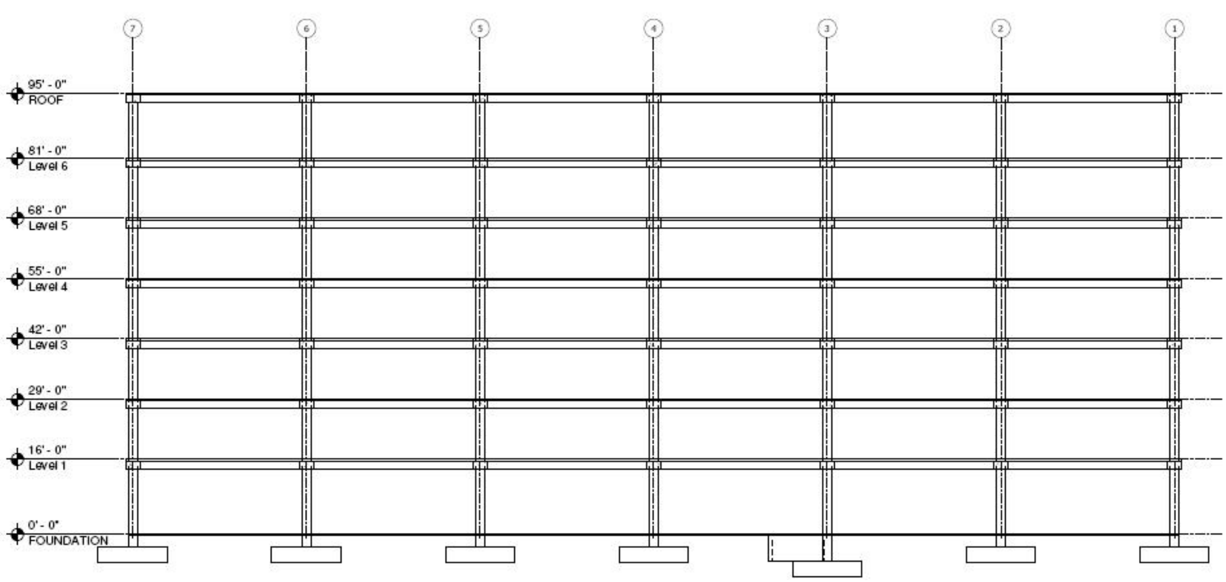
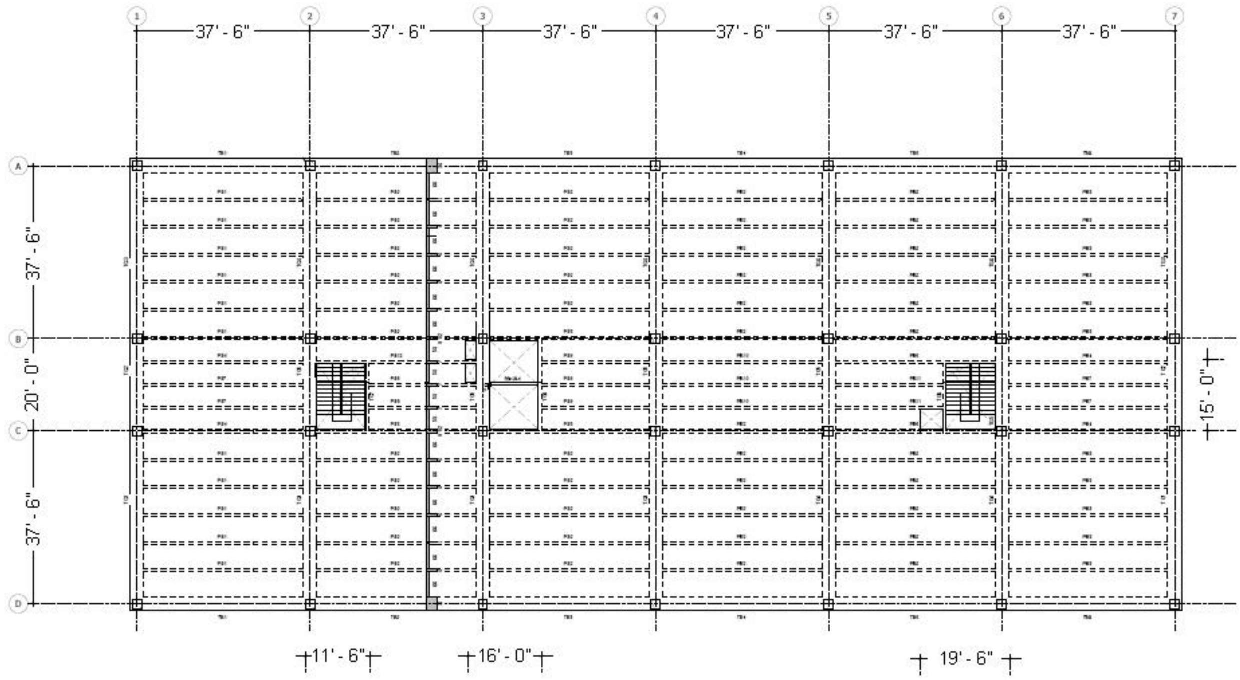


Figure B-2 Overall Building Plan



B-2 DESIGN CRITERIA DEVELOPMENT.

B-2.1 Procedures.

Follow procedure outlined in UFC 4-023-10.

B-2.2 Data Collection.

- Facility/Building Type: Headquarters and Operations
- Presence and Type of Classified Material and Sensitive Information:
  - Top Secret information storage
- Security Forces Evaluation: Security forces response time = 2 minutes

B-2.3 Planning Considerations.

Transit time: The distance from the furthest corner office on the 7th floor to the safe haven is approximately 204 feet (62 meter), based on the following distances: building corner to the stair well = ~56 feet (17 meter), 6 flights of stairs = 18 feet (5.5 meter) based on a 45-degree stair and a 13 feet (4 meter) story height and from the stairwell to the safe haven = ~40 feet (12 meter). The average distance from the parking area to the safe haven is approximately 288 feet (88 meter) based on the following distances: from parking lot to building entrance = 148 feet (45 meter) and from the building entrance to the safe haven = 140 feet (43 meter). Thus, the transit time will be less than 2 minutes, based on the longest distance from the parking area to safe haven and an estimated travel speed of 3 to 4 ft/s (0.9 to 1.2 m/s).

Duration of Occupancy: 2hrs- Short duration requirement based on the DBT and the security forces response time and evaluation of the situation.

Occupancy Level: Based on the distances involved, all occupants will be able to reach the safe haven in less than 5 minutes.

Floor Area:

Occupants:	135 adults standing	=	675 ft^2 (62.7 m^2)
	200 adults sitting	=	1000 ft^2 (93 m^2)
	5 wheelchair users	=	50 ft^2 (4.6 m^2)
	Total floor area	=	1725 ft^2 (160 m^2)

Equipment for destruction of classified materials, as specified by the building occupant and Facility Security Officer (FSO):

Storage safes	=	18 ft^2 (1.7 m^2)
Approved shredders	=	24 ft^2 (2.2 m^2)
Waste receptacles	=	50 ft^2 (4.6 m^2)
Work space	=	100 ft^2 (9.3 m^2)
Total floor area	=	192 ft^2 (17.8 m^2)

There are approved classified material shredders available with sheet capacity up to 16 sheets and speeds up to 44 ft/min (13 meters/min). The FSO will select the appropriate type and number of shredders based on the amount of sensitive information to destroy within the safe haven in the event of an emergency. In this example, the FSO has determined that six shredders are necessary in the safe haven, each taking up 4 ft^2 (0.37 m^2). All equipment listed above for the destruction of classified materials will be located in a separate secure room within the safe haven to prevent tampering or accidental damage.

Area for Operational supplies= 12 ft^2 (1.1 m^2)

Preliminary floor area:

Total floor area = 1725+192+12 = 1929 ft^2 (179 m^2)

Height: 13-ft (4-m) per drawings (minimum is 7.5-ft [2.3 m])

Preliminary Location, Type and Number of Safe Havens: The 75 ft x 50 ft (23 m x 15 m), 3750 ft^2 (348 m^2) cafeteria on the second floor, interior of the building will be the designated safe haven, as shown in Figure B-3 and Figure B-4. The design of the cafeteria will meet all criteria in UFC 4-023-10. This will be an internal, multi-use safe haven -- one for the complete building. There are four entrances/exits for the cafeteria, all of which satisfy ADA and life safety requirements.

Figure B-3 Elevation Showing Second Floor Cafeteria as Safe Haven

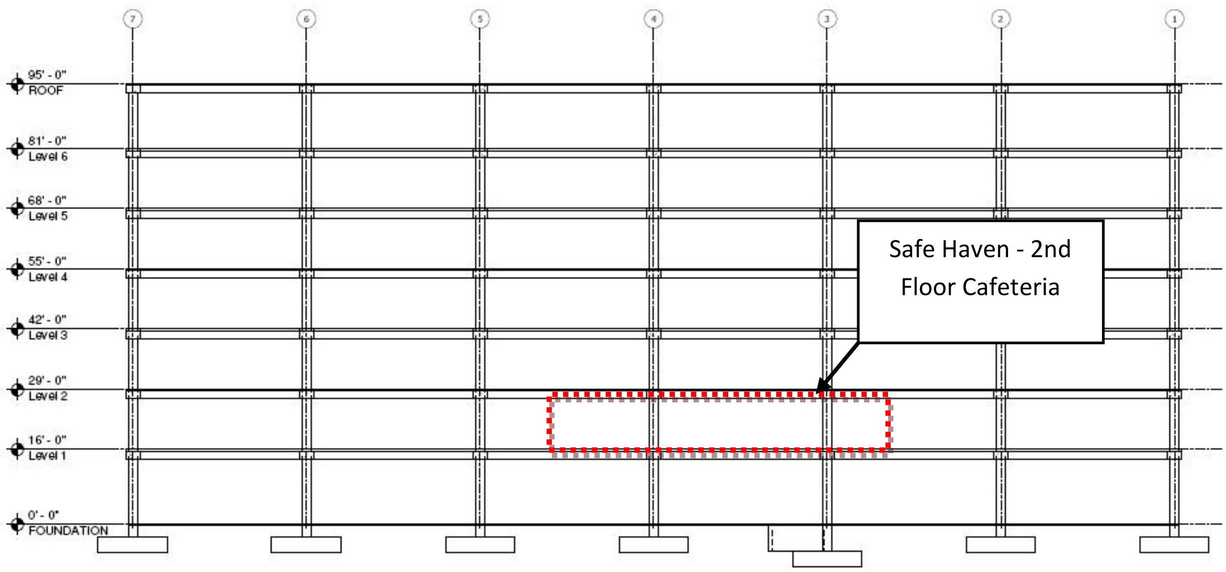
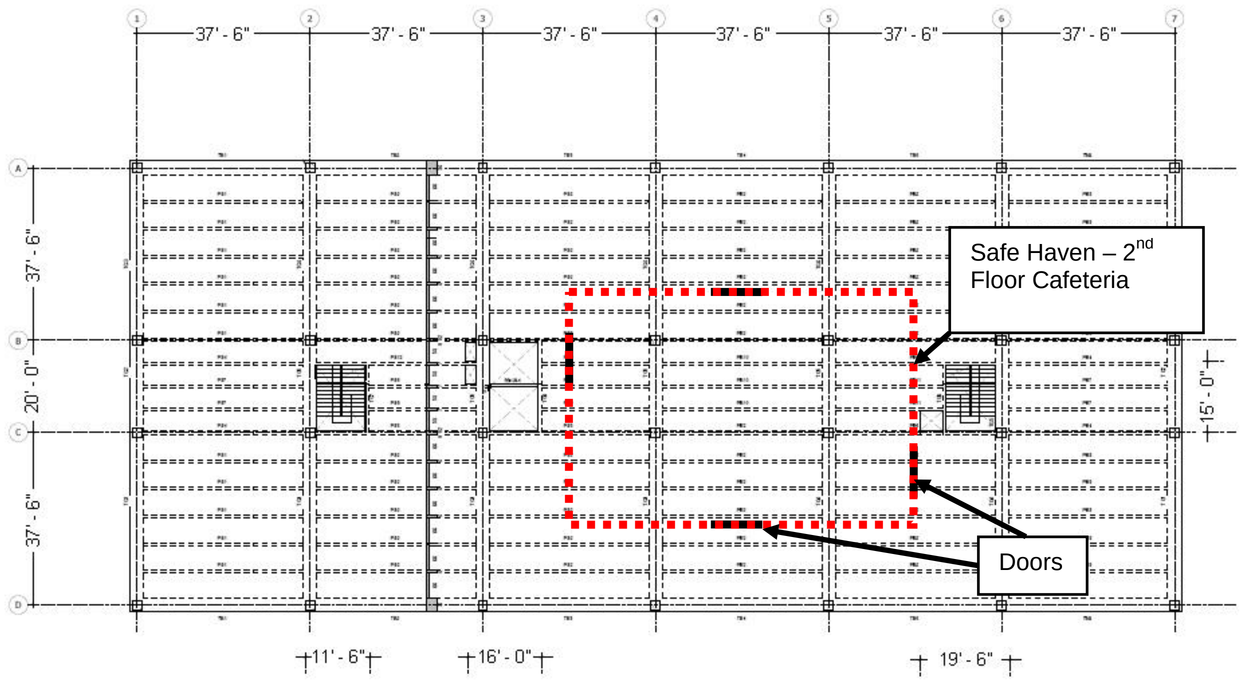


Figure B-4 Plan View of Second Floor with Cafeteria as Safe Haven



B-2.4 Design Criteria Development for Manmade Threats.

Use the processes in UFC 4-020-01 to determine the required LOP and DBTs for the safe haven design. Based on the worksheets prepared using UFC 4-020-01 (summary worksheet shown in Figure B-5), the calculated DBTs and LOPs are summarized in Table B-1 with an indication of the asset controlling the result. The weapons and tools associated with each threat and its corresponding DBT are also listed in the table.

Table B-1 DBTs and LOPs Determined Using UFC 4_020-01

Tactic	DBT, Controlling Asset*	LOP, Controlling Asset*	Weapons/Tools
Hand Delivered Devices	Medium, P	Low, P	IID, IED up to 2.2 lb. (1 kg) TNT, hand grenades
Indirect Fire Weapons	Low, P	Low, P	IID
Direct Fire Weapons	Low, P	Low, P	UL752 Level 3 (.44 magnum)
Forced Entry	Medium, P	High, SI	Unlimited hand tools, limited battery-powered tools
Airborne Contamination	Low, P	Low, P	Biological & radiological particulates release, chemicals/toxic industrials

P = Population; SI = Sensitive Information
IID = Improvised Incendiary Device, IED = Improvised Explosive Device

Figure B-5 UFC 4-020-01 Design Criteria Summary Worksheet

DESIGN CRITERIA SUMMARY WORKSHEET

Project or Building: Safe Haven Example	Analyst: Bowles	Date: 12/2/08

Assets	Asset Category	Asset Value Rating	Tactics: Explosive and Incendiary Devices						Standoff Weapons				Entry Tactics				Surveillance and Eavesdropping						Contamination Tactics					
			Moving Vehicle Devices		Stationary Vehicle Devices		Hand Delivered Devices		Indirect Fire Weapons		Direct fire weapons		Forced Entry		Covert Entry		Visual Surveillance		Acoustic Eavesdropping		Electronic Emanations Eavesdropping		Airborne Contamination		Waterborne Contamination		Waterfront Attack	
			DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP	DBT	LOP
Population	A	.7	L	L	L	L	M	L	L	L	L	L	M	L									L	L				
Sensitive Info	Q	.95											L	H														

DBT = Design Basis Threat severity level   LOP = Level of Protection

B-2.5 Design Criteria Development for Natural Threats.

Winds

Wind load of 130 mph (210 kph) based on FEMA P-361

Exposure = B, assumed

Importance factor = 1.15, based on UFC 3-301-01.

Earthquake

Magnitude = 6.4, based on historic data (earthquakes in Morocco)

Peak accelerations = 1.3 – 2.6 ft/sec^2 (0.4 – 0.8 m/sec^2)

The building/facility in which the safe haven will reside must be designed as Risk Category IV.

B-2.6 Other Applicable Design Requirements.

No additional design requirements.

B-2.7 Final Design Criteria.

Table B-2 Final Design Criteria Summary

Manmade			
Tactic	**DBT, Controlling Asset***	**LOP, Controlling Asset***	**Weapons/Tools**
Hand Delivered Devices	**Medium, P**	**Low, P**	**IID, IED up to 2.2 lb. (1 kg) TNT, hand grenades**
Indirect Fire Weapons	**Low, P**	**Low, P**	**IID**
Direct Fire Weapons	**Low, P**	**Low, P**	**UL752 Level 3 (.44 magnum)**
Forced Entry	**Medium, P**	**High, SI**	**Unlimited hand tools, limited battery-powered tools**
Airborne Contamination	**Low, P**	**Low, P**	**Biological & radiological particulates release, chemicals/toxic industrials**
Natural			
Threat	**Magnitude**		
Earthquake	**6.4**		

*P = Population, SI = Sensitive Information
IID = Improvised Incendiary Device, IED = Improvised Explosive Device

B-3 DESIGN PROCESS.

B-3.1 Procedure.

Follow procedure in UFC 4-023-10.

B-3.2 Initial Considerations.

Building Code: UFC 1-200-01

Siting: Use of the second floor cafeteria makes it internal and multi-use. There will be a separate room within the cafeteria for sensitive material storage or destruction.

Structural Integration: The safe haven is within the building, which has been designed to withstand external bombs, required wind loads, and designated earthquake loads. Thus, the internal safe haven automatically has protection against these loads (except for non-structural items). It also is partially shielded from debris threats. Personnel can reach the safe haven quickly and not be exposed to external threats while in transit. Since the safe haven is to contain GSA-rated safes for storage of classified material, the weight of this equipment must be taken into account when designing the floor system.

Use of Safe Haven: The cafeteria will be used on a daily basis in the absence of an emergency. The routine and maximum occupancy and required evacuation diagram will be posted according to UFC 3-600-01 and NFPA 101.

System Integration: All security elements, communication equipment, and power sources will be shared and/or compatible with the other facility resources and equipment.

B-3.3 Adjustments in Design.

Any design adjustments made during the design process will be rechecked against the criteria in UFC 4-023-10 Chapter 2.

B-3.4 Design for Manmade Threats.

The relevant man-made tactics include

- moving vehicle devices
- stationary vehicle devices
- hand delivered devices
- indirect fire weapons
- direct fire weapons
- forced entry
- airborne contamination
- forced entry

- airborne contamination

However, the building is already designed for applicable moving vehicle and stationary vehicle device threats, so the internal safe haven design does not need to consider these two threats. Use the DBTs summarized in Table B-2 as the design charge weight or load.

B-3.4.1 Hand Delivered Devices.

Per UFC 4-020-01, the general design strategy for this tactic is to detect the device at building entry points, before the device can reach the safe haven, and ensure that any assets inside the building are protected in accordance with the low LOP identified for this tactic in Table B-2. For low LOP, detection is only provided through operational procedures. For exterior attacks on the building, detection is based on visual observation of the unobstructed space surrounding the building. For attacks at building entry points, detection is provided using operational safeguards to prevent the device from proceeding past trained personnel dedicated to detection of such devices. Personnel qualified to respond to detection of an explosive or incendiary device, such as an explosive ordnance disposal team, must also be available.

The 2.2 lb. (1 kg) improvised explosive device (IED) threat will be used as the DBT. Per UFC 4-020-01, for a medium threat level and low LOP (Table B-2), conventional construction with no special requirements can be used for the exterior building walls and roof. Conventional hollow metal doors and ¼-inch (6-mm) laminated glass windows suffice. The interior cafeteria walls must be at least 6-inch (100-mm) thick, moderately reinforced concrete.

B-3.4.2 Indirect Fire Weapons.

Methods provided in UFC 4-020-01, and UFC 4-020-02FA, *DoD Security Engineering: Concept Design and* UFC 4-020-03FA, *DoD Security Engineering: Final Design*, will be used to design the safe haven for a DBT of an improvised incendiary device (IID) at a low LOP. The general design strategy for the indirect fire weapon tactic is to protect assets inside by hardening the structure to resist the effects of the DBT. At a low LOP; this requires fire resistant construction sufficient to prevent an IID from penetrating the structure shell. Materials used within the hallways and rooms surrounding the cafeteria must be selected to resist burning, flame spread, and smoke development. For low LOP, conventional construction can be used for the walls, roof, and doors. Windows are required to be ¼-inch (6-mm) plus 2 x1/8-inch (3-mm) glass with 0.03-inch (0.75-mm) PVB in narrow elevated windows.

B-3.4.3 Direct Fire Weapons.

UFC 4-023-07 *Design to Resist Direct Fire Weapon Effects* will be used to design the safe haven to resist the DBT for a low LOP of an UL752 Level 3 (.44 magnum) handgun. The effective distance for this weapon is 328 feet (100 meters).

The design strategy for low LOP is to block sight lines to building occupants or assets. The philosophy of that strategy is that aggressors will not shoot at what they cannot see. For an external or stand-alone safe haven, this strategy can be met using barriers of vegetation, fences, landforms, and walls placed to interrupt sight lines. For this internal safe haven example, blocking lines-of-sight will be accomplished using type A requirements for the walls, windows, and doors for the cafeteria, per UFC 4-020-01. The walls just need to be opaque for this requirement. The windows will be elevated per the requirement for indirect fire weapons tactic therefore providing no direct sight lines. Standard hollow metal doors are acceptable. There are no special design requirements for the roof since the safe haven is on the second floor of a 7-story building, and there are no direct sightlines to the roof.

B-3.4.4 Forced Entry.

The safe haven will be designed to resist the DBT of unlimited hand tools and limited battery-operated tools for a period of 2 minutes, the response time of the security forces provided in Section B-2.2 above. The guidance in UFC 4-020-02FA and UFC 4-020-03FA, will be used to design walls, doors, floors, and other necessary components.

Per UFC 4-020-01 for a medium threat severity level and a high LOP, the walls and roof will be designed as type E. The walls will be 8-inch (200-mm) reinforced concrete with #4 bars at 6 inches (150 mm) on center each way. Per UFC 4-020-02FA/ UFC 4-020-03FA, the required delay time for forced entry for this example would be 2 minutes. The roof will be 8-inch (200-mm) reinforced concrete with #4 bars at 6 inches (150 mm) on center each way on steel decking and with a built-up roofing system. The doors will be 10-inch steel clad solid wood (254-mm) swinging doors with ½-inch (13-mm) plate inside and out. There are no windows available to meet the requirements of this tactic, at the medium threat severity level and high LOP. Thus, either the cafeteria should be designed without windows, or the window openings must be limited to 96 sq. inches (0.06 sq. meters).

B-3.4.5 Airborne Contamination.

The methods and guidance in UFC 4-010-01, UFC 4-020-01 and UFC 4-024-01 *Security Engineering: Procedures for Designing Airborne Chemical, Biological, and Radiological Protection for Buildings* can be used to design the safe haven for the DBT specified in Table B-2. The design criteria summary worksheet (Figure B-5) indicates a low DBT and low LOP.

Limited chemical, biological, and radiological (CBR) protection is required in accordance with UFC 4-010-01 for all new inhabited facilities to provide very low and low levels of protection. Specific design strategies are to minimize air infiltration and to be able to limit dispersal of any agents that infiltrate the building. The very low and low levels of protection incorporate passive building component features at little or no additional cost when included in new facility designs and major retrofits. Protection measures that are recommended for all buildings and are required for new inhabited facility designs and major retrofits are a mass notification, public address, or alarm system; air distribution emergency shutoff; sealed mailrooms with separate, dedicated ventilation systems and exhaust fans; elevated outside air intakes; and restricted roof access. High efficiency particulate air (HEPA) filters will be used at air intakes, as required for the low LOP per

UFC 4-020-01. The HEPA filters will be installed in the central air-handling unit, filtering both the outside and recirculated air. A slight positive over pressurization of the building (Class II overpressure) will be maintained. The perimeter around the cafeteria/Safe Haven will be sealed with insulating foam.

Per UFC 4-024-01, a low design basis threat for airborne contamination is the threat of external release of biological particulates and toxic industrial chemicals (TICs). No toxic military chemical or radiological threat is expected.

If the presence of an airborne hazard is detected, there are four possible protective courses of actions: evacuation, sheltering in place, ventilation and purging, and the use of protective masks.

These actions do not provide protection on a continuous basis, of course, but are implemented singly or in combination for relatively short periods when a hazard is present or known to be imminent.

The use of protective masks in conjunction with evacuation is the most cost effective, efficient use of resources. New models of universal-fit escape masks have been developed for protection against chemical and biological agents. Such masks form a seal at the wearer’s neck and therefore fit a wider range of sizes than traditional masks that seal around the face. These masks do not require special fitting techniques or multiple sizes and can be used by people with facial hair. They are designed to store compactly and are practical to store at employees’ desks. Employees can also carry them on their belt. These masks have excellent protective capability and have a 5-year shelf life.

Sheltering in place for longer duration may require a collective protection (ColPro) strategy defined in UFC 4-020-01 and UFC 4-024-01 that can be used to ensure that agents introduced at entry points are kept out of the building and the safe haven. However with initial costs being high and the high expense to operate and maintain such as system makes this course of action not cost effective for the short duration required.

Designing to protect against a lower threat level equates to a higher risk of exposure and greater likelihood of defeat but entails lower costs. Designing to meet a higher threat level equates to a lower likelihood that the building will be compromised if attacked but entails high initial and operating costs.

The safe haven will be designed for the low LOP as required by UFC 4-010-01 and UFC 4-024-01 as described above. Protective masks will be provided to each employee, stored at their desks.

B-3.5 Design for Natural Threats.

The relevant natural threat is an earthquake, and typical wind loads must be considered as well. However, since the building structure is already designed for wind and seismic loads, these requirements have been met.

All non-structural components within the safe haven must be designed for seismic loads, per UFC 3-301-04, *Seismic Design of Buildings*.

B-4 OTHER DESIGN REQUIREMENTS.

B-4.1 Emergency Power.

If required, one internal-combustion generator in the cafeteria can provide backup power for the 2-hour duration, supporting lighting, ventilation, and communication systems. The generator must be vented to the outside without allowing airborne contamination to enter the safe haven. In general follow service guidance for approval of generator authorization and design.

B-4.2 Communication.

Hand-held radios and battery-powered radio transmitters for signaling emergency personnel will be provided in the safe haven. All communication devices will be tested at regular intervals defined by the Planning Team to ensure they are kept in working order, as described in FEMA P-361. A canned air horn will be in the safe haven to signal rescue personnel. Portable computers with internet capability, a fax machine, a copier, and a scanner are available in the cafeteria manager’s office, inside the safe haven.

B-4.3 Entry Point Monitoring.

An audible cue device will be mounted at all four entrances. When turned on, the cue should sound any time the doors are opened.

B-4.4 Fire Safety.

Safe havens must comply with all fire and life-safety code requirements per UFC 3-600-01. The fire and life safety system inside the safe haven must remain operational and provide life-safety protection after an incident and allow for safe evacuation of the building when appropriate for the required occupancy level. “The routine and maximum occupancy and required evacuation diagram will be posted according to UFC 3-600-01 and NFPA 101.”

B-4.5 Sanitation Management.

The cafeteria has 6 toilets, 3 each in one men’s and one women’s restroom, which more than meets the requirement of one toilet for every 75 occupants in the safe haven.

B-4.6 Additional Safe Haven Supplies.

The agency operating the safe haven will identify appropriate supplies based on items listed in Table 4-1 of FEMA 453, including food and water, if required. Any design requirements for storing these supplies must be considered in the safe haven design.

B-5 INTEGRATION.

Using the general population and sensitive information as the two main assets for the safe haven and considering all required tactics resulting from the design criteria analysis per UFC 4-020-01, the safe haven design is summarized in Table B-3.

Table B-3 Safe Haven Design Summary

Component	Governing Tactic	Construction Description
Walls	Forced Entry	8-inch (200-mm) reinforced concrete with #4 bars at 6 inches (150 mm) o.c. each way
Roof	Forced Entry	8-inch (200-mm) reinforced concrete with #4 bars at 6 inches (150 mm) o.c. each way, on steel decking, with a built-up roofing system
Doors	Forced Entry	10-inch (250-mm) steel clad solid wood swinging doors with ½-inch (13-mm) plate inside and out
Windows	Forced Entry	Limited to 96 sq. inches (0.06 sq. meters)
Non-structural	Earthquake	Peak acceleration of 2.6 ft/sec^2 (0.8 m/sec^2)

UFC 4-025-01
1 November 2012

UNIFIED FACILITIES CRITERIA (UFC)

SECURITY ENGINEERING: WATERFRONT SECURITY

UNIFIED FACILITIES CRITERIA (UFC)

SECURITY ENGINEERING: WATERFRONT SECURITY

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location

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

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

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

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

JAMES C. DALTON, P.E.
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Office of the Deputy Under Secretary of Defense
(Installations and Environment)

UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

Document: UFC 4-025-01 *Security Engineering: Waterfront Security*

Superseding: None

Description: Provide a unified approach to the development of waterfront protective measures intended to protect waterside assets.

Reasons for Document:

- This document is one of a series of security engineering criteria documents covering physical countermeasures for the current threat environment.

- The design of physical security measures is a specialized technical area that does not fall in the normal skill record and resume of commanders, architects, engineers, and project managers. This document provides guidance to those parties tasked with implementing existing and emerging physical protection system requirements for waterside assets.

Impact:

- This document does not set the requirement for protection measures for the waterfront. No additional cost impacts are anticipated by the publication of this document. This document should reduce the design and coordination efforts for waterfront design.

Unification Issues

There are no unification issues.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

Terrorist attacks on waterside assets such as the USS Cole emphasize the need for increased antiterrorism (AT) and physical security protective measures for waterfront assets.

1-2 PURPOSE.

Present a unified approach for AT and physical security systems that protect waterfront assets. Commanders, security personnel, planners, designers, architects, and engineers shall use this document when considering AT and physical security systems that protect waterfront assets.

1-3 APPLICABILITY.

This document provides planning and design criteria for DoD components and participating organizations. This document applies to all construction, renovation, and repair projects including expeditionary or temporary construction of waterfront facilities associated with waterfront assets onboard DoD installations. This document does not apply to ports of call.

1-4 SCOPE.

This document provides a methodology to design AT and physical security systems required to protect waterfront assets. It focuses on the protection of military warships and support vessels but the concepts within may be adopted for the protection of all DoD waterfront assets such as airfields, shore facilities, or other structures immediately adjacent to water.

The examples provided are for illustration only and should be modified and adapted to satisfy installation specific constraints. Issues such as tactics, techniques, and operational procedures are not addressed. However, a well-designed physical security system should not hinder operations and capabilities.

1-5 VULNERABILITY AND RISK ASSESSMENT.

In accordance with DOD O-2000.12H Antiterrorism handbook, a vulnerability and risk assessment must be conducted prior to beginning any security project. Upon identifying facility or asset vulnerabilities to threats, physical security measures such as fences, gates, and Electronic Security Systems (ESS) may be deployed to reduce vulnerabilities. In summary, this document assumes the pre-design phases, including the risk analysis, are complete prior to beginning design. For information on Security Engineering Planning and Design process, refer to UFC 4-020-01 and UFC 4-020-02 (described in the section “Security Engineering UFC Series” in this chapter). The engineering risk analysis conducted as part of UFC 4-020-01 should be consistent with the terrorism risk analysis conducted by the installation security/AT staff.

1-6 POLICY REQUIREMENTS.

The requirement to protect waterfront assets comes from DoD Instruction/Directives, Geographic Combatant Commander (GCC) Instructions, Service Instruction/Directives, and Regional or Installation requirements. Consult Headquarters, Major Command, Regional, and Installation personnel to established waterfront asset protection requirements.

1-6.1 Department of Defense.

There are several instructions and publications within the Department of Defense that establish requirements for access control and physical security for waterfront assets.

- DOD 5200.8-R: Requires DOD Components to determine the necessary access control based on the requirements of a developed physical security program. Emergency planning is specified to include establishment of a system for positive identification of personnel and equipment authorized to enter and exit the installation and maintenance of adequate physical barriers that will be deployed to control access to the installation. Planning will also include increasing vigilance and access restrictions during higher force protection conditions.

- DODD 2000.12: Provides DOD policies for ATFP and assigns responsibilities for implementing the procedures for the DOD ATFP Program. It authorized the publication of DOD 2000.16 Antiterrorism Standards as the DOD standards for ATFP and DOD O-2000.12-H DOD Antiterrorism Handbook as guidance for the DOD standards.

- DOD O-2000.12H: Defines the DOD Force Protection Condition (FPCON) System, which describes the potential threat levels and the applicable FPCON measures to be enacted for each level. FOCON measures in the 12-H were modified in DoDI 2000.16, Change 2 of 08 Dec 2006. DOD O-2000.12H also requires Commanders to develop and implement Random Antiterrorism Measures (RAM) as an integral part of their AT Program.

- DODI 2000.16: This instruction requires the installation or activity Commanding Officer to define the access control measures at installations. Additionally, DOD 2000.16 requires Commanders at all levels to develop and implement a comprehensive Antiterrorism (AT) Program, which should define the necessary action sets, including identification and inspection procedures, at each of the potential Force Protection Condition (FPCON) levels and lists the most current approved FPCONS.

1-6.2 Geographic Combatant Commander (GCC) Requirements.

GCC issue requirements for Antiterrorism and physical security for installations within their area of responsibility. Ensure any such requirements are incorporated in addition to the requirements found in DoD and Service Directive/Instructions. Resolve any differences in the requirements for the design of a waterfront security by applying the most stringent requirement.

1-6.3 Service Requirements.

Department of Navy.

- OPNAVINST 5530.14, Chapter 10 identifies the requirements for installation and restricted area access control. APPENDIX VIII identifies Waterside and Waterfront physical security requirements.

- NTTP 3-07.2.3 provides guidance for the physical security for Naval Installations to include Restricted Areas and Waterfront Security.

1-6.4 Installation Specific Requirements.

As required by DODI 2000.16 and service directives, each installation must have an Antiterrorism Plan. The plan provides procedures and recommendations for reducing risk and vulnerability of DOD personnel, their family members, facilities, and assets from acts of terrorism. As such, the installation AT plan reflects the foundation for requirements determination. Installation specific requirements need to be factored into all capital improvement initiatives.

1-7 CONSIDERATIONS.

The objective of waterfront security system is to secure the waterfront from unauthorized access and to detect and neutralize threats while minimizing impacts to port operations and the environment. Design considerations are:

- Security
- Port Operations
- Safety
- Appearance
- Environmental impact

1-7.1 Security.

Installations should focus first on threats at the first line of defense – the installation perimeter. Consideration of the waterfront is extremely important to defense-in-depth and effective risk mitigation.

The first priority of a waterside security system is to maintain perimeter security. The waterfront:

- is a part of the installation perimeter and a legal line of demarcation

- must be able to accommodate Random Antiterrorism Measures (RAMS) employment for sustained operations in order to validate installation's ability to affect directed security posture.

- must be able to operate at all FPCONs; and must have security features that protect against landside and waterside threats and unauthorized entry

1-7.2 Port Operations.

Design the waterfront security systems to maximize security while minimizing the impact on port operations. Ships must be able to sortie effectively without compromising safety, security, or causing undue delays that may affect port or fleet operations.

1-7.3 Safety.

Waterfronts must have a working environment that is both safe and effective for security forces and personnel working in the waterfront area. Safety includes provisions for personal protection against attack and mishaps.

1-7.4 Appearance.

Design waterfront security systems to impart an immediate impression of professionalism and convey the DOD's commitment to the security of DOD personnel and its mission critical assets, facilities, and resources.

1-7.5 Environmental Impact.

Design waterfront security systems to minimize environmental impact on the adjacent waterway. Include environmental representatives in the initial planning, design and construction of applicable projects to ensure there are no compliance issues, and that all regulatory approvals are received in a timely manner.

1-8 CORROSION PREVENTION AND CONTROL.

Design strategies for waterfront security structures and equipment shall consider corrosion prevention and control (CPC) preservation techniques for long term maintainability throughout their life cycle. Trade-off decisions involving cost, useful service life, and effectiveness shall address corrosion prevention and mitigation.

1-9 REFERENCES.

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

1-10 GLOSSARY.

Appendix B contains acronyms, abbreviations, and definitions of terms.

1-11 GENERAL BUILDING REQUIREMENTS.

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

1-12 SECURITY ENGINEERING UFC SERIES.

This UFC is one of a series of security engineering unified facilities criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include the following:

1-12.1 DoD Minimum Antiterrorism Standards for Buildings.

UFC 4-010-01and 4-010-02 establish standards that provide minimum levels of protection against terrorist attacks for the occupants of all DoD inhabited buildings. These UFCs are intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings. They also include recommendations that should be, but are not required to be incorporated into all such buildings.

1-12.2 DoD Security Engineering Facilities Planning Manual.

UFC 4-020-01 presents processes for developing the design criteria necessary to incorporate security and antiterrorism into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also addresses the tradeoffs between cost and risk. The Security Engineering Facilities Planning Manual is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

1-12.3 DoD Security Engineering Facilities Design Manual.

UFC 4-020-02 provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02 is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design.

The manual also provides a process for assessing the impact of protective measures on risk. The primary audience for the Security Engineering Design Manual is the design team, but it can also be used by security and antiterrorism personnel.

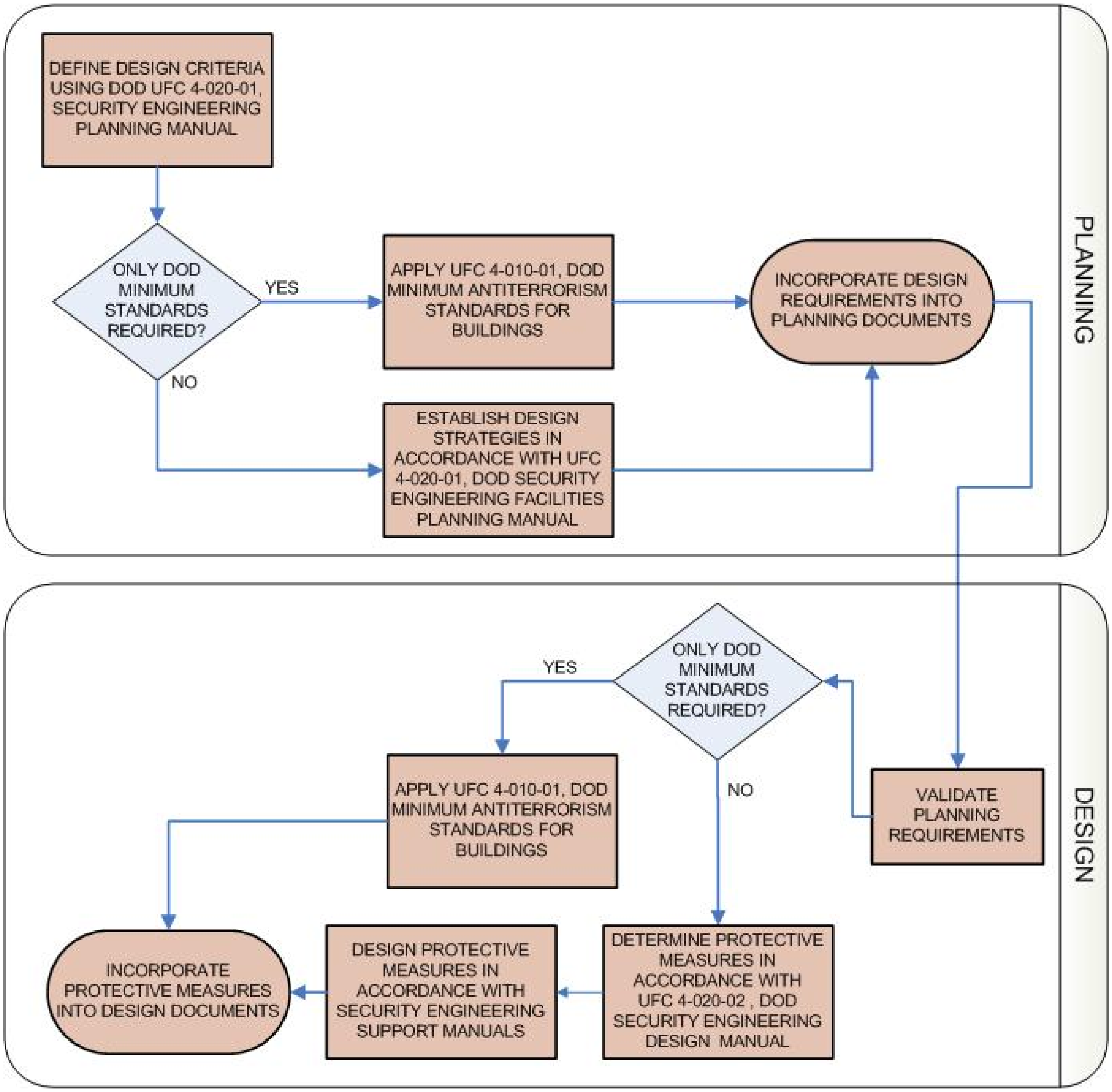
1-12.4 Security Engineering Support Manuals.

In addition to the standards, planning, and design UFCs mentioned above, there is a series of additional UFCs that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, forced entry, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mail rooms. Still others address details of designs for specific protective measures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

1-12.5 Security Engineering UFC Application.

The application of the security engineering series of UFCs is illustrated in Figure 1-1. UFC 4-020-01 is intended to be the starting point for any project that is likely to have security or antiterrorism requirements. By beginning with UFC 4-020-01, the design criteria will be developed that establishes which of the other UFCs in the series will need to be applied. The design criteria may indicate that only the minimum standards need to be incorporated, or it may include additional requirements, resulting in the need for application of additional UFCs. Even if only the minimum standards are required other UFCs may need to be applied if sufficient standoff distances are unavailable. Applying this series of UFCs in the manner illustrated in Figure 1-1 will result in the most efficient use of resources for protecting assets against security and antiterrorism related threats.

Figure 1-1 Security Engineering UFC Application



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CHAPTER 2 OVERVIEW

2-1 OVERVIEW.

DoD installations located adjacent to bodies of water face all the threats of land –locked installations. In addition, waterfront installations must defend against the waterside threat. Waterside attacks pose additional challenges for security forces and the installation's overall physical security system and include either surface (boat or swimmer) or subsurface (scuba diver or submersible) threats. Physical security systems protecting waterfront assets must enable/facilitate threat detection, assessment, delay, response, and threat neutralization for both waterside and landside threats.

2-2 WATERFRONT SECURITY SYSTEM.

Waterfront security system is that subset of an Installation's physical security system specifically designed to safeguard waterfront assets against espionage, sabotage, damage, or theft.

2-2.1 Waterfront Assets.

Waterfront assets are vessels, personnel, and facilities such as piers, wharves, docks or similar structures used to berth vessels.

2-2.2 Waterfront.

The area of the DoD installation adjacent to a body of water. This area comprises waterfront assets and the surrounding area including the adjacent waterway, land, facilities, parking, and roadways. This area may be designated as a restricted or controlled areas per DoD 5200.8-R. Within the controlled or restricted area, the waterfront is divided into the two areas of waterside and landside. See Figure 2-1.

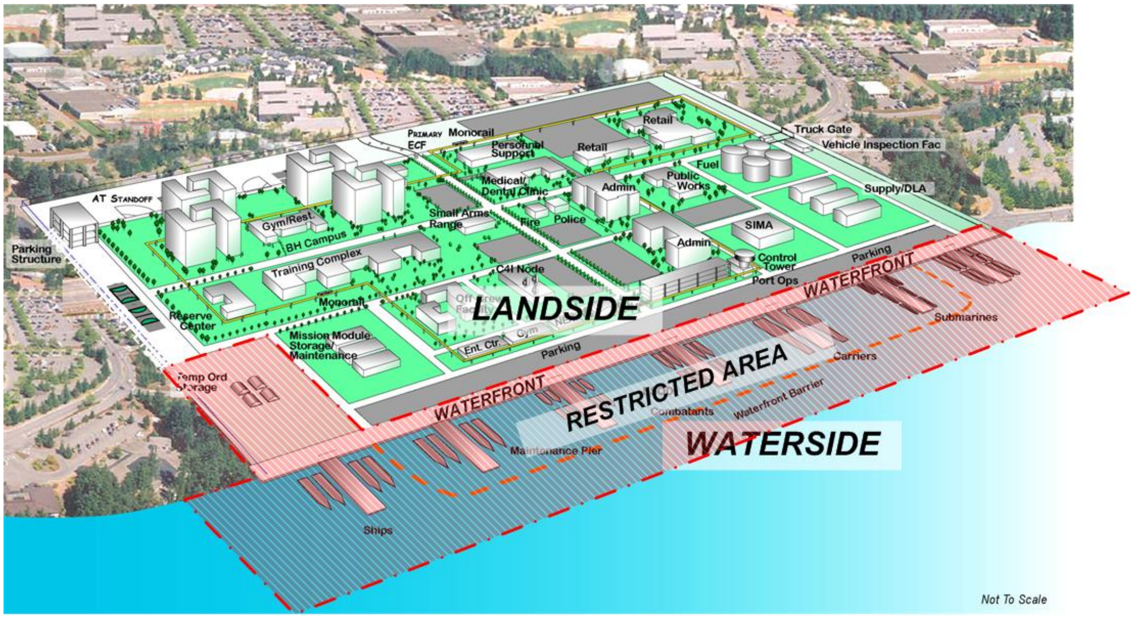
2-2.2.1 Waterside.

The body of water (waterway) adjacent to the DoD installation that is monitored and or controlled by the Installation. The waterside includes the piers and similar structures built out into the water.

2-2.2.2 Landside.

The land within the controlled or restricted area adjacent to the body of water. This includes facilities such as wharves or similar structures and includes the adjacent, facilities, parking and roadways.

Figure 2-1 Waterfront



2-2.3 Physical Security System.

A system of integrated protective measures comprised of people, equipment, and operational procedures that control access to facilities or assets.

Design physical security systems to ensure protective measures work as an integrated system rather than separate elements. The system must detect threats, delay threats, and then respond to threats. This concept is referred to as of detect, delay, and respond or detect, delay, and defend. To create an effective system, the time between detection and response by response capability must be less than the time it takes the threat to compromise the asset. Physical security systems accomplish this by detecting threats at the farthest possible distance from the asset and providing delays between the detection points and the asset giving the response capability time neutralize threat. This presents a challenge on the waterside due to limited distances between waterfront assets and unrestricted waterways.

Figure 2-2 diagrams the functions of a physical security system. Table 2-1 depicts the physical security protection measures of a waterfront security system.

Figure 2-2 Diagram of Physical Security System Functions

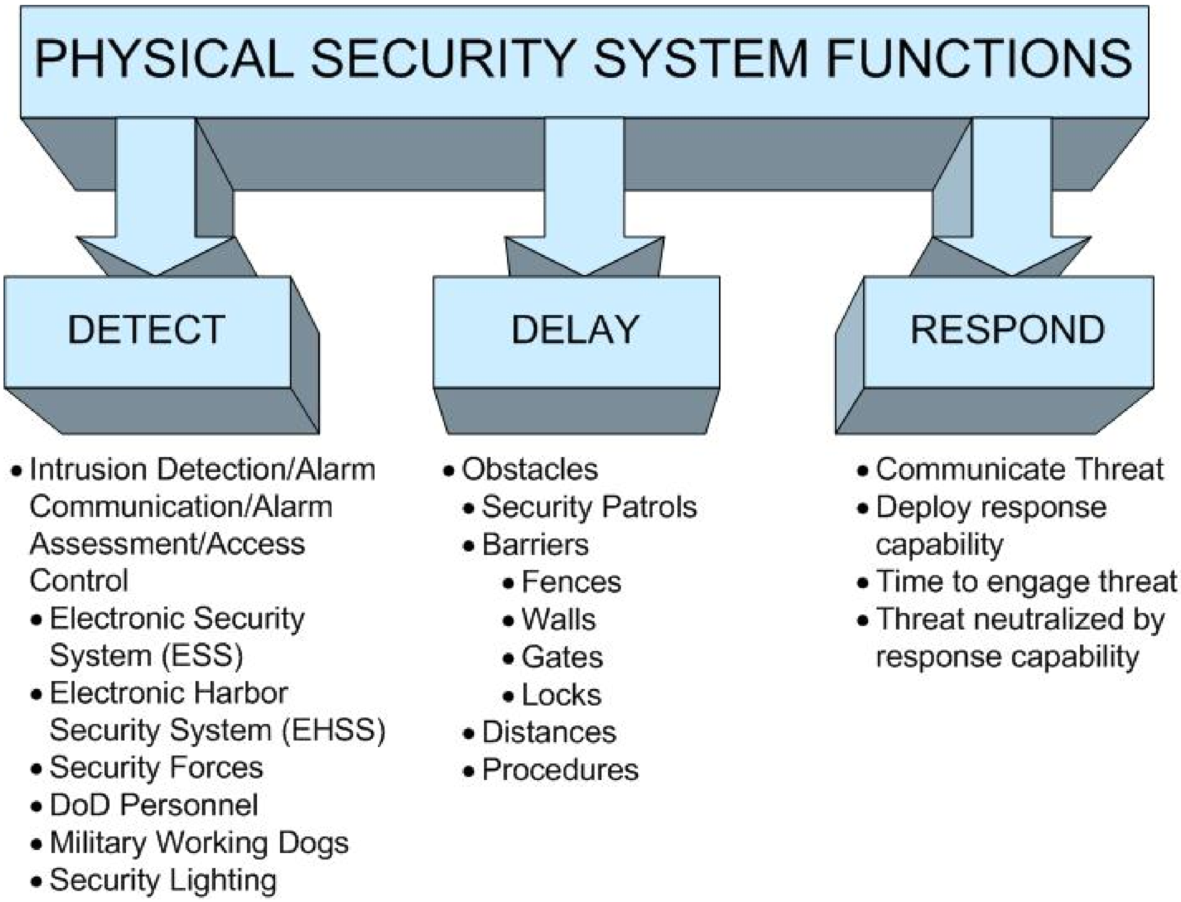


Table 2-1 Waterfront Security Elements

WATERSIDE	LANDSIDE	
WATER	**PIERS/ WHARFS**	**LAND**
Channel Markers Buoy line Barriers Signage Patrol Boats Electronic Harbor Security System (EHSS) • Surface detection/assessment o Cameras o Thermal Imagers o Radar o Video Analytics • Subsurface detection/assessment • Sonar	Guard Towers Security Lighting Access Control Point • Vehicle • Pedestrian Giant Voice	Fences Access Control Point • Vehicle • Pedestrian Security Lighting Electronic Security System (ESS) • Camera • Intrusion Detection • Access Control Giant Voice

2-3 PLANNING.

2-3.1 Establish Requirements.

For some waterfront assets, the minimum security measures are established by policy or regulation. See OPNAVINST 5530.14 for security measures associated with waterfront assets in U.S. Navy controlled ports. Always determine requirements for waterfront asset protection early in the project planning process.

Establish an interdisciplinary planning team with local considerations to include the following:

- Supported Command
- Security forces
- Port Operations
- Installation/Regional Anti-terrorism Officer (ATO)
- Communications Officers
- Safety Officers
- Engineering
- Environmental
- Planning
- Local, state, Federal, or host nation officials to ensure integrity of restrictive access to the installation and reduce the potential adverse effects on surrounding communities.

The interdisciplinary planning team will use the process in UFC 4-020-01 to identify the design criteria, which includes the assets to be protected, the threats to those assets, and the levels of protection required for the assets against the identified threats. The planning team may also consider user constraints such as appearance, operations, manpower requirements or limitations, and sustainment costs when determining the requirements for asset protection and components of the overall security solution.

2-3.2 Design Basis Threat (DBT).

The DBT links aggressor with tactic. It includes the aggressor tactics and the associated weapons such as explosives, tools, and agents. The DBT must be determined to plan and design the protective measures required to protect the assets from compromise.

The waterfront should have a DBT for the landside protection measures, and a different DBT for the waterside. For example, the landside may be a stationary vehicle bomb consisting of a 4,000 lb (1814 kg) vehicle containing a Type II explosive. The waterside may be a 2,000 lb (907 kg) powerboat containing a Type I explosive.

2-3.3 Level of Protection (LOP).

Defines the degree to which an asset is protected against DBT.

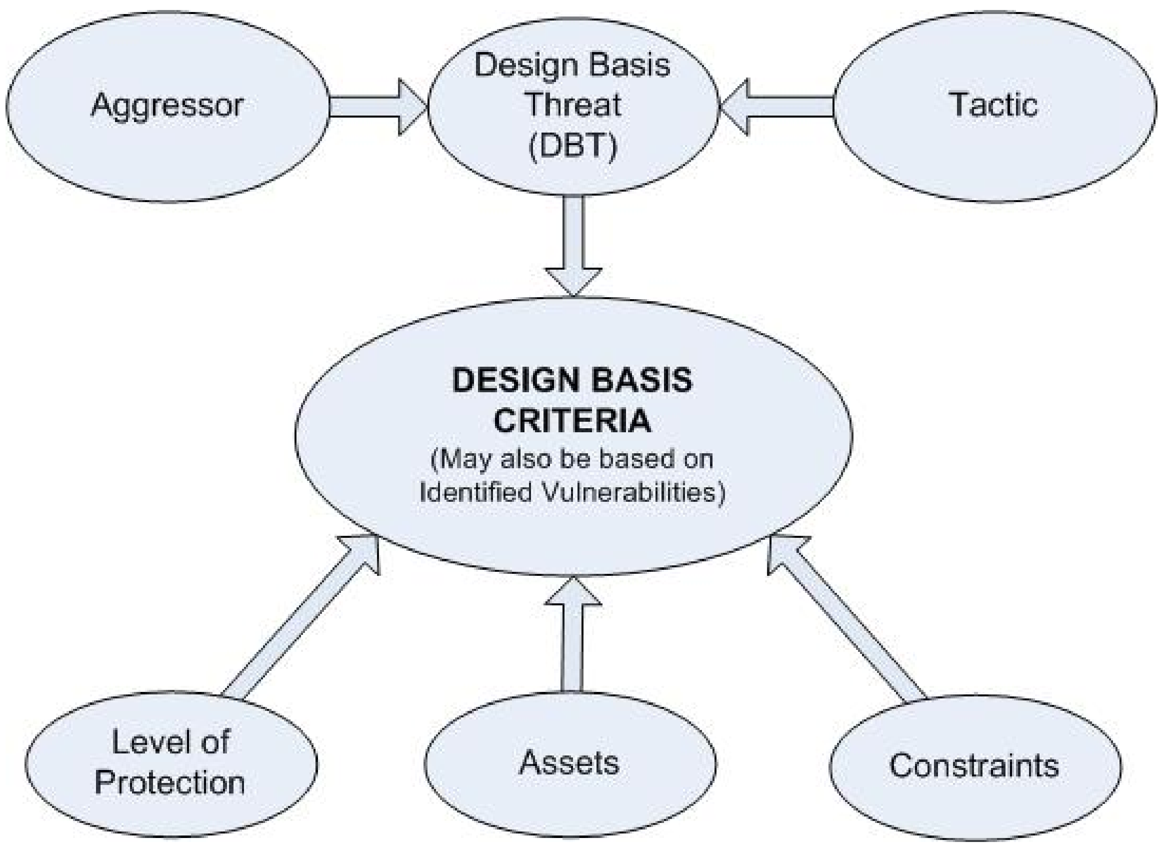
2-3.4 Future Development Plans.

The planning team must carefully evaluate future development plans for the installation and the surrounding community. All waterfront security development plans should accommodate future modifications necessitated by increased demand, additional assets, additional facilities, or revised security measures.

2-3.5 Document Requirements.

Document the planning requirements for endorsement by the Installation ATO and Port Ops Officers to ensure protective measures support the installation's physical security system, AT plan, and waterfront operations. Figure 2-3 provides a simplified flow chart of the overall process.

Figure 2-3 Project Process



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CHAPTER 3 DESIGN STRATEGY

3-1 INTRODUCTION.

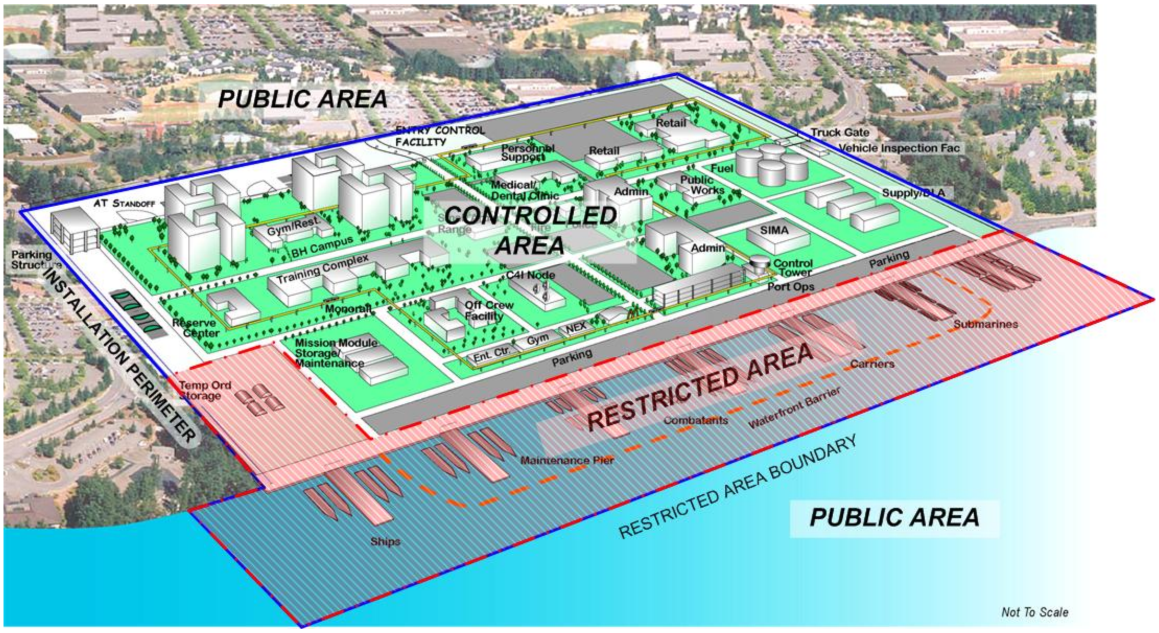
This chapter presents information to design a system of protective measures deployed on an installation that protect the waterfront from unauthorized access using the processes in UFC 4-020-01 and UFC 4-020-02 (delineated in Figure 2-3) to identify the design requirements. It assumes the waterfront is a controlled or restricted area (enclave), onboard a DoD installation with protective measures deployed on the installation and at the entry control points. It also does not address protective measures outside the waterfront area.

3-2 DESIGN STRATEGY.

All protective measures must support the concept of detect, delay and respond and facilitate security force's ability to determine capability, opportunity, and intent of would be aggressors. When possible, physical security systems shall use a defense-in-depth approach, which effectively employs human and other physical security measures throughout the installation to create a layered defense against potential threats. Defense-in-depth insures that no single point of failure would render assets vulnerable to compromise. This strategy utilizes a zone concept that establishes areas within the installation and their associated security measures. An installation must establish clearly defined sequence of boundaries through which personnel must pass to reach the restricted area. Security measures and access controls must increase as personnel transition from lower to higher security areas and personnel must understand the consequences associated with entering the restricted area. Figure 3-1 graphically describes this concept. This document will focus on the restricted area of the waterfront sometimes referred to as the waterfront enclave.

In the case of waterfront security, the first layer of defense is the Installation's perimeter including the Access Control Points (ACPs). For the landside, the installation's ACPs provide the first opportunity to detect and engage threats away from the critical assets. Access control at the installation's perimeter is extremely important to the defense-in-depth concept and effective risk mitigation. For the waterside, the first layer of defense may be the restricted area (waterway) boundary. The waterside restricted area should be visibly delineated in order to facilitate security force's ability to determine the intent of would be aggressor.

Figure 3-1 Zone Concept



- **Public Area:** Area outside an installation or controlled perimeter where the public has unrestricted access.

- **Access Control Area:** The installation's entry control points where authorized personnel transition from public zone to the DoD installation.

- **Controlled Area:** The area within the installation's controlled perimeter where authorized personnel have access. Installations are considered controlled areas for the purposes of national defense.

- **Restricted Area:** A defined area established to protect critical assets by providing a higher level of security than that afforded elsewhere on the installation.

3-2.1 Detect, Delay, and Respond.

A physical security system must operate on the principle of Detect, Delay, and Respond. To be effective, the time between detection of an intrusion and response by security forces must be less than the time it takes to damage or compromise the protected asset.

3-2.1.1 Detect.

Detection and assessment of the potential threats may be accomplished through ESS, electronic harbor security system (EHSS), security lighting, security forces, DoD personnel, military working dogs. Training and operational procedures are critical to detection and assessment as they improve personnel capabilities and support application of consistent concepts and practices. Security lighting, ESS and EHSS greatly enhance the probability of detection, reduce the time it takes to assess the threat, improve classification of potential threats, and may reduce the manpower required to accomplish these functions.

3-2.1.2 Delay.

Delay is the time it takes for the aggressor to get from the point of detection to compromising the protected asset. Physical security systems may deploy roving security patrols, barriers, or increase standoff distance to create obstacles to increase delay. The time delay that a physical security system provides is critical to asset security. The time delay of the system must be synchronized with security force response time to ensure that maximum security is afforded to critical assets.

3-2.1.3 Response.

Response is the time it takes for the response capability to interrupt or neutralize a threat. This includes communication, mobilization, travel time, and tactics.

3-3 SYSTEM EFFECTIVENESS.

A well designed physical security system will:

- Provide defense-in-depth
- Provide continuous protection
- Enhance detect, delay, and response function

Effective waterfront security systems must be compatible with the installation's operational and security procedures. Measures that are excessive, inappropriate may eventually be eliminated or bypassed. Poorly placed fencing or barriers can reroute cranes, forklifts or container carriers to pavement areas not designed for heavy loads. Forklift tines and crane hooks can damage security equipment rendering the system inoperable. Minimize impediments to waterfront operations and security hardware by placement and consolidation.

3-4 ESTABLISH PERIMETER.

To protect waterfront assets from unauthorized access, it is important to establish and maintain a defined perimeter. Before a person proceeds into the waterfront restricted area, they must perceive the area boundary and understand the consequences associated with crossing it. The use of ESS on the landside and EHSS on the waterside enhance:

- Detection of unauthorized access with an intrusion detection system (IDS)
- Improve the validation of credentials with access control systems (ACS)
- Threat detection, alarm assessment, surveillance, and archiving with video imaging.

The easiest and least costly opportunity for achieving the appropriate levels of protection against terrorist threats is to incorporate sufficient standoff distance to mitigate the defined threat. While sufficient standoff distance is not always available, maximizing the available standoff distance always results in the most cost-effective solution.

3-4.1 Landside Perimeter.

The landside perimeter of the enclave may consist of fences, walls, signage, natural barriers, and ACPs for authorized vehicles and pedestrians. In addition, a final denial boundary may be established at the foot of a pier creating defense-in-depth. See chapter 4 for Landside protection measures.

3-4.2 Waterside Perimeter.

The waterside boundary of the enclave may consist of channel markers, buoys, float lines, signage, or boat barriers. The transition from the public area to the restricted area may not go through additional areas or zones. Therefore, the boundary on the waterside may have to provide a higher LOP (delay) for critical assets than the landside counterparts to ensure critical assets are not compromised. See chapter 5 for Waterside protection measures.

3-5 SECURITY LIGHTING.

Security lighting or protective lighting provides illumination during periods of darkness or in areas of low visibility to aid in the detection, delay, and respond functions of a physical security system. Coordinate security lighting requirements with security personnel. Refer to UFC 3-530-01 for lighting design criteria and the Landside and Waterside Chapters of this UFC for specific security lighting guidance.

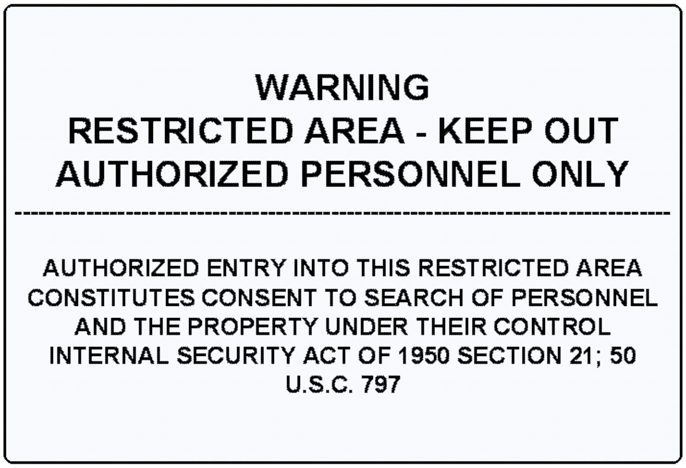
3-6 SIGNAGE.

Coordinate size, placement, wording, and use with security personnel. Signage should be consistent with applicable DoD/Service specific requirements. Any language in addition to English should be appropriate for the stated purpose.

3-6.1 Access Control Point (ACP) Signage.

Post reflective signs at all waterfront vehicle and pedestrian ACPs. For example see Figure 3-2.

Figure 3-2 ACP Sign Example



3-6.2 Restricted area signage.

Post reflective signs at intervals no greater than 100 feet (30.5 m) along the entire perimeter of the restricted area and where boundaries make abrupt changes in direction. For example see Figure 3-3.

3-6.3 Boat Barrier Signage.

Post reflective signs at intervals no greater than 100 feet (30.5 m) along the entire boat barrier perimeter and on moorings. For example see Figure 3-3.

Figure 3-3 Restricted Area Sign Example

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CHAPTER 4 LANDSIDE

4-1 INTRODUCTION.

This chapter presents information to design a system of protective measures deployed on the landside of an installation intended to protect waterfront assets.

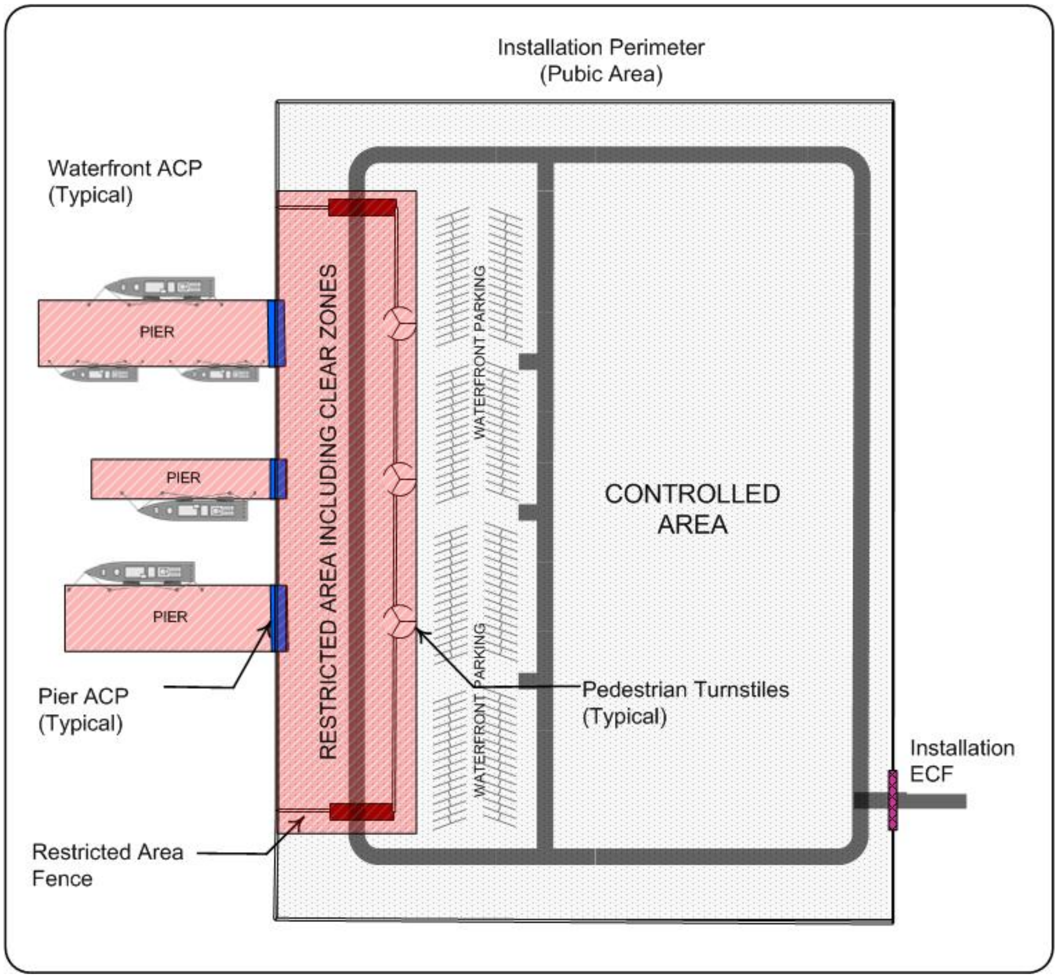
4-2 GENERAL DESIGN STRATEGY.

For the purposes of this chapter, threats are from the landside. The design strategy for the landside must be based on the concept of defense-in-depth. Establish multiple perimeters, boundaries, or zones through which unauthorized personnel must pass to access protected assets. Configuration of the physical perimeter and the LOP are dependent on assets to be protected and the DBT. In the case of the landside security, the Installation's controlled perimeter may be the first layer of defense.

The general design strategy for the landside is to establish and maintain defense in depth through the application of standoff, barriers, access control, operational procedures, and security zones, see Figure 4-1. The security zones or areas are defined as follows:

- **Asset location:** The area where the protected asset is located. For vessels, this would be a pier, wharf or dry dock.
- **Waterfront Restricted Area (enclave):** A defined waterfront area in which there are special measures employed to prevent unauthorized entry. Restricted areas may be of different types depending on the nature and varying degree of importance of the protected asset and may extend beyond the piers or wharfs to the surrounding areas. Restricted areas must be authorized by the installation commander, properly posted, and employ physical security measures.
- **Controlled Area:** The area within the installation's controlled perimeter where authorized personnel have access.

Figure 4-1 Landside Security Zones Adjacent to Piers



4-3 LANDSIDE ACCESS CONTROL.

Access control is established to prevent unauthorized access to restricted areas. As with any element of a physical security system, design must be based on the concepts of defense-in-depth. Design of the access control system begins at the Installation's perimeter and ACPs. Vehicles and personnel travel from one zone to another through the system to reach the restricted area. Physical security measures, including access control must increase from lower to higher security areas. The pier or wharf where critical assets are berthed are considered the final denial and should have the highest access control measures in the system, see Figures 4-2 and 4-3.

Figure 4-2 Landside Access Control Transitions

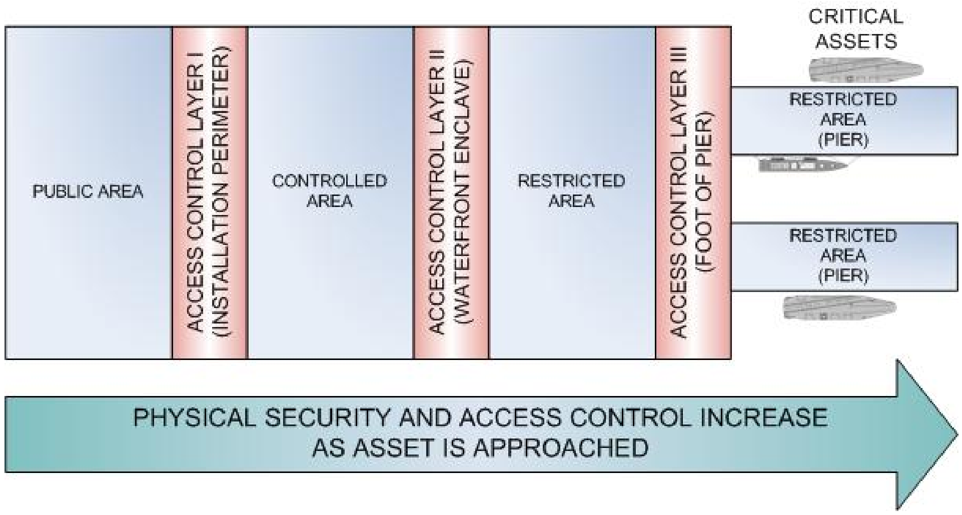
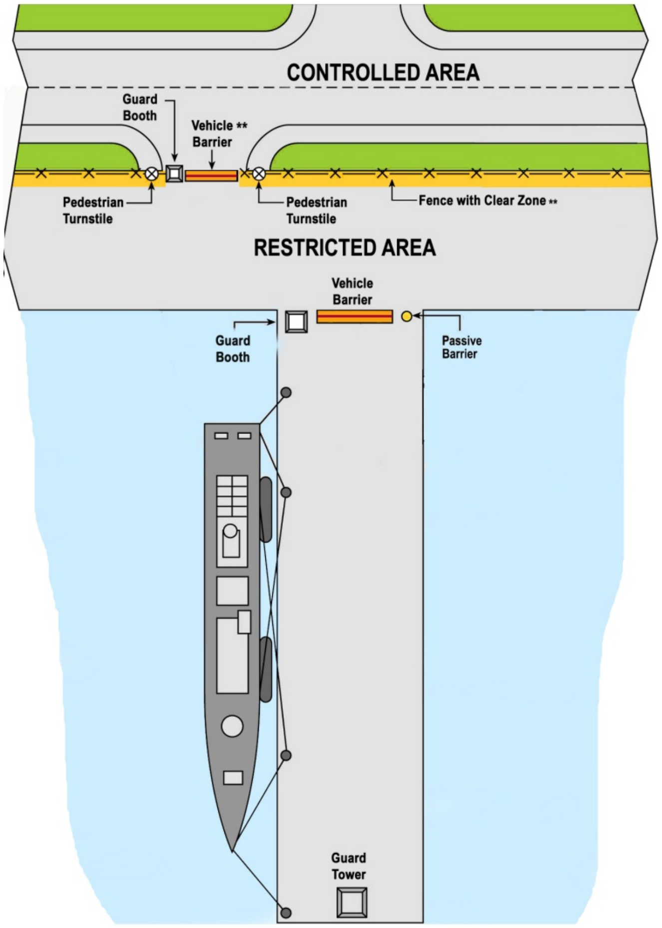


Figure 4-3 Waterfront Access Control



** If standoff from the asset is achieved at the foot of pier for the DBT, vehicle rated barriers at the restricted area boundary may not be required.

4-4 LANDSIDE STANDOFF.

While sufficient distance is not always available to provide the standoff required for a high LOP, maximizing the available standoff distance always results in the most cost-effective solution and also ensures that there is opportunity in the future to upgrade to meet increased threats or to accommodate higher force protection conditions (FPCON).

4-5 ACCESS CONTROL LAYER I: INSTALLATION PERIMETER.

The Installation's controlled perimeter and its related entry control points are not within the scope for this document. However, the Installation controlled perimeter, ACPs, and the related security procedures must be considered when determining the DBT and the resulting protective measures for the waterfront.

4-6 ACCESS CONTROL LAYER II: WATERFRONT ENCLAVE.

The access control and protection features for Layer II should be determined based on asset to be protected, DBT, and desired LOP. Coordinate requirements with supported command, ATO, and security personnel. To protect waterfront assets from unauthorized access, it is important to establish and maintain a defined perimeter. Before a person or vehicle proceeds into the waterfront restricted area (enclave), there must be a perceived perimeter boundary and an understanding of the consequences associated with crossing it. Design ACPs in accordance with UFC 4-022-01.

4-6.1 Layer II: Vehicle ACPs.

Minimize the number of vehicle ACPs into the waterfront to reduce operational requirement. However, provide a minimum of two gates for flexibility.

4-6.2 Layer II: Pedestrian ACPs.

Some waterfronts enclaves are very large and have a significant amount of pedestrian traffic. When pedestrian access control is required, ensure that proper sidewalk and safety provisions direct pedestrian traffic to the ACP separate from vehicular traffic. For pedestrian ACP at vehicular ACP, design pedestrian access to ensure security personnel maintain visual contact with the pedestrians as they approach the vehicular ACPs. If passive barriers are required, breaks in the passive barrier system for pedestrian access to the waterfront should not exceed 3.3 feet (1 m) in width for traffic having a 90-degree approach and 4.1 feet (1.25 m) in width for traffic paralleling the barrier.

Where warranted by pedestrian usage and size of the waterfront, incorporate turnstiles or similar devices in areas of high pedestrian traffic that can be automated to facilitate access control system. Provide infrastructure required to support automation to include a card reader, intercom, and video monitoring at each turnstile. Other considerations in the selection of turnstiles or similar access control devices include the control of potential tailgating and the likelihood that personnel will have equipment or luggage, which may require additional space in the turnstile. Consider if pedestrian inspection areas will be required based on pedestrian demand and any requirement to search personnel and packages. Design elements for pedestrians should be compliant with *ABA Accessibility Standard for Department of Defense Facilities*.

4-6.3 Layer II: Fence.

Fences, clear zones, signage, or other lines of demarcation shall delineate the waterfront restricted area. When required, design the fence and associated gates in accordance with UFC 4-022-03. Buildings, structures, and other barriers may be used as a part of a security fence line as long as they provide equivalent protection to the fencing enclosing the restricted area.

4-6.4 Layer II: Vehicle Barriers.

Vehicle rated barriers are only required for the moving vehicle threat. Consider the regional threat environment and coordinate with installation Antiterrorism Officer (ATO) to determine DBT. Depending on the DBT, reinforcement of the waterfront enclave may not be required if the standoff provided by the final denial barrier at the foot of the pier is adequate to meet the LOP. If vehicle rated barriers are required, conduct a site survey to determine where reinforcement of the waterfront enclave is required. Some areas may not require reinforcement due to existing site elements such as ditches, bio swales, or retaining walls. Design barriers in accordance with UFC 4-022-02.

4-7 ACP LAYER III: FOOT OF PIER.

The access control and protection features for Layer III should be determined based on assets to be protected, DBT, and desired LOP. Coordinate requirements with supported command, ATO, and security personnel. For high value assets, the ACP for a pier shall have a guard booth, barriers, security lighting, and signage.

4-7.1 Layer III: Vehicle Barriers.

Barriers may consist of either passive or active barriers designed to prevent vehicles or personnel from accessing the protected area. Active barrier systems are not recommended due to the extreme environmental conditions at the waterfront. For double deck piers, access for both the upper and lower decks must be controlled. See Figure 4-4 for an example of a double deck pier ACP.

Figure 4-4 Pier ACP

4-7.2 Layer III: Guard Booth.

A guard booth is a structure that provides a protected position to facilitate surveillance, assessment, and response to threats. It may be fixed or temporary/portable. Manning of the watch position will be in accordance with the installation physical security and AT plans. Location and elevation of the guard booth must enhance the ability of security personnel to process vehicles and personnel, observe and determine capability, opportunity, and intent of threats, initiate alarms, coordinate response, and attack with force if necessary and authorized. Coordinate the manning requirements of the guard booth with security personnel. Design the guard booth to provide maximum visibility of the approach to the guard position and pier deck from the interior. Provide overhangs sized to reduce glare on glazing, facilitate mounting of exterior lighting, and provide cover from the elements for security personnel. Refer to UFC 4-023-02 for ballistic design and other requirements. See Figure 4-4 for an example of a guard house at the foot of a double deck pier.

4-7.2.1 Communication and Information Technology.

Each guard booth should have at least two means of communication to a central monitoring point, e.g. installation emergency control center, central dispatch, or similar designated location. Coordinate the communication requirements with the installation. Provide a minimum of two 1 inch (2.54 cm) empty conduit raceways from the watch position to the roof to facilitate future roof mounted communication equipment.

4-7.2.2 Central Duress Alarm.

Provide a central duress alarm, which signals other guard positions and the central monitor point. Provide an enunciator in the guard tower to alert security personnel of alarm triggered at any other waterfront guard position or tower.

4-7.2.3 Guard Booth Lighting.

Lighting inside the guard booth must not degrade security personnel’s nighttime vision. All luminaires must be dimmable and should be mounted at or near desk level. Switch task and general lighting separately. When colors are not used to distinguished tasks (colored lights or controls for alarm annunciations), consider red light sources for task lighting to reduce adaptation problems. Lighting controls must be under the direct control of security personnel.

4-8 ELECTRONIC SECURITY SYSTEMS (ESS).

The need for an intrusion detection system (IDS) and video monitoring for the landside perimeter will be based on assets to be protected, threat environment, desired LOP, and defense-in-depth. Coordinate requirements with supported command, ATO, and security personnel. Design systems in accordance with UFC 4-021-02NF.

When turnstiles are provided for pedestrian access control, provide infrastructure required to support automation of turnstiles. Include lighting, card reader, intercom, and video monitoring at each turnstile.

4-9 SECURITY LIGHTING.

Security lighting aids in the detection of aggressors and assists personnel in the assessment and response to potential threats. The type of site lighting system provided depends on the installation environment and intended use. Provide full cut-off or fully shielded fixtures to limit glare. In general, high mast lighting provided for waterfront operations supply adequate illuminance for security requirements. Design lighting in accordance with UFC 3-530-01.

4-9.1 Perimeter Lighting.

The need for lighting for the landside perimeter will be based on assets to be protected, threat environment, desired LOP, and defense-in-depth. Coordinate requirements with supported command, ATO, and security personnel. Illumination of a restricted area perimeter includes the exterior and interior clear zones adjacent to the fence or, in some applications, the area between multiple fences. Provide poles, power circuits, and transformers within the protected area. Coordinate pole locations with the user to ensure that the applicable egress requirements and patrol routes of the clear zone are not violated. The distance of poles from the fence shall not be less than 5 feet.

4-9.2 Vehicle ACP Lighting.

For most of the ACPs (access zone), full cutoff or fully shielded luminaires will provide adequate lighting for most visual tasks. However, vertical illuminance on motorists' faces can be improved with the use of low brightness light sources (less than 3500 lumen lamp output). Luminaires mounted to the side and behind security personnel will improve identification tasks.

4-9.3 Pedestrian ACP Lighting.

Illuminate pedestrian zones for both pedestrians and security personnel. Pedestrians must have a clear view of gates and card access readers and security personnel must be able to see pedestrians approaching the ACP. Provide full cutoff or fully shielded luminaires mounted in the horizontal plane to minimize glare.

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CHAPTER 5 WATERSIDE

5-1 INTRODUCTION.

This chapter presents information to design a system of protective measures deployed on the waterside of an installation.

5-2 DESIGN STRATEGY.

For this chapter, threats are from the waterside. As with Landside, the design strategy for the waterside must be based on the concept of defense-in-depth by establishing multiple boundaries or zones in which unauthorized watercraft or personnel (i.e. diver or swimmer) must pass to access protected assets. Configuration of the physical perimeter and the LOP are dependent on assets to be protected and the DBT. The primary protective measure is maintaining stand-off through detection and delay of surface and subsurface threats.

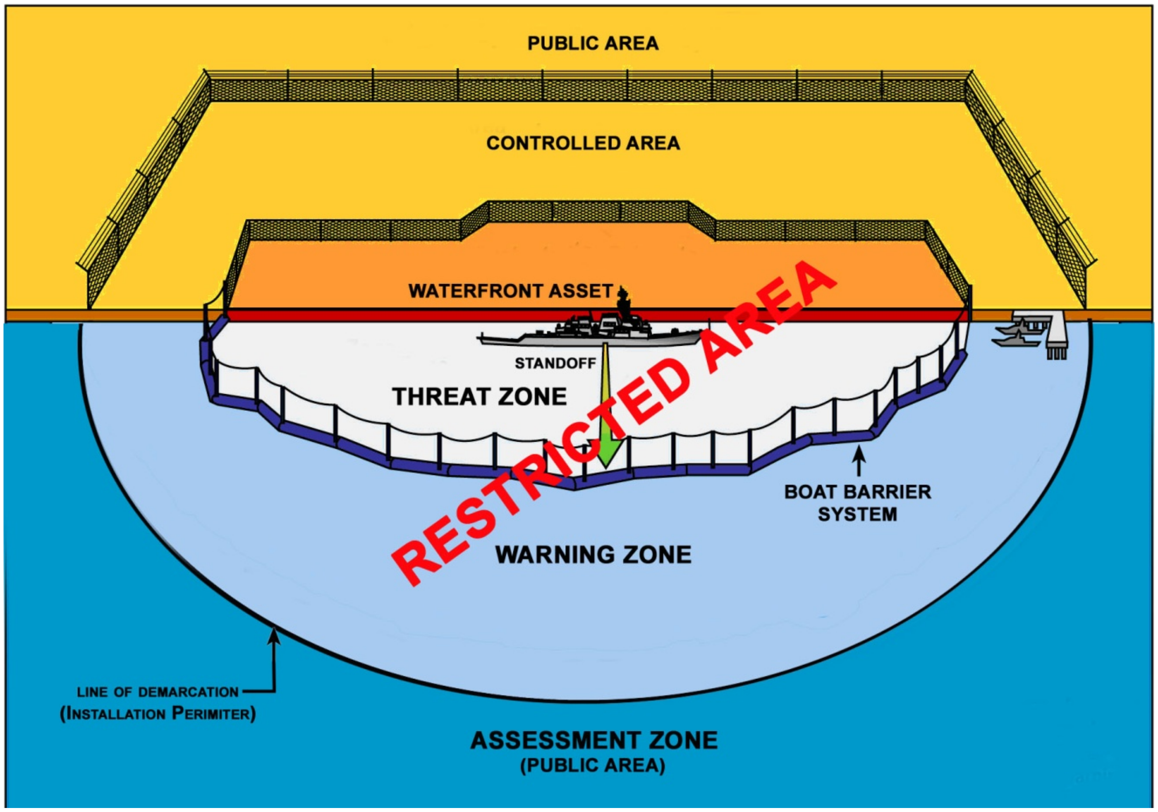
5-2.1 General Design Strategy.

Prevent waterfront attack by creating standoff and applying the defense in depth concept. Establish security zones with barriers, electronic harbor security systems (EHSS), and operational procedures from the high water mark to the waterside, installation perimeter. The security zones are defined as follows:

- **Waterside Assessment Zone:** An area beyond the DoD's property line from where surface and subsurface threats approaching the waterside warning zone may be detected, monitored, and tracked.
- **Waterside Warning Zone:** The area just outside the Threat Zone and within the waterside installation perimeter. In some locations a large warning zone is not feasible due to channel constraints.
- **Waterside Threat Zone:** The area between a line of floating barriers and an asset.

The Threat and Warning zones are determined by the Installation Commander.

Figure 5-1 Waterside Security Zones



Note: Restricted Area may extend out to the installation perimeter at some locations.

5-3 WATERSIDE STANDOFF.

Establish waterside standoff based on DBT. Ideally, this standoff distance extends from the protected assets to the maximum range of anticipated DBT (25 meters for small explosives to several thousand meters for portable anti-tank weapons). Security forces should endeavor to prevent the entry of surface and subsurface threats into the waterside standoff.

5-4 PERIMETER.

Establishing a perimeter is an important protective measure meant to deter and prevent unauthorized personnel from entering a DoD installation.

5-4.1 Waterside Perimeter.

Delineate the waterside perimeter by issuing a notice to mariners and with floating signage, signs on piles or other lines of demarcation to prevent innocent vessels from entering the Warning Zone. Methods of demarcation depend on the waterfront geography and the relation between installation and the navigational channel.

5-4.2 Waterside Restricted Area.

This is the designated restricted area in which special measures are employed to prevent unauthorized entry. The waterside restricted area may be the waterside perimeter or an enclave within that perimeter (Threat Zone). Identify waterside restricted area(s) with buoys and signs. Consider using a floating line of demarcation (LOD) to identify the waterside restricted area.

5-4.3 Line of demarcation (LOD).

A LOD is a system used to identify restricted waters, standoff distance, or an installation's waterside perimeter. It must be clearly visible to vessel operators in most weather conditions and be interspersed with signage indicating access control measures. LOD may be located at the perimeter of the Threat or Warning Zone. Coordinate location and requirement on floating LOD with installation. Figure 5-1 illustrates basic floating LOD.

5-4.4 Boat Barrier System.

A boat barrier system is a continuous, modular LOD intended to stop and/or delay waterborne threats. When required by DOD, GCC, or Service Instruction, provide boat barriers at the Threat Zone perimeter to prevent direct unchallenged access to waterfront assets. The boat barrier system's capability and configuration will depend upon the assets to be protected, DBT, port configuration, operations tempo, environmental constraints, and response capability. Attempting to cross a boat barrier establishes intent and provides time for security forces to arrive and escort the threat out of the area. Many DoD controlled waterfronts do not allow comprehensive waterside security layering due to proximity of waterfront restricted area to shipping channels. Therefore, the delay time afforded by the barrier system should be synchronized with other physical security system capabilities to ensure a comprehensive security. Figure 5-2 illustrates a boat barrier system. For more information on boat barrier systems and related products contact:

Waterfront Security Manager
Naval Facilities Engineering Service Center, Code 55
720 Kennon St SE Suite 333
Washington Navy Yard DC 20374-5063

Figure 5-1 Floating Line of Demarcation

Figure 5-2 Boat Barrier System (Port Security Barrier)

5-5 GUARD TOWERS.

Guard towers provide an elevated protected position to facilitate surveillance, assessment, and response to waterside threats. This position may be fixed or temporary/portable. Guard towers are not required at all locations. When required, there should be enough guard towers on the waterfront to ensure complete overlapping coverage of the protected area. Coverage should be such that the elimination of one guard tower does not preclude complete coverage.

Manning of the watch position will be in accordance with the installation physical security and AT plans. Locate and set the elevation of the guard tower to enhance the ability of security personnel to observe and assess threats, initiate alarms, coordinate response, and attack with force, if necessary and authorized. Coordinate the number and location guard towers with security personnel, waterfront operations, and EHSS infrastructure. Ensure towers have proper line of sight, are suitable for port operations, account for variations in port loading, and are suitable for port operations. In most cases, locate the guard tower at or near the end of the pier (head) to maximize visibility of the waterside restricted area. Provide 360-degree visibility from the interior of the guard tower and an open observation deck with overhang to facilitate assessment and engagement of threat, maintenance of watch position glazing, and access to roof mounted equipment. Size the overhang to reduce glare on glazing and provide cover from the elements for security personnel. Refer to UFC 4-023-02 for ballistic design and other requirements. See Figure 5-3 for an example of a guard tower at the head of a pier.

5-5.1 Communication and Information Technology.

Each guard tower should have at least two means of communication to a central monitoring point, e.g. installation emergency control center, central dispatch, or similar designated location. Coordinate the communication requirements with the installation. Provide a minimum of two 1 inch (2.54 cm) empty conduit raceways from the watch position to the roof to facilitate future roof mounted communication equipment.

5-5.2 Central Duress Alarm.

Provide a central duress alarm, which signals other guard towers and the central monitor point. Provide an enunciator in the guard tower to alert security personnel of alarm triggered at any other waterfront guard facility or towers.

5-5.3 Guard Tower Lighting.

Lighting inside the guard towers must not degrade security personnel’s nighttime vision. All luminaires must be dimmable and should be mounted at or near desk level. Switch task and general lighting separately. When colors are not used to distinguished tasks (colored lights or controls for alarm annunciations), consider red light sources for task lighting to reduce adaptation problems. A manually operated roof mounted searchlight may be required to assist security personnel to locate and assess waterside threats. Lighting controls must be under the direct control of security personnel.

Figure 5-3 Guard Tower on Pier

5-6 WATERFRONT SECURITY LIGHTING.

Provide full cut-off or fully shielded fixtures to limit glare. In general, high mast lighting provided for waterfront operations supply adequate illuminance for security requirements. Coordinate number, height, and location of poles and the associated concrete pedestals to minimize obstructions to pier and wharf operations. Refer to UFC 4-152-01 for Pier and Wharf operational lighting requirements and UFC 3-530-01 for lighting design criteria. Additional lighting (fully shielded or full cutoff) may be required on guard tower (below observation deck) to illuminate egress and the area on the opposite side from high mast lighting. Coordinate security lighting requirements with security personnel.

5-6.1 Water surface Lighting.

High mast lighting on piers and wharfs provide adequate illumination for security requirements. Glare, poor distribution, and excessive light levels reduce security personnel's ability to assess surface and subsurface threats.

5-6.2 Underwater Lighting.

Underwater lighting is not normally required for detection of subsurface threats and is discouraged due to limited benefit, high installation cost, and maintenance issues.

5-6.3 Under deck Lighting.

Dedicated luminaires located beneath the pier are not normally required and are discouraged due to limited benefit, high installation cost, and maintenance issues.

5-6.4 Lighting Interference.

Security lighting can visually interfere with lighting used as aids to navigation (ATON) by ships. Lighting ashore can camouflage, outshine, or otherwise conceal ATON. Ensure that lighting ashore and in the waterfront restricted area does not conflict with or otherwise conceal the ATON lights. Coordinate security lighting requirements with Port Operations

5-7 ELECTRONIC HARBOR SECURITY SYSTEMS (EHSS).

EHSS is provided when required by DOD, GCC, or Service Instruction. EHSS integrates electronic sensors and video systems to detect, assess, track, and archive capabilities for waterside surface and subsurface threats. The type of system utilized shall be based on assts to be protected and risk.

The EHSS can be configured to integrate all sensor and video information to provide a graphical display of all threats within waterside security zones to be protected (protected area). The waterside security zones may be programmed to generate alarm conditions dependant on location of threat relative to protected assets. As with all protection measures, the capability and configuration of the EHSS is dependent on the assets to be protected, DBT, port configuration, operations tempo, environmental constraints, and response capability. For more information on related products contact:

Waterside Security Systems
Space and Naval Warfare Systems Center, Code 71742
53560 Hull Street
San Diego, CA 92152-5001

waterside@spawar.navy.mil
(619) 553-5033 voice
(619) 553-6553 fax

5-7.1 Surface Detection and Assessment.

Radar and video equipment are used to detect, track and assess surface threats within the protected area. Radar and video systems should be located based on site specific conditions such as landside and waterside operations, landside and waterside terrain, climate, available power and communications, and technology capabilities. When available, equipment should be roof mounted on the guard towers to provide a solid elevated mounting platform and enclosed space for the related equipment.

5-7.1.1 Radar.

The radar element is the primary means for detecting surface threat. Systems include a radar set, tracking processor, and display. The tracking processor has acquisition zones that can be configured for each site based on local geography, port activity, and the installation’s security protocols. The radar element should utilize multiple radar transponders installed at various locations to provide a complete picture of the protected zone. See Figure 5-4.

5-7.1.2 Identification Friend or Foe (IFF).

This system provides the capability identify “friend” vessels authorized to be in the area and assists in determining bearing and range when vessels are equipped with IFF transponder.

Figure 5-4 Radar Antenna

5-7.1.3 Video Imaging.

The imaging system is a collection of cameras, recorders, switches, keyboards, and monitors that allow assessment and recording of security events. The imaging system is normally integrated into the overall EHSS and monitored at operator workstation. Capabilities of the imaging systems include assessment of alarm conditions, surveillance of the protected area, and archiving of events. The imaging system must have a minimum of 30 days storage capacity. When integrated with video analytics the imaging system can have a detection capability. Refer to UFC 4-021-02NF for the design of imaging systems.

For EHSS, the basic imaging element consists of two cameras. Provide one low light color; pan, tilt, zoom (PTZ) camera for daytime assessment and one PTZ night vision camera or imaging device at each location. Multiple technologies must be deployed to ensure adequate coverage of the waterside area. Available technologies include low-light cameras, infrared cameras, thermal imagers, and near infrared laser-camera systems. Table 5-2 provides a summary the various technologies.

Table 5-2 Visual-Imaging Element Technologies

Technology	Range (Nominal)	Light Source	Support	Cost	Advantages	Disadvantages
Low-light camera	Short 100 to 300 yards (90 to 275 m)	Visible light (sunlight, moonlight, artificial light)	Camera power, video cable	$3k to $5k	Low cost Uses available light	Unable to provide coverage in new moon (no moon) and dark or cloudy conditions
Infrared camera (camera with infrared illuminators)	Short 100 to 300 yards (90 to 275 m)	Infrared illuminators	Power for camera and illuminator, video cable Illuminators	$3k to $5k camera $1k per illuminator	100 percent night vision capable Low total cost of ownership	Limited to the range of the associated infrared illuminators Short range
Near-infrared system	Medium 1,000 to 3,000 yards 900 to 2700 m)	Near-infrared laser	Composite system of laser and camera	$50k to $90k	No interference from heat and visible light Natural-contrast night image	Performs best as synchronized system
Thermal camera (uncooled)	Long 1,000 to 5,000 yards (900 to 4500 m) (height of eye)	Heat energy emitted from object/scene	Camera power Internal temperature-adjusting controls	$7k to $20k	Autonomous system; does not require visible light or supporting illumination system	Non-natural image Requires trained operator to interpret thermal images
Thermal camera (cooled)	Long 1,000 to 10,000 yards (900 to 9000 m) (height of eye)	Heat energy emitted from object/scene	Camera power Internal refrigerant system	$100k plus	Highest detection sensitivity Autonomous system	High cost Periodic maintenance of coolant system Non-natural image

5-7.2 Subsurface Detection and Assessment.

The subsurface element detects an underwater threat. Current designs make use of underwater soundheads connected to signal processors for eventual display. Ensure proper EV permitting has been obtained to ensure conformance with the “Marine Mammal Protection Act (MMPA).

5-7.2.1 Sonar.

The sonar transponders are the primary means for detecting subsurface targets. Submerged non-visual elements include the use of sonar transponders installed at various underwater locations feeding their inputs to a central display (operator workstation). The soundhead can be bottom-mounted, side-mounted, or moored, See Figure 5-5. The sonar track processor evaluates contacts and assigns tracks to those exceeding preset levels. The use of multiple transponders helps eliminate holes and shadows in the non-visual submerged surveillance picture. Locate the devices so that they are not shrouded by berthed ships, and provide adequate coverage of the underwater approaches. Poorly placed devices can create hazards to shipping, interfere with dredging operations and can be difficult to maintain. An environmental assessment must be completed prior to the deployment of any sonar transponders.

Figure 5-5 Sound Transducer Being Lowered into the Water

5-7.3 Command, Control, Communication and Display (C3D).

The C3D element provides a situational display of the waterside. Multiple displays provide an overview of the waterside and include display of EHSS subsystem elements for surface and subsurface detection, assessment, and tracking.

5-7.4 Infrastructure.

Infrastructure includes the permanent facilities necessary to support the EHSS including mounting structures, power, communication cabling (connectivity), pathways, and space for workstations and rack mounted equipment.

Vehicles including forklifts and container carriers operate in all areas of a pier. Electrical gear located on pier decks have suffered casualty due to forklift tines and crane hooks. Minimize equipment mounted on the operational pier deck. Any deck mounted equipment must be approved by the Port Ops Officer.

5-7.4.1 Location.

For double deck piers, the generator and electronic equipment enclosure shall be located to the lower deck, within the guard tower, or located on the offshore side of the guard tower to minimize the total footprint, and enable the guard tower walls to be used for mounting the conduit system.

Do not mount equipment or conduits near cleats or bollards. Crews must haul mooring lines past these deck fittings in order to secure the ship. Equipment located in close proximity to these deck fittings create safety hazards for the crew and is subject to damage by the lines.

5-7.4.2 Space.

Space must be reserved in multiple locations to support the equipment and operation of the EHSS. This includes locations such as guard towers, piers, wharfs, and a central monitoring location.

5-7.4.3 Guard Towers.

Provide space for roof mounted equipment and weather tight pathways from the roof to the sensor equipment cabinet for associated communication and power cabling, See Figure 5-6. Provide a minimum of two 2 inch (50 mm) conduit per element (imaging, radar, and/or sonar) from sensor equipment cabinet to element location.

Provide space for a 19 inch (48 cm) telecommunications cabinet (sensor equipment cabinet) sized for the associated EHSS equipment. Consider providing space on first floor of guard tower for EHSS generator and controls. If the generator is located in guard tower, provide ventilation, vibration, an acoustic isolation from guard position.

Figure 5-6 Roof Mounted Equipment

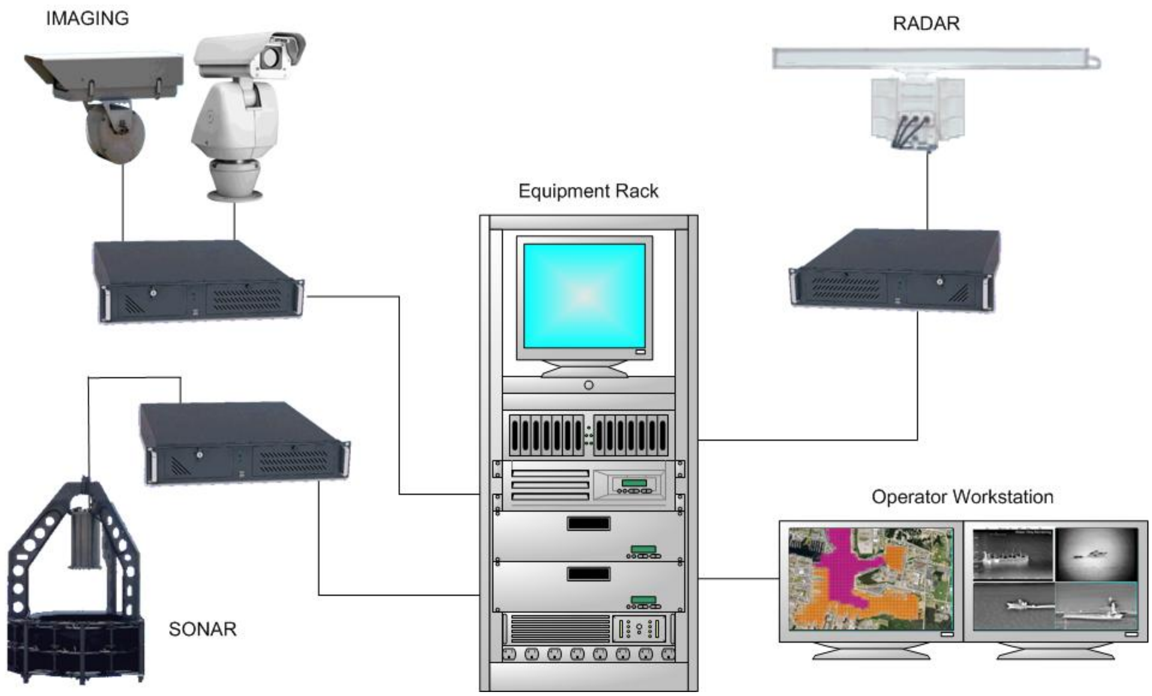
5-7.4.4 Piers and Wharfs.

Provide a dry location for a sensor equipment cabinet (19 inch (48 cm) telecommunications cabinet) sized for the EHSS equipment deployed. The preferred location is directly underneath or adjacent to the surface detection and assessment equipment mounting structure.

5-7.4.5 Central Monitoring Location.

Provide space for a full height freestanding 19 inch (48 cm) telecommunications cabinet, operator workstation, and multiple displays. Provide space, connectivity, and power receptacles for operator workstation including multiple desktop displays. Provide wall space, connectivity, and power receptacles for EHSS multiple large format flat panel displays EHSS subsystems monitoring. Reserve additional wall space for nautical chart displays. See Figure 5-7 for a notional configuration of the equipment associated with an EHSS.

Figure 5-7 EHSS Configuration



5-7.4.6 Backup Power.

EHSS systems require a backup generator. The supporting generator is normally located pierside in a weather-protected location or enclosure. Reserve a minimum of 8 foot 6 inch (259 cm) space x 3 foot 6 inch (107 cm) space for generator and associated controls. Coordinate actual space requirements with equipment provider. Do not locate generators on the upper (operational) deck of a double deck pier unless they are located on the offshore side of the guard tower.

5-7.4.7 Conduit Infrastructure.

Coordinate conduit requirements with equipment provider. At a minimum, provide one conduit per element (imaging, radar, and/or sonar) from sensor equipment cabinet to element location.

5-7.4.8 Communication and Information Technology.

Connectivity is required from each sensor equipment cabinet to the central monitoring location. Provide a minimum of one 12-strand, single mode, optical fiber cable from sensor equipment cabinet to the central monitoring station. Coordinate point of service with installation.

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APPENDIX A REFERENCES

GOVERNMENT PUBLICATIONS

ABA Accessibility Standard for Department of Defense Facilities, http://www.access-board.gov/ada-aba/aba-standards-dod.cfm

DEPARTMENT OF DEFENSE *http://www.dtic.mil/whs/directives/*
DOD 5200.8-R *Physical Security Program*

DODD 2000.12 *DOD Antiterrorism (AT) Program*

DODI 2000.16 DOD *Antiterrorism (AT) Standards*

DOD O-2000.12-H *Antiterrorism Handbook (FOUO)*

DEPARTMENT OF THE NAVY

OPNAVINST 5530.14 *Navy Physical Security and Law Enforcement Program* *http://www.fas.org/irp/doddir/navy/opnavinst/*

NTTP 3-07.2.3 *Navy Tactics, Techniques, and Procedures Law Enforcement and Physical Security*

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

UFC 3-530-01 *Design: Interior and Exterior Lighting and Controls*

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

UFC 4-010-02 *DoD Minimum Antiterrorism Standoff Distances for Buildings (FOUO)*

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

UFC 4-020-02 *DoD Security Engineering Facilities Design Manual*, currently in Draft and unavailable

UFC 4-021-02NF Security Engineering Electronic Security Systems

UFC 4-022-01 *Security Engineering: Entry Control Facilities / Access Control Points*

UFC 4-022-02 *Design and Selection and Application of Vehicle Barriers*

UFC 4-023-02 S*ecurity Engineering: Fences, Gates and Guard Facilities*, currently in Draft and unavailable. Utilize MIL-HDBK 1013/10 *Design Guidelines for Security Fencing, Gates, Barriers, and Guard Facilities* until UFC is published. (http://www.wbdg.org/ccb/NAVFAC/DMMHNAV/1013_10.pdf)

UFC 4-152-01 *Design: Piers and Wharves*

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APPENDIX B GLOSSARY

ACRONYMS

ACP	Access Control Point
AT	Antiterrorism
ATON	Aids to Navigation
CCTV	Closed Circuit Television
DBT	Design Basis Threat
EHSS	Electronic Harbor Security System
ESS	Electronic Security System
ESSC	Electronic Security System Console
FP	Force Protection
FPCON	Force Protection Condition
GCC	Geographic Combatant Commander
IDS	Intrusion Detection System
LOD	Line of Demarcation
LOP	Level of Protection
RAM	Random Antiterrorism Measures

DEFINITION OF TERMS

Controlled Area. A space extending upward and outward from a specified point. This area is typically designated by a commander or director, wherein sensitive information or operations occur and requires limitations of access.

Design basis threat (DBT) The threat against which an asset must be protected and upon which the protective system's design is based. It is the baseline type and size of threat that buildings or other structures are designed to withstand. The DBT includes the tactics aggressors will use against the asset and the tools, weapons, and explosives employed in these tactics.

Dispatch Center. The space that serves as a central monitoring and assessment facility for the ACS, CCTV, and IDS systems. The key components of a Dispatch Center include consoles, monitors, and printers. Normally, the Dispatch Center is staffed 24 hours a day, seven days a week by trained personnel. Other names for the Dispatch Center include Regional Dispatch Center (RDC), Security Operations Center (SOC), Security Command Center and Security Control Center (SCC), Central Monitoring Station, Data Transmission Center (DTC), and Alarm Control Center (ATC).

Electronic Harbor Security System (EHSS). An electronic system that integrates surface detection, subsurface detection, and video systems to detect, assess, track, and archive waterside threats.

Electronic Security System (ESS). The integrated electronic system that encompasses interior and exterior Intrusion Detection Systems (IDS), Closed Circuit Television (CCTV) systems for assessment of alarm conditions, Automated Access Control Systems (ACS), Data Transmission Media (DTM), and alarm reporting systems for monitoring, control, and display.

Electronic Security System Console (ESSC). While not always specifically referred to as the ESSC, most security systems have a console that houses monitoring and server interface equipment. Generally, this console is located in the Dispatch Center.

Foot of pier. The landside end of the pier

Force Protection (FP). Actions taken to prevent or mitigate hostile actions against DoD personnel (including family members), resources, facilities, and critical information.

Force Protection Condition (FPCON). A DoD-approved system standardizing the Department's identification, recommended preventive actions, and responses to terrorist threats against U.S. personnel and facilities.

Head of pier. The waterside end of the pier sometimes referred to as the pier head.

Installations. Real DoD properties including bases, stations, forts (including National Guard and Federal Reserve Centers), depots, arsenals, plants (both contractor and Government operated), hospitals, terminals, and other special mission facilities, used primarily for military purposes.

Level of protection. The degree to which an asset is protected against compromise.

Physical Security. That part of security concerned with physical measures designed to safeguard personnel; to prevent unauthorized access to equipment, installations, material, and documents; and to safeguard them against espionage, sabotage, damage, and theft.

Ports of Call. A port not located on a DoD installation where ships dock in the course of deployment to load or unload cargo, obtain supplies, liberty, or undergo repairs.

Restricted Area. An area under military jurisdiction in which special security measures are employed to prevent unauthorized entry.

Waterside Security. Measures or actions taken to prevent or guard against the use of a waterside approach to a waterfront facility or vessel by persons or vessels intent on theft, sabotage, terrorism, and/or belligerent acts

UFC 4-026-01
4 March 2020

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN TO RESIST FORCED ENTRY

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN TO RESIST FORCED ENTRY

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

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

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

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 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 Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. 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 web site http://www.wbdg.org/ffc/dod.

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

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UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

Document: UFC 4-026-01, *Design to Resist Forced Entry*

Superseding: MIL-HDBK-1013/1A, *Design Guidelines for Physical Security of Facilities,* dated 15 December 1993.

Description: Provide a unified approach to the development of protective measures intended to protected assets from a forced entry attack.

Reasons for Document:

- This document is one of a series of security engineering criteria documents covering physical countermeasures for the current threat environment.
- The design of physical security measures is a specialized technical area that does not fall in the normal skill record and resume of commanders, architects, engineers, and project managers. This document provides guidance to those parties tasked with implementing existing and emerging physical protection system requirements for assets.

Impact:

- No additional cost impacts are anticipated by the publication of this document. This document should reduce the design and coordination efforts for design of systems that protect against forced entry.

Unification Issues

There are no unification issues.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

1-1.1 Purpose.

The purpose of this document is to present engineering guidelines and cost-effective designs to protect assets in fixed facilities against a forced entry and providing egress in compliance with NFPA 101.

1-1.2 Scope.

Project leaders, architects, and engineers must use this UFC when designing facilities to resist aggressor forced entry. Technical information considered generally known to professional designers, architects, or engineers or readily available in existing technical references has not been included.

Designs to resist forced entry must be based on protecting specific assets, the applicable asset values, threat severity, and level of protection, which will be provided to designers as part of the design criteria developed during the security engineering planning and preliminary design phases.

1-2 APPLICABILITY.

This document provides design requirements for only fixed facilities that require forced entry threat mitigation. This UFC applies to all facilities either owned, leased, privatized, or otherwise occupied, managed, or controlled by or for DoD containing assets that required force entry protection pursuant to DOD policy.

1-3 SECURITY ENGINEERING UFC SERIES.

This UFC is one of a series of security engineering unified facilities criteria documents that cover minimum standards, planning, preliminary design, and detailed design for security and antiterrorism. Figure 1-1 illustrates the process from initial planning to the development of facility design requirements. The manuals in this series are designed to be used sequentially by a diverse audience to facilitate development of projects throughout the design cycle. The manuals in this series include the following:

1-3.1 DoD Minimum Antiterrorism Standards for Buildings.

UFC 4-010-01 establishes standards that provide minimum protection against terrorist attacks for the occupants of all DoD inhabited buildings. This UFC is intended to be used by security and antiterrorism personnel and design teams to identify the minimum requirements that must be incorporated into the design of all new construction and major renovations of inhabited DoD buildings. It also includes recommendations that should be but are not required to be incorporated into all such buildings.

1-3.2 DoD Security Engineering Facilities Planning Manual.

UFC 4-020-01 presents processes for developing the design criteria necessary to incorporate security and antiterrorism into DoD facilities and for identifying the cost implications of applying those design criteria. Those design criteria may be limited to the requirements of the minimum standards, or they may include protection of assets other than those addressed in the minimum standards (people), aggressor tactics that are not addressed in the minimum standards or levels of protection beyond those required by the minimum standards. The cost implications for security and antiterrorism are addressed as cost increases over conventional construction for common construction types. The changes in construction represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria. The manual also addresses the tradeoffs between cost and risk. The Security Engineering Facilities Planning Manual is intended to be used by planners as well as security and antiterrorism personnel with support from planning team members.

1-3.3 DoD Security Engineering Facilities Design Manual.

UFC 4-020-02 provides interdisciplinary design guidance for developing preliminary systems of protective measures to implement the design criteria established using UFC 4-020-01. Those protective measures include building and site elements, equipment, and the supporting manpower and procedures necessary to make them all work as a system. The information in UFC 4-020-02 is in sufficient detail to support concept level project development, and as such can provide a good basis for a more detailed design. The manual also provides a process for assessing the impact of protective measures on risk. The primary audience for the Security Engineering Design Manual is the design team, but it can also be used by security and antiterrorism personnel.

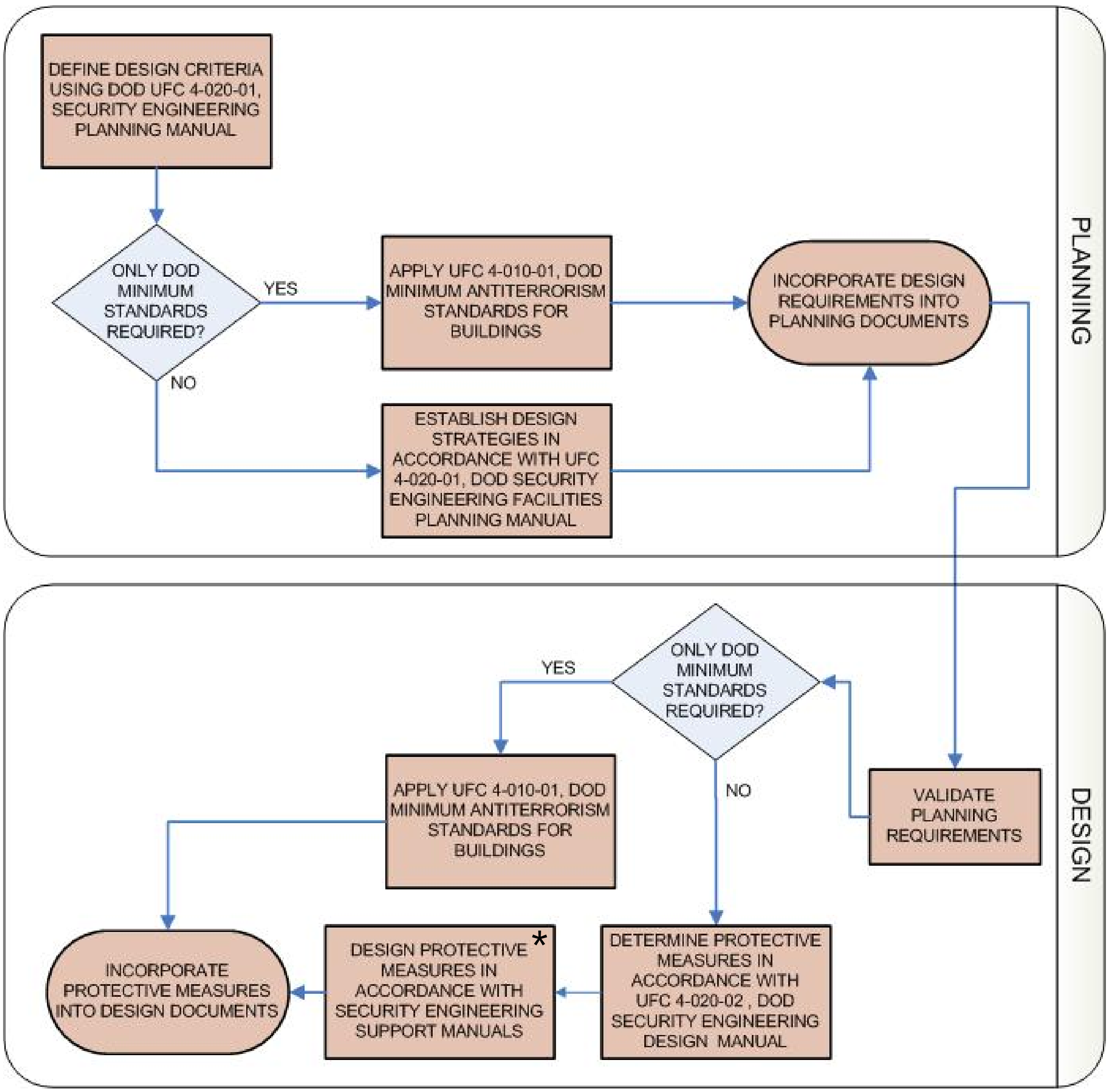
1-3.4 Security Engineering Support Manuals.

In addition to the standards, planning, and design UFCs mentioned above, there is a series of additional UFCs that provide detailed design guidance for developing final designs based on the preliminary designs developed using UFC 4-020-02. These support manuals provide specialized, discipline specific design guidance. Some address specific tactics such as direct fire weapons, vehicle borne improvised explosive devices, or airborne contamination. Others address limited aspects of design such as resistance to progressive collapse or design of portions of buildings such as mail rooms. Still others address details of designs for specific protective measures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended to be used by the design team during the development of final design packages.

1-3.5 Security Engineering UFC Application.

The application of the security engineering series of UFCs is illustrated in Figure 1-1. UFC 4-020-01 is intended to be the starting point for any project that is likely to have security or antiterrorism requirements. By beginning with UFC 4-020-01, the design criteria will be developed that establishes which of the other UFCs in the series will need to be applied. The design criteria may indicate that only the minimum standards need to be incorporated, or it may include additional requirements, resulting in the need for application of additional UFCs. Applying this series of UFCs in the manner illustrated in Figure 1-1 will result in the most efficient use of resources for protecting assets against security and antiterrorism related threats.

Figure 1-1 Security Engineering UFC Application



* **NOTE: UFC 4-026-01 is one of the Security Engineering Support Manuals.**

1-4 VULNERABILITY AND RISK ASSESSMENT.

During the pre-design phase of forced entry upgrade projects for existing facilities, a multi-functional security and antiterrorism planning team conducts a vulnerability assessment and develops risk mitigating protection requirements to a level that is both acceptable and cost effective. This document presumes risk analyses are complete prior to beginning the design phase.

For new forced entry projects, a criteria development analysis which addresses risk versus cost is conducted as part of the UFC 4-020-01 planning process.

1-5 PRESCRIPTIVE VS. RISK-BASED DESIGN REQUIREMENTS.

Dynamic conditions drive both vulnerability and risk assessments. Changes in forced entry tactics, technology, and tools of the trade affect residual risk levels. This document and other documents in the UFC series are designed to provide a method of balancing protection, budget, and risk.

The design to resist forced entry may be based on both prescriptive and risk-based requirements that together provide a solution to mitigate risk to an acceptable level.

1-5.1 Prescriptive Design Requirements.

The design for the protection of some assets may require the application of prescriptive measures contained in, or derived from, other non-UFC government regulations. For example, DoDM 5100.76 *Physical Security of Sensitive Conventional Arms, Ammunition, and Explosives (AA&E)* contains prescriptive requirements for facility design where arms, ammunition, or explosives are stored. Additionally, UFC 4-010-05 *Sensitive Compartmented Information Facilities Planning, Design, and Construction* contains design criteria for the construction of facilities to protect Sensitive Compartmented Information that is derived from DODM 5105.21, Vol 2, *Sensitive Compartmented Information (SCI) Administrative Security Manual: Administration of Physical Security, Visitor Control, and Technical Security;* and from the IC Tech Spec for ICD/ICS 705, *Technical Specifications for Construction and Management of Sensitive Compartmented Information Facilities.* (See CHAPTER 6 for further information on Protected Areas.)

1-5.2 Risk-Based Requirements.

Risk-based requirements are developed during the planning phase of the project using the procedures in UFC 4-020-01 and become a part of the project design criteria. When conditions subsequently change the risk level, designers should revisit the design criteria for methods to change or augment how protection is achieved. Not all solutions are sustainable or durable, but those based on current conditions can provide acceptable interventions for a shorter period. At end state, assessments reflect current conditions and protection is achieved at an acceptable risk level.

1-6 GENERAL BUILDING REQUIREMENTS.

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

1-7 CYBERSECURITY.

All control systems (including systems separate from an energy management 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.

1-8 HISTORIC PRESERVATION COMPLIANCE.

1-8.1 Security and Stewardship.

The Department of Defense remains the lead federal agency in balancing security threats with the protection of historic properties. The Department of Defense abides by federal legislation on protecting cultural resources and issues its own complementary policies for stewardship.

1-8.2 Compliance with Laws.

Implementation of these standards will not supersede DoD’s obligation to comply with federal laws regarding cultural resources to include the National Historic Preservation Act and the Archaeological Resources Protection Act. Installation personnel must determine possible adverse effects to historic structures and archaeological resources during project development and consult accordingly. Personnel at installations outside the United States should coordinate with the applicable host nation regarding possible adverse effects to cultural resources.

1-8.3 Compliance with DoD Standards.

Conversely, historic preservation compliance does not negate the requirement to implement other Department of Defense policy. Federal agencies are always the decision-maker in the Section 106 process of the National Historic Preservation Act. An agency should seek to avoid prolonged consultations that conflict with the imminent need to implement security requirements. Preservation considerations and antiterrorism standards are not mutually exclusive, and any compliance conflicts should be quickly and effectively resolved in consultation with appropriate stakeholders.

1-9 GLOSSARY.

APPENDIX A contains acronyms, abbreviations, and terms.

1-10 REFERENCES.

APPENDIX B 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.

CHAPTER 2 DESIGN CRITERIA

2-1 INTRODUCTION.

This chapter describes the forced entry tactic and the design criteria to be used to develop a protective system to address that threat.

2-2 FORCED ENTRY TACTIC.

Forced Entry is a tactic whereby aggressors penetrate a facility through the application of tools, explosives and small arms; then, generate a passageway to operate within the target. Aggressors steal or destroy assets, compromise information, injure or kill occupants, or disrupt operations. Access passageways include walls, roofs, floors, ceilings, doors, windows, and utility portals.

2-2.1 Tools and Effects.

Forced entry tools include hand, power, and thermal tools and explosives that can be carried by one or two aggressors. Categories of forced entry tools are based on levels of sophistication, required skills and risk of detection (observability). Refer to UFC 4-020-01 for the maximum tools and explosives that each threat severity level is projected to employ. When one threat severity level is contained in the design criteria, the threat also includes the tools in all lower threat severity levels. For the purposes of this UFC, weapons are not a tool to breach construction. They are potentially used to overpower guards. (See Table 2-1 for the tools that the aggressor can use for each threat severity level.)

Table 2-1 Forced Entry Tool Sets

<table>
<tr><th>THREAT SEVERITY LEVEL</th><th>WEAPONS</th><th>TOOLS</th></tr>
<tr><td>V</td><td rowspan="2">Handguns and sub-machine guns (up to UL 752 Level 3 to overpower guards)</td><td>Bulk explosives (up to 20 lbs. /9 kg TNT); linear shaped charges (up to 10,500 grains per foot); unlimited hand, power, and thermal tools</td></tr>
<tr><td>IV</td><td>Unlimited hand, power, and thermal tools</td></tr>
<tr><td>III</td><td rowspan="2">None</td><td>Unlimited hand tools - limited power tools</td></tr>
<tr><td>II</td><td>Limited hand tools - low observables</td></tr>
</table>

NOTE: For convenience, this table has been derived from information contained in UFC 4-020-01. Information in the current version of that document takes precedence over information in this table.

2-2.2 Employment of Tools.

Forced entry can involve a combination of tools used by different group sizes for varying lengths of time. Six is the maximum number of attackers able to work together effectively when concentrated on a single opening. The high number of possible combinations of factors makes it impossible to completely predict the actual effects of a forced entry attack. Forced entry attacks must be simulated by laboratories experienced in forced entry testing to predict the resistance of specific construction components and assemblies; therefore, the effects of forced entry tool attacks are discussed not in terms of loads on building components, but in terms of the predictable effects of various individual tools.

2-2.3 Hand Tools.

Hand tools include commonly available hand-held tools requiring only manual manipulation and human strength as sources of power. These tools are used for prying, screwing, pulling, shearing, pounding, cutting, sawing, drilling, and wedging. Hand tool effects include disassembly, breaking, deformation, notching, shaving, puncturing, moving, or spalling of components and the removal of fasteners or debris. Hand tools are used for attacks in which the aggressor manipulates either an operable component (prying open a locked door) or stationary components at their intersection or seams (popping metal wall panels away from their anchors). Attacks using hand tools generate relatively less noise than powered tools, but the motion of the aggressor and vibration of the building materials, as well as the noise, might all be detectable. Hand tools can be used to create holes in lighter weight components, such as by breaking glass with a hammer or by smashing plywood or concrete block assemblies with a sledgehammer. Hand tools can also be used in combination with other tools. For example, a bolt cutter can sever steel reinforcing bars after the encasing concrete has been demolished with explosives, or wrecking bars can be used to remove materials crushed but not displaced by more sophisticated tools.

- Limited hand tools carry a low observation profile when employed due to the noise associated with using them and include claw hooks, carpenter saws, hacksaws, bolt cutters, pliers, spanner wrenches, tin snips, and wire cutters. Limited hand tools are readily available and require little skill.
- Unlimited hand tools carry a high observation profile when employed. These include, but are not limited to Kelly tools, Halligan bars, sledgehammers, cutting mauls, shovels, and axes. These tools are less common than limited hand tools and are normally part of a firefighter equipment kit.

2-2.4 Power Tools.

Power tools include electrically powered or gasoline fueled cutting and drilling tools; portable power impact tools; and hydraulic cutting, ramming, and spreading tools. Effects of power tools are breaking (including cutting of anchors and fasteners), deformation, material weakening, notching, spalling, and removal of debris. Attacks using power tools generate detectable evidence during the actual attack that includes noise, motion, vibration of the construction assembly, smoke, heat, dust, and debris. Because these tools require fuel or a power source such as a battery, they are heavier and more awkward to transport than most hand tools. Many power tools also require adequate space in which to effectively manipulate the tools. Aggressors might use power tools to sever the anchors of components, to cut locks or closing devices, or to cut or pry openings through construction materials. Power tools can be used in combination with other tools. For example, a saw might be used to cut through a concrete wall and then a ramming device can be used to displace the severed material to create an opening.

- Limited power tools operate from a self-contained power source like batteries and hydraulics. The hydraulic jack is a self-contained manually operated spreading device that works quietly.
- Unlimited power tools operate from external electric, gasoline, hydraulic pump, or compressed air power sources.

2-2.5 Thermal Tools.

Thermal tools generate flames capable of burning through steel and concrete. They include thermal cutting devices such as an oxyacetylene torch, oxygen-fueled devices such as the Kerie Cable, and the burn bar (thermal lance). Oxygen-fueled cutting devices are used to swiftly cut openings in materials, including reinforced concrete or masonry. Effects of thermal tools include material weakening, breaking, burning, cutting, and melting. Different effects are obtained depending upon the composition of the materials attacked. For example, fiberglass might melt or deform, glass might shatter due to thermal stresses, and flame-resistant materials might resist actual destruction, but the fumes or smoke produced can inhibit further efforts to destroy the assembly. Materials likely to yield to thermal attack, such as wood or plywood assemblies, might resist oxygen-fueled cutting tools longer than other assemblies. Detectable evidence yielded by thermal tools during attacks includes heat, smoke, and light. Some of these tools require oxygen and acetylene fuel tanks, which contributes to the total weight of the tool kit, and they require adequate space and ventilation. In some instances, aggressors would need to use protective safety clothing or other gear to execute an attack with these tools.

2-2.6 Explosives.

Explosives are used as forced entry tools to breach obstacles. Explosive tools include linear shape charges (LSC) and untamped and tamped breaching charges. Refer to UFC 4-020-01 for limits imposed on explosives used as forced entry tools. LSC focus energy from the explosion directly underneath the strip. The practice of backing up a charge with mass to direct the explosive effect is tamping the charge.

Explosive weights are expressed as weights that have the equivalent explosive effect as the expressed weight of trinitrotoluene (TNT). The actual explosive compound may be but is unlikely to actually be TNT.

2-2.6.1 Linear Shaped Charges.

An LSC consists of a copper v-shaped liner embedded in a similarly shaped high-explosives charge. The purpose of an LSC is to sever material. Upon detonation of the explosives, the liner collapses and a high-velocity metallic linear jet is formed. Because of its high kinetic energy, the jet can cut through materials upon impact. Typically, four lengths of LSC are placed in a picture frame arrangement on the element to be breached. Commercially available LSC have explosive weights ranging from 100 to 30,000 grains of TNT per linear foot of charge.

2-2.6.1.1 Homogeneous Materials.

Experimental data shows that the thickness of mild steel that can be severed by an LSC can be reasonably estimated by using Equation 2-1.

Equation 2-1. LSC Delay Calculation Based on Weight of Explosives

$$t = 0.027 * W^{0.547}$$

Where:
t = the thickness in inches of mild steel that can be severed by a given charge weight.
W = the weight of explosives charge in grains per foot (gpf) (linear).

To obtain the severance capability of a linear shape charge against material other than mild steel, multiply the result of Equation 2-1 by the appropriate factor from Table 2-2. The thickness given by Equation 2-1 is the limit for complete severance. If a section is only slightly thicker than the thickness given by the equation and modification factors, it can probably be severed with only minimal effort using hand tools. Because the LSC is a very debilitating tool, it is in the threat severity level V tool kit. When combined with the other tools at this severity level, custom components or materials may need to be developed and tested for the project. Example: Applying the formula to the 10,500 gpf design charge results in a 4.3-inch (109-mm) severance capability for mild steel.

Table 2-2 Mild Steel Severance Factors for Various Materials

MATERIAL	FACTOR
Mild Steel	1.00
Lead	0.67
Steel Armor	0.80
Granite	1.20
Aluminum	1.40
Rock	1.40
Concrete	1.60
Water	2.24
Green Wood	2.88
Earth	4.80
Kiln-Dried White Oak (12% moisture)	5.36

2-2.6.1.2 Composite Construction.

The adequacy of an assembly made of layers of different materials can be determined by converting the thickness of each layer to an equivalent thickness of mild steel. Divide the actual thickness of each material by the appropriate factor from Table 2-2 and sum the results for all materials in the assembly. This total equivalent mild steel thickness is then compared to the result of Equation 2-1 for the given charge weight to determine the adequacy of the composite element.

2-2.6.2 Breaching Charges.

A breaching charge is an explosive placed in direct contact with an element and detonated. The explosive materials used are typically dynamite or plastic explosives such as composition C-4 (U.S.) or Semtex (Czech Republic). Breaching charges are very effective against concrete, masonry, and thin steel elements; however, steel reinforcing bars, if present in concrete or masonry elements, usually remain intact and must be removed with bolt cutters, saws, or thermal tools after the explosion.

Tamped breaching charges are placed on the surface of the target. They are tamped by covering explosives with tightly packed sand, clay, or other dense material.

2-2.6.3 Platter Charges.

Platter charges are not included in this UFC and not identified as a forced entry tool by UFC 4-020-01. A platter charge is a sheet of explosive (either rubberized sheet explosive or a thin sheet of plastic explosive) backed by a plate of copper or steel. When the explosive detonates, the blast wave is largely projected away from the backing plate. If another lighter weight plate or disk is placed on the opposite face of the explosive charge, it will be projected like a missile in the opposite direction.

A platter charge used as a breaching tool may cut and remove most or all the reinforcing material, depending on its configuration. This will minimize the need to cut reinforcing bars with hand, power, or thermal tools after the explosive attack. A platter charge requires more explosives by weight than would be required if a regular explosive charge were used to remove the same mass of concrete. Also, size and weight of the platter, material (copper or steel), size and type of the explosive charge, and the barrier design all play critical roles in how a platter charge will perform against a specific barrier cross section. These factors plus the technical complexity, the possibility of destroying the entire structure or target, and the potential risk to the adversary, makes the use of platter charges for forced entry penetration questionable. Consequently, the following designs in this UFC are based on the use of bulk explosives in combination with hand, power, and thermal tools.

2-3 PROJECT DESIGN CRITERIA.

The project design criteria that was produced by the procedures in UFC 4-020-01 include the assets to be protected, the threat severity level, and the level of protection to be achieved in the final design of the project. These criteria dictate the elements of the protective system that must be provided in the final design.

2-3.1 Assets.

A protective system is designed to protect specific assets within a facility rather than the facility itself. Forced entry assets are those to which the aggressor must gain access for the purpose of stealing, damaging / destroying, or otherwise compromising them; examples include sensitive information, funds, controlled substances, arms, ammunition, and explosives (AA&E). The project design criteria will list the assets to be protected against a forced entry.

2-3.2 Threat Severity Level.

A threat severity level defines the composition of an aggressor team and the tools, weapons, or explosives that the team can potentially use against a facility. Threat severity levels are designated as I, II, III, IV, and V with V being the most severe. Resistance to forced entry does not require protection against threat severity level I. The project design criteria will assign one threat severity level to each asset requiring protection. When the project design criteria contain more than one asset, the facility design can protect all assets at the highest threat severity level; but, protection of each asset at the assigned threat severity level will commonly result in the most cost-effective solution.

2-3.3 Level of Protection.

The level of protection is the degree to which the protective system must defend an asset against the threat severity level. Levels of protection can be designated as very low, low, medium, high, or very high. The higher the level of protection, the lower the risk of asset compromise. The project design criteria specify the level of protection to be provided for each asset. Since the associated cost increases as the level of protection increases, the level of protection must balance risk at a reasonable cost.

Levels of protection for the forced entry tactic relate to the probability that the aggressors will be intercepted by a response force before the assets are compromised. The probability of the intercept is composed of the probability of detecting the aggressors and the probability of the response force arriving in time. The probability of intercept is increased by increasing the number of detection layers, or by increasing the delay time provided by protection measures between the point of detection and the asset. Delay that occurs prior to a detection layer may provide a deterrent to low level aggressors but does little to improve the probability of intercept. The response time that must be met with delay elements varies from the minimum to the maximum expected time depending on the level of protection. Refer to UFC 4-020-01 for the levels of protection for the forced entry tactic. The probability of intercept is also a function of the sophistication and design of the detection system.

2-3.4 Design Constraints.

The project design criteria may include constraints on the protective system design based on the project user’s operational or functional considerations and constraints imposed by regulations.

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CHAPTER 3 DESIGN GUIDANCE TO RESIST FORCED ENTRY

3-1 GENERAL DESIGN STRATEGY.

The general design strategy for the forced entry tactic is to detect aggressors either prior to their reaching barriers or as they attempt to breach them and then to provide sufficient delay to forced entry in the construction of those barriers to allow responding forces to arrive and defeat the aggressors before they can compromise assets. Inherent in this strategy, therefore, is that there is an intrusion detection system that provides an alarm to a monitoring station in response to intrusion and that there is a response force that can respond to an alarm and reach its location before aggressors are able to breach the barriers between that point and the assets being protected.

3-2 SPECIFIC DESIGN STRATEGIES.

The specific design strategies associated with the different levels of protection vary by the amount of delay provided and the sophistication of the intrusion detection. Note that the levels of protection have specific delay times associated with them. Those delay times are generalized goals, but if the planning team is confident that response times are either more or less than those associated with the applicable levels of protection, the applicable delay times may have to be adjusted. All building elements in the protective envelope that provides the delay time must provide at least the minimum delay time associated with the applicable level of protection based on the assumption that aggressors will always be able to identify the weakest element in the envelope. That protective envelope may be all in one layer, such as the shell of a room or the exterior of a building, or it may encompass multiple layers such as the building exterior and multiple rooms arrayed in rings around the asset. The detection element of the protective system may also include closed circuit television (CCTV) to assess the validity of alarms. The criteria associated with the levels of protection are summarized in Table 3-1 and described below.

Table 3-1 Forced Entry Levels of Protection Summary

LEVEL OF PROTECTION	PERFORMANCE
Low	Provide construction that provides at least 1 minute of delay and provide intrusion detection sensors at all operational openings.
Medium	Provide construction that provides at least 5 minutes of delay and provide a complete ring of intrusion detection sensors
High	Provide construction that provides at least 15 minutes of delay and provide a complete ring of intrusion detection sensors with two different sensor phenomenologies
Very High	Provide construction that provides at least 30 minutes of delay and provide a complete ring of intrusion detection sensors with two different sensor phenomenologies

3-2.1 Low Level of Protection.

The specific design strategy associated with this level of protection incorporates an envelope of building elements (walls, roofs, floors, ceilings, doors, windows) surrounding an asset that provides a delay time to the specified threat tools of at least 1 minute. In addition, the protective system incorporates intrusion detection sensors at all operable openings. Entry though other building elements would be detected through operational procedures, such as roving patrols.

3-2.2 Medium Level of Protection.

The specific design strategy associated with this level of protection incorporates an envelope of building elements (walls, roofs, floors, ceilings, doors, windows) surrounding an asset that provides a delay time to the specified threat tools of at least 5 minutes. It also incorporates a complete ring of detection covering all possible approaches through the protective envelope.

3-2.3 High Level of Protection.

The specific design strategy associated with this level of protection incorporates an envelope of building elements (walls, roofs, floors, ceilings, doors, windows) surrounding an asset that provides a delay time to the specified threat tools of at least 15 minutes. It also incorporates a complete ring of detection covering all possible approaches to the asset. That ring must include two different sensor phenomenologies covering each approach.

3-2.4 Very High Level of Protection.

The specific design strategy associated with this level of protection incorporates the same delay and detection elements as the high level of protection, but the delay time is at least 30 minutes.

3-3 DESIGN PROCEDURES.

If the project is for new construction, review Paragraph 3-4 through Paragraph 3-8 of this document; then, use Chapters 4 through 7 to develop preliminary layout and design of the facility. Following preliminary layout and design, follow the procedures for calculating system delay starting in Paragraph 3-9. If the project is for an existing facility, review Paragraph 3-4 through Paragraph 3-8; then, follow the procedures for delay calculations starting in Paragraph 3-9.

3-4 PROTECTIVE SYSTEM.

Provide an integrated and layered protective system for the facility that is designed to deter, and if that fails, provide detection and physical barriers that provide enough delay time for a response force to defend/defeat the aggressor.

The protective system must operate on the principles of deter, detect, delay, deny, defend/defeat as defined in UFC 4-020-01.

- Deter is the prevention of an action by the existence of a credible threat of unacceptable counteraction or belief that the cost of action outweighs the perceived benefits.
- Detect is to assess possible aggressor action, or sensor/alert transmission that an event has occurred.
- Delay is the capability to interrupt or neutralize an aggressor’s activities.
- Deny prevents an aggressor from access, theft or generating casualties.
- Defend / defeat prevents unauthorized access and safeguards assets.

3-5 SECURITY IN DEPTH.

Security in Depth (SID) is a combination of layered and complementary security controls sufficient to deter, detect, and document unauthorized entry and movement within the installation and/or facility and the ability to delay and respond with force. Refer to UFC 4-020-01 for additional information on SID.

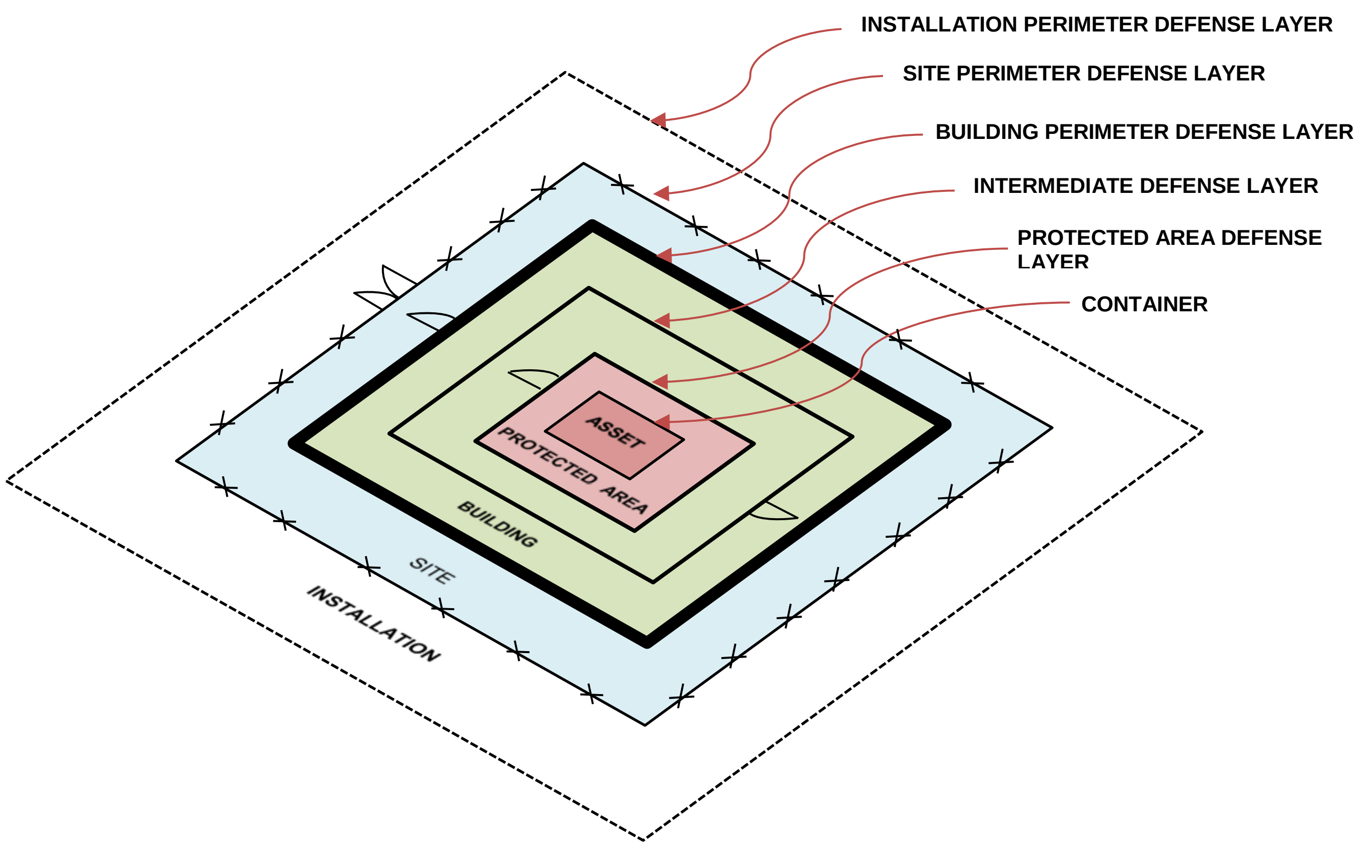
The project protective system should provide SID; and, when possible, consist of multiple defense layers and complementary control zones. If the project is being located within a larger installation, SID begins at the installation boundary.

3-6 DEFENSE LAYERS.

Each defense layer must consist of physical barriers that will delay the aggressor attempt to penetrate the layer and detection measures to provide early warning of the aggressor attempt. Detection measures may use electronic security systems (ESS) to provide the early warning or rely on visual observation by installation personnel or roving guards.

Figure 3-1 illustrates a protective system with multiple defense layers. Defense layers in the illustration are identified as installation perimeter, site perimeter, building perimeter, intermediate, protected area, and container.

Figure 3-1 Defense Layers

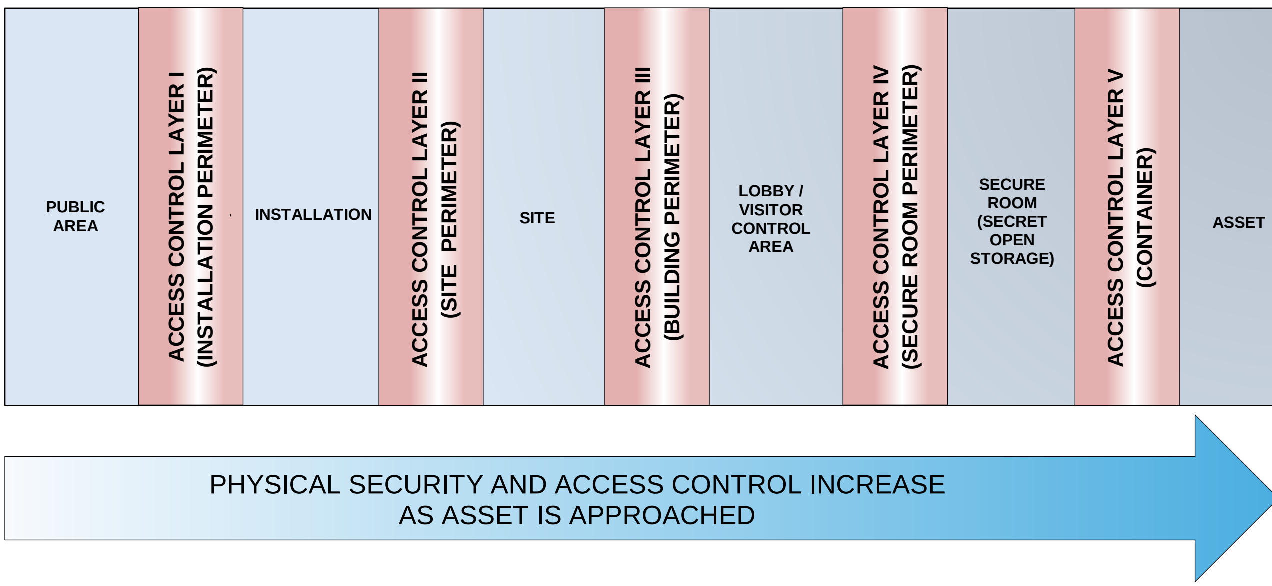


3-7 CONTROL ZONES.

Control zones are groupings of functional areas where access to a zone is restricted to site or building inhabitants who are required to work in the zone. If configured correctly, having multiple access control layers within an installation or facility can enhance the security of the higher security zones. This is accomplished by requiring personnel to transition through increasingly secure access control layers prior to accessing the protected area with the high value asset. Control zones may include installation access, site access, building access, restricted access, or protected area access.

Figure 3-2 illustrates a model for establishing control zones within a layered defense using an installation perimeter, site perimeter, building perimeter, secure room (protected area), and container.

Figure 3-2 Control Zones

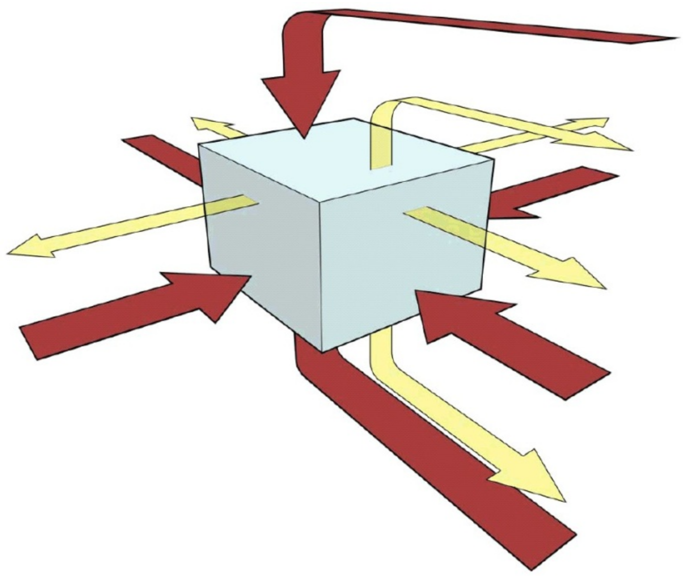


3-8 LAYOUT CONSIDERATIONS.

Except for a site perimeter, use a six-sided approach when designing each defense layer. The walls, floor, roof or ceiling, and any penetrations of the defense layer must be designed so that all elements meet the delay rating for the layer. See Figure 3-3 for a diagram of the six-sided approach.

Chapter 4 describes detailed site layout and design. Chapter 5 describes detailed building layout and design.

Figure 3-3 Six-Sided Approach



3-8.1 Multiple Assets.

Since the design basis threat is focused on assets, not all assets will require the same threat severity level and levels of protection. If there are multiple assets, evaluate each asset and the design criteria associated with it and factor that into how the building is laid out.

When the design criteria contain multiple assets to be protected, consider grouping the protected areas containing those assets together unless prohibited by prescriptive requirements such as a minimum interspatial distance required for explosives.

3-8.2 Multiple Buildings in Project.

When the design project contains more than one building, consider locating assets in a building near the center of the complex.

3-8.3 Multiple Aggressor Tactics.

When the design criteria contain multiple aggressor tactics, each tactic will have a threat severity level and an associated level of protection. Provide design features that protect the assets against the forced entry tactic and associated level of protection, enhanced by requirements to protect against other aggressor tactics and associated levels of protection.

When there are multiple applicable tactics, each tactic will have to be addressed separately and the resulting protective measures will have to be integrated into a comprehensive solution that addresses all tactics. In doing so, the tactics should be addressed in order from the one that has the greatest potential impact on building construction to the tactic with the least impact. For example, construction to protect against explosives related tactics may require heavy construction that may be a greater requirement than the forced entry resistance but may prove to be advantageous to forced entry resistance.

3-8.4 Multiple Defense Layers with Common Roofs or Ceilings.

Some forced entry projects may necessitate that two or more defense layers have common roofs or ceilings. The pathway to the asset may be through the roof and ceiling, the floor or through the walls and doors. Either pathway must meet the required system delay.

3-9 ESTABLISHING REQUIRED PROTECTIVE SYSTEM DELAY TIME.

An effective protective system requires that any aggressor attempt to attack the facility must be detected so that response forces can interrupt and neutralize the aggressor's attack before his goal can be achieved. Since it is usually not feasible to maintain a response force to provide immediate protection for all assets, a comprehensive aggressor detection and delay plan is needed.

3-9.1 Delays for Multiple Assets.

When the design criteria list multiple assets to be protected, each with an applicable level of protection, delay can be provided for the protection of all assets at the highest level of protection, but a more cost effective design may entail providing delay for each asset listed according to the level of protection assigned to that asset.

3-9.2 Establish Minimum and Maximum Response Times.

Minimum or maximum response time refers to the minimum or maximum possible time in which the response force can reach an engagement area. Consult with facility operations personnel, facility security personnel, and the base Facility Antiterrorism Officer to establish response force tactics including potential engagement areas and the minimum and maximum response times for each asset. For some assets, such as Sensitive Compartmented Information, response time is dictated by policy.

3-9.3 Establish Required Protective System Delay Times.

Defense layers surrounding an asset must collectively provide detection and enough physical delay for a response force to intercept the aggressors, either before the asset is compromised or before the aggressor escapes.

Calculate the required collective protective system delay time based on the minimum or maximum response times using the requirements in Table 3-2.

Table 3-2 Level of Protection Delay Times for Forced Entry

LEVEL OF PROTECTION	REQUIRED DELAY TIME
Very Low	Delay does not apply to this level of protection.
Low	The required delay time is greater than the minimum possible response time.
Medium	The required delay time is greater than the minimum possible response time.
High	The required delay time is greater than the maximum possible response time.
Very High	The required delay time is 25% greater than the maximum possible response time.

3-10 EVALUATING SYSTEM DELAY IN PRELIMINARY DESIGN.

Use the Forced Entry Design Worksheet, Figure 3-4, to document the delay times included in the preliminary design for each asset. Enter the project and asset descriptions; date; minimum/maximum response times, level of protection, and threat severity level assigned to the asset in boxes 1 through 5b.

Enter the protective system delay time calculated in Paragraph 3-9 in Box 5c of the Forced Entry Design Worksheet.

Figure 3-4 Forced Entry Design Worksheet

1. PROJECT / BUILDING IDENTIFICATION	2. ASSET IDENTIFICATION		3. DATE

4a. MINIMUM RESPONSE TIME	4b. MAXIMUM RESPONSE TIME	5a. LEVEL OF PROTECTION	5b. THREAT SEVERITY LEVEL	5C. REQUIRED DELAY

6. DEFENSE LAYER	7. LAYER ELEMENT	8. ELEMENT PHYSICAL DELAY RATING	9. LAYER PHYSICAL DELAY RATING	10. OUTER-MOST DEFENSE LAYER?
CONTAINER				
PROTECTED AREA				
INTERMEDIATE LAYER				
BUILDING PERIMETER				
SITE				

ESTIMATED AGRESSOR ESCAPE TIME	12.	SYSTEM DELAY RATING	11.	

3-10.1 Physical Delay Ratings.

The physical delay rating for a defense layer (construction) element is the time it takes for the aggressor to breach and pass through the element. This rating will include the attack time, the tool penalty, and the skill penalty, as applicable. For traditional elements such as walls, door, and windows used in both new and retrofit construction design, these delay ratings, based on threat severity levels can be found in Chapters 5 and 6.

Additionally, Chapter 7 discusses the use of dispensable barrier and shuttering systems that can be used to further delay a forced entry attempt. For use of these systems, consult with subject matter experts in coordination with facility operations and security personnel.

3-10.1.1 Defense Layer Element Physical Delay Ratings.

Enter the construction elements for each defense layer used in the preliminary design in the appropriate spaces in column 7. For example, building perimeter elements might include walls, roofs, floors, ceilings, doors, windows, and utility openings.

Enter the corresponding delay rating for each element in column 8. If there is no entry in Chapters 5 or 6 for a design element at the required threat severity level, use the delay time for the next lower threat severity level for which data is available.

3-10.1.2 Layer Physical Delay Ratings.

Ideally, all element delay ratings within a layer will be equal, providing a consistent defense; however, aggressors will exploit the weakest element in a defense layer. Thus, the layer delay rating for a given defense layer equals the least delay time among the elements of that layer. Determine the layer delay rating for each defense layer and enter that rating in the appropriate space in column 9.

3-10.1.3 System Delay Rating.

The total system delay is the sum of the defense layer delay ratings in Column 9. Enter the total system delay time in box 11.

3-10.1.4 Aggressor Escape Time.

If the goal in protecting an asset is to keep it from being removed from the facility rather than to deny access to the asset, enter an estimate of the time necessary for an aggressor to escape from the facility in box 12. Note that the escape delay time through each layer will likely be significantly shorter than for entry because of use of emergency exits or use of penetrations created during initial breaching of the layer.

3-10.2 Outermost Defense Layer.

The outermost defense layer is the layer at which the sum of the delay ratings for that layer and layers interior to it is equal to or greater than the required delay time (box 5c). Column 10 of the Forced Entry Design Worksheet is used to indicate the calculated outermost defense layer. The outermost defense layer is the point at which detection is achieved. Where electronic security systems (ESS) are used as part of the protective system, it is the point at which sensors will be placed. Refer to UFC 4-021-02 for design of ESS.

3-11 DESIGN ADJUSTMENT.

If the system delay rating (box 11 of the Forced Entry Design Worksheet) is less than the required delay time (box 5c) or if the outermost defense layer is at an unacceptable location, add defense layers or upgrade layer components. It is usually more efficient to upgrade layers closer to the asset because the size of the inner layers is smaller as is the resulting protected area volume. To upgrade existing defense layers, start with the component with the least delay rating. Select different construction components if the facility is new construction. Replace or retrofit vulnerable existing construction components. Fill out a new Forced Entry Design Worksheet if significant changes are made to the initial defensive system.

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CHAPTER 4 SITEWORK

4-1 INTRODUCTION.

This chapter applies when the design criteria require that the project establish a building compound with a dedicated site perimeter and open areas between the site perimeter and the building housing the asset to be protected. When required, the building compound may provide the first opportunity for forced entry delay.

a. Not all resistance to forced entry projects will require the establishment of a building compound. In that case, the building perimeter provides the first defense layer; refer to Chapter 5 for building designs.

b. Not all resistance to forced entry projects will be located on an existing Government installation. When the establishment of a building compound is required by the design criteria, this UFC is applicable for both a site located on an existing installation and a stand-alone site.

c. This UFC does not address the design of installation perimeters.

4-2 SITEWORK ELEMENTS.

Sitework elements such as chain-link fences, gates, and entry portals are not likely to delay a small group of well-equipped and dedicated aggressors; however, managing the site perimeter and open areas external to buildings:

- assists in building access control,
- minimizes hidden spots and concealed avenues of approach for an aggressor,
- provides opportunities for observation and detection, and
- may provide a platform for sensors (such as fence mounted sensors).

4-3 CRIME PREVENTION THROUGH ENVIRONMENTAL DESIGN.

Crime prevention through environmental design (CPTED) is the proper design and effective use of the built environment that can lead to a reduction in the fear and incidence of crime, and an improvement in the quality of life. Consider using CPTED concepts in the design of the projects to make the facility less attractive to aggressors considering forced entry. The main features of CPTED are natural access control, natural surveillance, and territorial reinforcement.

For further information on CPTED, See:

- Publications by the National Institute of Law Enforcement and Criminal Justice.
- Crowe, Timothy D., *Crime Prevention Through Environmental Design*. National Crime Prevention Institute (1991).

4-3.1 Natural Access Control.

Natural access control includes design features that clearly indicate public routes and discourage access to private structural elements. These features decrease an opportunity for crime by creating in an offender a perception of unacceptable risk when attempting access to private areas, which marks the stranger as a possible aggressor. Such design features include placement of entrances and exits, fencing, and landscaping to control traffic flow.

4-3.2 Natural Surveillance.

Natural surveillance includes design features that increase the visibility of a property. These features maximize the ability of persons in the area to see persons in the vicinity and avoid trouble and allow external activities to be seen from adjacent building structures by persons who could call for help. Such design features include landscaping, lighting, window and stairway placement, and building entrance and garage layouts.

4-3.3 Territorial Reinforcement.

Territorial reinforcement includes design features that clearly indicate public and private structural elements of a property. An individual will develop a sense of territoriality for a space with frequent activities in an area, a sense of ownership. With this feeling of ownership, the individual will want to defend his environment. This ownership does not necessarily mean legal ownership; it maybe a perceived ownership, such as the sense of ownership that employees feel for the office in which they work. The sense of territory and ownership by an individual is reinforced through regularly scheduled activities, inspections, and maintenance.

4-4 SITE LAYOUT CONSIDERATIONS.

To optimize the site layout for security and function, architects, engineers and security personnel must work together to understand the layout of operational spaces within the site such as parking, landscape and drainage features, lighting, and trash collection areas in addition to visitor and vehicle access and escort requirements. This takes an integrated design approach that balances the site's operational and space requirements. If space permits, the site layout should be designed to provide early detection of aggressor movement toward the building. See Paragraph 4-6 for application of clear zones and unobstructed space.

The following are site-related layout considerations:

- Establish a well-defined perimeter using fences, walls, or a combination of both.
- Provide an intrusion detection system (IDS) at site perimeter to detect aggressor attempt to penetrate site.
- Provide only one personnel entry control point (ECP) and one vehicle ECP into the site.

- Locate facility within view of other occupied facilities.
- Locate assets stored outside of the facility within view of occupied rooms of the facility.
- Eliminate potential hiding places for aggressors.
- Minimize or eliminate signs or other indicators of asset location.
- Illuminate building exterior or exterior sites where assets are located.

4-5 SECURITY FENCING.

Security fencing is effective at delineating a boundary and at keeping honest people honest, but ineffective for preventing a forced entry. The design strategy for forced entry is based on delaying the aggressor, and any serious aggressor could climb a fence in less than four seconds or can cut through a fence in less than ten seconds; however, fences can provide an important role in the early detection of an aggressor's forced entry attempt. An aggressor must make an overt action to breach the fence, which allows them to be intercepted in accordance to the rules of engagement. Refer to UFC 4-022-03 for the functions and design of security fences.

4-5.1 Gates for Fences.

Gates control authorized pedestrian and vehicular traffic and flow. They establish entry and exit points into an area defined by fences. They are a component of the perimeter fence and must be as effective as the associated fence in order to provide an equivalent deterrent. Gates normally require additional hardening features for hinges and locking mechanisms due to their operation and inherent vulnerability. Use designs in UFC 4-022-03 for gates and hardware. When required, design ESS in accordance with UFC 4-021-02 for associated alarms.

4-5.2 Utility Openings in Fence Lines.

Drainage ditches and culverts may pass through or under a perimeter fence. If those openings create a cross-sectional area greater than 96 square inches (619 cm^2) and a smallest dimension greater than 6 inches (150 mm), they must be protected using designs in UFC 4-022-03. Ensure that any addition of grilles or pipes to culverts or other drainage structures is coordinated with civil engineers so that they can compensate for the diminished flow capacity and additional maintenance that will result from the installation.

4-5.3 Walls in Fence Lines.

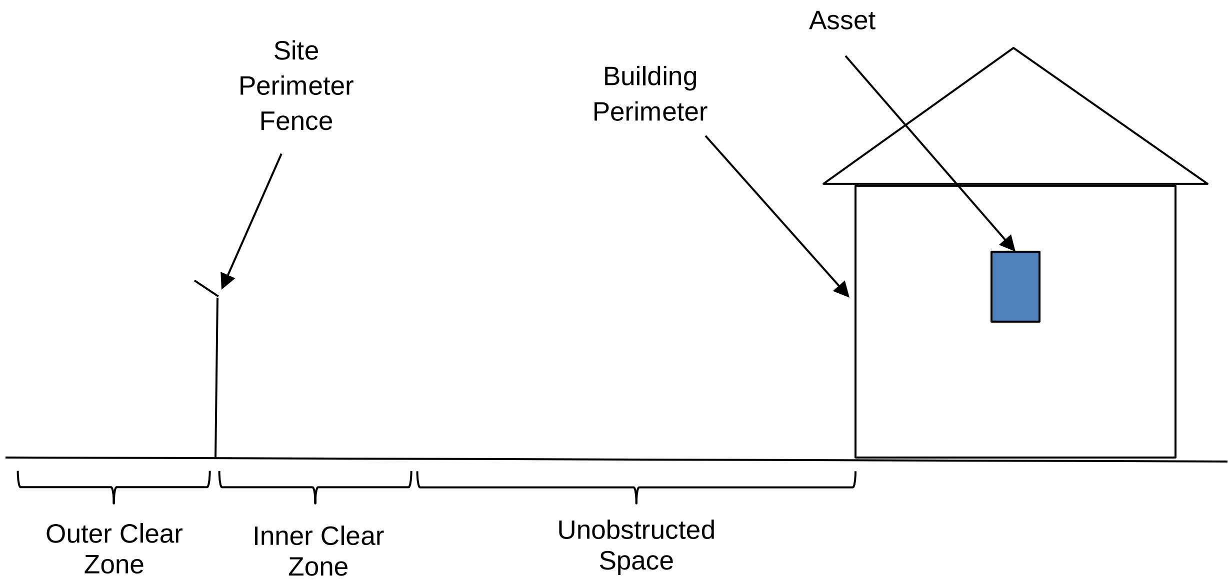
Walls can be used to replace part, or all, of a security fence in the site perimeter. Alternatively, a short wall topped by a fence can be used in the site perimeter.

Walls and walls topped with a fence should provide security features equivalent to that of a security fence. Refer to UFC 4-022-03 for the functions and design of security fences.

4-6 CLEAR ZONES AND UNOBSTRUCTED SPACE.

The space between the site perimeter (security fence) and the facility buildings consists of an inner clear zone and an unobstructed space (Figure 4-1). Additionally, there may be an outer clear zone that is outside of the site perimeter.

Figure 4-1 Site Areas



4-6.1 Clear Zones.

When a site perimeter fence is required, clear zones are areas established on both outer and inner sides of a security fence to provide an unobstructed view to enhance detection and assessment. Refer to UFC 4-022-03 for application of clear zones at fence lines and UFC 4-010-01 for application of clear zones around inhabited buildings.

4-6.2 Unobstructed Space.

Unobstructed Space is an area around inhabited buildings in which there are no opportunities for concealment from observation of explosive devices 6 inches (150 mm) or greater in height or width. Refer to UFC 4-010-01 for minimum requirements for unobstructed space.

4-7 SITE PERIMETER ENTRY CONTROL.

Depending on the project, entry control points may be required in the site perimeter. Consult with facility operations personnel and facility security personnel for entry control requirements for the project perimeter.

4-8 DETECTION.

For forces to respond to an attempted forced entry, the threat must be detected. This may be accomplished by visual observation, IDS, or CCTV. Initial threat detection should occur at the outermost defense layer, either at the site perimeter or at the building perimeter. Refer to UFC 4-021-02 for additional information and designs for IDS and CCTV employment at the outermost defense layer.

4-9 SECURITY LIGHTING.

Security lighting provides illumination during periods of darkness or in areas of low visibility to aid in the detection, assessment, and interdiction of aggressors by security forces. Lighting may also be a deterrent to some aggressors.

Consult with facility operations and facility security personnel, including ESS specialists, for security lighting requirements. When required, design lighting in accordance with UFC 3-530-01.

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CHAPTER 5 BUILDING ELEMENTS

5-1 INTRODUCTION.

Building elements include the building layout, walls, roofs, ceilings, floors, doors, windows, and utility openings. Designs for each element type are presented in separate sections within this chapter.

5-2 BUILDING LAYOUT.

Effective building layout enhances resistance to forced entry by making assets harder to find and more time-consuming to reach, by making escape more difficult, and by taking advantage of inherent monitoring opportunities by occupants. Some related considerations also influence building layout. Several defense layers surrounding an asset may be more cost-effective than a single layer that provides the total delay time. Minimizing the actual protective volume (all sides of a space must be considered) around an asset reduces construction and detection system costs and surveillance requirements. Deciding whether to consider delay time in terms of the aggressor's ingress time only (time required from detection until the aggressor reaches an asset) or ingress plus egress time (including escape time after compromising or stealing an asset) can also influence building arrangement. Finally, design the building such that interior signage, which may indicate an asset's existence or location is unnecessary.

To optimize the building layout for security and function, the designer must understand the various secure spaces in the facility, the security clearances of the occupants, visitor access and escort requirements and the separations or adjacencies required. This takes an integrated design approach that balances the occupant's operational and space requirements, visitor control requirements, security-in-depth and the concept of control zoning. If building operations permit, the building layout should be designed to complicate aggressors' movement toward the asset by requiring that they be forced to take complicated routes and be equipped with a number of different tools and skills. In developing the building layout:

- Maximize the vertical and horizontal separation between the lowest and highest security areas.
- Maximize grouping of secure areas to enhance floor/ceiling security and to minimize locations of secure elements.
- In large facilities, locate the highest security area in the building center, on an upper floor, or in the basement.
- When a facility has multiple security levels and functionally compatible missions, access to the highest security area should be through the area with the next lower security level.

5-3 BUILDING COMPONENTS.

Defense layers consist of construction components and assemblies including walls, roofs, floors and ceilings, doors, windows, and utility openings, which delay an aggressor from reaching an asset. Consider building components that may be attacked horizontally or vertically from all sides of a space. The penetration delay time for any layer equals the least penetration delay time for any single component of that layer.

The materials from one type of component can be used for another type of component; for example, wall materials can be used for ceilings or window materials can be used for skylights. When making these substitutions, penetration delay times must be adjusted since horizontal and vertical attacks on the same materials yield different penetration delay times; for example, the penetration delay time for a downward attack on a 6-inch (150-mm) concrete roof slab is lower than a similar attack on a 6-inch (150-mm) concrete wall.

5-4 FORCED ENTRY RESISTANT BUILDING COMPONENT TABLES.

This Chapter provides a series of tables containing forced entry resistant building components and the delay times they provide against the four possible threat severity levels for the forced entry tactic. There are separate tables for walls, doors, windows, roofs, floors, and utility openings. Each component table is located within the paragraph of this chapter devoted to the respective component.

5-4.1 Data Formulation.

The tables contain only components which have been tested or otherwise analyzed for forced entry resistance. Although the components in the tables are representative, they are not the only components available. New technology is used to develop improved components, and testing may have been performed that is not reflected in the tables. Users of this manual must therefore supplement it with whatever other data is available to them; however, only data based on actual testing or formal analysis should be used. Manufacturers' data may be based on limited testing or assumptions and may not accurately reflect the tools associated with the threat severity levels discussed in this manual.

The data in these tables was derived from actual tests and on estimates based on such tests. The total delay time consists of three elements: (1) the attack time, (2) the tool penalty, and (3) the skill penalty.

5-4.1.1 Attack Time.

The attack time is the actual time that it took the person or persons performing the test to make a man-passable opening of 96 square inches (619 cm^2) in the designated building component under laboratory conditions. Some data is based on estimates or delay times based on tests of similar materials with the same tools.

5-4.1.2 Tool Penalty.

The tool penalty is an additional delay time added to the attack time to account for difficulties associated with using some tools. It does not apply for all tools.

5-4.1.3 Skill Penalty.

The skill penalty is an additional delay time added to the attack time and tool penalty to reflect an unskilled user's inefficiency in using the tools. Again, the skill penalty does not apply to all tools.

5-4.2 Advantages of Composite Components.

A composite construction component such as a wall, floor, ceiling, or door built with two or more types of materials such as wood, metal, concrete, or foam provides significant delay over a component built with a single material since it requires aggressors to use multiple tools to breach the component.

Thermal tools can cut through metal but do not work well on wood, and power tools commonly get fouled up by foams. Explosives can blast holes in concrete but generally leave the reinforcing bars intact, requiring the aggressors to switch to cutting tools to complete the breach. Note that many of the entries in the tables in this chapter include such cross sections.

5-4.3 Data Application.

The attack time and the tool and skill penalties are already incorporated into the total delay times shown in the tables. All three quantities are applied to arrive at the total delay time for the threat severity levels II and III. The skill penalty is not applied for the threat severity level IV because aggressors operating at that threat severity level are assumed to be skillful at using the tools they select; they may still select tools which are difficult to use, and they are therefore still assigned a tool penalty. The aggressors to whom the threat severity level V applies are assumed to be skillful at using the tools they select and to select only tools which are not too difficult for them to use; therefore, no penalties are associated with the threat severity level V.

5-4.4 Using the Tables.

The tables provide the delay times for building components for the four possible threat severity levels applicable to the forced entry tactic. The second column in each table provides a description of each component with which a delay time is associated. Components may be used as a stand-alone application in new construction or as a retrofit. The third through sixth columns on the tables indicate the total delay times in minutes for various threat severity levels. Each identified building component resists the tools associated with the forced entry threat severity level for the time indicated. Where there are no entries under a given threat severity level, no testing or analysis has been done for that component for that level. In those cases, either select another component or use the next higher threat severity level for which data is available. Using higher threat severity levels will always be conservative.

5-4.5 References to Explosives Use.

The threat severity level V includes the potential for the use of explosives. The delay times associated with explosives are indicated by an asterisk (*). Where testing was done on a building component at threat severity level V without using explosives, that value is also indicated. In such cases the delay time entry will appear as two numbers, such as 10/<1*. The 10 refers to the delay without explosives and the <1* refers to the delay assuming the use of explosives. If the aggressor is unlikely to use explosives due to their noise, their potential for damaging the asset, or for any other reason the planning team establishes, use the value which does not include explosives.

5-5 NEW CONSTRUCTION.

This section provides design options for hardening a new building against forced entry penetration. The objective is to identify construction choices that assure a balanced security design between all building components; approximately equal penetration delays against a given threat severity level.

5-5.1 Walls.

Solid plywood or expanded metal construction can be used to resist a low severity threat. For threat severity levels III and IV, the choices are limited to grout-filled and reinforced concrete-masonry unit (CMU) for lower delay time requirements, and conventional or steel-fiber-reinforced (SFR) concrete for higher delay time requirements. Protection against threat severity level V will require sacrificial areas, multiple barriers, or reinforced concrete barriers.

5-5.1.1 Walls to Resist Threat Severity Level II.

Since conventional wall construction such as stud-girt construction using less than 3/4-inch (19-mm) plywood, stucco, gypsum, composite, light sheet metal, and conventional masonry provides a delay of less than one minute against threat severity level II, use one of the wall types shown in Table 5-4.

5-5.1.2 Walls to Resist Threat Severity Levels III and IV.

Use solid-filled and reinforced CMU; conventional reinforced concrete; SFR concrete; or masonry, wood, metal, and plastic composite walls.

Solid core, filled, and reinforced CMU, conventional, SFR concrete wall construction options and corresponding minimum penetration delay for threat severity levels III and IV are shown in Figure 5-1 through Figure 5-3. Note in Figure 5-1 through Figure 5-3 that the minimum penetration delay times are presented as a function of the thickness of the cross section and the size and spacing of reinforcing bars. Different combinations of reinforcing bar size and spacing are identified by capital letters from Table 5-1 for masonry and in Table 5-2 for reinforced concrete. In general, a required penetration delay time can be achieved either by providing a thicker cross section or by adding more reinforcement. Table 5-4 provides options that can be considered based on structural and cost considerations.

5-5.1.2.1 Security Threat Level III.

a. CMU walls: As shown in Figure 5-1 and Table 5-1, penetration delay times up to about 5.5 minutes are achievable using mortar filled CMU. The use of reinforcing bars in the core is required for higher penetration delay times.

b. Conventional Reinforced Concrete. As shown in Figure 5-2 and Table 5-2, penetration delay times up to 7.5 minutes are achievable with 6 inches (150 mm) of reinforced concrete with the B-curve reinforcing bar combination.

c. SFR Concrete. As shown in Figure 5-3 and Table 5-2, penetration delay times up to about 11 minutes are achievable with 6 inches (150 mm) of SFR concrete with the B-curve conventional reinforcing bar combination. The steel fiber is at least 5 percent by volume of the concrete mix.

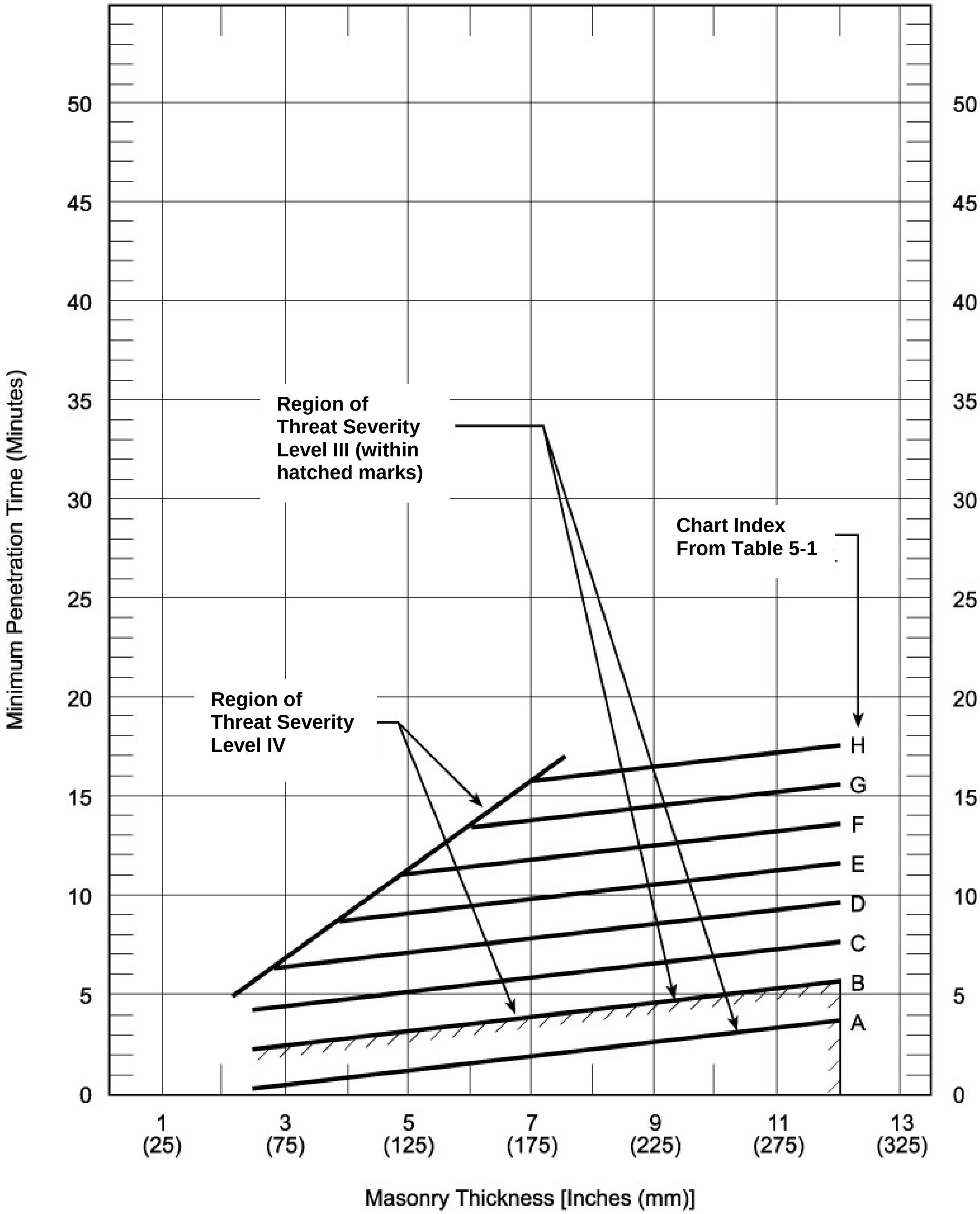
5-5.1.2.2 Security Threat Level IV.

a. CMU walls: Figure 5-1 with Table 5-1, gives CMU and reinforcing bar combinations that can provide penetration delay times up to 18 minutes.

b. Conventional Reinforced Concrete. Figure 5-2 with Table 5-2, gives conventional concrete thickness and reinforcing bar combinations that can provide penetration delay times up to 35 minutes.

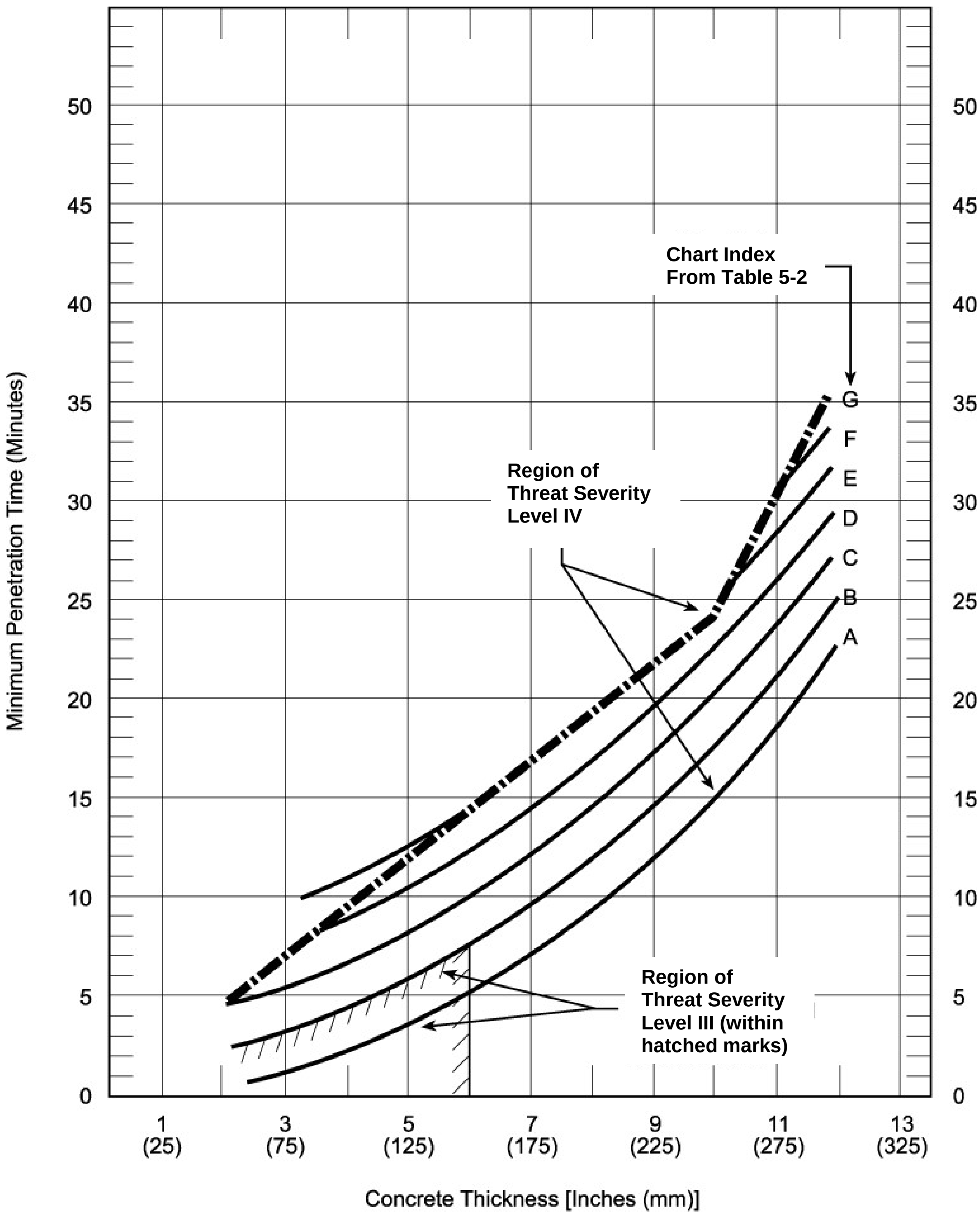
c. SFR Concrete: Figure 5-3 with Table 5-2, gives SFR concrete thickness and conventional reinforcing bar combinations that can provide penetration delay times up to 50 minutes.

Figure 5-1 Delay times for Solid Core Filled and Reinforced CMU Walls



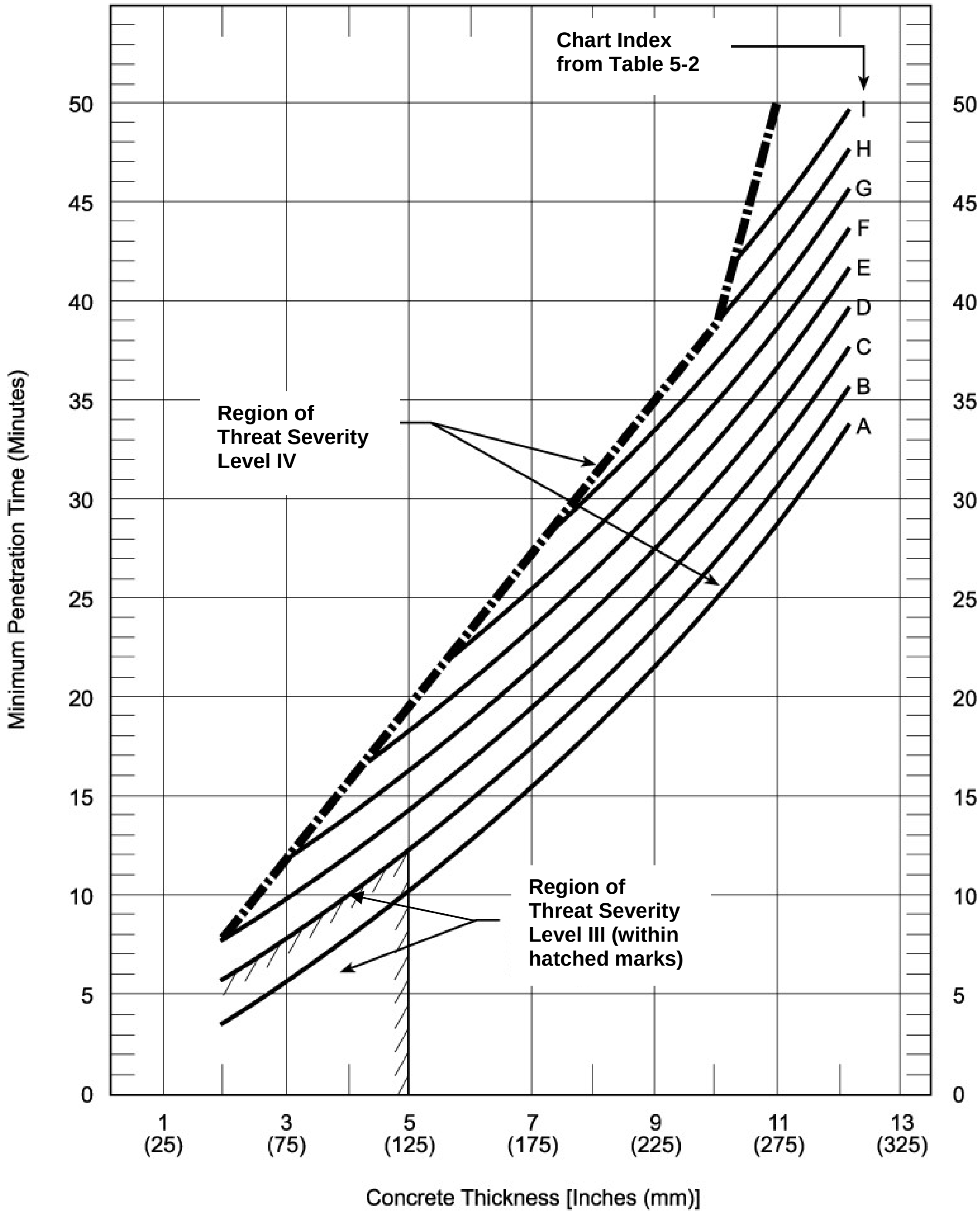
Note: the penetration times are minimum values based on the proper selection and optimal use of the attack tools. In this figure, the regions identified as threat severity level III assumes that only hand powered tools and some limited battery powered tools are used. For these cases, the thickness and/or reinforcing bar combination required is less than for the threat severity level IV where power and thermal tools also may be used.

Figure 5-2 Delay times for Conventional Reinforced Concrete Walls



Note: the penetration times are minimum values based on the proper selection and optimal use of the attack tools. In this figure, the regions identified as threat severity level III assumes that only hand powered tools and some limited battery powered tools are used. For these cases, the thickness and/or reinforcing bar combination required is less than for the threat severity level IV where power and thermal tools also may be used.

Figure 5-3 Delay times for SFR Concrete Walls



Note: the penetration times are minimum values based on the proper selection and optimal use of the attack tools. In this figure, the regions identified as threat severity level III assumes that only hand powered tools and some limited battery powered tools are used. For these cases, the thickness and/or reinforcing bar combination required is less than for the threat severity level IV where power and thermal tools also may be used.

Table 5-1 Reinforcing Bar Index for Concrete Masonry Walls

USING A SINGLE LAYER OF REINFORCING BARS							
HORIZONTAL SPACING IN INCHES (MM)	**REINFORCING BAR SIZE**						
	NONE	#3	#4	#5	#6	#7	#8
3 (75)	A	B	B	C	C	D	E
3-1/2 (90)	A	B	B	C	C	D	E
4 (100)	A	B	B	B	C	C	D
4-1/2 (115)	A	B	B	B	C	C	D
5 to 9 (125 to 225)	A	B	B	B	B	B	C
>10 (250)	A	A	A	A	A	A	A
USING A DOUBLE LAYER OF REINFORCING BARS							
HORIZONTAL SPACING IN INCHES (MM)	**REINFORCING BAR SIZE**						
	NONE	#3	#4	#5	#6	#7	#8
3 (75)	A	C	C	D	E	G	H
3-1/2 (90)	A	C	C	D	E	F	H
4 (100)	A	B	C	C	D	E	G
4-1/2 (115)	A	B	C	C	D	E	F
5 to 9 (125 to 225)	A	B	B	B	C	C	D
>10 (250)	A	A	A	A	A	A	A

NOTE: Vertical spacing at 8 inches (200 mm).

Table 5-2 Reinforcing Bar Index for Concrete

USING A SINGLE LAYER OF REINFORCING BARS							
SPACING ON CENTER EAH WAY, INCHES (MM)	**REINFORCING BAR SIZE**						
	NONE	#3	#4	#5	#6	#7	#8
3 (75)	A	B	B	C	C	D	E
3-1/2 (90)	A	B	B	C	C	D	E
4 (100)	A	B	B	B	C	C	D
4-1/2 (115)	A	B	B	B	C	C	D
5 to 9 (125 to 225)	A	B	B	B	B	B	C
>10 (250)	A	A	A	A	A	A	A
USING A DOUBLE LAYER OF REINFORCING BARS							
SPACING ON CENTER EACH WAY, INCHES (MM)	**REINFORCING BAR SIZE**						
	NONE	#3	#4	#5	#6	#7	#8
3 (75)	A	C	C	D	E	G	I
3-1/2 (90)	A	C	C	D	E	F	H
4 (100)	A	B	C	C	D	E	G
4-1/2 (115)	A	B	C	C	D	E	F
5 to 9 (125 to 225)	A	B	B	B	C	C	D
>10 (250)	A	A	A	A	A	A	A

5-5.1.3 Walls to Resist Severity Level V.

The only two ways to harden a structure against these types of threats are to construct massive reinforced concrete or sacrificial barrier walls.

The use of bulk explosives or LSCs designed to direct energy, can be especially effective in breaching barriers and producing holes large enough for an aggressor to crawl through. While bulk explosives can produce large holes, even in thick concrete walls, they will not cut internal reinforcing material. The shock waves produced by an explosion propagate throughout the concrete, resulting in internal fragmentation and spalling (breaking off) of the inner and outer surfaces. The pressure of the explosive will force concrete fragments out of a wall creating a relatively clean hole. Cutting and removing the reinforcing material to create a crawl hole creates most of the delay.

a. Thick, heavily reinforced concrete walls can provide significant penetration resistance. Use reinforced concrete 18 to 48 inches (0.46 to 1.2 m) thick. Table 5-3 presents the estimated minimum penetration delay times provided by varied thicknesses of reinforced concrete that has a compressive strength of at least 5,000 psi (35,500 kPa).

   Table 5-4 provides options that can be considered based on structural and cost considerations.

Table 5-3 Reinforced Concrete Designs for Threat Severity Level V

CONCRETE THICKNESS, INCH (M)	REINFORCING BAR LAYERS – NO. 6 (19 MM) ON 6-INCH (150-MM) CENTERS	MINIMUM PENETRATION DELAY TIME (MINUTES)[a]
≤8 (≤0.2)	1	≤1
12 (0.3)	2	2
18 (0.46)	3	3
24 (0.6)	4	4.5
36 (0.9)	6	8
48 (1.2)	8	13

[a] Use of bulk explosives to remove the concrete and using power and thermal tools to cut the reinforcing bars.

b. Sacrificial barriers can be employed above, below, and around the critical area in the building. The walls, doors, and other features of this sacrificial area may be damaged but will provide cumulative delay created by the necessity to breach multiple barriers, transport breaching tools through each barrier, and retreat to a safe distance before the next barrier is breached. In general, the critical area should be internal to the building, and away from exterior walls and roofs.

Table 5-4 Wall Materials

ITEM NUMBER	WALL MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
1	4" CONCRETE 6000 POUNDS PER SQUARE INCH (PSI) WITH #5 REINFORCING BARS AT 5" ON CENTER (OC) EACH WAY (EW)		9	5	3*
2	4" CONCRETE WITH #5 REINFORCING BARS AT 5" OC EW	6	6		1*
3	6" CONCRETE WITH #4 REINFORCING BARS AT 8" OC EW	9		2	2*
4	8" CONCRETE WITH #4 REINFORCING BARS AT 9" OC EW EACH FACE (EF)			15	14
5	8" CONCRETE WITH #5 REINFORCING BARS AT 6" OC EW			11	9/2*
6	8" CONCRETE WITH #6 REINFORCING BARS AT 6" OC EW				2*
7	8" CONCRETE 6000 PSI WITH #5 REINFORCING BARS AT 5" OC EW			6	5
8	8" CONCRETE WITH #6 REINFORCING BARS AT 12" OC EW			11	10
9	12" CONCRETE WITH #6 REINFORCING BARS AT 6" OC EF				3*
10	12" CONCRETE WITH #5 REINFORCING BARS AT 6" OC EF			31	3*
11	12" CONCRETE WITH #6 REINFORCING BARS AT 12" OC EF				2*
12	18" CONCRETE, 5000 PSI WITH 5/16" EXPANDED METAL 3" OC				2*
13	4" FIBROUS CONCRETE, 6500 PSI WITH #5 REINFORCING BARS AT 5" OC EW		13		10
14	8" FIBROUS CONCRETE WITH #5 REINFORCING BARS AT 5" OC EW		9	5	<1
15	8" FIBROUS CONCRETE, 6500 PSI WITH #5 REINFORCING BARS AT 6" OC EW				3*

ITEM NUMBER	WALL MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
16	12" FIBROUS CONCRETE, 6500 PSI WITH #5 REINFORCING BARS AT 6" OC EF			7	6
17	4" REINFORCED CMU	2			
18	4" CMU WITH #8 REINFORCING BARS AT 8" OC MORTAR FILLED	2			
19	8" CMU	2			
20	8" CMU WITH #4 REINFORCING BARS EVERY COURSE MORTAR FILLED		8	5	4
21	8" CMU WITH #*8* REINFORCING BARS MORTAR FILLED		7	3	
22	12" CMU	2			
23	12" CMU WITH #*5* REINFORCING BARS AT 8" OC MORTAR FILLED				1*
24	12" CMU WITH #6 REINFORCING BARS AT 8" OC MORTAR FILLED	21			1*
25	8" CMU WITH #*8* REINFORCING BARS AT 8" OC MORTAR FILLED, 4" FIBROUS CONCRETE, 6500 PSI				3*
26	8" CMU MORTAR FILLED, 3" FIBROUS CONCRETE	27		24	
27	8" CMU, WIRE FABRIC, 4" FERROCEMENT	8	8		
28	8" CMU, DIAMOND MESH PLASTER LATH, 2 LAYERS, 1" POLYURETHANE FOAM	3			
29	8" CMU, 3/4" PLYWOOD, #15 ROOFING MATERIAL, 3/4" PLYWOOD		9		
30	8" CMU, 1-1/2" PLYWOOD		9		
31	8" CMU, 3/4" PLYWOOD, 1" POLYURETHANE FOAM, #9 EXPANDED METAL 3/4"			3	
32	4" SOLID BRICK	1			
33	8" BRICK INTERLOCKED	3			

ITEM NUMBER	WALL MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
34	10 GAUGE (GA) HARDENED STEEL, 3/4" PLYWOOD, 10 GA HARDENED STEEL	7			
35	WOOD OR METAL STUDS WITH GYPSUM WALLBOARD (GWB) BOTH SIDES	<1			
36	WOOD STUDS WITH GWB ON INSIDE, STUCCO ON OUTSIDE WOOD STUDS WITH WOOD SIDING	1			
37	WOOD STUDS WITH GWB ON INSIDE, WOOD SIDING ON OUTSIDE	1			
38	2 LAYERS 3/8" GWB, 2” by 4” STUDS @ 16" OC, 1116 STEEL STUDS @ 16" OC, 1/8" MILD STEEL		7		
39	10 GA HARDENED STEEL, 3/4" PLYWOOD,10 GA HARDENED STEEL, 3/4" PLYWOOD, 10 GA HARDENED STEEL	12			
40	1/4" STEEL PLATE, 20 GA ROOF DECK 3", SILICATE FOAM 3", 1" PLYWOOD SHEATHING		12		<1*
41	2 LAYERS 3/8" GWB, 2” by 4” STUDS @ 16" OC, #l7 STEEL STUDS @ 16" OC, 1/4" MILD STEEL		13		1
42	9 GA HARDENED STEEL, 3/4" PLYWOOD, 9 GA HARDENED STEEL	14			5
43	10 GA HARDENED STEEL, #90 ROOF MATERIAL, 3/4" PLYWOOD, 10 GA HARDENED STEEL	20			
44	1/2" STUCCO, CHICKEN WIRE, TAR PAPER, 2” by 4” STUDS @ 16" OC, 1/2" Gypsum Wall Board (GWB)	1			
45	2” by 4” STUDS CONTINUOUS WITH 2” WOOD SIDING (TOTAL 6” THICKNESS NOMINAL)		5		
46	1-1/2" BEVELED CEDAR SIDING, FELT, l by 6 SHEATHING, 2” by 4” STUDS 16" OC, 3/8" GWB, 11 GA WOVEN WIRE 2” by 4” (6 LAYERS), FERROCEMENT 4"	5			
47	1-1/2" BEVELED CEDAR SIDING, FELT, l by 6 SHEATHING, 2” by 4” STUDS 16" OC, 3/8" GWB, 3/4" PLYWOOD, 1/6" SHEET METAL		10		
48	1-1/2" BEVELED CEDAR SIDING, FELT, lx6 SHEATHING, 2” by 4” STUDS 16" OC, 3/8" GWB, 3/4" PLYWOOD, #9 EXPANDED METAL 3/4”, 3/4" PLYWOOD			5	

ITEM NUMBER	WALL MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
49	4-INCH, SOLID-CORE, FILLED AND REINFORCED MASONRY CONSTRUCTION WITH INTERIOR WALL SYSTEM	1	1	1	
50	8-INCH, SOLID-CORE, FILLED CONCRETE MASONRY WITH #3 BARS AT 8 INCHES OC EW	5			1
51	8-INCH, SOLID-CORE, FILLED CONCRETE MASONRY WITH #5 BARS AT 8 INCHES OC EW		5		
52	8-INCH, MORTAR-FILLED CONCRETE BLOCK WITH #6 BARS AT 8 INCHES OC EW	15			
53	8-INCH, REINFORCED CONCRETE WITH # 4 BARS AT 6 INCHES OC EW		15		
54	12-INCH, MORTAR-FILLED, CONCRETE BLOCK WITH #6 BARS AT 8 INCHES OC EW	30			
55	8-INCH, SOLID-CORE, FILLED CONCRETE MASONRY WITH #6 BARS AT 4 INCHES OC VERTICALLY AND 8 INCHES OC HORIZONTALLY			5	
56	12-INCH, REINFORCED CONCRETE WITH # 5 BARS AT 6 INCHES OC EW			15	
57	12-INCH, REINFORCED CONCRETE WITH 2 LAYERS OF # 7 BARS AT 4 INCHES OC EW		30		
58	12-INCH, REINFORCED CONCRETE WITH 5/16 EXPANDED METAL 2½ INCHES OC (4 LAYERS)				5
59	12-INCH, REINFORCED CONCRETE WITH 5/16-INCH, EXPANDED, METAL MESH AT 2½ INCHES OC AND A ¼-INCH BACKING PLATE			30	15
60	18-INCH-THICK REINFORCED CONCRETE WITH 5/16-INCH EXPANDED METAL AT 2- 1/2 INCHES OC AND A 1/4-INCH BACKING PLATE				30

NOTES: For the use of the above table, refer to Paragraph 5-4.
Where not specified in the table, use 3000 psi concrete.

5-5.2 Roofs.

Conventional roof construction offers little resistance to downward forced entry attack, except where reinforced concrete slabs form the structure.

5-5.2.1 Roofs to Resist Threat Severity Level II.

Solid plywood roof construction provides a delay of less than one minute against threat severity level II. Since greater delay is required, use one of the roof types shown in Table 5-5.

5-5.2.2 Roofs to Resist Threat Severity Levels III and IV.

Protection against threat severity levels III and IV requires the use of conventional or fiber reinforced concrete. Use one of the concrete thickness options in Figure 5-2 and Figure 5-3 combined with the reinforcing bar options in Table 5-2 for roof designs; however, for a downward attack on a roof, penetration delay times are lower for a similar attack on a wall; therefore, to achieve the same delay rating, use an additional thickness of 1-inch (25-mm) concrete, or the same concrete thickness and increase the reinforcement by 2 bar sizes.

Table 5-5 contains several additional design options that provide delays from 2 to 30 minutes.

5-5.2.3 Roofs to Resist Threat Severity Level V.

Threat severity level V requires sacrificial areas, multiple barriers, or massive reinforced concrete. For the reinforced concrete design, use one of the options in Table 5-5 with entries for the threat severity level V.

Sacrificial barriers can be employed above the protected area in the building. The features of these sacrificial areas may be damaged but will provide cumulative delay created by the necessity to breach multiple barriers, transport breaching tools through each barrier, and retreat to a safe distance before the next barrier is breached. Any type of construction for the sacrificial barrier is acceptable if the barrier provides an equivalent level of penetration resistance to lower threat severity levels.

Table 5-5 Roof Materials

ITEM NUMBER	ROOF MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
1	GRAVEL ON ASPHALT, 2" INSULATION ON 2-1/2" CONCRETE	3			
2	5-1/2" CONCRETE, #4 REIFORCING BARS 8" by 12" OC			13	
3	GRAVEL ON ASPHALT, 2" INSULATION ON 2" CONCRETE ON 6' by 24" PRECAST SINGLE T-BEAM	4	4		
4	GRAVEL ON ASPHALT, 3" CONCRETE, 2" INSULATION ON 6' by 24" PRECAST SINGLE T-BEAM WITH 2"-4" TAPER	4	4	3	
5	20 GA SHEET METAL ON 3/4" FIBERGLASS INSULATION	2	2		
6	24 GA SHEET METAL, 1-1/2" FIBERGLASS INSULATION ON 1/8" STEEL MESH 8" BELOW SHEET METAL			2	
7	24 GA SHEET METAL, 1-1/2" FIBERGLASS INSULATION ON 1/8" STEEL WIRE BELOW SHEET METAL	2	2		
8	GRAVEL ON ASPHALT, 2" INSULATION ON 16 GA SHEET METAL	3			
9	GRAVEL ON ASPHALT, 2" INSULATION ON 22 GA SHEET METAL, WITH 12" STEEL MESH BELOW' SHEET METAL			6	
10	GRAVEL ON ASPHALT, 2" INSULATION ON 22 GA SHEET METAL		7	3	
11	GRAVEL ON ASPHALT, 2" INSULATION ON 4" 3500 PSI CONCRETE WITH #4 REINFORCING BARS @ 6" OC EW, 22 GA SHEET METAL		29		
12	GRAVEL ON ASPHALT, 2" INSULATION ON 4" 3500 PSI CONCRETE WITH #4 REINFORCING BARS 6" OC ONE WAY, EXPANDED METAL ON 22 GA SHEET METAL		26		
13	GRAVEL ON ASPHALT, 2" INSULATION ON 2-1/2" CONCRETE WITH 10 GA 6" by 6" WOVEN WIRE FABRIC ON 22 GA SHEET METAL		15		
14	GRAVEL ON ASPHALT, 2" INSULATION ON 2-1/2" CONCRETE WITH 10 GA 6" by 6" WOVEN WIRE FABRIC ON 22 GA SHEET METAL DECK WITH SCREEN MESH 8" BELOW SHEET METAL		10		
15	GRAVEL ON ASPHALT, 2" INSULATION ON 2-1/2" CONCRETE WITH 10 GA 6" by 6" WOVEN WIRE FABRIC ON 22 GA SHEET METAL DECK YITH SCREEN MESH 12" BELOW SHEET METAL	5	5		

ITEM NUMBER	ROOF MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
16	GRAVEL ON ASPHALT, 2" INSULATION ON 2" CONCRETE OVER #4 6" EXPANDED METAL ON 6” by 24" PRECAST SINGLE T-BEAM	5			
17	GRAVEL ON ASPHALT, 2" INSULATION ON 2" CONCRETE ON 16 GA SHEET METAL	4	4	4	
18	BUILT-UP ROOF WITH GRAVEL AND RIGID INSULATION ON STEEL DECKING	5	1	1	
19	BUILT-UP ROOF WITH GRAVEL AND RIGID INSULATION AND 4-INCH LIGHTWEIGHT CONCRETE WITH #5 BARS AT 8 INCHES OC EW ON STEEL DECKING				1*
20	4-INCH, REINFORCED CONCRETE WITH 6 BY 6 WELDED WIRE MESH, 10-GAGE REINFORCING ON STEEL DECKING AND A BUILT-UP ROOFING SYSTEM		5		
21	6-INCH, REINFORCED CONCRETE WITH #4 BARS AT 8 INCHES ON CENTER EACH WAY ON STEEL DECKING AND WITH BUILT-UP ROOFING	15			
22	6-INCH, REINFORCED CONCRETE WITH # 4 BARS AT 6 INCHES ON CENTER EACH WAY ON STEEL DECKING AND WITH A BUILT-UP ROOFING SYSTEM		15		
23	8-INCH, REINFORCED CONCRETE WITH #4 BARS AT 8 INCHES ON CENTER EACH WAY ON STEEL DECKING AND WITH BUILT-UP ROOFING	30			
24	6-INCH, REINFORCED CONCRETE WITH 6 BY 6 WELDED WIRE MESH, 10-GAGE REINFORCING ON STEEL DECKING AND A BUILT-UP ROOFING SYSTEM			5	
25	10-INCH, REINFORCED CONCRETE WITH # 5 BARS AT 6 INCHES ON CENTER EACH WAY ON STEEL DECKING AND WITH A BUILT-UP ROOF			15	
26	10-INCH, REINFORCED CONCRETE WITH 2 LAYERS OF #5 BARS AT 6 INCHES ON CENTER EACH WAY ON STEEL DECKING AND WITH A BUILT-UP ROOFING SYSTEM		30	30	5*
27	10-INCH, REINFORCED CONCRETE WITH 5/16 EXPANDED METAL 2½ INCHES ON CENTER ON STEEL DECKING WITH A BUILT-UP ROOFING SYSTEM				15*

ITEM NUMBER	ROOF MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
28	12-INCH-THICK, REINFORCED CONCRETE WITH 5/16-INCH EXPANDED METAL AT 2½ INCHES ON CENTER, ¼-INCH STEEL DECKING, AND BUILT-UP ROOFING				30*

NOTES: For the use of the above table, refer to Paragraph 5-4.
Where not specified in the table, use 3000 psi concrete.

5-5.2.4 Roof-Mounted Equipment.

Roof-mounted equipment, such as air-supply fans, exhaust fans, gravity ventilators, and filter banks, are usually welded or bolted to an equipment curb, duct system, or foundation and can be removed with simple hand tools. Openings uncovered when equipment is removed can provide entry to the interior of the building. In many installations, the removal of a small number of bolts, plus the removal of the equipment, can provide access. For protection of an exposed opening consider on the following alternatives:

- When possible, limit the exposed opening to less than 96 square inches (619 cm^2) with no dimension greater than 6 inches (150 mm).
- Provide grilles constructed of metal bars to provide delay. See Table 5-21 for the size and spacing of bars for the defense layer penetration delay time.
- Provide a hardened equipment cover to house the machinery. Equipment cover penetration delay time will depend on structural components, doors, and other openings. Specific penetration delay times can be estimated by the same methods described for structures throughout this manual. The use of the equipment cover option must be weighed against the probability, likelihood, and logistics involved with removal of the roof-mounted equipment.

5-5.2.5 Structural Openings.

Structural openings, such as skylights, roof hatches, scuttles, elevator shafts, ash dumps, rubbish chutes, fire escapes, and roof access ladders, offer access to aggressors and should be considered in hardening plans. The approach to upgrading miscellaneous openings is dictated by the structural elements involved (design of walls, roofs, doors, and locking mechanisms).

5-5.2.6 Other Openings.

Secure all hatches, penthouses, and exterior ladders.

5-5.2.7 Roof Styles and Railings.

Use steeply pitched roof structures where possible to make movement difficult and to minimize concealment opportunities provided by flat roofs.

For flat roofs, use railings instead of solid parapets to minimize concealment opportunities.

5-5.3 Ceilings and Floors.

Floor and ceiling assemblies are the horizontal (top and bottom) components of the 6-sided intermediate defense layers. Floors may be exposed to exterior forced entry if the asset is in the space above the floor and the aggressors gain access to the space below; and, ceilings may be exposed to forced entry if the asset is in the space below the ceiling and the aggressors gain access to the space above. Select floor and ceiling construction which provides the required delay time where applicable.

5-5.3.1 Ceilings and Floors to Resist Threat Severity Level II.

Conventional construction of 3/4 inch (19 mm) plywood on wood joists for ceilings and floors can be used to provide the required one minute of penetration delay.

5-5.3.2 Ceilings and Floors to Resist Threat Severity Levels III and IV.

Threat severity levels III and IV necessitate the use of conventional or fiber reinforced concrete. Use one of the concrete thickness options in Figure 5-2 and Figure 5-3 combined with the reinforcing bar options in Table 5-2 for ceiling and floor designs. Table 5-6 contains several additional design options that provide delays from 2 to 30 minutes.

In general, for reinforced concrete walls less than 12 inches (30 cm) thick, the following rules of thumb for companion ceilings will apply. Penetration delay times for an upward attack on a ceiling (floor of upper level) will be higher than the same attack on a wall; therefore, use the next lowest thickness of 1-inch (25-mm) concrete or use the same concrete thickness and decrease the reinforcement by 2 bar sizes. For a downward attack on a roof, penetration delay times are lower for a similar attack on a wall; therefore, to achieve the same delay rating, use an additional thickness of 1-inch (25-mm) concrete, or the same concrete thickness and increase the reinforcement by 2 bar sizes.

5-5.3.3 Ceilings and Floors to Resist Threat Severity Level V.

Thick, heavily reinforced concrete ceilings and floors can provide significant penetration resistance. Use reinforced concrete 18 to 48 inches (0.46 to 1.2 m) thick. Table 5-3 presents the estimated minimum penetration delay times provided by varied thicknesses of reinforced concrete that has a compressive strength of at least 5,000 psi (507,000 kPa). Table 5-6 provides options that can be considered based on structural and cost considerations.

Table 5-6 Floor or Ceiling Materials

ITEM NUMBER	FLOOR OR CEILING MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
1	PLYWOOD ON WOOD JOISTS	1	1	1	1
2	PLYWOOD ON WOOD JOISTS W/INSULATION	1		1	<1*
3	4-1/2" REINFORCED CONCRETE (#4 BARS @ 18" EW) AND 16 GA SHEET METAL	6			2*
4	5-1/2" REINFORCED CONCRETE (10 GA STEEL MESH)	6			
5	8" REINFORCED CONCRETE (#4 BARS @ 9" EW)			12	11/<2*
6	12" REINFORCED CONCRETE (#5 BARS @ 6" EW, EF)			23	22/<3*
7	3" CONCRETE, #10 6" STEEL MESH, 2-1/2" CONCRETE PLANK	6		2	
8	CARPET, 1-1/2" PLYWOOD, 3" SILICATE INSULATION		5	1	<1*

NOTES: For the use of the above table, refer to Paragraph 5-4.
Where not specified in the table, use 3000 psi concrete.

5-5.3.4 Slabs on Grade.

Use minimum 6-inch thick reinforced concrete with #4 bars (1/2-inch, 13 mm) reinforcing bars spaced at 6 inches OC, EW.

5-5.4 Personnel Entrances.

The number of entrances to a defense layer should be limited to one personnel entrance and the minimum number of emergency exit doors required for life safety per National Fire Protection Association (NFPA) 101.

5-5.4.1 Specifying Door Assemblies.

When specifying door assemblies, ensure that the threat severity level and required penetration delay time is included. Refer to UFGS-08 34 63 for design and installation requirements.

5-5.4.2 Personnel Entrances to Resist Threat Severity Level II.

Use doors and frames that are built and installed according to National Association of Architectural Metal Manufacturers/ Hollow Metal Manufacturers Association (NAAMM/HMMA) Hollow Metal Manual standards. Doors and frames meeting these requirements will provide at least a 1-minute penetration delay time against a threat severity level II. If more delay time is needed, use multiple doors placed in series.

Personnel door and frame details for severity threat level II are shown in Table 5-7 and Table 5-8. The frame is designed for installation in a wood-stud frame wall. Hinge-side protection should be provided as shown in Figure 5-4.

Table 5-7 Personnel Door Panel/Edge Details, Threat Severity Level II

COMPONENT	REQUIREMENT
Size	3 feet by 80 inches by 1-3/4 inches (0.9 m by 2 m by 44 mm).
Applicable Specifications	NAAMM/HMMA, Hollow Metal Manual – 1995., UFGS-08 34 01.
Type	Type A, full-flush with continuous welded-edge seams. Design F, full-panel flush door.
Panel	Steel-stiffened.
Face Sheet	16-gauge (1.6 mm) steel.
Stiffeners	Hat section, 16-gauge (1.6 mm) steel; maximum distance between stiffeners 4 inches (100 mm) OC.
Edge Construction	14-gauge (1.9 mm) steel channel, recessed.

Table 5-8 Personnel Doorframe Details, Threat Severity Level II

COMPONENT	REQUIREMENT
Applicable Specifications	Construct per NAAMM/HMMA, Hollow Metal Manual – 1995 except as noted, UFGS-08 34 01.
Frame Design	Single door, butt-type, double-rabbet type; 14-gauge (1.9 mm) steel, fully welded.
Jamb Depth	4 inches (100 mm).
Special Features	(See Figure 5-4 for hinge side protection.)
Frame Installation	Install per NAAMM/HMMA, Hollow Metal Manual – 1995. Install frame into a wood-stud frame wall.
Hardware Preparation	Prepare hardware per NAAMM/HMMA, Hollow Metal Manual – 1995.

Table 5-9 Door Hardware for Threat Severity Levels II and III

COMPONENT	REQUIREMENT
Mortise Lock	American National Standards Institute/Building Hardware Manufacturers Association (ANSI/BHMA) A156.13 Series 1000 Security Grade, with dead bolt and latch bolt.
Auxiliary Rim Lock	ANSI/BHMA A156.5, Security Grade drop bolt lock operated by key from inside and outside. Lock selected must conform to mounting bolt tensile test [12,000 pounds (5,450 kg)]. This lock should be used in conjunction with anti-wedge and anti-drill plates. To comply with life safety requirements, this lock should only be used during those hours when the space is unoccupied.
Hinges	ANSI/BHMA A156.1. Heavy Weight. Note: security door systems for threat severity level III require some form of hinge side protection. Some hinge manufacturers provide this type of protection in the form of shear plugs incorporated into the hinge or hinge pins that are not removable. If these types of hinges are not used, then some form of hinge side protection should be engineered into the door system. For added protection against door sag, surface-mounted continuous hinges can be used.
Panic Hardware	American Society for Testing and Materials (ASTM) F571, Grade 1, Mortise exit device. Use panic type exit devices as required by life safety codes in lieu of this mortise lock; however, to ensure resistance to threat severity level III, use in conjunction with an auxiliary rim lock.
Other Hardware	If the use of additional hardware such as closing devices and electric strikes, among others, is required, ensure that the hardware selected meets ANSI/BHMA requirements, and does not interfere with the security devices on the door systems. Consult with the DoD Lock Program, NAVFAC Engineering and Expeditionary Warfare Center, Toll Free: (800) 290-7607 Comm: (805) 982-1212, if there are any questions.

5-5.4.3 Personnel Entrances to Resist Threat Severity Level III.

Use doors and frames that are built and installed according to ANSI/NAAMM HMMA 863-14. Doors and frames meeting these requirements will provide at least a 4-minute penetration delay time against threat severity level III. If more delay time is needed, use multiple doors placed in series.

Personnel door and frame details for threat severity level III are shown in Table 5-10 and Table 5-11. The frame is designed for installation in a reinforced CMU wall. Hinge-side protection should be provided as shown in Figure 5-4.

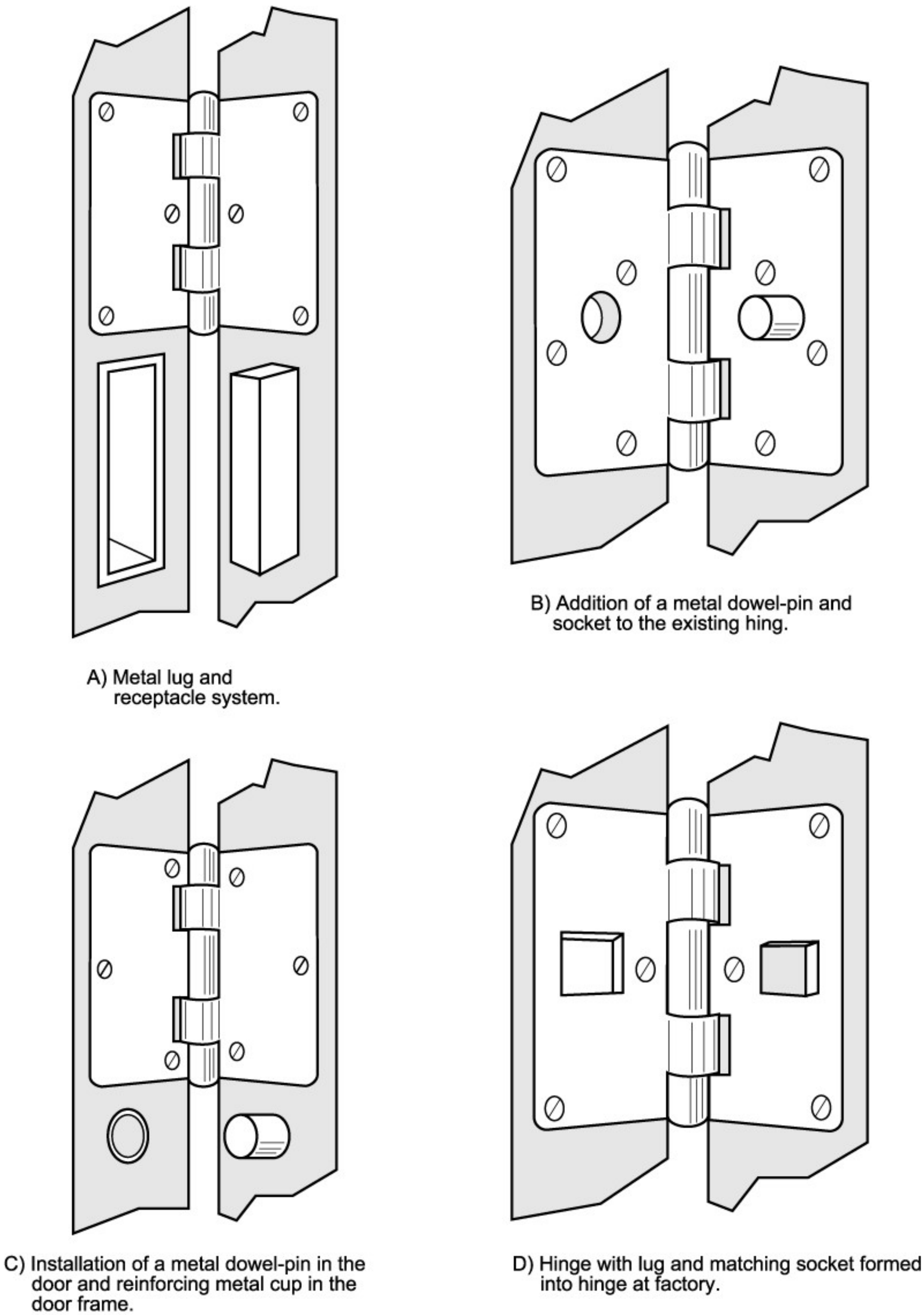
Table 5-10 Door Panel/Edge Details for Threat Severity Level III

COMPONENT	REQUIREMENT
Size	3 feet by 80 inches by 1-3/4 inches (0.9 m by 2 m by 44 mm).
Applicable Specifications	ANSI/NAAMM HMMA 863-14.
Type	Type A, full flush with continuous welded-edge seams. Design F, full-panel flush door.
Panel	Steel-stiffened.
Face Sheet	14-gauge (1.9 mm) steel.
Stiffeners	Hat section, 14-gauge (1.9 mm) steel; maximum distance between stiffeners 4 inches (100 mm) OC.
Edge Construction	12-gauge (2.7 mm) recessed steel channel.
Special Features	(See Figure 5-4 for the hinge side protection configuration and Figure 5-5 for the 7-gauge (4.5 mm) anti-pry strips).

Table 5-11 Doorframe Details for Threat Severity Level III

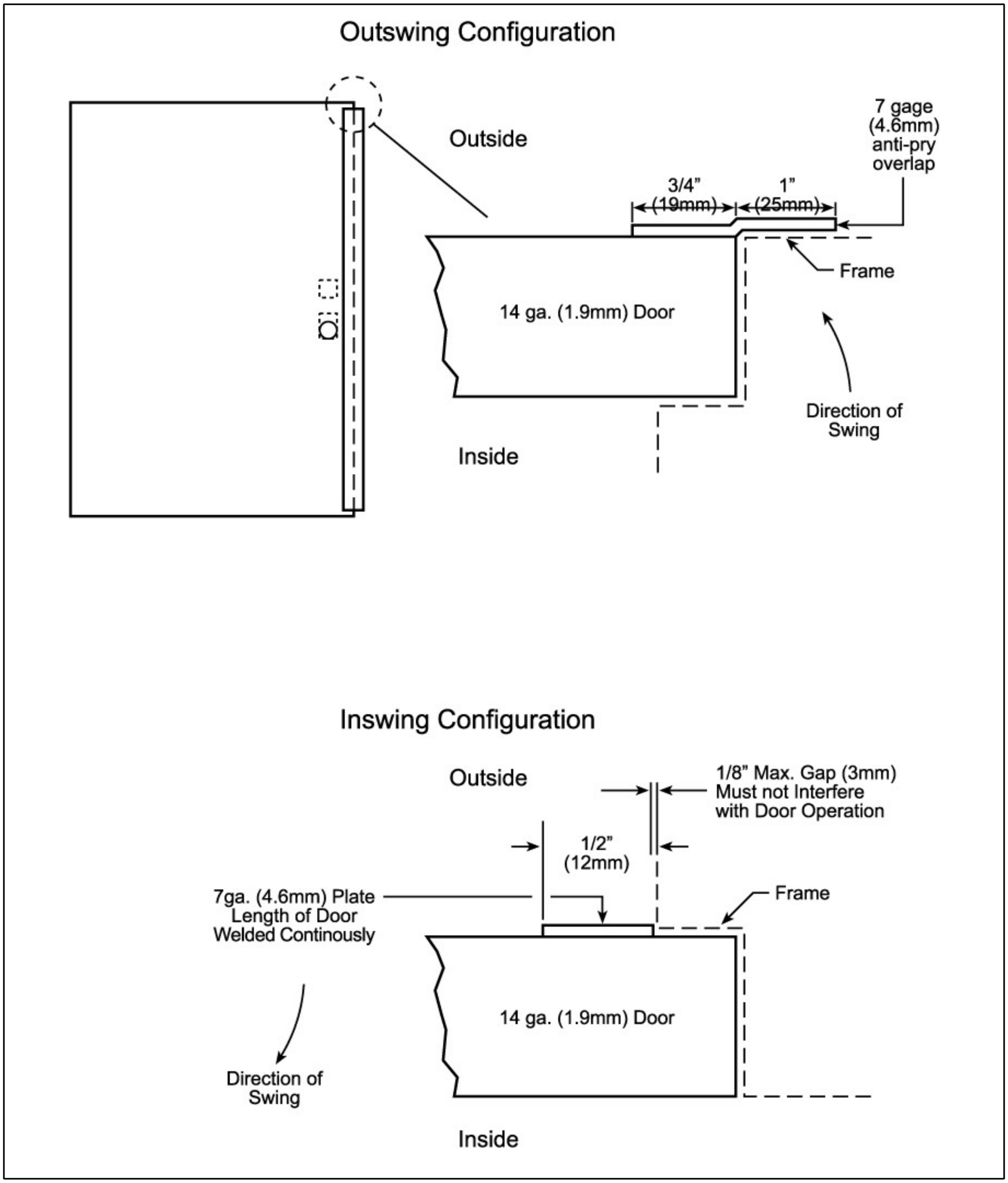
COMPONENT	REQUIREMENT
Frame Thickness	12 gauge (2.7 mm)
Applicable Specifications	Construct per HMMA 863-14 except as noted.
Frame Design	Single door, butt-type, double-rabbet type; 10-gauge (3.4 mm) steel, fully welded.
Jamb Depth	8 inches (200 mm)
Special Features	(See Figure 5-4 for details on hinge-side protection.)
Frame Installation	Install per HMMA 863-14 and NAAMM HMMA, Hollow Metal Manual
Hardware Preparation	Prepare for hardware per HMMA 863-14. Use one of the two cases below for selecting installation hardware: Frame to be installed in a CMU wall with the frame installed and the wall built to the frame. Provide adjustable 2- by 10-inch (50- by 254-mm) corrugated 12-gauge (2.7 mm) frame side. Ensure that the reinforcing bars of the CMU wall tie into the interior of the frame. Fill frame with a grout of compressive strength not less than 3,000 psi (21,000 kPa). Frame is to be installed in a prepared opening in a CMU wall. Frame must be punched and countersunk for expansion bolt anchors (four per side) and provided with 12-gauge (2.7 mm) hat shaped reinforcements secured in place with at least four spot welds each. Fill frame with a pour type grout with a compressive strength of not less than 3,000 psi (21,000 kPa).

Figure 5-4 Door Hinge-Side Protection Threat Severity Levels II and III



Note: Lugs, dowel-pins, etc. should be 1-inch-diameter (25.4mm) minimum.

Figure 5-5 Door Anti-Pry Strips for Threat Severity Level III



5-5.4.4 Personnel Entrances to Resist Threat Severity Levels IV and V.

There are no personnel doors rated to resist threat severity levels IV and V. Use multiple threat severity level III personnel doors mounted in series or use a vault door. Consider using a day gate during daytime operations.

5-5.5 Doors (Non-Entry).

The number of doors needed to secure a defense layer should be minimized. In cases where more than one door exists, only one (personnel entrance) should be provided with exterior mounted locks. All other non-entry doors to the defense layer must present blank, flush surfaces to the outside and have internal locking or bolting mechanisms to reduce the vulnerability to attack.

5-5.5.1 Door Panel Construction (Non-Entry).

Table 5-12 shows options for door panel construction to resist all threat severity levels. Although the penetration delay time through the door surface can usually be increased by use of thicker or composite materials, such hardening may be constrained by weight, functional requirements (disability access requirements or safety), mounting hardware, or locking system vulnerability. There is no value in hardening a door surface beyond the attack resistance of the available mounting hardware and locking system technology.

Table 5-12 Door Materials

ITEM NUMBER	DOOR MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
1	2 LAYERS 10 GA HOT-ROLLED STEEL, 1 LAYER 3/4" EXTERIOR PLYWOOD	6			
2	3 LAYERS 10 GA HOT-ROLLED STEEL, 2 LAYERS 3/4" EXTERIOR PLYWOOD	12			
3	2 LAYERS 9 GA ASTM A1008 HARDENED STEEL, 1 LAYER 3/4" EXTERIOR PLYWOOD	14			
4	2-LAYERS 9 GA ASTM A1008 HARDENED STEEL, 1 LAYER 3/4" EXTERIOR PLYWOOD, 2 LAYERS OF 90- LB GRAVEL FINISH ROOF PAPER	20			
5	9 LAYERS 3/4" PLYWOOD, 8 LAYERS 10 GA 27 STEEL PLATE	27			

ITEM NUMBER	DOOR MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
6	3 LAYERS 10 GA ASTM A1008 HARDENED STEEL, 2 LAYERS 1/2" ACRYLIC (TOTAL THICKNESS 1-1/4")	20			
7	3 LAYERS 10 GA ASTM A1008 STEEL, 2 LAYERS 1/2" POLYCARBONATE GLAZING	20			
8	2 LAYERS 1/4" HARDENED STEEL, 2 LAYERS URETHANE FOAM 3", 1/4" PERFORATED STEEL PLATE, 1-1/2" OAK				16/<1*
9	1/4" TYPE 304 STAINLESS STEEL PLATE, 1/2" POLYCARBONATE, 10 GA ASTM A1008 STEEL SHEET (TOTAL THICKNESS 0.88")	11			
10	1/2" HARDENED STEEL, 1-1/4" OAK, l/2" PLWOOD, 1/4" HARDENED STEEL (2 LAYERS)				12/<1*
11	3/8" STEEL, 3" REDWOOD, 0.036" STEEL	6			
12	3/8" A-36 STEEL PLATE (2 LAYERS), 4" POLYURETHANE FOAM, 3" OAK				18/<1*
13	3/8" A-36 STEEL PLATE (2 LAYERS), 4" SILICATE FOAM, 3" OAK				23/<1*
14	3/8" A-36 STEEL PLATE (2 LAYERS), POLYURETHANE FOAM 2.125, 1/4" PERFORATED STEEL PLATE, 2-1/2" OAK				17/<1*
15	3/8" A-36 STEEL PLATE (2 LAYERS), 3" OAK, 4" SILICATE FOAM				19/<1*
16	5/16" STEEL PLATE, 1" INSULATION, 22 GA SHEET METAL (2 LAYERS)				3/<1*
17	CLASS 5 VAULT DOOR	4			2
18	1/4" STEEL PLATE, PADLOCK	2	2		2/<1*
19	3/4" STEEL PLATE, 3" RIGID INSULATION, 1/8" STEEL PLATE	2			4/<1*
20	3/4" STEEL PLATE, 1/4" STEEL PLATE		10		4
21	3/4" STEEL PLATE, 3" REDWOOD IN CENTER, 1/4" STEEL PLATE		26		17
22	3/8" DRILL-RESISTANT STEEL, GSA CLASS 6 VAULT DOOR		22		
23	3/8" STEEL PLATE, 1/4" STEEL PLATE		14		4/<1*

ITEM NUMBER	DOOR MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
24	3/8" STEEL PLATE, .036" (20 GA) STEEL PLATE, 2 PADLOCKS	1		1	
25	16 GA SHEET METAL, PANIC HARDWARE, FULL SURFACE HINGE	2	2		2/<1*
26	16 GA SHEET METAL, PANIC HARDWARE, PANIC BAR PLATE, CYLINDER LOCK, BUTT HINGE, NONREMOVABLE PINS, HINGE Z STRIP, FRONT PRY STRIP	2			
27	STANDARD INDUSTRIAL VEHICLE DOOR 16 GA CORRUGATED SHEET METAL ROLL-UP	1			1*
28	STANDARD INDUSTRIAL VEHICLE DOOR, HOLLOW STEEL PANEL, 16 GA	1			<1*
29	CLASS FS FILING CABINET DRAWER			4	
30	16 GA HOLLOW STEEL	2			
31	STANDARD 16-GAGE, HOLLOW, METAL DOOR (3 FEET BY 7 FEET) WITH HINGE-SIDE PROTECTION, ANTI-PRY STRIP, AND DRILL-RESISTANT DEAD BOLT LOCK	5	1	1	1
32	12-GAGE, HOLLOW, METAL DOOR (3 FEET BY 7 FEET) WITH HINGE-SIDE PROTECTION, ANTI-PRY STRIP, AND DRILL-RESISTANT DEAD BOLT LOCK		5		
33	12-GAGE, HOLLOW, METAL DOOR WITH HINGE-SIDE PROTECTION, ANTI-PRY STRIP, DRILL-RESISTANT DEAD BOLT LOCK, AND FILLED WITH LIGHTWEIGHT FIREPROOFING			5	
34	12-GAGE, HOLLOW, METAL DOOR FILLED WITH LIGHTWEIGHT CONCRETE (3 FEET BY 7 FEET) WITH HINGE-SIDE PROTECTION, ANTI-PRY STRIP, AND DRILL-RESISTANT DEAD BOLT LOCK	15			
35	12-GAGE, HOLLOW, METAL DOOR (3 FEET BY 7 FEET) WITH HINGE-SIDE PROTECTION, ANTI-PRY STRIP, DRILL-RESISTANT DEAD BOLT LOCK, AND MULTIPOINT (3) LOCKING SYSTEM	30			
36	SWINGING DOOR (6 INCHES THICK) WITH 1/2-INCH PLATE INSIDE AND OUT, LIGHTWEIGHT CONCRETE FILL, AND AN INTERNAL LOCKING SYSTEM		30		

ITEM NUMBER	DOOR MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
37	SLIDING DOOR (6 INCHES THICK) FILLED WITH LIGHTWEIGHT CONCRETE THAT HAS BEEN REINFORCED WITH EXPANDED METAL MESH WITH A 3/4-INCH STEEL FRONT PLATE, 1/4–INCH BACK PLATE, AND AN INTERNAL LOCKING SYSTEM				5
38	SWINGING DOOR (10 INCHES THICK) WITH 1/2-INCH PLATE INSIDE AND OUT INTERNAL LOCK		15		
39	SWINGING DOOR (10 INCHES THICK) WITH 1/2-INCH PLATE INSIDE AND OUT, LIGHTWEIGHT CONCRETE FILL, AND AN INTERNAL LOCKING SYSTEM			15	
40	SWINGING DOOR (10 INCHES THICK) WITH 1/2-INCH PLATE INSIDE AND OUT, LIGHTWEIGHT CONCRETE FILL REINFORCED WITH EXPANDED METAL MESH, AND AN INTERNAL LOCKING SYSTEM			30	15
41	SWINGING DOOR (10 INCHES THICK) WITH 1/2-INCH PLATE INSIDE AND OUT, LIGHTWEIGHT CONCRETE FILL REINFORCED WITH EXPANDED METAL MESH, AND AN INTERNAL LOCKING SYSTEM WITH A WELDED C-STEEL GRATING VESTIBULE AROUND THE DOOR FOR STANDOFF PROTECTION				30

NOTE: For the use of the above table, refer to Paragraph 5-4.

5-5.6 Emergency Exit Hardware.

When the area is to be occupied and emergency exit hardware is required for fire protection requirements, use a light industrial door with an intrusion sensor and provide forced entry resistance interior to the door.

Since drilling a small hole large enough to pass a wire hook through is all that is required to trip emergency exit hardware, for unoccupied areas, auxiliary rim locks or mortise locks can be used to secure the doors.

5-5.7 Vehicle Access Doors.

Table 5-13 provides a summary of the door construction choices applicable to vehicle access doors for the threat severity levels II and III. There are no commercial vehicle access doors available that will provide penetration resistance equivalent to wall systems designed for threat severity threat level IV or V. If used for threat severity level IV or V, consider separating vehicle access areas from the protected asset. In this configuration delay time calculations may be layered beginning at the barrier system beyond the vehicle storage area and the vehicle storage area can be used as a detection buffer for the secure area.

5-5.7.1 Threat Severity Level II.

For threat severity level II, use a standard 18-gauge (1.2-mm) galvanized steel overhead coiling door with interlocking slats. Refer to UFGS-08 33 23 for installation details.

5-5.7.2 Threat Severity Level III.

For threat severity level III, use a 1-3/4-inch (44-mm) thick hollow metal door with 12-gauge (2.7-mm) skins and stiffeners on 6-inch (150-mm) vertical spacing similar to a sliding magazine door. Refer to UFC 4-420-01 for designs.

The trailing edge of the sliding magazine door must be restrained using a 4-foot (1.2-m) high, 8-inch (20-cm) diameter concrete filled steel bollard along the outside trailing edge to prevent wedging attacks that move doors away from walls.

Table 5-13 Vehicle Access Door Construction

THREAT SEVERITY LEVEL	CONSTRUCTION	PENETRATION DELAY TIME (MINUTES)
II	18-gauge (1.2-mm) galvanized steel with interlocking slats.	1
III	1-3/4-inch (44-mm) thick hollow metal door with 12-gauge (2.7-mm) skins and stiffeners on 6-inch (150-mm) vertical spacing.	4

5-5.8 Windows.

Because forced entry resistant window enhancements are costly, minimize windows where possible in defense layers that are counted on for penetration delay. Security glazing systems are commercially available that will meet the requirements for threat severity levels II, III, and IV (up to 5 minutes of delay). There are no cost-effective glazing cross sections available for threat severity levels V. For commercially available windows use the anchoring method prescribed by the window certification.

Consider the placement of windows in relation to doors. Even a small window in or next to a door could allow an aggressor to reach through and unlock the door. Use obscured glazing materials, blinds, shutters, or drapes to eliminate asset visibility.

5-5.8.1 Specifying Window Assemblies.

When specifying window assemblies, ensure that the threat severity level and required penetration delay time is included.

5-5.8.2 Windows to Resist Threat Severity Level II.

Glazing, frame, and anchor designs for windows to resist threat severity level II are provided in Table 5-14 through Table 5-16 for one minute of penetration delay. These designs are for installation in a wood frame wall. Other options for window components are available in Table 5-20.

Table 5-14 Glazing Specifications - Threat Severity Level II

TYPE	MINIMUM THICKNESS	CROSS-SECTION
Air Gap	1 inch (25 mm)	1/4 inch (6 mm) Laminated Annealed Glass, 1/4 inch (6 mm) AIR, 1/2 inch (13 mm) Laminated Polycarbonate
Extruded Ionomer	13/16 inch (20 mm)	3/16 inch (5 mm) Annealed Glass, 1/2 inch (13 mm) extruded IONOMER, 1/8 inch (3 mm) Annealed Glass
Glass-Clad Polycarbonate	11/16 inch (17 mm)	3/16 inch (5 mm) Annealed Glass, 3/8 inch (10 mm) Polycarbonate, 3/16 inch (5 mm) Annealed Glass
Monolithic Polycarbonate	3/8 inch (10 mm)	3/8 inch (10 mm) Polycarbonate

Table 5-15 Frame Specifications - Threat Severity Level II

COMPONENT	SIZE, INCH (MM)
Minimum Frame Thickness	1/4 inch (6 mm) Steel
Minimum Removable Stop Thickness	3/16 inch (5 mm) Steel
Minimum Bite Depth	1 inch (25 mm)
Minimum Glazing Rabbet Depth	1-1/4 inches (32 mm)
Maximum Width Between Frame Members	42 inches (107 cm)

Table 5-16 Miscellaneous Specifications - Threat Severity Level II

COMPONENT	REQUIREMENTS	
Anchor Lag Bolt	Minimum Diameter: 3/8 inch (10 mm)	Minimum Embedment: 3 inches (75 mm)
Lag Bolt Spacing	Frame Corner to Bolt - Maximum Spacing: 9 inches (230 mm)	Between Adjacent Bolts -Maximum Spacing: 18 inches (460 mm)
Removeable Stop Anchorage: Shouldered Bolt	Minimum Size: 3/8 inch (10 mm)	Minimum Number per Side: 2
Removeable Stop Bolt Spacing	Frame Corner to Bolt - Maximum Spacing: 9 inches (230 mm)	Between Adjacent Bolts - Maximum Spacing: 18 inches (460 mm)

5-5.8.3 Windows to Resist Threat Severity Level III.

Glazing, frame, and anchor designs for threat severity level III are provided in Table 5-17 through Table 5-19 for 4 minutes of penetration delay time. These designs are for installation of windows in grout-filled CMU and reinforced concrete walls. Other options for window components are available in Table 5-20.

Table 5-17 Glazing Specifications -Threat Severity Level III

TYPE	MINIMUM THICKNESS	CROSS-SECTION
Air Gap	1-3/4 inches (44 mm)	1/4 inch (6 mm) Laminated Annealed Glass, 1/4 inch (6 mm) AIR, 1-1/8 inches (28 mm) Laminated Polycarbonate
Extruded Ionomer	2-1/8 inches (54 mm)	7/8 inch (22 mm) Laminated Annealed Glass, 1 inch (25 mm) extruded IONOMER, 3/32 inch (4 mm) Annealed Glass
Glass-Clad Polycarbonate	15/16 inch (24 mm)	3/16 inch (5 mm) Strengthened Glass, 1/4 inch (6 mm) Annealed Glass, 3/8 inch (10 mm) Laminated Polycarbonate
Laminated Polycarbonate	1-1/4 inches (32 mm)	1-1/4 inches (32 mm) Laminated Polycarbonate

Table 5-18 Frame Specifications - Threat Severity Level III

COMPONENT	SIZE
Minimum Frame Thickness	1/4 inch (6 mm) Steel
Minimum Removable Stop Thickness	3/16 inch (5 mm) Steel
Minimum Bite Depth	1 inch (25 mm)
Minimum Glazing Rabbet Depth	1-1/4 inches (32 mm)
Maximum Width Between Frame Members	42 inches (107 cm)

Table 5-19 Miscellaneous Specifications - Threat Severity Level III

COMPONENT	REQUIREMENTS	
One-Piece Expansion Sleeve	Minimum Diameter: 1/2 inch (13 mm)	Minimum Embedment: 3 inches (75 mm)
Taper Bolt	Minimum Diameter: 3/8 (10 mm)	Minimum Embedment: 3 inches (75 mm)
Taper Bolt Spacing	Frame Corner to Bolt -Maximum Spacing: 6 inches (150 mm)	Between Adjacent Bolts - Maximum Spacing: 12 inches (300 mm)
Removeable Stop Anchorage: Shouldered Bolt	Minimum Size: 3/8 inch (10 mm)	Minimum Number per Side: 2
Removeable Stop Bolt Spacing	Frame Corner to Bolt -Maximum Spacing: 9 inches (230 mm)	Between Adjacent Bolts - Maximum Spacing: 18 inches (460 mm)

5-5.8.4 Windows to Resist Threat Severity Level IV.

There are few commercially available glazing systems that provide forced entry resistance against threat severity level IV. See Table 5-20 for window component options.

5-5.8.5 Windows to Resist Threat Severity Level V.

There are no commercially available glazing systems that provide forced entry resistance against threat severity level V. When the threat severity is established at level V, windows should be eliminated, sized below the man-passable threshold, or designed as slat windows (long narrow windows less than 6 inches (150 mm) wide).

Table 5-20 Window Materials

ITEM NUMBER	WINDOW MATERIAL DESCRIPTION	THREAT SEVERITY LEVEL			
		II	III	IV	V
1	1/2" POLYCARBONATE GLAZING	3	1		
2	1/4" ACRYLIC IN ALUMINUM FRAME	1	1		
3	1/8" PLATE GLASS, 1/2" A-36 STEEL BARS @ 6" EW		5		
4	1/8" PLATE GLASS, 10 GA STEEL MESH 6" by 6" COVER	2			
5	1/4" LAMINATED GLASS IN ALUMINUM FRAME	2			
6	1/4" WIRE GLASS IN ALUMINUM FRAME	1			
7	1/4" TEMPERED GLASS	1			
8	9/16" LAMINATED GLASS IN ALUMINUM FRAME	2			
9	1/2" ACRYLIC	1			
10	11/16-INCH, GLASS-CLAD WITH 3/8-INCH POLYCARBONATE CORE	1	1	1	
11	13/16-INCH, GLASS-CLAD WITH 1/2-INCH POLYCARBONATE CORE	15	5	5	
12	15/16-INCH, GLASS-CLAD WITH 3/4-INCH POLYCARBONATE CORE	30			

NOTE: For the use of the above table, refer to Paragraph 5-4.

5-5.8.6 Grilles and Grates.

Alternatives to the use of glazing systems may be grilles or gratings over the window openings. Combinations of glazing and grilles can also be used to increase delay time. Note that the use of grilles or grates over windows that can be used as fire exits must comply with the Life Safety Code.

Table 5-21 shows that penetration delay time is directly related to the diameter and spacing of the protective bars. If, for example, No. 5 (16mm) bars are spaced 3 inches (75 mm) apart (both vertically and horizontally) to form a grille, a penetration delay time of about 2.5 minutes can be achieved. When bars are used to delay penetration, properly anchoring them to the wall is critical, since it may be easier to break them loose than to cut them. Bar type grills should only be used with concrete walls, ceilings, roofs, slabs, or CMU walls. They must be embedded at least 6 inches (150 mm) into the wall, welded to a steel frame with concrete anchors, and cast in place during construction.

Table 5-21 Time Required for Making a Man-Passable Opening in Grilles

BAR SIZE	3/8 INCH (10 MM)	1/2 INCH (13 MM)	5/8 INCH (16 MM)	3/4 INCH (19 MM)
SEVERITY THREAT LEVELS II and III			SEVERITY THREAT LEVEL IV	
SPACING	TIME (MINUTES)	TIME (MINUTES)	TIME (MINUTES)	TIME (MINUTES)
3 inches (75 mm)	1.2	1.7	2.5	3.5
3.5 inches (90 mm)	0.8	1.2	1.6	2.3
4 inches (100 mm)	0.8	1.2	1.6	2.3
4.5 inches (115 mm)	0.8	1.2	1.6	2.3
5-9 inches (125-225 mm)	0.4	0.6	0.8	1.2

NOTES: Estimated times are for a single-layer grille composed of steel bars of the diameter shown, equally spaced both horizontally and vertically.

Times shown are total time measured in minutes required to provide a man-passable opening of at least 96-square-inch (619 cm^2) or with a single rectangular dimension greater than 6 inches (15 cm).

All reinforcing bar should be embedded at least 6 inches (15 cm) into the surrounding concrete wall and welded at intersections.

5-5.9 Utility Openings.

Utility openings, manholes, tunnels, air conditioning ducts, filters, or equipment access panels can provide aggressors with an easily accessible entrance or exit route. These passages can also circumvent existing IDS. Such openings must be eliminated or kept below the man-passable 96 square inches (619 cm^2) threshold. For long utility conduits, it is not always necessary to hold to the minimum man-passable threshold. For these cases, the threshold can be increased to 144 square inches (930 cm^2) depending on the configuration of the conduit. Bends in long utility runs effectively impede movement through the conduit. Where exits from a utility conduit (manholes and junction boxes, among others) can be effectively sealed from the secure side, the size of the conduit is immaterial unless direct access to the secure space and bypass of the IDS is possible. Ensure that mechanical designers are aware of any restrictions of utility openings being designed so they can adjust air flow designs to accommodate the restrictions; this is particularly import for HVAC designers.

5-5.9.1 Utility Opening Treatments to Resist Threat Severity Levels II and III.

When it is not feasible to hold to the minimum man-passable 96 square inches (619 cm^2) threshold, use single or multiple gratings or grilles for threat severity levels II and III. Protect man-passable openings with the treatments shown in Table 5-21 and Table 5-22 to provide the indicated delay times. Delay times in the tables are for a single layer.

Table 5-22 Utility Opening Materials

Item Number	Utility Opening Material Description	Threat Severity Level			
		II	III	IV	V
1	1/4" DIAMETER A-36 STEEL BARS 1-1/4" EW	15	7		
2	3/8" DIAMETER A-36 STEEL BARS 1-1/4" EW		8		
3	3/8" HARDENED STEEL BARS @ 4"V 8"H		5	1	
4	1/2" HARDENED STEEL BARS @ 4"V 8"H		5	2	<1
5	1/2" A-36 STEEL BARS @ 4"V 8"H	1	1		<1
6	1/2" A-36 STEEL BARS @ 4"V, 3/8" by 1-1/4" A-36 STEEL BARS @ 8"H	2	2		<1
7	1/2" A-36 STEEL BARS @ 4"V, l/8" by 1-1/2" A-36 STEEL BARS @ 8"H	2	2		<1
8	1/2" HARDENED STEEL BARS @ 6" EW		4	2	<1

Item Number	Utility Opening Material Description	Threat Severity Level			
		II	**III**	**IV**	**V**
9	1/2" A-36 STEEL BARS @ 6" EW		4		<1
10	1/2" A-36 STEEL BARS @ 2-1/4" EW	21	9		
11	7/8" HARDENED STEEL BARS@ 4"V, 3/8" by 2·1/4" HARDENED STEEL BARS @ 8"H		7		<1
12	7/8" A-36 STEEL BARS @ 4"V, 3/8" by 2-l/4" A-36 STEEL BARS @ 8"H		5		<1
13	#5 STEEL WIRE 3/4" EW		6		
14	#8 STEEL WIRE 5/8" EW		6		
15	22 GA SHEET METAL DUCT, DIFFUSER, 1/2" DIAMETER A-36 STEEL BARS 6" EW	3			1*
16	22 GA SHEET METAL DUCT, 36" DIAMETER, 20-FOOT VERTICAL		14		
17	24 GA SHEET METAL DUCT 24" by 24", 8-FOOT HORIZONTAL		6		

NOTE: For the use of the above table, refer to Paragraph 5-4.

5-5.9.2 Utility Opening Treatments to Resist Threat Severity Level IV.

Use grilles constructed with larger size bars (No. 5 (16 mm) or greater) and various constrictive barrier designs for threat severity level IV. Options are shown in Table 5-21.

5-5.9.3 Utility Opening Treatments to Resist Threat Severity Level V.

Threat severity level V requires sacrificial enclosing structures around openings.

5-5.9.4 Special Treatments for Utility Openings.

The following describes typical utility openings and protective design options for hardening them when they cannot be eliminated or sized below the man-passable threshold.

5-5.9.4.1 Sewers and Manholes.

Providing multiple pipes, each less than the man-passable opening threshold, is more desirable than a single large pipe. If a large passageway is required, structural walls, floors, and foundations that are accessible from underground passageways should provide penetration delay times equivalent to the basic structure. Access points from sewer lines into secure structures should be equipped with IDS that can detect intrusion activities. The use of grilles in storm and sanitation systems should be avoided because of the operation and maintenance problems caused by such structures. Where grilles are required on storm sewers, inlet filter screens are highly recommended to prevent clogging.

5-5.9.4.2 Pipe Chases.

Pipe chases are horizontal or vertical framed-in passageways that vary in size. They are typically constructed of studs and gypsum board. If unprotected, vertical chases connecting adjacent floors or horizontal chases running through walls may provide access to secure areas. Horizontal chases may provide little resistance to movement except obstacles such as internal equipment, piping, cable, and the entrance door(s). Chases provide entrance and exit points to overhead crawl spaces. Pipe chases that provide man-passable access to HVAC ducts and maintenance crawl spaces larger than the man-passable opening threshold should be alarmed or barriers inserted to prevent free movement through the pipe chase.

5-5.9.4.3 Exhaust Vents.

Exhaust vents through roofs and walls are usually protected by the associated equipment. Because the ductwork and dampers are usually constructed of light sheet metal, penetration can be easily accomplished with a low severity threat tool mix. Typical exhaust ducts range in size up to 4 by 8 feet (1,200 by 2,400 mm). The discussion of hardening techniques under gravity vents, ventilation ducts, and air distribution fixtures generally applies in the case of exhaust vents.

5-5.9.4.4 HVAC Ductwork and Vent Pipes.

If maintenance access is not required, filling duct openings with a 2-foot (0.6-m) length (minimum) of steel pipe, welded together and anchored securely in place by a welded steel plate on the inside (secure side) of the structure as shown in Figure 5-6 is an option. The honeycomb material should be made of steel. For this barrier system, penetration delay time will result from the length of the honeycomb and the necessity for multiple long cuts and debris removal in the relatively restricted space of the duct. If possible, such a barrier should be located at a sharp turn to further restrict the use of cutting tools. This arrangement can also be used for tunnels with electrical lines, since maintenance personnel can have access to both sides of the impediment (constriction), and cables can be threaded through the relatively short constriction.

An alternative option is to weld the steel pipes front and back at least 3 inches (75mm) on each end and at each point where the steel pipes intersect. No steel pipe diameter inside the pipe should be greater than the man-passable threshold opening. A second approach is to eliminate the center steel pipe and to connect the remaining pipes inside the tunnel with continuous welds; however, if this approach is taken, the designer should be careful to ensure that the area in the center, which would have been filled by the seventh center pipe, as shown in Figure 5-7, is not a man-passable opening. These constrictions should be located at secure walls with equivalent penetration resistance. The length of the constriction will force an aggressor to attack and remove each barrier separately. The confined working space and the necessity for debris removal further add to penetration delay time.

Figure 5-6 Vent and Duct Hardening Barriers

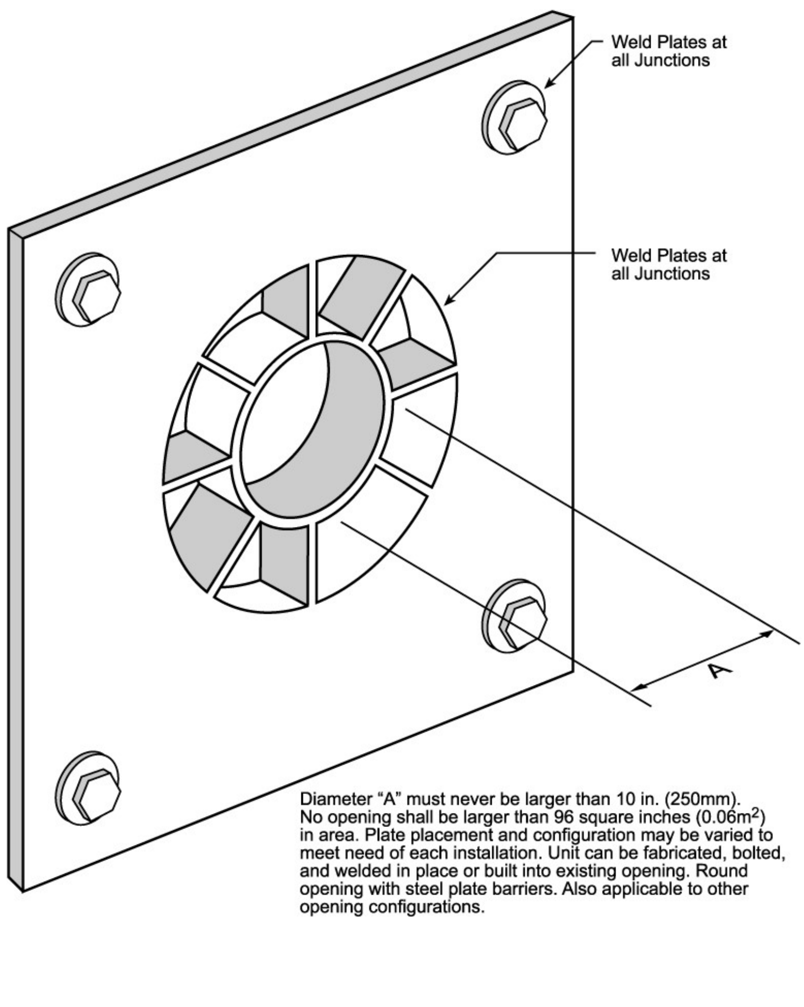
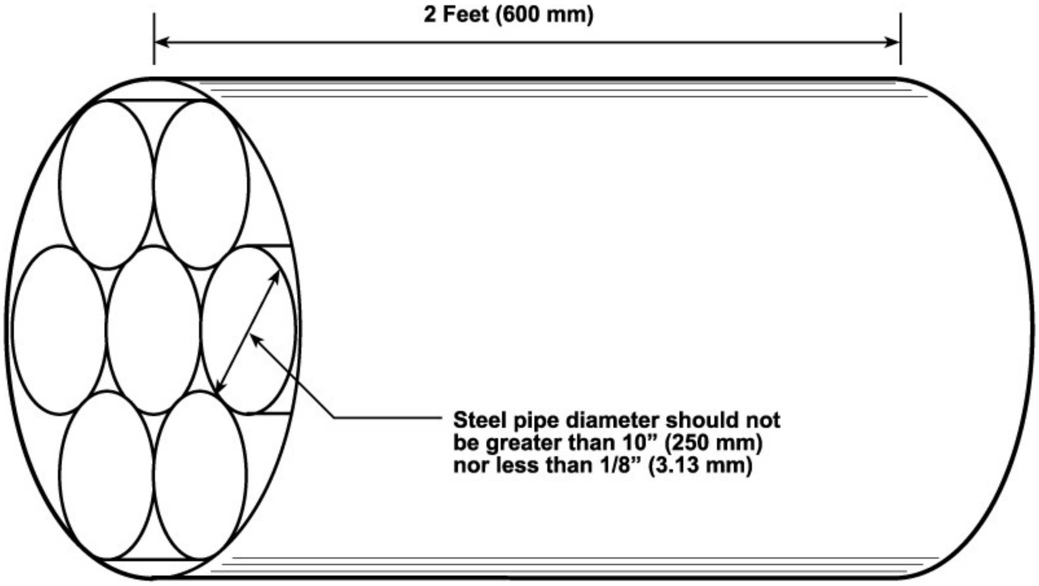


Figure 5-7 Vent Pipe and Chase Protection



5-5.9.4.5 Sleeves and Trays.

Sleeves are pipe penetrations through walls, roofs, and ceilings. Trays are removable, sheet-metal-covered conduits. Sleeves and trays that penetrate security walls should be less than the man-passable opening threshold. Penetrations should be angled upward and, to the extent practical, contain sharp turns to prevent the easy introduction of hooks, cables, or explosive devices. Penetration resistant barriers are similar to those used to protect pipe chases.

5-5.9.4.6 Ducts.

Ducts are round or square sheet metal or fiberglass conduits that may vary in size. Ducts constructed of sheet metal, usually 28 gauge (0.4 mm) through 14 gauge (1.9 mm), can readily be cut with hand tools and light power tools. These ducts do not present a significant barrier to penetration. Penetration resistance is, however, sometimes enhanced using ducts of less than man-sized cross section and the inclusion of required apparatus, such as turning vanes, dampers, pressure plates, and final air distribution fixtures. Duct dimensions should be kept at less than a man-passable cross section. Penetration resistant barriers are similar to those used to protect pipe chases.

5-5.9.4.7 Filter Banks.

Filter banks are unlikely to offer any significant penetration delay time. A hardened enclosure, with one of the vent or duct-hardening techniques should be used to prevent aggressor entry.

5-6 RETROFIT CONSTRUCTION.

This section provides design options for retrofitting an existing building against forced entry attack. The objective of the design is to increase the penetration resistance of the existing building using retrofit options that provide the required penetration delay against the threat severity level for the building. The design should also provide a balanced design between all building components. The following paragraphs provide forced entry delay expected from the existing construction followed by the penetration delay time enhancement of various retrofit options.

5-6.1 General.

Determine if the existing structure and foundations will support the additional weight of the enhanced construction. If not, the use of additional defense layers may be an alternative to retrofit.

5-6.2 Walls.

Solid plywood construction can be used to resist a low severity threat. For severity threat levels III and IV, the choices are limited to grout-filled and reinforced CMUs for lower delay time requirements, and conventional or SFR concrete for higher delay time requirements. Threat severity level V will require sacrificial areas, multiple barriers, or reinforced concrete barriers.

The following paragraphs provide information for estimating the penetration delay times for walls in existing facilities and retrofit options for hardening these walls if additional delay time is required.

5-6.2.1 Penetration Delay Times for Existing Walls.

Table 5-23 shows the maximum penetration delay times for representative stud-girt walls. If existing wall types are not represented in the table, either take credit for the closest type or take no credit.

For conventional concrete materials, the penetration delay times range from about 2 minutes to greater than 60 minutes.

5-6.2.2 Walls to Resist Threat Severity Level II.

If an existing stud-girt wall construction uses a combination of plywood, stucco, or gypsum that meets, or exceeds, 3/4-inch (19-mm) in thickness; light sheet metal; or conventional masonry, it will provide the required one minute penetration delay time against a threat severity level II attack. Otherwise, add materials to the inside of the wall to achieve the one minute penetration delay time or take no credit for delay.

Note that in cases where materials such as expanded metal are applied to a wall, it is common practice to cover those materials with gypsum wallboard for aesthetic purposes.

5-6.2.3 Walls to Resist Threat Severity Level III.

5-6.2.3.1 Stud-Girt Walls.

Table 5-23 shows recommended treatments for existing stud-girt walls to provide resistance to threat severity level III.

Table 5-23 Stud-Girt Construction Retrofit Options for Threat Level III

CONSTRUCTION		PENETRATION DELAY TIME (MINUTES)
1	2- by 4-inch (50- by 100-mm) wood stud frame at 16 inches (400 mm) on center w/bevel siding at 1.5-inch (37.5-mm) lap joints. One-layer No. 15 felt paper, and 1- by 6-inch (25- by 150-mm) sheathing diagonally and 3/8-inch (10-mm) GWB. Attach the following to secure side (opposite from attack side): • 3/4-inch (19-mm) plywood, No. 9 expanded metal and 3/4-inch (19-mm) plywood.	5.0
2	1-inch (25-mm) tongue-and-groove layered with 1/2-inch (13-mm) plywood. Attach either of the following to secure side (opposite from attack side): • 9-gauge (3.8-mm) chain-link fence fabric nailed to wall • 3/16-inch (4.7-mm) steel plate attached to wall with lag bolts.	1.8 1.9

5-6.2.3.2 Masonry Walls.

Several techniques for hardening both hollow and mortar-filled 8-inch (200-mm) CMU block are illustrated in Figure 5-8 through Figure 5-12. Note that the retrofit hardening layers are applied to the interior (secure side) of the cross section. These options were specifically designed and tested to provide enhanced attack resistance. The CMU sections vary in the type of retrofit materials used.

Figure 5-8 Retrofit Hardening of 8-inch (200mm) CMU Wall (1 of 4)

<table>
<tr><th rowspan="2">CONSTRUCTION</th><th colspan="2">PENETRATION TIME (MINUTES)</th></tr>
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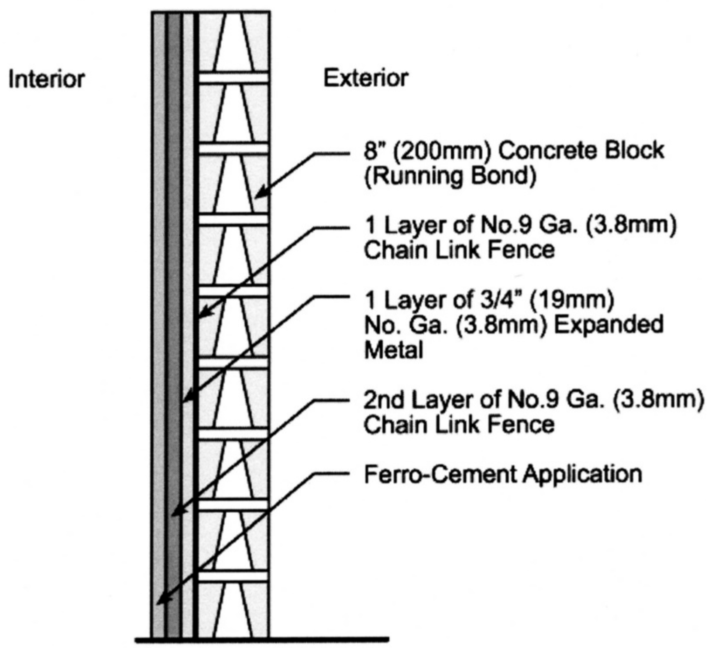
<tr><td>
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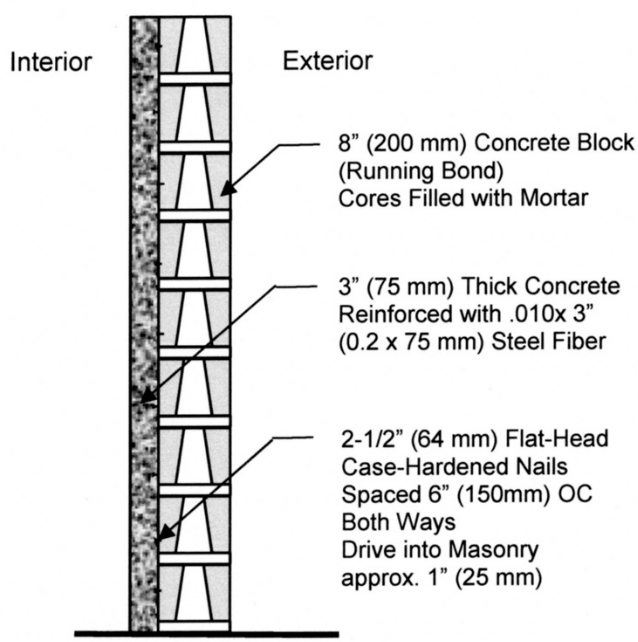
<tr><td>
</td><td>28</td><td>23</td></tr>
</table>

Figure 5-9 Retrofit Hardening of 8-inch (200mm) CMU Wall (2 of 4)

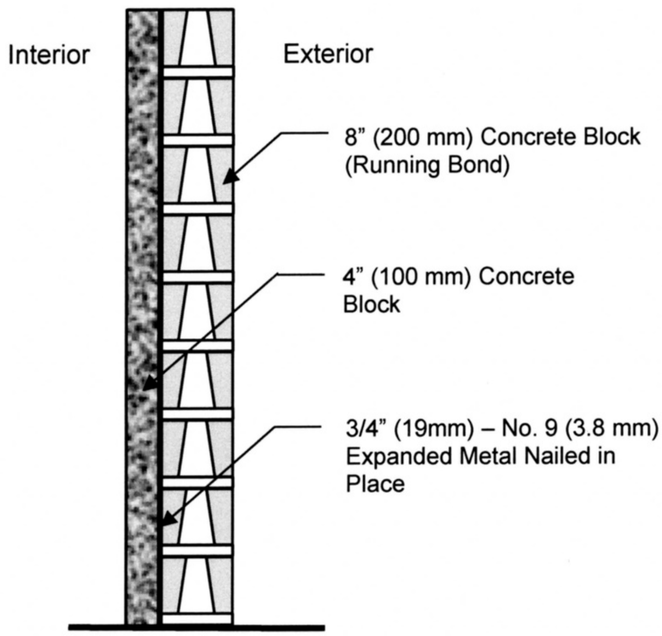
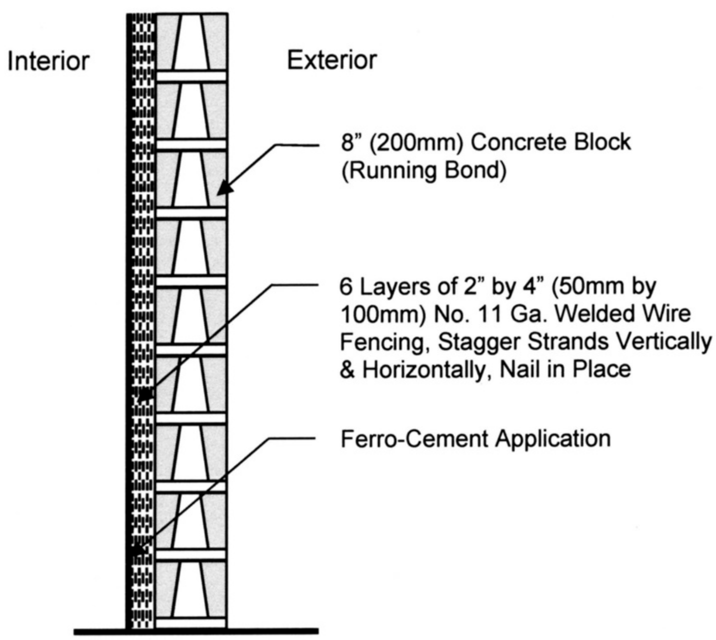
CONSTRUCTION	PENETRATION TIME (MINUTES)	
	III	IV
	4	4
	7	6

Figure 5-10 Retrofit Hardening of 8-inch (200mm) CMU Wall (3 of 4)

<table>
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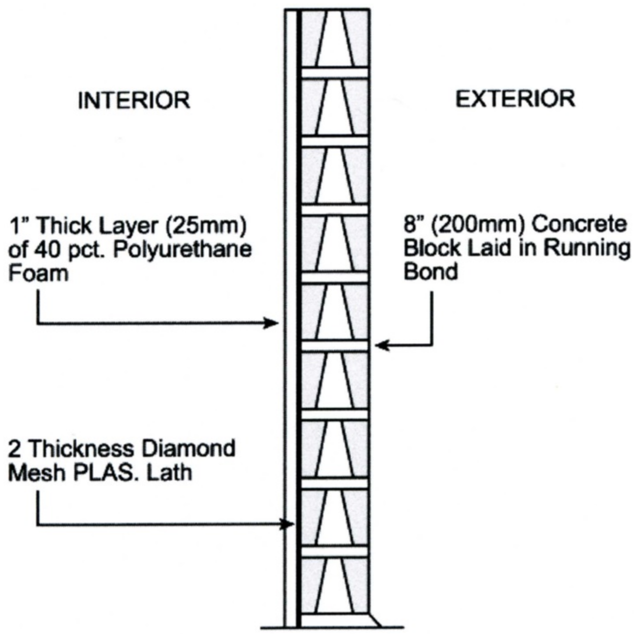
<tr><td>
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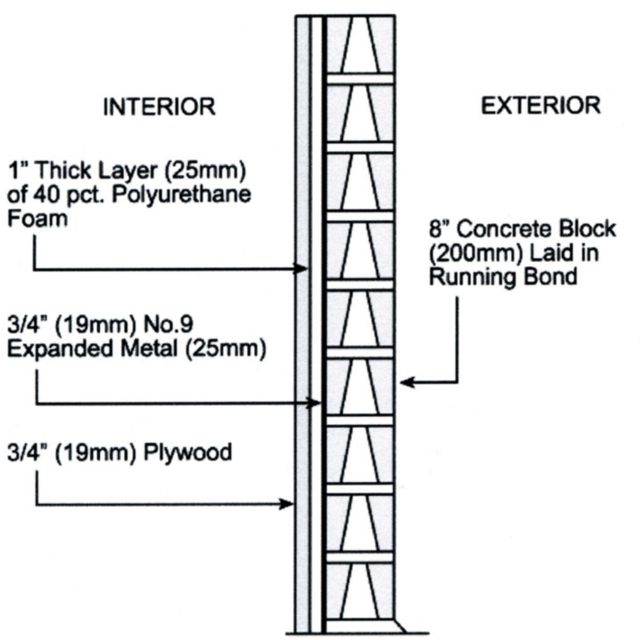
<tr><td>
</td><td>3.5</td><td>3.5</td></tr>
</table>

Figure 5-11 Retrofit Hardening of 8-inch (200mm) CMU Wall (4 of 4)

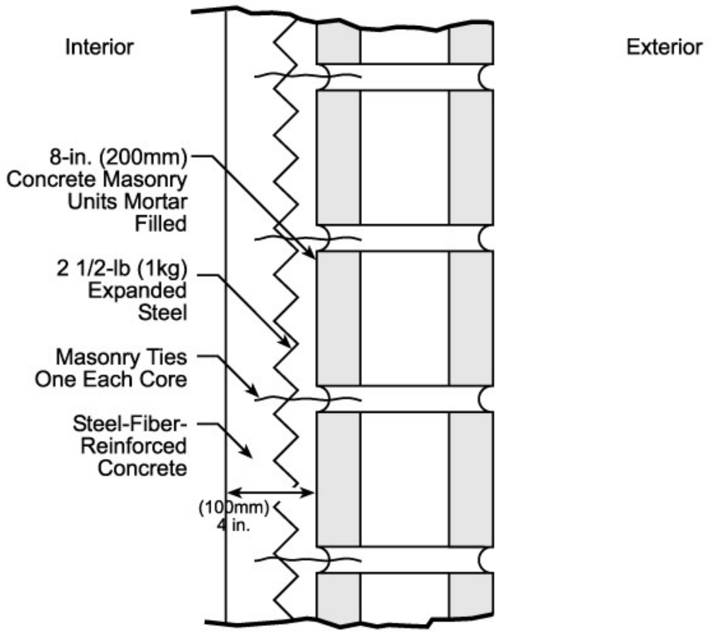
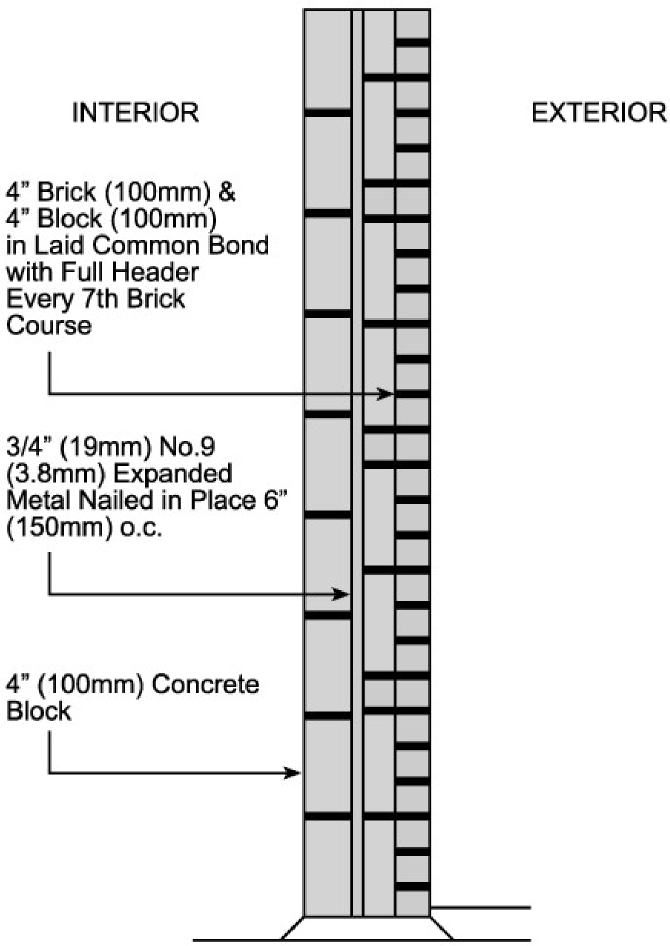
CONSTRUCTION	PENETRATION TIME (MINUTES)	
	III	IV
	(a)	30
(a) Not possible to penetrate at the indicated threat severity level		

Figure 5-12 Wood/Metal Composite Masonry Design Option

CONSTRUCTION	PENETRATION TIME (MINUTES)	
	III	IV
	3	3

5-6.2.3.3 Reinforced Concrete Walls.

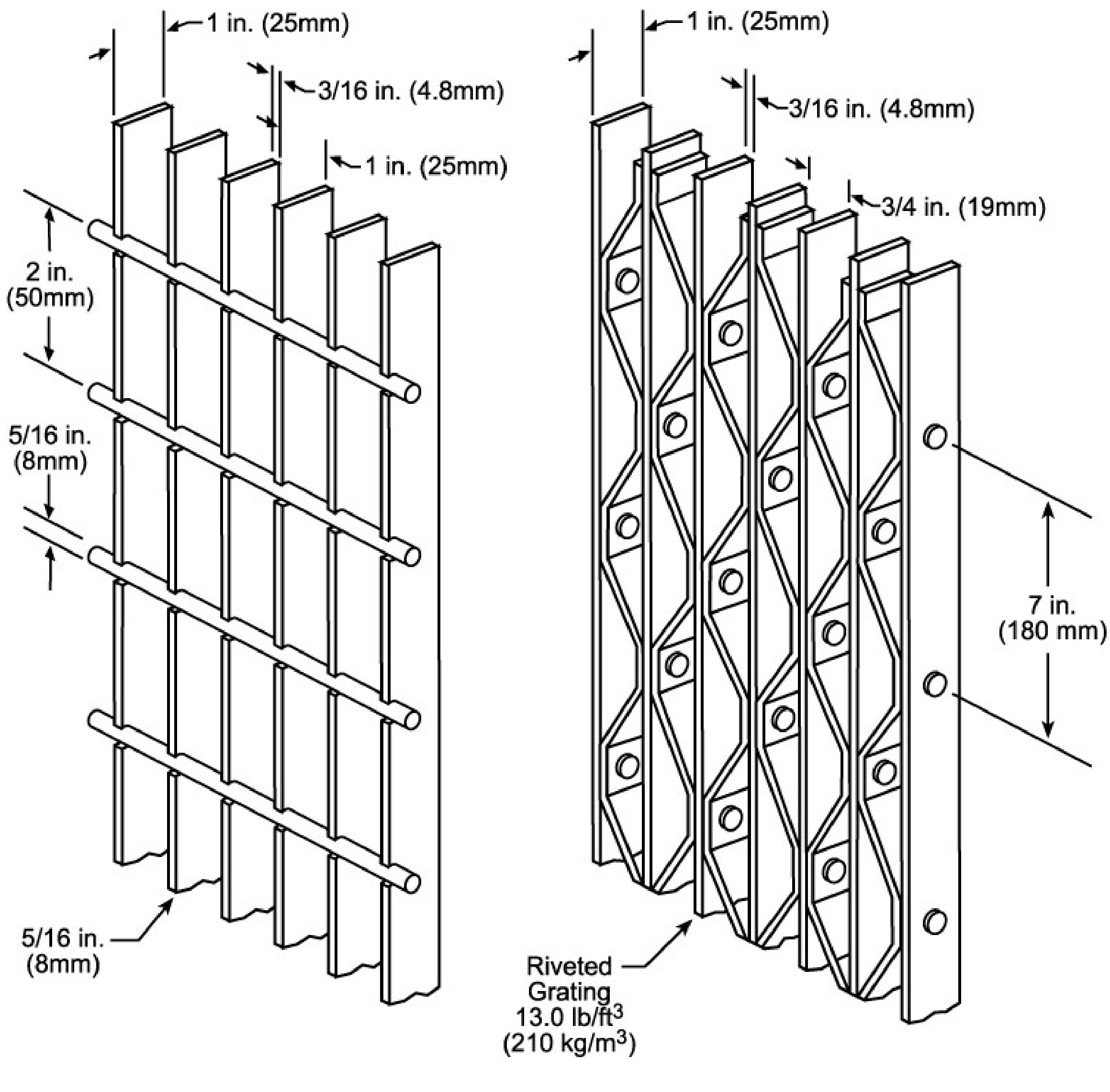
Reinforced concrete 6 inches (150 mm) thick with the “B” reinforcing bar combination (Table 5-2) provides minimum penetration delay times up to about 7.5 minutes for threat severity level III. If the concrete thickness and reinforcing bar combination is outside the threat severity level III region shown in Figure 5-2, using hand-held attack tools alone is not practical. In this case, the existing wall will provide penetration resistance. If the delay time provided by existing concrete construction is inadequate, penetration delay time can be doubled from the values shown in Figure 5-2 by bolting 10-gauge (3.4-mm) standard sheet steel to the interior surface of the wall using taper bolts or expansion sleeve anchors. This effect is gained by preventing internal spalling of the concrete.

5-6.2.4 Walls to Resist Threat Severity Level IV.

5-6.2.4.1 Stud-Girt Walls.

The riveted or welded steel grating shown in Figure 5-13 can be attached to the interior of a stud-girt wall with lag or through bolts to increase the delay time. Additional penetration times against threat severity level IV are approximately 2 minutes minimum for the riveted and 1 minute minimum for welded grating.

Figure 5-13 Welded and Riveted Steel Grating



5-6.2.4.2 Masonry Walls.

The retrofit designs in Figure 5-8 through Figure 5-10 can be used for resistance to threat severity level IV. In addition, the penetration delay times for solid core CMU block walls can be doubled by attaching 10-gauge (3.4-mm) sheet steel to the interior surface with taper bolts or expansion sleeve anchors.

If the penetration delay time is still not adequate, steel-plywood options can be used. Use a layer of 3/4-inch (19-mm) plywood sandwiched between two layers of 10 gauge (3.4-mm) hot-rolled steel to provide about 6 minutes of additional penetration delay time. The penetration delay time can be increased by about five minutes with the addition of another wood and steel layer. This rule of thumb can be applied to the addition of more layers until the desired penetration delay time is reached. Penetration delay time for steel-plywood systems can be increased by changing the steel material to 9-gauge (3.8-mm) ASTM A1008, Class 2, high-strength, low-alloy steel. One layer of 3/4-inch (19-mm) plywood sandwiched between two layers of this steel will provide 14 minutes of penetration delay time. Adding layers of 90-pound (200-kg) gravel finish roofing paper between the plywood and steel further increases the penetration delay time to about 20 minutes. These times are added to the increased penetration delay time provided by preventing internal spalling of the concrete (approximately double the initial penetration delay time).

5-6.2.4.3 Reinforced Concrete Walls.

If the delay time provided by existing concrete construction is inadequate, penetration delay time can be doubled by bolting (taper bolts or expansion sleeve anchor) 10-gauge (3.4-mm) standard sheet steel to the interior surface of the wall. This effect is gained by preventing internal spalling of the concrete.

If the penetration delay time is still not adequate, steel-plywood options as described in Paragraph 5-6.2.4.2 can be used. Standard welded and riveted steel grating can also be used to provide additional delay time. This grating is available in standard 2- by 10-foot (0.6- by 3-m) panels and can be attached to the secure side concrete walls with taper bolts or expansion sleeve anchors. They can also be assembled in a variety of free-standing configurations of any length (in 2-foot (0.6-m) increments). Additional penetration delay times against threat severity level IV are approximately two minutes minimum for the riveted and one minute minimum for welded grating, plus additional time gained by preventing spallation if attached to the secure side of the wall (approximately double the initial penetration delay time).

5-6.2.5 Walls to Resist Threat Severity Level V.

The use of bulk explosives can be effective in quickly producing man-passable openings. Only a reinforced concrete structure 12 inches (305 mm) or more in thickness can provide penetration delay times greater than one minute. In general, the options that will protect existing construction from an explosive penetration attack are retrofit prohibitive because of the weight restrictions and cost implications of retrofitting existing facilities. The only choice is to move the critical asset being protected away from exterior walls and roofs and develop one or more intermediate defense layers. The exterior of the building will then serve as a sacrificial barrier that will force the aggressor to penetrate multiple barriers and limit the use of explosives inside the structure.

5-6.3 Roofs.

Conventional roof construction offers little resistance to downward forced entry attack, except where reinforced concrete slabs form the structure.

5-6.3.1 Roofs to Resist Threat Severity Level II.

Since solid plywood or metal roof construction provides a delay of less than one minute against threat severity level II, replace the existing roof with one of the roof types shown in Table 5-5.

5-6.3.2 Roofs to Resist Threat Severity Levels III and IV.

Conventional or fiber reinforced concrete roofs are required to resist threat severity levels III and IV. If the existing roof is of stud-girt construction, the only choice is to move the critical asset being protected away from exterior walls and roofs and develop one or more intermediate defense layers. The exterior of the building will then serve as a sacrificial barrier that will force the aggressor to penetrate multiple barriers. Figure 5-2, Figure 5-3, and Table 5-2 can be used to estimate penetration times for existing reinforced concrete construction of roofs. In general, for reinforced concrete walls less than 12 inches (30 cm) thick, penetration delay times for a downward attack on a roof will be lower than a similar attack on a wall; therefore, use the next lowest thickness 1 inch (2.5 cm) of concrete in Figure 5-2 to determine the existing penetration delay rating.

If the penetration delay rating for the existing roof is not adequate, add a layer of 3/4-inch (19-mm) plywood sandwiched between two layers of 10 gauge (3.4-mm) hot-rolled steel to provide about 6 minutes of additional penetration delay time. The penetration delay time can be increased by about five minutes with the addition of another wood and steel layer. This rule of thumb can be applied to the addition of more layers until the desired penetration delay time is reached. Penetration delay time for steel-plywood systems can be increased by changing the steel material to 9-gauge (3.8-mm) ASTM A1008, Class 2, high-strength, low-alloy steel. One layer of 3/4-inch (19-mm) plywood sandwiched between two layers of this steel will provide 14 minutes of penetration delay time. Adding layers of 90-pound (200-kg) gravel finish roofing paper between the plywood and steel further increases the penetration delay time to about 20 minutes. These times are added to the increased penetration delay time provided by preventing internal spalling of the concrete (approximately double the initial penetration delay time).

5-6.3.3 Roofs to Resist Threat Severity Level V.

The use of bulk explosives or platter charges can be effective in quickly producing man-passable openings. Only a reinforced concrete structure 12 inches (305 mm) or more in thickness can provide penetration delay times greater than one minute.

In general, the options that will protect existing construction from an explosive penetration attack are retrofit prohibitive because of the weight restrictions and cost implications of retrofitting existing facilities. The only choice is to move the critical asset being protected away from exterior walls and roofs and develop one or more intermediate defense layers. The exterior of the building will then serve as a sacrificial barrier that will force the aggressor to penetrate multiple barriers and limit the use of explosives inside the structure.

5-6.3.4 Roof Equipment and Openings.

For retrofit projects, use the designs in Paragraphs 5-5.2.4 through 5-5.2.6. to secure roof-mounted equipment and utility openings. Eliminate skylights or use tested grille arrangements shown in Figure 5-13 to protect openings where required. Secure all hatches, penthouses, exterior ladders, and fire escapes.

5-6.4 Ceilings and Floors.

Floor and ceiling assemblies are the horizontal (top and bottom) components of the 6-sided intermediate defense layers. Floors may be exposed to exterior forced entry if the asset is in the space below; and, ceilings may be exposed to forced entry if the asset is in the space above. Select floor and ceiling construction which provides the required delay time where applicable.

5-6.4.1 Ceilings and Floors to Resist Threat Severity Level II.

Existing conventional floor and ceiling assemblies of 3/4-inch (19-mm) plywood on wood joists provide at least one minute of penetration delay, they are adequate for resistance to the threat severity level II.

5-6.4.2 Ceilings and Floors to Resist Threat Severity Levels III and IV.

Reinforced stud-girt or reinforced concrete ceilings and floors are required to resist threat severity levels III and IV. Figure 5-2, Figure 5-3, and Table 5-2 can be used to estimate penetration times for existing reinforced concrete construction of ceilings and floors. Penetration delay times for an upward attack on a ceiling (floor of upper level) will be higher than the same attack on a wall; therefore, use the next lowest thickness of concrete 1 inch (2.54 cm) or use a less compact configuration of reinforcing bar size and spacing. For a downward attack on a floor (ceiling of lower level), penetration delay times are lower for a similar attack on a wall; therefore, use the next highest thickness of concrete 1 inch (2.54 cm) or use a configuration with more layers of reinforcing bar size and spacing.

If the existing ceiling or floor is of stud-girt construction, the existing reinforced concrete ceiling or floor cannot provide an adequate penetration delay time, and supporting walls can bear the additional weight, use a layer of 3/4-inch (19-mm) plywood sandwiched between two layers of 10 gauge (3.4-mm) hot-rolled steel to provide about 6 minutes of additional penetration delay time. The penetration delay time can be increased by about 5 minutes with the addition of another wood and steel layer. This rule of thumb can be applied to the addition of more layers until the desired penetration delay time is reached. Penetration delay time for steel-plywood systems can be increased by changing the steel material to 9-gauge (3.8-mm) ASTM A1008, Class 2, high-strength, low-alloy steel. One layer of 3/4-inch (19-mm) plywood sandwiched between two layers of this steel will provide 14 minutes of penetration delay time. Adding layers of 90-pound (200-kg) gravel finish roofing paper between the plywood and steel further increases the penetration delay time to about 20 minutes. These times are added to the increased penetration delay time provided by preventing internal spalling of the concrete (approximately double the initial penetration delay time).

5-6.4.3 Ceilings and Floors to Resist Threat Severity Level V.

The use of bulk explosives or platter charges can be effective in quickly producing man-passable openings. Only a reinforced concrete structure 12 inches (305 mm) or more in thickness can provide penetration delay times greater than one minute. In general, the options that will protect existing construction from an explosive penetration attack are retrofit prohibitive because of the weight restrictions and cost implications of retrofitting existing facilities. The only choice is to move the critical asset being protected away from exterior walls and roofs and develop one or more intermediate defense layers. The exterior of the building will then serve as a sacrificial barrier that will force the aggressor to penetrate multiple barriers and limit the use of explosives inside the structure.

5-6.5 Personnel Entrances.

Existing personnel entrances should provide the same penetration delay times as the other components of the defense layer.

Refer to Table 5-7 through Table 5-12 for evaluating the penetration delay times for existing personnel entry doors. Where existing doors do not provide adequate penetration delay times, they must be upgraded or replaced. As an alternative, additional doors can be added in a vestibule layout to force aggressors to attack multiple doors in sequence before they can penetrate the defense layer.

5-6.6 Doors, Frames and Locks (Non-Entry).

If the existing building or intermediate defense layer perimeters have non-entry doors, perform a life safety evaluation to determine if any non-entry doors can be eliminated. If non-entry doors can be eliminated, fill in the walls to match existing materials.

Refer to Table 5-7 through Table 5-12 for evaluating the penetration delay times for existing doors. Where existing non-entry doors do not provide adequate penetration delay times, they must be upgraded or replaced.

5-6.7 Windows.

Conventional windows provide little resistance to even the lowest threat severity levels of the forced entry tactic. With special glazing materials and frame and anchorage design, forced entry resistant windows can resist the threat severity level II. With specially constructed grille or shutter enhancements, window openings can resist the threat severity levels III and IV. Refer to Table 5-14 through Table 5-20 for evaluating penetration delay times for existing windows. If existing window types are not in the tables, assume they offer no protection against attempted forced entry. Where existing windows do not provide adequate penetration delay times, they must be upgraded; replaced; or, because forced entry resistant window enhancements are costly, eliminated. Removal of existing windows will provide enhanced penetration delay time if the retrofit is accomplished properly. The most straightforward method is to seal the window opening with the same construction used in the wall where it is mounted.

Do not design man-passable window openings in defense layers where the threat severity level V applies. Also consider the placement of windows in relation to doors. Even a small window in or next to a door could allow an aggressor to reach through and unlock the door. Use obscured glazing materials or blinds, shutters, or drapes to eliminate asset visibility.

5-6.8 Utility Openings.

In conventional building designs, utility openings, manholes, tunnels, HVAC ducts, filters, and equipment access panels with openings greater than a man-passable 96 square inches (619 cm^2) provide aggressors with fast ingress and egress routes and provide no penetration delay time. Such openings must be eliminated, or their penetration delay times increased significantly to provide a consistent level of delay for a defense layer.

Methods for hardening man-passable utility openings are described in Paragraph 5-5.9.

CHAPTER 6 PROTECTED AREAS

6-1 INTRODUCTION.

Protected Areas contain the assets; their perimeters are the innermost defense layer and the last layer to provide delay to the aggressors' attempt to reach the assets. Paragraph 6-2 identifies protected asset types and the type of structure to be used to protect them. Construction design requirements for each type of structure is either covered in detail in this UFC; or, when other UFCs or DoD documents exist that contain those requirements, they are summarized, and references provided for the other documents. Paragraphs 6-3 through 6-11 provide the design requirements for structures not covered in other documents.

This UFC does not supersede any of the guidance in other regulatory publications. This UFC is intended to summarize the construction requirements in those documents and provide guidance if additional construction measures are required to protect the assets. If there are any inconsistencies between this UFC and any of the applicable references, the most stringent requirements will control.

6-2 PROTECTED ASSET TYPES.

The following asset types are those most likely to be identified as forced entry targets. Where an asset is identified in the design criteria that is not listed here, use the prescriptive protection requirements from the DoD regulatory documents that govern that asset.

6-2.1 High-Risk Personnel.

High-Risk Personnel (HRP) are DoD personnel who are likely to be terrorist or criminal targets based on their grade, assignment, symbolic value, criticality, and threat and vulnerability assessment. DoDI O-2000.22 defines High Risk Billets and HRP levels; assigns responsibilities; and establishes policy, processes, and procedures for the designation and protection of DoD HRP.

The project design criteria will identify if there are requirements for the protection of HRP including any need for safe havens. UFC 4-010-03 contains the minimum design requirements for the protection of HRP. UFC 4-023-10 contains the design requirements for safe havens.

6-2.2 Classified Information and Material.

The protection of classified information, which is governed by DoDM 5200.01, Volume 3 requires that classified information be secured under conditions adequate to prevent access by unauthorized persons. The storage requirements in DoDM 5200.01 are the same for all classification levels. Classified information and materials can be stored in General Services Agency (GSA)-approved storage containers, secure rooms, or vaults. For service specific regulatory requirements refer to AFI 31-101, AFI 16-1404, AR 380-5, and SECNAVINST M-5510.36.

(See Paragraph 6-11 for Class 5 GSA Storage Cabinets, Paragraph 6-3 for Secure Room design, and Paragraph 6-7 for Class A Vault design.)

6-2.3 Sensitive Compartmented Information.

Sensitive Compartmented Information is classified information concerning or derived from intelligence sources, methods, or analytical processes, which is required to be handled exclusively within formal control systems. The handling and storage of Sensitive Compartmented Information must be confined to a Sensitive Compartmented Information Facility (SCIF). Physical security standards for the construction and protection of SCIFs is governed by DoDM 5105.21, Volume 2.

Use the physical design requirements in UFC 4-010-05 as the minimum requirements for construction of a SCIF.

6-2.4 Special Access Program Information and Equipment.

A Special Access Program is established for a specific class of classified information that imposes safeguarding and access requirements that exceed those normally required for information at the same classification level. Physical security standards for the construction and protection of a Special Access Program Facility (SAPF) is governed by DoDM 5205.07, Volume 3.

Use the physical design requirements in UFC 4-010-05 as the minimum requirements for construction of a SAPF.

6-2.5 Communications Security (COMSEC) Materials.

COMSEC materials are used to secure or authenticate sensitive telecommunications. The protection of COMSEC materials is governed by DoDI 8523.01. COMSEC materials can be stored in security containers, secure rooms, or vaults in accordance with DoDM 5200.01 to the appropriate classification level.

(See Paragraph 6-11 for Class 5 GSA Storage Cabinets, Paragraph 6-3 for Secure Room design, and Paragraph 6-7 for Class A Vault design.)

6-2.6 Arms, Ammunition, and Explosives.

Security of AA&E is governed by DoD 5100.76-M. Storage requirements include security containers, arms rooms, modular vaults, or magazines. Classified AA&E are stored in accordance with DoDM 5200.01. For service specific regulatory requirements refer to AFI 31-101, AR 190-11, MCO 5530.14, and OPNAVINST 5530.13.

UFC 4-215-01 contains minimum design requirements for armories and arms rooms. For forced entry protection of AA&E, use design requirements in Paragraph 6-10.

6-2.7 Chemical Agents.

Chemical weapons storage is governed by DoDI 5210.65. In general, chemical agents are stored within Chemical Exclusion Areas in magazines or rooms constructed to vault standards and with an IDS. The Chemical Exclusion Area needs to be fenced with a perimeter IDS. Research and development level quantities of chemical agents can be stored in security containers within vaults or secure rooms. Classified agents are stored in accordance with DoDM 5200.01. AR 190-59 provides additional Army guidance.

For magazines to store chemical weapons, use the design requirements in UFC 4-420-01. For forced entry protection of research and development level quantities of chemical agents, use the design requirements in Paragraph 6-7.

6-2.8 Biological Agents.

Biological agent security is governed by DoDI 5210.88. That instruction requires agents to be stored in secure containers, including refrigerators, freezers, or other approved storage devices secured with GSA-approved locking devices located within Biological Restricted Areas. Those Biological Restricted Areas must be equipped with an IDS, at least two access control devices, and the entrance must be under constant surveillance.

For forced entry protection of biological agents, use the design requirements in Paragraph 6-7.

6-2.9 Nuclear Weapons.

Nuclear weapons physical security is governed by DoDD 5210.41/AFMAN 31-108. The weapons are stored similarly to chemical weapons within fenced weapons storage areas with a perimeter IDS. Storage is in magazines or rooms constructed to vault standards and with IDS.

6-2.10 Controlled Substances.

Controlled substance storage is governed by 21 CFR 1301.72 for all DoD components except for the Army. Army storage of controlled substances is governed by AR 190-51. In all cases, small quantities of controlled substances can be stored in safes or security containers as described in Paragraph 6-11. Greater quantities of controlled substances need to be stored in vaults. Pharmacy construction standards are in AR 190-51 and AFI 31-101.

For forced entry protection of large quantities of controlled substances, use the design requirements in Paragraph 6-7.

6-2.11 Funds.

The security of DoD funds is governed by DoDR 7000.14. Storage of funds in excess of $100,000 requires special construction for rooms in which funds storage containers are stored. Requirements for the Air Force are reflected in AFI 31-101.

For forced entry protection of funds in excess of $100,000, use the design requirements in Paragraph 6-4.

6-3 SECURE ROOMS.

Secure rooms are options for the storage of classified information and lower levels of COMSEC materials. Secure room construction can also be used for the storage of sensitive items such as funds, and small quantities of controlled substances; however, a secure room cannot be used to simultaneously store both classified information and sensitive items. Their construction is governed by DoDM 5200.01, Volume 3, which includes requirements for all the building elements associated with the perimeter of the room. A secure room may require an IDS if the area is not occupied on a twenty four-hour/seven-day basis; consult with facility security personnel for guidance.

The following paragraphs contain the minimum design requirements for a secure room; they provide little resistance to forced entry. If the secure room requires resistance to forced entry, use construction components from Chapter 5.

6-3.1 Walls, Floor, and Roof.

The walls, floor, and roof construction of secure rooms must be of permanent construction materials such as plaster, GWB, metal panels, hardboard, wood, plywood, or other materials offering resistance to, and evidence of, unauthorized entry into the area. Walls must be extended from the true floor to the true ceiling; and, if not, attached with permanent construction materials, mesh, or 18-gauge (1.2 mm) expanded steel screen.

6-3.2 Ceiling.

The ceiling must be constructed of plaster, GWB, hardboard or other acceptable material.

6-3.3 Door and Frame.

All doors in the secure room perimeter must be substantially constructed of wood or metal. The hinge pins of outswing doors must be peened, brazed, or spot-welded to prevent removal.

6-3.4 Locks.

The access door must be equipped with a built-in GSA-approved combination lock meeting FS FF-L-2740. Emergency exit doors should not have any external hardware installed.

6-3.5 Windows.

Windows that are less than 18 feet above the ground measured from the bottom of the window or are easily accessible by means of objects placed beneath the windows, must be constructed from or covered with materials that will provide protection from forced entry. The protection provided to the windows must provide the same penetration delay time as the contiguous walls.

Secure rooms which are located within a controlled compound or equivalent may eliminate the requirement for forced entry protection if the windows are made inoperable either by permanently sealing them or equipping them on the inside with a locking mechanism and they are covered by an IDS (either independently or by motion detection sensors within the area). This must be approved by the secure room's Security Manager.

6-4 FUNDS STORAGE ROOMS.

A funds storage room is a space specifically selected for containing a funds storage container during non-duty hours. The following construction requirements apply.

6-4.1 Walls, Floors, and Ceilings.

Walls, floors, and ceilings must be constructed or reinforced to provide protection equal to or greater than that of doors and windows. Effectively, most permanent construction will provide protection equal to or greater than that provided by the required windows and doors. Consider any concrete or masonry construction to be at least equivalent. Lightweight construction such as Exterior Insulating Finishing System may not provide equivalent protection, however. Add 5/16-inch expanded metal mesh to at least the walls of such construction. Add it to the floors and ceilings as well if they are constructed of something other than concrete.

6-4.2 Doors.

Doors should be constructed of 1-3/4 inch (44 mm) solid or laminated wood with US 12-gauge (2.7 mm) steel plate on the outside face; or standard 1-3/4 inch (44 mm) hollow metal, industrial type construction with minimum US 14-gauge (1.9 mm) skin plate thickness, internally reinforced vertically with continuous steel stiffeners spaced 6 inches maximum on center. A class 5 steel vault door with a changeable combination may be used instead of other doors and locks.

6-4.3 Door Frames and Hardware.

Door bucks, frames, and keepers should be rigidly anchored and provided with anti-spread space filler reinforcement to prevent disengagement of the lock bolt by prying or jacking the door frame. Also, the frames and locks for both interior and exterior doors should be designed and installed to prevent removal of the frame which faces the built-in locking mechanism. Frames should also be designed to prevent spreading sufficiently to disengage the lock bolt from outside the protected room when the door is closed and locked. Construction requirements for door frames and thresholds must be exacting as those for the door. For example, where metal doors are used, the frame and thresholds must also be metal.

When choosing the proper type of hinge for secure area doors, apply the following criteria:

- The hinge must be strong enough to withstand the rigors of constant use and the unusual weight of the door.
- Hinges should have fixed pins.
- Exposed hinges should be peened, or spot welded, or otherwise protected to prevent removal.
- Hinge mounting screws should not be exposed to the outside unless they are spot welded or peened to prevent removal.

6-4.4 Windows and Other Openings.

Windows should be filled in and sealed with material comparable to that forming the adjacent walls and otherwise limited to the essential minimum. Windows, ducts, vents, or similar openings large enough to permit entry [96-square-inch (619 cm^2) or with a single rectangular dimension greater than 6 inches (150 mm)] must be equipped with bars or mesh of one of the types below. Bars and steel mesh should be securely embedded in the structure of the building or welded to a steel frame that will be securely attached to the wall with fastenings inaccessible from the exterior of the facility.

- 3/8 inch (10 mm) or larger hardened steel bars, if the vertical bars are no more than 4 inches (100 mm) apart with horizontal bars welded to the vertical bars so that the openings do not exceed 32 square inches (206 cm^2).
- High carbon manganese steel mesh [US Number 8-gauge (4.0 mm)] with 2-inch (50-mm) diamond grid. (US Number 6-gauge (5.0 mm) steel mesh may be used if 8 gauge is unavailable.)

6-4.5 Security Lighting.

Interior and exterior security lighting is required for all government funds facilities and encouraged for all other funds facilities. The lighting must be bright enough to allow persons observing the structure or facility to recognize illegal acts. The following additional criteria apply.

- Locate switches for exterior lights so they are not accessible to unauthorized persons.
- Motion sensor lights may be installed to save energy.

Refer to UFC 3-530-01 for security lighting designs.

6-4.6 Locks and Keys.

Equip doors used for entry to funds storage rooms with, as a minimum, key actuated deadbolt locks with at least a 1-inch (25-mm) throw.

6-4.7 Intrusion Detection Systems.

AFI 31-101 requires accounting and finance offices and facilities storing $100,000 or more to have an IDS.

6-5 SECURE STORAGE STRUCTURES.

Army Regulation 190-51 identifies a class of storage facilities referred to as secure storage structures. They may be used to store a variety of asset types but cannot be used to store classified information or AA&E. The regulation has requirements for all building components in the perimeter of the space. The requirements vary by risk level as determined using DA Pamphlet 190-51.

6-5.1 Walls.

6-5.1.1 Risk Level I.

Walls should be constructed of at least 1/2–inch (13-mm) plywood, 1–inch (25-mm) tongue–in–groove wall boards, or 26–gauge (0.45 mm) steel siding.

6-5.1.2 Risk Level II.

Walls should be constructed of 4–inch (100-mm) minimum thickness brick and stud construction or of 8–inch (200-mm) minimum thickness concrete masonry (unreinforced). Alternatively, walls may be designed to provide delay equal to or greater than the actual response time.

6-5.1.3 Risk Level III.

Walls should be constructed of 8–inch (200-mm) minimum thickness core-filled concrete masonry reinforced with #6 (19 mm) reinforcing bars at 4 inches OC vertically and 8 inches (200 mm) OC horizontally, or 4–inch (100-mm) minimum thickness concrete reinforced with #5 (16 mm) reinforcing bars at 5 inches (125 mm) OC EW. Alternatively, walls may be designed to provide delay equal to or greater than the actual response time.

6-5.2 Floor and Ceiling.

The following requirements do not apply to slab on grade floors. No special requirements apply for such floors.

6-5.2.1 Risk Level I.

Floors and ceilings should be constructed of at least 1/2–inch (13 mm) plywood, 1–inch (25-mm) tongue–in–groove wall boards, or 24–gauge (0.6 mm) steel deck.

6-5.2.2 Risk Level II.

Floors and ceilings should be constructed as for Risk Level I with the addition of 5/16–inch (8 mm) expanded metal mesh or 10–gauge (3.4 mm) 6 inch by 6 inch (150 mm by 150 mm) woven wire fabric. Alternatively, floors and ceilings may be designed to provide delay equal to or greater than the actual response time.

6-5.2.3 Risk Level III.

Floors and ceilings should be constructed of 4–inch (100 mm) minimum thickness concrete reinforced with #5 (16 mm) reinforcing bars at 5 inches OC EW. Alternatively, floors and ceilings may be designed to provide delay equal to or greater than the actual response time.

6-5.3 Doors.

6-5.3.1 Risk Level I.

Doors should be a minimum of 1 3/4–inch (44 mm) thick solid core wood or hollow steel. Hollow steel doors will be industrial type construction with at least 20–gauge (0.88 mm) skin plate thickness and will be internally reinforced with continuously spaced stiffeners.

Door frames should be constructed of a minimum of 18–gauge steel. Doors with locking systems exposed to the outside should be kept to the absolute minimum number needed based on operational considerations. In addition, the doors should meet the following installation requirements:

- Door hinge mounting screws should not be exposed to the exterior of the facility. If screws are exposed, they should be spot welded, peened, covered, or filled with material in a way to prevent easy removal. Nails should not be used to mount hinges or any other door hardware.
- Door hinge pins should not be exposed to the exterior of the facility. If they are, they should be spot welded, covered, filled, or otherwise secured to prevent easy removal.
- Doors secured from the inside should be secured with a deadbolt locking device, crossbar, or similar locking device resistant to jimmying and manipulation from the outside. Latch style door locks should not be used.

6-5.3.2 Risk Level II.

Doors should be a minimum of 16–gauge (1.6 mm) hollow steel construction with a minimum of frame construction of 16–gauge (1.6 mm) steel. Installation requirements for Risk Level I also apply. Alternatively, doors or pairs of doors may provide delay time equal to or greater than the actual response time.

6-5.3.3 Risk Level III.

Doors should be a minimum of 1 3/4–inch (44 mm) solid core wood with wood block cores and 12–gauge (2.7 mm) minimum thickness steel plate on both sides or doors should be 12–gauge (2.7 mm) minimum thickness hollow steel doors reinforced with vertical stiffeners at 6 inches (150 mm) on center. Door frames should be constructed of 16–gauge (1.6 mm) steel minimum and be grouted full. Alternatively, doors or pairs of doors may provide delay time equal to or greater than the actual response time.

6-5.4 Windows.

The following apply to all first-floor openings, except doors, in excess of 96 square inches (619 cm^2) that are located less than 12 feet (3.7 m) from the ground level and to similar openings above the first floor which can be reached from an elevated portion of the structure or from an adjacent structure which provides ground level access. Long narrow openings with the shortest dimension measuring less than 6 inches (150 mm) are exempt from these requirements. If window air conditioning is used, bar, mesh, or fence fabric assemblies should completely enclose the air–conditioning unit protruding from the building or storage room exterior. If the window air conditioner is mounted through the wall, measures should be taken to ensure that it cannot be removed from the outside.

6-5.4.1 Risk Level I.

Operable windows should have adequate individual locking devices. Windows should also be covered with 1/2–inch (13 mm) diameter bars spaced at 6 inches (150 mm) on center each way, with 5/16–inch (8 mm) expanded metal mesh, or with 9–gauge (3.8 mm) chain link fabric.

6-5.4.2 Risk Level II.

Windows should be inoperable. They should be covered with bars or mesh as for Risk Level I and the glass should be covered with 4–mil (0.1 mm) fragment retention film or they should have 1/2–inch (13 mm) thick laminated glass or plastic security glazing. Alternatively, windows may provide delay time equal to or greater than the actual response time.

6-5.4.3 Risk Level III.

Windows should be inoperable, and they should be covered with bars or mesh as for Risk Level I and have 1/2–inch (13 mm) thick laminated glass or plastic security glazing. Alternatively, windows may provide delay time equal to or greater than the actual response time.

6-6 VAULTS.

Federal Standard 832 provides requirements for three classes of vaults for the storage of classified material and equipment: A, B, and C.

- Class A vaults provide penetration delay against threat severity levels II to IV. (See Paragraph 6-7 for the minimum construction requirements for Class A vaults.)
- Class B vaults provide penetration delay against threat severity levels II and III. Construction of a Class B vault must be in accordance with FS AA-V-2737. The door and frame of a Class B vault must conform to Federal Specification AA-D-600.
- Class C vaults offer no protection against a forced entry but may be used where unique structural circumstances do not permit concrete wall construction. They cannot be used as a defense layer unless substantially upgraded with designs from Chapter 5. (See Paragraph 6-8 for the minimum construction requirements for Class C vaults.)
- A lightweight, portable modular vault equivalent to a Class B vault that meets FS AA-V-2737 may also be used to store classified material and equipment. (See Paragraph 6-9 for modular vault design requirements).

DoD instructions on the protection of classified information and weapons systems require that vaults used to protect these assets must be cast-in-place reinforced concrete with a GSA-approved vault door that meets the requirements of FS AA-D-600. As alternatives within existing buildings where the use cast-in-place reinforced concrete is not structurally feasible, either a Class C vault or a GSA-approved modular vault can be used in place of a reinforced concrete structure.

6-7 CLASS A VAULTS.

This paragraph contains the minimum construction requirements for Class A vaults. (See Table 6-1 for penetration delay times provided by Class A vaults.)

Table 6-1 Penetration Ratings for Class A Vaults

MINIMUM CONSTRUCTION REQUIREMENT		MINIMUM PENETRATION DELAY TIME (MINUTES)			
		II	III	IV	V
Walls	8-inch (200-mm) Reinforced Concrete	(a)	(a)	12	<1
Floors	8-inch (200-mm) Reinforced Concrete	(a)	(a)	18 (b)	<1
Roof / Ceiling	8-inch (200-mm) Reinforced Concrete	(a)	(a)	10 (c)	<1
Door / Frame	Class 5 (FS AA-D-600)	(a)	10	2	<1

(a) Not practical to attack at this threat severity level.
(b) Penetration delay time is for an upward attack for other than floors on grade. Floors on grade not practical to attack.
(c) Penetration delay time is for a downward attack.

6-7.1 Walls.

Use 8-inch (200-mm) thick reinforced concrete with a minimum 28-day compressive strength of 3,000 psi (20.7 MPa). Reinforce concrete with 5/8-inch (16-mm) reinforcing bars, 6 inches (150 mm) on center each way, staggered each frame. Extend the reinforcement to the underside of the roof or ceiling slab above. Tie wall reinforcement into floor and ceiling or roof. When vault walls are part of the exterior walls, set the vault wall back from the exterior part of the exterior wall to allow 4 inches (100mm) for the normal wall facing to cover the vault wall.

6-7.2 Floor.

Use 8-inch (200-mm) thick reinforced concrete with a minimum 28-day compressive strength of 3,000 psi (20.7 MPa). Reinforce concrete with 5/8-inch (16-mm) reinforcing bars, 6 inches (150 mm) on center each way, staggered each frame. These requirements do not apply to slab on grade floors because these are not practical to attack; no special requirements apply for such floors.

6-7.3 Roof and Ceiling.

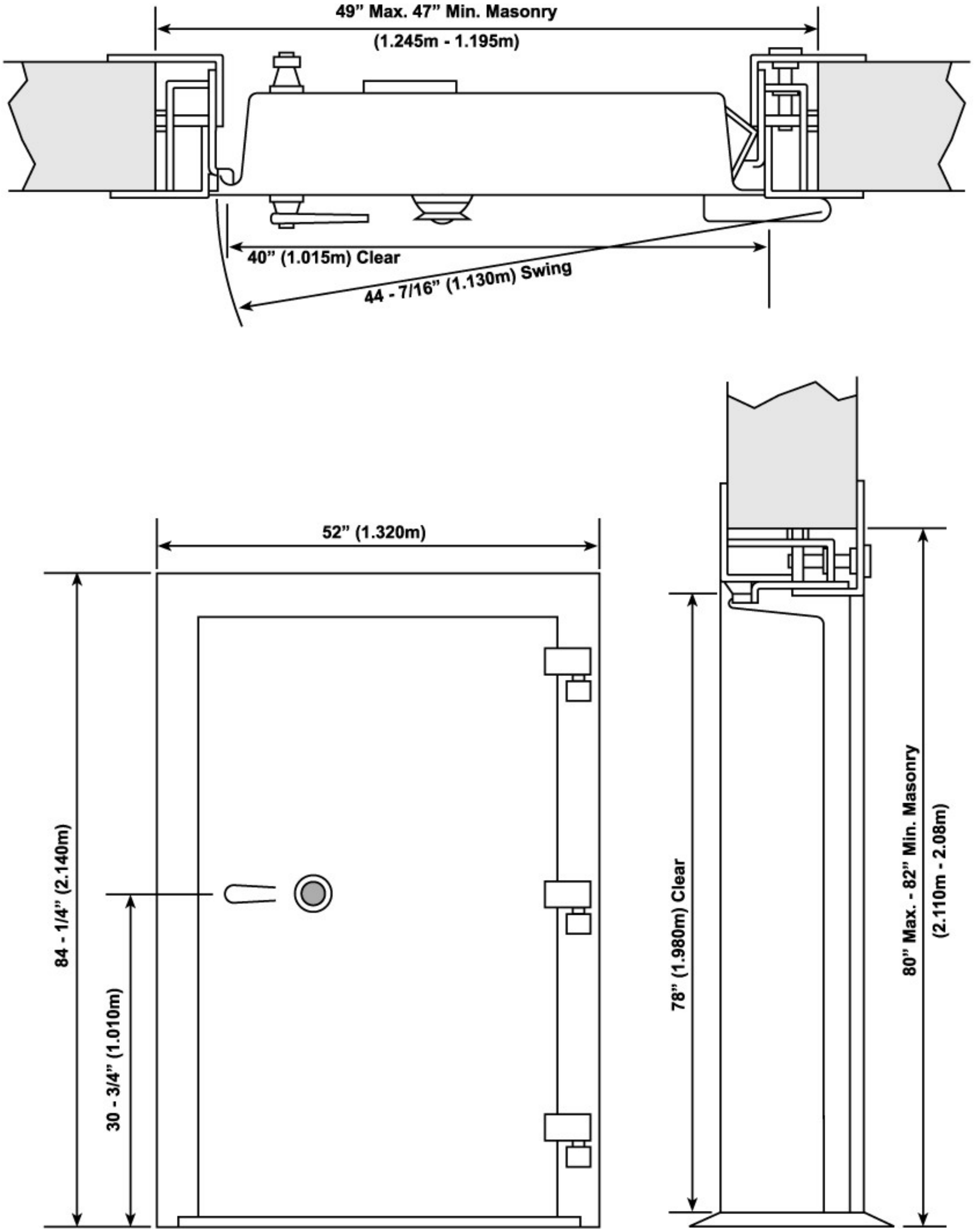
Use 8-inch (200-mm) thick reinforced concrete with a minimum 28-day compressive strength of 3,000 psi (20.7 MPa). Reinforce concrete with 5/8-inch (16-mm) reinforcing bars, 6 inches (150 mm) on center each way, staggered each frame.

6-7.4 Door and Frame.

Since vault doors are more vulnerable to attack than the vault enclosure itself, there should be only one entrance into a vault area. When a vault exceeds 1,000 square feet (93 $m^{2)}$ in floor space, or will have more than eight occupants, it should have a minimum of two exits for safety purposes. When more than one entrance is required, each must be equipped with an approved vault door with only one used for normal access. Where continued use of an entry barrier is required at a vault door, a day gate may be provided for the primary entrance to preclude undue wear of the door during operating hours.

Vault doors, frames, and locks must conform to FS AA-D-600. Doors other than those secured with locks meeting FF-L-2740 must be secured from the inside with deadbolt emergency egress hardware, a deadbolt, or a rigid wood or metal bar that extends across the width of the door. Figure 6-1 shows the dimensional requirements for a Class 5 vault door.

Figure 6-1 Class 5 Vault Door



6-7.5 Locks.

Use vault door locks that meet the requirements of FS FF-L-2740.

6-7.6 Miscellaneous Openings.

Install barriers in any miscellaneous openings, open ducts, pipes, register, sewers in excess of 96 square inches (619 cm^2) in area and over 6 inches (150 mm) in its smallest dimension. Acceptable barriers are 9 gauge expanded metal mesh, or rigid (steel) bars at least 1/2-inch (13-mm) in diameter, welded vertically and horizontally 6 inches (150 mm) on center. Securely fasten the rigid metal bars at both ends to preclude removal. Use crossbars to prevent spreading of the bars.

6-8 CLASS C VAULTS.

Class C vaults may be used in existing buildings where unique structural circumstances do not permit construction of a Class A concrete vault.

6-8.1 Walls.

Use 1/4-inch (6-mm) thick steel alloy-type metal plates having characteristics of high yield and tensile strength. The metal plates are to be continuously welded to load-bearing steel members of a thickness equal to that of the plates. If the load-bearing steel members are being placed in a continuous floor or ceiling of reinforced concrete, they must be firmly affixed to a depth of one-half the thickness of the floor and ceiling.

6-8.2 Floor and Ceiling.

If the floor and/or ceiling construction is less than six inches of reinforced concrete, use a steel liner with the same characteristics as the walls to form the floor and ceiling of the vault. Weld seams together where the steel plates meet horizontally and vertically.

6-8.3 Door and Frame.

Use a vault door and frame that conforms to F S AA-D-600.

6-8.4 Locks.

Use vault door locks that meet the requirements of FS FF-L-2740.

6-8.5 Miscellaneous Openings.

Equip any miscellaneous openings, open ducts, pipes, registers, sewers in excess of 96 square inches (619 cm^2) in area and over 6 inches (150 mm) in its smallest dimension with barriers. Acceptable barriers are 9-gauge (3.8-mm) expanded metal mesh, or rigid metal (steel) bars at least 1/2 inch (13 mm) in diameter, welded vertically and horizontally 6 inches (150 mm) on center. Securely fasten the rigid metal bars at both ends to preclude removal. Use crossbars to prevent spreading of the bars.

6-9 MODULAR VAULTS.

Modular vaults provide a minimum of 15 minutes of forced entry resistance against a multilevel tool attack up to threat severity level III. Modular vaults provide only minimal delay to threat severity levels IV and V.

An advantage of modular construction is that a modular vault can be reconfigured or disassembled and relocated as needed.

6-9.1 Advantages of Modular Vaults.

Advantages of using modular vaults instead of poured in place reinforced concrete vaults include:

- Ability to construct a new vault in a few hours rather than days or months.
- Ability to construct a new vault without the use of concrete forms and resulting construction debris.
- Lighter weight (up to 70 percent less) depending on the class of vault.
- Lower cost (up to 50 percent less) depending on the extent of structural modifications that would be required.
- Flexibility for installing a vault in or removing a vault from an existing operational building (depending on the extent of structural modifications required).
- Reduction in space required because the walls are up to 70 percent thinner.

6-9.2 Construction.

Vaults are made of modular panels, which are assembled to form a six-sided structure. The floor may be the concrete slab of the building, or it may consist of modular panels. Figure 6-2 shows a representative configuration of a modular vault.

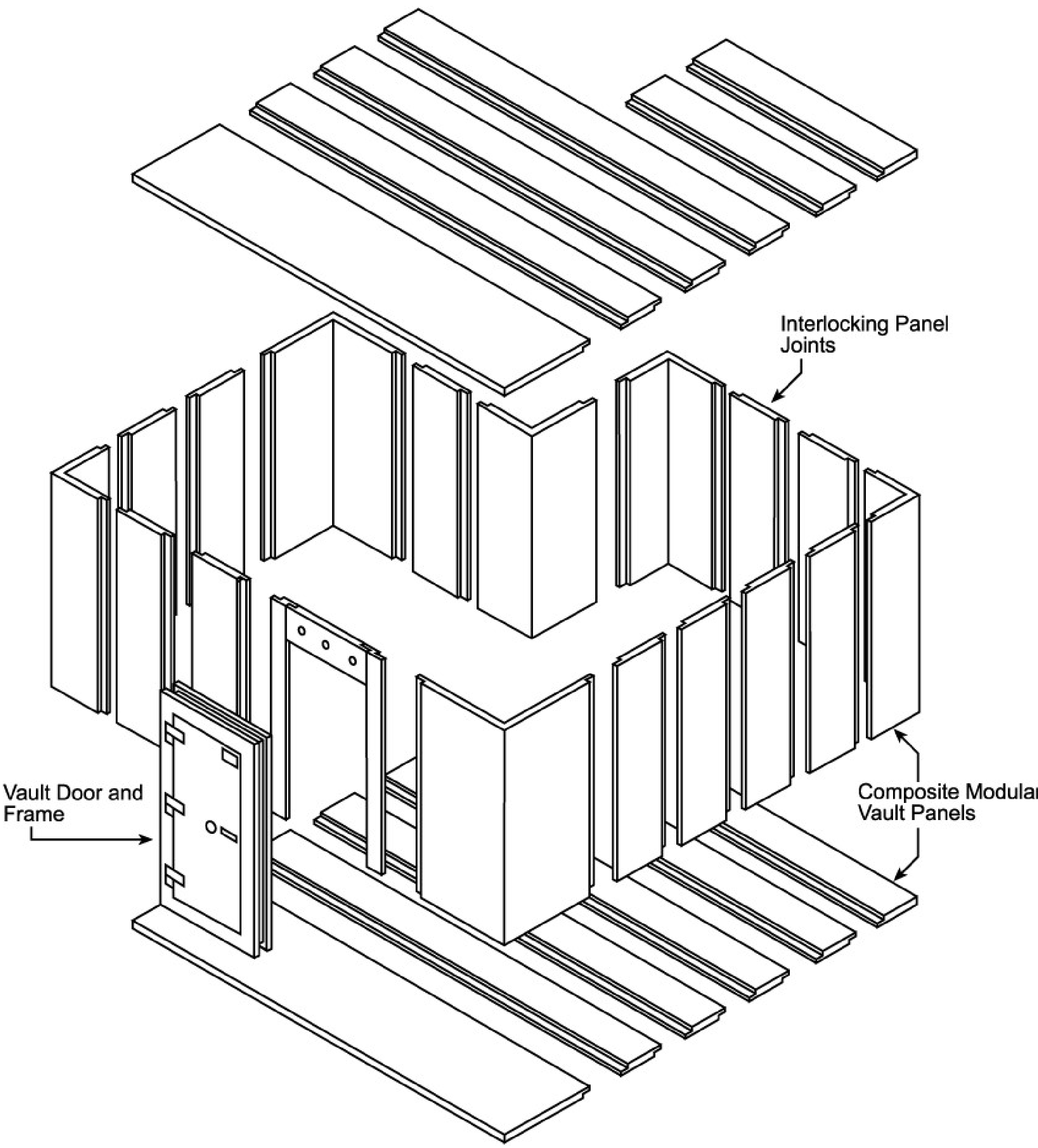
FS AA-V-2737 covers panels that may be assembled to form a GSA-approved modular vault. The vault must use a Class 5 GSA-approved vault door meeting requirements of FS AA-D-600.

Modular vault panels are either lightweight (less than 30 pounds per square foot) or heavyweight (unlimited weight). Lightweight panels are laminated of various materials which together provide the forced entry resistance time of at least 15 minutes against threat severity level IV. Heavyweight panels are typically made of concrete.

6-9.3 Availability.

Modular vaults are available from a variety of American manufacturers. Additional information is available from the Naval Facilities Engineering and Expeditionary Warfare Center (EXWC) Code CI8 Port Hueneme, CA, 93043 and from GSA.

Figure 6-2 Simple Modular Vault Panel and Door Arrangement



6-10 ARMS, AMMUNITION, AND EXPLOSIVES AREAS.

AA&E can be stored in magazines, arms rooms, or vaults depending on the risk category and quantities and use of the AA&E.

Table 6-2 lists AA&E Risk Categories and their application.

- All Risk Category I AA&E must be stored in standard magazines.
- AA&E Risk Categories II through IV must be stored in a structure with a minimum forced entry resistance of 10 minutes against threat severity level III including arms rooms or permanent and modular vaults with a Class 5 approved vault door.

Table 6-2 Security Risk Categories for AA&E (DODM 5100.76)

CATEGORY	WEAPONS	AMMUNITION & EXPLOSIVES
I	Nonnuclear man-portable missiles and rockets in a ready to fire configuration; for example, Redeye, Stinger, Dragon, Javelin, light antitank weapon (66mm), shoulder–launched multi–purpose assault weapon rocket (83 mm), and AT–4 anti–armor launcher and cartridge (84 mm). Also included are the tube–launched, optically tracked, wire–guided missile (TOW) weapon and the Hellfire missile.	Explosive complete rounds for Category I missiles and rockets
II	Light automatic weapons up to and including 0.50 caliber (13 mm), M16A2 rifle, M4 rifle, Squad Automatic Weapon, M60 machine gun, and 40mm MK 19 grenade launcher. Silencers, mufflers and noise suppression devices.	High explosive hand or rifle grenades and white phosphorous. Mines, antitank or antipersonnel with an unpacked weight of 50 pounds (23 kg) or less. Explosives used in demolition operations, C-4, military dynamite and TNT with an unpacked weight of 100 pounds (45 kg) or less. Critical binary munitions components containing “DF “and “QL” when stored separately from each other and from the binary chemical munition bodies in which they are intended to be employed.

CATEGORY	WEAPONS	AMMUNITION & EXPLOSIVES
III	Launch tube and grip stock for the Stinger missile. Launch tube, sight assembly and grip stock for Redeye missiles. Tracker for the Dragon missile. Mortar tubes up to and including 3.2 inch (81 mm). Grenade launchers. Rocket and missile launchers (unpacked weight of 100 pounds (45 kg) or less). Flame throwers. Launcher, missile guidance, or the optical sight for TOW.	Ammunition, .50 caliber (12.7 mm) and larger, with explosive filled projectile (unpacked weight of 100 pounds or less each). Grenades, incendiary, and fuses for high explosive grenades. Blasting caps. Supplementary charges (uninstalled or installed in projectiles in a manner allowing easy removal without special tools or equipment). Bulk explosives. Detonating cord.
IV	Shoulder-fired weapons other than grenade launchers, not fully automatic. Handguns. Recoilless rifles up to and including 4.2 inches (106 mm).	Ammunition with non–explosive projectile (unpacked weight of 100 pounds or less each). Fuses, except for those in Category III. Grenades, illumination, smoke, and tear gas (CS)/chloroacetophenone (CN) (tear–producing). Incendiary destroyers. Riot control agents, 100-pound package or less. Ammunition for weapons in Category III.

6-10.1 Magazines.

Refer to UFC 4-420-01 for construction requirements for ammunition and explosives storage magazines.

6-10.2 Arms Rooms.

Arms rooms are governed by DoDM 5100.76; they are similar in construction to vaults. They are treated as six-sided rooms, but there are door options in addition to vault doors. Unlike vaults, however, arms rooms must both meet minimum construction requirements and provide a minimum of 10 minutes of forced entry resistance against threat severity level III.

- Army arms rooms are constructed according to the requirements of AR 190-11; these are facilities, similar in function to the weapons storage spaces of armories, with very limited maintenance and repair facilities.
- Air Force arms rooms are governed by AFI 31-101 and AFMAN 32-1084. Air Force weapons repair and maintenance facilities are normally located in a Combat Arms Facility.
- Navy arms rooms must comply with OPNAVINST 5530.13.
- Marine Corps arms rooms must comply with MCO 5530.14.

6-10.3 General.

Permanently constructed arms rooms are normally cast-in-place concrete. Precast concrete of similar construction may be used, but it would have to be tested to ensure that the joints and connections meet the required delay time. Alternatively, precast panels meeting the requirements in Paragraph 6-10.4, and in which there are cast-in-place segments between panels, may be allowed if the continuity of reinforcement between panels and between floors or foundations and roofs or ceilings is maintained. In all cases, the construction in the paragraph below constitutes minimum requirements.

Structural requirements may require greater thicknesses and reinforcement. Use concrete in walls, floors, ceilings, and roofs with 3000 psi (20.7 MPa) minimum compressive strength. Use ASTM A615, Grade 60 for reinforcing bars and comply with ASTM A1064 for welded wire fabric. Reinforcement should be installed in accordance with ACI 318. Note that the reinforcing bars outside the United States may not be of the same dimensions or yield strengths as those in ASTM A615 and ASTM A1064. In those cases, use the closest greater diameter and tensile strength.

6-10.4 Walls.

Use a minimum of 8-inches (200 mm) thick concrete with a minimum 28-day compressive strength of 3,000 psi (20.7 MPa) reinforced with a minimum of #4 (1/2-inch, 13 mm) reinforcing bars in both directions on each face, spaced at 9 inches (225 mm), and staggered each face such that they form a projected grid approximately 4-1/2 inches (115 mm) square. Thinner cross sections can be used if heavier reinforcing is selected. For example, a 6-inch (150-mm) cross section could be used if there are two layers of #5 (16-mm) reinforcing bar spaced at 4-1/2 inches (115 mm) each way. Tie reinforcement in walls into ceilings and floors.

6-10.5 Roofs and Ceilings.

For roofs and ceilings, use a minimum of 8-inches (200-mm) thick concrete with a minimum 28-day compressive strength of 3,000 psi (20.7 MPa) reinforced with a minimum of #4 (1/2-inch, 13-mm) reinforcing bars in both directions spaced such that they form a grid such that the areas of any openings between bars will not exceed 96 square inches (619 cm^2). If the ceiling or roof must be pan-joist construction, the thinnest part may not be less than 6-inches (150-mm) and the clear space between joists may not exceed 20-inches (500-mm).

6-10.6 Floors.

Floors, if on grade, must be a minimum of 6-inches (150 mm) thick reinforced concrete with a minimum 28-day compressive strength of 3,000 psi (20.7 MPa) reinforced with minimum of 6-inch x 6-inch (150-mm x 150-mm) W4 x W4 welded wire fabric. Alternatively, use a minimum of #4 (1/2-inch, 12.5 mm) reinforcing bars in both directions spaced such that they form a grid such that the areas of any openings between bars will not exceed 96 square inches (619 cm^2). Bar spacings in each direction of 10 inches (254 mm) would result in a clear area between bars less than the minimum area.

Where floors of arms rooms are ceilings of spaces below them, follow the ceiling standard.

6-10.7 Existing Wall, Ceiling, Roof, and Floor Reinforcement.

Where existing construction is not up to the standards above, use any of the reinforcing methods listed below. When any of these are applied, fasten them to the existing structure so that destruction of the existing and reinforcing materials is required to remove them.

- Steel bars: Use 3/8-inch (10 mm) steel bars, 4 inches (100 mm) apart with bars in one direction welded to the bars in the opposite direction so that the openings do not exceed 32 square inches (0.02 m2). Ends of the steel bars must be embedded securely in the structure of the building or welded to a steel frame securely fastened to the building.
- Steel landing mat: Use Marsten, Irving, or pierced steel planking.

- Expanded metal: Use 3/16-inch (5 mm) thick expanded metal with a maximum grid opening of 1 inch by 3 inches (25 mm by 75 mm) and weighing a minimum of 4.27 pounds per square foot (20.8 kg/m2).
- Steel plate: Use 1/4-inch (6.4 mm) steel plate.
- Steel mesh: Use Number 8–gauge (4.1 mm) high carbon manganese steel, or for existing facilities, number 6–gauge (4.1 mm) cold drawn steel wire with a grid of not more than 2 inches (50 mm) center to center. The number 6–gauge (4.1 mm) wire is not authorized for future upgrading.
- Sheet metal: For existing facilities, use 16–gauge (1.6 mm) steel sheets or plates securely fastened together. This material is not authorized for future upgrading.

6-10.8 Doors.

Only the GSA-approved Class 5 Armory Door provides the required 10 minutes of delay; therefore, only that door is allowed for new construction. The Class 5 Armory Door is specified using FS AA-D-600.

The following doors are authorized for existing construction by DoDM 5100.76:

- 1-3/4-inch (44 mm) solid or laminated wood with 12-gauge (2.7 mm) steel plate on the exterior face.
- 1-3/4-inch (44 mm) hollow metal, industrial type construction with minimum 14-gauge (1.9 mm) skin plate thickness, internally reinforce vertically with continuous steel stiffeners spaced 6-inches maximum on-center.
- Solid hardwood or laminated wood of at least 2 inches (50 mm) thickness with a 1/4-inch (6 mm) thick steel plate on the outside face.
- A door constructed with a 3/8-inch (10 mm) thick steel plate or combines thickness of outside and inside surfaces of at least 3/8-inch (10 mm) steel.

6-10.9 Door Frames and Hardware.

For doors other than the Class 5 Armory Doors, door bucks, frames, and keepers must be rigidly anchored and provided with anti-spread filler reinforcement to prevent disengagement of the lock bolt by prying or jacking of the door frame. Door frames must be designed and installed in a manner that prevents removal of the frame facing. Their construction requirements must be as exacting as those for the doors themselves. For example, where metal doors are used, the frame and thresholds must also be metal. Door hinges must be located on the inside and must be of the fixed-pin security type or equivalent. Figure 6-3, Figure 6-4, Figure 6-5, and Figure 6-6 show designs of acceptable hinge side protection.

Figure 6-3 Hinge Side Protection Using a Pin-in Socket

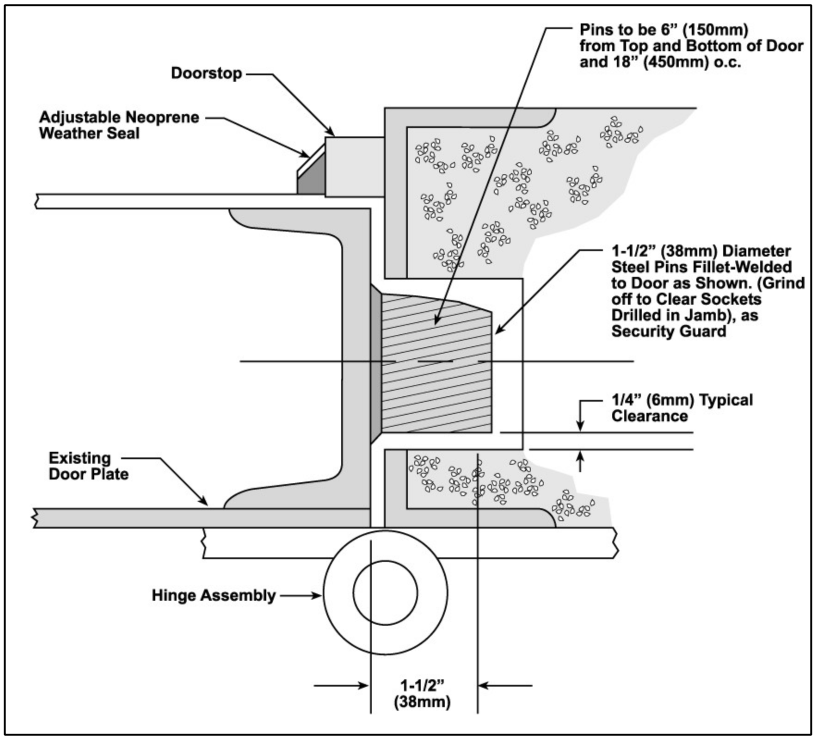


Figure 6-4 Hinge Side Protection Using a Forward Doorstop with Steel Angle

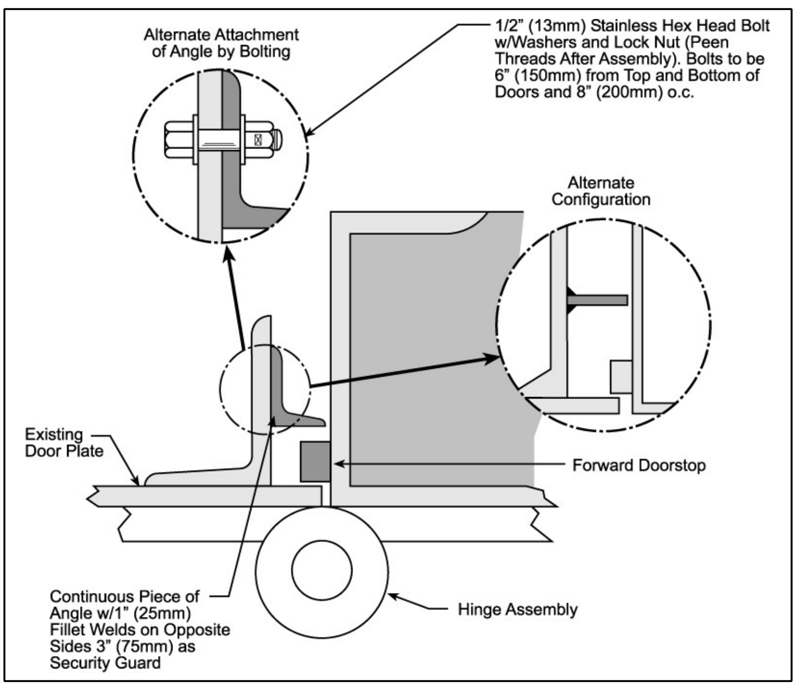


Figure 6-5 Hinge Side Protection Using an Angle Stop

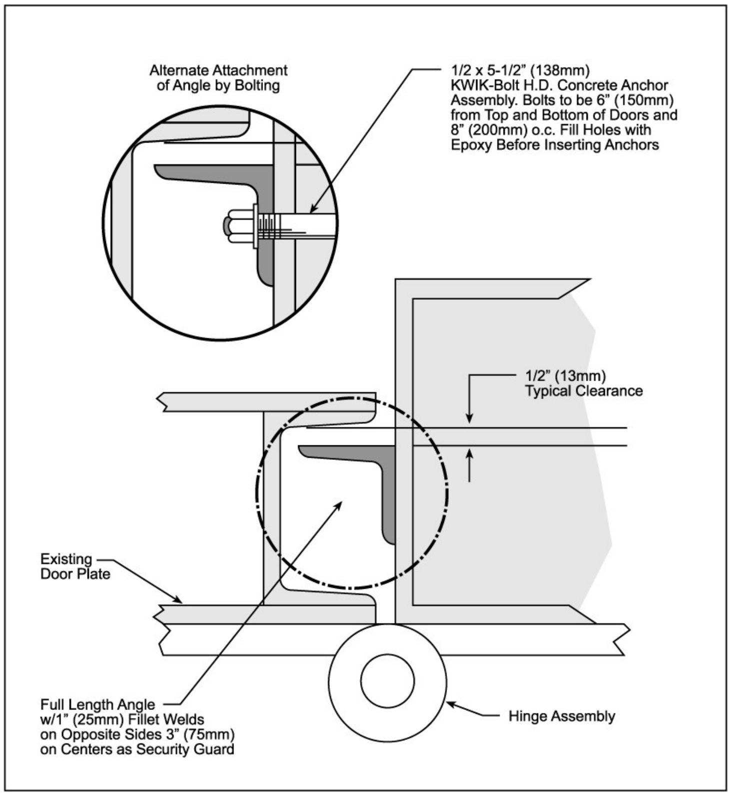
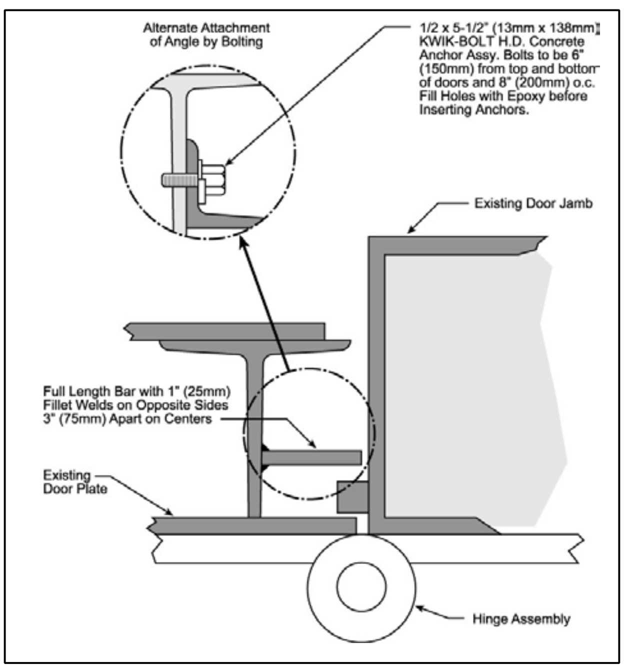


Figure 6-6 Hinge Side Protection Using a Bar Stop

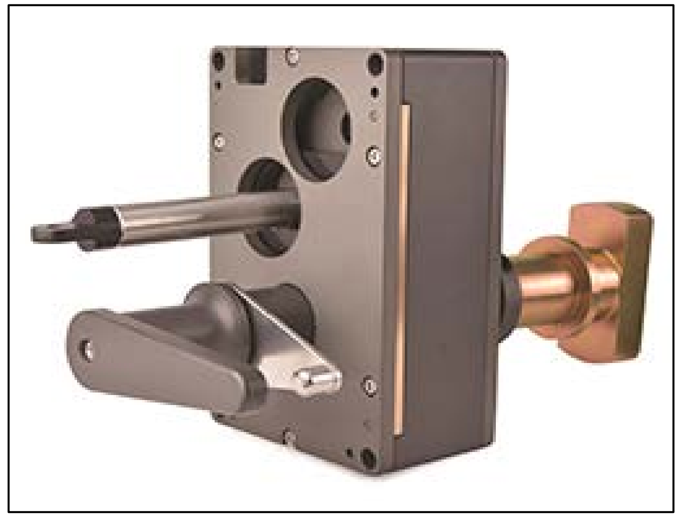


6-10.10 Locks.

Locks for Class 5 Armory Doors are covered in FS AA-D-600. They are combination locks that are listed in accordance with Group 1 of UL 768. Locks for new construction and upgrades of Category I and II AA&E areas must be the Internal Locking Device (See Figure 6-7 for all doors except for Class 5 Armory Doors.)

Figure 6-7 Internal Locking Devices

ILD Gen I



ILD Gen II

6-10.11 Miscellaneous Openings.

In general, windows and other openings must be kept to a minimum. Windows are not authorized for new construction for Army arms rooms. Where any openings are greater than 96 square inches (619 cm^2) with a least dimension greater than 6-inches (150 mm) one of the following can be used to secure them:

- Minimum 3/8-inch (10 mm) hardened steel rods with a maximum spacing of 4-inches (100 mm) and with horizontal bars attached to no openings exceed 32 square inches (0.02 square meters).
- Riveted steel grating weighing 13.2 lbs/square foot (64.4 kg/m^2) or welded steel grating weighing 8.1 lbs/square foot (39.6 kg/m^2) with 1 by 3/16-inch (25 by 5 mm) bearing bars.

6-10.12 Other Storage Options.

A vault that meets the requirements for arms rooms can be used to store all categories of Risk Category II, III and IV arms and ammunition depending on explosive safety restrictions. Modular vaults can also be used.

Security containers that meet the requirements of Federal Specification AA-F-363, Class 5, or Federal Specification AA-C-2859, can be used to store small quantities of Risk Category II, III and IV arms.

6-10.13 Other Requirements.

Unless a weapons storage site is continuously guarded, an IDS is required for Risk Category I and II AA&E storage areas. Refer to UFC 4-021-02 for IDS designs. Risk Category I and II AA&E must be fenced separately. Refer to UFC 4-022-03 for fencing and gate designs. Exterior lighting is required for Risk Category I and II AA&E only.

6-10.14 Retrofit of Existing Arms Rooms.

Existing facilities can be effectively upgraded to meet the AA&E storage requirement for ten minutes of penetration resistance against threat severity level III. To upgrade these facilities, reinforce walls, ceilings and floors as necessary using a layer of 3/4-inch (19-mm) plywood sandwiched between two layers of 10 gauge (3.4-mm) hot-rolled steel to provide about 6 minutes of additional penetration delay time. The penetration delay time can be increased by about five minutes with the addition of another wood and steel layer. This rule of thumb can be applied to the addition of more layers until the desired penetration delay time is reached. Penetration delay time for steel-plywood systems can be increased by changing the steel material to 9-gauge (3.8-mm) ASTM A1008, Class 2, high-strength, low-alloy steel. One layer of 3/4-inch (19-mm) plywood sandwiched between two layers of this steel will provide 14 minutes of penetration delay time. Adding layers of 90-pound (200-kg) gravel finish roofing paper between the plywood and steel further increases the penetration delay time to about 20 minutes. These times are added to the increased penetration delay time provided by preventing internal spalling of the concrete (approximately double the initial penetration delay time).

6-11 STORAGE CONTAINERS.

Class 5 storage containers are allowed as options for the storage of many of the assets that are governed by the regulatory documents described in Paragraph 6-2. They are not considered to be parts of facilities; however, they can provide resistance to forced entry at threat severity level II. Class 5 storage containers provide 10 man-minutes of delay against threat severity level II; they provide no delay against higher threat severity levels. See Figure 6-8 for storage container examples.

Storage containers must be approved by GSA. They are specified using one of the following Federal Specifications (FS) based on what is being stored inside them. The Federal Specifications include container construction and testing requirements as well as locking device specifications.

- FS AA-F-358, Filing Cabinet, Letter and Legal Size, Uninsulated, Security
- FS AA-F-363, Filing Cabinet, Security, Maps and Plans, General Filing and Storage
- FS AA-C-2859, Cabinet, Security, Weapons Storage
- FS AA-C-2786, Cabinet, Security, Information Processing System Storage, Class 5.

Figure 6-8 Storage Containers

	
FS AA-F-358 Filing Cabinet, Letter and Legal Size, Uninsulated, Security	FS AA-C-2859 Cabinet, Security, Weapons Storage

CHAPTER 7 EQUIPMENT AND SYSTEMS

7-1 INTRODUCTION.

This chapter contains information on systems that can be considered to supplement the barrier designs in Chapter 5 for high and very high levels of protection combined with threat severity levels IV and V.

7-2 DISPENSABLE BARRIER SYSTEMS.

Dispensable barriers are activated manually or automatically in response to attack. Such systems include sticky foam and cold smoke. Sticky foam is an aggressively tacky thermoplastic resin stored under pressure in canisters or wall panels. When punctured by tools or bullets, or when the system's detectors are tripped, the foam shoots out of the panels. The foam expands and adheres to whatever it contacts. Aggressors must be extricated from the foam with a solvent. The foam must also be cleaned off surfaces with the solvent. Because sticky foam may result in the death of the aggressor or anyone else who accidentally triggers it, apply it only where the use of deadly force is authorized. This system provides a minimum delay time of 15 minutes against motivated aggressors (according to the manufacturer). It is most effective when used in hallways. Cold smoke is a particulate material, which fills a room with a persistent dense cloud when activated. Aggressors cannot see in the cloud and therefore have difficulty locating assets. To be effective, both activated barrier systems must by sized for the volume of the protected space.

Dispensable barriers can, on command, stop or delay aggressors from accomplishing their objective. Several types are being developed and tested. This section identifies the major components of a dispensable barrier system and describes some of the attributes of dispensable materials. The information in this paragraph was developed by Sandia National Laboratories, Albuquerque, NM.

7-2.1 Typical Dispensable Barrier System.

A typical dispensable barrier system includes:

- A process for decision making to determine when the dispensable barrier is to be activated.
- Command and control hardware to implement this decision.
- The material that is deployed to physically deny access.
- The dispensing mechanism.
- A response force located on site.

7-2.2 Barrier Activation.

The dispensable barrier may be activated by a member of the response force, some form of intrusion sensing, or by the combined action of both the security force and sensors.

The major compromise is between assurance that activation can and will occur in an aggressor attack (reliability) and assurance that the probability of inadvertent activation is low (premature activation). Hardware design and effective operational procedures can reduce the probability of inadvertent activation to as low a value as required.

7-2.3 Command and Control Hardware.

The command and control hardware accepts the activation decision and operates the dispensing hardware. Command and control hardware stands between the decision mechanism and the dispensing hardware. Because the activation decision mechanism and the dispensing hardware may be separated by large distances, electromagnetic radiation, lightning, earthquakes, power surges, and other possible severe environments must be considered in the design. The command and control hardware improves personnel safety and assures that, if inadvertent activation occurs, authorized personnel in the area have time to exit.

7-2.4 Dispensable System.

7-2.4.1 Types of Dispensable Barriers.

Specific dispensable materials and associated dispensing hardware that are being developed and tested include:

- Rigid polyurethane foam.
- Stabilized aqueous foam.
- Obscurants smoke.
- Sticky thermoplastic foam.
- Various entanglement devices.
- Irritants.

7-2.4.2 Compact Storage and Rapid Expansion.

The dispensable material is normally stored in a compact form, and through a chemical or physical reaction, is expanded to provide additional delay. These properties that permit compact storage and rapid expansion make activated delay systems attractive in applications where operational considerations are dominant or where there are weight issues in the protective system design. For example, pyrotechnic and chemical obscurants have an expansion ratio of approximately 50,000 to 1, whereas most foams range from 50 to 1 to 500 to 1 for aqueous foams.

7-2.5 Dispensing Hardware.

Dispensing hardware consists of storage tanks, activation valves, pressure regulators, safety valves, filters, power sources, and plumbing hardware. The specific hardware design is unique for each material and application, but many of the components are similar. This uniqueness of design and limited application are factors that increase the cost of the dispensing hardware.

7-2.6 Response Force Time.

Dispensable barrier systems will only delay an adversary for a finite time. At some point in time, the aggressor will defeat any delay mechanism; therefore, either guards or the response force must respond and achieve control in a shorter time than the barrier delay time.

An effective dispensable barrier can reduce the critical need for an immediate reaction by the response force. This may allow the use of response personnel who are not always dedicated to security and therefore reduce overall protection system costs. In addition, the dispensing hardware requires that the adversary must be capable of doing more than just neutralizing the response force. This increased requirement on the aggressor can significantly increase the probability that the overall physical protection system will perform as desired.

7-3 SHUTTERING SYSTEMS.

Shuttering systems are doors, screens, or other barriers that can be used to supplement defense layer protection of assets. While these barriers provide only limited delay to a forced entry attempt, they do cause the aggressor to take time to breach them, thereby allowing additional time for a response force to deploy.

7-3.1 Automated Shuttering Systems.

Shuttering systems such as fire barrier doors and security shutters can be automatically deployed in response to detection devices such as smoke detectors, heat detectors, or intrusion detection sensors. They can also be deployed though commands from a guard or monitoring station.

During normal operations, fire barrier doors can be held open by magnetic door holders but released by remote command from fire alarm panels (automatic) or from a security command center. The doors also close upon loss of power. Security shutters are normally open until a command is received from the ACS (in response to sensor activation) or from a security command center. Shutters would remain open during loss of power.

7-3.2 Use of Automated Shuttering Systems.

Automated shuttering systems can be used to delay aggressors along predicable paths from building entrances to the protected areas containing the asset. Consider using them at personnel entrances and in hallways for high and very high levels of protection combined with threat severity levels IV and V.

APPENDIX A GLOSSARY

A-1 ACRONYMS.

AA&E Arms, Ammunition, and Explosives

ACI American Concrete Institute

ACP Access Control Point

ACS Access Control System

AFCEC Air Force Civil Engineer Center

AFI Air Force Instruction

ANSI American National Standards Institute

AR Army Regulation

ASTM American Society for Testing and Materials

AT&L Acquisition, Technology, and Logistics

BHMA Building Hardware Manufacturers Association

BIA Bilateral Infrastructure Agreement

CCR Criteria Change Request

CCTV Closed-Circuit Television

cm Centimeter

cm^2 Square Centimeter

COMSEC Communications Security

CMU Concrete Masonry Unit

DBT Design Basis Threat

ECP Entry Control Point

EF Each Face

ESS Electronic Security System

EW	Each Way
GA/ga	Gauge
GWB	Gypsum Wall Board
GSA	General Services Agency
HMMA	Hollow Metal Manufacturers Association
HNFA	Host Nation Funded Construction Agreement
HQUSACE	Headquarters, United States Army Corps of Engineers
HRP	High Risk Personnel
HVAC	Heating, Ventilating, and Air Conditioning
IC	Intelligence Community
ICD	Intelligence Community Directive
IDS	Intrusion Detection System
in	Inch
kPa	Kilopascal
lbs	Pounds
LSC	Linear Shaped Charge
Mil-Std	Military Standard
m	Meter
mm	Millimeter
mm^2	Square Millimeter
MPa	Megapascal
NAAMM	National Association of Architectural Metal Manufacturers
NAVFAC	Naval Facilities Engineering Command
NFPA	National Fire Protection Association

OC On Center

psi Pounds per square inch

SAPF Special Access Program Facility

SCI Sensitive Compartmented Information

SCIF Sensitive Compartmented Information Facility

SECNAVINST Secretary of the Navy Instruction

SFR Steel-Fiber-Reinforced

SOFA Status of Forces Agreement

TNT Trinitrotoluene

UFC Unified Facilities Criteria

UL Underwriters Laboratories

A-2 DEFINITION OF TERMS.

Access Control: For the purposes of this document, any combination of barriers, gates, electronic security equipment, and/or guards that can deny entry to unauthorized personnel or vehicles.

Aggressor: Any person seeking to compromise an asset. Aggressor categories include protesters, criminals, terrorists, and subversives.

Antiterrorism: Defensive measures used to reduce the vulnerability of individuals and property to terrorist acts, to include limited response and containment by local military and civilian forces.

Assessment: Visual verification of the validity of an alarm from an electronic security system.

Asset: A resource requiring protection.

Biological Agents: Pathogens and toxins that can be used to contaminate air or water.

Breaching: Making a hole completely through a building surface using tools or explosives.

Building: A structure, usually enclosed by walls and a roof, constructed to provide support or shelter for an intended occupancy. Note that other structures, such as canopies, are not considered buildings for the purposes of this UFC.

Building Compound: A controlled area established around a building or group of building that has a perimeter defined by fences or walls, and an open area between the perimeter and the buildings.

Building Elements: Components of buildings and countermeasures associated directly with building interiors and exterior surface features.

Building Hardening: Enhanced conventional construction that mitigates threat hazards where standoff distance is limited. Building hardening may also be considered to include the prohibition of certain building materials and construction techniques.

Chemical Agents: Chemicals, including toxic industrial chemicals, toxic industrial materials, and military chemical agents that can be used to contaminate air or water.

Controlled Perimeter: A physical boundary at which vehicle access is controlled at the perimeter of an installation, an area within an installation, or another area with restricted access. A physical boundary will be considered as a sufficient means to channel vehicles to the access control points. At a minimum, access control at a controlled perimeter requires the demonstrated capability to search for and detect explosives. Where the controlled perimeter includes a shoreline and there is no defined perimeter beyond the shoreline, the boundary will be at the mean high-water mark.

Critical Asset: Any facility, equipment, service or resource considered essential to DoD operations in peace, crisis, and war and warranting measures and precautions to ensure its continued efficient operation, protection from disruption, degradation, or destruction, and timely restoration. Critical assets may be DoD assets or other government, or private assets Critical assets include traditional physical facilities and equipment, non-physical assets (such as software systems), or “assets” that are distributed in nature (such as command and control networks, wide area networks or similar computer-based networks).

Critical Infrastructure: Infrastructure deemed essential to DoD operations or the functioning of a Critical Asset.

Delay Time. The time an adversary must work to breach a security barrier to gain access to a secured resource. Total delay time is the sum of penetration and ingress times by one or more barriers separating an aggressor from a secured asset required to breach and travel between barriers. Total delay time can include egress time required to load the asset and exit the facility.

Design Basis Threat: The threat upon which a system of countermeasures protecting assets is based. The design basis threat includes the aggressor tactics and the associated weapons, explosives, tools, and agents.

Design Criteria: For the purposes of this document, the basis for defining a protective system that mitigates vulnerabilities to assets. Design criteria include assets, threats, levels of protection, and design constraints.

DoD Building: Any building or portion of a building (permanent, temporary, or expeditionary) owned, leased, privatized, or otherwise occupied, managed, or controlled by or for DoD. DoD buildings other than leased buildings are categorized within these standards as low occupancy, inhabited, primary gathering, high occupancy family housing, and billeting.

DoD Personnel: Any U.S. military, DoD civilian, or family member thereof, host-nation employees working for DoD, or contractors occupying DoD buildings. For the purposes of these standards, non-DoD visitors to DoD owned or controlled visitor centers, visitor control centers, museums, and similar facilities will be included in DoD personnel populations of those facilities. Visitor counts will be based on routine visitor levels.

Egress Time: The interval required for an aggressor to load and carry stolen assets when theft is the purpose of the penetration. The egress time varies depending upon the interior layout of the facility; the availability of doors, windows, and utility ports that can be opened; and the weight and volume of the assets being stolen. In general, egress time increases with layout complexity and any limitation on the number of doors, windows, and utility openings available as exits.

Entry Control Point. A continuously or intermittently manned station at which entry through a perimeter is controlled.

Equipment: As part of a protective system, countermeasures such an electronic security system elements and other devices used by personnel for detection and assessment of threats or weapons, tools, explosives, or chemical, biological, or radiological agents.

Explosive Safety: The practice of providing the maximum possible protection to personnel and property, both inside and outside the installation, from the damaging effects of potential accidents involving DoD ammunition and explosives.

Ferrocement or **ferro-cement:** Also called thin-shell concrete or ferro-concrete; is a system of reinforced mortar or plaster (lime or cement, sand and water) applied over layer of metal mesh, woven expanded-metal or metal-fibers and closely spaced thin steel rods such as reinforcing bars.

Forced Entry Penetration Delay Time: Barrier penetration time is defined as the time interval during which an aggressor can create a man-passable opening through a barrier (such as a wall, roof, floor, door, or window) by forced entry. The penetration delay time is based on working time rather than elapsed time. Working time accounts for the interval that an attack tool is used to attack the barrier. Working time excludes the time required to change tools, change operators, rest, and transfer tools, and for personnel to pass through the barrier. In not accounting for these interruptions, the penetration delay time is inherently conservative. In the case of multiple barriers, the total penetration delay time is the sum of the individual penetration delay times provided by all barriers.

Fragment: For the purposes of developing protective systems, pieces of the materials surrounding an explosive that may be propelled at high velocity toward a building or other target as a result of an explosion of a bomb or a warhead.

Gravity Vent: Strategically placed opening in the building to take advantage of prevailing winds and thermal buoyancy or stack effect to remove heat from a building.

Halligan Bar: A tool used in fire and rescue service for forcible entry and other prying and striking tasks.

Historic Preservation: Protection afforded to districts, sites, buildings, structures, or objects listed on or eligible for inclusion on the National Register of Historic Places in accordance with the National Historic Preservation Act.

Incendiary Devices: Devices designed to spread fire.

Ingress Time: The sum of all-time intervals required for an aggressor to traverse from barrier to barrier within a site or facility. This includes the time required to climb (up or down) through horizontal barriers (for example, roofs or floors) and the time to traverse between vertical barriers (for example, walls or fences). In general, ingress time increases with increasing site or facility size, number of barriers separating the secured area from the exterior, and size and types of tools and equipment that must be transported between barriers. The designer can increase ingress time by properly laying out the exterior and interior of the facility.

Inhabited Facilities: Buildings or portions of buildings routinely occupied by 11 or more DoD personnel and with a population density of greater than one person per 430 gross square feet (40 gross m^2). This density generally excludes industrial, maintenance, and storage facilities, except for more densely populated portions of those buildings such as administrative areas. The inhabited building designation also applies to expeditionary and temporary structures with similar population densities. In a building that meets the criterion of having 11 or more personnel, with portions that do not have sufficient population densities to qualify as inhabited buildings, those portions that have sufficient population densities will be considered inhabited buildings while the remainder of the building may be considered uninhabited, subject to provisions of these standards. An example would be a hangar with an administrative area within it. The administrative area would be treated as an inhabited building while the remainder of the hangar could be treated as uninhabited.

Kerie Cable: A long flexible spiral cable with the center strand pulled out to allow for oxygen passage used as an exothermic cutting tool.

Kelly Tool: A tool used in fire and rescue service for forcible entry and other prying and striking tasks. The predecessor of the Halligan bar, it has largely been superseded by the latter, but still sees some use.

Level of Protection: The degree to which an is protected against injury or damage from an attack.

Man-Passable Opening: A man-passable opening is defined as the minimum area required for an aggressor to physically pass through a barrier and enter a secured area. DoDM 5100.76 defines man-passable as an opening of 96 square inches (619 cm^2), which is at least 6 inches (150 mm) wide or high. These values have been established to standardize laboratory test procedures and provide a built-in level of conservatism for the final test results. The forced entry test data presented in this UFC are based on tests and are conservative. The conservative nature of this approach is even more evident where the avenue of physical entry involves passage through a thick barrier, such as an 18-inch (450-mm) reinforced concrete wall, or a long passageway, such as a 20-foot (6-m) ventilation duct.

Manpower: Countermeasures that relate to the use of guards or other personnel necessary to implement or operate elements of the protective system.

Passive Perimeter Barriers: Vehicle barriers that are permanently deployed and do not require a response to be effective and fences, walls, screens, landforms, and lines of vegetation applied along an exterior perimeter used to obscure vision, hinder personnel access, or hinder or prevent vehicle access.

Penetration: Relating to bullets or fragments, entry into a material without passing all the way through.

Planning Team: A team of people with responsibilities relating to a project that is formed to develop design criteria and review material from all phases of the design process.

Protected Asset: An asset identified in the project design criteria that requires protection against a forced entry attack.

Protective System: An integrated system of countermeasures designed to protect assets against threats to specific levels of protection. Protective systems include building elements, sitework elements, equipment, and manpower and procedures.

Procedures: Countermeasures that relate to actions taken by people, including guards and building occupants, to implement or operate elements of the protective system.

Risk: A means to quantify the combined issues of the value of an asset or the impact of its loss, the likelihood of the asset being attacked, and the effectiveness of the protection afforded the asset that can be used as a tool in making decisions about asset protection.

Risk Analysis: The process of determining risk levels for assets.

Risk Management: The process of evaluating how changes in countermeasures application affect risk levels and costs for the purpose of decision making.

Sitework Elements: Countermeasures that are applied beyond 1.5 meters (5 feet) from a building, excluding countermeasures categorized under equipment.

Spall: The condition in which pieces of a material are broken loose from the inner surface of a wall, roof, or similar element by tensile forces that are created when a compression shock wave travels through the body and reflects from the surface.

Specific Design Strategy: The approach to applying general design strategies based on the applicable levels of protection.

Tactics: The specific methods of achieving the aggressor's goals to injure personnel, destroy assets, or steal materiel or information.

TNT Equivalent Weight: The weight of TNT (trinitrotoluene) that has an equivalent energetic output to that of a different weight of another explosive compound.

Unobstructed Space: Space within 10 meters (33 feet) of an inhabited building that does not allow for concealment from observation of explosive devices 150 mm (6 inches) or greater in height.

Vulnerability: Any weakness in the design or operation of a protective system for an asset that can be exploited by an aggressor to disrupt, damage, destroy, injure, or otherwise compromise the asset.

APPENDIX B REFERENCES

CODE OF FEDERAL REGULATIONS

https://www.deadiversion.usdoj.gov/21cfr/cfr/1301/1301_72.htm

21 CFR 1301.72*, Physical Security Controls for Non-Practitioners; Narcotic Treatment Programs and Compounders for Narcotic Treatment Programs; Storage Areas*

DEPARTMENT OF DEFENSE PUBLICATIONS

https://www.esd.whs.mil/directives/issuances/dodi/

DoDD 5210.41/AFMAN 31-108, Volumes 1–3*, Security Policy for Protecting Nuclear Weapons / The Air Force Nuclear Weapon Security Manual*

DoDI O-2000.22, *Designation and Physical Protection of DoD High Risk Personnel*

DoDI 5210.65, *Security Standards for Safeguarding Chemical Agents*

DoDI 5210.88, *Security Standards for Safeguarding Biological Select Agents and Toxins (BSAT)*

DoDI 8523.01*, Communications Security (COMSEC)*

DoDM 5100.76, *Physical Security of Sensitive Conventional Arms, Ammunition, and Explosives (AA&E)*

DoDM 5105.21, Volume 2, *Sensitive Compartmented Information (SCI) Administrative Security Manual: Administration of Physical Security, Visitor Control, and Technical Security*

DoDM 5200.01, Volume 3, *DoD Information Security Program: Protection of Classified Information*

DODM 5205.07/AFMAN 16-703, Volume 3, *DoD Special Access Program (SAP) Security Manual: Physical Security / Air Force Special Access Program (SAP) Security Manual: Physical Security*

DEPARTMENT OF AIR FORCE PUBLICATIONS

https://www.e-publishing.af.mil/Product-Index/#/?view=org&orgID=10141&catID=1&isForm=false&modID=449&tabID=131

AFI 16-1404, *Air Force Information Security Program*

AFI 31-101, *Integrated Defense*

AFMAN 32-1084, *Facility Requirements*

DEPARTMENT OF ARMY PUBLICATIONS

https://armypubs.army.mil/

AR 190-11, *Physical Security of Arms, Ammunition, and Explosives*

AR 190-51, *Security of Army Property at Unit and Installation Level*

AR 190-59, *Chemical Agent Security Program*

AR 380-5, *Information Systems Security*

DEPARTMENTS OF NAVY AND MARINE CORPS PUBLICATIONS

https://www.secnav.navy.mil/doni/default.aspx

MCO 5530.14, *Marine Corps Physical Security Program Manual*

OPNAVINST 5530.13, *Physical Security Instruction for Conventional Arms, Ammunitions, and Explosives*

SECNAV M-5510.36, *Information Security Program*

FEDERAL SPECIFICATIONS (FS)

https://www.gsa.gov/buying-selling/purchasing-programs/requisition-programs/gsa-global-supply/supply-standards/index-of-federal-specifications-standards-and-commercial-item-descriptions

FS AA-C-2859, *Cabinet, Security, Weapons Storage, Class 5*

FS AA-C-2786, *Cabinet, Security, Information Processing System Storage*

FS AA-D-6OO*, Security Vault Door*

FS-AA-F-358, *Filing Cabinet, Letter and Legal Size, Uninsulated, Security*

FS-AA-F-363, *Filing Cabinet, Security, Maps and Plans, General Filing and Storage*

FS-FF-L-2740, *Lock, Combination*

FS AA-V-2737, *Modular Vault Systems*

UNIFIED FACILITIES CRITERIA AND UNIFIED FACILITIES GUIDE SPECIFICATIONS PUBLICATIONS

http://www.wbdg.org/ffc/dod

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

UFC 3-350-01, *Interior and Exterior Lighting Systems and Controls*

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

UFC 4-010-03, *Security Engineering: Physical Security Measures for High-Risk Personnel*

UFC 4-010-05, *Sensitive Compartmented Information Facilities Planning, Design, and Construction*

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

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

UFC 4-020-02, *Security Engineering Facilities Design Manual*

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

UFC 4-022-03, *Security Fences and Gates*

UFC 4-023-10, *Safe Havens*

UFC 4-215-01, *Armories and Arms Rooms*

UFC 4-420-01, *Ammunition and Explosives Storage Magazines*

UFGS-08 33 23, *Overhead Coiling Doors*

UFGS-08 34 01, *Forced Entry Resistant Components*

UFGS-08 34 63, *Detention Hollow Metal Frames, Doors, And Door Frames*

NON-GOVERNMENT PUBLICATIONS

AMERICAN CONTRETE INSTITUTE (ACI), 38800 COUNTRY CLUB DRIVE, FARMINGTON HILLS, MI 48331

https://www.concrete.org/topicsinconcrete/topicdetail/318

ACI 318-14, *Building Code Requirements for Structural Concrete and Commentary*

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI), 11 WEST 42ND STREET, NEW YORK, NY 10036

https://webstore.ansi.org/Info/Sdolist

ANSI 297.1, *Safety Glazing Materials Used in Buildings-Safety Performance Specifications and Methods of Test*

ANSI/BHMA 156.1, *Butts and Hinges*

ANSI/BHMA 156.5, *Cylinder and Input Devices for Locks*

ANSI/BHMA 156.13, *Mortice locks*

ANSI/NAAMM HMMA 863-14, *Guide Specifications for Detention Security Hollow Metal Doors and Frames*

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM), 1916 RACE STREET, PHILADELPHIA, PA 19103

https://www.astm.org/

ASTM A615, *Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement*

ASTM A1008, *Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable*

ASTM A1064, *Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete*

ASTM F571, *Standard Practice for Installation of Exit Devices in Security Areas*

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA), PUBLICATIONS DEPT., 60 BATTERY MARCH ST., BOSTON, MA 02110

https://www.nfpa.org/

NFPA 101, *Safety to Life from Fire in Buildings and Structures*

UNDERWRITERS LABORATORIES (UL) INC., PUBLICATIONS STOCK, 333 PFINGSTEN ROAD, NORTHBROOK, IL 60062

https://www.ul.com/

UL 752, *Bullet-Resisting Equipment*

UL 768, *Combination Locks*

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OVERVIEW

This UFC supports physical security and force protection planning and design of deployed operational bases to protect personnel, assets, and infrastructure from terrorism and other deliberate man-made threats. The intended users of this UFC are engineers and planners responsible for project development and force bed down in the deployed environment. This UFC provides appropriate, effective, and economical protective designs to a level appropriate for project programming and provides commanders with the information they need to allocate resources. It covers minimum protection requirements and best practices applicable for temporary to semi-permanent facilities and infrastructure. The summary outline below is intended to guide potential inquiries regarding its scope.

SUMMARY OUTLINE

INTRODUCTION
- *Applicability*
- *Regulatory or functional authorities*
- *General building requirements*
- *Cybersecurity*
- *Security engineering UFC series*

PLANNING AND REQUIREMENTS DEVELOPMENT
- *Timelines and construction level for deployed operational bases*
- *Protective barriers*
- *Access control point (ACP) planning considerations*
- *Design strategies*
- *Planning resources and reachback*

MINIMUM AT DESIGN REQUIREMENTS
- *Site requirements*
- *Additional requirements*

BEST PRACTICE GUIDANCE – SITE SELECTION
- *Use of geographic information systems (GIS)*
- *Site selection factors*

BEST PRACTICE GUIDANCE – SITE LAYOUT DESIGN
- *General site layout considerations*
- *Layout of perimeter*
- *Layout of critical assets*

Layout of utilities
Layout of occupied structures
Traffic control
Perimeter security

BEST PRACTICE GUIDANCE – PROTECTIVE CONSTRUCTION
Protection construction concepts
Integration of protective design and construction
Protection from vehicle-borne improvised explosive devices (VBIED)
Protection from moving vehicle threat
Protection from hand-held devices
Protection from indirect fire
Protection from direct fire
Protection from airborne contamination
Protection from waterborne contamination
Protection from forced and covert entry

BOMB MITIGATION GUIDE
Implementation/guidance for blast and fragment mitigation from VBIED
Barriers
Safe distances for structures from VBIED
Expeditionary structures
Window retrofits
Test series for blast data
Personnel vulnerability

FP REQUIREMENTS CHECKLIST

UFC 4-133-01
19 April 2016
Change 2, 25 June 2019

UNIFIED FACILITIES CRITERIA (UFC)

AIR TRAFFIC CONTROL and AIR OPERATIONS FACILITIES

UNIFIED FACILITIES CRITERIA (UFC)

AIR TRAFFIC CONTROL and AIR OPERATIONS FACILITIES

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	**Date**	**Location**
1	December 2017	Revised UFC Summary Sheet and Para. 1-3 Army Applicability
2	June 2019	Changed references to USACE Mobile District to Savannah District on Pages 2, 3, and 5

This UFC supersedes UFC 4-133-01N, dated July 2007.

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

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

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

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

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UNIFIED FACILITIES CRITERIA (UFC)
NEW SUMMARY SHEET

Document: UFC 4-133-01, *Air Traffic Control and Air Operations Facilities*

Superseding: *UFC 4-133-01N, Navy Air Traffic Control Facilities, 30 July 2007*; *UFC 4-141-10N, Design Aviation Support Facilities \1\ Section 6 and Section 8 and all other content relating to facility types in this UFC 4-133-01 /1/*, *United States Air Force Design Guide for Air Traffic Control Towers and Radar Approach Control Facilities, 15 November 2001.*

Description:

UFC 4-133-01 provides requirements for evaluating, planning, programming, and designing Air Traffic Control (ATC) and Air Operations Facilities. This UFC contains guidance for Army, Navy and Air Force planners, engineers, and architects on the planning, engineering, and design of Air Traffic Control Towers (ATCT), Radar Approach Control Facilities (ARAC/RATCF/RAPCON), and Air Operations Buildings (AOB). This UFC is intended as a source of basic architectural and engineering information for all individuals involved in the planning, design, or evaluation of ATC and Air Operations Facilities.

Reasons for Document:

This UFC was developed to provide design requirements to accomplish the following:

- Assist planners in understanding the facility requirements to ensure accurate space programs and budgets,
- Provide architects, engineers and construction surveillance personnel with the essential, minimum requirements for the design and construction of Air Traffic Control and Air Operations Facilities.

Impact:

The following will result from the publication of this UFC:

- There are negligible cost impacts; however, a greater degree of standardization among the Service Branches will result.

\1\ Change 1:

- UFC Summary Sheet. **Superseding** paragraph revised to reflect that this UFC supersedes only certain content of UFC 4-141-10N.
- Para 1-3. Revised to clarify required coordination with respective Army Centers of Aviation Standardization and Expertise and change in availability of definitive designs./1/

\2\ Change 2:

- Paragraph 1-3. Changed "Mobile District Center of Standardization of Army Vertical Aviation Facilities (CESAM-AVN-COS-V)" to "Savannah District Center of Standardization for Air Traffic Control/Air Operations Facilities (CESAS-ATCT-COS)"
- Paragraph 1-6. Changed "Aviation Center of Standardization-Vertical (CESAM-AVN-COS-V), Mobile District" to " Air Traffic Control/Air Operations Facilities Center of Standardization (CESAS-ATCT-COS), Savannah District,"
- Paragraph 2-1. Changed "AVN COS-V" to "ATCT-COS" /2/

Unification Issues

The following table identifies items that are not unified among the services:

Section	Topic	Issue
3-9.1	Physical Security General Requirements	The Navy provides additional operational security requirements for ATC facilities.
4-1.2.20	Cab Consoles	Cab consoles are procured differently by each service.
4-1.7.7	Airfield Lighting Control Panel	Each Service branch has unique requirements for the Airfield Lighting Control Panel based on operational standards and interaction with established ATC systems.
4-2.7.7.4	Back-Up Radio Poles and Communications Antennas	The Air Force maintains a requirement for poles for mounting back-up radio antennas.
4-2.7.8.1	Operations/IFR Lighting	The Navy requires colored lights to provide continuity between shore and shipboard operations. The Army and Air Force do not have a requirement for colored lights in the Operations/IFR Room.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND

This Unified Facilities Criteria (UFC), UFC 4-133-01, provides requirements for evaluating, planning, programming, and designing Air Traffic Control (ATC) and Air Operations Facilities. The requirements contained in this UFC apply to Army, Navy, and Air Force facilities unless specifically referenced to a single service. This UFC is not intended as a substitution for thorough review during design by individual Program Managers and Operations Staff in the appropriate service.

The desired goal of this UFC is to maintain consistency in ATC and Air Operations Facility requirements across the Army, Navy and Air Force. This UFC is not intended as an operational manual.

Each service has unique requirements to fulfill specific missions. This document will highlight any key differences that impact the overall facility program, layout and design. Where one Service's criteria vary from the other Services' criteria, it is noted in the text.

1-2 PURPOSE AND SCOPE.

This UFC contains guidance for Army, Navy and Air Force planners, engineers, and architects on the planning, engineering, and design of ATC and Air Operations Facilities, which include three facility types:

- <u>Air Traffic Control Tower</u> (ATCT) – Houses equipment and personnel for control of aircraft approaching, departing, and transiting the terminal area or airport and aircraft and vehicular movement on the runways, taxiways and all other movement areas.

- <u>Radar Approach Control Facility</u> (RACF), referred to as the Army Radar Approach Control Facility (ARAC); the Navy Radar Air Traffic Control Facility (RATCF); or the Air Force Radar Approach Control Facility (RAPCON) – Enables the radar branch to provide radar ATC services to instrument flight rules (IFR) and visual flight rules (VFR) air traffic within assigned airspace.

- <u>Air Operations Building</u> (AOB), referred to as the Navy Air Operations Building; the Air Force Airfield Management Operations (AMOPS) Building; or the Army Airfield Headquarters Building/Airfield Operations Facility - Houses the central command, control, services, and management center of an air installation complex. It provides the management center for flight operations, services, and movement control for the entire air installation complex.

1-3 APPLICABILITY.

This UFC is intended as a source of basic architectural and engineering information for all individuals involved in the planning, design, construction or evaluation of ATC and Air Operations Facilities. Architects and engineers (A/Es) that provide design services will use this UFC under the direction of the Service design agencies. Installation and facility planning personnel will use this UFC, in conjunction with other required planning documents, for programming new or replacement facilities, pre-design planning, or assessing the extent of improvements required in an existing ATC or Air Operations Facility in order to achieve the standard established herein.

Refer to UFC 3-260-01, Sec. 1-4, for additional applicability description.

For more information, refer to the following **Service-specific** governing documents:

- **Army**: \1\ This UFC must be used in coordination with the \2\Savannah District Center of Standardization for Air Traffic Control/Air Operations Facilities (CESAS-ATCT-COS)/2/, and the Omaha District, Army Mandatory Center of Expertise for Horizontal Aviation (CENWO-MCX-Horizontal AVN) by authorities granted under ER 1110-345-100 and ER 1110-3-109. /1/
- **Navy**: This UFC is the primary guidance to be used in conjunction with Facility Requirements Documents (FRD), Facility Requirements Supplements (FRS), Intrusion Detection Systems Engineering Plans (IDSEP), Base Exterior Architecture Plans (BEAP), and other DoD and Department of Transportation (DOT) material for the planning and construction of ATCFs and the preparation of DD 1391 MILCON and Step II Special Project Submissions.
- **Air Force**: This UFC must be used in coordination with AF Project Manager Guide for Construction and AFMAN 32-1084, *Facilities Requirements*.

1-4 GENERAL BUILDING REQUIREMENTS.

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

1-5 FACILITY PROJECT TEAM.

The planning and design team for ATC and Air Operations Facilities must include the standard architectural and engineering (including civil, structural, MEP, and fire protection) disciplines along with the following representatives:

- Airfield or Heliport Operations
- Airfield or Heliport Maintenance Operations
- Environmental Quality and Protection

- Safety
- Fire Emergency Services
- Facility Maintenance
- Energy Management
- Flightline and AT/FP Security
- Space and Naval Warfare Systems Command (SPAWAR) - Navy only

1-6 PROGRAM AUTHORITIES.

Prior to project development, confirm the acquisition methodology and coordinate facility requirements with the appropriate Service. The functional proponent to justify the need, scope (size), and utilization of an ATC or Air Operations Facility is described below. Engineers and planners should assist operations personnel with the planning and programming, definition and scope, site selection, and design of the facility. The functional proponents for each Service are:

- **Army**: Coordinated effort of Air Traffic Services Command (ATSCOM), U.S. Army Aeronautical Services Agency (USAAA), the \2\Air Traffic Control/Air Operations Facilities Center of Standardization (CESAS-ATCT-COS), Savannah District,/2/ and the Transportation Systems Center (TSC), Omaha District.
- **Navy and Marine Corps**: Coordinated effort of the Station, SPAWAR, NAVAIR and NAVFAC
- **Air Force**: Air Force Final Authority A30-BAA, HQ AFFSA (operations) and AFCEC (technical).

1-7 APPENDICES.

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

Appendix B contains a list of background information, “lessons learned,” and other current, good design practices. The designer is expected to review and interpret this guidance and apply the information according to the needs of the project.

Appendix C contains an outline of the Site Selection Process.

Appendix D contains acronyms, abbreviations, and terms.

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CHAPTER 2 PLANNING AND LAYOUT

This chapter describes the technical requirements that should be addressed during the planning and layout phase in order to understand the unique requirements of Air Traffic Control (ATC) and Air Operations Facilities.

2-1 SPACE CRITERIA.

ATC and Air Operations Facility space needs are site and mission specific and must be individually programmed based on a facility study. Space program development guidance is provided in the following documents:

- **Army**: Actual size must be determined from the definitive standard design and criteria documents in conjunction with unique site requirements shown in the Design-Build Request for Proposals (DB RFP) documents for new ATCFs. Space modules, criteria, or components of the Airfield HQ/ATC Facility must be used to develop space allowances and/or requirements before consideration for development of unique or specialized space allowances from those set forth in this definitive standard design. When space standards and criteria and/or components are not used, the Functional Proponent, in accordance with the Aviation FDT, AVN \2\ATCT-COS/2/ (buildings), and AVN COS-H (siting), will review and validate functional or operational requirements prior to the development of any unique or specialized space allowance(s) and before incorporating into a project programming document or facility design.

- **Navy**: Actual size must be determined during the planning phase using UFC 2-000-05N, *Facility Planning Criteria for Navy and Marine Corps Shore Installations* and UFC 3-101-01, *Architecture*. Consult SPAWAR for the space requirements of the required ATC equipment.

- **Air Force**: Actual size must be determined during the planning process using AFMAN 32-1084, *Facility Requirements*.

Certain spaces are not defined specifically in space programming criteria, such as the Control Cab and Simulator Classroom. These spaces should be considered and added to the space criteria during the planning/DD 1391 development phase.

2-2 COLLATERAL EQUIPMENT.

ESD workbenches, storage cabinets, and shelving are usually procured with the rest of the facility furniture. The work benches, storage cabinets, and shelving are not “built in” during construction. Special ESD chairs are also required.

2-3 PROJECT PHASING AND COORDINATION.

If continuous operations are required, then ensure that project construction phasing does not interrupt ATC operations.

FAA and ATC equipment will need to be relocated from existing facilities, or procured and installed in a new ATC facility. Coordinate requirements and appropriate funding during the planning phase. Refer to Appendix B-20 of this UFC for more information.

2-4 FACILITY TYPES.

Design the ATC and Air Operations Facilities to provide space and equipment for the specific functions required by the project mission. In general, there are two (2) types of ATC Facilities and one (1) type of Air Operations Facility:

1. Air Traffic Control Tower (ATCT)
2. Radar Approach Control Facility (RACF) and
3. Air Operations Building (AOB)

2-4.1 Air Traffic Control Tower (ATCT).

2-4.1.1 Function

The Air Traffic Control Tower (ATCT) houses equipment and personnel for control of aircraft approaching and departing the terminal area and aircraft and vehicular movement on the runways, taxiways, and all other movement areas. It is an elevated structure having an unobstructed line-of-sight to the airfield approach areas, runways, taxiways, aircraft parking areas, and all other operational areas over which aircraft movements must be controlled. The ATCT may be an independent facility or combined with a Radar Approach Control Facility (RACF) or an Airfield Operations Building (AOB). If at all possible, the control tower should be an integral facility with the RACF, thus providing a complete, integrated air traffic control facility.

The ATCT is the nerve center for an air installation complex. All air movement within the Class D airspace and all ground movement are controlled via the ATCT when operational. In some locations, control is relinquished as an advisory service to Flight Operations during extended hours of operation. All aviation electronics (e.g. radios), navigational aids, and landing/approach systems are controlled and operated by ATC personnel. Hence, redundant capabilities in controlling lighting, communications, and data must exist at both the ATCT and Flight Operations. During emergency conditions, (e.g., severe weather), ATC activities may displace to Flight Operations when occupying a tall, narrow building becomes hazardous to ATC personnel.

2-4.1.2 Tower Location and Height.

Each Service branch maintains a Site Selection process that establishes overall Tower location and height. Siting is dependent on a Siting Report. Refer to Section 2-6 for more information.

2-4.1.3 Space Allowance.

Each Service branch maintains a program approval process that establishes overall ATCT size.

- **Army**: The tower gross square foot (GSF) area is a function of the required height for observation of aircraft. This is validated by G-3/5/7 (USAASA). The tower can be a single structure composed of a Control Cab and the tower vertical shaft, which accommodates the structure, functional areas, and provides a code compliant stairwell and elevator. In addition, a tower can be a single structure co-located with another facility structure, but separated seismically for force protection measures.
- **Navy**: The minimum installation is a basic tower containing an entrance level, five (5) intermediate levels, and the Control Cab. Towers of increased height can be provided by adding incremental levels. Cab dimensions are determined during the design phase. Reference UFC 2-000-05N.
- **Air Force**: Refer to Air Force Manual (AFMAN) 32-1084. Space requirements are generally dictated by the site survey and Statement of Intent (SOI) that defines some site specific design parameters. AF Operations (AOF, CCTLR, and AFFSA) will determine the Control Cab occupancy in the site survey.

Table 2-1 outlines the various ATCT Cab level controller and space allowances, either in net square feet (NSF) or gross square feet (GSF). The number of positions and total square footage for each service are based on current average standards. Additional Cab area may be required based on higher controller levels.

Table 2-1 ATCT Cab Controller and Space Allowances

ATCT Service Criteria	Typical ATC Controller Positions[1]	Cab Area (SF)	
Army			
Standard Cab 3 positions and 1 supervisor	4	600 Max NSF[2]	Based on AR 420-01 and TC 3-04.81
Navy			
Standard Small Cab 2 positions and 1 supervisor	3	370 GSF[3]	Based on NAVAIR 80-T-114
Standard Medium Activity Cab 3 positions and 1 supervisor	4	500 GSF	
Standard Large Cab 4 positions and 1 supervisor	5	620 GSF	
Air Force			
Standard Cab 3 positions and 2 supervisors (including SOF – Supervisor of Flying)	5	540 NSF + 64 NSF for each additional position	Based on AFMAN 32-1084

[1] Positions include space for trainees. Additional special positions may be required based on survey results.
[2] NSF = Net Square Feet
[3] GSF = Gross Square Feet

2-4.1.4 Functional Program Areas.

Typical functional program areas are listed and described briefly in Table 2-2 and described in greater detail in Chapter 5.

Note: Not all ATCT's contain all of the areas listed in the table. The functional areas required are dependent on operational requirements, and the functions required are determined by the user during the planning/DD 1391 development phase.

Table 2-2 ATCT Functional Program Areas

Functional Program Area	Description
Main Entrance Lobby/Vestibule (Table 5-1.1)	Main entrance to the ATCT. Include vestibule in cold weather climates.
Elevator and Elevator Lobby (Table 5-1.2)	One (1) elevator must be provided to service the ATCT. Elevator service is not required to serve the Control Cab and the floor immediately below the Control Cab. However, if a hydraulic elevator is used, the elevator can serve all floors including the one immediately below the Control Cab.
Elevator Machine Room (Table 5-1.3)	A room housing elevator machine equipment.
Tower Shaft Mechanical Room (Table 5-1.4)	A room housing mechanical equipment servicing the Tower Segment with a lockable door.
Tower Shaft Electrical Room (Table 5-1.5)	A room housing electrical equipment servicing the Tower Segment with a lockable door.
Telecommunications Room (Table 5-1.6)	Telephone / Data Communications Frame Room housing the communications distribution plant.
Fire Pump Room (Table 5-1.7)	A room housing the fire pump.
ATCT Simulator Room (Table 5-1.8)	A Simulator Room may be required in the ATCT or the RACF. Refer to description of Simulator Room in Table 2-3.
Administration Area (Table 5-1.9)	An area for the Facility Administrative Work Space.
Private Offices	Provide private offices for the following:

Functional Program Area	Description
(Table 5-1.10)	1. An office for the Chief Controller with a lockable door. The Chief Controller controls all operations of the ATCT and reports back to the AOF/CC. All personnel within the ATCT report to the Chief Controller.
	2. An office for the Chief of Airspace Information Center (Army only)
	3. An office for the Chief of Ground Controlled Approach (Army only)
Training Room (Table 5-1.11)	A room for mandatory training with a lockable door. May be combined with Break Room for space and budgetary constraints.
Toilet Rooms (Table 5-1.12)	Provide a minimum of two (2) toilet rooms, both unisex, one near ground level and one on the level directly below the Control Cab. If the ATCT is attached to a support building that has toilet rooms, then the First and Second floors of the Tower are not required to have a toilet room for those floors. Toilet rooms are only required for the Third floor and above.
Janitor Closet (Table 5-1.13)	A room for janitorial supplies and equipment.
Stairwell (Table 5-1.14)	Pressurized fire-rated stairwell providing emergency egress from the floor below the Control Cab to the ground floor
Lower Electronic Equipment Room (Table 5-1.15)	A room housing ATC electronic equipment with a lockable door. Divide electronic equipment room into two rooms on different floors only if equipment will not fit on one floor due to Occupational Safety and Health Administration (OSHA) standards (e.g. equipment rack spacing). Some stand-alone ATCTs could require three equipment rooms on different floors to accommodate additional equipment (such as a voice switch, recorder, etc.)

Functional Program Area	Description
Upper Electronic Equipment Room (Table 5-1.16)	Preferred location for communication equipment, equipment with antennas, and back-up radio systems.
UPS Room (Table 5-1.17)	A room housing batteries and the UPS system, with a lockable door. May be combined with the ATCT Electronic Equipment Room.
Ready/Break Room (Table 5-1.18)	A room with a small kitchenette and seating for mandatory controller breaks on a separate level from the ATCT Control Cab.
Control Cab Mechanical Room (Table 5-1.19)	A mechanical room providing HVAC service for the ATCT Control Cab separately.
Control Cab Electrical/ Telecommunications Room (Table 5-1.20)	A room housing electrical power and telecommunications equipment for the Control Cab.
Control Cab (Table 5-1.21)	A room with windows on all sides with minimal window framing to maximize view of the airfield.
Electronic Equipment Room (Table 5-1.22)	Additional room housing additional ATC Electronic Equipment, such as the Voice Communications Switching System (VCSS).
Catwalk	An exterior platform surrounding the Control Cab, providing exterior access for cleaning the Cab glass.
Mechanical Chase	A fire rated chase, open from the ground floor to the concrete sub-floor of the ATCT Cab that serves as a pathway for HVAC and plumbing utilities from the Tower Shaft Mechanical Room to the ATCT Mechanical Room.
Vertical Cable Chase	A fire rated chase, open from the ground floor to the concrete sub-floor of the ATCT Cab that serves as a pathway for communications cables from the first floor Telecommunications Room to the Lower Equipment Room, Upper Equipment Room, and the Control Cab.

Functional Program Area	Description
Antenna Cable Chase	Ducts or conduits located within or adjacent to the Control Cab structural columns that serve as pathways for antenna cables from the Equipment Room containing radios to the ATCT Roof.
Ground Controlled Approach (Table 5-1.23)	An office-type open work area for Ground Controlled Approach operations.
Airspace Information Center (Table 5-1.24)	An office-type open work area for Airspace Information Center operations.
ATC Equipment Maintenance (Table 5-1.25)	A building/room for ATC electronic equipment maintenance, including an area for soldering and storage, when an ATCT is located remotely from the Airfield Operations Building.
Mechanical Yard	A screened maintenance yard must be provided for the chiller, back-up generator fuel tank, transformer, etc. In cold-weather climates, the generator may be located in an enclosed generator room. Coordinate with AT/FP requirements.

2-4.1.5 Functional vs. Non-Functional Tower Shaft.

ATCTs may have a functional or a non-functional tower shaft supporting the Control Cab. The key programmatic differences between a functional and a non-functional tower shaft include the following:

- Functional Tower Shaft: Typically pertains to low and intermediate activity ATCTs where operations support functions can be located on most floors in the tower shaft. This eliminates the need for an administrative support building.
- Non-functional Tower Shaft: Typically pertains to major activity ATCTs where operations support functions cannot fill up all the floors in the tower shaft. The shaft includes only unoccupied spaces (i.e. egress stair, elevator and service shafts, etc.) to reduce the floor footprint for cost efficiency. Two to three floors immediately below the cab can be used for administrative support and equipment spaces (these floors can have a wider footprint).

In either case, the preferred layout for the tower shaft is rectangular or square to maximize the efficiency of the layout of the internal spaces.

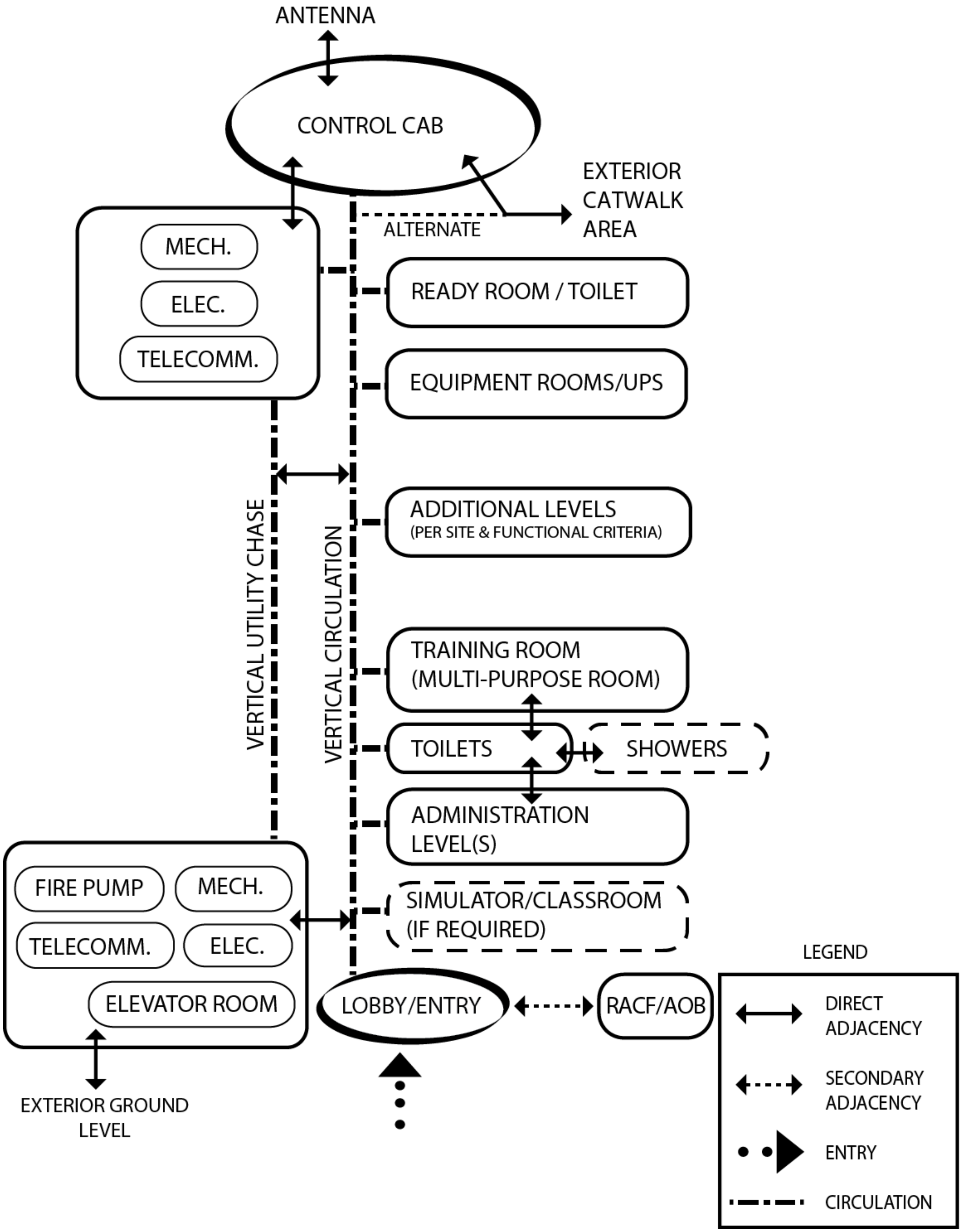
2-4.1.6 Adjacencies and Layout.

Figure 2-1 represents the vertical adjacencies in an ATCT. This diagram does not convey a building shape, but represents the required adjacencies in a typical ATCT. Figures 2-2 and 2-3 represent a notional Control Cab plan and Section Diagram, respectively.

Important adjacency requirements include the following:

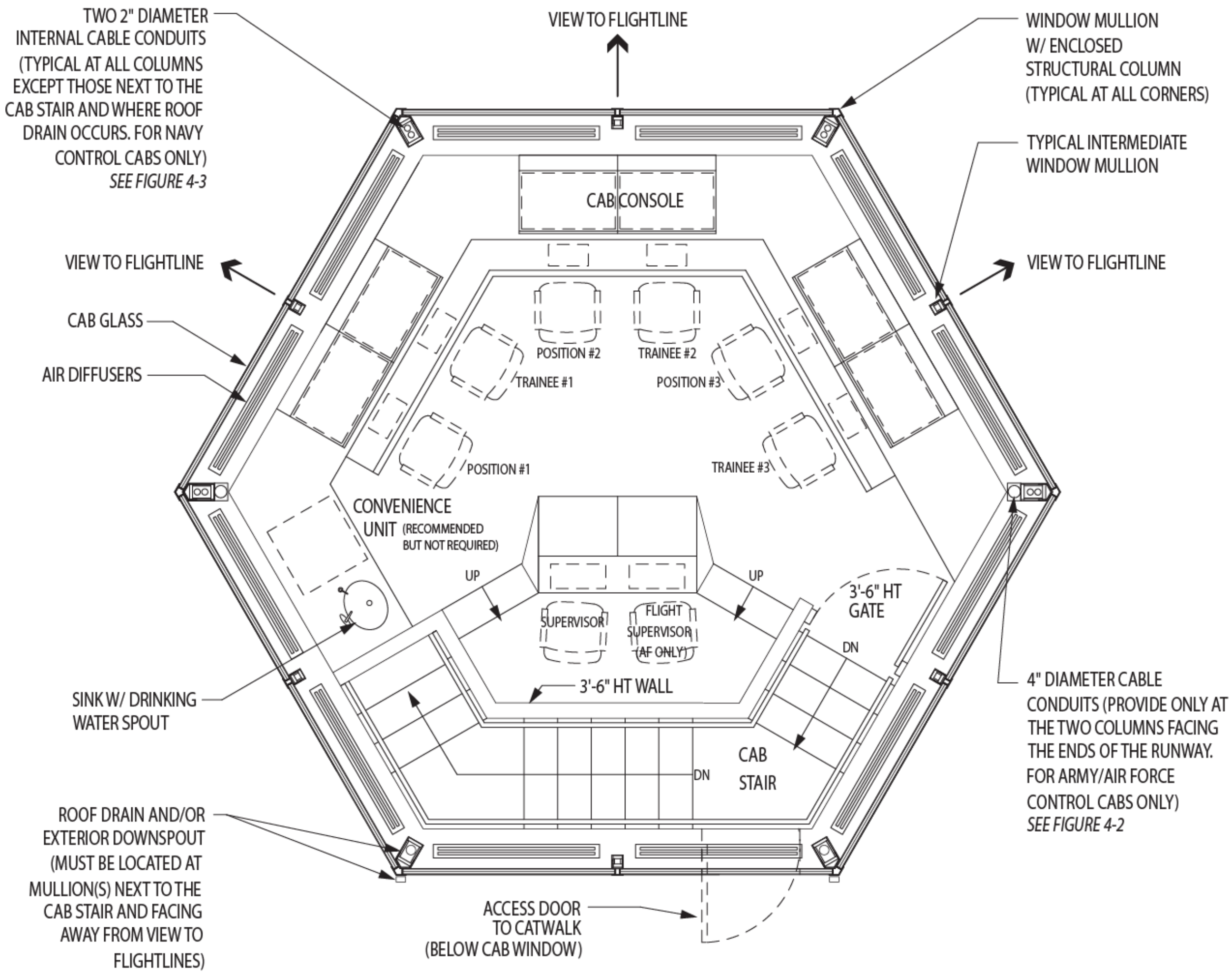
- ATC personnel normally request that a bathroom and break room be located on the floor directly below the ATCT Cab.
- The ATCT electronic equipment space(s) must be located on the uppermost available floor(s) below the Ready/Break Room to ensure that RF cable runs and communication signal losses are minimized. The exact arrangement of the electronic equipment will depend on the specific design of the ATCT and will be determined during design.
- Support functions such as training rooms may be housed separately in a RACF or AOB when the facilities are collocated.

Figure 2-1 ATCT Functional Shaft Vertical Adjacency Diagram



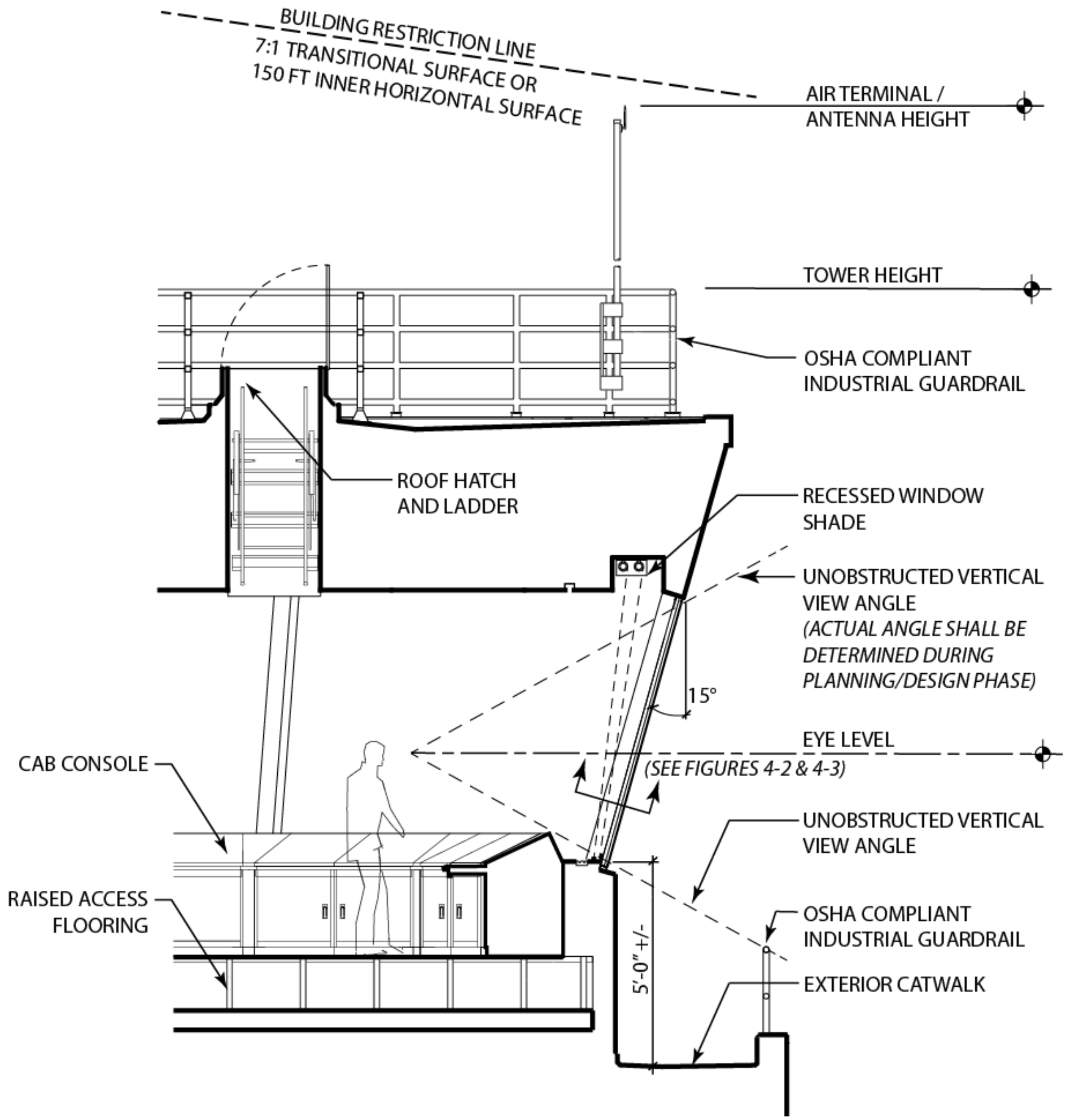
Note: The ATCT Functional Shaft Vertical Adjacency Diagram on the previous page is only illustrative, and is intended to demonstrate typical relationships between programmed spaces. It does not exclude other floor plan geometry, building configurations, or additional spaces required. More refined floor layouts should be developed during the design phase.

Figure 2-2 ATCT Control Cab Notional Floor Plan Diagram



Note: The ATCT Control Cab notional floor plan on this page is diagrammatic and intended to illustrate typical configurations. It does not exclude other tower geometry, Cab configurations, or additional spaces required. More refined floor layouts and should be developed during the design phase.

Figure 2-3 ATCT Control Cab Section Diagram



Note: The ATCT Control Cab section is diagrammatic and intended to illustrate typical configurations. It does not exclude other tower geometry and Cab configurations. More refined floor layouts should be developed during the design phase.

Height from exterior catwalk to top of window sill is typical per FAA standards. Maximum distance should allow for simultaneous Control Cab viewing and window washing.

Figure 2-4 ATCT Non-Functional Shaft with Support Building

Figure 2-5 ATCT Functional Shaft without Support Building

Figure 2-6 ATCT Functional Shaft with Support Building

Figure 2-7 ATCT Functional Shaft - Standalone

2-4.2 Radar Approach Control Facility (RACF).

2-4.2.1 Function.

A Radar Approach Control Facility (RACF) controls aircraft by using installed radar to provide ATC services to Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) air traffic within a certain assigned airspace. RACFs offer ATC services to aircraft arriving, departing, or transiting the airspace controlled by the facility.

The RACF contains equipment used for controlling air traffic and is staffed by air traffic controllers and air operations, administrative and maintenance support personnel. The scope of radar services provided will vary according to equipment installed and the delegated airspace. The scope and complexity of the services are the significant design drivers. The RACF contains an IFR control room that includes the radar display consoles and communications control equipment. An adjacent terminal equipment room houses all automation central (or terminal) equipment, maintenance positions and audio/video tape recorders.

Based on current practices and policies, each Service maintains unique names for its Radar Approach Control Facilities as follows:

- **Army**: Army Radar Approach Control (ARAC) facilities are located at U.S. Army installations that use surveillance radar (normally collocated with Precision Approach Radar (PAR) facilities) and air/ground communications equipment. ARAC facilities offer air traffic control services to aircraft arriving, departing, or transiting the airspace controlled by the facility. Service is available to both civil and military airports located within approach control airspace.

- **Navy**: Radar Air Traffic Control Facilities (RATCF) are located at U.S. Navy installations. The ASR, PAR, Precision Approach Landing System (PALS), Transmitting and Receiving Sites, and other NAVAIDS, all of which are remotely located, are monitored and controlled in the RATCF. Local agreements may dictate that an FAA air traffic representative be provided office space in the air traffic control facility. An office for the FAA liaison officer is required at joint-operated Navy/FAA terminal radar approach control (TRACON) facilities.

- **Air Force**: Radar Approach Control (RAPCON) facilities are located at U.S. Air Force installations.

2-4.2.2 Location.

RACFs can be sited anywhere within the range of the radar providing radar assisted approach control. The RACF functions well in a single-story facility, making it a candidate for siting near airfields where building heights are restricted by airport conical or imaginary surfaces.

It is preferable to locate the Radar Approach Control Facility (RACF) adjacent to the Air Traffic Control Tower (ATCT). However, the RACF is not required to be adjacent to the ATCT.

Provide drive-up service access to service entries, including the IFR Equipment Room, the Operations/IFR Room (through the IFR Equipment Room), and the Mechanical Room. Refer to Section 2-2 for more information.

2-4.2.3 Functional Program Areas.

Typical functional program areas are listed and described briefly in Table 2-3 and described in greater detail in Chapter 5.

Note: Not all RACFs contain all of the areas listed in the table. The functional areas required are dependent on operational requirements, and the functions required are determined by the user during the planning/DD 1391 development phase.

Table 2-3 RACF Functional Program Areas

Functional Program Area	Description
Lobby/Entry Vestibule (Table 5-2.1)	Main entrance to the RACF. Include vestibule in cold weather climates.
Administrative Offices (Table 5-2.2)	An open office area with freestanding systems furniture workstations for administrative personnel.
Private Offices (Table 5-2.3)	Provide private offices for the following:
	1. Airfield Operations Flight Commander's Office (AOF/CC). The AOF/CC office may or may not be included in the RACF design. This officer is responsible for the overall management of flight operations, which includes the ATCT, RACF, Airfield Management, and Base Operations. If possible, this office should be located in another facility other than the RACF so that flying customers can meet with them at a facility that is not in a controlled area.
Private Offices (cont'd)	2. Chief Controller. The Chief Controller controls all operations of the RACF and reports back to the AOF/CC. All personnel within the RACF report to the Chief Controller.

Functional Program Area	Description
	3. Chief, Air Traffic Control & Training (Air Force: NCOIC, Air Traffic Control Training). This individual is responsible for keeping all training materials up to date as well as for ensuring the training of new personnel and continuing education of current controllers.
	4. Chief, Standardization & Evaluation (Air Force: NCOIC, Standardization and Evaluation). This individual maintains the currency of the RACF, ensures compliance with Service standards, and evaluates procedures that are in operation.
	CBI (Computer-Based Instruction).
Toilet Rooms with Lockers and Showers (Table 5-2.4)	If space and budget allow, there should be toilet rooms available adjacent to the Operations/IFR Room and the Break Room. Toilet rooms for administrative personnel and visitors should be provided in the administrative area.
Janitor (Table 5-2.5)	A separate storage room for janitorial supplies and equipment, located near the toilet rooms.
Mechanical Room (Table 5-2.6)	A room housing mechanical equipment servicing the RACF with a lockable door.
Electrical Room (Table 5-2.7)	A room housing electrical equipment servicing the RACF with a lockable door.
Telecommunications Room (Table 5-2.8)	This room is the first termination point for all copper cabling and fiber optic entering the facility. All incoming lines will be surge-suppressed in this room.

Functional Program Area	Description
Terminal Instrument Procedures (TERPS)/Data System Specialist (DSS) Office (Table 5-2.9)	This area is the largest office requirement in the administrative area. The TERPS office is responsible for actual planning and plotting of approach and procedures, revising procedures that are in place, updating procedures based on new criteria such as airfield mishaps, new aircraft controls, etc. **Air Force**: TERPS Room is required only when the TERPS function is performed at the unit level. Many MAJCOMS have consolidated TERPS offices to control CONUS locations. The A/E must consult the MAJCOM to confirm the location of TERPS. **Navy**: TERPS/DSS Office not required.
Operations/Instrument Flight Rules (IFR) Room (Table 5-2.10)	This is the primary functional area of the RACF. This space should be located within the facility and never exit directly to the outside. All radar-controlled approaches are handled from this room.
Radar Simulator Room (Table 5-2.11)	A room housing radar simulators for Standard Terminal Automation Replacement System (STARS) simulators and the IPARTS (PAR Trainer).
ATCT Simulator Room (Table 5-2.12)	A room housing simulators for ATCT simulator operations. The ATCT Simulator Room contains the tower simulator.
Training Room (Table 5-2.13)	A room housing the Computer-Based Instruction (CBI) component of RACF training.
Briefing/Conference Room (Table 5-2.14)	This room should be sized to house the entire RACF shift, plus the AOF/CC and the shift Watch Supervisor. The Briefing Room should be sized to accommodate an adequately-sized conference table.
IFR Equipment Room (Table 5-2.15)	A room housing the communications racks that are the termination points for all lines entering and departing the RACF that provide data to and from the scopes in the Operations/IFR Room.

Functional Program Area	Description
UPS Room (Table 5-2.16)	A room housing the UPS system and its batteries. May be combined with the IFR Equipment Room or the Electrical Room.
Storage Room (Table 5-2.17)	An interior storage area for miscellaneous supplies for the office and operational functions of the RACF.
Flight Planning (Table 5-2.18)	Open office area containing flight dispatch and flight planning operations
Pilot Flight Planning (Table 5-2.19)	Open office area containing flight planning operations
ATC Equipment Maintenance Admin Area (Table 5-2.20)	An open office area for administrative functions required for ATC equipment maintenance.
ATC Equipment Maintenance Area (Table 5-2.21)	An area for ATC equipment maintenance, including space for soldering and storage.
Break Room (Table 5-2.22)	A room containing a wet sink, coffee service, refrigerator, microwave, and vending machines.
2M Room (Table 5-2.23)	A room for Micro-Maintenance repair. Refer to NAVAIR 01-1A-23 for additional requirements.
Secret Internet Protocol Router Network (SIPRNet) Room (if required)	For certain facilities, a room for SIPR equipment must be provided. Discuss space requirements with facility user.
Ground Electronics Maintenance Division Area	Provide an area for Ground Electronics Maintenance Division, including: 1. GEMO Office 2. ET Chief Office 3. GEMD Admin/LPO Area
Mechanical Yard	A screened maintenance yard must be provided for the chiller, back-up generator fuel tank, garbage dumpster with a separate screen wall enclosure, generator, transformer, etc.

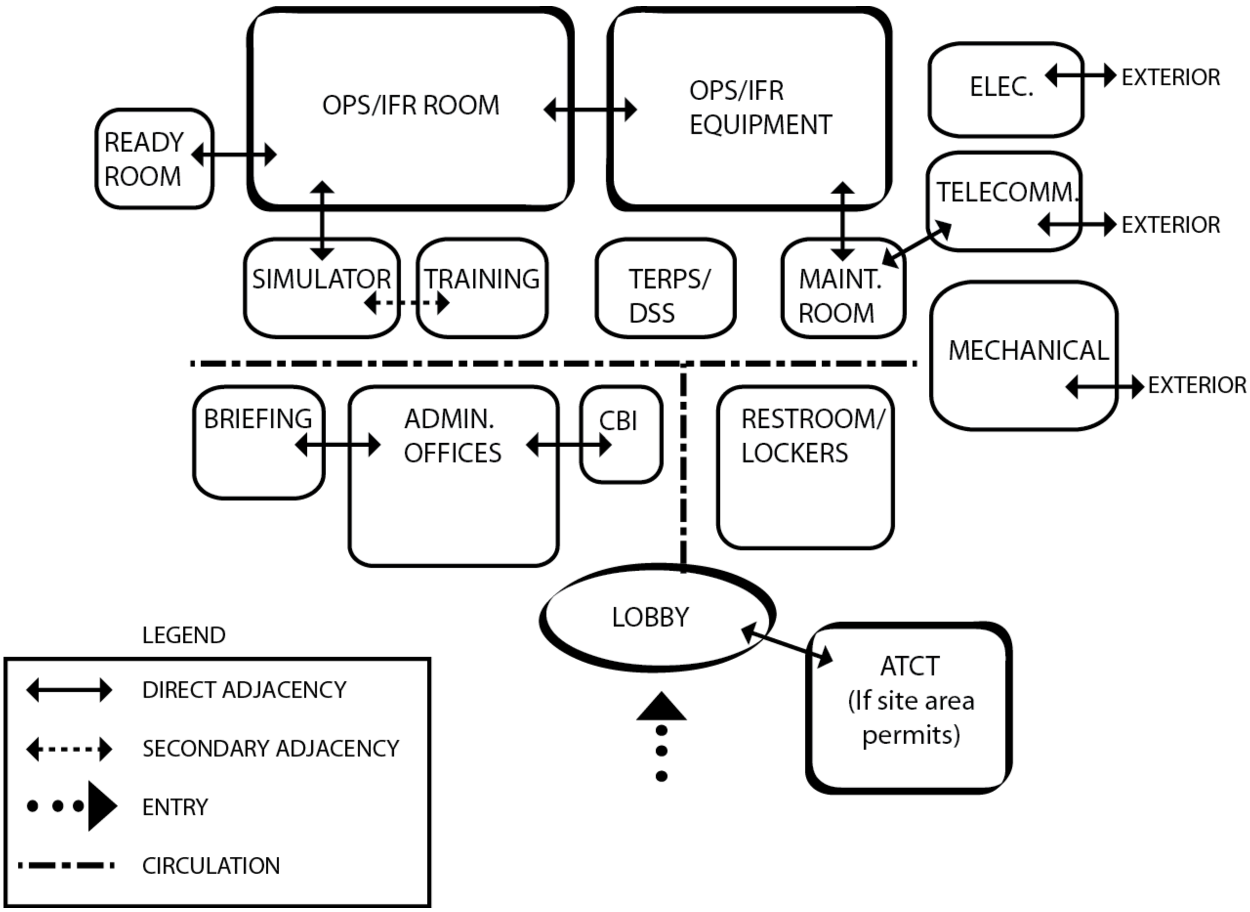
2-4.2.4 Adjacencies and Layout.

Appropriate building adjacencies are illustrated in Figure 2-8. This diagram does not convey a building shape, but represents the required adjacencies in a typical Radar Approach Control facility.

Important adjacency requirements include the following:

- ATC personnel normally request that an ATC/Simulator/Training Room be located adjacent to the Operations/IFR Room.
- Maintenance personnel normally request that the IFR Equipment Room be located adjacent to the Main Distribution Frame (MDF) Room.

Figure 2-8 RACF Adjacency Diagram



Note: The RACF Adjacency Diagram is only illustrative, and is intended to demonstrate typical relationships between programmed spaces. It does not exclude other floor plan geometry, building configurations or additional spaces required. More refined floor layouts should be developed during the design phase.

Figure 2-9 RACF IFR Room

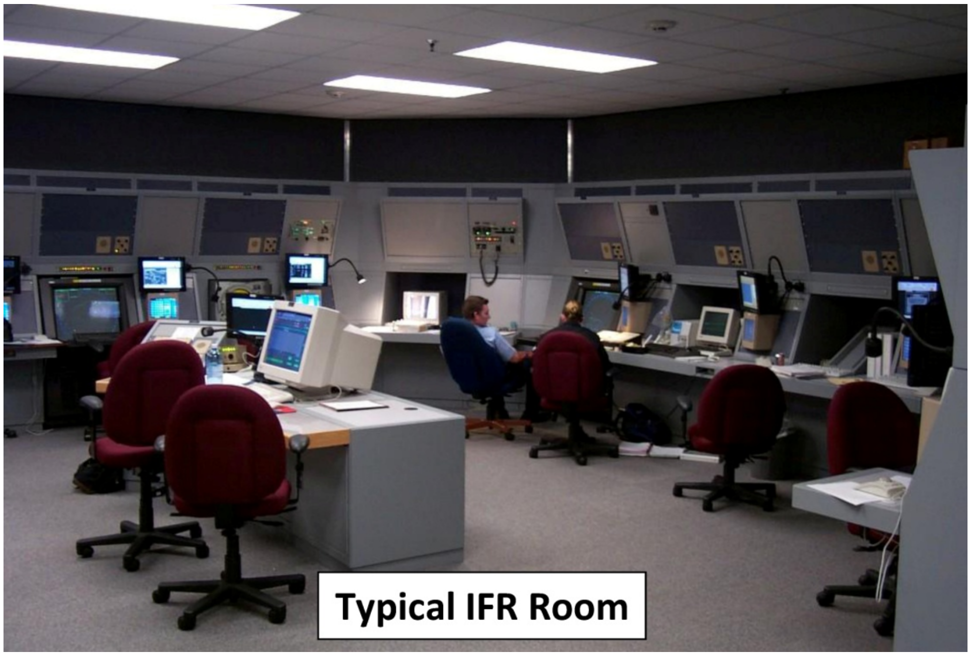


Figure 2-10 RACF IFR Equipment Room

2-4.3 Airfield Operations Building (AOB).

2-4.3.1 Function.

The Airfield Operations Building (AOB) is required to house flight operational and administrative functions of the airfield headquarters. The AOB includes all the functions of flight planning, flight personnel equipment and support rooms, passenger support facilities, and the communications, operations and weather services. Also included, unless otherwise provided in other permanent facilities, are an in-flight kitchen and/or snack bar, and a conference and/or briefing room which may also serve as a personnel training room or classroom. Because of differences in the aviation missions and the requirements of the facility commanders, the components for an AOB may vary considerably. The existence of available permanent facilities will also affect overall space requirements.

Certain airfield installations may enlarge the AOB to include the Airfield Headquarters (HQ). The Airfield HQ includes administrative space for the commander, military personnel, safety officer, and others.

2-4.3.2 Location.

The AOB adjoins the ATCT and RACF where site conditions permit. The AOB may be housed in a separate building or may be combined into a single structure with the ATCT.

The Air Operations Building must be located with direct access by personnel outside the airfield restricted area boundary.

2-4.3.3 Functional Program Areas.

Typical functional program areas are listed and described briefly in Table 2-4 and described in greater detail in Chapter 5.

Note: Not all AOBs contain all of the areas listed in the table. The functional areas required are dependent on operational requirements, and the functions required are determined by the user during the planning/DD 1391 development phase.

Table 2-4 Airfield Operations Building Functional Program Areas

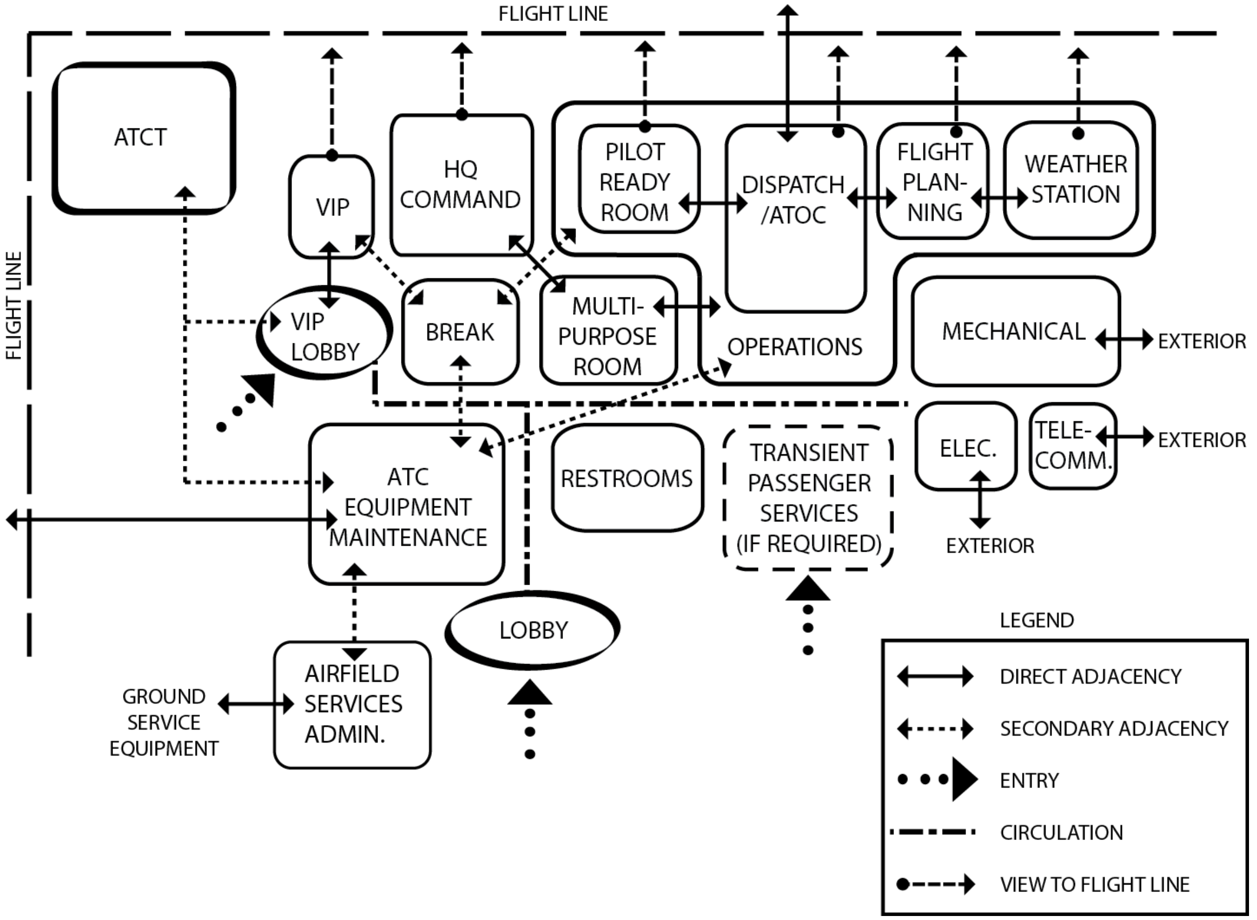
Functional Program Area	Description
Lobby/Vestibule (Table 5-3.1)	Main entrance to the AOB. Include vestibule in cold weather climates.
HQ / Command Suite	The HQ/Command Suite must be tailored to the specific requirements of each command echelon.
HQ/Command Suite - Reception Area (Table 5-3.2)	Controls access to the HQ/Command suite. Include receptionist workstation, visitor seating area, coat closet, and supply closet.
HQ/Command Suite – Private Offices (Table 5-3.3)	Provide Private Offices for: 1. Airfield Manager/Commander 2. Chief Controller (CCTLR) or Airfield Operations Flight Commander (AOF/CC) 3. Operations Officer 4. Airfield Safety Officer
Airfield Operations (Tables 5-3.4 – 5-3.8)	This space is comprised of several functional areas, including: 1. Air Operations Duty Officer 2. Airfield Management/Flight Planning 3. Pilot Flight Planning 4. Weather Station 5. Pilot Ready Room
Airfield Services (Tables 5-3.9 – 5-3.13)	Provide an area for Airfield Services consisting of: 1. General Purpose Workstations 2. Printer/Copier Station (non-secure data only) 3. Non-Sensitive Secure Storage Room 4. General Purpose Storage Room 5. File Storage Area 6. Fuel Handlers
ATC Equipment Maintenance Admin Area (Table 5-3.14)	An open office area with freestanding systems furniture workstations for administrative personnel.
ATC Equipment Maintenance Area (Table 5-3.15)	A room for ATC electronic equipment maintenance, including an area for soldering and storage.

Functional Program Area	Description
Break Area (Table 5-3.16)	A room containing a wet sink, coffee service, refrigerator, microwave, and vending machines.
Multipurpose Room (Table 5-3.17)	Briefings, conferences, press releases, and consolidated training.
Male and Female Toilet Rooms (Table 5-3.18)	Toilet rooms for administrative personnel and visitors should be provided near the main entrance.
Janitor (Table 5-3.19)	A separate room for janitorial supplies and equipment, located near the toilet rooms.
Mechanical Room (Table 5-3.20)	A room housing mechanical equipment servicing the AOB with a lockable door.
Electrical Room (Table 5-3.21)	A room housing electrical equipment servicing the AOB with a lockable door.
Telecommunications Room (Table 5-3.22)	This room is the first termination point for all copper and fiber optic cabling and fiber optic entering the facility. All incoming lines must be surge-suppressed in this room.
SIPR Room (if required) (Table 5-3.23)	For certain facilities, a room for SIPR equipment must be provided. Discuss space requirements with facility user.
Outside Covered Storage Area (Table 5-3.24)	One (1) outside storage building and one (1) outside covered storage area with fence and 10' wide lockable gate. The storage area is used to store airfield services related equipment and must have direct access to the parking aprons
Transient Passenger Services (Table 5-3.25)	Waiting area for transient passengers.
VIP Passenger Services (Table 5-3.26)	Waiting area for VIPs.

2-4.3.4 Adjacencies and Layout.

Appropriate building adjacencies are illustrated in Figure 2-11. This diagram does not convey a building shape, but represents the required adjacencies in an Airfield Operations Building.

Figure 2-11 AOB Adjacency Diagram



Note: The AOB Adjacency Diagram is only illustrative, and is intended to demonstrate typical relationships between programmed spaces. It does not exclude other floor plan geometry, building configurations, or additional spaces required. More refined floor layouts should be developed during the design phase.

2-5 COMBINING AIR TRAFFIC CONTROL AND AIR OPERATIONS FACILITY TYPES.

ATC and Air Operations Facilities may be provided in separate structures or combined into one structure. Locate the ATCT adjacent to the RACF where siting requirements permit. However, the ATCT may be separated from the RACF and the AOB in order to facilitate visual observation and control of aircraft movement.

2-6 SITE SELECTION AND APPROVAL PROCESS.

2-6.1 Site Location Requirements.

The location and height of the ATC and Air Operations Facilities must be based on a Siting Report that recommends the optimum location and relative orientation of all structures, including the optimum size and height of the ATCT.

Selection of a site within 1,000 meters (m) of a station Tactical Air Navigation (TACAN) system will require an analysis of impacts to the TACAN.

2-6.1.1 Air Traffic Control Tower.

The Air Traffic Control Tower (ATCT) must be sited in accordance with UFC 3-260-01, *Airfield and Heliport Planning and Design*. The ATCT must be physically oriented relative to the primary runways so as to obtain the best unobstructed view of the air installation complex and aircraft primary movement areas (i.e. runways and taxiways), their associated VFR and IFR approach paths, traffic pattern entry points, traffic patterns, ground routes, parking areas, and VFR and IFR departure paths. Consider planned runway and taxiway construction when siting the ATCT, as well as expected vegetation growth that cannot be cultivated due to various factors.

The ATCT itself should not be an obstruction or affect IFR operations. Care must be taken not to site the ATCT close to and/or under a flight path. When computing the height of the ATCT, the height of the antennas being installed (after construction is completed) must be included. The design of the antenna supports, installed as part of the construction, will affect the final antenna height. When computing the total ATCT height, the height of the tallest antenna must be added to the height of the top of the parapet wall or railing. The height of the lightning protection installed during construction must also be included in the total ATCT height if the lightning protection is designed to be higher than the antennas mentioned above. The total height of the ATCT, including antennas and lightning protection, must be shown on the design elevation drawings.

Other considerations for final siting include utility availability (water, sewer, storm, power, and gas), site access, security, and relationship to existing ATC Facilities and existing ATCTs. If an area directly below the ATCT requires controlling, consideration for relocating the ATCT to allow proper visual access to that area should be of prime importance.

All ATCTs have transmitting antennas on the roof. The site approval process requires that all projects having explosives safety, airfield safety, or electromagnetic safety implications, require a "Safety Certification." Also, consider the existing location of the airfield beacon during the site selection process. If the beacon will cause visibility problems for ATCT controllers, it will require relocation or a change in height, and should be included in the DD 1391 for the ATCT. The rotating beacon must not be located on top of the ATCT.

2-6.1.2 Radar Approach Control Facility.

The Radar Approach Control Facility (RACF) can be sited anywhere within the range of the equipment providing radar-assisted approach control. The RACF functions well in a single-story facility, making it a candidate for siting near airfields where building heights are restricted by airfield conical or imaginary surfaces.

Provide drive-up service access to service entries in the RACF, including the IFR Equipment Room, the Operations/IFR Room (through equipment room), and the Mechanical Room. Screen chillers, back-up generator fuel tanks, and dumpsters in maintenance/service yards.

2-6.1.3 Air Operations Building.

The Airfield Operations Building (AOB) can be sited anywhere within the air installation complex as long as it complies with the requirements of UFC 3-260-01. Preferred adjacencies are described above in Section 2-4.3.2.

2-6.2 Site Radiation Hazards.

Hazards of Electromagnetic Radiation to Personnel (HERP), Ordnance (HERO), and Fuel (HERF) surveys are crucial to the siting process. Radiating radio frequency (RF) antennas must be installed on top of the ATCT and a radiation hazard (RADHAZ) study to support their installation should be conducted during the site approval process. Facility siting criteria must consider radiating fields of existing antennas, such as the Airport Surveillance Radar (ASR), that support ATC operations.

Define the specific concerns with aiming of radar and various antennas so there is no interference from electrical propagation in the form of electromagnetic and RF waves.

2-6.3 Site Selection and Approval Process.

- **Army**: ATSCOM, through a site survey and in coordination with the USACE Transportation System Center selects the ATCT location. The IMCOM Regional Director, for the specific region approves the site location. The Headquarters, Department of the Army validates the project as part of the established Army process. Refer to project review requirements contained in AR 95-2.

  Army National Guard Bureau: The Director, Army National Guard, through the State Adjutant General, approves the location and project. As is appropriate, the State Adjutant General may be the final approval for the site location and project.

- **Navy**: NAVFAC Asset Management and SPAWAR are responsible to conduct the siting study. When a tower siting study is performed, the TSAR analyzes multiple sites and recommends one.

  Final site approval must be from the Base/Station Commanding Officer per current NAVFACINST 11010.45. A letter from the ATC Officer or Base/Station Commanding Officer selecting a particular site should be required.

- **Air Force**: The MAJCOM Programming and Requirements Manager requests a site survey from Headquarters Air Force Flight Standards Agency. HQ AFFSA will recommend a site selected for ATCF based on the survey results. Concurrence with the Base/Wing Commander signifies acceptance of the site recommendations.

Refer to Appendix C for an outline of a typical Site Selection Process.

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CHAPTER 3 GENERAL REQUIREMENTS

This chapter describes the general design criteria shared by all Air Traffic Control (ATC) and Air Operations Facilities.

3-1 AIRFIELD SAFETY.

Federal Regulation 14 CFR Part 157, section 77.13 requires FAA notification for anyone proposing to construct, alter, or deactivate a civil, military, or joint-use (civil/military) airport. Provide obstruction marking or lighting for facilities located in or near aviation operational areas in accordance with UFC 3-535-01, *Visual Air Navigation Facilities* and FAA Advisory Circular AC 70/7460, *Obstruction Marking and Lighting*.

3-2 ARCHITECTURAL.

3-2.1 Future Expansion Capability.

Discuss future expansion potential with local ATC operations personnel. If required, plan for building design that permits incremental additions. Future expansion capability should be carefully planned into the overall design. Future growth must be assumed to be horizontal and not vertical.

3-2.2 Acoustics/Noise Control.

Sound attenuation is necessary for all ATC and Air Operations Facilities in order to control disturbance from high energy noise levels and to minimize disturbance from intrusive speech. Acoustical control is required around toilet rooms, conference/training rooms, and private offices, as well as specialized spaces required in each facility type. Refer to Chapter 5, Functional Data Sheets, for specific sound level criteria for all rooms.

3-2.3 Accessibility for the Disabled.

Comply with the DoD Architectural Barriers Act Accessibility Standards (ABAAS), and provide barrier-free access to civilian workspaces and other spaces intended for public access.

3-2.4 Exterior Materials.

During design, a TACAN Subject Matter Expert must review the facility's proposed exterior materials and their possible impact on TACAN operations. Depending upon the materials used for the outside of an ATC or Air Operations Facility, the impacts can vary for the same location. Some exterior wall materials may interfere with TACAN operations. An example would be that corrugated steel siding would scatter the signal vice acting as a standard reflector and could degrade the signal enough to make the TACAN unusable.

3-2.5 Reflective Surfaces.

To prevent mirror-like reflections from building surfaces to aircraft in flight and air traffic controllers, provide roofs and other external surfaces with a specular reflectance compatible with the location of the building on the airfield. If the building is so located that glare may be an operational hazard, provide the critical surfaces of that building with a light reflectance of not more than 10, measured at an angle of 85 degrees in accordance with the ASTM D 523, *Standard Test Method for Specular Gloss*.

3-2.6 Windows.

Windows in ATC and Air Operations Facilities must comply with UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*. In addition, windows must meet EPAct-2005 and EISA-2007 energy requirements.

Consider windows for administrative and break areas, but do not provide windows in electronic equipment rooms, the RACF Operations/IFR Room, storage rooms, or mechanical and electrical rooms.

3-2.7 Raised Access Flooring.

Where required, provide Raised Access Flooring (RAF) to meet the requirements of NFPA 75, *Standard for the Protection of Information Technology Equipment*. RAF must be supported around the entire perimeter. Provide a bolted grid (stringer) or a rigid grid system. Utilize 24-inch (610 mm) stringer supports throughout (larger supports are not acceptable). Pedestal support systems without horizontal stringers must not be used.

The space between the concrete sub-floor and all raised access flooring will be used to route ATC system cabling to the electronic equipment. Ensure that there is no structural steel in these areas, including any additional seismic bracing that may be required. Keep all air supply panels and similar inserts flush with the flooring surface. Specify installation procedures to conform to FAA-STD-019e and FAA-STD-020b. Provide depressed structural framing and slabs in areas where access flooring occurs to result in uniform, continuous finish floor levels between adjacent floor spaces. Provide a RAF installation above a level permanent floor when it is not economical or practical to depress the structural framing and slab.

3-2.7.1 Bonding and Grounding of RAF.

RAF must be electrically continuous, properly bonded and grounded. Both systems must be connected to the below-floor signal reference grid system and to the perimeter ground cable with copper straps or cable that meets FAA-STD-019e. Stringers of the bolted grid must also be bonded per FAA-STD-019e.

3-2.7.2 Design Loads for RAF Installations.

Use the following Design Loads for RAF installations:

- Rolling: 400 lb min.

- Impact: 100 lb min.
- Concentrated: 1,000 lb. min.

3-2.7.3 RAF Floor Tiles.

Provide filled or unfilled floor tiles with integral, static dissipative carpet or vinyl coverings. The use of filled or unfilled floor tiles must be determined during the planning/DD 1391 development.

If carpeted floor tiles are required, carpet squares must be factory glued or glued to the tiles using adhesive provided by the manufacturer of the floor tile and per the manufacturer's instructions. Carpet squares must have the same dimensions as the RAF panels, instead of tiles with vinyl trim. Spare carpeted tiles (25% of installed area) and one quart of the same adhesive used must be provided and turned over to local ATC personnel upon completion of construction. The adhesive must be provided from the floor manufacturer.

3-2.8 Floor Finishes.

All exposed concrete floors or sub-floors without floor or carpet finish must be cleaned and sealed or painted with an appropriate type of concrete sealer or paint. Floors must be sealed prior to the installation of any conduits, piping, ventilation ducts or RAF.

3-2.8.1 Electronic Equipment Area Floor Finishes.

All areas housing electronic equipment must have static dissipative floor finish materials with a surface resistance between 2.5 x 104 and 1.0 x 108 Ω (ohms) measured in accordance with the ANSI ESD S7.1. Electronic equipment spaces must be provided with static dissipative carpet or laminate or vinyl tile. Cut pile carpeting with a performance factor of less than 2.0 (kV) static generation under worst possible conditions should be required for high traffic areas.

3-2.9 Building Signage.

Building directory, bulletin boards and interior signs must be in accordance with UFC 3-120-01, *Air Force Sign Standard*, unless directed to use installation standards. Confirm final details including size and location for all building signage with user group during the design phase.

- Provide a suitably sized building directory located near the main entrance of each ATC or Air Operations Facility. The directory case must be constructed of extruded aluminum with an architectural finish. It should have a changeable letter board with insertable letters and a sliding glass front.
- A bulletin board is required in the entrance. The bulletin board must be similar in construction to the building directory, except with a cork backboard.

3-2.10 Locker Area.

The locker area provides a space for ATC and Technical Operations personnel to secure their personal belongings while on duty, and serves as a place to store work equipment while off duty. All facets of locker rooms must comply with DoD ABAAS requirements. Include showers with changing rooms and half-height lockers (60% male/40% female). In overseas locations, full-height lockers must be provided.

3-3 STRUCTURAL.

3-3.1 Structural Design.

Except as indicated herein, use the model codes with modifications specified in UFC 1-301-01 along with other applicable UFC documents to develop design documents. Special design requirements for each facility type are provided in Chapter 4.

3-4 MECHANICAL.

3-4.1 Indoor Design Conditions.

The mechanical systems serving ATC and Air Operations Facilities must be based on maintaining the following temperature and humidity requirements:

<u>Critical Spaces</u>: Certain spaces in all ATC facilities are considered Critical and must have the capability to maintain certain temperature/humidity sound level design conditions. Normally, Critical spaces include the Control Cab, Communications Equipment Room, RACF Operations/IFR Room, UPS/Battery Room and all ATC Electronic Equipment Rooms.

- Temperature: 73° F stable ± 2° F
- Humidity: 35% to 60% R.H
- Control Cab and RACF Operations/IFR Room Sound: Maximum NC 35
- Equipment Room Sound: Maximum NC 45

Refer to Chapter 5, Functional Data Sheets, for information on program areas identified as Critical Areas.

3-4.2 Air Conditioning Loads.

Equipment heat loads must be provided during the planning/DD 1391 development process. Loads must be calculated using normal air conditioning load calculation procedures. Do not consider heat loads from electronic equipment when calculating heating requirements. Loads must be based upon personnel occupancy. Loads due to electronic equipment must be verified during design.

3-4.3 Acoustics/Noise Control.

HVAC system noise control is required for ATC facilities and electrical and mechanical rooms must be designed to control sound attenuation. Sound traps must be used, as required, on the supply and/or return air duct openings and where return air passes through sound treated walls. To minimize HVAC noise, equipment must be mounted on vibration isolators. All rooftop mounted air-handling systems and packaged air conditioning systems must be strategically mounted to alleviate noise attenuation.

3-4.4 General HVAC Requirements.

Detailed descriptions of required spaces and HVAC system requirements are as follows:

3-4.4.1 Radar, Communication, and Telecommunications Rooms.

These spaces house solid state electronic equipment and require complete heating and air conditioning. Cooling and humidity control is required for reliable equipment operation and cooling loads are generally constant, 24 hours per day, except during additions or equipment modifications. Humidification is required to prevent electrostatic charges from derogating equipment performance.

Multiple units designed for computer room environments must supply each equipment room. Two air handling units must house humidifiers and each must be sized for the maximum load for redundancy. Ventilation requirements are based on occupancy and the designer must collect information about room personnel occupancy during the planning process. Specialized computer room HVAC systems with air distribution through the RAF must be installed, and high efficiency air filtration must be integrated into the systems to minimize dust and contaminants.

3-4.4.2 Administrative Spaces.

These spaces require normal office environment cooling, humidification, and heating systems. Heating and cooling loads are variable. Administrative spaces are not normally occupied more than eight (8) hours a day and must be zoned by occupancy hours and similarities in comfort control requirements. Use night setback thermostats in areas occupied for eight (8) hours per day. HVAC systems with VAV are preferred and zones must be determined from building size and layout.

3-4.4.3 Break Rooms.

Provide HVAC capacity for 24-hour per day operation to handle the heat generated by existing and planned vending machine, cooking equipment, refrigeration compressor associated with under-the-counter refrigerators, and drinking water remote chillers when provided. The kitchen area must have its own exhaust fan ducted to the outside which is activated by a switch located near the cook-top or microwave oven.

3-4.4.4 Toilet, Shower, and Locker Rooms.

Provide tempered conditioned supply air ducted directly to toilet room ceilings in the amounts only as required to compensate for heating or cooling thermal envelope loads. Louvered door makeup air must not be used if toilet room entrance walls are fire-rated. Door louvers or undercuts must not be considered if requirements exceed 100 cfm (47.2

lps). Where appropriate, the exhaust fans serving toilets (and adjoining janitor closets) must be interlocked with the building HVAC fan(s). In low activity buildings without central HVAC systems, toilet rooms may be equipped with an exhaust vent fan operated with the room lighting switch.

3-4.4.5 Emergency Generator (E/G) Rooms (if required).

For summer conditions, provide an exhaust fan that is mounted to the side or on the building roof and is weatherproof for space ventilation, activated by an adjustable thermostat. Provisions must be considered to maintain room temperatures a maximum of 10° F above ambient conditions. Design must preclude drawing outside air that could be contaminated by the battery room exhaust. An additional high volume fan is required for simultaneous operation with the generator set. This fan must be sized to draw air through the E/G space at a rate sufficient to provide the necessary heat removal for the specified E/G. Alternatively, a two-speed thermostatically activated fan with activation set-points, sized as noted above, to operate with E/G operation, may be considered. Air intake for both normal ventilation and high-volume exhaust fans must be via low efficiency filtered storm-proof outdoor air louvers or intake hoods with multi-blade (sectioned) low-leakage motorized control dampers (insulated airfoil dampers or similar type preferred for all heating climate zone I through III inclusive). Dampers on fan intake throats must be of similar type, motorized, and interlocked with either fan operation or barometric backdraft.

For installation in colder northern regions, a low ambient thermostatic damper control to interlock intake damper blade sections for high volume exhaust fan to preclude the full damper area from opening on E/G start-up when outdoor ambient is below freezing. Other design options can be considered. For E/G sets equipped with bed-rail mounted integral radiators, the high volume exhaust fan is not typically required as air is drawn over the engine and discharged to the atmosphere via the integral radiator fan (requirements must be verified individually for such installations). E/G space must be provided with a thermostatically-activated unit heater to maintain this space at no less than 50° F.

3-4.4.6 UPS/Battery Equipment Rooms.

This room must be served with two 100% redundant cooling-only constant volume air conditioning systems with minimum MERV 11 filtration. Air-cooled direct refrigerant expansion condensing units, geothermal, and variable refrigerant volume systems are permitted when chilled water is not selected as a primary cooling source. Automatic switchover must be provided in the event of failure of the primary unit. Air distribution must be via an overhead or low sidewall supply directed toward the UPS gear base (integral) ventilation intakes. The UPS gear cooling load is continuous, 24-hours per day, year round, and is approximately constant. Consider the option of incorporating a hydronic run-around-loop heat recovery system or air-to-air heat exchanger for preheating winter ventilation air when justified by life cycle cost analysis. Outside air economizers must not be used due to dust and/or humidity exposure to the sensitive equipment within this room.

3-4.5 Energy Conservation.

The designer must use UFC 1-200-02, *High Performance and Sustainable Building Requirements (August 2012)* for guidance in developing an energy efficient design for ATC and Air Operations Facilities.

The use of alternate sources of energy, such as wind or solar, should be checked carefully to ensure any equipment required will not cause interference issues with the ATC equipment. System maintenance by local personnel should also be considered.

3-4.5.1 Solar Photovoltaic, Solar Lighting, and Heating.

The location of solar collectors should not create a sun reflection problem for aircraft or ground movement on the airfield.

3-4.5.2 Economizer Cycles.

Economizers should be provided as required by ASHRAE 90.1 except for the HVAC systems serving rooms with ATC electronic equipment, such as the ATCT Control Cab, the RACF Operations/IFR Room, all ATC electronic equipment rooms, all UPS Rooms, and all telecommunications rooms.

3-4.6 HVAC System Selection and Location.

HVAC systems should be located on the floor above or below the level housing the equipment. This allows better maintenance access to the mechanical equipment and the likelihood of an HVAC water leak causing damage to electronic equipment is reduced. Locating HVAC and related equipment above the ceilings in occupied Critical areas must be avoided to eliminate problems associated with noise, vibration, and access. Air conditioning equipment serving Critical spaces must be provided with low ambient control to allow cooling in the winter season. ATC Electronic Equipment Rooms with Raised Access Flooring (RAF) must be cooled by multiple floor-mounted Computer Room Air Conditioner (CRAC) units due to anticipated ceiling height restrictions. Rooms without raised access flooring may be served by CRAC units or overhead distribution from adjacent air handling units. The space required for CRAC units and other equipment, including ATC equipment and building systems, must be considered. CRAC units designed for RAF systems must only be used in rooms with RAF systems.

3-4.7 Critical Space Redundancy.

All Critical spaces in ATC and Air Operations Facilities must be provided with 100% redundancy so that if one unit goes down another unit must be capable of handling the entire load. Also, electronic equipment rooms typically need cooling, even when other rooms need heat. Consider having electronic equipment rooms on a dedicated, redundant unit with both humidifying and dehumidifying capabilities.

All cooling systems (central air handling units, DX package units, DX split systems, chillers, pumps, etc.) serving Critical spaces must have 100 percent redundancy and preclude any single-point failure. Include in commissioning requirements to confirm that all equipment serving critical spaces is connected to a power source that is backed up by the E/G.

If chilled water systems are selected, the systems should be sized for 75% (60% allowable with approval) of peak load for the entire facility. The chillers should share the entire load with the primary and secondary units alternating on a user programmable schedule. In the event of a chiller failure, control must be such that the non-Critical loads (all areas other than control cab and electronic equipment rooms) can be dropped. Alternate use of chillers and equalize run time to lengthen life span and improve efficiency. VRV systems must not be used. The use of dedicated Outside Air Units must be considered.

3-4.8 Air Filtration.

The inclusion of highly sensitive electronic equipment in ATC and Air Operations Facilities requires the use of high-quality air filtration systems. High-efficiency filters must be installed in equipment serving Critical areas. In addition, a minimum of 2-inch (50-mm) thick disposable MERV 7 pre-filters must be used in all units. If severe fuel/exhaust odor problems are anticipated due to site location, charcoal filters may be used for outside air intakes serving Critical areas.

Careful consideration must be made for specification of these systems due to the size and high maintenance cost of these filters. High-efficiency filters must be rated at a minimum of MERV 11. Electrostatic air filters may be considered for the Critical spaces in locations with high ambient dust levels such as airports in desert areas. During design, care must be taken to ensure that these filters will not produce electronic feedback or allow harmonics back into the system.

3-4.9 Equipment.

Computer rooms and electrical equipment rooms produce predominantly sensible heat and require specially designed HVAC equipment for optimal performance. Ensure mechanical systems do not interfere with electronic equipment or radiated signals. Provide adequate clear heights in MEP rooms for maintenance personnel throughout ATC and Air Operations Facilities.

Ensure that the locations of mechanical devices in ATC Facilities do not interfere with electronic systems to be installed or the support devices installed in conjunction with ATC equipment. In addition, ensure that mechanical assemblies do not interfere with post-construction access to power panels, cable chases, equipment hatches, or roof hatches.

Provide a snorkel type localized stand-alone exhaust system with timer and 100 fpm capture velocity for any spaces where soldering occurs.

3-4.10 Thermostats.

Remote and local control of thermostats can be allowed in spaces with ATC equipment but must be restricted to the temperature limits as defined in paragraph 3-4.1.

3-4.11 Batteries.

Wet cell lead acid or nickel-cadmium batteries must not be designed for use in the ATC Facilities, except as approved for emergency lighting.

3-5 PLUMBING.

3-5.1 Design Criteria.

Consult with the electrical and architectural design engineers to ensure that plumbing does not interfere with the cable tray installation.

Plumbing design must use UFC, 1-200-02, *High Performance and Sustainable Building Requirements* (August 2012).

3-5.2 Restrooms.

Vitreous china fixtures must be used in all restrooms. Flush valves must be used on ground or second floor only. Tank-type fixtures must be used above the second-floor elevation. Wall-mounted fixtures must be used whenever possible. Provide accessible fixtures required by DoD ABAAS for disabled access. Consider in-line hot water heaters for ATCT restrooms.

3-5.3 Emergency Generator (E/G) Rooms (if required).

An emergency eyewash station must be provided within the E/G Room. A floor drain should not be provided because of the potential for contamination of the sanitary sewer system with diesel fuel.

3-6 FIRE PROTECTION AND LIFE SAFETY.

3-6.1 Type of Construction.

Construction type must be in accordance with UFC 1-200-01.

3-6.2 Definitions:

- Control Cab: That portion of a building or structure used for the control of aircraft by visual observation, radio communication, and/or radar by Air Traffic Control specialists.
- Tower Shaft: That portion of a building, facility, or tower that structurally supports a control cab used for housing minimum mechanical, electrical power, and electronic equipment.
- Base Building: Buildings used for housing support equipment and personnel for ATC activities.

3-6.3 Floor and Wall Penetrations.

All ducts and chases must be fire/smoke-stopped by an approved and listed method. Through-penetration assemblies must be provided in cable duct wall penetrations in accordance with NFPA standards after installation of cables.

Openings in rated walls and floors for cabling, whether installed at the time of construction or for later use, must be completely filled and fireproofed, with a listed assembly. The fire rated assembly must permit repeated removal and replacement, without special tools, as necessary for the installation of cables and to support changing requirements.

3-6.4 Raised Access Flooring Areas.

Raised Access Flooring (RAF) areas may be used as supply air plenums only. Return air plenum use is not allowed.

All cabling and conductors installed in RAF areas must be plenum rated or installed in metal conduit or EMT.

3-6.5 Fire Suppression Systems.

For the purposes of the design and installation of suppression systems only, ATC and Air Operations Facilities are not to be considered “mission critical.”

All areas of ATC and Air Operations Facilities must be protected with wet pipe fire-suppression sprinkler systems. A single fire suppression system may serve an ATCT and an attached adjacent RACF provided that separate water flow indicators are provided for each.

Provide for concealed mounted sprinklers where suspended ceilings are installed.

3-6.6 Fire Alarm and Detection Systems.

Provide intelligent addressable fire alarm, detection and mass notification systems in all ATC and Air Operations Facilities. Audible notification shall be voice messages via speakers. The fire alarm and mass notification systems shall share speaker circuits and notification appliances.

Carbon Monoxide detection, in accordance with NFPA 720, is required in any facility provided with fossil-fueled equipment, such as a generator, boilers, hot water heaters, etc.

A single fire detection and notification system may serve an ATCT and attached adjacent RACF provided separate notification zones are provided for the ATCT and the RACF to prevent simultaneous evacuation of both technical areas.

3-6.7 Electronic Equipment Spaces.

3-6.7.1 Separation.

Provide separation from other areas of the facility with one-hour fire resistance-rated assemblies.

3-6.7.2 Automatic Sprinkler System.

Provide a wet pipe sprinkler system in Electronic Equipment Spaces (EES).

- Provide guards for sprinklers in EES's without ceilings. Provide concealed sprinklers for EES's with drop ceilings.
- Provide a single fire suppression line supplying the sprinklers in EES. This supply must be provided with a supervised shut off valve, check valve, flow switch, and test valve.
- Actuation of the flow switch must remove power to the electronic equipment.

3-6.7.3 Fire Alarm System.

For the EES:

- Provide smoke detection at ceilings, connected to the building fire alarm system to transmit local and remote signal as well as to activate the extinguishing system where provided.
- Provide manual fire alarm stations at all doors from the EES.
- Smoke detector(s) shall be spot type utilizing a laser light source technology. It shall be able to recognize and transmit at least two separate alarm threshold signals.
- Provide local audible alarm notification in each EES. The fire alarm system must be configured such that the first threshold smoke detection signal shall annunciate an alarm at the Fire Alarm Control Panel (FACP) and all remote annunciators, if provided, and initiate alarm notification from the local audible alarms, but will not initiate evacuation alarms throughout the facility.
- A signal indicating second threshold smoke detection, or a detection signal from a second detector, if provided in the EES, will silence the local alarm and initiate the facility evacuation system.
- Do not install heat/smoke detectors directly above ATC equipment cabinets. Equipment locations will be determined during design.

3-6.8 Seismic Restraint.

Fire protection systems and components shall be braced against damage from movement such as from seismic activity, regardless of the probability of such activity. Design and installation of system bracing shall be in accordance with the applicable design standards such as NFPA 13, NFPA 14, NFPA 70 and NFPA 72.

3-7 ELECTRICAL.

The criterion set forth in this section includes the minimum functional and design requirements of interior and exterior electrical systems for ATC and Air Operations Facilities. The power distribution system and components must meet overall power system and Critical system reliability requirements.

3-7.1 Emergency Electrical Power.

3-7.1.1 Emergency Generator.

All electrical power provided to ATC and Air Operations Facilities is considered "Essential", requiring back-up by an Emergency Generator (E/G). This Essential power must be supplied on a split-bus system, which is herein denoted as Critical and "Non-Critical". Equipment to be supplied from the Critical bus is limited to the ATC electronic equipment, the signal light guns, and select non-ATC computers, LAN, or other technical equipment that may be required. Non-Critical circuits include the facility mechanical and building systems, such as the HVAC, lighting, and fire protection systems.

To ensure equipment operation during extended power outages, the HVAC systems serving Critical spaces must be on E/G power. If an ATCT is located adjacent to an RACF or AOB, a common emergency generator must be considered.

3-7.1.2 Emergency Generator Location.

Consider an outdoor unit with a weatherproof enclosure in mild climate conditions. Where the E/G is located in a cold climate, the emergency generator must have an in-block heater to facilitate rapid start-up during cold winter snaps. If the cold weather is extreme, utilize a crankcase engine lubricating oil heater to reduce the oil's viscosity and facilitate an easier and faster start. Consider the use of a battery heat jacket in extreme frigid weather to facilitate full battery cranking power. An ether injection system for direct injection into the engine's intake manifold will enhance starting capability during very frigid weather.

Consider a below-ground generator vault for units which must be sited within airfield clear zones or primary surfaces.

3-7.1.3 Emergency Generator Fuel Storage.

- Design fuel storage for diesel or jet fuel powered generators in accordance with:
- UFC 3-460-01, *Design: Petroleum Fuel Facilities*, state and local regulations, and the following:

- Title 40, CFR Part 112, *Oil Pollution Prevention*
- Title 40, CFR Part 113, Liability Limits for Small Onshore Storage Facilities, Subpart A "Oil Storage Facilities"

Provide fuel storage capacity for a minimum of 36 hours of continuous generator operation. This will account for periodic engine testing while ensuring at least 24 hours of fuel supply for the full required load during an actual electrical emergency. Provide separation between fuel storage tanks and adjacent buildings, parking aprons and property lines in accordance with UFC 3-460-01. Provide double wall storage tanks and piping. The screen wall surrounding an exterior fuel storage tank must be at least 6 inches (150 mm) taller than the tank. Underground fuel storage tanks are not allowed for ATC Facilities.

3-7.1.4 Emergency Lighting.

Emergency lighting must be connected to the emergency bus and will have 100% backup power from the E/G. Stairways, exit corridors and vestibules must have sufficient general building luminaries connected to the emergency system to provide emergency exit illumination. Also provide emergency lighting at the UPS and backup generator systems for reading any operating instructions.

In addition, each continuously occupied room and each ATC Electronic Equipment Room must be supplied with at least one (1) light from circuits powered by the E/G. Consider providing additional emergency fixtures (conventional with battery back-up or inverter/rectifier located in the fixture ballast) in other locations if determined by local ATC personnel.

3-7.1.5 Emergency Power-Off Switch.

Per NFPA 70, a means to immediately secure all incoming Critical power is required in the ATC electronic equipment spaces and the Facility MDF. These Emergency Power-Off (EPO) switches must cause a main breaker trip (by activating a shunt trip) in the Critical power panel feeding the associated room. Under-voltage type devices must not be used. Circuit breaker number one of the associated power panel must be reserved for shunt trip power. (Local regulations must be consulted for deactivating each facility UPS via an EPO switch. Deactivation is required if over 600 VAC).

The EPO switch must be conveniently located in a conspicuous location near the room entrance(s), readily visible, and protected from accidental activation by means of a protective hinged cover. The EPO switch must have a label stating "Emergency Power-Off." Resetting after activation does not have to be controlled from within the space. An audible alarm on the EPO switch cover is not required.

3-7.1.6 Uninterruptible Power Supply (UPS).

Provide an Uninterruptible Power Supply (UPS) system in ATC and Air Operations Facilities for all Critical technical loads and the specific requirements of the Program Authorities. Install the UPS system in accordance with MIL-HDBK-1012/1, *Electronic*

Facilities Engineering. The UPS system must feed all Critical power panels. UPS sizing calculations are the responsibility of the Designer of Record.

- By design, UPS units must be physically near the load to be served. The UPS must be sized to provide the critical loads with power (plus a 25% spare capacity) for a minimum of 15 minutes to allow the E/G to start, stabilize, and assume the load. Provide remote monitoring of the UPS from a location determined by local ATC personnel.
- Connect the UPS so that the E/G provides input to the UPS during facility power outages. The UPS must be "double conversion" type. UPS output converters must include an isolation transformer. Size and install grounding electrode/bonding separately for derived neutral in accordance with the National Electrical Code (NEC). The UPS must be provided with dual inputs (one Normal UPS input and one Bypass input).
- The UPS is not normally located in the electronic equipment rooms due to space limitations, but must be located in a room serviced by the redundant HVAC system. The electronic equipment cabinets (to be installed after construction) will occupy most of the area in these spaces. If the UPS is to be located in any of these spaces, additional square footage will be required.

UPS systems that are built in are included in the MILCON construction and funding. Rack-mounted UPS systems for telecommunications, instrumentation or similar electronic equipment are not MILCON funded.

- **Navy:** Refer to OPNAVINST 11010.20 for updated guidance on UPS funding.
- **Army:** Refer to AR 415-15 for guidance on funding sources for UPS equipment.

3-7.2 400-Hz Power.

When required by the Program Authority, provide 400-Hz solid-state converter in accordance with UFGS 26 35 43, *400-Hz Solid State Frequency Converter*. Design in accordance with UFC 3-555-01N, *400 Hertz Medium Voltage Conversion/Distribution and Low Voltage Utilization Systems*. De-rate all 400-Hz cables and locate in separate non-magnetic raceway system. Also refer to MIL-HDBK-1012/1.

3-7.3 Grounding, Bonding, Lightning and Surge Protection.

Grounding, bonding, lightning protection, transient voltage protection, and shielding must be designed and installed in accordance with the requirements of NEC Article 250 and as specified in FAA-STD-019e, FAA-STD-020b, NFPA 780, Underwriters Laboratory (UL) 96A, Installation of Lightning Protection Systems, FAA-C-1217, and FAA Order 6950.19a. Specifically, ATC and Air Operations Facilities must have grounding electrode systems and safety grounding systems plus lightning protection, signal reference systems, and multipoint grounding systems. Designers should be aware that FAA requirements dramatically exceed those of the NEC. Special note: unless otherwise noted, there is no requirement for a single point ground system for ATC Facilities.

Lightning protection and grounding are crucial elements to an ATC Facility. Improper grounding and lightning protection can be the cause of many system failures and equipment damage. Any interruption of ATC services can cause severe flight safety issues.

3-7.3.1 Grounding.

Provide a grounding grid on all raised access flooring systems and isolated grounds for each piece of electronic equipment and equipment racks. Provide Equipotential Grounding Plane connections in the areas where equipment racks will be installed. Racks must be directly grounded for maintenance and should operate on a grounded power supply

3-7.3.2 Bonding.

Bonding of all metallic components in a facility is part of the complete facility grounding. Bonding of all metallic components in ATC Facilities is required per FAA-STD-019e. Special attention must be paid to the bonding of items that will be concealed upon completion of the construction effort, such as reinforcing bar.

3-7.3.3 Lightning Protection.

Due to the increased use of jointly procured (FAA/Department of Defense [DoD]) electronic systems for the National Airspace System Modernization (NAS Mod) Program, the lightning protection system requires that the structure be designed and installed per FAA-STD-019e.

Care must be taken to ensure lightning down conductors do not run within the building structure, take the shortest route possible, and are properly terminated to an earth ground. As specified in FAA-STD-019e, all down conductors are required to be connected to the earth electrodes by exothermic welds. This requirement must include the connection of any down conductors to the ground rod in the access well. The Government will ensure that all rooftop antennas installed by the Government are adequately bonded to the lightning protection system, and that all ATC antenna and ATC signal cables installed by the Government are adequately protected from lightning induced transients.

3-7.3.4 Transient Voltage Protection.

Transient voltage protection is required per FAA-STD-019e. Transient Voltage Surge Suppressors (TVSS) will help to prevent incoming surges from damaging any UPS installed. Additionally, the design must include TVSS on all critical power panels to prevent surge transmission between electronic equipment. TVSS is also required on any non-critical panels providing power to general-purpose outlets in any electronic equipment space. TVSS is optional on all other non-critical panels in the remainder of the facility. The lowest set of breakers (either right or left, according to which provides the shortest cable length) must be used in connecting the TVSS. Consult with local ATC personnel for additional non-critical power panel requirements.

The TVSS should be in a separate enclosure adjacent to the switchboard or panel board and be nippled with it. The nipple should be sealed with Oakum or duct seal.

3-7.3.5 Electronic Multipoint Ground System

An electronic multipoint ground system, per FAA-STD-019e, is required. This system must facilitate the interconnection of all non-current-carrying metal objects in the ATC Facility structure to the Earth Electrode System (EES). It is essential that no power grounds utilize this system.

- Electronic multipoint ground plates are required in ATC equipment spaces for the exclusive use of the ATC electronic equipment. One multipoint ground plate is required in the vicinity of the power panels in each of the ATC equipment spaces. A multipoint ground plate is not required in the Operations/IFR Room, IFR Equipment Room, ATC Simulator Room, or the ATCT Control Cab. The Signal Reference Grid (SRG) under the Raised Access Flooring (RAF) will be used to provide the grounding connection. Other multipoint ground plates may be installed as dictated by the facility design.
- All multipoint ground plates provided for ATC electronic equipment must be constructed of 4-inch (100-mm) wide x 20-inch (500-mm) long x 0.25-inch (6-mm) thick copper plate, mounted on standoff brackets. (NOTE: FAA-STD-019e states ground plates must be a minimum of 4 inches (100 mm) wide x 6 inches (150 mm) long). One half of each plate must have an evenly distributed pattern of holes, clear drilled for 0.375-inch (10-mm) hardware, on 1-inch (25-mm) centers. The other half must have a similar pattern of holes clear drilled for 0.125-inch (3-mm) hardware on 0.75-inch (20-mm) centers. All electronic multipoint ground plates in ATC Facilities must be mounted, have covers, and be labeled per FAA-STD-019e.
- To aid future testing of each facility grounding system, a Main Ground Plate must be installed in each facility, which must be easily accessible. The Main Ground Plate can be located in the IFR Equipment Room or in the ATCT Vertical Cable Chase on the ground floor. The Main Ground Plate must be identified by a predominantly green, permanently attached, plastic or metal label bearing the caption “MAIN GROUND PLATE” in black letters.

3-7.3.6 Electrostatic Discharge Prevention.

The electronic equipment to be installed in ATC Facilities will primarily consist of commercial off-the-shelf equipment containing circuit cards similar to those used in computer systems. This electronic equipment is highly susceptible to damage by electrostatic discharge (ESD). It is vital that design efforts concentrate on minimizing the potential for generating static electricity

All floors in rooms containing ATC electronic equipment have static dissipative surfaces connected to the electronic multipoint ground system and that floor coverings meet the requirements of ANSI-A148.1 (UL 779), *Electrically Conductive Floorings*. All chairs in rooms with ATC electronic equipment must have metal frames with conductive casters and chair-covering materials must have a low propensity to store static electricity.

Coordination with local Maintenance personnel is necessary to determine the requirements for any electronic repair or maintenance stations in ATC and Air Operations Facilities. If such work areas are requested, suitable ESD protection is required per FAA-STD-019e.

3-7.3.7 Earth Electrode System.

An EES is required for ATC Facilities per FAA-STD-019e. A survey to gather information concerning the subsurface conditions and soil resistance of the site is required per FAA-STD-019e. One access well is required per FAA-STD-019e so that periodic checks of the EES can be made.

At facilities that have two or more structures, the EES may be required to be interconnected per FAA-STD-019e. Additional guidelines are provided in FAA Orders 6950.19a and 6950.20.

3-7.4 Critical Power Distribution System.

All ATC and Air Operations Facilities require a Critical Power Distribution System (CPDS). Only 480 volt, three-phase, wye, three-wire distribution systems must be used, based on their superior harmonic resolution capability. This capability is applicable to all ATC and Air Operations Facilities unless 480 volt, three-phase utility power is not available.

ATC electronic equipment requires 120/208-volt service, and will generally be supplied from transformers 30 kVA to maximum 75 kVA (480 volt delta, 208Y/120 volt). The designer must follow guidelines in IEEE STD 1100, the Federal Information Processing Standard (FIPS PUB 94) power distribution publication for electronic equipment, and actual equipment loads to size transformer.

3-7.4.1 Main Distribution Panel Essential.

The Main Distribution Panel Essential (MDPE) will normally be rated 480 volt, 60 Hertz, three-phase, three-wire. This panel must be designed with a minimum spare capacity of 25 percent. All breakers 1000 ampere three-phase and higher must be installed in accordance with the NEC, have ground fault interruption protection option, and be rated to provide interrupting capacity in accordance with the short circuit study.

Provide an option to use 208 volt or 480 volt power. On smaller ATC Facilities, it could be more beneficial to use 208 volt power to eliminate the use of dry-type transformers.

3-7.4.2 Critical Power Panels.

Critical power panels are required for ATC Facilities. The critical power panels must be connected to the UPS and designated for ATC electronic equipment use. The combined equipment characteristics, estimated power panel loads, and proposed circuit designations should be identified during the planning/DD 1391 development process. Unless indicated otherwise, each critical panel in ATC Facilities must be 3-phase, 100 Amperes (A) with a 100A 3-phase shunt trip main breaker.

Flush mount panels in the ATC equipment spaces are required, except on masonry walls. Provide six (6) 3/4-inch (20-mm) empty spare conduits to a NEMA 3 enclosure below the RAF at each panel. These spare conduits will facilitate adding circuits in the future without exposing the bottom of the panel.

Each of the Critical power panels must be fed individually from the CPDS. The feeder to each 100 A critical panel must be designed for 100A 3-phase of load at rated voltage. The desired locations of the Critical power panels will be determined during design. Power panels must retain sufficient access for the future installation of additional conduits.

3-7.5 Non-Critical Power Panels.

Non-critical panels are required in ATC Facilities to support general facility requirements, such as overhead lighting and general-use duplex outlets. Desired locations for these power panels will be identified during design.

Non-critical power panels are typically located adjacent to the critical power panels.

3-7.6 Power Panel Access.

The individual room designs must ensure that there are no objects or equipment mounted above or below power panels. This will ensure nothing impairs the installation of conduit runs to support equipment being installed after construction.

Post-construction access to power panels must be designed into the facility. When a power panel is located above the RAF, there must be sufficient cable paths (conduit or 4-inch (100-mm) x 4-inch (100-mm) metal duct) to facilitate cable installation. When power panels are located in adjacent rooms to where the service is required, an adequate number of conduits must be installed from the panel to the room(s) serviced. Quantities and termination of additional cable paths should be specified during the planning process.

3-7.7 Critical Power Circuits

ATC equipment power circuits must be installed during construction. The circuits terminate in junction boxes below the RAF. During the equipment installation, the circuits are extended to the equipment. Everything installed under the RAF (except ATC circuit cables) is installed during construction. This places the burden of overcoming interference issues on the construction contractor.

Note: Not all junction boxes will require an individual conduit path to the Critical power panel. However, conduit sizes and junction boxes must conform to the NEC with respect to the fill requirements. Wiring and junction boxes must be labeled with the power panel designation and circuit number. Spare and unused circuits may be used in the future.

3-7.8 Exterior Electrical Outlets.

Any requirements for vehicle heater outlets or golf cart charging stations should be determined during the planning process. Watertight outlets may be provided for vehicle heaters in parking lots at cold weather sites or for golf cart charging stations when authorized by the local installation.

3-7.9 Neutral Conductor.

Every circuit should consist of one phase conductor, one neutral and one equipment ground. Up to three (3) circuits may be run in one raceway.

3-8 TELECOMMUNICATIONS.

3-8.1 General.

Administrative telephone wiring/cabling must be installed under the MILCON project and funded with MILCON appropriations. In addition, specialized communication wiring/cabling between facilities (e.g., cabling which extends from the ATCT to the RACF, navigation aids, remote transmitters and receivers, etc.) and all raceways, conduits, pullboxes, duct banks, etc., are considered permanent and must be installed as part of the construction contract.

The construction contractor must provide all Inside Plant (ISP) and Outside Plant (OSP) equipment for the facility. ISP includes outlets, jacks, cabling, conduit, cable trays, racks, cabinets, building protector assemblies, and passive termination devices such as patch panels and connector blocks. OSP includes exterior cabling, ductbanks, manholes and utility poles.

3-8.2 Operational Telephone Lines.

Administrative telephone service, not related to ATC, will be required in the ATC and Air Operations Facilities. Typically, this service includes dedicated lines for point-to-point communications (e.g. Crash Phone). Consult with local ATC personnel for guidance. As a preliminary recommendation, each room should have a minimum of one administrative telephone line.

3-8.3 Data Communication Lines.

Communications networking cable should be installed in each space and must be of a type consistent with current station or networking systems. Consult with local ATC personnel for guidance. As a preliminary recommendation, two network lines should be available in each space.

Two data ports are generally required at each location, one for a computer and one for a printer. Four outlet panels (Type RJ-45) are recommended for network and telephone services in each room. Exact requirements must be coordinated with local Facilities, Communications and Information Technology personnel.

3-8.4 Telecommunications Room.

Telecommunications Rooms for Telephone/Data communications systems must be provided for all ATC and Air Operations Facilities. This room is configured with termination blocks and patching hardware and serves as the communications distribution plant for the building supported. This room may require temperature and humidity control. The design must be coordinated with local Facilities personnel, and designed to accommodate all telecommunications and networking equipment.

Provide fireproof 3/4-inch (20-mm) thick plywood from floor to ceiling for telecommunication mounted equipment. Paint plywood to match the other walls in the facility. Provide Building Entrance Terminals (BETs) for the primary lightning protection at their entry point into this room and as necessary to meet the NEC. The BETs may be mounted horizontally or vertically. If mounted vertically, there must be 12 inches (300 mm) minimum between each BET. This will allow external cabling to be connected properly.

A cable management system must be used to create a neat, professional cable installation. Attention to detail is critical. Organize space on walls for each cable type and service. Provide space as necessary in the MDF for other services controlled by other factions (such as CATV and fire alarm systems). It may be necessary to design alternate security for each faction in this room.

3-8.5 Facility Main Distribution Frame.

The facility Main Distribution Frame (MDF) is the location in the facility where all exterior signal cabling (not power) is terminated and surge suppressed before being distributed throughout the facility. The types of conductors include (but are not limited to) telecommunications copper, communications fiber, control circuits for airfield lighting, CATV coaxial cabling, and ATC equipment circuits. The contractor is required to remove all waterproofing from exposed conductors. There must not be another room or communications closet within the ATC Facility for termination of outside plant services. This room may require temperature and humidity control. Coordinate with Mechanical Engineer on HVAC requirements for this room.

The MDF must be located in the Telecommunication Room and must be designed with a minimum spare capacity of 25 percent. A short circuit calculation and protective device coordination analysis for the entire facility must be accomplished to determine the appropriate available interrupting current capacity (AIC) requirement for all facility panels and breakers. This analysis must be performed in accordance with FAA Order 6950.27, *Short Circuit Analysis and Protective Device Coordination Study*. The design must allow only the over-current device closest to the fault to operate.

An elevation drawing of the MDF area must be included in the design showing the location of all installed components in this area, to include (but are not limited to): BETs, inter-site conduits, fiber and copper terminations.

3-8.6 Data Cable Tray.

All cable trays must be the dual flange type with a fill depth of at least 4 inches (100 mm) for electronic and telephone cabling and equipment. The cable trays must be designed to provide shielding consistent with equipment cabling requirements, FAA-STD-019e, and must be UL listed. The system design must be coordinated with specific equipment layouts as directed by the designated Electronics Engineer. Cable trays must not be located in fire rated corridors. Cable trays must be easily accessible for maintenance. Where feasible, cable tray installations must provide one foot of access between trays and three feet of access around trays. Cable trays must be bonded in accordance with FAA-STD-019e.

Design engineers must consult with each other to ensure that the cable tray does not interfere with other requirements. Designs for cable tray routing must ensure that the tray lies horizontally flat and is not mounted sideways on the tray edge.

3-8.7 Communications Outlets.

One Quad communications outlet is required every 100 square feet. A minimum of one outlet per quad is used for voice circuit.

Multiple outlets should be installed in every room. Installing wiring and multiple outlets within a room adds flexibility for future requirements.

Printers, fax machines and other similar electronics require a separate, dedicated communications outlet.

3-8.8 Telephone Outlets.

Telephone outlets are required in the offices of the facility. Provide a minimum of four (4) each (one per wall) "quad" jacks, two each CAT 6 data and two each CAT 6 telephone at each room. Conduit for telephones can be stubbed, with bushings provided, above the ceiling where suspended ceilings are used. A cable tray should run from the Telephone Terminal Backboard (TTB) to and along the centerline of the facility when this method of installation is used. Conduit is only necessary for areas where there is no ceiling or there is no access above the ceiling. When conduit is used, it must be prewired.

3-8.9 Internal Facility Connectivity.

Careful attention must be applied when designing cable access runs within ATC and Air Operations Facilities to ensure pathways are uninterrupted, provide accessibility along the routes, and provide enough clearance for feeding the cables from point of origin to point of terminations using industry standards.

3-8.10 Inter-Site Connectivity.

ATC remote facilities (navigational aids) are located on and off the airfield, and most require hard-wire connectivity back to the ATC and Air Operations Facilities. These inter-site conduits can be expensive to install, especially if the path is under runways, taxiways, or parking aprons. All conduits entering the facility must comply with FAA STD-019e.

- All inter-site cabling must be terminated utilizing the Western Electric color code. Provide detectable warning tape above any new duct banks installed for electronic detection.
- Where new facilities are proposed to replace existing ATC Facilities, the new ATC Facilities will require connectivity to the same remote sites as the existing ATC Facilities. This new connectivity must terminate at the RACF MDF. If existing facilities are to be demolished, the design must reroute any "through" cabling prior to the entry into these facilities. Splicing and burying cables beneath the demolished structures is not acceptable. There must be direct and unobstructed access between the vertical cable ladder and the inter-site cable trays/ducts, which provide connectivity to ATC systems in the other ATC facilities.
- If flooding is a possible issue, the conduits may require extensions so that water will not discharge into the ATCF. The penetration in the ATCF must be near the location of the MDF. Nylon pull-cords are required in all conduits. Manhole or conduit access requirements must be determined when the ATCF locations are finalized. A combination of copper, fiber optic, and coaxial cables, with sufficient spares for future use, must be installed. A dedicated ATC-related inter-site trunk cable (minimum 300 pair) is required between the new RACF and ATCT and the existing ATC facility.
- Existing inter-site connectivity may be utilized. However, any existing connectivity cannot be removed or interrupted.
- Every attempt must be made to minimize splices in all new copper and fiber inter-site cabling. Any splices required in the inter-site cabling must be installed by properly trained personnel. All fiber cables must be fusion spliced. All splices, copper and fiber, must be the direct bury, encapsulated, re-enterable type.
- All conduits must penetrate the RACF and ATCT so that installed communications cables can transition easily to their associated termination area or enclosure. The exact termination of the conduits will be determined during design.
- Any connectivity requirements to Flight Planning, the Weather Office, or Airfield Lighting Vaults should be identified during the planning/DD 1391 development process.
- LAN or telephone cabling must not be placed in the same cable tray or conduits as ATC circuits.

Site specific requirements for communication ducts, conduits, manholes, and stub-outs should be identified during the planning/DD 1391 development process.

3-9 PHYSICAL SECURITY.

Physical Security is defined as that part of security concerned with physical measures designed to safeguard personnel, to prevent unauthorized access to equipment, installations, material, and documents, and to safeguard them against espionage, sabotage, damage, and theft.

3-9.1 General Requirements.

In the context of these requirements, facilities may be sited within a restricted or controlled area (airfield enclave) or may be designated as a controlled or restricted area. Controlled and restricted areas are defined areas in which there are special restrictive measures employed to prevent unauthorized entry. Restrictive areas may be of different types depending on the nature and varying degree of importance of the protected asset. Restricted areas must be authorized by the installation commander, and properly posted, and shall employ physical security measures.

3-9.2 Specific Requirements.

All planned security design and installation must be coordinated in advance with the Base Antiterrorism Office (ATO), Security Officer, and Air Operations to determine the area or building designation (controlled or restricted), threat environment, design basis threat (DBT), level of protection, and access control or other ESS requirements. Use the process in UFC 4-020-01 to identify the design criteria, which includes the assets to be protected, the DBT, and the levels of protection. The engineering risk analysis conducted as part of UFC 4-020-01 should be consistent with the terrorism risk analysis conducted by the installation security/AT staff.

3-9.3 Electronic Security Systems.

Design electronic security systems (ESS) when required in UFC 4-021-02, *Security Engineering: Electronic Security Systems*.

3-9.4 Security Lighting.

Design all security lighting to meet the requirements as stated in UFC 3-530-01, *Design: Interior Exterior Lighting and Controls*.

3-10 SITE WORK.

3-10.1 Parking.

Provide parking spaces for staff on shift, plus accessible spaces required by ABAAS, two visitor spaces, and government vehicles as needed. Many airfields have alternative vehicles for Government use. Provisions for these vehicles including charging stations must be considered. Additional parking should be considered for shift changes. Specific criteria are given in UFC 3-210-02, *POV Site Circulation and Parking*.

3-10.2 Pavement Design.

Exterior paved areas include aircraft, pedestrian and vehicle access and parking. Vehicle access and parking should be in accordance with UFC 3-250-01FA, *Pavement Design for Roads, Streets, Walks, and Open Storage Areas*.

3-10.3 Site Utilities.

Reference UFC 3-210-01A, *Area Planning, Site Planning and Design*; UFC 3-210-06A, *Site Planning and Design*; and UFC 3-230-04A, *Water Distribution*.

3-10.4 Site Lighting.

Orient exterior fixtures to minimize glare on ramps and taxiways. Use full cut-off type fixtures. Refer to UFC 3-260-01, *Airfield and Heliport Planning and Design* for clearance requirements, obstruction lighting requirements, and airfield utility lighting information.

3-11 SAFETY AND HEALTH.

3-11.1 General Requirements.

Design occupied buildings with maximum consideration given to safety and health, with particular emphasis on noise control for hearing conservation.

3-11.2 Human Engineering.

Consider safety in relation to operational function, accessibility for maintenance and repair, physical layout for traffic, interface with other equipment, and environmental factors, such as lighting, temperature, and humidity. See MIL-STD-882, *Standard Practice for System Safety*, and MIL-STD-1472, *Human Engineering*.

3-11.3 Electromagnetic Hazards.

ATC and Air Operations facilities contain equipment that radiates an electromagnetic signal. Consider the effect of electromagnetic radiation (EMR) on personnel (HERP), ordnance (HERO) and fuel (HERF) when planning and designing facilities housing EMR emitting equipment. Provide safety measures to eliminate or reduce hazardous conditions. Refer to Section 2-6.2 and MIL-HDBK-1012/1, *Electronic Facilities Engineering*.

3-11.4 Life Safety.

All drawings must be reviewed by the Regional Safety Manager for safety issues such as lockout points, anchor points, confined spaces, fall hazards, noise hazard areas, and areas where eyewash stations or emergency showers may be necessary. These issues must be addressed at the design level to minimize hazards involved with the day-to-day activities and maintenance of the facility.

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CHAPTER 4 SPECIAL DESIGN REQUIREMENTS

This chapter describes the special design requirements that only apply to each type of Air Traffic Control and Air Operations Facility, including:

- Air Traffic Control Tower (ATCT). Section 4-1
- Radar Approach Control Facility (RACF, referred to as ARAC (Army), RATCF (Navy) and RAPCON (Air Force)). Section 4-2
- Air Operations Building (AOB, referred to as Air Operations Building (Navy), Airfield Management Operations (AMOPS) Building (Air Force) or Airfield Headquarters Facility (Army)). Section 4-3

4-1 AIR TRAFFIC CONTROL TOWER (ATCT).

Design the Air Traffic Control Tower (ATCT) to be generally consistent with FAA Order 6480.7e, *Airport Traffic Control and Terminal Radar Approach Control Facility Design Guidelines.* If a conflict exists between this UFC and FAA Order 6480.7e, this UFC governs. Sizing of Control Cab window mullions, Cab glazing and electrical grounding are examples of where most recent FAA criteria should be considered.

4-1.1 General Requirements.

4-1.1.1 Risk Category.

For Risk Category, see Table 2-2, UFC 3-301-01. This classification has an impact on the design of most design disciplines involved with an ATCT, including architecture and structural, mechanical, electrical and fire protection engineering. Ensure that non-structural components (e.g. raised access flooring, architectural components, utilities, etc.) are laterally braced as required for seismic load stability in accordance with UFC and building code provisions. Careful analysis of these requirements must be addressed in the planning/DD 1391 development phase. Coordinate additional bracing requirements to avoid interference with items to be installed post construction, such as cabling, conduit raceways and other infrastructure for electronic equipment.

4-1.1.2 Airfield and Ramp Blind Spot Monitoring.

If any portion of the airfield surface is actively used for aircraft movement or parking and the visibility from the ATCT is limited, Closed Circuit Television (CCTV) may be required to provide remote viewing of the area. Consult with the local ATC operations personnel for specific requirements. The entire runway surface must be visible. CCTV cameras must not be used for remote viewing of runways.

4-1.2 Architectural Requirements.

4-1.2.1 Accessibility for the Disabled.

In air traffic control towers, an accessible route is not required to serve the cab and the floor immediately below the cab. See ABAAS F206.2.3.

4-1.2.2 Raised Access Flooring.

Provide Raised Access Flooring (RAF) in the Control Cab with 18 inches (450 mm) of clearance between the floor panels and sub floor to accommodate wiring and insulated piping. The use of RAF in the ATCT Cab area is required to facilitate the periodic rearranging and upgrading of equipment and cables.

The RAF in the Cab must be supported around the perimeter in addition to the normal stringer support. Due to the shape of the Cab, some pieces of RAF can be small, odd shapes. These small pieces must be securely supported so that when stepped on, they do not create a safety hazard.

4-1.2.3 Floor Finishes.

Provide floor tiles with integral, static dissipative carpet coverings in the Control Cab. The use of carpet aids in sound dampening.

4-1.2.4 Interior Walls.

Use wall materials that will help with sound attenuation in the Control Cab and Cab access stairway.

The finish of any interior exposed wall surface in the Cab must be a dark, flat, non-reflective color to reduce night glare. Consult with local ATC personnel for color preferences.

4-1.2.5 Control Cab Walls.

The exposed Control Cab wall above the window and below the window sill must be finished with acoustical material, such as a heavy-gauge insulated metal panel with noise absorbent backing. Design decibel level no greater than 65 dB. Use of floor carpet on walls is not allowed.

4-1.2.6 Ceiling Finishes.

The Control Cab ceiling must be accessible acoustical ceiling tiles with low light reflectance in a suspended grid system. Use dark colored tiles with textured surface, and high acoustic damping. Flat black color is preferred to prevent reflections on the Cab windows. Suspended ceiling grids must be painted flat black.

Ceiling tiles must be constructed of material which is dyed black, so that the ceiling tiles are black throughout the entire tile. The grid system should not be painted black on site. The grid should be ordered from the manufacturer as black.

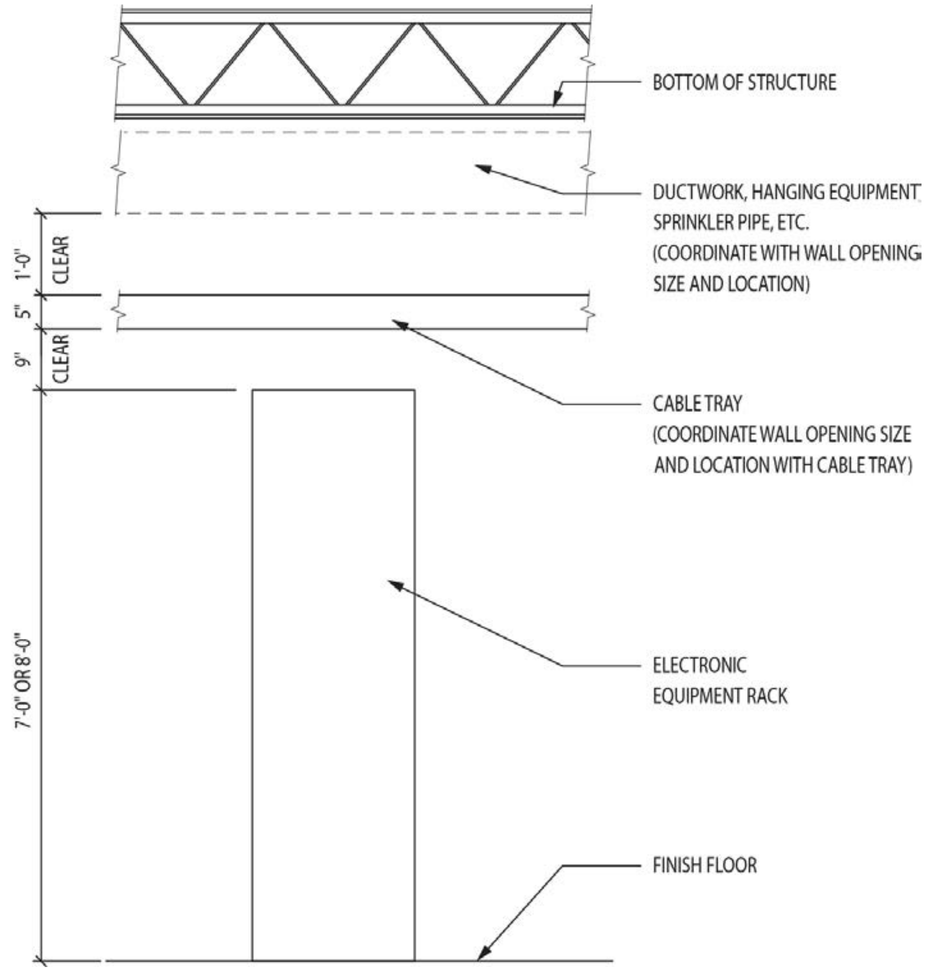
4-1.2.7 Ceiling/Clearance Heights.

The minimum clear height in the ATCT from the finished floor to the bottom of a finished ceiling must be 8’-0”, except for the following conditions:

- Control Cab must have a clear ceiling height of 10’-0” above worker floor (not the raised supervisor level).

- Electronic Equipment Rooms must have a minimum clear unobstructed area from the finished floor to any overhead obstruction of 9'-2". These rooms do not typically have a finished ceiling installed. Refer to Figure 4-1 below for more information.

Figure 4-1 Electronic Equipment Room Clearance Detail



The structural height (floor-to-floor) of each level should be enough to allow HVAC, sprinklers, and electrical equipment be installed without interference.

4-1.2.8 Windows.

Windows must be provided on all sides of the Control Cab, and may also be required in other spaces in the tower.

Window ledges in the Cab must be designed so as not to hinder an air traffic controller's ability to see aircraft movement areas. Deep window ledges extend control consoles away from windows and prevent controllers from viewing aircraft movement areas below and in close proximity to the ATCT. For this reason, the window sill wall thickness/depth must be as narrow as possible (no more than 18" deep).

- The ATCT window sill must be coordinated with the Cab consoles so that the sill and the consoles are the same height. The window sill height must be consistent at the entire Cab perimeter where the consoles will be installed. Refer to Figure 2-3 for window sill height and Cab console height details.
- The window sill must be capable of supporting a 250 lb point load for personnel standing on the sill for maintenance and repair purposes. All window sills and mullions must be covered with a laminate or other material to provide a durable, non-reflective surface. Materials such as gypsum board, plywood, or stained or painted wood are not acceptable.
- The length of the screws used to secure the cab window frames to the structure must be kept as short as possible. If the screws are too long, installing flexible non-metallic tubing or cables inside the tubular column is difficult.
- At a minimum, provide a single window on the runway side of the shaft tower in Training/Briefing Rooms and in the Chief Controller's office. Provide more windows if structurally feasible.

4-1.2.9 Control Cab Glass.

Control Cab glass is the glass in the windows of the Cab for observation of aircraft. Cab glass must be low-iron glass to optimize visible light transmittance. Tinted glass or heat strengthened glass must not be used for the Cab glass.

- Low-E coated glass may be used with the understanding that the coating may reduce visible transmittance. Coordination with HVAC design must take place during planning and design phases to determine the acceptable heat transmission for the low-E coated glass.
- The Cab glass must slope at an outward angle of 15 degrees from vertical.
- Use double pane glazing unless design conditions dictate otherwise.
- Window units must be constructed with a metal or composite plastic perimeter or a unitized extruded aluminum system frame. The frame must be bonded to the glass to provide an airtight, waterproof, and vapor proof seal.
- Cab glass must meet site-specific wind load and seismic requirements.
- Cab glass must allow light gun red, white and green light from inside the ATCT to the outside.

Coordinate with mechanical engineer on HVAC design to minimize condensation forming on Cab glazing, using humidity controls and attention to return air ducts adjacent to each side of the Cab. Cab glass must meet the requirements of the UFGS 08 88 58, *Air Traffic Control Tower Cab Glazing*.

4-1.2.10 Control Cab Window Mullions.

Minimize Control Cab window mullions for air traffic controller visibility. Window mullions should not be directly in the line of sight to critical aircraft movement areas such as the approach ends of the runways.

- If located in a high-wind zone, additional intermediate window mullions may be required to transfer glazing loads to the structure. These mullions, used to resist wind and seismic forces, may be considered only as a last resort.
- Cab window mullions are not limited to aluminum. There are innovations in steel mullion systems that are commercially available. The steel system has better design load properties than aluminum. Also, the coefficient of expansion is less (stainless steel has less thermal conductance than aluminum).
- To minimize sun reflections and hindrance of night vision, Cab window mullion and column finishes must be a non-reflective dark color, and must incorporate a high performance anti-corrosion protection coating. Particular attention must be paid to prevent sunlight reflections from the window sills and mullions. Consider butt glazing in place of non-load bearing mullions.

4-1.2.11 Control Cab Window Shades.

Provide manually-operated window shades for the Control Cab windows. Refer to FAA-E-2470b, *Transparent Plastic Window Shades* and FAA-ANI-300-380, *Transparent Plastic Window Shades.* The Cab shades must be at least 0.125 mm thick, color smoke gray, body dyed, supported by rollers with constant tension. Follow slope of windows and match size and shape of Cab windows. Manual operation is preferred - electric rollers are not encouraged. “Mini-blinds” or opaque, semi-opaque, or mesh type shades are prohibited. Design suspended ceiling so window shade roller is recessed in ceiling.

Local ATC personnel must determine if dual shades are required. If required, use a dual shade system with F-72 SR as the primary shade material and DS 8 SR as the secondary shade material.

4-1.2.12 Roof.

- The Control Cab roof must be sloped to drain away from the center; however, the slope must be kept to a minimum as maintenance personnel will be walking and working on the roof to maintain antennas. Walking pads are required on the Cab roof to protect the roofing material. These pads must provide a walking surface around the perimeter of the roof as well as a path from the perimeter to the roof hatch. Provide a place on the Cab roof to stand while safely shoveling snow away.

- It is recommended that the Cab roof be a flat thermoplastic roof with a Solar Reflective Index (SRI) of 78 or better to meet LEED "cool roof" requirements. Use a light color roof membrane to help achieve LEED criteria. No shingles are allowed. Minimize roof dripping at Cab windows to the greatest extent practicable.
- An OSHA-compliant industrial type safety railing (top rail, middle rail & kick plate) or a parapet wall with height to meet OSHA requirements is required on the roof. The 4-inch (100-mm) sphere rule does not apply to the railing system on the Cab roof because it is considered a "maintenance area" and the railing should comply with the regulations for maintenance areas. Coordinate railing shape and size with antenna mounting requirements.
- Antennas will be mounted to the railing and it shall be designed to carry the weight of the antennas. If a parapet wall is provided, a railing system is still required on the inside of the parapet wall for mounting antennas.

4-1.2.13 Roof Access Hatch.

A personnel access hatch and ladder/stairs is required to transit from the Control Cab to the roof. The opening between the suspended ceiling and the roof is required to be enclosed around the hatch opening and painted flat black on the inside. The portion of the hatch which is visible when stowed must also be painted flat black.

The access hatch must be provided with a concealed pull-down/retractable ladder with integral grab rail. Include OSHA-compliant railing and gate at roof access hatch.

The location of the roof hatch and ladder must not be over the controller position cabinetry. Additionally, it is essential that the location of where the roof ladder will bear on the raised access flooring be shown on the design drawings. This will confirm that the extended ladder does not interfere with the controller position cabinetry. The bearing feet of the ladder must rest on the finished floor when the ladder is fully extended.

4-1.2.14 Catwalk.

Provide safe access for walking around the exterior of the Control Cab to facilitate exterior observations, window washing, and general maintenance. The width of the catwalk must be selected to ensure that it does not interfere with the air traffic controller's visibility of the runway, taxiway, or apron areas. Locate the catwalk at a sufficient elevation below the Cab to permit the controllers a view of the field unobstructed by any railing. A concrete catwalk is preferred. The exterior catwalk can be a galvanized metal or aluminum grate that allows snow to melt directly through without building up at the edge. Corrosion issues must be taken into account if metal grating is used. Care must be taken during the design to eliminate the possibility of falling snow or ice from the catwalk.

Provide a weather-sealed access door to the catwalk from the ATCT Stairwell. The door must be a minimum of 32 inches (810 mm) wide and 36 inches (910 mm) high. The head of the door must not extend above the cab sill and the base of the door must not extend below the cab walkway extension. The height of this door is limited due to the Cab structure, but must be as tall as possible. Personnel access to the ATCT catwalk is required to allow washing of the exterior glass of the Cab without the need for a safety harness. Consult with the local ATC staff to discuss window cleaning methods and requirements.

The catwalk must be designed to meet ANSI and OSHA requirements, and should be wide enough to allow the windows to be washed without having to lean backwards over the railing. Catwalk guardrails must also meet ANSI and OSHA requirements, but are not designed to support antennas or other equipment.

4-1.2.15 Elevator.

For Army and Navy projects, comply with NAVFAC ITG 2013-01 *NAVFAC Elevator Design Guide* in addition to requirements below.

Provide an elevator in the ATCT. The elevator must operate from the ground floor to the floor below the floor directly below the Control Cab, or the floor below the Cab if possible.

A hydraulic elevator is acceptable if the Tower Control Cab floor level is less than 60 feet above grade. Otherwise, provide an electric traction elevator. Electric traction elevators must have elevator machine room with elevator machine and controller in a machine room. Elevator machine room may be located above or adjacent to the elevator hoistway.

- Elevator speed must be 150 feet per minute (fpm) if hydraulic, and 350 fpm if electric traction. Minimum rated load for a typical elevator must be 3500 lbs. Elevator capacity must be sufficient to transport equipment to be installed above the ground floor.
- Elevators must conform to ASME/ANSI A17.1, *Safety Code for Elevators and Escalators,* as well as the International Building Code (IBC), NFPA 101, and NEC. The ATCT elevator must be available for use on standby power.
- The elevator car must be sized to accommodate the stretcher requirements of IBC Chapter 30 (24 inches x 84 inches or 610 mm x 2130 mm). The recommended interior size of the elevator car must be 60 inches (1520 mm) wide x 84 inches (2130 mm) deep x 108 inches (2740 mm) high.
- The elevator car door opening must be at least 42 inches (1060 mm) wide and 84 inches (2130 mm) high. The elevator car door must be the single-speed, side-opening, horizontal sliding type. The elevator car must have retractable covers.
- Provide a ventilated elevator shaft.
- Elevator doors must not open directly to the ATCT Stairwell enclosure.
- Hydraulic elevators must be equipped with elevator car safeties and an overspeed governor. Position of the overspeed governor in the elevator hoistway must allow for a governor access door accessible inside the ATCT. Governor access must include a working platform with a platform height of 4 ft. below the bottom of the access door.

4-1.2.16 ATCT Stairwell and Control Cab Stairway.

A pressurized stairwell is required from the floor below the Control Cab to the ground floor. Stair width must be 44 inches (1120 mm) minimum.

A stairway from the floor below the Cab leading up into the Cab must be provided. This stairway must not be a ship's ladder-type stair, but must be a regular stairway meeting all applicable design codes. Code-compliant stairs are required from the Cab subfloor to the RAF. Care must be taken so that the stairwell does not take up a large portion of the Cab floor area.

4-1.2.17 Vertical Utility Chase.

4-1.2.17.1 Ground-to-Cab Mechanical Chase.

A fire-rated chase, open from the ground floor to the concrete sub-floor of the Control Cab that serves as a pathway for HVAC and plumbing utilities from the Tower Shaft Mechanical Room to the ATCT Mechanical Room.

4-1.2.17.2 Ground-to-Cab Vertical Cable Chase.

The ATCT Vertical Cable Chase is typically a 4-foot wide x 2-foot deep (clear inside dimensions) fire-rated chase, open from the ground floor to the concrete sub-floor of the Control Cab.

- A vertical ladder-type cable tray is required for ATC equipment cabling. This vertical cable tray must be accessible from all floors and must provide cable access from the first floor to the open area beneath the ATCT Cab RAF. The ladder must be centered on the chase access door. A minimum 18 inches (450 mm) wide x 4 inches (100 mm) deep (fill depth) ladder-type cable tray is required to provide a cable management system surface. Additional information for the vertical tray shall be provided during design.
- All power cables in the chase must be located in rigid metal conduit instead of the cable tray.
- Access between the top of the vertical cable chase and the Cab is provided as conduit stubs through the Cab sub-floor. Six stubs of 4-inch (100-mm) inside diameter (ID) conduit are required for the exclusive use of ATC equipment cabling. These stubs must be furnished with anti-chafing bushings on each end and must extend at least 4 inches (100 mm), but no more than 6 inches (150 mm), above and below the sub-floor. Additional conduit may be required for telephone and Local Area Network (LAN) cabling. Consult with local ATC operations personnel to confirm final requirements.
- Lockable access to the vertical cable chase must be designed into each floor of the structure. The design must provide sufficient opening to allow personnel to reach and dress cabling runs on the tray. Signs/labels stating "Cable Chase" must be provided for each cable chase access and match in style and size the other facility labels/signage.

- A full size door is not required at each level of the tower for access. A full size door is required on the ground floor and the equipment room floors. Access on the other floors can be via a 24-inch (610-mm) wide X 36-inch (910-mm) high fire-rated access panel/door. If there is no floor at a particular level of the ATCT, an access walkway is required from the stairwell to the front of the cable chase. Final door size will be determined during design.
- A wall opening 5 inches (125 mm) high x 14 inches (350 mm) wide must be provided for the cable tray that will connect the vertical cable tray to the suspended tray systems in the ATC Electronic Equipment Room(s). This opening must be centered above the lockable access door. The bottom of the opening must be a minimum of 110 inches (2790 mm) above the finished floor. Ensure openings comply with fire codes. The final location of this opening will be identified during design. The opening must be finished with smooth edges on both sides of the opening between the chase and equipment space and on the sides of the opening. This opening must be finished to match other openings in the walls, such as sheetrock, paint, and trim.
- Cable Separation. Power and communication cables must be physically separated by distance or by barrier to preclude power cables from coming into contact with communication cables in accordance with the NEC. Cable ladders must be provided. Vertical shafts must be provided with fire separation assemblies in accordance with the other paragraphs in this section.
- The vertical cable chase must be located so as to minimize cable distance to the ATC equipment space(s).

4-1.2.17.1 Control Cab-to-Roof Vertical Chase.

The path for all the RF cables to the roof must be through or adjacent to the tubular steel columns supporting the Control Cab roof. These cableways provide the means to run signal and antenna cables from beneath the Cab RAF to the area above the suspended ceiling and/or to the roof. Power cables for obstruction lights and any building system wiring (electrical and telecommunications) located above the ceiling or on the roof must pass through only the two (2) cableways at the back of the Cab near the Cab stairway. The cableways near the stairs are typically not accessible after construction is complete. All remaining cableways must be reserved for the ATC antenna and signal cabling.

These cableways must be free of obstructions. Cableways must be provided with nylon pull-cords and pull boxes on each floor, sized per the NEC. Pull boxes must be large enough to meet the minimum bending radius specifications of any transmission lines running to the roof. All cable paths must be free of burrs and sharp edges that would damage cables.

- **Army and Air Force**: Provide ducts within the Cab for ATC equipment cabling. Two (2) 4-inch (100 mm) Inside Diameter (ID) ducts must be provided for antenna cables between the ATC Equipment Room and the roof. These ducts are installed adjacent to the roof support columns and terminate in weatherheads on the roof. Ducts from the ATC Equipment Room extend to the floor just below the Cab. A ladder-type cable tray connects these ducts to two (2) 4-inch (100 mm) ID ducts that continue the run up to the weatherheads required at each of the Cab roof corners. Refer to Figure 4-2 for Plan Detail at Control Cab Window Mullion/Structural Column (Army and Air Force only).

- **Navy**: Access cutouts in the vertical columns are required below the Cab RAF and above the suspended ceiling area. These cutouts are typically slots of at least 2-1/2 inches (62 mm) x 6 inches (150 mm), opening directly into the columns. Reinforcement of these access holes may be required to maintain the structural integrity of the columns. The bottom of the slots below the RAF must be 2 inches (50 mm) to 6 inches (150 mm) above the sub-floor.
- The preferred location of the openings is on the surface of the column that faces the inside of the Cab. However, access holes on the sides of the column are acceptable. The primary requirement is for the access holes to accommodate two sleeves for antenna cables with a bend radius of up to 10 inches (250 mm). Clear access to these openings must be maintained. Nothing must be allowed to block access to these openings, such as HVAC ductwork.

A minimum of two (2) 2-inch (50-mm) ID smooth-walled, non-metallic, flexible sleeves/conduits must be installed in each of the mullions with enclosed structural column to provide a continuous path through the columns. These sleeves are for the exclusive use by SPAWAR Atlantic. One end of each sleeve must be terminated three (3) feet into the cable tray beneath the RAF and secured to the tray. The other end of each sleeve must terminate in the space above the suspended ceiling, within 6 inches (150 mm) of the weatherhead conduits in the same column area, and the ends secured. In addition to the two sleeves described above, one (1) 2-inch (50-mm) ID flexible sleeve must be installed in the column closest to the position labeled as "Local" in the FRS. One end of this sleeve must lay three (3) feet into the cable tray beneath the RAF. The other end must terminate in the area above the ceiling. Each end must be secured to prevent accidental movement into inaccessible areas. The column location for this sleeve will be identified in the FRS.

An ATCT with two local positions will require one conduit for each local position. The requirement for two sleeves or tubing will be identified in the FRS.

After the finished wall is installed in the Cab, access to the cutouts in the column below the RAF must be provided. Where drywall or other wall covering is installed, there must be approximately 6-inch (150-mm) x 6-inch (150-mm) openings provided to permit reaching the access holes in the columns. Protective flashing must be installed to prevent chipping the wall material during post-construction cable installation.

One (1) 4-inch (100-mm) ID galvanized conduit and weather head is required at each of the Cab roof corners. These conduits must be welded to the roof structure and must extend 18 inches (450 mm) to 24 inches (610 mm) above the roof and 8 inches (200 mm) below the roof structure into the space above the suspended ceiling. Anti-chafing bushings area required on the end of the conduit below the roof. The weatherhead must be galvanized with stainless steel hardware, and sized to accommodate cables with a minimum bending radius of 11-1/4 inches (285 mm). Refer to Figure 4-3 for Plan Detail at Control Cab Window Mullion/Structural Column (Navy only).

Figure 4-2 Plan Detail at Control Cab Window Mullion and Structural Column (Army and Air Force only)

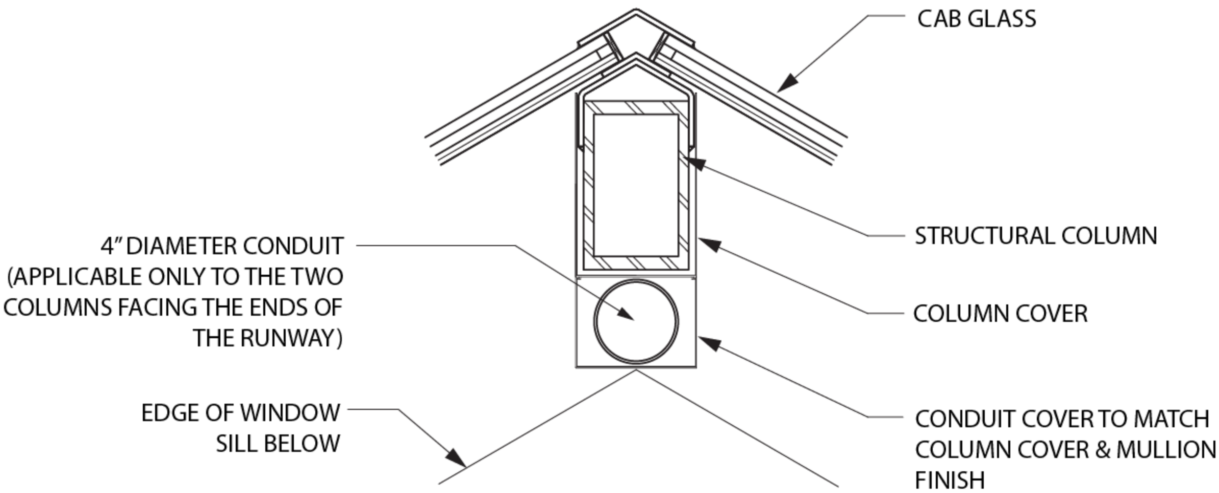
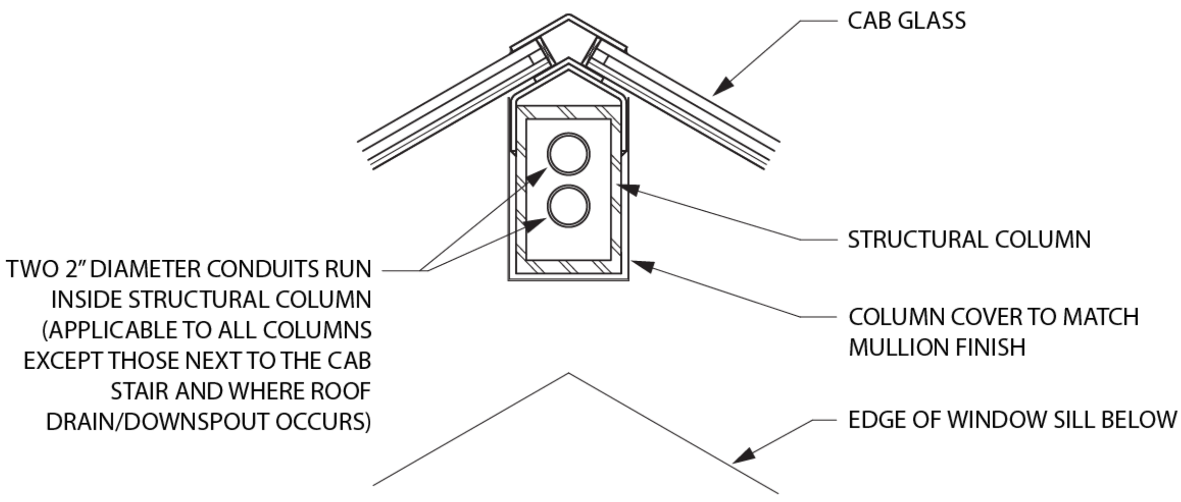


Figure 4-3 Plan Detail at Control Cab Window Mullion and Structural Column (Navy)



4-1.2.18 Cable Tray System.

In the Control Cab, an aluminum or steel ladder-type cable tray is required beneath the RAF, near the controller consoles, and connected to the vertical cable chase. The consoles will be located flush against the Cab wall. This cable tray must be 12 inches (300 mm) wide and 4 inches (100 mm) high (fill depth), with 6-inch (150-mm) on-center rung spacing, and must be installed flush with the front edge of the controller position cabinets. The tray must run continuously around the front of the ATCT Cab and mounted on 1-5/8 inch (40 mm) struts, secured to the concrete floor. The exact location of this cable tray will be determined during design.

In the ATCT Electronic Equipment Rooms, an aluminum or steel ladder-type suspended cable tray system is required. This cable tray must be 12 inches (300 mm) wide and 4 inches (100 mm) high (fill depth), with 6-inch (150-mm) on-center rung spacing. This tray must start at the opening above the access door to the vertical cable ladder and extend into the room above the electronic equipment cabinets. The bottom of the cable tray system must be at least 110 inches (9'-2" or 2790 mm) above the finished floor. If a suspended ceiling is installed, a minimum clearance of 12 inches (300 mm) must be provided between the top of the cable tray and the ceiling. Cable tray dividers, sized to fit the tray, must be provided. The dividers must be MILCON provided and installed by the Government. The location dimensions of the cable tray must be shown on the electrical design drawings to ensure the tray is installed in the correct location.

- NOTE: The specific design of the ATCT Electronic Equipment Rooms will determine the exact layout of the cable tray. The exact location of the electronic equipment cabinets and the cable tray must be determined during design.

4-1.2.19 Doors.

ATCT ground level entrance requires a minimum 42" (1070 mm) wide opening.

The doors to the ATCT Electronic Equipment Rooms must be a minimum of 36 inches (910 mm) wide x 80 inches (2030 mm) high to allow for the movement of electronic equipment racks and other ATC equipment. Equipment room doors must have closers and be lockable.

4-1.2.20 Control Cab Consoles.

- **Navy**: The Cab position consoles will be designed, procured and installed by SPAWAR Atlantic during the equipment installation.

- **Army/Air Force:** Use prefabricated modular consoles, vented type with flat top and/or slope top capability with solid surface extended shelf. Provide "spacers" of specific widths to allow the consoles to be installed from corner-to-corner with no gaps. Provide positions for local control, ground control, flight data, and airfield light controls. Provide supervisor overwatch position.

  In the Cab, ATC equipment is installed from the front of the consoles so there is no need to have access to the rear of the cabinets. Upgrading or replacing equipment is done from the front of the cabinets. Cabling comes from below the floor into the bottom of the cabinets.

Cab consoles must not obstruct the controller's visibility and must contain all necessary equipment. Consoles must be constructed as modules sized to permit removal from the Cab. Cab console colors, equipment location and surface configuration design will be coordinated with local ATCT staff.

The contractor must provide and install the airfield lighting panel, power outage indicator lights, door ajar indicator light, dimmer switch for overhead lights, and the master control for the intercom system in the Cab console. Place single "strip bays" at the Local Control Flight Data and Ground Control positions, in addition to the dual "strip bay" provided for the Flight Data position. All other equipment will be provided and installed by the Government. Government installers will accomplish console cut-outs for Government-installed equipment.

- **Army:** Cab consoles are CFCI.
- **Air Force:** Coordinate and validate the Cab console design through E&I, AFFSA, MAJCOM, and the station Air Operations Department to ensure the design accommodates the required equipment.

  The location of the Supervisor of Flying (SOF), where required, will be coordinated with the Operations Group (OG) Commander, or designated representative. Provide a sketch of the Cab layout to the ATC staff during design in order to finalize the operational requirements, positions, and equipment layouts.

4-1.2.21 Restrooms.

Provide a minimum of two unisex restrooms. Additional restrooms may be required, depending on functions located in the ATCT shaft. Provide one shower and locker area in towers with more than one restroom where the program requirements reflect a 24-hour work shift.

Restroom doors must be provided with a bathroom door lockset. Restrooms must have one water closet and one lavatory with mirror. Plumbing fixtures should be wall hung to facilitate cleaning and maintenance. Fully or partially recessed (depending on wall depth) towel dispensers with integral waste receptacles should be used. Dispenser/receptacle should have standard stainless steel architectural finish with a removable stainless steel waste container in the bottom receptacle portion. No sanitary napkin dispenser must be installed in unisex restrooms. A sign depicting "In Use" should be included and installed to aid in occupancy notification.

4-1.2.22 Building Signage.

Signage stating “Cell phone use not permitted” is required at the entrance to the Control Cab, IFR Equipment Room and Flight Planning Room. Signage style must match that used throughout the remainder of the facility.

4-1.3 Structural Requirements.

4-1.3.1 Basic Requirements.

It is desirable to provide flexibility for future modifications to occupancy and usage. The minimum floor live load specified below was selected to facilitate future modifications. The Control Cab perimeter walkway live load is required to allow for potential loads related to removal and replacement of window panels.

When a Base Building is required adjacent to the ATCT, design the two to be structurally independent when feasible. This approach is recommended to reduce structural complexity and to facilitate future modification to either structure.

Depending on geometry and stiffness, ATCT structures can be more sensitive to wind and seismic loads than typical buildings due to the slender geometry of the shaft and Cab. Follow procedures provided in applicable UFC documents and national standards for wind and seismic load analysis. Ensure the serviceability limits indicated below are met.

4-1.3.2 Design Live Loads.

Unless a larger load is required, design the structure to withstand the following minimum uniform live loads.

Table 4-1 Design Live Loads

Occupancy or Use	Uniform Load Psf (kPa)
All Floor Levels	150 (7.2)
Cab Perimeter Walkway	60 (2.9)

4-1.3.3 Serviceability.

Serviceability of Control Cab windows is particularly important. In addition to serviceability requirements indicated in UFC 3-301-01 for various components of the structure, take special care to ensure serviceability of window panels at the Cab level. Limit the drift ratio (story lateral deflection/story height) to 0.002 due to design wind loading. Coordinate and review window and mullion details to ensure that windows are designed for the required wind loads, seismic loads, and thermal effects. Coordinate with architectural discipline to provide davits (when required) to facilitate window washing.

Discuss drift requirements for seismic loads with the Government during the design phase. A reasonable approach may be to limit drift ratio to 0.002 for a seismic event less than the maximum considered earthquake.

4-1.3.4 Antenna Support.

Railing at the Control Cab roof is required to withstand the forces imposed by the antennas. Unless more stringent criteria are provided on a project basis, design the railing based on the following parameters in addition to model code criteria:

- Antennas spacing of 24 inches (610 mm) on center for the full length of the railing.
- Antenna size: 3 inch (75 mm) diameter x 17 feet (5180 mm) tall
- Antenna weight: 16 pounds (71 N) each.
- Railing is required to withstand forces imposed by the antennas with 1/2-inch (13 mm) of radial ice and with wind speeds as required by UFC 3-301-01.

4-1.3.5 Support of Control Cab Electronic Monitors.

There are three methods to accommodate electronic monitors used by controllers: Desktop monitors, ceiling tracks, and ceiling track support plates.

4-1.3.5.1 Desktop Monitors.

Due to recent improvements in computer technology, large and heavy television-like monitors are being replaced with lighter flat screens. Typical system monitors weigh an estimated 85lbs. These devices can be placed or mounted to the top of the Cab Consoles. Coordinate requirements with the design of the Cab Consoles.

4-1.3.5.2 Ceiling Tracks.

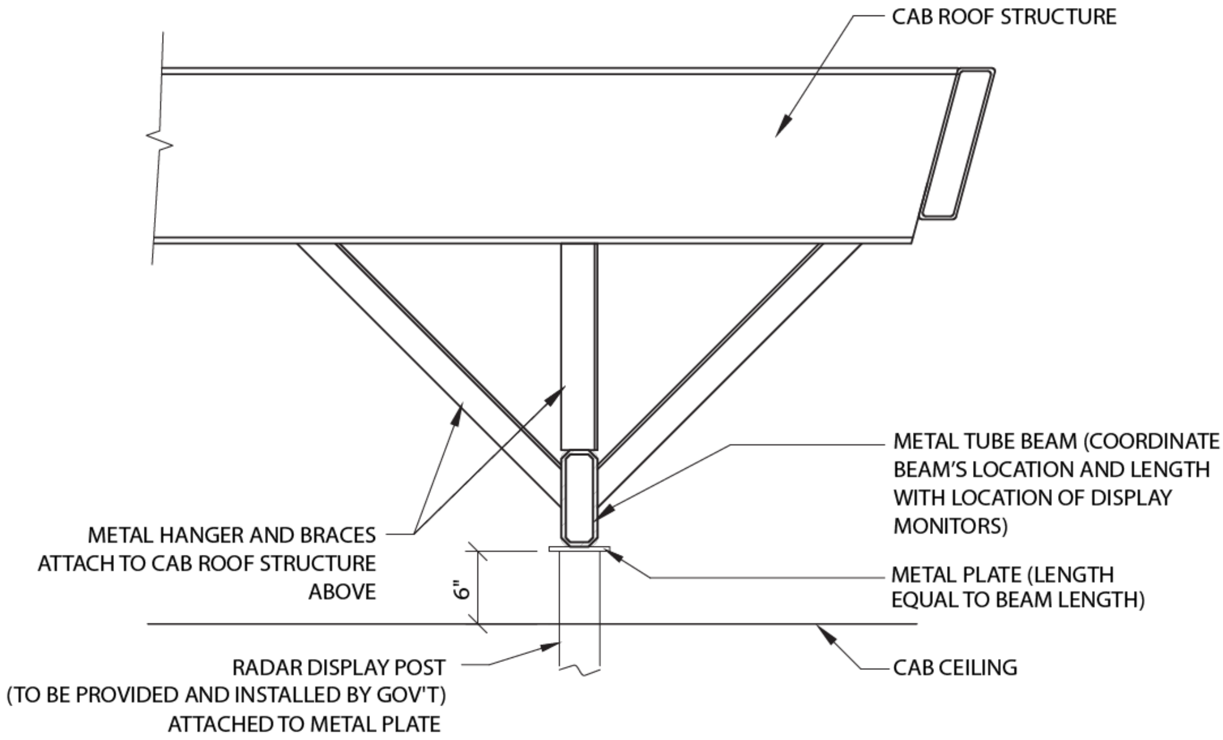
Some electronic monitors require mounting devices incorporated into suspended ceiling systems. Consult with local ATC personnel for preferences for ceiling track systems.

4-1.3.5.3 Ceiling Support Plate.

Some ATC personnel require a ceiling support plate for their electronic monitors. In this case, the ATCT structure must be designed to include secondary framing that runs directly over the controller position cabinetry of the ATCT Cab. This secondary framing beam should be suspended from the Cab roof structure and braced appropriately. The bottom surface of the suspended beam must be 6 inches (150 mm) clear distance above the suspended ceiling tiles. Align the beam with the interior Cab wall where the controller cabinets are installed. The beam will be used to support either a ceiling track or a mounting plate.

Coordinate the design such that no utilities (e.g. sprinkler system piping) are within 3 inches (75 mm) on either side of the beam. This will ensure that there is adequate clearance for the mounting bracket to be installed. See Figure 4-4 for ceiling track support plate detail.

Figure 4-4 Ceiling Support Plate Section Detail



4-1.3.6 Progressive Collapse.

Population density calculation of an ATC tower may not be used to designate a tower with 11 or more personnel as low occupancy. All ATC towers exceeding two stories and routinely occupied by 11 or more personnel must be designed to resist progressive collapse using the UFC 4-023-03 excluding the Tie Force method. Progressive collapse mitigation allows for only safe egress of the facility. Some ATC towers may require continued operation after an event which would require a higher level of protection. Therefore, ATC towers must be evaluated to determine if a higher level of protection is required. Use the process in UFC 4-020-01 to identify the design criteria, which includes the assets to be protected, the DBT, and the levels of protection.

4-1.3.7 Control Cab Roof and Columns.

The Control Cab must use a clear span roof structure so that controllers have 360 degrees of clear view.

Cab columns must be hollow structural shapes. Typically, the columns are sloped in order to provide support of windows with the required downward angle of view. Coordinate column sizes with local ATC personnel to maximize visibility of the airfield. The goal is to minimize the dimensions of the Cab columns in order to minimize obstructed views. Structural shapes should not exceed a width of 6 inches (150mm). Refer to Figure 2-2.

4-1.4 Mechanical Requirements.

4-1.4.1 HVAC Criteria.

The primary HVAC system design objective is to provide environmental control for ATC electronic equipment and personnel. In electronic equipment areas, provisions for temperature and humidity control within the room and under the Raised Access Flooring (RAF) must be installed. Special attention must be given to factors involving installation, maintenance, operation, and reliability with consideration given to diversity and economics. HVAC system design simplicity must be a design goal. HVAC equipment must be limited to serving one or two floors.

- The Control Cab and the supporting electronics equipment areas are considered Critical spaces. Refer to Indoor Design Conditions, General HVAC Requirements, and other information described in Chapter 3-4, *Mechanical*.
- Testing, balancing, adjusting, and commissioning of the HVAC system must take place prior to Government acceptance. This is critical because the heat load varies on each floor because of the different heat output of the equipment.
- Provide an Emergency Air Distribution Shutoff Switch on each floor. Activation of the Shutoff Switch shall shutdown ventilation to the entire building but shall not shut down critical space cooling. Activation of the Emergency Air Distribution Shutoff Switch shall close the outdoor air damper for the Cab Air Handling Unit but the unit shall continue to run on full return air.

4-1.4.2 HVAC Requirements.

Detailed descriptions of required spaces and HVAC system requirements are as follows:

4-1.4.2.1 Control Cab.

The Control Cab is a poorly insulated glass box subject to the maximum effects of changes in atmospheric conditions. Solar gain, greenhouse effect, humidity, conductive heat loss, and convection are forces that influence the design of a specialized Cab HVAC system. Proper air distribution must be controlled to maximize comfort in the Cab. When necessary, ceiling fans must be considered to improve air distribution throughout the space. Supply air must be equally distributed around the perimeter of the Cab and operated continuously at constant volume. Air distribution must be provided along the perimeter of the Cab to prevent glass fogging. Return air must be collected from registers located near the floor or down the stairway and designed to minimize noise transmission from the air handlers. Economizer cycles for the HVAC system must not be utilized, avoiding exposure of critical electronic equipment to wide fluctuations in humidity. The Cab HVAC system must be designed as multiple units in parallel to provide 100 percent cooling redundancy. The Cab HVAC system must serve only the Cab and adjoining spaces within the same fire area. Failure of one unit must allow continuing operation of the second unit. Cabs may be equipped with more than one temperature sensor to allow averaging temperatures throughout the Cab.

4-1.4.2.2 Control Cab HVAC Distribution.

The air distribution system must follow configurations and patterns that are standard to the industry (SMACNA standards). Low and medium pressure ductwork systems must be used where possible. Duct sections with inherently high airflow resistance must be avoided. The number of sharp turns and branching patterns that create airflow turbulence must be minimized. Ductwork must be thermal/noise insulated and must be free of obstruction from auxiliary hardware. Design ductwork to utilize minimum fan horsepower. Exterior insulation must be considered in lieu of duct lining material when required to reduce possible long-term moisture build-up that may lead to growth of mold.

Air distribution must be continuous under the window diffuser system. The duct system must be low noise with a maximum static resistance of 21.17 Pa per 30.5 m (0.085 in of water per 100 linear ft). The duct routing must be under the RAF and coordinated with electrical and equipment wiring routes. Access in the base of the structural columns is critical for installing antenna cables. Diffusers must be floor-grade, linear type, and located at the base of the windows, providing an even coverage of glazing preventing condensation and drafts. Duct system must be coordinated with the structure, electrical, control cabinet sizes, and proximity to the window.

4-1.4.2.3 Sill Area.

The Control Cab window sill area is often used to support the weight of a person cleaning the interior surface of the windows. The design must ensure the air vents located in the Cab window sill and the sills themselves are strong enough to support a 250lb point load for personnel standing on the sills and diffusers.

4-1.4.2.4 Control Cab HVAC System Location.

HVAC systems are located directly below the Control Cab, either on a mezzanine level in the overhead of the floor below the Cab, or on a full floor. Locating HVAC systems on a mezzanine level works well, provided enough space is allocated, including space for maintenance. Provide redundancy for the Cab air handling unit.

- Provide a ducted supply from the air handlers on the floor below the Cab to the diffusers in the Cab sills. HVAC units are not permitted on the Cab roof.
- HVAC ductwork, which may be installed inside the Control Cab wall, must be designed to be as narrow as practical to keep the wall as narrow as possible. HVAC ductwork installed in this wall must not interfere with access to the column cableways or the routing of cables into the cableway.
- It is preferred not to have HVAC systems in overhead spaces because of maintenance difficulty with the limited space available.
- Electrical rooms may require cooling due to the UPS batteries.
- HVAC ducting under the RAF must be routed such that the area along the Cab wall is not used entirely for ducting. Ducts running around the perimeter of the Cab blocks access to the concrete sub floor to secure the position cabinetry. Ducts should exit the Cab wall perpendicular to the wall.

During design, the locations of the duct work and floor penetrations must be reviewed to ensure that they will not interfere with the position consoles.

4-1.4.2.5 Utility and Elevator Shafts.

These spaces usually require natural ventilation only. Storm-proof louvers must be provided to the outside at the top portion of each shaft. Air intake at lower levels may be via passage door, space under doors, or louvers at the base level. Utility chase spaces containing water pipes and drain lines must be heated to maintain a minimum temperature of 40° F.

4-1.4.2.6 Stairwell.

Space conditioning for ATCT Tower Stairwell is not required. However, the stairwell must be controlled to mechanical room standards. Stair sections must be heated above the top elevator landing which leads to the Cab. Heating may be required in some locations due to extreme winter temperatures. Special attention may be required for high humidity areas to prevent condensation in the Stairwell.

4-1.4.2.7 Pipe Chase.

The pipe chase must be fire-stopped at every floor. To prevent freezing, the chase must be opened with louvers, one high and one low between each floor.

4-1.4.2.8 Smoke Dampers.

An elevator shaft smoke damper must be provided to meet life-safety criteria.

4-1.4.2.9 Energy Management and Control System (EMCS).

All new and altered ATCTs must be designed so they can be monitored by an Energy Management and Control System (EMCS). The EMCS must have the capability to monitor lighting systems, security systems, and other systems. Consult the base EMCS office for the design requirements since each base is different.

Due to “Mission Essential” staffing requirements and flight safety considerations, the ATCT occupants, must have direct control of the thermostat to regulate appropriate heating and cooling levels. Configure thermostats so Base EMCS can monitor but not control temperature levels.

Zone the HVAC system so that Control Cab occupants can control the temperature in the Cab. Electronic equipment rooms must be treated as separate zones with their own thermostats. Other floors must be controlled by thermostats zoned to those floors.

4-1.5 Plumbing Requirements.

4-1.5.1 Plumbing Fixtures and Equipment.

Any floor above ATCT Electronic Equipment Rooms must be provided with a floor drain to prevent flooding in case of a water leak. All floor drains must be provided with selfpriming traps or another means to maintain the water level in the traps, which will prevent sewage gasses from entering the ATCT spaces.

- Provide drainage from the elevator pit.
- The ATCT will likely need a water pressure booster system to get water to the Control Cab. Provide a duplex pump system and tanks to provide ample pressure for the domestic water system if the system does not have adequate pressure.
- In the Mechanical Room, provide floor sink for maintenance. Provide floor drains for all mechanical equipment with condensate drains. If ultrasonic humidifiers are used in the Electronic Equipment Rooms or the Cab, provide de-ionized water system to supply the humidifiers.
- In the Fire Pump Room, provide floor sink for system maintenance and back flow preventer drainage.
- In the Janitors Closet, provide floor-mounted mop sink and floor drain.
- Small instant type water heaters are required at each lavatory/sink. A larger instant type heater to serve multiple points of use can be considered if the fixtures are located close together.

4-1.5.2 Catwalk.

Provide freeze-proof hose bib at the exterior door to the Cab catwalk and at the exterior of the ground floor of the ATCT.

Area drains may be provided on the catwalk or the catwalk may be sloped to the exterior for positive drainage.

4-1.5.3 Control Cab Roof.

Provide roof drain and overflow roof drains or scuppers. Minimize exterior downspouts because roof drain pipes interfere with views from the Control Cab. All pipe routings between the roof and the Cab floor, including roof drainage and sprinkler piping, must be routed within or adjacent to the structural columns or mullions at the back of the Cab adjacent to the Cab stairway (away from the primary viewing areas).

In cold weather climates, roof drain hubs and downspout piping must be insulated. The insulation, for the downspout pipe within the Cab roof support column must be 1/2-inch (12-mm) thick foam rubber with the remaining tube void filled with foam insulation. It should be noted that the Cab structure tube configuration produces a significant interior space limitation. Provide electrical heat tapes and insulation for water pipes where required. Heat tapes shall include thermostat control with visual indicator for "ON" condition. Where possible, provide 18 inches (450 mm) heat tape clearance access all around. Heat tape shall not be used on fire protection piping.

4-1.5.4 Convenience Unit.

A convenience unit is required to allow the air traffic controllers on watch in the Control Cab to prepare light meals without leaving their duty station. These units typically contain a sink with hot (on-demand) and cold water, a drinking fountain, a frost-free refrigerator, and a microwave oven. Coordination with the local ATC personnel is required to determine the specific features desired.

4-1.6 Fire Protection and Life Safety Requirements.

4-1.6.1 Fire Alarm and Detection Systems.

All audible and visual notification devices must be "private mode" devices. Private mode audible devices in the Control Cab will sound for at least 180 seconds (required by NFPA 72 18.4.2.3). Provide a textural private mode device above each exit door for visual text alarm and notification messages.

Audible devices in the Cab must be capable of being manually acknowledged in the Cab, which will interrupt (silence) the audible devices in the Cab before 180 seconds (permitted by NFPA 72 18.4.2.3). Visual devices shall include a blue flashing incandescent light instead of a strobe fixture. Red lights are not allowed.

4-1.6.2 Sprinkler Head Cover Plates.

The cover plates for the sprinkler heads in the Control Cab must be flat black in color.

4-1.6.3 Standpipes.

Class 1 standpipe systems shall be installed in all ATCTs with a Control Cab floor more than 30 feet above the level of Fire Emergency Services (FES) access. Fire hose valves (FHV) shall be located in every stair at each landing serving an occupied or service area level.

4-1.6.4 Smoke Detectors.

Smoke detectors installed in the Control Cab ceiling must be flat black in color.

4-1.6.5 Remote Alarm Panel.

A remote annunciator panel with a local audible alarm is required to be installed in the Control Cab to allow air traffic controllers to monitor alarms. Provisions must be made to allow controllers to silence the local audible alarm generated by the annunciator panel, but not the fire alarm indication.

4-1.7 Electrical Requirements.

4-1.7.1 Critical Power Panels.

4-1.7.1.1 Control Cab.

One Critical power panel is required in the Control Cab, or the uppermost floor directly below the Cab, to provide the Critical power requirements. The preferred location of this power panel is near the stairwell for easy access in case of an emergency.

Note: Flush mounting is the preferred method of installation for the Cab power panels. An access gutter or spare conduits are required between the bottom of the flush-mounted panels and the void below the RAF. This provision will allow installation of branch circuits at a later time.

4-1.7.1.2 Electronic Equipment Spaces.

At least one Critical panel is required in the electronic equipment spaces of the ATCT to provide the power for electronic equipment installed in these spaces. The design of the ATCT will dictate the number of spaces required and therefore the number of Critical panels.

At least one Critical power panel is required in the space housing the Emergency Communications System (ECS) in order to provide the power for Voice Communications Switching System (VCSS) electronic equipment.

Note: Surface mounting is the preferred method of installation for the power panels in the electronic equipment spaces. The location of these panels must provide sufficient safety clearances for maintenance personnel per the NEC. Do not mount power panels directly below the cable tray penetration in ATCT Electronic Equipment Rooms.

4-1.7.2 Critical Power Circuits.

4-1.7.2.1 Control Cab.

Critical power circuits are required below the RAF in the Control Cab. Two Critical power circuits, with dedicated neutral conductors, are required to each controller position and must terminate in a 4-inch (100-mm) x 4-inch (100-mm) junction box under each controller position in the Cab. Provide a 24-inch (610-mm) service loop at each junction box. The quantity of circuits, the number of junction boxes, and the exact location of the junction boxes will be determined during design.

4-1.7.2.2 Control Cab Ceiling.

The Control Cab ceiling requires one or two pairs of ceiling junction boxes, each pair connected to a corresponding pair below the RAF. Each junction box must be 4-inch (100-mm) x 4-inch (100-mm) x 1-1/2-inch (38-mm). These junction boxes must be connected with flexible metal conduit, with one 3/4-inch (20-mm) conduit and one 1-1/4-inch (30-mm) for each pair. The conduit routing must be inside the window mullion. The exact quantity and location of the junction boxes will be identified during design.

Note: Additional wired outlets may be required in the ceiling area for relocated signal light guns. Consult with local ATC personnel for specific requirements.

4-1.7.2.3 Roof.

The ATCT roof will require Critical power service. This service must provide power to obstruction lights installed as part of construction. Any additional critical power required on the roof should be identified during design.

4-1.7.3 Non-Critical Power Circuits.

The ATCT roof requires non-critical power service, consisting of two weatherproof duplex 20A outlet boxes, which must be placed on opposite sides of the roof. These are required for electronic maintenance use. This service must be Ground Fault Interrupt (GFI) protected.

The ATCT catwalk requires non-critical power service, including one weatherproof duplex 20A outlet box, which must be placed adjacent to the access door. This outlet is required for maintenance use.

Non-critical outlets must not be designed into the Control Cab wall areas where ATC equipment consoles will be located.

4-1.7.4 Emergency Electrical Power.

4-1.7.4.1 UPS.

Provide a UPS system for critical power near the Control Cab and all ATC electronic equipment areas. Use the anticipated load to determine the size of the UPS. For UPS units serving ATCTs, minimum size must not be less than 20KVA. ATC electronic equipment loads should be provided during the planning/DD 1391 development process.

4-1.7.4.2 Remote Monitoring of Emergency Generator.

Remote monitoring of the ATCT generator must be provided. Personnel in the ATCT Control Cab may be unaware if the generator is running. Locate the monitor in the ATCT Cab.

4-1.7.4.3 Emergency Lighting.

Emergency lighting must be provided in the Control Cab. Provide additional emergency fixtures (conventional with battery-backup or inverter/rectifier located in the fixture ballast) in the Stairwell and ATC equipment rooms.

4-1.7.4.4 Emergency Power-Off Switch.

The electronic equipment space(s) in the ATCT require one Emergency Power-Off (EPO) switch in each room. A typical location for the Control Cab EPO switch is immediately adjacent to the top of the Cab stairway. The exact location of the EPO switches will be determined during design.

4-1.7.5 Lighting.

All fluorescent lighting fixtures require Radio Frequency Interference (RFI) suppression-type ballasts. All lighting controls in the facility, when more than one exists, should be labeled with which lights they control.

4-1.7.5.1 Control Cab.

Lighting in the Control Cab is divided into two groups: focused and non-focused. The first group is focused and is required to illuminate the controller positions. The second group is non-focused and is designed for general housekeeping usage. Each group requires independent controls and must be capable of variable intensity. The local ATC personnel must determine the location for all wall-mounted ceiling light variable intensity controls. All dimmer switches for controlling the lights in the Cab and Cab Stairwell must be located in the Cab.

Lighting should be compatible with night vision goggle requirements.

All lighting trim rings on ceiling lights shall be flat black.

- Focused Lighting

  The focused lighting group is required to illuminate the controller positions. The design must plan for pairs of focused white lights, with each pair illuminating one ATC controller position with its own intensity control. Focused lighting controls (dimmer switches) must be within easy reach of the person sitting in the controller position. Each pair must be recessed into the ceiling to prevent reflections on the window glass and positioned to cancel shadows at the controller console.

  After testing, the lighting intensity controls must be coiled and stored under the Raised Access Flooring (RAF) with sufficient cable length to permit mounting the controls on each controller console, which will be installed after construction is completed.

  Spotlights must be recessed pinhole lights with non-reflective grooved baffles, dimmer controlled, with approximately 2.5 inch (64 mm) opening and a 100-watt bulb.

- Non-Focused Lighting

  Separate, non-focused lighting is required for general use. Recessed white ceiling lights are required for general housekeeping purposes. A single, wall-mounted, variable intensity control is required. This light control must have a protective cover to prevent accidental activation of these lights during night operations.

  Additional non-focused lighting is required to properly illuminate the stairs leading to the Cab. The stairwell lighting must include variable intensity, white floor illumination (theater-style) lights as well as general purpose lighting. Ensure light fixtures do not create a hazard to personnel or restrict movement of equipment on the stairs.

  Overhead lighting must not be used above controller positions. Consider the use of desk-mounted gooseneck lamps to illuminate each position. The gooseneck lamp must be fully dimmable and controlled from each position.

4-1.7.5.2 Electronic Equipment Room(s) and Other Spaces.

Lighting in ATCT Electronic Equipment Room(s) must be consistent with that required in electronic maintenance and administrative spaces. Fluorescent-type lighting is acceptable and there is no requirement for variable intensity control. Light fixtures in the ATCT Equipment Rooms must not be located directly above proposed cabinet installations. To prevent interference with overhead-mounted cable tray, lights must be mounted at least 110 inches (9’-2” or 2790 mm) above the finished floor. Proposed cable tray and cabinet locations will be determined during design. See Figure 4-1 for minimum clearance height details.

Consult with the local ATC personnel for any specific requirements in administrative spaces.

4-1.7.5.3 Roof Obstruction Lights.

Per FAA Advisory Circular AC 70/7460, provide obstruction lighting on the ATCT during and after construction. Although some antennas have lights, the ATCT must have obstruction lighting as part of the structure. Lights that are part of the antennas may be removed at a later date if the communication requirements or communication system design changes.

4-1.7.5.4 Signal Light Guns.

Electrical design must include light gun mounting and power. Local ATC personnel must be consulted to determine if new light guns are required as part of the construction project.

Light gun outlet locations must be determined during design. Eye bolts for hanging the light guns must be installed by the Contractor.

4-1.7.5.5 Exterior Lighting.

Building entrances should be lit to 21.5 lx (2 foot-candles) by High Pressure Sodium (HPS) units. Specify the use of solar powered luminaries when they meet lighting requirements and are cost-effective.

4-1.7.6 Lightning Protection.

Air terminals on an ATCT roof must provide a zone of protection for all antennas to be installed by the Government except for those antennas with built-in lightning protection. These antennas have integral air terminals that must be connected to the lightning protection down conductors during installation. The down conductors on the ATCT roof must be accessible for the later connection of the ECS antennas.

4-1.7.7 Airfield Lighting Control Panel.

Provide an Airfield Lighting Control Panel (ALCP), with connections and interface to the airfield lighting vault. Request review with the local ATC staff to determine if the ALCP is required. If required, connectivity to the vault or other lighting sites would be installed by the construction contractor.

- **Army:** Where available, integrate ALCP with the Army Airfield Automation System.

- **Navy:** An ALCP is not required, but a connection to the airfield lighting vault may be required. Refer to FRS for specific connectivity requirements.

- **Air Force**: If required, include installation of the conduit and wiring for the ALCP. The size and number of conduit and conductors must be determined on a case-by-case basis. Provide and install the ALCP in the ATCT Control Cab console. -The Contractor should make the physical connection (including underground ducting) from the airfield lighting vault to the ALCP. Provide one 4-inch (10-cm) empty square duct between power panel and the space below the RAF in the ATCT Cab. The ALCP must conform to minimum requirements of FAA Advisory Circular AC 150/5345-3, *Specification of L 821 Panels for Remote Control of Airport Lighting*. Updated, improved controls are encouraged but must be approved by the MAJCOM.

  ALCPs in the Control Cab should be designed and programmed for ATC use. Specifically, Sequenced Flashing Lights must be programmed to work in concert with the settings of the Approach Lighting System. (For example, when ALS settings are adjusted, the SFL settings must be coupled to the ALS settings which means they must act as one system without requiring independent setting adjustments by ATC personnel.)

4-1.8 Telecommunications Requirements.

4-1.8.1 Main Distribution Frame (MDF)

An ATCT Main Distribution Frame (MDF) is not required if the ATCT is attached to the RACF.

If the ATCT is not attached to the RACF, provide an MDF in the Telecommunications Room on the ground floor of the ATCT for terminating all outside communications conductors. At this location, all outside plant communications and control conductors must terminate, be protected, cross connected, and distributed throughout the rest of the ATCT. This includes all cables between the RACF and ATCT if the buildings are not connected.

4-1.8.2 ATC Circuit Intermediate Distribution Frame (IDF).

An ATC Circuit Intermediate Distribution Frame (IDF) is where circuits are separated and routed to the ATC equipment. This IDF contains both copper and fiber cables. If required, the ATC Circuit IDF may be located in the ATCT Electronic Equipment Room or the Control Cab. The ATC IDF located in the ATCT must be located on 3/4-inch (20-mm) thick fire-rated plywood, at least 4 feet wide, from floor to ceiling.

4-1.8.3 Internal Facility Connectivity.

Two (2) 4-inch (100-mm) conduits are required between the ATCT MDF and ATCT cable chase exclusively for ATC circuit cabling. Conduits must terminate in the bottom of the ATCT MDF and the bottom of the ATCT cable chase. Bushings must be installed at each end. Nylon pull-cords are required in each conduit.

Any additional connectivity requirements should be addressed during the planning/DD 1391 development phase.

4-1.8.4 Primary Crash Alarm System.

One of the phone lines in the Control Cab will be uniquely identified as the "Crash Phone" line. This circuit will be terminated in a junction box under the raised access floor. The junction box shall have one CAT 6 telephone jack. The exact location of this circuit will be identified during design.

4-1.9 Safety and Security.

ATCTs are normally located within restricted areas that meet the minimum security measures for external security. If the facility is located within a restricted area of a lower level of security, provide additional measures to meet the minimum security requirements for the level of security assigned to the facility.

When the ATCT is outside the Security Zone perimeter, a 10-foot-high fence with single razor wire will completely enclose the tower structure. The fence must be not less than 15 feet from the structure exterior and include a lockable personnel gate not less than 40 inches (1015 mm) wide, and a vehicle lockable access gate not less than 15 feet wide.

4-1.9.1 Doors and Cipher Locks.

The exterior entry doors must be equipped with non-removable hinges and locking hardware including cipher locks. Doors equipped with electronic cipher locks are required to be powered from a critical power circuit (Uninterruptible Power Supply [UPS]).

Provide and install cipher locks, door closers, and electric strikes on the ground floor main entrance door to the ATCT and the door entering the stairs going to the Control Cab. The lock on the main entry and cab doors must have a remote control override switch, controlled from the Cab.

Provide a light in the Cab console which indicates when either of these doors is not closed. Any indicator lights for doors not closed should be wall mounted on the stair wall or other location.

To allow selective access to personnel who do not have the combination, ATCT doors with cipher locks must be releasable from inside the ATCT Cab via a door release switch. This switch must be provided with an electric strike for remote release from the Cab. Doors equipped with electronic cipher locks are required to be powered from a Critical power circuit (UPS).

The small door from the Cab to the catwalk should not be automatically lockable. A manually activated deadbolt engaged from the inside is acceptable. If an outside ladder or stair is provided from the catwalk to the pressurized stairwell, the door leading into the stairwell must not be capable of locking. This door serves as the secondary egress from the Cab.

ATCT electronic equipment spaces require doors with locking hardware. The locking hardware must comply with the requirements of NFPA 101. Standard commercial-grade key locks will suffice for the equipment spaces.

If the ATCT elevator design utilizes an elevator with a door that opens directly into the electronic equipment space(s), a means to "lock out" the elevator from stopping at these space(s) is required. This lockout capability must be activated from inside the elevator cab.

4-1.9.2 Access Control System.

Provide an intercom station and a video camera system to monitor the ATCT doors equipped with cipher locks such as the ATCT ground floor entrance and the final stairs leading to the Control Cab. This system allows the controllers in the Cab to identify, communicate if needed, and grant access to individuals not having pre-approved access. If the intercom station is located on the exterior of the ATCT, it must be installed in a weatherproof box. Consider including a canopy in the design if the main entry is not under the roof.

Typically, the video camera monitors are located in the Cab. The video from these cameras does not go anywhere but to the controllers' point of use.

The video cameras and monitors must be provided as part of MILCON construction. These cameras are used for access control only, and should not be classified as "security" cameras. Without these cameras, someone needing access could potentially wait for an extended length of time before gaining access, because the controllers can't always leave their position to open a door.

4-1.9.3 Airfield Monitoring Cameras.

Provide a video camera system for the monitoring of obstructed airfield areas, if necessary, for 100% visibility of all airfield traffic surfaces. Cameras cannot be used to view any runway surface, only taxiways, parking areas, loading areas, etc. Cameras are also used to monitor weapons loading areas if they are obstructed from view. Additional cameras are added as needed for each area that is obstructed. The obstructed areas must be identified during the Site Selection process.

4-1.9.4 Voice Communications.

Doors with cipher locks in the ATCT require two-way communications between personnel in the Control Cab and personnel not having the combination but needing access. Consult with the local Air Operations Department for specific requirements.

Provide and install an intercom station at the main entrance to the ATCT and at the entrance to the Cab. The intercom station located on the exterior of the ATCT must be installed in a weatherproof box.

An intercom system must be provided and installed to allow audible communication between all floors and stations. The intercom system must be simple and allow the Cab to do an "All-Call" to every floor, including the Simulator Classroom (if provided). Master control must be located in the Cab. The intercom system is purchased and installed by the Contractor.

Connect exterior intercom system to the base telephone system in case of emergency.

4-2 RADAR APPROACH CONTROL FACILITY (RACF).

4-2.1 General Requirements.

4-2.1.1 Risk Category.

For Risk Category, see Table 2-2, UFC 3-301-01. This classification has an impact on the design of most design disciplines involved with a RACF, including architecture and structural, mechanical, electrical and fire protection engineering. Ensure that non-structural components (e.g. raised access flooring, architectural components, utilities, etc.) are laterally braced as required for seismic load stability in accordance with UFC and building code provisions. Careful analysis of these requirements must be addressed in the planning/DD 1391 development phase. Coordinate additional bracing requirements to avoid interference with items to be installed post construction, such as cabling, conduit raceways and other infrastructure for electronic equipment.

4-2.2 Architectural Requirements.

4-2.2.1 Raised Access Flooring.

Provide Raised Access Flooring (RAF) in the Operations/IFR Room, the IFR Equipment Room, and the STARS and ATCT Simulator Room with 18 inches (450 mm) of clearance provided between the floor panels and sub floor to accommodate wiring and insulated piping.

4-2.2.2 Floor Finishes.

The Operations/IFR Room and Simulator Rooms must be provided with integral, static-dissipative carpet. The IFR Equipment Room must be provided with vinyl or laminate floor tiles or carpet with integral static dissipative coverings. Consult with local ATC personnel for preferred floor finishes.

4-2.2.3 Interior Walls.

Sound attenuating wall panels for the Operations/IFR Room are required to absorb noise generated from within the room.

All interior exposed surface treatments in the Operations/IFR Room must be non-glare and non-reflective.

4-2.2.4 Ceiling Finishes.

A black or white ceiling is required in the Operations/IFR room and the Simulator Rooms. Black tiles should be the same as the ceiling in the ATCT Control Cab. Consult with local ATC personnel for preferred ceiling color.

4-2.2.5 Ceiling Heights.

The minimum clear height in the RACF from the finished floor to the bottom of a finished ceiling must be 9'-0", except for the following conditions:

- The RACF Operations/IFR Room and the IFR Equipment Room must have a clear ceiling height of 10'-0" above the RAF.

Final floor-to-floor heights will be determined during design.

4-2.2.6 Acoustical Treatment.

Provide full height 3-1/2" (90-mm) thick sound attenuation batt. insulation in all walls surrounding the Operations/IFR Room:

- Partitions must be constructed to provide a minimum STC rating of 45. Consider increasing this requirement if the RACF if located adjacent to a runway.
- Operations/IFR Room doors must be solid core and rated STC 35 or higher.
- As a minimum, doors should have acoustical seals around all frames.
- An acoustical sill may be provided between Operations/IFR Room and external rooms. Do not provide a sill between the Operations/IFR Room and the IFR Equipment Room since it may obstruct movement of equipment.

4-2.2.7 Roof Access.

A personnel access hatch and ladder/stairs is required to transit from inside the RACF to the roof to maintain antennas mounted on the roof. Any requirement for roof walking pads must be identified during the planning/DD 1391 development phase.

4-2.2.8 Antenna Mounting.

An area for miscellaneous antenna mounting on the RACF roof may be required. If required, the system must consist of a 10 to 20 foot long railing with weather head(s) and conduit to an inside cable path, and must include lightning protection and grounding per FAA standards.

Any requirements for this antenna mounting area must be identified during the planning/DD 1391 development phase.

4-2.2.9 Roof Cable Access for GPS Antenna Infrastructure.

A cable path is required from the space below the RAF in the IFR Equipment Room to the roof of the RACF. One 2-inch (50-mm) rigid conduit is required. This conduit will be used to route antenna cabling to the roof.

- An enclosure with a back panel, mounted to the conduit, is required. The enclosure must be a 16-inch (400-mm) wide by 12-inch (300-mm) high by 8-inch (200-mm) deep, stainless steel, Hoffman-style enclosure.
- All conduits must utilize sweep bends.
- Anti-chafing bushings are required at both ends.
- The interior end of the conduit must be connected to the IFR Equipment Room cable tray or terminate within 6 inches (150 mm) of the cable tray.
- The conduit must protrude 18 inches (450 mm) above the roof and be bonded to the lightning protection system. The location of this conduit must be on the portion of the RACF roof that has a southern exposure. The exact location must be determined during design.

4-2.2.10 Doors.

- Double door access is required between the Operations/IFR Room and the IFR Equipment Room. In addition, double door access is required between the IFR Equipment Room and the outside loading area. At least one leaf of double-door sets must be 48 inches (1220 mm) wide, if the center support is not removable. Doors from the IFR Equipment Room to the Maintenance Room and from the Operations/IFR Room (if directly connected) to the Maintenance Room must be a minimum of 48 inches (1220 mm) to allow passage of equipment being maintained.
- All other doors in equipment areas must be a minimum of 42 inches (1050 mm) wide. All other doors (office, toilet, etc.) must be a minimum of 36 inches (910 mm) wide.
- The primary building entry door should be steel with a wire-glass vision lite and cipher lock. All exterior doors must be steel.
- Provide a small, narrow wire-glass lite in the Operations/IFR Room door.

4-2.2.11 Vertical Cable Chase.

If connectivity with the ATCT utilizes an overhead cable tray, a short vertical cable chase may be required in the IFR Equipment Room. Specific requirements will be identified during design.

4-2.2.12 Cable Tray System.

Connectivity of the cable tray between the Operations/IFR Room, the IFR Equipment Room, and the ATC/STARS Simulator Rooms is required. If bulkheads or walls are installed below the RAF between these rooms, two (2) penetrations will be required to connect the cable tray between the Operations/IFR Room and the IFR Equipment Room.

One (1) penetration is required for all other rooms. If required, cable tray penetrations connecting adjacent rooms must be located below the door access between those rooms. All cable tray penetrations between spaces must comply with applicable fire protection codes.

- A 12-inch (300-mm) or 18-inch (450-mm) wide by 4-inch (100-mm) high (fill depth) ladder-type cable tray is required below the RAF in the Operations/IFR Room. The exact size and location of this cable tray will be determined during design.
- A 12-inch (300-mm) or 18-inch (450-mm) wide by 4-inch (100-mm) high (fill depth) ladder-type cable tray is required below the RAF in the IFR Equipment Room. The exact size and location of this cable tray will be determined during design. Connectivity of this tray to the ATCT vertical cable chase is required utilizing either conduit or cable tray.
- A 12-inch (300-mm) wide by 4-inch (100-mm) high (fill depth) ladder-type cable tray is required below the RAF in the ATC Simulator and STARS Simulator Rooms. The exact location of this cable tray will be determined during design.

See Section 3-8.10 for connectivity requirements between the ATC MDF Enclosure and the IFR Equipment Room.

4-2.2.13 Building Signage.

Signage stating “Cell phone use not permitted” is required at certain ATC Facility operational spaces such as the entrance to the IFR Equipment Room, and the IFR Room. Signage style must match that used throughout the remainder of the facility.

4-2.2.14 Building Loading Area.

Provide an exterior building loading area adjacent to the double doors to the IFR Equipment Room. The driveway leading to this loading area must be at least 15 feet (4570 mm) wide.

4-2.3 Structural Requirements.

4-2.3.1 Design Live Loads.

Unless a larger load is required, design the structure to withstand the following minimum uniform live loads:

Table 4-2 Design Live Loads

Occupancy or Use	Uniform Load Psf (kPa)
RACF Operations/IFR Room	150 (4.8)
Loading Docks	200 (9.6)

Locker Rooms	50 (2.4)

4-2.4 Mechanical Requirements.

4-2.4.1 General HVAC Requirements.

Detailed descriptions of required spaces and HVAC system requirements are as follows:

4-2.4.2 RACF Operations/IFR Room.

RAF grilles must be sized and located to provide proper air distribution. Where RAF is not utilized or where two separate equipment and people conditioning systems are used, dampers in an overhead system must control proper air distribution. Either system designed for use in the RACF must provide a comfortable working environment. Economizer cycles for the HVAC system must not be utilized, avoiding exposure of critical electronic equipment to wide fluctuations in humidity. Under-floor pressure and air volumetric delivery, measured in cubic feet per minute (cfm) or liters per second (lps), must initially be balanced for the design load. The system must be re-balanced to take advantage of additional design capacity when future equipment is added. Where required by local environmental conditions, the outside air must be carbon filtered at the make-up air intakes for the RACF Operations/IFR Room.

4-2.4.3 Energy Management and Control System (EMCS).

The RACF must be connected to the installation's Energy Management and Control System (EMCS). The EMCS must have the capability to monitor lighting systems, security systems, and other systems. Consult the base EMCS office for the design requirements since each base is different.

Due to “Mission Essential” staffing requirements and flight safety considerations, the RACF occupants, not the base EMCS office, must have direct control of the thermostat to regulate appropriate heating and cooling levels for ATC electronic equipment spaces.

4-2.5 Plumbing Requirements.

No special plumbing requirements have been identified for the RACF.

4-2.6 Fire Protection and Life Safety Requirements.

4-2.6.1 Fire Alarm and Detection Systems.

Audible alarms must not be installed in the Operations/IFR Room. Provide a textural private mode device above each exit door for visual text alarm and notification messages. Two white strobes are required behind the controller position cabinets and two red strobes are required in front of the cabinets in the controller area.

Audible and visual notification devices in operational and technical areas must be 'private mode' devices. Audible and visual notification devices in public areas must be 'public mode' devices.

4-2.6.2 Light Blocking Curtain in Operations/IFR Room.

The Operations/IFR Room may include features such as a light blocking curtain installed over the controller position cabinetry. This curtain will extend from the top of the cabinets to the ceiling. The curtain on the ends of the cabinets will extend from the floor to the ceiling. This curtain must be considered when designing the placement of the recessed sprinklers. The specific location of the curtain will be identified during design.

4-2.7 Electrical Requirements.

4-2.7.1 Space Requirements.

Consult the Systems Integration Engineer (SIE) for power support requirements and panel locations. The SIE will provide a comprehensive list of equipment including their electrical requirements and significant watt or BTU output. Similarly, consult the equipment manufacturers for accurate power requirements, including requirements for power or frequency filters.

4-2.7.1.1 Operations/IFR and IFR Equipment Rooms.

Power distribution panels for the Operations/IFR Room and the IFR Equipment Room must be located in the IFR Equipment Room or adjacent Maintenance Room. These spaces must be supplied separately from the rest of the building.

Provide dedicated circuits for each piece of equipment in the Operations/IFR Room and for each rack in the IFR Equipment Room so that removal for maintenance of any piece of equipment has no effect on the balance of the RACF. Circuits in the Operations/IFR Room should be “clean” to eliminate electrical interference from any other equipment.

4-2.7.1.2 Electrical Room.

The Electrical Room must have exterior access as well as access from within the RACF. A pad-mounted transformer must be provided.

4-2.7.1.3 TERPS.

The TERPS office, if provided, has multiple equipment requirements (computers, scanners, plotters, etc.). Consider replacing standard office duplex locations with fourplex outlets. If practical, provide integral surge protection for these outlets.

4-2.7.1.4 Simulator Room.

Typically, the simulator will require a minimum of 10 each, single pole, 120 VAC, 20 amp circuit breakers and 2 each, single pole, 120 VAC, 30 amp circuit breakers from a 120/208VAC, 60 Hz, three-phase source designed to comply with ANSI C84.1. The total connected load will not exceed 100 amps. Design dedicated circuit breakers for the proposed tower simulator equipment and separate convenience outlets distributed throughout the classroom.

4-2.7.1.5 Other Building Areas.

Power distribution panels for the spaces outside the Operations/IFR Room and the IFR Equipment Room must be in an electrical closet accessible to base Maintenance personnel. All hallways must have at least one duplex outlet for janitorial personnel. Office spaces must have at least one duplex outlet located for the convenience of janitorial personnel in addition to the standard requirements for an office space.

4-2.7.2 Critical Power Panels.

4-2.7.2.1 Operations/IFR Room.

Two 100 amp critical power panels are required in the Operations/IFR Room. Proposed locations of these power panels will be identified during design.

4-2.7.2.2 IFR Equipment Room.

Two 100 amp critical power panels are required in the IFR Equipment Room. Proposed locations of these power panels will be identified during design.

4-2.7.2.3 ATC Simulator Room.

In lieu of a separate ATC Simulator/Training Room critical power panel, critical power circuits for this room will be provided by the panels located in the Operations/IFR Room.

4-2.7.3 Critical Power Circuits.

4-2.7.3.1 Operations/IFR Room.

Critical power circuits are required below the Raised Access Flooring (RAF) in the Operations/IFR Room. The critical circuits must terminate in a 6-inch (150-mm) by 6-inch (150-mm) by 4-inch (100-mm) deep junction box under the RAF directly below each controller position in the Operations/IFR Room. Each box must contain between one and four circuits. Provide a 24-inch (600-mm) service loop at each junction box.

4-2.7.3.2 IFR Equipment Room.

Critical power circuits are required below the RAF in the IFR Equipment Room. The critical circuits must terminate in a 6-inch (150-mm) by 6-inch (150-mm) by 4-inch (100-mm) deep junction box under the RAF directly below each electronic cabinet or rack in the IFR Equipment Room. Provide a 24-inch (600-mm) service loop at each junction box.

4-2.7.3.3 ATC Simulator/Training Room.

Critical power circuits are required either below the RAF or on the wall in the ATC Simulator/Training Room. The critical circuits must terminate in a standard duplex outlet under the RAF directly below each trainer position or on the wall. In lieu of a separate ATC Simulator/Training Room critical power panel, these junction boxes can be fed from the Operations/IFR Room critical power panel.

The quantity of circuits, the number of outlets, and the exact location of the outlets must be determined during design.

4-2.7.4 Non-Critical Power Circuits.

There are no specific requirements for the RACF non-critical power circuits.

4-2.7.5 Grounding.

In addition to the RACF grounding requirements in the IFR Equipment Room, Operations/IFR Room, and Simulator Room, a single point ground connected to the Equipotential Grounding Plane is required on the plywood panel for the telephone cable breakout. If the ETVS is on a separate rack, provide a grounding connection for this rack.

4-2.7.6 Transient Voltage Surge Suppressors (TVSS).

The power bus for other rooms must be isolated from technical power and critical-technical loads in the Operations/IFR, IFR Equipment and Simulator Rooms to protect such loads from transient voltage variations. Surge protection must reduce lightning and switching surges to within acceptable quality power limits.

4-2.7.7 Emergency Electrical Power.

4-2.7.7.1 Uninterruptible Power Supply (UPS).

Provide a UPS system for critical power near the IFR Equipment Room and all ATC electronic equipment areas. Use the anticipated load to determine the size of the UPS. ATC electronic equipment loads should be provided during the planning/DD 1391 development process.

4-2.7.7.2 Emergency Lighting.

Emergency lighting must be provided in the Operations/IFR Room (spots and floor lights only). In the Operations/IFR Room, emergency lighting should activate only when there is a power failure.

Exit lighting in the Operations/IFR Room must be screened so the lighting will not reflect or cause glare on operational positions. Use LED non-glare exit lighting design.

4-2.7.7.3 Emergency Power-Off Switch.

The IFR Room and IFR Equipment Room require two EPO switches in each. The exact location of the EPO switches will be determined during design.

4-2.7.7.4 Backup Radio Poles and Communications Antennas.

- **Air Force Only**: Provide a minimum of two poles at 25-50 feet (7.5 m – 15 m) from the building and 50 feet from each other for mounting back-up radio antennas. The type and construction of the poles should be verified with the installation's communications squadron. Provide a dedicated panel for troubleshooting lines.

4-2.7.8 Lighting.

All fluorescent lighting fixtures require Radio Frequency Interference (RFI) suppression-type ballasts. All lighting controls in the facility, when more than one exists, should be labeled with which lights they control. Additional guidance is as follows:

4-2.7.8.1 Operations/IFR Room.

Lighting in the Operations/IFR Room will be divided into four functional uses within each operational area ("horseshoe"): blue or red lights inside the horseshoe, white lights inside the horseshoe, theater wall lights inside the horseshoe, and white lights behind the horseshoe. Wall-mounted lighting controls must be installed with a safety switch cover to prevent accidental activation. Blue or red light controls must be readily distinguishable from white light controls. Consult with the local ATC personnel for preference of either red or blue lights. Location of the lighting fixtures with respect to the light blocking curtain will be identified during design.

- Blue or red operation area lights (white fluorescent lights with blue or red, semi-opaque tube covers that are often the center bank of two lights on a four-tube light fixture) must be variable and separately controlled from all other lights. One variable intensity control must be located near the room main entrance; a second variable intensity control must be located near the door to the IFR Equipment Room. If multiple operational areas are planned, each horseshoe must have an independent light control.

- White operations area lights, which are often the outer bank of two lights on a four-tube light fixture, must be variable and separately controlled from all other lights. One on/off switch with variable intensity control must be located near the room entrance; a second on/off switch with variable intensity control must be run under the RAF with sufficient cable so that the control can be mounted in the supervisor's console or near the entrance to the IFR Equipment Room. If multiple operational areas are planned, each horseshoe must have independent light control.
- Theater-type wall lighting to illuminate the walking area near the walls is required inside or between the horseshoes. One on/off switch with variable intensity control must be located near the room entrance. A second on/off switch with variable intensity control must be centrally located on the wall where the theater lights are installed.
- The area behind each horseshoe requires variable intensity white fluorescent lighting. These lights can be subdivided into left and right side controls. The double set of on/off switches with variable intensity control must be located at each entrance to the IFR Equipment Room. A second set of on/off switches with variable intensity control must be located near the other room entrance. If multiple operational areas are planned, each horseshoe must have independent light control.
- **Army and Air Force**: The Army and Air Force do not have a requirement for colored lights in the IFR Room. However, lights must be 0-100% dimmable in the Operations/IFR Room and 50% dimmable in immediate adjacent areas.

4-2.7.8.2 IFR Equipment Room.

Lighting in IFR Equipment Room must be consistent with that required in electronic maintenance and administrative spaces. Fluorescent-type lighting is acceptable and there is no requirement for variable intensity control. Light fixtures in the IFR Equipment Room must not be located directly above proposed cabinet installations. Lighting must be placed to ensure that the areas between equipment rows are illuminated. Proposed cabinet locations will be determined during design.

4-2.7.8.3 ATCT and STARS Simulator Rooms.

Lights in the ATCT and STARS Simulator Classrooms must be white and must be capable of variable intensity (fully dimmable).

4-2.7.8.4 Other Spaces.

Consult with the local ATC personnel for any specific requirements in administrative spaces.

4-2.8 Telecommunications Requirements.

4-2.8.1 RACF Main Distribution Frame (MDF).

Provide an MDF within the RACF for terminating all outside communications conductors. At this location, all outside plant communications and control conductors must terminate, be protected, cross-connected, and distributed throughout the rest of the RACF. This includes all cables between the RACF and the ATCT if the buildings are not connected.

If the RACF MDF and the IFR Equipment Room are adjacent to each other, RAF can be installed in both rooms and a cable tray must be used for the connectivity. If the two rooms are not adjacent (separated by other rooms or hallways), 4-inch (100-mm) conduits are used to provide the connectivity.

4-2.8.2 ATC MDF Enclosure.

The ATC MDF Enclosure is located within the RACF MDF and is exclusively where all ATC circuits are terminated before being distributed to the ATC equipment spaces. Trunk cables are utilized for the ATC circuits going to the IFR Equipment Room.

A Hoffman-style enclosure (Type 1, 48 inches (1220 mm) high by 36 inches (910 mm) wide by 11 inches (275 mm) deep), including a back panel, is required for termination of all operational ATC circuit inter-site cabling. This enclosure must be wall-mounted in close proximity to the RACF MDF. The bottom of the enclosure must be 24 inches (600 mm) above the finished floor. The door of the enclosure must incorporate a “T” handle latch. A closure accepting a padlock is required.

4-2.8.3 ATC Circuit Intermediate Distribution Frame (IDF).

The ATC Circuit Intermediate Distribution Frame (IDF) is located in the IFR Equipment Room and is where circuits are separated and routed to the ATC equipment and from the equipment to the ATCT. This MDF contains both copper and fiber cables. The IDF in the IFR Equipment Room is inside a prefabricated enclosure.

4-2.8.4 RACF to ATCT Connectivity.

4-2.8.4.1 Attached ATCT.

Four (4) 4-inch (100-mm) conduits or one (1) 12-inch (300-mm) wide and 4-inch (100-mm) deep (fill depth) cable tray is required from the RACF MDF to the ATCT cable chase exclusively for ATC circuit cabling. Conduits must terminate in the bottom of the RACF MDF and the bottom of the ATCT cable chase. Conduits must stub up 4 inches (100 mm) from the concrete floor. Bushings must be installed at each end. Nylon pull-cords are required in each conduit.

Four (4) 4-inch (100-mm) conduits or one (1) 12-inch (300-mm) wide and 4-inch (100-mm) deep (fill depth) cable tray is required from the ATC MDF to the ATCT cable chase exclusively for ATC circuit cabling. Conduits must terminate in the bottom of the ATC MDF and the bottom of the ATCT cable chase. Conduits must stub up 4 inches (100mm) from the concrete floor. Bushings must be installed at each end. Nylon pull-cords are required in each conduit.

4-2.8.4.2 Detached ATCT.

If the ATCT and the RACF are not attached, connectivity is required between the two.

- Four (4) 4-inch (100-mm) conduits are required from the RACF MDF to the ATCT MDF exclusively for ATC circuit cabling. Conduits must terminate in the bottom of each MDF. Conduits must stub up 4 inches (100 mm) from the concrete floor. Bushings must be installed at each end. Nylon pull-cords are required in each conduit.
- Four (4) 4-inch (100-mm) conduits or one (1) 12-inch (300-mm) wide and 4-inch (100-mm) deep (fill depth) cable tray is required from the ATC MDF to the ATCT cable chase exclusively for ATC circuit cabling. Conduits must terminate in the bottom of the ATC MDF and the bottom of the ATCT cable chase. Conduits must stub up 4 inches (100 mm) from the concrete floor. Bushings must be installed at each end. Nylon pull-cords are required in each conduit.

Any additional connectivity requirements should be addressed during the planning/DD 1391 development phase.

4-2.8.5 Internal Facility Connectivity.

Four (4) 4-inch (100-mm) conduits or one (1) 12-inch (300-mm) wide and 4-inch (100-mm) deep (fill depth) cable tray is required between the RACF MDF and ATC MDF exclusively for ATC circuit cabling. Conduits must terminate in the bottom of the RATCF MDF and the bottom of the ATC MDF enclosure. Bushings must be installed at each end. Nylon pull-cords are required in each conduit.

Three (3) 4-inch (100-mm) conduits or one (1) 12-inch (300-mm) wide and 4-inch (100-mm) deep (fill depth) cable tray is required from ATC MDF to the IFR Equipment Room. Conduits must stub up 4 inches (100 mm) from the concrete floor. Bushings must be installed at each end. Nylon pull-cords are required in each conduit. Exact location will be determined during design. This cable tray must be connected to the cable tray in the IFR Equipment Room.

Any additional connectivity requirements should be addressed during the planning/DD 1391 development phase.

4-2.9 Safety and Security.

The RACF is normally located within restricted areas that meet the minimum security measures for external security. If the facility is located within a restricted area of a lower level of security, or is located remote and outside of an established restricted area, provide additional measures to meet the minimum security requirements for the level of security assigned to the facility. Security at the main entrance to the RACF requires a single entry point with visitor control.

Remote locks, video cameras, card readers, and/or keypads may be required as components of the IDS. The level of security and the designer's responsibility for particular security elements will be designated by the User command.

4-2.9.1 Doors and Cipher Locks.

The exterior entry doors must be equipped with non-removable hinges and locking hardware including cipher locks. Doors equipped with electronic cipher locks are required to be powered from a critical power circuit (Uninterruptible Power Supply [UPS]).

Provide and install cipher locks, cameras, intercoms, door closers, and electric strikes on any outside or inside entrance doors to the Operations/IFR Room. This approach allows the controllers in the Operations/IFR Room to identify, communicate if needed, and grant access to individuals not having pre-approved access. Cameras are not required on the doors to the IFR Equipment Room. The exterior door into the IFR Equipment Room is required to have entry hardware. This door must be equipped with a cipher lock or standard locking hardware. The Maintenance division will determine the type of lock.

If exterior doors are provided out of the Operations/IFR Room, these doors must not have access hardware on the outside.

4-2.9.2 Access Control System.

Provide and install intercom stations with video camera system at the main entry door of the RACF and the entrance to the Operations/IFR Room to monitor RACF doors equipped with cipher locks. This system will allow for personnel identification, visitor check-in, and to monitor ingress and egress. Adequate space for the video monitor must be provided in the Watch Supervisor's area and in the entry vestibule.

If the intercom station is located on the exterior of the RACF, it must be installed in a weatherproof box. Consider including a canopy in the design if the main entry is not under the roof.

Additional video monitoring may be required at security fencing and guard post for facilities located outside the secure area of the installation. Consult with the local ATC personnel for specific CCTV requirements.

4-2.9.3 Voice Communications.

Provide communication between the main entry door into the Operations/IFR Room and the supervisor position in the Operations/IFR Room.

4-3 AIR OPERATIONS BUILDING (AOB).

4-3.1 General Requirements.

4-3.1.1 Risk Category.

For Risk Category, see Table 2-2, UFC 3-301-01. This classification has an impact on the design of most design disciplines involved with an AOB, including architecture and structural, mechanical, electrical and fire protection engineering. Ensure that non-structural components (e.g. raised access flooring, architectural components, utilities, etc.) are laterally braced as required for seismic load stability in accordance with UFC and building code provisions. Careful analysis of these requirements must be addressed in the planning/DD 1391 development phase.

4-3.2 Architectural.

4-3.2.1 Ceiling Heights.

The minimum clear height in the AOB from the finished floor to the bottom of a finished ceiling must be 9'-0".

Final floor-to-floor heights will be determined during design.

4-3.2.2 Floor Finishes.

The Operations-Airfield Management/Fight Planning Room must be provided with integral, static-dissipative carpet.

4-3.2.3 Roof Access.

A personnel access hatch and ladder/stairs is required to transit from inside the AOB to the roof to maintain antennas mounted on the roof. Any requirement for roof walking pads must be identified during the planning/DD 1391 development phase.

4-3.2.4 Antenna Mounting.

An area for miscellaneous antenna mounting on the AOB roof may be required. If required, the system must consist of a 10 to 20-foot (3 m – 6 m) long railing with weather head(s) and conduit to an inside cable path, and must include lightning protection and grounding per FAA standards.

Any requirements for this antenna mounting area must be identified during the planning/DD 1391 development phase.

4-3.3 Structural.

4-3.3.1 Structural Isolation.

If located adjacent to the ATCT, the AOB must be structurally isolated from the ATCT to prevent pounding during a seismic event.

4-3.4 Mechanical.

4-3.4.1 Energy Management and Control System (EMCS).

The AOB must be connected to the installation's Energy Management and Control System (EMCS). The EMCS must have the capability to monitor lighting systems, security systems, and other systems. Consult the base EMCS office for the design requirements since each base is different.

Due to "Mission Essential" staffing requirements and flight safety considerations, the AOB occupants, not the base EMCS office, must have direct control of the thermostat to regulate appropriate heating and cooling levels for ATC electronic equipment spaces.

4-3.5 Plumbing.

No unique plumbing requirements have been identified for the AOB.

4-3.6 Fire Protection and Life Safety.

No unique fire protection requirements have been identified for the AOB.

4-3.7 Electrical.

4-3.7.1 Space Requirements.

Consult the Systems Integration Engineer (SIE) for power support requirements and panel locations. The SIE will provide a comprehensive list of equipment including their electrical requirements and significant watt or BTU output. Similarly, consult the equipment manufacturers for accurate power requirements, including requirements for power or frequency filters.

4-3.7.2 Electrical Room.

The Electrical Room must have exterior access as well as access from within the AOB. A pad-mounted transformer must be provided.

4-3.7.3 Power Distribution.

Power distribution panels for the spaces in the AOB must be in an electrical closet accessible to base Maintenance personnel. All hallways must have at least one duplex outlet for janitorial personnel. Office spaces must have at least one duplex outlet located for the convenience of janitorial personnel in addition to the standard requirements for an office space.

4-3.7.4 Critical Power Panels.

4-3.7.4.1 Operations – Airfield Management/Flight Planning Room and Weather Station.

Critical power panels are required in the Operations – Airfield Management/Flight Planning Room and Weather Station. Proposed locations of these power panels will be identified during design.

4-3.7.5 Non-Critical Power Circuits.

There are no specific requirements for the AOB non-critical power circuits.

4-3.7.6 Grounding.

In addition to the grounding requirements in the Operations-Airfield Management/Flight Planning Room and the Weather Station, a single point ground connected to the Equipotential Grounding Plane is required on the plywood panel for the telephone cable breakout. If the ETVS is on a separate rack, provide a grounding connection for this rack.

4-3.7.7 Transient Voltage Surge Suppressors (TVSS).

The power bus for other rooms must be isolated from technical power and critical-technical loads in the Operations – Weather Station to protect such loads from transient voltage variations. Surge protection must reduce lightning and switching surges to within acceptable quality power limits.

4-3.7.8 Emergency Electrical Power.

4-3.7.8.1 Uninterruptible Power Supply (UPS).

Provide a UPS system for critical power near all ATC electronic equipment areas. Use the anticipated load to determine the size of the UPS. ATC electronic equipment loads should be provided during the planning/DD 1391 development process.

4-3.7.9 Lighting.

All fluorescent lighting fixtures require Radio Frequency Interference (RFI) suppression-type ballasts. All lighting controls in the facility, when more than one exists, should be labeled with which lights they control.

Consult with the local ATC personnel for any specific requirements in administrative spaces.

4-3.8 Telecommunications.

4-3.8.1 AOB Main Distribution Frame (MDF).

Provide an MDF within the AOB for terminating all outside communications conductors. At this location, all outside plant communications and control conductors must terminate, be protected, cross-connected, and distributed throughout the rest of the AOB.

4-3.8.2 ATC MDF Enclosure.

The ATC MDF Enclosure is located within the AOB MDF and is exclusively where all ATC circuits are terminated before being distributed to the ATC equipment spaces.

A Hoffman-style enclosure (Type 1, 48 inches (1220 mm) high by 36 inches (910 mm) wide by 11 inches (275 mm) deep), including a back panel, is required for termination of all operational ATC circuit inter-site cabling. This enclosure must be wall-mounted in close proximity to the AOB MDF. The bottom of the enclosure must be 24 inches (600 mm) above the finished floor. The door of the enclosure must incorporate a "T" handle latch. A closure accepting a padlock is required.

4-3.8.3 AOB to RACF Connectivity.

Connectivity between the RACF IFR Equipment Room and the AOB Operations-Airfield Management/Flight Planning Room is required. This and any additional connectivity requirements should be addressed during the planning/DD 1391 development phase.

4-3.9 Safety and Security.

The AOB is normally located within restricted areas that meet the minimum security measures for external security. If the facility is located within a restricted area of a lower level of security, or is located remote and outside of an established restricted area, provide additional measures to meet the minimum security requirements for the level of security assigned to the facility. Security at the main entrance to the AOB requires a single entry point with visitor control.

Remote locks, video cameras, card readers, and/or keypads may be required as components of the IDS. The level of security and the designer's responsibility for particular security elements will be designated by the User command during the planning/DD 1391 development process.

4-3.9.1 Doors and Cipher Locks.

The exterior entry doors must be equipped with non-removable hinges and locking hardware including cipher locks. Doors equipped with electronic cipher locks are required to be powered from a critical power circuit (Uninterruptible Power Supply [UPS]).

4-3.9.2 Access Control System.

Provide and install intercom stations with video camera system at the main entry door of the AOB to monitor AOB doors equipped with cipher locks. This system will allow for personnel identification, visitor check-in, and to monitor ingress and egress. Adequate space for the video monitor must be provided in the Command Suite or Airfield Operations area.

If the intercom station is located on the exterior of the AOB, it must be installed in a weatherproof box. Consider including a canopy in the design if the main entry is not under the roof.

Additional video monitoring may be required at security fencing and guard post for facilities located outside the secure area of the installation. Consult with the local ATC personnel for specific CCTV requirements.

4-3.9.3 Voice Communications.

Provide communication between the main entry door into the AOB and the Command Suite or Airfield Operations area.

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CHAPTER 5 FUNCTIONAL DATA SHEETS

5-1 INTRODUCTION.

This chapter identifies the specific design needs for the individual spaces within Air Traffic Control (ATC) and Air Operations Facilities. Building design criteria are provided in a standard Functional Data Sheet (FDS) table format that generally follows the Uniformat II / Work Breakdown Structure (WBS). The Interior Construction/Built-In Equipment category includes anything physically attached or plumbed to the building such as counters, cabinets, casework, toilet accessories, window treatments, and retractable overhead screens. The Furnishings and Equipment category includes loose or moveable items.

The Functional Data Sheets are presented as a guide for the designer, planner, or RFP preparer. It is intended that the information in them are the minimum requirements for the respective rooms and spaces. These minimum requirements apply in addition to all other requirements of this UFC and other referenced documents. In the event of a mutually exclusive conflict or where both requirements cannot be satisfied, the Functional Data Sheets take precedence. However, if in the best judgment of the designer, a more restrictive requirement is appropriate, the more restrictive requirement may be applied after consulting with the user.

Not all ATCT's contain all of the areas listed in the following tables. The functional areas required are dependent on operational requirements, and the functions required are determined by the user during the planning/DD 1391 development phase.

Table 5-1.1 ATCT – Main Entrance Lobby/Vestibule

Description / Usage	Main entrance to ATCT	
Ceiling Height	8'-0" minimum	
Windows	Not required	
Doors	Minimum 42" W x 96" H opening – provide vestibule in cold weather areas	
Interior Construction / Built-In Equipment	Building directory and bulletin board	
Finishes	**Walls**	Plaster or GWB - painted
	Floor	Hard surface (terrazzo, VCT, etc.)
	Base	Terrazzo, rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and Cooling (heating only in vestibule)	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office-type areas	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	As required for access control system
	CATV	
	Security	Intercom station and access control system in vestibule – cipher lock, door closer and electric strike on secured door between vestibule (or exterior) and lobby
Acoustics	NC 40	
Furnishings and Equipment		
Special Requirements	A covered or recessed entrance or vestibule is recommended.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.2 ATCT – Elevator and Elevator Lobby

Description / Usage	Provide one (1) elevator to service all floors of the ATCT from the ground floor to the floor below the floor directly below the Control Cab, or the floor below the Cab if possible. Provide an elevator meeting all IBC requirements on each floor.	
Ceiling Height	8'-0" minimum	
Windows		
Doors	Minimum 42"W x 84"H – single-speed, side-opening, horizontal sliding type	
Interior Construction / Built-In Equipment	Standard elevator cab with stainless steel retractable covers.	
Finishes	**Walls**	Standard elevator cab with plastic laminate panels
	Floor	Hard surface (terrazzo, VCT, etc.)
	Base	
	Ceiling	Standard elevator ceiling
Plumbing	Floor drain in elevator pit	
HVAC	Ventilate elevator shaft – air enters low and exits high	
Fire Protection and Life Safety	Conform to UFC 3-600-01 and ASME/ANSI A17.1, *Safety Code for Elevators and Escalators.* Provide smoke detection. For Army and Navy comply additionally with NAVFAC ITG 2013-01 *NAVFAC Elevator Design Guide.*	
Power		
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	Emergency telephone
	Data	
	CCTV	
	CATV	
	Security	
Acoustics		
Furnishings and Equipment		
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff/Other**	
Min. net ft^2 (m^2)		

Table 5-1.3 ATCT – Elevator Machine Room

Description / Usage	Room housing elevator equipment	
Ceiling Height	Exposed structure. Provide 8'-0" minimum clear height	
Windows	Not required.	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	Heating and cooling for elevator equipment, based on manufacturer's requirements	
Fire Protection and Life Safety	Conform to UFC 3-600-01 and ASME/ANSI A17.1, *Safety Code for Elevators and Escalators.* Provide smoke detection. For Army and Navy comply additionally with NAVFAC ITG 2013-01 *NAVFAC Elevator Design Guide.*	
Power	As required for elevator equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Elevator equipment, as required	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.4 ATCT – Tower Shaft Mechanical Room

Description / Usage	Room housing HVAC equipment for the lower levels of the ATCT.	
Ceiling Height	Exposed structure. Minimum 8'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing	Floor drain required if located above an ATC Electronic Equipment Room	
HVAC	Heating/cooling based on manufacturer's requirements	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for mechanical equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Mechanical HVAC equipment, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.5 ATCT – Tower Shaft Electrical Room

Description / Usage	Room housing electrical equipment for the lower levels of the ATCT.	
Ceiling Height	Exposed structure. Minimum 8'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	Heating and cooling as required for electrical equipment	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for electrical equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Electrical equipment, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-1.6 ATCT – Telecommunications Room

Description / Usage	Telephone/Data Communications Frame Room housing the communications distribution plant for the ATCT. Room only required if the ATCT is a standalone facility.	
Ceiling Height	Exposed structure. Minimum 8'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Painted 3/4-inch fire-rated plywood, floor to ceiling, all walls
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	Heating and cooling as required for telecommunications equipment	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system. Provide smoke detection.	
Power	Critical and non-critical power as required for telecommunications equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	As required for telecommunications equipment
	Data	As required for telecommunications and networking equipment
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Telecommunications and networking equipment, as required.	
Special Requirements	Multipoint ground system	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.7 ATCT – Fire Pump Room

Description / Usage	Room housing fire pump for the ATCT.	
Ceiling Height	Exposed structure. Minimum 8'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 84" H door; coordinate with fire pump equipment.	
Interior Construction / Built-In Equipment	Provide duplex pump system and tanks to provide ample pressure for the domestic water system. If an ATCT is deemed "mission critical," a redundant fire pump must be provided in accordance with UFC 3-600-01.	
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing	Provide floor sink and reduced pressure backflow preventer	
HVAC	Heating and ventilation only	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for fire pump(s) and related equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Fire pump(s) and related equipment, as required.	
Special Requirements	May be combined with Mechanical Room	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.8 ATCT – ATCT Simulator Room

Description / Usage	Room housing ATCT simulator for controller training.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system. Provide smoke detection.	
Power	Critical power as required for simulator equipment and standard power for office area	
Lighting	As required by UFC 3-530-01, with dimmable capability	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 30	
Furnishings and Equipment	Simulator equipment, as required and ESD chairs on casters for controllers.	
Special Requirements	Multipoint ground system	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.9 ATCT – Administration Area

Description / Usage	Open office area containing systems furniture workstations.	
Ceiling Height	8'-0" minimum	
Windows	Not required	
Doors		
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-1.10 ATCT – Chief Controller's Office, Chief AIC Office, Chief GCA Office

Description / Usage	Private office for Chief Controller, Chief AIC and/or Chief GCA.	
Ceiling Height	8'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet
	Data	Two outlets (computer and printer)
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 35	
Furnishings and Equipment	Desk, chair, credenza/bookcase, filing cabinets and two (2) visitor chairs	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.11 ATCT – Training Room

Description / Usage	Room for mandatory training.	
Ceiling Height	8'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	As required
	Security	Intercom and lockable door with standard commercial-grade key lock
Acoustics	NC 30	
Furnishings and Equipment	Freestanding furniture, as required	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-1.12 ATCT – Toilet Rooms

Description / Usage	Unisex restroom	
Ceiling Height	8'-0" minimum	
Windows		
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Include recessed towel dispensers with integral waste receptacles. No sanitary napkin dispenser shall be provided.	
Finishes	**Walls**	Ceramic tile on moisture resistant GWB – full height
	Floor	Ceramic tile
	Base	Ceramic tile
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing	One (1) water closet and one (1) lavatory with mirror in each restroom. Include a shower and changing area in at least one toilet room.	
HVAC	Exhaust fan only.	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power at lavatory with GFI outlets	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with bathroom lockset
Acoustics	NC 45	
Furnishings and Equipment		
Special Requirements	Locate one restroom at the ground level and one at the level directly below the Control Cab. Provide sign indicating "In Use".	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.13 ATCT – Janitor Closet

Description / Usage	Space for custodial supplies and equipment	
Ceiling Height	Exposed structure. Provide 8-0" minimum clear height.	
Windows		
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Include mop rack and storage shelving	
Finishes	**Walls**	48"H ceramic tile wainscot on moisture resistant GWB – painted GWB above
	Floor	Ceramic tile or sealed concrete
	Base	Ceramic tile
	Ceiling	No ceiling required
Plumbing	One (1) custodial-style floor sink and floor drain	
HVAC	Exhaust fan only	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power with GFI outlets	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment		
Special Requirements	Provide elevator access to the janitor mop sink	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.14 ATCT – Stairwell

Description / Usage	Pressurized fire-rated stairwell providing emergency egress from the floor below the Control Cab to the ground floor. Minimum stair width must be 44”.	
Ceiling Height	Exposed structure. Provide minimum clear height as required by code.	
Windows		
Doors	Minimum 36” W x 80” H, fire-rated as required	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	CMU, plaster or GWB - painted
	Floor	Sealed concrete
	Base	Rubber or vinyl
	Ceiling	No ceiling required
Plumbing		
HVAC	Stairwell must be pressurized. Heating and/or cooling, to be determined during the planning process	
Fire Protection and Life Safety	Fire-rated enclosure as required by code. Sprinklers as required by NFPA 13. Provide	
Power	Standard power at each landing	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Intercom and access control system – cipher lock, door closer and electric strike at upper door providing access to Control Cab
Acoustics	NC 50	
Furnishings and Equipment		
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft2 (m2)		

Table 5-1.15 ATCT – Lower Electronic Equipment Room

Description / Usage	Room for ATC Electronic Equipment	
Ceiling Height	Exposed structure. Provide 110 inches (9'-2") minimum clear height below any obstruction.	
Windows		
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Overhead cable tray system.	
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Static dissipative carpet or tile
	Base	Rubber or vinyl
	Ceiling	No ceiling required
Plumbing		
HVAC	CRITICAL AREA: Requires redundant heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system. Provide smoke detection.	
Power	Critical and non-critical power as required for ATC electronic equipment	
Lighting	Standard fixtures with RF shielding and suppression filters	
Communication	**Telephone**	One outlet
	Data	As required for ATC electronic equipment
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	ATC electronic equipment as required. ESD bench and chairs on casters if required.	
Special Requirements	Multipoint ground system. Elevator access is required for this room.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.16 ATCT – Upper Electronic Equipment Room

Description / Usage	Room for ATC Electronic Equipment. Preferred location for communications equipment, equipment with antennas, and back-up radio systems.	
Ceiling Height	Exposed structure. Provide 110 inches (9'-2") minimum clear height below any obstruction.	
Windows		
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Overhead cable tray system.	
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Static dissipative carpet or tile
	Base	Rubber or vinyl
	Ceiling	No ceiling required
Plumbing		
HVAC	CRITICAL AREA: Requires redundant heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system. Provide smoke detection.	
Power	Critical and non-critical power as required for ATC electronic equipment	
Lighting	Standard fixtures with RF shielding and suppression filters	
Communication	**Telephone**	One outlet
	Data	As required for ATC electronic equipment
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	ATC electronic equipment, as required. ESD bench and chairs on casters if required.	
Special Requirements	Multipoint ground system. Elevator access is required for this room. Locate room as high in the ATCT as possible to reduce RF loss in the antenna cables going to the roof.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.17 ATCT – UPS Room

Description / Usage	Room housing the UPS system for the ATCT.	
Ceiling Height	Exposed structure. Minimum 8'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	CRITICAL AREA: Requires redundant heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for UPS system equipment, include grounding per FAA Standard. Include EPO switch.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	UPS system equipment, as required.	
Special Requirements	May be combined with the Upper ATCT Electronic Equipment Room or the Electrical Room.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.18 ATCT – Ready/Break Room

Description / Usage	Room for mandatory controllers breaks on the level directly below the ATCT Control Cab	
Ceiling Height	8'-0" minimum	
Windows	Optional	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Base cabinets with plastic laminate countertop and wall cabinets above. Accommodate a wet sink.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	VCT or carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing	Sink (and floor drain, if located above an ATC electronic equipment room)	
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power with GFI outlets	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet
	Data	Yes
	CCTV	
	CATV	Yes
	Security	Intercom
Acoustics	NC 40	
Furnishings and Equipment	Coffee service, refrigerator, microwave, as well as one table with seating.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.19 ATCT – Control Cab Mechanical Room

Description / Usage	Room housing HVAC equipment serving the Control Cab. May be provided as a mezzanine space above the Ready/Break Room.	
Ceiling Height	Exposed structure. Minimum 8'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing	Floor drain required if located above an Electronic Equipment Room	
HVAC	Heating and ventilation only.	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for mechanical equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Mechanical HVAC equipment, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-1.20 ATCT – Control Cab Electrical/Communications Room

Description / Usage	Room housing equipment for electrical power and telecommunications service to the Control Cab. Locate near the Control Cab level.	
Ceiling Height	Exposed structure. Minimum 8'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	UPS system is required	
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	Heating and cooling as required for electrical and telecommunications equipment	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for electrical and telecommunications equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Electrical and telecommunications equipment, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.21 ATCT – Control Cab

Description / Usage	Elevated space having an unobstructed line of sight to the entire airfield and areas over which aircraft movements must be controlled. If required, provide a raised platform for the ATCT Supervisor.	
Ceiling Height	10'-0" ceiling height at controller positions	
Windows	360 degree view – minimize structural supports and window mullions to maximize view from Control Cab to airfield	
Doors	Minimum 36" W x 80" H Cab entrance door and minimum 36" x 42" access door to Catwalk.	
Interior Construction / Built-In Equipment	Raised Access Flooring (RAF), fully grounded and bonded – Data cable tray installed below RAF. Accommodate a convenience unit, if required.	
Finishes	**Walls**	Plaster or GWB – painted flat black – acoustical panels on exposed walls above windows and below windowsill
	Floor	Static dissipative carpet on RAF
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile – flat black tile and suspended grid – flat black trim on all lighting
Plumbing	(Optional) Convenience unit– floor drain at subfloor below RAF	
HVAC	CRITICAL AREA: Requires redundant heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system – special audible and visual alarm requirements – see Section 4-1.6. Provide smoke detection. Provide flat black sprinkler cover plates and flat black smoke detectors.	
Power	Critical and non-critical power as required for ATC electronic equipment	
Lighting	Focused and non-focused lighting with dimmable capability. Low level "theater" style lighting at treads in Cab stairway.	
Communication	**Telephone**	3 total. Refer to Sec. 4-1.8.4
	Data	As required
	CCTV	Access control monitors in Cab
	CATV	
	Security	Cipher lock, door closer and electric strike at door to Cab. Intercom and access control video camera at door to Cab
Acoustics	NC 25	
Furnishings and Equipment	Modular consoles for each controller position – provide ESD chairs that have metal frames with conductive casters and chair-covering material for controllers and supervisor – light guns as required	
Special Requirements	Multipoint ground system. Provide a stairway from the Cab level down to the entrance to the ATCT stairwell. Refer to Table 5-1.14 for ATCT stairwell security requirements.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-1.22 ATCT – Electronic Equipment Room for VCSS

Description / Usage	Additional Room for ATC Electronic Equipment (if required) for VCSS.	
Ceiling Height	Exposed structure. Provide 110 inches (9'-2") minimum clear height below any obstruction.	
Windows		
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Overhead cable tray system.	
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Static dissipating carpet or tile
	Base	Rubber or vinyl
	Ceiling	No ceiling required
Plumbing		
HVAC	CRITICAL AREA: Requires redundant heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system. Provide smoke detection.	
Power	Critical and non-critical power as required for ATC electronic equipment.	
Lighting	Standard fixtures with RF shielding and suppression filters.	
Communication	**Telephone**	One outlet
	Data	As required for ATC electronic equipment
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	ATC electronic equipment, as required. ESD bench and chairs on casters if required.	
Special Requirements	Multipoint Ground System	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-1.23 ATCT – Ground Controlled Approach

Description / Usage	Room housing Ground Controlled Approach (GCA) operations.	
Ceiling Height	8'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Static dissipative carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	Intercom speaker for monitoring ATCT access, lockable door with cipher lock access.
Acoustics	NC 30	
Furnishings and Equipment	Freestanding furniture, as required	
Special Requirements	Overhead cable tray	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-1.24 ATCT – Airspace Information Center

Description / Usage	Room housing Airspace Information Center (AIC) operations.	
Ceiling Height	8'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Static dissipative carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	Intercom speaker for monitoring ATCT access, lockable door with cipher lock access.
Acoustics	NC 30	
Furnishings and Equipment	Freestanding furniture, as required	
Special Requirements	Raised access floor	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-1.25 ATCT – ATC Equipment Maintenance Building

Description / Usage	When a standalone ATCT is remote and not attached to an Airfield Operations Building, a separate building with office/work bench space for technicians will be provided for ATC equipment maintenance. Refer to specific Army requirements in the COS Standard Design.	
Ceiling Height	Minimum 9'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H and 72" W x 84" H double door for receiving ATC equipment.	
Interior Construction / Built-In Equipment	Snorkel-type localized standalone exhaust system, as required.	
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Static dissipative VCT or carpet
	Base	
	Ceiling	Acoustical ceiling tile
Plumbing		
HVAC	Heating and ventilation as required	
Fire Protection and Life Safety	Wet pipe, automatic fire suppression sprinkler system	
Power	As required for maintenance equipment, including grounding per FAA Standard. TVSS required on the panel feeding this room.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	Two outlets (computer and printer) minimum
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics		
Furnishings and Equipment	ESD chairs on casters, ESD storage shelving, ESD cabinets, and ESD workbenches, as required.	
Special Requirements	Multipoint ground system.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.1 RACF – Lobby/Entry Vestibule

Description / Usage	Main entrance to RACF	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	Minimum 42" W x 96" H opening – provide vestibule in cold weather areas	
Interior Construction / Built-In Equipment	Building directory and bulletin board	
Finishes	**Walls**	Plaster or GWB - painted
	Floor	Hard surface (terrazzo, VCT, etc.)
	Base	Terrazzo, rubber or vinyl
	Ceiling	Acoustical Ceiling Tile or Painted GWB
Plumbing		
HVAC	Heating and Cooling (heating only in vestibule)	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office-type areas	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	Yes
	Data	
	CCTV	Access Control System
	CATV	
	Security	Intercom station and access control system in vestibule – cipher lock, door closer and electric strike on secured door between vestibule (or exterior) and lobby
Acoustics	NC 40	
Furnishings and Equipment		
Special Requirements	A covered or recessed entrance or vestibule is recommended. Provide a one-way reinforced window and a slot for passing of ID cards in the primary building entry door.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.2 RACF – ATC Administration Area

Description / Usage	Open office area containing systems furniture workstations	
Ceiling Height	9’-0” minimum	
Windows	Not required	
Doors		
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.3 RACF – Private Offices

Description / Usage	Private office for select RACF positions.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet
	Data	Two outlets (computer and printer)
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 35	
Furnishings and Equipment	Desk, chair, credenza/bookcase, filing cabinets and two (2) visitor chairs	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.4 RACF – Toilet Rooms with Lockers and Showers

Description / Usage	Men's and Women's Toilet Rooms	
Ceiling Height	9'-0" minimum	
Windows		
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Include lockers and recessed towel dispensers with integral waste receptacles. Provide half-height lockers (60% male, 40% female). In overseas locations, full-height must be provided.	
Finishes	**Walls**	Ceramic tile on moisture resistant GWB – full height
	Floor	Ceramic tile
	Base	Ceramic tile
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing	Water closets, urinals and lavatories with mirror. Include at least one shower and changing area in each toilet room.	
HVAC	Exhaust fan only.	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power at lavatory with GFI outlets	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with bathroom lockset
Acoustics	NC 45	
Furnishings and Equipment		
Special Requirements	Provide separate restrooms adjacent to the Operations/IFR Room and the Break Room if space and budget allow.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.5 RACF – Janitor Closet

Description / Usage	Space for custodial supplies and equipment	
Ceiling Height	Exposed structure. Provide 9'-0" minimum clear height.	
Windows		
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Include mop rack and storage shelving	
Finishes	Walls	48" H Ceramic tile wainscot on moisture resistant GWB – painted GWB above
	Floor	Ceramic tile or sealed concrete
	Base	Ceramic tile
	Ceiling	No ceiling required
Plumbing	One (1) custodial-style floor sink and floor drain	
HVAC	Exhaust fan only	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power with GFI outlets	
Lighting	As required by UFC 3-530-01	
Communication	Telephone	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment		
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	Staff	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.6 RACF – Mechanical Room

Description / Usage	Room housing HVAC equipment for the RACF.	
Ceiling Height	Exposed structure. Minimum 7'-6" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing	Floor sink required.	
HVAC	Heating and ventilation only.	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for mechanical equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Mechanical HVAC equipment, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.7 RACF – Electrical Room

Description / Usage	Room housing electrical equipment for RACF.	
Ceiling Height	Exposed structure. Minimum 9'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H – interior and exterior access required	
Interior Construction / Built-In Equipment	UPS system is required	
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	Heating and ventilation as required for electrical equipment	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for electrical equipment. Include UPS system if required. Include grounding per FAA standard.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Electrical equipment, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft2 (m2)		

Table 5-2.8 RACF – Telecommunications Room

Description / Usage	Telecommunications Frame Room housing the communications distribution plant for the RACF.	
Ceiling Height	Exposed structure. Minimum 9'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Painted 3/4- inch fire-rated plywood, floor to ceiling, all walls.
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	Heating and cooling as required for telecommunications equipment	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system. Provide smoke detection.	
Power	Critical and non-critical power as required for telecommunications equipment. Include grounding per FAA standard.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	As required for telecommunications equipment
	Data	As required for telecommunications equipment
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Telecommunications equipment, as required.	
Special Requirements	Multipoint ground system. Location of Main Distribution Frame (MDF) and ATC MDF enclosure.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.9 RACF – TERPS/DSS Office

Description / Usage	Office responsible for actual planning and plotting of aircraft approach and ATC procedures	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors		
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture for employee workstations. Also provide space for a large format plotter, drafting table, computer workstation, map storage drawers, and shelving for active Technical Orders.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.10 RACF – Operations/Instrument Flight Rules (IFR) Room

Description / Usage	Room for controlling radar approach by aircraft, including a station for the Watch Supervisor, who oversees all scope activity. The Operations/IFR Room requires a considerable amount of circulation space.	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	36" W x 80" H minimum – double door access (48" W x 80" H) is required to the IFR Equipment Room – include narrow wire-glass lite in all doors	
Interior Construction / Built-In Equipment	Raised Access Flooring (RAF), fully grounded and bonded – Data cable tray installed below RAF	
Finishes	**Walls**	Plaster or GWB – painted with acoustical wall panels
	Floor	Static dissipative carpet
	Base	Rubber or vinyl
	Ceiling	Black (dyed) or white acoustical ceiling tile
Plumbing		
HVAC	CRITICAL AREA: Requires redundant heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system – special audible and visual alarm requirements – see Section 4-2.6. Provide smoke detection.	
Power	Critical power as required for ATC equipment and standard power for office area	
Lighting	Special requirements, see Paragraph 4-2.7.8	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	Outside or inside entrance doors require cipher locks, cameras, intercoms, and electric door strikes
Acoustics	NC 40	
Furnishings and Equipment	Modular consoles for each controller position – provide ESD chairs that have metal frames with conductive casters and chair-covering material for controllers and supervisor – light curtain installed over cabinetry	
Special Requirements	Multipoint ground system. Doors between the Operations/IFR Room and the IFR Equipment Room must not be lockable.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.11 RACF – Radar Simulator Room

Description / Usage	Room housing Radar simulators for controller training.	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Raised Access Flooring (RAF), fully grounded and bonded – Data cable tray installed below RAF	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Static dissipative carpet
	Base	Rubber or vinyl
	Ceiling	Black (dyed) or white acoustical ceiling tile
Plumbing		
HVAC	CRITICAL AREA: Requires redundant heating and cooling. May be on same system as Operations/IFR Room	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Critical power as required for simulator equipment and standard power for office area.	
Lighting	As required by UFC 3-530-01, with dimmable capability.	
Communication	**Telephone**	One outlet per simulator
	Data	Two outlets per simulator (computer and printer)
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 30	
Furnishings and Equipment	Simulator equipment, as required – provide ESD chairs that have metal frames with conductive casters and chair-covering material	
Special Requirements	Multipoint ground system.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.12 RACF – ATCT Simulator Room

Description / Usage	Room housing ATCT simulator for controller training.	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Raised Access Flooring (RAF), fully grounded and bonded – Data cable tray installed below RAF	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Static dissipative carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	CRITICAL AREA: Requires redundant heating and cooling. May be on same system as Operations/IFR Room	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Critical power as required for simulator equipment and standard power for office area	
Lighting	As required by UFC 3-530-01, with dimmable capability	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 30	
Furnishings and Equipment	Simulator equipment, as required - provide ESD chairs that have metal frames with conductive casters and chair-covering material	
Special Requirements	Multipoint ground system.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.13 RACF – Training Room

Description / Usage	Room housing the Computer-Based Instruction (CBI) component of RACF training. Locate adjacent to or near the Operations/IFR Room.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	White board, projector and motorized recessed projection screen. If a single large room is provided, consider a moveable partition to subdivide the space, allowing two individual sessions to be held at the same time.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for multiple computer workstations	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 30	
Furnishings and Equipment	Freestanding furniture, as required. Typically contains between two and five computer workstations – provide ESD chairs that have metal frames with conductive casters and chair-covering material	
Special Requirements	May be combined with the RACF Briefing / Conference Room to reduce overall space requirements.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.14 RACF – Briefing/Conference Room

Description / Usage	Room sized to house the entire RACF shift, plus the AOF/CC and the shift Watch Supervisor, for joint briefings and conferences. This space will be used by ATC and Maintenance personnel.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	White board, projector and motorized recessed projection screen. If a single large room is provided, consider a moveable partition to subdivide the space, allowing two individual sessions to be held at the same time.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office-type areas	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	Two outlets (computer and printer) minimum
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 35	
Furnishings and Equipment	Conference Table(s) and chairs on casters as required	
Special Requirements	May be combined with the RACF Training Room to reduce overall space requirements.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.15 RACF – IFR Equipment Room

Description / Usage	Room housing communication racks that are the termination points for all lines entering and departing the RACF that provide data to and from the scopes in the Operations/IFR Room. Locate immediately adjacent to the Operations/IFR Room.	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	36" W x 80" H minimum – provide double door access (48" W x 80" H minimum) to the Operations/IFR Room(include narrow wire-glass lite in both doors) – provide double door access (48" W x 80" H minimum) to the exterior.	
Interior Construction / Built-In Equipment	Raised Access Flooring (RAF), fully grounded and bonded – Data cable tray installed below RAF.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Static dissipative carpet or vinyl tile
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	CRITICAL AREA: Requires redundant heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system. Provide smoke detection.	
Power	Critical power as required for ATC equipment and standard power for office area.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet
	Data	As required for ATC equipment
	CCTV	
	CATV	
	Security	Outside or inside entrance doors require cipher locks, door closers, and electric door strikes
Acoustics	NC 45	
Furnishings and Equipment	Communications racks and support equipment as required, including ESD workbenches, storage cabinets, shelving and chairs on casters.	
Special Requirements	Multipoint ground system. Doors between the Operations/IFR Room and the IFR Equipment Room must not be lockable. Location of ATC Circuit Intermediate Distribution Frame (IDF).	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-2.16 RACF – UPS Room

Description / Usage	Room housing the UPS system for the RACF.	
Ceiling Height	Exposed structure. Minimum 9'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H interior access door and a double door for exterior access as required	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	CRITICAL AREA: Requires redundant heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for UPS system equipment, include grounding per FAA Standard. Include EPO switch.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	UPS system equipment, as required.	
Special Requirements	Multipoint ground system. May be combined with the IFR Equipment Room or Electrical Room.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.17 RACF – Storage Room

Description / Usage	Room for storage of general purpose materials.	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Full height walls for secure storage.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	VCT
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for storage areas	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key locks
Acoustics	NC 40	
Furnishings and Equipment	Shelving and storage cabinets as required by user.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.18 RACF – Flight Planning Room

Description / Usage	Open office area containing flight dispatch and flight planning operations.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Provide eight (8) linear feet of counter open to hall or lobby. If required, provide Raised Access Flooring (RAF), fully grounded and bonded, with data cable tray installed below RAF.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Static dissipative carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Critical power (UPS) as required for ATC electronic equipment and standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	As required
	CATV	As required
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required. ESD chairs on casters for operations personnel.	
Special Requirements	Multipoint ground system. Connectivity to IFR Equipment Room required.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-2.19 RACF – Pilot Flight Planning Room

Description / Usage	Open office area containing flight planning operations.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet.
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-2.20 RACF – ATC Equipment Maintenance Administration Area

Description / Usage	An open office area for administrative functions required for ATC equipment maintenance.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.21 RACF – ATC Equipment Maintenance Area

Description / Usage	Room for maintenance of ATC equipment. Locate adjacent to the IFR Equipment Room with direct access to the Telecommunications Room.	
Ceiling Height	Minimum 9'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Snorkel-type localized stand-alone exhaust system, as required.	
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Static dissipative VCT or carpet
	Base	
	Ceiling	Acoustical ceiling tile
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for maintenance equipment, include grounding per FAA Standard. TVSS required on the panel feeding this room.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	Two outlets (computer and printer) minimum
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 45	
Furnishings and Equipment	ESD Chairs on casters, ESD storage shelving, ESD cabinets, and ESD workbenches, as required.	
Special Requirements	Multipoint ground system. Locate adjacent to the IFR Equipment Room with direct access to the Telecommunications Room.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-2.22 RACF – Break Room

Description / Usage	Room with a small kitchenette and seating accessible to trainees and RACF maintenance personnel as well as the on-duty controllers and administrative offices. Locate immediately adjacent to the Operations/IFR Room. Should also be accessible from the administrative office area.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 40" W x 80" H to provide access for vending machines.	
Interior Construction / Built-In Equipment	Base cabinets with plastic laminate countertop and wall cabinets above. Accommodate a wet sink.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	VCT
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing	Sink with hot and cold water	
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power with GFI outlets – provide outlet for wall-mounted television (if provided).	
Lighting	As required by UFC 3-530-01. Provide fully dimmable fixtures if located adjacent to the Operations/IFR Room.	
Communication	**Telephone**	One outlet
	Data	Yes
	CCTV	
	CATV	As required
	Security	Intercom
Acoustics	NC 40	
Furnishings and Equipment	Coffee service, refrigerator, microwave, a stove/range unit, and vending machines, along with seating and tables.	
Special Requirements	If a small break area, adjacent to the Operations/IFR Room, is provided for the controllers, another larger break room is required for the remainder of the facility. If approved, provide a stove/range unit with a filtered hood vented to the exterior.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-2.23 RACF – 2M (Micro Miniature) Electronic Repair Room

Description / Usage	A room for Micro-Maintenance repair. Refer to NAVAIR 01-1A-23 for additional requirements.	
Ceiling Height	Minimum 9'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Snorkel-type localized stand-alone exhaust system, as required.	
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Static dissipative VCT or carpet
	Base	
	Ceiling	Acoustical ceiling tile
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for maintenance equipment, include grounding per FAA Standard. TVSS required on the panel feeding this room.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	Two outlets (computer and printer) minimum
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 45	
Furnishings and Equipment	ESD Chairs on casters, ESD storage shelving, ESD cabinets, and ESD workbenches, as required.	
Special Requirements	Multipoint ground system. Locate adjacent to the IFR Equipment Room with direct access to the Telecommunications Room.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.1 AOB – Lobby/Entry Vestibule

Description / Usage	Main entrance to AOB.	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	Minimum 36" W x 84" H opening, or as required by code – provide vestibule in cold weather areas	
Interior Construction / Built-In Equipment	Building directory and bulletin board	
Finishes	**Walls**	Plaster or GWB - painted
	Floor	Hard surface (terrazzo, VCT, etc.)
	Base	Terrazzo, rubber or vinyl
	Ceiling	Acoustical Ceiling Tile or Painted GWB
Plumbing		
HVAC	Heating and Cooling (heating only in vestibule)	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office-type areas	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Cipher lock and door closer at main entry door
Acoustics	NC 40	
Furnishings and Equipment		
Special Requirements	A covered or recessed entrance or vestibule is recommended.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.2 AOB – HQ / Command Suite - Reception Area

Description / Usage	Open office area containing reception area for HQ / Command.	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Include visitor seating and coat closet	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.3 AOB – HQ / Command Suite - Private Offices

Description / Usage	Private office for select HQ / Command positions.	
Ceiling Height	9’-0” minimum	
Windows	Recommended but not required	
Doors	Minimum 36” W x 80” H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet
	Data	Two outlets (computer and printer)
	CCTV	
	CATV	As required
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 35	
Furnishings and Equipment	Desk, chair, credenza/bookcase, filing cabinets and two (2) visitor chairs	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-3.4 AOB – Air Operations Duty Officer

Description / Usage	Reception area with counter.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.5 AOB – Operations - Airfield Management/Flight Planning

Description / Usage	Open office area containing flight dispatch and flight planning operations.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Provide eight (8) linear feet of counter open to hall or lobby. If required, provide Raised Access Flooring (RAF), fully grounded and bonded, with data cable tray installed below RAF.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Static dissipative carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Critical power (UPS) as required for ATC electronic equipment and standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	As required
	CATV	As required
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required. ESD chairs on casters for operations personnel.	
Special Requirements	Multipoint ground system. Connectivity to IFR Equipment Room required.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.6 AOB – Operations – Pilot Flight Planning Room

Description / Usage	Open office area containing flight planning operations.	
Ceiling Height	9’-0” minimum	
Windows	Recommended but not required	
Doors	Minimum 36” W x 80” H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet.
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.7 AOB – Operations – Weather Station

Description / Usage	Open office area containing weather station operations.	
Ceiling Height	9’-0” minimum	
Windows	Recommended but not required	
Doors	Minimum 36” W x 80” H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Static dissipative carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Critical power is required for the Weather electronic equipment and standard power for office area. TVSS required on the panel feeding this room.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required.	
Special Requirements	Multipoint ground system.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.8 AOB – Operations – Pilot Ready Room

Description / Usage	Open office area containing pilot ready room.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-3.9 AOB – Airfield Services – Open Office Area

Description / Usage	Open office area containing airfield services operations.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.10 AOB – Airfield Services – Printer/Copier Station

Description / Usage	Room containing shared printers and copiers for airfield services.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Base cabinets with plastic laminate countertop and wall cabinets above.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet or VCT
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for printers and copiers. Provide standard outlets along countertop for portable equipment.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	As required for printers and copiers
	CCTV	
	CATV	
	Security	Lockable cabinets
Acoustics	NC 45	
Furnishings and Equipment		
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.11 AOB – Non-Sensitive Secure Storage Room

Description / Usage	Room for storage of non-sensitive materials.	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Full height walls for secure storage. Room construction must comply with service specific requirements.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	VCT
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for storage areas	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Shelving and storage cabinets as required by user.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-3.12 AOB – General Purpose Storage Room

Description / Usage	Room for storage of general purpose materials.	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Full height walls for secure storage.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	VCT
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for storage areas	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key locks
Acoustics	NC 40	
Furnishings and Equipment	Shelving and storage cabinets as required by user.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.13 AOB – File Storage Area

Description / Usage	Room for file storage.	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Full height walls for secure storage.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	VCT
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for storage areas	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key locks
Acoustics	NC 40	
Furnishings and Equipment	Shelving and storage cabinets as required by user.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.14 AOB – ATC Equipment Maintenance Administration Area

Description / Usage	Open office area containing systems furniture workstations	
Ceiling Height	9'-0" minimum	
Windows	Not required	
Doors		
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office area	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet per workstation
	Data	Two outlets per workstation (computer and printer)
	CCTV	
	CATV	
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Freestanding systems furniture, as required	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.15 AOB – ATC Equipment Maintenance Area

Description / Usage	Room for maintenance of ATC electronic equipment. Include general purpose storage room, non-sensitive secure storage room, and file storage area.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H – interior; minimum 36" W x 80" H exterior door access; confirm opening requirement with local ATC equipment maintenance personnel.	
Interior Construction / Built-In Equipment	Snorkel-type localized stand-alone exhaust system, as required.	
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Static dissipative VCT or carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing	Plumbed emergency eye wash station, as required.	
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for maintenance equipment, include grounding per FAA Standard. TVSS required on the panel feeding this room.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	Two outlets (computer and printer) minimum
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 45	
Furnishings and Equipment	General purpose workstations, ESD Chairs on casters, ESD storage shelving, ESD cabinets, and ESD workbenches, as required.	
Special Requirements	Multipoint ground system.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-3.16 AOB – Break Area

Description / Usage	Room with a small kitchenette and seating accessible to all occupants of the AOB.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 42" W x 80" H for vending machine access. Coordinate vending machine installation route.	
Interior Construction / Built-In Equipment	Base cabinets with plastic laminate countertop and wall cabinets above. Accommodate a wet sink.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	VCT or ceramic tile
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing	Sink with hot and cold water	
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power with GFI outlets – provide outlet for wall-mounted television (if provided).	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet
	Data	
	CCTV	
	CATV	
	Security	Lockable cabinets
Acoustics	NC 40	
Furnishings and Equipment	Coffee service, refrigerator, microwave, and vending machines, as well as seating and tables	
Special Requirements	If approved, provide a stove/range unit with a filtered hood vented to the exterior.	
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.17 AOB – Multipurpose Room

Description / Usage	Multipurpose room for conferences and training sessions.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H (provide two if a moveable partition is provided)	
Interior Construction / Built-In Equipment	White board, projector and motorized recessed projection screen. If a single large room is provided, consider a moveable partition to subdivide the space, allowing two individual sessions to be held at the same time.	
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office-type areas	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum (two if a moveable partition is provided)
	Data	Two outlets (computer and printer) minimum (four if a moveable partition is provided)
	CCTV	
	CATV	As required
	Security	Lockable door(s) with standard commercial-grade key lock
Acoustics	NC 35	
Furnishings and Equipment	Conference table(s) and chairs on casters, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft² (m²)		

Table 5-3.18 AOB – Male and Female Toilet Rooms

Description / Usage	Men's and Women's Toilet Rooms	
Ceiling Height	9'-0" minimum	
Windows		
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Include lockers and recessed towel dispensers with integral waste receptacles.	
Finishes	**Walls**	Ceramic Tile on moisture resistant GWB – full height
	Floor	Ceramic Tile
	Base	Ceramic Tile
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing	Water closets, urinals and lavatories with mirror. Include at least one shower and changing area in each toilet room.	
HVAC	Exhaust fan only	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power at lavatory with GFI outlets	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with bathroom lockset
Acoustics	NC 45	
Furnishings and Equipment		
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft2 (m2)		

Table 5-3.19 AOB – Janitor Closet

Description / Usage	Room for custodial supplies and equipment.	
Ceiling Height	Exposed structure. Provide 9'-0" minimum clear height.	
Windows		
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment	Include mop rack and storage shelving	
Finishes	**Walls**	48"H Ceramic Tile wainscot on moisture resistant GWB – painted GWB above
	Floor	Ceramic Tile or Sealed Concrete
	Base	Ceramic Tile
	Ceiling	No ceiling required
Plumbing	One (1) custodial-style floor sink	
HVAC	Exhaust fan only	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power with GFI outlets	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment		
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft2 (m2)		

Table 5-3.20 AOB – Mechanical Room

Description / Usage	Room housing HVAC equipment for the AOB.	
Ceiling Height	Exposed structure. Minimum 9'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing	Floor sink required.	
HVAC	Heating and ventilation only	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for mechanical equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Mechanical HVAC equipment, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft2 (m2)		

Table 5-3.21 AOB – Electrical Room

Description / Usage	Room housing electrical equipment for AOB.	
Ceiling Height	Exposed structure. Minimum 9'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H – interior and exterior access required	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	CMU, plaster or GWB – painted
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	Heating and cooling as required for electrical equipment	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for electrical equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Electrical equipment, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft2 (m2)		

Table 5-3.22 AOB – Telecommunications Room

Description / Usage	Telephone / Data Communications Frame Room housing the communications distribution plant for the AOB.	
Ceiling Height	Exposed structure. Minimum 9'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Painted 3/4 inch fire rated plywood, floor to ceiling, all walls
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	Heating and cooling as required for telecommunications equipment	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system. Provide smoke detection.	
Power	As required for telecommunications equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	As required for telecommunications equipment
	Data	As required for telecommunications equipment
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	Telecommunications equipment, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.23 AOB – SIPR Room

Description / Usage	For certain facilities, a room for SIPR equipment must be provided.	
Ceiling Height	Exposed structure. Minimum 9'-0" clear height	
Windows	Not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Painted 3/4 inch fire rated plywood, floor to ceiling, all walls
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC	Heating and cooling as required for SIPR equipment	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	As required for SIPR equipment	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	As required
	Data	As required
	CCTV	
	CATV	
	Security	Lockable door with standard commercial-grade key lock
Acoustics	NC 50	
Furnishings and Equipment	SIPR equipment, as required.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.24 AOB – Outside Covered Storage Area

Description / Usage	One (1) outside storage building and one (1) outside covered storage area with fence and lockable gate. The storage area is used to store airfield services related equipment and must have direct access to the parking aprons	
Ceiling Height	Exposed structure. Minimum 12'-0" clear height	
Windows		
Doors		
Interior Construction / Built-In Equipment		
Finishes	**Walls**	
	Floor	Sealed concrete
	Base	
	Ceiling	No ceiling required
Plumbing		
HVAC		
Fire Protection and Life Safety		
Power	As required for overhead lighting and convenience power	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	
	Data	
	CCTV	
	CATV	
	Security	
Acoustics		
Furnishings and Equipment		
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.25 AOB – Transient Passenger Services

Description / Usage	Waiting area for transient passengers.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system.	
Power	Standard power for office-type areas. Provide adequate USB charging outlets.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	Wireless internet access
	CCTV	
	CATV	Yes
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Seating as required by program.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

Table 5-3.26 AOB – VIP Passenger Services

Description / Usage	Waiting area for VIPs.	
Ceiling Height	9'-0" minimum	
Windows	Recommended but not required	
Doors	Minimum 36" W x 80" H	
Interior Construction / Built-In Equipment		
Finishes	**Walls**	Plaster or GWB – painted
	Floor	Carpet
	Base	Rubber or vinyl
	Ceiling	Acoustical ceiling tile or painted GWB
Plumbing		
HVAC	Heating and cooling	
Fire Protection and Life Safety	Wet-pipe, automatic fire suppression sprinkler system	
Power	Standard power for office-type areas. Provide adequate USB charging outlets.	
Lighting	As required by UFC 3-530-01	
Communication	**Telephone**	One outlet minimum
	Data	Yes
	CCTV	
	CATV	Yes
	Security	
Acoustics	NC 40	
Furnishings and Equipment	Seating as required by program.	
Special Requirements		
	For use during project execution by the appropriate Service agency	
Occupancy	**Staff**	
	Other	
Min. net ft^2 (m^2)		

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http://www.dsp.dla.mil

MIL-STD-882, *System Safety Program Requirements*

MIL-STD-1472, *Human Engineering Design Criteria for Military Systems, Equipment and Facilities*

MIL-STD-3007, *Standard Practice for Unified Design Criteria and Unified Facilities Guide Specifications*

UNDERWRITERS LABORATORY (UL)
www.ul.com

UL 96A, *Installation of Lightning Protection Systems*

UL 779, *Electrically Conductive Floorings*

A-2 NON-GOVERNMENT PUBLICATIONS

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)
www.nfpa.org

NFPA 13, *Sprinkler Systems*

NFPA 70, *National Electric Code (NEC), latest edition*

NFPA 72, *National Fire Alarm Code, latest edition*

NFPA 75, *Standard for the Protection of Information Technology Equipment*

NFPA 101, *Life Safety Code, latest edition*

NFPA 720, *Standard for the Installation of Carbon Monoxide (CO) Detection and Warning Equipment*

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

AMERICAN STANDARDS FOR TESTING AND MATERIALS (ASTM)
www.astm.org

ASTM D 523, *Standard Test Method for Specular Gloss*

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)
www.ansi.org

ASME/ANSI A17.1 & A17.3, *Safety Code for Elevators and Escalators*

ANSI A148.1, *Electrically Conductive Floorings*

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

ANSI/ESD S7.1, *Resistive Characterization of Materials – Floor Materials*

AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR CONDITIONING ENGINEERS (ASHRAE)
www.ashrae.org

ASHRAE 90.1, *Energy Standard for Buildings (except low-rise residential buildings)*

INTERNATIONAL CODE COUNCIL (ICC)
www.iccsafe.org

International Building Code (IBC)

APPENDIX B BEST PRACTICES

B-1 DEVELOPMENT OF REQUIRED BUILDING AREA AND LAYOUT.

During the planning/DD 1391 development process, the planner should contact appropriate local personnel to discuss and finalize specific space requirements. Confirm area requirements for electronic equipment areas with the requirements developer. In addition, there are unique mechanical/electrical requirements for ATCFs.

For the ATCT, the circulation factor is greater than normal due to limited building footprint.

B-2 ATCT HEIGHT DETERMINATION.

After site selection and issuance of siting report, the planner can determine the tower height and consequently, the number of floors in the ATCT.

B-3 USE OF DIMENSIONS ON FLOOR PLAN DIAGRAMS.

The use of floor plan diagrams is generally helpful to communicate the overall layout and adjacencies in each facility type.

B-4 PROJECT EXPERIENCE.

Require the use of experienced A/E, designers and builders.

B-5 AT/FP REQUIREMENTS.

Reduce the impact of AT/FP requirements.

B-6 TEMPORARY MOBILE ATCT.

During the planning/DD 1391 development phase, the need for a temporary mobile ATCT should be determined to avoid interruptions of continuous ATC operations.

B-7 ACCESSIBILITY VS. FUNCTIONALITY.

Improve accessibility without affecting functionality.

B-8 ELEVATOR MACHINE ROOM.

A room housing elevator machine equipment.

B-9 EXTERIOR CATWALK ACCESS.

The catwalk must be accessible directly from the Cab stair via an access door hatch. Using the Catwalk to provide secondary egress from the Cab is optional, not mandatory; the final decision on the requirement for secondary egress shall be determined by the local Authority Having Jurisdiction (AHJ).

B-10 CATWALK SCAFFOLD.

Consider a means to attach scaffolding to the catwalk for regular maintenance of the tower shaft. Reinforced holes may be designed into the catwalk on all four sides of the shaft to allow scaffolding cables to be routed through the holes and secured.

B-11 EXTERIOR OBSERVATION AREA GRATES.

There are corrosion concerns with the metal grates, especially ATCTs near the coast. The salt in the air helps speed up the corrosion process. Even if the grating is galvanized, some corrosion will still occur. Implement detailed solutions during the design and siting phase.

B-12 OVERALL TOWER SHAFT.

A rectangular tower shaft floor plan often provides an economical use of space. Electronic equipment racks, stairwells and elevators are rectangular in shape and fit more efficiently in a rectangular tower to reduce materials and cost.

B-13 ATCT POWER SHADES.

Recommend not using power shades in the tower Cab due to maintenance issues. If the electric motors fail, replacements may not be readily available and the shades remain broken.

B-14 CABLE TRAY LAYOUT/ROUTING.

Cable tray routing should be planned and designed to provide direct routing between equipment served. The preference is that cable tray routing should be confined within the operational spaces where possible, and avoid corridors especially in multi-occupancy buildings. Routing should minimize penetration of fire-rated walls and floors. Depending on facility configuration and required path between equipment, the cable trays may have to be routed through corridors.

B-15 ATCT CABLE LENGTH.

Minimizing the cable distance is of extreme importance and should not be sacrificed for other design considerations. An example would be offsetting the cable path to facilitate HVAC duct. Interdisciplinary coordination early in the design is very important in reducing cable length. Additionally, the cable chase is meant to be a straight vertical shaft with no horizontal jogs from one location to another. Coaxial cable connecting the radios to the antennas is very stiff and cannot easily be routed through offsets.

B-16 DESIGN SPECIAL LOADS.

The structural designer will provide for the support of communication, future ceiling track, and other special equipment.

Before undertaking unique antenna support designs, consider the use of existing commercial products suitable for the purpose.

B-17 LANDSCAPING AND BIRD ISSUES.

Contractor should be aware of bird issues when creating landscaping plan. For example, retention ponds tend to also attract birds, especially if there is water present all the time.

B-18 FOAM INSULATION.

Consider spray on foam in equipment and mechanical areas for sound attenuation that meets smoke development and flame spread criteria.

B-19 PARKING.

The ATC electronic equipment maintenance division typically has numerous Government vehicles used to travel on the airfield. If the facility is part of the airfield perimeter security fence, consider parking some of the Government vehicles used on the airfield on the airfield side.

B-20 WORK NOT INCLUDED IN CONSTRUCTION CONTRACT.

The following items, except as noted, are Government-Furnished Equipment (GFE) and will be installed by others during construction or upon completion of the construction contract.

1. Antennas. Antennas will be Government installed. All required safety features and lightning protection will be incorporated to protect property and personnel. Lightning protection is provided and installed by the Contractor, and must protect any antennas without integral lightning protection. The antenna mast must withstand wind loads based on the maximum gust conditions and take into consideration the projected heights of antennas to be mounted on the ATCT as well as being capable of resisting lateral loads required by the applicable safety codes. Also consider ice loads and wind-borne salt spray, and how it corrodes and affects radio inter-mod vulnerability.

2. Light Guns. Install eyebolts in the ceiling to hang light guns. These should be located adjacent to light gun outlets. If desired, the battery-operated desk mount type light gun may be installed in lieu of the ceiling mount type. The light gun(s) must be purchased with local Operations and Maintenance (O&M) funds. If battery-powered light guns are used, a 115 +/- 10 VAC outlet must be installed on the console within three feet of each proposed light gun location. Coordinate the location of the light guns with the user during the planning process. Consult with the local Air Operations Department to determine if any existing hard-wired light guns require relocation. If required, the Contractor is responsible for relocating any existing light guns.

3. CCTV Security System. The CCTV security system is Government furnished and installed (GFGI). The Contractor provides rough-in and conduits with pull wires as required.

4. Tower Radar Display Monitor. The Tower Radar Display monitor is GFGI.

5. ATC data or communications cabling internal to the facility, other than office telephone systems and local area network (LAN) cabling to desktop computers, is GFGI.

6. ATC Electronic Equipment Room communications racks, communications equipment, and radar/radar housing are GFGI. Wall-mounted data or telecommunications cabinets or related conduit are furnished and installed by the Contractor.

7. FAA Coordination. Coordinate relocation of existing equipment and connectivity with the FAA.

- **Army**: ATC equipment: radios, STARS, communication and recording equipment, Voice Communications Switching System (VCSS), etc. is installed by separate contract and is procured through Product Manager Air Traffic Control (PM ATC) at the Army Aviation and Missile Command (AMCOM) Redstone Arsenal, AL. Requirements and Technical oversight is a function of USAISEC Fort Detrick, MD. The Contractor is responsible for providing conduit and pull strings for installation. Console cut-out locations and instrument locations must be determined during design. Items to be transferred over from existing facilities must be identified. Weather station equipment and locations must be coordinated with the organization responsible for weather status on the installation.

- **Air Force**: ATC equipment: radios, STARS and RADAR consoles, communication and recording equipment, Enhanced Terminal Voice Switch (ETVS) etc. is installed by separate contract and is procured through UNK due to 38 EIG stepping away. Requirements and Technical oversight is a function of HQ AFFSA. The Contractor is responsible for providing conduit and pull strings for installation. Console cut-out locations and instrument locations must be determined during design. Items to be transferred over from existing facilities must be identified. Weather station equipment and locations must be coordinated with the organization responsible for weather status on the installation.

  Refer to ETL 02-12, *Communications and Information System Criteria for Air Force Facilities*, which delineates programming responsibilities for Real Property versus equipment.

APPENDIX C OUTLINE OF TYPICAL SITE SELECTION PROCESS

The air traffic control tower site selection process is a collaborative effort amongst the planner, Air Ops/Customer, and the representative performing the site evaluation study.

C-1 Establish Tower Siting Study Representative/Methodology (Government/Consultant, etc.)

- See Site Selection and Approval Process in Chapter 2.

C-2 Establish authority for tower site approval.

- See Site Selection and Approval Process in Chapter 2.

C-3 Base/authority recommends potential site(s) for consideration.

- Planner coordinates tower siting study.
- Perform preliminary desktop study:
- Use GIS and other basic available tools to evaluate proposed sites

C-4 Establish site viability and basic geometry compliance.

- Safety zones/clearances
- Site angle to critical areas
- Obstruction avoidance
- Establish preliminary tower height
- Re-work proposed options and results from preliminary study with feedback/input from Air Ops and Planner. Revise and establish new viable options as required.

C-5 Basic considerations in site selection.

- Clear Zone conflicts (existing and future – consider impact of planned/future projects)
- Existing infrastructure
- Future development
- Environmental/Archaeological Issues
- Anti-Terrorism/Force Protection (AT/FP)
- Exact site variance – consider that exact placement of tower on proposed site may vary during actual design for various reasons. Evaluate envelope of reasonable exact locations at a specified site.
- Other special design considerations (Light vault locations, special seismic design, special foundation design, etc.)
- Terminal Approach Procedures (TERPS)

- Existing equipment relocation – consider if space is required for relocation of existing equipment

C-6 Narrow recommended viable site(s) based on considerations.

- Visual tower site evaluation and validation study: (use recommended or equivalent process below)
- Visually validate Tower cab vantage point Height Options
- Perform physical site survey
- Utilize vertical man-lift and accurate GPS on proposed site location/cab vantage point
- Film 360-degree video from tower cab vantage point
- Validate control points
- Consider/evaluate alternate vantage points/elevations

C-7 Re-Evaluate and Rank viable tower sites.

- Assess visual vantage point study results
- Consider optimal visual vantage point
- Consider operational requirements

C-8 Prepare Final Report (forward to planner).

- Summary of viable tower sites
- Plan to resolve visual obstructions
- Maps, flight paths, and other relevant data
- Pros/Cons for viable sites
- Recommended site selection

C-9 Final Site Selection.

- Conduct meeting with selecting authority
- Review final study/recommendations

C-10 Begin formal site approval process.

- See Site Selection and Approval Process in Chapter 2.

C-11 Prepare activity 1391 (use worst case height).

APPENDIX D GLOSSARY

ACRONYMS

A	Ampere(s)
AAAS	Army Airfield Automation System
ABAAS	Architectural Barriers Act Accessibility Standards
A-E	Architect - Engineer
AF	Air Force
AFCEC	Air Force Civil Engineer Center
AFFSA	Air Force Flight Standards Agency
AFI	Air Force Instruction
AFPD	Air Force Policy Directive
AFJMAN	Air Force Joint Manual (Inter-service)
AFMAN	Air Force Manual
AIA	American Institute of Architects
ALCP	Airfield Lighting Control Panel
ANSI	American National Standards Institute
AOF	Airfield Operations Flight
AOF/CC	Airfield Operations Flight Commander
ARAC	Army Radar Approach Control (same as RAPCON and RATCF)
ARNGB	Army National Guard Bureau
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASR	Available Supply Rate OR Airport Surveillance Radar
ASTM	American Society for Testing and Materials
ATC	Air Traffic Control
ATCF	Air Traffic Control Facility

ATCT	Air Traffic Control Tower/ Airport Traffic Control Tower
AT/FP	Antiterrorism Force Protection
ATSCOM	Air Traffic Services Command
BEAP	Base Exterior Architecture Plans
BIA	Bilateral Infrastructure Agreement
BTU / H	British Thermal Unit per Hour
CATV	Cable Television
CBI	Computer-Based Instruction
CC	Commander
CCB	Construction Criteria Base
CCTLR	Chief Controller
CCTV	Closed Circuit Television
CFCI	Contractor Furnished, Contractor Installed
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations
CONUS	Contiguous United States
CM	Centimeter(s)
CMU	Concrete Masonry Unit
CPDS	Critical Power Distribution System
dB	Decibel
DB	Design-Build
DBT	Design Basis Threat
DoD	Department of Defense
DOT	Department of Transportation
DSS	Data Systems Specialist

E&I	Engineering and Installation
ECS	Emergency Communications System
EES	Earth Electrode System
E/G	Engine Generator
EMCS	Energy Management and Control System
EMR	Electromagnetic Radiation
EPA	Environmental Protection Agency
EPO	Emergency Power - Off
ESD	Electrostatic Dissipative OR Electrostatic Discharge
ESS	Electronic Security Systems
ETL	Engineering Technical Letter
ETVS	Enhanced Terminal Voice Switch
F	Fahrenheit
FAA	Federal Aviation Administration
FAA-STD	Federal Aviation Administration Standard
FIPS	Federal Information Processing Standards
FRD	Facility Requirements Documents
FRS	Facility Requirements Supplements
GCA	Ground Controlled Approach
GEMD	Ground Electronics Maintenance Division
GFE	Government Furnished Equipment
GFGI	Government Furnished, Government Installed
GFI	Ground Fault Interrupt OR Ground Fault Indicator
GPS	Global Positioning System
GSF	Gross Square Feet

GWB	Gypsum Wall Board
HERF	Hazards Of Electromagnetic Radiation To Fuel
HERO	Hazards Of Electromagnetic Radiation To Ordnance
HERP	Hazards Of Electromagnetic Radiation To Personnel
HNFA	Host Nation Funded Construction Agreements
HPS	High Pressure Sodium
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	Heating, Ventilating and Air Conditioning
Hz	Hertz
IDF	Intermediate Distribution Frame
IDS	Intrusion Detection System
IDSEP	Intrusion Detection System Engineering Plan
IFR	Instrument Flight Rules
LAN	Local Area Network
LB	Pound(s)
LPS	Liters Per Second
Lx	Lux
M	Meter(s)
MAJCOM	Major Command
MDF	Main Distribution Frame
MIL-HDBK	Military Handbook
MILCON	Military Construction Program
MIL STD	Military Standard
MM	Millimeter(s)
NAS	Naval Air Station or National Airspace System

NAS Mod	National Airspace System Modernization
NATOPS	Naval Air Training and Operating Procedures Standardization
NAVAIDS	Navigational Aids System
NAVAIR	Naval Air Systems Command
NAVFAC	Naval Facilities Engineering Command
NAVFACINST	Naval Facilities Instruction
NAVSEA	Naval Sea Systems Command
NCOIC	Non-Commissioned Officer in Charge
NEC	National Electric Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NSF	Net Square Feet
O&M	Operations and Maintenance
OP / OPS	Operations
OPNAVINST	Chief of Naval Operations Instruction
OSHA	Occupational Health and Safety Administration
PALS	Precision Approach Landing System
PAR	Precision Approach Radar
PM ATC	Product Manager Air Traffic Control
PSF	Pounds (lbs) per Square Foot
R&M	Reliability and Maintainability
RADHAZ	Radiation Hazard
RAF	Raised Access Flooring
RAPCON	Radar Approach Control (same as ARAC or RATCF)
RATCF	Radar Air Traffic Control Facility (same as ARAC or RAPCON)

RF	Radio Frequency
RFI	Radio Frequency Interference
RFP	Request For Proposal
SF	Square Foot / Feet
SIE	Systems Integration Engineer
SOFA	Status of Forces Agreements
SOI	Statement of Intent
SPAWAR	Space and Naval Warfare Systems Command
STARS	Standard Terminal Automation Replacement System
TACAN	Tactical Air Navigation
TERP / TERPS	Terminal Instrument Procedures OR Terminal Procedures
TI	Technical Instruction
TM	Technical Manual
TRACON	Terminal Radar Approach Control
TTB	Telephone Terminal Backboard
TVSS	Transient Voltage Surge Suppressor
UFC	Unified Facility Criteria
UL	Underwriters Laboratory
UPS	Uninterrupted / Uninterruptible Power Supply
US	United States
USAASA	US Army Aeronautical Services Agency
USACE	US Army Corps of Engineers
USAF	United States Air Force
VAC	Volt(s), Alternating Current
VCSS	Voice Communication Switching System

VFR	Visual Flight Rules
W	Watt(s)
WBDG	Whole Building Design Guide (www.wbdg.org)

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Indicate the Military Department Preparing Activity responsible for the document.

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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.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

This UFC provides criteria for new and renovated C5ISR facilities to adopt and align industry best practices for critical facility redundancy and Resilience with the Core UFCs and other DoD criteria for data centers. Industry best practices such as Uptime Institute's *Data Center Site Infrastructure Tier Standard; Topology*, ANSI/TIA-942-B *Telecommunications Infrastructure Standard for Data Centers*, and ANSI/BICSI 002 *Data Center Design and Implementation Best Practices* provide multiple paths to achieve a redundant and resilient facility. These best practices do not always align with the Core UFCs or provide a complete set of criteria to allow for prescriptive designs that can be executed with a degree of commonality across the DoD.

The planners, designers, and Functional Authorities must use this UFC in conjunction with service-specific requirements for planning to develop the program for the facility. The planning and design process must include development of the sponsor and user operational requirements statement and technical description of the infrastructure required to support the mission. Refer to Paragraph 2-3 for additional requirements for developing the Mission Engineering Systems Execution Plan (MESEP).

1-2 PURPOSE AND SCOPE.

This Unified Facilities Criteria (UFC) provides requirements for evaluating, planning, programming, and designing new construction and renovations of existing Command, Control, Computers, Communications, Cyber-Defense, Intelligence, Surveillance, and Reconnaissance (C5ISR) Facilities. This UFC provides prescriptive criteria to achieve the required redundancy and Resilience for C5ISR facilities.

1-3 APPLICABILITY.

This UFC follows the same applicability as UFC 1-200-01, paragraph 1-3 Applicability for C5ISR facilities.

1-3.1 Facility Types.

This UFC applies to the following DoD facility types and provides prescriptive criteria for the facility to meet the required reliability and availability:

- DoD Real Property Categorization System (RPCS) Basic Category Code 131: Communications Buildings
- DoD RPCS Facility Analysis Category (FAC) Code 1444: Miscellaneous Operations Support Buildings with C5ISR missions
- DoD RPCS FAC Code 1452: Missile Guidance Facility
- DoD RPCS FAC Code 6104: Automated Data Processing Center

Refer to the DoDI 4165.03 RPCS for cross reference between the three-digit DoD Basic Category Code, four-digit FAC Code, and the five- or six-digit Military Department Category Codes.

1-3.2 Users of this Document.

1-3.2.1 Planning/Programming Personnel.

Planning and programming personnel must use this UFC in conjunction with the applicable Service-specific governing document for pre-design planning or to assess the extent of improvements required in an existing facility to achieve the standard established herein.

1-3.2.2 Assessment of Existing Facilities.

Use UFC 3-520-02 to assess existing facilities' reliability and availability.

1-3.2.3 Design Services.

Professional architects, engineers, and interior designers must provide design services under the direction of the individual design agencies and this UFC.

1-3.2.4 Service-specific Users and Distribution of Responsibilities.

When Service criteria vary from standard criteria, it is noted in the text as a "Service Exception" or a "Service-specific" criteria. Since numerous and different program offices and functions may be housed in C5ISR Facilities, refer to the appropriate overseeing program office for the specific users and distribution of responsibilities to be housed in the facility. For more general planning questions, refer to the following Service-specific governing documents:

- Army — AR 405-70, IMCOM Space Planning And Criteria Manual
- Navy and Marine Corps — FC 2-000-05N
- Air Force — DAFMAN 32-1084

1-4 FUNCTIONAL AUTHORITIES.

Each facility user or service must appoint a Component Technical Representative (CTR). The CTR represents the project sponsor or customers and exercises authority to establish project requirements on behalf of the user or facility owner as described in UFC 1-200-01. The CTR must identify additional criteria above these requirements during the planning process and MESEP development.

Where Sensitive Compartmented Information Facilities (SCIFs) and Special Access Program Facilities (SAPFs) are included in the C5ISR facility space program, the planning, design, and construction teams must work closely with the supported command, designated Site Security Manager (SSM), and the Certified TEMPEST Technical Authority (CTTA) to determine the requirements for each SCIF. Refer to UFC 4-010-05 for additional requirements.

1-4.1 Planning Process and Facility Grading.

All C5ISR facilities must be at least Grade 3 (concurrently maintainable facility) and can be elevated to Grade 4 (fault-tolerant facility) or lowered to Grade 2 (Redundant Component) based on the mission. During the planning/1391 development phase, the CTR must validate the facility Grade. Justification for facility grades other than Grade 3 must be captured in the planning documents to pass along to the designers. Justification for other than Grade 3 is a service- and mission-specific determination. DoD IEA DC RA requires DoD Core Data Centers (CDCs) to target ANSI/TIA 942-B III Data Center requirements for availability which is equivalent to Grade 3 in this UFC. Refer to DoD IEA DC RA for requirements for other types of DoD Data Centers such as Component Enterprise Data Centers (CEDCs), Installation Processing Nodes (IPNs), Special Purpose Processing Nodes (SPPNs), Installation Services Node (ISN), Geographically Separated Unit (GSU), and Tactical Processing Nodes (TPNs). Refer to Paragraph 2-2 for description of Facility Grading.

Table 1-1 Grade Criteria Based on DoD IEA DC RA

	Data Centers					Other Nodes	
	CDC	CEDC	IPN	SPPN	TPN	ISN	GSU
Grade 1[1]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Grade 2	N/A	N/A	●[2]	●[2]	N/A	●[2]	●[2]
Grade 3	●	●	●	●	●	●	N/A
Grade 4	●	●	●	●	●	●	N/A

Notes:
1. Grade 1 is not acceptable for any DoD Communication Facility
2. Grade 2 is acceptable as minimum with exception.
N/A = Not Applicable

1-5 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.

1-6 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 INFORMATION SECURITY.

Where SCIFs and SAPFs are included in the C5ISR facility space program, refer to UFC 4-010-05 for planning, design, and construction requirements. In accordance with ICS 705-1, the designated SSM must develop a Construction Security Plan (CSP). Construction plans and all related documents must be handled and protected following the CSP.

1-8 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and terms.

1-9 REFERENCES.

APPENDIX C 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.

CHAPTER 2 PLANNING AND LAYOUT

2-1 RESILIENCE AND REDUNDANCY.

The continued operation of the facility is contingent upon the systems that maintain the operations. Systems must be reliable and provide both Resilience and redundancy. Refer to Table 1-1 for Grading criteria. C5ISR facilities are to have a minimum facility Grade of 3. Facilities that can operate at a decreased availability and reliability may be designed to have an infrastructure Grading of 2. Facilities that require increased mission availability and reliability may be designed to have an infrastructure Grading of 4. The decision to design a facility for Grade 2 or 4 must be made during the planning/DD1391 development phase. Data Center Infrastructure ratings are driven by the Resilience and redundancy of the systems as defined by Appendix A-2. Refer to UFC 3-520-02 for further definition and descriptions of Resilience.

2-1.1 Resilience.

Systems must be able to continue to support critical equipment in the event of unforeseen circumstances. System Resilience includes maintainability, survivability, and adaptability. Conceptually straightforward systems are easier to operate and maintain. Consider proximity to skilled labor and replacement parts. Systems must be designed to survive natural disasters and other unforeseen circumstances. Systems must be designed for the appropriate risk category to withstand seismic events and wind loads from storms common to their location. Design must comply with the antiterrorism requirements and consider other physical security preventive measures. Identify any other facility requirements with the mission owner, including but not limited to Chemical, Biological, Radiological, Nuclear, and Explosives, or electromagnetic shielding during the planning/DD1391 development phase.

Resilient systems provide an ability to adapt or recover from an event quickly. Work with mission owner engineering and maintenance personnel during the planning/DD1391 development and design process to incorporate resilient features. Resilient features may require higher first cost and increased maintenance. Carefully weigh and discuss resilient features, understanding that no facility can be designed for all unforeseen events.

2-1.2 Redundancy.

Redundancy in a facility is the ability to have multiple paths of system operation allowing for a component or components to be inoperable, while maintaining system function. For mission critical systems, it is important for the mechanical & electrical systems to allow facility operators to maintain equipment or replace faulty equipment while maintaining the mission operations with minimal or no downtime. Both mechanical and electrical can be configured with multiple redundant system architectures ranging from simplistic to more complex. More complex systems feature more components and equipment and may be less reliable. Simpler systems often feature fewer components and less equipment but may suffer from the ability to provide adequate support paths.

See mechanical and electrical discussions of redundancy in Chapter 3 for further discussion. Redundancy must focus on providing highly reliable operations.

System redundancy must be outlined during the planning/DD1391 development phase. Redundancy requirements carry a significant cost. If costs are not accounted for in the development phase, the project cost may be significantly larger than the enacted DD1391 cost.

2-2 FACILITY MISSION CLASSIFICATION (GRADING).

Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance, and Reconnaissance (C5ISR) facilities are mission critical facilities for multiple branches of the Department of Defense. They support the reception, processing, distribution, and/or transmission of classified and unclassified voice, data, and video communications. Refer to the individual services applicable policies and regulations for space types within these facilities based on their Military Department Category Code. Due to the redundancy and Resilience requirements for the C5ISR missions, non-mission space and users should be minimized and limited to the space and users required to execute the C5ISR mission. This requirement to limit space types and users in the C5ISR facility is to reduce risk to the mission (outside and insider threats), facility construction, and facility maintenance costs. The CTR identifies any spaces that must be part of the facility, but do not have the highest level of mission criticality. The CTR can allow these spaces to have a lower infrastructure Grade than the rest of the C5ISR facility.

All C5ISR facilities must be at least Grade 3. Facilities that can operate at a decreased availability and reliability may be designed to have an infrastructure Grading of 2. Facilities that require increased mission availability and reliability may be designed to have an infrastructure Grading of 4. The decision to design a facility for Grade 2 or 4 must be made during the planning/DD1391 development phase. During the planning phase, the CTR must validate the facility Grade. Grades are defined as the following:

2-2.1 Grade 1.

Not applicable to C5ISR facilities. A facility that has no redundant capacity components and no redundant distribution pathways. Maintenance or failures result in facility down time. For cross reference, this Grade 1 definition is a DoD specific definition that is similar in scope to Uptime Institute’s Tier I Data Center, ANSI/TIA-942-B I Data Center, and ANSI/BICSI 002 Class F1.

2-2.2 Grade 2.

A facility that contains single path(s) to critical loads while having some component redundancy. Component redundancy includes added equipment to exceed N requirements but not system level redundancy. This type of system would be vulnerable to component level faults with no added path around failures. It is possible to have planned component level maintenance but only on those components with the added redundancy. In most cases, maintenance or failures would cause downtime to the critical loads supporting the mission. For cross reference, this Grade 2 definition is a DoD specific definition that is similar in scope to Uptime Institute's Tier II Data Center Topology, ANSI/TIA-942-B II Data Center, and ANSI/BICSI 002 Class F2.

2-2.3 Grade 3.

A concurrently maintainable facility with redundant components to service critical operations. The facility must maintain operations for any scheduled maintenance routine without loss in availability. Major features of these facilities include mechanical and electrical systems with N+1 design architectures at a minimum. These architectures may be 50 percent higher in cost compared to a similar-sized facility with no redundancy. For cross reference, this Grade 3 definition is a DoD specific definition that is similar in scope to Uptime Institute's Tier III Data Center Topology, ANSI/TIA-942-B III Data Center, and ANSI/BICSI 002 Class F3.

2-2.4 Grade 4.

A fault-tolerant facility with independent systems that provide redundant paths to critical operations of the facility and automatic response to faults. Equipment associated with redundant paths are physically isolated to prevent catastrophic events from impacting the operations. This facility can maintain availability during a single component, system, or infrastructure failure by initiating an automatic sequence of operations. It may suffer from loss of operations if a component fails during a scheduled maintenance event. Major features of these facilities include mechanical and electrical systems with 2N design architectures at a minimum. These architectures may cost 100-300 percent more than a similar-sized facility with no redundancy. Cost will increase significantly with additional full capacity (N) redundant paths. For cross reference, this Grade 4 definition is a DoD specific definition that is similar in scope to Uptime Institute's Tier IV Data Center Topology, ANSI/TIA-942-B IV Data Center, and ANSI/BICSI 002 Class F4.

2-3 ENGINEERING SYSTEMS GRADING CHECKLIST.

The following checklist is adopted from ANSI/TIA-942-B, Annex F and aligned to DoD-specific requirements. Discipline designations reflect ANSI/TIA-942-B, Annex F and do not necessarily align with the discipline alignments of Chapter 3.

Engineering Systems Grading Checklist			
	Grade 2	**Grade 3**	**Grade 4**
TELECOMMUNICATIONS			
General			
Cabling, racks, cabinets, & pathways meet TIA specs.	IAW UFC 3-580-01	IAW UFC 3-580-01	IAW UFC 3-580-01
Racks & Cabinets	IAW UFC 3-580-01	IAW UFC 3-580-01	IAW UFC 3-580-01
Diversely routed access provider entrances and maintenance holes with minimum 20 m separation	Required	Required	Required
Redundant access provider services – multiple access providers, central offices, access provider rights-of-way	Not Required	Required	Required
Redundant Entrance Room	Not Required	Required	Required
Redundant Distribution Area	Not Required	Not Required	Optional
Redundant Backbone Pathways	Not Required	Required	Required
Redundant Horizontal Cabling	Not Required	Not Required	Optional
Routers and switches have redundant hot-swappable power supplies and processors	Required	Required	Required
Multiple routers and switches for redundancy	Not Required	Required	Required

	Grade 2	Grade 3	Grade 4
Patch panels, outlets, and cabling to be labeled per ANSI/TIA-606-D. Cabinets and racks to be labeled on front and rear.	Required	Required	Required
Patch cords and jumpers to be labeled on both ends with the name of the connection at both ends of the cable	Required	Required	Required
Patch panel and patch cable documentation compliant with ANSI/TIA-606-D.	Not Required	Required	Required
ARCHITECTURAL			
Parking			
Separate visitor and employee parking areas	IAW UFC 3-201-01	IAW UFC 3-201-01	IAW UFC 3-201-01
Separate from loading docks	IAW UFC 3-201-01	IAW UFC 3-201-01	IAW UFC 3-201-01
Proximity of visitor parking to data center perimeter building walls	IAW UFC 4-020-01	IAW UFC 4-020-01	IAW UFC 4-020-01
Multi-tenant occupancy within building	IAW UFC 4-020-01	IAW UFC 4-020-01	IAW UFC 4-020-01

	Grade 2	Grade 3	Grade 4
Fire Resistive Requirements			
Exterior bearing walls	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.
Interior bearing walls	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.
Exterior nonbearing walls	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.
Structural frame	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.
Interior non-computer room partition walls	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.
Interior computer room partition walls	2 hour minimum	2 hour minimum	2 hour minimum
Shaft enclosures	IAW UFC 1-200-01.	IAW UFC 1-200-01.	IAW UFC 1-200-01.
Floors and floor-ceilings	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.
Roofs and roof-ceilings	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.	IAW UFC 1-200-01. Minimum Type II construction.
Meet requirements of NFPA 75	Required.	Required.	Required

	Grade 2	Grade 3	Grade 4
Building Components			
Vapor barriers for walls and ceiling of computer room	Required for walls, add floors as well	Required, add floors as well	Required, add floors as well
Multiple building entrances with security checkpoints	IAW UFC 4-020-01 & 4-010-05	IAW UFC 4-020-01 & 4-010-05	IAW UFC 4-020-01 & 4-010-05
Floor panel construction	No Requirement	Computer grade all steel	Computer grade all steel or computer grade steel with concrete fill
Understructure	No Requirement	Bolted stringer access flooring	Bolted stringer access flooring with 48 in. x 48 in. (1200 mm x 1200 mm) basket weave pattern
Ceilings Within Computer Room Areas			
Ceiling Construction	If provided, suspended with clean room tile	If provided, suspended with clean room tile	If provided, suspended with clean room tile
Ceiling Height	9 feet (2.7 m) minimum	10 feet (3 m) minimum (not less than 18 in. (460 mm) above tallest piece of equipment)	10 feet (3 m) minimum (not less than 24 in. (610 mm) above tallest piece of equipment)
Roofing			
Class	**Class A**	**Class A**	**Class A**
Type	Non-redundant with non- combustible deck (no mechanically attached systems)	Non-redundant with non- combustible deck (no mechanically attached systems)	Double redundant with concrete deck (no mechanically attached systems)
Wind uplift resistance	Greater of FM I-90 or UFC 3-110-03	Greater of FM I-90 or UFC 3-110-03	Greater of FM I-120 or UFC 3-110-03
Roof Slope	IAW UFC 3-110-03	IAW UFC 3-110-03	IAW UFC 3-110-03

	Grade 2	Grade 3	Grade 4
Doors and Windows			
F Fire rating	IAW UFC 1-200-01	IAW UFC 1-200-01	IAW UFC 1-200-01
Door size	Minimum code requirements and not less than 36 in. (910 mm) wide and 96 in. (2400 m) high	Minimum Code requirements (not less than 36 in. (910 mm) wide into computer, electrical, & mechanical rooms) and not less than 96 in. (2400 m) high	Minimum Code requirements (not less than 48 in. (1200 mm) wide into computer, electrical, & mechanical rooms) and not less than 96 in. (2400 m) high
Windows on perimeter of computer room	IAW UFC 1-200-01, 4-010-05 & 4-020-01	IAW UFC 1-200-01, 4-010-05 & 4-020-01	IAW UFC 1-200-01, 4-010-05 & 4-020-01
Entry Lobby			
Physically separate from other areas of data center	Required	Required	Required
Fire separation from other areas of data center	IAW UFC 1-200-01	IAW UFC 1-200-01	IAW UFC 1-200-01
Security counter	Not Required	Required	Required (physically separated from other areas of data center)
Single person interlock, portal or other hardware designed to prevent piggybacking or pass back	Not Required	Required	Required

	Grade 2	Grade 3	Grade 4
Administrative Offices			
Physically separate from other areas of data center	Required	Required	Required
Fire separation from other areas of data center	IAW UFC 1-200-01	IAW UFC 1-200-01	IAW UFC 1-200-01
Security Office			
Physically separate from other areas of data center	Not Required	Required	Required
Fire separation from other areas of data center	IAW UFC 1-200-01	IAW UFC 1-200-01	IAW UFC 1-200-01
180-degree peepholes on security equipment and monitoring rooms	IAW UFC 4-010-05 & 4-020-01	IAW UFC 4-010-05 & 4-020-01	IAW UFC 4-010-05 & 4-020-01
Dedicated and hardened security equipment and monitoring room with 16 mm (5/8 in) plywood-lined walls and solid core door	IAW UFC 4-010-05 & 4-020-01	IAW UFC 4-010-05 & 4-020-01	IAW UFC 4-010-05 & 4-020-01
Operations Center			
Physically separate from other areas of data center	IAW MESEP or Planning Criteria	IAW MESEP or Planning Criteria	IAW MESEP or Planning Criteria
Fire separation from other non-computer room areas of data center	IAW UFC 1-200-01	IAW UFC 1-200-01	IAW UFC 1-200-01
Proximity to computer room	IAW MESEP or Planning Criteria	IAW MESEP or Planning Criteria	IAW MESEP or Planning Criteria

	Grade 2	Grade 3	Grade 4
Restrooms and Break Room Areas			
Proximity to computer room and support areas	If immediately adjacent, provided with leak prevention barrier	If immediately adjacent, provided with leak prevention barrier	Not immediately adjacent and provided with leak prevention barrier
Fire separation from computer room and support areas	IAW UFC 1-200-01	IAW UFC 1-200-01	IAW UFC 1-200-01
UPS and Battery Rooms			
Aisle widths for maintenance, repair, or equipment removal	IAW UFC 1-200-01 and not less than 36 in. (910 mm) clear	IAW UFC 1-200-01 and not less than 36 in. (910 mm) clear	IAW UFC 1-200-01 and not less than 36 in. (910 mm) clear
Proximity to computer room	IAW MESEP or Planning Criteria	IAW MESEP or Planning Criteria	IAW MESEP or Planning Criteria
Fire separation from computer room and other areas of data center	IAW UFC 1-200-01	IAW UFC 1-200-01	IAW UFC 1-200-01
Required Exit Corridors			
Fire separation from computer room and support areas	IAW UFC 1-200-01	IAW UFC 1-200-01	IAW UFC 1-200-01
Width	IAW UFC 1-200-01 and not less than 48 in. (1200 mm) clear	IAW UFC 1-200-01 and not less than 48 in. (1200 mm) clear	IAW UFC 1-200-01 and not less than 60 in. (1500 mm) clear

	Grade 2	Grade 3	Grade 4
Shipping and Receiving Area			
Physically separate from other areas of data center	IAW MESEP or Planning Criteria	IAW MESEP or Planning Criteria	IAW MESEP or Planning Criteria
Fire separation from other areas of data center	IAW UFC 1-200-01	IAW UFC 1-200-01	IAW UFC 1-200-01
Physical protection of walls exposed to lifting equipment traffic	Required (minimum 3/4 in. (19 mm) plywood wainscot)	Required (minimum 3/4 in. (19 mm) plywood wainscot)	Required (steel bollards or similar protection)
Number of loading docks	IAW MESEP or minimum of 1 per 25,000 square feet (2300 sm) (1 minimum)	IAW MESEP or minimum of 1 per 25,000 square feet (2300 sm) (2 minimum)	IAW MESEP or minimum of 1 per 25,000 square feet (2300 sm) (2 minimum)
Loading docks separate from parking areas	No Requirement	Required	Required (physically separated by fence or wall)
Security counter	No Requirement	Required	Required (physically separated)
Generator and Fuel Storage Areas			
Proximity to computer room and support areas	IAW UFC 1-200-01	IAW UFC 1-200-01	IAW UFC 1-200-01
Proximity to publicly accessible areas	IAW UFC 4-020-01 & 3-460-01	IAW UFC 4-020-01 & 3-460-01 and a 30 feet (9.1 m) minimum	IAW UFC 4-020-01 & 3-460-01 and a 30 feet (9.1 m) minimum
Security			
System CPU UPS capacity	IAW MESEP & UFC 4-021-02	IAW MESEP & UFC 4-021-02	IAW MESEP & UFC 4-021-02
Data Gathering Panels (Field Panels) UPS Capacity	IAW MESEP & UFC 4-021-02	IAW MESEP & UFC 4-021-02	IAW MESEP & UFC 4-021-02
Field Device UPS Capacity	IAW MESEP & UFC 4-021-02	IAW MESEP & UFC 4-021-02	IAW MESEP & UFC 4-021-02
Physical security staffing per shift	IAW UFC 4-020-01 & 4-010-05	IAW UFC 4-020-01 & 4-010-05	IAW UFC 4-020-01 & 4-010-05

	Grade 2	Grade 3	Grade 4
Security Access Control/Monitoring			
Generators	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
UPS, Telephone & MEP Rooms	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Fiber Vaults	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Emergency Exit Doors	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Accessible Exterior Windows / opening	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Security Operations Center	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Network Operations Center	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Security Equipment Rooms	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Doors into Computer Rooms	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Perimeter building doors	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Main door onto computer room floor	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01

	Grade 2	Grade 3	Grade 4
Bullet Resistant Walls, Windows, and Doors			
Security Counter in Lobby	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
CCTV Monitoring			
Building perimeter and parking	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Generators	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Access Controlled Doors	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Computer Room Floors	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
UPS, Telephone & MEP Rooms	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
CCTV Recording			
CCTV Recording of all activity on all cameras	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01
Recording rate (frames per second)	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01	Requirement determined by study IAW UFC 4-020-01

	Grade 2	Grade 3	Grade 4
Structural			
Facility designed to International Building Code (IBC) Seismic Design category (SDC) requirements	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01
Site Specific Response Spectra - Degree of local Seismic accelerations	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01
Importance factor - assists to ensure greater than code design	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01
Telecommunications equipment racks/cabinets anchored to base or supported at top and base	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01
Deflection limitation on telecommunications equipment within limits acceptable by the electrical attachments	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01
Bracing of electrical conduits runs and cable trays	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01
Bracing of mechanical system major duct runs	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01	Requirement determined IAW UFC 3-301-01
Floor loading capacity superimposed live load	250 lbf/sq ft (12 kPa) minimum	250 lbf/sq ft (12 kPa) minimum	250 lbf/sq ft (12 kPa) minimum
Floor hanging capacity for ancillary loads	50 lbf/sq ft (2.4 kPa) minimum	50 lbf/sq ft (2.4 kPa) minimum	50 lbf/sq ft (2.4 kPa) minimum

	Grade 2	Grade 3	Grade 4
Concrete Slab Thickness at ground	5 in. (127 mm) minimum	5 in. (127 mm) minimum	5 in. (127 mm) minimum
Minimum concrete topping over flutes for equipment anchorage when concrete filled metal deck structure used for elevated floors	4 in. (102 mm) minimum	4 in. (102 mm) minimum	4 in. (102 mm) minimum
Building LFRS (Shear wall/Braced Frame/Moment Frame) indicates displacement of structure	IAW UFC 3-301-01	IAW UFC 3-301-01	IAW UFC 3-301-01
Building Energy Dissipation - Passive Dampers/Base Isolation (energy absorption)	IAW UFC 3-301-01	IAW UFC 3-301-01	IAW UFC 3-301-01
Elevated floor construction. (Steel structures with concrete filled metal decks are more easily upgraded for intense loads in Battery/UPS rooms; and better for installing floor anchors.)	IAW UFC 3-301-01	IAW UFC 3-301-01	IAW UFC 3-301-01

	Grade 2	Grade 3	Grade 4
ELECTRICAL			
General			
System allows concurrent maintenance	Not required but preferred for critical parts of infrastructure	From utility down to but not including power distribution unit	Throughout distribution system
Single Point of Failure	Multiple single points of failure throughout the distribution system	Reduced single points of failure for distribution systems serving electrical equipment. Critical distribution has no single points of failure.	No single points of failure for distribution systems serving electrical equipment or essential load
Power System Analysis	Up-to-date short circuit study, coordination study, arc flash analysis, and load flow study. Selective Coordination provided down to 0.1s	Up-to-date short circuit study, coordination study, arc flash analysis, and load flow study. Selective Coordination provided down to 0.1s	Up-to-date short circuit study, coordination study, arc flash analysis, and load flow study. Selective Coordination provided down to 0.01s
Computer & Telecommunications Equipment Power Cords	Single Cord Feed with 100% capacity	Redundant Cord Feed with 100% capacity on remaining cord(s)	Redundant Cord Feed with 100% capacity on remaining cord(s)
Utility			
Utility Entrance	Single Feed	N+1 Redundant Feed	2N Redundant Feed from different utility substations or generator plant when capable.

	Grade 2	Grade 3	Grade 4
Main Utility Switchboard/Switchgear			
Service	Shared	Dedicated	2N. Two Dedicated from separate substations.
Construction	Switchboard with stationary circuit breakers	Switchboard with draw out circuit breakers	Switchgear with draw out circuit breakers
Surge Suppression	Not Required	Required	Required
Uninterruptible Power Supply (UPS)			
Redundancy	N+1	2N	2N, minimum. Other configurations (3N/2, 2(N+1)) to be evaluated.
Topology	Parallel Modules	Distributed Redundant Modules or Block Redundant System	Distributed Redundant Modules or Block Redundant System
Automatic Bypass	Required, with non-dedicated feeder to automatic bypass	Required, with dedicated feeder to automatic bypass	Required, with dedicated feeder to automatic bypass
Maintenance Bypass Arrangement	Non-dedicated maintenance bypass feeder to UPS output switchboard	Dedicated maintenance bypass feeder to UPS output switchboard	Dedicated maintenance bypass feeder to UPS output switchboard

	Grade 2	Grade 3	Grade 4
Output Power Distribution	Distribution equipment incorporating removable circuit breakers. For equipment main circuit breakers larger than 225 amps provide adjustable long time, short time and instantaneous functions with provision to turn off instantaneous function.	Distribution equipment incorporating removable circuit breakers. For equipment main circuit breakers larger than 225 amps provide adjustable long time, short time and instantaneous functions with provision to turn off instantaneous function.	Distribution equipment incorporating removable circuit breakers. For equipment main circuit breakers larger than 225 amps provide adjustable long time, short time and instantaneous functions with provision to turn off instantaneous function.
Dedicated Battery String for each module	Single or common string for multiple modules modular UPS. Dedicated string for standalone modules	Required	Required
Battery Type	IAW UFC 3-520-05	IAW UFC 3-520-05	IAW UFC 3-520-05
Battery minimum backup time with design load at end of battery life	IAW with MESEP.	IAW with MESEP.	IAW with MESEP.
Battery Monitoring System	String level by UPS system	String level by UPS system	Centralized automated system to check each cell for voltage and impedance or resistance
Power Distribution Unit			
Transformer	Harmonic cancelling, high efficiency	Harmonic cancelling, high efficiency	Harmonic cancelling, high efficiency
Surge Suppression	Required	Required	Required

	Grade 2	Grade 3	Grade 4
Static Transfer Switch (STS)			
Over-current Device	Not Required	Circuit Breaker	Circuit Breaker
Maintenance Bypass Procedure	Not Required	Manual guided with mechanical interlock	Automatic operation
Grounding			
Lightning protection system	Required	Required	Required
Lightning fixtures neutral isolated from service entrance derived from lighting transformer for ground fault isolation	IAW with UFC 3-520-01	IAW with UFC 3-520-01	IAW with UFC 3-520-01
Data center grounding infrastructure in computer room as required by ANSI/TIA-607-D	As required by ANSI/TIA-607-D	IAW MIL-STD-188-124B	IAW MIL-STD-188-124B

	Grade 2	Grade 3	Grade 4
Computer Room Emergency Power Off (EPO) Systems			
Installation	Army and Navy: Provide manual means for electronic equipment EPO as permitted by UFC 3-600-01. Air Force: Automatic EPO is permitted upon sprinkler water flow as guided by TSFPEWG G 3-600-01.01-18. Where provided, provide IAW with NEC 645. A minimum circuit reliability of Performance Level d (PLd) in accordance with ANSI B11.26.	Army and Navy: Provide manual means for electronic equipment EPO as permitted by UFC 3-600-01. Air Force: Automatic EPO is permitted upon sprinkler water flow as guided by TSFPEWG G 3-600-01.01-18. Where provided, provide IAW with NEC 645. A minimum circuit reliability of Performance Level d (PLd) in accordance with ANSI B11.26.	Army and Navy: Provide manual means for electronic equipment EPO as permitted by UFC 3-600-01. Air Force: Automatic EPO is permitted upon sprinkler water flow as guided by TSFPEWG G 3-600-01.01-18. Where provided, provide IAW with NEC 645. A minimum circuit reliability of Performance Level d (PLd) in accordance with ANSI B11.26.
Test Mode	Required	Required	Required
Alarm	Required	Required	Required
Abort Switch	As required by the MESEP	As required by the MESEP	As required by the MESEP

	Grade 2	Grade 3	Grade 4
Central Power Monitoring			
Monitored points	Utility, main transformer, UPS, generator, feeder circuit breakers, automatic static transfer switch, PDU, automatic transfer switches. Limited to circuit breakers 800A or greater.	Utility, main transformer, UPS, generator, feeder circuit breakers, automatic static transfer switch, PDU, automatic transfer switches. Limited to circuit breakers 800A or greater.	Utility, main transformer, UPS, generator, feeder circuit breakers, automatic static transfer switch, PDU, automatic transfer switches. Limited to circuit breakers 800A or greater.
Notification Method	Control Room Console	Engineer of the Watch Workstation via Windows based software.	Engineer of the Watch Workstation via Windows based software.
Battery Room			
Separate from UPS/Switchgear Equipment Rooms	Not Required	Required	Required
Individual Battery Strings contained within their own enclosure.	Not Required	Required	Required
Shatterproof Viewing Glass in Battery Room Door	Not Required	Not required	Required
Standby Generator System			
Generator Sizing	Sized for UPS and mechanical system without redundancy	Sized for station load with N+1 distributed redundancy	Sized for total station load with 2N distributed redundancy. N+1 can be considered if 2N utility is provided.
Generator Configuration	N	N+1 or better	2N on redundant busses

	Grade 2	Grade 3	Grade 4
Loadbank			
Installation	Provision for portable	Provision for portable	IAW with MESEP.
Equipment Tested	Generator	Generator, UPS	IAW with MESEP.
Auto Shutdown	Not Required	Automatic upon failure of utility	IAW with MESEP.
UPS Switchgear	Not Required	Not Required	IAW with MESEP.
Permanently Installed	No - Rental	No - Rental	IAW with MESEP.
Testing			
Factory Accepting Testing	Switchboards, Switchgear, UPS and generator systems, generator controls, STS. Primary injection and contact resistance test of all circuit breakers in critical and essential paths, 225 A and higher IAW UFC 3-560-01	Switchboards, Switchgear, UPS and generator systems, generator controls, STS. Primary injection and contact resistance test of all circuit breakers in critical and essential paths, 225 A and higher IAW UFC 3-560-01	Switchboards, Switchgear, UPS and generator systems, generator controls, STS. Primary injection and contact resistance test of all circuit breakers in critical and essential paths, 225 A and higher IAW UFC 3-560-01
Site Circuit Breaker Testing	Primary injection and contact resistance test of all circuit breakers in critical and essential paths, 225 A and higher IAW UFC 3-560-01	Primary injection and contact resistance test of all circuit breakers in critical and essential paths, 225 A and higher IAW UFC 3-560-01	Primary injection and contact resistance test of all circuit breakers in critical and essential paths, 225 A and higher IAW UFC 3-560-01
Commissioning	Component level, system level, and integrated system including Black Start testing	Component level, system level, and integrated system including Black Start testing	Component level, system level, and integrated system including Black Start testing

	Grade 2	Grade 3	Grade 4
Equipment Maintenance			
Operation and Maintenance Staff	Onsite Day Shift only. On-call at other times	Onsite 24 hrs M-F, on-call on weekends	Onsite 24/7
Preventative Maintenance	Comprehensive preventative maintenance program to include but not limited to Switchgear, switchboards, generators, ATS, STS, automatic sequence exercises and UPS.	Comprehensive preventative maintenance program to include but not limited to Switchgear, switchboards, generators, ATS, STS, automatic sequence exercises and UPS.	Comprehensive preventative maintenance program to include but not limited to Switchgear, switchboards, generators, ATS, STS, automatic sequence exercises and UPS.
Facility Training Programs	Comprehensive training program for normal operation of equipment	Comprehensive training program for normal and emergency operation of equipment.	Comprehensive training program for normal operation of equipment and manual operation of equipment during emergency operation
MECHANICAL			
General			
Redundancy for mechanical equipment (e.g., air conditioning units, coolers, pumps, cooling towers, condensers)	N+1 redundancy for mechanical equipment. Loss of electrical supply path or water supply (where applicable) could lead to loss of cooling	N+1 redundancy for mechanical equipment. Temporary loss of electrical power will not cause loss of cooling, but may cause temperature to elevate within operational range of critical equipment	2N or N+2 redundancy for mechanical equipment. Extended loss of electrical power will not cause loss of cooling outside operational range of critical equipment

	Grade 2	Grade 3	Grade 4
Routing of water or drain piping not associated with the data center equipment in data center spaces	Not permitted	Not permitted	Not permitted
Positive pressure in computer room and associated spaces relative to outdoors and non-data center spaces	Required	Required	Required
Floor drains in computer room for condensate drain water, humidifier flush water, and sprinkler discharge water	Required	Required	Required
Mechanical systems on standby generator	Required	Required	Required
Preventive Maintenance for critical equipment and sensor calibration	Required	Required	Required

	Grade 2	Grade 3	Grade 4
Water-Cooled System			
Indoor Terminal Air Conditioning Units	One redundant air conditioning unit per critical area	Qty. of AC Units sufficient to maintain critical area during loss of one source of electrical power	Qty. of AC Units sufficient to maintain critical area during loss of one source of electrical power. N+1 redundancy is required following loss of one unit.
Humidity Control for Computer Room	De-humidification/humidification, where applicable, provided	De-humidification/humidification, where applicable, provided	De-humidification/humidification, where applicable, provided
Electrical Service to Mechanical Equipment	Single path of electrical power to AC equipment	Multiple paths of electrical power to AC equipment. Connected in checkerboard fashion for cooling redundancy	Multiple paths of electrical power to AC equipment. Provided with ATS/MTS at each piece of equipment.
Heat Rejection			
Piping System	Single path	Headered parallel piped chilled water/ condenser water system or dedicated cooling piping system to ensure concurrent maintainability	Dual path condenser water system
Chilled Water Piping System	Single path	Dual path ladder loop chilled water system with isolation valves	Dual path chilled water system
Condenser Water Piping System	Single path	Headered parallel piped condenser water system	Dual path condenser water system

	Grade 2	Grade 3	Grade 4
Chilled Water System			
Humidity Control for Computer Room	De-humidification/ humidification, where applicable, provided	De-humidification/ humidification, where applicable, provided	De-humidification/ humidification, where applicable, provided
Electrical Service to Mechanical Equipment	Single path of electrical power to AC equipment	Multiple paths of electrical power to AC equipment	Multiple paths of electrical power to AC equipment
Air-Cooled System			
Electrical Service to Mechanical Equipment	Single path of electrical power to AC equipment	Multiple paths of electrical power to AC equipment	Multiple paths of electrical power to AC equipment
Humidity Control for Computer Room	De-humidification/ humidification, where applicable, provided	De-humidification/ humidification, where applicable, provided	De-humidification/ humidification, where applicable, provided
HVAC Control System			
HVAC Control System	Control system failure will not interrupt cooling to critical areas	Control system failure will not interrupt cooling to critical areas	Control system failure will not interrupt cooling to critical areas
Power Source to HVAC Control System	Single path of electrical power to HVAC control system	Redundant, UPS electrical power to BMS control	Redundant, UPS electrical power to BMS control
Plumbing (for Water-Cooled Heat Rejection)			
Dual Sources of Make-up Water	Dual sources of water, or one source + on-site storage with a minimum equal to duration of generator fuel supply	Dual sources of water, or one source + on-site storage with a minimum equal to duration of generator fuel supply	Dual sources of water, or one source + on-site storage with a minimum equal to duration of generator fuel supply
Points of Connection to Condenser Water System	Single point of connection	Two points of connection	Two points of connection

	Grade 2	Grade 3	Grade 4
Fuel Oil System			
Bulk Storage Tanks	Single storage tanks	Multiple storage tanks	Multiple storage tanks
Storage Tank Pumps and Piping	Multiple pumps, single supply pipes, redundant power for fuel control panel.	Multiple pumps, multiple supply pipes, redundant power for fuel control panel.	Multiple pumps, multiple supply pipes, redundant power for fuel control panel.
Fire Suppression			
Fire detection system	Required	Required	Required
Fire sprinkler system	Wet-pipe for Army and Navy. Preaction allowed in certain instances for Air Force per TSFPEWG G 3-600-01.01-18	Wet-pipe for Army and Navy. Preaction allowed in certain instances for Air Force per TSFPEWG G 3-600-01.01-18	Wet-pipe for Army and Navy. Preaction allowed in certain instances for Air Force per TSFPEWG G 3-600-01.01-18
Gaseous suppression system	Clean agent required.	Clean agent required.	Clean agent required.
Early Warning Smoke Detection System	Required	Required	Required
Water Leak Detection System	Required	Required	Required

2-4 MISSION ENGINEERING SYSTEMS EXECUTION PLAN (MESEP).

The MESEP translates the sponsor and user operational requirement statement into a technical description of command, control, communications and intelligence and IT systems and facility infrastructure required to provide the required command, control, communications, and intelligence mission capability. The MESEP must include mission-specific engineering and architecture requirements. The MESEP must include the space planning documents and the electronic equipment engineering requirements document. The requirements of the space planning documents are outlined in the applicable Service-specific governing document.

2-4.1 Minimum MESEP Requirements.

The electronic equipment engineering requirements document must include:

- Technical details related to the station orientation or layout
- Telecommunications equipment rack layouts and rack counts
- Power density per rack
- Network list
- Network Security Requirements (Black/Red/Special Red)
- Preliminary electrical distribution and sizing
- Preliminary mechanical system concept and sizing
- Preliminary fire protection systems (fire alarm, detection, suppression) concepts
- Facility physical security requirements
- Facility cybersecurity requirements
- Systems to be Commissioned.

Rack layouts must include every space that includes telecommunications racks or cabinets. Power density per rack must be provided in a kW per rack unit. The network list must be complete and thorough, giving thought to future networks. Network security must be provided, and verbiage aligned with CNSSAM TEMPEST 1-13. The preliminary mechanical plan is anticipated to assist the Architecture/Engineering (A/E) team in designing the mechanical system. The design process must determine the final mechanical and electrical systems, but it is important to coordinate the electronic equipment engineer’s expectations before design begins. The facility security requirements must be coordinated with the mission and security assessment provided in accordance with UFC 4-020-01. Cybersecurity requirements must be coordinated with mission requirements. At a minimum, include the required C-I-A ratings. This document must be completed during the planning/DD1391 development phase or preliminary project development process to capture required funding.

Navy Facilities: This document is equivalent to the Base Electronic System Engineering Plan (BESEP) for Navy projects, refer to OPNAVINST 11010.20J.

2-5 SITE CONSIDERATIONS.

The primary consideration in selecting a site is its technical adequacy for meeting performance objectives. Generally, the primary considerations are maximum signal-to-noise ratios at the receivers and maximum effective power radiated in the desired direction from the transmitters. Additional considerations include suitability for construction at a reasonable cost, link requirements between components of the communication station, land costs, and logistic support requirements. Other site-specific factors for consideration are the availability of utilities, climate, foundation stability, survivability, physical security, and expansion potential. Although other factors enter into the selection of a site, compromises for the sake of economy or logistics convenience must not interfere with performance.

2-5.1 Relationship to Design.

The designer does not select the site, but the considerations leading to its selection must be understood and incorporated into the design. The resulting findings must be incorporated into the final design for the project.

Navy Facilities: Before the designer begins work, the Field Technical Authority of Naval Information Warfare Systems Command (COMNAVWARSYSCOM) conducts a site selection survey and an Electromagnetic Compatibility (EMC) evaluation as part of the preparation of the MESEP.

2-5.2 Site Selection Survey and Risk Assessment.

Perform a site selection survey and risk analysis to determine the suitability of a site.

2-5.3 Natural and Man-Made Site Factors and Constraints.

Do not select project sites with the following site factors and constraints:

- Sites within 5 miles (8.1 km) of a commercial airport or the aircraft takeoff and landing paths.
- Sites within ¼ mile (0.4 km) of a chemical plant, landfill, river, coastline, or dam.
- Sites within one mile (1.6 km) of a nuclear, munitions, or defense plant.

Where feasible, avoid project locations with the following site factors and constraints during the site selection process:

- Sites near a geologic fault, on a hill subject to slide risk, or downstream from a dam or water tower.
- Sites that are within 300 feet (91.5 m) of the 500-year flood hazard area or less than 10 feet (3.1 m) above the highest known flood level.
- Sites within current or future flood hazard areas as defined by UFC 3-201-01. Unless otherwise stipulated in project-specific guidance provided by the using agency or Authority Having Jurisdiction (AHJ), assume that the

C5ISR facility is classified as Flood Design Class 4 (high risk, essential facilities).

- Sites with wetlands and protected habitats.
- Sites with unstable geotechnical conditions, such as expansive soils, subsurface contamination, or potential for sinkholes.
- Sites adjacent to properties with the potential for any development that could interfere with facility operations.
- Sites that may be impacted by vibrations from railroads or that may have access restrictions due to railroad crossings.

Refer to Appendix A-3 – Data Center Facility Grading Requirements for additional site factors based on the facility grade.

2-5.4 Site Accessibility and Infrastructure.

Consider the following site accessibility and infrastructure factors during the site selection process:

- Availability of electrical utility capacity at the site. Electrical utility capacity must be available at the project site to meet the facility's current and projected future needs. Coordinate with the Electrical Engineer to determine the project-specific electrical demands and projected future needs.
- Availability and economics of redundant utility feeders from separate utility substations.
- Availability and economics of redundant telecommunications pathways from separate telecommunications providers.
- Accessibility of the site from major roadway infrastructure. Where feasible, select a site with multiple access roads to the facility from existing major arterial roadways.
- The site's proximity to emergency services such as hospitals, fire stations, and police stations.

2-5.5 Electromagnetic Compatibility (EMC) Evaluation.

Any factor that prevents or degrades the reception of signals also degrades the ability of the site to perform its mission. Locate the receiving and direction-finding site where signal reception is known to be good. All pertinent information must be outlined in the MESEP.

2-5.6 Isolation.

Optimum radio communications depend largely on the site's isolation from sources of interference and the proper dispersion of structures within the site. Minimum separation distances for electromagnetic interference protection of receiver sites are provided in Table 2-1. Tabulated sources interference applies to Direction Finder (DF) stations of any frequency. Specific requirements for each project, including variations required by local conditions, are developed in the MESEP.

Table 2-1 Minimum Separation Distances for Receiver Sites

Facility	Source of Interference	Minimum Distance
Radio Receiver Station	High-power transmitter stations: Very low frequency	25 miles (40 km)
	Low frequency/high frequency	15 miles (24 km)
	Other transmitter stations not under DoD control	5 miles (8 km)
	Airfields and guide paths: general communications transmitting	5 miles (8 km)
	Airfields and guide paths: aeronautical receiving at air stations	1,500 feet (457 m)
	Teletype and other electromechanical systems installed in shielded rooms or level signaling and keying modified	No requirement
	Teletype and other electromechanical systems installed in unshielded rooms or high level signaling and keying operation: Large installation (communication center)	2 miles (3.2 km) from nearest antenna
	Teletype and other electromechanical systems installed in unshielded rooms or high signaling and keying operation: Small installation (one to six instruments)	200 feet (61 m) from nearest antenna
	Main highways	3,000 feet (914 m)
	High-tension overhead power-lines-receiver station feeders	1,000 feet (305 m) from nearest antenna
	Habitable areas (beyond limits of restriction)	1 mile (1.6 km)
	Areas capable of industrialization (beyond limits of restriction) – Light industry	3 miles (4.8 km)
	Areas capable of industrialization (beyond limits of restriction) – Heavy industry	5 miles (8 km)
	Radar installation	1,500 feet (457 m)
Radio Transmitter Stations	Airfield and glide paths: general communications transmitting	3 miles (8 km)
	Airfields and glide paths: aerological transmitting at air stations	1,500 feet (457 m)
	Main highways	1,000 feet (305 m)
	High-tension overhead power lines	1,000 feet (305 m) from nearest antenna

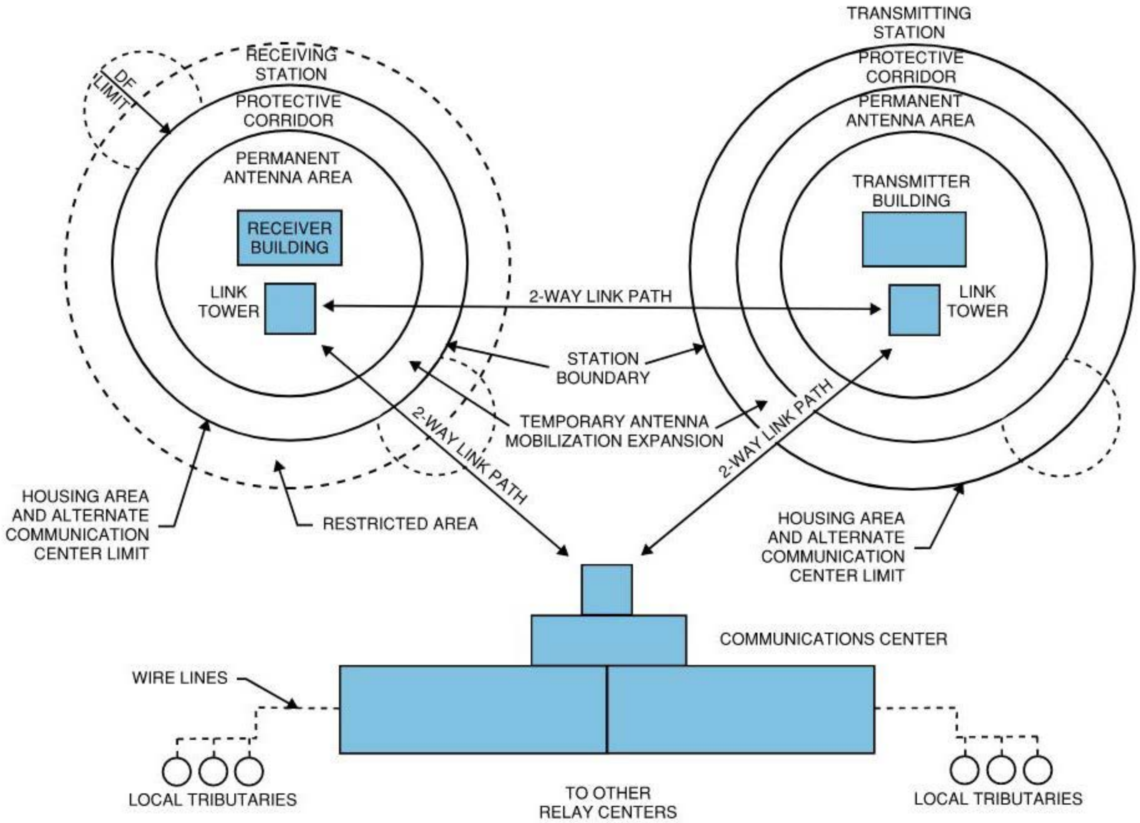
Facility	Source of Interference	Minimum Distance
Direction Finder (DF) Stations (other than Wullenweber type)	Elevated horizontal conductors	Must not subtend a vertical angle exceeding 3° at base of DF antenna
	Railroads	1/4 mile (0.4 km) from antenna
	Rivers and streams	No effect
	Major radio transmitter stations	10 miles (16 km)
	Minor or emergency radio transmitter stations	1 mile (1.6 km)
	Housing areas	1,500 feet (457 m) from DF site
Direction Finder (DF) Stations (other than Wullenweber type)	Ambient interference	Less than 3µV/meter throughout desired frequency range
Communications centers and terminal equipment building	Conform to the minimum separations from Receiver Station as given above	
Control Link Facilities	Separation between RF building and antennas	Max distance 300 feet (91 m)
	Separation between RF building and operations building	Max distance 1,500 feet (457 m)

2-5.7 Layout.

Technical details relating to the location and orientation of buildings are provided in the MESEP and furnished to the designer for adaptation to the site. The arrangement of facilities at a communication station varies according to the mission. Consider the functions of each facility in planning the layout. The locations of buildings are determined in relation to the antenna locations.

Site operating buildings, such as transmitter and receiver buildings, and the terminal point of transmission lines as close to the center of the station or antenna field as possible. Locate support buildings near the station boundary. Where radio interference is a problem, locate roads and parking areas to not have traffic interfere with reception at receiver stations. Orient buildings to provide maximum economy in heating and cooling and to keep paving to a minimum. Site the facility such that adjacent roadway traffic does not result in vehicular contact with the facility perimeter security fence or any external component of the mechanical or electrical systems. Figure 2-1 is a schematic representation of a typical major communication station system.

Figure 2-1 Typical Major Communication Station



2-6 BLACK START SYSTEMS CAPABILITIES.

Black Start capability as defined by National Renewable Energy Laboratory:

> *"Black start is the ability of generation to restart parts of the power system to recover from a blackout. This entails isolated power stations being started individually and gradually reconnected to one another to form an interconnected system again. It is used when the grid experiences a blackout and must be restarted from scratch. As such, black start is a critical resource for maintaining the reliability and resilience of the electric power system and is central to system restoration and recovery plans for system operators."*

For C5ISR facilities, this pertains not only to electrical systems but mechanical systems. The building must be able to be disconnected from its main utility power supply and provide independent power to emergency power system controls, mechanical system controls and start standby power systems. This requirement includes standby generators and UPS systems. Quantity and complexity of systems would be dependent on the Grade required by the mission.

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CHAPTER 3 GENERAL REQUIREMENTS

3-1 PHYSICAL SECURITY AND ANTITERRORISM.

Unless otherwise stipulated in project-specific guidance provided by the using agency or AHJ, assume that the C5ISR facility is an inhabited building in accordance with UFC 4-010-01. For any additional protective design requirements, the installation must establish explicit project-specific Design Basis Threats and Levels of Protection in accordance with UFC 4-020-01.

3-1.1 C5ISR Facilities Enhancements.

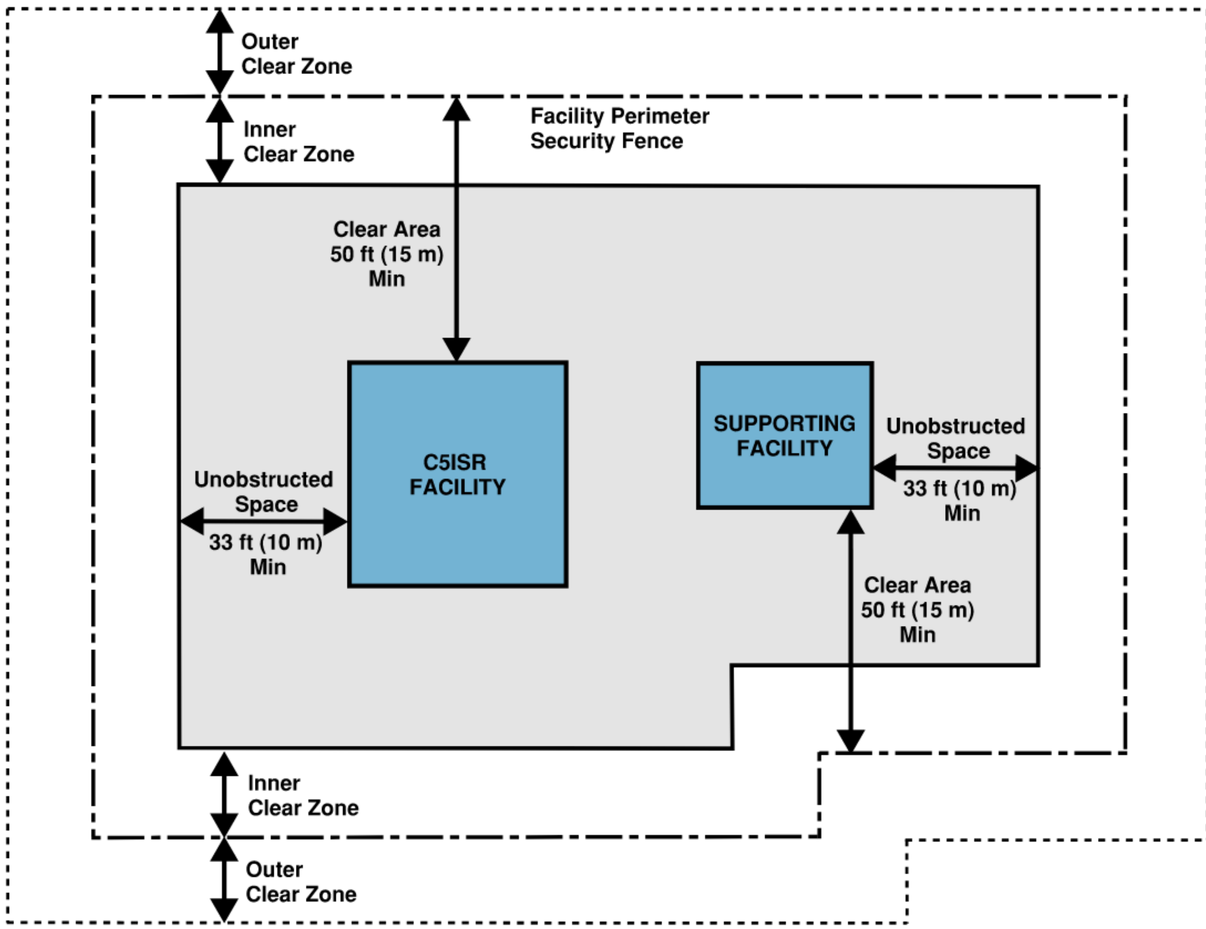
C5ISR facilities contain assets that are critical to the facility’s mission and personnel. The Design Basis Threat analysis must consider the criticality of the facility's assets to the success of the facility’s mission, including equipment located exterior to the facility, such as transformers and generators. When assets such as transformers or generators are in a standalone supporting facility structure, such as a central utility plant, the standalone structure must meet the same standards as the primary facility.

Due to the enhanced security requirements for C5ISR facilities, establish a minimum clear area around the facility and supporting structures. Clear areas must be free of all obstacles, topographical features, and vegetation exceeding 8 in. (200 mm) in height that could impede observations or provide cover and concealment of an aggressor. Provide a minimum of 50 feet (15 m) from the structures to the facility perimeter security fence. Regardless of the installation’s level of security, this requirement provides enhanced detection and assessment of potential threats. This also serves to protect the facility in the case of an insider threat as it establishes a minimum separation between the facility and the remainder of the installation. Provide a minimum unobstructed space of 33 feet (10 m) around the facility in accordance with UFC 4-010-01, Standard 2. Establish requirements for minimum clear zones on the inner and outer perimeter of the security fence in accordance with DoD and Service policy. Refer to Paragraph 3-3.5 for additional information on the perimeter security fence. See Figure 3-1 below.

3-1.2 Secure Facility Requirements.

Facilities with secure requirements must comply with UFC 4-010-05.

Figure 3-1 Facility Clear Zone and Perimeter Fence Requirements



3-2 ARCHITECTURE.

3-2.1

3-2.2 Space Planning.

3-2.2.1 General.

Provide in accordance with MESEP or as required by the individual services applicable policies and regulations.

A computer or equipment room can be defined as any room within the facility where data routing and switching equipment are installed and/or room where cable management is performed to facilitate the mission. When selecting the computer or equipment room site, avoid locations restricted by building components that limit expansion, such as elevators, building cores, outside walls, or other fixed building walls. Provide accessibility, including but not limited to pathways, corridors, and clear door openings for the delivery of large equipment to the equipment room for initial delivery, anticipated service, or replacement (see ANSI/TIA-569-D).

3-2.2.2 Equipment Spaces.

Provide in accordance with MESEP or as required by the individual services applicable policies and regulations.

3-2.2.3 Telecommunications Spaces.

Co-locate telecommunications spaces within the common secure boundaries for the areas being served to the greatest extent practicable.

3-2.3 Basic Construction Criteria.

3-2.3.1 Type of Construction.

Provide minimum Type II Construction for new C5ISR facilities.

Note: The mission can dictate a higher construction type if necessary. Also, depending on location (Outside Continental United States [OCONUS] or expeditionary structures) and for renovations of existing facilities, a lower construction type may be the only option available.

3-2.3.2 Exterior Construction.

3-2.3.2.1 Construction Type.

Facility construction type must be in accordance with Appendix A-3 – Data Center Facility Grading Requirements and the Facility Grade. Reference Section 3-5 STRUCTURAL ENGINEERING for additional requirements.

3-2.3.2.2 Roofs.

Provide Class A roofing as a minimum. Roof penetrations are not permitted in C5ISR mission spaces and telecommunications, mechanical, and electrical rooms that support the C5ISR mission. Antenna doghouses are considered an extension of the facility roof.

Design antenna platforms to be located at a height above the roof to facilitate replacement or repair of roof system without removal of antenna platform structure.

3-2.3.3 Interior Construction.

3-2.3.3.1 Partitions.

At the perimeter of computer rooms and at walls separating computer rooms, provide walls which span from floor slab (true floor) to underside of floor above or roof deck (true ceiling). Coordinate thicknesses to accommodate fully recessed electrical, mechanical and fire safety items (for example, switches, outlets, controllers, fire extinguisher cabinets, piping). Where partitions touch a deck or vertical structural members, provide a joint isolator to prevent the transfer of vibration and structural loads. Design walls and other structural elements for minimum deflection and securely fastened with isolation from all mechanical units and isolation pads or caulking at the top of the partitions.

Coordinate thermal insulation and vapor retarders required for interior partitions with humidity control requirements. Refer to Paragraph 3-6.5.8. Wood stud or other combustible interior framing is prohibited.

3-2.3.3.2 Permanent (Fixed) Flooring.

Provide in accordance with UFC 1-200-01 and UFC 3-101-01 requirements.

3-2.3.3.3 Raised Flooring - Construction.

Raised flooring must conform to the requirements of NFPA 75 and ANSI/TIA-569-D. The flooring system must be a rigid grid bolted grid (stringer) of computer-grade, all steel construction, or as required by the MESEP. Steel or concrete-filled steel flooring panels are acceptable. Galvanized steel components are not permitted. All air supply panels, and similar inserts, must be flush with the flooring surface. Install in accordance with MIL-HDBK-419A, Volumes 1 and 2.

Where under floor cooling is utilized, use floor tile cuts only to accommodate cabinet vents, cooling systems, or route cables from under floor to above floor. In all cases, design floor tile openings to seal, as tight as possible, against the penetrations to minimize loss of under floor air pressure. Use brushes, flaps, or other methods to contain static air pressure. Place floor tile cuts for cabinets under the cabinets or in other locations where the floor tile cut will not create a tripping hazard. Place floor tile cuts for racks either under the vertical cable managers between the racks or under the rack (at the opening between the bottom angles). Generally, placing the floor tile cut under the vertical cable managers is preferable as it allows equipment to be located at the bottom of the rack. Provide access floor tile cuts with edging or grommets along all cut edges. If the edging or grommets are higher than the surface of the access floor, install them so as not to interfere with the placement of racks and cabinets. Do not place the edging or grommets where the racks and cabinets normally contact the surface of the access floor. In the case of down-flow air conditioning (AC) systems where the access flooring is being used as an air distribution plenum, limit floor tile cuts in both size and quantity to ensure proper airflow. In addition, floor tiles with cement cores must have their exposed cut edges sealed to prevent core material from being blown into the computer room. Complete floor installation before mechanical testing and balancing, including all cuts and subsequent sealing.

3-2.3.3.4 Raised Flooring – Depth.

Raised access floor depth must consider future flexibility, with space for future re-configuration and addition of cabling and conduits. The design must ensure ample space is reserved for air distribution if underfloor air distribution is used.

Air Force Facilities: Provide a minimum raised access floor height of 24 in. (610 mm) where underfloor air distribution is utilized.

3-2.3.3.5 Ceilings.

Ceiling design must be consistent with lighting, air conditioning, ventilation, cable tray layout, acoustical treatment, and fire protection requirements. The minimum height of the room is 8.5 feet (2.6 m) from the finished floor to any obstruction, such as sprinklers, lighting fixtures, overhead cable trays, or cameras. Cooling requirements or racks/cabinets taller than 7 feet (2.1 m) may dictate higher ceiling heights. Maintain a minimum of 18 in. (460 mm) vertical and horizontal clearance from sprinklers. In the uninterruptible power supply, transmitter, and similar equipment spaces where heat dissipation is a design factor, a clear height of 10 feet (3 m) is required.

If suspended ceilings are installed, provide clean room tile in all computer rooms. To support the items hanging below the suspended ceiling, provide a structural ceiling grid with a hanging capacity of 25 lb/square foot (1197 N/m^2) and a point load capacity of 132 lb. (60 kg) at a minimum. Structural requirements and systems to be supported off the ceiling grid may require a higher hanging and point load capacity.

3-2.3.3.6 Doors.

For computer rooms and entrance rooms, doors must meet the minimum dimensions of the Engineering Systems Grading Checklist and must be sized to accommodate the largest expected equipment. The door must have no door sills and be hinged to open outward (code permitting). Doors must be fitted with locks and have either no fixed center posts / mullions or be provided with removable center posts / mullions to facilitate access for large equipment.

For computer rooms and entrance rooms, doors and frames must be acoustically treated to provide acoustic separation between computer rooms and program spaces, as required by the MESEP.

3-2.3.3.7 Windows.

No exterior windows are permitted in computer rooms, entrance rooms, equipment rooms, watch floors, or in other spaces defined by the MESEP or applicable security criteria.

3-2.3.3.8 Finishes.

Where wall terminations are to be used for protectors and termination hardware, cover adequate wall space for all anticipated protectors and termination hardware with 3/4 in. (19 mm) fire-retardant-treated plywood. The backboard must be 48 in. (1200 mm) x 96 in. (2400 mm) sheets, mounted vertically, and with the bottom of the plywood mounted 6 in. (150 mm) above finished floor (AFF) with the best side toward the room with markings visible. Plywood must be permanently fastened to the wall using wall anchors utilizing galvanized, zinc-plated, or stainless-steel hardware with a flat head. The finished installation must have a flush appearance with countersunk screw heads to prevent the splitting of the plywood. Drywall screws are not acceptable. Plywood must not be painted, stained, or otherwise finished so that the rating markings remain visible. Finish equipment rooms and related walls with a particulate-free, water-based epoxy paint finish, smooth finish. Before painting, the drywall board must be sealed with a compatible sealing primer.

Completely seal all penetrations in perimeter walls where the wall meets the deck (structure) above, following all security, acoustic, and fire protection requirements. All penetrations in the perimeter walls must be completely sealed, following all security, acoustic, and fire protection requirements.

3-2.3.4 Special Space Requirements.

3-2.3.4.1 Clearances.

Equipment paths from exterior doors and loading areas to computer rooms and equipment spaces must be sized to accommodate the movement of the largest anticipated piece of equipment.

3-2.3.4.2 Acoustical Treatment.

Provide as required by the MESEP.

For Army facilities: Meet the noise abatement requirements of DA PAM 40-501. The noise level must not expose the occupants to sound levels above those shown in MIL-STD-1472, MIL-STD-1474, and DA PAM 40-501. Sound pressure levels within the computer room must not exceed 60 dBA. The facility design and materials must interrelate and optimize the following factors: arrangement and spacing of the engines; acoustical insulation and design of exhaust and intake systems; and acoustical characteristics of the building construction.

3-2.3.4.3 Firestopping.

Provide in accordance with UFC 3-600-01.

3-2.3.4.4 Shielding.

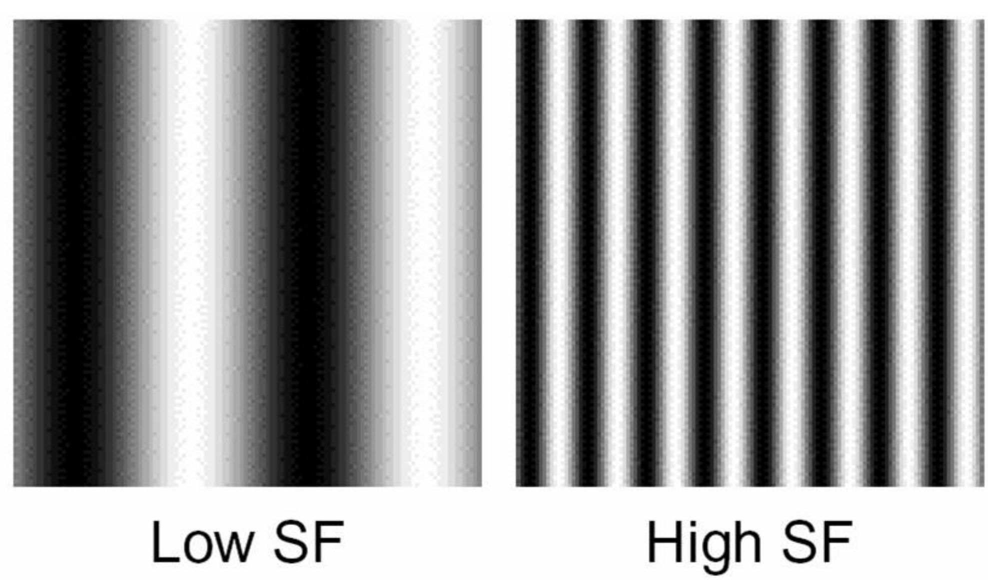
Provide in accordance with TEMPEST Countermeasures Review or as required by the MESEP.

3-2.3.4.5 Windowless Operating Environments (Command and Control / Operations Centers)

C5ISR facilities are mission critical facilities that maintain operations during severe weather and, in worst case, war. Some facilities may be operated and occupied 24 hours a day, 7 days a week. Some facilities support remote wartime operations with operators transitioning from wartime environments (remotely) to a peacetime environment (in person) once they leave the facility. The continuous operation of the facility and transitioning from wartime to peacetime environments makes them a high stress work environment. Many spaces within a C5ISR facility contain sensitive information, and, therefore, may not include windows. This type of environment can be stressful given its claustrophobic nature. Consider providing large frame TVs within the spaces with a continuous, scanning camera feed of the outside. This will allow occupants to maintain their bearings, observe the weather and reduce the stress caused by a confined environment. Visual relief in the form of views of nature may not be possible in the operations area but is highly effective in break areas. Every few hours, analysts need to reset their visual system with long distance viewing (relaxes the eye muscles) ideally with fractal patterns, best provided by views of nature. Visual relaxation is as important as mental relaxation for this high stress visual environment.

For spaces with continuous operation special consideration of interior patterns must be considered to reduce stress. Avoid the use of carpets, art, wall finishes or systems furniture with high spatial frequencies. High spatial frequencies have been associated with exacerbating stress and reducing cognitive functions.

Figure 3-2 Spatial Frequency Example



3-3 CIVIL ENGINEERING.

3-3.1 Siting Procedure.

Developing the optimum site configuration requires civil and electronic equipment engineering coordination. The designer must be provided with preliminary site layouts developed by the electronic system engineering activity showing the site dimensions, schematic building layout, utility requirements, access road layout, direction and number of transmission paths, size, and layout of supporting structures, and unique design considerations for optimum performance of the electronic system.

Provide for future expansion as required by the MESEP. If there are no specific requirements, plan for expansion as a matter of course. Locate support facilities near the boundary of the station to permit expansion without impacting the antenna area. Construction of separate structures or self-contained elements is preferred to expansion by extension of existing facilities.

3-3.2 Site Plan Components.

The designer is responsible for preparing a final site plan using the preliminary site layout prepared by the electronic system engineering activity, information from the site survey, and the criteria herein. In addition to the location of facility components, incorporate the following site components into the final plan as applicable:

- Site boundary and property lines
- Survey base line and benchmarks
- Access roads and parking areas
- Elevation, azimuth, and coordinates for the center of each antenna
- Underground utilities and services
- Existing buildings and facilities

In general, electronic facilities (structures) are similar to other shore facilities, and the criteria in UFC design manuals are applicable.

3-3.3 Surface and Subsurface Drainage.

Utilize surface drainage, such as swales, to the greatest extent possible. Design swales for minimal velocity to avoid erosion to swales or downstream receiving channels. Design storm sewer systems and stormwater management infrastructure based on a storm with a 50-year design frequency. Metallic pipe and reinforced concrete pipe may not be permitted at some sites. Restrictions on pipe material will be indicated in project MESEP. Storm drain piping may not be routed through an antenna ground plane.

Consider water table conditions at the site in the building design. Design the lowest level of the building and any utility piping above the water table. If the building has one or more subgrade floors, additional efforts may be required to protect it from water infiltration or the effects of seasonal variations in the water table.

3-3.4 Vehicular and Pedestrian Circulation.

Provide access roads, parking areas, pedestrian walks, and other traffic areas adjacent to buildings with bituminous concrete (asphalt) or Portland cement concrete surface. Design access roads from the nearest major arterial road to the site having a minimum height clearance of 14 feet (4.3 m). Design access roads to the site to allow for deliveries such as heavy components of the technical building systems, including mobile cranes, in any weather conditions. Avoid using curb and gutter unless necessary based on project or site-specific design constraints.

Provide guardrail where the work area is 4 feet (1.2 m) or more above a lower level.

3-3.5 Site Security Considerations.

Provide a facility layout that is compatible with an overall installation security plan and considers the location of guard posts, patrols, and security response forces; the location and characteristics of intrusion detection systems; facility access control; and natural factors.

External security requirements, in most cases, depend on the internal security measures provided in the facility design and the type of protection required. Normally, external considerations, including building location, orientation, and use of protective barriers and lighting, are developed as part of the facility's security plan and specified in the MESEP. The mode of operation, level of security, and designer's responsibility for particular security elements must be designated in the MESEP.

3-3.5.1 Perimeter Fencing.

Generally, chain-link fencing is used for permanent areas. General-purpose barbed tape and concertina wire are used for temporary installations or where the terrain does not allow the construction of chain-link fencing. The following requirements are the minimum for normal protection:

- Establish clear zones, clear areas, and locate the facility perimeter security fence in accordance with Paragraph 3-1.
- Provide chain-link fence fabric a minimum of 7 feet (1.9 m) high unless project-specific requirements dictate otherwise. Provide a fence topped by a 45-degree outrigger that is 15 to 18 in. (380 to 460 cm) long. Provide three evenly spaced strands of barbed wire strands attached to the outriggers. Provide grounding for all fence fabric and barbed wire strands.

- Protect utility openings, covers, sewers, culverts, tunnels, and other subsurface routes penetrating the fence line.

- Provided the minimum number of gates and perimeter entrances required for safe and efficient operation.

- Where security fencing is adjacent to vehicular travel lanes or parking areas, provide wheel stops, curbs, bollards, or guardrails as required.

- Provide guard shelters where required by the MESEP.

3-3.5.2 Exterior Equipment.

Locate all mechanical equipment, generators, fuel tanks, or other exterior equipment within the perimeter security fence and secure from public access.

3-3.6 Utility Services.

Refer to the MESEP for project-specific restrictions on the use of metallic pipe and reinforced concrete pipe. Refer to Section 3-6.12 for plumbing requirements.

3-4 LANDSCAPE ARCHITECTURE.

Provide landscaping and ground cover only to the extent that they reduce site maintenance. Vegetation must not interfere with antennas and ground mats. Some site areas must be kept free of vegetation. Maintain clear zones free of vegetation on either side of perimeter security fencing in accordance with Paragraph 3-3.1. Consult the electronic system engineering activity for additional restrictions.

Do not provide permanent irrigation for lawn areas or plantings.

3-5 STRUCTURAL ENGINEERING.

3-5.1 Risk Category.

Unless otherwise stipulated in project-specific guidance provided by the using agency or AHJ, assume that the C5ISR facility is a building or other structure having DoD mission-essential command, control, primary communications, data handling, and intelligence functions that are not duplicated at geographically separate locations, as designated by the using agency, and therefore classified as Risk Category IV, as defined by UFC 3-301-01.

3-5.2 Live Loads.

Use a minimum design floor uniform live load of 250 psf (12 kPa). For elevated floors, assume an additional uniform live load of 50 psf (2.4 kPa) minimum to account for the weight of overhead hanging equipment in spaces below. Coordinate with the user to determine if the actual anticipated equipment exceeds these minimum uniform live loads and design the floors accordingly.

3-5.3 Seismic Criteria.

Ensure that non-structural components are laterally braced as required for seismic load stability in accordance with UFC, building code provisions, and as described in this standard. Careful analysis of these requirements must be addressed in the planning/DD1391 development phase. Coordinate additional bracing requirements to avoid interference with items to be installed post construction, such as cabling, conduit raceways, and other infrastructure for electronic equipment.

Assign components required to support and sustain continued operations of the C5ISR mission a component Importance Factor of I_p = 1.5. Refer to UFC 3-301-01 for additional information.

3-5.4 Minimum Concrete Thicknesses.

Provide a minimum concrete thickness of 5 in. (127 mm) for slabs-on-grade. Coordinate minimum concrete thickness with any project security noise reduction requirements. Coordinate minimum concrete thickness with Paragraph 3-7.8 Grounding and Bonding requirements.

For elevated floor construction using a concrete-filled metal deck structure, provide a minimum 4 in. (102 mm) concrete thickness above the flutes of the metal deck to allow equipment anchorage using post-installed anchors.

3-5.5 Raised Flooring Minimum Loading Requirements.

Minimum loading and allowable deflection requirements for raised access flooring are as follows:

- Rolling load (access floor tile): 1,500 lb (680 kg). Local surface deformation 0.02 in. (0.5 mm). Total permanent set 0.04 in. (1 mm).
- Impact Load (access floor tile): 175 lb (80 kg). Drop weight, dropped from 12 in. (305 mm) height on 1 in^2 (645 mm^2) local surface with maximum deformation 0.06 in. (1.5 mm).
- Concentrated Load (access floor tile): 1500 lb (680 kg). Load on 1 in^2 (645 mm^2) point with maximum deflection 0.08 in. (2 mm) anywhere on the panel.
- Uniform Load (access floor system): 250 psf (12 kPa). Load rating of the access floor system, including panels, pedestals, and stringers.

3-5.6 Raised Flooring Seismic Requirements.

Design raised access floors for seismic considerations in accordance with UFC 3-301-01 or UFC 3-301-02 as applicable or ASCE/SEI 7 special access floor requirements, whichever is more stringent. Additionally, perform an in-structure response analysis to compute the coupled response of a raised access floor, then use it to develop response spectra for equipment mounted on the raised access floor. Compute the overturning of equipment mounted on the computer room floor, and if required, provide restraints for Seismic Design Categories C through F. Provide positive mechanical attachments as required to prevent overturning using direct fasteners or adhesive to the substrate. Treat raised access floors as Designated Seismic Systems.

3-6 MECHANICAL ENGINEERING.

All mechanical criteria from UFC 3-401-01 that apply to DoD facilities also apply to C5ISR facilities. Only items specifically applicable to C5ISR facilities are covered in this section.

3-6.1 Outside Design Conditions.

C5ISR spaces must utilize outside design temperature criteria for Specialized Technical Requirements.

3-6.2 Indoor Design Conditions.

C5ISR facilities have spaces with stringent indoor air temperature and humidity requirements.

3-6.2.1 C5ISR Space Temperatures.

C5ISR spaces with data equipment must always comply with ASHRAE Thermal Guidelines for Data Processing Environments. Air temperature and humidity must comply with the “Recommended” requirement. Liquid cooling temperature must comply with Class W17/W27. Heating, Ventilating, and Air-Conditioning (HVAC) systems and controls must account for temperature rise during primary power loss.

Comply with user criteria and MESEP requirements where more stringent.

3-6.2.2 Battery and UPS Space Temperatures.

Temperatures for battery and UPS rooms with batteries must be in accordance with the requirements of UFC 3-520-05.

3-6.2.3 Generator Room Temperatures.

Temperatures for generator rooms must be in accordance with UFC 3-540-01.

3-6.3 Redundancy and Resilience.

Mechanical systems serving C5ISR functions must meet the Facility-required Grade to provide the required level of redundancy and Resilience. Systems that do not serve C5ISR functions are not required to comply with the facilities mission classification.

To increase redundancy in the mechanical plant, use automatic transfer switches (ATS), manual transfer switches (MTS) or static transfer switches (STS) on individual mechanical equipment to provide a dual power path. Dual power feed mechanical equipment is an acceptable solution to reduce the required square footage. An ATS or STS must be provided for Grade 4 facilities to meet the fault tolerant requirements. An MTS is acceptable for Grade 3 facilities.

Air Force Facilities: Manual transfer switches are not allowed.

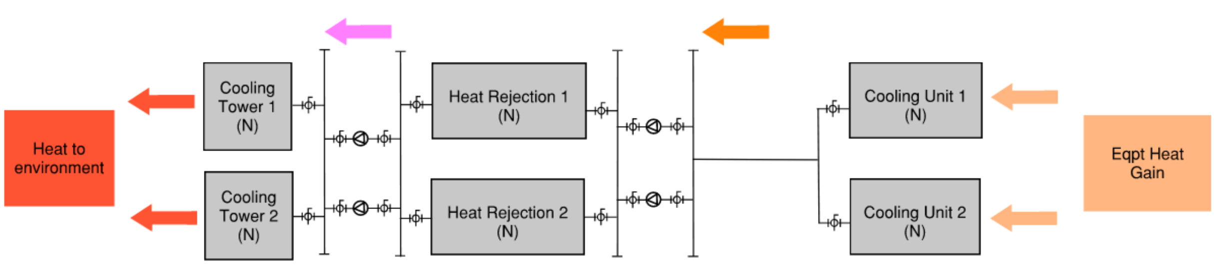
3-6.3.1 Grade 1 Mechanical Systems.

Not applicable.

3-6.3.2 Grade 2 Mechanical Systems.

Grade 2 systems provide critical equipment redundancy. Equipment serving a critical space must feature equipment N+1 redundancy. Redundancy must allow for routine maintenance to any piece of equipment without affecting the critical services being provided with cooling. Refer to Figure 3-3 for a Grade 2 common cooling heat rejection schematic and Figure 3-4 for a Grade 2 dedicated cooling heat rejection schematic. The size of equipment (% of N) can vary, but the system must maintain a minimum of N+1 redundancy. The systems mentioned represent typical cooling approaches but are not an exhaustive list of possible systems. For Grade 2 systems, utilize N+20% redundancy where N is met by five or more components.

Figure 3-3 Grade 2 Common Cooling Heat Rejection Schematic (N+1)



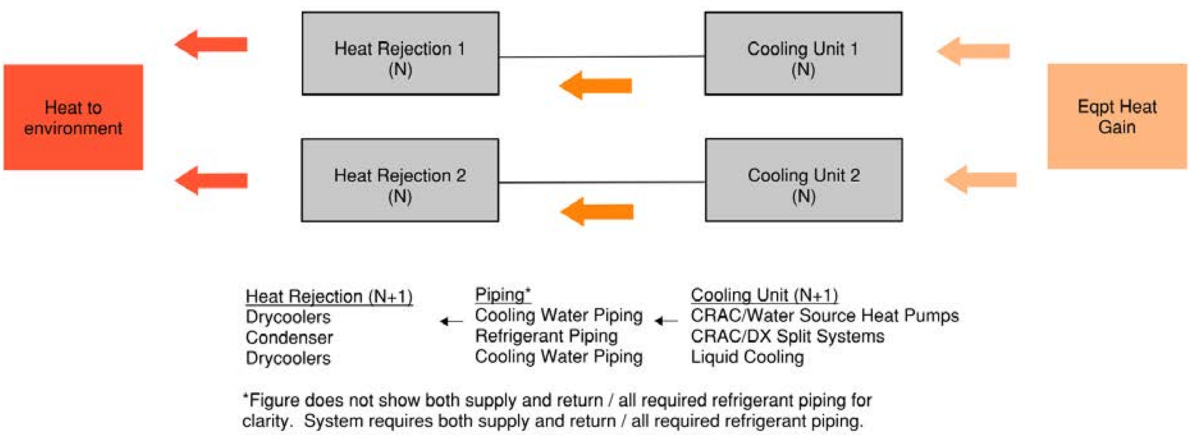
Cooling Tower / Condenser Water (N+1)	Heat Rejection (N+1)	Piping w/ headed pumps*	Cooling Unit (N+1)
Cooling Tower w/ headered pumps	Water Cooled Chiller Plant	Chilled Water	CRAH/Fan Coils
NA	Air Cooled Chiller Plant	Chilled Water	CRAH/Fan Coils
NA	Closed Circuit Cooling Tower	Condenser Water	CRAC/Water Source Heat Pumps
NA	Drycoolers	Cooling Water	CRAC/Water Source Heat Pumps
NA	Drycoolers	Cooling Water	Liquid Cooling

*Figure does not show both supply and return piping for clarity. System requires both supply and return piping.

Availability at Critical Technical Load	
System	Availability
Grade 2 Common Heat Rejection - Water Cooled Chiller (Cooling Tower) w/ CRAH/FCU	0.999999
Grade 2 Common Heat Rejection - Air-Cooled Chiller w/ CRAH/FCU	0.999999
Grade 2 Common Heat Rejection - Evaporatively Cooled w/ CRAC/WSHP	0.999999
Grade 2 Common Heat Rejection - Drycooler w/ CRAC/WSHP	0.999999
Grade 2 Common Heat Rejection - Drycooler w/ Liquid Cooling	0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

Figure 3-4 Grade 2 Dedicated Cooling Heat Rejection Schematic (N+1)



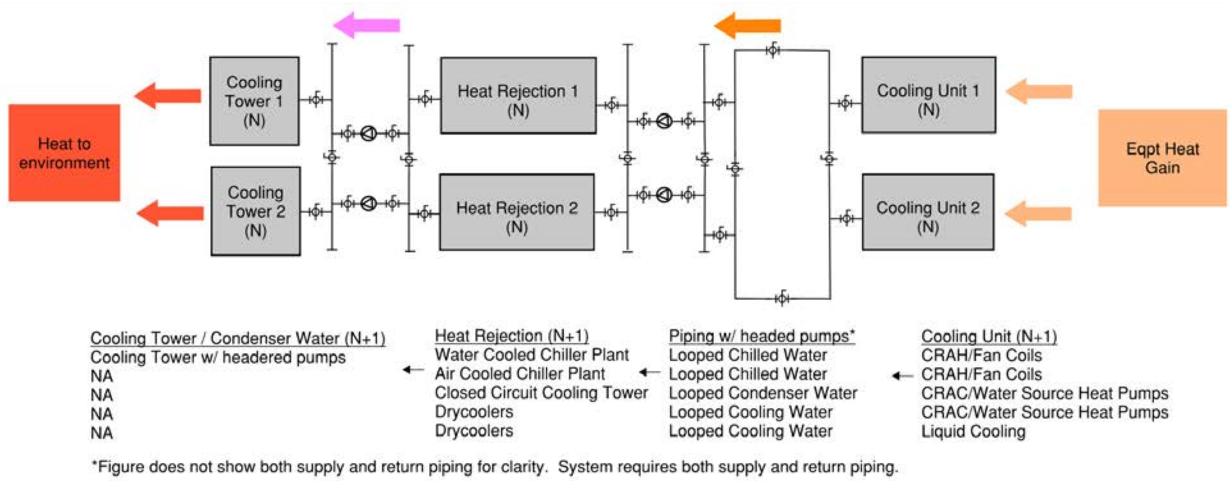
Availability at Critical Technical Load	
System	Availability
Grade 2 Dedicated Cooling – Drycooler w/ CRAC/WSHP	0.999999
Grade 2 Dedicated Cooling – Condenser w/ CRAC/DX Split System	0.999999
Grade 2 Dedicated Cooling – Drycooler w/ Liquid Cooling	0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

3-6.3.3 Grade 3 Mechanical Systems.

Grade 3 systems are concurrently maintainable. Concurrently maintainable mechanical systems must maintain critical space temperature and humidity at design conditions while allowing for active maintenance of any unit or utility path. Redundancy must enable the isolation of any item of equipment as required for essential maintenance without affecting the services being provided with cooling. Refer to Figure 3-5 for a Grade 3 common cooling heat rejection schematic and Figure 3-6 for a Grade 3 dedicated cooling heat rejection schematic. The size of equipment (% of N) can vary, but the system must maintain a minimum of N+1 redundancy. The systems mentioned represent typical cooling approaches but are not an exhaustive list of possible systems. For Grade 3 systems, utilize N+20% redundancy where N is met by five or more components.

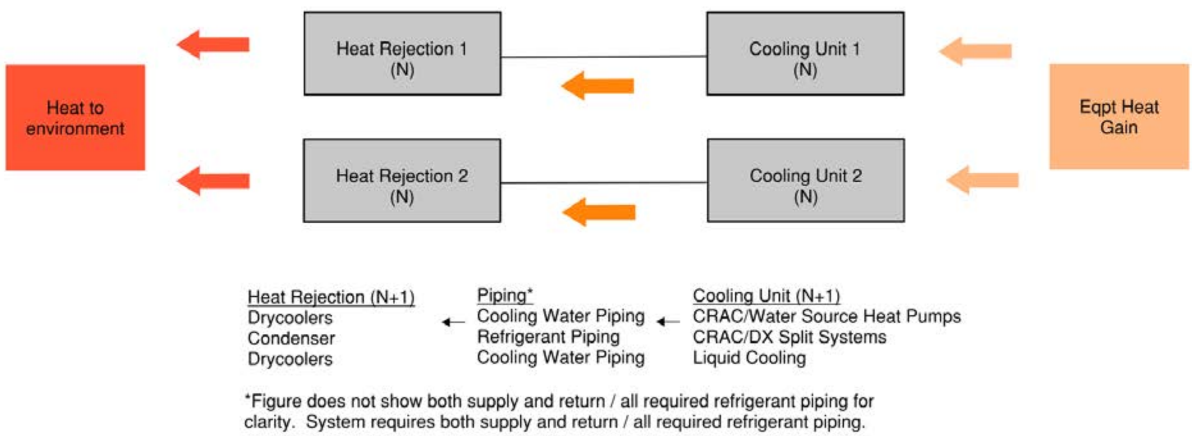
Figure 3-5 Grade 3 Common Cooling Heat Rejection Schematic (N+1)



Availability at Critical Technical Load	
System	Availability
Grade 3 Common Heat Rejection - Water Cooled Chiller (Cooling Tower) w/ CRAH/FCU	0.999999
Grade 3 Common Heat Rejection - Air-Cooled Chiller w/ CRAH/FCU	0.999999
Grade 3 Common Heat Rejection - Evaporatively Cooled w/ CRAC/WSHP	0.999999
Grade 3 Common Heat Rejection - Drycooler w/ CRAC/WSHP	0.999999
Grade 3 Common Heat Rejection - Drycooler w/ Liquid Cooling	0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

Figure 3-6 Grade 3 Dedicated Cooling Heat Rejection Schematic (N+1)



Availability at Critical Technical Load	
System	Availability
Grade 3 Dedicated Cooling – Drycooler w/ CRAC/WSHP	0.999999
Grade 3 Dedicated Cooling – Condenser w/ CRAC/DX Split System	0.999999
Grade 3 Dedicated Cooling – Drycooler w/ Liquid Cooling	0.999999

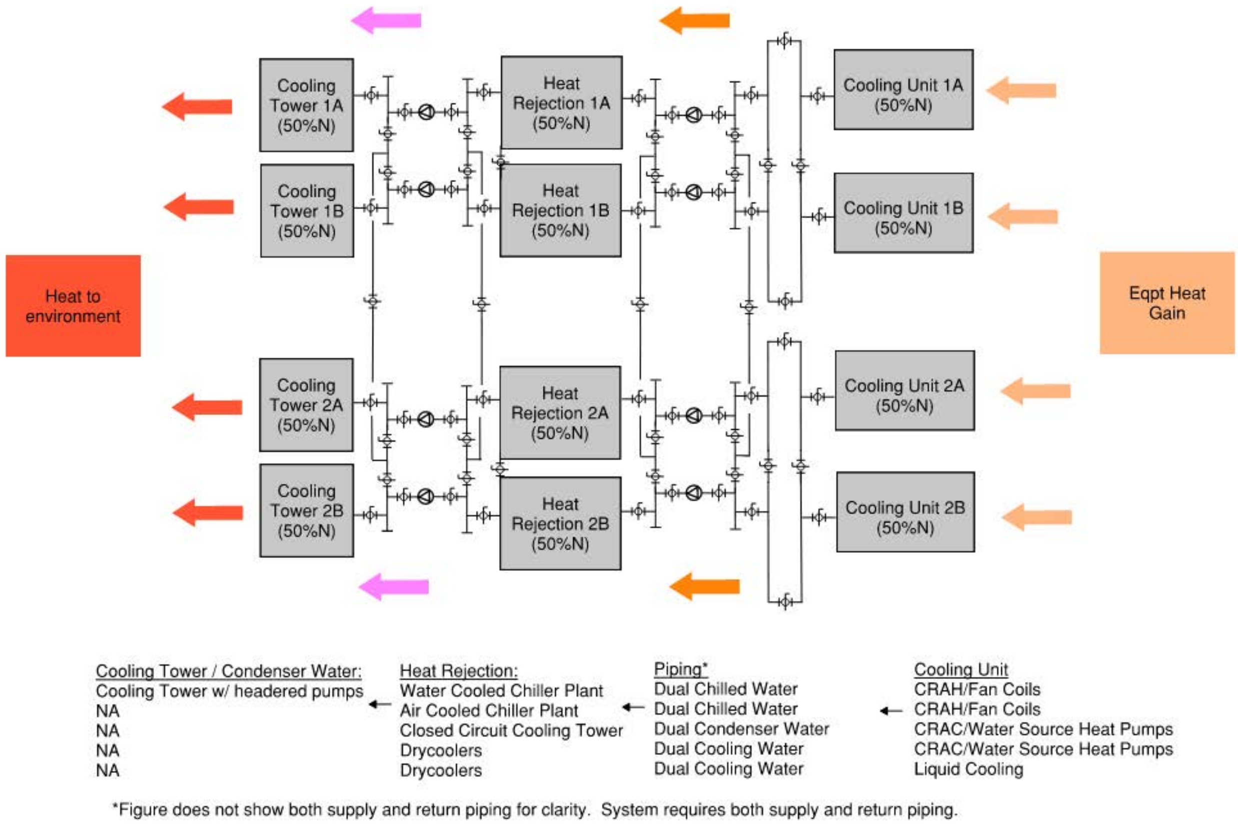
1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

3-6.3.4 Grade 4 Mechanical Systems.

Grade 4 systems are fault tolerant. Fault-tolerant mechanical systems must maintain critical space temperature and humidity at design conditions while allowing failure of / or service to one electrical switchboard. Redundancy must enable the isolation of any item of equipment as required for essential maintenance or failure without affecting the services being provided with cooling. Refer to Figure 3-7 for a Grade 4 common cooling heat rejection schematic with 2N redundancy, Figure 3-8 for a Grade 4 common cooling heat rejection schematic with N+2 redundancy, Figure 3-9 for a Grade 4 dual path heat rejection schematic, and Figure 3-10 for a Grade 4 dedicated cooling heat rejection schematic. The size of equipment (% of N) can vary, but the system must have a minimum of N+2 redundancy. N+1 redundancy must be maintained if any unit is lost. The systems mentioned represent typical cooling approaches but are not an exhaustive list of possible systems.

For Grade 4 systems with N+2 redundancy, utilize N+40% redundancy where N is met by five or more components.

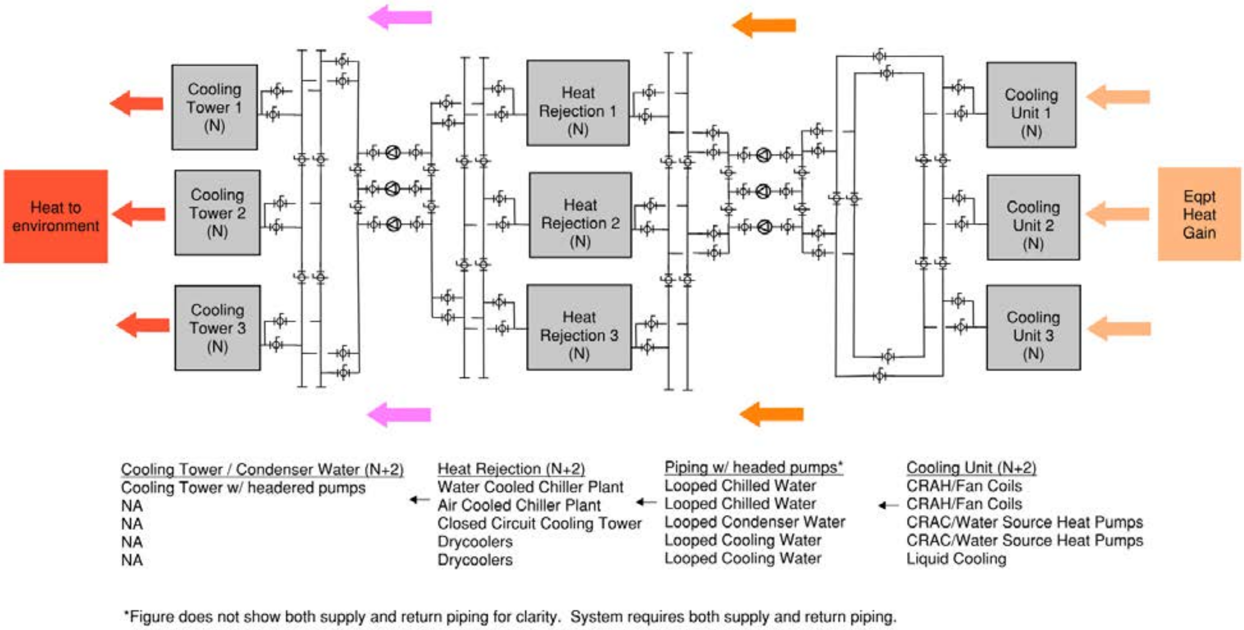
Figure 3-7 Grade 4 Common Cooling Heat Rejection Schematic (2N)



Availability at Critical Technical Load	
System	Availability
Grade 4 Common Heat Rejection (2N) - Water-Cooled Chiller (Cooling Tower) w/ CRAH/FCU	0.999999
Grade 4 Common Heat Rejection (2N) - Air-Cooled Chiller w/ CRAH/FCU	0.999999
Grade 4 Common Heat Rejection (2N) - Evaporatively Cooled CRAC/WSHP	0.999999
Grade 4 Common Heat Rejection (2N) - Drycooler w/ CRAC/WSHP	0.999999
Grade 4 Common Heat Rejection (2N) - Drycooler w/ Liquid Cooling	0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

Figure 3-8 Grade 4 Common Cooling Heat Rejection Schematic (N+2)



Availability at Critical Technical Load	
System	Availability
Grade 4 Common Heat Rejection (N+2) - Water-Cooled Chiller (Cooling Tower) w/ CRAH/FCU	0.999999
Grade 4 Common Heat Rejection (N+2) - Air-Cooled Chiller w/ CRAH/FCU	0.999999
Grade 4 Common Heat Rejection (N+2) - Evaporatively Cooled w/ CRAC/WSHP	0.999999
Grade 4 Common Heat Rejection (N+2) - Drycooler w/ CRAC/WSHP	0.999999
Grade 4 Common Heat Rejection (N+2) - Drycooler w/ Liquid Cooling	0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

Figure 3-9 Grade 4 Dual Path Heat Rejection Schematic (N+2)

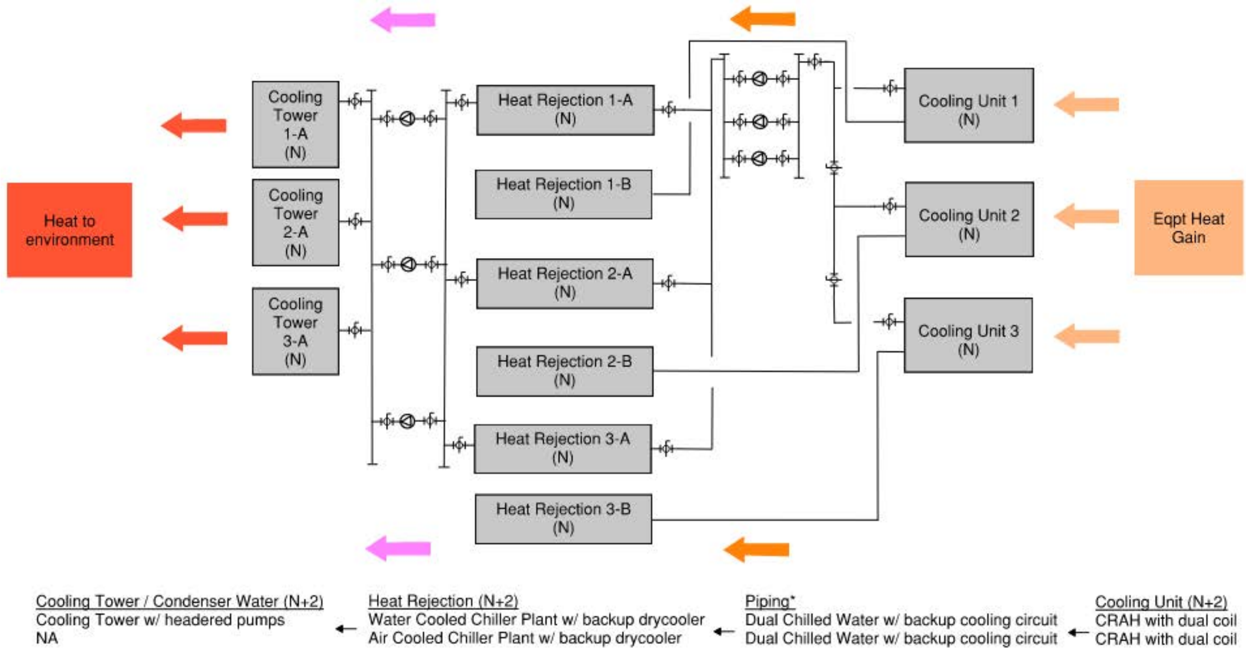
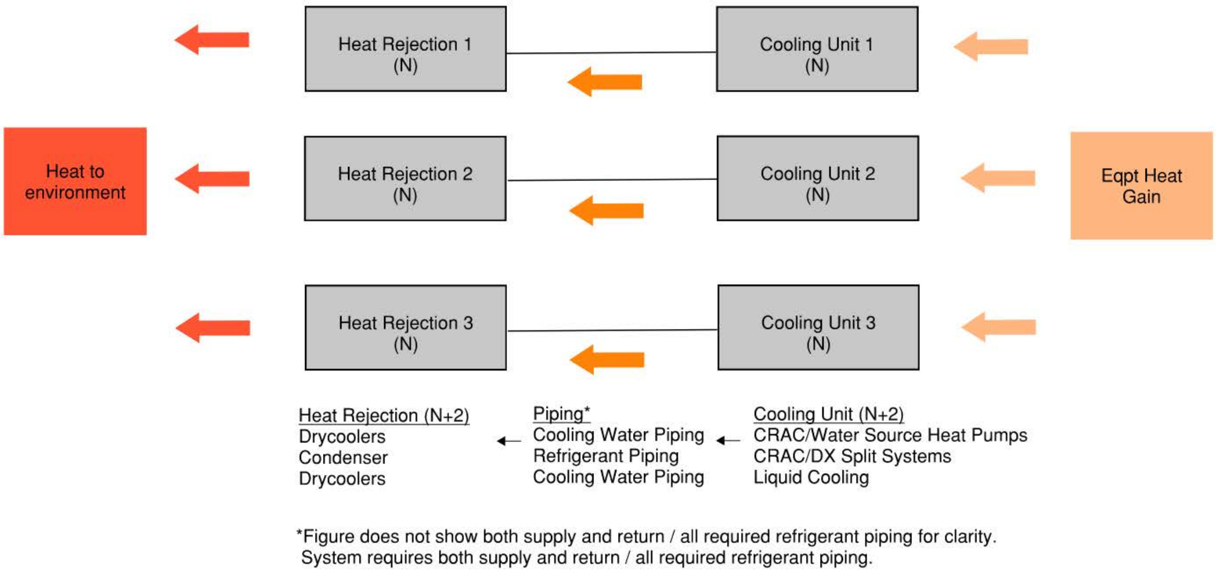


*Figure does not show both supply and return / all required refrigerant piping for clarity.
System requires both supply and return / all required refrigerant piping.

Availability at Critical Technical Load	
System	Availability
Grade 4 Dual Path Cooling – Water-Cooled CRAC/WSHP	0.999999
Grade 4 Dual Path Cooling – Air-Cooled CRAC/DX Split System	0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

Figure 3-10 Grade 4 Dedicated Cooling Heat Rejection Schematic (N+2)



Availability at Critical Technical Load	
System	Availability
Grade 4 Dedicated Cooling – Water-Cooled CRAC/WSHP	0.999999
Grade 4 Dedicated Cooling – Air-Cooled CRAC/DX Split System	0.999999
Grade 4 Dedicated Cooling – Liquid Cooling	0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, table 10-4.

3-6.4 Air Conditioning Loads.

Equipment heat loads must be established during the planning/DD1391 development process. When a MESEP is available, use it for equipment loads. When a MESEP is not provided, the mission owner must verify, document, and approve electrical equipment loads during design.

3-6.5 HVAC System Design.

HVAC systems selected for C5ISR facilities must consider proximity to service organizations and be maintainable. Equipment requirements must consider the installed environment. Utilize the most life cycle cost effective system considering available utilities, energy consumption, first cost, and maintenance cost over the life of the system. HVAC systems must be capable of meeting the specialized requirements of electronic equipment rooms. Systems must provide air filtration, positive pressurization, and humidity control.

Central utility plants are often used at larger facilities as they are typically more efficient and centralize maintenance. See paragraph 3-6.6 for Central Cooling Equipment. Smaller facilities often utilize packaged/unitary equipment. See paragraph 3-6.7 on Packaged/Unitary Cooling Equipment.

3-6.5.1 Proximity to Service Organizations.

Mechanical equipment must account for facility location and local support resources. Match the level of sophistication with regionally available service personnel expertise and procurement ability. Ensure factory certified service organizations can support the selected systems and equipment to provide regular and emergency service. Organizations must be close to the facility and be able to render service in under 8 hours. Organizations must be capable of obtaining standard replacement parts within 24 hours.

3-6.5.2 Installed Environment.

Mechanical equipment must be configured for the installed environment. Corrosive-prone locations must feature corrosion-resistant materials and coatings in accordance with UFC 1-200-01 and UFC 3-410-01. Equipment in coastal conditions must be rated for wind loads and potential damage from tropical storm wind-borne debris. Equipment in cold environments must be capable of operation in mean extreme winter temperatures and must have features to prevent freezing. Heat rejection equipment must be capable of operating at site specific humidity and dry bulb design temperatures.

3-6.5.3 HVAC System Life Cycle Cost Analysis.

Work with mission owner engineering and service design review engineer to develop three proposed systems. Systems must comply with UFC 3-410-01. Perform Life Cycle Cost Analysis (LCCA) in accordance with UFC 1-200-02 and UFC 3-410-01 of the proposed systems. Utilize system that is life cycle cost effective.

3-6.5.4 Specialized Equipment Room Characteristics.

Equipment rooms typically have high sensible heat gain and require specialized cooling equipment selection. Utilize mechanical equipment capable of operating efficiently with high sensible heat ratios. Also, consider tight temperature and humidity environmental requirements when selecting equipment and controls. Computer Room Air Conditioning Units (CRACs) and Computer Room Air Handling Units (CRAHs) offer a solution, as they are designed to meet stringent equipment room requirements. Units serving electronic equipment rooms must be dedicated to equipment rooms. Units also cannot serve both electronic equipment rooms and non-critical climate cooled rooms, as the sensible heat ratios vary significantly between them.

The use of air-side economizers is not permitted for the primary system serving equipment rooms as they make precise humidity control difficult. Economizers may be allowed for emergency cooling when approved by the mission owner and design authority review engineer.

Air Force Facilities: Economizers for emergency cooling are not allowed.

3-6.5.5 Equipment Room Cooling.

Air distribution and heat management can result in significant energy savings and improved thermal performance of equipment rooms. The design must provide good air distribution across the entire data center or equipment room and must comply with ASHRAE Thermal Guidelines for Data Processing Environments.

Equipment rooms larger than 1000 square feet (92 sm) or with cooling design loads greater than 100kW must be validated using computational fluid dynamics (CFD) modeling. The model must validate all rack inlet temperatures conform with ASHRAE Thermal Guidelines for Data Processing Environments at design load with N capacity components. The model must be submitted for review with the initial design submission or prior to the 50% design completion, whichever is soonest.

3-6.5.5.1 Traditional Equipment Room Cooling Methods.

Below-grade air distribution in the raised access floor and ducted overhead conditioned supply air have traditionally been used. While convenient, both distribution methods have challenges. Unless the equipment is specifically designed to receive raw supply air, avoid the direct connection between the air plenum and the equipment. Instead, supply air to the room through relocatable floor registers and configure equipment to draw tempered air from the room. If overhead distribution is provided, low velocity/low-pressure ductwork is desirable. Systems with overhead and underfloor air distribution air terminal devices must be located to allow the air to reach the area of the loads. When underfloor power distribution is implemented, ensure floor register air flow is not constricted due to power/network cabling. Overhead network and power distribution is preferred when using an underfloor air plenum. When electronic equipment is in a high-bay area with an overhead cable grid network, air outlets must not be located directly above electrical equipment, cabling, or power networks to facilitate good air distribution. Poor air distribution results in thermal hot spots within the space.

Underfloor air distribution with ducted return utilizes traditional underfloor plenum supply air distribution but utilizes a ducted return to eliminate hot spots that develop away from air conditioning units or at high-density racks. This method utilizes cold aisles for rack intake and hot aisles at the discharge of the racks. Locate return inlets over the hot aisles. Air returns must not be located directly above electrical equipment, cabling, or power networks to facilitate good air distribution. The use of containment structures can increase efficiency and thermal performance.

3-6.5.5.2 Alternative Equipment Room Cooling Methods.

Flooded room cool air distribution with rack containment can be used to increase energy efficiency. Flooded rooms utilize a cool air discharge of 60-68°F (15.5-20°C). The equipment room remains cool (65-72°F, [18.3-22.2°C]); air is drawn into racks by server fans which discharge to a hot aisle or directly to the return duct via rack chimneys.

Other cooling strategies, including in-row cooling units and equipment-based cooling, are also used. In-row cooling benefits from dedicated hot and cold aisles and is effective at preventing thermal hot spots caused by uneven rack loading. Equipment or rack-based cooling is gaining more attention due to its ability to remove heat from the source, increasing cooling efficiency and preventing thermal hot spots. Both in-row and equipment-based cooling may result in security concerns if secure networks are present. Secure networks require a physical separation between unsecure and secure networks. The separation requirements for in-row or equipment-based cooling may be overcome by designating the unit control system as a secure network. Secure cooling controls require approval by the mission owner, as the system cannot be tied into a non-secure building Direct Digital Control (DDC) system. All critical controls must be continuously monitored.

3-6.5.5.3 Equipment Room Cooling Coordination.

Rack location must be coordinated with the mission owner, electrical engineer, and telecommunications engineer. Where cold aisles are used, front of racks/cabinets must face each other. The rear of cabinets/racks must face each other to create a hot aisle. Where underfloor supply air is utilized, floor registers/tiles must be installed only in the cold aisles. Utilize blanking plates racks to prevent re-circulation of hot air within racks.

Air Force Facilities: Provide hot or cold aisle containment. Do not duct CRAC/CRAH units; return air chimneys are allowed.

3-6.5.5.4 Clean Agent Fire Suppression Considerations.

Equipment rooms with clean agent systems must be protected with overpressure relief dampers as required and have an exhaust system in accordance with UFC 3-600-01. See Fire Protection and Life Safety Section for smoke exhaust requirements.

3-6.5.6 Air Filtration.

Filter all outside and recirculated air. Equipment providing outside air must have a minimum of Minimum Efficiency Reporting Value (MERV) 8 prefilter with a MERV 13 final filter. Provide equipment room air conditioning units with a minimum of MERV 8 filters. Provide high-performing filters as required by the mission owner or specific equipment requirements. Utilize replaceable media filters. To extend the life of high-performing filters, use prefilters of lower efficiency upstream of higher-efficiency filters. All filter banks must have pressure switches with a dirty filter maintenance alarm when the pressure drop exceeds the maximum recommended loading.

3-6.5.7 Pressurization

Equipment rooms must be slightly positively pressurized relative to the outdoors and surrounding rooms/areas. Positive pressurization limits particulate and moisture infiltration into the equipment room.

3-6.5.8 Humidity Control.

Systems must be capable of maintaining space temperature and humidity. Work closely with the architect during the preliminary design phase to conduct a vapor barrier analysis. The vapor barrier analysis must ensure condensation does not occur in interior partitions or exterior walls.

3-6.5.8.1 Dehumidification.

A Dedicated Outdoor Air System (DOAS) is an acceptable solution to provide filtered dehumidified air to the space in accordance with UFC 3-410-01. Where outside air requirements are not large enough to justify a DOAS, outside air and space latent loads can be met by a dehumidifier controlled by a local humidistat. Do not rely on equipment room cooling units to meet the latent cooling load of outside air. Dehumidification must not rely on full load capacity of equipment as equipment rooms typically operate at part load and are built-out with racks and equipment over several years following construction completion. Avoid reheat where possible and, if required, utilize waste heat.

3-6.5.8.2 Humidification.

Electronic equipment areas require less humidification per thousand British Thermal Units (BTUs) per hour (MBH) of heating than comfort applications. Humidification needs are higher if excessive fresh air is admitted to the space, dehumidification during the cooling process is excessive, or if the humidity ratio of the outside ventilation air is less than the desired humidity ratio. When needed, consider humidifiers mounted integral to the cooling equipment or standalone wall-mounted humidifiers. Humidifiers must have automated controls and report alarms to the building control and automation system. UFC 3-410-01 does not permit atomized water and evaporative humidifiers. Protect domestic water connections to humidifiers with backflow prevention devices.

3-6.6 Central Cooling.

Central cooling is often used at C5ISR facilities. Central cooling equipment has higher efficiencies and centralized maintenance. Since cooling is required year-round, evaluate the life cycle cost effectiveness of condenser heat recovery. Condenser heat recovery can prevent simultaneous heating and cooling, resulting in significant energy savings.

Central cooling plants must include provisions to keep space temperatures within ASHRAE Thermal Guideline “Recommended” requirements for allowable temperature and humidity. Liquid cooling temperature must comply with Class W17/W27. In addition to placing cooling equipment on backup power systems, consider using thermal storage, controls on UPS power, and rapid restart chillers. If space and liquid cooling temperatures cannot be maintained within allowable ranges after primary power is lost and backup power is established, pumps can be placed on the UPS system.

3-6.6.1 Water-Cooled Chiller Plants.

Water-cooled chiller plants often result in the most energy savings. However, water-cooled plants may have a higher overall cost of ownership due to the cost of makeup water, chemical treatment, and replacement cost. Water-cooled plants also require more maintenance. Locate water-cooled chillers and pumps indoors. Consider physical separation of chillers with fire-rated walls to safeguard against the loss of all cooling in the event of a fire in one of the chiller rooms. Chiller rooms must comply with ASHRAE Standard 15 and protective provisions required for Class A2L refrigerants, where used. Chilled water pumps must be headered and match the plant's redundancy scheme. Condenser water pumps must also be headered to allow any pump combination to operate any cooling tower combination. Condenser water cleanliness is critical to the efficiency and reliability of a water-cooled plant. In addition to chemical treatment, a side stream condensing water filter is an acceptable solution to minimize condenser piping and chiller condenser tube fouling. Cooling towers must be specified to conform with NFPA 214 or have a self-extinguishing fill with a flame spread index of 5 or less when tested by ASTM E84.

3-6.6.2 Air-Cooled Chiller Plants.

Air-cooled chiller plants often use more energy than water-cooled plants but often have lower life cycle costs. The cost of makeup water, backup makeup water, reduced maintenance, and replacement can result in air-cooled chiller plants with a lower total cost of ownership than water-cooled plants. Air-cooled chillers are typically located outside, while their pumps can be mounted on the chiller frame or inside a mechanical room. Chilled water pumps must be headered to allow any pump to operate with any chiller. If unit-mounted pumps are used, redundant pumps on each chiller can be used. Redundant pumps cannot share a motor as a shared motor has a single point of failure.

3-6.6.3 Piping and Valves.

Piping must support facility redundancy grade, see Appendix A. Valves on critical Grade 3 and 4 hydronic systems must be installed to allow isolation for maintenance or repairs without disrupting critical loads. Valving must allow isolation of any cooling component.

3-6.7 Packaged/Unitary Cooling.

Packaged/unitary cooling is often used at smaller C5ISR facilities and outlying equipment buildings. Packaged/unitary equipment tends to have lower efficiencies and requires maintenance at the unit. Packaged/unitary equipment includes packaged direct expansion (DX)-cooled floor-mounted or roof-mounted equipment, split system DX, variable refrigerant flow/volume (VRF/VRV), water source heat pumps (WSHPs), and CRACs with a remote condenser or drycooler. Packaged units may have a lower first cost than centralized cooling but are often more expensive over the system's life. Packaged units typically have a shorter service life and a higher overall maintenance burden as they are not centralized. Packaged units are also very dependent on refrigerant and often require factory-trained technicians to maintain refrigerant circuits.

If space temperature cannot be maintained within “Recommended” requirements for temperature range after primary power is lost and backup power is established, unitary equipment can be placed on the UPS system.

3-6.7.1 Packaged/Unitary Design Considerations.

Packaged units can be configured to allow for redundancy and support concurrently maintainable and fault-tolerant configurations. The design must account for dehumidification and part loading, as packaged units may cycle at lower loading and provide inadequate dehumidification.

3-6.8 Controls and Automation Systems.

Mechanical controls and automation systems must be robust and capable of maintaining the equipment room environment within ASHRAE Thermal Guideline “Recommended” temperature and humidity range. Powering the control system from the UPS system allows the system to remain online if main power is lost. Controls must resume programmed operations if power is lost and must be capable of standalone operation if connection to controls is lost.

3-6.8.1 Facility Central Control System.

Central DDC controls systems allow mission owner engineers and maintenance teams to continuously monitor systems from a dedicated engineer watch station. Control systems must report critical and maintenance alarms and be capable of trending data. Work with the mission owner engineering and maintenance team to establish critical control overrides or initiate critical procedures from the watch station. DDC control systems must be in accordance with UFC 3-410-02.

Provide an automated central Power and Environmental Monitoring and Control System (PEMCS). The system must be capable of continuously monitoring the following systems where utilized: utility transformers, main distribution switchboard, switchgear, UPS, batteries, generator, generator fuel tanks, ATS, PDUs, STSs, CRAHs, AHUs, central cooling plant, central heating plant, dampers, fans, and control devices. The system must be capable of providing an external alarm by phone, text, and email. The system must continuously poll using non-proprietary industry standard protocols. Grade 3 PEMCS may utilize a single central processing unit, while Grade 4 PEMCS must have a 2N redundancy.

Army and Navy Facilities: When required by CTR the PEMCS and associated controllers must be on central mission UPS system power, with Grade 4 provided with dual path UPS power.

Air Force Facilities: The PEMCS and associated controllers must be on central mission UPS system power, with Grade 4 provided with dual path UPS power.

3-6.8.2 Cybersecurity.

The controls system must be provided with cybersecurity protections in accordance with UFC 4-010-06. Standalone control networks may be utilized where central DDC controls pose a risk to secure networks. Standalone controls are required to comply with cybersecurity requirements and must be capable of being continuously monitored. Ethernet switches provided in the controls architecture must be an Open Source Interconnection (OSI) layer 2/3 managed switch.

Identify Confidentiality, Integrity, and Availability (C-I-A) rating of controls system during the planning/DD1391 development process.

Air Force Facilities: Controls system must not tie into a non-Classified base wide network.

3-6.8.3 Leak Detection.

Equipment rooms served by hydronic systems must be provided with leak detection. Utilize leak detection at cooling units and floor drains, where provided. Raised Access Floor where utilized, must be provided with leak detection.

3-6.9 UPS/Battery Rooms.

Mechanical systems serving UPS rooms must consider the loss of primary power. Systems must be designed to prevent the temperature in the UPS room from exceeding 104°F (40°C) or manufacturer maximum temperature, whichever is less, when primary power is lost. Mechanical systems serving battery rooms must consider the loss of primary power. Systems must be designed to prevent the temperature in the battery rooms from exceeding UFC 3-520-05 maximum or manufacturer maximum temperature, whichever is less, when primary power is lost. If UPS and/or battery room temperature cannot be maintained within allowable range after primary power is lost and backup power is established, work with CTR to determine which components of the cooling system will be placed on the UPS system.

Army and Navy Facilities: A ventilation fan on UPS power is allowed to serve as a backup system where the outside air temperature and air quality are suitable when acceptable to CTR.

Air Force Facilities: Provide redundant cooling system for UPS rooms. Backup mechanical ventilation of the UPS room is not acceptable.

3-6.10 Physical Security.

Locate critical exterior equipment within the secure perimeter. Facilities with secure requirements must comply with UFC 4-010-05.

3-6.11 Backup Power and Generators.

Mechanical systems serving equipment rooms must be on backup power. Work with the mission owner to identify mechanical equipment and controls that require UPS power.

Design systems supporting generators in accordance with UFC 3-540-01.

3-6.11.1 Fuel Storage and Piping.

Fuel storage systems serving backup power generators must be in accordance with UFC 3-460-01 and meet Environmental Protection Agency (EPA), state, and local environmental requirements.

3-6.11.1.1 Fuel Storage Capacity.

Indoor fuel storage volume must comply with NFPA 30. Grade 2 facilities must have a minimum of 24 hours of fuel storage. Grade 3 facilities must have a minimum of 72 hours of onsite fuel storage with a confirmed delivery source. Grade 4 requires a minimum of 96 hours of onsite fuel storage with a confirmed delivery source. Storage must be based upon full load fuel consumption. The need for additional fuel storage capacity must be established with the mission owner during the planning/DD1391 development process.

Grade 2 facilities may utilize a single storage tank, while Grade 3 and 4 facilities must utilize multiple storage tanks. Grade 3 systems must be concurrently maintainable, while Grade 4 systems must be fault tolerant.

Air Force Facilities: Provide a minimum of 7 days of fuel storage. The Air Force allows Grade 2 and 3 facilities to utilize a fueling agreement provided there is 24 hours of integral/day tank fuel storage. Grade 4 facilities must be provided with N+1 storage tanks.

3-6.11.1.2 Fuel Controls.

The fuel controls must tie into the building control system. The fuel controls must alarm on high fuel level, low fuel levels, and upon leak detection. The fuel system must provide N+1 transfer pump redundancy.

3-6.11.1.3 Fuel Maintenance.

Design for maintenance in accordance with UFC 3-460-03.

3-6.12 Plumbing.

Where plumbing services feed critical systems (cooling tower makeup water or once-through cooling), redundant sources are required.

3-6.12.1 Backup Cooling Water.

Facilities using evaporative heat rejection must be provided with a minimum of 24 hours of makeup water for Grade 2, 72 hours of makeup water for Grade 3, and 96 hours of makeup water for Grade 4. Once through cooling systems can be used as a backup cooling source, but often have drawbacks. Cooling systems typically have high flow requirements. Municipal water is often dependent on electric pumps and may not be reliable if primary electrical power is unavailable. A well can be used to provide backup cooling water. Wells have a higher first cost and recurring maintenance costs. Sustained use of a well for backup cooling may negatively impact the aquifer. Carefully weigh the use of once-through cooling systems. A closed-circuit heat rejection source is an acceptable alternative. When a combination of evaporative cooling and closed-circuit cooling is utilized, a backup water source is not required, provided the heat rejection component has N capacity.

Where water storage is used as a backup cooling source, this water is considered non-potable water and must meet EPA Guidelines for Water Reuse and AWWA M24.

3-7 ELECTRICAL ENGINEERING.

The core UFCs define the minimums for electrical systems. The requirements set forth in this document are more stringent requirements above the core UFCs and are the minimums for C5ISR facilities. If more stringent requirements are presented, beyond the scope of this document by the end users, then the most stringent requirement must be implemented. Analyze stricter user requirements with minimums to determine a cost delta and determine if the implementation is feasible.

C5ISR facilities come in many different types with a large range of electrical requirements. There may be small projects under 250 kVA, medium projects up to 2,500 kVA, and large capacity projects greater than 2,500 kVA. Projects may also contain multi-site facilities that can be as large as 10 MVA with multiple buildings and primary power circuits from a commercial power company. Appropriate electrical distribution architecture must be implemented to meet the facility Grade requirement determined by the mission. For Army projects, refer to TM 5-691 Utility Systems Design Requirements for guidance. Refer to MESEP for more stringent and specific engineering requirements.

3-7.1 Utility Requirements.

Grade 2 and 3 facilities must be provided with independent utility power sources supplied by a commercial power company when available and economically feasible. Grade 4 facilities must be provided with two independent utility power sources supplied by a commercial power company. Investigate the independence of commercial power company feeds; each should originate from an independent substation. Provide a cost for an added utility feeder to assess its economic feasibility to the project overall costs. An added feeder is not economically feasible if it exceeds 10 percent of the total construction budget. Common substation utility feeders for Grade 4 are only acceptable when unavoidable. Each utility feed to the building must be maintained within its own pathway, separate from each other. For new utilities, maintain a 66-foot (20.2 m) separation between feeders along the route and maintain a minimum separation of 4 feet (1.2 m) between other utilities. Redundant feeders must not share duct banks or maintenance holes. When separation requirements cannot be met due to existing utilities and conditions, document the process to resolution in the basis of design narrative. When commercial power is not readily available, an on-station primary power plant must be provided. Generation systems must meet the requirements as outlined in UFC 3-540-01. Utility capacity requirements must be for 100 percent of the station demand load.

3-7.2 Load Categories.

The facility Grade is to be determined in accordance with MESEP. Load categories during design must be labeled and referred to as indicated:

3-7.2.1 Station Load.

Total power requirement of the facility.

3-7.2.2 Operational.

Loads required to maintain continuous operation of the facility.

3-7.2.3 Non-Technical.

Part of the total operational load used for the administration of the facility. Non-technical loads include general lighting, convenience outlets, HVAC, and other normal operation functions and do not require emergency power. These types of loads can be load shed to maintain synchronous operation of the critical technical load.

3-7.2.4 Technical.

Part of the operational load required for the critical technical load and the utilities serving this equipment. Technical load is essential to the facility's mission and must be on emergency power. The project’s electronic equipment engineers must determine this load.

3-7.2.5 Non-critical Technical Load.

Load that is a portion of the technical load not required for synchronous operation. This includes nonsynchronous electronic equipment, test equipment, emergency lighting, and HVAC for critical technical load. The outage time tolerance for specific facilities will vary based on the facility Grade and end user.

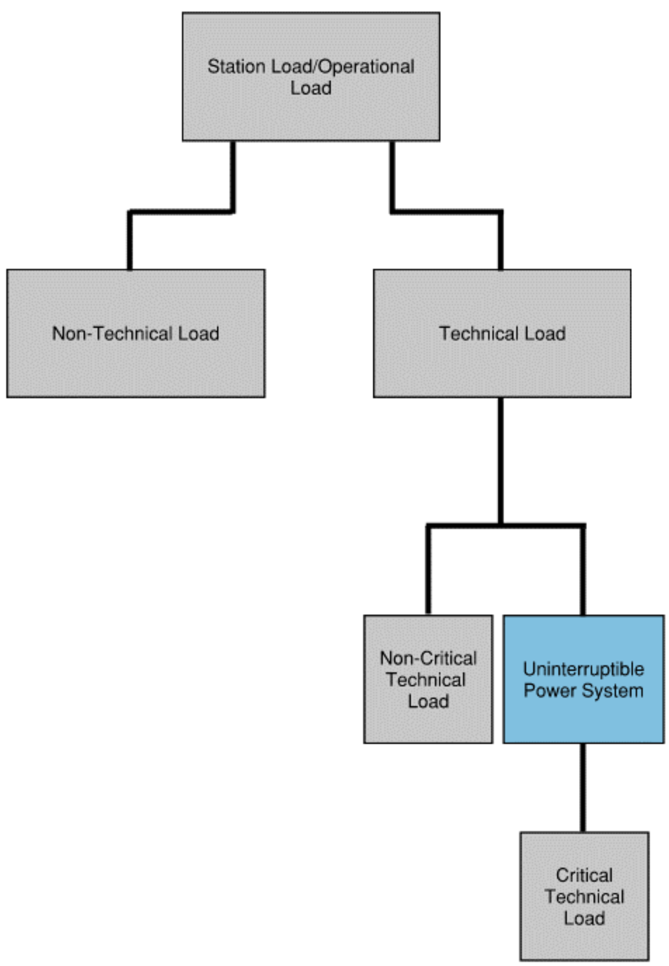
- HVAC Equipment/distribution components supporting critical loads.
- Point-of-use UPS equipment
- Elevators

3-7.2.6 Critical Technical Load.

Part of the total technical load required for continuous synchronous operation of electronic equipment. This includes any equipment malfunctioning during a momentary power dropout and causing additional outages after power is restored due to the need to resynchronize, loss of real-time count by master time sources, or loss of data in Automatic Data Processing (ADP) systems. These loads must be served from a UPS. Some examples of critical technical load include but not limited to:

- Rack-mounted IT Equipment
- Mission communications equipment
- Network equipment
- Facility Related Control Systems
- Key components of security systems

Figure 3-11 Load Categories



3-7.3 Redundancy and Resilience.

Figures associated with Grades are only examples to demonstrate a possible topology. Intent is to show limitations of each grade and help easily navigate pathing to critical loads. Engineered solutions are to be included in the drawing set one-line or riser diagram and demonstrated to meet their intended grade during design development.

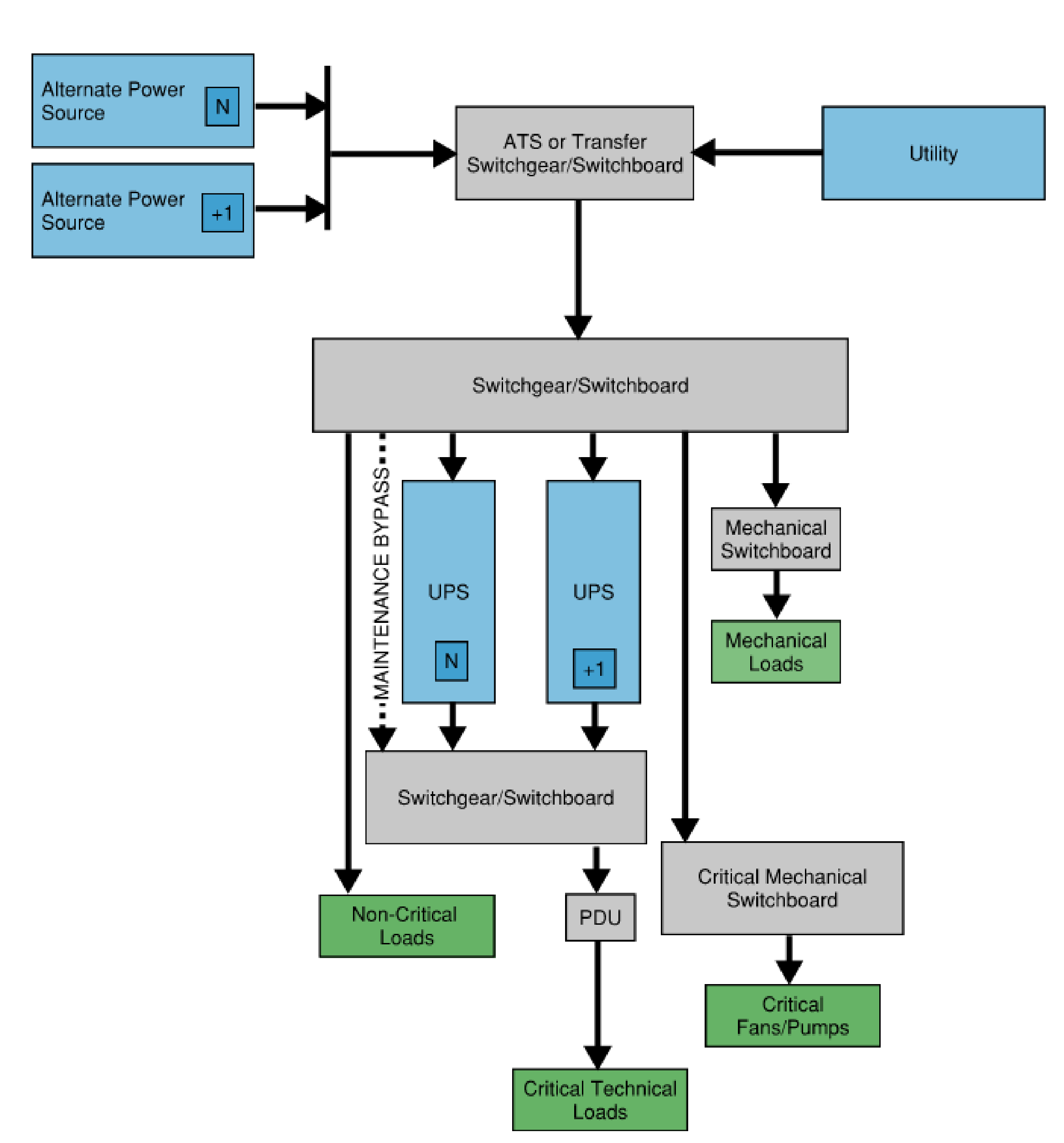
3-7.3.1 Grade 1 Electrical Systems.

Not applicable.

3-7.3.2 Grade 2 Electrical Systems

An electrical system that contains a single path to critical loads while having component redundancy. Component redundancy includes added equipment to exceed N requirements but not system level redundancy. This type of system would be vulnerable to component level faults with no added path around failures. It is possible to have planned component level maintenance but only on those components with the added redundancy. In most cases maintenance or failures would cause downtime to the critical loads supporting the mission. Figure 3-12 is an example of Grade 2 distribution architecture. One-line figures are example solutions only; the final electrical distribution system must meet or exceed the Grade 2 definition.

Figure 3-12 Grade 2 Single Utility with Alternate Power Sources



Availability at Critical Technical Load
0.9999

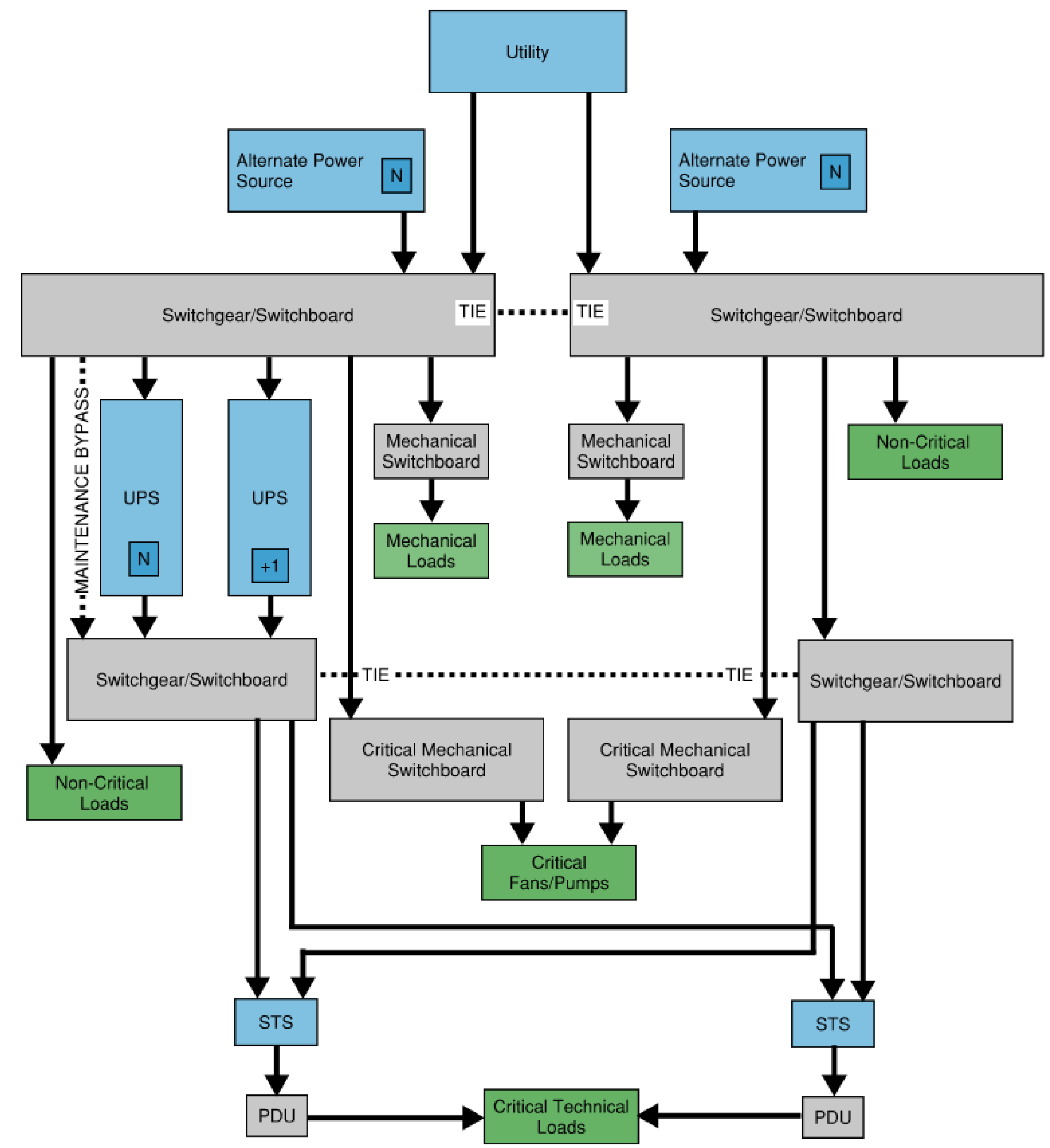
1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

3-7.3.3 Grade 3 Electrical Systems

An electrical system that is concurrently maintainable with a minimum redundancy of N+1. Concurrently maintainable systems can effectively maintain power during maintenance operations; it is not fault tolerant. It is common for Grade 3 mechanical systems architecture to push electrical into a 2N architecture similar to Grade 4. Analyze requirements with minimums to determine a cost delta and determine if the implementation is feasible. Figure 3-13 and Figure 3-14 are both examples of Grade 3 distribution architectures. One-line figures are example solutions only; the final electrical distribution system must meet or exceed the Grade 3 definition.

Redundant equipment must be physically separated in a redundant architecture to avoid damage due to catastrophic failures. Maintain 3-ft between redundant equipment or the NFPA 70 working clearance; whichever is greater.

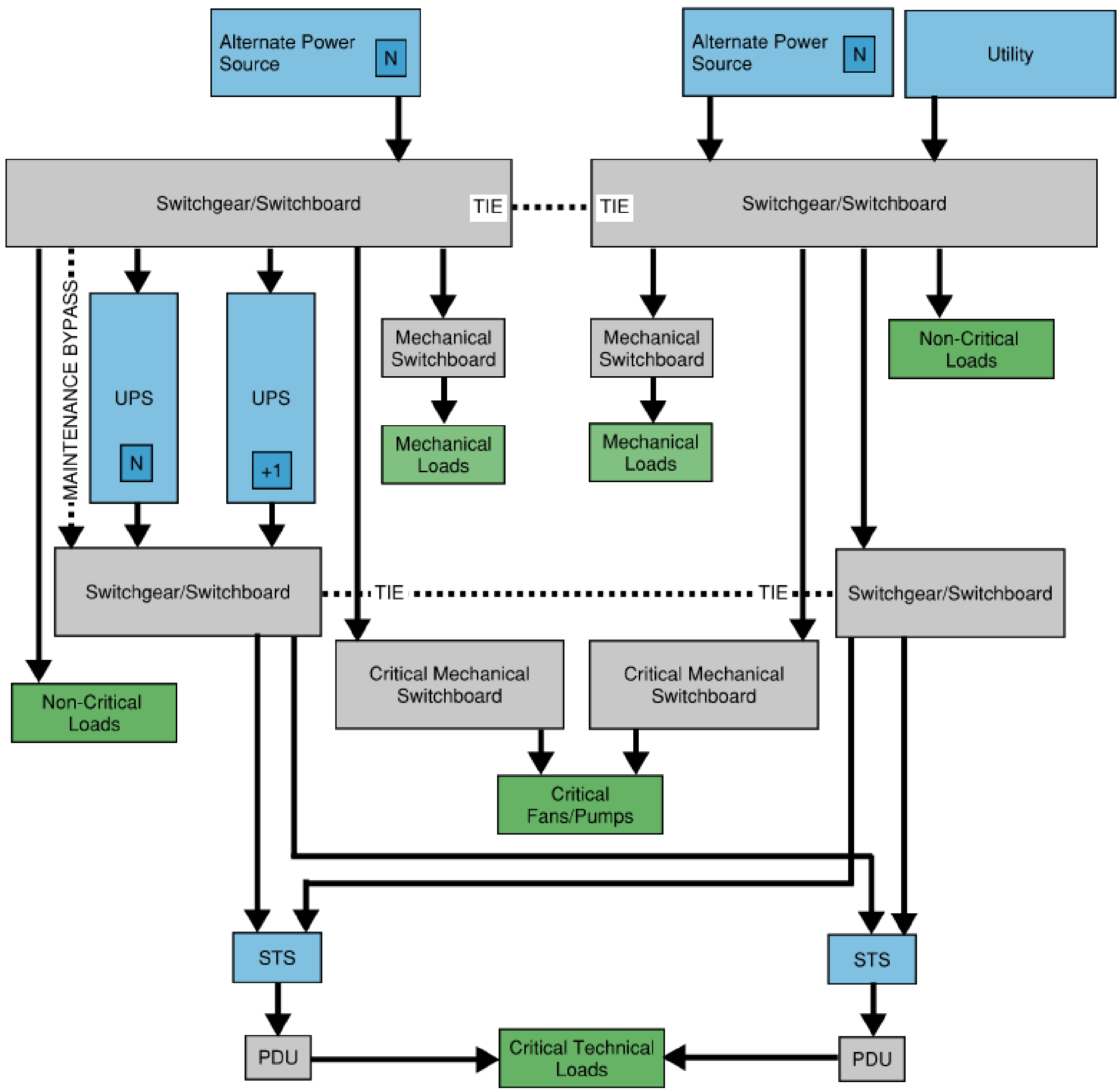
Figure 3-13 Grade 3 Single Utility with Two Utility Inputs



Availability at Critical Technical Load
0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

Figure 3-14 Grade 3 Single Utility Source with Single Utility Input



Availability at Critical Technical Load
0.999999

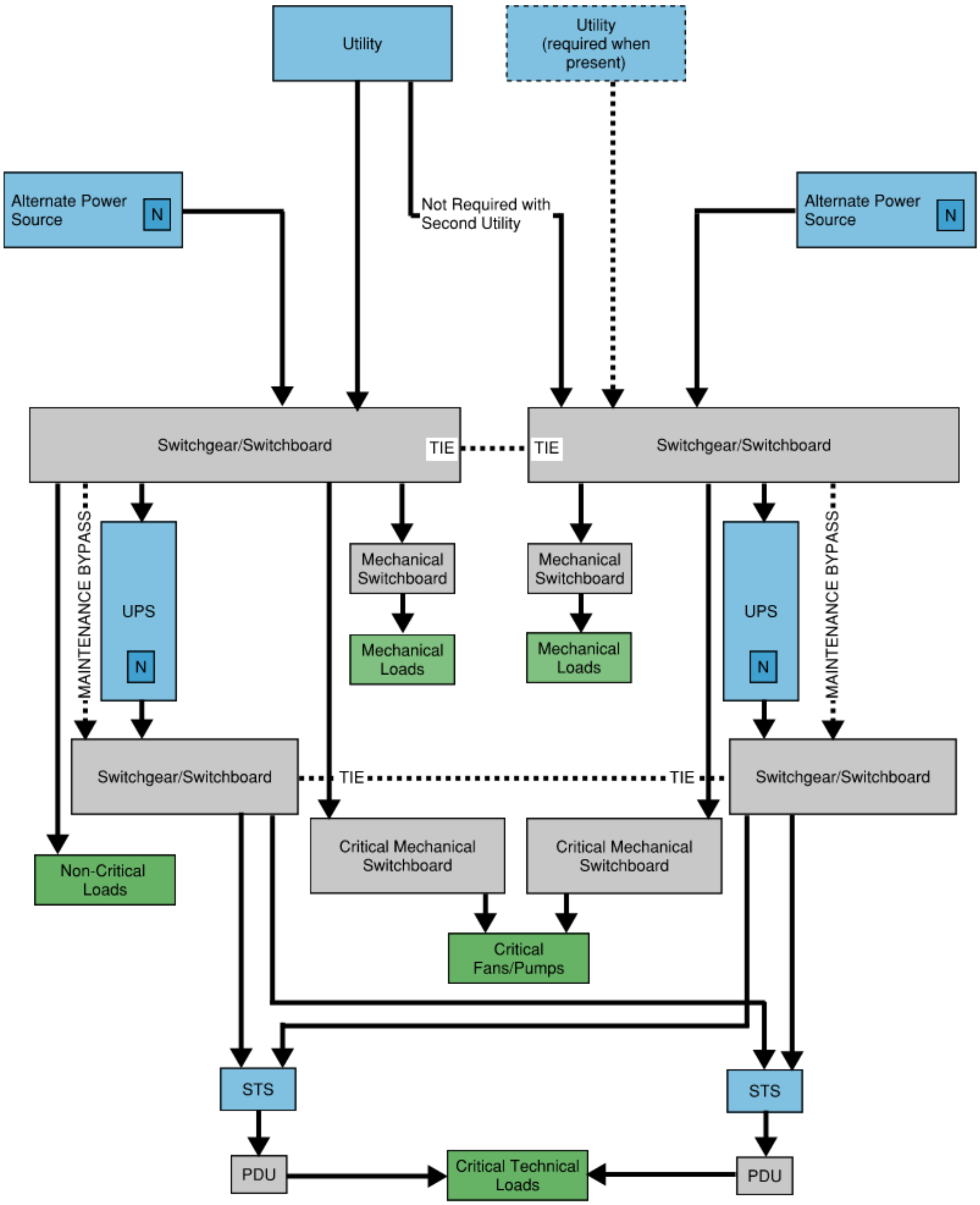
1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

3-7.3.4 Grade 4 Electrical Systems

An electrical system that is tolerant to faults or unexpected failures of both mechanical and electrical equipment within the distribution system. The electrical distribution network must have a 2N redundancy architecture including two separate utility feeds from independent substations. If 2N utility is provided, an N+1 generator power source may be considered to reduce cost. Provide a 2N uninterruptible alternate power source for critical technical loads.

When multi-path architecture is utilized, all equipment associated with the path is considered a subsystem and must be separated. Electrical subsystems must be separated by a minimum 1-hour fire-rated wall or structure. The critical technical power subsystem must be separated from other subsystems that do not support the data center. If a multi-path architecture is utilized, all equipment associated with the path is considered a subsystem and must be separated. Pathways serving subsystems must be separated by 3 feet (910 mm) when routed in a common space. A reduction to the 3 feet (910 mm) requirement is acceptable when not obtainable. For reference, Figure 3-15 would be considered dual path (2N), Figure 3-16 would be considered dual path (2(N+1)), and Figure 3-17 has three paths (3N). One-line figures are example solutions only; the final electrical distribution system must meet or exceed the Grade 4 definition.

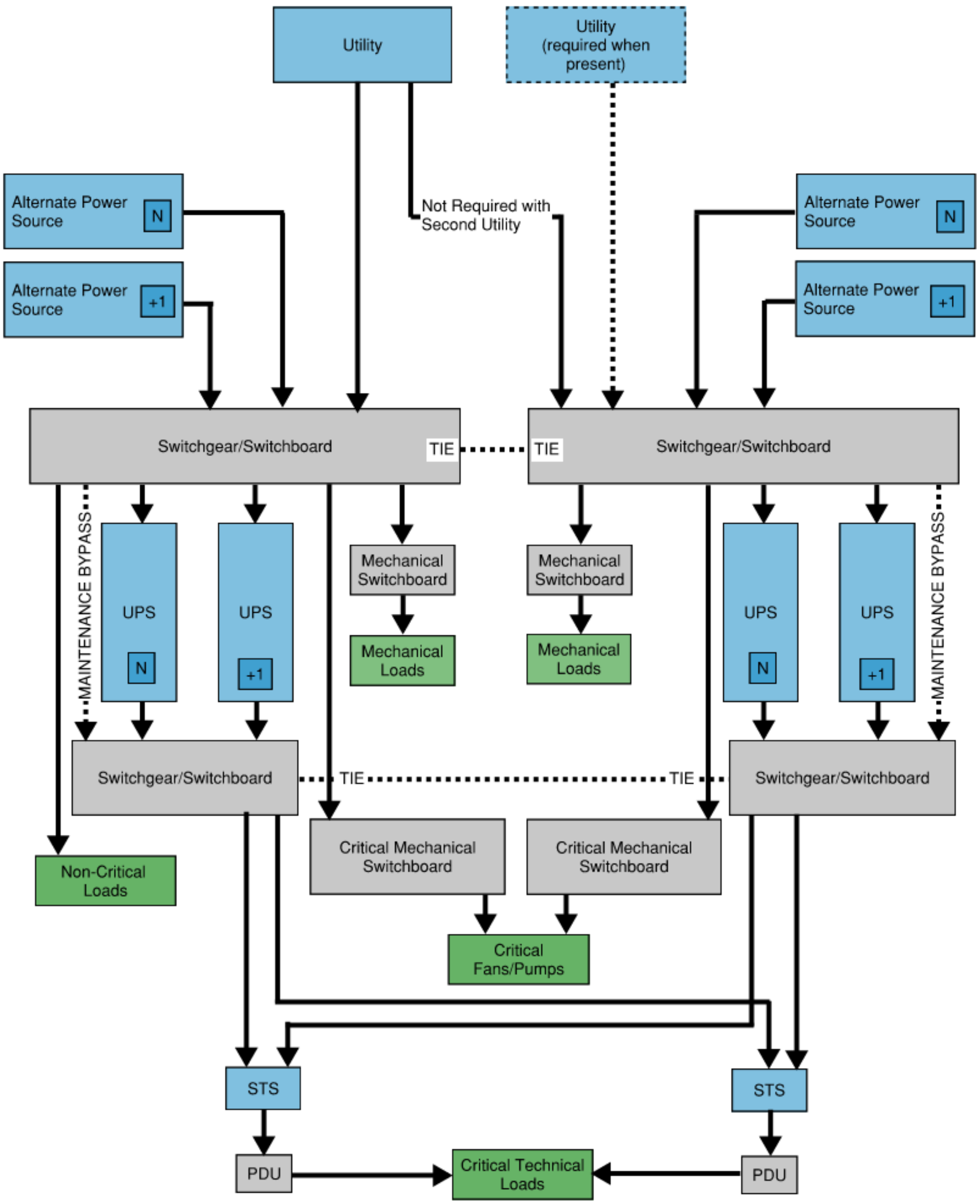
Figure 3-15 Grade 4 2N



Availability at Critical Technical Load
0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

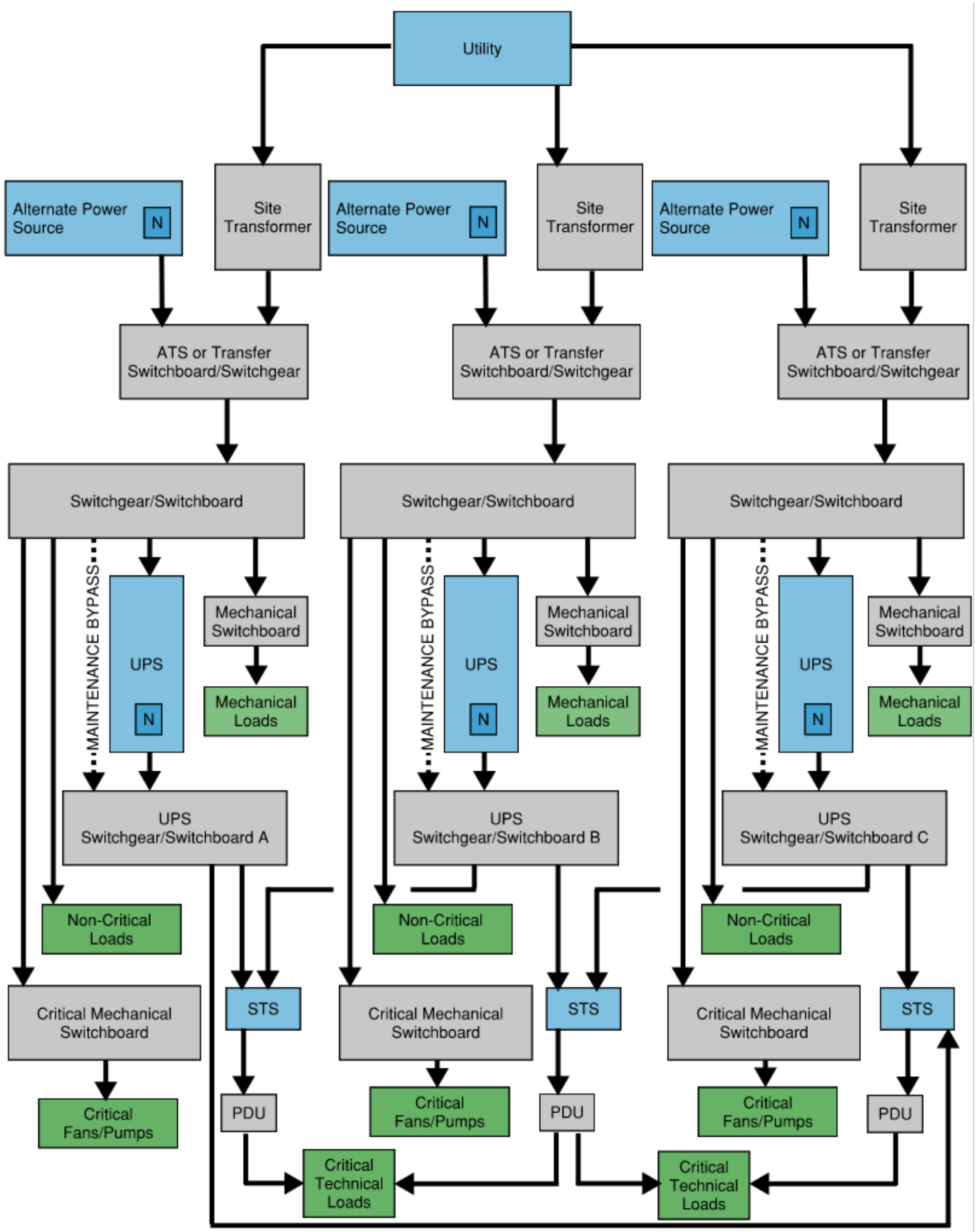
Figure 3-16 Grade 4 2(N+1) (System-Plus-System)



Availability at Critical Technical Load
0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

Figure 3-17 Grade 4 xN or Distributed Redundant



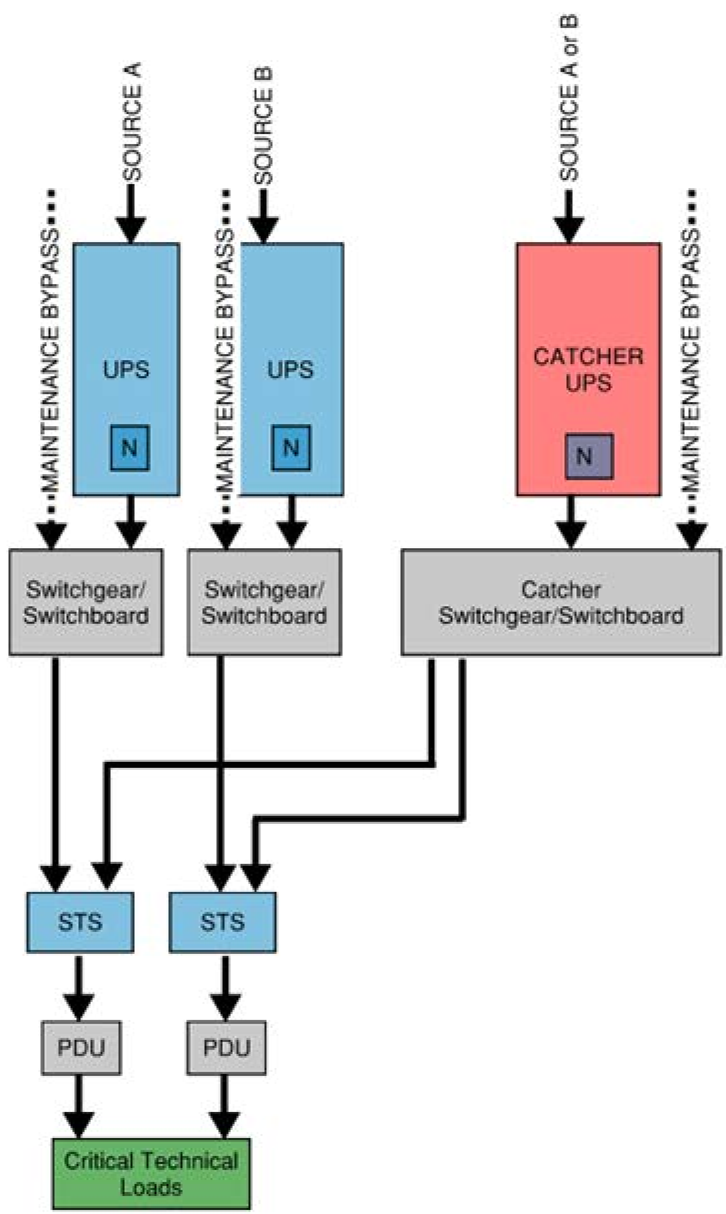
Availability at Critical Technical Load
0.999999

1. Availability equations are taken from UFC 3-520-02. Calculator utilizes the "block diagram" model.
2. Availability values are taken from IEEE 493-2007, Table 10-4.

3-7.3.5 Architectures with Uninterrupted Transfer of Loads

It is possible to provide additional flexibility in the system by utilizing a “catcher” topology. This is when a redundant UPS feeds the static bypass inputs of the normal UPSs (“N” or Need). By having the static bypass feed from the catcher UPS, the normal UPSs sync their outputs with the input from the redundant UPS. This allows switching in the downstream system to be completed much easier and simplifies syncing of UPS outputs. The “catcher” must seamlessly assume the load of a single normal UPS failure. The outputs of the redundant and normal UPSs are tied together allowing for a manual switching between the two sources for maintenance of the normal UPSs. This can be utilized on any distribution paths with UPSs.

Figure 3-18 UPS “Catcher” Topology



3-7.4 Electrical Power Characteristics.

3-7.4.1 Voltage.

Steady-state voltage variation must not exceed plus or minus five percent of the nominal voltage level. The preferred voltage is 480Y/277V for systems above 300 kVA. For systems below 300 kVA, provide 208Y/120V systems.

3-7.4.2 Frequency.

Steady-state variations must not exceed plus or minus 0.5 percent of the nominal frequency. The preferred frequency is 60 hertz (Hz). If 60 Hz is not available overseas, the use of 50 Hz is acceptable. If frequency conversion is required, a synchronous generator or solid-state converter is required. Provide calculations for conversion equipment. Consult UFC 3-510-01 Foreign Voltages and Frequency Guide.

3-7.4.3 Availability.

Availability is the ability for a utility to be ready for use or to maintain its state. Not to be confused with reliability which is the measure of failures of a system or product over a period of time. A system can have poor reliability products in its network, but a given network architecture may provide high availability. Critical loads for C5ISR facilities require high availability to maintain mission operations. Different electrical architectures provide differing levels of availability.

3-7.4.4 Dynamic or Transient Variation.

This is the change of electrical conditions at the operational bus due to system operations, for example, motor starting. Voltage must not exceed minus 15 percent or plus 10 percent. Identify large motors and utilize reduced voltage starters or select a variable speed drive starting operation that reduces voltage requirements. Systems upstream of the Operational load bus may exceed these tolerances.

3-7.4.5 Power Factor.

Provide power factor correction when required. Minimum power factor must not exceed 0.85 lagging.

3-7.5 Medium Voltage (1kV-35.4kV).

Utilize medium voltage distribution within the facility when low voltage service requirements exceed 5 MW or 6000 A at lower utilization voltages (<600V). One-for-one replacement of existing equipment must match existing equipment and not be subject to this requirement.

Where increased safety and reduced footprint are desired, evaluate the use of Gas or Solid Insulated Switchgear (GIS or SIS). Provide all medium voltage circuit breakers with an electronic trip protective relay and when control is required, provide means to open and close the circuit breaker remotely. Protective relays must have the ability to network for advanced control schemes. Protective relays must be compatible with the selected DDC controls or Building Automation System (BAS). Provide connection into the DDC/BAS and monitor relay status at the facility control room. Review available protective relay control points with mission engineering and integrate those into the DDC/BAS.

3-7.5.1 Medium Voltage Controls.

Controls for switchgear operations must be integral to the equipment and have black start capabilities. Black start systems can maintain operations with no external power, carrying their own power supply to regain either primary or standby power. Allocate space for a DC battery supply for operating controls and circuit breakers in the switchgear lineup when located exterior of the facility. Batteries are to be provided in accordance with UFC 3-520-05. Mission central Uninterruptible Power Supply (UPS) circuits to provide power to controls is required. Control operations must be remote from the facility control room.

3-7.6 Low Voltage Electrical Distribution (<1000V).

3-7.6.1 Switchgear, Switchboards, Motor Control Centers, and Panelboards.

For Grade 3 and Grade 4 facilities provide switchgear with the following:

- Overhead lifting means for removing draw out circuit breakers.
- An arc-resistant switchgear assembly tested and certified to IEEE C37.20.7.
- Draw out compartment shutters to protect operators during hot operations.
- Infrared viewing windows for thermal imaging bus and connections without opening equipment doors or access panels.

For main service entrance switchgear and switchboards, consider using 4-pole circuit breakers that can alleviate the use of complicated ground fault schemes. With 4-pole circuit breakers, residual ground fault protection may be utilized in lieu of a modified differential ground fault scheme since the system switches neutrals between sources. When equipment is separated and requires communications connections for proper operation, provide two 4 in. (102 mm) conduits between the equipment to support these communications. When double ended switchgear or switchboards are utilized, they must be configured as Main-Tie-Tie-Main (M-T-T-M). When the utility owns the outdoor transformer, provide disconnecting means ahead of the main service entrance equipment to test black start capabilities.

3-7.6.2 Remote Power Panels (RPP).

Remote power panels (RPPs) can extend a large power capacity into the data center in a small footprint. RPPs have similar footprints to data racks, with some fitting entirely onto a 24in. by 24 in. (610 mm by 610 mm) tile while having the ability to contain four 42-pole panelboards. Consider using RPPs to remove transformers and PDUs, which increase the heat load on the data center floor. When desired, provide branch circuit monitoring capabilities compliant with paragraph 3-7.6.5 for branch circuits less than 800 A.

3-7.6.3 Circuit Breakers and Relays.

The use of low voltage protective relays may be used for better selective coordination on large drawout power circuit breakers over 800 A. For selective coordination purposes, all circuit breakers 225 A or larger must have adjustable long-time, short-time, and instantaneous (LSI) trip settings. Molded case thermal magnetic fixed trip circuit breakers are acceptable up to 225 A.

3-7.6.4 Low Voltage Controls (<600V).

Controls for switchgear and switchboard operations must be integral to the equipment and have black start capabilities. Control operations must also be remote from the facility control room. Black start systems can maintain operations with no external power, carrying their own power supply to regain either primary or standby power. A mission central Uninterruptible Power Supply (UPS) circuits to provide power to controls is required in a 2N configuration with separation of independent pathways. For Grade 3 and above, provide redundant controls with a physical separation, for example, control sections at opposite ends of the gear lineup or in a separate lineup. For Grade 4 provide controllers within separate rooms with 1hr fire barrier. For example, if switchgear A and B are located in different rooms but function together to maintain operations, switchgear A may have the primary controller while switchgear B contains the redundant controls. All controls are to be completely 2N, having automatic failover to the redundant controls system. No controls equipment can be shared for independent operation. Provide a 2N communication path between primary and redundant controls. Provide separate pathways/conduits for each communication link provided. The controls must be provided with cybersecurity protections in accordance with UFC 4-010-06. Ethernet switches provided in the controls’ architecture must be an OSI layer 2/3 managed switch.

3-7.6.5 Metering.

Metering is to be provided for all circuit breakers 800 A and above. All digital metering systems must be networked and consolidated at a single Electrical Power Monitoring System (EPMS). Connect consolidation location to DDC/BAS. Provide points to DDC/BAS to monitor phase current, voltage, frequency, crest factor, total harmonic distortion (THD), transient capture, Power (kW, kVA, kVAR), power factor, and energy consumption (kWh) per individual circuit breaker. Ethernet switches provided in the metering architecture must be an OSI layer 2/3 managed switch.

3-7.6.6 Transformers.

Transformers that directly serve critical technical loads must be harmonic mitigating type. Harmonic Analysis must identify which harmonics are the largest in the system and assist in selecting transformer harmonic mitigation techniques. Transformers must have a winding temperature sensor connected to a local and remote alarm system. Local alarms must be visual and audible. Provide connection and integration into the DDC/BAS and monitor the over temperature alarm.

3-7.6.7 Emergency Power/Alternate Power Source.

Categorize loads in accordance with NFPA 70 for Emergency, Legally Required Standby and Optional Standby. Provide a detailed Sequence of Operations (SoO) for generator operations. SoO must include dry contacts or input/output (I/O) blocks for generator running signals to initiate a sequence of operations for other systems. For outdoor generator units 1 MVA and larger, walk-in enclosures are required for ease of maintenance during adverse weather conditions. Size generator sets to their manufactured prime rating in lieu of standby rating to increase generator longevity in extended outages. Provide generators with a nameplate that states “Emergency Standby Use Only.”

Consider providing generator set(s) indoors when space is available. Provide when dictated by the design basis threat analysis. When considered, provide an LCCA comparing indoor and outdoor costs. The LCCA must account for building costs, including architecture, structure, mechanical, and electrical versus outdoor installation costs. The generator transient performance class must be G3 or better.

3-7.6.7.1 Emergency Power System Monitoring (EPSM).

Emergency power system monitoring must be compatible with the selected DDC controls or Building Automation System (BAS). Provide connection into the DDC/BAS and monitor the required Safety Indications and Shutdowns as indicated in NFPA 110 per level type. It is recommended to review optional points with end users for incorporation into the Safety Indications and Shutdowns list. If the EPSM is powered from the generators 12V starting system provide the controls with a power supply buffer that can maintain operating voltages above 9V for a minimum of 0.3 seconds. Multiple buffers can be placed in parallel to increase the duration beyond 0.3 seconds to cover cranking time. It is common during starting to have a large voltage drop which can lead to power issues at the controls. Monitoring system must have a 2N power supply.

3-7.6.7.2 Emergency Power Controls.

Controls for generator operations must be integral to the equipment and have black start capabilities. Allocate space for a DC battery supply for operating controls. If the controls are powered from the generators 12V starting system, provide with a power supply buffer that can maintain operating voltages above 9V for a minimum of 0.3 seconds. Multiple buffers can be placed in parallel to increase the duration beyond 0.3 seconds. It is common during starting to have a large voltage drop which can lead to power issues at the controls. The controls must be provided with cybersecurity protections in accordance with UFC 4-010-06.

3-7.6.7.3 Uninterruptible Power Supplies (UPS).

Provide batteries in accordance with UFC 3-520-05. Provide to meet the transient voltage requirements indicated in 3-7.4.4. Provide monitoring system capable of recording and trending individual battery voltage and impedance. Temperature must be monitored. UPS and monitoring systems must be compatible with the selected DDC controls or BAS. All alarms must be visible at the control room central monitoring station via the DDC or BAS. The use of small DIN rail mounted UPS and batteries is allowable for mechanical and electrical controls and monitoring equipment for ride through until main emergency power is initiated. When calculating runtimes use battery system end-of-life (EOL) runtime. Assume battery system EOL is 80% of initial capacity.

Air Force Only: UPS minimum runtime must be 15 minutes.

3-7.6.8 Loadbanks.

To provide an adequate load to maintain generator(s), provide a loadbank sized at 50 percent minimum of the generator nameplate rating. Loadbanks sized for less than 100 percent of a single generator must be able to be paralleled with the facility loads for full load testing. In facilities with multiple paralleled generator sets, provide a sequence of operations to test each generator set individually to keep the required loadbank size to a minimum. This sequence of operations must be activated via the paralleling switchgear human machine interface (HMI).

For Level 1 generators as defined by NFPA 110, provide a loadbank sized at 75 percent minimum of the generator nameplate rating with the ability to step from 25 percent to 50 percent to 75 percent. This will allow the yearly NFPA 110 required testing to be performed. This will also reduce annual maintenance costs and minimize the logistics of providing a third-party tester onto a secure site.

3-7.6.9 Busway.

The use of continuous open channel busway systems with modular plug-in units is acceptable for providing power to operational racks and cabinets. Coordinate plug-in unit circuit breaker and receptacle types with the facility’s electronic equipment engineer. Provide plug-in units with intelligence to monitor the following points: phase current, voltage, frequency, crest factor, THD, Power (kW, kVA, kVAR), Power factor, and energy consumption (kWh) per individual plug-in circuit breaker. Data protocols must be compatible with DDC/BAS system. All points must be integrated into the DDC/BAS and visible at a central monitoring station.

3-7.6.10 Pathways.

For Grade 3 and 4, at a minimum, redundant circuits must not be routed in common duct banks, maintenance holes, conduits, pathways, raceways, or cable trays.

3-7.6.11 Wiring and Wiring Devices.

Coordinate specific wiring device requirements with the facility's electronic equipment engineer. All receptacles other than general purpose, 120V, 20A receptacles must be marked with amperage, voltage, phase, and frequency.

3-7.7 Motors and Motor Control.

Adjustable speed drives must have an Insulated-Gate Bipolar Transistor (IGBT) rectifier or “active front end.” Active front end drives have reduced harmonics that affect the sensitive electronics within the system. Provide adjustable speed drives with three contactor bypasses to allow power to be completely disconnected from the drive during replacement. Locate redundant motor control circuits within their own pathway separate from primary control circuits. Faults on the primary control circuits must not inhibit the operation of the redundant motor.

Modern HVAC equipment utilizes electronically commutated (EC) motors. These motors use a built-in inverter for operation. Inverters add harmonics to the system and therefore include EC motors as non-linear loads in the harmonic analysis.

3-7.8 Grounding and Bonding.

Provide in accordance with NFPA 70, TIA-607-D, and MIL-STD-188-124B. TIA-607 grounding is not required in spaces where MIL-STD-188-124B apply. MIL-STD-188-124B grounding includes an equipotential ground plane (copper mesh) imbedded in the concrete floors/slab which will increase the design thickness. Provide the TIA-607 excluded spaces within the MESEP. Radio equipment with manufacturer warranties require specialized grounding. Provide grounding in accordance with Motorola R56 for Motorola equipment and AE/LZT 123 4618/1 R3A for Harris equipment. Earth electrode subsystem must not exceed 5 ohms.

3-7.8.1 Neutrals.

All neutrals must be fully rated. Coordinate systems furniture circuiting requirements with interiors implementing the built-in electrical through specifications.

3-7.8.2 Screen Rooms and Shielded Enclosures.

Screen rooms/shielding enclosures must be grounded and bonded in accordance with MIL-HDBK-1195.

3-7.8.3 Lightning Protection.

Provide lightning protection for all facilities to include antenna platforms.

3-7.9 Static Transfer Switches (STS).

Static transfer switches are provided to switch power sources with little to no interruption in service. Provide rack-mounted STSs (rSTS) for single-corded network equipment to provide a dual power path. Distribution STSs can be provided for serving mission critical work areas. Distribution level STSs must be provided when required by the MESEP. Do not provide the rSTS with intelligence/ metering capabilities via ethernet.

3-7.10 Power Distribution Units (PDU).

3-7.10.1 Distribution Level PDU.

A distribution level PDU is a single piece of equipment that integrates power distribution and transformer to reduce installation times and costs. When utilized, PDUs must have harmonic mitigating transformers (HMT). PDU must have a main input circuit breaker on the transformer primary. Provide PDUs with sub-feed output sections on the secondary of the transformer. A fully configured HMI display must be provided. Provide with surge suppression device.

3-7.10.2 Rack Level PDU (rPDU).

A rack power distribution unit distributes power to the rack loads and is typically either vertically or horizontally mounted within the rack or cabinet. Provide rPDUs in each rack and coordinate input and output receptacle types with the electronic equipment engineer. Utilize basic non-metered rPDUs unless increased metering is required at the local rPDU level. If remote monitoring is required, provide a monitored rPDU. Monitored rPDUs must be connected to the metering network. Discuss if the facility Operational Technology (OT) network can reside within the cabinet with the mission network(s). Switched rPDUs are an industry option that can remotely switch on/off rPDUs. Switched rPDUs must not be utilized unless specifically required by the electronic equipment engineer. Most rPDUs do not include surge protection; therefore, it is not required at the rPDU level. Coordinate rPDU amperage, voltage and phase requirements with electronics engineer to include in the facility MESEP.

Air Force Only: Provide two 3-phase rPDUs per rack/cabinet with power monitoring in data centers.

3-7.11 Transient Voltage and Surge Protection.

Voltage transient protection must be installed on both transient sources and power distribution equipment serving electronic equipment.

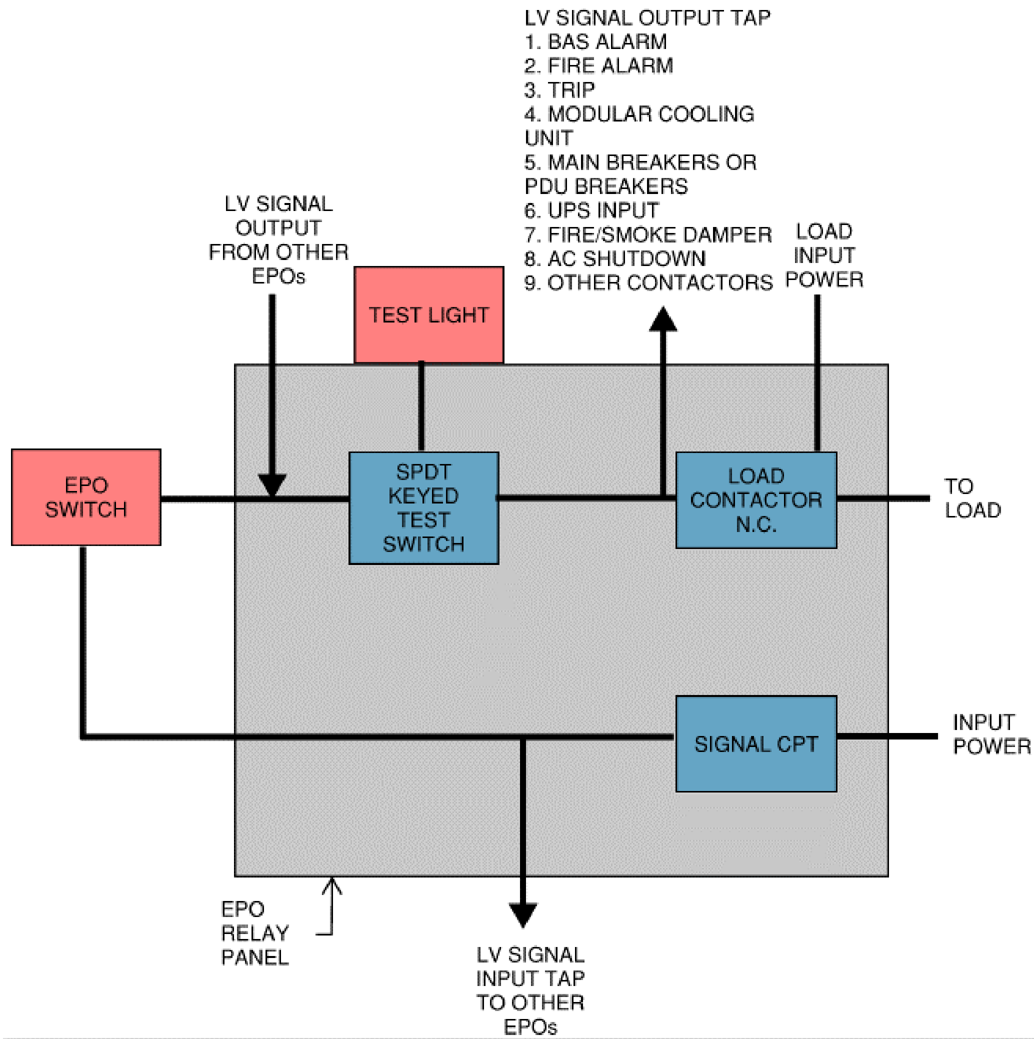
3-7.12 Selective Coordination.

Selective coordination must be provided to 0.1 seconds at a minimum. For instantaneous regions, provide manufacturer test documentation that circuit breakers must operate to open the nearest circuit breaker to the fault based on the calculated fault current. Proper coordination may lead to the deactivation of larger upstream circuit breaker instantaneous operations or instantaneous delay settings above 3 cycles (0.05s). Where this occurs, circuit breakers must be provided within a UL 1558 switchgear designed for a 30-cycle withstand rating. To properly coordinate molded case circuit breakers, consider maintaining a 2:1 or 3:1 ratio of the largest branch to the main rating. Properly document all miscoordinations in the power system study in accordance with UFC 3-501-01.

3-7.13 Emergency Power Off (EPO).

When provided, emergency power off buttons and circuits must have a Performance Level d (PLd) in accordance with ANSI B11.26. This implies structure Category 4 in accordance with ISO 13849-1, adding high diagnostic coverage and common cause failure avoidance techniques. Monitor circuit power at the Fire Alarm Control Unit (FACU) for circuit power failure and EPO activation. EPO system must have a means to test the signal pathway that deactivates the signal to the load contactors and activates a test light.

Figure 3-19 EPO Diagram



3-7.14 Lighting and Lighting Controls.

3-7.14.1 Lighting for Windowless Operating Environments (Command and Control / Operations Centers)

C5ISR facilities are high stress work environments, refer to paragraph 3-2.2.4.5. These high stress work environments are illuminated with two different scenarios; a high and low light environment. For areas of the facility that have high stress associated with them such as Command and Control Operations, Watch Floors, Operations Centers, or War Rooms refer to UFC 3-530-01 section on Command and Control/Operations Centers for the high light environment. The high light scenario will be used for housekeeping of the spaces. The users of these spaces operate in a low light environment much like a movie theater. Therefore, consideration must be given to the amount of light given off by computer screens which adds a measurable amount of usable light to the space. Provide lighting of the low light environment as follows:

- Horizontal Foot-Candles: 1.5 fc at desk
- Vertical Foot-Candles: 6 fc at 6'-0" on walls. 2 fc MAX at screen.
- Correlated Color Temperature: 2700-5500K
- Lighting Orientation: Uplight ON. Downlight OFF.

Use a mixture of direct, indirect and wall washers to meet the requirements and provide flexibility for user comfort. Provide spectral tuning luminaires to enhance operator quality of life in Command and Control/Operations spaces that mimic the natural circadian rhythm of a 24/7 schedule. For additional information refer to U. S. Air Force Lighting for Stressful Environments Report.

3-7.14.2 Lighting Controls

If automatic lighting controls are desired in the data center, provide automatic controls on a per row basis. When a networked system is utilized, integrate it into the DDC/BAS in accordance with UFC 3-530-01. Provide a SoO for lighting controls. SoO must include dry contacts or I/O blocks for outgoing or incoming signals to integrate other systems. Wireless controls are prohibited. The controls must be provided with cybersecurity protections in accordance with UFC 4-010-06. Ethernet switches provided in the lighting controls architecture must be an OSI layer 2/3 managed switch.

When applying lighting controls to secure spaces be mindful of using microphonics due to the microphone used to listen to activity in the space. Secure spaces do not allow the installation of active microphones. Obtain documentation that the sensor is passive and does not transmit intelligible voice data beyond the device. A proper passive device must utilize an op-amp comparator. Provide a lighting control network or lighting control panel inside all common secure areas and connect using fiber optics. For example, if there are multiple compartmentalized secure areas, provide one for each area. Provide location and specifications of all required media conversion equipment to connect control panels by fiber.

3-7.14.2.1 Mission Lighting Controls

Spaces that have continuous 24/7 operations must be provided with a separate control system capable of adjusting individual luminaire spectral color and color shift to meet circadian rhythm requirements. This control system must control the low light scenario of the environment. To meet the low light scenario requirement, provide addressable luminaires and control devices. The color shift must happen over a duration that corresponds to the time of the year of the facility's geographical location. The intent is to maintain the natural circadian rhythm of the operators in 24/7, high stress environments which has shown to reduce stress. The color shift must be adjusted from 2700k as a minimum to 5500K maximum.

3-7.14.3 Security Lighting.

Security lighting for facilities must be provided. Lighting must be installed inside the perimeter security fence to illuminate the fence completely and prevent an intruder from using the light poles and guy wires to gain access to the area. Illuminate areas shadowed by structures. Ensure that the failure of one lamp in a circuit does not affect other lamps in the same circuit. Provide overlapping light distribution to minimize reductions in illumination levels upon lamp failure. Protect all components of the system from vandalism. Provide lights on buildings. The emergency power source must be adequate to sustain security lighting of all critical areas and structures for 8 hours and must go into operation automatically when the primary power fails. The facility must have battery-powered lights at key control points if a failure disables the alternate power supply. Install special-purpose lighting (such as for fog penetration) when climatic or other local factors dictate. Provide additional lighting for (CCTV) security surveillance, as necessary. Vapor type lighting must not be used within 0.5 miles (0.8 km) of antenna receiving areas.

3-7.15 Telecommunications.

Similar to the electrical system, the telecommunications system can be determined using a small, medium, and large scale. Regardless of scale, C5ISR facilities contain large amounts of data processing equipment, typically in a central room or multiple rooms within the facility called data centers. These data centers may process information for multiple missions and must be properly networked for redundancy and flexibility. C5ISR facilities rooms/spaces/areas must be labeled as indicated when applicable:

3-7.15.1 Entrance Facility (EF).

The room or area where the outside plant cabling terminates inside the facility. In some cases, this room will be the same as the main distribution area if the facility provider owns the OSP cabling. When there is an outside service provider, provide a demarcation room to allow separate access for provider cable termination and equipment.

3-7.15.2 Main Distribution Area (MDA).

The room or area that supports customer-owned core equipment, including routers, core switches, firewalls, load balancers, DNS, and possibly core SAN fabric switches. This area is typically found in support of the core data center. MDAs may serve one or more HDAs, IDAs, EDAs, or TRs within a facility. May also be called data center.

3-7.15.3 Intermediate Distribution Area (IDA).

The room or area that supports the intermediate cross connect. Typically used in large facilities when the number of connections between MDAs and HDAs is large and cannot be supported by these rooms or areas. This area is typically found in support of the core data center. IDAs are optional spaces dependent on networking demand.

3-7.15.4 Horizontal Distribution Area (HDA).

The room or area that supports horizontal cabling to ZDAs, EDAs, IT equipment, or equipment outlets. This area is typically found in support of the core data center. HDAs are optional areas that assist with cable decongestion in medium to large scale data centers.

3-7.15.5 Equipment Distribution Area (EDA).

Area that houses IT processing equipment.

3-7.15.6 Zone Distribution Area (ZDA).

An optional interconnection point within the horizontal cabling located between the HDA and the EDA to allow frequent reconfiguration and added flexibility.

3-7.15.7 Telecommunications Room (TR).

A room that supports operations outside of the data center or mission directly serving the data center. This room may also extend the core data center service outside the data center room or area and into the facility for mission use.

In small data centers, a single MDA is required with no supporting area, such as HDAs or IDAs, to provide necessary connections. Provide HDAs and IDAs for larger data centers to support the increased number of cross connects and horizontal cabling. Close coordination with the facility's electronic equipment engineer is required to determine networking requirements and needs for these specific areas.

3-7.16 Telecommunications Infrastructure Grade.

The Grade is to be determined in accordance with MESEP.

3-7.16.1 Grade 1 Telecommunications System.

Not applicable.

3-7.16.2 Grade 2 Telecommunications System.

The incoming outside plant cabling to the facility must be redundant via two separate paths and maintenance holes. Redundant feeds terminate in a single entrance facility room. Telecommunications equipment for supporting services are to have redundant components such as processors and power supplies. Backbone cabling between telecommunications rooms must have redundant stands or pairs which can be shared within the same sheath of a single cable; independent cabling is not required. It is acceptable to incorporate ring or mesh topologies along with the required star topology.

3-7.16.3 Grade 3 Telecommunications System.

Two separate feeds from separate buildings should serve the facility. Cabling should be separated by 66 feet (20 m) along their entire routes when possible. Document any restrictions of feed separation in the Basis of Design. The facility must have two entrance rooms at preferably opposing ends of the building. A separation distance of 66 feet (20 m) between the two rooms is acceptable if opposing ends are not viable. Sharing entrance feed equipment, fire protection zones, power distribution, and air conditioning equipment between the two entrance rooms is prohibited. The equipment in each entrance room must be able to maintain the mission if the equipment in the opposing entrance room is undergoing planned maintenance. Redundant backbone pathways must be between the entrance rooms, MDA, IDAs, and HDAs. The redundant connections must be in separate pathways or by separate cables.

3-7.16.4 Grade 4 Telecommunications System.

Grade 4 facility must meet all the provisions of Grade 3 plus the following: Backbone cabling and distributor rooms/area must be redundant. Backbones and horizontal cabling between two spaces must be separate paths, with common paths only inside the termination rooms/areas. There should be an automatic backup for all critical telecommunications equipment. The facility must have redundant MDAs. A separation distance of 66 feet (20 m) between the two rooms is acceptable if opposing ends are not viable. Sharing fire protection zones, power distribution units, and air conditioning equipment between MDAs is prohibited. The MDAs must have separate pathways to each entrance room. There must be a telecommunications cabling pathway between the facility MDAs. HDAs must be provided with connections to two different IDAs or MDAs. When provided, each IDA must be provided with connections to both MDAs. Critical systems should have connections to two HDAs.

3-7.17 Telecommunications Cabling, Topology, and Installation.

This section outlines the architecture and product performance requirements of the telecommunications system.

3-7.17.1 Backbone Cabling and Topology.

Maintain backbone cabling outside of horizontal cabling cable trays. When backbones are routed within a large data center space, cabling may be routed inside cable trays or conduits. Backbone topologies will vary based on facility Grade. Refer to project MESEP and Appendix A for exact requirements.

Figure 3-20 Grade 3 Concept Topology

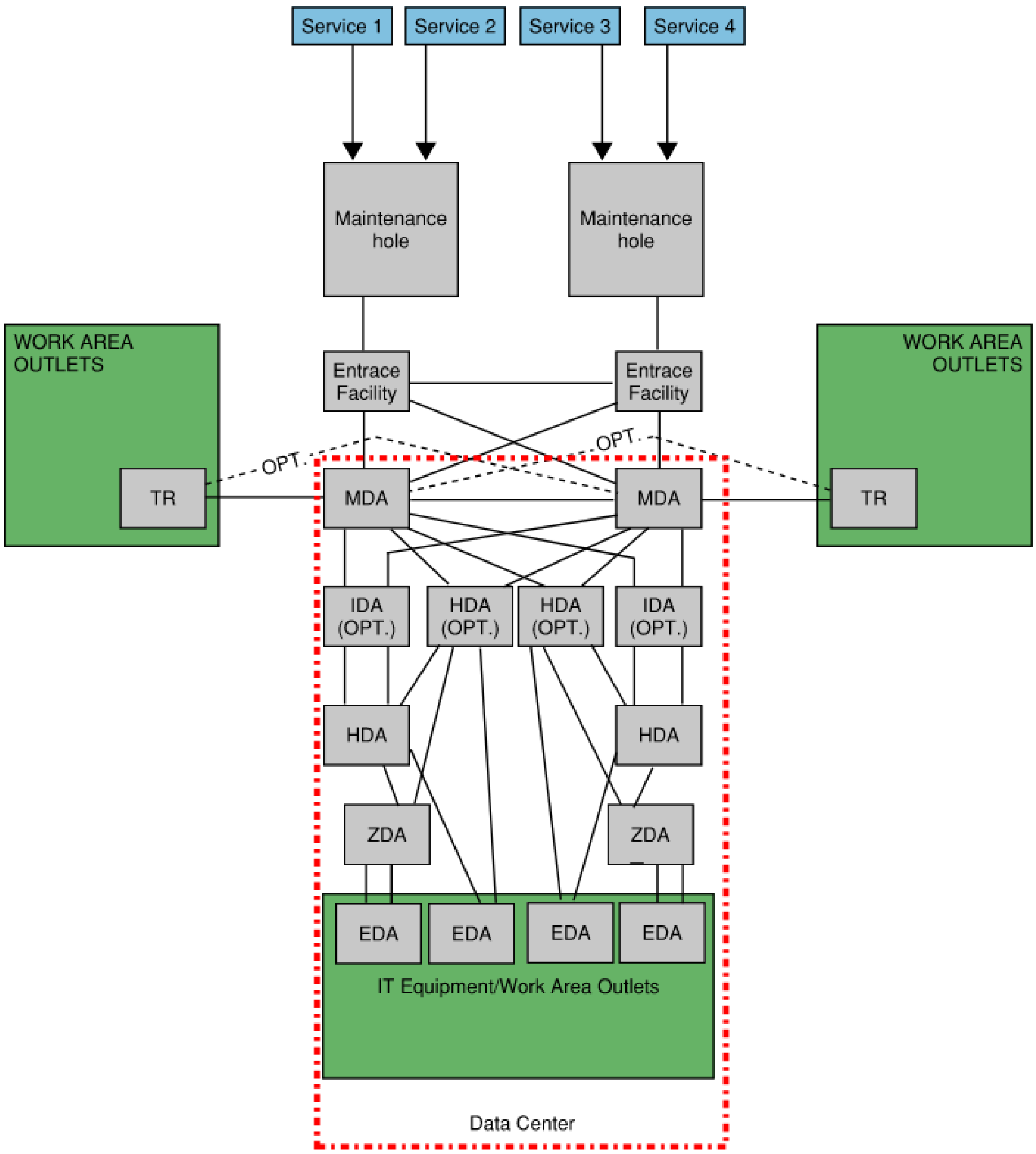
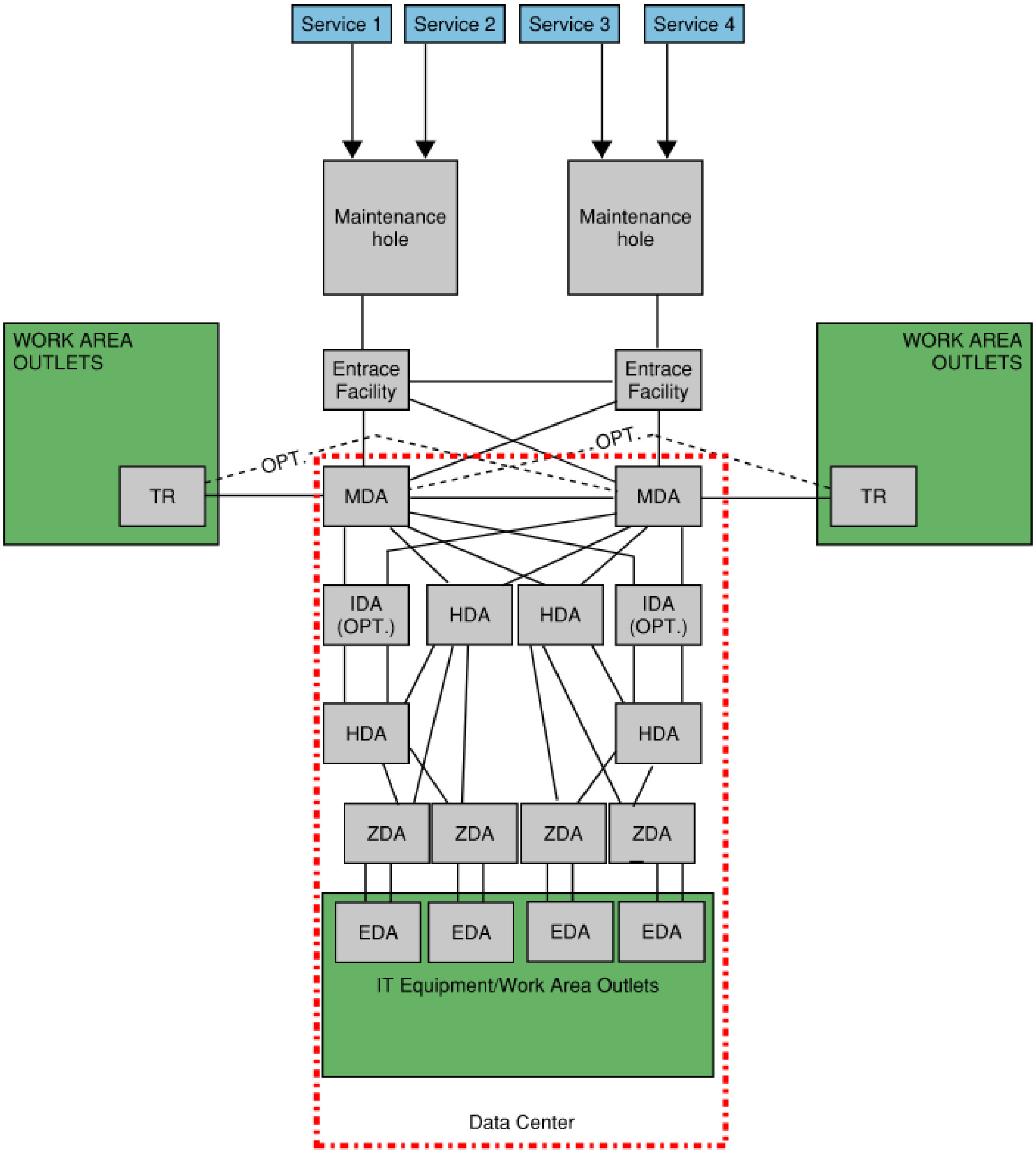


Figure 3-21 Grade 4 Concept Topology



3-7.17.2 Horizontal Cabling and Topology.

Horizontal cabling must be provided in a star topology. Refer to project MESEP and Appendix A for exact requirements. If workstations require redundant horizontal cabling, provide from two separate spaces/rooms. If not possible, route from separate rack/cabinets and provide a cable tray divider between the primary and redundant cabling. Redundant horizontal cabling is not required for workstations serving Grade 3 or 4 facilities. Secure and unsecure networks must maintain separation in accordance with CNSSAM TEMPEST 1-13. The use of cable tray dividers to maintain separation of networks sharing a cable tray is acceptable but not required. This will minimize cable trays within the building reducing overall space required. If dividers are not acceptable special networks with higher security than Red networks must be in their own cable trays.

3-7.18 Telecommunications Spaces and Pathway.

TR spaces should be provided with no ceiling. In facilities with a high structure, a hard ceiling is acceptable 24” above the highest infrastructure within the room.

Data center rooms and areas must be sized for the equipment and mission. Secure and unsecure networks must maintain separation in accordance with CNSSAM TEMPEST 1-13; add square footage for separation requirements. Consider the use of structural grid ceilings in data centers for equipment mounting. Include preferred space sizes in the project MESEP.

For Navy Only: Refer to FC 2-000-05N for guidelines for sizing spaces per rack/cabinet quantities.

3-7.18.1.1 Protected Distribution System (PDS).

Minimize the amount of PDS within the facility as much as possible. Verify with electronics engineer or base communications officer the strategy for decryption within secure spaces. It is not uncommon to have multiple secure areas but a single decryption device provided to support them. PDS is required in this situation to route secure backbones between secure areas. If a decryption device can be located in each secure area, then no PDS would be required between those spaces.

3-7.18.2 Telecommunications Cabinets and Racks.

Coordinate cabinet requirements with the selected mechanical system provided within the data center/equipment room space. Provide blanking panels for empty rack unit spaces when air control is required to maintain hot and cold aisles. If a containment system is required, coordinate the cabinet size/type to maintain proper containment/sealing of the system. Refer to project MESEP for exact requirements.

3-7.18.3 Outside Plant Cabling Infrastructure.

Refer to project MESEP for exact requirements.

3-7.18.3.1 Underground Pathways.

Concrete encase all duct banks providing incoming services to the facility.

3-7.18.3.2 Aerial Pathways.

Do not provide overhead services unless necessary.

3-7.19 Television Systems (CATV).

Provide copper to fiber to copper media conversion for CATV traversing secure boundaries when required.

3-7.20 Electronic Security Systems (ESS).

Provide in accordance with UFC 4-021-02 and coordinate with the security assessment per the design basis threat analysis. Coordinate exact requirements with stakeholders. Provide copper to fiber to copper media conversion for ESS traversing secure boundaries when required. Refer to project MESEP for exact requirements. Ethernet switches in the ESS architecture must be an OSI layer 2/3 managed.

3-7.21 Audio Visual (A/V)

Provide space in accordance with TIA-569 within the telecommunications rooms or local served spaces for A/V equipment.

3-8 FIRE PROTECTION AND LIFE SAFETY.

Provide buildings and systems in accordance with UFC 3-600-01 except where requirements are added/modified by this UFC. Electronic Equipment Areas, as defined by UFC 3-600-01, must follow UFC 3-600-01 requirements except as modified herein.

3-8.1 Physical Security.

For buildings requiring locking arrangements for security purposes, comply with NFPA 101, Life Safety Code locking requirements.

3-8.2 Areas Not Containing Electronic Equipment and Incidental Electronic Equipment Areas.

Comply with UFC 3-600-01.

3-8.3 Electronic Equipment Areas.

3-8.3.1 Electronic Equipment Area Separation.

Provide minimum 2-hour fire barriers to separate Electronic Equipment Areas from the rest of the facility.

3-8.3.2 Vaults, Other Electrical/Telecom Rooms Supplying Electronic Equipment Areas.

All vaults and other telecom and/or electrical rooms within C5ISR facilities that contain communication/data and/or electrical equipment that serve the Electronic Equipment Areas must be protected the same as the Electronic Equipment Areas in the facility and comply with all requirements in 3-8.3. Follow NFPA 70 Article 110. Provide clean agent fire extinguisher(s) sized and spaced in accordance with NFPA 10 in all vaults.

3-8.3.3 Fire Suppression Systems.

3-8.3.3.1 Classification of Hazard.

Follow UFC 3-600-01.

Army Facilities: Minimum sprinkler hazard classification for Electronic Equipment Areas must be Ordinary Hazard.

3-8.3.3.2 Automatic Sprinkler Protection for Electronic Equipment Areas.

Label and identify valves controlling water to Electronic Equipment Areas to indicate the Electronic Equipment Areas they serve.

Army and Navy Facilities: Provide wet-pipe automatic sprinkler protection in these areas of the facility where the facility is fully sprinkled. Use of preaction sprinkler systems is not permitted.

Air Force Facilities: Refer to UFC 3-600-01 and the use of TSFPEWG G 3-600-01.01-18 for automatic sprinkler system guidance, including areas permitting preaction sprinkler systems.

For areas with hot aisle and cold aisle containment, provide sprinklers inside the compartments to comply with NFPA 13 obstruction requirements.

3-8.3.3.3 Clean Agent Systems.

Provide total-flooding clean agent systems in addition to automatic sprinkler protection for all Electronic Equipment Areas in C5ISR facilities regardless of Grade. Comply with UFC 3-600-01 and activate system by a Very Early Warning Fire Detection System (VEWFD).

Note: Additional preventative maintenance requirements are incurred when using a total-flooding clean agent system such as maintaining the enclosure integrity. See UFC 3-601-02 for the required annual, 2-year, 5-year, and other Inspection, Testing, Maintenance requirements.

3-8.3.3.4 Portable Fire Extinguishers

Provide clean agent fire extinguisher(s) sized and spaced in accordance with NFPA 10 in all Electronic Equipment Areas.

3-8.3.4 Fire Alarm Systems.

Provide addressable fire alarm system in accordance with UFC 3-600-01.

3-8.3.4.1 Very Early Warning Fire Detection.

Provide VEWFD port spacing in accordance with NFPA 76 VEWFD port installation requirements. Design system using manufacturer-provided listed criteria, which includes the pipe air pressure, airflow rate through sampling port, percentage of total pipe flow through sampling port, and transport time required for a smoke sample to be drawn from the sampling port to the detector. For areas with hot aisle and cold aisle containment, provide detection inside the compartments. Utilize cross-zoned detection or an equivalent method to minimize potential for false discharges of the clean agent system.

Provide supervisory alert level notification (at lowest smoke obscuration level) with silence switch outside of the protected area in a readily apparent location to notify building occupants. If building occupants do not have access to the protected area, provide signage indicating contact information of personnel who have access to space. Where the protected area is always occupied, outside the space notification is not required.

3-8.3.5 Electronic Equipment Power Disconnect.

Must meet the requirements set forth in section 3-7.13.

Army and Navy Facilities: Provide manual means for electronic equipment EPO as permitted by UFC 3-600-01.

Air Force Facilities: Automatic EPO is permitted upon sprinkler water flow as guided by TSFPEWG G 3-600-01.01-18.

3-8.3.6 Air Handling Equipment Shutdown.

CRAC and CRAH units must not automatically shut down if electronic equipment remains energized and heat generated in the room will be sufficient to activate sprinkler heads. Duct smoke detectors and automatic shutdown are not required where air distribution systems are incapable of spreading smoke beyond the enclosing walls, floors, and ceilings of the room or space in which the smoke is generated.

Clean agent system activation must shut down any equipment cooling system where the airflow passes outside of the clean agent discharge envelope/volume. Equipment cooling systems with airflow completely within the discharge envelope/volume must continue to operate.

3-8.3.7 Smoke Exhaust Systems.

Army and Navy: Smoke exhaust of Electronic Equipment areas is not required in accordance with UFC 3-600-01.

Air Force: Refer to TSFPEWG G 3-600-01.01-18 for smoke exhaust guidance.

CHAPTER 4 SPECIAL REQUIREMENTS

4-1 MAINTENANCE AND COMMISSIONING REQUIREMENTS.

4-1.1 Maintenance.

Design for accessibility and maintenance. Provide egress pathways for all critical equipment to allow removal/replacement without interrupting service. Include in design package drawings indicating travel pathway for equipment removal. Ensure all equipment is readily accessible for inspection and ease of maintenance.

4-1.2 Commissioning.

Provide commissioning in accordance with UFC 1-200-02 and ANSI/NETA ECS. A third party must provide Integrated Systems Testing (IST) for all systems within the facility. Introduce mission critical events that initiate all emergency systems' sequence of operations. Verify that all mechanical, fire protection, and electrical systems operate per the designed sequence of operations and maintain the mission.

For Army only: Provide commissioning in accordance with ER 1110-345-723 and UFC 1-200-02.

4-1.2.1 Grade 1 Facility Scheduled Maintenance Event Test Requirements.

Not applicable.

4-1.2.2 Grade 2 Facility Scheduled Maintenance Event Test Requirements.

Initiate a mission critical scheduled maintenance event by removing equipment from the path of operation that has redundant components. Verify the mission's planned operating procedures by manually shutting down a single piece of equipment requiring maintenance and initiating the redundant mode of operation. Test must be repeated for each piece of equipment in the path of operation for each redundant component. Components are to be tested independently.

4-1.2.3 Grade 3 Facility Scheduled Maintenance Event Test Requirements.

Initiate a mission critical scheduled maintenance event by removing equipment from the intended path of operation. Verify the mission's planned operating procedures by manually shutting down a single piece of equipment requiring maintenance and initiating the redundant mode of operation. Test must be repeated for each piece of equipment in the intended path of operation and each path of operation.

4-1.2.4 Grade 4 Facility Critical Failure Event Test Requirements.

In addition, for Grade 4 facilities, initiate a simulated mission critical failure event by removing equipment from the intended path of operation without a planned procedure. Verify automatic operations of the system to the redundant path equipment for maintaining the critical load. Verify the intended redundant path is operating. Test must be repeated for each piece of equipment or system in the intended path of operation and each path of operation.

4-1.2.5 Systems Manual Requirements.

The Designer of Record (DOR) must incorporate the SM requirements into the construction documents via UFGS 01 91 00.15 Building Commissioning.

For Army only: Provide Systems Manual (SM) for all C5ISR facilities in accordance with ER 1110-345-723 and ER 25-345-1.

4-1.3 Staff Training.

Training of systems must cover the project system Sequence of Operations. It must demonstrate how to maintain facility operations during maintenance or fault conditions.

For Army only: Provide staff training for all C5ISR facilities in accordance with ER 1110-345-723.

4-2 ELECTRICAL.

4-2.1 400 Hz Power.

When 400 Hz is required, provide using either a motor generator or static converter. Provide calculations for conversion equipment in accordance with UFC 3-501-01. Consideration should be given to standby requirements when selecting and locating frequency converters. Both types of converters must be adequately grounded to prevent electromagnetic interference. Power at 400 Hz requires that the distribution system be carefully engineered. Consider using larger conductors, parallel feeders, non-magnetic conduits, and load drop compensators. All cables carrying 400-Hz power must be run in separate raceway systems.

4-2.2 Direct Current (DC) Power Systems.

Electronic facilities often require direct-current power supplies and distribution systems. These power systems utilize 24 to 48-volts DC. The facility’s electronic equipment engineer must provide these systems. Coordinate with the facility’s electronic equipment engineer to support equipment requirements. If others are not providing these systems, determine their impact on project cost and implementation if economically feasible for the project.

4-2.3 Data Center Infrastructure Management (DCIM).

Provide DCIM software integrated with the building's DDC/BAS computer. Integration of Information Technology (IT) and facility management disciplines centralizes monitoring, management, and intelligent capacity planning of a data center's critical systems. It is achieved by implementing specialized software, hardware, and sensors. DCIM enables common, real-time monitoring and management platform for all interdependent systems across IT and facility infrastructures. DCIM allows the user to record equipment installation dates and set maintenance intervals that alarm the user to perform preventative maintenance. The software can also integrate with more advanced sensors to address equipment on the verge of failure due to abnormal operating parameters. For example, a server cabinet operating at a higher temperature may require more frequent replacements of active equipment. DCIM can also track maintenance work orders and perform audits for compliance.

4-2.4 Power Conditioning.

For secure areas requiring filtering or conditioning of power refer to UFC 4-010-05. Any power conditioning equipment must meet the electrical power characteristics stated in Section 3-7.

4-2.5 Antenna Systems.

Size cable entry ports into facilities as required based on quantity and size. Cable boots must be provided and sized according to the cables to enter the entry port. Multi-cable modular-based compression-type transit systems are acceptable. Provide power to exterior antenna systems by underground cable trench with removable covers. Fluorescent and LED lighting can cause interference in radio systems. Consider using incandescent lighting for radio systems easily influenced by EMI. Discuss lighting with radio operators to verify EMI impact on systems.

4-2.6 Audio Visual.

Provide audio visual equipment as required. A/V equipment must utilize all hardwired connections; wireless operability is prohibited.

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APPENDIX A BEST PRACTICES

A-1 GENERAL.

A-1.1 Antiterrorism (AT).

Incorporate AT issues at the initial phase of the design. Coordinate all protection features with the current standards and any additional requirements in place at the time of the design. Ascertain the requirements for protection based on a site-specific survey, or lacking one, and provide the minimum protection standards outlined in the standards. Coordinate all AT issues with the base that may be a part of another project or impact adjacent facilities, such as security fencing and parking.

Design basis threat must consider both the occupants of the building and the equipment within the building necessary for the mission's success.

A-2 ENGINEERING SYSTEMS GRADING.

A-2.1 Grade 1.

Not applicable.

A-2.2 Grade 2.

These facilities have redundant componentry but not system level redundancy. Some maintenance activities will interrupt or impede the performance of the mission.

A-2.3 Grade 3.

These facilities can have any capacity component or distribution element serviced or repaired on a planned basis without interrupting or impeding the performance of the computer equipment.

A-2.4 Grade 4.

The facilities systems can continue operations uninterrupted despite the failure of one or more components.

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APPENDIX B GLOSSARY

B-1 ACRONYMS

A/E	Architecture/Engineering
AC	Air Conditioning
AFCEC	Air Force Civil Engineer Center
AFF	Above Finish Floor
ADP	Automatic Data Processing
AHJ	Authority Having Jurisdiction (See MIL-STD 3007, Change 2, Nov 2018)
ASCE	American Society of Civil Engineers
AT	Antiterrorism
ATS	Automatic Transfer Switch
A/V	Audio/Visual
BAS	Building Automation System
BESEP	Base Electronic System Engineering Plan
BIA	Bilateral Infrastructure Agreement
BTUs	British Thermal Units
C5ISR	Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance, and Reconnaissance
CATV	Television Systems
CDC	Core Data Center
CEDC	Component Enterprise Data Center
CFD	Computational Fluid Dynamics
C-I-A	Confidentiality, Integrity, and Availability
COMNAVWARSYSCOM	Naval Information Warfare Systems Command
CRAC	Computer Room Air Conditioning Units

CRAH	Computer Room Air Handling Units
CSP	Construction Security Plan
CTTA	Certified TEMPEST Technical Authority
CTR	Component Technical Representative
DC	Direct Current
DCIM	Data Center Infrastructure Management
DDC	Direct Digital Control
DF	Direction Finder
DOAS	Dedicated Outdoor Air System
DoD	Department of Defense
DOR	Designer of Record
DX	Direct Expansion
EC	Electronically Commutated
EDA	Equipment Distribution Area
EF	Entrance Facility
EMC	Electromagnetic Compatibility
EPA	Environmental Protection Agency
EPSM	Electrical Power System Monitoring
EPO	Emergency Power Off
ESS	Electronic Security Systems
FAC	Facility Analysis Category
FACU	Fire Alarm Control Unit
GIS	Gas Insulated Switchgear
GSU	Geographically Separated Unit
HDA	Horizontal Distribution Area

HMI	Human Machine Interface
HMT	Harmonic Mitigating Transformers
HNFA	Host Nation Funded Construction Agreements
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	Heating, Ventilating, and Air-Conditioning
Hz	hertz
in.	Inches
in^2	Square Inches
I/O	Input/Output
IDA	Intermediate Distribution Area
IGBT	Isolated Gate Bipolar Transistor
IPN	Installation Processing Node
ISN	Installation Services Node
IST	Integrated Systems Testing
IT	Information Technology
kg	Kilogram
kPa	Kilopascal
lb	Pounds
LCCA	Life Cycle Cost Analysis
LSI	Long-time, Short-time, and Instantaneous
mm	Millimeter
mm^2	Square Millimeter
MBH	**T**housand BTU per Hour
MDA	Main Distribution Area
MERV	Minimum Efficiency Reporting Value

MESEP	Mission Engineering Systems Execution Plan
MTS	Manual Transfer Switch
M-T-T-M	Main-Tie-Tie-Main
NAVFAC	Naval Facilities Engineering Systems Command
OCONUS	Outside Continental U.S.
OSI	Open Source Interconnection
PDS	Protected Distribution System
PDU	Power Distribution Unit
PEMCS	Power and Environmental Monitoring and Control System
PLd	Performance Level d
psf	Pounds per Square Foot
RPCS	Real Property Categorization System
RPP	Remote Power Panel
rPDU	Rack Mounted PDU
rSTS	Rack Mounted STS
SAPF(s)	Special Access Program Facility(ies)
SCIF(s)	Sensitive Compartmented Information Facility(ies)
SEI	Structural Engineering Institute
SIS	Solid Insulated Switchgear
SM	Systems Manual
SOFA	Status of Forces Agreements
SoO	Sequence of Operations
SPPN	Special Purpose Processing Node
SSM	Site Security Manager
STS	Static Transfer Switch

THD	Total Harmonic Distortion
TPN	Tactical Processing Node
TR	Telecommunication Room
UFC	Unified Facilities Criteria
UPS	Uninterruptible Power Supply
USACE	U.S. Army Corps of Engineers
U.S.	United States
VRF/VRV	Variable Refrigerant Flow/Volume
VEWFD	Very Early Warning Fire Detection
ZDA	Zone Distribution Area

B-2 DEFINITION OF TERMS.

Electronics Engineer: Person(s) responsible for the active equipment design of the mission systems to be contained within the facility.

Equipment Rooms: Rooms containing mission active data processing equipment.

Grade: A DoD specific term that is similar to Uptime Institute's Tiering, ANSI/TIA 942 Data Centers, and ANSI/BICSI 002 Class models.

APPENDIX C REFERENCES

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MIL-HDBK-419A, *Grounding, Bonding, and Shielding for Electronic Equipments and Facilities*

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ARMY

https://armypubs.army.mil/

AR 405-70, *Utilization of Real Property*

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ER 25-345-1, *Systems Manual*

TM 5-691, *Utility Systems Design Requirements for Command, Control Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*

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BUILDING INDUSTRY CONSULTING SERVICE INTERNATIONAL (BICSI)

https://www.bicsi.org/

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https://standards.ieee.org/

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IEEE 493, *Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems*

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NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

https://www.nfpa.org/

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Note: The NEC must be effective for new design projects awarded after January 1 of the year following the issuance of a revised edition unless specifically identified otherwise in contract documents

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UFC 4-141-10
22 September 2022

UNIFIED FACILITIES CRITERIA (UFC)

AIRFIELD OPERATIONS SUPPORT FACILITIES

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UFC 4-141-10
22 September 2022

UNIFIED FACILITIES CRITERIA (UFC)

AIRFIELD OPERATIONS SUPPORT FACILITIES

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

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

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This UFC supersedes UFC 4-141-10N, dated January 2004.

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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 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 Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC S), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. 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 web site http://www.wbdg.org/ffc/dod.

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

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

This Unified Facilities Criteria (UFC), UFC 4-141-10, *Airfield Operations Support Facilities* provides requirements for evaluating, planning, programming, and designing Airfield Operations Support Facilities. The requirements contained in this UFC apply to Army, Navy, and Air Force facilities unless specifically referenced to a single service. This UFC is not intended as a substitution for thorough review during design by individual Program Managers and Operations Staff in the appropriate service.

The desired goal of this UFC is to maintain consistency in Air Operations Support Facility requirements across the Army, Navy and Air Force. This UFC is not intended as an operational manual.

Each service has unique requirements to fulfill specific missions. This document highlights any key differences that impact the overall facility program, layout and design. Where one Service's criteria vary from the other Services' criteria, it is noted in the text.

1-2 INCORPORATES AND CANCELS.

UFC 4-141-10N, *Design: Aviation Operation and Support Facilities*, 16 January 2004.

1-3 PURPOSE AND SCOPE.

This UFC is organized with general requirements for several different categories of airfield operations support facilities included in separate chapters. Within each chapter, the planning and design requirements for one or more system are described, with differences between Service requirements identified.

1-4 APPLICABILITY.

The information in this UFC applies to the design of all new construction projects, to include additions, alterations, and renovation projects within the United States and its territories and possessions outside of the United States.

1-5 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.

1-5.1 Facility Requirements Document (FRD)

The airfield operations support facility manufacturer's FRD or equivalent document is an integral requirement of facility design that contains additional specific facilities requirements that must be considered and satisfied in addition to this UFC.

FRDs are typically authored by the system manufacturer and contain many specific details, are often quite voluminous and difficult to obtain. The FRD may have additional technical facility requirements, special maintenance procedures, systems, data or other items that may impact the airfield operations support facility design. This UFC is not a substitute for the FRD of the support facility.

1-6 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*, and as required by individual Service Implementation Policy.

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

1-7 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and terms.

1-8 REFERENCES.

APPENDIX C 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.

CHAPTER 2 GENERAL PLANNING AND DESIGN CONSIDERATIONS

2-1 INTRODUCTION.

2-2 SERVICE CONTACT AGENCIES.

For additional information and guidance on the topics covered in this UFC, contact the following agencies within each Service. These agencies were instrumental in providing the contents of this UFC.

2-2.1 Army.

Fixed Base Division
Air Traffic Services Command (ATSCOM)
Ft Rucker, AL
Email: usarmy.rucker.forscom.mbx.afat-ats-cb@mail.mil

2-2.2 Navy.

a. Instrument Landing System and Shore Instrument Carrier Landing System Facilities

   Naval Air Warfare Center Aircraft Division – Webster Outlying Field (NAWCAD WOLF)
   17464 Webster Field Road, Building 8131
   St. Inigoes, MD 20684
   Email: shore_ls@us.navy.mil

b. Shore Based Airport Surveillance Radar (ASR), ATC Communications Facilities, and Automated Surface Observing System (ASOS)

   Naval Information Warfare Center (NIWC) – Atlantic
   ATC Engineering Division
   P.O. Box 190022
   North Charleston, SC 29419
   Email: atcweb@navy.mil

c. TACAN & PAR Facilities

   Naval Information Warfare Center (NIWC) – Pacific
   Code 41110 Tactical Air Navigation Branch
   53560 Hull Street
   San Diego, CA 92152-5001
   Email: tacan@navy.mil, NIWC_4110_TACAN_ISEA@us.navy.mil

2-2.3 Air Force.

ATCALS Maintenance Division
Air Force Flight Standards Agency
HQ AFFSA/XM
Oklahoma City, OK
Email: HQAFFSA.XM.ATCALS.1@us.af.mil

2-3 GENERAL PLANNING CONSIDERATIONS.

2-3.1 Key Planning Documents.

UFC 2-000-05N	*Facility Planning for Navy and Marine Corps Shore Installations*
UFC 2-100-01	*Installation Master Planning*
UFC 3-201-01	*Civil Engineering*
UFC 3-260-01	*Airfield and Heliport Planning and Design*
NAVFACINST 11010.45A	*Site Approval Request Process*

2-3.2 Planning Process.

The planning process is used to define and consolidate requirements for a new facility and then select a site that meets those requirements while also fitting within site constraints. Each Service has their own defined process for site selection that must be followed for every facility project. The planning process ensure that the full range of factors that may influence site selection are considered before site approval is achieved.

Factors that must be considered include:

- Installation Master Plan
- Land Use Compatibility (AICUZ)
- Topography and Flood Protection
- Airfield Clearances
- Airspace Clearances
- Roadway Access
- Environmental Constraints
- Natural, Historic and Cultural Resources
- Future Development
- Explosive Safety Quantity-Distance Arcs

- Security
- Connections to other Facilities

All new construction must be evaluated for potential environmental impacts following the requirements of the National Environmental Policy Act (NEPA). See Service-specific guidance for implementation of this process.

Ensure the Lead Service Agencies are consulted early in the planning and programming process to explore all viable options and make the best possible site selection.

In most cases, the facilities described in this UFC must be sited in a particular location to properly function. However, site-specific conditions might require a non-standard installation. Where a non-standard installation is required and conflicts with the airfield clearances described in UFC 3-260-01, follow the Service-specific waiver processing procedures outlined in UFC 3-260-01, Appendix B, Section 1 during site selection and approval, before detailed design or construction has begun.

2-4 GENERAL DESIGN CONSIDERATIONS.

2-4.1 Key Design Documents.

These are a partial list of key design documents that contain additional requirements for the respective subjects. Requirements in this UFC related to those subjects are additive and intended to conservatively supplement these documents and references. See Section 1-4 for General Building Requirements.

UFC 1-200-01	*General Building Requirements*
UFC 2-000-05N	*Facility Planning Criteria for Navy/Marine Corps Shore Installations*
UFC 3-101-01	*Architecture*
UFC 3-110-03	*Roofing*
UFC 3-201-01	*Civil Engineering*
UFC 3-220-01	*Geotechnical Engineering*
UFC 3-250-01	*Pavement Design for Roads and Parking Areas*
UFC 3-260-01	*Airfield and Heliport Planning and Design*
UFC 3-260-04	Airfield and Heliport Marking
UFC 3-301-01	*Structural Engineering*
UFC 4-010-01	*DoD Minimum Antiterrorism Standards for Buildings*

UFC 4-022-03	*Security Fences and Gates*
UFC 3-401-01	*Mechanical Engineering*
UFC 3-410-01	*Heating, Ventilating and Air Conditioning Systems*
UFC 3-420-01	*Plumbing Systems*
UFC 3-450-01	*Noise and Vibration Control*
UFC 3-460-01	*Design: Petroleum Fuel Facilities*
UFC 3-501-01	*Electrical Engineering*
UFC 3-520-01	*Interior Electrical Systems*
UFC 3-530-01	*Design: Interior and Exterior Lighting and Controls*
UFC 3-535-01	*Visual Air Navigation Facilities*
UFC 3-540-01	*Engine-Driven Generator Systems for Prime and Standby Power Applications*
UFC 3-575-01	*Lightning and Static Electricity Protection Systems*
UFC 3-580-01	*Telecommunications Building Cabling Systems Planning and Design*
UFC 3-600-01	*Fire Protection Engineering for Facilities*
UFC 4-133-01	*Air Traffic Control and Air Operations Facilities*
TSEWG TP-19	*Static Uninterruptible Power Supply (UPS)*
FAA AC 70/7460-1	*Obstruction Marking and Lighting*
FAA AC 150/5220-23	*Frangible Connections*
FAA AC 150/5320-5	*Surface Drainage Design*
SDDCTEA Pamphlet 55-17	*Traffic and Safety Engineering for Better Entry Control Facilities*

2-4.2 Site Selection.

In addition to the following paragraphs, site facilities in accordance with UFC 3-260-01. For Navy and Marine Corps, also check UFC 2-000-05N for airfield safety clearances.

2-4.2.1 Siting Criteria/Land Requirements.

For each Airfield Operations Support Facility there are specific criteria that must be met to allow the device to function properly. These requirements are described in the chapters for each system. The optimum location of the device relative to the runway/taxiway or airport varies by the function of the device. There are tolerances to the ideal device siting location, which allow some flexibility to fit existing facilities.

2-4.2.2 Separation/Clearance.

In addition to the location of the facility and the land needed, there are specific separation and clearance standards for each device for it to function properly and provide a safe environment for aircraft operations. Each device has allowable height and separation distances for above-ground objects around the device so that the electronic or light signal is not impacted. The size, shape, mass and material nature of the object can impact the function of a device that transmits an electronic signal. For communications and surveillance antennas, including some NAVAID antennas, there is a critical area immediately around the device that must be kept clear of all above-ground objects. Once a NAVAID is installed, it is essential to maintain the separation and clearance standards as future construction is considered in the vicinity of the facility. A Notice of Proposed Construction or Alteration (FAA Form 7460-1) must be submitted to the FAA to allow an evaluation of the potential impact of any proposed construction in the vicinity of a NAVAID. Sometimes the nature of construction activity will by itself mean that the NAVAID must be temporarily turned off, to prevent a false signal from being transmitted.

2-4.2.3 Critical Areas.

Many NAVAIDs and ATC facilities have a defined critical area that must be protected to ensure adequate performance.

a. <u>Geometry</u>. Each critical area extends a certain distance out in all or select directions. It can be circular-, rectangular- or wedge-shaped. The dimensions may vary based on the aircraft and terminal operations the NAVAID and ATC facility is designed to serve and the precision of the device in use.

b. <u>Grading</u>. There are standards for grading the ground around each of the NAVAIDs. In general, grade the immediate area around the device relatively smooth, level and well drained.

c. <u>Protection</u>. Coordinate maintenance activities, such as mowing or the use of service vehicles, within the critical area with the tower and airfield management offices to prevent a degradation of the function of the NAVAID during Instrument Flight Rules (IFR) conditions when the operation of the NAVAID is critical. Proposed construction in the vicinity of any NAVAID must be reviewed and analyzed by the Lead Service Agency to determine any potential impacts to the function of the NAVAID. For off-airport NAVAIDs, installation of fencing or guardrails along the perimeter of the critical area is needed to keep these areas clear. For certain systems, due to false reflective targets or poor accuracy, exercise care when a decision to fence around a critical area is made.

2-4.2.4 Jet Blast/Exhaust.

Locate NAVAIDs, monitoring devices, and equipment shelters at least 600 feet (183 m) behind the source of jet blast to minimize the accumulation of exhaust deposits on antennas.

2-4.3 NAVAIDs as Obstacles.

Any object, including NAVAIDs, that are located near an active runway can present an increased risk to aircraft operations. In particular, UFC 3-260-01 recognizes the need to limit NAVAIDs except those required to be in a certain location to perform their function and may fall within the Primary Surface or penetrate Imaginary Surfaces. Any NAVAID object that remains inside the Primary Surface must be supported by frangible structures that minimize damage to any aircraft that might strike the object.

2-4.3.1 Permissible Deviations (Army and Air Force) and Standard Exceptions (Navy and Marine Corps).

While it is desirable not to have any objects in areas that could be a hazard to aircraft, some properly sited NAVAIDs have been classified as being Permissible Deviations (Army and Air Force per UFC 3-260-01, Appendix B, Section 13) or Standard Exceptions (Navy and Marine Corps per UFC 3-260-01, Chapter 2). In other words, the NAVAID location is critical for its proper functioning and the safety benefit derived from the operation of the NAVAID outweighs the potential risk of an aircraft striking the NAVAID. A permissible deviation or standard exception determination allows NAVAIDs to be in the Primary Surface. However, the power and control equipment and shelters associated with certain NAVAIDs are not considered to be a permissible deviation or standard exception in regard to the Primary Surface, unless operational requirements require them to be near the NAVAID.

2-4.3.2 Frangibility.

NAVAID objects located within operational areas on the airport are generally mounted with frangible couplings, with the point of frangibility no higher than 3 inches (75 mm) above the ground on the mounting legs, which are designed to break away upon impact. This reduces the potential damage to an aircraft that inadvertently leaves the paved surfaces. FAA AC 150/5220-23 provides guidance on frangible connections to meet frangibility requirements.

2-4.3.3 Non-Standard Installations.

Any NAVAID or associated equipment that remains inside the Primary Surface and is not a permissible deviation or standard exception and does not meet frangibility requirements is a non-standard installation. The NAVAID must be removed from the Primary Surface if practicable.

2-4.3.4 Marking and Lighting.

NAVAIDs that penetrate the Imaginary Surfaces defined in UFC 3-260-01 are marked with international orange and white paint and lights, with red obstruction lights placed on the highest point. This makes the NAVAID and other ATC Facilities more visible to the pilot. See UFC 3-260-04 for marking requirements. See UFC 3-535-01 for obstruction lighting requirements.

2-4.4 Site Considerations.

2-4.4.1 Site Suitability.

Basic considerations for site selection include terrain characteristics and meteorological conditions. Locate facilities requiring technical adequacy for radiation, reception, visibility, etc., following the requirements established by the governing agency or command responsible for the project. Ensure site selection considerations are fully understood and incorporated into the design. Site considerations for electronic facilities are generally contained in facility-specific FAA Orders or FRDs referenced in the following chapters. Ensure new systems do not encroach on Compass Calibration Pads. See UFC 3-260-01, Chapter 6 for specific requirements.

2-4.4.2 Separation of Structures.

Comply with UFC 3-600-01.

2-4.4.3 Access and Parking.

Provide paved access drives and parking lots for attended facilities. Access drives and parking facilities for <u>unattended</u> facilities may be unpaved except where access to the facility is directly from runways and taxiways. In these cases, pave minimum 300 feet (100 m) prior to connecting to an airfield operations surface (runway, taxiway, apron) to avoid the scattering of debris onto the operational surfaces. At facilities adjacent to runways and taxiways, provide parking space off the operational surface for a maintenance vehicle. Locate the parking space to avoid interference with the operation of any facilities in the area (e.g., provide adequate wingtip clearances). Ensure roadway and vehicle parking surfaces within the airfield operations area are flush with the surrounding ground surface. See UFC 3-250-01 for roadway design procedures. Grade unpaved access roads and parking areas to rapidly drain surface water and constructed with materials that remain stable to support maintenance vehicles in all local environmental conditions.

2-4.4.3.1 Parking.

The number of parking stalls required at each facility varies dependent upon the function, location, and size of the user command. Consider double work shifts and shift changes when determining the required number of parking stalls. Criteria for establishing the required number of parking stalls based on the type of facility and size of the work force are provided in SDDCTEA Pamphlet 55-17. In addition to requirements established in the reference document, conform to the following restrictions:

2-4.4.4 Access for Fire Department Vehicles.

Consult local authorities having jurisdiction for criteria regarding access to the area and clearance around the buildings for fire apparatus maneuvering. The equipment expected to respond to an emergency will control these decisions. See National Fire Protection Association (NFPA) 1141, Fire Protection in Planned Building Groups.

2-4.4.5 Site Drainage.

Provide drainage design in accordance with UFC 3-201-01. Metallic pipe and reinforced concrete pipe are inappropriate at some sites. Establish requirements for use of metallic pipe and reinforced concrete pipe early in facility planning. Consider drainage swales with minimal velocities to avoid erosion. See also FAA AC 150/5320-5 for surface drainage on airfields.

2-4.4.6 Protection of Fixed Objects.

In areas where frangibility is not a concern, provide barriers or bollards to protect non-frangible fixed objects (electrical transformers, generators, fuel tanks, fire hydrants, etc.) outside the primary surface from damage due to vehicles and moving equipment.

2-4.4.7 Airfield Safety.

Consider safety clearances listed in UFC 3-260-01 when siting facilities in or near aviation operational areas. For Navy and Marine Corps, also check UFC 2-000-05N for airfield safety clearances. Fabricate objects located within the Primary Surface for low impact resistance in accordance with FAA AC 150/5220-23. Provide obstruction marking or lighting for facilities located in or near aviation operational areas in accordance with UFC 3-260-04 and UFC 3-535-01.

2-4.5 Architectural Requirements.

Comply with requirements of UFC 3-101-01. Place design emphasis on fire resistance, minimal maintenance and repair cost, and ease of facility expansion or modification. Electronic communications equipment housed in the building varies with the mission of the installation. Design facility exterior in accordance with the base architectural compatibility guidance or local command architectural guidance.

2-4.5.1 ADA Requirements.

Provide barrier-free access to civilian workspaces and other spaces intended for public access. Design facilities to locate handicapped access spaces on first floor only unless the size of the facility's administration and other accessible areas requires a second floor. Areas hazardous to handicapped persons need not be accessible. Comply with current criteria in Uniform Federal Accessibility Standards (UFAS). Refer to UFC 3-101-01.

2-4.6 Structural Requirements.

Design in accordance with UFC 3-301-01. Base an economical structural system on facility size, projected load requirements, quality of local available materials, local labor and construction materials, and local wind, snow, seismic, geologic, and permafrost conditions. Design structural systems to support roof-mounted and/or suspended loads, when required.

2-4.7 Construction Materials.

Design attended facility buildings using styles and materials as approved by the ordering authority. Unless otherwise directed, design unattended facility buildings using concrete, concrete masonry, pre-engineered metal, or premanufactured metal or fiberglass-reinforced plastic. Use construction methods that provide maximum overall economy consistent with functional and aesthetic requirements, reasonable comfort, and sound architectural and engineering practices. Select materials, equipment, and methods to result in low costs consistent with economic maintenance for the required use and life expectancy of the facility. Refer to UFC 1-200-01.

2-4.7.1.1 Reflective Surfaces.

To prevent mirrorlike reflections from building surfaces to aircraft in flight, provide roofs and other external surfaces with a specular reflectance compatible with the location of the building on the airfield. If the building is located such that glare may be an operational hazard, provide the critical surfaces of that building with a light reflectance of not more than 10, measured at an angle of 85 degrees in accordance with American Society for Testing and Materials (ASTM) D 523, Standard Test Method for Specular Gloss.

2-4.7.2 Floors and Foundations.

Construct antenna foundations, equipment pads and building floors with reinforced concrete on a compacted subbase or subgrade in accordance with UFC 1-200-01, UFC 3-220-01, and UFC 3-301-01. Site-specific design is required for all foundations and floors, considering the local soils, climate and environmental loads.

Unless otherwise indicated in this UFC or in specific system FRDs, provide equipment pads for prefabricated or modular shelters minimum 12-inches larger than the supported equipment on all sides.

For foundations on airfields, construct foundations or equipment pads 2 inches (50 mm) +/- 1 inch (25 mm) above the surrounding grade. When the foundation is surrounded by airfield pavement or shoulder pavement, construct the foundation flush with surrounding pavement.

2-4.7.3 Roofing.

Provide roof system and insulation to meet the requirements of UFC 3-110-03. Determine thermal resistance of roof insulation by design criteria and life cycle costs.

2-4.8 Mechanical Requirements.

Comply with the requirements of UFC 3-401-01.

2-4.8.1 Energy Conservation.

Design climate-controlled facilities for energy efficiency. Consider isolated ventilation or air conditioning systems for equipment with high heat loads or that require more critical temperature or humidity control than would otherwise be required for the remainder of the occupancy.

2-4.8.2 Equipment Selection.

Select adequately sized air conditioning equipment for personnel comfort applications to remove the sensible and latent heat loads generated within these areas. Computer rooms and electrical equipment rooms produce predominantly sensible heat and require specially designed units. Ensure mechanical systems do not interfere with electronic equipment or radiated signals.

2-4.8.3 Heating and Air Conditioning.

Provide heating and air conditioning in accordance with UFC 3-401-01 and UFC 3-410-01. Provide duct smoke detectors and controls in accordance with UFC 3-600-01.

2-4.8.4 Plumbing.

Provide plumbing for facilities in accordance with UFC 3-420-01. Ensure that plumbing work not covered by UFC criteria meets the requirements of the National Plumbing Code Handbook.

2-4.8.4.1 Water and Sanitation.

Unattended facilities are not normally provided with water and sanitation facilities (sink and toilets). However, provide water and sanitary facilities at unattended facilities where a significant amount of maintenance is anticipated, and sanitary facilities are not available in the vicinity. Consider the use of chemical toilets and bottled water.

2-4.8.5 Fire Protection.

Design fire protection systems in accordance with UFC 3-600-01.

2-4.8.6 Noise and Vibration Control.

Design mechanical systems and equipment to limit noise and vibration in accordance with UFC 3-450-01.

2-4.9 Electrical Systems.

Design electrical systems in accordance with UFC 3-501-01.

2-4.9.1 Lighting.

Design interior lighting in accordance with UFC 3-530-01.

2-4.9.2 Lightning Protection.

Design facilities for lightning protection. Refer to NFPA 78, *Lightning Protection Code*, and UFC 3-575-01 for minimum standards.

2-4.9.3 Emergency Electrical Power.

2-4.9.3.1 Emergency Generator.

Provide emergency generators with electronic line monitoring equipment and automatic starting and switching capability. Design in accordance with UFC 3-540-01. When used in conjunction with an UPS, provide generator output at least 1.5 times the output rating of the UPS. Provide the following for emergency generators:

a. Unless otherwise noted, provide automatic starting and switching capable of supplying the rated load within 15 seconds of a power failure, except where Category II instrument operations are conducted.
b. During Category II instrument operations, a 1-second power transfer is required. This is normally accomplished by providing a remote start capability which permits operation of the systems on the generator during Category II weather conditions. Standby power is then subject only to switching time. The actual procedure must be locally coordinated.
c. An isolation switch to bypass the emergency generator during generator maintenance.
d. An automatic battery charger for maintenance of generator starting batteries.
e. An isolated mounting slab for the generator to reduce noise and vibration transmission.
f. Provide the following when an indoor emergency generator is required:
    - A separate generator room with an independent ventilation system.

- An engine exhaust system connected to the exterior of the facility with an exterior muffler. Configure the exhaust system to prevent rainwater or condensation from entering the engine manifold.
- Adequate engine cooling by a radiator duct or externally mounted radiator.

g. Consider a premanufactured building to house an indoor generator. Consider an outdoor unit in mild climate conditions. Consider a below ground generator vault for units which must be sited within airfield clear zones or primary surfaces.

2-4.9.3.2 Emergency Generator Fuel Storage.

Design fuel storage for generators in accordance with UFC 3-460-01 and UFC 3-540-01 as well as state and local regulations. Provide fuel storage capacity for 24 hours of continuous generator operation, unless otherwise noted in subsequent chapters. Provide double wall storage tanks and piping.

2-4.9.4 Uninterrupted Power Supply (UPS)

Provide an UPS in electronic facilities and air traffic control installations for critical technical loads and the specific requirements of the ordering authority. Install the UPS in accordance with UFC 3-501-01, UFC 3-520-01 and TSEWG TP-19.

2-4.10 Communications Systems.

Provide voice, data, and equipment control communications systems in accordance with UFC 3-580-01. Consider fiber optic systems in facilities requiring extensive internal communications systems for electronic cable protection.

Bury communication cables minimum 24 inches (610 mm) below ground. Install cables in concrete-encased conduit or duct bank beneath runways, taxiways, aprons, roadways and parking areas with regularly spaced manholes or handholes. Concrete-encase conduits where appropriate to protect critical communications systems from accidental damage during digging.

2-4.10.1 Cable Loop System.

For the benefit of redundancy and uninterrupted service, provide a cable loop system. FAA Order 6950.23 addresses control/monitor, digital data, voice/voice frequency and radar video/trigger signals.

2-4.11 Physical Security.

Comply with UFC 4-010-01. Where fences are required, comply with UFC 4-022-03.

2-4.12 Air Traffic Control Towers.

This UFC does not apply to Air Traffic Control Towers. See UFC 4-133-01.

2-5 STORMWATER MANAGEMENT.

Determine whether on-site stormwater management to address the added impervious surfacing associated with the concrete pads and gravel surfacing is required. If thresholds are exceeded, implement stormwater management strategies to meet the local, state, or federal guidelines for stormwater treatment. Typical strategies used include bioretention swales or cells, dispersing stormwater through existing or new vegetation, and infiltration facilities. See UFC 3-260-01, Chapter 2 for precautions and prohibitions regarding stormwater management facilities on or near airfields.

2-6 EROSION AND SEDIMENT CONTROL.

Install erosion control measures to prevent construction stormwater from leaving the project site and entering any adjacent storm system or critical areas. Measures must meet local, state, and federal guidelines. Typical erosion control measures that may be used include filter fabric fencing, silt sock fabric, and catch basin filter inserts.

2-7 FRANGIBILITY REQUIREMENTS.

Army and Air Force: Comply with frangibility requirements included in UFC 3-260-01, Appendix B, Section 13.

Navy and Marine Corps: Comply with frangibility requirements described in FAA AC 150/5220-23.

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CHAPTER 3 AIR NAVIGATION AIDS

3-1 GENERAL INFORMATION.

Air Navigation Aid facilities are fixed ground station electronic equipment which transmit bearing, identification, and distance information to properly equipped aircraft. These facilities are unattended.

3-1.1 Function.

Air Navigation Aid facilities may consist of the following types of facilities.

Table 3-1 Types of Air Navigation Aid Facilities

Designation	Type of Facility
VOR	VHF navigational facility, omnidirectional azimuth only
DME	UHF navigational facility, distance only
TACAN	UHF navigational facility, omnidirectional azimuth and distance
VOR/DME	Associated VOR and DME navigational facilities
VORTAC	Associated VOR and TACAN navigational facilities

3-1.1.2 Very High Frequency (VHF) Omni-Directional Range (VOR) Systems.

The VOR facility is a VHF, fixed ground-based station which continuously transmits bearing, identification, and with proper equipment (DME), distance information to properly equipped aircraft. Figure 3-1 illustrates a typical VOR facility. See FAA AC 150/5300-13 and FAA Order 6820.10 for a detailed description of the features and different types of VOR facilities.

Figure 3-1 VOR (VOR) Facility

3-1.1.3 Distance Measuring Equipment (DME).

The DME provides pilots with a measurement of distance to the runway in nautical miles. The DME is a terminal area or en route navigation facility that provides the pilot with a direct readout indication of aircraft distance from the identified DME. It can be co-located with a VOR and/or a Localizer shelter. Figure 3-2 illustrates a typical DME antenna located adjacent to a Localizer Shelter.

Figure 3-2 Omni-Directional Distance Measuring Equipment (DME) Antenna

3-1.1.4 Tactical Air Navigation (TACAN) Systems.

The TACAN facility is an ultra-high frequency (UHF) ground-based station, developed by the military, which continuously transmits bearing, identification, and distance information to properly equipped aircraft when interrogated. Figure 3-3 illustrates a typical TACAN facility.

Figure 3-3 Typical TACAN Facility

3-1.1.5 Very High Frequency (VHF) Omni-Directional Range/Tactical Air Navigation (VORTAC).

The VORTAC facility is a VHF/UHF fixed ground-based station which continuously transmits bearing, identification, and distance information to properly equipped aircraft when distance measuring equipment (DME) is installed. It combines a VOR and TACAN into one facility. Figure 3-4 illustrates a typical VORTAC.

Figure 3-4 VORTAC Facility

3-2 VERY HIGH FREQUENCY (VHF) OMNI-DIRECTIONAL RANGE (VOR) SYSTEMS.

3-2.1 Key Documents.

UFC 3-260-01	*Airfield and Heliport Planning and Design*
FAA AC 150/5300-13	*Airport Design*
FAA Order 6780.5	*DME Installation Standards Handbook Type FA-96-39 (Request from Lead Service Agency)*
FAA Order 6780.8	*Distance Measuring Equipment (DME) Installation Standards Handbook Type FA-9783 (Request from Lead Service Agency)*
FAA Order 6820.10	*VOR, VOR/DME, and VORTAC Siting Criteria*
AF T.O. 31Z3-822-2	*Air Traffic Control Landing Systems (ATCALS) Site Requirements 404L*

3-2.2 Siting.

If possible, locate the VOR in an area adjacent to the intersection of the primary runways. Locate the facility at the minimum distances from the centerline of runways and taxiways according to Table 3-2 and Figure 3-5. When the facility is located off the airfield, consider selecting a site with one or more flight path courses providing an approach to the primary runway. When sited outside these distances, include obstruction lighting if the VOR is within the primary surface or penetrates the imaginary surfaces defined in UFC 3-260-01. See UFC 3-260-01 and FAA Order 6820.10 for more details about siting considerations.

Table 3-2 VOR Siting Dimensions

Item		Legend in Figures	Requirement		Remarks
No.	Description				
1	Distance to Runway Centerline	A	Army	250 ft (76 m)	Source: UFC 3-260-01, App. B, Section 13
			Navy	750 ft (229 m)	Source: UFC 4-141-10N (Jan 2004)
			Air Force	500 ft (152 m)	Source: UFC 3-260-01, App. B, Section 13
2	Distance to Taxiway Centerline	B	Army	150 ft (46 m)	Source: UFC 3-260-01, App. B, Section 13
			Navy	250 ft (76 m)	Source: UFC 4-141-10N (Jan 2004)
			Air Force	200 ft (61 m)	Source: UFC 3-260-01, App. B, Section 13

The area around the VOR must be clear and reasonably smooth. Per FAA Order 6820.10, all obstructions within 1,000 feet (305 m) of the antenna are to be removed except as noted below. See Figure 3-6 for airspace clearances surrounding the VOR.

- Trees and Forests. Trees close to the VOR antenna can cause severe scalloping. Single trees of moderate height (up to 30 feet (9 m)) may be tolerated beyond 500 feet (152 m), but no closer. Groups of trees are not allowed within a 1,000-ft (305 m) radius or subtend a vertical angle of more than 2 degrees.
- Wire Fences. Ordinary farm-type wire fences about 4-feet (1 m) high are not permitted within 200 feet (61 m) of the antenna; fences of the chain type 6 feet (1.8 m) or more in height are not permitted within 500 feet (152 m) of the antenna; beyond these distances wire fence is not permitted to extend more than 0.5 degrees above the horizontal, measured from the antenna.
- Power and Control Lines. Install power and control line extensions underground for a minimum distance of 600 feet (183 m) from the antenna. Overhead power and control lines may be installed beyond 600 feet (183 m) if they are essentially radial to the antenna for a minimum distance of 1,200 feet (366 m).
- Structures. Structures are not allowed within 1,000 feet (305 m) of the antenna, except for buildings such as the transmitter building at a mountain top site located on a slope below the ground level of the antenna so that they are not visible from the antenna.

3-2.2.1 Army and Air Force.

When used as a terminal navigational aid, the VOR facility may be sited not less than 500 feet (152 m) from the centerline of any runway to the edge of the facilities, provided the elevation of the antenna does not exceed 50 feet (15 m) above the highest point of the adjacent runway centerline. For an on-base installation, the maximum angle of convergence between the final approach course and the runway centerline is 30 degrees. Align the final approach course to intersect the extended runway centerline 3,000 feet (914 m) outward from the runway threshold. When an operational advantage can be achieved, this point of intersect may be established at any point between the threshold and a point 5,200 feet (1,585 m) outward from the runway threshold. Also, where an operational advantage can be achieved, a final approach course which does not intersect the runway centerline or intersects at a point greater than 5,200 feet (1,585 m) outward from the runway threshold may be established, provided that such a course lies within 500 feet (152 m) laterally of the extended runway centerline at a point 3,000 feet (914 m) outward from the runway threshold.

3-2.3 Security.

VOR facilities are normally located within the airfield restricted area. This siting typically meets the minimum security measures for external security. When the facility is located within a restricted area of a lower level of security or is located remote and outside of an established restricted area, provide additional measures to meet the minimum security requirements for the level of security assigned to the facility.

3-2.4 Facility Design Guidance.

Provide an equipment building with roof-mounted antenna. See Figures 3-7 and 3-8 for typical site plan and building layout. See Figure 3-9 for a typical building section. See service-specific guidance for allowable building size. Typical building size is 300 square feet (28 square meters) to house the electronic equipment, monitoring and test equipment, and mechanical equipment.

3-2.4.1 Site Work.

Provide an access road to allow maintenance vehicles access to the VOR. Provide parking space for two maintenance vehicles. See Chapter 2, paragraph “Access and Parking” for roadway and parking area design requirements.

3-2.4.2 Architectural Requirements.

Provide the following:

- Adequate space for equipment and equipment maintenance.
- Clear ceiling height of 10 feet (3 m).
- Work bench.

Do not provide a restroom.

Do not provide windows.

Consider the use of a premanufactured building.

3-2.4.3 Structural Requirements.

Provide sufficient roof area to accommodate the VOR roof mounted antenna and counterpoise. Consider an extended roof overhang or an antenna tower to accommodate a large antenna counterpoise.

3-2.4.3.1 Concrete Pad.

For a shelterized unit, provide a minimum 15’ x 20’ (5 m x 6 m) concrete pad, minimum 6” (150 m) thick with welded wire mesh, and minimum 10” (250 mm) thick at the edges tapering to 6” (150 mm) thick at 2’ (0.6 m) from all edges. In the 10” (250 mm) thick region, place reinforced steel bars (rebar) under the mesh at mid-depth. These requirements for thickness and reinforcement are for optimal soil conditions.

Size of concrete pad may be designed to be larger, as determined by the site-specific requirements.

3-2.5 Mechanical Requirements.

Provide HVAC system to maintain shelter temperature between 65° and 80° F (18° and 27°C). Provide humidity control to maintain humidity between 0 and 95%, with no condensation.

Air Force: See Environmental Control Unit requirements (e.g., allowable temperature and humidity ranges) in AF T.O. 31Z3-822-2, Chapter 3.

3-2.6 Electrical Power.

To avoid potential interference with radar transmissions, locate power, communications, and control cables underground within 1,000 feet (305 m) from the facility. Ensure electrical systems do not interfere with radar transmissions.

Provide 120/240V, 100A, single-phase, 60 HZ commercial power service to the VOR facility.

Air Force: See Commercial Power, Uninterruptible Power Supply, and Backup Power, in AF T.O. 31Z-822-2, Chapter 1. See Grounding, Bonding Shielding and Lightning Protection requirements in AF T.O. 31Z-822-2, Chapter 2.

3-2.6.1 Emergency Electrical Power.

Provide an emergency generator with automatic starting and switching capability as described in Chapter 2. Provide emergency power to the entire facility.

3-2.6.2 Grounding and Bonding.

Install two (2) ground rods, one on each 20' (6 m) side of the concrete pad. Provide separate ground cables, one for the shelter and one for a direct path to ground from the antenna lightning arrestor.

3-2.7 Communications.

Provide 12-strand single mode fiber optic cable or 25 twisted pair communications line to provide required connectivity for data and telephone.

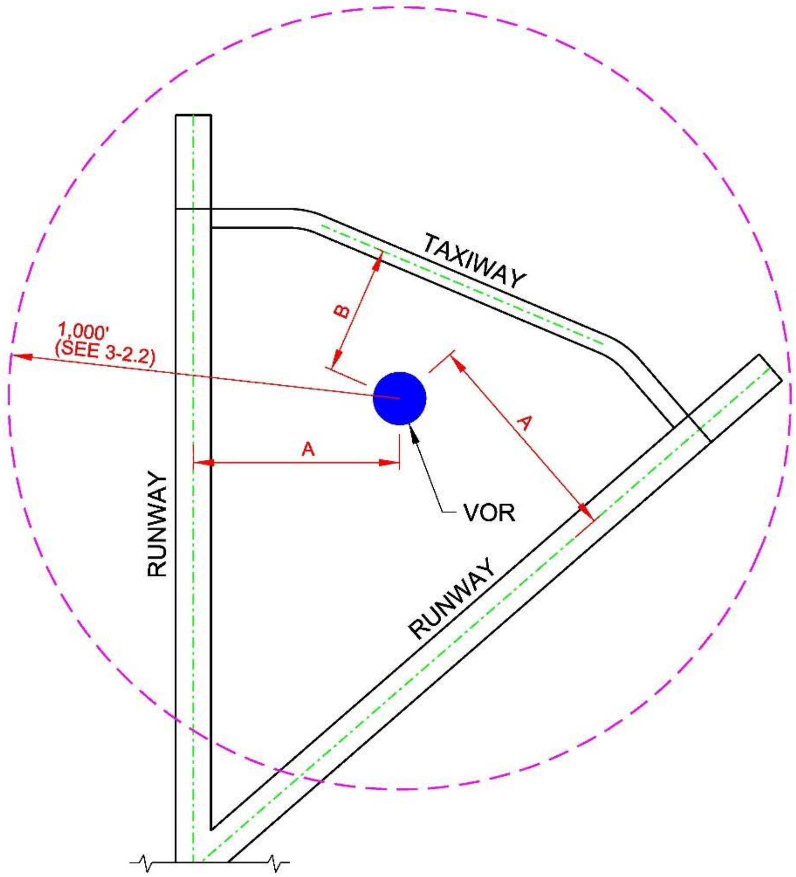
- Data connectivity from the VOR Shelter to Remote Unit located in the ATC Tower.
- Data connectivity from the VOR Shelter Fire Alarm to external monitoring system.
- Telephone line for distance support to troubleshoot system.

Air Force: See fiber optic cable and modem requirements in AF T.O. 31Z-822-2, Chapter 4.

3-2.8 Connection/Interrelation to other Facilities.

Connect a dedicated DSN-capable telephone connection through to the VOR to facilitate distant support, troubleshooting, and corrective maintenance due to the remote location. Connect the VOR to the ATC Tower via fiber optic cable for remote monitoring.

Figure 3-5 VOR Siting



	MINIMUM DISTANCE	
	A	B
ARMY	250'	150'
NAVY	750'	250'
AIR FORCE	500'	200'

Figure 3-6 VOR Clearances

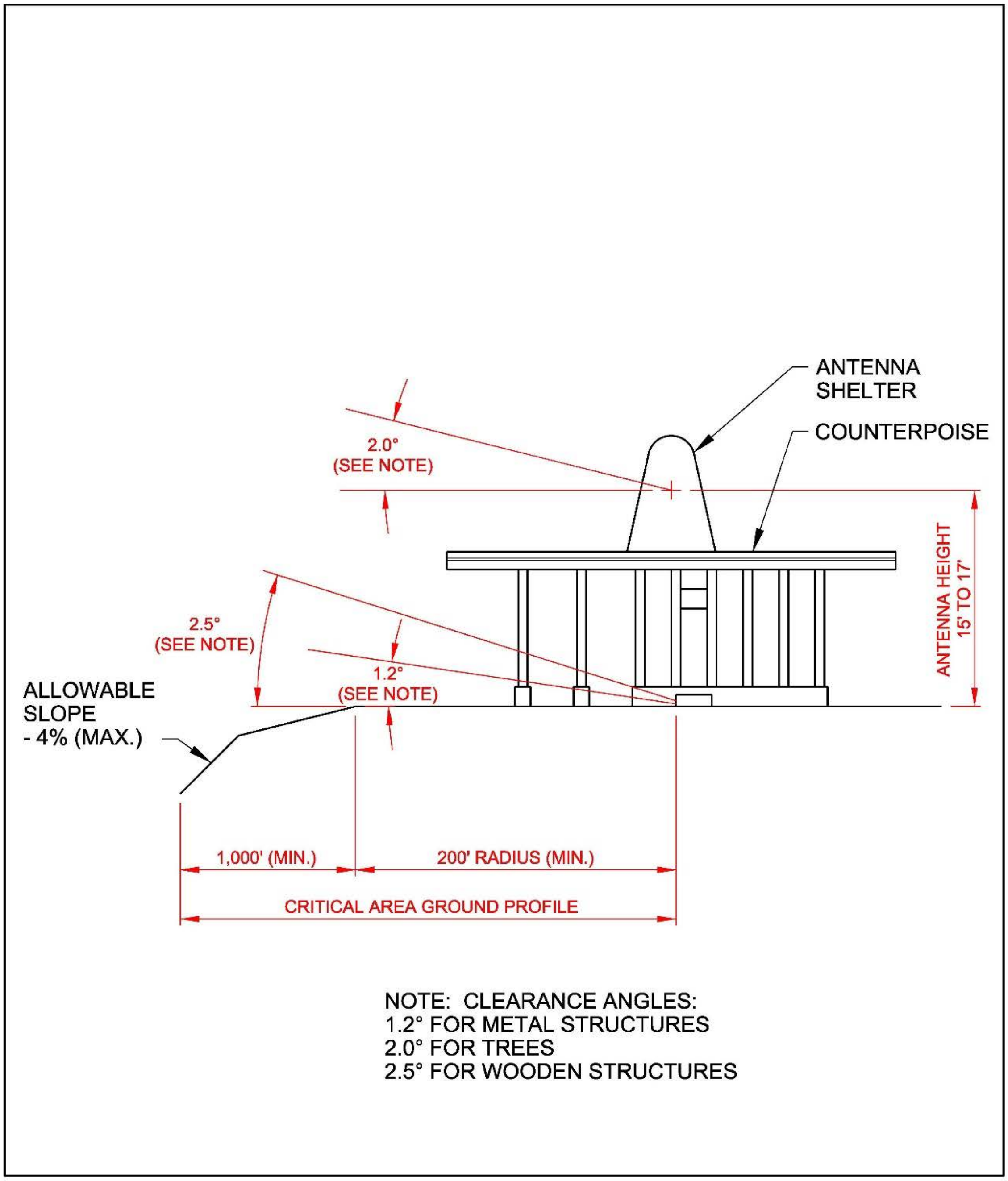


Figure 3-7 VOR Facility Site Plan

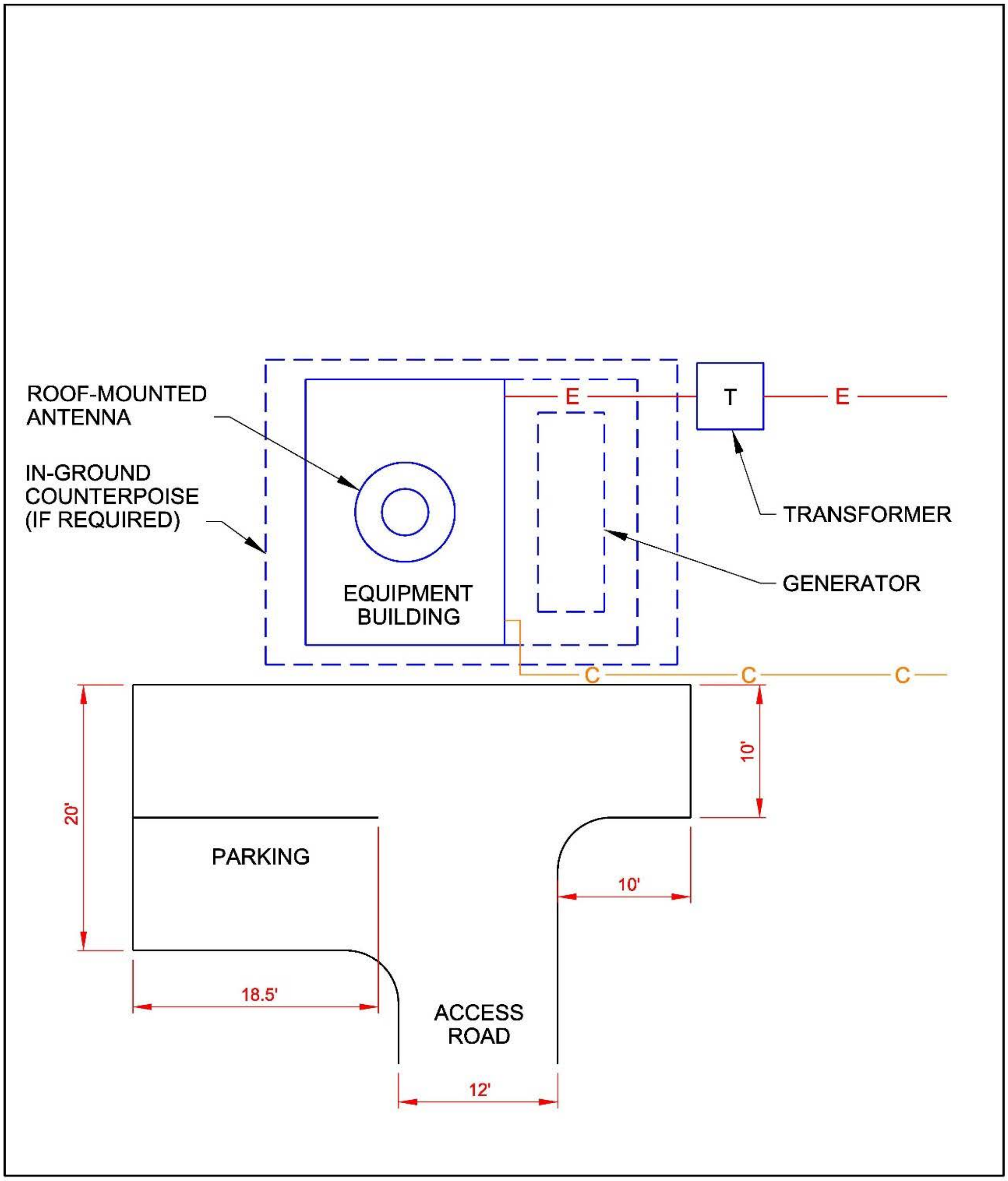


Figure 3-8 VOR Building Layout

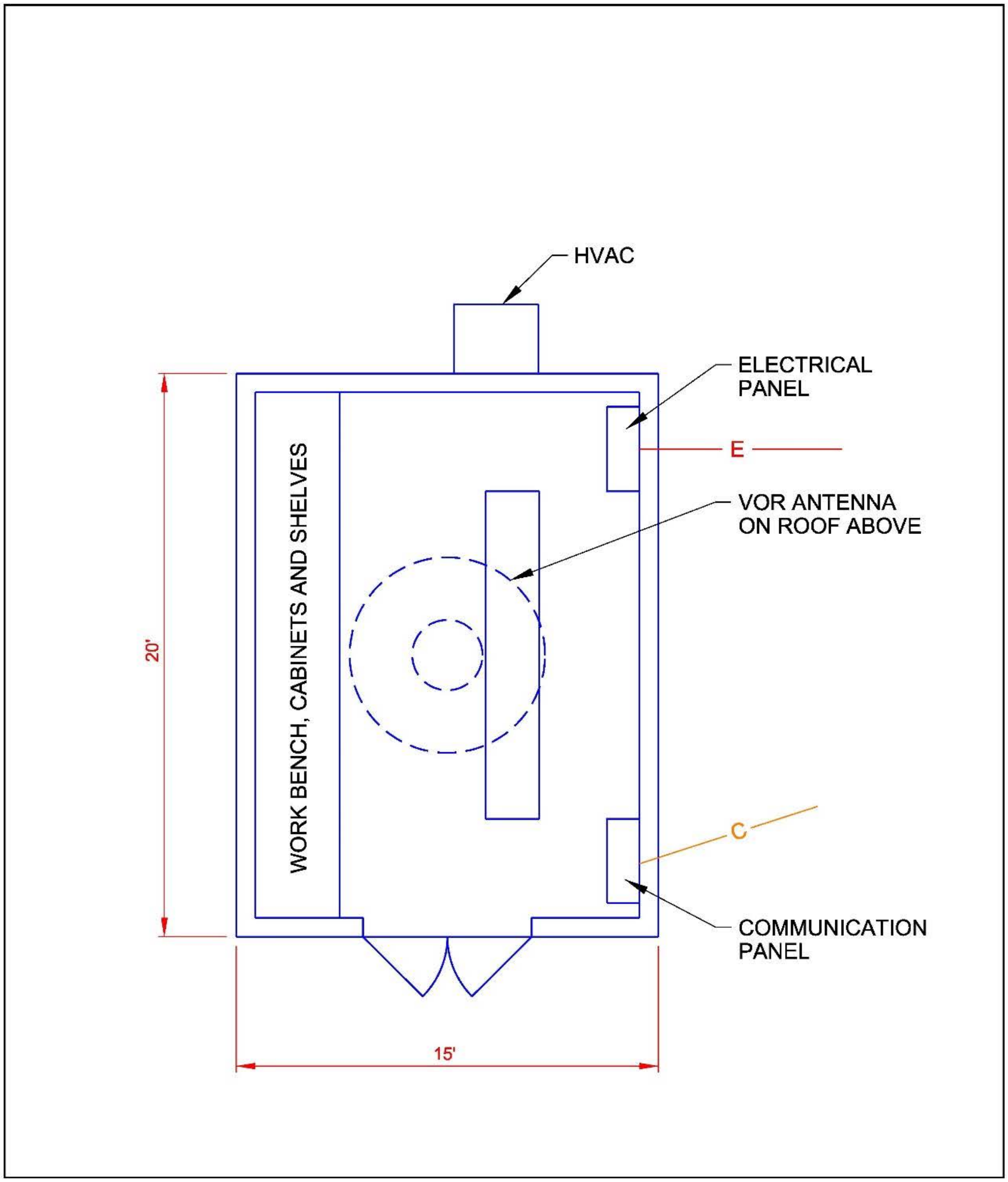
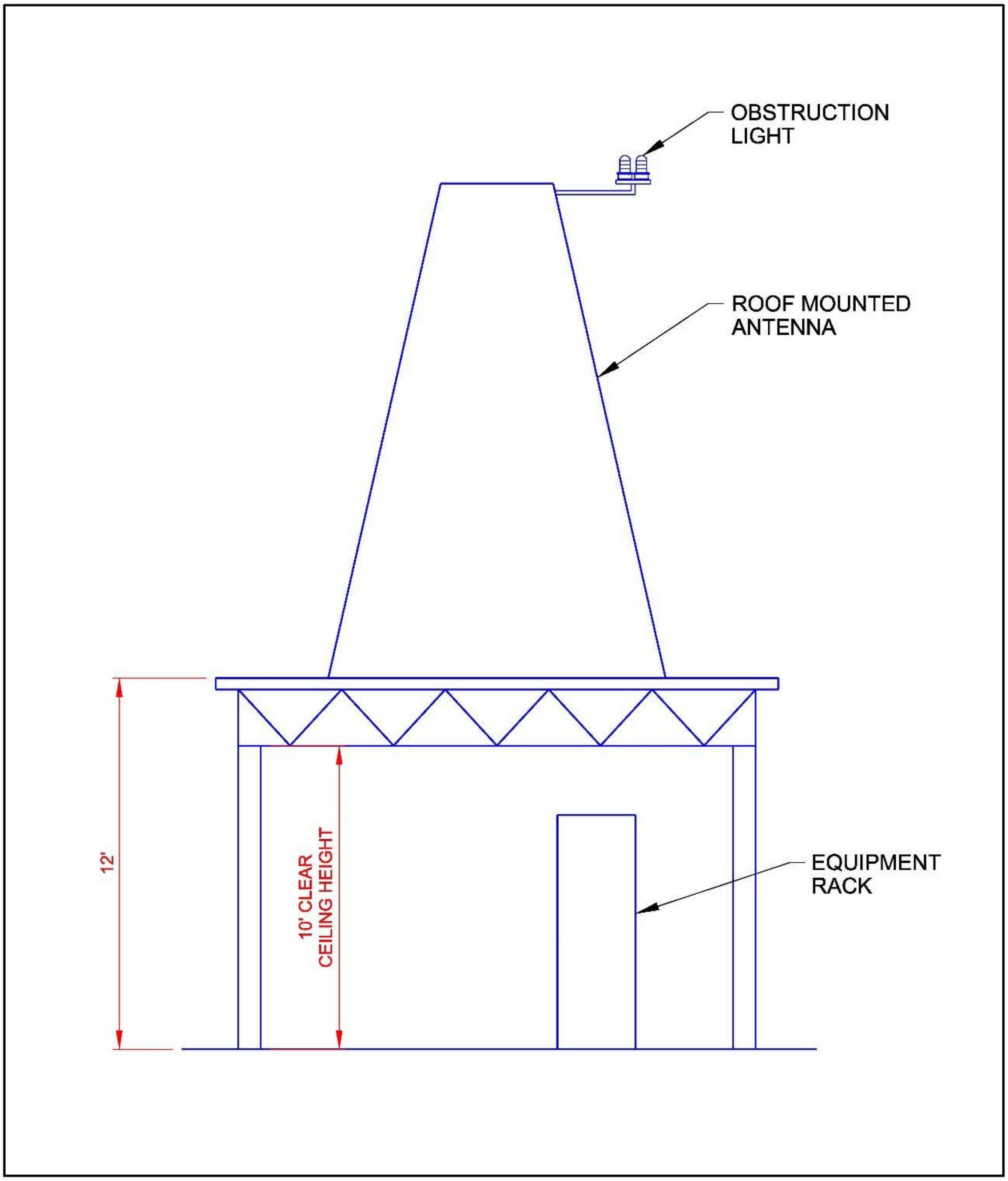


Figure 3-9 VOR Building Section



3-3 TACTICAL AIR NAVIGATION (TACAN) SYSTEMS.

3-3.1 Key Documents.

UFC 3-260-01	*Airfield and Heliport Planning and Design*
FAA AC 150/5300-13	*Airport Design*
FAA Order 6780.5	*DME Installation Standards Handbook Type FA-96-39 (Request from Lead Service Agency)*
FAA Order 6780.8	*Distance Measuring Equipment (DME) Installation Standards Handbook Type FA-9783 (Request from Lead Service Agency)*
FAA Order 6820.10	*VOR, VOR/DME, and VORTAC Siting Criteria*
AF T.O. 31Z3-822-2	*Air Traffic Control Landing Systems (ATCALS) Site Requirements 404L*

3-3.2 Siting.

If possible, locate the TACAN in an area adjacent to the intersection of the primary runways. Locate the facility at the minimum distances from the centerline of runways and taxiways according to Table 3-3 and Figure 3-10. When the facility is located off the airfield, consider selecting a site with one or more flight path courses providing an approach to the primary runway. When sited outside these distances, include obstruction lighting if the VOR is within the primary surface or penetrates the imaginary surfaces defined in UFC 3-260-01. See FAA Order 6820.10 for more details about siting considerations.

Table 3-3 TACAN Siting Dimensions

Item		Legend in Figures	Requirement		Remarks
No.	Description				
1	Distance to Runway Centerline	A	Army	250 ft (76 m)	Source: UFC 3-260-01, App. B, Section 13
			Navy	750 ft (229 m)	Source: UFC 4-141-10N (Jan 2004)
			Air Force	500 ft (152 m)	Source: UFC 3-260-01, App. B, Section 13
2	Distance to Taxiway Centerline	B	Army	150 ft (46 m)	Source: UFC 3-260-01, App. B, Section 13
			Navy	250 ft (76 m)	Source: UFC 4-141-10N (Jan 2004)
			Air Force	200 ft (61 m)	Source: UFC 3-260-01, App. B, Section 13

The area around the TACAN must be clear and reasonably smooth. Per FAA Order 6820.10, all obstructions within 1,000 feet (305 m) of the antenna are to be removed except as noted below.

- Trees and Forests. Trees close to the TACAN antenna can cause severe scalloping. Single trees of moderate height (up to 30 feet (9 m)) can be tolerated beyond 500 feet (152 m), but no closer. Groups of trees are not allowed within a 1,000-ft (305 m) radius or subtend a vertical angle of more than 2 degrees.
- Wire Fences. Ordinary farm-type wire fences about 4-feet (1.2 m) high are not permitted within 200 feet of the antenna; fences of the chain type 6 feet (1.8 m) or more in height) are not permitted within 500 feet (152 m) of the antenna; beyond these distances wire fence is not permitted to extend more than 0.5 degrees above the horizontal, measured from the antenna.
- Power and Control Lines. Install power and control line extensions underground for a minimum distance of 600 feet (183 m) from the antenna. Overhead power and control lines may be installed beyond 600 feet (183 m) if they are essentially radial to the antenna for a minimum distance of 1,200 feet (366 m).
- Structures. Structures are not allowed within 1,000 feet (305 m) of the antenna, except for buildings such as the transmitter building at a mountain top site located on a slope below the ground level of the antenna so that they are not visible from the antenna.

3-3.2.1 Army and Air Force.

When used as a terminal navigational aid, the TACAN facility may be sited not less than 500 feet (152 m) from the centerline of any runway to the edge of the facilities, provided the elevation of the antenna does not exceed 50 feet (15 m) above the highest point of the adjacent runway centerline. For an on-base installation, the maximum angle of convergence between the final approach course and the runway centerline is 30 degrees. Align the final approach course to intersect the extended runway centerline 3,000 feet (914 m) outward from the runway threshold. When an operational advantage can be achieved, this point of intersect may be established at any point between the threshold and a point 5,200 feet (1,585 m) outward from the runway threshold. Also, where an operational advantage can be achieved, a final approach course which does not intersect the runway centerline or intersects at a point greater than 5,200 feet (1,585 m) outward from the runway threshold may be established, provided that such a course lies within 500 feet (152 m) laterally of the extended runway centerline at a point 3,000 feet (914 m) outward from the runway threshold.

3-3.3 Security.

TACAN facilities are normally located within the airfield restricted area. This siting typically meets the minimum security measures for external security. When the facility is located within a restricted area of a lower level of security or is located remote and outside of an established restricted area, provide additional measures to meet the minimum security requirements for the level of security assigned to the facility.

3-3.4 Facility Design Guidance.

Provide an equipment building with roof-mounted antenna. See Figures 3-11 and 3-12 for typical site plan and building layout. See Figure 3-13 for a typical building section. See service-specific guidance for allowable building size. Typical building size is 300 square feet (28 square meters) to house the electronic equipment, monitoring and test equipment, and mechanical equipment.

Alternatively, a standard configured shelterized TACAN is a self-contained unit. If this type of facility is selected, provide a 20’ x 15’ (6 m x 4.6 m) concrete pad capable of supporting 12,000 lbs (5,443 kg) on four (4) 12” (300 mm) by 12” (300 mm) support feet.

A typical shelterized TACAN consists of the following items:

- Concrete Pad
- TACAN Shelter/ roof mounted TACAN Antenna
- Backup power (Generator) with associated power transfer equipment
- Electrical conduits/ Ground points (not specifically shown)
- Equipment shelter for the electrical transfer switch, electric main cutoff, and communications enclosures to minimize their exposure to the elements

3-3.4.1 Site Work.

Provide an access road to allow maintenance vehicles access to the TACAN. Provide parking space for two maintenance vehicles. See Chapter 2, paragraph “Access and Parking” for roadway and parking area design requirements.

3-3.4.2 Architectural Requirements.

Provide the following:

- Adequate space for equipment and equipment maintenance.
- Clear ceiling height of 10 feet (3 m).
- Work bench.

Do not provide a restroom.

Do not provide windows.

Consider the use of a premanufactured building.

3-3.4.3 Structural Requirements.

If not using a shelterized unit, provide sufficient roof area to accommodate the TACAN roof-mounted antenna and counterpoise. Consider an extended roof overhang or an antenna tower to accommodate a large antenna counterpoise.

3-3.4.3.1 Concrete Pad.

For a shelterized unit, provide a minimum 15’ x 20’ (4.6 m x 6 m) concrete pad, minimum 6” (152 mm) thick with welded wire mesh, and minimum 10” (250 mm) thick at the edges tapering to 6” (150 mm) thick at 2’ (0.6 m) from all edges. In the 10” (250 mm) thick region, place reinforced steel bars (rebar) under the mesh at mid-depth. These requirements for thickness and reinforcement are for optimal soil conditions.

Size of concrete pad may be designed to be larger, as determined by the site-specific requirements.

Construct the concrete pad above the 100-year flood plain.

3-3.4.3.2 Equipment Shed Requirements.

For a shelterized unit, provide a shed enclosure large enough to house the electrical and communication panels/enclosures. It may be three sided as shown in Figure 3-14 or completely enclosed.

3-3.5 Mechanical Requirements.

Provide HVAC system to maintain shelter temperature between 65° and 80° F (18° and 27°C). Provide humidity control to maintain humidity between 0 and 95%, with no condensation.

Air Force: See Environmental Control Unit requirements (e.g., allowable temperature and humidity ranges) in AF T.O. 31Z3-822-2, Chapter 3.

For a shelterized unit, the AN/FRN-48(V)3 TACAN is a self-contained unit with internal power distribution, emergency lighting, smoke detection equipment, thermostatically controlled environmental control unit with humidity controls, aircraft obstruction and exterior lighting. This equipment is designed, built, tested, and configuration managed by each Service. No additional mechanical systems are required.

3-3.6 Electrical Requirements.

To avoid potential interference with radar transmissions, locate power, communications, and control cables underground within 1,000 feet (305 m) from the facility. Ensure electrical systems do not interfere with radar transmissions.

Provide 120/240V, 100A, single-phase, 60 HZ commercial power service to the TACAN facility.

Air Force: See Commercial Power, Uninterruptible Power Supply, and Backup Power, in AF T.O. 31Z-822-2, Chapter 1. See Grounding, Bonding Shielding and Lightning Protection requirements in AF T.O. 31Z-822-2, Chapter 2.

3-3.6.1 Emergency Electrical Power.

Provide an emergency generator with automatic starting and switching capability as described in Chapter 2. Provide emergency power to the entire facility.

3-3.6.2 Grounding and Bonding.

Install two (2) ground rods, one on each 20’ (6 m) side of the concrete pad. Provide separate ground cables, one for the shelter and one for a direct path to ground from the antenna lightning arrestor.

3-3.6.3 Lighting.

The TACAN shelter comes equipped with an external red filtered door light and obstruction light. Provide additional lighting for the external electrical shed, but include features (aiming, shielding) not to interfere with night-time flight operations.

3-3.7 Communications.

Provide 12-strand single mode fiber optic cable or 25 twisted pair communications line to provide required connectivity for data and telephone.

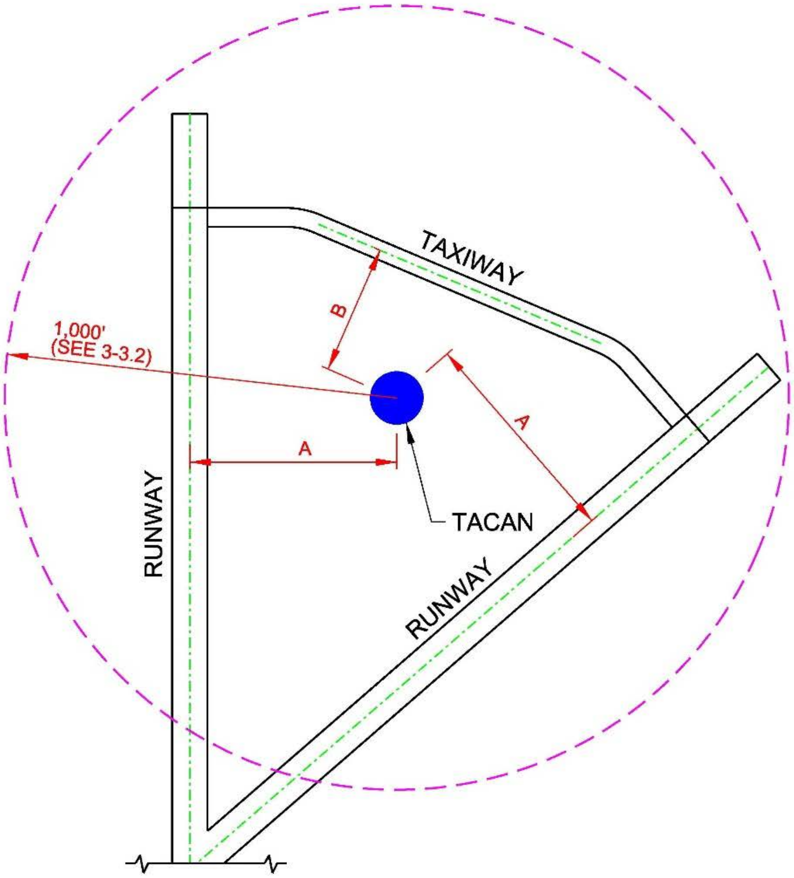
- Data connectivity from the TACAN Shelter to Remote Unit located in the ATC Tower.
- Data connectivity from the TACAN Shelter Fire Alarm to external monitoring system.
- Telephone line for distance support to troubleshoot system.

Air Force: See fiber optic cable and modem requirements in AF T.O. 31Z-822-2, Chapter 4.

3-3.8 Connection/Interrelation to other Facilities.

Connect a dedicated DSN-capable telephone connection through to the TACAN to facilitate distant support, troubleshooting, and corrective maintenance due to the remote location. Connect the TACAN to the ATC Tower via fiber optic cable for remote monitoring.

Figure 3-10 Typical TACAN Facility Siting Criteria



	MINIMUM DISTANCE	
	A	B
ARMY	250'	150'
NAVY	750'	250'
AIR FORCE	500'	200'

Figure 3-11 Typical TACAN Facility Site Plan

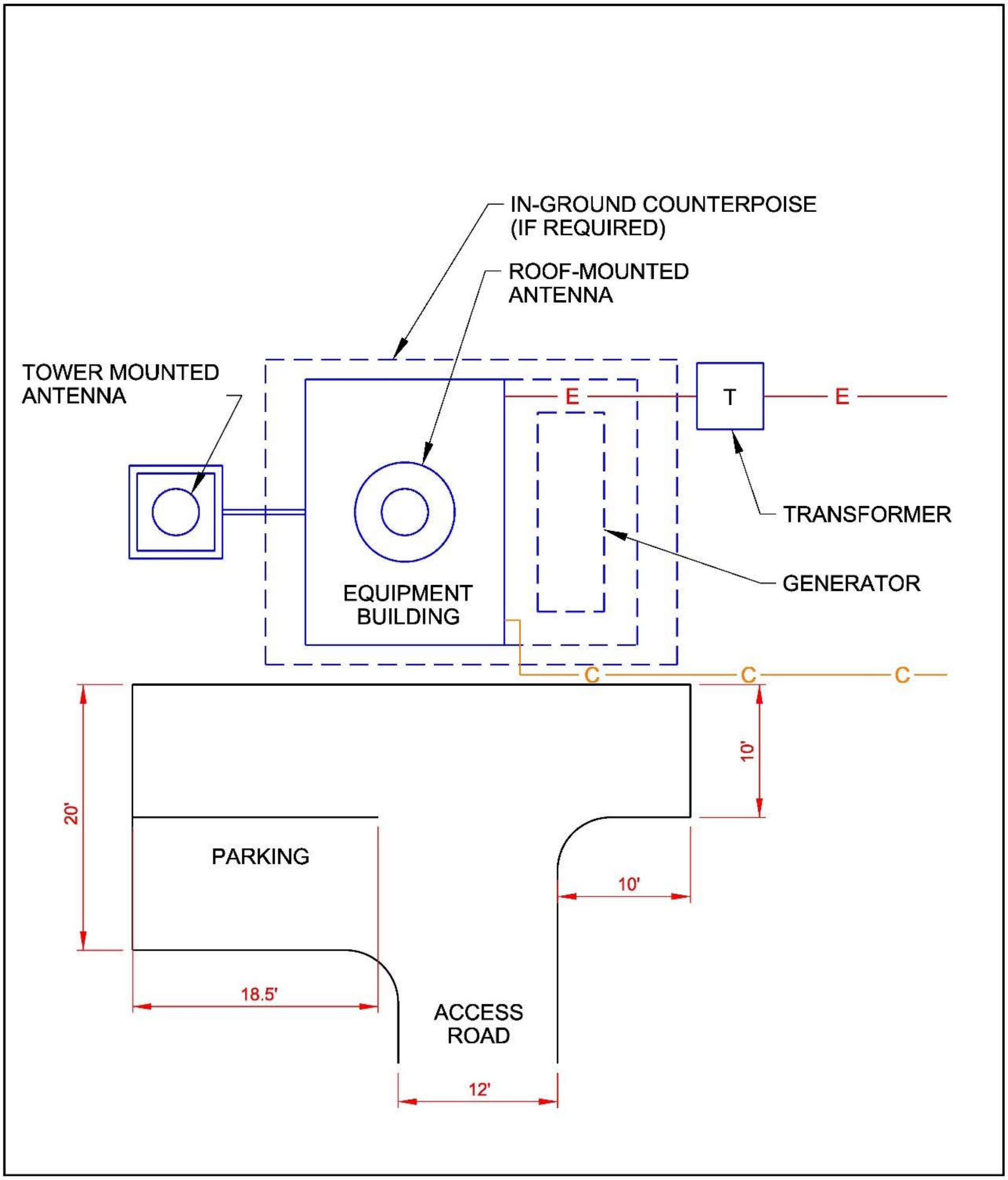


Figure 3-12 Typical TACAN Building Layout

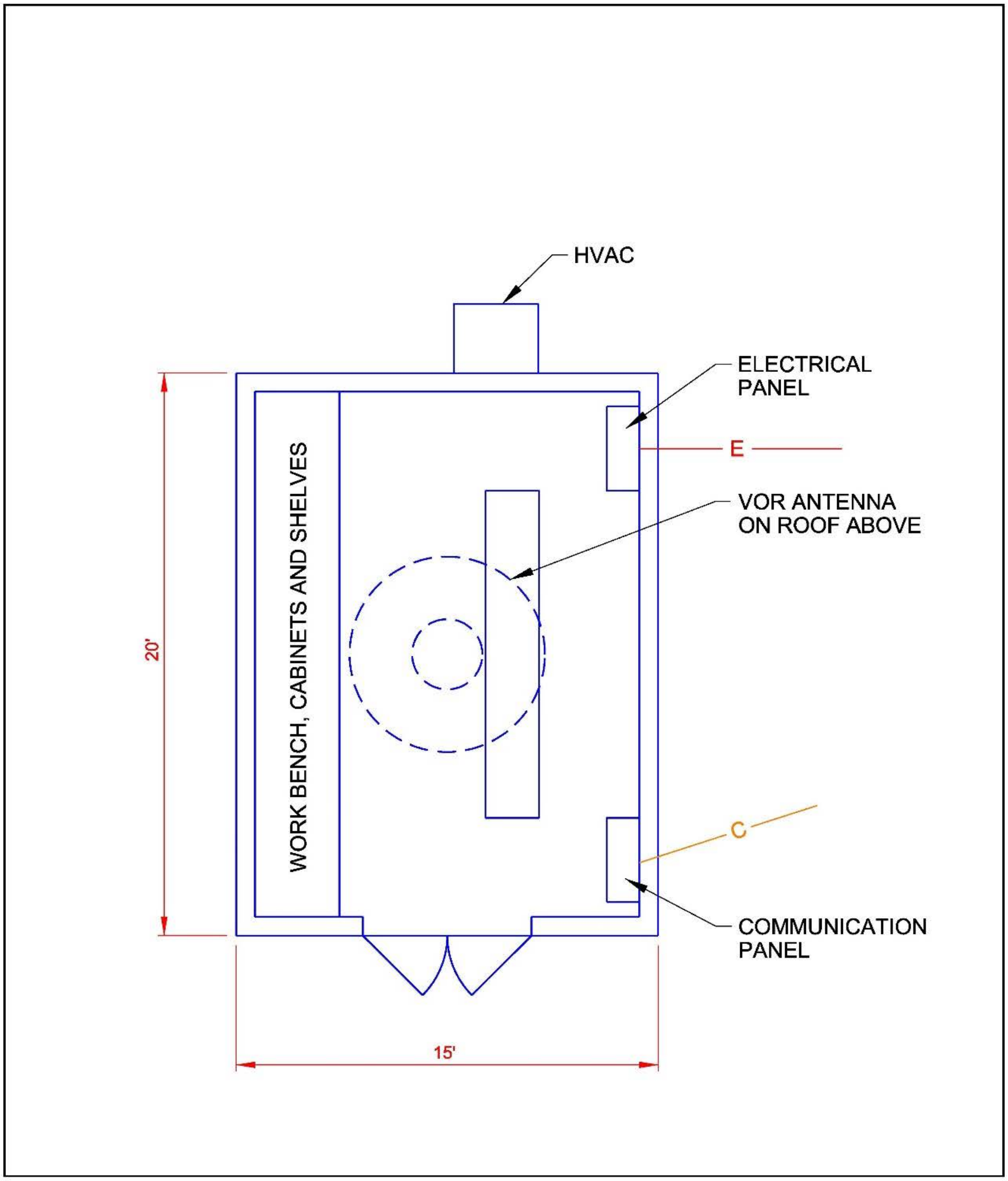


Figure 3-13 Typical TACAN Building Section

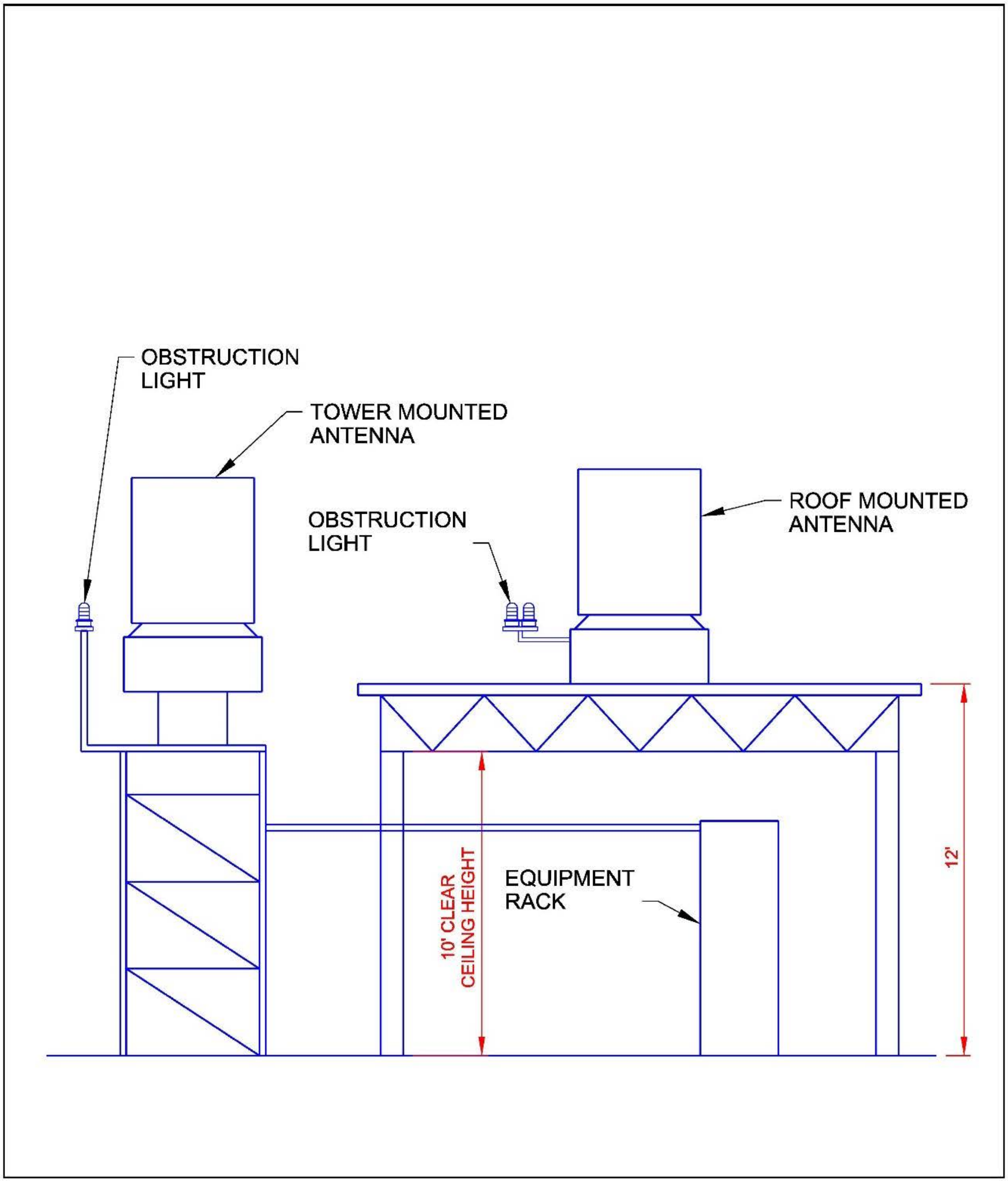


Figure 3-14 Typical Shelterized TACAN Antenna with Adjacent Electrical Shed

3-4 VERY HIGH FREQUENCY (VHF) OMNI-DIRECTIONAL RANGE/ TACTICAL AIR NAVIGATION (VORTAC).

3-4.1 Key Documents.

UFC 3-260-01 — *Airfield and Heliport Planning and Design*

FAA AC 150/5300-13 — *Airport Design*

FAA Order 6780.5 — *DME Installation Standards Handbook Type FA-96-39 (Request from Lead Service Agency)*

FAA Order 6780.8 — *Distance Measuring Equipment (DME) Installation Standards Handbook Type FA-9783 (Request from Lead Service Agency)*

FAA Order 6820.10 — *VOR, VOR/DME, and VORTAC Siting Criteria*

AF T.O. 31Z3-822-2 — *Air Traffic Control Landing Systems (ATCALS) Site Requirements 404L*

3-4.2 Siting.

If possible, locate the VORTAC in an area adjacent to the intersection of the primary runways. Locate the facility at the minimum distances from the centerline of runways and taxiways according to Table 3-4 and Figure 3-15. When the facility is located off the airfield, consider selecting a site with one or more flight path courses providing an approach to the primary runway. When sited outside these distances, include obstruction lighting if the VORTAC is within the primary surface or penetrates the imaginary surfaces defined in UFC 3-260-01. See FAA Order 6820.10 for more details about siting considerations.

Table 3-4 VORTAC Siting Dimensions

Item		Legend in Figures	Requirement		Remarks
No.	Description				
1	Distance to Runway Centerline	A	Army	250 ft (76 m)	Source: UFC 3-260-01, App. B, Section 13
			Navy	750 ft (229 m)	Source: UFC 4-141-10N (Jan 2004)
			Air Force	500 ft (152 m)	Source: UFC 3-260-01, App. B, Section 13
2	Distance to Taxiway Centerline	B	Army	150 ft (46 m)	Source: UFC 3-260-01, App. B, Section 13
			Navy	250 ft (76 m)	Source: UFC 4-141-10N (Jan 2004)
			Air Force	200 ft (61 m)	Source: UFC 3-260-01, App. B, Section 13

The area around the VORTAC must be clear and reasonably smooth. Per FAA Order 6820.10, all obstructions within 1,000 feet (305 m) of the antenna are to be removed except as noted below.

- Trees and Forests. Trees close to the VORTAC antenna can cause severe scalloping. Single trees of moderate height (up to 30 feet (9 m) may be tolerated beyond 500 feet (152 m), but no closer. Groups of trees are not allowed within a 1,000-ft (305 m) radius or subtend a vertical angle of more than 2 degrees.
- Wire Fences. Ordinary farm-type wire fences about 4-feet (1.2 m) high are not permitted within 200 feet (61 m) of the antenna; fences of the chain type 6 feet (1.8 m) or more in height) are not permitted within 500 feet (152 m) of the antenna; beyond these distances wire fence is not permitted to extend more than 0.5 degrees above the horizontal, measured from the antenna.
- Power and Control Lines. Install power and control line extensions underground for a minimum distance of 600 feet (183 m) from the antenna. Overhead power and control lines may be installed beyond 600 feet (183 m) if they are essentially radial to the antenna for a minimum distance of 1,200 feet (366 m).
- Structures. Structures are not allowed within 1,000 feet (305 m) of the antenna, except for buildings such as the transmitter building at a mountain top site located on a slope below the ground level of the antenna so that they are not visible from the antenna.

3-4.2.1 Army and Air Force.

When used as a terminal navigational aid, the VORTAC facility may be sited not less than 500 feet (152 m) from the centerline of any runway to the edge of the facilities, provided the elevation of the antenna does not exceed 50 feet (15 m) above the highest point of the adjacent runway centerline. For an on-base installation, the maximum angle of convergence between the final approach course and the runway centerline is 30 degrees. Align the final approach course to intersect the extended runway centerline 3,000 feet (914 m) outward from the runway threshold. When an operational advantage can be achieved, this point of intersect may be established at any point between the threshold and a point 5,200 feet (1,585 m) outward from the runway threshold. Also, where an operational advantage can be achieved, a final approach course which does not intersect the runway centerline or intersects at a point greater than 5,200 feet (1585 m) outward from the runway threshold may be established, provided that such a course lies within 500 feet (152 m) laterally of the extended runway centerline at a point 3,000 feet (914 m) outward from the runway threshold.

3-4.3 Security.

VORTAC facilities are normally located within the airfield restricted area. This siting typically meets the minimum security measures for external security. When the facility is located within a restricted area of a lower level of security or is located remote and outside of an established restricted area, provide additional measures to meet the minimum security requirements for the level of security assigned to the facility.

3-4.4 Facility Design Guidance.

Provide an equipment building with roof-mounted antenna. See Figures 3-16 and 3-17 for typical site plan and building layout. See Figure 3-18 for a typical building section. See service-specific guidance for allowable building size. Typical building size is 300 square feet (28 square meters) to house the electronic equipment, monitoring and test equipment, and mechanical equipment.

3-4.4.1 Site Work.

Provide an access road to allow maintenance vehicles access to the VORTAC. Provide parking space for two maintenance vehicles. See Chapter 2, paragraph “Access and Parking” for roadway and parking area design requirements.

3-4.4.2 Architectural Requirements.

Provide the following:

- Adequate space for equipment and equipment maintenance.
- Clear ceiling height of 10 feet (3 m).
- Work bench.

Do not provide a restroom.

Do not provide windows.

Consider the use of a premanufactured building.

3-4.4.3 Structural Requirements.

Provide sufficient roof area to accommodate the VORTAC roof mounted antenna and counterpoise. Consider an extended roof overhang or an antenna tower to accommodate a large antenna counterpoise.

3-4.4.3.1 Concrete Pad.

For a shelterized unit, provide a minimum 15’ x 20’ (4.6 x 6 m) concrete pad, minimum 6” (150 mm) thick with welded wire mesh, and minimum 10” (250 mm) thick at the edges tapering to 6” (150 mm) thick at 2’ (0.6 m) from all edges. In the 10” (250 mm) thick region, place reinforced steel bars (rebar) under the mesh at mid-depth. These requirements for thickness and reinforcement are for optimal soil conditions.

Size of concrete pad may be designed to be larger, as determined by the site-specific requirements.

Construct the concrete pad above the 100-year flood plain.

3-4.5 Mechanical Requirements.

Provide HVAC system to maintain shelter temperature between 65° and 80° F (18° and 27°C). Provide humidity control to maintain humidity between 0 and 95%, with no condensation.

Air Force: See Environmental Control Unit requirements (e.g., allowable temperature and humidity ranges) in AF T.O. 31Z3-822-2, Chapter 3.

3-4.6 Electrical Power.

To avoid potential interference with radar transmissions, locate power, communications, and control cables underground within 1,000 feet (305 m) from the facility. Ensure electrical systems do not interfere with radar transmissions.

Provide 120/240V, 100A, single-phase, 60 HZ commercial power service to the VORTAC facility.

Air Force: See Commercial Power, Uninterruptible Power Supply, and Backup Power, in AF T.O. 31Z-822-2, Chapter 1. See Grounding, Bonding Shielding and Lightning Protection requirements in AF T.O. 31Z-822-2, Chapter 2.

3-4.6.1 Emergency Electrical Power.

Provide an emergency generator with automatic starting and switching capability as described in Chapter 2. Provide emergency power to the entire facility.

3-4.6.2 Grounding and Bonding.

Install two (2) ground rods, one on each 20’ (6 m) side of the concrete pad. Provide separate ground cables, one for the shelter and one for a direct path to ground from the antenna lightning arrestor.

3-4.6.3 Lighting.

The VORTAC shelter comes equipped with an external red filtered door light and obstruction light.

3-4.7 Communications.

Provide 12-strand single mode fiber optic cable or 25 twisted pair communications line to provide required connectivity for data and telephone.

- Data connectivity from the VORTAC Shelter to Remote Unit located in the ATC Tower.

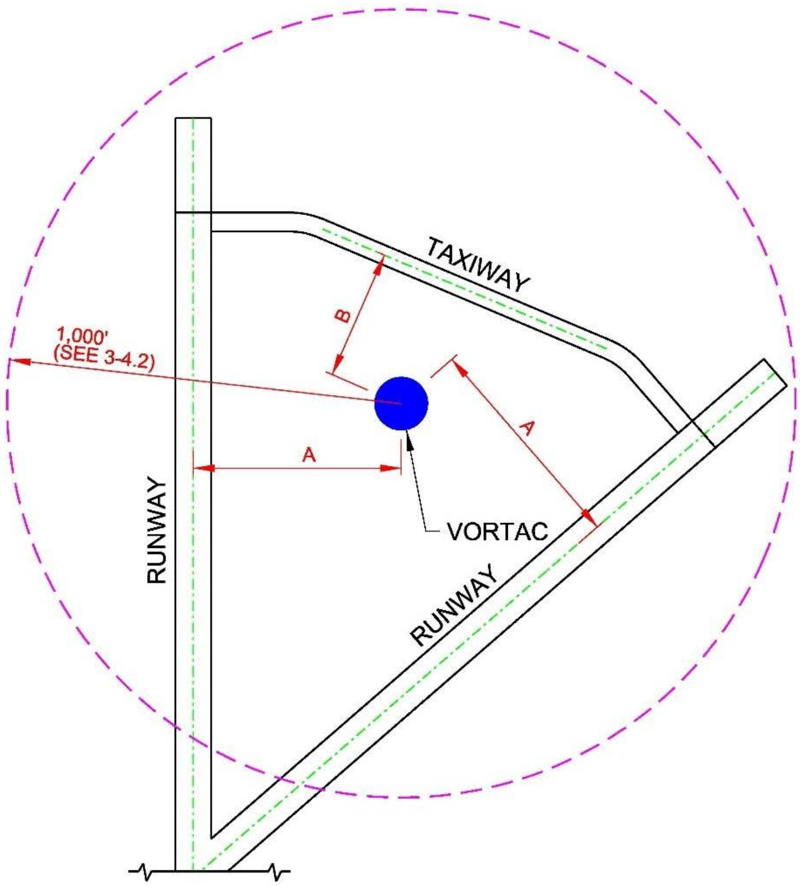
- Data connectivity from the VORTAC Shelter Fire Alarm to external monitoring system.
- Telephone line for distance support to troubleshoot system.

Air Force: See fiber optic cable and modem requirements in AF T.O. 31Z-822-2, Chapter 4.

3-4.8 Connection/Interrelation to other Facilities.

Connect a dedicated DSN-capable telephone connection through to the VORTAC to facilitate distant support, troubleshooting, and corrective maintenance due to the remote location. Connect the VORTAC to the ATC Tower via fiber optic cable for remote monitoring.

Figure 3-15 VORTAC Facility Siting Criteria



	MINIMUM DISTANCE	
	A	B
ARMY	250'	150'
NAVY	750'	250'
AIR FORCE	500'	200'

Figure 3-16 VORTAC Facility Site Plan

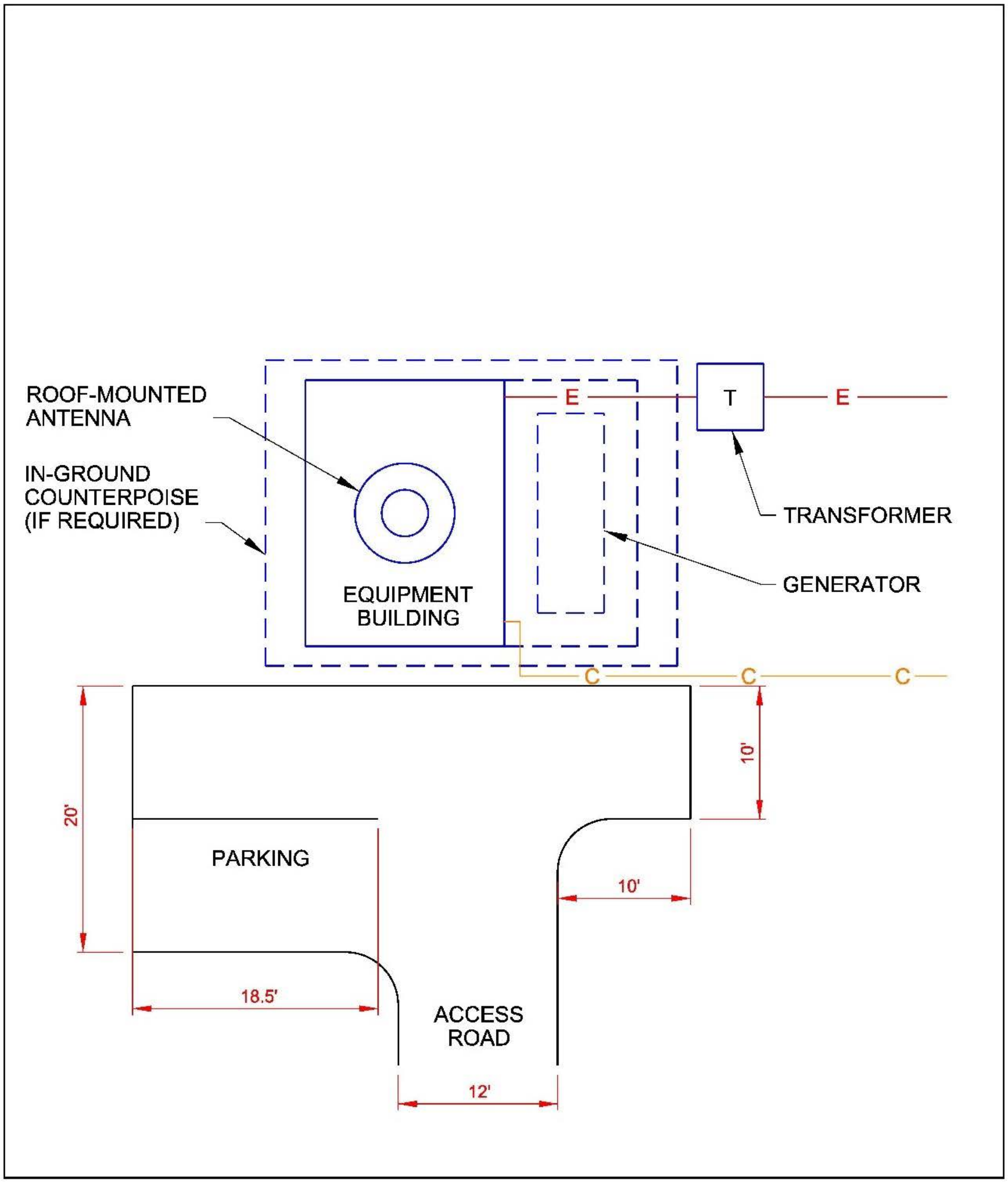


Figure 3-17 VORTAC Building Layout

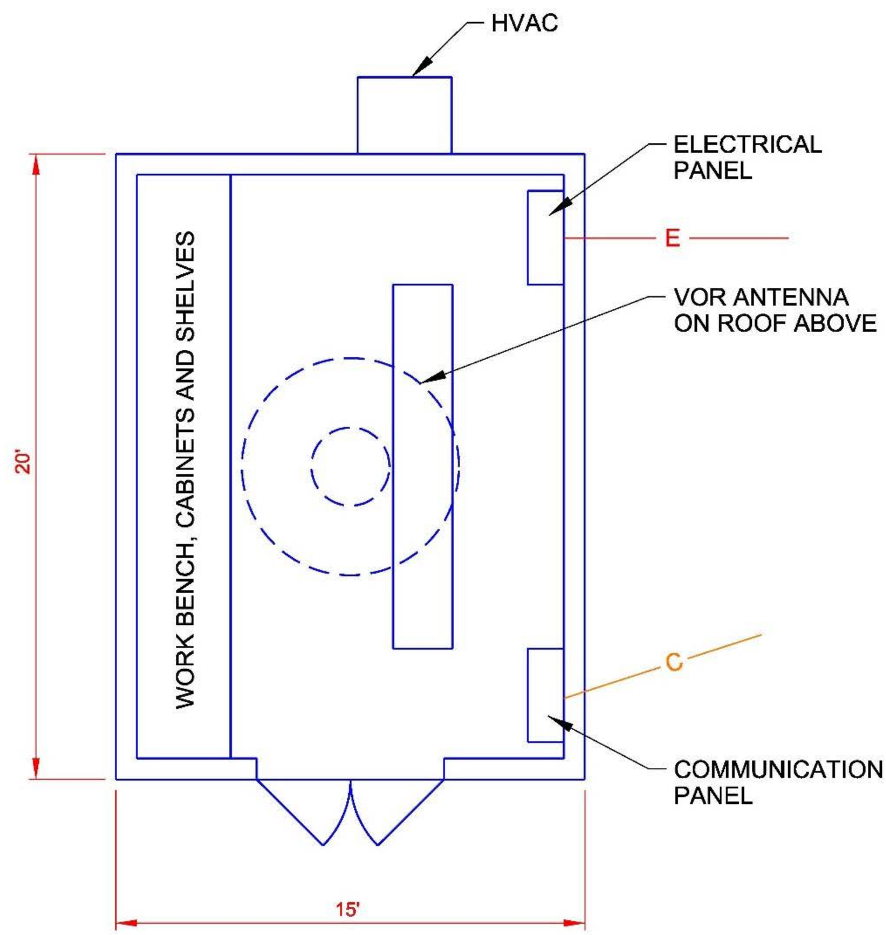
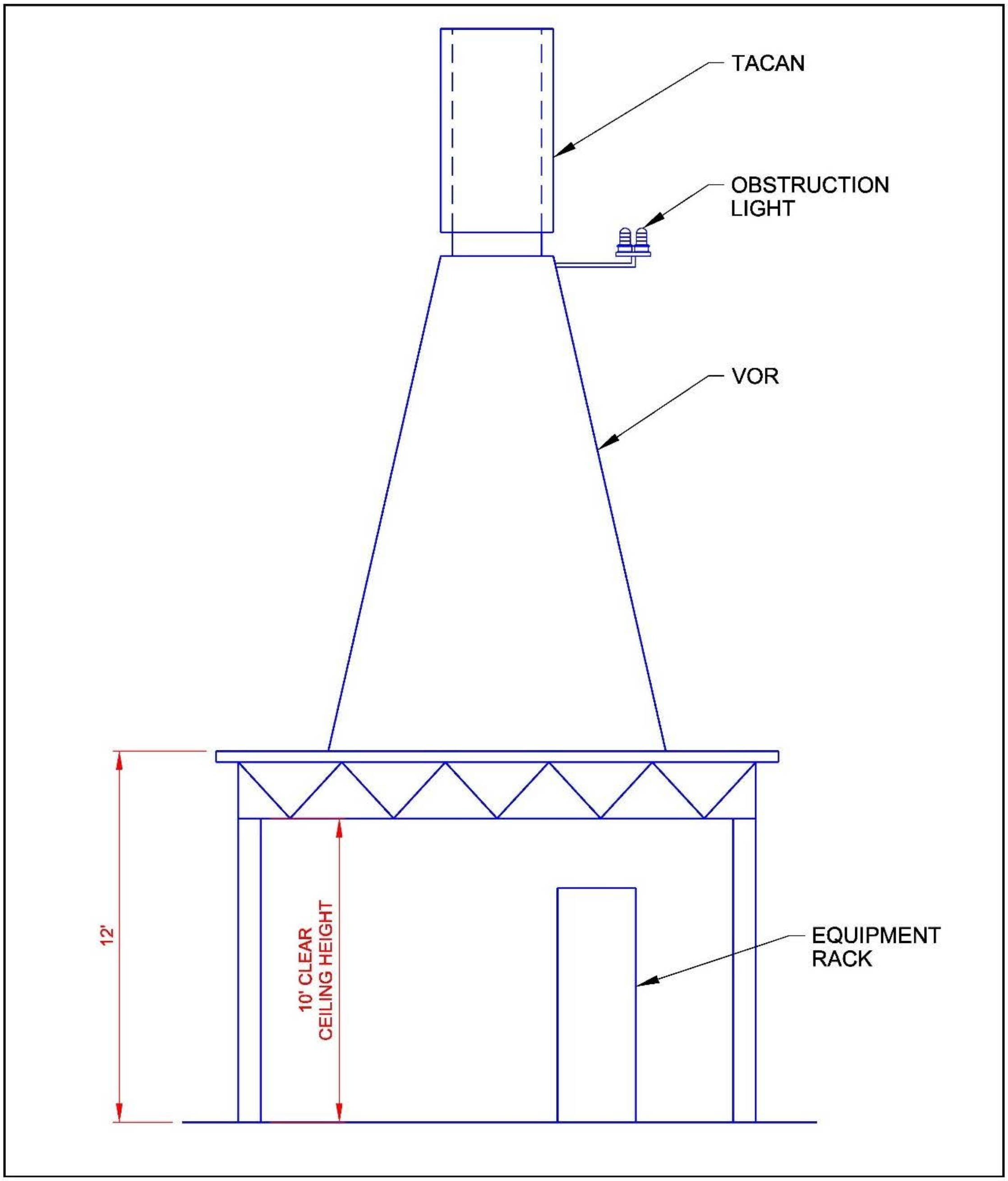


Figure 3-18 VORTAC Building Section



CHAPTER 4 AIRCRAFT LANDING SYSTEMS

4-1 GENERAL INFORMATION.

4-1.1 Function.

The MLS, SBICLS, ILS and PAR facilities contain electronic equipment used in precision instrument approaches. These facilities are unattended.

4-1.1.1 Microwave Landing System (MLS).

The MLS provides azimuth, distance, elevation, and glide path position to aircraft on a precision approach to the MLS instrumented runway. The MLS operates in a narrow band microwave frequency. Figure 4-1 shows a typical MLS antenna and shelter.

4-1.1.2 Shore-Based Instrument Carrier Landing System (SBICLS).

The SBICLS is a microwave-based precision instrument landing aid that provides guidance to appropriately equipped Navy or Marine Corps carrier-based aircraft. The system can be used for conducting carrier-controlled approach training, field carrier landing practice (FBLP), or as a stand-alone instrument landing system. The system is comprised of the identical transmitter equipment used for shipboard aircraft landing operations but in a shore-based configuration. As of 2021, the AN/FRN-49(V) is the current equipment package being installed and replacing the older AN/TRN-28 system. Figure 4-2 shows a typical SBICLS Elevation Transmitter system.

4-1.1.3 Instrument Landing System (ILS).

The ILS provides azimuth, distance, elevation, and glide path position to aircraft on a precision approach to the ILS instrumented runway. The ILS operates in the VHF and UHF radio bands. The ILS consists of two different antennas – Localizer (LOC) and Glide Slope (GS). Figures 4-3 and 4-4 show typical ILS antennas.

4-1.1.3.1 Far Field Monitor (FFM).

ILS monitor systems are of three basic types: integral/aperture, near field and far field, which attempt to predict localizer and glide slope guidance quality on the glide path. A full-fledged Far Field Monitor provides the most complete response of the ILS system to effects which cause degradation to the glide path guidance.

The FFM is not required for CAT I ILS systems; however, it is required for CAT II and above systems. The FFM is considered part of the localizer system. However, it is sited at the opposite end of the runway from the localizer antenna array. Figure 4-5 illustrates a typical FFM antenna.

4-1.1.4 Precision Approach Radar (PAR).

The PAR is an unattended self-contained radar system. The PAR detects azimuth, elevation, and range information of aircraft on final landing approach to PAR instrumented runways. This information is displayed in the Military Terminal Radar Approach Control Facility (MTRACON). The PAR can be mounted on a fixed base or on a turntable. Figure 4-6 illustrates a typical PAR.

Figure 4-1 Typical MLS Facility

Figure 4-2 SBICLS Elevation Transmitter Station

Figure 4-3 ILS Localizer Antenna Array

Figure 4-4 ILS Glide Slope Antenna and Equipment Shelter

Figure 4-5 Typical Far Field Monitor

Figure 4-6 Typical PAR-2000/AN/FPN-68 PAR

4-2 MICROWAVE LANDING SYSTEM (MLS)

4-2.1 Key Documents.

UFC 3-260-01	*Airfield and Heliport Planning and Design*
FAA Order 6830.5	*Criteria for Siting Microwave Landing Systems*
FAA-STD-019f	*FAA Standard, Lightning and Surge Protection, Grounding, Bonding and Shielding Requirements for Facilities*
AF T.O. 31Z3-822-2	*Air Traffic Control Landing Systems (ATCALS) Site Requirements 404L*

4-2.2 Siting.

Locate the azimuth transmitter on the extended runway centerline, 700 to 1,200 feet (213 to 366 m) from the end of runway. Locate the elevation transmitter 600 to 900 feet (183 to 274 m) set back from the runway approach threshold and offset 250 to 600 feet (76 to 183 m) from runway centerline on the runway side opposite of taxiways. See Figure 4-7 for an illustration of the general siting criteria.

4-2.2.1 MLS Obstacle Free Zones.

The MLS obstacle free zones shown in Figures 4-8 and 4-9 must always remain clear of fixed objects as well as moving aircraft and vehicles.

4-2.3 Security.

MLS facilities are normally located within the airfield restricted area which would typically meet the minimum security measures for external security. When the facility is located within a restricted area of a lower level of security or is located remote and outside of an established restricted area, determine the additional measures required to meet the minimum security requirements for the level of security assigned to the facility.

4-2.4 Facility Design Guidance.

4-2.4.1 Site Work.

The MLS consists of two stations, an azimuth station and an elevation station.

Provide an access road to allow access to both MLS stations. Provide parking space for two maintenance vehicles. Typical site layouts are illustrated in Figures 4-8 and 4-9. See Chapter 2, paragraph “Access and Parking” for roadway and parking area design requirements.

4-2.4.2 Architectural Requirements.

There are no architectural requirements for the MLS.

4-2.4.3 Structural Requirements.

MLS transmitter equipment is provided in a self-contained structure by the system supplier. Provide concrete foundations flush with surrounding grade to mount equipment structures. Ensure MLS structures are frangible.

4-2.5 Mechanical Requirements.

Mechanical systems for the shelter system supporting the MLS are self-contained within the shelter and provided as part of the equipment package.

4-2.6 Electrical Power.

To avoid signal interference, install power, communications, and control cables underground within 1,000 feet (305 m) from the facility. Locate electrical equipment which is not frangible, such as transformers, outside the runway clear zone or primary surface. Ensure electrical systems do not interfere with radio transmissions.

Provide 120/240V, 100A, single-phase, 60 HZ commercial power service to the MLS equipment shelter.

4-2.6.1 Emergency Electrical Power.

MLS equipment is supplied with backup battery power. No emergency generator is required.

4-2.6.2 Lighting.

No site lighting is required. Obstruction lighting is provided with the equipment.

4-2.6.3 Grounding and Bonding.

Provide grounding and bonding systems in accordance with FAA STD-019f.

4-2.7 Communications.

Provide 12-strand single mode fiber optic cable or 25 twisted pair communications line to provide required connectivity for data and telephone.

- Data connectivity from the MLS Shelter to Remote Unit located in the ATC Tower.
- Data connectivity from the MLS Shelter Fire Alarm to external monitoring system.
- Telephone line for distance support to troubleshoot system.

Air Force: See fiber optic cable and modem requirements in AF T.O. 31Z-822-2, Chapter 4.

4-2.8 Connection/Interrelation to other Facilities.

Connect the MLS to the ATC Tower via fiber optic cable for remote monitoring.

Figure 4-7 MLS Facility: Site Plan

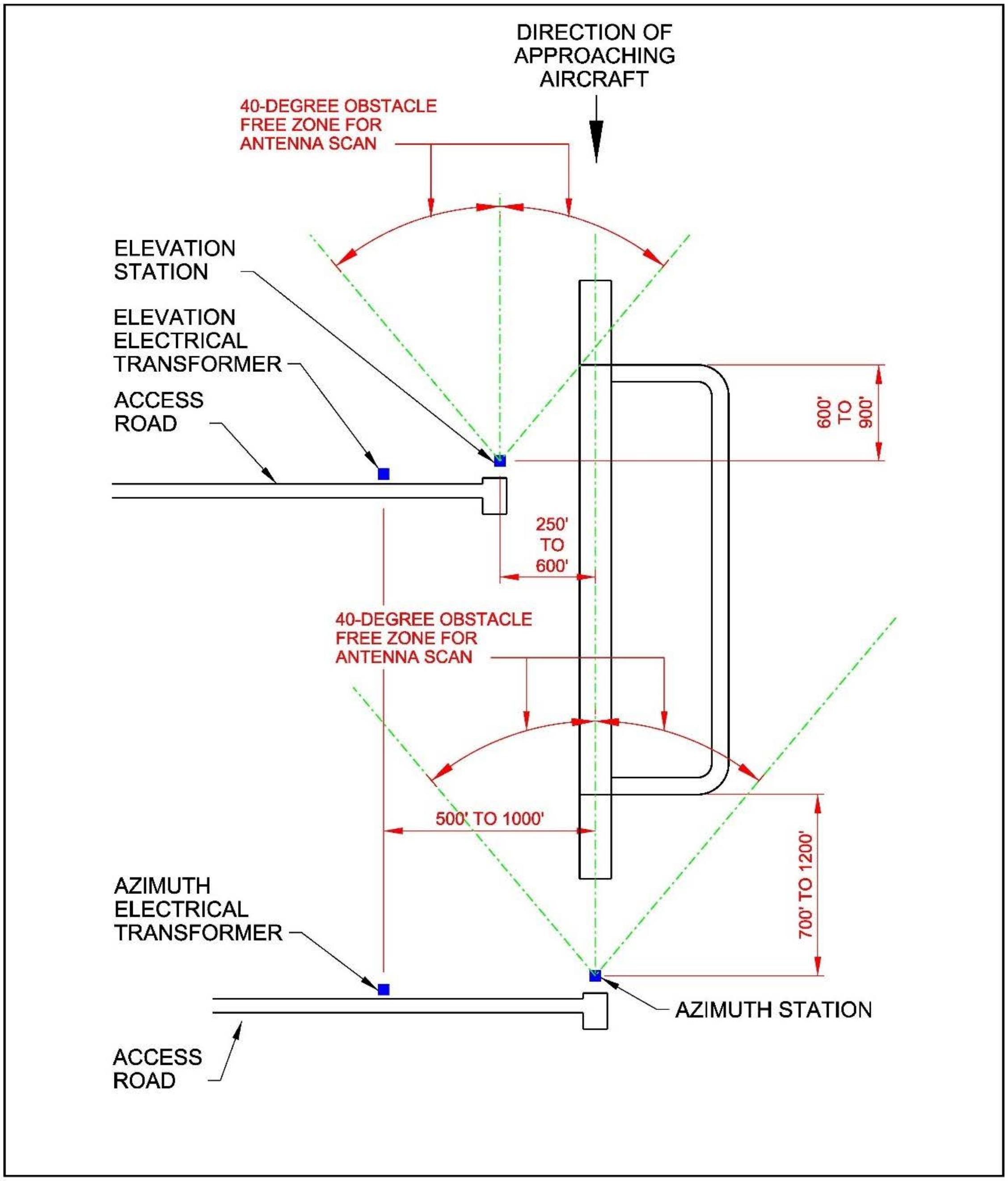


Figure 4-8 MLS Facility: Azimuth Station Site Plan

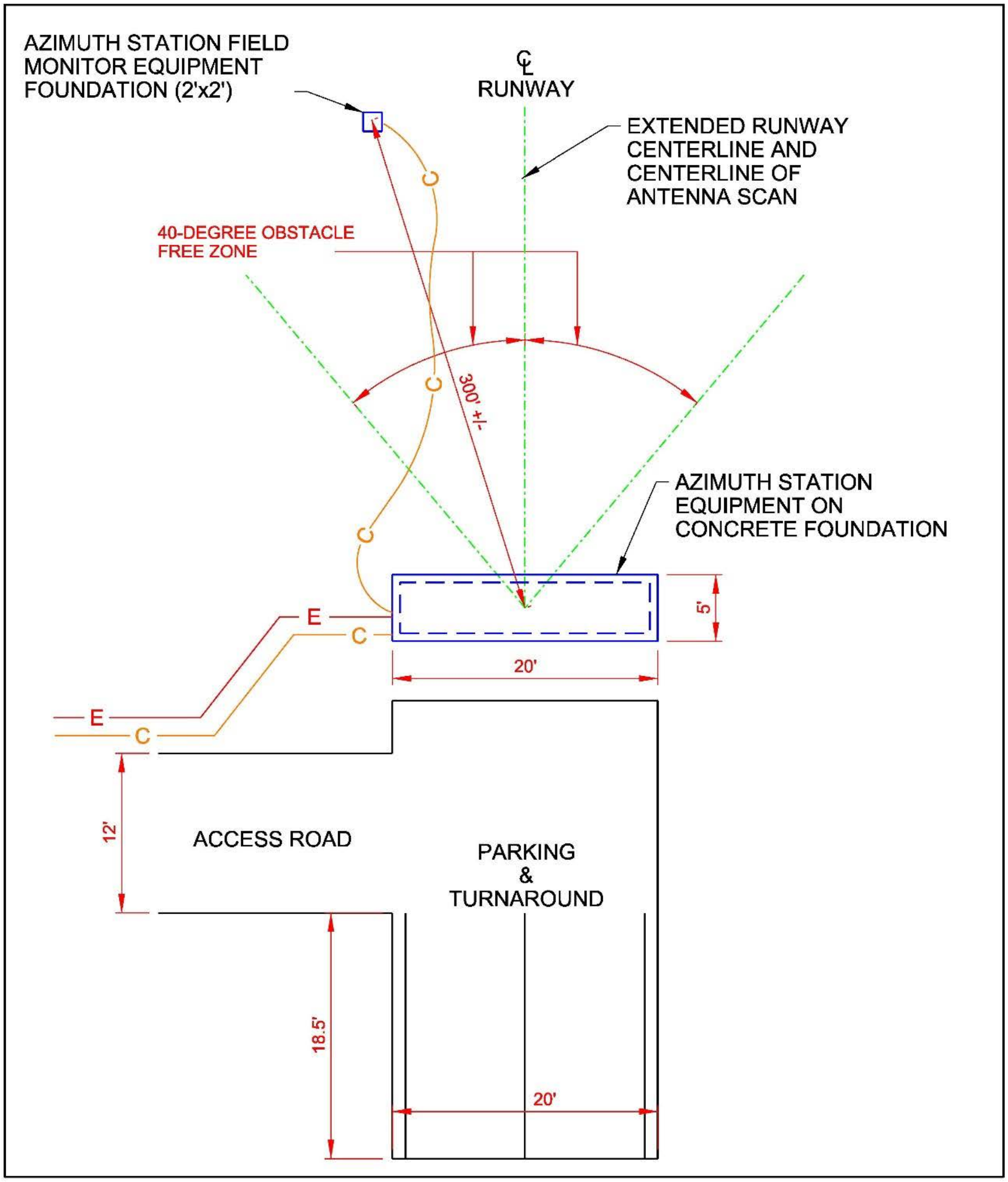
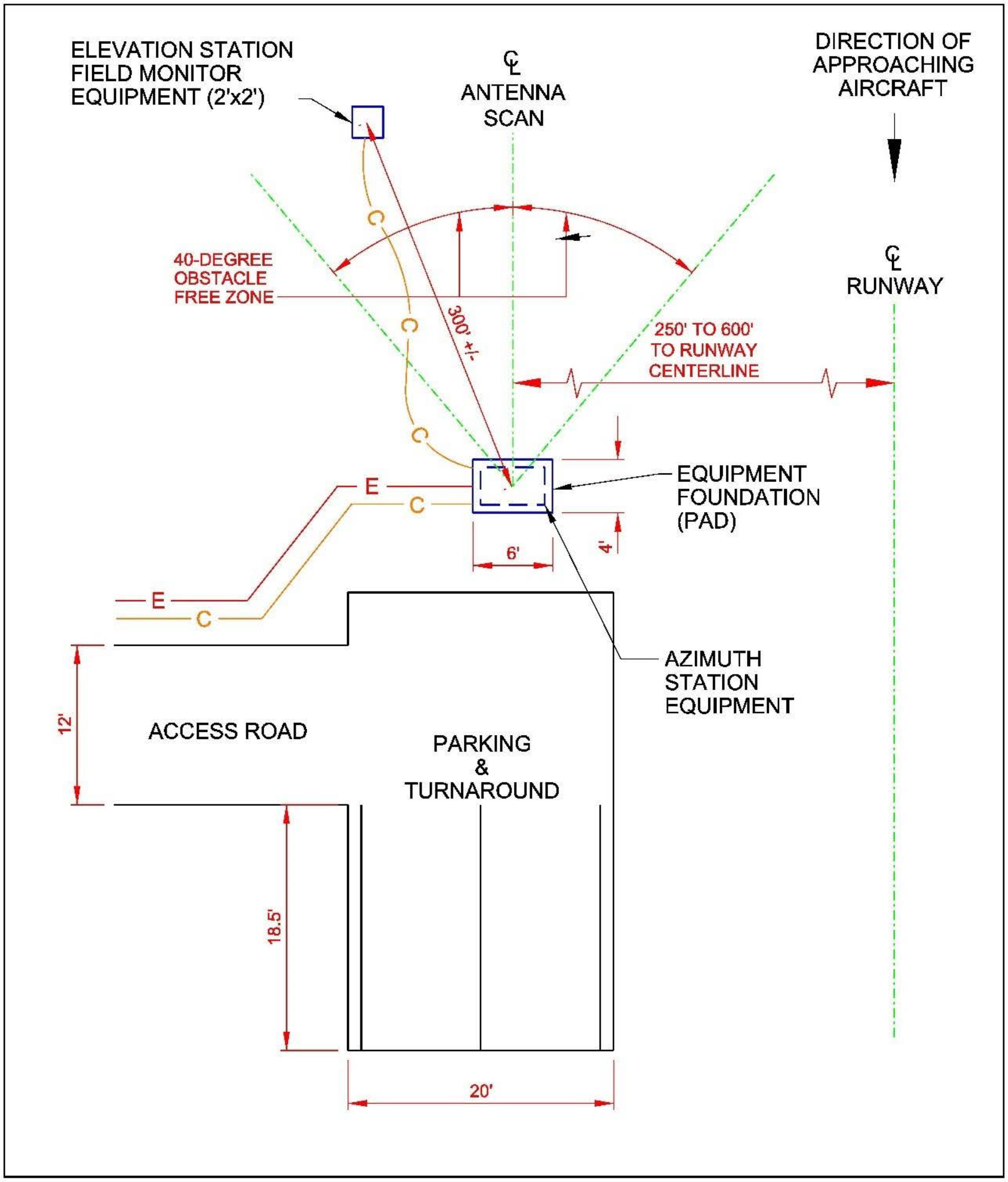


Figure 4-9 MLS Facility: Elevation Station Site Plan



4-3 SHORE-BASED INSTRUMENT CARRIER LANDING SYSTEMS.

4-3.1 Key Documents.

4K73-D2018-011	*Facility Requirements Document (FRD) for the Shore Instrument Carrier Landing System (ICLS) AN/FRN-49(V)*
FAA AC 70/7460-1M	*Obstruction Marking and Lighting*

4-3.2 Siting.

Locate the azimuth transmitter on the extended runway centerline. Locate the elevation transmitter adjacent to the runway, preferably 400-ft to 500-ft (122 to 152 m) from the runway centerline. See the FRD for specific distances. General siting requirements are illustrated in Figure 4-10.

Do not install the SBICLS if a Fresnel Lens Optical Landing System (FLOLS)/Improved Fresnel Lens Optical Landing System (IFLOLS) is not installed to the landing runway or a marked simulated carrier deck on a runway.

The SBICLS consists of three sites, as described below.

4-3.2.1 Elevation Station Site.

This site consists of the elevation transmitter and its associated waveguide (W/G) horn which provides vertical guidance. The elevation transmitter group is located adjacent to the runway near the touchdown point associated with the simulated carrier deck markings. The elevation transmitter group may also be sited to provide for traditional vertical guidance to a runway touchdown point similar to an ILS glide slope antenna.

4-3.2.2 Azimuth Station Site.

This site consists of the azimuth transmitter and its associated W/G horn, and it provides lateral guidance similar to an ILS localizer antenna array. The signal is provided through a transmitter located along the extended centerline or simulated carrier deck centerline at the far end of a runway approach.

4-3.2.3 Operations Station Site.

This site consists of the transmitter control group and the transmitter control unit. The purpose of this site is to provide a graphical user interface, controls, system status and alerts, synchronization, and built-in test to maintenance personnel and operators.

4-3.2.4 SBICLS Critical Areas.

The SBICLS critical areas shown in Figures 4-11 and 4-12 must always remain clear of fixed objects as well as moving aircraft and vehicles.

4-3.3 Security.

SBICLS facilities are normally located within the airfield restricted area which would typically meet the minimum security measures for external security.

4-3.4 Facility Design Guidance.

4-3.4.1 Site Work.

Provide an access road to allow access to both SBICLS stations. Provide parking space for two maintenance vehicles. See Chapter 2, paragraph “Access and Parking” for roadway and parking area design requirements. Typical site layouts are illustrated in Figures 4-11 and 4-12.

4-3.4.2 Architectural Requirements.

There are no architectural requirements for the SBICLS.

4-3.4.3 Structural Requirements.

SBICLS transmitter equipment is provided in a self-contained structure by the system supplier. Provide concrete foundations flush with the surrounding grade to mount equipment structures. See FRD for additional requirements and foundation details.

4-3.5 Mechanical Requirements.

Mechanical systems for the shelter system supporting the SBICLS are self-contained within the shelter and provided as part of the equipment package.

4-3.6 Electrical Power.

To avoid signal interference, install power, communications, and control cables underground within 1,000 feet (305 m) from the facility.

Provide 120/240V, 100A, single-phase, 60 HZ commercial power service to each SBICLS equipment shelter. The minimum required transformer size for each SBICLS shelter is 15 kVA, in a pad-mounted configuration.

4-3.6.1 Emergency Electrical Power.

Emergency generators are not supplied with the ICLS equipment and are not required for IFR approach certification. The requirements for individual generators at the equipment shelter sites are a base-level determination. If required, the base will provide the generator.

An integrated battery backup UPS will be supplied as part of each ICLS transmitter shelter. The UPS is rated for 4 hours at full load and meets the requirements for IFR certification.

4-3.6.2 Lighting.

No site lighting is required. Provide obstruction lights in accordance with FAA AC 70/7460-1 on transmitter shelters.

4-3.7 Communications.

Provide a minimum 12-strand single-mode fiber optic cable to each system (elevation and azimuth) through underground conduits and handholes.

4-3.8 Connection/Interrelation to other Facilities.

Each SBICLS system must be connected to the remote monitoring site (usually the Air Traffic Control Tower) with fiber optic cables. See the FRD for additional details.

Figure 4-10 SBICLS Facility: Site Plan

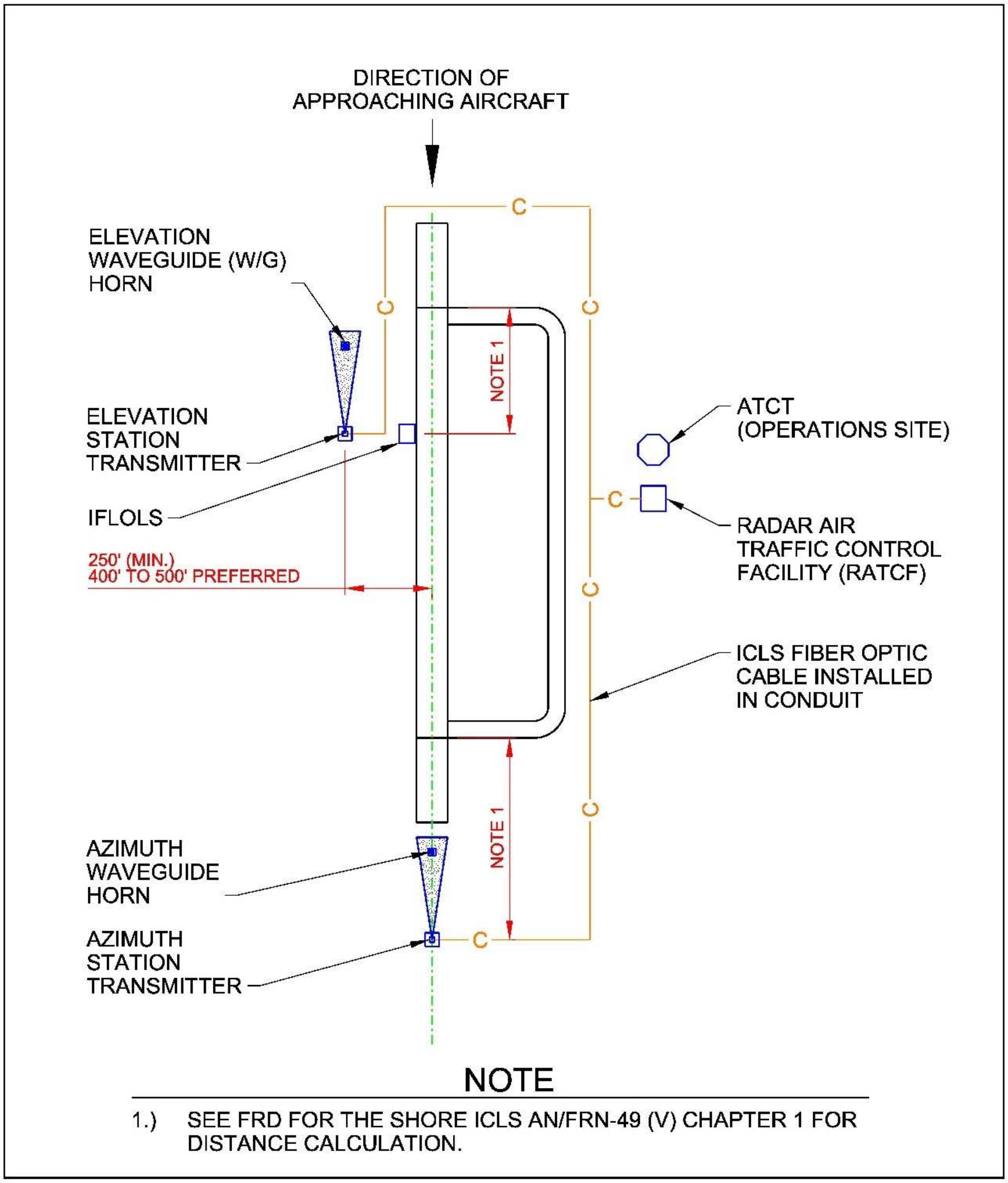


Figure 4-11 SBICLS: Azimuth Station Site Plan

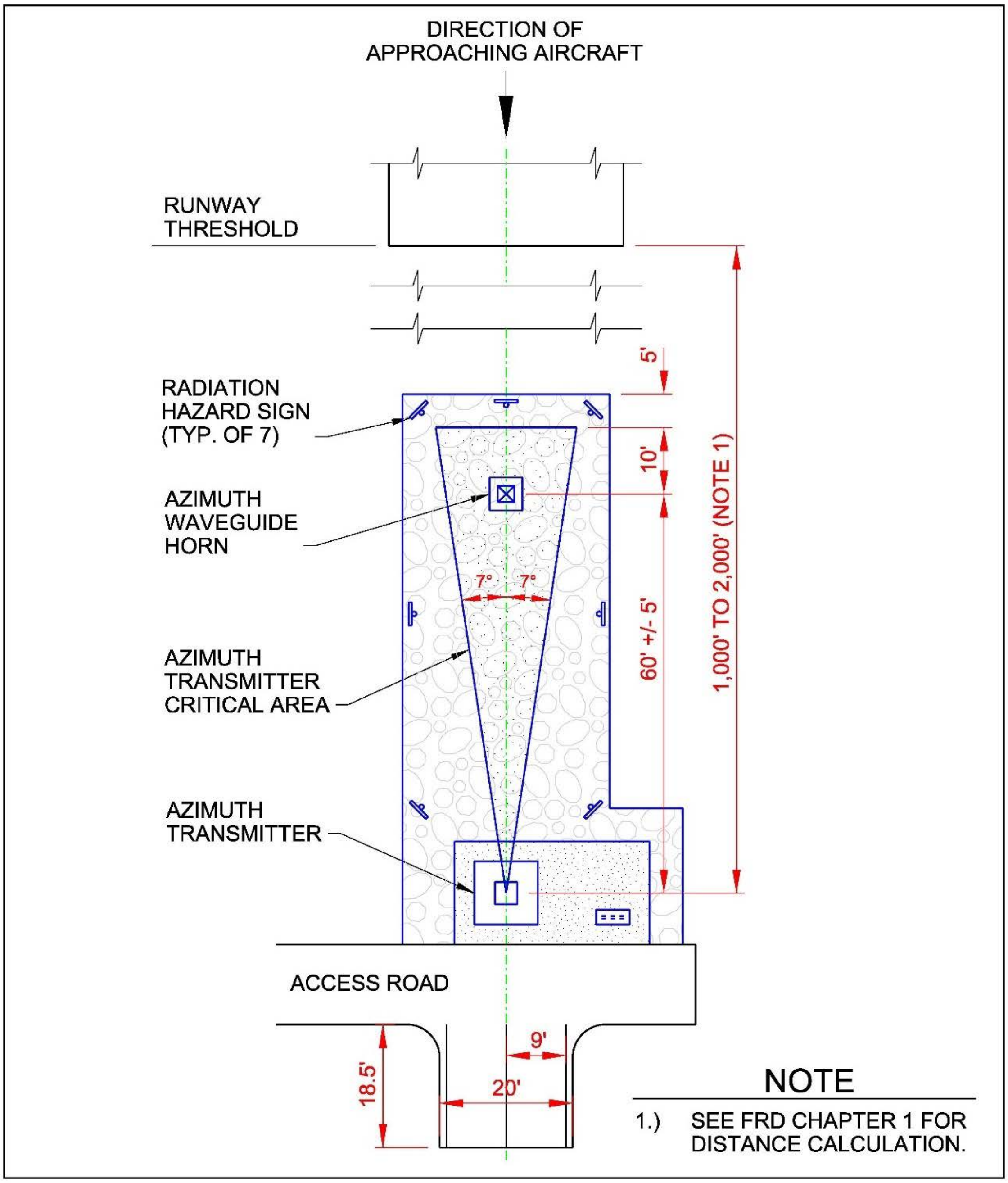
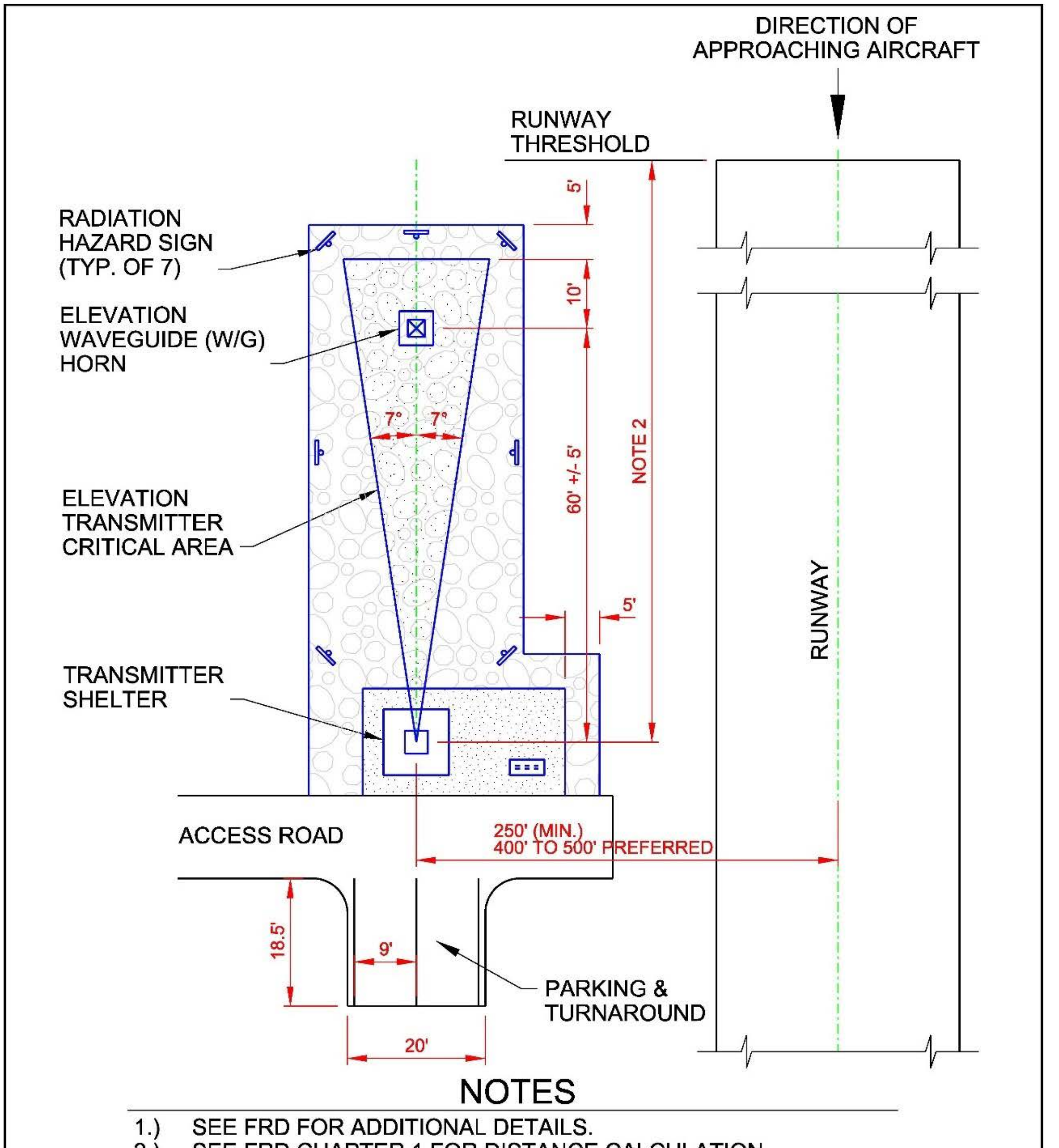


Figure 4-12 SBICLS Facility: Elevation Station Site Plan



NOTES

1.) SEE FRD FOR ADDITIONAL DETAILS.
2.) SEE FRD CHAPTER 1 FOR DISTANCE CALCULATION.
3.) MINIMUM DISTANCE BETWEEN ELEVATION TRANSMITTER AND NEAREST TAXIWAY CENTERLINE IS 150 FEET.

4-4 INSTRUMENT LANDING SYSTEM (ILS).

4-4.1 Key Documents.

UFC 3-260-01	Airfield and Heliport Planning and Design
AF T.O. 31Z3-822-2	Air Traffic Control Landing Systems (ATCALS) Site Requirements 404L
AF T.O. 31R4-2GRN30-32	*Combined Maintenance Operating Instructions: Radio Transmitting Set (Localizer Station)*
FAA AC 150/5300-13	*Airport Design*
FAA Order 6750.16	*Siting Criteria for Instrument Landing Systems*

4-4.2 Siting.

Provide separate facilities for glide slope (GS) antenna transmitter equipment, for localizer (LOC) antenna transmitter equipment and for Far Field Monitor (FFM) antenna equipment. Refer to FAA Order 6750.16 and FAA AC 150/5300-13. See Figure 4-13 for general layout requirements.

4-4.2.1 General.

The ILS uses a line-of-sight signal from the LOC antenna and marker beacons and a reflected signal from the ground plane in front of the GS antenna.

a. ILS antenna systems are susceptible to signal interference sources such as power lines, fences, metal buildings, cell phones, etc.

b. Since ILS uses the ground in front of the GS antenna to develop the signal, this area must be free of high-growth vegetation and graded to remove surface irregularities.

c. GS and LOC equipment shelters are located near, but are not a physical part of, the antenna installation.

d. The FFM is considered part of the localizer system. However, it is sited at the opposite end of the runway from the localizer antenna array.

4-4.2.2 ILS Localizer Antennas (Frangible).

Site the LOC antenna array between 1,000 feet and 2,000 feet (305 and 610 m) beyond the stop end of the runway. Siting must conform to approach-departure clearance surface criteria discussed in UFC 3-260-01, Chapters 3 and 4. Refer to FAA Order 6750.16 if standard localizer antenna placement is not an option. See Figure 4-16 for a typical LOC site plan.

a. The critical area depicted in Figure 4-14 surrounding the LOC antenna and extending toward and overlying the stop end of the runway must be clear of objects and high growth of vegetation.

b. The critical area must be smoothly graded. A constant +1.0% to -1.50% longitudinal grade with respect to the antenna is recommended. Allowable transverse grades from -0.5 percent to -3.0 percent, with smooth transitions between grade changes. Antenna supports are frangible and foundations must be flush with the ground.

c. Place the LOC equipment shelter at least 250 feet (76 m) to either side of the antenna array and within 30 degrees of the extended longitudinal axis of the antenna array.

4-4.2.2.1 ILS Localizer Transmitter Shelter (Non-Frangible).

The ILS localizer transmitter shelter is sited adjacent to the localizer antenna array. It must be located at least 250 feet (76 m) from the extended runway centerline, or a waiver is required.

4-4.2.3 ILS Glide Slope Antenna (Non-Frangible).

Locate the antenna mast or monitor a minimum distance of 400 feet (122 m) from the runway centerline to the centerline of the antenna, and not exceeding 55 feet (17 m) in height above the nearest runway centerline elevation. A mast height of over 55 feet (17 m) is permitted if the minimum distance from the runway centerline is increased by 10 feet (3 m) for each 1 foot (0.3 m) the mast exceeds 55 feet (17 m). When the mast cannot, for technical or economic reasons, be located at a minimum distance of 400 feet (122 m) from the runway centerline, the minimum distance may be reduced to not less than 250 feet (76 m) from the centerline, provided the basic mast height of 55 feet is reduced 1 foot (0.3 m) for each 5 feet (1.5 m) it is moved toward the runway from the 400-foot (122 m) point. Glide slope monitor units are considered part of the parent equipment. Emergency power generators must be as close to the facilities they support as practical, but no closer than the glideslope main facility. See Figure 4-17 for a typical GS site plan.

a. The GS antenna may be located on either side of the runway. The most reliable operation is obtained when the GS is located on the side of the runway offering the least possibility of signal reflections from buildings, power lines, vehicles, aircraft, etc. The GS critical area is illustrated in Figure 4-15.

b. The critical area must be smoothly graded. A constant +1.0 percent to -1.50 percent longitudinal grade with respect to the antenna is recommended. Allowable transverse grades range from -0.5 percent to -3.0 percent, with smooth transitions between grade changes. Antenna supports are frangible and foundations must be flush with the ground.

c. Signal quality is dependent upon the type of antenna used and the extent of reasonably level ground immediately in front of the antenna.

d. The GS equipment shelter is located behind the antenna and a minimum of 400 feet (122 m) from the runway centerline.

4-4.2.3.1 ILS End Fire Glide Slope Antenna (Frangible).

Site in accordance with FAA Order 6750.16. For the end-fire glide slope, the antenna array typically extends to 25 feet (7.6 m) from the runway edge. This is allowed due to antenna frangibility.

4-4.2.4 Far Field Monitor (FFM).

The FFM is not required for CAT I ILS systems; however, it is required for CAT II and above systems. The FFM is considered part of the localizer system. However, it is sited at the opposite end of the runway from the localizer antenna array. Typical locations are 365.8 meters (1,200 feet) to 914.4 meters (3,000 feet) prior to the landing threshold. FFM antenna height is determined by line of sight to the localizer antenna array. The line-of-sight requirement can be relaxed if satisfactory localizer signal reception is proven with a portable ILS receiver at the proposed lower height of the FFM site. Just as with the localizer antenna array, the FFM antenna must not penetrate the approach-departure clearance surface criteria discussed in UFC 3-260-01, Chapters 3 and 4. Army siting requirements are contained in FAA Order 6750.16.

4-4.3 Security.

ILS facilities are normally located within the airfield restricted area which would typically meet the minimum security measures for external security. When the facility is located within a restricted area of a lower level of security or is located remote and outside of an established restricted area, determine the additional measures required to meet the minimum security requirements for the level of security assigned to the facility.

4-4.4 Facility Design Guidance.

4-4.4.1 Site Work.

The ILS consists of two stations, a localizer and antenna station, and a glide slope equipment station.

Provide a roadway to allow access to the LOC and GS antennas. Provide parking space for two maintenance vehicles.

When included, the FFM also requires an access road and a parking space for one maintenance vehicle.

See Chapter 2, paragraph “Access and Parking” for roadway and parking area design requirements.

4-4.4.2 Architectural Requirements.

There are no architectural requirements for the ILS. Localizer and Glide Slope shelters are prefabricated units.

4-4.4.3 Structural Requirements.

ILS transmitter equipment is provided in a self-contained structure by the system supplier. Provide concrete foundations flush with grade that extend below the frost depth to mount equipment structures. Ensure ILS structures are frangible.

The LOC station requires an 18 by 20-foot (5.5 by 6 m) concrete pad for the localizer equipment shelter and a 12 by 18-foot (3.7 by 5.5 m) concrete pad for the glide slope equipment shelter.

The FFM requires pier foundations flush with grade that extend below the frost depth.

4-4.5 Mechanical Requirements.

Localizer and Glide Slope shelters are prefabricated units that include HVAC systems.

Air Force: See Environmental Control Unit requirements (e.g., allowable temperature and humidity ranges) in AF T.O. 31Z3-822-2, Chapter 3.

4-4.6 Electrical Power.

To avoid potential interference with antenna transmissions, install power, communications, and control cables underground within 1,000 ft (305 m) of each facility. Locate electrical equipment which is not frangible, such as transformers, outside the runway clear zone or primary surface. Ensure electrical systems do not interfere with radio transmissions.

Provide 120/240V, 100A, single-phase, 60 HZ commercial power service to the LOC and GS facility shelters.

Air Force: See Commercial Power, Uninterruptible Power Supply, and Backup Power, in AF T.O. 31Z-822-2, Chapter 1. See Grounding, Bonding Shielding and Lightning Protection requirements in AF T.O. 31Z-822-2, Chapter 2.

4-4.6.1 Emergency Electrical Power.

ILS equipment is supplied with backup battery power. No emergency generator is required. Backup power is not required for the FFM.

4-4.6.2 Lighting.

No site lighting is required. Obstruction lighting is provided with the equipment.

4-4.7 Communications.

Provide a minimum 12-strand single-mode fiber optic cable to each system (elevation and azimuth) through underground conduits and handholes.

Air Force: See fiber optic cable and modem requirements in AF T.O. 31Z-822-2, Chapter 4.

4-4.8 Connection/Interrelation to other Facilities.

Each ILS system must be connected to the remote monitoring site (usually the Air Traffic Control Tower) with fiber optic cables.

Figure 4-13 ILS Facility: Site Plan

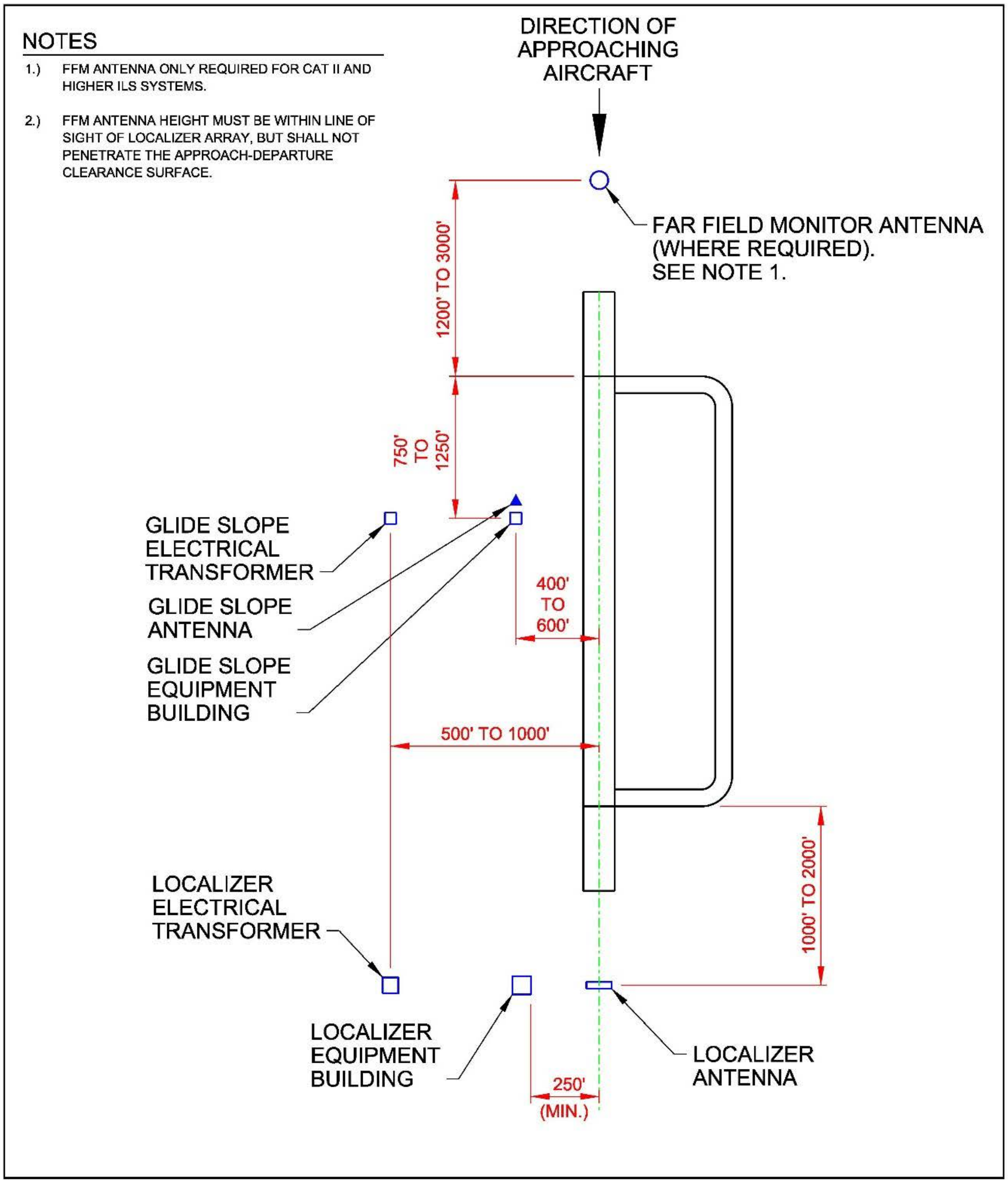
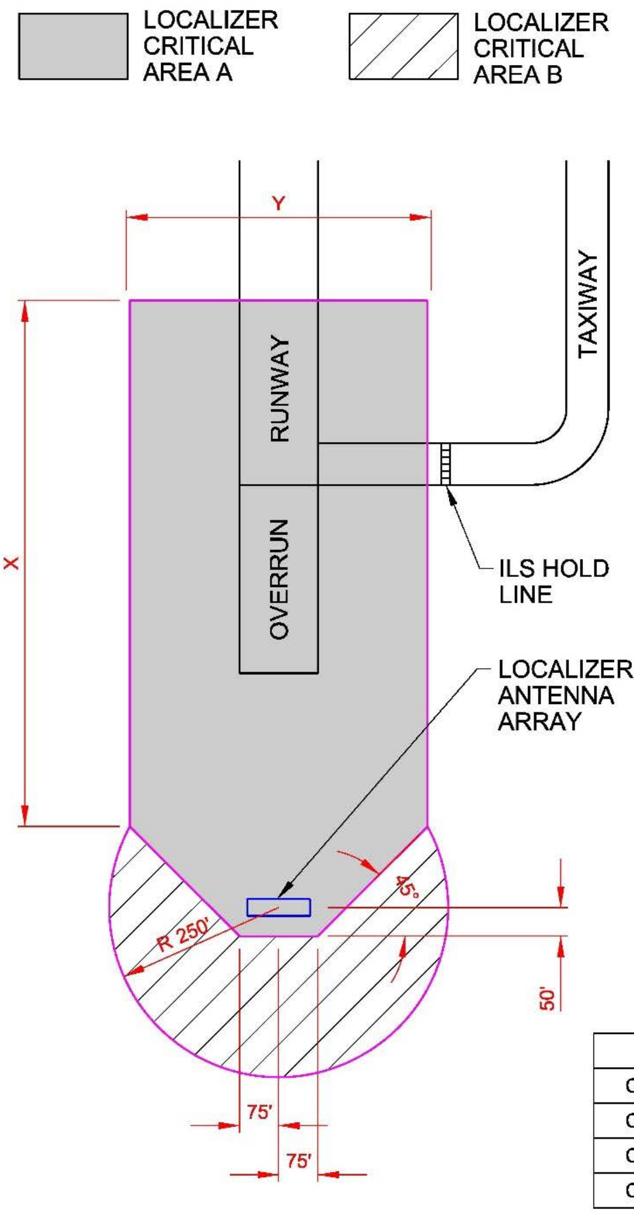


Figure 4-14 ILS Facility: Localizer Antenna Siting and Critical Area



NOTES

1.) CRITICAL AREA IS INDICATED BY SHADED ZONES.

2.) HOLD LINES/SIGNS INDICATE THE POSITION BEYOND WHICH AIRCRAFT/VEHICLES WILL REQUIRE ATCT AUTHORIZATION BEFORE PROCEEDING ON OR ACROSS RUNWAY.

3.) AREA B IS DELETED FROM THE CRITICAL AREA WHEN A UNIDIRECTIONAL LOCALIZER ANTENNA IS INSTALLED. THE STANDARD LOG PERIODIC DIPOLE ANTENNA IS IN THIS CATEGORY.

4.) FOR 8-ELEMENT LOCALIZER ARRAY WITH COURSE WIDTHS LESS THEN 4' AND RUNWAYS WHICH OPERATE B-747 SIZE AND LARGER AIRCRAFT THE "Y" DIMENSION IS 600' [183 M].

5.) THESE DIMENIONS APPLY WHERE AIRCRAFT SIZE IS EQUAL TO OR LESS THAN 135' [41 M] IN LENGTH OR 42' [13M] IN HEIGHT, E.G. B-737.

6.) CRITICAL AREA FOR LDA, SDF AND OFFSET LOCALIZER FACILITIES ARE THE SAME AS FOR CATEGORY I, BUT ARE CENTERED ABOUT THE COURSE LINE.

	X	Y	
CAT I	2000	400	NOTE 4
CAT II/III	2000	400	NOTE 5
CAT II	4000	500	
CAT III	7000	500	

Figure 4-15 ILS Facility: Glide Slope Antenna Siting and Critical Area

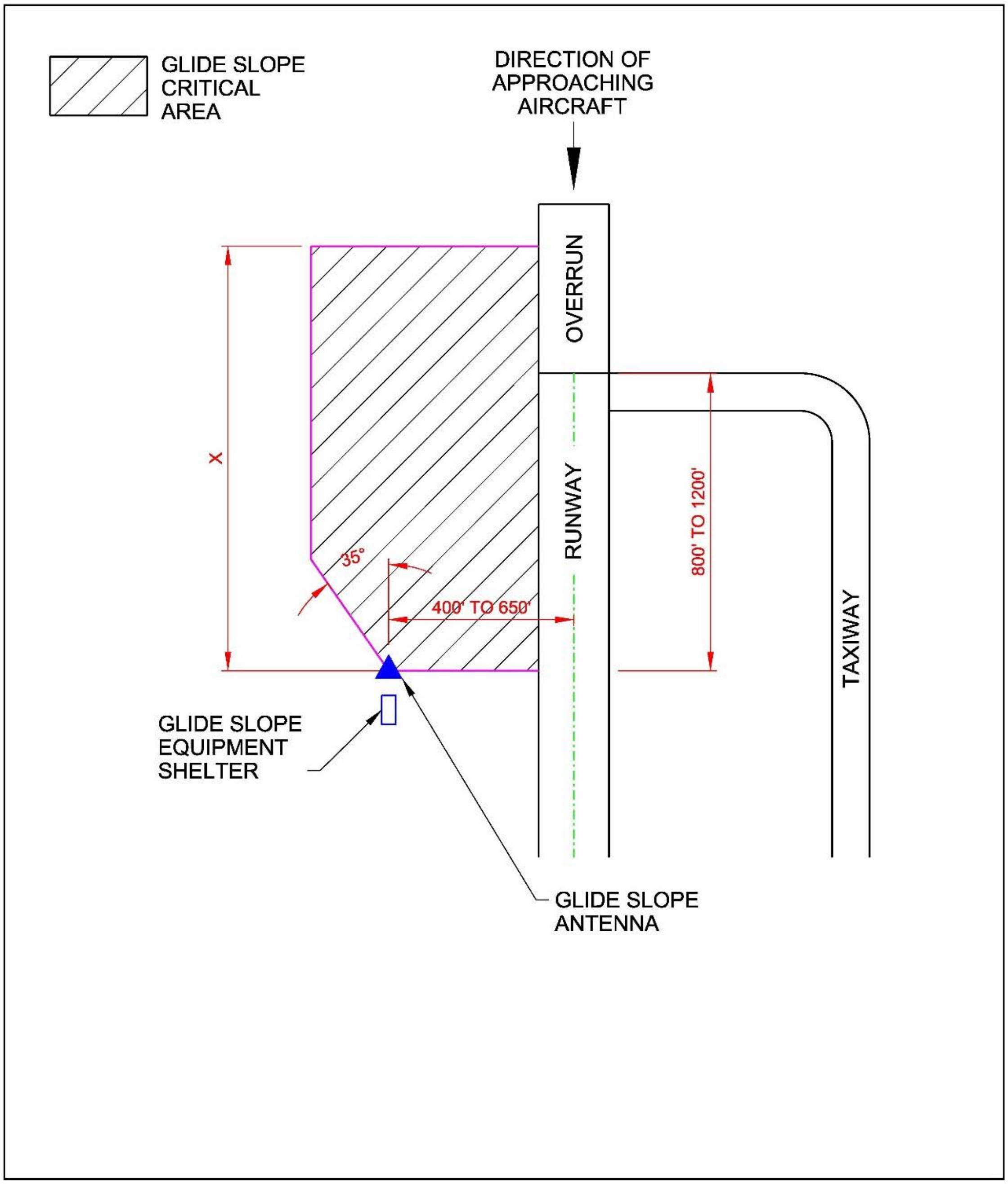


Figure 4-16 ILS Localizer Equipment and Antenna Site Plan

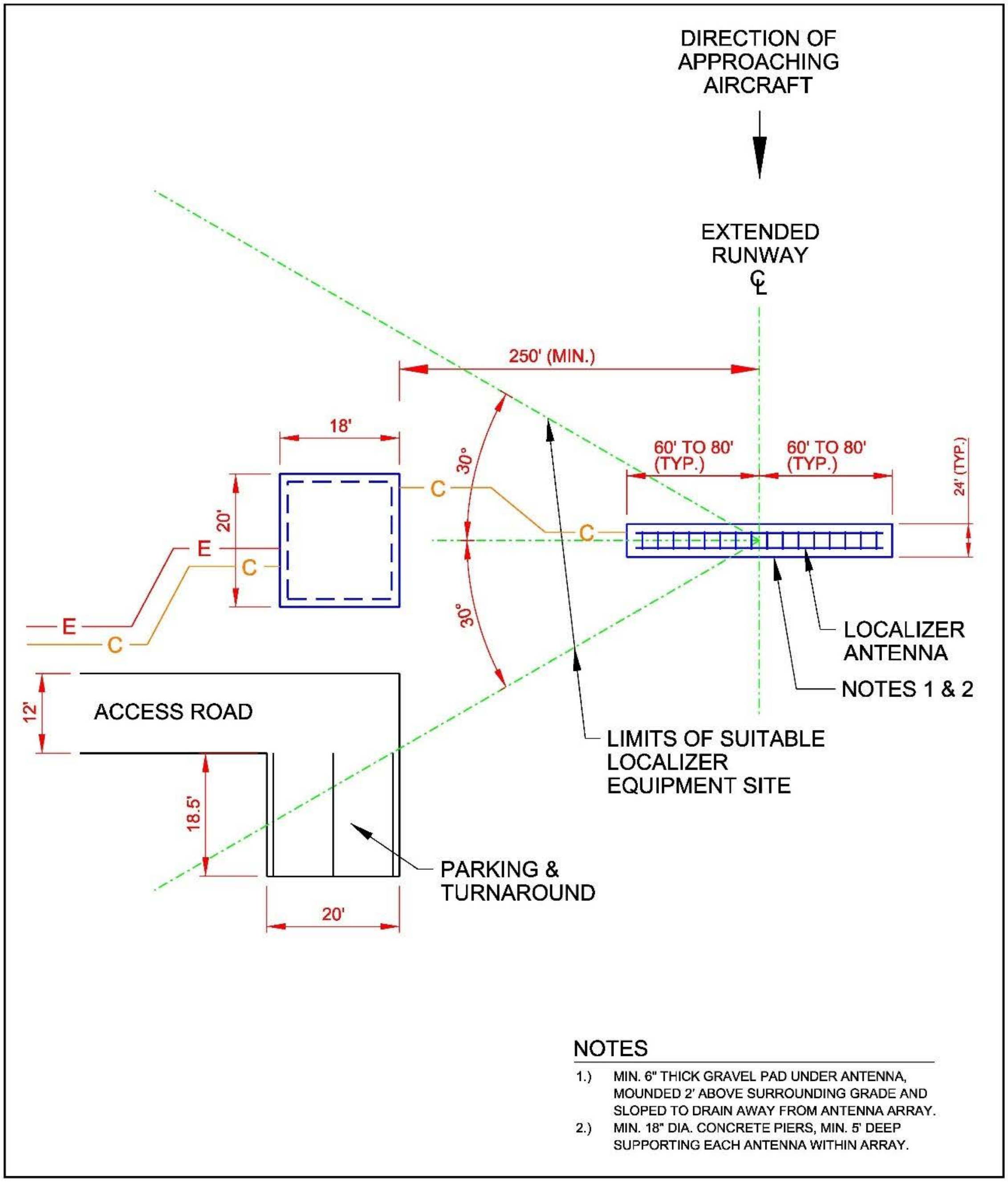
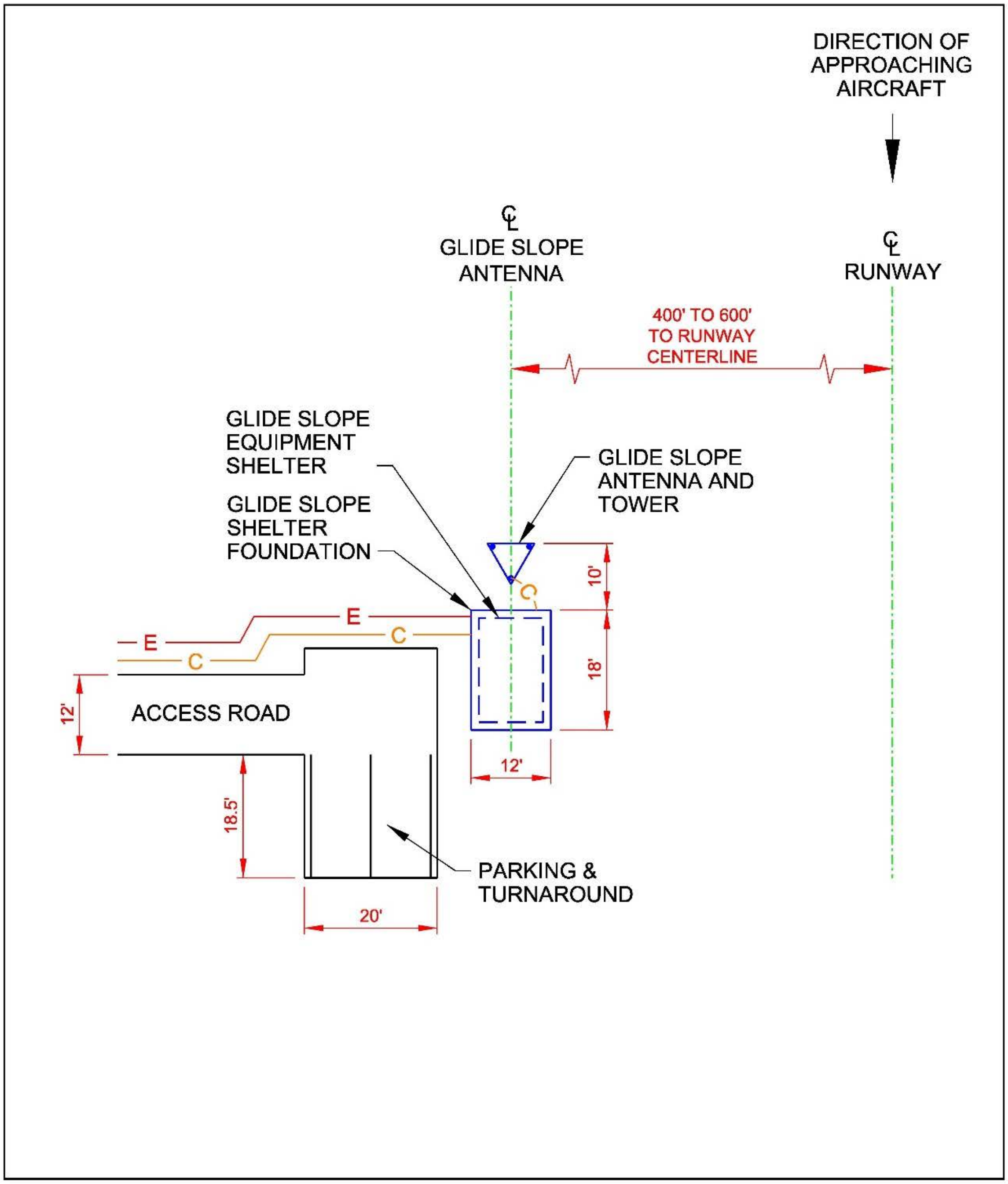


Figure 4-17 ILS Glide Slope Equipment and Antenna Site Plan



4-5 PRECISION APPROACH RADAR (PAR).

4-5.1 Key Documents.

UFC 3-260-01	*Airfield and Heliport Planning and Design*
UFC 3-301-01	*Structural Engineering*
AF T.O. 31Z3-822-2	*Air Traffic Control Landing Systems (ATCALS) Site Requirements 404L*
AF T.O. 31P5-2GPN22-12	*Facility Manual – Radar Set Group, Type AN/GPN-22(V)*
SSC PAC PAR SPSPP	*SPAWARSYSCEN Pacific (SSC PAC) Precision Approach Radar (PAR) Site Preparation Standard Plan Package*

4-5.2 Siting.

4-5.2.1 Navy PAR Siting.

Locate PAR sites adjacent to the instrumented runway or runway intersection. See the SSC PAC PAR Site Preparation Standard Plan Package for additional information.

4-5.2.2 Army and Air Force Siting for GPM-22 PAR.

PAR systems (AN/GPN-22) must be sited not less than 512 feet (156 meters) from the centerline of a runway to the near edge of the equipment. The reference reflector must be positioned so that the reflector and the radar antenna are parallel with the runway centerline (± 0.005°), be in clear and unobstructed view of the radar antenna and be located in an area where there are no large reflecting objects. Specific siting criteria for this system is provided in AF T.O. 31P5-2GPN22-12. When it is necessary to place units between parallel runways with insufficient distance to allow a 512-foot (156-meter) clearance to each runway centerline, site the system to provide the minimum distance to the centerline of the primary instrument runway and the lesser clearance to the centerline of the other runway. While it is desirable, from a safety standpoint, to keep these units as low as possible, AFFSA ATCALS will determine the final elevation for the units. The elevation is dependent on the necessary lines of sight between the unit and calibration reflectors and the touchdown areas of the runways. If it is necessary to change the existing ground elevation to provide a proper height for these units, follow grading requirements discussed in UFC 3-260-01, Chapter 3. These systems are non-frangible.

4-5.2.3 AN/FPN-67 or FBPAR (Fixed Base Precision Approach Radar).

The AN/FPN-67 is a modern, solid-state, reliable, ground-based, precision approach radar in a fixed-shelter (or integrated with the ATNAVICS system). AN/FPN-67 systems must be sited not less than 512 feet (156 meters) from the centerline of a runway to the near edge of the equipment.

4-5.2.4 PAR Reflectors (Frangible and Non-Frangible).

4-5.2.4.1 Air Force.

Site moving target indicator (MTI) reflectors, or “target simulators,” not less than 150 feet (46 meters) from the near edge of a runway nor less than 125 feet (38 meters) from the near edge of a taxiway or apron boundary marking to the centerline of the equipment. The height of these reflectors must be held to a minimum consistent with the operational requirements of the system. MTI reflectors sited less than 500 feet (152 meters) from the centerline of any runway must be of frangible construction, using breakaway sections in reflector masts. Tracking reference reflectors must not be installed closer than 500 feet (152 meters) to the centerline of any runway, nor exceed 60 feet (18 meters) in height above the centerline elevation of the nearest runway at the intersection of the equipment centerline perpendicular with the runway centerline.

4-5.2.4.2 Army.

Site MTI reflectors not less than 250 feet (76 meters) from the near edge of a runway nor less than 125 feet (38 meters) from the near edge of a taxiway or apron boundary marking to the centerline of the equipment.

4-5.2.5 Airborne Radar Approach Reflectors (Non-Frangible).

Place airborne radar approach reflectors not less than 325 feet (99 meters) from the runway edge and not less than 400 feet (122 meters) nor more than 750 feet (229 meters) from the runway centerline to the edge of the equipment in a pattern parallel to the runway.

4-5.2.5.1 Army.

Locate at least one reflector within the AN/FPN67/AN/TPN-31 PAR azimuth angle coverage area in order to provide a horizontal reference point. Reflectors may not be sited less than 150 feet (46 meters) from the near edge of a runway nor less than 125 feet (38 meters) from the near edge of a taxiway or apron boundary marking to the centerline of the equipment. Reflectors sited less than 250 feet (76 meters) from the runway centerline must be of frangible construction, using breakaway sections of reflector masts, nor exceed 10 feet (3 meters) in height above the centerline elevation of the nearest runway at the intersection of the equipment centerline perpendicular with the runway centerline.

4-5.3 Security.

PAR facilities are normally located within the airfield restricted area which typically meets the minimum security measures for external security. When the facility is located within a restricted area of a lower level of security or is located remote and outside of an established restricted area, provide additional measures to meet the minimum level of security assigned to the facility.

4-5.4 Facility Design Guidance.

4-5.4.1 Site Work.

Provide a roadway to allow access to the PAR system. Provide parking space for two maintenance vehicles. Include access roads located around the COTS PAR concrete pad and from any nearby access road. See Chapter 2, paragraph "Access and Parking" for roadway and parking area design requirements. The use of asphalt pavement for access routes is not allowed. Slope the access roads and concrete pads to provide positive drainage away from the COTS PAR equipment and toward any stormwater management facility or existing vegetation.

Provide a reinforced concrete pad approximately 20' x 40' (6 x 12 m) to accommodate the main PAR facility equipment. A site-specific concrete pad may be installed to accommodate a generator, transformer, or fuel tank. Install additional concrete pads to accommodate reflector towers and guy wire anchor pads. The number of reflector towers required is site specific.

4-5.4.2 Architectural Requirements.

There are no architectural requirements for the PAR. The building is a prefabricated shelter.

4-5.4.3 Structural Requirements.

The PAR system is housed in a transportable shelter provided by the system manufacturer. Provide a reinforced concrete pad for the fixed mounted PAR and reinforced concrete foundations to support the turntable-mounted PAR frame. Provide concrete anchor blocks for turntable stop anchor bolts.

4-5.4.3.1 Design Criteria and Loads.

Base the structural design on a Risk Category of IV, as noted in UFC 3-301-01, Structural Engineering, Table 2-2. See the SSC PAC PAR SPSPP for additional structural design criteria.

Place the PAR and associated infrastructure on a minimum 6-inch (150 mm) thick 40' x 20' (12 m x 6 m) concrete slab on grade. Provide a slab with a thickened footing at the edge with a minimum embedment below the finished grade of 12 inches (300 mm). Provide a thickened footing at the edge a minimum of 15 inches (380 mm) thick and 12 inches (300 mm) wide. Adjust the dimensions of this footing based on the frost depth penetration at each site and based on the findings of the site-specific geotechnical investigation.

Place the PAR Sensor on a 4-ft (1.2 m) tall, 6’ x 6’ (1.8 m x 1.8 m) cast-in-place concrete pedestal. Support the cast-in-place concrete pedestal with a foundation of variable size, designed based on the wind category applicable to the facility location. Install the Antenna Mounting assembly within the concrete pedestal. This assembly consists of two mounting plates and 12 anchor bolts, nuts, and washers.

4-5.5 Mechanical Requirements.

Air Force: See Environmental Control Unit requirements (e.g., allowable temperature and humidity ranges) in AF T.O. 31Z3-822-2, Chapter 3.

4-5.6 Electrical Power.

To avoid potential interference with antenna transmissions, install power, communications, and control cables underground within 1,000 ft (305 m) of the PAR facility. Ensure electrical systems do not interfere with radio and radar transmissions.

Provide commercial power service to the PAR. Provide service maximum 25kVA, 208Y/120V, 3 Phase, 4-wire, 60Hz.

Provide the PAR site with a new 100-amp electrical panelboard: 208Y/120V, 3 Phase, 4-wire, 60Hz. Provide a panelboard with a 100A, 3-Pole, ground fault protected main circuit breaker. Mount the panelboard on two concrete imbedded stainless steel channel stanchions, minimum 5 feet exposed above grade. Install the panelboard at a location aligned with the corner of the PAR power/electronics equipment shelter where the enclosure-provided disconnect is positioned.

Air Force: See Commercial Power, Uninterruptible Power Supply, and Backup Power, in AF T.O. 31Z-822-2, Chapter 1. See Grounding, Bonding Shielding and Lightning Protection requirements in AF T.O. 31Z-822-2, Chapter 2.

4-5.6.1 Emergency Electrical Power.

Provide a backup power generator, minimum 30 kVA. See Chapter 2 for additional requirements.

4-5.6.2 Grounding and Bonding.

Install four perimeter ground rods with an interconnecting below grade #2/0 Bare Copper ground conductor. Install one of the corner ground rod locations in a round test handhole with H20 traffic rated cover. Place the ground loop 6.5 feet from the edge of the PAR Site concrete pad. Bond the grounding systems for the generator and transformer below grade to the ground loop. Install a 12' x 12' (3.7 m x 3.7 m) copper ground mesh 2 feet below grade between the PAR power/electronics shelter and the PAR Sensor. Install three additional ground rods in a triangular pattern with the tops exposed, bonded to the mesh, the perimeter ground loop, and bonded together above grade. Connect two of the exposed ground rods to the PAR power/electronics shelter and the PAR Sensor. Connect the third exposed ground rod below grade to the electrical panelboard ground bus and a communication termination box ground bus. Configure the placement of the three triangular pattern grounds to allow for installation of an above ground cable tray between the power/electronics shelter and the PAR Sensor.

Install a separate isolated ground rod exposed a minimum of 6 inches (15 cm) above grade at a maximum distance of 1 foot (31 cm) from the edge of the concrete pad to support connection from a lightning protection tower cable.

The ground impedance at all locations of the grounding system must not exceed 10 ohms. Ideal ground impedance is less than 1 ohm.

4-5.6.3 Lighting.

No site lighting is required. Obstruction lighting is provided with the equipment.

4-5.7 Communications.

Provide a minimum 12-strand single-mode fiber optic cable to each system (elevation and azimuth) through underground conduits and handholes.

Air Force: See fiber optic cable and modem requirements in AF T.O. 31Z-822-2, Chapter 4.

4-5.8 Connection/Interrelation to other Facilities.

The PAR system must be connected to the remote monitoring site (usually the Air Traffic Control Tower) with fiber optic cables.

Figure 4-18 PAR Facility Siting Criteria

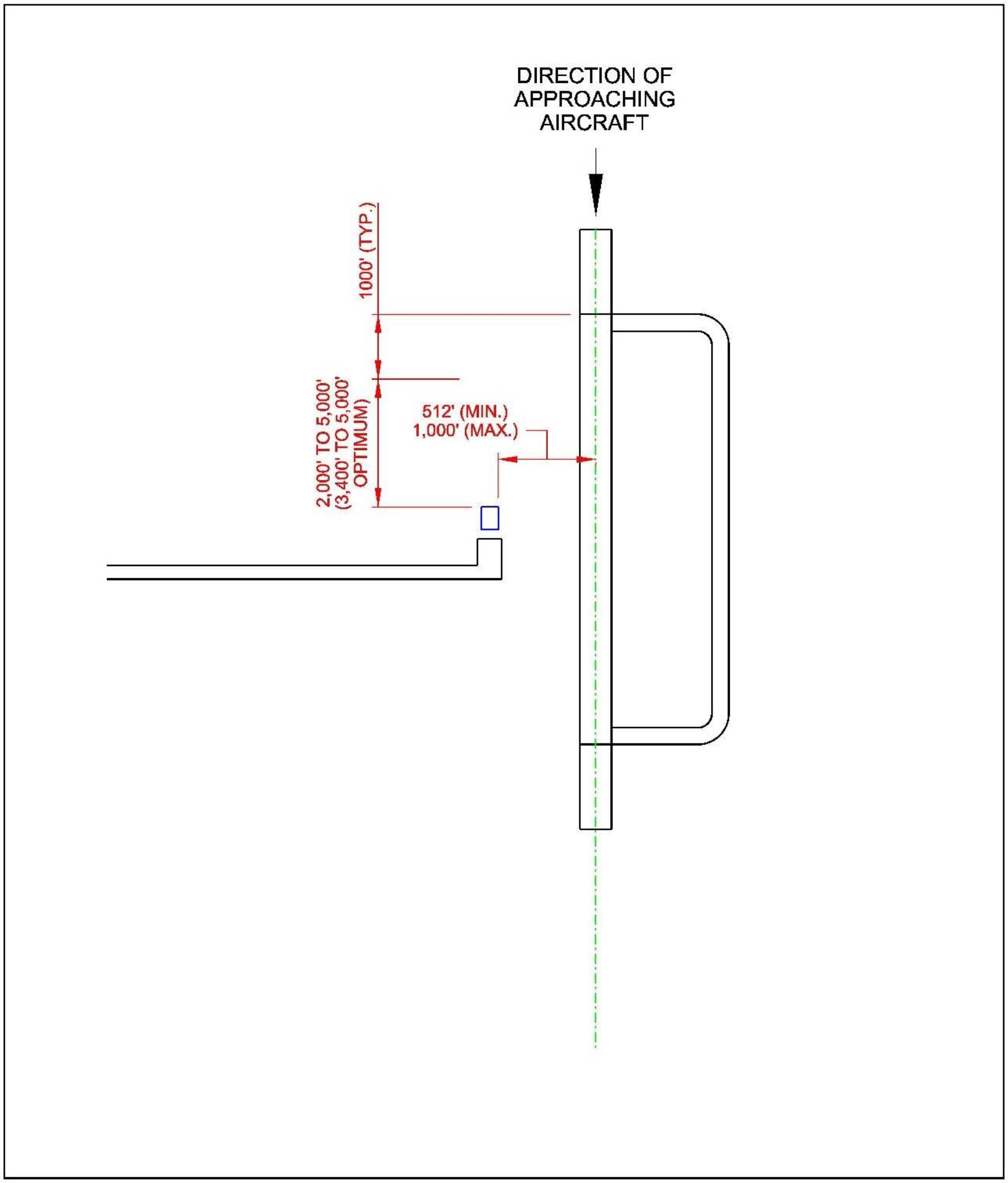


Figure 4-19 PAR Facility Site Plan

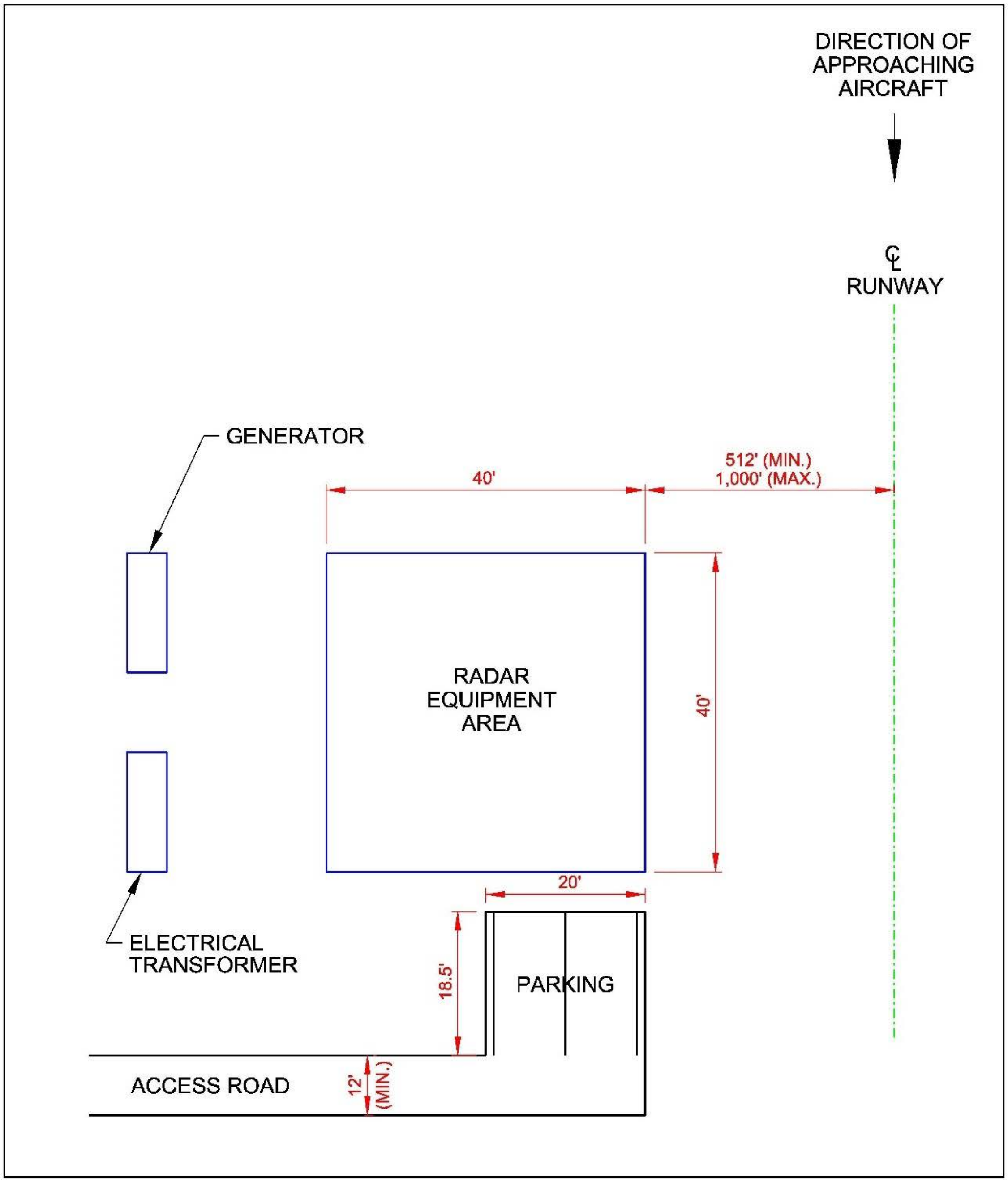


Figure 4-20 PAR Facility: Turntable Mounted Radar Plan and Elevation

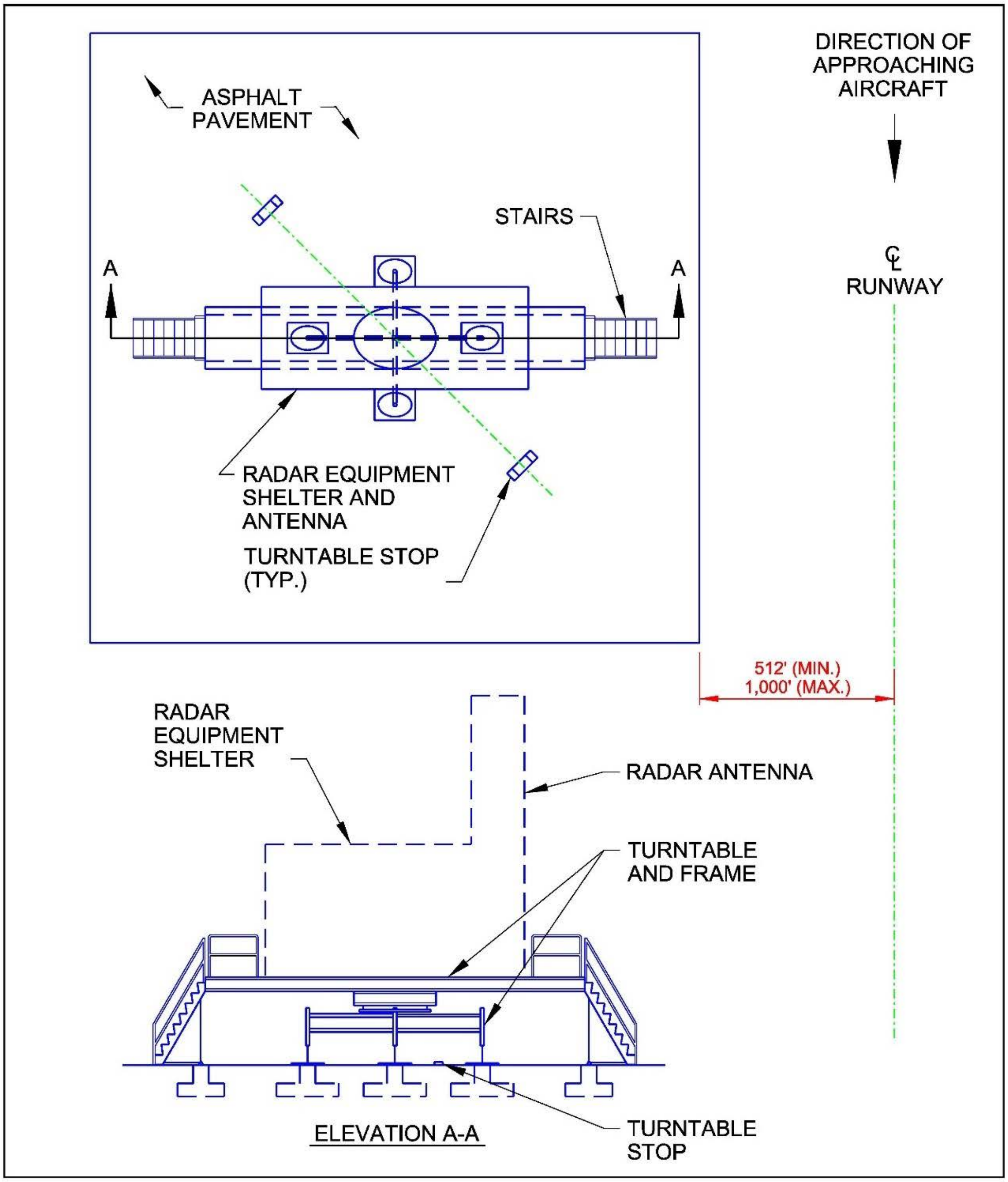
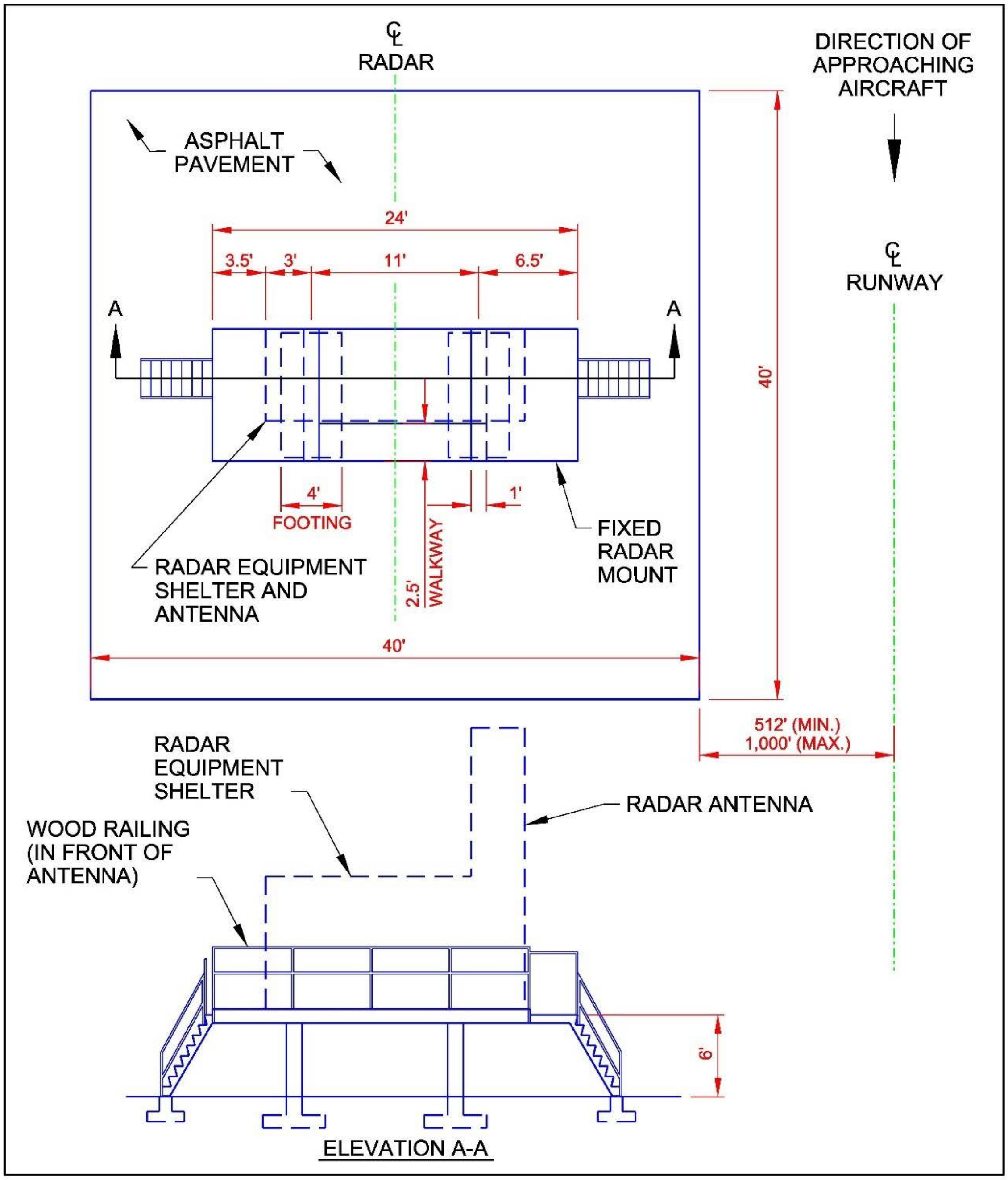


Figure 4-21 PAR Facility: Fixed Mounted Radar Plan and Elevation



CHAPTER 5 AIR SURVEILLANCE RADAR SYSTEMS

5-1 GENERAL INFORMATION.

5-1.1 Function.

Air Surveillance Radar (ASR) facility buildings provide housing for electronic radar equipment used to detect and display location information about in-flight aircraft. These facilities are unattended.

5-1.1.1 Air Surveillance Radar (ASR).

The ASR is an electronic radar system used to obtain the range and azimuth of an aircraft. When equipped with an Air Traffic Control Radar Beacon System (ATCRBS), the ASR obtains altitude and azimuth of an aircraft. When equipped with an ATCRBS, the ASR obtains altitude and identification of the aircraft. Information obtained by the ASR and ATCRBS is displayed in the Military Terminal Radar Approach Control Facility (MTRACON), the air traffic control tower with ground-controlled approach or a Joint Control Facility (JCF). The ASR is used to control aircraft on overflight, approach, and departure flight paths at a terminal facility. Figures 5-1 through 5-3 show a typical ASR.

5-1.1.2 Air Route Surveillance Radar (ARSR).

The ARSR is an electronic radar system used to obtain the range and azimuth of an aircraft. These systems are only owned and operated by the FAA, and therefore are not included in this UFC.

Figure 5-1 Typical Airport Surveillance Radar (ASR) Steel Tower

Figure 5-2 Typical Digital Airport Surveillance Radar (DASR) (Army)

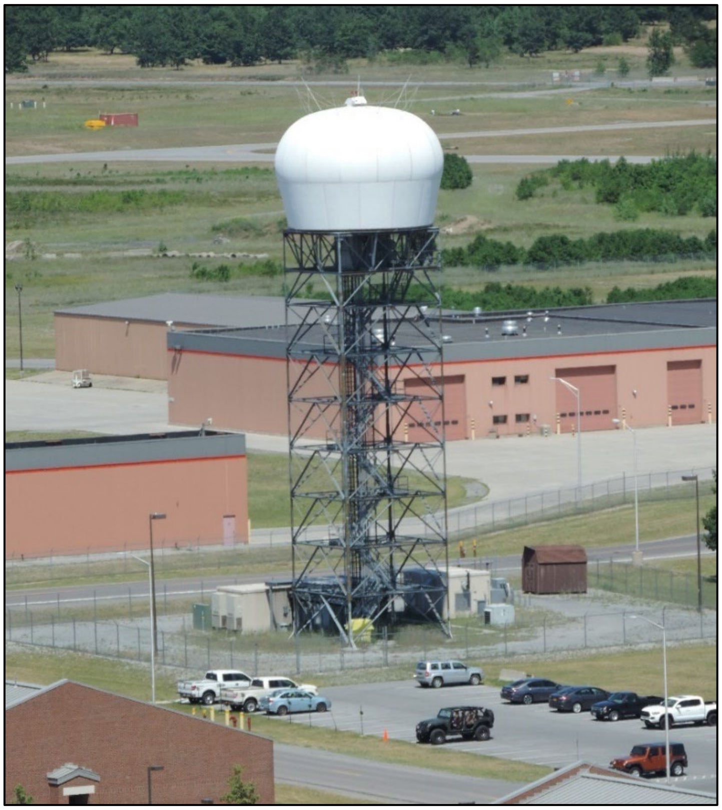


Figure 5-3 Typical DASR without Antenna Cover (Army)

5-2 AIRPORT SURVEILLANCE RADAR (ASR).

5-2.1 Key Documents.

FAA Order 6310.6	*Primary/Secondary Terminal Radar Siting Handbook*
FAA Order 6340.15	*Primary/Secondary En Route Radar Siting Handbook*
AF T.O. 31Z3-822-2	*Air Traffic Control Landing Systems (ATCALS) Site Requirements 404L*

5-2.2 Siting.

Locate the ASR adjacent to the radar facility antenna tower. Locate the ASR facility radar no closer than 0.5 nautical miles from the approach and departure ends of the runway. Do not locate the radar below the approach/departure paths or ground-controlled approach patterns. Care should be exercised in the placement of the ASR in relation to the Air Traffic Control tower as it can create a screening object for the radar. The only limit to the radar's distance from the airfield for ASR approaches is 20 nautical miles as defined in the 8200.1D United States Standard Flight Inspection Manual. This is based upon current radar accuracy to place an aircraft target on a standard runway width. The ASR facility at Range Airspace Surveillance Sites (RASS) may be located further away. Locate the facility to minimize obstruction to radar transmissions. Refer to FAA Order 6310.6 and FAA Order 6340.15. See Figure 5-4 for general siting requirements.

Clearances: Prior to determining final antenna placement, conduct an analysis as part of the site approval process for transmitters of electromagnetic radiation. Electromagnetic Environmental Effects (E3) analysis will determine Hazards to Personnel (HERP), Hazards to Ordinance (HERO), Hazards to Fuel (HERF), and Electromagnetic Interference (EMI).

Produce a Radar Siting Analysis (RSA), using FAA order 6310.6 as a guide, to analyze operational requirements and facilitate final site selection. Radar siting analysis is typically conducted by the Program Office deploying the radar asset in conjunction with the local Air Traffic Control Facilities Officers. ASR antennas may be elevated to obtain line-of-sight clearance. Typical ASRs (antenna platform heights – mezzanine level) range from 17 to 77 feet (5 to 23.5 m) above ground level (AGL). The antenna tower is a standard 24 feet × 24 feet (7 m × 7 m) galvanized steel structure. Additional ten-foot (3 m) sections are usually added incrementally until the radar platform reaches the desired elevation. Trees and other structures must always stay below the mezzanine level. Carefully evaluate the presence of wind turbines in the vicinity of an airport while siting the location of a radar antenna system as such objects do cause reflectivity issues and are the cause of false targets.

5-2.3 Security.

Air surveillance radar facilities are normally located within restricted area which typically meets the minimum security measures for external security. When the facility is located within a restricted area of a lower level of security or is located remote and outside of an established restricted area, provide additional measures to meet the minimum security requirements for the level of security assigned to the facility.

5-2.4 Facility Design Guidance.

See Figures 5-5 and 5-6 for typical ASR site plan and building layout. See service-specific guidance for allowable building size. Typical building size is 1,400 square feet (130 square meters) to house the electronic equipment, monitoring and test equipment, and mechanical equipment.

5-2.4.1 Site Work.

Provide an access road to allow maintenance vehicles access to the ASR. Provide parking space for four maintenance vehicles. See Chapter 2, paragraph “Access and Parking” for roadway and parking area design requirements.

5-2.4.2 Architectural Requirements.

Provide the following:

- Adequate space for equipment and equipment maintenance.
- Clear ceiling height of 10 feet (3 m).
- Work bench.
- Vinyl tile flooring in equipment room.

Do not provide a restroom.

Do not provide windows.

Consider the use of a premanufactured building.

5-2.4.3 Structural Requirements.

Design roof structural system to support cable trays and radar equipment wave guides.

5-2.5 Mechanical Requirements.

Design mechanical systems to meet the general criteria in Chapter 2. Ensure mechanical systems do not interfere with radar transmissions.

Air Force: See Environmental Control Unit requirements (e.g., allowable temperature and humidity ranges) in AF T.O. 31Z3-822-2, Chapter 3.

5-2.5.1.1 Heating.

Provide a minimum temperature of 70 degrees F (21°C).

5-2.5.1.2 Air Conditioning.

Provide two separate air conditioning systems, each capable of handling the entire load independently. One unit functions as a secondary backup unit if the primary unit fails. Provide the following:

- Separate thermostat controls for each unit.
- Interlocked primary and secondary units to prevent simultaneous operation.

5-2.6 Electrical Power.

To avoid potential interference with radar transmissions, install power, communications, and control cables underground within 1,000 ft (305 m) of each facility. Ensure electrical systems do not interfere with radio transmissions.

Provide 120/240V, 100A, single-phase, 60 HZ commercial power service to the ASR.

5-2.6.1 Emergency Electrical Power.

Provide an emergency generator with automatic starting and switching capability as described in Chapter 2. Provide emergency power to the entire radar facility.

5-2.6.2 Uninterrupted Power Supply (UPS).

Provide non-redundant UPS in accordance with Chapter 2. Use the anticipated load to determine the size of the UPS.

5-2.6.3 Lighting.

Reserved.

5-2.7 Communications.

Provide 12-strand single mode fiber optic cable or 25 twisted pair communications line to provide required connectivity for data and telephone.

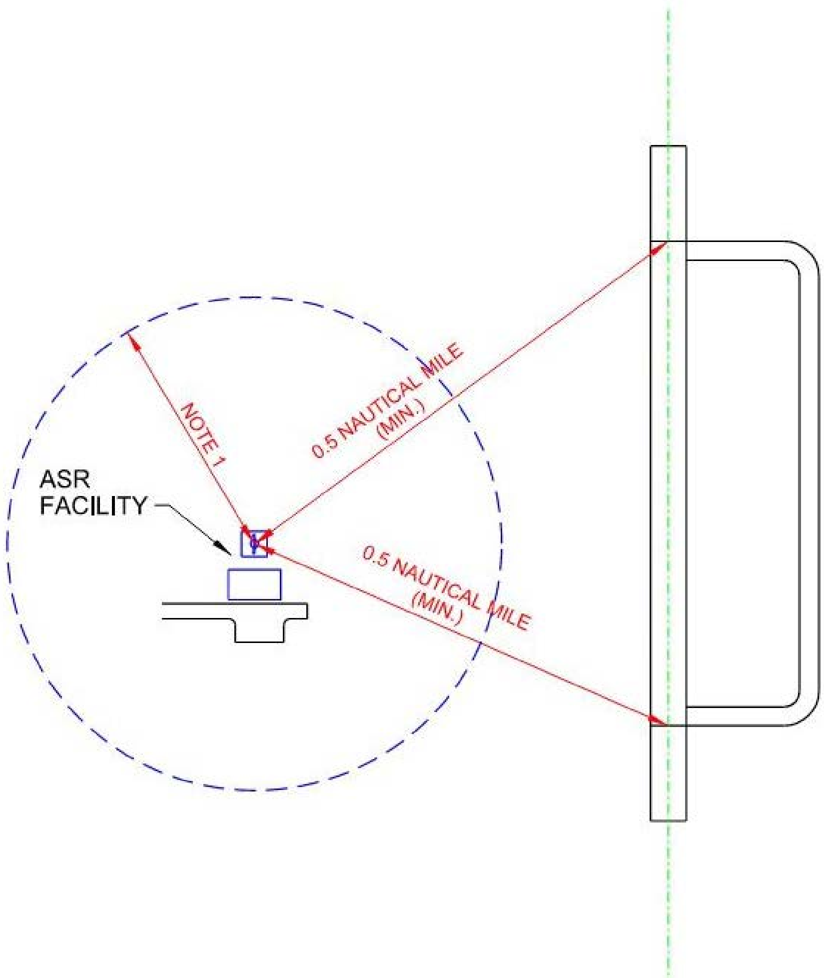
- Data connectivity from the ASR to Remote Unit located in the ATC Tower. (Dedicated pair)
- Data connectivity from the ASR Fire Alarm to external monitoring system. (Dedicated pair)
- Telephone line for distance support to troubleshoot system.

Air Force: See fiber optic cable and modem requirements in AF T.O. 31Z-822-2, Chapter 4.

5-2.8 Connection/Interrelation to other Facilities.

Connect a dedicated DSN-capable telephone connection through to the ASR to facilitate distant support, troubleshooting, and corrective maintenance due to the remote location. Connect the ASR to the ATC Tower via fiber optic cable for remote monitoring.

Figure 5-4 ASR Facility Siting Criteria



NOTE

1.) LOCATE ASR AT LEAST 1,500 FEET FROM ANY BUILDING OR OBJECT THAT MAY CAUSE SIGNAL REFLECTIONS AND 0.5 MILE FROM OTHER ELECTRONIC EQUIPMENT.

Figure 5-5 ASR Site Plan

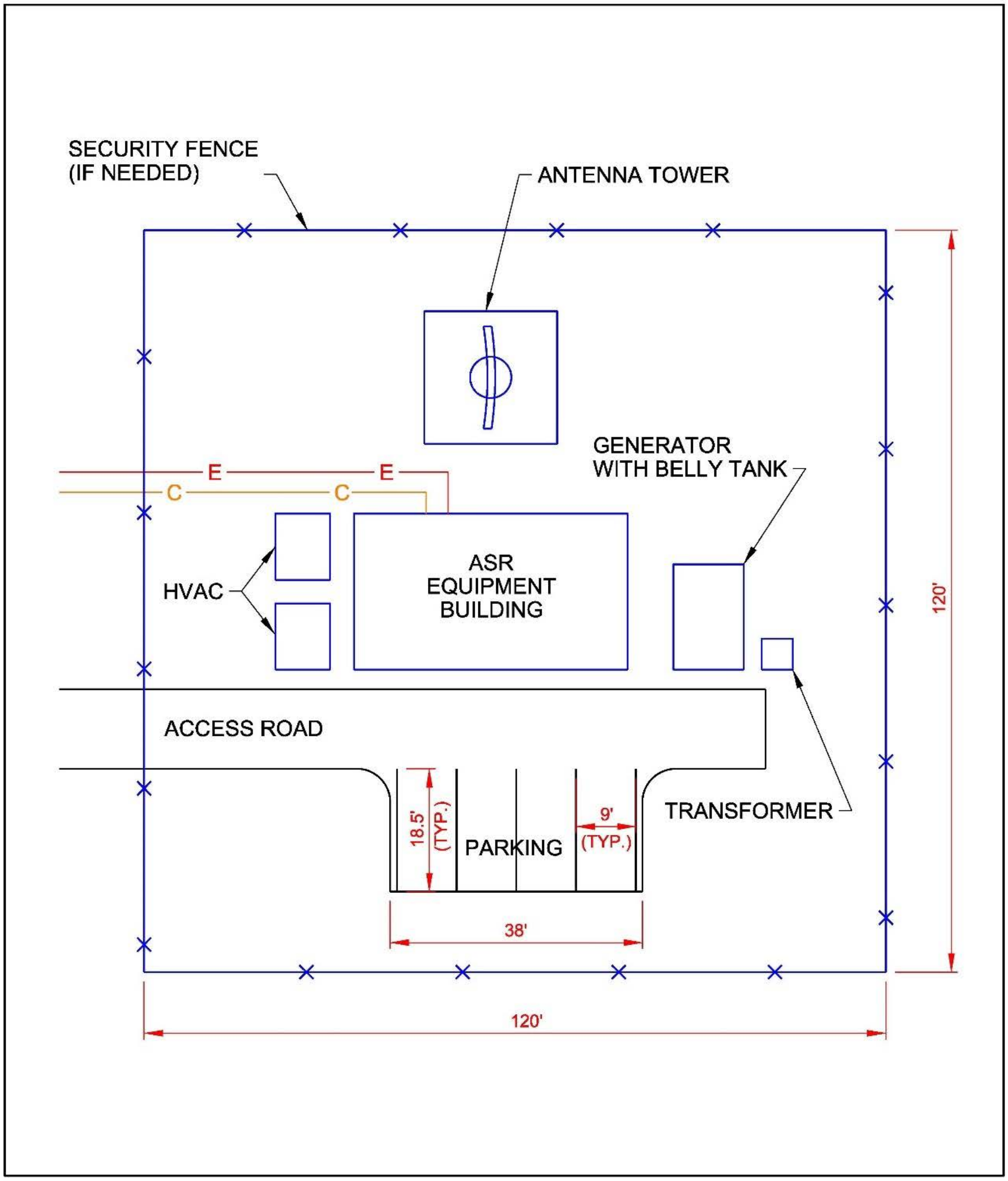
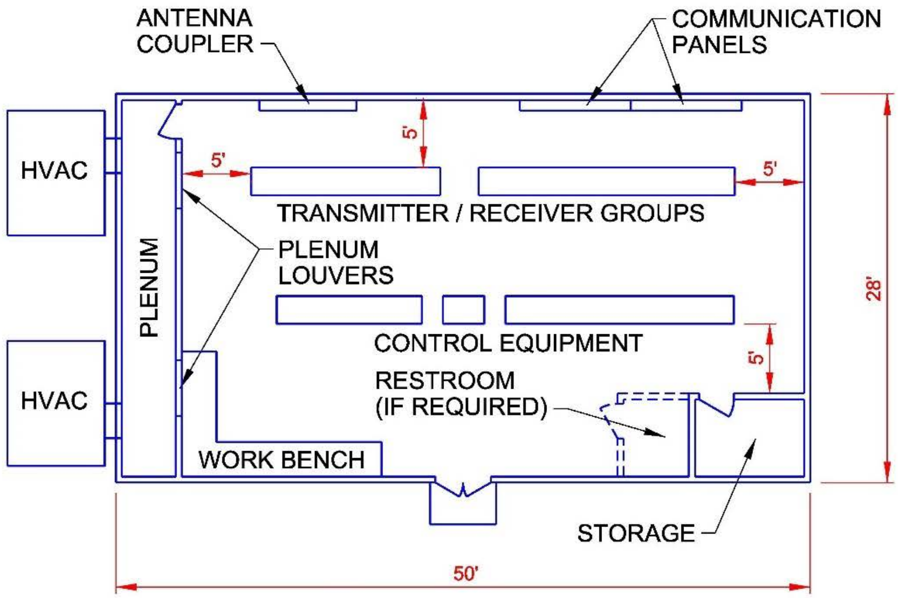


Figure 5-6 ASR Building Layout



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CHAPTER 6 COMMUNICATIONS FACILITIES SUPPORTING AIRFIELDS

6-1 GENERAL INFORMATION.

6-1.1 Function.

Air Traffic Control (ATC) communications facilities provide environmentally controlled spaces that house radio frequency (RF) Transmitter (Tx) and/or Receiver (Rx) equipment used to communicate with aircraft for ATC operations and for regulating all types of aircraft on an airfield.

ATC communications facilities contain remote electronic communications and linking equipment used for ground-to-air (G/A) communications with tactical and transient aircraft, to control aircraft departures and arrivals, and to communicate with other agencies involved in ATC or aviation support.

There are three types of ATC Communications Facilities:

- Transmitter Facilities (Tx)
- Receiver Facilities (Rx)
- Collocated Transmitter/Receiver (Tx/Rx) Facilities

Figure 6-1 Remote Transmitter/Receiver (RTR) Communication Facility

6-1.1.2 Transmitter (Tx) Facility.

The transmitter building contains transmitting equipment, antenna coupling equipment, and maintenance and test equipment.

6-1.1.3 Receiver (Rx) Facility.

The receiver building contains receiver and repeater equipment, antenna coupling equipment, and maintenance and test equipment.

6-1.1.4 Collocated Transmitter and Receiver (Tx/Rx) Facility.

The collocated Rx/Tx facility contains both Rx and Tx equipment, antenna coupling equipment, and maintenance and test equipment.

6-1.1.5 Remote Data Link Building.

The remote data link building provides housing for a suite of communications linking equipment. Equipment suites typically include satellite communications, radio, and television microwave.

6-1.1.6 Continuity of Operations.

6-1.1.6.1 Coordination

Normal air traffic control (ATC) operations may be affected by construction, renovation, and/or repair of the ATC communications facility. Give careful consideration to the operational impact of a proposed facility design/specification; the goal is to minimize these impacts. Coordinate any design that results in construction that has the potential to affect safety of flight (SOF) with the Airfield Manager. Coordinate any construction that affects structures currently housing electronic equipment required to support air operations through each Service’s subject matter expert.

6-1.1.6.2 Temporary Facilities

If existing facility demolition or repair efforts are required prior to construction of the new ATC communications facility, demolition/repair efforts must not start until all communications functions have been fully transferred to a temporary facility and the temporary facility has been certified fully operational by the Air Traffic Control function. This stipulation is vital to maintaining ATC operations and SOF.

6-2 ATC COMMUNICATIONS FACILITY.

Whether constructing a Tx, Rx or collocated Tx/Rx facility, the components and requirements are the same, with the exception of the space required for a collocated facility. Collocated facilities require more space inside the building to house additional radio equipment and may require more parking space outside the facility.

6-2.1 Key Documents.

UFC 3-260-01	*Airfield and Heliport Planning and Design*
UFC 3-301-01	*Structural Engineering*
UFC 3-600-01	*Fire Protection Engineering for Facilities*
UFC 4-133-01	*Air Traffic Control and Air Operations Facilities*
NAVAIR 01-1A-23	*Standard Maintenance Practices Miniature/Microminiature (2M) Electronic Assembly Repair*
NAVSEA OP 3565, Vol. 2	*Electromagnetic Radiation Hazards*
N65236-ATCF-FRD-0003 v2.0	*NIWC - Air Traffic Control Remote Communications Facility – Facility Requirements Document*
NAVFACINST 11010.45A	*Site Approval Request Process*
FAA Order 6580.2	*Remote Communications Facility Siting Criteria Handbook*
FAA Order 6580.3B	*Remote Communications Facilities Installation Standards Handbook* (not accessible outside FAA)
FAA Order 6580.6A	*Remote Communications Facilities Siting Process* (not accessible outside FAA)
FAA-STD-019f	*FAA Standard, Lightning and Surge Protection, Grounding, Bonding and Shielding Requirements for Facilities*
AF T.O. 31Z3-822-2	*Air Traffic Control Landing Systems (ATCALS) Site Requirements 404L*

6-2.2 Siting.

Locate radio communications buildings within the antenna field to provide minimum length of cable from antenna to radio communications equipment. Refer to the Base Master Plan and consider planned expansion of airfield systems when locating communications facilities. See FAA Order 6580.2 for additional details. Figure 6-2 illustrates general siting requirements.

6-2.2.1 Site Selection.

a. Use a coordinated effort between Air Operations, Air Traffic Control, and the service-specific engineering and equipment maintenance organizations to select potential facility sites. Site selection must consider the requirements listed in this document, UFC 3-260-01, and current service-specific publications.

b. Select construction sites to account for an antenna field next to or surrounding the ATC communications facility. The facility's antenna field typically has up to 10 antenna towers, with six to eight antennas on each tower. A minimum separation of 80 feet (24 m) is required between antenna towers; a separation of 120 feet (37 m) is preferred. See Figure 6-3 for a typical ATC communications facility site plan. See Figure 6-5 for a typical antenna tower. Towers can be a maximum of 350 feet (107 m) from the ATC communications facility.

c. The size (diameter) of the RF cable is dependent on the total length of the cable path from the antennas to the radios. Determine the exact RF cable diameter during design. Note: The diameter of RF cable can be as large as 1-5/8". Typically, 7/8" (22 mm) cable is used for exterior runs exceeding 100 ft (30 m).

d. Antennas mounted on towers require an unobstructed Line of Sight (LOS) to all runways, taxiways, ramps, and parking aprons. The service-specific electronics maintenance office (e.g., NIWC Atlantic) is required to perform an RF coverage/propagation analysis to select the optimal site locations to ensure the locations and tower heights provide operational coverage for ATC communications.

6-2.2.2 Radiation Hazards

Hazards of Electromagnetic Radiation to Personnel (HERP), Ordnance (HERO), and Fuel (HERF) surveys are crucial to the siting process. Contact service-specific offices to conduct these surveys (e.g., NIWC Atlantic, NSWC Dahlgren Division, etc.) NIWC Atlantic and the facility Air Operations Department can assist with information concerning the electronic equipment to be installed in the facility to support ATC operations. Radiating RF antennas are installed on the antenna towers; therefore, a radiation hazard (RADHAZ) study to support the antenna installation must be conducted during the siting process. Facility siting criteria must consider the radiating fields of existing antennas supporting ATC operations, such as the Airport Surveillance Radar

(ASR). NAVSEA OP 3565, Vol. 2 provides detailed information concerning HERP, HERO, and HERF.

6-2.2.3 Site Approval.

Navy: Final site approval must comply with current NAVFACINST 11010.45A requirements.

6-2.3 Security.

Communications facilities are normally located within restricted areas which would typically meet the minimum security measures for external security. When the facility is located within a restricted area of a lower level of security or is located remote and outside of an established restricted area, provide additional measures to meet the minimum security requirements for the level of security assigned to the facility.

6-2.3.1 Fencing

Chain link fences are required around the facility and antenna tower field. Provide fences 8 ft. high and include three strands of barbed wire at the top. Ground all fences in accordance with FAA STD-19f. Provide one motorized or manual vehicle gate and one personnel gate. Determine the exact locations of these items during the design process.

Note: A minimum distance of 30 ft (9 m). is required between the communications building and the fence on all sides.

6-2.4 Facility Design Guidance.

6-2.4.1 General.

6-2.4.1.1 This section is divided into engineering disciplines associated with the design effort in order to consolidate requirements and simplify distribution. Designers for each discipline must consult with each other to verify that design conflicts do not exist and that all aspects of the design support a suitable final product.

6-2.4.1.2 Tx and Rx buildings are composed of interlaced engineered systems. The design of the facility does not lend itself to late involvement by engineering disciplines (e.g., mechanical and electrical). All engineering disciplines must be actively involved during floor plan inception. At the 35% design submittal, develop all engineered facility systems that affect ATC communications equipment to a level such that the minimum required square footages identified in the FRS are assured.

6-2.4.1.3 Contact Service-specific agencies (e.g., NIWC Atlantic) to obtain drawings of the electronic equipment cabinet layout during the design process. See Figure 6-3 for a typical layout of facility equipment.

6-2.4.1.4 Paragraphs in this section identify requirements to support electronic equipment or construction recommendations for general use. Specific details of some requirements identified in this section must be obtained from the facility Air Operations Department. These paragraphs serve as reminders to ensure requirements are not overlooked. Consider the following design details:

a. Provide water and sanitation at unmanned facilities where sanitation is not available in the vicinity.
b. Place ATC electronic equipment in a dedicated space not shared with mechanical rooms or administrative offices.
c. Clean and seal all unfinished concrete floors, to include concrete sub floors under raised access flooring.
d. Provide any mechanical, electrical, or other facility systems in the electronic equipment space(s) in direct support of ATC communications equipment and strictly abide by working clearance definitions in the latest NEC.
e. Determine the exact locations of ATC communications equipment with input by the service-specific agencies that operate the facility (e.g., NIWC Atlantic and the Air Operations Department) as the initial design plan is developed. Note that depending upon the airfield's ATC requirements, the amount of equipment installed may vary. However, all facilities must adhere to the service-specific agency's clearance, installation, physical security, and location requirements for ATC communications equipment, which are based on the type of equipment to be installed, regulatory codes, and Service policies.
f. Do not include windows in ATC communications equipment spaces.
g. If electronic component repair involving soldering will be performed in the ATC communications facility, a designated work area is required. Navy: This work area must meet the requirements of NAVAIR 01-1A-23.

6-2.4.1.5 Due to the increased use of electronic systems procured jointly by the FAA and Department of Defense (DOD), the facility grounding system must be designed and installed in accordance with FAA standards (FAA-STD-019f).

6-2.4.2 Site Work.

Provide an access road to allow maintenance vehicles access to the ATC Communications Facility. Provide parking space for two maintenance vehicles. See Chapter 2, paragraph "Access and Parking" for roadway and parking area design requirements.

6-2.4.2.1 Sidewalks/Ramp

Provide an 8 ft (2.4 m). wide sidewalk/ramp from the main facility driveway to the main facility entrance. Provide a sidewalk that can support the weight of a small truck. If the finished floor is above grade, a small loading dock and a ramp from the sidewalk to the main entrance are required. If the finished floor is at grade, a loading dock and ramp are not required.

6-2.4.3 Architectural Requirements.

Provide the following:

- Adequate space for equipment and equipment maintenance.
- Clear ceiling height of 10 feet (3 m).
- Work bench.
- Provide water and sanitation at unmanned facilities where sanitation is not available in the vicinity.
- Raised access floor or suspended cable trays.

Do not provide windows.

See NIWC – ATC Remote Communications Facility – FRD for more specific requirements.

6-2.4.3.1 Critical Dimensions.

Provide a facility with an equipment room with minimum interior dimensions of 36 ft x 22 ft (11 m x 6.7 m)

6-2.4.3.2 Equipment and Personnel Space Requirements.

The ATC communications facility must include space for the following:

a. Equipment
b. Lavatory (only if sanitation facilities not available in the vicinity).
c. Electrical (including uninterruptible power supply)
d. Mechanical
e. Emergency generator (E/G) space (can be outside on pad)
f. Data Communications Frame Area/Main Distribution Frame (MDF)
g. Antenna Towers

6-2.4.3.3 Access Flooring.

An 18 in (450 mm) raised access floor system is required in ATC communications equipment spaces in lieu of floor trenches. See NIWC – ATC Remote Communications Facility – FRD for more specific requirements.

6-2.4.4 Structural Requirements.

Design and install foundations for each ATC communications facility antenna tower. Follow structural design requirements of UFC 3-301-01. Foundation design is dependent upon antenna tower height and soil conditions.

6-2.4.5 Pre-manufactured Buildings.

Consider using a pre-manufactured building as described in Chapter 2.

6-2.5 Mechanical Design Requirements.

a. Refer to UFC 4-133-01 for general and specific mechanical design requirements for ATC-related facilities. See also NIWC – ATC Remote Communications Facility – FRD for more specific requirements.

b. A chiller, boiler, and four-pipe distribution system with separate air handlers for each zone is not required if suitable Direct Expansion (DX) units can be used.

c. Do not use HVAC systems specifically designed for use with raised floors in facilities without raised floors.

6-2.5.1 Fire Protection Requirements.

Design and install fire protection and alarm systems in accordance UFC 3-600-01.

6-2.6 Electrical Requirements.

To avoid potential interferences with radar communications, locate power, communications, and control cables underground within 1,000 feet (305 m) of the antenna site. Ensure facility electrical systems do not interfere with radio communications.

Provide 120/208V, 100A, three-phase, 60 HZ commercial power service for the ATC Communcations Facility with a minimum 30-circuit power panel.

All electrical power provided to the facility requires backup by an emergency generator. Power must be supplied on a split-bus system, which is herein denoted as “critical” and “non-critical.”

See NIWC – ATC Remote Communications Facility – FRD for more specific requirements.

6-2.6.1 National Electrical Code Compliance.

Provide ATC communications facility electrical grounding that comply with the requirements outlined in NEC Article 250, and FAA-STD-019f. Specifically, provide the ATC communications facility with grounding electrode systems and safety grounding systems in accordance with the NEC plus lightning protection, signal reference systems, and multipoint grounding systems. Be aware that FAA requirements exceed those of the NEC.

6-2.6.2 Emergency Electrical Power.

Provide an emergency generator with automatic starting and switching capability as described in Chapter 2. Provide emergency power to the entire communications facility.

a. A minimum of 24 hours of emergency backup power is required for the ATC communications facility. Obtain ATC equipment loads from the service-specific agency that operates the facility. To ensure equipment operation during extended power outages, HVAC systems serving electronic equipment spaces must be supported by emergency generator (E/G) power. Consult with the facility users for E/G fuel storage capacity requirements above 24 hours.

b. Provide remote electronic monitoring and control of the E/G. Provide electronic control with the capability to monitor power status and fuel level as well as starting and stopping the generator. Coordinate the location of the remote monitoring equipment with the facility users.

6-2.6.3 Uninterruptible Power Supply.

a. A Facility UPS is required for the ATC communications facility.

b. The Facility UPS must be sized to provide the critical loads with power (plus a 25% spare capacity) for a minimum of 30 minutes to allow the emergency generator (E/G) to start, stabilize, and assume the load. See NIWC – ATC Remote Communications Facility – FRD for more specific requirements.

6-2.6.4 Facility Lightning Protection.

a. Design the lightning protection system to meet FAA-STD-019f requirements.

b. Take care to ensure lightning down-conductors do not run within the building structure, take the shortest route possible, and are properly terminated to an earth ground.

c. As specified in FAA-STD-019f, all lightning protection down-conductors must be connected to the EES via exothermic welds, including the connection of any down-conductors to the ground rod in the access well.

d. In accordance with the NEC, protect signal cables entering the ATC communications facility against lightning-induced transient voltage at the building entrance.

e. Air terminals on the facility roof are required to provide a zone of protection for any miscellaneous antennas mounted on the roof, such as the fire alarm antenna.

6-2.6.5 Grounding and Bonding.

In the design of the grounding and bonding system unless otherwise noted, FAA-STD-019f takes precedence. See NIWC – ATC Remote Communications Facility – FRD for more specific requirements.

6-2.6.6 Lighting.

LED lighting must meet the requirements of CFR 47, Part 15 (B), but is preferred and acceptable. Fluorescent lighting requires radio frequency interference (RFI) suppression ballasts. See NIWC – ATC Remote Communications Facility – FRD for more specific requirements.

6-2.7 Communications.

Provide 12-strand single mode fiber optic cable or 25 twisted pair communications line to provide required connectivity for data and telephone.

- Data connectivity from the Communications Facility to the Remote Unit located in the ATC Tower. (Dedicated pair)
- Data connectivity from the Communications Facility Shelter Fire Alarm to external monitoring system. (Dedicated pair)
- Telephone line for distance support to troubleshoot system.

Air Force: See fiber optic cable and modem requirements in AF T.O. 31Z-822-2, Chapter 4.

6-2.8 Safety Considerations.

6-2.8.1 Eyewash Station.

Provide an Occupational Safety and Health Administration (OSHA)-approved eyewash station in each equipment space.

6-2.8.2 Fire Extinguisher.

Provide at least one OSHA-approved fire extinguisher in the ATC communications facility.

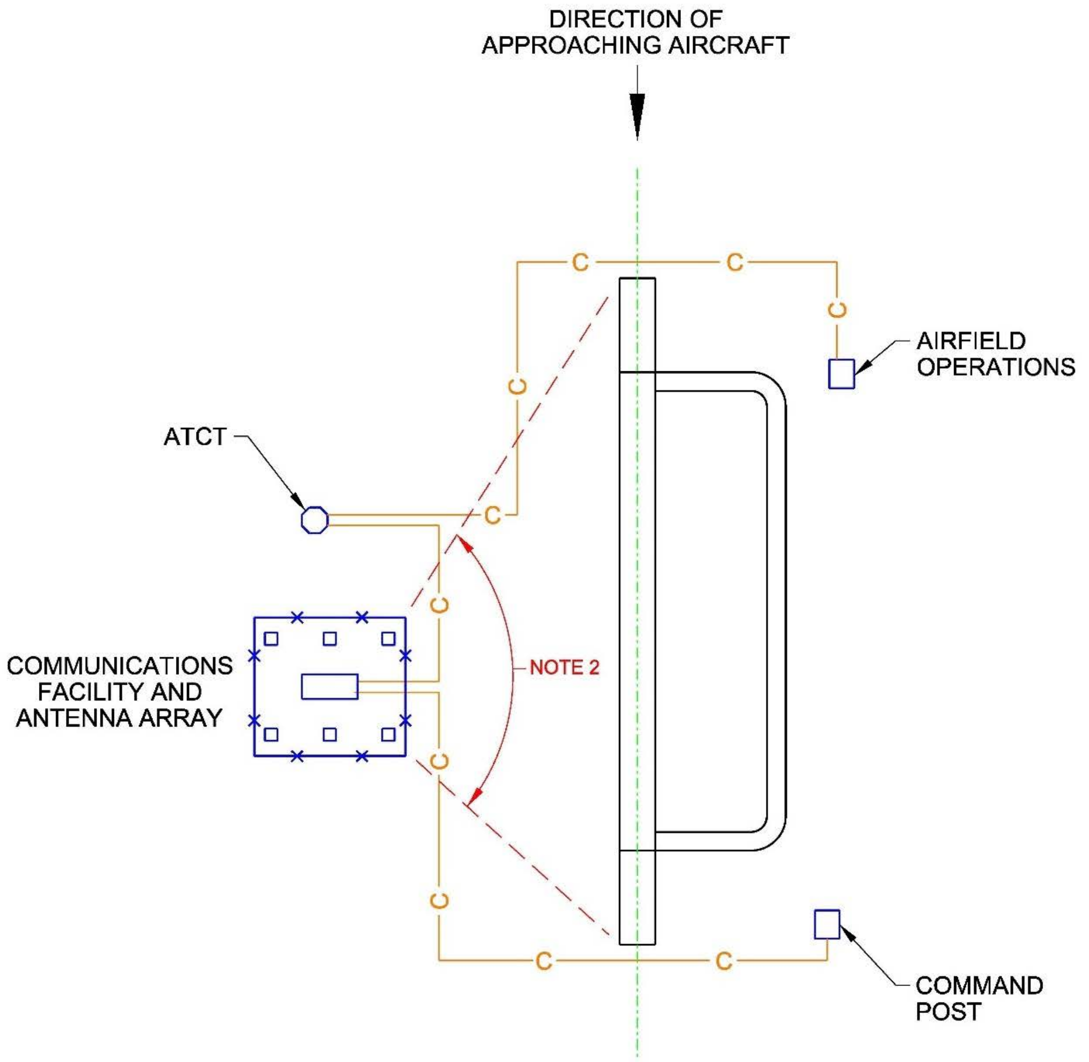
6-2.8.3 First Aid Kits and Safety Gear.

The facility GEMD/ATCMD is responsible for providing any first aid kits and safety gear required for the ATC communications facility.

6-2.9 Connection/Interrelation to other Facilities.

Connect a dedicated DSN-capable telephone connection through to the proposed Communications Facility to facilitate distant support, troubleshooting, and corrective maintenance due to the remote location. Connect the Communications Facility to the ATC Tower via fiber optic cable for remote monitoring.

Figure 6-2 Typical ATC Communications Facility Siting Criteria



GENERAL SITING REQUIREMENTS

1.) COORDINATE SITE WITH BASE MASTER PLAN AND CONSIDER PLANNED EXPANSION OF AIRFIELD SYSTEMS.

2.) ANTENNAS ON TOWER REQUIRE UNOBSTRUCTED LINE OF SIGHT TO ALL RUNWAYS, TAXIWAYS, RAMPS AND PARKING APRONS.

Figure 6-3 Typical Communications Facility Site Plan

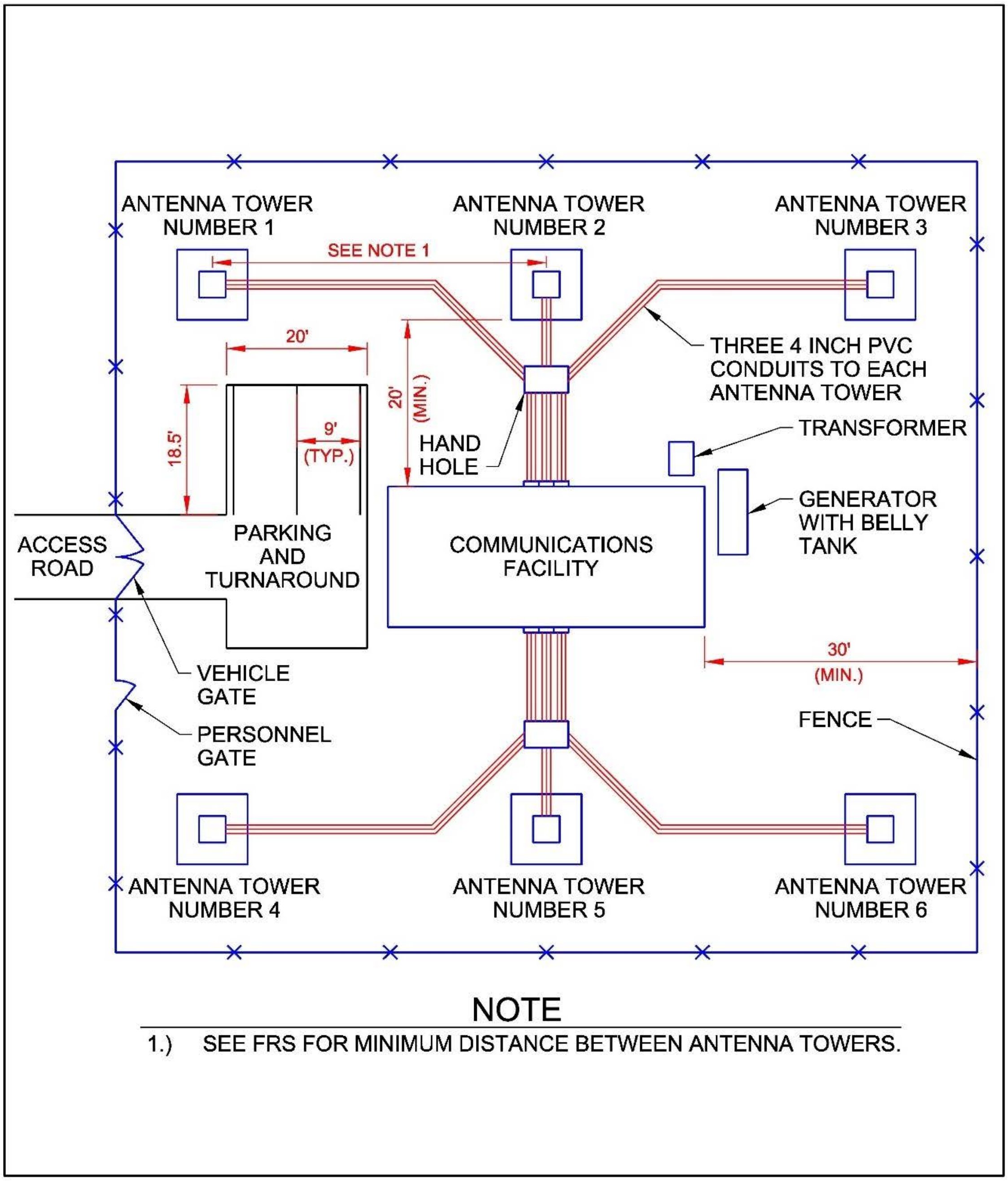


Figure 6-4 Typical Communications Equipment Building Layout

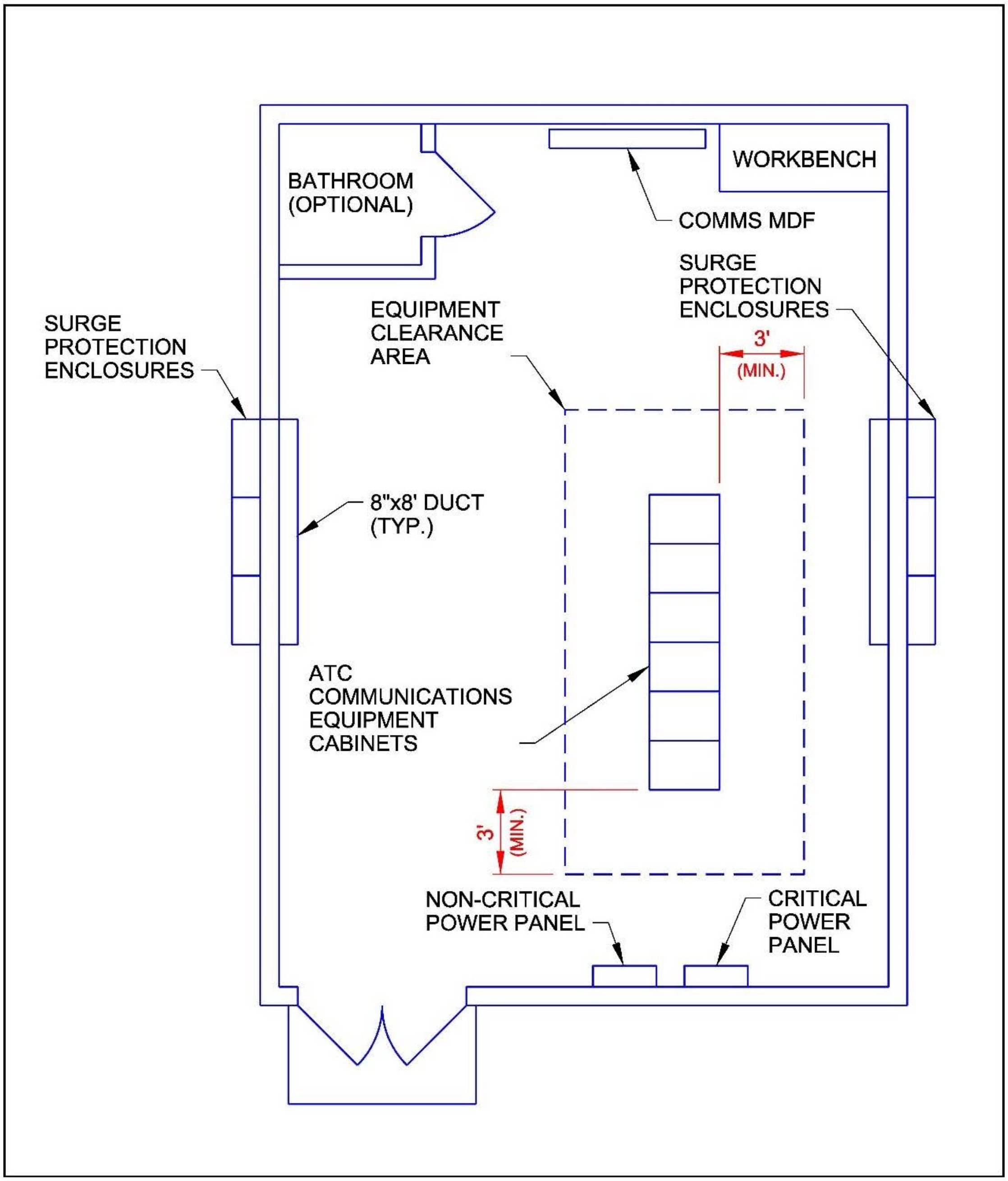
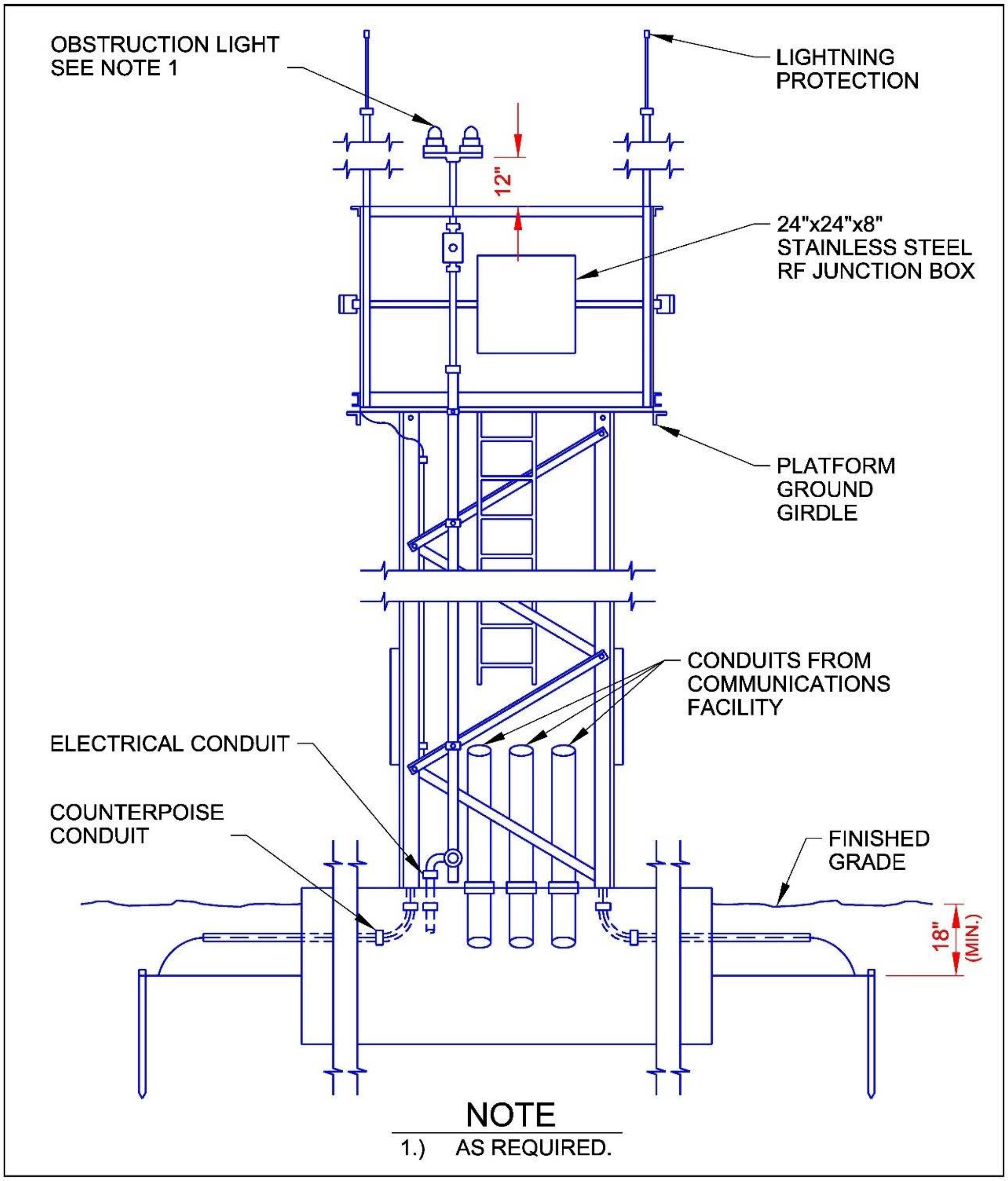


Figure 6-5 Typical Communications Antenna Tower



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CHAPTER 7 WEATHER EQUIPMENT SUPPORTING AIRFIELDS

7-1 GENERAL INFORMATION.

7-1.1 Function.

The office where weather is recorded, analyzed and forecasted goes by different names within the Services and within different organizational structures. The equipment used to collect weather information on airfields are more common among the Services.

7-1.1.1 Weather Office.

The Weather Office is most often located within a building, adjacent to Airfield Management or Air Operations. In some cases, the Weather Office may even be located at another installation. For those reasons, no facility requirements for a Weather Office are included in this UFC.

7-1.1.2 Automated Surface Observing System (ASOS) and Fixed Base Weather Observing System (FBWOS).

A permanently installed automated ASOS or FBWOS (e.g., AN/FMQ-19, AN/FMQ-22, AN/FMQ-23) consists of a suite of weather sensors and processors capable of collecting, measuring or calculating and reporting a myriad of weather elements. These elements include, but are not limited to, wind direction and speed, prevailing visibility, present weather and visibility obstructions, cloud coverage and cloud base height, temperature, dew point, atmospheric pressure, lightning, and precipitation amounts. The observing system's primary sensor suite contains the majority of the sensors. Many locations also have additional discontinuity sensor suites. The discontinuity suite contains fewer sensors than the primary suite and is sited at the runway's roll out, midfield, or in the case of a multi-runway configuration, at an adjacent site along a parallel or intersecting runway to provide critical weather element readings that are representative of the respective location.

ASOS or FBWOS are automated stations operated and controlled by the DoD, National Weather Service, and FAA. They help the national weather system compile data on the entire United States and OCONUS sites, and not just for aviation purposes. ASOS reports are issued hourly with special reports issued more frequently when conditions change rapidly. The system went into operation in the early 1990s.

AWOS are automated stations generally operated and controlled by the FAA for aviation purposes. New reports are generated and transmitted every minute. The AWOS was the original aviation weather reporting system and AWOS stations are located solely at airports.

7-1.2 Certification and Commissioning.

To provide confidence in the quality of the meteorological data that the ASOS and FBWOS provides to users in the aviation community, the FAA has initiated a three-part

ASOS and FBWOS quality assurance process consisting of type certification, site-specific commissioning and annual revalidation.

For ASOS and FBWOS installed on military bases, follow the certification, commissioning and annual revalidation process described in FAA AC 150/5220-16, Chapter 2.

Figure 7-1 ASOS Combined Sensor Group (CSG)

7-2 AUTOMATED SURFACE OBSERVING SYSTEM (ASOS) OR FIXED BASE WEATHER OBSERVING SYSTEM (FBWOS).

The ASOS or FBWOS is a modular system consisting of two general components at two separate locations.

The sensor group (Combined Sensor Group (CSG) and discontinuity sensor groups for ASOS or primary and discontinuity sensor groups for FBWOS) is located near the runway and collects a variety of weather sensors. The ASOS Data Collection Package (DCP) or FBWOS Field Data Collection Unit (FDCU) in the sensor group then formats and transmits the data to the ASOS Acquisition Control Unit (ACU) or FBWOS Terminal Data Acquisition Unit (TDAU).

The ACU or TDAU is typically located in close proximity to the Air Traffic Control equipment (e.g., ATCT equipment room). The ACU or TDAU receives data from the sensor group (via radio frequency modem link or via a direct line link) and performs the algorithmic functions to produce weather products. The weather data is provided via local displays, remote dial-in, voice phone, and one way transport via modem to an Advanced Weather Interactive Processing System (AWIPS) hub. Then the weather data is transported to the NWS gateway.

Potential sensors included in an ASOS or FBWOS are listed below.

- Surface Wind Speed and Direction
- Ambient Air Temperature
- Dew Point Temperature
- Atmospheric Pressure
- Visibility
- Sky Condition
- Precipitation Type Discrimination (rain, snow, drizzle, etc.)
- Precipitation Occurrence (Yes/No)
- Freezing precipitation detection
- Precipitation Accumulation
- Lightning detection

7-2.1 Key Documents.

UFC 3-260-01	*Airfield and Heliport Planning and Design*
FCM-S4-2019	*Federal Standard for Siting Meteorological Sensors at Airports, Office of the Federal Coordinator for Meteorological Services and Supporting Research*
FAA AC 70/7460-1M	*Obstruction Marking and Lighting*
FAA AC 150/5220-16	*Automated Weather Observing Systems (AWOS) for Non-Federal Applications*
FAA Order JO 6560.20C	*Siting Criteria for Automated Weather Observing Systems (AWOS)*
FAA-STD-019f	*Lightning and Surge Protection, Grounding, Bonding and Shielding Requirements for Facilities and Electronic Equipment*

7-2.2 Siting.

Site ASOS or FBWOS equipment on DoD airfields and heliports using the guidance included in FCM-S4-2019. Special care is necessary in selecting appropriate locations for installation of sensors to assure that the resultant observations are representative of the meteorological conditions affecting aviation operations. When applying these criteria, consider future plans for the airport that could impact placement of sensors, e.g., installation of an Instrument Landing System (ILS), Microwave Landing System (MLS), runway construction, etc.

Figure 7-2 illustrates the typical position of weather sensors relative to the runway. Figure 7-3 illustrates the typical position of weather sensors relative to the Glide Slope antenna and shelter. Figure 7-4 shows one arrangement for multiple items in a Combined Sensors Group.

<u>Navy</u>: Site ASOS equipment on DoD airfields and heliports using the guidance included in FCM-S4-2019.

- For airports with only Visual or Non-Precision Runways, site the ASOS minimum 500 feet (152 m) and maximum 1,000 feet (305 m) from the centerline of the runway.
- For airports with Precision Instrument Runways without RVR instrumentation, there are two options for siting from centerline: a) minimum 750 feet (229 m) and maximum 1,000 feet (305 m); or b) locate the ASOS behind the Glide Slope shelter or MLS elevation station.
- For airports with Precision Instrument Runways with RVR instrumentation, site the ASOS minimum 400 feet (122 m) from the centerline of the runway and in accordance with FCM-S4-2019.
- For all runways, site the ASOS longitudinally as close as possible to the touchdown point (between 1,000 and 3,000 feet (305 and 914 m) from the runway threshold).

<u>Army and Air Force</u>: Align the FBWOS primary and discontinuity sensor groups parallel to the runway and not less than 300 feet (91 m) (Class A/Rotary-Wing Runways) or 400 feet (122 m) (Class B Runways) from centerline of the runway, as close as possible to the touchdown point (between 1,000 and 3,000 feet (305 and 914 m) from the runway threshold). For siting criteria of a FBWOS near taxiways and parking aprons on airfields and heliports, use Tables 5-1, 5- 2, and 6-1 of UFC 3-260-01 to provide appropriate clearances between aircraft and the weather equipment. Selecting appropriate locations to install sensor groups is a critical consideration for flight operations safety as well as to ensure the weather elements collected are representative of the meteorological conditions affecting flight operations.

See FCM-S4-2019 for clearance and mounting height requirements for individual sensors in the sensor group.

7-2.3 Security.

ASOS and FBWOS facilities are normally located within the airfield restricted area. This siting typically meets the minimum security measures for external security. When the facility is located within a restricted area of a lower level of security or is located remote and outside of an established restricted area, provide additional measures to meet the minimum security requirements for the level of security assigned to the facility.

7-2.4 Facility Design Guidance.

7-2.4.1 Site Work.

Provide an access road to allow maintenance vehicles access to the sensor group(s) on the airfield. Provide parking space for one maintenance vehicle. See Chapter 2, paragraph “Access and Parking” for roadway and parking area design requirements.

7-2.4.2 Architectural Requirements.

There are no architectural requirements for the ASOS or FBWOS equipment.

7-2.4.3 Structural Requirements.

The wind sensor tower is mounted on a concrete foundation and may vary in dimension depending on type of system suite. Other sensors are mounted on metal posts set into the 12” diameter concrete foundations minimum 24” into the ground (or extending below frost line) with gravel around the posts. Install the top surface of these concrete foundations flush with the surrounding surface grade. See Figure 7-5 and 7-6 for typical concrete foundations for a ASOS CSG. Site adapt the minimum size and depth for local environmental conditions and soils.

7-2.5 Mechanical Requirements.

There are no mechanical facility requirements for the ASOS or FBWOS.

7-2.6 Electrical Power.

Provide 120V, 30A, single-phase, 60 Hz commercial power service to the sensor group. Provide 120V, 20A single-phase, 60Hz commercial power service to the ACU or TDAU.

7-2.6.1 Emergency Electrical Power.

The ASOS system is designed to return to normal operation without human intervention after a power outage. The system is equipped with UPS battery back up to allow for orderly shutdown of the system in the event of source power loss. When power is restored, the system automatically returns to service and begins outputting sensor data only after internal sensor diagnostics allow data to pass, preventing dissemination of erroneous data.

7-2.6.2 Lighting.

If a separate tower is used for the wind sensor, provide daytime marking and nighttime lighting in accordance with the guidelines set forth in the latest edition of FAA AC 70/7460-1.

7-2.6.3 Lightning Protection, Grounding and Bonding.

Install lightning protection systems in accordance with FAA-STD-019f.

7-2.7 Communications.

Provide 12-strand single mode fiber optic cable, 25 twisted pair communications line or RF antenna signal between the DCP and ACU or FDCU and TDAU. Provide required data connectivity (fiber optic preferred) to receiving units located in the ATC Tower, Base Operations and Weather Office.

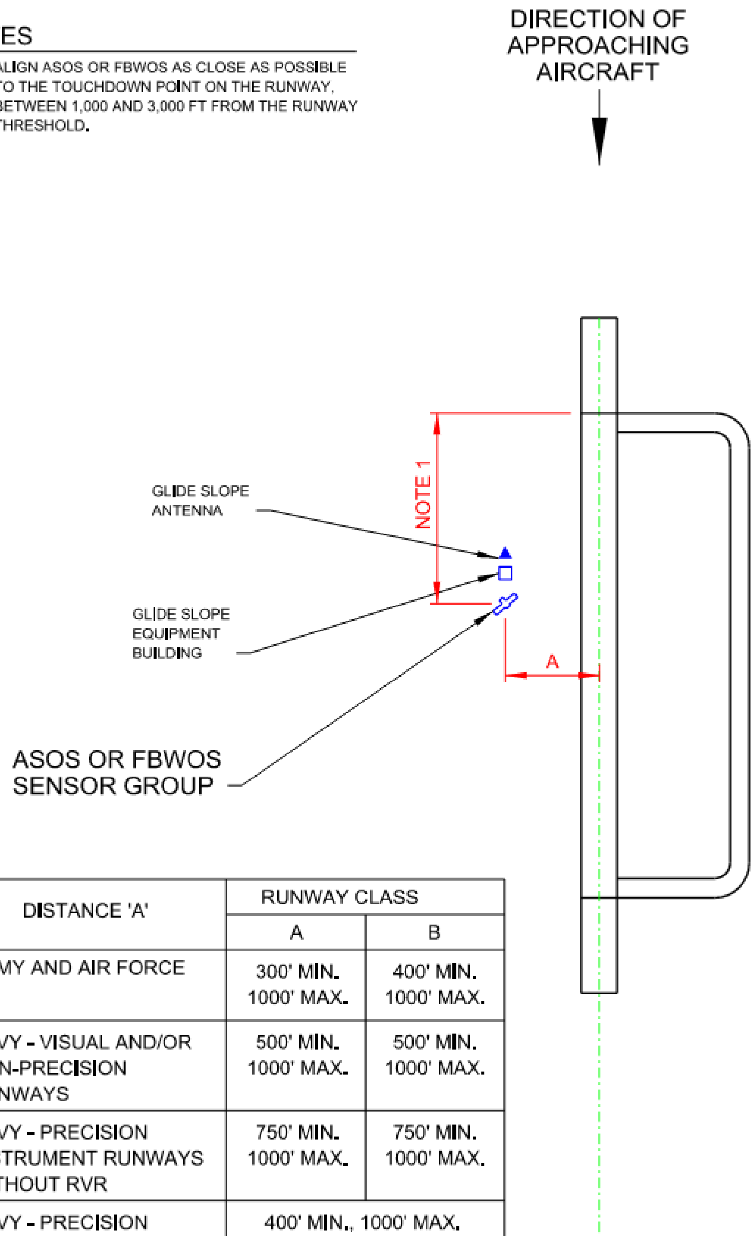
7-2.8 Connection/Interrelation to other Facilities.

Connect the ASOS ACU or FBWOS TDAU to the ATC Tower, Base Operations and Weather Office via fiber optic cable or twisted pair communications cable for remote monitoring.

Figure 7-2 ASOS or FBWOS Siting

NOTES

1.) ALIGN ASOS OR FBWOS AS CLOSE AS POSSIBLE TO THE TOUCHDOWN POINT ON THE RUNWAY, BETWEEN 1,000 AND 3,000 FT FROM THE RUNWAY THRESHOLD.



DISTANCE 'A'	RUNWAY CLASS	
	A	B
ARMY AND AIR FORCE	300' MIN. 1000' MAX.	400' MIN. 1000' MAX.
NAVY - VISUAL AND/OR NON-PRECISION RUNWAYS	500' MIN. 1000' MAX.	500' MIN. 1000' MAX.
NAVY - PRECISION INSTRUMENT RUNWAYS WITHOUT RVR	750' MIN. 1000' MAX.	750' MIN. 1000' MAX.
NAVY - PRECISION INSTRUMENT RUNWAYS WITH RVR	400' MIN., 1000' MAX. SEE ALSO FCM-S4-2019	

Figure 7-3 ASOS or FBWOS Site Layout

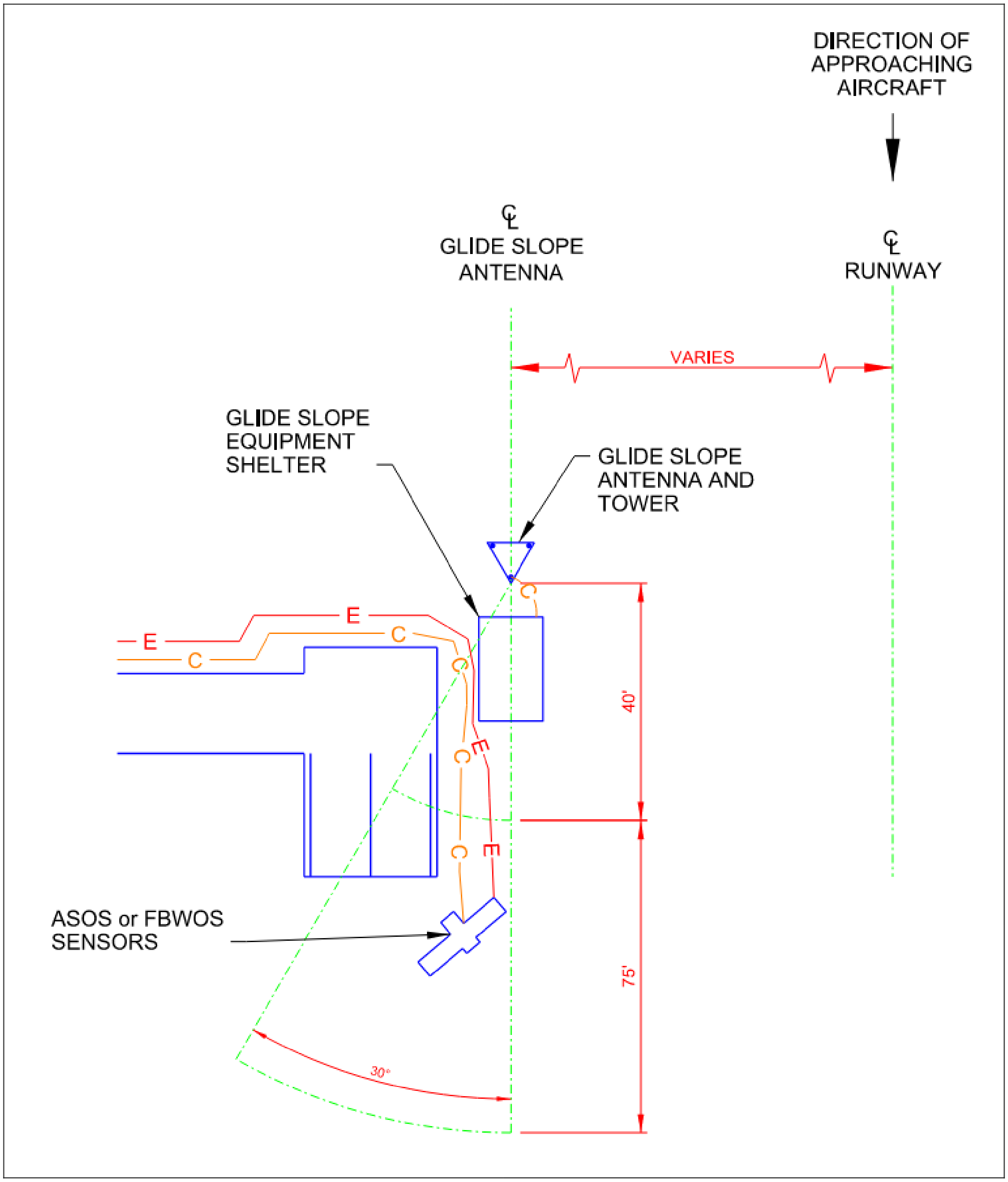
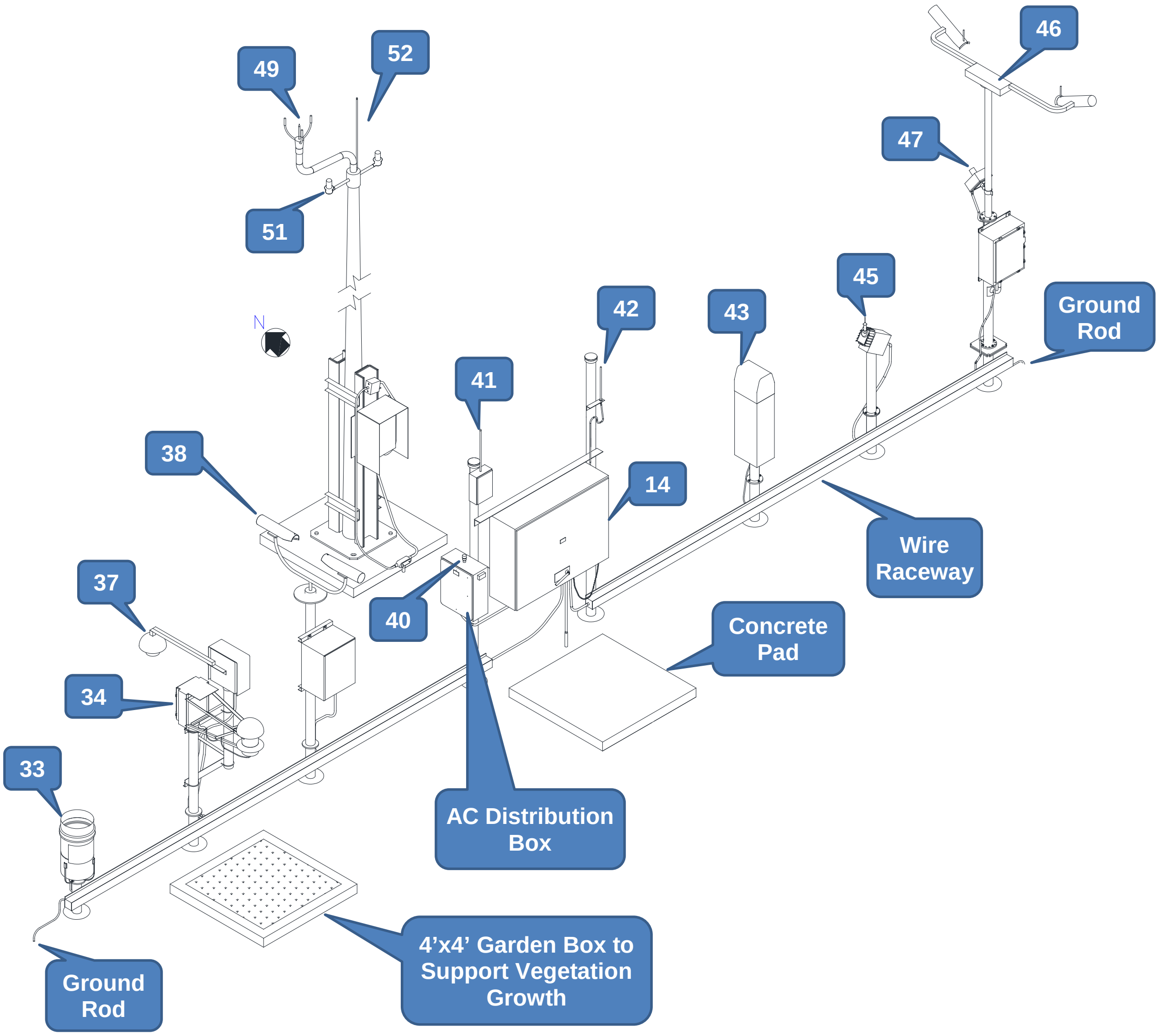


Figure 7-4 Typical ASOS Combined Sensor Group



Item No.	Description
14	Data Collection Package (DCP)
33	Tipping Bucket
34	Sensor, Temperature
37	Sensor, DTS1 Dew Cell
38	Sensor, Present Weather
40	Sensor, Day/Night
41	Sensor, Thunderstorm
42	Antenna, RF
43	Ceilometer, CL31
45	Sensor, Freezing Rain
46	Sensor, Visibility
47	Sensor, Day/Night
49	Sensor, Wind Speed/Direction
51	Light, Obstruction
52	Rod, Lightning

Figure 7-5 Typical ASOS Foundation Plan

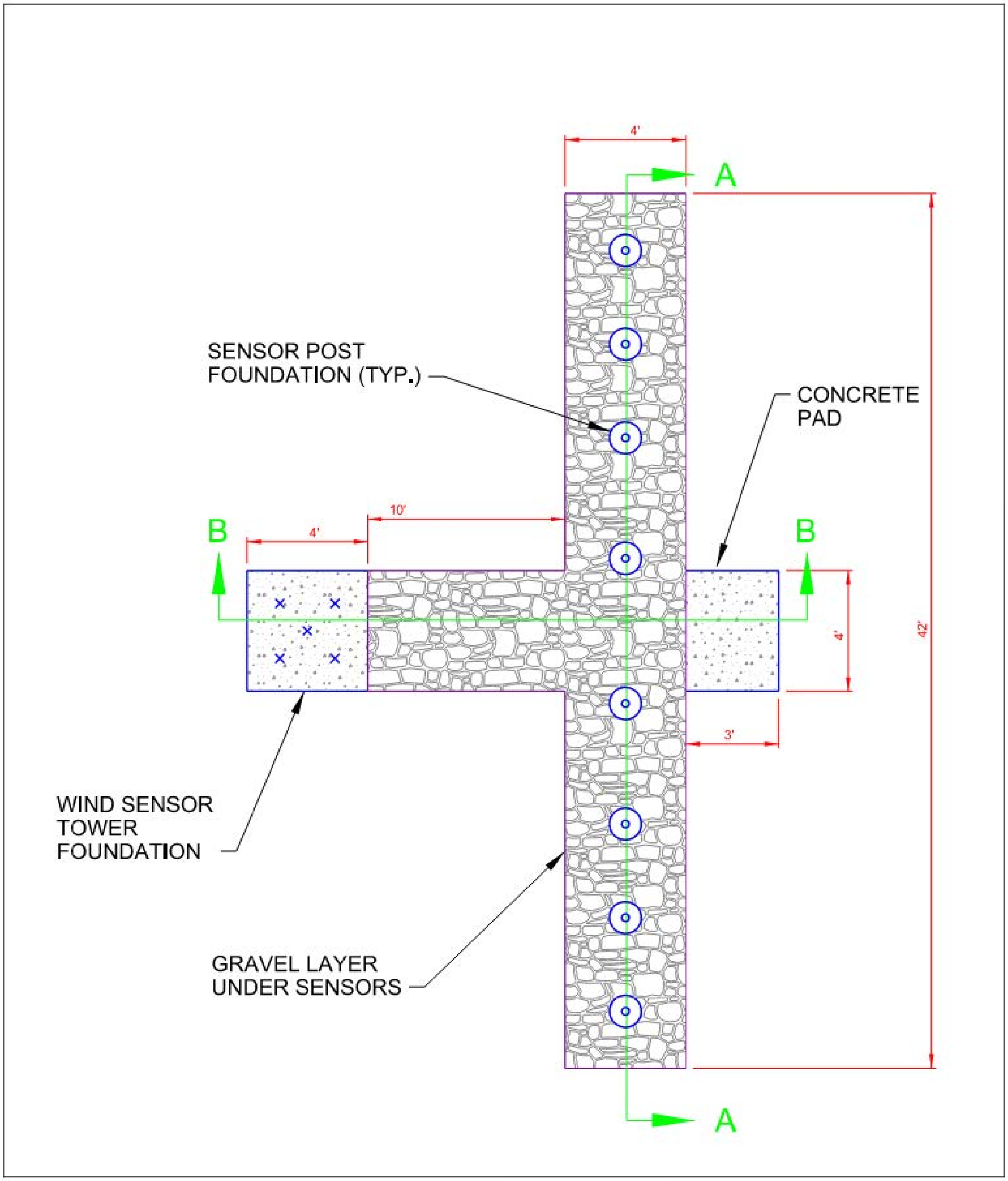
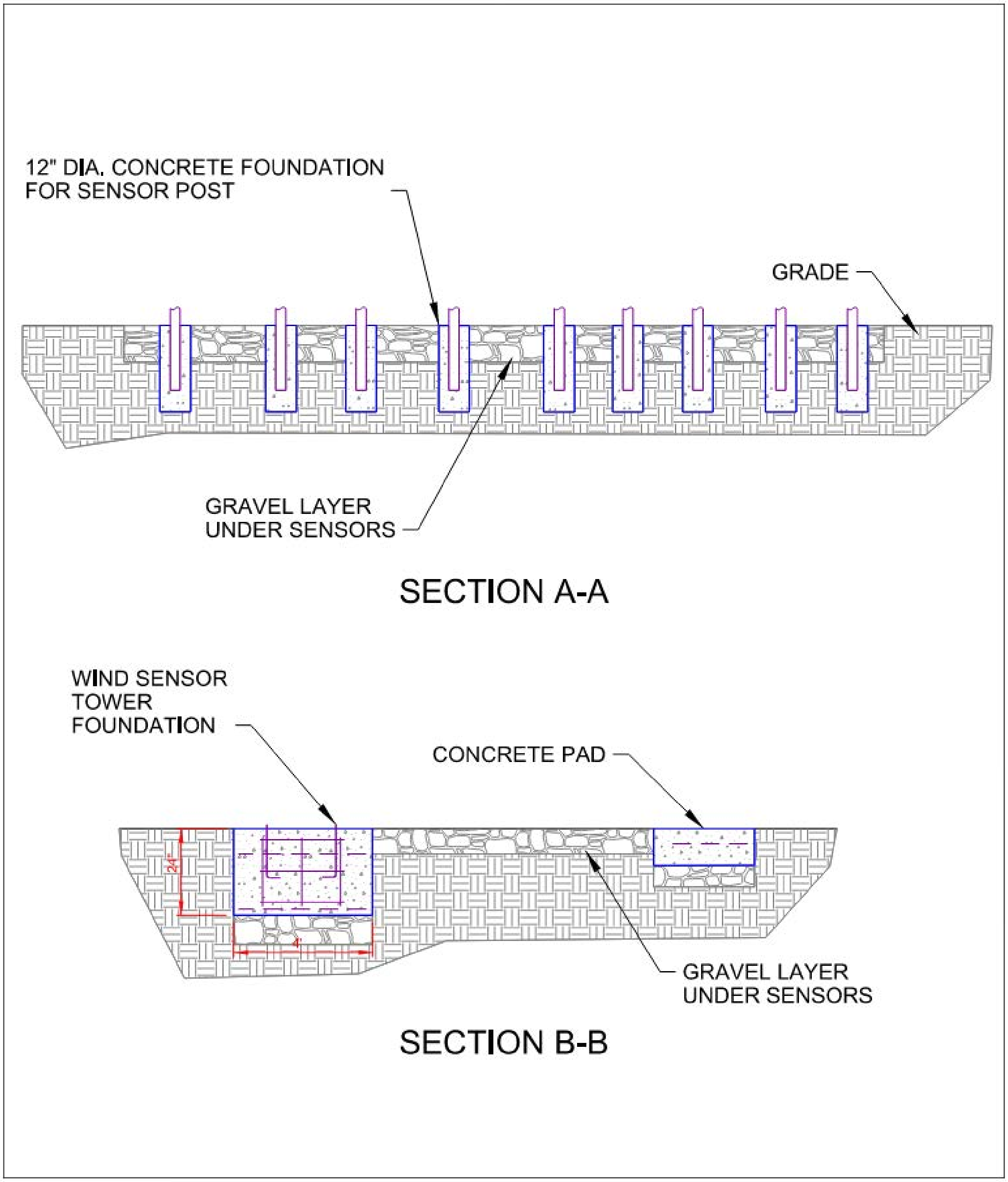


Figure 7-6 Typical ASOS Foundation Sections



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APPENDIX A BEST PRACTICES

A-1 SUBJECT MATTER EXPERTS (SMEs).

The facilities described in this UFC are unique and not routinely constructed. Contact Service Specific SMEs for guidance early in the programming, siting and design processes to obtain the most up-to-date guidance.

A-2 FACILITIES REQUIREMENTS DOCUMENTS (FRDs).

Many of the facilities described in this UFC support specialized equipment that may have been purchased in large quantities and then distributed to individual airfields. Whenever possible, obtain the FRD associated with the specific equipment to be installed for more detailed installation guidance.

A-3 UFC COORDINATION.

Coordinate all design elements with the Core Discipline requirements listed in UFC 1-200-01.

A-4 WAIVERS/EXEMPTIONS.

Site the facility to be compatible with the requirements of UFC 3-260-01. Where unusual circumstances require a non-standard installation, consult UFC 3-260-01, Appendix B, Section 1 for waiver processing procedures. For standard exceptions from waivers, consult UFC 3-260-01, Appendix B, Section 13 (Army and Air Force) or UFC 3-260-01, Chapter 2 (Navy and Marine Corps).

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APPENDIX B GLOSSARY

B-1 ACRONYMS

A & E	Architectural and Engineering
ACU	Acquisition Control Unit
AFCEC	Air Force Civil Engineer Center
AGL	Above Ground Level
AICUZ	Land Use Compatibility
ARSR	Air Route Surveillance Radar
ASR	Air Surveillance Radar
ASTM	American Society for Testing and Materials
ATC	Air Traffic Control
ATC&LS	Air Traffic Control and Landing Systems
ATCRBS	Air Traffic Control Radar Beacon System
ATSCOM	Air Traffic Service Command
ASOS	Automated Surface Observing System
AWIPS	Advanced Weather Interactive Processing System
AWOS	Automated Weather Observing Systems
BIA	Bilateral Infrastructure Agreement
CCR	Criteria Change Request
CSG	Combined Sensor Group
DCP	Data Collection Package
DME	Distance Measuring Equipment
DoD	Department of Defense
DX	Direct Expansion
E/G	Emergency Generator

FAA	Federal Aviation Administration
FBPAR	Fixed Base Precision Approach Radar
FBWOS	Fixed Base Weather Observing System
FDCU	Field Data Collection Unit
FFM	Far Field Monitor
FLOLS	Fresnel Lens Optimal Landing System
FRD	Facility Requirements Document
G/A	Ground-to-Air
GS	Glide Slope
HERF	Hazards of Electromagnetic Radiation to Fuel
HERO	Hazards of Electromagnetic Radiation to Ordnance
HERP	Hazards of Electromagnetic Radiation to Personnel
HNFA	Host Nation Funded Construction Agreements
HQUSACE	Headquarters, U.S. Army Corps of Engineers
ICLS	Instrument Carrier Landing System
IFLOLS	Improved Fresnel Lens Optical Landing System
IFR	Instrument Flight Rules
ILS	Instrument Landing System
JCF	Joint Control Facility
LOC	Localizer
LOS	Line of Sight
MDF	Main Distribution Frame
MLS	Microwave Landing System
MTI	Moving Target Indicator
MTRACON	Military Terminal Radar Approach Control Facility

NAVAID	Navigational Aid
NAVFAC SYSCOM	Naval Facilities Engineering Systems Command
NAWCAD	Naval Air Warfare Center Aircraft Division
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Administration
PAR	Precision Approach Radar
RADHAZ	Radiation Hazard
RASS	Range Airspace Surveillance
RF	Radio Frequency
RFI	Radio Frequency Interference
RTR	Remote Transmitter/Receiver
RVR	Runway Visual Range
Rx	Receiver
SOF	Safety of Flight
SOFA	Status of Forces Agreements
TACAN	Tactical Air Navigation
TDAU	Terminal Data Acquisition Unit
Tx	Transmitter
Tx/Rx	Collocated Transmitter/ Receiver Facility
UFAS	Uniform Federal Accessibility Standards
UFC	Unified Facilities Criteria
UHF	Ultra High Frequency
UPS	Uninterrupted Power Supply
U.S.	United States

VHF	Very High Frequency
VOR	Very High Frequency Omni-Directional Range
W/G	Waveguide

APPENDIX C REFERENCES

FEDERAL AVIATION ADMINISTRATION – ADVISORY CIRCULARS

https://www.faa.gov/airports/resources/advisory_circulars/

FAA AC 70/7460-1, *Obstruction Marking and Lighting*

FAA AC 150/5220-16, *Automated Weather Observing Systems (AWOS) for Non-Federal Applications*

FAA AC 150/5220-23, *Frangible Connections*

FAA AC 150/5300-13, *Airport Design*

FEDERAL AVIATION ADMINISTRATION – ORDERS AND STANDARDS

https://www.faa.gov/regulations_policies/orders_notices/

FAA Order 6310.6, *Primary/Secondary Terminal Radar Siting handbook*

FAA Order 6340.15, *Primary/Secondary En Route Radar Siting Handbook*

FAA Order 6580.2, *Remote Communications Facility Siting Criteria Handbook*

FAA Order 65580.3B, *Remote Communications Facilities installation Standards Handbook* (not accessible outside FAA)

FAA Order 6580.6A, *Remote Communications Facilities Siting Process* (not accessible outside FAA)

FAA Order 6750.16, *Sitting Criteria for Instrument Landing Systems*

FAA Order 6780.5, *DME Installation Standards Handbook Type FA-96-39* (Request for Lead Service Agency)

FAA Order 6780.8, *Distance Measuring Equipment (DME) Installation Standards Handbook Type FA-9783* (Request for Lead Service Agency)

FAA Order 6820.10, *VOR, VOR/DME, and VORTAC Siting Criteria*

FAA Order 6830.5, *Criteria for Siting Microwave Landing Systems*

FAA Order JO 6560.20C, *Siting Criteria for Automated Weather Observing Systems (AWOS)*

FAA-STD-019f, *Lighting and Surge Protection, Grounding, Bonding and Shielding Requirements for Facilities*

NATIONAL FIRE PROTECTION ASSOCIATION

https://nfpa.org/Codes-and-Standards

NFPA 70, *National Electric Code*

NFPA 101, *Life Safety Code*

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

US AIR FORCE

https://www.e-publishing.af.mil/

AF T.O. 31Z3-822-2, *Air Traffic Control Landing System (ATCALS) Site Requirements 404L*

AF T.O. 31P5-2GPN22-12, *Facility Manual – Radar Set Group, Type AN/GPN-22(V)*

US ARMY MILITARY SURFACE DEPLOYMENT & DISTRIBUTION COMMAND, TRANSPORTATION ENGINEERING AGENCY

https://www.sddc.army.mil/sites/TEA/Pages/default.aspx

SDDCTEA Pamphlet 55-17, *Traffic and Safety Engineering for Better Entry Control Facilities*

US NAVY

https://www.atc.navy.mil (CAC card required to access)

N65236-ATCF-FRD-0003 v2.0, NIWC – *Air Traffic Control Remote Communications Facility – Facility Requirements Document*

NAVFACINST 11010.45A, *Site Approval Request Process*

OPNAVINST 5100.23G,

SSC PAC PAR SPSPP, *SPAWARSYSCEN Pacific (SSC PAC) Precision Approach Radar (PAR) Site Preparation Standard Plan Package*

TRI-SERVICES ELECTRICAL WORKING GROUP

https://www.wbdg.org/ffc/dod/supplemental-technical-criteria

TSEWG TP-19, *Static Uninterruptible Power Supply (UPS)*

UNIFIED FACILITIES CRITERIA

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

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

UFC 2-000-05N, *Facility Planning for Navy and Marine Corps Shore Installation*

UFC 2-100-01, *Installation Master Planning*

UFC 3-101-01, *Architecture*

UFC 3-110-03, *Roofing*

UFC 3-201-01, *Civil Engineering*

UFC 3-220-01, *Geotechnical Engineering*

UFC 3-250-01, *Pavement Design for Roads and Parking Areas*

UFC 3-260-01, *Airfield and Heliport Planning and Design*

UFC 3-301 01, *Structural Engineering*

UFC 3-401-01, *Mechanical Engineering*

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

UFC 3-420-01, *Plumbing Systems*

UFC 4-133-01, *Air Traffic Control and Air Operations Facilities*

UFC 3-450-01, *Noise and Vibration Control*

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

UFC 3-501-01, *Electrical Engineering*

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

UFC 3-530-01, *Design: Interior and Exterior Lighting and Controls*

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

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

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

UFC 3-580-01, *Telecommunications Building Cabling Systems Planning and Design*

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

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

UFC 4-022-03, *Security Fences and Gates*

UFC 4-010-06, *Cybersecurity of Facility-Related Control System*

US DEPARTMENT OF COMMERCE/NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

https://www.icams-portal.gov/publications/fmh/siting/fcm-s4-2019.pdf

FCM-S4-2019, *Federal Standard for Sitting Meteorological Sensors at Airports, Office of the Federal Coordinator for Meteorological Services and Supporting Research*

UFC 4-150-02
12 November 2020

UNIFIED FACILITIES CRITERIA (UFC)

DOCKSIDE UTILITIES FOR SHIP SERVICE

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UNIFIED FACILITIES CRITERIA (UFC)

DOCKSIDE UTILITIES FOR SHIP SERVICE

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

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location

This UFC supersedes UFC 4-150-02, dated May 2003, with Change 5, 1 Sept 2012.

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 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.

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

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

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

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

Superseding: UFC 4-150-02, dated 13 May 2003, With Change 5, 1 September 2012

Description: This document provides a reference for the utility requirements of DoD and Coast Guard vessels and best practices for the design and maintenance of those utilities.

Reasons for Document:

- This document provides facility managers and engineers with a consolidated reference of utility requirements for active duty vessels.
- Revision includes updates to ship utility requirements.

Impact:

- There are no cost impacts.

Unification Issues:

- There are no unification issues.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

This UFC has been developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other Government agencies, and the private sector. This UFC was prepared using, to the maximum extent feasible, national professional society, association, and institute standards. Deviations from this criteria, in the planning, engineering, design, and construction of DoD shore facilities, cannot be made without prior approval of the cognizant Service.

1-2 PURPOSE AND SCOPE.

This UFC provides design criteria and guidance in the design of utility systems for piers, wharves, and dry docks. Criteria are given for Type I Piers (Fueling, Ammunition, and Supply); Type II Piers (General Purpose Piers); and Type III Piers (Repair Piers). Utilities covered include steam, compressed air, salt or non-potable water, potable water, oily waste/waste oil (OWWO) or petroleum, oil and lubricants (POL), Collection-Holding-Transfer (CHT), electric power, and telecommunications.

1-3 APPLICABILITY.

This document applies to all service elements and contractors designing dockside utilities for ship service construction, repair, and maintenance projects.

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 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems* and as required by individual Service Implementation Policy.

1-6 GLOSSARY.

APPENDIX E contains acronyms, abbreviations, and definition of terms.

1-7 REFERENCES.

APPENDIX F 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.

CHAPTER 2 GENERAL UTILITY REQUIREMENTS

2-1 SHIPS UTILITY REQUIREMENTS.

Ships utility demands and other pertinent data for individual ships utilities are available from APPENDIX A. Planners and designers must access this information in order to obtain design data regarding dockside utilities for all ship services. Data provided in APPENDIX A is the best available at the time of publication of this document. Data is incomplete, may not be completely accurate, and must be verified by planning and design team. In general, ship utility demands for active berthing are based on the ship's complement without deployed forces such as air wings or marine troops. Diversity factors are provided for use in determining demand in multiple berthing. If the designer is basing the project design on a specific ship that is not included in APPENDIX A, use data from a similar ship, or obtain the expected demand from the cognizant Service. For graving dry docks, refer to UFC 4-213-10*, Graving Dry Docks*. This information is for use at new facilities and for use in additions, modifications, and replacements at existing facilities. While means of diversification are provided for multiple ships and multiple piers by these diversity factors, metered data from existing facilities and ships should be used for planning and design whenever such data are available.

2-2 UTILITY-CONNECTION LAYOUT.

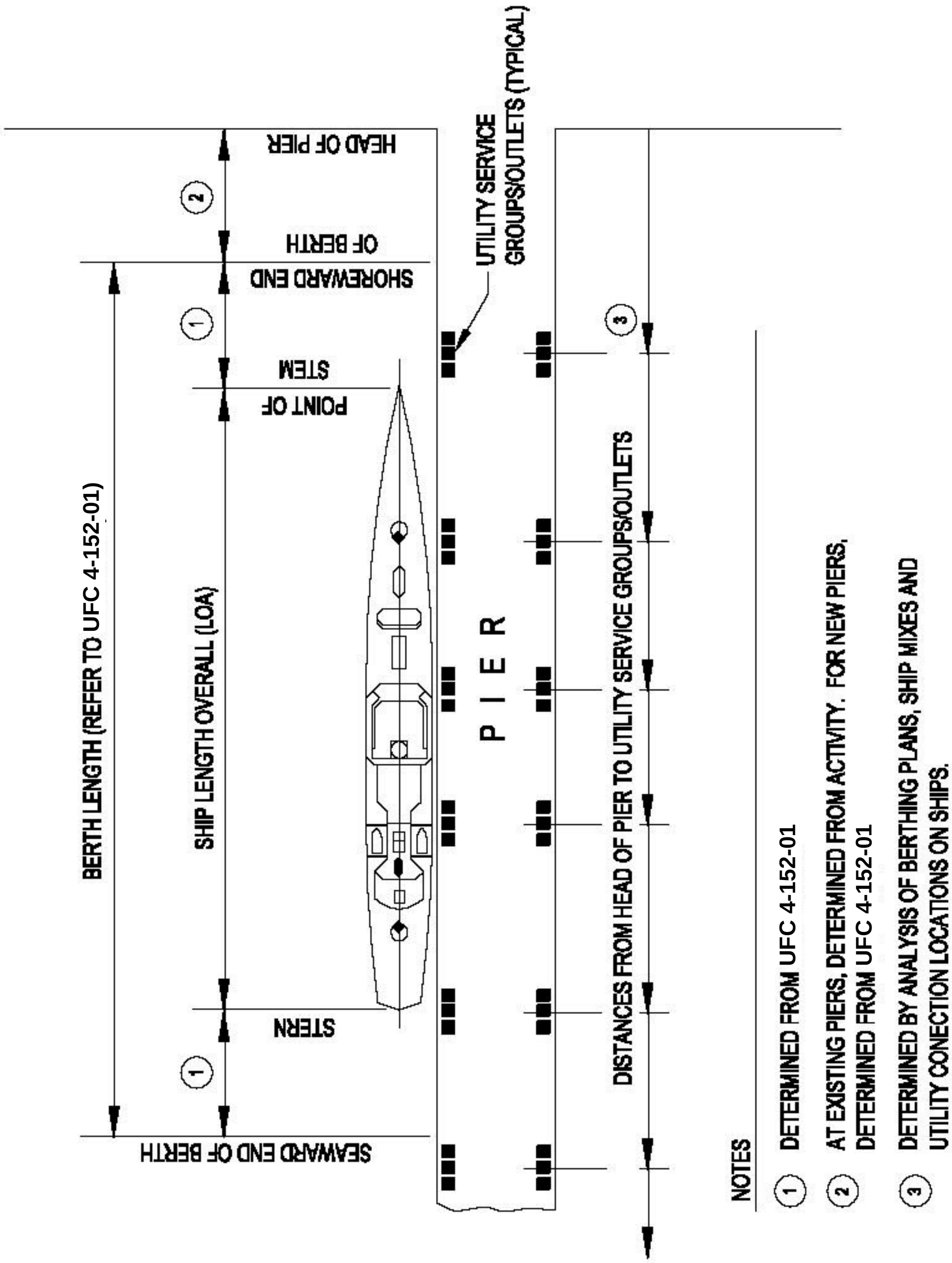
Figure 2-1 shows the dimensional relationships normally encountered in placement of shore utility connections. APPENDIX A provides size/shape data for typical ship hulls and dimensioned reference points that define the ship's utility connection locations. Ideally, the locations of shore utility connections for a given berth would simply correspond to their respective connection locations on the ship to be berthed. In practice, however, utility connection locations can never be ideal, due to largely nondedicated berthing, interference with other pier or wharf activities, other deck equipment, and the grouping of connections. The designer must optimize the location of all utility outlet assemblies based upon the projected berthing mix.

2-2.1 Connection Grouping.

Utility connections should be confined to specific locations along a shore facility so that interference with line handling and other facility operations is reduced. Connections may be in large groups to encompass all utilities, or may be in subgroups, such as the following:

- Freshwater, saltwater (if required), steam, and compressed air;
- Electrical power and communications;
- Sewer and oily waste; and
- POL, when required.

Figure 2-1 Typical Ship-Berth-Pier-Utilities Relationships



Regardless of the variations in utility groups that may be necessary to accommodate deck fittings and pier construction, sewer and oily waste connections must always be located 10 ft (3.1 m) or more from domestic water connections. Electrical outlet assemblies must be separated from other utility outlets by at least 10 ft (3.1 m) whenever possible. Additionally, where fueling is required, separation between such connections and electrical equipment is mandatory. See UFC 3-460-01, *Design: Petroleum Fuel Facilities* and consult with the cognizant Fire Protection Engineer to ascertain the minimum separation distances. Separation distances will vary depending upon the type of fuel or fuels.

2-2.2 Hose and Cable Lengths.

Experience has shown that if utilities are to be grouped, not all of the shore connections can be placed optimally in regard to their respective ship connections, even at a dedicated berth. This being the case, the location of connections for certain utilities should be given preference in order to minimize required hose lengths. Preference should be given, in order of importance, to electrical power, fire protection water (if required), steam, sewage, oily waste collection, and potable water. Excessive hose and cable lengths have significant disadvantages as defined below.

2-2.2.1 Electrical Power.

Excessive lengths of power cable increase the possibilities of accident, fire, and excessive voltage drop.

2-2.2.2 Fire Protection Water.

Losses in the fire protection system hoses could be critical in the event of fire, particularly when ship's pumps are under repair. Coordinate with NAVSEA or cognizant Service to determine how much hose is required to ensure proper flow and pressure.

2-2.2.3 Steam.

Steam hoses have a very short life, are expensive, and usually have high-pressure losses from shore to ship.

2-2.2.4 Sewage.

Although added hose pressure loss is not normally a problem, sewage hose is heavy, difficult to support, and must be disinfected when the ship's connection is broken.

2-2.3 Group Locations and Spacing.

The locating dimensions for shipboard utility connections of various ship classes are presented in APPENDIX A. These dimensions, when used with the ships configuration drawings and the parameters given in this UFC, provide guidance in spacing determinations for the shore connections. The locations of required deck equipment (capstans, bollards, cleats, ladders, and railings) and deck operations (brows, cranes, dumpsters, etc.) must always be coordinated with locations of utility connections. Pier berthing plans (graphic plots) must be made for the most likely ship mixes, and should consider local berthing practices as defined by the Activity. The berthing plans provide the basis for the design and operations of the pier's utility systems and must be included in the construction contract drawings when included under the design contract. Suitable shore connection spacing for the range of possible ships must be provided. Individual utilities within groups for mixed berthing should generally not be more than 200 ft (66 m) apart. Whenever possible, shore utility connection spacing should be such that connections are not offset more than 50 ft (15 m) from corresponding ships connections when other ship types occupy their prescribed berths.

2-3 UTILITY CONNECTION GROUP DESIGN.

2-3.1 Configurations to Avoid Interference.

Utility outlet groups should be designed for minimum interference of hoses and cables with each other, with deck equipment, and with deck operations. Check weights of hose lengths and cables with crane's lifting capability. Outlet groups may be placed above deck or in deck pits. They may also be placed in open galleries below the main deck where the pier has sufficient elevation to avoid submergence of the utility connections. An example is a double-deck pier system such as Pier 6 at Naval Station Norfolk as shown in Figure 2-2.

The type of connector at outlets must be compatible with hoses in use, or intended for use, at a given site. It is noted that the profile presented by utility groups above deck is dependent upon the height of the pier and the type of ship at berth. This is an important consideration in the design of dockside utilities for ship service. Required hose or cable connection types and sizes are given in individual utility descriptions in the following chapters. Provide for future expansion of utilities by the appropriate sizing of valve pits, pipe trenches, electrical vaults, and electrical duct banks. Likewise, a specific project may require the immediate design for future utility services. Lastly, always design for proper and safe access and maintenance of all utility systems.

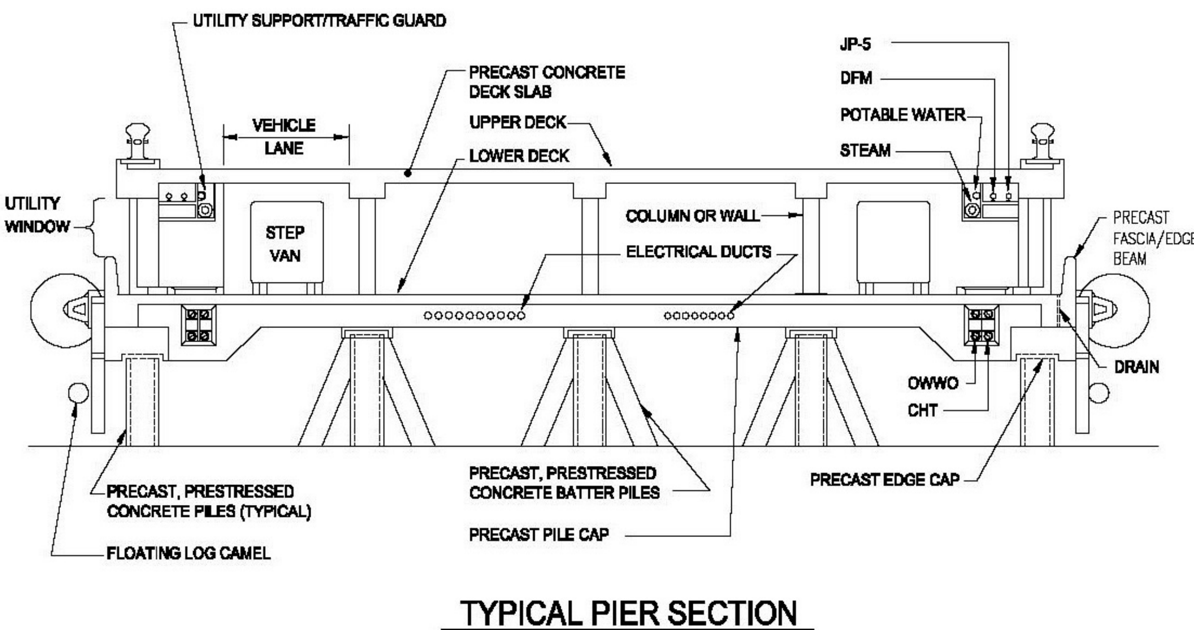
2-3.1.1 Layout.

In order to avoid hose-connection difficulties and interferences with pier traffic, outlet connections should have centerlines parallel with berths or at not more than a 30-degree angle. The distance of connections from the pier face should be as short as is consistent with structural restraints and with convenience. However, on some aircraft carrier berths such as those using narrow breasting camels, locate the utilities to clear ship elevators.

2-3.1.2 Mooring Lines.

Mooring lines for ships such as destroyers are relatively low and present a greater hazard to utility connections. Low-profile utility outlet arrangements are usually preferred. Whenever possible, mooring line patterns for the specific ships to be berthed should be observed at a similar berth before utility group design is commenced. The berthing plans are to include mooring line patterns and must uncover conflicts with utility outlets. Some typical above-deck utility connection details are shown in figures in subsequent chapters. Other arrangements are also possible and may be acceptable. A specific arrangement may be required by the cognizant Service to match existing outlet designs.

Figure 2-2 Double-Deck Pier Example



2-3.2 Design for Nesting of Ships.

Where berthing plans include the nesting of ships, provide a sufficient quantity of adequately sized services and connections. Design according to the number of ships that may simultaneously use each such berth. Unless instructed otherwise, provide internal shipboard port-to-starboard utility headers for all utilities except for potable water. For potable water, use dual connections with individual backflow devices to provide separately protected supplies to two ships at each group location.

2-4 PROTECTION.

2-4.1 Protection of Mains and Laterals.

Mains and laterals serving utility connections must be protected from damage by waves, wind, floating debris or ice, and tidal immersion. Where these lines could be subjected to such damage, they must be placed in the utility corridor of a double deck pier, placed in the trenches or tunnels of a single deck pier, or special construction techniques must be used to provide a barrier. Electrical conduits may be embedded in new concrete structures. It is preferable to place electrical duct banks, manholes, and pull boxes such that they are cast integrally with the pier deck and at least 2 ft (0.6 m) above the mean high water level.

There are cases where conduit and piping mains and laterals (except for POL systems) may be hung exposed from the bottom of pier decks in protected locations. This is not a preferred situation and is discouraged. In such cases, it is necessary to coordinate with the structural design to secure inspection ladders and deck inserts, and to facilitate installation of access platforms for maintenance purposes. New mains placed on existing piers may be placed on top of the pier deck if other construction techniques are impractical and if approved by the cognizant Service.

Corrosion protection requirements are defined in the following paragraphs. Requirements for POL systems are defined in Section 3-5 entitled “POL Systems” and refer to UFC 3-460-01, *Design: Petroleum Fuel Facilities*.

2-4.1.1 Utility Trenches.

The use of utility trenches is highly preferred. Trench covers may be concrete, steel plate, grating, or a combination of these, and as dictated by structural loading, maintenance, and cost considerations. Coordinate design with structural requirements. Note that permanently fixed covers (concrete and steel) create confined workspaces. This is a significant operational problem (regarding inspection and maintenance) that is generally undesirable and should be avoided if possible. Identifiable markings should be located on the trench entrances.

2-4.1.2 Above-deck Lines.

At most types of berthing facilities, clear deck space is at a premium, rendering above-deck mounting of utility services inappropriate, operationally difficult, and generally unacceptable. A notable exception to this general rule applies to dedicated fueling facilities. In these cases, above-deck mounting of fuel lines is often the most functional solution because it allows for the proper and safe access and maintenance of the fuel lines. See UFC 3-460-01 for additional information and criteria.

2-4.1.3 Under-deck Lines.

Except as noted above, utility service pipelines should not be located on the operating deck. At single deck piers, utilities should be contained in trench structures, shielding the enclosed pipes from exposure to saltwater and spray. Utility trench covers are of three basic types: solid, solid with personnel access, and open gratings. Solid covers are generally used over most of the trench length. Solid covers with 30 inch (760 mm) diameter manhole covers should be located over those portions of utility trenches containing valves, expansion mechanisms, or branch connections which require easy access for inspection, maintenance, and repair. Gratings may be substituted for solid trench covers with personnel access wherever ready visibility of the respective utilities is required or where ventilation of trench is advisable (steam line drip assemblies). Unless specifically curbed against vehicular traffic, covers must be designed for the same uniform loads and wheel loads as the nominal pier deck with the exception that crane outrigger reactions need not be addressed. It is therefore necessary that utility trenches not be located within the pier cross-section where mobile cranes are likely to position their outriggers.

2-4.1.4 Hangers and Support Assemblies.

Hangers, bolts and specially fabricated supports and braces steel must be hot-dip galvanized after fabrication or stainless steel. Many Activities prefer the state-of-the-art fiberglass hangers containing ultraviolet inhibitors and polyester resin (NEC type RTRC in article 355). Consult with the Activity and the cognizant Service. Where salt spray exposure is severe, incorporate appropriate additional anticorrosion measures for hangers. This includes the application of epoxy coatings, the use of stainless steel or monel bolting. Lastly, hangers must be designed based upon the maximum potential weight of the utility system. For example, for steam piping, allow the piping to be full of water.

2-4.2 Protection of Utility Connections.

Means to protect utility connections, hoses, and cables from damage due to traffic and snagging by mooring lines are essential. Conventional protection schemes consist of curbs, pits, concrete structures, or railings. Where pier width is sufficient, consider the use of continuous curbs located at sufficient distance from the edge of the pier. The design should exclude pier traffic from the areas containing utility connections, hoses, and cables. Where utility pits are used, sufficient pit length must be incorporated to ensure that hoses may be connected and led from pits to ships without kinking or chafing.

2-4.2.1 Outlets, Connections, and Access Hatches.

Access hatches in decks should have flush-mounted covers and must be designed to eliminate any danger of tripping. Where outlets and connections must appropriately protrude above the deck level, shield them in a manner that will ensure personnel safety and prevent mooring lines from being snagged on the piping and equipment. Certain utility connections such as sanitary sewer, fuels, oily waste, and waste oil must be contained within a curb or vault. Provide a drainage system to an appropriate collection system. Additionally, fuel hoses must be provided with a curbed lay-down area for the collection of drippings. Also, refer to UFC 4-152-01, *Piers and Wharves*, for other typical details.

2-4.3 Seismic Protection.

2-4.3.1 Performance of Utility Lines.

Provide special and detailed considerations for seismic protection. This applies to pierside utility systems and the associated landside utility systems. Specific details are required for storage structures and the interface transition between the landside systems and the pierside systems. Except POL lines, design all piping and utility lines as "essential" construction. See UFC 4-152-01. (The design requirements for POL lines are defined in the following paragraph.) In general, essential construction is expected to:

- Resist the maximum probable earthquake likely to occur one or more times during the life of the structure (50% probability of exceedance in 50 years) with minor damage, without loss of function, and the structural system to remain essentially linear.
- Resist the maximum theoretical earthquake with a low probability of being exceeded during the life of the structure (10% probability of exceedance in 100 years) without catastrophic failure and a repairable level of damage.

2-4.3.2 Performance of POL and Hazardous Utilities.

Design lifeline service associated with construction categorized as containing "hazardous materials" with the same levels of service. In general, hazardous material containment construction is expected to:

- Conform with criteria for essential construction.
- Resist pollution and release of hazardous materials for an extreme event (10% probability of exceedance in 250 years).

2-4.3.3 Liquefaction.

Design of structures should include provisions to evaluate and resist liquefaction of the foundation and account for expected potential settlements and lateral spread deformation. Refer to UFC 3-220-10N, *Soil Mechanics*. Special care must be given to buried pipelines in areas subject to liquefaction to preclude breaks resulting in release of hazardous materials. It is imperative to avoid areas of landslide and lateral spread. The presence of any potentially liquefiable materials in foundation or backfill areas should be fully analyzed and expected settlements computed.

2-4.3.4 Pipelines.

Design pipelines to resist the expected earthquake induced deformations and stresses. In general, permissible tensile strains are on the order of 1 to 2% for modern steel pipe. To accommodate differential motion between pipelines and storage tanks, it is recommended that a length of pipeline greater than 15 pipe diameters extend radially from the tank before allowing bends and anchorage and that subsequent segments be of length not less than 15 diameters. Flexible couplings should be used on long pipelines. In general, pipes should not be fastened to differentially moving components; rather, a pipe should move with the support structure without additional stress. Unbraced systems are subject to unpredictable sway whose amplitude is based on the system fundamental frequency, damping, and amplitude of excitation. For piping internal to a structure, bracing should be used for system components. Additional seismic protection considerations are as follows.

- In potentially active seismic areas, no section of pipe should be held fixed while an adjoining section is free to move, without provisions being made to relieve strains resulting from differential movement unless the pipe is shown to have sufficient stress capacity.
- Flexible connections should be used between valves and lines for valve installation on pipes 3 in (76 mm) or larger in diameter.
- Flexibility should be provided by use of flexible joints or couplings on a buried pipe passing through different soils with widely different degrees of consolidation immediately adjacent to both sides of the surface separating the different soils.
- Flexibility should be provided by use of flexible joints or couplings at all points that can be considered to act as anchors, at all points of abrupt change in direction, and at all tees.
- Piping containing hazardous materials should contain numerous shutoff valves and check valves to minimize release of materials if there is a break. Seismic shutoff valves should be used where necessary to control a system or process. A secondary containment system should be incorporated where feasible.
- When piping is connected to equipment or tanks, use of braided flexible hoses is preferable to bellow-type flexible connectors. Bellow-type flexible connectors have been noted to fail from metal fatigue. Welded joints are preferable to threaded or flanged joints. If flanged joints cannot be avoided, the use of self-energizing or spiral wound gaskets can allow a bolt to relax while continuing to provide a seal. (Reference: *Association of Bay Area Governments*, 1990.)

2-4.3.5 Supports.

Piers may contain pipelines for freshwater, saltwater, steam, compressed air, waste oil, sewer, and fuels systems; and may also contain electrical power and communication lines. Ship demands dictate the utility system configurations. In general, design of these lines follows the general provisions discussed herein. It is essential that the lines be attached to the supporting structure with sufficient rigidity that the lines are restrained against independent movement. Attachments to a pier may be analyzed as simple two-degree-of-freedom systems. Resonance amplification can occur when the natural period of the supported pipe is close to the fundamental period of the pier structure.

Flexible connections/sections should be used to bridge across expansion joints or other locations where needed.

2-4.4 Cathodic Protection Systems (CPS).

Provide special and detailed considerations for cathodic protection systems (CPS). This applies to pierside utility systems and the associated landside utility systems. Specific details are required for storage structures and the interface transition between the landside systems and the pierside systems. The services of a qualified corrosion engineer must be provided unless defined otherwise by the cognizant Service. For additional information and requirements see UFC 3-570-01, *Cathodic Protection* and guide specifications: UFGS 26 42 13.00 20, *Cathodic Protection by Galvanic Anodes*; UFGS 26 42 17.00 10, *Cathodic Protection System (Impressed Current)*; and UFGS 26 42 15.00 10, *Cathodic Protection System (Steel Water Tanks)*. Specific requirements are as follows:

- Provide CPS and protective coatings for the following buried or submerged metallic utility systems regardless of soil or water corrosivity:
  - Petroleum, Oil and Lubricant (POL) pipelines.
  - Oxygen pipelines.
  - Underground POL and gasoline storage tanks.
  - Underground hazardous substance storage tanks.
  - All water storage tanks interiors.
  - Other systems defined by the cognizant Service's Corrosion Control Coordinator.
- Provide a CPS and bonded protective coatings on other buried or submerged new steel, ductile iron, or cast-iron utility pipelines not mentioned above when the resistivity is below 30,000 Ohms at the installation depth at any point along the installation. Do not use unbonded protective coatings such as loose polyethylene wraps. Provide joint bonding on all ductile iron installations.
- When an existing CPS is being modified or extended, the new CPS must be compatible with the existing CPS system. When plastic pipe is selected to replace or extend existing metallic pipe, thermal weld an insulated No. 8 AWG copper wire to the existing pipe and run the full length of the plastic pipe for continuity and locator tracing purposes.
- The CPS must provide protective potentials according to the requirements of the National Association of Corrosion Engineer (NACE) Standard RP0169 (latest revision), *Control of External Corrosion on Underground or Submerged Metallic Piping Systems* and NACE Standard RP0285 (latest revision), *Standard Recommended Practice – Corrosion Control of Underground Storage Tank Systems by Cathodic Protection*.

- Unless instructed otherwise by the cognizant Service, provide an engineering life-cycle cost (LCC) analysis for the CPS. Coordinate with the cognizant Service's Corrosion Control Coordinator to establish design efforts and field test efforts. Obtain preliminary approval from the Corrosion Control Coordinator prior to accomplishing the LCC analysis. Define the proposed elements of the LCC analysis and a general description of the proposed CPS design.
- Unless instructed otherwise, Architect-Engineer (A/E) CPS surveys and designs must be accomplished under the supervision of one of the following individuals:
    - Registered Professional Corrosion Engineer.
    - Registered Professional Engineer who is also a NACE certified corrosion protection specialist or cathodic protection specialist or has a minimum of five years of experience in the applicable CPS.
    - NACE certified corrosion protection specialist or cathodic protection specialist with a minimum of five years of experience in the applicable CPS.
- Unless instructed otherwise by the cognizant Service, perform field tests (resistivity, pH, current requirements, etc.) at the proposed installation to evaluate, as a minimum, soil and/or water corrosivity. The tests are used to design the CPS and assumptions must be supported by the field test data. Design the CPS for overall system maintainability.
- Project Managers must contact the cognizant Service's Corrosion Control Coordinator regarding the CPS design and, upon request, will forward the design documents to the Coordinator for review. Design submittals must include, as a minimum, the following:
    - Preliminary Engineering Plan (PEP): soil and/or water corrosivity data, current requirements test data (if applicable), and all design calculations.
    - Final drawings: the CPS one-line diagrams, locations of all cathodic protection equipment (anodes, rectifiers, test stations, etc.), interference test points, installation details, insulating fittings, and bond connections.
    - Final specifications: acceptance testing procedures including static (native) potentials, initial and final system potentials, and interference tests.

2-5 METERING.

In general, all utilities should be metered unless instructed otherwise by the cognizant Service. Metering actual utility usage provides accurate data for billing and historical purposes. Install meters in accessible vaults or in above-grade enclosures ashore or on piers. Specify state-of-the-art electronic meters unless instructed otherwise. Consult with the Activity to determine if there is an existing metering program and integrate new meters into such existing programs. Where metering is not initially provided, then include provisions for the easy future addition of meters. This may include providing concrete meter vaults or access covers in pipe trenches. Consult with the cognizant Service for specific instructions.

2-6 PAINT AND FINISH REQUIREMENTS.

Evaluate the requirements for paint and finish systems. Final requirements will be based upon geographical location, the respective utility system, Station standards and preferences, and the guidance defined in UFC 3-190-06, *Protective Coatings and Paints*. The designer must confer with the Activity and the cognizant Service. Final designs must be based upon the paint manufacturers written instructions, especially with respect to surface preparation and paint/finish application.

2-7 UTILITY CONNECTIONS COLOR CODES.

To ensure safety, shore-to-ship utility service connections use the standardized federal color codes as an identification system on wharf and pierside connections and hose assemblies. The primary identifiers should be plain language tags, nameplates, or labels. Special emphasis should be applied to potable water, nonpotable water and the sewer system. The color code system is defined in CHAPTER 5.

2-8 DEPERMING PIERS AND FACILITIES.

Deperming piers and magnetic silencing facilities require special design consideration because of the magnetic operations. As a result, non-magnetic piping and conduit materials are required. This includes materials such as PVC, fiberglass and aluminum.

CHAPTER 3 ACTIVE AND REPAIR BERTHING

3-1 STEAM SYSTEMS.

Provide steam service at 150 psi (1,034 kPa) (saturated) along all piers and other waterfront structures used for active berthing and ship repair, and at the perimeter of graving dry docks. Provide 125 psi (862 kPa) only if approved by the Activity and the cognizant Service. Laundries on many vessels use the highest pressure at 100 psi (689 kPa). Provisions for returning condensate from ships will not be required except in special cases, and as directed by the cognizant Service. Newer ships do not require steam services. Contact the cognizant Service to waive the mandatory steam requirement.

3-1.1 Demands.

Steam requirements for selected ship classes are given in APPENDIX A. Generally, steam demand is considerably less in port than at sea. Loads must be selected for the appropriate local climate as indicated in Table 3-1. For ships not included in APPENDIX A, use data from a similar ship, or obtain the expected demand from the cognizant Service. For graving dry docks, refer to UFC 4-213-10.

3-1.2 Sizes of Piping.

Size the piping for single berths to meet the demands indicated. Include nested ships that are indicated on berthing plans. For multiple berthing, use diversity factors determined from Table 3-1. Branch steam lines from main to outlet locations should be sized for the full demands and should be no smaller than the outlet riser pipe. For ships that require two connection locations, assume 75% of the demand for sizing each branch. Refer to Section 3-1.5 entitled “Outlet Design” for minimum outlet and riser sizes. Determination of pipe sizes should be in accordance with UFC 3-430-09, *Exterior Mechanical Utility Distribution*.

3-1.3 Piping System Design Criteria.

For steam piping and condensate return piping design requirements, refer to UFC 3-430-09 subject to the following exceptions and additions. It is noted that steam piping on piers and wharves is often specified to be ASTM A53 steel.

3-1.3.1 Pitch.

For steam piping on or under a pier, the pitch of piping required by UFC 3-430-09 may be impractical due to elevation limitations or structural interference. In such cases, the designer must compensate by proper sizing of piping and by provision for adequate condensate removal. Tidal submergence of piping should be avoided by whatever means are practical.

Table 3-1 Diversity Factors (DF) for Steam Usage [a]

Ship Type	Outdoor Temperature Range (°F)	Diversity Factor (DF) [b] for: 1 Ship	3 Ships	5 Ships	9 Ships
Surface Combatants	0 - 20	1	0.97	0.96	0.94
	20 - 40	1	0.93	0.89	0.86
	40 - 60	1	0.86	0.80	0.76
	> 60	1	0.80	0.73	0.68
Aircraft Carriers	0 - 20	1	0.97	0.96	0.95
	20 - 40	1	0.96	0.94	0.91
	40 - 60	1	0.93	0.90	0.86
	> 60	1	0.82	0.76	0.74
Amphibious	0 - 20	1	0.95	0.96	0.95
	20 - 40	1	0.87	0.94	0.91
	40 - 60	1	0.80	0.90	0.86
	> 60	1	0.78	0.76	0.74
Auxiliary	0 - 60	1	0.91	0.87	0.84
Aggregate	0 - 20	1	0.96	0.93	0.92
	20 - 40	1	0.93	0.90	0.88
	40 - 60	1	0.90	0.86	0.83
	> 60	1	0.86	0.81	0.78

Note:

[a] Use of Diversity Factors (DF):
If the total number of ships in aggregate is greater than nine:
- Group the ships by types.
- Determine the maximum demand of each ship from the utility data. (See Appendix)
- Sum the individual demands within each type of ship.
- Multiply the total demand of each ship type by the appropriate DF, relative to the number of ships and temperature range.
- Total the demands obtained for the different ship type groups.

If the total number of ships in aggregate is nine or less:
- Determine the maximum demand for each ship from the utility data.
- Sum the individual demands of each ship.
- Obtain the aggregate DF from Table 3-1.
- Multiply the total demand by the "aggregate" DF in Table 3-1.

[b] Linear interpolation is permissible for actual ship quantities.

3-1.3.2 Protection.

For steam and condensate piping under a pier or wharf, or in a dry dock where submergence may occur, piping should be encased in a pressure-testable, prefabricated conduit system. Corrosion-resistant conduit coatings should be selected, and polyethylene heat-shrinkable sleeves and/or high temperature tape wrapping must be used at joints and fittings. Provide pipe hangers and associated support assemblies in accordance with Section 2-4.1.4 entitled “Hangers and Support Assemblies”. Hangers should be designed based upon the maximum potential weight of the steam system; that is, the piping is full of water. Identify piping and outlets and color-code in accordance with CHAPTER 5.

3-1.4 Location and Arrangement of Piping Mains and Branches.

As a general rule, for all active berthing piers, provide a single main with cross-branch piping to outlets. For repair piers, provide a main on each side of the pier and a cross connection at the outboard end of the pier (loop configuration). It is normally more desirable operationally to provide a looped main rather than an equivalent single main. Provide isolation valves at appropriate locations for reliability of service during emergency repairs. Coordinate piping with structural conditions and arrange mains for the best combination of versatility, security, and overall cost. For graving dry docks, refer to UFC 4-213-10. The location of ships steam connections may be found in APPENDIX A. For discussion of methods to be used to establish shore utility-station spacing on piers and wharves, refer to CHAPTER 2.

3-1.5 Outlet Design.

See Figure 3-1. Naval facilities use 2 inch (51 mm) hoses (from 1 to 10 per ship) almost exclusively for ship-to-shore steam connections. At locations where 1-1/2 inch (38 mm) and 1 inch (25 mm) hoses are used, design for 2 inch (51 mm) hoses and utilize reducing fittings at hose connections. Total numbers of shipboard steam connections are found in APPENDIX A. The number of hoses actually connected to shore per ship varies with the severity of the climate. For facilities in the coldest climates (see APPENDIX B, Figure B-1, Regions I and II), assume that all ships connections will be connected to shore. For warmer climates, obtain the demand for the appropriate design temperature; divide by 2,500 for 2 inch (51 mm) hose and by 1,250 for 1-1/2 inch (38 mm) hose. For existing facilities, the maximum number of hose connections actually made for the ships to be berthed may be obtained from the cognizant Service. Refer to CHAPTER 2 for a general description of the arrangement and spacing of utility outlets.

3-1.5.1 Steam Outlet Assemblies.

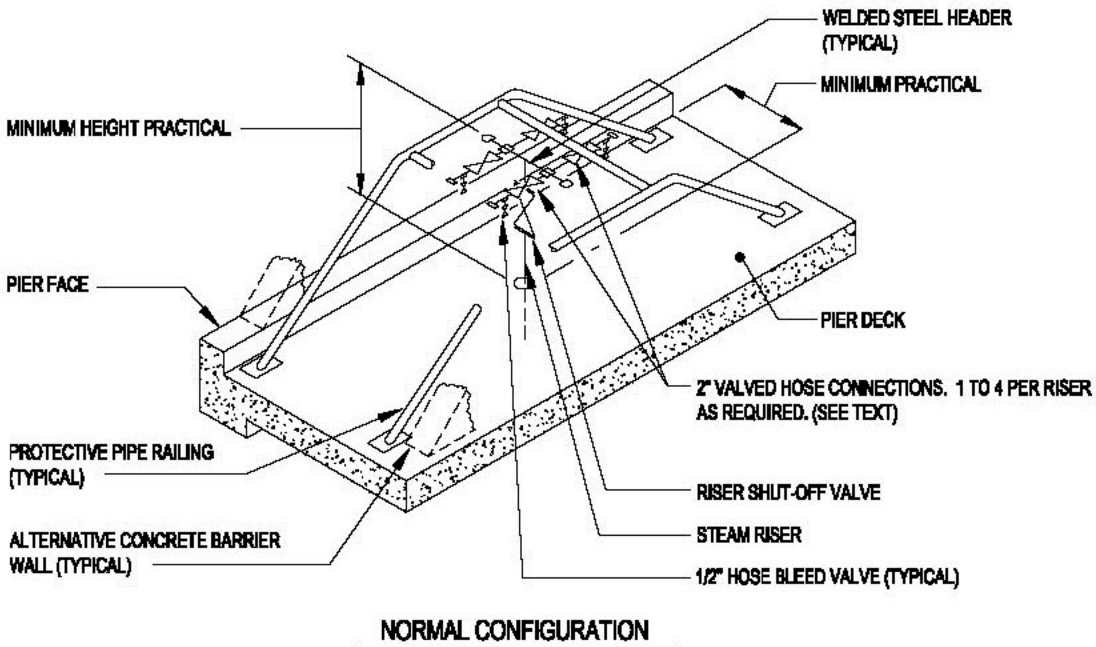
The design of steam outlet assemblies is to include the following conditions.

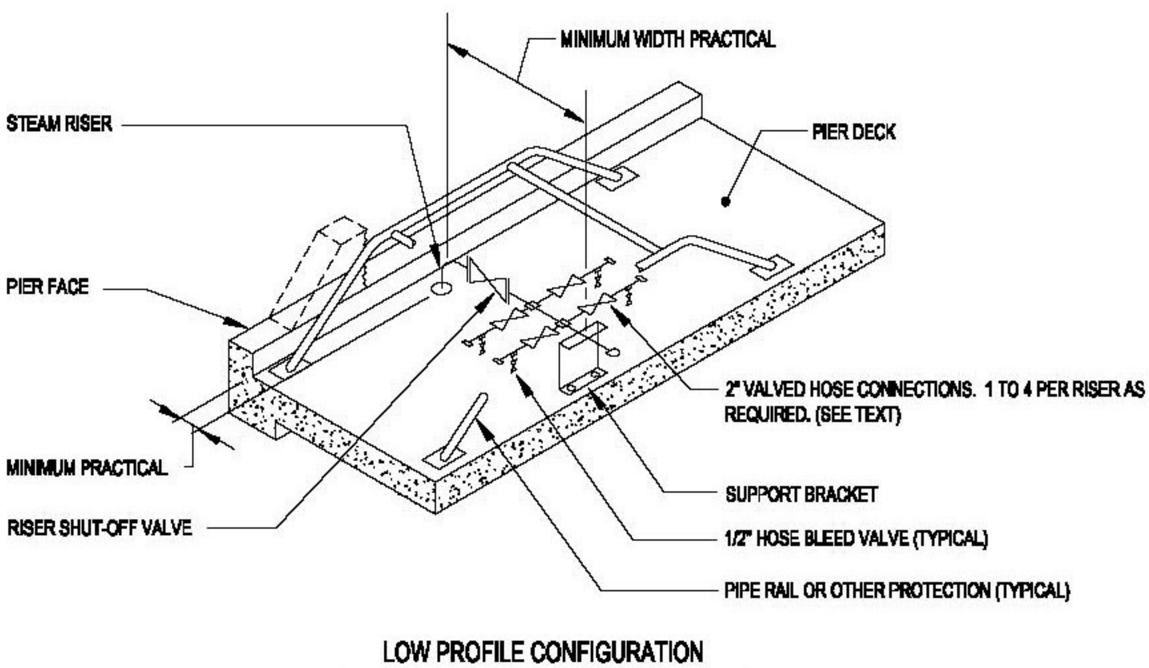
- Provide a shut-off valve for each riser assembly. The valve must be easily accessible.

- Provide a welded steel header after the riser shut-off valve. The header must serve the hose connections.
- The designer is responsible for determining the number of hose connections required at each outlet assembly.
- Hose connections must be 2 inch (51 mm) unless instructed otherwise.
- Each hose connection must include a shut-off valve, a 1/2 inch (13 mm) hose bleeder valve, and a hose connector. Threaded connections are to be avoided in order to prevent loosening of joints due to hose tension.
- Minimum pipe size of each rise assembly must be as follows:

Number of Hoses Connected to Riser	**Riser Size inch (mm)**
1	2-1/2 (64)
2	3 (76)
3 or 4	4 (102)

Figure 3-1 Typical Steam Outlet Assembly





3-1.6 Specific Ship Requirements.

3-1.6.1 CVN Ship Requirements (All Classes).

These ships are normally berthed starboard side-to. Steam is provided to CVNs certified pure at 150 psi (1,034 kPa). Galley and hot water requirements should be increased by 50% where it is reasonable to assume that the ship's air wing may be on board.

3-1.6.2 Nuclear-Powered Submarine Requirements.

Steam supply for nuclear-powered submarines is not required at operational berths. For ship construction or major repair activities, high-pressure steam at 2,000 to 4,000 psi (13.8 to 27.6 MPa) may be required for test purposes. This supply may be from a permanent plant or from a portable steam generator. The proper selection is dependent upon local weather conditions. Evaluate each location on an individual basis. The cognizant Service will approve.

3-1.6.3 Troop Carrier Special Requirements (LHA, LHD, LPD, and LSD).

Provide steam service at 150 psi (1,034 kPa) certified pure. For LHA, LHD, LPD, and LSD increase galley and hot water requirements by 100% if it is probable that troops will be aboard while at active berths.

3-1.6.4 Nested Ships.

Maximum nested ships demand at shore connections is 17,950 lb/h (8142 kg/h) based on the requirements of nested CG 47s.

3-1.7 Shore-to-Ship Steam and Feedwater Requirements.

3-1.7.1 Quality.

Naval Sea Systems Command (NAVSEA) shore-to-ship steam and feedwater quality standards are provided in NAVSEA S9086-AB-ROM-010, *Naval Ship's Technical Manual (NSTM)*, Chapter 220, *Boiler Water/Feedwater - Test and Treatment*, paragraphs entitled: “Shore Steam and Condensed Shore Steam Used as Feedwater”; “Navy and Commercial Facility Shore Steam Certification Requirements”; “Shore Processed Feedwater (Demineralizers, Reverse Osmosis)”; “Shore Source Feedwater Requirements”; and “Makeup Feedwater Demineralizer System”. These standards are given in Table 3-2 and Table 3-3.

Table 3-2 Shore Steam and Condensed Shore Steam Quality Requirements [a]

Constituent or Property	Requirement
pH	8.0 to 9.5
Conductivity	15 µ S/cm maximum [b]
Dissolved Silica	0.2 ppm maximum
Hardness	0.10 ppm max or 5 ppm as $CaCO_3$ total hardness
Total Suspended Solids	0.10 ppm maximum

Note:

[a] Steam must be generated from feedwater which is either treated with a chemical oxygen scavenger or mechanically deaerated to a maximum dissolved oxygen content of 15 parts per billion. Shore steam and condensed shore steam used as feedwater must meet the above standards. The use of filming amines is prohibited.

[b] µS/cm = micro-Siemens/centimeter = micro-mho/centimeter. The lowest reading on the shipboard conductivity meter is 40.

Table 3-3 Bulk Shore Feedwater Quality Requirements [a]

Constituent or Property	Requirement
pH	5.4 to 8.2 (process effluent)
Conductivity	2.5 µS/cm maximum (at point of delivery) [b]
Silica	0.2 ppm maximum

Note:

[a] Produced by method other than condensed steam.
[b] µS/cm = micro-Siemens/centimeter = micro-mho/centimeter.

3-1.7.2 Use of Steam Separators.

Provide steam separators as required to meet the NAVSEA criteria for the purity of shore-to-ship steam in Navy ports. Properly selected steam separators may be installed in steam mains at piers, wharves, and dry docks. (See S9086-AB-ROM-010 NSTM Chapter 220). These will provide additional protection against condensate carryover and the resultant steam contamination where such problems are known to exist. Normally, steam separators are not required on piers, wharves, or dry docks if adequate condensate removal is provided at the boiler plant and in shore mains. Steam separators should be used only when necessary and as based upon a case-by-case evaluation of local conditions. If a steam separator should be necessary, then Figure 3-2 provides a typical installation detail that should be used in conjunction with the guidelines of NFESC Test Report No. TN 1586, *Steam Separator Test and Evaluation*.

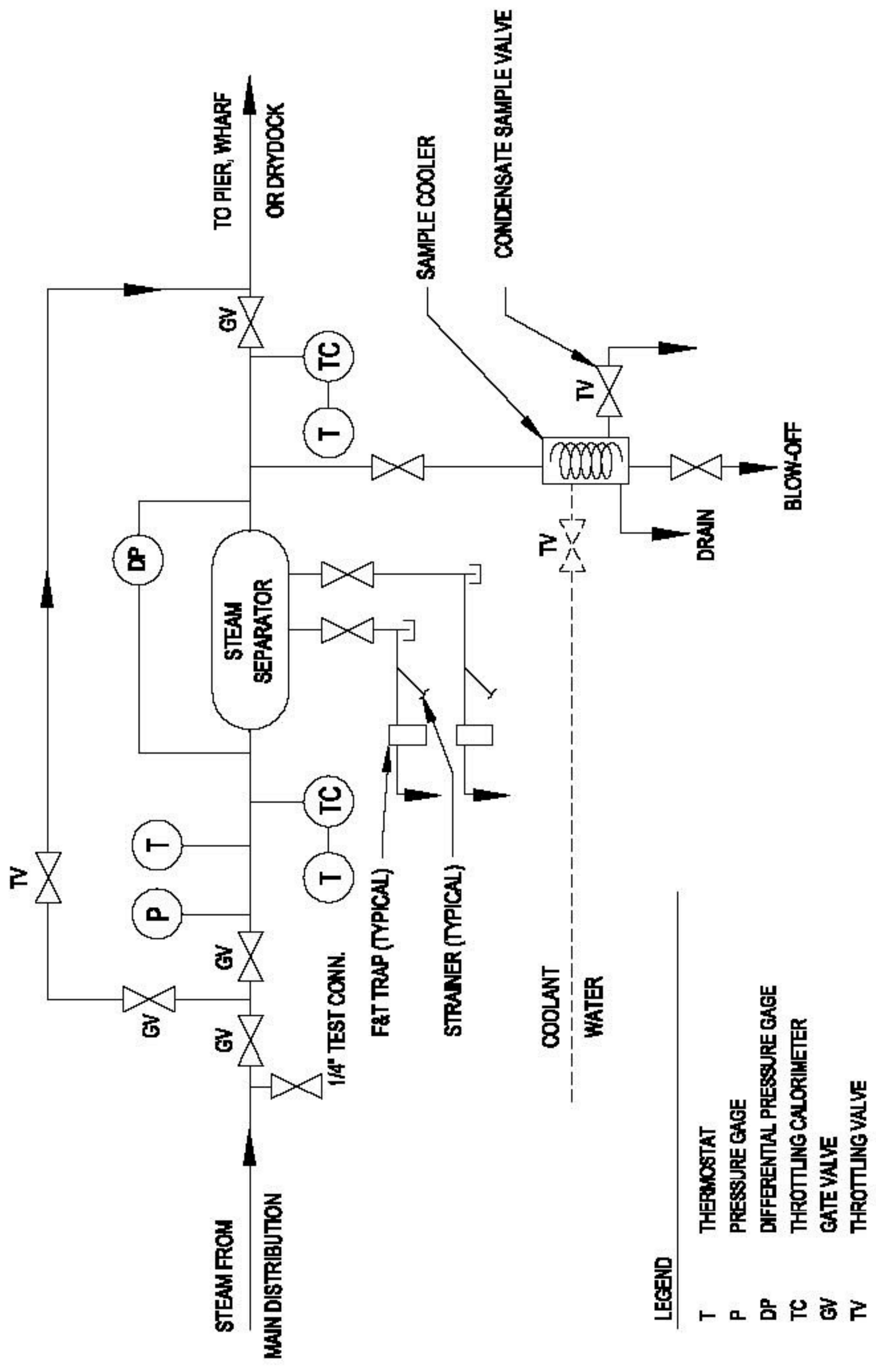
3-1.7.3 Sampling.

Due to the harsh marine environment, conductivity and pH meters should not be installed permanently on piers or wharves. Condensate sampling stations should be provided at piers and at steam plants. Figure 3-2 also shows a typical installation of a sampling station.

3-1.8 Metering.

Where monitoring of usage is required, provide metering of steam flows to piers, groups of piers, or dry docks. Install meters in accessible vaults or in above grade enclosures ashore or on piers. At individual piers or dry docks, use pressure and/or temperature compensated electronic microprocessor type flow meters for good mass flow accuracy and range. Consult with the cognizant Service to determine if a steam meter installation and maintenance program exists at the Activity. Consult the Activity steam meter program coordinator to integrate the flow meter type selection into any existing meter program. Where metering is not initially required, make provision for ease of future installation by means of concrete vaults or pier access covers.

Figure 3-2 Schematic Steam Separator and Sampling Station



3-2 COMPRESSED AIR SYSTEMS.

In general, a compressed air system (low pressure) is required at all active and repair berths. However, final needs and requirements vary on a pier-by-pier basis. Consult with the Activity for actual requirements, existing construction standards, and preferences. Requirements for graving dry docks are given in UFC 4-213-10. See Section 3-2.7 for high pressure compressed air requirements.

3-2.1 Demands.

Compressed air requirements for selected ship classes are defined in APPENDIX A. For ships not included in APPENDIX A, use data from a similar ship, or obtain the expected demand from the cognizant Service.

3-2.2 Piping System Design Criteria.

Design compressed air piping to conform to commercially available standard practices. Also, the designer may consult UFC 3-430-09, *Exterior Mechanical Utility Distribution*. In addition, provide corrosion protection of steel pipes. Consider an extruded polyethylene or polypropylene exterior coating. Extruded plastic coatings must contain an ultraviolet inhibitor. For coated pipe, use polyethylene, heat-shrinkable sleeves and/or tape wrapping at joints and fittings. Provide pipe hangers and associated support assemblies in accordance with the Section 2-4.1.4 entitled “Hangers and Support Assemblies”. Identify piping and outlets and color-code in accordance with CHAPTER 5.

3-2.3 Quality.

Compressed air should normally be "commercial" quality. Where breathing quality air and/or an oil-free system is necessary use an oil-free source and/or purification systems. Compressed breathing air compressors must meet the requirements of 29 CFR 1910.134 and the requirements for Grade D breathing air described in ANSI/CGA G-7.1, *Commodity Specification for Air*. Locate compressors used to supply breathing air so as to prevent entry of contaminated air into the air supply system and breathing air couplings are incompatible with outlets for nonrespirable worksite air or other gas systems.

3-2.4 Size of Piping.

For single berths, size the mains in accordance with air quantity per ship data given in APPENDIX A. Multiple pier demand data for use in design of new compressed air plants and at new facilities should be obtained by evaluating demands at operating Naval berthing and repair facilities which are similar to the proposed facility. The designer should consult with the cognizant Service. For multiple berthing at a single pier or wharf, including nested ships, use the following diversity factors:

Number of Ships	Diversity Factor
1	1.0
2	0.8
3	0.7
4	0.6
5 or more	0.5

3-2.4.1 Branches.

Branch-pipe sizes should be in accordance with the ships' usage data defined in APPENDIX A. Where a variable mixture of ships is probable at a given pier, all branch lines should be 3 inch (76 mm) minimum. However, where carriers may be berthed, branch lines should be 4 inch (102 mm) minimum.

3-2.4.2 Sizing Method.

Determination of pipe size should be in accordance with available friction loss tables. Size mains for a pressure drop of not greater than 5 psi (34.5 kPa) total friction loss from pier or wharf entrance to farthest outlet, and as based upon the designed flow rates. For looped mains, assume flow in both legs of the loop. In all cases, mains should be sized to supply the most outboard ship with 100% of the quantity defined in APPENDIX A, and then adjusted for its full-diversified demand.

3-2.5 Location and Arrangement of Piping Mains and Branches.

As a general rule, for all active berthing piers, provide a single compressed air main with cross branch piping to outlets. For repair and submarine piers, provide a piping main on both sides of the pier and provide a cross connection at the outboard end of the pier (loop configuration), unless not feasible or practical on a submarine pier. It is normally more desirable operationally to provide a looped compressed air main rather than an equivalent single main. Provide isolation valves at appropriate locations for reliability of service during emergency repairs. Coordinate piping with structural conditions and arrange mains for the best combination of versatility, security, and overall cost. The number of shore compressed air outlets and risers for various ship types is defined in APPENDIX A. Specific ships connection locations (one or two per ship) are also defined. However, compressed air may be required at many locations both on and alongside a ship during maintenance or repair operations. The number of outlets and risers per berth should therefore be integrated within utility groups designed and spaced as discussed in CHAPTER 2.

3-2.6 Outlet Design.

See Figure 3-3. The size of outlet risers should be the same as that of branch piping. Provide a full-sized accessible shut-off valve in each branch near the outlet riser. Hose couplers for maintenance and repair connections should be quick coupler type and must match those used by the Activity. When the site is an existing facility, the number and size of maintenance and repair hose connections required to match a facility standard may be used in lieu of those given in the following table. Shore couplings for 2-1/2 inch (64 mm) ship-to-shore connections should be male cam-locking connector with cap which complies with Commercial Item Description (CID) A-A-59326, *Coupling Halves, Quick-Disconnect, Cam-Locking Type* (with supplements). Shore couplings for 4 inch (102 mm) ship-to-shore connections should be 150-pound flanges with blind flange covers. Refer to CHAPTER 2 for general description of the arrangement and spacing of utility outlets. Provide a header at the outlet riser, with hose connections (valved outlets and hose couplers) sized as follows:

Size of Riser inch (mm)	Maintenance and Repair Connections Number, inch (mm)	Ship-to-Shore Connection inch (mm)
2 (50.8)	Four 3/4 (19.1)	None
3 (76.2)	Two 3/4 (19.1) & Two 1-3/4 (44.5)	4 (102)
4 (102)	Two 3/4 (19.1) & Two 1-1/4 (31.8)	4 (102)

3-2.7 Requirements for High Pressure Compressed Air.

Submarines and aircraft carriers (CVN 68 class and higher) (ref NSTM Chapter 9490) require a high pressure compressed air (HPA) supply in addition to the customary low pressure compressed air (LPA) requirements. This service may be provided by tapping an available 3,000 psi (21 MPa) or 4,500 psi (31 MPa) source, or by utilizing portable compressors. Required ships service size is normally 1/2 inch (13 mm) or 3/4 inch (19 mm). The ship's compressors will be used for top off under emergency conditions. Air quality should be in accordance with NAVSEA S9086-AB-ROM-010, *Naval Ship's Technical Manual (NSTM)*, Chapter 551, *Compressed Air Plants and Systems*. This chapter requires air to be oil free and dehumidified by a desiccant type dehydrator to a dew point (at atmospheric pressure) of -60 °F (-51 °C). High pressure compressed air service is normally portable and provided by the Activity, but the need must be determined on an individual site basis.

3-2.8 Submarine Pier Requirements.

Submarine and UUV piers/berths require both LPA and HPA. Provide permanently installed LPA and HPA systems at submarine and UUV piers/berths. However, this must be determined on a case-by-case basis.

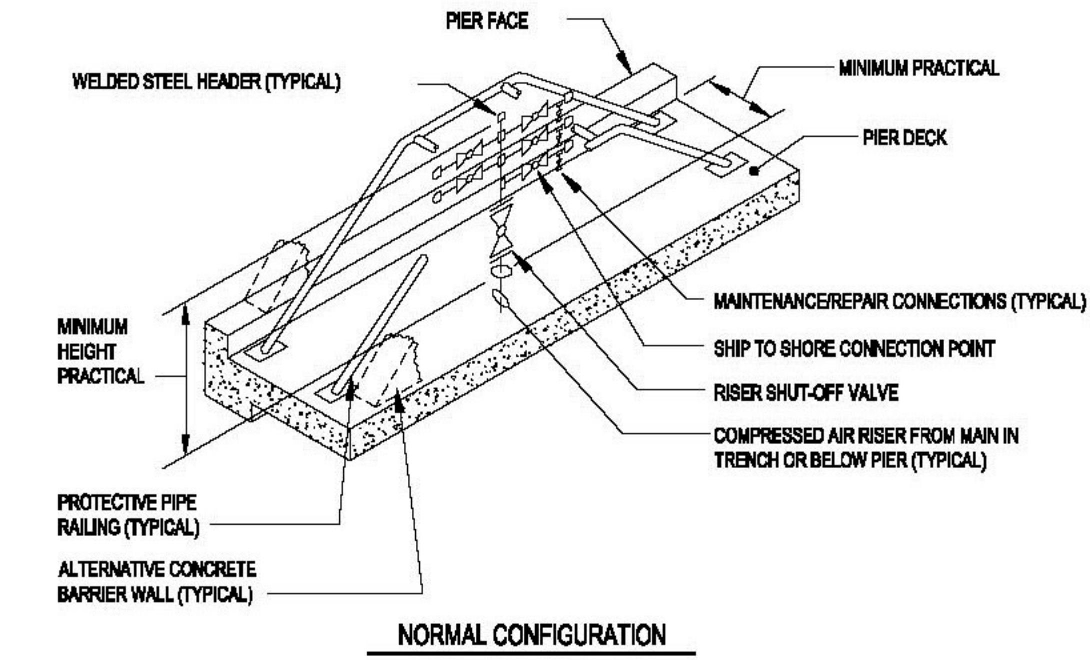
Where not feasible or practical to provide a permanently installed utility systems, a suitable solution that limits operational impacts must be developed and fully vetted through the various stakeholders to meet this utility requirement. Project team must document the variation in providing the utility, alternatives, mitigation measures, and resolution.

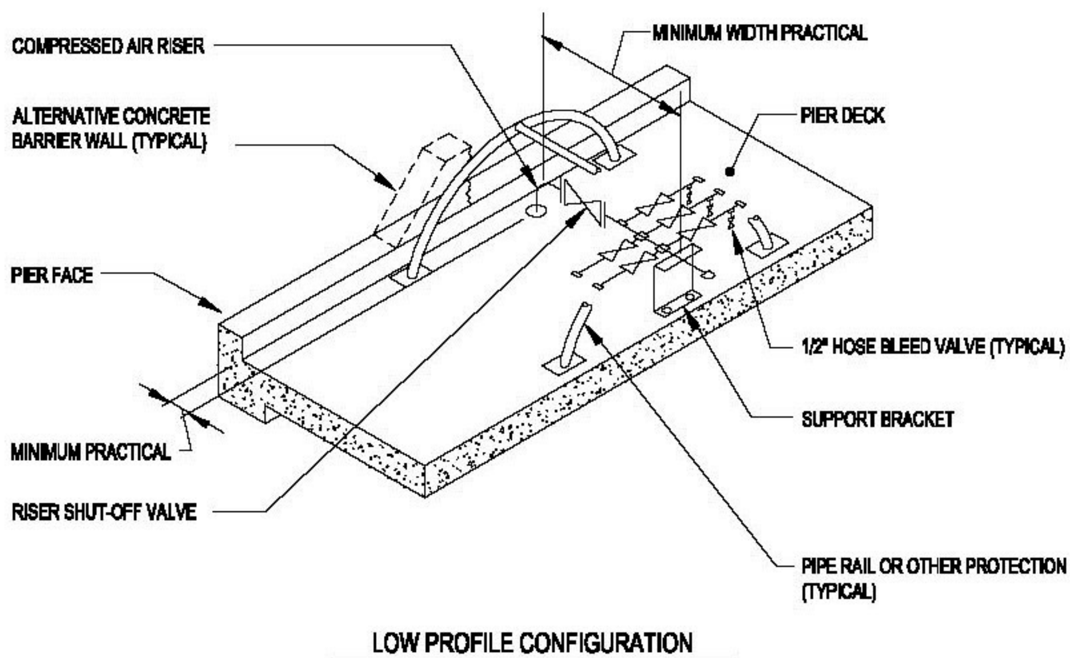
Permanently installed systems are preferred. But, require adequate pier width, deck space, shoreside space, and/or a remote facility for supply. Permanently installed piping with connections for temporary/portable equipment is an option, but is not preferred. This requires a location for portable equipment that limits impacts to operational areas. It is less desirable to provide portable compressors with hoses since they will impact pier deck space and interfere with operations.

3-2.9 Metering.

Provide metering of LPA and HPA supply to piers or groups of piers unless instructed otherwise. See Section 2-5 entitled “Metering” in CHAPTER 2.

Figure 3-3 Typical Compressed Air Outlet Assembly





3-3 SALTWATER OR NONPOTABLE WATER SYSTEMS.

Do not provide shore-supplied saltwater or nonpotable water to active berthing piers and wharves unless instructed by the cognizant Service. Refer to the paragraphs below for guidance regarding justification for the use of permanent salt or nonpotable water systems. For dry docks, refer to UFC 4-213-10. For pier and wharf fire protection requirements, refer to UFC 3-600-01, *Fire Protection Engineering for Facilities*, as well as the criteria in this UFC. Also, refer to NAVSEA 8010, *Industrial Ship Safety Manual for Fire Prevention and Response* for requirements for any industrial work being performed pierside on in a dry dock. Consult with the cognizant fire protection engineer, both at the local level and at the cognizant Service level.

3-3.1 Justification.

The use of permanent salt or nonpotable water systems must be justified and approved in advance by the cognizant Service. Use the following criteria to establish approval requirements for these systems.

3-3.1.1 Repair Piers and Dry Docks.

At facilities used for major ship repair in which the repaired ships do not have use of their own pumping capabilities, permanent shore salt or nonpotable water systems are normally utilized. These types of installations do not require prior approval. Design such systems in accordance with applicable requirements defined herein and beginning with Section 3-3.2 entitled “Demands and Pressure Requirements”.

3-3.1.2 Active Berthing.

Permanent salt or nonpotable water systems must not be provided at active berthing facilities unless instructed otherwise. It is the Navy's intent that ships at active berth will normally rely upon their own pumping capabilities to supply saltwater for flushing/cooling and firefighting. In the event of a major fire or other emergency, shore-based portable pumps and other available station fire apparatus would be utilized to augment the ship's saltwater pumping capability.

Generally, fixed fire protection systems are not required for active berthing piers when the level of the pier is low enough to the waterline such that the responding fire crews can perform drafting operations from the pier. However, with the development of the double-decker type piers, normal fire department operations are restricted due to the elevation of the pier above the water level. Provide dry standpipe systems for piers where construction features restrict fire department vehicle access and/or prevent the fire department from performing drafting evolutions from the pier. The system consists of multiple inlet, or pumper, connections and multiple outlet (standpipe) connections located on both levels of the pier.

3-3.1.2.1 Connections.

Locate inlet connections on both sides of the access ramp and size to support flows of 3,000 gpm (190 L/s). Pumper connection type should be as preferred by the base fire department, but typically will consist of both 5 inch (127 mm) Storz and 2-1/2 inch (64 mm) connections. This configuration will permit the fire department to obtain water from adjacent fire hydrants, drafting operations from the relieving platform, or a combination of both.

Outlet connections consist of the following:

- Upper level connections consist of a single 5 inch (127 mm) Storz outlet and valve or four (4) 2-1/2 inch (64 mm) hose valves. Locate connections at each stair access point to the lower level and at the top of the pier access ramp.
- Lower level standpipe or hose stations consist of two (2) 2-1/2 inch (64 mm) hose valves. Locate hose stations along both sides of the pier, spaced so that all portions of the lower level are within 150 ft (45 m) of a hose connection. Measure distances along a path of travel originating at the hose connection.

3-3.1.2.2 Identification.

Identify locations of the lower level connections on the upper level by color coordinated reflective markers located on the curb along the pier edge. Provide reflective markers to identify all fire protection and ship service connections. Identify locations of lower level connections on the lower level by painting the adjacent pier structural column (bent) red in color.

3-3.1.2.3 Piping.

Main distribution piping on the pier must be a minimum 8 inch (203 mm) diameter, Schedule 40-Galvanized. Loop piping to supply hose stations along both sides. Piping must not infringe on vehicle lanes with respect to clear height requirements.

3-3.1.3 Justification Requirements.

At locations where special conditions or hazards exist, permanent salt or nonpotable water systems will be allowed for active berthing and inactive berthing facilities on a case-by-case basis provided: (1) it is adequately justified by the Activity; and (2) it is approved in advance by the cognizant Service Chief Fire Protection Engineer. Each pier or wharf at a given facility must be considered separately unless the usage of two or more piers is identical. The Station/Activity should submit the following when requesting approval for these systems.

- Identify the type of facility and activities, and describe the special condition(s) or hazard(s) peculiar to this facility upon which this request is based.
- Establish the required pier or facility demand and pressure parameters based on the methods given in Section 3-3.2 entitled “Demands and Pressure Requirements”.
- Provide description and analysis of the options available to provide the required protection such as: (1) permanent system to supply the entire demand; (2) portable pumping systems(s) dedicated or otherwise; and (3) combinations of items (1) and (2). All existing Navy assets must be included in the analysis including any existing permanent systems.
- Provide a life cycle cost analysis for all viable options on a site-specific basis. Perform the analysis in accordance with the cognizant Service P-442, *Economic Analysis Handbook*. The analysis must take into consideration the costs of owning and operating all pertinent plants, both on ships and ashore.
- Make recommendations for the best system to meet the required demand as based on consideration of the special conditions(s) or hazards(s) and on the life cycle cost analysis.
- The demands and pressure parameters of an approved permanent salt or nonpotable water system should be designed as described in Section 3-3.2 entitled “Demands and Pressure Requirements” and all subparagraphs.

3-3.2 Demands and Pressure Requirements.

Berthing facilities should conform to the requirements specified below. Note that the requirements differ for overhaul and dry dock berthing versus those for active berthing.

3-3.2.1 Dry Dock, Repair and Inactive Berthing.

Nonpotable or saltwater supply should be furnished at dry docks, piers, and wharves as described below. Requirements for selected ship classes are defined in APPENDIX A. For ships not included in APPENDIX A, use data from a similar ship, or obtain the expected demand from the cognizant Service. The following criteria should also apply.

- Dry dock: Provide sufficient saltwater to meet the requirement of the ship with the highest saltwater demand anticipated to be docked at the dry dock. Use the "Total Demand" quantity listed in APPENDIX A. Refer to UFC 4-213-10 and NAVSEA 8010 for additional requirements at dry docks.
- Repair Berthing: Provide sufficient saltwater to meet the "Total Demand" requirement defined in APPENDIX A for the largest ship to be berthed at the pier plus the aggregate cooling/flushing demand of all remaining ships

at the pier, and then multiplied by the diversity factors given below. In general, allow 1,000 gpm (63 L/s) minimum for piers serving frigate ships and larger and 500 gpm (32 L/s) minimum for piers serving ships smaller than frigates. Also, do not include nested ships.

Number of Ships	Diversity Factor
1	1.0
2	0.9
3	0.8
4	0.7
Over 4	0.6

- Total System Demand: Where a system serves more than one pier, assume only one ship fire will occur for the group of repair piers. The multiple pier supply system should be designed to meet the requirement of the pier with the highest demand plus the aggregate cooling/flushing demand from ships at all remaining piers, and then adjusted by the same diversity factors defined above. To obtain an overall demand that includes dry docks, add the sum of all dry dock demands to the multiple pier demand as described herein.
- Pressure Requirement: The saltwater pressure should be 150 psi (1,034 kPa) residual pressure (for all ships except submarines) at the most remote outlet. Submarines require only 40 psi (276 kPa). These pressure requirements should be available within 3 minutes of system activation.

3-3.2.2 Active Berthing (Single or Multiple Berths).

As stated previously in Section 3-3 entitled “Saltwater or Nonpotable Water Systems”, shore supplied saltwater or nonpotable water should not be provided to active berthing piers or wharves. However, there are instances where this occurs. In the criteria given below for saltwater or nonpotable water demands, one of the following conditions of flow governs. (Note: Either the fire protection demand or the cooling/flushing demand may govern. Use whichever is greater.)

- Base fire demand on a fire occurring aboard the ship with the largest fire protection demand plus the cooling/flushing ratings of all other ships connected to the fire protection water systems, and then adjusted for diversity.
- Base cooling/flushing demand on the aggregate of connected ships and then adjusted for diversity.

Requirements for selected ship classes are defined in APPENDIX A. For ships not included in APPENDIX A, use data from a similar ship, or obtain the expected demand from the cognizant Service. For aircraft carriers (CVN 68 class and higher) include saltwater for firefighting and cooling/flushing when potential exists for ship to be in cold iron status. Total demand equals firefighting plus cooling/flushing flow.

3-3.3 Pumping Equipment.

Pumps may be permanent, portable or mobile as justified and approved under the requirements defined in Section 3-3.1 entitled “Justification”. In general, pump capacities and heads should be selected to provide for both fire protection and cooling/flushing requirements. Use separate pumps for the two requirements only when specifically allowed or when upgrading an existing system as defined in Section 3-3.5.2 entitled “Upgrading”. Refer to UFC 3-600-01 for requirements of fire pumps and associated equipment. Centrifugal fire pumps should comply with NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*.

3-3.3.1 Drives.

As defined by NFPA 20, fire pumps may be driven entirely by electric motors if either a single reliable power source is available, or if two independent power sources are available. Single reliable power sources need not include dual substations or starting equipment. If the above conditions for use of "electric drive only" cannot be met, design the system such that a minimum of 50% of pumping capacity is driven by approved alternative drives such as diesel engines. Portable or mobile pumping equipment is normally driven by remote-starting electric motors (when appropriate) or by diesel or gas-turbine engines.

3-3.3.2 Pressure Control.

Pressure must be controlled under varying demands by staging of pumps and by incorporation of surge tanks and/or other suitable equipment. It is imperative to prevent excessive surges due to starting and stopping of pumps. Use a small pressure-maintenance pump to handle low flows. Fire pumps must be equipped for automatic startup upon pressure drop, manual stop, and provision for "manual override startup".

3-3.3.3 Alternative Pump Drive.

When a separate cooling/flushing water system is used, a variable speed electric drive may be used to control pressure. Variable speed equipment may also be used for combined fire protection and cooling/flushing systems when approved by the cognizant Service. Variable speed drive equipment should be selected from types that have been proven by successful use. Adjustable frequency type variable speed systems are preferred because of their higher efficiency. See UFC 3-520-01, *Interior Electrical Systems*, for additional requirements regarding variable speed systems.

3-3.3.4 Location.

Permanent pumping equipment for individual piers, wharves, or dry docks should be located ashore and as near as possible to the pier, wharf or dry dock. It is highly preferred to provide vertical pumps with wet sump/intake configuration. Where this is impractical, then the pumps may be placed in an enclosure on or alongside a pier or wharf. The pump columns must be adequately protected from wave action and floating debris. Portable or mobile pumping equipment may also be placed on pier decks or on floating platforms moored to the pier.

3-3.3.5 Materials.

Care must be taken when specifying pump materials for nonpotable water service. Where salt or brackish waters are present, the potential for galvanic and crevice corrosion is severe. Steel and cast iron, ordinary brass and bronze, and most stainless steels are not suitable for these corrosive water sources. Specially coated steel and cast iron as well as 400 series stainless steel have proven to be ineffective. Material selection should be based on a thorough investigation of the site and operational conditions. The construction specifications should be explicit as to materials required for each major part, indicating appropriate ASTM designation and Unified Numbering System (UNS) number per ASTM E527, Numbering Metals and Alloys in the Unified Numbering System (UNS). Since it is impractical to list all parts, a sentence such as the following should be included:

"Minor parts not listed should be of comparable materials with equivalent corrosion resistance to the materials listed."

Submittals for Government approval, including material lists, should be required for pumps. Materials generally considered appropriate for salt and brackish waters are as follows:

Application	Material	ASTM	UNS
All wetted parts	316 SS, or	A276	S31600
	316L SS	A276	S31603
Shafts/Couplings	Nickel-Copper	B164 [a] and	N04400
	(Monel)	B165 [a]	N04499
All wetted parts,	Alum Bronze, or	B148 [a]	C95200
except shafts/couplings	Ni-Alum Bronze	B148 [a]	C95500

Note:

[a] Full titles for ASTM Standards can be found in APPENDIX F.

In salt water it is important to avoid dissimilarity of parts. Pumps constructed of type 316L stainless steel or nickel aluminum bronze with monel shafts are preferred. In brackish water, cost savings can be realized by allowing acceptably small dissimilarities. Aluminum bronze pumps with type 316 stainless steel shafts are a reasonable alternative. The presence of sand/grit must also be considered. Pumps constructed of stainless steels handle sand/grit better than pumps constructed of bronze and other copper alloys. However, saline waters corrosion concerns are still paramount.

3-3.4 Piping and Outlets.

3-3.4.1 Size of Mains.

Piping systems must be designed to provide the required residual pressure at the rated design flows to the berths farthest from the pumping location. Where a common shore pumping and distribution system feeds several piers or dry docks, the shore distribution system must be sized to deliver the design firefighting flow to any one of the piers or dry docks while cooling/flushing flows continue to all other locations.

3-3.4.2 Location and Arrangement of Mains.

As a general rule, provide a permanent main on both sides of a pier with a cross connection at the outboard end of the pier (loop configuration). When permanent mains are placed on piers 50 ft (15 m) or less in width or in unique situations, provide a single main with branch lateral pipes for outlets on both sides of the pier. It is normally more desirable operationally to provide a looped main than an equivalent single main. Provide isolation valves at appropriate locations for reliability of service during emergency repairs. Coordinate piping with structural conditions and arrange mains for the best combination of versatility, security, and overall cost. Segregation valve should be placed in the fire main loop so that the maximum distance between any two adjoining valves does not exceed 200 ft (61 m).

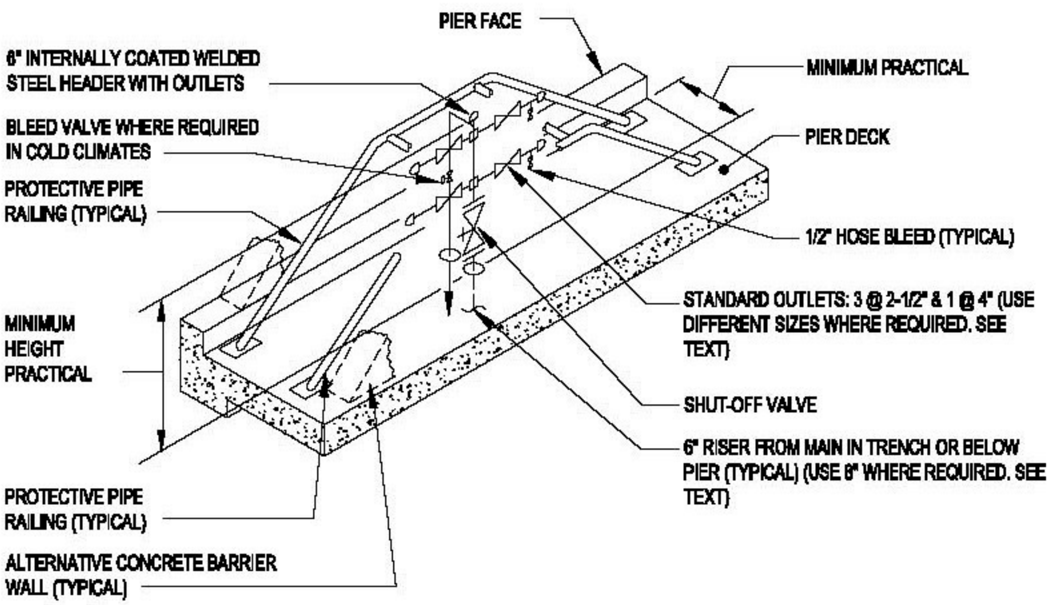
3-3.4.3 Location and Spacing of Outlets.

The pier location of ships' saltwater connections are defined in APPENDIX A. Refer to CHAPTER 2 for a description of the methods to be used in establishing shore utility-station spacing on piers and wharves. Hose valve manifolds should be provided in sufficient numbers such that all parts of the ship can be reached by at least two 100 ft (31 m) hoses. For spacing in dry docks, refer to UFC 4-213-10.

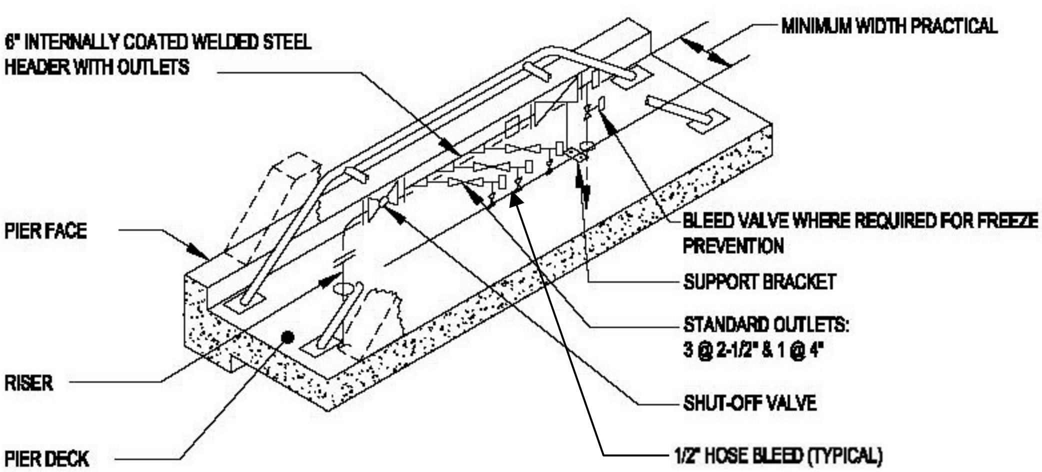
3-3.4.4 Outlet Design.

See Figure 3-4. The typical outlet should consist of a 6 inch (152 mm) branch main and riser feeding a manifold arrangement of three 2-1/2 inch (64 mm) and one 4 inch (102 mm) valved hose connections. Where portable pumping systems are used, standpipe connections may be provided on some (or each) of the outlet risers for connection to the portable pumping system discharge hose. For certain large ships, the above outlet requirements should be modified as defined in Section 3-1.6.1 entitled “CVN, LHA, and LHD Requirements (All Classes)”. Provide four 4 inch (102 mm) valved hose connections in a manifold arrangement at the outboard end of large piers. These outlets are to serve fireboat or large-volume portable-pump connections. Where berthing is designed exclusively for tugboats, work boats, or other small craft having a "Salt Water From Shore" requirement of not more than 625 gpm (39 L/s), properly spaced 4 inch (102 mm) risers having two to three 2-1/2 inch (64 mm) connections may be used in lieu of the above. All connections should be protected by a corrosion resistant chained cap, sized to properly support the weight of the cap on the chain for extended periods of time. At each designated pier in each naval station where oceangoing U.S. merchant and foreign ships are expected, provide two international shore connections. See Figure 3-5.

Figure 3-4 Typical Salt or Nonpotable Water Outlet Assembly

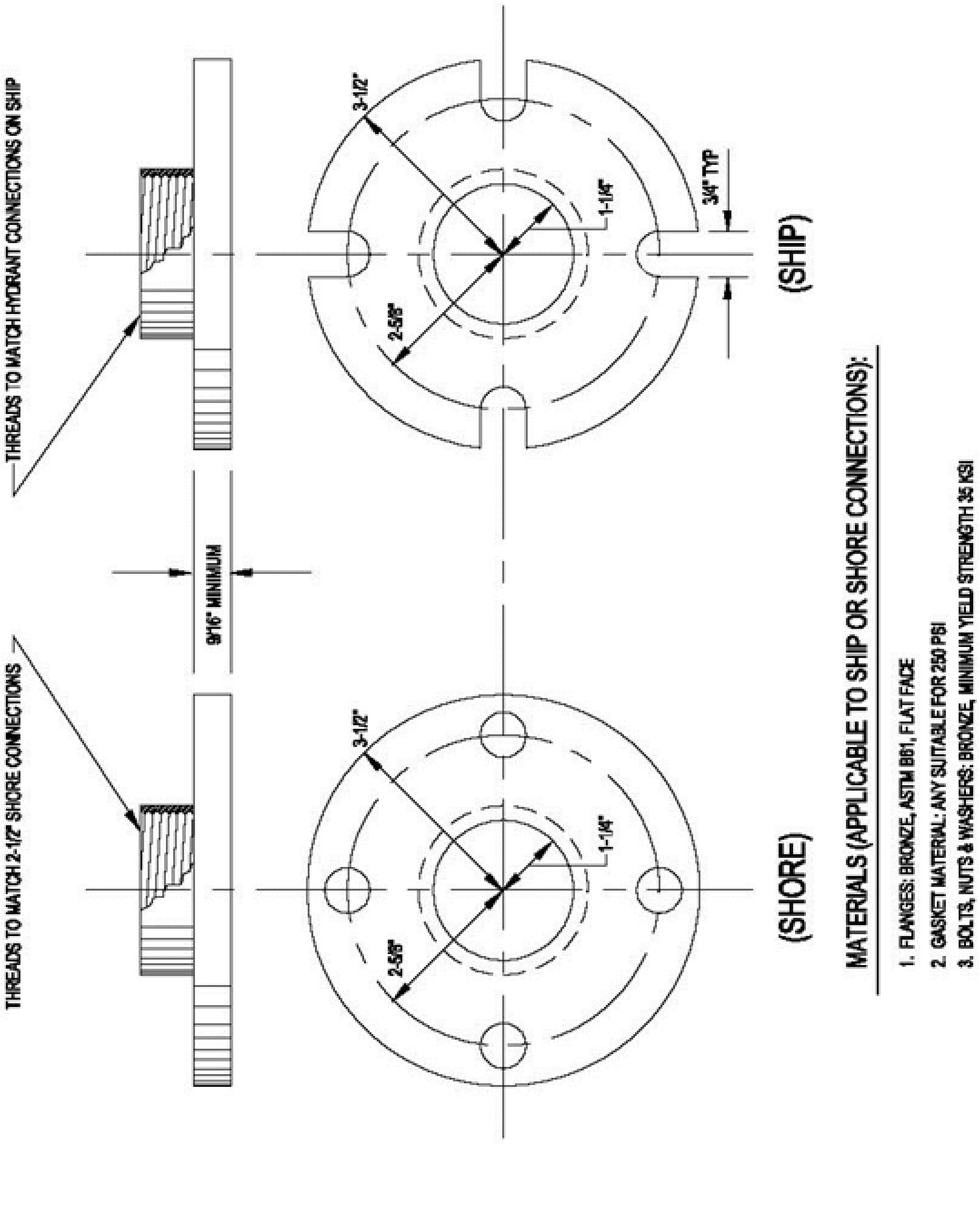


NORMAL CONFIGURATION



LOW PROFILE CONFIGURATION

Figure 3-5 International Shore Connection for Ship Fire Mains



3-3.4.5 Materials and Installation Criteria.

Pipe and fittings should conform to UFC 3-230-01, *Water Storage and Distribution*, as applicable to piers and wharves. Use pipe, fittings and valves pressure-rated at 250 psi (1,724 kPa) minimum. Hose threads should be National Standard hose-coupling threads, 7-1/2 threads/inch, or as approved by the cognizant Fire Protection Engineer. Materials for valves should conform to requirements for pumps as defined in Section 3-3.3.5 entitled “Materials”. For piping on a pier or wharf, evaluate the relative advantages of cement-lined ductile iron versus cement-lined steel pipe with an extruded polyethylene or polypropylene exterior coating. An ultra violet inhibitor must be used in polyethylene coatings that will be exposed to sunlight. For coated pipe, use polyethylene heat-shrinkable sleeves and/or tape wrapping at joints and fittings. Provide pipe hangers and associated support assemblies in accordance with Section 2-4.1.4 entitled “Hangers and Support Assemblies”. Provide means of pipe movement due to thermal expansion, preferably by the use of expansion loops and offsets. Also, provide for differential movement of piping at pier expansion joints. Piping and outlets must be identified and color-coded in accordance with CHAPTER 5.

3-3.5 CVN, LHA, and LHD Requirements (All Classes).

At existing installations where insufficient saltwater pressure exists, the pressure should be increased to provide 150 psi (1034 kPa) residual pressure at the pier outlets. Pump-discharge pressure must be sufficient to provide the required residual at the rated design flow. The following special requirements apply to these large class ships:

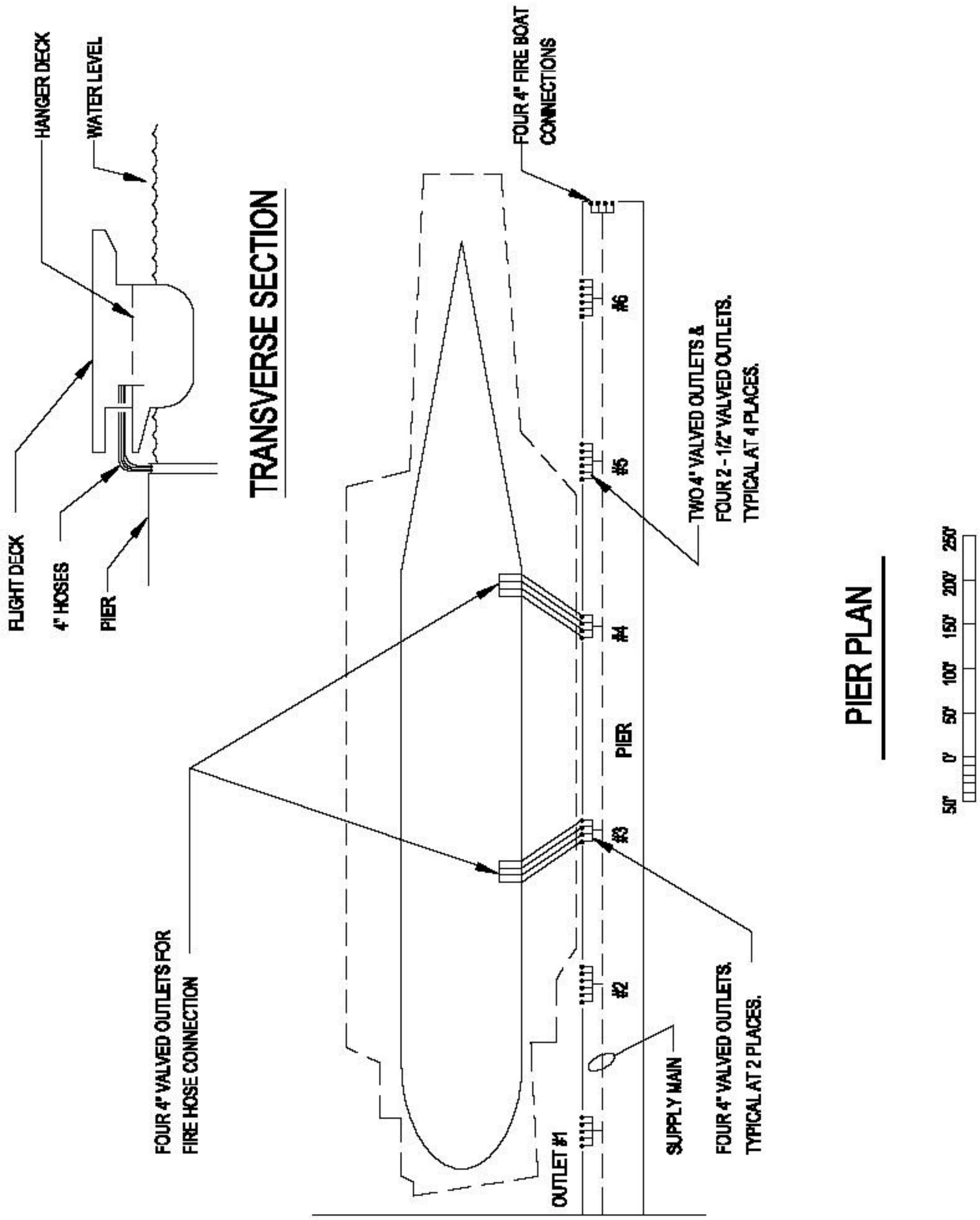
3-3.5.1 Special Outlets.

In lieu of the typical outlet assembly, provide four 4 inch (102 mm) gate valve hose connections in an 8 inch (203 mm) manifold arrangement with an 8 inch (203 mm) riser at each of two locations. Approximate locations of outlets for aircraft carriers are indicated on Figure 3-6. For LHA and LHD ships, determine locations from NAVSEA or from the Activity. Except for the riser size, outlet design and configuration should be similar to outlets at other locations and which serve the smaller ships.

3-3.5.2 Upgrading.

Permanent changes to existing pier systems for upgrading of the fire protection system (where permanent system has been justified) should be a separate high-pressure system. Provide pipes, fittings, and valves with a pressure rating of 250 psi (1,724 kPa) minimum. Existing low-pressure saltwater systems may remain in place for cooling/flushing and for fighting fires on piers when handheld hose lines are required.

Figure 3-6 Salt or Nonpotable Water for CVN Classes at Pier



3-3.5.3 Portable or Mobile Pumps.

Supplemental large-volume portable or mobile pumps may be utilized to augment the salt-water supply from a permanent system. Existing systems that can supply a portion of the requirement at 150 psi (1,034 kPa) residual pressure may remain unchanged. However, when portable or mobile systems are used at dry docks or repair facilities, the capacity of the permanent system should be no less than 5,000 gpm (18,925 L/min).

3-3.6 Other Nuclear-Powered Ship Requirements.

For active and repair berthing or docking, the requirements are the same as those for conventionally powered ships of similar type.

3-4 POTABLE WATER SYSTEMS.

Provide potable water via a permanently installed fixed piping system to all berthing spaces. For graving dry docks, refer to UFC 4-213-10. Supplemental utility data as well as specialized technical data and specific ship requirements are provided at the end of this chapter. See Section 3-4.6.3 entitled “Additional Requirements for Nuclear-Powered Ships” for pure water requirements.

3-4.1 Quantity and Pressure Requirements.

3-4.1.1 Active Berthing (Single or Multiple Berths).

For single berths, provide a potable water supply of 1,000 gpm (63 L/s) for all berth lengths up to 2,000 ft (610 m). Design for a minimum residual pressure of 40 psi (276 kPa) downstream of an RP2 backflow preventer located at the most remote outlet on the pier. Where the pier length accommodates more than one berth, provide a potable water supply of 1,000 gpm (63 L/s) for the first 2,000 ft (610 m) of berth, plus 500 gpm (32 L/s) for each additional 2,000 ft (610 m), up to a maximum of 2,000 gpm (126 L/s), and with a minimum pressure of 40 psi (276 kPa) downstream of an RP2 backflow preventer located at the most remote outlet. Potable water requirements for selected ship classes are defined in APPENDIX A. For ships not included in APPENDIX A use data from a similar ship or obtain the expected data from the cognizant Service.

3-4.1.2 Repair Berthing.

The potable water requirements are defined in APPENDIX A. Add the quantities indicated for each ship (including nested ships) and that total available on the pier. Base the peak rate of flow for sizing the main on providing the entire daily flow requirements defined in APPENDIX A, applied to all ships on a pier or wharf, at a constant flow rate, within an 8 hour period, and at a residual pressure of 40 psi (276 kPa) minimum at the furthest shore connections. It is noted that this data is based on 30 gpd/person (114 L/d/person).

3-4.1.3 Multiple Piers.

Determine total usage for multiple piers by summing daily flows for all ships at all piers or wharves assuming 30 gpd/person (114 L/d/person). Determine the peak-flow rate for multiple piers by summing peak-flow rates for all piers or wharves as determined by the method described above and then multiplied by a diversity factor of 0.75.

3-4.2 Piping System Design Criteria.

For piping materials and installation requirements, refer to UFC 3-230-01. Ductile iron is typically used for the main lines while PVC or copper is used for branch lines. For piping under a pier or wharf, evaluate the relative advantages of cement-lined ductile iron versus cement- lined steel pipe with an extruded polyethylene or polypropylene exterior coating. Provide an ultra violet inhibitor in polyethylene or polypropylene coatings exposed to sunlight. For coated pipe, use polyethylene, heat-shrinkable sleeves and/or tape wrapping at joints and fittings. Type of joint requires particular consideration. Provide pipe hangers and associated support assemblies in accordance with Section 2-4.1.4 entitled “Hangers and Support Assemblies”. Provide means of pipe movement due to thermal expansion, preferably by use of expansion loops or offsets. Also, provide for differential movement of piping at pier expansion joints. Consider effects of transients from water hammer.

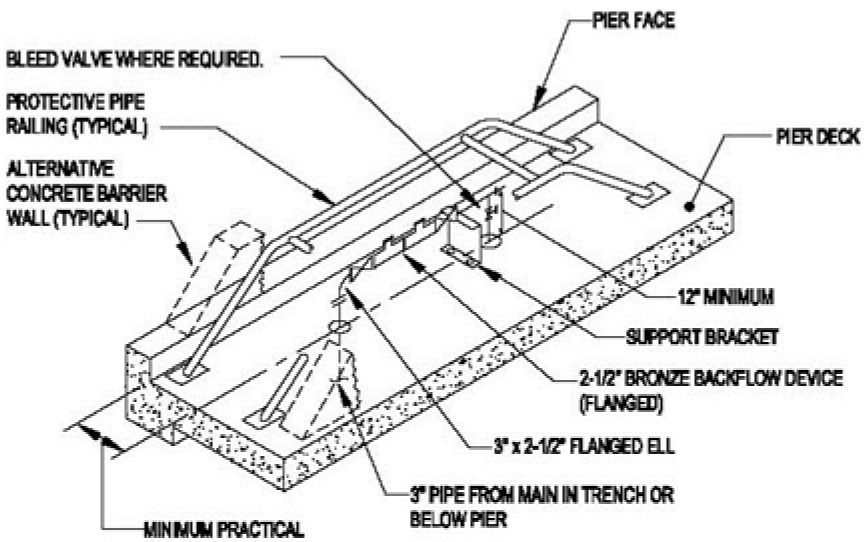
3-4.3 Location and Arrangement of Piping Mains.

As a general rule, provide a single water main with cross-branch piping to outlets for active berthing piers. For repair and submarine piers, provide piping mains on both sides of the pier with a cross connection at the outboard end of the pier (loop configuration), unless not feasible or practical on a submarine pier. Normally, it is more desirable to provide a looped main rather than an equivalent single main. Provide isolation valves at appropriate locations for reliability of service during emergency repairs. Coordinate piping with structural conditions and arrange mains for the best combination of versatility, security, and overall cost.

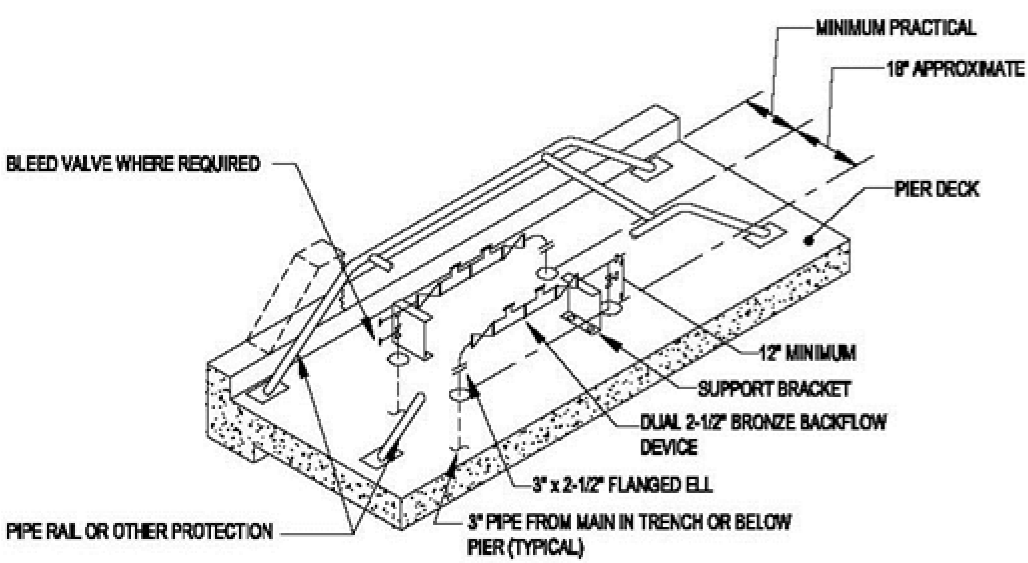
3-4.4 Piping and Outlets.

See Figure 3-7. Provide at least one 2-1/2 inch (64 mm) connection at each service outlet except as specified in Section 3-4.6 entitled “Specific Ship Requirements” for large ship requirements or where nesting is anticipated. Branch piping from mains to outlet risers should be not less than 2-1/2 inches (64 mm), and not less than 4 inches (102 mm) where dual 2-1/2 inch (64 mm) connections are fed by a common branch. Terminate shore connections with a 2-1/2 inch (64 mm) gate valve with hose threads (national hose threads) and a chained cap. Provide a reduced-pressure type backflow prevention device in accordance with UFC 3-230-01. Identify and color-code potable water outlets on piers and wharves in accordance with CHAPTER 5. If static pressure in supply mains is greater than 80 psi (552 kPa) for any portion of the day, then provide regulators set at 80 psi (552 kPa) maximum. All connections should be protected by a corrosion resistant chained cap, sized to properly support the weight of the cap on the chain for extended periods of time.

Figure 3-7 Typical Potable Water Outlet Assembly



SINGLE OUTLET



DUAL OUTLET

3-4.5 Location and Spacing of Outlets.

The pier locations of ships potable water connections may be determined by the data defined in APPENDIX A. Refer to CHAPTER 2 for a description of methods to be used in establishing shore-utility station spacing on piers and wharves.

3-4.6 Specific Ship Requirements.

3-4.6.1 CVN Ship Requirements (All Classes).

Design systems as specified above except provide a 4 inch (102 mm) branch line, a 4 inches (102 mm) reduced pressure backflow prevention device, and an outlet assembly at outlet locations 3 and 4 of Figure 3-6. Provide a 4 inch to 2-1/2 inch (102 mm to 64 mm) reducer for each location to allow the use of these outlets by ships other than carriers.

3-4.6.2 LHA and LHD.

Design systems as specified for CVN class ships except provide dual outlets at each utility connection group, one 4 inch (102 mm) reduced-pressure backflow prevention device, and an outlet assembly near the center of the berth. Provide a 4 to 2-1/2 inch (102 to 64 mm) reducer to allow use of the 4 inch (102 mm) outlet with other ships.

3-4.6.3 Additional Requirement for Nuclear Powered Ships.

A "pure" water supply as defined by NAVSEA is required for all nuclear-powered ships. Quantities for CVNs and submarines are 20,000 gpd (75,708 Lpd) and 10,000 gpd (37,854 Lpd) respectively. Applicable reference documents include MIL-STD-767, *Control of Hardware Cleanliness (NOFORN)* and MIL-STD-2041, *Control of Detrimental Materials (NOFORN)*. A project team will be established for pure water delivery systems for new projects. The project team (consisting of at least the cognizant Service project manager and a Shipyard pure water engineering representative) will agree on the pure water delivery system for new projects with NAVSEA 08 concurrence. Viable options include:

- At locations where there is an existing remote demineralized water plant of sufficient capacity, pure water can be produced from the demineralized water plant and processed through a polishing unit for either direct delivery to the ship via permanent piping system or delivered via pure water tanker delivery trailer.*
- At locations where there is neither an existing demineralized water plant nor one of sufficient capacity, pure water can be produced from a portable demineralizer unit processed through a portable polishing trailer for either direct delivery to the ship or delivered via pure water tanker delivery trailer.*

- At locations where usage quantities or berth arrangements dictate, design and construction of a pure water production plant and/or permanent piping delivery system may be considered.*

* NOTE: Final connections to the ship from either the trailers or the permanent piping system are made with hoses.

3-4.6.4 Submarine Pier Requirements.

Submarine piers/berths require both potable water and pure water. Provide permanently installed potable water system and pure water system at submarine piers/berths. See Section 3-4.6.3 entitled “Additional Requirement for Nuclear Powered Ships” for pure water requirements.

Where not feasible or practical to provide a permanently installed “pure” water system, a suitable solution that limits operational impacts must be developed and fully vetted through the various stakeholders to meet this utility requirement. Project team must document the variation in providing the utility, alternatives, mitigation measures, and resolution.

Preferred option is a permanently installed pure water system with an on-site pure water plant. But, this requires space for the production plant shoreside or remotely. Water quality and O&M are a concerns with this option. A less preferred option is permanently installed piping with connections for temporary pure water supply. But, this will require portable equipment or tanker truck. The least preferred option is to provide pure water directly to ship via pure water tanker. But, tanks and hoses take up deck space and interfere with operations.

3-4.7 Quality.

Refer to UFC 3-230-01. The quality of water must meet or exceed the requirements of 40 CFR, Part 141, *U.S. Environmental Protection Agency's National Primary Drinking Water Regulations*.

3-4.8 Metering.

Provide metering of potable water supply to piers or groups of piers unless instructed otherwise. See Section 2-5 entitled “Metering” in CHAPTER 2. Use compound-disc or magnetic-flow meters to achieve a high range of registration.

3-5 POL SYSTEMS.

Refer to UFC 3-460-01, *Design: Petroleum Fuel Facilities*. Fuel and lube oil connection locations on various ships are defined in APPENDIX A. Pier fueling connections and hoses must be kept a minimum of 25 ft (8 m) away from any possible ignition sources, such as pier power outlets, telephone terminal panels, and fire alarm equipment. Required POL connection sizes must be obtained from specific ship data available from NAVSEA. General requirements for pipe hangers and support assemblies (see Section

2-4.1.4 entitled "Hangers and Support Assemblies") and for metering (Section 2-5) are applicable. Identify POL outlets on piers and wharves and color-code in accordance with CHAPTER 5. POL piping systems also require special consideration for protective coatings and cathodic protection systems. See Section 2-4.4 entitled "Cathodic Protection Systems (CPS)". Refer to military specifications MIL-C-52404, *Connection Hose, Fire and Water* and MIL-S-12165, *Strainer Suction, Fire Hose, and Strainers, Suction, Hose* for POL connection types. Consult with the cognizant fire protection engineer, both at the local level and at the cognizant Service level.

3-6 OILY WASTE SYSTEMS.

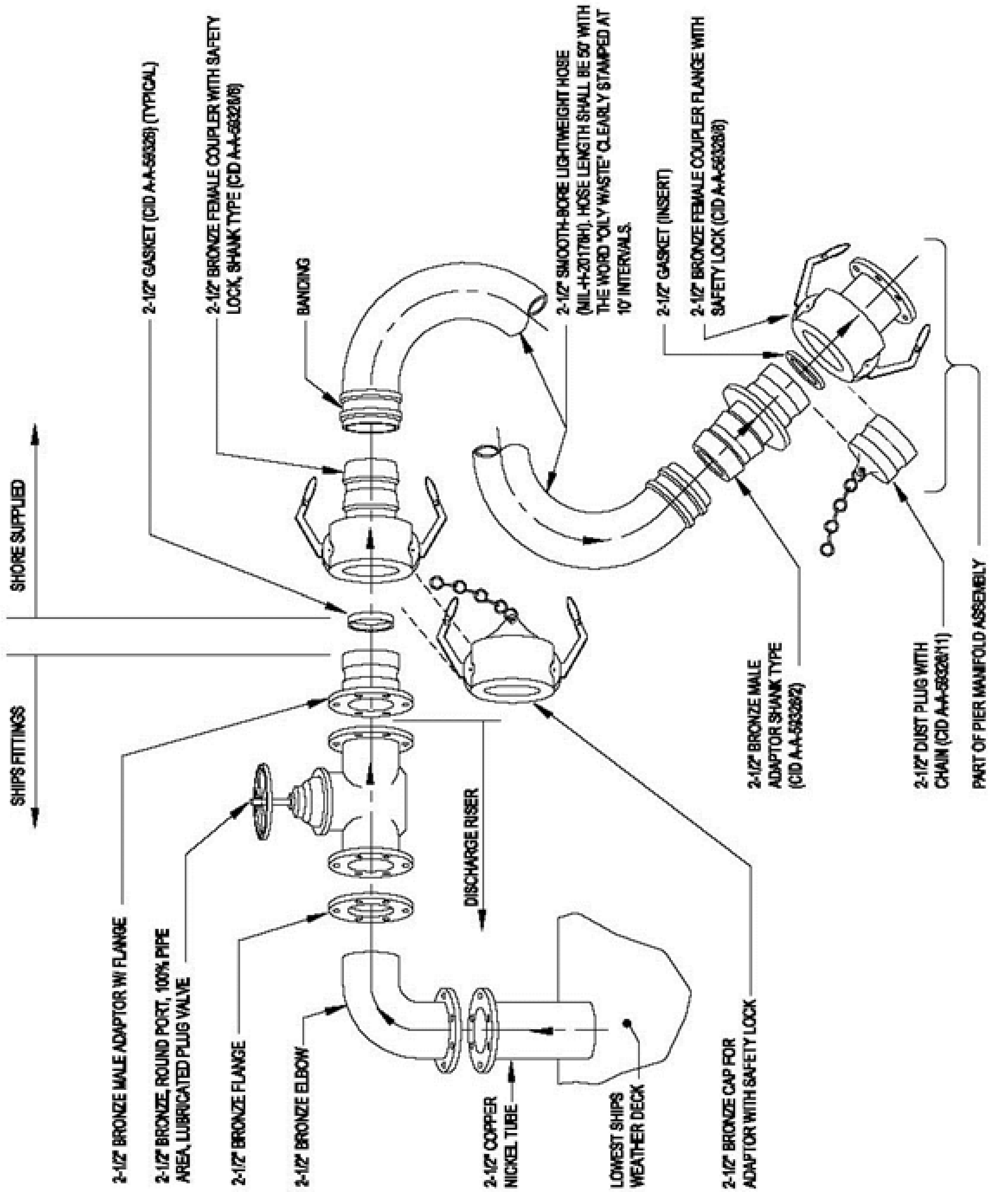
For typical ship-to-shore connection requirements, see Figure 3-8. Oily waste collection must be provided at all berths for 100 gpm (6.3 L/s). Oily waste system requirements for selected ship classes are defined in APPENDIX A. For ships not included in APPENDIX A, use data from a similar ship or obtain the expected demand from the cognizant Service.

The system is usually a fixed piping system. However, tanker truck or barges may be used for transient berths if allowed by the Activity. Ship waste oily barges (SWOB) should not be used at submarine berths due to potential hull damage. Provide a permanently installed oily waste collection system at submarine piers, see Section 3-6.6. Design ships oily waste (bilge water) systems in accordance with UFC 4-832-01N, *Industrial and Oily Wastewater Control*. Also, refer to *40 CFR, Part 1700, Uniform National Discharge Standards for Vessels of the Armed Forces*, and to *NAVSEA S9593-BF-DDT-010, Oil Pollution Abatement System* for ship design. Connection locations for ships oily waste are defined in APPENDIX A. Refer to CHAPTER 2 for a description of utility spacing requirements. In climates subject to freezing temperatures, oily waste lines must be properly protected. Refer to CHAPTER 5.

3-6.1 Pierside and Barge Collection of Shipboard Oily Waste.

Shipboard oily waste must not be directly discharged to public waters. In many cases it is unsuitable for discharge to a publicly owned treatment works (POTW). Requirements are: (1) provide full treatment to direct discharge standards; or (2) provide pretreatment to reduce pollutants to acceptable levels for municipal sewer discharge. Bilge wastes are normally the primary influent (both in volume and contaminant concentration) to an oily waste treatment system. Occasionally, compensating ballast water is discharged from ships and barges directly overboard. As of this writing, Puget Sound, Washington, activities are required by the local regulatory agencies to collect compensating ballast water during ship's refueling operations. This waste contains lower contaminant levels than bilge wastes but usually requires treatment before disposal. Lastly, the designer should refer to the Naval Facilities Engineering Service Center's (NFESC), *Bilge and Oily Wastewater Treatment System* as an alternative system for pollution prevention. Every project must be evaluated on a project-by-project basis. The designer must consult with the cognizant Service, the Activity, and the responsible Environmental Engineers, both at the local level and at the cognizant Service level.

Figure 3-8 Ship-to-Shore Oily Waste Hose Connection



3-6.2 Ship Oily Waste Generation.

Collection may take the form of transfer systems to trucks or barges, or a facility pipeline system. Coordinate with environmental requirements to provide an environmentally acceptable collection system with the most economical life cycle cost.

3-6.2.1 Oil Content.

Primary sources of ship-generated oily wastewater are bilges, oily waste holding tanks for collecting lubricating oils and water contaminated fuel, condensate lines, and tank cleaning water. Sonar dome pumping water is not normally collected as part of the oily waste collection system. The oil content in the bilge water normally varies from 100 ppm (0.01%) to 10,000 ppm (1.0%). The rest is mostly saltwater of unknown chloride content. The oil content of ship discharges overboard is limited to 20 ppm or less within 12 nautical miles of the nearest land. In ports that restrict the direct discharge of ballast water, the ballast water can be discharged from most ships (other than tankers) through a large diameter piping system to a ship waste oily barge (SWOB) or a YON Fuel Oil Barge. Compensating ballast water can also be discharged directly to a pier collection system provided the liquid can discharged by gravity flow (from ship to pier connection) and the back pressure can be kept to a minimum. The Navy policy on classification of oily wastewater is that the oily waste and waste oil (OWWO) become a waste only upon removal from the ship. In general, bilge water should be treated like any other waste.

3-6.3 Pumping Equipment.

Provide basket or bar type screens on a pump inlet that can be easily removed and cleaned from an easily accessible and safe location.

Determine pump capacity and operating cycle. In order to reduce mechanical formation of emulsion at oily waste treatment plants, use positive displacement pumps (in lieu of centrifugal pumps) with pressure relief valves. Pumps should pass solids having a diameter 0.125 inch (3 mm).

Provide controls suitable for Class I, Division 1, Group D hazardous classification. Use float or sonic type level controllers for pump control and alarm. Air bubbler type controllers must not be used. Provide a discharge pump control valve to minimize surge effects on equalization basins located at oily waste treatment plants. (This requirement is not applicable for positive displacement pumps.) Provide an alarm system for overflow or power failure. Provide manual override of automatic pump controllers. Low-level alarm conditions must lock out all pumps and must require manual resetting.

3-6.4 Piping Systems.

Piping requirements are similar to requirements for sewage systems. See Section 3-7 entitled “Sewage Systems” and the associated subparagraphs. Piping material is typically galvanized steel. However, some local environmental regulations require double-wall piping systems. Consult with the Activity and the cognizant Service.

Provide pipe hangers and associated support assemblies in accordance with Section 2-4.1.4 entitled “Hangers and Support Assemblies”. Identify oily waste outlets on piers and wharves and color-code in accordance with Chapter 6.

3-6.5 Metering.

Unless instructed otherwise, specify the following to monitor the system: (1) accumulating flow meter; (2) elapsed time meter for pumps and ventilator; and (3) pump suction and discharge pressure gages. Provide gages with oil-filled diaphragm and cutoff valves. Consult with the cognizant Service for any additional requirements. See Section 2-5 entitled “Metering” in CHAPTER 2 for additional metering requirements.

3-6.6 Submarine Pier Requirements.

Submarine piers/berths require an OWWO collection system. Provide a permanently installed OWWO system at submarine piers/berths.

Where not feasible or practical to provide a permanently installed OWWO utility system, a suitable solution that limits operational impacts must be developed and fully vetted through the various stakeholders to meet this utility requirement. Project team must document the variation in providing the utility, alternatives, mitigation measures, and resolution.

Preferred option is a permanently installed system connected to an on-base collection system. But, this requires a base treatment or collection and transfer facility. A less preferred option is permanently installed piping with connections for tanker truck transfer. But, this may infringe on deck and shoreside space. The least preferred option is to provide OWWO collection directly from pier to a tanker truck, but tanker truck and hoses will take up deck space and interfere with operations.

3-7 SEWAGE SYSTEMS.

3-7.1 Introduction.

Design information on wastewater collection and transmission systems is extensively covered in Water Environment Federation (WEF) MOP FD-5, *Gravity Sanitary Sewer Design and Construction*. This section addresses two wastewater collection and transmission topics that are not addressed in WEF MOP FD-5: (1) pier and wharf facilities; and (2) dry dock facilities.

3-7.2 Specialized Shipboard Sewage Characteristics and Parameters.

Designing sewage collection systems for shipboard wastewater requires special and unique conditions that the designer must take into account. All of these special issues must be addressed and resolved.

3-7.2.1 Characteristics of Ship Holding Tank Discharges.

Ship holding tank discharges can be a major source of wastewater. These wastewaters have the following general characteristics.

- A ship's wastewater is primarily domestic wastewater but may also contain industrial wastewater depending on the ship operations.
- A ship's wastewater is more concentrated than typical domestic wastewater, a result of specific design features of the ship's wastewater collection systems.
- A ship's wastewater may contain high concentrations of dissolved solids, chloride, sulfates, and sodium if seawater flushing or ballast systems are used.

3-7.2.2 Ship Discharge Values.

APPENDIX A defines the maximum sewage discharge values of a ship's complement, daily flow, maximum discharge, number of pumping stations, total number of pumps, and number and location of discharge connections. Where destroyers or submarines are nested next to a tender berthed at a pier, the nested ships will discharge into the tender. The tender will then discharge to the pier's sewage collection system at the rate listed for the tender. For nested ships, it is suggested to provide a pressure manifold to reduce peak demand flow.

3-7.2.3 Flow Rate Variations.

Domestic wastewater flows at piers, wharves, and dry docks can be expected to exhibit seasonal and other weather-influenced flow variations. In addition, the effect of industrial and ship discharge flows as well as the variable nature of military operations may significantly affect flow variations. To minimize flow variations, flow equalization should be considered. Equalization can be applied to specific flows (such as industrial flows or other specialized flow types) that exhibit wide variations to the entire wastewater flow. When calculating flows, consider the following.

- Industrial flows, such as vehicle and aircraft wash facilities. If these flows coincide with peak domestic flows, then they should be added to the peak flows.
- Ship holding tank discharge flows. Flow rates will depend on the total volume of flow and the time required to convey the wastewater to the treatment facility. Design equalization systems to equalize the flows in order to minimize their effects on peak flows. Consider conveying the ship wastewaters to the treatment facility at night when domestic flows are low.
- Intermittent flows due to military functions. Periods of increased sewage flows will occur because of training activities or other personnel mobilization exercises common to military installations. Training activities

or other mobilization exercises will create short-term increases in domestic wastewater and possibly industrial flows. These intermittent activities may create the peak wastewater flow rate. Design the sewage collection system to handle routine variations in flow resulting from training and other routine military exercises. The design must ensure acceptable performance with reasonable operational costs. (For example, an equalization system may provide flow and load dampening to accommodate these significant variations.) However, do not design facilities to accommodate peak surges resulting from emergency military mobilizations.

- Intermittent periods of reduced use. Low flows can also be a problem. Therefore, design the wastewater facility to operate efficiently over a range of flows. (For example, provide parallel trains that can be taken out of service.)
- Changes in requirements or military mission. Designs should include provisions for the system's expansion and contraction as well as system modifications due to more stringent effluent requirements or military mission changes. In general, maximize operational flexibility.

3-7.2.4 Wastewater Loadings.

Wastewater loadings are typically calculated based on the projected flows and wastewater pollutant concentrations and are expressed in pounds per day (lb/d) (kilograms per day (kg/d)). Where possible, determine loadings by analyzing the wastewater to be treated. Consult with the Activity and the cognizant Service to obtain collected data and specific instructions.

3-7.2.5 Ship Sewage.

Ship sewage settles well and is amenable to biological treatment, but it may be septic. Table 3-4, "Typical Ship Sewage Concentrations", define typical concentration values. Wastes from shipboard industrial activities are not included. High dissolved solids, chloride, sulfates, and sodium concentrations apply when seawater flushing or ballast systems are used. For more information on ship sewage, refer to *NAVSEA S9086-AB-ROM-010, Naval Ship's Technical Manual (NSTM), Chapter 593, Pollution Control*.

3-7.2.6 Effect of Wastewaters with High Seawater Content.

- <u>Performance:</u> High concentrations of seawater tend to inhibit biological treatment. Process inhibition is related to the chloride concentration of the wastewater.
    - o For new designs: Currently, there is an absence of pilot plant data or treatment data from similar wastewaters. Consequently, compensate for high seawater content according to the data presented in Table 3-4.

- In analyzing the capacity of existing treatment facilities to receive ship's wastewater, use figures defined in Table 3-5. If these indicate overloading solely because of chloride inhibition, conduct pilot plant tests before planning any expansion. Consult with the Activity and the cognizant Service for instructions.
- Sudden changes in chloride concentration may upset biological processes. Consider equalization storage to limit chloride variation at the wastewater facility. For chloride concentrations in excess of 5,000 mg/L, provide design limitations of 200 mg/L/h.

- Maintenance: High seawater content in wastewater will aggravate incrustation problems. Avoid fine bubble air diffusion systems and design orifices to facilitate periodic cleaning of mineral deposits. This is especially applicable to orifices in trickling filter flow distributors or in aeration devices. Use care in selecting construction and equipment materials.

Table 3-4 Typical Ship Sewage Concentrations

Characteristic	Concentration (mg/L)
Total suspended solids	600
Total dissolved solids	20,000
Chlorides	11,000
Sulfates	1,500
Sodium	6,200
Other dissolved solids	1,300
Biochemical oxygen demand (BOD)	400

Table 3-5 Chloride Inhibition of Biological Nitrification

Process	Maximum Chloride Concentration for No Inhibition (mg/L)	Concentration for Chlorides in Excess of Maximum Level [a]
Trickling filters and rotating biological contactors	5,000	Referring to appropriate design loading curve, decrease loading an amount corresponding to one percentage point of removal efficiency per 1,000 mg/L of chlorides in excess of 5,000 mg/L
Activated sludge	5,000	Decrease loading by 2% per 1,000 mg/L chlorides in excess of 5,000 mg/L
Aerobic and facultative lagoons	8,000	Increase detention time by 2% per 1,000 mg/L chlorides in excess of 8,000 mg/L

Note:

[a] Highest average chloride concentration expected over 24 hours.

3-7.3 Pier and Wharf Systems.

Provide a permanently installed sewage collection system at all active berths. Design the ship sewage collection system for the peak flow from the maximum planned berthing with sewer flowing full. Base the design on maximum discharge of ship pumps. Provide a gravity flow system unless approved otherwise.

3-7.3.1 Layout/Location.

See Figure 3-9. Provide a single (1) 4 inch (102 mm) pressure rated manifold assembly at each berth. Each manifold assembly should have four (4) single (1) 4 inch (102 mm) diameter pressure sewer connectors. This layout has the following advantages:

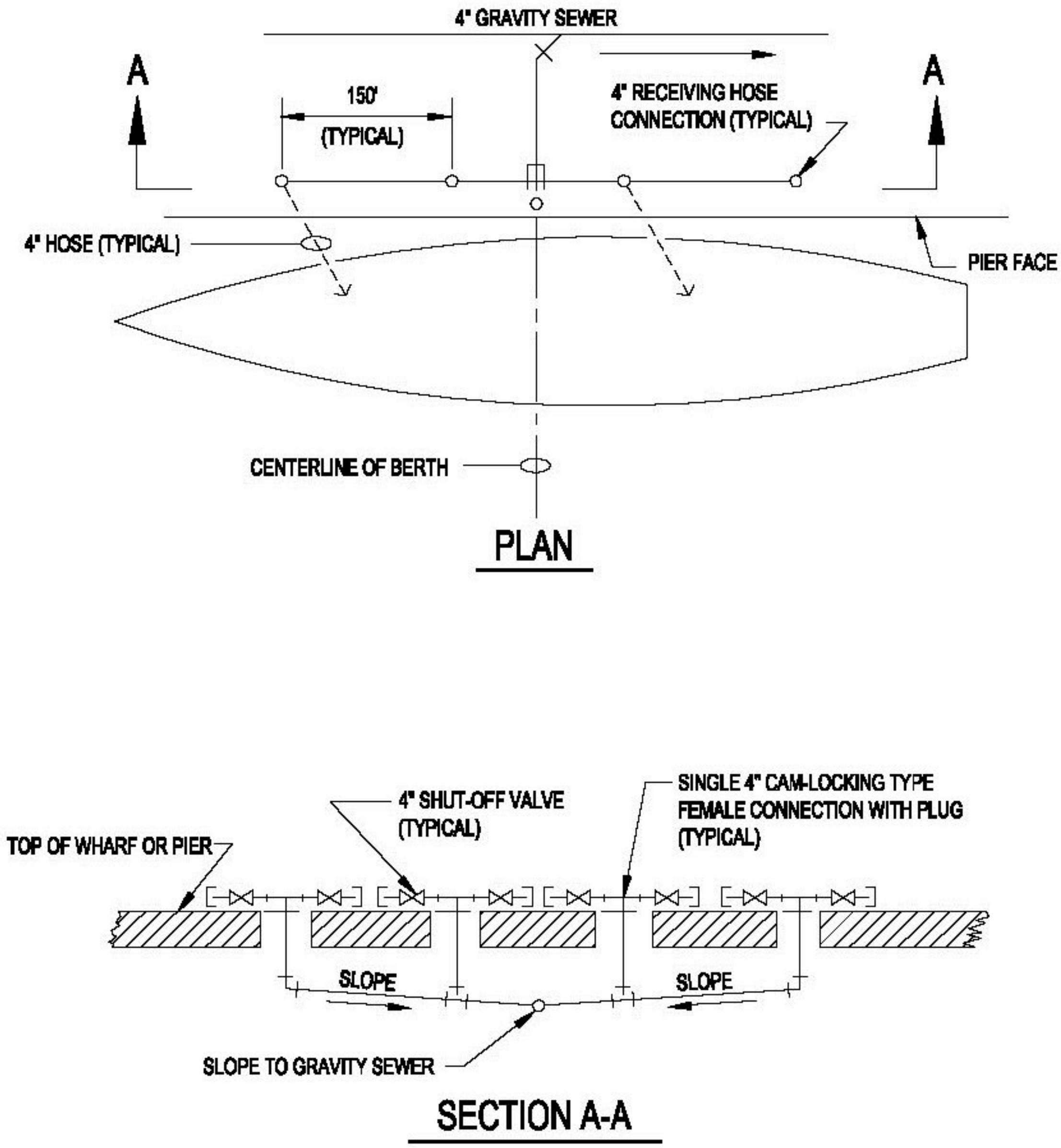
- It provides large reduction in peak flows by combining multiple discharges from a ship (or nested ships) into a single stream, thereby increasing the head on the ship's pumps.
- By reducing peak flow, it allows berthing of other ship types included in the berthing plan.
- It is self-regulating and self-cleaning plus avoids failure or maintenance problems inherent in regulating valves or other similar devices.

3-7.3.2 Additional Requirements.

See Figure 3-10 for typical collection sewer layouts on different pier types. Properly isolate each berthing space in order to prevent pumping from one berth into another and to allow ships with lower head pumps to discharge into the pier sewer.

Isolate the berths by providing one separate manifold assembly at each berth and then connect the manifold assembly directly to the pier's gravity sewer system. Where the berthing space is less than 600 ft (183 m), the number of manifold assemblies should be reduced to fit the space available. In such cases, it may be necessary to reduce the 150 ft (46 m) spacing between the assemblies. For carrier berths, two (2) standard manifold assemblies each with four (4) 4 inch (102 mm) outlet connectors should be provided.

Figure 3-9 Pressure Manifold Schematic for Pier and Wharf Systems



NOTE: DESIGN RECEIVING HOSE CONNECTIONS FOR 3000LB PULL IN ANY DIRECTION.

Figure 3-10 (a) Sewer Layout for Alternative Pier Types (1 of 2)

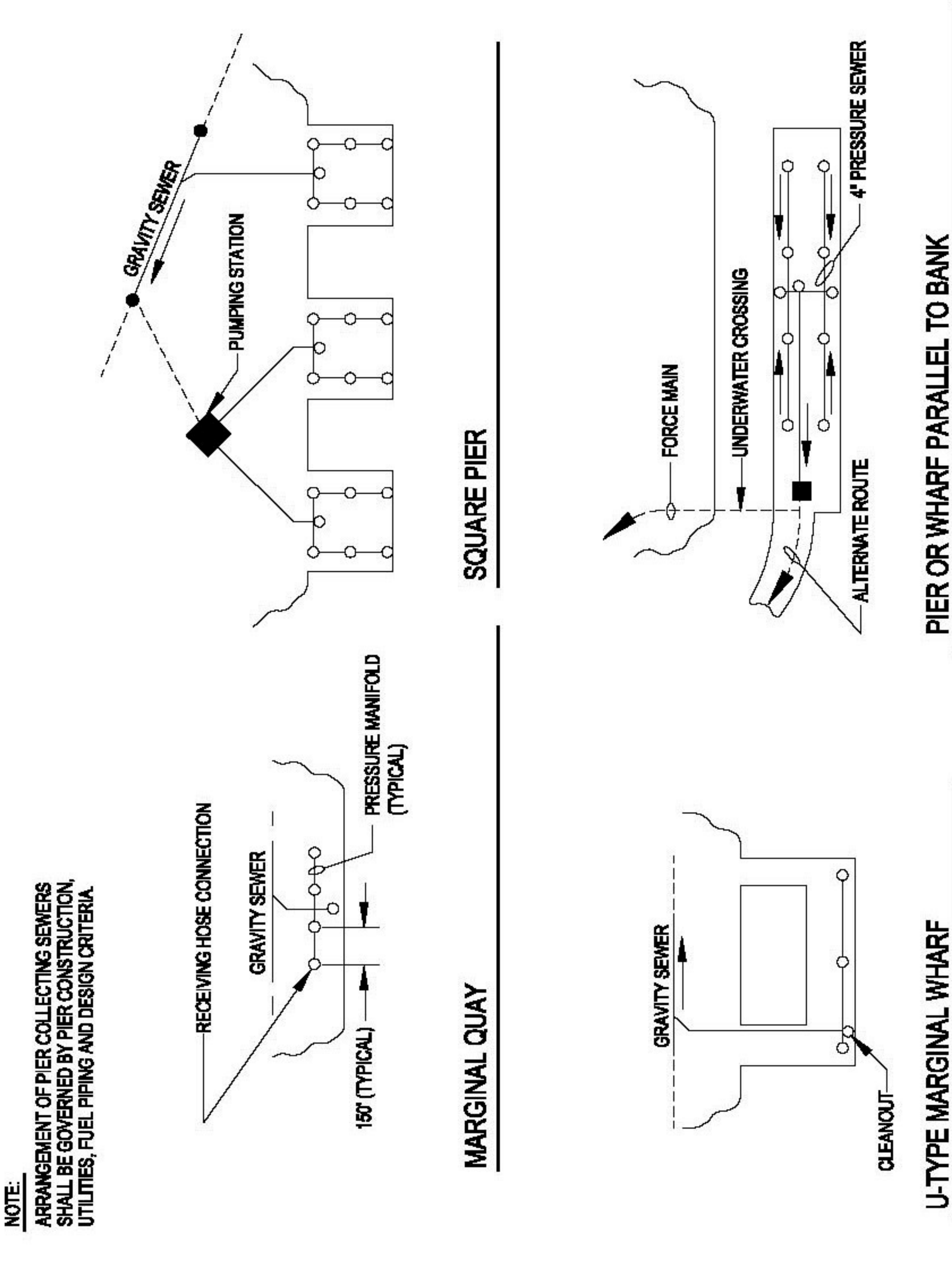
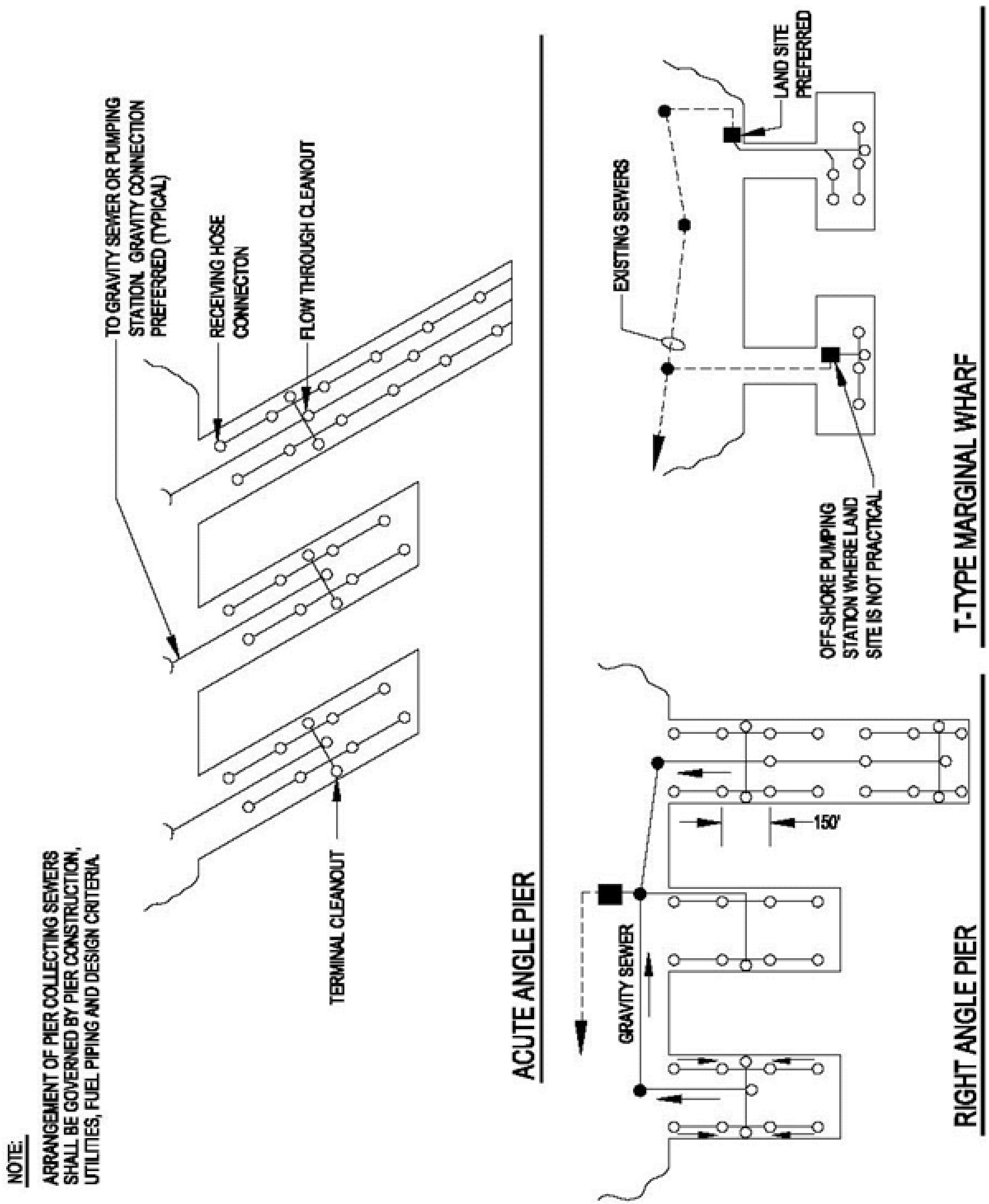


Figure 3-10 (b) Sewer Layout for Alternative Pier Types (2 of 2)



3-7.3.3 Location Details.

See Figure 3-11 and Figure 3-12 for typical installation on piers and quay walls. Locate all collecting sewers behind the permanent wharf or pier construction and away from the fender systems. Locate pump stations off the pier and behind the bulkhead lines. If location along the pier deck is required, then do not restrict working area on the pier. Lines behind wharves should always be buried. For design of new piers and quay walls, consider locating sewers in utility tunnels. This arrangement will reduce external corrosion and improved maintainability of the sewer lines, and thus may offset higher construction costs.

3-7.3.4 Environmental Considerations (Corrosion and Freeze Protection).

- Evaluate paint and finish requirements. See Section 2-6 entitled “Paint and Finish Requirements”. For ship to shore sewer connections (including ductile iron sewer pipe and all exposed metal such as steel support members, gratings, angles, pipe support hangers, fastening devices, and other appurtenances) it is generally recommended to provide a two coat, coal tar epoxy coating, conforming to Steel Structures Painting Council (SSPC) Paint No. 16. Specify a total dry film thickness of 16 mils (0.4 mm) minimum.
- Evaluate freeze protection requirements. See Figure 3-13. Pipes installed under piers or wharves in any geographic location must be protected from wave action and floating objects. Provide protective jacketing of the insulation using aluminum, stainless steel, or coal tar epoxy coated steel where freeze protection is required. Provide structural protection for the entire length of pipe run in addition to jacketing. Use steel cage of fabricated shapes or consider the use of a catwalk system that would provide both access and piping protection. Specialized freeze protection features are defined in CHAPTER 5.

3-7.3.5 Odor/Septicity Control.

Slope sewer pipes as much as possible to minimize detention time. Provide aeration in accordance with sound engineering practices. Holding tanks must be aerated unless detention time is less than 3 hours at average 24-hour flow. Keep force mains as short as possible and avoid sulfide generation. Control sulfide generation by using an injection of oxidizing chemicals such as chlorine, permanganate, or hydrogen peroxide. Consult suppliers of chemicals feed equipment regarding costs and expected performance. Refer to WEF MOP FD 5, Gravity Sanitary Sewer Design and Construction, for rational methods to predict sulfide generation rates and methods of control. Maintain minimum flow velocity of 3 ft/s (0.9 m/s). Provide cleanouts and air relief valves at strategic and accessible locations. Provide check valves at pump stations.

Figure 3-11 (a) Typical Sewage Collection Facilities (1 of 2)

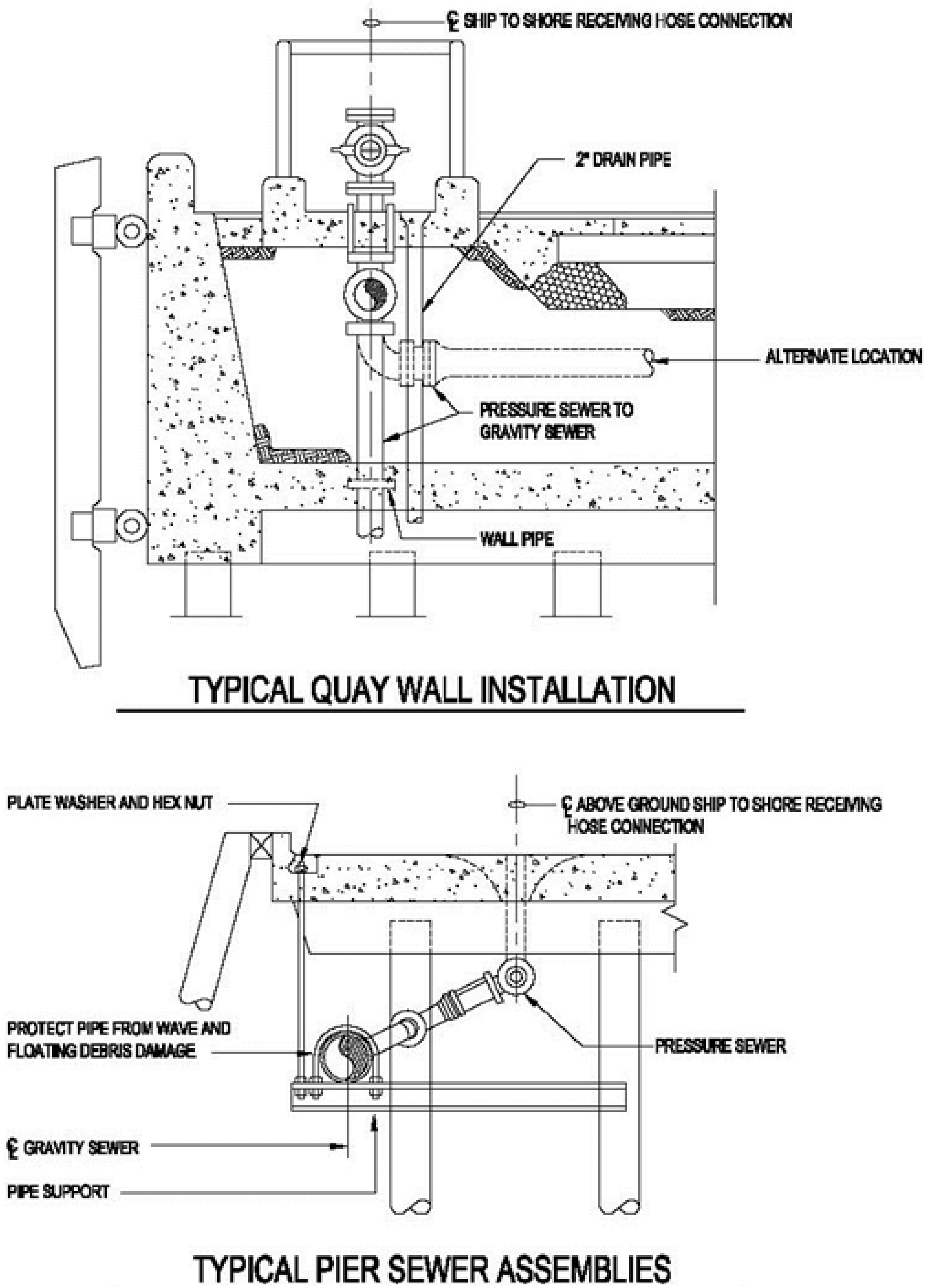
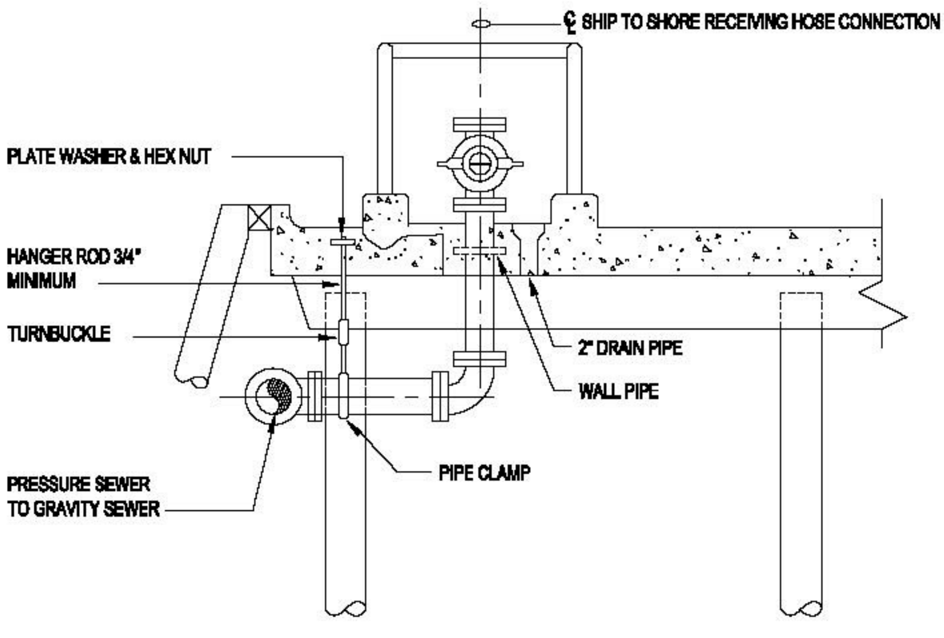
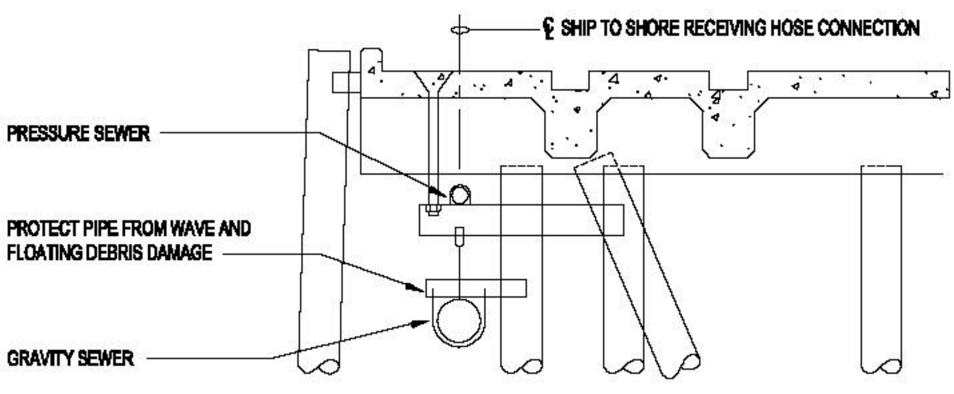


Figure 3-11 (b) Typical Sewage Collection Facilities (2 of 2)



ALTERNATE PIER SEWER ASSEMBLY



TYPE (2) PIER

Figure 3-12 (a) Details for Sewage Collection Facilities (1 of 2)

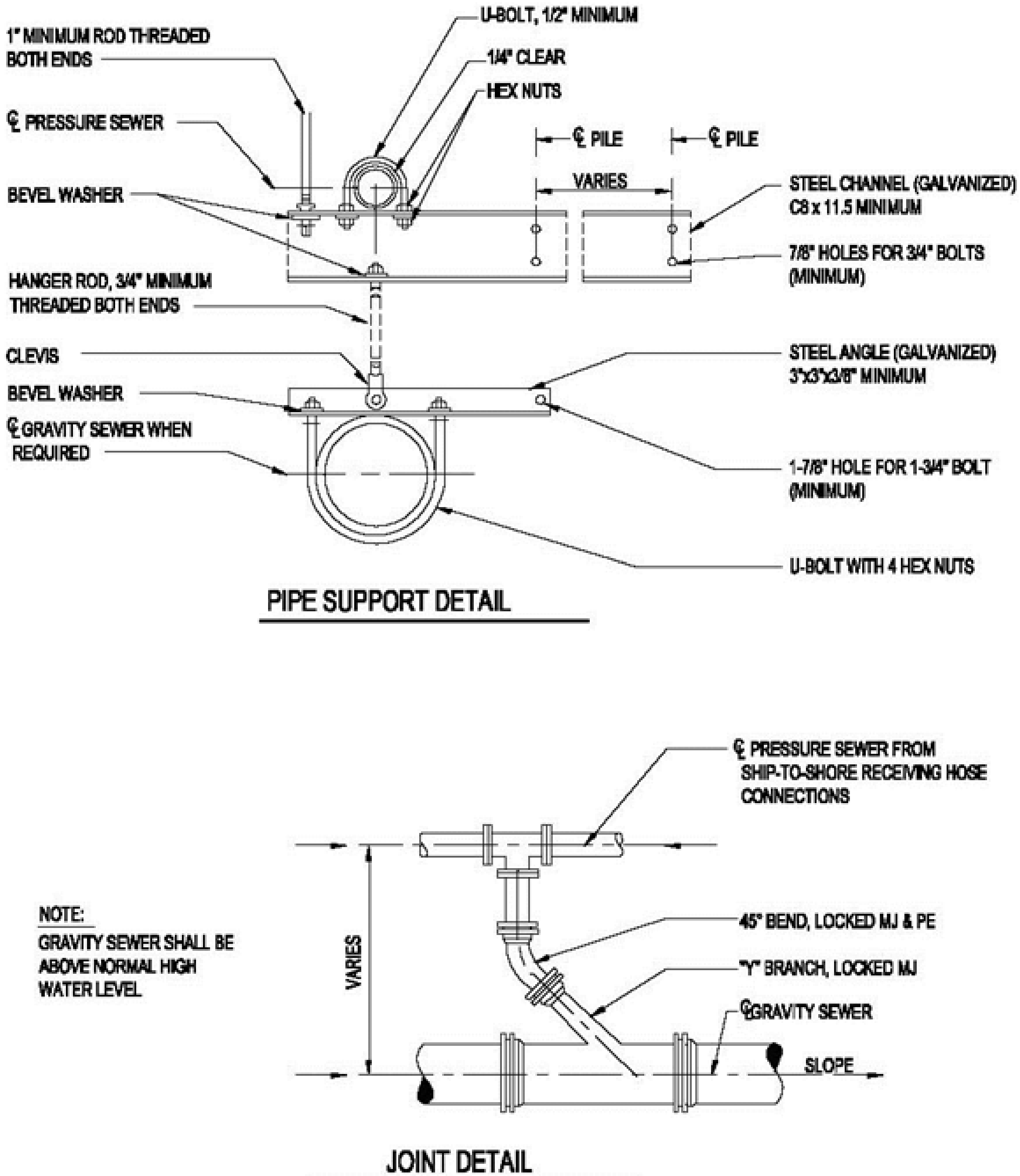
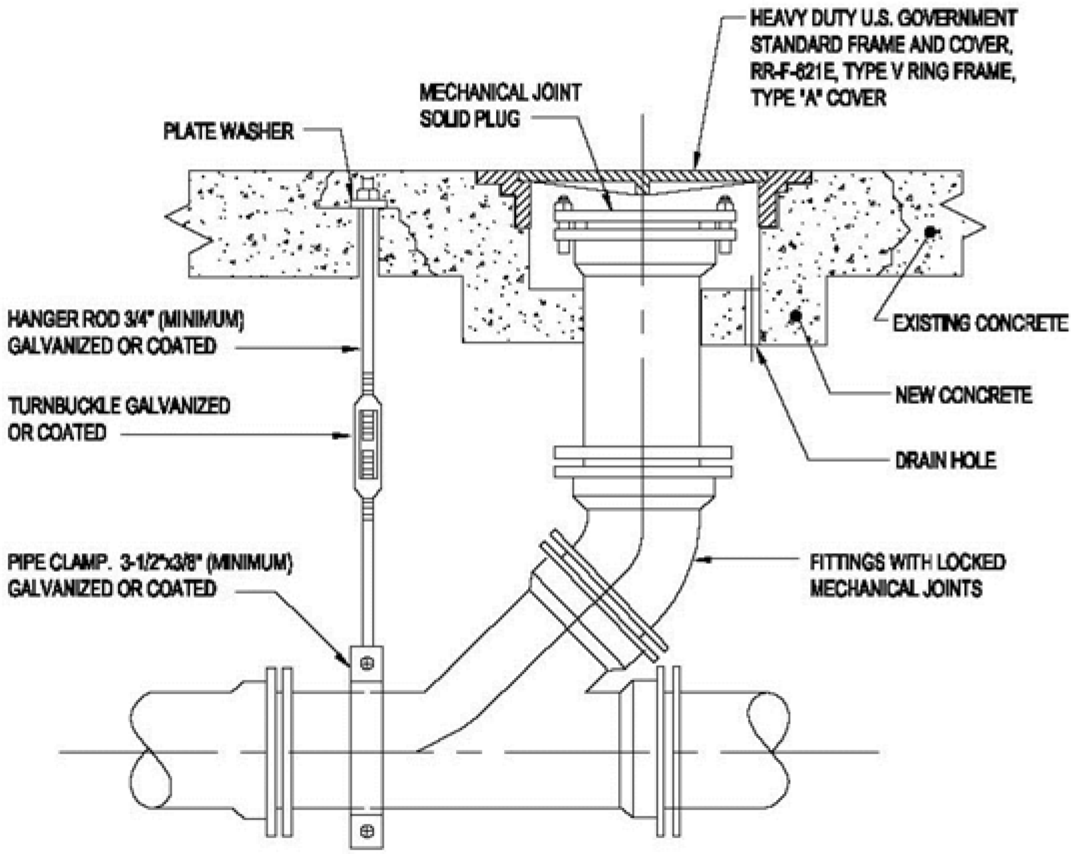


Figure 3-12 (b) Details of Sewage Collection Facilities (2 of 2)



FLOW THROUGH CLEANOUT DETAIL

CONCRETE DECK INSTALLATION

CLEANOUT SPACING

400' MAXIMUM FOR PIPES 15" & SMALLER

500' MAXIMUM FOR PIPES 18" & LARGER

NOTE:

FOR TERMINAL CLEANOUT USE 90° ELBOW IN PLACE OF LATERAL.

Figure 3-13 (a) Piping Details for Sewage Collection Facilities (1 of 2)

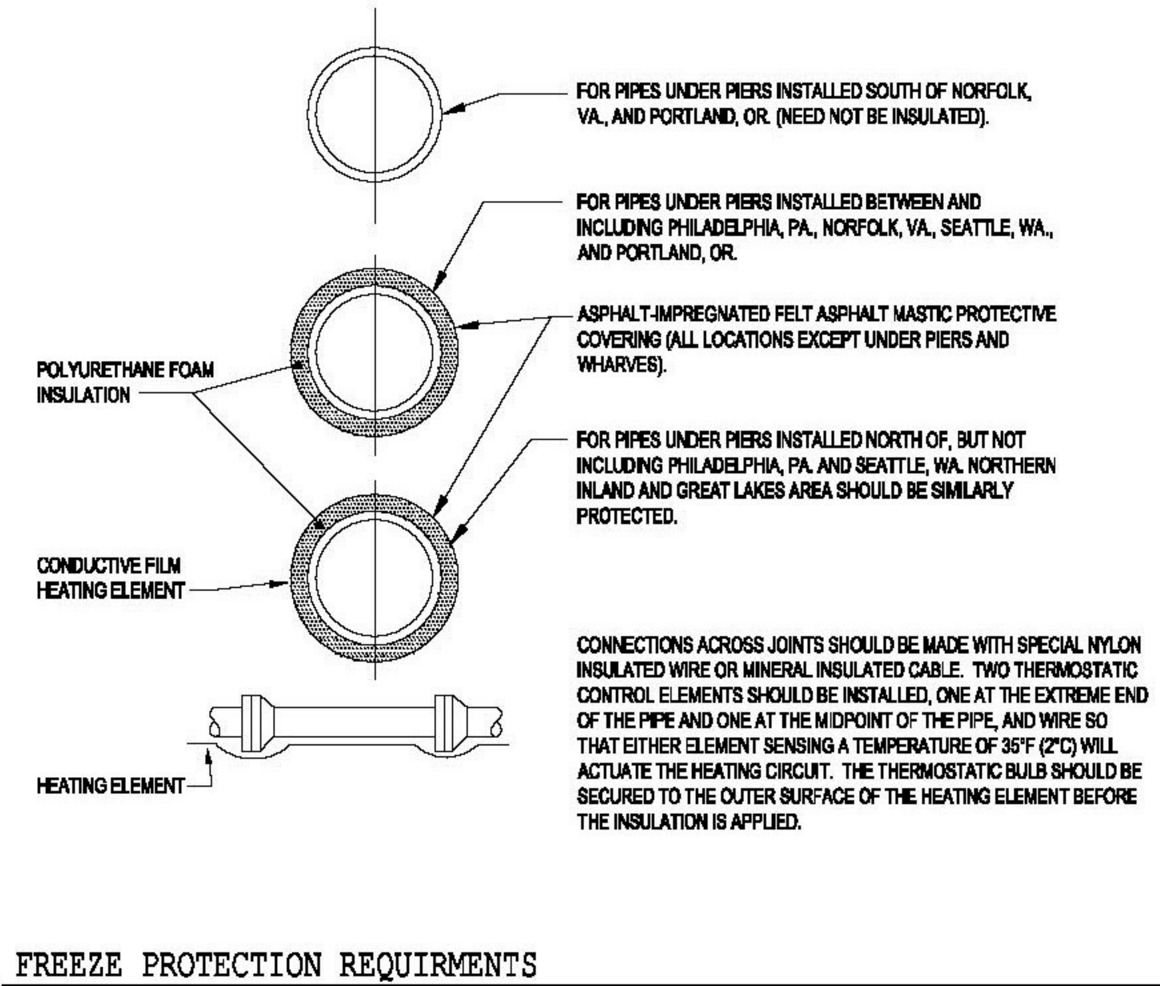
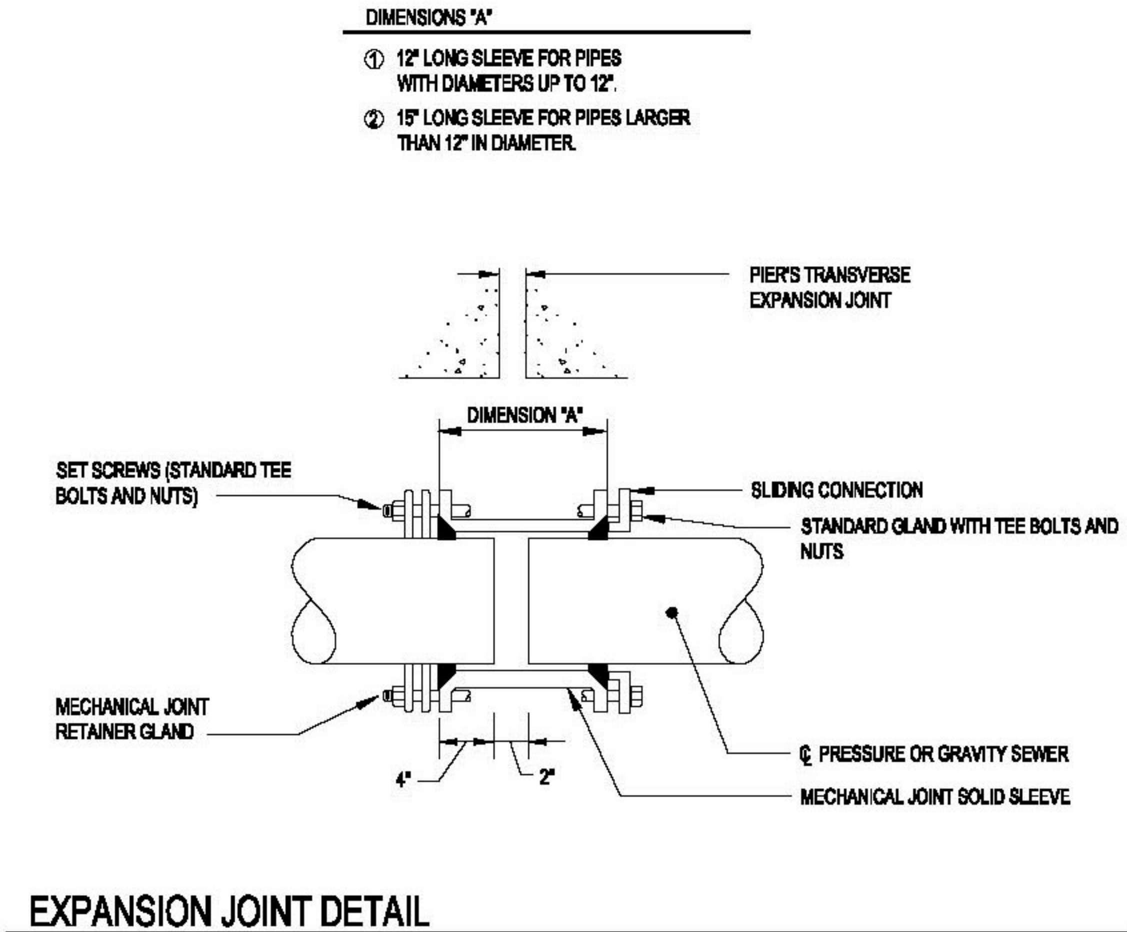


Figure 3-13 (b) Piping Details for Sewage Collection Facilities (2 of 2)



3-7.3.6 Structures and Appurtenances.

Some sewer structures and appurtenances have already been defined in Figure 3-11, Figure 3-12, and Figure 3-13. Additional features are defined in Figure 3-14, and Figure 3-15. Also, see Table 3-6.

3-7.3.7 Pump Stations.

The design of sewage pump stations at waterfront facilities requires the careful consideration of all associated parameters including the premium value of real estate. The system must account for all ship flows and the connection to the station's central sewage distribution system. Careful coordination is required with the Activity and the cognizant Service. It is imperative to provide a properly operational system at minimum construction cost and operational cost while optimizing the use of waterfront property.

3-7.3.8 Pipe.

A variety of pipe materials may be acceptable to specify and will vary on a pier-by-pier basis. Consult with the Activity and the cognizant Service for the final material selection. In general, PVC pipe may be used for gravity systems. Ductile iron pipe is preferred for pressurized systems. However, PVC pipe and HDPE pipe has been specified for pressurized systems at some pier facilities. Lined ductile iron with mechanical joints should be used for exposed locations and where high impact resistance is important. Support exposed pipe in accordance with manufacturer’s recommendations. In other exposed locations where corrosion resistance is a major concern, consider specifying thermoplastic (high density polyethylene) pressure pipe with butt fusion joints. Plastic piping on pier and wharf systems should be protected from impact by floating debris and other hazards. In these cases, consider a specially designed utility trench. For buried lines, apply general sewer pipe selection guidelines.

Figure 3-14 Ship-to-Shore Sewage Hose Components

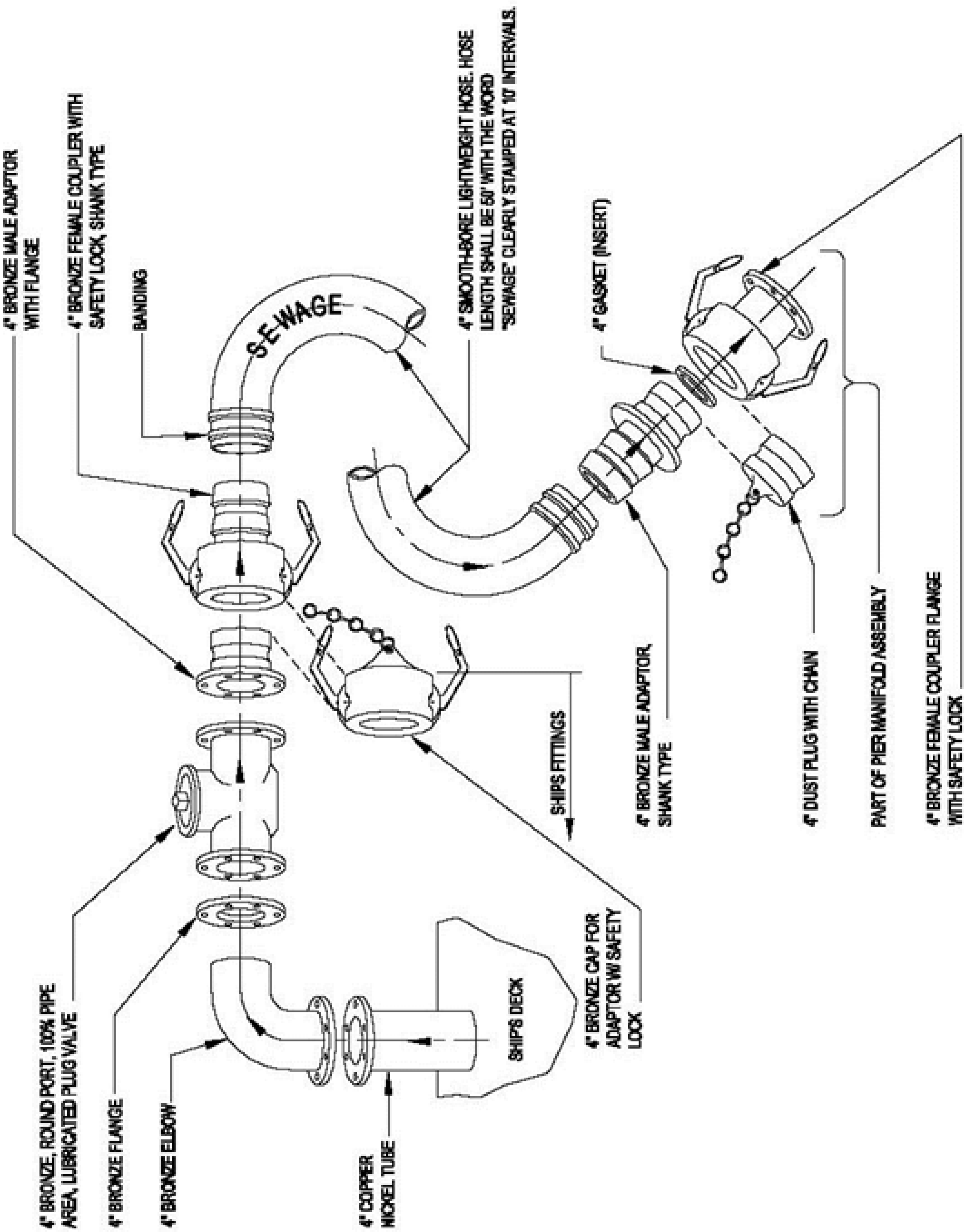


Figure 3-15 Above Pier Hose Connection

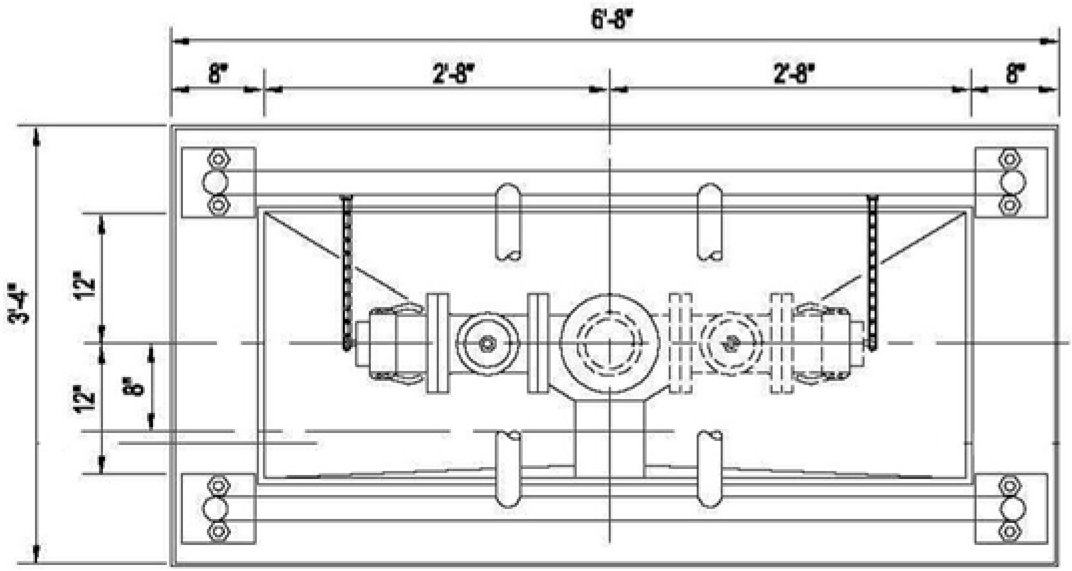


Table 3-6 Special Pier Structures and Appurtenances

Structure or Appurtenance	Where To Use	Details	Requirements
In-line Cleanout	Note 1	See Figure 3-12	
Regular Manhole	Note 2	Refer to UFGS 33 30 00, *Sanitary Sewerage*	Note 3
Drop Manhole	Note 4	Refer to UFGS 33 30 00, *Sanitary Sewerage*	Note 5
Siphons	Note 6	Note 7	Note 8
Intercepting Sewers	Note 9		Note 10
Traps and Interceptors	Note 11	Note 12	
Terminal Cleanout	Note 13	See Figure 3-12	Note 14
Receiving Hose Connections		See Figure 3-14 & Figure 3-15	Note 15
Sewer Pipe Supports	Note 16	See Figure 3-11 & Figure 3-13	

Note:

1. Use in-line cleanout at junctions and changes of direction and when required according to spacing shown in details under regular manhole below.
2. Use regular manhole: terminally on all lines; at all junctions and changes of direction; at changes in invert elevation or slope. Otherwise, according to spacing shown below:

Pipe Size inch (mm)	Maximum Spacing ft (m)
18 (450) or less	400 (120)
18-48 (450-1200)	500 (150)
48 (1200) and greater	600 (180)

3. Requirements for regular manholes: lower invert through manhole a distance equal to expected loss of head in manhole, plus 0.8 times any change in sewer size. For junction manholes, check which upstream invert is critical in determining outlet invert. Raise top of manhole above possible flooding level.
4. Use drop manhole when difference between inlet and outlet inverts exceed 2 ft (0.6 m).
5. Requirements for drop manholes: for difference less than 2 ft (0.6 m), increase upstream sewer slope to eliminate drop.
6. Use siphons for carrying sewers under obstructions or waterways.
7. For siphons: maintain velocity of 3 fps (0.9 m/s). Use no less than two barrels with minimum pipe size of 6 inches (150 mm). Provide for convenient flushing and maintenance.
8. Requirements for siphons: use WEF MOP FD-5 for hydraulic design.
9. Use intercepting sewers where discharge of existing sewers must be brought to a new concentration point.

10. Requirements for intercepting sewers: take special care against infiltration due to depth or proximity of surface water.
11. Use traps and interceptors on all outlets from subsistence buildings, garages, mechanical shops, wash pits, and other points where grease or oil can enter the system.
12. For traps and interceptors: use a displacement velocity of 0.05 fps (0.015 m/s). Grease removal: in absence of other data use 300 to 400 mg/L. Provide for storage of 1 week's grease production (1 day if continuous removal is provided). Length = twice depth.
13. Use terminal cleanouts terminally on all pier collection systems.
14. Requirements for terminal cleanouts: locate where it will not interfere with other operations on the pier or other utilities.
15. Requirements for receiving hose connections: design connections to receive the discharge from ships.
16. Properly support all sewer pipes, especially pipes located under the pier. See Section 2-4.1.3 entitled “Hangers and Support Assemblies”.

3-7.3.9 Sewage Transfer Hoses.

See Figure 3-14 and Figure 3-15. Provide a washing facility for washing the end couplings and the exterior of the hose. The facility should include hot potable water and a standard stock detergent. Hose washing/storage facilities must be designed so that manual lifting or pulling of hoses is minimized through the use of mechanical devices and/or arrangement of the area. Caps for each end of the hose should be provided and installed after washing. The clean hose should be stored in drying racks.   For further information, refer to NAVFAC MO-340, *Ship-to-Shore Hose Handling Operations Manual*.

3-7.4 Dry Dock Facilities.

For dry dock facilities, design the sewage collection system for the maximum planned docking pattern and the designed peak flow conditions. Consider the following when designing dry dock collection systems.

- Separation of hydrostatic leakage from dry dock wastewater: The dry dock wastewater is generally not contaminated and can be discharged directly to storm sewers or open water depending on regulatory conditions.
- Separation of ship's domestic wastes from the industrial wastes generated by dry dock activities: These industrial wastes include leakage, precipitation runoff, and washdown that carries sandblasting residue and paint.

3-7.4.2 Layout.

Ships fitted with collection-holding-transfer (CHT) should be connected to dockside sanitary sewers for CHT discharge. Ships without CHT should use scuppers and manifold connections to the ship's discharge points and then transfer to the sanitary sewer system. See Figure 3-16 for typical collection system layouts in dry dock facilities.

3-7.4.3 Pump Station Features.

Make capacity equal to that of maximum combined ship's discharge rate of ships in dry dock. Furnish portable auxiliary pumping facilities when required. Refer to UFC 4-213-10.

3-7.4.4 Sewage Receiving Connections and Transfer Hoses.

See Figure 3-17 for underground dry dock receiving hose connections. Figure 3-15 is also applicable for aboveground dry dock receiving hose connections. Aboveground receiving hose connections should be used whenever possible. See Section 3-7.3.9 entitled "Sewage Transfer Hoses" regarding transfer hoses.

3-7.4.5 Special Structures and Appurtenances.

See Figure 3-16 for typical cleanout locations for dry dock sewers. Locate cleanouts in main sewer at a maximum spacing of 300 ft (91 m).

Figure 3-16 (a) Typical Sewage System Layouts for Dry Dock Facilities (1 of 2)

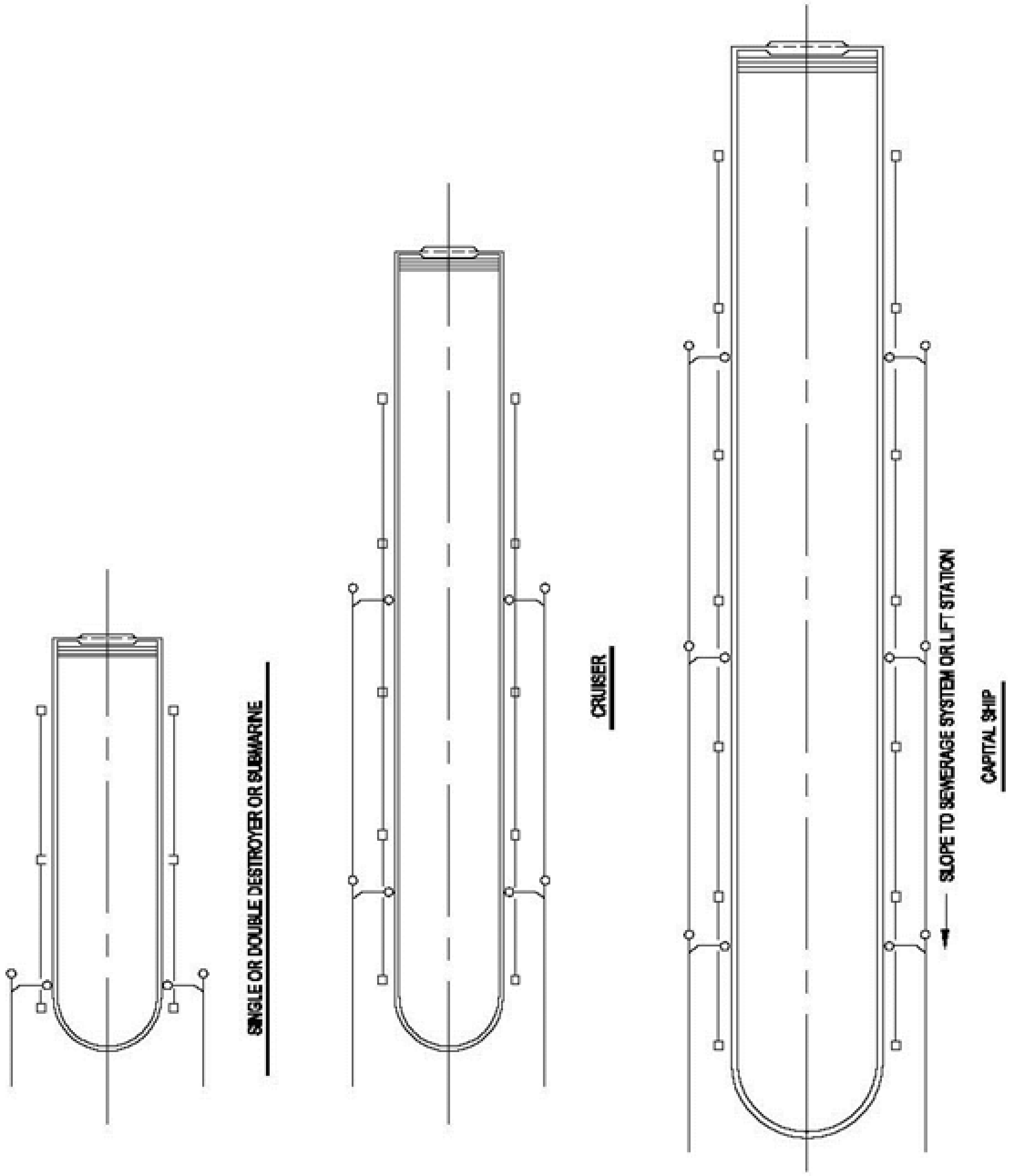


Figure 3-16 (b) Typical Sewage System Layouts for Dry Dock Facilities (2 of 2)

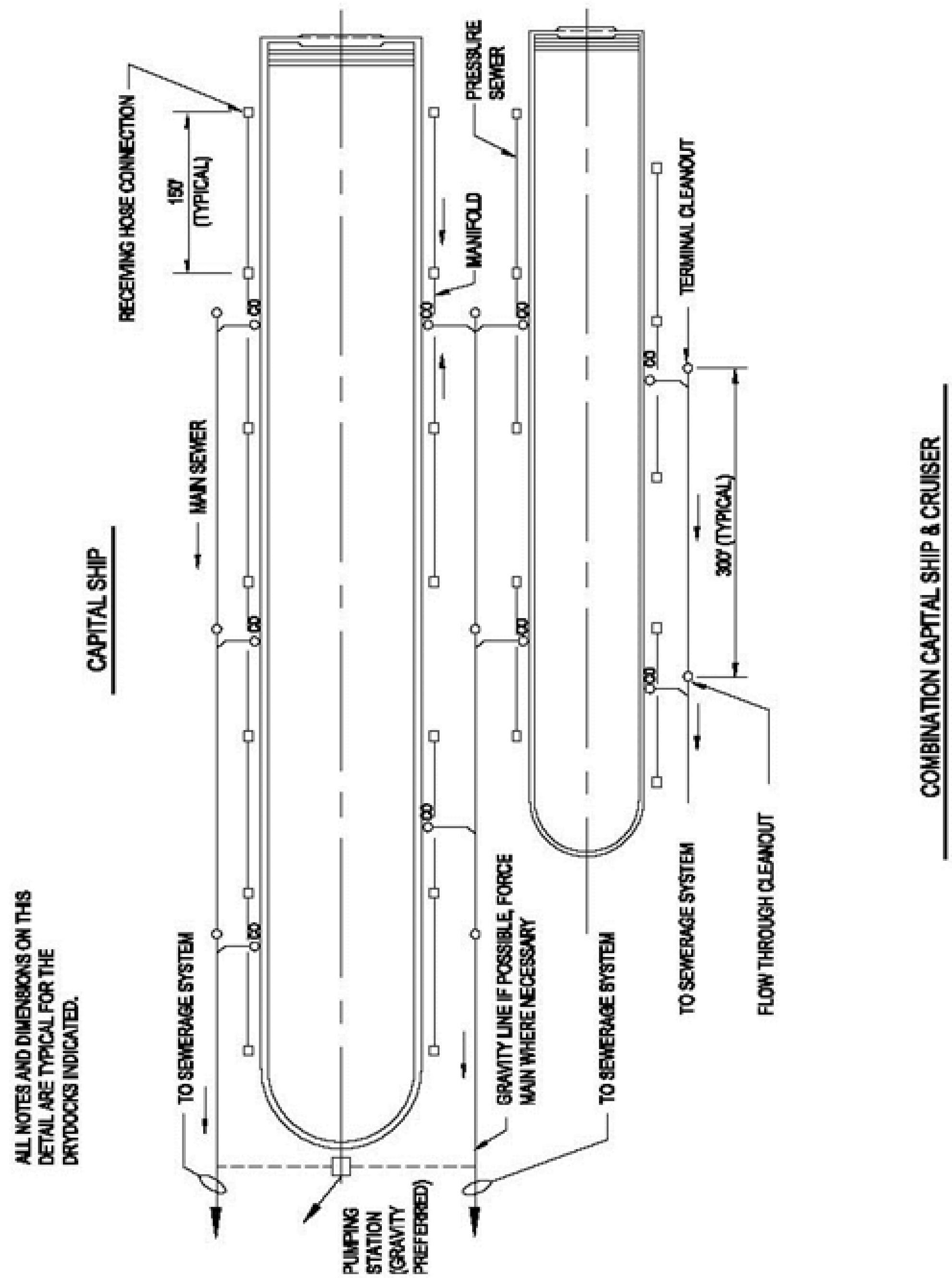


Figure 3-17 (a) Underground Hose Connection (1 of 2)

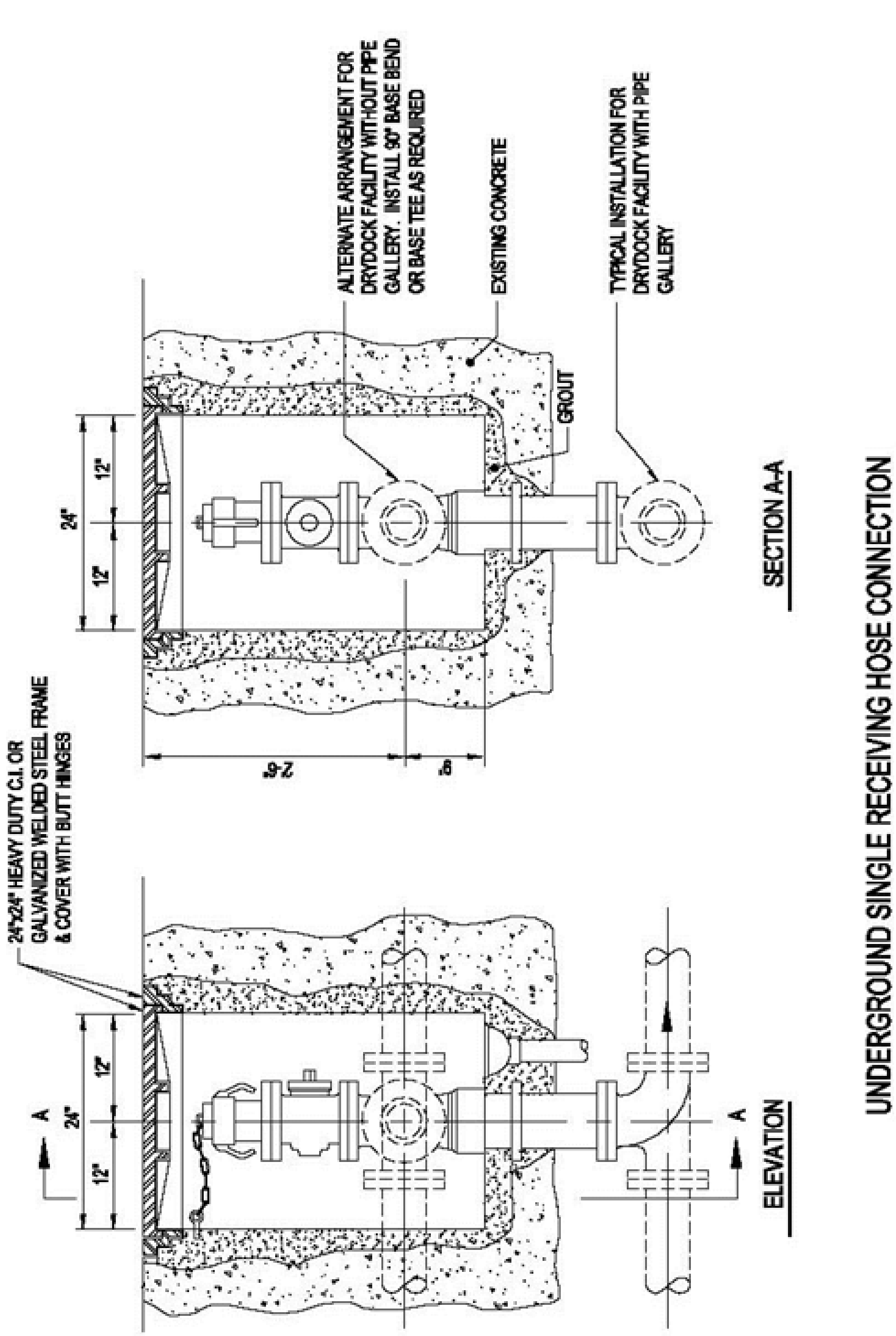
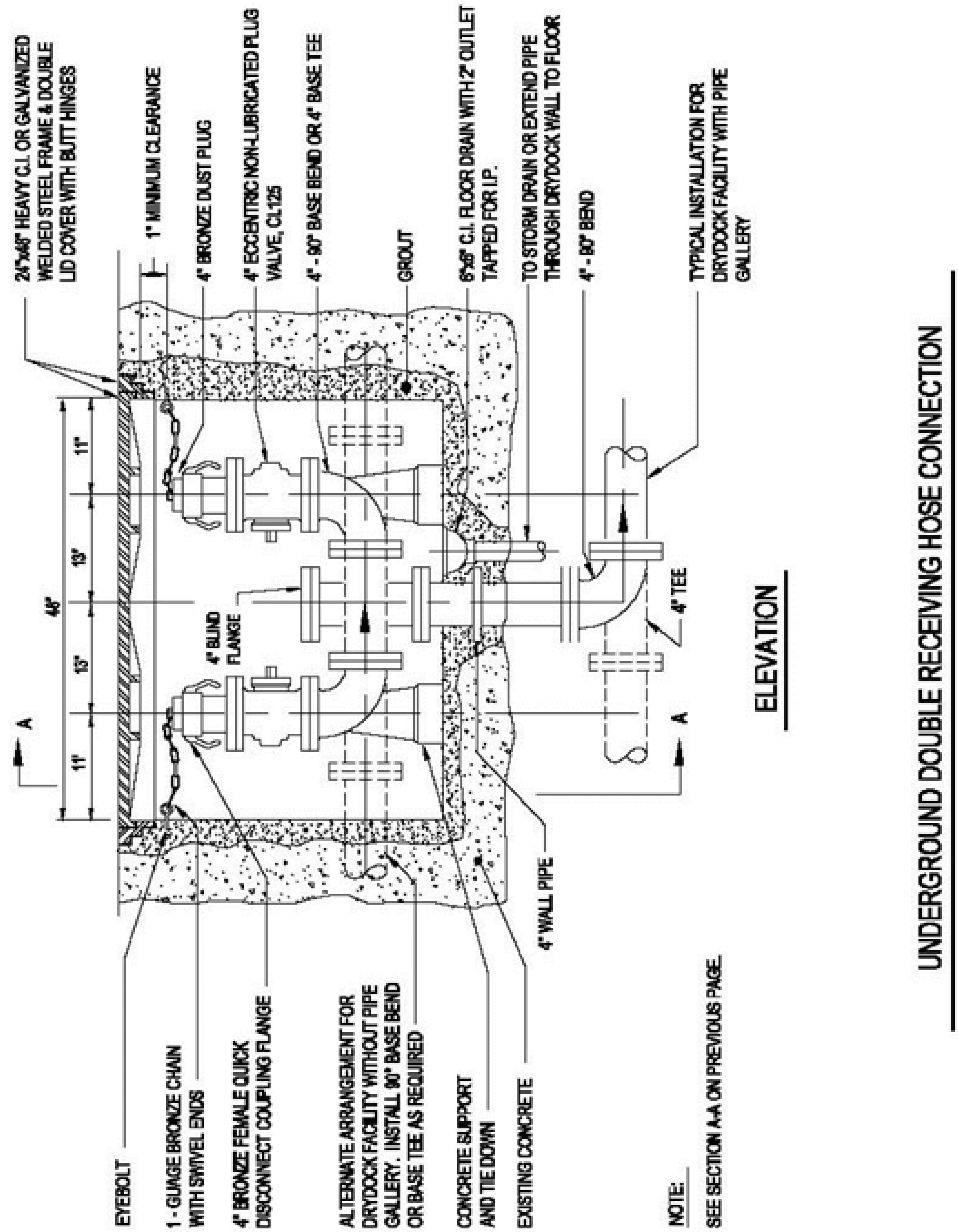


Figure 3-17 (b) Underground Hose Connection (2 of 2)



3-8 ELECTRICAL SYSTEMS.

Electrical power is required on piers, wharves, and at dry docks for ships services. This includes hotel service (shore-to-ship power), ship repair (industrial power), ships systems testing, pier weight-handling equipment, cathodic protection systems, pier lighting, and miscellaneous pier electrical systems. Materials and installation must conform to the requirements given in UFC 3-501-01, *Electrical Engineering*, and in NFPA 70, *National Electrical Code*. For dry docks, refer to additional criteria in UFC 4-213-10. Utility data and specialized technical data is available in APPENDIX A or it may be obtained directly from the cognizant Service. In addition to the design criteria provided in this particular section, operation and maintenance guidance for electrical systems is provided in APPENDIX C.

3-8.1 Types of Electrical Services.

Design electrical services for piers, wharves, and dry docks for one of the two types of service listed below, as directed by the cognizant Service.

3-8.1.1 Permanent Service.

At naval stations, shipyards, repair piers, dry docks, and other continuously occupied waterfront facilities, provide electrical substations and associated facilities to accommodate the normal, maximum electrical demand load. The design may include the use of portable substations. The electrical design must include: (1) ships power requirements (hotel services) on a dedicated un-grounded power system; and (2) other facility loads on a separate grounded power system that includes loads such as lighting, weight-handling equipment, cranes, pumps, general utilization power, and the industrial power system (dedicated for ship's repair work while berthed) when required. There are three basic types of substation installations: (1) the substation is installed on the lower deck of a double-deck pier; (2) the substation is installed on the pier deck of a single-deck pier or at grade level adjacent to the pier or associated waterfront facility, and (3) the substation is installed in an electrical vault located below the pier deck. The vault system has been used on many existing piers, however it is not recommended for new installations and requires approval of the cognizant Service. See APPENDIX C and Section 3-8.4.1 entitled "Substations" for additional information.

3-8.1.2 Temporary Service.

Provide temporary electrical service at waterfront facilities not continuously occupied, or at any facility where a substantial portion of the peak load will be occasional or intermittent. Provide primary feeders and high voltage outlet assemblies (5 kV and 15 kV) for connections to portable substations. Examples of high temporary loads include: (1) power for testing certain ships weapons systems; and (2) power for testing ships plant nuclear systems. That portion of the load serving basic pier, wharf, or dry dock functions (lighting, weight-handling equipment, and receptacles not related to ship service or repair service) must be fed from the permanent service.

3-8.2 Primary Power System.

The primary distribution system on the pier or other waterfront facility normally operates in the medium-voltage range between 5 kV and 35 kV and will depend upon the shore-side utility voltage(s) available. The shore-side utility system is normally already in existence. It may have to be expanded or upgraded to support a new or increased capacity pier, but will rarely require a completely new electrical utility service point. Upgrades to the system should provide the pier with a dedicated normal circuit and provisions for switching to a backup circuit. The Activity is responsible for providing justification for alternate primary feeders and standby power services required for essential operations. Special electrical primary systems may be required for certain classes of ships. These specific requirements are included in APPENDIX A. Provide selective coordination between system equipment components to ensure minimized downtime of ships systems due to external or internal electrical system faults. Refer to UFC 3-501-01, *Electrical Engineering*, for a description of the different types of distribution systems.

3-8.2.1 Pier, Wharf, or Dry Dock Primary Systems.

For permanent service, provide dual primary feeders from the shore primary system to the switching stations or substations serving the ships' hotel services and industrial loads. For temporary service, provide dual primary feeders from the shore primary system to strategic locations that serve portable substations. Conduits, ductbanks, and manholes cast integrally with the pier structure are preferred for new piers. Conduits on piers may also be installed in dedicated electrical trenches or in piping trenches that serve other utilities, or hung from above on double deck piers. To avoid damage to the conductor's insulation, electrical conduits should not be placed in close proximity to high temperature systems such as steam piping. Refer to CHAPTER 2 for general protection requirements.

3-8.3 Secondary Power Systems.

The secondary electrical distribution system is evolving to higher voltages as the power demand on the ships continues to increase. It must be designed with the flexibility to serve the various classes and categories of ships that are anticipated to utilize the facility.

3-8.3.1 Ships Power.

Historically, the electrical system providing power for most ships has been a dedicated 480 V (nominal), three-phase, 60 Hz, ungrounded system. This system has been supplied from substations located on piers (or at the head of the pier for shorter piers), and connected through dedicated receptacles located at the perimeter of the pier, wharf, or dry dock. Currently, 4,160 V (nominal), three-phase, three-wires, 60 Hz power is required for nuclear aircraft carriers (CVN 68 class and higher). These carriers are sometimes capable of accepting 480 V power as well. Future classes of ships (surface combatants and amphibious assault) will require 4,160 V (nominal), three-phase, three-wires, 60 Hz power. CVN 78 class ships will require 13,800 V (nominal), three phase, three wires, 60 Hz power. The pier electrical distribution system must be designed to limit the fault current contribution from the shore power, at the ship's bus, to 100,000 A (rms) for 480 V distribution, 35,000 A for 4,160 V distribution, and 15,000 A (rms) for 13,800 V distribution. The use of UL listed current limiting breakers is recommended to limit the let-thru I^2t energy during a fault to not more than the available energy during a half-cycle of the prospective symmetrical short circuit current.

3-8.3.2 Other Ships Power Requirements.

When required, provide direct current (DC) power and 400 Hz power for ships service. These systems must be derived from portable rectifiers or conversion equipment provided by the Activity. Provide an electrical power connection system that is supplied from the pier's permanent / industrial power system rated 277/480 V, three-phase, four-wires, grounded, 60 Hz. These special power systems must not be connected to the ships' dedicated shore power service(s). Conduit for 400-Hz systems requires the use of non-magnetic conduit such as aluminum conduit. This is due to the higher reactive inductances at 400 Hz which occurs in magnetic conduit resulting in large voltage drop issues (such as when using rigid galvanized steel conduit).

3-8.3.3 Permanent Pier Loads and Industrial Power.

Other electrical requirements such as pier lighting, receptacles, weight-handling equipment and industrial power must be supplied from dedicated 480Y/277 V transformers. A delta primary winding for transformers prevents 3^{rd} harmonics from being transmitted to the primary line and limits voltage distortion impacts to the electrical distribution system whereas a wye-wye wound transformer does not. Industrial power is defined as power specifically for equipment utilized for the repair and overhaul of ships at berth and is normally only required in naval shipyards. Do not provide permanent pier load power or industrial power from the same transformers providing shore to ship hotel power.

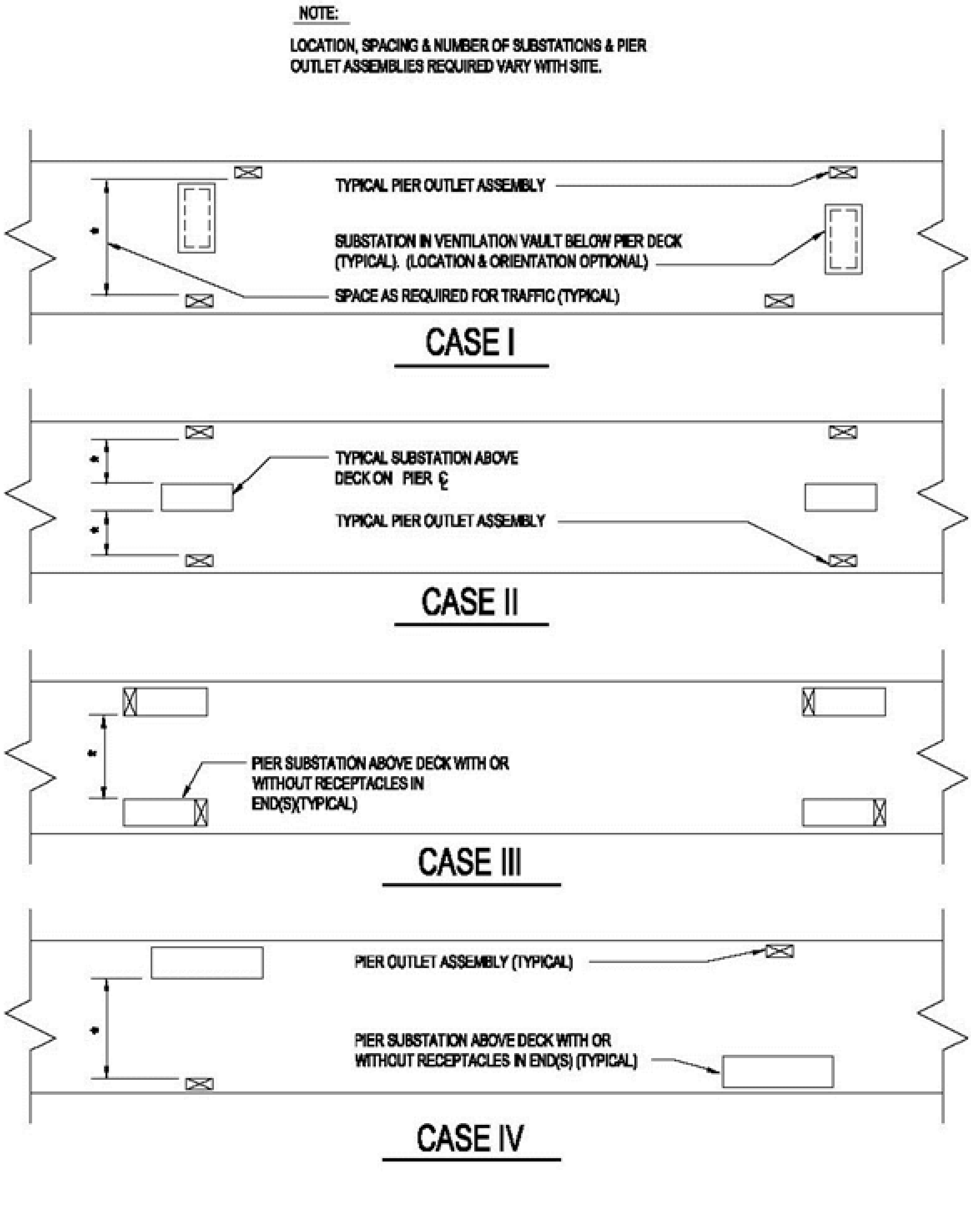
3-8.4 Location and Arrangement of Equipment.

Final locations of equipment must be made on a pier-by-pier basis in concurrence with the Activity and the cognizant Service. Selection must be coordinated with the pier design type, other pier utilities and the pier's operational requirements. In general, provide as much clear space for cranes and vehicular traffic on the pier deck as possible. Examples of pier equipment arrangements are shown in Figure 3-18.

3-8.4.1 Substations.

The three main types of arrangements for substations are discussed in the following subparagraphs with an example of their use, where appropriate. The unit substations should be outdoor construction.

Figure 3-18 Typical Alternative Pier Electrical Equipment Arrangements



3-8.4.1.1 Double-Deck Pier Substations.

On a double-deck pier, the upper deck is used for conventional pier functions while the lower deck serves utility systems and utility connections. The electrical service for a double deck pier should be a permanent service. The substations should be located on the lower deck and may be symmetrically arranged around the pier centerline. Cross sections of a double-deck pier are shown in Figure 2-2. One recent example of substation arrangement and power distribution system is Pier 6 at the NS Norfolk (NSN). It consists of two electrical service clusters with each service cluster consisting of four 4,000 kVA unit substations, totaling 32 MVA. The output of these substations serves fixed low voltage outlet assemblies. These outlets are defined on the Pier 6 project drawings as “shore power stations” (SPS). Each SPS contains 12 sets of three (3), single pole, low voltage cable connectors (36 connectors total) that in turn serve the shore-to-ship service cables. Illustrations of the electrical system for the NSN double-deck Pier 6 are shown in Figure D-1. (Note the one-line drawing in Figure D-1(a) the nominal medium voltage is 34.6 kV and the distribution conductors are 750 MCM EPR copper.) Pier 6 was designed as a general berthing pier to support all ship classes except SSN and CVN, and may not be directly applicable for double-deck SSN and CVN piers or piers designed for specific ships. See Appendix C-5 “Cable Connectors” for additional information on the various types of connectors currently being used.

3-8.4.1.2 Single Deck Pier Substation.

On a single deck pier the substation can be deck mounted or at grade level adjacent to the pier. The unit substation illustrated in the vault system in Figure D-2 could also be utilized in the pier deck mounted or grade level installation system. The deck mounted/grade level substations may include walk-in aisle features, however they are not recommended when located on the pier due to the significant increase in size.

3-8.4.1.3 Existing Pier Vaults.

Many existing piers utilize the electrical vault system. This system is described in Figure D-2. This type of electrical service, commonly used on many existing piers, is not authorized for the design of new piers. It was based upon electrical vaults located below the pier deck that were designed as an integral part of the pier’s structural system. The vaults house secondary unit substations and may also contain primary switching equipment. The vaults require proper ventilation, pumping systems, and an access system integrally designed into the pier’s deck. This type of electrical system has four significant disadvantages: (1) the vaults are considered to be a “confined space”; (2) the vaults are subject to flooding; (3) the vault’s environment is excessively corrosive to the electrical equipment, even under normal conditions; and (4) replacement of a unit substation creates significant interference to pier operations and results in deck pavement removal and replacement.

When a vault system is used, the substation vaults must be ventilated and flood resistant for protection of the electrical equipment. Prevent flooding with dual sump pumps that discharge at a point above highest tide. Provide a "float switch and alarm system" to alert personnel of sump pump failure and high water level. The sump pump power must be connected to a source other than the vault substation. That source must remain energized when the pier electrical hotel service power and permanent / industrial power systems are turned off. Freeze protection must be provided in climates where any element of the pumping system could freeze. Ventilation cooling must be provided with air quantity based upon the highest site temperature and the highest vault temperature that can be tolerated by the electrical equipment. One approved method of vault ventilation is shown in Figure D-2. Separate ventilation air intake and exhaust louvers by as much distance as possible. They may be on opposite sides of the pier if the ventilation ducts are above high tide. Provide an access system for the electrical vault that includes personnel access and equipment replacement access. Personnel access usually consists of manhole frame with cover and vertical ladder. Equipment access systems are a significant structural element that are required to withstand vehicular traffic and must be designed as an integral part of the pier deck.

3-8.4.2 Outlet Assemblies.

The number of electrical shore service stations, their location aboard ship, the per station ampacity, and appropriate voltage for each ship are defined in APPENDIX A. For a general discussion of methods to be used to establish shore utility station spacing on piers and wharves, refer to CHAPTER 2. For spacing at dry docks, refer to UFC 4-213-10.

3-8.4.3 Cable Lengths.

Most ships have to be served from multiple 400 Amp circuits. Design the electrical system to maintain balanced impedances and reduce unbalanced phase currents. Route cable from the substation to the outlet assemblies in the parallel circuits to achieve approximately equal cable lengths (within 10%). When routing shore power feeder conduits through concrete decks, avoid routing individual shore power PVC conduits through closed rebar loops due to possible inductive coupling causing current unbalance with feeder PVC conduits not routed through the same rebar loop(s). Where single phase connections and cabling are used for ship to shore connections, care must be taken to bundle phases of each circuit to maintain balanced impedances and reduce unbalanced phase currents.

3-8.4.4 Combined Equipment.

Electrical substations and outlets may be consolidated in an integral package, with the receptacles placed in the side (or sides) of the substation enclosure. These consolidated outlet assemblies may be spaced as necessary along the pier or dry dock perimeter. See Figure 3-18, Cases III and IV.

3-8.4.5 Outlet Assemblies for Portable Equipment.

When supplying ships loads from portable substations, locate primary outlet assemblies in the same manner as required for regular outlet assemblies. Primary outlet assemblies, provided for temporary services that supplement permanent substations, should be placed in the vicinity of their intended use. Coordinate these locations with the Activity and the cognizant Service.

3-8.5 Distribution System Equipment and Materials.

Equipment and materials selected for waterfront electrical systems must be coordinated with the cognizant Service and the standards and preferences of the Activity. Since significant technical information for many of the distribution system components is available in the Unified Facilities Guide Specifications (UFGS) Sections UFGS 26 11 16, *Secondary Unit Substations*, UFGS 26 13 00, *SF6/High-Firepoint Fluids Insulated Pad-mounted Switchgear*, and UFGS 26 23 00.00 40, *Switchboards and Switchgear*, the nomenclature and requirements for the equipment must be thoroughly coordinated in the project documentation (plans and specifications).

3-8.5.1 Fixed Substations for 480 Volts Service.

There are several methods for providing substations for permanent 480 V services on piers. Based on the overall system design, the substation should contain primary, secondary, auxiliary, and transformer sections. See APPENDIX C. The primary section would either contain the primary overcurrent protection features, a disconnect switch, and a service circuit selector switch if the system includes multiple primary circuits, or it would be limited to the primary circuit terminations if separate pad-mounted primary switchgear is used. Where transformer differential relays are used, the primary section should contain a circuit breaker instead of fused disconnects to allow disconnecting primary side power to the transformer via a trip circuit connection to the breaker from the differential relay. There must be separate 480 V secondary unit substations designated for the ships hotel loads and for the other pier loads including industrial power (if required). The main transformers should be of the liquid-cooled type, standard three-phase, 480 V, with four (4) full-capacity, 2-1/2-percent taps, two above and two below the nominal primary voltage rating unless actual operational conditions require other tap settings. Maximum transformer rating should be 4,000 kVA. Substations, including transformers should be stainless steel with a paint coating system in compliance with ANSI/NEMA C57.12.29. If specific operational conditions require parallel operation with the shipboard generators, coordinate with the cognizant Service to determine the additional features that must be added to the equipment. In these cases, the shipboard generator and other equipment ratings are available upon request from NAVSEA.

Substation must be designed with maintainability in mind and provisions and/or clearance for removing the circuit breakers must be factored into the design.

3-8.5.1.1 Shore Power Circuit Breakers.

The equipment should provide 480 V (nominal), three-phase, 60 Hz power, as defined in ANSI/NEMA C84.1, *Voltage Ratings for Electrical Power Systems and Equipment (60 Hz)*, voltage range "A." via low voltage power circuit breakers. The power circuit breakers shall be electrically operated, drawout-type, with adjustable electronic trip features. Feeder circuit breakers shall provide circuit protection up to a maximum overcurrent setting of 480 Amps and interrupting ratings up to 100 kA at 480 VAC without fuses. Provide a circuit breaker for each individual shore power service receptacle. The adjustable trip module long time pick-up (LT setting) for submarine shore power circuit breakers shall be adjusted per APPENDIX C, C-4.1.

3-8.5.1.2 Shunt Trip Interlocks.

- Provide a shunt trip interlock circuit to open all possible paralleled circuit breakers in the event that any shore power circuit breaker trips due to an overcurrent operation.
- For existing installations, provide a shunt trip interlocking scheme on all ship power service circuit breakers for submarines.
- For new construction a remote trip capability shall be provided on all ship power services for submarines.

3-8.5.1.3 Space Heaters.

Space heaters should be incorporated within individual substation sections in order to prevent condensation.

3-8.5.2 Substations for 4,160 or 13,800 Volts Service.

Provide substations with a secondary voltage of 4,160 V or 13,800 V (nominal, as defined in ANSI/NEMA C84.1, voltage range "A), when required by APPENDIX A for the classes of ships to be berthed. Design of primary unit substations is similar to fixed 480 V substations except for voltage classifications and outlet assembly provisions. Circuit breakers should be 5 kV or 15 kV vacuum drawout type, with interrupting current rating based on available fault.

3-8.5.3 Portable Substations.

See Figure D-3. The pier design must include space allocation for the portable substations and provide the electrical primary distribution system required to energize the portable substations. This includes primary circuits, their disconnect switches, and the primary outlet assemblies. Design is similar to fixed substations except for portability provisions.

3-8.5.4 480 Volt Outlet Assemblies.

480 V outlet assemblies (receptacles and cable connections) vary with Activities but should be standardized on a Station-by-Station basis. Additional information on the outlet assemblies and the actual operational procedures used on the piers is available in UFC 3-560-01, *Electrical Safety O&M*, Section 9, “Shore-to-Ship Electrical Power Connections”. Detailed specifications for the outlet assemblies are also included in guide specification UFGS 26 05 33, *Dockside Power Connection Stations*.

3-8.5.4.1 Receptacles.

Ships hotel service receptacles must be provided in weatherproof, corrosion-resistant pier outlet assemblies, or combined with the substations. Provide the number of receptacles required to serve the specific ship types and classes in accordance with APPENDIX A.

There are currently two types of ship hotel service receptacles being used, a three-pole receptacle and a single-pole receptacle. Existing facilities and NATO, Army, and USCG ships utilize a three-pole, 500 Amp receptacle in accordance with Mil Spec MIL-C-24368/1, *Connector Assemblies; Plug, Power Transfer, Shore-to-Ship and Ship-to-Ship*. A typical MIL-C, three-pole outlet assembly is illustrated in Figure D-4. Other facilities and the Navy utilize a single-pole, 500 Amp receptacle, grouped in a cluster of three. Typical details of the single-pole receptacle system are shown in Figure D-5. The preferred connection is the single-pole receptacle which must be used for new construction for the Navy.

3-8.5.5 Primary Outlet Assemblies.

Primary voltage outlet assemblies must have weatherproof, corrosion-resistant enclosures and high voltage connectors. Connectors must match the standard primary voltage coupler in use by the Activity and as required by the cognizant Service. Disconnects should have an interlocking key which can only be removed when the switch is opened. Design should be such that, after the disconnect has been opened, the interlocking key must be used to unlock and make possible the insertion or removal of the corresponding primary voltage pier coupler plug. Provide 500 Amp coupler receptacles at each 4,160 and 13,800 V pier outlet assembly. Incorporate outlet assemblies into substations as applicable. See Figure D-6 for typical 15 kV details.

3-8.5.6 Coordination of Shipboard Phase Rotation.

Shipboard alternating current systems have a standard phase rotation. To minimize the phasing procedure and to reduce the time required to connect shore-to-ship power cables, shore power connectors should be phased so that they are compatible with the shipboard system. Refer to *NAVSEA 59300-AW-EDG-010/EPISM*, Section 2, Group E, Sheets 14 and 15, to determine phase rotation required for shore power connections.

3-8.5.7 Conduit Systems.

For electrical conduit exposed under or on a pier, wharf, or dry dock, evaluate the relative advantages of Schedule 80 PVC, and Reinforced Thermosetting Resin Conduit (RTRC). Avoid the use of PVC where it will be exposed to sunlight and moving objects. Although PVC Coated steel conduits have been used on many piers, the alternatives are more attractive from an economic and durability standpoint. The potential exists for loss of integrity of the PVC Coating systems in the harsh and corrosive environment. Fiberglass cable trays may be used in lieu of conduit where adequately protected from physical damage and the elements. Coordinate hangers with the requirements in Section 2-4.1.4 entitled “Hangers and Support Assemblies”.

3-8.6 Ships’ Shore Power Requirements.

APPENDIX A provides a listing of shore electrical loads of ships while homeported or undergoing alteration and repair. Substation and feeder sizing on piers and wharves must be based upon the electrical loads given in the "Design Load" for the largest ship (or largest number of ships) of all classes which could be berthed at the pier. The minimum number of receptacles provided in a secondary outlet assembly should match the number of receptacles in the ship’s respective receptacle stations. Nested ships must also be considered in the electrical outlet assembly design where indicated by the facility berthing plan or where conceivable at a future date.

3-8.6.1 Alternating Current (AC) Power.

Hotel service loads include the ship's electronics, weapons systems, cargo booms, galley equipment, space heating, and miscellaneous lighting and power loads. The number of circuits shall be as requested by ship’s force. These loads are supplied with either 480 V (nominal) or 4,160 V (nominal) ungrounded power, or 13,800 V (nominal) ungrounded power. The 480 V system shall supply approximately 480 V at no load and 450 V (plus or minus 5%) under loaded conditions and at the ship's load center. The 4,160 V system shall supply approximately 4,160 V plus or minus 5% under loaded conditions and at the ship's load center. The 13,800 V system shall supply approximately 13,800 V plus or minus 1% with up to 60 seconds time delay under loaded conditions. Cable ratings must be sized to exceed the ships’ loading requirements of APPENDIX A and the associated circuit breaker trip settings. System design must be coordinated with the planned nesting requirements of the pier to maintain the voltage within the allowable tolerances at outboard ships.

3-8.6.2 Direct Current (DC) Power.

When required, DC power should be provided for certain ships in accordance with instructions provided by the Activity. Portable rectifier units will be provided by the Activity. Provide sufficient AC power and receptacles to serve such equipment. Coordinate connection requirements with the Activity.

3-8.6.3 400-Hz Power.

400-Hz power for ship service may be supplied from the 480 V system utilizing portable generating equipment furnished either by the Activity or by the ship. Provide 60 Hz power and receptacles to serve such equipment. Coordinate connection requirements with the Activity.

3-8.6.4 Shipboard Equipment Ratings.

Most ship distribution circuit breakers operate at 440 V and are protected with 100,000-Amp interrupting current, current-limiting fuses in series with the breakers. In most cases, these circuit breakers are type AQB-LF400 as described in NAVSHIPS Publication 362-2333, *Air Circuit Breakers (Fused), Navy Type* AQB LF400. The main breaker for the shipboard system on nuclear carriers is an air-type breaker rated at 250,000 Amps asymmetrical interrupting capacity, and without current-limiting fuses. The shore distribution system must be designed in accordance with UFC 3-501-01, *Electrical Engineering*, to ensure that available fault is within the capability of the ship's distribution system. Contact the cognizant Service for information on shoreside fault current data to determine the required interrupting capacities and equipment design characteristics.

3-8.7 Supplemental Requirements for Nuclear Submarines (SSN, SSBN, SSGN) and UUVs.

Nuclear submarine (SSN, SSBN, SSGN) and Unmanned Underwater Vehicles (UUVs) piers and berths should conform to the following shore power requirements.

3-8.7.1 Substations for 480 Volts Service.

Substations serving hotel loads at submarine piers must be designed in accordance with Section 3-8.5.1 entitled "Fixed Substations for 480 Volts Service" for fixed substations, or Section 3-8.5.3 entitled "Portable Substations" for portable substations, and in accordance with the supplemental requirements below. The substation's primary section should be built with dual primary feeders. Switchgear and breaker equipment should be designed so that automatic reset and restoration of power to submarine services will be delayed a minimum of 5 to 10 seconds after loss of commercial power. This is required in order to prevent damage to the submarine's electric plant equipment. The maximum time to restore power should be 5 minutes. Provide undervoltage and underfrequency relays at substations. Relay types and set points for undervoltage and underfrequency should be evaluated separately for each installation and coordinated with the cognizant Service.

3-8.7.2 Standby Power.

Power requirements for normal operation are given in APPENDIX A. Standby backup power to the normal shore supply is required. A standby backup electrical power source for the reactor plant is required which is capable of providing 450 V, 3 Phase 60 Hz power with a capacity of at least 850 kW with the ability to start a 260 hp induction motor with an initial load of 650 kW. The standby backup power source should use the normal ship's shore power connections. This source of standby power will only be required to be available when power from the ship's battery or diesel generator are not available. The standby backup power source can be, for example, a portable generator set, or separate power sources to the facility, provided that the loss of one source will not result in a long duration power outage.

3-8.7.3 Maximum Downtime.

For the shore facility and overhaul yard dry dock permissible outage time allowed is 5 minutes. System downtime is defined as: (1) the time required to restore power to the pier when maintenance or repair activities are required; or (2) the time required to transfer from one power source to another after system disturbances. This includes the time required for protective devices to operate and the time to start standby generators.

3-8.7.4 Super Shore Power.

APPENDIX A lists “super shore power” requirements for nuclear submarines. Super power is required for the ship's testing, checkout, and refueling operations. These super shore power requirements are in addition to the normal power requirements. Provide super power from a separate substation that supplies no other loads. Portable substations connected to temporary service outlets are recommended for this service. Extend primary service and provide connections for these portable substations. The special requirements for submarine piers given in subparagraphs 3-8.7.1, 3-8.7.2, and 3-8.7.3 entitled “Substations for 480 Volts Service,” “Standby Power,” and “Maximum Downtime” above do not apply to super shore power.

3-8.7.5 Shorepower Booms.

Provide permanently installed shorepower booms at submarine/UUV piers and berths. See UFC 4-152-01, *Piers and Wharves*, for additional submarine/UUV pier/berth configuration, construction, berthing, fendering, access, and utility infrastructure requirements.

3-8.7.6 UUV Requirements.

Special considerations must be given to ensure all power and infrastructure requirements for current and future UUVs are met.

3-8.8 Ground System.

Provide a ground system at piers, wharves, quay walls, and other waterfront structures that measures not more than 5 Ohms for all permanent electrical equipment. Ground systems should be in accordance with NFPA 70. Stranded-copper-wire ground conductors, sized in accordance with NFPA 70, should be used to interconnect equipment enclosures and the ground system.

3-8.9 Pier Lighting.

Information on pier lighting is available in UFC 4-152-01, *Piers & Wharves*.

3-8.10 Lightning Protection.

Provide lightning protection systems when required. Coordinate with the cognizant Service. Design in accordance with UFC 3-575-01, *Lightning and Static Electricity*

Protection Systems, and NFPA 780, Standard for the Installation of Lightning Protection Systems. Consider the protection of cranes, above deck substations, pier mounted buildings, and lighting system masts.

3-9 TELECOMMUNICATION SYSTEMS.

The purpose of this section is to provide requirements for Base Level Information Infrastructure (BLII) Pier Connectivity Specifications, telephone service, and other telecommunications systems.

3-9.1 BLII Pier Connectivity.

These guidelines are provided for planning, designing, engineering, and constructing new or repairing existing Navy piers. Figure 3-19 illustrates the three major components that are required to provide end-to-end connectivity to IT-21 compatible ships. They are the Pier Head ITN Building Node; the Pier Fiber Distribution Center, and the Fiber Optic Riser Panels.

3-9.1.1 Pier Head ITN Building Node.

The Pier Head ITN Building Node is connected to the Base Area Network (BAN) and becomes the interface for adding additional piers to the infrastructure for SIPRNET/NIPRNET connectivity. A 144-strand hybrid fiber optic cable (72 multi-mode and 72 single mode) is required between the Pier Head ITN Building Node and the Pier Fiber Distribution Center. Where a hybrid cable is not readily available and the designer deems it appropriate, two individual cables, one 72 strand single-mode and one 72 strand multi-mode, are permitted for use in lieu of the hybrid cable. The fiber optic cable may already exist if the pier is being repaired; however, for new pier construction, the cable will need to be installed. The designer should coordinate with the local Information Technology (IT) group to ensure that the proper Pier Head ITN Building Node has been identified. All cabling and interconnections inside the Pier Head ITN Building Node are the responsibility of the local IT group unless other prior arrangements have been made.

3-9.1.2 Pier Fiber Distribution Center.

The Pier Fiber Distribution Center provides a breakout point for the 144-strand hybrid fiber optic cable coming from the Pier Head ITN Building Node and the Fiber Optic Riser Panels. Figure 3-20 shows the fiber optic cable entering into the splice can from the Pier Head ITN Building Node. The fiber is spliced onto another 144-strand fiber optic cable (72MM/72SM) for submarine piers or 96-strand fiber optic cable (48MM/48SM) for surface ship piers. This is routed to the Environmental Distribution Center 1 (EDC 1) patch panel. Using internal patch cables, EDC 1 is patched to EDC 2. From EDC 2, a 144 or 96 strand hybrid fiber optic cable is routed to a second splice can where it is spliced to several 24-strand hybrid fiber optic cables (12MM/12SM) that run to the Fiber Optic Riser Panels. Figure 3-21 through Figure 3-24 provide detailed information on the EDC 1 and EDC 2 patch panels located inside the Pier Fiber Distribution Center and their interconnections. (Note that the patch panels are shown for both surface ship piers and submarine piers).

Submarine piers/berths require validation that the hardware supports or exceeds the requirements of data throughput and cyber security as mandated by CTF 10, NAVIFOR, and PMW 160.

3-9.1.3 Fiber Optic Riser Panel.

The Fiber Optic Riser Panel is the interface for the ship to shore connectivity. The panel is provided with a 24-strand hybrid fiber optic cable (12MM/12SM) coming from the Pier Fiber Distribution Center. This provides a fiber optic receptacle, J1, to interface with the umbilical cable assembly that goes to the ship (note that details on the J1 pigtail assembly may be found on NAVSEA drawing 7325760D). Figure 3-25 shows the Fiber Optic Riser Panel. Figure 3-26 and Figure 3-27 show the patch panel connections inside the EDC for a surface ship and submarine respectively. Figure 3-28 and Figure 3-29 show the rubber gasket cutouts for a surface ship and submarine respectively.

Figure 3-19 Block Diagram of Pier Structure

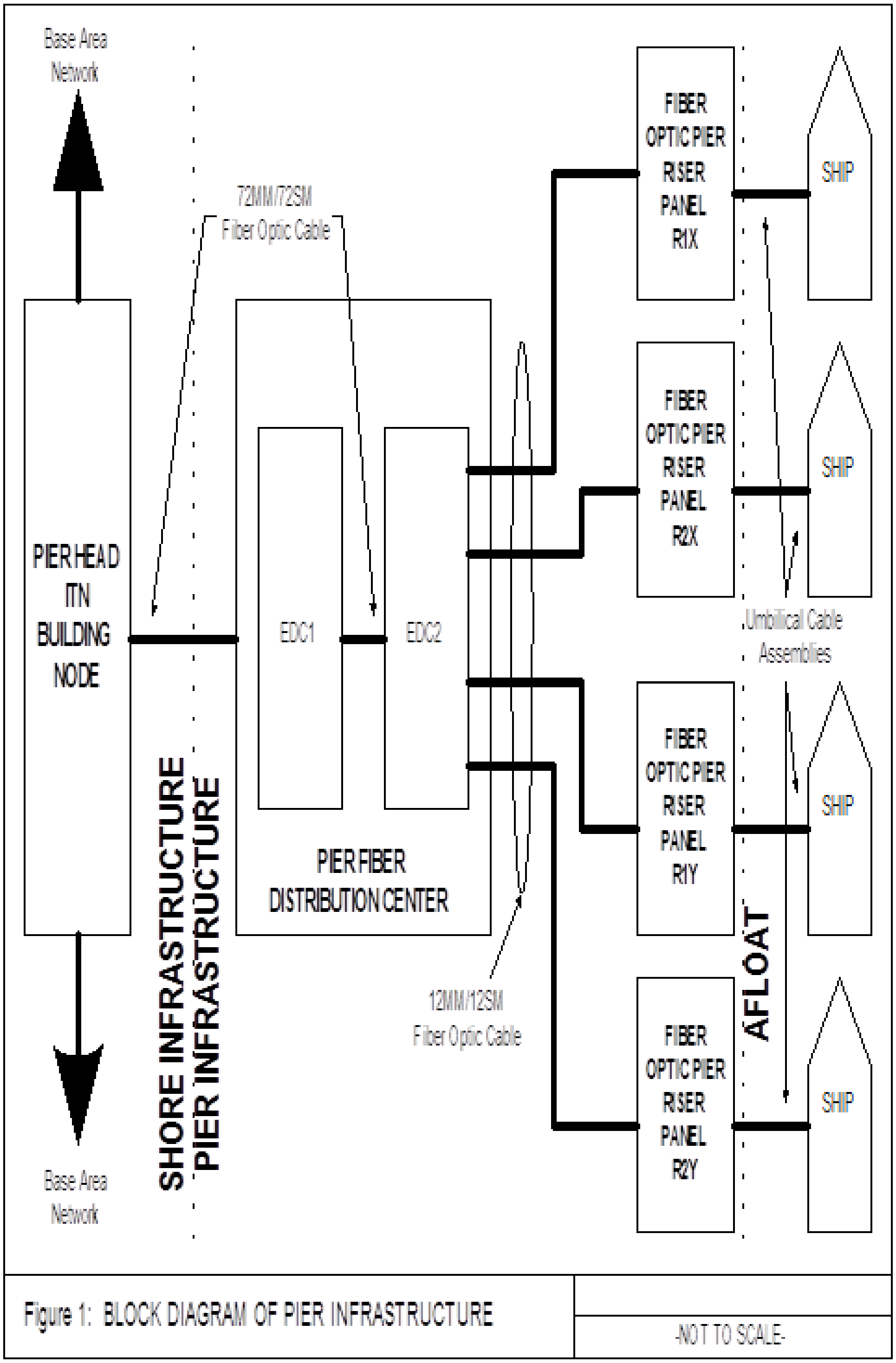


Figure 3-20 Pier Fiber Distribution Center

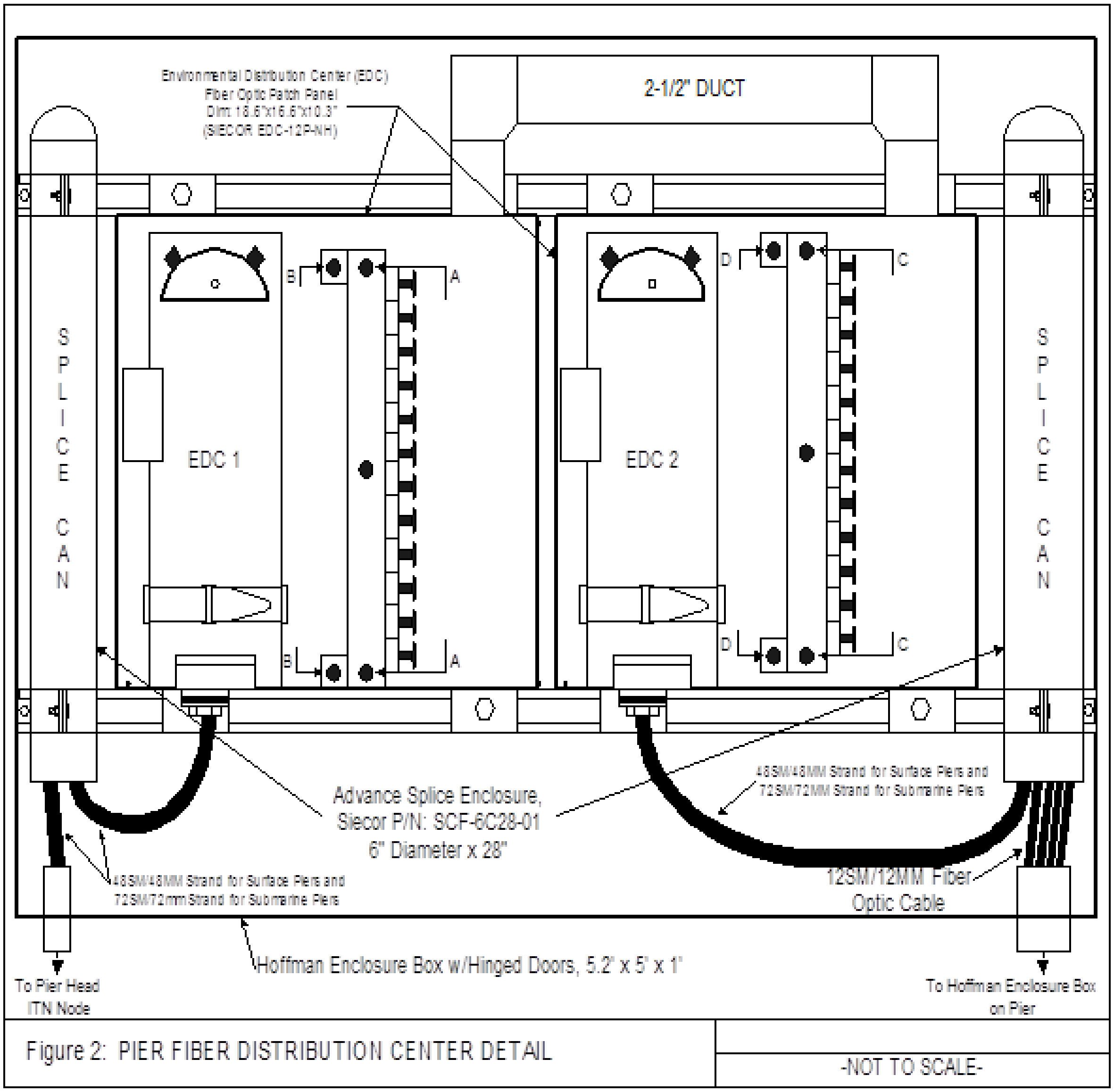


Figure 3-21 Pier Fiber Distribution Center EDC 1 Rear Detail (Surface Ship Pier)

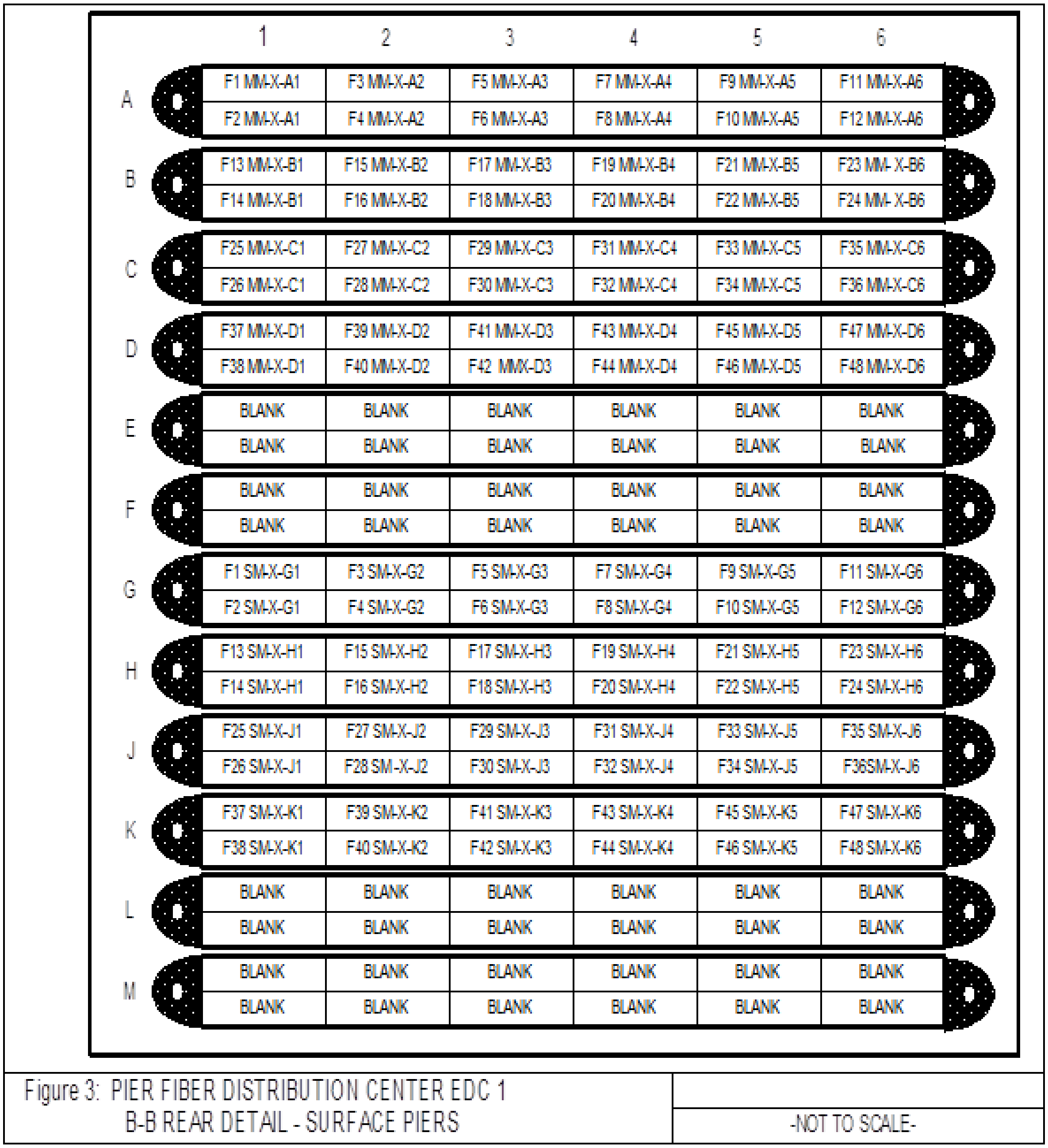


Figure 3-22 Pier Fiber Distribution Center EDC 1 Rear Detail (Submarine Pier)

	1	2	3	4	5	6
A	F1 MM-X-A1	F3 MM-X-A2	F5 MM-X-A3	F7 MM-X-A4	F9 MM-X-A5	F11 MM-X-A6
	F2 MM-X-A1	F4 MM-X-A2	F6 MM-X-A3	F8 MM-X-A4	F10 MM-X-A5	F12 MM-X-A6
B	F13 MM-X-B1	F15 MM-X-B2	F17 MM-X-B3	F19 MM-X-B4	F21 MM-X-B5	F23 MM-X-B6
	F14 MM-X-B1	F16 MM-X-B2	F18 MM-X-B3	F20 MM-X-B4	F22 MM-X-B5	F24 MM-X-B6
C	F25 MM-X-C1	F27 MM-X-C2	F29 MM-X-C3	F31 MM-X-C4	F33 MM-X-C5	F35 MM-X-C6
	F26 MM-X-C1	F28 MM-X-C2	F30 MM-X-C3	F32 MM-X-C4	F34 MM-X-C5	F36 MM-X-C6
D	F37 MM-X-D1	F39 MM-X-D2	F41 MM-X-D3	F43 MM-X-D4	F45 MM-X-D5	F47 MM-X-D6
	F38 MM-X-D1	F40 MM-X-D2	F42 MMX-D3	F44 MM-X-D4	F46 MM-X-D5	F48 MM-X-D6
E	F49 MM-X-E1	F51 MM-X-E2	F53 MM-X-E3	F55 MM-X-E4	F57 MM-X-E5	F59 MM-X-E6
	F50 MM-X-E1	F52 MM-X-E2	F54 MM-X-E3	F56 MM-X-E4	F58 MM-X-E5	F60 MM-X-E6
F	F61 MM-X-F1	F63 MM-X-F2	F65 MM-X-F3	F67 MM-X-F4	F69 MM-X-F5	F71 MM-X-F6
	F62 MM-X-F1	F64 MM-X-F2	F66 MM-X-F3	F68 MM-X-F4	F70 MM-X-F5	F72 MM-X-F6
G	F1 SM-X-G1	F3 SM-X-G2	F5 SM-X-G3	F7 SM-X-G4	F9 SM-X-G5	F11 SM-X-G6
	F2 SM-X-G1	F4 SM-X-G2	F6 SM-X-G3	F8 SM-X-G4	F10 SM-X-G5	F12 SM-X-G6
H	F13 SM-X-H1	F15 SM-X-H2	F17 SM-X-H3	F19 SM-X-H4	F21 SM-X-H5	F23 SM-X-H6
	F14 SM-X-H1	F16 SM-X-H2	F18 SM-X-H3	F20 SM-X-H4	F22 SM-X-H5	F24 SM-X-H6
J	F25 SM-X-J1	F27 SM-X-J2	F29 SM-X-J3	F31 SM-X-J4	F33 SM-X-J5	F35 SM-X-J6
	F26 SM-X-J1	F28 SM -X-J2	F30 SM-X-J3	F32 SM-X-J4	F34 SM-X-J5	F36SM-X-J6
K	F37 SM-X-K1	F39 SM-X-K2	F41 SM-X-K3	F43 SM-X-K4	F45 SM-X-K5	F47 SM-X-K6
	F38 SM-X-K1	F40 SM-X-K2	F42 SM-X-K3	F44 SM-X-K4	F46 SM-X-K5	F48 SM-X-K6
L	F49 SM-X-L1	F51 SM-X-L2	F53 SM-X-L3	F55 SM-X-L4	F57 SM-X-L5	F59 SM-X-L6
	F50 SM-X-L1	F52 SM-X-L2	F54 SM-X-L3	F56 SM-X-L4	F58 SM-X-L5	F60 SM-X-L6
M	F61 SM-X-M1	F63 SM-X-M2	F65 SM-X-M3	F67 SM-X-M4	F69 SM-X-M5	F71 SM-X-M6
	F62 SM-X-M1	F64 SM-X-M2	F66 SM-X-M3	F68 SM-X-M4	F70 SM-X-M5	F72 SM-X-M6

Figure 4: PIER FIBER DISTRIBUTION CENTER EDC 1
B-B REAR DETAIL - SUBMARINE PIERS

-NOT TO SCALE-

Figure 3-23 Pier Fiber Distribution Center EDC 1 Front Detail (Surface Ship Pier)

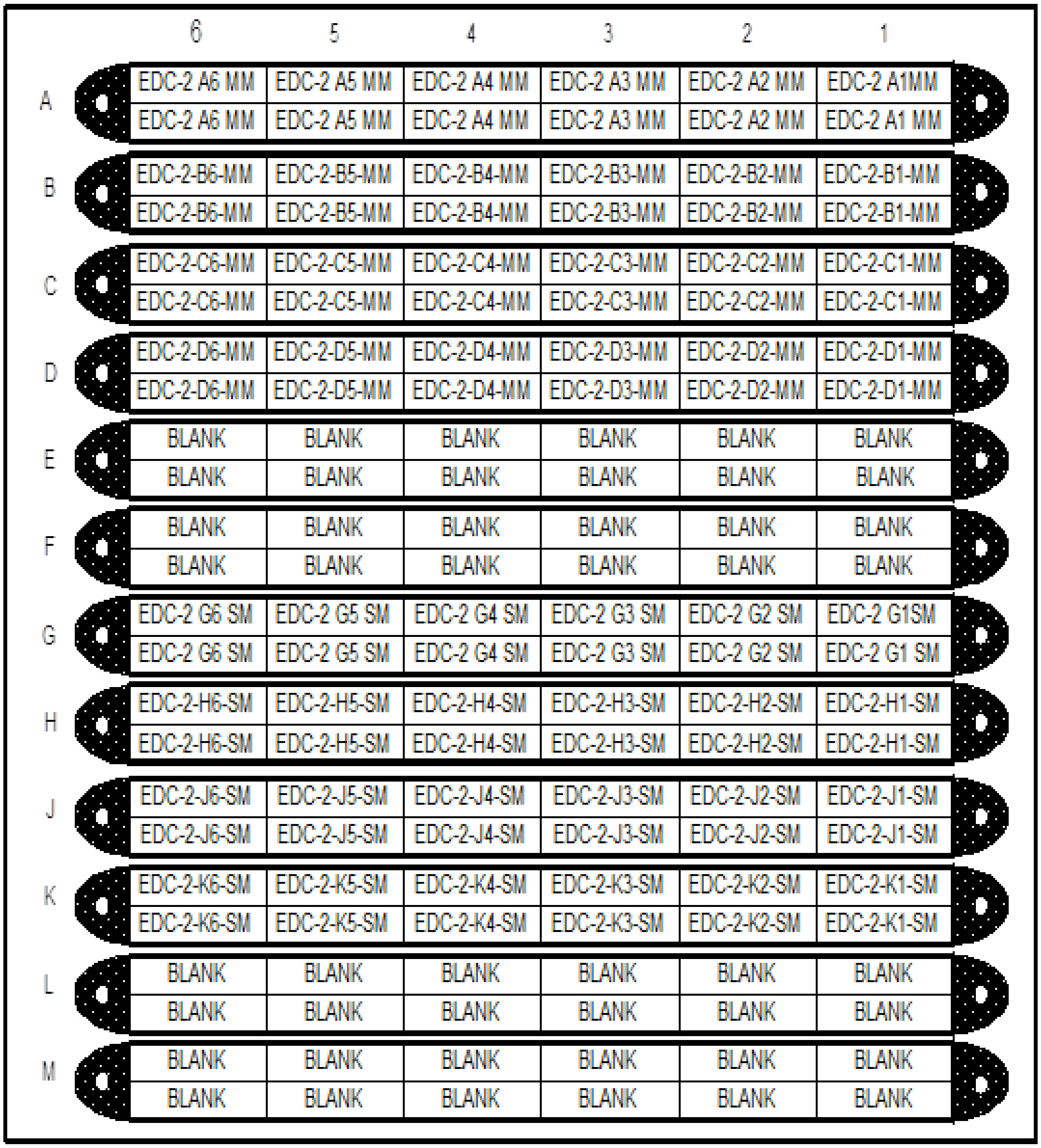


Figure 5: PIER FIBER DISTRIBUTION CENTER EDC 1
A-A FRONT DETAIL - SURFACE PIERS

-NOT TO SCALE-

Figure 3-24 Pier Fiber Distribution Center EDC 1 Front Detail (Submarine Pier)

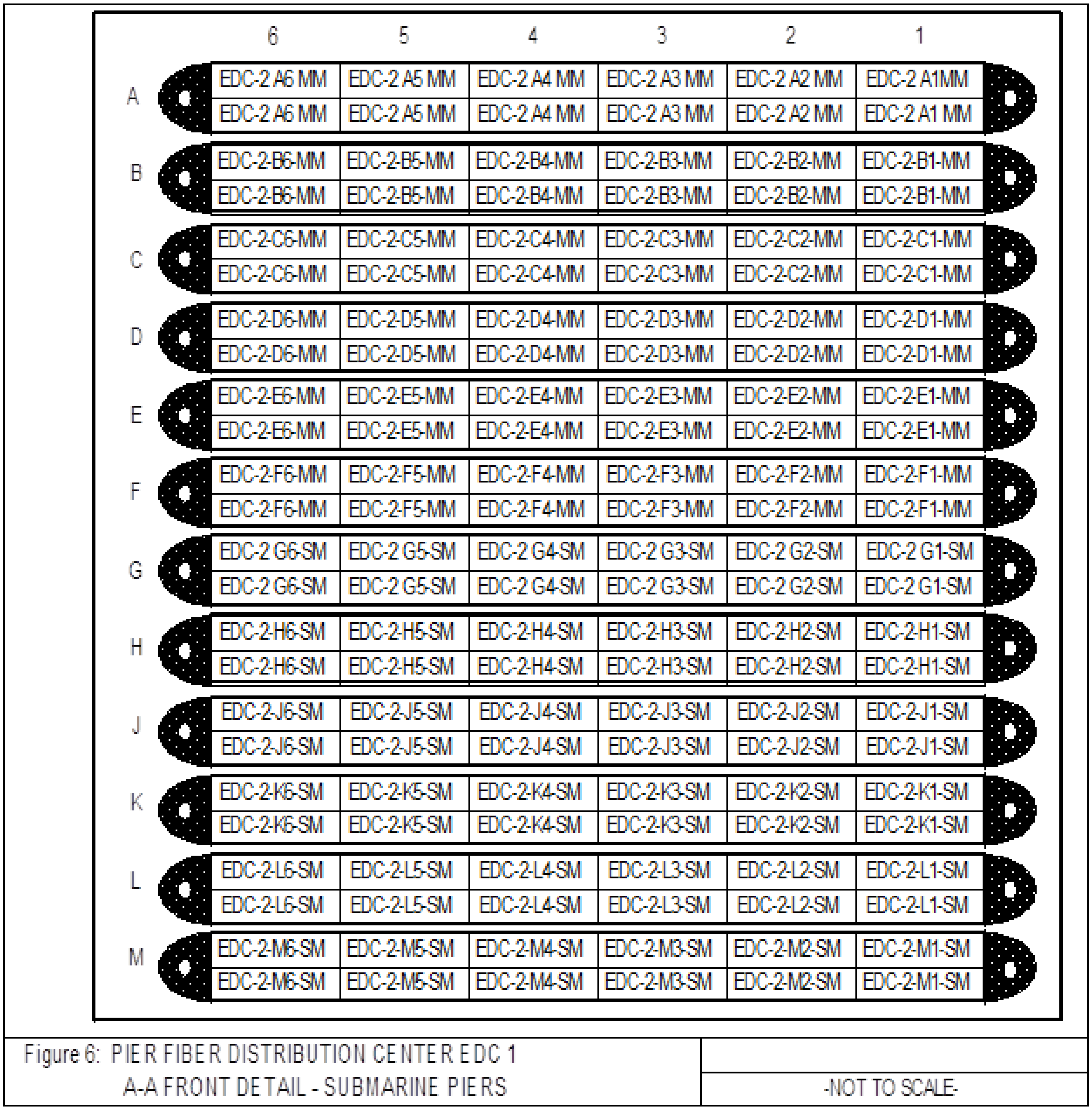


Figure 3-25 Fiber Optic Connectivity Riser Panel Detail

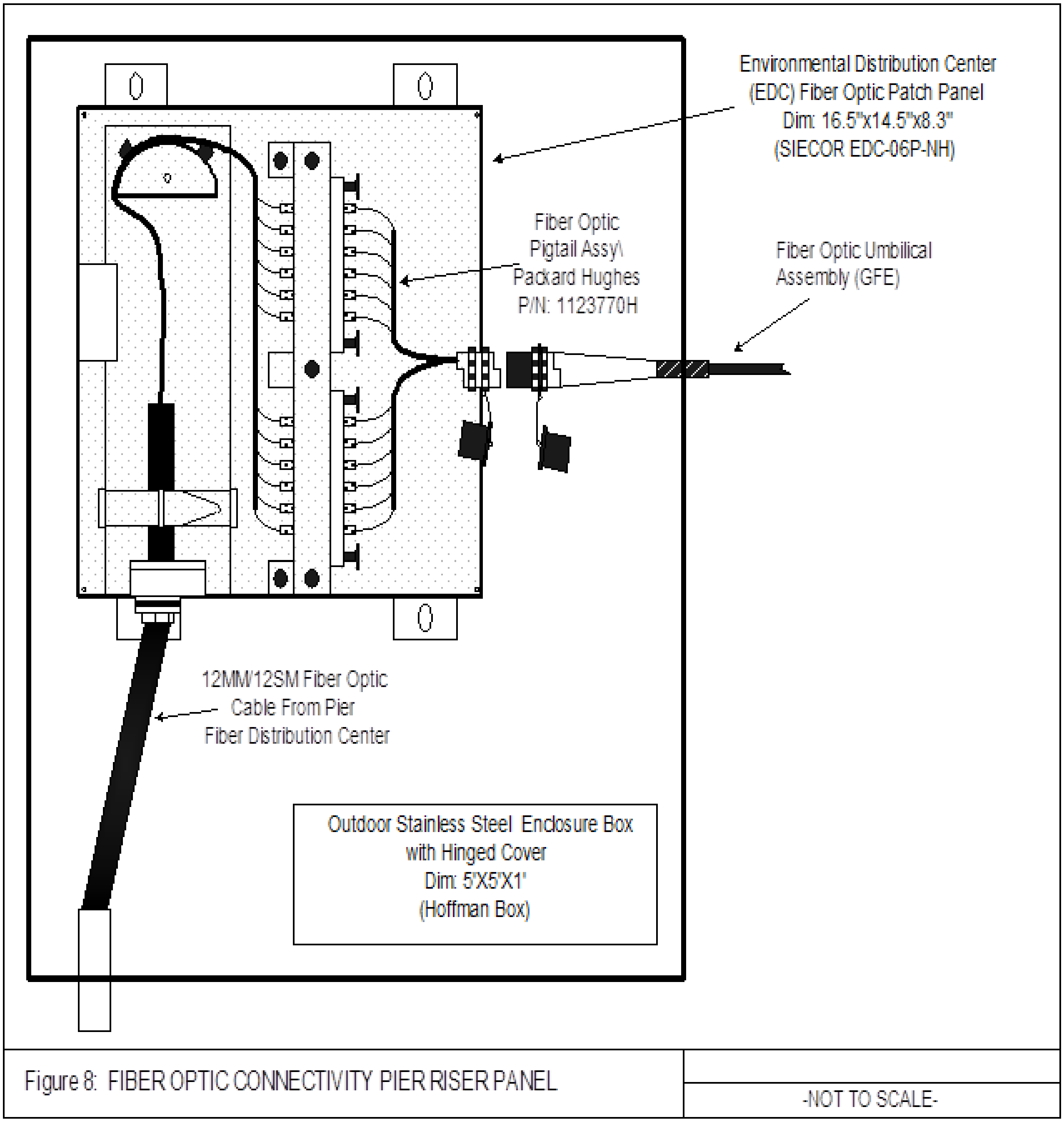


Figure 3-26 EDC Fiber Optic Patch Panel Surface Pier

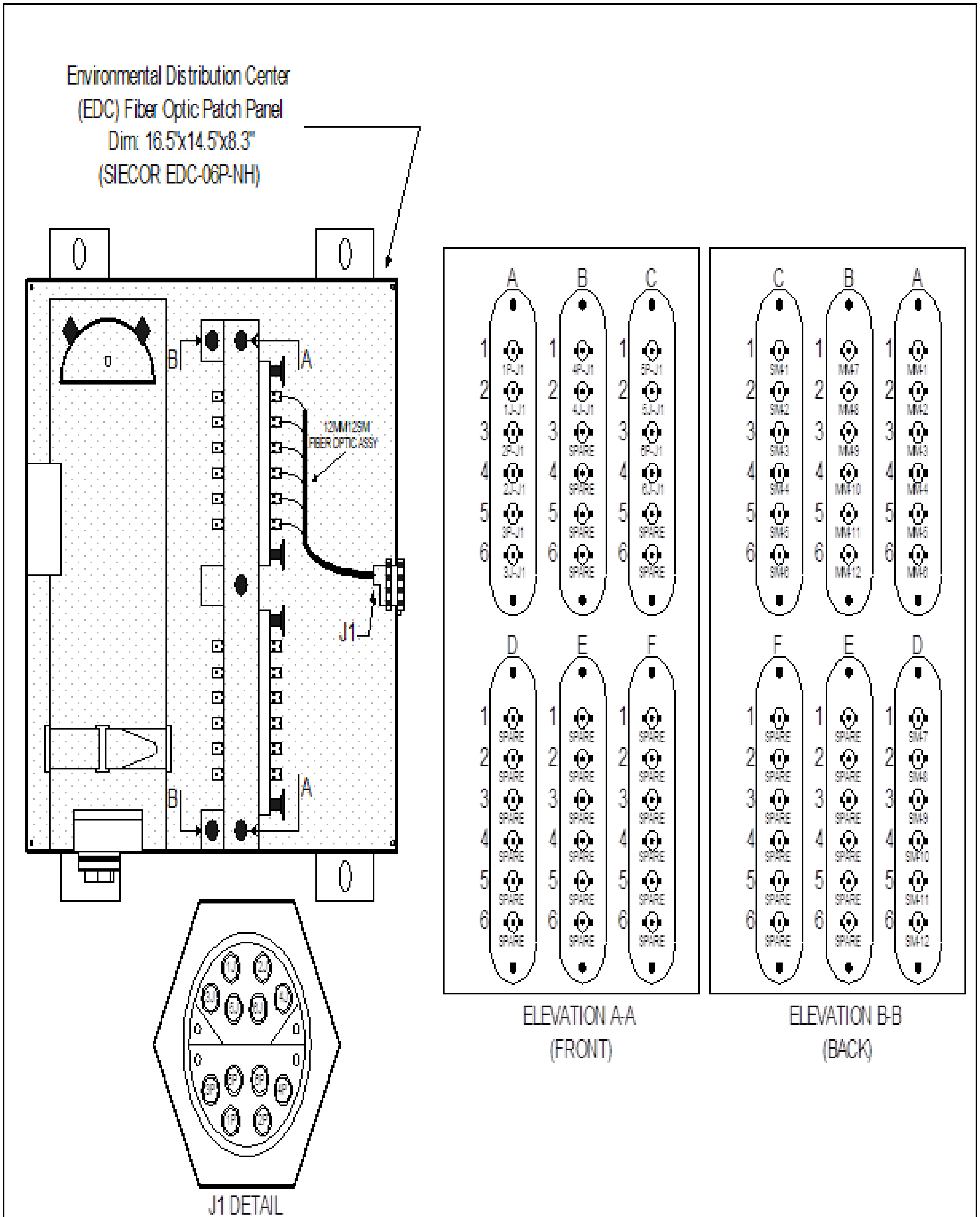


Figure 9: Environmental Distribution Center (EDC)
Fiber Optic Patch Panel (SURFACE PIERS)

-NOT TO SCALE-

Figure 3-27 EDC Fiber Optic Patch Panel Submarine Pier

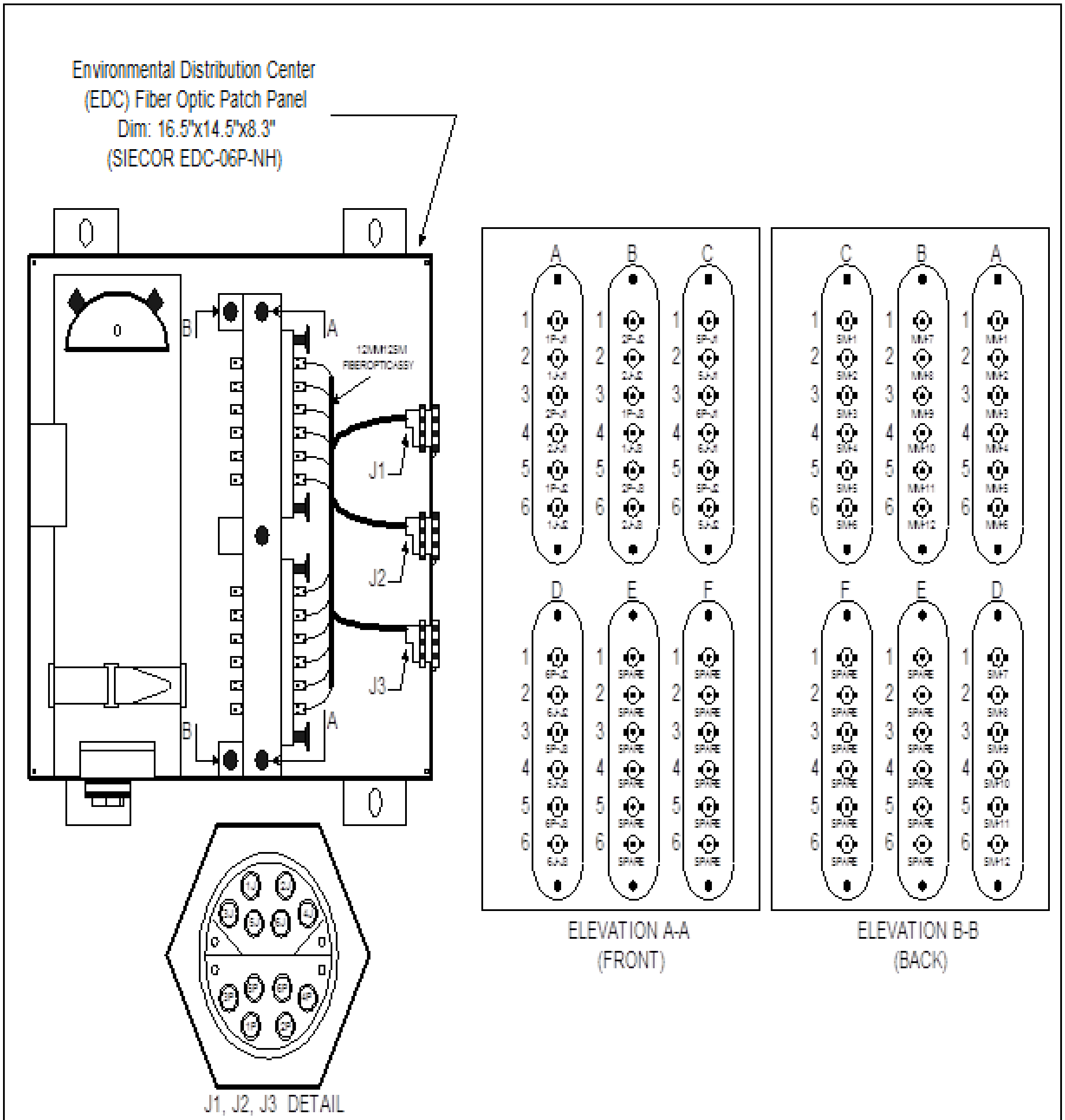


Figure 10: Environmental Distribution Center (EDC) Fiber Optic Patch Panel (SUBMARINE PIERS)	-NOT TO SCALE-

Figure 3-28 Rubber Gasket Cutout Surface Pier

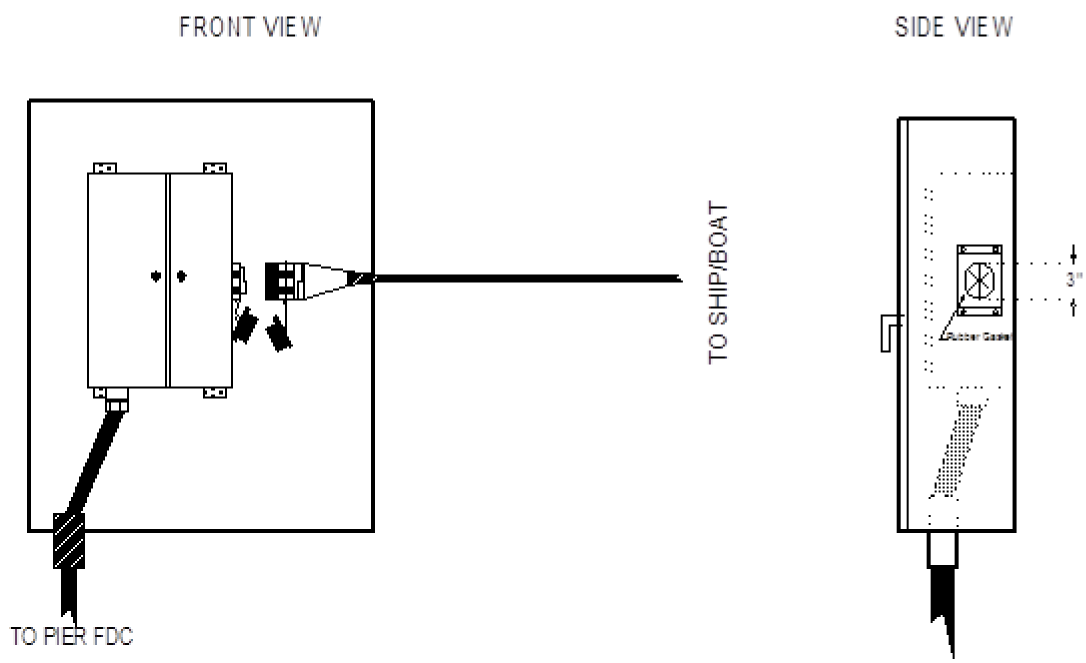


Figure 11: HOFFMAN ENCLOSURE LAYOUT (SURFACE PIERS)

-NOT TO SCALE-

Figure 3-29 Rubber Gasket Cutout Submarine Pier

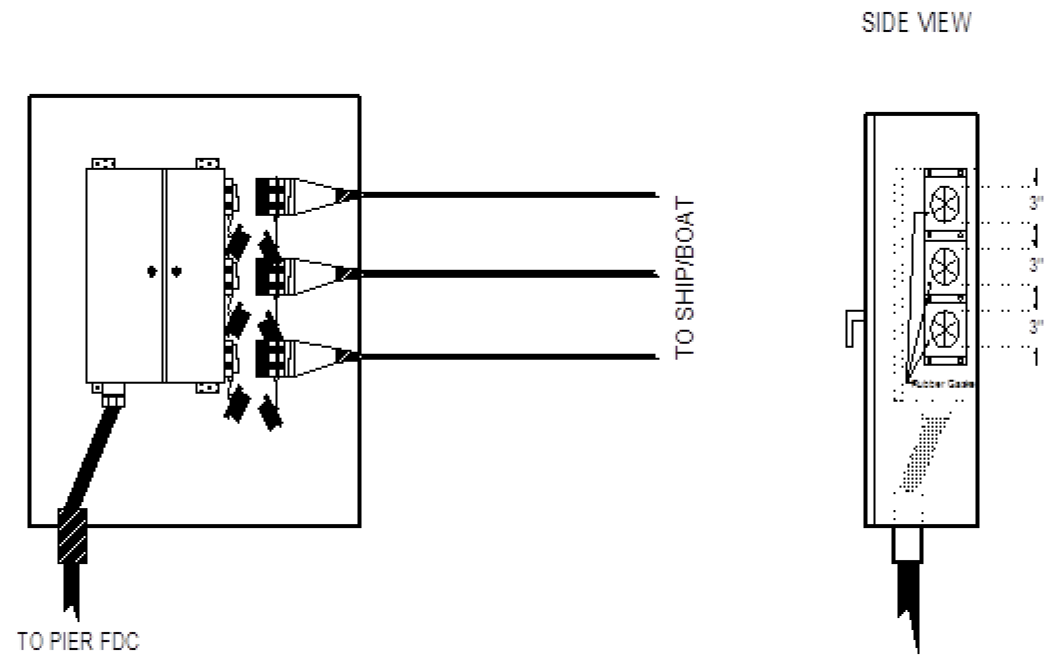


Figure 12: HOFFMAN ENCLOSURE LAYOUT (SUBMARINE PIERS)

-NOT TO SCALE-

3-9.2 Telephone Systems.

Provide a voice telephone distribution system to each berth on piers and at dry docks unless specifically instructed otherwise. Provision should be made for the telephone cable to be terminated in a telecommunications outlet assembly adjacent to each berth. Provide a Main Distribution Frame (MDF) at the shore end of the pier for the cross-connect devices. The assembly must include connectors mounted to the exterior of the enclosure. These connectors will be connected to the shore end of the ship-to-shore telephone cable. Commercial "dial tone" services and the telephone switching system is the responsibility of the Station's Communications Officer. Figure 3-30 provides a typical telephone connection with surge protector module.

3-9.2.1 Ships Demand.

APPENDIX A identifies the number of telephone pair shorelines required by each ship type. Cable sizes include the ship requirement, the appropriate embarked-staff requirement, and an allowance for spare pairs. Cable sizes have been rounded up to the next larger standard telephone cable. The pier telephone distribution cable system should be designed using the pier's berthing plan. Provide cable sizes based upon the worst case at each berth. Berths designed for nested ships should be provided with the total number of cables indicated for all ships in the nest.

3-9.2.2 Other Demand.

Provide telephone service to security checkpoints and watchstand stations. These requirements may occur at the head and end of the pier, and at intermediate points along the pier. Coordinate with the Activity's security representatives.

3-9.2.3 Location and Arrangement of Pier Telephone Distribution System.

Each berth should be served by an independent run of conduit. The telecommunications outlet assembly must be an independent, freestanding structure. Outlet assemblies must be designed to prevent damage by ships lines and by traffic on the pier.

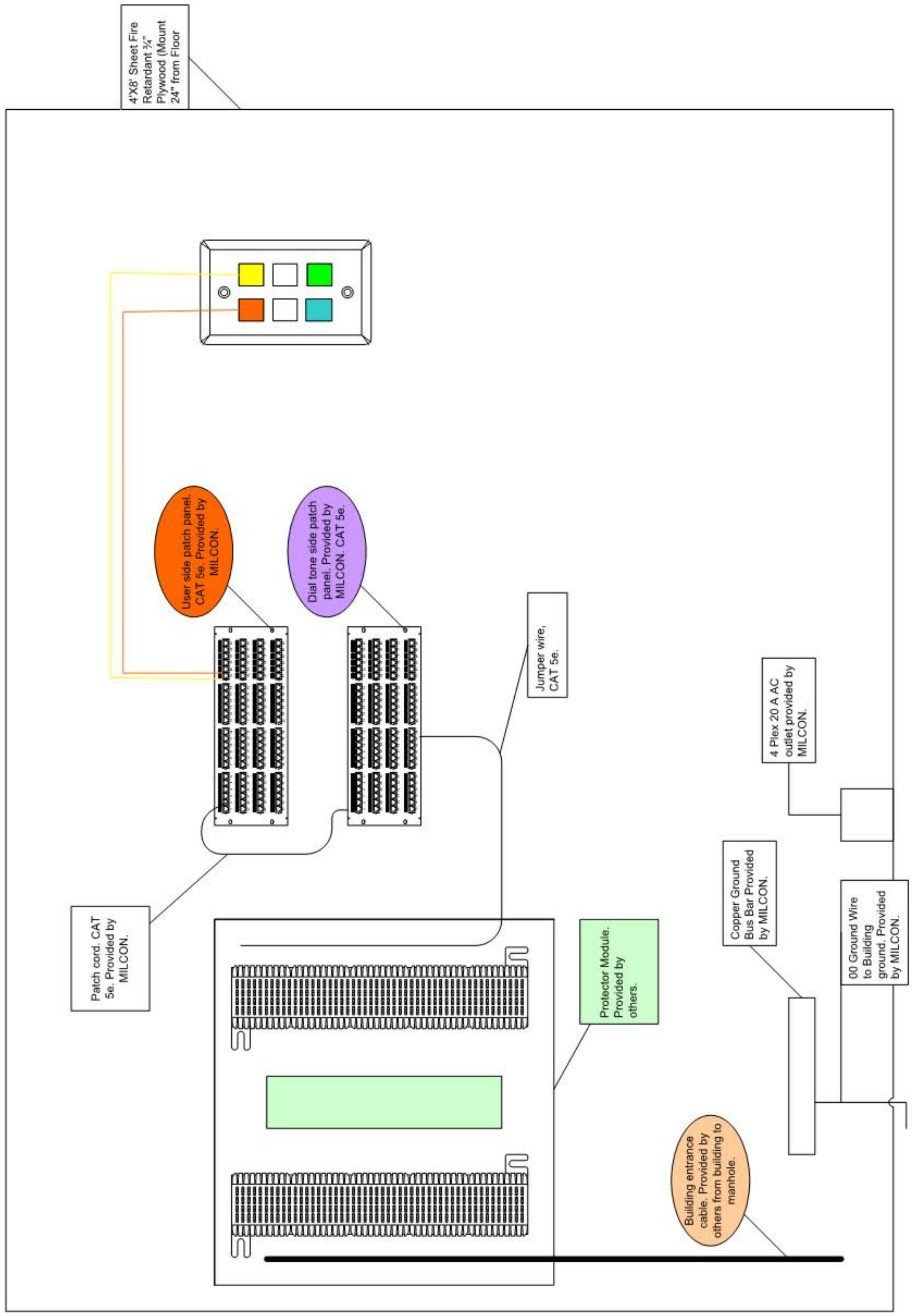
3-9.3 Other Telecommunications Systems.

The need for the systems described below should be evaluated on a site-by-site basis. Provide these systems as directed by the Activity and the cognizant Service.

3-9.3.1 Dedicated Communication Circuits.

Provide one (1) 2 inch (51 mm) conduit from the manhole or cross-connect cabinet at the head of the pier to each telecommunications outlet assembly. This conduit must be dedicated for communication circuits that cannot use the telephone system.

Figure 3-30 Typical Telephone Connection Detail with Surge Protector Module



3-9.3.2 Cable Television.

Provide a conduit system (from the manhole at the head of the pier to each telecommunications outlet assembly) to support cable television requirements. Unless instructed otherwise, the cable television system will be provided by a commercial vendor. The designer must coordinate with the vendor and provide a complete raceway system.

3-9.3.3 Alarm and Signal Circuits.

Provide two (2) 1-1/4 inch (32 mm) conduits (from the manhole at the head of the pier to each telecommunications outlet assembly) to serve alarm and signal circuits that cannot use the telephone system. Provide all conductors to serve these systems unless instructed otherwise. Coordinate with the Activity and the cognizant Service.

3-10 PIER POWER METERING SYSTEMS.

Naval ships connected to shore power utilize a large percentage of the Navy's infrastructure electricity. Many bases are now requiring the electricity usage to be measured and recorded. Since multiple circuits are normally used to provide the required capacity to the ships, often in a "nested" configuration, standard metering/ monitoring equipment may not be appropriate. There are however, commercial and government developed systems, including hardware and software that are available. Coordinate with the cognizant Service to determine if the Activity has a desired or required system that must be utilized.

3-10.1 Pier Power Monitoring System (PPMS).

One of the power measurement systems available has been developed by the NAVFAC Engineering and Expeditionary Warfare Center (EXWC, formerly NFESC). The system is defined as the Pier Power Monitoring System (PPMS) and consists of specialized embedded computer circuit boards, embedded software, and personal computer (PC) software that enable the Activity to measure, record, and study the electricity consumption and usage patterns of the connected ships. The PPMS was developed to be cost effective and to be easily installed. It involves the simple utilization of a conventional utility metering system. Typically, each monitored electrical outlet assembly will have one set of circuit boards. Battery backup features ensure that no data or operating software is lost when electrical power is disconnected. The data are sent to a central PC station. The PC can program the circuit boards and retrieve data. Parameters available on the PC are megawatt-hours and instantaneous values of Amps, Volts, power factor, and megawatts. Time-of-use (TOU) data are also available for the present 24-hour period. The PPMS correctly identifies the receptacles allocated to each ship and the total power consumed. Both the ship (customer) and the Activity (provider) can easily track shore supplied ship electricity. Software can be easily tailored to send the data directly from the PPMS to a master data collection and billing system. By providing complete energy use pattern information and consumption data, the PPMS enables Navy managers to educate, monitor, and encourage energy conservation for ships using shore supplied electricity. An operating PPMS demonstration system is presently installed on Pier 1 at Naval Station San Diego, CA.

3-11 ADDITIONAL SUBMARINE AND UUV REQUIREMENTS.

Submarines and UUVs have specific pier requirements to meet berthing needs. These differ from other platforms and have specific needs to support surge requirements. Additional requirements will be provided as they are identified. Coordinate with the Activity on other unique requirements for these platforms.

See UFC 4-152-01, Piers and Wharves, for additional submarine/UUV pier/berth configuration, construction, berthing, fendering, access, and utility infrastructure requirements.

3-12 OTHER SERVICES.

Although their design is not covered by this UFC other services will occasionally be required at active and repair berthing facilities. Such systems include: jet fuel, chilled water, pure water, oxygen, acetylene, MAPP gas, and inert gases. These services may be permanent or temporary (tank truck, gas containers or similar means) depending upon required quantity, location and economic considerations. The designer must consult with the Activity and the cognizant Service for specific instructions.

CHAPTER 4 SUPPLY AND AMMUNITION PIERS

4-1 STEAM AND COMPRESSED AIR.

In general, steam and compressed air services are not required on supply and ammunition piers. However, ammunition piers that serve ballistic submarines require special considerations.

4-2 SALTWATER AND NONPOTABLE WATER.

Provide fire protection water as required for active berthing facilities. However, consult with the Activity and the cognizant Service regarding ammunition piers that are in an isolated area and are far removed from mobile fire apparatus. For remote ammunition piers, design a pumping station to supply between 2,500 and 3,500 gpm (9,463 and 13,248 L/min) at sufficient pressure to provide 75 psig (517 kPa) residual pressure at the most remote outlet. Outlet connection threads must be national standard male hose threads unless required otherwise to serve an existing system.

4-3 POTABLE WATER, SEWER, AND OILY WASTE.

For supply piers, requirements are the same as those for active berthing facilities. For ammunition piers, provide potable water only when indicated in the project directive. However, oily waste and sewer collection systems should always be provided. For all three systems, see the requirements defined in CHAPTER 3.

4-4 ELECTRICAL SERVICE.

Shore power for ships hotel service, lighting, and power for industrial services (as required) will be provided on ammunition piers and wharves that load missiles for nuclear powered vessels. This provision lengthens the life of vessel reactors and decreases manpower requirements during the loading / unloading operation. Electrical systems provided on ammunition piers must be designed for the hazardous rating actually encountered and in accordance with NFPA 70.

4-5 TELECOMMUNICATION SYSTEMS.

Both supply piers and ammunition piers require telecommunication systems. However, full services that are defined for active and repair berths are not required except for ammunition piers that serve ballistic submarines. Consult with the Activity and the cognizant Service for specific requirements. In general, the design guides for active and repair berths are applicable. The systems required are to be evaluated on a project-by-project basis. Lastly, comply with all hazardous requirements associated with ammunition piers.

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CHAPTER 5 FUELING PIERS

5-1 STEAM AND COMPRESSED AIR.

In general, steam and compressed air services are not required on fueling piers.

5-2 SALTWATER AND NONPOTABLE WATER.

Ships loading or unloading POL products at fueling piers will never be cold iron and will therefore not require a shore-to-ship fire protection water connection.

5-3 POTABLE WATER, SEWER, AND OILY WASTE.

Supply potable water systems at locations where connections may be made to existing systems. Maximum potable water requirements are 1,000 gpm (3,785 L/min) with 40 psi (276 kPa) residual pressure at the most remote outlet. Design outlets as for active berthing and space about 200 ft (61 m) apart. Provide oily waste and sewage collection systems at all fueling piers unless instructed otherwise. Consult with the Activity and the cognizant Service. Provide all three systems in accordance with the criteria defined in CHAPTER 3.

5-4 POL SYSTEMS.

Refer to UFC 3-460-01, *Design: Petroleum Fuel Facilities* for information on piping and other appurtenances, including manifolds, hoses and shelters, connections and adapters, hose handling equipment, bilge and ballast lines, stripper pumps, environmental protection, and other equipment. In general, ships use a 6 inch (152 mm) commercial flanged connection. Verify before commencing design of shore connections.

5-5 ELECTRICAL SERVICE.

Ships service, temporary lighting, and ships industrial power are not required for fueling piers and quay walls. Consult with the Activity and the cognizant Service regarding electrical systems that directly serve the pier. Evaluate all hazardous requirements and preferences that may be encountered.

5-6 TELECOMMUNICATION SYSTEMS.

Fueling piers require telecommunication systems. However, full services that are defined for active and repair berths are not required. Consult with the Activity and the cognizant Service for specific requirements. In general, the design guides for active and repair berths are applicable. The systems required are to be evaluated on a project-by-project basis. Lastly, comply with all hazardous requirements associated with fueling piers.

5-7 ADDITIONAL REQUIREMENTS.

Refer to UFC 3-460-01, *Design: Petroleum Fuel Facilities* for additional requirements.

5-8 FIRE PROTECTION.

Refer to UFC 3-600-01, *Fire Protection Engineering for Facilities*. Consult with the Fire Protection Engineering Departments, both at the local level and at the cognizant Service level.

CHAPTER 6 MISCELLANEOUS PROVISIONS

6-1 FREEZE PROTECTION.

6-1.1 Where Required.

Provide freeze protection for saltwater, fresh-water, sanitary-waste (sewage), and oily-waste (bilge) pipes exposed on piers and wharves and in dry docks when located in freezing climates.

6-1.2 Regional Weather Differences.

See Figure B-1 and Table B-1. For design purposes, coastlines within the United States can be divided into the five regions listed below. Table B-1 lists average historical weather data for the five regions. For freeze protection systems at locations outside of the United States, match weather data (insofar as possible) to one of the regions in Table B-1 and design accordingly. The five weather regions are defined as follows:

Region I: "Severe": Alaska, Maine, New Hampshire, Great Lakes and inland locations.

Region II: "Cold": Connecticut, Massachusetts, Rhode Island, and New York.

Region III: "Moderate": Pennsylvania, New Jersey, Delaware, Maryland, and Washington, DC.

Region IV: "Mild": Washington, Oregon, Virginia, and North Carolina.

Region V: "Very Mild": California, South Carolina, Georgia, Texas, Mississippi, Louisiana, Alabama, and Florida.

6-1.3 Methods.

The methods described below vary with climate. Use the methods recommended below when the relative costs of electricity, sewage disposal, and freshwater are not abnormally high. Where the cost of electricity, sewage disposal, or water is abnormally high, then modify the freeze protection system and use an approved method that minimizes operating cost. Use approved life cycle cost procedures and submit analysis.

6-1.4 Protection in Regions I and II.

6-1.4.1 Water Lines.

For water lines, provide freeze protection by using a combination of electric heat tape and pipe insulation. The suggested combinations of insulation thickness and heating (Watt density) for various pipe sizes are shown in Table B-2. Heat tape should be controlled by remote thermostats having sensors taped to the surface of pipes and under the insulation. Consult with the Activity and the cognizant Service regarding preferred heat tape systems and methods. Several sections of heat tape may be required due to overall pipe length. Provide each section of heat tape with a dedicated thermostat. Thermostats must be in a protected location that is also accessible. The heating requirement given in Table B-2 (6 Watts/ft) is the Watt density available for a typical electric heat tape. Any Watt density from 4 to 10 Watts/ft would be suitable, but insulation thicknesses must be adjusted to compensate. Insulation thicknesses given in Table B-2 are based upon polyurethane. Adjust thickness for other insulation materials as based upon their rated thermal conductivity values. Protect backflow devices, valves, and risers with electric heat tape and preformed polyurethane insulation kits. Heat tape systems must be maintainable to be successfully used for the system's expected life span. To improve maintainability, use multiple sections of heat tape instead of extended single circuits. The designer may need to consider special heating systems in which heating elements are placed in channels alongside the pipe. These systems periodically terminate in accessible junction boxes. Maintenance personnel can then easily replace an inoperable section. It is also much easier to troubleshoot when the heating system is divided into reasonable segments with accessible test points.

6-1.4.2 Sewer and Oily Waste Lines.

A combination of electric heat tape and pipe insulation should be used in accordance with Table B-2 for: (1) exposed gravity sewer piping which drains fixtures directly; (2) exposed oily waste piping; and (3) for those portions of exposed pressure lines (sewage and oily waste) which will not completely drain upon cessation of pumping. Heat tape may not be required (insulation only) for exposed pressure and gravity sewer and oily waste piping (or portions thereof) which receive material intermittently and which drain well when pumping stops. Neither heat tape nor insulation may be required for pipe risers and valves above pier decks and in dry dock galleries.

6-1.5 Protection in Regions III and IV.

6-1.5.1 Fresh Water Lines.

For water lines, the preferred method of freeze protection in these regions is to use a combination of insulation and a flushing of water through the pipes. Insulation thickness for various pipe sizes, and pipe sizes for which flushing is necessary, are defined in APPENDIX B Table B-3. Insulation thicknesses are such that for expected durations of subfreezing temperatures less than 50 percent of pipe contents will freeze. Where flushing is indicated, use thermostatically actuated solenoid valves. Size each valve for a rate at which the entire contents of exposed piping can bleed in 8 to 12 hours. Thermostats should be in protected locations and sensors are to be taped to the surface of pipes and under the insulation. Thermostats should be factory set to open the flushing valves at 30 °F (-1 °C) and to close the valves at approximately 35 °F (2 °C). Flushing valves (freeze protection valve) and associated thermostats should be located at each ship's connection and at any other line extremity to protect the most remote valve component in the system. Insulation thicknesses given in Table B-3 are based upon polyurethane. Adjust thickness for other insulation materials as based upon their rated thermal conductivity values. Insulation must also be applied to backflow devices and valves. Special care must be taken to prevent the freezing of flushing valves and associated pipe connections. If water is scarce, or if the winter temperature of buried water mains is below 45 °F (7.2 °C), heat tape should be used in lieu of flushing. In this event, the design should be based upon the data defined in Table B-4.

6-1.5.2 Sewer and Oily Waste Lines.

A combination of electric heat tape and pipe insulation should be used in accordance with Table B-4 for: (1) exposed gravity sewer piping which drains fixtures directly; (2) exposed oily waste piping; and (3) those portions of exposed pressure lines (sewage and oily waste) which will not drain completely upon cessation of pumping. Neither insulation nor heating is required for exposed sewer and oily waste piping (or portions thereof) which receive material intermittently and which drain well when pumping stops. This applies to both pressure lines and gravity lines.

6-1.6 Protection in Region V.

In portions of Region V in which the temperature can drop below 25 °F (-4 °C), use a properly sized flushing valve, atmospheric thermostat, and timer to bleed approximately 35 gallons per inch (132.5 L per 25 mm) of pipe diameter for each 100 ft (30.5 m) of fresh water pipe. This flushing is to be applied over an 8 to 12 hour period on each day that the ambient temperature drops below 25 °F (-4 °C). Pipes need not be insulated, but flushing valves and connections must be located at system extremities and must be protected from freezing.

6-1.7 Modification of Requirements for Saltwater.

Because seawater freezes at a temperature approximately 4.5 °F (-15.3 °C) lower than that at which freshwater freezes, make the following adjustments when designing freeze protection for exposed saltwater mains:

- In Regions I and II, treat saltwater the same as required for freshwater.
- In Region III, design as for region IV.
- In Region IV, design as for region V.
- In Region V, no freeze protection is necessary for saltwater at any location.

6-1.8 Materials.

6-1.8.1 Pipe.

Piping materials must be metallic where heat tape is required. Where a flushing system is utilized, any approved piping material may be used.

6-1.8.2 Heat Tape.

Flat style electric heat tape is recommended. Heat tape should be easy to splice and repair and must be waterproof. A low Watt density (4 to 10 Watts per lineal foot (13 to 33 W/m) of pipe) is recommended, and the ability to lap the tape without damage should be required. When heat tape is used with the insulation thicknesses listed in Table B-2 and Table B-4, they will cycle 30 to 60% of the time on the coldest days.

6-1.8.3 Insulation and Covering.

Closed-cell foam-type insulations (such as cellular glass) having low moisture absorption qualities should be used for Regions I and II due to the destructive effect of freezing on wet insulations. Use closed-cell foam-type insulation for Regions III and IV if wave action and/or immersion are possible. Cover all insulation with a watertight metallic or plastic system.

6-1.8.4 Valves and Thermostats.

Select single-seated solenoid valve shaving flow constants suitable for bleeding proper quantities of water in the prescribed interval. Temperature sensors should be ambient air temperature sensing type. Thermostats may be bimetallic, thermistor, or Resistance Temperature Detector (RTD) type, having differentials of 2 to 5 °F (-16.6 to -15 °C).

6-2 PIPING IDENTIFICATION.

6-2.1 Primary Identification.

Identify each valve on a pier, wharf, or dry dock by a plain language brass tag, and labeled. (Example: "potable water" or "sewer".) Additionally, at each shore-to-ship utility connection, name plates or stenciled letters near the connection must identify the utility in plain language.

6-2.2 Color Coding.

Two sources of design requirements govern color-coding for pier, wharf, and dry dock piping.

6-2.2.1 Distribution Piping On or Under Deck and Ashore.

Such piping, exclusive of shore-to-ship utility connections, must be color coded in accordance with MIL-STD-101, *Color Code for Pipelines and for Compressed Gas Cylinders*. Applicable requirements must be specified in the design documents.

6-2.2.2 Shore-to-Ship Utility Connections.

Such piping (including valves, operating levers, ends of hose assemblies, risers, and adjacent piping) must be specified to be color-coded in accordance with Table 6-1. Color-coding may also extend to adjacent curbs, protective rails, posts, and walls.

6-3 OPERATIONAL NOTICES.

Provide the following operational notices. Consult with the Activity and the cognizant Service regarding other desired notices, nameplates, warning signs, and so forth.

- Bleed systems must be marked with the following warning:

  ”Freeze protection valve.
  Water will flow below 35 °F.
  Do not close.”

- Heat tape systems must be marked with the following warning:

  “Heat tape system (self-limiting).
  Do not disconnect power.”

Table 6-1 Color Code for Shore-to-Ship Utility Connections [a, d]

Shore Service [b]	Color	Reference Number [c]
Potable Water 40-81 psi (276-558 kPa)	Blue, Dark	15044
Nonpotable Water for Fire/Flushing/Cooling 100-175 psi (689-1207 kPa)	Red	11105
Chilled Water	Stripped Blue/White	11044/17886
Oily Waste Discharge	Striped Yellow/Black	13538/17038
Sewer	Gold	17043
Steam and condensate 150 psig (1,034 kPa)	White	17886
Compressed Air 100-125 psi (689-862 kPa)	Tan	10324
High Pressure Air 3,000 psi (20.7 MPa)	Stripped Yellow/Gray	13538/16081
Fuel	Yellow	13538

Note:

[a] If additional information is needed on color-coding systems, contact the cognizant Service.
[b] Pressures shown are nominal pressures and represent average conditions.
[c] The reference numbers refer to Federal Standard 595B, Colors Used in Government Procurement.
[d] Also, see “General Specifications for Ships of the U.S. Navy”, COMNAVSEASYSCOM, 1991.

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CHAPTER 7 U.S. ARMY REQUIREMENTS

7-1 APPLICABILITY.

This chapter is applicable for waterfront facilities designed for U.S. Army vessels.

7-2 POTABLE WATER.

Provide potable water in sufficient capacity to permit the filing of a vessel's tank in such time as to avoid delays in the operation of the vessel.

7-2.1 Quantity and Pressure Requirement.

Provide a minimum flow of 100 gpm (6.3 L/s) with a minimum residual pressure of 25 psi (173 kPa) at the most remote outlet.

7-2.2 Piping and Outlets.

Install one (1) 2-1/2 inch (64 mm) connection at each service outlet. Potable water outlets on piers and wharves should have a reduced pressure-type backflow prevention device. The piping must be insulated and provided with electrical heat tape if the lines are normally full of water and subject to freezing temperatures. Where thermal expansion is a problem, provision should be made for expansion joints or loops. Figure 7-1 shows a typical potable water connection in the pier deck.

7-3 ELECTRIC POWER.

7-3.1 Electrical System Characteristics.

The main electrical system providing power to ships will be nominal 480 V, three-phase, 60-Hz, supplied from substations preferably located on the piers. For lighting service, a 120 V, 60-cycle, single-phase power may be provided.

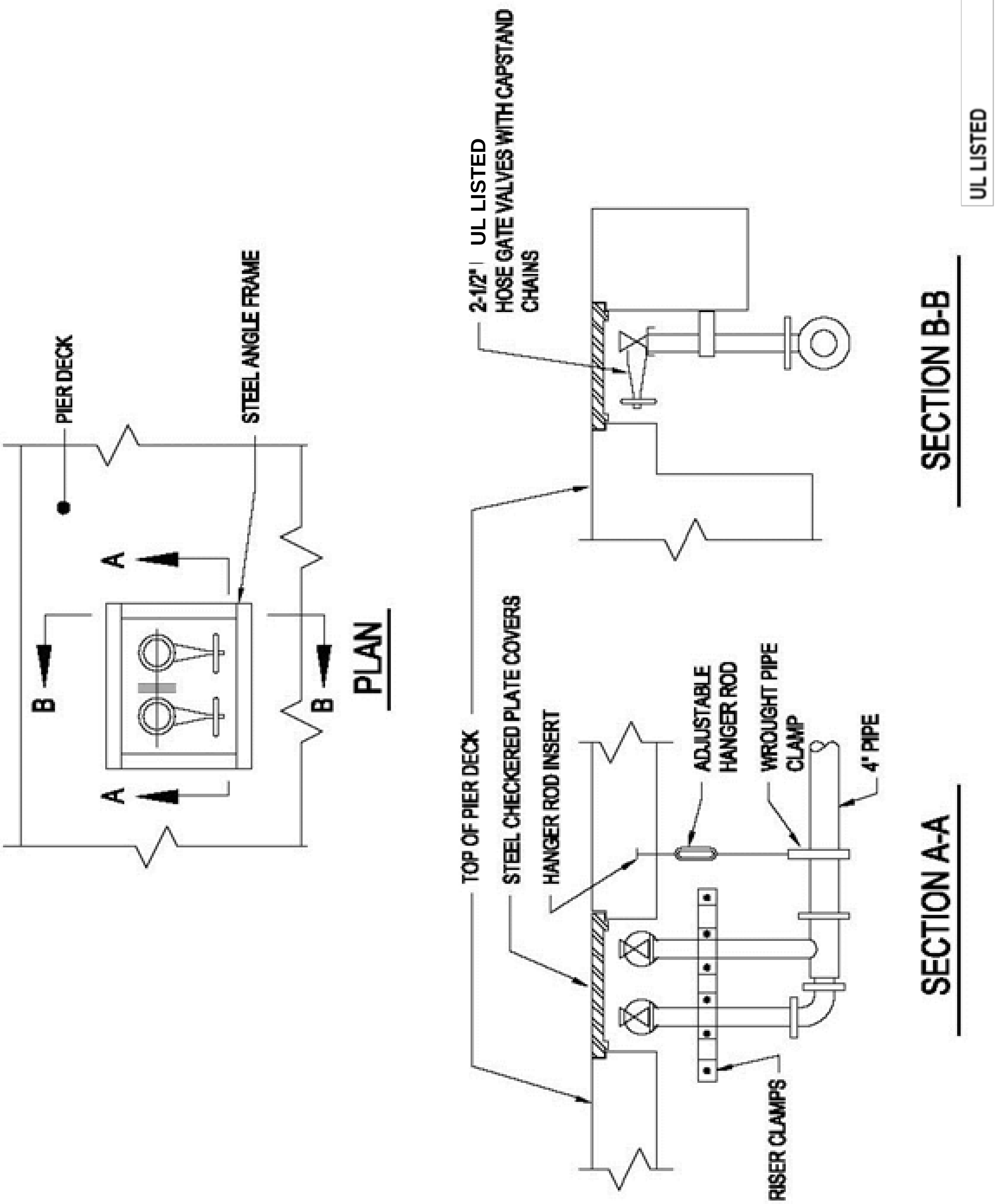
7-3.2 Ground System.

At piers, wharves, and other waterfront structures, a ground system that will measure not more than 3 ohms must be provided for permanent electrical equipment.

7-4 LOCATION AND NUMBERS OF SERVICE POINTS.

A minimum of two service points will be provided for each berth and located for the convenience of the using vessels. Each service point must supply electric power and water service as outlined above. Depending upon the physical site conditions of each specific installation, the point of connection for each service may be located in a single service box, or may be placed in separate but closely grouped boxes. Boxes should be located as close as practicable to the berthing face of the structure so that connected hoses and electric cables are not subject to vehicular traffic damage.

Figure 7-1 Typical Water Supply Connection for an Army Pier



7-5 MISCELLANEOUS.

7-5.1 Telephone Service.

Provide telephone service and outlet connectors for each berth. Locate for the convenience of the using vessels.

7-5.2 Lighting.

Satisfactory illumination shall be ensured for night operations. For open watering areas on the pier where ship loading or unloading occurs, a lighting intensity of at least 5 footcandles (54 lux) should be maintained. The illumination level of 5 footcandles (54 lux) should also be provided for areas of warehouses or storage buildings.

7-5.3 Fire Protection.

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

7-5.4 Sanitary Facilities and Sewage Disposal.

A dockside connection to a sewage disposal system must be provided for the disposal of sewage and oily wastes from vessels.

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APPENDIX A SHIP UTILITY REQUIREMENTS

Table A-1 Shore Services - Steam

Table A-2 Shore Services - Compressed Air

Table A-3 Shore Services - Salt or Nonpotable Water - Overhaul and Dry Dock

Table A-4 Shore Services - Potable Water

Table A-5 Shore Services - Oily Waste/Waste Oil (OWWO) Discharge

Table A-6 Shore Services - Sanitary (CHT) Discharge

Table A-7 Shore Services - Electrical

Table A-8 Shore Services -Telecommunications

Note:

* Data provided in this appendix is for general informational and basic planning purposes only. It is the best data available at the time of publication of this document. Data is incomplete and may not be completely accurate. Ship utility requirements shown are for various classes of ships and may not include all ships, modifications, flights, blocks, and other variants between ships in a class. Information is for ship demands only and may not reflect the full requirements at a berth/pier/facility. If additional shore side utilities are necessary, coordinate with the installation and/or Activity on the requirements.

Designer/Planner needs to verify ship utility requirements with specific ship(s) being berthed, Activity, Facilities Planning Criteria (FPC), PEO, Port Ops, and/or cognizant Command or Service.

Submit any updates, changes, or additions directly to the NAVFAC Engineering and Criteria Program Office or by submitting a CCR (http://www.wbdg.org/ffc/dod).

Table A-1 Shore Services – Steam

Steam *, a, b, c										
Ship Classification Symbol	(a) Intermittent Heating Loads (lb/h) [d] for Outdoor Temperatures of:				(b) Constant Load [e] (lb/h)	Overhaul (lb/h)	Ships Connection Data **			
	10 °F	30 °F	50 °F	70 °F			L	H	N	Size
AIRCRAFT CARRIERS										
CVN 68	45,000				5,000		493 P	23	1	4 - 2" angle stop V.
							528 S	23	1	4 - 2" angle stop V.
							698 S	23	1	6 - 2" angle stop V.
CVN 78 [f]	---	---	---	---	---	---	---	---	---	---
SURFACE COMBATANTS										
CG 47 [g]	11,200	11,200	11,200	8,745	3,270		335 P	25	1	2" male steam boss
							328 S	25	1	2" male steam boss
DDG 51 [f]	---	---	---	---	---	---	---	---	---	---
DDG 1000 [f]	---	---	---	---	---	---	---	---	---	---
FFG 7 [f]	---	---	---	---	---	---	---	---	---	---
LCS 1 [f]	---	---	---	---	---	---	---	---	---	---
LCS 2 [f]	---	---	---	---	---	---	---	---	---	---
SUBMARINES										
SSN 21 [h]										
SSN 688						3,000	210 C			6" 600# weld neck
SSN 774 [l]						50,000	246 S			5" NPS, class 600
SSBN 726 & SSGN [i]										
SSBN 826										
AMPHIBIOUS										
LCC 19, 20	7,000	5,500	4,700	4,100	3,000		304 P/S	26	3	
LHA 1	11,500	7,500	3,800	1,600	2,500		375 P/S	46	2	2" male steam boss
LHA 6 [f]	---	---	---	---	---	---	---	---	---	---
LHD 1	8,000	6,000	4,000	4,000	2,500		375 P/S	46	2	2" male steam boss
LHD 8 [f]	---	---	---	---	---	---	---	---	---	---
LPD 4 (AFSB (I))	6,000	3,700	2,200	1,300	2,200		328 P/S	34	4	
LPD 17 [f]	---	---	---	---	---	---	---	---	---	---
LSD 41 [j, k]					7,400		220 P/S	22	2	
LSD 49 [k]					7,400		220 P/S	35	2	
MINE WARFARE										
MCM 1										

Steam *, a, b, c										
Ship Classification Symbol	**(a) Intermittent Heating Loads (lb/h) [d] for Outdoor Temperatures of:**				**(b) Constant Load [e] (lb/h)**	**Overhaul (lb/h)**	**Ships Connection Data ****			
	10 °F	**30 °F**	**50 °F**	**70 °F**			**L**	**H**	**N**	**Size**
AUXILIARY										
T-AH 19										
T-AKE 1 [f]	---	---	---	---	---	---	---	---	---	---
T-AO 187										
T-AO 205										
T-AOE 6							545 P	28		
							515 S	28		
T-APL 2										
T-APL 15										
T-ARS 50	---	---	---	---	---	---	---	---	---	---
T-AS 39	6,000	6,000	6,000	6,000	6,000		636 S	58	2	
T-AVB 3										
EXPEDITIONARY										
T-EPF 1 (JHSV)	---	---	---	---	---	---	---	---	---	---
ESB 3										
ESB 4	---	---	---	---	---	---	---	---	---	---
PATROL										
PC 1										
ARMY										
TBD										
USCG										
NCS (WMSL)										
WAGB 399					370 @ 100 psi					
WAGB 420					@ 150 psi					
WHEC 717										
WLB 201										
WLBB 30										
WLM 551										
WMEC 615	---	---	---	---	---	---	---	---	---	---
WMEC 901										
WPB 1301										

Notes to Table A-1:

* See note (*) at beginning of APPENDIX A; information provided in this table is for general reference purposes only; information is incomplete and may not be accurate; verify utility requirements with ships/program office(s). Blanks in table indicate information is missing or unavailable at this time.

** Designations of locations of ship connections are as follows:

- L is the distance (in feet) of the connection aft of the stem of the ship.
- H is the height (in feet) of the connection above the design waterline.
- P, S, C, CL refer to Port side, Starboard side, and Center/Centerline of a ship respectively.
- P/S indicates one connection on each side of ship at distance L.
- N is the number of shipboard connections at given location(s).
- Where more than one connection exists, all locations are shown.

[a] Loads based on ship's peacetime complement (no air wing or troops).

[b] Maximum single ship demand at shore connections is column (a) plus column (b).

[c] For multiple ships, see Steam Service Diversity Factors.

[d] Steam quantity required to achieve normal environmental temperature in ship spaces relative to the outdoor temperatures shown. Interpolation between temperature columns is permissible. Determine specific site design temperature from UFC 3-400-02, Design: Engineering Weather Data, 99 percent 4 basis, whenever available. Design temperatures for sites not listed may be obtained from the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., ASHRAE Handbook, 97-1/2 percent basis.

[e] Galley, laundry, hot water, etc.

[f] Not required. '---'

[g] Loads based on absolute, worst case condition. Upon completion of ShipAlt CG47-00588K (All Electric), there will no longer be a requirement for steam.

[h] Information contained in NAVSEA Dwg 6726570 Rev C (NOFORN)

[i] Information contained in NAVSEA Dwg 4639983 Rev E (NOFORN)

[j] Figure based on normal supply to ship when berthed at NNSY.

[k] Steam used for hot water and ship services not significantly affected by outside temperatures. Mid-Life electrical upgrades will remove steam from these ships.

[l] Shore steam not expected for commissioned vessels; required only during dry dock periods; if needed, use 5 NPS ANSI B.16.5 flange 600.

Table A-2 Shore Services – Compressed Air

Compressed Air *, [a]								
Ship Classification Symbol	Quantity [b]	Pressure [c]	Minimum Branch Size [d]	Minimum Outlet Risers	Ships Connection Data **			
	(scfm)	(psig)	(inch)	per Berth	L	H	N	Size
AIRCRAFT CARRIERS								
CVN 68 [e]	2,400	125	4	5				
CVN 78 [f]	2,400	115-125	4	5	780 P	25	1	3”
					612 S	25	1	3”
SURFACE COMBATANTS								
CG 47	1,000	125	3	4				
DDG 51	1,000	125	3	3	146 C	21	1	2.5"
					274 S	21	1	2.5"
DDG 79 [g] (Flight IIA)	300 [a]	100	3		144 C	22	1	2.5” fem QDISC, Type V Class 2
					274 S	22	1	2.5” fem QDISC, Type V Class 2
	3,200 [c]	300	3		144 C	22	1	4” flg
					274 S	22	1	4” flg
DDG 1000 [h]	---	---	---	---	---	---	---	---
FFG 7	1,000	125	3	3	360 S	28	1	1.5"
LCS 1 [f]								
LCS 2 [f]								
SUBMARINES								
SSN 21 [i]	750	125						
SSN 688 [i]	750	125	2	2				
SSN 774 [i, j]	150	5,100			at aft charging station			1.750 – 12UN-3A x 0.500 NPS
SSBN 726 & SSGN [l, k]								
SSBN 826								
UUV								
AMPHIBIOUS								
LCC 19	1,050	125	2.5	4	369 P/S	46		
LCC 20	300	125	2.5	4				
LHA 1 [e]	800	125						
LHA 6 [h]	---	---	---	---	---	---	---	---
LHD 1 [e]	800	125						

Compressed Air *, [a]								
Ship Classification Symbol	Quantity [b]	Pressure [c]	Minimum Branch Size [d]	Minimum Outlet Risers	Ships Connection Data **			
	(scfm)	(psig)	(inch)	per Berth	L	H	N	Size
LHD 8 [g]	---	---	---	---	---	---	---	---
LPD 4 (AFSB (I)) [l]	1,000	125						
LPD 17 [m]								
LSD 41	300	125	3	4	220 C	35		
LSD 49	300	125	3	4	220 C	35		
MINE WARFARE								
MCM 1								
AUXILIARY								
T-AH 19								
T-AKE 1	207	125	---	N/A	N/A	N/A	N/A	N/A
T-AO 187								
T-AO 205								
T-AOE 6					475 P	28		
					470 S	28		
T-APL 2								
T-APL 15								
T-ARS 50	---	---	---	---	---	---	---	---
T-AS 39								
EXPEDITIONARY								
T-EPF 1 (JHSV)								
ESB 3	177	125	3	2	600 C	70	1	
ESB 4		150	2	1	600 C	16	2	
PATROL								
PC 1								
ARMY								
TBD								
USCG								
NSC (WMSL)		125						
WHEC 717								
WLB 201								
WLBB 30								
WLM 551								
WMEC 615	---	---	---	---	---	---	---	---
WMEC 901	---	---	---	---	---	---	---	---
WPB 1301								

Notes to Table A-2:

- * See note (*) at beginning of APPENDIX A; information provided in this table is for general reference purposes only; information is incomplete and may not be accurate; verify utility requirements with ships/program office(s). Blanks in table indicate information is missing or unavailable at this time.

- ** Designations of locations of ship connections are as follows:
  - L is the distance (in feet) of the connection aft of the stem of the ship.
  - H is the height (in feet) of the connection above the design waterline.
  - P, S, C, CL refer to Port side, Starboard side, and Center/Centerline of a ship respectively.
  - P/S indicates one connection on each side of ship at distance L.
  - N is the number of shipboard connections at given location(s).
  - Where more than one connection exists, all locations are shown.

[a] Low pressure compressed air requirements shown.

[b] For multiple ships, use diversity factor.

[c] Minimum required at connections. Higher pressures may be necessary where specifically directed by the cognizant Service or the using agency.

[d] This is size of pipe from main to (and including) outlet riser.

[e] No shore connection; normal procedure is for ship's force to identify valve in system to be pulled and temporary hoses are attached where valve was pulled

[f] FPC for CVN 78 Class from PMS 378 (Rev 4, May 2015) states, High pressure air: none. Low pressure air, nitrogen, oxygen, and divers air: portable only. NAVSEA 05V3 states the values listed are required.

[g] DDG 51 Arleigh Burke class is currently comprised of three separate variants or “Flights”: DDG 51-71 represent the original design and are designated Flight I ships; DDG 72-78 are Flight II ships; DDG 79 through DDG 123 are or will be built to the Flight IIA design.

[h] Not required. ‘---‘

[i] Submarine and UUV piers/berths require low pressure and high pressure compressed air.

[j] For SSN 774, 1.750 – 12UN-3A X 0.500 NPS adapter assembly at aft charging station. Limited charging flow rate at 150 scfm.

[k] Information contained in NAVSEA Dwg 4639983 Rev E (NOFORN).

[l] No designated shore air connections on board.

[m] Not required at normal pier tie up.

Table A-3 Shore Services – Salt or Nonpotable Water – Overhaul and Dry Dock Berthing

Salt or Nonpotable Water – Overhaul and Dry Dock Berthing *							
Ship Classification Symbol	Total Demand	Fire-Fighting Flow	Cooling/ Flushing Flow	Ships Connection Data **			
	(gpm @ psi)	(gpm)	(gpm)	L	H	N	Size
AIRCRAFT CARRIERS							
CVN 68	10,000	3,000	7,000	530 P	25	4	3.5" gate 250 psig
				785 P	34	4	3.5" gate 250 psig
				546 S	25	4	3.5" gate 250 psig
				777 S	25	4	3.5" gate 250 psig
CVN 78 [h, i]	17,620 or 29,000 @ 150-175 [h, i]	3,000	14,620	500 P	25	4	4" hoses
				780 P	25	4	4" hoses
				620 S	25	4	4" hoses
				860 S	25	4	4" hoses
SURFACE COMBATANTS							
CG 47	1,250	1,000	250	158 P	24	4	2.5"
				360 S	24	4	
DDG 51 [g] & (Flight IIA)	2,000 @ 150	1,000		194 P/S	22	4	2.5" NPS
DDG 1000		1,000 @ 175	240-300 @ 20-40			3	2.5"
FFG 7	1,250	1,000	250	282 S	28	4	2.5"
LCS 1 [a]	---	1,000	---	---	---	---	---
LCS 2 [a]	---	1,000	---	---	---	---	---
SUBMARINES							
SSN 21 [b]				144/235			two 2.5”-7.5” NH hose conn. male
SSN 688 [c]				275 P/S			
SSN 774	1,180	230 @ 100	950	150/250		2	2.5"
SSBN 726 & SSGN [d, e]			110				2.5"
SSBN 826							
UUV							
AMPHIBIOUS							
LCC 19	1,250	1,000	250				
LCC 20	1,250	1,000	250	multiple	21		6” flange or multiple 1.5” hose
LHA 1 [f]	3,125	2,500	625				
LHA 6	8,000	2,500		238 P	54	4	4" fire hose
				707 P	55	4	4" fire hose
				273 S	55	4	4" fire hose
				644 S	55	4	4" fire hose

Salt or Nonpotable Water – Overhaul and Dry Dock Berthing *							
Ship Classification Symbol	Total Demand	Fire-Fighting Flow	Cooling/ Flushing Flow	Ships Connection Data **			
	(gpm @ psi)	(gpm)	(gpm)	L	H	N	Size
LHD 1		2,500		210 P	55	4	4" fire hose
				700 P	55	4	4" fire hose
				266 S	55	4	4" fire hose
				644 S	55	4	4" fire hose
LHD 8	8,000	2,500		252 P/S	54	4	4" fire hose
LPD 4 (AFSB (I))	1,875	1,500	375				
LPD 17	2,000 @ 125	1,000		190 P/S	24	2	2 four hose manifolds
				541 P/S	24	2	2 four hose manifolds
LSD 41	2,500	2,000	500				
LSD 49	2,500	2,000	500				
MINE WARFARE							
MCM 1		750					
AUXILIARY							
T-AH 19		1,000					
T-AKE 1	1,000	1,000	N/A				
T-AO 187		1,500					
T-AO 205		1,500					
T-AOE 6	1,875	1,500	375	179 P	28		
				575 P	28		
				180 S	28		
				608 S	28		
T-APL 2							
T-APL 15							
T-ARS 50	750	500	250	110 P/S	18	2	4” fire hose
T-AS 39	1,875	1,500	375				
T-AVB 3							
EXPEDITIONARY							
T-EPF 1 (JHSV)							
ESB 3	792	633	158	600 C	70	1	
ESB 4	2,069	2,069	3,742	600 C	70	1	
PATROL							
PC 1		500					
ARMY							
TBD							
USCG							
NSC (WMSL)							
WHEC 717							
WLB 201							
WLBB 30							

Salt or Nonpotable Water – Overhaul and Dry Dock Berthing *							
Ship Classification Symbol	Total Demand	Fire-Fighting Flow	Cooling/ Flushing Flow	Ships Connection Data **			
	(gpm @ psi)	(gpm)	(gpm)	L	H	N	Size
WLM 551							
WMEC 615							
WMEC 901							
WPB 1301							

<u>Notes to Table A-3:</u>

* See note (*) at beginning of APPENDIX A; information provided in this table is for general reference purposes only; information is incomplete and may not be accurate; verify utility requirements with ships/program office(s). Blanks in table indicate information is missing or unavailable at this time.

** Designations of locations of ship connections are as follows:

- L is the distance (in feet) of the connection aft of the stem of the ship.
- H is the height (in feet) of the connection above the design waterline.
- P, S, C, CL refer to Port side, Starboard side, and Center/Centerline of a ship respectively.
- P/S indicates one connection on each side of ship at distance L.
- N is the number of shipboard connections at given location(s).
- Where more than one connection exists, all locations are shown.

[a] Not required. '---'

[b] Provide 600 gpm @ 65 psi for cooling (inboard connection in engine room) and 336 gpm @ 100 psi for flushing and firefighting.

Inboard connections fore and aft.

[c] Provide 2,000 gpm @ 40 psi; also provide 600 gpm @ 40 psi from separate, but simultaneous source as emergency backup.

Dry dock provides (F10) steel bolted fire hose connection (male) for standard fire hose.

Dry dock also provides connection for 12" ASW hull valves.

[d] For cooling/flushing; only flushing value is provided.

[e] Information contained in NAVSEA Dwg 4639983 Rev E (NOFORN).

[f] Planning Yard (NNSY) advises no shore connections; use 15 hose connections to ships fire plugs.

[g] DDG 51 Arleigh Burke class is currently comprised of three separate variants or "Flights": DDG 51-71 represent the original design and are designated Flight I ships; DDG 72-78 are Flight II ships; DDG 79 through DDG 123 are or will be built to the Flight IIA design.

[h] NAVSEA calculated total minimum 'critical load' saltwater flow is 17,620 gpm. Total (minimum + habitability/testing) saltwater required calculated by NNSY for all ship and dock systems is 29,000 (rounded from 28,072) gpm. Pressure at ship is 150 psi and pressure at shoreside manifold is 175 psi.

[i] NAVSEA letter Ser 14-0452, *Norfolk Naval Shipyard Request for CVN 78 Class Drydock Seawater Flow Requirements*;

NAVSEA Response of 09 May 14; NNSY letter C240 Ser 240-008-17, *Norfolk Naval Shipyard Request for CVN 78 Drydock Seawater Flow Requirements, Follow Up*, 14 Nove 2017 (NOFORN)

Table A-4 Shore Services – Potable Water

Potable Water *							
Ship Classification Symbol	Normal Requirement with Ships Compliment		Requirement with Air Wing or Troops Aboard	Ships Connection Data **			
	(gpd)	(gpm @ psi)	(gpd)	L	H	N	Size
AIRCRAFT CARRIERS							
CVN 68	100,000		185,000	300 P/S	29	1	2.5" globe
				540 P/S	29	1	2.5" globe
CVN 78 [a]	152,750	225 @ 30-40	235,000	501 P	27	2	2.5" hose conn.
				777 P	27	2	2.5" hose conn.
				417 S	27	2	2.5" hose conn.
				673 S	27	2	2.5" hose conn.
SURFACE COMBATANTS							
CG 47	16,000	@ 75		242 P/S	21	1	2.5" hose conn.
DDG 51	9,500	100 @ 40		52 S	34	2	2.5" hose conn.
				202 P/S	22	2	
DDG 79 [b] (Flight IIA)		200 @ 100		202 P/S	22	2	2.5” NPSH, Fed Std H28
DDG 1000		100					2.5" hose conn.
FFG 7	10,800			325 P/S	32	1	2.5" hose conn.
LCS 1	4,500	225 @ 30-40		115 S	23	1	2.5" hose conn.
LCS 2	4,500	225 @ 30-40		230 S	15	1	2.5" hose conn.
SUBMARINES							
SSN 21	5,000			138.3 (16.3' off CL-P)		1	1.5 NPS hose conn.
SSN 688 [c]	5,000			150 (2.5' off CL-P)		1	
SSN 774	5,000	50 @ 50		150 C		1	1.5" hose conn. with 1.5-11.5 NPSH connector/adapter type
SSBN 726 & SSGN	5,000			312.9		1	2.5" hose conn
SSBN 826							
UUV							
AMPHIBIOUS							
LCC 19, 20	33,000		55,000	313 P	44		
				281 S	44		
LCC 20 [d, e]	21,000		40,000	320 P/S	26	1 or 2	1 x 1.5” or 2 x 1.5”
LHA 1	28,000		85,000	337 S	46	1	2.5" hose conn.
LHA 6		200 @ 87		371 P	15	1	2.5" hose conn.
				427 S	63	1	2.5" hose conn.
				553 S	34	1	2.5" hose conn.

Potable Water *							
Ship Classification Symbol	Normal Requirement with Ships Compliment		Requirement with Air Wing or Troops Aboard	Ships Connection Data **			
	(gpd)	(gpm @ psi)	(gpd)	L	H	N	Size
LHD 1	32,000		90,000	680 S	45	1	2.5" hose conn.
LHD 8	35,840		101,185	371 P	15	1	2.5" hose conn.
				427 S	63	1	2.5" hose conn.
				553 S	34	1	2.5" hose conn.
LPD 4 (AFSB (I))	15,000		48,300	356 P	35		
				327 S	35		
LPD 17	15,000	200 @ 87	40,000	200 P/S	24	1	2.5”
LSD 41	14,000		25,000	208 P	36		
				260 S	36		
LSD 49	12,000		25,000	216 P	37		
				260 S	37		
MINE WARFARE							
MCM 1		@ 60-70					
AUXILIARY							
T-AH 19							
T-AKE 1	6,000			487 P	30	1	2.5" hose conn.
				487 S	45	1	2.5" hose conn.
T-AO 187							
T-AO 205							
T-AOE 6	21,000			321 P/S	68		
				449 P	68		
				433 S	68		
T-APL 2							
T-APL 15							
T-ARS 50		75	N/A	128 P/S	18	1	2.5" hose conn.
T-AS 39				fan tail	main deck	1	2.5" hose conn.
T-AVB 3							
EXPEDITIONARY							
T-EPF 1 (JHSV)							2”
ESB 3	10,000		18,000	600 C	70	1	
ESB 4	18,800		31,800	670	60	2	2.5”
PATROL							
PC 1							
ARMY							
TBD							

Potable Water *							
Ship Classification Symbol	Normal Requirement with Ships Compliment		Requirement with Air Wing or Troops Aboard	Ships Connection Data **			
	(gpd)	(gpm @ psi)	(gpd)	L	H	N	Size
USCG							
NSC (WMSL)	3,000						1.5” hose conn.
WHEC 717		200 @ 50					
WLB 201	1,500	@ 55-65					1.5” threaded conn.
WLBB 30							
WLM 551							
WMEC 615		20 @ 50-55					1.5” hose conn.
WMEC 901	4,000	@ 40-50					
WPB 1301		@ 55					1.5” hose valve

Notes to Table A-4:

* See note (*) at beginning of APPENDIX A; information provided in this table is for general reference purposes only; information is incomplete and may not be accurate; verify utility requirements with ships/program office(s). Blanks in table indicate information is missing or unavailable at this time.

** Designations of locations of ship connections are as follows:

- L is the distance (in feet) of the connection aft of the stem of the ship.
- H is the height (in feet) of the connection above the design waterline.
- P, S, C, CL refer to Port side, Starboard side, and Center/Centerline of a ship respectively.
- P/S indicates one connection on each side of ship at distance L.
- N is the number of shipboard connections at given location(s).
- Where more than one connection exists, all locations are shown.

[a] Reduce requirement by 35% if airwing is not embarked.

[b] DDG 51 Arleigh Burke class is currently comprised of three separate variants or “Flights”: DDG 51-71 represent the original design and are designated Flight I ships; DDG 72-78 are Flight II ships; DDG 79 through DDG 123 are or will be built to the Flight IIA design.

[c] Connection is PW-8; 1.5" NPS globe valve w/hose connection; silver-bronze union end (MIL-F-1183) w/adaptor for Hose 'B' thread size; 1.5" male x 11.5 fem.

[d] Includes additional capacity to fill technical (flushing) water system. Technical water system is not dependent on shore potable water and may be filled using dedicated onboard water generating equipment if required.

[e] LCC-20 Potable water connections are configurable to either 2 x 1.5” or 1 x 2.5” Hose Connections.

Table A-5 Shore Services - Oily Waste/Waste Oil (OWWO) Discharge

Oily Waste/Waste Oil (OWWO) Discharge *									
Ship Classification Symbol	Pump Station	Pump	Pump Rating	Q_{PEAK}	Q_{AVE}	Ship Connection Data **			
			(gpm @ psi)	(gpd)	(gpd)	L	H	N	Size
AIRCRAFT CARRIERS									
CVN 68 to 71	1	1A	90 @ 50	80,000	35,000	512 P	23	1	2.5"
						680 S	23	1	2.5"
CVN 72 to 77	1	1A	90 @ 50	80,000	35,000	512 P	23	1	2.5"
		1B	90 @ 50			680 S	23	2	2.5"
CVN 78 [a]	1	1A, 1B	90-180	a	a	316 S	25	1	2.5"
				a	a	673 S	25	1	2.5"
				a	a	819 S	25	1	2.5"
SURFACE COMBATANTS									
CG 47	1	1A, 1B	50 @ 60 each	12,000	3,000	386 P, 384 S OW transfer pump	24	1	2.5"
	2	2A, 2B	15 @ 60 each			380 P, 386 S gas turbine drain pump	24	1	2.5"
DDG 51	1	1A, 1B	50 @ 10 each	12,000	3,000	244 P/S	22	1	2.5"
DDG 79 [c] (Flight IIA)	1	1A, 1B	100 @ 10			244 P/S	22	1	2.5”
DDG 1000								1	2.5"
FFG 7	1	1A	50	6,750	1,500	244 P/S	28	1	2"
LCS 1	1	1A	90-180 @ 60		500	208 S	45	1	2.5"
LCS 2	1	1A	90-180 @ 60		500	230 S	15	1	2.5"
SUBMARINES									
SSN 21	1	1A	280	500	250	202.5’ (14' off CL-S)		1	
		1B	280			205.2' (4' off CL-S)		1	
SSN 688	1	1A	230	500	250	215		1	2.5"
SSN 774	1	1A	230			159.56’ (15.4' off CL-P)		1	1.5"
						218.47' (8.87' off CL-S)		1	1.5"
SSBN 726 & SSGN	1	1A	230	500	250	152'-11" (12'-10" off CL-P)		1	2.5"
SSBN 826									
UUV									
AMPHIBIOUS									
LCC 19, 20	1	1A	100	21,000	6,400				
LCC 20	1	1A	100	6,000	4,000	324 P/S	26	1	2.5"

Oily Waste/Waste Oil (OWWO) Discharge *									
Ship Classification Symbol	Pump Station	Pump	Pump Rating	Q_{PEAK}	Q_{AVE}	Ship Connection Data **			
			(gpm @ psi)	(gpd)	(gpd)	L	H	N	Size
LHA 1	1 (fwd)	1A	18	21,000	6,400	448 S	45		2.5"
		1B	18			448 P	45		2.5"
		1C	18						
		1D	18						
	2	2A	54						
LHA 6	1	1A				455 P (oily waste)	24	1	2.5"
		1B				455 P (synthetic oil)	24	1	2.5"
	2	2A				553 S (oily waste)	34	1	2.5"
		2B				553 S (synthetic oil)	34	1	2.5"
LHD 1	1 (fwd)	1A	54	21,000	6,400	441 P	55		2.5"
		1B	54			539 S	45		2.5"
		1C	54						
LHD 8 [b]	1	1A				455 P (oily waste)	24	1	2.5"
		1B				455 P (synthetic oil)	24	1	2.5"
	2	2A				553 S (oily waste)	34	1	2.5"
		2B				553 S (synthetic oil)	34	1	2.5"
LPD 4 (AFSB (I))	1	1A	18	21,000	6,400				
	2	2A	90						
LPD 17	1	1A	54	21,000	6,400	338 P (mineral oily waste)	13	1	2.5"
		1B	18			338 P (synthetic oil)	13	1	2.5"
	2	2A	54	21,000	6,400	463 S (mineral oily waste)	24	1	2.5"
		2B	18			463 S (synthetic oil)	24	1	2.5"
LSD 41				4,800	2,700				
LSD 49				4,800	2,700				
MINE WARFARE									
MCM 1									
AUXILIARY									
T-AH 19									
T-AKE 1	1	1A	22	N/A	N/A	487 P	30	1	3"
	2	2A	22	N/A	N/A	487 S	45	1	3”
T-AO 187									

Oily Waste/Waste Oil (OWWO) Discharge *									
Ship Classification Symbol	Pump Station	Pump	Pump Rating	Q_{PEAK}	Q_{AVE}	Ship Connection Data **			
			(gpm @ psi)	(gpd)	(gpd)	L	H	N	Size
T-AO 205									
T-AOE 6	1	1A	50			526 P	30	1	2.5"
	2	2A	15			528 P	30	1	2.5"
	3	3A	15			515 S	30	1	1.25"
	4	4A	50			516 S	30	1	1.25"
T-APL 2									
T-APL 15									
T-ARS 50	1	1A	168	500	275	128 P/S	18	1	2.5"
T-AS 39				15,000	10,000				
T-AVB									
EXPEDITIONARY									
T-EPF 1 (JHSV)									1.5" OW 2.5" BW
ESB 3									
ESB 4									
PATROL									
PC 1									
ARMY									
TBD									
USCG									
NSC (WMSL)									
WHEC 717									
WLB 201									
WLBB 30									
WLM 551									
WMEC 615									
WMEC 901			@ 10-15						2" ship conn.
WPB 1301									2.5" BW to 4" flange 4 bolt

Notes to Table A-5:

* See note (*) at beginning of APPENDIX A; information provided in this table is for general reference purposes only; information is incomplete and may not be accurate; verify utility requirements with ships/program office(s). Blanks in table indicate information is missing or unavailable at this time.

** Designations of locations of ship connections are as follows:

- L is the distance (in feet) of the connection aft of the stem of the ship.
- H is the height (in feet) of the connection above the design waterline.
- P, S, C, CL refer to Port side, Starboard side, and Center/Centerline of a ship respectively.

- P/S indicates one connection on each side of ship at distance L.
- N is the number of shipboard connections at given location(s).
- Where more than one connection exists, all locations are shown.

[a] Oily Water 8,000 gpd (45,000 gal); Waste Oil 40,000 gal/offload; Aircraft Waste Fuel 9,400 gal/offload. All use same 2.5” deck connection.

Ship OWWO system has two 90 gpm pumps and is capable of discharging 90-180 gpm. Shipboard standard operating procedure while pierside is to operate with only one pump and discharge at the lower rate of 90 gpm.

[b] Oily waste requirement to be determined; Synthetic oily waste = 54 gpm.

[c] DDG 51 Arleigh Burke class is currently comprised of three separate variants or “Flights”: DDG 51-71 represent the original design and are designated Flight I ships; DDG 72-78 are Flight II ships; DDG 79 through DDG 123 are or will be built to the Flight IIA design.

Table A-6 Shore Services – Sanitary (CHT) Discharge

Sanitary (CHT) Discharge *							
Ship Classification Symbol	Pump Station	Pump	Pump Rating (gpm @ psi)	Ships Connection Data ** L	H	N	Size
AIRCRAFT CARRIERS							
CVN 68 to 71	1	1A	400	485 P	23		4"
		1B		536 S	23		4"
	2	2A		740 P	23		4"
		2B		759 S	23		4"
	3	3A					
		3B					
CVN 72 to 77	1	1A	400	485 P	23		4"
		1B		309 S	23		4"
	2	2A		759 P	23		4"
		2B		802 S	23		4"
CVN 78 [a]	1, fwd	1A	250	500 P	25	1	4"
		1B	250	304 S	25	1	4”
	2, aft	2A	300	764 P	25	2	4"
		2B	300	840 S	25	2	4”
SURFACE COMBATANTS							
CG 47	1	1A, 1B	100 @ 30 each	190 P, 200 S	34	1	4"
	2	2A, 2B		362 P/S	34	1	4"
	3	3A, 3B					
DDG 51	1	1A, 1B	40 @ 30 each	149 P, 146 S	21	1	4"
	2	2A, 2B		331 P, 329 S	21	1	4"
DDG 79 [c] (Flight IIA)	1	1A, 1B	80 @ 40	149 P/S	22	1	4”
	2	2A, 2B		334 P/S	22	1	4”
DDG 1000	1					1	4"
FFG 7	1	1A, 1B	100	204 P/S	28	1	4"
LCS 1			250	115 S	23	1	4"
LCS 2			250	230 S	15	1	4"
SUBMARINES							
SSN 21	1	1A	25	132’ (3' off CL-P)			2.5"
SSN 688	1	1A	25	77’ (11' off CL-P)		1	2.5"
SSN 774	1	1A	100	173’ (12' off CL-P)			2.5"
SSBN 726 & SSGN	1	1A	25	153'-5" (9'-9" off CL-P)		1	2.5"
	2	2A	25	292'-5" (12'-6" off CL-P)		1	2.5"
SSBN 826							
UUV							
AMPHIBIOUS							

Sanitary (CHT) Discharge *							
Ship Classification Symbol	Pump Station	Pump	Pump Rating	Ships Connection Data **			
			(gpm @ psi)	L	H	N	Size
LCC 19, 20	1	1A, 1B	150 each	184 P/S	26	1	4"
	2	2A, 2B	150 each	380 P/S	26	1	4"
LHA 1	1	1A, 1B	400	231 P/S	45	1	4"
	2	2A, 2B	300	448 P/S	45	1	4"
LHA 6	1	1A	400 each	301 P	24	2	4"
	2	2A		294 S	34	2	4"
	3	3A		455 P	24	2	4"
	4	4A		434 S	24	2	4"
LHD 1	1	1A	300 each	280 S	55	1	4"
		1B		287 P	55	1	4"
	2	2A		420 S	55	1	4"
		2B		441 P	55	1	4"
LHD 8	1	1A	400 each	301 P	24	2	4"
	2	2A		294 S	24	2	4"
	3	3A		455 P	24	2	4"
	4	4A		434 S	24	2	4"
LPD 4 (AFSB (I))	1	1A, 1B	150	2 P/2 S		1	
	2	2A, 2B	150			1	
	3	3A, 3B	150			1	
LPD 17	1	1A, 1B	200	200 P/S	24	2	4"
	2	2A	200	338 P	13	2	4"
	3	3A	200	463 S	24	2	4”
LSD 41	1	1A, 1B	100	P/S		1	
	2	2A, 2B	100	P/S		1	
LSD 49	1	1A, 1B	100	P/S		1	
	2	2A, 2B	100	P/S		1	
MINE WARFARE							
MCM 1	1	1	25	FR 32 (14.5’ off CL–P/S)	01 level	1	1.5"
AUXILIARY							
T-AH 19							
T-AKE 1	1	1A	50	407 S	45	1	3"
	2	2A, 2B	17	414 P	31	1	3"
	3	3A, 3B	310				
		3A	200	487 P/S	30	1	3"
		3B	200	487 S	45	1	3"
T-AO 187							
T-AO 205							
T-AOE 6 [b]	1	1A, 1B	100	265 P/S	33	1	
	2	2A	100	440 P	33	1	
		2B	100	430 S	33	1	
T-APL 2							

Sanitary (CHT) Discharge *								
Ship Classification Symbol	**Pump Station**	**Pump**	**Pump Rating**	**Ships Connection Data ****				
			(gpm @ psi)	**L**	**H**	**N**	**Size**
T-APL 15							
T-ARS 50	1	1A, 1B	100	92 P/S	18	1	
T-AS 39	1	1A, 1B	100	P/S		1	
	2	2A, 2B	100	stern		1	
	3	3A, 3B	100				
	4	4A, 4B	100				
	5	5A, 5B	100				
T-ATF 166							
T-AVB 3							
EXPEDITIONARY							
T-EPF 1 (JHSV)							
ESB 3	2	2	150	619 P/S	116	1	
ESB 4	2	1	264	660	60	2	3”
PATROL							
PC 1	1	1	60	FR 30.5 (3' fwd of midships; 9' off CL-S)	10’ above WL, main deck	1	2.5"
ARMY							
TBD							
USCG							
NSC (WMSL)			350 gpm, 4,000 gpd				4” camlock
WHEC 717			120				
WLB 201			500 gpd				3” camlock
WLBB 30							
WLM 551							
WMEC 615			30 @ 12				3” camlock
WMEC 901			8,000 gpd				4” camlock
WPB 1301			550 gpd	P	main deck	1	4"

Notes to Table A-6:

* See note (*) at beginning of APPENDIX A; information provided in this table is for general reference purposes only; information is incomplete and may not be accurate; verify utility requirements with ships/program office(s). Blanks in table indicate information is missing or unavailable at this time.

** Designations of locations of ship connections are as follows:

- L is the distance (in feet) of the connection aft of the stem of the ship.
- H is the height (in feet) of the connection above the design waterline.

- P, S, C, CL refer to Port side, Starboard side, and Center/Centerline of a ship respectively.
- P/S indicates one connection on each side of ship at distance L.
- N is the number of shipboard connections at given location(s).
- Where more than one connection exists, all locations are shown.

[a] CVN 78 utilizes a Type III Vacuum CHT (VCHT) system (50,000 gal tank forward and 100,000 gal tank aft). CHT transfer (discharge) pumps come on and empty tanks at ratings indicated. CHT tanks are only opened when there is maintenance/repair required in the tank. HMR 104 and HMR 104 Rev 1 authorized the change to a Type III VCHT system from a Type II (treatment).

[b] CHT fwd and aft systems are independent and must both be hooked up for shore discharge of sewage.

[c] DDG 51 Arleigh Burke class is currently comprised of three separate variants or “Flights”: DDG 51-71 represent the original design and are designated Flight I ships; DDG 72-78 are Flight II ships; DDG 79 through DDG 123 are or will be built to the Flight IIA design.

Table A-7 Shore Services – Electrical

Electrical *						
Ship Classification Symbol	Ampacity Per Station [a]	Required Ampacity of Shore Power Service [b]	Ships Connection Data **			
			L	H	N	Size
AIRCRAFT CARRIERS						
CVN 68, 69	1,440 [c]	2,800	548 S	30	1 - 4	
	1,440 [c]		704 S	30	1 - 4	
	4,000	16,000	300 S	30	1	
	4,000		312 S	30	1	
	4,000		1,000 S	40	1	
	4,000		1016 S	40	1	
CVN 70 to 77 [d]	1,440 [c]	2,800	548 S	30	1 - 4	
	1,440 [c]		704 S	30	1 - 4	
	4,000	16,000	296 S	30	2	
	4,000		1,016 S	40	2	
CVN 78 [e]	837	1,674	460 S	25	4	3 conductor (350 kcmil)
	837		704 S	25	4	
SURFACE COMBATANTS						
CG 47 to 51 [f]	4,000	5,200	316 P/S	44	1 - 10	
	1,200		316 P/S	44	1 - 3	
CG 52 and up [f]	4,000	4,000	511 C	18	1 - 10	
DDG 51	4,800	4,800	265 C	25	1 – 10 to 12 cables	400 A 3 conductor
DDG 79 [g] (Flight IIA)	3,800 to 4,800	4,800	274 S	22	1 - 10 to 12 cables	Std 400 A 3 conductor
DDG 1000 [c]		470	260 P/S	10	1 - 2	
FFG 7	2,800	2,800	252 C	35	1 - 7	
LCS 1	1,600	1,600	208 S	45	1 - 4	
LCS 2	1,600	1,600	152 C	35	1 - 4	
SUBMARINES [h]						
SSN 21	1,600	1,600	52 C		1 - 4	
	1,600		73 C		1 - 4	
SSN 688	1,600	1,600	146 C		1 - 4	
	1,600		210 C		1 - 4	
SSN 774 [i] (Block I-IV)	400	2,400	144 C		1 - 1	
	800		222 P		1 - 2	
	1,200		222 S		1 - 3	
SSN 774 (Block V) [i, j]	400	2,800	fwd		1 - 1	
	1,200		aft P		1 - 3	
	1,200		aft S		1 - 3	
SSBN 726 & SSGN	1,600	1,600	137 C		1 - 4	
	1,600		406 C		1 - 4	
SSBN 826	1,600	1,600	C		1 - 4	
	1,600		C		1 - 4	

Electrical *						
Ship Classification Symbol	Ampacity Per Station [a]	Required Ampacity of Shore Power Service [b]	Ships Connection Data **			
			L	H	N	Size
UUV						
AMPHIBIOUS						
LCC 19, 20			442 P/S	28	2	
LCC 20	4,000	4,000	424 P/S	28	10	400 A ea
LHA 1	4,000	7,200	445 P/S	37	1 - 10	
	3,200		791 P	57	1 - 8	
LHA 6 [c]	1,600	1,903	441 P	24	2 - 2	
	1,600		434 S	24	2 - 2	
	800		812 C	53	1 - 2	
LHD 1	4,000	7,200	420 P	25	1 - 10	
	4,000		440 S	25	1 - 10	
	3,200		800 C	48	1 - 8	
LHD 8 [c]	1,600	2,400	420 P	25	2 - 2	
	1,600		440 S	25	2 - 2	
	800		800 C	48	1 - 2	
LPD 4 (AFSB (I))	1,600	1,400	240 C	50	1 - 4	
LPD 17	8,000	8,000	88 C	48	1 - 20	
LSD 41 [k]	2,400	2,400	252 C	34	1 - 6	
LSD 49 [k]	3,200	2,160	252 P	34	1 - 8	
MINE WARFARE						
MCM 1		800				
AUXILIARY						
T-AH 19						
T-AKE 1 [l]	4,000	8,000	310 C	55	1 - 10	
			333 C	55	1 - 10	
T-AO 187						
T-AO 205						
T-AOE 6	4,000	3,200	435 P/S	55	1 - 10	
T-APL 2						
T-APL 15						
T-ARS 50	400	1,200	92 P	30	4	
T-AS 39 [m]	4,000	A 4,200	370 P/S	38	1 - 1	
	4,000		370 P/S	48	1 - 1	
	8,000	B 8,000	610 S	28	1 - 2	
T-AVB						
EXPEDITIONARY						
T-EPF 1 (JHSV)	800	800	320 P/S	28	1 - 2	
ESB 3	6,000	6,000	708 P/S	229	2 - 15	
ESB 4	6,000	6,000	650 P/S	135	1 - 15	THOF-400
PATROL						

Electrical *						
Ship Classification Symbol	**Ampacity Per Station [a]**	**Required Ampacity of Shore Power Service [b]**	**Ships Connection Data** **			
			L	**H**	**N**	**Size**
PC 1	200	170	107 P	11	1	
ARMY						
TBD						
USCG						
NSC (WMSL)	400	1,600			4	
WHEC 717					2	
WLB 201	400				2	
WLBB 30						
WLM 551						
WMEC 615					1	
WMEC 901	400				2	
WPB 1301	200					97.7 kW recp.

Notes to Table A-7:

* See note (*) at beginning of APPENDIX A; information provided in this table is for general reference purposes only; information is incomplete and may not be accurate; verify utility requirements with ships/program office(s). Blanks in table indicate information is missing or unavailable at this time.

** Designations of locations of ship connections are as follows:

- L is the distance (in feet) of the connection aft of the stem of the ship.
- H is the height (in feet) of the connection above the design waterline.
- P, S, C, CL refer to Port side, Starboard side, and Center/Centerline of a ship respectively.
- P/S indicates one connection on each side of ship at distance L. Two station locations, one port and one starboard, at an equal distance from the bow, of which only one may be used at a time to receive power, one half of the total number of stations given are on port side, one half are on starboard.
- ST is stern station location; if power is delivered to the stern station, the port and starboard stations would normally not be used for receiving power.
- N is the number of service points - number of cables per service point (ex: 1 – 4, one service point with four cables).
- Where more than one connection exists, all locations are shown.

[a] Capacity is given in amperes. Unless otherwise indicated, power to load center is 450 V, 3-phase, three-wire, 60 Hz, ungrounded. Power factor is approximately 0.8. The number of receptacles per station may be obtained by dividing per station ampacity by 400.

[b] Required ampacity of shore power service is the maximum power that the ship will demand from the shore power system. The shore power service transformer shall be sized to provide the "Required ampacity of shore power service" for the ship moored at the respective berth. Note that the shore power service transformer is not necessarily sized to provide the ampacity equivalent to the product of the required number of shore power circuits and the rating (400 A) of the shore power circuits.

[c] Power is 4,160 V, 3-phase, three wire, 60 Hz, ungrounded. .

[d] CVN 70 and higher will not require any 480 V electrical services.

[e] Power to load center is 13,800 V, 3-phase, three wire, 60 Hz, ungrounded; 1307/1569 correspond to 25 MW load (without air wing) and 30MW load (with air wing). For additional information regarding the shore-to-ship interface, refer to *NAVSEA Drawing 802-7094558*, CVN Class Aircraft Carrier Electrical Interface Characteristics (NOFORN).

[f] CG 47 through CG 51: A total of 26 shore power receptacles are provided, 13 at each port and starboard station. Three receptacles (1,200 A) are used for a feed-through circuit to a tended ship and 10 receptacles (4,000 A) are used for the ships shore power station. CG 52 and following have no feed-through circuits.

[g] DDG 51 Arleigh Burke class is currently comprised of three separate variants or “Flights”: DDG 51-71 represent the original design and are designated Flight I ships; DDG 72-78 are Flight II ships; DDG 79 through DDG 123 are or will be built to the Flight IIA design.

[h] Normal hotel service load is 1,600 Amps.

Special testing of submarines, usually conducted at shipyards, requires an increased level of shore power (super shore power). Depending upon local operating policies, either additional circuits from the same service(s) are connected in conjunction with the normal "hotel" circuits to provide a combined increased level of shore power or additional circuits from completely separate service(s) are provided in addition to the normal "hotel" service. Note that for both modes of operation, the additional circuits are connected directly to the ship's switchboard bus.

[i] It is required that the shunt interlock circuits for the three SSN 774 Class services be independent of each other and the interlock should insure that all of the breakers for a given service (e.g. port) trip open at the same time in the event of an overcurrent condition.

[j] Only SSN 774 Block V (with VPM) requires a total of 6 circuits (cables) to the aft service points, 3 Port and 3 Starboard. One additional circuit (cable) is required to the Port bus for Block V (with VPM). Block V (w/o VPM) does not require an additional circuit. SSN 774 Block V (w/o VPM) – 2,400 A total. SSN 774 Block V (with VPM) – 2,800 A total.

[k] Between FY08 & FY14 LSD Class goes through a Mid Service Life Electrical Upgrade.

- LSD 41-48 goes from 6 cables (2,400 A) to 10 cables (4,000 A).
- LSD 49-52 goes from 8 cables (3,200 A) to 12 cables (4,800 A).

[l] T-AKE 1 requires that shore power be delivered at 505 to 515 V.

T-AKE 1 uses its own DC system to detect grounds, whereas shoreside facility uses an AC system to detect grounds. Prior to arrival at berth, shoreside facility must disable its ground detection system for that particular berth and rely upon the T-AKE 1 ground detection system.

[m] A = Requirement shown represents the demand of the tender while not tending.

B = Requirement shown represents the demand of the tender while tending; this includes the requirements of the tender plus the maximum requirements of the ships being tended.

Table A-8 Shore Services – Telecommunications

Telecommunications *						
Ship Classification Symbol	**Telephone Lines (Pairs)**		**Ships Connection Data ****			
	Active Lines [a]	**Cable Size at Berth [b]**	**L**	**H**	**N**	**Size**
AIRCRAFT CARRIERS						
CVN 68	60	200	303 S	26	1	
			1,008 S	35	1	
CVN 78 [c]	60 min/100 max		545 P	25		
			613 S	25		
SURFACE COMBATANTS						
CG 47	15	50	287			
DDG 51	15	50	274 P/S	21		
DDG 79 [c] (Flight IIA)	15	50	274 P/S	21		
DDG 1000 [d]	20 to 40 lines					
FFG 7	8	50				
LCS 1 [e]	10					
LCS 2 [e]	10		230 S	15		
SUBMARINES						
SSN 21	8		80			
SSN 688	5	25	98			
SSN 774	10		95.69' (0.67' off CL-P)			
SSBN 726 & SSGN	10	25	136'-10"			
SSBN 826						
UUV						
AMPHIBIOUS						
LCC 19	150	180	208 P/S			
LCC 20	12	100	188 P/S			
LHA 1	120		80 P/S			
LHA 6 [f]	80		434 S	24		
			441 P	24		
			812 S	54		
LHD 1	120		78 P/S			
LHD 8 [f]	80		434 S	24		
			441 P	24		
			812 S	54		
LPD 4 (AFSB (I))	10	15	270 C			
LPD 17			463 P/S			

Telecommunications *						
Ship Classification Symbol	Telephone Lines (Pairs)		Ships Connection Data **			
	Active Lines [a]	Cable Size at Berth [b]	L	H	N	Size
LSD 41	10	50	250 P/S			
LSD 49	20	30	250 P/S			
MINE WARFARE						
MCM 1						
AUXILIARY						
T-AH 19						
T-AKE 1	16 Digital	18 AWG	415 P/S	30	1	18 AWG
T-AO 187						
T-AO 205						
T-AOE 6	10	50	205 C			
T-APL 2						
T-APL 15						
T-ARS 50	20		92 P	30		
T-AS 39						
T-AVB 3						
EXPEDITIONARY						
T-EPF 1 (JHSV)						
ESB 3	10		610 P/S	116		
ESB 4	2	FHOF4	470	140	1	FHOF4
PATROL						
PC 1						
ARMY						
TBD						
USCG						
NSC (WMSL)	*TBD*					
WHEC 717	*TBD*					
WLB 201						6 pair
WLBB 30						
WLM 551						
WMEC 615						
WMEC 901						
WPB 1301		SKW				4 pair

Notes to Table A-8:

* See note (*) at beginning of APPENDIX A; information provided in this table is for general reference purposes only; information is incomplete and may not be accurate; verify utility requirements with ships/program office(s). Blanks in table indicate information is missing or unavailable at this time.

** Designations of locations of ship connections are as follows:

- L is the distance (in feet) of the connection aft of the stem of the ship.
- H is the height (in feet) of the connection above the design waterline.
- P, S, C, CL refer to Port side, Starboard side, and Center/Centerline of a ship respectively.
- P/S indicates one connection on each side of ship at distance L.
- N is the number of shipboard connections at given location(s).
- Where more than one connection exists, all locations are shown.

[a] Total number of active lines required for any ship is sum of column for "active lines" for the ship class and the embarked staff requirements necessary where specifically directed by the cognizant Service or the using agency.

[b] Column "cable size at berth" lists the size of cable to be provided at berths designated for various ship types. Cable sizes given in column "cable size at berth" include the ship requirement, the appropriate embarked staff requirement, and an allowance for spare pairs.

[c] Also requires Internet T-1, T-100, ISDN, SIPRNET/NIPRNET Digital T-1/ISDN type, 2 lines.

[d] Also requires fiber optic LAN connectivity.

[e] Also requires (1) Internet T-1, T-100, ISDN Digital T-1/ISDN - 1 line; (2) SIPRNET/NIPRENET BL II 1 connection.

[f] Also requires 2 fiber optic connections for IT21/ISNS and BFTT.

[g] Embarked staff requirements.

Fleet Commander - 20

CARGRU Commander - 8

CREWDESGRU COMMANDER - 12

DESRON COMMANDER - 10

PHIBGRU COMMANDER - 12

PHILBRON COMMANDER - 15

MAB STAFF - 12

SERVGRU COMMANDER - 8

SUBRON COMMANDER - 15

PHMRON COMMANDER - 12

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APPENDIX B CLIMATOLOGICAL DATA

Figure B-1 U.S. Winter Weather Severity by Region

Table B-1 Regional Weather Data

Table B-2 Freeze Protection by Insulation and Heating: Suggested Combinations for Regions I and II

Table B-3 Freeze Protection by Insulation and Flushing: Suggested Combinations for Regions III and IV

Table B-4 Freeze Protection by Insulation and Heating: Suggested Combinations for Regions III and IV

Figure B-1 U.S. Winter Weather Severity by Region

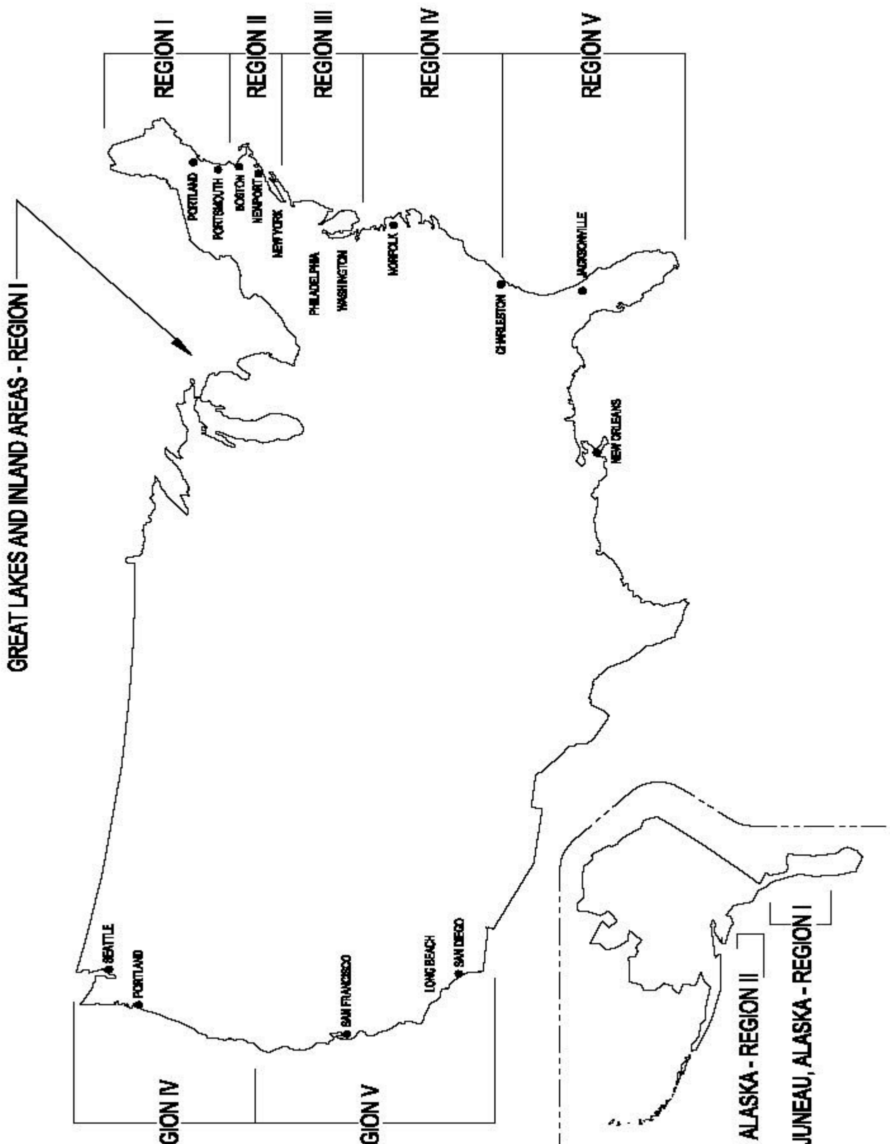


Table B-1 Regional Weather Data

Region	Average January Temp.	Extreme Minimum Temp.	Median Annual Extremes	97.5% Temp.	Average of 97.5% Temp. and Extreme Minimum	Degree Days
	(°F)	(°F)	(°F)	(°F)	(°F)	
I	24	-30	-11	0	-15	1,275
II	29	-14	1	10	-2	1,125
III	34.5	1	7	15	8	950
IV	34.5	3	16	24	13	750
V	50.5	17	21	32	24	450

Table B-2 Freeze Protection by Insulation and Heating: Suggested Combinations for Regions I and II

Nominal Pipe Size	Region I		Region II	
	Insulation Thickness	Heating	Insulation Thickness	Heating
(inch)	(inch)	(Watts/ft)	(inch)	(Watts/ft)
2	1/2	6	1/2	6
3	1/2	6	1/2	6
4	1	6	1	6
6	1	6	1	6
8	1-1/2	6	1-1/2	6
10	1-1/2	6	1-1/2	6
12	1-1/2	6	1-1/2	6

Table B-3 Freeze Protection by Insulation and Flushing: Suggested Combinations for Regions III and IV

	Region III		Region IV	
Nominal Pipe Size	Insulation Thickness	Heating	Insulation Thickness	Heating
(inch)	(inch)	(Watts/ft)	(inch)	(Watts/ft)
2	1	Yes	1	Yes
3	1	Yes	1	Yes
4	1	Yes	1	Yes
6	1	Yes	1	Yes
8	1	No	1	No
10	1	No	1	No
12	1	No	1	No

Table B-4 Freeze Protection by Insulation and Heating: Suggested Combinations for Regions III and IV

Nominal Pipe Size	Region III		Region IV	
	Insulation Thickness	Heating	Insulation Thickness	Heating
(inch)	(inch)	(Watts/ft)	(inch)	(Watts/ft)
2	1/2	6	1/2	6
3	1/2	6	1/2	6
4	1/2	6	1/2	6
6	1/2	6	1/2	6
8	1	None	1	None
10	1	None	1	None
12	1	None	1	None

APPENDIX C OPERATION AND MAINTENANCE CRITERIA FOR SHORE-TO-SHIP POWER

C-1 CRITICAL COMPONENTS.

All electrical components whose failure could affect the reliability of the electrical distribution system supplying power to ships are identified as critical components of the shore to ship power system and are placed under the maintenance program defined in this enclosure. Critical components are the shore power primary circuit breaker, step down transformer, secondary circuit breakers, the permanently installed cables between the shore power circuit breakers and the power connection station (turtleback), the power connection station receptacles, and the portable power cable assemblies used for supplying shore power services to ships. Each portable power cable assembly is defined to consist of two electrical connectors and the cable in between.

C-1.1 Critical Component Inventory Records.

A history record will be established and maintained covering each shore to ship power system critical component. The record will document via inspection checklists all work completed and by whom. Cable and connections shall be tagged in accordance with the Shore Power Cable Assembly Nomenclature Detail, as shown in Figure C-6 and entered into Single Platform MAXIMO and other appropriate maintenance planning databases.

- **One-line diagram:** One-line diagrams, illustrating the equipment ratings and system configuration from the utility point of service, are prepared and kept current by the activities in accordance with the cognizant Service Manual MO-201, Electric Power Distribution Systems. Plot plans will be annotated to show the location of all shore to ship power system components.
- **Power System Study:** An activity power system study, including load flow, fault current analysis, coordination of protective devices, and arc flash is prepared in accordance with MO-201, Electric Power Distribution Systems.

C-2 PARALLELING TRANSFORMERS.

If a ship is supplied by two or more shore transformers, the ship's force will be directed, through standard ship operating procedures, not to parallel the transformers through the ship's bus unless the senior ship's electrician verifies correct phase orientation between power sources, and the supplying activity authorizes the parallel operation. If shore transformers are paralleled through the ship's bus, short circuit currents may be increased to unsafe levels and circulating currents may overheat and destroy cables, transformers, and switchgear on board ship or on shore.

C-2.1 Paralleling Shipboard Generation with the Shore Power System.

Paralleling of ship's service generators with the shore power system is prohibited except for the shortest time necessary to transfer load to or from shore power.

C-3 CABLES FOR SHORE-TO-SHIP SERVICE.

Shore-to-ship cables are normally provided by the Activity. For 480 V, three-phase, three-wire service, cables should be ungrounded, standardized lengths of single cable with three conductors, Type THOF-500, conforming to military spec MIL-DTL-915, Cable, Electrical, for Shipboard Use, and should be used for loads not exceeding 400 A. For 4,160 V, three-phase service to nuclear aircraft carriers, cables should be SHD350GC 8 kV, non-shielded insulated, PVC-jacketed cable, in accordance with Insulated Cable Engineers Association (ICEA) S 66 524, Cross-Linked-Thermosetting Polyethylene Insulated Wire and Cables.

C-3.1 Low Voltage Cables.

- Existing portable cables used for 480 V shore to ship power service may be MIL-DTL-915 type THOF-500 or type SHOF-500 in accordance with MIL-DTL-915. Low smoke cable specified by MIL-DTL-24643 which is for use on ships, shall not be used for shore-to-ship power applications. Its softer jacket is susceptible to damage.
- New portable cables used for 480 V shore to ship power service shall be three conductor type "Enhanced THOF-500" or "Enhanced Plus THOF-500" as shown in Figure C-6, Figure C-6, Figure C-6. Equivalent or better cables from other sources may be considered as approved by Navy technical authority.

C-3.2 Medium Voltage Cables.

The portable cables used for 4,160 V and 13,800 V shore to ship power service shall be three conductor, 350 kcmil type SHD-GC with Chlorinated Polyethylene (CPE) jacket. Insulation and jacket shall conform to ICEA S-75-381. Cables for 4,160 V service shall be 8 kV or 15 kV. Cables for 13,800 V service shall be 15 kV. However, cable sizes larger than 350 kcmil may be used with approval by Navy technical authority.

C-3.3 Standard Cable Lengths.

Activities will maintain an inventory of portable shore to ship electric power cables in lengths required for the ships. Lengths will be selected and constructed to service ships without the use of in-line connectors. Approval by Navy technical authority is required for an exception allowing the use of in-line connectors for specific conditions. All cable runs will be of equal length to minimize unequal load sharing.

C-3.4 Cable Storage.

Cables not in use should be stored appropriately. Covered off pier storage locations are highly desirable.

C-4 SHORE POWER CIRCUIT BREAKERS.

C-4.1 Low Voltage Cable Overcurrent Protection for Submarines.

The long-time pickup settings of the 450 V shore to ship power service circuit breakers for submarines shall be adjusted so that they match nominal ratings of equipment on the submarine. (Currently, the limiting ratings for equipment on the submarine is 435 A. If the 435 A setting is not a standard setting on the existing equipment, then the next higher setting is acceptable up to 480 A. Circuit breaker settings in excess of 435 A shall be documented and submitted to the cognizant Service with sufficient technical justification of the setting. Shore activities shall provide written notification to the submarines prior to connection focusing on the load requirements and load monitoring, breaker settings, and safety impacts. The instantaneous pickup setting shall be coordinated with the available short circuit amperes and associated system devices.

C-4.2 Low Voltage Cable Overcurrent Protection for Surface Ships.

The long-time pickup settings of the 450 V shore to ship power service circuit breakers for surface ships shall be adjusted to 430 A. If the 430 A setting is not a standard setting on the existing equipment, then the next higher setting is acceptable up to 480 A. Circuit breaker settings in excess of 430 A shall be documented and submitted to the cognizant Service with sufficient technical justification of the setting. The instantaneous pickup setting shall be coordinated with the available short circuit amperes and associated system devices.

C-4.3 Medium Voltage Cable Overcurrent Protection.

The long-time pickup setting of the shore to ship power service circuit breakers shall be adjusted to 400 A. If the 400 A setting is not a standard setting on the existing equipment, then the next higher setting is acceptable. The cable overcurrent protection will be based on the lowest rated service system device which is usually the fixed cables (normally 350 kcmil 105C conductors rated 440 A in conduit in air) between the substations and the receptacles for the portable cables, therefore the service rating could be as high as 440 A. Metal-clad switchgear with vacuum power circuit breakers will be equipped with programmable microprocessor relays which will allow the over current pickup to be set precisely to the desired setting. Circuit breaker settings in excess of 400 A shall be documented and submitted to the cognizant Service with sufficient technical justification of the setting. The instantaneous pickup setting shall be coordinated with the available short circuit amperes and associated system devices.

C-5 CABLE CONNECTORS.

Connectors. Cable connectors are available in two types: (1) one single, multiple conductor type (1-3/c cable); and (2) single conductor type grouped in a cluster of three (3-1/c cables). A typical three-conductor outlet assembly is illustrated in Figure D-4. Figure D-5 illustrates the single-conductor type connector.

- Low Voltage Terminations:
  - All low voltage portable power cables will be terminated with a MIL-C-24368/1 (procured from vendors on the Qualified Products List (QPL)) plug at the ship end of the cable for surface ships.
  - All low voltage portable power cables will be terminated with a MIL-C-24368/5 (procured from vendors on the QPL) plug at the ship end of the cable for submarines.
  - The termination device at the service end of the cable must be compatible with the design of the dockside power connection station (turtleback) and may be terminated with one of the following:
    - a MIL-C-24368/1 plug, for existing installations
    - a single pole connector which meets the environmental and test requirements of the MIL-C-24368 and the additional requirements identified is shown in Figure D-5
    - a UL 486A listed plug
    - an equivalent or better connector as approved by Navy technical authority
  - Install terminations in accordance with manufacturer's recommendations.
- Low Voltage In-line Connections: In-line single pole connectors and lug to lug connections shall meet the same requirements as identified above. Male and female cable mount in-line connectors may be used to connect shorter cable segments together to make longer cable circuits as necessary.
- Medium Voltage Terminations: All medium voltage portable power cables will be terminated at the ship end of the cable with a heat shrinkable termination (Institute of Electrical and Electronics Engineers standard IEEE-48 class 1) specifically designed for SHD-GC cables. Medium Voltage portable power cables for CVN 78 will be terminated at the ship end of the cable with a 15 KV Patton & Cooke cable coupler specifically designed for SHD-GC cables. The termination device at the service end of the cable must be compatible with the design of the dockside power connection station (turtleback) and may be terminated the same as the ship end of the cable or with a coupler plug that is compatible with the receptacle at the dockside power connection station. The termination devices shall be assembled on to the cable per the manufacturer's instructions. Terminate the SHD-GC cable ground and check

conductors within the cable breakout boot or to the appropriate termination pin integral with the coupler plug.

C-6 MAINTENANCE OF PORTABLE POWER CABLE ASSEMBLIES.

C-6.1 Tests and Inspections for Submarine Portable Power Cable Assemblies.

Electrical tests and inspections shall be in accordance with Maintenance Standard (MS) Number 3420-08 1-089. These tests and inspections shall be conducted annually. Results of the contact tightness checks, conducted in accordance with paragraph 1.g of Maintenance Standard (MS) Number 3420-081-089, shall be included on the written notification provided to ships forces prior to each shore power service connection to the submarine, identified in Section C-4.1 above entitled “Low Voltage Cable Overcurrent Protection for Submarines”.

C-6.2 Tests and Inspections for Surface Ship Portable Power Cable Assemblies.

Electrical tests and inspections shall be in accordance with ANSI/NETA MTS Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems (most recent edition) for cables and the manufacturer's instructions for connectors. Over potential tests are not required, but may be performed on the cable assemblies that fail insulation-resistance tests as a means to locate cable faults and to verify cable integrity. These tests and inspections shall be conducted annually.

C-6.3 Cable Repair.

Cables with damage other than to the outer jacket shall be removed from service permanently. Repair jackets using a heat shrinkable wrap around mining cable repair sleeve, cold repair elastomeric strips for mining cables, or a similar product. Repair of the coupler plugs and receptacles shall be performed in accordance with the manufacturers' instructions of these cable repair products or shall be in accordance with reference (b) MS NO.3420-08 1-089.

C-6.4 Connector Repairs.

Repairs to MIL-C-24368/5 connectors shall be in accordance with reference (b) MS NO. 3420-08 1-089 Repairs to MIL-C-24368/1 and MIL-C-24368/4 connectors, and medium voltage coupler plugs shall be in accordance with manufacturer's instructions.

C-6.5 Splicing.

Splicing of portable shore to ship power cables is not recommended for 480V shore power cables. Medium voltage portable power cables shall not be spliced under any conditions.

C-7 MAINTENANCE OF SHORE TO SHIP POWER PERMANENT COMPONENTS.

C-7.1 Electrical Tests and Inspections.

Electrical tests and inspections for shore power circuit breakers and associated protective relaying and the permanently installed cables between the shore power circuit breaker and the power connection station (turtleback) shall be performed in accordance with the latest edition of ANSI/NETA Maintenance Testing Specifications (MTS).

Note: Complete visual inspection of inaccessible components is not required.

For low voltage power air circuit breakers, Visual and Mechanical Inspections and Electrical tests shall follow ANSI/NETA MTS recommendations and be performed every two years, with the exception of primary current injection testing. Primary current injection testing shall be performed every 3rd breaker maintenance cycle (6 years) unless a problem is suspected, in which case the test shall be done immediately. Secondary current injection testing with primary current verification to verify proper operation of the current transformers and remaining connection points shall be a substitute for primary current injection testing every 1st and 2nd breaker maintenance cycle (2 and 4 years respectively).These intervals may be reduced, as required, based upon equipment condition or operating environment.

For medium voltage circuit breakers, Visual and Mechanical Inspections and Electrical tests shall follow ANSI/NETA MTS recommendations and be performed every two years. This interval may be reduced, as required, based upon equipment condition or operating environment.

All new low and medium voltage circuits breakers shall follow acceptance testing requirements set forth in ANSI/NETA Acceptance Testing Specification (ATS).

Electrical tests and inspections for the power connection station receptacles shall be in accordance with the manufacturer's instructions. Over potential tests are not required, but may be performed on the cable assemblies that fail insulation-resistance tests as a means to locate cable faults and to verify cable integrity.

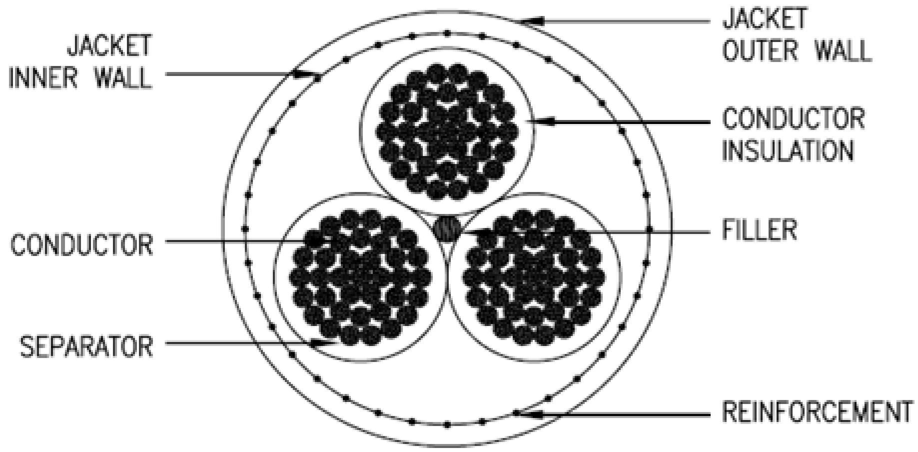
C-7.2 Repair.

Repair of permanent components shall be performed in accordance with the manufacturer's instructions.

C-7.3 Breaker Operation.

Whenever shore power circuit breakers operate on instantaneous trip, do not re-energize associated shore power circuits until the cause of the fault has been cleared and the circuit breaker has been inspected for damage to contacts, arc chutes, frame and operating mechanism. Whenever shore power circuit breakers operate because of an over current, the ships forces shall be notified and the associated shore power circuits may be reenergized per local SOPS with concurrence from the ships forces.

Figure C-1 3/C Enhanced THOF Cable

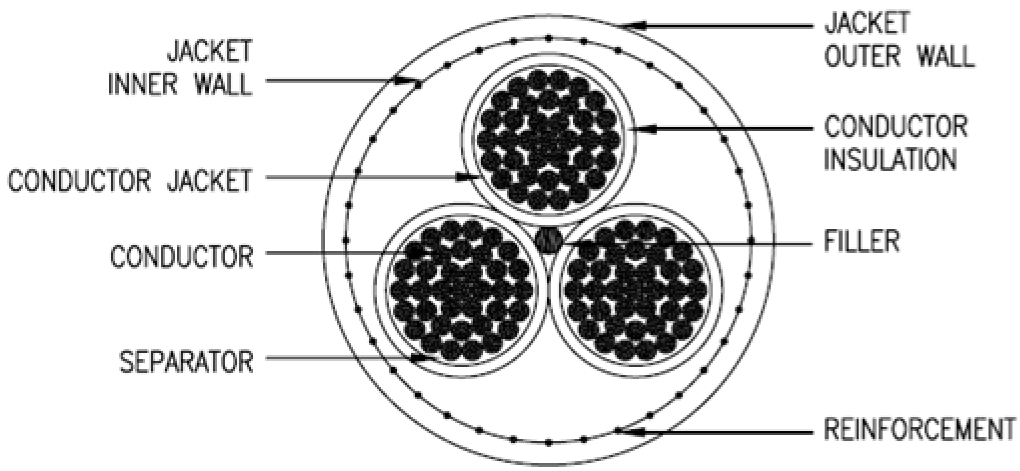


		TYPICAL
1.	CONDUCTOR – 500 KCMIL (37 x 33 / 0.0201") 1221W TINNED COPPER.	OD: 0.888"
2.	SEPARATOR – 2 MIL WHITE MYLAR PULLED LONGITUDINALLY.	OD: 0.893"
3.	CONDUCTOR INSULATION – 90 MILS (MIN AVG) OF UV RESISTANT ETHYLENE PROPYLENE RUBBER (EPR).	OD: 1.100"
4.	PHASE ID – PIGMENT COLORED INSULATION (BLACK, WHITE, RED).	
5.	FILLER – RUBBER AS REQUIRED TO FILL CENTER INTERSTICE.	
6.	JACKET INNER WALL – APPX. 100 MILS OF BLACK HEAVY DUTY CHLORINATED POLYETHYLENE (CPE).	
7.	REINFORCEMENT – TWO REVERSE/OPEN WRAPS OF POLYPROPYLENE FILAMENT.	
8.	JACKET OUTER WALL – APPX. 135 MILS OF BLACK EXTRA–HEAVY DUTY CHLORINATED POLYETHYLENE (CPE) 90°C RATED.	
9.	APPX WEIGHT – 7,563 POUNDS PER THOUSAND FEET.	OD: 2.875"
10.	CABLE IDENTIFICATION – INDENT MARKING TO READ: (MFG NAME) 500 KCMIL 3/C 600V ENHANCED SHORE–TO–SHIP POWER CABLE 90C (YEAR OF MFG) PROPERTY OF U.S. NAVY.	
12.	VOLTAGE RATING – 600 VOLTS.	
13.	TEMPERATURE RATING OF CONDUCTOR – 90°C.	
14.	TOLERANCE: +/–5%, DRAWING NOT TO SCALE.	
15.	SEE SPECIFICATION SHEET FOR ADDITIONAL INFORMATION.	

3/C ENHANCED THOF

REVISED: CIEE	MARCH 24, 2006	ATTACHMENT 2–1.1

Figure C-2 3/C Enhanced Plus THOF Cable



		TYPICAL
1.	CONDUCTOR – 500 KCMIL (37 x 33 / 0.0201") 1221W TINNED COPPER.	OD: 0.888"
2.	SEPARATOR – 2 MIL WHITE MYLAR PULLED LONGITUDINALLY.	
3.	CONDUCTOR INSULATION – 65 MILS (MIN AVG) OF ETHYLENE PROPYLENE RUBBER (EPR).	
4.	CONDUCTOR JACKET – 65 MILS (MIN AVG) OF UV RESISTANT CHLORINATED POLYETHYLENE (CPE) OR HYPALON.	
5.	PHASE ID – PIGMENT COLORED INSULATION (BLACK, WHITE, RED).	
6.	FILLER – RUBBER AS REQUIRED TO FILL CENTER INTERSTICE.	
7.	JACKET INNER WALL – APPX. 100 MILS OF BLACK HEAVY DUTY CHLORINATED POLYETHYLENE (CPE).	
8.	REINFORCEMENT – TWO REVERSE/OPEN WRAPS OF POLYPROPYLENE FILAMENT.	
9.	JACKET OUTER WALL – APPX. 125 MILS OF BLACK EXTRA-HEAVY DUTY CHLORINATED POLYETHYLENE (CPE) 90°C RATED.	
10.	APPX WEIGHT – 7,854 POUNDS PER THOUSAND FEET.	OD: 3.003"
11.	CABLE IDENTIFICATION – INDENT MARKING TO READ: (MFG NAME) 500 KCMIL 3/C 600V ENHANCED PLUS SHORE-TO-SHIP POWER CABLE 90C (YEAR OF MFG) PROPERTY OF U.S. NAVY.	
12.	VOLTAGE RATING – 600 VOLTS.	
13.	TEMPERATURE RATING OF CONDUCTOR – 90°C.	
14.	TOLERANCE: +/-5%, DRAWING NOT TO SCALE.	
15.	SEE SPECIFICATION SHEET FOR ADDITIONAL INFORMATION.	

3/C ENHANCED PLUS THOF

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Figure C-3 3/C Enhanced & Enhanced Plus THOF Cable Specification

CONDUCTOR – CLASS I, UNIDIRECTIONAL LAY-UP, MAXIMUM RESISTANCE: 0.0238 OHMS/1000FT AT 25°C.

CONDUCTOR INSULATION – EPR PER ICEA S-75-381.
ABRASION RESISTANCE TEST IN ACCORDANCE WITH ISO 4649 – INDEX OF 50 MINIMUM.
PHYSICAL AND AGING TESTS IN ACCORDANCE WITH ICEA S-75-381.
TEAR RESISTANCE, MINIMUM, 20LB/IN.
UN-AGED VALUES.
TENSILE STRENGTH, MINIMUM – 1200 PSI.
ELONGATION AT RUPTURE, MINIMUM % – 150.
AFTER AGING IN AIR 168 HOURS AT 121 ± 1°C.
TENSILE STRENGTH, MINIMUM % OF UN-AGED VALUE – 75.
ELONGATION AT RUPTURE, MINIMUM % OF UN-AGED VALUE – 75.
LONG TERM INSULATION RESISTANCE IN 75°C WATER SHALL BE IN ACCORDANCE WITH UL 44.

CONDUCTOR JACKET (ENHANCED PLUS ONLY) – CPE OR HYPALON – COMPOSITE, TYPE RHH/RHW-2.
ABRASION RESISTANCE IN ACCORDANCE WITH ISO 4649 – INDEX OF 50 MINIMUM.
PHYSICAL AND AGING TESTS IN ACCORDANCE WITH ICEA S-75-381.
TEAR RESISTANCE, MINIMUM, 30 LB/IN.
UN-AGED VALUES.
TENSILE STRENGTH, MINIMUM – 2000 PSI.
ELONGATION AT RUPTURE, MINIMUM % – 400.

OVERALL JACKET – MOLD CURED, TWO LAYER REINFORCED JACKET FILLING THE CABLE INTERSTICES.
INNER WALL – HEAVY DUTY CPE.
PHYSICAL AND AGING TESTS IN ACCORDANCE WITH ICEA S-75-381.
UN-AGED VALUES.
TENSILE STRENGTH, MINIMUM – 1800 PSI.
ELONGATION AT RUPTURE, MINIMUM % – 300.
AFTER AGING IN AIR 168 HOURS AT 100 ± 1°C.
TENSILE STRENGTH, MINIMUM % OF UN-AGED VALUE – 85.
ELONGATION AT RUPTURE, MINIMUM % OF UN-AGED VALUE – 55.
OUTER WALL– EXTRA HEAVY DUTY CPE.
ABRASION RESISTANCE IN ACCORDANCE WITH ISO 4649 – INDEX OF 75 MINIMUM.
PHYSICAL AND AGING TESTS IN ACCORDANCE WITH ICEA S-75-381.
TEAR RESISTANCE, MINIMUM, 50 LB/IN.
UN-AGED VALUES.
TENSILE STRENGTH, MINIMUM – 2400 PSI.
ELONGATION AT RUPTURE, MINIMUM % – 300.
AFTER AGING IN AIR 168 HOURS AT 100 ± 1°C.
TENSILE STRENGTH, MINIMUM % OF UN-AGED VALUE – 70.
ELONGATION AT RUPTURE, MINIMUM % OF UN-AGED VALUE – 55.

ENHANCED & ENHANCED PLUS THOF SPECIFICATION

REVISED: CIEE JANUARY 31, 2007 ATTACHMENT 2-1.3

Figure C-4 3/C Enhanced & Enhanced Plus THOF Cable Specification

ASSEMBLY

ENHANCED THOF CABLE SHALL HAVE INSULATED CONDUCTORS.
ENHANCED PLUS THOF CABLE SHALL HAVE INSULATED AND JACKETED CONDUCTORS.
SEE DRAWINGS FOR DIMENSIONS AND SUPPLEMENTAL INFORMATION.

THREE CONDUCTORS SHALL BE CABLED WITH A MAXIMUM LAY LENGTH OF 26 INCHES. EXCEPT FOR A CENTER EXTRUDED RUBBER ROD FILLER, NO OTHER FILLERS ARE PERMITTED. NO ASSEMBLY BINDER TAPE IS TO BE USED. MOLD RELEASE AGENTS, IF USED SHALL NOT CONTAIN SILICONE OR WAX.

FUNCTIONAL TESTS

THE GOVERNMENT RESERVES THE RIGHT TO WITNESS ANY OR ALL CABLE TESTS. ONCE FUNCTIONAL TESTING HAS BEGUN, ALL TESTS MUST BE COMPLETED IN NO MORE THAN 36 HOURS. FUNCTIONAL TESTS ARE REQUIRED USING A TEST CABLE AS DESCRIBED BELOW. TESTS SHALL BE CONDUCTED AFTER THE CABLE HAS BEEN EXPOSED TO THE SPECIFIED TEST TEMPERATURE FOR AT LEAST 8 HOURS. THE FUNCTIONAL TESTS SHALL BE PERFORMED IN THE FOLLOWING ORDER USING THE SAME PIECE OF CABLE:

1. DIELECTRIC PRE–FLEX TEST.
2. SUMMER FLEXIBILITY WITH NATURAL BEND.
3. SUMMER FLEXIBILITY AGAINST NATURAL BEND.
4. WINTER FLEXIBILITY WITH NATURAL BEND.
5. WINTER FLEXIBILITY AGAINST NATURAL BEND.
6. CUT–BACK.
7. DIELECTRIC POST–FLEX TEST.

TEST CABLE DESCRIPTION

THE TEST CABLE WILL BE 12 FEET IN LENGTH CUT FROM A CABLE WITH A MINIMUM LENGTH OF 100 FEET, ROLLED ONTO A CABLE REEL FOR AT LEAST 168 HOURS WHOSE SPOOL DIAMETER DOES NOT EXCEED 3 FEET. THE TEST CABLE WILL BE CUT FROM THE LAYER OF CABLE IN CONTACT WITH THE SPOOL. AFTER THE DIELECTRIC PRE–TEST EACH END WILL BE SEALED TO PREVENT MOISTURE INFILTRATION.

ENHANCED & ENHANCED PLUS THOF SPECIFICATION (CONT'D)

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Figure C-5 3/C Enhanced & Enhanced Plus THOF Cable Specification

FLEXIBILITY TEST

ALL FLEXIBILITY TESTS WILL BE PERFORMED BY LAYING THE TEST CABLE ON A 20 INCH DIAMETER SHEAVE OR DRUM (IE WHEEL) AND LIFTING IT VERTICALLY UNTIL THE CABLE HANGS FREE IN AIR. THE PLACEMENT OF THE CABLE ONTO THE WHEEL WILL ALLOW APPROXIMATELY ONE-HALF OF THE CABLE TO HANG DOWN ON EACH SIDE. AS THE CABLE HANGS FREE, ATTACH 80 POUNDS TO EACH END AND MEASURE TANGENTIALLY (IE PERPENDICULAR TO VERTICAL) THE SHORTEST DISTANCE BETWEEN THE CABLE MEASURED AT THE BOTTOM OF THE WHEEL. THE CABLE SHALL HANG FOR NO MORE THAN 30 SECONDS BEFORE THE MEASUREMENT IS TAKEN. NO FORCE TENDING TO BRING THE CABLE ON EACH SIDE OF THE WHEEL CLOSER TOGETHER WILL BE PERMITTED. ONLY THE WEIGHT OF THE CABLE AND THE TEST WEIGHTS WILL BEND IT AROUND THE TOP OF THE WHEEL.

DIMENSIONS BETWEEN CABLE AT BOTTOM OF WHEEL.
SUMMER: 25 INCHES MAXIMUM AT 25°C, ± 2°C.
WINTER: 28 INCHES MAXIMUM AT 5°C, ± 2°C.

CUT-BACK TEST

NOT LESS THAN 24 INCHES OF THE CABLE JACKET WILL BE REMOVED FROM BOTH ENDS OF THE TEST CABLE USING A KNIFE, 10 INCH CHANNEL LOCK OR VICE GRIP TYPE PLIERS, AND 8 INCH NEEDLE NOSE PLIERS. REMOVAL OF THE JACKET SHALL BE ACCOMPLISHED WITHOUT THE APPLICATION OF HEAT TO THE JACKET AT ROOM TEMPERATURE OF 20°C ±2°C. VERIFY THE FOLLOWING:

NO BONDING OF CONDUCTOR INSULATION (OR CONDUCTOR JACKET) TO CABLE JACKET
NO REMOVAL OF CONDUCTOR INSULATION (OR CONDUCTOR JACKET) BY TEARING
BOND BETWEEN INNER WALL AND OUTER WALL OF OVERALL JACKET SHALL BE STOCK TEARING.

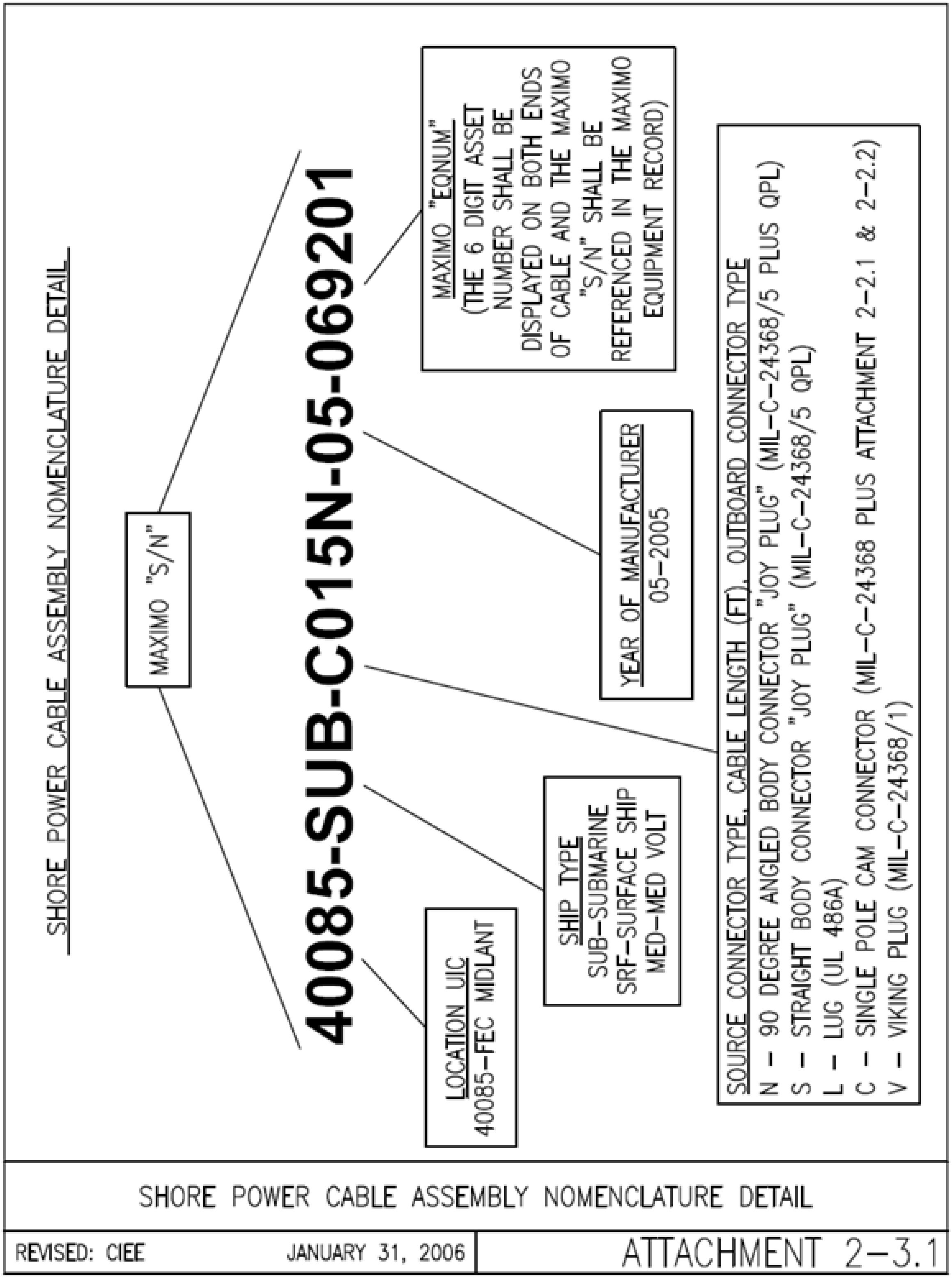
DIELECTRIC TESTS

DIELECTRIC TESTS (BOTH PRE AND POST FLEXIBILITY TESTING), PER ICEA T-27-581.
AC HI POT; 9.5 KV FOR 5 MINUTES.
INSULATION RESISTANCE: NOT LESS THAN 100 MEG-OHMS.

ENHANCED & ENHANCED PLUS THOF SPECIFICATION (CONT'D)

REVISED: CIEE	JANUARY 31, 2006	ATTACHMENT 2-1.5

Figure C-6 Shore Power Cable Assembly Nomenclature Detail



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APPENDIX D TYPICAL ELECTRICAL DIAGRAMS AND DETAILS

Figure D-1 Electrical System for a Double-Deck Pier

Figure D-2 Pier Electrical Distribution

Figure D-3 Portable Substation

Figure D-4 Ship Service Outlet Assembly

Figure D-5 Single Pole Connector Details

Figure D-6 Pier Electrical Distribution for Temporary Services

Figure D-1 (a) Electrical System for a Double-Deck Pier (1 of 9)

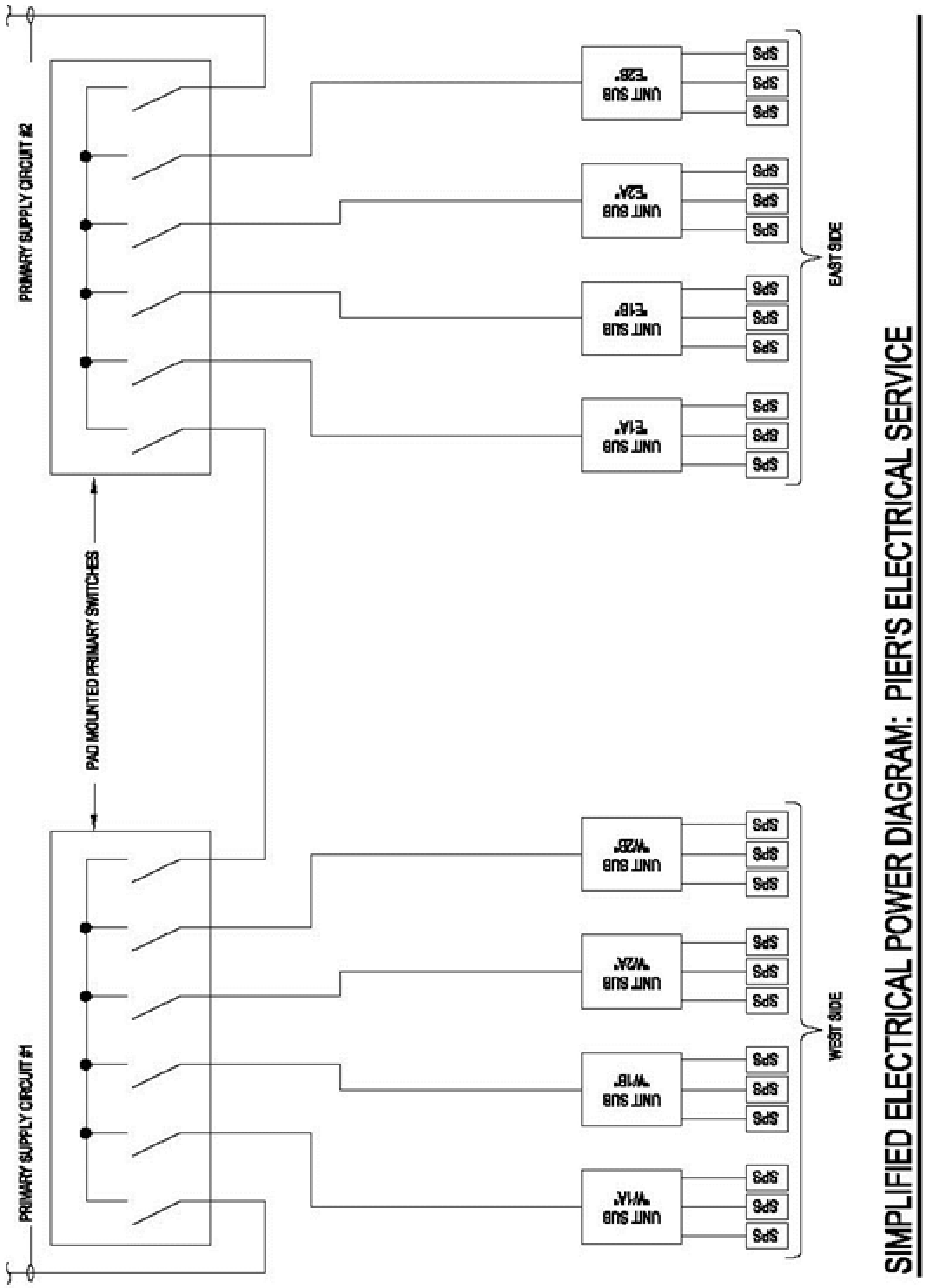


Figure D-1 (b) Electrical System for a Double-Deck Pier (2 of 9)

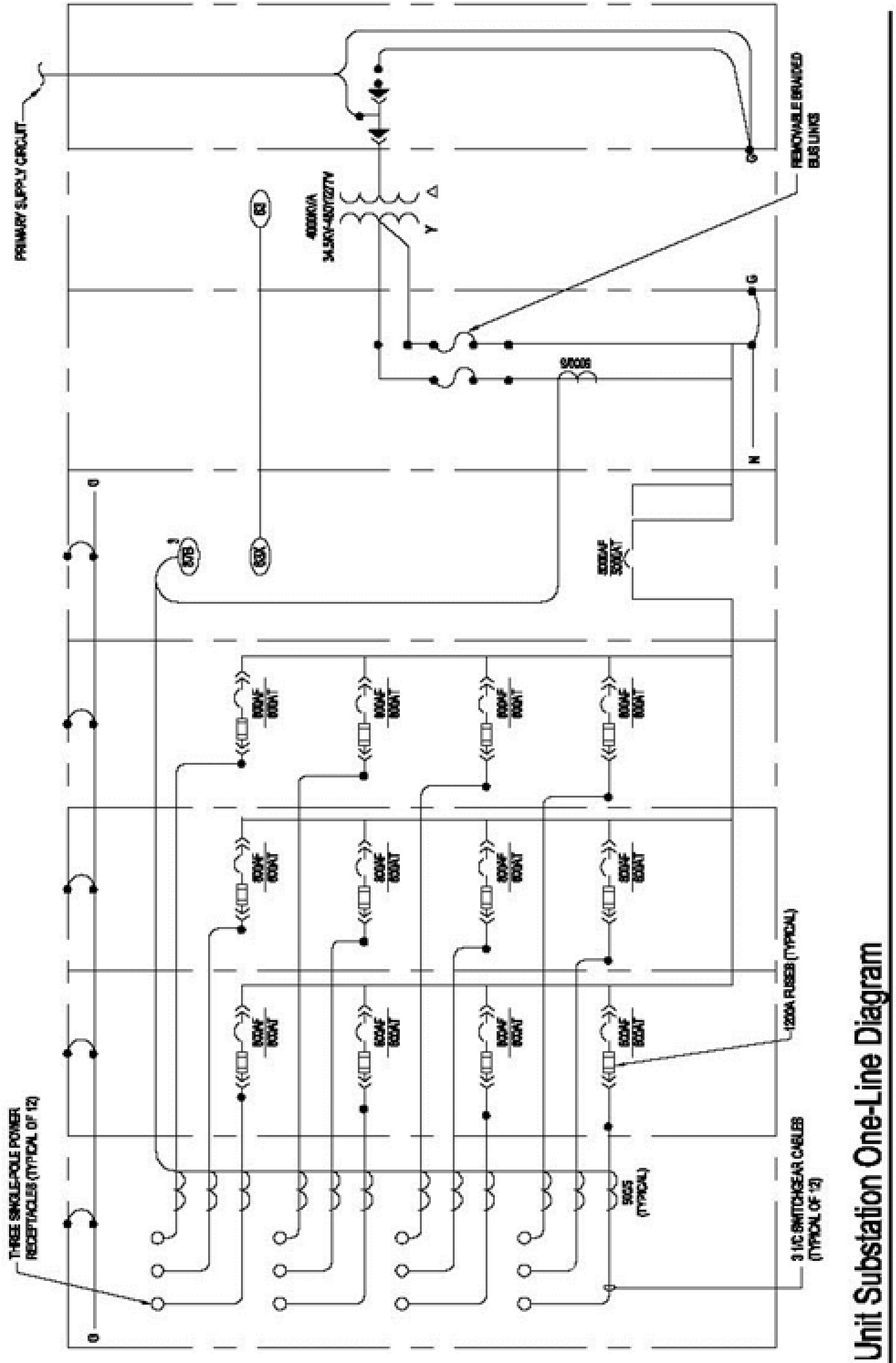


Figure D-1 (c) Electrical System for a Double-Deck Pier (3 of 9)

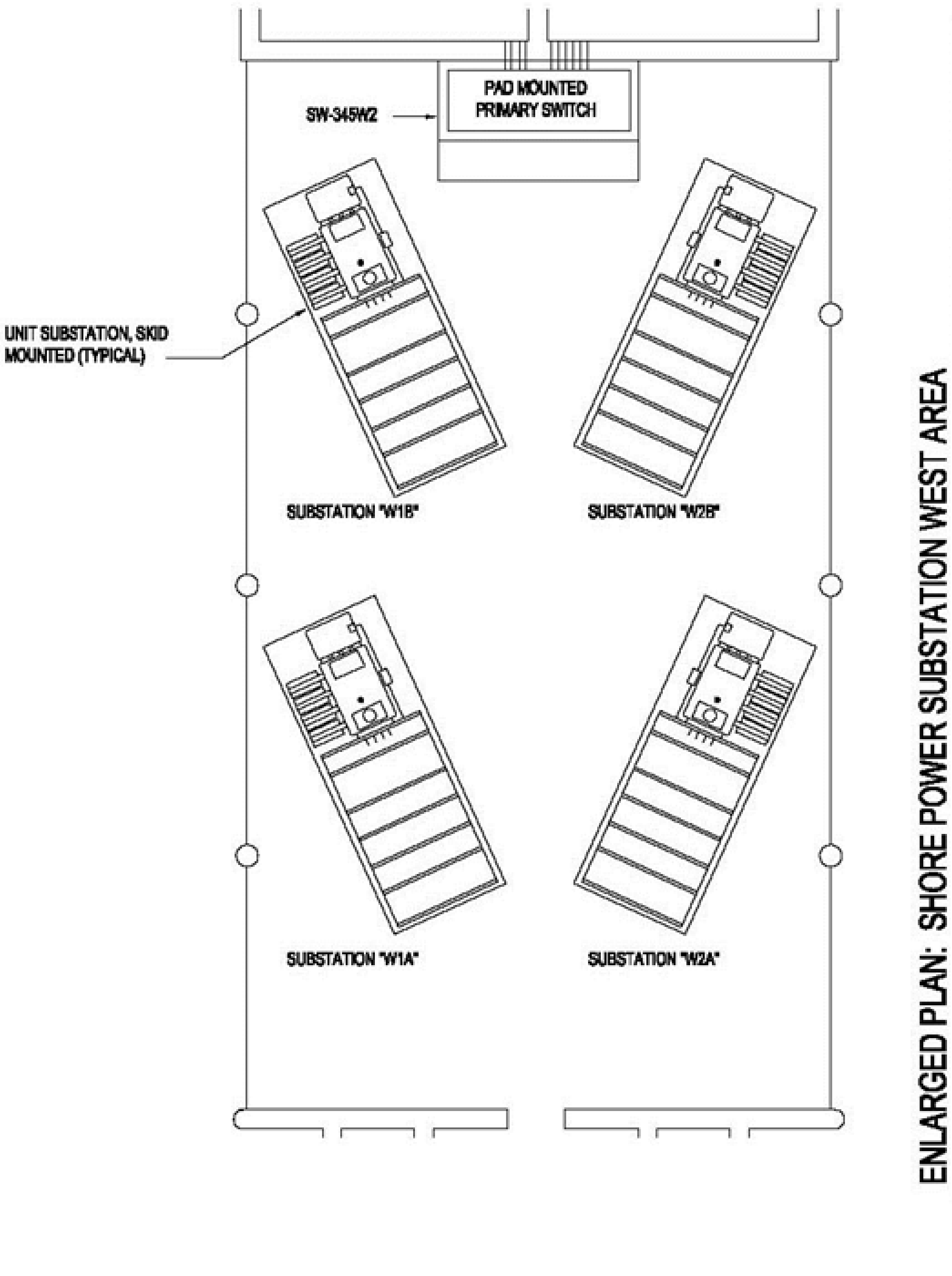
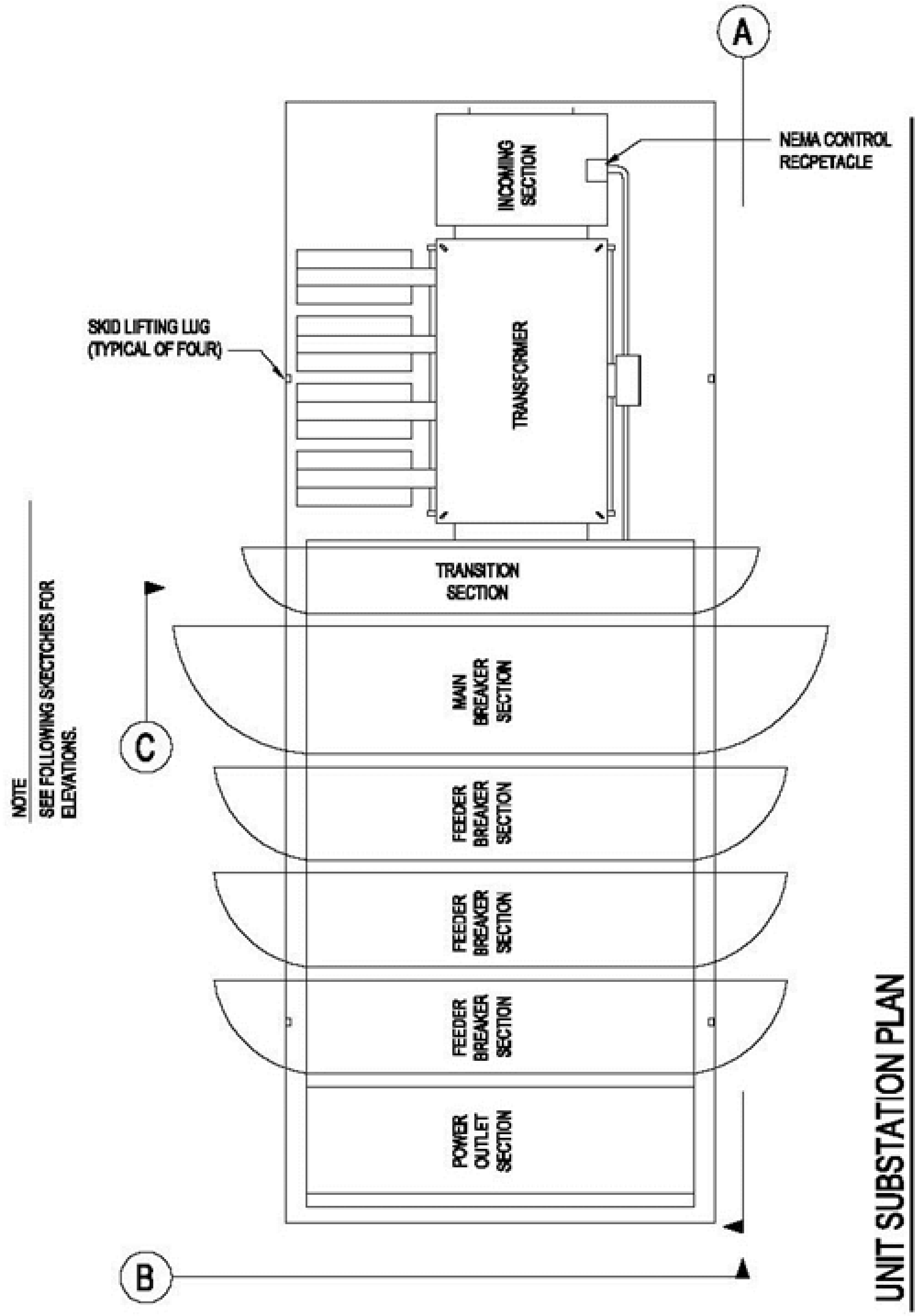


Figure D-1 (d) Electrical System for a Double-Deck Pier (4 of 9)



*** Substation must be designed with maintainability in mind and provisions and/or clearance for removing the circuit breakers must be factored into the design. Provide adequate clearance in front of the circuit breakers for a lifting cart.

Figure D-1 (e) Electrical System for a Double-Deck Pier (5 of 9)

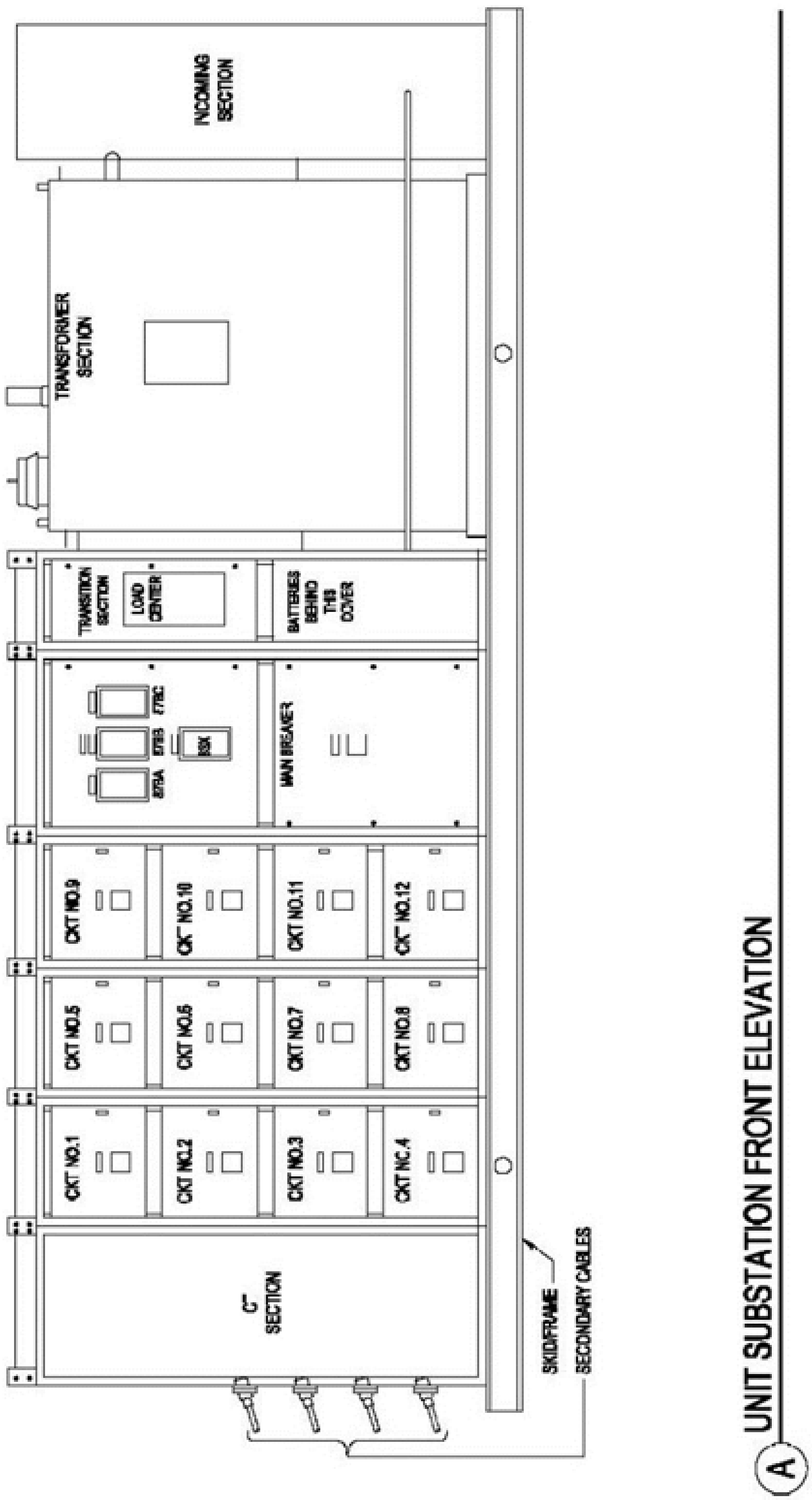


Figure D-1 (f) Electrical System for a Double-Deck Pier (6 of 9)

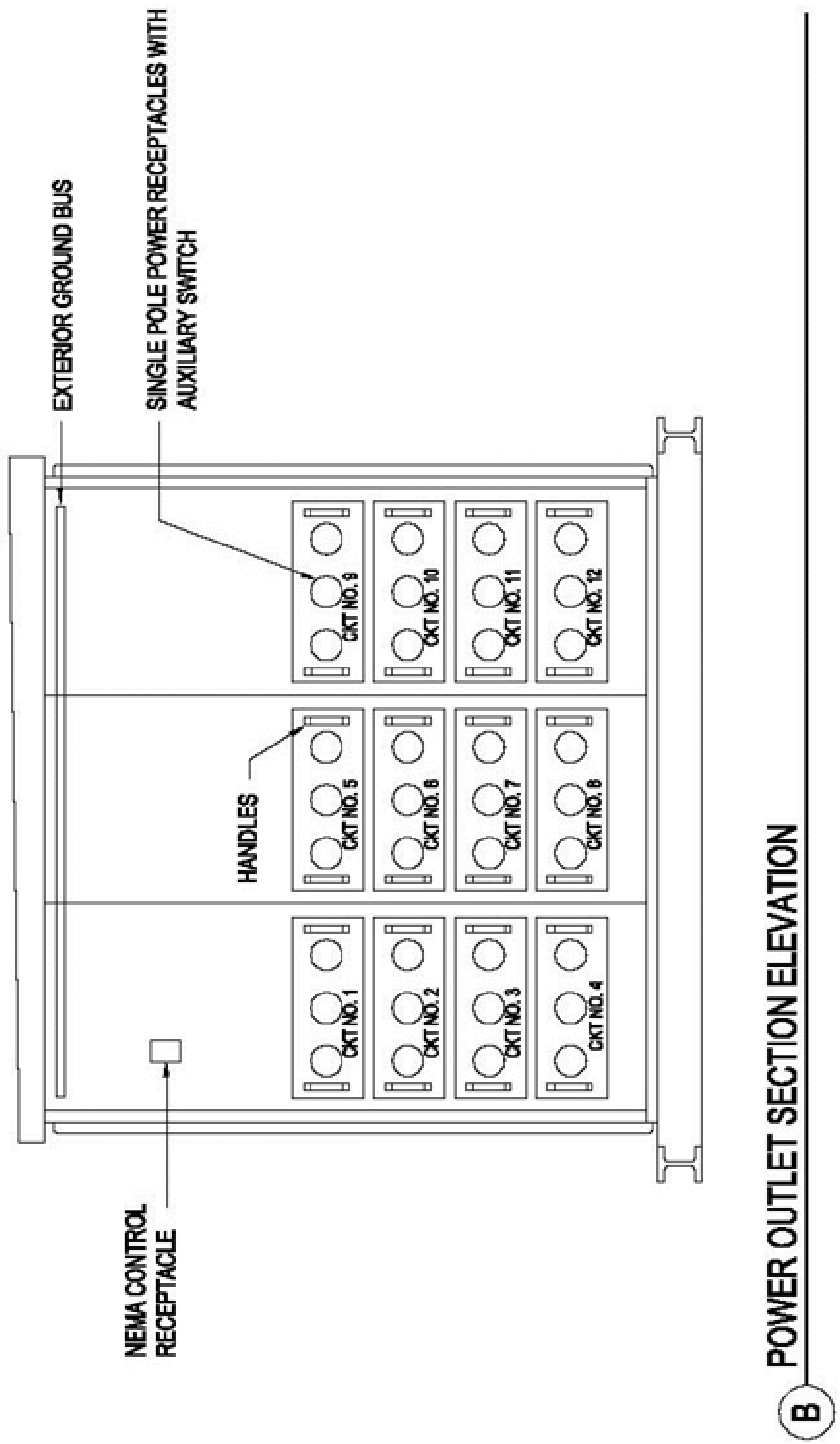


Figure D-1 (g) Electrical System for a Double-Deck Pier (7 of 9)

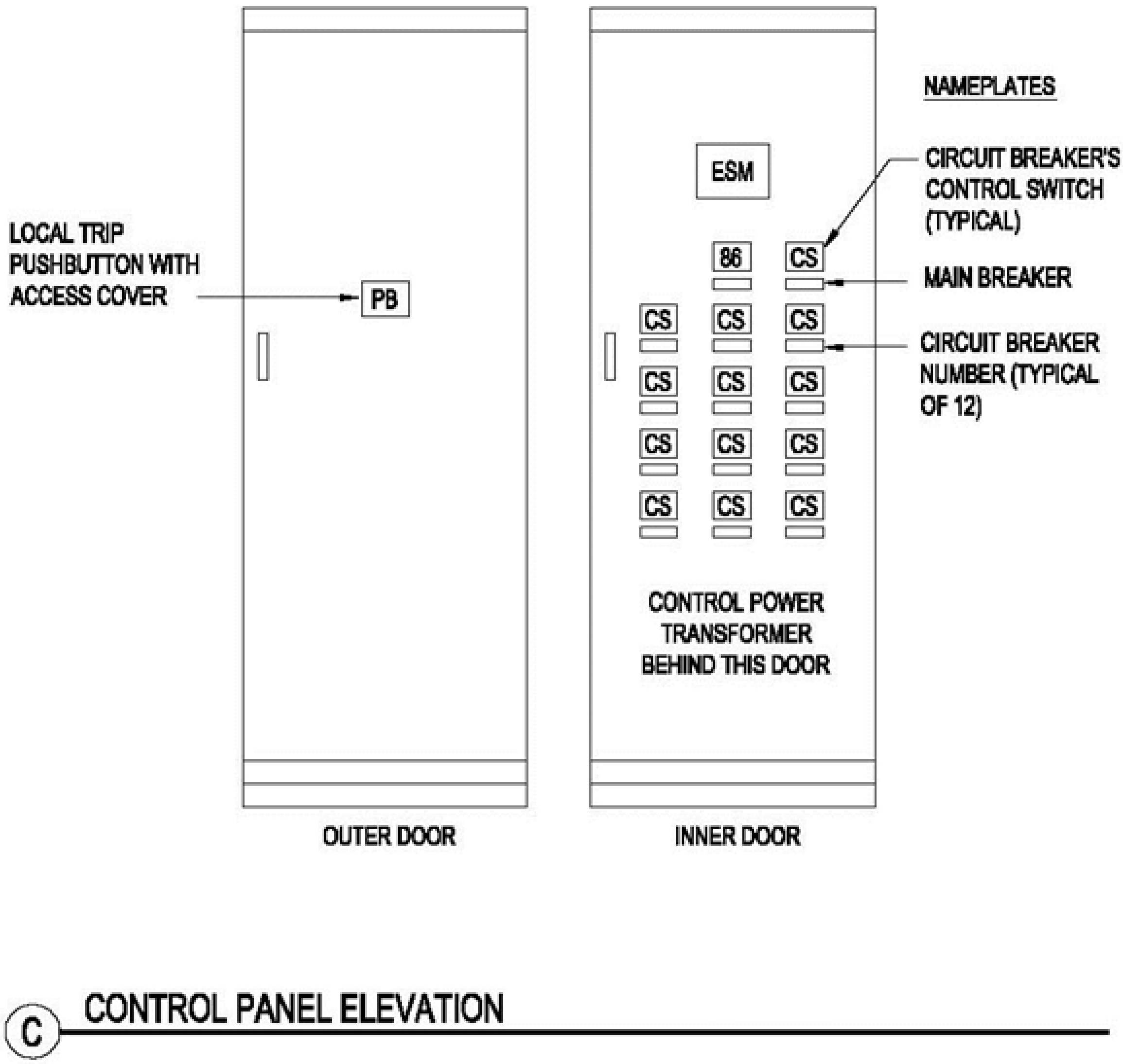
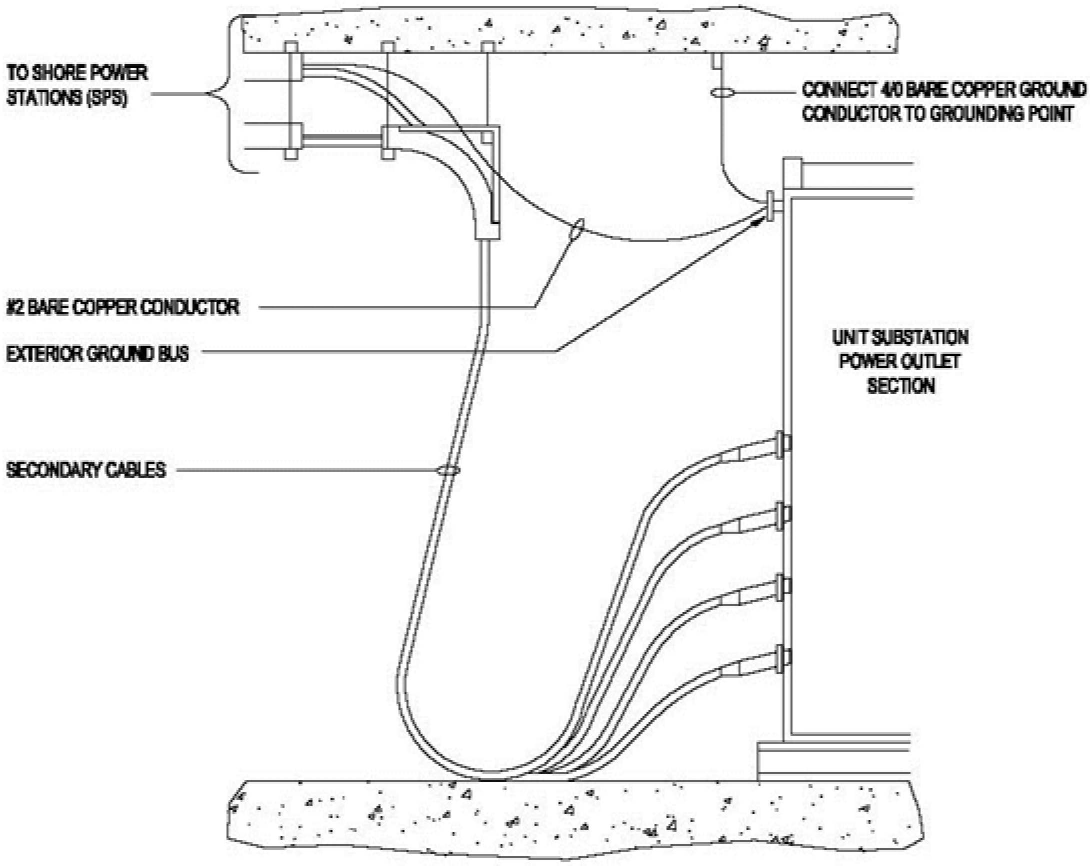


Figure D-1 (h) Electrical System for a Double-Deck Pier (8 of 9)



TYPICAL POWER OUTLET CONNECTIONS

Figure D-1 (i) Electrical System for a Double-Deck Pier (9 of 9)

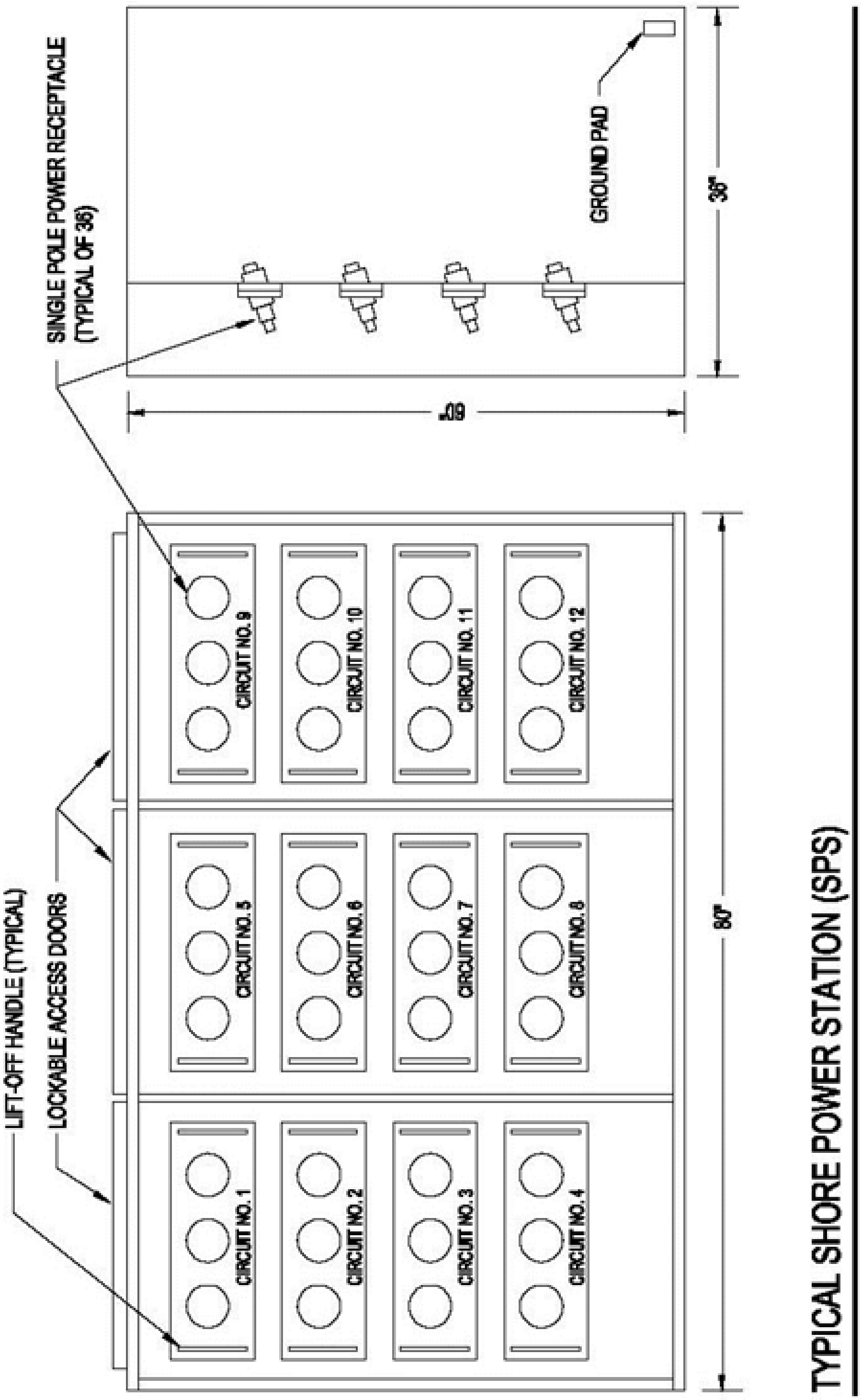


Figure D-2 (a) Pier Electrical Distribution: Typical Vault System (1 of 5)

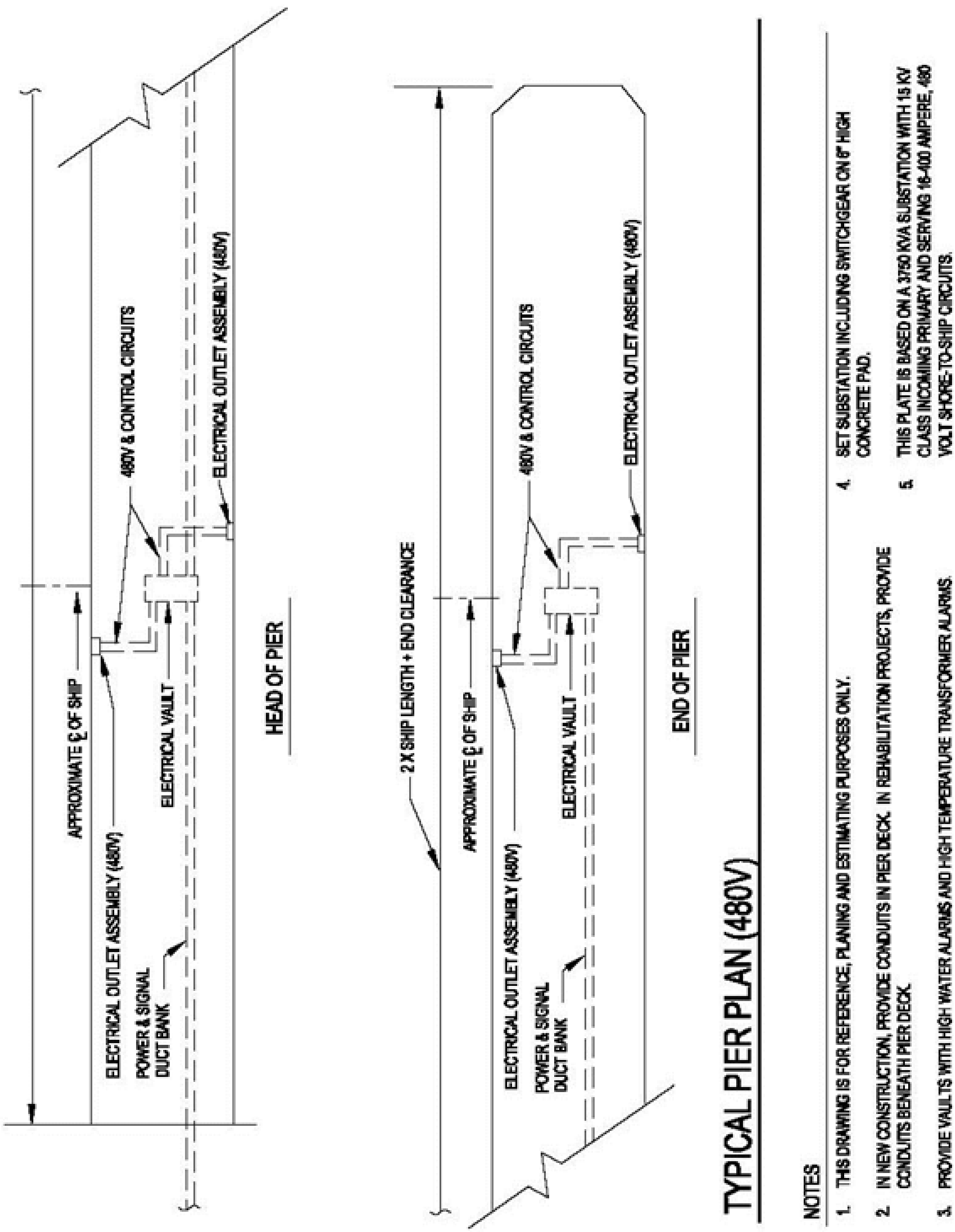
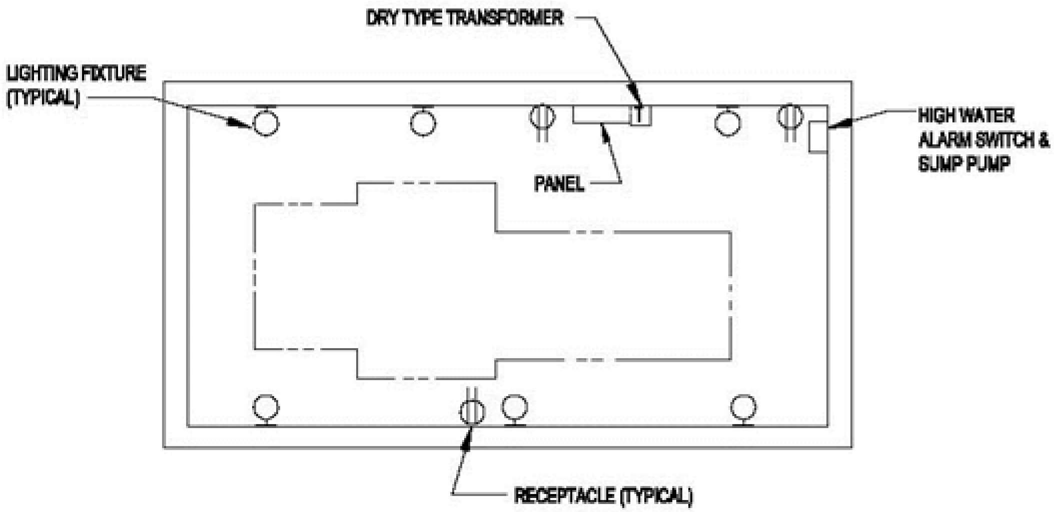
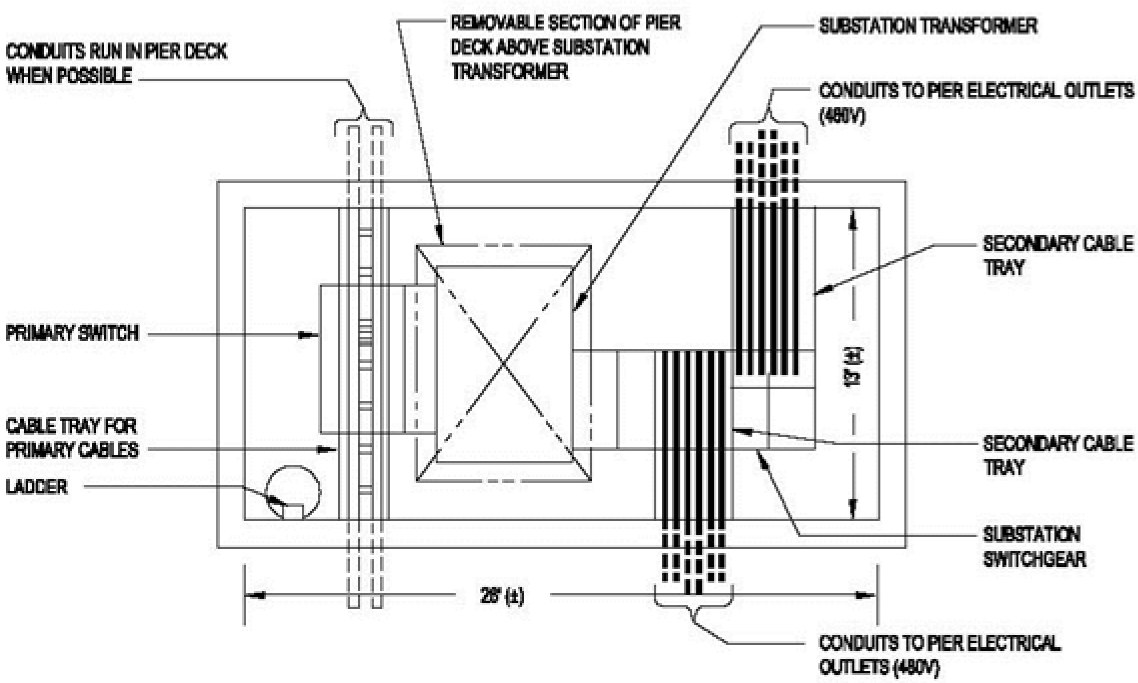


Figure D-2 (b) Pier Electrical Distribution: Typical Vault System (2 of 5)



LIGHTING AND SMALL POWER PLAN



ELECTRICAL VAULT PLAN

Figure D-2 (c) Pier Electrical Distribution: Typical Vault System (3 of 5)

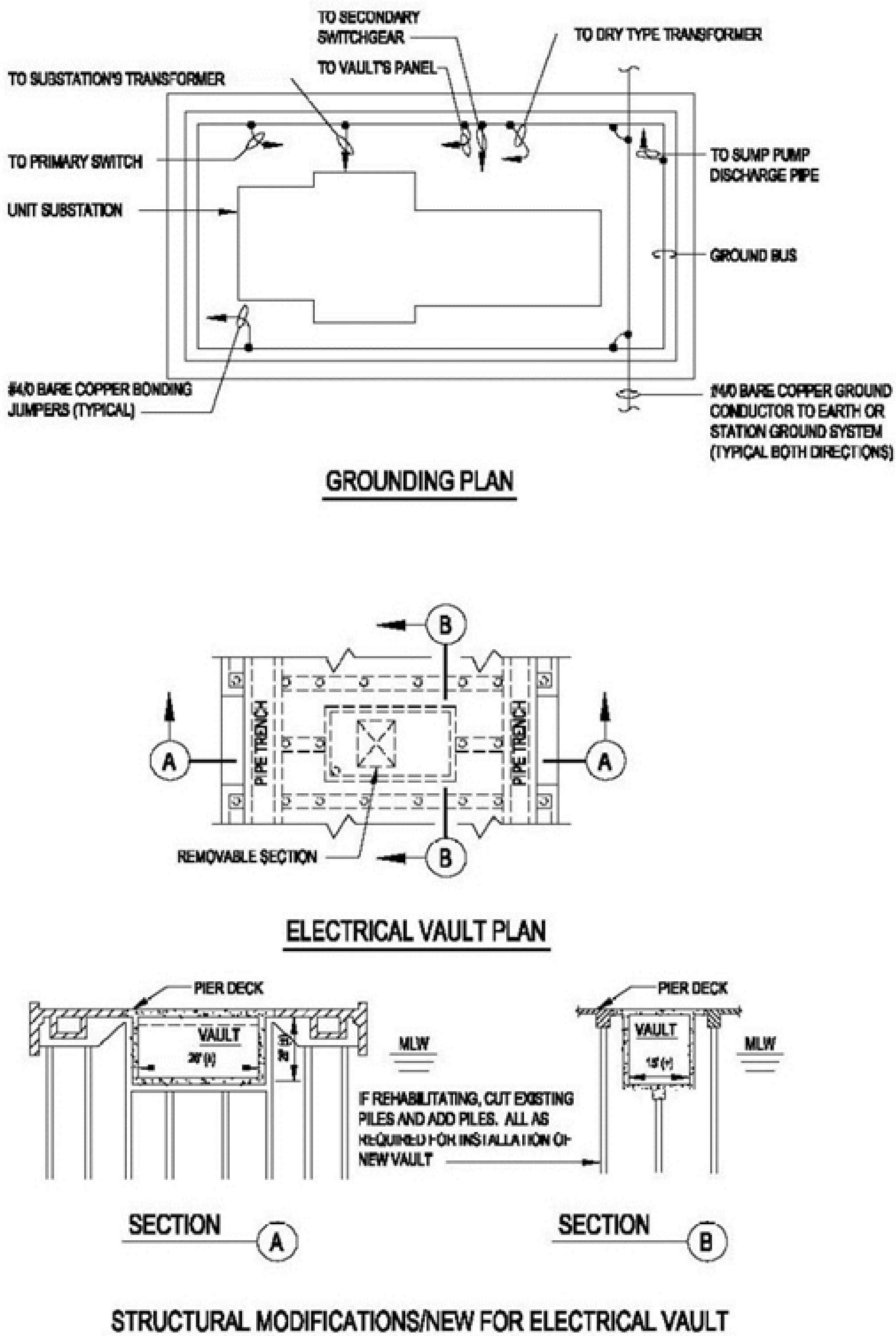


Figure D-2 (d) Pier Electrical Distribution: Typical Vault System (4 of 5)

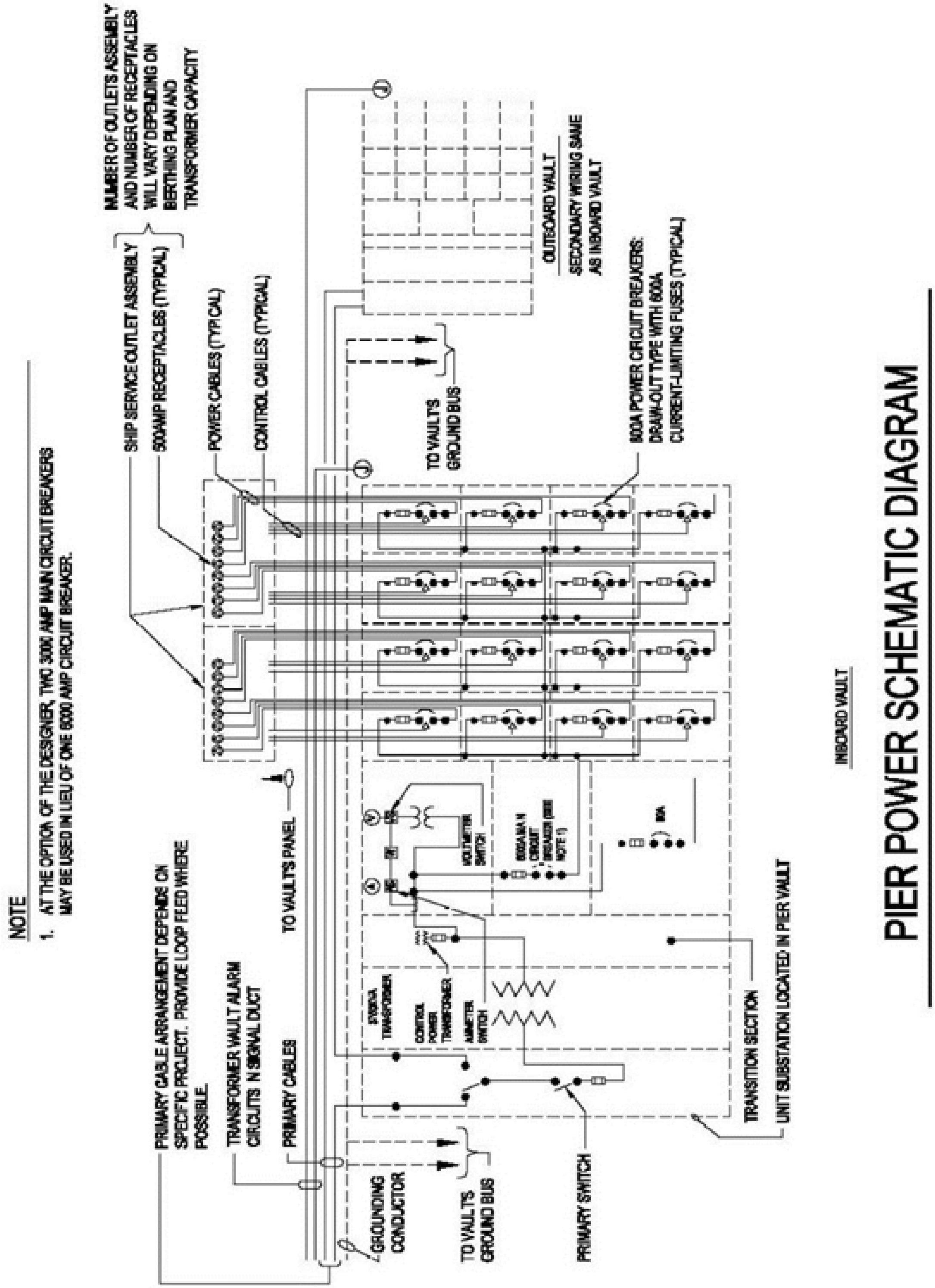


Figure D-2 (e) Pier Electrical Distribution: Typical Vault System (5 of 5)

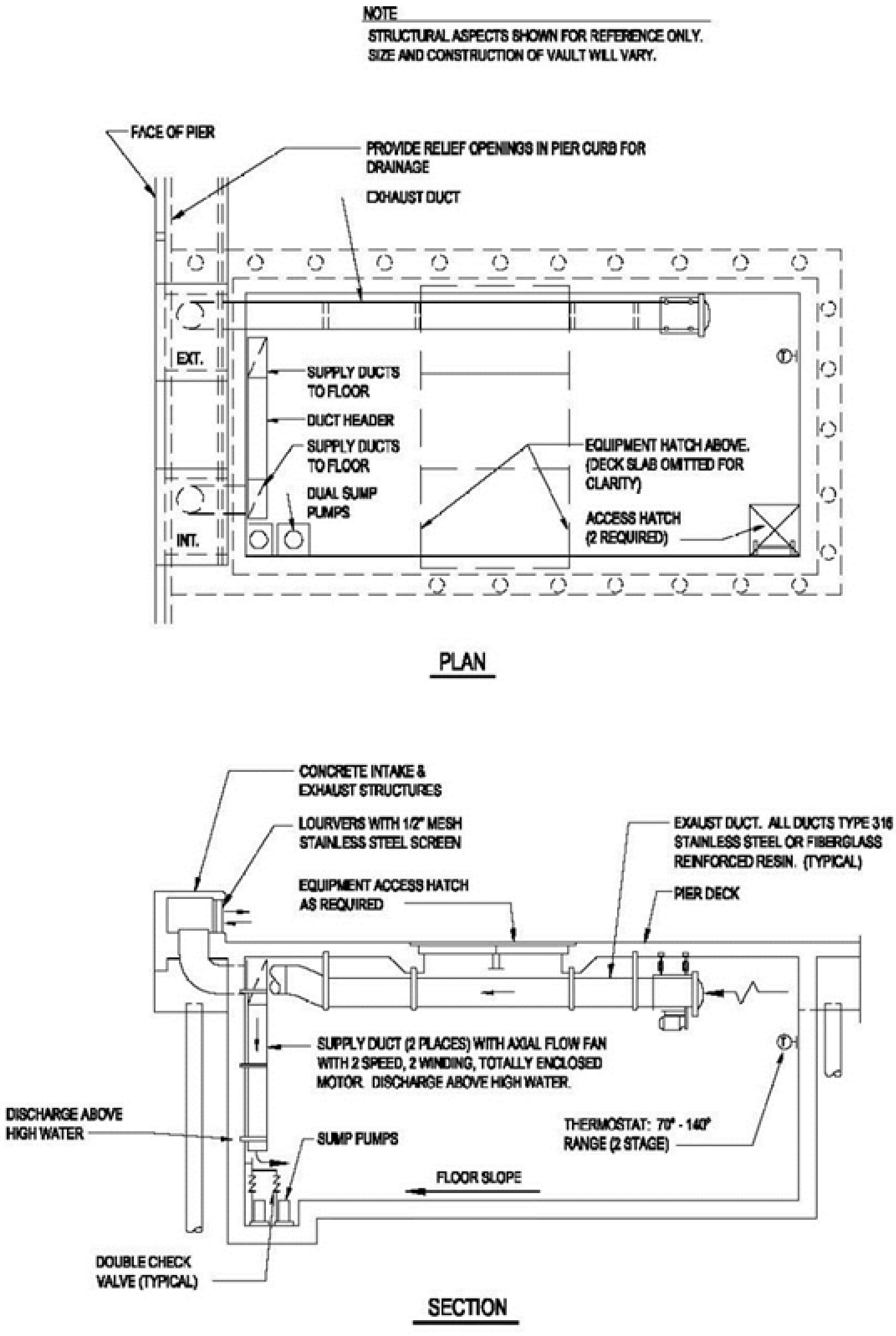
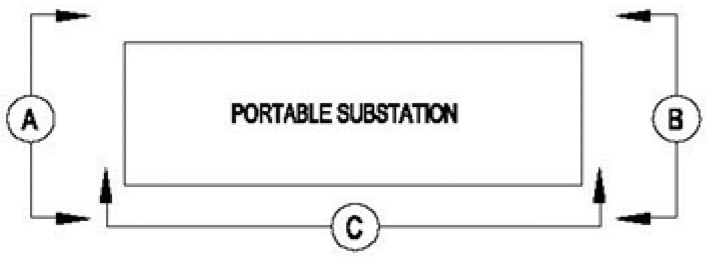


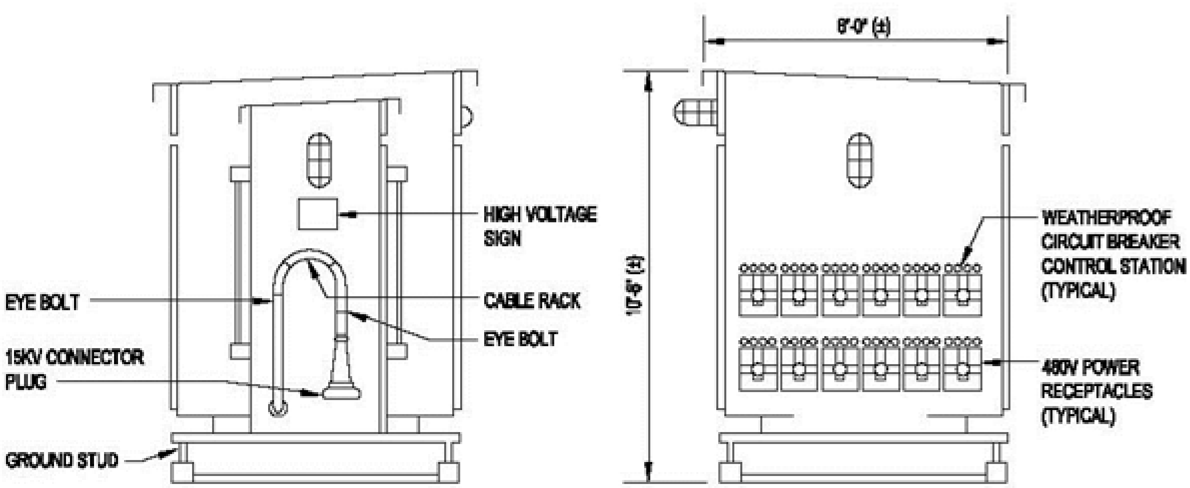
Figure D-3 (a) Portable Substation (1 of 3)

NOTES

1. DRAWING IS FOR REFERENCE, PLANNING AND ESTIMATING PURPOSES ONLY.
2. DRAWING IS DESIGNED FOR A 3 PHASE, 13.2KV GROUNDED NEUTRAL SYSTEM. THE CONNECTORS ARE NOT AVAILABLE FOR UNGROUNDED NEUTRAL SYSTEMS ABOVE 8.32KV.
3. THE NUMBER OF CIRCUIT BREAKERS AND RECEPTACLES AND THE LENGTH AND WEIGHT OF THE SUBSTATION WILL VARY DEPENDING ON THE TRANSFORMER KVA SIZE. THE TRANSFORMER SIZE WILL NORMALLY VARY FROM 1000KVA TO 2500KVA, THE NUMBER OF CIRCUIT BREAKERS AND RECEPTACLES FROM 6 TO 12, THE SUBSTATION LENGTH FROM 22' TO 28', AND THE SUBSTATION WEIGHT FROM APPROXIMATELY 22,500 POUNDS TO 33,500 POUNDS.

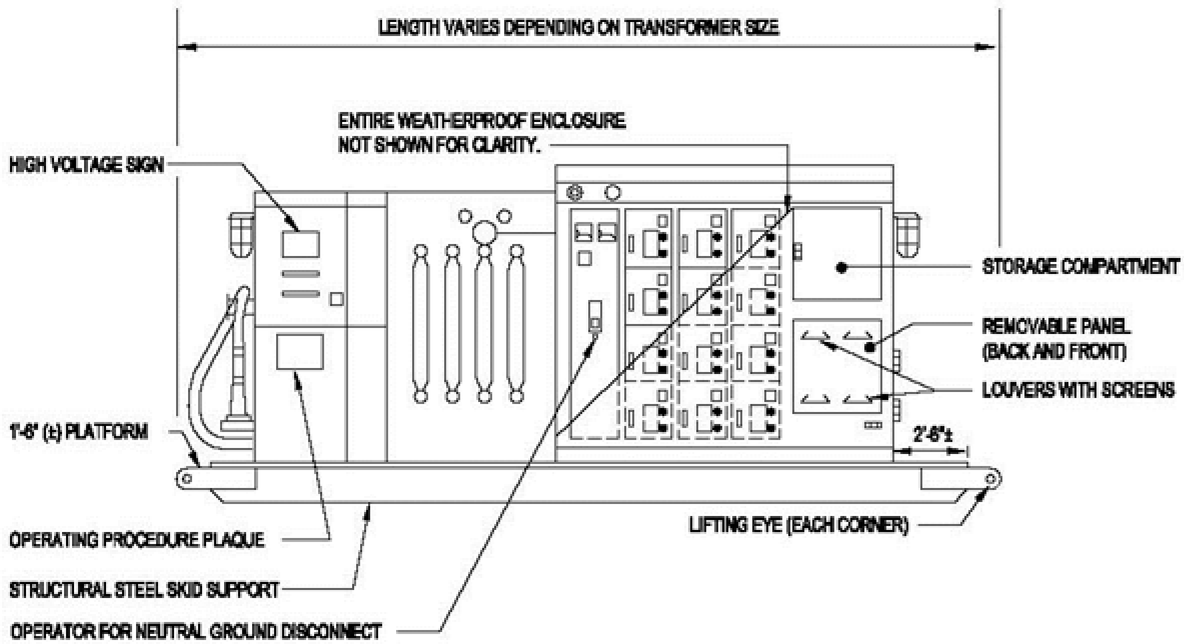


KEY PLAN

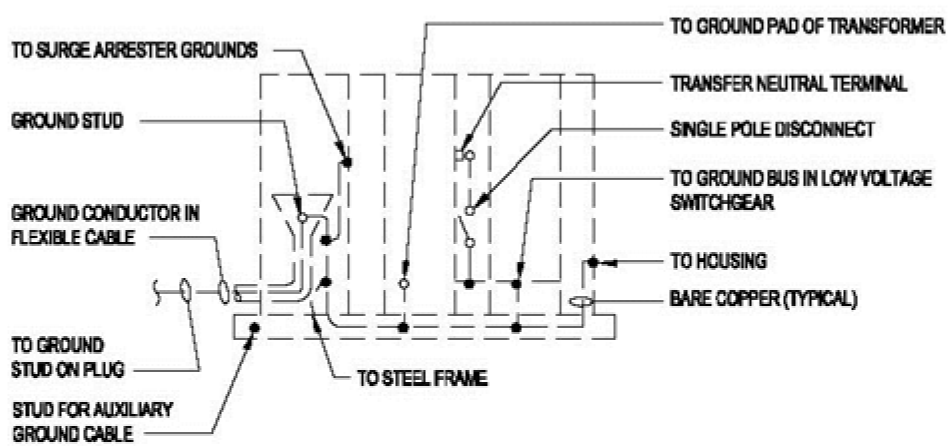


ELEVATION A-A (PRIMARY INPUT) ELEVATION B-B (SECONDARY OUTPUT)

Figure D-3 (b) Portable Substation (2 of 3)



ELEVATION C-C (FRONT VIEW)



GROUNDING SCHEMATIC

Figure D-3 (c) Portable Substation (3 of 3)

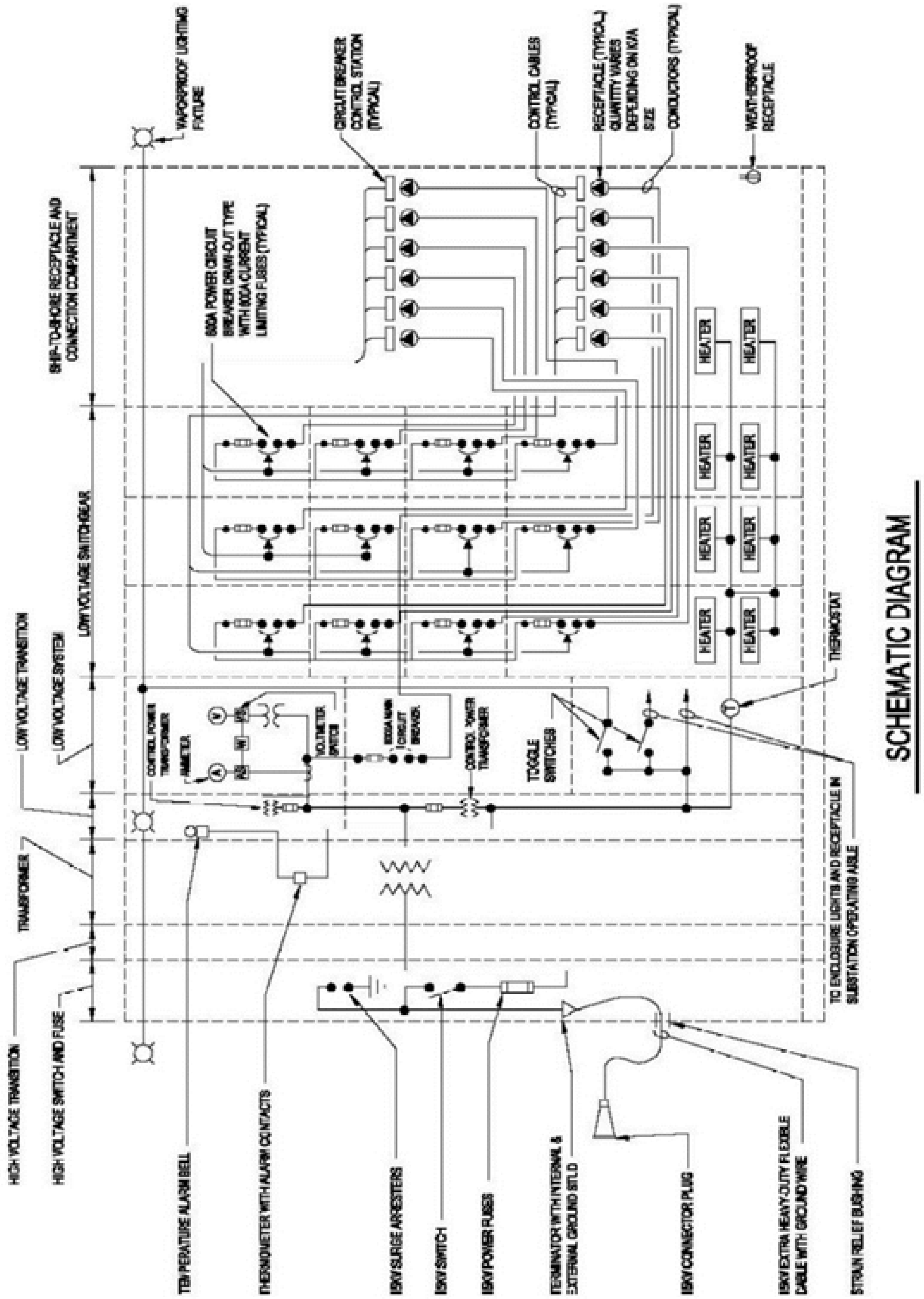


Figure D-4 (a) Ship Service Outlet Assembly (1 of 2)

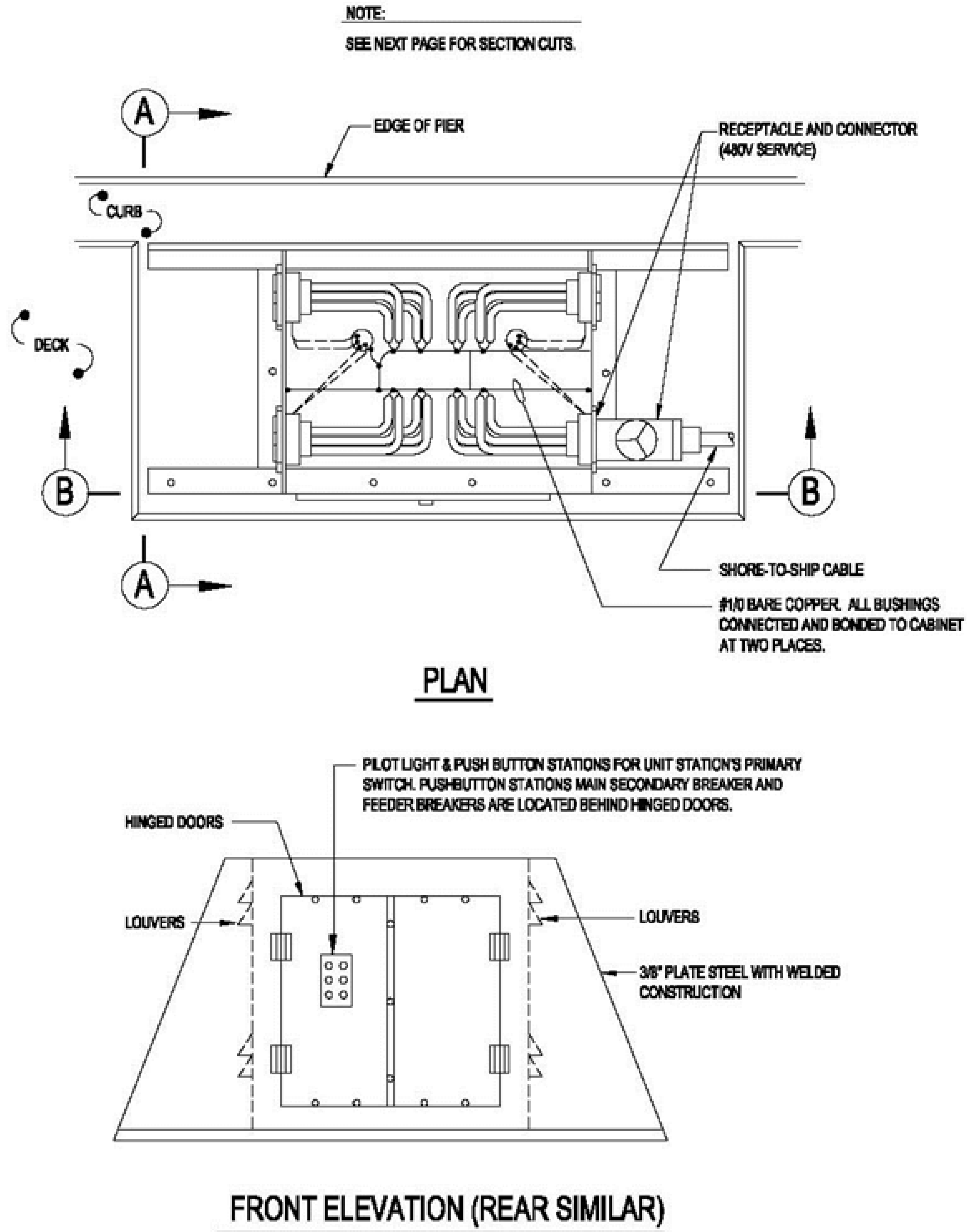
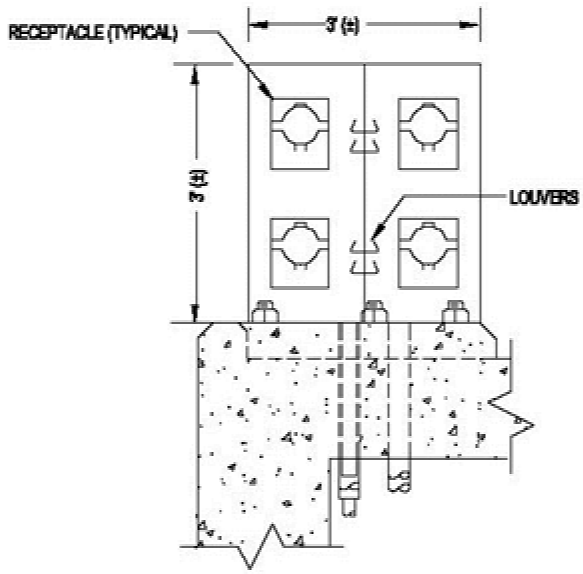


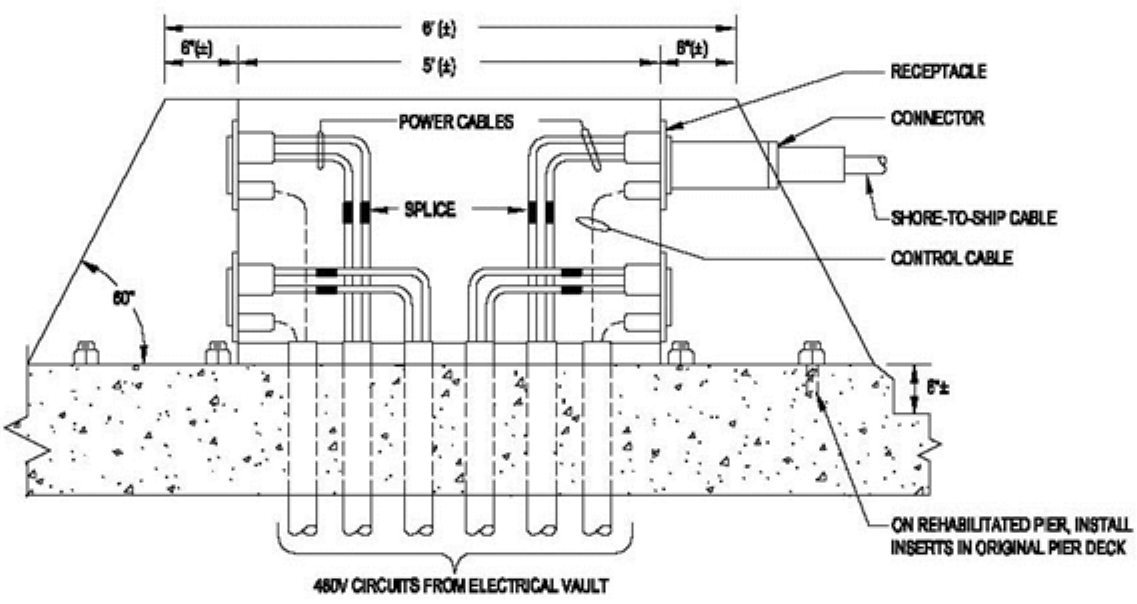
Figure D-4 (b) Ship Service Outlet Assembly (2 of 2)

NOTE

SEE PREVIOUS PAGE FOR DESCRIPTION WHERE SECTIONS ARE CUT.



SECTION A



SECTION B

Figure D-5 (a) Single Pole Connector Details

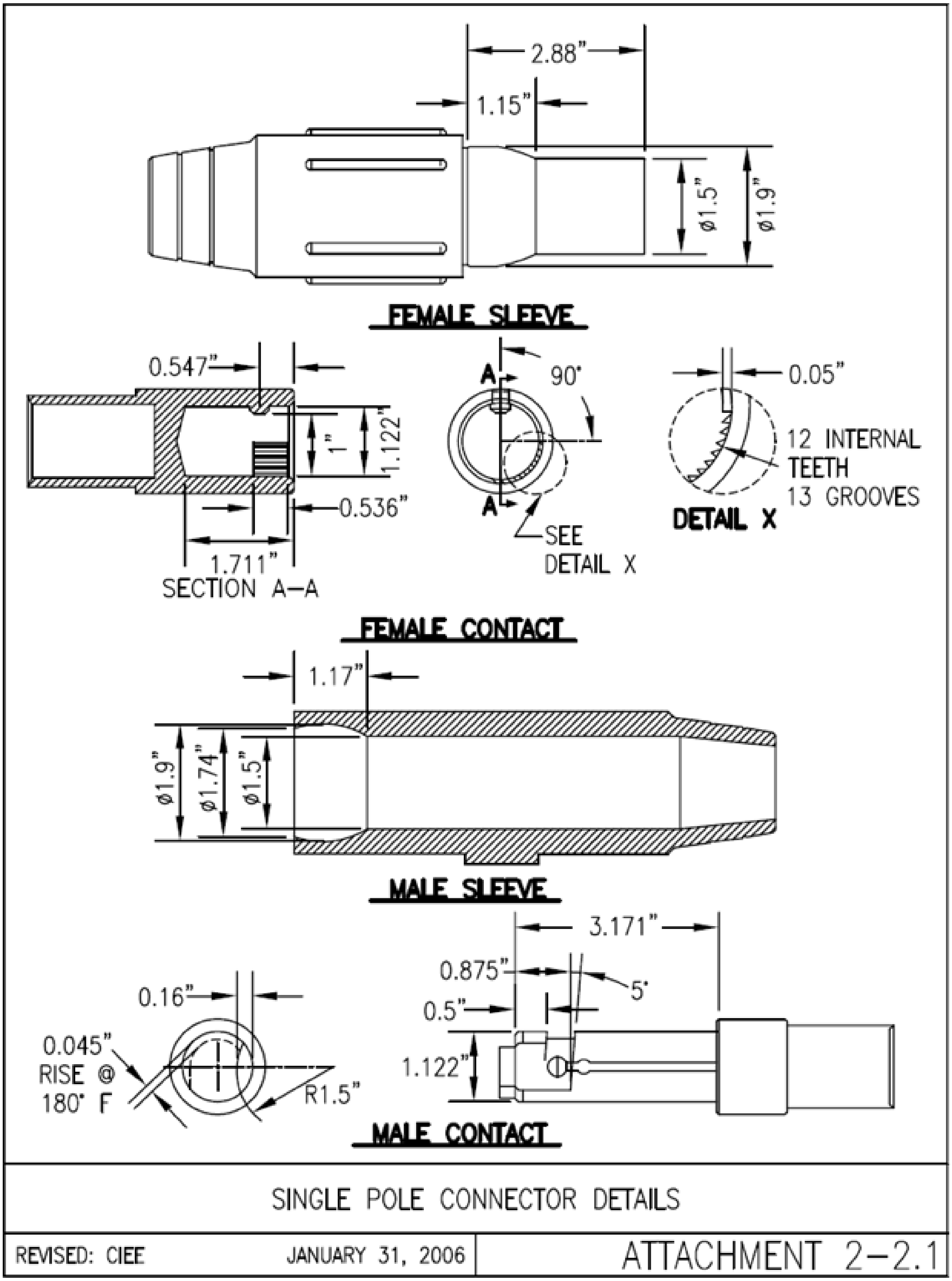


Figure D-5 (b) Single Pole Connector Specification

1. RATED FOR 600 VOLTS, 690 AMPERE MAX, 60 HERTZ, SINGLE POLE CAM, CONTINUOUS DUTY OPERATION.
2. INLINE CONNECTORS SHALL LOCK TOGETHER SO THAT THEY CAN NOT TWIST OR TURN LOOSE UNLESS A PUSH-BUTTON RELEASE MECHANISM IS ENGAGED.
3. POWER CABLE TERMINATION TO THE CONNECTOR CONTACTS SHALL BE VIA A CRIMP CONNECTOR.
4. THE INSULATED SLEEVES SHALL BE MECHANICALLY SECURED TO THE CONNECTOR CONTACTS TO GIVE A MINIMUM OF 700 LBS SHEAR FORCE.
5. BALL NOSE INSULATED SLEEVES SHALL BE MOLDED OF AN ETHYLENE PROPYLENE THERMOPLASTIC RUBBER (EPTR) COLORED BLACK PHASE A, WHITE PHASE B, AND RED PHASE C.
6. THE EPTR SLEEVES SHALL HAVE THE FOLLOWING MINIMUM REQUIREMENTS:
   - CONSTANT SERVICE TEMPERATURE RANGE: −60°C TO +135°C (−81°F TO +275°F)
   - FLAMMABILITY: UL 94 HB RATED
   - ELECTRICAL: UL RELATIVE THERMAL INDEX (RTI): 100°C (212°F)

SINGLE POLE CONNECTOR SPECIFICATION

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Figure D-6 (a) Pier Electrical Distribution for Temporary Services (1 of 3)

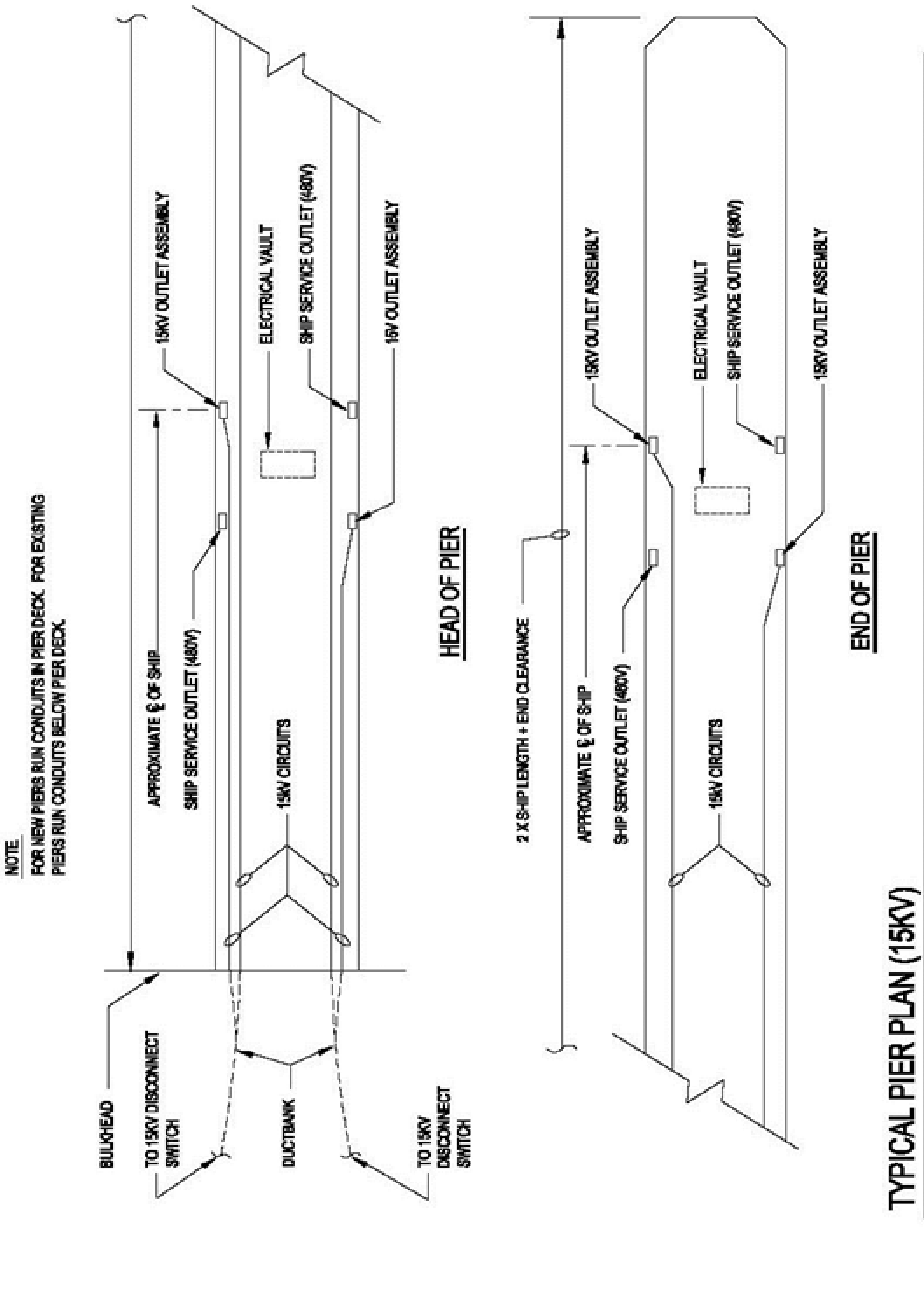


Figure D-6 (b) Pier Electrical Distribution for Temporary Services (2 of 3)

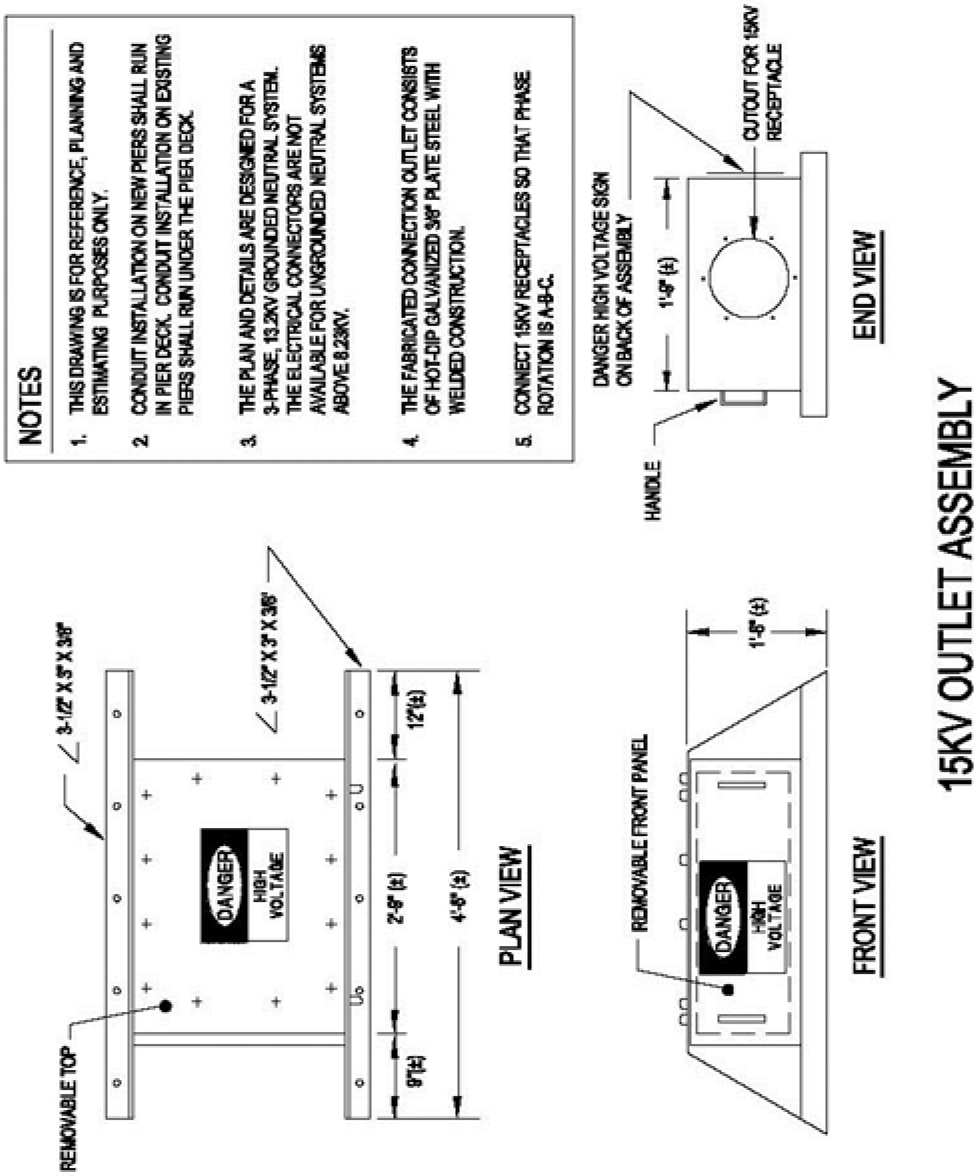
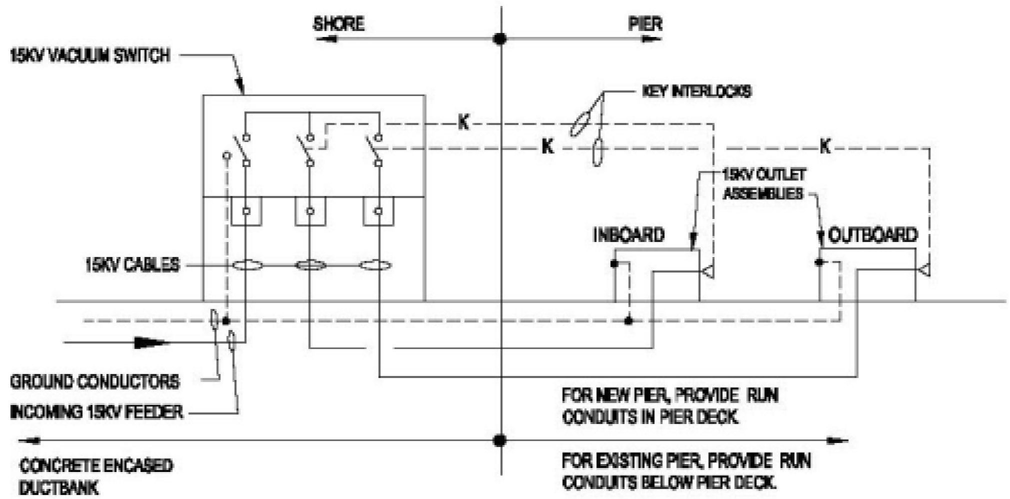
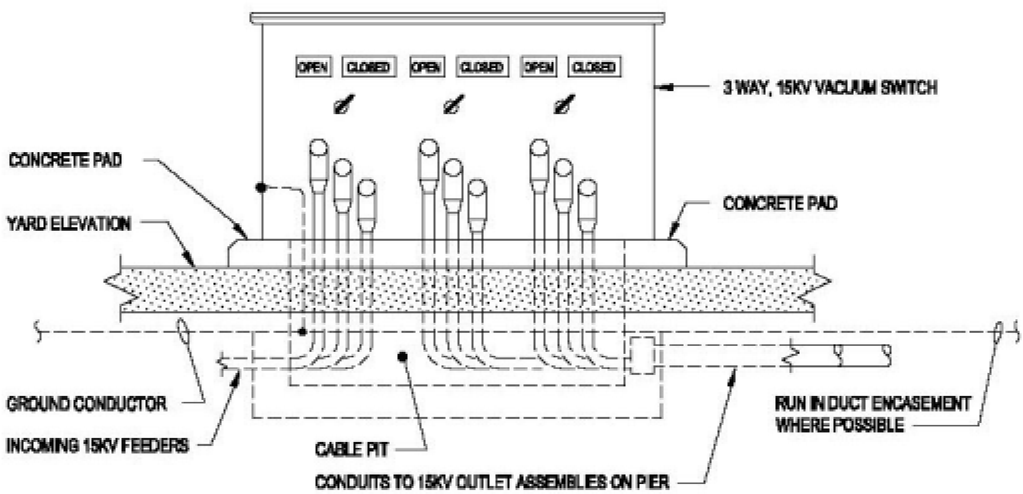


Figure D-6 (c) Pier Electrical Distribution for Temporary Services (3 of 3)



ONE-LINE DIAGRAM



SHORE INSTALLATION OF 15KV DISCONNECT SWITCH

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APPENDIX E GLOSSARY

E-1 ACRONYMS

AC	Alternating Current
A/E	Architect-Engineer
AFCEC	Air Force Civil Engineer Center
ANSI	American National Standards Institute
APTS	Activity Providing Telephone Service
ASME	American Society of Mechanical Engineers
ATFP	Anti-terrorism / Force Protection
ATS	Acceptance Testing Specification
AWS	American Welding Society
BAN	Base Area Network
BIA	Bilateral Infrastructure Agreement
BLII	Base Level Information Infrastructure
BOD	Biochemical Oxygen Demand
CBC	Naval Construction Battalion Center
CFR	Code of Federal Regulations
CHT	Collection-Holding-Transfer
CO	Commanding Officer
CPE	Chlorinated Polyethylene
CPS	Cathodic Protection System
CSF	Commander Submarine Forces
CSL	Commander Submarine Forces Atlantic
CSP	Commander Submarine Forces Pacific
DC	Direct Current

DLA	Defense Logistics Agency
DoD	Department of Defense
EDC	Environmental Distribution Center
EDM	Electronic Distance Measurement
EIC	Engineer-in-Charge
EPA	Environmental Protection Agency
EXWC	NAVFAC Engineering and Expeditionary Warfare Center
FAA	Federal Aviation Administration
FEC	NAVFAC Facilities Engineering Command
FPC	Facilities Planning Criteria
FPR	Fiberglass Polyester Resin
FRP	Fiber Reinforced Polymer
FSW	Feet Sea Water
FWD	Forward
GPS	Global Positioning System
HDPE	High Density Polyethylene
HMPE	High Modulus Polyethylene
HNFA	Host Nation Funded Construction Agreements
HPA	High Pressure Compressed Air
HQUSACE	Headquarters, U.S. Army Corps of Engineers
IAW	In Accordance With
ICAP	Infrastructure Condition Assessment Program
ICEA	Insulated Cable Engineers Association
IEEE	Institute of Electrical and Electronics Engineers
ISDN	Integrated Services Digital Network

IT	Information Technology
ITN	Information Technology Node
LCC	Life-cycle Cost
LPA	Low Pressure Compressed Air
MDF	Main Distribution Frame
MIL	Military
MPM	Mooring Program Manager
MS	Maintenance Standard
MTS	Maintenance Testing Specification
NACE	National Association of Corrosion Engineers
NAD	North American Datum
NAVSEA	Naval Sea Systems Command
NCC	Navy Crane Center
NFESC	Naval Facilities Engineering Service Center
NFPA	National Fire Protection Association
NIPRNET	Non-classified Internet Protocol Router Network
NMCI	Navy-Marine Corps Intranet
NNB	Norfolk Naval Base
NSN	Naval Station Norfolk
NSTM	Naval Ship's Technical Manual
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
OIC	Officer In Charge
OSHA	Occupational Safety and Health Administration
OWWO	Oily Waste / Waste Oil

PC	Personal Computer
PEA	Propellant Embedment Anchors
PEO	Program Executive Office
PEP	Preliminary Engineering Plan
POC	Point Of Contact
POL	Petroleum, Oil, and Lubricants
POTW	Publicly Owned Treatment Works
PPE	Personal Protective Equipment
PPMS	Pier Power Monitoring System
PVC	Polyvinyl Chloride
PWO	Public Works Office
QA/QC	Quality Assurance/Quality Control
QPL	Qualified Products List
ROV	Remotely Operated Vehicle
RTD	Resistance Temperature Detector
RTRC	Reinforced Thermosetting Resin Conduit
SIPRNET	Secret Internet Protocol Router Network
SPM	Single Point Mooring
SOFA	Status of Forces Agreements
SOPS	Standard Operating Procedure
SPS	Shore Power Station
SSPC	Steel Structures Painting Council
SWOB	Ship Waste Oily Barge
TBD/TBP	To Be Determined, or Provided
TOU	Time-of-Use

UCT	Underwater Construction Team
UFC	Unified Facilities Criteria
USCG	U.S. Coast Guard
UTM	Universal Transverse Mercator
UUV	Unmanned Underwater Vehicle
VPM	Vertical Payload Module
WEF	Water Environment Federation
WGS84	World Geodetic System 1984

E-2 ABBREVIATIONS AND SYMBOLS

A	ampere
ABL	above baseline
abv.	above
AVG	average
C	center
CL	centerline
DWL	design waterline
ea	each
fps	foot per second
ft	foot
FR	frame
fwd	forward
g	gravity
gpd	gallon per day
gpd/person	gallon per day per person
gpm	gallon per minute
hp	horsepower
H	height
Hz	hertz
in	inch
k	kips (1,000 lb)
kcmil	area in thousands of circular mils
kg	kilogram
kg/h	kilogram per hour

kg/m^3	kilogram per cubic meter
km/h	kilometer per hour
kN	kilonewton
kN/m	kilonewton per meter
kN/m^2	kilonewton per square meter
kPa	kilopascal
ksf	kips per square foot
kV	kilovolt
kVA	kilovolt ampere
kW	kilowatt
L	length, distance
L/d	liter per day
L/s	liter per second
L/m	liter per minute
lb	pound
lb/ft	pound per foot
lb/ft^2	pound per square foot
lb/ft^3	pound per cubic foot
lb/h	pound per hour
lb/in^2	pound per square Inch
m	meter
m^2	square meter
mg/L	milligram per liter
mg/L/h	milligram per liter per hour
mil	0.001 inch

mm	millimeter
mm^2	square millimeter
MPa	megapascal
MPa/m	megapascal per meter
mph	miles per hour
m/s	meter per second
MVA	megavolt ampere
MW	megawatts
N	number
P	port side (left side of vessel when facing forward)
pci	pound per cubic inch
pcf	pound per cubic foot
plf	pound per linear foot
ppm	part per million
psf	pound per square foot
psi	pound per square inch
psig	pound per square inch gauge
S	starboard side (right side of vessel when facing forward)
scfm	standard cubic feet per minute
V	volt
VAC	volt alternating current
W/ft	watts per foot
W/m	watts per meter
w/o	without
WL	waterline

E-3 DEFINITIONS OF TERMS

Active Berthing: A pier or wharf with berths used for homeport or light repair purposes, usually with a full or partial crew aboard, and always with ships in active status.

Activity: The organization (or organizations) that is responsible for the daily and routine operation and maintenance of the associated waterfront facility.

APTS: Activity providing telephone service. The organization responsible for the daily and routine operation and maintenance of the waterfront's telecommunication system (or systems).

Berth: A specific, marked-off length, along a pier or wharf, containing ships services appropriate for the ship classes which may be assigned to it.

Berthing Pier: A general term for a pier with berths and ships services.

Berthing Plan: A plan devised by each facility showing all berthing areas with ships assignments. May be permanent or temporary, depending upon the type of facility.

Bollard: A single-post fitting to which mooring lines from vessels are attached.

Capstan: A motorized, vertical-drum device used to tension lines for positioning ships, usually in dry dock.

Cleat: A mooring fitting having two diverging horizontal arms to which mooring lines from vessels are attached.

Cold Iron: Used to describe the condition of a ship when all shipboard boilers, engines, and generators are inoperative during repairs and can furnish none of the required ships services.

Cooling/Flushing Water: Water (usually nonpotable or salt) supplied to ships for condenser-cooling, fixture-flushing and other miscellaneous uses.

Dedicated Berth: A berth having required services for, and dedicated to use by, a specific ship for an extended period of time.

Graving Dry Dock: A permanent concrete drydocking structure requiring the use of caisson and dewatering pumps.

Hotel Services: Dockside utilities provided for a ship at berth (also called ships services, utility services, and cold iron services).

Inactive Berthing: Permanent or semi-permanent berthing areas for ships out of service, with crew normally not aboard.

Nested Ships: Two or more ships berthed side by side, with utility services supplied from berth side to the outer ships via ships header systems or hoses and cables strung across decks.

Oily Waste: Water (usually salt) from ships bilge which has been contaminated with petroleum products (fuel or lube oils) and which cannot discharge either to surface waters or to sanitary sewer.

Overhaul Facility: Generally used interchangeably with Repair Facility.

Pier: A dock, built from the shore out into the harbor, which is used for berthing and mooring vessels.

POL: Petroleum, oil and lubricants. An acronym used to describe petroleum products, and the facilities used in their storage and handling. As used herein, applies to marine fuels, jet fuels and lubricants.

Quay Wall: A heavy gravity or platform structure fronting on navigable water, behind which earth fill is placed to a level grade along its length.

Repair Facility: Locations where ship repair activities take place, such as at a shipyard or ship-repair facility. Facilities may utilize repair piers, dry docks, or both. (Also, Overhaul Facility.)

Telecommunications: Systems of communicating speech or impulses via wire or cable over distances, such as telephone, data transmission, coded transmission, cable TV and signal or alarm circuits.

Wharf: A dock, oriented approximately parallel to shore, with more than one access connection with the shore; a wharf is used for berthing or mooring vessels. May also be as above, except with continuous connection to shore.

APPENDIX F REFERENCES

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UNIFIED FACILITIES CRITERIA (UFC)

https://www.wbdg.org/ffc/dod

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

UFC 3-190-06, *Protective Coatings and Paints*

UFC 3-220-10N, *Soil Mechanics*

UFC 3-230-01, *Water Storage and Distribution*

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

UFC 3-430-09, *Exterior Mechanical Utility Distribution*

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

UFC 3-501-01, *Electrical Engineering*

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

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

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

UFC 3-570-01, *Cathodic Protection*

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

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

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

UFC 4-152-01, *Piers and Wharves*

UFC 4-213-10, *Graving Dry Docks*

UFC 4-832-01N, *Design: Industrial and Oily Wastewater Control*

UNIFIED FACILITIES GUIDE SPECIFICATIONS (UFGS)

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

UFGS 26 05 13.00 40, *Medium-Voltage Cables*

UFGS 26 05 33, *Dockside Power Connection Stations*

UFGS 26 11 16, *Secondary Unit Substations*

UFGS 26 12 19.10, *Three-Phase, Liquid-Filled Pad-Mounted Transformers*

UFGS 26 13 00, *SF6/High-Firepoint Fluids Insulated Pad-Mounted Switchgear*

UFGS 26 18 23.00 40, *Medium-Voltage Surge Arresters*

UFGS 26 23 00.00 40, *Switchboards and Switchgear*

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UFGS 26 32 13.00 20, *Single Operation Generator Sets*

UFGS 26 36 23.00 20, *Automatic Transfer Switches*

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UFGS 26 42 17.00 10, *Cathodic Protection System (Impressed Current)*

UFGS 33 30 00, *Sanitary Sewerage*

DOD SINGLE STOCK POINT FOR MILITARY SPECIFICATIONS, STANDARDS AND RELATED PUBLICATIONS

http://dodssp.daps.dla.mil/

CID A-A-59326, *Coupling Halves, Quick-Disconnect, Cam-Locking Type*

FED-STD-595, *Colors Used in Government Procurement*

MIL-C-24368/1, *Connector Assemblies, Plug, Power Transfer, Shore-to-Ship and Ship-to-Ship, 500 Volts, 500 Amperes, 60 Hertz, Symbol Number 1160*

MIL-C-24368/4, *Connector Assemblies, Plugs and Receptacles, Electric, Power Transfer, Shore to Ship and Ship to Ship, 500 Volts, 500 Amperes, 60 Hertz, Symbol Numbers 1162.1, 1162.2, 1162.3*

MIL-C-24368/5, *Connector Assemblies, Plug, Submarine Shore Power Transfer, Shore to Ship and Ship to Ship, 500 Volts, 400 Amperes, 60 Hertz, Three-Phase, Symbol Number 1149*

MIL-C-52404, *Connection Hose, Fire and Water*

MIL-DTL-915, *Cable, Electrical, for Shipboard Use*

MIL-DTL-24643, *Cables, Electric, Low Smoke Halogen-Free, for Shipboard Use*

MIL-S-12165, *Strainer Suction, Fire Hose, and Strainers Suction, Hose*

MIL-STD-101, *Color Code for Pipelines and for Compressed Gas Cylinders*

MIL-STD-767, *Control of Hardware Cleanliness (NOFORN)*

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MIL-STD-2041, *Control of Detrimental Materials (NOFORN)*

NAVFAC ATLANTIC

P-442, *Economic Analysis Handbook*

MO-201, *Electric Power Distribution Systems*

MO-340, *Ship-to-Shore Hose Handling Operations Manual*

NAVAL FACILITIES ENGINEERING SERVICE CENTER (NFESC)

TN-1586, *Steam Separator Test and Evaluation*

Bilge and Oily Wastewater Treatment System

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA)

https://www.osha.gov

29 CFR 1910, Occupational Safety and Health Administration, Department of Labor: *Occupational Safety and Health Standards*

ENVIRONMENTAL PROTECTION AGENCY (EPA)

https://www.epa.gov/laws-regulations/regulations

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NAVAL SEA SYSTEMS COMMAND (NAVSEASYSCOM)

www.navsea.navy.mil

S0570-AC-CCM-010/8010, *Industrial Ship Safety Manual for Fire Prevention and Response*

S9086-AB-ROM-010, *Naval Ship's Technical Manual (NSTM)*

S9593-BF-DDT-010, *Oil Pollution Abatement System*

362-2333, *Air Circuit Breakers (Fused), Navy Type AQB-FL400*

NAVAL SHIP WEAPONS SYSTEMS ENGINEERING STATION

59300-AW-EDG-010/EPISM, *Electrical Plant Installation Standards Methods (EPISM)*

SUBMARINE MAINTENANCE ENGINEERING, PLANNING AND PROCUREMENT ACTIVITY (SUBMEPP)

Maintenance Standard (MS) Number 3240-081-089, *Inspect and Repair Shore Power Cables*

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AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

http://www.ansi.org/

ANSI/NEMA C57.12.29, *Pad-Mounted Equipment—Enclosure Integrity for Coastal Environments*

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

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

https://ww.ashrae.org

ASHRAE, Handbook, *Fundamentals*

AMERICAN SOCIETY FOR TESTING AND MATERIALS INTERNATIONAL (ASTM)

https://www.astm.org

ASTM A276, *Standard Specification for Stainless Steel Bars and Shapes*

ASTM B148, *Standard Specification for Aluminum-Bronze Sand Castings*

ASTM B164, *Standard Specification for Nickel-Copper Alloy Rod, Bar and Wire*

ASTM B165, *Standard Specification for Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube*

ASTM D2240, *Standard Test Method for Rubber Property—Durometer Hardness*

ASTM E527, *Numbering Metals and Alloys in the Unified Numbering System (UNS)*

COMPRESSED GAS ASSOCIATION (CGA)

http://www.cganet.com

CGA G-7.1, *Commodity Specification for Air*

INSULATED CABLE ENGINEERS ASSOCIATION (ICEA)

http://www.icea.net

ICEA S-66-524, *Cross-Linked-Thermosetting Polyethylene Insulated Wire and Cables (Also known as NEMA WC7)*

ICEA S-75-381, *Portable Power Feeder Cables (Also known as NEMA WC 58)*

ICEA T-27-581, *Standard Test Methods for Extruded Dielectric Cables (Also known as NEMA WC 53)*

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

http://www.ieee.org

IEEE-48, *Standard Test Procedures and Requirements for Alternating Current Cable Terminations 2.5 kV through 765 kV*

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

http://www.netaworld.org

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

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

http://www.iso.org

ISO 4649, *Rubber, Vulcanized or Thermoplastic – Determination of Abrasion Resistance Using Rotating Cylindrical Drum Device*

NATIONAL ASSOCIATION OF CORROSION ENGINEERS (NACE) INTERNATIONAL

https://www.nace.org/

NACE RP0169, *Control of External Corrosion of Underground or Submerged Metallic Piping Systems*

NACE RP0285, *Standard Recommended Practice – Corrosion Control of Underground Storage Tank Systems by Cathodic Protection*

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http://www.nema.org/

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NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

http://www.nfpa.org

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*

NFPA 70, *National Electrical Code*

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

SOCIETY FOR PROTECTIVE COATINGS (SSPC)

http://www.sspc.org

Painting Manual, Volume 2, Systems and Specifications (Includes color identification index system)

UNDERWRITERS LABORATORIES, INC (UL)

http://www.ul.com

UL 44, *UL Standard for Thermoset-Insulated Wires and Cables*

UL 486A-486B, *UL Standard for Wire Connectors*

UL 94, *UL Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances Testing*

WATER ENVIRONMENT FEDERATION (WEF)

http://www.wef.org

MOP FD-5, *Gravity Sanitary Sewer Design and Construction*

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MILITARY HARBORS AND COASTAL FACILITIES

UNIFIED FACILITIES CRITERIA (UFC)

MILITARY HARBORS AND COASTAL FACILITIES

U.S. ARMY CORPS OF ENGINEERS
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AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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This UFC supersedes DESIGN MANUAL 26.1, 26.2 and 26.3.

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

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

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

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

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CHAPTER 1 INTRODUCTION

1-1 SCOPE.

The objective of this document is to cite and supplement existing government and commercial standards for design and construction of harbor and coastal facilities. It serves as planning, engineering and design guidance for professional facility planners, designers, constructors, and maintainers, including Navy personnel and Government contractors. Designers and planners will use this handbook for individual project planning, for preparing engineering documentation, and for preparing contract documents for construction and repair. This document extensively references the U.S. Army Corps of Engineers (USACE) *Coastal Engineering Manual* (CEM). The CEM is in the final stages of development and can be accessed at http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;101.
For sections not currently available contact the NAVFAC LANT Engineering Criteria and Programs Office.

1-2 PURPOSE.

The purpose of UFC 4-150-06 is to provide adequate harbor and dredging project criteria, design and maintenance guidance, and relevant lessons learned with respect to shore infrastructure. This document also provides the complete criteria and guidance package needed by appropriate end users. To the extent practical, it addresses the range of harbor and dredging criteria needed at stateside and overseas military installations. **Note**: This document does not include overseas data.

1-3 ORGANIZATION.

The majority of the information for subjects of this handbook is introduced as references to the applicable government and consensus standards in which the original information resides. Where other documents are not available or are inadequate, additional narrative information regarding Navy-specific issues has been developed and inserted, as appropriate.

1-4 CANCELLATION.

UFC 4-150-06 cancels and supersedes NAVFAC Design Manual 26.1, *Harbors*, dated 1 December 1984, NAVFAC Design Manual 26.2, *Coastal Protection* and NAVFAC Design Manual 26.3, *Coastal Sedimentation and Dredging*, dated 1 September 1986.

CHAPTER 2 HYDRODYNAMICS

2-1 INTRODUCTION.

This chapter covers design considerations related to the physical effects on structures caused by various types of water movement, such as tides, currents, and wave action along the open shore line and those occurring within restricted bodies of water. This subject is thoroughly covered by the *Coastal Engineering Manual* (CEM) but is outlined below by subjects of interest to Navy coastal facilities designers and then cross-referenced to the appropriate section of the CEM and other applicable references. Note that references made to sections in the draft CEM may change once the final version is published. The most current version of the CEM at the time of this publication can be found on the web at http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;101

Port, harbor and facility issues, such as trends in port and harbor development, deep versus shallow draft projects and motivation, are discussed in CEM, Section V-5. These issues are discussed as explanations and justifications for harbor needs. For example, the motivation for developing new or existing port and harbor facilities is the importance of overseas trade to the U.S. economy and government.

Development of local design criteria is essential in many cases due to the variation in meteorological and geological conditions at different geographical sites. These criteria are based upon raw and hindcast environmental information and the forecasting of data with analytical descriptor models.

2-2 WATER WAVE MECHANICS.

The very complex phenomenon of wave action on the sea surface, and how it affects structures, is a primary concern in design of coastal facilities. An extensive study to characterize regular and irregular waves is contained in Section II-1 of the CEM.

2-2.1 Selection of Design Waves.

The selection of design waves should be related to the economics of construction, maintenance, and repairs. The selection of design conditions for larger structures requires more detailed consideration of the economics of the design. Wave analysis yields the recurrence interval of a given wave height. The economics of increasing the initial cost versus making occasional repairs must be evaluated. Furthermore, the cost and extent of damages to areas that the structure is designed to protect must also be considered. Physical and economic factors, such as design wave height versus annual costs, must be optimized. For small projects, a 20- to 25-year design wave, coupled with an annual extreme water level, is appropriate. In addition to the general design parameters for determining cost-benefit relationships, specific local design criteria must be determined and applied. For example, Norfolk, VA would not use a 50-year hurricane, although it may be an appropriate criterion for other locations. Refer to the CEM, Section II-8: Coastal Hydrodynamics, for further details.

2-3 METEOROLOGY AND WAVE CLIMATE.

A basic understanding of marine and coastal meteorology and the relationship between meteorological processes and wave generation is important to coastal design and planning. Section II-2 of the CEM contains an analysis of this subject.

2-4 ESTIMATION OF NEARSHORE WAVES.

The size and directions of nearshore waves that impact coastal design are strongly influenced by underlying seafloor geometry and currents. While overestimating wave height can inflate the price of a project, underestimating can result in catastrophic loss. Section II-3 of the CEM evaluates wave transformation analyses methods and provides guidance for selecting a reasonable approach for making wave transformation calculations.

2-5 SURF ZONE HYDRODYNAMICS.

Breaking waves, and the resulting dissipation of energy, induce nearshore currents and other hydrodynamic processes that make the surf zone the most dynamic coastal region. Section II-4 of the CEM describes shallow-water wave breaking and associated hydrodynamic processes that affect shoreline and beach profile, which impact the design of coastal structures and beach fills.

2-5.1 Coastal Bottom Boundary Layers.

The severe interaction between the slowly varying current boundary layer and the turbulent wave bottom boundary layer during severe storm events plays a significant role in sediment transport. This interaction, which occurs primarily in the area just outside the surf zone, in water depth ranging between 6.6 to 9.8 ft (2 or 3 m) up to 65.6 to 98.4 ft (20 to 30 m), affects sediment that is not usually suspended under normal wave conditions. The fate of the sediments in this zone is a complex question for coastal engineers. The factors and complexities that make analysis of this activity so difficult are discussed in Section III-6 of the CEM. An extensive analysis of this process is contained in *Coastal Bottom Boundary Layers and Sediment Transport* by Peter Nielsen.

2-6 WATER LEVELS AND LONG WAVES.

A significant component of coastal design is protection of structures from some predefined water surface elevation. The following sections, the scope of which is summarized in Section II-5, of the CEM, classify the various types of surface elevation variation generated by long waves and guidance for developing a preliminary study approach and applicable design procedure. A discussion of the geological effects of wave action is contained in Section IV-2 of the CEM.

2-6.1 Water Wave Classification.

Section II-5-2 of the CEM gives a brief review of wave classification criteria and a summary of long wave properties.

2-6.2 Astronomical Tides.

Astronomical tides represent an important example of long waves. Section II-5-3 of the CEM describes tidal processes and effects.

2-6.3 Water Surface Elevation Datums.
Section II-5-4 of the CEM describes the various means of defining water surface elevation datums and the relationship between tidal observation-based datums, which account for spatial variability of sea level and vary according to locale, and the National Geodetic Vertical Datum (NGVD), which does not. It also discusses several processes that result in long-term changes in relative mean sea level. An additional discussion of datums and relationship to coastal geology is contained in Section IV-2-4 of the CEM. The selected datum and a rationale for its choice should be stated specifically in the design documentation.

2-6.4 Storm Surge.
High-wind systems and low barometric pressures over shoaling water will create a temporary water-level rise along shorelines. Especially susceptible are areas where large cyclonic storm systems (such as hurricanes and typhoons) track across relatively shallow offshore water. A relatively short-duration water-level rise (setup) will occur along coastlines during episodes of high-wave attacks. The rise in water level is caused by breaking waves trapping a water mass along the shoreline. This water rise can increase water heights in protected water areas hydraulically linked to the coast, shoreward of the breaker line. This phenomenon, and generated currents associated with it, can be significant in harbor sites located behind reefs or large shoals. Section II-5-5 of the CEM discusses the effect of tropical and extra-tropical storm activity on water surface elevation.

2-6.5 Seiche.
Defined as a standing-wave oscillation of an enclosed body of water that continues, pendulum fashion, after the cessation of the originating force, seiche may be either seismic or atmospheric in origin. Seiche is a phenomenon associated with ocean waves having periods in excess of those of normal sea swell. Such waves, commonly known as "long waves," have periods ranging from 20 seconds to several hours. Long waves exhibit relatively low heights, on the order of 0.1 to 0.4 foot (0.03 to 0.12 meters). They are highly reflective, even off flat-slope beaches, and will pass virtually unimpeded through porous breakwaters. Seiche occurs within a basin, harbor, or bay during certain critical wave periods when the period of incident long-wave energy matches the resonating period of the basin. The result is a standing wave system comprising reinforced wave heights greater than those of the incident wave. The water surface exhibits a series of nodes and antinodes with respect to the water column. Antinodes are regions where the vertical motion is a maximum and the horizontal velocities are minimum. Where wavelength is sufficiently greater than ship length, a ship berthed at the antinode will experience a gentle rise and fall with the standing-wave period. At the node, the ship will be subject to a periodic horizontal surging action due to currents. A ship in combination with its mooring lines behaves as a spring-mass system which, when excited, can resonate at certain critical frequency ranges. During seiching action,

the horizontal surging motion of a vessel located near a node can interfere with loading operations and, in severe cases, can cause the mooring lines to part. Section II-5-6 of the CEM discusses further details of this phenomenon.

2-6.6 Tsunamis.
In certain ocean regions, waves generated by seismic disturbances or landslides occur. From event history, some shoreline locations are more susceptible to damage from tsunamis than others. Probability approximations of water-level height exist for some coastal locations. These are included in reports by the U.S. Army Corps of Engineers (USACE) and licensing studies by Public Utility Commissions. If warranted, a site-specific risk analysis can be performed, which relies heavily upon probability parameters for specifics of the underwater seismic movement. Contact the NAVFAC LANT Engineering Criteria and Programs Office regarding when to perform such site-specific risk analyses. This is coupled with a three-dimensional numerical analysis of ocean-basin propagation and near-shore site shoaling of the resulting long wave.

2-6.7 River Discharge and Flood Control Channel Discharge.
Where a harbor site is hydraulically influenced by river discharge, present as well as future river flood discharge effects on water levels need to be considered. Effects of river discharge on harbor hydrodynamics are discussed briefly in Section II-7-6 of the CEM. Deltaic processes, river mouth flow, and sediment disposition, and inlet processes and dynamics are discussed in Section IV-3.

2-6.8 Extreme Water Levels.
The estimation of extreme water levels is discussed in Section II-8-6-e of the CEM.

2-6.9 Numerical Modeling of Long Wave Hydrodynamics.
Due to the complexity of most natural flow systems, engineering analyses for coastal engineering design projects often require numerical modeling of the hydrodynamic processes. Methods for applying this analytical tool are described in Section II-5-7 of the CEM. NAVFAC LANT Engineering Criteria and Programs Office should be contacted when contemplating using numerical modeling.

2-7 HARBORS.
Because harbors are, by nature and design, protected from short wave effects, long wave processes primarily drive their hydrodynamic environment. Specific information on these processes is examined in the sections on tides, seiche, storm surge and other long wave phenomenon. Section II-7 of the CEM covers the hydrodynamics of harbors, including effects of wave action, flushing/circulation, and vessel interaction. The discussion of inlet hydrodynamics contained in Section II-6 of the CEM also adds insight into the processes that take place at the entrance of a harbor and impact its overall hydrodynamic environment. The impact of these processes on moored ships and criteria for acceptable ship motions in safe working conditions is contained in the Permanent International Association of Navigation Congresses (PIANC) report titled *Criteria for Movements of Moored Ships in Harbours - A Practical Guide*.

2-7.1 General Function.
A harbor is described as a water area that is bounded by natural features or manmade structures or a combination of both. As such, it provides refuge and safe moorings and protection for vessels during storms or accommodations for such water to water or water to land activities as resupply, refueling, repairs, or transferring cargo and personnel. In such cases when a harbor is used to transfer commercial cargo or passengers, it is designated as a “port”. More specifically, when military services use a harbor or portions thereof, the facility is referred to as a “military harbor”. The landside areas adjacent to military harbors are also included under this designation because they support various waterborne naval activities. Additional terms such as naval base, naval station, naval depot, and naval shipyard are also used depending upon the appropriate support activity.

2-7.2 Purpose of Harbor Construction.
The intended goals in designing and constructing a harbor are twofold: to obtain a relatively large area of water, with adequate depth during all tidal stages that will provide shelter for ships and to provide a means by which to transfer cargo and passengers between ships and shore locations and facilities.

2-7.3 Harbor Features.
Though it may not be feasible to provide all of the desirable characteristics of an ideal harbor at any one location, the ideal waterside harbor would include the following features:

- shelter from open-sea waves,
- minimum tidal range and moderate currents,
- freedom from troublesome long-wave agitation (seiche),
- freedom from fog and ice,
- access through one or more safe navigational channels under all weather conditions,
- adequate room and depth to maneuver ships within the sheltered area,
- space for an adequate number of fixed moorings,
- shelter from strong winds from all directions,
- minimum maintenance dredging, and
- room for future expansion.

The following landside features provide accommodation for naval ship activities:

- layout of quays, piers, and wharves to accommodate ships of varying lengths and drafts,
- waterfront structures of dimensions and strength to accommodate weight-handling equipment and cargo-hauling vehicles, including both road and rail,
- utility services at berth
- covered and uncovered transit storage in the immediate area of the berth, with additional long-term and depot storage at a more remote location where required,
- space for adequate road and rail transportation linkage between the waterside area and inland distribution,
- provisions for the transfer and accommodation of passengers,
- provisions for small craft, shore boats, lighters, and tugs,
- safety from fire hazards,
- minimum general maintenance,
- proximity to labor and material sources,
- proximity to air-transport facilities,
- adaptability of shore installations for alternate uses, and
- room for expansion.

2-7.4 Types of Harbors.

The locations for constructing harbors range from open coastlines requiring artificial impoundments to natural bays, estuaries, and navigable rivers that need a minimum of manmade structures for the necessary storm protection. Within limits, harbors may be built wherever suitable water depth exists or can be provided and maintained with dredging operations. The degree of artificial works necessary to construct a viable harbor varies with the site's natural features. Examples of various siting classifications are shown in Figure 2-1. The characteristics of harbor location types are given in Table 2-1.

Figure 2-1 Examples of Harbor Siting Classifications

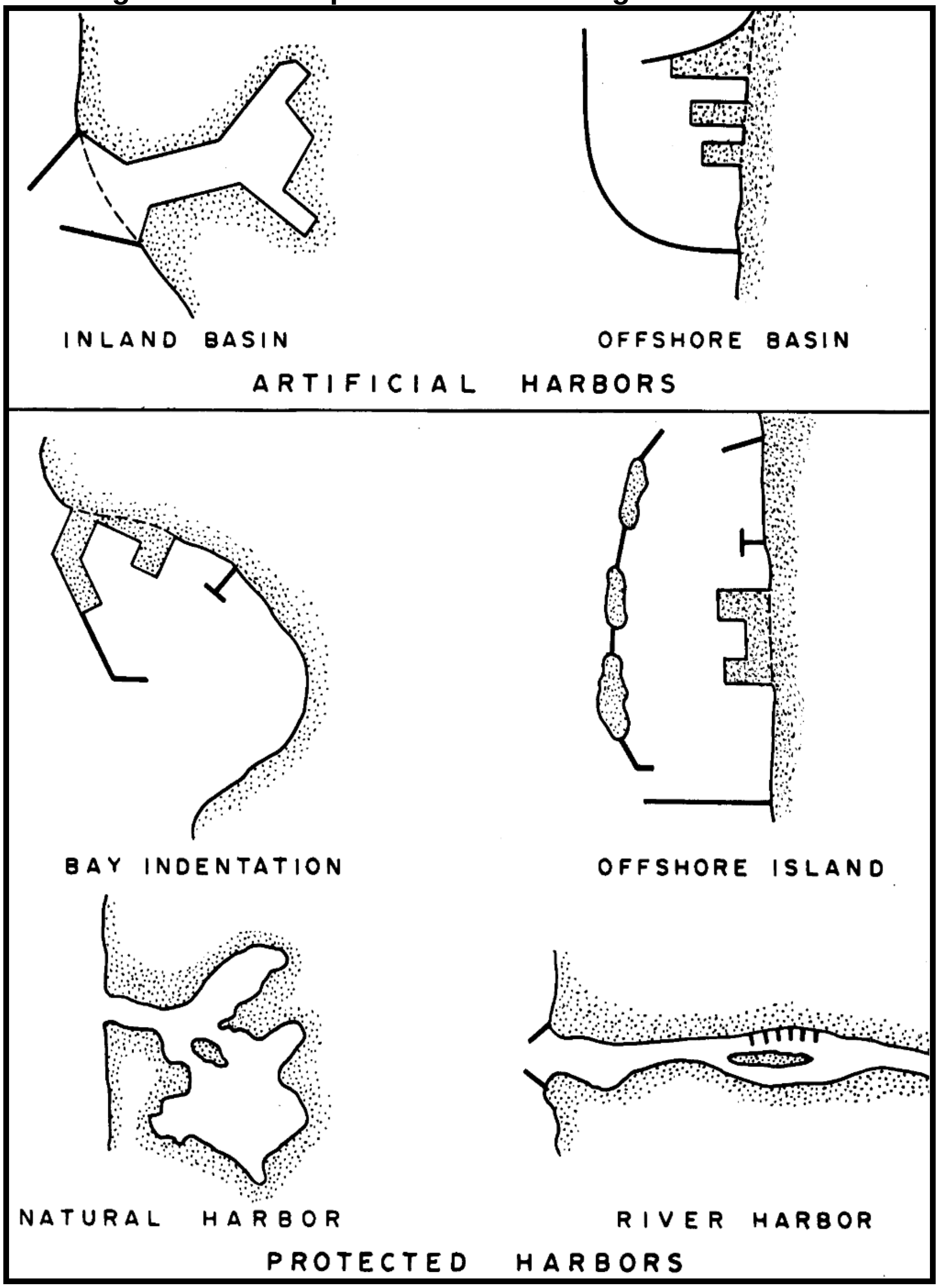


Table 2-1 Characteristics of Harbor Location Types

Type		Characteristics
Artificial – inland basin	Needs:	Low elevation; economical excavation.
	Advantages:	Less breakwater costs; feasibility of expansion.
	Concerns:	Low ground may contain poor soils; potential of flooding and sedimentation from upland sources; distance to offshore navigational water depth; littoral drift; silting.
Artificial – offshore basin	Needs:	Adequate sources for extensive breakwater construction material.
	Advantages:	Normally good foundation conditions can be developed with minimal dredging.
	Concerns:	Construction costs relatively high for harbor size; minimum expansion capability; littoral drift; shoaling.
Protected	Needs:	Shoreline relief features help to reduce storm-wave exposure.
	Advantages:	Less breakwater development cost.
	Concerns:	Can be same as other locations.
Natural	Needs:	Natural ocean access passage of adequate dimensions leading to embayment protected from storm waves.
	Advantages:	Minimal effort required for developing protected water area.
	Concerns:	If not historically used as ship refuge area, ascertain reason (example: Lituga Bay, Alaska, which is subject to landslides and massive waves); natural sediment regime should be thoroughly investigated if extensive deepening of natural depths is proposed.
River	Needs:	Historically stable river of adequate natural depths and widths to accommodate proposed vessel sizes.
	Advantages:	Minimal effort required for developing protected water area.
	Concerns:	Currents and water-level fluctuations due to variation in river stages; effects of new works on river’s natural alluvial regime require thorough analysis, including effects of salinity changes; extensive basin dredging and channel deepening should be avoided where possible.

2-7.5 Open Coastlines.

When harbors are situated on open coastlines, a high degree of artificial work is required to provide shelter. Consequently, as the coastline itself becomes more winding and offshore islands appear, the degree of natural shelter provided in turn reduces the harbor's exposure to wind and waves. Thus a corresponding decrease in the amount of artificial protection is required.

2-7.6 Bays, Estuaries, and Navigable Rivers.

When the harbor is situated entirely within an enclosed bay or estuary having a narrow opening into the sea, an environment of total natural protection results. Depending on the orientation of the naturally occurring protective features, these harbor sites need little or no additional protection. Nonetheless, a degree of entrance improvement is usually required to ensure safety during storms and as the entrance widens, the degree of protection required increases as well.

2-7.7 Hydraulic Impoundments.

Hydraulic impoundments are defined as harbor basins in which the vessel mooring depth is constantly maintained behind locks, versus the case in harbors where free-flowing water linkages to the sea or other large bodies of water exposed to storms exist. Since harbors are not located in bays, estuaries, and rivers, the hydraulic-impoundment harbors are not influenced by tidal fluctuations. Either admitting or releasing water through the locks maintains water levels. Though constructed worldwide economically efficient for commercial port facilities, the constricted access of hydraulic impoundments makes then generally undesirable for military purposes.

2-7.8 Roadsteads.

In cases when protection is provided only as a moored-ship refuge, the protected harbor area is referred to as a "roadstead." Roadsteads need a bottom in the protected area in the protected area that is suitable for sufficient anchor holding power. Examples of roadstead anchorages in a natural bay and a protected harbor are shown in Figure 2-2.

2-8 HYDRODYNAMIC INVESTIGATIONS.

Effective coastal engineering studies require appropriate understanding of the hydrodynamics of the project area and its impact on design parameters. A summary of the considerations and procedures for hydrodynamic investigations is contained in Section II-8 of the CEM.

2-9 SHIP DYNAMICS IN CHANNELS.

Ships moving in shallow or restricted waterways experience dynamic behavior different from that exhibited in open water that can significantly affect control of the ship. The width and depth of the channel, if insufficient, can interfere with the normal passage of water around the hull of the ship and inhibit steering control. The sinkage and trim of a vessel in a navigation channel depend primarily on vessel speed, the ratio of the channel cross section area to the vessel wetted cross section area, and the ratio of the water depth to the vessel draft. The maximum vessel draft is determined through consideration of the effects on vessel draft by such factors as squat, variation in salinity, effects of wave motion, and loading. In addition, some judgment needs to be exercised in considering the conditions that could realistically be expected to occur. For example, it wouldn't be practical to design a ship channel for extremes of vessel draft during a hurricane, because the ships probably will not attempt to transit the channel during the storm. The effect of these and other factors on design parameters are discussed in the CEM, Section II-7-7-b(4). Additional analysis of this subject is contained in *Principles of Naval Architecture, Vol. 3* (Lewis, 1990).

2-10 SOURCES OF HYDRODYNAMIC INFORMATION.

Because coastal engineering design requires considerable knowledge of many physical sciences and engineering disciplines, the CEM contains a summary of sources for available information in Section II-8.

2-11 COMBINING DESIGN EVENTS.

Consideration of specific event extremes is the first step toward determination of design requirements. However, there are situations where the probability of coincident events is significant enough to warrant a further analysis of the combined effects of those events. As stated in the CEM, Section II-5-5-a(3), the importance of the timing of a storm event with tide phase cannot be over-emphasized because the resulting combined effect can be catastrophic. Methods for determining the frequency of occurrence for a 25- or 50-year storm are discussed in Section II-5-5-b of the CEM.

2-11.1 Earthquake and Low Tide.

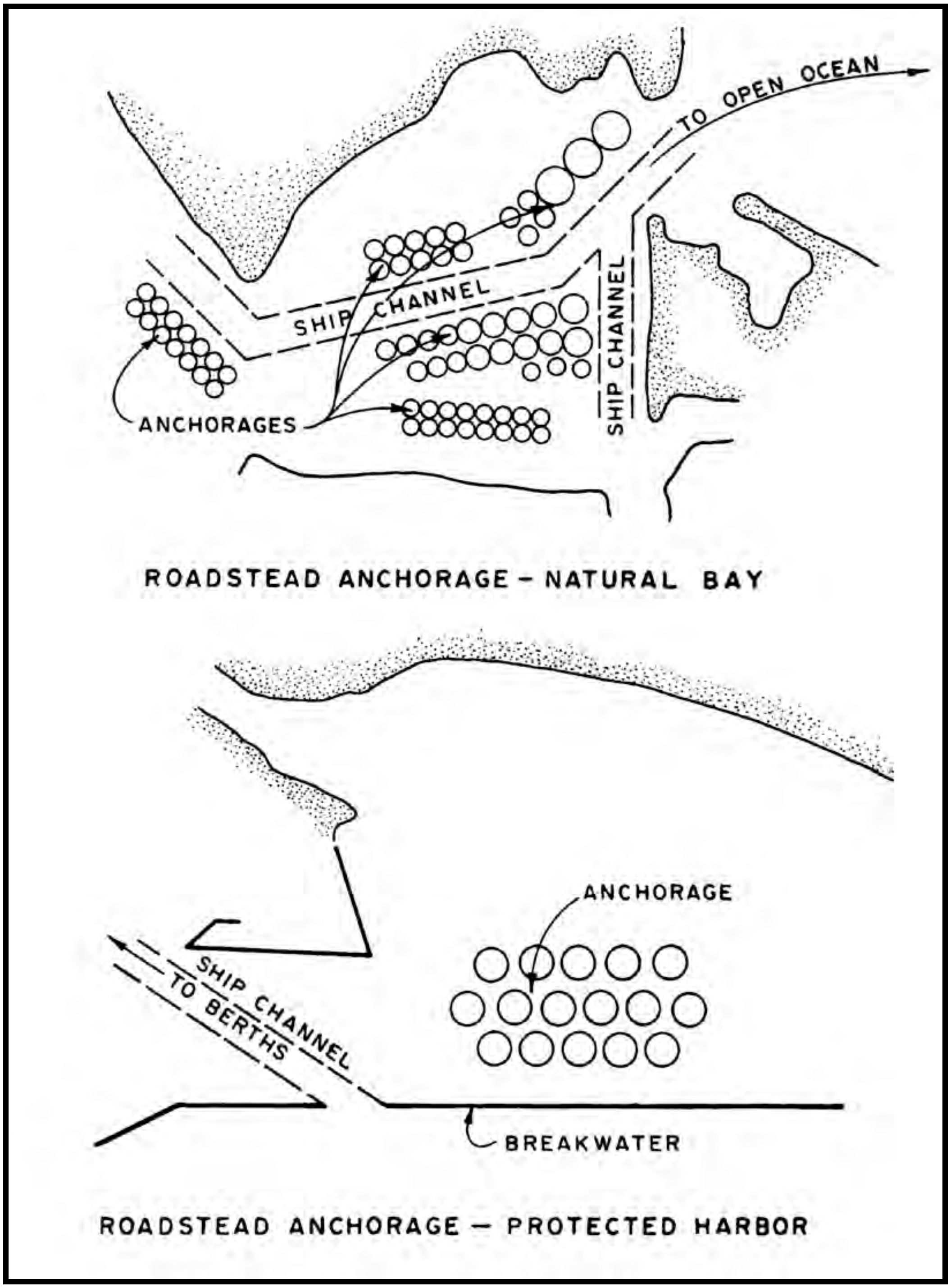
Coastal projects in areas with a high probability of seismic activity need to consider potential impacts related to ground deformation and severe liquefaction. The decision to allow for seismic loading in a coastal project design may hinge on such factors as estimated repair costs versus replacement costs, if loss of life and interruption of vital services are not considerations. Flexibility of the structure is a consideration in areas where rubble mound structures tend to be less affected by seismic activity than monolithic structures. Although not discussed in available texts, there is the potential that the stability of bluffs and coastal structures can be catastrophically affected if that activity occurs at a time of extreme low tide.

2-11.2 Storm Surge and High Tide.

Coastal areas are susceptible at certain times of the year to the effects of storm surge associated with high surf, which, if combined with an extreme high tide, can cause disastrous erosion of the shoreline. The importance of considering this interaction in coastal design is discussed in Section II-5-5-a(3) of the CEM.

The majority of coastal structures are designed to provide a level of protection to the beach and the surrounding population and supporting structures. This level of protection is generally based on a determination of the frequency-of-occurrence of a storm surge of a specified maximum elevation selected through an assessment of the risks of structural failure or consequences of overtopping versus project design costs. Consequently, it is important to determine stage frequency or frequency-of-occurrence relationships for the area in question. The designer must investigate and determine such factors as how to define high tide (2 min per day or 2 hours per day) and the probability of this happening with an extreme event such as a 25- or 50-year hurricane. Essentially, the phasing of the storm and tide both impact the design of the structure and the probability analysis of the design.

Figure 2-2 Examples of Roadstead Moorings



2-11.3 Storm Water Runoff and High Tide or Storm Surge.
The orientation, magnitude, and thickness of storm water runoff plumes are functions of the amount of river discharge, wind speed, direction, and duration, local ocean currents due to tides and surge, and local bathymetry. The runoff plume generally spreads out in a thin-layer over a large area as it mixes with ambient seawater. As a river discharges along the coast, the storm water runoff plume tends to spread in a longshore direction, parallel to the coast.

It is unclear as to whether or not dissolved and suspended plume components spread similarly throughout the water column. Thus, sufficient turbulence caused by river eddies or strong winds can cause particles to remain in suspension. With time, as turbulence decreases, particles will come out of suspension and deposit on the seafloor.

Coastal engineers should be aware that a coupling action between storm water runoff dynamics coincident with high tide or storm surge would undoubtedly have an effect on coastal project designs.

A lack of information covering this topic in the literature indicates that a need exists to more closely study these phenomena by conducting *in situ* observation and combining this data with analytical models to simulate the coupled effects. We solicit any comments and information regarding this phenomenon.

CHAPTER 3 SEDIMENT DYNAMICS

3-1 INTRODUCTION.

This chapter describes the important physical processes related to the movement of sediment around and in harbors and coastal facilities. An understanding of sediment movement is required for the proper design and maintenance of coastal facilities, such as siltation in harbors, shoreline erosion near structures, scour and burial of cables and pipelines, or anchoring in the nearshore. Much of the information related to these topics is contained in the CEM and the draft American Society of Civil Engineers (ASCE) “Standard for Shore Protection Systems". These and other applicable references are cross-referenced below by subject. The development of local criteria is essential in many cases due to the variation in meteorological and geological conditions at different geographical sites. If there are specific additional criteria to be considered, recommendations should be provided to Naval Facilities Engineering Service Center, Code 51, Port Hueneme, CA 93043, telephone (805) 982-1170.

3-2 SEDIMENT TRANSPORT PROCESSES.

Sediment transport in the nearshore zone is generally a result of the combination of breaking waves and various patterns of nearshore currents, characterized as a vector with both longshore and cross-shore components. Analysis of these two components has historically been performed separately because one or the other tends to dominate in a particular scenario. A discussion of the components of sediment transport and methods of analysis is found in Section III of the CEM, starting with a discussion of sediment classification by size and properties, followed by transport processes of cohesionless and cohesive sediments, and concluding with a discussion of sediment transport outside the surf zone.

3-2.1 Sediment Transport Rates.

Estimates of sediment transport rates can be derived either from calculations or through analysis of historical data. Although analysis of historical shoreline changes may provide a higher level of confidence, underestimation of the transport rate has not been uncommon in past practice. Where accuracy is critical to project development, construction and monitoring of a test groin to verify the estimate should be considered. However, the test groin must extend seaward far enough to trap all the littoral material. Representative examples of historical data for various coastal locations are shown in Table 3-1.

Sediment transport and deposition occur on open coasts, in tidal inlets, estuaries, harbors, and rivers. Sedimentation problems occurring in locations such as these are a function of soil type, continuity of materials, and the potential for fluid motion to transport material.

3-2.2 Harbor Siting.

Assess sedimentation processes when siting a harbor or an open-coastal littoral system, in an inlet system, or in a river-mouth estuary system. In each of these systems, transport capacity and sediment supply factors must be taken into account. A state of natural equilibrium may be due to unchanging channel depths or stable shoreline positions; alternatively, gradual and long-term sedimentation or erosion processes may be occurring. Refer to Sections III and V-6 of the CEM.

Table 3-1 Longshore-Transport Rates at Selected U.S. Coastal Locations

Location	Predominant Direction of Transport	Longshore Transport[a] cu yd/yr (m^3/yr)	Date of Record
Atlantic Coast			
Suffolk County NY	W	200,000 (152,920)	1946-55
Sandy Hook, NY	N	493,000 (376,948)	1885-1933
Sandy Hook, NY	N	436,000 (333,366)	1933-51
Asbury Park, NJ	N	200,000 (152,920)	1922-25
Shark River, NJ	N	300,000 (229,380)	1947-53
Manasquan, NJ	N	360,000 (275,256)	1930-31
Barneget Inlet, NJ	S	250,000 (191,150)	1939-41
Absecon, Inlet, NJ[b]	S	400,000 (305,840)	1935-46
Ocean City, NJ[b]	S	400,000 (305,840)	1935-46
Cold Spring Inlet, NJ	S	200,000 (152,920)	-
Ocean City, MD	S	150,000 (114,690)	1934-36
Atlantic Beach, NC	E	29,500 (22,556)	1850-1908
Hillsboro Inlet, FL	S	75,000 (57,345)	1850-1908
Palm Beach, FL	S	1150,000-225,000 (114,690 to 172,035)	1925-30
Gulf of Mexico			
Pinellas County, FL	S	50,000 (38,230)	1922-50
Perdido Pass, AL	W	200,000 (152,920)	1934-53
Pacific Coast			
Santa Barbara, CA	E	280,000 (214,088)	1932-51
Oxnard Plain Shore, CA	S	1,000,000 (746,600)	1938-48
Port Hueneme, CA[c]	S	1,000,000 (746,600)	-
Santa Monica, CA	S	270,000 (206,442)	1936-40
El Segundo, CA	S	162,000 (123,865)	1936-40
Redondo Beach, CA	S	30,000 (22,938)	-
Anaheim Bay, CA[b]	E	150,000 (114,690)	1937-48
Camp Pendleton, CA	S	100,000 (76,460)	1950-52
Great Lakes			
Milwaukee County, WI	S	8,000 (6117)	1894-1912
Racine County, WI	S	40,000 (30,584)	1912-49
Kenosha, WI	S	15,000 (11,469)	1872-1909
IL State Line to Waukegan	S	90,000 (68,814)	-
Waukegan to Evanston, IL	S	57,000 (43,582)	-
South of Evanston, IL	S	40,000 (30,584)	-
Hawaii			
Waikiki Beach, HI[b]	-	10,000 (7646)	-

[a]Transport rates are estimated net transport rates. In some cases, these approximate the gross transport rates.
[b]Method of measurement is by accretion except for Absecon Inlet, NJ, Ocean City, NJ, and Anaheim Bay, CA (by erosion) and Waikiki Beach, HI (by suspended load samples).
[c]Reference for Port Hueneme, CA, is U.S. Army (1980).

3-3 COASTAL GEOLOGIC MORPHOLOGY.

Classification of coastal geology and geologic character is of great importance to coastal engineers because of the complexity and diversity of the coastal environment. Section IV-3 of the CEM describes the historical emergence of coastal geologic classifications and summarizes the current preferred classifications and their influence on contemporary coastal design.

3-4 COASTAL MORPHODYNAMICS.

The discussion of coastal morphodynamics in Section IV-4 of the CEM states that coastal landforms are the result of the interactions of many physical processes, man-made influences, global tectonics, local underlying geology, and biology. Significant to the coastal designer is the fact that the physical conditions along the coast are constantly changing in response to many processes and often, in a relatively limited area, influence the formation of a combination of the four types of coastal environments: deltas, inlets, sandy shores, and cohesive shores (CEM, Section IV-4).

3-5 FOUNDATIONS AND ANCHORING.

Seafloor conditions and materials must be considered when placing structures and establishing an area for anchorage. Considerations for seafloor foundation design are discussed in Section VI-3-1 of the CEM. “Scour” occurs where sediment is eroded from beneath or around a structure’s foundation making it susceptible to failure. A summary of this process and its effects is found in the *Handbook for Marine Geotechnical Engineering*, edited by K. Rocker (Naval Civil Engineering Laboratory (NCEL), 1985). Additional design considerations regarding sediment transport are discussed in Section III-1-1 of the CEM.

3-5.1 Anchoring.

Selection of anchor type is based on bottom conditions. Information on this subject is also contained in the “Handbook for Marine Geotechnical Engineering” (Rocker, 1985). Where possible, locate the anchorage over a bottom of loose sand or gravel, clay, or soft coral. Avoid locations where the bottom consists of rock, hard gravel, deep mud, and deep silt.

3-6 SEDIMENT BUDGET.

Sediment budget is based on the principle of continuity or conservation of mass as applied to coastal sediments. A discussion of the processes and methods of evaluation are found in Section III-2-3-g of the CEM. Related information concerning windblown sediment transport is contained in Section III-4-5-c of the CEM.

3-7 EFFECTS OF STRUCTURES ON SEDIMENT TRANSPORT.

Man-made structures have a significant influence of sediment transport mechanisms. Groins, seawalls, jetties, breakwaters and piers all affect sediment transport and deposition processes. Numerous examples given in Sections III-2 and III-3 of the CEM indicate that the effect of these man-made structures on sediment deposition is significant in coastal engineering design. These effects can often be a source of technical data when investigating sediment transport.

3-8 MATERIAL PROPERTIES.

Sediment transport and deposition occur on open coasts, in tidal inlets, in estuaries, in harbors, and in rivers. The types of sedimentation problems that occur at each of these locations depend, in part, on the soil type. Properties and composition of coastal sediments are discussed in Section III-1 of the CEM. Additional information can be found in *Technical Notes, Technical Area 2: Material Properties Related to Navigation Dredging, published by the USACE Waterways Experiment Station (WES) for the Dredging Research Program (DRP)*. The Dredging Research Program Bibliography can be found on the web at http://wesda.org/related_links.htm#.

3-9 OPEN WATER DISPOSAL.

Disposal of project-removed sediment in open water can be an appropriate alternative where transportation costs for land disposal become prohibitive. In some cases, it is also useful for replenishment of shoreline where erosion is a problem. However, when foreign sediment is introduced into the marine environment, associated environmental issues arise. Whether from dredging operations or any other construction activity that affects the natural sediment environment, the coastal engineer needs to evaluate the impact on bottom dwelling and water column organisms due to such factors as blockage of light or toxicity of the sediment. Additional information is contained in Technical Notes published by the U.S. Army Engineer Waterways Experiment Station (WES) for the Dredging Research Program (DRP).

3-9.1 Contaminated Sediment Risk Assessment.

The sediment property of most environmental consequence is grain size. Turbidity in the water column depends on the fall velocity of the sediment particles, which is largely a function of the grain size. Turbid waters can be carried away by currents from the immediate project site, blocking the light to organisms over a wide area. As the sediments settle out, they blanket the bottom at a rate faster than the organisms can accommodate. Fine sediments (silts and clays) get greater scrutiny under environmental regulation because they produce greater and longer-lasting turbidity, which will impact larger areas of the seafloor than will coarser, sand-sized material. The dredging of sand usually encounters less severe environmental objection, provided that there are few fine sediments mixed with it and that the site has no prior toxic chemical history. Environmental regulation is changing, and many regulatory questions are outside the usual experience of coastal engineers. However, a basic coastal engineering contribution to facilitating the progress of a project through regulatory review is the early collection of relevant sediment samples from the site and obtaining accurate data on their size, composition, and toxicity. These issues are discussed in Sections III-1-1-b(2) and V-6-1-d of the CEM. Environmental requirements are discussed further in the paragraph titled “Regulatory Requirements” of this handbook.

3-10 GEOLOGICAL INVESTIGATIONS.

Effective coastal engineering studies require appropriate understanding of the geology of the project area and its impact on design parameters. A presentation of the considerations and procedures for coastal geological investigations is contained in Section IV of the CEM.

3-11 SOURCES OF SEDIMENT PROCESS INFORMATION.

A summary of sources of available coastal information and data can be found in Section IV of the CEM.

CHAPTER 4 CONSTRUCTION MATERIALS

4-1 INTRODUCTION.

The majority of materials utilized in coastal construction are quite similar to those used in dry-land construction. However, their introduction into the marine environment results in a need for the designer to expand his view of material degradation methods. In addition to the increased corrosive environment and possible freeze-thaw cycles, they must withstand relentless wave pounding and marine organisms that can attack most materials in a variety of ways. Primary material selection criteria are physical properties and strength, durability, adaptability, cost, availability, handling requirements, maintenance requirements, and environmental impact. Much of the information related to this topic is contained in Section VI-4 of the CEM.

4-2 CONSTRUCTION MATERIALS CONSIDERED, ANALYZED, OR COMMONLY USED.

The primary materials used in construction of coastal projects are stone, concrete, beach sand, steel, timber, composites, and geotextiles. These materials are critically important to the success and longevity of the project. Knowledge of past material performance on similar coastal projects is an important consideration for the design engineer. Detailed information on the materials discussed below and their selection criteria can be found in Section VI-4 of the CEM.

4-2.1 Availability.

In addition to the technical considerations for material selection, local availability of materials plays a big role in cost, both for initial construction and for future maintenance and repair planning. A summary of this and other material availability issues is contained in Section VI-3-7 and VI-4-1 of the CEM.

4-3 EARTH AND SAND.

Coastal projects tend to be fairly large and require a significant volume of construction materials. When feasible, structures are designed to use earth or sand as an economic filler material, and in many cases the mechanical strength properties of the soil are an integral part of the design. Some varieties, properties, and common uses of earth and sand in coastal construction are described in Section VI-4-2 and VI-4-3 of the CEM.

4-4 STONE.

Used extensively to construct coastal structures, stone is by far the most common material used in the United States for breakwaters, jetties, groins, revetments, and seawalls. A description of types of stone and their uses for coastal projects is contained in Section VI-4-1 and VI-4-3 of the CEM.

4-5 CONCRETE.

Concrete is the predominant construction material for waterfront facilities due to its durability, strength, and economy as a bulk construction material, and the basic components to make concrete are readily available at most locations. To optimally design a breakwater, for example, it is important to budget for minimum capital cost without excessive maintenance costs over the lifetime of the structure. Common breakwater designs based on an inner mound of small rocks or rubble provide stability, while an outer armor of large boulders protects the structure from wave action. Outer armoring designs range from simple concrete cubics or rectangulars, dense natural rock, and four-legged tetrapods (with each leg projecting from the center at an angle of 109 1/2° from each of the other three), to solid breakwaters made of concrete or masonry. Section VI-4-4 of the CEM summarizes specific applications of concrete in coastal construction.

4-6 STEEL.

Use of steel and considerations for appropriate applications are discussed in Section VI-4-5 of the CEM.

4-7 WOOD AND TIMBER.

Wood and timber members are widely used for the construction and maintenance of waterfront facilities due to availability, economy, and ease of handling relative to other construction materials. Wood can be used in coastal projects such as seawalls, revetments, bulkheads, piers, wharves, sand fences, and floating platforms. It's also used for temporary constructions such as formwork, bracing, and blocking. Uses of wood and timber and applicable properties, benefits, and drawbacks are described in Section VI-4-6 of the CEM.

4-8 COMPOSITES.

Though the subject of composite materials is applicable to the design of piers and wharves, this relatively new field is not addressed in the CEM. Nonetheless, many of the nation's leading academic institutions are investigating the use of fiber reinforced composite materials for concrete reinforcement.

The use of fiber reinforced plastics as an outside shell has been found to increase the load capacity and durability of piers, wharves, and bridges. These materials offer particular advantages over traditional reinforcements, though an understanding of their long term performance characteristics in aggressive environments is necessary before their use is widely accepted.

4-9 GEOTEXTILES.

As strong fabrics consisting of strong woven plastic filaments, geotextiles are predominantly used as filter cloth and are sometimes called filter fabrics, construction fabrics, plastic filter cloth, or engineering fabrics. The most frequent use of geotextiles in coastal construction is as a filter between fine granular sands or soils and overlying gravel or small stones that forms the first under layer of a coastal structure such as a revetment. A discussion of their properties and design considerations for their application is contained in Section VI-4-7 of the CEM.

CHAPTER 5 PROJECT PLANNING

5-1 INTRODUCTION.

In order to properly plan a project, a basic sequence of tasks should be considered as a basis for project planning:

- Problem Definition
- Initial Site Characterization
- Criteria Development (Functional, Accepted Damage Level, Performance)
- Define Without Project Condition
- Formulate Alternatives
- Detailed Site Characterization
- Refine Alternatives
- Evaluate/compare Alternatives
- Select Plan
- Final Design
- Plans and Specifications
- Cost Assessment/bid and Award
- Construction
- Quality Assurance
- Post Construction Inspection and Monitoring
- Operation and Maintenance
- Modifications to Existing Elements.

This process is discussed in detail in Section V-1 of the CEM.

5-2 DESIGN DATA.

Factors to be considered in general harbor site selection are listed in Table 5-1. Some sources of site data information are listed in Table 5-2.

Table 5-1 Principal Factors in Harbor Siting

Factor	Considerations
External Access	1. Vessel access to harbor site contains adequate depths and clearance for safe navigability. 2. Land access to harbor site is or can be reasonably developed to provide required land transportation linkage.
Size and Depth	1. Protected water depth and space adequate to accommodate intended vessel traffic in the following areas: (a) entrance and turning basins, (b) mooring areas, and (c) berthing areas. 2. Land areas of sufficient size and elevation to accommodate support needs free from flooding or inundation. 3. Potential for future enlargement or change in harbor use.
Physical and Topographic	1. Sheltering from winds and ocean waves; natural sheltering features such as headlands, offshore reefs, and islands will reduce both artificial sheltering requirements (breakwaters) and costs. 2. Limited fetch. The protected water area shall not contain segments of sufficient fetch to act as a generating area for waves that would cause difficulties within the harbor. 3. Bottom. Heavy, stiff, or overconsolidated clays furnish the best holding ground for anchors. Sands will provide acceptable holding ground. Sites should be avoided where the bottom consists of extremely hard clays, rocks, or very soft clays. If this is not possible, costly provisions (such as mooring islands) must be made to secure ships. Similarly, the costs of breakwaters, piers, and shore side structures will also depend upon the underlying soil conditions. Location of extensive structural systems in areas of deep, soft clays should be avoided. 4. Dredging. Avoid locations involving dredging of large quantities of rock or other hard bottoms. 5. Shoreline relief. Land adjacent to shoreline should gradually slope away from beach. Avoid locations with pronounced topographic relief (cliffs) adjacent to shoreline. 6. Upland drainage. Preferably, the upland area should be naturally well drained. Evaluate occurrence of health hazards due to local conditions.
Hydrographic and Hydrological	1. Variations in water level. The range between water level extremes due to cumulative effects of astronomical and storm tides as well as flood flows in river-affected harbors should be minimized as far as practicable. 2. Currents. Current velocity should be minimum and, except for localized areas and/or special considerations, should not exceed 4 knots. 3. Fouling rate. Desirable factor is a low fouling rate and relative freedom from marine borers, hydroids, and other biofouling organisms, which can be drawn into the cooling systems of ships. 4. Water circulation. Water basins should have sufficient natural circulation. 5. Sedimentation. The effect of the harbor site on natural regimes of coastal and riverine sediment transport and supply must be thoroughly evaluated. It is desirable not to interfere with the natural regime of sediment movements. The effects of harbor development on the sediment system may require maintenance dredging and/or shore-stabilization needs that must be considered as part of the overall development effort.
Meteorological	1. Storm. Avoid locations subject to the direct effects of pronounced, severe, and frequent storms. 2. Fog. Consider local variation in fog intensity and avoid the more severe sites where practicable. 3. Ice. Avoid locations that might be ice-locked for several months a year.
Other	1. Availability of construction material. In particular, rock for breakwater and jetty construction. 2. Fresh water availability. In particular, water for potable water supply.

Table 5-2 Informational Sources for Harbor Site Selections

Data Required	Sources
Underwater Bathymetry	**\1\ National Geospatial-Intelligence Agency – NGIA /1/** (https://www1.nga.mil/Pages/Default.aspx), NOAA's National Ocean Service - NOS (http://www.nos.noaa.gov), U.S. Naval Oceanography Portal - NAVO (http://www.navo.navy.mil), U.S. Army Corps of Engineers - USACE (http://www.usace.army.mil/), local Government Public Works and/or Hydrographic Survey Offices; where such is not available, survey is required.
Upland Topography	U.S. Geological Survey – USGS (http://www.usgs.gov), **\1\ National Geospatial-Intelligence Agency – NGIA /1/** (https://www1.nga.mil/Pages/Default.aspx); local Government Public Works mapping offices.
Subsoil Characteristics	Borings, probings or seismic survey; use diver for preliminary reconnaissance.
Astronomical Tides	NOAA's National Ocean Service – NOS (http://www.nos.noaa.gov), U.S. Naval Oceanography Portal - NAVO (http://www.navo.navy.mil; observation at site.
Storm Surge/Tsunamis	Site history. Probability forecasts for some areas have been prepared by U.S. Army Corps of Engineers – USACE (www.usace.army.mil) and Federal Emergency Management Agency, Storm Watch (http://www.fema.gov/plan/prevent/nhp/stormwatch.shtm); review available tide records (marigrams) to compare predicted astronomical tide to measured water levels during storm or tsunami occurrences.
Seiche	Historic experience in general area including marigram inspection can provide some indication of potential activity; long-term observations at site are desirable.
Currents	U.S. Naval Oceanography Portal - NAVO (http://www.navo.navy.mil), NOAA's National Ocean Service - NOS (http://www.nos.noaa.gov), Pilot Manuals, U.S. Geological Survey – USGS, for riverine currents (http://www.usgs.gov).
Meteorological Characteristics	Weather Bureau - National Oceanic and Atmospheric Administration (NOAA), (http://www.noaa.gov); Fleet Numerical Meteorology and Oceanography Center (http://www.usno.navy.mil/FNMOC).
Waves	National Oceanic and Atmospheric Administration, (http://www.noaa.gov); National Climatic Data Center, http://www.ncdc.noaa.gov/oa/ncdc.html; Fleet Numerical Meteorology and Oceanography Center (http://www.usno.navy.mil/FNMOC), U.S. Army Corps of Engineers (http://usace.army.mil); WIS Reports – see references.
Sedimentation/Erosion	U.S. Army Corps of Engineers, (http://www.usace.army.mil), U.S. Geological Survey, (http://www.usgs.gov); analysis of shoreline and hydrographic changes in comparison of successive surveys from initial to present conditions.
Fouling Conditions	Observations at site; consultation with local residents and authorities.

5-3 COASTAL PROJECT PLANNING AND DESIGN.

The type of structure required for a particular design situation depends upon the protection required, such as harbor protection, beach erosion control, and stabilization of an entrance channel. The primary types of coastal structures and methods of marine improvement and shore protection are breakwaters, jetties, revetments, bulkheads, seawalls, groins, headlands, and beach restoration and nourishment. The paragraph of this document titled "Navigation Aids" provides introductory descriptions and figures showing each of these. In many cases, more than one type of structure may provide a possible solution. Studies of alternative solutions, including consideration of first and annual costs, maintenance, construction methods, and environmental impacts, should be conducted to select the most appropriate one. Selection of the structure type requires that the foundation condition, availability of construction materials and equipment, and probable impacts on the adjacent shores be considered.

5-3.1 Planning and Design Process.

The CEM, Section V-1, discusses this topic at length. It emphasizes function of components, concepts, non-structural, dynamic and static structures. It offers information regarding coastal zone management, coastal armoring, sediment issues, temporary solutions, and others.

5-4 REGULATORY REQUIREMENTS.

Permitting, inspection, and enforcement activities are conducted by various organizations.

5-4.1 USACE.

The responsibilities of USACE are outlined below:

5-4.1.1 Jurisdiction.

All works located in the waters of the United States and its territories are under the jurisdiction of the USACE. This zone is generally located seaward from the mean high water line. A USACE permit is required for all dredging, filling, construction, or maintenance works. The permit must be approved prior to commencement of work. Therefore, processing of permits should be initiated well in advance of the date work is scheduled to begin because of the lead time required to obtain USACE permits. The USACE's jurisdiction also includes interior wetlands, rivers, and lakes. Questions regarding the extent of the jurisdiction for specific areas inland of the high-tide line should be addressed to the local USACE District Office.

5-4.1.2 Review Procedure.

In reviewing permit applications for works in U.S. waters, the USACE circulates the application to other Federal and local agencies. In accordance with various executive actions, the USACE cannot, at a local level, override the permit objections of the following:

- Department of the Interior, U.S. Fish and Wildlife

- Environmental Protection Agency (EPA)
- Department of Commerce, Bureau of Commercial Fisheries

In addition to input by Federal agencies, input by State or regional agencies are considered. To date, most concerns address changes in water quality and loss of marine habitat. In specific cases critical to national defense, regulations and procedures can be modified through the Office of the Secretary of the Navy. However, most Navy facility projects are subject to the concerns and regulations of other authorities, which have jurisdiction. Specific contact should be made at project inception with the agencies affected. Liaison is particularly important where harbor works involve:

- dredging and disposal of dredged materials,
- work in or around existing marshes, and
- significant reduction of existing intertidal or shallow-water areas.

5-4.2 U.S. Coast Guard.
All aids to navigation for U.S. waters are prescribed and installed under the jurisdiction of the U.S. Coast Guard (USCG). In addition, USCG jurisdiction extends to drawbridges and encompasses construction clearances for new drawbridges, modifications of existing drawbridges, and drawbridge operations.

Prior to construction of any coastal project that may impact navigation or interrupt any existing aids to navigation, complete project information should be provided to local authorities (USCG district commander). This information should include details about project authorization, proposed construction schedule, and detailed drawing showing the project location relative to existing feature. Local authorities may require a set of “as-built” plans after the project has been completed, and it may be necessary to include new aids to navigation as part of the project design (CEM, Section VI-3-8).

5-4.3 Harbor Control Lines.
USACE, through the Secretary of the Army, establishes harbor control lines for all U.S. ports. Control lines include:

- bulkhead lines – seaward limit of solid-fill structures;
- pierhead lines – seaward limit of open waterfront structure; and
- channel lines – extent of channel limits usually maintained by the Federal Government.

5-4.4 Jurisdiction.

USACE has jurisdiction over construction and dredging in the navigable waters of the United States and of its territories and possessions. EPA has jurisdiction over water quality relating to dredging, disposal of dredged material, and fill activities. Dredging activities and equipment must comply with USCG regulations. Consultation with the district office of the USCG is recommended before dredging projects are started.

5-4.4.1 Federal Permits.
A USACE permit is required to locate a structure, excavate, or discharge dredged or fill material in waters of the United States. A USACE permit is also necessary for transport of dredged materials into ocean waters for the purpose of dumping. Application for Federal permits can be made through the local district office of the USACE. Applications must be accompanied by drawings of the dredge and disposal areas and a description of the proposed work. Although there are general guidelines established for the permit process, each district is somewhat autonomous and has the authority to amend the requirements for each particular project. These requirements include explanatory documentation of existing data, supplementary chemical and biological testing, and additional environmental surveys. The extent of each requirement is dependent upon the quantity and quality of the dredged material, the proposed form of disposal, and the environmental sensitivity of the area. To expedite permit application processing, appropriate regulatory agencies (e.g., USACE and EPA) should be contacted early in project planning. In extreme cases, early notification can expedite processing emergency dredging permits by the USACE.

5-4.4.2 State Permits.
Federal law assures the right of any state or interstate agencies to control the discharge of dredged or fill material in any portion of the navigable waters of any state jurisdiction. Typically, a water-quality certificate, a hydraulic-fill permit, or both, are required at the state level.

5-4.4.3 Local Permits.
In certain areas, a local permit may be required. Most states have federally endorsed coastal development and water quality plans. Many consider the operation and maintenance of existing Navy facilities as consistent with, and part of, their planning documentation. Direct authority over new Navy construction works does not presently extend to local State agencies; however, for consistency with local plans, notification of new works is desirable. Notification of concerned local agencies may be through circulation of an environmental impact statement for new works, public notice in the case of operation or maintenance projects, or directly through an exchange of memoranda.

5-4.5 Disposal of Dredged Material.
Dredging may be required to gain access to the project site, for entrenching toe materials, for backfilling higher quality foundation material, or for other reasons. When dredging is to occur, dredging volume should be estimated, and the method of dredged material transport and disposal should be determined. Beneficial uses of the dredged

material should be considered, particularly if the displaced material consists primarily of beach-quality sediment. Some dredged sediments may be disposed offshore in a designated and permitted Ocean Dredged Material Disposal Site (ODMDS); note that management of an ODMDS requires predicting the response of the sediment mound to wave and current forces with the aid of validated numerical models for the region in question. Guidance on dredging disposal and beneficial uses of dredging material can be found in Engineer Manuals (EM) 1110-2-5025 (USACE, 1983) and 1110-2-5026 (USACE, 1987). Also, papers from technical specialty conferences, e.g., Dredging '94 (American Society of Civil Engineers, 1994), provide useful information; for additional information, see Section VI-3-8 of the CEM.

5-4.6 Environmental Considerations.

Understanding and mitigating environmental impacts of coastal projects are key considerations throughout the planning, design, construction, and maintenance phases of all projects. Refer to CEM Sections V and VI-3-6.

5-4.6.1 Discussion.

The Coastal Zone Management (CZMA) Act of 1972, PL 92-583, establishes a national policy to preserve, protect, develop, and, where possible, restore and enhance the resources of the coastal zone of the United States. DoD Implementation of the Coastal Zone Management Act, DOD Instruction 4165.59 of 29 December 1975, authorized the Navy to implement programs to achieve the objectives of PL 92-583. The Navy will cooperate and provide information on Navy programs within the coastal zone to states responsible for developing state CZMA plans. Naval operations, activities, projects, or programs affecting coastal lands or waters shall insure that such undertakings, to the maximum extent practicable, comply with state-approved coastal-zone programs.

5-4.6.2 Guidelines and Standards.

All natural resources management programs on naval installations in the coastal zone have potential effects on the coastal zone and should be reviewed for consistency with approved state Coastal Zone Management plans. The Navy shall develop, in cooperation with a designated state agency, a set of criteria and standards for judging the consistency of natural resource management programs with respect to approved state management programs. Consistency determinations shall be made in accordance with provisions of PL 92-583.

Agricultural out lease of real property affecting land or water uses in the coastal zone shall provide a certification that the proposed use complies with the coastal state's approved program and that such usage will be conducted in a manner consistent with the program.

Technical assistance requested by the states to assist their implementation of CZMA will be provided to the extent practicable. Data collected by the Navy on subjects such as beach erosion, hydrology, meteorology, and navigation may be useful for coastal-zone planning and shall be made available.

5-4.7 Natural Resource Protection Criteria.

In recognition of the intrinsic value of natural resources, the National Environmental Policy Act (NEPA) of 1969, amended in 1970, 1975, and 1982, provides a vehicle for arresting any rapid degradation and destruction of critical natural resources. Appropriate permitting procedures shall be followed by the design team prior to beginning any activity that will be located in, on, or over any protected natural resource or is located adjacent to an activity that will cause material or soil to impact coastal wildlife habitats, among others. The importance of working to conserve and restore endangered and threatened species and the ecosystems upon which they depend on for survival is also recognized via the Endangered Species Act (ESA) of 1973 and the Marine Mammal Protection Act of 1972. The attendant dredging, displacement, and filling of soil during construction projects in the coastal zone underlines the necessity for the Navy to address natural resource protection issues early in the planning process.

5-5 SITE CHARACTERIZATION AND DESIGN CRITERIA.

Many coastal failures can be traced back to inadequate site characterization analysis. Site characterization involves identifying distinguishing qualities and features of a region that have a direct and indirect impact on the conception, design, economics, aesthetics, construction and maintenance of a coastal project. The coastal environment varies spatially and temporally and therefore a design that is functionally, economically, and environmentally appropriate at one location may be inappropriate at another. Physical, biological, and cultural attributes need to be delineated so that an acceptable project is adopted and potential effects of the project are determined. Sections V-2 and VI-3 of the CEM cover this topic in detail.

5-5.1 Hydrographic Surveys and Subbottom Profiling.

It is important to perform surveys to identify bottom conditions and to determine if any structures are present which need to removed or avoided. This knowledge pertains to both construction efforts and dredging. Table 5-2 provides information on some of the bathymetric, Differential Global Positioning System (DGPS), and sidescan sonar sources available to the design engineer.

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5-6 PORT AND HARBOR PROJECT DESIGN - DREDGING AND NAVIGATION PROJECTS.

Planning efforts must consider environmental policies such as the National Environmental Policy Act (NEPA), the Environmental Assessment (EA), and the Environmental Impact Statement (EIS). Project Assessment and Alternative Selection, and Development of a Navigation Project, are addressed in the following sections.

5-6.1 Project Assessment and Alternative Selection.

This information is readily available from the CEM, Section V-5, which acts as a complement to EM 1110-2-1613, *Hydraulic Design Guidance for Deep-Draft Navigation Projects* and EM 1110-2-1615, *Hydraulic Design of Small Boat Harbors*.

5-6.1.1 General Harbor and Port Facility Issues.
Within limits, any site may be modified to accommodate the required vessel use. Ideally, the minimum and maximum area requirements must be estimated in order to properly evaluate a proposed location. For military purposes, it is desirable to allow for unrestricted operation of all vessels at all times. However, it is not always practical to design for statistically infrequent low-water conditions or an all-weather navigable entrance at locations exposed to extreme wave climates. Before proceeding with the design, trade-offs based upon the probabilities of occurrences should be discussed with the using agency.

5-6.1.1.1 Major Water-Area Elements.
Figure 5-1 illustrates the arrangement of major water-area elements associated with a harbor facility. Depending upon siting, a harbor facility may include all of, or portions of, these elements. Functionally, approach- and entrance-channel elements provide the transition between open-sea and protected water environments. Further, channels are differentiated between open and restricted types as shown in Figure 5-2. The protected interior channel serves as a navigational linkage; in riverine situations, this channel length can become of increasing importance. Turning basins provide area for a ship to maneuver while approaching its final terminus, either alongside berths or in open mooring areas. In some harbors, special water areas are required for vessel electronic and navigation calibration. Sizing of water-area dimensions is related to both capacity and operational requirements.

Figure 5-1 Water-Area Elements

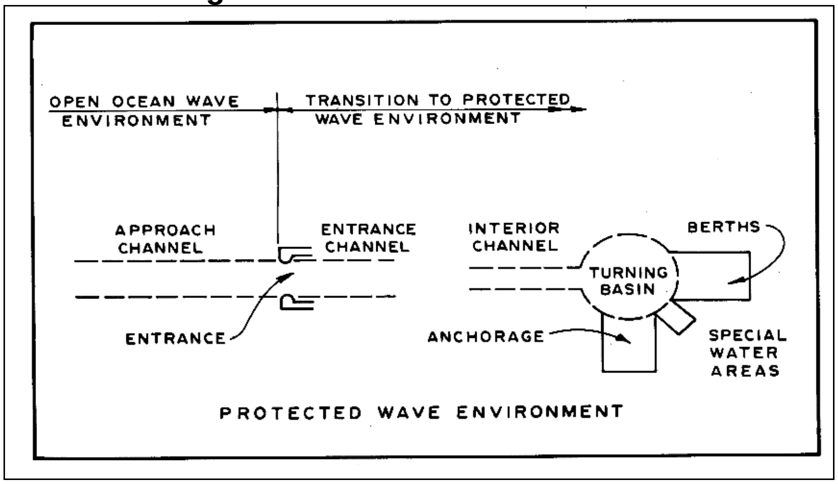
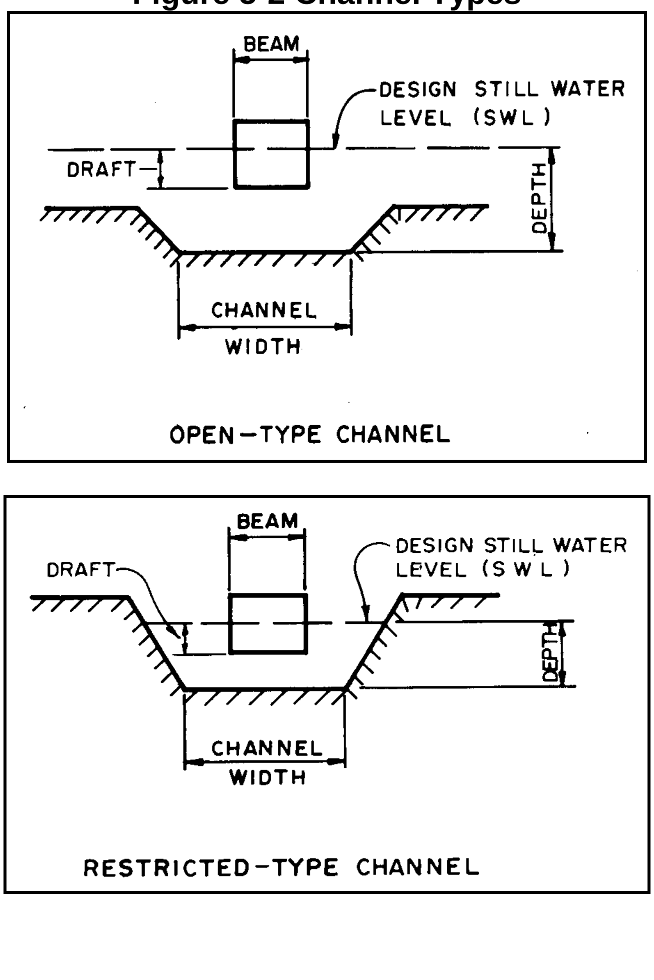


Figure 5-2 Channel Types



5-6.1.1.2 Capacity.
Ascertain the approximate anticipated capacity requirement from the using agency in terms of numbers, types, and sizes of vessels expected to simultaneously anchor within the harbor limits. Also estimate the number of these vessels that must be simultaneously accommodated at pier or wharf berths and determine the needs for special water areas for ship calibration.

5-6.1.1.3 Operation.
Proposed vessel-handling methods and navigational minimums need to be defined. Included in this assessment is the use of pilots and tugs for ship handling and berthing. Tolerances for ship movement restrictions in cases of extreme tide or weather conditions need to be defined.

5-6.1.1.4 Dimensioning.
Guidelines for dimensioning harbor water-area elements, and spatial and water-depth values are provided below. Alternative evaluations may be made through comparison using existing operating Navy facilities. However, caution should be exercised in making such operational comparisons in that, to do so, the wind, wave, and current environments must also be similar.

5-6.1.1.5 Economics.
Economic considerations must be weighed against depth requirements. In harbors where tidal range is very large and, particularly, where an entrance channel is long, consider the possibility of restricting the entrance of the largest draft ships using the harbor to the higher tidal stages. Where hard bottoms prevail and excavation costs are high, consider the exclusion of certain classes of deep-draft vessels, with provision of lighter service between deep-water anchorage and docks.

5-6.1.2 General Depth Requirements.
In general, the depth of harbor areas vary. Certain areas are reserved for small craft usage while larger areas are set aside for larger ships. Additionally, channel depth requirements differ from those at anchorages and berths. Depending upon the specific area under consideration, it is imperative to provide for adequate depths at all anticipated water levels. Project depths shall be determined for each of the following harbor elements:

- Berth
- Turning Basin
- Inner Channel
- Outer Channel

Additionally, when determining project depth, there are a number of factors/parameters that must be considered (see Figure 5-3):

5-6.1.2.1 Maximum Static Draft.
Maximum static drafts for vessels currently in use by the U.S. Navy and Military Sealift Command are provided in Table 5-3. Values shown include static trim and appendages and are based upon saltwater condition. For areas where freshwater, brackish, or significant freshwater inlets exist, draft will be greater and should be properly accounted for. If vessel list is a consideration, that should be accounted for as well.

Figure 5-3 Factors Affecting Maximum Vessel Draft

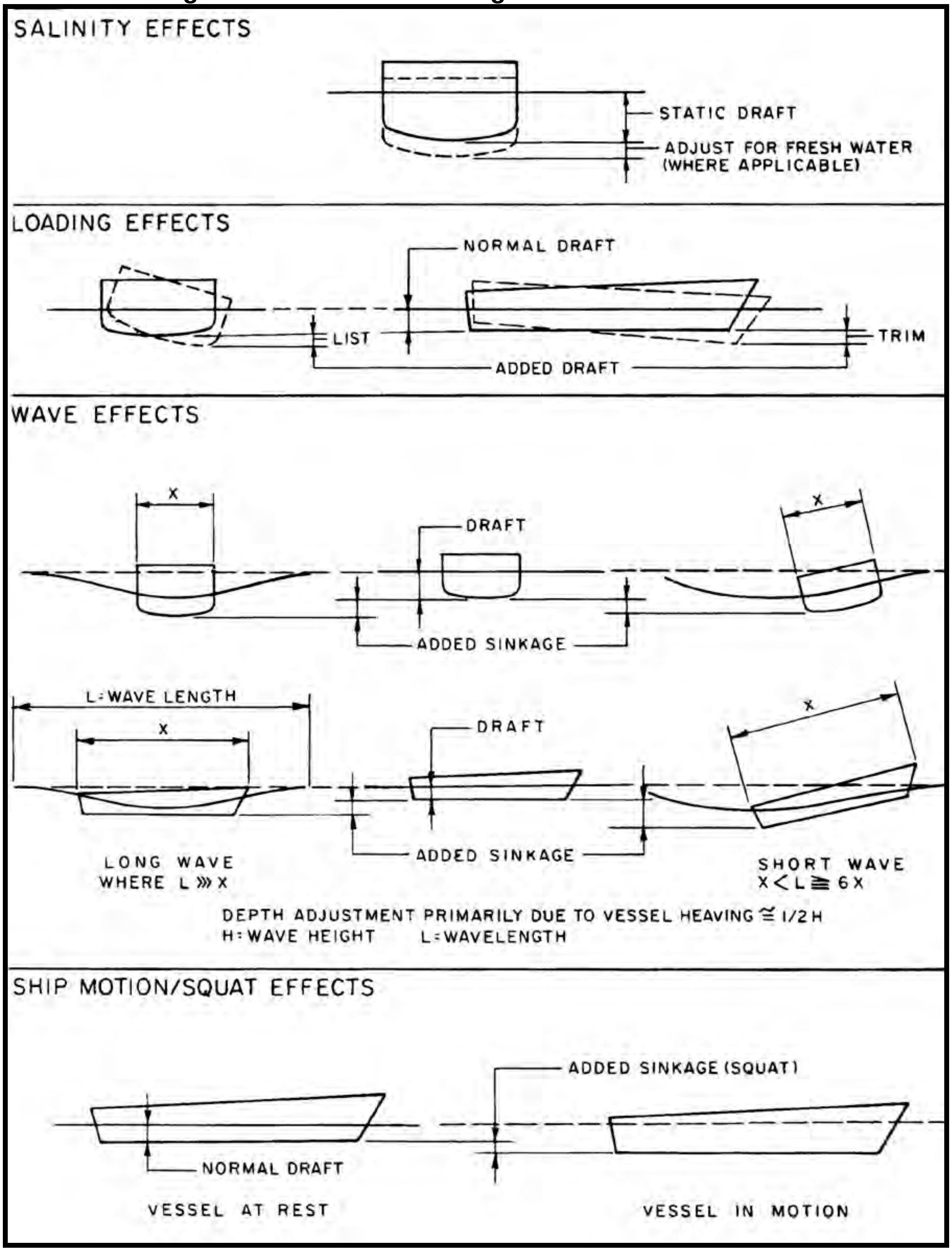


Table 5-3 U.S. Navy Vessels Maximum Static Draft[1]

U.S. NAVY SHIP CLASS	MAX STATIC DRAFT (ft)	(m)	MSC SHIP CLASS	MAX STATIC DRAFT (ft)	(m)
CVN 65	38.95	11.87	AE 26	28.06	8.55
CVN 68	40.21	12.26	AFS 1	27.50	8.38
CVN 71	42.72	13.02	AFS 8	25.37	7.73
CVN 76	42.61	12.99	AG 195	23.67	7.21
CVN 77	40.83	12.45	AGF 11	23.00	7.01
CG 47	34.07	10.38	AGM 23	27.79	8.47
DDG 51	33.64	10.25	AGM 24	14.92	4.55
DDG 79	33.54	10.22	AGM 45	23.05	7.03
DDG 1000	28.60	8.72	AGOS 19	24.83	7.57
FFG 7	26.13	7.96	AGOS 23	27.09	8.26
LCS 1	14.07	4.29	AGS 51	14.00	4.27
LCS 2	14.19	4.33	AGS 60	19.00	5.79
SSBN 726	36.37	11.09	AH 19	32.82	10.00
SSGN 726	36.33	11.07	AK 3000	32.88	10.02
SSN 688	31.92	9.73	AK 3005	33.50	10.21
SSN 21	34.09	10.39	AK 3008	32.06	9.77
SSN 23	34.60	10.55	AK 3015	36.00	10.97
SSN 774	32.18	9.81	AK 3016	35.25	10.74
LCC 19	31.84	9.70	AKE 1	31.82	9.70
LHA 1	28.65	8.73	AKR 287	36.79	11.21
LHA 6	31.65	9.65	AKR 295	37.00	11.28
LHD 1	28.05	8.55	AKR 296	37.00	11.28
LHD 5-6	27.50	8.38	AKR 300	37.00	11.28
LHD 7	27.75	8.46	AKR 310	37.00	11.28
LHD 8	29.08	8.86	AOT 187	36.00	10.97
LPD 4	23.21	7.07	AOE 6	40.67	12.40
LPD 17	23.40	7.13	ARC 7	25.98	7.92
LSD 41	21.38	6.52	ARS 50	16.92	5.16
LSD 49	21.30	6.49	AS 39	31.50	9.60
MCM 1	15.15	4.62	ATF 168	15.56	4.74
MHC 51	11.42	3.48			

[1] *Dredge Depths for Active US Navy Combatants and Military Sealift Ship Classes – Update,* NSWCCD-50-TR-2008/048, October 2008

5-6.1.2.2 Squat.
When a vessel is underway in shallow water or situated in a restricted channel, the water surface near the quarter point of the vessel drops below the normal level and the vessel tends to settle itself or squat in the depression (Figure 5-4). The amount of squat depends upon the:

- Speed of the vessel through the water
- Distance between the keel and the bottom
- Trim of the vessel
- Cross-sectional area of the channel
- Presence of other vessels in the channel passing or overtaking the subject vessel, and
- Location of the vessel relative to the channel's centerline.

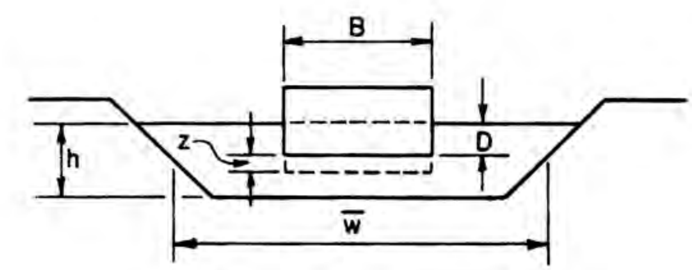
The following procedure is recommended for performing preliminary estimations of squat:

1. Compute $S = \frac{A}{\overline{w}h}$.
2. Using Figure 5-5, obtain F; compute V_L using $F = \frac{V_L}{\sqrt{gh}}$.
3. Compute $\frac{V}{V_L}$ and $\frac{h}{D}$; obtain $\frac{z}{h}$ using Figure 5-6.
4. Multiply by h to obtain z_{max}, valid for $\frac{\overline{w}}{B} = 6$.
5. For other values of $\frac{\overline{w}}{B}$, find $\frac{\Delta z}{z_{max}}$ from Figure 5-7.
6. Compute z using $z = z_{max} + \Delta z$.

The amount of squat will increase when vessels travel near one side of the channel. This effect has been shown in a model test for a 32-ft (9.8 m) draft by 113-ft (34.4 m) beam vessel in a 500-ft (152.4 m) wide by 45-ft (13.7 m) deep channel with 1-on-1 side slopes. The results of this test, given in Figure 5-8, show that the additional squat due to a vessel traveling near the side of a channel is small for slower velocities. For higher velocities, additional squat due to a vessel traveling near the side of the channel may be 50 percent greater than if the vessel were in the center of the channel.

Squat will also increase if there are two or more vessels passing one another, side by side. A vessel will normally travel near the side of a channel when it is passing alongside another vessel. In this case, the effective cross-sectional area of the channel will be reduced by the cross-sectional area of the vessel being passed. The total squat for a vessel can be approximated by first calculating the centerline squat with the reduced effective cross-sectional area of the channel. To this centerline squat is added the additional squat resulting from the vessel being off the centerline of the channel.

Figure 5-4 Factors Affecting Squat



where:

z	=	depth of squat [ft]
h	=	channel depth [ft]
$\overline{w}$	=	average channel width [ft]
A	=	underwater midship cross section [ft^2] = DB
D	=	vessel draft [ft]
B	=	vessel beam [ft]
V	=	vessel speed through water [ft/sec]
V_L	=	theoretical limiting vessel speed [ft/sec]
g	=	gravitational acceleration [32.2 ft/sec^2]
S	=	ratio of underwater midship cross section to the channel cross section $= \frac{A}{\overline{w}h}$
F	=	Froude number $= \frac{V_L}{\sqrt{gh}}$

Figure 5-5 Sogreah Laboratory Squat Curve (Wicker, 1965)

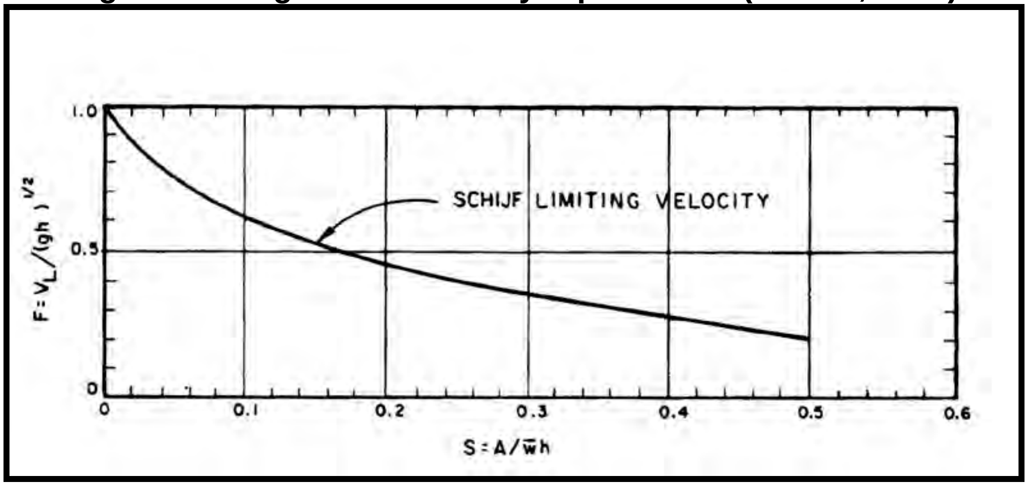


Figure 5-6 Sogreah Laboratory Squat Curves (Wicker, 1965

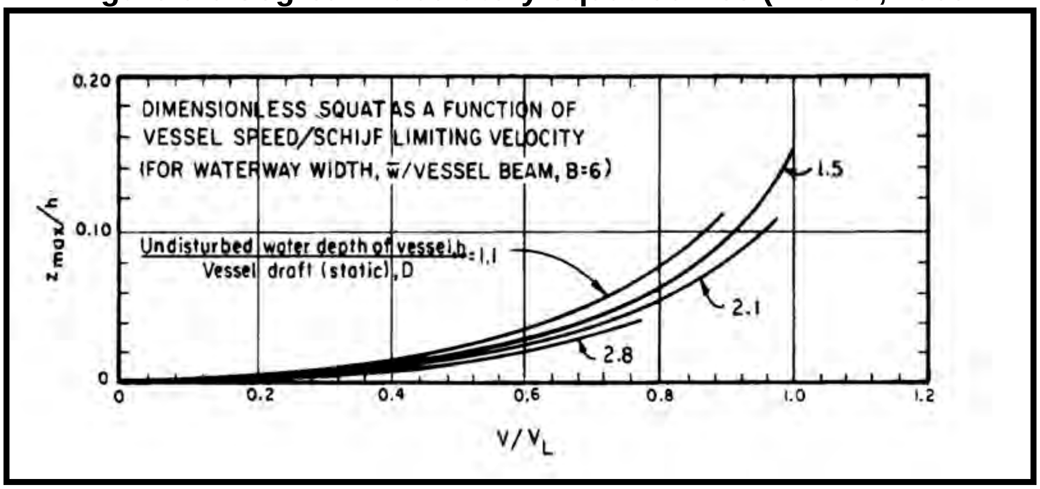


Figure 5-7 Sogreah Laboratory Squat Curves (Wicker, 1965)

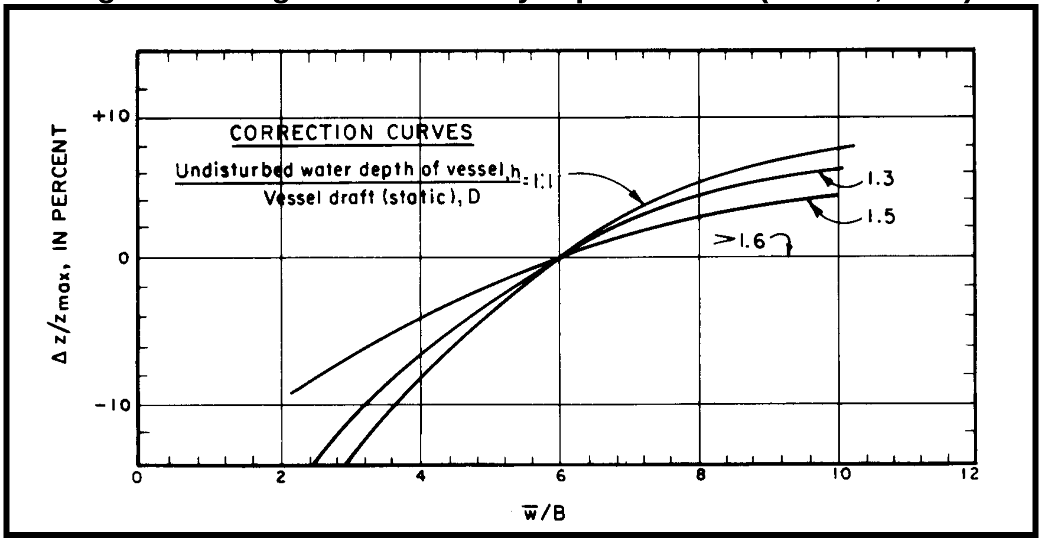
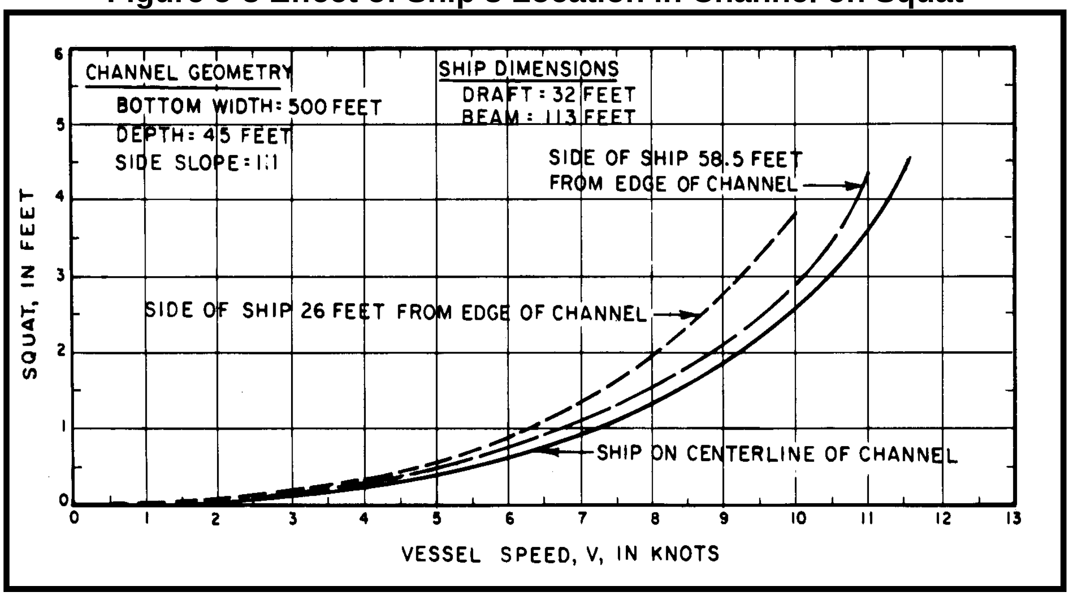


Figure 5-8 Effect of Ship's Location in Channel on Squat



In considering U.S. Navy and Military Sealift Command vessels transiting at speeds of 5 knots, 10 knots and 15 knots, Tables 5-4, 5-5, and 5-6 have been prepared to show the dynamic (underway) draft. Values came from *Dredge Depths for Active US Navy Combatants and Military Sealift Ship Classes – Update,* NSWCCD-50-TR-2008/048, October 2008

5-6.1.2.3 Wave Motion.
In cases where a vessel is in a water area that is subject to wave action, vertical motions will increase the extreme draft relative to the still water level. Rotational motions of pitch and roll, as well as vertical displacement through heaving motion, will take place. The motion of the ship subjected to steep waves requires that a dynamic analysis take into account the physical property of the ship modeled in the sea condition. Under certain critical ratios of vessel length to relative wavelength, the added vertical sinkage of the vessel can be appreciably greater than the water-level displacement at the wave trough. Generally, these critical ratios are generally believed to lie within the 0.3 to 0.6 range. This situation is normally critical where the unprotected harbor-entrance approach is situated in shoaling water. A recent harbor site selection at a particularly stormy site suggests that an overdepth in the approach and entrance channels on the order of 35 percent of the draft is required. In semi-protected water areas, such as when a ship is subjected to swell, but not to local seas, the increased displacement of the vessel due to pitch and heave can be determined by placing two points of the vessel on a trochoidal wave surface at two-thirds the vessel waterline-length normal to the wave crests, as is shown in Figure 5-9. Semi-protected water areas are shown in Figure 5-10. Dynamic draft increase due to wave motion is a highly specialized analysis that is normally applicable to the outer channel area of a project.

Table 5-4 U.S. Navy Vessels Squat @ 5 Knots

SHIP CLASS	MAX STATIC	DRAFT	5 KNOTS UNDERWAY	SINKAGE	5 KNOTS UNDERWAY	DRAFT
	(ft)	(m)	(ft)	(m)	(ft)	(m)
CVN 65	38.95	11.87	0.44	0.13	39.39	12.01
CVN 68	40.21	12.26	0.47	0.14	40.68	12.40
CVN 71	42.72	13.02	0.45	0.14	43.17	13.16
CVN 76	42.61	12.99	0.46	0.14	43.07	13.13
CVN 77	40.83	12.45	0.53	0.16	41.36	12.61
CG 47	34.07	10.38	0.15	0.05	34.22	10.43
DDG 51	33.64	10.25	0.20	0.06	33.84	10.31
DDG 79	33.54	10.22	0.20	0.06	33.74	10.28
DDG 1000	28.60	8.72	0.35	0.11	28.95	8.82
FFG 7	26.13	7.96	0.10	0.03	26.23	7.99
LCS 1	14.07	4.29	0.92	0.28	14.99	4.57
LCS 2	14.19	4.33	1.37	0.42	15.56	4.74
SSBN 726	36.37	11.09	0.18	0.05	36.55	11.14
SSGN 726	36.33	11.07	0.18	0.05	36.51	11.13
SSN 688	31.92	9.73	0.32	0.10	32.24	9.83
SSN 21	34.09	10.39	0.38	0.12	34.47	10.51
SSN 23	34.60	10.55	0.30	0.09	34.90	10.64
SSN 774	32.18	9.81	0.39	0.12	32.57	9.93
LCC 19	31.84	9.70	0.37	0.11	32.21	9.82
LHA 1	28.65	8.73	0.49	0.15	29.14	8.88
LHA 6	31.65	9.65	0.38	0.12	32.03	9.76
LHD 1	28.05	8.55	0.49	0.15	28.54	8.70
LHD 5-6	27.50	8.38	0.47	0.14	27.97	8.53
LHD 7	27.75	8.46	0.46	0.14	28.21	8.60
LHD 8	29.08	8.86	0.43	0.13	29.51	8.99
LPD 4	23.21	7.07	0.43	0.13	23.64	7.21
LPD 17	23.40	7.13	0.58	0.18	23.98	7.31
LSD 41	21.38	6.52	0.54	0.16	21.92	6.68
LSD 49	21.30	6.49	0.52	0.16	21.82	6.65
MCM 1	15.15	4.62	0.28	0.09	15.43	4.70
MHC 51	11.42	3.48	0.42	0.13	11.84	3.61
AE 26	28.06	8.55	0.48	0.15	28.54	8.70
AFS 1	27.50	8.38	0.45	0.14	27.95	8.52
AFS 8	25.37	7.73	0.47	0.14	25.84	7.88
AGOS 19	24.83	7.57	0.10	0.03	24.93	7.60
AGS 60	19.00	5.79	0.53	0.16	19.53	5.95
AH 19	32.82	10.00	0.56	0.17	33.38	10.17
AK 3000	32.88	10.02	0.50	0.15	33.38	10.17
AK 3005	33.50	10.21	0.42	0.13	33.92	10.34
AK 3008	32.06	9.77	0.66	0.20	32.72	9.97
AKE 1	31.82	9.70	0.64	0.20	32.46	9.89
AKR 287	36.79	11.21	0.36	0.11	37.15	11.32
AKR 295	37.00	11.28	0.45	0.14	37.45	11.41
AKR 296	37.00	11.28	0.36	0.11	37.36	11.39
AKR 300	37.00	11.28	0.43	0.13	37.43	11.41
AKR 310	37.00	11.28	0.42	0.13	37.42	11.41
AOT 187	36.00	10.97	0.56	0.17	36.56	11.14
AOE 6	40.67	12.40	0.50	0.15	41.17	12.55
ARC 7	25.98	7.92	0.48	0.15	26.46	8.07
ARS 50	16.92	5.16	0.50	0.15	17.42	5.31
AS 39	31.50	9.60	0.36	0.11	31.86	9.71

Table 5-5 U.S. Navy Vessels Squat @ 10 Knots

SHIP CLASS	MAX STATIC	DRAFT	10 KNOTS UNDERWAY	SINKAGE	10 KNOTS UNDERWAY	DRAFT
	(ft)	(m)	(ft)	(m)	(ft)	(m)
CVN 65	38.95	11.87	1.94	0.59	40.89	12.46
CVN 68	40.21	12.26	2.06	0.63	42.27	12.88
CVN 71	42.72	13.02	2.04	0.62	44.76	13.64
CVN 76	42.61	12.99	2.01	0.61	44.62	13.60
CVN 77	40.83	12.45	2.35	0.72	43.18	13.16
CG 47	34.07	10.38	0.69	0.21	34.76	10.59
DDG 51	33.64	10.25	0.91	0.28	34.55	10.53
DDG 79	33.54	10.22	0.93	0.28	34.47	10.51
DDG 1000	28.60	8.72	1.58	0.48	30.18	9.20
FFG 7	26.13	7.96	0.50	0.15	26.63	8.12
LCS 1	14.07	4.29	3.87	1.18	17.94	5.47
LCS 2	14.19	4.33	1.31	0.40	15.50	4.72
SSBN 726	36.37	11.09	0.83	0.25	37.20	11.34
SSGN 726	36.33	11.07	0.83	0.25	37.16	11.33
SSN 688	31.92	9.73	1.38	0.42	33.30	10.15
SSN 21	34.09	10.39	1.62	0.49	35.71	10.88
SSN 23	34.60	10.55	1.32	0.40	35.92	10.95
SSN 774	32.18	9.81	1.64	0.50	33.82	10.31
LCC 19	31.84	9.70	1.59	0.48	33.43	10.19
LHA 1	28.65	8.73	2.27	0.69	30.92	9.42
LHA 6	31.65	9.65	1.88	0.57	33.53	10.22
LHD 1	28.05	8.55	2.26	0.69	30.31	9.24
LHD 5-6	27.50	8.38	2.18	0.66	29.68	9.05
LHD 7	27.75	8.46	2.17	0.66	29.92	9.12
LHD 8	29.08	8.86	2.03	0.62	31.11	9.48
LPD 4	23.21	7.07	2.05	0.62	25.26	7.70
LPD 17	23.40	7.13	2.62	0.80	26.02	7.93
LSD 41	21.38	6.52	2.56	0.78	23.94	7.30
LSD 49	21.30	6.49	2.55	0.78	23.85	7.27
MCM 1	15.15	4.62	1.43	0.44	16.58	5.05
MHC 51	11.42	3.48	2.23	0.68	13.65	4.16
AE 26	28.06	8.55	2.16	0.66	30.22	9.21
AFS 1	27.50	8.38	1.99	0.61	29.49	8.99
AFS 8	25.37	7.73	2.12	0.65	27.49	8.38
AGOS 19	24.83	7.57	1.98	0.61	26.81	8.17
AGS 60	19.00	5.79	2.41	0.73	21.41	6.53
AH 19	32.82	10.00	2.48	0.76	35.30	10.76
AK 3000	32.88	10.02	2.25	0.69	35.13	10.71
AK 3005	33.50	10.21	1.98	0.61	35.48	10.81
AK 3008	32.06	9.77	2.93	0.89	34.99	10.66
AKE 1	31.82	9.70	2.81	0.86	34.63	10.56
AKR 287	36.79	11.21	1.64	0.50	38.43	11.71
AKR 295	37.00	11.28	1.98	0.61	38.98	11.88
AKR 296	37.00	11.28	1.63	0.50	38.63	11.77
AKR 300	37.00	11.28	1.93	0.59	38.93	11.87
AKR 310	37.00	11.28	1.89	0.57	38.89	11.85
AOT 187	36.00	10.97	2.44	0.74	38.44	11.72
AOE 6	40.67	12.40	2.20	0.67	42.87	13.07
ARC 7	25.98	7.92	2.17	0.66	28.15	8.58
ARS 50	16.92	5.16	2.48	0.76	19.40	5.91
AS 39	31.50	9.60	1.61	0.49	33.11	10.09

Table 5-6 U.S. Navy Vessels Squat @ 15 Knots

SHIP CLASS	MAX STATIC	DRAFT	15 KNOTS UNDERWAY	SINKAGE	15 KNOTS UNDERWAY	DRAFT
	(ft)	(m)	(ft)	(m)	(ft)	(m)
CVN 65	38.95	11.87	5.23	1.59	44.18	13.47
CVN 68	40.21	12.26	5.07	1.55	45.28	13.80
CVN 71	42.72	13.02	5.41	1.65	48.13	14.67
CVN 76	42.61	12.99	5.34	1.63	47.95	14.62
CVN 77	40.83	12.45	6.65	2.03	47.48	14.47
CG 47	34.07	10.38	2.15	0.66	36.22	11.04
DDG 51	33.64	10.25	2.80	0.85	36.44	11.11
DDG 79	33.54	10.22	2.81	0.86	36.35	11.08
DDG 1000	28.60	8.72	4.73	1.44	33.33	10.16
FFG 7	26.13	7.96	1.92	0.59	28.05	8.55
LCS 1	14.07	4.29	-	-	-	-
LCS 2	14.19	4.33	2.57	0.78	16.76	5.11
SSBN 726	36.37	11.09	4.54	1.38	40.91	12.47
SSGN 726	36.33	11.07	4.49	1.37	40.82	12.44
SSN 688	31.92	9.73	3.70	1.13	35.62	10.86
SSN 21	34.09	10.39	4.29	1.31	38.38	11.70
SSN 23	34.60	10.55	3.64	1.11	38.24	11.66
SSN 774	32.18	9.81	4.28	1.30	36.46	11.11
LCC 19	31.84	9.70	4.56	1.39	36.40	11.09
LHA 1	28.65	8.73	6.71	2.05	35.36	10.78
LHA 6	31.65	9.65	5.40	1.65	37.05	11.29
LHD 1	28.05	8.55	6.73	2.05	34.78	10.60
LHD 5-6	27.50	8.38	6.57	2.00	34.07	10.38
LHD 7	27.75	8.46	6.57	2.00	34.32	10.46
LHD 8	29.08	8.86	6.18	1.88	35.26	10.75
LPD 4	23.21	7.07	6.57	2.00	29.78	9.08
LPD 17	23.40	7.13	7.90	2.41	31.30	9.54
LSD 41	21.38	6.52	8.18	2.49	29.56	9.01
LSD 49	21.30	6.49	8.05	2.45	29.35	8.95
MCM 1	15.15	4.62	3.59	1.09	18.74	5.71
MHC 51	11.42	3.48	5.20	1.58	16.62	5.07
AE 26	28.06	8.55	6.21	1.89	34.27	10.45
AFS 1	27.50	8.38	5.83	1.78	33.33	10.16
AFS 8	25.37	7.73	6.36	1.94	31.73	9.67
AGOS 19	24.83	7.57	4.18	1.27	29.01	8.84
AGS 60	19.00	5.79	7.38	2.25	26.38	8.04
AH 19	32.82	10.00	6.80	2.07	39.62	12.08
AK 3000	32.88	10.02	6.29	1.92	39.16	11.94
AK 3005	33.50	10.21	5.68	1.73	39.18	11.94
AK 3008	32.06	9.77	7.75	2.36	39.81	12.13
AKE 1	31.82	9.70	7.44	2.27	39.26	11.97
AKR 287	36.79	11.21	4.69	1.43	41.48	12.64
AKR 295	37.00	11.28	5.57	1.70	42.57	12.98
AKR 296	37.00	11.28	4.82	1.47	41.82	12.75
AKR 300	37.00	11.28	5.45	1.66	42.45	12.94
AKR 310	37.00	11.28	5.37	1.64	42.37	12.91
AOT 187	36.00	10.97	6.52	1.99	42.52	12.96
AOE 6	40.67	12.40	5.82	1.77	46.49	14.17
ARC 7	25.98	7.92	6.39	1.95	32.37	9.87
ARS 50	16.92	5.16	8.12	2.47	25.04	7.63
AS 39	31.50	9.60	4.85	1.48	36.35	11.08

Figure 5-9 Increase in Vertical Sinkage Due to Wave Action

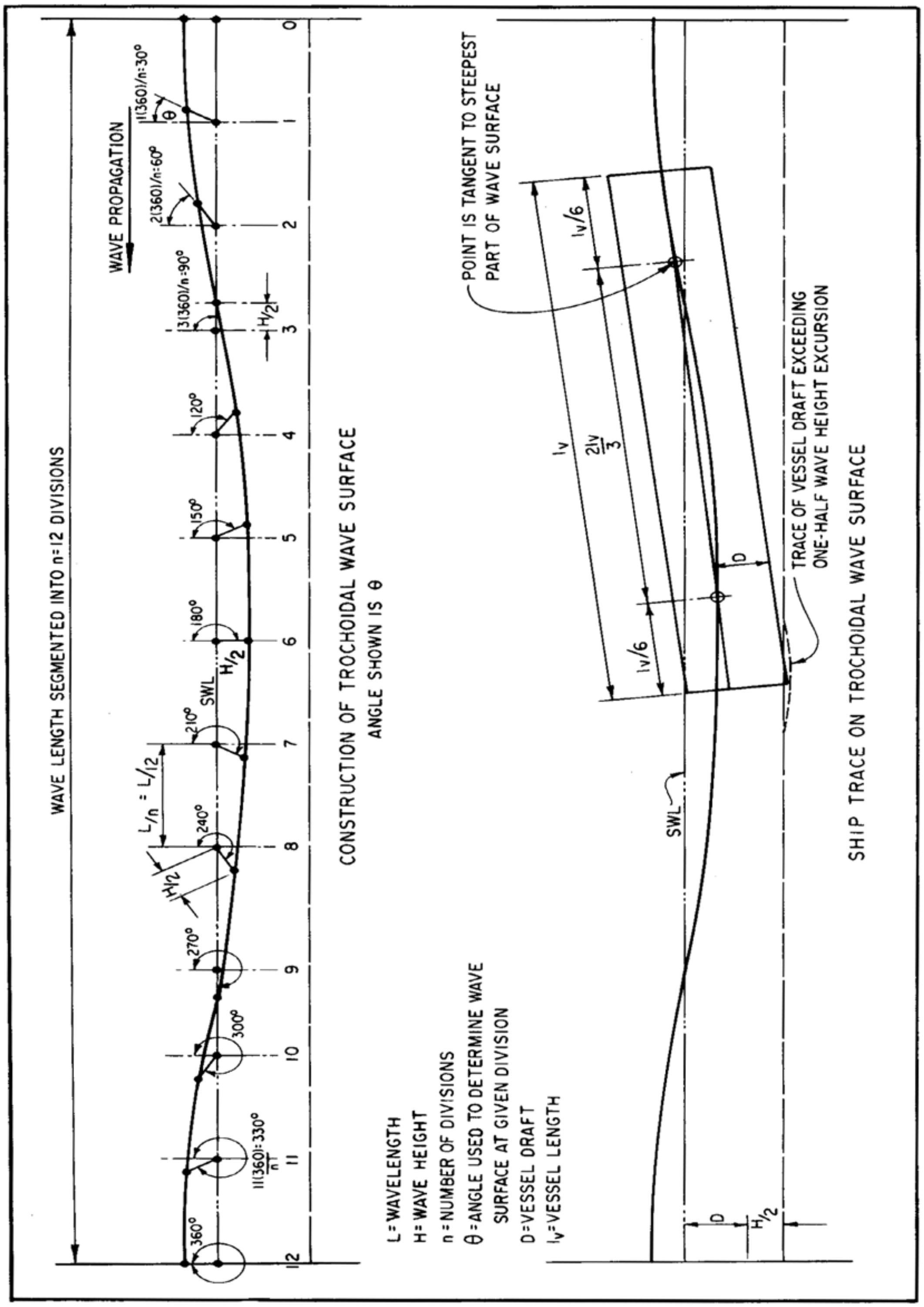
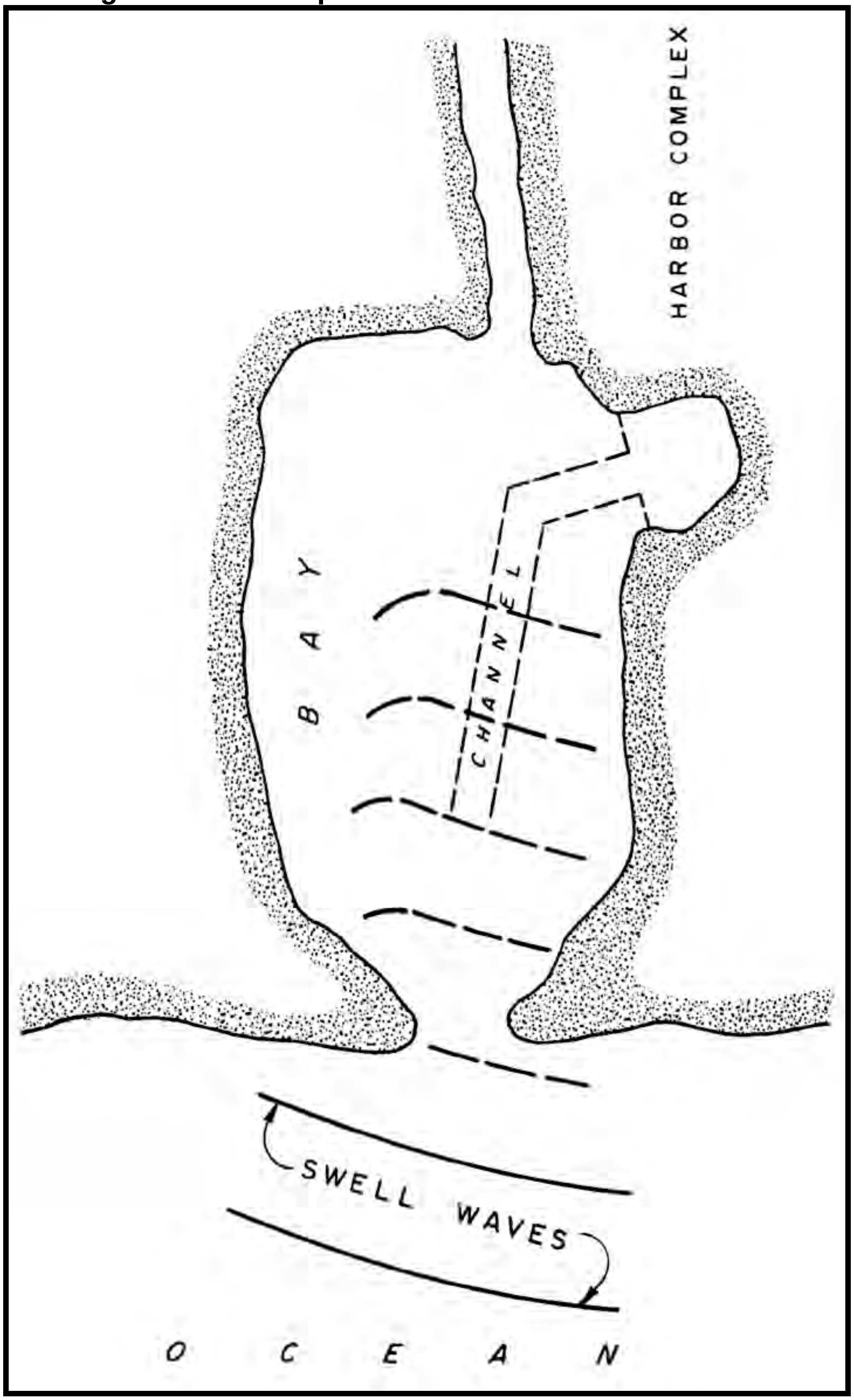


Figure 5-10 Example of Semi-Protected Water Area



5-6.1.2.4 Underkeel Clearance.

Factors in addition to those presented above that must be considered in determining the clearance between the maximum vessel draft and the bottom are vessel operation, type of bottom material, and a factor of safety. Bottom material is an important consideration when accounting for underkeel clearance. Soft bottom material can be displaced and shoaled by passing vessel propeller action. Hard bottoms with sharp outcroppings can cause severe damage to vessels upon grounding. In active sedimentation areas, bottom shoals can also occur during relatively short periods of storm activities. The following shall be used for underkeel clearance:

Table 5-7 Underkeel Clearance

Vessel Type	Berth Soft/Hard	Turning Basin Soft/Hard	Inner Channel Soft/Hard
Submarine[1]	2'/3'[3]	2'/3'	2'/3'
Surface Ship[2]	6'/6'[4]	2'/'3'	2'/3'
MSC Ship[2]	6'/6'[4]	3'/3'	3'/3'

[1] PEO-SUB ltr Ser 07T236/0436 of 4 Oct 2007
[2] NAVSEA ltr Ser 05D/058 of 5 Feb 09
[3] "X'/X' represents soft/hard bottom typical
[4] Underkeel clearance at berth for Surface Ship and MSC Ship is based upon Mean Low Water (MLW) datum

5-6.1.2.5 Depth Determination.

In all cases, with the exception of the instance noted in Table 5-7, project depth shall be determined with respect to Mean Lower Low Water (MLLW) datum Based upon the foregoing, project depth shall be determined by selecting the "controlling" design vessel for the project location and using the following procedure:

- Obtain maximum static draft (Table 5-3)
- Provide additional draft due to freshwater if applicable (See Figure 5-3)
- Provide additional draft due to ship list if applicable (See Figure 5-3)
- Provide additional draft due to squat if applicable (Tables 5-4,5,6)
- Provide additional draft due to heel (experienced) during ship turn if applicable
- Provide additional draft due to wave motion if applicable
- Provide underkeel clearance (Table 5-7)

Above procedure shall be followed for each harbor element under consideration, i.e. berth, turning basin, inner channel, and outer channel. The following examples are provided:

Example 1:

Determine project depth for DDG-51 class ship at a berth at Navsta Norfolk
Maximum static draft = 33.64 feet
Freshwater inlet = 0.5 feet (additional draft due to freshwater inlet)
List, squat, heel, wave motion not applicable.
Soft bottom – underkeel clearance = 6 feet

Project Depth:	Maximum Static Draft	33.64 feet	(Table 5-3)
	Salinity	0.5 feet	(Estimated)
	Underkeel Clearance	+ 6.00 feet	(Table 5-7)
		40.14 feet MLW	

Example 2:

Determine project depth for LHA-1 class ship in a turning basin at Navsta San Diego
Maximum static draft = 28.65 feet
Freshwater, list, squat, heel, wave motion not applicable.
Soft bottom – underkeel clearance = 2 feet

Project Depth:	Maximum Static Draft	28.65 feet	(Table 5-3)
	Underkeel Clearance	+ 2.00 feet	(Table 5-7)
		30.65 feet MLLW	

Example 3:

Determine project depth for T-AKE1 class ship transiting inner channel at 5 knots at Navsta San Diego
Underway draft @ 5 knots = 32.46 feet (Table 5-4, includes maximum static draft and squat)
Freshwater, list, heel, wave motion not applicable.
Soft bottom – underkeel clearance = 2 feet

Project Depth:	Underway Draft @ 5 knots	32.46 feet	(Table 5-4)
	Underkeel Clearance	+ 2.00 feet	(Table 5-7)
		34.46 feet MLLW	

5-6.1.3 Aircraft Carrier Facility Special Requirements.
Dredge depth requirements for Nimitz Class Aircraft Carriers are summarized below.

5-6.1.3.1 Water Depth Requirements
Water depth requirements for Nimitz Class Aircraft Carriers transiting to and moored at homeports, ports of call, and shipyards are delineated in COMNAVSEASYSCOM ltr 4790PMS312 Ser 05-045 dtd 11 Jan 05, included as Appendix B. It specifies the minimum water depth required while the ship is in the waterway; however, it does not specify dredge depth requirements. The minimum water depth required to operate carriers in inner channels and turning basins on the way to and at piers at home ports is between 49 and 50 ft (14.9 and 15.24 m) depending on harbor salinity. These numbers

are similar for ports of call. Due to the reduced draft when visiting shipyards, the minimum water depth required to operate carriers in inner channels and turning basins on the way to and at piers at shipyards is between 46 and 47 ft (14 and 14.3 m) depending on harbor salinity. Applying these requirements to determine dredge depths requires additional port specific information. Appendix B specifies the following:

- “The dredging project depth can be traded off with tides to obtain the necessary water depth in inner channels and turning basins with the corresponding operational conditions." Therefore, planners should consider channel accessibility and operational restrictions imposed when selecting a design water level above the extreme low water. To facilitate uniform application of the minimum water depth requirement in referenced letter, formal criteria guidance is required.

- “Shallower and/or narrow channels and/or higher speeds will require greater allowance for squat.” Since narrow channel widths and greater speeds result in greater ship sinkage during transit (squat), and thus deeper water, planners should also include these effects.

- “Port specific fouling clearance studies can be performed if requested and funded” to possibly reduce the 6.0 ft (1.83 m) fouling clearance criteria. The clearance criteria was derived from condenser fouling studies on stationary ships berthed at NAVSTA Norfolk, VA in 1980. Locations that exhibit more or less potential for fouling may require more or less clearance to prevent it.

- “Ship motions analyses of the remaining home ports and shipyards will be completed...after receipt of funding.” The motion analyses that NAVFAC prepared for Mayport and San Diego predicted days of access and generated nomographs for other locations. For channels subjected to significant waves, engineers and planners must evaluate these wave effects on ship motions.

- Therefore, as provided for in Appendix B, facility engineers and planners should determine dredge depth requirements by including the additional considerations of design water level, channel width and ship speed impacts, dynamic effects of sea chest intake fouling, and wave effects. Additionally, they should include effects from sedimentation and dredging tolerances.

5-6.1.3.2 Consistency

The requirements provide consistency and reliability in the determination of acceptable dredge depths for channels and berths used by active Nimitz class aircraft carriers. The NAVFAC LANT Engineering Criteria and Programs Office will address reserve status condition of CVNs when required. Deviation from minimum criteria requires a waiver from the NAVFAC LANT Engineering Criteria and Programs Office which will be coordinated with cognizant Major Claimants, Naval Sea Systems Command, and Chief of Naval Operations.

5-6.1.3.3 Waterway Type

Ideally, engineers and planners should base ship channel designs on physical model testing, risk analysis, and ship simulator analysis. However, time and funding constraints may prevent this process. In any event, the requesting activity should determine the required dredge depths for Military Construction Projects. Dredge depth requirements for Nimitz class aircraft carriers depend on the type of waterway to be dredged. Four categories exist based on the magnitude of wave-induced and speed-induced ship movement:

- Outer channels – entrance channels or waterways subject to significant wave action, that is, wave energy resulting in vertical ship motions greater than 0.5 ft (0.15m) under design conditions.

- Inner channels – interior protected channels or waterways subject to minimal wave action, that is, wave energy resulting in vertical ship motions less than 0.5 ft (0.15m) under design conditions.

- Berths – water areas where ship velocity approaches zero, such as anchorages, slips, and pier and wharf berths that are subject to minimal wave action under design conditions; generally includes turning basins except as noted below.

- Special berths – defined as berths subject to significant wave action under design conditions.

5-6.1.3.4 Definitions

The following definitions apply:

- Datum – the horizontal plane from which the dredge depth requirement is referred, normally the local tidal datum of Mean Lower Low Water (MLLW).

- Design depth – the distance below the datum that must be maintained for safe navigation and berthing, also called the advertised, nominal, or project depth. This depth usually appears on Navigational Charts.

- Contract depth – the distance below the datum that is initially dredged by the contract and includes advanced maintenance dredging requirements but not the dredging tolerance (allowable overdepth). Also called the required depth, it is the depth noted on the DD-1391 Project Documentation and indicates the minimum depth required under the dredging contract.

- Permitted depth – the distance below datum to the lowest depth authorized by the regulatory agencies and normally includes the dredging tolerance (allowable overdepth). Planners and engineers should use this depth to determine estimated dredging quantities.

5-6.1.3.5 Parameters

Determine required dredge depths using sound engineering practice. The design depth is determined by summing the following parameters:

- Minimum water depth requirement – the minimum water depth that must be available for safe operation. For existing locations, use Appendix B implemented as follows for design water level, squat, ship motions, and underkeel clearances. For locations not addressed in the Appendices, contact the NAVFAC LANT Engineering Criteria and Programs Office for assistance.

- Design water level – the distance above the datum from which the dredge depth is calculated. For outer channels – use 0 f (0 m). The design water level should equal the datum to provide enough water depth and ensure that the ship can transit at all times. For inner channels and turning basins – use a water level that ensures safe passage to the berth or basin. This water level should be selected by the Activity based on optimizing cost and operation. Ship operators generally accept some minor operational restrictions and transit shallow channels at mid to high tide levels. Therefore, the design water level should be selected so that the carrier can transit from deep water to the berth, or vice versa, as frequently as expected without encroaching on the minimum water depth requirement noted in Appendix B. The user should identify for the planner the expected ship transit speed and desired days of accessibility, realizing that slow transits at low tide levels result in excessive dredge depths.

An example of this procedure is as follows:

- Determine level of accessibility; e.g. minimum of 339 days per year of access to homeports and 300 days per year of access to shipyards and ports of call. These accessibility levels equate to operational restrictions of approximately 2 consecutive days per month of encroachment on the underkeel clearance for homeports and 5 consecutive days per month for shipyards and ports of call, respectively.

- Based on local traffic and regulations, assume an average ship speed through channel; e.g. 5 knots.

- Using assumed transit speed and navigational charts, calculate the time required to accomplish the transit from the outer channel to the turning basin or berth.

- Using the calculated transit time, days of accessibility, and the charts in the Appendices, determine the channel depth requirement.

- Subtract the water depth requirement from the channel depth requirement to obtain the design water level. This number will usually be negative and thus result in a design water level above MLLW.

For all berths, except turning basins – use 0 ft (0 m). Since 6 ft (1.83 m) of clearance is provided, as noted later, the design water level may equal the datum (MLLW)

- Squat – the downward displacement of a vessel while underway. Assume no squat in berths. Appendix B incorporates squat for infinitely wide channels with ship speeds equal to or less than 10 knots. Ship squat greatly increases when CVNs transit channels less than 600 ft (182.88 m) in width or move at speeds faster than 10 knots. To determine squat for conditions other than those addressed in Appendix B, use the method contained in the paragraph titled “Squat” of this manual. All channels used by aircraft carriers in the United States, except the Southern Branch, Lower Reach, of the Elizabeth River, Norfolk, VA (450 ft (137.2 m)) at narrowest point) and the Entrance Channel, Mayport, FL (500 ft (152.4m) at narrowest point), are wide enough to be considered infinitely wide. For these narrow channels, the squat increases by 2 ft (0.6 m) The water depth requirement determined above should be modified to incorporate any difference in calculated squat.

For outer channels, assume ship speed of 15 knots. For inner channels, base on local traffic and regulations, but as a minimum, assume an average ship speed through channel of 10 knots and include the effects of narrow channels as noted above. For berths and special cases, assume ship speed of zero.

- Ship motion -- vertical excursion of vessel from waves. Appendix C addresses ship motions only for San Diego and Mayport. For other locations, use nomographs in Appendix D. H_S is defined as the significant wave height. Each set of nomographs reflects the direction of the significant wave relative to the direction of the CVN in transit; i.e., Following Seas are collinear with and in the same direction of ship movement, Quartering Seas are those that approach the aft quarter of the ship at 45 degrees, Beam Seas impact broadside to the ship, Bow Seas are those that approach the forward quarter of the ship at 45 degrees, and Head Seas are collinear with but opposite to the ship movement. The wave height and period should be transformed to and through the channel entrance using local wave data or Army Corps of Engineers reports entitled, *Wave Information Studies of U.S. Coastlines*.

For outer channels, use H_s for periods greater than 10 seconds with a 6 days/month recurrence interval. Exclude hurricane waves. Here is an example: Determine the wave climatology using available data determine the significant wave height, direction, and period. Transform waves into harbor based on shoaling, refraction, and diffraction, etc. Then based on local traffic and regulations, assume an average ship speed through channel; e.g. 14 knots. Using the calculated wave climatology, assumed ship speed and the charts in Appendix C, determine the predicted vertical ship motion for all applicable directions. For inner channels and berths, use $H_s = 0$. For special cases, use H_s for periods greater than 10 seconds with a 25 yr recurrence interval, unless directed differently by the Activity. Include hurricane waves if the berth is expected to be occupied during that extreme event.

- Clearance – distance from the lowest point on the vessel to the design depth. For berths, turning basins, and inner channels, Appendix B incorporates a 6 ft (1.83 m) clearance to prevent ingestion of benthic biota. This clearance when combined with installed discharge diffusers reduces the possibility of condenser fouling. Additional studies may reduce the requirement and can be performed if funded. The planner must collect all historical data available regarding fouling of condensers to ascertain the extent of the problem. The NAVFAC LANT Engineering Criteria and Programs Office is available to assist in analyzing this data. Notwithstanding, at berths the planner must ensure that a minimum of 2 ft (0.6 m) of clearance is provided at Extreme Low Water. See Table 5-8 for other categories:

Table 5-8 Required Clearances

LOCATION CATEGORY	SOFT BOTTOM	HARD BOTTOM
1. Outer channel	3.0 ft (0.9 m) for 50 ft (15.24m) depth	4.0 ft (1.22 m) for < 52 ft (15.85 m) depth
	4.4 ft (1.34 m) for 54 ft (16.46 m) depth	
	5.5 ft (1.68 m) for > 58 ft (17.68 m) depth	5.5 ft (1.68 m) for > 58 ft (17.68 m) depth
2. Special berths	6 ft (1.82 m) (min.) coupled with discharge diffusers	6 ft. (1.82 m) (min.) coupled with discharge diffusers

5-6.1.3.6 Contract Depth

Determine the contract depth by adding the advanced maintenance dredging requirement to the design depth requirement. The advanced maintenance dredging is the additional depth to reduce life-cycle maintenance costs by decreasing the frequency of dredging. Base the quantity on the anticipated local channel sedimentation rates corresponding to the anticipated dredging cycle. Use a dredging frequency of not less than 3 years, but based on local conditions. Include a minimum of 1 ft advanced maintenance dredging to prevent contractor change orders for differing site conditions on future maintenance dredging contracts. This minimum also provides the Contracting Officer field flexibility if the contractor does not achieve the contract depth in spot locations. The dredging tolerance, or overdredge, is the additional depth below the contract depth paid for by the dredging contract. The contract permits this additional depth because of inaccuracies in the dredging process. It is normally either +1 or +2 feet (+.3 or +.6 m). Local conditions and anticipated dredging equipment may warrant a different value.

5-6.1.3.7 Permitted Depth

Determine the permitted depth by adding the dredging tolerance, or overdredge, to the contract depth. Material samples for environmental testing should be accomplished at least to this depth.

5-6.1.3.8 Responsibilities

OPNAVINST 11010.20E, Part 5 designates responsibilities of the Chief of Naval Operations, Lead Activities, Shore Activities having assigned water areas, Public Works Centers and Public Works Lead Activities, Naval Facilities Engineering Command and Engineering Field Divisions, and Major Claimants regarding dredging coordination.

- Lead Activities and Shore Activities having assigned water areas – determine dredge depth requirements for Nimitz class aircraft carriers following procedures contained herein.

- NAVFAC Headquarters NAVFAC LANT, NAVFAC PACand FECs

    - Provide technical advice and assistance to lead activities and shore activities having assigned water areas.

    - Plan, design, and construct channels in compliance with the guidance stated herein.

- NAVFAC LANT Engineering Criteria and Programs Office will provide technical advice and assistance to: lead activities, shore activities having assigned water areas and FECs.

5-6.1.4 Currents.

The influence of entrance widths on the magnitude of the current also influence harbor site selection. Entrance widths should be adequate to reduce currents to acceptable values. The maximum allowable current in an entrance channel is a function of the type of ship or ships to be accommodated. It is only under special circumstances that the current exceed 4 knots.

5-6.1.4.1 Nonconstricted Entrance

If the entrance is not constrictive, as is shown in Figure 5-11 and the following conditions are met:

- the basin is relatively short and deep; that is

$$\frac{l_b}{\left(\sqrt{gd}\right)(T)} \leq 0.05 \qquad (5\text{-}1)$$

where l_b = basin length [ft]
d = average basin depth [ft]

- the bay water area is relatively constant
- freshwater inflow is minimal, and
- the ocean tide is approximately sinusoidal, then a good approximation for the current velocity is

$$\overline{V}_m = \frac{2\pi a_s A_b}{A_c T} \qquad (5\text{-}2)$$

where $\overline{V}_m$ = average cross-section velocity at maximum tidal flow [ft/sec]
T = period of tide [sec]
A_b = surface area of basin [ft2]
A_c = cross section of opening at mean tide level [ft2]
a_s = ½ range of the ocean tide [ft]

The circumstance that the entrance is not constrictive, together with the condition in Equation 5-1, implies that the water surface in the bay fluctuates uniformly and equals the ocean tide.

5-6-1.4.2 Constricted Entrance

If the entrance is constrictive, as shown in Figure 5-12, it reduces the tide range in the bay, so the above expression will overestimate the tidal currents. If conditions outlined in the paragraph titled "Nonconstricted Entrance" are satisfied, the maximum current in the entrance can be determined from this equation:

$$\overline{V}_m = \frac{2\pi\, a_s\, A_b\, e}{A_c\, T} \qquad (5\text{-}3)$$

where $\overline{V}_m$ = average cross-section velocity at maximum tidal flow [ft/sec]
A_c = cross section of opening at mean tide level [ft^2]
T = period of tide [sec]
a_s = ½ range of the ocean tide [ft]
e = dimensionless factor which depends on coefficients K_1 and K_2; see Figure 5-13.

The coefficients K_1 and K_2 are defined as follows:

$$K_1 = \frac{a_s\, A_b\, F_c}{2\, l_b\, A_c} \qquad (5\text{-}4)$$

$$K_2 = \frac{2\,\pi}{T}\sqrt{\frac{l_c\, A_b}{g\, A_c}} \qquad (5\text{-}5)$$

where l_c = channel length [ft]
F_c = $k_{en} + k_{ex} + \left(\frac{f\, l_c}{4\,R}\right)$
k_{en} = entrance-loss coefficient (≈ 0.1)
k_{ex} = exit-loss coefficient (≈ 1.0)
f = Darcy-Weisbach friction factor (≈ 0.03)
R = hydraulic radius of inlet channel [ft]

K_l represents the ratio of the magnitude of the friction forces and inertia forces. K_2 is a measure of the magnitude of the inertia forces relative to the magnitude of the pressure (water-level) gradient.

Since the entrance is constrictive, the amplitude of the bay tide will differ from the amplitude of the tide range in the ocean. The bay-tide amplitude can be determined from the following relationship:

$$\frac{a_b}{a_s} = \varepsilon \qquad (5\text{-}6)$$

where ε = dimensionless factor which depends on the coefficients K_1 and K_2 (see Figure 5-14))
a_b = ½ range of bay tide [ft]

Note that for small values of K_1, which denotes large inertia forces, the value of ε is greater than one.

For irregular entrance channels, an effective channel length, l_c', can be used in place of l_c.

$$l_c' = \sum_{i}^{n} \left(\frac{\overline{R}}{R_n} \right) \left(\frac{\overline{A}_c}{A_n} \right)^2 \Delta X_n \qquad (5\text{-}7)$$

where:

$\overline{R}$ = average hydraulic radius of channel [ft]
$\overline{A}_c$ = average cross section of channel at mean tide level [ft^2]
R_n = hydraulic radius at each of n sections of equal length, ΔX_n, [ft]
A_n = cross section of channel at each of n sections of length, ΔX_n, [ft^2]

This analysis provides an estimate of the channel-inlet hydraulics applicable to design situations. However, if the conditions in paragraph the paragraph titled “Nonconstricted Entrance” are not satisfied, or if the current velocities are critical to the channel design, a more detailed analysis to include mathematical or physical-model simulation is necessary.

Figure 5-11 Basin With Nonconstricted Entrance

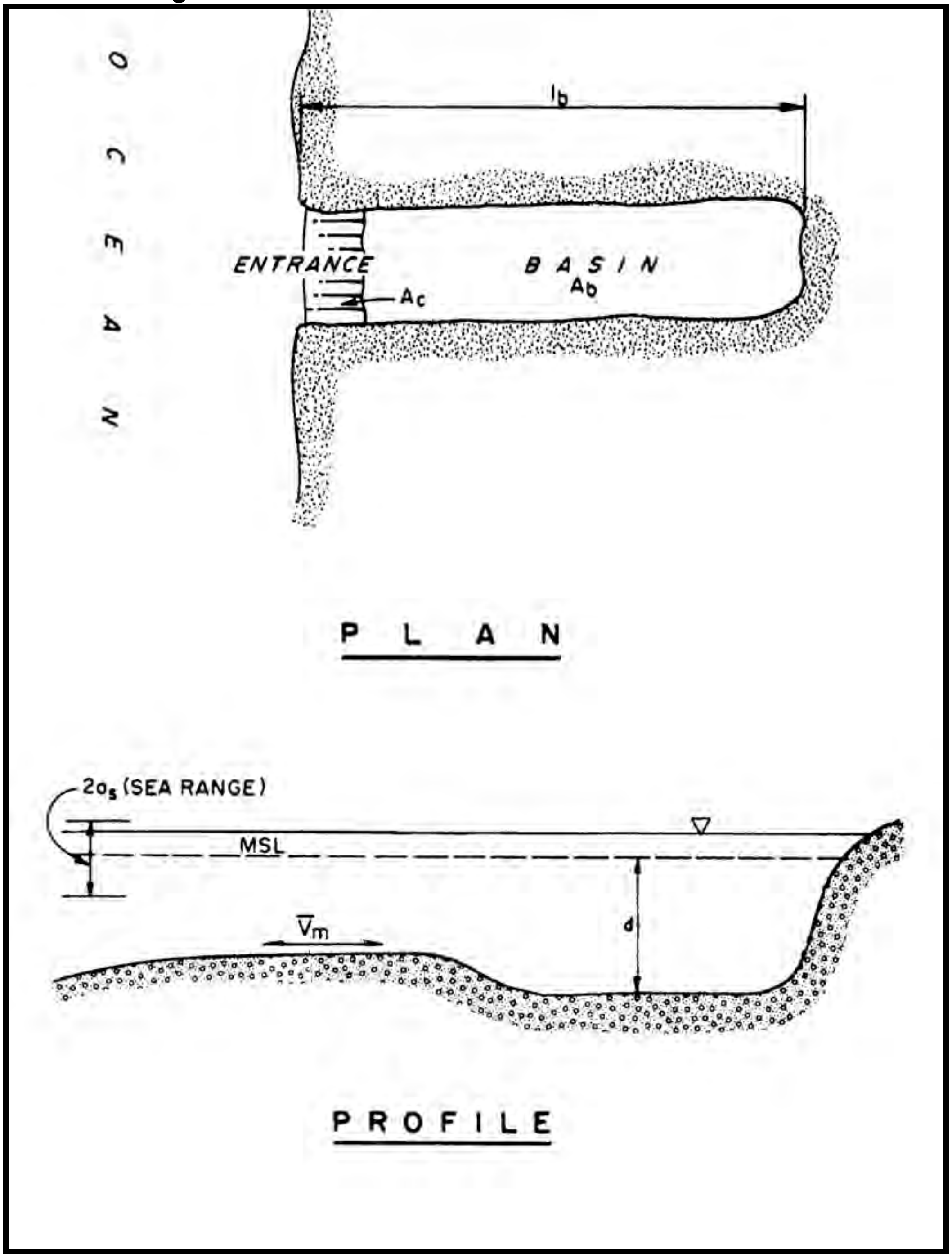


Figure 5-12 Sea-Inlet-Bay System (Sorenson, 1977)

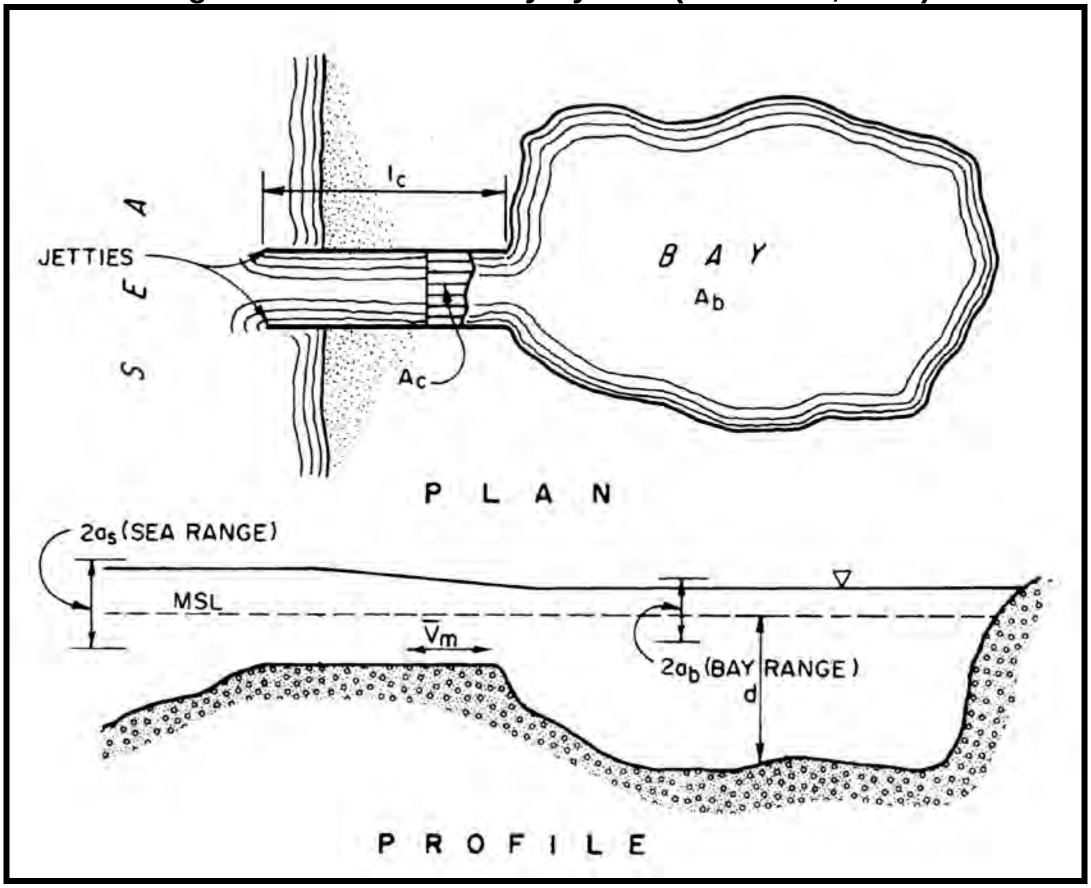


Figure 5-13 Dimensionless Maximum Velocity Versus K_1 and K_2 (Sorenson, 1977)

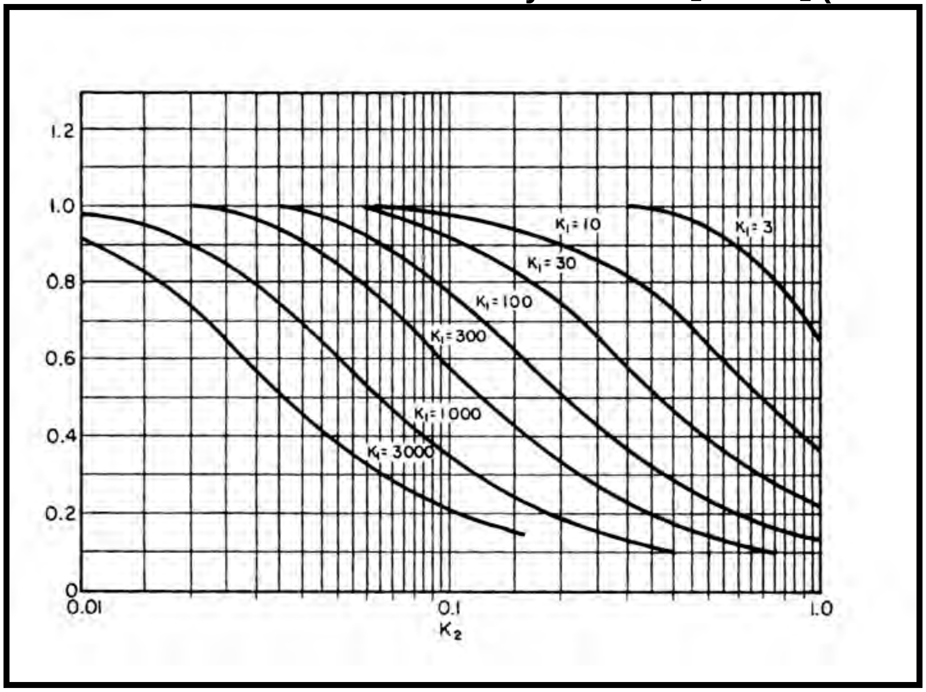
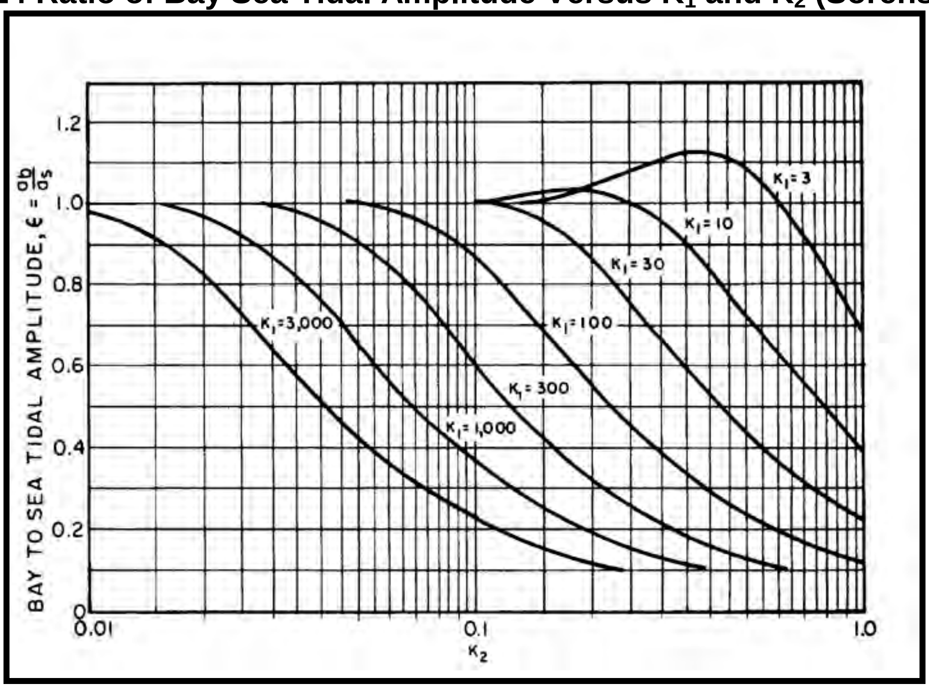


Figure 5-14 Ratio of Bay Sea Tidal Amplitude Versus K_1 and K_2 (Sorenson, 1977)



5-6.1.5 New Facilities in Existing Harbors.

Where new facilities are to be developed in an existing port, these facilities are subject to the same criteria as the development of a new port. Although some information is contained in CEM, additional information is required. Further topics worthy of consideration are basin depth, Navy ship size and draft, ordnance issues, and new types of Electronic Counter Measures (ECM), such as deperming and degaussing.

5-6.1.6 Submarine Facility Special Requirements.

The following submarine-specific requirements are provided:

5-6.1.6.1 Special Considerations.

Harbors designed to accommodate naval submarines of the various classes require special attention during the planning stage. Since surfaced submarines are relatively unwieldy deep-draft vessels with low freeboards, channels and other water areas to be used by submarines must be wide and deep enough for safe maneuvering.

5-6.1.6.2 Entrances and Channels.

Surfaced submarines are susceptible to wave action, surge and currents. Submarines require still water not only during docking and mooring operations, but also especially while negotiating the entrance and channels. Where moorings are located in estuaries and rivers subject to strong currents, or where entrances are subject to moderate to strong wave action, protection in the form of jetties or breakwaters should be provided.

5-6.1.6.3 Moorings.

Because of its “barrel” cross-section, a submarine’s beam underwater exceeds the width of its above-water superstructure. Thus, to safely moor submarines, an underwater fendering system is mandatory. Either submarine camels or hydropneumatic fenders are used to buffer the widest point of the vessel. The depth required depends upon the specific submarine. For example, if the draft of the submarine is 33 ft (10.1 m) the separator must extend a minimum of 18 ft (5.5 m) below the surface. Separators are normally between 30 and 50 ft (9.1 and 15.2 m) in length. Facilities for docking submarines and the design of deep draft separators are described in UFC 4-152-01. However, it should be remembered when designing harbors to accommodate submarines that ample storage area is needed for camels/fenders when not in use. Further, consideration should be given to water-area docking or mooring requirements for small craft servicing camels/fenders and other support structures.

5-6.1.6.4 Piers and Wharves.

Special requirements for the design of piers and wharves to accommodate submarines are contained in UFC 4-152-01. It is noted that in the absence of tug assist, the water approaches to submarine docking facilities should be designed to accommodate the largest vessel anticipated.

5-6.1.7 Dangerous Cargo Requirements.
Anchorages for tankers and similar vessels should be at least 500 ft (152.4 m) from adjacent berths, and located so that prevailing winds and currents carry spillage away from general anchorage and berthing areas.

Anchorages for vessels carrying explosives should be separated in accordance with quantity-distance relationships established in Ammunition and Explosives Safety Standards, DOD 5154.45 (DOD, 1978), which was superseded by DOD 6055.9 (DOD, 1997), and Ammunition and Explosives Ashore, NAVSEA OP 5 Vol 1, 6^{th} edition (NAVSEA, 1999).

5-6.1.8 Shipyard Special Requirements.
The following information is provided:

5-6.1.8.1 Mission and Requirements.
Harbors or sections of harbors designed as shipyards require special facilities and designs. Shipyard facilities consist of navigation basins, piers, drydocks, and backland. Outfitting or repair piers are generally arranged as in Figure 5-15c or f. Less commonly, where space permits, repair stations could be arranged along a marginal quay, as in i. Drydocks may be either the floating or graving type.

5-6.1.8.2 Waterways.
he shipyard portion of the harbor requires a channel sufficiently large to accommodate the largest vessel to be served by the shipyard. The water area fronting the shipyard should be a navigable basin in which the largest vessel is capable of maneuvering to and between repair facilities. It is essential that the shipyard has quiet water and be free of strong currents. Ships at repair are frequently in “hotel” status and short of the operating personnel needed to operate them in case currents should tear them loose from their moorings.

5-6.1.8.3 Piers.
Special considerations for repair and outfitting piers include crane rails for portal cranes, railroad tracks between crane rails, and special service piping to shipside galleries or service boxes. For pier design, refer to UFC 4-152-01.

5-6.1.8.4 Drydocks.
Drydocks are of two basic types: floating and graving. Floating drydocks may be moved from place to place and are suitable for servicing smaller ships and submarines. A floating drydock must be moored or anchored in a location where the water is considerably deeper than the draft of the ships it serves, and it must have access to the shore for supplies and utilities. A staging and laydown area alongside the drydock is required to provide operational support.

A graving drydock is a permanently placed facility dug into the embankment. Such drydocks are usually equipped with portal cranes that travel around the perimeter of the dock and are surrounded by service and laydown areas for large ship parts and equipment. Space along the quay near the drydock or other moorage and clear of vessels maneuvering into the dock is required for storage of the drydock's caisson gate. For all types of drydocks, keel blocks for the various vessels served must be stored nearby.

5-6.1.8.5 Ancillary Facilities.
Additional facilities and water area should be allocated for anchorage or moorage of ships awaiting repair service and for tugboats and fireboats. These facilities and areas may not be required within the shipyard limits if they are available nearby in the harbor.

5-6.1.8.6 Land Needs.
Land area should be allocated to shipyard use in sufficient quantity to provide for rail or highway access, including onsite storage of vehicles and goods required for shipyard operations. Shop and office buildings, storage areas, and laydown spaces should be arranged to provide the most efficient flow of work and personnel within the facility consistent with the available space and mission of the shipyard. Figure 5-16 is an example of the space allocation and arrangement of a sample shipyard.

5-6.1.9 Degaussing and Deperming Requirements.
NAVORD OP 2706, Introduction to Degaussing (NAVORD, 1960) and NAVSEASYSCOM SS475-AD-MMD-010/MAG FAC, Magnetic Silencing Facilities Description and Installation of Permanent and Portable Equipment (NAVSEASYSCOM, 1980) cover the two methods used in magnetic silencing: magnetic compensation (degaussing coils) and magnetic treatment (deperming). Deperming which reduces the permanent magnetization accumulated by a ship during construction and operation complements the use of opposing magnetic fields in degaussing.

Figure 5-15 Types of Berthing Layouts

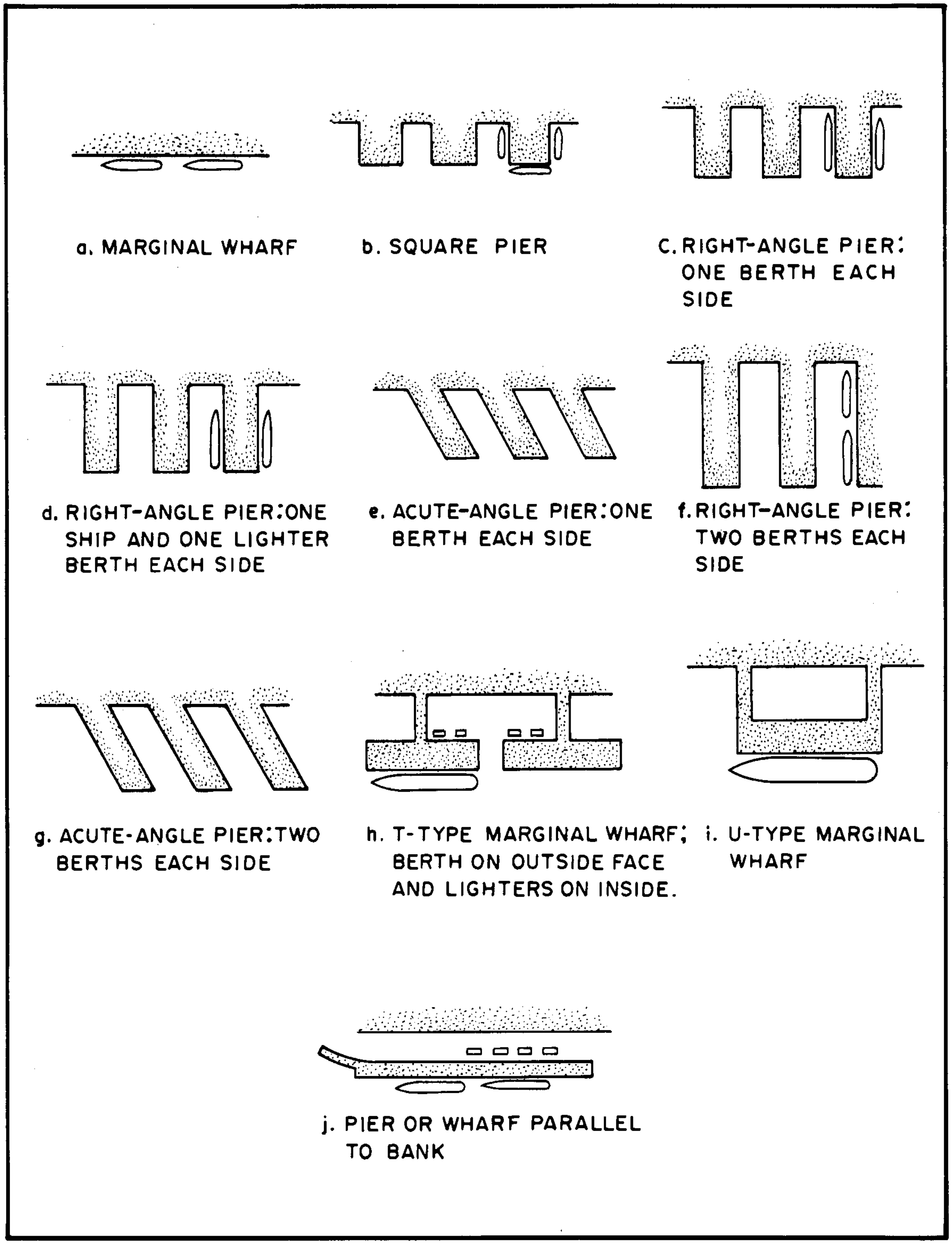
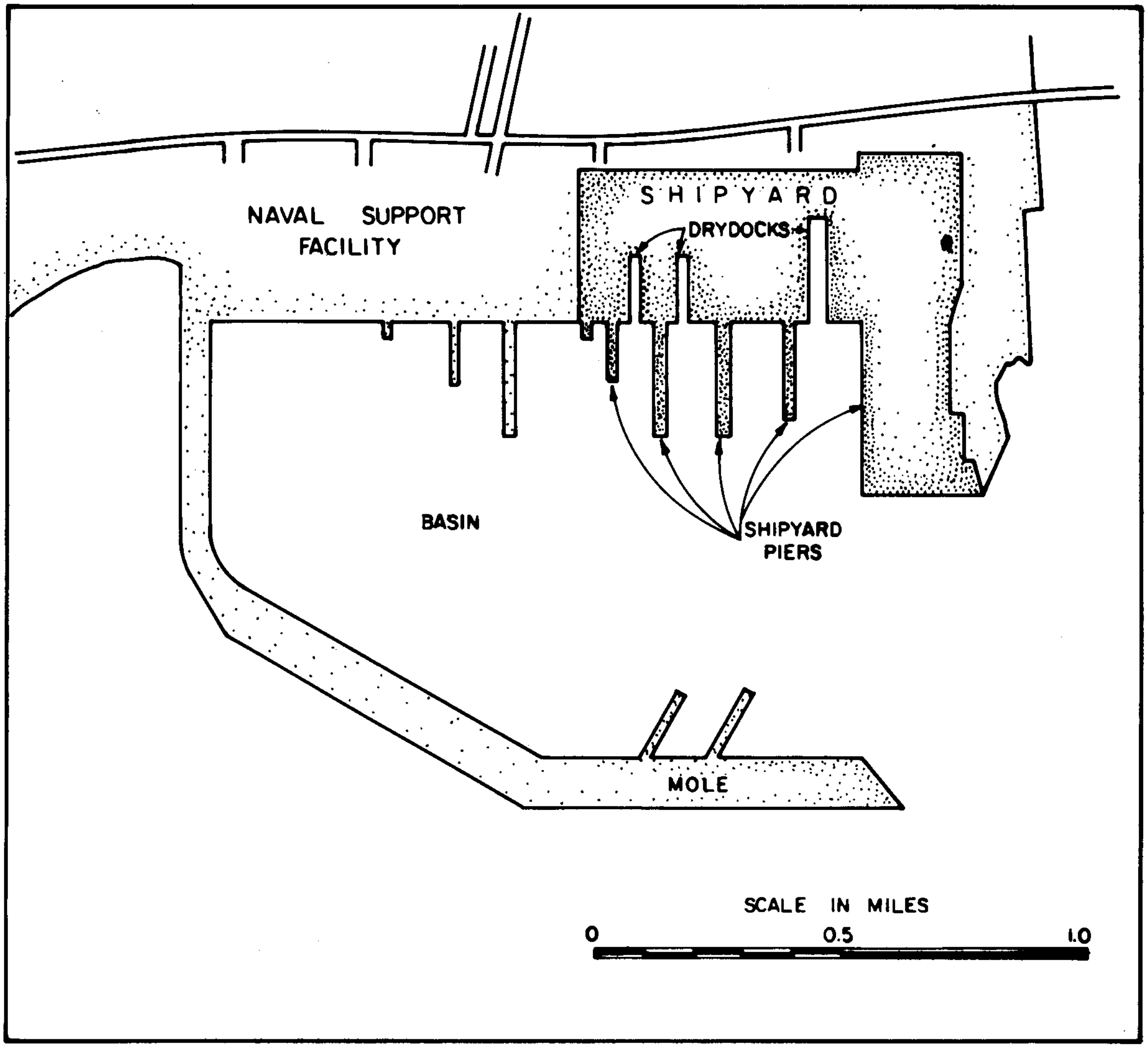


Figure 5-16 Sample Shipyard Layout



5-6.1.9.1 A steel object under the magnetic forces of the earth will itself become polarized and set up a magnetic field of its own. A steel-hulled ship will become a huge floating magnet itself. In addition, there are induced magnetic signatures caused by inside electronics and motors. This magnetic field makes the ship vulnerable to magnetically sensitive mines or other magnetic influence detecting devices.

5-6.1.9.2 The science of degaussing deals with reducing the ship's magnetic field, or signature. Normal deperming techniques based on alternate reversals of ship polarity are used to reduce the ship's permanent structural hull signature whereas equipment induced signatures are controlled by interior degaussing cables. In order to determine the characteristics of a ship's magnetic field it is necessary to make periodic measurements of the field, referred to as "ranging". The primary type of degaussing/magnetic silencer range consists of a linear pattern of instrumentation tubes containing magnetometers embedded in the channel bottom.

5-6.1.9.3 There are three depth classifications of check ranges based on class of ship:

- Minesweeper – shallow (30 ft (9.1 m))
- Medium depth (55 ft (16.8 m)); and
- Deep (85 ft (25.9 m))

There are now 6 Forward Area Combined Degaussing and Acoustic Ranges (FACDAR) for forward deployed areas where no permanent ranges are available.

5-6.1.9.4 In order to deal with magnetic silencing facilities for degaussing and deperming purposes, it is necessary to design with dredging in mind. If the facilities are already in place, a dredging method, which will not impact the facilities, must be chosen.

5-6.1.10 Seismic Loading.

Coastal projects constructed in regions known to experience seismic activity may need to consider potential impacts related to ground deformation and severe liquefaction. Seismic loading may also be a concern in design of confined dredge material berms (subaerial) and caps (subaqueous) where liquefaction could release contaminated sediments. CEM Section VI-3-4 provides further guidance. Areas of seismic activity may produce tsunamis. Designs should also consider the potential for tsunamis and their assoiciated effects, i.e. extreme tide ranges and surges.

5-6.1.11 Ice Loading.

At some latitudes, fresh water lakes and coastal regions experience annual ice formation during portions of the year. Thus, in project planning stages, it is important to determine if the presence of ice adversely impacts the project functionality; furthermore, during design, it is important to consider the effect that ice loads and impacts might have on individual coastal project elements. CEM Sections VI-3-5, and EM 1110-2-1612, Ice Engineering**,** provide further guidance. Chapter 10 of the Report on Ship Channel Design provides a cursory view of design of channels with ice cover, locks, erosion and sediment movement, and vibration and mitigation of ice problems in channels (ASCE, 1993).

5-6.1.12 Debris Entering Harbors.
Marine debris entering harbors is composed of a broad range of materials, which include litter (e.g., aluminum cans, plastic pieces, glass pieces, and cigarette butts), waste (e.g., medical, galley, operational, and sewage), and wood from branches from trees and other inland vegetation. As such, it can interfere with harbor operations. Assessment and strategies to reduce marine debris in the coastal and ocean environment can be accomplished by managing uses and activities that contribute to the entry of such debris. Existing regulations include, but are not limited to, prohibiting littering and dumping of debris and discharging pollutants in near shore waters. Harbor activities are also subject to the same rules and statutes relating to debris control.

5-6.1.13 Drydocks.
This subject is covered in detail in UFC 4-213-10.

5-6.2 Development of a Navigation Project.
Often a navigation project requires one or more engineered structures to accomplish its objectives. Structures can serve a variety of purposes. However, their presence also establishes a major hazard for vessels. Hence, a navigation structure must be designed with regard to several functional concerns. Basic types of structures and functions involved in navigation projects are briefly discussed in CEM Section V-5. Sediment processes and management at inlets and harbors are discussed in CEM Section V-6. Detailed guidance on structure design is given in CEM Section VI.

5-6.2.1 Defining Fleet Requirements.

- All dredging activities must be coordinated with the NAVFAC Criteria Office.
- The activity should coordinate the following issues with the major claimant: classes of ships used at the facility, access frequency, days of harbor access required, and function performed in the harbor,
- Most harbors cannot design for 100 percent accessibility, so the amount of risk the claimancy wants to take on should be addressed.
- Seakeeping issues in the channel shall also be addressed.
- Check for criteria of thickness of ice; refer to paragraph titled “Ice Loading” for references.

5-6.2.2 Entrance Channel Configuration.
Designing approach-channel and entrance-channel widths for harbors located in exposed ocean-wave environments is largely accomplished by comparing presently operating harbors. The forces of waves and currents acting on a vessel in exposed locations induce excursions of the vessel from its intended path of travel. For example, to pass in the lee of an entrance structure, a vessel needs maneuvering room in order to adjust to the rapid changes in sea conditions.

Where naval activities share common entrance approaches with commercial port activities, entrance-channel widths greater than 1,000 ft (304.8 m) are common. Table 5-9 gives entrance-channel dimensions for several typical harbors. Table 5-10 provides typical harbor entrances serving naval facilities.

For new entrance designs, preliminary width approximations can be made as given in paragraph titled “Entrance Channels”, by adjusting ship beam with yaw angle increase and then proceeding as for an interior-channel design. In the case where the hydraulic environment at the entrance is unique and without precedent, navigational studies involving suitable-scale physical model methods are recommended.

5-6.2.2.1 Interior Channels.
The dimensioning of interior channels protected from open sea waves and strong cross currents is shown in Figure 5-17 , where B = beam of vessel.

- Ship-Lane Widths. Where good operating conditions (that is, a maximum ship speed of 10 knots, currents less than 3 knots, good visibility, and wind less than 15 knots) exist, the following ship-lane widths should be used:

Vessel Maneuvering Characteristics	Lane Width as a Multiple of Beam
Excellent – CG and DD	1.6
Good – FFG, CV, AOE, and LSD 36	1.8
Poor – Submarines, Tenders, AE, and AS	2.0

- Ship Clearance. Ship clearance is normally assumed to be equal to the beam at waterline of the largest vessel. Where a channel is to be frequently used by aircraft carriers having large overhanging decks, increase the clearance between ship lanes to maximum vessel breadth.

- Bank Clearance. Vessels traveling in restricted waterways experience hydrodynamic suction from the banks. This is offset by rudder-angle adjustment. Results of limited model studies are shown in Figure 5-18.

For sustained travel by a naval vessel in a restricted channel, a 5-degree rudder angle is a desired maximum.

Figure 5-17 Dimensioning Protected Interior Channels

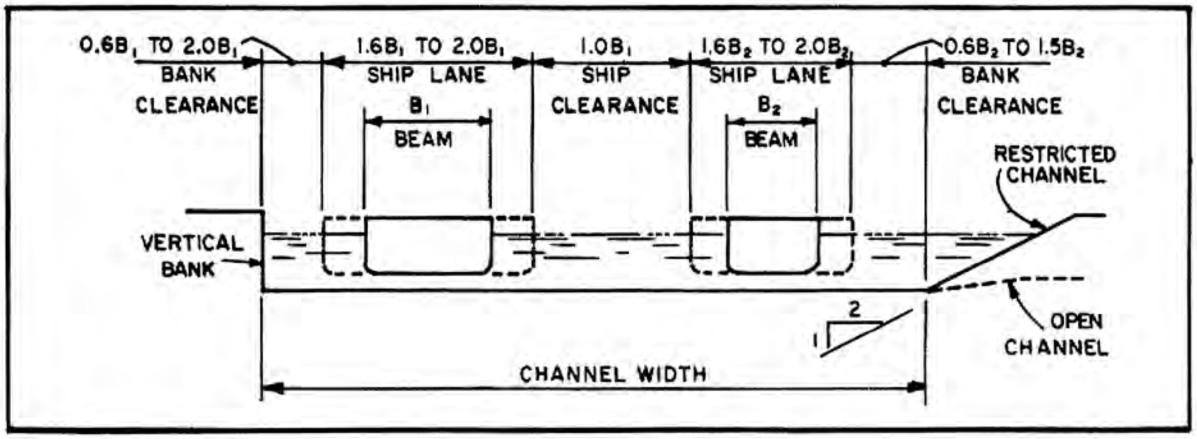


Figure 5-18 Bank Clearance versus Rudder Angle

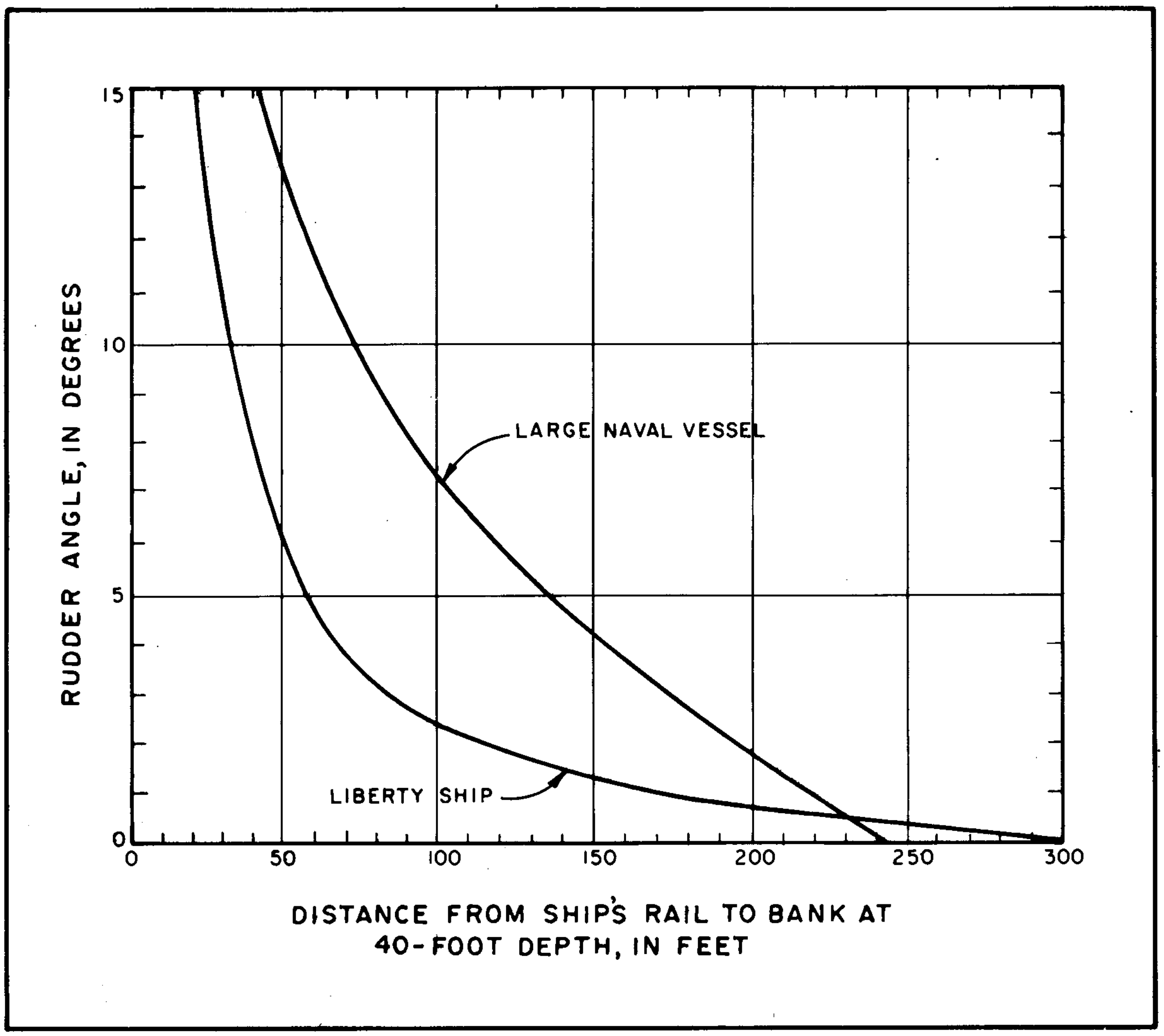


Table 5-9 Typical Entrance-Channel Dimensions

Harbor	Width (ft (fm))	Depth (m (ft))	Remarks
Boston, MA	1,100 (335.3)	40 (12.2)	Access to port entrance
New York, NY	1,800 (548.6)	44 (13.4)	Access to port entrance
Charleston, SC	1,500 (457.2)	35 (10.7)	Non-restricted outlet for three rivers
Columbia River, OR	2,640 (804.7)	48 (14.6)	River bar crossing in severe wave environment – closed during certain storms
Long Beach, CA	1,800 (548.6)	60 (18.3)	Breakwater gap
San Diego, CA	800 (243.8)	41 (12.5)	Entrance channel through parallel jetties
Apra Harbor – Guam	1,350 (411.5)	120 (36.6)	Entrance between breakwater head and shore

Table 5-10 Typical Harbor Entrances Serving Naval Facilities

Harbor	Width (ft (m))	Depth (ft (m))	Largest Naval Vessel – Normal Use	Remarks
Mayport, FL	900 (274.3)	42 (12.8)	Unrestricted	Entrance through parallel jetties
Port Hueneme, CA	600 (182.9)	39 (11.9)	Destroyer	Entrance through non-parallel jetties
Pearl Harbor, HI	1,580 (481.6)	60 (18.3)	Unrestricted	Broad, ill-defined entrance
Seal Beach, CA	600 (182.9)	38 (11.6)	Destroyer	Entrance through non-parallel jetties

In addition to rudder-angle and vessel-handling criteria, overall vessel safety must be considered in determining bank-clearance distance. In an open channel, the markings of the channel limits may not be as fully defined as in a restricted channel. This can be compounded in times of poor visibility. Similarly, where there exists a high damage probability for grounding, as in the case of an underwater rock ledge, additional bank-clearance margins should be considered. Extra allowance should also be made where the channel is subject to siltation from the side slopes. Under conditions such as those mentioned above, the minimum desired bank clearance for design purposes should be equal to the beam of the largest vessel frequenting the harbor. For open channels with steeper than 1-on-3 side slopes, this minimum clearance should be 1.2 times the beam. Examples of existing interior channels are given in Table 5-11.

5-6.2.2.2 Channel Bends.

Bends in channels should be avoided if possible. If channel bends are unavoidable, the channel should be widened to account for the fact that the path of a ship in a bend is wider than in straight sections. The criteria for designing channel bends depend upon:

- The angle of deflection, defined as the angle between the two straight sections of the channel,
- The speed of travel of and the properties of the vessel,
- The characteristics of the channel,
- The visibility, obstructions, and aids to navigation in the vicinity of the bend, and
- Human elements.

Table 5-11 Examples of Existing Interior Channels

Harbor	Width		Depth		Remarks
	m	ft	m	ft	
Baltimore-Fort McHenry Channel	121.9	400	10.7	35	Open-type channel
Norfolk- Thimble Shoal	469.4	1540	13.7	45	Open-type channel
Charleston-Naval Weapons Annex, Kingston	152.4	500	10.7	35	Riverine, open-type channel
Columbia River-Astoria Range	182.9	600	12.2	40	Riverine, open-type channel
Oakland-Bar Channel	91.4	300	10.7	35	Open-type channel
San Pablo Bay-Pinhole Shoal	182.9	600	10.7	35	Open-type channel
Long Beach	304.8	1000	10.4	34	Restricted-type channel
San Diego	213.4	700	12.5	41	Open-type channel

- Open-Type Channels. A change from one direction of the channel into another can be accomplished for an open-type channel without the introduction of a curved bend, provided the vessels encountering the bend are highly maneuverable and the change in direction is not too large. Such a bend is called a straight-line bend and is shown with alternative methods of widening the channel in Figure 5-19.

- Restricted-Type Channels. If the bend occurs in a restricted-type channel, the change of direction is large, or the maneuvering characteristics of the vessels frequently using the channel are poor, introduction of a curve in the channel becomes necessary. In designing a channel curve, the critical factor is determination of the radius of the curve. The criteria upon which the radius, R, is based are the length, l_v, of the ship entering the channel and the angle of deflection, α, of the channel bend. The general rules governing determination of the radius are as follows:

    - Minimum R = 3,000 ft (914.4 m) for a ship under its own power.

    - R = 1,200 to 2,000 ft (365.8 to 609.6 m) for tug assistance.

    - If the angle of deflection is greater than 10 degrees, the curve should be widened at the inside curve.

    - The tangent length between consecutive curves where there are no obstructions should be 1,000 ft (304.8 m) or 2 l_v (where l_v = length of the largest ship using the channel), whichever is larger.

- Reverse curves should not be used except in special situations.

Rules governing the radius, based on angle of deflection, are:

$R = 3\ l_v$ minimum for $\alpha < 25$ deg.

$R = 5\ l_v$ minimum for 25 deg. $< \alpha <$ 35 deg.

$R = 10\ l_v$ minimum for $\alpha > 35$ deg.

Rules governing the radius, based on vessel length, are:

R = 1219.2 m (4,000-ft) minimum for $l_v <$ 152.4 m (500 ft)

R = 2133.6 m (7,000-ft) minimum for $l_v =$ 152.4 m (500 ft)

R = 2133.6 to 3048 m (7,000 to 10,000 ft) for (152.4 m (500 ft) $< l_v <$ 213.4 m (700 ft)

The radius of the curve must fulfill the above criteria. Once R has been determined, the channel-bend geometry must be determined. This consists of widening the channel at the bend and providing a smooth transition from the straight portions of the channel through the curve. This can be done in several ways, as shown in Figures 20 to 24. The entire amount of widening in the channel could be added to the inside of the channel, as shown with curved transitions in Figure 21 and straight transitions in Figure 22. The widening could also be split on the inside and outside of the curves equally, as shown in Figure 23, or unequally, as shown in Figure 24. For final design, an investigation considering local conditions and dredging costs is required to optimize bend geometry. If widening the channel cannot be achieved due to existing soil conditions or structures, tugs must be used to assist ships.

5-6.2.2.3 Entrance Channels.

- Entrance Channel Widths

  - Breakwater gaps. In practice, vessels transit gaps between breakwaters one at a time. Observations reveal that in practice a second vessel will normally standoff and allow the first vessel to complete its passage through the gap to and from protected water. A minimum entrance gap width of 0.8 to 1.0 times the length of the vessel appears to be adequate for most sea conditions.

  - Channel entrances. Vessels require more room to maneuver in and out of channels leading to protected harbor waters. Therefore, prescribed widths for interior channels must be increased to allow for additional channel width at the entrance. By utilizing vessel beam and its length, the increase in vessel beam can be approximated by the following equation:

$$B' = B + l_v \tan \theta \qquad (5\text{-}8)$$

where: B' = adjusted vessel beam

B = vessel beam

l_v = vessel length

θ = yaw angle

Yaw angle should be assumed to range from 5 to 15 degrees, depending upon entrance exposure. The adjusted vessel width, B', is used in ship lane width determinations with ratio factors similar to those used in interior-channel design (see Figure 5-17).

- Entrance Channel Length. In order to safely negotiate the entrance channel, vessels normally must maintain a higher rate of speed than is required or permitted within a harbor. Thus, the entrance channel should be of a length sufficient to allow vessels to reduce velocity before entering the harbor proper. For vessels entering with speeds in the range of 5 to 10 knots, allow one vessel length of slowing distance per knot of entering speed between the entrance and the turning basin. For medium-sized vessels with no tug-assisted speed arrestment, a minimum of 3,500 ft (1066.8 m) should be provided. CEM Section V-5 deals with the crucial elements of channel design: width, depth and alignment. In addition, the special requirements of entrance channels are discussed.

Figure 5-19 Straight-Line Bend - Alternative Methods of Widening Open-Type Channel

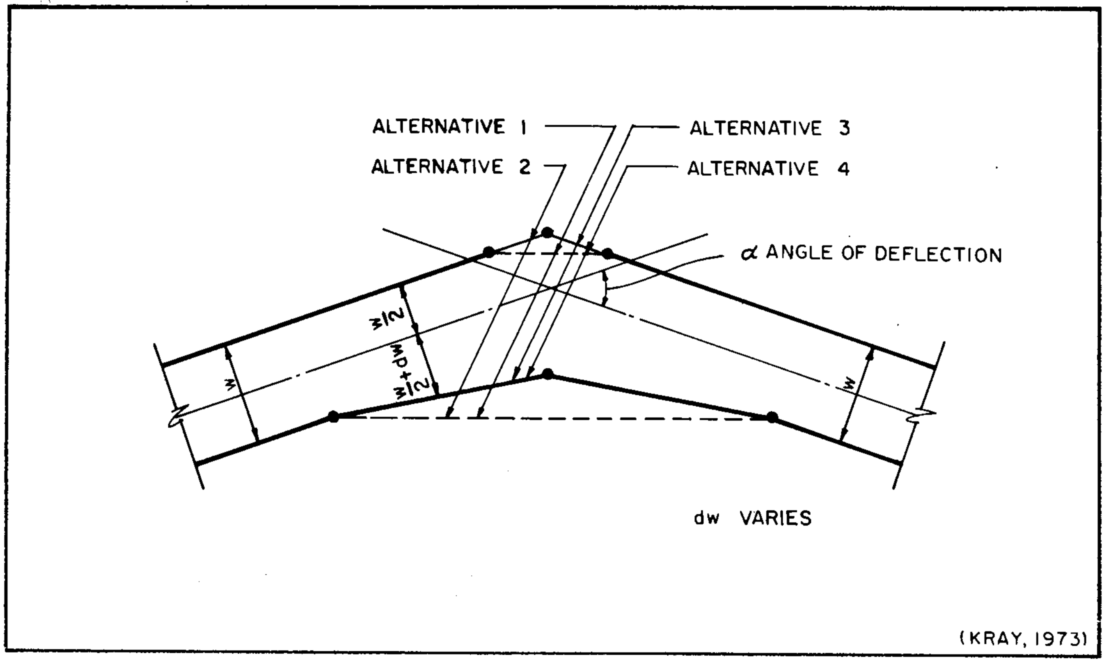


Figure 5-20 Parallel Constant – Width Turn in Channel

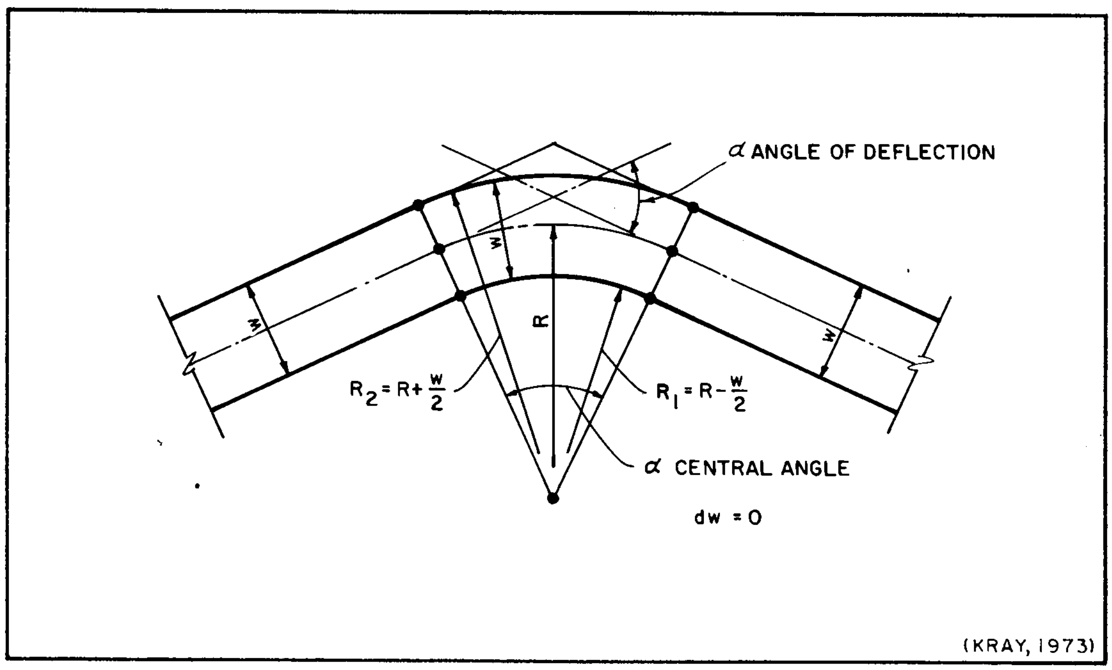


Figure 5-21 Unsymmetrically Widened Turn With Curved Transitions

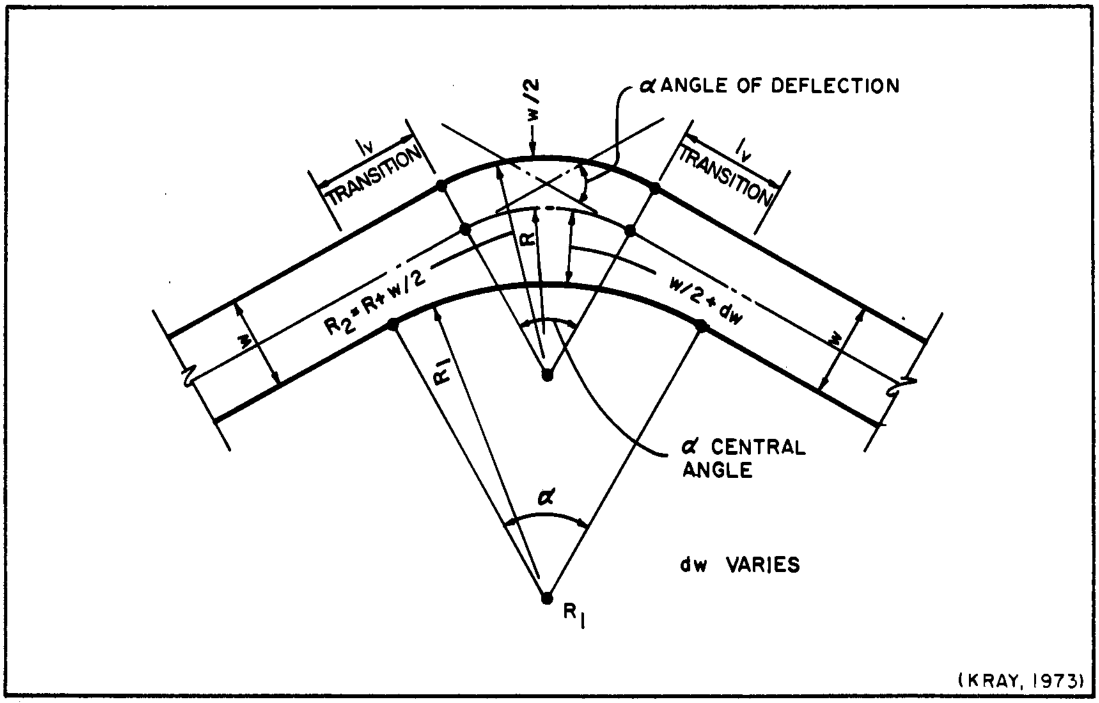


Figure 5-22 Unsymmetrically Widened Turn With Straight Transitions

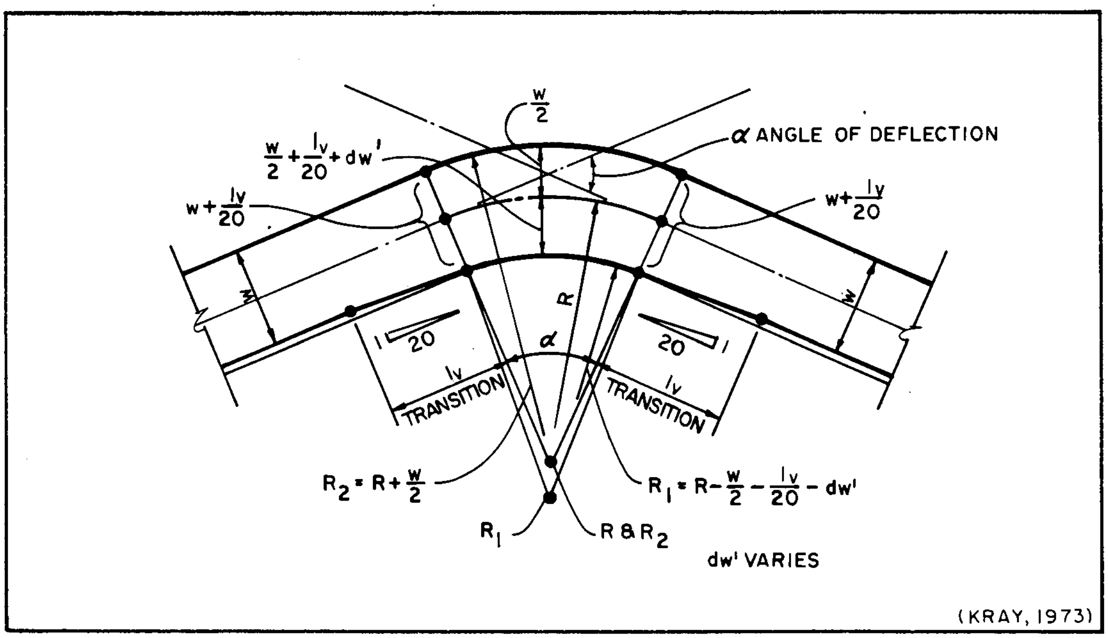


Figure 5-23 Parallel Widened Turn in Channel

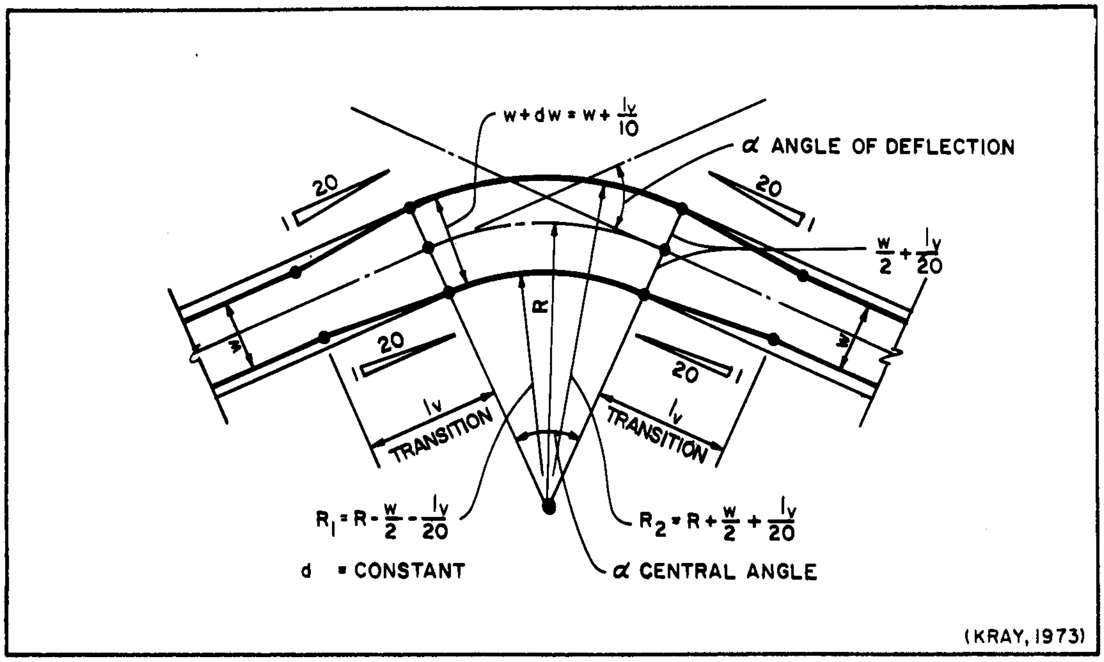
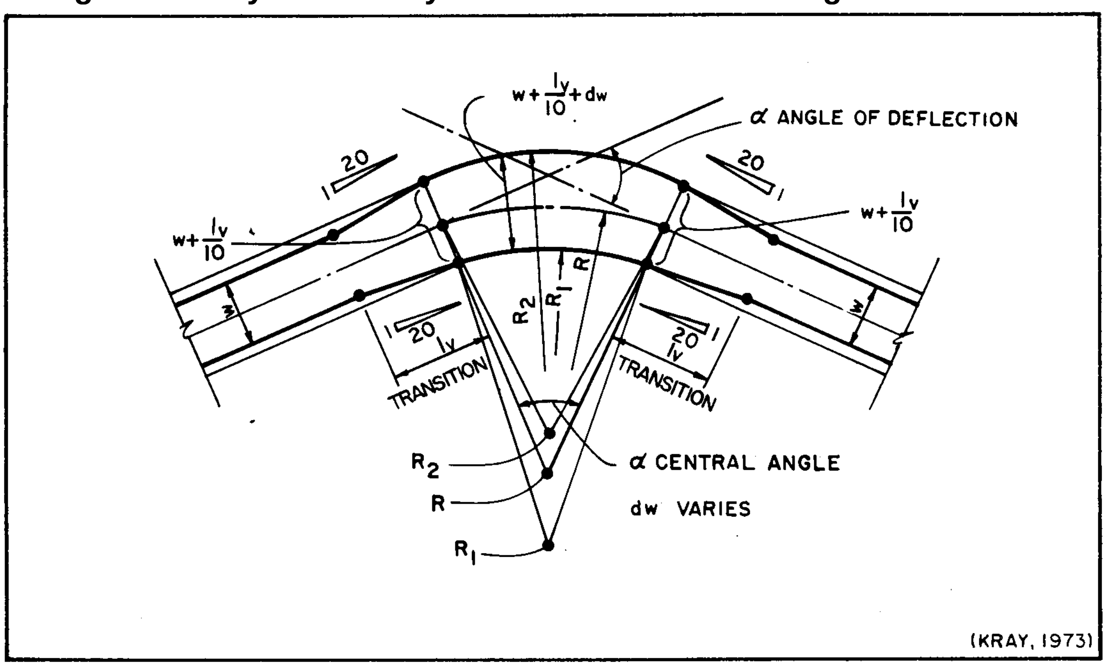


Figure 5-24 Symmetrically Widened Turn With Straight Transitions



5-6.2.3 Berths and Berthing Basins.

Figure 5-15 showed types of berth arrangements. Table 5-12 lists factors affecting the selection of the location of berthing basins. A rule of thumb is that the wave height in the berthing basin should not exceed 2 ft (0.6 m) for comfortable berthing, but in no case shall the wave height exceed 4 ft (1.2 m).

5-6.2.3.1 Quayage Required.

Quayage requirements of piers and wharves for the various classes of vessel may be estimated from tabulated data in UFC 4-152-01. Consult with the using agency for data on the maximum number of ships of various classes (including lighters) to be simultaneously accommodated.

5-6.2.3.2 Arrangement of Berths.

- Selection. The arrangement of berths must fit the proposed site without encroaching on pierhead or bulkhead lines. For steeply sloping subgrades, the berths must fit within the depth contour below which the driving of piles is impractical. In selecting the berthing arrangement, consider the factors relating to economics and utility (see Table 5-13).

- Relative Berthing Capacities. Table 5-14 shows linear feet of berthing space per 1,000 ft (304.8 m) of shorefront.

5-6.2.3.3 Size and Depth of Basin and Berths.

For the general depth requirements for the basin, see paragraph titled “General Depth Requirements”.

- Berthing Area. For berthing-area requirements for piers, see 5-15. For ships berthed at marginal wharves or quay walls, provide twice the total area requirement shown in Table 5-15 for pier berthing. Allow additional area within the harbor limits for channels, special berths, turning basins, and other facilities.

- Depth. Except where heavy silting conditions require greater depth at individual berths at low water, the depth should equal the maximum navigational draft of the largest vessel to be accommodated plus 10 percent. On mud or silt bottoms, consider increasing depth requirements if investigation indicates probable fouling of condensers on the vessel due to the proximity of the mudline to intake pipes of the condenser system. Where vessels to be accommodated are not specifically known, the values in Table 5-16 may be used.

- Clear Width of Slips Between Piers; see UFC 4-152-01.

- Length of Berth; see UFC 4-152-01.

- Width of Piers.

  - Square pier systems. Width should be capable of berthing the longest expected ship. The net area of the pier should be three times that required for a single berth terminal.

  - Finger pier system. Pier width varies. Width requirements may be estimated from data in UFC 4-152-01.

- Special Berths.

  - Fueling vessels. Berths should be at least 500 ft (152.4 m) from adjacent berths.

  - Explosives. Berths should be separated in accordance with the quantity-distance relationships established in DOD 5154.45 and NAVSEA OP 5.

5-6.2.4 Turning Basins.
Where space is available, providing turning basins will minimize tug usage. However, where space is restricted, tugs may be used to turn vessels, thereby eliminating the need for turning basins.

5-6.2.4.1 Location.
The following location requirements must be met:

- locate one turning basin at the head of navigation

- locate a second turning basin just inside the breakwater

- in areas where especially heavy traffic is anticipated, provide intermediate basins to reduce congestion and save time

- where feasible, use an area of the harbor, which in its natural state has the required size and depth.

- it is frequently advantageous for a turning basin to be located at the entrance to drydocks or at the interior or landward end of long piers or wharves that provide multiple-length berthing.

5-6.2.4.2 Size and Form.
As a rule of thumb, a vessel can be turned comfortably in a radius of twice the vessel length, or, where ease of maneuver is not an issue, in a radius equal to the vessel length. For shorter turning radii, tug assistance for the vessel is necessary. Also in this case, where wind and current effects are not critical, naval vessels can be turned in a

circle with a diameter of 1.5 times the vessel length. Table 5-17 provides dimensions of typical turning basins in existence.

5-6.2.5 Anchorage Basins

5-6.2.5.1 Siting Factors.

Table 5-18 lists factors affecting location, size, and depth of anchorage basins.

- Free-Swinging Moorings and Standard Fleet Moorings.
  For the diameter of the swing circle and the area requirements per vessel, see Tables 5-19, 5-20, and 5-21. For size of berth for floating drydocks, spread-moored, see Tables 5-22 and 5-23. Additional area allowance should be made for maneuvering vessels into and out of berths and for waste space between adjacent berths.

a) Demarcation. Anchorage areas should be marked.

b) Dangerous Cargo.

- Tankers. Anchorages for tankers and similar vessels should be at least 500 ft (152.4 m) from adjacent berths, and located so that prevailing winds and currents carry spillage away from general anchorage and berthing areas.

- Explosives. Anchorages for vessels carrying explosives should be separated in accordance with quantity-distance relationships established in DOD 5154.45 (DOD, 1978), which has since been superceded by DOD 6055.9 (DOD, 1997), and NAVSEA OP 5 (NAVSEA, 1999).

CEM Section V-5 discusses the details of inner harbor elements.

Table 5-12 Factors Affecting Location of Berthing Basins

Factor	Requirement and Comment
Protection	Locate berthing basins in harbor areas that are best protected from wind and wave disturbances and/or in areas remote from the disturbances incident upon the harbor entrance.
Orientation	Orient berths for ease of navigation to and from entrance and channel.
Offshore Area	Provide sufficient area offshore of berths for turning ships, preferably without use of tugs.
Quayage adequacy	Adequate quayage shall be provided for expected traffic.
Expansion	Provide area for future expansion.
Fouling and Borers	Where possible, locate berthing basin in area of harbor with minimum fouling conditions and minimum incidence of marine borers. Elliott, Tressler, and Meyers (1952) indicate some advantages for locations in the ebb side of an estuary harbor. The ebb side of an estuary in the Northern Hemisphere is the right side looking seaward.
Foundations	Where feasible, locate in area of favorable subsoil conditions, in order to minimize cost of berthing structures.
Supporting shore facilities	Locate supporting shore facilities in proximity to their respective berths. Adequate space and access for upland road and railroad facilities are essential. In general, it is desirable to have a wide marginal street at the inshore ends of the piers or wharves and a wide street on the pier axis. Annual capacity per terminal is based on commercial throughput values obtained from Hockney (1979).

Single Berth Terminal by Cargo Class	Cargo Throughput (tons per year)
Break-bulk general	66,000
Neo-bulk general cargo	130,000
Containerized general cargo	360,000
Dry bulk – silo storage	1,000,000
Dry bulk – open storage – low density	500,000
Dry bulk – open storage – high density	1,000,000
Liquid bulk – other than petroleum	80,000
Petroleum bulk – up to 50,000 dwt ships	1,500,000
Petroleum bulk – 30,000 to 200,000 dwt ships	6,000,000

Table 5-13 Selection Factors for Berthing Arrangements

Berthing System	Advantages	Disadvantages
Marginal Wharf (Figure 5-15a)	Solid fill supports deck loads without expensive framing. Accessibility of entire upshore area for working space, storage space, laydown operations, and traffic circulation adds to the utility of the wharf as compared to pier or offshore wharf systems. Permits utilization of surplus fill material. Suitable for sites where pier cannot be projected out from shore and where dredging of a recessed basin for piers would be expensive. Also suitable where the navigation channel is too narrow to permit maneuvering into finger piers.	Costs per berth greater than for pier systems. Ratio of berthing space to length of waterfront is low. Berthing length is limited to length of face of wharf, unless mooring dolphins are used to extend usable length.
Square Pier (Figure 5-15b)	Solid fill supports deck loads without expensive framing. Upshore area is accessible for storage and traffic circulation. Side-berth accommodations add to linear feet of berthing accommodations. Permits utilization of surplus fill material.	Economy depends on availability of inexpensive fill. The requirements for fill or piling are great compared to the usable space provided on the deck.
Rectangular Pier and Slip (Figures 5-15c, 15d, and 15f)	Length of accommodation for a given length of shoreline is great. In general, this system has the lowest relative cost per berth.	In some bottom formations, any considerable later dredging of slips may be hazardous. Space between slips is limited, and adds to the density of navigation traffic. Reduces width of navigation channel. Cargo handling is restricted unless pier has at least 6 acres per berth.
Angle Pier and Slip (Figures 5-15e and 5-15g)	Layout is advantageous compared to rectangular pier-and-slip system where navigation channel is too narrow for perpendicular pier layout. Currents or prevailing winds may also dictate the use of angle piers.	Construction is more difficult and expensive than that for rectangular pier-and-slip system. Corners of the pier are waste space where cargo-handling equipment cannot work.
Offshore Marginal Wharves (Figures 5-15h, 5-15i, and 5-15j)	Layout adaptable to many types of construction methods, including floating wharfage. Moorings for shallow-draft craft may be provided along the sides of the causeway. When multiple causeways are used, a movable section can be provided to give access to space between causeways. Suitable along rocky shores. Suitable where water of adequate depth is located at large distance offshore.	When a single causeway is used, craft along the causeway create loading and unloading and traffic problems. Usually requires separate moorings, supported by the wharf structure, because a relatively large area of the wharf structure is not tied to shore anchorages.
Floating Wharves	Floating wharves can be moored in water too deep for pile driving. Pontoon or prefabricated sections can be used. Equipment can be quickly assembled, moved, and replaced.	Maintenance is high. (Maintenance of steel floating wharves is higher than that of concrete floating wharves.) Not suitable for heavy craft nor in exposed locations without heavy anchorage requirements. Difficult to maintain alignment in heavy tide range. Restricted cargo-handling capability.

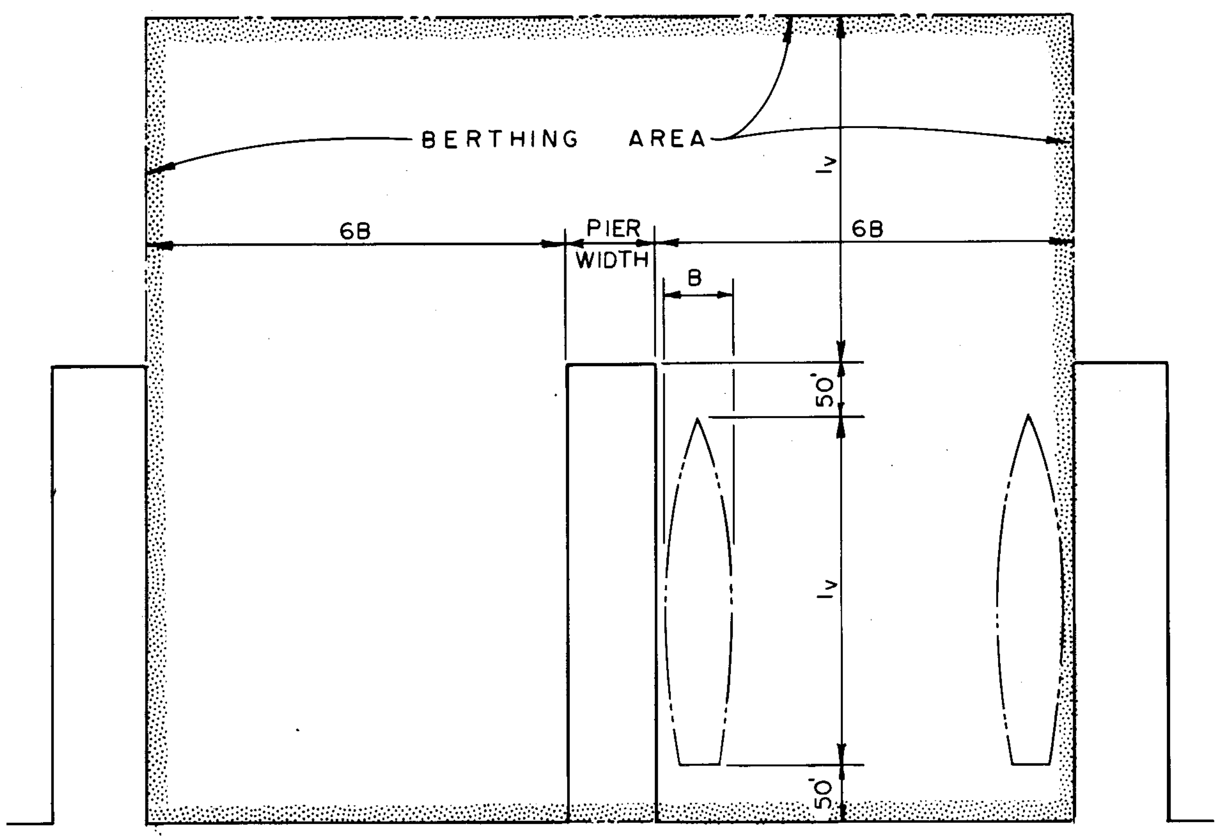
Table 5-14 Linear Feet of Berthing Space per 1,000 ft (305 m) of Shore Front

Type of Layout	Freighter[a]	Lighter[a]	Total[a]
Marginal wharf	1,000 (305)	-	1,000 (305)
Square pier	2,143 (653)	-	2,143 (653
Right-angle pier for one freighter on each side	3,120 (951)	313 (95)	3,433 (1046)
Right-angle pier for one freighter plus one lighter on each side	3,120 (951)	1,250 (381)	4,370 (1332)
Acute-angle pier for one freighter on each side	2,690 (820)	270 (82)	2,960 (902)
Right-angle pier for two freighters on each side	4,160 (1268)	208 (63)	4,368 (1331)
Acute-angle pier for two freighters on each side	3,600 (1097)	180 (55)	3,780 (1152)
T-type marginal wharf for freighter on outside face and lighters on inside face	770 (235)	1,380 (421)[b]	2,150 (655) [b]
U-type marginal wharf	1,000 (305) or less	-	1,000 (305) or less
Pier or wharf parallel to bank	2,000 (610)	-	2,000 (610)

[a]These figures are for purposes of comparison only.
[b] 1,682 ft (513 m) and 2,452 ft (747 m), respectively, if traffic conditions are such that lighters can be worked along the faces of the causeway.

Table 5-15 Approximate Berthing Area Requirements for Single-Berth Piers[a]

Class of Ship	Sizes of Piers (ft (m))	Spacing of Piers (ft (m))	Total Area Required in Harbor (acres (hectares))
Submarines	60 x 520 (18 x 159)	330 (101)[b]	16 (6.48)[b]
Destroyers	80 x 670 (24 x 204)	330 (101)	21 (8.50)
Auxiliaries	80 x 900 (24 x 274)	640 (195)	53 (21.45)
Aircraft Carrier	100 x 1,250 (30 x 381)	780 (238)	88 (35.61)



[a]Area = [2 1_v + (2) (50*)] [^{2}12B + pier width]. (See diagram.) Values for 1_v, B, and pier width are from UFC 4-152-01 for purposes of this table.
[b]At submarine slips, pier spacing should be increased by at least four vessel beams.
*100 ft (30 m) for aircraft carrier.

Table 5-16 Berthing Depths for Typical Naval Vessels

Vessel	Depth[a] (ft (m)
Small boats	8 to 15 (2.4 to 4.6)
Minesweepers	18 (5.5)
Landing ships	24(7.3)
Frigates	30 (9.1)
Tenders, cargo, and transport ships	34 (10.3)
Guided missile cruisers, destroyers, and medium submarines	36 (11)
Carriers and fast combat support ships[b]	45 (13.7)

[a]These depths are referenced to mean low water (MLW) or mean lower low water (MLLW) statistics for the area under study.
[b]To obtain optimum berthing depth for CVN, AOE, and CV vessels, refer to *Underkeel Clearance Study,* Hydro Research Science, Inc., Project Report No. 092-81, 21 Mar 1981.

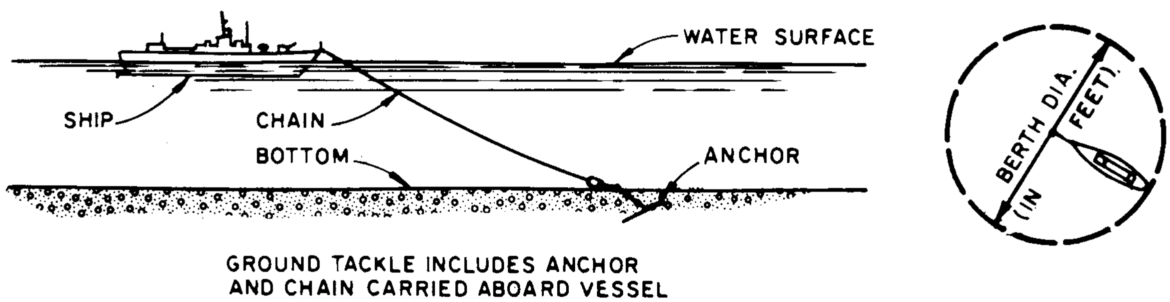
Table 5-17 Dimensions of Typical Existing Turning Basins

Location	Depth Below MLW (ft (m))	Dimensions (ft (m))	Area (acres (hectares))
Port Arthur, East Turning Basin	36 (11)	420 x 1,800 (128 x 549)	17.35 (7.02)
Port Arthur, West Turning Basin	36 (11)	600 x 1,700 (183 x 519)	18.12 (7.33)
Brazosport Turning Basin	32 (9.8)	700 x 700 (213 x 213)	11.25 (4.55)
Norfolk Harbor, Virginia South Branch Project	35 (10.7)	600 x 600 (183 x 183)	8.25 (3.34)
Wilmington Harbor	32 (9.8)	1,000 x 800 (305 x 244)	18.36 (7.43)
Miami Harbor	30 (9.1)	1,350 x 1,400 (411 x 427)	20.43 (8.27)
Tampa Harbor	30 (9.1)	700 x 1,200 (213 x 266)	19.38 (7.84)
Alameda Naval Air Station	42 (12.8)	4,000 x 2,500 (1219 x 762)	230.00 (93.08)
San Diego Harbor	40 (12.2)	2,400 x 3,000 (732 x 914)	165.29 (66.89)

Table 5-18 Factors Affecting Location, Size, and Depth of Anchorage Basins

Consideration	Factor	Requirement and Comment
Location	Isolation	Locate near entrance, away from channels, out of traffic, and in shelter. The area should be isolated, insofar as possible, from attack by surface or subsurface craft.
	Depth	Locate in area of sufficient natural depth to avoid dredging.
	Currents	Area should be free from strong currents.
	Accessibility of shore facilities	The area should be accessible to fresh water, fuel, and fleet recreation facilities. Shore facilities shall be provided to accommodate liberty parties, mail, light freight, and baggage.
	Foundation conditions	Where possible, locate over a bottom of loose sand or gravel, clay, or soft coral. Avoid locations where the bottom consists of rock, hard gravel, deep mud, and deep silt.
	Subaqueous structures	Anchorage areas should be free of cables and pipelines and cleared of wrecks and obstructions.
	Expansion	Leave provision for future expansion.
Size and Depth		Sizes of individual free-swinging moorings and of spread moorings for floating drydocks are contained in Tables 5-17, 5-18, and 5-19. Use free-swinging moorings where available area will permit. Where available area is limited, use fixed moorings or moorings in which the swing of the vessel is restricted. Various types of restricted moorings are described in DM 26.5.

Table 5-19 Diameter of Berth, in Meters, Using Ship's Anchor and Chain[a]



Overall Vessel Length, In Meters	31	61	91	122	152	183
Depth of Water at MLLW (m)						
3.1	151	215	274	334	-	-
6.1	187	247	311	370	430	494
9.1	224	283	347	407	466	530
12.2	261	320	384	443	503	567
15.2	297	357	416	480	540	599
18.3	334	389	453	517	576	636
21.3	357	402	489	553	613	678
24.4	375	421	521	585	649	704
27.4	389	434	540	613	668	722
30.5	407	448	553	626	686	736
33.5	421	462	567	640	700	750
36.6	434	471	581	654	713	764
39.6	448	485	594	672	727	777
42.7	462	498	608	681	741	791
45.7	471	507	622	695	754	800
48.8	485	521	636	709	764	814
51.8	494	531	649	722	777	823
54.9	507	542	658	732	791	837
57.9	517	549	672	745	800	846
61	531	562	681	759	814	860

Table 5-19 Diameter of Berth, in <u>Meters</u>, Using Ship's Anchor and Chain[a] - Continued

Overall Vessel Length, In Meters	213	244	274	305	335	366
Depth of Water at MLLW (m)						
3.1	-	-	-	-	-	-
6.1	-	-	-	-	-	-
9.1	590	649	713	-	-	-
12.2	596	686	750	809	869	933
15.2	663	722	809	846	905	965
18.3	700	759	818	882	933	1001
21.3	736	796	855	919	978	1038
24.4	764	823	892	951	992	1079
27.4	777	837	905	965	1006	1093
30.5	796	850	919	978	1033	1106
33.5	809	864	933	992	1047	1120
36.6	823	878	946	1001	1061	1134
39.6	832	887	956	1015	1074	3348
42.7	846	901	969	1029	1084	1157
45.7	860	914	983	1038	1097	1170
48.8	869	924	992	1055	1106	1180
51.8	882	937	1006	1061	1116	1193
54.9	892	946	1015	1070	1129	1202
57.9	901	956	1024	1079	1138	1212
61	914	965	1038	1093	1148	1221

[a]For shallower water depths, the swing radii implied by this table are based on the following
assumptions:

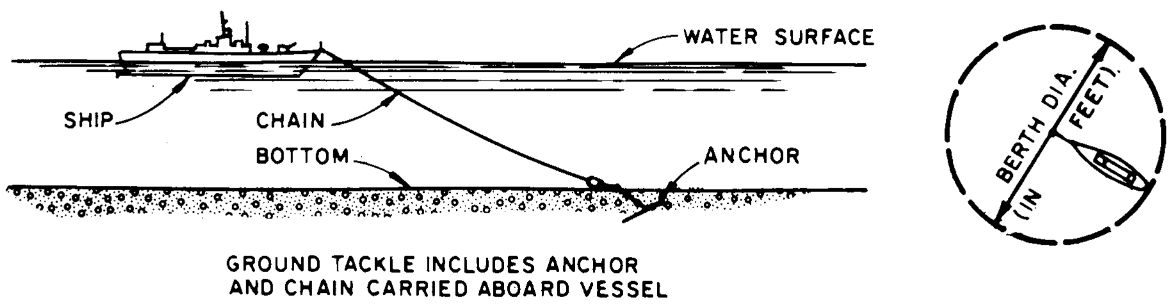
a) Scope = 6 x depth
b) Anchor rode has no sag
c) Allowance for anchor drag = 27.4 m

For depths greater than about 21.3 m, the 6:1 scope is excessive, and swing radii are based on the computed horizontal length of the anchor chain under heavy load. Typical ship characteristics and chain sizes have been selected for each ship length category.

Assumed load conditions are as follows:

a) Wind speed = 50 knots
b) Current = 4 knots, aligned with wind direction
c) Vertical projection of anchor chain = depth + height of hawse hole
d) Vertical angle of chain at anchor = 0 degrees

Table 5-20 Diameter of Berth, in Feet, Using Ship's Anchor and Chain[a]



Overall Vessel Length, In Feet	100	200	300	400	500	600
Depth of Water at MLLW (ft)						
10	495	705	900	1,095	-	-
20	615	810	1,020	1,215	1,410	1,620
30	735	930	1,140	1,335	1,530	1,740
40	855	1,050	1,260	1,455	1,650	1,860
50	975	1,170	1,365	1,575	1,770	1,965
60	1,095	1,275	1,485	1,695	1,890	2,085
70	1,170	1,320	1,605	1,815	2,010	2,205
80	1,230	1,380	1,710	1,920	2,130	2,310
90	1,275	1,425	1,770	2,010	2,190	2,370
100	1,335	1,470	1,815	2,055	2,250	2,415
110	1,380	1,515	1,860	2,100	2,295	2,460
120	1,425	1,545	1,905	2,145	2,340	2,505
130	1,470	1,590	1,950	2,205	2,385	2,550
140	1,515	1,635	1,995	2,235	2,430	2,595
150	1,545	1,665	2,040	2,280	2,475	2,625
160	1,590	1,710	2,085	2,325	2,505	2,670
170	1,620	1,740	2,130	2,370	2,550	2,700
180	1,665	1,779	2,160	2,400	2,595	2,745
190	1,695	1,800	2,205	2,445	2,625	2,775
200	1,740	1,845	2,235	2,490	2,670	2,820

Table 5-20 Diameter of Berth, in Feet, Using Ship's Anchor and Chain[a] - Continued

Overall Vessel Length, In Feet	700	800	900	1,000	1,100	1,200
Depth of Water at MLLW (ft)						
10	-	-	-	-	-	-
20	-	-	-	-	-	-
30	1,935	2,130	2,340	-	-	-
40	1,955	2,250	2,460	2,655	2,850	3,060
50	2,175	2,370	2,655	2,775	2,970	3,165
60	2,295	2,490	2,685	2,895	3,060	3,285
70	2,415	2,610	2,805	3,015	3,210	3,405
80	2,505	2,700	2,925	3,120	3,255	3,540
90	2,550	2,745	2,970	3,165	3,300	3,585
100	2,610	2,790	3,015	3,210	3,390	3,630
110	2,655	2,835	3,060	3,255	3,435	3,675
120	2,700	2,880	3,105	3,285	3,480	3,720
130	2,730	2,910	3,135	3,330	3,525	3,765
140	2,775	2,955	3,180	3,375	3,555	3,795
150	2,820	3,000	3,225	3,405	3,600	3,840
160	2,850	3,030	3,255	3,450	3,630	3,870
170	2,895	3,075	3,300	3,480	3,660	3,915
180	2,925	3,105	3,330	3,510	3,705	3,945
190	2,955	3,135	3,360	3,540	3,735	3,975
200	3,000	3,165	3,405	3,585	3,765	4,005

[a]For shallower water depths, the swing radii implied by this table are based on the following
assumptions:

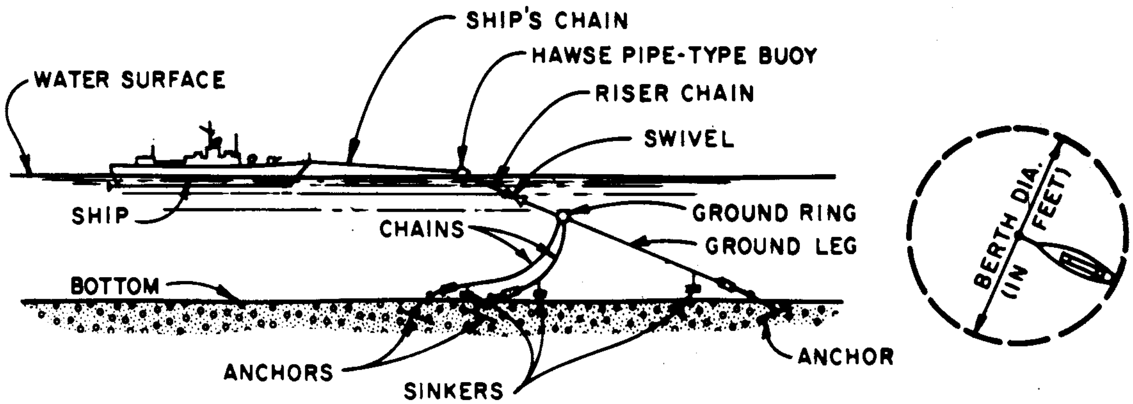
d) Scope = 6 x depth
e) Anchor rode has no sag
f) Allowance for anchor drag = 90 ft

For depths greater than about 70 ft, the 6:1 scope is excessive, and swing radii are based on the computed horizontal length of the anchor chain under heavy load. Typical ship characteristics and chain sizes have been selected for each ship length category.

Assumed load conditions are as follows:

e) Wind speed = 50 knots
f) Current = 4 knots, aligned with wind direction
g) Vertical projection of anchor chain = depth + height of hawse hole
h) Vertical angle of chain at anchor = 0 degrees

Table 5-21 Diameter of Berth, Using Standard Fleet Moorings, Rise Chain[a]



Overall Vessel Length, ft (m)	100 (31	200 (61)	300 (91)	400 (122	500 (152)
Depth of Water at MLLW (ft (m))					
10 (3.1)	825 (251)	1,020 (311)	1,215 (370)	1,425 (434)	-
20 (6.1)	840 (256)	1,035 (315)	1,245 (379)	1,440 (438)	1,635 (498)
30 (9.1)	855 (261)	1,065 (325)	1,260 (384)	1,455 (443)	1,655 (504)
40 (12.2)	855 (270)	1,080 (329)	1,275 (389)	1,485 (453)	1,680 (512)
50 (15.2)	900 (274)	1,095 (334)	1,305 (398)	1,500 (457)	1,695 (517)
60 (18.3)	915 (279)	1,125 (343)	1,320 (402)	1,515 (462)	1,725 (526)
70 (21.3)	945 (288)	1,140 (347)	1,335 (407)	1,545 (471)	1,740 (530)
80 (24.4)	960 (293)	1,155 (352)	1,365 (416)	1,560 (475)	1,755 (535)
90 (27.4)	975 (297)	1,185 (361)	1,380 (421)	1,575 (480)	1,785 (544)
100 (30.5)	1,005 (306)	1,200 (366)	1,395 (425)	1,605 (489)	1,800 (549)
110 (33.5)	1,020 (311)	1,215 (370)	1,425 (434)	1,620 (494)	1,815 (553)
120 (36.6)	1,035 (315)	1,245 (379)	1,440 (439)	1,635 (498)	1,845 (562)
130 (39.6)	1,065 (325)	1,260 (384)	1,455 (443)	1,665 (507)	1,860 (567)
140 (42.7)	1,080 (329)	1,275 (389)	1,485 (453)	1,680 (512)	1,875 (572)
150 (45.7)	1,095 (334)	1,305 (398)	1,500 (457)	1,695 (517)	1,905 (581)
160 (48.8)	1,125 (343)	1,320 (402)	1,515 (462)	1,725 (526)	1,920 (585)
270 (51.8)	1,140 (347)	1,335 (407)	1.545 (471)	1,740 (530)	1,935 (590)
180 (54.9)	1,155 (352)	1,365 (416)	1,560 (475)	1,755 (535)	1,965 (599)
190 (57.9)	1,185 (361)	1,380 (421)	1,575 (480)	1,785 (544)	1,980 (604)
200 (61)	1,200 (366)	1,395 (425)	1,605 (489)	1,000	1,995 (608)

Table 5-21 Diameter of Berth, Using Standard Fleet Moorings, Rise Chain[a] - Continued

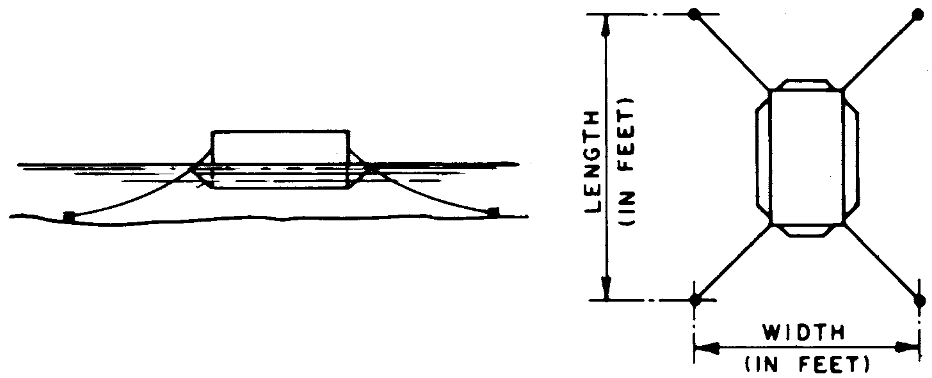
Overall Vessel Length, ft (m)	600 (183	700 (213)	800 (244)	900 (274)	1,000 (305)
Depth of Water at MLLW (ft (m))					
10 (3.1)	-	-	-	-	-
10 (6.1)	1,845 (562)	-	-	-	-
30 (9.1)	1,860 (567)	2,055 (626)	-	-	-
40 (12.2)	1,875 (572)	2,085 (636)	2,280 (695)	2,475 (754)	2,685 (818)
50 (15.2)	1,905 (581)	2,100 (640)	2,295 (700)	2,505 (764)	2,700 (823)
60 (18.3)	1,920 (585)	2,115 (645)	2,325 (709)	2,505 (764)	2,715 (828)
70 (21.3)	1,935 (590)	2,145 (654)	2,340 (713)	2,585 (788)	2,745 (837)
80 (24.4)	1,965 (599)	2,160 (658)	2,355 (718)	2,565 (782)	2,760 (841)
90 (27.4)	1,980 (604)	2,175 (663)	2,385 (727)	2,580 (786)	2,775 (846)
100 (30.5)	1,995 (608)	2,205 (678)	2,400 (732)	2,595 (791)	2,805 (855)
110 (33.5)	2,025 (617)	2,220 (677)	2,415 (736)	2,625 (800)	2,820 (860)
120 (36.6)	2,040 (622)	2,235 (681)	2,455 (748)	2,640 (805)	2,835 (864)
130 (39.6)	2,055 (626)	2,265 (690)	2,460 (750)	2,655 (809)	2,865 (873)
140 (42.7)	2,085 (636)	2,280 (695)	2,475 (754)	2,685 (818)	2,880 (878)
150 (45.7)	2,100 (640)	2,295 (700)	2,505 (764)	2,700 (823)	2,895 (882)
160 (48.8)	2,115 (645)	2,325 (709)	2,520 (768)	2,715 (828)	2,925 (892)
170 (51.8)	2,145 (654)	2,340 (713)	2,535 (773)	2,745 (837)	2,940 (896)
180 (54.9)	2,160 (658)	2,355 (718)	2,565 (782)	2,760 (841)	2,955 (901)
190 (57.9)	2,175 (663)	2,385 (727)	2,580 (786)	2,775 (846)	2,985 (910)
200 (61)	2,205 (678)	2,400 (732)	2,595 (791)	2,805 (855)	3,000 (914)

[a]This table is based on the following assumptions:

(a) Length of riser chain is equal to depth of water at mean high water.
(b) Ground chains are of length called for by drawings and are pulled taut when installed.
(c) Anchor drags 90 ft (27 m) from initial position.
(d) 55 m (180 ft) of ship's chain used between vessel and buoy.
(e) Basic formula $b = (2/3)(d + 1_v + C_1)$

Where: b = diameter of berth, in feet
d = depth of water, in feet at MHW
l_v = length overall of vessel, in feet
C_1 = 300 ft (91 m) (includes 30 ft (9 m) allowance for increase in radius of berth for drop in waterline due to fall of tide, 180 ft (55 m) from buoy to ship, and 90 ft (27 m) allowance for drag of anchor

Table 5-22 Size of Berth, in Meters, for Floating Drydocks and Spread Moorings[a]



Depth of Water at MLLW (m)	ARD		AFDL 2,800 T Concrete		AFDB 10 Sections		AFDB 9 Sections	
	Width	Length	Width	Length	Width	Length	Width	Length
10	-	-	-	-	-	-	-	-
11.6	183	288	-	-	-	-	-	-
12.5	183	288	187	274	-	-	-	-
15.2	210	306	210	297	-	-	-	-
17.4	233	320	238	315	-	-	-	-
19.8	233	325	238	329	-	-	-	-
22.6	256	343	261	347	-	-	-	-
25.6	283	361	288	366	347	521	347	494
27.4	306	375	311	379	357	530	357	507
30.5	306	384	311	402	375	553	375	526
33.5	306	398	334	416	393	567	393	540
36.6	347	407	361	430	407	581	407	558
39.6	370	425	384	443	421	594	421	572
42.7	393	434	384	462	434	608	434	581
45.7	416	453	402	475	448	622	448	594
48.8	416	453	425	489	457	631	457	604
51.8	430	462	425	503	466	640	466	613
54.9	448	475	448	512	471	645	471	617
57.9	471	489	471	526	475	649	475	622
61	471	494	471	530	475	649	475	622

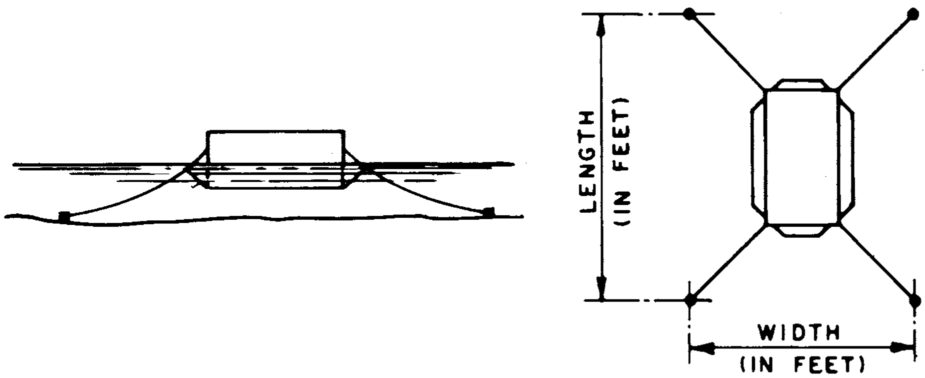
Table 5-22 Size of Berth, in Meters, for Floating Drydocks and Spread Moorings[a] -
Continued

Depth of Water at MLLW (m)	AFDB 7 Sections		YFD 18,000 T		AFDL 1,000 T Steel		AFDL 1,900 T Steel	
	Width	Length	Width	Length	Width	Length	Width	Length
10	-	-	-	-	183	229	-	-
11.6	-	-	-	-	183	229	183	261
12.5	-	-	-	-	183	229	183	215
15.2	-	-	-	-	206	251	206	283
17.4	-	-	251	384	233	274	233	302
19.8	-	-	251	393	233	283	233	320
22.6	306	453	270	410	256	306	256	343
25.6	306	453	293	443	283	329	279	366
27.4	325	475	320	462	311	352	306	375
30.5	352	498	320	471	311	361	306	398
33.5	352	498	339	494	334	379	329	411
36.6	306	512	357	517	361	402	352	430
39.6	389	535	379	535	384	485	379	448
42.7	407	558	379	544	384	430	684	462
45.7	416	558	398	567	407	448	398	475
48.8	416	567	413	585	430	471	421	494
51.8	434	585	413	590	430	475	421	507
54.9	434	585	421	608	457	494	439	521
57.9	439	585	439	626	480	521	462	535
61	439	585	439	631	480	521	471	549

[a]The width and length of berths for floating drydocks include out to out of anchors, assuming that anchors are placed in accordance with the diagram. Berth diameter for free-swinging floating drydocks may be obtained from Tables 5-19, 5-20, 5-21; in addition to that for drydock length, allowance must be made for vessel entering dock.
Berth types are as follows:

ARD = Auxiliary Repair Drydock
AFDL = Small Auxiliary Floating Drydock
AFDB = Large Auxiliary Floating Drydock
YFD = Floating Drydock

Table 5-23 Size of Berth, in Feet, for Floating Drydocks and Spread Moorings[a]



Depth of Water at MLLW (ft)	ARD		AFDL 2,800 T Concrete		AFDB 10 Sections		AFDB 9 Sections	
	Width	Length	Width	Length	Width	Length	Width	Length
33	-	-	-	-	-	-	-	-
38	600	945	-	-	-	-	-	-
41	600	945	615	900	-	-	-	-
50	690	1,005	690	975	-	-	-	-
57	765	1,050	780	1,035	-	-	-	-
65	765	1,065	780	1,080	-	-	-	-
74	840	1,125	855	1,140	-	-	-	-
84	930	1,185	945	1,200	1,140	1,710	1,140	1,620
90	1,005	1,230	1,020	1,245	1,170	1,740	1,170	1,665
100	1,005	1,260	1,020	1,320	1,230	1,815	1,230	1,725
110	1,005	1,305	1,095	1,365	1,290	1,860	1,290	1,770
120	1,140	1,335	1,185	1,410	1,335	1,905	1,335	1,830
130	1,215	1,395	1,260	1,455	1,380	1,950	1,380	1,875
140	1,290	1,425	1,260	1,515	1,425	1,995	1,425	1,905
150	1,365	1,485	1,320	1,560	1,470	2,040	1,470	1,950
160	1,365	1,485	1,395	1,605	1,500	2,070	1,500	1,980
170	1,410	1,515	1,395	1,650	1,530	2,100	1,530	2,010
180	1,470	1,560	1,470	1,680	1,545	2,115	1,545	2,025
190	1,545	1,605	1,545	1,725	1,560	2,130	1,560	2,040
200	1,545	1,620	1,545	1,740	1,560	2,130	1,560	2,040

Table 5-23 Size of Berth, in Feet, for Floating Drydocks and Spread Moorings[a] -
Continued

Depth of Water at MLLW (ft)	AFDB 7 Sections		YFD 18,000 T		AFDL 1,000 T Steel		AFDL 1,900 T Steel	
	Width	Length	Width	Length	Width	Length	Width	Length
33	-	-	-	-	600	750	-	-
38	-	-	-	-	600	750	600	855
41	-	-	-	-	600	750	600	705
50	-	-	-	-	675	825	675	930
57	-	-	825	1,260	765	900	765	990
65	-	-	825	1,290	765	930	765	1,050
74	1,005	1,485	885	1,365	840	1,005	840	1,125
84	1,005	1,485	960	1,455	930	1,080	915	1,200
90	1,065	1,560	1,050	1,515	1,020	1,155	1,005	1,230
100	1,155	1,635	1,050	1,545	1,020	1,185	1,005	1,305
110	1,155	1,635	1,110	1,620	1,095	1,245	1,080	1,350
120	1,200	1,680	1,170	1,695	1,185	1,320	1,155	1,410
130	1,275	1,755	1,245	1,755	1,260	1,395	1,245	1,470
140	1,335	1,830	1,245	1,785	1,260	1,410	2,245	1,515
150	1,365	1,830	1,305	1,860	1,335	1,470	1,305	1,560
160	1,365	1,860	1,355	1,920	1,410	1,545	1,380	1,620
170	1,425	1,920	1,355	1,935	1,410	1,560	1,380	1,665
180	1,425	1,920	1,380	1,995	1,500	1,620	1,440	1,710
190	1,440	1,920	1,440	2,055	1,575	1,710	1,515	1,755
200	1,440	1,920	1,440	2,070	1,575	1,710	1,545	1,800

[a]The width and length of berths for floating drydocks include out to out of anchors, assuming that anchors are placed in accordance with the diagram. Berth diameter for free-swinging floating drydocks may be obtained from Tables 5-19, 5-20,5-21; in addition to that for drydock length, allowance must be made for vessel entering dock. Berth types are as follows:

ARD = Auxiliary Repair Drydock
AFDL = Small Auxiliary Floating Drydock
AFDB = Large Auxiliary Floating Drydock
YFD = Floating Drydock

/1/

5-7 NAVIGATION AIDS.

Aids to navigation are the markers and signals vessels require to safely use a navigation project. The navigation safety of a project is directly related to the clarity and visibility of aids to navigation. Channel design must be planned so that the layout, dimensions, and alignment facilitate clear marking. A reduced width may be possible in a well-marked channel as compared to a poorly marked channel, so a tradeoff between channel widening cost and aids to navigation costs should be considered in design; additional information is available in CEM Section VI-3.

5-7.1 Jurisdiction.

Where aids to navigation, such as lights, daybeacons, or buoys, are required, consult the District Office of the USCG or, in the case of areas where no district office has jurisdiction, the Commandant, USCG. This organization will advise as to requirements for aids to navigation. The aids, which conform to USCG specifications, may be purchased from the USCG. Structures for supporting the aids (towers for lights or daybeacons and moorings for buoys) shall be provided by or under the cognizance of the NAVFAC. The USCG has specific jurisdiction over all aids to navigation in the continental United States and in all outlying territories and possessions. Refer to Code of Federal Regulations, Title 33, for information relating to establishing aids to navigation. In foreign countries, the regulations of local agencies, where such agencies exist, govern in lieu of the USCG, but the USCG will assist, when requested, in establishing aids to navigation, even in foreign countries.

5-7.2 Types of Aids.

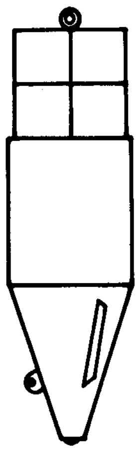
The following general data on aids to navigation are given to assist in preliminary layouts and as a basis to discuss requirements with the regulating agency. Aids to navigation include, but are not limited to, lighthouses (light stations), range lights, directional lights, minor lights, lighted and unlighted buoys, daybeacons, and sound signals. Other types of aids to navigation that are not under the primary cognizance of the NAVFAC include lightships, radio beacons, radar beacons, and loran stations. Several types of navigational aids are illustrated in Figure 5-25 through Figure 5-29.

5-7.2.1 Lighted Aids.

The placing of lights is a function of local navigation requirements and topography. General rules are not applicable. Height of the lantern and type and candlepower of illuminant shall be specified. For daytime use, light structures shall be distinctively marked or painted in order to provide easy identification.

- Primary Seacoast Lights. These lights, which may be attended or automatic, are established on seacoasts, bays, sounds, and lakes for the purpose of marking landfalls and coastwise passages from headland to headland, and in harbors where powerful candlepower is necessary. The light source is designed to obtain the maximum geographic range.

Figure 5-25 The 2 CR Buoy



1952 TYPE STANDARD

FUNCTION

THE 2 CR BUOY IS DESIGNED AND CONSTRUCTED FOR EXPOSED OR SEMIEXPOSED LOCATIONS WHERE AN UNLIGHTED BUOY IS REQUIRED.

PHYSICAL CHARACTERISTICS

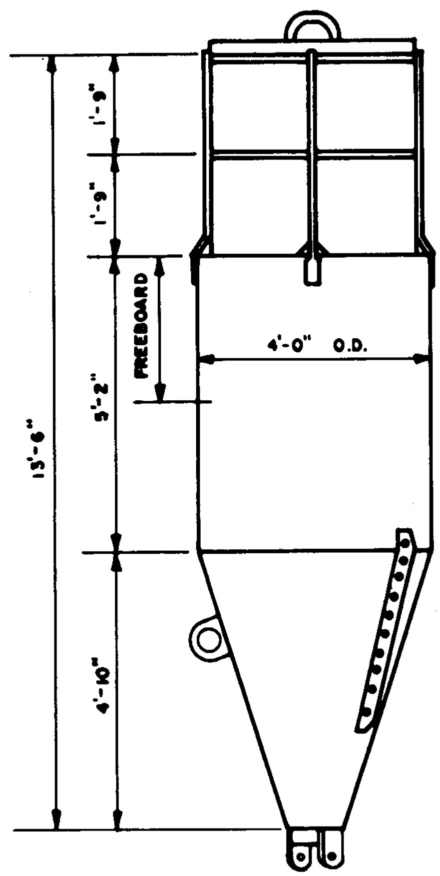
BUOY WEIGHT	2,700 LB
BUOY DRAFT (NO MOORING)	6 FT - 1 IN
FREEBOARD (NO MOORING)	3 FT - 11 IN
MINIMUM FREEBOARD	1 FT - 0 IN
POUNDS PER INCH OF IMMERSION	67

RELATED EQUIPMENT

MOORING CHAIN SIZE	7/8 IN
SINKER SIZE	4,000 LB

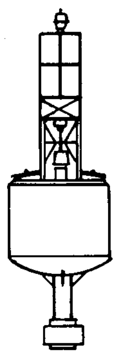
OPERATIONAL CHARACTERISTICS

NOMINAL VISUAL RANGE OF DAYMARK	2.8 NMI
RADAR RANGE	2.5 NMI
MAXIMUM CURRENT	6 K
MINIMUM MOORING DEPTH	15 FT
MAXIMUM MOORING DEPTH	200 FT



DIMENSIONS OF THE 2 CR

Figure 5-26 The 8 x 26 LBR Buoy



1962 TYPE STANDARD

FUNCTION

THE 8x26 LBR BUOY IS DESIGNED AND CONSTRUCTED FOR EXPOSED OR SEMIEXPOSED LOCATIONS. THIS BUOY CONFIGURATION IS USED WITH A 225-LB BELL, WAVE-ACTUATED SOUND SIGNAL. THE BASIC BUOY IS THE SAME AS THE 8x26 LR.

PHYSICAL CHARACTERISTICS

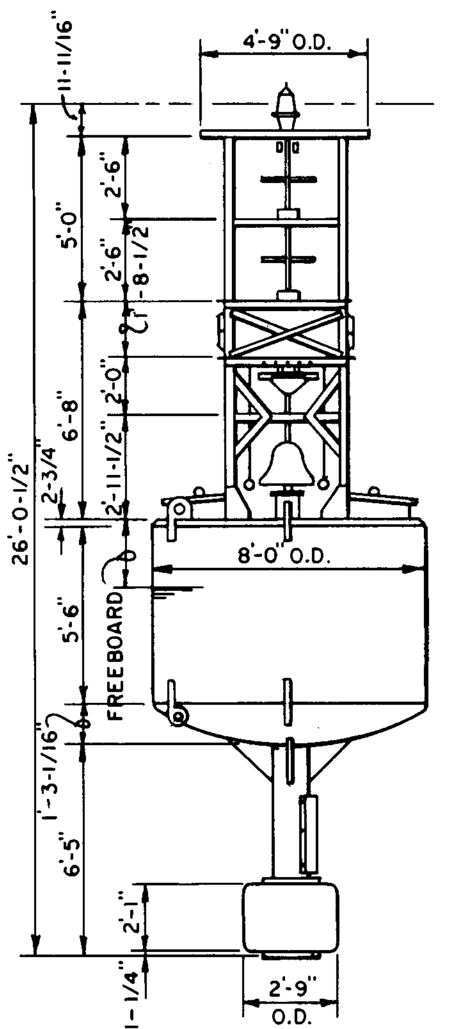
BUOY WEIGHT	11,917 LB
BUOY DRAFT (NO MOORING)	10 FT-3 IN
FOCAL HEIGHT OF LIGHT (NO MOORING)	15 FT.-8 IN
FREEBOARD (NO MOORING)	3 FT-1 IN
MINIMUM FREEBOARD	1 FT-3 IN
POUNDS PER INCH OF IMMERSION	270

RELATED EQUIPMENT

POWER UNITS (MAXIMUM NUMBER AND SIZE)	2-B30
SOUND EQUIPMENT	225-LB BELL
BRIDLE SIZE (CHAIN DIAMETER AND LENGTH)	1-1/4 IN x 15 FT
MOORING CHAIN SIZE	1-1/4 IN
SINKER SIZE	8,500 LB

OPERATIONAL CHARACTERISTICS

NOMINAL VISUAL RANGE OF DAYMARK	3.2 NMI
RADAR RANGE	3.7 NMI
MAXIMUM CURRENT	4 K
MAXIMUM MOORING DEPTH	25 FT
MAXIMUM MOORING DEPTH (B10)	220 FT
(B30)	190 FT



DIMENSIONS OF 8x26 LBR.

Figure 5-27 Single Pile Steel Beacon Structure

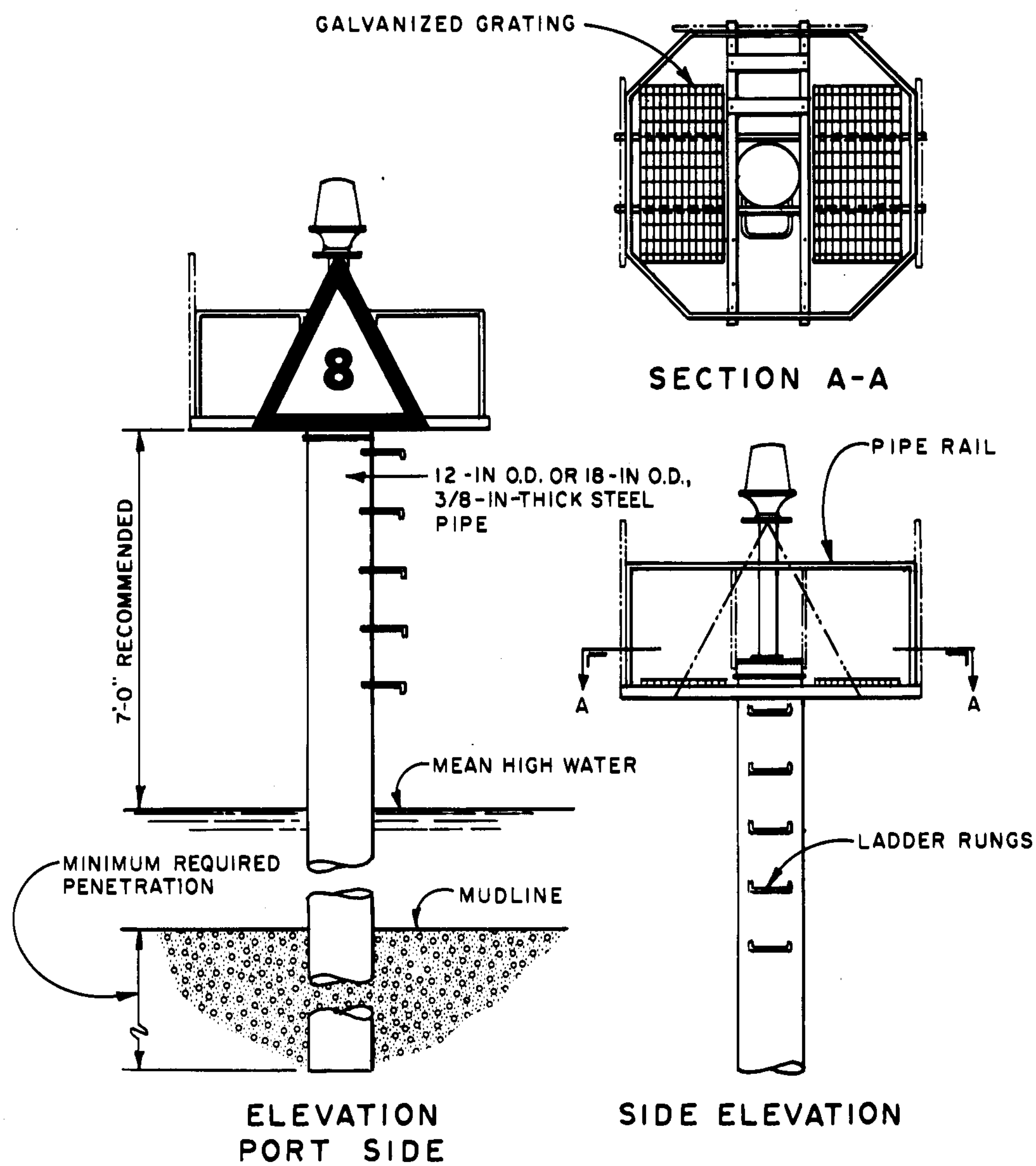
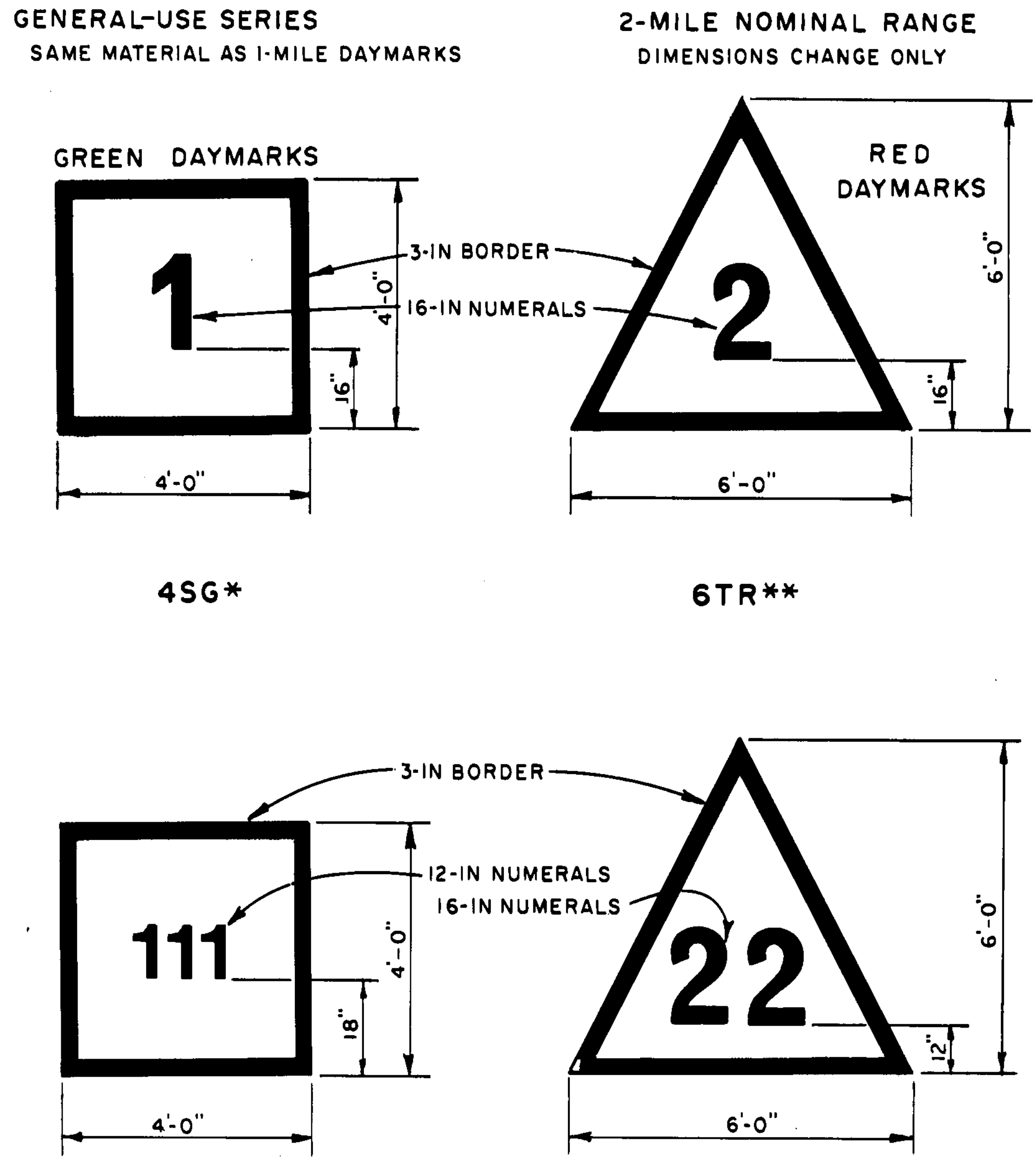
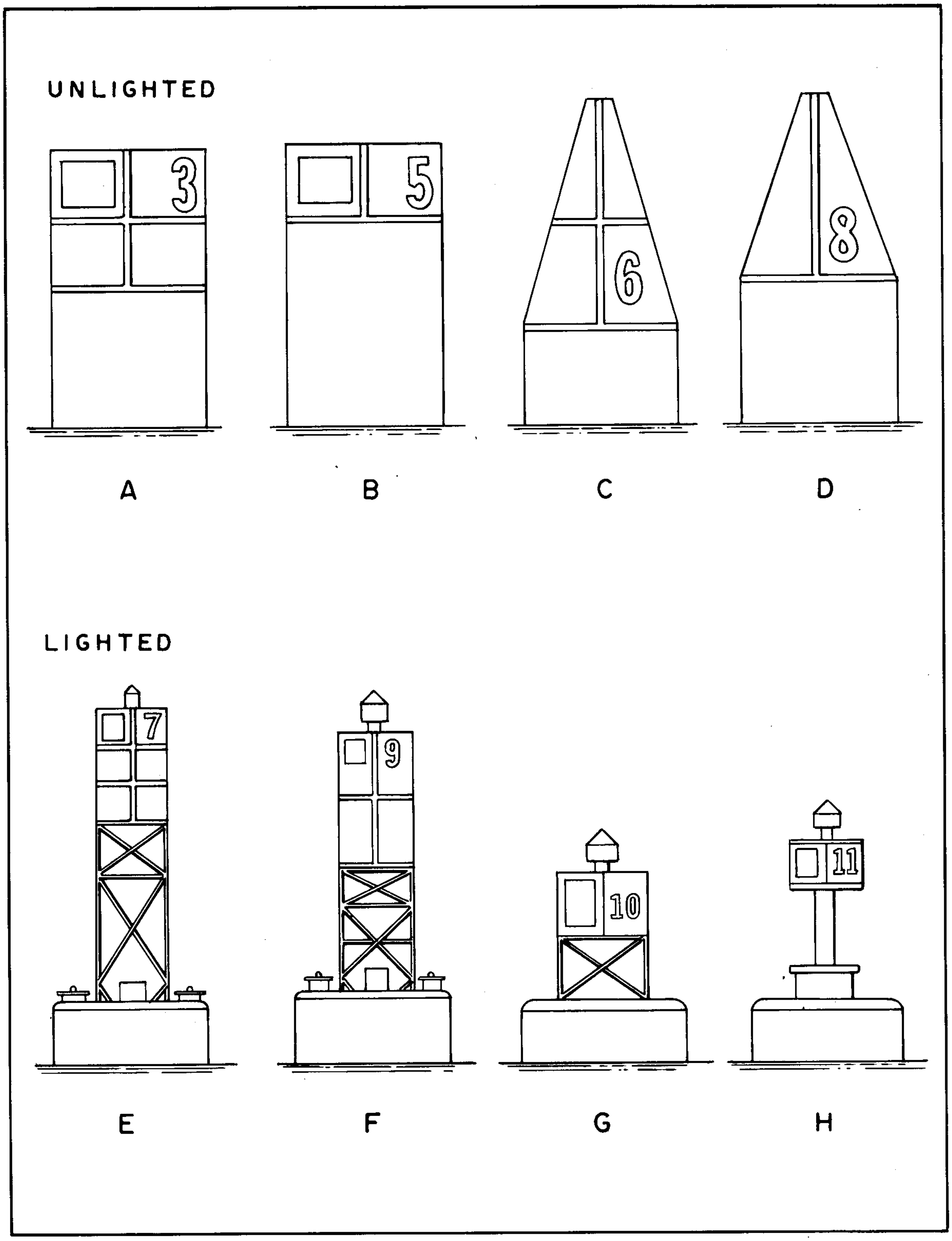


Figure 5-28 Lateral Daymarks



* FOR 2 NUMERALS USE 16-IN NUMERALS AT HEIGHT OF 16 IN OFF BASE
** FOR 3 NUMERALS USE 12-IN NUMERALS AT HEIGHT OF 12 IN OFF BASE
NOTE: DAYMARKS CONSIST OF RETROREFLECTIVE BORDERS AND NUMERALS ON A FLUORESCENT BACKGROUND.

Figure 5-29 General Use Series Buoys, Radar Reflector Type



- Secondary Lights. These lights, which also may be attended or automatic, are established at harbor entrances and other locations where the needs for high candlepower and long range are less necessary, and on large inland waterways as intermediate aids in harbor channels and in other inshore channels where the requirements of navigation indicate that the range and candlepower of this class are necessary.

- Range Lights. These are pairs of lights located to form a range in line with the center of a channel or entrance to a harbor. The rear light is higher than the front light and a considerable distance in back of it. The length of the range and width of the channel govern the height and distance of separation necessary between the lights. Range-light structures shall be equipped with daymarks for ordinary daytime use. Ranges may be used either ahead or over the stern.

- Directional Lights. A directional light is a single light which will project a beam of high intensity, separate color, or other special characteristic, in a given direction. It has limited use in those cases where a two-light range may not be practicable or necessary, and for other special applications. The directional light is essentially a narrow-sector light with or without adjacent sectors which give information as to the direction of and relative displacement from the narrow sector.

- Minor Lights. These are lights of relatively low candlepower usually established in harbors, along channels, along rivers, and in isolated locations. They are generally unattended and unwatched and should operate automatically. Depending upon circumstances, these lights may be displayed from towers, skeleton structures, or from a group of piles. They shall be colored to distinguish them from the surrounding background and from adjacent structures.

- Lighted Buoys. These are floating aids showing from the upper of their structures an automatically operated, low-candlepower light. Colors and characteristics vary. Lighted buoys are established for the purpose of definitely identifying spots. These include the entrance and side limits of natural and dredged channels, centers of fairways, obstructions and wrecks, isolated natural dangers in offshore or restricted waters, and for special purposes such as quarantine or general anchorages. These lights are powered by batteries.

5-7.2.2 Unlighted Aids.

- Unlighted Buoys. These are floating aids of varying size, shape, and color. They serve the same general purposes as lighted buoys. They are used in areas of lesser importance or as intermediate aids to supplement lighted buoys in the more important areas.

- Daybeacons. Although all aids, whether lighted or unlighted, serve as a daymark to the mariner, daybeacons are specifically designed as unlighted structures used to mark isolated dangers, channels, edges, or alignment.

5-7.2.3 Sound Signals.

Sound signals are sound-producing devices operated mechanically or by the action of the sea, consisting of horns, sirens, diaphones, bells, gongs, and whistles. They are installed on shore structures and on buoys.

- Operation. Most sound signals on structures are attended. Sound signals on a few minor shore structures or on buoys shall be automatically operated. Other signals on buoys shall be operated by action of the sea.

- Purpose. Sound signals are intended to warn of danger and provide the mariner with the best practicable means of determining his position. This is in relation to the sound signal station at such times as the station, or any light that it might display, is obscured from view by fog, haze, smoke, or generally poor visibility.

- Range. To be effective, sound signals must be capable of a useful range, and they must be of such characteristic duration as to permit their direction to be judged with reasonable accuracy by ear. It must be remembered that due to the uncertainty of passage of sound through the atmosphere, the range of sound signals cannot be depended upon or specifically fixed. Major fog signals shall have a minimum range of 1-1/2 miles (2.4 km).

5-7.3 Lights.

Due to the increase in shore illumination along navigable waters, the usefulness of fixed white lights is limited to areas where the usable range is short or where the natural background includes few other lights.

5-7.3.1 Length of Period.

The period of a flashing or occulting light is the time required to go through a full set of changes. The limiting basis for the period of light characteristics is 60 seconds, since it is considered that the mariner cannot always safely watch the light to the exclusion of everything else for a longer period. Light characteristics that are so similar as to require careful timing in order to differentiate between them should not be established in close proximity to one another.

5-7.3.2 Colors.

White, red, yellow, and green are used for navigational lights. Other colors are not used.

- Means of Obtaining Color. The light source in all illuminating apparatus is white. Color is produced by the addition of colored-glass shades or screens.

- Alternating Colors. In certain instances, light characteristics consist of alternations of colors, with either two or three colors being used in combination. Where an alternating white and red or white and green light is desired, the candlepower of the colors shall be equalized by selection of the lens panels.

5-7.3.3 Visibility.

The distances at which lights may be seen in clear weather are computed for a height of the observer's eye of 15 feet (4.6 m) above sea level. Table 5-20 gives the approximate geographical range of visibility for objects of varying elevations that may be seen by an observer whose eye is at sea level. To determine the distance of visibility for an observer whose eye is at an elevation other than sea level, add to the distance of visibility (determined from Table 5-20) the distance of visibility from Table 5-20 which corresponds to the elevation of the observer's eye above sea level.

5-7.3.4 Suppliers.

Lights built to USCG specifications may be purchased from the USCG or from a manufacturer.

Table 5-24 Distances of Visibility for Objects of Various Elevations above Sea Level

Elevation (f (m))	Distance (nmi)	Elevation (ft (m))	Distance (nmi)	Elevation (ft (m))	Distance (nmi)
5 (1.5)	2.5	70 (21.3)	9.6	250 (76.2)	18.2
10 (3.0)	3.6	75 (22.9)	9.9	300 (91.4)	19.9
15 (4.6)	4.4	80 (24.4)	10.3	350 (106.7)	21.5
2020 (6.1)	5.1	85 (25.9)	10.6	400 (121.9)	22.9
25 (7.6)	5.7	90 (27.4)	10.9	450 (137.2)	24.3
30 (9.1)	6.3	95 (29)	11.2	500 (152.4)	25.6
35 (10.7)	6.8	100 (30.5)	11.5	550 (167.6)	26.8
401 (12.2)	7.2	110 (33.5)	12.0	600 (182.69)	28.0
45 (13.7)	7.7	120 (36.6)	12.6	650 (198.1)	29.1
50 (15.2)	8.1	130 (39.6)	13.1	700 (213.4)	30.3
55 (16.8)	8.5	140 (42.7)	13.6	800 (243.8)	32.4
60 (18.3)	8.9	150 (45.7)	14.1	900 (274.3)	34.4
65 (19.8)	9.2	200 (61)	16.2	1,000 (304.8)	36.2

5-7.4 Buoys.

Buoys are used for lateral identification for channels in navigable waters. Demarcation of the channel is accomplished by arranging the colors, shapes, numbers, and light characteristics of the buoys. The standard coding system of the USCG should be followed, where possible, and shall be obtained from that organization. Special buoys, having no lateral significance, should be used for marking anchorages, nets, and dredging and other special-purpose areas. For characteristics of buoys, consult the USCG.

5-7.5 Daybeacons.

Daybeacons shall be constructed and painted in order to be distinct and conspicuous. Only white, green, or red color shall be used, either separately or in combination. Where a number of daybeacons are to be used within a limited area, use different types of construction to assist in distinguishing among them. Daybeacons should be reflectorized for night use.

5-7.6 Fog Signals.

Design fog signals at stations, where a continuous watch is maintained, to be sounded both when the visibility decreases to 5 miles (8.1 km) and when the fog whistle of a passing vessel is heard. Design fog signals at locations where no watch is maintained to operate continuously or automatically. Fog signals on buoys generally should be operated by the motion of the sea and should operate continuously.

5-7.6.1 Sound Intervals.

Time blasts for a minimum 2 seconds in length, occurring at intervals not exceeding 60 seconds; preferable interval length is 15 seconds.

5-7.6.2 Suppliers.

Fog signals built to USCG specifications may be purchased from the USCG or from a manufacturer.

5-7.7 Ranges.

Height, distance apart, size of daymark, and color marking are dependent on local conditions, and general rules are not applicable. There are no rules as to shape of the daymark, except that it should be the most distinctive possible shape in the range system.

5-7.8 Design of Support Structures.

Design dolphins, towers, and similar supports for lights, daybeacons, and similar aids in accordance with requirements for the same or similar structures established elsewhere in this manual.

5-7.9 Moorings.

Design moorings for buoys according to the requirements of \1 UFC 4-159-03 /1/.

5-7.10 Buoy Systems.

The U.S. and most Western-Hemisphere countries use a buoy system based on green daymarks/black buoys for port hand and red daymarks/red buoys for starboard hand when returning from sea. Many Eastern-Hemisphere countries use green for starboard and red for port hand. The system that is used in the local area is an important consideration when designing a new aid system.

5-7.11 Environmental Monitoring and Operator Guidance System.
As an operational underkeel clearance (UKC) forecasting system, the Environmental Monitoring and Operator Guidance System (EMOGS) was developed to provide safe transit of deep draft vessels through shallow entrance channels. A risk-based system used to avoid vessel grounding and to minimize channel depth requirements, EMOGS can predict the estimated UKC during a specified transit through a shallow water channel for the vessel in question. Silver et al.'s David Taylor Research Center (DTRC) publication, Environmental Monitoring and Operator Guidance System (EMOGS) Overall Technical Description, DTRC Report SHD-1283-16, provides for further details.

- The EMOGS, as installed at Kings Bay to protect OHIO class submarines, is used because it is not economically feasible to dredge the channel to provide safe transits of the vessels in all weather conditions. EMOGS provides the clearance between the vessel hull and the bottom in near real time. EMOGS software uses bottom survey data, statistical and measured wave and tidal data, and calculated ship motions to assess the risk of the submarine touching the channel bottom. Where the MicroVAX computer is not available, there is a manual procedure for carrying out the calculations; refer to the EMOGS User Handbook by Silver et al. (DTRC Report SHD-1283-02).

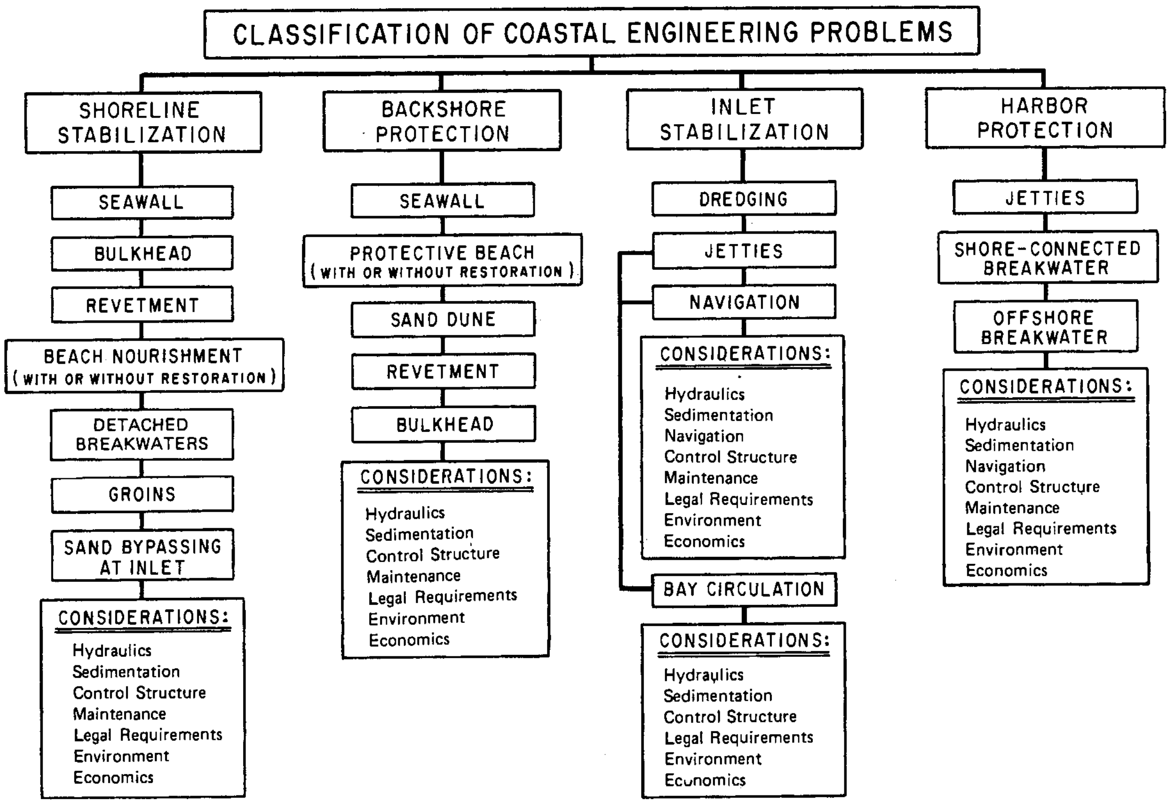
- The level of risk is sensitive to sedimentation rates and dredging activities, and any change in environmental conditions must be represented in the predictions.

5-7.12 Carrier Channel Guidance System.
A guidance system was developed to reduce the risk of aircraft carriers touching the channel bottom while transiting entrance channels at Norfolk, Mayport, Pensacola, San Diego, and Pearl Harbor. This system is used by the navigation officer to determine the advisability of transiting the channel at a scheduled date and time. The system is PC based and is set up in the Meteorological Office aboard ship. The system provides the predicted clearance between the vessel hull and the bottom in near real time using bottom survey data, statistical and measured meteorological data, water depth measurements and calculated ship motions.

5-8 MARINE IMPROVEMENT AND SHORE PROTECTION.
Coastal engineering problems may be classified into four general categories: shoreline stabilization, backshore protection (from waves and surge), and inlet stabilization and harbor protection (Figure 5-30). A coastal problem may fall into more than one

category. Once classified, various solutions are available to the coastal engineer. Some of the solutions are structural; however, other techniques may be employed such as zoning and land-use management. The primary types of coastal structures and methods of marine improvement and shore protection are discussed in Chapter 7.

Figure 5-30 General Classification of Coastal Engineering Problems (USACE, 1984b).



5-9 SEDIMENT MANAGEMENT PROJECTS.

The development of sediment management projects is available in CEM Section V-5. Discussions are presented on the use of weir jetties, sediment traps, and training dikes to interrupt longshore sand movement, to accumulate sand on the shore, or to retard sand losses. Maintenance in existing channels, berthing areas, and the expansion of coastal facilities requires dredging in areas that may contain elevated levels of heavy metals, pesticides, and other contaminants. Though concentrations of these contaminants may not always approach hazardous levels, contaminated sediments are not suitable for unconfined ocean disposal. Remediation of these sites may require dredging and disposal of contaminated dredged materials, which requires special management. Material may be placed in a confined, aquatic disposal site, capped, disposed in an upland site, or possibly treated and then undergo beneficial re-use. Management alternatives, cumulative impacts, and long-term solutions to prevent re-contamination of sediment are issues that need to be addressed with respect to the ecological and health implications of contaminated dredged material disposal. All project areas are to be evaluated for environmental risks early in the planning stages of a project. Subsequently, if a hazardous substance is suspected at a project site, the sediment should be left undisturbed and the appropriate Environmental Department or Regional Environmental Coordinator of the appropriate activity be notified.

5-10 PHYSICAL SECURITY.

The physical security of harbor and coastal facilities must be addressed in the early stages of project planning. The NAVFAC LANT Engineering Criteria and Programs Office is presently developing Anti-Terrorism, Force Protection (AT/FP) design and construction criteria for the programming, planning, design, and construction of AT/FP systems for waterfront facilities. Interim Technical Guidance on Anti-Terrorism, Force Protection and Physical Security of Waterfront Facilities and Installation can be obtained by contacting the NAVFAC LANT Engineering Criteria and Programs Office at 757-322-4202.

CHAPTER 6 DESIGN OF DREDGING PROJECTS

6-1 INTRODUCTION.

Dredging is generally carried out either to increase the depth of a body of water, or to replace, re-configure or mine for *in situ* sediments. It may involve new construction (Capital dredging), such as excavation for harbors or canals, the construction of stable bases for tunnels or reclamation of submerged land. Maintenance dredging on the other hand is used for such purposes as maintaining waterway utility and restoring the hydraulic efficiency of reservoirs. Section V-5-3 of the CEM contains information on dredging. Additional extensive detailed information on dredging project design can be found in the Handbook of Dredging Engineering by J.B. Herbich; Dredging: A Handbook for Engineers by Bray, Bates and Land and the ASCE Engineering Practice #80, “Report on Ship Channel Design (Herbich, 1992; Bray et al., 1997; ASCE, 1993).

6-2 ACCOMPLISHMENT OF WORK.

Government-owned dredges should be used to the maximum extent consistent with economy. When the only suitable dredging equipment is in private ownership, or when the workload exceeds the capability of available government dredging facilities, private contractors may accomplish dredging. Some of the factors to be considered in planning a dredging project are:

- Marine environment, including water depths, waves, tides, currents;
- Nature and character of the sediments;
- Dredged quantities and disposal areas;
- Social, biological, regulatory and institutional factors;
- Long term dredging and disposal problems.

More detailed information on dredging project implementation is found in Chapter 2 of Dredging: A Handbook for Engineers (Bray, 1997).

6-3 TERMINOLOGY.

Some common terminology is provided in the section below. For additional information on this subject, refer to the Dredging Desk Reference (Verna and Maciejewski, 1994).

Centrifugal Pump. A pump operated by centrifugal force, the force outward exerted by a body moving in a curved path.

Clamshell. A dredging bucket made of two similar pieces hinged together at one end.

Drag Head. A device placed on the end of a suction pipe (connected to a dredge) used for loosening or cutting away the bottom material that is to be dredged.

Dredge. (1) To excavate or move soil or rock underwater. (2) A vessel, or item of floating plant, equipped with means to move or excavate soil or rock underwater.

Hopper. A funnel-shaped chamber in which materials are stored temporarily and later discharged through the bottom.

6-4 CURRENT DREDGING DESIGN PRACTICE.

Dredging practice and plant equipment is determined based on whether one is dealing with river dredging, estuary or coastal dredging, ocean dredging, beach replenishment, etc. Preliminary investigations must first be conducted to provide data to confirm that dredging will be necessary and that environmental regulations can be satisfied. A preliminary study will provide estimates of the sedimentation regimes, disposal areas, and the type of dredging plant that will be employed.

6-4.1 Navy Harbors.

The dredging of Navy harbors may involve the dredging of clay and silt from estuarine harbors or the dredging of sand from harbors on open coasts. By 1980, 87 percent of the Navy's total annual maintenance-dredging volume consisted of cohesive sediments, while 13 percent consisted of sand. A large part of the total dredging in naval harbors consists of removing shoaled material from under berthing piers. Other dredging activities include dredging of navigation channels and turning basins, as well as channel-entrance bypassing.

6-4.2 Dredging Research Program.

The USACE Dredging Research Program (DRP) conducts studies to develop up-to-date information on dredging technology. The results of these studies are compiled in technical reports that may be obtained from WES. Additional information can be found on the USACE web site.

6-4.3 Methods.

Extensive discussion of current practices, including agitation dredging, barrier curtains, water injection dredging, sediment bypassing, and jet scour arrays, can be found in Chapter 7 of Dredging: A Handbook for Engineers (Bray et al., 1997) and the Handbook of Dredging Engineering (Herbich, 1992).

6-5 PROJECT DEPTH.

According to the Permanent International Association of Navigational Congresses (PIANC), the required dredge depth for ship channels is determined by summing up the following components:

- Reference Water level minus lowest low water level
- Admissible ship draft, including trim and density change allowances
- Vertical ship motions, including squat, pitch and roll

- Net required under-keel clearance
- Depth sounding precision
- Sediment deposition thickness between scheduled dredgings
- Dredging accuracy tolerances

Discussions of this subject are contained in various sources including the joint PIANC and IAPH Final Report entitled, "Approach Channels - A Guide for Design," PTC II-30, dated June 1997; the Report of Ship Channel Design (ASCE, 1993); Chapters 3.2.1 and 8.3.1 in Dredging: A Handbook for Engineers (Bray et al., 1997).

6-5.1 Overdepth Dredging.
Previous studies have shown up to 20 percent of over excavation on typical dredging projects. In addition to the additional dredging costs encountered, this can also result in premature filling of scarce disposal areas. Two factors that control overdepth dredging are dredge control and dredge survey. Modern dredge control is achieved by instrumentation, which provides real time knowledge of cutterhead depth and velocity and density of the slurry being pumped (Herbich, 1992). However, in some situations, it is less expensive to overdredge an area by 1 or 2 feet (0.3 or 0.6 m) than to pay for the careful manipulation of dredging equipment and for the extra time involved in dredging to the exact depth required. Overdepth dredging also allows for some additional shoaling before dredging is required again. Overdepth dredging should be investigated for each specific site as it cannot be used in every situation. For example, it may jeopardize stability of nearby structures.

6-5.2 Advanced Maintenance Dredging.
It is advantageous to minimize maintenance costs by performing advanced maintenance dredging to increase the interval between dredgings. The channel is dredged deeper and/or wider than its original design or authorized depth, thereby allowing for shoaling to occur while the channel can still be navigable. Advance maintenance dredging can also greatly increase the time intervals between maintenance dredging operations, which can reduce the number of mobilization and demobilization tasks and the costs associated with them. This method is economically feasible if the money saved through a reduced dredging frequency schedule is greater than the cost of removing any additional sediment that may have been deposited as a result of the deeper and wider channel.

To determine whether or not advanced maintenance dredging is economically feasible, the design engineer must analyze and extrapolate shoaling data for "prior to dredging" depths of the channel and use numerical models to simulate site-specific estuarine hydrodynamics and sediment transport mechanisms. If appropriate data are unavailable for performing analytical studies, and numerical modeling studies are cost prohibitive, a minimal advance maintenance effort can be put into effect and the results evaluated. Thus, if money is saved, advanced maintenance dredging efforts can be stepped up and, conversely, if money is lost, the efforts can be abandoned (Sedimentation Control To Reduce Maintenance Dredging of Navigational Facilities in Estuaries, 1987).

6-5.3 Disposal Areas.
The selection of an appropriate disposal area depends upon the physical characteristics of the dredged material, potential environmental impacts, size of the project and social, political, economic and regulatory considerations. Dredged material disposal sites may be offshore or onshore sites, confined by levees or containment dikes, or unconfined. Because of environmental considerations, confined upland sites are generally preferred unless the dredge spoil is being used to create wetlands. Selection of an upland site requires consideration of return of effluent water to the waterway. Unnecessary entrapment of water that may cause flooding must be avoided. It must be assured that effluent water does not pick up additional turbidity or toxic chemicals as it returns to the waterway. A more thorough discussion of these options is contained in the Handbook of Dredging Engineering (Herbich, 1992), Chapter 8, and in Chapter 5 of Dredging: A Handbook for Engineers (Bray et al., 1997). Bray also discusses the various types of sites for disposal as well as various processes of disposal and cleaning of dredged material and the decision making process for disposal (Bray et al., 1997). The PIANC bulletin, Management of Dredged Material From Inland Waterways (PIANC, 1990) and USACE EMs 1110-2-5026 and 1110-2-5027 are also useful and recommended sources of information.

6-5.3.1 Upland Open Site.
This disposal location is generally used for placement of coarse, cohesionless sediments. Material placement is controlled with small berms constructed by a bulldozer or similar land-construction equipment.

6-5.3.2 Upland Diked Site.
This type of disposal location is generally used for the confined placement of fine-grained sediments. Dikes constructed prior to sediment placement typically have overflow weirs to minimize turbidity in receiving waters. Dikes may be constructed of existing soil or may be built up with hydraulically placed fill. Soil embankments should have a maximum slope of 1 vertical to 2 horizontal on the exterior face and 1 vertical to 3 horizontal on the interior face. Hydraulic fill must be placed at the natural angle of repose. Care should be taken to provide a cross-sectional area sufficient to withstand the water depths in the fill. A minimum freeboard of 2 feet is typical. Placement of dredged material at an upland diked site may cause ground-water contamination; investigations should be made to determine if this possibility exists. Certain situations require that the diked site be lined with filter cloth or a layer of clay to prevent penetration of pollutants into the ground-water system.

6-5.3.3 Open-Water Site.

With this type of disposal location, materials are generally limited to coarse sediments due to environmental considerations. EPA regulations and designated disposal areas should be investigated.

6-5.3.4 Contained-Water Site.
For this type of disposal location, earthen dikes are usually constructed prior to dredging. The use of silt curtains instead of earthen dikes is possible under certain combinations of sediment, tides, currents, and environmental considerations.

6-5.4 Downtime Criteria for Projects and Water Level Extremes.
An acceptable method for determining the design basis for water level extremes, such as the frequency and duration of low and high water levels should be determined from the historical record and used to define the maximum level of planned and unplanned downtime with respect to project scheduling.

6-6 ECONOMIC FACTORS.
The economic factors affecting the dredging of Navy harbors are the following.

6-6.1 Amount of Material to be Dredged.
The mobilization and demobilization costs will constitute a significant portion of the total project cost for small-volume dredging projects. For large-volume dredging projects, the mobilization and demobilization costs will only increase the cost per cubic yard by a relatively small amount.

6-6.2 Distance From the Dredging Site to the Disposal Site.
This distance depends on the availability of disposal sites, the volume, and the environmental mental quality of the dredged material. If the sediment is contaminated, regulatory agencies may require dumping at a "contained" land disposal site. In many areas these sites are limited. Ocean disposal sites are attractive alternatives because of their unlimited capacity and general proximity to Navy harbors. In either case, additional costs and time delays may be incurred because the dredged material must be proven environmentally clean prior to issuance of a dredging permit. Regardless of where the material is dumped, cost is a function of distance to the disposal site and mode of transport.

6-6.3 Environmental Considerations.
Some form of environmental documentation is required for every dredging project, which can add substantially to project costs. The minimum requirement is a Preliminary Environmental Assessment. Additional chemical or biological testing may be required to supplement this documentation. If ocean disposal is proposed, it is likely that bioassays will be required at an additional cost. Most costly of all are environmental surveys of the dredge site and the disposal site which may be required in environmentally sensitive areas or cases of critical contamination. It is recommended to involve the local environmental office in the planning discussions from the inception of the project.

6-6.4 New Work versus Maintenance Dredging.
Where an area has not been dredged before, the bottom sediments may be consolidated and difficult to dredge. The added time required to dredge new material may incur additional costs.

6-6.5 Other Factors.
Other factors include the cost of fuel, competition between private and public dredgers, and the configuration and use of the naval harbor to be dredged. Refer to either Chapter 8 of The Handbook of Dredging Engineering (Herbich, 1992) for an Economic Analysis for Disposal or Chapter 10 in Dredging: A Handbook for Engineers (Bray et al., 1997) for a discussion of Dredging Costs and Prices.

6-7 GEOTECHNICAL FACTORS.
Soil investigations and testing techniques are generally similar to terrestrial procedures except that trial dredging may be resorted to where conditions for a particular type of dredge are marginal. Soil classifications generally refer to the PIANC adopted system.

6-7.1 Sediment Analysis.
Sediment samples from the dredge area should be obtained and analyzed.

- *Grab samples*. Samples for maintenance dredging are often not necessary as review of historical records reveals sediment characteristics. If samples are necessary for maintenance projects they are usually grab sampled taken from the bed surface.

- *Subsurface investigation*. New-work dredging requires subsurface investigation. Recoverable cores are recommended where consolidated sediments may be encountered.

- *Probing or sonar profiling*. If rock pinnacles or debris are detected by grab or core samples, extensive probing or sonar profiling of the dredging area should be accomplished to locate and quantify rock and debris.

- *Sediment testing*. To evaluate dredging-plant requirements and disposal procedure, cohesionless samples should undergo mechanical sieve analysis. A chemical analysis is necessary for cohesive sediments. Bioassays may be necessary for cohesive sediments, depending on results of chemical analysis and proposed disposal action. If the project involves dredging of new sediments, a principal element of interest may be the density (or consistency) of material and, for cohesive sediments, the shear strength.

6-8 UNEXPLODED ORDNANCE.
Currently the Navy has embarked on a number of efforts to locate and dispose of unexploded ordnance (UXO). Where there is a past history indicating potential

existence of such ordnance, it must first be located so that care can be exercised to avoid injury to individuals or property damage.

6-9 MAGNETIC SILENCING FACILITIES.

In order to deal with magnetic silencing facilities (for degaussing and deperming), the facility should be designed with future dredging requirements in mind. If the facilities are already in place, a dredging method that will not impact the facilities must be chosen.

6-10 DREDGING EQUIPMENT.

A comprehensive summary of descriptions and optimum uses for various types of dredging equipment is found in Chapter 7 of The Handbook of Dredging (Herbich, 1992) and in Chapter 7 of Dredging: A Handbook for Engineers (Bray et al., 1997).

6-10.1 Mechanical Dredges.

Mechanical dredges dislodge and raise sediment by mechanical means. Mechanical-dredging methods are generally used in protected waters, but because the equipment is relatively mobile, some mechanical dredging may be accomplished in open water during short-term, calm-water conditions. Mechanically dredged sediments may be disposed alongside the dredge at a dumpsite or may be transferred to scows which transport the sediments to a dump site. The production rate by means of mechanical dredging is relatively low. Mechanical dredges produce a more irregular bottom than hydraulic dredges.

6-10.1.1 Types of Mechanical Dredges.

- *Clamshell, grab, or bucket dredge*. This system consists of a crane, or derrick, mounted on a floating barge, with a clamshell, orange peel, or dragline bucket used to pick up sediment and transfer it to an adjacent scow or barge. This dredge may be a specially built machine or may consist of land equipment on a suitable floating platform. This form of dredging can remove loose, unconsolidated sediments ranging in size from silts and clays to blasted rock. The dredge can be used in moderate-swell conditions. The system is not exceedingly efficient but has the advantage of high mobility. This mobility enables dredging at the base of bulkheads, piers, and fender piles without damaging these structures or the dredge equipment.

- *Ladder, or bucket-ladder, dredge*. This dredge consists of a floating dredge that has a continuous chain of buckets on a frame which is called a ladder. Each of the buckets possesses a cutting edge for digging into the sediment. The ladder is lowered to the bed so that the buckets can reach and cut sediments to be dredged. The buckets dump the dredged sediment by gravity at the opposite end of the ladder onto a conveyor system or an adjacent open barge. The barge may then transport the material to the disposal site. This dredging system is effective in hardpan and cemented sediments, but is ineffective in firm rock. The system cannot be used in swell conditions. This system is not often used in the United States.

- *Dipper-barge dredge*. This dredge consists of a backhoe mounted on a barge equipped with a trapdoor shovel. Sediment is removed from the bed and deposited alongside the dredge, in another barge, in the water, or onshore. Where the sediment is deposited depends on the length of backhoe reach. Spuds, which penetrate the bottom, are usually used to keep the barge from moving during a dredging activity. This dredging method is effective for hardpan and cemented sediments, as well as for firm rock that has been blasted. The effectiveness of this type of dredging system is limited in moderate-swell conditions.

6-10.2 Hydraulic Dredges.
Hydraulic dredges lift sediment from the bottom and transport it by means of a centrifugal pump. Hydraulic dredges can be used in either open or protected waters, depending on the type of dredge. The dredged material is transported in a slurry and is generally discharged by a pipeline in the hull of the dredge; the slurry is discharged alongside the dredge, or it may be pumped ashore. The rate of production depends on sediment type, depth of cut, and dredge size and power; it generally exceeds that of mechanical dredges.

6-10.2.1 Types of Hydraulic Dredges.

6-10.2.1.1 Pipeline, or suction, dredge.
This dredge consists of a barge-mounted centrifugal pump. A suction line, or pipe, extends from the pump beyond the bow and is lowered to the bed by means of an "A" frame and ladder. At the end of this ladder, the pipe moves along the bottom dislodging the material. The material is then pumped in a slurry to a discharge line extending beyond the stern of the dredge. The material may then be pumped to the disposal site through a discharge line. Using booster pumps can extend the distance through which the material may be pumped. Sweeping the suction pipe over an area at constant depth will result in the excavation of the channel bottom. Pipeline dredges are not self-propelled, but move by forward-mounted swing wires and aft-mounted walking spuds or wires. This type of dredge can be operated safely only in the absence of moderate to high swell; it can excavate material ranging from clays and silts to blasted rocks. The dredge is generally capable of dredging large volumes of material. Pipeline dredges are usually limited to excavation depths of approximately 60 feet (18.3 m). The rate of production will decrease with increased length of discharge line, increased lift, and increased bed-sediment compaction.

6-10.2.1.2 Cutterhead dredge.

This dredge consists of a pipeline dredge equipped with a rotary cutter at the end of the ladder. The cutter is used to dislodge bed sediments.

6-10.2.1.3 Dustpan dredge.
This dredge consists of a pipeline dredge with a dustpan-shaped head at the end of the ladder. The head is equipped with water jets that are used to dislodge bed sediments.

6-10.2.1.4 Bucket-wheel excavator.
This dredge consists of a pipeline dredge with a bucket wheel rotating (on a horizontal axis) at end of the ladder.

6-10.2.1.5 Trailing suction dredge.
This dredge consists of a self-propelled or tug-assisted vessel. The hull of the vessel contains a hopper and the dredge is equipped with one or two suction pipes (normally fitted with drag heads) extending below the hull to the bed. This dredge usually operates while underway, drawing slurry by centrifugal pumps to the hopper, where excess water is overflowed back to the waterway. Sediment is discharged at the disposal site by opening doors located on the hopper bottom or by pumping out the hopper. This dredge is a self-contained unit and is capable of operating in higher swell conditions. Because the dredge is self-propelled, it is capable of dredging material from sites which are large distances from the point of disposal.

6-10.2.1.6 Hopper Dredge.
This dredge consists of a trailing suction dredge with a ship shaped hull, a bridge, an engine room, and crew quarters. This dredge is typically used for the dredging of estuary and river-mouth bars that are prone to ocean-swell conditions.

6-10.3 Special Equipment.

6-10.3.1 High Solids-Content Dredge.
This dredge consists of a floating system capable of pumping high concentrations of solids through the use of compressed air. It is primarily used for removal of industrial wastes from rivers and harbors. The production rates are generally low and the distance over which the material may be pumped is limited. This type of dredge is not generally available.

6-10.3.2 Elevated-Platform Dredge.
This system consists of a pipeline dredge that incorporates a "jack-up" barge to elevate the equipment above the surface swells. The system incorporates a submerged discharge pipeline. Availability of this type of dredge is very limited.

6-10.4 Selection of Dredging Equipment.
Principal considerations upon which equipment selection is made include:

- exposure of dredging site

- volume and distribution of materials to be dredged
- type of material to be dredged
- location of disposal area
- distance to disposal area
- time available for work
- vessel traffic
- availability of equipment.

The US ACE DRP Technical Areas 3 and 4 contain numerous reports on the types of mechanical dredges listed in this chapter.

6-11 DISPOSAL OPTIONS.

Disposal of dredged material generally presents problems, particularly when there is a lack of candidate disposal sites. The beneficial use of dredged materials should be investigated.

6-11.1 Landfill.

Dredged sediments may be used as a landfill for commercial, industrial, and recreational purposes.

6-11.2 Construction Materials.

Coarse sediments are often suitable for use as construction aggregate. These sediments may be stockpiled for present and future use.

6-11.3 Marshland Wetland Habitat.

After intertidal- and submerged-fill operations are completed, shellfish larvae, wetland vegetation, or other organisms indigenous to the locale may be placed in the area to create a productive marshland.

6-11.4 Upland Wildlife Habitat.

During and after completion of above-water fills, seeding and contouring of sediments can provide a habitat indigenous to wildlife; this procedure may also prevent erosion.

6-11.5 Beach Nourishment.

Placement of suitable fill in water or on beaches can help to replenish losses of material caused by seasonal storms, washouts, currents, and other natural phenomena.

CHAPTER 7 DESIGN OF MARINE IMPROVEMENT PROJECTS

7-1 INTRODUCTION TO COASTAL PROJECT ELEMENT DESIGN.

The CEM Section VI-2 contains sections on the introduction to coastal project element design, types and functions of coastal structures, site specific design conditions, materials and construction aspects, fundamentals of design, reliability based design of coastal structures, design of specific project elements, and designing for repair, rehabilitation, and modification.

7-2 TYPES AND FUNCTIONS OF COASTAL STRUCTURES.

Coastal structures are used in coastal defense schemes with the objective of preventing shoreline erosion and flooding of the hinterland. Other objectives include sheltering of harbor basins and harbor entrances against waves, stabilization of navigation channels at inlets, and protection of water intakes and outfalls. An overview of the various types of coastal structures and their application is given in CEM Section VI-2. Overall planning and development of coastal projects is covered in CEM Section V.

7-2.1 Breakwaters.

Primary applications of breakwaters are to provide protection against waves for shore areas, harbors, anchorages, and basins, and to enable maintenance-dredging operations. A secondary purpose is beach erosion control.

7-2.2 Jetties.

Jetties are devices parallel to a navigation channel used to protect the channel from shoaling with littoral drift and to stabilize the entrance to a tidal inlet. They may also provide wave and wind protection and direct or confine the flow of river or tidal currents. Sand bypassing of jettied inlets is often necessary to preclude erosion of the downdrift coast.

7-2.3 Revetments, Bulkheads, and Seawalls.

These structures are used to protect embankments or shore structures from eroding or from damage due to wave attack or currents and to retain or prevent sliding of land. Revetments are generally rubble construction. Seawalls and bulkheads are generally more rigid structures constructed of steel, concrete, or timber. Another design for seawalls is to use Igloos, patented by Nippon Tetrapod (
Figure 7-1). Igloos can be used as space-saving wave absorbers or breakwaters. Prefabricated concrete units have been used successfully as wave-dissipating walls in harbors.

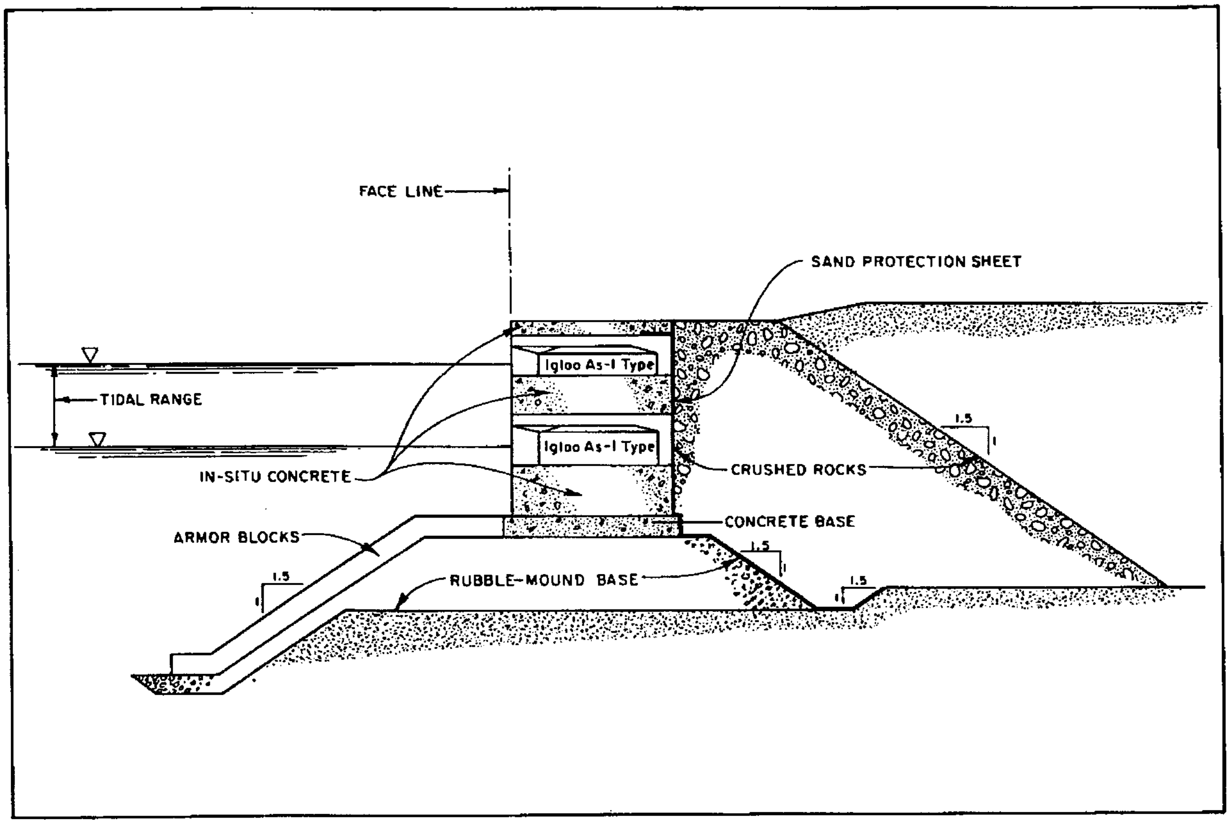
7-2.4 Groins.

Groins are used to protect the coast from erosion and to retard or control littoral transport to stabilize a beach. Groin fields should generally be filled with imported material to preclude erosion of the downdrift coast.

7-2.5 Headlands.

Headlands are high, steep-faced border points of land extending into the ocean or other body of water. Large segments of shorelines can be stabilized by construction of artificial headlands.

Figure 7-1 Typical Igloo Seawall



7-2.6 Beach Restoration and Nourishment.

Beaches that are eroding due to an interrupted or inadequate sand source can be stabilized by deposition of sand brought from a source on land or of dredged materials.

7-3 SITE SPECIFIC DESIGN CONDITIONS.

When developing a harbor or other coastal project, much of the information that is required is site specific. This requires the engineer to pursue various methods of field testing or existing data regarding a site. The various types of information that are typically required are foundation/geotechnical requirements, seasonal profile variation, flanking possibility, seismic activity, ice, environmental considerations, construction considerations and other design considerations (including regulatory, maintenance, etc.). CEM Section VI-3 presents an overview of these subjects.

7-4 RELIABILITY OF DESIGN.

CEM Section VI-6 discusses reliability in design in depth. First, the engineer must decide on what design life is desired and/or permitted by the budget. The level of protection must then be considered.

The CEM also provides information on the factors to be considered in a complete design, necessary baseline data (field surveys, etc.) and concept of risk/reliability in project design. Finally, the CEM discusses overall performance criteria.

7-5 FUNDAMENTALS OF DESIGN.

Planning and design procedures for coastal projects are described in CEM Section V-1. The engineering design steps related to a specific type of coastal structure can be schematized as follows:

- Specification of functional requirements and structure service life time.
- Establishment of the statistics of local short-term and long-term sea states as well as estimation of possible geomorphological changes.
- Selection of design levels for the hydraulic response: wave runup, overtopping, wave transmission, and wave reflection.
- Consideration of construction equipment and procedures, and of availability and durability of materials (e.g., only land based equipment operational and available at reasonable costs, rock of sufficient size easily available).
- Selection of alternative structure geometries to be further investigated (e.g., composite caisson structures, rubble structures with and without crown walls).
- Identification of all possible failure modes for the selected structure (e.g., armor layer displacement).
- Selection of design damage levels for the identified failure modes (e.g., 50 percent probability of displacement of 5 percent of the armor units within 50 years).
- Conceptual design of the structural parts based on the chosen design levels for failure mode damage and hydraulic responses (e.g., determination of armor layer block size and crest height for a breakwater).
- Evaluation of costs of the alternative structures and selection of preferred design(s) for more detailed analysis and optimization.
- Detailed design including economical optimization and evaluation of the overall safety of the structure. This stage will involve scale model tests

and/or advanced computational analyses for non-standard and major structures.

7-6 DESIGN OF SPECIFIC PROJECT ELEMENTS.

The design of specific coastal project elements is outlined below. For additional information and case studies, see CEM Section VI-7-1.

7-6.1 Sloping-Front Structures.

The types of structures discussed here are armor units, one-sided shoreline sloping and two-sided sloped structures. Refer to CEM Part VI-7-2 for further information regarding this subject.

Rubble-mound structures generally have a core covered with one to several quarry stone underlayers that are protected with armor units of stone or specially shaped concrete units. Breakwaters have a core material of randomly dumped, well-graded quarry run, sand or coral. This material is generally impermeable. Successive underlayers cover the core; the material in each successive layer is carefully increased in size to prevent loss of the smaller-sized core material. Armor units are placed on the outer surface to hold to core and the underlayers in place against wave attack. Rubblemound revetments, groins, and jetties are similarly built in that armor units hold the underlying material in place. Rubble-mound structures are well suited to the coastal zone because they can absorb the forces of waves with relatively minor damage even when design conditions are exceeded to a moderate degree.

7-6.2 Vertical Front Structures.

The types of structures of concern in this chapter are gravity structures and sheet-pile structures. CEM Section VI-7-3 is the nominal source.

7-6.3 Beach Fill Systems.

Adding fill to a beach is an economical and effective method to replace lost beach materials or to increase the size of an existing beach. The added fill increases the backshore width and moves the high water line farther offshore. The choice of fill type should resemble the original beach material and the slope of the beach should also match the original slope as closely as possible. Note that the cost and ease of beach fill as an erosion control method depends on the rate of material loss from the beach. If fill is readily available from a nearby location, the initial cost of refilling the beach would be low. However, regular refilling translates into recurrent maintenance costs. See CEM Section VI-7-4 for information on beach fill systems.

7-6.4 Floating Structures.

Floating breakwaters are a special classification of breakwater. A floating breakwater comprises a float, of sufficient size relative to the wavelength, held in place by mooring lines fixed to anchors or to guide piles. Floating breakwaters can be constructed of barges, pontoons, floating docs, or rubber tires, or one can be specifically designed. The recommended source for more information on this subject is CEM Section VI-7-5.

7-6.5 Pile Structures.

As the most common type of deep foundation, piles are used to transmit loads through upper weak and/or compressible soil strata to underlying competent zones. These include driven piles, drilled piles, drilled piers/caissons, sheet piles (for containing fills), and fender piles for docking. Piles also provide support in areas where shallow foundations are impractical, such as underwater, in close proximity to existing structures, and other conditions, and to provide uplift resistance and/or lateral load capacity. The performance of a deep foundation is highly dependent on the installation procedures and quality of workmanship. Forces on piles and piers and pile design are addressed in the recommended source for information on this subject, CEM Section VI-7-6.

7-6.6 Pipelines and Outfalls and Submarine Cables.

Pipelines, outfalls and submarine cable systems that cross a shoreline, harbor, river or other bodies of water are exposed to many hazards. Fishing activity, anchors, wave action, currents, ice scour, and vandalism are just a few of the causes of damage to these systems. A variety of methods are used for protection and stabilization including, armor, split pipe, rock riprap, concrete encasement, mechanical anchoring, trenching and horizontal direction drilling. The recommended source for information on this subject is CEM Section VI-7-7.

7-6.7 Miscellaneous Structure Examples.

Examples of low-cost shore protection, sand-filled beach structures, low-energy shore protection, and beach draining are provided in CEM Section VI-7-8.

7-7 DESIGNING FOR REPAIR, REHABILITATION, AND MODIFICATION.

CEM Section VI-8 provides information on this topic with emphasis on the reliability of existing structures, sloping-front structures, vertical-front structures and monitoring of structures.

Chapter 8 HARBOR AND COASTAL MAINTENANCE

8-1 INTRODUCTION.

After a navigation project has been designed and constructed, operation and maintenance are required to sustain safe and efficient use of the project. Operation and maintenance requirements and costs can be substantial. They are typically estimated with care and optimized against initial construction costs in planning and designing a navigation project. Anticipated maintenance costs are based on predictions of physical changes after the project is constructed.

A completed navigation project must be monitored to insure safe operation and to plan for maintenance activities as needed; see CEM Section V-2-1-q. Monitoring typically includes hydrographic surveys, beach profile surveys, tide and wave data collection, and navigation structure condition surveys. Surveys are typically done on a planned schedule, such as annually, and before and after periods of maintenance and repair. Surveys should be analyzed comparatively to determine rates of erosion, shoaling, and structure deterioration. The recommended source for information on this subject is CEM Section V-4-3.

8-2 HARBOR AND CHANNEL SEDIMENTATION AND MAINTENANCE.

Often periodic dredging to maintain project depths is the major maintenance need (CEM, Appendix VII-4). Maintenance dredging intervals are dependent on factors such as shoaling rate, dredge availability, and dredge mobilization costs. Typical maintenance intervals are on the order of 1-3 years at some projects. However, environmental forces impacting a navigation project are highly variable. The number and intensity of storms affecting a project each year can only be predicted in terms of probabilities. Maintenance needs are often strongly influenced by storm events. A single severe storm can cause major shoaling and structure damage. Consequently, monitoring and maintenance activities may occasionally need to respond quickly to maintain project integrity. See CEM Section V-4-3 for further information.

8-2.1 Navigation Aids.

Information on Navigation Aids can be found in the Code of Federal Regulations: 33 CFR Part 62 and 33 CFR Part 209.325.

8-3 INSPECTION AND REPAIR OF MARINE IMPROVEMENTS.

The recommended source for information on this topic is the “ASCE Standard for Shore Protection Systems - Draft,” August 20, 1997.

8-3.1 Revetments.

The recommended source for information on this topic is the “ASCE Standard for Shore Protection Systems - Draft” (ASCE, 1997).

8-3.2 Beach Nourishment.

The recommended sources for information on this topic are the CEM Chapter V-3-3-a(1) and "ASCE Standard for Shore Protection Systems – Draft," August 20, 1997.

8-3.3 Sedimentation Around Piers and Basins.
Deepening harbors to provide for deeper draft ships and the installation of piers can increase the rate of sedimentation, in those cases where the entire sediment supply isn't already depositing itself. The ramifications of siltation around piers, for example, can induce localized changes; silt or microorganisms can be picked up through a ship's saltwater intakes, thereby causing significant damage to vessels and high repair costs.

Since sedimentation control is a site-specific phenomenon, each location must be accessed and the best method chosen for the area. Modeling sites can provide valuable information, but all sites cannot be modeled at full scale due to cost limitations; additionally, scaling can be problematic. Research and development into sediment limitation by way of stopping the sediment from reaching the site, keeping the material in suspension through the site, or diverting the sediment flow from critical areas has produced ideas for several different systems and methods: the venting canal, the scour jet array, the vortex foil array, the barrier curtain, and the maintenance trench (Sedimentation Control to Reduce Maintenance Dredging of Navigational Facilities in Estuaries, 1987).

APPENDIX A - REFERENCES

GOVERNMENT PUBLICATIONS

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NAVFAC LANT Engineering Criteria and Programs Office 6506 Hampton Blvd.
Norfolk, VA 23508-1278
Phone: 575-322-4202
Fax: 757-322-4416

DM 38.2
Dredging EquipmentMIL-HDBK-1025/3 (Textbook), Cargo Handling Facilities

MIL-HDBK-1025/4
Seawalls, Bulkheads and Quaywalls

MIL-HDBK-1025/5
(Textbook), Ferry Terminals and Small Craft Berthing Facilities

2. Unified Facilities Criteria
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http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4 /1/

\1\ UFC 4-150-02
Dockside Utilities for Ship Service /1/

UFC 4-151-10
General Criteria for Waterfront Construction

\1\ UFC 4-152-01
Design: Piers and Wharves /1/

\1\ UFC 4-159-03
Design: Moorings /1/

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3. Naval Ordnance Systems Command

NAVORD OP 2706 Introduction to Degaussing, 1 December 1960

4. Naval Sea Systems Command

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5. US Army Corps of Engineers http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;101	Coastal Engineering Manual
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Coastal Engineering Research Center Fort Belvoir, VA	Coastal Engineering Technical Aid No. 77-8, Procedures for Preliminary Analysis of Tidal Inlet Hydraulics and Stability, December 1977
Dredging Research Program http://wesda.org/related_links.htm#	Technical Notes, Technical Area 2: Material Properties Related to Navigation and Dredging
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http://www.dtic.mil/whs/directives/	Ammunition and Explosives Safety Standards, January 1978 DOD 6055.9 Ammunition and Explosives Safety Standards, August 1997 DODI 4165.59 DOD Implementation of the Coastal Zone Management Act, December 1975
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9. U.S. House of Representatives http://uscode.house.gov/lawrevisioncounsel.shtml hard copy from: Superintendent of Documents U.S. Government Printing Office P.O. Box 371954 Pittsburgh, PA 15250-7954	Endangered Species Act of 1973, UCS Title 16, Chapter 35 Coastal Zone Management Act of 1972, USC Title 16, Chapter 33. Marine Mammal Protection Act of 1972, USC Title 16, Chapter 31 National Environmental Policy Act of 1969, as amended 1 January 1970, 3 July 1975, 9 august 1975, and 13 September 1982, USC Title 42, Chapter 55
10. National Archives and Records Administration (NARA) 700 Pennsylvania Avenue, N.W. Washington, D.C. 20408	Code of Federal Regulations, Title 33, Navigation and Navigable Waters

1-800-234-8861
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\1\

APPENDIX B - NAVSEA ltr 4790 PMS 312 Ser 05-045 of 11 Jan 05

DEPARTMENT OF THE NAVY
PROGRAM EXECUTIVE OFFICER
AIRCRAFT CARRIERS
514 SICARD STREET SE STOP 7007
WASHINGTON NAVY YARD DC 20376-7007

IN REPLY REFER TO

4790
PMS 312
Ser 05-045
JAN 11 2005

FIRST ENDORSEMENT on NAVSEA ltr 11460 Ser 05N/022 of 22 Dec 04

From: Program Executive Officer, Aircraft Carriers (PMS 312)
To: Chief of Naval Operation (N46)
Chief of Naval Operation (N78)

Subj: AIRCRAFT CARRIER WATER DEPTH REQUIREMENTS

Ref: (a) PEO Carriers ltr 4790 PMS312 Ser 04-329 of 9 April 2004
(b) NAVSEA ltr 11460 Ser 05N/022 of 22 Dec 04

1. Reference (a) provided water depth beneath the keel guidance, for operational and dead stick transits of CVN 68 and non-CVN 68 Class carriers. Reference (b) provides a consolidated update to that guidance in accordance with reference (a).

2. In order to minimize the risk of fouling heat exchangers for either operational or dead stick transits of CVN 68 and non-CVN 68 Class carriers, a water depth beneath the keel of at least 6 feet should be maintained.

3. PEO Carriers will task NAVSEA 05 with further updating the requirements of reference (b) based on a detailed engineering analysis by July 2005.

4. The PEO Aircraft Carriers Technical POC is Mr. Russell Knowles, 202-781-4140, DSN 326-4140, knowlesrp@navsea.navy.mil. The NAVSEA 05 Technical POC is Ms. Ye-Ling Wang, (202) 781-3656, DSN 326-3656, Email wangyl@navsea.navy.mil.

T. J. MOORE

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NAVSHIPYD Norfolk (Code 261)
COMNAVAIRFORCES (N43, N9)

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND
1333 ISAAC HULL AVE SE
WASHINGTON NAVY YARD DC 20376-0001

IN REPLY TO
11460
Ser 05N/022
22 Dec 04

From: Commander, Naval Sea Systems Command
To: Chief of Naval Operation (N46)
Chief of Naval Operation (N78)
Via: Program Executive Office, Aircraft Carriers

Subj: AIRCRAFT CARRIER WATER DEPTH REQUIREMENTS

Ref: (a) NAVSEA ltr 11460 Ser 03D/242 of 3 Jan 95

Encl: (1) Aircraft Carrier Home Port Water Depth Requirements
(2) Aircraft Carrier Shipyard Water Depth Requirements

1. Purpose. The purpose of this letter is to update the information in reference (a) to current requirements. This letter also states the requirement for a minimum water depth of six feet beneath the keel of aircraft carriers for all transits in homeports, ports of call, and shipyards.

2. Background. In reference (a), NAVSEA provided the pier and channel water depth requirements for CVN 68 Class aircraft carriers in homeports, ports of call, and shipyards.

3. Discussion.

a. The requirements previously provided in reference (a) for CVN 68 Class aircraft carriers have been updated and reference (a) is hereby superceded. These updates are summarized as follows:

(1) The requirements have been extended to all aircraft carriers.

(2) The requirements have been extended to apply to "dead stick" (towed) conditions.

(3) References to Long Beach Naval Shipyard have been deleted.

(4) Enclosure (3) of reference (a) has been deleted. This enclosure described plans for aircraft carriers to improve

shallow water navigation aids that predict ship's motions provide real time channel condition measurement, improve ship's draft and attitude indication and provide a load management system.

(5) Minor changes to displacements and drafts have been made to the charts in the enclosures.

(6) Estimates of the impact of water depth from ship motions in the outer channel for Pearl Harbor Naval Shipyard and Norfolk area facilities have been included.

b. Enclosures (1) and (2) provide water depth requirements for all aircraft carriers in under power or "dead stick" (towed) conditions. "Dead stick" is defined as propulsion plants shut down, emergency diesel generators operating on high suction, all other ship and reactor plant cooling loads (8000 to 10,000 gpm) supplied by the firemain system and no main injection or SSTG/CTG cooling requirements.

(1) Enclosure (1) provides aircraft carrier water depth requirements for homeports. Attachment (1) of enclosure (1) also applies to ports of call. The ship's mean draft used for homeports corresponds to the limiting displacement and is considered the proper basis for determining the appropriate channel, turning basin and pier water depths since it will permit operations of a fully loaded ship.

(2) Enclosure (2) provides water depth requirements for shipyards. The ship's mean draft used for shipyards was reduced based on the assumption that only 55% of the ship's loads (aircraft, fuel, personnel stores, etc.) would be onboard. Each enclosure describes and quantifies the components that contribute to aircraft carrier draft and clearance:

(a) the governing depth requirements for the pier, turning basin, inner channel, and outer channel for each homeport and shipyard

(b) general tide information for each homeport and shipyard

(c) a graphical representation of the relationship between the number of days of access to the turning basin and inner channel, the length of the tide window, and the dredging project depth for the governing depth requirement of each homeport and shipyard.

c. Water Depths. While at the pier, in the turning basin, or in the inner channel of a homeport or a port of call, it is recommended that there be a minimum of 50 feet of water depth. While at the pier, in the turning basin, or in the inner channel of a shipyard, it is recommended that there be a minimum of 47 feet of water depth. Entering a shipyard without offloading should be treated as a port of call.

Clearance. These water depth requirements are governed by the sea chest fouling clearance criterion established as a result of sea chest fouling problems experienced at Norfolk. Note that this criterion also provides clearance for divers (5 feet) while at the pier.

Dredging Project Depths. The dredging project depth can be traded off with tides to obtain the necessary water depth in inner channels and turning basins with the corresponding operational restrictions; however, tide tradeoffs cannot be used at piers. Localized pier dredging in way of sea chests can save 2 feet of dredging cost outside of the sea chest area; however, operational restrictions may result (e.g., less transit time in tide window and limited diver access).

d. In the outer channel, wave action usually dominates the depth requirements and can have a large variance. A ship motions analysis was performed for the outer channels of San Diego and Mayport to account for the statistical nature of the tides and wave action. The ship motions analyses of Pearl Harbor and Norfolk outer channels have been estimated based on wave height data for these areas and compared to San Diego wave data and previously accomplished ship motions analysis. The ship draft changes are derived relative to these analyses.

4. Action. Many of the factors that affect channel transit are operational issues, such as operating schedule and contingencies, port operations, ship displacement, trim, list, and speed as well as weather and tides. Actual transit situations will vary and will involve different combinations of these factors. Consequently, a given transit could require more or less water depth. However, to minimize the risk of fouling heat exchangers for either operational or "dead stick" (towed)

Subj: AIRCRAFT CARRIER WATER DEPTH REQUIREMENTS

transits in restricted waters for all aircraft carriers, a water depth beneath the keel of at least 6 feet should be maintained.

5. The NAVSEA point of contact is Mr. F.E. Horacek, NAVSEA 05N25, (202) 781-0649, DSN 326-0649, e-mail: franklin.horacek@navy.mil.

Ye-ling Wang

P. E. SULLIVAN
Rear Admiral, U.S. Navy
Deputy Commander for Ship Design, Integration and Engineering

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COMNAVAIRPAC (Code N43), N9)
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Subj: AIRCRAFT CARRIER WATER DEPTH REQUIREMENTS

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SEA 08J
SEA 08P
SEA 00C5

AIRCRAFT CARRIER HOMEPORT WATER DEPTH REQUIREMENTS

Attachments:

(1) Aircraft Carrier Home Port and Ports of Call Draft and Clearance requirements
(2) Aircraft Carrier Water Depth Requirements for Norfolk Operating Base
(3) Sewell's Point Tide Access, 50 foot Depth Requirement
(4) Aircraft Carrier Water Depth Requirements for San Diego
(5) San Diego Inner Channel Tide Access, 50 foot Depth Requirement
(6) Aircraft Carrier Water Depth Requirements for Everett
(7) Everett Tide Access, 50 foot Depth Requirement
(8) Aircraft Carrier Water Depth Requirement for Bremerton
(9) Rich Passage Tide Access, 50 foot Depth Requirement
(10) Aircraft Carrier Water Depth Requirements for Mayport
(11) Mayport Tide Inner Channel Access, 50 foot Depth Requirement

Aircraft Carrier Home Port and Ports of Call
Draft and Clearance Requirements

Static Draft					
Mean	40.9 ft 103,800 tons (CVN 68-75) 104,300 tons (CVN 76)				- Accounts for: Actual operating condition (+2000 tons) Service life weight growth (+70 tons/year) Unreported weight - Assumes weight is added in best location. - Assumes good ship weight control.
Trim	0.25 degrees		Bow	2.3 ft	- Based on operational experience. Instances of greater trim do occur, but rarely when the ship is at or near the limiting displacement.
			Sea Chest	0.8 ft	
			Rudder	2.1 ft	
List	Pier	2 degrees	Bilge Keel	2.3 ft	- Based on operational experience. Instances of greater list do occur, but rarely when the ship is at the limiting displacement.
			Sea Chest	1.4 ft	
	Channel	0 degrees			- Assumed ship is leveled prior to transit. TYCOM confirmation is needed.
Appendages	9 inches				- All of the CVN 68 Class except CVN 70 have discharge sea chest diffusers. - Assumed to be overshadowed by trim.
Salinity & Temperature	0.5 feet (50% salinity reduction & 10° temperature rise)				- This calculation is port, season, and tide specific. - Assumed constant.
Dynamic Draft					
Wind & Waves	Outer Channel			See Note	- This calculation is port specific. - See indiv. port summary sheet for details.
	Inner Channel			0 ft	- Protected harbor.
	Pier & Turning Basin				
Squat	10 kts		Forward	0.9 ft	- Based on wide channel that is 50 ft deep. - Shallower and/or narrower channels and/or higher speeds will require a greater allowance for squat.
			Aft	1.3 ft	
			Sea Chest	1.0 ft	
Heel	1.4 degrees		Bilge Keel	1.6 ft	- Based on operational experience, 10 kts and 10 degrees rudder.
			Sea Chest	0.8 ft	
Clearance					
Fouling	6 ft				- Based on operational experience at NOB and NAVFAC study and applies to soft bottoms and bottoms with loose sea growth. - Assumes diffusers are installed.
Grounding	Soft Bottom			2 ft	- NAVFAC deterministic standard.
	Hard Bottom			3 ft	
	1/100				- Proposed probabilistic standard.

Aircraft Carrier Water Depth Requirements for Norfolk Operating Base

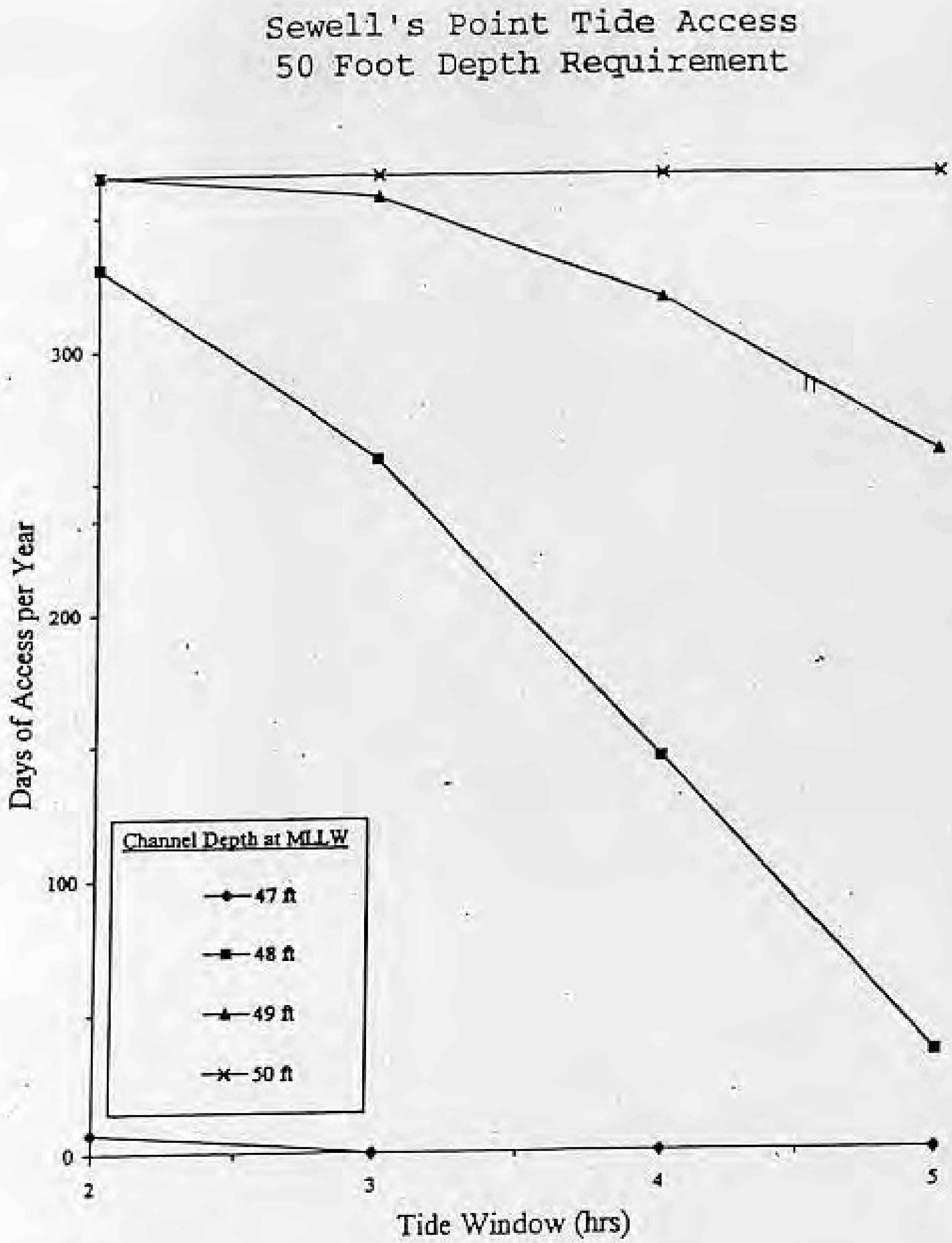
	Pier	Turning Basin	Inner Channel	Outer Channel
Draft	40.8	40.8	40.8	40.8
Trim	0.8	0.8	0.8	2.1
List	1.4	1.4	-	-
Appendages	-	-	-	-
Salinity & Temp (a)	0.5	0.5	0.5	0.5
Motions (b)	-	-	-	5.0/30.0 (f)
Squat (c)	-	-	1.0	1.3
Heel (d)	-	-	0.8	-
Clearance (e)	6.0	6.0	6.0	2.0
TOTAL	**49.5**	**49.5**	**49.9**	**51.7/76.7**

Notes: (a) Harbor contains fresh water inlet.
(b) Unprotected harbor; significant wave action.
(c) Based on wide, 50 ft deep channel
(d) Operational experience.
(e) Standard clearances.
(f) Weighted average value at sea chest and extreme value at rudder. Estimated from wave height data.

NOB Tide Data

Mean Higher High Water	2.8 feet
Mean Lower Low Water	0.0 feet
Extreme Low Water	-3.5 feet

Enclosure (1)
Attachment (2)



Enclosure (1)
Attachment (3)

Aircraft Carrier Water Depth Requirements for San Diego

	Pier	Turning Basin	Inner Channel	Outer Channel
Draft	40.8	40.8	40.8	40.8
Trim	0.8	0.8	0.8	2.1
List	1.4	1.4	-	-
Appendages	-	-	-	-
Salinity & Temp (a)	-	-	-	-
Motions (b)	-	-	-	4.2/27.7 (f)
Squat (c)	-	-	1.0	1.3
Heel (d)	-	-	0.8	-
Clearance (e)	6.0	6.0	6.0	2.0
TOTAL	**49.0**	**49.0**	**49.4**	**50.4/73.9 (g)**

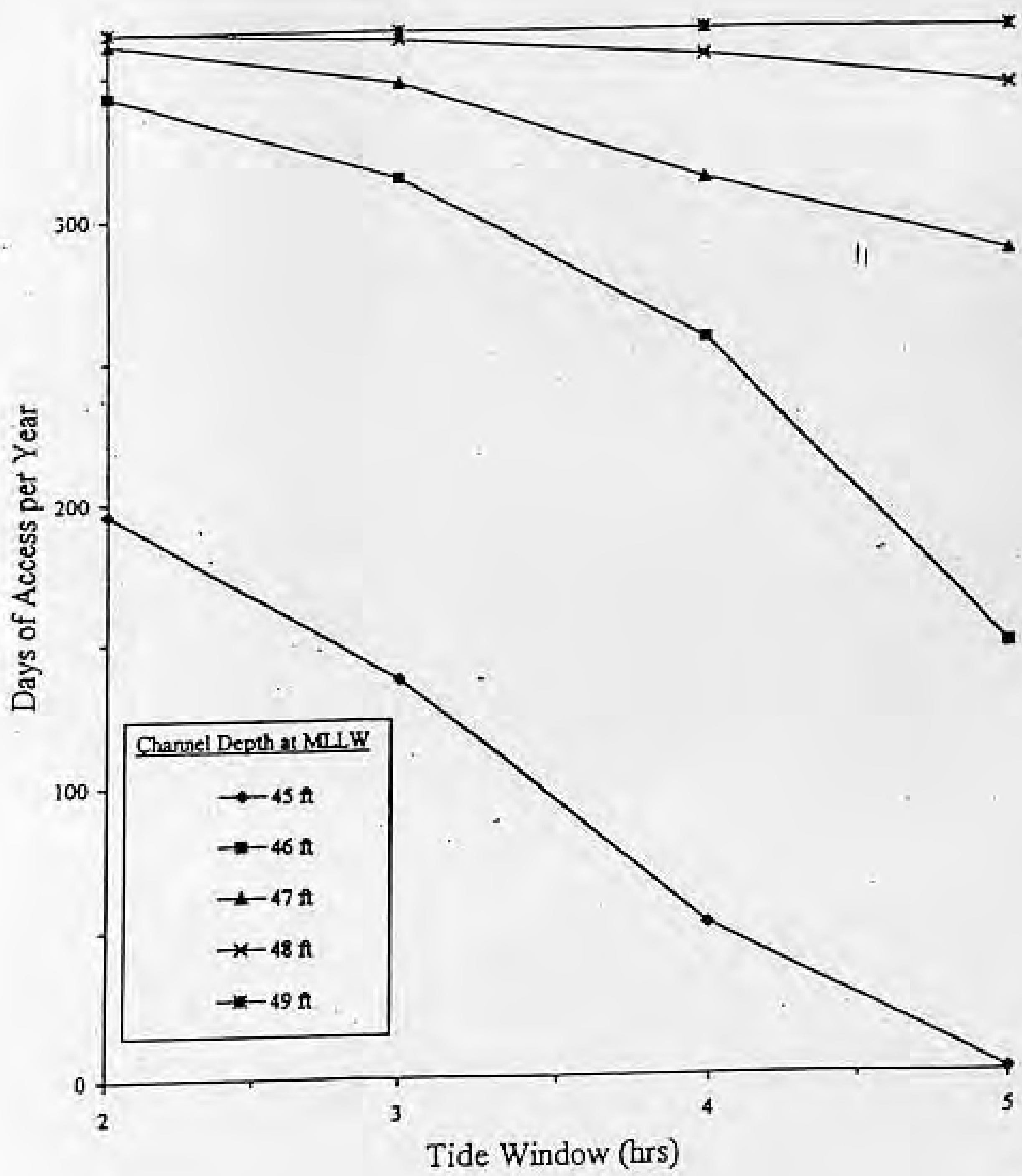
Notes: (a) Salt water port; no correction required.
(b) Unprotected harbor; significant wave action.
(c) Based on wide, 50 ft deep channel
(d) Operational experience.
(e) Standard clearances.
(f) Weighted average and extreme values.
(g) A water depth of 74 feet provides unrestricted access.

San Diego Tide Data

Mean Higher High Water	5.8 feet
Mean Lower Low Water	0.0 feet
Extreme Low Water	-2.0 feet

Enclosure (1)
Attachment (4)

San Diego Inner Channel Tide Access
50 Foot Depth Requirement



Enclosure (1)
Attachment (5)

Aircraft Carrier Water Depth Requirements for Everett

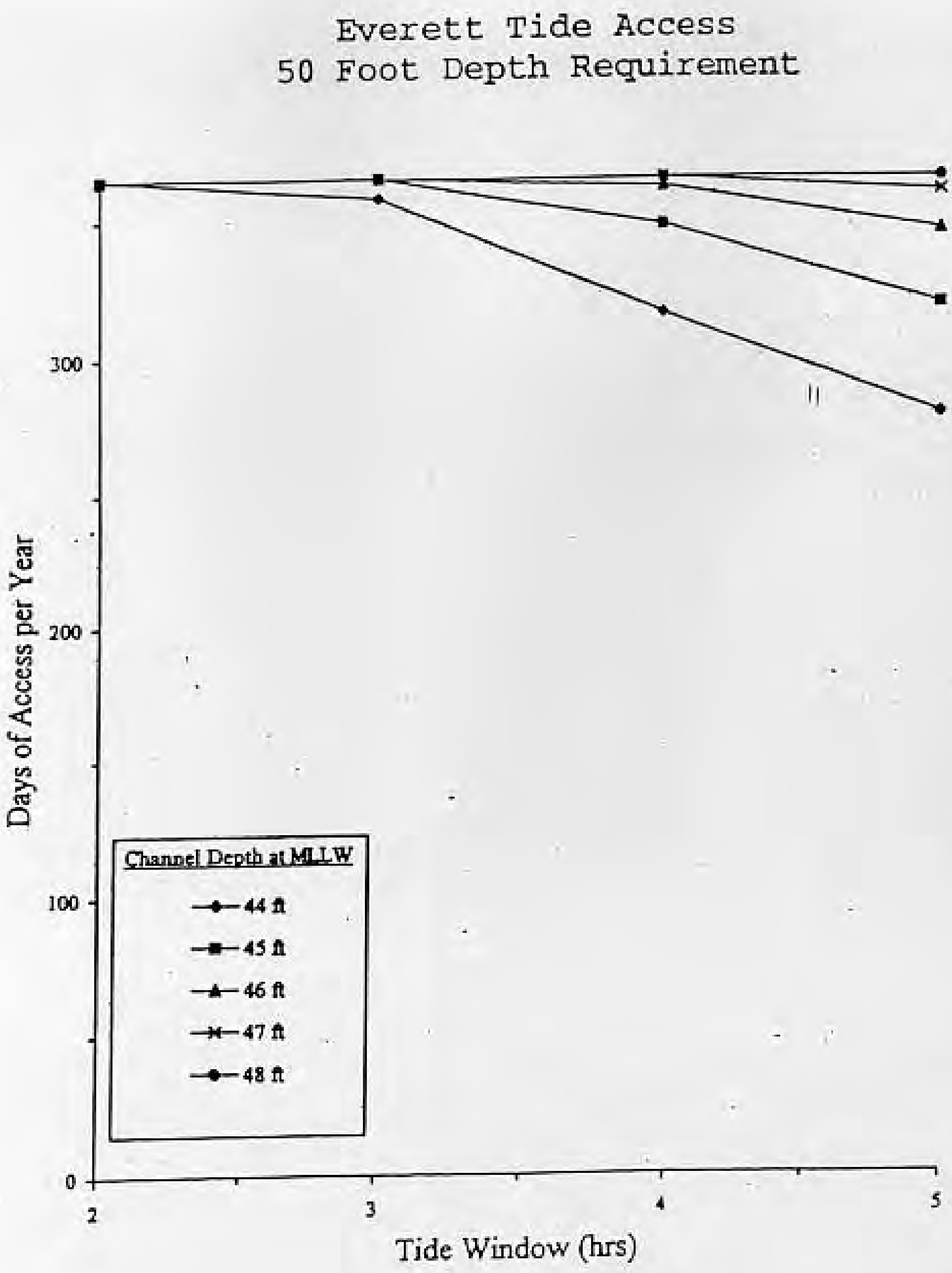
	Pier	Turning Basin	Inner Channel	Outer Channel
Draft	40.8	40.8	40.8	(f)
Trim	0.8	0.8	0.8	
List	1.4	1.4	-	
Appendages	-	-	-	
Salinity & Temp (a)	0.5	0.5	0.5	
Motions (b)	-	-	-	
Squat (c)	-	-	1.0	
Heel (d)	-	-	0.8	
Clearance (e)	6.0	6.0	6.0	
TOTAL	49.5	49.5	49.9	

Notes: (a) Harbor contains fresh water inlet.
(b) Protected harbor; no significant wave action.
(c) Based on wide, 50 ft deep channel
(d) Operational experience.
(e) Standard clearances.
(f) Unrestricted outer channel due to deep depth.

Everett Tide Data

Mean Higher High Water	11.1 feet
Mean Lower Low Water	0.0 feet
Extreme Low Water	-4.5 feet

Enclosure (1)
Attachment (6)



Enclosure (1)
Attachment (7)

Aircraft Carrier Water Depth Requirements for Bremerton

	Pier	Turning Basin	Inner Channel	Outer Channel
Draft	40.8	40.8	40.8	(f)
Trim	0.8	0.8	0.8	
List	1.4	1.4	-	
Appendages	-	-	-	
Salinity & Temp (a)	0.5	0.5	0.5	
Motions (b)	-	-	-	
Squat (c)	-	-	1.0	
Heel (d)	-	-	0.8	
Clearance (e)	6.0	6.0	6.0	
TOTAL	**49.5**	**49.5**	**49.9**	

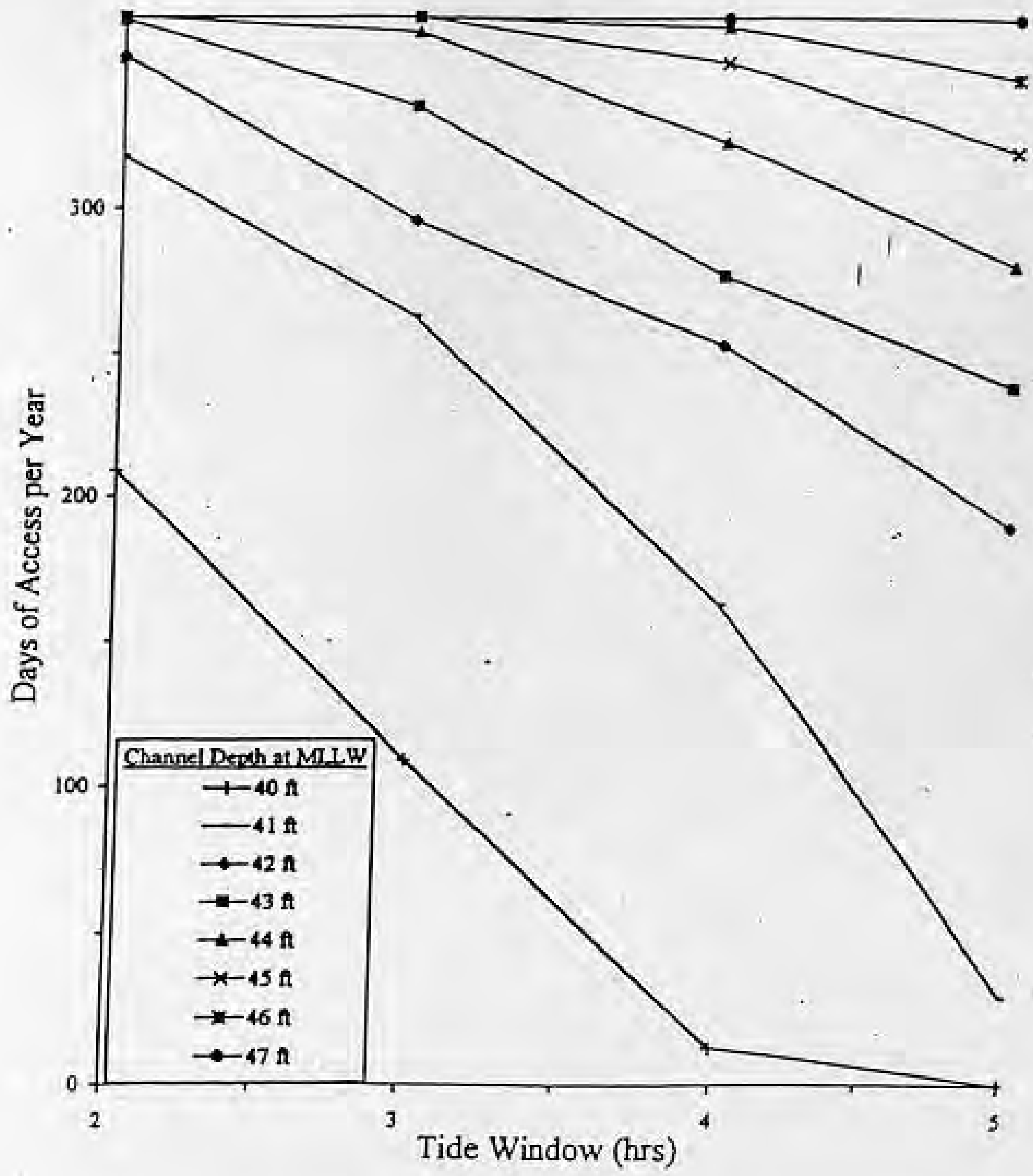
Notes: (a) Harbor contains fresh water inlet.
(b) Protected harbor; no significant wave action.
(c) Based on wide, 50 ft deep channel
(d) Operational experience.
(e) Standard clearances.
(f) Unrestricted outer channel due to deep depth.

Bremerton Tide Data

Mean Higher High Water	11.7 feet
Mean Lower Low Water	0.0 feet
Extreme Low Water	-4.7 feet

Enclosure (1)
Attachment (8)

Rich Passage Tide Access
50 Foot Depth Requirement



Enclosure (1)
Attachment (9)

Aircraft Carrier Water Depth Requirements for Mayport

	Pier	Turning Basin	Inner Channel	Outer Channel
Draft	40.8	40.8	40.8	40.8
Trim	0.8	0.8	0.8	0.8/2.1
List	1.4	1.4	-	-
Appendages	-	-	-	-
Salinity & Temp (a)	0.5	0.5	0.5	0.5
Motions (b)	-	-	-	0.5/14.3 (f)
Squat (c)	-	-	1.0	1.0/1.3
Heel (d)	-	-	0.8	-
Clearance (e)	6.0	6.0	6.0	6.0/2.0
TOTAL	**49.5**	**49.5**	**49.9**	**49.6/61.0 (g)**

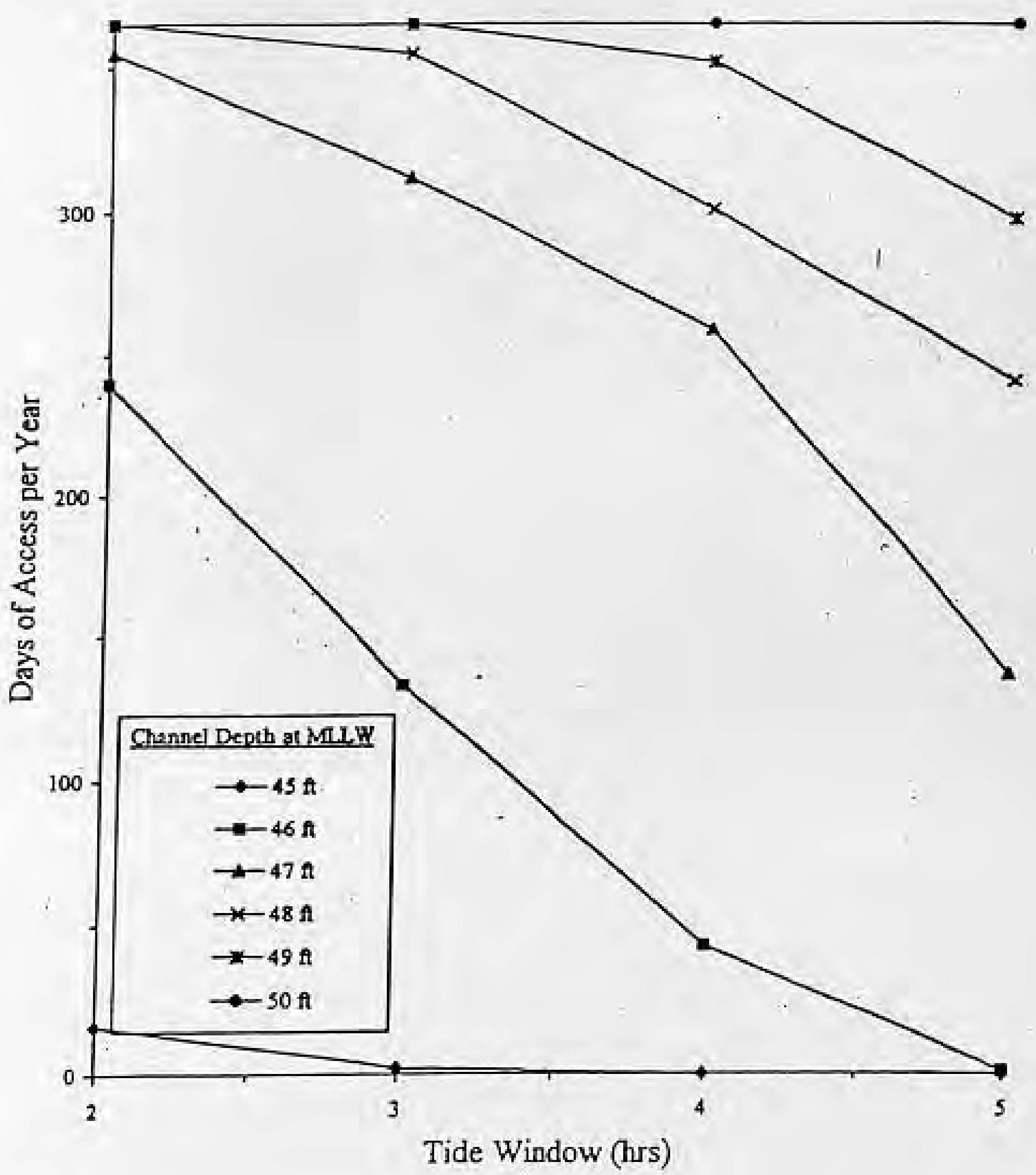
Notes:
- (a) Harbor contains fresh water inlet.
- (b) Unprotected harbor; significant wave action.
- (c) Based on wide, 50 ft deep channel
- (d) Operational experience.
- (e) Standard clearances.
- (f) Weighted average value at sea chest and extreme value at rudder.
- (g) A water depth of 61 feet provides unrestricted access. The minimum water depth (50 feet) is governed by fouling.

Mayport Tide Data

Mean Higher High Water	5.4 feet
Mean Lower Low Water	0.0 feet
Extreme Low Water	-3.0 feet

Enclosure (1)
Attachment (10)

Mayport Inner Channel Tide Access
50 Foot Depth Requirement



Enclosure (1)
Attachment (11)

AIRCRAFT CARRIER SHIPYARD WATER DEPTH REQUIREMENTS

Attachments:

(1) Aircraft Carrier Shipyard Draft and Clearance Requirements
(2) Aircraft Carrier Water Depth Requirements for Norfolk Naval Shipyard
(3) Elizabeth River Tide Access, 47 Foot Depth Requirement
(4) Aircraft Carrier Water Depth Requirements for Northrop Grumman Newport News Shipbuilding
(5) Sewell's Point Tide Access, 47 Foot Depth Requirement
(6) Aircraft Carrier Water Depth Requirements for Puget Sound Naval Shipyard
(7) Rich Passage Tide Access, 47 Foot Depth Requirement
(8) Aircraft Carrier Water Depth Requirements for Pearl Harbor Naval Shipyard
(9) Pearl Harbor Inner Channel Tide Access, 47 Foot Depth Requirement

Aircraft Carrier Shipyard Draft and Clearance Requirements

Static Draft				
Mean	38.0 ft 94,800 tons (CVN 68-75) 95,200 tons (CVN 76)			- Accounts for: Actual operating condition (+2000 tons) Service life weight growth (+70 tons/year) Unreported weight Variable loads at 55% full load capacity. - Assumes weight is added in best location. - Assumes good ship weight control.
Trim	0.25 degrees	Bow	2.3 ft	- Based on operational experience. Instances of greater trim do occur, but rarely when the ship is at or near the limiting displacement.
		Sea Chest	0.8 ft	
		Rudder	2.1 ft	
List	Pier, 2 degrees	Bilge Keel	2.3 ft	- Based on operational experience. Instances of greater list do occur, but rarely when the ship is at the limiting displacement.
		Sea Chest	1.4 ft	
	Channel	0 degrees		- Assumed ship is leveled prior to transit. TYCOM confirmation is needed.
Appendages	9 inches			- All of the CVN 68 Class except CVN 70 have discharge sea chest diffusers. - Assumed to be overshadowed by trim.
Salinity & Temperature	0.5 feet (50% salinity reduction & 10° temperature rise)			- This calculation is port, season, and tide specific. - Assumed constant
Dynamic Draft				
Wind & Waves	Outer Channel		See Note	- This calculation is port specific. - See indiv. port summary sheet for details.
	Inner Channel		0 ft	- Protected harbor.
	Pier & Turning Basin			
Squat	10 kts	Forward	0.9 ft	- Based on wide channel that is 50 ft deep. - Shallower and/or narrower channels and/or higher speeds will require a greater allowance for squat.
		Aft	1.3 ft	
		Sea Chest	1.0 ft	
Heel	1.4 degrees	Bilge Keel	1.6 ft	- Based on operational experience, 10 kts and 10 degrees rudder.
		Sea Chest	0.8 ft	
Clearance				
Fouling	6 ft			- Based on operational experience at NOB and NAVFAC study and applies to soft bottoms and bottoms with loose sea growth. - Assumes diffusers are installed.
Grounding	Soft Bottom		2 ft	- NAVFAC deterministic standard.
	Hard Bottom		3 ft	
	1/100			- Proposed probabilistic standard.

Aircraft Carrier Water Depth Requirements for Norfolk Naval Shipyard

	Pier	Turning Basin	Inner Channel	Outer Channel
Draft	37.9	37.9	37.9	37.9
Trim	0.8	0.8	0.8	2.1
List	1.4	1.4	-	-
Appendages	-	-	-	-
Salinity & Temp (a)	0.5	0.5	0.5	0.5
Motions (b)	-	-	-	5.0/30.0 (f)
Squat (c)	-	-	1.0	1.3
Heel (d)	-	-	0.8	-
Clearance (e)	6.0	6.0	6.0	2.0
TOTAL	**46.6**	**46.6**	**47.0**	**48.8/73.8**

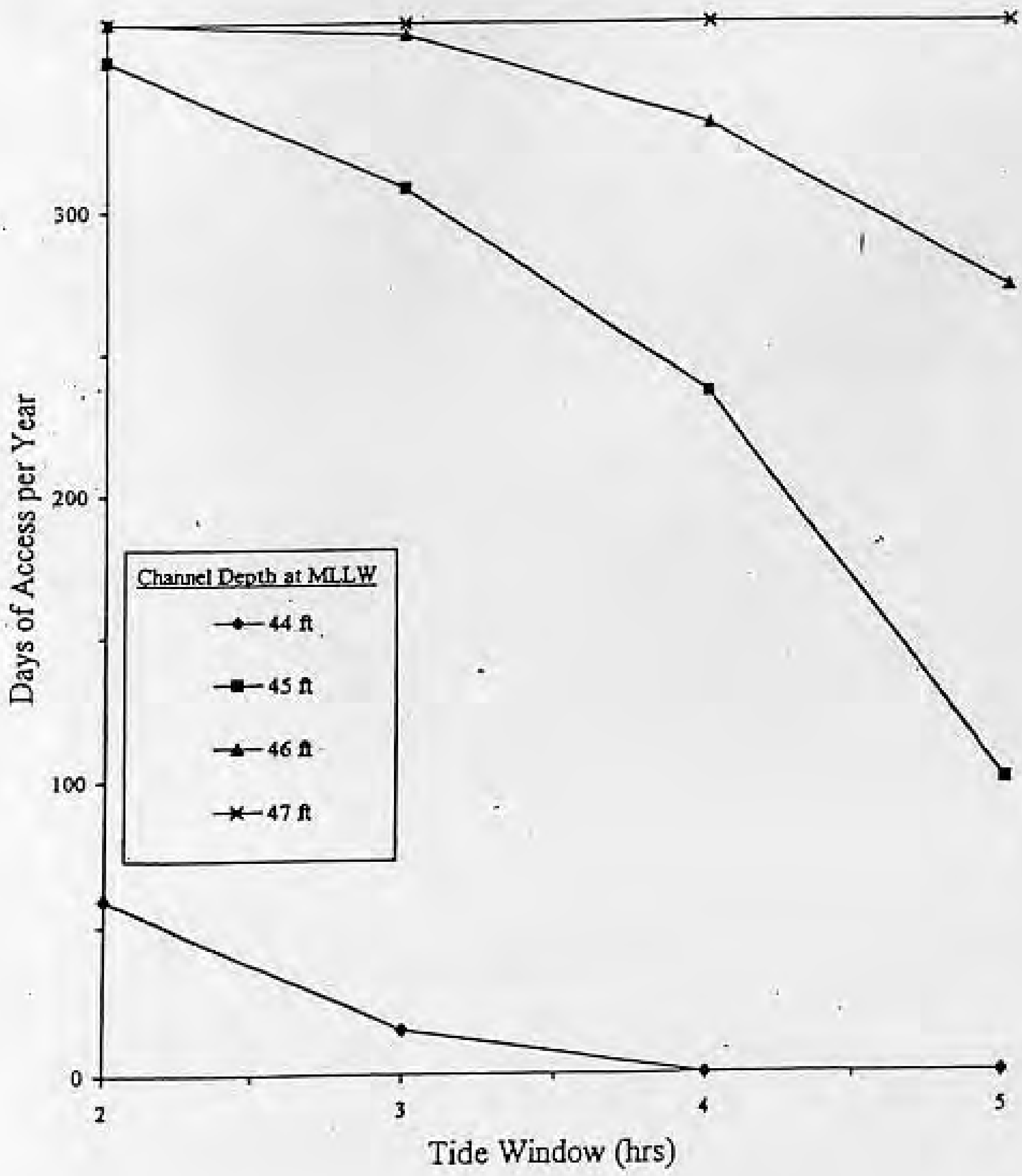
Notes:
(a) Harbor contains fresh water inlet.
(b) Unprotected harbor; significant wave action.
(c) Based on wide, 50 ft deep channel
(d) Operational experience.
(e) Standard clearances.
(f) Weighted average value at sea chest and extreme value at rudder. Estimated from wave height data.

NNSY Tide Data

Mean Higher High Water	3.2 feet
Mean Lower Low Water	0.0 feet
Extreme Low Water	-3.5 feet

Enclosure (2)
Attachment (2)

Elizabeth River Tide Access
47 Foot Depth Requirement



Enclosure (2)
Attachment (3)

Aircraft Carrier Water Depth Requirements for Northrop Grumman Newport News Shipbuilding

	Pier	Turning Basin	Inner Channel	Outer Channel
Draft	37.9	37.9	37.9	37.9
Trim	0.8	0.8	0.8	2.1
List	1.4	1.4	-	-
Appendages	-	-	-	-
Salinity & Temp (a)	0.5	0.5	0.5	0.5
Motions (b)	-	-	-	5.0/30.0 (f)
Squat (c)	-	-	1.0	1.3
Heel (d)	-	-	0.8	-
Clearance (e)	6.0	6.0	6.0	2.0
TOTAL	**46.6**	**46.6**	**47.0**	**48.8/73.8**

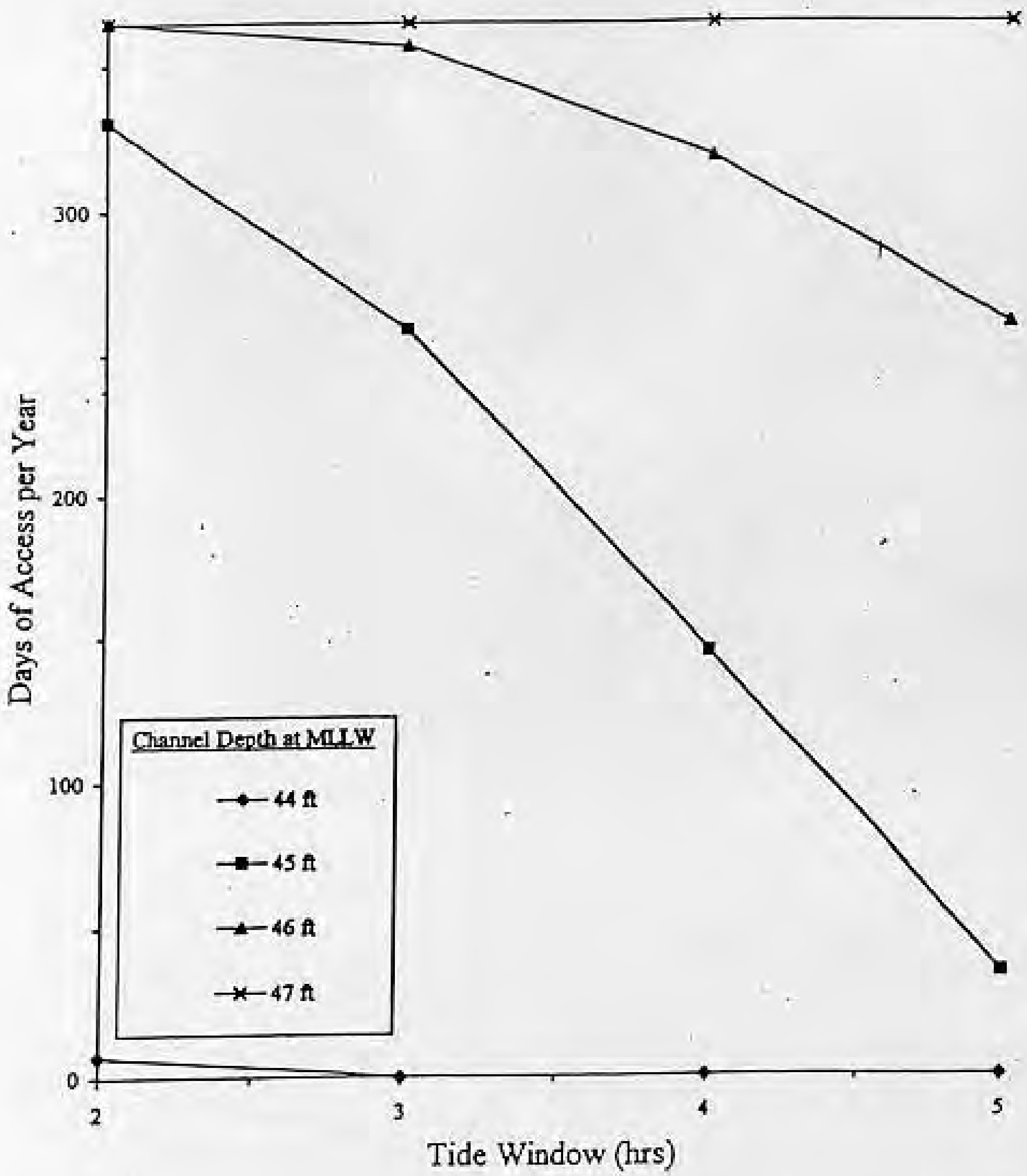
Notes: (a) Harbor contains fresh water inlet.
(b) Unprotected harbor; significant wave action.
(c) Based on wide, 50 ft deep channel.
(d) Operational experience.
(e) Standard clearances.
(f) Weighted average value at sea chest and extreme value at rudder. Estimated from wave height data.

Newport News Tide Data

Mean Higher High Water	2.9 feet
Mean Lower Low Water	0.0 feet
Extreme Low Water	-3.5 feet

Enclosure (2)
Attachment (4)

Sewell's Point Tide Access
47 Foot Depth Requirement



Enclosure (2)
Attachment (5)

Aircraft Carrier Water Depth Requirements for Puget Sound Naval Shipyard

	Pier	Turning Basin	Inner Channel	Outer Channel
Draft	37.9	37.9	37.9	(f)
Trim	0.8	0.8	0.8	
List	1.4	1.4	-	
Appendages	-	-	-	
Salinity & Temp (a)	0.5	0.5	0.5	
Motions (b)	-	-	-	
Squat (c)	-	-	1.0	
Heel (d)	-	-	0.8	
Clearance (e)	6.0	6.0	6.0	
TOTAL	46.6	46.6	47.0	

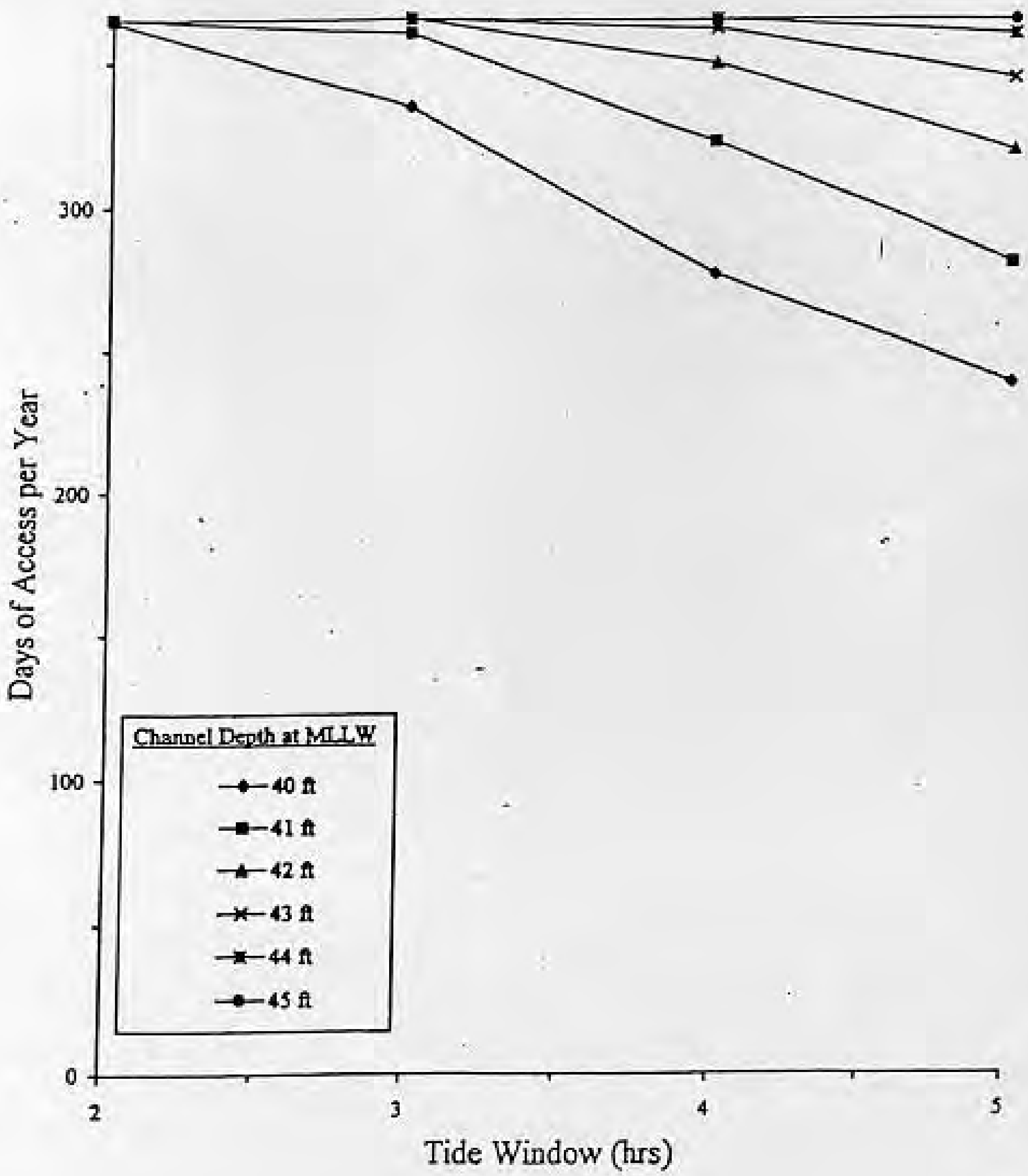
Notes: (a) Harbor contains fresh water inlet.
(b) Protected harbor, no significant wave action.
(c) Based on wide, 50 ft deep channel
(d) Operational experience.
(e) Standard clearances.
(f) Unrestricted outer channel due to deep depth.

Bremerton Tide Data

Mean Higher High Water	11.7 feet
Mean Lower Low Water	0.0 feet
Extreme Low Water	-4.7 feet

Enclosure (2)
Attachment (6)

Rich Passage Tide Access
47 Foot Depth Requirement



Enclosure (2)
Attachment (7)

Aircraft Carrier Water Depth Requirements for Pearl Harbor Naval Shipyard

	Pier	Turning Basin	Inner Channel	Outer Channel
Draft	37.9	37.9	37.9	37.9
Trim	0.8	0.8	0.8	2.1
List	1.4	1.4	-	-
Appendages	-	-	-	-
Salinity & Temp (a)	-	-	-	-
Motions (b)	-	-	-	5.0/30.0 (f)
Squat (c)	-	-	1.0	1.3
Heel (d)	-	-	0.8	-
Clearance (e)	6.0	6.0	6.0	2.0
TOTAL	46.1	46.1	46.5	48.3/73.3

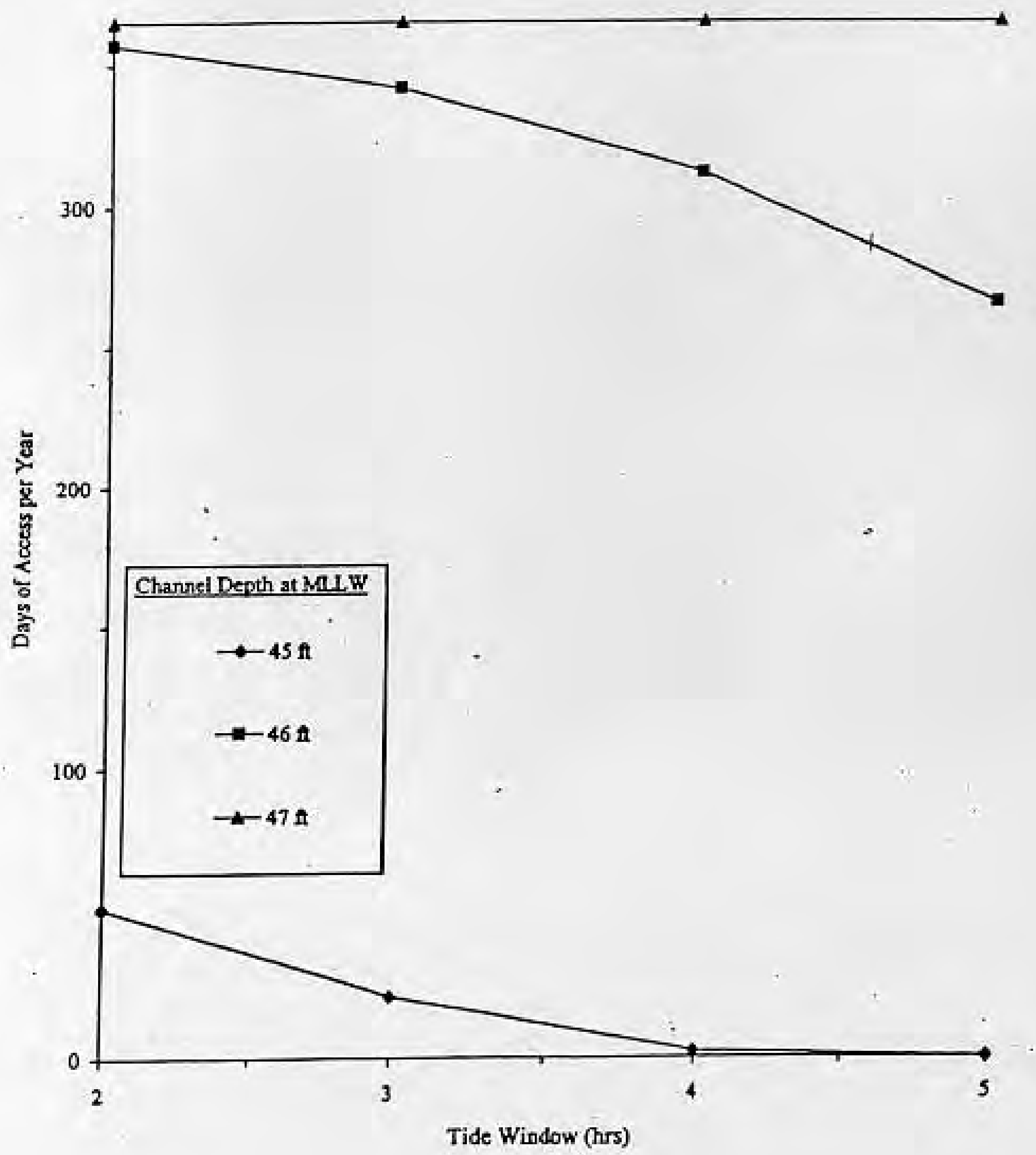
Notes:
(a) Salt water port; no correction required
(b) Unprotected harbor; significant wave action.
(c) Based on wide, 50 ft deep channel
(d) Operational experience.
(e) Standard clearances.
(f) Weighted average value at sea chest and extreme value at rudder. Estimated from wave height data.

Pearl Harbor Tide Data

Mean Higher High Water	2.0 feet
Mean Lower Low Water	0.0 feet
Extreme Low Water	-1.6 feet

Enclosure (2)
Attachment (8)

Pearl Harbor Inner Channel Tide Access
47 Foot Depth Requirement



Enclosure (2)
Attachment (9)

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APPENDIX C - Appendix C CVN68 Class Shallow Water Navigation Improvements

CVN 68 CLASS SHALLOW WATER NAVIGATION IMPROVEMENTS

Due to the deep draft of the CVN 68 Class aircraft carriers, port and shipyard access can be restricted, in order to minimize the cost and environmental impacts of deep dredging, actual ship loading, tides, and favorable weather conditions can be used. Utilizing these factors affects operational issues such as operating schedule and contingencies as well as ship loading and speed. Actual transit situations will vary and will involve different combinations of these factors. Current dredging plans will not provide unrestricted access to CVN 68 Class home ports and shipyards. To reduce the risk of grounding, it is recommended that shallow water navigation aids be improved.

The wave and motion determination process in shallow water is complex. Wave conditions are port dependent; each port must be individually studied for an accurate assessment. The most extreme CVN motions are generated from seal swells originating from storms hundreds of miles away; consequently, they are difficult to detect. Waves and swells are predicted from the Fleet Numerical Oceanographic Center or observed by the crew. Waves seen in or predicted for the open ocean may not be that which are experienced at any given port. Local land and bottom effects and changes due to wind, tides, and currents are not included.

This plan improves onboard shallow water navigation aids by:

(a) Providing a channel guidance system.
(b) Providing real time channel condition measurement.
(c) Improving ship's draft and attitude indication.
(d) Providing a load management system.

These systems and other supporting systems would be integrated as appropriate to facilitate overall functionality and minimize cost.

<u>Channel Guidance System</u>

NAVSEA has developed and tested an onboard CV Channel Guidance System (CVCGS). This system aids in the determination of under keel clearances and the probability of grounding while operating in ports. It is a PC computer program which calculates depth requirements based on data from the ship's force concerning load and trim conditions. Environmental conditions are down loaded from Fleet Numerical or input from the ship's navigator. Ship motions, under keel clearance, and probability of grounding predictions are then calculated for channel transits. The CVCGS has been validated by ship model tests and full scale wave measurements. This system will be sent to all CVs by the and of FY95.

Channel Condition Measurement

The Environmental Monitoring and Operator Guidance System {EMOGS) incorporates analysis capabilities of the CVCGS. However, instead of using predicted information from Fleet Numerical and the navigator, EMOGS uses real time wave and tide data from sensors installed in the channel. Because this is a far more accurate prediction of waves and variable water levels, substantial risk reductions are realized. The following table shows the accessibility levels of CVCGS and EMOGS associated with different dredge depths for San Diego and Mayport. An EMOGS type system is successfully being used by SUBLANT at Kings Bay, Georgia for SSBN 726 Class transits. EMOGS is recommended for channels not dredged for unrestricted operations and are subject to wave action, particularly swells. EMOGS is a facilities improvement cost tradeoff with dredging.

OUTER CHANNEL ACCESSIBILITY
FOR A RISK OF EXCEEDING DREDGE DEPTH 1 IN 100 TIMES

CHANNEL DEPTH (feet)	DAYS PER YEAR	
	CVCGS	EMOGS
SAN DIEGO:		
55	227	333
59	295	355
MAYPORT:		
47	254	262
50	362	363

Without guidance of any sort in avoiding extreme wave conditions, risk may increase to 1 in 2.

Draft and Attitude Indication

Currently, the CVN 68 Class only has one Remote Draft Indicator and list and trim inclinometers. The Profile Draft Indicator has been removed because it contained about a pint of mercury. Consequently, the ship does not have the ability to accurately determine the ship's draft, list, and trim. Installation of two more Remote Draft Indicators would provide the ability to triangulate accurate draft, list, and trim values. Based on simple geometry, the ship could then accurately determine the extreme draft point. A JCF and ECPs are being prepared to add two Remote Draft Indicators.

Load Management System

The CVN 68 Class carries roughly 20,000 tons of loads (aircraft, fuel, personnel, stores, etc.). There are some 415 tanks and voids and some 245 storerooms and magazines. The amount of material continuously being brought onboard, moved, and being consumed is large. Aircraft carrier operations require the flight deck to be as level as possible. There is a list control system to account for aircraft movement. A system similar to those used on tankers (commercial and AOEs) would provide the ship with a tool to better track and manage loads. This would enable the crew to minimize displacement list, and trim; thereby, minimize operational restrictions. A load Management system is being investigated by the CVN 76 IC effort.

APPENDIX D - Appendix D Nomographs of CVN68 Motion in Shallow Water

APPENDIX D   NOMOGRAPHS OF CVN 68 MOTION IN SHALLOW WATER

Background

Shallow water motion transfer functions where developed for the CVN 68 class ship to aid in predicting the ship's underkeel clearance for a variety of different entrance channels. The motion transfer functions were validated by model tests conducted at the US Army Corps of Engineers Waterways Experiment Station.

Description

The nomographs of CVN 68 motion in shallow water were developed by combining the shallow water motion transfer functions with a variety of wave and ship operating conditions. The waves used in calculating ship motions were developed to simulate the shallow water environments. The modal wave periods ranged from 6 to 14 seconds and the significant wave height ranged from 1 to 10 feet. The wave energy was spread using the idealized JONSWAP spectrum which is consistent with fetch limited conditions generally found in shallow water, and the energy was spread +/- 90^{o} to simulate shortcrested seas.

The ship operating conditions used for these nomographs were the following. The ship speeds were 6, 10, and 14 knots which covers most transit conditions for CVN 68 class ships. The ship-to-wave heading on the nomographs are head, bow, beam, quartering and following seas. Defining these headings, head seas are directly at the bow of the ship, bow seas are 45 ^{o} off the bow, beam seas are directly at the beam or side of the ship, quartering seas are 45 ^{o} off the stern, and following seas are directly off the stem.

The vertical motion and velocity at the bow and stern of the ship is calculated for each of these conditions. The extreme motion expected in 100 transits is then calculated from the vertical motion and velocity using a statistical formula generated by Ochi (1973). The largest resulting vertical motion is then used in the nomographs.

Reference

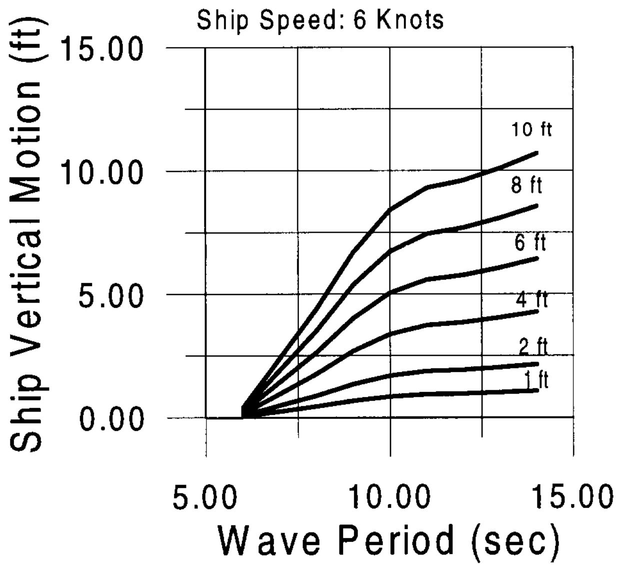
Ochi, M.K., "On Prediction of Extreme Values," Journal of Ship Research, Vol. 17 (1973).

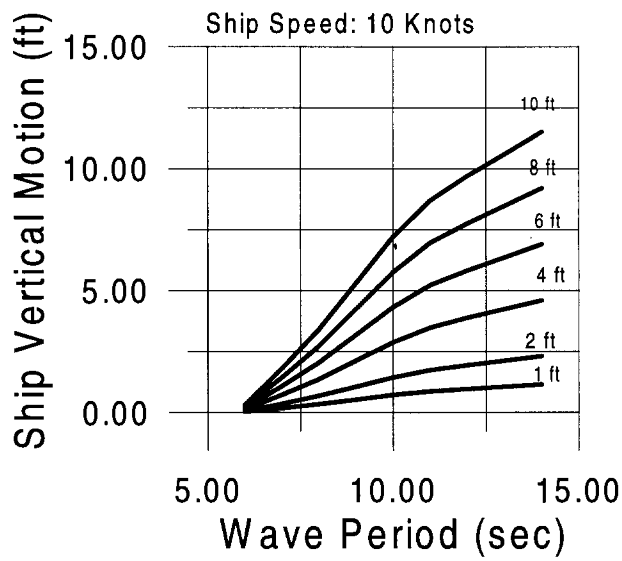
CVN 68 VERTICAL MOTION BY WAVE HEIGHT AND PERIOD

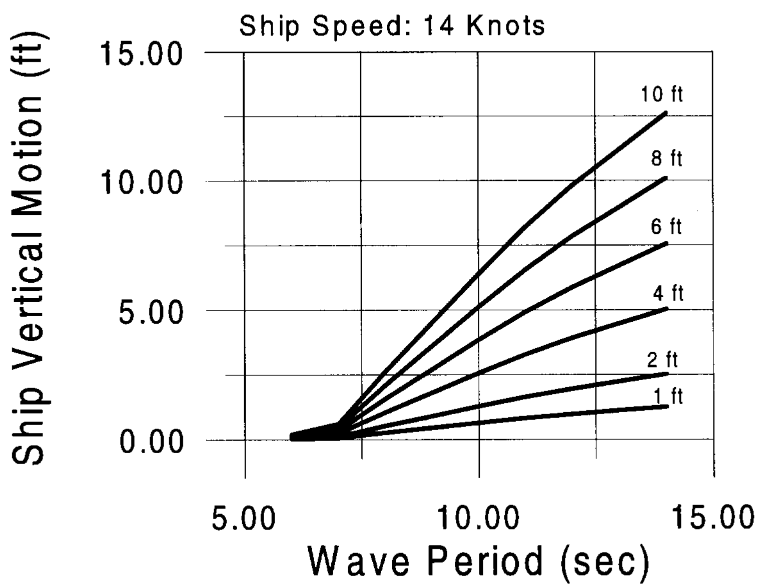
Vertical Motion Represents Extreme in 100 Transits

Curves represent significant wave height in feet

HEAD SEAS



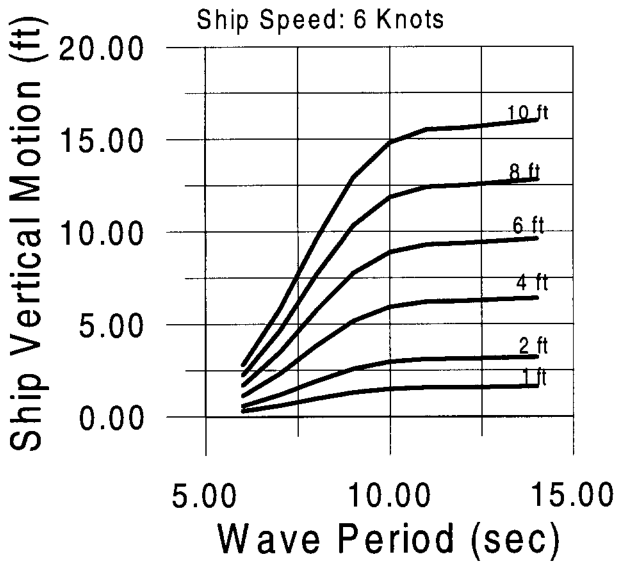


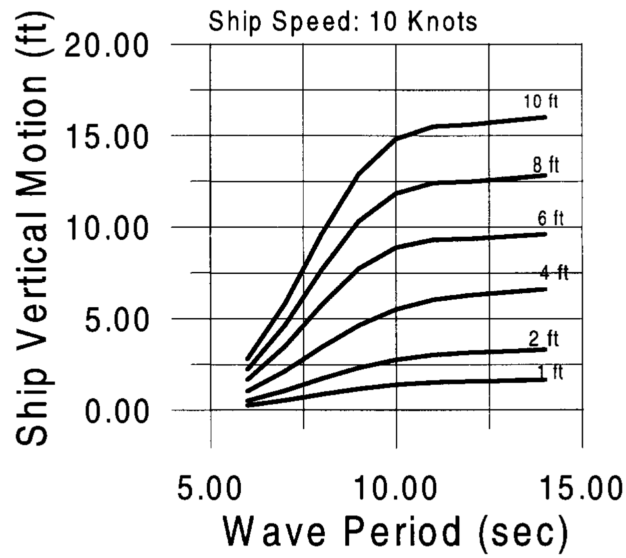


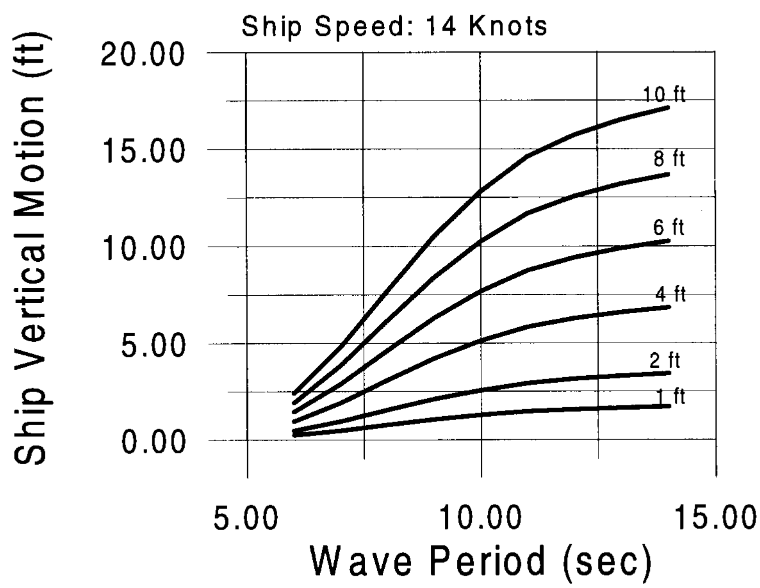
CVN 68 VERTICAL MOTION BY WAVE HEIGHT AND PERIOD

Vertical Motion Represents Extreme in 100 Transits
Curves represent significant wave height in feet

BOW SEAS





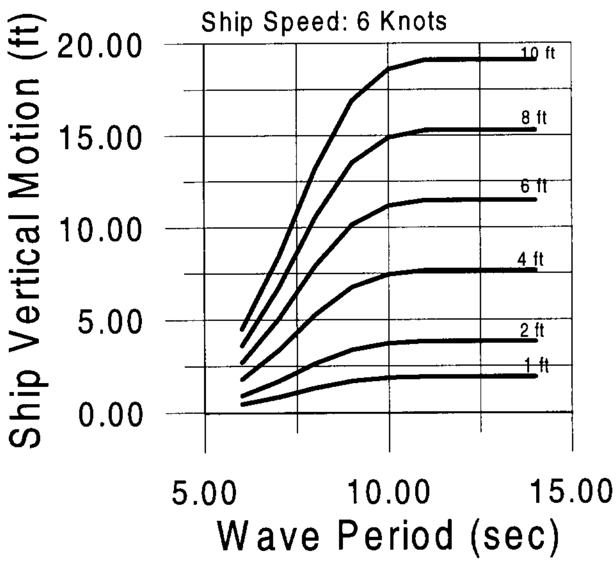


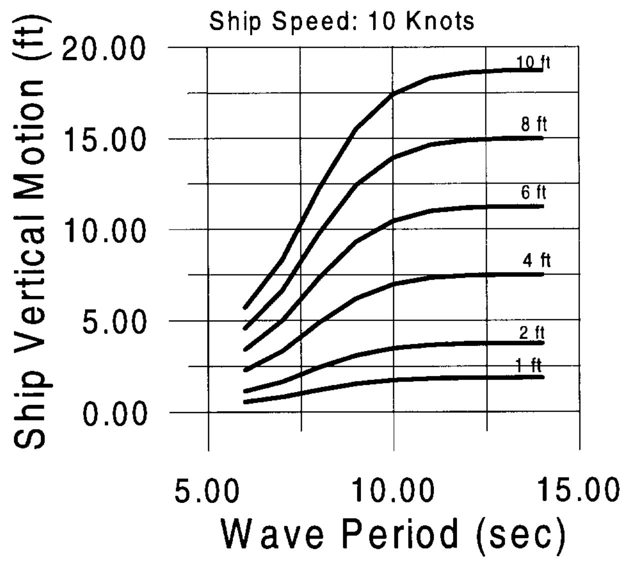
CVN 68 VERTICAL MOTION BY WAVE HEIGHT AND PERIOD

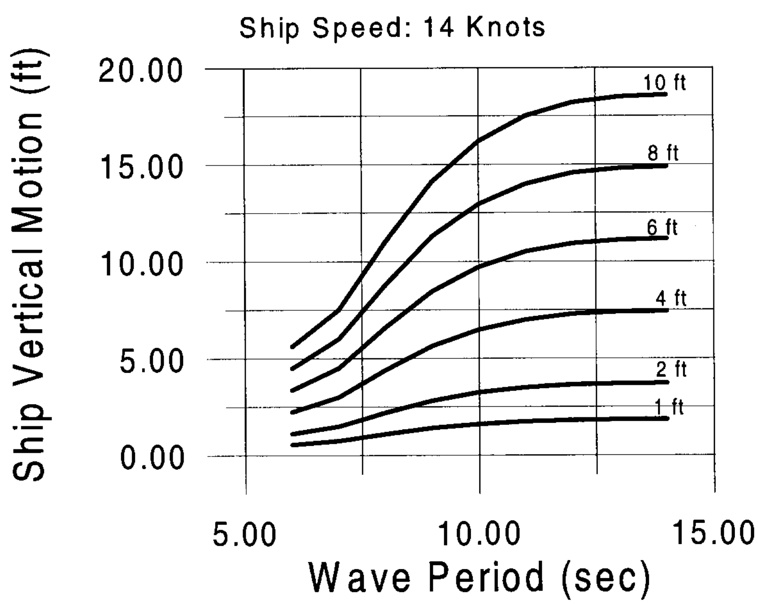
Vertical Motion Represents Extreme in 100 Transits

Curves represent significant wave height in feet

BEAM SEAS





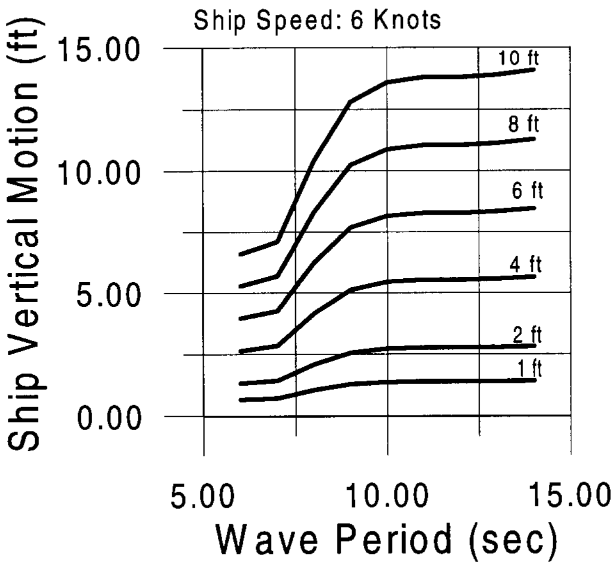


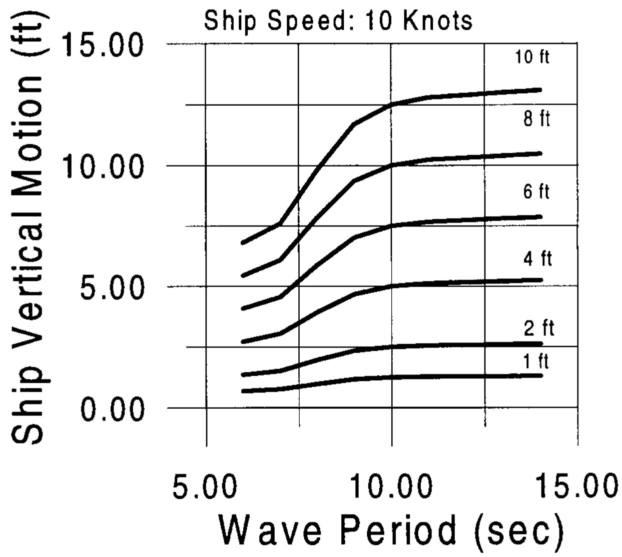
CVN 68 VERTICAL MOTION BY WAVE HEIGHT AND PERIOD

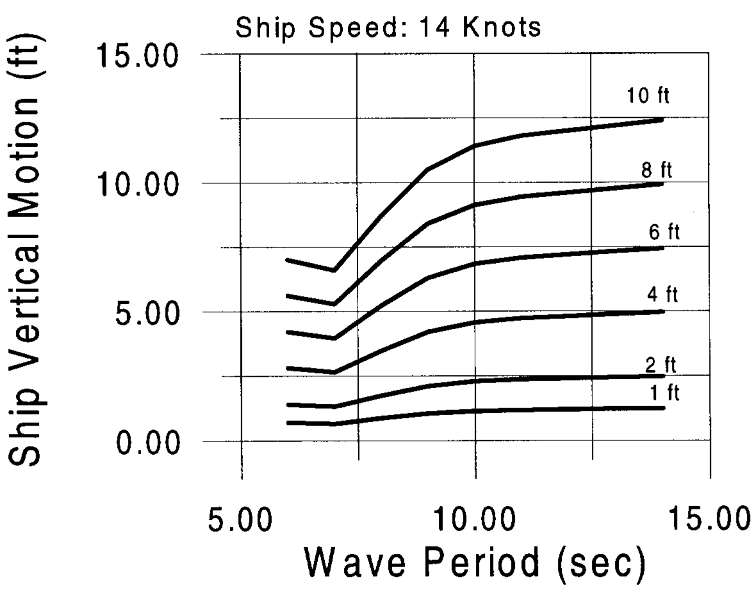
Vertical Motion Represents Extreme in 100 Transits

Curves represent significant wave height in feet

QUARTERING SEAS

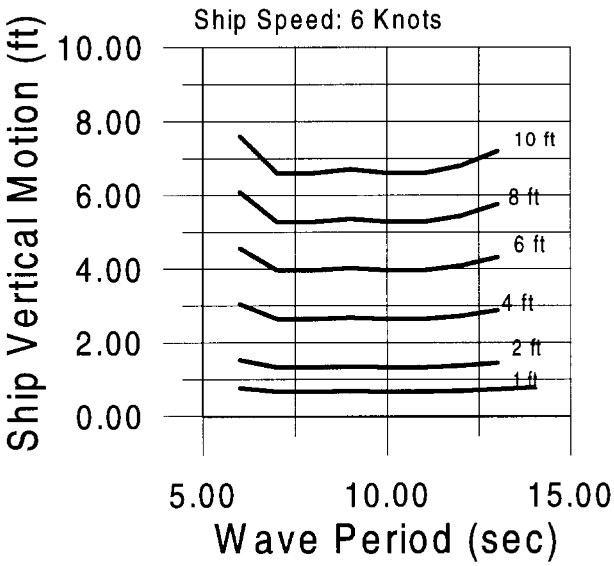


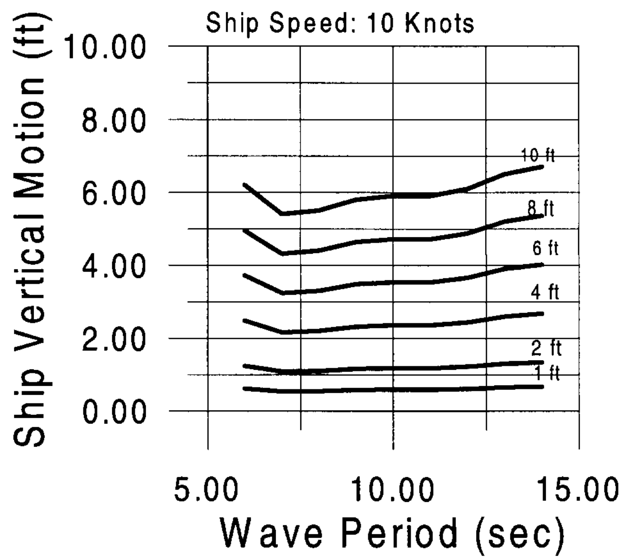


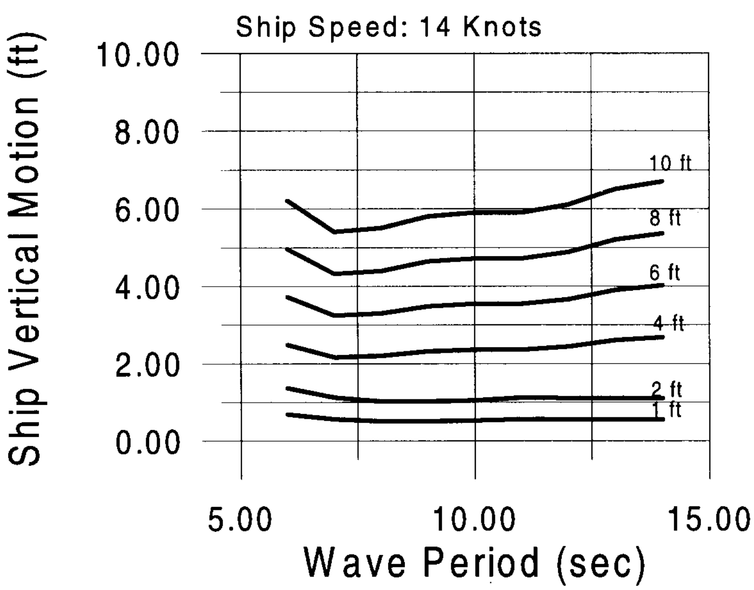


CVN 68 VERTICAL MOTION BY WAVE HEIGHT AND PERIOD
Vertical Motion Represents Extreme in 100 Transits
Curves represent significant wave height in feet

FOLLOWING SEAS







UFC 4-150-07
19 June 2001
Change 1, 1 September 2012

UNIFIED FACILITIES CRITERIA (UFC)

MAINTENANCE AND OPERATION:

MAINTENACE OF WATERFRONT FACILITIES

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MAINTENANCE AND OPERATION: MAINTENANCE OF WATERFRONT FACILITIES

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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

Change No.	**Date**	**Location**
1	1 Sept 2012	Various updates and editorial changes throughout.

This UFC supersedes MIL-HDBK-1104, DATED 10 December 1999.

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 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.

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CHAPTER 1

INTRODUCTION

1-1 **SCOPE**. UFC 4-150-07 is a guide for the inspection, maintenance, and repair of waterfront structures and related facilities. It is a source of reference for planning, estimating, and performing technical maintenance and repair work; and may serve as a training manual for waterfront facilities maintenance personnel.

1-2 **PURPOSE**. This document provides guidance for maintenance and repair of waterfront facilities to retain them in continuous readiness for use by the Fleet and in support of military marine operations.

1-3. **APPLICATION**. The types of waterfront facilities covered include:

- Berthing facilities for mooring and for providing support to ships and craft.
- Drydocks used for modification, inspection, maintenance and repair of ships.
- Components of waterfront structures such as piling, dolphins, bulkheads, and decks.

Fender systems are briefly considered. Refer to MO-104.1, *Maintenance of Fender Systems and Camels*, for detailed coverage.

Not specifically considered in this document are:

- Coastal protection structures designed to protect shorelines or harbors.
- Components of waterfront structures such as utility distribution systems and fleet moorings.

The maintenance and repair of coastal protection structures is included in the Army Corps of Engineers, *Shore Protection Manual*, Volumes I and II. Repair of coastal structures is covered in more detail in USACE, *Coastal Engineering Technical Notes and Repair, Evaluation, Maintenance, and Rehabilitation Technical Notes*. The maintenance of utility distribution systems is covered by various service manuals and commercial publications. NAVFAC MO-124, *Mooring Maintenance Manual*, provides details on the maintenance of fleet mooring systems.

These documents, and all Government documents referenced in this document, provide additional guidance primarily to DOD and U.S. Coast Guard activities.

They may also be useful, however, to commercial firms that provide waterfront repair for these activities. \1\ /1/

1-4 **TECHNICAL SECTIONS**. The technical sections following this introduction include:

MAINTENANCE PLANNING AND TYPES OF FACILITIES (Chapter 2):

- Joint service responsibilities, maintenance policies, and the basic elements of maintenance planning.
- Overview of waterfront facilities.

MATERIALS AND PREVENTIVE MAINTENANCE (Chapter 3):

- Describes materials at the waterfront and the types of deterioration likely to be encountered.
- Describes preventive maintenance measures for each type of material.

SAFETY AND ENVIRONMENTAL CONSIDERATIONS (Chapter 4):

- Guidelines for personnel and work site safety.
- Guidelines for assuring compliance with environmental policies and regulations.

INSPECTION (Chapter 5):

- Overview of inspection levels, methods, planning, equipment and documentation.
- Guidance and checklists for above and underwater inspection of timber, concrete, steel, synthetics, and rubble-mound structures.

REPAIR (Chapters 6, 7, 8, 9, and 10):

- Describes and illustrates repair methods and techniques for the problems encountered.
- Guidance for selecting material along with pertinent references and standards.

CHAPTER 2

MAINTENANCE PLANNING AND TYPES OF FACILITIES

2-1 MAINTENANCE PLANNING

2-1.1 Cooperation and Coordination

2-1.1.1 **Intraservice Functions**. Cooperation and coordination of waterfront maintenance activities among the installation departments concerned should be continuous. Properly planned and executed maintenance programs prevent undesirable interruption of operations on military installations. Supply officers, through normal channels, provide standard items of materials and equipment for waterfront maintenance.

2-1.1.2 **Interservice and Interdepartmental Functions**. Cooperation and coordination in conducting waterfront maintenance are encouraged at all levels of command. Appropriate liaison should be established and maintained between major commands and installations in a geographical area. Cross-service assistance should be provided as necessary in the interests of economy and maximum utilization of manpower and equipment. Technology transfer of improved maintenance methods and materials should be continuously encouraged.

2-1.1.3 **Fleet Requirements**. All maintenance and repair activities should be scheduled and coordinated to minimize pier down time for the fleet. Direct communication with the fleet command is vital for ensuring fleet requirements are considered when planning pier maintenance or repair.

2-1.2 **Joint Service Responsibility**. The responsibility for inspection, maintenance, and repair of waterfront structures and related facilities rests with each service. Because of the quantity of waterfront facilities in inventory, the Navy retains a strong technology base in design, construction, and maintenance of waterfront structures: such as piers, wharves, quaywalls, dry-docks, dolphin assemblies, and moorings. The Army maintains a similar capability for coastal harbor facilities, such as breakwaters, jetties, groins, and seawalls.

2-1.2.1 **Army**. Staff, command, and technical responsibility for maintenance and repair of waterfront structures at Army installations will conform to assignments set forth in AR 415 and 420-10 series. Policy and standards for the maintenance of shore protection works are contained in ER-1110-2-2902, *Prescribed Procedures for the Maintenance and Operation of Shore Protection Works*.

U.S. Army Engineer divisions and districts provide specialized expertise in evaluation of coastal erosion, and design and maintenance of coastal and harbor facilities.

\1\ /1/2-1.2.2 **Navy**. The Naval Facilities Engineering Command (NAVFAC), \1\ is /1/ responsible for organizing and performing waterfront inspection, maintenance, repair, and minor construction programs to support the Commanding Officer at each Naval shore installation. NAVFAC MO-322, *Inspection of Shore Facilities*, (Volumes 1 and 2) contains Navy guidelines for shore facilities inspection and preventive maintenance programs.

\1\ NAVFAC provides design, maintenance, and repair management expertise to assist the shore activities in carrying out their mission of maintaining waterfront facilities. Requests for assistance should be directed to the appropriate local NAVFAC office. /1/

Specialized expertise in waterfront materials, structures, and related topics can be provided to DOD and other Federal activities by the Naval Facilities Engineering Service Center (NFESC), Port Hueneme, California. Current criteria documents for maintenance and repair of waterfront facilities are developed and maintained by \1\ NAVFAC LANT CI1. /1/

The Navy's underwater construction teams (UCT) provide military responsive capability for construction, installation, inspection, repair, and removal of ocean facilities. \1\ NTRP 4-04.2.8, *Conventional Underwater Construction and Repair Techniques* and NTRP 4-04.2.9*, Expedient Underwater Construction and Repair Techniques*, provide guidelines /1/ for UCT teams in underwater inspection and repair techniques that may be useful to facilities maintenance personnel. UCT ONE is located in Norfolk, Virginia; UCT TWO is located in Port Hueneme, California.

2-1.2.3 **Air Force**. Policy and standards for the maintenance, repair, and minor construction of Air Force facilities are set forth in Air Force Instruction \1\ 32-1023, *Design and Constructing Military Construction Projects*. /1/

The installation commander, assisted by the Base Civil Engineer (BCE) and others on the staff, is responsible for identifying, planning, and programming all real property maintenance, repair, and minor construction requirements necessary to properly support assigned missions and people (including tenants) and to care for and preserve Air Force real property. Major commands provide oversight to ensure compliance with law, Department of Defense (DOD) and Air Force policies and are responsible for establishing quality standards. The Civil Engineer, HQ USAF/ILE provides programming guidance, oversight, and policy as required. The Air Force Civil Engineer Support Agency (AFCESA) and Air Force Center for Environmental Excellence (AFCEE) provide technical engineering guidance.

2-1.3 **Maintenance Standards and Criteria**.

2-1.3.1 **Engineering**. The need for and accomplishment of major repairs and rehabilitation of existing waterfront facilities will be based on experience, judgment, and engineering evaluation. The services of qualified technical personnel will be used to assist in the establishment of waterfront maintenance programs.

2-1.3.2 **Related Published Material**. \1\ Navy requirements for the design and construction of waterfront facilities are found in UFC 4-152-01, *Design: Piers and Wharves* and UFC 4-151-10, *General Criteria for Waterfront Construction*. These documents provide guidance and recommendations on port design and construction and port maintenance primarily for Navy activities. MO-322, NTRP 4-04.2.8, and NTRP 4-04.2.9 /1/ are especially important relative to inspection of waterfront structures. Maintenance of fendering systems and camels are described in MO-104.1. Reference to other published materials, which provide related or more extensive information on specific areas of waterfront maintenance, is made where appropriate throughout this handbook. A Glossary of waterfront terms is provided in this handbook.

2-1.4 **Maintenance Program**. The maintenance program shall be designed to include prevention of deterioration and damage, prompt detection of deficiencies, and early accomplishment of maintenance and repairs to prevent interruptions to operations or limiting full use of a facility. The Navy's principal guide for maintenance management is NAVFAC MO-321, *Facilities Management.*

2-1.4.1 **Planning and Economic Considerations**. In maintenance planning and execution, consider future expected use of each facility, the life expectancy of the facility, and the life cycle cost of periodic repairs versus replacing a facility or major components. The level of maintenance and programming of major repairs should be planned in consonance with the future requirement for the facility and planned replacement. When waterfront structures are in an inactive status, the maintenance policies will be in accordance with the inactivation plan.

2-1.4.2 **Inspection**. Periodic, rigorous inspections are necessary for an effective maintenance program. Types of inspections and detailed procedures for waterfront facilities are described in Chapter 5.

2-1.4.3 **Maintenance**. Maintenance is the recurrent day-to-day, periodic, or scheduled work that is required for a facility to be used for its designed purpose. It includes routine work undertaken to prevent damage or deterioration of a facility that otherwise would be more costly to restore. The more common concerns in maintenance of waterfront facilities are:

- Painting and protective coating.

- Routine replacement or mending of fender components (e.g., rub strips) to prevent damage to ships and the pier.
- Maintenance of utility systems to prevent outages.
- Routine mending of protective plastic wraps.
- Routine patching of small concrete spalls and cracks.
- Maintenance of the cathodic protection system.

Chapter 3 provides details of maintenance procedures in addition to descriptions of waterfront materials and deterioration causes.

2-1.4.4 **Repair**. Repair is the restoration of a facility to such a condition that it can be used for its designed purpose. The repair is done by overhaul, reconstruction, or replacement of deteriorated constituent parts or materials that have not been accomplished through maintenance. The more common repair projects for waterfront facilities are:

- Replacement or reconstruction of fender systems.
- Repair of eroded or failing quaywalls.
- Repair and resurfacing of pier decks.
- Reconstruction of major concrete spalls and cracks.

Chapters 6 through 10 provide details of repair options for waterfront structures. These sections are organized to guide engineering and maintenance personnel in selecting repairs to waterfront facilities. Each repair procedure is a stand alone document, with the repair description on the left and the illustration on the right hand page. In Sections 6, 7 and 8, repair procedures are numbered (for example, TR-1; timber repair number one) to permit identification and reference. For many of the repair procedures, problem definition and application constraints are also provided to guide the user in selecting the proper repair technique to match the problem.

2-2 **TYPES OF FACILITIES**. The types of waterfront facilities include:

- Berthing facilities for mooring and for providing support to ships and craft.
- Drydocks used for construction of ships and to expose the underwater portion of the ship for repair, modification, inspection, or maintenance.

- Coastal protection structures designed to protect shorelines or harbors.

- Components of waterfront structures such as fender systems, piling, dolphins, utility distribution systems, deck and mooring hardware, and fleet moorings.

2-2.1 **Berthing Facilities**. The basic facilities to provide berthing support for ships and craft are piers and wharves. These facilities provide a safe space for ships to moor and receive shore utilities and other hotel services. They provide a platform for loading and unloading cargo and personnel, transferring ordnance, receiving fuel, and performing ship maintenance; repair; and fitting out. Berthing facilities are also provided for tugboats, small craft, barges, and harbor support equipment.

2-2.2 **Piers**. Piers are berthing facilities that extend outward from the shore into the water. Piers may be used for berthing on one or both sides of their length. There are three types of pier structures with distinct differences in configuration: open, closed, and floating piers. Combination piers combine open and closed configurations.

Open piers are pile-supported platform structures that allow water to flow underneath. Pile supported piers can be single-deck or double-deck structures. Figures 2-1 and 2-2 show schematics of a single- and double-deck, open piers.

Figure 2-1 Single-Deck, Open Pier

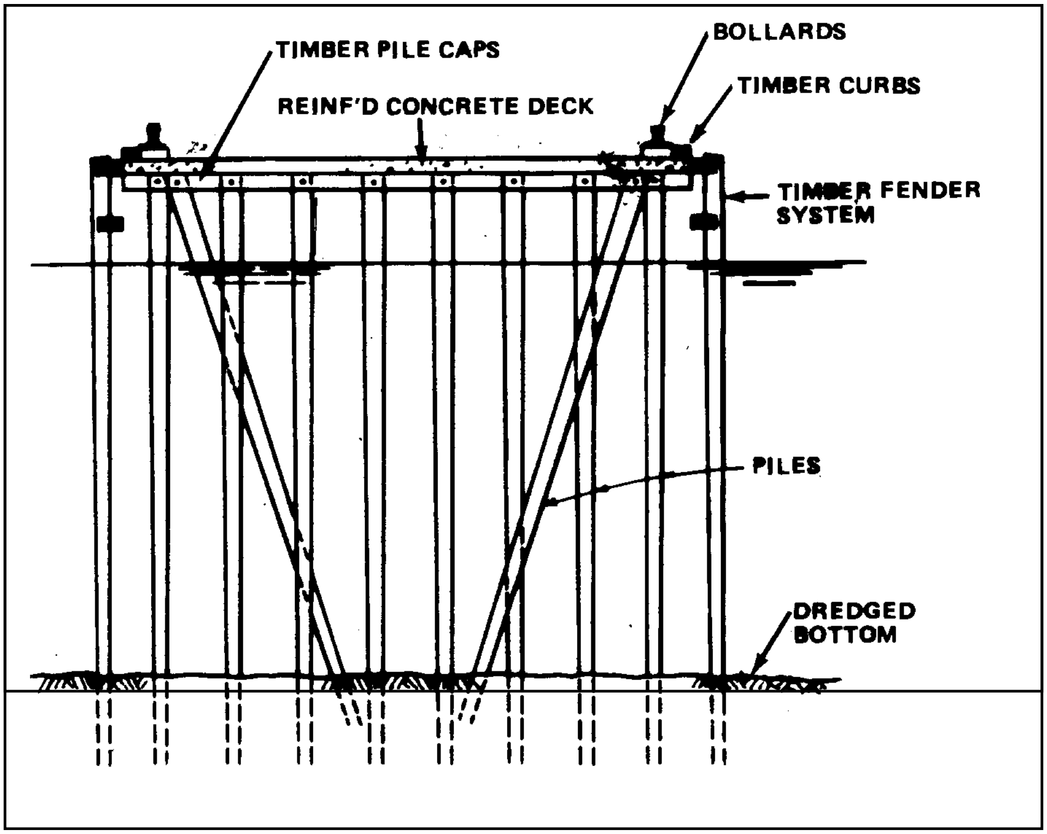
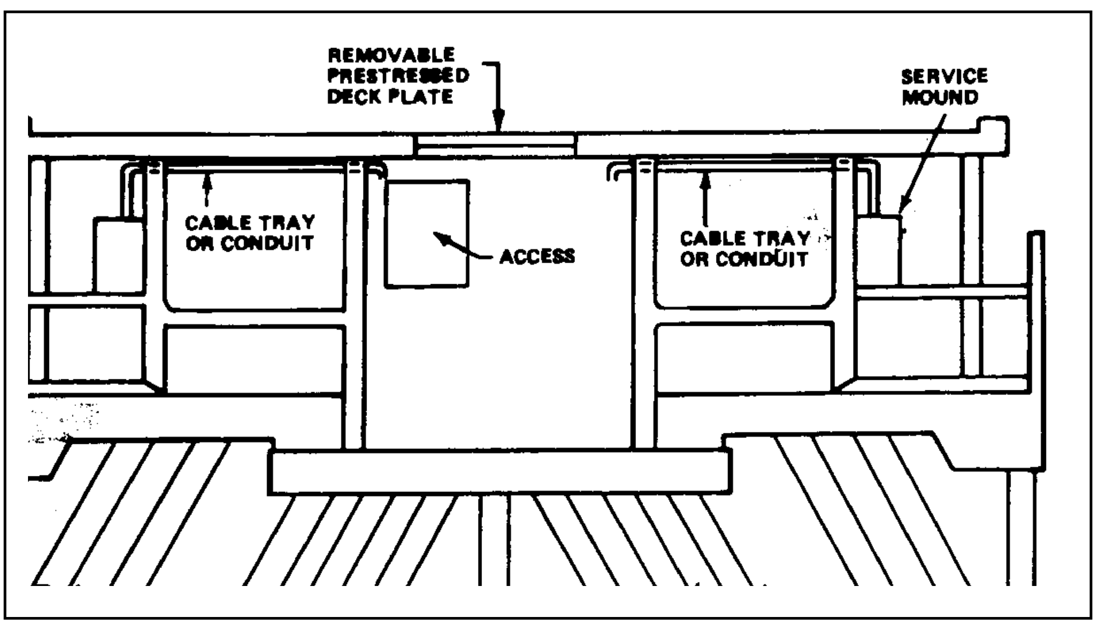


Figure 2-2 Double-Deck, Open Pier



Closed piers, or solid fill piers, are constructed so that water is prevented from flowing underneath. The solid fill pier is surrounded along the perimeter by a bulkhead to hold back fill. Figure 2-3 shows a schematic of a solid fill pier. A special type of solid fill pier is a mole pier. Mole piers are earthen structures that extend outward from the shore. The sides and offshore end of the pier are retained and protected by sheet piles, circular cells or walls of either masonry or concrete. If the water is deep, the pier can be used to berth ships.

Floating piers are constructed of steel or concrete and are connected to the shore with access ramps. Guide piles in the center of the pier, or a chain anchorage system, prevent lateral movement and allow the pier to move up and down with the tide. The floating pier may be a single-deck or a double-deck structure. A floating pier design concept developed by the Navy is shown in Figure 2-4.

A more detailed discussion of the design and configuration of piers is documented in \1\ UFC 4-152-01 /1/, *Design: Piers and Wharves*.

2-2.3 **Wharves and Quaywalls**. Wharves are berthing facilities that are parallel to the shore. They are normally connected to the shore along their full length, and a retaining structure is used to contain earth or stone placed behind the wharf. This retaining structure is often referred to as the quaywall or bulkhead. Ships are moored along the outshore face of the wharf. The wharf types are the same as the basic pier types and include open and closed (or solid fill) configurations. Figure 2-3 shows a solid-fill pier with a configuration similar to a closed wharf.

2-2.4 **Drydocking Facilities**. Navy drydocking facilities are used to expose the underwater portion of ships for repair, modification, inspection, or maintenance. Several different types of drydocks exist, including graving drydocks, floating drydocks, marine railways, and vertical ship lifts.

- Graving drydocks are fixed basins adjacent to the water's edge and are constructed of stone masonry, concrete, or sheet pile cells. They can be closed off from the waterway by a movable watertight barrier (entrance caisson or flap gate). After closing the barrier, the basin is pumped dry, which allows the ship to settle on blocking set on the dock floor. Figure 2-5 shows a schematic of a graving drydock.

Figure 2-3 Solid-Fill Pier

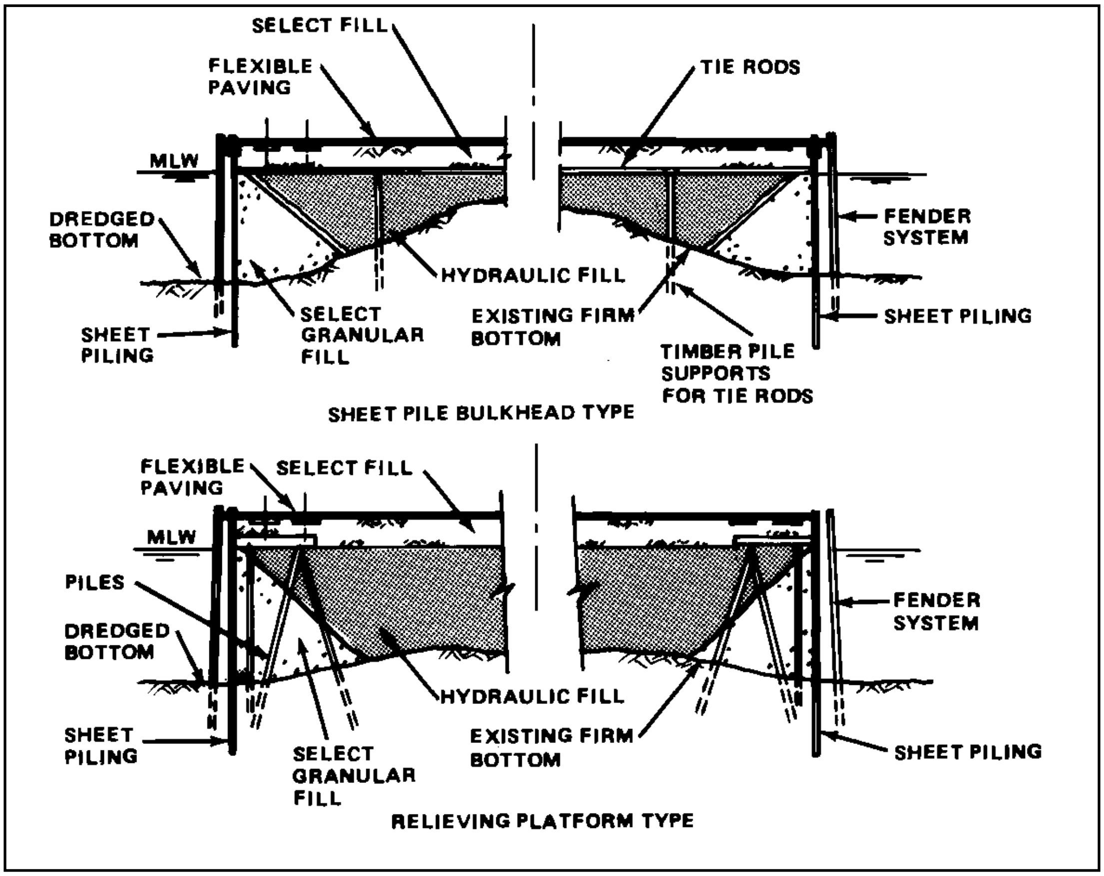


Figure 2-4 Floating Pier Design Concept

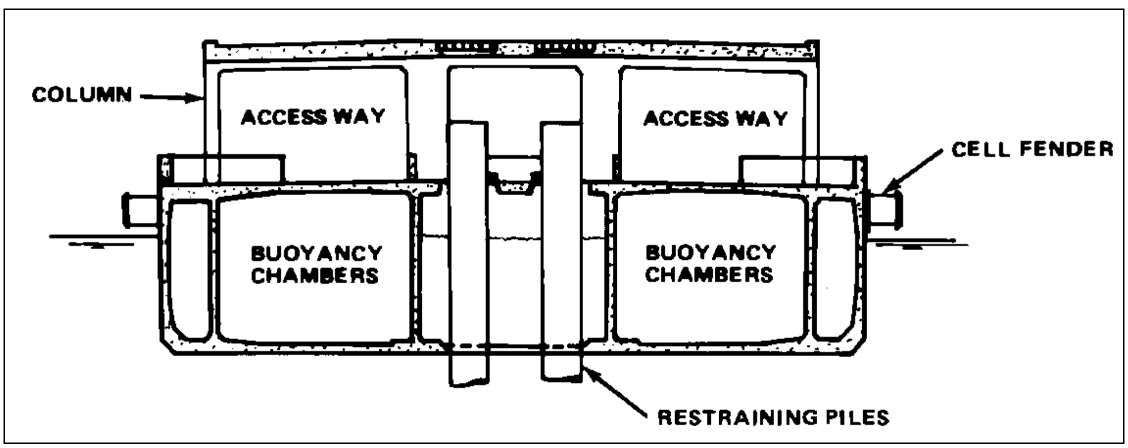
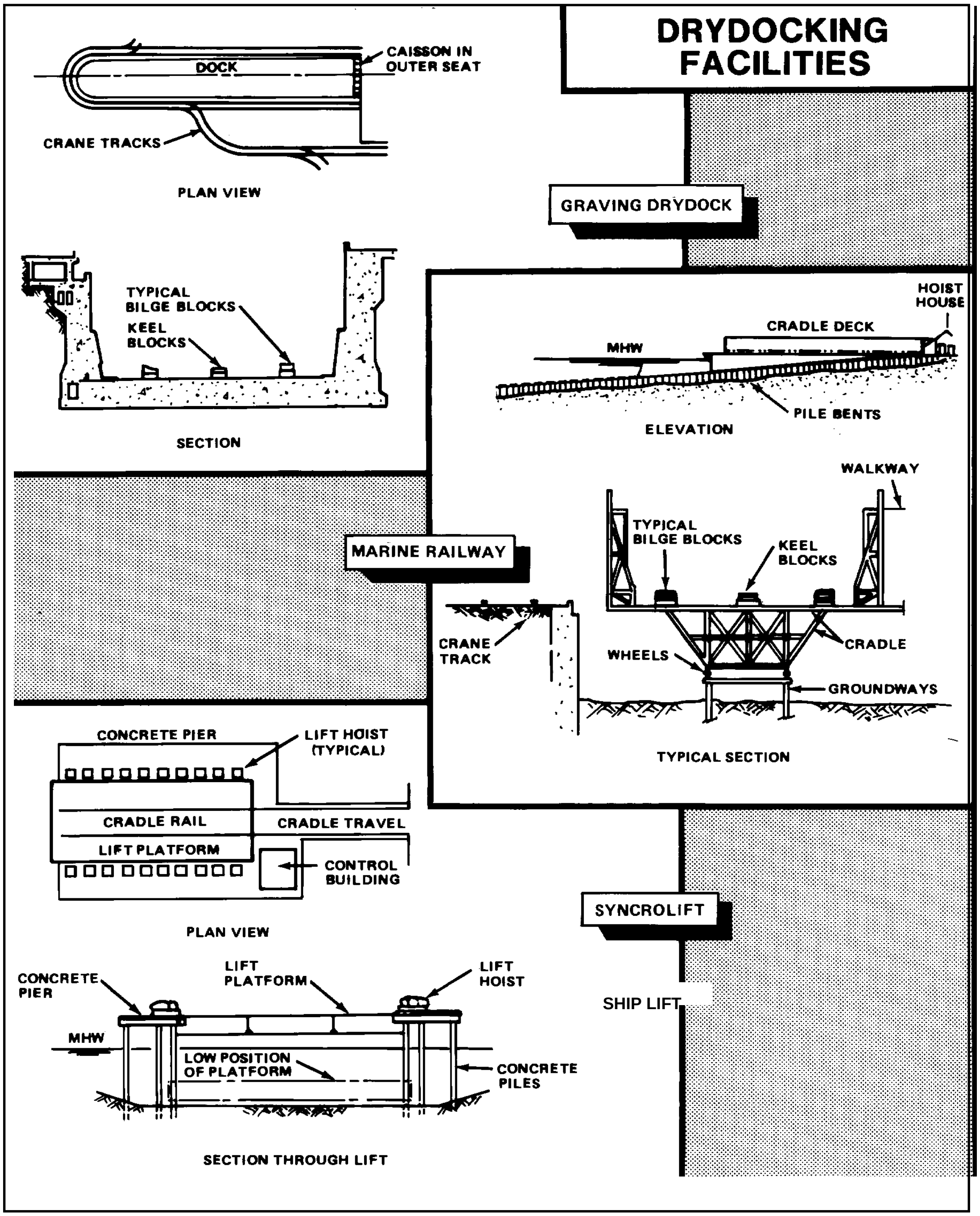


Figure 2-5 Drydocking Facilities



- Floating drydocks are ship or U-shaped structures that are submerged by flooding to permit a vessel to enter and then pumped dry to raise the vessel out of the water.

- Marine railways consist of a ramp extending into the water, a mobile ship cradle on wheels or rollers, groundway ship cradle tracks, hoisting machinery, and chains or cables for hauling the ship cradle endwise or sidewise. Figure 2-5 shows a marine railway.

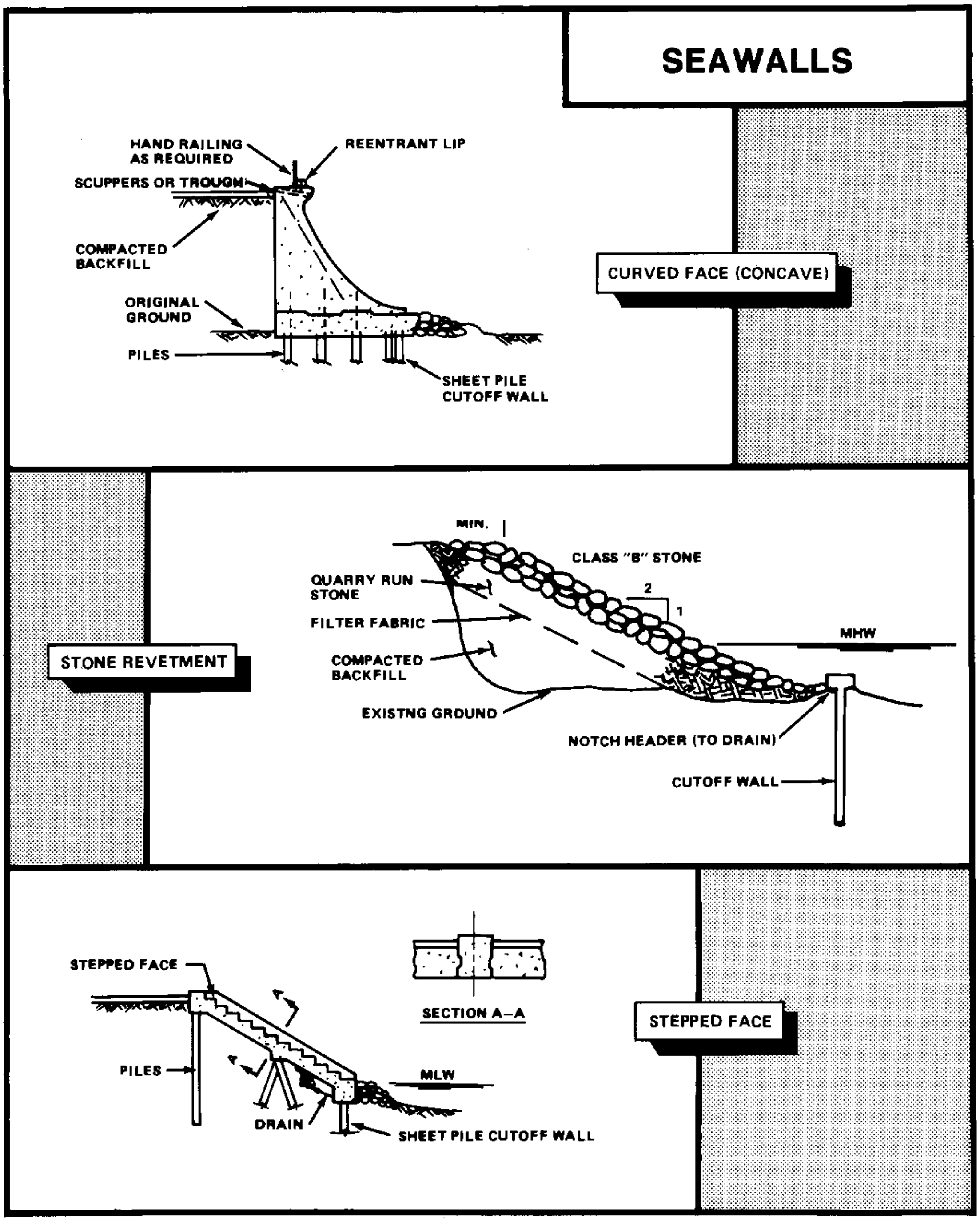
- Ship lifts consist of platforms that are lowered into the water to receive ships. The ship is then lifted out of the water on the platform by electrical powered hoist equipment. Figure 2-5 shows a vertical ship lift drydocking system.

More detailed discussions of drydocking and marine railway facilities can be found in \1\ UFC 4-213-10, *Design: Graving Drydocks* and UFC 4-213-12, *Drydocking Facilities Characteristics. /1/* Maintenance of drydocking facilities is not specifically covered in this manual.

2-2.5 **Coastal Protection Structures**. Structures designed to reduce the erosive effects of wave action, or to protect harbors from excessive wave action and the formation of sandbars, are classified as coastal protection structures. The common coastal protection structures are seawalls, groins, jetties, and breakwaters. \1\ The U. S. Army Corps of Engineers, *Shore Protection Manual* provides /1/ additional information on the design and configuration of coastal protection structures. Maintenance of coastal protection structures is not specifically covered in this handbook. Bulkheads are included, however, because they are an integral part of solid fill piers.

2-2.5.1 **Seawalls**. Seawalls are massive coastal structures built along the shoreline to protect coastal areas from erosion caused by waves and flooding during heavy seas. Seawalls are constructed of a variety of materials including rubble-mounds, granite masonry, or reinforced concrete. They are usually supplemented by steel or concrete sheet pile driven into the soil and are strengthened by wales and brace-type piles. Figure 2-6 shows three seawall configurations.

Figure 2-6 Seawall Configurations



2-2.5.2 **Groins**. Groins are structures designed to control the rate of shifting sand by influencing offshore currents and waves so that erosion of the shoreline is minimized. Groins project outward, perpendicular to the shoreline, and are constructed of large rocks, pre-cast concrete units, reinforced or prestressed concrete piles, steel sheet piles, or timber cribbing filled with rock. Figure 2-7 is an example of a groin.

2-2.5.3 **Jetties**. Jetties are structures that extend from the shore into deeper water to prevent the formation of sandbars and to direct and confine the flow of water due to currents and tides. These structures are normally located at the entrance to a harbor or a river estuary. Jetties are usually constructed of mounds of large rubble about a meter above the high tide mark. Figure 2-8 shows the position of jetties at a harbor entrance.

Figure 2-7 Groin

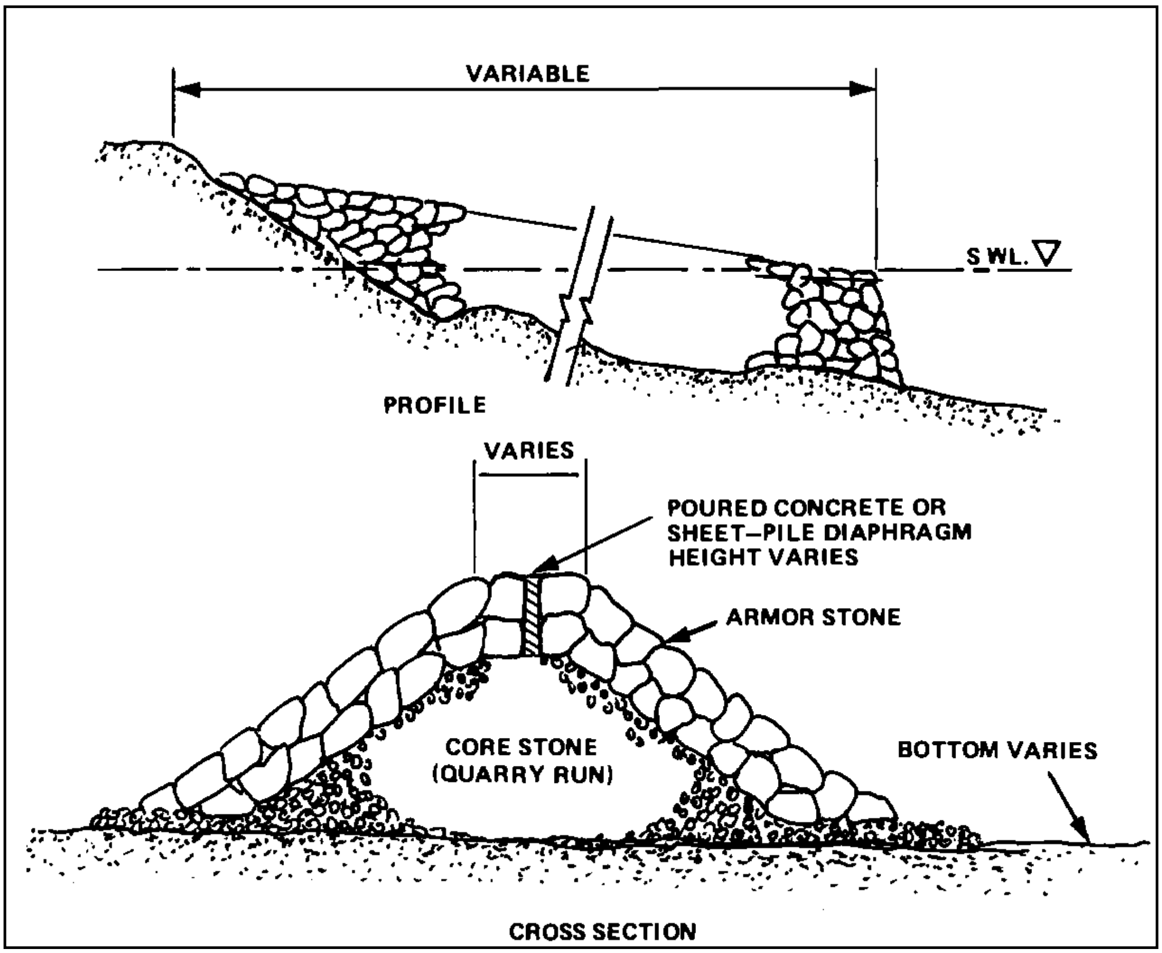
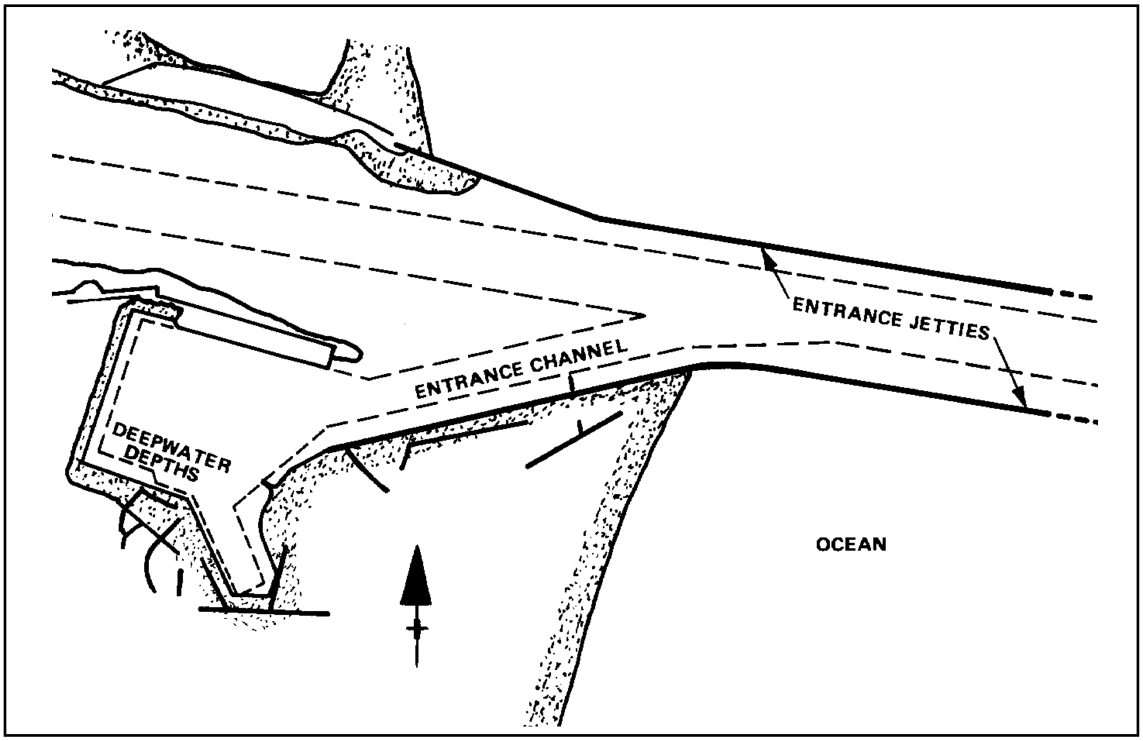


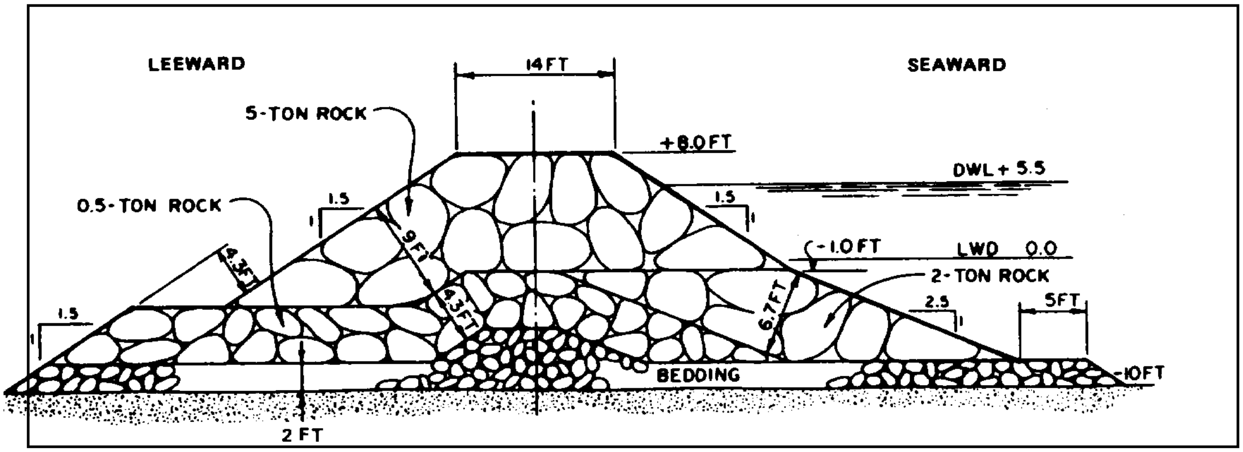
Figure 2-8 Typical Location of Jetties



2-2.5.4 **Breakwaters**. Breakwaters are large rubble-mound structures located outside of a harbor, anchorage, or coastline to protect the inner waters and shoreline from the effects of heavy seas. These barriers help to ensure safe mooring, operating, loading, or unloading of ships within the harbor. Breakwaters may be connected to the shore or detached from the shore. There are three general types of breakwaters, depending on the type of exposed face. The exposed face may be vertical, partly vertical and partly inclined, or inclined. Figure 2-9 shows a section of a breakwater.

2-3 **COMPONENTS OF WATERFRONT STRUCTURES**. Numerous components of basic facilities are present at the waterfront to aid in port operations. These components are integral parts of piers and wharves and include fender systems, piling, dolphins, deck and mooring hardware, and utility distribution systems, or they may be offshore systems vital to ship operations, such as fleet moorings. Utility distribution systems and offshore systems are not specifically covered in this manual.

Figure 2-9 Breakwater Section



2-3.1 **Fender Systems**. Fender systems are used on piers to protect the ship and the pier during berthing operations and while the ship is moored. The most widely used fender system consists of timber fender piles, timber wales, and chocks, with rubber compression fender units between the system and the pier to absorb berthing impacts. This type of system is the highest maintenance cost portion of the pier. The trend is toward using longer lasting and more resilient fender systems with less reliance on treated timber because of environmental concerns.

The main types of fenders, and their components, that may be found installed in ports are:

- Fender pile systems: timber, steel, concrete, or composite piles.

- Fenders fixed to the pier ("rubber" refers to various elastomeric plastic materials):

  a. Rubber-in-compression units: cylindrical, rectangular, trapezoidal, wing-type, and D-shaped units.

  b. Rubber-in-shear fenders: rectangular rubber column and Raykin fender.

  c. Buckling fender: buckling column fender and cylindrical cell fender.

- Resilient, floating pneumatic and foam-filled fenders connected or suspended from the pier or backed up by closely driven steel or concrete fender piles. \1\ UFC 4-152-01 /1/ gives more in-depth descriptions of types of fender systems. The maintenance of fender systems is covered in MO-104.1.

2-3.2 **Piling**. Piling is an integral part of all open piers and wharves. The exposure of piling makes it susceptible to severe environmental attack: corrosion, marine borers, and erosion. Piling is made from concrete, wood, steel, or composite materials and requires protective coatings, preservatives, or wraps to ensure a long life.

There are four functional types of piling: vertical bearing piles, batter piles, fender piles, and sheet piles. Bearing piles are used to support the weight of the pier and loads on the pier. Batter piles provide lateral and longitudinal stability. Fender piles are used to absorb the impact of berthing ships. Sheet piling is used for various waterfront structures, e.g., quaywalls to retain fill.

2-3.3 **Dolphins**. A dolphin is a group of piles placed near piers and wharves, or in turning basins and ship channels. These structures are used to guide vessels into their moorings, to mark underwater structures (shoals or shore), and to support navigational aids.

2-3.4 **Fleet Mooring**. A fleet mooring is an offshore anchoring system that consists of various hardware items: chain, cable, sinkers, anchors, and buoys. The offshore anchoring system is placed in a fixed location so that vessels, when entering the port, can anchor to the buoys. NAVFAC MO-124, *Mooring Maintenance Manual* provides details on the maintenance of fleet mooring systems, therefore, they are not covered in this handbook.

2-3.5 **Deck and Mooring Hardware**. Various deck and mooring hardware, such as gratings, handrails, bollards, bitts, cleats, chocks and rings, are used on piers and wharves. These items require inspection and maintenance to ensure personnel safety and adequate mooring facilities for ships.

2-3.6 **Utility Distribution Systems**. Utility distribution systems are provided on most piers and wharves to service the ships. Utilities available at most piers and wharves include:

- Steam
- Potable water
- Saltwater
- Sewage and oily waste collection
- Compressed air

- Electricity
- Fuel
- Telephone service
- Fire alarm systems

These utility systems require maintenance of conduit, piping, valves, expansion joints, drains, regulators, and insulation. The maintenance of utility systems and their components is covered by various service manuals and commercial publications, and is not included in this manual.

CHAPTER 3

MATERIALS AND PREVENTIVE MAINTENANCE

3-1 **GENERAL.** Common structural materials used for construction and repair in waterfront areas are: wood, reinforced concrete, steel, and plastic. Selecting the proper materials and systems can reduce maintenance costs and increase the life of facilities. Wood preservatives, coatings, quality control of the reinforced concrete materials, cathodic protection, and carefully selecting alloys and synthetic materials help extend the life of the materials and structures.

This Section describes types of materials used in the construction and repair of waterfront facilities; types of deterioration, corrosion, and other problems that may be encountered; and preventive maintenance (PM) actions that should be taken. Table 3-1 summarizes PM actions that should be a part of all waterfront maintenance programs.

Table 3-1. Summary of Preventive Maintenance Actions

PREVENTIVE MAINTENANCE ACTION	PARAGRAPH TITLE
Wood and Timber – General	
Use pressure-treated member	Pressure Treatment
Treat exposed areas: cuts, bolt holes, pile tops	Field Treating Exposed Areas of Wood Before Installation
Embed fumigant in pile top	Encasements and Retardants
Use pile top bonnet and preservative	Encasements and Retardants
Timber Piles	
Install plastic wrapping or jacket	Protection of Timber Piles
Concrete - General	
Use Type II or V cement	Cement
Avoid marine aggregates	Aggregates
Provide adequate cover over reinforcing steel	Reinforcing Steel
Use coating on concrete above splash zone	Preventive Maintenance for Concrete
Treat cracks with a flexible elastomeric or with polyurethane injection	Treatment of Cracks
Steel – General	
Design Actions	
Select proper protective coating for immersed steel	Protective Coatings for Steel
Provide cathodic protection system	Cathodic Protection of Steel
Substitute corrosion resistant metals for steel	Nonferrous Metals and Alloys
Increase thickness to allow for corrosion over life cycle	
Minimize galvanic corrosion:	Preventive Maintenance for Nonferrous Metals and Alloys

Minimize use of different metals	Preventive Maintenance for Nonferrous Metals and Alloys
Insulate different metals from each other	Preventive Maintenance for Nonferrous Metals and Alloys
Maintain protective coatings	Preventive Maintenance for Nonferrous Metals and Alloys
Keep cathodic area small relative to active metal	

3-2 **WOOD AND TIMBER**. Wood and timber members have been used for construction and maintenance of waterfront facilities due to availability, economy, and ease of handling relative to other construction materials.

Common wood products used include: dimension lumber, timber, piles, and poles. Engineered wood products such as glued and laminated timbers (glulam) are common and, if, properly preserved or protected, may be used. Plastics and composites can be used as substitute materials for non-load bearing wood members. The primary applications at the waterfront include:

- Older piers, wharves, bulkheads, and quaywalls built from timber piles.
- Fender systems built from timber and round timber piles.
- Pile dolphins built from round timber piles.
- Floats and camels built from logs, timber, dimension lumber, glued and laminated wood, or miscellaneous forms.
- Groins built from timber and round timber piles.

\1\ One critical aspect of timber construction is connection hardware. Typcially, bolts are used. Problems observed from hardware misalignment and corrosion are exhibited in terms of: “necking down” of bolt shank, distortion/enlargement of washer holes, and bolt heads popping off or being drawn through the washer. /1/

3-2.1 **Maintenance.** Maintenance of wooden structures involves replacing decayed or damaged wood with properly treated wood or other suitable material. If repairs are to be reduced in the future, exposed wood and pile caps must be treated with an effective preservative to retain its strength and longevity against destructive fungi, marine organisms, insects, and bacteria attack.

Many wood species are used for treated dimension lumber and timber in the United States. Primarily, Douglas fir is used on the West Coast and southern pine is used on the East Coast due to availability. See Unified Facilities Guide Specification \1\ UFGS-06 13 33, *Pier Timberwork* /1/ for proper Navy procurement and product inspection criteria of pier timber work. Round timber piles for marine use are also usually made from Douglas fir or southern pine according to availability and size requirements for piling. For Navy use, these piles must conform to \1\ UFGS 31 62 19.13, *Wood Marine Piles*. /1/

All wood products, including treated wood, must be inspected by agencies certified by the American Lumber Standards Committee (ALSC) and must be properly graded and marked before acceptance. General Navy criteria for accepting wood products are well described in NAVFAC MO-312.2, *A Field Guide for the Receipt and Inspection of Treated Wood Products by Installation Personnel.*

3-2.2 **Wood Deterioration**. Biological and physical deterioration of wood can bring about rapid destruction of waterfront facilities. Improper design and construction procedures that lead to biological deterioration include:

- Inadequate preservative treatment.
- Improper handling of treated wood.
- A design that promotes retention of water.
- A design that unnecessarily places wood timbers below water.

Major design deficiencies, which promote physical deterioration, include:

- Insufficient strength of piles resulting in overloading (loss of strength and embrittlement caused by treatment with salts and other preservatives are an important design considerations).
- Improper connection hardware or pile connections that restrict load transfer to other parts of the structure.
- Inability of sheet pile walls to retain backfill or insufficient strength in the soil foundation that results in sheet pile movement.

3-2.2.1 **Biological Deterioration**. Wood-destroying organisms infest wood structures both above and below the waterline. Marine borers are the principle cause of deterioration in the immersed zones and are found in harbors and estuaries worldwide. Marine fouling organisms found on the wood surface do not cause wood deterioration and may even serve to retard marine borer damage. Insects and fungi are the main wood-destroying organisms above the waterline.

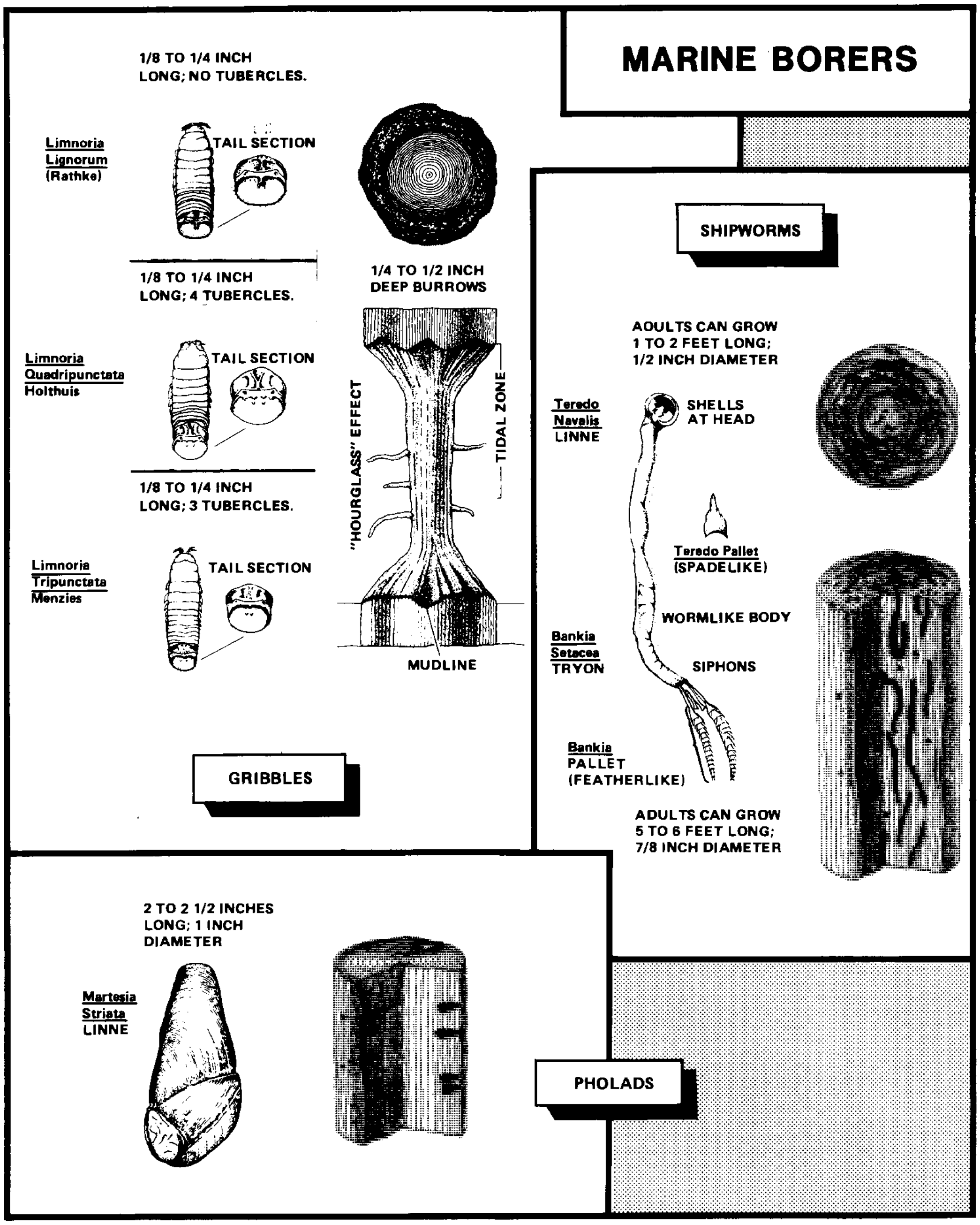
3-2.2.1.1 **Marine Borers**. There are two general types of marine borers that attack marine timbers: crustaceans and mollusks. The major wood-boring crustaceans are the Limnorians; the principle wood-destroying mollusks are the Teredines (Teredo and Bankia) and the Pholads (Martesia). See Figure 3-1.

- Crustaceans. Of the three common crustacean wood borers - Limnoria, Sphaeroma, and Chelura - Limnoria is considered to be the most economically important. These borers burrow just below the wood surface forming a network of interlacing tunnels. The weakened wood is easily eroded by wave action often resulting in a characteristic "hourglass" shape. Limnoria tripunctata is of particular importance because it can attack creosoted wood.

- Teredines. The Teredines are commonly referred to as "shipworms" because of their wormlike appearance. Penetration of the wood occurs during the microscopic larval stage. As the shipworms grow, their tunnels increase in diameter and length while the entrance holes remain about the same size. Attacked piles may appear sound on the surface, yet be completely riddled.

- Pholads. Pholads bore into wood, soft rock, or concrete for protection. These clams have pear-shaped shells that can reach 6 cm in length. Like the Teredines, Martesia can cause considerable structural damage to wood, but both of these mollusks can be more effectively controlled by creosote preservative treatment than the Limnorians.

Figure 3-1. Three groups of Marine Borers.[1]



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NOTE: Gribbles are 1/8 to ¼ inch (3mm to 6mm) in length; Shipworms are 1 to 2 feet (30 to 60 cm) in length, 1/2 inch (12.7mm) in diameter; and Pholads are 2 to 21/2 inches (51mm to 63.5mm) in length.

[1] From *Oregon State Research Bulletin 48*, October 1984.

3-2.2.1.2 **Insects**. Termites are the most destructive wood-destroying insects found on waterfront structures. Other insect pests include: wood-boring beetles, ants, and bees. An insect frequently associated with damage to piers and docks is the wharf-borer, Nacerda, a beetle about 0.32 inch (8 mm) long, yellowish-brown to dark red in color. Some insects, such as termites, require wood for food and shelter; others, such as carpenter ants, require wood for nesting only. Most wood-destroying insects thrive under damp conditions.

3-2.2.1.3 **Fungi**. Three categories of wood-decay fungi are: white rot, which tends to bleach the affected wood; brown rot, often termed "dry rot," which produces a brown, crumbling type of decay; and soft rot, which softens the wood. Slight strength reduction of infected wood can be caused by stain fungi, which produce bluish black to steel gray or brownish discoloration of the wood. Molds also produce a discoloration of the wood surface and are regarded as merely a blemish, but their presence indicates that conditions may be favorable for decay organisms. Most wood-destroying fungi require damp conditions for growth.

3-2.2.2 **Physical Deterioration**. Physical deterioration of timber piles and other wood structures is generally due to the following causes:

3-2.2.2.1 **Abrasion**. Abrasion of timber piles occurs principally in the intertidal zone. The rate at which piles are destroyed by abrasion depends on the amount of floating debris in the harbor, the velocity of water moving past the piles, ice in the harbor, and the action of marine borers. Fender piles are also abraded by camels and ships.

3-2.2.2.2 **Overload**. Overloading of piles may result from a continuous heavy load or infrequent, severe loads. Overloading may be caused by vertical and horizontal loads. Failure of one pile requires the adjacent piling to carry the extra load. Continual overloading can lead to collapse of the entire structure.

3-2.2.2.3 **Connection Failure**. When a timber pile connection fails, the structure is free to move and will eventually fail. If untreated wood is exposed, connection failure may first allow the entry of marine borers if below the waterline, or insects and fungi if above the waterline.

3-2.2.2.4 **Timber Wall Movement**. Outward wall movement can result from horizontal loading of the backfill material caused by excessive loading behind the structure or failure of tie-backs. Loss of backfill material can result in movement in the opposite direction. If either condition continues, the structure will fail.

3-2.2.2.5 **Single Timber Piles.** Single timber piles or those used in light structures may be lifted by ice freezing to the pile and pulling it as the ice moves with the tide.

3-2.3 **Preventive Maintenance for Wood and Timber.** The primary preventive maintenance (PM) measure at the waterfront is to select the type of wood best suited for the particular use and to purchase wood products and timber piles that have been treated with quality preservatives and methods. Field techniques should be used to eliminate or minimize cuts and holes made in the members at the site, particularly for those members to be placed below water. If cuts and holes must be made, special field PM preservative treatment is required. In addition, there are other PM measures applicable to timber piles using encasements and retardants. The most important field PM for the exposed wood of waterfront buildings and related structures is the application of paint and other coatings. Preventive maintenance measures discussed in this section are summarized in Table 3-1.

3-2.3.1 **Pressure Treatment**. Pressure treatment of the outer sapwood of timbers with preservatives is the most important and effective method of protecting wood. Using pressure treatment allows the preservative to uniformly penetrate deeper and allows closer control of retention levels. The preservative penetrates the wood from .39 to 3.93 inches (1 cm to 10 cm), depending on the type of wood, and provides protection from fungi, marine borers, insects and bacteria. \1\ American Wood Protection Association (AWPA) /1/ Standards govern the treatment processes that must be performed on wood used in waterfront areas. MO-312.2, *A Field Guide for the Receipt and Inspection of Treated Wood Products by Installation Personnel,* is a field guide for acceptance of treated wood products and must be consulted by Navy activities and followed whenever treated wood is used.

The choice of preservative treatment depends on how and where the wood is to be used. Wood preservatives are classified in three categories: creosote preservatives, oil-borne preservatives, and water-borne preservatives.

3-2.3.1.1 **Creosote.** Creosote preservatives have been the most commonly used preservatives at the waterfront because they are not easily leached from the wood and are not corrosive to metals. Creosote and creosote-coal tar solutions, both derived from bituminous coal, can be used for immersed wood. Creosote is commonly diluted with petroleum oil for treatment of wood not subject to immersion. An important disadvantage of creosoted piling, however, is that it is readily attacked by the marine borer, Limnoria tripunctata. In addition, creosote and creosote solutions cannot be used where it may come in contact with people or where local environmental concerns have restricted its use in the marine environment. Consult your environmental office for the latest policies and regulations regarding its use.

3-2.3.1.2 **Oil-Borne.** Oil-borne preservatives are dissolved in a petroleum solvent and include pentachlorophenol, copper naphthenate, tributyl tin oxide, and copper-8-quinolinolate. Oil-borne preservatives are suitable for wood members out of the water for protection against insects and fungi but does not provide adequate protection against marine borers and, thus, cannot be used for immersed wood. Treated wood can be painted, does not swell and distort, is easily handled, and will not corrode metal. Before the solvent evaporates, it is more flammable than untreated wood. Pentachlorophenol is the most effective of these preservatives but is also highly toxic. Consult the Consumer Information Sheet and your safety and environmental office before you consider using it.

3-2.3.1.3 **Water-Borne.** Water-borne preservatives are toxic metallic salts dissolved in water for easier application. The water-borne preservatives include chromated copper arsenate (CCA), ammoniacal copper zinc arsenate (ACZA), and ammoniacal copper arsenate (ACA). Wood treated with one of these water-borne preservatives can be used either above or below the waterline (wood used below the waterline is treated at higher retention levels). In addition, these salts in combination with creosote (dual treatment) are more effective in preventing marine borer damage than any single treatment. Other water-borne preservatives for use above the waterline include acid copper chromate (ACC), ammoniacal copper citrate (CC), and ammoniacal copper quat (ACQ)-Type B.

3-2.3.1.4 **Negative Aspects**. All preservative treatments have drawbacks that should be considered. Metallic salts, for example, will seriously embrittle wood. More importantly, these toxic chemicals present environmental and personnel safety concerns. All treated wood should be supplied with a Consumer Information Sheet that provides use, handling, and disposal precautions. Proper safety procedures should be carefully followed.

Plans for handling pressure-treated wood removed from service should be carefully considered, especially in areas where the disposal of treated wood may be restricted. Alternatives to landfilling include reuse as landscape timbers, recycled as fuel, etc. Wood treated with CCA should never be used as a fuel, and treated wood should not be recycled as mulch. Other restrictions may apply; Consult with your environmental office.

3-2.3.2 **Field Treating Exposed Areas of Wood Before Installation**. Cut surfaces of wood members, pile cutoffs, bolt holes, and any other exposed surfaces of treated wood members must be treated in the field before installation. All exposed, untreated wood should be treated in accordance with \1\ American Wood Protectors Association, Standard U1, *Use Category System: User Specification for Treated Wood* /1/. Treat holes for bolts and wood plugs inserted in piles and timbers with the same general type of wood preservative originally used for the member. Bolt holes should be treated under pressure with a mechanical bolt hole treater, if available, or thoroughly saturated. Wood preservatives are restricted use pesticides and must be applied in compliance with applicable standards. Consult your safety office or nearest EFD applied biologist.

Timber pile tops, cut off after the pile is driven, expose the untreated heartwood of the pile to rapid decay. AWPA Standard \1\ U1 /1/ provides recommendations for preservative treatments for pile tops. Creosoted piles may be field treated with creosote solutions, or where particularly heavy coatings are required, a coal-tar roof cement meeting ASTM D4022/D4022M, *Specification for Coal Tar Roof Cement, Asbestos Containing*. Piles treated with ACA, ACZA, or CCA can be field treated with any of these water-borne preservatives. After field treatment, the pile top must be covered with a cap or bonnet consisting of two layers of tar saturated fabric, tar paper, or fiberglass cloth, which shall overlap the side of the pile at least 2 inch (5 cm) and securely fastened.

3-2.3.3 **Remedial Treatment of Wood**

3-2.3.3.1 **Fumigants.** Fumigants are used to prevent or eradicate fungal decay of large (6 by 6 inch (15 by 15 cm) or greater cross-sectional area) wood members. These products may be an available option in your area for waterfront structures. They are highly toxic, restricted use pesticides, and can be handled only by certified personnel. The most widely available product currently available is applied only by the manufacturer. Generally, an inspection of the prospective treatment site and a treatment plan is carried out by the contractor prior to actual treatments. Consult your environmental and safety offices before using these products.

3-2.3.3.2 **Brush On.** Brush on preservative pastes and bandages are commonly used as a remedial groundline treatment for southern pine utility poles. They may have some application to waterfront timbers. Diffusion of the preservative ingredients into the decayed portion of the wood depends on the moisture in the wood. Typically, the level of preservative penetration and long-term efficacy of these products is less than that of fumigants.

3-2.3.3.3 **Liquid Internal.** Liquid internal treatments are sometimes used when voids and cavities are present in wood. This treatment is not generally recommended for waterfront timbers. If voids and cavities are present, replacing the wood member is advisable.

3-2.3.3.4 **Solid Rod.** Solid rod treatments commercially available today are fused borate rods available in a variety of sizes. They are relatively easy and safe to handle. Like brush on pastes and preservative bandages, diffusion of the borate in these rods depends on wood moisture and the level of preservative penetration and long-term efficacy of these products is less than that of fumigants.

3-2.3.3.5 **Encasements and Retardants.** Two methods are available to protect timber pile tops by using encasements and retardants. They include:

- Remedial Treatment with Fumigant Vials. Commercial fumigant vials are embedded in the cut top of timber piles and slowly leach into the pile to retard and prevent rot. Holes are bored in the top of the pile, vials inserted, and the holes plugged with hardwood. See Figure 3-2. A pile cap can be installed (see following bulleted paragraph) after fumigants are applied. This method is useful where the pile top is accessible and subject to wetting by rain or spray. These are restricted use pesticides; application of fumigants over water is restricted in California and other areas. Consult your environmental or safety office before using.

- Pile Top Bonnet. This method uses liquid preservative in the pile top and a protective bonnet or cap fabricated of two layers of tar saturated fabric or tar paper or fiberglass. Formation of reservoir is optional. See the Paragraph entitled, “Field Treating Exposed Areas of Wood Before Installation” for selecting a preservative. This method can be used to repair a rotted pile top, as shown in Figure 3-3, or as a preventive measure on a sound pile.

Figure 3-2. Fumigant Vials for Timber Piles

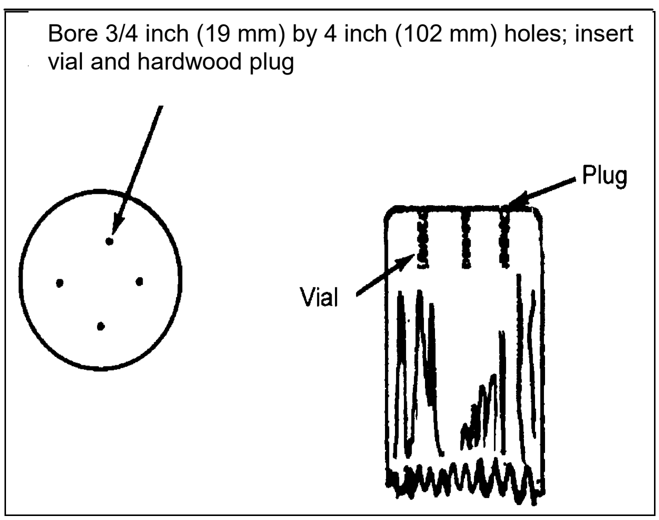
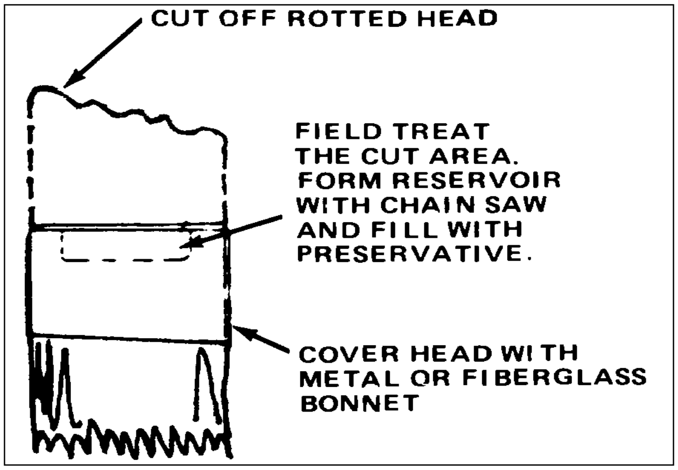


Figure 3-3. Pile Top Bonnet for Timber Piles



3-2.3.4 **Coatings for Wood Buildings.** Wooden structures continuously immersed in seawater or subject to immersion during tidal changes are not usually painted except for marking identification or location. In general, coating wood is confined to structures such as buildings located in waterfront areas to protect the wood from weathering and for appearance. Surface preparation of either previously coated wood or uncoated wood may consist of the following procedures:

- 100% removal of biological growth,
- removal of unsound coatings,
- removal of surface contamination such as oil, grease, dirt,
- light sanding of sound coatings and exposed wood.

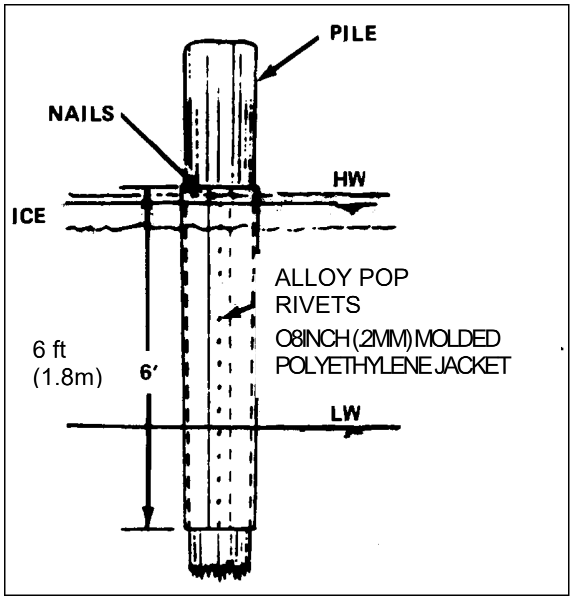
Two coating systems may be used for either previously coated wood or uncoated wood as follows:

- 40% volume solids, exterior latex (water-based): 1 or 2 coats at 1.97 to 5.9 mils (0.05 to 0.15 mm) dry film thickness (DFT)
- 55% volume solids, flexible acrylic waterborne (water-based): 1 or 2 coats at 3.94 to 11.81 mils (0.1 to 0.3 mm) DFT.

3-2.3.5. **Protection of Timber Piles.** All timber piling in the marine environment, including piling properly treated, are eventually attacked by wood destroying organisms. Pilings are also commonly subjected to ice lift and abrasion. As a result, protection with plastic wraps is often required, in order to minimize the impact of these environmental factors. In tropical environments, such as Roosevelt Roads, Puerto Rico, even dual-treated pilling should be wrapped.

The use of plastic wrapping to protect piling against marine borer damage, at and below the waterline, does offer considerable economic benefit by effectively eliminating borer damage, reducing future repair costs. The polyvinyl chloride (PVC) or polyethylene wrapping smothers borers already in the wood and prevents the entry of more borers. Installation of barrier wraps are described in repair technique TR-3 in Chapter 6. Fender piles pre-wrapped with a thick, heat-shrink polyethylene provides a slippery surface that prevents exposure of untreated wood due to wear from camels. An example of a molded polyethylene jacket used for ice protection is shown in Figure 3-4.

Figure 3-4. Timber Pile Jacket for Ice Protection



3-3 **CONCRETE**. Reinforced concrete is the predominant construction material for waterfront facilities due to its durability, strength, and economy as a bulk construction material. Steel and wood do not have the bulk properties and adaptability of concrete. In addition, basic components to make reinforced concrete are readily available at most locations. Applications of reinforced concrete at the waterfront include:

- Seawalls, bulkheads (quaywalls), and revetments use reinforced concrete as the dominant material of construction. It is used as the facing material to absorb wave impact, retain fill, and reduce the erosive effects of wave action. Concrete is used in piles, curved-faces, sheet piling, and other forms.

- Piers and wharves are usually built with reinforced concrete. Concrete is also used to protect wood or steel from corrosion, weathering, fungal decay, or marine organism attack. Prestressed concrete fender piles are effective and long lasting.

- Groins are built from concrete sheet piles and panels. The piles or panels are usually prestressed units and are tied in place with a concrete cap.

- Breakwaters use various shapes of precast concrete. These interlocking building blocks can be assembled in various shapes.

- Submerged structures use reinforced concrete that are cast in place or precast and used to support pilings and structures.

- Floating structures use reinforced concrete for pontoons, quays, wharves, piers, and facilities for small boats.

- Drydocks are made of reinforced concrete.

3-3.1 **Deterioration.** Deterioration of reinforced concrete near or in seawater is due to corrosion of the reinforcement. This corrosion can be accelerated due to improper concrete mix, insufficient concrete cover (thickness of concrete over the reinforcing steel), improper curing, operational loads, chemical attack, and volume changes. Using well established mix designs and construction practices, however, will enhance reinforced concrete durability.

Reinforced concrete in waterfront facilities must meet the criteria set by the American Concrete Institute (ACI) Standard 318, *Building Code Requirements for \1\ Structural /1/ Concrete*. This standard covers the building code requirements for concrete with and without reinforcing. Additional design information, with emphasis on waterfront facilities, is included in \1\ UFC 4-151-10, *General Criteria for Waterfront Construction*. /1/ These manuals provide general design and application data for a variety of waterfront structures. Unified Facilities Guide Specification UFGS 03 31 29, *Marine Concrete*, provides guidance for cast-in-place concrete subject to exposure to the marine environment. Unified Facilities Guide Specifications \1\ UFGS 31 62 13.13, *Cast-in-Place Concrete Piles*, UFGS 35 59 13.13, *Prestressed Concrete Fender Piling*, and UFGS 31 62 13.20, *Precast/Prestressed Concrete Piles*, provide guidelines on concrete piling. /1/

3-3.2 **Components of Concrete**. Concrete is a mixture of Portland cement, coarse and fine aggregate, and water. Various admixtures, and pozzolans may be used to improve the strength, workability, and service life. Preparation and proportioning of concrete mixtures should follow the recommendations of the Portland Cement Association's, *Principles of Quality Concrete*, and ACI 211, *Recommended Practice for Selecting Proportions for Concrete*.

3-3.2.1 **Cement**. Five types of Portland cement are described in \1\ ASTM C150 / C150M, Standard Specification for Portland Cement /1/. For concrete structures exposed to seawater, Types II and V should be used. Type II is a sulfate-resisting cement. Type V, however, is no longer being produced. Low alkali cements should be used with potentially reactive aggregates.

Do not use any product containing sodium or calcium, as it will likely accelerate the onset of rebar corrosion.

3-3.2.2 **Aggregates**. Aggregates are used in concrete mixtures to improve durability and reduce costs. They usually make up 60 to 80 percent of the volume of the concrete. The shape and size of the aggregate should meet the requirements specified in ASTM C330/C330M. Aggregates are a mixture of sand and rock. Marine aggregates, such as coral, should not be used. However, if marine aggregate is the only available material, it must be washed thoroughly with freshwater to remove the salt.

In some applications, special aggregates may be used to make lightweight concrete for lightweight structures. Most lightweight concretes have a density between 79.9 and 109.87 pounds/cubic foot (1,280 and 1,760 kg/m^3) compared to 149.83 pounds/cubic foot (2,400 kg/m^3) for normal weight concrete. Lightweight aggregate concrete is generally more durable in the marine environment than concrete made with normal weight aggregate.

3-3.2.3 **Water**. Water quantity and quality will affect the durability, strength, and workability of concrete. In practice, use water equal in quality to drinking water. The ratio of water to cement has a direct effect on the strength of the concrete and its permeability. A maximum water-to-cement ratio of 0.40 by weight is crucial for concrete used in a marine environment. Seawater should never be used for making concrete because the salts will dramatically increase the corrosion rate of reinforcing steel.

3-3.2.4 **Admixtures**. Various chemical admixtures are used to give specific properties to the concrete to improve durability, finishability or workability. If admixtures are required, they should meet the appropriate ASTM or ACI specifications.

3-3.2.4.1 **Water Reducing.** Water-reducing admixtures are available to allow a reduction in the water-to-cement ratio while maintaining a workable slump. Normal range water reducers and superplasticizers are admixtures that permit the reduction of the water-to-cement ratio.

3-3.2.4.2 **Air-Entraining.** Air-entraining admixtures are available to improve the concrete's ability to resist freeze-thaw conditions and enhance workability. Air-entraining agents should be used to incorporate from 5 to 7 percent of entrained air into the concrete. \1\ ASTM C233 / C233M, Test Method for Air Entraining Admixtures for Concrete /1/, covers the air-entraining agents. Air-entraining agents also improve the workability of the concrete.

3-3.2.4.3 **Accelerator.** Accelerator admixtures are available for rapid setting products. These increase the early strength of concrete but have little effect on the final strength. Accelerators containing excessive chloride should not be used since they increase corrosion of reinforcing steel.

3-3.2.4.4 **Pozzolan Minerals.** Pozzolan minerals (fly ash Class F) are highly recommended as a replacement of 25% of the Portland cement. The ash reduces permeability, eliminates alkali-silicon reactions, and improves workability. Silica fume can reduce permeability but may cause finishing problems and surface cracks. Avoid silica fume dosages about 5% by weight to concrete.

3-3.3 **Reinforcing Steel**. Reinforcing steel for concrete in waterfront facilities is the same as for conventional concrete structures and should conform to ASTM A615,*Specification for Deformed and Plain \1\ Carbon-Steel /1/ Bars for Concrete Reinforcement* \1\ or ASTM A996/A996M, *Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement* /1/. Place 3.15 inch (8 cm) concrete cover, which is critical for durability, over the plain steel. \1\ /1/

3-3.4 **Special Types of Concrete Mixtures**. Special concrete mixtures include polymer concrete and polymer-Portland cement concrete. Concrete mixtures containing polymers are useful for repairing concrete and may provide improvements over conventional concrete mixtures when used and applied correctly.

3-3.4.1 **Polymer .** Polymer concrete does not contain Portland cement. Epoxy concrete is one common type of polymer concrete that is readily available and possesses excellent bond and tensile strength qualities. Use extreme caution when using polymer concretes for structures subject to thermal resistance due to a high coefficient of thermal expansion that often results in repair failure.

3-3.4.2 **Fiber Reinforced.** Fiber reinforcements may improve the tensile strength, toughness, and ductility of concrete. In general, steel fibers should not be used in the marine environment. Polypropylene fibers avoid the corrosion problem of steel fibers and improve impact resistance. Fiber should not be considered as a replacement for the reinforcement.

3-3.5 **Causes of Concrete Deterioration**. Cracking and spalling of concrete are the results of chemical attack and rebar corrosion.

3-3.5.1 **Chemical Attack**. The most common chemical attack is from sulfates in seawater that cause a softening of cement paste. Other causes of chemical attack are poor quality aggregates reacting with alkali in the cement (alkali-aggregate reaction). The alkali-aggregate reaction expands the aggregate and results in cracking throughout the concrete in the presence of moisture. Use of 25% Class F fly ash is extremely effective in reducing chemical attack.

3-3.5.2 **Corrosion of Reinforcing Steel**. The high alkalinity of cement paste protects steel from corrosion. With improper mix designs, chloride contamination and carbonation eventually reduce the alkali film around the steel. Corrosion will then occur if sufficient moisture and oxygen are present. In the splash zone, the wet and dry cycles provide conditions for the chloride and oxygen to corrode the steel. Accordingly, steel corrosion in concrete is most severe directly above the mean low water (MLW).

When steel corrodes, the rust product increases in volume many times over its original volume. Expansion of the rust causes cracking of the concrete. These cracks run parallel to the reinforcement. Eventually, concrete covering the reinforcing steel spalls off.

3-3.5.3 **Cracking of Concrete**. As concrete dries it shrinks, which in turn, can cause cracks. These cracks may increase in size as the internal water is lost over time and the concrete cannot contract freely. Temperature changes can also cause cracking. In addition, freezing water in the concrete can lead to deterioration, cracking, and spalling. Overload conditions can cause cracks. Waterfront structures are subject to settlement conditions. When settlement is uneven, cracks usually result.

Shrinkage cracking can be minimized by proper curing and using a minimum amount of cement and water in the mix. Temperature cracking can be controlled in concrete by using expansion joints and temperature reinforcement. Air entrainment is critical to minimize freeze-thaw damage.

Prevention and control of cracking may be improved by proper design of the concrete structure and measures taken during construction. The measures that must be taken during repair of concrete structures are discussed in Chapter 7.

3-3.6 **Preventive Maintenance for Concrete**. Measures to minimize deterioration of reinforced concrete must be taken during design of the structure and during construction. Proper design for concrete is contained in ACI standards and service design manuals.

The main objectives of preventive maintenance are to:

- Keep water out of the concrete.
- Protect the reinforcing steel.
- Prevent and control cracking.
- Prevent chemical actions.

The primary PM measure that should be considered for existing reinforced concrete structures is the application of a surface coating. Coatings should be reapplied periodically to concrete that was coated when new. This measure can be applied to old concrete but rebar corrosion, the principal cause of concrete deterioration and the reason these PM measure are applied, will not likely be inhibited.

The treatment of cracks, described briefly in this Chapter, is best considered as a repair technique and is presented in detail in Chapter 7.

3-3.6.1 **Surface Coatings for Concrete Waterfront Structures**. Sound concrete piles and other waterfront concrete structures are generally left uncoated and provide years of excellent service. Existing concrete structures, above the splash zone, however, may be successfully coated for aesthetics, for marking purposes, and for protection against wind driven rain and sand, and salt spray. The application of a coating over a penetrating sealer is not recommended because the sealer reduces the bond strength of the coating to the concrete.

It is both difficult and labor intensive to coat immersed concrete and concrete in the splash zone. These areas require using either cofferdams or divers to apply "splash zone mastics," high performance coatings that cure underwater, and other specialty coatings. The benefit of applying these coatings, however, may not warrant the high cost.

3-3.6.2 **Coatings for Deck Marking**. For use in identifying walkways and traffic lines, the following marking paints may be applied to clean/dry concrete decks.

- 54% volume solids, solvent-based, chlorinated rubber: 1 coat at 7.87 to 9.84 mils (0.2 to 0.25 mm) DFT
- 50% volume solids, solvent-based alkyd: 1 coat at 7.87 to 9.84 mils (0.2 to 0.25mm) DFT
- 60% volume solids, waterborne acrylic (water-based): 1 coat at 7.87 to 9.84 mils (0.2 to 0.25mm) DFT

3-3.6.3 **Other Coatings**. Concrete buildings above the splash zone may be coated for aesthetics and protection against wind driven rain. Surface preparation of concrete surfaces may consist of the following sequential procedures:

- 100% removal of biological growth
- removal of unsound coatings
- removal of surface contamination such as oil, grease, dirt, and efflorescence
- removal of weak surface cement (laitance)
- removal of surface chloride contamination
- brush-off blasting of sound coatings
- light abrasive blasting of uncoated concrete

The below acrylic system may be used as an overcoat for sound coating systems whereas all three systems are acceptable for use on uncoated concrete.

- 55% volume solids, flexible acrylic waterborne (water-based): 1 to 2 coats at 3.94 to 15.75 mils (0.1 to 0.4 mm) DFT

- Two-component, epoxy polyamide primer followed by two coats of a flexible acrylic topcoat: 3 coats at 19.67 mils (0.5 mm) total DFT (5.9 mils (0.15 mm) primer, 7.87 mils (0.2 mm) topcoat

- Two-component, epoxy polyamide primer followed by two coats of a two-component, aliphatic urethane topcoat: 3 coats at 9.84 mils (0.25 mm) total DFT (5.9 mils (0.15 mm) primer, 3.94 mils (0.1 mm) topcoat, 3.94 mils (0.1 mm) topcoat)

3-3.6.4 **Treatment of Cracks**. Cracks in concrete are typically caused by shrinkage during curing, thermal expansion and contraction, rebar corrosion, operational loading, or structure settlement. Cracks are routed out and repaired using a flexible elastomer over bond-breaker tape. Hairline cracks may be repaired by pressure injecting polyurethane or methyl methacrylate through injection ports. Chapter 7 provides details of materials and procedures to use to repair both static and dynamic cracks in concrete.

3-4 **STEEL**. Steel is used extensively in construction and repair of water-front facilities due to availability, cost, ease of fabrication, physical and mechanical properties, and design experience. Structural steel and cast or fabricated steel are used in all areas of the waterfront. Typical applications include:

- Piers and wharves use steel H-piles or pipe piles to support or brace the structure. Structural steel shapes are used for framing.

- Bulkheads and quaywalls use interlocking steel sheet piling with tie rods and wales. Steel sheet piling is used to retain fill.

- Fender systems incorporate steel H-piles.

- Mooring hardware such as cleats, bollards, bitts, and chocks are made from cast or fabricated steel.

- Other items such as utility lines, grating, opening frames, manhole covers, fences, bolts and nuts, handrails, and concrete reinforcement are made of steel.

- Steel components are used in some camels.

Maintenance of steel structures and components will entail repair or replacement of damaged or corroded steel, periodic coating of steel surfaces for corrosion protection, and maintenance of cathodic protection systems. Although physical damage from impact or loading may occur, corrosion is the major cause of the deterioration of steel structures. The extent or severity of corrosion will vary with the exposure zone of the material; that is, whether it is in the atmospheric zone, the splash or tidal zone, or the submerged zone. The selection of materials for waterfront use must consider each of these varied conditions. \1\ Additionally, instances of failure of steel structures, i.e. sheet pile bulkheads with interior wales resulting from galvanic incompatibility have occurred. Consult NFESC metallurgist for proper selection of materials. /1/

The use of steel should follow design guidelines in \1\ UFC 4-151-10, *General Criteria for Waterfront Construction*; UFC 3-301-01, *Structural Engineering*, /1/ and the American Institute of Steel Construction's *Manual of Steel Construction*. The material specifications of ASTM and other organizations document chemical and physical characteristics of the various types of steel. Material selection and procurement should conform to these specifications.

3-4.1 **Steel for Waterfront Construction**. Carbon steel and carbon steel alloys are the most important types of metals used for construction of waterfront facilities. In general, only low carbon steels with a carbon content less than 0.35 percent by weight are used due to welding characteristics.

3-4.1.1 **Carbon Steel**. Carbon steel is an alloy of iron and carbon with a carbon content less than 2 percent. The requirements for structural carbon steel are contained in ASTM A36/A36M and this grade is suitable for welding.

Carbon steel will corrode in all exposure zones, but the most severe corrosion occurs in the splash zone and just below MLW. Coatings and cathodic protection are necessary to prevent excessive corrosion of steel in the waterfront environment. Coatings are covered in the Paragraph entitled, "Protective Coatings for Steel". Cathodic protection is covered in the Paragraph entitled "Cathodic Protection of Steel".

3-4.1.2 **Low-Alloy Carbon Steels**. Corrosion resistant, low-alloy carbon steel may be used instead of carbon steel if greater corrosion resistance is required. Low-alloy carbon steels contain small amounts of other elements such as copper, chromium, nickel, molybdenum, silicon, and manganese. Up to 1.5 percent of these elements is added for increased strength or heat treatment capability. These alloys have a better resistance to corrosion because the rust does not easily break away from the metal surface.

The common low-alloy steels include:

- ASTM A690/A690M, \1\ Specification for High-Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments /1/, (also called "Mariner steel").

- ASTM A572/A572M, *Specification for High-Strength, Low-Alloy Columbium-Vanadium \1\ Structural Steel /1/*.

- ASTM A242/A242M, *Specification for High-Strength, Low-Alloy Structural Steel*.

Steel conforming to ASTM A690/A690M is recommended for steel H-piles and sheet piling, because of its greater corrosion resistance over plain carbon steel in the splash zone. The low-alloy steels offer no more resistance to corrosion than ordinary carbon steel, however, when submerged. Under this condition, the low-alloy steels require coatings or cathodic protection, or both. Composite piles of ASTM A690/A690M and ASTM A36/A36M, *Specification for \1\ Carbon /1/ Structural Steel* may be used when more resistance in the splash zone is required. ASTM A242/A242M steels are not recommended for buried structures, submerged conditions, and marine atmospheres unless they are exposed to the wind, rain, and sun.

Coatings for, and cathodic protection of, low-alloy steels are the same as for plain carbon steel as discussed in the Paragraph entitled, “Preventive maintenance for Steel”.

3-4.1.3 **Stainless Steels**. Stainless steels have application in the marine environment under certain conditions. They do well when exposed to wind, rain, sun, or high-velocity conditions in seawater. In calm or stagnant waters, salt spray zones, or in buried conditions, corrosion is likely to occur. Stainless steels in the 300 series (302, 304, 316) are substantially more corrosion resistant than the 400 series stainless steels. Except in certain atmospheric environments, stainless steels should only be used for specialized applications where performance experience has been superior to more commonly used materials to justify the high cost.

3-4.2 **Deterioration of Steel**. Although exposure to the atmosphere, severe temperature changes, and wind erosion all contribute to the deterioration of steel in waterfront facilities, exposure to saltwater is the major concern. Corrosion rates of metals exposed to seawater are much higher than those of similar metals exposed to freshwater.

Biological fouling, the growth of marine organisms on the steel, also contributes to increased corrosion. This type of fouling can be decreased by using antifouling coatings.

The other major causes of deterioration are: wave and current effects, abrasion from objects, and elements in the seawater.

3-4.3 **Preventive Maintenance for Steel**. The primary preventive measures available to increase the life of steel are protective coatings and cathodic protection. The decision of which approach to use is a function of location on the waterfront structure (submerged or not) and economics. The use of cathodic protection is restricted to submerged or buried structures.

3-4.3.1 **Protective Coatings for Steel**. Steel in a marine environment will corrode freely if left unprotected and without a coating system. Coating systems are designed according to three marine zones:

- constantly submerged
- intertidal and splash zone
- above the splash zone

Steel in the submerged zone is best protected through a combination of a coating system and cathodic protection. Maintenance coating systems are employed as follows:

- Overcoats on sound coatings
- Repairs to coating systems with spot failing
- Complete reapplication where coating systems have failed

Surface preparation of previously coated steel may consist of the following sequential procedures:

- 100% removal of biological growth
- removal of unsound coatings and rust
- removal of surface contamination such as oil, grease, dirt
- removal of surface chloride contamination
- brush-off blasting of sound coatings
- abrasive blasting of uncoated steel to produce an angular anchor profile between 2 to 3 mils (0.05 to 0.08 mm)

3-4.3.2 **Coating Systems.** The below coating systems have displayed high performance and may be used for either spot repairs or complete reapplication. It is recommended that a coating specialist be contacted prior to specifying one of the below coating systems for overcoating sound coatings. DOD and other Federal activities may wish to contact an NFESC coating specialist.

3-4.3.2.1 **Submerged**

- Underwater cure, two-component, 100% solid liquid epoxy: 1 to 2 coats at 7.87 to 11.81 mils (0.2 to 0.3 mm) DFT
- Underwater cure, two-component, 100% solid epoxy putty: 1 coat at 118.1 to 236.22 mils (3 to 6 mm) DFT

3-4.3.2.2 **Intertidal/Splash Zone**

- Two-component, coal tar epoxy: 1 to 2 coats at 7.387 to 15.75 mils (0.2 to 0.4 mm) DFT
- Single-component, coal tar urethane: 1 to 2 coats at 3.94 to 11.81 mils (0.1 to 0.3 mm) DFT
- Three-component, aggregate-filled epoxy: 1 coat at 118.1 to 236.22 mils (3 to 6 mm) DFT
- Additional systems are presented in \1\ UFGS 09 97 13.26, *Coating of Steel Waterfront Structures. /1/*

3-4.3.2.3 **Above Splash Zone**

- Two-component epoxy polyamide primer followed by two coats of a two-component, aliphatic urethane topcoat: 3 coats at 9.84 mils (0.25 mm) DFT (5.9 mils (0.15 mm) primer, 3.94 mils (0.1 mm) topcoat, 3.94 mils (0.1 mm) topcoat)
- Single-component, zinc-rich urethane primer followed by two coats of a single-component, aliphatic urethane topcoat: 3 coats at 7.87 mils (0.2 mm) DFT (3.94 mils (0.1mm) primer, 3.94 mils (0.1 mm) topcoat, 3.94 mils (0.1 mm) topcoat)
- Two-component epoxy polyamide primer followed by two coats of a flexible acrylic topcoat: 3 coats at 19.67 mils (0.5 mm) DFT 5.9 mils (0.15 mm) primer, 7.87 mils (0.2 mm) topcoat, 7.87 mils (0.2 mm) topcoat)

3-4.3.3 **Cathodic Protection of Steel**. The natural corrosion of steel structures immersed in water or buried in soil can effectively be controlled by using anodes and direct current systems to minimize or stop the corrosion process, by establishing the steel as a cathode. Cathodic protection systems are best installed when the structure is constructed, but can be added to existing structures. They can effectively stop corrosion but cannot restore the material already lost by corrosion. Design and maintenance of cathodic protection systems can be found in \1\ UFC 3-570-02N, *Electrical Engineering Cathodic Protection*. /1/

3-4.3.3.1 **Galvanic Anode.** Galvanic anode cathodic protection systems rely on the corrosion of active metals such as zinc, magnesium or aluminum to generate the electrical current needed to protect buried or submerged steel structures. Since these anodes are sacrificed to protect the structure, they are known as sacrificial anodes. The anodes must be buried or submerged near the structure to be protected and electrically connected to it with a low resistance bond. As the anodes are consumed, they must be periodically monitored and replaced when over 80 percent of the metal is consumed, or when they will be consumed before the next scheduled inspection. The level of protection provided can be determined by measuring the potential of the structure being protected by comparison with a standard reference electrode.

3-4.3.3.2 **Impressed Current.** Impressed current cathodic protection systems use an external source of electrical alternating current, and a rectifier, to provide the protective direct current to be impressed across the system. This system also requires anodes buried or submerged in the vicinity of the structure being protected, but these anodes can last much longer than galvanic anodes, since they only conduct the protective current into the water or soil and are not the source of the current. Impressed current cathodic protection systems also require periodic inspection and maintenance to ensure effectiveness in controlling corrosion.

3-5 **NONFERROUS METALS AND ALLOYS.** A variety of materials are available that, if used properly, are more resistant to corrosion by seawater and marine atmosphere than steel. These materials are used for specialized applications and are not used as much as steel due to higher costs. The common nonferrous metals are aluminum, copper, nickel, titanium, and alloys of each.

3-5.1 **Aluminum**. Many alloys of aluminum are available for applications requiring high corrosion resistance to the marine atmosphere as well as good strength-to-weight ratios. The common uses of aluminum at the waterfront include: Brows and platforms, decking and catwalks, and light poles and bases.

Aluminum should not be used as a substitute for steel solely for its corrosion resistance quality. Aluminum and its alloys are subject to pitting and crevice corrosion in marine environments, especially in submerged conditions. If pitting can be tolerated and crevices eliminated, aluminum alloys may be used successfully where low weight and other unique properties are required.

ASTM specifications define compositions and mechanical properties of aluminum alloys. Alloys 5083, 5086, 5052 and 6061 are the most popular alloys for structures exposed to the marine atmosphere.

3-5.2 **Copper**. Copper and copper alloys are suitable for waterfront use because of their uniform, low corrosion rate. Copper is used for electrical conductors, pipe, sheathing, and many hidden uses on supporting equipment at the waterfront. The copper alloys usually selected for marine corrosion resistance are: copper, cupro-nickel 90-10, cupro-nickel 70-30, arsenical admiralty brass, and most true (zincless) bronzes. These alloys form films of corrosion products that provide protection even in flowing water.

3-5.3 **Nickel**. Nickel base alloys have good corrosion resistance to seawater and to cavitation damage. These materials are used for specialized applications in springs, cable connectors, expansion joints, rupture disks, valves, fasteners, heat exchangers, and piping. The high cost of these materials makes them unsuitable for bulk construction at the waterfront.

The most common nickel alloys used are: Inconel Alloy 625 (nickel-chrome alloy), Hastelloy Alloy "C" (nickel-chrome-molybdenum alloy), and Monel 400 (nickel-copper alloy). Inconel and Hastelloy "C" are essentially immune to corrosion in marine environments. Monel 400 has good corrosion resistance when it has been cathodically protected with a more active metal. If not protected, Monel will develop pitting and crevices.

3-5.4 **Deterioration of Nonferrous Metals and Alloys**. Nonferrous metals and alloys will corrode and develop pits and crevices under normal atmospheric conditions. In general, these metals are not given preservative coatings, but may be painted for color/appearance in certain uses. Corrosion rates can be greatly accelerated when two or more dissimilar metals are in contact with each other and exposed to a corrosive environment. Particularly when they are buried or submerged, accelerated corrosion of one of the metals can occur due to an electrochemical reaction called galvanic corrosion. Galvanic corrosion rates depend on the metals' electrical properties and the medium in which the metals are exposed. Galvanic series tables have been developed indicating lists of metals in order of decreasing corrodibility when exposed to a certain solution or medium. Generally, the closer one metal is to another in the galvanic series, the lower the corrosion rate with the more active metal, and conversely, the further apart, the greater will be the corrosion rate of this metal.

3-5.5 **Preventive Maintenance for Nonferrous Metals and Alloys**. PM measures depend on whether or not dissimilar materials are involved:

- Similar Nonferrous Metals and Alloys. The only formal PM measure is regular and careful inspection to determine the condition of the component. In the later part of a component’s life expectancy, it may prove economical to coat the metal to prevent further corrosion rather than to replace the component.

- Avoiding Galvanic Corrosion. Galvanic corrosion can effectively be eliminated by making the structure out of as much of the same metal as possible, placing a protective insulator between the two dissimilar metals, and by providing cathodic protection if buried or immersed. When galvanic corrosion cannot be effectively eliminated, it can be reduced by using appropriate protective coatings on the steel, ensuring not to coat the anodes. Detailed information on treatments of galvanic corrosion is given in MIL-STD-889B, *Dissimilar Metals* for metal exposed to the saltwater environment.

If dissimilar metals must be joined, the following preventive measures should be taken:

- Choose metals close together in the galvanic series.
- Keep the cathodic area small in relation to the anode area; for instance, bolts or screws of stainless steel for fastening aluminum sheets, but not the reverse.
- Provide a protective insulator between the two metals.
- Use special coatings on the metals.

3-6 **SYNTHETIC MATERIALS**. Numerous synthetic materials are used in waterfront facilities and components. They are extremely versatile in application and serve as a structural material, coating material, or buoyancy material. In general, these materials do not corrode in the marine environment, but deteriorate due to other reasons, such as water absorption and swelling and degradation by ultraviolet light. The common synthetic materials include:

- Fiber-reinforced plastics (FRP)
- Foams, rubbers, and elastomers
- Plastic pile wraps and piping
- Synthetic fibers
- Adhesives

Deterioration of these synthetics, other than physical damage, increases with aging; plastics crack or separate, some become brittle; foams crumble with age and lose resiliency; and elastomers stretch and deteriorate from the effects of sun and exposure. In general, no preventive maintenance measures are performed other than inspection. Certain materials and components can be economically repaired when damaged.

3-6.1 **Fiber-reinforced Plastics (FRP).** FRP are used for applications requiring high strength-to-weight ratios and resistance to deterioration, such as:

- Pile jackets for steel, concrete, and timber piling to reduce corrosion or erosion; for reinforcement; and to prevent marine borer attack.

- Lightweight, sandwich construction for small buildings and containers.

- Floating structures, such as buoys and landing floats, when used in combination with closed-cell foams.

- Deck hardware such as lighting posts, grating, utility line hangars, and handrails on piers.

- Filament wound piping for lightweight, low temperature pipelines transporting steam condensate, seawater, freshwater, sewage, oil, and potable water.

Carbon fiber sheets, strips, and rods are used to upgrade existing pier decks. The sheets and strips can be used by bonding them to the underside of the deck and the rods embedded into the top deck for negative reinforcement. These techniques can increase the shear capacity of the deck to permit greater loads. For more information see Chapter 7 on concrete.

FRP are a composite of resin and fibrous material. The common resins are polyester and epoxy. Polyester resins are general purpose resins that cost less than epoxy. Epoxy resins have superior strength properties, greater resistance to chemical and water degradation, and lower shrinkage during curing.

Materials used as reinforcement for FRP include: continuous strands, woven cloth, chopped fibers, and in some cases, glass flakes.

3-6.2 **Plastic and Fiberglass Piles**. Piles made primarily of plastic or fiberglass are being used as replacements for timber fender piles. Among the plastic piles are recycled plastic piles of which there are two basic types. One type uses a steel pipe core encapsulated in a mixture of high density and low density polyethylene. The second uses either steel or fiberglass rebar as the reinforcement in high-density polyethylene (HDPE). Early versions of the plastic piles had problems associated with cracking of the outer skin. Later editions of the plastic piles have had fewer cracking problems attributed to them. In addition to the plastic piles, there are fiberglass piles that consist of a fiberglass tube, which can be filled with concrete for increased strength. The fiberglass piles have performed extremely well as fender piles.

In general, the fiberglass tube type piles that are filled with concrete provide more stiffness than the plastic piles. However, the fiberglass piles are vulnerable to abrasion. High- density polyethylene or ultra high molecular weight polyethylene (UHMW) should be used as a rub strip on the fiberglass fender piles. Both the plastic and composite fender piles have been employed successfully at many Navy piers. Most of the plastic and composite piles have been used as part of the secondary fendering system. It is recommended that the plastic and composite piles not be used as the primary fendering system at this time. Furthermore, the plastic and composite piles are not recommended for use as bearing piles. Currently, there are no ASTM or other industry standards for these piles, but they are being developed.

3-6.3 **Foams.** Foams are used at the waterfront as filler material for sandwich construction, to provide buoyancy for buoys; landing floats; and floating brows, and in foam-filled fenders to absorb the energy of berthing ships. Foams are resistant to deterioration in the marine environment if encased in an impermeable, durable material.

The common foams are polyurethane, polystyrene, polyethylene, and foams formed of ionomer resins. Polyurethane foams can be foamed on-site. However, before the foam hardens it is unstable in direct sunlight and is flammable.

Polystyrene foams are relatively inexpensive compared to polyurethane. They can be purchased in large quantities and cut to shape. Polystyrene foams are used in decks for buoyancy of small boat moorings in marinas.

Closed cell cross-linked polyethylene foams are used in foam-filled fenders. The foam, encased in an elastomer cover, absorbs the impact energy of berthing ships. Ionomer foams have been used in buoys and fenders. The outer skin of the products is a denser version of the low-density encased foam.

3-6.4 **Rubber and Elastomers**. Numerous natural and synthetic rubbers and elastomers are used at the waterfront in hose lines, gaskets, fender system components, and other specialized applications. These materials are resistant to the marine environment provided the appropriate rubber or elastomer is used. The more common material is a urethane elastomer as used for the shell of foam-filled fenders. The elastomer ethylene propylene dimonomer (EPDM) is used in arch-type rubber fenders.

3-6.5 **Other Synthetic Materials**. Synthetic materials are also used at the waterfront for pile wraps, piping, and as adhesives. Pile wraps are made of flexible polyvinyl chloride (PVC) or polyethylene (PE) films and prevent growth of wood boring organisms. PVC piping is widely used for numerous applications, as it is lightweight and corrosion resistant. Some degradation of the piping will occur if exposed to sunlight and other weathering factors. Normally, PVC pipe becomes brittle as it ages.

Adhesives, coatings, and putties made from epoxy have been developed for bonding to damp and underwater surfaces. They are used to bond structures or components, connections, joints, and other metal configurations susceptible to corrosion; to fill voids; and to protect surfaces. They can also be used to patch holes above the water or underwater.

3-7 **SOIL FILL FOR QUAYWALLS AND MOLES**. Soil is the most common backfill material behind quaywalls, shoreline walls, and solid fill/mole piers; dikes; and levees. Refer to \1\ UFC 3-220-10N, , *Soil Mechanics*, and UFC 3-220-01N, *Geotechnical Engineering Procedures for Foundation Design of Buildings and Structures* /1/ for further information on geotechnical issues.

3.7.1 **Description**. A complete description of a soil includes classification, density, shear strength, moisture content, and mineralogic content. For soils used in waterfront structures, it is often sufficient to classify them according to size (clay, silt, sand, and gravel.) The density, plasticity, and moisture content are important for the finer-grained soils, while soundness and gradation are applicable to the coarser-grained soils and rock fills.

The particle size, which marks the boundary between the fine-grained, generally cohesive soils (silts and clays) and the coarse-grained, granular soils (sands and gravels), is approximately the minimum size retained on the No. 200 standard sieve. Organic soils, such as elastic silts and peats, are never used in the construction or repair of engineering structures.

Maintenance problems increase as the grain size of the soil gets smaller. Finer-grained soils in the cohesionless range are extremely susceptible to leaching and erosion, whereas fine-grained cohesive soils are difficult to compact satisfactorily and may undergo undesirable shrinkage or swelling.

With granular soils, gradation is important. Uniformly graded soils with a narrow range of particle sizes are difficult to compact, are extremely porous, and have lower densities and strengths than soils with a broader distribution of particle sizes. However, where compaction of sands and gravels is involved, large, oversize cobbles can interfere with the compaction of the finer materials present. Such large particles should be removed from the compacted fills and used as riprap or slope protection.

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CHAPTER 4

SAFETY AND ENVIRONMENTAL COMPLIANCE

4-1 **INTRODUCTION**. Diverse types of work are performed at the waterfront during maintenance and repair of facilities. Much of this work contains elements hazardous to personnel, equipment, and property, as well as to the environment. The purpose of this chapter is to familiarize the reader with the areas of safety and environment that must be addressed during the planning and execution of waterfront maintenance or repair projects.

This section is divided into two topics: Occupational Safety and Environmental Compliance. Responsibility for safety and environmental compliance lies with each individual during each phase of a maintenance and repair project. However, all safety and environmental issues must be considered during the planning stage and be adequately relayed to the work site employees through training and consultation by the appropriate work supervisor.

There are many references to safety and environmental compliance that can be applied to waterfront construction and operations. Several primary military references are:

- OPNAVINST 5100.23, *Navy Occupational Safety and Health Program Manual*, U. S. Department of the Navy Instruction.
- OPNAVINST 5090.1, *Environmental and Natural Resources Program Manual*, U. S. Department of the Navy Instruction.
- COE EM 385-1-1, *Safety and Health Requirements Manual*, U.S. Army Corps of Engineers Manual.
- AFPD 91-3, *Occupational Safety and Health*, U. S. Department of the Air Force Publications Document.
- 29 CFR 1910, *Occupational Safety and Health Standards for General Industry*
- 20 CFR 1915, *Occupational Safety and Health Standards for Shipyard Employment*
- 29 CFR 1917, *Occupational Safety and Health Standards for Marine Terminals*
- 29 CFR 1926, *Occupational Safety and Health Standards for Construction*

- NAVFAC P-307, *Management of Weight Handling Equipment Maintenance and Certification.*

4-2 **OCCUPATIONAL SAFETY**. At each Navy installation, a Safety Office exists to oversee all base operations for compliance with federal, state, and local occupational safety regulations. The Safety Office is the primary point of contact for information and assistance with project safety issues. It is their responsibility to give direction and guidance on what safety regulations are applicable for each project, and which safety measures are required for compliance. To adequately identify the hazards associated with this type of work operation, the Safety Office may require a safety plan for any new project. The safety plan is sometimes called an “accident prevention plan” or “job hazard analysis” and includes activity hazard analyses for each phase of the project. This plan identifies the sequence of work operations, hazards associated with each task and the recommended controls (engineering, elimination, isolation, substitution and/or personal protective equipment) to ensure safe work operations. This plan is submitted by the project planner(s) before the project begins. COE EM-385-1-1 recommends submitting the safety plan at least 15 calendar days before the work starts at the job site. However, individual Safety Offices may require longer review periods. The Safety Office reviews the plan and provides feedback to the project planner on safety requirements. Appendix A of \1\ USACOE EM-385-1-1 /1/ provides a minimum basic outline for Accident Prevention Plans. An example of a safety plan format is given in Figure 4-1. Project work for a new project is usually not allowed to proceed until the safety plan has been signed and approved.

Figure 4-1 Safety Plan Format

1. Proposed Project: ____
   a) Description: ____
   ____
   b) Project Site/Diagrams: ____
   c) Dates/Times of Operation: ______________________________________
   d) Project Personnel: ____
   e) Safety Coordinators: ____

2. Preliminary Hazard Analysis:
   a) List hazards, triggering events, and estimate seriousness:___________
   ____
   b) Assign Risk Assessment Code (based on hazard severity and mishap probability): ____
   c) Hazard Control Mechanisms/Safety Measures (attach SOPs): _______
   ____

3. Training and Medical Surveillance (list project personnel, their training, medical surveillance dates and signatures): ____________________________________
____

4. Hazardous Waste Operations and Emergency Response (describe applicable HW operations and emergency plans):_________________________________
____

5. Personal Protective Equipment (list all PPE to be used for each task): _
____

6. Medical surveillance (list personnel who have had the required medical surveillance exams for each task):____________________________________
____

7. Industrial hygiene (identify requirements for air, personnel and environmental monitoring):____
____

8. Site control measures (identify any site control measures instituted):____
____

9. General information:____

10. Phone contacts:____

11. Emergency contacts:____

4-3 **ENVIRONMENTAL COMPLIANCE**. Environmental compliance is a facility's or project's status with respect to a wide variety of federal, state, and local environmental regulations in existence to protect our environment. Environmental compliance involves aspects that affect the operation of a project, such as:

- Wastewater discharge
- Noise abatement
- Air quality attainment
- Hazardous waste (HW) and hazardous materials (HAZMAT) management

4-3.1 **Environmental Regulations.** Environmental regulations have increased exponentially in recent years due to a growing concern about the environment. All shore activities are now regulated by a number of federal, state, regional, and local agencies. Thus, compliance to all of the applicable regulations for a particular project can vary greatly depending on the project's nature and location.

Navy policies on environmental compliance are contained in OPNAVINST 5090.1. Although this instruction generally addresses the responsibilities of the facility's Commanding Officer and higher agencies, it should be reviewed for general policy and reference by all project personnel. OPNAVINST 5090.1 contains information on specific environmental topics including:

- Management of ozone-depleting substances
- Clean air ashore
- Clean water ashore
- Drinking water and water conservation
- Oil and hazardous substances contingency planning
- PCB management
- Pesticide compliance
- Noise prevention
- Installation restoration

- Natural resources management
- Solid waste management

4-3.1.1 **Other Services Documents.** The equivalent Army document is Army Regulation AR 200-1, *Environmental Protection and Enhancement*. The Air Force equivalent is the Air Force 32 Series instructions.

4-3.1.2 **Environmental Instructions.** In addition, most commands and activities have developed instructions that provide policy guidance for complying with regulatory requirements applicable to activity personnel. Consult with the Environmental Office to obtain relevant guidelines for that activity.

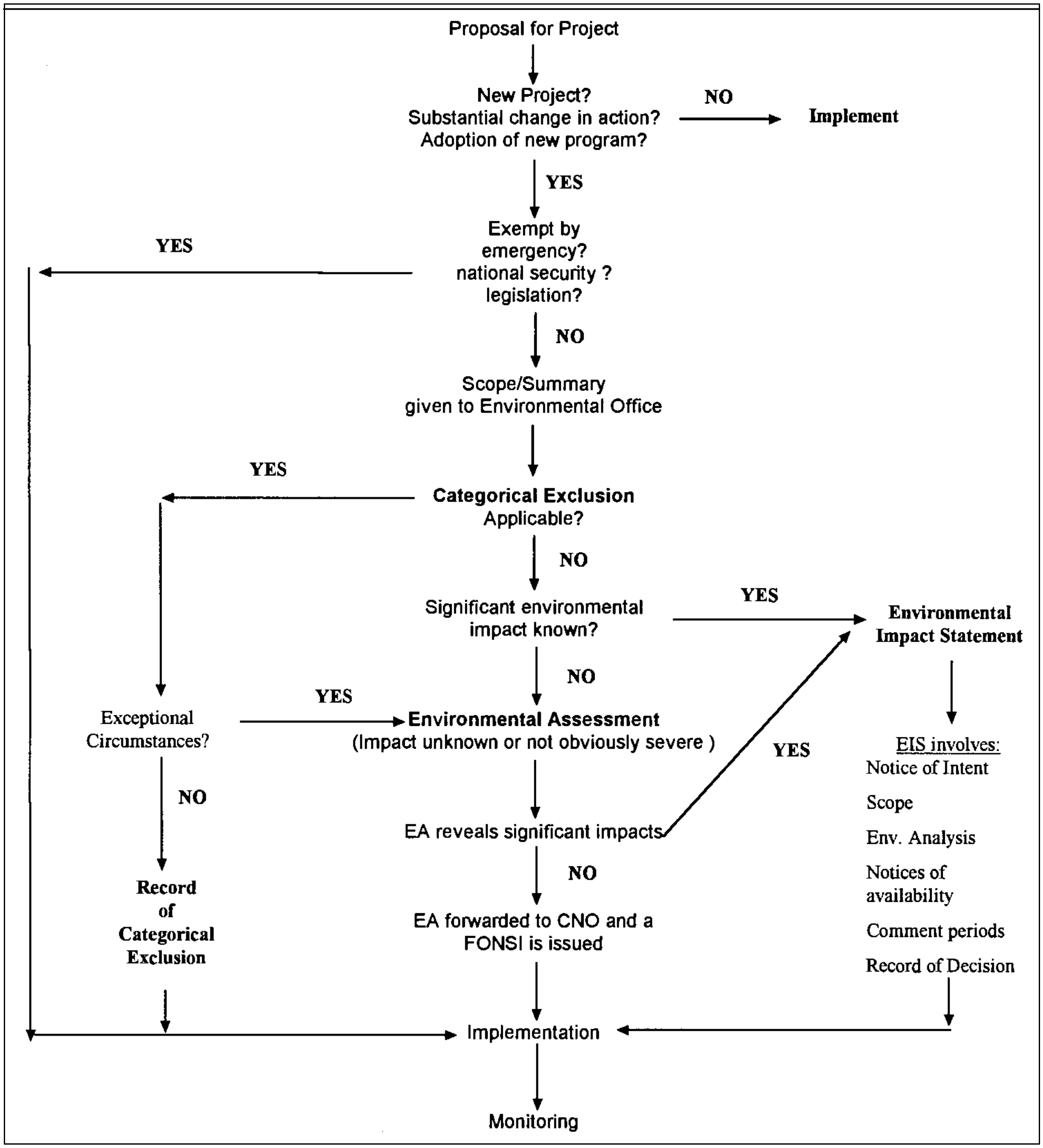
4-3.1.2.1 **Environmental Compliance Responsiblity.** Environmental compliance is everyone's responsibility, from the Commanding Officer of the activity to the people performing the actual tasks of a project. The Department of Defense is fully committed to strict compliance, not only to protect our environment and conserve our natural resources, but also for the overall benefit to the mission or project. In the long run, proper compliance prevents time delays and operational shutdowns, and improves public relations.

4-3.1.2.2 **Environmental Office.** Depending on the reader's role in a waterfront maintenance and repair project, whether a planner or estimator, or a member of the activity requesting waterfront maintenance and repair, involvement with environmental documentation will vary. In all cases, however, each activity should have an Environmental Office that is responsible for overseeing the environmental aspects of all projects at that facility. Environmental Office personnel are responsible for: developing and implementing activity instructions and providing guidance on procedures for ensuring environmental compliance for projects. Specific services provided by the Environmental Office include:

- Preparing categorical exclusions
- Obtaining any necessary local permits
- Issuing site-approvals
- Contacting \1\ local NAVFAC offices /1/ and contractors when an Environmental Assessment (EA) or Environmental Impact Statement (EIS) preparation is appropriate

The flow chart in Figure 4-2 shows a typical process of environmental documentation.

Figure 4-2 Environmental Documentation Process



4-3.1.3 **National Environmental Policy Act (NEPA).** The National Environmental Policy Act (NEPA), first enacted in 1969, is the national charter (within the United States and its territories) for protection of the environment. It establishes policy, sets goals, and provides a means for carrying out environmental policy within the United States and its territories. NEPA impacts a wide variety of existing environmental legislation including the:

- Clean Water Act (CWA)
- Clean Air Act (CAA)
- Pollution Prevention Act (PPA)
- Coastal Zone Management Act (CZMA)
- Endangered Species Act (ESA)
- Marine Protection Research and Sanctuaries Act (MPRSA)

4-3.2 **Environmental Documentation**. Under the NEPA Council on Environmental Quality (CEQ), a three-tiered approach of environmental consideration and documentation has been established:

- Categorical Exclusion (Cat. Ex)
- Environmental Assessment (EA)
- Environmental Impact Statement (EIS)

4-3.2.1 **Categorical Exclusion**. A categorical exclusion is a statement that the intended project work or action does not have, under normal circumstances, individually or cumulatively, a significant effect on the environment. If a categorical exclusion is allowed, an EA or EIS will not be required. The Environmental Office is generally responsible for deciding on and preparing a categorical exclusion. To do this, the Environmental Office will require from the project coordinator or planner(s) a summary or scope of the work to be performed. This summary does not need to be a lengthy document but must contain sufficient detail of the work to allow the EO to determine whether a categorical exclusion is appropriate. Categorical exclusions include:

- Routine repair and maintenance of facilities and equipment to maintain existing operations and activities, including maintenance of improved and semi-improved grounds.

- Alteration and additions of existing structures to conform or provide conforming use specifically required by new or existing applicable regulations.

- Routine actions normally conducted to operate, protect, and maintain military-owned or controlled properties.

- New construction that is consistent with existing land use and, when completed, complies with existing regulatory requirements.

- Routine movement, handling, and distribution of materials, including HAZMAT or HW that is moved, handled, or distributed under applicable regulations.

- Demolition, disposal, or improvements involving buildings or structures neither on nor eligible for listing on the National Register of Historic Places.

- Actions which require the concurrence or approval of another Federal agency, where the action is a categorical exclusion of the other Federal agency.

- Maintenance dredging and debris disposal where no new depths are required, applicable permits are secured, and disposal will be at an approved site.

Even though a proposal generally fits the definition of a categorical exclusion, the categorical exclusion will not be used if the proposed action affects public health and safety, or involves an action that is determined to have the potential for significant environmental effects on wetlands, endangered species, HW sites, or archeological resources.

When it is unknown beforehand whether or not the proposed action will significantly affect the human environment or be controversial with respect to environmental effects, a categorical exclusion cannot be used.

4-3-2.1.1 **Environmental Office Documentation.** The Environmental Office must document the categorical exclusion(s), the facts supporting their use, and specific considerations of whether the exceptions to the use of categorical exclusions are applicable. This Record of Categorical Exclusion need not be more than a page or two, but must be signed by the Commanding Officer or a designee. The signed Record of Categorical Exclusion must be retained within the project files and be available for review during environmental compliance evaluations. Additionally, many Environmental Officers will prepare an Environmental Review Document (ERD), an in-house document listing impacts, or lack thereof, of the project on several environmental areas.

Even though a categorical exclusion is granted, it does not mean the end of the environmental compliance process. Local, regional, state, and federal agencies may require permits for certain operations, or for a specific type of equipment. It is the Environmental Officer's responsibility to obtain these permits, using the technical input from the project team. When work is contracted out, the contractor is responsible for providing an environmental protection plan, along with applicable permits and reports via the Contracting Officer.

4-3.2.1.2 **Permits.** Waterfront maintenance projects usually do not require permits unless special construction is required. Additionally, they will not need a new categorical exclusion if the work has been previously reviewed by the Environmental Officer. However, the Environmental Officer needs to be informed of any work taking place at the waterfront to ensure that environmental procedures are being followed. Normally, maintenance projects evolve from an annual inspection of waterfront structures by the Public Works Centers. The repair and/or maintenance requirements are then relayed to the facility customers who then submit a summary of the proposed work to the Environmental Office.

4-3.2.2 **Environmental Assessment**. An environmental assessment (EA) is an analysis of the potential environmental impact of a proposed action. An EA is prepared for projects or actions that do not fall under one or more of the listed categorical exclusions and that have the potential for significant environmental impacts. If significant impacts are obvious, an Environmental Impact Statement is directly prepared.

The EA discusses the need for the action, alternatives, impacts, and any environmental monitoring required. Additional information may be required of the project coordinators and other project planners to complete the EA. The EO will likely turn the preparation of an EA over to \1\ a local NAVFAC office /1/ or a contractor.

If after completion of the EA, it is determined that the proposed project will not significantly impact the environment, a Finding of No Significant Impact (FONSI) will be prepared and the project implemented. If it is determined that the proposed project will significantly impact the environment, an EIS must be prepared.

4-3.2.3 **Environmental Impact Statement**. An EIS is a detailed document that provides a full discussion of significant environmental impacts and informs decision makers and the public of reasonable alternatives that would avoid or minimize adverse impact, or enhance the quality of the human environment. EIS can be lengthy and are frequently prepared by contractors who can provide an unbiased analysis, thus avoiding a conflict of interest. An EIS is completed with a Record of Decision (ROD) and signed by the Secretary of the Navy. The likelihood that an EIS would be required for a normal waterfront maintenance/repair project is small.

4-3.3 **Working in Compliance**. Once all permits for a project have been obtained and all documentation has been completed, the Environmental Officer will issue a “site-approval.” Generally, the Public Works Center performing the maintenance or repair will not start work until the site-approval has been issued.

Often, contact with the activity’s Environmental Office during planning and execution of waterfront maintenance and repair projects is all that will be required to assure compliance with environmental regulations. Project personnel in some circumstances, however, may need to establish direct contact with the various permitting and regulatory agencies concerned with the work. These might include but are not limited to:

- Port officials
- State Department of Health
- Department of Fish & Game
- State EPA office
- Coast Guard
- Army Corps of Engineers

Contact with these agencies should not be used to circumvent communication with the Environmental Office, but should be used to compliment it to help ensure environmental compliance and agency approval of the planned project tasks.

4-3.4 **Environmental Training**. All project personnel should be provided with formal training on the principles of environmental compliance and the regulations that govern them. Personnel working on projects that involve hazardous materials and wastes, operations which potentially could cause air, water, or noise pollution, or that may endanger the marine environment need more extensive training in these specific areas. OPNAVINST 5100.23 gives Navy requirements for training for hazardous materials handling and hazard communication.

The primary source of information concerning environmental training requirements is, again, the Environmental Office. They provide guidance on who must be trained, what training is required, and how often. They frequently conduct the training sessions themselves.

4-3.5 **Treated Wood - Environmental Issues**. Since there is extensive use of treated wood at waterfront facilities, and since wood preservatives likely constitute the greatest percentage of chemicals used on the waterfront, a special mention about the environmental issues is warranted. In recent years, using treated wood in the marine environment raised concerns about its effect on surrounding aquatic life. Currently, wood preservatives are registered by the EPA for use in the marine environment, and treated wood is not considered a hazardous waste nor banned from landfills, according to Federal law. However, local and state regulations are more restrictive. The Environmental Office should be consulted for applicable restrictions at the waterfront facility of interest. See Chapter 6 of this handbook for more information on the environmental concerns of treated wood.

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CHAPTER 5

INSPECTION

5-1 **GENERAL CONSIDERATIONS**. The fundamental purpose of any inspection is to provide the information necessary to assess the condition (capacity, safety, and rate of deterioration) of a structure. Waterfront structures to be inspected include: piers, pilings, wharves, quaywalls, fender systems, dolphins, and drydocks.

5-1.1 **Inspection Objectives**. Inspections are classified according to the objectives. These include:

- Baseline - to obtain data on a facility that has not been inspected. This inspection involves the greatest "pre-inspection" effort.
- Routine - to obtain data on general condition, confirm drawings, estimate repair costs, etc.
- Design Survey - to obtain data for specifications or for detailed cost estimates.
- Acceptance - to obtain data confirming that a repair has been completed according to plan or specification.
- Research - to obtain data on deterioration rates, etc.

The usefulness of an inspection depends on establishing a clear and complete record. Although the level of inspection will determine the extent of information to be provided, in general the inspection will address the:

- Identification and description of all major damage and deterioration of the facility.
- Description of facilities inspected including updated layouts of pile plans (which occasionally differ significantly from the drawings available at the activity).
- Documentation of types and extent of marine growth, if applicable.
- Water depth, visibility, tidal range, and water current.
- Assessment of general physical condition including projected load capacities.
- Recommendations for required maintenance and repair (M&R).

- Budgetary estimates of costs of this M&R, including examples of how estimates were derived.
- Identification of any problems associated with mobilization of equipment, personnel, and materials to accomplish repairs/maintenance.
- Estimate of expected life of each facility.
- Recommendations for types and frequencies of future underwater inspections.

5-1.2 **Information an Inspection Should Provide**. There are a number of reference documents dealing with waterfront inspections. The inspection procedures and planning factors outlined in this section have been taken from several of them. Two important references are:

\1\

- NAVFAC MO-322, *Inspection of Shore Facilities*
- NTRP 4-04.2.8, *Conventional Underwater Construction and Repair Techniques*
- NTRP 4-04.2.9, *Expedient Underwater Construction and Repair Techniques*

/1/

5-2 **LEVELS OF INSPECTION**. For any inspection objective, three levels of inspection effort are used for inspecting waterfront facilities:

5-2.1 **Level I - General Visual Inspection**. This inspection involves no cleaning of any structural elements and, therefore, is the most rapid of the three types of inspection. The purpose of the Level I inspection is to confirm as-built structural plans, provide initial input for an inspection strategy, and detect obvious major damage or deterioration due to overstress, impacts, severe corrosion, or extensive biological growth and attack.

5-2.2 **Level II - Close-Up Visual Inspection**. This inspection is directed toward detecting and identifying damaged or deteriorated areas that may be hidden by surface biofouling or deterioration and obtaining a limited amount of deterioration measurements. The data obtained should help estimate the facility's load capability. Level II inspections will often require cleaning the structural elements. Since cleaning is time consuming, it is generally restricted to areas that are critical or which may be representative of the entire structure. The amount and thoroughness of cleaning to be done is governed by what is necessary to determine the general condition of the overall facility.

5-2.3 **Level III - Highly Detailed Inspection**. It is recommended that a "Level III" above and under water inspection be performed on piers identified for mooring use during heavy weather conditions. This inspection normally includes underwater inspections, and will often require the use of nondestructive testing (NDT) techniques. It may also require using partially destructive techniques, such as core sampling of concrete and wood structures, physical material sampling, or surface hardness testing. The purpose of this type of inspection is to detect hidden or interior damage, loss in cross-sectional area, and material homogeneity. A Level III examination will normally require cleaning. The use of NDT techniques are usually limited to key structural areas, areas that may be suspect, or structural members that may be representative of the underwater structure. Level III inspections require more experience and training than Level I or Level II inspections, and should be done by qualified engineering or nondestructive testing personnel. This type of inspection is covered in MO-104.2.

Inspection of waterfront facilities is considered to be a specialized control inspection within the Navy. The underwater inspection should be done by a qualified, certified diver supervised by an engineer or a qualified engineering diver. The structural assessment must be done by an engineer with experience and skill in inspection procedures and techniques.

Table 5-1 lists the types of damage that are detectable with the three levels of inspection.

5-3 **PLANNING FOR INSPECTION**. The levels of inspection to be used for a particular task must be decided early in the planning phase. The inspection objectives (i.e., baseline, design survey, repair acceptance, research) should be clearly defined. A site survey of the facilities should be obtained, or conducted if doing a first-time inspection. A site survey for underwater inspections includes: bathymetric, oceanographic, and geological data, as well as information on nearby obstructions or activities. A site survey accelerates the planning process and will help determine the levels of inspection to be used.

The time and effort required to carry out the three different levels of inspection are quite different. The time required also depends on whether the inspection is surface or underwater; on environmental factors, such as visibility, currents, wave action, water depth, tides, severity of marine growth; and on the inspector's skill and experience.

Table 5-1. Capability of Each Level of Inspection for Detecting Damage to Waterfront Structures

Level	Purpose	Detectable Defects		
		Steel	Concrete	Wood
I	General visual to confirm as-built conditions and detect severe damage	Extensive corrosion Severe mechanical damage	Major spalling and cracking Severe reinforcement corrosion Broken piles	Major losses of wood due to marine borers \1\ (limnoria; see earlier section on Marine Borers) /1/ Broken piles and braces Severe abrasion or marine borer attack
II	Detect surface defects normally obscured by marine growth	Moderate mechanical damage Major pitting	Surface cracking and crumbling Rust staining Exposed rebar and/or pre-stressed strands	External pile diameter reduction due to marine borers Splintered piling Loss of bolts and fasteners Early borer and insect infestation
III	Detect hidden and imminent damage	Reduced thick-ness of material	Location of rebar Beginning corrosion of rebar Internal voids	Internal damage due to marine borers,\1\ internal voids (teredines and pholads; see earlier section on Marine Borers) /1/ Decrease in material strength \1\ (based upon section loss as determined by either nondestructive and/or destructive testing which are discussed in this chapter) /1/

Table 5-2 provides a guide for estimating the time required to conduct Level I and Level II surface and underwater inspections.

Level III inspections depend on the extent of existing damage, the type of inspection techniques, and the equipment used (ultrasonic thickness measurements, increment borings, caliper measurements). Therefore, estimates of time for Level III inspection are not included in Table 5-2.

Table 5-3 shows daily rates for underwater inspection of piles and bulkheads.

Table 5-2 Production Rate for Surface and Underwater Inspection of Structural Elements

Structural Element	Inspection time per Structural Element (minutes)			
	Level I		Level II	
	Surface	Underwater	Surface	Underwater
12 inch (30 cm) steel H-pile	2	5	15	30
12 inch (30 cm) wide strip of steel sheet pile	1	3	8	15
12 inch (30 cm) square concrete pile	2	4	12	25
12 inch (30 cm) wide strip of concrete sheet pile	1	3	8	15
12 inch (30 cm) diameter timber pile	2	4	10	20
12 inch (30 cm) wide strip of timber sheet pile	1	3	7	15

NOTE: This information is based on a 11 to 15 yard r (10 to 14 meter) water depth; 3.1 to 6.6 feet (1 to 2 meter) visibility; warm, calm water; moderate marine growth about2 inch (5 cm) thick; and an experienced engineering diver or diver supervised by an engineer. For the Level II inspection, it is assumed that 3.1 feet (1 meter) of the structural element is in the splash zone, 12 inch (30 cm) at mid-depth, and 12 inch (30 cm) at the bottom, and will be completely cleaned of marine growth. It is also assumed that the most efficient method of removing marine growth will be used.

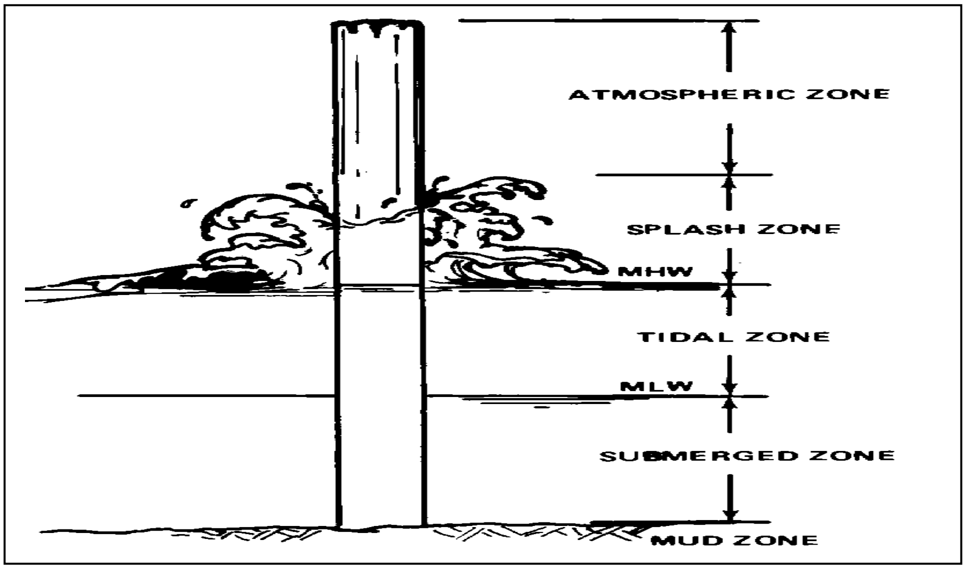
Table 5-3. Daily Rates for Underwater Inspection Tasks*

Inspection Task	Pile/Day	Bulkhead in Linear Meters Day
Swim by	300 to 600	150 to 450
Cleaning	30 to 70 at 3 to 15% of each pile	150 to 450 at 15 to 90meter (16 to 98 yard) intervals
Measurements	50 to 200 for wood at 5 to 15% of each pile 30 to 60 for steel at 3 to 10% of each pile 30 to 70 for concrete at 3 to 15% of each pile	150 to 450 at 15 to 90meter (16 to 98 yard) intervals

*Rates vary widely depending on the effects of many factors, such as: water visibility, facility size and age, marine growth, and construction.

5-3.1 **Inspection Frequency**. The frequency of routine or periodic inspections will depend on whether the inspection is on the surface or underwater, and the expected rate of deterioration and damage. An example of an area requiring more inspections is ships berthing, which deteriorates both fender and bearing piling. The frequency and level of inspection should, therefore, be closely tied to the historical deterioration rate of the facility. Statistical software has been developed that identifies inspection frequencies based on cost when known or estimated structural data. The frequencies obtained will be unique to the activity’s situation (from NCEL CR 87-005, *Inspection Frequency Criteria Models for Timber, Steel, and Concrete Pile Supported Waterfront Structures*, December 1986.) As a general guide, recommended frequencies of inspection for the different types of waterfront structures are:

Figure 5-1. Exposure zones on piling.



a. All superstructure and piling/sheet piling above the waterline, including the splash and tidal zones (Figure 5-1), should be inspected annually.

b. Concrete/steel structural members at the splash/tidal zones (Figure 5-1) and downward should be inspected at least every 6 years. As deterioration is discovered, the level of inspection and frequency needs to increase accordingly. For steel structures, the age of the structures is a primary factor since the rate of deterioration due to corrosion is fairly constant. Likewise, concrete in a saltwater environment deteriorates chemically with time, especially if cracks are present to allow the seawater to reach the structure's interior.

c. Timber members should be inspected at least every 3 years and, as above, more frequently and intently as deterioration is discovered. In areas where marine animal infestation is known to be a problem, increased inspections are especially important.

If it is not feasible to thoroughly inspect all elements of a structure (e.g., underwater inspection of a series of piers with many piles), selecting an optimum number of structural elements or members is crucial to obtaining accurate information representative of the overall condition of the structure. Development and validation of sampling criteria and procedures has been reported in Naval Civil Engineering Laboratory's TN-1762 *Sampling Criteria and Procedures for Inspection of Waterfront Facilities*, September 1988. Statistical sampling techniques using probability theory provide a method for determining condition parameters for the entire population based on information from the sample elements, with a calculated confidence level and precision.

5-3.2 **Inspectors.** Inspections may be by a variety of individuals at different times for different reasons. It should be notes that periodic comprehensive inspections are done as part of the Underwater Inspection Program administered by the \1\ Naval Facilities Engineering Service Center, East Coast Detachment. /1/

5-3.3 **Collecting Inspection Plan Data**. Before starting an inspection, all available information about the facility should be gathered. This includes prior maintenance and inspection records, facility drawings and site survey reports, general background information, and environmental data, including:

- Atmospheric temperature range
- Water temperature range
- Tidal range
- Water depths
- Water visibility
- Currents

Any condition could have a direct impact on the time required to perform an inspection, such as: the amount of biofouling growth on piles; ice; or seasonal flooding. Any other unique feature or special problems that may be encountered should also be noted.

The inspection plan should include CADD drawings showing individual piles and other structural members. The inspection could use pile numbering/designation systems often available on existing "as-built" drawings. Usually, combinations of numbers and letters are used with the number designating the bent and letter indicating the pile within the bent. CADD drawings should also be developed for the above and below deck portions of the pier. The existing positions of all topside bollards, bitts, cleats, capstans, utility covers, as well as any under deck utilities and fittings should be shown on the CADD drawings. A legend should be created to represent such things as the:

- Degree of deterioration of individual structural members
- Level of inspection given to designated portions of a facility
- Shape of individual piles

- Type of materials
- Condition of bollards and bitts

Pile plans should be prepared for piers showing the lengths, widths, and spacing of bents. The plans must also include the numbering system used in the inspection and in the report, and these must be correlated with existing drawings of the facility. Also include design live load data on all pile plans, if available. Load testing of the pier decking, if heavy equipment or vehicles are driven onto the pier, should be considered.

Particular attention should be paid to mooring hardware as it relates to safe mooring of naval vessels during heavy weather. A more thorough treatment of this topic is contained in \1\ UFC 4-150-08, *Inspection of Mooring Hardware.* /1/

5-3.3.1 **Developing Inspection Plan.** Once the information about the facility structure and environment has been collected, an inspection plan is developed. The plan should be based on the inspection objective and the level of inspection required to meet that objective. It is important to select enough inspection areas per structural member. The written plan should be similar to a statement of work (SOW) specifying the sampling criteria, tasks, schedules, equipment to be used, and any additional responsibilities. The inspection plan must be prepared by a qualified engineer who is familiar with the structure.

The plan must specify that a qualified diver supervised by a qualified engineering diver should conduct the underwater inspections and an experienced engineer must perform the structural assessment of the entire pier.

5-3.4 **Equipment and Tools**

5-3.4.1 **Surface Cleaning Tools**. To perform a Level II and Level III inspection, the marine growth on the structure must be removed. How this is done depends on the surface support available. For small sample areas, wire brushes, probes, and scrapers may be adequate. For larger areas or more detailed inspections underwater, a hydraulic grinder with barnacle buster attachment, or high-pressure water jet gun, may be used. Take care to prevent damage to pile wraps or coatings and to the preservative-treated layers of timber or deteriorating surfaces of concrete.

5-3.4.2 **Inspection Tools**. Inspection tools and equipment include:

5-3.4.2.1 **Hand-Held Tools.**

- Portable flashlight, ruler, and tape measure for documenting areas

- Small or large hammers or pick-axes for performing soundings of the structural member
- Calipers and scales for determining thickness of steel flanges, webs, and plates, or diameters of piling
- Increment borer and T-handles for extracting core samples from timbers
- Chipping tools for prodding the surface of the concrete to determine the depth of deterioration.

5-3.4.2.2 **Mechanical Devices.** Mechanical devices including a Schmidt test hammer for measuring concrete surface hardness and rotary coring equipment for taking core samples from concrete structures.

5-3.4.2.3 **Electrical Equipment.** This includes electrical equipment, such as an underwater voltmeter for determining the level of cathodic protection on steel structures and underwater sonic and ultrasonic equipment for detecting voids in \1\ /1/ concrete and thickness of structural steel. It also includes underwater magnetic particle testing to locate and define surface discontinuities in magnetic materials. Figure 5-2 shows typical equipment applications used in underwater inspections.

5.3.4.3 **Recording Tools**. Recording tools and equipment are required to provide a complete documentation of the condition of the structure. Simple tools such as a clipboard, forms, and cassette recorder for above water inspections; or Plexiglas® slate and grease pencil for underwater inspection, provide the basic documentation tools. More in-depth documentation may be obtained with above water or underwater photography using either colored still-frame cameras, colored video, or closed-circuit television. The latter may be very valuable in expediting major underwater inspections. For underwater inspections in turbid water, a clear-water box may be fitted to the lens of the photographic or video equipment to improve visibility between the lens and surface to be inspected.

5-3.5 **Preparing Inspection Documentation**. For the information to be useful, documentation must be clear and concise. Inspectors should maintain daily logs of inspection details including measurement data, locations of observation, and water depths, if relative. Fill out inspection forms as the inspection progresses, and complete the reports soon after the inspection has been finished. Standard forms and report formats facilitate the documentation procedure and are essential for comparing the results of the present inspection with past and future inspections. Figure 5-3 is a standard form that may be used for reporting the condition of piles; Figure 5-4 is an explanation of the condition ratings for concrete piles used on the form; and Figure 5-5 is an explanation of the condition ratings for timber piles. Steel pile inspection results are usually recorded in terms of remaining metal thickness.

Figure 5-2 Tools and Equipment Used for Waterfront Inspection

Figure 5-3 Standard Pile Inspection Report Form.

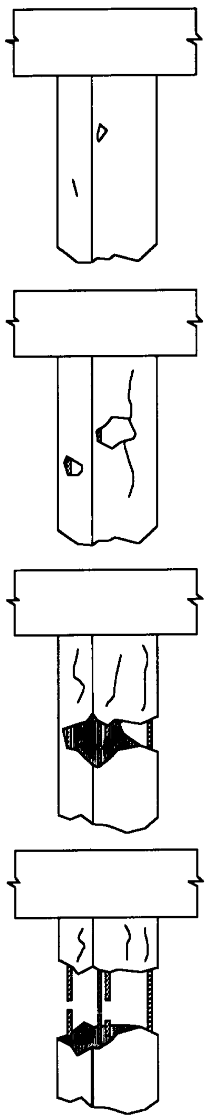
PILE INSPECTION RECORD

LOCATION		DATE	DIVERS
PIER NAME/NO		PILE TYPE ☐ BEARING ☐ FENDER ☐ SHEET	PILE MATERIAL ☐ TIMBER ☐ STEEL ☐ REINFORCED CONCRETE
WATER DEPTH	TIME OF DAY	TIDE	DEPTH OF DAMAGE FROM DATUM=GAUGE DEPTH-TIDE

BENT NO	PILE NO	NI	PILE CONDITION					TYPE DAMAGE			GAUGE DEPTH DAMAGE	DIMENSIONS OF DAMAGE			COMMENTS
			ND	MN	MD	MJ	SV	MECH	BIO	FUNC		HGT	WIDTH	PENETR	

Figure 5-4 Pile Condition Ratings for Concrete Piles

CONCRETE PILES



CONCRETE PILE CONDITION RATING	EXPLANATION
NI	NOT INSPECTED, INACCESSIBLE OR PASSED BY
ND	NO DEFECTS: - hairline cracks - good original surface, hard material
MN	MINOR DEFECTS: - good original surface - minor cracks or pits - small chips or popouts - slight rust stains - hard material, sound - corrosion of the wires
MD	MODERATE DEFECTS: - limited spalling of concrete - minor corrosion of exposed re-bar - rust stains along re-bar - softening of concrete - reinforcing steel ties exposed - popouts or impact damage
MJ	MAJOR DEFECTS: - spalling of concrete results in (10-15%) loss - large spalls six inches or more in width or length - deep wide cracks along re-bar - major rust stains along rebar - wide spread surface disintegration
SV	SEVERE DEFECTS: - exposed rebar with 50% loss of steel section area - more than 15% loss of concrete

NOTE: Explanation of defect should be placed in the comments column.

Figure 5-5 Pile Condition Ratings for Timber Piles

TIMBER PILE CONDITION RATING	EXPLANATION
NI	NOT INSPECTED, INACCESSIBLE OR PASSED BY
ND	NO DEFECTS: - Less than 5% lost material - sound surface material - no evidence of borer damage
MN	MINOR DEFECTS: - 5% to 15% lost material - sound surface material - no evidence of borer damage - minor abrasion damage
MD	MODERATE DEFECTS: - 15% to 45% lost material - significant loss of outer shell material - evidence of borer damage - significant abrasion damage
MJ	MAJOR DEFECTS: - 45% to 75% lost material - significant loss of outer shell and interior material - evidence of severe borer damage - severe abrasion damage
SV	SEVERE DEFECTS: - more than 75% lost material - no remaining structural strength - severe borer damage

NOTE: Explanation of defect should be entered in the comments column.

When appropriate, visual inspection should be documented with still photography and closed-circuit television. Still photography provides the necessary high definition required for detailed analysis, while video provides a continuous view of the inspection. All photographs should be numbered and labeled with a brief description of the subject. A slate or other designation identifying the subject should appear in the photograph. Video tapes should be provided with a title and lead-in describing what is on the tape. The description should include the inspection method used, the nature and size of the structure being inspected, and any other pertinent information.

5-4 INSPECTION OF TIMBER STRUCTURES

5-4.1 **Scoping the Problem**. Timber damage is caused by:

- Fungal rot
- Marine borer and insect attack
- Shrinkage
- Overloading
- Connector Corrosion
- Abrasion
- Ice Lift

These are described in detail in Chapter 3. Typical damage found is illustrated in Figures 5-6, 5-7, 5-8, and 5-9.

Waterfront deterioration and damage is found by walking the pier, by inspecting dolphins and below pier decks in a small boat or barge, and by underwater inspections.

When inspecting above the water, the inspector should take maximum advantage of low tide conditions in order to visually inspect the overall condition of the piling. This may determine that an underwater inspection is necessary. The underwater inspection should, on the other hand, take advantage of high water conditions in order to compile the most comprehensive field data on existing conditions.

5-4.2 **Surface Inspections**. Use Figure 5-10, “Timber Structures and Attachments (Above Water) Checklist” to ensure that a thorough inspection of all timber structures and their attachments above water is done. Include annual load testing of the pier decking if heavy equipment or vehicles are driven onto the pier. Sampling equipment and inspection data to be compiled are in Table 5-4.

Figure 5-6 Damage Areas Involving Timber Members

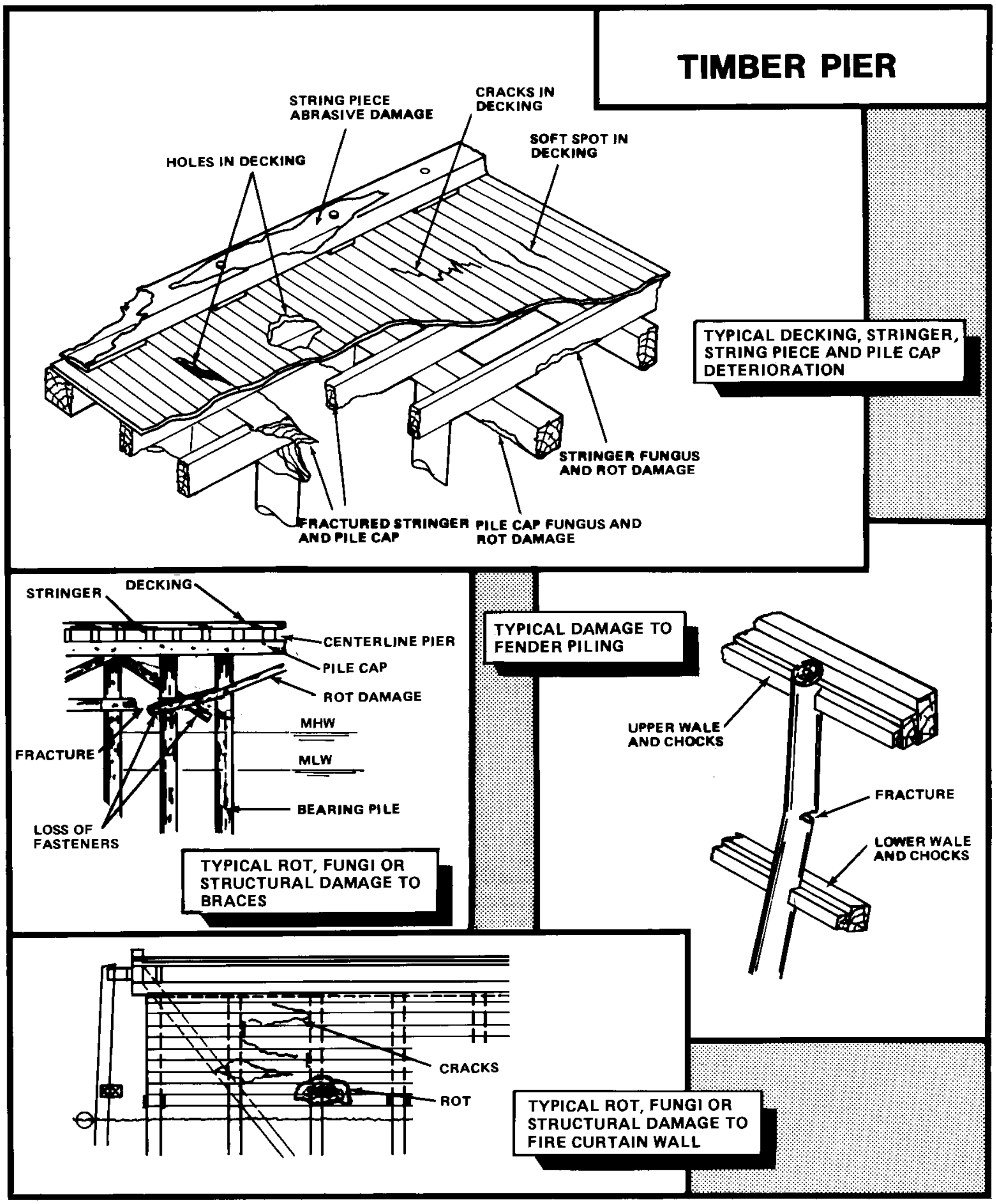


Figure 5-7 Damage to Timber Piles from Biological Sources

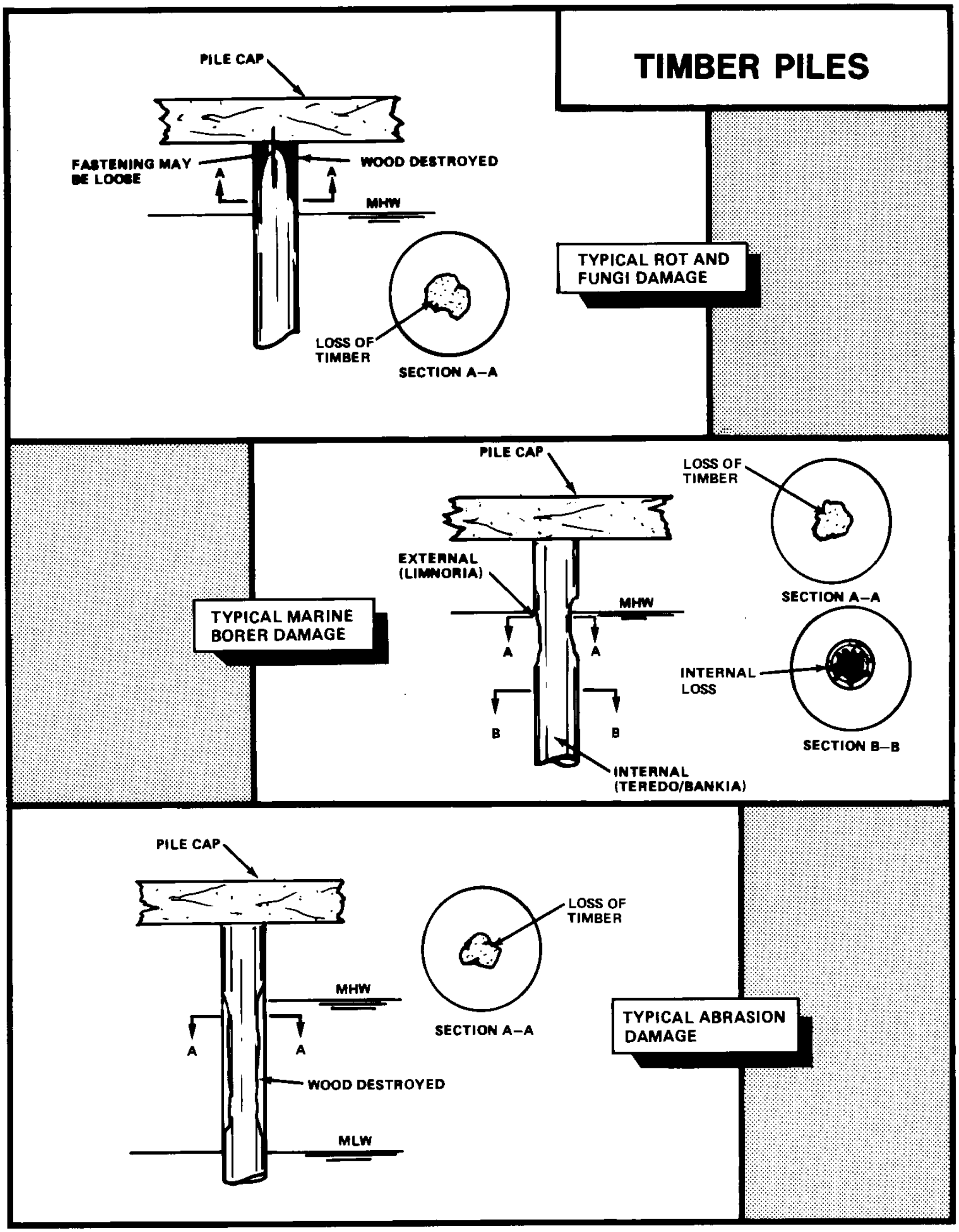


Figure 5-8 Damage to Timber Piles from Non-Biological Sources

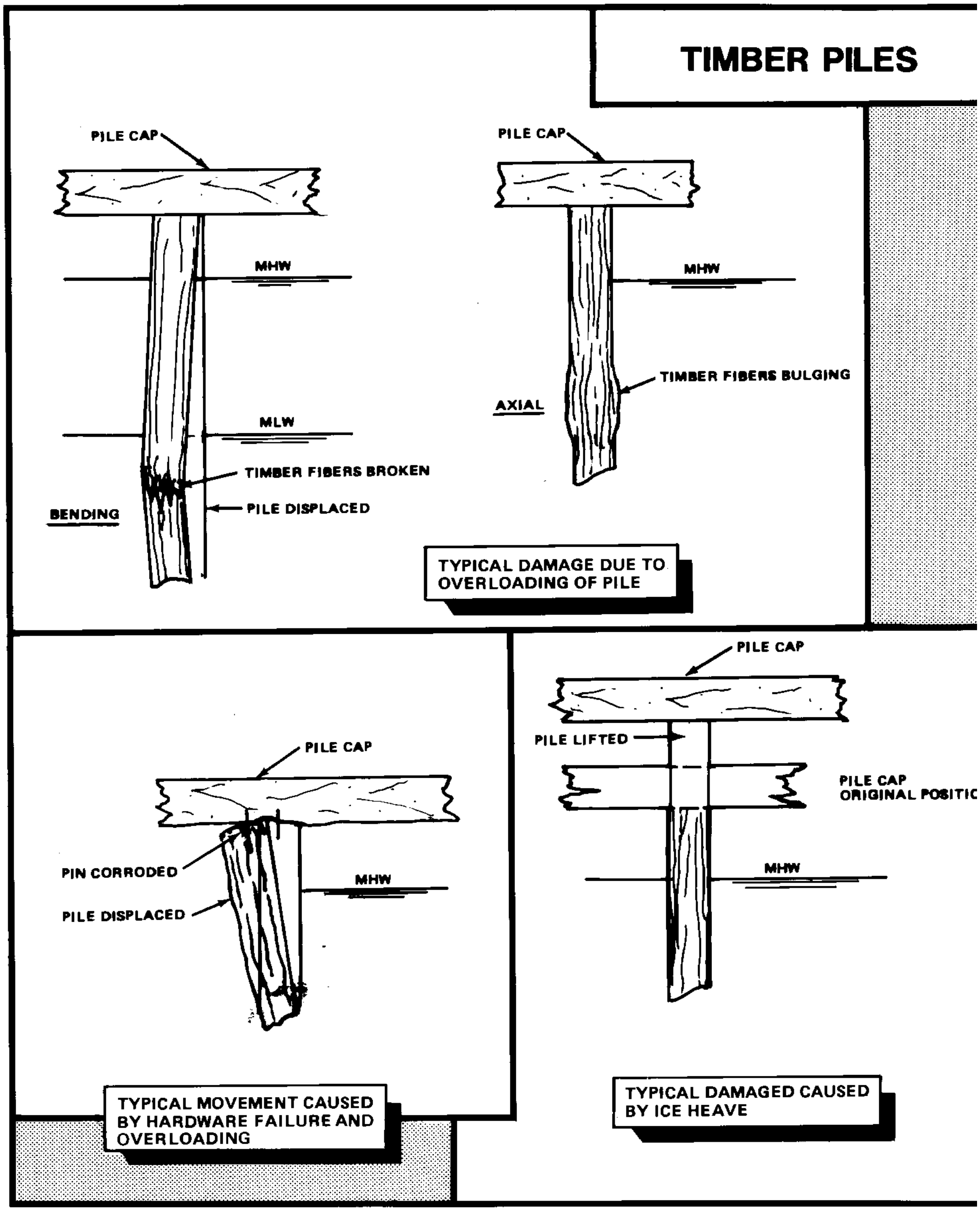
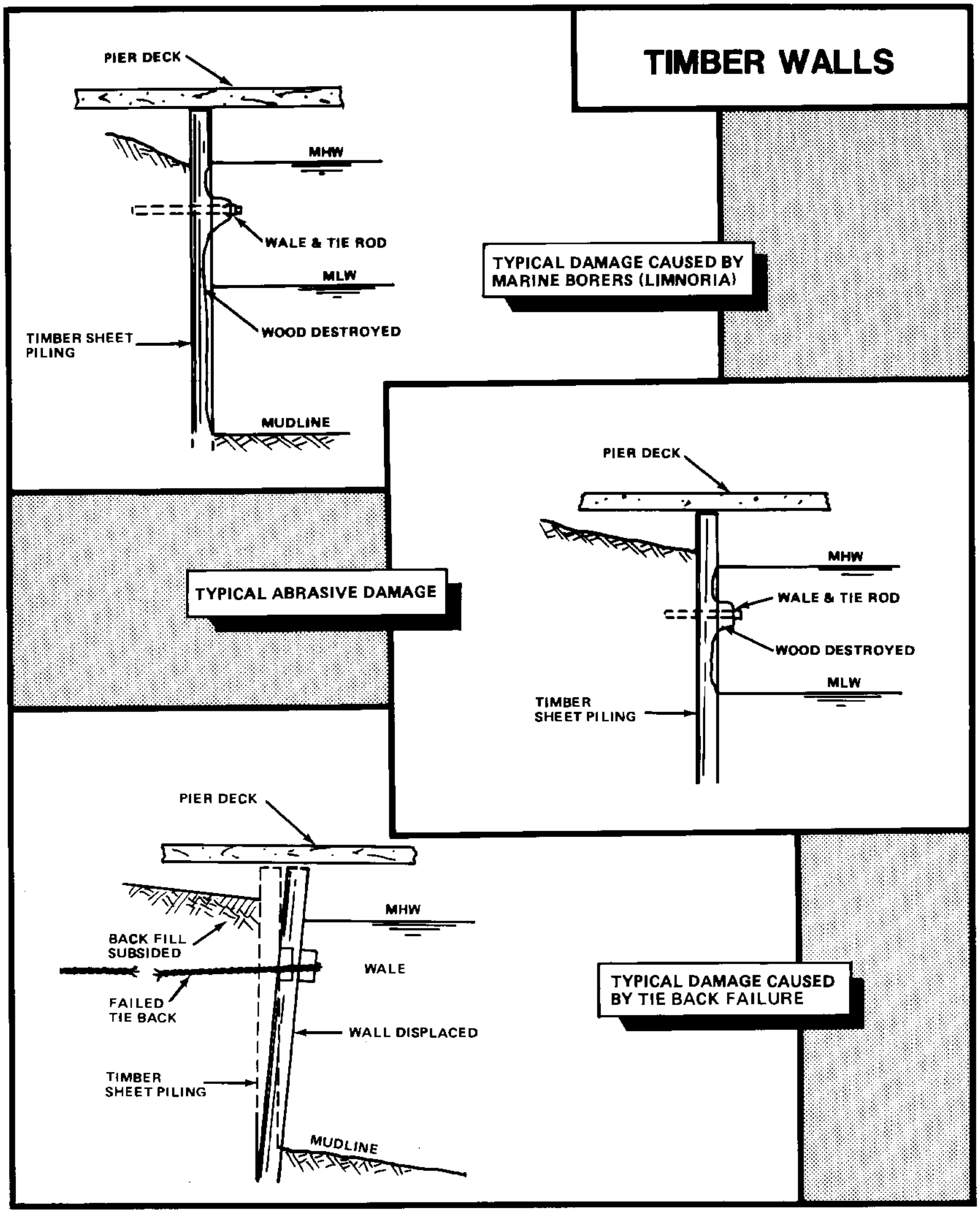


Figure 5-9 Damage to Timber Sheet Piling



The inspector should be alert, specifically in the areas of stringers, pile caps and top of piles, for signs of discoloration and softening of the wood, accompanied by a fluffy or cotton appearance. This may be an early sign of fungi damage. More advanced deterioration may take on the appearance of fruiting bodies, such as mushrooms. Further down the pile, the inspector should look for burrows or hollows in the wood, surface trenches in the outer layers of the pile, and loss of pile diameter. This may be evidence of marine borer attack.

Table 5-4 Sampling Equipment, Measurements, and Ratings for Timber Structures

Special Sampling Equipment	Measurements or Ratings
Increment borer (Install Treated wooden plugs in holes left after boring)	Quality of preservative or soundness of piling
Calipers	Pile diameter; rating of piling condition
Sonic Equipment	Data from sonic equipment; detection of hollow areas in piling
Ice pick or other sharp probe	Location and size of damaged areas Depth of cracks and other damaged areas

5-4.3 **Underwater Inspection**. Use Figure 5-11 “Timber Structures and Attachments (Below Water) Checklist” to ensure that a thorough inspection of all timber structures and their attachments below water is done. An engineer should explain to the diver exactly what should be looked for: number and size of piles, type and depth of bulkheads, location of tiebacks, and cross bracing. The engineer shall evaluate the diver's observations and determine the degree of hazard.

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Additionally, when observing damage from marine borers (teredos) precautions need to be taken. As the diver swims up to the pile, he may be able to see the cilia, “waving,” as the worm filters food from the water, Otherwise, the worm feels the disturbance and withdraws the feeding hairs (and closes the opening). The diver is unable to see anything because the opening is:

- Small
- Closed
- Obscured by marine growth and shellfish

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Figure 5-10 Timber Structures and Attachments (Above Water) Checklist

	Deck Area
___	Check for cracked, rotted, loose or worn decking or string pieces, loose hardware, soft spots in decking (Figure 5-6), and termite or pest infestations.
___	Check the tops of fender piles and visible chocks and wales for physical damage, dry rot and termite or pest infestations.
___	Check horizontal and vertical alignment.
___	Check for missing, broken, or loose connections; obstructions; and other hazardous conditions of curbing, handrails, and catwalks.
___	Check bollards, bits, cleats and capstans for wear, breaks, rough or sharp surfaces or edges and missing or loose bolts.
___	Check deck drains and scuppers for loose, missing or broken screws, standing water, and other deficiencies.
___	Check manhole covers and grating for rust, corrosion, bent or worn hinge pins, and other damage.
___	Inspect asphalt deck coverings (if applicable) for cracks, holes, and other damage.
___	Check ladders for rust and corrosion, broken, bent or missing rungs, and rot, termite or pest infestations.
___	Check grounding connections for tightness.
	Exposed Area Under Pier or Along Wharf or Dolphin Assembly
___	Check wood stringers, pile caps, bearing, batter and fender piles, for missing or broken members and evidence of fungal decay and insect damage. Check for loose, fractured or missing wales and chocks.
___	Check dolphins for broken, worn or corroded cables and cable connectors; and corroded, loose, broken or missing wedge block, chafing strips and bands, or chock bolt hangers.
___	Check dolphins for poor vertical pile alignment.
___	Visually examine piling and other wood in the splash and tidal zones for marine borer damage.
___	Sound the pile areas with a hammer and carefully probe with a thin-pointed tool such as an ice pick.
___	Check for pile shrinkage, overloading damage, connector corrosion, abrasion, and ice heaving damage.
___	Take a small boring for laboratory analysis using and increment borer if an area of rot or marine borer damage is in question. Once the core is extracted, seal the hole with a creosote treated plug to prevent easy access of borers to the interior of the pile.

Figure 5-11 Timber Structures and Attachments (Below Water) Checklist

___	Start at the splash/tidal zones. Note: A Level I inspection should be done first to identify areas of mechanical damage, repair and new construction.
___	Clear a section of the structure of all marine growth and visually inspect it for surface deterioration. This is done at spot locations rather than cleaning the entire structure.
___	Sound the cleaned area with a hammer and carefully probe with a thin-pointed tool, such as an ice pick.
___	If an area is in question, take a small boring for laboratory analysis using an increment borer. Plug the hole with a creosote treated plug to prevent easy access for marine borers.
___	Descend down to the pile, sounding the structure with a hammer wherever there is minimal marine growth, as well as probing carefully with an ice pick.
___	At the bottom, note and record the depth of the water on a Plexiglas® slate with a grease pencil.
___	Record visual observations, i.e., the presence of marine borers, losses of cross-sectional area, organism-caused deterioration, location and extent of damage, alignment problems, and condition of fastenings. Use calipers and scales and required.
___	Use ultrasonic techniques if internal marine borer damage is suspected. Ultrasonic techniques are available to support the underwater inspection program.
___	After finishing the underwater work, return to the surface and record all data into the inspection log. Similar procedures would be followed for timber retaining walls.

5-5 INSPECTION OF CONCRETE STRUCTURES

5-5.1 **Scoping the Problem**. Concrete damage appears in the following forms:

- Corroded rebar
- Alkali-silica reaction
- Freeze/thaw deterioration
- Abrasion wear
- Chemical deterioration from saltwater
- Overloading deterioration
- Shrinkage

These forms of damage are described in detail in Chapter 3. As with timber structures, concrete damage is found by walking the pier deck, inspecting below the pier deck in a small boat or barge, and underwater inspections.

The primary method of inspecting concrete is visual observation and sounding with a hammer. Only after problems are detected should other inspection methods be used. These other methods may include chipping away loose concrete to reveal the steel, coring, or Schmidt hammer.

5-5.2 **Surface Inspections**. Use Figure 5-12 “Concrete Structures and Attachments (Above Water) Checklist” to do a thorough inspection of all concrete structures and their attachments above water. Include annual load testing of the pier decking if heavy equipment or vehicles are to be driven onto the pier. Sampling equipment and inspection data to be compiled are given in Table 5-5.

Areas where the inspector should be particularly watchful for signs of deterioration, include:

- Inside corners and areas where radical changes occur in size of deck sections, curbs, and bollards.
- Construction joints.
- Poorly designed scuppers, drips, and curb slots, and other areas where inadequate drainage exists.

- Joints between the deck and pile cap, expansion joints where insufficient gap is allowed, and rigid joints between precast piles and cast-in-place pile caps.

Table 5-5 Sampling Equipment, Measurements and Ratings for Concrete Structures

Special Sampling Equipment	Measurement, Ratings or Samplings
Half-cell potential measurements	Location and size of damaged area
Schmidt hammer	
Hammer	
Chipping tool	Depth of chips, cracks, spalls, etc. Powder samples for chloride contamination
Concrete-core rotary drill	Drilled concrete cores for laboratory analysis
Pachometer	Rebar locator

The inspector should be alert for any change in appearance of the concrete surface and any change in the sound from the hammer:

- Erosion of the surface material or by cracking on the surface are signs of chemical attack.
- Erosion of surface material is a sign of freeze-thaw deterioration.

Use a hammer or gad (sharp pointed tool) to chip or probe the surface to detect the depth of deterioration.

Corrosion of the reinforcement can be detected from rust stains on the surface. More advanced stages of corrosion is indicated by cracks that run parallel to the steel reinforcing bars. At times, corrosion is hidden from view, but will be indicated by a hollow sound from the hammer. This can occur on heavily reinforced slabs, such as pier decks, where the reinforcement has corroded enough to delaminate a layer of concrete at the level of the reinforcing mat.

Figure 5-12 Concrete Structures and Attachments (Above Water) Checklist

Deck Area	
___	Check horizontal and vertical alignment
___	Check for missing, broken, or loose connections, obstructions and other hazardous conditions of curbs, handrails and catwalks.
___	Check bollards, bits, cleats and capstans for wear, breaks, rough or sharp surfaces or edges, and missing or loose bolts.
___	Check deck drains and scuppers for loose, missing or broken screws, water ponding and other deficiencies.
___	Check manhole covers and grating fro rust, corrosion, bent or worn hinge pins, and other damage.
___	Inspect concrete deck surface, curbs, utility trenches and gallery areas for cracks, spalling, loose joint sealers, and other damage. Closely inspect for corrosion of reinforcing steel and visual signs of rust.
___	Check ladders for corrosion, and broken, bent or missing rungs.
___	Check grounding connections for security
Exposed Area Under Pile or Along Wharf or Dolphin Assembly	
___	Check pile caps and bearing, batter and fender piles for damaged or broken members, cracks and spalling of concrete, rust stains, and exposed reinforcing steel.
___	Check for efflorescence, and general disintegration of the underside of pier decking and pile caps (Figure 5-13).
___	Check bottom scouring or undermining.
___	Check for evidence of shrinkage, swelling, and chemical deterioration; freeze/thaw deterioration; abrasion wear; and overload damage of piles as shown in Figure 5-14.
___	Sound the piling or structure with a hammer to detect any loose layers of concrete or hollow spots. A sharp ringing noise indicates sound concrete. A soft surface will be detected, not only by a sound change, but also by the change in the rebound, or feel, of the hammer. A thud or hollow sound indicates a delaminated layer of concrete, most likely for corrosion of steel reinforcement.

Figure 5-13 Inspection Areas for Visual Indications of Concrete and Reinforcement Deterioration

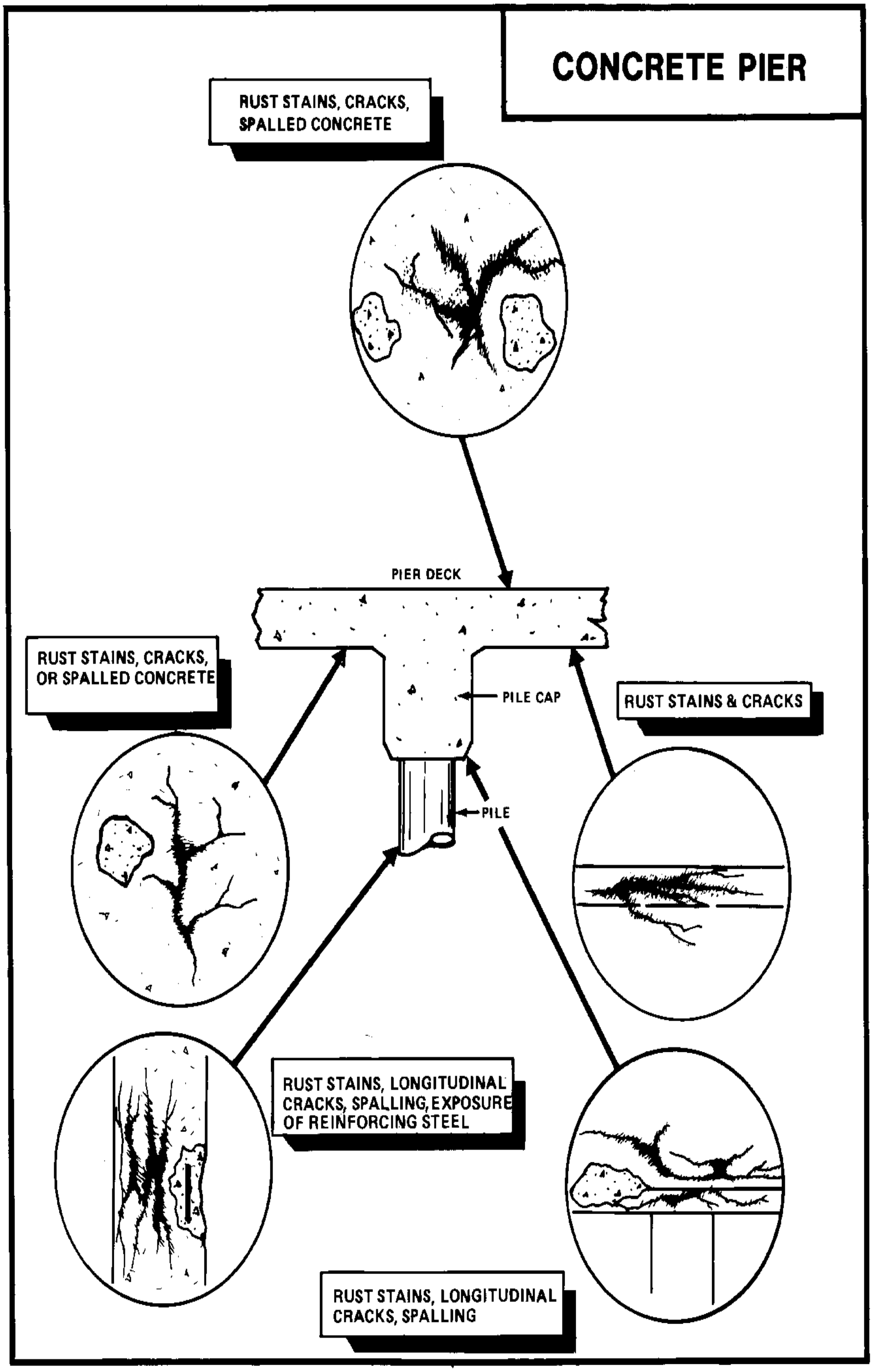
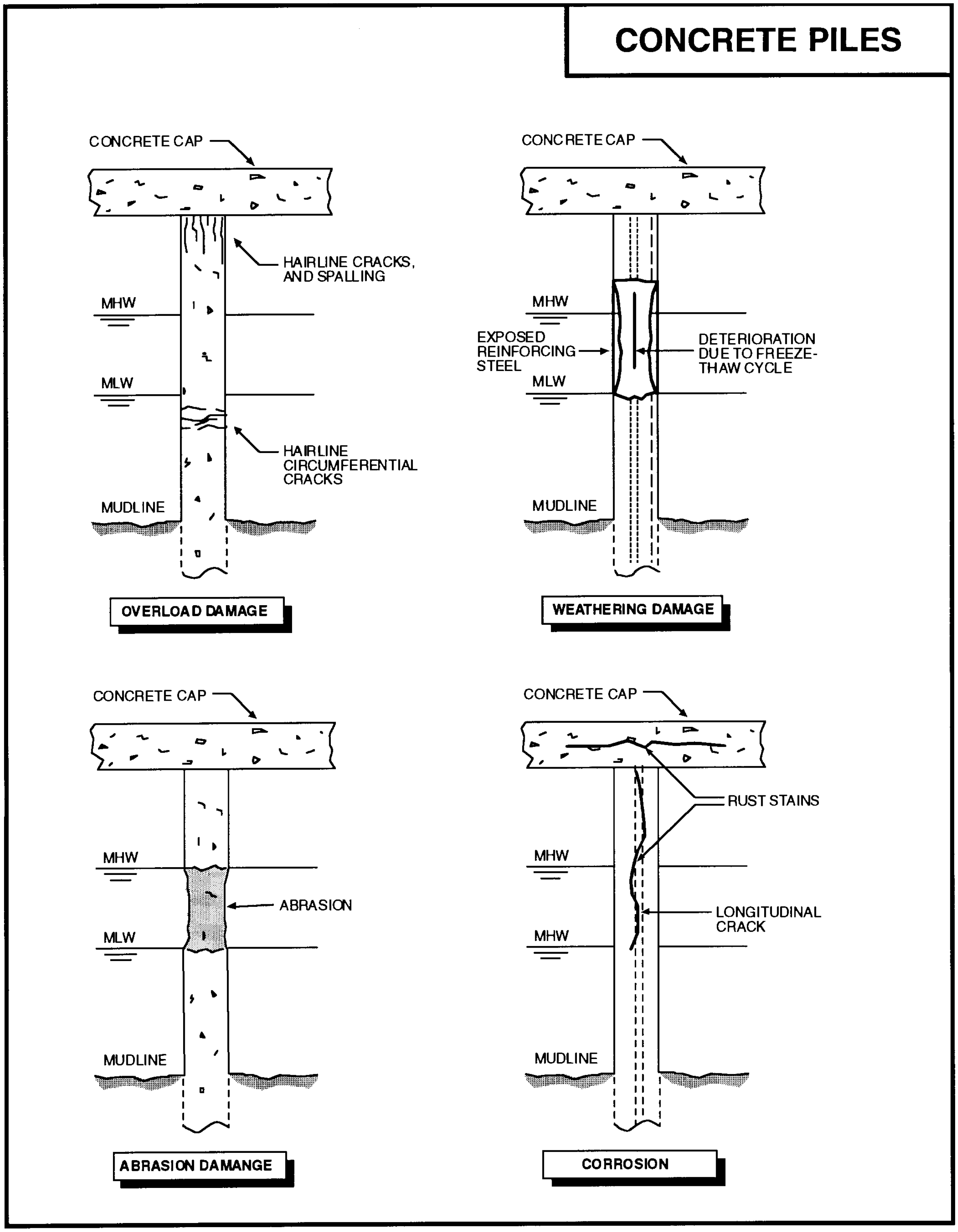


Figure 5-14 Typical Damage to Concrete Piles from Non-Biological Sources



Give special attention to cracks found on the surface of a concrete structure. Make sketches that show the length and direction of the cracks. Overall cracking patterns and changes in crack length, width and direction with time are meaningful data to a structural engineer. Photographs are helpful, but only as a supplement to the sketches.

If there is evidence of significant deterioration, more detailed NDT techniques may be used in a scheduled Level III inspection. Refer to the Level III test procedures for concrete inspection for mechanical and electrical test methods in the Paragraph entitled, “Level III Test Precedures for Concrete Inspection”. The plan and sampling techniques shall be tailored to the specific areas of concern.

5-5.3 **Underwater Inspection**. Use Figure 5-15 “Concrete Structures and Attachments (Below Water) Checklist” to ensure that a thorough inspection of all concrete structures and their attachments below water is done. An engineer should explain to the diver exactly what should be looked for: number and size of piles, type and depth of bulkheads. The engineer will evaluate the diver’s observations and determine the degree of corrosion.

5-5.4 **Level III Test Procedures for Concrete Inspection**. If signs of deterioration or damage are found by Level I or II inspections then a Level III inspection, involving either nondestructive or destructive tests, may be required. Level III concrete inspections use mechanical and electrical test methods.

Mechanical and electrical test methods include:

- The Schmidt test hammer may be used in order to compare the relative surface quality of concrete at different locations on the same structure. The instrument measures the hardness of concrete surfaces by the extent of rebound of a spring-loaded steel plunger in a tubular frame. The relative surface quality of the concrete, which is also an indication of its compressive strength, can be obtained. Surface texture may reduce values obtained.

- Core samples are destructive in nature and should only be used if other techniques cannot satisfactorily define the damage. Core samples may be taken from selected areas in order to determine the cause and depth of deterioration, chloride, ion contamination for petrographic analyses, and the actual compressive strength. Take special care when setting up to drill a core, in order to avoid hitting steel reinforcement, especially prestressed steel. Steel reinforcement near the surface can be located by using a pachometer (rebar locator). The length of the core sample should be twice the diameter. After the core has been taken, patch the hole with non-shrink cementitious mortar.

Figure 5-15 Concrete Structures and Attachments (Below Water) Checklist

___	Inspect the structure beginning in the splash/tidal zone. This is where most mechanical and biological damage is normally found.
___	Clear a section about 16 to 24 inches (40 to 60 cm) in length of all marine growth.
___	Visually inspect this area for cracks with rust stain, spalling or impact damage, and exposed reinforcing steel.
___	Sound the cleaned area with a hammer to detect any loose layers of concrete or hollow spots in the pile or structure. A sharp ringing noise indicates sound concrete. A soft surface will be detected, not only by a sound change, but also by a change in the rebound, or feel, of the hammer. A thud or hollow sound indicates a delaminated layer of concrete, most likely from corrosion of steel reinforcement.
___	Visually inspect the pile or structure where marine growth is minimal, and sound with a hammer.
___	Inspect, in greater detail, the base of mass concrete structures, such as retaining walls and foundations. These structures are prone to undermining by wave and current action, which, if not rectified, could lead to failure of the structure.
___	At the bottom, record the water depth along with any observations of damage on a Plexiglas® slate.
___	After returning to the surface, immediately record all information into the inspection log.

- ASTM C876*, Corrosion Potentials of Uncoated Reinforcing Steel in Concrete* can be used to determine the extent of active corrosion and the degree of susceptibility of corrosion in other areas in the structure. Corrosion can be detected before visible signs appear. The method detects corrosion by measuring the electrical potential of the steel. An electrical connection is made from one side of a voltmeter to an embedded steel-reinforcing bar that has been exposed. The other side of the voltmeter is connected to a copper sulfate half-cell, which is then put in contact with the concrete surface at various locations. The magnitude and sign of the resulting voltage is an indication of corrosion activity.

- Ultrasonic methods are available to inspect concrete for voids that cannot be seen, such as honeycomb pockets, and for internal deterioration by cracking. Pulse velocities and fundamental frequencies are imposed in the concrete structure to search for imperfections. Sonic methods conducted at specific time intervals can monitor progressive deterioration. Interpretation of data is a highly specialized skill.

Before starting any of the above tests, a test plan must be prepared and the areas to be tested must be cleaned thoroughly.

5-6 INSPECTION OF STEEL STRUCTURES

5-6.1 **Scoping the Problem**. There are six major types of steel structure deterioration to watch for in the marine environment:

- Corrosion
- Abrasion
- Loosening of structural connections
- Fatigue
- Overloading
- Loss of foundation material

The causes and forms of steel deterioration are described in detail in Chapter 3.

5-6.2 **Surface Inspections**. Generally, visual inspections will detect most forms of deterioration of steel structures. Use Figure 5-16 “Inspection of Steel Structures (Above Water) Checklist” to ensure a thorough inspection of steel structures above water is done. In the event that more detailed NDT techniques are required under a Level III inspection, a plan and sampling techniques must be developed and tailored to the specific areas of concern.

Some types of corrosion, however, may not be detected by visual inspections. For example, inside steel pipe piling, anaerobic bacterial corrosion caused by sulfate-reducing bacteria (Figure 5-17) is difficult to detect by visual inspection. Fatigue distress can be recognized by a series of small hairline fractures perpendicular to the line of stress but these are difficult to locate by visual inspection. This type of problem, however, is more prevalent to offshore platforms with welded structural connections than to standard piers and wharves.

Cathodic protection systems need to be closely monitored both visually and electrically for signs of loss of anodes, wear of anodes, disconnected wires, damaged anode suspension systems, and low voltage.

Table 5-6 summarizes special sampling equipment, measurements required, and ratings used in the inspection of steel structures.

Table 5-6. Inspection Equipment, Measurements, and Ratings of Steel Structures

Special Sampling Equipment	Measurements, Ratings, or Samplings
Scale or calipers for deter-mining thickness	Metal thickness
Ultrasonic equipment for determining thickness	Deformation of structural members Cathodic protection potentials
Voltmeter and half-cell for measuring electronic potentials on cathodically protected steel	Location and size of damaged areas
Pit Gauge	Depth of pits and extent of their occurrence.
Scraper	Samples of corrosion products or damaged coatings

5-6.3 **Underwater Inspections**. Use Figure 5-19 “Under Water Steel Structures Checklist” to ensure that a thorough inspection of underwater steel structures is done. An engineer should explain to the diver exactly what to look for: number and size of piles, type and depth of bulkheads. The engineer shall evaluate the diver's observations and determine the degree of hazard.

Figure 5-16 Inspection of Steel Structures (Above Water) Checklist

	Deck Area
___	Refer to either Timber Structures (Figure 5-10) or Concrete Structures (Figure 5-12) Surface inspection Checklist, depending on construction.
	Exposed Area Under Pier or Along Wharf
___	Check for corrosion evidence: rust, scale and holes, in H-piles and sheet piling, especially in the splash zone and approximately 24 inches (60 cm) below mean water low water (Figure 5-17).
___	Sound the surface with a hammer to detect any scaled steel or hollow areas.
___	Indicate the location, extent and type of corrosion (density pitting, etc.) found.
___	Check for loosening of structural connections as indicated by misalignment of mating surfaces and by looseness or distortion of structural members
___	Check for deformation or distortion of a structural member in the form of a sharp crimp, or compression of a bearing or batter pile (Figure 5-18). This indicates possible overloading.
___	Check for deflection of steel sheet piling caused by failure of tiebacks or overload of backfill or live load.
___	Check for abrasion of steel structures as indicated by a worn, smooth, polished appearance.
___	Check for loss of foundation material caused by scour of materials from around the piles supporting the structural element (Figure 5-18). A loss of foundation material in front of a sheet pile bulkhead may cause kick-out of the toe of the wall and result in total failure.
___	Inspect welds for signs of corrosion, cracking or looseness.
___	Inspect coating or wraps for any peeling, blistering, erosion, tears, etc.
___	Inspect holes in steel sheeting for loss of backfill material through the opening and subsidence of adjacent ground surface.

Figure 5-17 Corrosion Damage to Steel Bearing and Sheet Piling

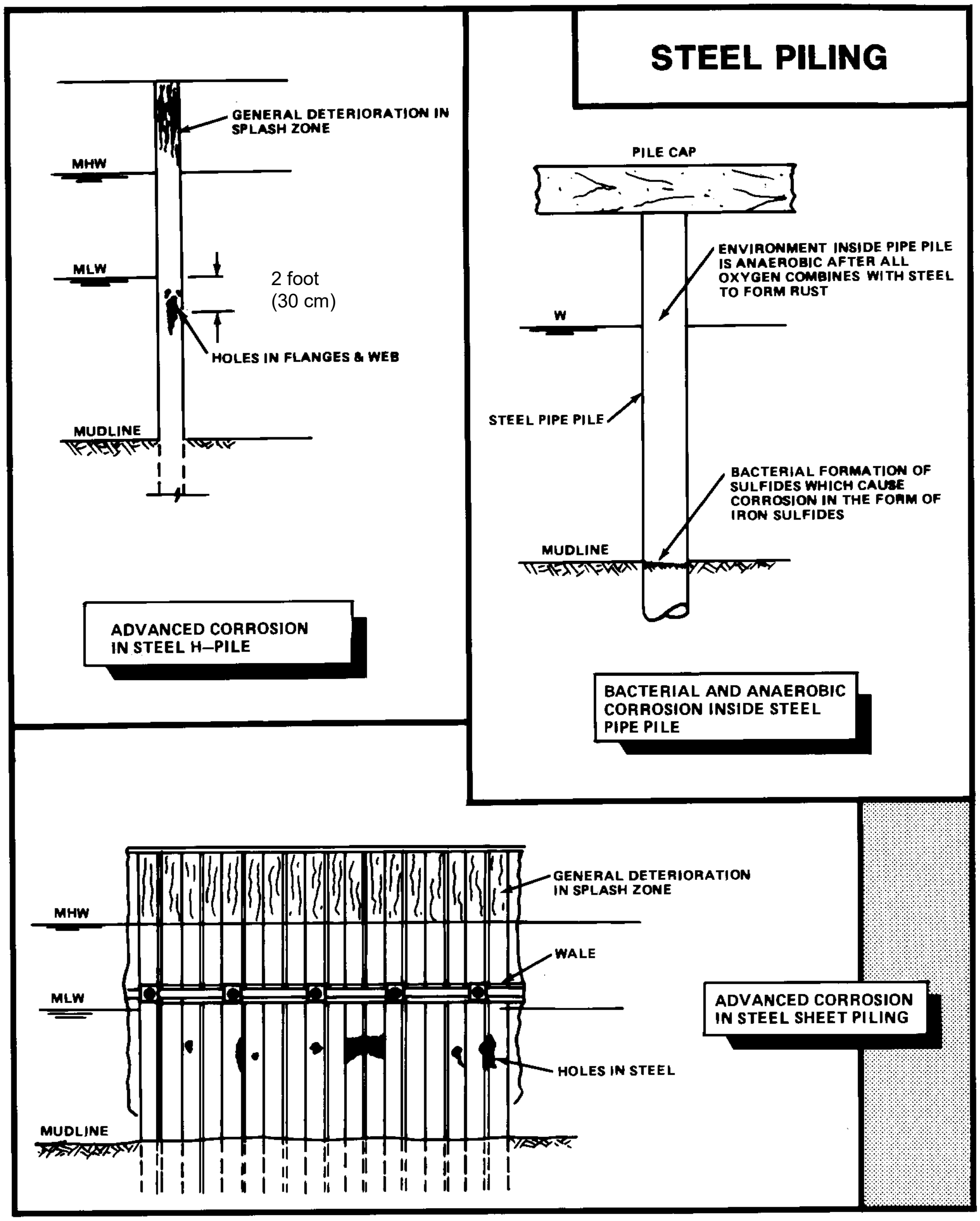


Figure 5-18 Damage to Steel Bearing and Sheet Piles from Overloading, Wall Movement or Scour.

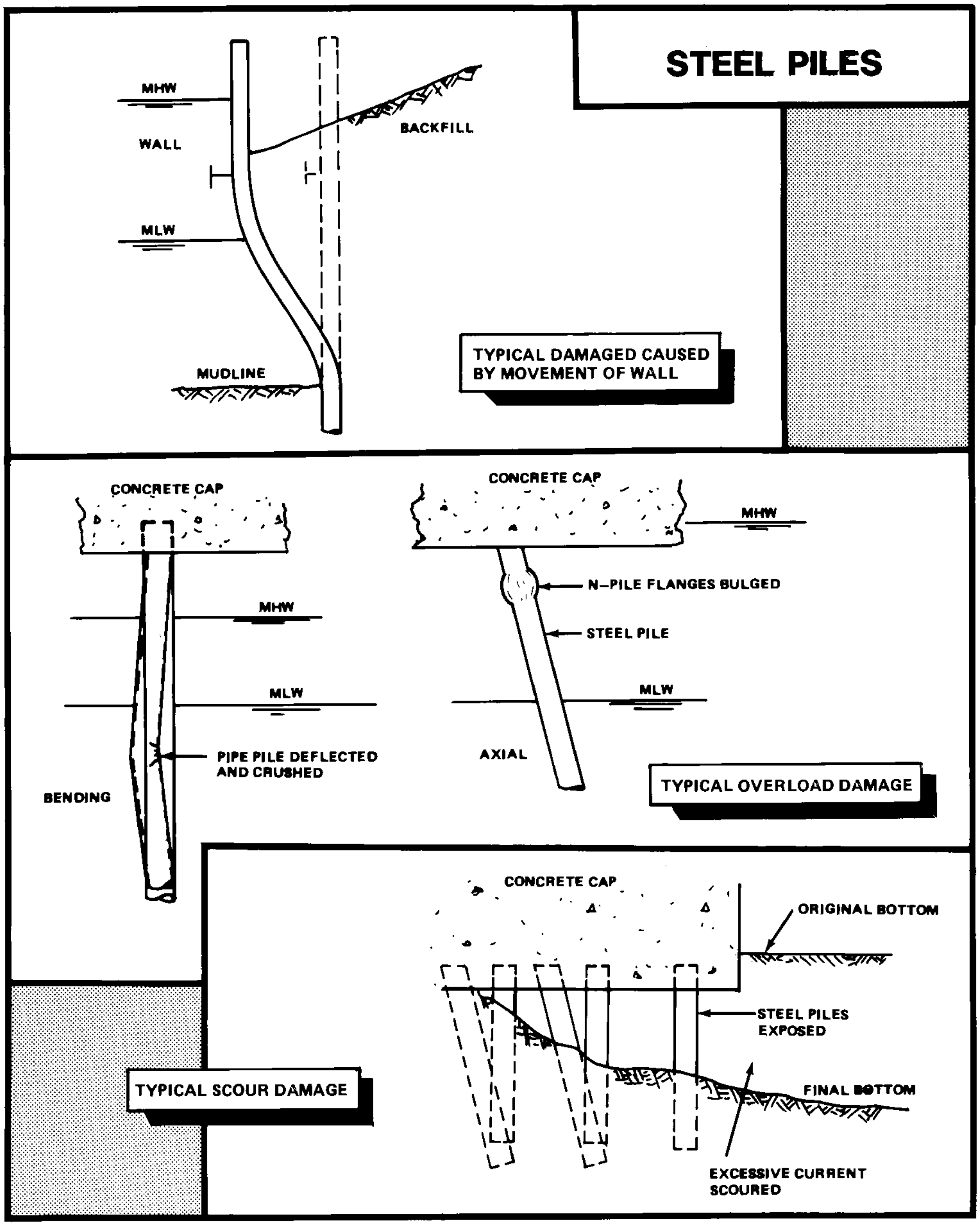


Figure 5-19 Underwater Steel structures Checklist

___	Start the inspection at the splash/tidal zones and at depth of about 24 inches (60 cm) below mean low water (MLW). This is where most mechanical and corrosion damage is found.
___	Clean all marine growth from a 12 inch (30 cm) square section of pile (clean a larger area if inspecting sheeting) and visually inspect for rust, scale and holes.
___	If the structure has a cathodic protection system, check the cleared area with an underwater voltmeter to determine its effectiveness. Acceptable levels of cathodic protection are between -0.80 to -0.90 volts when compared to a silver/silver chloride reference cell.
___	Sound the surface with a hammer to detect any scaled steel or hollow areas. Inspect holes in steel sheeting for loss of backfill material through the opening and subsidence of adjacent ground surface.
___	Visually inspect the structure and sound with a hammer where there is minimal marine growth.
___	At the bottom, record the water depth, using a wrist depth gauge, on a Plexiglas® slate with a grease pencil.
___	Record other visual observations, such as coating condition (peeling, blistering, erosion). Closely inspect splices for loss of weld materials and looseness of splices.
___	Record the condition of cathodic protection equipment (broken or corroded conduits, loose wires, consumed or lost anodes).
___	Record the extent and type of corrosion, structural damage, or any other significant observations, using calipers and scales to determine thickness of steel flanges, webs and plates.
___	Return to the surface and immediately record the observation data in the inspection log.
___	If more sophisticated means are required to evaluate the condition of steel piling, ultrasonic inspection is available for more complete thickness measurements. These measurements must be made in areas clear of all marine growth and scale. Using ultrasonic equipment in areas with corrosion pitting can give erroneous thickness measurements. Magnetic particle inspection may be used, particularly on welded connections, to detect cracks and small defects.

5-7 **INSPECTION OF SYNTHETIC MATERIALS AND COMPONENTS**. Inspection of synthetic materials and components is subdivided into the following three categories:

5-7.1 **Structural Members**. Structural members should be inspected annually. The inspection should detect:

- Cracked, worn, brittle, or deformed plastic railings, stanchions, gratings, light standards, or piping; loose or damaged fittings and connections; and exposed fiberglass.
- Cracked, worn, or deformed rubber resilient fender components, and/or loose or damaged fittings and connections.

Basic inspection procedures are the same as those outlined for timber or concrete structures.

5-7.2 **Coatings, Patches and Jackets**. Coatings, patches, and jackets should be inspected annually, or more frequently, depending on the failure rate of the application. The inspection should detect:

- Pits, cracks, scars, or abrasions in coatings.
- Cracked, loose, or dislodged epoxy patches.
- Punctures, brittleness, tears, rips, or abrasions in fabric, or unlocking of fabric seams in pile jackets.

Basic inspection procedures are the same as those outlined for timber, concrete, and steel structures.

5-7.3 **Foam-Filled Fenders**. Foam-filled fenders should be inspected more than normal pier inspections and should cover:

- Condition of the fender-to-pier connection hardware. Check for operability and signs of corrosion. Check to ensure that the fender is constrained horizontally so that it contacts the bearing surface for its full length. Ensure that the fender is free to vertically float with the tide and rotate around its long axis.
- Condition of the fender chain and tire net for net fenders. Check to see that the chain is symmetrical on the fender and that the end fittings are in good working order. Ensure that the chains are protected from the ship hull by the tires, and that the net is not loose.

- Condition of end fittings on netless fenders. Check to see that the fittings are in good working order, and corrosion is minimal. Check to see that the fender shell is not cracked or separated around end fittings.

- Condition of the fender elastomer shell. Check for cuts, tears, and punctures. Record the size and location of damage on a sketch.

- Measure or estimate the diameter of the fender at its smallest point to record permanent set.

Inspections will be done by walking the pier and using a small boat.

Record keeping for foam-filled fenders is very important. In this regard, the fenders should be treated as an item of high-cost equipment rather than an appurtenance to a fixed facility. Each fender should have a unique identification number with a history record that includes date of procurement, manufacturer, date of installation or when fender was put into service, and berth location if permanently installed.

5-8 **INSPECTION OF QUAYWALLS**. Quaywalls are an integral part of wharves and should be included when other pier components are inspected.

Deterioration of quaywalls is indicated by:

- Shifts in horizontal and vertical alignment of sheet piling.

- Damage or deterioration of the wood, concrete, or steel sheet piling.

- Wash-out of substrate under the sheet piling, particularly at the toe of the structure.

Alignment shifts can be detected by visual observation. A complete description of shifts and any apparent cause should be provided. Deterioration of wood is covered by the Paragraphs entitled, “Inspection of Timber Structures”, Inspection of Concrete Structures” and “Inspection of Steel Structures”. Wash-out may be detected by visual inspection in clear water at low tide. If not, then an underwater inspection is required. Figure 5-20 “Quaywall Surface and Underwater Inspection Checklist,” is a useful guide.

Figure 5-20 Quaywall Surface and Underwater Inspection Checklist

___	Swim around the base of the structure looking for weaknesses in the base of these structures, e.g., washout of small stones and core material.
___	Note signs of detrimental wave action, e.g., scouring and sloughing.
___	Record all pertinent information on a Plexiglas® slate and transfer the information to the inspection log.
___	Record the result of the above water inspection, which should include a description of the alignment and general condition of the seawall.

5-9 **THE INSPECTION REPORT**. For each inspection, a report is prepared. The report includes facility plans with updated descriptions, such as: size and pile arrangement, an evaluation of the assessed conditions, and recommendations for further action. The report should provide enough technical detail to support the assessments and recommendations. The Paragraph entitled, “Planning for Inspection” provides guidance for preparing inspection documentation to be used in preparing the report.

NAVFAC MO-322, *Inspection of Shore Facilities* calls for a three-part inspection report package for shore facilities consisting of a: facility inspection checklist, facility condition summary report sheet, and facility condition detailed deficiency list. Forms for these three sections are shown in Chapter 4, Volume 1 of MO-322. They are, however, geared more for inspecting buildings and are not specifically designed for waterfront structures.

Since waterfront inspections are specialized, a report format such as the one presented in Table 5-7 would be more appropriate. This format is used by NFESC \1\ /1/ when conducting underwater inspections and assessments at Naval waterfront facilities.

Table 5-7. Report Format of Underwater Inspections and Assessments

Report Cover

Title Page

Executive Summary

Executive Summary Table

Table of Contents

List of Figures

List of Photographs

List of Tables

Body of report:

Section 1: Introduction

1.1 Background/ Objectives

1.2 Inspection Exit Briefing

Section 2: Activity Description (Information that affects inspection, repair, rate of deterioration, etc.)

2.1 Location

2.2 Existing Waterfront Facilities at Activity

2.3 Waterfront Facilities Inspected

Section 3: Inspected Facilities

3.1 Name of Facility

3.1.1 Description of Facility

3.1.2 Observed Inspected Condition

3.1.3 Structural Condition Assessment

3.1.4 Mooring Hardware Assessment (Note 1)

3.1.5 Recommendations

Repeat the above as necessary for each facility

Appendices

A - Key Personnel

B - Inspection Procedure/Level

C - Structural Data

D - Pertinent Background Information

E - Calculations for Structural Assessment

F - Backup Data for Cost Estimates

G - Cost Estimate Summary

H - References

Note 1: With increased emphasis on Heavy Weather Mooring, pay particular attention to mooring hardware, i.e. type, location, strength, capacity of cleats, bitts and bollards.

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CHAPTER 6

REPAIR OF WOOD AND TIMBER STRUCTURES

6-1 **GENERAL.** The most common uses of wood and timber structures in waterfront facilities involve:

- Older piers, wharves, bulkheads, and quaywalls constructed from dimension lumber, beams and stringers, and round timber piles.
- Fender systems constructed from beams and stringers and round timber piles
- Pile dolphins constructed from round timber piles.
- Log floats and camels, glued and laminated wood, and miscellaneous forms.
- Degaussing facilities that require using nonmagnetic construction materials.
- Groins constructed from beams and stringers and round timber piles.

With the exception of fender systems, floats and camels, most systems have been installed for several decades, in many cases dating back to World War II.

The need to conduct an effective repair program for these facilities is essential if the facilities will continue to be used and if escalating costs of repairs are to be avoided. Postponing the repairs, particularly for bearing piles, can lead to costly replacement or downgrading of the structural capacity of the facility.

6-1.1 **Repair Methods.** Repair methods for wood and timber structures are generally directed at correcting one or more of the following problem areas: fungal decay, insect damage, marine borer deterioration, abrasion, and overload.

The repair methods to be used must consider the following elements.

- Facility mission and required life.
- Extent of damage and deterioration.
- Estimated life expectancy with and without repairs.
- Projected load capacities.

- Problems associated with mobilization of equipment, personnel, and materials to accomplish repairs/maintenance.

- Economic trade-offs.

6-2 **REFERENCES**. Materials used to develop repair techniques and planning factors outlined in this section have been taken, in part, from:

- Scheffer, T.C., *Observations and Recommendations Regarding Decay in Naval Waterfront Structures*, Forest Products Laboratory, September 1966.

- Morrell, J. J. and et. al, *Marine Wood Maintenance Manual: A Guide for Proper Use of Douglas-fir in Marine Exposures*, Forest Research Lab, Oregon State University Research Bulletin 48, October 1984.

- Childs Engineering Corp., *Survey of Techniques for Underwater Maintenance/Repair of Waterfront Structures*, Revision No. 1, for the Naval Civil Engineering Laboratory, December 1985.

- \1\ Southern Forest Products Association /1/, *Marine Construction Manual: A Guide to Using Pressure-Treated Southern Pine in Fresh and Saltwater Applications*, October 1994.

6-3 **PLANNING THE REPAIRS**. Repairing timber structures will be controlled by the availability of skilled personnel and equipment. In many cases structural repairs, particularly those involving bearing and sheetpiling, will be done by contract.

6-3.1 **Reviewing Inspection Reports**. The initial planning step must involve a review of prior inspection reports to determine the scope and rate of damage or deterioration, and specific operational constraints placed on the facilities because of the deterioration. Once the scope of repair requirements (including priorities) is established, determining how to do the repairs (whether in-house or by contract) must be determined.

6-3.2 **Engineering Considerations**. Any repair of structural members will require experienced design professionals with knowledge of local tidal conditions, building codes, materials, substrate analysis, and construction practices.

6-3.3 **Special Skill Requirements**. Surface repairs covering pier decking, string pieces, stringers, pile caps, braces, and fender piles require skills common to the wharf-building trade. Underwater repairs, however, require special skill levels that may not be available with in-house forces. This includes how to remove marine growth, jetting or air lifting procedures, underwater cutting and drilling techniques, and jacketing and wrapping materials used in underwater construction.

6-3.4 **Equipment Requirements**. Surface repairs to the pier superstructure and fender system require equipment common to in-house shop forces. Equipment for underwater repairs, however, may include:

- High-pressure water blaster
- Hydraulic grinders with barnacle buster attachment
- Hydraulic drill with bits
- Hydraulic power unit
- Hydraulic chain saw
- Concrete pump with hosing
- Jetting pump and hose
- Rigging equipment
- Float stage and scaffolding
- Clamping template for cutting piles
- Special clamping equipment
- Crane

6-4 **REPAIR PROCEDURES.** Repair procedures for waterfront wood and timber structures are summarized in Table 6-1. Using any of the repair techniques that follow should adhere to the preservation treatment requirements outlined for wood and timber structures in Chapter 3.

Every effort should be made in rafting and handling to prevent damage to treated piles and timbers, particularly in portions of the work exposed to marine borer attack. Care should also be taken in driving piles to prevent checking or splitting of the treated wood, and butts shall be trimmed and headed so that the hammer will strike only untreated wood. Piles and timbers should be inspected before and during the time they are driven or placed. Where the protective preservative shell is broken or damaged in any way, the holes or crevices should be repaired by drilling, and neatly and tightly plugged in accordance with AWPA Standard \1\ U1 /1/. Where abrasions or other damages cannot be sealed against marine borers, other protection must be provided in an approved manner. All piles shall be handled in accordance with AWPA Standard \1\ U1 /1/.

Table 6-1 Repair Techniques for Wood and Timber Structures

Repair No.	Description
PIER SUPERSTRUCTURE AND FENDER SYSTEMS	
TR-1	Repairing timber pier superstructure
TR-2	Repair by replacing timber fender pile and damaged chocks and wales
BEARING PILES	
TR-3	Protecting timber piles with Polyvinyl Chloride Polyethylene Wrapping
TR-4	Partial posting of damaged pile with concrete encasement
TR-5	Repairing timber piles with concrete encasement
TR-6	Repair of retrofit timber piles with an underwater curing epoxy and fiber-reinforced wrap
TR-7	Replacing damaged pile with new timber pile under timber pier deck
TR-8	Replacing damaged pile with new concrete pile under concrete deck
TIMBER SHEET PILING WALLS	
TR-9	Reinforcing tie-back system for timber sheet piling wall
TR-10	Installing a tie-back system on the top of a timber sheet piling wall
TR-11	Installing a concrete cap / face on a timber sheet piling wall
DOLPHINS	
TR-12	Repair of dolphins

6-5 **ENVIRONMENTAL CONCERNS**. Federal environmental regulations allow the use of treated wood in the marine environment. A possible exception is the sheen created when creosoted piling is driven but this can be mitigated. Wood preservatives are EPA-registered pesticides and treated wood products for the marine environment will be widely available for the foreseeable future. Treated wood removed from service is not a hazardous waste and is not banned by Federal law from landfills.

Local and state environmental regulations, especially along the west coast, have restricted the marine use of treated wood. In some cases, where there is cause for environmental concern, conduct a site-specific risk assessment before starting on a project that involves installing a large amount of treated wood in the marine environment.

The handling of treated wood removed from service should be considered as an important part of any repair project. Discarded treated wood may generally be disposed at municipal landfills approved to receive the material by the state or local authorities. Some non-hazardous waste landfills, however, may classify treated wood as a “special waste” and require documentation of its status. Reuse of treated wood is a preferred option and is not currently regulated by Federal law, provided such reuse is consistent with the intended end use. Examples of reuse include fence posts, retaining walls, landscaping, decking, bulkheads, general construction, etc. Energy recovery may be an option if there is a facility relatively near that uses treated wood waste as a fuel. Bioremediation is another option that is encouraged, but is not yet widely available.

Since potential restrictions can vary widely with locale and can change, contact your Environmental Office before using, recycling, or dispersing of treated wood.

6-6 **QUALITY ASSURANCE CONCERNS.** In the recent past, Navy activities have too often accepted and used treated wood products that did not meet industry standards. This has resulted in poor performance and costly premature failure of waterfront wood structures and the perception that wood products are inappropriate for modern facilities. It is imperative that industry best management practices (BMP) be used to avoid receiving unacceptable treated wood products. These BMP include:

- Specify the appropriate material in terms of performance as defined in the \1\ American WoodProtectors Association /1/ Standards. Specify that wood treatments and handling methods comply with current industry BMP.

- Specify that treated wood be inspected by an independent agency certified by the American Lumber Standards Committee. Specify an on-site inspection before installation to assure proper lumber grades, moisture contents, and treatment standards have been met. For environmental reasons, if the treated wood does not appear clean and dry, i.e., no surface deposits, it should be rejected.

TR-1: REPAIRING TIMBER PIER SUPERSTRUCTURE

Problem: Wood components are damaged and no longer fully serve intended purpose or present a safety risk.

Description of Repair:

Decking**.** Replace decking with properly treated quarter-sawn timber or other suitable material when its top surface becomes uneven, hazardous, or worn to a point of possible failure. Spacing between decking planks is normally provided for ventilation and drainage. Blacktopping of decking may not provide a completely protective cover against rain wetting beneath it because cracks often develop in the material. Limit washing decks with freshwater as this promotes wood decay.

Pile Caps**.** Replace decayed or damaged pile caps with properly treated wood (including glulam) or other suitable material. Replacement caps should be the same size and length as the original caps unless redesigned.

Curbs, Chocks, and Wales**.** Replace these members with properly treated lumber (including glulam) or other suitable material when decay or other damage renders them unfit for service. Make butt-type joints, not lap-type joints, in connecting wood curbs and wales to reduce decay damage potential. Replacement sections should be long enough to reach a minimum of two bents. Place new preservative-treated wood blocks or other suitable material, 2 to 3 inches (5 to 8 cm) thick, under each curb (upper string piece) replacement section at intervals of about 3.3 feet (1 meter) to provide for drainage (Figure 6-1).

Braces**.** Replace diagonal braces that are broken or attacked by fungi or marine borers with wood or other suitable material. Place pressure-treated wood braces well above high water and treat all bolt holes with a preservative. An alternative to using pretreated wood is plastic barriers, either polyethylene or polyvinyl chloride plastic wraps or polyurethane coatings. The braces, with bolt holes, can be fashioned to fit and the plastic applied before the braces are attached to the pier piling. Where braces are fastened to a piling, the pile should not be cut or dapped to obtain a flush fit. Where decking has been removed for repairs, it is often possible to drive diagonal brace piles to provide lateral stiffness. This procedure eliminates all bolt holes except those at the top of the structure immediately below the decking.

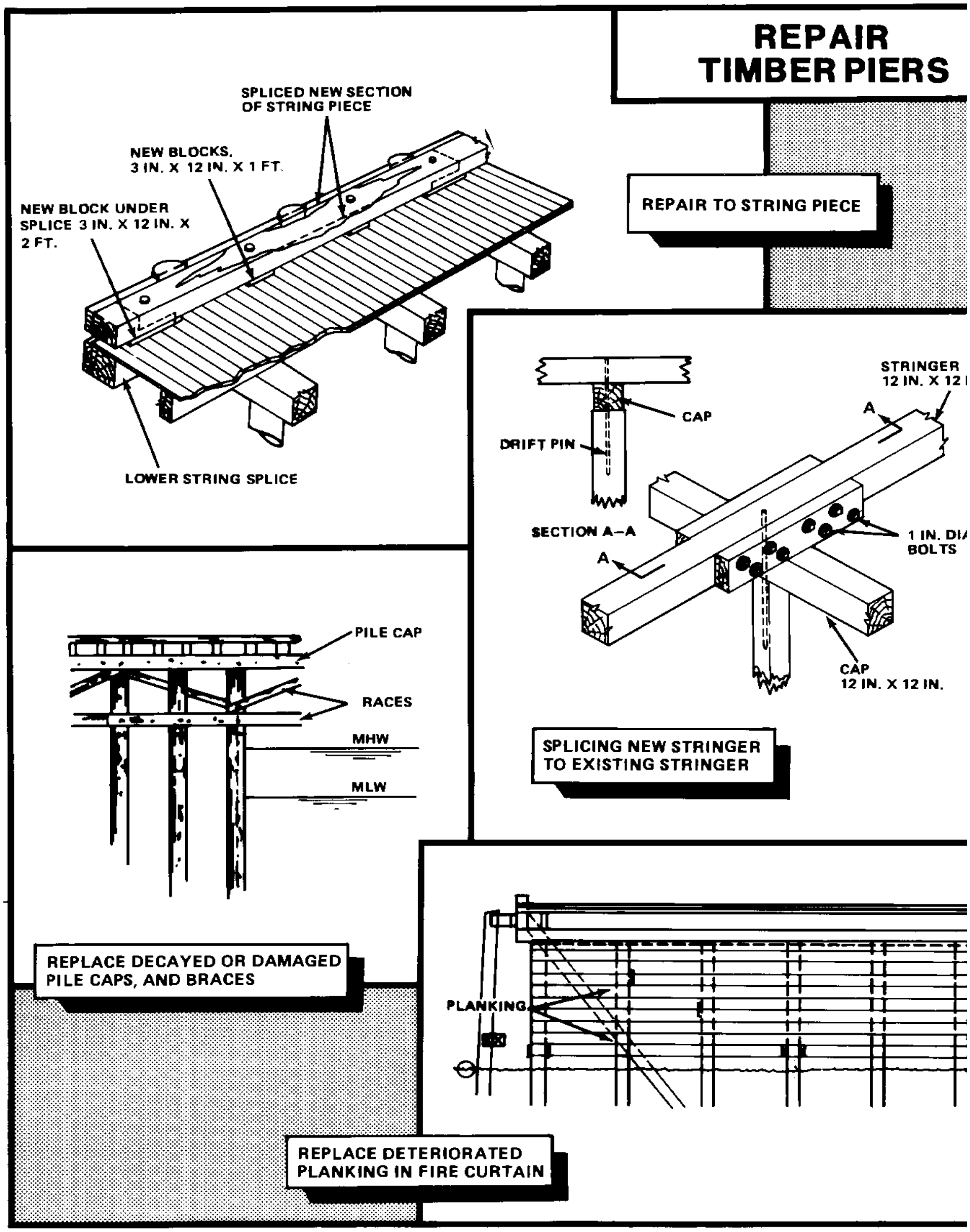
Stringers**.** Replace decayed or damaged short stringers with properly treated wood or other suitable material. Replace decayed or damaged areas of long stringers with new sections. Make connections between replacement and existing stringers directly over a pile cap and stringers. Tightly bolt or pin the stringers to the pile cap (Figure 6-1). Stagger the splices in adjacent stringers where possible. Avoid checks and splits, which promote decay, when driving deck spikes by pre-drilling small holes.

***Fire Curtain Walls*.** Wood fire curtain walls are usually made of two layers of planking that run diagonally to one another. Replace all deteriorated planks to restore the wall to its original condition - as watertight as possible. In addition, each side of the wall should be protected by automatic sprinklers or by nearby openings in the deck through which revolving nozzles or other devices can be used to form an effective water curtain.

Application: These methods are routinely used.

Future Inspection Requirements: Areas near replaced wood may be susceptible to similar damage and should receive special emphasis in future inspections.

Figure 6-1 Repairs to Timber Pier Structure



TR-2: REPAIR BY REPLACING TIMBER FENDER PILE AND DAMAGED CHOCKS AND WALES

Problem: Fender pile broken or damaged and no longer functional.

Description of Repair (see Figure 6-2): Pull and replace decayed, marine borer damaged, or broken fender piles with new piles. Consider using alternative materials instead of treated wood for the new piles. Recommend installing a steel shoe on the outer surface of each wooden fender pile.

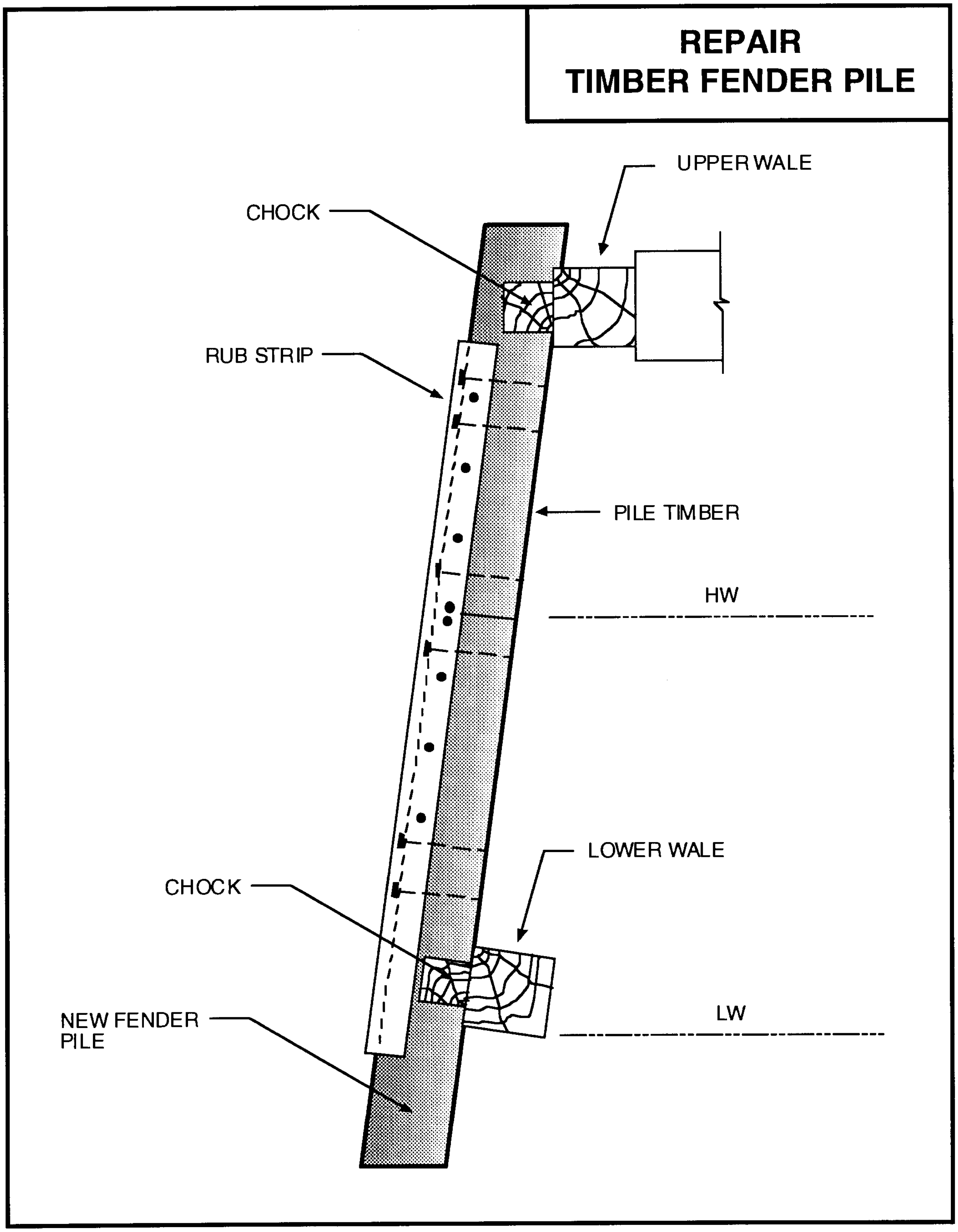
Replace deteriorated chocks with tightly fitting chocks that are bolted to one string piece or to a wale below the deck. Wood treatment requirements will be locally determined.

Replace deteriorated or damaged wales with the same size and length as the original wales unless redesigned. Wood treatment requirements for the wales will be locally determined.

Application: Repair by replacement is applicable to virtually all timber fender systems.

Future Inspection Requirement: Inspections should be based on historical records of fender pile damage.

Figure 6-2 Repair by Replacing Timber Fender Pile and Damaged Chocks and Wales



TR-3: PROTECTING TIMBER PILES WITH POLYVINYL CHLORIDE OR POLYETHYLENE WRAPPING

Problem: Either a new pile or pile butt is being installed that requires a protective covering or marine borer deterioration has been discovered in an existing pile, and further damage needs to be prevented. This method can also be used to protect untreated piling from marine borer damage.

Description of Repairs: \1\ /1/ Clean the surface of the pile to remove all sharp or protruding objects that would penetrate or deform the plastic wrapping on the pile.

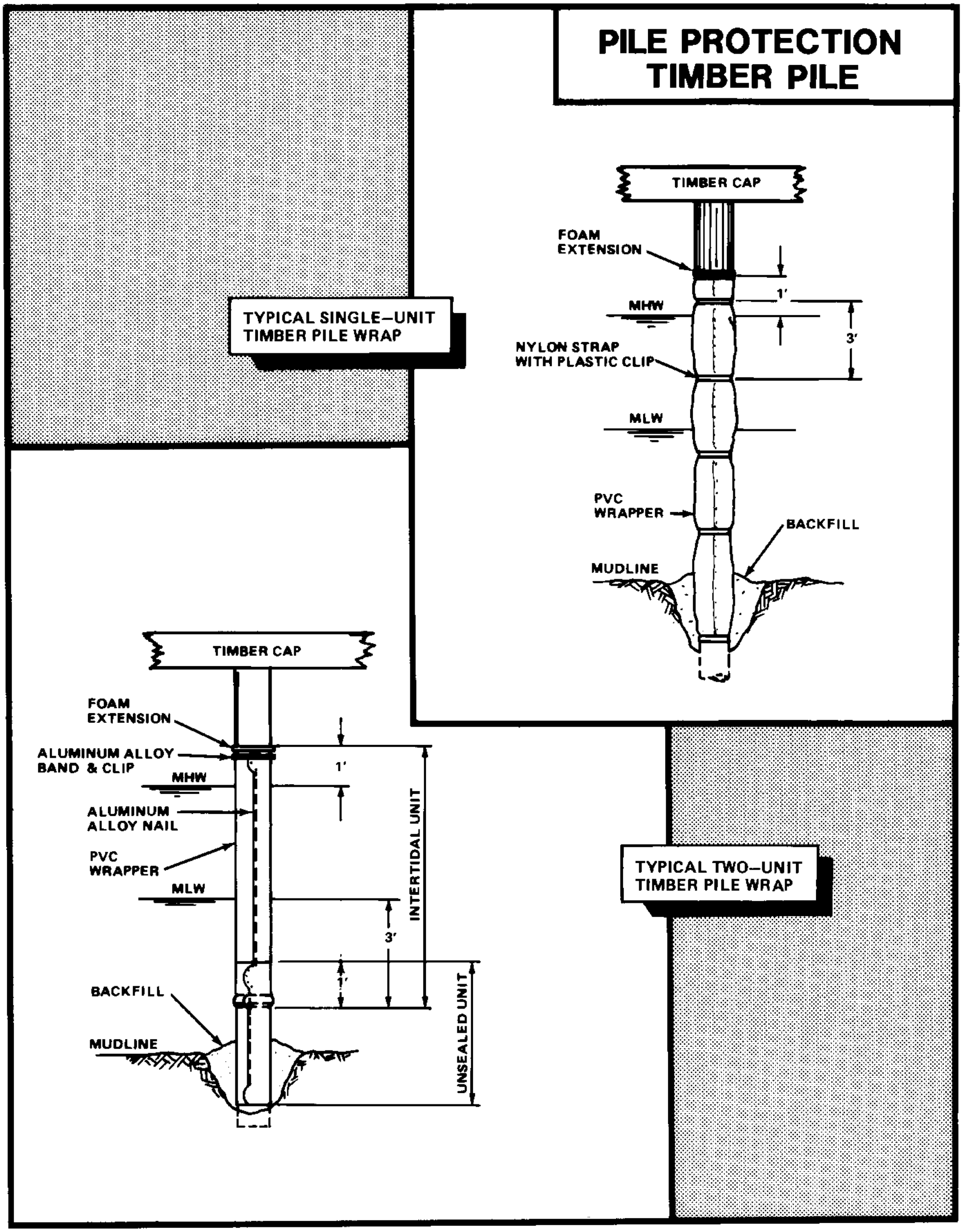
> "If a polyvinyl chloride (PVC) wrap is used on a relatively new creosoted piling, first wrap a 1.0 mm (4-mil) polyethylene sheet around the pile to protect the PVC wrap from the creosote. Install the PVC or polyethylene (PE) wrap starting with the upper intertidal unit at least 30 cm (1 foot) above mean high water (MHW). The lower units then overlap the upper units and extend below the mudline. Tighten the PVC wrap using wood poles and a ratchet wrench. Fasten the wrapper with aluminum alloy bands around the top and bottom and with aluminum alloy nails along the vertical joints (see Figure 6-3)."

Once the wrap is completed, backfill the area around the base of the pile.

Application: This method is widely used for preventing or arresting marine borer attack. It is more economical than concrete encasement or pile repair or replacement. Plastic wraps have been placed on creosoted piling in California to prevent the migration of creosote into the water, thus avoiding any environmental restrictions. Using a 150-mil (3.8 mm) polyethylene wrap in the intertidal area can provide protection against abrasion.

Future Inspection Requirement: Look for punctures or tears in the plastic wrap; any damage to wraps over untreated piles can result in rapid borer damage.

Figure 6-3 Wrapping Timber Piles with Polyvinyl Chloride



TR-4: PARTIAL POSTING OF DAMAGED PILE WITH NEW PILE BUTT

Problem: Top of pile has rotted or has major insect damage. No other major detectable deterioration of piling found.

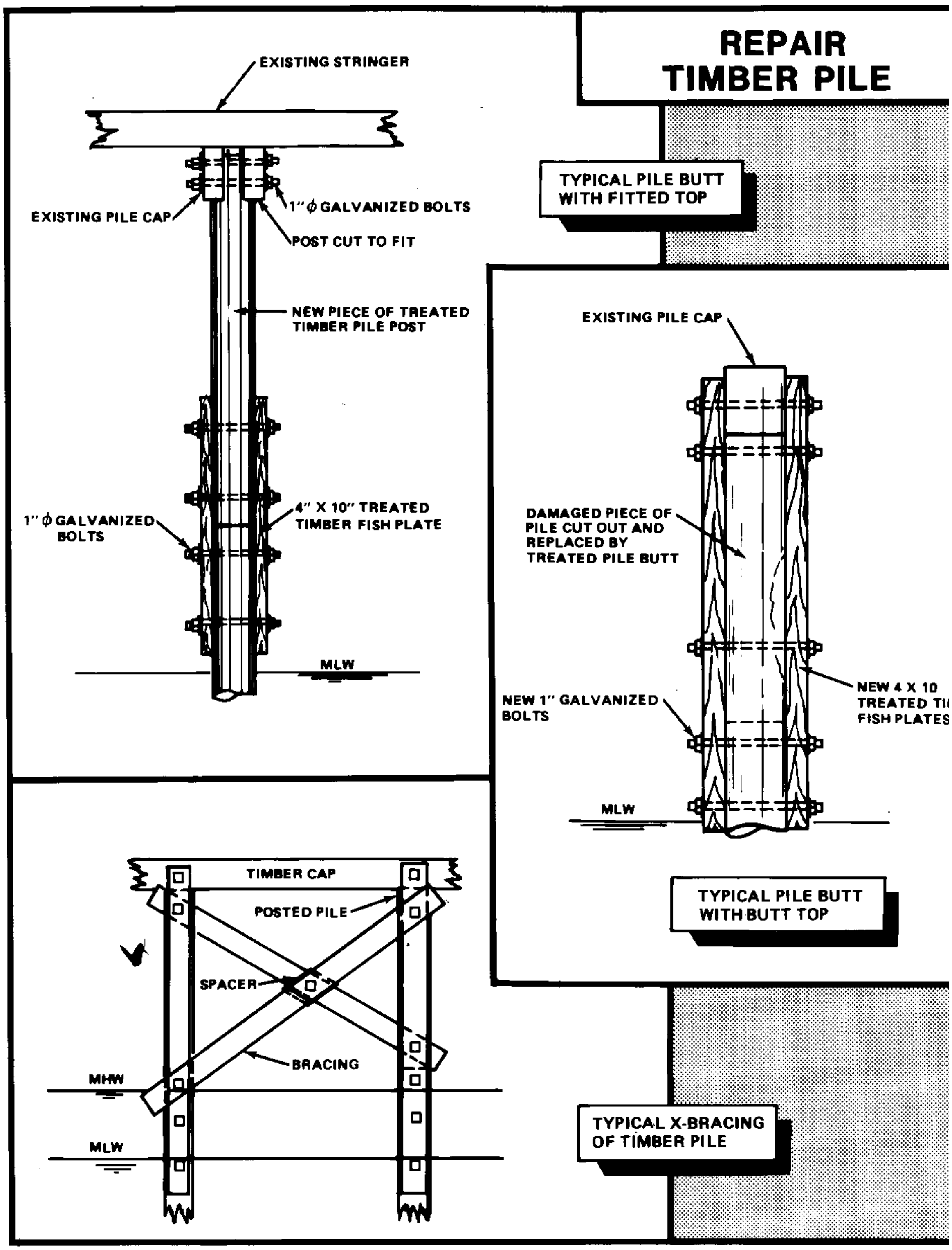
Description of Repairs: Cut the pile below the damaged, rotted, or insect infested area. Cut the pile butt to length and shape head to fit pile cap (if required). See Figure 6-4 for two methods of interfacing pile butt with pile cap. Make the joint with two pretreated timber fishplates bolted to existing pile and pile butt using 100 mil (2.55 mm) galvanized bolts. Treat the ends of all cuts with creosote. Treat bolt holes with the same wood preservative as used for the pile butt. Place shims between new pile butt head and pile cap. Bolt pile or fishplates, depending on the method selected, to pile cap.

When adjacent timber piles have been repaired using either posting or fishplating techniques, it is necessary to provide some resistance to lateral loads imposed on the structure. This can be done by installing X-bracing between piles, as illustrated in Figure 6-4. Treated timbers are fastened high on one pile and low on the adjacent pile, forming an X pattern. Where X-bracing crosses, a timber spacer should be bolted between the bracing pieces to shorten the unsupported length of span.

Application: This method works well where not many piles need repair. This method may be more expensive than replacing the pile. The cause of damage, e.g., water entrapment, must be remedied before using this method.

Future Inspection Requirement: Even with X-bracing, weak joints will exist where column buckling may occur. All splices and holes below MHW may be subject to accelerated marine borer attack. This may be offset by adding a PVC wrap around the splice. Above MHW these areas are subject to accelerated fungal attack.

Figure 6-4 Posting Timber Pile with Pile Butt and Fish Plates



TR-5: REPAIRING TIMBER PILES WITH CONCRETE ENCASEMENT

Problem: Approximately 10 to 50 percent of the cross-sectional area has been lost as a result of marine borer attack.

Description of Repairs: Clean the timber pile thoroughly from below the mudline to above MHW. Two types of forms are available:

- Flexible forms
- Split fiberboard forms

After piles have been thoroughly cleaned, place a 6- by 6-inch (15- by 15-cm) reinforcing mesh around the pile, using spacers to maintain clearance between pile, reinforcing, and fabric form. The fabric form should be placed around the pile.

For the flexible form, the zipper should be closed, and the form secured to the pile at top and bottom with mechanical fasteners (see Figure 6-5).

For the fiberboard form, straps are installed and secured every 1 foot (30 cm). Maintain a minimum of 1-9/16 inch (40 mm) spacing between pile and reinforcing and between reinforcing and form (see Figure 6-5).

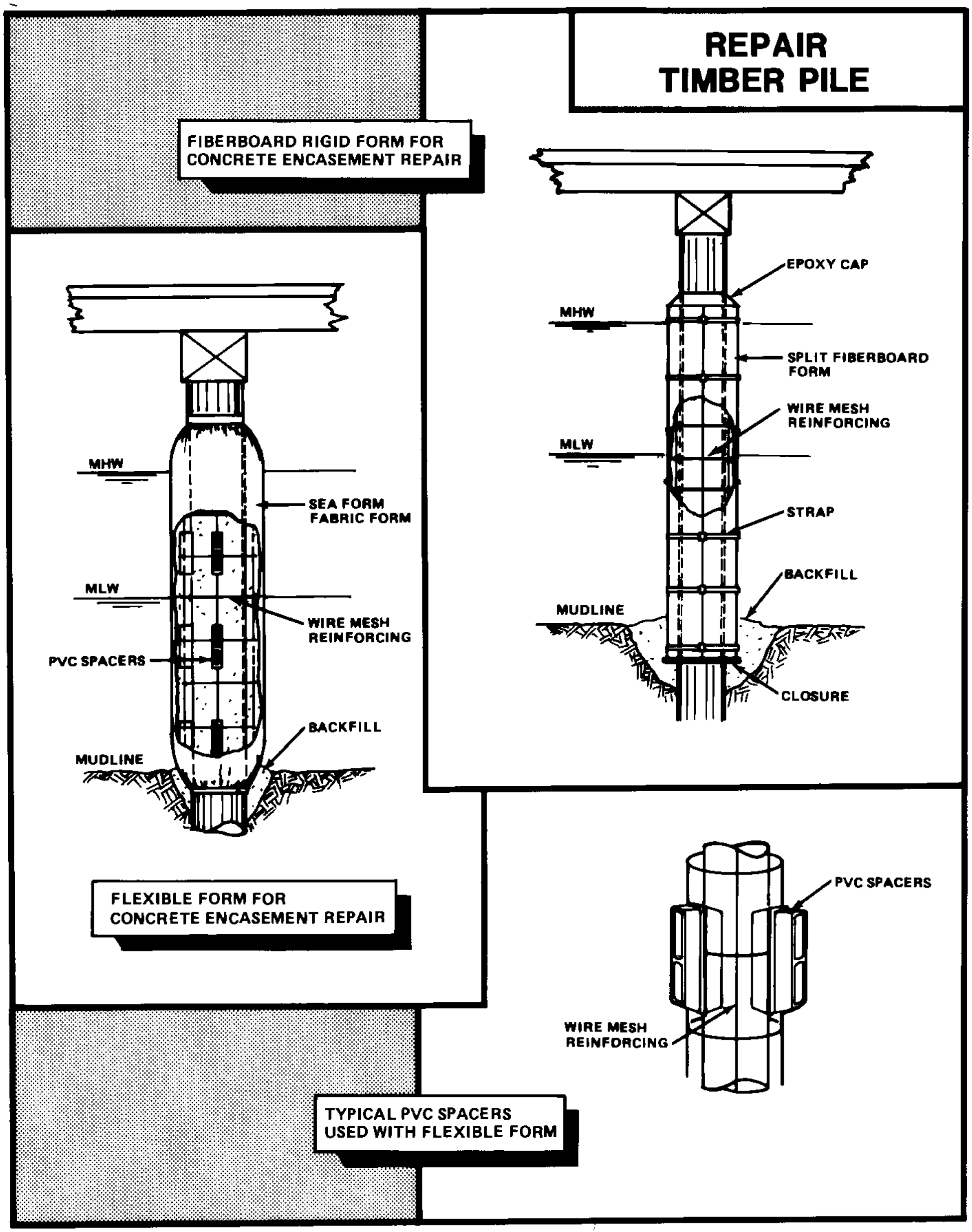
The space between pile and form is then filled to overflowing with concrete grout. Use a tube or hose extended to the lowest point of the form.

The form is left in place and the base is backfilled to above the concrete.

Application: This method can be used as a repair or as protection against marine borer attack and abrasion, and may be more expensive than replacing one or more timber piles. Economics will dictate decision.

Future Inspection Requirement: Increased inspections may be required to detect signs of ripped fabric forms, unzipped or locked form seams, or abrasion and failure of concrete encasement.

Figure 6-5 Concrete Encasement Repairs to Timber Pile



TR 6: REPAIR OR RETROFIT TIMBER PILES WITH

AN UNDERWATER CURING EPOXY AND FIBER-REINFORCED WRAP

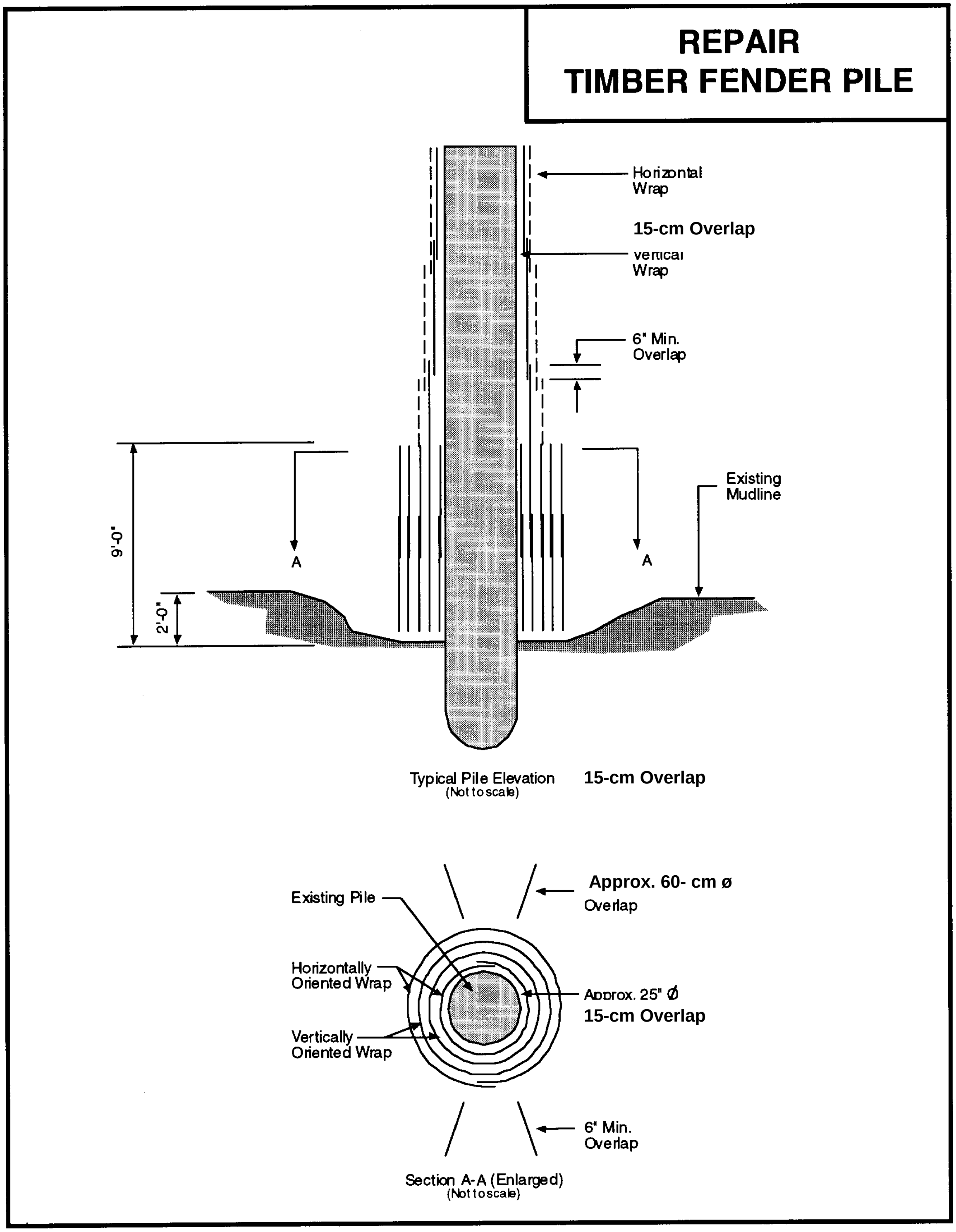
Problem: Pile deterioration by marine borers has occurred. Load requirements preclude resolving the problem by using PVC or PE wraps or an increase in strength (retrofitting) of intact piles is desired. In either case, deterioration cannot be so extensive as to require replacing the pile.

Description of Repair: Remove rotted or damaged wood and all sharp or protruding objects that could penetrate or deform the fiber wrap of the pile to be repaired or retrofitted (see Figure 6-6). Fill in any holes and gaps with material recommended by the system manufacturer. Saturate the wrap with the underwater curing epoxy before applying. Apply vertical layers of the fiber wrap with a 6-inch (15-cm) overlap. In most cases, it is advisable to wrap the fabric around the pile from below the mudline to above the high water mark. Apply horizontal layers of the fiber wrap with a 6-inch (5-cm) overlap. Additional vertical and horizontal wraps are applied as required for sufficient strength and as recommended by the manufacturer.

Application: This technology is designed to increase pile strength characteristics, but may be limited by cost and confidence levels. In most cases, PE or PVC wraps or pile replacement will be more cost effective for damaged piles. In addition, because this is a relatively new technology option, long-term performance has not yet been demonstrated. Environmental issues related to the use of underwater curing epoxies must be considered.

Future Inspection Requirement: Basically the same as for a PVC-wrapped pile. Any damage to the fiber wrap, however, could reduce the pile’s load bearing capacity.

Figure 6-6 Repair by Oriented Fiber Wraps



TR-7: REPLACING DAMAGED PILE WITH NEW TIMBER PILE

UNDER TIMBER PIER DECK

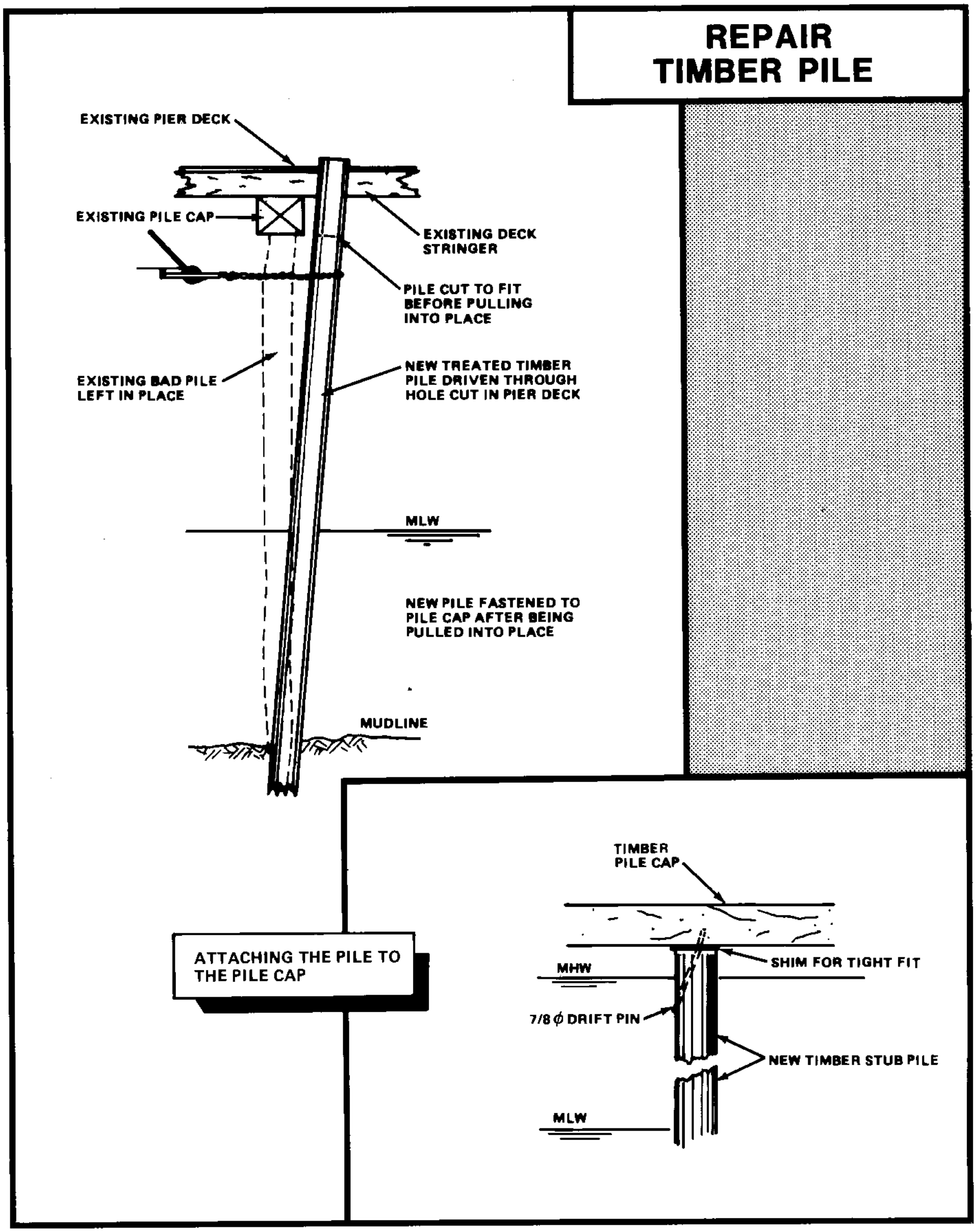
Problem: Physical damage or severe pile deterioration has been experienced below mudline, and/or a number of piles with severe deterioration (above mudline) is too extensive to maintain structural integrity with partial pile replacement.

Description of Repair: Cut an opening in the timber pier deck adjacent to the damaged pile. Drive the new pile and cut to fit under the pile cap. Spring the pile into place (see Figure 6-7). Place shims between the pile and pile cap, then fasten pile to pile cap with a 7/8-inch (22-mm) diameter drift pin.

Application: Limited mainly by cost. If fixed structures are on deck, this method may not be cost effective. If damage to the original pile(s) is due to marine borers, remove old pile(s) so that it does not provide bait to attract and nourish more borers. This application can also be used to replace damaged concrete or steel piles.

Future Inspection Requirement: Basically the same as for a new pretreated pile.

Figure 6-7 Replacing Damaged Pile with a New Timber Pile



TR-8: REPLACING DAMAGED PILE WITH NEW CONCRETE PILE UNDER CONCRETE DECK

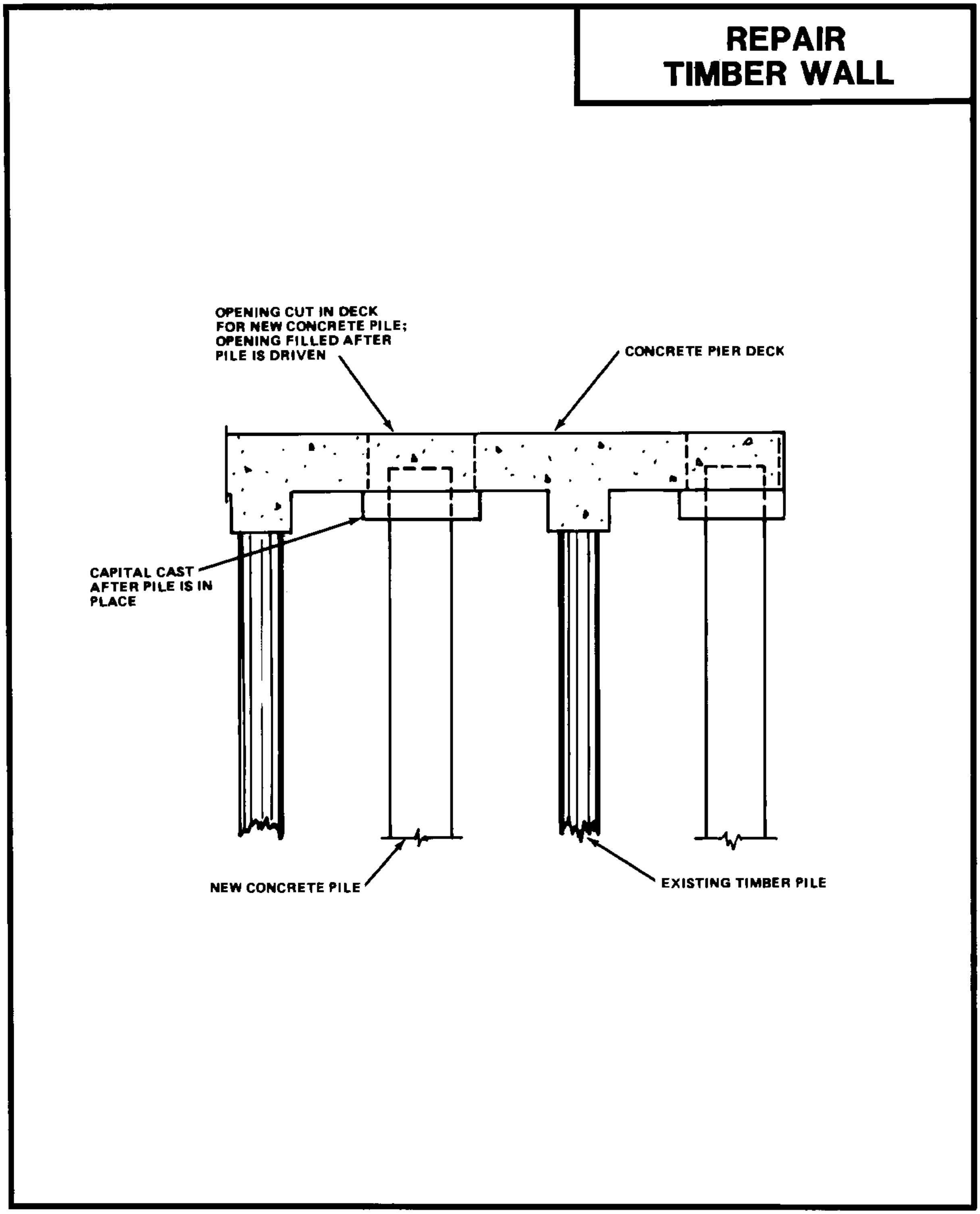
Problem: Pile deterioration or damage has been experienced to significantly reduce the structural integrity of the section of pier. Concrete pile cap and decking precludes replacing with timber pile.

Description of Repair: Cut a hole in the concrete deck between timber pile bents. Drive new concrete pile. Cut the pile below the top of the concrete deck. Form the capital under the deck, on top of the new pile. Cast the capital and the new section of concrete deck (see Figure 6-8) including splicing in new reinforcing bars. Epoxy coat bars where possible.

Application: Limited, mainly due to cost. If fixed structures are on deck, or if deterioration is wide spread, this approach may not be practical.

Future Inspection Requirement: Same as with new concrete piles and concrete deck areas.

Figure 6-8 Replacing a Damaged Timber Pile with a New Concrete Pile under a Concrete Deck



TR-9: REINFORCING TIE-BACK SYSTEM FOR TIMBER SHEET PILING WALL

Problem: Light to moderate movement of the top of the timber sheetpiling wall has occurred due to tie-back failure or excessive loading behind the wall. The area behind the wall is accessible to perform repairs.

Description of Repairs: Install a new wale slightly above the existing wale. Locate the new deadman anchors based on engineering calculations. Trench for the tie rods between the wall and the deadman anchors. Place the tie rods through the wale and sheet piles and secure in place to the deadman anchors (see Figure 6-9). Install zinc or magnesium packaged anodes to prevent further corrosion of the rods.

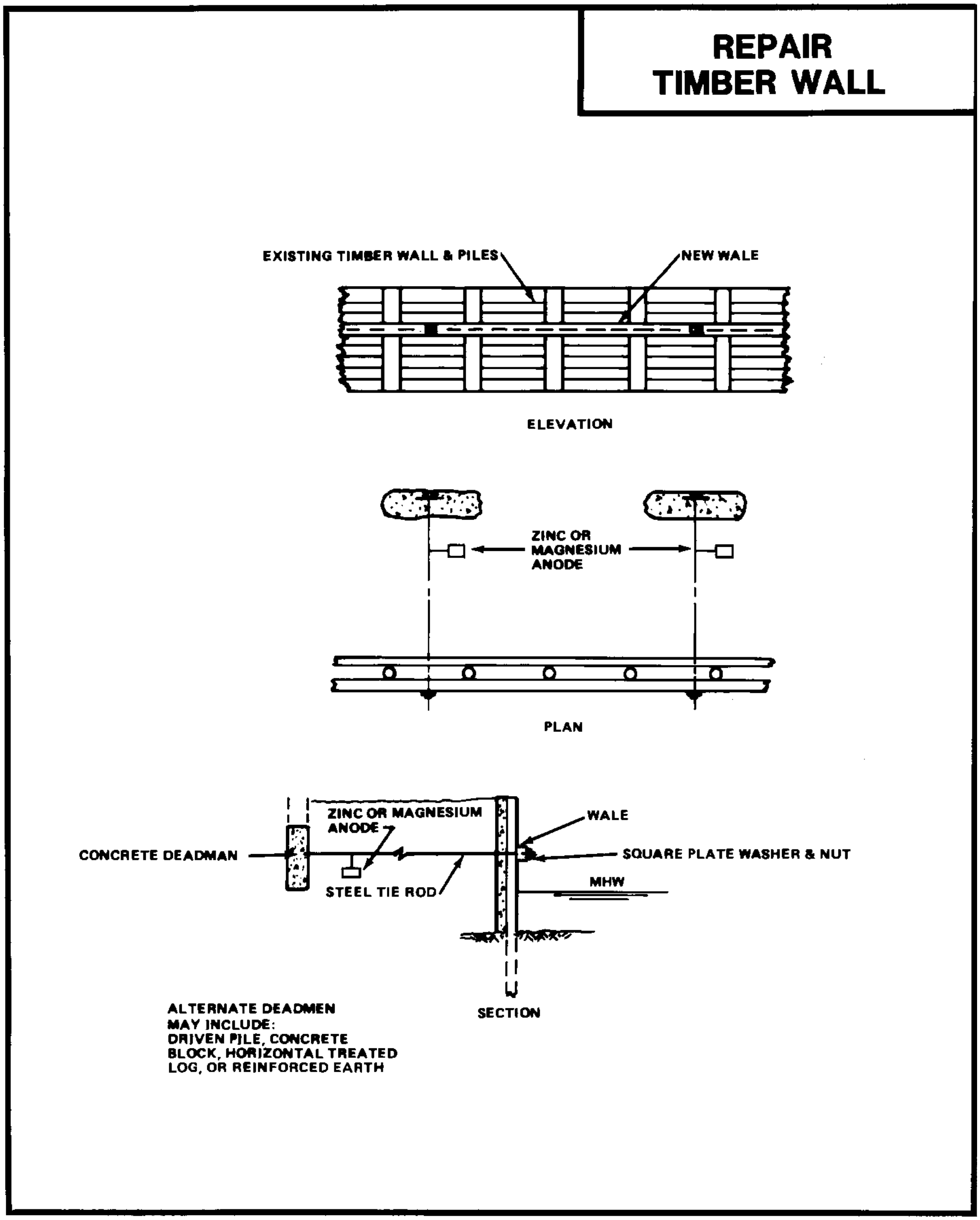
Replacing an existing tie-back system may involve replacing any or all of the existing components, depending on the amount of deterioration that has taken place.

Sheet pile wall movement can also be arrested by changing the soil load acting on the wall. For example, stone riprap dumped against the exterior toe of the wall will add resistance to the movement of the toe. Alternatively, or in addition, backfill can be removed from behind the wall and replaced with lightweight granular fill. This type of fill frees drains, which reduces the hydrostatic pressure behind the wall and allows the water level on both sides to balance.

Application: Reinforcing or replacing the tie-back system may be restricted to correct slight to moderate wall deflection. Excessive deflection may require replacing the wall or major restoration. With timber construction, it is unlikely that excavation and pulling the wall back into position can be done without high risk of failure of the timber members.

Future Inspection Requirement: Pay careful attention to wall inspection for further signs of continued deflection or timber member failure.

Figure 6-9 Installing or Replacing Tie-Back System for Timber Sheet Piling Wall



TR-10: INSTALLING A TIE-BACK SYSTEM ON THE TOP OF A TIMBER SHEET PILING WALL

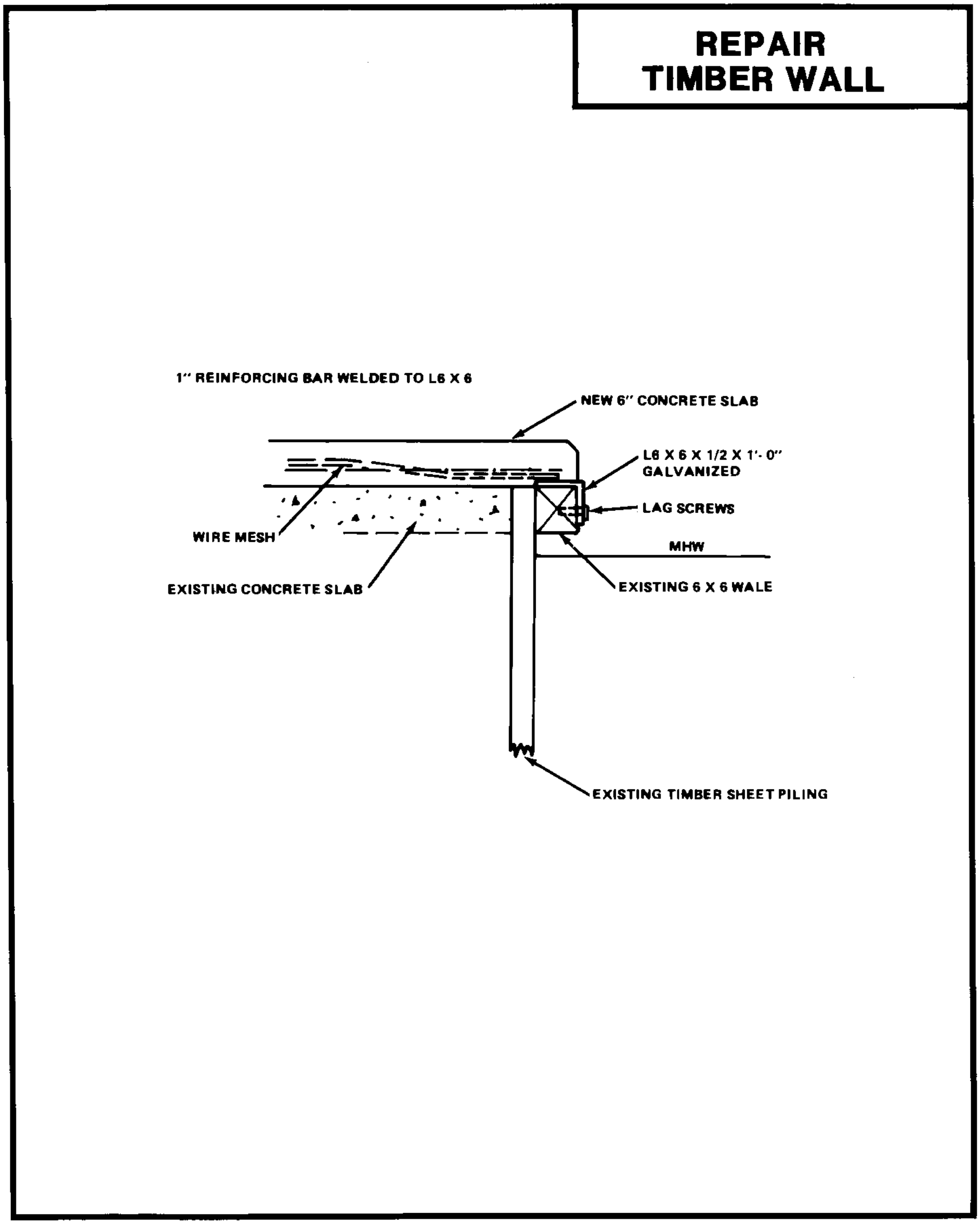
Problem: The top of the timber sheetpiling wall has moved, lightly to moderately, due to tie-back failure or excessive loading behind the wall. The area behind the wall is inaccessible for repairs.

Description of Repair: Cast a new concrete slab with extra reinforcing, from the face of the wall back behind the wall to the end of the existing slab. Tie the front edge of the new slab to wall through use of a steel angle (see Figure 6-10).

Application: Limited. Additional restraint is limited to top of sheetpiling. If excessive loading or loss of regular tie-back anchors are experienced, further failure, including shearing of sheetpiling tops, may occur.

Future Inspection Requirement: Pay careful attention to wall inspection for further signs of continued deflection or timber member failure.

Figure 6-10 Installing a Tie-Back System at Top of a Timber Sheet Piling Wall



TR-11: INSTALLING A CONCRETE CAP/FACE ON A TIMBER SHEET PILING WALL

Problem: Large-scale deterioration of the timber sheet pile structure has occurred precluding the use of patches for repairs.

Description of Repairs: Excavate the soil from behind the wall to a level required for the new concrete cap or attachment of form ties for a concrete face. Remove all marine growth and deteriorated wood, and clean the surfaces.

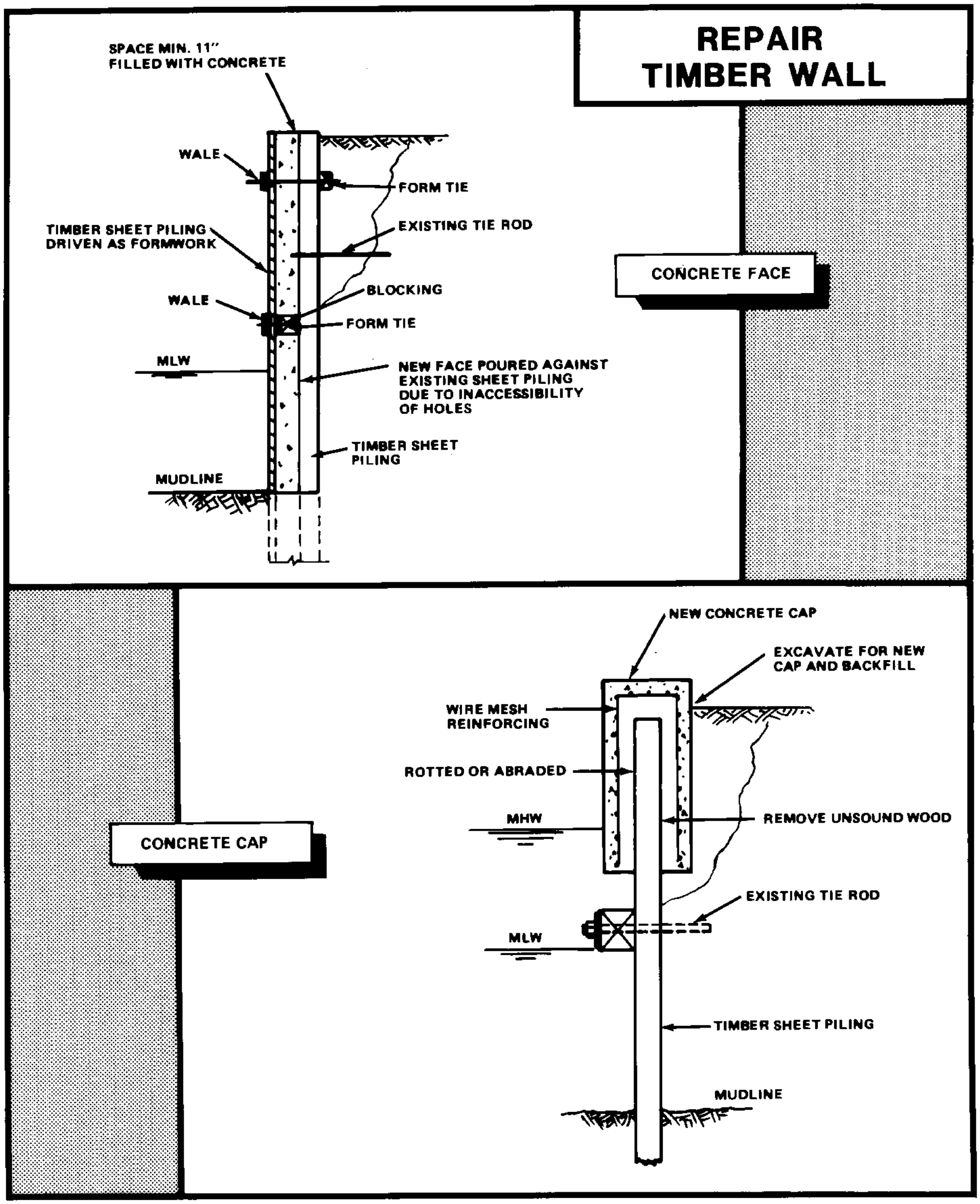
***To repair a concrete cap* –** Build forms, place reinforcing, and pour concrete at MLW. After curing, remove forms and backfill behind the wall (see Figure 6-11).

***To repair a concrete face* --** Place and fasten blocking and low wale against existing sheetpiling. Drive the timber sheet pile wall about 1 foot (30 cm) in front of existing sheetpiling using the wale as a guide. Attach outside wales to timber sheeting and place concrete by pumping or tremie. Leave timber sheet piling in place or remove as desired (see Figure 6-11).

Application: Used to restore structural strength at the top of the wall (cap) or prevent further loss of soil through holes in the sheetpiling (face). Does not restore bending moment capacity in wall. Provides protection against further deterioration.

Future Inspection Requirement: Do an annual inspection of sheetpiling areas immediately under the pile cap, in order to ensure that fungi, insect, or marine borer damage is not weakening the support for the concrete cap.

Figure 6-11 Installing a Concrete Cap and/or Face on a Timber Sheet Piling Wall



TR-12: REPLACING DAMAGED DOLPHIN PILE

Problem: One or more timber piles are broken or damaged by marine borers and the dolphin can no longer fully serve its purpose**.**

Description of Repair: Before replacing any piles, the fastenings should be removed only as far as is necessary to release the damaged piles. Take care to drive new piles at an angle so that they will not have to be pulled too far to fit them in place. Carefully note the size of piles to be replaced, particularly at the head or intermediate point where they are fitted together with other piles. Trouble cutting and fitting replacement piles can be avoided by selecting piles with the proper size head. Replace and drive all piles before any are brought together. After all the piles are driven, the center cluster should be brought together first, fitted, chocked, bolted, and pinned; when all rows have been properly fitted, etc., wrap with wire rope. All cuts in piles for fittings, bolts, and wrappings should be thoroughly field-treated with creosote. Avoid these cuts as much as possible because field treatment with creosote gives only marginal protection against marine borer attack.

Wrapping the dolphin with PVC may provide protection. See repair technique TR-3.

Application: This method is routinely used.

Future Application Requirements: Remaining piles should receive special attention.

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CHAPTER 7

REPAIR OF CONCRETE STRUCTURES

7-1 **CONCRETE FOR REPAIRS**. Quality, lasting concrete for repair of waterfront facilities depends on the quality of the concrete mix, and careful attention to preparation and construction techniques. Both factors are important in making and placing conventional Portland cement concrete and the special types of repair concretes.

Some of the information in this section was extracted from the following references:

- \1\ UFC 4-151-10, *General Criteria for Waterfront Construction*. /1/
- *Survey of Techniques for Underwater Maintenance/Repair of Waterfront Structures*, Revision No.1, Childs Engineering Corporation, December 1985.
- NCEL TM-43-85-01CR *UCT Conventional Inspection and Repair Techniques Manual*, October 1984.
- CEL CR 81.009, *Survey of Techniques for Underwater Maintenance/Repair of Waterfront Structures*, Childs Engineering Corporation, February 1981.

7-1.1 Portland Cement Concrete

7-1.1.1 Important Properties

- Durability. Concrete of low permeability is important for waterfront facilities. The objective is to keep salt and water out of the concrete to protect the reinforcing steel from corroding, which result in the concrete spalling. The most important factors are a low water-to-cement ratio (0.40) in the mix, use of 25% Class F fly ash, and proper curing of the concrete when placed.
- Strength. 5000 psi (35 MPa) concrete is recommended for most repairs. Design of the mix and proper curing will determine the final strength.
- Workability. Concrete must be easily handled and placed. A dense concrete is important. This workability must be obtained without increasing the water content beyond the mix design. Enhanced workability is obtained by using 25% Class F fly ash. Use of admixtures conforming to ASTM C494/C494M, *Standard*

Specification for Chemical Admixtures for Concrete; Types A, D, E, F and G are approved but not required.

7-1.1.2 **Preparation and Construction**. To obtain quality concrete repairs, the following basics are mandatory for all jobs:

- Properly prepare the surface of the old concrete to be adjoined.
- Ensure a good bond between the old and new concrete.
- Do not add more water than specified for the concrete mix.
- Do not patch across active cracks or joints.
- Cure the concrete properly.

7-1.1.2.1 **Surface Preparation**. All deteriorated concrete must be removed down to sound concrete. For some old concretes, exposed surfaces will soften after a few days of exposure; therefore, the surfaces should be checked closely before patching. Clean the old surface thoroughly just before placing new concrete.

Normally, when removing concrete hand tools or light duty hand-held power tools are used, particularly around the edges, to prevent damaging the remaining concrete. Do not use an impact hammer greater than 15 pound (67 Newtons). Edges should be square, preferably cut by sawing to about a 1 inch (25-mm) depth. Feathered edges must be absolutely avoided. Reinforcing bars should be exposed around their entire circumference by a 1 inch (25-mm) clearance.

Sandblasting surfaces removes loose concrete fragments and scaling rust from steel. Once the steel is clean, protect the coating with a slurry of Portland cement grout or latex modified Portland cement grout. This procedure improves the life of the repair.

7-1.1.2.2 **Bonding**. Before patching, the existing base concrete should be kept damp (except for epoxy concrete repair) for several hours, preferably overnight. Remove free water or shiny wet areas by vacuuming or with oil-free compressed air. Then scrub a bonding agent into the surface with a stiff brush. The bonding agent can be Portland cement mortar or a latex modified Portland cement mortar. Do not use epoxy bonding agents. The mortars should be one-part cement and 1 part sand passing the No. 30 sieve, and have a consistency of thick cream. In all cases, it is important to place the repaired concrete immediately after placing the bonding agent.

7-1.1.2.3 **Curing**. Concrete used in repairs must be protected and cured more carefully than usual. Curing should last for 7 days. The old concrete could absorb moisture too fast from the new concrete, or the temperature of the old concrete could be too low to permit early development of strength of a concrete patch. Shrinkage of the repair is the most common reason for delamination of the repair from the substrate.

Curing is important to allow strength development and minimize drying shrinkage. For Portland cement mixes, water curing by ponding with water, fog misting, or covering with wet burlap are the best methods. If continuous moisture curing is not possible, then use two applications of a liquid curing compound. The repaired concrete should be kept wet or moist for a minimum of 7 days. When water evaporates from the concrete, drying shrinkage occurs. Shrinkage of a repair patch can cause the patch to crack or partially debond.

Curing for epoxy concrete is to provide the correct temperature for the epoxy resin to develop full strength. Epoxy resins that use 100 percent solids and no solvents do not shrink. Epoxy resins do, however, have a much greater coefficient of expansion than concrete. This often leads to failure in large patches and in environments that experience large temperature differentials between day and night. Epoxy can be mixed with sand (1 part epoxy : 7 parts sand) to minimize the difference in the thermal expansion characteristics.

7-1.1.3 **Guidelines.** General guidelines for concrete used in waterfront repairs include:

- Use 5000 psi (35 MPa) concrete.
- Use only Type I or II.
- Use a minimum of 8.3 bags (360 kg) to a maximum of 10.4 bags (445 kg) of cement per cubic meter in the concrete mix.
- Use a maximum water-cement ratio of 17 L per bag of cement (0.40 by weight).
- For most small volume repairs, use aggregate no larger than 4/5 inch (2 cm).
- Make sure the concrete cover over reinforcing steel is at least 3-1/5 inches (8 cm).

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- Pay particular to the use of admixtures: DO NOT use an admixture containing chloride.

- For concrete subject to freeze-thaw cycles, use air-entraining agent to obtain 5 to 7 percent air content.
- Use a water-reducing admixture (ASTM C494/C494M) when concrete is placed in area congested with reinforcing or in pours difficult to consolidate. This will decrease chance of voids and temptation to add water to the concrete.

Specific guidelines for underwater concrete include:

- Water-cement ratio must not exceed 0.40 (5 gallons (19 L) per bag of cement).
- Use a minimum of 10.4 bags (445 kg) to a maximum of 11.25 bags (556 kg) of cement per cubic meter.
- Use an air-entraining admixture to obtain 3 to 6 percent entrained air for improved workability.
- A water-reducing plasticizing admixture may be used to enhance placement and consolidation.

7-1.2 Special Types of Repair Concrete

7-1.2.1 **Fiber-Reinforced Concrete**. Concrete and mortar containing fibers of steel, glass or polypropylene are sometimes used in repair work. Fiber reinforcement provides improved tensile strength, toughness and ductility to concrete. The fibers reinforce crack repair material by distributing tensile strains.

Fiber-reinforced shotcrete is good to use in marine repair work. In some applications, the fibers can replace steel mesh. Although steel fibers corrode near the surface, in the interior sections they are protected from corrosion by the high alkali of the cement paste. Steel fibers are usually 1/100 to 1/5 inch (0.3 mm to 5 mm) in diameter and 1/2 to 1 3/5 inch (13 to 40 mm) long. The quantity of steel fibers used varies from 6.2 to 18.5 psf (30 to 90 kg/m^2).

Glass fibers in concrete can lose strength over periods of time in a wet environment and are not recommended. Synthetic fibers reduce crack size due to plastic shrinkage, but should not be the primary reinforcement.

7-1.2.2 **Latex Modified Portland Cement Concrete**. Latex modified Portland cement concrete should not be confused with epoxy or polymer concrete discussed in the Paragraph entitled, “Epoxy Concrete”. Latex modifiers improve the bond and tensile strength and reduce the permeability of Portland cement concrete. Latex formulations of acrylics, styrene-butadiene, and polyvinyl acetates are available. The first two latexes are suitable for wet environments.

Polyvinyl acetates should not be used in concrete for repairs exposed to water. Latex modified concrete is recommended for overhead and vertical repairs when placed in lifts less than 1-3/5 inch (4 cm).

Latex modified concrete, compared to epoxy concrete, is vapor permeable and lower in cost. Even though permeable to vapor, it is not very permeable to liquids. Repairs requiring thin sections, which will be exposed to the sun, should be breathable so that vapor pressure does not build up behind the patches or overlays. Vapor pressure can debond and cause a patch to spall off.

Recommended mix proportions for thin and medium thickness repairs are in Table 7-1.

Table 7-1 Recommended Mix Proportions

		Finished Thickness
	1/2 to 1 ¼ inch (13 mm to 32 mm)	1 ¼ inch and up (32 mm and up)
Latex to cement ratio	0.10 to 0.20	0.10 to 0.20
Water to cement ratio	0.30 to 0.40	0.30 to 0.40
Fine aggregate to 1 part cement	3.0 to 3.5 parts	2.5 to 3.1 parts
Coarse aggregate to 1 part cement	2.5 to 3.1 parts	1.4 to 2.0 parts

Prepackaged latex modified mortars, or just the liquid latex modifiers, are commercially available. The mortar mixes can be converted to concrete by adding coarse aggregate. Latex modified concretes are sensitive to improper placement techniques, and noted failures have occurred. Carefully follow the manufacturers' recommendations.

7-1.2.3 **Epoxy Concrete**. Epoxy concrete does not contain Portland cement. It is a mixture of an epoxy resin and aggregate. Epoxy concrete is the most popular polymer concrete used because of its many physical properties that can be obtained, good adhesion to existing concrete, and availability. Other commercially available polymers are acrylics, polyesters, polyurethanes, and polyvinyl acetate.

Epoxy resin, when mixed with a curing agent, forms a thermosetting plastic that rapidly develops adhesive strength. Epoxy mixes are used for several purposes:

- To repair cracks by injecting the resin.
- To make epoxy mortar or concrete by mixing the resin with fine and coarse aggregate.

Because the cost is high and the material is inflexible in thick layers, epoxy concrete is used mainly for thin section repairs. Proprietary, prepackaged systems should be used. Generally, the aggregate is a silica sand with little or no material passing the No. 100 sieve (dust). The aggregate must be clean and absolutely dry. Not all epoxy resins will bond to damp or wet concrete, so check the manufacturer's specifications.

Epoxy mortars consist of 1 part epoxy resin to 4 to 7 parts sand by weight. The resin is usually made up of two components that are batched by volume and thoroughly mixed before combined with the aggregate. Epoxy concrete contains 1 part epoxy resin to 6 to 10 parts aggregate by weight. Equal parts of the fine and coarse aggregate are used. Epoxy concrete should be placed in layers no more than 2 inches (5 cm) thick, so that excessive heat build up does not occur. Generally, one should avoid using epoxy mortars because of their high coefficient of thermal expansion that leads to early disbondment of the repair.

7-2 **PLANNING THE REPAIRS**. The first steps in planning a repair will be to:

- Conduct an inspection to determine the course and scope of damage or deterioration.
- Determine operational or functional constraints on the facility because of the needed repair.
- Establish a priority for the repair.

Based on these factors, planning will then proceed to determine if the job should be done in-house or on contract, the repair technique to be used, method of placing the concrete, special skills required, and unique equipment requirements. If underwater repairs are involved, give special attention to planning for the unique requirements, particularly involving safety.

7-2.1 **Seismic Impact of Repairs**. Any concrete repair that alters significantly the mass of a structure may increase seismic vulnerability. A structural analysis by a qualified structural engineer is required to ensure earthquake safety is not compromised by the repair.

7-2.2 **Special Skill Requirements**. Most concrete repair techniques and methods of placement require:

- Normal skills associated with concrete construction
- Building forms
- Setting reinforcing steel
- Mixing concrete
- Vibration
- Finishing
- Curing

Special skills and experience are required for placing shotcrete and for handling and placing concrete for underwater repairs. Shotcrete, in particular, requires a skilled nozzle operator to ensure quality results. Use experienced personnel when using epoxy components, epoxy injection, and sealing cracks and joints require experienced personnel.

Underwater repairs, depending on the complexity of the job, require special skills beyond placing the concrete, such as how to remove marine growth, underwater jetting and blasting, how to use underwater tools for cutting and drilling, and how to use certain materials for coating and caulking underwater.

7-2.3 **Special Equipment Requirements**. Unique equipment requirements exist on many jobs and often dictate the personnel skill requirements. Applying shotcrete requires a complete set of special equipment, as does pumped concrete. See the outlines in concrete placement methods (CPM) CPM-4 and CPM-6. Also, underwater work can require the same equipment listed in the Paragraph entitled, “Equipment Requirements”.

Above water repairs require conventional equipment for surface abrasive blasting and air-jet cleaning, form construction, and mixing, placing, and finishing concrete.

7-3 **METHODS OF PLACING CONCRETE AND MORTARS**. The seven most common methods for the placing concrete and mortars in waterfront repair are listed and describer in Table 7-2.

Table 7-2 Placement of Concrete and Mortar

No.	Description
CPM-1	Hand Placement
CPM-2	Dry Pack
CPM-3	Cast-in-Place
CPM-4	Shotcrete
CPM-5	Tremie
CPM-6	Pumped
CPM-7	Prepacked

CPM-1: HAND PLACEMENT

Description: Troweling a mortar into shallow, relatively small areas requiring patching.

Uses: Patching surface areas small enough for hand work and shallow cavities not suitable for dry pack.

Materials and Curing: Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05 percent per ASTM C157/C157M modified and proper curing.

Preparation:

a. Remove all loose and unsound old concrete.

b. If reinforcing steel is exposed, ensure 1 inch (25 mm) clearance all around and wire brush steel bar.

c. Thoroughly clean repair area immediately before applying bonding coat.

Bonding: Vigorously brush coat repair area with sand-cement slurry: 1 part Type II cement; 1 part sand; and enough water or latex for a consistency of thick cream.

Mortar Mix: The proportions of the mix depend on the overall size and depth of the repair, accessibility, and whether the repair is large enough to require coarse aggregate. A typical cement-to-sand ratio is 1:2.5 to 1:3. The water-cement ratio should be no greater than 0.40.

Placement:

a. If repair is in direct sun or wind, build shade/wind break and leave in place during curing period.

b. Wet the surface of repair area for 24 hours. Do not leave any free water.

c. Brush coat repair area surface with cement slurry.

d. Immediately trowel on mortar mixture; completely fill voids and dense placement.

Curing: Use wet burlap for 7 days or use a curing compound.

CPM-2: DRY PACK

Description: Packing a stiff mortar into a confined hole or cavity.

Uses: Filling narrow slots cut during repair of dormant cracks, and filling cavities/small holes in cross-sectional area that are relatively deep.

Restrictions/Cautions:

a. Use for holes no larger than 35 inches^2 (225 cm^2) in cross-sectional area.

b. The depth of the cavity should be equal to or greater than the smallest surface dimension.

c. DO NOT use for:

1. Shallow depressions where lateral restraint is not obtained.
2. Filling behind exposed reinforcing steel.
3. Holes that extend through the structure.

d. Maintain water content of mortar carefully.

Preparation:

a. Thoroughly clean cavity.

b. Remove all loose or cracked aggregate.

c. Allow to dry at least 2 days before packing.

Bonding: Vigorously brush inside of cavity with a cement slurry: 1 part Type II Portland cement; 1 part clean, dry fine sand; and enough water for a consistency of thick cream.

Dry Pack Mix: 1 part cement, 2.5 parts sand passing No. 16 sieve, only enough water so mortar sticks together when squeezed with slight pressure. Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05 percent and proper curing.

Placement:

a. Place and compact in layers 2/5 inches (10 mm) thick.

b. Scratch surface of each layer for good bond of next layer.

c. Fully compact each layer over entire surface with hardwood stick and hammer.

d. If a layer becomes rubbery, delay about 30 minutes for mortar to stiffen and then compact.

e. Finish surface with flat side of stick. Steel tools and water are not recommended.

f. Patch is usually darker than surrounding concrete. For appearance, use white cement in mix for outside layers.

Curing: Use wet burlap for 7 days or use a curing compound.

CPM-3: CAST-IN-PLACE CONCRETE

Description: Placing conventional concrete mix with a concrete mixer truck, chute, bucket, wheel barrows, concrete carts, or shovels.

Uses: Use in all repairs where the quantity of concrete required is too large for hand placement, and where special placement methods CPM-4 through CPM-7 are not required. Control of the concrete mix and strength of the completed repair is much better than with any other methods. Should be used when:

- The hole/cavity extends through the concrete section.
- The cavity in un-reinforced concrete is larger than 139 ½ in^2 (900 cm^2) in area and over 4 inches (10 cm) deep.
- The cavity in reinforced concrete is over 69 ¾ in^2 (450 cm^2) in area and deeper than the reinforcing steel.

Major concerns are quality of the mix, good bonding to old surfaces, keeping a low water-cement ratio, and proper curing.

Restrictions/Cautions:

a. Temperature shall be over 40 degrees F (4.5 degrees C) during placement.

b. Concrete settles after placement, therefore, proper consolidation is essential to prevent cracking

Preparation: See concrete repair (CR) procedure CR-3.

a. Delay several days after demolition of old, deteriorated concrete to confirm the soundness of remaining concrete and excavated surfaces.

b. Check forms for tightness and stability.

c. Ensure that old surfaces are cleaned before repairs begin.

d. Ensure that reinforcing steel is cleaned of rust and scale and exposed at least 1 inch (2.5 cm) all around.

Bonding: Usually, a sand-cement grout will suffice. See CR-3 for more information.

Concrete Mix: Give particular attention to:

a. Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05 percent and proper curing.

b. Consider moisture in aggregate when calculating quantity of water.

c. Use a water-reducing plasticizer admixture wherever placement and consolidation are restricted, or slumps greater than 4 inches (10 cm) are required.

Placement: The equipment used depends on size of the pour, accessibility and working space, and availability of equipment. Concerns are placement speed and consolidation. In confined, hard to access locations, aid consolidation by using admixtures and mechanical vibrators and tampers. Elimination of voids and honeycombing is very important.

Curing: The most effective moist-curing method is using wet burlap for 7 days. Do not cut corners or try to economize. This is critical.

CPM-4: SHOTCRETE (GUNITE)

Description: Sprayed concrete applied directly by an air jet gun. Equipment includes a mechanical feeder, mixer, and compressor. If using a dry-mix, water is added at the nozzle.

Uses: Shotcrete is relatively economical where deterioration is shallow and area is large and irregular in shape. Shotcrete requires no form work and thin patches can be made that have a high strength, is an efficient method for vertical and overhead surfaces, and is also used for encasing timber and steel piling.

Restrictions/Cautions:

a. Must have enough repair work to justify the cost of equipment.

b. Normally restricted to a depth of 4 inches (10 cm) per lift.

c. Can have a high porosity if improperly applied.

d. Drying shrinkage rate and thermal expansion can be different than concrete being repaired.

e. Can have wide variation in application/composition. Quality depends almost entirely on the operator's skill. Follow ACI SP-14 guidelines.

Preparation:

a. Thoroughly remove all defective and loose concrete.

b. Clean all rust off exposed reinforcing steel.

c. Roughen all smooth surfaces.

d. Wire brush or abrasive blast exposed concrete surfaces to be covered.

Bonding: A bonding agent is not required.

Shotcrete Mix:

a. Cement-to-aggregate maximum ratio 1 to 3.5. This will result in an in-place mix of about 1 to 2.5 after rebound.

b. Minimize the water-to-cement ratio.

c. May use a non-chloride type admixture for rapid setting.

d. Fiber reinforcing may help minimize shrinkage cracks.

Placement:

a. Install reinforcing wire fabric to ensure the laps project no more than 4/5 inch (20 mm) from surface being covered.

b. Usually start work at bottom and move up; may follow the tide down.

c. Fix the profile.

d. Fill out the area to the original face.

e. Apply each coat at least 2 inches (5 cm) thick. The final coat should be at least 1/2 inch (13 mm) thick.

f. Ensure that rebound material is not trapped in corners or edges.

g. Ensure reinforcing bars are properly encased.

Curing: Use wet burlap for 7 days or use a curing compound.

CPM-5: TREMIE CONCRETE

Description: The primary method of placing concrete underwater when gravity flow is adequate. The tremie, a steel tube or rigid hose, runs from a hopper for filling its upper end into the form and is moved vertically as the concrete is placed.

Uses: All underwater pours at easily accessible locations that require a quantity of concrete to warrant the equipment set-up.

Restrictions/Cautions:

a. Do not use an aluminum alloy tremie to avoid reaction with the concrete mix.

b. Location, and space in the form, must be accessible for positioning and moving the tremie vertically and horizontally.

c. Slump of concrete mix must be carefully controlled within 6 to 8 inches (15 to 20 cm). Too wet a mix may segregate and too dry a mix will not flow properly in the form.

d. If practicable, place concrete when water temperature is above 50 degrees F (10 degrees C).

Preparation: Prepare the repair location in the same manner as cast-in-place concrete. Also, ensure that the tremie pipe is heavy enough to be negatively buoyant, and that the joints in the tremie are well gasketed and sealed. The diameter of the tremie should be at least eight times the largest size aggregate used.

Bonding: Not usually required.

Concrete Mix:

a. A typical mix proportion for cement, sand, aggregate, is 1:1.7:2.4 by weight with a water-cement ratio of 0.45.

b. Use air-entraining and water-reducing plasticizer admixtures as required for the underwater repair. Admixtures conforming to ASTM C494/C494M are acceptable.

c. Use a mineral admixture of pozzolan in thick sections to control heat buildup. This will reduce amount of cement in the mix.

Placement:

a. Once the tremie pipe is filled, carefully lift the bottom end from the bottom of the form not more than 6 inch (15 cm) to start the flow of concrete.

b. Placement should be as continuous as possible. The end of the tremie must remain embedded in the concrete by as much as 40 inches (1 meter).

c. If the tremie is lifted out and the seal is lost, remove it, reseal, and start again.

d. Move the tremie horizontally while concrete is flowing

Curing: Not applicable.

CPM-6: PUMPED CONCRETE

Description: Placing concrete through a pipe or hose using a concrete pump with attached hopper.

Uses: Often used for placement above water. May be used for underwater placement in locations with limited accessibility, where the tremie method is not efficient. The advantages for underwater repairs include:

- High quality concrete can be pumped. The mixture must be both workable and cohesive without blocking the pump.

- Workable mixtures containing relatively small coarse aggregate particles provide an easily placed and dense concrete.

- Concrete can be transferred from a barge directly into the forms.

- Pumped concrete fills forms from the bottom upwards, displacing the seawater as more concrete is added.

Restrictions/Cautions: See CPM-5, Tremie Concrete. Also:

a. Carefully control slump of concrete to 6 to 8 inches (15 to 20 cm).

b. Avoid inclines in the pipe whenever possible.

c. If delays are encountered, move concrete about 40 inches (1 meter) every 5 minutes. If concrete becomes stiff due to a long delay, discard the mix. Do not retemper by adding water.

d. Use rubber hose only for discharge end and short pumping distances.

Preparation: Prepare the repair location in the same manner as cast-in-place concrete. Also, carefully plan location of pump and routing of pipeline to minimize moves. The pipeline should be horizontal or vertical whenever possible.

Bonding: Not usually required underwater; for above water, see CPM-3: Cast-in-Place Concrete.

Concrete Mix:

a. A typical mix proportion is 1:3:1 by weight with a water-cement ratio of 0.45. Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05 percent and proper curing.

b. Use rounded coarse (2/5 inch (10 mm) minimum) aggregate when possible.

c. Sand should have a higher proportion of finer sizes.

d. Avoid porous aggregates such as expanded clay, foamed slag, and pumice.

Placement: The principles of placing tremie concrete apply. Also:

a. Before filling hopper, lubricate the pipe with water, then a cement-water slurry.

b. Take all precautions to avoid separation of the mix.

c. Always keep discharge buried in the fresh concrete.

d. Control discharge to keep lateral flow of concrete within 0.7 to 1 meter.

Curing: Not applicable underwater. If above water, use wet burlap for 7 days or use a curing compound.

CPM-7: PREPACKED CONCRETE

Description: Placing coarse aggregate in the form and filling the voids with grout. It is used on large repair jobs, and usually grout is pumped through grout pipes from the bottom up.

Uses: Prepacked concrete is used where placement of cast-in-place concrete is not practical. It is also used underwater where the tremie or pumped methods are not practical due to inaccessibility. It is suitable for vertical surface repairs that have a minimum thickness of 3 to 4 inches (8 to 10 cm).

Restrictions/Cautions:

- Prior to injecting grout, be sure fines have not collected in the coarse aggregate. Fines in the aggregate can impede the flow of grout and create voids.
- Protect the aggregate from contamination after it is placed.

Preparation: Prepare the repair location in the same manner as for cast-in-place concrete. Also, ensure grout pipes are well installed and fixed to forms or reinforcing. A vent must be provided at the highest point.

Bonding: Not required.

Concrete Mix: Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05 percent and proper curing. Coarse aggregate is sized to the size of repair. The sand-cement grout is usually richer than a 1:1 mix. Admixtures are used as required by the circumstances. Usually, a chemical admixture is used as an intrusion aid for the grout. This suspends solids and provides fluidity. An air-entraining admixture is used to obtain about 9 percent air in the grout.

Placement: Pump the grout soon after the aggregate is placed. Ensure that all voids are filled and that segregation in layers does not take place. When forms are filled, apply a closing pressure of about 14.5 psi (0.1 MPa) to drive out air and water through the vent.

Curing: Use wet burlap for 7 days or a curing compound.

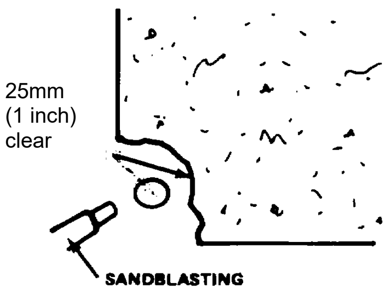
7-4 **CONCRETE REPAIR PROCEDURES**. Figure 7-1 summarizes the general steps taken in concrete repairs. The more standard repair procedures and techniques used for waterfront facilities are listed in Table 7-3 and included in the following pages. These repair techniques should be used in conjunction with the guidelines for concrete in the Paragraph entitled, “Concrete for Repairs”, the descriptions of methods of placement in the Paragraph entitled, “Methods of Placing Concrete and Mortars” and the preservation measures outlined in Chapter 3.

Table 7-3 Repair Techniques for Concrete Structures

No.	Description
CR-1	Repair Small to Medium Cracks by Epoxy Grout Injection
CR-2	Major Joint and Crack Repair
CR-3	Repairs to Concrete Seawall
CR-4	Miscellaneous Repairs to Concrete Piles
CR-5	Concrete Jacketing of Concrete Piles
CR-6	Typical Combination Repair: Cast-in-Place Concrete and Epoxy Grout Injection
CR-7	Typical Repair Using Polymer Concrete
CR-8	Typical Concrete Wall Repair

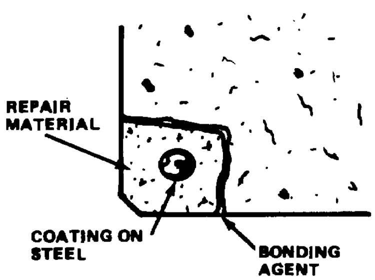
Figure 7-1 General Steps to Concrete Repair

REPAIR CONCRETE STRUCTURES



SURFACE PREPARATION

- Remove all deteriorated and loose concrete.
- Expose all uncovered reinforcing steel at least 1 inch clear all around.
- Sandblast/waterblast/wire brush concrete and steel as necessary to clean thoroughly.
- Keep concrete surface wet for several hours.
- Coat reinforcing steel with cement slurry.
- Just before placing repair material, apply cement slurry to old concrete.

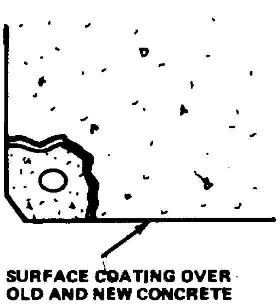


PLACE REPAIR MATERIAL

- Depending on size and type of repair, material may be a mortar or concrete, Portland cement concrete, or latex modified concrete.
- Above water placement: hand placement, dry pack, cast-in-place, or shotcrete.
- Underwater placement: tremie, pumped, or prepacked.

CURING

- Use most efficient moist curing for at least 7 days if practicable. Wet burlap is the best.
- Use two curing applications of compound. Wet burlap is not practical.



SURFACE COATING

- Determine if surface coating is required.
- Prepare surface by air/abrasive blasting.
- Apply coating applicable to location, exposure, and use of concrete.

CR-1: REPAIR SMALL TO MEDIUM CRACKS BY EPOXY GROUT INJECTION

Problem: Cracks caused by weathering, deterioration, or reinforcing steel corrosion allow water to penetrate the structure.

Description of Repairs: Filling and sealing small to medium cracks by injecting a low-viscosity urethane and sealing the outside with an epoxy paste. Routing and cleaning of cracks are performed with conventional hand and power tools. Injection for smaller jobs can be done with a hand-operated caulking gun. Large jobs are usually done with special equipment.

Materials:

a. Low-Viscosity Epoxy - Select a urethane suitable for wet surfaces and underwater application that is compatible with crack volume, crack movement, and equipment to be used for injection. \1\ /1/b. Sealing Epoxy - Use a quick-setting epoxy paste adhesive suitable for underwater application that has good bonding characteristics for concrete being repaired.

Preparation:

a. Rout out cracks to remove all deteriorated and loose concrete and aggregate. Clean area to receive sealing epoxy with wire brush, high-pressure water jet, or sandblasting.

b. Drill injection holes every 6 inches (15 cm) along the length of the crack for larger jobs with deep cracks. Install a tube or one-way polyethylene valve in the holes as injection ports.

c. Repair small and shallow cracks with a hand gun, injection ports may be openings left in the sealing epoxy every 6 inches (15 cm).

Repair Procedures: See Figure 7-2.

a. Perform repairs when ambient/water temperature is at least 50 degrees F (10 degrees C).

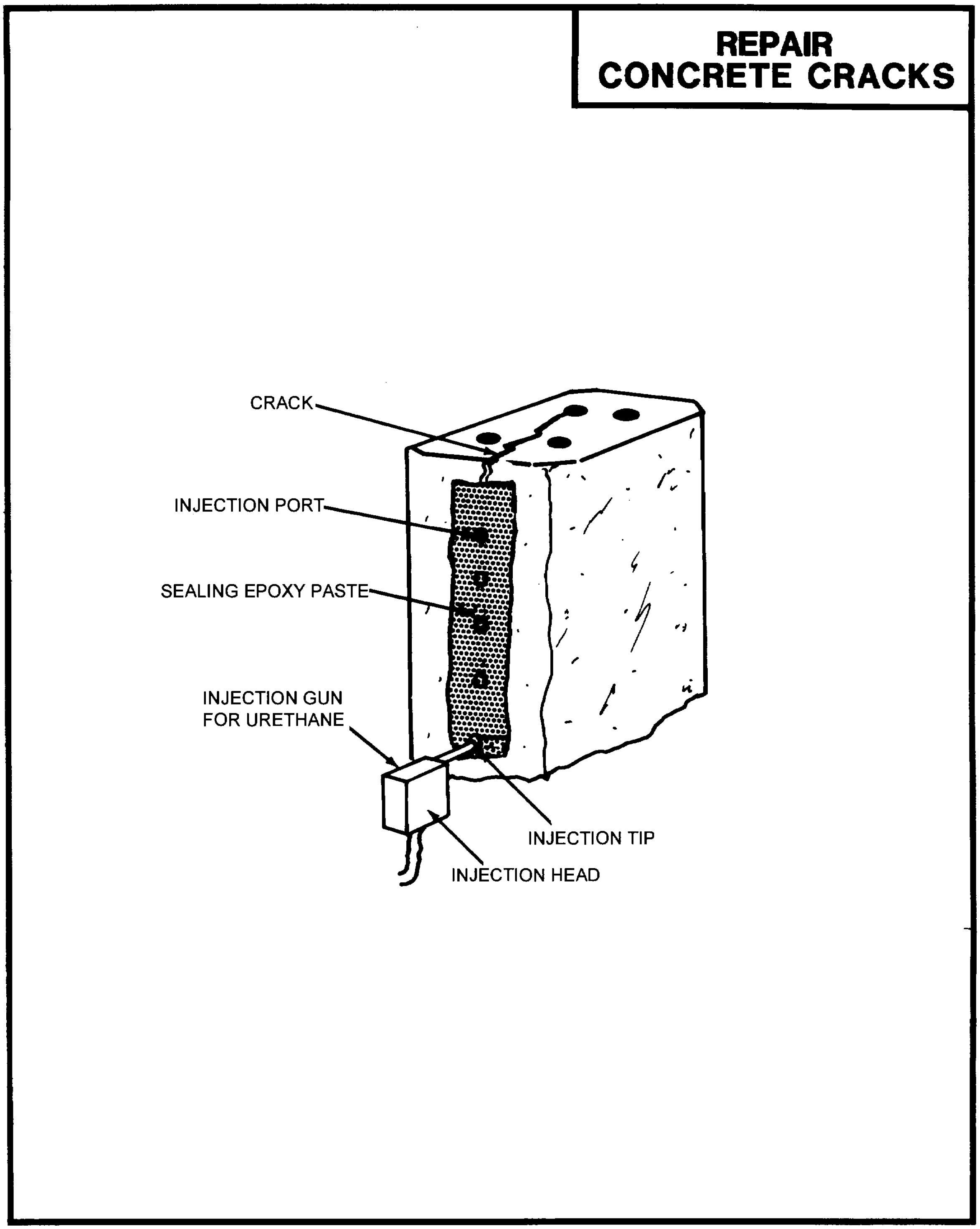
b. Seal the outside surface of the crack with the epoxy paste, carefully sealing around the injection ports.

c. After the surface seal has set, inject the urethane grout, starting at the bottom port for a vertical crack. Continue injection until grout shows in the next port then continue up the crack until the entire crack is filled.

d. Plug the port holes with the sealing epoxy paste.

Application: Epoxy grout injection does not stop spalling due to rebar corrosion. This method is most useful in making structural repairs of cracked concrete that is static only. Cured epoxy is rigid, therefore, epoxy injection is not recommended where there is any additional cracking or movement of concrete anticipated. Follow International Concrete Repair Institute (ICRI) Technical Guide \1\ No. 210.1, Guide for Verifying Field Performance of Epoxy Injection of Concrete Cracks (formerly No. 03734) /1/.

Figure 7-2 Typical Crack Repair with Epoxy Grout Injection



CR-2: MAJOR JOINT AND CRACK REPAIR

Problem: Large cracks or construction joints allow water to penetrate in or leak through the structure.

Description of Repairs: Sealing of cracks and construction joints to prevent leakage. This repair is performed after grouting of cracks is completed. Example given is for drainage and discharge tunnels, and should be modified for less demanding applications. Repair requires conventional hand and power tools and a heating bucket.

Materials:

a. Sealant No. 1 - Two-component epoxy coating system. See \1\ /1/ CR-4, Applications.

b. Sealant No. 2 - Non-meltable mastic of refined asphalts, resins, and plasticized compounds reinforced with non-asbestos fiber. Resistant to seawater, salts, acids, and dilute alkalis.

c. Primer for Sealant No. 2 - Asphaltic liquid primer compatible with sealant.

d. Sealant No. 3 - Two-component, moisture insensitive epoxy resin mortar; 1 part mixed epoxy to 7 parts aggregate by volume.

e. Copper Plate - 16 gauge conforming to ASTM B370, *Copper Sheet and Strip for Building Construction*.

Preparation: Chip out and saw cut concrete as shown on Figure 7-3. Clean all surfaces to receive sealants of all loose and deteriorated concrete and marine growth by chipping, scraping, and sandblasting. Provide clean, sound bond surfaces. Prepare surfaces to meet sealant manufacturer's requirements.

Repair Procedures:

a. Perform repairs when ambient or water temperature is at least 50 degrees F (10 degrees C), depending on whether structure is exposed or submerged.

b. Apply Sealant No. 1 with a brush to cleaned surfaces.

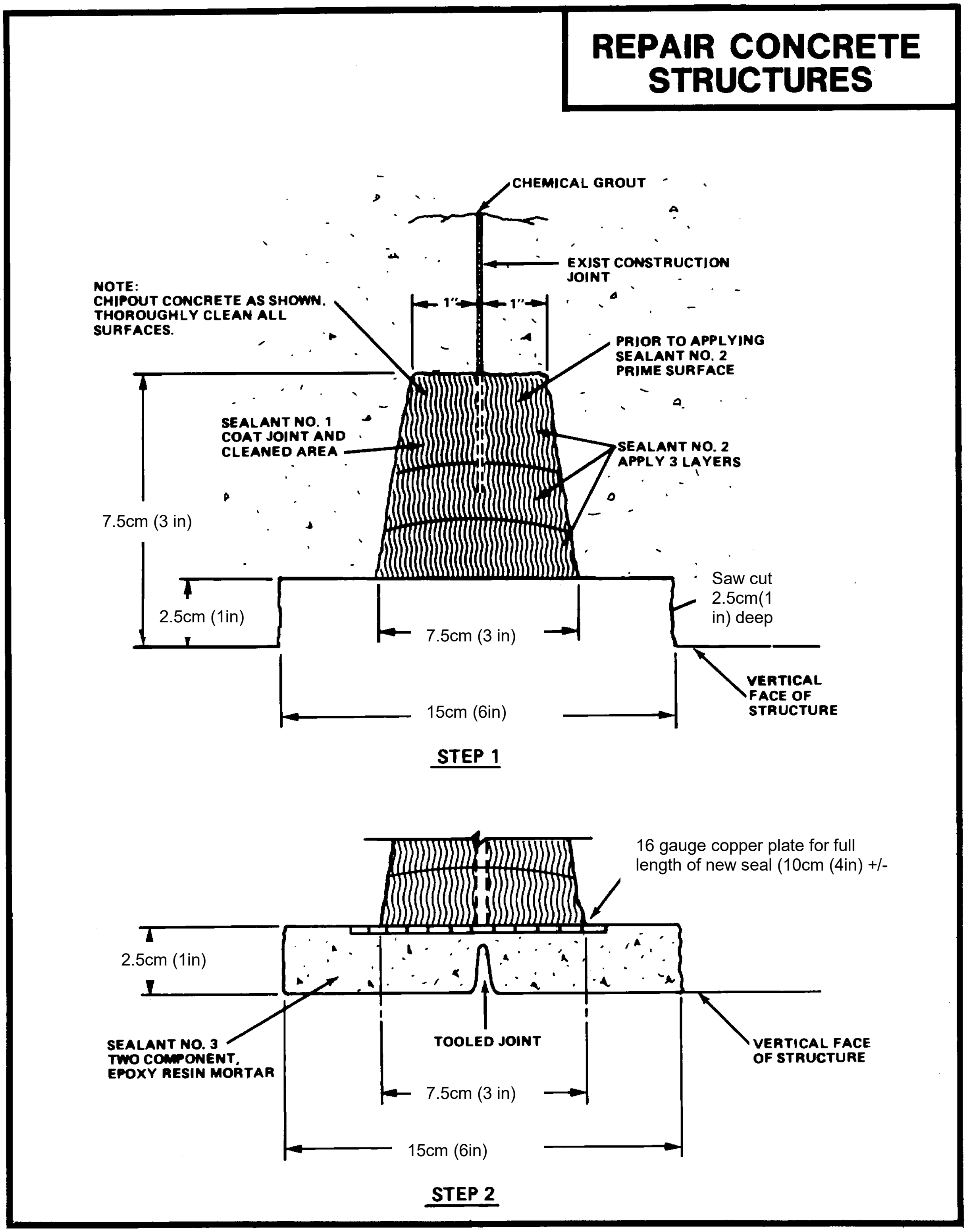
c. Prime all surfaces to receive sealant No. 2 with primer and let dry.

d. Apply three layers of Sealant No. 2 (heat sealant) as shown in Figure 7-3. Pound each layer during and after cooling.

e. Fasten copper strip in place for placement of sealant No. 3. Do not use fasteners of dissimilar metal.

f. Apply sealant No. 3 as shown and tool the joint as required.
Curing: Cure sealants per manufacturer's specifications.

Figure 7-3. Joint and crack repair



CR-3: REPAIRS TO CONCRETE SEAWALL

Problem: Sulphate attack has caused limited disintegration of the seawall within the tidal zone.

Description of Repairs: Contact between the existing concrete and seawater is eliminated by adding a repair layer of sulphate-resisting concrete. Old concrete is replaced only to the extent necessary to repair damage and to isolate the old concrete from the seawater reaction. See Figure 7-4.

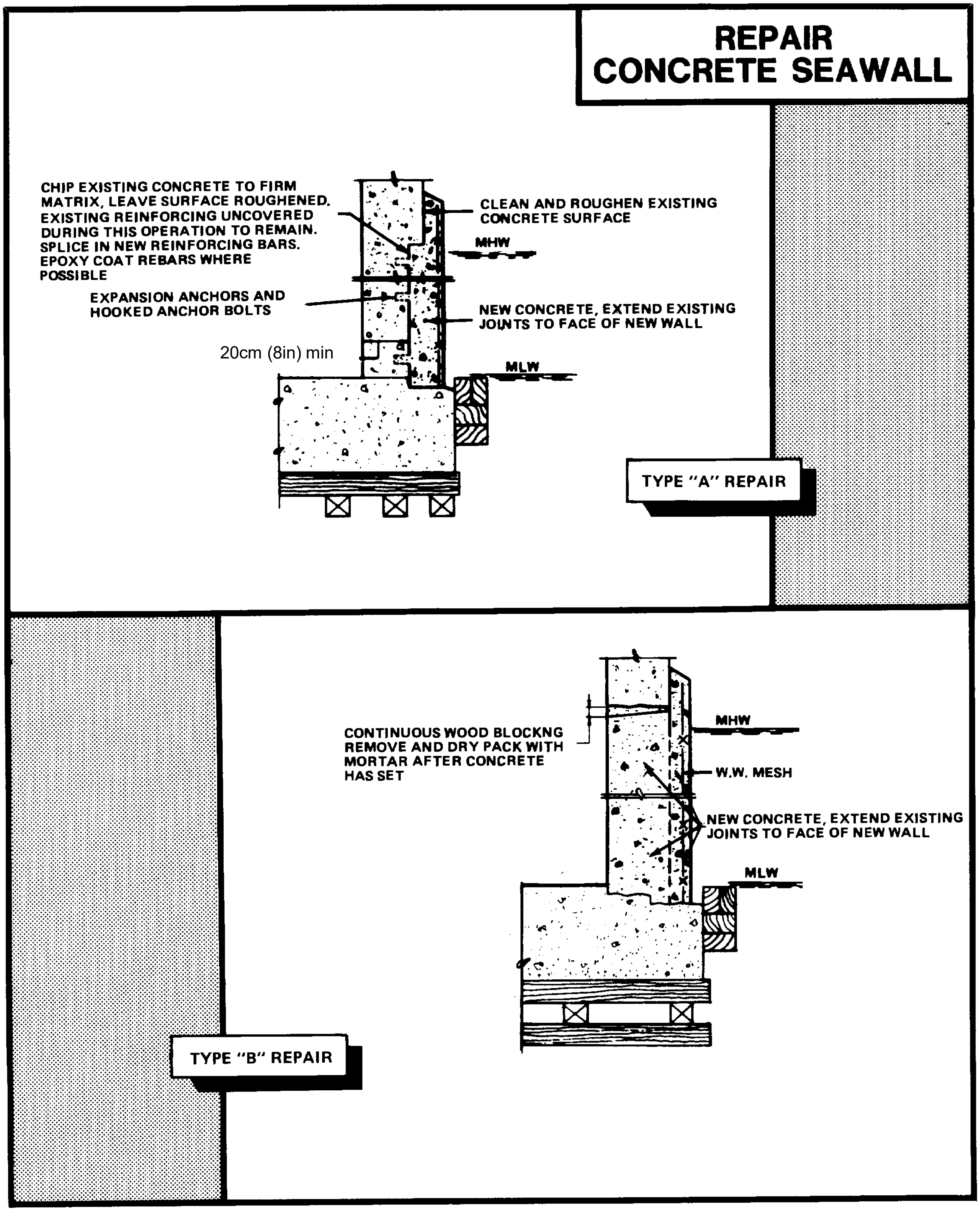
Repair procedures are as described in CPM-3 for cast-in-place concrete or CPM-5 if the tremie method is required. Also, see repair CR-8 for certain applicable procedures.

- Type "A" Repair: In this case, a minimum of 7 7/8 inch (20 cm) of the existing wall thickness must be sound concrete. A facia of new concrete is added, well anchored to the existing wall.

- Type "B" Repair: In this case, a section of the wall is replaced, through its entire width, which includes the facia on the water side. This type of repair uses the dry pack method, CPM-2, to close the gap between the top of the new concrete and the existing concrete. See CR-8 and Figure 7-7 for a similar wall repair.

Application: These types of repair are applicable where the extent of the deterioration is limited and is not threatening to the entire height of the seawall, and a partial repair from foundation to above high water will solve the problem. The wall foundation must be in good condition. Extensive deterioration along a length of the seawall would call for a complete demolition and replacement of a section of wall.

Figure 7-4 Repairs to Concrete Seawall



CR-4: MISCELLANEOUS REPAIRS TO CONCRETE PILES

Problem: Concrete pile is worn from abrasion at waterline; has spalled areas above the tidal zone; or is badly cracked.

Description of Repairs: In all cases, the repair area must be cleaned thoroughly of marine growth. All loose and deteriorated concrete must be removed. If reinforcing steel is exposed, it must be cleaned of all rust and scale and exposed at least 1 inch (2.5 cm) clear all around.

Figure 7-5 illustrates:

- Concrete Jacketing:

  a. Wrap pile with spiral reinforcing length of jacket.

  b. Place form around pile (metal, fiberglass, fiber, or other material).

  c. Fill form with 5000 psi (35 MPa) concrete, either pumped or placed with a tremie (see CPM-5 and CPM-6).

  d. Form may be removed or left in place.

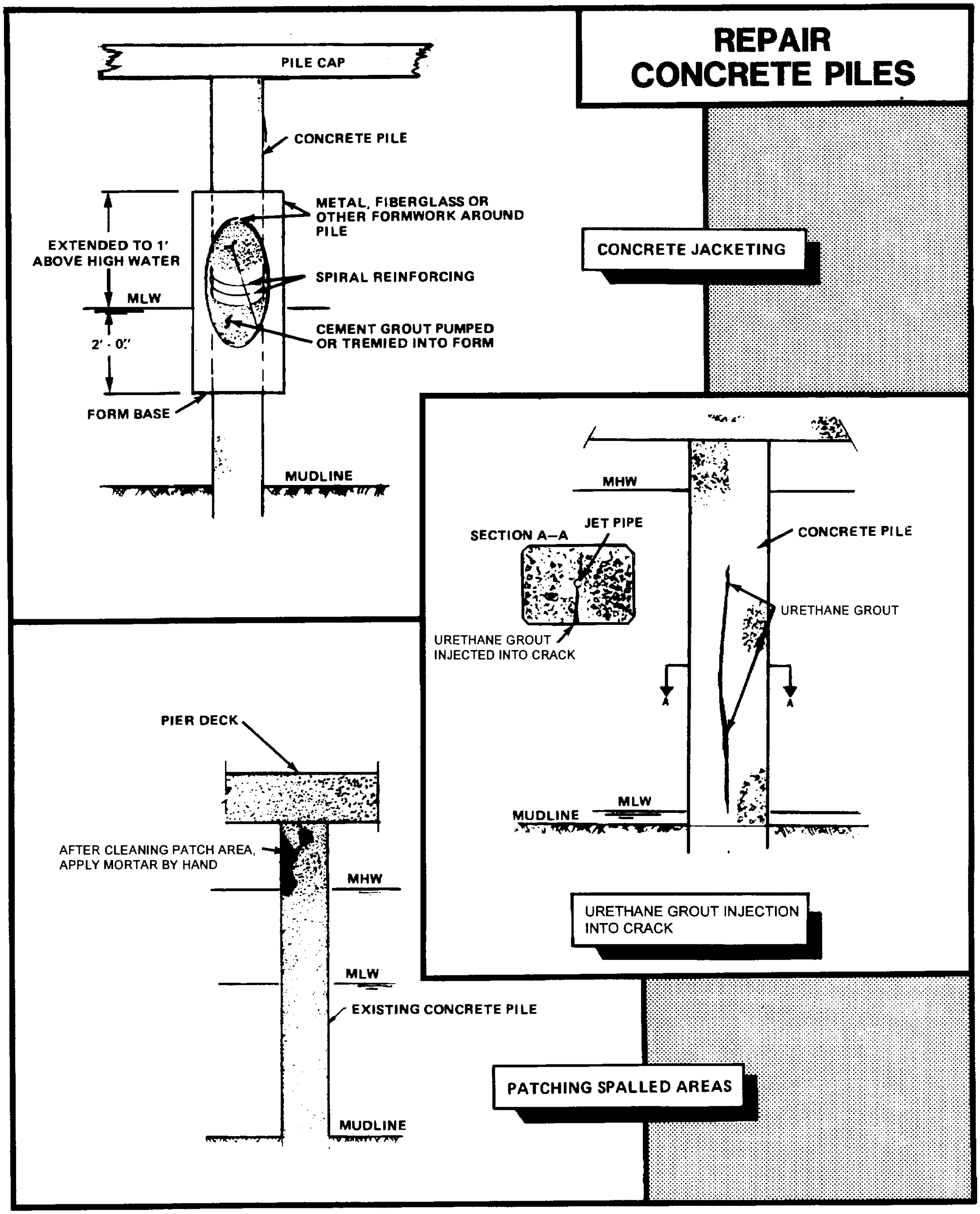
- Patch Spalled Areas: Repair the spalled areas by hand (see CPM-1) or form and pour.

- Fill Crack with Urethane Grout: See repair CR-1.

Applications: The concrete jacketing repair is a partial restoration when the pile is worn/deteriorated only in the tidal zone and sound below and above water. See repair CR-5 for more complete concrete pile restoration.

The spall patching and crack filling repairs are relatively minor, inexpensive techniques to protect the reinforcing steel from seawater. The effectiveness of the spall patches depend on the bond that is obtained with the old concrete and the corrosion activity on-going in the rebar in the substrate.

Figure7-5 Miscellaneous Repairs to Concrete Piles



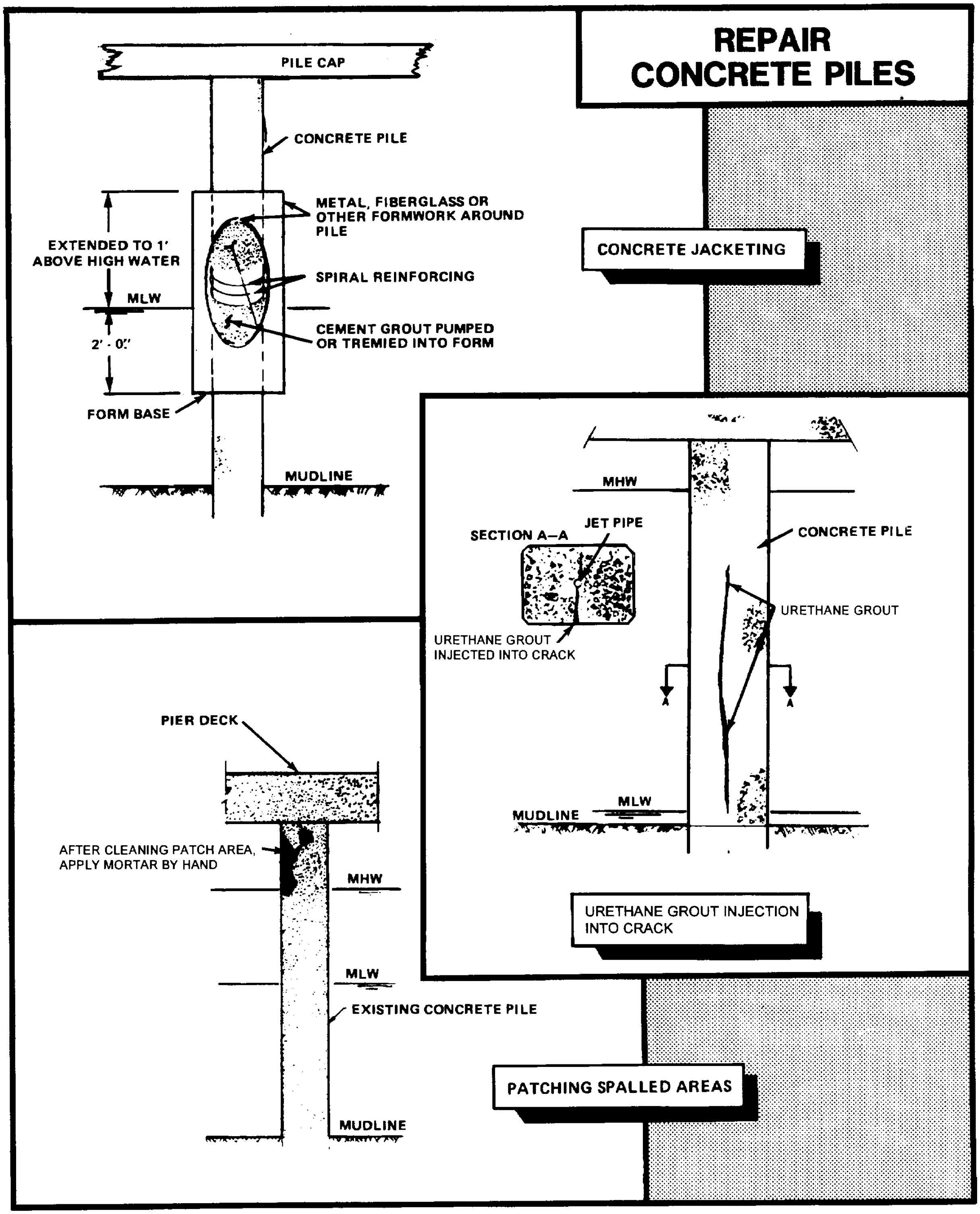
CR-5: CONCRETE JACKETING OF CONCRETE PILE

Problem: Precast concrete piles have major deterioration due to sulphate attack. Deterioration extends to the mud line.

Description of Repairs: See Figure 7-6. In this example, the original pile section was 15 ¾ inches (40 cm) square. The concrete jacket, as shown, is 30 inches (76 cm) in diameter. A timber encasement, with galvanized steel bands, is used in the tidal zone. A corrugated sheet metal form is used down below the mud line. See CPM-6 for the pumped concrete method of injecting the new concrete. Figure 7-6 shows the top portion of the pile encased with either a pneumatically placed (CPM-4) or hand-placed grout (CPM-1).

Applications: This method is applicable when the remaining section of pile is structurally sound and judged to be worth saving. Jacketing versus complete replacement is an economic decision.

Figure 7-6 Jacketing Concrete Piles



CR-6: COMBINATION REPAIR CAST-IN-PLACE CONCRETE AND EPOXY GROUT INJECTION

Problem: Concrete footings with many cracks with some spalling, scaling, and delaminated areas.

Description of Repairs: Repair footings using a combination of restoration with Portland cement concrete, and filling cracks and delaminated concrete by injecting urethane resin. Tools required: air hammer, conventional hand and power tools, and injection gun or pump for urethane.

Materials:

a. Portland cement concrete.

b. Urethane resin for injection.

Preparation:

a. Remove all unsound concrete.

b. Wire brush or sandblast all surfaces to receive bonding agent and clean thoroughly.

c. Thoroughly clean and coat any exposed reinforcing steel with cement slurry.

d. Sound concrete with metal rod to determine extent of delamination and outline the areas.

e. After restoration of concrete is completed, rout and clean racks to be filled with injected urethane.

Repair Procedures:

a. Place, cure, and finish concrete repairs to restore structure to its original shape (CPM-3).

b. Select epoxy injection points and drill holes if required. Insert injection tubes or valves if required. See repair CR-1.

c. Fill cracks 3.1 mils (0.08 mm) wide and larger, and delaminated areas, by injecting the low-viscosity urethane. For jobs with large areas of delamination and deep cracks, pressures up to 1,000 psi (6.9 MPa) may be required.

d. Plug the injection holes with epoxy paste.

CR-7: REPAIR USING POLYMER CONCRETE

Problem: Concrete roof deck spalling due to corrosion of reinforcing steel and cracks around support columns.

Description of Repairs: Patch spalled areas with PCC mortar. Coat roof deck. Reseal joints with polyurethane joint sealer. Requires conventional hand and power tools. May not be suitable for vehicle traffic areas.

Materials: Take careful measures to minimize drying shrinkage by selecting a material mix design with a maximum allowable shortage of 0.05 percent and proper curing.

a. Latex modified portland cement.

b. Polyurethane joint sealant that meets ASTM C920, *Specification for Elastomeric Joint Sealants*.

Preparation:

a. Remove all unsound concrete in the spalled areas. Expose reinforcing steel all around.

b. Clean the exposed reinforcing steel and entire deck area by sandblasting.

c. Thoroughly clean areas to receive new material immediately prior to placement.

Repair Procedures:

a. Patch spalled areas with Latex Modified Cconcrete.

b. Seal entire deck area with neat polyester resin.

c. Remove all joint sealant and reseal joints.

Limitations: The corrosion processes will continue to cause cracks and delaminations.

CR-8: TYPICAL CONCRETE WALL REPAIR

Problem: Holes or severely deteriorated areas require replacing the wall section with cast-in-place concrete.

Description of Repairs: Defective section of wall is removed, surfaces and reinforcing steel are prepared, form work built, and wall is restored with cast-in-place concrete. Repair may be an internal section, as shown in Figure 7-7, or may be the top of a wall or pier deck curb requiring an open-top form. Equipment used includes: sandblasting and air-water jet cleaning equipment, concrete saw, air chipping hammer, air-suction gun for mortar if available, power vibrator and tamper, and conventional concrete placement tools.

Materials: Portland cement concrete with maximum shrinkage of 0.05 percent.

Preparation:

a. Use air hammer or hand tools to remove all unsound concrete to the limits of the repair area.

b. Cut the top edge of the hole at the face of the structure to a fairly horizontal line (see Figure 7-7). Where a hole passes through a structural element, it may be necessary to fill the hole from both sides. In this case the slope of the top of the cut should be modified accordingly.

c. Cut the bottom and sides of the hole sharp and square with the face of the wall. When the hole goes entirely through the concrete section, spalling and feather edges can be avoided by having chippers work from both faces. All interior corners should be rounded to a minimum radius of 1 inch (25 mm).

d. Do not leave reinforcing steel partially embedded. Ensure there is a minimum of a 1 inch (25 mm) clearance around each exposed bar. Remove unnecessary tie wires.

e. Clean all surfaces to bond to new concrete with wet sandblasting and air-water jet. Clean exposed steel with abrasive blasting or wire brushing.

Repair Procedures:

a. Construct front forms for patches more than 18 inches (46 cm) high in horizontal sections so the concrete can be placed in lifts not more than 1 foot (30 cm) high. The back form can be built in one piece. Sections to be set as concreting progresses should be fitted before concrete placement is started. See Figure 7-7.

b. For irregularly shaped holes, chimneys (accesses) may be required at more than one level. In some cases, such as when beam connections are involved, a chimney may be needed on both sides of the wall or beam. In all cases, the chimney should extend the full width of the hole.

c. Ensure forms are constructed so that pressure can be applied to the chimney cap at the proper time.

d. Ensure forms are mortar tight at all joints between adjacent sections, between the forms and concrete, and at the tie-bolt holes to prevent the loss of mortar when pressure is applied to the concrete during the final states of placement. Place twisted or stranded caulking cotton, folded canvas strips, or similar material between the joints as the forms are built.

e. Keep concrete surfaces wet for several hours, preferably overnight, before placement.

f. Before placing the front section of form for each lift, coat the surface of the old concrete with a 118 mils (3-mm) thick layer of mortar. This mortar should have the same sand and cement content and the same water-cement ratio as the new concrete. The surface should be damp, but not wet. The mortar can be applied with an air-suction gun, brush, or rubbed into the surface by hand. (Be sure worker is wearing rubber gloves if doing by hand.)

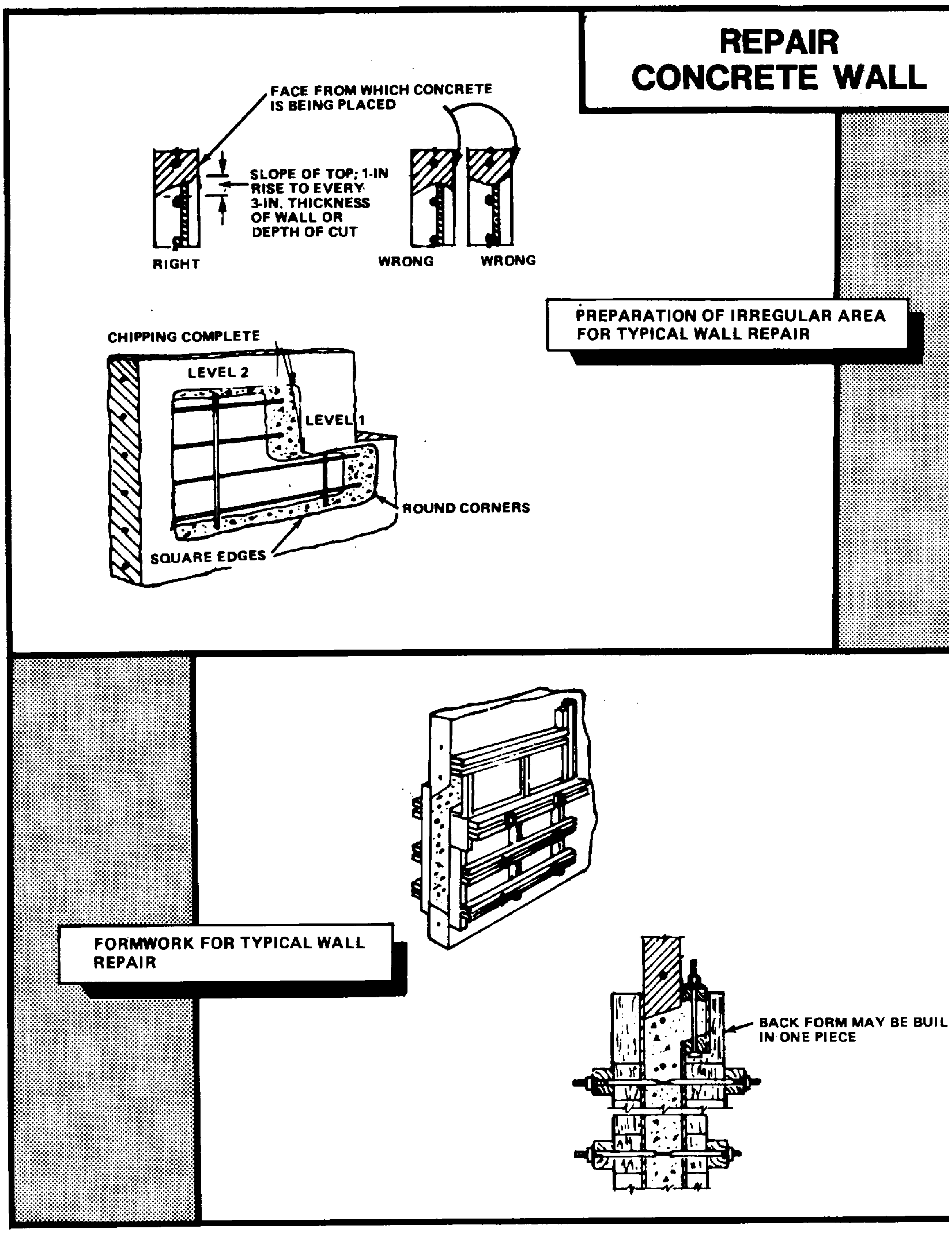
g. Place concrete immediately. Ensure thorough compaction by vibration or pressure grouting to14.5 psi (0.1 MPa).

h. Remove forms the day after placement. If chimneys were used, remove the remaining projections the second day working up from the bottom.

i. Thoroughly moist-cure the new concrete.

j Finish with a wood float. Tool or chamfer edges and corners as required. Avoid using water in finishing.

Figure 7-7 Typical Concrete Wall Repair



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CHAPTER 8

REPAIR OF STEEL STRUCTURES

8-1 **GENERAL**. Steel is used extensively in construction and repair of waterfront facilities due to availability, cost, ease of fabrication, physical and mechanical properties, and the design experience with its use. Structural steel and cast or fabricated steel are used in all areas of the waterfront. Typical applications requiring maintenance include:

- Piers, wharves, bulkheads, and quaywalls using steel H-piles or pipe piles to support or brace the structure; steel sheet piling used to retain fill; structural steel shapes used for framing.
- Fender systems incorporating steel H-piles.
- Mooring hardware such as cleats, bollards, bitts, and chocks made from cast or fabricated steel.
- Other items such as utility lines, grating, opening frames, space manhole covers, fences, bolts and nuts, handrails, and concrete reinforcement.
- Steel components of camels.

Corrosion is the major cause of deterioration of steel structures and components. The extent or severity of corrosion will vary with the exposure zone of the material; that is, whether it is in the atmospheric zone, the splash or tidal zone, or the submerged zone. Selection of the repair technique must consider each of these varied conditions and such other elements as:

- Facility mission and required life.
- Extent of damage and deterioration.
- Estimated life expectancy with repairs and without repairs.
- Projected load capacities.
- Problems associated with mobilization of equipment, personnel, and materials to accomplish repairs/maintenance.
- Tides and currents
- Economics and trade-offs.

Maintenance and repair of steel structures and components fall into five general categories: coating and wrapping, cathodic protection, concrete encasement, partial replacement, and complete replacement.

8-2 **PLANNING THE REPAIRS**. Repairing steel structures are often controlled by the availability of skilled personnel and equipment. In many cases, structural repairs, particularly of bearing piles and sheet piling, will be done by contract.

The initial planning step for establishing the repair approach must involve review of prior inspection reports to determine the scope of damage or deterioration, the rate of deterioration, and specific operational constraints placed upon the facilities because of the deterioration. Once the scope of repair requirements, including priorities, is established, how the work will be done, whether in-house or by contract, must be determined.

8-2.1 **Special Skill Requirements**. Repairing the pier decking and curbs, pile caps, fender system, and deck hardware involves having skills common to in-house shop forces. Underwater repairs require special skill levels that may not be available with in-house forces. These include general diving capability plus knowledge of:

- removing marine growth
- jetting or air lifting procedures
- underwater cutting, welding and drilling techniques
- underwater lifting procedures
- application techniques for underwater protection coatings
- wrapping materials used in underwater construction

8-2.2 **Equipment Requirements**. Repairing pier decking and curbs, pile caps, fender system and deck hardware requires equipment common to in-house shop forces. Equipment for bearing or sheet piling repairs, however, may include:

- high-pressure water blaster
- hydraulic grinders with barnacle buster attachment
- hydraulic drill with bits
- hydraulic power unit

- oxygen arc cutting and oxy-acetylene torch equipment
- protective clothing and gloves for personnel handling epoxy coatings for steel
- concrete pump with hose
- jetting pump and hose
- rigging equipment
- float stage and scaffolding
- cofferdams
- clamping template for cutting piles
- special clamping equipment
- crane

8-3 **REPAIR PROCEDURES**. Repair techniques for waterfront steel structures are summarized in Table 8-1. Selecting a technique must address both immediate repairs necessary to restore the structure to full (or other designated) usage and protective measures needed to prevent further corrosion. Selecting a means for restoring the structural capacity of the facility may be straightforward, being generally controlled by the level and rate of deterioration. Decisions on the level of protection needed to inhibit future corrosion may be more difficult. Generally, these decisions are economically driven.

Each repair decision must carefully weigh the long-term operational requirements and existing environmental factors (tides and currents) that can help accelerate corrosion before evaluating initial and life cycle costs. In many cases, combining cathodic protection and protective coating in the repair decision may be the most cost effective in the long term. Using any of the repair techniques that follow should fully adhere to the preservation treatment requirements outlined for steel structures in Chapter 3.

Damaged steel hardware such as cleats and bollards in general should be replaced in kind. Care should be taken that the engineer determine the cause of failure and that the replacement item conforms to NAVFAC Standard Details.

Table 8-1 Repair Techniques for Steel Structures

Repair No.	Description
Bearing Piles	
SR-1	Protecting Steel Piles by Coating
SR-1	Cathodic Protection for Steel Bearing Piles
SR-3	Partial Replacement of Steel Piles
SR-4	Repairing Steel Pile with Concrete Encasement
SR-5	Complete Replacement of Steel Pile
Sheet Piling Walls	
SR-6	Coating and Cathodic Protection for Steel Sheet Pile Wall
SR-7	Patching of Steel Sheet Pile Wall
SR-8	Reinforcing Tie-Back Systems for Steel Sheet Pile Wall
SR-9	Replacement of Existing Steel Sheet Pile Wall
SR-10	Installing a Concrete Cap or Face on a Steel Sheet Pile Wall
SR-11	Scour Protection for Steel Pile Supported Waterfront Structure

SR-1: PROTECTING STEEL PILES BY COATING OR JACKETING

Problem: A new steel pile has been installed or an existing pile has experienced slight deterioration (less than 15 percent) of the cross-sectional area at some point. Protection against further corrosion is required.

Description of Repairs: Clean steel above water with abrasive blasting equipment and underwater with water jet cleaning equipment.

Epoxy-Polyamide Coating: See the Paragraph entitled, "Protective Coatings for Steel" (see Figure 8-1).

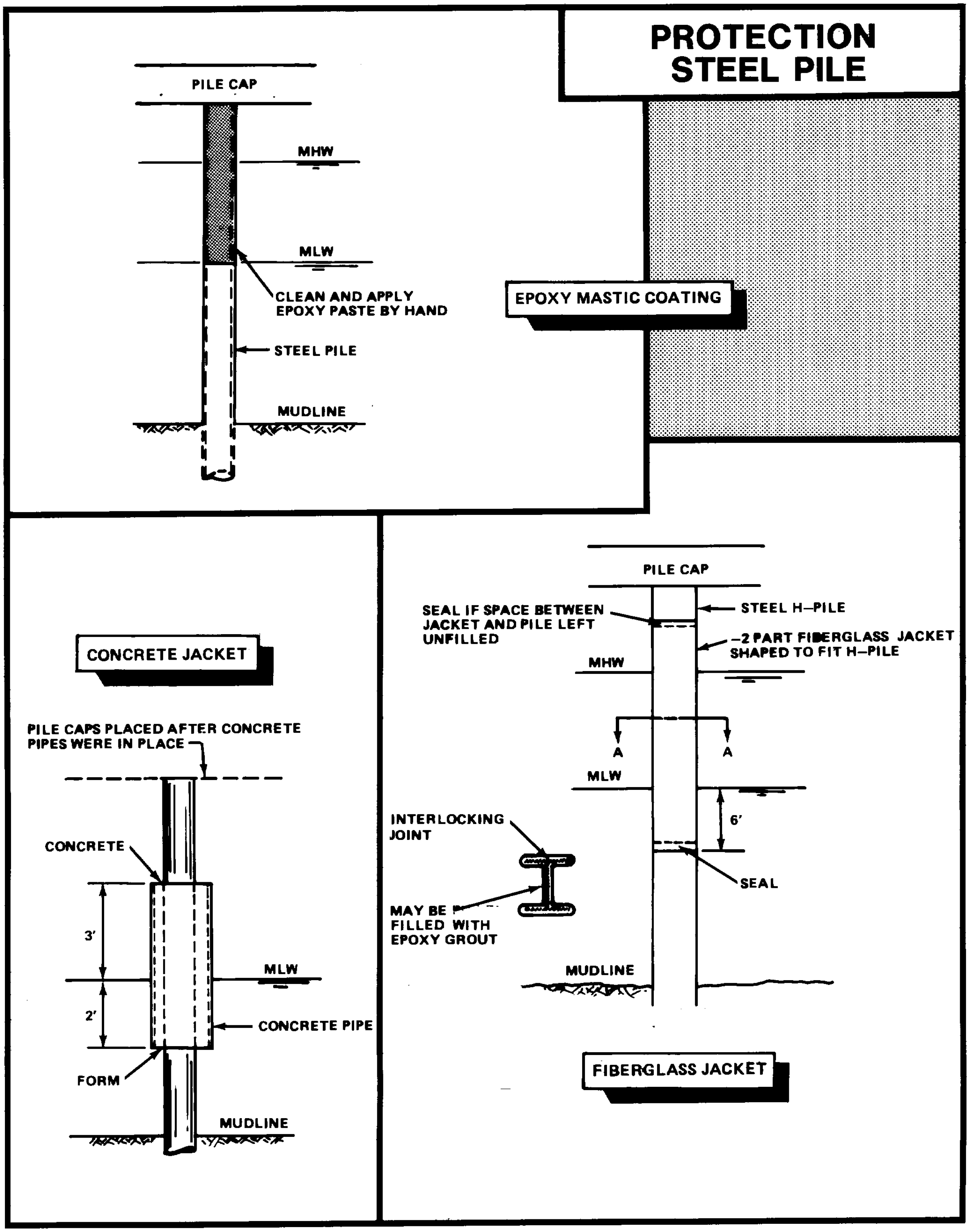
Fiberglass Jacket: Place jacketing around pile and secure. Pour epoxy grout inside sleeve if grout is used. Seal the top and bottom of the pile to prevent water entering inside jacket, if mortar is placed between pile and jacket (see Figure 8-1).

Concrete Jacket: During installation of steel pile, place a concrete pipe jacket around pile after it is driven. Fill the annular space between concrete jacket and pile with concrete (see Figure 8-1). The pile must be accessible from the top.

Application: These methods can be used to prevent further rusting. Economics will govern which method is used based on the extent of overall facility deterioration, access to pile, and availability of alternatives.

Future Inspection Requirement: Increased inspections may be required, particularly in areas where ice may be present, to detect signs of abrasion of the mastic or jacketing and renewed corrosion of the pile.

Figure 8-1 Protecting Steel Piles by Coating or Jacketing



SR-2: CATHODIC PROTECTION FOR STEEL BEARING PILES

Problem: New steel bearing piles have been installed or existing piles have experienced slight surface deterioration. Anticipated corrosion is high. Protection against further corrosion is required.

Description of Repairs: Two methods are available for providing cathodic protection for steel bearing piles:

Sacrificial Anode System: Secure sacrificial anodes below low water on steel by welding or bolting. Size, type, and spacing of anodes must be determined to suit structure and environment (see Figure 8-2). A good electrical connection between elements must be maintained.

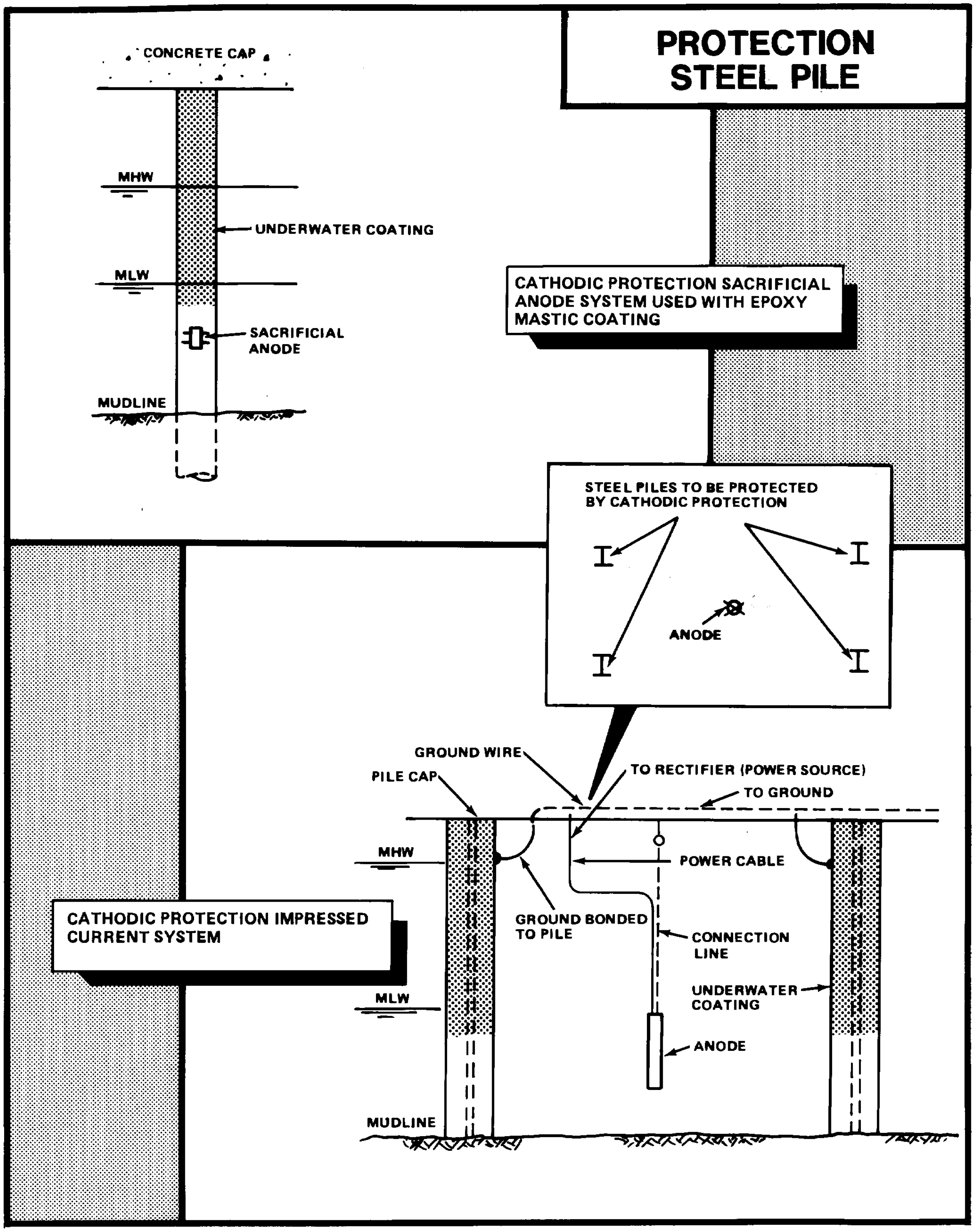
Impressed Current System: Install the cathodic protection system as shown in Figure 8-2. Basic components include:

- Anode: Material to be consumed over a long period of time.
- Electrical potential: Power source (rectifier) to provide constant electrical potential between anode and steel pile.
- Ground between piles and power source to provide closed cell.

Application: Requires careful design and installation. System is not effective for mitigating corrosion above mean low water.

Future Inspection Requirements: The cathodic protection system must be carefully monitored and maintained. If anodes for an impressed current system are placed between bents, special inspections must be made to ensure that floating debris has not damaged or removed the individual anodes.

Figure 8-2 Cathodic Protection for Steel Bearing Piles



SR-3: PARTIAL REPLACEMENT OF STEEL PILE

Problem: Moderate to heavy deterioration (greater than 35 percent) of the upper cross-sectional area of the H-pile has occurred.

Description of Repairs: Cut out the corroded section of pile; be sure that the bottom cut and top cut (if applicable) are square. Temporary supports may be needed to transfer the load from the pile being repaired to adjacent piles. Fabricate a welded assembly consisting of: a 1-inch (25 mm) steel bearing plate, two 2/5-inch (10 mm) steel side plates, and four steel angles. Place over the bottom cut. Drill and bolt the bearing assembly to the remaining lower steel pile using 1 ¼-inch (32 mm) galvanized steel bolts. Add cathodic protection to new the section.

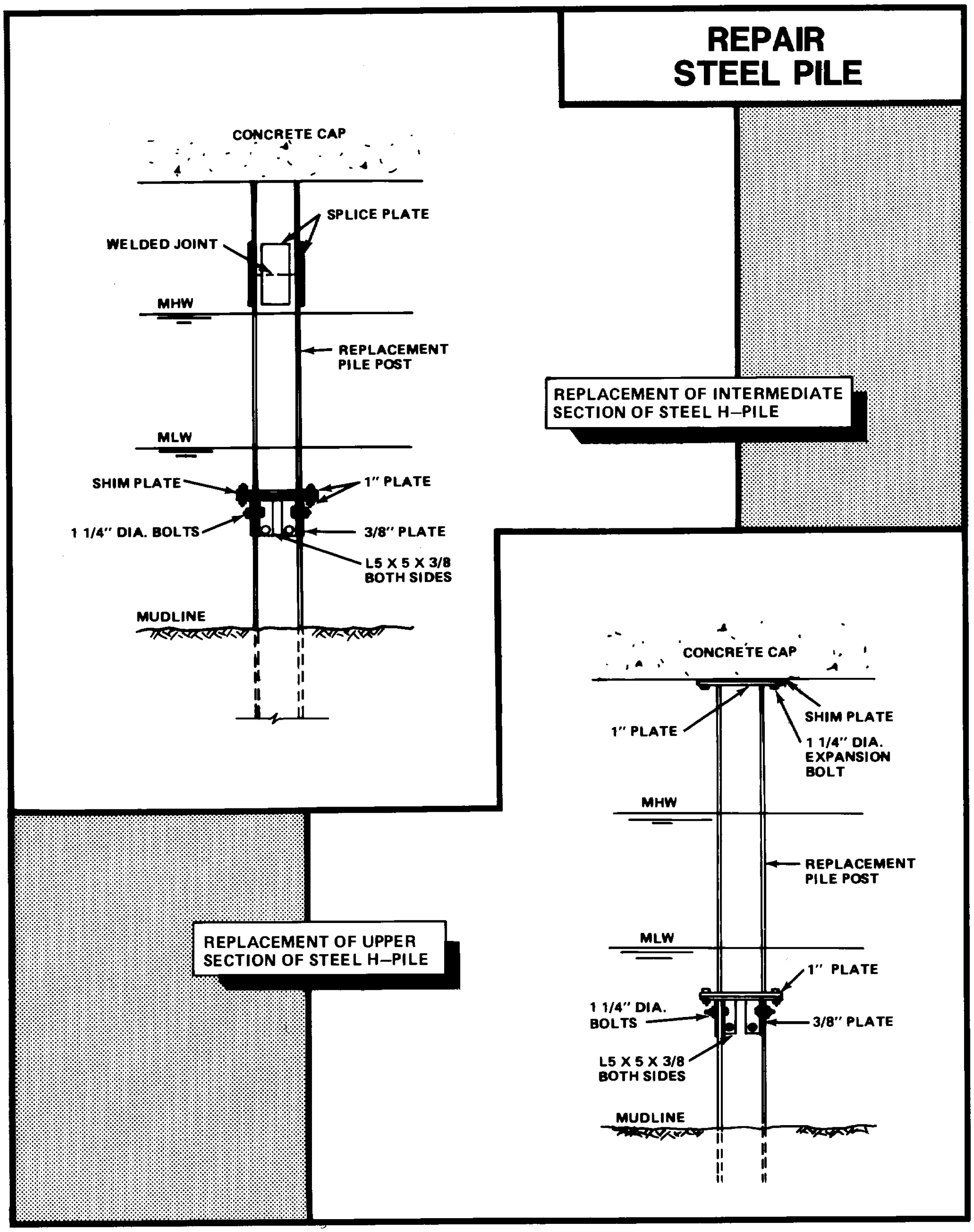
Intermediate Replacement (see Figure 8-3): Cut a section of new H-pile to fit the missing length of pile and weld a 1-inch (25 mm) steel bottom bearing plate to the new section. Place the intermediate section into position and bolt the bearing plates together. Weld the upper joint and four 5/8-inch (16 mm) steel splice plates to both old upper and new H-pile sections.

Total Upper Section Replacement (see Figure 8-3): Cut a new section similar to that required for intermediate replacement, except cut to fit under the concrete cap using a 1-inch (25 mm) steel bearing plate bolted to the cap. This arrangement is necessary when the steel has corroded extensively at the concrete-steel interface. All new metal should be cleaned and coated before installation. Welded joints should be cleaned and coated after welding. All welded joints should be watertight.

Application: This method restores the structural strength lost in the deteriorated upper section. Corrosion can again occur once the coating fails. Economics will govern approach.

Future Inspection Requirement: Same as for new steel pile sections.

Figure 8-3 Repair by Partially Replacing the Steel Pile



SR-4: REPAIRING STEEL PILE WITH CONCRETE ENCASEMENT

Problem: Slight to moderate deterioration (less than 35 percent) of the cross-sectional area has occurred; or protection against corrosion and abrasion is required.

Description of Repairs: Clean the steel pile of all marine growth and loose rust using a high-pressure water blaster. Two methods may be used to provide the concrete encasement: flexible and rigid form. In addition, steel angles may be used with the rigid form, to regain some of the reinforcement in the steel pile where greater levels of deterioration have occurred (see Figure 8-4). After the piles have been thoroughly cleaned, place a 6- by 6-inch (150- by 150-mm) reinforcing mesh around the pile, using spacers to maintain clearance between the pile, reinforcing, and fabric form. The fabric form should be placed around the pile.

For the flexible form, the zipper should be closed, and the form secured to the pile at the top and bottom with mechanical fasteners (see Figure 8-4).

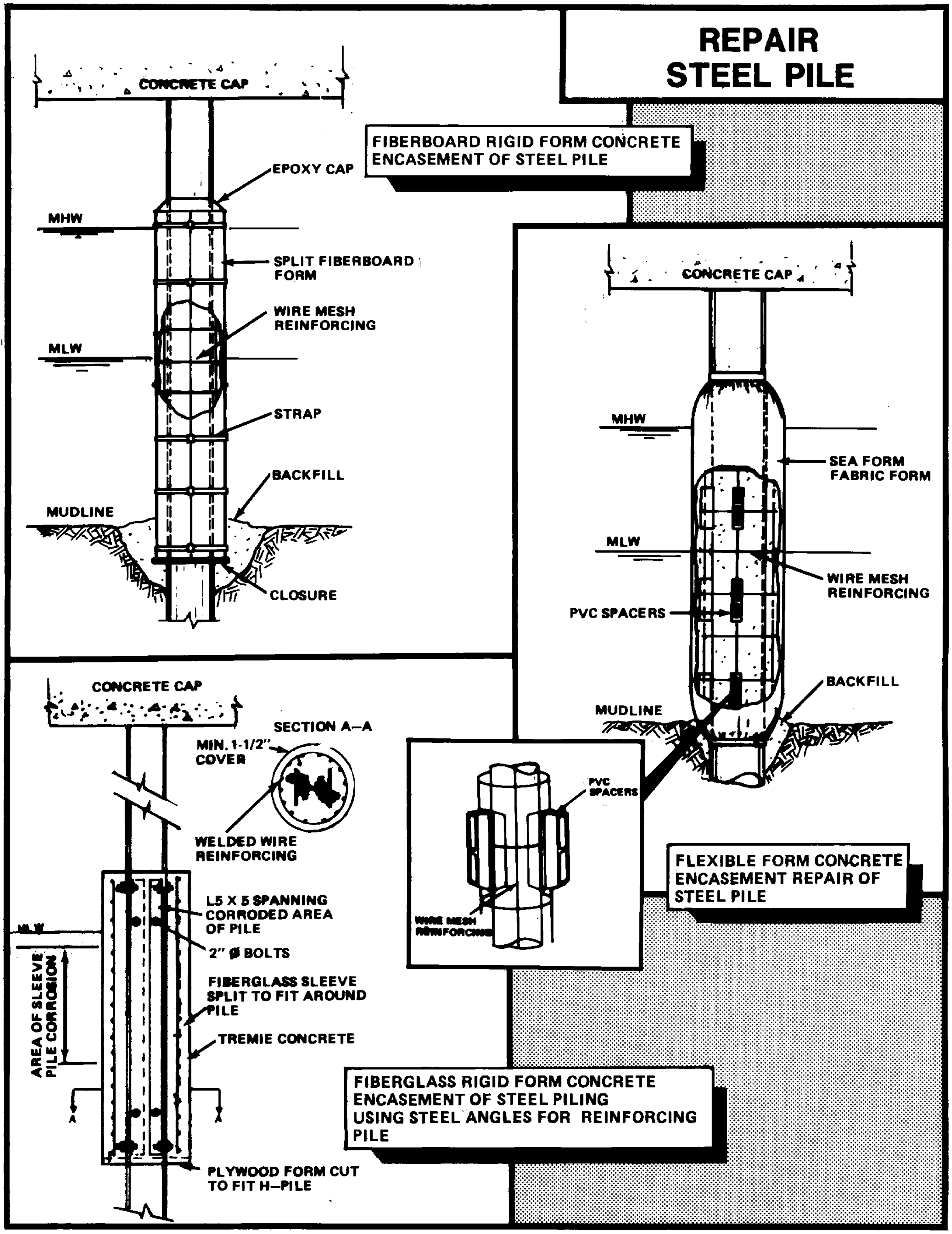
For the fiberboard form, the straps are installed and secured every 12-inch (300-mm). Maintain a 1 ½-inch (38-mm) space between the pile and reinforcing and between the reinforcing and form (see Figure 8-4).

The annular space between the pile and the form is then filled to overflowing with concrete grout using a tube or hose extending down to the lowest point of the form. The form is left in place and the base is backfilled to above the concrete.

Application: This method can be used as a repair or as a protection technique to prevent further rusting or abrasion. The method will not restore bearing capacity lost by the deterioration of the steel cross section. Partial restoration of compressive strength may be gained by the using steel angles with the concrete encasement. This is not a generally accepted practice, however, so care must be used to ensure that the connections are made to sound metal. Many times, posting the existing pile with a new H-pile section may be more cost effective. Economics would normally govern the decision.

Future Inspection Requirement: Increased inspections may be required to detect signs of potential failure of the repair.

Figure 8-4 Repair Steel Pile Using Concrete Encasement



SR-5: COMPLETE REPLACEMENT OF STEEL PILE

Problem: Moderate to heavy deterioration (greater than 35 percent) of the cross sectional area, or damage has occurred to a steel H-pile.

Description of Repairs:

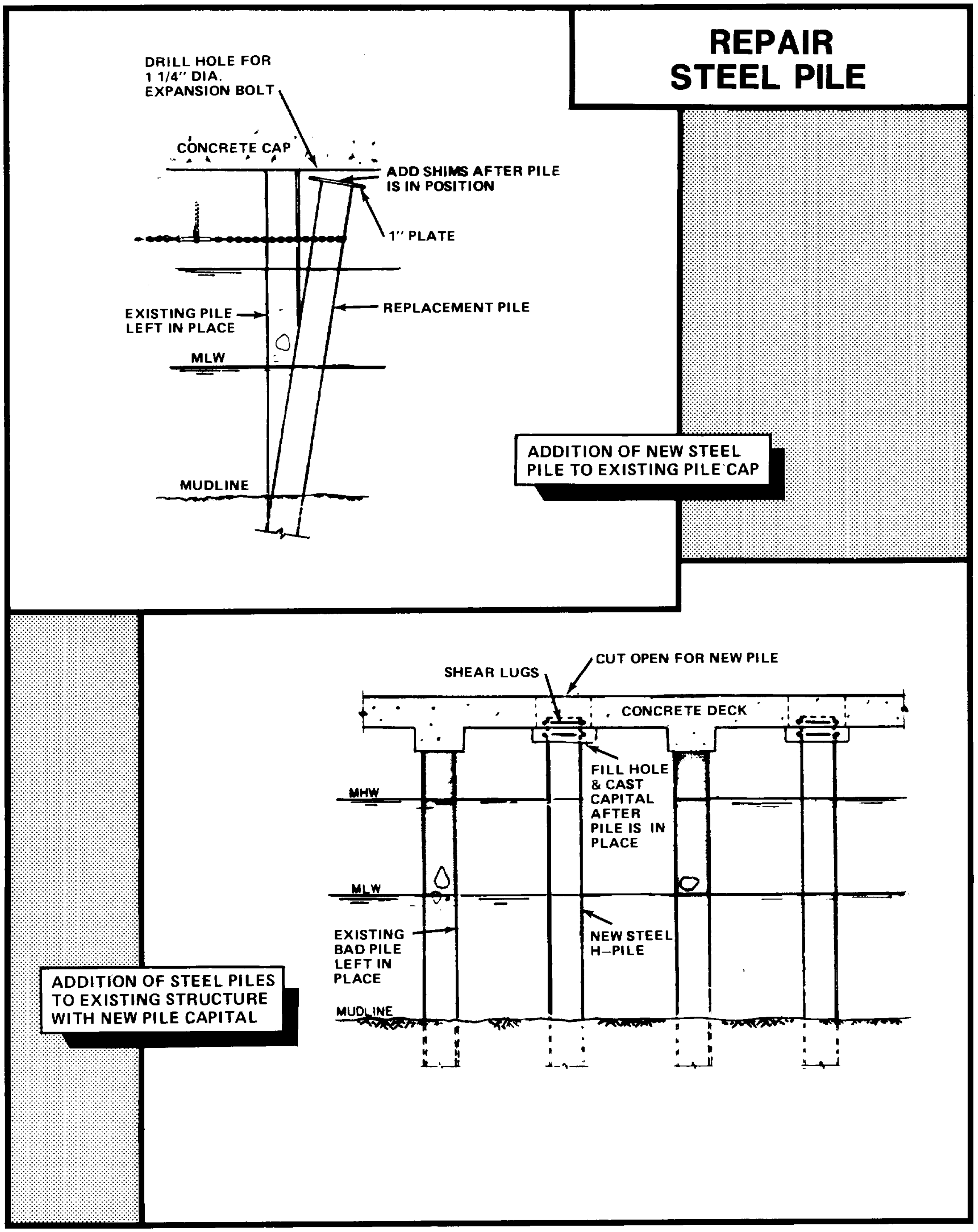
Using Existing Pile Cap. Cut an opening in the concrete deck adjacent to the damaged pile. Drive the new steel pile and cut to fit under the existing pile cap. Pull the pile laterally into place (see Figure 8-5). Shim between the pile and pile cap and secure the pile to the pile cap using 1 ¼-inch (32-mm) expansion bolts.

With New Pile Cap. Cut an opening in the concrete deck between existing pile locations. Drive the new steel pile through the hole cut in the deck and cut off below the top of the concrete deck (see Figure 8-5). Weld horizontal reinforcing bars to the top of the steel replacement pile or provide suitable reinforcing steel transitions with concrete piles, to ensure load transfer. Form the pile capital under the deck and around the new pile, and fill the form and deck space with concrete. Ensure that new and existing piles are electrically isolated otherwise accelerated corrosion may be experienced with the new piles.

Application: This method restores the structural strength lost with the deteriorated pile. The same corrosion can occur, however, with the new pile. Concrete encasement or cathodic protection can be used to extend life expectancy. Economics will govern approach.

Future Inspection Requirement: Same as for new steel or concrete pile sections.

Figure 8-5 Replacing Damaged or Deteriorated Steel Piles



SR-6: COATING/CATHODIC PROTECTION OF STEEL SHEET PILE WALL

Problem: Sheet pile wall has surface deterioration. Protection against further corrosion is required.

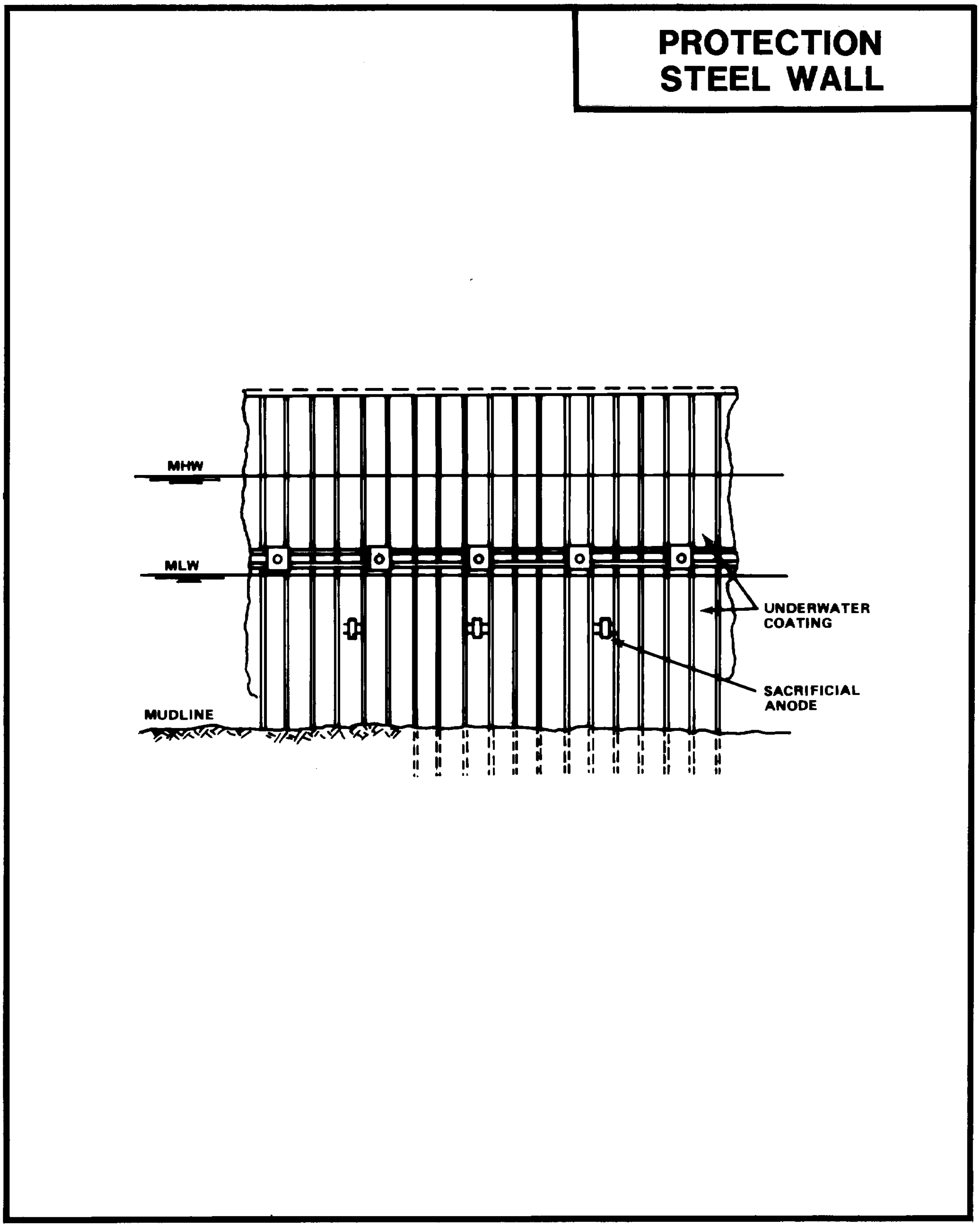
Description of Repairs: Two procedures provide corrosion protection for steel sheet piling:

Coatings. See the Paragraph entitled, “Protective Coatings for Steel” (Submerged and Splash Zone). See Figure 8-6.

Cathodic Protection: For sacrificial anode system, weld or bolt anodes below low water on the steel. Determine size, type, and spacing of anodes to suit structure and environment. A low resistance electrical connection between adjacent piling must be made (see Figure 8-6). For impressed current systems, place anodes off the face of the sheet pile wall.

Future Inspection Requirement: Increased inspection may be required, particularly in areas where ice may be present, in order to detect signs of abrasion of the mastic or removal of the anodes and renewed corrosion of the sheet piling.

Figure 8-6 Coating/Cathodic Protection of Steel Sheet Pile Wall



SR-7: PATCHING STEEL SHEET PILE WALL

Problem: Steel sheet pile wall has small to medium holes. General condition of sheet piling is otherwise sound with minimum signs of corrosion.

Description of Repairs: Clean around area to be patched. For larger holes using steel plate patches, clean sheet piling from 18-inch (460-mm) below holes to above mean low water.

Epoxy Patch: Weld wire mesh or bolt fabric mesh over holes and cover with epoxy-polyamide putty smeared on by hand (see Figure 8-7). Good for a limited number of small holes.

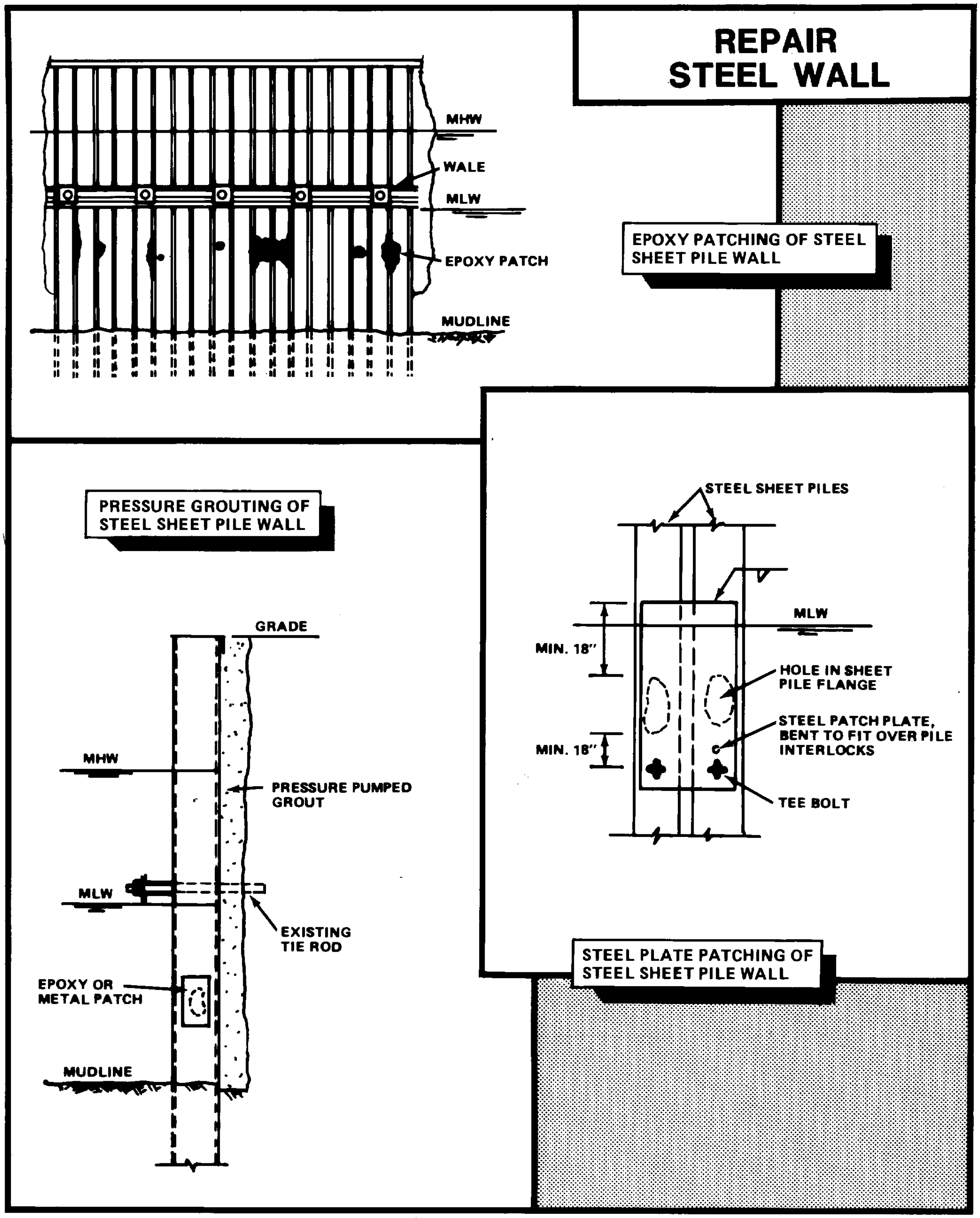
Steel Plate Patch: Determine size of patch plate needed. Cut plate to size and bend plate to fit over sheet pile interlocks. Weld plate in place at top, above low water. Cut holes for Tee bolts in sheet piling behind holes in plate; place and tighten Tee bolts (see Figure 8-7). Alternative is to weld plate all around, which is more appropriate for larger holes or several small holes.

Patch and Pressure Grouting: Where several small holes make pure patching cost expensive, a combination of patching and grouting may be a better solution. In this approach, cover the larger holes with epoxy or steel plate patches, then pressure grout the area behind the wall (see Figure 8-7).

Application: This approach will not prevent further corrosion and its success depends on the surrounding areas of sheet piling being relatively sound and free from rust. Continued deterioration of a weak structure, particularly near tiebacks, could lead to rapid failure and poor use of repair funds. Economics should govern final selection of the repair method.

Future Inspection Requirement: Increased inspection will be required at the patch areas to ensure that welds and bolted connections continue to hold.

Figure 8-7 Repairs to Steel Sheet Pile Walls Using Different Patching Methods



SR-8: REINFORCING TIE-BACK SYSTEMS FOR STEEL SHEET PILE WALL

Problem: Light to moderate movement of the top of the steel sheet pile wall has occurred due to tieback failure or excessive loading behind the wall. The area behind the wall is accessible to perform repairs.

Description of Repairs: Install a new wale slightly above the existing wale. Locate the new deadman anchors based on engineering calculations. Trench for the tie rods between the wall and the deadman anchors. Place the tie rods through the wale and sheet piles and secure in place to the deadman anchors (see Figure 8-8). Be sure that enough clearance is allowed through the sheet piles to electrically isolate the tie rods from the piling.

Install zinc or magnesium packaged anodes to prevent future corrosion of the rods.

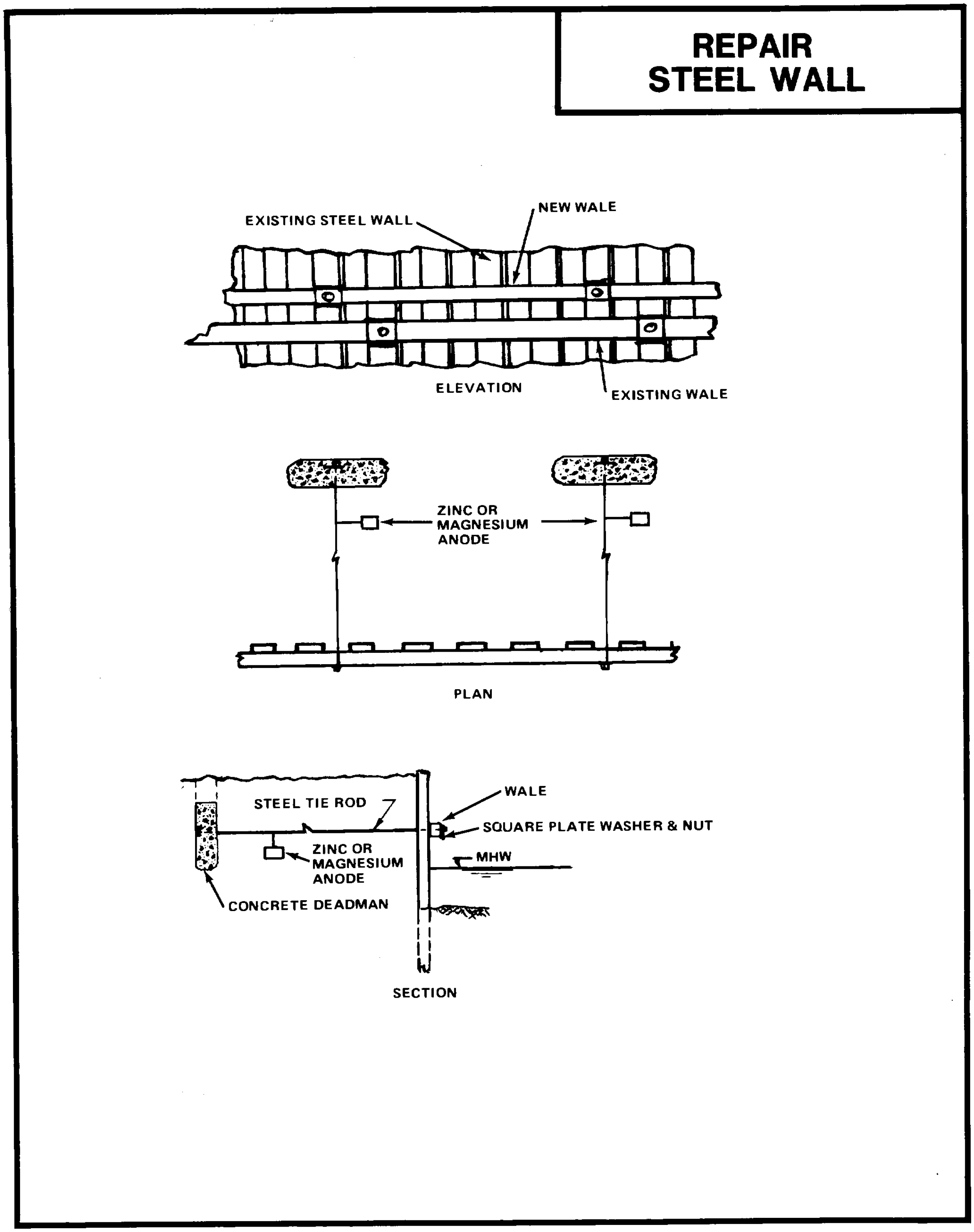
Replacing an existing tieback system may involve the replacing any or all of the existing components, depending on the amount of deterioration that has taken place.

Sheet pile wall movement can also be arrested by changing the soil loading acting on the wall. For example, stone riprap dumped against the exterior toe of the wall will add resistance to the movement of the toe. Alternatively, or in addition, backfill can be removed from behind the wall and replaced with lightweight granular fill. This type of fill is free draining, which reduces the hydrostatic pressure behind the wall and allows the water level on both sides to balance.

Application: Reinforcing or replacing the tieback system may be restricted to correcting slight to moderate wall deflection. Excessive deflection may require wall replacement or major restoration.

Future Inspection Requirement: Carefully inspect the wall for further signs of continued deflection or steel member failure.

Figure 8-8 Installing or Replacing Tieback Systems for Steel Sheet Pile Wall



SR-9: REPLACEMENT OF EXISTING STEEL SHEET PILE WALL

Problem: Serious deterioration of the steel sheet pile structure has occurred; patches cannot be used for repairs.

Description of Repairs: Two methods are available for replacing deteriorated steel sheet piling:

Timber Sheet Piling: Remove decking (if required) behind existing steel sheet pile wall to provide enough space to excavate and drive timber piling. Excavate to expose tie rods (usually these are above mean low water). Place new timber wales to act as template for driving timber sheeting. Drive timber sheeting (see Figure 8-9). Backfill may not be possible between steel sheeting and timber sheeting below wales. Replace decking (as applicable).

Steel Sheet Piling: Drive new steel sheet piling in front of existing sheet piling. Drill hole for tie rod and pipe casing through both walls into stiff clay, out of active zone behind old wall. Pressure grout inside casing forming bulb in clay at end of casing (see Figure 8-9). Fill space between old and new sheet piling with concrete. If stiff clay is not available, deadmen may need to be added to secure the tie rods. Ensure electrical isolation is maintained between the existing and new sheet piling, especially through tie rods.

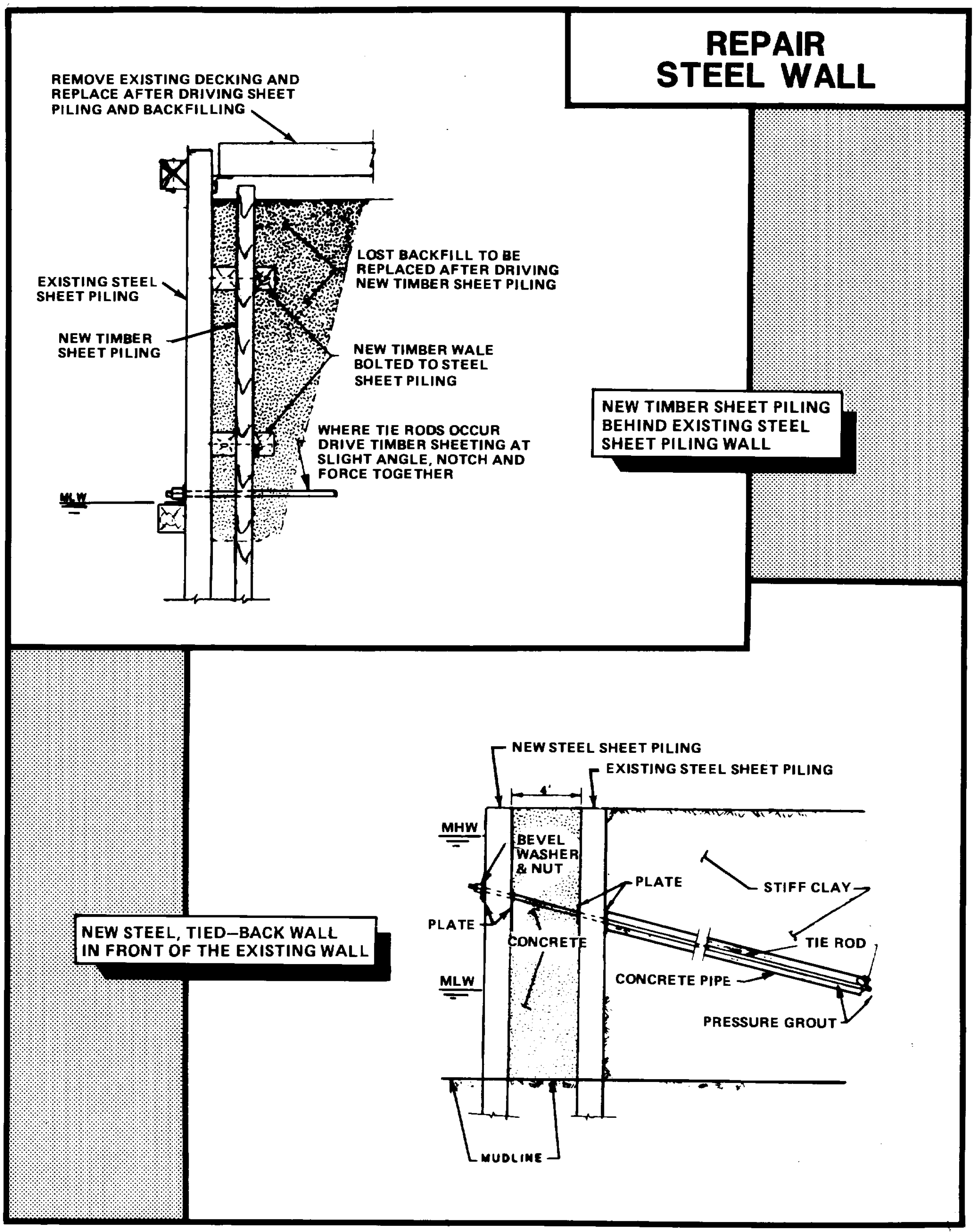
Application: Either solution should stop the loss of backfill through the existing steel sheetpiling wall.

The timber sheet piling should be less expensive than the new steel sheetpiling wall. However, the timber piling will require access behind the existing wall, and continued corrosion of the existing steel sheet piling can be expected.

The new steel sheet piling can provide a new wall with equal or greater strength; and construction can be done without excavating behind the existing wall. This approach does, however, require grouted tie rods be secured in existing soil. If stiff clay or other suitable soil is not available, this method may not be appropriate unless deadmen are added.

Future Inspection Requirement: Normal inspection requirements should suffice for the new steel sheet pile wall. If the timber piling approach is used, more extensive annual inspections may be required to watch for signs of timber piling deterioration and failure behind the existing wall.

Figure 8-9 Replacing Existing Steel Sheet Pile Wall With New Steel Sheetpiling Or Timber Sheet Pile Wall



SR-10: INSTALLING A CONCRETE CAP/FACE ON A STEEL SHEET PILE WALL

Problem: Large-scale deterioration of the steel sheet pile structure has occurred; patches can not be used for repairs.

Description of Repairs: Excavate the soil from behind the wall to a level required for the new concrete cap or attachment of form ties for a concrete face. Remove all marine growth and deteriorated steel and clean surfaces. Two methods are available for installing a concrete cap/face:

For Concrete Cap: Build forms, place reinforcing, and pour concrete at mean low water. After curing, remove forms and backfill behind wall (see Figure 8-10).

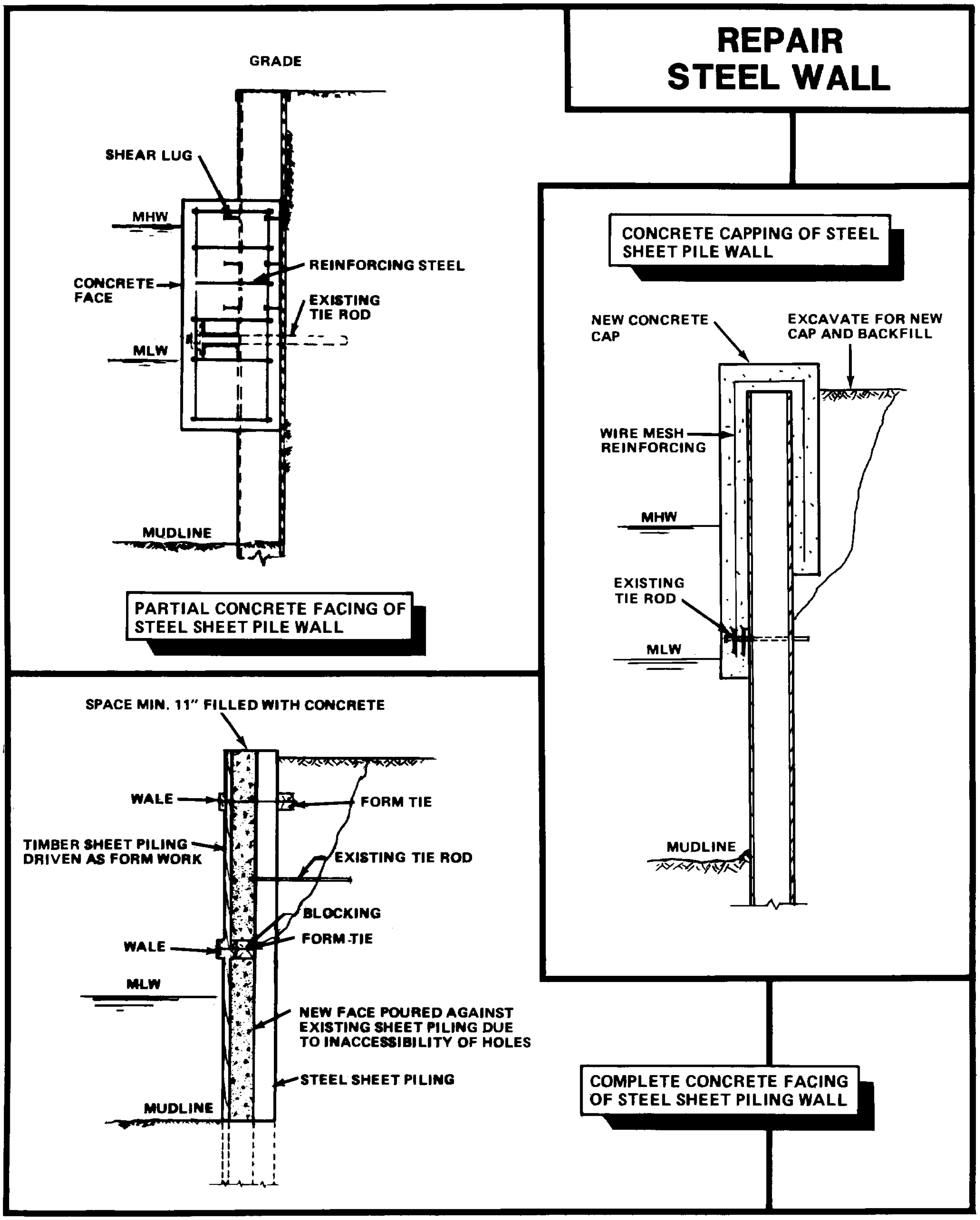
For Concrete Face: Place and fasten blocking and low wale against existing sheet piling. Drive the timber sheet pile wall about 12 inches (300 mm) in front of existing sheet piling using wale as a guide. Attach outside wales to timber sheeting and place concrete by pumping or tremie. Leave timber sheet piling in place or remove as desired (see Figure 8-10).

For partial concrete facing of steel sheet pile wall, techniques exist to repair a deteriorated wall from the exterior side without requiring excavating. One method uses timber formwork (see Figure 8-10), welding steel studs to the steel sheet pile at locations where the metal is sound. The shear lugs help to hold the concrete in place. A temporary steel frame, which supports the timber formwork, is suspended from the top and welded to the exterior of the wall above the waterline. Blocking is used to maintain a 12-inch (300-mm) minimum space, and reinforcing is placed in the center of the space. Concrete is placed by pumping or tremie method. The form work can be removed within a few days.

Application: Used to restore structural strength at the top of the wall (cap) or prevent further loss of soil through holes in the sheet piling (face). Does not restore bending moment capacity in wall. Provides protection against further deterioration.

Future Inspection Requirements: Annually inspect the sheet piling areas immediately under the pile cap to ensure that further corrosive damage is not being weakening the support for the concrete cap. Follow similar procedures for partial concrete faces. For complete concrete facing, follow normal inspection procedures.

Figure 8-10 Installing a Concrete Cap and/or Face on a Steel Sheetpiling Wall



SR-11: SCOUR PROTECTION FOR STEEL PILE SUPPORTED WATERFRONT STRUCTURE

Problem: Serious erosion of seabed material has occurred around a marine structure as a result of wave action and/or strong current.

Description of Repairs: Two methods are available for scour protection:

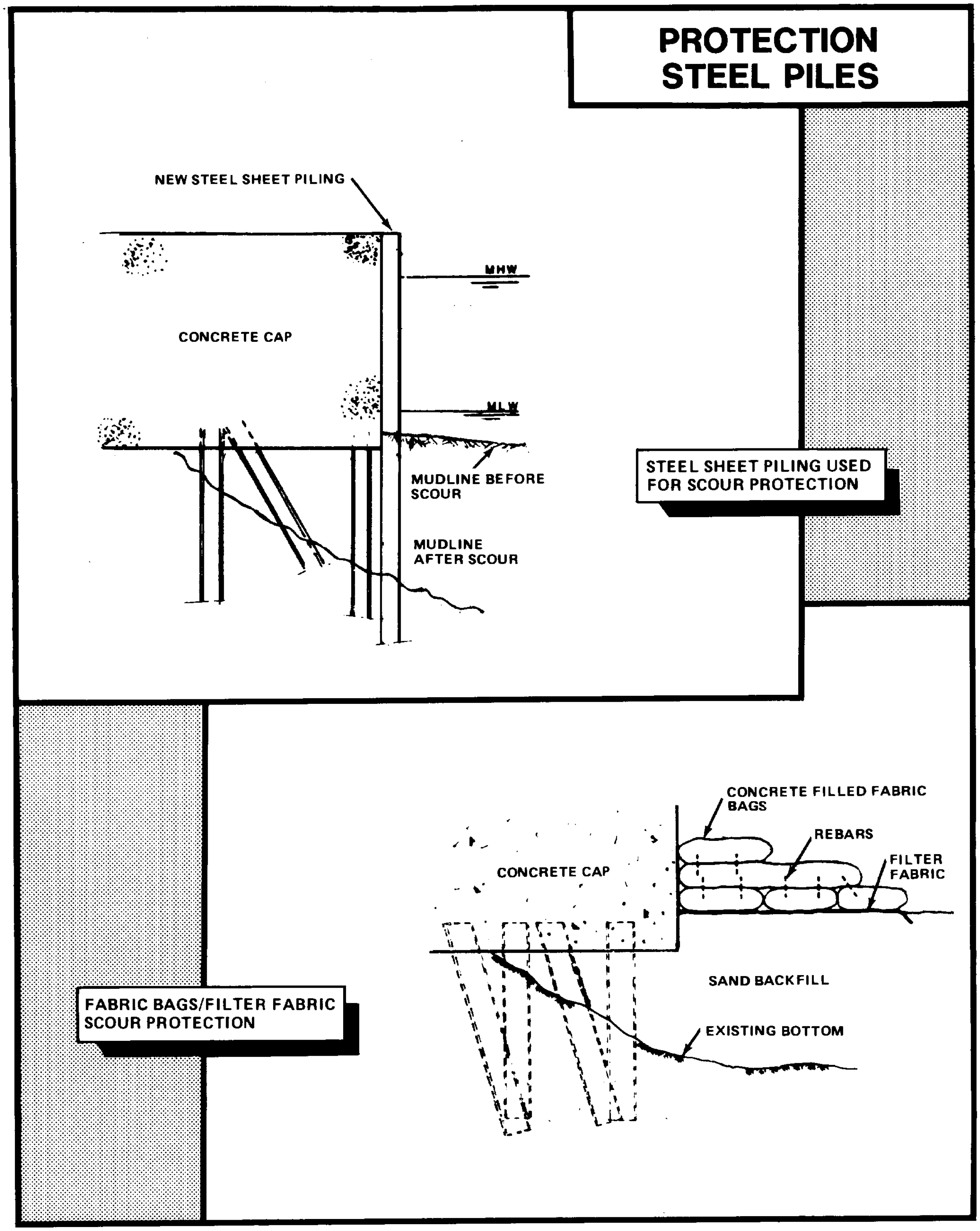
Riprap Placement: Replace the lost foundation material by dumping stones randomly into place. If stone riprap is not available, use bags of synthetic fiber woven water-permeable material filled with concrete. On sandy seabeds, a filter fabric may be required under the riprap or bags to prevent scour through the individual units (see Figure 8-11). The materials most commonly used are commercially available synthetic fiber, non-woven fabrics weighing between 8 and 12 ounces per square yard (269 and 405 grams per square meter) or woven fabrics weighing between 5 and 7 ounces per square yard (169 and 236 grams per square meter.)

Steel Sheet Piles: Drive steel sheet piling around structure to protect soil around the bearing piles (see Figure 8-11). The decision to replace the lost foundation material under the structure should be based on the strength of the exposed piles.

Application: A careful evaluation should be performed to determine if: (1) any settlement of the structure has occurred due to the scour, or (2) suitable bearing capacity exists within the remaining structural foundation to support the loading. Selecting either scour protection technique should ensure that suitable structural integrity exists before beginning the repairs.

Future Inspection Requirement: Normal inspection requirements will generally suffice. If riprap is used, annual underwater inspection will be required to ensure that material is not lost.

Figure 8-11 Scour Protection for Steel Pile Supported Waterfront Structure



CHAPTER 9

REPAIR OF SYNTHETIC MATERIALS

9-1 **GENERAL**. Synthetic materials used on waterfront structures include:

- Structural components such as railings and stanchions, resilient fenders, camels, chocks, wales, piles, light standards, gratings, and piping.
- Coatings, wraps, and jackets for piles and piping.
- Buoyancy materials used in buoys, floats and foam-filled and pneumatic fenders

Deterioration of synthetic materials results from physical damage, exposure to the environment, aging, or a combination of these factors. Physical damage is the most common type of deterioration for most waterfront synthetic components. Exposure results in plastics cracking, separating or becoming brittle; foams crumble with age and lose resilience; and elastomers stretch and deteriorate from the effects of sun and exposure.

9-2 **INSPECTION OF SYNTHETIC MATERIALS**. All synthetic materials should be inspected periodically to ensure that they are clean and in good working order. If any component is damaged then it should be repaired or replaced as necessary. Repairs to synthetic materials and components will normally be controlled by the position of the components (or material) within the waterfront structure. Components, such as: railings, stanchions, resilient rubber fenders, camels, wales, chocks, light standards, gratings, and piping, will normally be replaced and may be done by shop personnel. In general, small surface damage such as burns, scratches, chips, or small cracks can be repaired, but if the damage is structural then replacement is the recommended course of action. (Table 9-1.)

Table 9-1 Repair Techniques for Synthetic Materials

Repair No.	Description
Small Surface Damage	
PR-1	Repair of Fiberglass, Guard Rail
Repair by Replacement	
PR-2	Repair Dry Dock Caisson Seal (See Figure 9-1)

If damage to fiber-reinforced plastic (FRP) products, either fiberglass or carbon fiber, is detected then the manufacturer should be contacted to help determine if the product can be repaired or if it needs to be replaced. Repairing these products requires specialized expertise and will require contracting services.

Repairing coatings or jackets on piling involve skilled personnel and specialized equipment; repairs may have to be done by contract. Specialized skills and equipment for applying coatings, jackets, and patches on piling are covered in Chapters 6, 7 and 8.

Special instructions and equipment requirements for repairing foam-filled fenders are covered in NAVAFAC MO-104.1, *Maintenance of Fender Systems and Camels.*

PR-1: Repair of Fiberglass Guard Rail

Problem: Fiberglass guard rail is chipped and is a safety hazard.

Procedure: Sand and clean the damaged area and ensure it is dry. Apply epoxy or a catalyzed resin to the damaged area with a putty knife or spatula. Cover the repair with cellophane and secure it. Allow the repair to cure; then remove the cellophane and sand the area smooth.

Application: This procedure can be routinely used for any fiberglass component. Similar procedures can be used for other synthetic components.

Future Inspections: Basically the same as for other deck components.

PR-2: Repair of Drydock Caisson Seal by Replacement

Problem: Caisson wood or “rubber” seal is deteriorated or damaged and leaks.

Procedure: Move the caisson into the drydock and secure. Remove the existing wood or synthetic “rubber” seal assembly (see Figures 9-1 and 9-2.) Unless the old seal is “rubber” and the existing studs are still serviceable and in the correct configuration, remove the old mounting studs. Clean any wood or “rubber” remnants or any other obstruction on the caisson seal mounting surface. Repair surface flaws and irregularities in the caisson seal substructure to within an allowable tolerance as follows.

- Caisson seal mounting surface roughness profile should not deviate from the nominal profile by more than 98 mils (2.5 mm).
- Caisson seal mounting surface waviness profile should not deviate from its nominal profile by more than 12 mils (0.3 mm) over a waviness spacing of 12 inches (30 cm).
- Caisson seal mounting surface should be parallel to within at least 393 mils (10 mm) over the length of a span section (9 feet (2.75 meters)).

Install new mounting studs onto the caisson seal sub-structure if required. The stud material should be a MONEL alloy with the weld filler material and weld process conforming to the correct specifications for welding MONEL to carbon steel. A wood template duplicating the seal configuration hole pattern must be made for each type of seal configuration. These templates are used to properly position the new studs. Starting with the corner section, position and align the wood templates around the caisson. Mark the stud locations on the caisson using a center punch.

Mount a new isoprene “rubber” seal onto the caisson seal sub-structure. Use MONEL washers and nuts to mount the seal assemblies. Use the following procedure starting with the corner section. Be careful not to damage the assembly.

- Position the lifting fixture at the top end of the seal and lower the fixture retaining bar over the seal.
- Lift the seal out of the crate and position the bottom end of the seal over the corresponding mounting studs. The bottom of the seal should make contact with the caisson first.
- Apply a coating of rubber adhesive to mitered joints before mating.
- Install at least two nuts and washers onto the studs at the bottom to

hold the seal in place while the lifting fixture is removed.

- After the lifting fixture is removed, push the top of the seal against the caisson and install all remaining nuts and washers.
- Move the seal into position so that the mating surface at the mitered joint is aligned with the previously installed seal assembly. There should not be a gap or misalignment.
- Once the seal is in position, tighten all mounting nuts one and a half turns beyond the point where initial contact is made between the seal, caisson, nut, and washer.

Application: Caisson wood seals should be replaced as required by new "rubber" isoprene seals. Greenheart wood is NOT immune to marine borer attack; DO NOT USE in saltwater or brackish water.

Future Inspections: Caisson seals should be visually inspected before each use and if any leakage occurs.

Figure 9-1 Typical Caisson Wood Seal Assembly

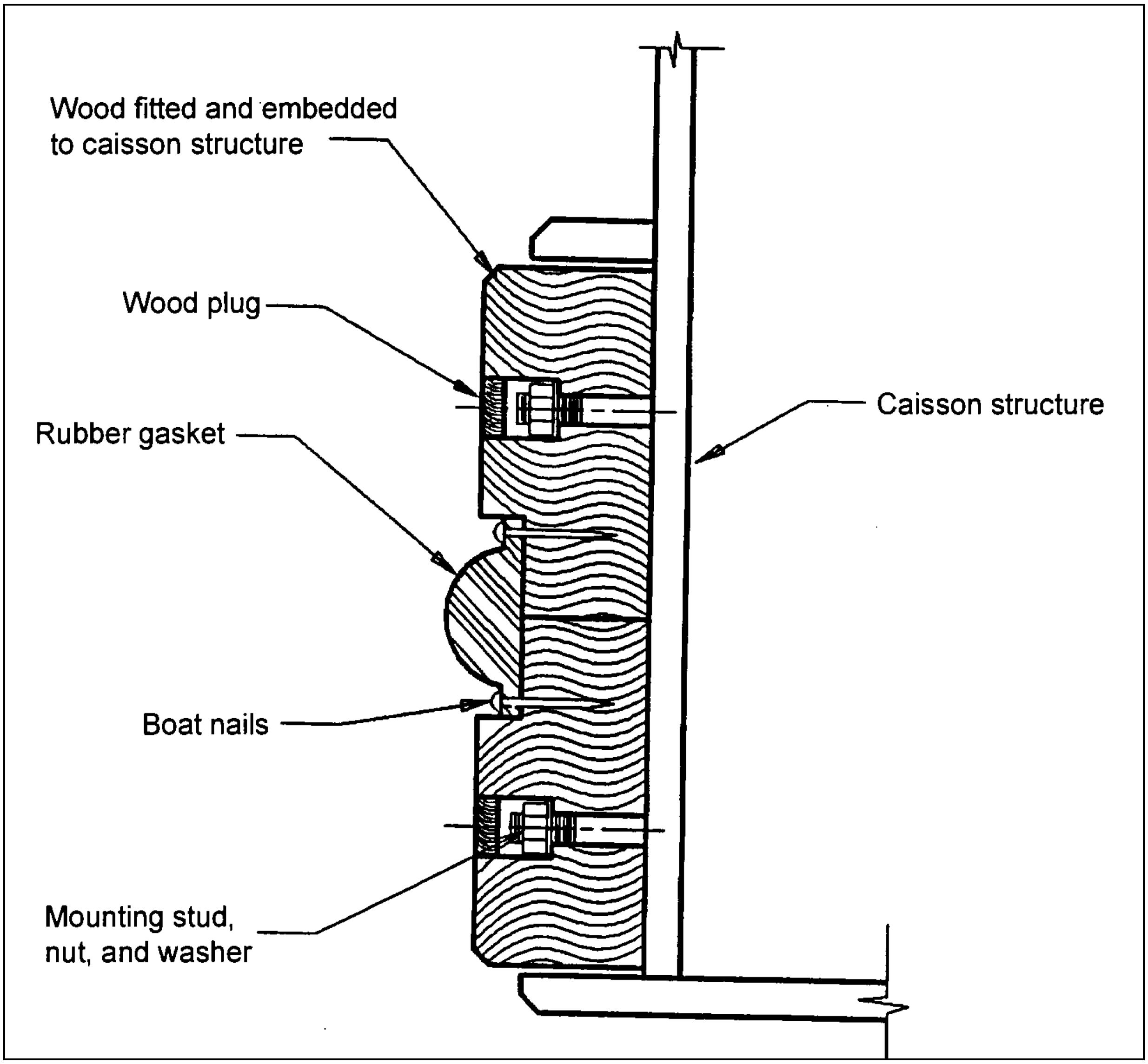
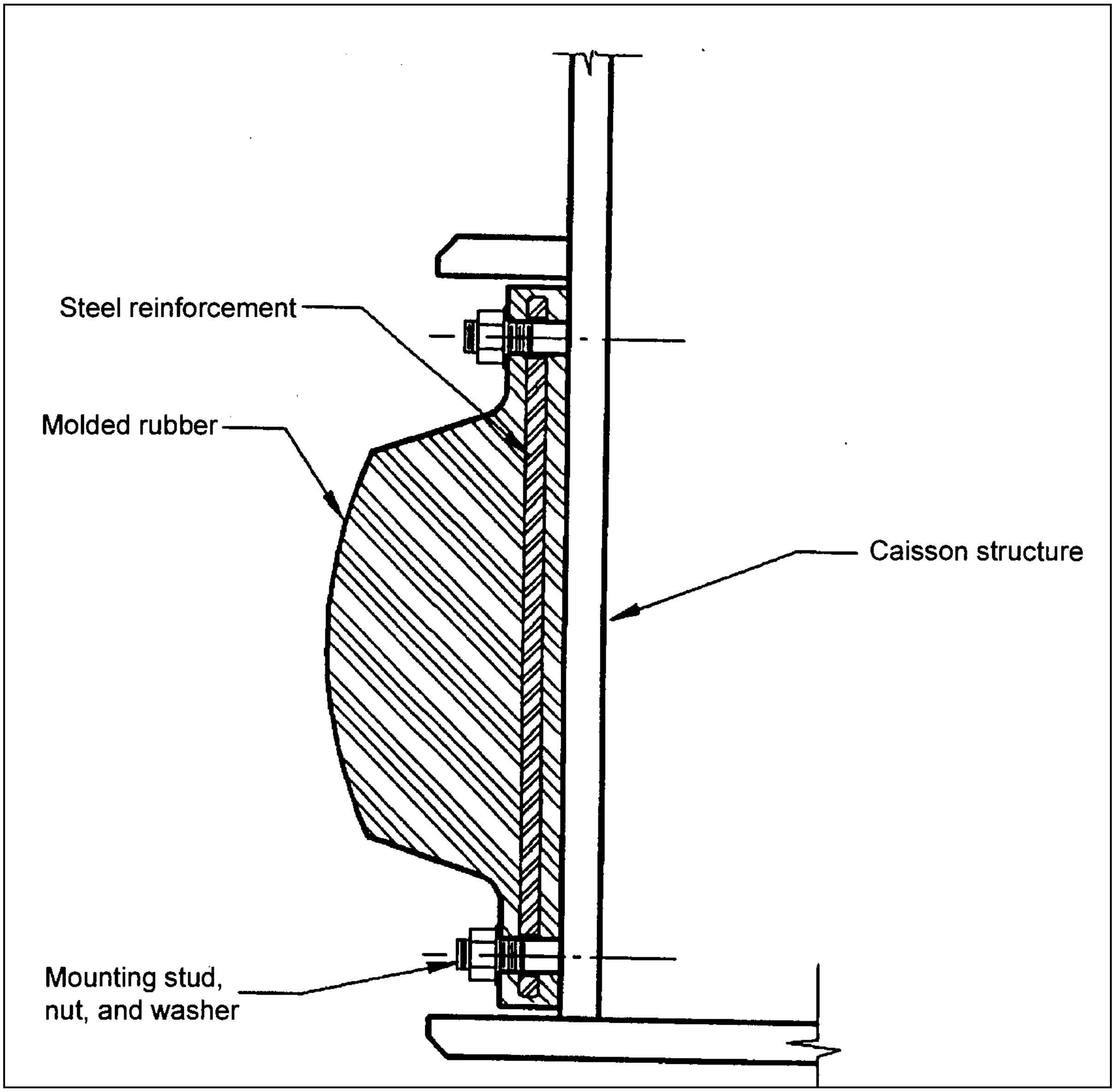


Figure 9-2 Steel Reinforced All-Rubber Caisson Seal Assembly



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CHAPTER 10

REPAIR OF BULKHEADS AND QUAYWALLS

10-1 **GENERAL**. Bulkheads and quaywalls are used as berthing facilities and thus are included in this handbook. Similar structures such as seawalls and breakwaters, designed primarily for coastal protection functions, are covered extensively in USACE manuals. \1\ /1/ Since the basic functions and designs of these structures overlap, there is considerable overlap in repair procedures.

Bulkheads and quaywalls are constructed primarily of sheet piling with soil fill overlaid with concrete or asphalt. Chapters 6 through 9 address the repair of sheetpiling. This section describes the repair of soil fill and overlay.

The common causes of damage to earth-filled structures are erosion by water and settlement due to undermining, washouts, etc. In addition, the sheet piling may deteriorate. Sheet piling repair procedures depend on the type of material used and are included in Chapter 8.

10-2 **PLANNING THE REPAIRS**. Before repairing earth-filled structures, consider the following:

- Scope of damage and/or deterioration.
- Rate of deterioration and overall age of the structure.
- Mission requirement for the structure.
- Operational constraints placed on the facility because of the deterioration.
- Changes to environmental conditions, such as currents, caused by other coastal or harbor changes.
- Alternatives for repairing the structure.

In many cases, usage requirements for the facility may have changed. Stone masonry bulkheads and earth-filled vertical bulkhead structures, as an example, may no longer be required for other than retaining the surrounding shoreline. The solutions may involve using riprap to shore up the structure or reduce seepage and loss of backfill, rather than performing expensive repairs to the structures.

Once the scope of repair requirements, including priorities, is established, then determine if the repairs should be done in-house or by contract.

10-3 **REPAIR PROCEDURES OF EARTH-FILLED STRUCTURES**. The procedures contained below describe the general approach involved in most repairs.

10-3.1 **Problem**. Erosion or settlement has occurred. Any breaching of, or impairment to, an earth structure exposed to moving water sharply increases its susceptibility to damage. For this reason it is critical that any required maintenance be identified and carried out as quickly as possible.

10-3.2 **Description of Repair/Maintenance**

10-3.2.1 **Replacing Soil**. Where there is evidence of erosion or loss of soil, protective coverings, such as rock fill or armor units, should be removed and the internal fill material inspected. Any necessary repairs in the form of replacement of properly compacted soil should be made, and the protective slope-covering replaced in a manner that ensures no further erosion. A series of soil layers of varying coarseness may be used to ensure that the finer, central materials cannot be washed out through the coarser, shell materials. The use of a geotextiles (see below) might be appropriate. In some cases, it may be economical to protect the side slopes with asphalt concrete, soil cement, or even reinforced Portland cement concrete. In cases where the side slopes are exposed only to atmospheric erosion, vegetation such as ice plant or grasses may be adequate.

10-3.2.2 **Geotextiles**. A rapidly emerging geotechnical engineering technology involves use of geotextiles for seepage and erosion control, and for soil strength reinforcement, see Koerner (Koerner, R. M. (1990), *Designing with Geosynthetics*, 2nd Edition, Prentice-Hall, Inc., Englewood Cliffs, NJ). Geotextiles are porous, flexible polymeric fabrics used for separating soil types, soil retention, and strength reinforcement. When used for soil retention, the fabric must meet permeability or permittivity requirements (ASTM D4491, *Test Methods for Water Permeability of Geotextiles by Permittivity*) relative to the permeability of the retained soil. Also the openings in the fabric must be small enough to impede loss of soil particles. This usually requires a fabric opening size not more than twice the 85% size of the soil (sieve size through which 85% of the soil grains will pass). Where a geotextile is used to provide drains for pressure relief, the transmissivity or flow capacity in the plane of the fabric is the important parameter.

Geotextile strength must also be considered in any design, see ASTM D4595, *Test Method for Tensile Properties of Geotextiles by the Wide Width Strip Method*\1\ /1/. In order to prevent excess creep under load, geotextiles should have design strength factors of safety in the range of 2 to 4. This is particularly important where soil grids are used for the express purpose of reinforcing or strengthening the soil mass.

10-3.2.3 **Compaction Control**. The performance of soil embankments improves with density, so fill materials should generally be placed at as high a density as is economically feasible, particularly with the finer-grained soils at a density of at least 90% Proctor (ASTM D698, see below). Where the soil will be subjected to heavy loads, or where settlement of the fill would be undesirable, soil density should be increased, even up to 100% modified Proctor (ASTM D1557, see below). There is a specific moisture content for each soil type at which the maximum density is obtained under a specific compaction effort. Therefore, moisture control is an important factor in efficient compaction techniques, particularly with silts, clays, and mixed soils.

10-3.2.3.1 **Compaction Control Standards**. The two most common standards for compaction control are the standard Proctor (ASTM D698, \1\ *Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft lbf/ft3 (600 kN m/m3)) /1/*) and the modified Proctor (ASTM D1557, \1\ *Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft lbf/ft3 (2,700 kN m/m3)) /1/*) tests. The latter method represents a larger compactive effort than the former and has been adopted to account for the higher compactive capability of modern construction equipment. However, the standard considered most pertinent for waterfront structures is still the standard Proctor. This is because the lower compactive effort results in a slightly higher optimum moisture content for maximum density, and the higher moisture content is more compatible with the expected in-service conditions of waterfront structures.

10-3.2.3.2 **Compaction Selection**. The type of compaction selected should be based on the soil type. Vibratory compaction is more efficient with granular soils, whereas kneading types of equipment, such as sheepsfoot rollers, are more applicable to cohesive soils. Vibratory rubber-tired compactors in the 24,250 to 30,865 pounds (11- to 14-metric ton) range are reasonably effective for all types of soil. Soil lifts should generally be limited to layers having a compacted thickness of no more than 5.9 inches (15 cm), except where it has been demonstrated that the compactors are capable of achieving the required densities throughout the full depth of thicker lifts. Such a situation might exist with a vibratory compactor on relatively clean, non-cohesive material. For backfilling sheet pile cofferdams or other structures with limited space, it may be necessary to use small hand-operated tampers or compactors. The difficulty of compaction generally increases with the decrease in grain size of the soil.

10-3.2.3.3 **Compaction Requirements**. A typical requirement for many waterfront structures is to specify a compacted density of 95 percent of standard Proctor, but this may vary with the type of structure and its present condition. It is desirable to place a soil material in a structure in as close to its long-term stable condition as possible. Although clean, granular materials should be placed in as saturated a condition as is practicable, fine-grained or mix-grained soils may require moisture contents to be maintained within a particular optimum range. Often, control of water content with respect to the optimum value is left up to the contractor, since he can elect to replace rigorous moisture control with increased compactive effort. Where excess compactive effort could result in damage to the structure, such as in quaywalls or cofferdams, the compactive effort should be minimized and the moisture content controlled as well as is practicable. For these latter types of structures, it is also very important that design densities not be exceeded. Excessive compaction might result in undesirable lateral stresses in structural members.

10-3.2.4 **Dewatering**. Where excavation and replacement of soil takes place below the water table, it may be necessary to dewater the site by using seepage barriers, such as sheet piles. Where soil permeability is high, subsurface drainage by well points or deep wells may be necessary. Prior to planning dewatering procedures, it is necessary to determine permeability and piezometric levels by field observations. The major concern is to avoid instability through piping or heaving by controlling the upward hydraulic gradient at the base of the excavation. Hydraulic gradients (head loss per unit length of flowpath) equal to the ratio of buoyant density of the soil divided by the density of water lead to immediate instability in all cases. This ratio varies from > 1 for dense soils to < 1 for loose soils. Exit gradients of 0.5 to 0.75 will cause unstable working conditions even in clean sands. Silty materials are even more critical.

10-3.2.5 **Sealing/Filling Voids**.

10-3.2.5.1 **Sealing**. The loss of soil from behind quaywalls, or from within sheet pile cofferdams, requires sealing the structure to prevent further loss of material before replacing with a suitable backfill. Coarser-grained materials and/or geotextile filters are preferred, since they are less subject to leaching or erosion. Fine-grained materials are desirable only where very low permeability is required, such as in the core of an earth dam. When fine materials are used, construction of inverted geotextile filters and/or sealing of structural joints are necessary to prevent erosion. Where materials consist of the very erodible silts or fine sands, the structure must be sealed to prevent influx of surface water.

10-3.2.5.2 **Grouting**. In some cases, it may be more expedient to either seal or repair a damaged structure by injecting grout. Grout may be used to reduce the permeability of the soil fill or its foundation and, thereby, minimize erosion or leaching. It may also be used to physically strengthen the structure to make it more resistant to wave or ship loading, and superimposed dead loads.

Cavities or voids in the soil structure may be grouted using sand/water mixtures, Portland cement, clay, chemical grouts, or a combination of these materials depending on the size of voids. Sand/water mixtures are applicable where large cavities are present and the paths of soil loss have been sealed off. Cement grout is not applicable if the effective grain size of the in-place soils, D (the sieve size through which only 10 percent of the soil would pass), is less than 19.7 mils (0.5 mm) for loose soils and 55.1 mils (1.4 mm) for dense soils. Portland cement grout is most applicable where the grout can be pumped directly into cavities.

An effective grouting procedure for sandy materials consists of injecting solutions of sodium silicate and calcium chloride. This procedure both solidifies the soil and makes it impermeable, but it is extremely expensive. Mixtures of cement and clay are also used, sometimes adding a chemical deflocculant.

One of the more recently developed chemical grouts polymerizes in the soil voids; however, it is also expensive. With fine-grained backfills, grouting is generally of no benefit except to fill cavities or to seal off paths of soil removal.

10-3.2.6 **Preventing Loss or Settlement of Soil**. Maintaining good surface drainage is the most important preventive maintenance measure for earthwork structures. Efficient runoff of rainfall and overflow water must be ensured. If subsurface drainage features exist, they must be kept clear (for example, periodic cleaning of weep holes). Hand-placed riprap can be added to the slope just behind the sheet piling, if storm runoff results in heavy soil loss.

10-3.3 **Future Inspection Requirements**. Where the rate of erosion or settlement has been increasing the structure must be closely monitored to provide early warning of impending failure. Where a major problem has been encountered and corrected, increased inspection may be necessary to ensure that the repair is effective.

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APPENDIX A

REFERENCES

GOVERNMENT PUBLICATIONS

\1\ Unified Facilities Criteria (UFC): http://dod.wbdg.org /1/	\1\ UFC 3-220-01N, Geotechnical Engineering Procedures for Foundation Design of Buildings and Structures UFC 3-220-10N, Soil Mechanics UFC 3-301-01, Structural Engineering UFC 3-570-02N, Electrical Engineering Cathodic Protection UFC 4-150-08, Inspection of Mooring Hardware UFC 4-151-10, General Criteria for Waterfront Construction UFC 4-152-01, Design: Piers and Wharves UFC 4-213-10, Design: Graving Drydocks UFC 4-213-12, Drydocking Facilities Characteristics /1/
\1\ Unified Facilities Guide Specifications http://dod.wbdg.org /1/	\1\ UFGS 03 31 29, Marine Concrete UFGS 06 13 33, Pier Timberwork UFGS 09 97 13.26, Coating of Steel Waterfront Structures UFGS 31 62 13.13, Cast-In-Place Concrete Piles

	UFGS 31 62 13.20, Precast/Prestressed Concrete Piles UFGS 31 62 19.13, Wood Marine Piles UFGS 35 59 13.13, Prestressed Concrete Fender Piling /1/
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\1\ Navy Crane Center Norfolk Naval Shipyard Bldg 491 Portsmouth, VA 23709 https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_ww_pp/navfac_ncc_pp/tab33578 /1/	\1\ P-307, Management of Weight Handling Equipment Maintenance and Certification./1/
\1\NAVFAC ATLANTIC 6506 Hampton Blvd Norfolk, VA 23508-1278 http://www.wbdg.org/ccb/browse_cat.php?c=86 /1/	MO 104.1, Maintenance of Fender Systems and Camels MO 124, Mooring Maintenance Manual \1\ MO 104.2, Specialized Underwater Waterfront Facilities Inspections /1/ MO 312.2, A Field Guide for the Receipt and Inspection of Treated Wood Products by Installation Personnel MO 321, Facilities Management MO 322, Inspection of Shore Facilities (Vol 1 and 2)

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U.S. Army Corps of Engineers www.hnd.usace.army.mil/techinfo	\1\ AR 200-1, Environmental Protection and Enhancement /1/ AR 415 Series AR 420-10 Series Shore Protection Manual, Vol 1 and 2 EM-1110-2-1614, Design of Coastal Revetments, Seawalls, and Bulkheads

	EM-1110-2-2904, Design of Breakwaters and Jetties EM-1110-2-1204, Environmental Engineering for Coastal Protection EM-1110-2-1414, Water Levels and Wave Heights for Coastal Engineering Design EM-1110-2-2302, Construction with Large Stone EM-1110-2-1617, Coastal Groins and Nearshore Breakwaters EM-385-1-1, Safety and Health Requirements Manual EM-1110-2-1004, Coastal Project Monitoring ER-1110-2-2902, Prescribed Procedures for the Maintenance and Operation of Shore Protection Works
Air Force \1\ http://www.e-publishing.af.mil/ /1/	Air Force Instruction 32-1023, Design and \1\ Constructing Military /1/ Construction Projects AFPD 91-3, Occupational Safety and Health
Defense Standardization Program www.dsp.dla.mil	MIL-STD-889B, Dissimilar Metals

NON-GOVERNMENT PUBLICATIONS

ACI International (ACI) PO Box 9094 Farmington Hills, MI 48333 www.aci-int.org	ACI 211, Recommended Practice for Selecting Proportions for Concrete ACI Standard 318, Building Code Requirements for \1\ Structural /1/ Concrete \1\ ACI SP-14, Shotcreting /1/
American Institute of Steel Construction One East Wacker Drive, Suite 3100 Chicago, IL 60601-2001 www.aisc.org	LRFD Manual of Steel Construction, 2nd edition LRFD Manual of Steel Construction, Metric Conversion, 2nd edition ASD Manual of Steel Construction, 9th edition
American Society for Testing Materials (ASTM) 100 Bar Harbor Drive West Conshohocken, PA 19428-2959 www.astm.org	\1\ ASTM A36/A36M, Specification for Carbon Structural Steel ASTM A242/A242M, Specification for High-Strength, Low-Alloy Structural Steel ASTM A572/A572M, Specification for High-Strength, Low-Alloy Columbian-Vanadium Steels Structural Steel ASTM A615/A615M, Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement \1\ /1/ ASTM A690/A690M, Specification for High-Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments

	ASTM A775/A775M, Specification for Epoxy Coated Steel Reinforcing Bars ASTM A996/A996M, Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement ASTM B370, Specification for Copper Sheet and Strip for Building Construction ASTM C150 / C150M, Specification for Portland Cement ASTM C157/C157M, Test Method for Length Change of Hardened Hydraulic Cement Mortar and Concrete ASTM C233 / C233M, Test Method for Air Entraining Admixtures for Concrete ASTM C330/C330M, Specification for Lightweight Aggregates for Structural Concrete ASTM C494/C494M, Specification for Chemical Admixtures for Concrete ASTM C876, Corrosion Potentials of Uncoated Reinforcing Steel in Concrete ASTM C920, Specification for Elastomeric Joint Sealants ASTM D698, Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft lbf/ft3 (600 kN m/m3)) \1\ /1/ ASTM D1557, Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft lbf/ft3 (2,700 kN m/m3))

	ASTM D4022/D4022M, Specification for Coal Tar Roof Cement, Asbestos Containing ASTM D4491, Test Methods for Water Permeability of Geotextiles by Permittivity ASTM D4595, Test Method for Tensile Properties of Geotextiles by the Wide Width Strip Method /1/
\1\American Wood Protection Association (AWPA) P.O. Box 36784 Birmingham, AL 35236-1784 www.awpa.com /1/	\1\ Standard U1, Use Category System: User Specification for Treated Wood /1/
Portland Cement Association 5420 Old Orchard Road Skokie IL 60077 www.cement.org	Principles of Quality Concrete
\1\ Southern Forest Products Association 2900 Indiana Avenue Kenner, LA 70065-4464 /1/ www.southernpine.com	Marine Construction Manual: A Guide to Using Pressure-Treated Southern Pine in Fresh and Saltwater Applications, October 1994
Sheffer, T.C. Information Services, USDA Forest Service Forest Products Laboratory One Gifford Pinchot Drive Madison, WI 53705-2398 www.fpl.fs.fed.us	Observations and Recommendations Regarding Decay in Naval Waterfront Structures, September 1996
Morrell, J.J. et. al Oregon State University College of Forestry http://www.forestry.oregonstate.edu/	Marine Wood Maintenance Manual: A Guide for Proper Use of Douglas fir in Marine Exposures, Forest Research Laboratory Bulletin 48, October 1984
International Concrete Repair Institute \1\ 10600 West Higgins Road, Suite 607, Rosemont, IL 60018 /1/ www.icri.org	ICRI No. 210.1, Guide for Verifying Field Performance of Epoxy Injection of Concrete Cracks (formerly No. 03734)

UFC 4-150-08
28 October 2020

UNIFIED FACILITIES CRITERIA (UFC)

MOORING HARDWARE INSPECTION

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

MOORING HARDWARE INSPECTION

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

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

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

This UFC supersedes UFC 4-150-08 Change 1, dated 19 June 2001.

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 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 Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. 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 web site http://www.wbdg.org/ffc/dod.

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

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 4-150-08, *Mooring Hardware Inspection*

Superseding: UFC 4-150-08 Change 1, dated 19 June 2001

Description: This UFC provides guidance for the specialized inspection and testing of mooring hardware at waterfront facilities and related facilities. Inspection levels, methods, and testing procedures are presented for the mooring hardware. The testing procedures presented herein are a precursor for a more detailed load capacity assessment of specified mooring hardware. The resulting findings of inspections of mooring hardware and fendering are to guide facility personnel in the selection of appropriate analysis, repair and replacement techniques, maintenance, inspection of fieldwork for acceptability, and planning the follow-on inspection requirements.

Reasons for Document:

- Document was due for revision.
- Provides coordination with ASCE MOP130, *Waterfront Facilities Inspection and Assessment*.
- Mooring condition ratings updated and coordinated with other UFCs. Mooring hardware testing procedures updated.
- Several references had been superseded and required updating.

Impact:

- This UFC is a guide for the inspection and evaluation of mooring hardware used at waterfront facilities that provide berthing for U.S. Military Ships.

Unification Issues:

- None.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

This UFC 4-150-08, is a guide for the inspection and evaluation of mooring hardware used at waterfront facilities that provide berthing for U.S. Military Ships. It is a source of reference for the planning, inspection, and reporting of mooring hardware conditions in a standardized format.

Initial chapters in this UFC provide a summary of responsibilities and policies, field inspection guidelines, and mooring hardware types. Inspection levels, methods, planning, and techniques and checklists are covered for above water inspection. General load capacity testing procedures are described and illustrated for general mooring hardware.

1-2 PURPOSE AND SCOPE.

This UFC provides guidance for the planning, inspection, assessment, and reporting of mooring hardware conditions. It should be used as a tool for helping personnel tasked with maintaining the readiness of shore side facilities for use by the fleet and in support of military marine operations. The Mooring Hardware Report has the following objectives:

- Establish adequacy of mooring facilities.
- Enable facility users to develop efficient berthing plans.
- Establish baseline data on existing mooring hardware and berthing capacity.
- Provide facility users with information sufficient to determine level of effort to maintain or upgrade existing capacity.

1-3 APPLICABILITY.

This UFC provides guidance for the specialized inspection and testing of mooring hardware at waterfront facilities and related facilities. Inspection levels, methods, and testing procedures are presented for the mooring hardware. The testing procedures presented herein are a precursor for a more detailed load capacity assessment of specified mooring hardware. The resulting findings of inspections of mooring hardware and fendering are to guide facility personnel in the selection of appropriate analysis, repair and replacement techniques, maintenance, inspection of fieldwork for acceptability, and planning the follow-on inspection requirements.

The standards and methods presented herein are a guide to the planning, inspection, assessment, and reporting of mooring hardware conditions. The standards and methods outlined have been developed from the best technical sources in industry and the military services.

1-3.1 Facilities Covered.

Types of facilities covered as related to mooring hardware include:

- Berthing facilities (piers, wharves, and dolphins) for mooring and for providing support to ships and craft.
- Dry docks used for modification, inspection maintenance, and repair of ships.

1-3.2 Facilities Not Covered.

Facilities not covered in this UFC are:

- Fleet moorings - which are covered in UFC 4-150-09, *Permanent Anchored Moorings: Operations and Maintenance*.
- Mechanical capstans.

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 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and terms.

1-6 REFERENCES.

APPENDIX C 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.

CHAPTER 2 PLANNING FACILITY INSPECTION

2-1 MAINTENANCE PLANNING.

Maintenance planning criteria can be found in Chapter 2 of UFC 4-150-07, *Waterfront Facilities Operations and Maintenance*. Development of a long-term inspection and maintenance program involving all aspects of waterfront facilities is covered in the above document. A long-term inspection program involving regular field inspection of mooring hardware at established intervals should be part of the overall facility maintenance program.

2-2 PLANNING.

2-2.1 General.

This section covers the planning required to conduct an inspection and assessment of mooring hardware. Critical aspects of planning an inspection of this nature include the establishment of a clear scope of work and gathering all available data. Figure 2-1 depicts the Mooring Hardware Inspection Process.

2-2.2 Scope of Work.

Planning the inspection of mooring hardware will begin with the establishment of a scope of work. The scope of work will define the facilities to be inspected and level of inspection. The scope of work should include:

- Number of hardware.
- Type of hardware.
- Type of support structure.
- Level of inspection required.
- Date of last inspection.
- Fender system type and quantity.
- List of ships that normally use hardware, (i.e. mission critical ships).

2-2.3 Existing Data.

All available relevant data on the facilities to be inspected and assessed should be gathered at the earliest possible date. This information should be provided to the persons responsible for planning and organizing the inspection and assessment effort such that the level of effort for inspecting a specific facility can be determined. Data and information may be available in many forms as listed below.

2-2.3.1 Drawings.

- As-Built Construction Drawings – Original construction drawings will often have vital information regarding mooring and berthing design loads. This information is usually the most accurate data available to the inspector. Caution should be taken to confirm that the data on the plans is accurate and changes to the structure have been investigated and confirmed.
- Repair and Maintenance Drawings – All modifications to the original structure should be investigated and analyzed as to their impact to the structure.
- Site Plans – Site plans can provide layout data and, in some cases, will have sufficient detail to show mooring hardware position. This data is often out dated and should be confirmed.
- Hydrographic Survey Plans – Hydrographic data is important to establish depth of water at the berth.

2-2.3.2 Calculations.

Design calculations to establish the capacity of the supporting structure. Calculations used to determine loads on hardware.

2-2.3.3 Existing Reports.

Previous inspection reports such as a Waterfront Facilities Inspection Report, Prior Mooring Hardware Condition report or Annual Inspection Summaries.

2-3 FIELD INSPECTION / DATA GATHERING.

2-3.1 General.

The purpose of any mooring hardware inspection is to gather information to assess the condition of the mooring hardware system inspected. The level of inspection will determine the amount and type of information gathered. The inspection will focus on gathering the following information:

- Identification of damage.
- Confirmation of available data.
- Changes in the known supporting structure.
- Identification of potential problems with interacting equipment and fixtures.
- Establishing the position of mooring hardware and fenders.
- General condition of fender system and hardware.
- Gather available background information at the site.

2-3.2 Field Inspection.

Personnel assigned to conduct a field inspection of mooring hardware should acquire the appropriate tools necessary to accomplish the work. The level of inspection will dictate the required tools. All levels require appropriate record keeping. Information should be recorded in logbooks. The time and level of effort required to conduct an inspection will depend on the amount of background information that is available, level of inspection required, site conditions, site access and activity, as well as the skill of the inspector.

2-3.2.1 Tools Required.

2-3.2.1.1 Hand Tools.

Various hand tools are required to accomplish the task of inspecting mooring hardware. Tape rules, folding rules, measuring wheels, and in some instances surveying equipment will be required to perform tasks such as: dimensioning structural components, finding the position of mooring hardware, and measuring distress within the structural system. Other tools such as wire brushes, chipping hammers, and scrapers can be used to clean and uncover structural components that are not readily visible. Marking devises such as paint stick, keel, paint, and ink pens can be used to establish identifying marks on each hardware unit for reference.

2-3.2.1.2 Equipment.

Heavy equipment may be required to conduct Level 3 Inspections. Equipment such as diving gear, compressions, jacks, hoists, rigging, load cells, and cranes should be used as necessary to accomplish the work.

2-3.2.1.3 Note Keeping.

Field inspection data and notes should be kept in a surveyor's field book or the Mooring Hardware Inspection Sheet (see Figure 2-2) and in an orderly and legible fashion. Photographic documentation of each piece or representative piece of mooring hardware should be taken and recorded in the field book. Notes can be kept in tabular form within the notebook. The following minimum data is required:

- <u>Hardware Number or Designation</u> – Each fitting should have a unique alphanumeric designation. If an existing system is in place it should be used. If there is no system for identifying hardware, unique designations should be assigned. For example, identifying systems such as "B1-C3" for Berth 1, Cleat Number 3 may be used.
- <u>Size and Type of Hardware</u> – Record the casting number or serial number that identifies each type of hardware. Standard U.S. Navy fittings can be found in Figure 2-3 (see Table 6-11 and Figure 6-3 in UFC 4-159-03). If the hardware number cannot be found or identified in the field, then the overall dimensions should be recorded.

Additional information concerning the sizes and working capacities of pier and wharf mooring fittings is found in UFC 4-159-03, *Moorings*. Further information on inspection can be found in ASCE MOP 130, *Waterfront Facilities Inspection and Assessment*.

- Position of hardware (X, Y, Z coordinates) – A coordinate system should be identified and established such that the location of each hardware can be established along the berth. The relationship between the hardware and the tidal datum should also be established.
- Reference position of coordinates – All coordinate systems should be referenced to a local system for each facility i.e. reference benchmark on site, or activity base map coordinates.
- Condition of the hardware – The condition of each piece of mooring hardware should be rated in the field. The rating system should be on a scale of 1 to 5, as described in Figure 2-4.
- Condition of the base structure – The base structure of each piece of hardware should be rated on a scale of 1 to 5, as described in Figure 2-5.
- Condition of the fender system should be noted and rated as described in UFC 4-150-07.
- Fasteners – The number, pattern and size of the fasteners on each piece of mooring hardware should be recorded.
- Additional remarks – Additional notes such as odd conditions, qualifying remarks, and other information that might be deemed useful should be recorded.
- Photo identification number and description.
- All sketches and other ancillary notes should be kept in the same notebook.

2-4 ENGINEERING EVALUATION.

An evaluation of the data can only be conducted once the inspection is complete. The field data as well as the existing data should be reviewed and analyzed to formulate allowable load criteria.

2-5 TYPE OF MOORING SERVICE.

The type of mooring service should be considered when planning the inspection frequency. For example, Berths with Mooring Service Type III should be considered high priority as ships moored at these berths may not have the ability to get under way in case of an approaching storm. See Table 3-4 in UFC 4-159-03, *Moorings* for an explanation of mooring service types (MST).

Figure 2-1 Mooring Hardware Inspection Process

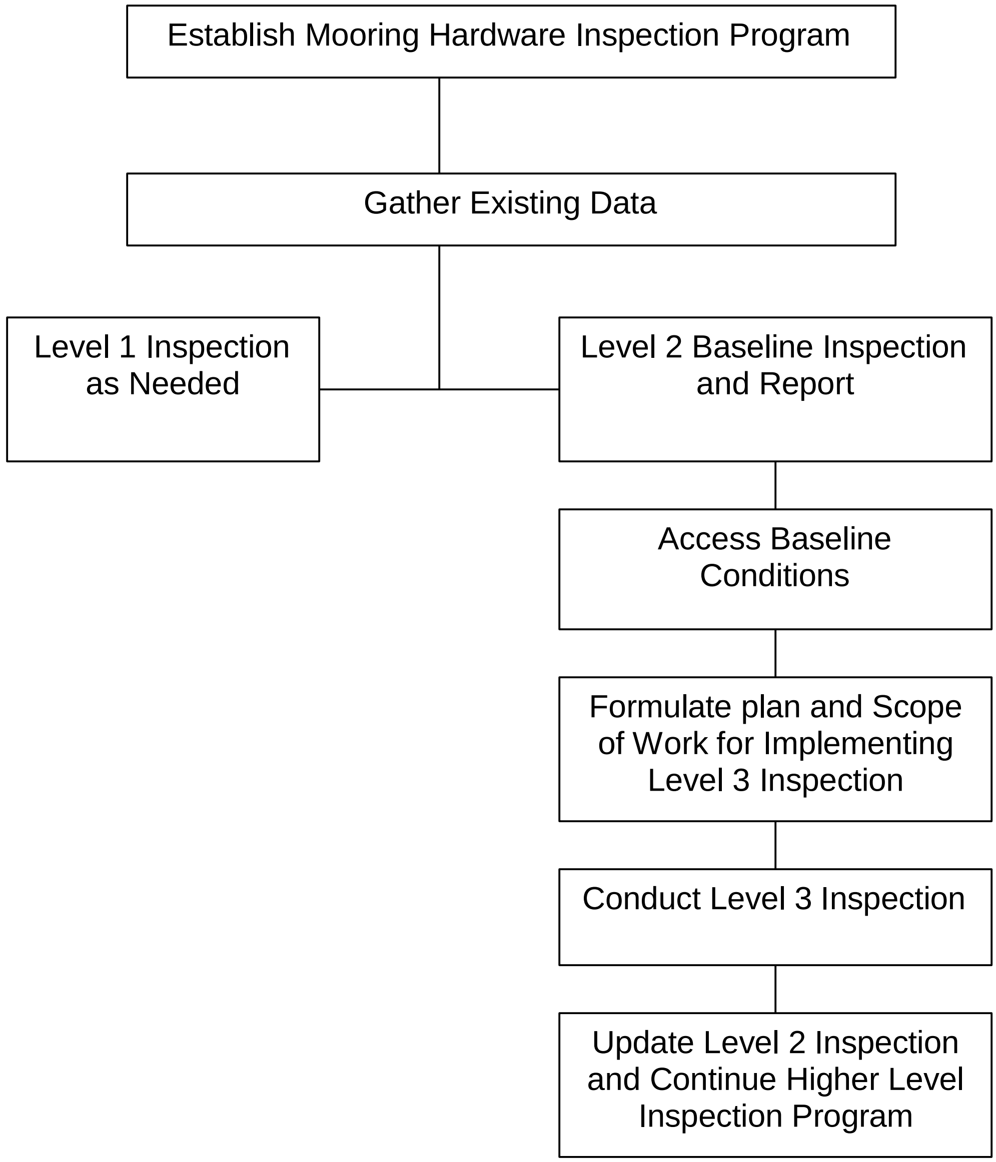

Figure 2-2 Mooring Hardware Inspection Record

MOORING HARDWARE INSPECTION RECORD									
LOCATION						DATE:			
FACILITY NAME						COORDINATE REFERENCE / BENCHMARK			
INSPECTOR						LEVEL OF INSPECTION			
Hardware Designation	Description	Design Capacity	X Coord	Y Coord	Z Coord	Condition Rating		Photo #	Comments
						Hardware	Base Str.		

Figure 2-3 Typical Profiles of Mooring Hardware

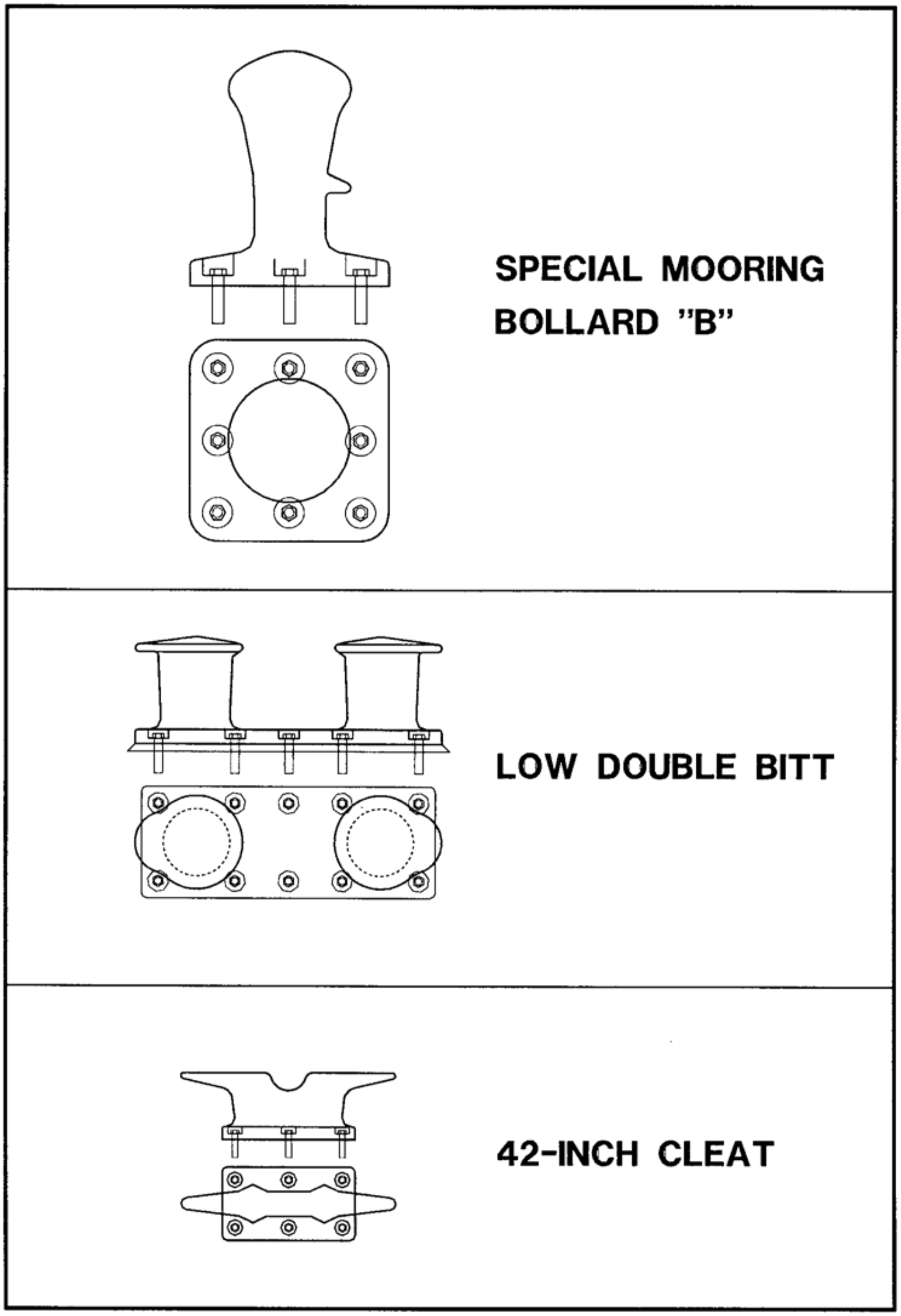

Figure 2-4 Condition Rating Scale for Mooring Hardware

Example of Condition | **Mooring Hardware Condition Rating**

#1 No Defects:
- Material and connections sound
- Less than 10% surface corrosion
- Surface coating in good condition
- Bolt countersinks grouted or sealed

#2 Minor Defects:
- Surface corrosion over 10-25% of area
- Minor wear marks or pitting are less than 1/8 in. (3.2 mm) deep
- Minor corrosion of fasteners with no significant section loss

#3 Moderate Defects:
- Surface corrosion with loose scale over 25-50% of its area
- Moderate wear marks or pitting are less than 1/4 in. (6.4 mm) deep
- Fasteners corroded with less than 25% section loss

#4 Major Defects:
- Surface corrosion with loose scale over 50% or more of its area and/or less than 25% section loss
- Significant wear marks or pitting are 1/4 in. (6.4 mm) deep or greater
- Fasteners corroded with loose scale or greater than 25% section loss

#5 Severe Defects:
- Heavy surface corrosion and loose scale with greater than 25% section loss at critical areas
- Movement, rotation, or deformation of fitting; components are broken, cracked, or delaminated
- Loose, missing, or broken fasteners

Figure 2-5 Condition Rating Scale for Base Structure

Example of Condition | **Mooring Foundation Condition Rating**

#1 <u>No Defects:</u>

- Good original sound condition with no visible defects

#2 <u>Minor Defects:</u>

- Hairline cracks in concrete from thermal expansion, mooring hardware corrosion, and/or age; no significant section loss
- Light surface corrosion of steel, no significant section loss, coating weathered
- Timber or composite weathered; presence of fungal decay; minor checks, splits, and gouges up to 1/4 in. (6.4 mm) wide

#3 <u>Moderate Defects:</u>

- Noticeable cracking of concrete without loss of interlock
- Steel corrosion with less than 10-25% section loss
- Timber or composite cracked or checked up to 1/2 in. (12.7 mm) wide, weathered surfaces, fungal decay with section loss up to 1 in. (25.4 mm)

#4 <u>Major Defects:</u>

- Noticeable cracking or spalling of concrete with loss of interlock
- Steel corrosion with 25-50% section loss
- Timber cracked or checked greater than 1/2 in. (12.7 mm) wide; fungal decay up to 3 in. (76.2 mm) deep; dry rot
- Composite elements cracked or split

#5 <u>Severe Defects:</u>

- Displacement or yielding; loss of full bearing
- Major cracking or spalling of concrete base under hardware
- Significant corrosion of steel members with greater than 50% section loss at any location
- Timber members broken or damaged or fungal decay greater than 3 in. (76.2 mm)
- Composite elements broken or damaged

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CHAPTER 3 QUALIFICATIONS

3-1 PERSONNEL.

If a contract is used, the inspection of mooring hardware must be conducted under the supervision of a Registered Professional Engineer (P.E.) who has experience in the design and inspection of marine structures. At a minimum, the supervising engineer (P.E.) must be onsite and involved in the inspection to assess and record conditions encountered using standard engineering practice. Level 1 inspections may be conducted by technicians under the supervision of a Registered Professional Engineer. For Level 2 or Level 3 inspections, which may require underwater inspection as well as the operation of equipment, personnel must be fully qualified and should have adequate levels of support to accomplish the task. All work operations must be accomplished in accordance with the standards identified in APPENDIX C. Guidance for underwater inspections can be found in UFC 4-150-07, *Waterfront Facilities Operations and Maintenance.*

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CHAPTER 4 INSPECTION FUNDAMENTALS

4-1 LEVELS OF INSPECTION.

4-1.1 Level 1 - Walk through Inspection.

This inspection is a walk-through inspection to assess damage following a storm event and to confirm any changed conditions. Gross deficiencies can be identified during this inspection. This level of inspection cannot provide sufficient data to assess the capabilities of a mooring system.

4-1.2 Level 2 - Visual Inspection.

This inspection will involve visual observation of the condition of exposed components of the mooring hardware and supporting structure. The hardware should be visually inspected for cracks or other anomalies. Hardware geometry should also be inspected to determine if displacement has occurred. Bolts, if exposed, can be inspected to determine their relative tightness. The general condition of the supporting base structure should be inspected for anomalies such as cracking and/or displacement. Under this level of inspection, the position of the hardware should be determined. The relative position in relation to the three principal axis coordinates (X, Y, Z) should be established to the nearest foot. The Level 2 visual inspection is required to establish baseline conditions.

4-1.3 Level 3 - Detailed Inspection.

This inspection is performed in addition to the inspection tasks performed under the Level 1 and Level 2 inspections. A detailed inspection will involve the observation of exposed components of the supporting structure such as the underside of the pier deck and piles.

In addition, a detailed inspection may involve partly destructive techniques related to dismantling and load testing mooring hardware. Removal of sealing material and fasteners for inspection and load testing will be accomplished as directed by the Scope of Work under this level of inspection. Individual fasteners may be load tested in tension by using a jacking apparatus. The entire hardware piece may be load tested using various methods. The method employed for load testing of hardware will be dependent upon the type of hardware piece and site conditions. Guidelines for load testing hardware and fasteners can be found in APPENDIX A of this document.

4-1.4 Fender System.

A Level 1 visual inspection of the fender system should be conducted concurrently with all levels of mooring hardware inspection. The type of fender system will be noted, and the general configuration will be established as it relates to the mooring hardware. Size and location of fender system components will be noted to determine the placement of ships.

4-2 FREQUENCY OF INSPECTION.

Under most circumstances, all mooring hardware in satisfactory or better condition should receive a Level 1 Inspection annually, and a Level 2 maximum inspection interval of 4 to 6 years, depending upon the aggressiveness of the environment and the level of hardware protection. The type of structure and the class of service will also dictate the inspection frequency and level of inspection. For timber structures that are susceptible to impact and severe environmental conditions the frequency of Level 2 inspections should be set at every 3 years. For structures that are high priority, the berthing officer will determine the level of inspection. In instances where extreme storm events have resulted in the potential overloading of mooring hardware, a Level 1 inspection should be conducted to determine post storm conditions. Level 3 Inspections involving load testing should be conducted as directed by the Berthing Officer or as described in APPENDIX A, based on hardware priority level.

4-3 INSPECTION METHODS.

4-3.1 Local Conditions.

4-3.1.1 Mooring Hardware Fittings.

Each piece of mooring hardware should be visually inspected for anomalies. Conditions that are commonly found include cracks, abrasion (due to wire rope), corrosion and displacement. Cracks are usually the result of impact loading or overloading the hardware under extreme conditions. Abrasion normally occurs when mooring lines are pulled around the hardware causing friction and erosion of the casting under the barrel or horn. If this condition is severe, it will weaken the casting through loss of cross sectional area. Documentation of the depth of abrasion, location, and area are required to establish loss of strength. The condition of the coating should be noted. Coatings that have mechanical damage, i.e., cracks, peeling, or abrasion, should be described. Coating systems that have failed or are worn out should also be described, as well as any resulting corrosion. Levels of corrosion can be described as rust stains, light scale, and heavy scale. The surface roughness of the steel should also be described. Corrosion of the casting should be assessed to determine the loss of section at critical points on the casting. Heavy corrosion will also affect the surface roughness of the hardware increasing the chafing and wearing of mooring lines. Observations of the mooring hardware plumbness and level should be made to determine prior overloading and failure of the surrounding soil or fasteners.

4-3.2 Fasteners.

Fasteners consisting of steel bolts are used to anchor the mooring hardware to the supporting structure. In some cases, mooring hardware is embedded directly in the supporting structure. Where fasteners are used, their function within the mooring system is critical and is almost always the crucial structural element. Fasteners are generally inaccessible because of typical mooring hardware details, calling for protection usually in the form of lead fill, bituminous fill or grout being placed in the bolt pockets. If the fasteners are not visible, then a Level 1 or 2 inspection will result in minimal fastener data. A Level 3 inspection is required to determine the condition of the fasteners. For newer structures, the fasteners may pass through blocking and terminate with nuts and washers bearing on heavy plates. This part of the structure is accessible and should be inspected for loss of section due to corrosion. If fasteners are embedded in the structure and the bolt pockets are filled, the only inspection technique available to the inspector is to remove the casting and observe the fastener for corrosion and loss of cross sectional area. Load testing of the fasteners can be conducted without removal of the casting and will result in the determination of an allowable load. See APPENDIX A for load testing criteria.

4-3.3 Supporting Structure.

4-3.3.1 Concrete.

The majority of heavy load mooring hardware is attached to concrete decks. Concrete acts well to resist the forces applied by mooring hardware. The compressive strength of concrete resists the shear forces generated as well as providing excellent distribution of load through the structure. Factors to consider when inspecting concrete that supports mooring hardware include cracking, disintegration and corrosion of reinforcing steel. Cracking occurs in all concrete through many processes both as a result of natural factors and from outside forces such as impact. The inspector must be able to determine the differences between the various types of cracks, their causes and the structural implications of those cracks. Cracks of a concerning nature include: shear cracks near the edge of the pier deck (running at 45 degrees through the corner); diagonal cracking on the deck surface running at 45 degrees from the hardware to the edge; and radial cracking around fasteners indicating cone failure. Gaps at the hardware base or crushing of bedding grout indicate movement or overloading and should be noted. General deterioration of the concrete should be observed and noted.

The mooring hardware should be founded on a solid concrete matrix and/or bedded in grout to provide full contact on the bottom and sides. The concrete should be solid and not exhibit any significant disintegration or spalling.

4-3.3.2 Timber.

Timber structures should be inspected for structural failures such as: crushing of the timber under the hardware or the fastener bearing plates, cracking or failed members, and displaced members. Timber also exhibits deterioration in several forms such as: dry rot or decay, marine borers, and termites or other insects. These conditions should be noted and assessed based on their impact to the structure and mooring hardware.

4-3.3.3 Steel.

Steel supporting structures exhibit conditions such as corrosion, buckling, and cracking. Steel members are generally fastened with either bolts or welds. Bolts should be inspected for tightness, loss of cross sectional area due to corrosion, and bearing. Welds should be inspected visually for cracking.

4-3.4 Fender System.

Visual observation of the fender system should be made in sufficient detail to establish the typical cross-section and to detail the energy absorbing characteristics of the system. Where timber fender systems are employed, the general condition of the timber components should be noted in terms of berthing capability. Where other types of fender systems are in place, the overall capacity of the system should be documented. Locations where damage has occurred should be noted. Missing fender units should be noted and identified.

4-3.5 Global Conditions.

Global conditions refer to the condition of the supporting pier, wharf, or dolphin structure. The inspection of these structures is closely related to the condition of the mooring hardware with respect to the capacity of the mooring system. For example, the sum of the capacities of the mooring hardware may exceed the total capacity of the structure to resist these loads. In this case the mooring hardware cannot be fully developed. Berthing plans are required to factor these limitations into the allowable berthing capacity for the facility. Inspection of pier facilities is addressed in UFC 4-150-07, *Waterfront Facilities Operations and Maintenance*.

4-3.5.1 Pier Structure.

The significant loading imposed on the pier structure by mooring hardware is in the lateral direction (horizontal "x" direction), which in most cases is resisted by batter piles or passive earth pressure. Piers vary in their construction and the methods employed to transmit these loads to the soil. Open pier structures generally have battered piles (piles at an angle) along with plumb piles (vertical piles,) as well as significant dead loads to resist the lateral and resulting uplift loads. Solid pier structures rely on their massive dead load for stability, as in cellular structures or in the resistance of deadman in the case of tied-back sheet pile bulkheads.

4-3.5.2 Structural Analysis.

The inspecting engineer must collect all available data to ascertain the capacity of the pier structure to resist lateral loads. Available information may include:

- Original design drawings and calculations.
- Modifications to the structure.
- Previous inspection reports.

4-3.5.2.1 Calculations.

When directed, a licensed professional engineer must calculate the lateral capacity of the facility based on available data and according to UFC 4-152-01, *Piers and Wharves*. For each ship that uses the facility, the analysis should provide the maximum wind speed for safe mooring. Caution should be exercised in using appropriate factors of safety based on the accuracy and scope of available data.

4-4 PHOTOGRAPHY.

Photography should be used to document the condition of each piece of hardware. This can be used in future assessments to determine the change in conditions. Photographs should include a general overview of the hardware piece and any significant conditions. The hardware should be identified within the photograph. An overview of each berth showing the fender system should be taken and included within the report.

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CHAPTER 5 REPORT

5-1 REPORT PURPOSE AND OBJECTIVES.

The mooring hardware report should present the data acquired during the field investigation and the results of the analysis of that data for the use by Berthing Officers in the formulation of berthing plans, scheduling repairs, and instituting a mooring hardware load test program.

5-2 REPORT FORMAT.

For consistency, all reports should follow the Report Outline in Figure 5-1. The contents of each section are described below. Each report should be submitted in MS Word (.doc) and Adobe Acrobat (.pdf). The quantity of each submittal should be determined in the scope of work. The digital files should be submitted on CD-ROM media or other approved file transfer system.

5-3 REPORT STRUCTURE.

5-3.1 Outline.

See Figure 5-1.

5-3.2 Introduction.

This section is largely a descriptive overview with sections including:

1.1 Background/Objectives

1.2 Report Description

1.3 Condition Rating

1.4 Digital Model

5-3.3 Activity Description.

This section has subsections including:

2.1 Location

2.2 Existing Waterfront Facilities along with regional, area, and facility maps that are the same as in the Waterfront Facilities Inspection Report.

Additional subsections include:

2.3 Inspection Procedure and

2.4 Hardware Numbering System

In these subsections, the inspection procedure and hardware numbering system are explained in detail to the reader. In the inspection procedure subsection, the condition rating system is described as well as the method of locating the position of the mooring hardware. This will provide the reader with an understanding of the level of accuracy of the inspection and data. The subsection on the Hardware Numbering System will provide the reader with an understanding of the system used and why this system was employed, (i.e. whether the system was in place or developed for a specific inspection).

5-3.4 Facilities Inspected.

This section constitutes the body of the report and has the following subsections:

3.1.1 Description

3.1.2 Design Structural Capacity

3.1.3 Existing Condition

5-3.5 Facilities Description.

Includes a summary of the history of the facility structure including the date of original construction, type of structure, length of berth, deck elevation, depth of water (MLLW datum), and a description of the fender system. The intent of this section is to give the reader a solid background on the specifics of the structure while being concise. In addition to structure description, the current use of the facility should also be described. The types of vessel usage complement as well as the type of service (I, II, III, or IV) should be noted. See UFC 4-159-03, *Moorings*.

5-3.6 Design Structural Capacity.

This section consists of a table reviewing mooring hardware data associated with the facility. The data within this table includes: mooring hardware type and quantity, design load rating of the hardware, the calculated load capacity of the hardware if manufacturer's data is not available, and the design and/or calculated capacity of the base structure. This table is a structural summary intended to provide the reader with information required to determine berthing capacity.

5-3.7 Existing Condition.

This section provides a summary of the conditions found during the inspection. A discussion of hardware rated at #3 or #4 is included to highlight conditions that warrant attention. Following the existing condition text are photo pages that present a photographic example of each type of hardware found on the facility and photos of anomalous conditions. Following the photo page(s) is the figure showing the 3-D perspective view of the facility (when requested). Following this is the figure (drawing) showing the plan view of the facility with the condition of the fittings and fender system noted. Following this is the data table. The data table has all the information available about each piece of mooring hardware. This information includes; hardware #, node #, X-coord., Y-coord., Z-coord., type of hardware, line pull rating, and the condition of both the hardware and it's support structure.

5-3.8 Appendices.

5-3.8.1 Key Personnel.

Each report should have a list of key personnel responsible for organizing, conducting, and implementing the investigation.

5-3.8.2 Load Test Procedures.

This section will include a description of any load testing undertaken. The level of testing, quantity, and location of load tests will be described (see APPENDIX A).

5-3.8.3 Calculations.

All calculations to determine the load capacity of mooring hardware and/or supporting structures is presented in APPENDIX A.

5-3.8.4 Mooring Hardware Inspection Records.

The actual mooring hardware inspection records should be included in this section.

5-3.8.5 Deck Fitting Load Test Reports.

The load testing reports should be presented in this section.

5-3.8.6 References.

All references used in the body of the report should be identified in this section.

5-4 3D MODEL.

A three-dimensional model of each facility will be generated when requested for Level 2 inspections in AutoCAD 2010 or greater to assist facility users in the placement of ships and camels along the pier or wharf in conjunction with fender systems that are in place. At a minimum the model must include: all mooring hardware, main components of the permanent fender system, mudline representation, water level representation, and all fixtures and buildings within 50 feet (15.2 m) of the berth face or that would cause obstruction to berthing lines. A perspective view of the berth should be presented in the body of the report for each facility in the form of a figure in 8.5 in. x 11 in. (216 mm x 279 mm) format.

5-5 DRAWINGS.

The report will include plan views of each berth showing the location of each mooring hardware piece with the hardware identification number as well as its condition. The condition of the hardware should be color-coded to match the color-coding of the data tables. The condition of the fender system should also be noted with a color line running parallel to the face of the berth. The plans will be to scale such that laying out mooring lines can be planed and facilitated.

Obstructions to mooring lines will also be shown on the plan. The north arrow and direction of current ebb and flood will also be shown.

5-6 DATA TABLES.

Data tables will be included in the report and in spreadsheet format. At a minimum the data tables will include: X, Y, Z coordinates of each piece of hardware, its identification number, its node number, the condition of the hardware and its base, the type of hardware, and its allowable line pull rating. The hardware condition will be annotated both numerically and in color as noted in Table 5-1. The data table will be produced in Excel format as shown and should have the ability to be manipulated in to the EMOOR database (see UFC 4-159-03, *Moorings*) The node number, coordinates, and the line pull should be numbers (not labels) to facilitate import into a database in Excel format.

Table 5-1 Condition of Color Schemes

Condition Color Level	Color	AutoCAD 2010 Color Number
1 = Excellent	Green	90
2 = Satisfactory	Blue	160
3 = Marginal	Yellow	40
4 = Poor	Red	240

Figure 5-1 Report Outline

Report Cover Title

Page

Executive Summary

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APPENDIX A MOORING HARDWARE TESTING

A-1 INTRODUCTION.

A-1.1 Scope.

This Appendix is a guide for the testing of mooring hardware at waterfront facilities. It is a source of reference for the planning, testing, and reporting of current load capacities of mooring hardware at waterfront facilities in a standard format.

A-1.2 Purpose.

This Appendix provides guidance for the planning, testing, and reporting of current mooring hardware load capacities. It should be used as a tool for assisting personnel tasked with maintaining the readiness of shoreside facilities for use by the fleet and in support of military marine operations.

The objectives of the Mooring Hardware Report are:

- To establish adequacy of mooring facilities.
- Enable facility users to develop efficient berthing plans.
- Establish baseline data on existing mooring hardware and berthing capacity.
- Provide facility users with information sufficient to determine the level of effort necessary to maintain or upgrade existing capacity.
- This UFC covers berthing facilities for mooring and providing support to ships and craft, as well as dry docks used for modification, inspection, maintenance, and repair of ships.

This UFC does not cover fleet moorings (covered in UFC 4-159-03, *Moorings*) or mechanical capstans.

A-2 PLANNING HARDWARE TESTING PROGRAM.

A-2.1 General Description.

This section covers the planning required to conduct the testing of mooring hardware. Critical aspects of planning testing of this nature include the establishment of a clear scope of work and gathering all available data as well as understanding the prioritization of berths and fittings.

A-2.2 Scope of Work.

Planning the testing of mooring hardware will begin with the establishment of a scope of work. The scope of work will define the mooring hardware to be tested and the level of testing to be conducted. The scope of work should be made following initial findings of the Level 2 Inspection and Report (covered in UFC 4-159-03). The scope of work should include:

- Hardware to be tested, by established designation.
- Type of hardware.
- Type of support structure.
- Level of testing required.
- Accessibility.
- Date of last inspection/testing.

A-2.3 Existing Data.

All available relevant data on the mooring hardware to be tested should be gathered at the earliest possible date. This information should be provided to the persons responsible for planning and organizing the testing effort such that the level of effort for testing a specific piece of hardware can be determined. Data and information may be available in many forms as listed below:

- Mooring Hardware Inspection report.
- Design plans.
- Berth priority ratings.
- Hardware priority ratings.

A-2.4 Site Conditions.

The portion of the waterfront facility surrounding the mooring hardware to be tested should be evaluated for accessibility. If there are no limitations to accessibility of the mooring hardware, all options for testing should be considered. This information assists in formulating accurate cost estimates for the testing.

A-2.5 Testing Plan.

Testing of fittings is relatively expensive and time consuming, so it is recommended that periodic testing is used on a statistical basis. Prioritize the tests based on the importance of the mooring facility.

Various levels of testing can be instituted to achieve the desired results. For example, if it is determined that the required level of accuracy is 100%, then all fittings will need to be tested. If 95% accuracy is required, then the number of tests can be reduced significantly. The sampling criteria can be based on statistical sampling techniques.

Statistical sampling provides an objective method for determining sample size for a desired confidence level and precision. The result of a statistical sampling program would determine the approximate number of fittings that are marginal or unacceptable; however, it would not be able to determine the location of those fittings. An estimation of the load carrying capacity and condition of the fittings in general could be made.

Testing of every fitting would be required for 100% accuracy. A statistical approach may be a reasonable cost effective method of initiating a testing program that would determine the overall adequacy of the berthing system.

Standard sampling plans are presented in ANSI/ASQ Z1.9, *Sampling Procedures and Tables for Inspection of Variables for Percent Nonconforming* or ANSI/ASQ Z1.4, *Sampling Procedures and Tables for Inspection by Attributes* based on choice of inspection methods; inspection by variables or by attributes. ANSI/ASQ Z1.4 may be well suited for a testing program where the fittings are either passing or failing the load test.

A-2.6 Facility Prioritization.

Review mooring facilities and prioritize each mooring hardware unit as ‘HIGH’, ‘MEDIUM’ or ‘LOW’ to determine the extent of testing required. Consider the following factors in assigning testing priorities.

- Visual inspections and non-destructive testing (such as ultrasonic) may find possible problems and indicate that certain mooring fittings need to be assigned the highest priority. Visual inspections should include the fasteners (nuts and bolts) including the under-deck connections if available. Some mooring fittings should be taken out of service and should not be tested if the fasteners are in poor condition.
- Berths providing Mooring Service Type III (Heavy Weather Mooring) are especially high priority, because the ships under repair at these piers and wharves cannot get under way in case of an approaching storm.
- High capacity fittings secure a larger portion of a mooring load at a given facility, and should be assigned higher priority (i.e. a Special Mooring Bollard 'A' holds more load than a 30-in. (76.2 cm) cleat, so the bollard is assigned a higher priority).
- Older facilities not previously pull tested are more likely to suffer from structural deterioration and should be assigned higher priority. Testing recommendations are shown in Table A-1.
- Facilities that do not know the rated load capacities of their mooring fittings should develop a test plan to first estimate the capacities using engineering tools and comparison to similar designs. Then test a sample set of mooring fittings to their estimated capacity by applying incremental loads while monitoring for deflection and other failure modes.

Table A-1 Pull Testing Interval Recommendations

Hardware Priority	Testing Interval	Minimum % of Hardware	Description
High	12 years	20%	For older and very important facilities, up to 100% of fittings can be tested. If any of the tested fittings fail, then testing should be expanded to include a higher percentage of fittings.
Medium	18 years	10%	For older or very important facilities, up to 50% or more of fittings can be tested. If any of the tested fittings fail, then testing should be expanded to include a higher percentage of fittings.
Low	TBD	TBD	A responsible authority should determine what level, if any, pull testing is required.
Mooring Anchors	During installation	100%	All anchors are pull tested during initial installation.

A-3 QUALIFICATIONS.

A-3.1 Personnel.

If contracted, the testing of mooring hardware must be conducted under the direct supervision of a Registered Professional Engineer (P.E.) who has experience in the design and inspection of marine structures. At a minimum, the supervising engineer (P.E.) should be on site and involved in the testing to assess and record conditions encountered using standard engineering practice. NAVFAC EXWC has the capability of providing mooring hardware analysis and testing on a reimbursable funding document for any U.S. government or military agency. All rules governing workplace safety should apply, and it is recommended to have a site safety supervisor available to review safety plans and oversee the work.

A-4 BACKGROUND.

A-4.1 General.

An understanding of the following information regarding the testing of mooring hardware is essential. Each test will consider the following:

- Orientation: The position (X, Y, Z coordinates) of the hardware should be based on the coordinate system established during the mooring hardware inspection. Direction of the forces applied should be established and recorded utilizing the same coordinate system.
- Magnitude: The load applied to the hardware should be 110% of its rated load capacity, applied incrementally while monitoring for deflection and other failure modes. The rated load capacity of the hardware can be gathered from existing data or estimated using engineering tools and comparison to similar designs.
- Duration: The duration that test loads are applied should be dependent upon the level of the test and the discretion of the supervising engineer (P.E.).

A-4.2 Load Path.

The load path followed by the mooring line load through the fitting into the supporting concrete slab can be considered the same for all the mooring fittings.

The mooring line load is applied under the horn or lip at the mooring fitting. The upward vertical load component from the mooring line causes a vertical shear at the base of the horn or lip for loads with nonzero vertical load components. The horizontal load component at the load point induces shear stresses in the cross section of the mooring fitting. The upward tensile force causes tensile stress in the cross section of the mooring fitting as well as a constant bending moment along the mooring fitting axis about a horizontal axis normal to the load. The horizontal load component induces a bending moment that increases with distance from the load point toward the base of the mooring fitting. This bending moment is a maximum at the base of the mooring fitting.

The axial and shear forces and bending moments at the base of the mooring fitting are resisted by the base plate through flexure and shear action. At the bottom of the base plate, the resulting forces and moments are resisted by the tensile and shear stresses in the anchor bolts. However, a small portion of these forces and moments is resisted by friction between the toe of the base plate and the concrete and by bearing of the vertical sides of the base plate against the adjacent concrete. The shear and tensile forces in the anchor bolts are resisted by the concrete base through bearing, shear and tensile stresses in the slab. The concrete slab transfers these loads from the anchor bolts to the pile cap through shear and tensile stresses and then to the support piles. In turn, the piles transfer the forces to the supporting soil.

A-4.2.1 Load Failure.

The failure of any component along the load path described above from the load point to the ground disrupts the flow of forces unless there are sufficiently strong adjacent parallel load paths to take up the load carried by the failed component. A disruption of the load path can lead to the failure of the load resisting system as a whole.

A-4.3 Supporting Structures.

Consideration of the supporting structure is a critical component of planning a hardware test. Personnel responsible for carrying out the testing program must determine the following:

- The structural adequacy of the system to support the test load.
- General condition of the supporting structure.

Once it is determined that the supporting structure was designed to handle the fitting and the condition of the structure is sound, the test can be carried out.

A-4.4 Failure Modes.

There are various modes of failure associated with mooring hardware. Most cases of failure under in-service conditions occur in the fasteners. When the fitting is embedded in concrete and does not utilize a bolted connection the fitting will generally fail by cracking in areas of high tensile stress or excessive bearing stress. It has been observed that some failures of mooring hardware do not result from mooring line loads. These failures result from overload due to vehicular impact, cranes accidentally setting loads upon the fitting, and other miscellaneous incidents. This type of failure should be observed prior to conducting a load test and should be grounds to abort the test. Mooring hardware with obvious distress must be taken out of service immediately.

Failure under load test is generally associated with corrosion of the fasteners or failure of the supporting structure. The following methods should be used for detection of failure:

- Visual observation of distress or movement.
- Measured permanent yielding or displacement following release of test loads.
- Observation of cracking.

A-5 METHODS.

A-5.1 General.

The purpose of a hardware test is to ensure that the mooring hardware is capable of holding its design load. If a mooring fitting fails, take out of service immediately and replace or repair as soon as possible. Several general methods exist to test fittings:

A-5.1.1 Pull Testing.

There are four methods of pull testing:

- Pull test with a test rig, which may include jacking equipment.
- Pull test with a land-based crane or winch.
- Pull test with a water-based crane or winch.
- Pull test similar mooring hardware one-against-the-other to test two pieces of mooring hardware at once using weight handling equipment to apply the load.

A-5.1.2 Bolt Testing.

Fasteners transmit the load to the structure and are often the critical component in many fittings. Therefore, consider testing the bolts in lieu of testing the entire hardware if the mooring fittings are in good condition. Bolts act in tension and shear to resist loads applied to mooring fitting. Since most mooring fittings are set in a grout or concrete base and have shear keys integral with the fitting, most of the shear stresses are resisted by the concrete or grout base. This is not the case on structures constructed of timber or steel where all loads are resisted by the fasteners. If the fitting is set in concrete, the fasteners need only to be tested in tension. In cases such as timber structures or steel structures, the fasteners are readily accessible and can be removed for inspection, eliminating the need for in-situ load test. Bolts that have their anchorage in concrete should be load tested in tension using the procedures outlined in ASTM E 488, S*tandard Test Methods for Strength of Anchors in Concrete and Masonry Elements*. Ultrasonic or other non-destructive testing may also be utilized before pull testing to detect voids, cracks, corrosion, and other discontinuities along the bolts. It should be noted that tension and testing of fasteners will not provide a comprehensive indication of load capacity of the system.

The bolt testing procedure is:

- Remove the grout and nuts from the bolts.
- Pull-test each bolt to 110% of its working load using a pull test rig. The pull test procedure must follow the procedure for testing anchors described in ASTM E 488, Standards Test Methods for Strength of Anchors in Concrete and Masonry Elements.
- If test is successful, reinstall the nuts and grout to the design condition.
- If bolt fails, take out of service and replace as soon as possible.

A-5.2 Results.

Load testing results are reported on the form provided in Figure A-1. Remove any mooring hardware that does not pass the pull test and plan and allocate resources for appropriate replacement.

A-5.3 Levels of Load Testing.

- Level I - Bolt pull test (tension). Bolts are tested individually to determine tensile strength of the bolt and anchorage.
- Level 2 - Indirect line load. Mooring fittings are pull-tested with actual line force but not in actual direction of mooring line due to cost and convenience, e.g., bollard-to-bollard pull. This level of testing will confirm the strength of the mooring hardware system including the casting, fasteners, and structure.
- Level 3 - Load applied in actual direction of mooring line force. This will confirm the working load of the entire system including base structure, anchor bolts, and fitting.

A-5.4 Testing Procedure.

A-5.4.1 Test Prerequisites.

Area adjacent to fitting to be tested should be open and clear of vehicles, vessels, or other equipment and associated personnel.

A-5.4.1.1 Prior to Testing.

Prior to testing, a review should be conducted of the test equipment by qualified personnel to determine its adequacy for the loads to be applied.

A-5.4.1.2 Fittings.

Fittings should not exhibit outward signs of distress or failure prior to conducting a load test.

Figure A-1 **Example Deck Fitting Load Test Report**

MOORING FITTING LOAD TEST REPORT Fitting No.:

Pre-Test Condition:

Casting	Anchor Bolts	Concrete Foundation
Size:	Size:	Geometry: (dimensions, height above deck)
Type: Condition: (paint, rust)	Type: Condition: (lead fill, paint, rust)	Condition: (cracks, spalls, stains)
___________	___________________	_____________________
___________	___________________	_____________________

Distress: (cracks, abrasions) Design load capacity: (known / estimated)

____

Description of Testing Method_________Pull Test_____________Bolt Test

Fitting Position: (with respect to reference point)

Pre-Test Coordinates	Post-Test Coordinates
X =__________________	X =__________________
Y =__________________	Y =__________________
Z = __________________	Z =__________________

TEST DATE: _______________________ TEST LOAD:________________________

LOAD HELD FOR:___________(sec) (incremental at 10% steps)

Test Time: Start______________Finish ______________TEST ANGLE:_______________

RESULTS: (Record any manifestation of distress observed, change to cracks in foundation, rust flakes shed, foundation movement, fitting rotation, distortion, fastener yield, etc.)

____

____

Test Director:____Date:______________

A-5.4.2 Test Preparation – General.

A-5.4.2.1 Testing Personnel.

Testing personnel should provide test rigs, jacks, pumps, wire rope rigging, surveying instruments for measuring deflection and movement (such as an optical level or a total station), chain falls and dynamometer, and all subject matter expertise as required to perform the test.

A-5.4.2.2 Precautionary Measures.

Precautionary measures should be taken to prevent damage to the fitting, dock structure, or fender system. Lumber blocks, sheet copper, etc. should be provided to prevent chafing and rope burns as necessary. Where needed, rubber padding should be provided to absorb and distribute point loads on concrete.

A-5.4.2.3 Monitoring Points.

Monitoring points should be established on the fitting or fastener to track movement under load. Movement should be recorded in the three principal axes. A reference point independent of the fitting or fastener and its foundation should be established to find movement. Surveying methods can be employed to track movement from a safe distance. A target could be affixed to the fitting and readings taken (X, Y, Z) during the test.

A-5.4.2.4 Base.

The strip of concrete surrounding the base plate of each fitting and the surface of the free edge of the concrete in front of the fitting must be visually inspected for shear cracks. To aid in the detection of potential shear cracks, it is recommended that an approximately 1 ft (0.3 m) wide strip surrounding the base plate and the surface of the free edge of the concrete in front of the fitting, be painted with whitewash or light-colored brittle paint.

A-5.4.3 Test Precautions.

A-5.4.3.1 Standards.

Perform all work operations in accordance with the safety standards identified in APPENDIX C (such as U.S. Army Corps of Engineers EM-385-1-1 and OSHA Standards). Provide U.S. Coast Guard (USCG) approved life jackets or buoyant work vests to employees working over or near water, where the danger of falling into the water and/or drowning exists. Evaluate the requirement for the use of personal floatation devices (PFDs) on piers, taking into consideration falling/tripping hazards, proximity to edge, obstacles/obstructions, availability and placement of life rings with lines, access ladders, etc. Follow site specific weight handling equipment safety rules as required.

A-5.4.3.2 Provisions.

Provisions should be made for keeping personnel not involved in the test clear of the test site and any danger areas.

A-5.4.4 Test Procedure.

A-5.4.4.1 Horizontal Pull.

Using the test rig, chain falls, dynamometer, etc. and a wire rope pendant, begin by exerting a pull equivalent to 10% of the rated load capacity for the mooring fitting or fastener. Application of the load should be 4 in. (102 mm) below the lip, horn, or other line holding device on fittings. Increase the load incrementally, in 10% steps or as directed by the test engineer. Hold each incremental load for one minute or as directed by the test engineer, monitoring for deflection, movement, and other failure modes. Increase to a final load of 110% of the rated load capacity. The 110% load should be held for 10 minutes. At the end of 10 minutes, the fitting or fastener should be examined for any evidence of failure and any deformation, movement, or other failure modes recorded. Slowly remove the load from the fitting after recording all information.

The results should be recorded on the load test record sheet.

A-6 REPORTING.

All results of testing should be recorded on the deck fitting load test record shown in Figure A-1 or a similar record sheet. These records should be included in the report described in Section 5 of this document.

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APPENDIX B GLOSSARY

B-1 ACRONYMS.

AFCEC	Air Force Civil Engineer Center
ASTM	American Society for Testing and Materials
ASQ	American Society for Quality
BIA	Bilateral Infrastructure Agreement
DoD	Department of Defense
EXWC	Engineering and Expeditionary Warfare Center
HNFA	Host Nation Funded Construction Agreements
HQUSACE	Headquarters, U.S. Army Corps of Engineers
MLLW	Mean Lower Low Water
MST	Mooring Service Type
NAVFAC	Naval Facilities Engineering Command
P.E.	Professional Engineer
PFD	Personal Floatation Device
SOFA	Status of Forces Agreements
UFC	Unified Facilities Criteria
U.S.	United States
USCG	United States Coast Guard

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APPENDIX C REFERENCES

C-1 GOVERNMENT PUBLICATIONS.

NAVAL FACILITIES ENGINEERING COMMAND (NAVFAC)

MO 124, *Mooring Maintenance Manual*

UNIFIED FACILITIES CRITERIA (UFC)

https://www.wbdg.org/ffc/dod

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

UFC 4-150-07, *Waterfront Facilities Operations and Maintenance*

UFC 4-150-09, *Permanent Anchored Moorings: Operations and Maintenance*

UFC 4-152-01, *Piers and Wharves*

UFC 4-159-03, *Moorings*

C-2 NON-GOVERNMENT PUBLICATIONS.

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

https://www.asce.org/

ASCE MOP 130, *Waterfront Facilities Inspection and Assessment*

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 488, *Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements*

AMERICAN SOCIETY FOR QUALITY (ASQ)

ASQ Z1.4, *Sampling Procedures and Tables for Inspection by Attributes*

ASQ Z1.4, *Sampling Procedures and Tables for Inspection by Variables for Percent Nonconforming*

UFC 4-150-09
27 February 2019

UNIFIED FACILITIES CRITERIA (UFC)

PERMANENT ANCHORED MOORINGS OPERATIONS AND MAINTENANCE

UFC 4-150-09
27 February 2019

UNIFIED FACILITIES CRITERIA (UFC)

PERMANENT ANCHORED MOORINGS, OPERATIONS AND MAINTENANCE

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location

This UFC supersedes MO-124, dated August 1987.

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 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 Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should 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 web site http://www.wbdg.org/ffc/dod.

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

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UNIFIED FACILITIES CRITERIA (UFC)
NEW SUMMARY SHEET

Document: UFC 4-150-09, *Permanent Anchored Moorings, Operations and Maintenance*

Superseding: MO-124, Mooring Maintenance Manual, August 1987
FPO-1-84(6), Fleet Mooring Inspection Guidelines, 1984
FPO-1-88(40), Fleet Mooring Buoy Surface Inspection Guidelines, December, 1988
NAVFAC P-1110, Fleet Mooring Handbook

Description: The UFC 4-150-09, *Permanent Anchored Mooring, Operations and Maintenance* represents another step in the joint Services effort to bring uniformity to the maintenance and operations of moorings. This UFC contains extensive modifications in the following areas:

- Inclusion of lessons learned from past operations
- The use of commercial, industrial and offshore industry standards where appropriate
- Updating, conversion and combining of several NAVFAC manuals and local command guidelines to a more uniform format and a document to be used by all services with general updates and revisions

Reasons for Document:

The existing guidance was inadequate for the following reasons:

- Need to convert to UFC format
- Incorporation of changes described above
- Update to referenced documents

Impact:

The following direct benefits will result from the update of UFC 4-150-09, *Permanent Anchored Moorings, Operations and Maintenance*

- Although primarily a U.S. Navy document, a single, comprehensive, up to date criteria document exists to cover mooring operations and maintenance.
- Eliminates misinterpretation and ambiguities that could lead to conflicts.
- Facilitates updates and revisions and promotes agreement and uniformity of design and construction between the Services.

Unification Issues:

- There are no unification issues.

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CHAPTER 1 INTRODUCTION

1-1 BACKGROUND.

This UFC provides requirements, guidance and procedures for operation and maintenance of permanent anchored moorings for U.S. Department of Defense (DoD) vessels. This manual provides important technical data, information and recommended procedural guidelines for the operation, inspection, maintenance, repair, removal and refurbishment. This document will supersede all the documents and drafts of documents currently being used to conduct inspections, maintenance and repairs of fleet moorings, such as the NAVFAC P-1110 Fleet Mooring Handbook, FPO-1-84(6) Fleet Mooring Underwater Inspection Guidelines, NAVFAC MO-124, Mooring Maintenance Manual, etc. OPNAVINST 5450.348 states NAVFACENGCOM serves as the technical authority responsible for permanent anchored “fleet” moorings for the U.S. Navy.

1-2 PURPOSE AND SCOPE.

This UFC provides requirements, guidance and procedures for operation and maintenance of permanent anchor moorings for U.S. Department of Defense (DoD) vessels. This manual provides important technical data, information and recommended procedural guidelines for the operation, inspection, maintenance, repair, removal and refurbishment.

A mooring is any structure whose purpose is to restrain a ship’s movement and keep it in a relatively fixed location. A mooring is of two general types, fixed moorings and compliant anchor moorings. Fixed moorings are defined as a system that includes both tension and compression members. These systems include facilities like piers and wharves, the components that connect the vessel to the fixed facility (lines, chain, etc.) as well as the fendering used to protect the vessel from damage due to contact with the facility. Compliant anchor moorings are defined as a stationary system that includes primarily tension members with mooring loads transferred into the earth via anchors. Active ship’s anchor systems are excluded. This manual only addresses compliant anchor moorings, but many of the procedures described here are applicable to the inspection and maintenance of fixed mooring systems or their components.

This document standardizes mooring inspection procedures for both surface and underwater inspection and assist inspection personnel by describing the various typical permanent anchor mooring types and materials used and defining what should be accomplished before, during and after a mooring inspection. Also defined are the types of data and documentation that must be gathered and captured in the inspection report. The inspection’s Engineer-in-Charge (EIC) will evaluate the inspection data and provide an assessment of the mooring’s condition to meet its design requirements.

The document provides the inspector with a standard inspection template for the inspection of a mooring system, a sample preliminary inspection results email, a sample inspection report, inspection checklist, details of go no-go gauges and other inspection tools, and guidance on surveying of permanent anchor mooring buoys and anchors.

This document provides guidance for the maintenance and repair of the moorings based on the results of the inspection.

1-3 APPLICABILITY.

The information presented in this manual is applicable to planners, quality assurance and quality control personnel, supervisors and technicians who are involved in DoD mooring operations, inspections, and maintenance.

Planners can use this information to assist in developing budgetary input, inspection schedules and maintenance and repair schedules. The information will be useful in preparing specific plans for each major task and evolution in the life cycle of a mooring system.

In addition to safety, Quality Assurance (QA) and Quality Control (QC) must be the paramount consideration in the execution of every phase of the operation of a mooring system. The information will assist QA personnel in determining the number and type of checks and inspections that must be performed to ensure that the stringent quality control procedures are adhered to. QC personnel will find the information useful for identifying test equipment and procedures and personnel qualifications necessary to meet the requirements of the QC plan.

Supervisory personnel will use the information to assist in selection equipment and qualified personnel for each task and in executing each task in the safest and most efficient manner possible.

Technicians will find the manual useful as a training tool and a useful reference.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code (General Building Requirements)*. 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 BEST PRACTICES.

APPENDIX A provides documentation on Best Practices to be used during the operations, inspections, maintenance and repair of mooring systems. Included in this appendix is a section on Safety.

1-6 GLOSSARY.

APPENDIX M contains acronyms, abbreviations, and terms.

1-7 REFERENCES.

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

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CHAPTER 2 TECHNICAL REQUIREMENTS

2-1 PERMANENT ANCHOR MOORINGS.

2-1.1 Compliant Anchor Mooring Systems.

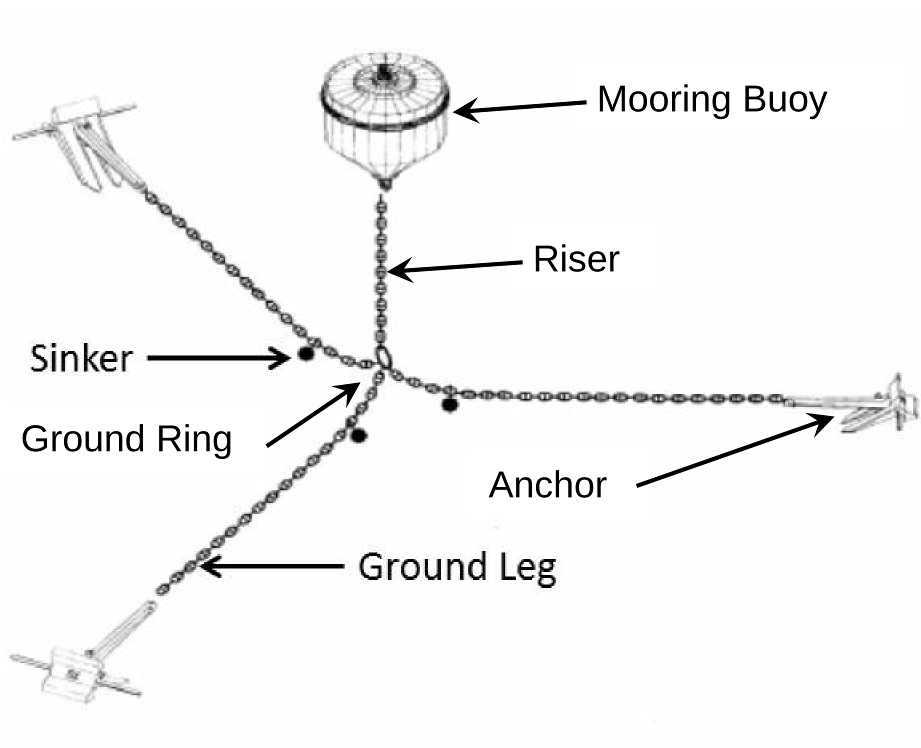
A compliant anchor mooring is used to provide temporary or permanent berthing for vessels in ports and harbors where pier space is limited or unavailable or in the open ocean. The most common moorings consist of one or more buoy systems. A buoy system includes the surface mooring buoy, the attendant chain, the anchor(s), the fittings, and the accessories. There are mooring systems that do not require a surface mooring buoy. Buoy and non-buoy mooring systems are described in subsequent paragraphs of this chapter. The complete mooring is defined by type and by classification, regardless of the existence of a surface mooring buoy. Type refers to the physical configuration of the mooring and classification refers to the holding capacity. There are several basic types of mooring systems, each serving a specific purpose and each offering advantages and disadvantages. The most commonly used mooring arrangements are discussed below.

2-1.1.1 Single Point (Free Swinging) Mooring System.

A single point mooring (SPM) system consists of a single buoy or attachment point to which a ship may moor. This single point of attachment permits the ship to swing freely and weathervane in response to environmental loading such as wind and currents. Single point moorings consist of an attachment point (in most cases a buoy), a riser assembly and either one or multiple ground leg assemblies. Most SPM systems used by the Navy have a buoy, a riser assembly with three ground legs attached to the riser by a ground ring and equally separated from each other (Figure 2-1). Ground legs can be secured to the seafloor by a variety of anchoring assemblies including gravity anchors, drag anchors, stake piles or embedded plate anchors. The single point mooring, having only one surface attachment point, minimizes material requirements, installation effort, and maintenance requirements.

The major disadvantages of this type of mooring are the large amount of real estate required by the moored vessel and the possibility of the vessel "fishtailing" or "horsing" about the buoy. A free-swinging mooring must be sufficiently clear of shoreline, shoal waters, structures, and other moorings. This will allow the moored ship to swing freely about the mooring, without interference, as it responds to the weather conditions.

Figure 2-1 Riser-Type Single Point Mooring



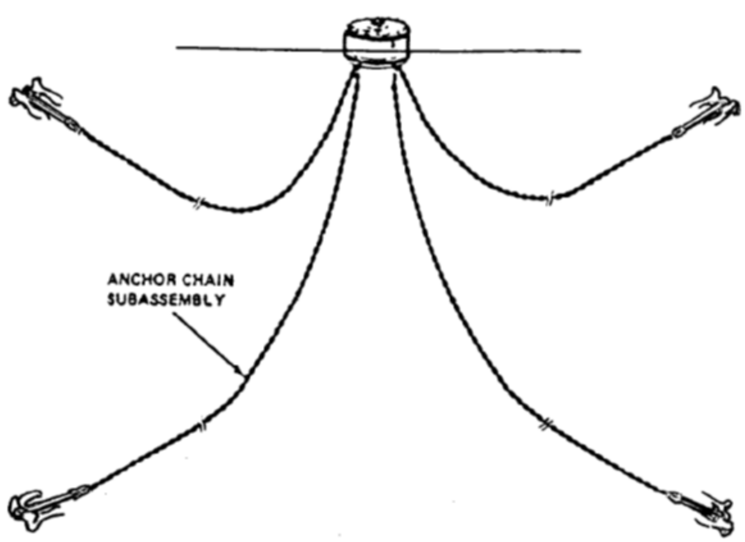
Single point moorings have three mooring configuration types. One type is the “Riser-Type” mooring with a buoy, a riser assembly and three ground legs attached to the riser by a ground ring, equally separated from each other as shown in Figure 2-1. Many single point moorings in the fleet mooring program are configured as a riser-type mooring. The riser-type mooring is preferred because it allows the ship to moor with a short hawser and not risk any damage to its hull by rubbing against a chain.

The second configuration type is the single riser-leg type mooring where a single chain assembly acts as both the riser and ground leg and is connected to either a plate anchor or in special cases, another type of anchor assembly. Figure 2-2 shows a Single Riser Leg Mooring. Most single riser-leg moorings in the Navy are secured to an embedded plate anchor and are used to create a spread moor (Paragraph 2-1.1.3 and Figure 2-5).

Figure 2-2 Single Riser Leg Mooring

The third configuration type is the “non-Riser” type mooring. In the non-Riser type mooring, the ground legs are attached directly to padeyes or chain capture devices on the buoy. These moorings do not permit the buoy to rotate and can be used to bring up electrical power or signal (telephone) cables or fuel lines to the ship. Although these moorings have the largest holding capacities, ships must be careful when mooring to them. A ship that is moored too closely, risks damaging its hull with the chain that is suspended in the catenary. There are some moorings within Department of Defense that utilize a non-riser type mooring. Figure 2-3 shows a Non-Riser Mooring.

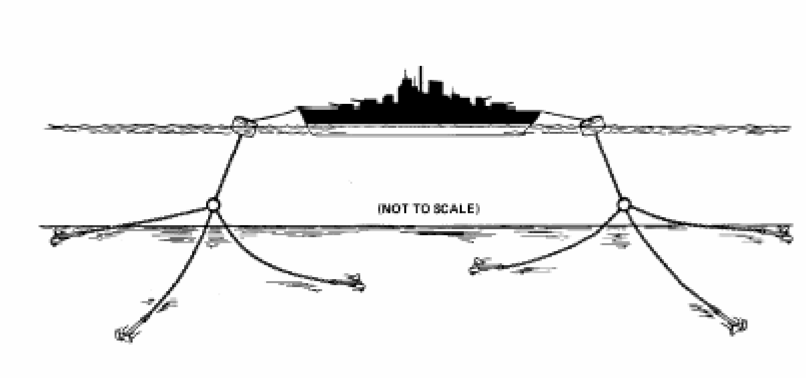
Figure 2-3 Non-Riser Mooring



2-1.1.2 Bow and Stern Mooring System.

A bow and stern mooring system provides two surface points to which a ship may attach its fore and aft mooring lines (Figure 2-4). Bow and stern moorings consist of two single point mooring systems. Most bow and stern moorings have two single point riser-type moorings consisting of a mooring buoy, a riser assembly and two ground leg assemblies.

Figure 2-4 Bow and Stern Mooring

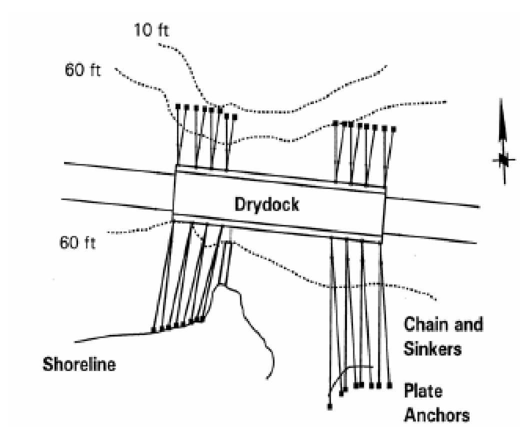


This type of mooring is designed to maintain the orientation of the moored ship into the prevailing currents and requires less area than a single point mooring. The major disadvantage of a bow and stern mooring is that each leg of the mooring usually must have a greater holding capacity than a single point mooring to resist strong loads imposed on the mooring legs by broadside winds.

2-1.1.3 Spread Mooring.

A spread mooring system (Figure 2-5) is installed to moor a single ship or cluster of ships in a fixed position for a long period of time. This system is used primarily to provide berthing for inactive ships or to moor floating dry-docks.

Figure 2-5 Spread Mooring



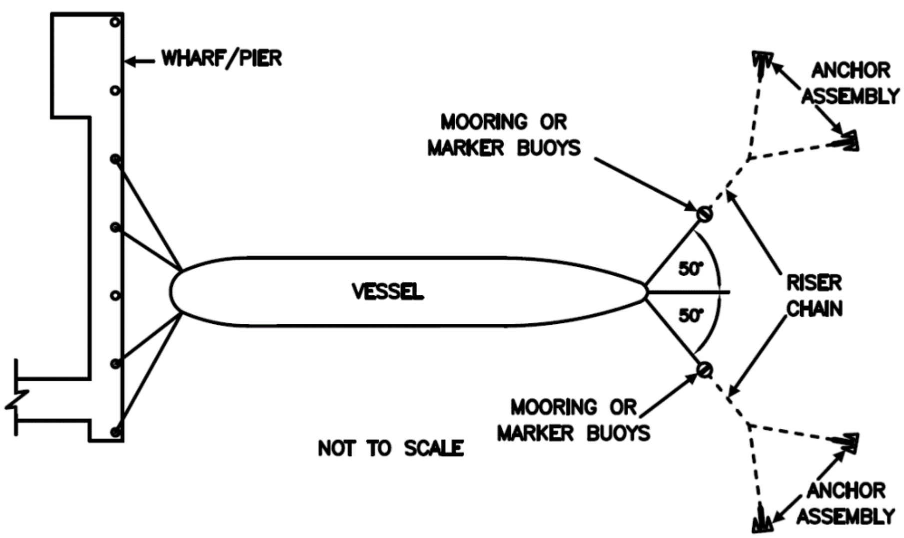
A spread mooring consists of four or more single point moorings installed in a specified pattern to provide multiple attachment points for the moored vessel(s). Single point moorings within a spread mooring may or may not have a buoy for an attachment point. Ship chains are either attached to the buoy or directly to the mooring's riser.

2-1.1.4 Mediterranean Mooring.

A Mediterranean mooring (Med-moor) is similar to a bow and stern mooring. The vessel is oriented perpendicular to a wharf or pier, or parallel, centered and in line with the end of a pier. The stern is generally secured to shore fittings on the pier or wharf. The bow of the vessel is secured using mooring chains to buoy attachment points provided on two single point moorings (Figure 2-6).

The moorings consist of a buoy, a riser-leg or multiple ground legs secured to a common riser with a ground ring. Under normal circumstances, ground legs for the bow moorings in a Med-moor are secured by either multiple drag anchors or a buried large deadweight anchor.

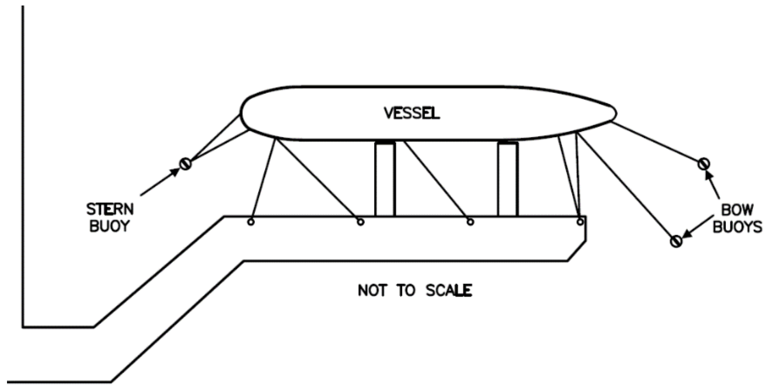
Figure 2-6 Mediterranean Mooring



2-1.1.5 Buoy Dolphins Mooring.

Single point moorings acting as mooring dolphins are installed to provide bow and stern attachment points for a ship moored alongside a short pier or to one or more finger piers (Figure 2-7). Single point moorings with buoy are used instead of permanent concrete or timber dolphins. The length of the ship that may moor to the buoy dolphins is limited by the distance between the buoys.

Figure 2-7 Buoy Dolphin Mooring System



2-1.2 Mooring Systems Assemblies.

2-1.2.1 Buoy Assembly.

The buoy assembly consists of the buoy and the top jewelry (to connect the vessel to the mooring buoy. See the descriptions of the various components in Section 2-2.

2-1.2.2 Riser Assembly.

The riser assembly connects the ground ring to the buoy. It consists of chain (or other tensile strength member) and all the connecting hardware used to connect the riser to the buoy (usually including a riser swivel shackle) as well as to connect the riser to single or multiple ground leg assemblies (usually an anchor joining link and a ground ring). See the descriptions of the various components in Section 2-2.

2-1.2.3 Ground Leg Assembly.

Ground leg assemblies consist of the chain (or other tensile strength member) and associated hardware to connect the anchor to the ground ring. Sinkers may also be used on the ground legs to help minimize or reduce the dynamic loads put on the mooring system by the moored vessel. See the descriptions of the various components in Section 2-2.

2-1.2.4 Riser Leg Assembly.

Riser leg assemblies consist of the chain (or other tensile strength member) and associated hardware to connect the buoy directly to the anchor assembly. Sinkers may be used on the ground legs to help minimize the dynamic loads put on the mooring system by the moored vessel. See the descriptions of the various components in Section 2-2.

2-1.2.5 Anchor Assembly.

The anchor assembly consists of the anchor that holds the system in place, and the hardware to connect the anchor to the ground leg or riser leg assembly. See the descriptions of the components in Section 2-2.

2-1.2.6 Cathodic Protection Assembly.

This assembly helps prevent corrosion of the mooring system by providing zinc anodes to corrode before the steel in the mooring system. Anodes are usually attached to each chain link as well as to the bottom of the buoy’s attachment padeye. See the descriptions of the components in Section 2-2.

2-2 MOORING COMPONENTS.

2-2.1 Mooring Buoys.

Mooring buoys are classified based on their shape and their construction. The type of buoy used in a mooring depends on the mooring's rated capacity and the method of attachment used by the serviced vessel. Buoys are generally equipped with a center tension bar which provides a lower padeye attachment for the mooring riser and an upper padeye attachment for an anchor bolt shackle where connecting hardware to secure the vessel is attached to. Buoys may also be equipped with a hawse pipe that allows the riser chain to pass through the center of the buoy and be the attachment point for connecting hardware to secure the vessel. Both of these two styles are designed for riser-type moorings.

Buoys may also be designed to attach directly to multiple ground legs. These buoys are prevented from rotating by the attached ground legs. These types of buoys are used when electrical power wires, communication wires or fuel hoses are being brought up to vessel from the sea floor. One would find this type of buoy on a non-riser type mooring system.

A buoy's size depends primarily on the weight of the mooring system it must support in the water column. The following types of buoys are utilized.

Peg-Top Buoys – Peg-Top buoys have bottoms that are conical in shape and upper vertical sides, similar to the drum buoy. The buoy serves to support a riser type system. They may have either a tension bar or a hawse pipe design. They may be coated with either a standard ship paint, a fiberglass coating or a polyurethane coating. Peg-Top buoys can be manufactured of steel or of foam encapsulating steel core and covered by an outer nylon reinforced urethane shell.

Drum Buoys – Drum buoys are so called because of their resemblance to the shape of a drum. Drum buoys are available in a variety of sizes and are used to support a riser type buoy system, having a hawse pipe or tension bar through them. They may be coated with either a standard ship paint, a fiberglass coating or a polyurethane coating.

Drum buoys can be manufactured of steel or of foam encapsulating steel core and covered by an outer nylon reinforced urethane shell.

Non-Riser Type Buoys – Non-riser type buoys are also shaped like a drum but have no hawse pipe or tension bar. Instead, they have padeyes or chain capture devices equally spaced around the bottom perimeter of the hull for attaching ground leg chains and have a swivel fitting on the top to support the top jewelry. These buoys are generally larger than riser-type buoys because of the added weight of the several chains they must support in the water column and because they are a load-bearing member of the mooring system. Non-riser buoys are also known as "telephone buoys".

Spherical Buoys – Spherical buoys are normally used only to mark and retrieve the riser chain of a mooring system. Ships attach their mooring hardware directly to the riser chain rather than to the buoy. The most commonly used spherical buoy is of steel construction, 54 inches (1.37 m) in diameter and may be foam filled.

2-2.1.1 Foam Buoys.

The foam buoy (Figure 2-8) is a buoy encased in rigid, closed-cell foam that is covered by a flexible crossed-linked polyethylene foam bonded to the rigid interior foam. The entire foam assembly is then encased in a urethane elastomer (Figure 2-9). Two sizes of foam peg-top buoys are primarily stocked in the Fleet Mooring Program; 8-foot (2.44 m) diameter (referred to as a small foam buoy) and 11.5-foot (3.51 m) diameter (referred to as a medium foam buoy). General data is provided in Table 2-1.

Figure 2-8 Foam Buoy

Figure 2-9 Foam Buoy Cross Section

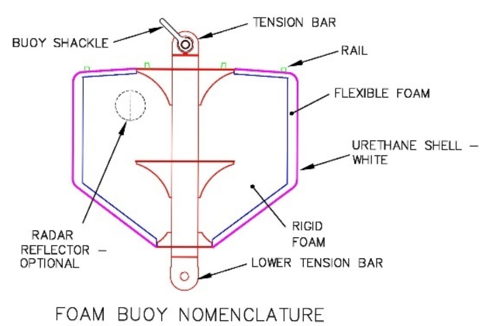


Table 2-1 Foam Buoy Data

PARAMETERS	8 ft BUOY	11.5 ft BUOY
Size	Small	Medium
Weight in Air	4,500 lbs (2,041 kg)	10,400 lbs (4,717 kg)
Net Buoyancy	15,000 lbs (6,804 kg)	39,000 lbs (17,690 kg)
Working Buoyancy (24 inch freeboard)	6,150 lbs (2,790 kg)	20,320 lbs (9,217 kg)
Reserve Buoyance (24 inch freeboard)	8,850 lbs (4,014 kg)	18,680 lbs (8,473 kg)
Proof Load on Tension Bar	300,000 lbs (1,334 kN)	600,000 lbs (2,669 kN)
Working Load on Tension Bar	150,000 lbs (667 kN)	300,000 lbs (1,334 kN)
Diameter Overall (w/fenders)	8 ft 6 in (2.591 m)	12 ft (3.658 m)
Diameter of Hull	8 ft (2.438 m)	11 ft 6 in (3.505 m)
Length of Hull Overall	7 ft 9 in (2.362 m)	8 ft 9 in (2.667 m)
Length of Tension Bar	11 ft 4 in (3.454 m)	13 ft 1 in (3.988 m)
Height of Cylindrical Portion	4 ft 4 in (1.321 m)	5 ft 7 in (1.702 m)
Height of Conical Portion	3 ft 5 in (1041 mm)	3 ft 2 in (9652 mm)
Bar Thickness (top/bottom)	4.5/3 in (114/76 mm)	5/3.5 in (127/89 mm)
Padeye ID (top/bottom)	3.5/3.5 in (89/89 mm)	4.5/5 in (114/127 mm)
Shackle on Top	3 in	4 in
Maximum Chain Size	2.75 in	4 in
Minimum Recommended Riser Weight	1,068 lbs (484 kg)	7,500 lbs (3402 kg)
Riser Weight for 24 inch Freeboard	8,850 lbs (4,014 kg)	18,680 lbs (8,473 kg)
Maximum Recommended Riser Weight	7,500 lbs (3,402 kg)	21,264 lbs (9,645 kg)
Moment to Heel 1 degree (Min Riser Wt)	108 ft-lbs (14.9 m-kg)	1,183 ft-lbs (163.6 m-kg)
Moment to Heel 1 degree (Max Riser Wt)	648 ft-lbs (89.6 m-kg)	2,910 ft-lbs (402.3 m-kg)

A foam buoy is superior to a steel buoy for a number of reasons:

- It will not flood or sink if the outer shell is punctured, see Figure 2-10;
- It is considerably lighter than the steel buoy that would be required to support the equivalent weight of chain in the water column;
- It requires significantly less preventive and corrective maintenance, resulting in lower projected operation and maintenance (O&M) costs than for a steel buoy;
- The resiliency of the foam greatly reduces the probability of damage to a vessel from a collision.

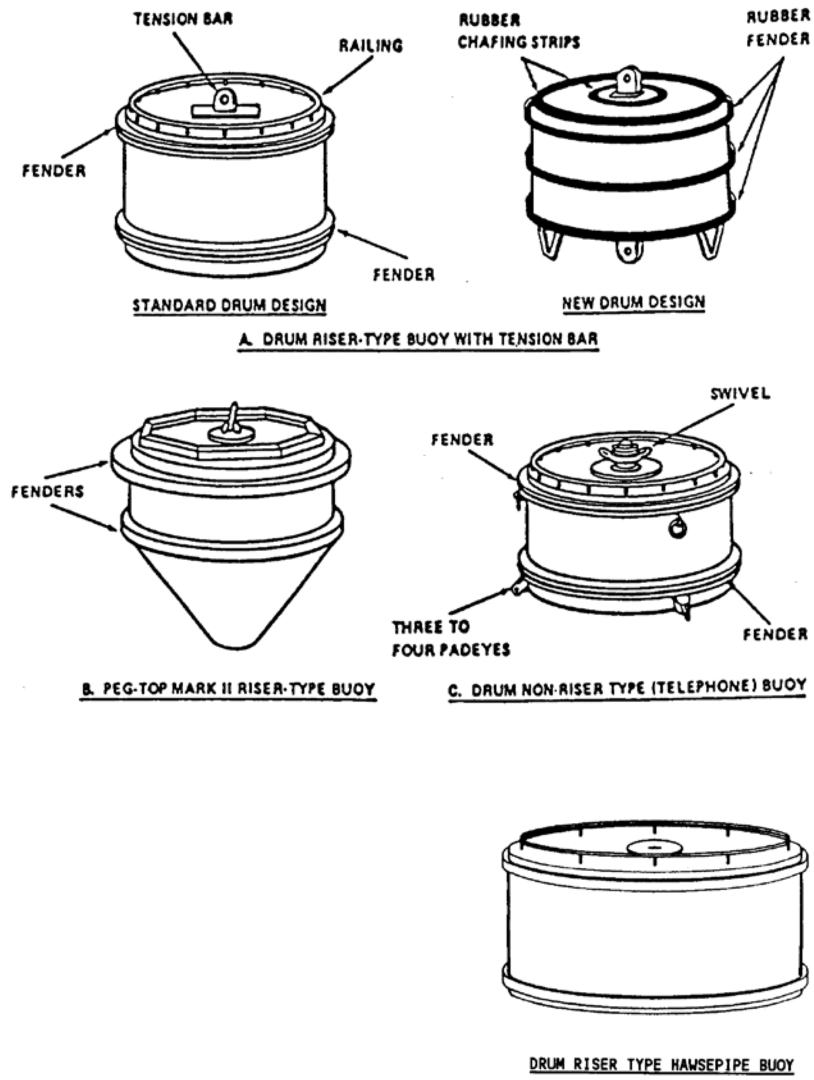
The working buoyancy is the amount of weight the buoy can support and still maintain a 2-foot freeboard above the deck line (when level). The deck line of a buoy is at the elevation on the buoy top shell where the top deck transitions to the buoy sides. For the buoys listed in Table 2-1, the deck line is at the bottom of the outer chafe rail.

Figure 2-10 Punctured Foam Buoy

2-2.1.2 Steel Buoys.

Older riser type buoys were fabricated out of steel. Like the foam buoys, most steel buoys have either a tension bar or a hawse pipe to bring the mooring load from the vessel to the chain/anchors. All non-riser buoys have been constructed of steel. See Figure 2-11 for various types of steel buoys.

Figure 2-11 Steel Buoys



Note:

All efforts should be made to replace steel buoys with foam buoys since steel buoys are much more difficult to inspect and maintain. Steel tension bar buoys can still be used, but hawse pipe buoys shall be taken out of service, disassembled and disposed of in accordance with local steel recycling programs.

2-2.1.3 Buoy Accessories.

2-2.1.3.1 Chafing Strips.

Chafing strips are heavy, molded rubber strips attached to the buoy at the top edge and around the top jewelry to prevent wear in the areas where the ship's mooring chain or hawser may drag against the buoy. Additionally, chafing strips provide both foot and hand hold points for operators. Not all buoys are equipped with chafing strips. Standard small and medium foam buoys have urethane chafing strips integrally casted as part of the outer shell or attached to the buoy's shell.

2-2.1.3.2 Rails.

Some steel buoys have rails attached to the outer perimeter of the top of the buoy to serve the same purpose as chafing strips. The rails are usually made of steel. Recent foam buoy procurements are using either D-rubber toe rails or cast elastomer toe rails in lieu of urethane chafing strips used for the standard Fleet Mooring foam buoy.

2-2.1.3.3 Fenders.

Fenders are installed in one or more rows around the circumference of the buoy's sides to absorb the shock of collision and prevent damage to the buoy hull. Fenders may be wood, rubber or a combination of the two materials. The fenders may be may be connected to steel buoy using studs, welded brackets (segmented or continuous) or metal retaining bands. Standard small and medium foam buoys have a single fender that is integrally casted as part of the outer shell (sometimes referred to as a rub rail).

2-2.1.3.4 Reflective Markings.

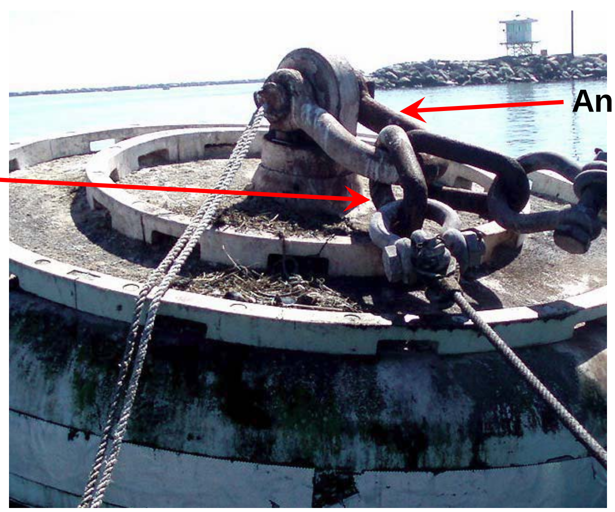
Mooring buoys are painted white or are coated with a white material. However, to make them more visible at night, one or more rows of reflective tape is bonded to the circumference of the buoy's sides. Mooring buoys within the Navy's restricted zone generally have white reflective tape. Mooring buoys in other locations will have reflective tape conforming to the cognizant USCG authority. Figure 2-12 illustrates a buoy with two strips of reflective tape.

Figure 2-12 Reflective Tape on Foam Buoy

2-2.1.3.5 Top Jewelry.

Top jewelry is the fitting or fittings attached to the chain or the tension bar padeye on top of the buoy. Top jewelry serves as the transition piece from the installed mooring system to the ship's mooring hawser or chain. Standard top jewelry has become an anchor bolt shackle and two pear links (Figure 2-13).

Figure 2-13 Top Jewelry on a Buoy



2-2.1.3.6 Buoy Lighting.

The lighting requirements will be specified by the United States Coast Guard (USCG) on the approved Aids to Navigation Application. If buoy lighting is required, it must be maintained by the custodian. See Figure 2-14.

Figure 2-14 Buoy Light

2-2.2 Anchors.

The most commonly used anchoring systems are either direct embedment anchors or drag-embedment anchors. Embedment anchors, by design, are installed below the seafloor and are not visible for inspection. The most common direct embedment anchors used by the Navy are plate anchors. Other direct embedment anchors include pile anchors and propellant embedment anchors (PEA). As of 2010, no PEA anchors are in service for U.S. Navy moorings.

The most common drag-embedment anchors found are either the Navy stockless anchor or the high capacity NAVMOOR anchor. Other types of drag embedment anchors that may be found include the NAVFAC STATO anchor and LWT anchor. Drag embedment anchors are generally not visible for inspection since they will tend to bury themselves during proof loading of the ground legs during installation. However, in hard rocky or even dense sand seafloors, they may be partially or completely visible for inspection.

Other anchor types that are found are deadweight or gravity anchors. Though they can be shaped to aid the anchor in digging into the soil and may be jetted into the seafloor during installation, they primarily resist mooring forces through their large submerged weight.

2-2.2.1 Direct-Embedment Anchors.

2-2.2.1.1 Plate Anchor.

Plate anchors can be used in place of the much larger and costlier pile anchor or a standard drag anchor. Like a pile anchor, installation equipment is composed of standard pile driving barges and hammers. The plates are driven into the soil using a follower that is removed when the anchor reaches proper depth. Plate anchors can be used in soils with poor engineering properties or where there is not enough room for the long legs of a typical drag anchor mooring. Plate anchors have been proven to hold well in soils that are not good candidates for drag anchors, such as coral limestone and hard glacial till. Figure 2-16 shows a picture of a plate anchor and Figure 2-15 provides a schematic of how to install a plate anchor.

Figure 2-15 Plate Anchor Installation Schematic

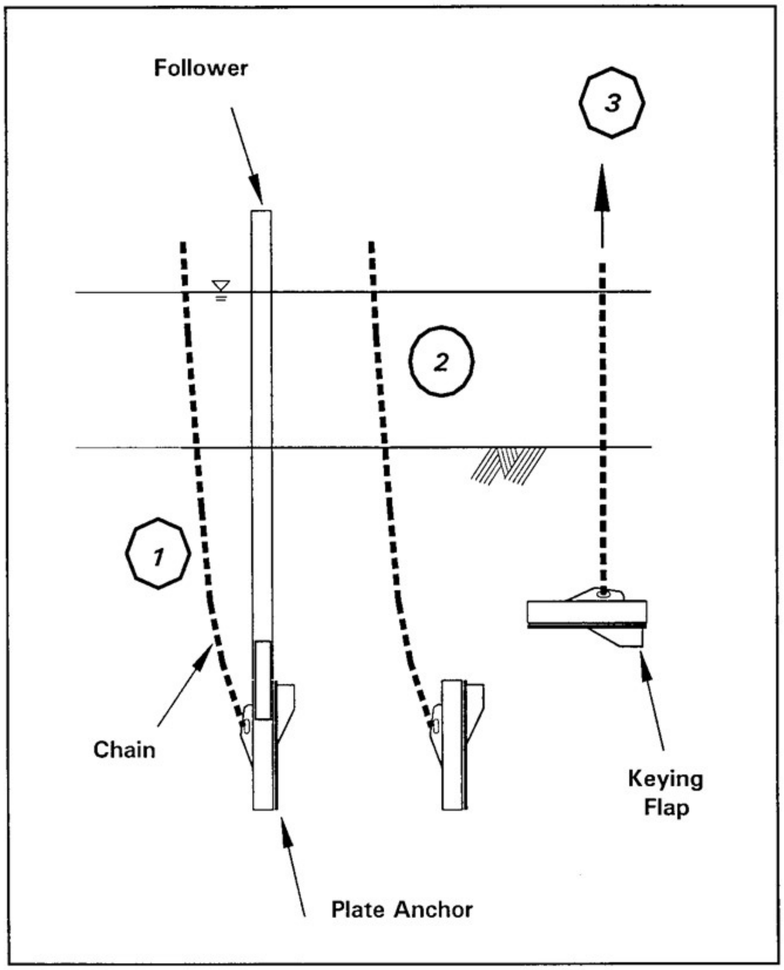


Figure 2-16 Plate Anchor

2-2.2.1.2 Pile Anchor.

Pile anchors are fabricated from structural steel shapes, such as H beams, or pipes with appropriate attachment points for connecting the ground leg chain. Pile anchors are installed by driving, drilling and grouting, or other underwater construction methods. Pile anchors can resist large uplift forces or horizontal forces from various directions and are generally installed in bottom soils characterized by stiff clays or medium to dense sands. Pile anchors develop holding power as a result of the surface friction of the soil in which they are driven.

2-2.2.1.3 Propellant-Embedment Anchor (PEA).

PEAs are composed of a plate anchor attached to wire rope pendants. During installation, the PEA fluke is fitted to a reaction vessel that houses a cannon barrel. When the reaction vessel touches the seafloor, the explosive charge in the barrel explodes, embedding the fluke into the bottom. PEAs usually have a wire rope to chain connector. Due to environmental concerns, life cycle of the wire pendant and training of operators, PEA anchors are no longer installed by the Navy. All existing Navy moorings utilizing PEA anchors have been either disestablished or replaced with mooring systems that utilize another type of anchoring system.

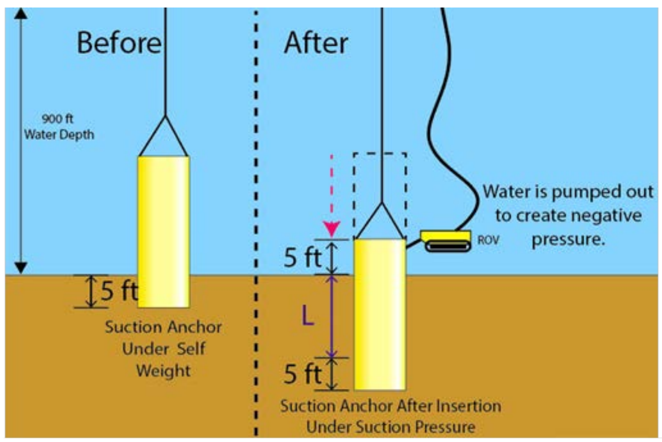
2-2.2.1.4 Suction Anchor.

A suction anchor can effectively be described as an upturned bucket that is embedded in the marine sediment. This embedment is achieved by creating a negative pressure inside the anchor skirt; securing the anchor into the seabed. The foundation can also be rapidly removed by reversing the installation process, applying an overpressure inside the anchor skirt.

The concept of suction technology was developed by the oil and gas industry for projects where gravity loading is not sufficient for pressing foundation skirts into the ground. The technology was also developed for anchors subject to large tension forces due to waves and stormy weather. The suction anchor technology functions very well in a seabed with soft clays or other low strength sediments. The suction anchors are in many cases easier to install than piles, which must be driven (hammered) into the seabed. Mooring lines are usually attached to the side of the suction anchor at the optimal load attachment point, which must be calculated for each anchor. Once installed, the anchor acts much like a short rigid pile and is capable of resisting both lateral and axial loads.

Suction anchors have not been used in Navy moorings but their existence should be recognized and they may be used in the future. See Figure 2-17.

Figure 2-17 Suction Anchor



2-2.2.2 Drag-Embedment Anchors.

There are many types of drag embedment anchors in existence. Navy Stockless and NAVMOOR anchors are the most common used in Navy moorings and are currently stockpiled by the Fleet Mooring Program. This document will limit its description to those two types of anchors.

2-2.2.2.1 Navy Stockless Anchor.

This type anchor is a drag-embedment anchor, ranging in size from 5,000 to 40,000 pounds (22 to 178 kN). Navy stockless anchors are used extensively in Navy applications, primarily because of the availability of the anchors. The Navy stockless anchor is prone to overturning, or rolling over to an upside-down orientation, during proof testing. The possibility of this type failure can be minimized by welding stabilizers to the anchor. Flukes are generally fixed at a specified angle based on the expected soil conditions at the site. Figure 2-18 shows a Navy stockless anchor with stabilizers and flukes fixed. Characteristics of the most common Navy stockless anchors used in fleet mooring are provided in Table 2-2.

Figure 2-18 Navy Stockless Anchor with Stabilizers

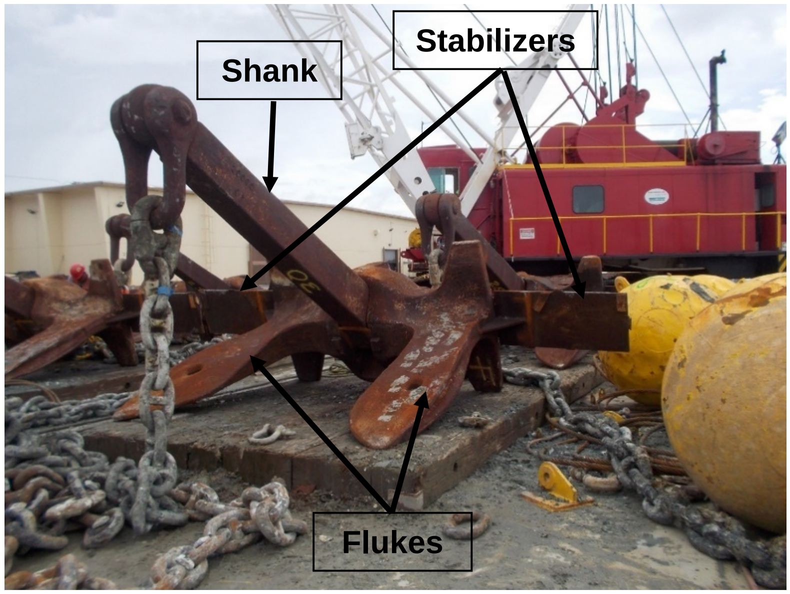


Table 2-2 Navy Stockless Anchor Characteristics

Anchor Nominal Size	20-kip	25-kip	30-kip
Anchor Wt. in Air, lbs (kg)	20,000 (9,072)	25,000 (11,340)	30,000 (13,608)
Length, inches (mm)	127.25 (3,232)	137 (3,479)	145.63 (3,699)
Stabilizer Extension, inches (mm)	45 (1,143)	48 (1,219)	50 (1,270)
Fluke Length, feet (mm)	7.65 (2,331)	8.24 (2,511)	8.94 (2,724)
Fluke Area, ft^2 (m^2)	35.1 (3.26)	40.7 (3.78)	46.9 (4.35)

2-2.2.2.2 NAVMOOR Anchor.

The NAVMOOR anchor is a high capacity drag-embedment anchor designed specifically for mooring use. The anchor's flukes are streamlined hollow shells which enable good penetration in hard soils. The large tripping palms are permanently affixed to the anchor to ensure reliable tripping in soft soils. Some designs are equipped with a 32-degree stopping wedge attached to one side to provide maximum holding power in sand or hard clay. Removing the wedge and welding the flukes open to 50 degrees provides maximum holding power in soft mud. NAVMOOR anchors can come in a number of sizes, but the most common sizes found in Navy moorings are 12,000 pounds (NAVMOOR10) and 18,000 pounds (NAVMOOR15). Figure 2-19 shows a NAVMOOR10 anchor. Characteristics of NAVMOOR anchors in use are provided in Table 2-3.

Figure 2-19 NAVMOOR10 Anchor

Table 2-3 NAVMOOR Anchor Characteristics

Anchor Size	NAVMOOR10	NAVMOOR15
In Air Weight, lbs (kg)	12,400 (5625)	19,200 (8709)
Overall Length, inches (m)	192 (4.9)	219 (2.6)
Stabilizer Width, inches (m)	192 (4.9)	219 (2.6)
Fluke Length, feet (m)	8.54 (2.60)	9.73 (2.97)
Fluke Area, ft^2 (m^2)	38.54 (3.58)	50.07 (4.65)
Proof Load, 1000 lbs (kN)	165 (734)	213.7 (950.6)
Tandem Link Padeye Diameter, inches (mm)	3.5 (88.9)	4 (101.6)
Shank Shackle Size, inches (mm)	3 (76.2)	3.5 (88.9)

2-2.2.3 Deadweight Anchors.

Any heavy object that can be placed on the seafloor can be used as a deadweight anchor if it can be shown that the anchor selected is capable of satisfying design requirements. Deadweight anchors can rest on the seafloor, be partially or completely buried, or dig into the bottom under load. The most common type of deadweight anchor encountered in fleet moorings is the Pearl Harbor anchor which is designed to dig into the soil to a limited extent as the anchor is dragged. The ultimate holding power of the deadweight anchor is the minimum force required to overturn, lift, or drag the large weight over the bottom. Resistance to uplift, or vertical force, is simply the submerged weight of the anchor plus the suction and friction effects of the bottom soil. Figure 2-20 shows a Pearl Harbor style deadweight anchor.

Figure 2-20 Pearl Harbor Style Deadweight Anchor

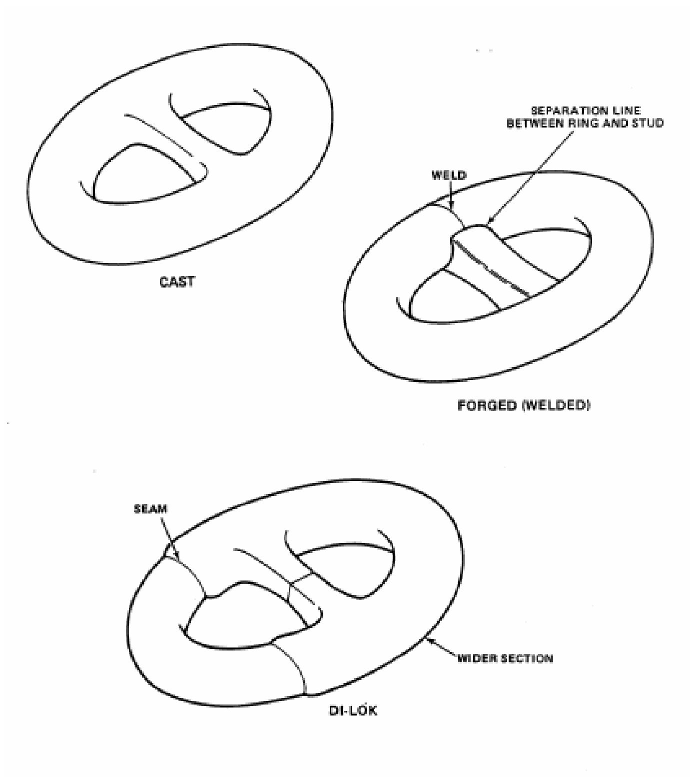
2-2.3 Chain.

2-2.3.1 Chain Grades and Types.

Chain grade is determined by the properties of the steel used to form the chain links. Chain manufactured to NAVFAC specifications for mooring purposes is similar in chemical content to that manufactured to commercial standards meeting the classification of American Bureau of Ships (ABS) Grade 3 (ABS3). Chain and chain accessories procured by the Navy for use in Fleet Moorings are classified as Fleet Mooring Grade 3 or FM3. FM3 chain and chain accessories have tighter mechanical property parameters imposed than those imposed on corresponding Grade 3 chain manufactured to commercial standards. Other commercially available chain grades use different steel alloys to have either higher or lower tensile strengths.

Chain type is identified by the manufacturing process used to form the links. The different chains that may be encountered in existing moorings include forged stud link, cast, and Dilok chain (Figure 2-21). The majority of installed Navy moorings utilize FM3 stud-link chain. Dilok and cast chains are no longer manufactured. However, since some of these types of chain may still remain in the system (in older moorings installed prior to 1990), they are described here for recognition purposes.

Figure 2-21 Types of Chain



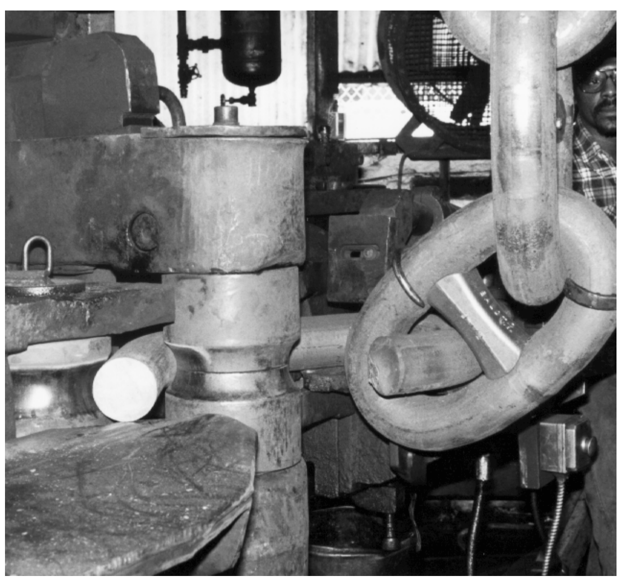
2-2.3.1.1 Stud-Link Chain.

Each link of stud-link chain is formed by bending a length of heated bar stock into the shape of a link and flash welding the ends together. A center crossbar, or stud, is inserted into the link while it is still hot and pressure is applied to both sides of the link to secure the stud in place. Stud-link chain is also referred to as flash-butt-welded chain. The stud in each link of FM3 chain is welded to the link on the end opposite the flash-butt weld. The welding of the stud is unique to FM3 chain as it is not required on ABS chains. The primary purpose of the weld is to provide a metallic path to the chain link for the sacrificial anode that is attached to the stud on FM3 stud-link chain. In addition to unique identification stamping requirements, the presence of this weld, along with a threaded hole attachment point on the stud for the zinc anode, is the primary method of identification of FM3 chain as opposed to commercial stud-link chain. Chain-stud zinc anodes are discussed in Section 2-2.6.2.2. Figure 2-22 shows the forming of a link of stud-link chain and Table 2-4 shows the characteristics of FM3 chain.

Table 2-4 FM3 Chain Characteristics

NOMINAL SIZE (inches)	**1.75**	**2**	**2.25**	**2.5**	**2.75**	**3.5**	**4**
NUMBER OF LINKS PER SHOT	153	133	119	107	97	77	67
LINK LENGTH *(avg.)*, inches (mm)	10.63 (270)	12.15 (309)	13.67 (347)	15.20 (386)	16.70 (424)	21.26 (540)	24.30 (617)
WEIGHT PER SHOT IN AIR *(min.)*, (lbs (kg)	2,525 (1,145)	3,276 (1,486)	4,143 (1,879)	5,138 (2,331)	6,250 (2,835)	10,258 (4,653)	13,358 (6,059)
BREAKING STRENGTH, 1,000 lbs (kN)	352 (1,556)	454 (2,019)	570 (2,535)	692 (3,078)	826 (3,674)	1,285 (5,716)	1,632 (7,259)
WORKING STRENGTH *(33% of break)*, 1,000 lbs (kN)	117.2 (521)	151.2 (672)	189.8 (844)	230.4 (1025)	275.1 (1224)	427.9 (1903)	543.5 (2418)

Figure 2-22 Formation of Stud-Link Chain



2-2.3.1.2 Cast Chain.

Cast chain, as the name suggests, is formed by a die-casting method. This type chain is easily recognizable as the stud is integral to the link and there is no link butt joint.

2-2.3.1.3 Dilok Chain.

Each link of Dilok chain is formed from two U-shaped sections, male and female. The male section has a forged, serrated, stem end while the female section has hollowed ends. The male ends are inserted into the heated female ends and drop forged. This results in the heated interior of the female section forming to the serrated stem on the male end and creating a lock. Use of Dilok chains are not recommended for mooring use due to the inability to inspect corrosion that may be present inside the “locked” ends.

2-2.3.2 Chain Markings.

The stud of the last link of each shot of FM3 chain bears a symbol or marking that shows the contract year and serial number of the shot. Additionally, the stud of each link bears permanent markings that denote chain size, manufacturer and “FM3”. The markings on the last link of each shot are stamped; the markings on the stud of each link are raised figures. Note that for ABS anchor chain, markings are on the end link body.

2-2.4 Chain Accessories.

2-2.4.1 Joining Links.

There are two main types of joining links, Chain Joining Links (CJL) and Anchor Joining Links (AJL) found in U.S. Navy mooring systems.

There are two different designs for joining links based on the manufacturer and how they are put together: the Baldt type and the Kenter type. The Baldt type can be distinguished by the two T-shaped plates that enclose the pin and make up the stud. The Kenter style has two C- shaped halves with a removable stud. The two C-shaped halves of a Kenter style link are similar.

CJLs are normally used to connect two shots of chain or chain to another chain component with a similar wire diameter and look similar to a normal chain link. Figure 2-23 and Figure 2-24 show the different types of CJLs.

It is important to not interchange parts between connecting links, especially the Kenter style or they may not properly be reassembled.

Figure 2-23 Baldt Style Chain Joining Link

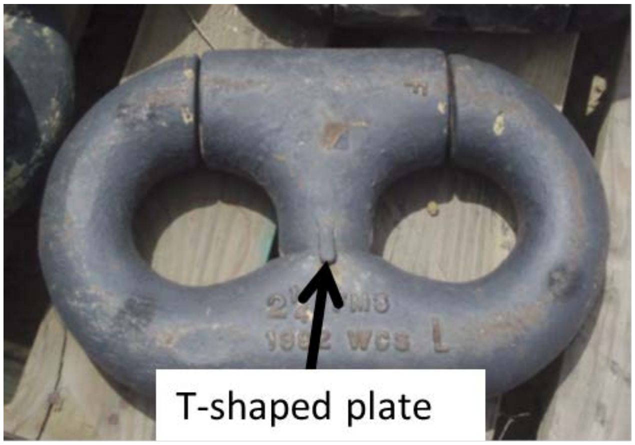
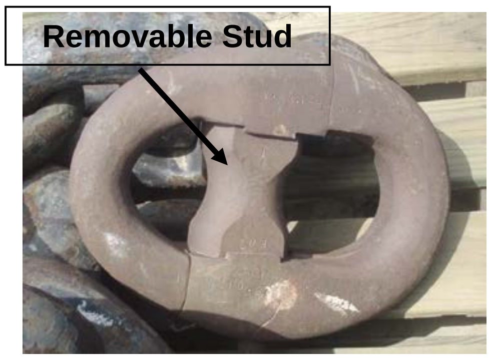


Figure 2-24 Kenter Style Chain Joining Link

AJLs are used to connect chain to chain components with a larger diameter (ground rings, spider plates, shackles on anchors, etc.). It is larger on one end to accommodate the larger diameter wire of those components. Figure 2-25 and Figure 2-26 show the different types of AJLs.

Figure 2-25 Baldt Style Anchor Joining Link

Figure 2-26 Kenter Style Anchor Joining Link



When a connecting link is reassembled, the pieces are secured with a pin which is held in place by a lead plug. Lead plugs are either pounded into place using a heavy hammer or the lead is melted into the hole from a long lead bar. All joining links should have a visible lead plug (some cleaning may be required for joining links that are below the waterline to locate the lead plug) in the large pin hole (see Figure 2-27). Figure 2-28 shows a missing lead plug.

Figure 2-27 Lead Plug in CJL

Figure 2-28 Missing Lead Plug

Disassembled joining links should not be mixed with parts from other disassembled links as the tracking of serial number data on the installed link would be interrupted and the mixing of parts may result in the joining link not be able to be reassembled due to fit interferences among the mixed parts.

Safety Note

All personnel at or near a mooring component being secured by lead shall wear PPE commensurate with EM 385-1-1 (such as safety glasses, foot protection, floatation vest) and other required PPE for mooring operations.

2-2.4.2 Ground Ring.

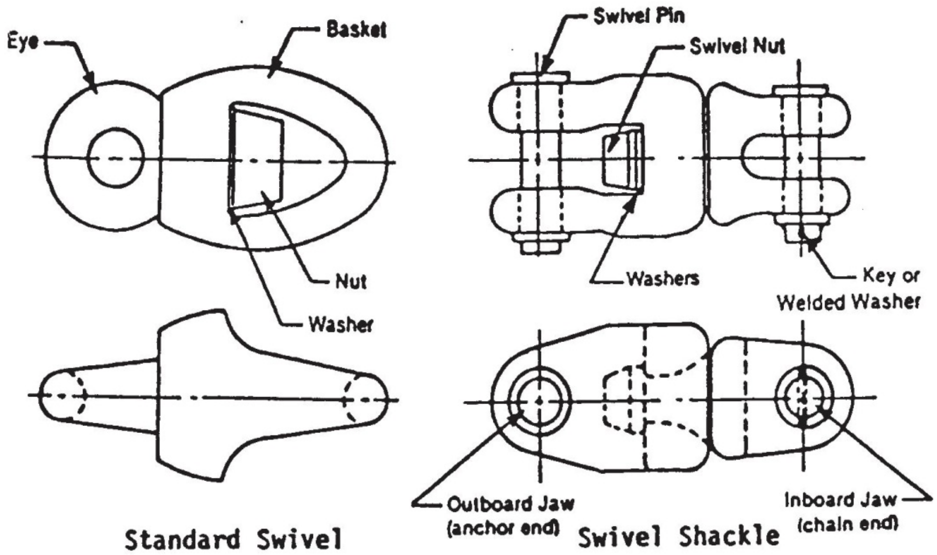
The ground ring is a steel ring used in a riser type mooring to connect multiple chain leg assemblies to the riser chain. Ground rings are classified by the size chain they support, and not the bar diameter of the ground ring. Figure 2-29 shows a ground ring.

Figure 2-29 Ground Ring

2-2.4.3 Swivel Fittings.

Swivel fittings are used in mooring systems to prevent twisting of the chain legs during installation and to prevent twisting of the riser chain during use. See Figure 2-30 shows the different types of swivels.

Figure 2-30 Swivel Fittings



2-2.4.3.2 Riser Swivel Shackle.

A riser chain subassembly should contain a riser swivel (Figure 2-31) that is attached to the lower tension bar padeye of a buoy before the riser chain starts. The purpose of the swivel is to permit a ship to swing 360 degrees around a buoy without twisting the riser chain. Swivel shackles are capable of rotating 360 degrees when supporting a full shot of chain of its rated size. The jaws on the riser swivel shackle are different sizes on each end, one end is designed to fit over a link of chain and the other end to fit over the padeye on the buoy. Pins on the riser swivel shackle are secured by tapered stainless pins which are then prevented from coming out with lead plugs (Figure 2-32) similar to joining links.

Figure 2-31 Riser Swivel Shackle

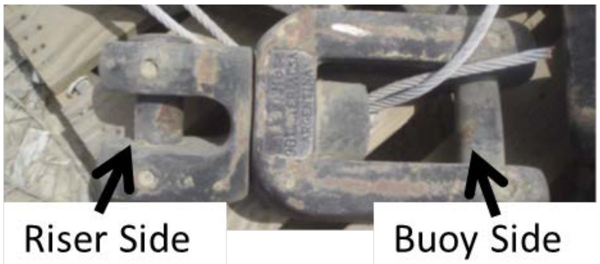
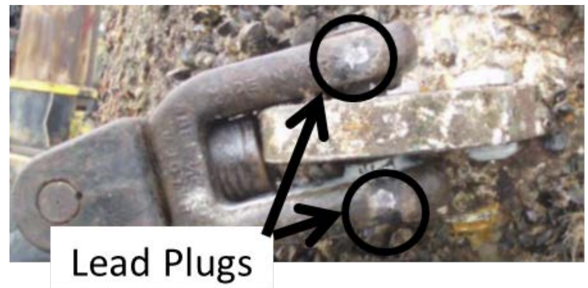


Figure 2-32 Lead Plugs Securing the Riser Swivel Shackle



2-2.4.3.3 Chain Swivel Shackle.

The chain swivel shackle is a swivel fitting with jaws of equal size on both ends (as opposed to the Riser Swivel Shackle that has different size jaws). The jaw openings are sized to fit over a link of a specified size of chain. A chain swivel shackle is secured in the same manner that the riser swivel shackle is.

2-2.4.3.4 Standard Swivel.

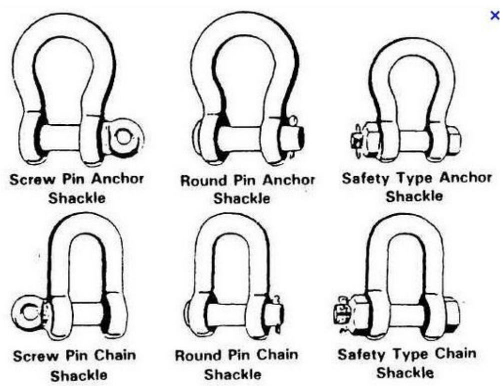
The standard swivel (Figure 2-33) has a fitting on each end to accommodate a standard link of chain. This fitting may be used on either a ground leg or the riser leg of a mooring system and are attached to the chain using a CJL.

Figure 2-33 Standard Swivel

2-2.4.4 Shackles.

Shackles come in three general types, depending on how the bolt is fastened to the body: Round Pin which uses a cotter pin to ensure that the pin doesn't slip out; Screw Pin, in which the pin screws directly into the body of the shackle; and Bolt Pin (sometimes called a Safety Type Shackle), which uses a bolt and nut/cotter pin combination. Figure 2-34 shows the various shackles. The primary shackle type used on mooring systems is the bolt pin.

Figure 2-34 Shackles



2-2.4.4.1 Anchor Shackle.

Anchor shackles (Figure 2-35) have also been referred to as bow shackles. With a large "O" shape to the bale, this shackle can take loads from many directions without developing as much side load. However, the larger, wider bale does reduce its overall strength when compared to a chain shackle. Anchor shackles are usually found on the top jewelry of a mooring tension bar foam buoy. Anchor shackles may also be found connecting the riser chain to the lower tension bar padeye on steel buoys or foam buoys as well. They may also be found as connecting hardware between ground leg assemblies and the riser assembly.

Anchor shackles used on the surface are equipped with a cotter pin or a safety bolt and nylok nut. Anchor bolt shackles used below the waterline, in addition to the cotter pin or safety bolt, will have a fillet weld between the outer perimeter of the nut and the shackle bolt (Figure 2-36).

Figure 2-35 Anchor Shackle

Figure 2-36 Anchor Shackle for Underwater Use

2-2.4.4.2 Chain Shackle.

Chain shackles, sometimes referred to as a D-Shackle, are narrow shackles whose bale has a similar shape as one end of a link of chain, with a threaded pin (bolt) and nut closure and the nut is secured with a cotter pin or safety bolt with a nylok nut although some are secured with a non-threaded pin held in place with a driven pin similar to a joining link. The shackle bale can take high loads primarily in line only as side and racking loads may twist or bend a chain shackle (Figure 2-37). Consequently, chain shackles are not generally used in mooring systems.

Figure 2-37 Chain Shackle

2-2.4.4.3 Sinker Shackle.

Sinker shackles (Figure 2-38) are similar to a chain shackle but have a longer and narrower bale. With their long and narrow bale, sinker shackles are used to attach a sinker to a ground leg or a suspended riser chain assembly by slipping over a chain link.

Figure 2-38 Sinker Shackle

2-2.4.4.4 Plate Shackle.

Plate shackles (Figure 2-39) consist of 2 plates in the shape of a “dog bone”, 2 bolts with nuts and are primarily used to attach a sinker to a ground leg assembly. After the plate shackle is attached to the sinker and ground leg, the nuts are also secured to the bolts with a fillet weld to the outside of the bolt. Plate shackles are not normally used on moorings to carry the mooring loads, due to their lack of strength and their susceptibility to bending.

Safety Note
Follow safe welding procedures per EM 385-1-1 and wear required PPE for welding operations.

Figure 2-39 Plate Shackle Attaching Sinker to Chain

2-2.4.5 Sinkers.

Sinkers, or clump weights, are attached to the chain legs in the water column to provide damping to a mooring system to reduce dynamic peak tensions. Sinkers are generally concrete clumps or modified stockless anchors that have their flukes welded close and an additional padeye welded at the anchor crown (Figure 2-40). Sinkers generally range in weight from 3,000 to over 25,000 pounds (13.3 to 111.2 kN) in air.

Figure 2-40 Navy Stockless Anchor Rigged as a Sinker

2-2.4.6 Pear Link.

A pear link (Figure 2-41) is an open link, wider at one end then at the other. It may also be called a pear-shaped link or pear-shaped ring. It is often used as top jewelry on a buoy, serving as the attachment point for the lines from the moored vessel.

Figure 2-41 Pear Link

2-2.4.7 Spider Plate.

The spider plate (Figure 2-42) is a steel plate or casting, triangular in shape, with a hole at each point of the triangle. It is most commonly used to connect the two chains of a paired-leg assembly to a single attachment to provide additional holding capacity. NAVFAC stocks a 4-inch (102 mm) and a 2.25-inch (57 mm) spider plate.

Figure 2-42 Spider Plate

2-2.4.8 Yoke Assembly.

The yoke assembly (See Figure 2-43) is specially configured to connect the two chains of a paired anchor installation to a single ground leg. The assembly generally consists of two modified (two cross plates are welded between end plates to form 1 assembly) plate shackles, a spider plate and a chain swivel shackle or it may consist of three modified plate shackles and a spider plate, eliminating the swivel shackle. They may be found on old mooring systems with tandem anchors installed in the 1980’s.

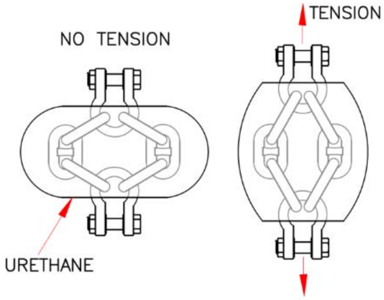
Figure 2-43 Yoke Assembly

2-2.4.9 Kinetic Links.

A Kinetic Link is a short open loop segment of chain links that is encased in polyurethane. A shackle is provided at both ends for attachment of the kinetic link within a mooring riser or ground leg. Like sinkers, they are used to provide a shock absorber to minimize dynamic loads. Figure 2-44 is a picture of kinetic links. Figure 2-45 is a drawing of the kinetic link details. There are some very specialized moorings that have single or multiple kinetic links within the mooring riser or ground leg assemblies. As attached sinkers provide similar damping of dynamic loads and are less expensive to construct, kinetic links are not generally used.

Figure 2-44 Kinetic Links

Figure 2-45 Kinetic Link Details



2-2.4.10 Chain Equalizer.

Chain equalizers are specialty hardware that can be used to moor large vessels to pier or wharf fittings or 2 ground legs to a single riser on a buoy (See Figure 2-46). Chain equalizers distribute the tension equally to both parts of chain as the vessel or buoy responds to environmental forces. Although equalizers contain no movable parts, they do resemble large pulleys. The chain is free to slide back and forth through the equalizer so that each end of the chain is under equal tension. Figure 2-47 shows a chain equalizer.

Figure 2-46 Chain Equalizer on a Mooring

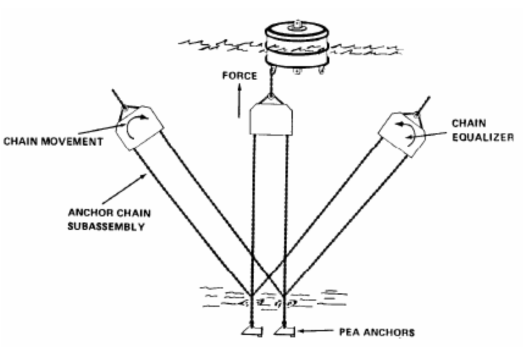


Figure 2-47 Chain Equalizer

2-2.5 Miscellaneous Special Links.

There are a variety of special links used in industry to connect chain and chain accessories that sometimes make their way into mooring systems. The PEAR LINK, described in Paragraph 2-2.4.6 is the only special link used in U.S. Navy mooring systems today. Other special links that may be encountered in older, existing fleet moorings are the ENLARGED LINK or B-LINK, the END LINK or E-LINK, and the C-LINK. The B-link is an adaptor used between the last common link of a chain and the E-link. The E-link is a studless link used as the last link in a shot of chain. The C-link is similar to the E-link but has an off-center stud. The use of these special links, other than the Pear link, should be avoided in mooring installations whenever possible.

Drawings for FM3 mooring components are provided in APPENDIX G.

2-2.6 Cathodic Protection System.

The galvanic action of seawater, acting electrolytically on the submerged portions of a mooring system, greatly increases the rate of corrosion on these components. This galvanic action can be inhibited by impressing a negative electrical potential on the exposed steel surfaces thus prolonging the useful life of the mooring system. The required electrical potential is provided by attaching sacrificial anodes to all steel surfaces with the water column.

2-2.6.1 Cathodic Protection for Buoys.

The submerged portion of a steel buoy must be cathodically protected. Buoy anodes, manufactured from a zinc composition in accordance with MIL-A-18001, are attached to the buoys in such a manner that the anodes are protected from impact or collision. They may be on the bottom of the buoy, in seachests built into the buoy, or attached to the sides of the buoy, depending on the type of buoy. The lower padeye of foam tension bar buoys is also protected by anodes (see Paragraph 2-2.6.2.2)

2-2.6.2 Cathodic Protection for Chain.

All chain in a mooring system that is between the mudline and the buoy must be cathodically protected. Protection is achieved by attaching anodes in such a manner that each link is protected. Several methods and several types of anodes have been used for this purpose. The preferred method is the chain-stud anode; however, since other methods may still be encountered on existing mooring systems, each method will be discussed below.

2-2.6.2.1 Clump Anodes.

A clump anode is simply a cast zinc shape attached to the chain assembly using a sinker shackle or other methods of attachment. Sometimes, approximately 500 pounds (2.2 kN) of zinc is cast over an elongated chain link and this is called a link anode. A wire rope, called a continuity cable, is attached to the clump anode and passed through every 4th link of the chain to provide continuity throughout the chain leg. Hose clamps are then used to secure the continuity wire to every 8th link.

Generally, one clump anode is used for every shot (90 feet (27.4 m)) of chain in the ground leg or riser. These methods are less effective than the stud link anode method discussed in section 2-2.6.2.2 for several reasons: (1) The continuity between links may be lost when the chain is not in tension and; (2) The contact area between the chain link and the continuity wire must be cleaned to bare metal to ensure conductivity and (3) No assurance is given that the connecting wire rope will remain in constant contact throughout the chain leg especially at locations where the chain leg is moving due to loading or tidal effects. Figure 2-48 shows clump anodes in storage.

Figure 2-48 Link and Clump Anodes

2-2.6.2.2 Chain-Stud Anodes.

This method of protecting chain consists of an anode attached to the stud of each link of FM3 mooring chain. Attaching an anode to each link ensures maximum protection as each link is in contact with an anode whether or not the system is in tension. Additionally, the anodes are easily replaced by divers and do not require removal of the mooring system for this routine maintenance task. Replacement of chain-stud anodes generally occurs during the fleet mooring underwater inspection. All FM3 chain links are manufactured with a tapped 0.375-16UNC-2B hole in each stud to accept an anode. Currently, chain-stud anodes are made from a zinc alloy.

Figure 2-49 provides details of the chain stud link anode assembly and Figure 2-50 shows the assembly on the stud of a chain link. Table 2-5 provides the characteristics of the chain-stud anodes. Though there is a specified chain-stud anode for each nominal size of FM3 chain, current maintenance practices are to replace chain-stud anodes with ones manufactured for a larger size of chain and to stockpile only a few sizes of zinc anodes. Two to four chain-stud anodes are also attached to the lower padeye on fleet mooring foam tension bar buoys (Figure 2-51).

Figure 2-49 Chain Stud Anode Assembly

Figure 2-50 Chain Stud Anode Installed

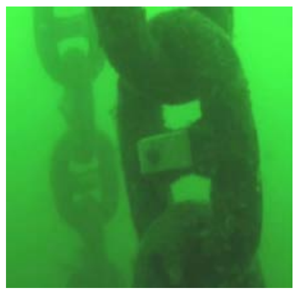


Figure 2-51 Chain Stud Anode on Buoy Tension Bar

Table 2-5 Chain Stud Anode Characteristics

NOMINAL SIZE (inches)	1.75	2	2.25	2.5	2.75	3.5	4
ANODE WEIGHT lbs (kg)	0.80 (0.36)	1.10 (0.5)	1.38 (0.63)	1.70 (0.77)	2.04 (0.93)	3.58 (1.62)	4.41 (2.0)
SCREW LENGTH inches (mm)	1.25 (31.8)	1.5 (38.1)	1.75 (44.5)	1.75 (44.5)	2.00 (50.8)	2.25 (57.2)	2.25 (57.2)
ANODE WIDTH inches (mm)	1.50 (38.1)	1.62 (41.2)	1.75 (44.5)	1.94 (49.3)	2.06 (52.3)	2.38 (60.5)	2.69 (68.3)
ANODE LENGTH inches (mm)	3.25 (82.6)	3.5 (88.9)	3.5 (88.9)	3.5 (88.9)	4.0 (101.6)	5.5 (139.7)	6.0 (152.4)
ANODE HEIGHT inches (mm)	.73 (18.54)	.90 (22.86)	.94 (23.88)	.97 (24.64)	1.15 (29.21)	1.31 (33.27)	1.32 (33.53)
ANODE SURFACE AREA in^2 (mm^2)	14.6 (9,419)	18.2 (11,742)	21.9 (14,129)	24.6 (15,871)	26.4 (17,032)	40.6 (26,194)	50.7 (32,710)
ANODE VOLUME in^3 (mm^3)	3.10 (50,800)	4.28 (70,137)	5.42 (88,818)	6.64 (108,810)	8.01 (131,260)	14.06 (230,400)	17.32 (283,820)
LINK GAP inches (mm)	3.74 (93.98)	4.24 (107.7)	4.74 (120.4)	5.24 (133.1)	5.74 (145.8)	7.48 (189.99)	8.48 (215.39)
ANODES PER FULL DRUM (approx.)	1106	822	615	550	400	158	122
WEIGHT PER FULL DRUM (approx.) lbs (kg)	976 (443)	979 (444)	917 (416)	993 (450)	869 (394)	602 (273)	550 (249)
RECOMMENDED ANODE SIZE FOR CHAIN SIZE	2.75	2.75	2.75	2.75	4	4	4

Notes:

1. All screws are SAE .375-16UNC-2A, Grade 5, Hex Cap.
2. All screw heads are 9/16 inch.

2-2.7 Wire Rope.

In general, wire rope is not used by the Navy in mooring systems. The service loads for offshore mooring lines are extremely difficult to predict and, thus, difficult to maintain a safe working load. The permanent immersion of mooring lines in seawater poses problems with corrosion and corrosion-assisted fatigue and access to the rope for regular inspections. Wire ropes are used in commercial moorings, especially for semi-submersible platforms. Since this type of platform is typically used for exploratory drilling, the mooring lines are constantly being hauled in to permit the rig to be moved to another location. This permits a better inspection of the wire rope on a reasonable basis. New mooring designs are now using synthetic rope instead of wire rope.

Wire ropes may also be found in deep water moorings, such as tension leg platforms, where the weight of chain would be prohibitive.

Wire rope is a loosely applied term, referring to a multitude of different constructions. The general accepted terminology is:

- Wire – is a single wire filament.
- Strand – is a number of single wires wound helically around a central wire in a series of concentric layers
- Rope – a number of strands wound helically together around a core of other strands (or of synthetic or natural fiber materials). The core can be composed of fiber, another wire strand, or an independent wire rope (IWRC). See Figure 2-52 and Figure 2-53.
- Cable – a number of ropes wound helically together

Figure 2-52 Structure of Wire Rope

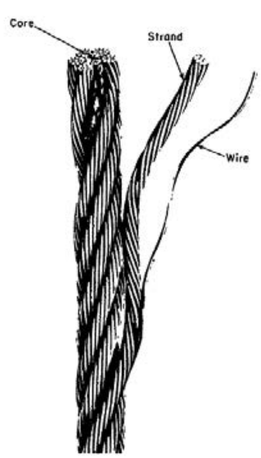
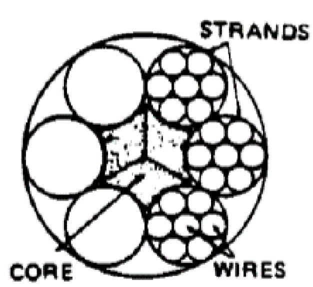


Figure 2-53 Wire Rope Structure

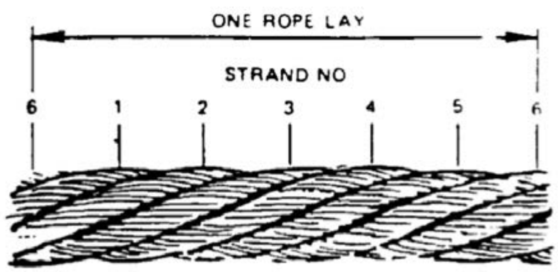


Most common construction of wire ropes are 6x19, 6x25 or 6x37, meaning there are six strands on the outside of the rope composed of 19, 25 or 37 wires respectively, with the six strands wrapped around either a fiber or a wire core. The more wires that are used to construct a strand, the more flexible the rope will be but the more susceptible the rope will be to physical damage or corrosion problems.

In addition to the rope diameter, other items to know in describing wire rope are:

- Lay length - distance parallel to the axis of the rope in which the outer strands make one complete turn (or helix) about the axis of the rope. See Figure 2-54.

Figure 2-54 Lay Measurement of Wire Rope



- Lay direction of strand – The direction of the lay of the outer layer of wires in relation to the longitudinal axis of the strand.
- Lay direction of rope – The direction of the lay of the outer strands in relation to the longitudinal axis of the rope
- Lay Type – Ordinary or regular lay has the lay direction of the strand in the opposite direction to the lay direction of the rope while Lang lay has the strand lay direction in the same direction as the rope lay. See Figure 2-55.
- Core Type – The core of the rope can be made from either natural fibers (fiber core usually hemp or sisal) or steel (IWRC – Independent Wire Rope Core). See Figure 2-56.

Figure 2-55 Wire Rope Lays

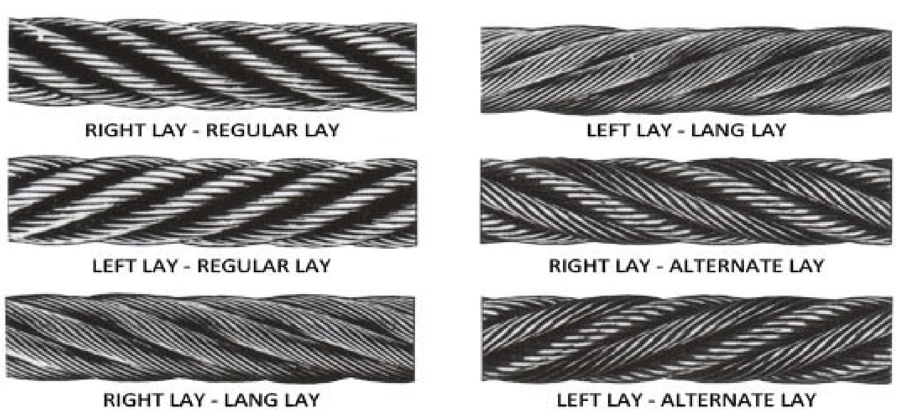


Figure 2-56 Wire Rope Cores

Safety Note

Wear appropriate gloves when handling wire rope.

2-2.8 Synthetic Line.

Natural fiber ropes (Manila, hemp, jute, sisal) have been in use since the beginnings of boating. For working lines, they have largely been replaced by synthetic lines. Synthetic lines come in two main types, low tenacity ropes composed of older synthetic fibers (polyester, polyethylene, polypropylene, nylon) or newer, high tenacity fibers such as: aramid (Kevlar); HMPE (High Modulus Polyethylene such as Spectra, Dyneema, Amsteel).

The use of synthetic lines for anything other than tying the vessel to the mooring is relatively uncommon. Commercially, the high tenacity synthetics might be used for extremely deep-water moorings, but for DoD uses, they are extremely uncommon.

Like wire ropes, synthetic lines are extremely difficult to inspect, if they cannot be removed from the mooring. In addition, damage to inner filaments may not be apparent.

Synthetic ropes are typically constructed in a 3-strand twisted rope, 8-strand or 12-strand braid, 8-strand plaited, double braid or a core-dependent braid. The difference between a double braided rope and a core-dependent braided rope is that with the double braid, the load is shared by both the inner rope and outer jacket while with a core-dependent braided rope, the outer jacket simply acts to provide abrasion protection and the load is take strictly by the inner rope.

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CHAPTER 3 MOORING INSPECTION

Safety Warning:

Ensure all personnel have, maintain, and wear PPE (steel toed shoes, personal floatation vest, hard hat and other PPE for specific tasks i.e. leather gloves, safety glasses, etc.).

Daily safety briefs should emphasize everyone’s responsibility for applying risk management.

3-1 MOORING INSPECTION PLANNING.

This section describes the responsibilities and inspection planning tasks of each person involved in a mooring inspection as well as the equipment and material that will be needed to conduct a thorough inspection.

3-1.1 Mooring Program Manager.

The Program Manager is responsible for program management of the inspection portion of the mooring program. He will perform the following program tasks in support of planning for the mooring inspection:

- Reviews all available historical maintenance records and develops a list of those moorings which should be scheduled for underwater inspection during a particular fiscal year.
- Develops the planned mooring inspection schedule for the next three fiscal years.
- Submits mooring inspection requests to the Underwater Construction Teams (UCT).
- Designates a Mooring Inspection Engineer-in-Charge (Inspector) for each planned mooring underwater inspection during the current fiscal year.
- Maintains an archive of previous inspection reports, mooring configuration drawings, property records and mooring usage charts of current moorings.
- Maintains an adequate supply of chain-stud anodes at the mooring inventory to support changing out zinc anodes during inspections.
- Provides the inspector with a copy of the last underwater inspection report, mooring usage chart, and latest drawings of the moorings scheduled for inspection.
- Provides the inspector with catalog dimensional information for the mooring components to be inspected at the site.

- Allocates funding for the onsite inspection and post-inspection documentation.
- Ensures that the inspection report is provided to the custodian.
- Reviews and approves the inspection report to include its findings and recommended maintenance actions.
- Executes required maintenance actions on moorings in accordance with the inspection report.
- Funds local activity custodians to execute annual surface inspections or performs annual surface inspections using other in-house or contracted assets.
- Informs the local activity custodian of the planned fleet mooring inspections at their site.

3-1.2 Mooring Inspection Engineer-In-Charge (EIC or Inspector).

The Inspector is responsible for planning and monitoring the inspection. The Inspector is also responsible for collecting the inspection notes, the pictures, and the survey data. The inspector may execute portions of the mooring inspection such as the performing the surface inspection tasks and surveying the buoys. If the inspector is Navy dive certified, the inspector may become a part of a military dive inspection team. The Inspector, whether or not dive qualified, must interpret the results of the inspection before leaving the site to ensure that that the inspection is complete. Upon return, it is the Inspector’s responsibility to send out written preliminary inspection results within 14 calendar days and the completed inspection report within 60 calendar days, to include any supporting engineering documentation for inspection results.

The Inspector will establish a tentative schedule for the mooring inspection in conjunction with available dive support team. This schedule will be based on the maximum availability of station support, anticipated favorable weather conditions, vessel movement, and diver availability. The inspection may be required to meet deployment scheduling requirements of the supporting dive team. The dive team must be familiar with the project requirements in order to assist in inspection planning. Equipment requirements must be coordinated with the dive team. The Inspector shall perform the following program tasks in support of planning for the mooring inspection:

- The Inspector shall review the mooring drawings and previous inspection reports to determine the required amount of time that will be needed on site to perform the inspection, amount and size of chain-stud anodes required for the inspection, the size and quantity of go/no-go gauges and other inspection tools needed.
- The Inspector shall arrange for area clearances, camera clearances or passes, passport, and on-site transportation. If using a contractor dive team, he will coordinate the administrative requirements for the contractors with the local shore activity.

- The Inspector shall arrange for his (her) own travel requirements.
- The Inspector shall provide the mooring program manager a cost estimate for the inspection. This estimate will be reviewed by the program manager to verify adequate funding for the inspection is available.
- In conjunction with the inspection dive team, the Inspector shall plan the inspection procedures to be used on the inspection for surface and underwater inspection tasks, anode replacement and survey requirements.
- The Inspector or the dive team's designated representative shall coordinate any logistical requirements required at or by the shore activity to perform the inspection with the activity's mooring custodian.
- The Inspector shall contact the local activity's mooring custodian of the planned inspection schedule and brief the custodian on the goals of the inspection. Obtain, from the mooring custodian, any base operational requirements, Force Protection requirements, and vessel mooring requirements that may impact the inspection.
- The Inspector shall coordinate and arrange with the local activity's custodian, the assigned inspection dive team, and the mooring program manager for all required inspection tools to include survey equipment, go no-go gauges, calipers, etc.
- If the dive team has the responsibility to plan and execute the logistical requirements for the inspection, the Inspector should then coordinate with the dive detachment to ensure that all required tools and equipment are identified and arranged to be available for the inspection.
- If the inspection is being performed by a contractor dive team, the Inspector shall arrange for review and approval of the contractor's dive plan by a qualified District Diving Coordinator (DDC) at the location of the inspection or in accordance with command policy.
- The inspector shall arrange for base logistical support at the inspection location in accordance with established command policy.
- In conjunction with the project superintendent, the Inspector shall conduct an in-brief to the local activity's custodian going over the goals of the inspection, the inspection schedule, and communication and safety procedures to be followed during the inspection period.

3-1.2.1 Inspection Planning Information.

The Inspector should obtain the following information from the Mooring Program Manager (MPM) and the mooring custodian. This information should be thoroughly reviewed by the Inspector prior to departure for an inspection site:

- Class and type of moorings to be inspected.
- Latest "as-built" documentation, usage chart and property records of the moorings to be inspected.
- Copies of mooring configuration drawings.
- Last inspection report and installation report or latest mooring repair documentation report.
- Geographic positions of moorings, if not in previous installation or inspection reports.
- Type of cathodic protection system and its last reported condition.
- Environmental data; such as seasonal weather and potential for extreme weather, tides and currents during the inspection period at the site, water depth and type bottom at the moorings, and any potential diving hazards at the site (such as obstructions, ship movements, sonar operations, intakes, etc.).

3-1.2.2 Inspection Planning Equipment.

The Inspector should carry to, or make arrangements for, the following to be on the inspection site:

- Inspection data sheets and forms.
- Digital still camera and digital video camera.
- Tape measure (20-foot (6.1 m) minimum).
- Local nautical and tide charts.
- Calculator.
- Pre-inspection briefing data.
- Survey equipment when it is not available on site.
- Calipers. Tear drop (or outside) type calipers are recommended but dial and vernier type calipers will also work but it may be easier to maneuver the tear drop calipers into the tight places to take measurements. The calipers need to open large enough to fit over the pieces to be measured (such as 24-inch sized calipers). See Figure 3-1 and Figure 3-2.
- Go/No-Go gauges.
- Underwater voltmeters.
- Inclinometer (if necessary).
- Anodes with screws (if necessary).
- 9/16-inch hand wrench (to remove old anodes).
- Pneumatic wrench with 9/16-inch socket (for attaching anodes).
- Cleaning tools to remove growth and coating on selected chain links for inspection.

Figure 3-1 Diver Using Tear Drop Calipers

Figure 3-2 Tear Drop (Outside) Calipers

The dive team might be capable of providing some of this equipment. The Inspector should coordinate with the dive team supervisor or dive detachment OIC to ensure what equipment will be provided by the divers.

3-1.2.3 Anode Replacement Planning.

Most Fleet Moorings have been installed with FM3 chain which has a chain-stud anode attached to every link. Inspections generally include replacing these anodes. Subsequent to the initial installation, some fleet mooring’s original anode size has been replaced with larger anodes on subsequent inspections. It is the Inspector’s responsibility to determine the size and quantity of the anodes that will be installed.

Anodes are currently located at the Naval Construction Battalion Center (CBC) Gulfport, MS or CBC Port Hueneme, CA, the fleet mooring inventory sites, and can be shipped to either the project site or to the assigned dive team by submitting a DD1149 shipping document. A sample DD1149 is provided in APPENDIX C.

3-1.2.4 Survey Planning.

It is the Inspector's responsibility to ensure the surveying is conducted by qualified individuals and that the surveying is conducted correctly. It is the Inspector's responsibility to ensure the survey calculations are correct and that the results are transferred to the coordinate system required by the activity.

Initially, mooring surveying of the buoys utilized single or multiple transits, tripods, electronic distance measurement devices (EDM) and prism poles and surveying was done by surveying the buoys from single to multiple survey benchmarks using conventional surveying principles. These techniques are rarely used today.

Recent mooring surveying and inspections have been performed using commercial Global Positioning System (GPS) handheld receivers that are linked to either a nearby U.S. Coast Guard (USCG) beacon, FAA satellites (SBAS) or a commercial service such as OMNISTAR to receive corrections to provide sub-meter survey accuracy. GPS allows a more efficient method of obtaining the geographic location of the mooring. The GPS unit can be set up to provide the coordinates in the required coordinate system used by the shore activity. Programs such as CORPSCON or GeoGraphic Calculator are available for coordinate system conversions to other datum's such as World Geographic System 1984 (WGS84) latitudes and longitudes, Universal Transverse Mercator (UTM) Northings and Eastings (units in meters), or state plane coordinates, Northings and Eastings, in either North American Datum (NAD) 1927 (units in US Feet) or 1983 (units in meters). Figure 3-3 shows a hand-held GPS being used to survey the location of a buoy.

There are numerous commercial GPS devices available. Low cost units generally have limited coordinate systems to use as well as reduced levels of accuracy.

If practical, mooring buoys should be surveyed during periods of slack tide and with no attached vessels. For mooring systems secured by embedment anchors, a low-cost GPS is adequate. Mooring systems secured with drag embedment anchors should have the buoy and found anchors surveyed with a GPS having sub-meter accuracy.

Figure 3-3 Using a Handheld GPS to Survey a Mooring

3-1.2.5 Notes and Reports.

It is the Inspector's responsibility to collect the inspection notes, the survey data, the pictures, and the inspection results. It is recommended that the Inspector use waterproof paper and pens. The Inspector must make a preliminary assessment of the results before leaving the site in order to ensure the inspection is completed. Upon return from the site, the Inspector must write the inspection report within 60 days.

An inspection sheet template (APPENDIX D) and an inspection report template (APPENDIX E) that the inspector can utilize to help in planning for the inspection. Items, such as points of contact information, references, email addresses, mooring class, type and configuration, buoy sizes, riser and ground leg sizes, project site maps, etc., are information that is provided in the inspection report that are needed for the inspection planning process.

As section one and the majority of section two of the inspection report are standardized information, the Inspector can complete a good portion of the inspection report before arriving on site for the inspection.

3-1.3 Inspection Dive Team.

Dive teams can be provided through a variety of sources, as selected by the PM/EIC/Inspector and as dictated by the situation and based on the available schedules and funding. The dive team can be from the Navy UCTs, other DoD diving units, commercial divers, or AE divers. It is important that the Inspector understand the differences in using these different groups.

Much of the fleet mooring inspections are performed by a diving detachment from the UCTs. For inspections performed by the UCTs, a lot of the inspection planning will be executed by the detachment OIC and Project Superintendent as the inspection provides an opportunity to develop project planning and management skills. The EIC/Inspector should coordinate with the OIC or Project Superintendent ensuring all required logistical requirements are accounted for. The EIC/Inspector is still responsible for submitting the completed inspection report.

3-1.3.1 Dive Team Responsibilities.

The responsibilities of the assigned diving team or detachment include:

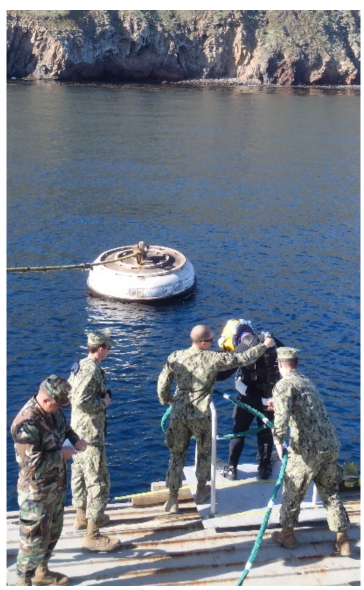
- Interface with the Inspector on all inspection planning matters to ensure that the Inspector is aware of the planned dates of the inspection, the type of diving that will be utilized, the estimated duration on site for the inspection, and any equipment requirements for the inspection that the dive team cannot provide.
- Coordinates with the Inspector to ensure that all logistical arrangements to perform the inspection are occurring; including diving equipment, inspection tools, shipping of anodes to the project site, and if necessary, arranging for local chamber support, dive platform support, forklift support, etc.
- Arranges for own travel orders, area clearances, camera clearances or passes, passports, and on-site transportation. If using a contractor dive team, the Inspector coordinates these administrative requirements for the contractors with the local shore activity.
- Based on the inspection requirements and site conditions, plans for either scuba or surface-supplied diving. A means of diver to surface communications should be incorporated into the selected diving procedures (Figure 3-4).

- Develops the inspection safety plan and diving emergency plans to include phone numbers and directions to the nearest hospital or urgent care center, nearest recompression chamber (Figure 3-5), etc.
- Plans dive operations in accordance with the US Navy Diving Manual, or if using non-DoD divers, diving regulations in accordance with EM 385-1-1.

Figure 3-4 Inspection Diver using SCUBA with Diver/Topside Communications Equipment

Figure 3-5 Portable Recompression Chamber at Dive Site

Figure 3-6 Surface Supplied Diver Entering Water



3-1.3.2 Dive Team Inspection Tools and Equipment.

In addition to inspection and anode replacement tools listed in paragraph 3-1.2.2 and 3-1.2.3, the dive team provides the following equipment and material required for the underwater inspection:

- Underwater digital camera or digital camera in a housing with a strobe and spare batteries.
- Underwater digital video camera system.
- Cleaning equipment (wire brushes, K-bars, chipping hammers, chisels, etc.).
- 100-foot (30.5 m) underwater tape measure.
- Marker tags (such as nylon zip ties) to relocate or mark links or accessories.
- Hand-held radios.
- Underwater compass.
- Underwater writing tablets and grease or underwater pencils.
- Binoculars.
- Surface marker buoys with lines to mark the location of anchors.
- All diving equipment and small boats as required.
- Tide tables and nautical charts of the project area.

The underwater writing tablets can be developed specifically for inspection of riser assemblies, ground leg assemblies, buoy assemblies or even specific mooring components (riser swivel shackles, joining links, etc.) that can aid the inspector. Example inspection sheets are provided in APPENDIX D.

3-1.4 Shore Activity Custodian.

The activity custodian, whose moorings are scheduled for inspection should provide support to EIC and the inspection team by forwarding, when requested, the following information:

- Copies of the latest local area harbor charts.
- Historical use and future plans for the existing moorings and future moorings.
- Clearances and passes for inspection team members and their cameras.
- Coordinates of known benchmarks and personnel cognizant of their location.
- Responses to requests for other pertinent inspection data.
- Information regarding protocol requirements to include force protection requirements.
- Information regarding ship movements or mooring usage that may impact the planned inspection schedule.

It is the responsibility of the Inspector to request the cooperation and support of the activity in matters related to the inspection.

3-1.5 Go/No-Go Gauges.

A list of inspection tools and equipment are presented in sections 3-1.2.2 and 3-1.3.2 One of the primary inspection tool used for underwater mooring inspections are Go/No-Go gauges. These gauges come in single link and double link sizes for nominal chain sizes ranging from 1.75 to 4 inches (44 to 102 mm). One side of the gauge has a jaw opening that is equal to 90% of the original wire diameter (OWD) while the other jaw on the gauge has an opening equal to 80% of the original wire diameter. For double link gauges, one jaw is equal to 2 x 0.9 x OWD of the nominal chain size with the other side equal to 2 x 0.8 x OWD of the nominal chain size.

Go/No-Go gauges should be made from stainless steel with a thickness of 1/4 inch (6 mm) minimum. Gauges can be made from aluminum but must be thick enough to avoid being bent during inspection operations. A hole on the gauge should be provided to attach a lanyard.

It is recommended that a white strip of electrical tape be wrapped around the middle of the jaws representing 90% of the OWD for easy identification by the divers.

A fabrication drawing for Go/No-Go gauges for common chain sizes is provided in APPENDIX H. Jaw gap dimensions for fleet mooring chain sizes are provided in Table 3-1. Figure 3-7 shows a double link Go/No-Go gauge for 2.5-inch (64 mm) nom FM3 chain.

Figure 3-7 Double Link Go/No-Go Gauge for 2.5" FM3 Chain

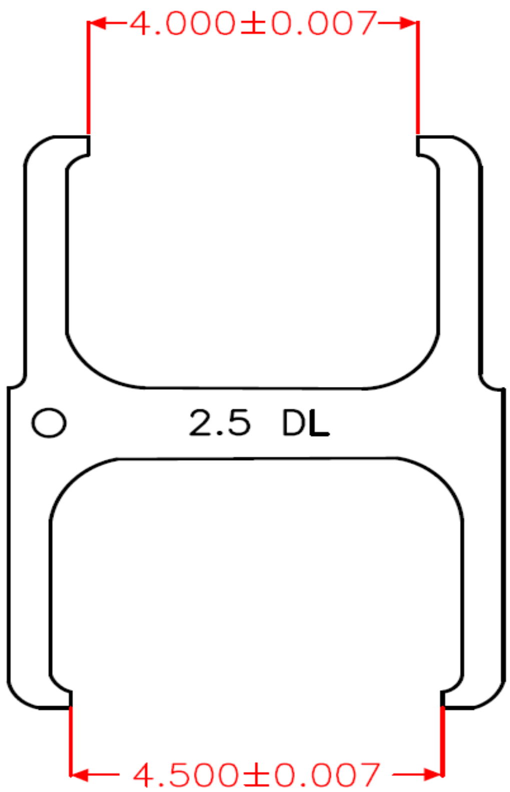


Table 3-1 Go/No-Go Gauges

Diameter	Single Link		Double Link	
	.90D	.80D	.90D	.80D
inches	inches	inches	inches	inches
4.0	3.60	3.20	7.20	6.40
3.5	3.15	2.80	6.30	5.60
3.0	2.70	2.40	5.40	4.80
2.75	2.475	2.20	4.95	4.40
2.5	2.25	2.00	4.50	4.00
2.25	2.025	1.80	4.05	3.60
2.0	1.80	1.60	3.60	3.20
1.75	1.575	1.40	3.15	2.80

3-2 MOORING INSPECTION.

3-2.1 Inspection Responsibilities.

3-2.1.1 Inspector Responsibilities.

The primary responsibility of the Inspector is Quality Assurance. The Inspector will ensure that all of the data collected is accurate and complete enough to make an informed evaluation of the condition of the mooring.

The assigned Inspector should arrive on site a minimum of one working day before the start of the inspection. This provides the opportunity to meet with appropriate station personnel in order to:

- Brief station personnel on the plans, techniques, and purpose of the inspection.
- Obtain any information concerning the moorings that was previously unavailable.
- Confirm mooring usage or ship movements during the inspection period in order to establish the order in which the moorings will be inspected.
- Obtain the latest weather forecast for the local area.
- Obtain other information from the shore activity custodian that may affect the inspection.

Prior to beginning diving operations, the Inspector shall brief the Dive Superintendent on the latest information obtained from station personnel and ensure that the Dive Superintendent is aware of any changes to the inspection procedures. As the lead of this inspection, the Inspector is authorized to modify inspection procedures on site as necessary, as long as modifications are acceptable to the Dive Superintendent in maintaining diver safety. In addition, the Inspector must:

- Interface with the Dive Superintendent in all matters related to the inspection.
- Report the status of the inspection and advise the program manager and the activity custodian of any schedule or procedural changes.
- Arrange with the Dive Superintendent to conduct the post dive briefing at the completion of each dive.
- Evaluate the inspection data as it is gathered and determine if additional data is required.
- Brief activity personnel on mooring conditions following completion of the inspection.

Prior to beginning diving operations, the Inspector shall brief the Dive Superintendent on the latest information obtained from station personnel and ensure that the Dive Superintendent is aware of any changes to the inspection procedures. As the lead of this inspection, the Inspector is authorized to modify inspection procedures on site as

necessary, as long as modifications are acceptable to the Dive Superintendent in maintaining diver safety. In addition, the Inspector must:

- Interface with the Dive Superintendent in all matters related to the inspection.
- Report the status of the inspection and advise the program manager and the activity custodian of any schedule or procedural changes.
- Arrange with the Dive Superintendent to conduct the post dive briefing at the completion of each dive.
- Evaluate the inspection data as it is gathered and determine if additional data is required.
- Brief activity personnel on mooring conditions following completion of the inspection.

3-2.1.2 Dive Team Responsibilities.

The Dive Superintendent is the interface between the Inspector and the inspecting divers. The Dive Superintendent is responsible to:

- Interface with the Inspector on all inspection-related matters.
- Ensure safe performance of the underwater portion of the inspection.
- Provide underwater photographs and video as required.
- Submit all inspection data, notes, and inspection-related film to the Inspector prior to departing the site.
- Accompany and assist the Inspector in briefing station personnel.

3-2.2 Inspection Limitations.

3-2.2.1 Mooring Inspection Limitations.

Moorings are inspected using underwater inspection procedures to the maximum extent possible to include riser assemblies, ground leg assemblies and anchor assemblies. The riser or ground leg is inspected as far as practicable until the riser or ground leg assembly is completely buried and unable to be inspected by the diver. The use of lift bags or other lifting devices to raise riser and ground leg assemblies out of the seafloor are not used during mooring inspections for diver safety. Most portions of the ground legs that are completely buried and unavailable for inspection are generally unaffected by tidal changes and have seen minimal movement. The inspection results obtained on the riser or ground leg that are in the moorings “thrash zone” (portion of the mooring riser and ground legs that are raised and lowered by tidal effects) will provide a good indication of the overall condition of the mooring riser or ground legs. Moorings that are in locations with a large tidal change (> 5 foot (1.5 m)) should be inspected during periods of high tides. As fleet moorings proof test drag-embedment anchors, these anchors will be buried and unable to be inspected unless they are in hard soil conditions. Embedment anchors are also not available for inspection.

3-2.2.2 Diving Limitations.

The majority of moorings are installed in harbor locations where the water depth is less than 50 feet (15.2 m), making them suitable for dive operations performed using either scuba or surface supplied diving within the no-decompression dive limits (though it may take more than 1 dive to fully inspect a mooring). A few moorings (i.e. outer Apra Harbor, Guam; and Wilson Cove, San Clemente Island, CA) are in water depths between 130 to over 190 feet (39.6 to 57.9 m) sea water (FSW) and may require restrictions, command approval, and decompression diving procedures. Portions of some moorings may have to be inspected using remotely operated vehicle (ROV) equipment. Moorings that are in water depths 100 feet (30.5 m) or greater should be identified early in the inspection planning phase to ensure proper diving procedures, equipment and command clearances are planned and obtained prior to arrival at the project site.

3-2.3 Mooring Rating Criteria.

3-2.3.1 Mooring Rated Condition.

Moorings are satisfactory or unsatisfactory for continued use based on an engineering assessment of all inspection data – buoy condition, chain measurements, anchor and buoy position, and other factors. The relationship between mooring condition and rating is summarized below and in Table 3-2.

- If the mooring chain wire diameter measures between 90% and 100% of its original wire diameter and surface components measure 90% to 100% of the original wire diameter, the mooring is considered as C1 (formerly referred to as Good).
- If the mooring chain wire diameter measures between 90% and 100% of its original wire diameter and only topside components measure 80% to 90% of their original wire diameter, the mooring is assessed as C2 (formerly referred to as Fair).
- If the mooring chain wire diameter measures between 80% and 90% of its original wire diameter and topside components measure at least greater than 80% of their original diameter, the mooring is assessed as C3 (also formerly referred to as Fair).
- If the mooring chain or surface components measure less than 80% of the original wire diameter for the required mooring class, the mooring is assessed as C4 and is not satisfactory for continued use (formerly referred to as Poor).

Table 3-2 Mooring Rating Criteria

FACLITY RATING	FACILITY IMPACT ON OPERATIONS	FACILITY CONDITION
C1- FACILITY OPERATIONAL	No impact on operations.	Condition of mooring is considered satisfactory for continued use.
C2 – FACILITY PARTIALLY OPERATIONAL AT A REDUCED CAPACITY	Mooring may be unable to be used at its full design capacity. An engineering assessment is required. Restrictions could impair operations. Vessels may have to find alternate facilities to moor.	Mooring inspection has revealed irregular or degraded surface materials and may no longer be able to hold rated capacity. Topside components or mooring buoy must be replaced or repaired to restore to original design condition
C3 – FACILITY PARTIALLY OPERATIONAL AT A REDUCED CAPACITY	Mooring may be unable to be used at its full design capacity. Restrictions could impair operations. An engineering assessment is required. Vessels may have to find alternate facilities to moor.	Mooring chain or underwater connecting jewelry is degraded and may no longer be able to hold rated capacity. Underwater components must be replaced or repaired to restore to original design condition.
C4 – FACILITY NOT OPERATIONAL	Mooring is restricted from use. Vessels must use alternate facilities. Failure of mooring is imminent.	Mooring must be replaced. Mooring chain or connecting jewelry has degraded below 80% of required Mooring Class.

3-2.3.2 Mooring Condition Readiness.

Mooring condition readiness is a numerical value assigned to a mooring that provides the mooring custodian or local Public Works Officer (PWO) an assessment of the mooring's readiness condition using the Infrastructure Condition Assessment Program (ICAP). It is similar to the Mooring Rated Condition described in paragraph 3-2.3.1 above, but through the assigned numerical value, provides additional information as to the condition of the mooring and sustainment requirements. The mooring condition readiness values and associated condition is shown in Table 3-3.

Table 3-3 Mooring Condition Readiness Scale

VALUE	CONDITION
90	All > 90%; minimal corrosion present.
80	All > 90%; moderate corrosion present or partial damage to fenders or chafe rails or reflective tape in need of replacement.
75	All > 90%; heavy corrosion present or fenders or chafe rails completely missing or top jewelry not secure.
70	All > 90%; buoy refurbishment required.
60	Topside < 90%; minimal to moderate corrosion present.
55	Topside < 90%; moderate to heavy corrosion present.
50	Below water connection assembly not secure.
40	Underwater < 90%; minimal to moderate corrosion present.
30	Underwater < 90%; moderate to heavy corrosion present.
20	Underwater < 80%; minimal corrosion present or legs dragged off location.
10	Underwater < 80%; moderate corrosion present.
0	Underwater < 80%; heavy corrosion present or a ground leg is detached.

3-2.4 Chain Wire Diameter Sampling.

The most common measurements performed in the mooring underwater inspection is selective sampling using Go/No-Go gauges. A selective sampling of chain wire diameter measurements is used to evaluate the condition of a mooring. See Appendix L-1 for a video link for the inspection of chain using double and single link Go/No-Go Gauges.

3-2.4.1 Selective Sampling Locations on the Riser Assembly.

For a riser assembly in water depths less than 90 feet (27.4 m), minimum selective sampling is performed at three locations; (1) One or two links below the buoy connection in the splash zone (area near the surface where it is rich in oxygen due to wave action and the presence of uniform corrosion may be present); (2) At mid-water depth; and (3) Just above the seafloor or the ground ring connection in the thrash zone (area where mechanical wear may be present due to mechanical wear by cyclical tidal action). If the riser is in water depths greater than 90 feet (27.4 m), then the amount of mid-water selective sampling should be increased by one for every 30 feet (9.1 m) the water depth is greater than 90 feet (27.4 m).

For example, if the water depth at the mooring site is 100 feet (30.5 m), minimum selective sampling should be performed in the splash zone just below the buoy connection, the thrash zone just above the seafloor or ground ring connection and two interior locations on the riser. These four locations should be approximately equally separated from themselves.

Since FM3 connecting links have a larger bar diameter than their corresponding nominal size FM3 chain, measurements are taken one to two links away to ensure that a connecting link is not part of the double link measurement.

3-2.4.2 Selective Sampling Locations on a Ground Leg Assembly.

For a ground leg assembly, minimum selective sampling is performed just past the ground leg's connection to the ground ring, at 30 feet (9.1 m) intervals, and one to two links from its connection to the anchor or where the ground leg disappears into the mud line and cannot be further inspected. The number of links for approximately 30 feet (9.1 m) of FM3 chain is provided in Table 3-4.

Table 3-4 Chain 30 Foot Length Link Count

CHAIN SIZE	LINK QTY	CHAIN SIZE	LINK QTY
1.75	51	2.75	32
2	43	3.5	26
2.25	40	4	22
2.5	36		

3-2.4.3 Double Link and Single Link Go/No-Go Gauges.

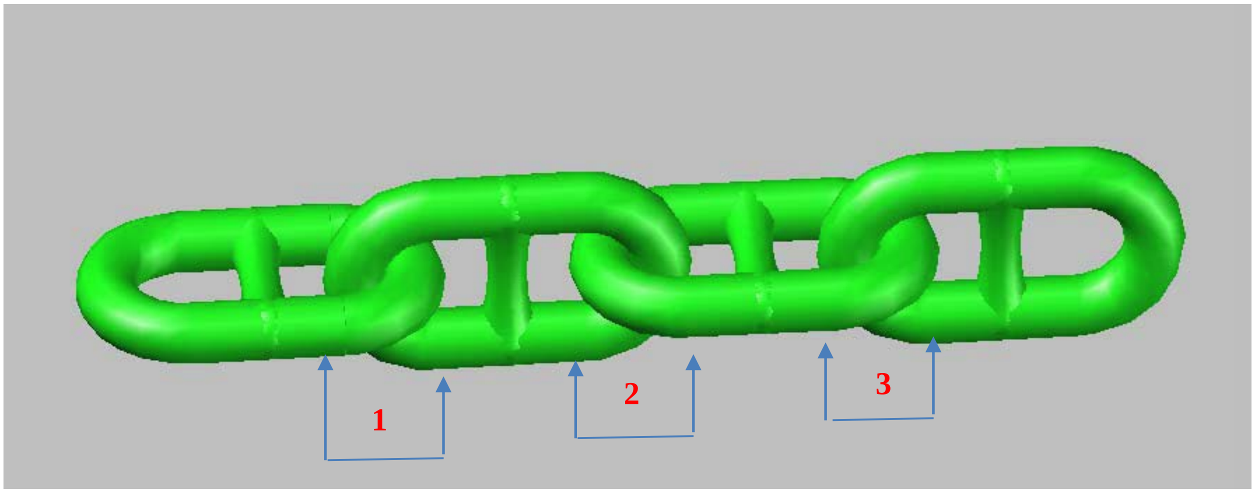
Go/No-Go gauges come in single link and double link sizes. Double link gauges are used to measure the combined bar diameter of two joined links where the two links connect under tension to detect the combined effects of corrosion and mechanical wear. Suspended portions of chain, particularly the riser, are in tension so double link Go/No-Go gauges are frequently used to inspect riser assemblies.

Single link gauges are used to measure the bar diameter of an individual chain link. Single link gauges are used on portions of the riser and ground legs that are not in tension or are slack. Portions of a ground leg or riser that is laying along the seafloor may be slack since its weight is being supported by the seafloor and chain tension is resisted by static friction between the chain links and the seafloor. Chain not in tension will have points of no contact between adjacent links and must be inspected using single link gauges procedures.

3-2.4.4 Measurement Set.

At each selective sampling location, a measurement set is taken using either the double link or the single link Go/No-Go gauges. A measurement set is defined as three consecutive measurements of a chain link joint. A chain link joint contains the connected ends of two adjacent chain links. A measurement set will contain both chain link connection points for 2 chain links and one chain link connection point for 2 other chain links. Therefore, one measurement set provides inspection data on 4 chain links. Figure 3-8 shows one measurement set with three consecutive measurements.

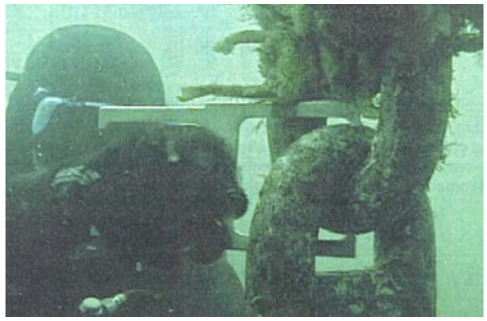
Figure 3-8 Measurement Set



3-2.4.5 Double Link Measurement Set.

Each of three consecutive measurements are taken using double link gauges as shown in Figure 3-9. At each measurement, both ends of a chain link joint are measured simultaneously with one measurement as the double link gauge is held approximately parallel to the plane bisecting the long axis of the joined chain links in performing the measurement.

Figure 3-9 Double Link Measurement at a Chain Link Joint

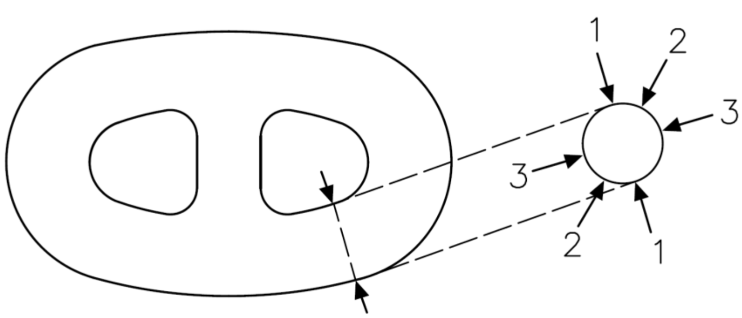


3-2.4.6 Single Link Measurement Set.

Single link measurements are more time consuming because one must take multiple single link measurements on both chain links in a single chain link joint. Since the links are slack or have a gap somewhere between them, one must measure the link from several (at least three) directions of approach around the link. Care must be taken to do these measurements as far as practical from the stud of the chain link, as this area is normally larger in diameter and generally not a contact point for wear. As the other joined link will tend to hinder taking single link measurements, several measurements are taken from different directions of approach as close as possible to where the chain contact points on the link are.

Once one chain link end is done, the same quantity of single link measurements is taken on the adjacent end of the other joined link. When both ends are inspected multiple times from different approach directions, that constitutes one measurement. This is repeated at the next two adjacent chain link joints to complete the measurement set at that location on the mooring assembly. Figure 3-10 shows single link gauge measurements on the end of one chain link.

Figure 3-10 Single Link Measurement



3-2.4.7 Using the Correct Go/No-Go Gauge Size.

Though one of the planning requirements is to review prior inspection reports and obtain a copy of the mooring configuration drawing, the inspector and inspecting divers should not take the information for granted and verify the chain size prior to performing chain measurements using the Go/No-Go gauges. This can be done in the field by fully cleaning the marine growth and excessive corrosive materials off one chain link a few feet below the buoy connection and measuring the overall outer length of a single link using a ruler. The length of the link divided by 6 will provide the nominal chain size. Chain link lengths for fleet mooring chain are provided in Table 3-5.

Table 3-5 Chain Link Lengths

CHAIN SIZE	LINK LENGTH (inches/centimeters)	CHAIN SIZE	LINK LENGTH (inches/centimeters)
1.75	10.5 (26.67)	2.75	16.5 (41.91)
2	12 (30.48)	3.5	21 (53.34)
2.25	13.5 (34.29)	4	24 (60.96)
2.5	15 (38.10)		

3-2.4.8 Cleaning of Chain Link Joint for Inspection.

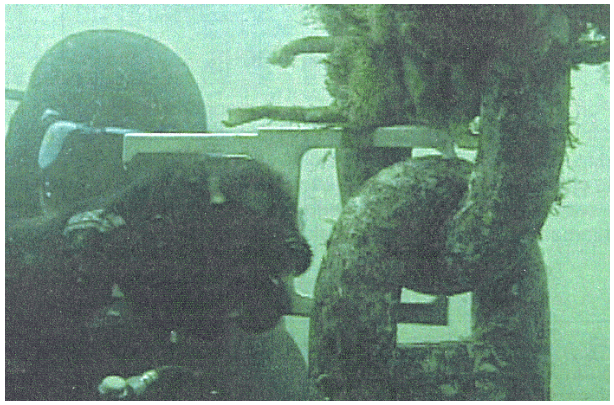
One of the important steps in the mooring inspection is the proper cleaning of the chain links for inspection. The portion of the chain links for inspection is cleaned to “bare metal”, i.e. all the marine growth is removed as well as heavy oxidation materials in the areas of the chain link where single or double link measurements are to be taken (Paragraph 3-2.4.1 and Paragraph 3-2.4.2). Note that the entire link doesn’t have to be cleaned, just the outer side of the ends of each link in a chain link joint where the gauge measurements will be taken. Note for single link measurements, a larger portion of the chain link ends will require cleaning. Due to the proximity of available light, increased presence of oxygen, less motion and sometimes warmer temperature, not to mention that the movement of the chain in the thrash zone can keep the links free of growth and corrosion, there will be more cleaning required in the splash zone than the thrash zone.

Safety Warnings:

Failure to properly clean the inspection area of the chain links may provide erroneous measurements leading the inspector, custodian, and users of the mooring system to an improper conclusion on the mooring condition that could result in an unsafe mooring condition for a moored vessel.

Divers should be aware of the potential movement of the chain, especially when working on the ground legs.

Figure 3-11 Chain Link End Cleaned for Inspection



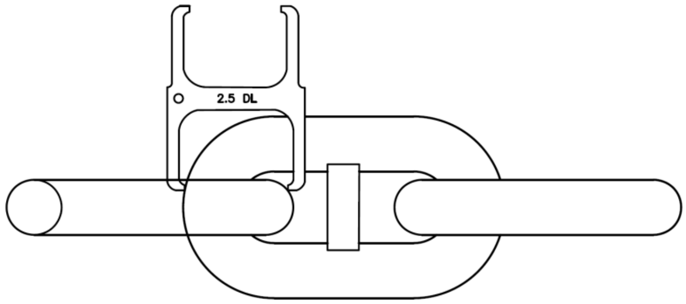
3-2.4.9 Go/No-Go Gauge Measurements.

Whether you are using double link or single link Go/No-Go gauges the procedural steps at each measurement location are the same. Once the inspecting divers have verified the chain size and have the correct set of gauges and the chain link areas have been cleaned, the following steps are performed:

(1) Note the water depth at the measurement set location on the riser or ground leg. When taking readings on a ground leg, note the distance from the ground ring to the measuring set location. On the riser, this measurement is less critical but the diver should still note the distance between the buoy shackle and the measurement set location.

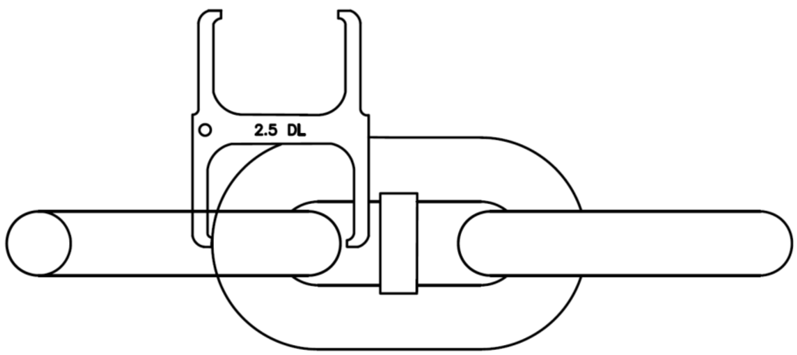
(2) Start with the 90% side (the larger of the two jaws) of the gauge. It is recommended that a single white strip of electrical tape be wrapped around the sides of the 90% jaw for easy recognition in low visibility conditions. Try to pass the 90% jaw over the end of the link (or the ends of both chain link ends at a chain joint if using double link gauges). If the gauge does not pass through, then the measurement is recorded as >90% of the chain's original wire diameter (OWD). See Figure 3-12. Then the inspecting diver would proceed onto the next consecutive measurement location. (Remember for using single link gauges one has to inspect the ends of both connected links individually from at least three angles of approach.)

Figure 3-12 Chain >90% of OWD Using Double Link Go/No-Go Gauges



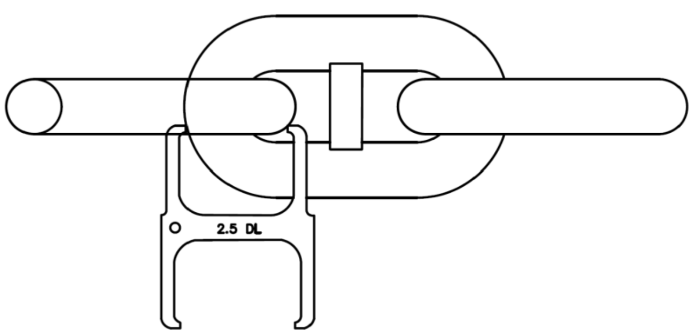
(3) If the >90% jaw does pass through (or if doing single link gauge measurements the 90% jaw passes through on at least one time), we know that the chain is <90% of OWD. See Figure 3-13.

Figure 3-13 Chain <90% of OWD Using Double Link Go/No-Go Gauges



(4) The diver then will flip the gauge so the 80% jaw (smaller of the two jaws on the gauge) and repeat the measurement process. If the 80% jaw does not pass through, then the measurement is recorded as >80% of OWD. See Figure 3-14. Then the inspecting diver would proceed on to the next measurement location.

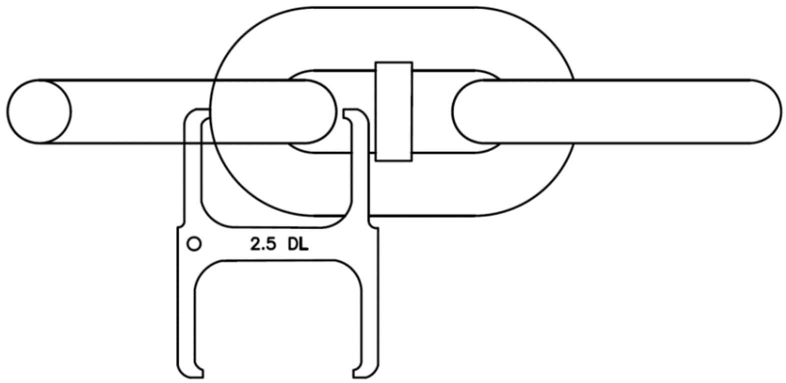
Figure 3-14 Chain >80% of OWD Using Double Link Go/No-Go Gauges



(5) If the >80% jaw does pass through (or if doing single link gauge measurements, the 80% jaw passes through on at least one time), then the

measurement is recorded as <80% of OWD. We don’t know the exact %, but we do know that it is <80% of OWD. See Figure 3-15.

Figure 3-15 Chain <80% of OWD Using Double Link Go/No-Go Gauges



(6) Attach a tie-wrap (zip tie) around the stud(s) on both links (for double measurements) or single link (for single link measurements) that were <90% of OWD. The inspecting divers should get a still photo showing the 90% or 80% jaw passing through the single link or link joint or a video recording of the measurement. Then the inspecting diver would proceed on to the next measurement location.

(7) The above sequence is repeated at each measurement location within a measurement set and at each selective sampling location on the riser and ground leg. For mooring risers and exposed portions of ground legs that are 9 links or less in length, perform single or double link measurements on all chain links as described in Paragraph 3-2.4.1 and 3-2.4.2.

Some moorings have oversized chain on the mooring riser and/or ground legs that are located in the thrash zone to extend the mooring’s operational use before sustainment operations are required. Oversized mooring chain that is found to be <80% OWD should be remeasured using calipers, to the maximum extent possible to determine its actual % remaining to allow for an engineering assessment on the continued use of the oversized mooring chain.

3-2.4.10 Go/No-Go Gauge Measurement Evaluation.

Measurements >90% of OWD indicate that the chain is still in “Good” condition. Measurements between 80% and 90% of OWD indicate that the chain is in “Fair” condition. Measurements <80% of OWD indicate that the chain is in “Poor” condition.

Once all ground leg assemblies and riser assemblies are fully inspected, the mooring is assigned an overall rating per section 3-2.3 based on the lowest condition found. As the mooring is only as good as the “weakest” link, only one measurement found to be between 80% and 90% of OWD will require the entire mooring system to be rated in C2 or C3 (Fair) condition. Likewise, all it takes is one measurement <80% of OWD for the entire mooring system to be rated in C4 (Poor) condition. It takes all measurements to be >90% of OWD for the mooring system to be rated in C1 (Good) condition.

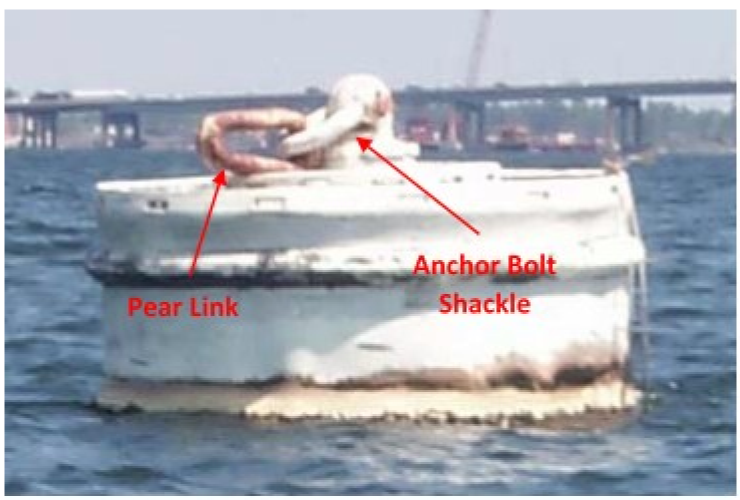
Locations where a measurement <80% of OWD is found should be verified by the dive superintendent, inspector or project superintendent. Additionally, still photo or video documentation should be performed at any location where measurements were found to be <90% of OWD to aid the mooring custodian to seek funding to repair the mooring.

3-2.5 Top Jewelry Inspection Requirements.

Standard top jewelry on fleet moorings include an anchor bolt shackle and two pear links (Figure 3-16). Inspection of top jewelry and surface inspection of mooring buoys should be done on an annual basis. See Appendix L-4 for a video showing the methods to inspect the top jewelry on the buoy.

Similar condition terms as “Good”, “Fair” and “Poor” as described in paragraph 3-2.4.10 will be used in evaluating top jewelry components. The inspection report should note the type and quantity of top jewelry present on the buoy.

Figure 3-16 Buoy Top Jewelry



3-2.5.1 Anchor Bolt Shackle.

Anchor bolt shackles are inspected by caliper measurements at their wear points, an assessment of its overall condition with regard to mechanical wear, corrosion, serviceability, and security of shackle components. See Table 3-6 for Anchor Bolt Shackle dimensions.

- Using calipers, measure the bar diameter of the shackle’s pin between the bale of the shackle and the tension bar padeye Figure 3-17).

Figure 3-17 Measure Pin Diameter Close to Tension Bar Padeye

- Using calipers, measure the bar thickness of the bale of the shackle by its connection points with other hardware (Figure 3-18 and Figure 3-19).

Figure 3-18 Measure Wear Point Using Calipers

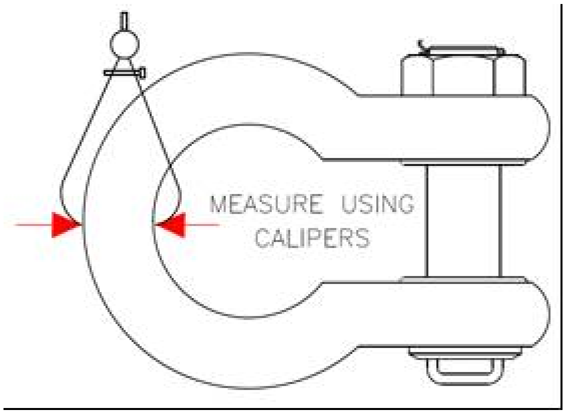
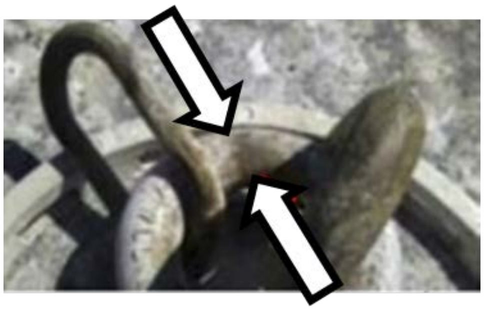


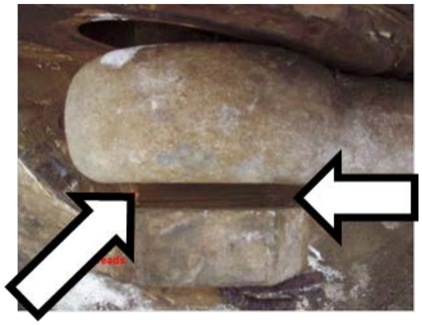
Figure 3-19 Measure Along Wear Point Axis



- Verify if the correct shackle size is on the buoy. Fleet mooring 8 foot (2.44 m) diameter (small) foam buoys have a 3-inch (76 mm) anchor bolt shackle. Fleet mooring 11.5-foot (3.51 m) diameter (medium) buoys have a 4-inch (102 mm) anchor bolt shackle (Figure 3-20).
- Verify if a cotter pin or safety bolt is present on the shackle nut. Note its condition with regard to corrosion.
- Check if the nut is tight on the shackle pin (Figure 3-21).

Figure 3-20 3-inch Shackle on Medium Foam Buoy

Figure 3-21 Nut on Shackle Pin Not Fully Seated



- Note the overall condition of the shackle with regard to corrosion (Figure 3-22 and Figure 3-23).

Figure 3-22 Minimal Corrosion

Figure 3-23 Heavy Corrosion

For mechanical wear at the pin and bale contact points, the buoy anchor bolt shackle is assessed as C1, C2 or C4 using similar criteria as done for chain measurements. Table 3-6 provides catalog dimensions for Fleet Mooring anchor bolt shackles and 90% and 80% levels. Rust products should be removed prior to performing caliper measurements to obtain accurate measurements at the wear points.

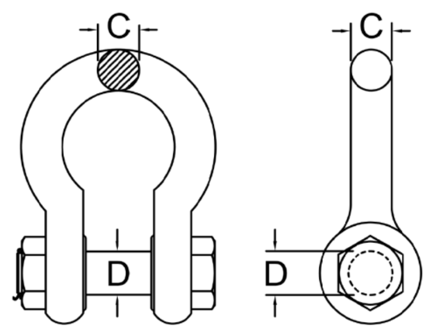
Assessment of the overall condition of the shackle is generally based on the judgment of the inspector. If the shackle shows excessive corrosion, it should be scheduled for replacement. Note that the safe working load of a 3-inch Crosby G-2140 anchor bolt shackle (smallest shackle found on fleet mooring foam buoys) is 110 tons (979 kN) and will be found on Class E moorings that are rated for 25 tons (222 kN). As the buoy shackle is significantly stronger than the mooring rating, moderate to heavy corrosion can be tolerated provided that caliper measurements are >90% of the design dimensional value. However, if the shackle is assessed to have excessive corrosion, it should be scheduled for replacement.

Shackles found without a safety bolt or cotter pin should be corrected by either the local custodian or the inspection team. The absence should be documented in the inspection report as well as the corrective action taken.

Loose nuts should be tightened up immediately by the local custodian or the inspection team. This finding should be documented in the inspection report as well as the corrective action taken.

Table 3-6 Anchor Bolt Shackle Dimensions

Size (inch)	Location	Catalog (inch)	90%	80%
3	Pin	Dim D – 3.25	2.93	2.60
3	Bale	Dim C – 3.62	3.26	2.90
4	Pin	Dim D – 4.25	3.83	3.4
4	Bale	Dim C – 4.56	4.10	3.65



3-2.5.2 Pear Links.

Pear links are inspected by caliper measurements at their wear points, as well as an assessment of its overall condition with regard to corrosion.

- Using a tape, measure the inside length of the pear link.
- Using a tape, measure the overall length of the pear link.
- Using calipers, measure the bar diameter of the pear link at both ends as close as possible to the contact points (Figure 3-24).
- Verify that the correct size pear links are on the buoy. The pear link size should be equal or greater in diameter than the required size chain for the design class rating for the mooring.
- Record the serial number, year of manufacture and manufacturer of the pear link. Typical serial number information on fleet mooring pear links are shown in Figure 3-25.

Figure 3-24 Wear Point & Direction On Fleet Mooring Pear Link

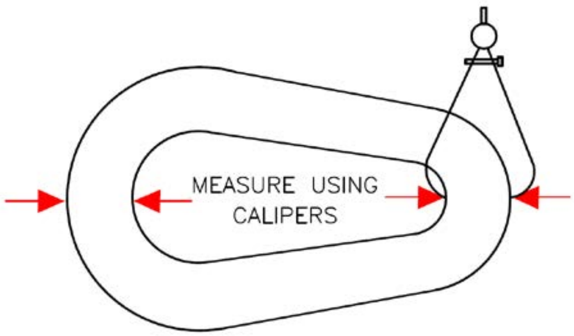
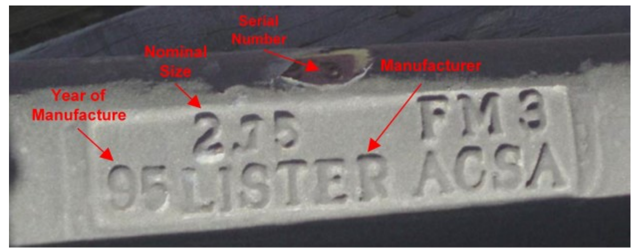


Figure 3-25 Pear Link Marking Data



3-2.6 Mooring Buoy Inspection Requirements.

3-2.6.1 Surface Inspection of Mooring Buoys.

Surface inspection of the buoy includes freeboard measurements, damage assessment, tension bar padeye condition assessment, reflective tape, and chafing and fender rail damage assessment. If the buoy has a navigation light, it should be inspected for functionality and its attachment bracket inspected for condition assessment. See Appendix L-5 for a video showing the techniques for a surface inspection of a foam Buoy.

- For foam buoys, record the serial number, contract number, year of manufacture and manufacturer of the buoy. Typical serial number information on foam buoys are shown in Figure 3-26.

Figure 3-26 Foam Buoy Identification Plate

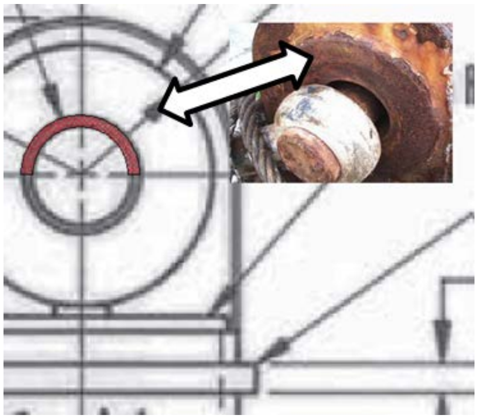
- Record the size (diameter), type (foam or steel), style (drum or peg top), method of connection (tension bar of hawse pipe) presence or absence of any attached vessels. If the identification plate is illegible, exclude the fenders when measuring the buoy diameter.
- Note the overall condition of the tension bar padeye with regard to corrosion (Figure 3-27 and Figure 3-28).

Figure 3-27 Minimal Corrosion on Tension Bar Padeye

Figure 3-28 Excessive Corrosion on Tension Bar Padeye

- Visually inspect the condition of the wear bushing inside the padeye along the upper half of the padeye hole in the direction of pull (Figure 3-29).

Figure 3-29 Location of Tension Bar Padeye Wear Bushing



- Record the freeboard of the buoy from the waterline to the deck line (the top flat surface of the buoy, not counting the rub rails) at the edge of the buoy. Measure from the top surface of the buoy. If the buoy has a severe list due to an attached vessel or excessive attached hardware, measure the high and low sides to obtain an average freeboard.
- Assess the buoy hull for damage, holes and or dents. On steel buoys, note level and type of corrosion (i.e. pitting, rust bleeding, level of corrosion) on buoy shell. If buoy has an outer fiberglass or urethane coating note any cracks, peeling or other damage (Figure 3-30).

Figure 3-30 Outer Coating Loss on Steel Buoy

- Visually inspect the upper chafing rails for damage. Remove debris from drainage holes on chafing rails. On a buoy, record the quantify of chafing strips, method of attachment and presence of any broken mounting brackets, bolts, etc.
- Visually inspect the fenders for damage. On a steel buoy, record the quantity of fenders, method of attachment and presence of any broken mounting brackets, bolts, etc.
- Assess the condition of the reflective tape and legibility and correctness of buoy identification markings.
- Note and record any significant listing not caused by a moored vessel, the moored diving platform or top jewelry.

Tension bar padeyes are made from mild A36 grade steel, which is a softer steel than that used for the shackle pin. Consequently, they are subject to elongation of the padeye in the direction of the load once the wear bushing has worn through. Dents to the outer buoy shell should be inspected closely, especially on steel buoys, to ensure that the water tightness of the buoy is not compromised. These buoys should be monitored in annual inspections as these points will form local points of corrosion that will spread over time.

Assessment of the overall condition of the buoy is generally based on the judgment of the inspector. Buoys with damaged fenders, chafing rails, reflective tape in need of replacement, minor dents to the hull on foam buoys, moderate corrosion on the tension bar padeye may still be satisfactory for continued fleet use as these are either minor repairs or do not affect the ability of the buoy to support the suspended portions of the mooring system or reduce its load carrying capacity.

Depending on the level of corrosion on the buoy tension bar padeye, the amount of outer hull damage, presence of an unexplained buoy list or excessively low freeboard (i.e. is the freeboard significantly less than from the last inspection?), condition of the padeye wear bushing, the buoy may be assessed as in C2 (Fair topside) or C4 (Poor topside) condition. Assessing the buoy in Poor condition indicates that there is sufficient damage or corrosion on the buoy indicating a significant reduction in buoyancy and/or mooring load capacity or its condition presents a risk of either loss of buoyancy, mooring load capacity or operational safety if not immediately replaced or repaired.

A rating of C4 (Poor) on a buoy will also cause the entire mooring system to be rated in C4 condition and unsatisfactory for continued fleet use. Lack of marine growth cover or the removal of the outer cover in one area of the buoy may be an indication of a vessel coming into contact with the buoy. Usually, impact damage will be seen above the waterline.

Note:

All efforts shall be made to replace steel buoys with foam buoys since steel buoys are much more difficult to inspect and maintain. Steel tension bar buoys can still be used, but hawse pipe buoys should be taken out of service.

3-2.6.2 Subsurface Inspection of Mooring Buoys.

While a surface inspection of a mooring buoy should be conducted on an annual basis, the subsurface buoy inspection will normally be conducted with the underwater inspection of the mooring system as a whole. Divers shall thoroughly inspect the buoy below the waterline.

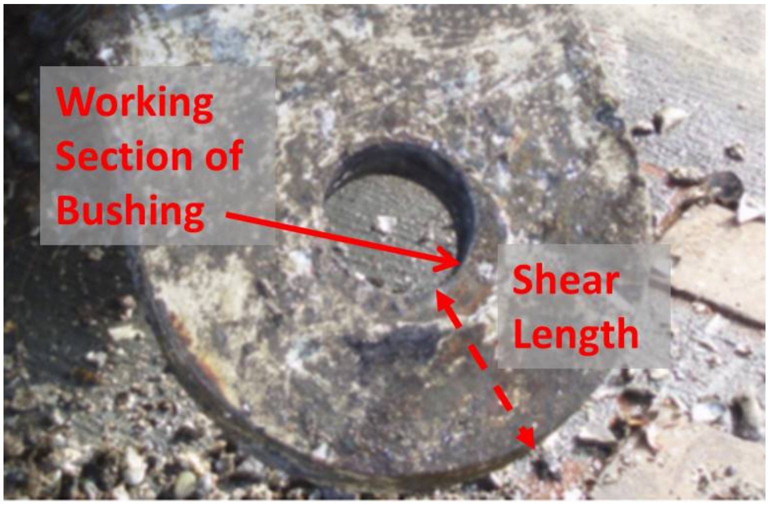
Safety Warning:

Divers should use extreme caution when working directly below a live/moving buoy.

- Record marine growth thickness. Care should be taken not to puncture the outer urethane shell on foam buoys or fiberglass/urethane coating on steel buoys.
- Lack of growth cover may be an indication of a vessel coming into contact with the buoy. In most cases, impact damage will also be seen above the waterline.
- Clean off the lower tension bar and visually inspect the condition of the lower tension bar zinc anodes. Replace zinc anodes if the remaining amount of zinc anode is >25% depleted.
- Visually inspect any submerged fenders for damage. On a steel buoy, record the quantity of fenders, method of attachment and presence of any broken mounting brackets, bolts, etc.
- Clean off the lower tension bar padeye and visually inspect the condition of the wear bushing inside the padeye along the lower half of the padeye hole in the direction of riser pull (Figure 3-31).

- Measure the tension bar thickness and shear length of the lower tension bar padeye (Figure 3-31). Divers should look for the bushing seam then trace it toward the wear direction. They should note if it thins out or if the base metal of the padeye is being penetrated. The measurement of the shear length is difficult with the swivel shackle in the way. It is suggested that divers use a thin metal rule to make that measurement.

Figure 3-31 Lower Tension Bar Padeye



Information from the underwater inspection of the buoy is combined with the inspection results from the above water inspection of the buoy to provide an overall buoy assessment as described in Paragraph 3-2.6.1

3-2.6.2.1 Bottom Buoy Jewelry Inspection Requirements.

The most common bottom buoy jewelry is the riser swivel shackle or the anchor bolt shackle.

3-2.6.2.2 Riser Swivel Shackle.

The riser swivel shackle is the most common connection of the mooring riser to the buoy. The inspection includes pin diameter caliper measurements, checking for full assembly and verification that tapered pins securing the swivel pins are secured by lead plugs. See Appendix L-2 for a video showing the techniques to inspect a Riser Swivel Shackle.

- Thoroughly clean off all marine growth on the swivel shackle at the swivel “gap” and along the front and back of the narrow sides of both the upper and lower jaw. Verify the presence of 2 lead plugs per side on both the upper and lower jaws (Figure 3-32).
- Using calipers, measure the bar diameter of the upper riser swivel shackle’s pin by the tension bar padeye. Measure the pin closest to the

buoy shackle or riser chain to not accidently measure the casted shim located on the inside of the swivel top and bottom bales.

- Using calipers, measure the bar diameter of the lower riser swivel shackle's pin by the end link on the mooring riser.

Figure 3-32 Riser Swivel Shackle Inspection Points

- Thoroughly clean off all marine growth by the swivel "gap" (Figure 3-32). Inspect the swivel gap for uniformity all around the swivel. The swivel "gap" should be less than 0.75-inch (19 mm). Gaps larger than 0.75-inch (19 mm), may indicate that the swivel shackle is in the process of coming apart. As shown in Figure 3-33, the outer sleeve is secured to the lower jaw extension with an all-around fillet weld. Larger gaps may indicate that this weld has failed and the lower portion of the swivel shackle is starting to unscrew itself from the upper jaw. If a gap >0.75-inch (19 mm) is measured, the divers should clean off the top of the jaw extension and inspect the condition of the weld as well as the level of the lower jaw extension to the locking tube. A failed weld or the lowering of the jaw extension in the locking tube is a sign that the swivel shackle is in need of immediate replacement. Moorings that have a "loose" riser swivel shackle are assessed as C4 and unsatisfactory for continued fleet use. Riser swivel measurement points are shown in Figure 3-34, Figure 3-35, Figure 3-36, and Figure 3-37.

Figure 3-33 Welding of Lower Jaw Extension

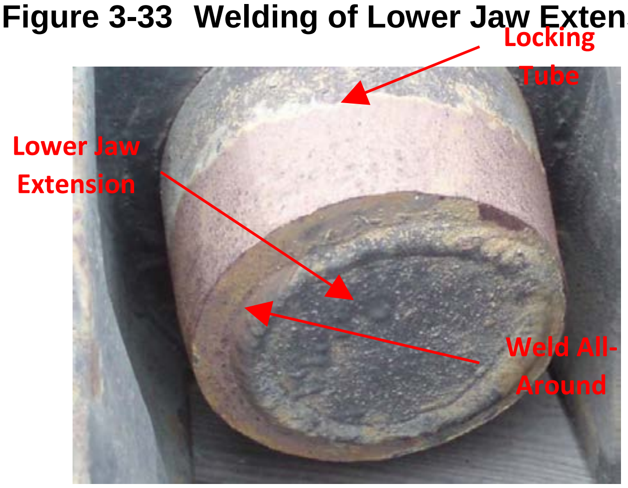


Figure 3-34 Top of Riser Swivel Shackle by Buoy

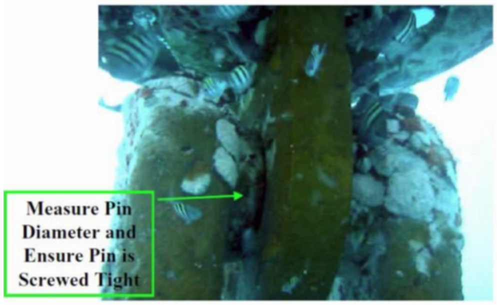


Figure 3-35 Cleaning and Inspection of Swivel Gap

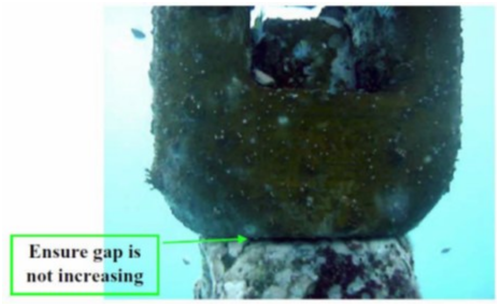


Figure 3-36 Bottom of Riser Swivel Shackle by Chain

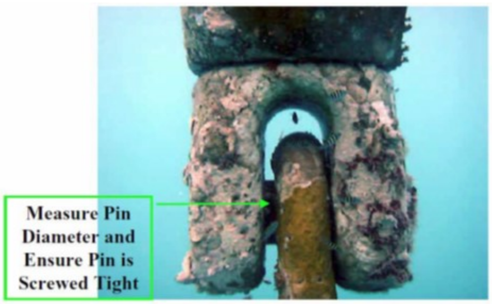
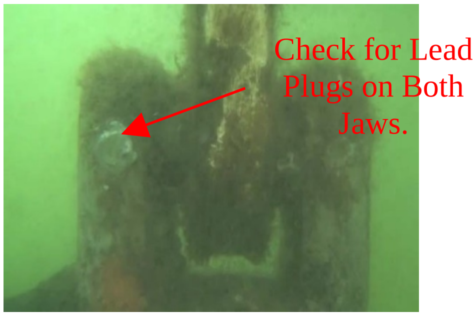


Figure 3-37 Lead Plugs in Riser Swivel Shackle Jaw



3-2.6.2.3 Anchor Bolt Shackle.

The anchor bolt shackle is inspected in a similar manner as stated in Paragraph 3-2.5.2.

- Clean the anchor bolt shackle.
- Using calipers, measure the bar diameter of the shackle’s pin between the bale of the shackle and the tension bar padeye (Figure 3-17).
- Using calipers, measure the bar thickness of the bale of the shackle by its connection points with other hardware (Figure 3-18 and Figure 3-19).
- Verify if a cotter pin or safety bolt is present on the shackle nut. Note its condition with regard to corrosion.
- Check if the nut is tight on the shackle pin (Figure 3-21).
- Check if the nut is secured to the anchor bolt with a fillet weld. Check the condition of the fillet weld.

3-2.7 Riser Chain Subassembly Inspection Requirements.

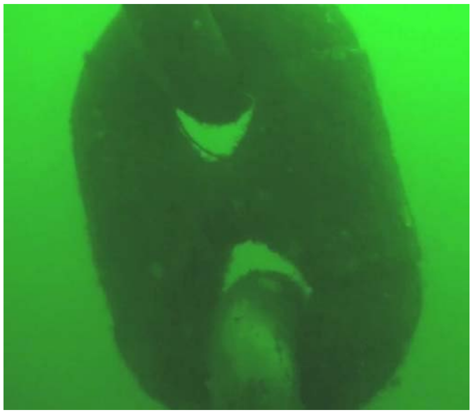
Inspection of the riser assembly includes verification of riser chain size, selective sampling and inspection of connecting hardware found along the mooring riser.

- Determine selective sampling locations in accordance with Paragraph 3-2.4.1. Clean one link near the buoy that will be the upper measurement set.
- Record type of chain found (i.e., forged, cast or Dilok).
- At the upper measurement set location, measure the overall outer length of a single link using procedures described in Paragraph 3-2.4.7
- At each measurement set, record water depth below the waterline. If the riser is laying along the seafloor, a link count referenced to the touchdown point on the seafloor or a connecting link may be used instead.
- At each measurement set, perform go/no-go gauge measurements per procedures as described in 3-2.4.5 (Figure 3-38). Record results.
- Note the presence of pitting found on any areas of links cleaned for measurements as well as on chain that is already “cleaned” in the thrash zone (Figure 3-40). Measure the diameter and depth of any pits found and record results. The length of the pits can be measured using the tape, while any probe that goes into the pit can be used to measure the depth of the pit.
- At chain joining link locations along the riser, clean off the connecting link, note type of CJL (Kenter, Baldt), report any broken, missing or loose parts and verify that a lead plug is secured in the large pin hole on top of the joining link

Figure 3-38 Double Link Go/No-Go Measurement

FM3 chain joining links are larger than the size chain they attach to (Figure 3-39). Therefore, they should look larger than the attached chain.

Figure 3-39 Chain Joining Link



Though chain joining links are the most common connection hardware found on a riser between the buoy connection and the ground ring or anchor connection, other connecting hardware may be found. They should be inspected in accordance with information provided throughout this manual.

Though most moorings have a riser made from a single size chain, some moorings use a larger size riser chain in the thrash zone. Therefore, mooring configuration drawings should be checked ahead of time and taking a link length measurement for each measurement set will prevent using the wrong size gauges.

Examples of worn chain found during inspections is shown in Figure 3-40, Figure 3-41, and Figure 3-42.

Figure 3-40 Pitting Corrosion on Chain in the Thrash Zone

Figure 3-41 Worn 3.5-inch Chain with Stud Missing

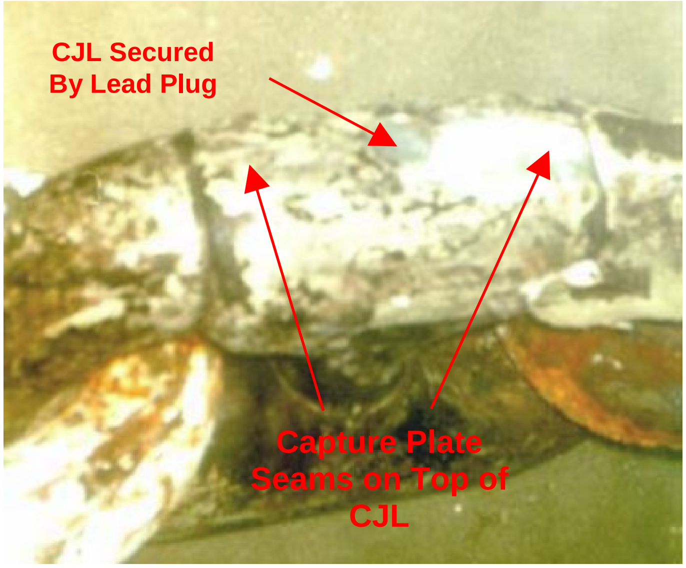
Figure 3-42 OWD <80% Chain in Mooring Thrash Zone

3-2.8 Connecting Hardware Inspection Requirements.

Chain joining links may be found along the riser and the riser is generally secured to a ground ring with an anchor joining link. The inspection process for both types of connecting links is the same. See Appendix L-3 for a video link showing the techniques to inspect chain and anchor joining links.

- Clean the connecting link of marine growth to identify the seams of the T-shaped capture plates (Baldt style-Figure 2-23 or Figure 2-25) or the link joints (Kenter-style-Figure 2-24 or Figure 2-26).
- Check the joining link for complete assembly.
- Check that the connecting link is at least equal or larger than the chain that is attached to it.
- Verify that the top pin hole on the connecting link is filled with lead (Figure 3-43). For the Kenter style joining link, there is no top or bottom pin hole. The larger hole is filled with lead while the other smaller hole is not. The large hole is located on top of the Baldt-style joining link where the T-shaped capture plate seams are located.

Figure 3-43 Lead Plug Present on CJL



3-2.9 Ground Ring Assembly Inspection Requirements.

The ground ring assembly consists of a ground ring and several anchor joining links (Figure 3-44) connecting the riser, ground legs and sometimes a sinker. Anchor joining links are inspected in accordance with the procedures outlined in Paragraph 3-2.4.8.

Figure 3-44 Ground Ring Assembly

- Check the ground ring for roundness (i.e. has it elongated in one direction?).
- Measure the inside diameter of the ground ring.
- Clean and measure the bar diameter of the ground ring near a connecting link (or at locations that show evidence of wear).

3-2.10 Sinker Connection Inspection Requirements.

Sinkers found on the riser are generally secured with a sinker shackle or a sinker hook. Sinkers found on the ground legs are generally secured with a plate shackle (Figure 3-45).

- Clean and check the plate shackle, sinker shackle or sinker hook for complete assembly.
- Check that the shackle nuts are tight on the shackle bolts.
- Check the integrity of the fillet welds that secure the plate shackle nut to the plate shackle bolt. For sinker shackles, check for the presence of a safety bolt or cotter pin.

Figure 3-45 Sinker and Plate Shackle

<u>Safety Note:</u>

Divers should inspect the connections of suspended sinkers with caution as motions imposed on the mooring system from surface weather conditions or attached vessels can cause the suspended sinker to move within the water column.

3-2.11 Ground Leg Chain Assembly Inspection Requirements.

3-2.11.1 Chain Measurements.

Ground legs are inspected using similar procedures performed for the riser chain assembly (Paragraph 3-2.7). The first measurement set is taken one to two links from the ground ring assembly. Subsequent measurement sets are performed along the ground leg every 30 feet (9.1 m) until reaching the anchor assembly or the ground leg buries into the seafloor and is no longer available for inspection. At the point of burial, a final measurement set is taken.

Connecting hardware such as chain joining links or sinker connections found along the ground ring are inspected using procedures outlined in Paragraphs 3-2.8 and 3-2.10.

Measurement sets on the ground leg will most likely include double link as well as single link measurements. As double link measurements are performed at locations where the chain is under tension, measurements taken on the suspended portions of the ground leg are usually done using double link Go/No-Go gauges. Measurements along portions of the ground leg that is lying on the seafloor may have to be performed using single link Go/No-Go gauges as the chain may be slack and gaps between the adjoining links may be present. The inspecting divers should carefully inspect the ground leg chain along the bottom to determine the correct type of Go/No-Go gauges to use.

Double and single link measurement procedures are addressed in Paragraph 3-2.4.

3-2.11.2 Compass Headings.

A compass heading should be taken for each ground leg. The compass heading should be referenced for the ground leg's direction from either ground ring to the anchor or vice-versa. The inspecting diver should record which reference was done during the inspection. Sometimes it is difficult to initially determine the ground leg direction (Figure 3-46) due to poor visibility, burial of the ground leg into the seafloor close to the ground ring, a minimal length of ground leg visible or excess slack in the mooring leg near the ground ring assembly. It is recommended that the diver swim out the leg until a consistent heading is obtained.

Figure 3-46 Ground Legs Just Below the Ground Ring

3-2.12 Anchor Assembly Inspection Requirements.

Anchors assemblies are generally buried and unable to be inspected. However, in locations having a hard bottom, embedment drag anchors may be partially buried or visible on the seafloor.

> **<u>Safety Note:</u>**
>
> While inspecting the anchors, divers should not go under the flukes or shank of the anchor.

Inspection of anchor assemblies include the following:

- Checking the connection hardware for presence of lead plugs on connecting hardware.
- Inspect the swivel gap for uniformity all around the swivel. The swivel "gap" should be minimal. For safety, the diver should not go under the anchor.
- Record whether the flukes are pointing into the seafloor or away from the seafloor. Record whether the flukes appear to be fixed or not fixed.
- Record the presence or absence of stabilizers. Check if the stabilizers are still welded along the back of the anchor crown.
- Referencing Figure 3-47, measure the width of the anchor's flukes along the backside (dimension B), the fluke length (dimension C) and the length of the anchor's shank (dimension A). This will aid in determining the size of the anchor.
- Record the presence of anchors found upside down or improperly installed (Figure 3-48 and Figure 3-49).
- Attach a plumbed surface float to the anchor crown. This can be used to obtain a location coordinate for the anchor as well as to verify the compass heading of the attached ground leg.

Figure 3-47 Stockless Anchor Nomenclature

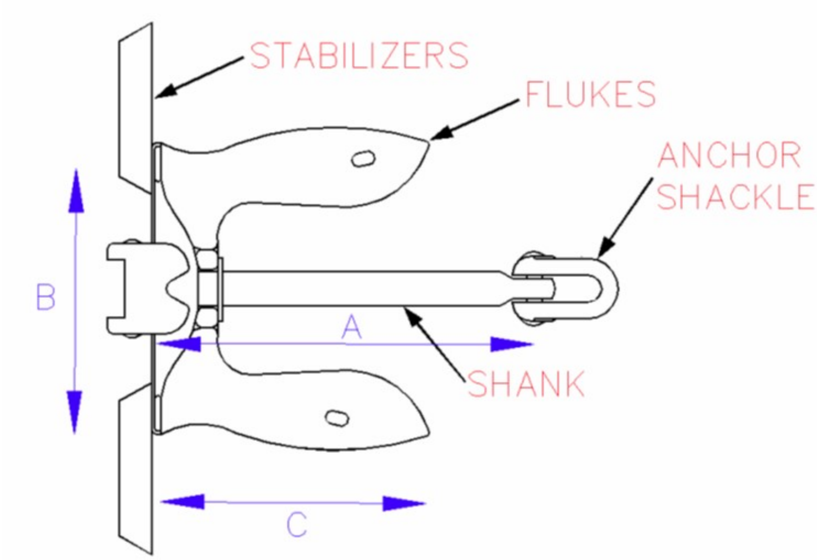


Figure 3-48 Upside Down Anchor

Figure 3-49 Upside Down Anchor and Incorrect Alignment

3-2.13 Cathodic Protection System Inspection Requirements.

3-2.13.1 Fleet Mooring Chain Link Zinc Anodes.

Records should be checked to determine if zinc anodes have been used on the mooring, but, it is pointed out that all chain used for fleet mooring ground legs and risers have been fabricated with a threaded hole in the chain link stud to attach a sacrificial zinc anode (Figure 3-50). As part of the mooring underwater inspection, zinc anodes, if present, should be inspected and replaced as required.

Figure 3-50 Zinc Anode Installed on a Chain Link

Existing zinc anodes are replaced when the anodes are less than 75% of their original size. Anodes that appear to be >75% of their original size should be tapped with a cleaning tool Figure 3-51 or a dive knife to see if the anode is actually solid or if it easily crumbles, indicating that it is spent and requires replacement. A representative anode from the riser and each ground leg should be brought to the surface and compared with a replacement anode to determine if the existing anodes require replacement.

Figure 3-51 Tapping the Zinc Anode

In addition to noting the reduction in volume of the existing anodes, divers should also check for the presence of the oxidation deposit on the zinc anodes. A whitish coating indicates that the anodes are working properly. A black coating, or no coating at all indicates that the anodes are not working properly, most likely due to a break in the metallic path (i.e. the zinc anode is not tight on the chain link, or there is some debris preventing metal-to-metal contact between the chain's stud and the anode's sleeve).

3-2.13.2 Assessment of the Chain's Cathodic Protection System.

Assessment of the chain's cathodic protection system is done either visually, or with a bathycorrometer, or both.

It is expected that zinc anodes installed previously will exhibit some degradation. This loss of individual link zinc anode material may be complete, leaving nothing more than the anode's sleeve and screw. This is common to moorings in areas with a strong tidal current and near the surface. In some cases, a good percentage of the anode will still be present. This may be found in moorings where tidal currents are relatively weak and the chain links are fully encrusted with soft coral growth.

The evidence of a white oxidation on the surface area of the individual anodes, in addition to having some percentage of depletion (remember to tap the anode with a knife or metal tool to determine its actual remaining size), will provide the inspector with an assessment of the chain's cathodic protection.

A diver-held bathycorrometer can also be used to provide a measure of the effectiveness of the cathodic protection system. (Figure 3-52).

Figure 3-52 Diver-Held Bathycorrometer

A diver held Bathycorrometer consists of a silver/silver chloride reference electrode, a self-cell, a digital voltmeter and a probe. The unit operates by measuring the potential difference between the reference electrode and the material being measured. The potential reading is displayed on a liquid crystal display.

The bathycorrometer should be soaked in water at the dive site for 20 to 30 minutes prior to initial use. In addition, the area of the chain that will be in contact with the bathycorrometer's probe must be cleaned to bare metal.

Readings between -0.80 to -0.90 Volt will indicate that the cathodic system is performing properly. After the attachment of new zinc anodes, a full day should be allowed for the cathodic protection system to set up before checking with the Bathycorrometer.

3-2.13.3 Oversize Chain Link Zinc Anodes.

When possible, oversized zincs are used to replace existing zincs to extend the cathodic protection to the next underwater inspection cycle. Table 2-5 provides recommended "oversized" zinc anodes per nominal chain size. As the length of the anode screw differs between various anode sizes, when replacing existing anodes with oversized anodes, be sure to use the screws that come with the new oversize anodes.

Note:

Regardless of using the design anode size or oversized anodes, the mounting hole must be free of debris and the anode tightened to the recommended torque for the anodes to work properly.

3-2.13.4 Replacement of Mooring Chain Link Zinc Anodes.

Mounting holes for anodes are on the same side of every other chain link in a shot as shown in Figure 3-53.

Replacement of zinc anodes is generally performed using the following procedures:

- Using an adjustable wrench or a 9/16-inch socket wrench, remove the existing anode screw and anode body from the chain link. For chain links that do not show an existing zinc anode, some cleaning of the chain link at the stud may be required to find the remaining anode. If all that is found is a screw inside a sleeve, that indicates that the anode material has been completely consumed. Pneumatic wrenches can be used as long as they are powered from a separate air source.
- Using a small brush, clean out the anode mounting hole of debris.
- Attach a new anode to the stud of the chain link using a new screw.
- Tighten the anode to the chain link by applying a torque approximately 20 to 30 foot-pounds (27 to 41 N-m).
- See Figure 3-54 for a picture of a diver attaching an anode to a chain link.

As the bolts are only 3/8-inch in diameter, applying too much torque could shear the screw. If the zinc feel's tight when grabbed by the diver's hand, it has sufficient torque to provide the necessary metallic path for the cathodic protection to properly perform.

Figure 3-53 Location of Anode Mounting Holes on FM3 Chain Links

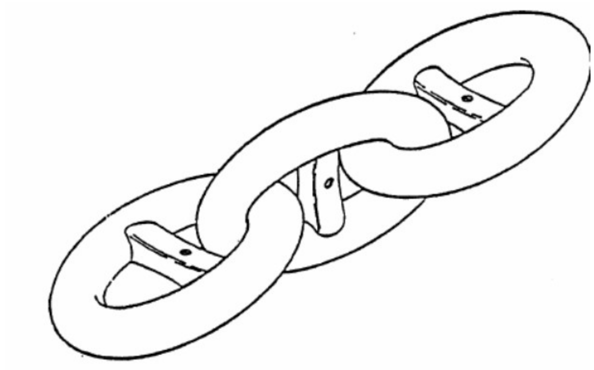


Figure 3-54 Diver Attaching Anode to Chain

Periodically, the diver will find chain links where the anode bolts were sheared at the stud during installation, preventing anodes to be attached to the chain link. The quantity of chain links unable to attach a zinc anode to should be recorded in the comment section of the mooring's inspection data sheet.

In addition to replacing the anodes on the chain, divers should replace the anodes on the bottom padeye of the buoy, see Figure 3-55.

Figure 3-55 Diver Installing a Zinc Anode on the Bottom Buoy Padeye

There are several methods that have been used on site to perform anode change out operations. Most methods involve the initial removal of the existing anodes, the initial loose attachment of new anodes followed by the tightening up of the new anodes. A supply of zincs is usually placed in a canvas bag positioned near the divers by topside support personnel. These tasks are usually divided among a dive buddy team based on diving conditions at the site, the quantity of zincs to be replaced and the direction of the dive supervisor. Divers should police up the area, removing zinc anodes and screws and all other materials.

CHAPTER 4 DOCUMENTATION OF MOORING INSPECTION RESULTS

4-1 RECORDING OF MEASUREMENTS IN THE FIELD.

Recording of measurements and observations in the field should be performed as soon as possible during the inspection to ensure that the data is not lost and that all required measurements are taken during the dive to minimize additional dives and the associated logistics to obtain the missing inspection data.

The data can be recorded by the diver using a dive slate. If topside communications are available, the information should be provided concurrently with the inspection process and recorded by topside personnel. Table 4-1 provides a list of necessary inspection data for type or mooring component to be recorded.

Table 4-1 Inspection Data

Component	Data Recorded	Comments
	Buoy Assembly Inspection Data	
Buoy Topside	Type and condition of buoy hull Diameter Freeboard Serial Plate Date (manufacturer, contract #, serial #, manufacture date) Buoy surveyed location Fender type and condition Chafe rail type and condition Reflective tape condition. Replacement of reflective tape if needed Tension bar padeye corrosion condition	Usually performed by the On-site Engineer Note type of survey system used, accuracy and datum of coordinates
Topside Jewelry	Pin diameter for shackles Pear Link measurements Assessment of cotter pins or safety bolts for shackles Wear assessment on shackles Wear assessment on pear links Serial number data on topside jewelry (spec, serial #, manufacturer) Top jewelry corrosion condition	Usually performed by the On-site Engineer
Buoy Below the Waterline	Condition of the buoy Marine growth assessment Tension bar padeye condition Wear bushing assessment	

Component	Data Recorded	Comments
Riser Assembly Inspection Data		
Riser Connecting Hardware Below the Waterline	Pin diameter for shackle or riser swivel shackle If riser swivel shackle, verify lead plugs and swivel gap measurement If anchor bolt shackle, assessment of cotter pins or safety bolt and bale measurement	
Riser	Water depth of all measurement sets Go/No-Go results for each measurement in a set Anode condition assessment (% depletion, oxidation coating) Type and amount of marine growth on riser	
Anodes	Percent remaining on existing anodes Size of replacement anodes Quantity of anodes replaced on the riser	25 – 30 ft-lbs (34 – 41 N-m) torque
Connecting Links	Type of connecting link Presence of lead plug on top of connecting link Assembly assessment of connecting link Wear assessment	Only the hole on top will be leaded
Sinkers	Assessment of attachment hardware of sinker to riser Condition of sinker	
Ground Ring	Inside diameter Bar thickness near connected components	

Component	Data Recorded	Comments
Ground Leg Inspection Data		
Ground Leg	Link distance of measurement sets from ground ring Go/No-Go results for each measurement in a set Anode condition assessment (% depletion, oxidation coating) Type and amount of marine growth on ground legs Leg compass headings to or from anchor and ground ring Location of legs along seafloor and assessment (buried or exposed, twisted, slackness, entanglement, etc.)	Single link go/no go gauges may be required
Anodes	Percent remaining on existing anodes Size of replacement anodes Quantity of anodes replaced on ground legs	25 – 30 ft-lbs (34 – 41 N-m) torque
Swivels	Presence of 4 lead plugs on open jaw swivels Gap assessment Wear assessment on pins	
Connecting Links	Type of connecting link Presence of lead plug on top of connecting link Assembly assessment of connecting link Wear assessment	Only the hole on top will be leaded
Shackles	Assessment of cotter pin and/or safety bolt Shackle nut to bolt weld assessment (except for topside shackles) Pin and bale wear assessment and measurements	
Sinkers	Assessment of attachment hardware of sinker to riser or ground leg Condition of sinker	

Component	Data Recorded	Comments
	Anchor Assembly Inspection Data	
Anchors	Type of Anchor Percentage of burial for anchors located Orientation of anchor Are the flukes fixed or free Are there stabilizers? If so, assess the condition of the weld along the anchor crown. Measure the anchor (fluke length, distance between flukes, shank length)	Note type of survey system used, accuracy and datum of coordinates
Shackles	Assessment of cotter pin and/or safety bolt Shackle nut to bolt weld assessment (except for topside shackles) Pin and bale wear assessment and measurements	
Anchor Joining Link	Type of AJL Presence of lead plug on top of connecting link Assembly assessment of AJL Wear assessment	Only the hole on top will be leaded
	Miscellaneous	
Water Conditions	Current condition Visibility Max water depth during inspection	
Seafloor	Type Presence of a crater caused by the ground ring	

An inspection form for each major component or subassembly that can be used to develop inspection slates is provided in APPENDIX D.

4-2 MOORING INSPECTION FORM.

Inspection results are recorded for each mooring using a mooring inspection form. Sample mooring inspection forms for both mooring surface inspections as well as mooring underwater inspections are provided in APPENDIX E.

The form is broken into 3 parts; (1) General Information; (2) Inspection Measurement Results; and (3) Inspection Comment Results.

4-2.1 General Information.

This section contains general information listing the following information:

- Mooring identification and report number
- Mooring assessment and condition ratings
- Mooring survey results
- Mooring zinc anode results
- Mooring buoy topside and top jewelry results

Provide both a geodetic location as well as Northing and Easting location for survey results. Provide the size and quantity of zinc anodes replaced. Provide caliper results of top jewelry measurements.

It is recommended that measurements found to be in C2 or C4 condition be highlighted in the inspection sheet.

4-2.2 Underwater Inspection Measurement Results.

This section is devoted primarily to recording the results of the Go No-Go gauge measurement sets or individual link measurements. If measuring the chain links using calipers, record these results in this section as well.

- If recording by measurement sets, record the condition % of the smallest of the 3 consecutive measurements. In the inspection comment results section, provide additional detail as to the actual measurements taken for the measurement set in the riser or ground leg block. If all measurements in a measurement set are identical, record this as “all 3 >90 (or >80 or <80)” in the condition % block.
- If recording each specific chain link measurement, then record the specific location and condition % result for each.

For riser swivel shackles and ground rings, catalog dimensions for measurement points, the nominal size of the component and the caliper measurement is recorded. Note that assessment of connecting components, presence of lead plugs, etc. are provided in the respective block on the Inspection Comment Results section.

Provide the location from waterline for riser measurements or from a well-defined reference hardware location for ground legs (i.e. the ground ring) either in feet (most commonly used for the riser) or in links (most commonly used for ground legs).

It is recommended that measurements found to be in C3 or C4 condition be highlighted in the inspection sheet.

4-2.3 Inspection Comment Results.

This section provides the inspector to record a more detailed and descriptive evaluation of the condition of the mooring for several different subjects. A minimum list of subject areas is provided in the APPENDIX F inspection forms. Additional subject areas may be added to the form as deemed necessary by the inspector. For example, a separate subject block may be provided for each specific ground leg, or inspection information on all the ground legs may just be provided under one block.

The following comment headings are provided in the basic inspection form.

General: State the final condition assessment of the mooring to include both its condition rating (i.e. C1-C4) and overall condition readiness (Maximo) value. If the mooring has been downgraded from its original design use, state the revised limitations to its usage. State what is required to return the mooring to a rating of C1 and its intended design use. Record vessel class moored to the vessel during the inspection. List marine conditions (i.e. currents, tide conditions) encountered during the inspection.

Buoy: List serial data found on the buoy. Provide supporting documentation to the buoy inspection results provided in section one.

Top Jewelry: List serial data found on top jewelry components. Provide supporting documentation to the top jewelry inspection results provided in section one. State presence or absence of cotter pins, safety bolts, lead plugs, etc. Provide any additional caliper measurements taken.

Riser: State the overall condition of the riser (i.e., good, fair, poor) and how measurements were taken (i.e. single or double link). Summarize the overall results of caliper measurements. If measurement sets have different results, then provide this detail in this section. Provide assessment to swivel shackles, connecting links and other attachments as to wear, assembly, presence/absence of lead plugs, caliper measurements, etc. State water depth of the ground ring recorded during the inspection.

Ground Legs: State the overall condition of the ground legs (i.e., good, fair, poor) and how measurements were taken (i.e. single or double link). Summarize the overall results of caliper measurements. If measurement sets have different results, then provide this detail in this section. Provide assessment to swivel shackles, connecting links and other attachments as to wear, assembly, presence/absence of lead plugs, etc. List the headings of the ground legs and the heading reference (i.e. from ground leg toward the anchor, or vice-versa). State if and when ground legs become buried and unable to be inspected. State tension condition and overall layout of the ground legs (i.e. are they slack or in tension; do they generally head in a straight line or have significant changes in headings; are they twisted with other legs, etc.). If sinkers are found, state their location and condition assessment of the sinker's attaching hardware. One may add additional blocks for each ground leg if needed.

Anchors: If anchors are found, state the overall condition of the anchors, whether they are buried and how deep, if the flukes are pointing up or down, if there are stabilizers. Record the percentage of anchors improperly installed or upside down. State the measurements of the anchors and verify the proper size. State if the anchors were surveyed (results though will be included in the survey paragraph below).

Anodes: State the size anode used for replacement. State the quantity of anodes replaced on the mooring system to include those installed on the buoy's lower tension bar padeye. State the overall assessment of the existing anodes found on the mooring system.

Marine Growth: Provide an overall condition assessment as to the type, hardness and amount of marine growth found on the bottom of the buoy, the top section of the riser, the bottom section of the riser and on the ground legs.

Survey: State whether the mooring buoy was surveyed or not. If the anchors are also surveyed, provide results in this block as well. State the type of survey equipment used and its reported accuracy. List the complete datum description used to record the survey and its surveyed reference measurements (i.e. U.S. feet or meters). State if a vessel was using the mooring during the survey. State software used for any coordinate conversions.

Bottom: State the type of soils found at the mooring.

Photo: Provide an identification photo of the mooring buoy. If the buoy identification is stenciled on the buoy, ensure that it is visible in the photo. Other specific photos from the underwater inspection of interest would be provided in section 3 of the body of the main report (Engineering Results).

It is recommended that supporting statements for C2, C3 or C4 conditions be highlighted in within the inspection comments.

4-3 INSPECTION FIELD OUT BRIEF.

A post-inspection out brief (debrief) should be performed by both the EIC and the project dive superintendent, providing initial results of the mooring inspection and any immediate revisions to the operational use of the mooring known at the time. The post-inspection debrief should be presented to the local activity custodian, but may include representatives from vessels, FEC or base tenants as local protocols dictate.

Ensure that the activity custodian knows that a preliminary inspection email providing initial inspection results will be sent out within 2 weeks and that the final inspection report will be provided within 90 calendar days.

4-4 PRELIMINARY INSPECTION EMAIL.

A preliminary inspection email is sent out by the EIC within 2 weeks of completion of the on-site inspection for underwater inspections only. The inspection message should be addressed to the local activity custodian's command as well as any activity that uses the moorings. Other commands whose responsibilities include base and mooring conditions should be included. The diving detachment's command (or private company) should also be included.

The preliminary inspection email should provide preliminary results of the inspection to include whether zinc anodes were changed out or not. The message should include contact information for the Inspector and when the detailed inspection report is expected to be released.

A sample preliminary inspection email is provided in APPENDIX E. This sample provides the body of the email.

4-5 DOWNGRADING OF FLEET MOORING SYSTEMS.

A mooring that is assessed to be in C2 or C3 condition (Fair) is downgraded to the next lower mooring class until repairs are performed to return the mooring system back to a C1 (Good) condition and satisfactory for continued fleet use.

Moorings that are assessed to be in C2 or C3 condition should be evaluated by a mooring engineer to determine what restrictions must be imposed on the mooring system until repairs can be performed to restore the mooring to its original design requirement. These restrictions can include reductions in environmental criteria before the vessel must vacate the mooring or a reduction in vessel class that can use the mooring under the original design criteria. The mooring capacity of the assessment must be within the downgraded class.

Sometimes the downgraded mooring class may not impact mooring operations at the site as the design vessel may have changed over the life of the mooring and current design requirements (i.e. a smaller class vessel) are lower than the original mooring design criteria (sometimes the inspector may find that the requirements for the mooring have increased requiring upgrades to the mooring as well as an engineering evaluation of the mooring for the new increased requirements). If the mooring was overdesigned for the design vessel (i.e. larger size components were used due to availability rather than what the design would call for) then the mooring in its interim class may still meet the original mooring requirement. Nevertheless, a full engineering evaluation of a downgraded mooring is required.

4-6 MOORING INSPECTION DOCUMENTATION REPORT.

A mooring inspection report is sent out by the EIC within 90 calendar days of completion of the on-site inspection. The inspection is provided to the local activity custodian's command as well as any activity that uses the moorings. In addition, the report should be sent to concerned higher commands as well as the inspecting organizations commands.

The inspection report is divided into three sections as described below.

4-6.1 Section One – Purpose.

This section states who, when and where the inspection was performed. It states the purpose of the inspection, as well as the use of zinc anodes. The section should include the inspection rated condition and condition readiness criteria of the mooring.

4-6.2 Section Two – Inspection.

This section provides background information on the location of the mooring systems that were inspected, their mooring configuration, the type of diving requirements used to perform the inspection, the type of survey used to perform the inspection and representative photographs of the mooring system buoys or components. To aid in inspection planning for future inspections at the location, a table should be included that lists all moorings at the location, their riser and ground leg chain sizes, the buoy type and diameter and, if appropriate, the quantity of zincs replaced during the inspection. A Points of Contact (POC) table is included at the end of Section 2, providing a listing of the points of contact for the inspection. Theses POC's are usually the Inspector, Mooring Manager, the custodian, the diving superintendent, etc.

4-6.3 Section Three – Results.

This section provides the inspection results, discussion of inspection findings, results of engineering analysis and recommendations for mooring sustainment actions, repairs, upgrades, etc.

4-6.4 References.

A separate section, after Section 3, Results, and before any Appendices. References used to document the inspection report are included here. These references will always include the design and installation reports but can also include from this guideline, mooring drawings, software analysis of the mooring, previous inspection reports, etc.

4-6.5 Documentation Report Appendices.

The following appendices are included in the inspection report document.

- **Appendix A -** Inspection Data: Provides the completed mooring inspection forms for all moorings inspected.
- **Appendix B -** Survey Results: Provides a description of the survey equipment used during the inspection, benchmarks used and surveyed location of buoys and/or anchors computed during the inspection. If using a DGPS (Differential Global Positioning System), what was used to

provide what was used to serve as the base station or what commercial service was used. The coordinates used to record results are provided in Easting and Northings as needed by the local activity or custodian. If different, results should also be provided in the same datum used for prior inspections. Results should also be provided in geodetic latitudes and longitudes, World Geodetic System 1984 (WGS84). This Appendix may also include the actual survey data and tables listing comparison of surveyed locations between the inspection and prior inspections and/or installations.

- **Appendix C -** Mooring Usage Charts: Provide a copy of the current mooring usage chart for all inspected moorings. These charts are revised in accordance with results obtained during the inspection. Actions such as downgrading the mooring, new design requirements, rated conditions below C1 would require an updated mooring usage chart be provided to the custodian.
- **Appendix D -** Mooring Property Records: Provide a copy of the current mooring property record to include the most recent mooring configuration drawings for all inspected moorings. These records are revised in accordance with results obtained during the inspection. As these records also tell the custodian when the next planned fleet mooring action is to be performed (i.e. sustainment, repair, upgrade, removal, etc.) as the next scheduled inspection, they are updated as part of the documentation of an underwater inspection.
- **Appendix E -** Engineering Analysis: This section provides support documentation of engineering analysis performed as part of the inspection report. These files may consist of wind and current force calculations, chain wear assessment, analysis input and output files, etc.

Since the mooring inspection report is standardized, completion of sections one and two are very similar in format and content to prior inspection reports for that site. The Inspector will spend the majority of his/her time completing section three as well as Appendices A. B and E (if necessary).

A mooring inspection report template is provided in APPENDIX F.

CHAPTER 5 MOORING MAINTENANCE AND REPAIR

Safety Warning:

Ensure all personnel have, maintain, and wear PPE (steel toed shoes, personal floatation vest, hard hat and other PPE for specific tasks i.e. leather gloves, safety glasses, etc.).

Daily safety briefs should emphasize everyone's responsibility for applying risk management.

5-1 MOORING STUD LINK ANODE REPLACEMENT.

Anode replacement has been covered previously, see Section 3-2.13, and is usually done as part of a mooring inspection. The method to replace these anodes is repeated here.

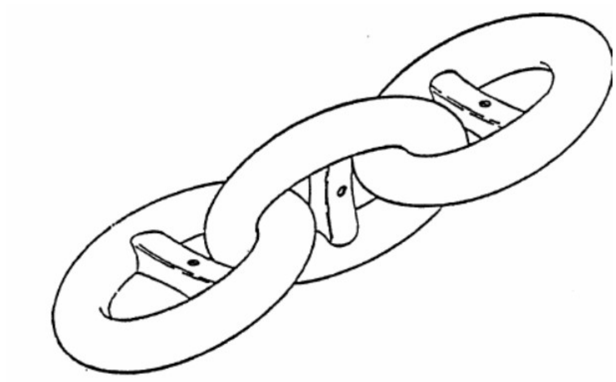
Replacement of zinc anodes is generally performed using the following procedures:

- Using an adjustable wrench or a 9/16-inch socket wrench, remove the existing anode screw and anode body from the chain link. For chain links that do not show an existing zinc anode, some cleaning of the chain link at the stud may be required to find the remaining anode. If all that is found is a screw inside a sleeve, that indicates that the anode material has been completely consumed.
- Using a small brush, clean out the anode mounting hole of debris.
- Attach a new anode to the stud of the chain link using a new screw.
- Tighten the anode to the chain link by applying a torque approximately 20 to 30 foot-pounds (27.1 to 40.7 N-m).

As the bolts are only 3/8-inch (9.5 mm) in diameter, applying too much torque could shear the screw. If the zinc feel's tight when grabbed by the diver's hand, it has sufficient torque to provide the necessary metallic path for the cathodic protection to properly perform.

Mounting holes for anodes are on the same side of every other chain link in a shot as shown in Figure 5-1.

Figure 5-1 Location of Anode Mounting Holes on FM3 Chain Links



Periodically, the diver will find chain links where the anode bolts were sheared at the stud during installation, preventing anodes to be attached to the chain link. The quantity of chain links unable to attach a zinc anode to should be recorded in the comment section of the mooring's inspection data sheet.

There are several methods that have been used on site to perform anode change out operations. Most methods involve the initial removal of the existing anodes, the initial loose attachment of new anodes followed by the tightening up of the new anodes. A supply of zincs is usually placed in a canvas bag positioned near the divers by topside support personnel. These tasks are usually divided among a dive buddy team based on diving conditions at the site, the quantity of zincs to be replaced and the direction of the dive supervisor. Diving operations shall be performed in accordance with US Navy Diving Manual (DoD dive units) or EM35-1-1, chapter 30 (non DoD dive units).

5-2 MOORING IN-SERVICE MAINTENANCE AND REPAIR.

5-2.1 Scope.

In-service maintenance and repair will be limited to the following:

- Minor underwater repairs.
- Minor buoy and riser assembly repairs.
- Replacement of damaged buoys and/or riser assemblies.

It should be noted that sufficient lift capability will be needed for replacement of buoys and/or riser assemblies and, in many instances, for repairs.

All mooring hardware must be tied down to prevent unplanned movements on the deck during transiting or from vessel motions during operations.

5-2.2 Equipment.

The following equipment must be readily available for use as needed:

- Crane barge, floating crane or vessel with lifting capacity, stability, quantity and size hooks, boom length and reach and if at all possible, means of self-mooring.
- A chain capture device (CCD) to securely stop off the chain to permit placement of the buoy onto the deck without personnel going underneath the load or in the fall zone.
- Tugboat, mule, or other vessel (for maneuvering and positioning the crane platform).
- Plenty of spare mooring connector hardware.
- High-pressure water pump (100 psi) and hose (for cleaning).
- Oxygen/acetylene kit and welder for chain cutting and welding operations.

5-2.3 Procedures.

Safety Warning:

At no time shall personnel be directly under a suspended load when the load is out of the water. Personnel on the barge deck shall be kept clear of the fall zone of the buoy and the riser chain to the maximum extent possible. The fall zone includes the area where a suspended load may fall. Personnel should be aware that the fall zone is moving as the buoy is lifted over the deck. Only qualified personnel, in accordance with EM385-1-1, under specific instruction from the designated Marine Construction Superintendent, may enter the fall zone to handle a load.

The buoy should be lifted only as high as minimally required.

Operation planning must include the use of a chain capture method that minimizes the necessity for personnel to work under suspended load.

Use a Load Indicating Device (LID) or crane equipped LID or Load Moment Indicator to determine the load for all installation/retrieval lifting operations.

Every attempt should be made to plan operations that keep DIVERS from working under the load. If no alternatives can be found, every effort should be done to minimize the diver’s time spent under the load.

5-2.3.1 Buoy Replacement (Riser-Type Mooring System).

A buoy in a riser-type mooring system can be replaced without removing the mooring. Proceed with the replacement as follows:

5-2.3.1.1 Lifting the Buoy out of the Water.

While planning the lift, make sure the type of buoy is known (foam or steel, peg-top or drum, tension bar or hawse pipe). If steel, make sure that the inspection showed no evidence of buoy flooding (visible holes, listing, etc.). Conduct pre-lift inspections of all connections on buoys prior to connection. If the buoy is flooded, it can still be lifted, but the weight of the entrapped water must be taken into account. If a tension bar buoy, make sure that there is no evidence of damage/excessive wear to the tension bar. If there is damage, it would be best to lift the buoy from the riser just below the buoy. If a steel hawse pipe buoy, then it is extremely difficult to ascertain the strength of the capture plate assembly between the riser and the buoy. Therefore, lift the buoy from the riser rather than from the top jewelry. Do not use the side pad eyes for lifting unless specific "as built" drawings of the buoy are available that a Professional Engineer can use to determine the padeye's working capacity for the planned use (i.e. lifting, lashing, maneuvering of buoy in water, small boat tie-downs, etc.). The crane should have two hooks, a main and an auxiliary of sufficient lift capacity at the working area. Use the main hook to lift from the riser and the auxiliary hook to lift and control the buoy in a 2-point pick. Attaching to the riser may require either divers to attach rigging or a heavy and long wire rope assembly to secure the mooring riser in either a choker hitch or in a basket hitch. Alternatively, remove the capture plate and lower the mooring riser to the bottom for future recovery. Recover the buoy by itself by lifting from suitable padeyes or from a chain bridle or other lifting device that is passed through the hawse pipe. The lift plan for recovery of steel hawse pipe buoys should be reviewed by a Professional Engineer. The lift plan must meet requirements of EM 385-1-1 for critical lifts as all in-water mooring lift operations are critical lifts.

On the newer foam hawse pipe buoys, the hawse pipe extends out of the urethane shell. The capture plate and its connecting bolts to the hawse pipe flange are exposed, but it is still difficult to determine the condition of the bolts. On these foam hawse pipe buoys, the existing capture plate and bolts can be replaced with new bolts and a capture plate specifically used for lift operations only.

Make sure you are familiar with crane safety and how it applies in this application. Review Paragraph 5-2.4 below on Crane Safety. Prepare and submit critical lift plans in accordance with EM 385-1-1 for acceptance by the cognizant authority. Ensure that operations are conducted within allowable wind and/or sea state conditions. It is preferable to conduct these types of operations during periods of minimal winds (moderate breeze, 11 knots or less), low tide and slack current conditions and from an anchored barge or a barge with winch operated spuds.

As floating crane or material barges generally have a freeboard between 5 to 8 feet, review the mooring drawings and water levels at the site to ensure that the mooring buoy will be able to be lifted onto the deck of the barge.

The following are generic steps for replacement of a mooring buoy:

- Bring the vessel alongside the buoy such that the crane can reach the buoy. If the vessel has its own anchors, anchor the vessel alongside the buoy. If the vessel is a spud barge, drop the spuds to the bottom to maintain position. Otherwise use the vessels drives or supporting tugboats to maintain position.
- Tie a soft line from the vessel to the buoy.
- Conduct a pre-lift briefing, if not already done so, with all personnel to include signalmen, riggers, crane operator, marine construction superintendent, safety personnel, deck winch operators and representatives from supporting tugboats.
- Rig the buoy in accordance with the accepted critical lift plan.
- Lower the crane hook(s) and attach the rigging to the crane hook(s).
- Begin taking in on the crane until the crane begins to see a load and the wire becomes taut.
- Untie the soft line from the vessel to the buoy.
- At this point, the vessel is effectively moored. The further up and out of the water, the tighter the mooring and the less movement will be seen. However, care must be taken not to overload the anchors, so continue to monitor the vessel location and use the vessels propulsion system to maintain position.
- Continue to lift the buoy until the bottom of the buoy is between 5 and 10 feet (1.5 and 3.1 m) over the chain capture device on the deck of the barge.
- Position the mooring riser into the chain capture device and secure the mooring riser into the chain capture device. One should keep at least 5 feet (1.5 m) of mooring riser chain above the chain capture device’s locking mechanism.
- Lower the buoy onto the deck (see Figure 5-2). Add blocking, bracing or tiedowns to prevent buoy rolling or movement during operations.

Figure 5-2 Mooring Riser Secured into a CCD

- Attach a secondary connection to the mooring riser, if not integral to the chain capture device. The secondary connection should be designed to support the loads as configured.
- Disconnect the mooring buoy from the riser. This can be done by either disconnecting the connecting hardware (usually either a riser swivel shackle or an anchor bolt shackle and anchor joining link) or one can cut the mooring riser (using an oxygen/acetylene torch) 2 to 3 full links above where it is secured in the chain capture device. Then use a spare chain joining link to reconnect the new buoy to the riser.

Safety Warning:

Adhere to EM 385-1-1 and OSHA 1910.253 for safe use of oxygen/acetylene torch.

- Disassemble the connections to the bottom of the buoy from the riser.
  - If the bottom connection is a swivel shackle, melt the lead plugs on the upper bale of the swivel shackle to remove the tapered pins. Place dunnage underneath the swivel shackle to prevent it from dropping onto the deck and potentially onto a worker’s foot. Using a heavy sledge hammer, remove the top swivel pin until it clears the buoy padeye. Ensure all appropriate personal protective equipment (PPE) is being used (i.e. gloves and eye protection).
- If the riser connection to the buoy is an anchor shackle-anchor joining link combination, remove cotter pins and/or safety bolts and if present, grind the weld off between the nut and pin. Place dunnage from dropping onto the deck and potentially onto a worker’s foot underneath the shackle. Take off the shackle nut and pin to disconnect it from the buoy. Melt the lead plug and using a pin punch and a sledge, knock out the tapered that holds the AJL together. ensure that the tapered pin is not knocked overboard.

Disassemble the AJL, making sure to save all the parts. Ensure all appropriate personal protective equipment (PPE) is being used (i.e. steel toes shoes, life vest, hard hat, gloves and eye protection).

- If the connecting hardware cannot be disassembled, you can cut it using a torch.
- Rig and swing the removed buoy to its storage location on the deck. It is recommended that the buoy be lifted using a 2-point pick. For hawse pipe buoys, attach rigging to the chain pigtail sticking out of the hawse pipe at both ends. For tension bar buoys, one can use the top buoy shackle as one connection point and the empty bottom buoy padeye as the other connection point. Using a 2-point lift on a tension bar pegtop shaped buoy will make it easier to place the buoy into a buoy cradle, if present or on dunnage if no buoy cradle is available. Providing that the bottom connecting hardware is in satisfactory condition, one could also attach rigging to the bottom buoy connection hardware, move the buoy to its storage location and disconnect the hardware at that location.
    - Note that as the buoy is already on its side, another option would be to flip the buoy upside down and store the buoy on its top. If doing so, one must remove the top jewelry from the top of the buoy. Bear in mind that enough dunnage is needed under the buoy to keep the top tension bar padeye or top deck capture plate assembly off the deck.
    - For either option, personnel should be clear of the moving fall zone and the buoy should be lifted only as high as minimally required.
- Disconnect the crane from the old buoy.

5-2.3.1.2 Installing the New Buoy.

The following are generic steps for installation of the replacement mooring buoy:

- Pre-rig the new buoy's bottom connection using either the removed connecting hardware or new connecting hardware.
    - Confirm that the AJL is fully assembled and lead plug is properly in place. For the buoy shackle, confirm that all the safety features are used, the cotter pin is in and spread and that the nut is tack welded to the shackle.
    - If using a riser swivel shackle, confirm that the swivel shackle is fully assembled and all 4 lead plugs are properly in place.
    - Confirm and note the manufacturing data for all components installed onto the new buoy to include the new buoy as well as the chain joining link if joining a short piece of chain to the mooring riser.
- Rig the original or new top jewelry on to the buoy. Confirm that all safety features are used on the attached top jewelry, such as cotter pins and/or safety bolts on shackles and buoy release hooks.

- If a section of the mooring riser was cut to free the old buoy, and if this cut section of chain is still in good condition, attach it to the new buoy's connecting hardware.
- Connect the crane to the new buoy using a 2-point pick to place the buoy sideways near the mooring riser. Lift the new buoy and swing it over where the riser chain is tied to the vessel. Personnel should be clear of the moving fall zone and the buoy should be lifted only as high as minimally required.
- Lower the buoy to the deck with the bottom connecting hardware of length of chain close to the bitter end of the riser. Place dunnage along both sides of the buoy to keep the buoy from rolling.
- Using a CJL, attach to riser to the chain under the buoy. Confirm that the lead plug is properly in place.
- Rig the connected buoy in accordance with the accepted critical lift plan. Disconnect the secondary connection to the mooring riser.
- Lift the buoy and swing outboard until the riser is over the chain capture device. Continue to lift until the load of the riser chain is on the crane. Once the load is off the chain capture device, release the mooring riser from the chain capture device.
- Lower the buoy into the water. When the sling is slack, tie the buoy to the ship using a soft line and then rigging from the mooring system. Untie the soft line, freeing the buoy.
- Move the vessel away from the buoy.
- Using high-pressure hose, wash the marine growth from the old buoy if permitted by local base policy. Otherwise, using flat shovels or scrapers, remove marine growth and place into plastic bags for disposal in accordance with local base policy.

An operational risk management (ORM) approach should be used to develop specific buoy replacement procedures based on local environmental conditions, project equipment and vessels and experience of the deck force.

Safety Warning:

If lifting a hawse pipe buoy, treat the lift as if the capture plate assembly is damaged and lift from below, while simultaneously lifting the buoy. On the newer ATFP and FMP foam hawse pipe buoys, the bolts that make this connection are exposed, but it is still difficult to determine the condition of the bolts. On these foam hawse pipe buoys, the existing capture plate and bolts can be replaced with new bolts and a capture plate specifically used for lift operations only.

Safety Warning:

Additional care is needed to make sure the additional loads on the crane (from lifting the ground ring out of the water) are taken into account. In addition, the stability issues based on these extra loads must also be accounted for.

Safety Warning:

If the tension bar is damaged, it is best to lift the buoy from below to take most of the weight off of the buoy/tension bar. A secondary crane hook should be used to simultaneously lift the buoy, keeping the buoy weight off the lift.

Section 5-2.3.2 through 5-2.3.6 provides an overview of some of the mooring sustainment operations. Actual procedures used are dependent on local environmental conditions, the mooring design, local environmental permit requirements, project equipment and vessels and experience of the deck force. These conditions will require the project team to develop a detailed execution plan specific to the mooring system to be repaired.

5-2.3.2 Riser Replacement.

Make sure you are familiar with crane safety and how it applies in this application. Review Paragraph 5-2.4 below on Crane Safety. Prepare and submit critical lift plans in accordance with EM 385-1-1 for acceptance by the cognizant authority. Ensure that operations are conducted well within allowable wind and/or sea state conditions. It is preferable to conduct these types of operations during periods of minimal winds (moderate breeze, 11 knots or less), low tide and slack current conditions and from an anchored barge or a barge with winch operated spuds.

Site conditions (water depth, currents, tides, predominant winds), mooring riser age and/or condition (C3 or C4), amount of chain slack (can the portion to be replaced be brought onto the deck of the work barge?) mooring configuration (riser-leg or riser-type), presence of ground legs (must the ground ring be brought on deck?, is there sufficient slack in the ground legs or must one or more be removed?), previous installation documentation will require the repair team to develop specific plans and procedures for the mooring ground leg repair operations.

The buoy removal from the mooring riser and subsequent attachment to the repaired mooring riser can be performed as described in Paragraph 5-2.3.1.2. Whether the riser is attached to multiple ground legs via a ground ring (Riser-type) or is a single riser that is attached to the anchor (riser-leg) will dictate the specific installation procedures.

For a riser-leg mooring system, the primary concern would be if the portion of the riser needing replacement can reach the deck with enough slack for the deck force to secure the riser into a CCD and perform the repairs. The local tides should be consulted and the repair procedures developed to perform the repairs at a decreasing tide level and be completed before the tide levels start to significantly increase (particularly at locations that have a large diurnal tide range). The repair team should monitor the tides to ensure that the secured mooring riser doesn't overload its deck attachments.

For a riser-type mooring system, the presence and condition of multiple ground legs will dictate the installation procedures. If the ground legs do not have sufficient slack for the portion of the mooring riser to be repaired to deck with enough slack for the deck force to secure the riser into a CCD and perform the repairs, then one or multiple ground legs may have to be removed. Additionally, any attached ground legs will need to be secured onto additional deck attachment points. Once the mooring riser is repaired, some additional chain may need to be added to the last detached ground leg to get all of the mooring system reconnected before lowering the system overboard to a point where the mooring buoy can be reattached.

An operational risk management (ORM) approach should be used to develop specific riser replacement or repair procedures based on local environmental conditions, project equipment and vessels and experience of the deck force.

5-2.3.3 Ground Leg Section Replacement

Make sure you are familiar with crane safety and how it applies in this application. Review Paragraph 5-2.4 below on Crane Safety. Prepare and submit critical lift plans in accordance with EM385-1-1 for acceptance by the cognizant authority. Ensure that operations are conducted well within allowable wind and/or sea state conditions. It is preferable to conduct these types of operations during periods of minimal winds (moderate breeze, 11 knots or less), low tide and slack current conditions and from an anchored barge or a barge with winch operated spuds.

Replacement of sections of the ground leg is usually performed on the portion of the ground leg that is connected to the ground ring.

Site conditions (water depth, currents, tides, predominant winds), mooring age and/or condition (C3 or C4), amount of chain slack (or lack thereof), mooring configuration (riser-leg or riser-type), previous installation documentation (how were the ground legs originally installed? Do they have sufficient slack? Estimated catenary forces of the ground legs once the end is recovered on deck), will require the repair team to develop specific plans and procedures for the mooring ground leg repair operations.

If only a few links need to be replaced, and there is sufficient slack in the ground legs, then each ground leg can be cut from the ground ring and the short section replaced in a similar manner as replacing a riser segment.

It is preferable to replace long sections of a ground leg using a double drum winch with two wires recovering the ground leg over a roller (see Figure 5-3) in a “hand-over-hand” procedure with the anchoring system, or tugboats, pulling the crane barge in the direction of the ground leg. The other ground legs can remain attached to the ground ring with a recovery wire attached to the ground ring or attached riser segment and to a pick-up buoy. Once the worn section of the ground leg is recovered, multiple stoppers are secured to the ground leg on the portion of the ground leg near the barge edge that will remain. One can then replace the worn portion of the ground leg in a similar manner as replacing a riser segment as described in Paragraph 5-2.3.2.

Figure 5-3 Recovery of a Ground Leg over a Roller

The repaired ground leg is placed back into the water using the double drum winch in a similar fashion, but in reverse, with the anchoring system, or tugboats, pulling the crane barge back toward the ground ring pick-up buoy.

The ground ring is recovered and the replaced ground leg reattached to the ground ring. Note that it may be required to detach the next ground leg to be repaired first.

This process is followed until all ground legs are repaired as required. The last ground leg may need to be lengthened in order to be attached to the ground ring.

An operational risk management (ORM) approach should be used to develop specific ground leg replacement or repair procedures based on local environmental conditions, project equipment and vessels and experience of the deck force.

5-2.3.4 Buoy Replacement (Non-Riser-Type Buoy).

A non-riser-type buoy will be more difficult to retrieve than a riser-type. If the mooring has been properly installed, there will be a catenary section of chain suspended in the water between the buoy and the anchor. If the catenary angle is large (as in a taut, properly installed mooring), then it may not be possible to stopper off all four anchor chain leg subassemblies on the barge deck simultaneously. It should also be noted that, in this type of installation, the buoy is kept in place by balanced opposing forces created by the catenaries of the anchor chain leg subassemblies. When one of the leg subassemblies is cut, the buoy will be pulled in the direction of the opposing leg. This pull will result in a potentially dangerous side loading (horizontal force) on the crane boom, especially if the buoy is being held aloft when the chain is cut. Connecting the replacement buoy to the anchor chain subassemblies is also difficult under these conditions. Therefore, in the case of a taut mooring, it is recommended that the non-riser buoy system be completely recovered prior to replacing the buoy, and that the mooring be reinstalled. This may involve the use of divers and cutting the chain at the seafloor. However, in many non-riser installations, significant slack exists in the anchor chain leg subassemblies directly below the buoy. In such cases, it may be possible to lift the buoy and simultaneously stopper off the legs on the barge deck. The new buoy can then be connected to the anchor chains and replaced in the water. There are actually very few of these buoys still in service with DoD, therefore procedures will need to be developed that are unique to that site.

5-2.3.5 Steel Buoy Minor Repairs.

In-service minor repairs to a steel buoy, such as replacing a fender, repairing an upper hull puncture, patching fiberglass or polyurethane, replacing anodes, replacement of the top hardware or spot painting the buoy, can be accomplished without taking the buoy ashore. In most cases, it is better to lift the buoy on to the deck rather than attempt the repair with the buoy still in the water.

Safety Warning:

Never cut or weld to the surface on an enclosed void (such as a steel buoy) until the interior has been properly ventilated and gas free. Potentially explosive gases can accumulate within the buoy.

Safety Warning:

No person should enter the buoy while the buoy is still in the water. A person should only enter the buoy when there is no possibility of the buoy sinking, i.e. either on the deck of the barge or ashore.

Entry of personnel into a buoy must comply with EM 385-1-1 and cognizant base requirements for confined space entry.

Safety Warning:

On a steel buoy, the buoy manhole cover must not be removed while the buoy is still in the water.

If a wood fender has been damaged and requires replacement, have a new fender cut to shape and holes drilled as required. While this should work, a drill and properly sized bit should be brought out to the buoy. Simply remove the bolts holding the fender in place and remove the old fender. Replace it with the new fender.

If the fender attachments have been damaged, it will be necessary to scarf off the old attachment pieces and weld on new ones. This can be done on site but must be accomplished on the deck of the barge. Never cut or weld to a surface on an enclosed void as potentially explosive gases can accumulate within the buoy. Open the manhole cover and let the buoy ventilate before any cutting or welding. A fan or blower can speed up the ventilation process. Once the interior has been properly ventilated and assured that it is gas free by a certified marine chemist, cutting and welding can occur.

If it is necessary to enter a buoy, this should be done only when the buoy is ashore or aboard a barge where there is no possibility of the buoy’s sinking. Special care must be taken to reseal the manhole and assure watertight integrity.

During the inspection of a mooring buoy, its associated top and bottom hardware should be closely inspected to determine whether any components need to be reconditioned or replaced. When reconditioning/replacement is required, the following should be observed:

- Welding chain appendages or cutting out retaining pins or rivets with a torch should never be done because heating will introduce internal stresses and reduce the strength of heat-treated steel components.
- Ensure that shackles, joining links, and other such fittings with removable parts are treated with an appropriate grease preservative and refitted. Care should be taken not to interchange matched parts of joining links. This can be avoided by tagging each part of the joining link with a unique identification number or by matching the stamped numbers on the parts. Locking pins of joining links and shackles should never be welded in place due to the probable resultant loss of tensile strength of the component.

5-2.3.6 Steel Buoy Coatings.

Because protective coatings are frequently damaged by impact or abrasion, it may be necessary to make in-service repairs to coatings of mooring buoys. In order to repair these coatings, it is necessary to first clean the exposed steel and the area surrounding the steel of rust, salt, and loose material. This can be accomplished by wire brushing the steel (preferably power wire brushing) or by scrubbing with a bristle brush and then drying the area with an air hose connected to an oil free compressor (when required). The intact coating surrounding the damaged areas should be abraded to ensure proper bond of the repair material. There are several proprietary putty-like coatings available called splash-zone compounds, that can be spread over the cleaned area, wet or dry. MIL P-28579(YD) describes such a curing epoxy-polyamide formulation. There are also available a number of proprietary brush on coatings that can be applied to damp surfaces and will cure either above or under the water. Either type of coating should completely cover the steel and extend at least 1/2 inch (13 mm) over the cleaned coating surrounding the steel.

General coating operations, materials and safety precautions are described in NAVFAC MO-110, Paints and Coatings. The recommended coating system for steel mooring buoys is the Navy epoxy-polyamide system for interior and exterior ship surfaces, MIL-DTL-24441D(SH). Procedures for its use are described in Naval Ships Technical Manual, NAVSEA S9086-VD-STM-010 and S9086-VD-STM-020. For optimal results, the coating should be applied to a clean dry surface.

Fiberglass patching should be accomplished in accordance with NAVSEA 0900-LP-006-0010. Fiberglass coating materials should be prepared and applied by personnel who have demonstrated proficiency in the application of the materials.

5-2.3.7 Foam Buoys.

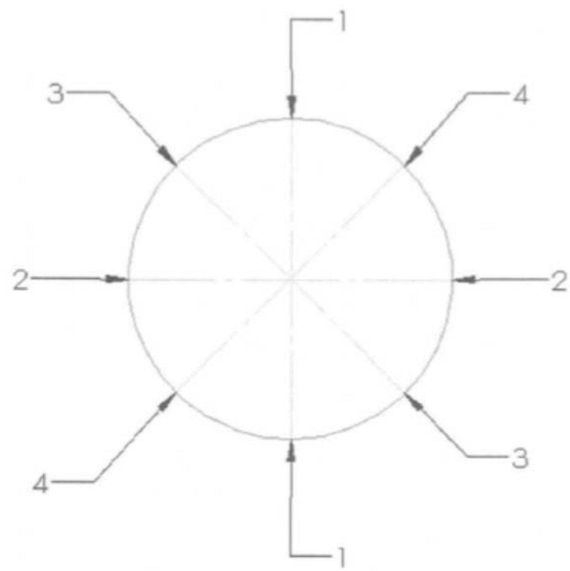
Minor damage to foam-filled polyurethane buoys can be repaired with commercially available patching kits containing the materials and procedures necessary to affect the repairs. Field repairs to the buoy hull should be limited to small rips, tears, punctures or gouges in the buoy skin and underlying foam.

The exposed tension bar and padeye on the tension bar should be cleaned to SSPC-SP3, Power Tool Cleaning and meet acceptable standard as listed in SSPC VIS-3 to permit proper inspections. The exposed tension bar and padeye should be coated with a phenalkamine epoxy meeting NAVSEA MIL-PRF-24647 to provide a dry film thickness of 8 to 12 mils. A topcoat of an aliphatic acrylic polyurethane finish having a dry film thickness of 2-4 mils should then be applied.

Chipped or missing paint on the padeye can be touched up with an epoxy-polyamide coating applied in accordance with MIL-C-22751D.

The bushing in the padeye should be inspected and replaced if the bushing has lost 50% or more of its original thickness (1/4-inch) or is severely corroded. To inspect the bushing, clean off rust and other debris using a steel wire brush. Using inside calipers, measure the inside diameter of the tension bar padeye with the bushing (Figure 5-4). Determine the remaining minimum thickness of the bushing by reviewing the buoy drawings to determine the original inside diameter of the bushing, padeye and bushing thickness.

Figure 5-4 Bushing inspection Points



If the bushing needs to be replaced, a new bushing of same size and material conforming to Abrasion-Resistant Bushing steel, ASTM A519, Grade 4140 should be used. Replacement bushings should be fabricated ahead of time to have onsite during foam buoy field refurbishment operations. Remove the existing bushing using a small right-angle grinder having a thin cut off wheel that can pass through the bushing, or a reciprocating saw with a 6 inches long blade. Care must be taken that you don’t cut into the padeye itself. The appropriate PPE should be worn (specifically gloves and safety glasses).

Installation of the replacement bushing requires an interference fit of 0.001 to 0.004 inch (0.025 to 0.102 mm) radially. Clean and debur the inside of the padeyes to remove any sharp edges for the bushing to hang up on. Sand the edges and inside diameter of the padeye smooth and clean with rags and a degreaser.

Apply an epoxy adhesive to the inside diameter of the padeye just immediately before the bushing is installed.

The bushing should be cooled with liquid nitrogen to cause it to shrink in size and allow for it to be installed into the padeye. The bushing should be handled with pliers when placing into the liquid nitrogen and into the tension bar padeye. In addition to standard PPE for barge operations (steel toed, shoes, floatation vest, hard hat) leather gloves and safety glasses should be worn.

If the padeye was found to be enlarged in one area, it may need to be rounded out and an evaluation be made if the tension bar padeye is still strong enough to meet its design requirements for the mooring. Unless spare bushings having a larger outer diameter are available, a standard sized bushing may have to be used with a high strength epoxy to fill the gap. The mooring system may have to be downgraded until the buoy is replaced.

If there is a chance for bushing replacements to be performed during field repairs, it may be more cost efficient to replace the foam buoy with a spare foam buoy and complete foam buoy refurbishment ashore.

Replacement of the reflective tape involves removal of the old tape using a wide scraper and removing remaining adhesives from the buoy shell using warm soapy water, isopropyl alcohol or a biodegradable cleanser. Apply the replacement reflective tape tightly around the buoy shell using a squeegee insuring that air bubbles are removed. Attach the top band 6 inches below the buoy deckline and the next band 6 inches below the top band so that both tape bands are in the top 2 feet from the top deck of the buoy (mooring buoys should maintain an average minimum freeboard of 2 feet below its deckline). Note that for the standard small and medium foam buoys applying the reflective tape just above and just below its single urethane fender will keep both tapes within the top two feet.

As it is much easier to be replaced when the buoy is on deck, replacement of reflective tape should always be part of mooring repair operations that involve recovery of the buoy. However, though it is more difficult, the reflective tape can be replaced with the buoy in the water from a small boat.

Reflective tape replacement should be planned to be performed as part of the three-year underwater inspection.

Major repairs on foam buoys should be undertaken only with the advice and assistance of the buoy manufacturer.

should be undertaken only with the advice and assistance of the buoy manufacturer.

5-2.4 Crane Safety.

See APPENDIX B for a discussion of crane safety.

5-3 MOORING INSTALLATION AND REMOVAL OPERATIONS OVERVIEW

5-3.1 Scope

Installation and removal operations overview will be limited to the following:

- Installation of a drag embedment riser-type or riser-leg mooring system.
- Installation of an embedment anchor riser-leg mooring system.
- Removal of a drag embedment riser-type or riser-leg mooring system.
- Mooring anchor pull test.

This section provides an overview of some of the mooring installation operations. Actual procedures used are dependent on local environmental conditions, the mooring design, local environmental permit requirements, project equipment and vessels and experience of the deck force. These conditions will require the project team to develop a detailed execution plan specific to the mooring system to be installed, modified, repaired or removed.

All mooring hardware must be tied down to prevent unplanned movements on the deck during transiting or from vessel motions during operations.

5-3.2 Equipment

The following equipment must be readily available for use as needed:

- Crane barge, floating crane or vessel with sufficient lifting capacity, stability, quantity and size hooks, boom length and reach and if at all possible, means of self-mooring.
- A chain capture device (CCD) to securely stop off the chain to permit placement of the buoy onto the deck without personnel going underneath the load or in the fall zone.
- Tugboat, mule, or other vessel (for maneuvering and positioning the crane platform).
- Spare mooring connecting hardware.
- High-pressure seawater (100 psi) pump and hose (for cleaning) for removal operations.
- Oxygen/acetylene kit and welder for chain cutting and welding operations.

5-3.3 Procedures Overview

Safety Warning:
Every attempt should be made to plan operations that keep personnel from working under the load. If no alternatives can be found, every effort should be done to minimize the time spent under the load.

5-3.3.1 Drag Embedment Riser-Type or Riser-Leg Installation

Safety Note:
While preparing the anchors, positioning on deck for deployment and deploying the anchor, personnel should not go under the flukes or shank of the anchor.

Make sure you are familiar with crane safety and how it applies in this application. Review APPENDIX B on Crane Safety. Prepare and submit critical lift plans in accordance with EM385-1-1 for acceptance by the cognizant authority. Ensure that operations are conducted well within allowable wind and/or sea state conditions. It is preferable to conduct these types of operations during periods of minimal winds (moderate breeze, 11 knots or less), low tide and slack current conditions and from an anchored barge or a barge with winch operated spuds.

Site conditions, such as water depth, currents, tides, predominant winds, soil conditions (type soil, bottom slope), environmental constraints and restrictions (presence of corals, mammal watches, construction window, turbidity constraints, eelgrass, etc) as well as available installation vessels (type and capacity of floating crane barge, tugboats and material barges) and the mooring system design (number of legs, type of drag embedment anchors, length of ground legs, allowable ground leg slack, chain sizes, etc) will require the installation team to develop specific plans and procedures for the mooring installation operations.

For a drag embedment mooring system installation, unique concerns would be the (1) Anchor's fluke angle; (2) Orientation of the anchor as placed on the bottom; and (3) Its final location after proof testing.

The soil conditions will dictate the desired angle between the anchor flukes and the anchor shank (fluke angle). Most drag embedment anchors typically used, such as the common U.S. Navy stockess anchor, STATO and NAVMOOR anchors have a desired fluke angle for mud or sand/stiff clay or hard bottom conditions. Though the stockless anchor with flukes fully open is at the fluke angle for mud condition, it is still recommended to fix the flukes at the fully open position to ensure that it will bury into the soil during proof testing. Not fixing the flukes to its desired fluke angle may lead to excessive drag distances to meet the proof load or failure of the anchor to meet the proof load. The above drag embedment anchors should be equipped with stabilizers to reduce the risk of the anchor rolling during proof testing. Typical drag embedment anchor features are shown in Figure 5-5. Fluke angles for sand or mud for these typical drag anchors are shown in Figure 5-6.

Figure 5-5 Features of a drag anchor

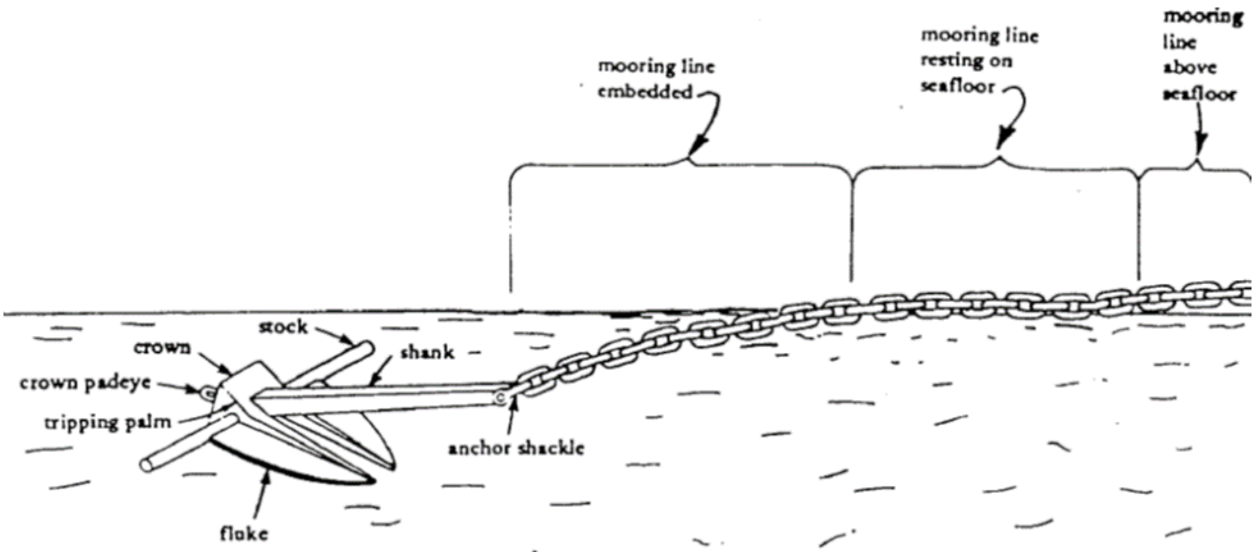
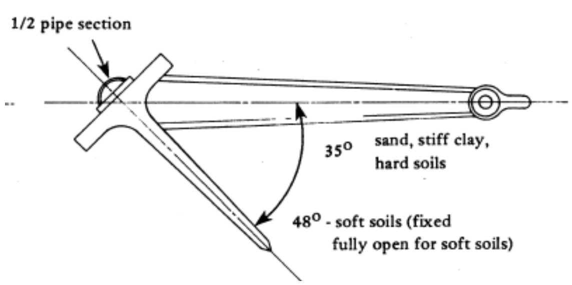
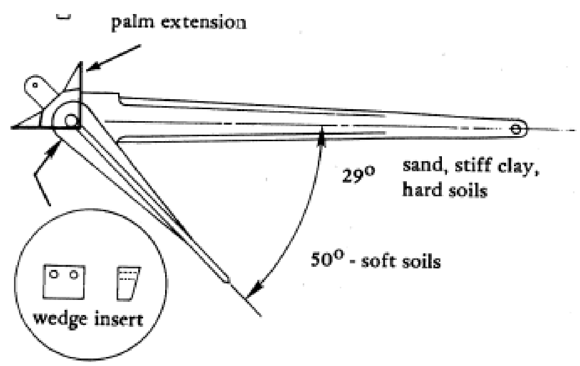


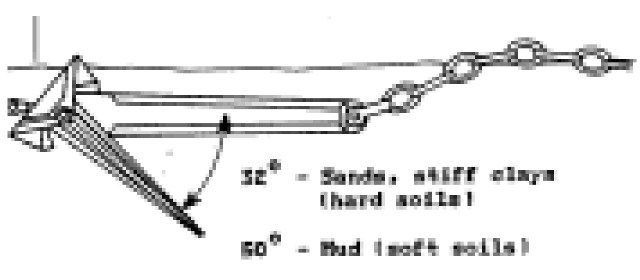
Figure 5-6 Fluke Angle Recommendations



Navy Stockless Anchor



STATO Anchor



NAVMOOR Anchor

High capacity drag embedment anchors such as the NAVMOOR come with a sand wedge that can be welded onto the shank if soils are not soft/mud conditions (see

Figure 2-19). Otherwise, steel plate or bar can be used to lock the flukes in the desired angle (see Figure 2-18 for a stockless anchor).

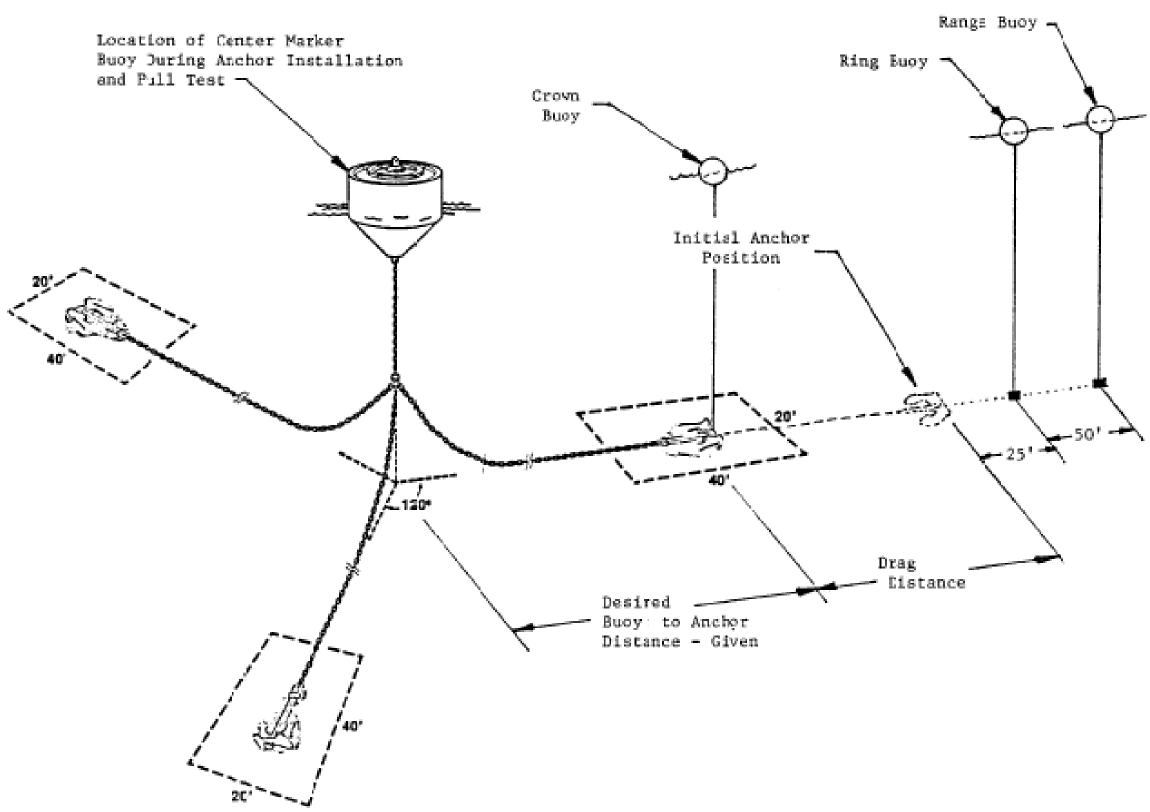
Once the flukes have been fixed, the anchor needs to be placed on the bottom with the flukes angled down toward the bottom and not toward the surface. As most locations, water depth is less than 50 FSW (MLLW) and floating crane barges with sufficient boom height will allow for a stockless anchor to be rigged and lowered in a horizontal configuration (Figure 5-7, NAVMOOR and Figure 5-8). Care must be taken to ensure that the attached ground leg chain does not impose any significant lateral tension on the anchor during deployment and initial touchdown. Lowering the anchor in a vertical orientation with its crown onto the seafloor risks the anchor's flukes not digging into the seafloor and the anchor sliding along the seafloor; particularly for the stockless anchor in soft sediments.

Figure 5-7 NAVMOOR Anchor Deployment

Figure 5-8 Stockless Anchor Deployment

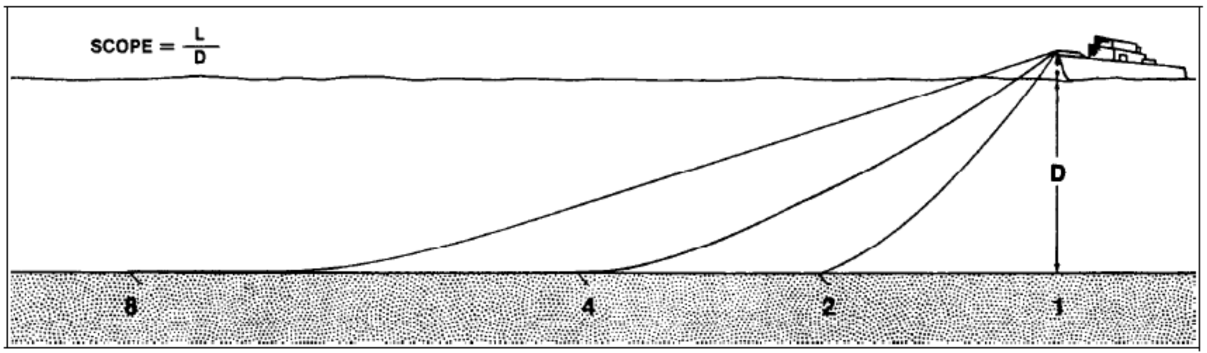
Several technical references are available to estimate drag distances for various types of drag embedment anchors. Drag distance is dependent on (1) soil conditions; (2) depth of the soil as there must be sufficient depth of soil for the anchor to develop its resistance; (3) fluke length; and (4) anchor line scope. For typical drag embedment anchors such as stockless, STATO or NAVMOOR, in addition to UFC 4-159-03, technical references such as ex-Naval Civil Engineering Laboratory (NCEL) tech data sheet 83-09 (Stockless and STATO anchor) and 87-05 (NAVMOOR) provide guidance on estimating drag anchor distances. Additionally, APPENDIX H provides drag distance tables taken from NAVFAC MANUAL MO-124. During installation operations, a marker buoy is placed both at the mooring center (where the buoy would ideally be) and at the location to initially place the anchor as well as a range marker to aid the installation team as shown in Figure 5-9. A crown buoy is also attached to the anchor.

Figure 5-9 Anchor Placement Allowable Area



As drag anchor capacity is based on a near horizontal orientation of the attached ground leg (6^{O} or less), it is important to proof test the anchor along the design direction of the ground leg and at an anchor line scope of 10:1 (10 feet of anchor line per foot of water depth) as shown in Figure 5-10. If the anchor ends up further away from its design distance to the mooring center (buoy), additional chain can be added to the ground leg (a reason to have spare chain and connecting hardware on site). However, if the anchor ends up closer to the mooring center, the ground leg may not have sufficient scope for the anchor to meet its design load at the desired factor of safety. Though this can be modified by the addition of sinkers along the ground leg, spare sinkers are usually not available and the anchor may have to be recovered and reinstalled at a location further away from the initial drop point and slightly off to one side to avoid the anchor dragging into the disturbed soil from the first proof test. APPENDIX I provides an extract from MO-124 of general installation procedures for a drag embedment riser-type mooring system.

Figure 5-10 Drag Embedment Anchor Proof Test Orientation



Scope is the ratio of length of rode (L) to depth of water (D), plus allowance for heigth of bow above water. At (1) length of rode equals the depth. At (2) rode length is twice the depth, at (4) four times the depth. Note how the angle between rode and bottom decreases. At (B) the scope is 8:1 and the short length of chain at the anchor lies flat on the bottom.

For all drag embedment anchor installation operations, all plans and procedures should ensure the following:

- Only qualified welders and riggers are used.
- Connecting links are secured with lead.
- Underwater shackles are secured.
- Ground legs or riser-legs are installed without twists and along its design path on the seafloor within 5 degrees.
- Data on all installed mooring components, such as manufacturer, specification, size, year of manufacturer and serial number are recorded from the anchor to the buoy.
- Critical lift plans are developed, reviewed and accepted by the cognizant authority.
- A roller or curved surface should be placed over the edge of the barge for ground leg deployment.
- A CCD is used.
- Hard points where rigging is to be positioned are protected with softeners.
- Rigging is designed and certified and with sufficient capacity, as placed, to withstand planned tensions with a recommended reserve of 25%. Rigging shall meet requirements of EM 385-1-1, as well as NAVFAC P-307 or the applicable agency document.

An operational risk management (ORM) approach should be used to develop specific riser-type or riser-leg drag embedment anchor mooring system installation procedures based on local environmental conditions, project equipment and vessels and experience of the deck force. APPENDIX J provides an extract from MO-124 of general procedures for drag embedment anchor pull testing.

5-3.3.2 Drag Embedment Anchor Riser-Type or Riser Leg Removal

Make sure you are familiar with crane safety and how it applies in this application. Review APPENDIX B on Crane Safety. Prepare and submit critical lift plans in accordance with EM385-1-1 for acceptance by the cognizant authority. Ensure that operations are conducted well within allowable wind and/or sea state conditions. It is preferable to conduct these types of operations during periods of minimal winds (moderate breeze, 11 knots or less), low tide and slack current conditions and from an anchored barge or a barge with winch operated spuds.

Site conditions, such as water depth, currents, tides, predominant winds, soil conditions (type soil, bottom slope), environmental constraints and restrictions (presence of corals, mammal watches, construction window, turbidity constraints, eelgrass, etc) as well as available installation vessels (type and capacity of floating crane barge, tugboats and material barges) and the mooring system design (number of legs, type of drag embedment anchors, length of ground legs, ground leg slack, chain sizes, etc) will require the installation team to develop specific plans and procedures for the mooring removal operations.

For a drag embedment mooring system removal, unique concerns would be (1) Removal of the initial ground leg; and (2) Break out of the buried drag embedment anchor.

For some riser-type mooring systems where there is insufficient slack, one or more ground legs may have to be disconnected from the common ring by divers cutting a chain link on the ground leg near the common ground ring using underwater cutting techniques. Underwater cutting (Figure 5-11) is performed using surface supply diving techniques and specific dive and crane operating procedures and diver safety requirements in accordance with the US Navy Diving Manual or EM 385-1-1 will need to be adhered to.

Once the first ground leg is cut off, it can be recovered by the installation team. The remaining 2 ground legs can be brought on deck and 1 ground leg cut off topside and then recovered as well.

The amount of force needed to free the drag anchor will depend on (1) Size and type of drag embedment anchor; (2) type of soils; (3) embedment depth; (4) time the anchor has been installed; and (5) whether the anchor was proof tested during installation or has been loaded to its design load during operational use.

As drag embedment anchors are designed to withstand horizontal forces by soil resistance on the face of the flukes that face the ground leg, recovery of the anchor is best accomplished by either (1) Applying a vertical force once the crane barge is directly over the anchor; (2) pulling the anchor in the opposite direction to how it is installed; or (3) A combination of both.

Figure 5-11 Navy Diver Cutting Connecting Shackle

Drag anchors embedded in sands can achieve their holding capacity with minimal burial (1 to 2 fluke lengths) while drag anchors embedded in soft sediments bury deeper to achieve their holding capacity (2.5 to 4.5 fluke lengths). Breakout of a drag anchor will be more sudden in sand and more gradual in soft sediments.

The ground leg should be attached to the primary hook of the floating crane barge with strong rigging that has a working load equal to the maximum load that the crane can apply based on its load chart. Breakout of 9-ton NAVMOOR anchors proof tested in soft sediments in New York City harbor for one week were on the order of 60 to 70 tons during recovery operations.

When applying a vertical load over the embedded anchor, the load should be applied in a slow manner and gradually building up to the allowable load that can be applied by the crane and or attached rigging and ground leg hardware. The load should be carefully monitored by a calibrated load cell rigged in line between the ground leg and the crane hook. It may be best to slowly reduce the load to no less than the weight of the anchor and suspended ground leg and then repeat the load every 10 minutes.

Breakout of the anchor will be seen by a reduction in load tension along with the raising of ground leg chain out of the water. Once this is noticed, the load can be held and then reduced as needed as the anchor comes out of the seabed (Figure 5-12). This technique is more suitable for soft sediment conditions than sand conditions.

Figure 5-12 NAVMOOR Anchor Recovery

For sand conditions as well as soft sediments, one can secure the end of the ground leg chain to a suitable deck attachment point on a tugboat or the crane barge and then transit the tugboat or barge in the opposite direction of how the anchor was initially set. This technique may need to be repeated to free the anchor.

Other techniques such as jetting or securing the ground leg to a deck fitting overnight to allow for an incoming tide to break the anchor free may need to be considered. Jetting will require divers and additional equipment and may not be practical due to time (cost) constraints. Calculations will be needed to ensure that any deck connection used to secure the ground leg will not break off when using the tide to free the anchor. For most applications, gradual vertical lifts on the anchor from a floating crane barge and/or with pulling the anchor it its opposite set direction will be suffice in recovery of the anchor.

APPENDIX I provides an extract from MO-124 of general installation procedures for a drag embedment riser-type mooring system.

For all drag embedment anchor removal operations, all plans and procedures should ensure the following:

- Only qualified welders and riggers are used.
- Critical lift plans are developed, reviewed and accepted by the cognizant authority. Break out of the anchor would be a critical lift.
- A roller or curved surface should be placed over the edge of the barge for ground leg deployment.
- A CCD is used.

- Hard points where rigging is to be positioned are protected with softeners.
- Rigging is designed and certified and with sufficient capacity, as placed, to withstand planned tensions with a recommended reserve of 25%. Rigging shall meet requirements of EM 385-1-1, as well as NAVFAC P-307 or the applicable agency document.

An operational risk management (ORM) approach should be used to develop specific riser-type or riser-leg drag embedment anchor mooring system removal procedures based on local environmental conditions, project equipment and vessels and experience of the deck force.

APPENDIX K provides an extract from MO-124 of general removal procedures for a drag embedment riser-type mooring system.

5-3.4 Embedment Anchor Installation

Make sure you are familiar with crane safety and how it applies in this application. Review APPENDIX B on Crane Safety. Prepare and submit critical lift plans in accordance with EM385-1-1 for acceptance by the cognizant authority. Ensure that operations are conducted well within allowable wind and/or sea state conditions. It is preferable to conduct these types of operations during periods of minimal winds (moderate breeze, 11 knots or less), low tide and slack current conditions and from an anchored barge or a barge with winch operated spuds.

Site conditions, such as water depth, currents, tides, predominant winds, soil conditions (type soil, bottom slope), environmental constraints and restrictions (presence of corals, mammal watches, construction window, turbidity constraints, eelgrass, etc), available installation equipment (follower and hammers), installation vessels (type and capacity of floating crane barge, tugboats and material barges) and the mooring system design (plate anchor size, required embedment depth, required pull test type and load, chain sizes, etc) will require the installation team to develop specific plans and procedures for the mooring installation operations.

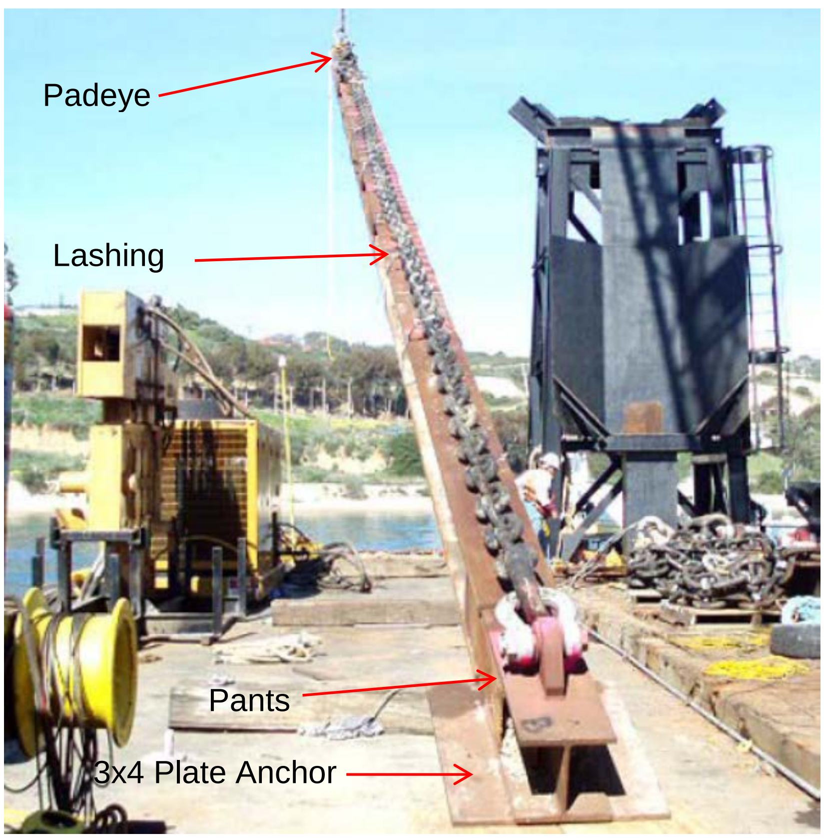
For an embedment mooring system installation, unique concerns would be the (1) Plate (or pipe) anchor follower system rigging and handling; and (2) Driving hammers.

A follower is a beam that is used to embed the plate anchor into the seabed to its required tip depth. It is usually a W14x283 beam but can also a combination of pipe with a W14x283 stinger. The length of the stinger is based on the required embedment depth for the anchor as well as its structural resistance to bending. The anchor end of the follower has an extension, commonly referred to as the “pants” that slides over the plate anchor beam to capture the plate anchor. Lifting as well as chain padeyes are found on the hammer end of the follower. The padeyes are spaced below the top of the follower to allow for placement of the driving hammers. The length of the follower is determined by the required plate (or pipe) anchor embedment depth, water depth, tides and barge freeboard.

Unlike conventional pile driving for piers and wharves where refusal criteria will govern the capacity of the pile for bearing, multiple variables in the plate anchor capacity equation are related to the embedment depth below the seafloor for the plate anchor. At locations with little or no knowledge of the soils, a soil boring may need to be obtained and a wave equation analysis (WEAP) may need to be performed to determine the required hammers to drive the anchor to its design tip depth.

The initial shot of mooring chain is stretched tight along the top of the follower and secured to a suitable turnbuckle. The total length of chain should be kept to 1 shot, but it must be long enough for deck personnel to secure to a barge deck fitting once the anchor has been driven to its tip elevation. Wire rope lashing is spaced out at an interval between 5 to 10 feet to tightly secure the chain to the follower. A rigged follower is shown in Figure 5-13. Rigged follower means that the anchor and mooring chain are secured on the follower.

Figure 5-13 Rigged Follower



The follower design should be performed by a Professional Engineer to ensure that it is structurally strong enough for driving and well as lifting operations to include both chain and lifting padeyes.

Lift plans should be detailed for handling of the follower at all stages to include positioning an empty follower onto the barge, lifting the rigged follower to be placed into its template (Figure 5-14) and lowering the empty follower onto the barge after extraction of the follower.

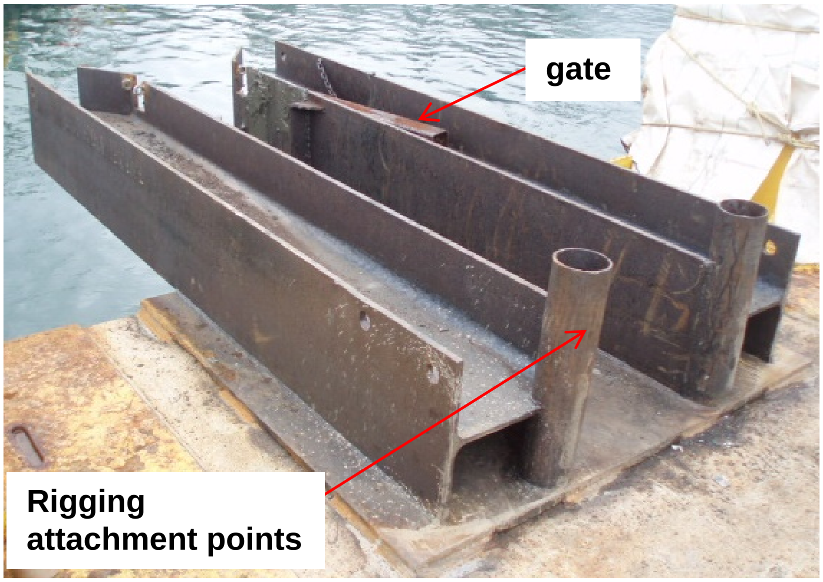
General steps for follower rigging and handling include:

- Positioning of the follower on dunnage on the crane barge or material barge.
- Positioning of the plate anchor into the follower pants
- Laying out the initial shot of chain along the top of the follower.
- Securing the rigged mooring leg tightly on the follower.
- Attaching lift rigging as well as safety rigging.
- Inspecting the follower and completing the follower checklist.
- Lifting the follower to a vertical position near the template in accordance with the accepted lift plan. Softeners such as welded slotted pipe should be used at locations along the follower where lifting rigging will come into contact.
- Positioning the follower into the template and lowering the follower until its weight is supported by the seabed. The follower is plumbed and template gate (lateral piece of steel used to help alignment of the follower and prevent it from coming out of the template if the rigged follower self-penetration is minimal) is closed.

Another piece of equipment needed for follower operations is either a manlift or a man basket. These are needed for personnel to disconnect lift rigging from the follower to free the crane hooks for lifting of the hammers. They will also be used at the end to reattach lifting rigging to remove the follower from the template. Both pieces of equipment have specific safety requirements for both personnel and equipment operation that are found in EM 385-1-1. Deck personnel will be needed to be trained in the use of fall protection.

The follower is usually positioned with the chain facing the barge for ease of operations by deck personnel. For hard clay or sand soil conditions, it is not important for the plate anchor padeye to be aligned along the design path of the mooring leg as the chain will be vertical at the anchor. This can be calculated using the program Chain-Soil Analysis Program (CSAP) and the anchor depth adjusted during the design period to ensure the chain is vertical. However, for soft sediment conditions, it is important for the padeye to be aligned with the design path of the mooring leg as the chain will not be vertical at the padeye.

Figure 5-14 Follower Template



Once the follower is positioned in the template, its weight supported by the seabed and lifting rigging detached, it is ready to be driven using conventional pile driving techniques.

Most embedment anchor installation operations have both a vibratory and an impact hammer. The vibratory hammer is generally used to extract the follower from the embedded anchor and the impact hammer is used to drive the embedment anchor to its design tip depth. For sand and mud conditions, the vibratory hammer can be used to drive the anchor partway or to its design tip depth.

Driving the rigged follower is similar to conventional pile driving operations to include operating the hammers and completing a driving record. The follower is also marked at 1-foot increments with the forward edge of the plate (top of pipe) anchor being the "zero" mark.

Unlike conventional pile driving operations, a chain is attached to the beam being driven. This chain usually has chain link zinc anodes attached on all chain links or on an upper portion. As the screws for the zinc anodes are only 3/8-inch and designed to secure the zinc anode at a 20 to 30 foot-pound torque, personnel need to be aware of zinc anodes falling off during driving operations, particularly when the vibratory hammer is being used. Several wraps of electrical tape will reduce the potential for zinc anodes from falling, but it is still a safety concern so deck personnel need to stay clear.

The design of the padeye as well as the addition of the mooring chain will increase the driving resistance of the rigged follower. Additionally, the anchor center of gravity will not be aligned with the follower and attached chain. This will create a bending moment to be generated each time the rigged follower is hit with the hammer. At locations with hard soils with multiple anchors to be embedded, spare follower sections/stingers will need to be available to perform repairs to the lower section of the follower. Bending usually occurs near the joint between stinger and pipe (Figure 5-15) or at the point along a W14x283 where lateral stiffener plates end or the upper embedment of the follower into a hard soil layer.

Figure 5-15 Bent Follower Stinger

Once the follower is extracted, a suitable sea water pump will be needed to remove the plug of soil that normally forms within the flanges of the follower at cohesive soil conditions. As the extracted follower will form a vertical plug below the seabed, sometimes steel plate is welded between the flanges to stiffen the follower at the bottom end. However, this adds additional cost and weight to the follower.

For all embedment anchor installation operations, all plans and procedures should ensure the following:

- Only qualified welders and riggers are used.
- Connecting links are secured with lead.
- Underwater shackles are secured.
- Data on all installed mooring components, such as manufacturer, specification, size, year of manufacturer and serial number are recorded from the anchor to the buoy.
- A rigged follower lift plan is developed by a Professional Engineer, reviewed and accepted by the cognizant authority.
- Critical lift plans are developed, reviewed and accepted by the cognizant authority.
- The follower design, to include associated attachment padeyes is performed by a Professional Engineer.

- A follower checklist is developed and completed prior to lift operations to verify the anchor and mooring chain is properly configured, oriented, positioned, secured along the follower, component data is recorded and lift rigging is correctly positioned according to the accepted lift plan.
- A driving record is completed to include information on the type hammer, fuel setting, recording of blow counts per foot of driving, water depth, tide, average blow count per minute, start and end times, type of follower and helmet/cushions used, final anchor tip depth to include adjustment to required datum (i.e. MLLW, etc.) and final anchor horizontal anchor location in required datum (i.e. Northings and Eastings to state plane or UTM coordinates, etc.).
- A CCD and a follower template are used.
- Hard points where rigging is to be positioned on the follower are protected with softeners.
- Rigging is designed and certified and with sufficient capacity. Rigging shall meet requirements of EM 385-1-1, as well as NAVFAC P-307 or the applicable agency document.

An operational risk management (ORM) approach should be used to develop specific embedment anchor mooring system installation procedures based on local environmental conditions, project equipment and vessels and experience of the deck force.

5-3.5 Mooring Anchor Pull Tests

Make sure you are familiar with crane safety and how it applies in this application. Review APPENDIX B on Crane Safety. Prepare and submit critical lift plans in accordance with EM385-1-1 for acceptance by the cognizant authority. Ensure that operations are conducted well within allowable wind and/or sea state conditions. It is preferable to conduct these types of operations during periods of minimal winds (moderate breeze, 11 knots or less), low tide and slack current conditions and from an anchored barge or a barge with winch operated spuds.

Site conditions, such as water depth, currents, tides, predominant winds, soil conditions (type soil, bottom slope), installation equipment (winches and multi-part blocks), available installation vessels (type and capacity of floating crane barge, tugboats and material barges), type of anchor (drag embedment or embedment anchor) and type of pull test (vertical or horizontal) will require the installation team to develop specific plans and procedures for the mooring pull test operations.

Unlike mooring hardware, mooring anchor pull tests are used to proof the installed anchor to only its design load. Plate anchors and high capacity drag embedment anchors have a design load factor of safety of 2 to its ultimate holding capacity. Drag embedment anchors such as the stockless anchor have a design load factor of safety of 1.5 to its ultimate holding capacity.

Generally, two types of mooring pull tests are performed. Horizontal pull tests are always performed on drag embedment anchors. APPENDIX J provides an extract from MO-124 for guidance on drag embedment anchor pull tests.

Vertical pull tests are usually performed on embedment anchors, but soil and design requirements at the specific site may require a horizontal pull test. Horizontal pull tests are usually performed by pulling one newly installed embedment anchor against another newly installed embedment anchor to increase installation efficiency.

All mooring pull tests should include the use of a calibrated remote load cell placed in line and at a location where frictional effects from the pull test configuration can be eliminated. For vertical pull tests, the load cell is positioned inline between the ground leg chain and the crane hook, as shown in Figure 5-16.

Figure 5-16 Vertical Pull Test Load Cell Positioning

Horizontal pull tests involving two embedment anchors have one end referred to as the “running” end and its opposite end referred to as the “static” end. The static end is where the mooring chain on one embedment anchor is secured to a suitable deck attachment point. The load cell is positioned just outside of the edge of the barge in line with the static leg. This provides a readout of the pull test tension on the embedment anchors eliminating the contributions of friction between the chain and the deck of the barge. Figure 5-17 shows the load cell placement on a static leg.

For horizontal pull tests involving only one anchor, the load cell should still be positioned in line with the mooring leg and at a location where frictional contributions can be eliminated from the load cell readout.

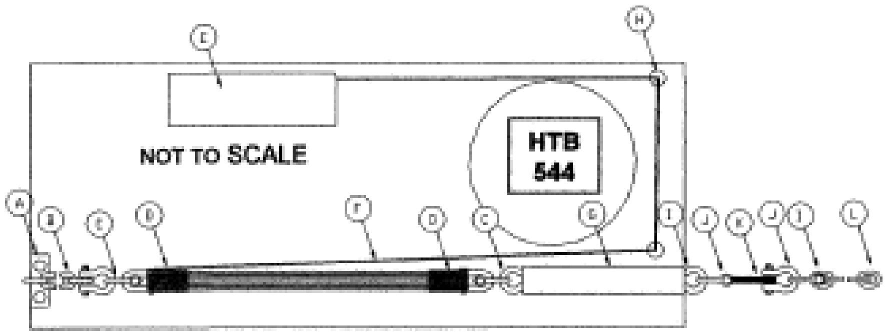
Figure 5-17 Horizontal Pull Test Load Cell Positioning

Embedment anchors installed in mud or soft sediments may have a wire rope between the anchor and the mooring chain to aid in the leg cutting through the soil and to minimize the keying (or net upward movement) distance to obtained the required test load.

The running end is usually configured with a multi-block system with wire rope reeved through the blocks. The reeving of the blocks will impose additional tensions on the individual wire rope parts as well as the friction between the running leg being pulled onto the barge (a roller or softener should be used where the running leg is to be pulled onto the barge). Though the load cell is positioned to avoid frictional contributions, pull test wire rope and other rigging must be sufficiently sized to account for all frictional contributions. Several sources are available to aid the design engineer in computing the additional frictional tensions.

For most horizontal pull tests, the barge should end up in vicinity of the middle between embedded anchors. This will mean adding additional chain to both the static and the running end, with more chain added to the running end. At the beginning of the pull test, the barge is positioned closer to the static anchor so at the completion of the pull test it ends in vicinity of the center between the anchors. It is still preferable to work in half to full shots of chain to minimize the amount of connecting links used. A general pull test schematic is shown in Figure 5-18.

Figure 5-18 Horizontal Pull Test Configuration



A	BOLSTER
B	RUNNING CHAIN LEG
C	DOUBLE 3-INCH G-2140 CROSBY SHACKLES
D	140 TON MCKISSICK 6-SHEAVE BLOCKS
E	AMERICAN WINCH
F	1.25-INCH 6X19 IWRC EIPS WIRE ROPE 13-PART
G	8 FT W14X283 LBS I-BEAM PADEYE
H	DECK SHEAVE
I	SINGLE 3-INCH G-2140 CROSBY SHACKLE
J	125 TON G-2160 CROSBY SHACKLE
K	EILON RON2000 125 TON LOAD CELL
L	STATIC CHAIN LEG

Both vertical and horizontal pull tests should be executed in a slow controlled manner by applying the load in increments of 5 to 10 tons until the pull test load is achieved. At each increment and wait of one minute should be done to allow for deck personnel to record the applied load, time, number of chain links recovered (from a reference point) and to visually check the rigging.

Upon completion of the pull test, the final embedment depth of the plate anchor padeye should be recorded. The actual orientation of the anchor plate is not known due to (1) A Factor of Safety of 2 is used for embedment anchors; and (2) Conservative estimates of soil strength during anchor design. The padeye location can be determined from the driving record, anchor drawing and results from the pull tests. It should be at or below the design depth for the anchor; however, embedment anchors that pass the pull test are generally not recovered unless post-test calculations or other geometry considerations indicate otherwise. This consideration would most likely be at a location with soft sediment or mud conditions.

For all mooring anchor pull test operations, all plans and procedures should ensure the following:

- Only qualified welders and riggers are used.
- Connecting links are secured with lead.

- A pull test plan is developed by a Professional Engineer, reviewed and accepted by the cognizant authority.
- Load cells have current calibration and positioned inline to the line of pull with the least amount of frictional or other effects. For horizontal pull tests, the load cell is positioned just outboard of the barge between the fixed deck attachment and the standing leg.
- A pull test rigging checklist is developed and completed prior to pull test operations to verify the pull test is properly configured and pull test rigging is correctly positioned according to the accepted pull test plan.
- A pull test record is completed to include information on the type load cell, depth of anchor padeye below the seabed at the start and end of the pull test, water depth, tide, link count at the start and end of the test above a reference point, links pulled in during pull test increments and final padeye depth below the seabed to include required datum (ie MLLW, etc).
- A CCD is used to secure the chain before and after a vertical pull test and after completion of horizontal pull tests.
- Rigging is designed and certified and with sufficient capacity, as placed, to withstand planned tensions to include additional tensions from frictional forces at the running end as well as within multi-part blocks. Rigging shall meet requirements of EM 385-1-1, as well as NAVFAC P-307 or the applicable agency document.

An operational risk management (ORM) approach should be used to develop specific mooring pull test procedures based on local environmental conditions, project equipment and vessels and experience of the deck force.

5-4 ASHORE INSPECTION AND REFURBISHMENT OF BUOYS.

5-4.1 Scope.

Ashore inspection and refurbishment of buoys will include visual inspections, repairs, tests, and replacement of damaged components. There are two types of buoy inspections: preliminary and detailed. The purpose of a preliminary inspection is to determine whether the buoy is in a condition for a further, more detailed inspection and subsequent refurbishment or whether it should be disposed of at this stage. If the results of the preliminary inspection indicate that refurbishment will be cost-effective, then a detailed inspection will be conducted. The buoy must be cleaned, completely inspected, and tested for airtight integrity to determine all repair requirements. The buoy can also be sandblasted to near white metal and, if required, a liquid dye penetrant or magnetic particle test conducted.

5-4.2 Preparation for Ashore Inspections.

Prepare the buoy(s) for ashore inspection as follows:

- Clean off buoy with high-pressure water during recovery.
- When brought ashore, place the buoy on chocks (railroad ties, cinder blocks, etc.) to keep the tension bar clear of the ground. For ease of working, the peg-top type buoy should be placed inverted on chocks.
- Remove the top and bottom jewelry, fenders, chafing strips, and manhole covers. Mark manhole cover positions before removal for later replacement in the same location.
- Remove shackles and joining links from the buoy, as necessary. After removal, shackles and joining links should be reassembled as complete units, including pins. Shackle pins and tapered locking pins should be used only in their original parent component.

5-4.3 Inspection Procedures.

Bear in mind that most of these inspection procedures are geared toward steel buoys. Inspections of foam buoys can be accomplished on the deck, since the fendering and chafing rails are integrally cast as part of the buoy. If the inspection reveals that damage to the buoy has occurred, it is often easier to repair the damage ashore and replace the buoy with another one.

5-4.3.1 Preliminary Inspection.

Before beginning the preliminary inspection, a 1-foot-square (0.09 m^2) section of the top and bottom and four 1-foot-square (0.09 m^2) sections (two above and two below the water line) of the side hull plates should be cleaned to bare metal. Visually inspect these four sections for pitting. In addition, perform a visual inspection as follows:

- Inspect the fenders and chafing strip fastenings for corrosion and wear.
- Check hull and deck plates for corrosion, cracks, pitting, and watertight integrity.
- Inspect the upper and lower ends of the tension bar (if the buoy is so constructed) for wear, cracks, rust, or pitting.
- If the buoy is a non-riser (telephone) type, check the padeyes for wear or cracks.
- Check the overall condition of the paint, fiberglass, or polyurethane coating.
- Ensure that the buoy is gas free by ventilating and certification by a marine chemist.
- Check the interior of the buoy for rust or corrosion.

Note:

If the buoy is a steel hawse pipe type, remove the buoy from service without doing any additional work by turning it in to the base steel recycling or local DLA Disposition Services.

Based on the results of this inspection (i.e., internal structural weaknesses, hull plate cracks, severe pitting or rusting, broken tension bar, excessive corrosion, etc.), a decision will be made whether to prepare the buoy for a detailed inspection or to dispose of it.

5-4.3.2 Detailed Inspection.

Detail Inspection is performed as follows:

Ultrasonic Inspection:

- Sandblast the buoy to near white metal in accordance with SSPC-SP-10/NACE 2.
- Inspect the buoy for damage, cracks, etc.
- Conduct an ultrasonic thickness test at four points on the buoy top, four points on the bottom, and eight points around the circumference of the hull. Four of the foregoing eight points will be below the waterline and four above the waterline.
- Using a pitting gauge, measure the depths of any pits observed on the hull of the buoy.

Pitting Inspection:

A visual inspection of the buoy hull plates will be made for pitting. The extent of pitting will determine the remaining life of the plates. ASTM G46-94, "Standard Guide for Examination and Evaluation of Pitting Corrosion" will be the standard reference used to evaluate the damage and to formulate a quantitative expression that will indicate its significance. To obtain a quantitative expression, ASTM G46-94 recommends that the deepest pit be measured, and that metal penetration be expressed in terms of the maximum pit depth or the average of the 10 deepest pits. Metal penetration can also be expressed in terms of a pitting factor. This is a ratio of the deepest metal penetration to the average metal penetration as shown in the following relationship:

$$Pitting\ Factor = \frac{Deepest\ Metal\ Penetration}{Average\ Metal\ Penetration}$$

A pitting factor of "one" represents uniform corrosion. The larger the number, the greater the depth of penetration. Pits will be rated in terms of density, size, and depth.

Welds:

Carefully check all welds, both internal and external, for cracks or corrosion. If any cracks, fissures, or other flaws are found or are suspected, then a liquid dye penetrant or magnetic particle test should be performed to determine the extent of the defects.

Buoy Air-Pressure Test:

Each buoy compartment will be tested for tightness at the joints by the application of air pressure. Unless the buoy is under cover, at least 2 hours of clear weather will be required for the test. The gauge used for the test must have a current calibration certification. Proceed as follows:

- Install a test plug fitted with a gauge in the top of each buoy compartment.
- Pressurize the compartment to 2 pounds per square inch (14 kPa). Allow 30 minutes to pass after pressure stabilization.
- Brush all joints and seams with a commercial leak testing solution. A 2% solution of potassium bichromate may be added to the leak testing solution to inhibit rust.
- Leaks detected will be repaired and the buoy retested.
- When all tests and repairs are finished, completely remove the leak testing solution before applying surface primers.

5-4.4 Buoy Repairs and Modifications.

5-4.4.1 General.

Steel Buoy repairs and modification will include manhole cover replacement, test plug and aperture maintenance, fender and chafing strip repairs, welding requirements and air pressure testing.

5-4.4.2 Procedures.

Steel buoy repair and modifications will be accomplished as follows:

5-4.4.2.1 Manhole Cover Replacement.

Manhole cover replacement will be accomplished as follows:

- Clean and lubricate the studs and use chaser nuts where required.
- Make match marks on the cover and the buoy body to ensure that the manhole cover goes in the proper location and in the correct orientation.
- Remove the manhole cover.

- Replace old gasket with a new 1/8-inch (3.2 mm) silicone rubber gasket held in place with RTV silicone gasket adhesive sealant (MIL-A-46106). Apply sealant only to bottom surface of gasket.
- Lift manhole cover by the extension lip and position it over studs.
- Lower manhole cover on studs.
- Secure cover bolts. Tighten in at least three steps using an opposite bolt tightening sequence. Apply final 45 foot-pounds (61 N-m) of torque.

Note:

Each manhole cover will be replaced on the opening from which it was originally removed. Match marks shall be made on cover and deck plate prior to removal to facilitate its replacement in the correct location and position.

Exercise care in lowering the cover on the studs so that stud threads and gasket are not damaged.

5-4.4.2.2 Test Plugs and Hull Apertures.

Clean and check test plug threads before placement of the plugs in the hull apertures. Teflon sealant tape should be applied to the threads to ensure a watertight seal.

5-4.4.2.3 Fenders and Chafing Strips.

Overhauled steel buoys will be provided rubber fenders and chafing strips. In most cases, this will require removal of the wooden fenders and their channeling, and the wooden chafing strips and connecting brackets. Channeling and brackets will be replaced by stainless steel stud bolts, 3/4-inch in diameter by 2 1/2 inches long (10 threads per inch). The bolts will be positioned and welded to conform to predrilled holes in the rubber fenders and chafing strips. If the rubber fenders and chafing strips are not predrilled, they will be drilled to conform to the positions of the stud bolts. Spacing of the bolts shall not exceed 16 inches (406 mm) on center.

5-4.4.2.4 Welding.

All welding will be accomplished by trained and qualified personnel following accepted procedures and standards contained in the latest edition of AWS D1.1, *Structural Welding Code - Steel*.

Safety Warnings:

Never cut or weld to the surface on an enclosed void (such as a steel buoy) until the interior has been properly ventilated and gas free. Potentially explosive gases can accumulate within the buoy.

Use qualified welding procedures and follow safe welding procedures per EM 385-1-1 and wear required PPE for welding operations

5-4.4.2.5 Buoy Air Pressure Test.

Each buoy compartment will be tested for tightness at the joints by the application of air pressure. Unless the buoy is under cover, at least 2 hours of clear weather will be required for the test. The gauge used for the test must have a current calibration certification. Proceed as follows:

- Install the test plug fitted with a gauge in the top of each buoy compartment.
- Pressurize each compartment with 2 pounds per square-inch (14 kPa) of air pressure for a minimum of 30 minutes after stabilization of the pressure.
- Brush all joints and seams with a solution of commercial leak testing fluid. Two percent potassium bichromate may be added to the solution to inhibit the formation of rust.
- Leaks detected will be repaired and the buoy retested.
- When all tests and repairs are completed, completely remove the leak testing solution before applying surface primers.

5-4.5 Protective Coatings.

5-4.5.1 Preparation for Application.

Preparation of buoys for application of protective coatings will include the following:

- Remove fenders, chain links, steel plates etc. from the buoy.
- When possible, open the buoy manhole and check the interior of the buoy for rust and water damage.
- Examine the hull areas that may need repair or replacement.
- Pits found that are 3/16 inch (4.8 mm) deep or more will be filled with clad welding or epoxy repair compounds conforming with MIL-C-24176.
- Buoys which are fiberglassed should have a steel reinforcing ring welded around the outside edge of the manhole opening if one is not already

present. The purpose of the ring is to provide a clean, secure surface on which to seat the manhole cover gasket as well as to reinforce the buoy deck. The ring should be of 1/2-inch (13 mm) steel plate and should extend a minimum of two inches outward from the edge of the manhole opening. If a ring is not used, then the manhole opening must be welded closed using flush steel plates which are reinforced on the underside by steel backup strips. If this is the case, the buoy will have to be cut open for subsequent inspections.

- Sandblast exterior surfaces of the metal hull in accordance with the latest edition of the *Steel Structures Painting Manual, Vol. II, Systems and Specifications*, Specification SSPC-SP-10. All sharp and irregular edges will be ground smooth. Be aware of potential for presence of Chromium VI during removal of existing coatings on older type steel buoys.

Note:

Do not apply paints or fiberglass coatings to the top surface of the reinforcing ring.

No sandblasted surface will remain uncoated for more than 4 hours.

Be aware of the presence of hazardous components such as lead or chromium VI that may be present on remaining coatings on old steel buoy coatings.

5-4.5.2 Foam Filled Elastomer Covered Buoys.

In the event of small rips, tears, punctures, or gouges in the skin and underlying foam, a repair kit containing the components and procedures required to accomplish minor repairs can be obtained from commercial vendors. If the buoy should be severely damaged and major repairs are required, the manufacturer of the buoy should be contacted for advice and/or assistance.

5-4.5.3 Fiberglass Polyester Resin (FPR) Coating Repair.

Fiberglass patches will be applied as follows:

- Sandblast the area around the repair to ensure a clean surface.

Note:

The term sandblasting here is used as a general term. Sand is not the recommended media for blasting fiberglass, softer media is recommended such as walnut shell grit, plastic grit or even dry ice.

No sandblasted surface will remain uncoated for more than 4 hours.

- Immediately after sandblasting the areas to be repaired, apply one coat of pretreatment primer (MIL-P-15328, Formula 117), 0.3 to 0.5 mil (7.6 to 12.7 μm) thickness. The thickness of the primer shall not exceed 0.5 mil (12.7 μm). Film thickness will be checked with a microtest thickness gauge or a comparable instrument.
- After the pretreatment primer has dried, apply one coat of clear polyester resin (MIL-R-21607) to the surfaces that are to receive the FPR coating patches.
- Commence with the first FPR lamination, which consists of the polyester resin and chopped fiberglass mat (MIL-M-43248). Apply the mat to the pre-coated surface and roll/squeeze to remove all lumps and air bubbles. Lay on additional polyester resin until the mat is thoroughly wet. Roll/squeeze until smooth, adding additional resin as necessary.
- Immediately after the first lamination is ready, apply three additional laminations, as follows, to give a maximum dry film thickness of 3/16 inch (4.8 mm). One lamination of fiberglass woven roving (MIL-C-19663) will be applied in a manner similar to the initial lamination. Apply one lamination of fiberglass mat. Apply one lamination of fiberglass woven roving. Note: Adjacent portions of mat or woven roving in all laminates shall overlap a minimum of 6 inches (152 mm).
- Apply additional polyester resin coatings for each successive lamination before and after the individual lamination reinforcement. The reinforcement will be rolled and squeegeed as in the initial lamination, and the polyester resin will be added and distributed, as needed, before starting the next lamination.
- Apply a generous, smooth-finished topcoat of the polyester resin mixture on the final lamination. The topcoat will be pigmented with 4 ounces (0.113 kg) of white color pigment per gallon of resin.
- NOTE: Personnel applying the FPR may, in lieu of the laminations of fiberglass mat, use a chopped fiberglass-polyester lamination sprayed on the surface being refinished at the rate of 2 ounces per square foot (0.61 kg/m2).
- If breaks occur on the surface such as around the tension bar, padeyes, and bolts and studs, the FPR coating will be edge-finished carefully using polyester resin.

5-4.5.4 Paint Coatings.

General coating operations, materials, and safety precautions are described in UFC-3-190-06, *Protective Coatings and Paints*. The recommended coating system for mooring buoys is the Navy epoxy-polyamide system for interior and exterior ship surfaces (MIL-P-24441 Type III). Procedures for its use are thoroughly described in the Naval Ships Technical Manual (NAVSEA S9086-VD-STM-010). For optimum results, this coating should be applied to dry steel cleaned to a near white metal surface, SSPC-SP-10/NACE 2. As a minimum, surfaces should be cleaned to commercial blast, SSPC-SP-6/NACE 3.

- The above coating should be applied in three coats, each at about 4-mil (101.6 μm) film thickness, to give an approximate 3-mil (76.2 μm) dry film thickness per coat and a minimum 8-mil (203.2 μm) total dry film thickness. There should be 16 hours of curing time between coats. The first coat should be the green primer (Formula 150); the second, haze gray (Formula 151); and the third, white (Formula 152).
- The two components of all MI L-P-24441 coatings should be mixed in equal volume by first thoroughly stirring each component separately and then stirring them together. After mixing, there should be a waiting period of about 2 hours at 50 to 60 °F (10 to 15.6 °C); 1 to 1 1/2 hours at 60 to 70 °F (15.6 to 21.1 °C); and 1/2 to 1 hour above 70 °F (21.1 °C) before applying the coating to ensure complete curing later. The mixed paints do not require thinning, but the low temperature application properties can be improved by adding 10%, by volume, of a mixture of equal parts of n-butyl alcohol and AMSCO Super High Flash Naphtha, or an equivalent mixture.

Usual paint spray equipment, either conventional or airless, can be used. The pot life of the mixed coating is about 6 hours at 73 °F (22.8 °C). If more than 7 days elapse between epoxy coats, the surface should be cleaned with water and detergent, rinsed with fresh water, dried, and then a tack coat (1 to 2 mils (25.4 to 50.8 μm) wet film thickness) of the last coat applied before application of the next full coat.

The above coating system, when properly applied, will provide at least 3 to 5 years of protection, depending upon the severity of the environment. Experience has shown that an antifouling paint is usually unnecessary because fouling will not damage the coating, add a significant amount of weight to the buoy, or otherwise adversely affect the mooring. In addition, the effective life of antifouling paint is usually much shorter than the time between buoy overhauls, so that significant fouling will still occur before the next overhaul. Should an antifouling paint be desired for the underwater portion of the buoy, MIL-P-15931, Formula 121/63, applied in two coats, is recommended. The antifouling paint, which is red, must be applied while the topcoat of epoxy (MIL-P-24441, Formula 152) is still tacky (within 4 to 6 hours after its application). If the epoxy has hardened, a tack coat of MIL-P-24441 (1 to 2 mils (25.4 to 50.8 μm) wet film thickness) must be applied and allowed to cure for 4 hours before the first coat of antifouling paint is applied.

Safety Note:

Painters shall use the appropriate PPE.

MSDS for all components shall be readily available on site.

All painting shall comply with USACE EM 385-1-1.

The emphasis is on the replacement of steel buoy with foam buoys. Over the 20 year life of a buoy, the steel buoy will normally require 4 overhauls while the foam buoy will require minimum maintenance, bringing a huge cost savings over that 20 year life span to the operator.

5-4.5.5 Quality of Work.

All of the workmanship on the coating systems shall be in accordance with the Naval Ships Technical Manual, NAVSEA S9086-VD-STM-010. The work shall be performed by or under the immediate and direct supervision of skilled personnel who have demonstrated a continuing proficiency in the application of multilayered coatings on extensively contoured areas similar and comparable to the exterior of mooring buoys. Quality of workmanship shall meet the highest standards as set forth in the specifications and manuals noted herein.

5-4.5.6 Coating Documentation Report.

After a buoy is coated, a documentation report, traceable to the buoy, should be prepared that shows the coatings used, the date the coatings were applied, the surface preparation performed to include surface profile measurements, wet and dry film measurements, measurement of ambient conditions during coating operations, QC procedures used, etc. The report shall be placed as part of the mooring documentation and provided to the mooring custodian. Sufficient inspection should be performed to ensure that the surface was properly prepared, the coating properly prepared and applied and the required dry film thickness and coverage obtained.

5-5 ASHORE INSPECTION AND REFURBISHMENT OF CHAIN AND ACCESSORIES.

5-5.1 Scope.

Chain and fittings are inspected to determine their suitability for continued use in the mooring system. The inspection process is two-phased, PRELIMINARY and DETAILED.

The preliminary inspection is conducted to determine if the chain or fitting is adequate for continued use, if it can be made serviceable by repair or refurbishment, or if it should be disposed of.

The results of the preliminary inspection are analyzed to determine the need for further inspection. If the results of the preliminary inspection indicate that the chain or fitting can be made serviceable by repair or refurbishment, a detailed inspection is conducted to develop a specification for the repair or refurbishment. If the preliminary inspection results indicate that the chain is adequate for continued use, then a detailed inspection should also be conducted to ensure that no faults in the chain have been missed prior to returning to service.

In planning an inspection of mooring chain and fittings, the inspection activity should consult the cognizant authority for guidance as to the extent of the inspection required. Some of the material in the mooring may be planned for reuse if found acceptable and some may be scheduled for disposal without further action.

5-5.2 Preliminary Inspection.

All fittings should be disassembled, removed from the chain, and reassembled as complete units until ready to be inspected. When joining links are disassembled, care should be taken that the parts of one joining link are not interchanged with the parts from another joining link. Chain should be arranged in shots or partial shots so that each link is accessible for inspection. Known or suspected high wear areas should be thoroughly cleaned with a scaling tool and wire brush or lightly sandblasted to SSPC SP-2 or SP-3 criteria.

The preliminary inspection should begin with a visual inspection of each fitting and each chain link. Visually inspect each link of chain for abnormal wear, cracks, deformation, or missing studs. Mark all links with obvious problems and all areas to be measured.

After the visual inspection is complete, measurements should be taken in known or suspected high wear areas and in any suspect areas noted during the visual inspection. Take single or double-link measurements on the first two to four links of chain at the end of each shot or partial shot and at any location in the chain where high wear is indicated by shiny metal or visible loss of wire diameter. Remember that the chain must be under tension to take accurate double-link measurements.

Disassemble each fitting and visually inspect each component of the fitting for indications of wear, deformation, or cracks. Pay particular attention to pins and pin locking holes. Check pins for loose fit before disassembling. Measure the wire diameter of joining links, shackles, and ground rings at known or suspected high wear areas. Reassemble all fittings as complete units on completion of the inspection. Apply a liberal coating of grease to all internal surfaces of joining links (mating surfaces, pins and pin locking holes) prior to reassembly. Grease should be in accordance with MIL-PRF-10924.

Based on the results of the preliminary inspection, tentatively classify the chain and fittings as good, fair, or poor in accordance with Table 5-1. Chain and fittings tentatively classified as good or fair should be retained for detailed inspection; chain and fittings tentatively classified as poor should be disposed of through normal disposal procedures.

Table 5-1 Classification of Mooring Component Condition

Condition	Amount of Deterioration
Good	90% or greater of original wire diameter
Fair	80 – 90% of original wire diameter
Poor	80% or less of original wire diameter

5-5.3 Detailed Inspection.

All chain and fittings that have been tentatively classified as good or fair as a result of the preliminary inspection should receive a detailed inspection to determine the action required to return the components to serviceable status. No further inspection should be conducted on chain or fittings that do not pass the visual inspection for any reason other than a slight deterioration of wire diameter. Before beginning the detailed inspection, all chain and fittings to be inspected should be sandblasted in accordance with the latest edition of the Steel Structures Painting Manual, Vol. II, Systems and Specifications, Specification SSPC-SP-6/NACE-3.

Single-link measurements should be taken on each link of the chain. Visually inspect each link for cracks, deformation, missing studs, or any other abnormalities. If a crack is suspected but not readily obvious to the naked eye, conduct an MT in the suspected area.

The wire diameter of each fitting should be taken in normal wear areas and in any areas designated as suspect as a result of the preliminary inspection. Check for worn pins, worn pin locking holes, cracks, or deformation. If cracks are suspected, conduct an MT to verify. Disassemble each joining link and shackle and inspect all components. Reassemble as complete units. Apply a liberal coating of grease to all internal surfaces of joining links in accordance with MIL-PRF-10924 prior to reassembly.

Classify the chain and fittings in accordance with Table 5-1. Material classified as good or fair may be coated and returned to inventory. It should be tracked separately, by classification, from new material. Material classified as poor, should be disposed of through normal disposal procedures.

The results of all inspections, including a record of all measurements taken, should be included in the pertinent material history file or mooring maintenance file and a copy forwarded the mooring manager.

5-5.4 Protective Coatings.

Chain and fittings classified as good or fair should be should be abrasive blasted to Steel Structures Painting Manual, Vol. II, Systems and Specifications, Specification SSPC-SP-6 or NACE-3. Spray, dip, or brush the abrasive blasted chain/fittings with an approved rust preventative (MIL-PRF-16173 Grade 1). Place the chain on a clean surface to dry. Once dry, put the chain back into inventory noting the condition of this chain.

- If the chain/fittings have not been sitting around too long after the blasting for the detailed inspection and no visible rust, dirt, etc. is apparent, then a reblasting is not required.
- For accessories with pins or bolts, ensure that the applied coating is not too thick. Otherwise, it will be difficult to remove or assemble the shackle pins or bolts.
- Coating operations should be avoided on cold/damp days.

5-6 ASHORE INSPECTION AND REFURBISHMENT OF ANCHORS.

5-6.1 Scope.

The primary purpose of inspecting an anchor is to determine its general physical condition and its suitability for reuse. The inspection of an anchor should only be conducted when the anchor is either temporarily aboard a barge or in a storage area ashore. There are two types of anchor inspections: preliminary, which can be conducted either aboard a barge or ashore, and detailed, which is normally conducted ashore. These inspections should be accomplished as soon as possible after the anchor is removed from the water.

5-6.2 Preliminary Inspection.

The anchor should be cleaned with a high-pressure water wash-down before beginning the preliminary inspection. When cleaned, the anchor should be laid on the deck or on the ground within reach of a crane so that it can be lifted and turned to gain access to all surface areas.

Every surface for the anchor and anchor shackle should be visually inspected for the presence of cracks, casting irregularities, abnormal wear, or any other obvious damage or defect. Caliper measurements should be taken to determine the wire diameter of the anchor shackle at the bow and at the wear area at the lugs of the shackle. Ensure that the shackle is free to move, not frozen in position.

Visually check the anchor for casting irregularities, cracks or obvious mechanical damage. If the anchor is of welded construction (STATO or NAVMOOR), or if the anchor has stabilizers welded to it, all weldments should be closely scrutinized for cracks, fissures, pitting corrosion, or other defects. Special attention should be paid to the very end of the shank, the fit of the shackle in the shank, and the base of the flukes.

A hammer test will determine whether there are major invisible cracks or other abnormalities in the anchor. The test is conducted by suspending the anchor from a crane hook and striking each fluke with a large (> 5 pounds or 2.2 kilograms) hammer. If a ringing tone results the anchor is sound. If a dull thud results, there are serious cracks or other irregularities in the anchor.

The results of the above preliminary inspection measurements, observations, and tests should be documented. If the inspected anchor is determined to be in satisfactory condition as a result of this inspection, no further effort will be expended, and the anchor will be made ready for further use or placed in a designated storage area. Anchors returned to service or placed in inventory in a ready status should be coated with a black-gloss solvent-type paint (MIL-P-2430).

5-6.3 Detailed Inspection.

A detailed inspection will only be conducted if, as a result of the preliminary inspection, abnormalities are suspected or if the condition of the anchor is questionable. The detailed inspection will include the following:

- Clean the anchor by abrasive blast clean to SSPC-SP-10/NACE-2 near white blast cleaning.
- Visually inspect the anchor for cracks or casting irregularities. Pay particular attention to the anchor flukes and welds.
- Perform a liquid dye penetrant or magnetic particle test on any suspected cracks or abnormalities in accordance with NAVSEA Technical Publication T9074-AS-GIB-010/271 Requirements for Non-Destructive Testing Methods.
- If the results of this testing indicate that cracks or other abnormalities do exist, a decision will have to be made to determine if these abnormalities can be corrected by grinding and welding or if they are too numerous or too deep for economical refurbishment of the anchor. If repairs can be made, then as soon as they are accomplished, the anchor should be protectively coated with a black-gloss solvent type paint (MIL-P-24380). If it is determined that refurbishment of the anchor is not economically feasible, then the anchor may be retained in storage for future use as a sinker/clump or disposed of. All findings/results of the detailed inspection shall be fully documented and filed.

CHAPTER 6 STORAGE OF MOORING MATERIALS

6-1 GENERAL REQUIREMENTS.

Mooring components are usually stored in open areas near a coastline, thus exposing them to weather and a marine environment. To prevent deterioration while in storage, some preventive maintenance will be required in addition to the routine material handling and inventory control tasks normally performed by a storage facility. The job of handling, maintaining, and controlling stored components will be made much easier if some basic guidelines, as noted below, are followed.

- The storage area should be large enough to permit efficient movement of forklifts, cranes, and other large mobile equipment.
- Arrangement of components should allow easy access for inspections, inventory checks, and selection.
- To reduce corrosion, all components except cathodic protection materials should be coated with paint, approved rust preventatives, or other suitable preservatives as detailed in CHAPTER 5.
- All components should be tagged or labeled to ensure proper identification and accurate inventory reporting.
- Chain accessories such as joining links, swivels, ground rings, and shackles should be crated or banded together on pallets to permit easy handling.

6-2 STORAGE AREA REQUIREMENTS.

Shore activities requiring spare mooring materials will require a suitable storage area. The following should be observed:

- The mooring materials should normally be stored in a secure area designated by activity personnel responsible for space allocation.
- The storage area should be on solid ground or on improved surfaces, and graded for drainage.
- The area should be large enough, as well as configured, to allow easy access of equipment and personnel involved in chain handling and other maintenance operations.
- The area should be close to maintenance areas, transportation equipment, and the waterfront to reduce both maintenance and transportation costs.

6-3 STORAGE PROCEDURES.

6-3.1 Buoys.

Store buoys as follows:

Place all drum type buoys on chocks or dunnage, with all metal parts clear of the ground, and tilted (using additional chocks or dunnage under one side) to facilitate water runoff.

Store peg-top buoys in a horizontal position (see Figure 6-1).

Figure 6-1 Proper Storage of a Foam Peg Top Buoy

Foam buoys should be stored on specially designed wood buoy cradles to avoid a permanent flat spot.

Buoys should be periodically inspected to aid in the detection and prevention of localized corrosion areas. If corrosion is found, corrective action should be implemented. Corrosion commonly develops in the web of channel irons securing wooden fenders, in the hull behind rubber fendering, and on the nuts/studs used to secure manhole covers, fenders, and chafing strips. Ground or chock contact points are also susceptible to higher corrosion rates. Any area on the top of the buoy that could collect water is susceptible to accelerated corrosion. In addition, the steel cradle for foam buoys should be inspected for corrosion.

6-3.2 Chain and Chain Accessories.

Chain is normally stored ranged out in tiers, a single shot of chain placed on a pallet, loaded in shipping crates, or in bundles. The ground where the chain is stored should be clear of all debris and growth, and well drained.

Mooring chain and accessories of different specifications and grades should always be stored separately, to prevent mooring components of a lesser grade being mixed into a mooring system that requires a higher grade of chain or accessories.

6-3.2.1 Tiered Chain.

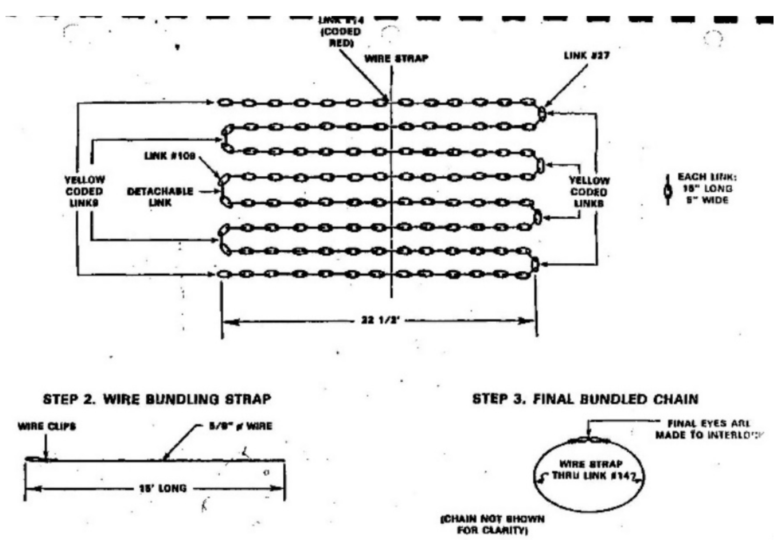
Store chain in tiers as follows:

- Lay chains down stretched out taut and free of turns.
- Pile tiers in multiple layers to reduce storage space.
- Each tier should contain chain of similar construction, size, and condition for ease of access and accurate inventory control.
- The ends of each length of chain should have an identification tag attached to it which contains the chain size (in inches), type (cast/forged/etc.), length (in feet), and manufacturer.

6-3.2.2 Palletized Chain.

Chain may also be stored and handled on pallets. Normally, chain is palletized in single shot lengths to reduce handling weights and to simplify inventory. Chain pallets normally consist of wooden or steel pallets onto which the chain is piled or bundled (see Figure 6-2).

Figure 6-2 Chain Bundling Method



It is recommended that the lashing not be used to lift the pallet/chain bundle unless it meets the local base policy for lift operations. One can pass the lifting sling through the captured links that can be used for lift operations or the pallet with the chain can be lifted with a forklift.

6-3.2.3 Crated Chain.

Reusable wooden crates can be used for the shipment and storage of chain and will normally contain a single shot of chain. The crates can be stacked to reduce deck space requirements if not loaded beyond the design capacities stamped on the crates (see Figure 6-3).

Figure 6-3 Stacked Crates of Chain

6-3.3 Mooring Accessories.

Store mooring accessories by type, by size and by specification/grade in either a crate, box or on a pallet. Connecting links, anchor bolt shackles and riser swivel shackles should be greased and loosely assembled, but they should never be stored disassembled and the parts stored separately. Plate shackles may be stored disassembled.

6-3.4 Anchors.

Place anchors on dunnage and in a vertical position. Store according to type and size for ease of inventory control. U.S. Navy anchors have identification marks cast, stamped, or cut on the anchor crown. When stored vertically, this information should be transferred to a suitable tag or stenciled to the anchor's shank.

6-3.5 Cathodic Protection Materials.

Larger anodes stored outside should be sealed in plastic liners and boxed to preclude premature galvanic action. Do not store anodes in the open or near other dissimilar metals, which could result in corrosion of the anodes. Chain stud anodes should be stored in HDPE 57-gallon plastic drums with removable lids. Only one size of anode shall be packed in each drum. Store screws in sealed plastic bags to prevent corrosion.

Cathodic protection material should be kept clean and should not be painted or coated with oil or grease during either storage or use.

6-3.6 Marking and Identification.

Marking and identification of components should be accomplished as described.

6-3.6.1 General.

Proper marking and identification of all mooring components will assist in conducting inventories, will help prevent use of improper or substandard materials, and will speed assembly and installation times when required components must be drawn from inventory.

6-3.6.2 Color Coding.

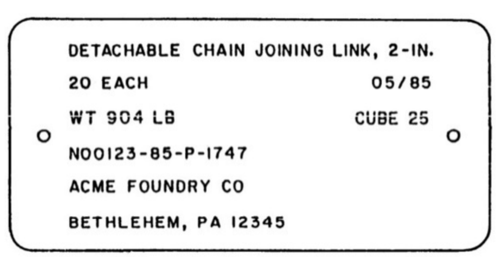
It is good practice to color code chain to identify its condition. Recommended colors to be applied to the last link on each end of a chain length are:

- White - for chain in new or good condition.
- Yellow - for chain in fair condition.
- Red - for chain in poor condition and ready for disposal.

6-3.6.3 Identification.

Identification of chain and accessories shall be on tags of 0.031-inch (0.787 mm) thick aluminum alloy 1100 or 3003, attached using 0.031-inch (0.787 mm) diameter 300 series corrosion resisting stainless steel wire through 0.125-inch (3.175 mm) diameter holes at each end of the tag. Characters shall be metal stamped using 0.25-inch (6.35 mm) high characters. Tag size and information content shall be as shown in Figure 6-4. On chain shots, tags shall be attached to the last link on each end of the shot. Tags will be attached snugly to each accessory in a location away from the grip area of the component and shall be bent to conform to the contour of the component to minimize risk of snagging or damaging the tag.

Figure 6-4 Example Shipping Tag

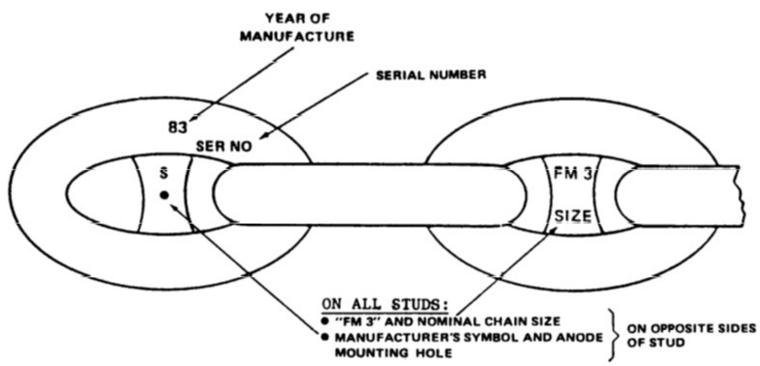


6-3.6.4 Fleet Mooring Inventory Chain and Accessories.

Chain and accessories procured under contract for the Fleet Mooring Inventory are marked and identified as followed:

- The size and the name of the manufacturer are stamped or forged on each chain link or accessory during manufacture.
- New FM3 chain will also have a unique serial number on each accessory, on the end links of each shot, and on the 3rd link from each end of chain (see Figure 6-5). The serial number will be used together with documentation furnished by the manufacturer (heat number, chemical composition, etc.) to monitor the performance of different heats of chain.
- Crates used to ship new chain and accessories from the manufacturer will be marked to show: contents, weight, contract and shipping data, and stacking limitations.

Figure 6-5 Chain Markings



6-3.6.5 Buoys.

New buoys should have an identification plate (Figure 6-6) showing the following:

- Serial number,
- Manufacturer,
- Date of manufacture,
- Diameter,
- Height,
- Weight in air,
- Maximum tension bar load, and
- NAVFAC drawing number.
- This plate should be protected during sandblasting and should not be painted or coated.

Steel buoys in service may not have an identification plate. If they are to remain in service an identification plate with the above information, based on available information, should be attached to the top of the buoy near, but not onto the tension bar (to avoid welding onto the load carrying component of the buoy). A serial number should be generated for maintenance and operations tracking purposes.

Figure 6-6 Buoy ID Plate

6-3.6.6 Anchors.

Identification information for anchors is cast on the crown, on the flukes, or on the side of the shank. Minimum information provided is as follows:

- Manufacturer
- Weight
- Serial number

6-3.7 Pre-Issue Inspection.

Items that are issued from inventory should be inspected prior to shipping or movement from the storage facility. A bill of material should be reviewed to ascertain the components required and a check of all material sizes accomplished. To ensure all mooring components fit when shipped to the field, a physical fit check should be accomplished prior to shipment. The many configurations and designs of mooring hardware increase the likelihood of a misfit if a physical fit check is not accomplished.

APPENDIX A BEST PRACTICES

A-1 NOTES AND SAFETY WARNINGS.

This section will highlight by repetition all the boxed warnings and safety notices throughout this document.

All efforts should be made to replace steel buoys with foam buoys since steel buoys are much more difficult to inspect and maintain. Steel tension bar buoys can still be used, but hawse pipe buoys shall be taken out of service, disassembled and disposed of in accordance with local steel recycling programs.

All personnel at or near a mooring component being secured by lead shall wear PPE commensurate with EM 385-1-1 (such as safety glasses, foot protection, floatation vest) and other required PPE for mooring operations.

Follow safe welding procedures per EM 385-1-1 and wear required PPE for welding operations.

Wear appropriate gloves when handling wire rope.

Ensure all personnel have, maintain, and wear PPE (steel toed shoes, personal floatation vest, hard hat and other PPE for specific tasks i.e. leather gloves, safety glasses, etc.).

Daily safety briefs should emphasize everyone’s responsibility for applying risk management.

Failure to properly clean the inspection area of the chain links may provide erroneous measurements leading the inspector, custodian, and users of the mooring system to an improper conclusion on the mooring condition that could result in an unsafe mooring condition for a moored vessel.

Divers should be aware of the potential movement of the chain, especially when working on the ground legs.

All efforts shall be made to replace steel buoys with foam buoys since steel buoys are much more difficult to inspect and maintain. Steel tension bar buoys can still be used, but hawse pipe buoys should be taken out of service.

Divers should use extreme caution when working directly below a live/moving buoy.

Divers should inspect the connections of suspended sinkers with caution as motions imposed on the mooring system from surface weather conditions or attached vessels can cause the suspended sinker to move within the water column.

While inspecting the anchors, divers should not go under the flukes or shank of the anchor.

Regardless of using the design anode size or oversized anodes, the mounting hole must be free of debris and the anode tightened to the recommended torque for the anodes to work properly.

Ensure all personnel have, maintain, and wear PPE (steel toed shoes, personal floatation vest, hard hat and other PPE for specific tasks i.e. leather gloves, safety glasses, etc.).

Daily safety briefs should emphasize everyone's responsibility for applying risk management.

At no time shall personnel be directly under a suspended load when the load is out of the water. Personnel on the barge deck shall be kept clear of the fall zone of the buoy and the riser chain to the maximum extent possible. The fall zone includes the area where a suspended load may fall. Personnel should be aware that the fall zone is moving as the buoy is lifted over the deck. Only qualified personnel, in accordance with EM385-1-1, under specific instruction from the designated Marine Construction Superintendent, may enter the fall zone to handle a load.

The buoy should be lifted only as high as minimally required.

Operation planning must include the use of a chain capture method that minimizes the necessity for personnel to work under suspended load.

Use a Load Indicating Device (LID) or crane equipped LID or Load Moment Indicator to determine the load for all installation/retrieval lifting operations.

Every attempt should be made to plan operations that keep DIVERS from working under the load. If no alternatives can be found, every effort should be done to minimize the diver's time spent under the load.

Adhere to EM 385-1-1 and OSHA 1910.253 for safe use of oxygen/acetylene torch.

If lifting a hawse pipe buoy, treat the lift as if the capture plate assembly is damaged and lift from below, while simultaneously lifting the buoy. On the newer ATFP and FMP foam hawse pipe buoys, the bolts that make this connection are exposed, but it is still difficult to determine the condition of the bolts. On these foam hawse pipe buoys, the existing capture plate and bolts can be replaced with new bolts and a capture plate specifically used for lift operations only.

Additional care is needed to make sure the additional loads on the crane (from lifting the ground ring out of the water) are taken into account. In addition, the stability issues based on these extra loads must also be accounted for.

If the tension bar is damaged, it is best to lift the buoy from below to take most of the weight off of the buoy/tension bar. A secondary crane hook should be used to simultaneously lift the buoy, keeping the buoy weight off the lift.

Never cut or weld to the surface on an enclosed void (such as a steel buoy) until the interior has been properly ventilated and gas free. Potentially explosive gases can accumulate within the buoy.

No person should enter the buoy while the buoy is still in the water. A person should only enter the buoy when there is no possibility of the buoy sinking, i.e. either on the deck of the barge or ashore.

Entry of personnel into a buoy must comply with EM 385-1-1 and cognizant base requirements for confined space entry.

On a steel buoy, the buoy manhole cover must not be removed while the buoy is still in the water.

Every attempt should be made to plan operations that keep personnel from working under the load. If no alternatives can be found, every effort should be done to minimize the time spent under the load.

While preparing the anchors, positioning on deck for deployment and deploying the anchor, personnel should not go under the flukes or shank of the anchor.

If the buoy is a steel hawse pipe type, remove the buoy from service without doing any additional work by turning it in to the base steel recycling or local DLA Disposition Services.

Each manhole cover will be replaced on the opening from which it was originally removed. Match marks shall be made on cover and deck plate prior to removal to facilitate its replacement in the correct location and position.

Exercise care in lowering the cover on the studs so that stud threads and gasket are not damaged.

Never cut or weld to the surface on an enclosed void (such as a steel buoy) until the interior has been properly ventilated and gas free. Potentially explosive gases can accumulate within the buoy.

Use qualified welding procedures and follow safe welding procedures per EM 385 1 1 and wear required PPE for welding operations

Do not apply paints or fiberglass coatings to the top surface of the reinforcing ring.

No sandblasted surface will remain uncoated for more than 4 hours.

Be aware of the presence of hazardous components such as lead or chromium VI that may be present on remaining coatings on old steel buoy coatings.

The term sandblasting here is used as a general term. Sand is not the recommended media for blasting fiberglass, softer media is recommended such as walnut shell grit, plastic grit or even dry ice.

No sandblasted surface will remain uncoated for more than 4 hours.

Painters shall use the appropriate PPE.

MSDS for all components shall be readily available on site.

All painting shall comply with USACE EM 385-1-1.

Wind and current conditions will usually dictate which subassembly is laid first.

Divers may be used to inspect connections and to check the orientation and tautness of the anchor chains. They may also be used to jet the anchors into the bottom if included as part of the design specification.

Ensure that the anchor is not recovered and reset in the furrow or disturbed bottom area caused by the initial pull test.

In the case of a taut mooring, one anchor chain subassembly may have to be separated from the ground ring by cutting the first A-link below the ground ring with a torch.

If the joining link cannot be removed, cut the first A-link with a torch.

A-2 SAFETY.

Safety is critical for all work on and around moorings, including inspection work and repair work.

Daily safety briefs should emphasize everyone's responsibility for applying risk management. Pay attention to what could go wrong and how it could go wrong.

Ensure all personnel have, maintain, and wear PPE (steel toed shoes, personal floatation vest, hard hat and other PPE for specific tasks i.e. leather gloves, safety glasses, etc.).

APPENDIX B CRANE SAFETY

B-1 CRANE SAFETY.

The definitive reference on crane safety is NAVFAC P-307, Management of Weight Handling Equipment (for Navy shore activities) and EM 385-1-1 (U.S. Army Corps of Engineers and NAVFAC Contractors). This section is not meant as a replacement for this standard but as a guide to help the users of this manual understand the basics as they apply to mooring work. Note that chapter 11 of NAVFAC P-307 lists requirements for NAVFAC Contractors performing weight handling operations at a Navy facility.

In general, you will be dealing with one of two types of cranes, either floating cranes which are built into a ship or barge or mobile cranes that are temporarily mounted on the deck of a barge or ship. There are many advantages to using a floating crane. The load curves include the listing of the vessel and other naval architectural considerations and you don’t have to worry about tying the crane down. On the other hand, mobile cranes are more readily available. You just have more planning efforts prior to the project.

B-2 CRANE SAFETY GUIDELINES.

The following documents serve as the basis for crane safety, as applicable.

a) SECNAVINST 11260.2, Navy Weight Handling Program for Shore Activities.
b) NAVFAC P-307, Weight Handling Program Management
c) OPNAVINST5100.23, Navy Occupational Safety and Health Program Manual
d) NAVSEA 0989-030-7000, Lifting Standard (If Applicable)
e) USACE 385-1-1, Safety and Health Requirements Manual
f) 29 CFR 1926 Subpart CC, Safety and Health Regulations for Construction, Cranes & Derricks in Construction
g) ASME B30.5 Mobile Cranes
h) ASME ASME B30.22 Articulating Boom Cranes,
i) ASME B30.9 Slings
j) ASME B30.26 Rigging Hardware

B-3 PLANNING.

As you begin planning the inspection/repair, you begin working toward a selection of a crane. If the work is being done by contract, you need to check the crane’s documentation, including the certificate of compliance (required by both NAVFAC P-307 and ACOE EM 385-1-1), as well as additional required documentation as described in section 11 of NAVFAC P-307 and Chapter 16 of EM385-1-1. The documentation needs to be supplied to the contracting officer. If the crane being considered is run by the military, as opposed to a commercial entity, the military organization will be maintaining the crane’s documentation. Documentation needs to be current. Most contractor cranes will have to submit an annual and a quadrennial certification for the floating crane.

In addition, crane operator certifications, to include medical examiner's certification, and rigger and signal person's qualifications should also be provided and be current.

If a mobile crane is to be mounted on a barge or vessel, this and additional information needs to be provided.

- A naval architectural stability analysis of the barge or vessel while conducting the planned lifts as well as lifts at the rated loads and reaches. Reduced load charts are usually required to ensure that the list/trim is taken into account for the additional loading it will impose on the crane and that the barge/vessel does not exceed its maximum list or trim. This revised load chart must be present in the cab of the crane during operations.
- An analysis of the barge/vessel's deck should be conducted. This analysis shall include loading on the deck of the outriggers and of the tie-downs. The outriggers shall rest on wooden blocking. The tie downs should be calculated to resist any lateral loads the crane may sustain. Except for crawler cranes without outriggers, the cranes shall be used with the outriggers.

A lift plan should be developed detailing all the lifts, reaches and loads expected to be seen. In addition, required critical lift plans need to be developed, detailing the lift plan with the maximum load and reach, and submitted to the cognizant authority for their approval. Requirements for critical lift plans are in both EM 385-1-1 and NAVFAC P-307.

B-4 MOBILIZATION.

The first thing that may need to be done in preparing the vessel is to obtain a "Gas Free" Certificate from a marine chemist. This will permit you to weld padeyes or other hold down devices to the vessel as well as to cut things off the vessel if needed. These padeyes will be needed to secure a mobile crane and possibly to tie down the mooring hardware. However, before any welding, cutting, grinding, etc. can be done on the vessel, a "Hot-Work" Certificate may also need to be obtained.

Once the welding is complete and inspected by qualified personnel, the crane will be brought on board, set up and tied down in accordance with the approved barge stability analysis and engineering drawings for the positioning of the mobile crane. Remember that the crane must be on its outriggers and the outriggers on wooden blocks. Before the crane can be operated on board the vessel, it must be inspected by the Navy Crane Center. This inspection involves two items. The first is an inspection to ensure that the crane is properly tied down and that it is ready to operate. The second is a test lift of the critical lift. The crane will pick up a weight equal to the maximum weight as described in the critical lift plan and hold it out at its expected reach. The inspection will not just test the crane but ensure that the list and trim caused by that lift are within allowable limits.

Once these tests have been conducted, the crane can be used on the vessel to support all operations.

B-5 OPERATIONS.

While many of the safety concerns with operating a crane on a vessel are the same as when operating a crane ashore, there are several additional concerns that need to be considered during at sea operations.

While weather is always a concern, wind and waves become much larger additional factors at sea. Waves and seas cause rolling, pitching and swaying motions of the vessel, which, in turn, cause swinging of the lifted load. Wind, especially gusty winds, also cause swinging of the loads. The use of tag lines to help control this swinging motion is useful but only to a point. If the weather becomes too severe, it will be necessary to halt operations. In absence of guidance from the crane manufacturer, a maximum wind speed of 15 knots (7.717 meters/second, 17.262 mph, 25.317 fps) shall be used.

Cranes are not designed to take side loading. While this is true, for either ashore or at sea operations, it is more likely to be attempted at sea, especially during mooring repairs. The desire might well be to keep the load (buoy) close to the deck, dragging the chain out of the water. While this does help to eliminate the distance that the load can fall if something fails, it places a large side load on the crane, very potentially damaging the crane and making it unusable. A better practice is to lift the buoy, secure the mooring riser in a CCD and remove the buoy. Then lift the rest of the mooring riser as needed, secure it into a CCD and lower the riser to the deck. Personnel on the barge deck shall keep clear of the fall zone of the buoy and the riser chain unless qualified and directed to complete a specific task under the direction of the Marine Construction Supervisor.

Use extreme care in lifting of any hawsepipe buoy or any tension bar buoy where the conditions of the tension bar is questionable. The actual lift point should be below the buoy on the riser chain. An auxiliary crane hook can be used to support the weight of the buoy while the main crane hook lifts the riser chain. Ensure the rigging methods are appropriate to support both the hawse pipe buoy and riser chain to ensure that both the buoy and riser chain are adequately supported during the lift.

B-6 DEMOBILIZATION.

While there is little beyond standard safety concerns during demobilization, before any cutting, welding or grinding is done on the vessel, a Gas-Free Certificate and a Hot-Work Permit need to be obtained.

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APPENDIX C SAMPLE 1149

SHIPPING CONTAINER TALLY ——— 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50

REQUISITION AND INVOICE/SHIPPING DOCUMENT

RESET PAGE

OMB No. 0704-0246
OMB approval expires Apr 30, 2009

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to the Department of Defense, Executive Services Directorate (0704-0246). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ORGANIZATION. RETURN COMPLETED FORM TO THE ADDRESS IN ITEM 2.

1. FROM: *(Include ZIP Code)* ATTN: First & Last Name **Phone/Email:** Office phone/government email address
Activity: NAME & UNIT IDENTIFICATION CODE
Address: COMMAND ADDRESS
City/St/Country:Zip: CITY, STATE XXXXX

2. TO: *(Include ZIP Code)* POC: First & Last Name **Phone/Email:** Office phone/government email address
Activity: NAME & UNIT IDENTIFICATION CODE
Address: FULL SHIPPING ADDRESS
City/St/Country:Zip: CITY, STATE XXXXX NO FPO OR AP ADDRESS FOR OCONUS SHIPMENTS

3. SHIP TO - MARK FOR
POC Name, Phone Number and email
Mark for: Mooring Inspection at XXXXX

SHEET NO.	NO. OF SHEETS	5. REQUISITION DATE	6. REQUISITION NUMBER
1	1	2016-11-01	12 digit number assigned by shipping

7. DATE MATERIAL REQUIRED *(YYYYMMDD)*: 2017-01-31
8. PRIORITY: III - 9 THRU 15
9. AUTHORITY OR PURPOSE: Mooring Underwater Inspection & Zinc Anode Change Out
10. SIGNATURE:
11a. VOUCHER NUMBER & DATE *(YYYYMMDD)*:
12. DATE SHIPPED *(YYYYMMDD)*:
b.
13. MODE OF SHIPMENT: Surface (Ship)
14. BILL OF LADING NUMBER:
15. AIR MOVEMENT DESIGNATOR OR PORT REFERENCE NO.:

4. APPROPRIATIONS DATA
TAC NO: XXXX WORK CENTER: XXXXX
TAC OWNER: XXXXXXX JON: XXXXXX
ADDITIONAL SHIPPING INSTRUCTION: Forklift is required for loading
Door to Door delivery to XXXXX
AMOUNT: $ 5,500.00

ITEM NO. (a)	FEDERAL STOCK NUMBER, DESCRIPTION, AND CODING OF MATERIEL AND/OR SERVICES (b)	UNIT OF ISSUE (c)	QUANTITY REQUESTED (d)	SUPPLY ACTION (e)	TYPE CON-TAINER (f)	CON-TAINER NOS. (g)	UNIT PRICE (h)	TOTAL COST (i)
1	ZINC ANODE, 2.5-INCH W/SCREW; 550 PER DRUM, WEIGHT APPROX 1000 LBS	DR	1				$ 5,550.00	$ 5,550.00
								$ 0.00
								$ 0.00
								$ 0.00
								$ 0.00

16. TRANSPORTATION VIA AMC OR MSC CHARGEABLE TO XXXX
17. SPECIAL HANDLING

18. RECAPITULATION OF SHIPMENT	TOTAL CON-TAINERS	TYPE CON-TAINER	DESCRIPTION	TOTAL WEIGHT	TOTAL CUBE
ISSUED BY					
CHECKED BY					
PACKED BY	0		← TOTAL →	0	0

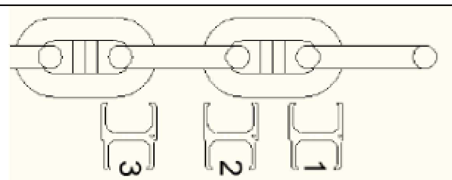
19. RECEIPT	DATE (YYYYMMDD)	BY	
CONTAINERS RECEIVED EXCEPT AS NOTED			SHEET TOTAL $ 5,550.00
QUANTITIES RECEIVED EXCEPT AS NOTED			GRAND TOTAL $ 5,550.00
POSTED			20. RECEIVER'S VOUCHER NO.

DD FORM 1149, JUL 2006 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100
PREVIOUS EDITION IS OBSOLETE.
Adobe Designer 8.0

APPENDIX D SAMPLE MOORING INSPECTION SHEETS

The following are sample mooring inspection sheets for various points on the mooring.

MOORING ________

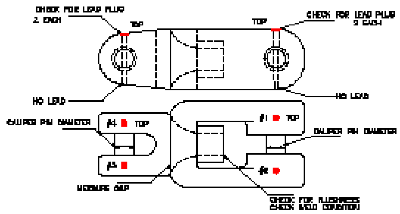


SET	DEPTH	>90%	>80%	<80%
1				
2				
3				
4				
MAX DEPTH				

RISER INSPECTION

MOORING _______

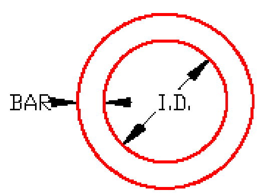
SWIVEL				



PLUGS				
0	1	2	3	4

T-PIN		IN
B-PIN		IN
GAP		IN

GROUND RING



BAR		IN
I.D.		IN

RISER INSPECTION

MOORING ________ LEG_______

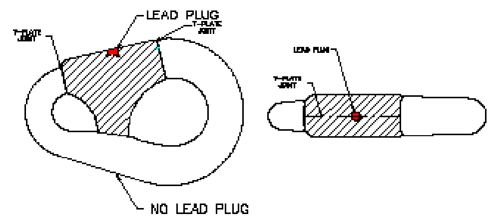
SINGLE GAUGES IF CHAIN IS SLACK	

SET	LINK COUNT	>90%	>80%	<80%
1				
2				
3				
4				
MAX DEPTH				

LEG INSPECTION

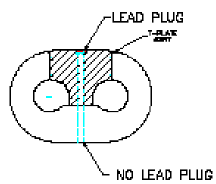
MOORING ________ LEG______

ANCHOR JOINING LINK



PLUG	**YES**	**NO**
INTACT	**YES**	**NO**

CHAIN JOINING LINK



CJL #1	**LINK COUNT**	
PLUG	**YES**	**NO**
INTACT	**YES**	**NO**
CJL #2	**LINK COUNT**	
PLUG	**YES**	**NO**
INTACT	**YES**	**NO**

LEG INSPECTION

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APPENDIX E SAMPLE PRELIMINARY INSPECTION EMAIL

The following is a sample of a preliminary inspection email:

NAVFAC Engineering and Expeditionary Warfare Center (EXWC) East Coast Detachment conducted an underwater inspection of Fleet Mooring 7 located in vicinity of pier 1 at Naval Weapon Station (NWS) EARLE on 21 July 2010. The inspection was conducted by an engineer from EXWC and divers from underwater construction team one. The following is a preliminary report of the inspection results:

A. Fleet Mooring 7 was found to be in C3, fair condition, due to measurements on the riser chain between 80% and 90% of its original wire-diameter.

B. Measurements on the top jewelry pear links were found to be between 80% and 90% of its original wire diameter.

Mooring will be scheduled for repair in FY11 by the Fleet Mooring Program.

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APPENDIX F UNDERWATER INSPECTION REPORT TEMPLATE

FLEET MOORING UNDERWATER INSPECTION RESULTS

Mooring Id	XX	Activity	XX
Report Date	Month Year	Report Number	XX

GENERAL INSPECTION INFORMATION

Design Class	AAA,AA,A,B,C,D,E,F,G	Rated Capacity (1000 lbs.)	100
Buoy Type	Foam, tension bar	Buoy Dia. (ft.)	12
Mooring Type	Riser-Type	Quantity of ground legs	3
Anchor Type	Stockless	Anchor Size (kip)	20
Riser size (in)	2.5	Ground leg size (in)	2.5

OVERALL INSPECTION ASSESSMENT

Mooring Condition Readiness	C1/2/3/4	Inspection Date	mm/dd/yyyy
Mooring Rated Condition (ICAP)	50	Required Repairs	X
Current Class	X	Rated Capacity (1000 lbs.)	100
Divers	Organization – last names	Engineer-In-Charge	X
Buoy Freeboard (in)	XX	Water Visibility (ft.)	X
Water Depth (ft.)	XX	Bottom condition	X

INSPECTION SURVEY RESULTS

System Datum Geodetic	WGS84	Latitude	Nxx° xx' xx.xx"	Longitude	Wxxx° xx' xx.xx"
System Datum Projected	State NAD83/ UTM Zone XXY	Northing	XXXXX	Easting	XXXXXX

INSPECTION CATHODIC PROTECTION RESULTS

% Anodes Depleted (0-99)	XX%	Anodes Replaced (Y/N)	Y/N
Replacement Anode Size (in)	X.X	Quantity Of Anodes Replaced	X

BUOY TOPSIDE INSPECTION ASSESSMENTS

Component	Type/ Qty	Damage/ Wear	Corrosion/ Discoloration	Overall Condition
Connection	Padeye/Hawse	X	X	X
Padeye Bushing		X	X	X
Hawse Pipe Bolts/Screws	XX or N/A	X	X	X
Hull	Pegtop/Drum	X	X	X
Coating	Urethane/Paint	X	X	X
Fender	Single Urethane	X	X	X
Reflective Tape	Double Tape	X	X	X
Chafe Strips	Urethane/Rubber	X	X	X

BUOY TOP JEWELRY INSPECTION MEASUREMENTS

Item	Inspection Point	Catalog Value (in)	Caliper Results (in)	Condition (%)
Buoy Shackle	Bale	4.56	4.375	96
Buoy Shackle	Pin	4.25	4.125	97
Pear Link	Minimum Bale	4.25 – 4.37	4.0625	96

INSPECTION MEASUREMENT RESULTS

Item	Criteria	Inspection Point	Unit of Measure	Reference Point	Size (in)	Condition (%) / (in)
Riser	All 3 >90	13	Feet	Waterline	2.75	All 3 >90
Riser	All 3 >90	30	Feet	Waterline	2.75	All 3>90
Riser	All 3 >90	40	Feet	Waterline	2.75	All 3 >90
Ground Leg 1	All 3 >90	2	Links	Ground Ring	2.50	All 3 >90

FLEET MOORING UNDERWATER INSPECTION RESULTS						
Mooring Id	XX		Activity	XX		
Report Date	Month Year		Report Number	XX		
Ground Leg 1	All 3 >90	37	Links	Ground Ring	2.50	All 3 >90
Ground Leg 1	All 3 >90	72	Links	Ground Ring	2.50	All 3 >80
Ground Leg 1	All 3 >90	107	Links	Ground Ring	2.50	**All 3 <80**
Ground Leg 2	All 3 >90	1	Links	Ground Ring	2.50	All 3 >90
Ground Leg 2	All 3 >90	37	Links	Ground Ring	2.50	2 >90;1>80
Ground Leg 2	All 3 >90	72	Links	Ground Ring	2.50	All 3 >80
Ground Leg 2	All 3 >90	107	Links	Ground Ring	2.50	**All 3 <80**
Ground Leg 3	All 3 >90	2	Links	Ground Ring	2.50	All 3 >90
Ground Leg 3	All 3 >90	37	Links	Ground Ring	2.50	1 >90;2>80
Ground Leg 3	All 3 >90	72	Links	Ground Ring	2.50	2>80;**1<80**
Ground Leg 3	All 3 >90	107	Links	Ground Ring	2.50	**All 3<80**
Swivel Pin	4.45 – 4.67	Top Pin	Inch	Top Pin	3.50	4.50
Swivel Pin	4.45 – 4.67	Bottom Pin	Inch	Top Pin	3.50	**3.50**
Ground Ring	5.25 – 5.50	Bar	Inch	Ground Ring	2.25	5.25
Ground Ring	11.70 – 12.30	Inside Diameter	Inch	Ground Ring	2.25	12.50

INSPECTION COMMENT RESULTS	
Comment Type	Comment
General	
Buoy	
Top Jewelry	
Riser	
Ground Legs	
Anchors	
Anodes	
Marine Growth	
Survey	
Bottom	
Photo	

Notes and legend for completing inspection sheet

<table>
<tr><th colspan="2">GENERAL INSPECTION INFORMATION</th></tr>
<tr><td>Activity</td><td>List Activity</td></tr>
<tr><td>Report Date</td><td>List report date as shown on cover page</td></tr>
<tr><td>Report Number</td><td>List report number as shown on cover page</td></tr>
<tr><td>Design Class</td><td>List the design Class of the mooring.
The following table lists the standard fleet mooring classes
<table>
<tr><th>CLASS</th><th>CAPACITY (1000 lbf)</th><th>CLASS</th><th>CAPACITY 1000 lbf)</th></tr>
<tr><td>AA</td><td>300</td><td>C</td><td>100</td></tr>
<tr><td>BB</td><td>250</td><td>D</td><td>75</td></tr>
<tr><td>CC</td><td>200</td><td>E</td><td>50</td></tr>
<tr><td>DD</td><td>175</td><td>F</td><td>25</td></tr>
<tr><td>A</td><td>150</td><td>G</td><td>5</td></tr>
<tr><td>B</td><td>125</td><td>SPEC</td><td>OTHER</td></tr>
</table>
If the mooring’s rated capacity does not match the standard class, then it is “SPEC” and its rated capacity is as stated in its design report.</td></tr>
<tr><td>Rated Capacity</td><td>List the original corresponding rating of the mooring per design.
Note that units are already defined in “Rated Capacity” cell. Ensure rated capacity matches design class (unless “SPEC”).</td></tr>
<tr><td>Buoy Type</td><td>List buoy shape (drum or pegtop) if not a standard Fleet Mooring (small or medium) buoy, material type (foam or steel) & style (tension bar or hawse pipe)</td></tr>
<tr><td>Buoy Diameter</td><td>List buoy diameter of the hull, in feet. Note that standard fleet mooring foam tension bar buoys have diameters of 8 feet (small) or 11.5 feet (medium).
Note that units are defined in “Buoy Dia.” cell.</td></tr>
<tr><td>Mooring Type</td><td>Riser-type - riser with ground ring and 1 to multiple ground legs
Riser-leg - single riser from buoy to anchor.</td></tr>
<tr><td>Anchor Type</td><td>Pile, Plate, Propellant embedment, Deadweight; stockless, NAVMOOR; STATO; LWT, Concrete Pearl Harbor, etc.</td></tr>
<tr><td>Anchor Size</td><td>For pile anchors, list diameter and length
For propellant embedment anchors list rated capacity
For plate anchors list plate dimensions in ft.
For other anchors, list nominal weight.
This data is found in the mooring’s installation report or the moorings design and/or as-built drawings.
Note that units are defined in “Anchor Size” cell.</td></tr>
<tr><td>Riser size</td><td>List nominal size(s) of chain on the riser.
Note that units are defined in “Riser Size” cell.</td></tr>
<tr><td>Ground leg size</td><td>List nominal size(s) of chain on the ground leg(s).
Note that units are defined in “Ground Leg Size” cell.</td></tr>
<tr><td>Quantity ground legs</td><td>List quantity of ground legs</td></tr>
</table>

OVERALL INSPECTION ASSESSMENT

Current Class

List the corresponding Class of the mooring based on the results of the inspection.
The following table lists the standard fleet mooring classes

CLASS	***CAPACITY (1000 lbf)***	***CLASS***	***CAPACITY 1000 lbf)***
AA	300	C	100
BB	250	D	75
CC	200	E	50
DD	175	F	25
A	150	G	5
B	125	SPEC	OTHER

If the mooring's rated capacity does not match the standard class, then it is "SPEC" and its rated capacity is as stated in its design report.

Rated Capacity

List the corresponding rating of the mooring based on the results of the inspection.
Note that units are already defined in "Rated Capacity" cell. Ensure rated capacity matches design class (unless "SPEC").

Mooring Rated Condition (ICAP)

The following table lists mooring condition rating values based on the results of the inspection.

VALUE	***CONDITION***
90	All >90%; minimal corrosion present
80	All >90%; moderate corrosion present or partial damage to fenders or chafe rails or reflective tape in need of replacement
75	All >90%; heavy corrosion present or fenders or chafe rails completely missing or top jewelry not secure
70	All >90%; buoy refurbishment required or replacement of attached buoy connection hardware required.
60	Topside <90%; minimal -moderate corrosion present
55	Topside <90%; moderate-heavy corrosion present
50	Below water connection assembly not secure
40	Underwater <90%; minimal -moderate corrosion present
30	Underwater <90%; moderate-heavy corrosion present
20	<80%; minimal corrosion present or legs dragged off location
10	<80%; moderate corrosion present
0	<80%; heavy corrosion present or a ground leg detached

<table>
<tr><td>Mooring Condition Readiness</td><td>The following table lists the mooring condition readiness based on the results of the inspection.
<table><tr><th>RATING</th><th>MOORING CONDITION</th></tr><tr><td>C1 (Good)</td><td>Mooring is in Good condition and considered satisfactory for continued use.</td></tr><tr><td>C2 (Fair)</td><td>Topside measurements between 80% and 90% recorded. Mooring can be repaired without underwater work. Mooring may be unable to be used at its full design capacity. Restrictions could impair operations. Vessels may have to find alternate facilities to moor. An engineering assessment is required. Restrictions could impair operations. Failure of mooring is possible.</td></tr><tr><td>C3 (Fair)</td><td>Below waterline measurements between 80% and 90% recorded. Mooring will require underwater work for repairs. Mooring may be unable to be used at its full design capacity. An engineering assessment is required. Restrictions could impair operations. Failure of mooring is probable.</td></tr><tr><td>C4 (Poor)</td><td>Measurements found <80%. Mooring is restricted from use until repairs are completed. Failure of mooring is imminent.</td></tr></table></td></tr>
<tr><td>Required Repairs</td><td>List the mooring component(s) requiring repair or replacement to restore the mooring to C1 condition. If none, state “None”</td></tr>
<tr><td colspan="2">INSPECTION SURVEY RESULTS</td></tr>
<tr><td colspan="2">The coordinate results shown in this section should match what is provided in the survey appendix of the inspection report.</td></tr>
<tr><td>Datum
Geodetic</td><td>Provide coordinates in WGS84 geodetic latitude and longitude or geodetic datums used on nautical charts at the mooring location.</td></tr>
<tr><td>Latitude/Longitude</td><td>Provide as WGS84 in degrees-minutes-seconds to at least 2 decimal places. Include N or S for latitudes, E or W for longitudes.</td></tr>
<tr><td>Datum
Projected</td><td>Provide projected datum (ie NAD83, NAD27), state plane to include Zone identifier and units used. If using UTM WGS84, provide Zone identifier and use meters for units.</td></tr>
<tr><td>Northings/Eastings</td><td>Provide to at least 2 decimal places.</td></tr>
<tr><td colspan="2">INSPECTION CATHODIC PROTECTION RESULTS</td></tr>
<tr><td>% Anodes Depleted (0-99)</td><td>Provide an overall assessment of the percentage of anodes depleted. Anodes that crumble or disintegrate when tapped are considered to be depleted.
Note % defines the amount of the zinc that has been depleted.</td></tr>
<tr><td>Anode Size</td><td>List size anodes, by size, used for replacement.</td></tr>
<tr><td>Anode quantity</td><td>List qty, by size, anodes replaced.</td></tr>
<tr><td colspan="2">BUOY TOPSIDE INSPECTION ASSESSMENTS</td></tr>
<tr><td colspan="2">This section is used to describe the type of mooring buoy and to assess its’ overall condition.</td></tr>
<tr><td>Connection</td><td>List type of buoy connection; tension bar padeye or hawse-chain.</td></tr>
<tr><td>Padeye Bushing</td><td>Condition of wear bushing on upper padeye.</td></tr>
<tr><td>Hull</td><td>List type of hull form; peg-top, spherical or drum.</td></tr>
</table>

Hawse pipe bolts or screws	If applicable, list type and quantity of bolts or screws; list whether exposed or recessed.
Coating	List coating type; urethane (foam buoys), fiberglass, painted, none.
Fender/Rubrail	List type (urethane, rubber, wood, etc) and quantity.
Reflective Tape	List type (tape) and quantity.
Chafe/Rub Rails	List type (steel pipe, urethane, D-rubber, etc) and quantity.
Damage	Describe as major, moderate, minimal or none. For condition of buoy hull, hawse-chain connection buoy capture plate assembly (to include connecting hardware), fenders, chafe rails, reflective tape.
Wear	Describe as major, moderate, minimal or none. For assessment of tension bar padeyes and tension bar padeye bushings and hawse-chain buoy capture plate assembly (to include connecting hardware).
Discoloration	Describe as heavy, moderate, minor or none. Discoloration of non-metal components due to rust bleeding from metal components on buoy hull, etc. UV degradation or fading of reflective tape.
Corrosion	Describe as major, moderate, minimal or none. Corrosion of external steel buoy connections or other components to include haws pipe assembly connecting hardware.
Overall condition	Describe overall buoy condition as Good, Fair or Poor.
BUOY TOP JEWELRY INSPECTION MEASUREMENTS	
This section documents go no/go and caliper measurements of components inspected on top of the mooring buoy.	
Buoy Shackle	
Bale	Define bale dimension from catalog for new shackle. Take caliper measurements on the bale of the shackle *at the wear point and in the wear direction.* Ensure all rust debris is cleaned off prior to taking caliper measurement. List actual percentage based on “caliper measurement/minimum catalog value).
Pin	Define pin dimension from catalog for new shackle. Take caliper measurements on the pin adjacent to the buoy padeye *near the wear point*. Ensure all rust debris is cleaned off prior to taking caliper measurement. List actual percentage based on “caliper measurement/minimum catalog value).
Pear Link	
Bend	Define pear link bar diameter minimum and maximum dimensions from catalog values. Take caliper measurements on the bend of the pear link at the *wear point and in the wear direction*. Can report the smallest measurement of the 2 pear link bales. Ensure all rust/debris is cleaned off prior to taking caliper measurement. List actual percentage based on “caliper measurement/minimum PD value).
Chain Link or Joining Link	
Link Bar	Define bar dimension from catalog for new link.

	Take caliper measurements on the bar of the link *at the wear point and in the wear direction near contact points.* Ensure all rust debris is cleaned off prior to taking caliper measurement. List actual percentage based on "caliper measurement/minimum catalog value). If connecting link is an anchor joining link, take caliper measurements of bar diameters at both the larger and smaller ends and report both findings.
INSPECTION MEASUREMENT RESULTS	
This section documents go no/go and caliper measurements of components inspected on the mooring system below the buoy. **Record go no/go measurement results or caliper measurements in bold red font and highlight go no/go measurement results or caliper measurements found to be <90% in yellow.**	
Item	State mooring component inspected (riser, ground leg 1, ground leg 2, swivel shackle, ground ring, etc). Riser Set - a set of 3 consecutive go no-go measurements taken on the riser. Riser Link - one go no-go measurement taken on a riser link. Ground Leg 1 set - a set of 3 consecutive go no-go measurements taken on ground leg 1. Ground Leg 1 link - go no-go measurement taken on a link on ground leg 1.
Criteria	Criteria is "all 3>90" for measurement sets or ">90" for individual link measurements. Inspection points for riser and ground legs are taken as measurement sets. For accessory components, criteria is the minimum to maximum catalog value for the dimensions to be measured on the accessory component.
Inspection Point	Location of the measurements along the mooring riser, ground leg or on the accessory component. This cell entry is based on the entered data for Unit of Measure and Reference Point.
Unit of Measure	State units of measurements (inches, feet, meters, etc) or Links for the inspection points.
Reference Point	State the reference point for the inspection point for the inspected component. For risers, the reference point is usually the waterline. For ground legs, this can be the ground ring if the unit of measure is the links. For accessory components, repeat the name of the item being inspected.
Size/(in)	List the nominal size of the mooring chain or accessory component being inspected. *Note that this cell is not to record your measurement finding.*
Condition (%)/(in)	Reported as "All 3>90, All 3 >80 or All 3<80. If measurements within a set are not the same, provide the breakdown (ie; 2>90;1>80, etc). For connecting or accessory components, record the actual calipered measurement taken (in inches).
INSPECTION COMMENT RESULTS	
Below are some of the most common inspection comment blocks. Others can be added/removed by the document writer as needed to document inspection results of the mooring system. These sections are used to provide additional information on the inspection findings.	
General	State buoy's Mooring Condition Readiness and operational use or restrictions. State if and type of vessel moored to the buoy during the inspection. If Mooring Condition Readiness is C2 or worse, list required repairs to restore mooring to its original design rating and a C1 condition. Example: *Mooring X is in C1 (Good) condition and satisfactory for continued use as a Class Y mooring. No vessel attached to the buoy during inspection.*

Buoy	State the type of mooring buoy (type, shape, connection, diameter) and identification plate data (Manufacturer, serial number, contract number, month/year of manufacture). State condition of fenders, chafing or rub rails, reflective tape and any other buoy hull accessories. State condition of the buoy hull. State condition of padeye bushings. State condition of and if buoy zinc anodes were replaced. State hull condition. Assess buoy heel. Assess buoy draft.
Top Jewelry	List top jewelry components attached to the mooring buoy. State condition of all top jewelry components to include levels of corrosion and assessment of caliper measurements to its listed minimum catalog value. State size, manufacturer, year and serial numbers of top jewelry components.
Riser Assembly (includes, attachment hardware to the buoy and ground ring, ground ring, riser or ground ring sinker and ground leg connecting hardware on the ground ring)	State the condition of the riser. State type of measurements, type go/no gauges, quantity of measurements and locations the riser was measured. State the results of the go/no go measurements. If measurements are found to be <90%, list the location and amount of the riser (number of links) that needs to be repaired. Example: "*The riser is in good condition.* Consecutive *measurement sets were taken at four locations along the riser using double link go, no-go gauges. All measurements were found to be >90% of original wire diameter*". State the results of the inspection of the riser swivel shackle to include swivel shackle gap measurement, presence and quantity of lead plugs. State assessment of swivel shackle pin caliper measurements to its listed minimum catalog value. All four lead plugs in the swivel shackle were intact. If found, list water depth of chain joining links, presence of lead plug and joining link assembly assessment. If available for inspection, state assessment of ground ring bar caliper and inside diameter measurements to its listed minimum catalog value. State water depth of ground ring. If available for inspection, state quantity of anchor joining links connected to the ground ring, presence of lead plugs and joining link assembly assessment. If found, state presence, water depth and condition of sinkers found on riser or attached to the ground ring.
Ground Legs	State if all or quantity of ground legs buried and unable to be inspected. State the condition of all ground legs. State type of measurements, type go/no gauges, quantity of measurements and locations the ground legs was measured. State point of burial for ground legs inspected. Example: "Consecutive m*easurement sets were taken every 30 feet along all ground legs using double link go, no-go until the ground leg became buried and unable to be inspected. All measurements were found to be >90% of original wire diameter*". List ground leg headings from ground ring toward anchor. If found, list link count or chain length from the ground ring of chain joining links, presence of lead plug and joining link assembly assessment. *Note-a separate comment block may be used for each ground leg.*
Anchors	State if the anchors are buried and unable to be inspected. For drag embedment or deadweight anchors that are found and inspected, state if stabilizers are present, if the anchor is rightside up or upside down, if aligned with the ground leg heading, if the anchor is partially buried or completely exposed and the condition of connecting links and swivel shackles that attaches the anchor to the ground leg.

Anodes	State size of replacement anodes and quantity of new anodes installed on mooring riser, ground legs and lower buoy tension bar padeye. List any installation problems in attaching new anodes (i.e. sheared bolts, missing studs, etc).
Marine Growth	Describe marine growth type (soft, hard, shells) thickness and location along the riser (top, middle, bottom) and bottom of buoy.
Survey	If the buoy was surveyed, list the equipment used to perform the survey. If a GPS was used, list the accuracy of the GPS to include quantity of satellites, and level of precision (ie PDOP or HDOP). State the system and datum used to include units (i.e. US Feet or meters). State software used for coordinate conversions. Other than the dive or survey boat, state if a vessel was moored to the buoy during the survey.
Bottom	Describe the type of seafloor conditions found at the mooring site.
Photo	Provide a identification photo of the buoy that shows the entire buoy. The buoy should fill up the majority of the photo, and if present, include the stenciled buoy name.

WITHIN A REPORT, BE CONSISTENT IN COMMENT FORMAT THROUGHOUT ALL INSPECTION SHEETS.

APPENDIX G FM3 MOORING COMPONENT DATA

This Appendix provides data on FM3 components. Data on commercial components can be obtained from the manufacturer or distributer.

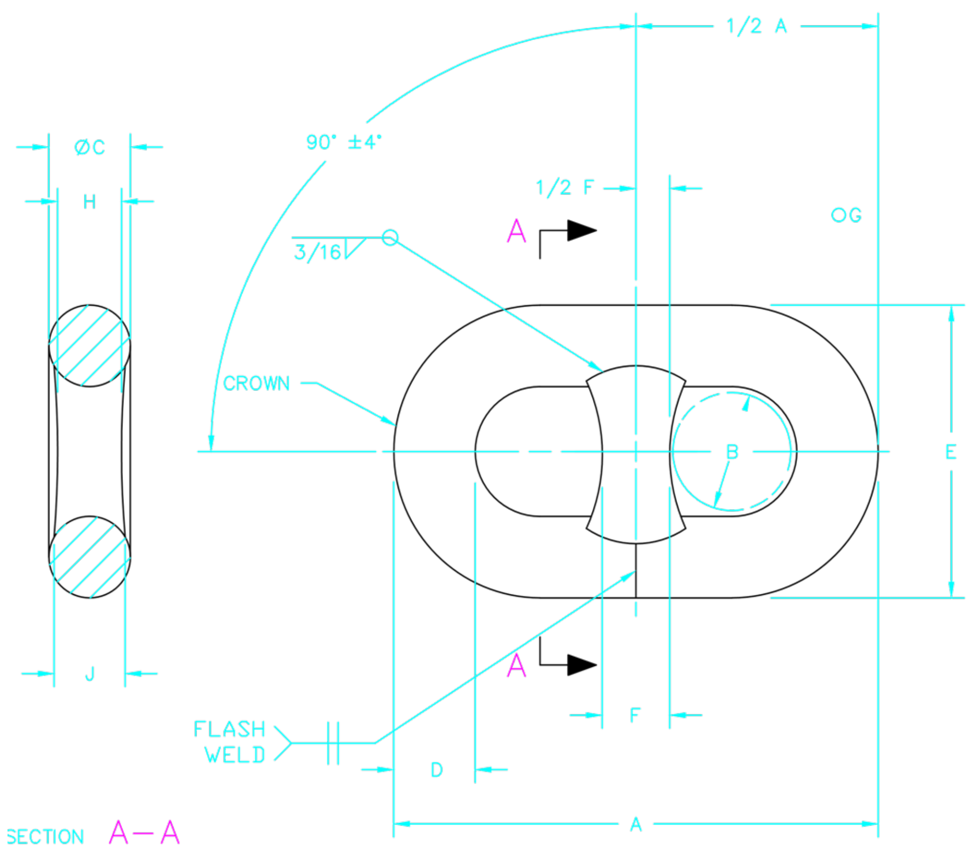
G-1 FM3 STUD LINK CHAIN.

Figure G-1 FM3 Stud Link Chain

(All Dimensions in Inches)

Nominal Diameter	A (min)	A (max)	B (min)	C (min)	C (max)	D (min)	E (min)	E (max)	F (min)	G (min)	H (max)
1−3/4	10.50	10.76	2.62	1.75	1.81	1.69	6.21	6.50	1.50	1.41	1.58
2	12.00	12.30	3.00	2.00	2.06	1.94	7.10	7.37	1.65	1.59	1.77
2−1/4	13.50	13.84	3.42	2.25	2.34	2.19	8.04	8.35	1.80	1.59	2.09
2−1/2	15.00	15.38	3.76	2.50	2.59	2.44	8.88	9.20	1.95	1.64	2.23
2−3/4	16.50	16.91	4.12	2.75	2.84	2.79	9.76	10.18	2.10	1.80	2.48
3	18.00	18.45	4.49	3.00	3.09	2.94	10.65	11.05	2.25	1.94	2.62
3−1/2	21.00	21.53	5.25	3.50	3.59	3.38	12.43	12.81	2.40	2.38	3.12
4	24.00	24.60	6.20	4.00	4.10	3.88	14.40	14.78	2.70	2.58	3.58

Note: 'C' dimension is tolerance range for bar stock
'D' dimension is minimum bar diameter at crown
'E' dimension does not include flashing at weld



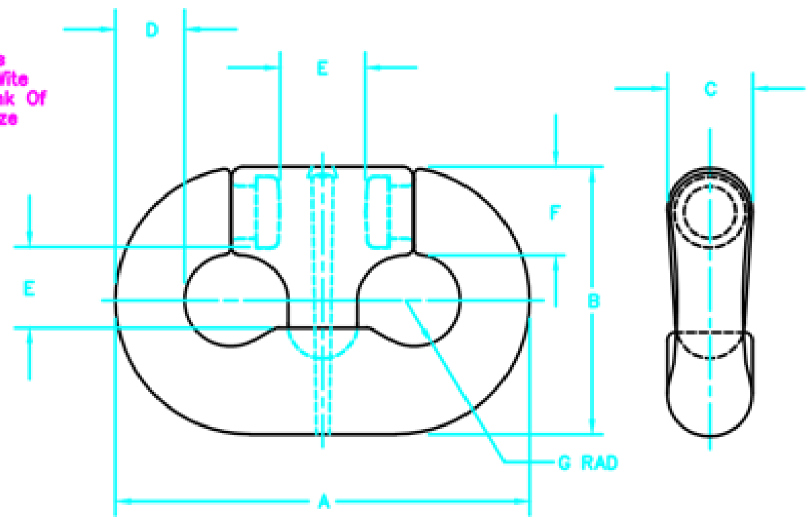
G-2 FM3 CHAIN JOINING LINK.

Figure G-2 FM3 Chain Joining Link Data

(All Dimensions In Inches)

Nominal Diameter	A (min)	A (max)	B (min)	B (max)	C (min)	C (max)	D (min)	D (max)	E (min)	E (max)	F (min)	F (max)	G (min)	G (max)
1-3/4	11.97	12.03	7.72	7.78	2.33	2.61	1.97	2.03	2.34	2.47	2.47	2.53	1.30	1.33
2	13.47	13.53	8.69	8.75	2.61	2.95	2.22	2.28	2.65	2.78	2.78	2.84	1.45	1.51
2-1/4	14.79	15.03	9.65	9.72	2.90	3.28	2.47	2.53	2.91	3.06	3.06	3.12	1.64	1.67
2-1/2	16.47	16.53	10.78	10.84	3.59	4.03	2.84	2.90	3.25	3.30	3.44	3.50	1.80	1.83
2-3/4	18.34	18.41	11.98	12.03	3.97	4.47	3.16	3.22	3.34	3.40	3.81	3.87	1.89	1.92
3	19.72	19.78	12.84	12.91	4.38	4.62	3.34	3.40	3.47	3.63	4.06	4.17	2.11	2.18
3-1/2	23.22	23.28	14.97	15.03	4.67	5.26	3.84	3.90	4.58	4.72	4.72	4.78	2.61	2.64
4	25.40	25.60	17.34	17.40	6.33	6.67	4.34	4.40	5.22	5.38	5.84	5.91	2.87	2.91

Note:
All Chain Joining Links Must Be Compatible Wite The Common Stud Link Of The Same Nominal Size



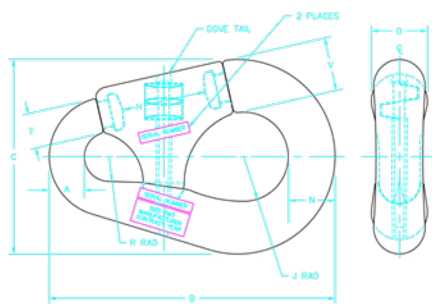
G-3 FM3 ANCHOR JOINING LINK.

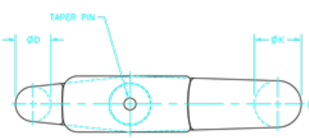
Figure G-3 FM3 Anchor Joining Link Data

(All Dimensions in Inches)

Nominal Diameter	A (min)	A (max)	B (min)	B (max)	C (min)	C (max)	D (min)	D (max)	H (min)	H (max)	J (min)	J (max)
1-3/4	1.97	2.03	14.84	14.90	10.22	10.28	3.00	3.18	3.91	3.97	2.05	2.08
2	2.34	2.41	17.84	17.90	12.28	12.34	3.62	3.86	4.72	4.78	2.51	2.54
2-1/4	3.09	3.15	22.09	22.15	14.78	14.84	4.75	5.03	5.84	5.91	2.98	3.01
2-1/2	3.09	3.15	22.09	22.15	14.78	14.84	4.75	5.03	5.84	5.91	2.98	3.01
2-3/4	3.09	3.15	22.09	22.15	14.78	14.84	4.75	5.03	5.84	5.91	2.98	3.01
3	3.59	3.66	25.72	25.78	16.47	16.53	5.25	5.57	6.06	6.17	3.11	3.14
3-1/2	3.59	3.66	25.72	25.78	16.47	16.53	5.25	5.57	6.06	6.17	3.11	3.14
4	4.87	5.12	36.77	37.23	23.75	24.25	7.87	8.12	7.87	8.12	4.25	4.50

Nominal Diameter	N (min)	N (max)	R (min)	R (max)	T (min)	T (max)	V (min)	V (max)
1-3/4	2.47	2.53	1.23	1.26	2.22 X 2.34	2.38 X 2.41	2.87	2.94
2	2.97	3.03	1.45	1.48	2.41 X 2.84	2.47 X 2.91	3.44	3.50
2-1/4	3.72	3.78	1.89	1.92	3.09 X 3.34	3.15 X 3.41	4.34	4.41
2-1/2	3.72	3.78	1.89	1.92	3.09 X 3.34	3.15 X 3.41	4.34	4.41
2-3/4	3.72	3.78	1.89	1.92	3.09 X 3.34	3.15 X 3.41	4.34	4.41
3	4.67	5.06	2.11	2.14	3.97 X 4.34	4.03 X 4.41	5.09 X 5.22	5.16 X 5.28
3-1/2	4.64	5.06	2.11	2.14	3.97 X 4.34	4.03 X 4.41	5.09 X 5.22	5.16 X 5.28
4	6.68	7.06	2.95	3.06	6.00	6.16	7.68	8.06





Note: All Anchor Joining Links Must Fit The Common Stud Link and the Ground Ring of the Same Nominal Size. 2-1/4 to 2-3/4 Inch Anchor Joining Links Shall be Tested to the 2-3/4 Inch Requirements and Marked With The Range of 2-1/4 to 2-3/4 Inches. Same Requirement for 3 and 3-1/2 Inch Sizes.

G-4 FM3 GROUND RING.

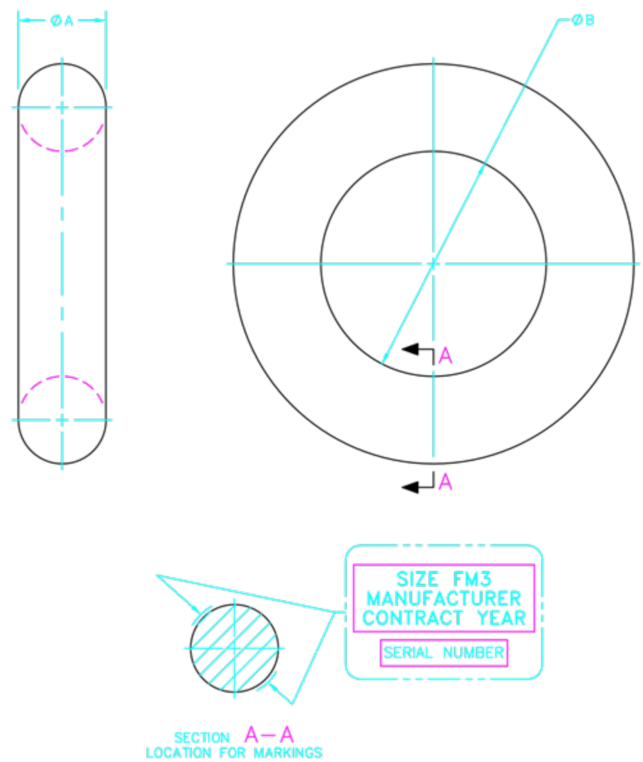
Figure G-4 FM3 Ground Ring Data

(All Dimensions in Inches)

Nominal Diameter	A (min)	A (max)	B (min)	B (max)
1-3/4	3.41	3.59	8.78	9.23
2	3.66	3.84	10.24	10.76
2-1/4	5.25	5.50	11.70	12.30
2-1/2	5.25	5.50	11.70	12.30
2-3/4	5.25	5.50	11.70	12.30
3	5.50	5.75	13.16	13.84
3-1/2	5.75	6.00	13.16	13.84
4	7.31	7.69	19.00	19.95

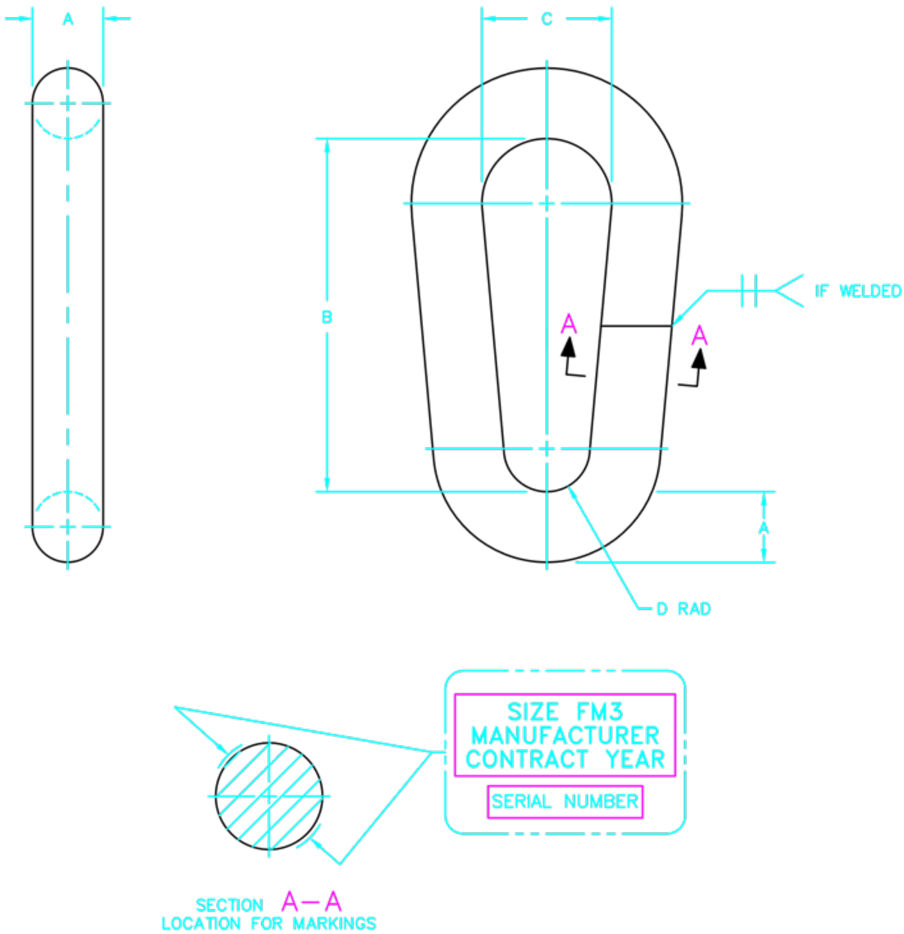
NOTE:

1. 2-1/4 to 2-3/4 inch Ground Rings shall be tested to the 2-3/4 inch requirements and marked with the range of 2-1/4 to 2-3/4.
2. Markings shall be as specified in Section 3.8.



G-5 FM3 PEAR LINK.

Figure G-5 FM3 Pear Link



(All Dimensions in Inches)

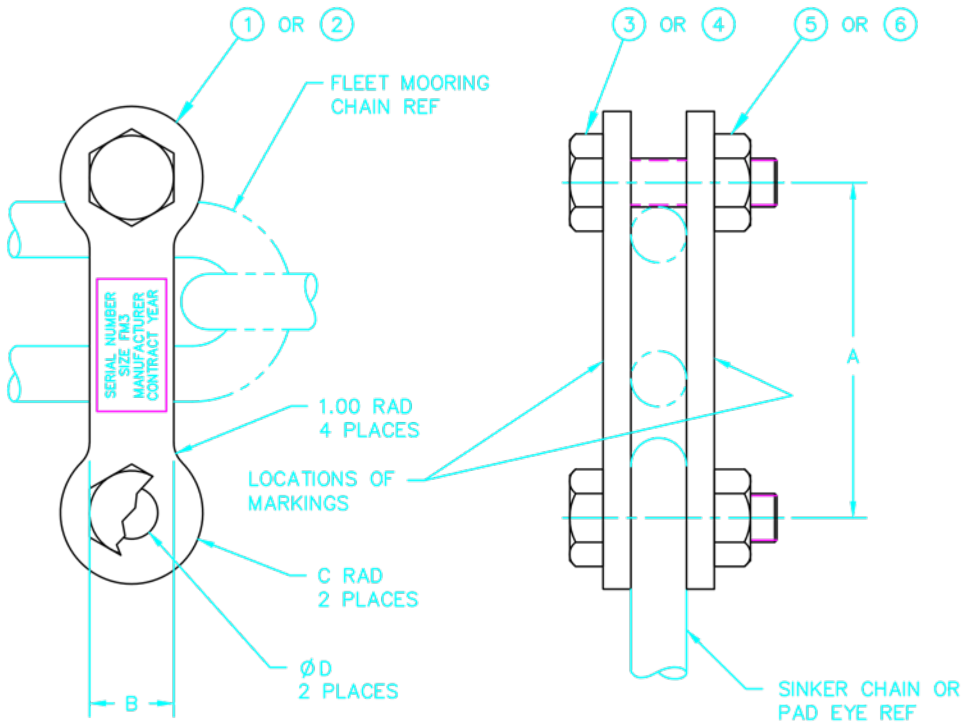
Nominal Diameter	A (min)	A (max)	B (min)	B (max)	C (min)	C (max)	D (min)	D (max)
1–3/4	2.25	2.38	11.50	11.67	4.19	4.32	1.38	1.44
2	2.50	2.63	13.73	14.03	4.91	5.21	1.64	1.74
2–1/4	2.75	2.87	14.50	14.69	5.37	5.50	1.73	1.83
2–1/2	3.00	3.13	16.16	16.34	5.92	6.05	1.92	2.02
2–3/4	3.50	3.63	17.17	17.88	6.47	6.60	2.11	2.21
3	3.75	3.83	19.21	19.33	6.82	7.28	2.28	2.40
3–1/2	4.25	4.33	23.90	24.08	8.77	8.90	2.85	2.79
4	4.75	4.87	26.22	26.40	9.61	9.74	3.13	3.25

NOTES:

1. MARKINGS SHALL BE AS SPECIFIED IN SECTION 3.7.

G-6 PLATE SHACKLE.

Figure G-6 Plate Shackle



DASH NO.	SINKER CHAIN OR PAD EYE DIA REF	DIM. A ±.12	DIM. B ±.12	RAD C ±.12	DIA D ±.06
-1	1 3/4 TO 2	12.06	3.03	2.56	1.88
-2	2 1/4 TO 4	22.06	4.03	3.56	2.38

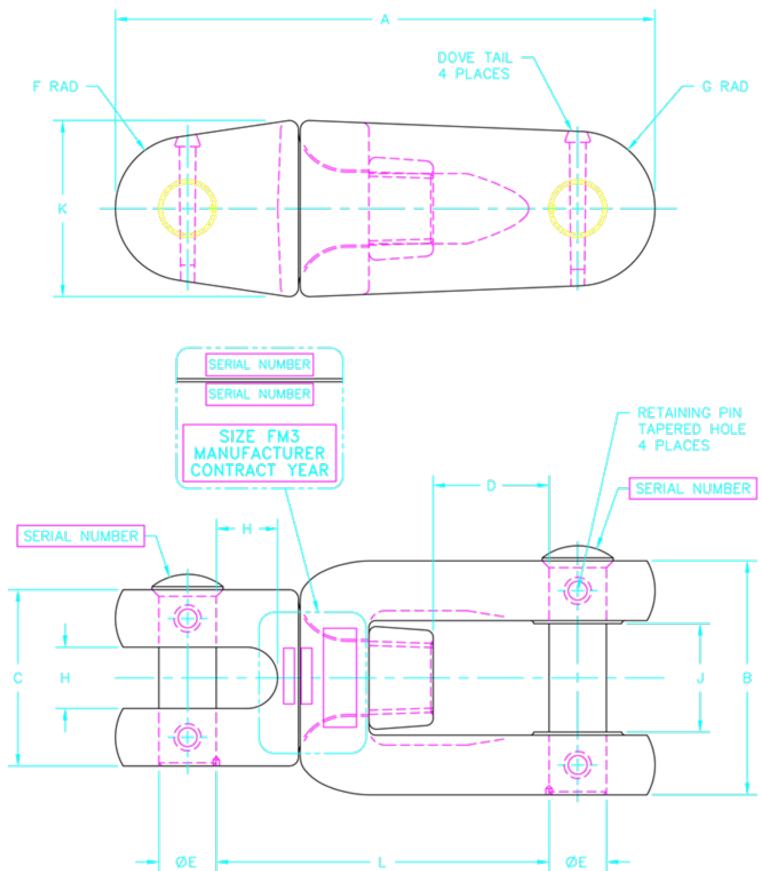
2	–	6	GRADE DH	NUT, HEAVY, HEX, 2.250-8UN-2B	ASTM A563	STEEL
–	2	5	GRADE DH	NUT, HEAVY, HEX, 1.750-8UN-2B	ASTM A563	STEEL
2	–	4	GRADE BD	BOLT, HEX HD, 2.250-8UN-2A X 9.25L	ASTM A354	STEEL
–	2	3	GRADE BD	BOLT, HEX HD, 1.750-8UN-2A X 6.25L	ASTM A354	STEEL
2	–	2		PLATE, 1.25 STK	ASTM A36	STEEL
–	2	1		PLATE, 1.00 STK	ASTM A36	STEEL
QTY REQD	QTY REQD	FIND NO.	PART OR IDENTIFYING NO.	PART OR IDENTIFYING NO.	SPEC	MATERIAL
-2	-1	PARTS LIST				

NOTES:

1. PLATE SINKER SHACKLE MARKINGS SHALL BE AS SPECIFIED IN SECTION 3.7.

G-7 FM3 RISER SWIVEL SHACKLE DATA.

Figure G-7 FM3 Riser Swivel Shackle Data



(Dimensions are specified on following page.)

(All Dimensions in Inches)

Nominal Diameter	A (min)	A (max)	B (min)	B (max)	C (min)	C (max)	D (min)	E (min)	E (max)	F (min)	F (max)
1-3/4	20.91	22.44	9.07	9.53	6.83	7.18	5.62	2.22	2.34	2.80	2.94
2	25.36	26.66	11.21	11.79	7.99	8.39	5.62	2.57	2.71	3.29	3.45
2-1/4	27.44	30.50	12.29	12.92	8.76	9.20	8.00	2.84	2.98	3.61	3.79
2-1/2	31.89	33.53	13.74	14.44	9.83	10.32	8.00	3.23	3.39	4.07	4.27
2-3/4	34.09	35.83	15.04	15.82	10.74	11.30	8.00	3.23	3.39	4.42	4.64
3	38.74	40.72	16.43	17.27	12.05	12.67	9.00	3.76	3.96	4.99	5.25
3-1/2	45.90	48.26	19.34	20.34	13.82	14.52	9.00	4.45	4.67	5.53	5.81
4	52.11	54.79	21.96	23.08	15.74	16.54	9.00	4.62	4.87	6.44	6.78

Nominal Diameter	G (min)	G (max)	H (min)	H (max)	J (min)	J (max)	K (min)	K (max)	P (min)	P (max)
1-3/4	2.99	3.15	2.38	2.50	3.75	4.87	6.83	7.18	12.90	14.75
2	3.69	3.87	2.76	2.90	3.75	4.87	7.99	8.39	15.81	16.63
2-1/4	4.03	4.23	3.07	3.23	3.75	4.87	8.76	9.20	16.97	19.56
2-1/2	4.56	4.80	3.45	3.63	3.75	4.87	9.83	10.33	20.04	21.06
2-3/4	4.95	5.21	3.76	3.96	3.75	4.87	10.74	11.30	21.22	22.31
3	6.03	6.33	4.07	4.27	3.75	4.87	12.05	12.67	23.96	25.18
3-1/2	6.30	6.62	4.84	5.08	3.75	4.87	13.82	14.52	29.63	31.15
4	7.22	7.59	5.53	5.81	3.75	4.87	15.74	16.54	33.39	35.11

Note: Pin diameter to hole diameter looseness shall be +.090 max. for sizes 2-1/2, 2-3/4, 3, 3-1/2, 4, and +.072 max. for sizes 2 1/4, 2, 1 3/4.

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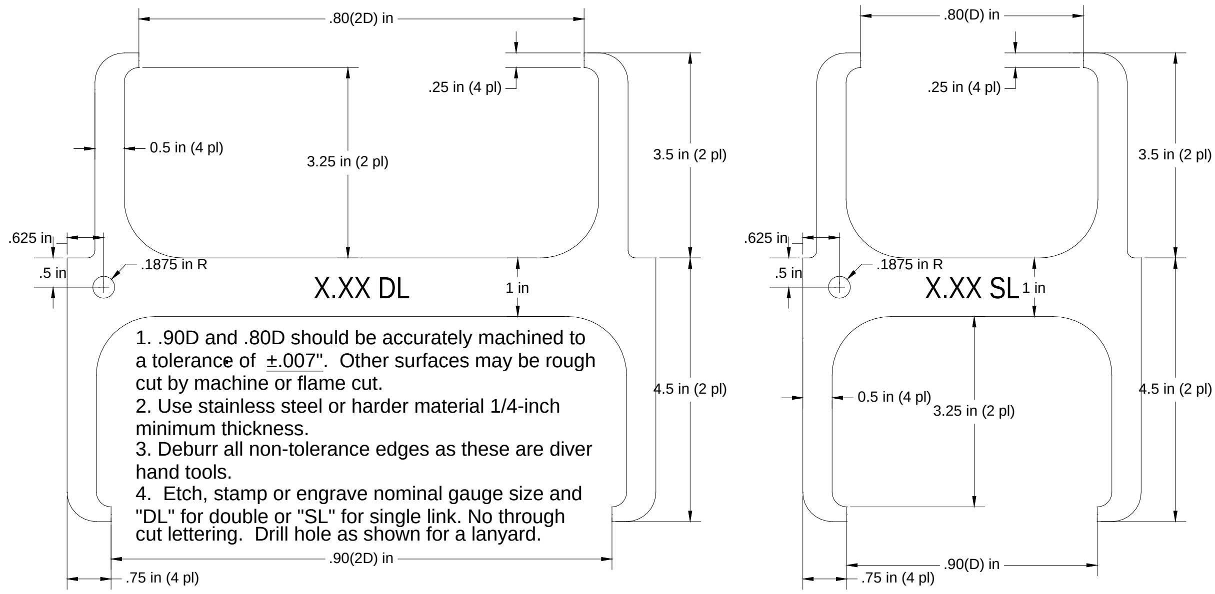
APPENDIX H GO/NO-GO GAUGE DIMENSIONS



Diameter	Single Link		Double Link		Diameter	Single Link		Double Link	
	.90D	.80D	.90D	.80D		.90D	.80D	.90D	.80D
inches	inches	inches	inches	inches	inches	inches	inches	inches	inches
6.5	5.85	5.20	11.20	10.40	2.5	2.25	2.00	4.50	4.00
6.0	5.40	4.80	10.80	9.60	2.25	2.025	1.80	4.05	3.60
5.5	4.95	4.40	9.90	8.80	2.0	1.80	1.60	3.60	3.20
4.5	4.05	3.60	8.10	7.20	1.785	1.687	1.500	3.375	3.000
4.0	3.60	3.20	7.20	6.40	1.75	1.575	1.40	3.15	2.80
3.5	3.15	2.80	6.30	5.60	1.5	1.350	1.200	2.700	2.400
3.0	2.70	2.40	5.40	4.80	1.25	1.125	1.000	2.250	2.000
2.75	2.475	2.20	4.95	4.40					

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APPENDIX I GENERAL INSTALLATION PROCEDURES FOR A DRAG EMBEDMENT ANCHOR/RISER TYPE MOORING SYSTEM

The following is an excerpt from MO-124 providing general installation instructions for a drag embedment riser type mooring system.

I-1 GENERAL.

General installation procedures for the typical three-legged riser mooring system are presented below. The procedures are preceded by a description of the main parts of the mooring system which should be assembled before offshore operations begin.

I-1.1 Riser-Type Mooring System.

Installation of this mooring system shall generally follow the procedure set forth below.

I-1.1.1 Preinstallation Assembly.

A three-legged riser-type mooring system is normally assembled in three parts (see Figure I-1):

- Part I. This part is the first anchor chain subassembly with a sinker and anchor.
- Part II. This part includes the buoy, the riser chain subassembly from the buoy to the ground ring, and the second anchor chain subassembly with a sinker and anchor.
- Part III. This part is the third anchor chain subassembly with a sinker and anchor.

I-1.1.2 Installation Procedures.

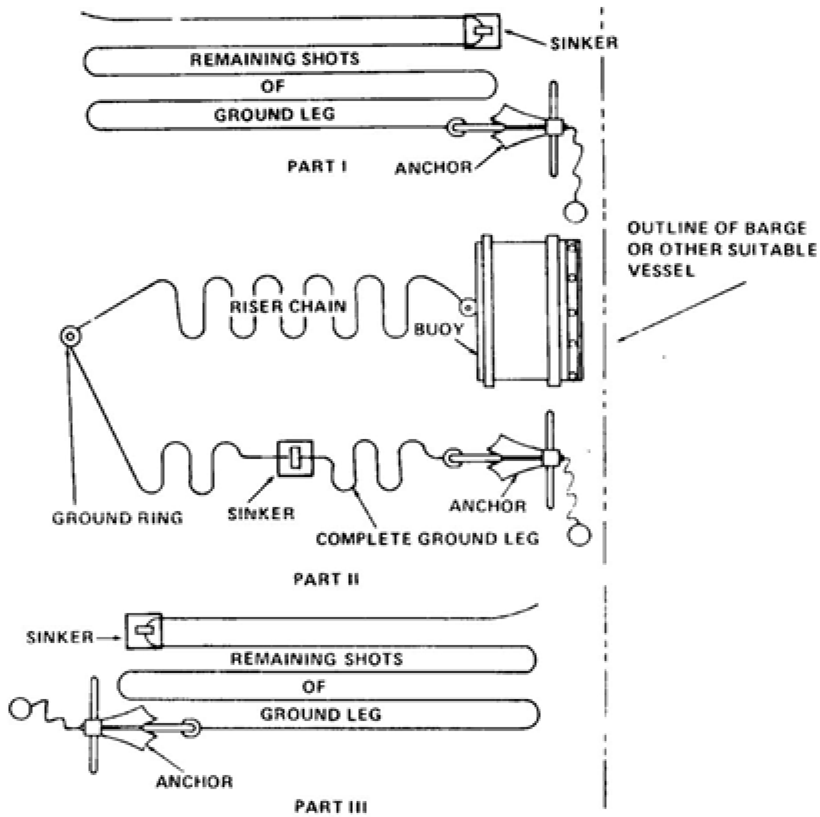
The marker buoys will be placed in their desired locations. The center marker buoy will be placed in the desired position of the mooring buoy. The ring marker buoys will be installed 25 feet past the point that the anchors will be lowered to the bottom and released. Predicted drag distance of the anchor is needed to determine this point. Table J-1 through Table J-8 provides predicted drag distances. The desired final location of the anchors should be indicated on the design drawing. provided by the mooring designer. After pulling the anchor to set it and test its capacity, (see 2.2.2.3) the final position of the anchor must be within a 40 foot by 20-foot box with the desired location at the center of the box (see Figure I-4). The range marker buoys should be installed about 50 feet beyond the ring marker buoys on the extension of the lines from the center marker buoy to the ring marker buoys.

Before beginning installation of the system, the free end of the first anchor chain subassembly of Part I should be attached to a pickup buoy for easy recovery during the placement operation.

Note:

Wind and current conditions will usually dictate which subassembly is laid first.

Figure I-1 Typical Riser-Type Mooring Material Pre-Installation Layout

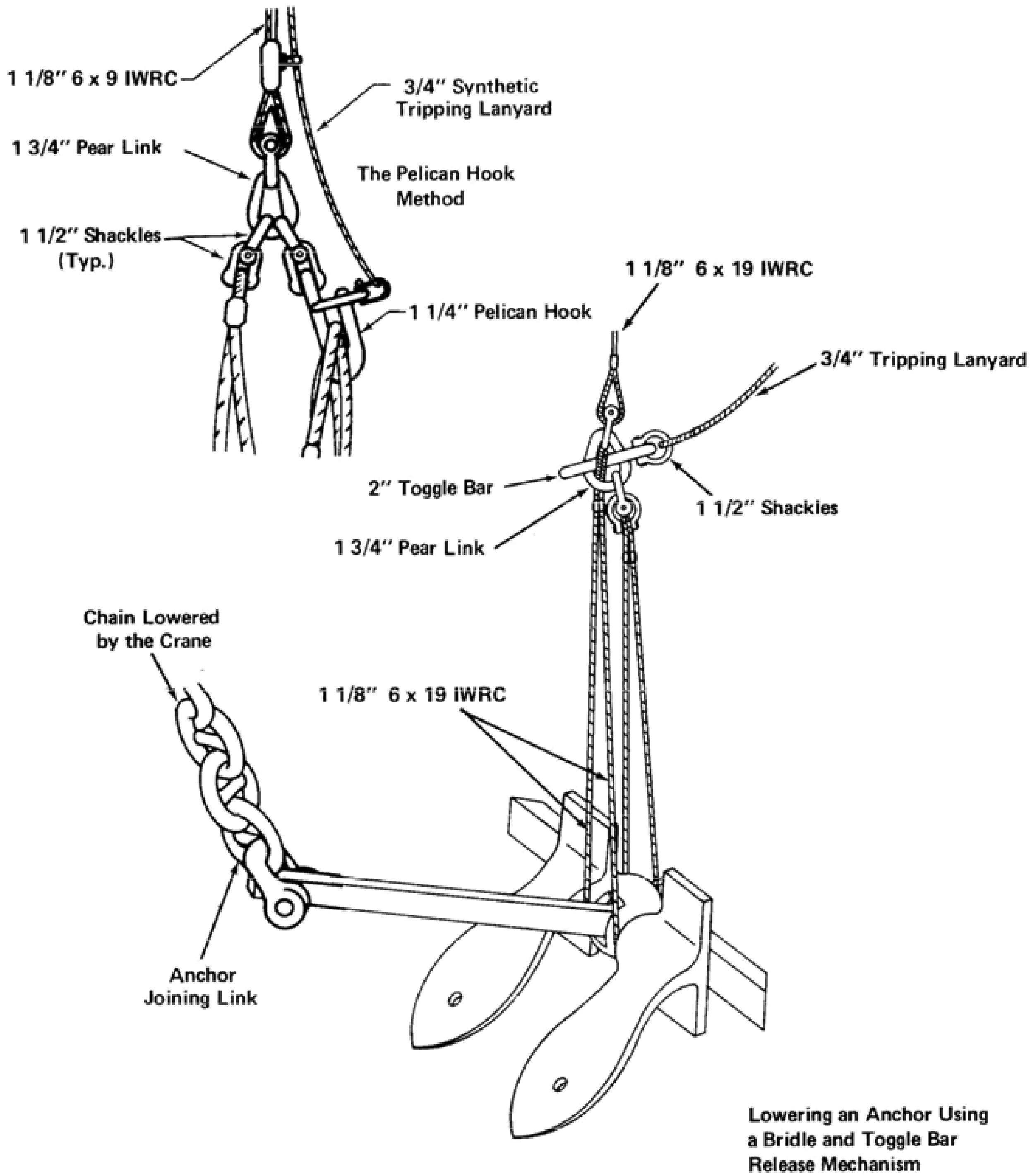


These general installation procedures should then be followed:

- Position the crane barge near one of the ring marker buoys (the one within 25 feet of the desired position for the anchor of the first anchor chain subassembly of Part I). During some installations, it may be necessary to weld the anchor flukes to a predetermined angle.
- The first anchor is slung by a bridle in a horizontal position and has attached to it a crown marker buoy and one anchor leg subassembly. The anchor is fitted with a pelican hook or a toggle bar quick release system as shown in Figure I-2. The crane lowers the anchor and chain simultaneously over the side. When installing moorings equipped with chain stud anodes, care must be exercised that the chain does not drag over sharp edges which can result in some of the anodes being stripped off.

- Upon reaching the bottom, release the anchor and recover the bridle. Move the barge toward the center marker buoy while slowly lowering the chain with a flat catenary.

Figure I-2 Lifting Bridle and Release Mechanism



- Upon approaching the center marker buoy, pull the subassembly taut so that the anchor is properly set. Then, lower the bitter end of the chain (with a pickup buoy attached to it) to the bottom.
- The crane barge now proceeds to the second marker buoy and lowers the anchor (of Part II) 25 feet from the marker toward the center marker buoy. The anchor is fitted with a quick release mechanism and has a crown buoy attached to it.
- Upon reaching the bottom, release the anchor and recover the bridle. Move the barge toward the center marker buoy while slowly lowering the chain with a flat catenary. Upon approaching the center marker buoy, pull the subassembly taut so that the anchor is properly set. Then, using the pickup buoy, retrieve the end of the first anchor chain subassembly and attach it to the ground ring. Attach the bitter end of the third anchor chain subassembly (Part Ill) to the ground ring also. Then lower the ground ring, riser, and buoy into the water alongside the center marker buoy.
- The crane barge will slowly lower the third anchor chain subassembly while proceeding toward the third ring marker. This ring marker and its range marker should be used to ensure that the chain is being installed in a straight line.
- When approaching the ring marker buoy, pull the anchor until the chain leg is taut and then lower the anchor (in a bridle with the flukes pointed downward) to the bottom and release it using the quick release mechanism (see Figure 2-7).
- Conduct a final inspection of the mooring. Site the three crown marker buoys from ashore. The positions of these three markers will be the positions of the anchors. If available, have divers make an underwater inspection of the mooring installation.
- Remove all marker buoys with their cables and anchors.

I-1.1.3 Pull Testing of Anchors.

Fleet moorings will be pull tested to the holding capacity of the mooring class listed in APPENDIX J.

I-1.1.4 Installation Barge.

Whenever possible, the YD or similar barge type craft to be used for mooring installation should be equipped with two stern winches to be used for pulling on kedge anchors. The installation barge should have the capability to anchor itself.

Note:

Divers may be used to inspect connections and to check the orientation and tautness of the anchor chains. They may also be used to jet the anchors into the bottom if included as part of the design specification.

Figure I-3 Typical Riser-Type Mooring Installation

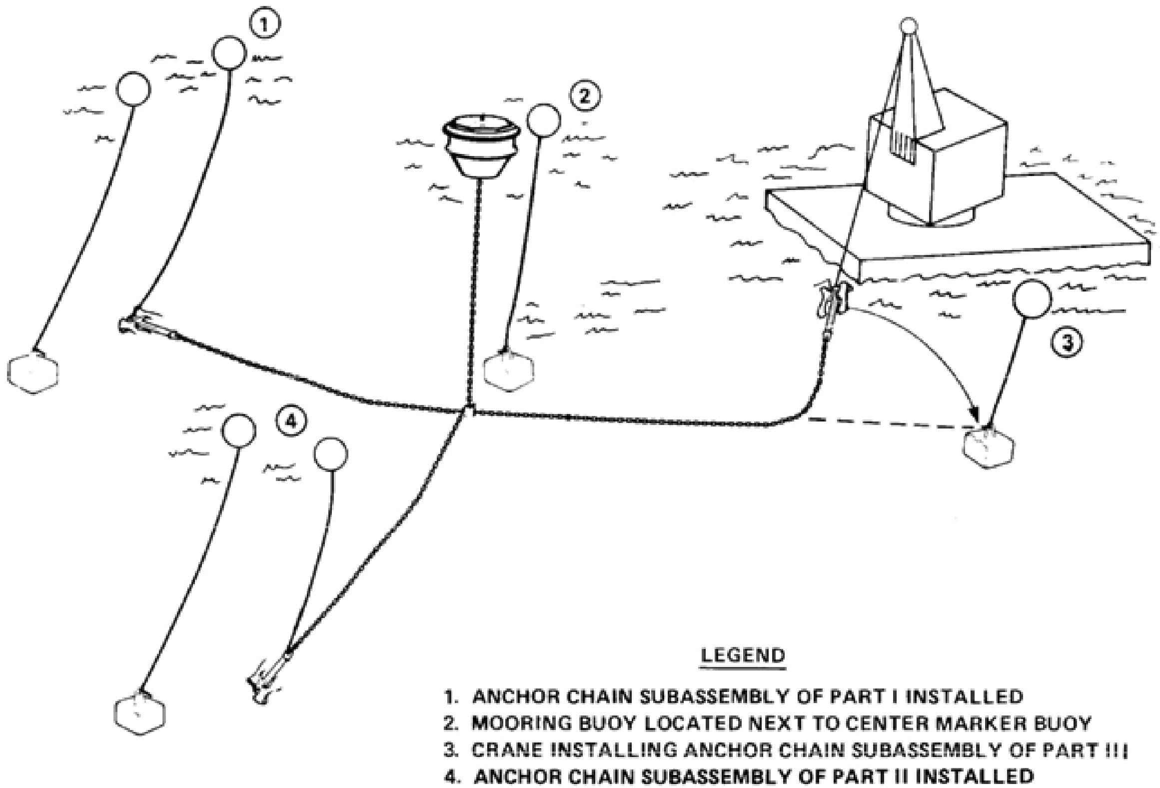
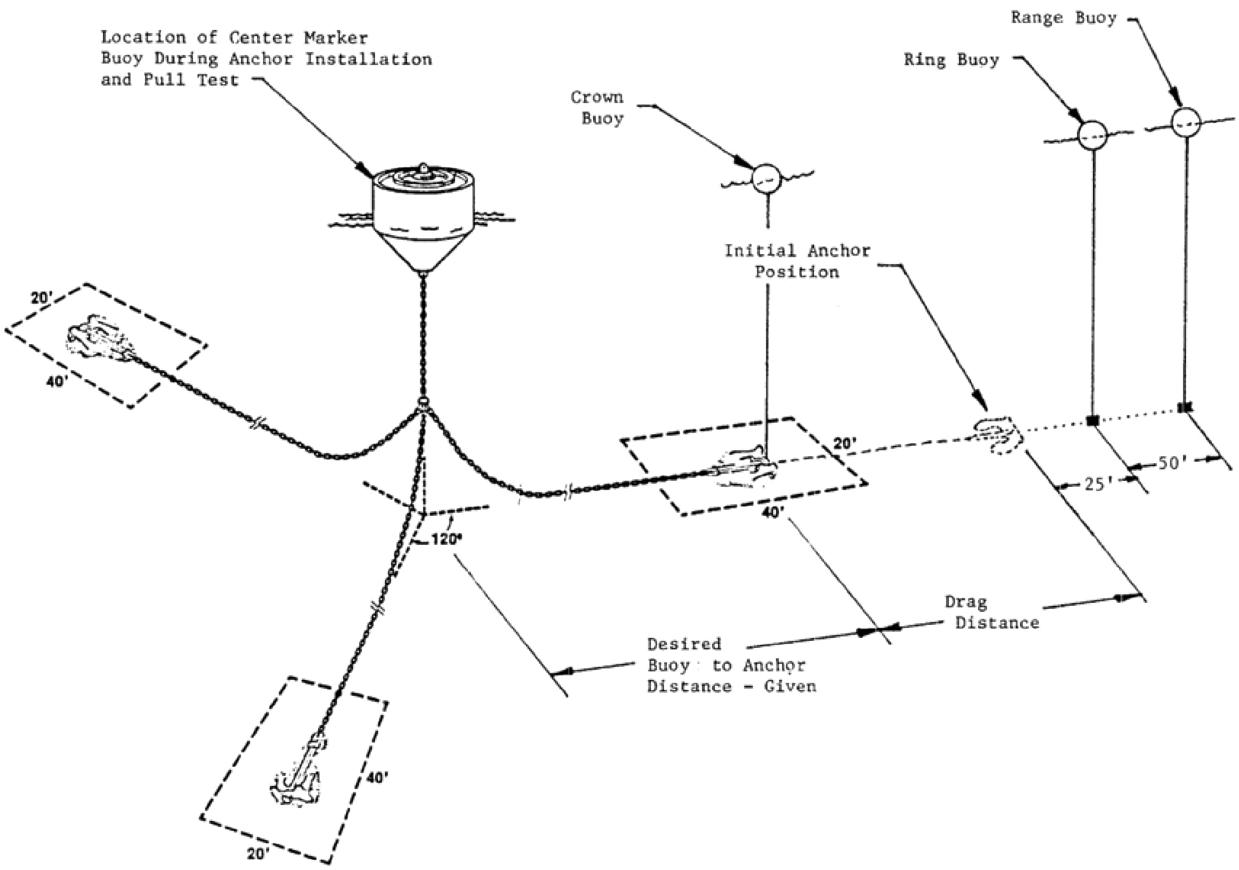


Figure I-4 Allowable Anchor Areas



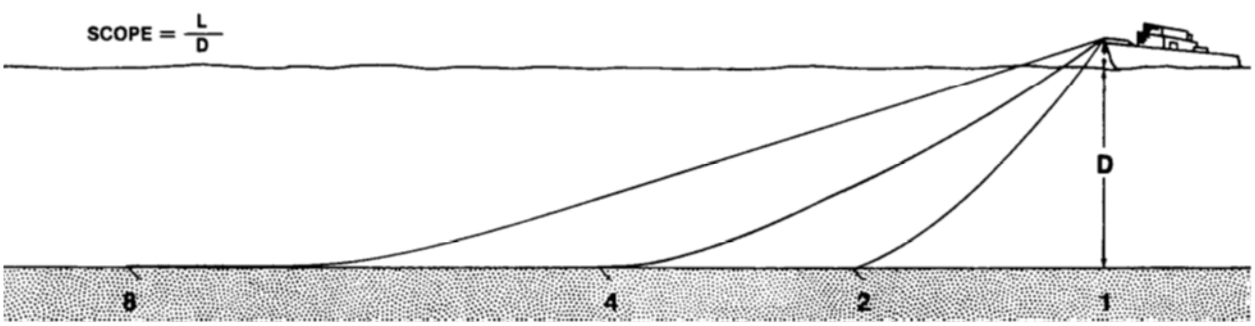
APPENDIX J DRAG EMBEDMENT ANCHOR PULL TESTING GUIDANCE

The following is an excerpt from MO-124 providing general installation instructions for a drag embedment anchor pull testing.

J-1 SETTING DRAG ANCHORS.

Proof setting of each anchor leg should be accomplished using harbor tugs, Fleet tugs or by pulling diametrically opposite anchor legs against each other. When setting the anchor, it is desirable to have a 10 to 1 scope (see Figure J-1 for definition) in the mooring line. This may be accomplished by adding chain or a work wire. The anchor drag distance to achieve the specified load level must be known to enable proper anchor placement prior to proof loading. Setting shall be accomplished by pulling to the design load of the mooring.

Figure J-1 Mooring Leg Scope



Scope is the ratio of length of rode (L) to depth of water (D), plus allowance for height of bow above water. At (1) length of rode equals the depth. At (2) rode length is twice the depth, at (4) four times the depth. Note how the angle between rode and bottom decreases. At (B) the scope is 8:1 and the short length of chain at the anchor lies flat on the bottom

J-2 DRAG DISTANCE.

- Single Anchors. The predicted anchor drag distance for single anchors can be obtained from Table J-1 through Table J-4.
- Tandem Anchor Systems. The predicted anchor drag distance for tandem anchor systems can be obtained from Table J-5 through Table J-8.

J-3 LOAD MEASUREMENT.

While setting the anchor, it is desirable to monitor the loads. A currently calibrated dynamometer should be placed in line to measure the load.

J-4 FINAL ANCHOR POSITION.

It is expected that the desired holding capacity can be achieved during setting and that the anchor will be within the 40-foot-long by 20-foot-wide allowable anchor area (see

Figure I-4). If after setting, the desired load is not obtained, or if the anchor drags outside the tolerance box, then the anchor must be repositioned and the pull test repeated.

J-5 PULL TESTING.

After the anchor is set, the pull test should be conducted. It is important that a length of chain equal to the total length of riser and ground leg be used for the test. Use of shorter chain lengths will create an uplift force on the anchor.

J-6 LOADING PROCEDURE.

Each anchor leg should be pull tested independently. The vessel performing the pull should gradually build up to the proof test load. Increase the load in 10,000 pound increments up to the required proof test load. After each 10,000-pound increase allow the dynamometer reading to stabilize. Once the required pull test load is reached, allow the dynamometer reading to stabilize, then hold the pull test load for 3 minutes.

J-6.1 Anchor Leg Adequate.

If the desired load is obtained and the anchor is positioned within the tolerance box, the anchor leg is adequate.

J-6.2 Anchor Leg Inadequate.

If either the pull test load is not achieved or the anchor is out of position, the anchor must be repositioned and the pull test repeated.

J-6.3 Pull Test Not Achieved.

If the pull test load cannot be achieved, the anchor system design may not be correct. Several options exist for increasing the anchors capacity:

- Changing the anchor fluke angle. Usually the fluke is fixed fully open for muds and partially open (approximately 35°) for sands.
- Soaking. When deploying anchors in silt or clay (muds) it is desirable to allow the anchors to soak. “Soaking” of an anchor is the practice of allowing a newly embedded anchor to rest for a period of time, typically 24 hours, before applying the required proof load.
- Jetting. If a drag anchor does not bury to a sufficient depth to develop the required capacity, it may be possible to use divers to jet the anchor to the required depth. The anchor should be jetted to a depth equal to or greater than the length of the anchor fluke.

J-6.4 Anchor Out of Position.

If the anchor is not within the tolerance box, reposition the anchor accordingly, reset and repeat the pull test

Note:

Ensure that the anchor is not recovered and reset in the furrow or disturbed bottom area caused by the initial pull test.

Table J-1 Drag Distance - Stockless Anchor with Stabilizers and Flukes Fixed at approximately 45^0, Seafloor Type: Mud

Anchor Wt (kips)	Horizontal Design Load (Kips)											
	25	50	75	100	125	150	175	200	225	250	275	300
6.	54.	*	*	*	*	*	*	*	*	*	*	*
7.	32.	*	*	*	*	*	*	*	*	*	*	*
8.	21.	*	*	*	*	*	*	*	*	*	*	*
9.	13.	*	*	*	*	*	*	*	*	*	*	*
10.	9.	*	*	*	*	*	*	*	*	*	*	*
11.	6	183.	*	*	*	*	*	*	*	*	*	*
12.	6.	99.	*	*	*	*	*	*	*	*	*	*
13.	6.	64.	*	*	*	*	*	*	*	*	*	*
14.	5.	47.	*	*	*	*	*	*	*	*	*	*
15.	5.	40.	*	*	*	*	*	*	*	*	*	*
16.	5.	33.	*	*	*	*	*	*	*	*	*	*
17.	4.	27.	*	*	*	*	*	*	*	*	*	*
18.	4.	22.	154.	*	*	*	*	*	*	*	*	*
19.	4.	17.	95.	*	*	*	*	*	*	*	*	*
20.	3.	14.	77.	*	*	*	*	*	*	*	*	*
21.	3.	12.	64.	*	*	*	*	*	*	*	*	*
22.	2.	10.	53.	*	*	*	*	*	*	*	*	*
23.	2.	8.	48.	*	*	*	*	*	*	*	*	*
24.	2.	8.	42.	202.	*	*	*	*	*	*	*	*
25.	1.	8.	37.	152.	*	*	*	*	*	*	*	*
26.	1.	8.	33.	104.	*	*	*	*	*	*	*	*
27.	1.	7.	29.	89.	*	*	*	*	*	*	*	*
28.	1.	7.	25.	78.	*	*	*	*	*	*	*	*
29	1.	7.	21.	68.	*	*	*	*	*	*	*	*
30.	0.	7.	19.	59.	245.	*	*	*	*	*	*	*
	Drag Distance (Feet)											

*Exceeds anchor ultimate holding capacity

Table J-2 Drag Distance - Stockless Anchor with Stabilizers and Flukes Fixed at approximately 36⁰, Seafloor Type: Sand

Anchor Wt (kips)	Horizontal Design Load (Kips)										
	25	50	75	100	125	150	175	200	225	250	275	300
5.	20.	*	*	*	*	*	*	*	*	*	*	*
6.	19.	*	*	*	*'	*	*	*	*	*	*	*
7.	18.	37.	*	*	*	*	*	*	*	*	*	*
8.	17.	33.	*	*	*	*	*	*	*	*	*	*
9.	17.	29.	*	*	*	*	*	*	*	*	*	*
10.	17.	28.	*	*	*.	*	*	*	*	*	*	*
11.	17.	27.	46.	*	*	*	*	*	*	*	*	*
12.	17.	26.	43.	*	*	*	*	*	*	*	*	*
13.	17.	26.	39.	*	*	*	*	*	*	*	*	*
14.	17.	25.	37.	*	*	*	*	*	*	*	*	*
15.	17.	24.	35.	*	*	*	*	*	*	*	*	*
16.	17.	24.	34.	52.	*	*	*	*	*	*	*	*
17.	17.	23.	33.	49.	*	*	*	*	*	*	*	*
18.	17.	23.	32.	46.	*	*	*	*	*	*	*	*
19.	18.	23.	32.	44.	*	*	*	*	*	*	*	*
20.	18.	23.	31.	41.	*	*	*	*	*	*	*	*
21.	18.	22.	31.	40.	57.	*	*	*	*	*	*	*
22.	18.	22.	30.	39.	54.	*	*	*	*	*	*	*
23.	18.	22.	30.	38.	52.	*	*	*	*	*	*	*
24.	18.	22.	29.	37.	50.	*	*	*	*	*	*	*
25.	18.	22.	29.	36.	48.	*	*	*	*	*	*	*
26.	17.	22.	28.	36.	46.	62.	*	*	*	*	*	*
27.	17.	23.	28.	36.	45.	60.	*	*	*	*	*	*
28.	17.	23.	28.	35.	43.	58.	*	*	*	*	*	*
29	17.	23.	28.	35.	43.	56.	*	*	*	*	*	*
30.	17.	23.	27.	35.	42.	54.	*	*	*	*	*	*
	Drag Distance (Feet)											

*Exceeds anchor ultimate holding capacity

Table J-3 Drag Distance - STATO Anchor with Stabilizers and Flukes Fixed at approximately 50^0, Seafloor Type: Mud

Anchor Wt (kips)	Horizontal Design Load (Kips)											
	25	50	75	100	125	150	175	200	225	250	275	300
5.	4.	23.	64.	158.	*	*	*	*	*	*	*	*
6.	3.	15.	45.	96.	236.	*	*	*	*	*	*	*
7.	2.	10.	34.	68.	127.	322.	*	*	*	*	*	*
8.	2.	7.	25.	52.	93.	168.	398.	*	*	*	*	*
9.	1.	6.	18.	43.	72.	120.	205.	*	*	*	*	*
10.	1.	6.	14.	35.	57.	94.	148.	280.	*	*	*	*
11.	1.	5.	11.	27.	50.	76.	118.	183.	352.	*	*	*
12.	0.	4.	9.	21.	43.	63.	96.	140.	216.	418.	*	*
13.	0.	4.	8.	18.	36.	56.	81.	118.	169.	266.	*	*
14.	0.	3.	7.	15.	29.	50.	68.	99.	138.	200.	333.	*
15.	0.	3.	7.	13.	24.	43.	61.	85.	118.	158.	229.	395.
16.	0.	3.	6.	10.	21.	37.	55.	73.	102.	138.	188.	265.
17.	0.	2.	6.	10.	18.	32.	50.	66.	90.	120.	156.	216.
18.	0.	2.	5.	9.	16.	27.	44.	61.	78.	106.	138.	179.
19.	0.	2.	5.	8.	14.	24.	39.	56.	71.	94.	122.	156.
20.	0.	1.	5.	8.	12.	21.	34.	51.	66.	83.	109.	139.
21.	0.	1.	4.	7.	11.	19.	30.	46.	61.	75.	98.	124.
22.	0.	1.	4.	7.	10.	17.	26.	41.	56.	70.	88.	112.
23.	0.	1.	4.	7.	10.	15.	24.	36.	52.	66.	79.	102.
24.	0.	1.	3.	6.	9.	13.	22.	32.	47.	61.	74.	92.
25.	0.	1.	3.	6.	9.	12.	20.	28.	43.	57.	70.	83.
26.	0.	0.	3.	5.	8.	11.	18.	26.	39.	53.	66.	78.
27.	0.	0.	2.	5.	8.	11.	16.	24.	35.	49.	62.	74.
28.	0.	0.	2.	5.	8.	10.	15.	22.	31.	44.	58.	70.
29	0.	0.	2.	5.	7.	10.	13.	21.	28.	41.	54.	66.
30.	0.	0.	2.	4.	7.	10.	12.	19.	26.	37.	50.	63.
	Drag Distance (Feet)											

*Exceeds anchor ultimate holding capacity

Table J-4 Drag Distance - STATO Anchor with Stabilizers and Flukes Fixed at approximately 30^0, Seafloor Type: Sand

Anchor Wt (kips)	Horizontal Design Load (Kips)											
	25	50	75	100	125	150	175	200	225	250	275	300
5.	15.	21.	28.	39.	55.	*	*	*	*	*	*	*
6.	15.	20.	27.	36.	45.	63.	*	*	*	*	*	*
7.	15.	20.	27.	32.	42.	51.	77.	*	*	*	*	*
8.	15.	20.	26.	30.	39.	47.	59.	91.	*	*	*	*
9.	15.	20.	25.	30.	36.	45.	53.	67.	103.	*	*	*
10.	15.	21.	24.	30.	33.	42.	50.	58.	74.	116.	*	*
11.	16.	20.	24.	29.	33.	40.	47.	55.	65.	88.	*	*
12.	16.	20.	24.	28.	33.	37.	45.	52.	59.	72.	101.	*
13.	16.	20.	24.	28.	33.	36.	43.	50.	57.	65.	79.	114.
14.	17.	20.	24.	27.	32.	36.	41.	48.	55.	61.	72.	91.
15.	17.	20.	24.	27.	32.	36.	39.	46.	53.	59.	65.	78.
16.	17.	20.	24.	27.	31.	36.	38.	44.	51.	57.	63.	72.
17.	17.	20.	24.	27.	31.	35.	38.	42.	49.	55.	61.	67.
18.	18.	20.	24.	27.	30.	35.	38.	41.	47.	54.	59.	65.
19.	18.	20.	24.	27.	30.	34.	38.	41.	46.	52.	58.	63.
20.	18.	20.	24.	27.	30.	34.	38.	40.	44.	50.	56.	62.
21.	18.	20.	24.	27.	30.	33.	37.	40.	43.	49.	55.	60.
22.	19.	21.	24.	27.	30.	33.	37.	40.	43.	47.	53.	59.
23.	19.	21.	24.	27.	30.	32.	36.	40.	43.	46.	52.	57.
24.	19.	21.	24.	27.	30.	32.	36.	40.	42.	45.	50.	56.
25.	19.	21.	24.	27.	30.	32.	36.	40.	42.	45.	49.	54.
26.	19.	21.	24.	27.	30.	32.	35.	39.	42.	44.	47.	53.
27.	20.	21.	24.	27.	30.	32.	35.	39.	42.	44.	46.	52.
28.	20.	21.	24.	27.	30.	32.	35.	38.	42.	44.	46.	50.
29	20.	22.	24.	27.	30.	32.	34.	38.	41.	44.	46.	49.
30.	0.	0.	2.	4.	7.	10.	12.	19.	26.	37.	50.	63.
	Drag Distance (Feet)											

*Exceeds anchor ultimate holding capacity

Table J-5 Drag Distance - Tandem Stockless Anchors with Stabilizers and Flukes Fixed at approximately 45^0, Seafloor Type: Mud

Anchor Wt (kips)	Horizontal Design Load (Kips)											
	25	50	75	100	125	150	175	200	225	250	275	300
5.	6.	*	*	*	*	*	*	*	*	*	*	*
6.	4.	54.	*	*	*	*	*	*	*	*	*	*
7.	4.	32.	*	*	*	*	*	*	*	*	*	*
8.	3.	21.	*	*	*	*	*	*	*	*	*	*
9.	3.	13.	70.	*	*	*	*	*	*	*	*	*
10.	2.	9.	47.	*	*	*	*	*	*	*	*	*
11.	2.	6.	35.	183.	*	*	*	*	*	*	*	*
12.	1.	6.	27.	99.	*	*	*	*	*	*	*	*
13.	1.	6.	21.	64.	*	*	*	*	*	*	*	*
14.	0.	5.	15.	47.	200.	*	*	*	*	*	*	*
15.	0.	5.	12.	40.	128.	*	*	*	*	*	*	*
16.	0.	5.	10.	33.	79.	*	*	*	*	*	*	*
17.	0.	4.	7.	27.	63.		*	*	*	*	*	*
18.	0.	4.	7.	22.	50.	154.	*	*	*	*	*	*
19.	0.	4.	7.	17.	44.	95.	*	*	*	*	*	*
20.	0.	3.	7.	14.	38.	77.	*	*	*	*	*	*
21.	0.	3.	6.	12.	33.	64.	179.	*	*	*	*	*
22.	0.	2.	6.	10.	28.	53.	124.	*	*	*	*	*
23.	0.	2.	6.	8.	23.	48.	90.	*	*	*	*	*
24.	0.	2.	6.	8.	19.	42.	77.	202.	*	*	*	*
25.	0.	1.	5.	8.	17.	37.	65.	152.	*	*	*	*
26.	0.	1.	5.	8.	15.	33.	56.	104.	*	*	*	*
27.	0.	1.	5.	7.	13.	29.	51.	89.	224.	*	*	*
28.	0.	1.	5.	7.	11.	25.	46.	78.	177.	*	*	*
29	0.	0.	4.	7.	10.	21.	42.	68.	132.	*	*	*
30.	0.	0.	4.	7.	9.	19.	38.	59.	101.	245.	*	*
	Drag Distance (Feet)											

*Exceeds anchor ultimate holding capacity

Table J-6 Drag Distance - Tandem Stockless Anchors with Stabilizers and Flukes Fixed at approximately 36⁰, Seafloor Type: Sand

Anchor Wt (kips)	Horizontal Design Load (Kips)										
	25	50	75	100	125	150	175	200	225	250	275	300
5.	13.	20.	32.	*	*	*	*	*	*	*	*	*
6.	13.	19.	27.	*	*	*	*	*	*	*	*	*
7.	13.	18.	25.	37.	*	*	*	*	*	*	*	*
8.	13.	17.	24.	33.	*	*	*	*	*	*	*	*
9.	13.	17.	23.	29.	42.	*	*	*	*	*	*	*
10.	13.	17.	22.	28.	38.	*	*	*	*	*	*	*
11.	13.	17.	21.	27.	34.	46.	*	*	*	*	*	*
12.	13.	17.	21.	26.	32.	43.	*	*	*	*	*	*
13.	13.	17.	20.	26.	31.	39.	*	*	*	*	*	*
14.	13.	17.	20.	25.	30.	37.	47.	*	*	*	*	*
15.	13.	17.	20.	24.	29.	35.	44.	*	*	*	*	*
16.	13.	17.	20.	24.	29.	34.	41.	52.	*	*	*	*
17.	13.	17.	20.	23.	28.	33.	39.	49.	*	*	*	*
18.	13.	17.	20.	23.	28.	32.	37.	46.	*	*	*	*
19.	13.	18.	20.	23.	27.	32.	36.	44.	53.	*	*	*
20.	13.	18.	20.	23.	27.	31.	35.	41.	50.	*	*	*
21.	13.	18.	20.	22.	26.	31.	35.	40.	48.	57.	*	*
22.	13.	18.	20.	22.	26.	30.	34.	39.	46.	54.	*	*
23.	13.	18.	20.	22.	26.	30.	34.	38.	44.	52.	*	*
24.	14.	18.	20.	22.	25.	29.	33.	37.	42.	50.	58.	*
25.	14.	18.	20.	22.	25.	29.	33.	36.	41.	48.	56.	*
26.	14.	17.	20.	22.	25.	28.	32.	36.	40.	46.	54.	62.
27.	14.	17.	20.	23.	25.	28.	32.	36.	40.	45.	52.	60.
28.	14.	17.	21.	23.	25.	28.	32.	35.	39.	43.	50.	58.
29	14.	17.	21.	23.	25.	28.	31.	35.	38.	43.	49.	56.
30.	14..	17.	21.	23.	25.	27.	31.	35.	38.	42	47.	54.
	Drag Distance (Feet)											

*Exceeds anchor ultimate holding capacity

Table J-7 Drag Distance - Tandem STATO Anchors with Stabilizers and Flukes Fixed at approximately 50^0, Seafloor Type: Mud

Anchor Wt (kips)	Horizontal Design Load (Kips)											
	25	50	75	100	125	150	175	200	225	250	275	300
5.	0.	4.	10.	23.	41.	64.	99.	158.	324.	*	*	*
6.	0:	3.	6.	15.	29.	45.	66.	96.	140.	236.	*	*
7.	0.	2.	5.	10.	19.	34.	48.	68.	94.	127.	182.	322.
8.	0.	2.	5.	7.	14.	25.	39.	52.	70.	93.	122.	168.
9.	0.	1.	4.	6.	11.	18.	30.	43.	55.	72.	93.	120.
10.	0.	1.	3.	6.	8.	14.	22.	35.	46.	57.	74.	94.
11.	0.	1.	3.	5.	7.	11.	18.	27.	39.	50.	60.	76.
12.	0.	0.	2.	4.	7.	9.	15.	21.	32.	43.	53.	63.
13.	0.	0.	2.	4.	6.	8.	12.	18.	25.	36.	46.	56.
14.	0.	0.	1.	3.	5.	7.	10.	15.	21.	29.	40.	50.
15.	0.	0.	1.	3.	5.	7.	9.	13.	18.	24.	34.	43.
16.	0.	0.	1.	3.	4.	6.	8.	10.	16.	21.	28.	37.
17.	0.	0.	0.	2.	4.	6.	8.	10.	13.	18.	24.	32.
18.	0.	0.	0.	2.	4.	5.	7.	9.	11.	16.	21.	27.
19.	0.	0.	0.	2.	3.	5.	7.	8.	10.	14.	19.	24.
20.	0.	0.	0.	1.	3.	5.	6.	8.	10.	12.	17.	21.
21.	0.	0.	0.	1.	3.	4.	6.	7.	9.	11.	15.	19.
22.	0.	0.	0.	1.	2.	4.	5.	7.	9.	10.	13.	17.
23.	0.	0.	0.	1.	2.	4.	5.	7.	8.	10.	11.	15.
24.	0.	0.	0.	1.	2.	3.	5.	6.	8.	9.	11.	13.
25.	0.	0.	0.	0.	1.	3.	4.	6.	7.	9.	10.	12.
26.	0.	0.	0.	0.	1.	3.	4.	5.	7.	8.	10.	11.
27.	0.	0.	0.	0.	1.	2.	4.	5.	7.	8.	9.	11.
28.	0.	0.	0.	0.	1.	2.	4.	5.	6.	8.	9.	10.
29	0.	0.	0.	0.	1.	2.	3.	5.	6.	7.	9.	10.
30.	0.	0.	0.	0.	1.	2.	3.	4.	6.	7.	8.	10.
	Drag Distance (Feet)											

*Exceeds anchor ultimate holding capacity

Table J-8 Drag Distance - Tandem STATO Anchors with Stabilizers and Flukes Fixed at approximately 30^0, Seafloor Type: Sand

Anchor Wt (kips)	Horizontal Design Load (Kips)											
	25	50	75	100	125	150	175	200	225	250	275	300
5.	12.	15.	18.	21.	25.	28.	34.	39.	45.	55.	78.	*
6.	13.	15.	18.	20.	24.	27.	30.	36.	41:	45.	52.	63.
7.	13.	15.	18.	20.	23.	27.	29.	32.	37.	42.	46.	51.
8.	13.	15.	18.	20.	22.	26.	28.	30.	34.	39.	43.	47.
9.	14.	15.	18.	20.	22.	25.	28.	30.	32.	36.	40.	45.
10.	14.	15.	18.	21.	22.	24.	27.	30.	32.	33.	38.	42.
11.	15.	16.	18.	20.	22.	24.	26.	29.	32.	33.	35.	40.
12.	15.	16.	18.	20.	22.	24.	26.	28.	31.	33.	35.	37.
13.	15.	16.	18.	20.	23.	24.	26.	28.	30.	33.	35.	36.
14.	16.	17.	18.	20.	23.	24.	26.	27.	30.	32.	34.	36.
15.	16.	17.	18.	20.	22.	24.	26.	27.	29.	32.	34.	36.
16.	16.	17.	18.	20.	22.	24.	26.	27.	29.	31.	34.	36.
17.	16.	17.	18.	20.	22.	24.	26.	27.	28.	31.	33.	35.
18.	17.	18.	19.	20.	22.	24.	26.	27.	28.	30.	32.	35.
19.	17.	18.	19.	20.	22.	24.	26.	27.	28.	30.	32.	34.
20.	17.	18.	19.	20.	22.	24.	26.	27.	29.	30.	32.	34.
21.	17.	18.	19.	20.	22.	24.	26.	27.	29.	30.	31.	33.
22.	18.	19.	19.	21.	22.	24.	26.	27.	29.	30.	31.	33.
23.	18.	19.	20.	21.	22.	24.	26.	27.	29.	30.	31.	32.
24.	18.	19.	20.	21.	22.	24.	26.	27.	29.	30.	31.	32.
25.	18.	19.	20.	21.	22.	24.	26.	27.	29.	30.	31.	32.
26.	19.	19.	20.	21.	22.	24.	26.	27.	29.	30.	31.	32.
27.	19.	20.	20.	21.	22.	24.	26.	27.	29.	30.	31.	32.
28.	19.	20.	21.	21.	22.	24.	26.	27.	29.	30.	31.	32.
29	19.	20.	21.	22.	23.	24.	26.	27.	29.	30.	31.	32.
30.	19.	20.	21.	22.	23.	24.	26.	27.	29.	30.	31.	32.
	Drag Distance (Feet)											

*Exceeds anchor ultimate holding capacity

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APPENDIX K GENERAL REMOVAL PROCEDURES FOR A DRAG EMBEDMENT RISER TYPE MOORING SYSTEM

The following is an excerpt from MO-124 providing general installation instructions for a drag embedment riser type mooring system.

K-1 GENERAL

General removal procedures for the typical three-legged riser mooring system are presented below. The procedures are preceded by a description of the main parts of the mooring system which should be assembled before offshore operations begin.

K-1.1 RISER-TYPE MOORING SYSTEM.

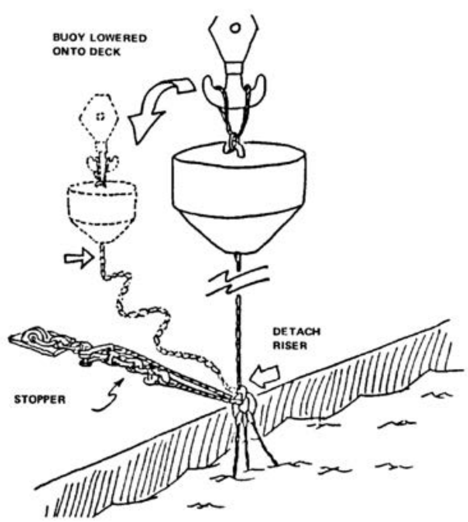
These systems are recovered by removing one anchor chain subassembly at a time. Proceed as follows:

- Sling the buoy from the top jewelry.
- Lift the buoy and riser until the ground ring is level with the deck of the crane barge.

Note:
In the case of a taut mooring, one anchor chain subassembly may have to be separated from the ground ring by cutting the first A-link below the ground ring with a torch.

- Stopper off the ground ring (see Figure K-1).

Figure K-1 Ground Ring Stoppered Off on Deck



- Lower the buoy down to the deck on its side. Disconnect the riser, and either block the buoy on its side or place it on blocks to avoid damaging the tension bar.

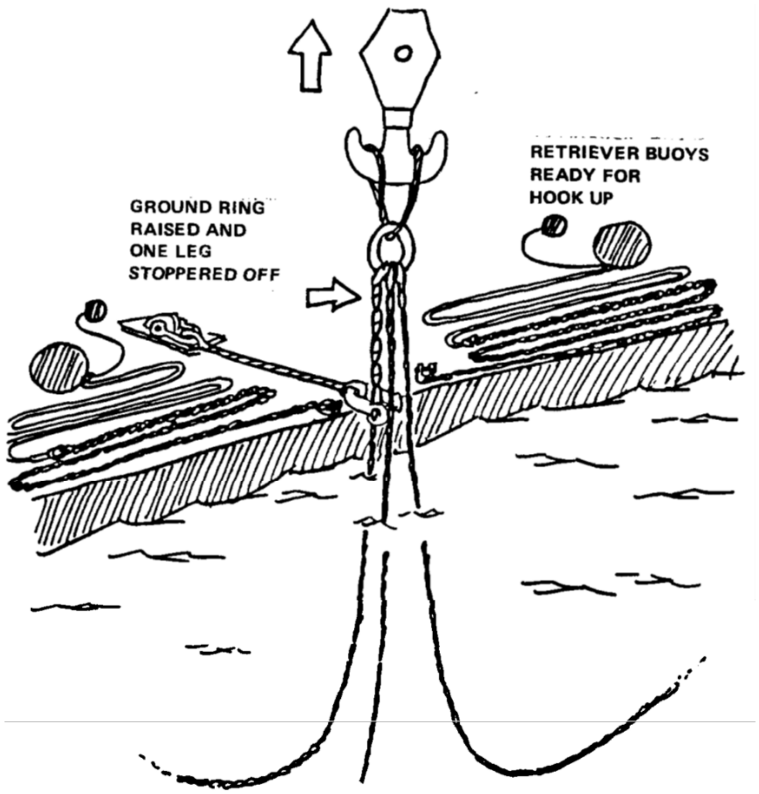
- Disconnect the riser from the ground ring and buoy.

Note:

If the joining link cannot be removed, cut the first A-link with a torch.

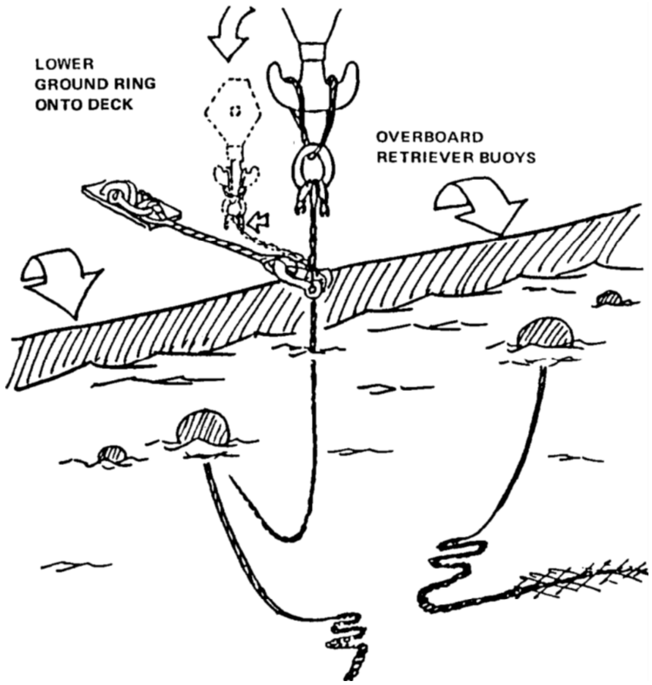
- Sling the ground ring and lift it until the anchor chain subassemblies accessible.
- Stopper off one subassembly (see Figure K-2).

Figure K-2 One Leg Stoppered Off



- Attach a retrieval buoy to each of the other two subassemblies. The third subassembly and the ground ring will be considered together. Fake the retriever buoy lines on deck to allow easy running.
- Cut one subassembly free from the ground ring one link below the chain joining link. Allow the chain to drop and retriever buoy to run free and over the side.
- Repeat with the other leg that has a retriever buoy attached. Lower the ground ring on deck (see Figure K-3). Disassemble the chain joining link, if possible, and disconnect the ground ring from the subassembly.

Figure K-3 Two Anchor Chain Subassemblies Overboarded



- Sling the chain to the main hoist, raise and remove the stopper.
- Continue raising until the next chain joining link is above deck. Stopper the chain, 3 links below the chain joining link, and lower the chain joining link to the deck for disassembly,
- When severed, move this shot of chain aside.
- Sling the chain and continue lifting and detaching chain shots as before.
- When all of the chain has been recovered, bring the anchor aboard.
- Pick up a retriever buoy and, using the same procedures, recover a second subassembly and anchor. Then recover the third.

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APPENDIX L VIDEO LINKS

L-1 INSPECTION OF MOORING CHAIN USING SINGLE AND DOUBLE LINK GO/NO GO GAUGES.

http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-4-150-09/inspection-b

L-2 INSPECTION OF RISER MOORING SWIVEL SHACKLE.

http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-4-150-09/inspection-e

L-3 INSPECTION OF CHAIN AND ANCHOR JOINING LINKS.

http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-4-150-09/inspection-c

L-4 SURFACE INSPECTION OF ANCHOR BOLT SHACKLE AND PEAR LINKS.

http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-4-150-09/inspection-d

L-5 SURFACE INSPECTION OF FOAM-FILLED BUOY.

http://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc/ufc-4-150-09/inspection-a

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APPENDIX M GLOSSARY

M-1 ACRONYMS.

ABS	American Bureau of Ships
AFCEE	Air Force Center for Engineering and the Environment
AJL	Anchor Joining Link
ASME	American Society of Mechanical Engineers
ATFP	Anti-terrorism / Force Protection
AVG	Average
AWS	American Welding Society
BIA	Bilateral Infrastructure Agreement
CBC	Naval Construction Battalion Center
CCD	Chain Capture Device
CFR	Code of Federal Regulations
CJL	Chain Joining Link
CO	Commanding Officer
CSAP	Chain-Soil Analysis Program
DDC	Designated Dive Coordinator
DLA	Defense Logistics Agency
DoD	Department of Defense
EDM	Electronic Distance Measurement
EIC	Engineer-in-Charge
EXWC	Engineering and Expeditionary Warfare Center
FAA	Federal Aviation Administration
FEC	Facilities Engineering Command
FM	Fleet Mooring
FMG	Fleet Mooring Grade

FMP	Fleet Mooring Program
FPO	Fleet Post Office
FPR	Fiberglass Polyester Resin
FRP	Fiber Reinforced Polymer
FSW	Feet Sea Water
GPS	Global Positioning System
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HDPE	High Density Polyethylene
HMPE	High Modulus Polyethylene
HNFA	Host Nation Funded Construction Agreements
IAW	In Accordance With
ICAP	Infrastructure Condition Assessment Program
IWRC	Independent Wire Rope Core
LWT	Light Weight Type Anchor
Med-Moor	Mediterranean Mooring
Mil	Military
MLLW	Mean Lower Low Water
MPM	Mooring Program Manager
MT	Magnetic Testing
NAD	North American Datum
NAVFAC	Naval Facilities Engineering Command (NAVFACENGCOM)
NAVSEA	Naval Sea Systems Command
NCC	Navy Crane Center
NDT	Non-Destructive Testing
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer

OIC	Officer In Charge
OSHA	Occupational Safety and Health Administration
OWD	Original Wire Diameter
PEA	Propellant Embedment Anchors
POC	Point Of Contact
PPE	Personal Protective Equipment
PWO	Public Works Office
QA/QC	Quality Assurance/Quality Control
ROV	Remotely Operated Vehicle
SDS	Safety Data Sheet
SPM	Single Point Mooring
SOFA	Status of Forces Agreements
UCT	Underwater Construction Team
UFC	Unified Facilities Criteria
U.S.	United States
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
UTM	Universal Transverse Mercator
WEAP	Wave Equation Analysis of Piles
WGS84	World Geodetic System 1984

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APPENDIX N REFERENCES

GOVERNMENT

UNIFIED FACILITIES CRITERIA

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

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

UFC 3-190-06, *Protective Coatings and Paint*

UFC 4-159-03, *Mooring Design*

UFC 4-150-08, *Inspection of Mooring Hardware*

NAVAL FACILITIES ENGINEERING COMMAND

NAVFAC P-307, *Management of Weight Handling Equipment*

NAVFAC P-1110, *Fleet Mooring Handbook*

NAVFAC MO-124, *Mooring Maintenance Manual*

NAVFAC MO-104.1, *Maintenance of Fender Systems and Camels*

FPO-1-84(6), *Fleet Mooring Underwater Inspection Guidelines*

FPO-1-88(40), *Fleet Mooring Buoy Surface Inspection Guidelines*

NAVAL SEA SYSTEMS COMMAND

NAVSEA Technical Publication, T9074-AS-GIB-010/271, *Requirements for Nondestructive Testing*

NAVSEA 0900-LP-006-0010, *Reinforced Plastics Preventive Maintenance and Repair Manual*

NAVSEA Naval Ships Technical Manual, Chapter 583, S9086-TX-STM-010, *Boats and Small Craft*

NAVSEA Naval Ships Technical Manual, Chapter 631(V1), S9086-VD-STM-010, *Preservation of Ships in Service General*

NAVSEA Naval Ships Technical Manual, Chapter 631(V2), S9086-VD-STM-020, *Preservation of Ships in Service Surface Preparation and Painting*

NAVSEA Naval Ships Technical Manual, Chapter 631(V3), S9086-VD-STM-030, *Preservation of Ships in Service Surface Ship/Submarine Applications*

NAVSEA Naval Ships Technical Manual, Chapter 634, S9086-VG-STM-010, *Deck Coverings, General*

US NAVY DIVING MANUAL, SS521-AG-PRO-010.

MILITARY SPECIFICATIONS AND STANDARDS

PERFORMANCE SPECIFICATION, MIL-PRF-16173E, *Corrosion Preventive Compound, Solvent Cutback, Cold-Application*

DETAIL SPECIFICATION, MIL-DTL-24441D(SH), *Paint, Epoxy-Polyamide, General Specification For*

DETAIL SPECIFICATION, MIL-P-28579(YD), *Plastic Compound Epoxy-Polyamide, Marine Splash Zone Application*

DETAIL SPECIFICATION, MIL-C-24176, *Cement, Epoxy, Metal Repair and Hull Smoothing*

DETAIL SPECIFICATION, MIL-C-19663, *Cloth, Woven Roving, For Plastic Laminate*

DETAIL SPECIFICATION, MIL-M-43248, *Mats, Reinforcing, Glass Fiber*

DETAIL SPECIFICATION, DOD-P-15328, *Primer (Wash), Pretreatment (Formula No. 117 For Metals)*

DETAIL SPECIFICATION, DOD-P-24380, *Paint, Anchor Chain, Solvent Type, Gloss Black*

DETAIL SPECIFICATION, MIL-R-21607, DETAIL SPECIFICATION, DOD-P-15328, *Primer (Wash), Pretreatment (Formula No. 117 For Metals)*

DETAIL SPECIFICATION, DOD-P-15328, *Primer (Wash), Pretreatment (Formula No. 117 For Metals)*

DETAIL SPECIFICATION, MIL-R-21607, *Resins, Polyester, Low Pressure Laminating, Fire-Retardant*

DETAIL SPECIFICATION, MIL-P-15931, *Paint, Antifouling, Vinyl (Formulas No. 121A, and 129A)*

UNITED STATES ARMY CORPS OF ENGINEERS

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

U.S. NAVY, OFFICE OF THE CHIEF OF NAVAL OPERATIONS

OPNAVINST 5450.348, *Mission, Functions, and Tasks of Naval Facilities Engineering Command*

NON-GOVERNMENT

AMERICAN WELDING SOCIETY

AWS D1.1, *The Structural Welding Code*

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

NACE No. 3, Commercial Blast Cleaning

NACE No. 2, *Near White Blast Cleaning*

SOCIETY FOR PROTECTIVE COATINGS

SSPC SP-6, *Commercial Blast Cleaning*

SSPC SP-10, *Near White Blast Cleaning*

SSPC SP-2, *Hand Tool Cleaning*

SSPC SP-3, *Power Tool Cleaning*

OCCUPATIONAL HEALTH AND SAFETY ADMINISTRATION (OSHA)

Directive CPL 02-00-151 (29 CFR Part 1910 Subpart T)

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10 September 2001
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UNIFIED FACILITIES CRITERIA (UFC)

GENERAL CRITERIA FOR WATERFRONT CONSTRUCTION

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN: GENERAL CRITERIA FOR WATERFRONT CONSTRUCTION

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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

Change No.	**Date**	**Location**
1	1 Sept 2012	Removed 5-5.2 “Emergency Power”; modified 4—1 and 5-1; editorial changes throughout, including updating references.

This UFC supersedes MIL-HDBK-1025/6, DATED May 1988.

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 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.

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CHAPTER 1

INTRODUCTION

1-1 **SCOPE**. This UFC contains general criteria for the design of piling, deck, and substructure framing and bracing, and hardware and fittings for waterfront construction. Unless indicated otherwise, these criteria also apply to the design of offshore structures. This document, and all references contained herein, provides guidance primarily to DOD and U.S. Coast Guard activities. They may also be useful, however, to commercial firms that are engaged in the design and construction of waterfront facilities.

1-2 **CANCELLATION**. This UFC cancels and supersedes MIL-HDBK-1025/6, *General Criteria for Waterfront Construction*, (May 1988).

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CHAPTER 2

PILING

2-1 GENERAL REQUIREMENTS

2-1.1 Capacity

2-1.1.1 **Capacity as a Structural Member**. For pile sections embedded in the ground refer to \1\ UFC 3-220-01N, *Geotechnical Engineering Procedures for Foundation Design of Buildings and Structures* and UFC 3-220-10N, *Soil Mechanics*. /1/ For sections freestanding in water, treat piles as structural columns with accommodation made for their un-braced length. Where, due to long-term creep effects, the use of the coefficient of sub-grade reaction would be inappropriate or if one is unavailable, the following assumptions may be made:

2-1.1.1.1 In soft, cohesive soils, the point of fixity may be assumed to occur at a depth of 3.05 m (10 ft.) below the mudline for piles having modulus of elasticity - moment of inertia products (EI) of 2.925 x 10^9 kg-cm^2 (10 x 10^9 lb-in^2) or less. The point of fixity may be assumed to occur at a depth of 3.66 m (12 ft) below the mudline for piles having an EI greater than 2.925 x 10^9 kg-cm^2 (10 x 10^9 lb-in^2.) (E equals Modulus of Elasticity of Pile in pounds per in^2 and I equals moment of inertia of pile in in^4.)

2-1.1.1.2 In loose, granular soils and in medium cohesive soils, the point of fixity may be assumed to occur at a depth of 2.44 m (8 ft) below the mudline for piles having an EI of 2.925 x 10^9 kg-cm^2 (10 x 10^9 lb-in^2) or less, and at a depth of 3.05 m (10 ft) below the mudline for piles having an EI greater than 2.925 x 10^9 kg-cm^2 (10 x 10^9lb-in^2.)

2-1.1.1.3 For other cases, assume a point of fixity at a depth of 1.5 m (5 ft) below the mudline. The effective length factor K shall be taken as:

- 0.80 - when the deck structure is light, the piles have minimum embedment into the pile cap and there is no special provision for moment transfer into the deck structure.

- 0.73 - when the deck structure is light and provision is made for moment transfer by embedment or other device into the deck structure.

- 0.65 - when the deck structure is heavy and a positive means for moment transfer is provided.

NOTE: These provisions do not apply if pile embedment is less than 3.05 m (10 ft) into firm material or 6.10 m (20 ft) into soft or loose material. If lesser penetration is achieved, assume that the pile tips are hinged. Also, the indicated effective length factors (K) apply only if batter piles (minimum batter of one horizontal to three vertical) or some other means are provided to resist lateral loads, i.e., the plumb piles are not intended to resist lateral loads. If no such means are provided, side-sway can occur, and correspondingly increased K factors shall apply (usually taken as 2.0).

Design piles for a minimum eccentricity of 0.10 times the equivalent diameter of the pile. The moment resulting from this minimum eccentricity is not additive to the moments indicated by analyses of the actual applied loads.

2-1.1.2 **Capacity of the Ground to Support the Pile**. Refer to provisions of \1\ UFC 3-220-01N, *Geotechnical Engineering Procedures for Foundation Design of Buildings and Structures* and UFC 3-220-10N *Soil Mechanics* /1/, pertaining to friction, end bearing resistance, and settlements of single piles and pile groups.

2-1.1.3 **Lateral Load Capacity**. For pile groups within which individual piles are spaced between three and six diameters center-to-center, assume that the soil reacts laterally on an equivalent pile having a diameter equal to three times the actual diameter. For closer spacing, reduce the assumed equivalent diameter proportionally to the spacing.

NOTE: A number of design curves have already been published to illustrate this arching effect within a "retained" soil mass.

2-1.1.4 **Capacity of Existing Piles**. Refer to Chapter 6 for information pertaining to the capacity of existing piles.

2-1.2 **Details Applicable to All Pile Types**

2-1.2.1 **Minimum Penetration**. Conform minimum penetration of piles to the following:

- Penetrate sufficiently into an acceptable bearing stratum to distribute the axial pile load within the supporting capacity of the soil (refer to \1\ UFC 3-220-01N, *Geotechnical Engineering Procedures for Foundation Design of Buildings and Structures* and UFC 3-220-10N, *Soil Mechanics*. /1/).

- Penetrate sufficiently below any probable future dredge depth to distribute the pile load within the supporting capacity of the soil, discounting the resistance of soil that may be removed by future dredging. Depth should account for possible scour problems. All piles should be designed for a minimum of 1.5 m (5 ft) of potential scour or future dredging.

- Minimum values. If pile penetration is less than 3.05 m (10 ft) into firm material or less than 6.10 m (20 ft) into soft or loose material, assume the pile tip to be "pinned" and incorporate special provisions such as driving hardened tips into the refusing stratum, drilled sockets, or drilled dowels to secure the tips of the piles against lateral displacements due to eccentricities and intentional lateral forces. Develop a minimum lateral resistance of at least 5 percent of the pile's design axial load. Increase the effective length factors as described above.

2-1.2.2 **Tolerances on Installation**. For piles fully, or near fully, embedded in the ground, the provisions of Unified Facilities Guide Specifications apply. The following provisions relate to piling installed for elevated platforms where the piles project several feet above the mudline:

- A slope within 4 percent of plumb or the specified batter, as a reasonable compromise between the design requirements and the practicality of installation.

- In locating the pile head, there is no limit, provided the structure can tolerate the revised pile spacing. However, consider residual stresses in the piles due to forcing the pile into the pile cap in evaluating the capacity of the pile. Do not apply an increase (or additional increase) in allowable stress to stress-combinations that include these residual stresses.

NOTE: For effective un-braced length, divided by radius of gyration (Kl/r) between about 40 and 100, these effects can be substantial. But for fully embedded piles, Kl/r commonly is less than 40 and locked-in stresses can be neglected. Exercise caution when using driving frames because they prevent lateral movements of the head of the pile and mask the existence of locked-in stresses. Provide ample edge distances so that the piles will fit into the cap without excessive force or restraint. Allow for tolerance in the location of the pile head of at least 1.5 percent of the exposed height up to a maximum of 152 mm (6 inches).

2-1.2.3 **Minimum Spacing**. The minimum spacing requirements of piles are as follows:

- Provide for adequate distribution of the load on a pile group to the supporting soil. Recommend 1 m (36 inch) spacing.

- No minimum values are specified other than practical limitations to avoid piles interfering with or intersecting each other. One technique is to use a center-to-center spacing equal to 5 percent of the pile length for parallel piles.

2-1.2.4 **Pile Caps in Contact With the Ground**. Design piles to carry the entire superimposed load with no allowance made for the supporting contribution of the material between the piles.

2-1.2.5 **Connection of Piles to Caps**. The following requirements pertain to the connection of piles to pile caps:

2-1.2.5.1 **Timber Piles with Timber Caps**

- No Tension in piles - Secure pile tops to caps with spiral-drive drift pins or steel straps.

- Tension in piles - Secure pile top to clamp-type cap with thru-bolts with spike grids.

2-1.2.5.2 **Timber Piles with Concrete Caps**

- No Tension in Piles - Embed pile top 102 mm (4 inches) into cap and secure with single #5 dowel driven into pile butt.

- Tension in Piles - Secure pile tops with through-bolted dowel anchorage

2-1.2.5.3 **Concrete Piles with Concrete Caps**

- No Tension in Piles - Embed pile top 102 mm (4 inches) into pile cap and secure with deformed dowels or exposed pre-stressing strands as required to develop a tensile load equivalent to one-half the pile's rated compressive bearing capacity.

- Tension in Piles - Embed pile top 102 mm (4 inches) into pile cap and secure with deformed dowels or exposed pre-stressing strand as required to develop the tensile structural capacity of the pile cross-section.

2-1.2.5.4 **Steel Piles with Concrete Caps**

- No Tension in Piles - Embed pile top 102 mm (4 inches) (min.) into pile cap and secure with deformed dowels welded to the pile (within the jacketed length) capable of developing a tensile load equivalent to one-half the pile's rated compressive bearing capacity.

- Tension in Piles - Embed pile top 102 mm (4 inches) (min.) into pile cap and secure with deformed dowels welded to the pile (within the jacketed length) capable of developing a tensile load equivalent to the pile's rated compressive bearing capacity.

2-1.2.6 **Batter Piles**. Make connections to adjacent piles or to the pile cap capable of developing a tensile load equivalent to the smaller of the pile's compressive bearing capacity or the tensile structural capacity of the pile cross-section.

2-1.2.7 **Splicing**. The necessity for pile splicing should be avoided through selection of pile type and cross-section. However, where unavoidable, construct splices to provide and maintain true alignment and position of the component parts of the pile during installation. Construct splices capable of developing all germane structural capacities of the spliced pile cross-sections regardless of the expected design loads of the pile.

2-1.2.8 **Mixed Types or Capacities of Piling and Multiple Types of Installation Equipment or Methods**. Mixed types or capacities of piling and different types of installation equipment or methods are permitted, provided that the effects on the superstructure of differential elastic shortening and settlement are considered.

2-1.2.9 **Slope of Batter Piles**. Unless special provisions are made for the difficulties of installation and the effects of diminished driving energy on the capacity, keep the maximum slope of the batter piles to 5 horizontal to 12 vertical maximum batter or 4 horizontal to 12 vertical preferred or steeper.

2-2 REQUIREMENTS FOR SPECIFIC TYPE OF PILES

2-2.1 **Untreated Timber Piles.** Refer to \1\ UFGS 31 62 19.13, *Wood Marine Piles* /1/.

2-2.1.1 **Marine / Brackish Water Environment**. In general, do not use untreated timber piles without total encasement in a marine or brackish water environment. The one notable exception is their use as fender piles in volatile berthing areas where pile longevity is dictated by impact damage rather than by biological attack. Otherwise, encapsulate untreated piles exposed to air and water in one of the many flexible barrier products now available. It is becoming increasingly common to install untreated piles with these “wraps” as new construction, adding rub strips as appropriate for fender piles. Untreated piles are also required in some locations, i.e. San Diego, due to local environmental concerns over using salt treated timber in the marine environment.

2-2.1.2 **Fresh Water Environment**. Untreated, un-encased timber piles may be used in fresh water applications as long as they are not exposed to air. They must be cut off below the permanent ground water level or below MLW. As in the marine environment, it is becoming more common to install untreated piles with flexible “wraps” to protect the air-exposed portions as new construction.

2-2.1.3 **Geometry**. Where they are applicable, use untreated timber piles that conform to ASTM D25, *Specification for Round Timber Piles*. The greatest economy can be achieved by selecting the geometric property of butt diameter with respect to length in accordance with \1\ ANSI O5.1 /1/, Class 3 poles, those most commonly used by utility companies.

2-2.1.4 **Seasoning**. Seasoning for untreated timber piles is not required.

2-2.1.5 **Protection for Tops of Piling**. Protection for the tops of untreated, un-encapsulated timber piling is not required.

2-2.1.6 **Species**. Any species of wood may be used that will provide the necessary structural capacity and that will withstand the driving stresses.

2-2.1.7 **Peeling**. Peeling of untreated timber piles is not required.

2-2.2 **Treated Timber Piles**. Refer to \1\ UFGS 31 62 19.13, *Wood Marine Piles* /1/.

2-2.2.1 **Piles**. Use piles that conform to ASTM D25, *Specification for Round Timber Piles*. The greatest economy can be achieved by selecting the geometric property of butt diameter with respect to length in accordance with \1\ ANSI O5.1/1/ , Class 3 poles, those most commonly used by utility companies and most likely to be stocked at mills.

2-2.2.2 **Preservative Treatment**. Use treated marine piling that bear the appropriate American Wood Preservers Association (AWPA) Quality Mark as follows: MP-1 (dual treatment) for use in areas of extreme borer hazard and in marine waters where Limnoria and Pholadidea attack may be expected, or where oil slicks may contribute to borer attack, and MP-2 for other conditions where pholad attack is not expected. MP-4 treatment (water-borne preservatives) may be considered. For specific requirements at particular locations, \1\ consult NAVFAC Engineering Command, Pacific (NAVFAC PAC), Atlantic (NAVFAC LANT), Northern Division (NAVFAC ML), Southern Division (NAVFAC SE), NAVFAC WEST, /1/ and PWC Yokuska Applied Biology Offices. Refer to the paragraph entitled “Timber” for properties of treated wood.

2-2.2.3 **Seasoning**. Seasoning of treated timber piles is required prior to treatment.

2-2.2.4 **Species**. The preferred species are Southern pine and Douglas fir. Use of other species is subject to NAVFAC approval. \1\ AWPA Standard U1 /1/ requires that the species be either Southern pine or Douglas fir. It is not normally necessary to differentiate between these two species, as selection will be a function of geographic availability. In areas where treatable soft woods are scarce or unavailable in the length required, concrete piling often represents a more economical alternative than transported timber piles.

2-2.2.5 **Protection for Pile Tops**. Treat cut ends by puddling creosote. Puddling is accomplished by using a sheet metal band to form a reservoir on top of the pile. The reservoir is filled with creosote oil and left to stand for 8 to 12 hours. Alternative protection methods include coating pile tops with pitch (with or without sheet metal or plastic covers).

NOTE: Use of sheet metal covers as end protection for fender piles is discouraged because they are easily torn by impact and become a personnel hazard. However, sheet metal covers for bearing piles under pile caps provide good protection. In general, fit structural piling with waterproof caps.

2-2.3 **Precast (Including Prestressed) Concrete Piles.** These piles are covered in both \1\ UFGS 35 59 13.13, *Prestressed Concrete Fender Piling* and UFGS 31 62 13.20, *Precast/Prestressed Concrete Piles* /1/. Reference is also made to UFGS \1\ 03 31 29 /1/, *Marine Concrete*.

2-2.3.1 **Minimum Dimensions**. The minimum dimensions are 304.8 mm (12 in) for piles of uniform section and 203.2 mm (8 in) for tapered piles.

2-2.3.2 **Cover**. The minimum clear cover for reinforcement for permanent installations in salt water is 76.2 mm (3 in). For temporary installations and in fresh water, cover requirements may be relaxed to conform to the requirements of \1\ UFC 1-200-01, *General Building Requirements* /1/, for normal exposure conditions.

2-2.3.3 **Minimum Reinforcement**. Excluding pre-stressed piles, the minimum longitudinal reinforcement shall be 1.5 percent of the total cross section.

2-2.3.4 **Ties**. Provide spirals or ties for longitudinal reinforcement. Proportion spirals and ties in accordance with \1\ ACI 318/318R, *Building Code Requirements for Structural Concrete and Commentary* for structural columns except provide additional ties or spirals at ends as indicated in PCI STD-112, *Standard Prestressed Concrete Piles Square, Octagonal and Cylinder.* /1/

2-2.3.5 **Impact**. Forces induced by handling and driving shall be imposed magnified by a load factor of 1.25 (allowable overstress of 33 percent).

2-2.3.6 **Jetting**. Where jetting is contemplated, the jet pipe may be cast into the pile.

2-2.3.7 **Concrete Strength**. The minimum compressive concrete strength required is 34.47 MPa (5,000 psi) for pre-stressed concrete, and 27.58 MPa (4,000 psi) for non-pre-stressed concrete.

2-2.3.8 **Standard Details**. For information on standard details, refer to PCI STD-112.

2-2.3.9 **Minimum Residual Prestress**. The minimum residual pre-stress is 4.83 MPa (700 psi).

2-2.3.10 **Minimum Wall Thickness (Cylindrical Piles or square Piles With Voids)**. Provide a minimum of 3.81 mm (1-1/2 in) clear cover on inside (void) face. In no case may wall thickness be less than 102 mm (4 in).

2-2.3.11 **Venting**. If a void is provided which extends through to the lower end of the pile, vent the pile head to prevent the buildup of internal pressure during driving.

2-2.3.12 **Tolerances**. Locate voids, when used, within 9.5 mm (3/8 in) of the position shown on the plans. The maximum departure of the pile axis from a straight line, measured while the pile is not subject to bending forces, should not exceed 3.17 mm (1/8 in) in any 3.05 m (10 ft) length or 9.5 mm (3/8 in) in any 12.2 m (40 ft) length. Overall sweep should not exceed 0.1 percent of the pile length.

2-2.4 **Cast-in-Place Concrete Piles.** These piles are covered in \1\ UFGS 31 62 13.13, *Cast-In-Place Concrete Piles*. Reference is also made to UFGS 03 31 29, *Marine Concrete*. /1/

2-2.4.1 **General**. Cast-in-place concrete piles are not recommended for applications characterized by severe marine exposures and / or long un-braced lengths.

2-2.4.2 **Casings**. Use casings that meet the following criteria:

- Adequate strength to withstand driving stresses and to resist distortions imposed by the driving of adjacent piles.

- Except for portions of piles embedded more than 1.52 m (5 ft) below the mud line, casings are to remain in place to reinforce and / or protect the concrete core. Regardless of any coatings or other means of corrosion protection provided, do not consider casing metal thicknesses of 3.2 mm (1/8 in) or less as contributing to the structural capacity of the pile. Extend casings intended to provide flexural reinforcement to the point of fixity (defined in the paragraph entitled "Capacity as a Structural Member") and apportion the casings so that the metal thickness remaining at the end of the design service life equals or exceeds that required by analysis. Provisions for corrosion protection are discussed further in the paragraph entitled "On Hard Bottom (Rock or Hardpan)".

2-2.4.3 **Minimum Tip Diameter**. Use minimum tip diameter of cast-in-place concrete piles of 203 mm (8 in).

2-2.4.4 **Reinforcement**. Detail sections of piling requiring internal reinforcing in the same manner as pre-cast concrete piles. Cover requirements for reinforcing are the same as for pre-cast piles with spacers provided for longitudinal reinforcement to ensure that cover requirements are maintained.

2-2.4.5 **Concrete Strength**. The minimum concrete compressive strength to be used in the marine environment is 27.58 MPa (4,000 psi) and 24.13 MPa (3,500 psi) in freshwater applications.

2-2.5 **Steel H-Piles.** These piles are covered in UFGS \1\ 31 62 16.16 /1/, *Steel H-Piles.*

2-2.5.1 **Minimum Thickness of Metal**. Determine the thickness of metal from consideration of loss of section as established in \1\ UFC 1-200-01, *General Building Requirements* /1/ unless corrosion protection is provided as described in the paragraph entitled "Corrosion Protection". In any case, the minimum thickness should not be less than 10.55 mm (0.40 in). Splice plates should not be less than 9.5 mm (3/8 in) thick.

2-2.5.2 **Corrosion Protection**. When the required initial minimum thickness of unprotected metal would be excessive, provide alternative corrosion protection in the form of concrete encapsulation, bituminous or plastic (epoxy) coatings, flexible membrane / tape wrappings, or cathodic protection. For cathodic protection refer to \1\ UFC 3-570-02N, *Electrical Engineering Cathodic Protection* , UFGS 26 42 13.00 20, *Cathodic Protection by Galvanic Anodes*, and UFGS 26 42 19.00 20, *Cathodic Protection by Impressed Current*. /1/ Bituminous or plastic coatings are not considered effective below the mudline and require special care to avoid damage during driving. In tropical environments, and other locations where corrosion is particularly severe, encase steel pilings in concrete jackets to at least 0.61 m (3 ft) below MLLW and provide cathodic protection for the submerged and buried sections of steel.

2-2.5.3 **Cap Plates**. Bearing cap plates are not normally required for steel compression piles embedded in concrete pile caps. Where pile flexure or tension is intended, tie the tops of steel piles into the cap with reinforcing bars or structural sections welded to the pile and lap-spliced to the cap reinforcing.

2-2.5.4 **Hardware and Fittings**. Refer to Chapter 4 for guidance on specifications for hardware and fittings for H-piling.

2-2.5.5 **Limitation on Use**. The tips of all steel H-piles having a web thickness of less than 12.69 mm (1/2 in), and driven to end-bearing on sound rock by an impact hammer, must be reinforced with a driving tip (shoe). Both penetration resistance and equipment operation must be closely monitored so as to terminate pile driving immediately upon reaching refusal on the rock surface.

2-2.6 **Drilled Caissons and Auger-Placed Grout Piles**. These piles are covered in both \1\ UFGS 31 63 26, *Drilled Caissons* and UFGS 31 63 16, *Auger Cast Grout Piles.* /1/

2-2.6.1 **Applicability**. Usage of drilled caissons and / or auger-placed grout piles is normally reserved for conditions where the driven piles would bear on rock or other hard bottom, at shallow depth, without sufficient penetration for lateral support or uplift resistance.

2-2.6.2 **On Hard Bottom (Rock or Hardpan)**. Use a constant diameter shaft without the bell. Level sloping surfaces to receive the shaft. Anchorage in the form of grouted dowels or excavated keys should be considered.

2-2.6.3 **On Other Bottom Surfaces**. Consider shaft and bell construction if loads are heavy enough to warrant use of the bell. Unless supported on piling, embed the bell 0.61 to 1.22 m (2 to 4 ft) into firm material.

2-2.6.4 **Minimum Reinforcement**. Determine reinforcement by design requirements, not by a minimum reinforcement ratio.

2-2.6.5 **Embedment of Piling into the Bell**. Embed piling into the bell as required for transfer of load. Where tremie placement is employed, use 69 kPa (10 psi) bond resistance between pile and concrete, plus compression resistance of top of pile bearing in bell.

2-2.6.6 **Protection for Reinforcement**. The requirement for protection for reinforcement is the same as for concrete piling.

2-2.6.7 **Thickness of Metal Shell and Corrosion Protection**. The requirements for thickness of metal shell, and corrosion protection, are the same as for steel cased cast-in-place concrete piles.

2-2.6.8 **Installation**. Tremie placement of concrete fill is permitted. Provide for final cleanout of the bell or base of the cylinder immediately before concreting.

2-2.7 **Steel Pipe Piles**. Use pipe piles that conform to the applicable requirements for both steel H-piles and cast-in-place concrete piles (refer to the paragraphs entitled "Steel H-Piles and Drilled Caissons" and "Auger-Placed Grout Piles" \1\ /1/.) 2-2.7.1 **Material**. Use material conforming to ASTM A252, \1\ *Welded and Seamless Steel Pipe Piles* /1/, unless otherwise approved.

2-2.7.2 **Open-End Piles**. Reseat pipes installed with an open tip to full bearing after being cleaned out. If the pipe exhibits 50.8 (2 in) or more of additional penetration during re-seating, cyclically re-clean and re-drive until penetration on subsequent re-driving is less than 50.8 mm (2 in). If leakage of water into the pile is minor, pump the pile out and place one cubic yard of grout as an initial seal before the balance of concrete or sand fill is installed. If water leakage renders dry grout placement impractical, fill the pipe pile to its top with clean water and tremie the grout plug. Deposit the grout seal by means of a grout pipe to an elevation of at least 0.91 m (3 ft) above the bottom of the pile. After a sufficient time has elapsed to allow the grout to set, pump the pile dry and fill remaining space with concrete or clean dry sand.

2-2.7.3 **End Closure**. For friction piles, tip closures should not project more than 12.7 mm (1/2 in) beyond the pipe wall.

2-2.8 **Composite Piles**. These piles are seeing increase application throughout the Navy. \1\ NAVFAC LANT /1/ has prepared a regional guide specification, \1\ UFGS 35 59 13.14 20, *Polymeric Fender Piles* /1/ which covers their use.

2-2.9 **Sheet Piling--Steel**. This is covered in \1\ UFGS 31 41 16, *Metal Sheet Piling* /1/. The requirements for steel sheet piling are the same as previously established for steel H-piling (refer to the paragraph entitled "Steel H-Piles"), except as modified in the paragraphs below.

2-2.9.1 **Splices**. Use full-penetration butt welds for splices.

2-2.9.2 **Connection to Caps**. Embed steel sheet piles 52.3 mm (6 in) minimum into concrete caps. The use of structural sections for mechanical anchorage of sheet piling into the cap is neither required nor advised. However, provide stirrups (open to the side) through the handling hole near the top of each sheet as a positive connection between the steel sheet piles and the cap's longitudinal reinforcing. For steel channel caps, tack-weld each sheet to the cap member.

2-2.9.3 **Sleeves and Openings**. Detail all sleeves and openings for utilities and drains passing through the sheets to prevent loss of fill.

2-2.9.4 **Minimum Thickness of Metal**. For exposed faces of cofferdams, use a minimum sheet pile thickness of 12.7 mm (1/2 in). Elsewhere, use a minimum thickness consistent with the applied loading environment over the design service life of the structure. In no case should the minimum thickness be less than 3/8 in. (38 mm).

2-2.10 **Sheet Piling - Concrete**. Use piling that conforms to the requirements stated above for pre-cast, pre-stressed concrete piles (refer to the paragraph entitled "Precast (Including Prestressed) Concrete Piles**"**) except as modified in the paragraphs below.

2-2.10.1 **Joints**. Flush and grout joints tight to the mudline. Use of plastic sleeves is recommended.

2-2.10.2 **End of Sheets**. Use sheets cast with a drift-sharpened point. Embed tops of sheets 152.4 mm (6 in) into a continuous concrete cap.

2-2.10.3 **Sleeves and Openings**. The treatment of sleeves and openings in concrete sheet piling is similar to the procedure followed with steel sheet piling (refer to the paragraph entitled "Sheet Piling--Steel ").

2-2.11 **Sheet Piling - Timber**. Use timber sheet piling conforming to the requirements in the paragraphs entitled "Untreated Timber Piles**"** and "Treated Timber Piles**"** for treated and untreated timber piles except as modified in the paragraphs below.

2-2.11.1 **Applicability**. Timber, for the most part, no longer represents an economically competitive alternative for the construction of bulkheads. Within the range of structural applicability, aluminum and the burgeoning industry of plastic products represent lower life cycle costs than timber in all but the most benign marine environments. Therefore, the selection of timber will most probably be made based on specific aesthetic parameters.

2-2.11.2 **Treatment**. \1\ Use timber sheet piling in accordance with AWPA Standard U1 /1/. The types of treatment are as described for treated timber piles.

2-2.11.3 **Joints**. Use tongue and groove or splined joints (or Wakefield Type sheeting may be used). Install sheet piling tight to the mudline.

2-2.11.4 **Drift Sharpening**. Use drift sharpened timber sheet piling.

2-2.11.5 **Tops of Sheets**. Bolt tops of sheets to a continuous timber cap, with a width equal to or greater than the thickness of the sheet piling. Where a concrete cap is used, embed the sheets 152.4 mm (6 in).

2-2.11.6 **Sleeves and Openings**. Detail sleeves and openings through timber bulkheads to preclude the loss of fill material.

CHAPTER 3

DECK AND SUBSTRUCTURE FRAMING AND BRACING

3-1 **SUBSTRUCTURE**. The substructure includes pile caps, under-deck bracing, and other structural members (other than stringers) at and below the level of the pile caps.

3-1.1 **Pile Caps - All Types**. The effects of differential axial deformation among piles must be investigated where:

- heavy concentrated loads occur,
- piles are long,
- there is an appreciable variation in pile lengths
- pile types or installation methods vary.

Differential deformations will not appreciably affect ultimate strength if the cap can deform elastically without buckling or fracture.

3-1.2 **Timber**

3-1.2.1 **Hardware and Fittings**. For requirements pertaining to hardware and fittings, refer to Chapter 4.

3-1.2.2 **Species and Preservative Treatment**. Except for temporary structures, give substructure timbers a preservative treatment. Use a species that will accept deep treatment such as Southern pine or Douglas fir. Do not use untreated timber for permanent structures. Resistance to borers and decay of any untreated lumber - even of species presumed to be of superior resistance - is still inadequate for long-term use. Encase species that do not accept preservative treatment.

3-1.2.3 **Seasoning**. Use only seasoned timber for framing.

3-1.2.4 **Minimum Dimension**. The minimum nominal timber size should be 76 mm (3 in). National Fire Protection Association requires the following minimum dimensions: cross bracing – 102 mm (4 in); pile caps – 203 mm (8 in); stringers – 152 mm (6 in); and decking – 102 mm (4 in) with stringers, 76 mm (3 in) without stringers.

3-1.2.5 **Retention and Penetration of Preservative**. For guidance on the use of preservatives, conform to requirements of \1\ AWPA Standard U1 /1/.

3-1.3 **Concrete**. Refer to UFGS \1\ 03 31 29 /1/, *Marine Concrete.*

3-1.3.1 **Cover**. Use a cover that conforms to the requirements of the paragraph entitled “Cover”.

3-1.3.2 **Chamfer**. The minimum chamfer for all exposed outside corners should be 25.4 mm (1 in).

3-1.4 **Steel**. Use components comprising steel substructures that conform to the requirements for steel H piles (refer to the paragraph entitled “Steel H-Piles”).

3-2 **DECK**. The "deck" includes treads, planks, slabs, stringers, and other elements supported by the pile caps.

3-2.1 **Timber**. Use timber in the deck structure conforming to the requirements for substructure framing and bracing except as modified below.

3-2.1.1 **Treatment**. Give deck framing and bracing a preservative treatment. For the deck itself, do not use creosote on walking surfaces or surfaces normally touched by people (handrails, for example).

3-2.1.2 **Hardware and Fittings**. Refer to Chapter 4 for information on hardware and fittings.

3-2.1.3 **Decking**. Conform decking to the following materials and dimensions:

- Oak, maple, birch, black gum, or other species resistant to wear, may be used untreated for treads or traction cleats.
- Use decking not more than 300 mm (12 in) nor less than 100 mm (4 in) wide (nominal sizes).
- Use decking not less than 76 mm (3 in) thick (nominal size); 102 mm (4 in) when laid on timber stringers. Topping is 51 mm (2 in) sheathing, concrete, or asphalt.
- Provide a 10 mm (3/8 in) gap (minimum) between adjacent deck timbers.

3-2.2 **Concrete**

3-2.2.1 **General**. Conform to requirements for substructure framing and bracing.

3-2.2.2 **Deck Finish**. Broom-finish the deck to provide a skid-resistant surface.

3-2.3 **Steel**. When steel is used for stringers, use steel conforming to the requirements for steel H piles (refer to the paragraph entitled “Steel H-Piles”).

CHAPTER 4

HARDWARE AND FITTINGS (PERMANENT INSTALLATION)

4-1 **SALTWATER—IN OR BELOW SPLASH ZONE.** \1\ For information on mooring fittings, refer to UFC 4-159-03, *Design: Moorings*. /1/

4-1.1 **Minimum Diameter of Bolts**. Use bolt with minimum diameter of 25 mm (1 in).

4-1.2 **Minimum Thickness of Metal in Straps and Fittings**. Use metal with minimum thickness of 12.7 mm (1/2 in).

4-1.3 **Coatings**. Typically, mooring fittings are cast and painted.

4-1.4 **Washers**. Provide ogee washers for all bolts used in timber construction. Provide bolts used in concrete or steel structures with plate or standard circular washers with no more than two at any location. Fit inclined bolts or bolted surfaces with beveled washers.

4-1.5 **Size of Bolt Holes**. Drill all bolt holes in timber (other than holes for drift bolts) with a bit having a diameter 1.6 mm (1/16 in) larger than the diameter of the bolt shank. Align bolt-holes to allow insertion by tapping with a mallet. Do not drive or force-fit bolts. Drill holes for drift bolts 3.17 mm (1/8 in) less in diameter than the bolt diameter. Keep all drill bits sharp and control feed rate to produce shavings, rather than chips.

4-1.6 **Locking of Bolts**. Tack-weld nuts or damage the bolt threads outboard of the nut to lock all bolted connections.

4-2 **SALTWATER--ABOVE SPLASH ZONE**. Use same requirements as for installations in or below splash zone except as modified below:

- Minimum bolt diameter may be reduced to 19 mm (3/4 in).
- 10 mm (3/8 in) minimum thickness metal in straps and fittings.
- 6 mm (1/4 in) minimum thickness plate washers.

4-3 **FRESHWATER**. Requirements are the same for installation in saltwater, in or below splash zone, except as modified below:

- 15.87 mm (5/8 in) minimum diameter bolts.
- 6 mm (1/4 in) minimum thickness metal in straps, fittings, and plate washers.

4-4 **SPECIAL APPLICATIONS**

4-4.1 **Stainless Steel Fittings**. Stainless steel fittings may be used for special applications, if warranted, but should be used judiciously because many stainless steels do not perform well in saltwater. They often experience severe pitting and crevice corrosion more than regular carbon steel.

4-4.2 **Through Bolts**. Use through bolts to the fullest extent possible.

CHAPTER 5

SPECIAL CONSIDERATIONS

5-1 **SERVICE LIFE**. Unless specifically intended for a limited service life, or unless otherwise stipulated in job-specific criteria, design structures for a service life of 25 years. Where a service life of 1 year or less is intended, design may be predicated on an overall load factor of 1.15 for dead plus live load combined with any other single load; or 1.10 when combined with two or more other loads. Load factors for designs are intended for limited service life.

- Estimating Service Life. Assume structures detailed in accordance with this handbook meet the service life requirement in the paragraph entitled “Service Life”.

- Accessibility. Since waterfront structures frequently serve longer than 25 years, detail so that all components with an anticipated service life of less than 50 years can be inspected and repaired or replaced.

5-2 **CORROSION OF STEEL**. The principal factors affecting rate of corrosion loss are:

- Geographical location,
- Localized zones relative to tidal planes,
- Exposure to salt spray,
- Sand, earth, or other cover,
- Protective coating(s),
- Abrasive conditions (surf zone versus deep water),
- Stray electric currents, and
- Soil type.

5-2.1 **Service Life of Coating Systems**. Refer to Table 5-1 for approximate expected periods of protection afforded by various coating systems.

5-2.2 **Tropical Climates**. Encase steel H-piling in concrete in and above the tidal range and to a minimum depth of 1.5 m (5 ft) below MLW. Cap steel sheet piling with concrete rather than with a steel channel or timber.

Table 5-1 Period of Protection for Steel to be Expected from Various Coating Systems of Common Use[a]

COAT DESCRIPTION[b]	PERIOD OF PROTECTION[c]
Coal tar epoxy (15 to 20 mils thickness)	10 - 20 years
Galvanizing (7 to 9 mils thickness)	10 - 15 years
Metallized Aluminum	15 - 20 years
Concrete Encasement	25 years

Notes: (a) Marine exposure
(b) Coatings applied properly
(c) Periods of good to excellent protection, i.e. negligible loss of metal

5-2.3 **Use of Weathering Steels**. Use “weathering” steels conforming to the following requirements:

- The following steels require coating in the splash zone and other areas not boldly exposed to sun, wind, and rain: \1\ Alloy steels conforming to ASTM A242/A242M, *High-Strength, Low-Alloy Structural Steel*; A588/A588M, *High-Strength, Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point with Atmospheric Corrosion Resistance*; or A690/A690M, *High-Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments*; and copper bearing steels conforming to ASTM A709/A709M, *Structural Steel for Bridges*. /1/

There are no consistent data on the rate of corrosion loss for steel surfaces in contact with various soils, so that consideration should be given to coating these surfaces in the same manner and degree as for \1\ ASTM A36/A36M, *Carbon Structural Steel*. /1/

- If an alloy conforming to \1\ ASTM A690/A690M is used, use hardware conforming to ASTM A588/A588M. /1/

5-3 **CATHODIC PROTECTION**. Consider cathodic protection for all buried or submerged steel structures or utilities in accordance with \1\ UFC 3-570-02N, *Electrical Engineering Cathodic Protection* /1/.

5-3.1 **Cathodic Protection Systems.** Consider a Cathodic Protection System (CPS) in conjunction with other protective measures such as material thickness incrementation, protective coatings and encasement for the following waterfront metallic structural systems:

- Steel sheet piling bulkheads
- Steel Bearing piles for piers
- Steel fender piles for piers
- Mooring components

In marine environments, CPS are most effective and can greatly extend the life of the submerged zones of steel waterfront structures. The splash and atmospheric zones will require reapplication of coatings and encasements for maximum system service life. Partial concrete encasement of steel piles creates a zone of high potential at the concrete encasement-to-bare steel pile interface where submerged. Provide CPS in these circumstances in addition to the partial encasement.

5-3.2 **Economic Feasibility.** Evaluate providing CPS for the following buried or submerges systems:

- Existing steel waterfront structures
- Reinforcing steel in concrete

Base implementation of CPS on life-cycle economics. Requirements for CPS will be determined by the corrosion engineer.

5-3.3 **Rehabilitation.** When rehabilitating existing steel pile bulkheads by driving new sheets outboard of the existing, include the following requirements for the CPS:

- Electrically isolate new piling from old piling
- Electrically isolate tie rods from existing sheet piling by cutting a hole in the old piling and providing a dielectiric sleeve through the pile.
- Coat tie rods and new piling on all sides.
- Consider CPS as part of the total corrosion protection system. Use conventional soil side anodes to protect the seaside and landside of the pile and to protect the tie rods if field tests indicate this to be feasible. Otherwise, consider using a deep anode bed system. Waterside anodes are appropriate only in areas not subject to maintenance dredging, water turbulence from ship/boat traffic, normal or storm generated heavy wave action, or constant movement of the sea bottom. Conduct a site survey to

determine the appropriate anode configuration and cathodic protection system requirements.

5-3.4 **Efficacy**. In general, the rate of corrosion loss below MLW is two-thirds to one-half the rate just below, at, and above MLW. Since cathodic protection is effective only below MLLW, it follows that cathodic protection should be accompanied by use of a concrete fascia or encasement to and below MLLW. Therefore, the obvious cost comparison is between such a composite system and complete concrete encapsulation.

5-3.5 **Maintenance Cost**. Consider the cost of electricity, replacement of anodes, and general repair of damage to wires and hangers in the economic analysis.

5-3.6 **Reliability of Maintenance Effort**. A cathodic protection system rendered fully or partially inoperative due to a lack of maintenance and repair is all too common. Implement regularly scheduled maintenance inspections to minimize risk of failure of the cathodic protection system.

5-4 EXPANSION, CONTRACTION, AND CONTROL JOINTS

5-4.1 **Open-Pile Platforms**. For open-pile pier and wharf platforms, refer to \1\ UFC 4-152-01, *Design: Piers and Wharves* /1/.

5-4.2 **Bulkheads**. In normal practice, no expansion or contraction joints are provided in the sheeting regardless of type. Assuming that a concrete cap will effectively grip the sheeting, there is no rational reason to joint the cap either as it is not free to strain axially anywhere along its length. Similarly, no special joints are required for timber or steel caps or for any anchor wall.

5-4.3 **Concrete Quaywalls**. Provide joints every 90 to 120 m (300 to 400 ft). Such formed joints need not be carried more than 1.52 m (5 ft) below MLLW.

5-5 MISCELLANEOUS REQUIREMENTS

5-5.1 **Protective Lighting**. \1\ Refer to UFC 4-025-01, *Waterfront Security Design,* currently in final draft and near final publication. /1/

\1\ /1/

5-5.2 **NAVAIDS**. Provide navigational aids at ends of piers, wharves, or quays. The cost of prominent, well-lighted markers is negligible in comparison to that of a collision. Refer to \1\ UFC 4-150-06, *Military Harbors and Coastal Facilities* /1/, for specific requirements.

5-6 **TIMBER**. The use of timber in the marine environment should be based on life-cycle economics. If timber is placed in the marine environment, it should be pressure treated according to American Wood Preservers Association Standards unless state and local regulations restrict its installation, cutting, use, or disposal. Conversely, the timber may be wrapped by plastic according to \1\ UFGS 31 62 21, *Piling: Composite, Wood and Cast In-Place Concrete* /1/. Field divisions and Activities should conduct site-specific risk assessments for each area containing a significant quantity of timber to determine the impact on the local marine environment. The risk assessment method may employ the software developed by the Western Wood Preservers Institute or other similar systems. The assessment may also include a leachability analysis if required by the locale. Most Field Divisions and Field Activities have applied biologists on staff to assist in the planning and design process.

For treated Douglas fir and Southern pine, see Table 5-2 for examples of structural characteristics as functions of preservative type.

5-7 FIRE PROTECTION REQUIREMENTS

5-7.1 **General**. Apply the provisions of the National Fire Protection Association (NFPA) Standard NFPA 307, *Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves*, and of \1\ UFC 3-600-01, *Fire Protection Engineering for Facilities* /1/.

5-8 **ANTI-TERRORISM / FORCE PROTECTION.** Refer to UFC 4-025-01, *Waterfront Security Design*, currently in final draft and near final publication /1/.

\1\ /1/

Table 5-2 Properties of Treated Woods

Type of Treatment	Average Properties							
	Modulus of Rupture		Modulus of Elasticity in flexure		Energy Absorption in Flexure		Compressive Strength	
	PSI	%	PSI	%	PSI	%	PSI	%
Fir								
Untreated	8394	100	1.922	100	6.388	100	3346	100
Creosote	6862	82	1.584	82	4.202	66	N/A	N/A
ACA Dual	6111	73	1.637	80	3.069	48	2714	81
CCA Dual	3844	46	1.171	61	3.364	63	2333	70
ACA	5620	67	1.416	74	2.078	33	2462	74
Pine								
Untreated	8007	100	1.942	100	5.24	100	N/A	N/A
Creosote	6960	74	N/A	N/A	N/A	N/A	N/A	N/A
ACA Dual	4726	59	1.568	81	2.829	64	N/A	N/A
CCA Dual	4167	52	1.441	74	2.413	46	N/A	N/A
ACA	5534	69	1.538	79	N/A	N/A	N/A	N/A
CCA	5410	68	N/A	N/A	N/A	N/A	N/A	N/A

NOTES:
1) "N/A" indicates a large spread in measured values for a small number of samples.
2) % = percent of the value for untreated wood.
3) Source: Civil Engineering Laboratory, Technical Note (TN) No. N1636 Mechanical Properties of Preservative Treated Marina Piles - Results of Limited Full - Scale Testing.

CHAPTER 6

STRENGTH EVALUATION OF EXISTING WATERFRONT STRUCTURES

6-1 **EVALUATING STRENGTH OF EXISTING MATERIALS.** Recent work by Naval Facilities Engineering Service Center (NFESC) has accomplished much in evaluating the strength of existing materials. NFESC has conducted impact load tests, followed by finite element analysis to evaluate the strength of a number of waterfront locations. This was followed by development of innovative repair techniques such as installation of a laminate composite overlay on the underside of existing Navy piers. \1\ A series of reports have been published on this topic that can be obtained from NFESC: https://portal.navfac.navy.mil/portal/page/portal/navfac/navfac_ww_pp/navfac_NFESC_pp . /1/ For strength evaluation of mooring hardware, reference UFC 4-150-08 *Inspection of Mooring Hardware.*

6-1.1 **General**. Apply the provisions of \1\ UFC 3-301-01, *Structural Engineering* /1/ relating to the use of used and / or unidentified materials.

6-1.2 **Number of Tests Required to Establish Strengths of Undocumented Materials**. Where no documentation exists pertaining to the strength of an existing material, the strength must be established by tests of the material. Use the value that sampling and testing indicates to have a 95 percent probability of being exceeded, as the strength of material to be assumed for strength evaluation of the structure. Use no fewer than four samples of a given material for testing.

6-1.3 **Tests and Test Specimens**

6-1.3.1 **Steel Members**. For steel members, take test specimens from locations and as described in \1\ ASTM A6/A6M, *Standard Specifications for General Requirements for Rolled Structural Steel Bars, Plates, Shapes and Sheet Piling.* /1/

6-1.3.2 **Concrete Members**. For concrete members, use drilled cores and sawed beams as described in \1\ ASTM C42/C42M, *Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.*/1/

6-1.3.3 **Wood Members**. For wood members, stress-grade visually as described in \1\ ASTM D245, *Standard Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber*. /1/

6-2 **COMPUTING STRENGTH OF THE STRUCTURE**. Base analyses on measured in-place dimensions and existing conditions. A badly deteriorated or obviously overloaded structure often continues to support the applied loads with no discernible indications of distress. It is important to consider the factors contributing to this phenomenon when evaluating the strength of an existing structure. The more important of these factors are presented in the following paragraphs.

6-2.1 **Simplifying Design Assumptions**. Structural design commonly employs simplifying assumptions intended to make the design effort more manageable. These assumptions are invariably conservative and often result in substantial excess strength, for example, in presenting the distribution of concentrated loads to a slab, and in the structural design of variable sections.

6-2.1.1 **Distribution of Concentrated Loads to a Slab**. Conventional procedures, such as those described in the references of \1\ UFC 1-200-01, *General Building Requirements* /1/ and the American Association of State Highways and Transportation Officials (AASHTO), underestimate distribution of concentrated loads applied to a slab. Previous discussion in the paragraph entitled "Evaluating Strength of Existing Materials**"** relates here.

6-2.2 **Locations of Weakened Sections**. Members are proportioned for maximum stress conditions. The section required at points of maximum stress frequently is carried for the full length of the member to minimize the costs of fabrication or of form work, or for aesthetic reasons. If the deterioration of a member is localized and does not occur at a point of maximum stress, the "strength" of the overall member may not be impaired by exhibited deterioration.

6-2.3 **Changed Design Methodology**. If a structure was originally designed based on an elastic analysis, re-analysis based on ultimate strength, plastic redistribution of moments, or moment distribution based on the concept of yield line theory will frequently yield a greater analytical capacity.

6-2.4 **Design Live Loads**. Design live loads are seldom realized in practice. Therefore, original design loadings should be assessed and compared to actual load requirements for continuing validity.

6-2.5 **Excess Section**. Designs often contain excess strength by way of provision of sacrificial metal, rounding member sizes to the next heavier section, or to a lighter but stronger section, or for satisfaction of requirements for minimum thickness of metal or limiting deflection. Piling, in particular, is often sized beyond its structural requirement to resist driving stresses or for load transfer to the soil.

6-2.6 **Change of Structural Action**. The structural response to an applied load may differ from that assumed during design. Ordinary beams and slabs are a common case in point. These are proportioned on the basis of pure flexural behavior. However, except for large ratios of span to depth, pure flexural action is not realized, and the member resists the load, at least partly, by catenary action or arching. Composite actions between separate different structural elements may develop over time, which had not yet developed during original construction. Yield points may develop, changing the moment diagram and reactions, thus increasing some and decreasing others, with the changes often being non-critical.

6-2.7 **Change in Loading**. In some cases, the design load represents a temporary or construction condition, and the service loads are of lesser severity. For example, if a retaining wall is well drained, maximum lateral pressure will occur during and shortly after back-filling, dissipating somewhat with time. Another example is that of a hydraulic fill. The lateral pressure decreases as the fill drains. Borings will help in evaluating actual, in-place soil properties at the time that evaluation is made.

6-3 EVALUATING CONCRETE STRENGTH USING LOAD TESTS

6-3.1 **Method**. Apply the provisions of \1\ ACI 318/318R /1/, supplemented as described in the following paragraphs.

6-3.2 **Test Load**. Use test load magnitudes of 1.4D + 1.7L where live load is the reduced load (for tributary area). This increased loading intensity will require careful observation and control to preclude precipitating collapse. For this purpose, load in six increments, rather than four, and where feasible, use water-loading for safe provision of emergency drainage and load removal.

6-3.3 **Lateral Loads**. Simulate lateral loads expected to occur simultaneously with vertical loads in the test.

6-3.4 **Loaded Area**. Make the loaded area large enough to ensure that additional strength due to continuity and three-dimensional action within the structure is properly reflected in the test.

6-4 SPECIAL PROVISIONS REGARDING CAPACITY OF EXISTING PILES

6-4.1 **Structural Capacity**. Check existing piles checked for effects of deterioration. A reconnaissance survey should be made to identify areas of "worst conditions." Measurement of overall residual strength in 1 percent to 2 percent (but not less than 4) of the piles will be considered an adequate statistical sample on which to base judgment of capacity. Use the "worst" piles of the group as identified in the reconnaissance survey.

Give consideration to probable, future progression of loss of strength. Usually, the mudline under a platform has accreted well above the normal, stable slope line drawn from the existing dredge level alongside the platform. Discount this material in estimating the un-braced pile length (L). Should future dredging to greater depth be contemplated, consider the increased un-braced pile length that would result.

6-4.2 **Capacity of the Soil to Support the Pile**. Unless the embedded length of a pile has been reduced by scour or dredging, assume no reduction in bearing capacity from that initially achieved during driving. Where installed capacity is not known, consider the use of load tests to establish capacity.

6-4.3 **Sheet Piling**. Take the capacity of sheet piling to support vertical loads one-half the value indicated by conventional formulae relating capacity to driving resistance.

6-4.4 **Interpretation of Load Tests**. For interpretation of load tests refer to \\1\ UFC 3-220-01N, *Geotechnical Engineering Procedures for Foundation Design of Buildings and Structures* and UFC 3-220-10N, *Soil Mechanics*. /1/

CHAPTER 7

DETERIORATION OF WATERFRONT STRUCTURES

7-1 **GENERAL.** Considerable treatment of this topic may be found in UFC 4-150-07 *Maintenance of Waterfront Facilities* and UFC 4-150-08 *Inspection of Mooring Hardware.*

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APPENDIX A

REFERENCES

\1\ GOVERNMENT PUBLICATIONS

1. Unified Facilities Criteria (UFC): http://dod.wbdg.org	\1\ UFC 1-200-01, *General Building Requirements* UFC 3-220-01N, *Geotechnical Engineering Procedures for Foundation Design of Buildings and Structures* UFC 3-220-10N *Soil Mechanics* UFC 3-301-01, *Structural Engineering* UFC 3-570-02N, *Electrical Engineering Cathodic Protection* UFC 3-600-01, *Fire Protection Engineering for Facilities* UFC 4-025-01, *Waterfront Security Design; currently in final draft and near final publication* UFC 4-150-06, *Military Harbors and Coastal Facilities* UFC 4-150-07, *Maintenance of Waterfront Facilities* UFC 4-150-08, *Inspection of Mooring Hardware*

	UFC 4-152-01, *Design: Piers and Wharves* UFC 4-159-03, *Design: Moorings* /1/
Unified Facilities Guide Specification http://www.wbdg.org/references/pa_dod.php	\1\ UFGS 03 31 29, *Marine Concrete* UFGS 26 42 13.00 20, *Cathodic Protection by Galvanic Anodes* UFGS 26 42 19.00 20, Cathodic Protection by Impressed Current UFGS 31 41 16, *Metal Sheet Piling* UFGS 31 62 13.13, *Cast-In-Place Concrete Piles* UFGS 31 62 13.20, *Precast/Prestressed Concrete Piles* UFGS 31 62 16.16, *Steel H-Piles* UFGS 31 62 19.13, *Wood Marine Piles* UFGS 31 62 21, *Piling: Composite, Wood and Cast In-Place Concrete* UFGS 31 63 16, *Auger Cast Grout Piles* UFGS 31 63 26, *Drilled Caissons*

	UFGS 35 59 13.13, *Prestressed Concrete Fender Piling* UFGS 35 59 13.14 20, *Polymeric Fender Piles* /1/

NON-GOVERNMENT PUBLICATIONS

American Society for Testing and Materials (ASTM) 100 Bar Harbor Road West Conshohocken, PA 19428-2959 http://www.astm.org	\1\ ASTM A6/A6M, Standard Specifications for General Requirements for Rolled Structural Steel Bars, Plates, Shapes and Sheet Piling ASTM A36/A36M, Carbon Structural Steel ASTM A242/A242M, High-Strength, Low-Alloy Structural Steel ASTM A252, Welded and Seamless Steel Pipe Poles ASTM A588/A588M, High-Strength, Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point with Atmospheric Corrosion Resistance ASTM A690/A690M, High-Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments ASTM A709/A709M, Structural Steel for Bridges

	ASTM C42/C42M, Obtaining and Testing Drilled Cores and Sawed Beams of Concrete ASTM D25, Specification for Round Timber Piles ASTM D245, Standard Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber /1/
American National Standards Institute (ANSI) 1899 L Street, NW Washington, DC 20036 http://www.ansi.org	\1\ ANSI O5.1, Class 3 Poles /1/
\1\ American Wood Protection Association (AWPA) P.O. Box 36784 Birmingham, AL 35236-1784 /1/ http://www.awpa.com	\1\ AWPA Standard U1 /1/
American Concrete Institute (ACI) International P.O. Box 9094 Farmington Hills, MI 48333 http://www.aci-int.org	ACI 318/318R, Building Code Requirements for Structural Concrete and Commentary
Portland Cement Association 5420 Old Orchard Road Skokie, IL 60077 http://www.cement.org/	\1\ PCI STD 112, Standard Prestressed Concrete Piles Square, Octagonal and Cylinder /1/
National Fire Protection Association (NFPA) 1 Batterymarch Park Quincy MA 02269-9101 http://www.nfpa.org	NFPA 307, Standard for Construction and Fire Protection of Marine Terminals, Piers, and Wharves

/1/

UFC 4-152-01
24 January 2017
Change 1, 28 August 2024

UNIFIED FACILITIES CRITERIA (UFC)

PIERS AND WHARVES

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

PIERS AND WHARVES

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING **\1** SYSTEMS **/1/** COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location
1	28 Aug 2024	• Various format updates and editorial changes throughout. • Chapter 1 mandatory paragraphs updated. • Added definition of a Type IIA ‘Hybrid’ General Purpose/Repair pier. • Chapter 2, various requirements.

This UFC supersedes UFC 4-152-01, dated 28 July 2005 with Change 1, dated 1 September 2012.

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 web site http://www.wbdg.org/ffc/dod.

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

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 4-152-01, *DESIGN: PIERS AND WHARVES*

Superseding: UFC 4-152-01, *DESIGN: PIERS AND WHARVES*, dated 28 July 2005 with Change 1, dated 1 September 2012.

Description of Change: UFC 4-152-01*, DESIGN: PIERS AND WHARVES* represents another step in the joint services effort to bring uniformity to the planning, design and construction of piers and wharves. This UFC contains extensive modifications in the following areas:

- Loads and seismic considerations
- Fender Systems
- Camels
- UFC general updates and revisions

Reasons for Change: The existing guidance was inadequate for the following reasons:

- Incorporation of changes described above
- Update to referenced documents

Impact: The following direct benefits will result from the update of 4-152-01, *DESIGN: PIERS AND WHARVES*:

- Although primarily a U.S. Navy document, a single, comprehensive, up to date criteria document exists to cover design of piers and wharves.
- Eliminates misinterpretation and ambiguities that could lead to design and construction conflicts.
- Facilitates updates and revisions and promotes agreement and uniformity of design and construction between the Services.

Service Exceptions: None.

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CHAPTER 1 INTRODUCTION

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1-1 PURPOSE AND SCOPE.

This UFC contains descriptions and design criteria for pier and wharf construction, including subsidiary, contiguous, and auxiliary structures. Loading details, regulations, furnishings, appurtenances, and other information are discussed when applicable. This UFC provides minimum facility planning and design criteria for efficient homeporting facilities of DoD vessels. Existing ports, facilities, and berths may not meet all criteria and may therefore, perform less efficiently, but do not necessarily require upgrade. This UFC focuses on the entire homeport operation. For example, ships will visit fueling and ammunition piers for short periods, but generally berth at general purpose berthing piers.

[C] 1-1 Triggers requiring an entire upgrade or replacement are under consideration for future revisions to this document.

1-2 APPLICABILITY.

This UFC applies to the design and construction of new, renovated, and repaired waterfront facility projects for the Department of Defense (DoD). It is applicable to all methods of project delivery and levels of construction. However, existing structures may not be able to meet some of the requirements in this UFC, but do not necessarily need to be upgraded. Incorporate requirements as best as possible and operationally for existing structures. Requirements in this UFC may support the need to replace an inadequate facility.

1-3 GENERAL FUNCTION.

An important consideration that often comes up has to do with differentiation between homeports and ports of call. A homeport for a specific ship has been identified as such by Commander Fleet Forces Command and is listed in the Naval Vessel Register (http://www.nvr.navy.mil). The homeport is where the ship is assigned and offers all requisite services required by the ship to include the full complement of hotel services. In contrast, a port of call would be any port where a ship stops along the way other than its homeport, e.g.: a fueling pier, an ammunition pier, a supply pier, or a repair pier. The only real requirements for a port of call would be that it has sufficient dredge depth and that it provides secure mooring. A ship does not go cold iron in port of call and uses its organic systems. However, local determinations and justifications can warrant adding specific features at ports of call. Many of the new classes of ships have concepts of operations and special mission requirements that have resulted in making accommodations at ports in forward operating areas that ordinarily would not be required, i.e. hotel services. These are handled on a case-by-case basis and driven by operational requirements. Generally, piers and wharves provide:

- Berths with sufficient dredge depths for vessels.

- Secure mooring for vessels berths.
- Transfer points for cargo and/or passengers between water carriers and land transport.
- Facilities for repair; and specialized functions.

1-4 CATEGORIES.

Piers and wharves are categorized into four (4) primary facility types and sub-types as follows:

1-4.1 Type I – Fueling, Ammunition, and Supply.

1-4.1.1 Fueling.

These are dedicated piers and wharves equipped with facilities for off-loading fuel from ship to storage and for fueling ships from storage. For additional design criteria, see UFC 4-150-02, *Dockside Utilities for Ship Service.*

1-4.1.2 Ammunition.

These are dedicated piers and wharves used for discharging ammunition for storage and for loading ammunition on outgoing ships. Explosives and ammunition quantity/distance standards are discussed in NAVSEA OP 5, Volume 1, *Ammunition and Explosives Safety Ashore*.

1-4.1.3 Supply.

Supply piers and wharves are used primarily for the transfer of cargo between ships and shore facilities. Provide standard gage railroad tracks when supplies will be brought in by rail.

1-4.2 Type II – General Purpose.

1-4.2.1 Berthing.

General purpose berthing piers and wharves are used primarily for mooring ships. Furthermore, berthing facilities may be active, as when ships are berthed for relatively short times and are ready to put to sea on short notice, and inactive, as when they are berthed for long periods in a reserve status. Depending upon intended pier usage, i.e. active berthing, maintenance/repair, inactive berthing, consider appropriate mooring service type as it relates to design/capacity of mooring fixtures. Activities that typically take place on berthing piers and wharves are personnel transfer, maintenance, crew training, cargo transfer, and waste handling. Under some circumstances, fueling and weapons system testing may also be carried out in these facilities.

1-4.2.2 Type IIA – Hybrid General Purpose/Repair.

A Type IIA 'Hybrid' General Purpose/Repair pier or berth is a Type II General Purpose pier/berth with enhanced features, similar to a Type III Repair pier typically found at a shipyard. It can support more advanced ship maintenance and repairs at a non-shipyard installation, but is not fully Type III compliant. It may be:

- A dedicated Type III repair pier/berth at a DoD general berthing installation that may or may not be situated in an enclave.
- A Type II pier or berth that does not meet the full requirements of a Type III repair pier/berth, but has limited capabilities to perform ship maintenance and repair.
- Or a Type II pier with dedicated berths that meet requirements of a Type III repair pier.

[C] There is not a definitive definition of a Type IIA 'Hybrid' repair/berth. Each requirement, location, function, and situation must be evaluated and balanced with operations and risks considered to determine what level of ship maintenance and repair can be provided at a non-shipyard Type III facility. The cognizant ship operating command and shore installation will have to determine who is responsible and fund the ship requirements.

A Type IIA pier/berth must meet the Type II requirements of this UFC, UFC 4-150-02, NAVSEA 8010, other UFCs, and include, but not limited to, the following:

- Heavy Weather Moorings (HWM).
- Permeant or temporary utility services, including a dedicated shore-supplied saltwater or nonpotable water supply for ship firefighting.
- Dedicated fire lane(s).
- Suitable capacity for crane operations.

Risks to be evaluated by installations and maintenance and repair activities (i.e. NAVSEA, CNIC, NAVFAC, DoD, and non-DoD commands) include:

- Limited availability of utilities.
- Limited deck space and laydown areas.
- Limited access.
- Limited crane operations.
- Limited dredge depth, slip width, clearance.

See other portions of this UFC, UFC 4-150-02, UFC 4-159-03, other applicable waterfront and facilities UFCs, and NAVSEA documents.

Each installation and project must consider, evaluate, and accept the risks of designating a Type IIA or Type III repair pier/berth at a DoD installation. This includes private shipyards.

1-4.2.3 Non-DoD Berthing.

Non-DoD agencies may be a tenant command at DoD installations. They may utilize DoD waterfront and supporting facilities on a DoD installation or fund and build their own facilities. They must have a MOA on record showing the agreement between the agencies. It must include the responsible Government Agency, financial commitment, criteria commitment, operations and maintenance plan, and plan to turn over a facility to the DoD if the non-DoD agency leaves the DoD installation.

1-4.3 Type III – Repair.

An important consideration for repair piers is the need to provide heavy weather mooring capability. This includes properly sized and spaced storm bollards and a compliment of heavy weather mooring lines. This consideration is predicated upon the fact that ships under repair may not be able to get underway during a heavy weather event.

See Type IIA definition for considerations regarding a ‘Hybrid’ Type II General Purpose pier and a fully capable Type III Repair pier.

1-4.3.1 Repair.

Repair piers and wharves are constructed and equipped to permit overhaul of ships and portions of a hull above the waterline. These structures are generally equipped with portal cranes or designed to accommodate heavy mobile cranes.

1-4.3.2 Floating Dry Docks.

Piers and wharves for floating dry docks are constructed and equipped to permit overhaul of ships above and below the waterline. Some floating dry docks have portal cranes on tracks on the wingwalls and some floating dry docks use cranes from the pier side. Provide adequate dredge depth at these facilities to accommodate the floating dry dock when submerged. Floating dry docks are normally moored using two or more vertical spuds that maintain the horizontal position of the dock throughout its full range of vertical movement from fully submerged to fully dewatered. Design the pier/wharf structure to accommodate mooring spud placement and loading. The pier or wharf layout should also consider personnel, material, and vehicle access to the dry dock pontoon deck when the dry dock is in the raised (dewatered) position. In the design of a pier or wharf structure, consider variations of the floating dry dock in the unballasted, ballasted, and partially ballasted positions.

1-4.4 Type IV – Specialized.

1-4.4.1 Magnetic Treatment and Electromagnetic Roll Piers.

These are piers that moor ships over an array of underwater instruments and large-area cable solenoids used specifically for removing and/or modifying the magnetic signature characteristics of surface vessels and submarines, as well as calibrating the on-board degaussing systems of mine countermeasure vessels. Magnetic treatment facility designs vary using slips, T-piers, or single piers depending upon location and requirement. Magnetic treatment piers designed to accommodate surface vessels are typically configured as T-shapes; whereas, submarines and mine countermeasure vessels are typically treated at drive-in piers built in parallel configurations.

1-4.4.2 Training, Small Craft, and Specialized Vessels.

These piers and wharves are typically light structures designed for specific but limited functions. Specific requirements are usually provided by the activity. Additional guidance can be found in UFC 4-152-07, *Small Craft Berthing Facilities*.

1-5 FLEXIBILITY OF BERTHS.

Typically, piers and wharves are designed to provide space, utility service, and other supporting facilities for specific incoming or homeported ships. However, berthing plans and classes of ships berthed change with time. While it is not economically feasible to develop a single facility to accommodate and service all known ship classes, design the facility with a certain amount of built-in flexibility to allow for anticipated future changes in the functional requirements. This is especially true for berthing piers and wharves that will be used to accommodate different classes of ships as well as support a variety of new operations.

1-6 APPURTENANCES AND FEATURES.

The following is a range of appurtenances and features that may be required for piers and wharves.

- Mooring devices to safely secure the ship.
- Fender systems, camels and separators.
- Hotel and ship service utilities.
- Communications.
- Cranes and crane trackage.
- Access facilities for railroad cars and trucks.
- Waste handling facilities.
- Cargo handling equipment.
- Covered and open storage spaces for cargo.

- Support building, tool shed, office space, and control rooms.
- Lighting poles and equipment.
- Lightning protection.
- Security systems.
- Firefighting equipment.
- Emergency medical facilities.
- Access structures and facilities.
- Fueling facilities.
- Safety ladders.
- Life-safety rings.

1-7 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.

1-8 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and terms.

1-9 REFERENCES.

APPENDIX A 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.
/1/

CHAPTER 2 FACILITY PLANNING

2-1 LOCATION AND ORIENTATION.

2-1.1 General.

The location and alignment of piers and wharves in a harbor should consider factors such as:

- Maneuverability.
- Required quayage.
- Harbor line restrictions.
- Geotechnical conditions.
- Isolation requirements.
- Prevailing wind and current directions.
- Wave climate.
- Sea level change.
- Clearance between moored or passing vessels.
- Project depth.
- Shoaling patterns.
- Environmental permit restrictions.
- Port regulations.
- Landside access/proximity.
- Shoreside elements required as part of a pier/wharf project.
- Proximity to commercial and military airfields (potential restriction to crane operations).

For further discussion and criteria, see UFC 4-150-06, *Military Harbors and Coastal Facilities*.

2-1.2 Orientation for Environmental Conditions.

To the extent practical, orient piers and wharves so that a moored ship is headed into the direction of the prevailing winds and currents. Thus, the forces induced on mooring lines by these conditions would be kept to a minimum. If such an arrangement is not feasible, consider an orientation in which the wind or current holds the ship off the facility, although do not overlook the difficulty in mooring a ship under such conditions. In locations where criteria for both wind and current cannot be met, orient the berth parallel to the direction of the more severe condition. At locations exposed to waves and swell, locate the facility so that a moored ship is headed into the wave or swell front. If planning criteria dictate that a pier or wharf be oriented so that a moored ship is positioned broadside to the prevailing winds, currents, or waves, consider breast-off buoys to keep the ship off the facility and diminish the possibility of damage to the structure and ship. At oil storage terminals located in areas where meteorological and hydrological conditions are severe, consider using a single point mooring which allows a moored tanker to swing freely when acted upon by winds, waves, and currents from varying directions. See UFC 4-159-03, *Moorings*.

2-1.2.1 Pier Orientation.

A pier is oriented either perpendicular to or at an angle with the shore. There are generally ships on both sides, although there are instances where only one side has a ship because of site conditions or because there is no need for additional berthing. Piers may be more desirable than wharves when there is limited space available because both sides of a pier may be used for mooring ships. When both sides of a moored ship need to be accessed, two parallel piers with a slip in between may be preferred. Magnetic Treatment and Electromagnetic Roll piers usually require a magnetic north/south orientation, irrespective of other considerations.

2-1.2.2 Wharf Orientation.

A wharf is a structure oriented approximately parallel to the shore. Ships can only be moored at the offshore face of a wharf. When water depths close to shore are not adequate to accommodate deep draft ships, the wharf, consisting of a platform on piles, is located offshore in deep water and is connected to shore at one or more points by pile-supported trestles, usually at right angles to the wharf. If the trestle is located at the center of the wharf, the structure is referred to as a T-type wharf; if the trestle is located at an end, the facility is known as an L-type wharf; if trestles are located at both ends, the wharf is called a U-type wharf. Ships may be berthed on both sides of a T- or L-wharf. When the offshore wharf is used for transfer of bulk liquid cargo from the unloading platform to shore via submarine pipelines, the structure is referred to as an island wharf. A trestle from the offshore wharf to shore is not provided and both sides of the island wharf may be used for mooring ships. Launches are used for wharf access. Where a U-shaped berth is formed by a cut into land by two approximately parallel wharves, this may be referred to as a slip. For examples of pier and wharf types, see Figures 2-1 and 2-2. For general cargo, supply, and container terminals, a wharf structure, connected to upland shore area for its full length, is preferred because such an arrangement is more adaptable to loop rail and highway connections and the distance from wharf apron to transit sheds and open storage areas is shorter.

2-1.3 Vessel Ingress and Egress.

On occasion, a moored vessel is required to make a hasty departure from its berth and head out to sea. Accordingly, when planning a pier or wharf, consider providing adequate turning area so that a ship can be turned before it is docked, and moored with a heading that will permit a convenient and rapid departure.

Figure 2-1 Pier and Wharf Types

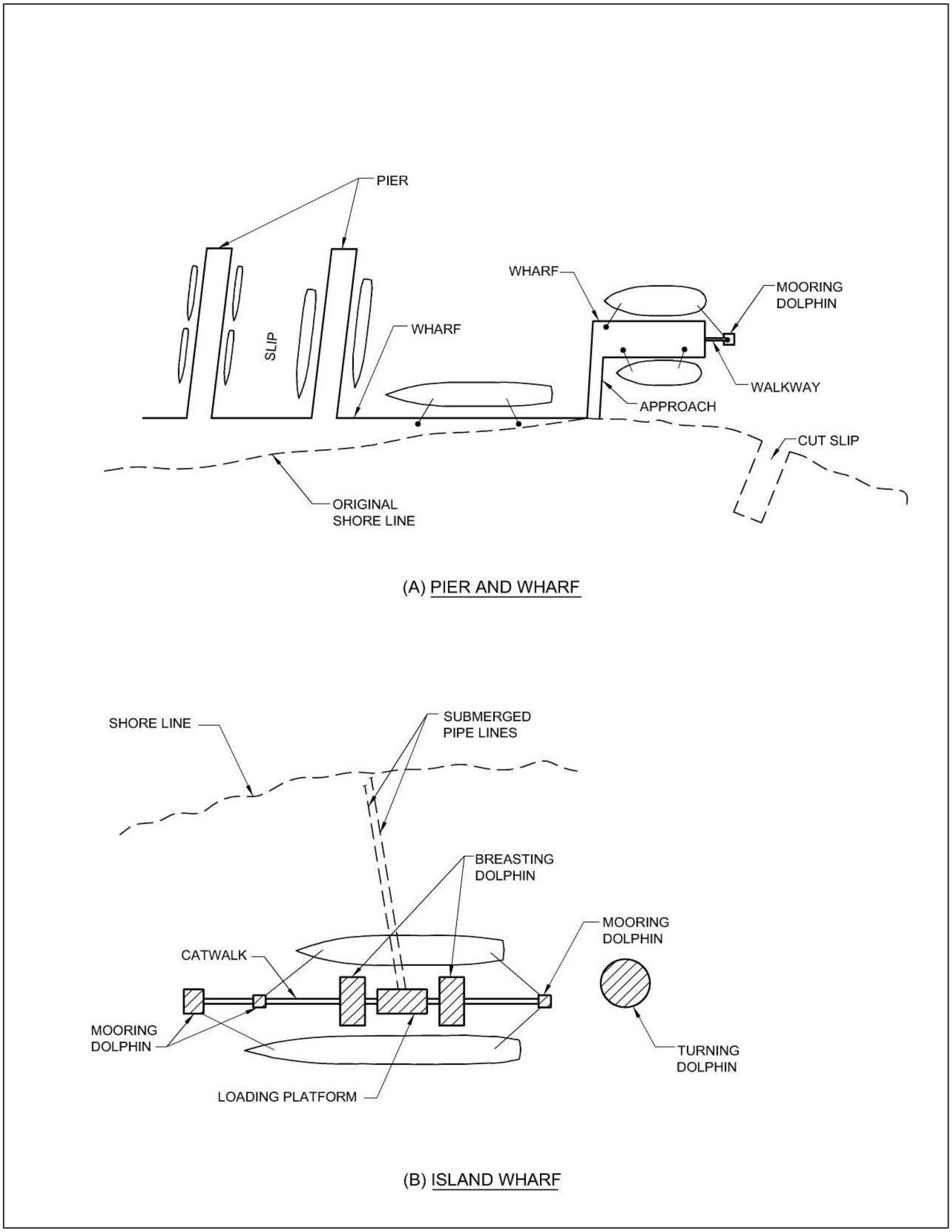
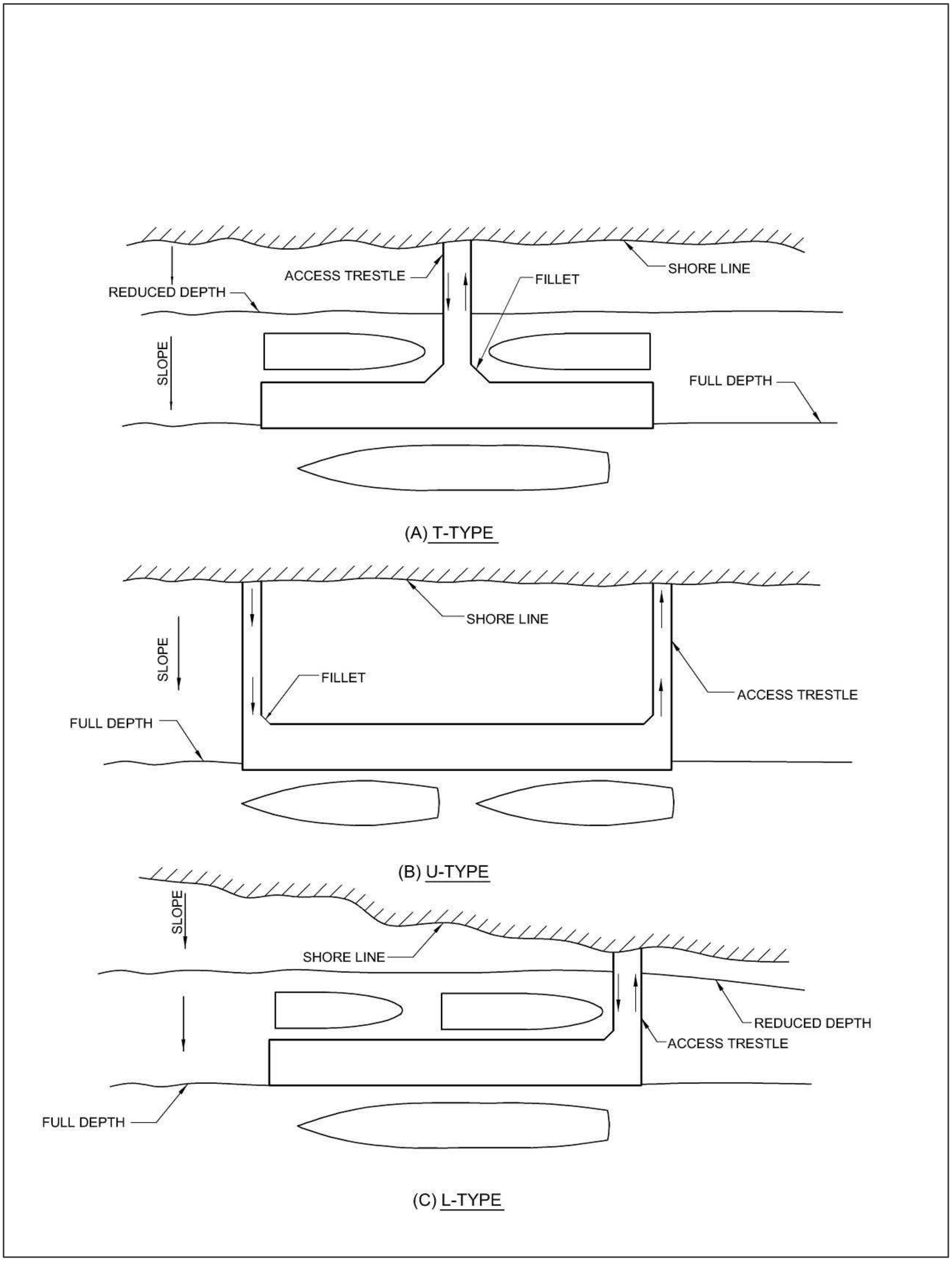


Figure 2-2 Wharf Types



2-1.3.1 Disaster Control and Emergency Plans.

In an emergency, tugs may not be available. Therefore, the slip, berth, basin, and channels should allow the ship to get underway without assistance. See OPNAVINST 3040.5D, *Procedures and Operations Reporting Requirements for Nuclear Reactor and Radiological Accidents*. There will be cases where a ship will not be able to leave prior to heavy weather (such as during a Phased Maintenance Activity (PMA) or Planned Incremental Availability (PIA) for CVN). General-purpose berths are designed for Mooring Service Type IIB. Repair berths are designed for Mooring Service Type III. See the heavy weather mooring criteria contained in UFC 4-159-03, *Design: Moorings.*

Design facility systems for continuous operation in the event of a power outage, in other words, pier/wharf remains operational with exception of having shore power and lighting.

2-1.3.2 Harbor Elements.

Information on channel approaches (outer channels), entrances (inner channels), and turning basins to include recommended widths and depths is contained in UFC 4-150-06, *Military Harbors and Coastal Facilities.*

2-1.4 Water Depth.

Consider a wharf structure at locations where the required depth of water is available close to shore and the harbor bottom slopes steeply out to deeper water. At locations where water depths are shallow and extensive dredging would be required to provide the required depth of water close to shore, consider locating the facility offshore, in deeper water, by utilizing a T-, L-, or U-type wharf.

2-1.5 Dolphins.

These are small independent platforms or groups of piles used by themselves or in conjunction with a pier or wharf for specialized purposes. A mooring dolphin is sometimes used at the offshore end of a pier or both ends of a wharf to tie up the bow or stern lines of a ship at a more favorable angle. Mooring dolphins are usually accessed by a catwalk, as illustrated in Figure 2-1, and are provided with a bollard or capstan. Breasting dolphins are sometimes used for roll-on/roll-off facilities and at fueling terminals where a full-length pier or wharf is not required. They may also be used as part of the fender system. A turning dolphin is an isolated structure used solely for guiding the ships into a berth or away from known obstructions. Occasionally, a mooring dolphin may also be designed to function as a turning dolphin. Approach dolphins are used where the end of a pier or ends of a slip require protection from incoming ships. Breasting, berthing and turning dolphins are normally designed as semi- flexible structures with full utilization of their energy absorption capacity within elastic range, while mooring dolphins are normally designed as rigid systems.

2-2 COORDINATION OF REPAIR.

2-2.1 General.

Ships will undergo a Phase Maintenance Program based on the Class Maintenance Plan (CMP). These maintenance activities will generally be conducted at a repair berth. Ships in dry dock and in inactive status require specialized criteria that NAVFAC will provide as requested. Coordinate capability of local ship repair facilities and salvage operations with NAVSEA SUPSHIP. The following facilities should be available within a reasonable distance from the support facility homeport.

a. A Ship Maintenance Facility (SMF) housing the machine tools, industrial processes and work functions necessary to perform non-radiological depot level maintenance on ship propulsion plants.

b. A Maintenance Support Facility (MSF) housing both administrative and technical staff offices supporting ship propulsion plant maintenance, as well as central area for receiving, inspecting, shipping, and storing hazardous/mixed waste materials and maintenance materials, and controlled radiological tank storage.

c. A Controlled Industrial Facility (CIF) or Radiological Work Facility used for the inspection, modification, and repair of radiological controlled equipment and components associated with Naval nuclear propulsion plants. It also provides facilities and equipment for the treatment, reclamation, and packaging for disposal of radiologically controlled liquids and solids. It includes non-radiologically controlled spaces for administration and other support functions.

d. Dry dock facilities for various classes of ships. Refer to UFC 4-213-12, *Dry Docking Facilities Characteristics* for listing and details on active U.S. Navy graving dry docks. Consult with NAVSEA and the ship's Maintenance Program Master Plan and Class Master Plan (CMP) for specific requirements. Few floating dry docks remain active as service craft in the U.S. Navy inventory. Special moorings may be required for floating dry docks and special consideration for dredging (and shoaling) to allow for lowering of the dock is required.

e. Phased Maintenance Activities (PMA). PMA is a short, labor-intensive availability for ships in a Phased Maintenance Program for the accomplishment of maintenance and modernization. At some Naval stations, PMA is performed at general purpose berthing piers. PMA is discussed in detail in a subsequent section.

2-2.1.1 Aircraft Carriers.

Every 18 months an aircraft carrier will undergo a 6-month "Planned Incremental Availability (PIA)" at the repair berth. For CVN's, also coordinate with NAVSEA PMS 312 and NAVSEA 08, COMNAVAIRLANT N4, or COMNAVAIRPAC N4. Dry dock facilities for CVNs exist only at Puget Sound Naval Shipyard (PSNS), Norfolk Naval

Shipyard (NNSY), and Newport News Shipbuilding. NAVSEA 08 defines emergency dry dock facilities for CVNs. CVNs will be located at these facilities when this service is required.

2-3 OVERALL DIMENSIONS AND CLEARANCES.

2-3.1 General.

The overall dimensions and clearances required for piers and wharves are dependent on characteristics of the ships to be berthed and the support services provided. Comprehensive information on all U.S. Navy ships is found in the following locations or by contacting NAVFAC Atlantic - Engineering Criteria & Programs:

- Naval Vessel Register (NVR) (http://www.nvr.navy.mil/nvrships/index.htm). Note also that NVR provides a good reference regarding hull classification symbols, e.g. CVN = Multi-purpose aircraft carrier (nuclear propulsion)
- Military Sealift Command (MSC) (http://www.msc.navy.mil/inventory)

\1 Other Navy ship information can be found in a ship's Facility Planning Criteria (FPC). Contact other Services and Agencies for ship specific information on their ships.

2-3.1.1 Ship Characteristics.

Ship characteristics are provided in Tables 2-1 and 2-2. Data in tables is for various ship classes and is not all inclusive. There are many variants, blocks, and flights within a ship class. Designer is responsible for verifying information is correct and accurate for the ship(s) that will be berthed. **/1/**

\1\

Table 2-1 Ship Characteristics for Selected Ships (Fully Loaded)

Ship Class	LOA	LWL	LBP	D [b, c]	M	B	A_y	A_x	h_h	h_s
CVN 68 [a]	1115.0	1056.0	1040.0	40.2	91490.0	134.0	79450.0	14750.0	70.8	117.0
CVN 78 [d]	1092.0	1040.0	1040.0	TBD	TBD	134.0	TBD	TBD	TBD	TBD
CG 47 [e]	568.0	530.0	530.0	34.1 [c]	9407.0	55.0	24995.0	5330.0	28.8	80.4
DDG 51 [a]	505.0	466.0	466.0	33.6	8276.0	58.3	19130.0	4538.0	22.4	64.0
DDG 1000 [a]	607.0	600.0	600.0	28.6	14062.2	79.7	17098.6	1215.9	29.3	93.6
LCS 1 [d]	378.0 [c]	324.0	324.0	14.1	3292.0	57.0	TBD	TBD	TBD	TBD
LCS 2 [a]	418.6	388.9	390.0	14.2	3138.0	99.9	16721.0	5180.0	31.2	101.3
JHSV [a]	337.9	311.1	311.0	12.8	2461.0	93.5	16146.0	4931.0	42.9	68.7
LCC 19 [e]	620.0	580.0	580.0	31.8	18972.0	108.0	34350.0	6950.0	44.0	90.0
LHA 1 [e]	820.0	765.0	765.0	28.7	39251.0	106.0	71250.0	10750.0	74.5	111.0
LHD 1 [a]	840.0	788.0	778.0	28.1	40674.0	106.0	61075.0	8800.0	65.1	137.0
LHD 8 [d]	847.0	778.0	778.0	29.1	41684.0	106.0	TBD	TBD	TBD	TBD
LPD 4 [a]	570.0	557.0	548.0	23.2	16420.0	84.0	31100.0	7700.0	36.0	69.0
LPD 17 [a]	684.0	661.0	657.8	23.4	23880.0	96.7	43057.0	9460.0	36.2	77.2
LSD 41 [a]	612.0	580.0	580.0	21.4	16481.0	84.0	34350.0	7100.0	41.9	92.8
MCM 1 [e]	224.0	212.9	212.9	15.2	1261.0	39.0	5400.0	1520.0	11.9	45.0
SSN 21 [a]	361.0	319.0	352.8	37.8 [f]	8144.0	30.3	2383.0	236.0	7.0	24.9
SSN 23 [d]	453.0 [c]	453.0	453.0	41.3 [f]	12130.0	40.0	TBD	TBD	TBD	TBD
SSN 688 [a]	362.0	341.0	TBD	33.2 [f]	6132.0	32.1	2194.0	104.0	5.9	23.4
SSN 774 [a]	377.0	355.0	377.0	33.8 [f]	6958.0	24.0	2050.0	200.0	4.8	22.9
SSBN 726 [a]	559.3	526.1	TBD	37.5 [f]	16871.0	30.0	4158.0	505.0	6.3	12.0
SSGN 726 [a]	559.3	526.1	TBD	37.9 [f]	16871.0	30.0	4158.0	505.0	6.3	12.0
PC 1 [d]	178.0	178.0	178.0	8.0	334.0	TBD	TBD	TBD	TBD	TBD
T-AGER 2 [e]	177.0	171.0	171.0	10.0	945.0	32.0	2800.0	830.0	TBD	TBD
T-AGOS 19 [e]	234.5	190.0	190.0	24.8	3408.0	80.1	TBD	TBD	23.9	41.9
T-AGS 60 [e]	329.0	310.0	310.0	19.0	5137.0	57.0	TBD	517.0	9.0	37.0
T-AH 19 [a]	894.0	855.0	855.0	32.8	69522.0	105.8	56830.0	9265.0	44.7	114.7
T-AKE 1 [d]	689.0	654.0	654.0	31.8	42528.0	106.0	TBD	TBD	TBD	TBD
T-AO 187 [d]	677.0	650.0	650.0	36.0	40700.0	97.0	TBD	TBD	TBD	TBD
T-ARS 50 [d]	255.0	240.0	240.0	16.9	3181.0	51.0	TBD	TBD	TBD	TBD
T-AS 39 [d]	644.0	620.0	620.0	31.5	22978.0	85.0	TBD	TBD	TBD	TBD
T-ATF 166 [d]	226.0	204.0	204.0	15.6	2000.0	42.0	TBD	TBD	TBD	TBD

Table 2-2 Ship Characteristics for Selected Ships (Lightly Loaded)

Ship Class	LOA	LWL	LBP	D [b]	M	B	A_y	A_x	h_h	h_s
CVN 68 [a]	1115.0	1056.0	1040.0	31.2	70920.0	134.0	86550.0	15650.0	71.6	124.0
CVN 78	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
CG 47 [e]	568.0	532.0 [e, g]	530.0	20.0 [e, g]	7392.0	55.0	26685.0 [e, g]	5435.0 [e, g]	31.8 [e, g]	83.6 [e, g]
DDG 51 [a]	505.0	464.7	466.0	17.7	6513.0	57.0	20340.0	4688.0	25.0	66.6
DDG 1000 [a, g]	607.0 [a]	588.2	600.0 [a]	20.9	13695.1	79.7	17098.6	1215.9	29.3	93.6
LCS 1 [g]	378.0	324.0	324.0	TBD	2707.0	57.0	TBD	TBD	TBD	TBD
LCS 2 [a]	418.6	393.4	390.0	9.9	2181.0	99.5	18579.0	5382.0	36.0	106.1
JHSV [a]	337.9	313.0	311.0	8.5	1575.0	93.5	17493.0	5094.0	47.2	73.0
LCC 19 [e]	620.0	580.0	580.0	24.0	12315.0	108.0	37250.0	7360.0	TBD	TBD
LHA 1 [e]	820.0	765.0	765.0	18.9	25555.0	106.0	76750.0	11500.0	74.5	111.0
LHD 1 [a]	840.0	750.0	778.0	27.8	27839.0	100.0	66375.0	9475.0	67.0	140.0
LHD 8 [d]	847.0	778.0	778.0	TBD	28176.0	106.0	TBD	TBD	TBD	TBD
LPD 4 [a]	570.0	557.0	548.0	14.5	9179.0	84.0	35450.0	8350.0	44.0	78.0
LPD 17 [a]	684.0	656.0	657.8	TBD	19208.0 [d]	TBD	46202.0	9930.0	41.0	82.0
LSD 41 [a]	612.0	580.0	580.0	18.5	11414.0	84.0	35029.0	7200.0	43.1	94.0
MCM 1 [e]	224.0	212.9	212.9 [d]	TBD	1161.0	39.0	TBD	TBD	TBD	TBD
SSN 21 [a]	361.0	319.0	352.8	TBD	7568.0 [d]	30.3	TBD	TBD	TBD	TBD
SSN 23	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
SSN 688 [a]	362.0	341.0	TBD	TBD	5700.0 [d]	32.1	TBD	TBD	TBD	TBD
SSN 774 [a]	377.0	355.0	377.0	TBD	6454.0 [d]	24.0	2050.0	200.0	4.8	22.9
SSBN 726 [a]	559.3	526.1	TBD	TBD	15275.0 [d]	30.0	TBD	TBD	TBD	TBD
SSGN 726 [a]	559.3	526.1	TBD	TBD	15275.0 [d]	30.0	TBD	TBD	TBD	TBD
PC 1 [g]	178.0	178.0	178.0	8.0	288.0	TBD	TBD	TBD	TBD	TBD
T-AGER 2 [e]	177.0	171.0	171.0	7.0	610.0	32.0	3350.0	920.0	TBD	TBD
T-AGOS 19 [e]	234.5	190.0	190.0	14.8	2610.0	79.5	TBD	TBD	33.9	51.9
T-AGS 60 [e]	329.0	310.0	310.0	12.9	2970.0	57.0	TBD	870.0	15.1	43.1
T-AH 19 [a]	894.0	855.0	855.0	32.8 [c]	24946.0	105.8	75040.0	11460.0	65.3	135.3
T-AKE 1	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
T-AO 187	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
T-ARS 50	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
T-AS 39	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
T-ATF 166	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

SHIP CHARACTERISTICS TABLE NOTES AND LEGEND

Notes in column and row headers apply to all contents in that column or row unless otherwise noted in table.

[a] FIXMOOR Database **\1** Database is no longer available ***/1/***
[b] Values correspond to brackish water
[c] UFC 4-150-06, *Military Harbors and Coastal Facilities*, Table 5-3
[d] http://www.nvr.navy.mil/nvrships/S_TYPE.HTM
[e] Ships Characteristics Database (SCDB) **\1** Database is no longer available ***/1/***
[f] NAVSEA ltr ser 392T236/117 dtd 8 May 15
[g] 1/3 Cargo Stores
LOA = Length overall, feet
LWL = Length at waterline, feet
LBP = Length between perpendiculars, feet; also = L
D = Static draft of vessel, feet
M = Displacement of vessel, long tons
B = Beam at waterline, feet (Note: Not maximum beam)
A_y = Longitudinal projected area of ship, square feet
A_x = Transverse projected area of ship, square feet
h_h = Average height of hull above waterline, feet
h_s = Average height of superstructure, feet. Use the lightly loaded height of 180 feet (54.9 m) above the waterline. This includes combined superstructure and all communications / antenna array supported by the superstructure. Governing vessel is the LPD 17. Use the lightly loaded height of 215 feet (65.5 m). above the waterline for CVN's.

2-3.1.2 Supporting Items.

a. Provide fender/camel systems for the following arrangements:

- Multiple/nested berths for CG, DDG, LCS (surface combatants). Note that LCS 1 may be nested and LCS 2 may not be nested.
- Single berths for LHD, LHA, multiple berths for LPD, LSD (amphibious assault).
- Single berths for T-AKE, T-AO, T-AOE, (auxiliary).
- Single berths for CVNs. CR-NAVFAC-EXWC-CIOFP-1316, Oct. 2013, *USS Gerald R. Ford (CVN 78) Operational In-Port Analysis including Berthing, Mooring and Officers Brow Placement* has determined that extended CVN camels are required at double deck piers for both CVN 68 and CVN 78 class vessels.
- Multiple/nested berths for SSN, SSBN, SSGN.
- Multiple/nested berths for MCM, PC.

b. Aircraft require extensive support. Those requirements are not addressed herein.

c. A minimum of 5 acres (20,234 m^2) of laydown area in addition to pier/wharf space is desirable. The laydown area should be within 1/2 mile (0.8 km) of the pier or wharf.

d. Brows and Platforms are usually placed at ship's designated entry/egress points to the main deck. For CVN, two 45-foot (14 m) brows are usually placed on the ship's #2 elevator and one 60-foot (18 m) brow placed between elevators #2 and #3 to the main deck. Brow design length will be based on camel design and resulting standoff distance. CR-NAVFAC-EXWC-CIOFP-1316, Oct. 2013, *USS Gerald R. Ford (CVN 78) Operational In-Port Analysis including Berthing, Mooring and Officers Brow Placement* provides specific guidance concerning officer's brow placement for CVN 78 class vessel. To further define the unique brow requirements for CVN 78 a comprehensive 3D lift plan has been developed to model the lifting sequence for both installing and removing the brow. Similarly a 70- by 5-foot (21 by 1.5 m) counterweighted aluminum truss brow has been developed. For additional information, contact NAVFAC Atlantic - Engineering Criteria & Programs.

e. For criteria related to access to piers or wharves refer to: UFC 1-200-01, *DoD Building Code (General Building Requirements)*; *ABA Standards*; and Department of Defense Deputy Secretary of Defense Memorandum Subject: *Access for People with Disabilities*, October 31, 2008.

f. Sideport loading ramp access is of primary concern to LHA 1, LHD 1, and LPD 17. For double deck piers special ramps are required to access sideport loading ramp. Refer to *Amphibious Warfare Ship to Pier Interface Study* which provides details on the access problem as well as recommended special ramps.

g. Generally, design CVN berths to accommodate a variety of other classes of ships as well.

h. Design general warehouse space to be accessible to large trucks and handling equipment.

i. Do not permit pier interferences such as utilities and deck appurtenances in the zone of elevators for CVN (#1, #2, and #3), LHA, or LHD. At times these ships may have to move off of their normal berth bridge mark, i.e. move CVN offshore for ordnance load or move LHA/LHD toward bulkhead for stern gate ramp placement. Objective is to keep edge of pier free of obstructions.

j. Provide parking for ship's government and privately owned vehicles in proximity to entrance to the pier or wharf.

k. Provide sufficient security for ships on the pier. Consider minimally manned ships.

l. Provide safety equipment.

m. In the event that a building is required on a pier or wharf, give consideration to both wind and seismic loading in compliance with current, applicable codes and standards. Consider seismic mass of both structure and pier or wharf as well as interaction between structure and pier or wharf. For the building reference UFC 3-301-01, *Structural Engineering*. **/1/**

2-3.2 Pier and Wharf Length.

2-3.2.1 Single Berth.

The length of pier or wharf should equal the overall length of the largest ship to be accommodated, plus an allowance of 50 feet (15.2 m) at each end of the ship. For aircraft carriers (CVN), increase the allowance at each end of the vessel to 100 feet (30.5 m). Refer to Figure 2-3. Single berths are commonly used by LHA, LHD (amphibious assault ships), T-AKE, T-AO, T-AOE, (auxiliary), and CVNs. **\1** Other ships may berth in a single berth configuration or in multiple berth configuration with the same or a mixture of ship classes depending on pier/wharf and available berthing space. **/1/**

2-3.2.2 Multiple Berths.

The length of a pier or wharf should equal the total overall length of the largest ships simultaneously accommodated, plus clear distance allowances of 100 feet (30.5 m) between ships and 50 feet (15.2 m) beyond outermost moored ships. Refer to Figure 2-3. Multiple berths are commonly used by CG, DDG, LCS (surface combatants), SSN, SSBN, SSGN (submarines), MCM (mine warfare), and PC (patrol). **\1** See paragraph 2-3.2.4 for further requirements for submarines. **/1/**

2-3.2.3 Container and RO/RO Berths.

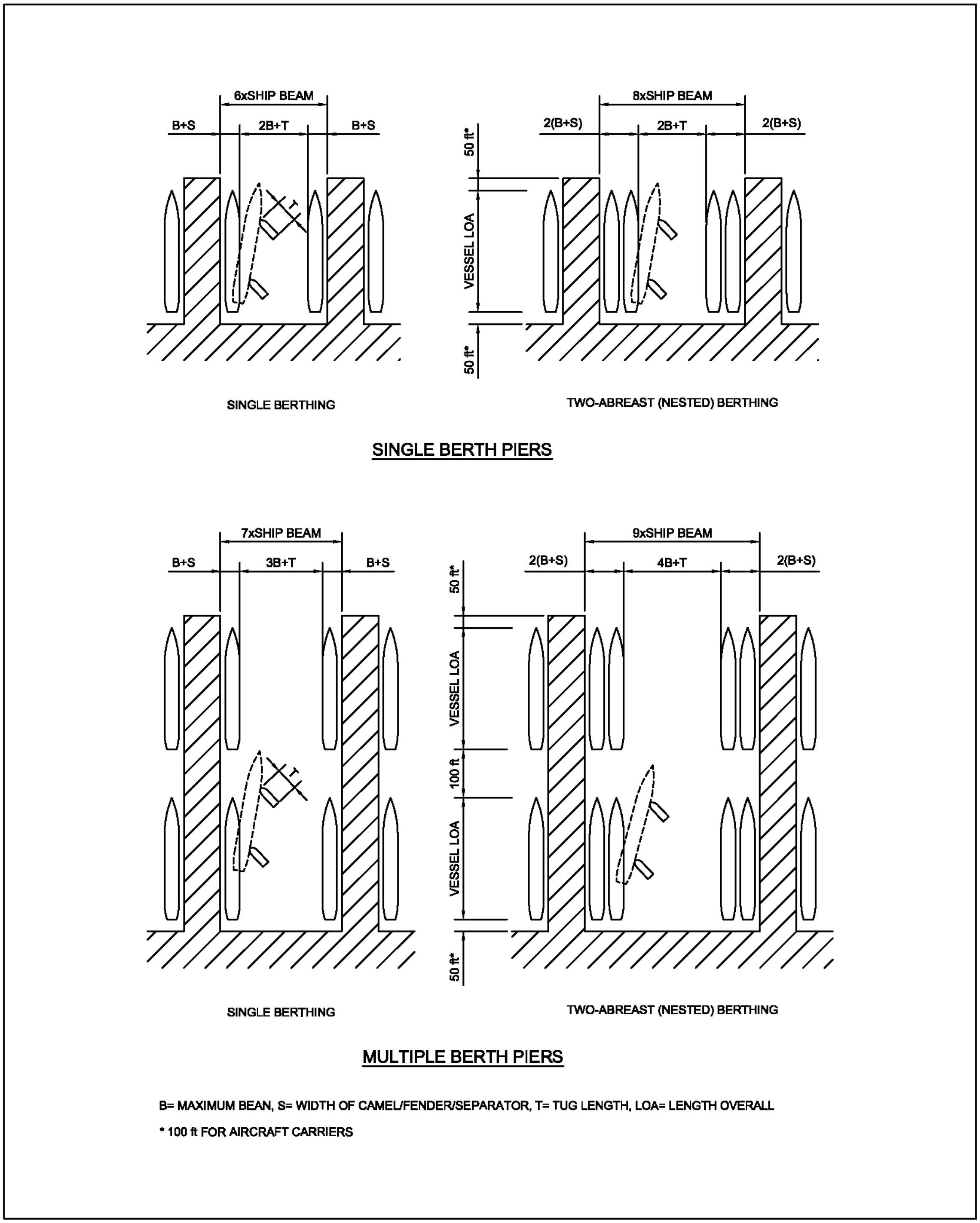
The length of berths used for container or RO/RO berths should account for the requirements of the container cranes or special ramps. Where shipboard ramps are used, provide adequate berth length to allow for efficient vehicle maneuvering.

2-3.2.4 Submarine Berths.

For most classes of submarines, a 50-foot (15.2 m) end distance to a quaywall or bulkhead is adequate. The nose-to-tail spacing for multiple berthing should also be a minimum of 50 feet (15.2 m). **\1** However, the nose-to-tail spacing and end distance at the stern of some submarines may require 100 feet (30.5 m) of clearance. Larger submarines such as the Ohio class (Trident, SSBN/SSGN) require 150 feet (45.7 m) or more nose-to-tail spacing and clearance to bulkhead or quay wall. **/1/** Where explosive safety distance considerations require the use of fragmentation barriers, or specific separation distances, provide spacing adjusted per the requirements of NAVSEA OP-5, *Ammunition And Explosives Safety Ashore*.

\1\

Figure 2-3 Length and Width of Slip



Note: Ship beam (B) is the extreme/maximum beam of the ship and not the beam at waterline.

/1/

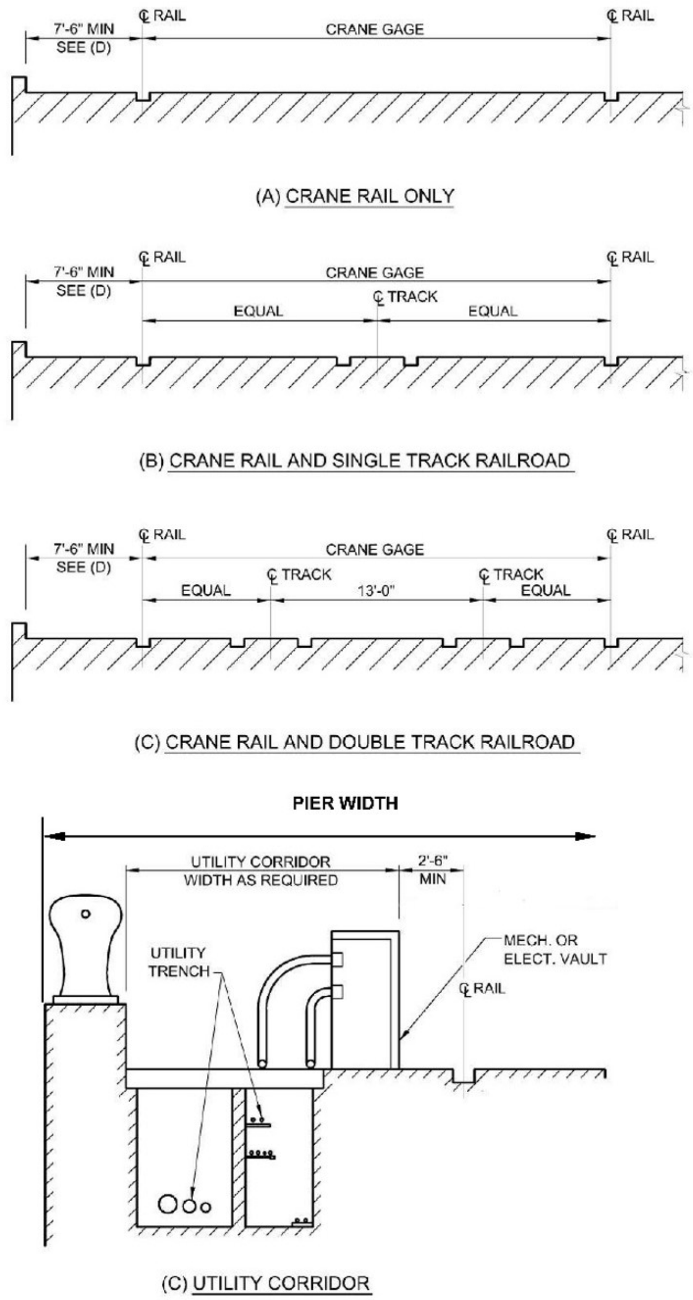
2-3.2.5 CVN Berths.

CVNs are typically moored “starboard-side-to” to allow access to the ship’s elevators for loading/unloading.

2-3.3 Pier and Wharf Width.

\1 Pier width as used in this UFC refers to the edge to edge width of the structure, exclusive of fender systems. Refer to Figure 2-4. This definition also holds for U-, L-, and T-type wharves. However, with reference to wharves, the width is the dimension to a building, roadway, or other identifiable obstruction. Refer to Table 2-3 for minimum widths established for each functional type and ship. The dimensions in Table 2-3 are minimums for any pier or wharf constructed on a DoD installation and apply to all DoD and non-DoD tenant Commands. The pier and wharf widths must be followed unless a specific Memorandum of Agreement (MAO) is established and pier or wharf is completely funded and maintained by occupying tenant and facility will never be turned over to the DoD. Review with specific functional and operational requirements and physical constraints of the individual installation in mind before a final selection on width is made. /1/ Functional requirements include space for: cargo loading operations, line handling, ship maintenance, maintenance of utilities and layout of cables and hoses, solid waste collection, brows and platforms, crane operation, and other operations. For crane operation, consider crane outriggers, tail swing of crane counterweights, and overhang of vessels. For CVNs, coordinate the tail swing of gantry cranes with the overhang of the flight deck and elevators considering available camels and potential list of the ship. Also, these dimensions should not be less than the widths determined by geotechnical and structural considerations. Factors to be considered in the determination of pier and wharf width are discussed below.

Figure 2-4 Location of Crane Rails, Railroad Tracks, and Utilities



LOCATION OF CRANE RAILS, RAILROAD TRACK AND UTILITIES

\1

Table 2-3 Minimum Pier and Wharf Widths

Function Classification/Type	Ship Type	Typical Pier Width (feet)		Typical Wharf Apron Width (feet)	Railroad Track (Standard Gage)	Rail Mounted Cranes
		Single Deck Pier	Double Deck Pier			
Ammunition	Ammunition	100	-	100	-	-
General Purpose Berthing	Auxiliary	115	93	65	-	-
	Surface Warfare	115	93	65	-	-
	CVN	150	93	90	-	-
	Submarine [a]	65	-	65	-	-
	Submarine [b]	85	-	65	-	-
Repair (Type III)	Surface Warfare	125	-	75	4 tracks; 2 each side	(2) 40-ft gage; 1 each side
	CVN	150	-	100	-	-
	Submarine	100	-	100	-	-
Type IIA	* must meet minimum requirements for a Type III	*	*	*	-	-
Fueling	Auxiliary	50	40/50 [c]		-	-
Supply (General)	Auxiliary	125	-	100	2 tracks	-
Supply (Container)	Auxiliary	125	-	100	Up to 3 tracks	(1) 100-ft gage

Note:

[a] Pier width is shown for a pier with only in-shore berths
[b] Pier width is shown for a pier with in-shore and off-shore berths (multiple berths along its length)
[c] Operational deck = 40 feet (12 m); utility deck = 50 feet (15 m)

/1/

2-3.3.1 Utilities.

One of the primary functions of a pier or wharf is to provide connections for utilities from ship to shore. Fixed utility terminals are usually provided close to the edge of the pier or wharf along the bullrail. Flexible hoses and cables are then connected to these terminals and to the ship. Depending upon the type of utility hoods, the terminals, hoses, and cables may require 10 to 15 feet (3 to 4.6 m) of space along the edge. Consider the types of utility hoods that require additional edge space for cable and hose laydown.

\1 For single deck piers, locating substations off of the pier deck is preferable. However, on some single deck piers, substations need to be mounted on the deck due to various constraints. This will take up approximately 25 feet (7.6 m) of pier width and may require a pier to be wider. If substations are mounted on the deck, locate them in areas that will minimize impacts on useable deck space and operations. Balance physical constraints with acceptable operational and local practices where necessary. **/1/** Double deck piers are used to clear the operations deck of obstructions or where the width of the berth area is constrained by adjacent facilities or other limitations. This configuration allows the utility enclosures and the associated hoses, cables and maintenance activities to be segregated from the operational areas and allow crane operations closer to the edge of the pier or wharf.

2-3.3.2 Berths on One Side.

For general purpose berthing of surface ships at wharves or piers with berths only on one side, the typical width is 65 feet (19.8 m) comprised of: 15 feet (4.6 m) bollards and utilities, 30 feet (9.1 m) mobile crane ops, and 20 feet (6.1 m) fire lane. For CVNs with berth on one side, the typical width is 90 feet (27.4 m) comprised of: 20 feet (6.1 m) bollards and utilities, 30 feet (9.1 m) mobile crane ops, 20 feet (6.1 m) fire lane, and 20 feet (6.1 m) for loading area.

2-3.3.3 Berths on Both Sides.

For general purpose berthing of surface ships at a single deck pier with berths on both sides, the typical width is 115 feet (35 m) comprised of: 30 feet (9.1 m) bollards and utilities, 65 feet (19.8 m) mobile crane ops/loading area, and 20 feet (6.1 m) fire lane. A typical single deck pier is shown in Figure 2-5. For a single deck pier with CVNs (or combination CVN/AOE) berthed on both sides, the typical width is 150 feet (45.7 m) comprised of: 40 feet (12.2 m) bollards and utilities, 65 feet (19.8 m) mobile crane operations, 25 feet (7.6 m) loading area, and 20 feet (6.1 m) fire lane. This 150 feet (45.7 m) recommended width is based largely upon operational experience of existing facilities.

2-3.3.4 Double Deck Pier with Berths on Both Sides.

\1 For double deck piers, typical width of top deck is 93 feet (28.3 m) comprised of: 8 feet bollards (2.4 m), 65 feet (19.8 m) mobile crane ops/loading area, and 20 feet (6.1 m) fire lane. A double deck pier provides: clear unobstructed pier to ship interface, isolation of operations deck services from lower deck utilities services (i.e. substation located on lower deck), reduced offset requirements for mobile crane operation (thereby reducing the requirement for floating cranes), higher main deck, improving mooring line angles and lessening need for brow platforms. A typical double deck pier is shown in Figure 2-6. **/1/**

2-3.3.5 Mobile Crane Operation.

With the exception of magnetic treatment/electromagnetic roll and fueling piers where a lighter duty mobile crane and/or forklift truck is sufficient, piers and wharves are subject to frequent usage by mobile cranes, forklifts, and straddle carriers. Typically, the cranes will be used to lift light loads (5 to 10 tons) (44 kN to 89 kN) but at a longer reach. This requires a high-capacity crane. If the crane operations are not allowable because of utility trenches and trenches with light-duty covers, such areas should be clearly marked with striping or separated by a raised curb to prevent accidental usage. Typically, mobile crane operators want to get as close as possible to the edge of the pier or wharf to reduce the reach. However, the edges of piers and wharves are also the best places for locating utility trenches and utility trenches. This conflict can be resolved by either designing all utility covers to the high concentrated load from the mobile crane or by allowing crane operations in discrete and dedicated spaces along the edges. Weight-handling equipment requires maneuvering and turnaround space on the deck for effective operation. If possible the deck space should be planned to allow mobile cranes to be backed up perpendicular to the bullrail. This permits the maximum load/reach combination. Make allowance for tail-swing of crane counter-weight. Refer to Navy Crane Center Instruction 11450.2, *Design of Navy Shore Weight Handling Equipment*. The Navy Crane Center may also be consulted for operating requirements.

Figure 2-5 Single Deck Pier

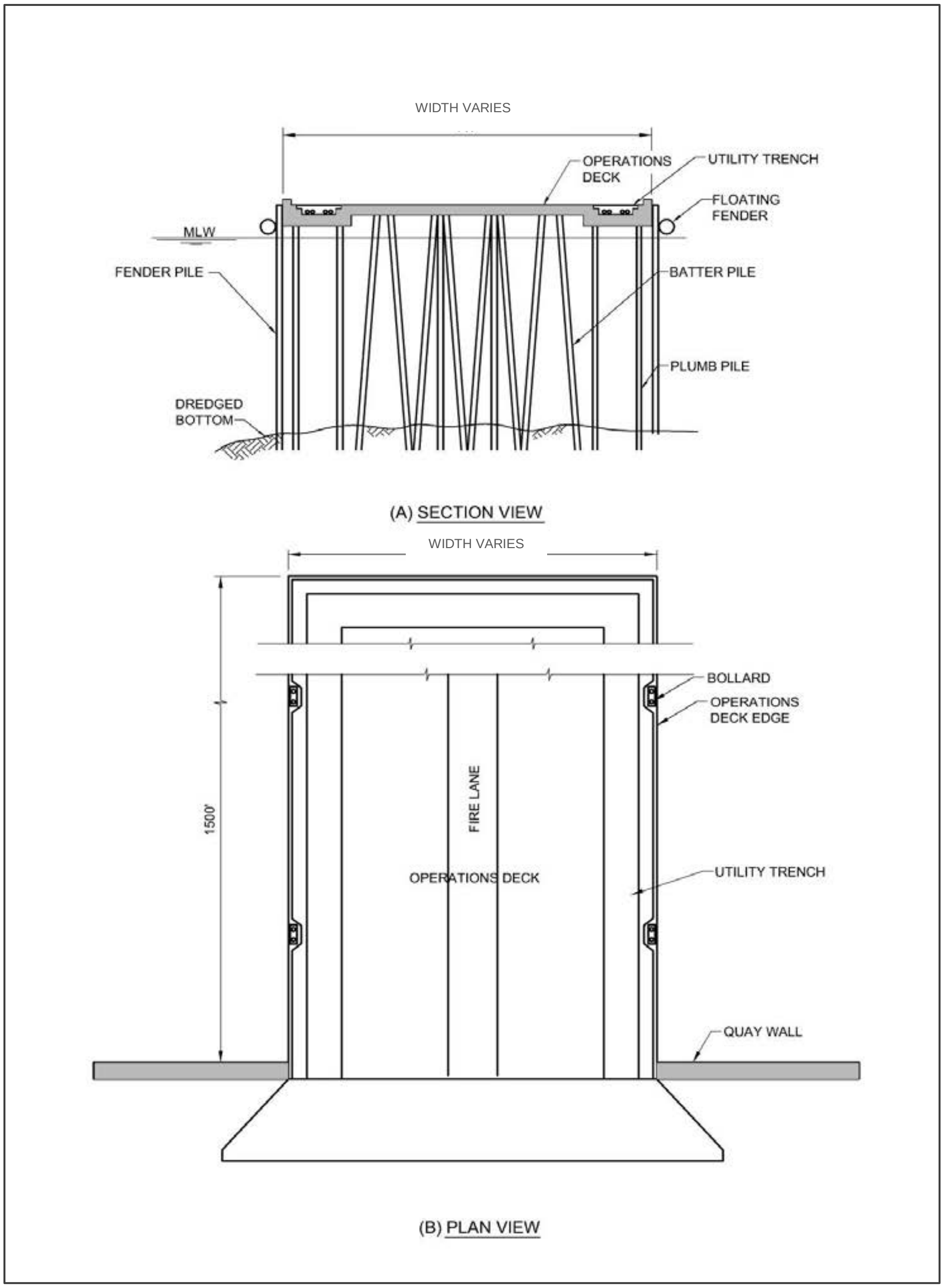
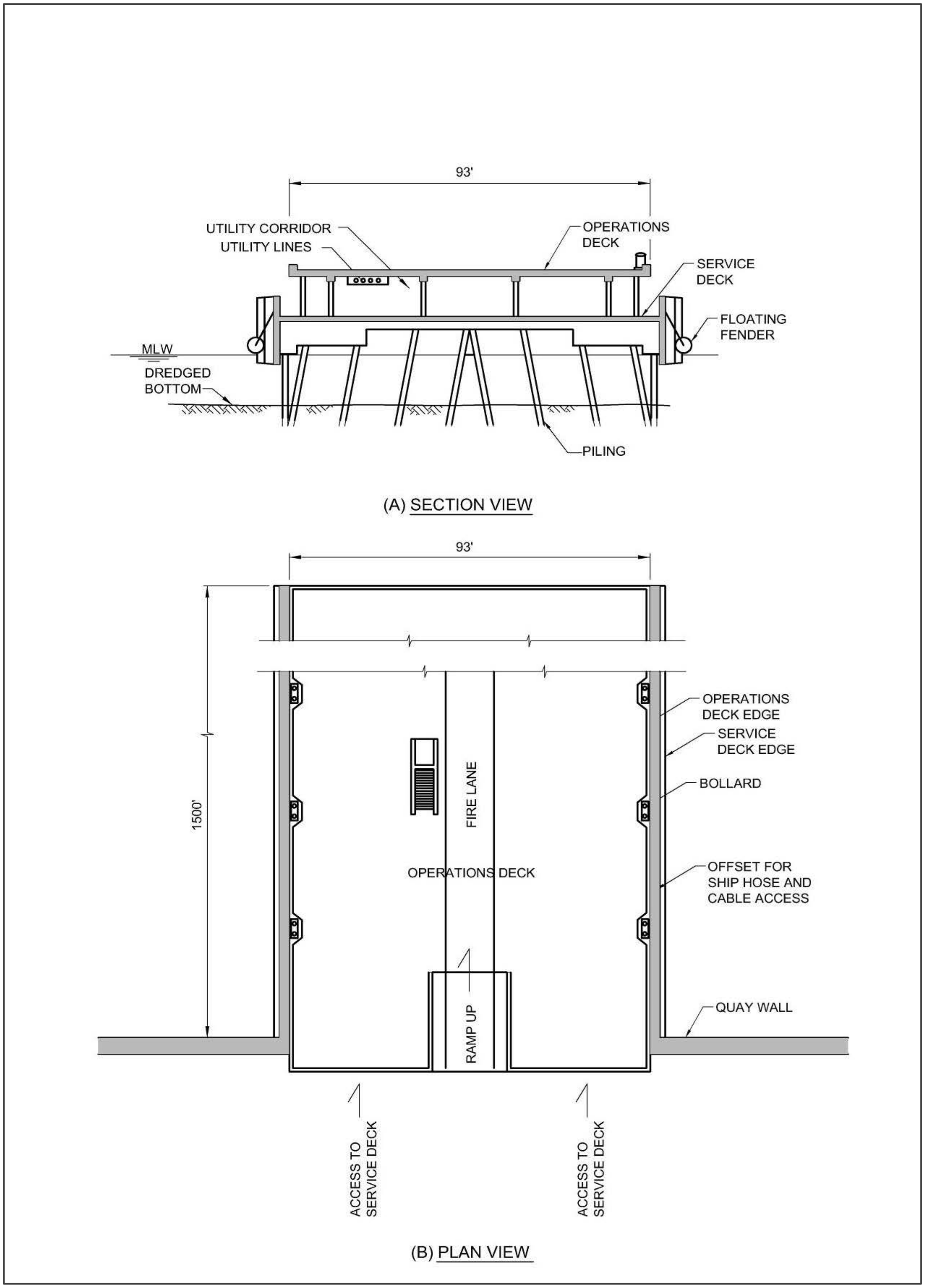


Figure 2-6 Double Deck Pier



2-3.3.6 Railroad and Crane Trackage.

The number of railroad and crane tracks required and type of weight-handling equipment furnished on piers and wharves are dependent on the type of function, ships to be accommodated, amount of cargo to be handled, and rate of cargo transfer. Specific service requirements of the individual installation should be evaluated in conjunction with the following considerations:

Rail mounted cranes are often needed for loadout in repair facilities. Width requirements depend on equipment selected. The use of wide gage crane service at repair, ammunition and supply piers, and wharves should be considered. Provide rail gage of 40 feet (12.2 m) (portal crane gage at PSNS and IMF Bremerton Site is 20 feet (6.1 m)) for new cranes, except at container terminals or where it is necessary to conform to gages of existing tracks. When cranes are furnished, the distance from the waterside crane rail to the edge of the pier or wharf should be adequate to provide clearance for bollards, cleats, capstans, pits housing outlets for ship services, crane power conductors, and other equipment. Some electric powered gantry cranes may require either open or covered (panzer-belts) cable trenches in the pier or wharf deck for the power conductors. Where locomotive cranes are used on piers and wharves, the distances between tracks and curbs should be increased to accommodate the tail swings of the crane. For discussion of crane power conductors, see Navy Crane Center Instruction 11450.2, *Design of Navy Shore Weight Handling Equipment*. For trackage requirements, UFC 4-860-03, *Railroad Track Maintenance and Safety Standards*.

In general, do not consider railroad trackage for use on berthing piers and wharves (active or inactive). In cases where stations receive most of their cargo by rail, consider one or more tracks for use on active berthing piers. When there are existing railroad networks at the station, tracks should be considered for installation on repair, ammunition and supply piers and wharves. When trackage is required along aprons of piers and wharves, at least two tracks should be provided so that one track may be used as a running track when the other track is occupied. Track gage should conform to gage of existing trackage on adjacent piers and wharves to avoid creation of "captive" cranes. Except where local conditions require otherwise, standard gage should be used for trackage. Width of piers and wharves should be adequate to allow passing of trains and forklift trucks (or other material-handling equipment). Make allowances for stored cargo and other obstructions.

Where sponsons or flight decks of CVNs or other ship types with large deck overhangs are anticipated to be berthed, locate the crane rail so that all parts of the crane will clear the deck overhang.

Railroad and crane trackage should not be considered for use on piers and wharves used primarily for fueling (petroleum) operations. When railroad and crane trackage is required on piers and wharves, the spacings shown on Figure 2-4 may be used as a guide.

2-3.3.7 Trucks and Other Vehicles.

A variety of service trucks and vehicles can be expected to use piers and wharves for moving personnel, cargo, containers, and supplies to and from the ships. Provide adequate width allowing for operation and maneuvering of such vehicles. Turnaround areas should be provided.

2-3.3.8 Sheds and Buildings.

Storage sheds and buildings of any kind should be kept off piers and wharves unless their location can be justified by operational or security considerations. Transit sheds may be considered on piers and wharves where a suitable upland area is not available. When used on a pier, the transit shed should be located along the centerline with clear aprons on both sides consistent with the requirements set forth herein but not less than 20 feet (6.1 m) or more wide. On wharves, transit sheds and support buildings should be located on the land side edge with a clear apron toward the waterside. In general, support buildings on piers and wharves should be kept as small as feasible and located away from high-activity areas for least interference.

2-3.3.9 Movable Containers and Trailers.

During active berthing of ships, various containers of different sizes are temporarily or permanently located on pier deck to support the operations. These include shipyard toolboxes, garbage dumpsters, training trailers, and supply trucks. Adequate deck space should be available for locating and accessing these containers and trailers.

2-3.3.10 Fire Lane.

Retain and mark, with a painted yellow line, a 15-foot-wide (4.6 m) unobstructed fire lane. Provide a marked (with dashed, painted yellow lines) 2.5-foot wide (0.8 m) "dual use" buffer on both sides of the 15-foot-wide (4.6 m) unobstructed fire lane. Examples are shown in Figure 2-X. Local enforcement would keep this area clear enabling a total available fire lane width of 20 feet (6.1 m). However, encroachment into the "dual use" buffer by cranes is acceptable. Any other encroachment into the "dual use" buffer will be handled on a case-by-case basis. For wharves, provide a 20-foot-wide (6.1 m) unobstructed fire lane immediately adjacent to the operating area. These requirements need not be applied to small craft or yard craft piers.

\1 Retain and mark temporary traffic lanes including vehicular and pedestrian movements that may encroach upon the unobstructed fire lane. Parking, storage, and staging is not allowed within a fire lane. Mark fire lane with:

FIRE LANE **DO NOT BLOCK**

This includes bright yellow letters 12 inches (0.3 m) tall and 4 inch (102 mm) font spaced at 50 ft intervals.

On existing piers and wharves, mark fire lanes as close as possible to these requirements. It is understood that existing structures cannot meet these requirements due to construction and layout.

In some cases a crane may need to encroach or set up within a fire lane. In such cases, local crane operations must notify the local fire department and develop a safety plan include setting up a marked temporary fire lane.

> [C] The following background is necessary to understand the reasoning for the current fire lane width specified for piers. Previous criteria called for a 12 ft (3.7 m) fire lane which was later increased to 15 ft (4.6 m), allowing for one-way traffic and some adjacent working area.
>
> Later, an NFPA requirement calling for 20 ft (6.1 m) fire lanes was identified. Though it does not specifically apply to DoD piers, it was decided that it was a best practice and would be incorporated as a requirement with some stipulations. The current philosophy is supported by the fact that there are a number of considerations that go into development of pier width and pier area. Provide width and area for the following functions in addition to fire protection: berthing, maintenance, crew training, cargo transfer, light repair work, waste handling, fueling/ordnance handling (under some circumstances) and utilities that provide hotel services. Increasing pier width, by another 5 feet (1.5 m), over the length of the pier would cause a significant increase in construction cost and require additional real estate where multiple piers are arranged. Recognizing the fact that area is allotted for crane location along the length of the pier, this area will not be occupied a majority of the time, therefore, it is anticipated that additional area besides the 15 ft (4.6 m) fire lane and 2.5 ft (0.8 m) wide "dual use" buffer will be available along the pier for additional staging in the event of an emergency.

/1/

2-3.3.11 Fuel-Handling Equipment.

At specified berths, stationary fuel-handling equipment consisting of self-adjusting loading arms is often furnished to offload fuel products from tankers to onshore storage facilities. Pier or wharf width requirements depend on equipment selected and facilities furnished.

2-3.3.12 Phased Maintenance Activities (PMA).

The four levels of PMA and their estimated space requirements are as follows and as detailed in Table 2-4. For additional information, see NCEL TM-5, *Advanced Pier Concepts, Users Data Package* and OPNAVINST 4700.7L, *Maintenance Policy for U.S. Navy Ships*.

a. Intermediate Maintenance Availability (IMA). IMA consists of removal and repair of shipboard equipment performed by Regional Maintenance Center (RMC) personnel or tender forces, with a duration of approximately 30 days.

Gross deck requirements range from 2000 to 3000 square feet (185.5 to 287.8 m^2) with work area dimensions varying from 30 by 65 feet (9.1 by 19.8 m) to 30 by 100 feet (9.1 by 30.5 m).

b. Planned Restricted Availability (PRA). PRA consists of limited repairs of shipboard equipment and systems by contract forces under Supervisor of Shipbuilding and Repairs (SUPSHIP) control, with a duration of 30 to 60 days. Gross deck area requirements are about 10,800 square feet (1003.4 m^2) or 35 by 310 feet (10.7 by 94.5 m).

c. Selected Restricted Availability (SRA). SRA consists of expanded repairs and/or minor ship alterations to shipboard equipment and systems by SUPSHIP contract forces, with a duration of approximately 60 days. Gross deck area requirements are about 18,000 square feet (1672.3 m^2) or 35 by 515 feet (10.7 by 157 m).

d. Regular Overhaul (ROH). ROH consists of major repairs and ship alterations to shipboard equipment and systems by SUPSHIP contract forces, with a duration of six to eight months. Gross deck area requirements are about 24,000 square feet (2229.7 m^2) or 35 by 690 feet (10.7 by 210.3 m). In addition, there would be a requirement for turnaround areas on deck and warehousing off the pier or wharf.

Table 2-4 Estimated Space Requirements for PMA

Activity	PRA (ft^2)	SRA (ft^2)	ROH (ft^2)
Command Area [a]			
Mobile Administration Building	-	2,800	5,600
Parking Area	250	250	500
Bicycle Racks	70	140	200
Subtotal	320	3,120	6,300
Operating Area			
Demineralizer	-	1,500	1,500
Bilge Water/Stripping Tank	-	400	400
Dumpsters	1,150	1,440	1,730
Portable Solid-State Generators	-	240	240
Air Compressors	290	290	290
Welding	1,500	1,500	1,500
Flammable Storage	150	600	600
Transportation Laydown	600	900	1,500
Crane Work	3,850	3,850	5,250
Offload Area (oils, fuels, etc.)	3,000	3,600	4,500
Potable Heads	-	70	70
Additional Brow	-	400	400
Subtotal	10,540	14,790	17,980
Total	**10,860**	**17,980**	**24,280**

[a] For piers with ordnance handling berths, do not provide command area

2-3.4 Slip.

2-3.4.1 General Considerations.

The clear distance between piers, or slip width, should be adequate to permit the safe docking and undocking of the maximum size ships that are to be accommodated in the slip. The size of a slip should also permit the safe maneuvering and working of tugboats, barges, lighters, and floating cranes. At multiple berth piers, where ships are docked either one per berth, two abreast per berth, or more, sufficient clearance should be available to permit the docking and undocking of ships at the inboard berth without interfering with ships at the outboard berth. Because the size of a slip is affected by docking and undocking maneuvers, consideration should be given to the advice of local pilots who are familiar with the ships to be handled and with prevailing environmental conditions such as winds, waves, swells, and currents. Slip width is also influenced by

the size and location of camels/separators used between ship and structure and between ships. The width should be reviewed with specific functional requirements of the individual installation before a final determination is made.

2-3.4.2 Minimum Slip Length.

Slip length basically follows the same criteria provided previously under section 2-3.2.

2-3.4.3 Minimum Width of Slip for Active Berthing.

2-3.4.3.1 Minimum Slip Width.

Minimum slip width should be the greater of the two dimensions shown on Figure 2-3. Additionally, the width should not be less than 300 feet (91.4 m). Slip widths discussed in this section are applicable only if ships are turned outside the slip area. Refer to Tables 2-1 and 2-2 for the beam of typical ship types (Note: Beam (B) shown tables is the beam at waterline and not the extreme beam. Use the widest beam (extreme/maximum beam) to determine horizontal clearances and slip width both for single berth and nested configurations.

Location of homeport berthing facilities should allow nesting of DDG, CG, SSN, LCS 1, MCM, and PC class ships. Minimum slip width for surface combatant in a multiple berth, nested configuration is 600 feet (183 m). Minimum slip width for single amphibious warfare and combat logistic ship berths is 600 feet (183 m). Other typical berthing arrangements can be found in paragraph 2-3.1.2.

2-3.4.3.2 CVN Slips.

For CVN’s, minimum width is 600 feet (183 m) with no other ships, 800 feet (244 m) with CVN on opposite berth. Add 100 feet (30.5 m) to width if other ships are berthed at the bow or stern of the CVN. Use the widest beam to determine horizontal clearances and slip width both for single berth and nested configurations. Note that the waterline beam for CVN 68-77 is 134 feet (40.8 m) and the width of the flight deck structure (with antenna platforms, walkways, and portable flight deck sections removed) is 252 feet (76.8 m). Without removing these appurtenances, CVN 68 is 260 feet (79.2 m), CVN 76 is 280 feet (85.3 m), and CVN 78 is 256 feet (78 m) wide.

2-3.4.3.3 Submarines Slips.

At submarine slips, width requirements must consider fender system, camels, and separators, barges, and other items that will encroach (takeup, occupy, etc.) slip width or width should be increased two beam widths [need Port Ops and SUBFOR input to reduce four beam requirement to 2B or delete; appears to be a holdover from DM 25.1 when just XxB was used and before B+S was added] to account for camels and separators, to provide for ships' vulnerability if their safety is involved, to provide for special maneuvering requirements of other ships during berthing or passing, and to provide for special environmental conditions such as currents, waves, and winds. Use extreme beam of submarine including the width of the planes and any added appurtenances when determining slip width. Beam widths can very between vessels in the same class, so verify beam width of ships to be berthed and use the widest.

2-3.4.3.4 Slip Width for Nested Ships.

When more than two abreast berthing (nesting) is employed, the width of slip should be increased by one ship beam for each additional ship added in order to maintain adequate clearances between moored ships during berthing and unberthing maneuvers. Thus, for three-abreast berthing on both sides of a slip, the slip width for single-berth piers would be equal to 10 times ship beam and the slip width for multiple-berth piers would be equal to 11 times ship beam. Slip width may also be increased by accounting for appropriate ship beam plus separator (B + S).

2-3.4.3.5 Berthing on One Side of Slip.

The requirements discussed above apply where ships are berthed on both sides of a slip. Where ships are berthed on only one side of a slip, the width may be reduced by one ship beam plus separator (B + S). See Figure 2-3.

2-3.4.4 Minimum Width of Slip for Inactive Berthing.

At slips containing inactive berths where ships are stored for long periods of time on inactive status in nests of two, three, or more, clear distances between moored ships and slip width may be reduced by one or two ship beams to reflect the reduction in the frequency of berthing maneuvers and the decrease in activities of small boats and floating equipment.

2-3.4.5 Water Depth in Slips.

Information on required water depth in slips and at berths is contained in UFC 4-150-06, *Military Harbors and Coastal Facilities*.

2-3.5 Pier and Wharf Deck Elevation.

Set deck elevation as high as possible for surface ship berthing and as low as possible for submarine berthing, based on the following considerations. When determining proper deck elevation, give due consideration to different vessels that will occupy berths. Interferences often occur with appurtenances that rise above actual deck elevation, e.g. cleats, bollards, utilities, igloos, turtlebacks, etc.

2-3.5.1 Overtopping.

To avoid overflow, deck elevations should be set at a distance above mean higher high water (MHHW) level equal to two thirds of the maximum wave height, if any, plus a freeboard of at least 3 feet (1 m). Bottom elevation of deck slab should be kept at least 1-foot (0.3 m) above extreme high water (EHW) level. Where deck elevation selected would result in pile caps or beams being submerged partially or fully, consideration should be given to protecting the reinforcing from corroding. Also, when establishing deck elevation, consider utility trenches as they must be kept dry in all circumstances. In establishing the deck elevation, consideration may be given to the combined effects of sea level change, extreme water levels, and wave effects. Also, the intended service life of the structure should be taken into consideration as it relates to sea level rise and setting deck elevation. In locations where portal crane trackage is required, consider tie in with landside and limitations on grade change between pier/wharf and landside.

2-3.5.2 Ship Freeboard.

Consider the varying conditions of ship freeboard in relation to the use of brows and the operation of loading equipment such as conveyors, cranes, loading arms, and other material handling-equipment. Consider maintaining appropriate mooring line angles. Fully loaded ships at mean lower low water (MLLW) level and lightly loaded ships at MHHW level should be considered for evaluating the operation of such equipment.

2-3.5.3 Utilities.

Deck elevations should be set high enough above MHHW levels to allow for adequate gradients in drainage piping as well as to prevent flooding of utilities/trenches that are located below the pier deck.

2-3.5.4 Deck Elevation for CVN Berths.

Ensure that deck elevation does not conflict with CVN elevators. When lowered, the lowest projection of the elevator is 9 feet (2.7 m) above the design water line for a CVN. Use properly designed camels and pier fendering to provide sufficient standoff to prevent interference with appurtenances located on edge of pier deck such as mooring fittings, utility connections, igloos, etc.

2-3.5.5 Adjacent Land.

If possible, set deck elevation as close as possible to grade of the adjacent land for smooth access of mobile cranes, service vehicles, personnel vehicles, and railroad. Ramps may be used to access the deck set higher or lower than adjacent land. A maximum gradient of 15 percent may be used for such ramps when railroad access is not provided. Consideration should be made to reduce grade to 6 to 8 percent, comparable to state DOT requirements, in cold regions where snow or ice can be a problem. Ramps for pedestrian access should have a gradient less than 12 horizontal to 1 vertical, with 5 feet (1.5 m) minimum landings for every 30 inches (0.76 m) of rise to conform to American with Disabilities Act (ADA) of 1990. Vertical curves should be large enough so that long wheelbase or long overhang vehicles do not or drag. Where track mounted cranes are specified, all the deck areas serviced by the crane should be kept at the same elevation.

2-4 UTILITIES.

2-4.1 General.

For design criteria of utilities on piers and wharves, refer to UFC 4-150-02, *Dockside Utilities for Ship Service*. Usually, utility connection points (hoods, vaults, or mounds) are located and spaced along the pier or wharf edge to be as close as possible to the ships' utility terminals in the assumed berthing position. The connection points should be planned and located to accommodate reasonable future changes in berthing plan or in the type of ships served. Typical hotel services are: potable water, non-potable/saltwater, collection, holding, and transfer (CHT), oily waste/waste oil (OWWO), compressed air, steam, telecommunications, and shore power. All utility lines should be kept where they can be conveniently accessed from above deck. Typical utility configurations on piers and wharves are described below.

2-4.1.1 Utility Trenches.

These are basically protected trenches running along the waterside edge of a pier or wharf accessed by removable covers from the top. Refer to Figure 2-5. On a pier, the lines can go along one edge all the way to the end and be "looped" to the other edge back to land. On a wharf, the lines can be supplied and returned through smaller lateral "trenches." Where the number and size of lines is large enough, a utility tunnel or gallery can be utilized with access from the top or side. Where a fuel line is provided, it should be kept in a separate trench for containment of leaks.

2-4.1.2 Double Deck Pier.

As shown in Figure 2-6, utility lines are isolated on the lower deck and can be easily accessed. The upper deck is thus clear of all utility lines and terminations and is free for operations. There are situations on double deck piers (due to physical space and structural limitations) where some utilities are hung from underneath the lower deck (i.e. OWWO, CHT, and electrical).

2-4.1.3 Ballasted Deck.

This concept consists of a sloping deck filled with 1.5 to 3 feet (0.8 to 0.9 m) of crushed rock ballast, which provides a convenient medium to bury the utility lines and crane or rail trackage. The ballast is topped with concrete or asphalt paving, which will provide a firm working surface for operations. The paving and ballast can be removed to access the utility lines. Concrete pavers have been used successfully for paving ballasted decks and provide improved access to utilities buried in the wharf ballast. Future changes in utilities and trackage can similarly be accommodated. Also, the ballast helps to distribute concentrated load to the deck slab, thus allowing heavier crane outrigger loads. Ballast on the deck not only helps to distribute concentrated load to the deck slab, but also reduces or eliminates impact.

2-4.1.4 Precast Utility.

Precast tabletop slab sections discussed in section: Tabletop Pile Caps can be used for the utility trenches. This concept consists of a reinforced concrete or prestressed concrete platform that is integrated into the deck diaphragm. It is a durable structural element that is ideal for designs that orient pile cap beams in the longitudinal direction by creating a path for utility lines that do not interfere with key structural components along the length of the pier. Cantilevered ends and supplemental prestress should be used so that the concrete faces exposed to seawater remain uncracked under handling loads during erection and under service loads. Tie beams may be required to transfer berthing and mooring loads to the table top sections. A key element to the performance of the precast tabletop sections for utilidors is to ensure that they are watertight. Further details for tabletop slab sections can be found in TR-NAVFAC-EXWC-CI-1413, *The Use of Prestressed Concrete for Corrosion Prevention in US Navy Piers.*

2-5 LIGHTING.

Pier lighting is needed for security, safety, and operations. Provide safety and operations pier lighting in accordance with UFC 3-530-01, *Interior and Exterior Lighting Systems and Controls* and as follows:

2-5.1 Topside Lighting.

Refer to UFC 3-530-01, *Interior and Exterior Lighting Systems and Controls*. Instances of failures of high mast lighting light ring assembly failures have been reported. Additional information is contained in Appendix C. It is imperative that a registered structural engineer review all contract documents (plans and specifications) and construction contract submittals specifically related to high mast light ring assemblies. This is to ensure that design of light ring assembly provides for safe lowering, raising, and locking/securing into position.

2-5.2 Lower Deck Lighting.

Refer to UFC 3-530-01, *Interior and Exterior Lighting Systems and Controls*.

2-5.3 Underdeck Lighting.

Refer to UFC 3-530-01, *Interior and Exterior Lighting Systems and Controls*.

2-6 SECURITY.

For waterfront security and anti-terrorism/force protection criteria, refer to UFC 4-025-01, *Security Engineering: Waterfront Security*.

2-7 LANDSIDE APPROACHES.

2-7.1 Function.

Approaches are required to provide access from shore to piers and wharves located offshore. Usually, the approach is oriented at right angles to the shoreline. Except in special situations, provide approaches consisting of open-type trestle structures that minimize impediments to water flow and disturbances to the characteristics and ecology of the shoreline. Consider the volume of traffic flow, circulation of traffic, existing roads on shore side, fire lane requirements, and interruption of service due to accidental collision damage when planning and designing the landside approach. As approaches are also used to route utilities to the pier or wharf, the width of approaches will be further influenced by the space requirements of the utility lines being carried. Vehicle and pedestrian approach can usually be combined on the same structure. Consider a separate pedestrian approach when a large number of personnel are anticipated to access the facility.

2-7.2 Roadway Width.

a. Provide an approach roadway with a minimum width of 10 feet (3.1 m) curb to curb for one-lane vehicular traffic for infrequently accessed facilities (such as magnetic treatment / electromagnetic roll piers).

b. Provide an approach with a minimum width of 15 feet (4.6 m) curb-to-curb for clear access of emergency vehicles for fueling piers and wharves.

c. For all other functional types, provide a two-way 24-foot wide (7.3 m) curb-to-curb roadway. If two separate one-way approaches are provided, provide a minimum width of 12 feet (3.7 m) curb-to-curb. Notwithstanding, provide approaches with a width adequate to permit fast movement of all vehicles anticipated for use on the facility, including emergency vehicles and mobile cranes.

2-7.3 Walkway Width.

Provide a minimum clear width of 3 feet (1 m) for separate walkway structures. Where the walkway is attached to a vehicle traffic lane, provide a minimum width of 2.5 feet (0.8 m) clear, from curb to safety railing.

2-7.4 Roadway Deck Elevation.

The requirements for pier and wharf deck elevation are also applicable to the approaches. Where the adjacent land is higher or lower than pier or wharf, the approach can be sloped up or down to serve as a transition ramp. For approaches longer than 100 feet (30.5 m) limit the slope to 6 percent. For shorter approaches, limit the slope to 8 percent.

2-7.5 Number of Approaches.

2-7.5.1 One Approach.

For fueling and magnetic treatment/electromagnetic roll facilities, provide at least one single-lane approach structure, unless the facility is built as an island wharf or pier with access by watercraft.

2-7.5.2 Two Approaches.

a. Where volumes of vehicular movements are large, provide at least two approaches to ensure continuous uninterrupted traffic flows from pier or wharf to shore. At multiple-berth facilities, consider approach structures at least every 500 feet (152 m).

b. Where the width of the pier or wharf is not sufficient to permit turning of vehicles, provide two approaches. Thus, vehicular traffic may enter and leave the facility without having to turn around. Since it is easier for a truck to negotiate a left turn, design traffic patterns to favor left turns.

2-7.5.3 Railroad Access.

Where rail access is planned for either crane or railroad, a separate approach is not necessary. However, consider a separate walkway. Consider approach slope limit for crane or railroad.

2-7.6 Turning Room.

At the intersection of approach and piers and wharves, provide fillets or additional deck area at corners to allow for ease in executing turns. Where a one-lane approach roadway is provided as the only access, provide the pier or wharf with sufficient turnaround space on the facility so that outgoing vehicles do not have to back out along the approach.

2-7.7 Barriers.

On all approaches, provide safety barriers adequate for the type of traffic using the facility (pedestrian, vehicular, and/or rail). However, safety barriers should not be provided in areas where mission operations, such as ship or small craft berthing, are performed. Rail only approaches do not normally require safety barriers. Provide traffic barriers between pedestrian and traffic lanes. Conformance with AASHTO *Guide Specifications for Bridge Railings* and AASHTO *Bridge Guide and Manual Interim Specifications* is required for traffic and pedestrian barrier design.

2-8 STRUCTURAL TYPES.

2-8.1 General.

The three major structural types for piers and wharves are open, solid, and floating. Open type piers and wharves are pile supported platform structures that allow water to flow underneath. Figure 2-7 illustrates the open type. Another type of an open type pier is a jack-up barge. Solid type uses a retaining structure such as anchored sheet pile walls or quaywalls, behind which a fill is placed to form the working surface. Solid type will prevent stream flow underneath. Figure 2-7 illustrates the solid structural type. Floating type is a pontoon structure that is anchored to the seabed through spud piles or mooring lines and connected to the shore by bridges or ramps. A floating double deck pier is shown in Figure 2-8. For additional information, contact NAVFAC Atlantic - Engineering Criteria & Programs.

Figure 2-7 Open and Solid Type Piers/Wharves

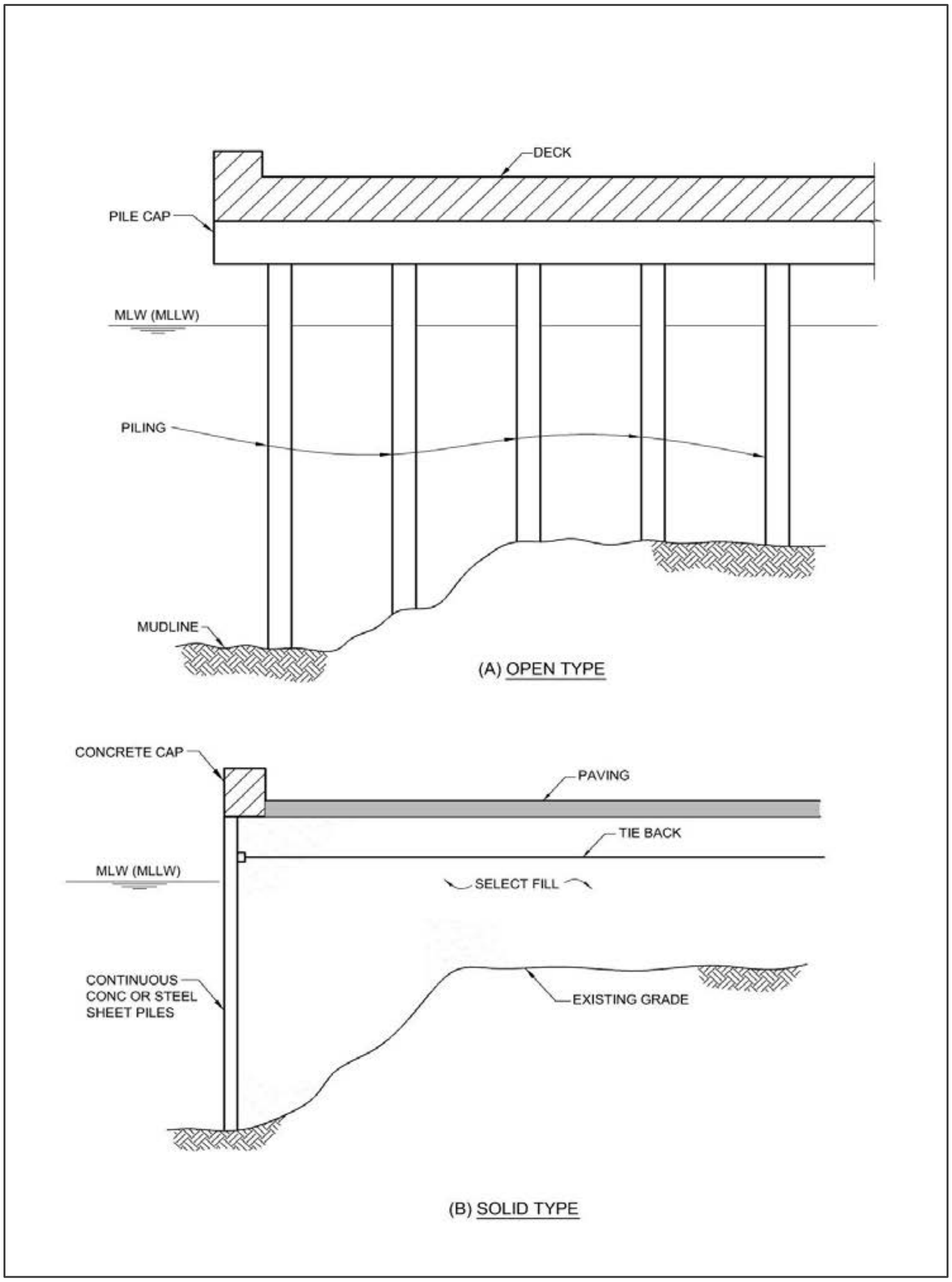
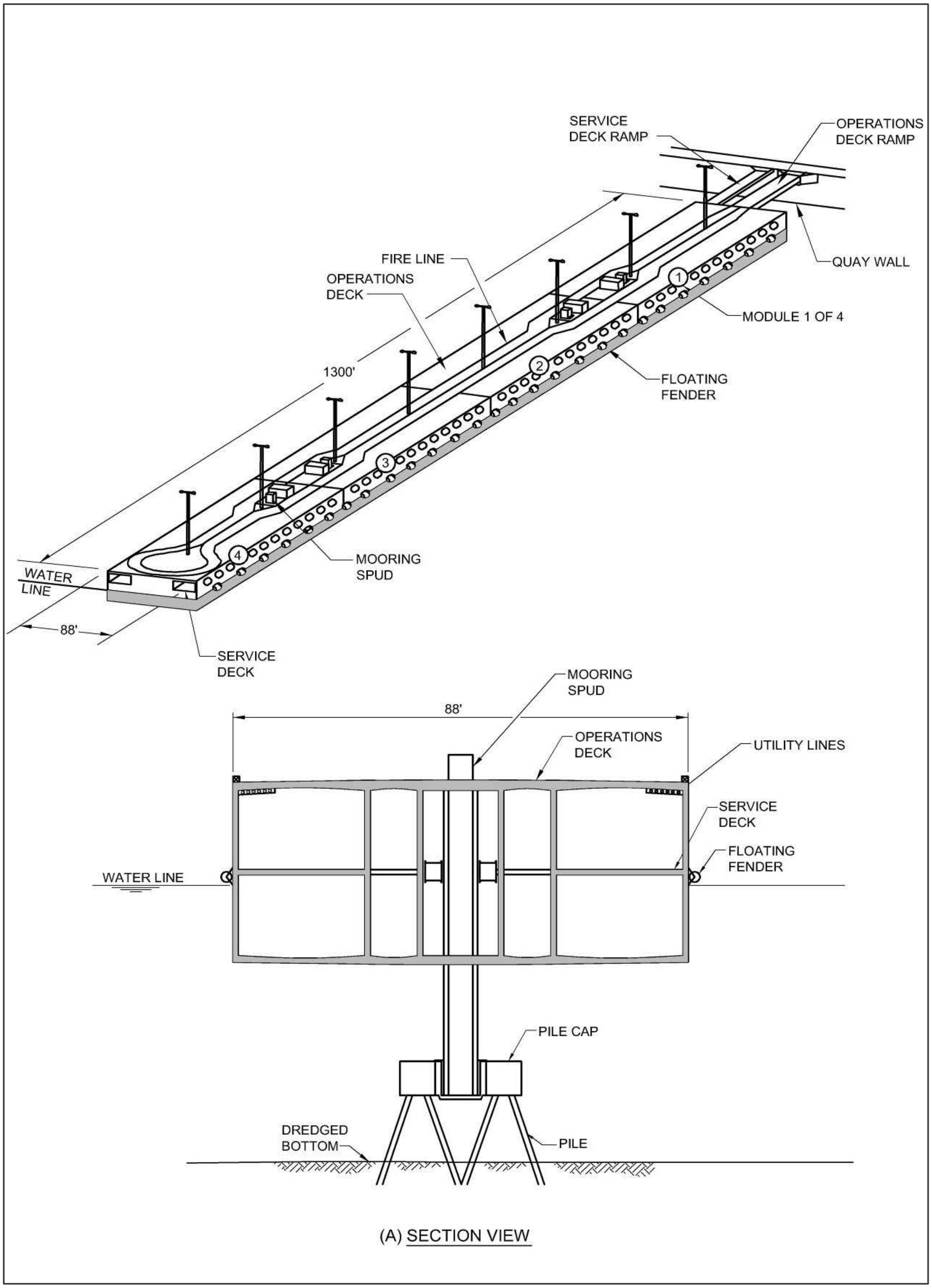


Figure 2-8 Floating Double Deck Pier



2-8.2 Selection of Type.

Numerous factors influence the selection of one structural type over the other. Evaluate each of these factors against the construction and operating costs of the facility before a final decision is made on the structural type. Place greater emphasis on selecting the type that will withstand: unexpected berthing/mooring forces, adverse meteorological and hydrological conditions, and the corrosive effects of a harsh marine environment such that it will require little or no maintenance. The geotechnical characteristics of a given site, and economic analysis of alternate structural types will often dictate structural requirements. For instance, in areas with poor near surface soils but with good end bearing for piles, an open pile supported structure with a shallow bulkhead (or no bulkhead) will be most economical. Conversely, in areas with good near surface soils and poor pile bearing, a solid bulkhead may be more economical. Consider environmental impacts when selecting type.

2-8.2.1 Shoreline Preservation.

The structural type is seriously influenced by aquatic and plant life existing along the shore of the planned facility. In environmentally sensitive areas such as river estuaries, the solid-type wharf, which would disturb or destroy a considerable length of shoreline, should not be considered. Select the open structural type, which would have the least impact on the shoreline.

2-8.2.2 Bulkhead Line.

When the facility extends beyond an established bulkhead line (the limit beyond which continuous solid-type construction is not permitted) use open type construction.

2-8.2.3 Tidal or Stream Prisms.

Where it is required to minimize restrictions of a tidal or stream prism (the total amount of water flowing into a harbor or stream and out again during a tidal cycle) use open type construction.

2-8.2.4 Littoral Drift.

Along shores where littoral currents transporting sand, gravel, and silt are present, use open type construction to mitigate shoreline erosion and accretion.

2-8.2.5 Ice.

In general, open type structures are vulnerable and should be carefully investigated at sites where heavy accumulations of sheet or drift ice occur. Also, when ice thaws, large blocks of ice may slide down the piling, impacting adjacent batter or plumb piles. Thus, the solid type may be preferable at such sites. To mitigate the effects of large blocks of ice sliding up and down the plumb and battered piles within the tide fluctuation zone, consider protecting piles from abrasion utilizing pile jackets within the tide fluctuation zone + 2 feet (0.6 m) beyond the tidal fluctuation. Consider bulkhead protection from the ice abrasion utilizing cementitious epoxy coating for the exposed surface of the sheet pile bulkhead.

2-8.2.6 Earthquake.

Consider the potential for liquefaction in areas of high seismic activity. Often, mitigation measures, such as soil improvements have been used. Recent wharf projects in Guam are good examples. P-204 Wharf Improvements Uniform and Tango used stone columns to mitigate liquefaction of soils behind a new bulkhead. P-518 X-Ray Wharf Improvements used deep soil cement mixing to mitigate liquefaction and create a soil-cement structure which would significantly reduce loads on the new bulkhead structure. When considering liquefaction, a number of good references are available, namely:

a. TR-2077-SHR, *Seismic Design Criteria for Soil Liquefaction (1997)*

b. NCEER-97-0022, *Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*

c. NCHRP Report 611, *Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankments (2008)*

d. ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures*

e. ASCE/COPRI 61-14, *Seismic Design of Piers and Wharves*

In areas of high seismic activity, carefully consider construction utilizing sheet pile bulkheads or walls because of the high lateral earth pressures that can develop on the sheet piling. When a pile-supported platform (with curtain wall) is used for a wharf structure in conjunction with hydraulic fill, which is susceptible to liquefaction, consider a rock dike to resist the lateral forces that may be caused by liquefaction of the fill. The use of an engineered soil filter fabric between the rock dike and granular fill should also be considered. In areas of extremely high seismic risk, and where tsunamis and seiches are anticipated, seriously consider the floating type as it is less likely to be affected by or will suffer only minor damage from the seismic activity. The floating double deck pier has been developed as a viable option in areas of high seismicity. This is due to the fact that the pier structure is basically isolated from the seismic event at the interface of the pier structure and the founding shaft. Rubber arch fenders in the pier's moonpool accomplish the desired seismic isolation.

2-8.2.7 Water Depths.

Consider open type construction in all depths of water when accommodating naval vessels, cargo vessels, and tankers. Depth limits for solid-type construction, utilizing sheet pile bulkheads, are imposed by the magnitude of the applied surcharge, subsurface conditions, and freeboard of the bulkhead above the low waterline. Generally, anchored sheet pile bulkheads may be considered in water depths up to 30 to 35 feet (9.1 to 10.7 m) where favorable soil conditions exist. When greater water depths are required at solid type bulkhead structures, consider the use of relieving platforms, bulkheads consisting of reinforced high-strength steel sheet piles, or cellular construction.

2-8.2.8 Subsurface Conditions.

Generally, subsurface conditions do not limit the use of open type construction. For almost all subsurface conditions, with the possible exception of rock close to the harbor bottom surface, suitable piles or caissons can be designed. Where rock is close to the surface and pile seating may be difficult and costly, consider cellular construction. When open type construction is required in an area where rock is close to the surface, piles should be socketed and anchored into the rock. Consider sheet piling, used for bulkheads or retaining walls in conjunction with platform wharf structures or combination piers, only when subsurface conditions indicate that suitable anchorage and restraint for the toe of the sheet piling can be achieved and where select material is available for backfill.

2-8.2.9 Fill Loss.

When precast concrete and steel sheet pile bulkheads are used in pier and wharf construction, take special care to prevent fill leaching through the interlocks, causing subsidence of retained fill. Install a filter blanket or other method that could prevent or control fill leaching to reduce subsidence and consequent paving maintenance.

2-8.2.10 Construction Time.

Where an existing pier or wharf has to be replaced in active naval stations, the floating type has the advantage of minimizing the "downtime." Conventional construction may take too long where the loss of berths cannot be tolerated. The floating type in such situations may turn out to be the most expedient.

2-8.2.11 Ship Contact.

In certain situations, where tugboats or camels are not available, sheet pile bulkheads located along the offshore face of pier and wharf structures may be less desirable than open type construction because of the greater danger for contact between the sheet piling and the bulbous bow or sonar dome of a ship during berthing and unberthing maneuvers.

2-8.2.12 Track Mounted Crane.

Where a track-mounted crane is required for the pier or wharf, the solid type may not be suitable. The susceptibility of the solid filled type to settlement and movement will make it very difficult to maintain the close tolerance required for rail gage, elevation, and alignment. The surcharge loading on the sheet pile will also be considerable. For such cases, use an independent pile supported track.

2-8.3 Construction.

Several aspects of construction that are unique to each structural type should be considered.

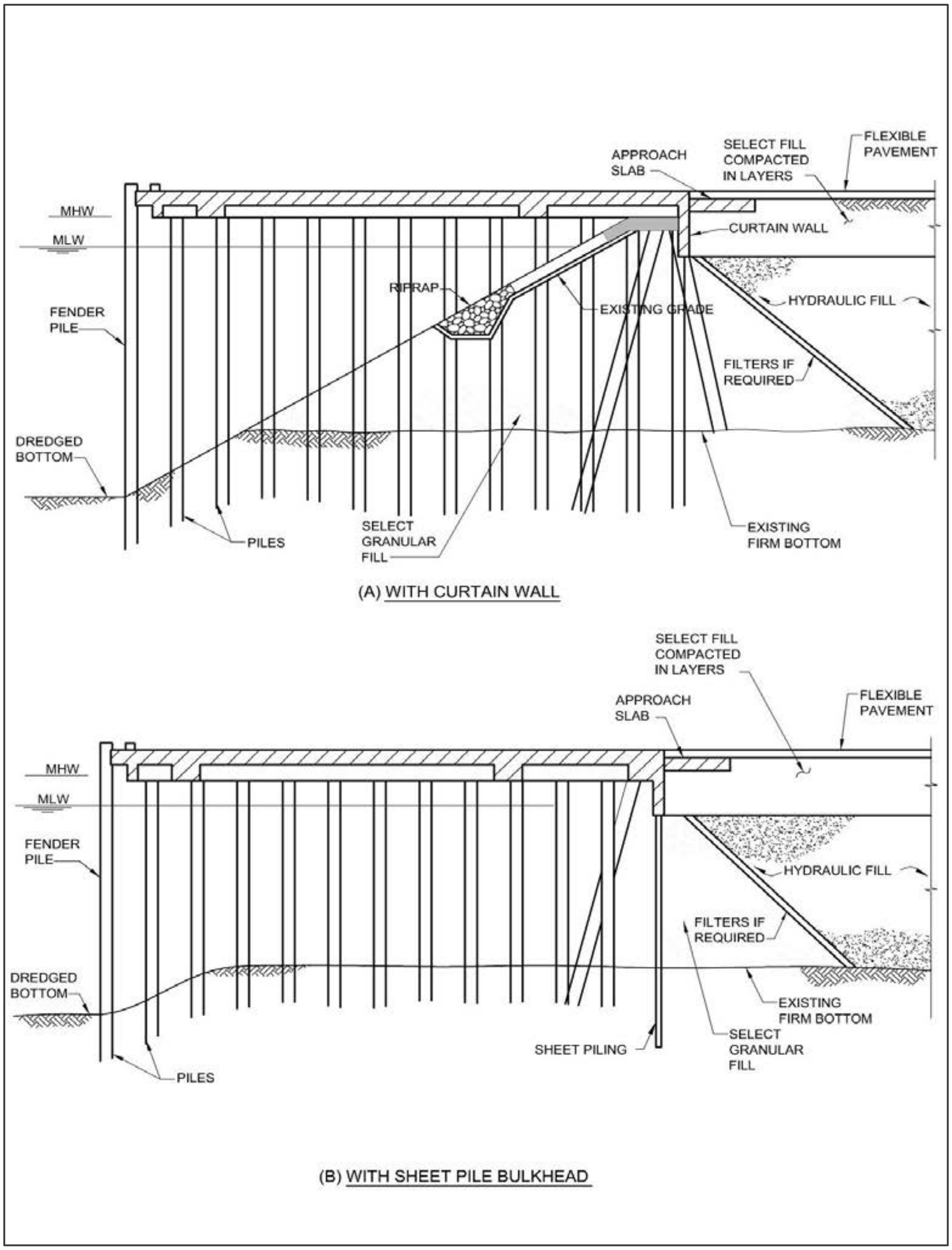
2-8.3.1 Open.

For open type wharves and landside ends of open piers, the following schemes should be considered for retaining upland fill:

a. Platform on Piles and a Curtain Wall at the Inshore Face. See Figure 2-9. The underwater slope should be as steep as possible, as limited by both constructional and geotechnical parameters, thus making the pile-supported platform narrow and more economical. In seismically active areas, where hydraulic fill susceptible to liquefaction is used for upland fill, a rock dike may be used instead of the granular fill dike to resist the lateral forces caused by liquefaction of the fill. The use of a filter fabric also should be considered at the hydraulic fill interface.

b. Platform on Piles and a Sheet Pile Bulkhead at the Inshore Face. See Figure 2-9. The sheet pile bulkhead permits a narrower platform. The cost tradeoff between platform width and bulkhead height should be investigated as the bulkhead may be found to cost as much or more than the pile supported platform width saved.

Figure 2-9 Open Type Wharf Concepts



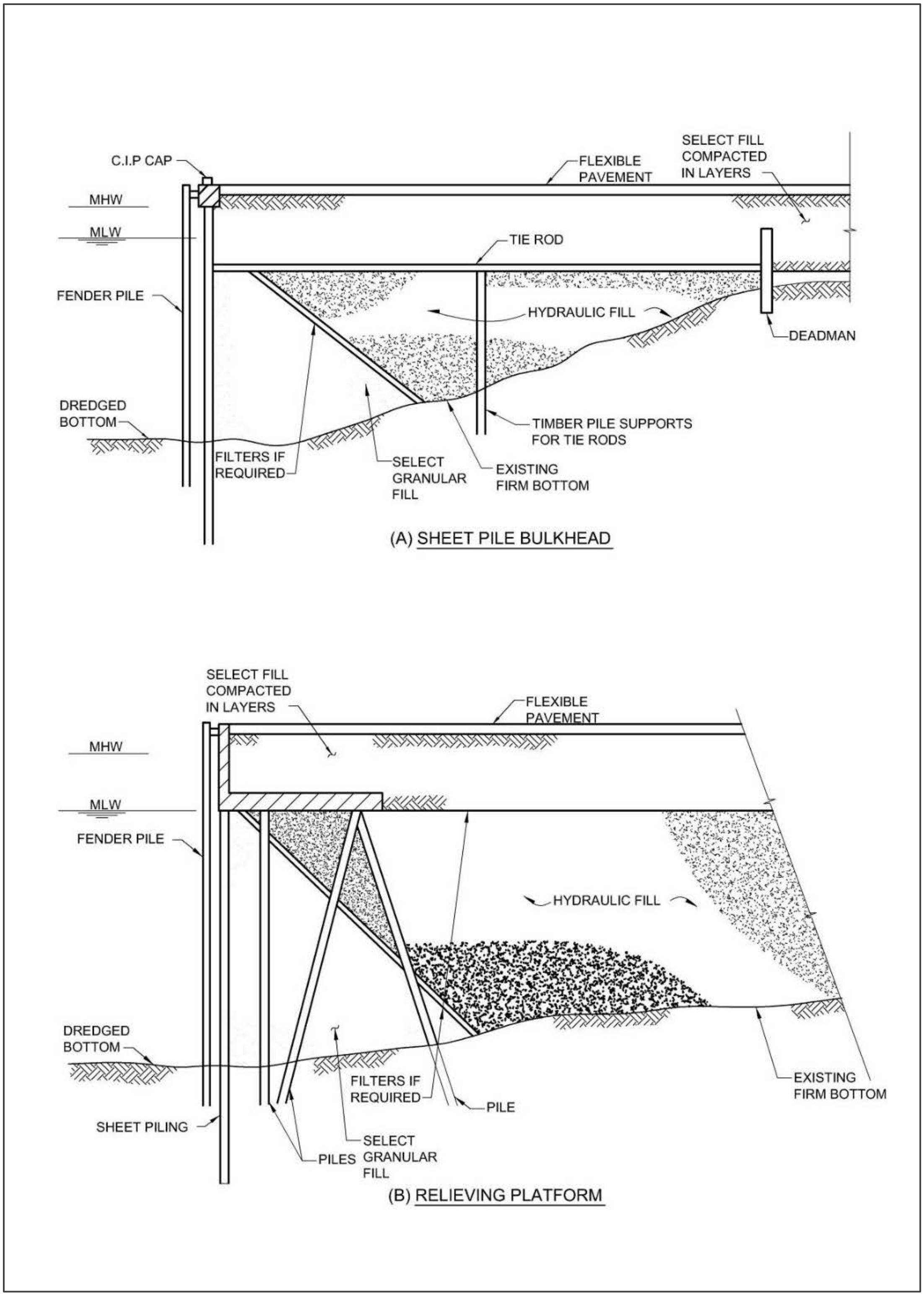
2-8.3.2 Solid.

Retaining structures may be constructed by the following means:

a. Sheet Pile Bulkhead. See Figure 2-10. The bulkhead consists of a flexible wall formed of steel or concrete sheet piling with interlocking tongue and groove joints and a cap of steel or concrete construction. The bulkhead is restrained from outward movement by placing an anchorage system above the low water level. Many types of anchorage systems can be used. The most common types in use in the United States consist of anchor rods and deadman anchors. The latter could be made of concrete blocks, steel sheet piling, or A-frames of steel, concrete, or timber piles. In countries outside the United States, an anchorage system consisting of piles, attached near the top of the sheet pile bulkhead and extending at batters up to 1 on 1 to embedment in firm material, is often used. Rock or earth anchors consisting of high-strength steel rods or steel prestressing cables are sometimes preferred in place of the anchor batter piles. Provide granular free-draining material adjacent to sheet pile bulkheads, extending from dredged bottom to underside of pavement on grade. Grade this material to act somewhat as a filter to limit subsequent loss of fines through the sheet pile interlocks. Placement of free-draining material should be in stages, commencing at the intersection of sheet piling and dredged bottom and progressing inshore. Eliminate mud and organic silt pockets. In general, do not consider hydraulic fill for backfill unless provision is made for the effects of fill settlement, potential liquefaction of fill in seismic zones, and high pressure exerted on sheet piling. Consider vibro-compaction for consolidation of hydraulic fill. In areas with tidal ranges greater than 4 feet (1.2 m), provide 2 inch (51 mm) diameter weep holes for the sheet piles above the mean low water level. If a waterline is located behind the bulkhead, provide weep holes. When weep holes are used, provide graded filters to prevent loss of finer backfill material. Provide openings in pavement or deck for replenishment of material in order to compensate for loss and settlement of fill. In general, flexible pavement using asphaltic concrete is preferred over rigid pavement with Portland cement concrete, as it is more economical to maintain and better able to accommodate underlying settlement.

b. Sheet Pile Bulkhead and Relieving Platform. The relieving platform is used in conjunction with a sheet pile bulkhead to reduce the lateral load on the sheet piling created by heavy surcharges and earth pressures. See Figure 2-10. Lateral restraint is provided by the batter piles supporting the relieving platform. A variation of this type of construction is to use only vertical piles for the relieving platform and to furnish an independent anchorage system consisting of tie rods and deadman, similar to the types specified for sheet pile bulkheads.

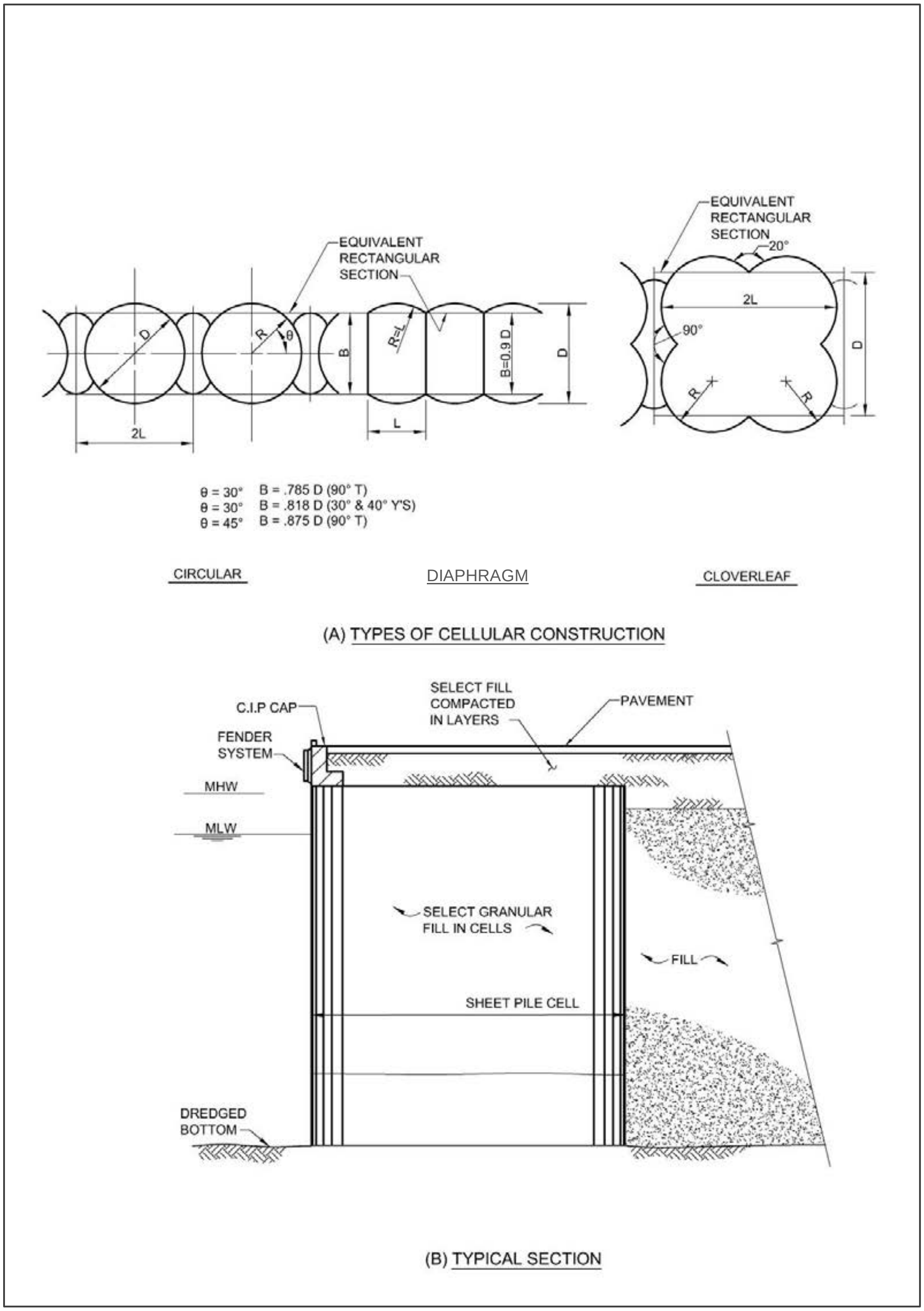
Figure 2-10 Closed Type Wharf Concepts



c. Cellular Construction Consisting of Sheet Pile Cells. For design procedures and selection of type, see UFC 3-220-01, *Geotechnical Engineering* and USACE EM 1110-2-2503, *Engineering and Design: Design of Sheetpile Cellular Structures, Cofferdams, and Retaining Structures.* Cellular structures are gravity retaining structures formed from the interconnection of straight steel sheet piles into cells. Strength of cellular structures derives from resistance to shear caused by friction and tension in the sheet pile interlocks and also from the internal shearing resistance of the fill within the cells. Accordingly, clean granular fill materials such as sand and gravel are usually used to fill the cells. Exercise extreme care in the construction of cellular structures because excessive driving onto boulders or uneven bedrock may cause ruptured interlocks, which can later unzip under hoop tension (from filling) and cause failures of the cell. Similarly, carefully control all aspects of fill placement, as cofferdams can unzip and cause sudden (little to no warning) failures of the cell. Compensate for movement and expansion of cells during construction of the cells and carefully control fill placement to satisfactorily maintain alignment of the face of the wharf. A concrete facing may be employed to protect the steel within the tidal zone. Cellular structures are classified according to the configuration and arrangement of the cells. The basic types are discussed below and are shown on Figure 2-11.

- Circular. This type consists of individual large-diameter circles connected together by arcs of smaller diameter. Each cell may be completely filled before construction of the next cell is started. Construction of this type is easier than the diaphragm type because each cell is stable when filled and thus may be used as a platform for construction of adjacent cells. Because the individual cells are self-supporting units, accidental loss of one cell will not necessarily endanger adjoining cells. Compared to a diaphragm type cellular structure of equal design, fewer piles per linear foot of structure are required. The diameter of circular cells is limited by the maximum allowable stresses in the sheet pile interlocks and, when stresses are exceeded, cloverleaf cells are used.
- Diaphragm. This type consists of two series of circular arcs connected together by diaphragms perpendicular to the axis of the cellular structure. The width of cells may be widened by increasing the length of the diaphragms without raising interlock stress, which is a function of the radius of the arc portion of the cell. Fill cells in stages so that the heights of fill in adjoining cells are maintained at equal levels to avoid distortion of the diaphragm walls. Diaphragm type cells present a flatter faced wall than circular cells and are considered more desirable for marine structures.

Figure 2-11 Solid Type, Cellular Construction



- Cloverleaf. This type is a modification of the circular cell type and is generally used in deep water where the diameter required for stability would result in excessively high interlock stress if diaphragms were not added.
- Modified Open Cell. This type relies on steel sheet walls as a form of tieback to the fill.

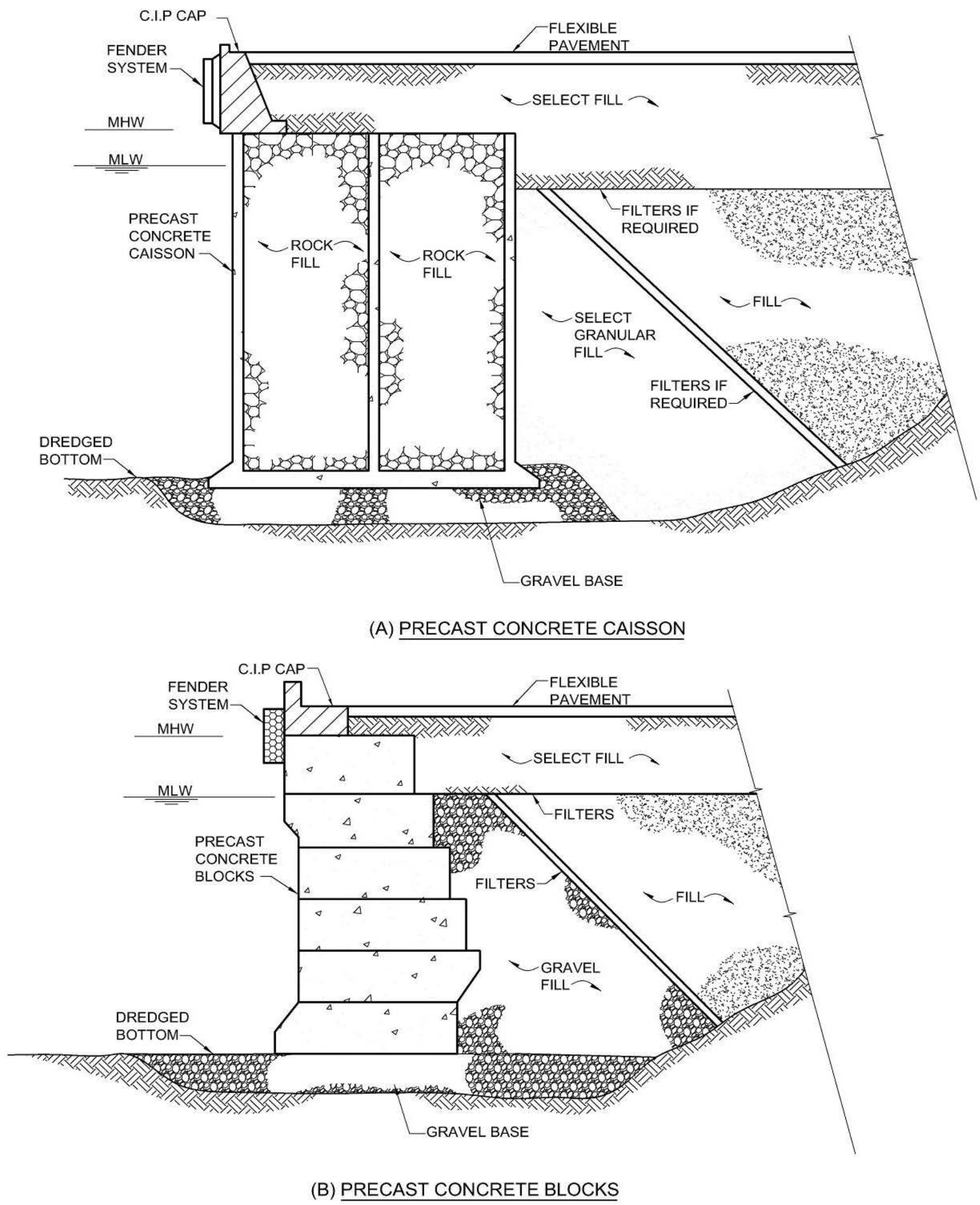
d. Reinforced Concrete Caisson. See Figure 2-12. In this type of construction, concrete caissons are cast in the dry, launched, and floated to the construction site where they are sunk on a prepared foundation. The caisson is filled with gravel or rock and a cast-in-place retaining wall is placed from the top of the caisson to the finished grade. This type of construction is prevalent in countries outside the United States. Reinforced concrete caissons come in two variations: closed and open end caissons (caissons without the bottom slab). Closed end caissons are normally floated and then sunk in place. Open bottom caissons are barge delivered, but are easier to install and have better rotational stability due to mobilization of the infill soil shear action (see cellular cofferdams). Closed end caissons require sub base leveling and sub base stabilization for prevention of the caisson roll off, particularly in areas with extreme wave climate. Sometimes, caissons are fabricated as the ring modules, barge delivered and preassembled at the site prior to installation.

e. Precast Concrete Blocks. See Figure 2-12. This form of solid wharf is a gravity type wall made up of large precast concrete blocks resting on a prepared bed on the harbor bottom. A select fill of granular material is usually placed in the back of the wall to reduce lateral earth pressures. This type of construction is popular outside the United States.

2-8.3.3 Floating.

Construction of the floating type usually requires a flood basin, graving dock, or dry dock. The units are essentially constructed in the dry and floated out and transported (on their own or on barges) to the site. Availability of such a facility and transportation of the floating units through open ocean waters and restricted inland waters for deployment at the site are serious considerations. In this respect, the floating type has a significant advantage over others in that the bulk of construction activity can be shifted to other parts of the country where labor, economic, and environmental conditions are more favorable. Other concepts of construction such as barge-mounted construction and floating-form construction are described in NCEL UG-0007, *Advance Pier Concepts, User's Guide*.

Figure 2-12 Solid Type, Caisson and Concrete Block Construction



2-8.3.4 Jack-up Barge.

This type consists of a structural steel seaworthy barge provided with openings for steel caissons, which are lowered to the harbor bottom when the barge has been floated into final position. The barge may be completely outfitted during construction with ship fenders, deck fittings, and utilities including power, lighting, communications, water supply, sanitary facilities, etc., so that once it is jacked into position and utility tie-ins are made, it is ready to receive ships. Circular pneumatic gripping jacks, mounted on the deck above the caisson openings, permit the barge to be elevated in steps. The barge is loaded with steel caissons, a crane for pile erection, and other tools and materials required for the fieldwork, and is towed to the site. At the site, the barge is moved into approximate position and the caissons are dropped through the jacks and hull by the crane. The caissons, suspended above the harbor bottom and supported by engaging the jacks, are then released and seated into the harbor bottom by dead weight. The barge-like deck is jacked to the required elevation and locked. Each caisson is then released from its jack and driven to refusal or required penetration. When all caissons are driven, the hull of the barge is welded to the caisson, the jacks are removed, and the caissons are cut off flush with the deck and capped with steel plates. In some situations, the caissons are filled with sand to avoid buoyancy problems. Jack-up barge type structures are also constructed using hydraulic jacks and open-trussed towers instead of pneumatic jacks and circular caissons.

2-9 HYDRAULIC FILL.

The soil drawn up by the suction head of a dredge, pumped with water through a pipe, and deposited in an area being filled or reclaimed is referred to as "hydraulic fill." At port and terminal facilities, where land is not available onshore and where dredging is required to provide adequate water depths for vessels at berths and approach channels, hydraulic fill is commonly used for land reclamation because of its availability and low cost. Hydraulic fill may be of good quality, consisting of granular materials, or may consist of plastic organic silt, which is considered poor quality. When hydraulic fill is used, investigate the stability of the structure retaining the fill, taking into consideration the effects of adjacent surcharge loadings in addition to the loadings from the fill. The placement of a select granular fill adjacent to the retaining structure may be required if the hydraulic fill is of poor quality. Hydraulic fill is in a loose condition when placed. To avoid fill settlements due to loadings from other structures, stacked cargoes, and mobile equipment, stabilization of the fill may be required. In areas of seismic activity, investigate the liquefaction of hydraulic fills. Stability with regard to both settlements and liquefaction may be enhanced by methods such as deep densification or by use of sand drains. Material other than hydraulic fill should be used when the cost of material obtained from onshore borrow areas is cheaper than the cost of material obtained from offshore borrow areas or where good quality fill material is required and is not available offshore.

CHAPTER 3 LOAD REQUIREMENTS

3-1 GENERAL.

Where loading conditions exist that are not specifically identified in this UFC, rely on accepted industry standards. Where applicable, reference is made to UFC 3-301-01, *Structural Engineering*. However, in no case will other standards supersede the requirements provided by this UFC.

3-2 DEAD LOADS.

3-2.1 General.

The dead load consists of the weight of the entire structure, including all the permanent attachments such as mooring hardware, light poles, utility booms, vaults, sheds, and service utility lines. A realistic assessment of all present and future attachments should be made and included. For floating piers and wharves, overestimating of dead loads would overstate draft and could have a significant effect on cost.

3-2.2 Unit Weights.

Use actual and available construction material weights for design. See Table 3-1 for unit weights that should be used for construction materials (unless lesser unit weights can be demonstrated by local experience). Pertinent information may also be found in ASCE 7, *Minimum Design Loads for Buildings and Other Structures.*

Table 3-1 Unit Weights

Material	Unit Weight (pcf)
Steel or cast steel	490
Cast iron	450
Aluminum alloys	175
Timber (untreated)	40 to 50
Timber (treated)	45 to 60
Concrete, reinforced (normal weight)	145 to 160
Concrete, reinforced (lightweight)	90 to 120
Compacted sand, earth, gravel, or ballast	150
Asphalt paving	135 to 150

3-3 VERTICAL LIVE LOADS.

3-3.1 General.

Although a number of loading conditions will be presented in subsequent sections, the advent and subsequent heavy usage of mobile cranes on piers will generally produce the controlling loading condition. For example, on a general purpose berthing pier, a design drawing will typically present different design live loads including uniform, vehicular (i.e. HS 20-44), forklift, and maximum outrigger float load. The outrigger load from the mobile crane invariably controls with the other loads more or less provided for informational purposes. Further, it is incumbent upon the designer to identify and document all of the particular loadings associated with his design that may not be included in the discussions in this section.

3-3.2 Uniform Loading.

See Table 3-2 for recommended uniform loadings for piers and wharves. Impact is not applied when designing for uniform loads.

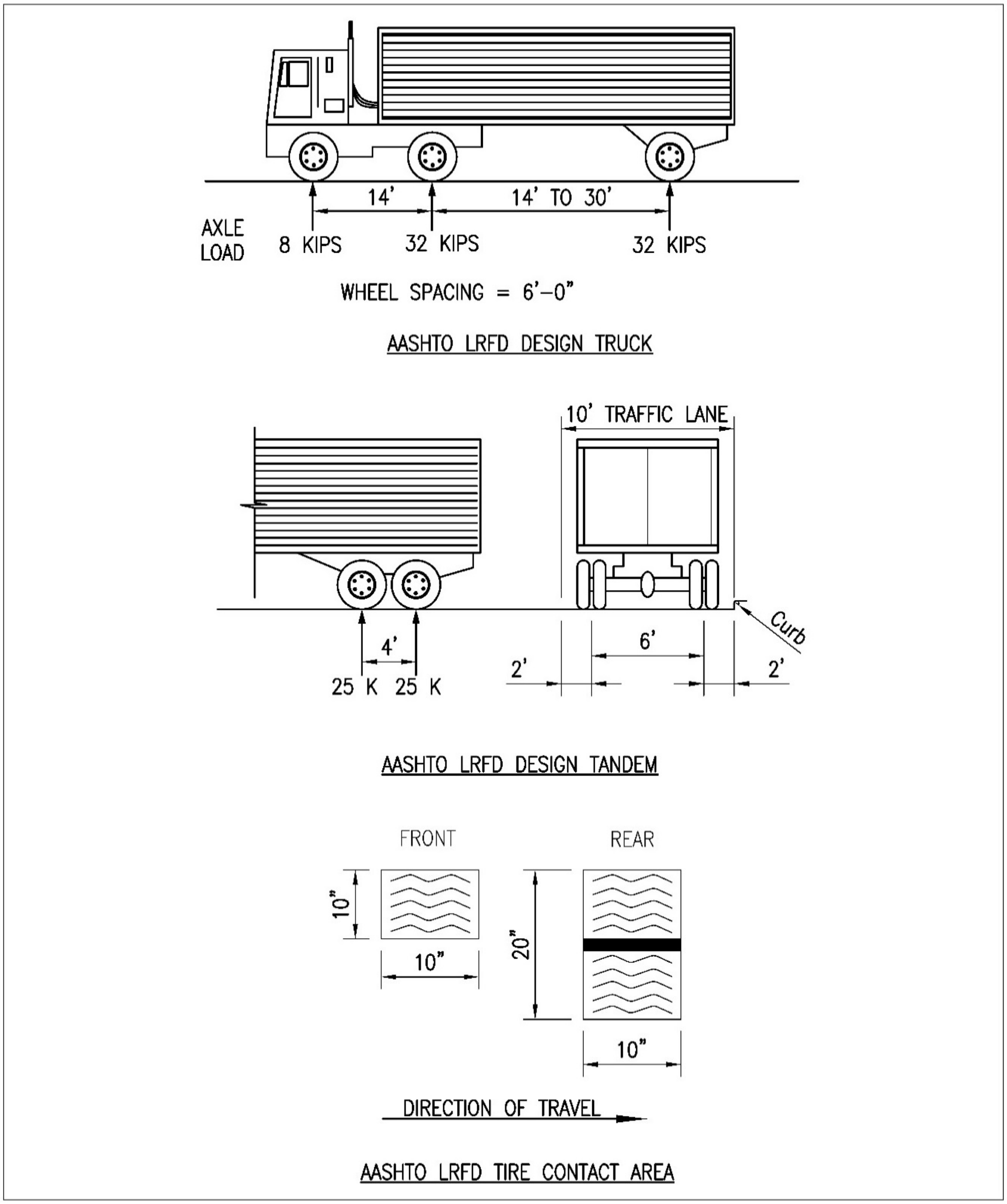
Table 3-2 Vertical Live Loads for Pier and Wharf Decks

Classification	Uniform Loading (psf)	Mobile Crane (tons)	Rail-Mounted Crane (tons)	Other Handling Equipment (tons)
Ammunition	600	90	--	20-lift truck
Berthing (carriers)	800	140	--	20-lift truck
Berthing (all others)	600	90	--	20-lift truck
Berthing (submarines)	600	90	--	20-lift truck
Repair	600	140	60/151 Portal	20-lift truck
Fueling	300	50	--	10-lift truck
Supply (general cargo)	750	140	--	20-lift truck
Supply (containers)	1,000	140	40/50 (long tons) Container	20-lift truck 33-straddle carrier

3-3.3 Truck Loading.

Calculate truck wheel loads in accordance with the AASHTO *Standard Specifications for Highway Bridges* except as modified below. Figure 3-1 is provided to show both AASHTO LRFD Design Truck and Design Tandem. In the design of slabs, beams, and pile caps, apply an impact factor of 15 percent. Structural elements below the pile caps need not be designed for impact. When truck loading is transferred through 1.5 feet (0.46 m) or more of crushed rock ballast and paving, and for filled construction, the impact forces need not be considered for design. Also, check with local activity for use of an overload vehicle such as weapons cradles, missile hauling vehicles, etc. which may have significantly higher wheel loads.

Figure 3-1 AASHTO LRFD Design Truck and Design Tandem



3-3.4 Rail-Mounted Crane Loading.

3-3.4.1 Portal Cranes.

For design of new piers and wharves, obtain specific crane wheel loads for the actual crane to be used. If the crane resources are not known at the time of design, consult the Navy Crane Center for design loading and crane procurement. When choosing design wheel loads, provide flexibility, considering different makes of cranes and ultimate crane replacement as well as future use of the pier or wharf. Piers and wharves have greater longevity than rail-mounted cranes. To this end, a wheel load of 110,000 pounds (489 kN) minimum on 4-foot (1.2 m) centers allows for a practical range of options. See Table 3-2 for typical rated capacities of cranes for a variety of pier and wharf deck uses.

Figure 3-2 lists a sampling of wheel loads for 60 ton (534 kN) and 151 ton (1343 kN) capacity portal cranes recently procured by the Navy. These cranes were procured around capacities of existing piers and wharves and have wheel loads that are somewhat restrictive for new design. The values provided are typical for existing equipment used by the Navy and are useful for design feasibility studies on existing structures. The rail gage should be approximately 30 feet (9.1 m) minimum for a 60 ton (534 kN) capacity portal crane, and up to 40 feet (12.2 m) for a portal crane of 100 tons (890 kN) capacity or greater. For handling of fuel containers at repair piers, portal cranes with up to 151-ton (1343 kN) capacity are required.

3-3.4.2 Container Cranes.

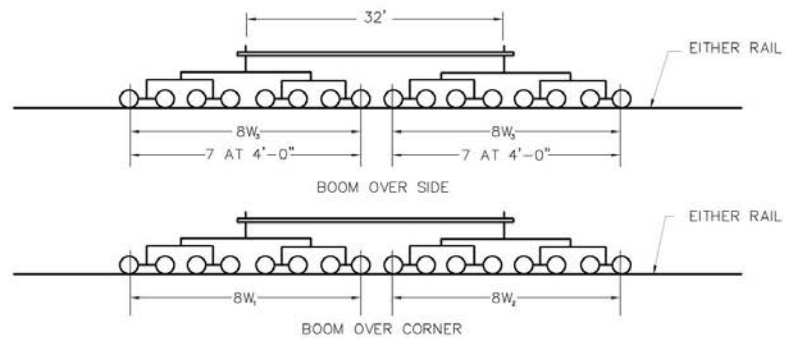
See Figure 3-3 for crane configuration and wheel loads of container cranes and Table 3-2 for the rated capacities of container cranes applicable to piers and wharves. The configuration and wheel loads are derived from several manufacturers and should be used only as a guide. A recent trend in the shipment of containerized cargo is to use larger ships, and this is the driving force in the design of container cranes. The size of the ship to be serviced will dictate the capacity, configuration, operational characteristics, and gage of the crane. The evolution in container crane design has been to increase the gage to 100 feet (30.5 m) and outreach on the boom to 150 feet (45.7 m) and larger while maintaining the lift capacity between 40 and 50 long tons (399 and 498 kN). Hence, specific information on the size of the ship to be serviced and details from the crane manufacturer needs to be obtained for final crane design.

3-3.4.3 Wheel Load Uncertainty.

Portal and container cranes are usually procured separately from the construction funds. The maximum allowable wheel loads are normally specified on the crane procurement documents. The number and spacing of wheels are critical to the structural capacity of an existing facility and structural design of a new facility. Having established the required capacity and configuration of a crane, the designer of a pier or wharf should consult with the Navy Crane Center and obtain wheel loads for which the supporting structure should be designed. In the absence of hard information, the 110,000 pound (489 kN) wheel load presented in the previous paragraph on portal cranes may be used. However, the container crane wheel loads presented in Figure 3-3 are only provided as a guide. Determine the design characteristics noted in the previous paragraph on container cranes in order to determine realistic wheel loads.

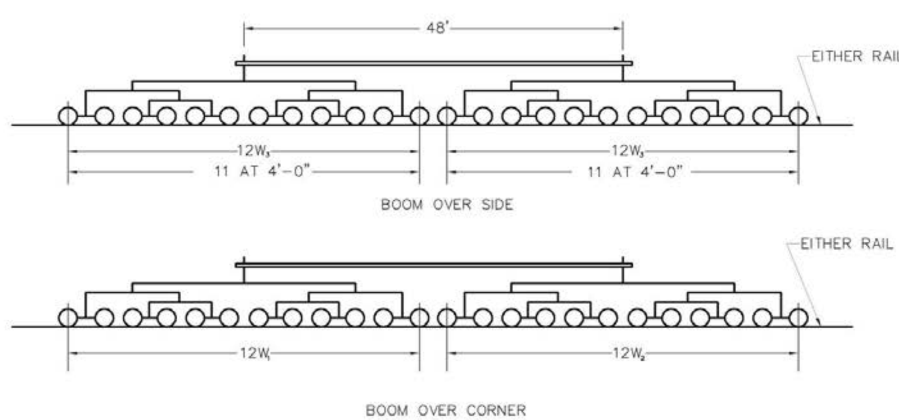
Figure 3-2 Wheel Loads for Portal Cranes

60 Ton Portal Crane



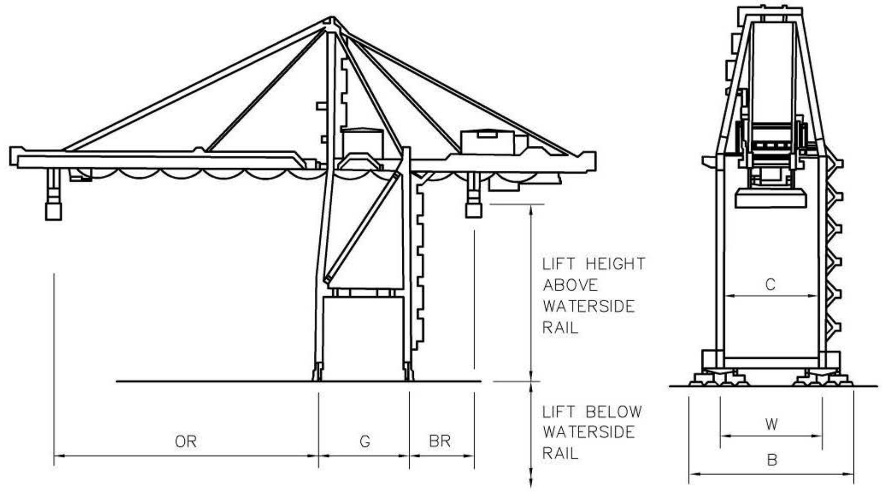
Main Hook Capacity	Rail Gage (ft)	Boom Over Corner		Boom Over Side
		W_1 (lbs)	W_2 (lbs)	W_3 (lbs)
120,000 lbs. at 90ft.	18	83,000	52,000	72,000
90,000 lbs. at 110 ft.	20	80,000	48,000	70,000
* 40 ft gage cranes have a jib extension and increased boom hinge height. "Boom over side" position is parallel to the rails for the 40 ft gage.	30	73,000	41,000	62,000
	40*	71,000	49,000	64,000

151 Ton Portal Crane



Main Hook Capacity	Rail Gage (ft)	Boom Over Corner		Boom Over Side
		W_1 (lbs)	W_2 (lbs)	W_3 (lbs)
302,000 lbs. at 65ft. 200,000 lbs. at 90 ft. 146,000 lbs. at 110 ft. 123,000 lbs. at 120 ft.	18	81,000	65,000	76,000
	40	70,000	58,000	65,000

Figure 3-3 Configuration and Wheel Loads for Container Cranes



ITEM			CRANE CAPACITY	
			40' LONG TONS	50' LONG TONS
GAUGE – G			50' TO 100'	100'
OUTREACH – OR			115' TO 155'	125' TO 172'
BACK REACH–BR			30' TO 60'	30' TO 60'
WHEEL BASE – W			45' TO 55'	45' TO 55'
CONTAINER CLEARANCE – C			55' TO 60'	55' TO 60'
BUMPER TO BUMPER – B			79' TO 90'	85' TO 90'
WHEEL SPACING (8 WHEELS/LEG)			4' TO 5'	4.5' TO 5'
LIFT HEIGHT ABOVE WATERSIDE RAIL LIFT HEIGHT BELOW WATERSIDE RAIL			90' TO 110' 55'	89' TO 110' 65'
MAXIMUM WHEEL LOAD IN KIPS (UNFACTORED WITH 10 PSF WIND)	OPERATING	WATERSIDE RAIL	87^k TO 120^k	110^k TO 170^k
		LANDSIDE RAIL	75^k TO 112^k	95^k TO 125^k
	STOWED	WATERSIDE RAIL	56^k TO 135^k	90^k TO 150^k
		LANDSIDE RAIL	60^k TO 150^k	100^k TO 165^k

3-3.4.4 Impact.

Apply an impact factor of 25 percent to the maximum listed wheel loads for the design of deck slab, crane girders, and pile caps. The impact factor is not applicable to the design of piles and other substructure elements.

3-3.5 Mobile Crane Loadings.

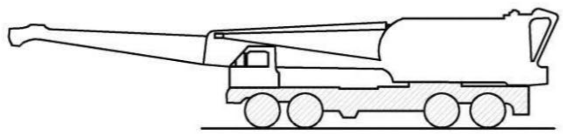
The deck design for open and floating structural types of piers and wharves is usually controlled by mobile crane loading. However, the operational constraints imposed by under specifying mobile crane loadings are severe. Consequently, take care to specify realistic loading. Refer to Table 3-2 for designated mobile cranes applicable to each functional type of pier and wharf. As a minimum design the pier or wharf for the designated mobile crane, however, check with the local activity to confirm whether a crane larger than that designated could be used at the facility, as the additional structural design cost for larger mobile cranes may be minimal at the preliminary design stage. Larger cranes may be used at a facility provided the demands are less than that of the design cranes listed in Figure 3-4, and Table 3-3. To assist the facility determine suitability of larger cranes provide the following on the design drawings structural notes:

- The maximum single outrigger load, ground bearing pressure.
- The maximum double outrigger load, ground bearing pressure, outrigger spacing.
- The maximum single axle load, tire pressure, footprint.
- The maximum multiple axle load, tire pressure, footprint, axle spacing, maximum number of axles.

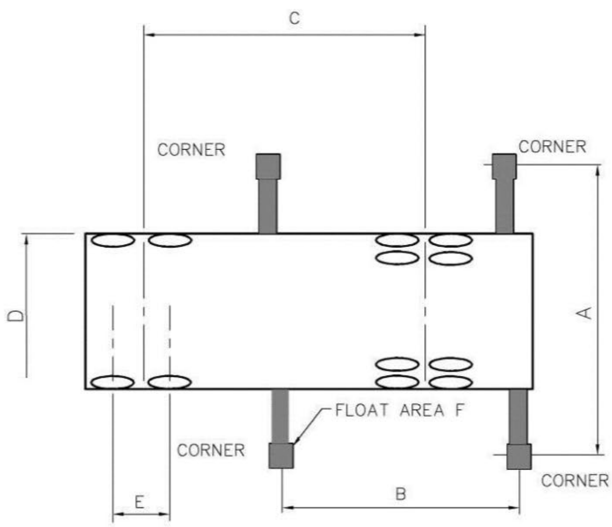
3-3.5.1 Wheel Loads.

See Figure 3-4 for wheel loads for 50-, 70-, 90-, 115-, and 140-ton capacity mobile cranes. The information in Figure 3-4 is for typical truck cranes, although rough-terrain type mobile cranes are also used on piers and wharves. Tire contact area should be as defined by AASHTO LRFD. As a rule of thumb, ground pressures for "on rubber" lifts are about 10 percent higher than tire inflation pressure. Crane manufacturers recommend that the majority of lifts be made on outriggers. In addition, capacities for "on rubber" lifts are substantially less than for "on outrigger" lifts. Hence, loads for "on rubber" lifts are not listed. Design all piers and wharves and their approaches for the wheel loads from the designated truck crane.

Figure 3-4 Wheel Loads and Dimensions for Truck Cranes



CRANE TRAVELING – BOOM OVER FRONT



CRANE TRAVELING – WHEEL LOADS WITH BOOM OVER FRONT				CRANE DIMENSIONS					
CRANE CAPACITY	TOTAL WEIGHT (lbs)	FRONT AXLE LOAD (lbs)	REAR AXLE LOAD (lbs)	A (ft)	B (ft)	C (ft)	D (ft)	E (ft)	F (in^2)
50 TON	82,000	28,000	54,000	20 TO 23	18 TO 23	12 TO 19	8.5 TO 9	4 TO 5.5	250 TO 400
70 TON	105,000	34,000	71,000	20 TO 24	18 TO 24	13 TO 19	8.5 TO 9.5	4 TO 5.5	350 TO 450
90 TON	135,000	40,000	95,000	22 TO 26	18 TO 27	13 TO 19	8.5 TO 10	4 TO 5.5	400 TO 530
115 TON	180,000	40,000	140,000	23 TO 27	20 TO 27	18 TO 24	9 TO 10	4 TO 5.5	450 TO 730
140 TON	200,000	44,000	156,000	23 TO 27	20 TO 27	19 TO 24	9.5 TO 11	4 TO 5.5	560 TO 910

Table 3-3 Outrigger Float Loads for Mobile Cranes

Capacity	Radius	Boom Over Corner	Boom Over Back or Side (ea)
tons	ft	lbs	lbs
50	20 and less 30 40 50 and more	97,000 83,000 78,000 72,000	89,000 69,000 60,000 55,000
70	20 and less 30 40 50 and more	130,000 115,000 104,000 99,000	114,000 90,000 85,000 78,000
90	20 and less 30 40 50 and more	160,000 144,000 130,000 117,000	144,000 120,000 107,000 98,000
115	20 and less 30 40 50 and more	195,000 180,000 156,000 144,000	183,000 151,000 131,000 120,000
140	20 and less 30 40 50 60 and more	232,000 222,000 211,000 198,000 187,000	207,000 176,000 164,000 150,000 142,000

3-3.5.2 Outrigger Float Loads.

Table 3-3 lists outrigger float loads for different capacity cranes. The maximum single float load from a boom over corner position and maximum concurrent pair of float loads from a boom over side and back positions are listed. Typically, the float loads are at the maximum when lifting the rated load at a short radius (20 feet (6.1 m) and less) and should be used for design. However, for existing piers and wharves, the other listed loads may be used to analyze deck capacity. Typical outrigger float spacing is shown in Figure 3-4. Apply outrigger float loads to a 1.5 foot by 1.5 foot (0.46 m by 0.46 m) area unless actual float size is known, in which case use the actual float size for analysis.

3-3.5.3 Impact.

Apply an impact factor of 15 percent for all wheel loads when designing slab, beams, and pile caps. The impact factor need not be applied when designing for maximum outrigger float loads, piles and other substructure elements, filled structures, and where wheel loads are distributed through paving and ballast (1.5 foot (0.46 m) or more).

3-3.6 Forklift and Straddle Carrier Loadings.

3-3.6.1 Forklifts.

See Figure 3-5 for wheel loads from forklifts. Determine contact areas for wheel loads in accordance with AASHTO. For hard rubber wheels or other wheels not inflated, assume the wheel contact area to be a point load.

3-3.6.2 Straddle Carriers.

See Figure 3-6 for wheel loads for a straddle carrier. The straddle carrier shown is capable of lifting a loaded 20-foot (6.1 m) container or a loaded 40-foot (12.2 m) container.

3-3.6.3 Impact.

Apply an impact factor of 15 percent to the maximum wheel loads in the design of slabs, beams and pile caps. The impact factor need not be applied when designing piles and other substructure elements, when designing filled structures, and where wheel loads are distributed through paving and ballast (1.5 feet (0.46 m) or more).

3-3.7 Loading on Railroad Tracks.

For freight car wheel loads, use a live load of 8000 pounds per foot (117 kN/m) of track corresponding to Cooper E-80 designation of the American Railway Engineering Association (AREA) *Manual for Railway Engineering*. In the design of slabs, girders, and pile caps, apply an impact factor of 20 percent. Impact is not applicable for the design of piles and filled structures, or where loads are distributed through paving and ballast (1.5 feet (0.46 m) or more).

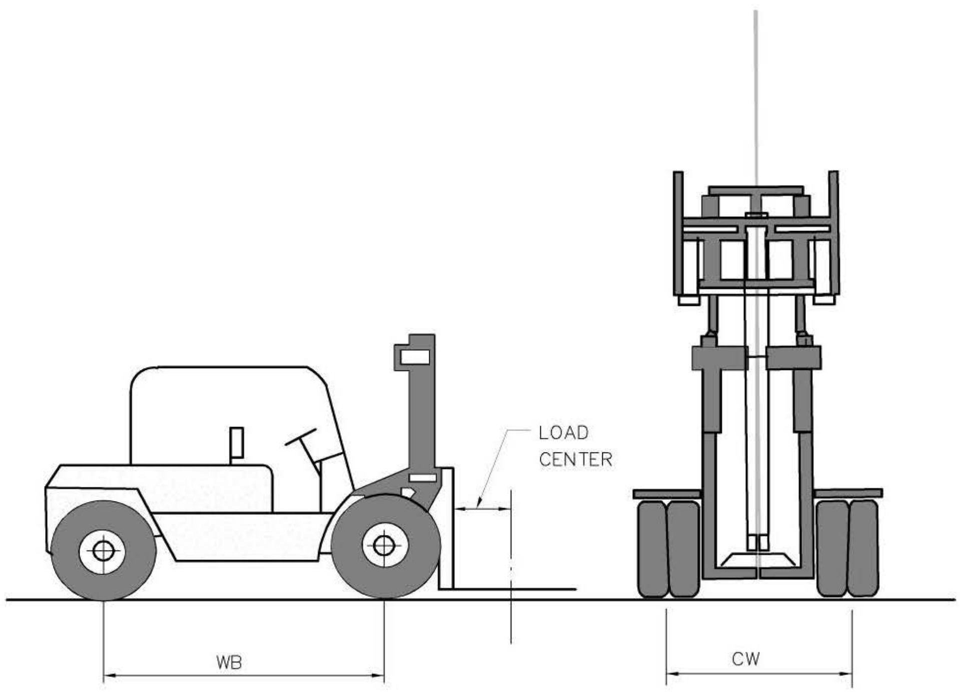
3-3.8 Buoyancy.

Typically, piers and wharf decks are not kept low enough to be subjected to buoyant forces. However, portions of the structure, such as utility trenches and vaults, may be low enough to be subject to buoyancy forces, which are essentially uplift forces applied at the rate of 64 psf (3064 kPa), for normal seawater at sea level, of plan area for every foot of submergence below water level.

3-3.9 Wave Loading.

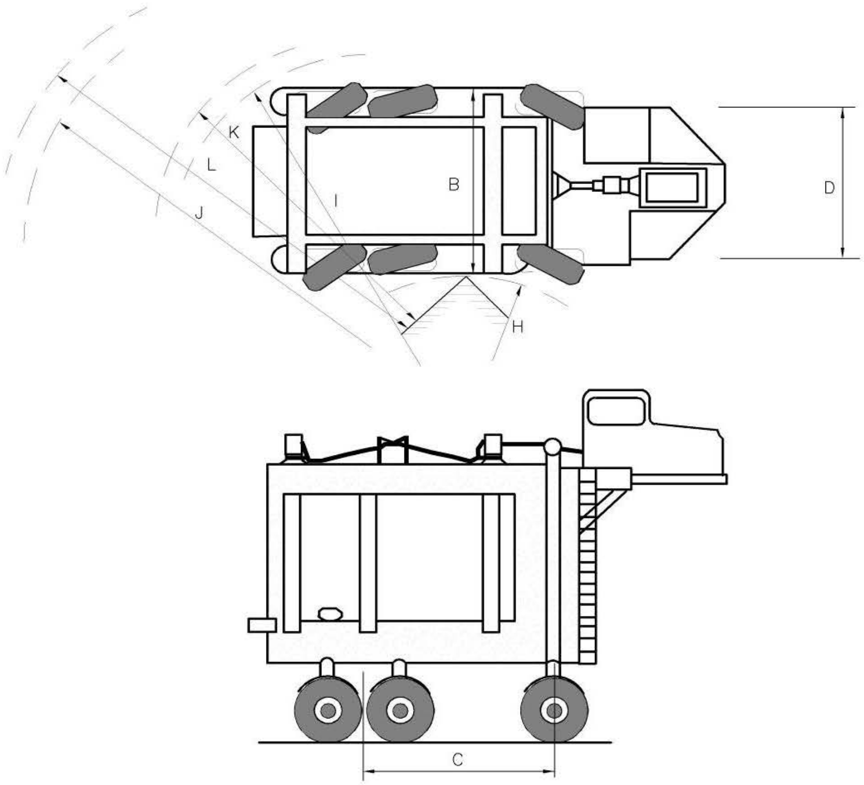
For piers and wharves exposed to waves which may produce significant lateral or hydrostatic forces, determine wave loading in accordance with the procedures defined in UFC 4-150-06, *Military Harbors and Coastal Facilities.* Consider also that wave loading, may be vertical, resulting in uplift on the structure.

Figure 3-5 Wheel Loads for Forklifts



MAXIMUM LOAD (LBS)	LOAD CENTER (IN)	SERVICE WEIGHT (LBS)	TURNING RADIUS (FT.–IN)	WHEEL–BASE(WB) (FT.–IN)	WHEEL SPAC.(CW) (FT.–IN)	WHEEL LOADS (LOADED) EACH REAR SINGLE TIRE (LBS)	WHEEL LOADS (LOADED) EACH FRONT DUAL TIRE (LBS)
10,000	24	15,000	12–10	8–3	6–3	2,000	10,500
12,000	24	16,000	12–10	8–3	6–3	2,500	11,500
15,000	24	19,000	13–0	8–9	6–4	2,500	14,500
16,000	24	19,500	13–0	8–9	6–4	2,500	15,250
20,000	24	20,000	14–0	9–6	6–4	2,500	17,500
24,000	24	25,300	14–9	10–0	6–4	2,500	22,150
30,000	24	34,000	15–3	10–9	6–6	3,000	29,000
40,000	36	63,000	14–11	10–0	8–0	2,500	49,000

Figure 3-6 Wheel Loads for Straddle Carriers



DEAD WEIGHT		67,000 LBS
SERVICE WEIGHT		89,000 LBS
WHEEL LOAD–EACH		26.000 LBS
OVERALL WIDTH	(B)	13'–4"
WHEELBASE	(C)	13'–4"
WHEEL CENTERS	(D)	11'–6"
INSIDE TURNING RADIUS	(H)	11'–3"
OUTSIDE TURNING (20ft. CONTAINER)	(I)	27'–10"
OUTSIDE TURNING (40ft. CONTAINER)	(J)	33'–4"
MINIMUM (20ft. CONTAINER)	(K)	19'–4"
MINIMUM (40ft. CONTAINER)	(L)	25'–4"

3-3.10 Application of Loadings.

3-3.10.1 Concentrated Loads.

Wheel loads and outrigger float loads from designated pneumatic-tired equipment, such as trucks, truck cranes, forklifts, and straddle carriers may be oriented in any direction and the orientation causing the maximum forces on the structural members should be considered for design. Significant loads from fuel containers (exceeding 300 kips (1334.5 kN)) at repair piers may be encountered. Design manhole covers and frames for pneumatic-tired equipment only. Design trench covers, utility trench covers, and access hatch covers to handle the concentrated loads, where they are accessible to mobile equipment. However, designated areas on the pier deck may be exempted from wheel loads or outrigger float loads, or designed for lesser loads, when curbs, railings, and other physical barriers are provided to isolate those areas from vehicle access. Concentrated wheel loads from these vehicles are applied through small "footprints" to the deck structure. The distribution of these loads and computation of maximum moments and shears may be in accordance with the AASHTO *Standard Specification for Highway Bridges*. However, this method is conservative and more reasonable results may be obtained using NCEL R-935, *Lateral Load Distribution on One-Way Flat Slab*; *Influence Surfaces for Elastic Plates,* for different edge conditions, or finite element analysis. Maximum mobile crane concentrated loads should not be combined with maximum wind, seismic, mooring or berthing loads.

3-3.10.2 Simultaneous Loads.

Apply uniform and concentrated live loads in a logical manner. Do not apply designated uniform live loadings and concentrated live loading from pneumatic-tired equipment simultaneously in the same area. However, apply uniform live load between crane tracks (for 80 percent of gage). When railroad tracks are present between crane tracks, apply track loads simultaneously. However, the maximum loads from each track need not be assumed. Unique operations may warrant a more conservative approach, i.e., during a “trans-shipment operation” (handling of fuel containers), there could be a portal crane straddling a railroad car loaded with a container, with another container sitting on the pier deck in the immediate vicinity.

3-3.10.3 Skip Loading.

For determining the shear and bending moments in continuous members, apply the designated uniform loadings only on those spans that produce the maximum effect.

3-3.10.4 Critical Loadings.

Concentrated loads from trucks, mobile cranes, forklifts, and straddle carriers, including mobile crane float loads, are generally critical for the design of short spans such as deck slabs and trench covers. Uniform loading, mobile crane float loading, rail-mounted crane loading, and railroad loading are generally critical for the design of beams, pile caps, and supporting piles.

3-4 HORIZONTAL LOADS.

3-4.1 Berthing Energy.

Procedures for calculation of berthing energy are found in the subsequent section: BERTHING ENERGY DETERMINATION of this UFC.

3-4.2 Mooring Loads.

Forces acting on a moored ship are produced by winds, currents, and waves. The determination of mooring loads involves an evaluation of many variables including: direction and magnitude of winds, currents, and waves; exposure of the berth; orientation of the vessel; number and spacing of mooring points; layout and type of mooring lines; tides; and the loaded condition of the vessel (light, one-third stores, fully loaded). In sheltered waters where piers and wharves are usually constructed, wave forces are not significant and may be ignored. Type III and Type IV mooring design requires 30-second gust, 50 and 100 year return period wind speed respectfully. The wind speed provided in UFC 3-301-01, *Structural Engineering* is a 3-second gust with a return period from 300 to 1,700+ years, depending upon the importance of the structure. Therefore, in order to attain the appropriate wind speed for mooring design of Type III and IV structures, a procedure is required for converting: the 3-second gust to a 30-second gust (referenced at a 33 feet (10.1 m) height above mean sea level), and for determining 50 year and 100 year Exposure D design winds. This is illustrated below for converting to a 50 year return period wind (associated with Mooring Service Type III):

Step 1: Convert 1700 year return period wind speed to 50 year return period wind speed.

V_{1700} = 124 mph (Naval Station Norfolk: Cat III-V; 1700 year return wind)

$V_{50\text{-}3sec} = V_{1700} / (0.36 + 0.1*LN(12*1700))$ = 92 mph (Peterka & Schahid 1998)

Step 2: Convert 3 second wind gust to a 30-second wind.

$V_{50\text{-}30sec} = V_{50\text{-}3sec} / 1.175$ = 78 mph (UFC 4-159-03 Fig 3-5, Hurricane Region)

Step 3: Convert wind from Exposure C value to Exposure D.

$V_{III} = V_{50\text{-}30} * \text{sqrt}(1.18)$ = 85 mph (74 knots) – Type III Mooring Design Wind

Procedures for calculation of mooring loads are found in UFC 4-159-03, *Design: Moorings*. Local anchorage design of the mooring foundation shall exceed the working capacity of the fitting times the Mooring load factor for LRFD design. Global design of the pier or wharf is based on the demands from the mooring analysis (e.g. not all of the storm bollards will be engaged at one time).

3-4.3 Wind Loads on Structures.

Use UFC 3-301-01, *Structural Engineering* to provide minimum wind load on structures. Keep in mind that UFC 3-301-01 is based wind is a 3-second gust with a return period of 300 years or greater, thus wind on structure typically will not be combined with berthing, or mooring loads (e.g. vacant condition).

3-4.4 Loads on Piles.

In addition to the axial loads, bending moments, and shears caused by lateral loads at deck level due to berthing, mooring and seismic forces, piles are also subjected to other types of lateral loads acting along the length of the pile. Keep in mind that, in areas having large tidal ranges, lateral loads are applied much lower than the deck elevation creating significant shear and flexural stresses in the piles.

3-4.4.1 Current and Waves.

These loads are applied at and near the water level and may be significant where large size piles are used in high-current waters. An estimate of current and wave forces can be made using the UFC 4-150-06, *Military Harbors and Coastal Facilities.*

3-4.4.2 Sloping Fill Loads.

These loads are transmitted along the shaft of the piles by the lateral movement of the soil surrounding the piles beneath the structure, such as may occur along a sloping shoreline at marginal wharves, as shown in Figure 2-9. The maximum moments in the piles for this category of loading are determined by structural analysis and the methods outlined in UFC 3-220-01, *Geotechnical Engineering,* after the conditions of pile support in the pile cap and the soil have been established and the effective length of pile has been determined.

Piles of relieving platform types of solid wharves, shown on Figure 2-10, may be subjected to lateral earth loads if the stability of the slope beneath the platform is minimal and soil creep occurs. In such cases, stabilizing measures should be introduced, prior to installation of piles, to prevent movement of the soil along the slope. Among the stabilizing measures that may be used are surcharging (preloading), installation of sand drains or soil compaction piles, or replacement of unstable materials. If the piles supporting the structure are used to increase slope stability, or if time-dependent stabilizing measures are introduced after the piles are in place, calculate the resistance to soil movement provided by the piles and the piles checked for the bending moments induced by the calculated lateral earth loads, in addition to the increased loading caused by the downdrag of the settling soil.

The pile resistance to soil movement may be obtained from a stability analysis by determining the additional resistance, provided by the piles, which will provide a factor of safety that corresponds to zero soil movement. The minimum factor of safety required for this type of analysis varies and should be selected after evaluating the soil conditions, which exist at the site. The embedment length of piles needed for developing the required lateral resistance may be determined in accordance with the criteria given in UFC 3-220-01*, Geotechnical Engineering*.

3-4.4.3 Pile Driving Loads.

Piles are subjected to high compressive and tensile stresses during driving and should be proportioned to resist these in addition to the service loads. Where prolonged driving in alternately soft and hard layers of soil or driving through stiff "quaky" clays is anticipated, very high tensile stresses are set up and will require a higher level of effective prestress (1000 psi (6895 kPa) or more) in prestressed concrete piles. Give attention to controlling driving stresses by specifying frequent cushion replacement, and by requiring use of hammers capable of adjusting driving energy.

3-4.5 Loads on Utilities.

Utilities should be located above pier deck. It is important to keep utilities high above the water level and preferably protected in trenches. In some cases utilities are located under the pier deck and are therefore, more susceptible to damage from wind, wave, current, and impact from debris. Regardless of utility location, consider environmental loads, e.g. wind, wave, current. In evaluating these loads, consideration must also be given to the appropriate water level. An estimate of current and wave forces can be made using the UFC 4-150-06*, Military Harbors and Coastal Facilities.*

3-4.6 Earthquake Loads.

Use the procedures and methods contained in ASCE/COPRI 61-14 *Seismic Design of Piers and Wharves,* hereafter known as ASCE 61, for seismic design of Piers and Wharves unless otherwise directed herein. Note that the ASCE 61 committee made a conscious decision to reference ASCE 7-05 throughout and not to include ASCE 7-10, mainly because ASCE 7-10 was published after the ASCE/COPRI 61-14 had been prepared. The ASCE 61 committee will reconsider referencing the most recent version of ASCE 7 in future versions.

3-4.6.1 Design Approach:

Use the design approach from Section 3.4 of ASCE 61 as modified below unless approval for an alternative approach is obtained from the approving authority.

a. Define the Design Classification in accordance with Table 3-4.
b. Determine which performance levels along with associated hazard levels need to be satisfied per ASCE 61 Table 2-1.
c. Determine the design method per 3-4.6.3.
d. Base definition of ground motion for Design Earthquake (DE) on the procedures in ASCE 7-10, see 3-4.6.4.
e. Determine soil/structure modeling parameters (p-y and t-z springs) per ASCE 61 Sections 4.8 and 4.10.

f. Determination of other special geotechnical considerations or loads in ASCE 61 Chapter 4.

g. Development of the structural model, including general modeling considerations of ASCE 61 Section 3.7.

h. Calculations of structural demands per ASCE 61.

i. Calculation of structural capacity per ASCE 61.

j. Development of connection details per ASCE 61 Chapter 7.

k. Design of ancillary components per ASCE 61 Chapter 8.

3-4.6.2 Design Classification.

Table 3-4 Seismic Design Classifications

Classification	Pier/Wharf
High [a]	Ammunition Fueling Supply Explosive Handling General Purpose Berthing Repair Magnetic Silencing Access Trestle Deep Water Bulkhead
Moderate [b]	
Low	Inactive Berthing Cargo Staging Area Shallow Water Bulkhead Seawalls and Riprap Fleet Landing Small Craft Berthing Small Craft Boat Ramp

[a] Only consider Operating Level Earthquake when S_{DS} exceeds 0.33
[b] Site/project specific considerations may dictate moderate versus high or low classification

3-4.6.3 Determine Seismic Analysis Procedure:

a. Non-linear time history analysis should be considered for high value national assets such as Explosive Handling Wharves when warranted.

b. Displacement-based design is permitted for all design classifications.

c. Force-based design is permitted for “low” design classifications per Table 3-4.

d. Force-based design is permitted for all design classifications when S_{DS} < 0.33

e. Force-based design is permitted for all design classifications where it can be demonstrated that the capacity of all primary structural members exceeds the elastic earthquake demand when using a value of R = 1.0.

f. Force-based design is permitted for the design of equipment, piping supports, and minor structures.

g. Allowable stress design (ASD) is permitted for geotechnical design of shallow and deep foundations when the soils report does not contain LRFD soils values.

3-4.6.4 Design Spectra.

In the absence of a site specific ground motion study reference tables from UFC 3-301-01, *Structural Engineering* for Design Earthquake (DE), 10/50 and 20/50 spectral acceleration values. For structures with a High Performance Level and S_{DS} >0.33, use the following equation to determine the spectral acceleration values associated with ground motion with a probability of exceedance of 50% in 50 years (72 year return period):

The spectral acceleration values for earthquakes with a 2 and 10% probability of exceedance in a 50-year period are typically well defined. To obtain seismic spectral accelerations for other recurrence intervals use the following formula based upon the procedure presented in Section 1.6.1.3 of FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*.

$$S_i = S_{i(10/50)} (C_i)$$

where:

S_i = Spectral acceleration parameter ("*i*" = "*s*" for short-period, or "*i*" = "1" for 1-second period)

$S_{i(10/50)}$ = Spectral acceleration parameter ("*i*" = "*s*" for short-period, or "*i*" = "1" for 1-second period) at a 10 % probability of exceedance in 50 years

C_i = Modifier provided in Tables 3-5 and 3-6 below ("*i*" = "*s*" for short-period, or "*i*" = "1" for 1 second period).

Table 3-5 Values of C_S, Modifier for Short-Period Spectral Acceleration

Design Earthquake Probability of Exceedance in 50 Years

Region	10%	15%	20%	50%	65%	75%
California	1.0	0.83	0.72	0.44	0.36	0.32
Pacific Northwest	1.0	0.79	0.67	0.36	0.29	0.25
Eastern US	1.0	0.72	0.56	0.23	0.17	0.14
Other locations	1.0	0.79	0.67	0.36	0.29	0.25

Notes:

1. The modifier C_s includes a statistical adjustment factor, "P_R ", and a location adjustment factor, "n", as defined in section 1.6.1.3 in FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, Nov. 2000. The value of "n" is taken as 0.54 for locations outside of the continental US.

2. This table is valid at locations where the Mapped MCE spectral acceleration for short-periods, S_S, is less than 1.5*g*.

Table 3-6 Values of C_1, Modifier for 1-Second Period Spectral Acceleration

Design Earthquake Probability of Exceedance in 50 Years

Region	10%	15%	20%	50%	65%	75%
California	1.0	0.83	0.72	0.44	0.36	0.32
Pacific Northwest	1.0	0.77	0.64	0.33	0.26	0.22
Eastern US	1.0	0.71	0.55	0.22	0.16	0.13
Other locations	1.0	0.77	0.64	0.33	0.26	0.22

Notes:

1. The modifier C_1 includes a statistical adjustment factor, "P_R ", and a location adjustment factor, "n", as defined in section 1.6.1.3 in FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, Nov. 2000. The value of "n" is taken as 0.59 for locations outside of the continental US.
2. This table is valid at locations where the Mapped MCE spectral acceleration for short-periods, S_S, is less than 1.5g.

3-4.6.5 Dynamic Fill Loads.

In general, piles subjected to seismic forces behave as flexible members and their behavior is controlled primarily by the surrounding soil. Both vertical and batter piles move together with the surrounding soil during an earthquake. Provided that shear failure or liquefaction of the surrounding soil does not occur during ground shaking, the pile-supported structure will move a limited amount and remain stable after an earthquake. The magnitude of the horizontal movement depends on the earthquake magnitude and duration, design details of the platform, flexibility of the piles, and the subgrade modulus of the foundation soil. If the soil surrounding the piles is susceptible to liquefaction or if slope failure occurs, the piles will move excessively, resulting in serious damage to the piles and the structure. For these conditions, remove and replace unstable materials. When the piles penetrate a deep soft layer first and then a stiff layer of soil, the soils displace cyclically back and forth during an earthquake. During the cyclic ground shaking, the piles will move with the ground and return essentially to their original position if the soil does not fail during these cyclic displacements. Accordingly, if piles are to continue to safely support loads after an earthquake, it will be necessary for the piles to have the capability to withstand the induced curvature without failure.

3-4.6.6 Embankments and Fills.

For determining the stability of embankments and fills at solid wharves, when subjected to earthquake forces, refer to UFC 3-220-01, *Geotechnical Engineering*, NCEL TR-939, *The Seismic Design of Waterfront Retaining Structures* and NCHRP Report 611, *Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankments*.

3-4.6.7 Floating Structures.

Usually, floating structures are not directly affected by seismic events. However, waves created by offshore seismic activity such as a seiche or tsunami will affect floating structures. Also, the mooring system employed (spud piles and chain) will be subjected to the ground motions and should be investigated.

3-4.6.8 Earthquake Induced Hydrodynamic Loads.

Refer to STANDARD 61 Section 3.7.3 "*for 24 in. and smaller piles hydrodynamic mass may be ignored*." For larger piles include the hydrodynamic water mass inside and outside of the pile/structure in accordance with STANDARD 61 Section 3.7.3.

3-4.6.9 Crane Wharf Interaction.

Refer to STANDARD 61 Sections 3.7.3 and 8.5.2. "The mass of container cranes shall be determined in accordance with Section 8.5.2 and distributed over the length of the pier or wharf."

3-4.6.10 Dry Docks.

Refer to MIL-STD 1625D (SH) *Safety Certification Program for Dry docking Facilities and Shipbuilding Ways for U.S. Navy Ships* as it relates to seismic requirements for dry docks. Reference requires that a new seismic analysis be performed for dry docks and specifies design earthquake levels and performance criteria. Method(s) of performing analysis is currently under development by NAVFAC EXWC.

3-4.7 Earth and Water Pressures on Retaining Structures.

Consider the effects of tidal lag, overdredging, the potential for dredge depth increases to accommodate deeper draft vessels, and sloughing of fill.

3-4.7.1 Static Case.

Static earth pressures, acting on retaining structures, are determined in accordance with the criteria detailed in UFC 3-220-01*, Geotechnical Engineering.*

3-4.7.2 Dynamic Case.

Seismic forces may cause increased lateral earth pressures on earth retaining wharf structures accompanied by lateral movements of the structure. The degree of ground shaking that retaining structures will be able to withstand will depend, to a considerable extent, on the margin of safety provided for static loading conditions. In general, wharf retaining structures, designed conservatively for static loading conditions, may have a greater ability to withstand seismic forces than those designed, more economically, by less conservative procedures. Methods for determining lateral earth pressures due to seismic forces are discussed in UFC 3-220-01, *Geotechnical Engineering*, NCEL TR-939, *The Seismic Design of Waterfront Retaining Structures* and NCHRP Report 611, *Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankments*.

3-4.7.3 Water Pressure.

Consider pressures due to water level differentials, resulting from tidal fluctuations (tidal lag) and/or groundwater accumulations, in the design of sheet pile bulkheads, cells, and curtain walls, and in stability investigations for embankments and fills. Consider additional loading due to hydrodynamic pressure for retaining structures as addressed in UFC 3-220-01*, Geotechnical Engineering*.

3-4.8 Thermal Loads.

3-4.8.1 Temperature Differential.

The effect of thermal forces that build up in the structure due to fluctuations in temperature will vary from those measured at the time of construction. For piers and wharves, the large body of adjacent water has a substantial moderating effect on the structure. Consequently, the structure may not attain an overall temperature 10 to 20 °F (5.6 to 11.1 °C) higher or lower than the water temperature. The effect will be even less for ballasted deck construction (5 to 10 °F (2.8 to 5.6 °C) higher or lower than water temperature). However, unballasted decks may see a large temperature differential through depth. Consult with AASHTO for recommended thermal gradients over water. Solid-type piers and wharves and floating structures are not likely to be affected by temperature variations.

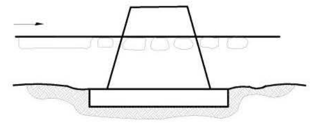
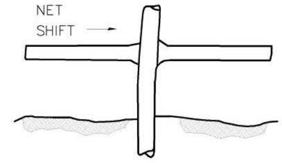
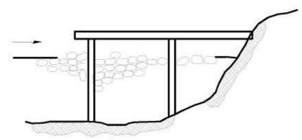
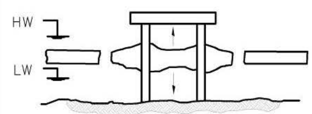
3-4.8.2 Pile-Supported Structures.

Typically, decks of pile-supported structures will be subjected to temperature differential. However, since the axial stiffness of the deck elements will be much higher than the flexural stiffness of piles, the deck will expand or contract without any restraint from piles (for narrow marginal wharves, the short inboard piles may offer some restraint, and hence need to be analyzed) and will subject the piles to bending moments and shear forces. Locate batter piles so as not to restrain thermal motion (usually in the middle portion of a long structure).

3-4.9 Ice Forces.

In addition to the weight of accumulated ice on the structure, consider the forces exerted by floating ice. The principal modes of action of floating ice are shown in Figure 3-7 and discussed below.

Figure 3-7 Principal Modes of Ice Action

NO.	DESCRIPTION	TYPICAL ENVIRONMENT	ILLUSTRATION
1	IMPACT OF MOVING SHEETS AND FLOES.	RIVERS AT BREAK-UP. COASTAL WATERS WITH APPRECIABLE CURRENTS	
2	STATIC PRESSURE FROM EXPANDING OR CONTRACTING SHEETS.	LAKES, SHELTERED COASTAL WATERS. TEMPERATURE CHANGES AND JACKING BY REFREEZING OF CRACKS.	
3	SLOW PRESSURE FROM ICE PACK OR JAM.	EXPOSED COASTAL WATERS, RIVERS.	
4	VERTICAL MOVEMENT	TIDAL LOCATIONS WITH HEAVY ICE BUILD-UP.	

3-4.9.2 Dynamic Impact.

Follow the criteria in the AASHTO standard to the extent feasible. For lightly loaded structures and for open pile platforms, these criteria may result in structures of unreasonable proportions. In such cases, consider reducing the AASHTO criteria in accordance with CSA-S6 *Canadian Highway Bridge Design Code*. See AASHTO *Dynamic Ice Forces on Piers and Piles*. The values of effective pressure are:

- AASHTO .... 400 psi (2,758 kPa)
- CSA-S6 .... 100 to 400 psi (689 to 2,758 kPa) (highway bridges)
- CSA-S6 .... 200 to 250 psi (1379 to 1,724 kPa) (wharf piles)

3-4.9.3 Static Pressure.

Freshwater ice will exert less pressure on a structure than seawater ice of the same thickness. For freshwater ice, assume pressures of 15 to 30 psi (103 to 207 kPa). For sea ice, pressures of 40 psi (276 kPa) to as much as 150 psi (1,034 kPa) may be assumed. These are maximum values and relate to crushing of the ice. If the ice sheet can ride up on the nearby shore, the pressure exerted will be less than if the ice sheet is confined within vertical boundaries.

3-4.9.4 Slow Pressure.

Broken ice flows will exert less pressure than a solid ice sheet. In general, the pressures developed in this mode of action will be less than those experienced under the static pressure mode of action. Reliable values of pressure are not presently available.

3-4.9.5 Vertical Movement.

Assume that the structure will lift or depress a circular sheet of ice. Calculate the radius of the affected ice sheet on the basis of the flexural strength of ice as 80 to 200 psi (552 to 1,379 kPa). Check the shear on the basis of the strength (and adhesion) as 80 to 150 psi (552 to 1,034 kPa). Consider the formation of bustle (added thickness) of ice around the structure. See AASHTO *Ice Pressure on Engineering Structures*.

3-4.10 Shrinkage.

Open pier and wharf decks, which are usually constructed from concrete components, are subject to forces resulting from shrinkage of concrete from the curing process. Shrinkage loads are similar to temperature loads in the sense that both are internal loads. For long continuous open piers and wharves and their approaches, shrinkage load is significant and should be considered. However, for pile-supported pier and wharf structures, with cast-in-place concrete pile caps and decks, the effect is not as critical as it may seem at first because, over the long time period in which the shrinkage takes place, the soil surrounding the piles will slowly "give" and relieve the forces on the piles caused by the shrinking deck. The PCI Design Handbook (section 7.3.1.1) and ACI 209.2R 08, *Guide for Modeling and Calculating Shrinkage and Creep in Hardened Concrete* are recommended for design.

3-4.11 Creep.

This is also a material-specific internal load similar to shrinkage and temperature and is critical only to prestressed concrete construction. The creep effect is also referred to as rib shortening and should be evaluated using the *PCI Design Handbook.*

3-5 LOAD COMBINATIONS.

3-5.1 General.

Proportion piers and wharves to safely resist the load combinations represented by Tables 3-7 and 3-8. Analyze each component of the structure and foundation elements for all the applicable combinations.

3-5.2 Load Symbols.

The following load symbols are applicable for Table 3-7 and Table 3-8:

D = Dead load

L_u = Live load (uniform)

L_c = Live load (concentrated)

I = Impact load (for L_c only)

B = Buoyancy load

H = Loads due to lateral earth, ground water, or pressure of bulk material

Be = Berthing, for Accidental Berthing see section: Accidental Berthing

C = Current load on structure

EQ = Earthquake load

k = 50% of Peak Ground Acceleration (PGA)

k' = 0.7k = (0.7)(0.5)PGA = (0.35)PGA

W = Wind or wave load on structure

M = Mooring/Breasting load

R = Creep/rib shortening

S = Shrinkage

T = Temperature load

Ice = Ice load (includes snow load)

3-5.3 Load and Resistance Factor Design (LRFD).

Load combinations are presented in Table 3-7. For load cases not listed consult IBC Section 1605.2.

3-5.4 Service Load Design/Allowable Stress Design (ASD).

Load combinations are presented in Table 3-8. For load cases not listed consult IBC Section 1605.3.

Table 3-7 Load Combinations - Load and Resistance Factor Design (LRFD)

Load	U0	U1	U2	U3	U4	U5	U6	U7	U8	U9
D [a]	1.4	1.2	1.2	1.2	1.2	1.2	1.0+k	1.0-k	1.2	1.2
$(L_c+I)\|L_u$	-	1.6 [b]	-	1.6 [b]	-	1.6 [b]	0.1	-	1.6 [b]	1.0
B	1.4	1.2	1.2	1.2	1.2	1.2	1.2	0.9	1.2	1.2
Be	-	-	1.6 [c]	-	-	-	-	-	-	-
C	-	-	1.2	1.2	1.2	1.2	-	-	-	1.2
H [d]	-	1.6	1.6	1.6	1.6	1.6	1.0	1.0	1.6	1.6
Eq	-	-	-	-	-	-	1.0	1.0	-	-
W	-	-	-	-	1.0	-	-	-	-	1.0
M	-	-	-	-	-	1.6	-	-	-	-
R+S+T	-	-	-	1.2	-	-	-	-	-	-
Ice		-	-	0.5	-	-	-	-	1.0	1.0

Table 3-8 Load Combinations - Allowable Stress Design (ASD)

Load	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
D [a]	1.0	1.0	1.0	1.0	1.0	1.0	1+k’	1-k’	1.0	1.0
$(L_c+I)\|L_u$	-	1.0	-	1.0	-	1.0	0.1	-	1.0	0.75
B	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.6	1.0	1.0
Be	-	-	1.0	-	-	-	-	-	-	-
C	-	-	1.0	1.0	1.0	1.0	-	-	1.0	1.0
H [d]	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Eq	-	-	-	-	-	-	0.7	0.7	-	-
W	-	-	-	-	0.6	-	-	-	-	0.6
M	-	-	-	-	-	1.0	-	-	-	-
R+S+T	-	-	-	1.0	-	-	-	-	-	-
Ice	-	-	-	0.2	-	-	-	-	0.7	0.7

Notes:

[a] 0.9 (0.6 ASD) for checking members for minimum axial load and maximum moment.

[b] 1.3 for the maximum outrigger float load from a truck crane.

[c] Accidental Berthing: 1.2 support structure, 1.0 fender system components.

[d] Where the effect of H resists the primary variable load effect, a load factor of 0.9 (0.6 for ASD) shall be included with H where H is permanent and H shall be set to zero for all other conditions.

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CHAPTER 4 STRUCTURAL DESIGN

4-1 CONSTRUCTION MATERIALS.

4-1.1 Timber.

For the major functional types of piers and wharves such as ammunition, berthing, repair, and supply facilities subject to high concentrated wheel loads, timber construction should not be considered. Timber may be more effective and optimal for fender systems, dolphins, walkways, utility trays, and deck-supported small buildings. For light-duty piers and wharves, such as fueling, temporary, and Magnetic Treatment and Electromagnetic Roll piers, timber framing for deck and piling may be considered. Consult with the local activity and Facilities Engineering Command (FEC) for local requirements and restrictions on the use of treated timber. Obtaining permits for treated timbers, especially creosoted fender pile, is becoming very difficult in various areas of the country.

4-1.1.1 Preservative Treatment.

All timber members, with the exception of some fender piling, exposed to the marine environment and immersed in salt water or fresh water should be pressure treated. Per AWPA UC5C, treatment with CCA or ACZA in accordance with Best Management Practices is acceptable. Treat with waterborne (salts) chemical preservatives to protect against deleterious effects of decay, insects, and marine borers. In warmer waters, where severe marine borer activity can be anticipated, treat with salt. Consult the staff entomologist at the cognizant FEC for specific information on marine organisms present and the treatment required.

If possible, make pressure treatment after all holes and cuts are made. When holes and cuts are made in the field, treat timber members with preservative to prevent decay from starting in the holes or cuts. Consult a staff entomologist for the proper preservative. Field treatments are difficult in the tidal zone and are typically not very effective against marine borers. Therefore, whenever possible, design and detailing should avoid the necessity for making cuts or holes on underwater timber members. For example, avoid bracing or connections below mean high water. All connection hardware should be suitable for the saltwater exposure. For above water construction, waterborne salt treatment is preferable to creosote treatment due to the staining effect that creosote treatment produces.

4-1.1.2 Timber Species.

Douglas fir and southern pine are the most popular species for waterfront construction. Southern pine piles are limited to 65 feet (19.8 m) in length, whereas Douglas fir piles and poles can be used in up to 100-foot (30.5 m) lengths. Large beams and timber sizes needed for chocks and wales are generally available only in Douglas fir and southern pine. Treat chocks and wales with waterborne salts and not oilborne preservatives such as creosote. Evaluate the cost and availability of timber piles and other members for the project.

4-1.2 Steel.

When protected against corrosion by the use of coal tar epoxy or other marine coatings and cathodic protection systems, steel construction may be considered for all types of marine structures. Active cathodic systems are difficult to design, construct, and maintain properly, therefore, passive systems are preferred. UFC 3-570-01, *Cathodic Protection* provides criteria regarding cathodic protection system design. Additional steel thickness may be provided as a sacrificial corrosion allowance. Steel is particularly adaptable for use: in template and jack-up barge construction at advance base facilities; as piles for structures located in deep water where high lateral forces exist; as fender piles and fender panels; as piles for structures located in areas of high seismic activity; and where difficult driving is anticipated. When the utilization of other construction materials is considered feasible, the use of steel construction may be restricted due to cost and maintenance considerations.

Coating of structures and materials in the harsh marine environment is of the utmost importance, particularly in the area known as the splash zone. The “Splash Zone” is defined as the area between the year’s lowest tidal mark and up to ten feet above the year’s highest tidal mark. An earlier generation coating was developed formulated from polysulfide modified novolac epoxy. This was renamed Zero VOC, Coal Tar Free Splash Zone Coating (SZC). SZC is expected to provide at least “twice” the performance compared to the currently specified coating systems. ESTCP Project WP-200528 Zero VOC, Coal Tar Free Splash Zone Coating (SZC), Final Report provided a full scale validation of the SZC for use as an in-service waterfront maintenance system and enables the transition of this coal tar free coating directly into the hands of DOD end users who require waterfront metal (e.g., sea walls, sheet pile) maintenance painting. Further, this project addressed performance and environmental requirements for sustainment and reduction of VOC and HAP emissions due to the SZC being free of toxic metals, hazardous air pollutant free, contains no coal tar pitch, and has zero VOC’s.

4-1.3 Concrete.

For piers and wharves, concrete is generally the best material for construction. Properly designed and constructed facilities are highly durable in the marine environment. New advances in concrete technology have improved concrete durability. Concrete enhanced with fly ash and corrosion inhibitors has demonstrated superior performance and should be used whenever possible. UFGS 03 31 29, *Marine Concrete* contains the latest developments in marine concrete. Caution should be exercised when using silica fume considering the guidance and precautions contained in the UFGS. Concrete is also ideal for deck construction in open-type piers and wharves and, when properly designed, is more economical for floating structures. Proprietary stainless steel reinforcement bars, wires, and strands have been developed for use in concrete construction where nonmagnetic properties are desired as in Magnetic Treatment and

Electromagnetic Roll piers. In contrast to new concrete, repair concrete requires different considerations in terms of design, materials, construction and quality control. In this regard, TR-NAVFAC-EXWC-CI-1304 *Enhanced Guidelines for Marine Concrete Repair,* has been prepared documenting some of the key considerations for marine concrete repair and pointing to the need of a dedicated UFGS. Three primary advancements to be contained in the specification include: enhance quality control/quality assurance, use of embedded galvanic anodes, and use of form and pressure pump repair methods. Consider protection of the concrete reinforcement from corroding to all construction located in a spray zone, not only to partially submerged construction, but to concrete in a dry-wet zone. Consider achieving concrete densification using a fly ash as substitute in a concrete matrix and / or utilization of the cementitious epoxy coating for protection of the concrete and structural steel in the dry-wet zone.

4-1.3.1 Precast Concrete Piles.

Precast concrete piles should preferably be prestressed to resist the tensile forces frequently encountered during driving. Corrosion of reinforcement in prestressed concrete piles can be controlled by proper mix design and, in extreme cases, by epoxy coating the reinforcement. However, exercise sufficient control during driving of concrete piles to minimize cracking. Where difficult driving into very compact sands, gravels, or rock is anticipated, the tip of the piles may be equipped with a WF-shape or H-pile "stinger" to achieve needed penetration. Exercise caution when selecting the material for an internal jet pipe in solid precast piles. There have been issues on some projects during pile driving when plastic/PVC is used for the internal jet pipe. Issues arise when concrete piles are driven and jetted at the same time in clayey soils. The clays can clog the jet pipe resulting in water hammer. The plastic/PVC jet pipes tend to crack under these conditions resulting in cracks forming in the concrete pile.

Very large hollow cylindrical piles (48-inch (1.2 m) diameter and larger) have also been successfully employed for waterfront construction on the East coast. However, longitudinal cracking was encountered with these same types of piles during construction of Pier D at Bremerton, Washington. Recently, proprietary carbon fiber pre-stressing and post tension strands have come into the market. These strands could have future applications such as for Magnetic Treatment and Electromagnetic Roll piers.

4-1.4 Composites.

Composites made of concrete and steel, concrete and fiberglass, plastic and fiberglass, and plastic and steel have been successfully employed in piers and wharves. Composites offer many advantages over conventional materials but often have limitations that need to be considered. Some advantages may include improved corrosion resistance, lightweight, and ease of construction. Some of the disadvantages may include low strength, UV light deterioration, long-term durability and high cost.

4-1.4.1 Concrete and Steel.

Concrete-filled pipe piles, steel H-piles with a concrete casing, and steel beams with concrete decks are the more common composite types. The concrete casing or jacket for the steel H-piles may be required only in the splash or tidal zone. However, due to instances of severe deterioration of the pile just below the jacket, extend the jacket to Extreme Low Water (ELW) or to below mudline. Concrete may also be added to steel pipe piles for deadweight purposes to resist uplift forces or to increase the stiffness of the pile.

4-1.4.2 Concrete and Fiberglass.

Concrete-filled fiberglass piles have been used in facilities where high axial capacities are not required. The lightweight fiberglass piles are easily installed and do not require high capacity handling equipment.

4-1.4.3 Plastic and Fiberglass.

Fiberglass reinforced plastic piles and beams have been successfully used in pier and wharf construction primarily as fender piles, wales and chocks.

4-1.4.4 Plastic and Steel.

Recycled plastic piles with steel cage reinforcement have also been used in pier and wharf construction.

4-1.5 Aluminum.

For deck-supported structures and for support of piping and conduits, aluminum members are useful. However, do not use unprotected aluminum underwater or in the splash zone. To prevent corrosion, aluminum should be electrically isolated from adjacent materials by nonconductive gaskets, washers, or bolt sleeves. Aluminum construction may be used in the superstructure of Magnetic Treatment and Electromagnetic Roll piers, due to the nonmagnetic characteristics of the material.

4-1.6 Plastics.

Fiberglass-reinforced plastics (FRP), ultra-high molecular weight (UHMW) plastics, and high-density polyethylene (HDPE) are being increasingly used in waterfront construction. FRP grating and shapes are highly durable in the marine environment when shielded from ultraviolet rays. UHMW plastics are useful in fender systems design as rub strips where a high abrasion resistance and low coefficient of friction are required. UHMW plastics are available in various grades. The use of corrosion-resistant FRP components including reinforcing bars, prestressing tendons, structural shapes, and unidirectional or woven fabrics, are being developed and have been successfully used in the repair of piers and wharves. Consider using these materials when the situation warrants, but give special attention to the design of connections.

Carefully evaluate the use of FRP components as structural elements for new construction.

4-2 ALLOWABLE STRESSES.

4-2.1 General.

Allowable stresses for materials used in pier and wharf construction generally conform to industry standard codes for the type of material and the purposed application unless modified herein. Allowable stresses for fender system design are discussed in section: FENDER SYSTEMS.

4-2.2 Timber.

Design timber structural elements in accordance with UFC 1-200-01, *DoD Building Code (General Building Requirements)*. Allowable stresses are generally not affected by preservative treatment. However, modulus of rupture and modulus of elasticity are considerably reduced by preservative treatment. When preservative treatment for fire retardation is used, consult the National Design Specification (NDS) for reductions in allowable stresses.

4-2.3 Steel.

Design steel structural elements in accordance with UFC 1-200-01, *DoD Building Code (General Building Requirements)*.

4-2.4 Castings.

Design cast steel and cast iron mooring fittings with the following minimum factors of safety (FS), Minimum FS towards yield = 2.0, Minimum FS towards fracture = 3.0.

4-2.5 Concrete.

Design concrete structural elements in accordance with UFC 1-200-01, *DoD Building Code (General Building Requirements)*. For prestressed concrete members, “zero” tension design is preferred. When combining precast and cast-in-place concrete in composite deck systems required prestress level to prevent tensile stresses is likely to be governed by differential creep and shrinkage strains, which are sensitive to humidity, temperature, curing conditions, and age of precast at integration. All reinforced concrete deck members should meet the crack control requirements for severe exposure.

4-2.6 Other Materials.

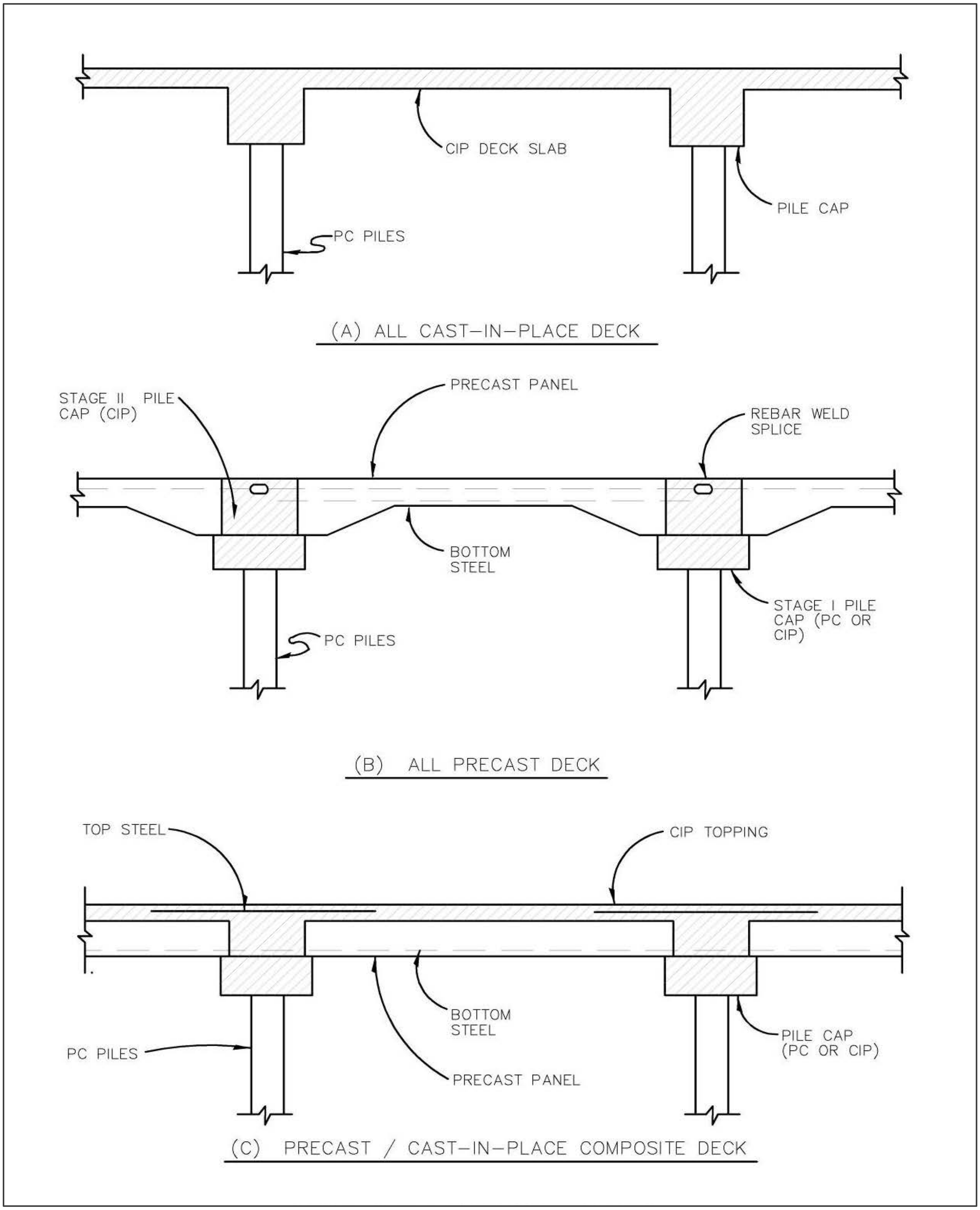
FRP, UHMW, and other new materials should be governed by the accepted industry standards for structural design and detailing.

4-3 DECK STRUCTURE DESIGN.

4-3.1 Deck Framing.

Concrete is generally considered the best material for deck framing and should be used for most pier and wharf decks. Although timber, steel, steel/concrete composite, and timber/concrete composite decks have been used in the past, they are neither cost-effective nor suitable for the high concentrated load capacities currently demanded of decks. From durability, maintenance, and life-cycle-cost viewpoints, a concrete deck is superior and is highly recommended. The deck framing should be slabs supported on pile caps, using an all cast-in-place, all precast, or composite construction, as shown in Figure 4-1. For the concentrated loads which typically control the deck design, a solid slab with its high punching shear resistance is recommended. Framing systems using thin slabs, as in cast-in-place slab/beam/girder systems, should not be used because of the tendency to spall along beam/girder corners and edges. Map cracking in the cast-in-place topping at the precast panel joints is sometimes seen. In precast/cast-in-place concrete composite structures design, consider differential creep and shrinkage when specifying post-tensioning stress level. Studies have demonstrated that prestress losses and redistribution of prestress forces can be significant in this construction type, minimizing the effectiveness of the intended crack mitigation measures. For distribution of horizontal loads, pier and wharf decks should be continuous, with as few expansion joints as possible. Where expansion joints are needed, the deck on each side of the joint should be supported on a separate pile cap or girder. Other options are flat plate requiring no pile cap.

Figure 4-1 Concrete Deck Construction



4-3.2 Pile Caps.

Orienting pile caps transverse to the length of the structure provides improved lateral stiffness for berthing and mooring forces. When this orientation is used, longitudinal pile caps are not needed unless crane trackage support or longitudinal seismic resistance is to be provided. For marginal wharves where lateral loads from mooring and berthing loads are transferred to the land, a longitudinal orientation of the pile cap may be considered if feasible for construction. Moments and shears on pile caps from live loads should take into account the elastic shortening of the piles and the effect of soil deformation at and near pile tips.

4-3.2.1 Pile Cap Orientation.

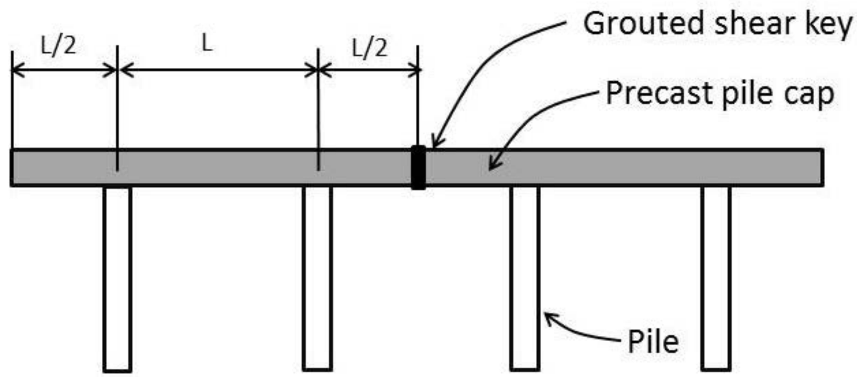
Traditionally, it was assumed to be more cost-effective to orient pile caps (and hence pile bents) transverse to the length of the structure. However, orientation of the pile caps longitudinal to the length of the pile provides uninterrupted paths for utilities that run in this direction, which may result in cost-savings over piers with pile caps in the transverse direction by minimizing conflicts between cap beams and utilities. Use of pile caps oriented in the longitudinal direction will require tie beams designed to transfer lateral loads from mooring and berthing loads to the foundation. Additional stiffness can be added to piers with pile caps in the longitudinal direction with the use of tabletop sections. An example of a cost-effective pier with pile caps oriented in the longitudinal direction and tabletop pile caps can be found in NAVFAC-EXWC-CI-TR-1413, *The Use of Prestressed Concrete for Corrosion Prevention in US Navy Piers.*

For computation of forces from high concentrated loads, the cap behaves as a beam on elastic foundation, and distributes the concentrated load to a number of piles adjacent to the load.

4-3.2.2 Precast/Prestressed Pile Cap.

A durable concept for precast/prestressed pile caps is a single span beam supported on two piles, which is balanced by two cantilevered ends that extend to the mid-span of the adjacent bays as shown in Figure 4-2. Prior to integration with the deck elements, it can be shown with a moment-diagram that the soffit of the cap beam will remain in compression under uniform load. This prestress from gravity will enhance durability by minimizing cracking of the concrete in the splash zone of the pier as illustrated in Figure 4-3. Additional prestress can be a specified for the cap beam during fabrication to maintain compression in the concrete under crane loads during installation and for service level loads after integration with the deck elements. Details for this design can be found in NAVFAC-EXWC-CI-TR-1413, *The Use of Prestressed Concrete for Corrosion Prevention in US Navy Piers.* A recommended detail for the joint between adjacent pile cap beams in shown in Figure 4-2.

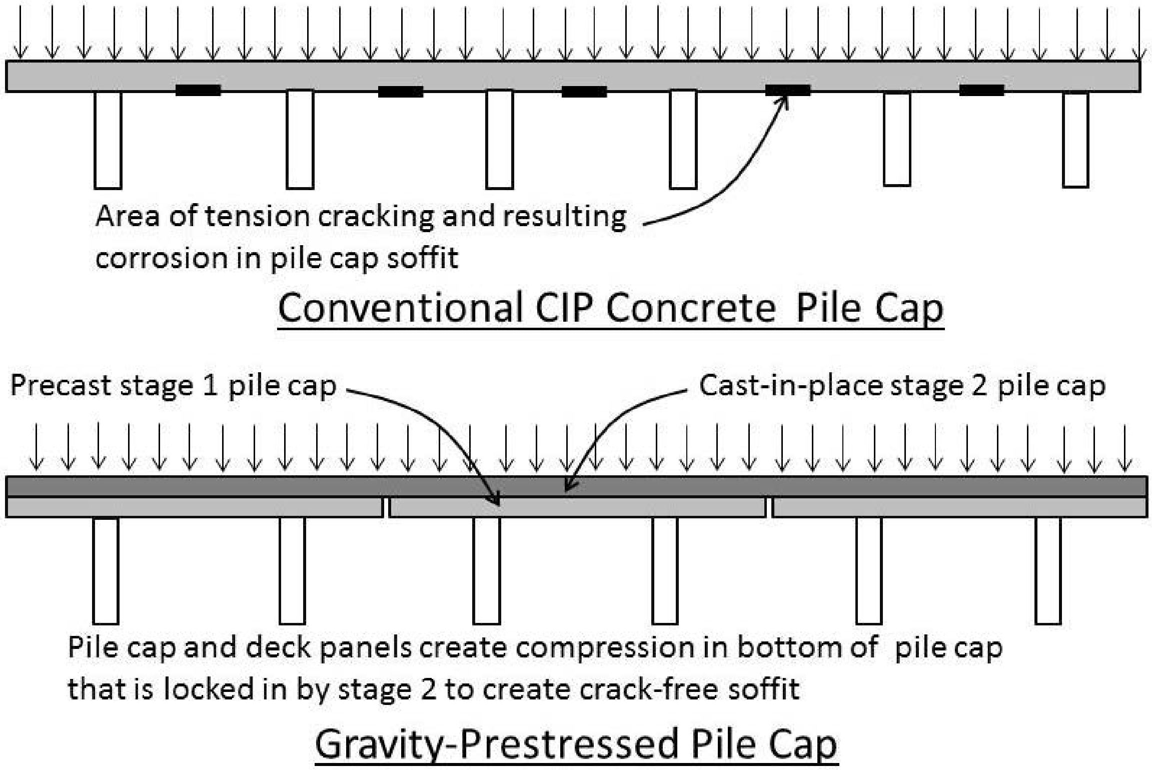
Figure 4-2 Cantilevered Precast Pile Cap



4-3.3 Tabletop Pile Caps.

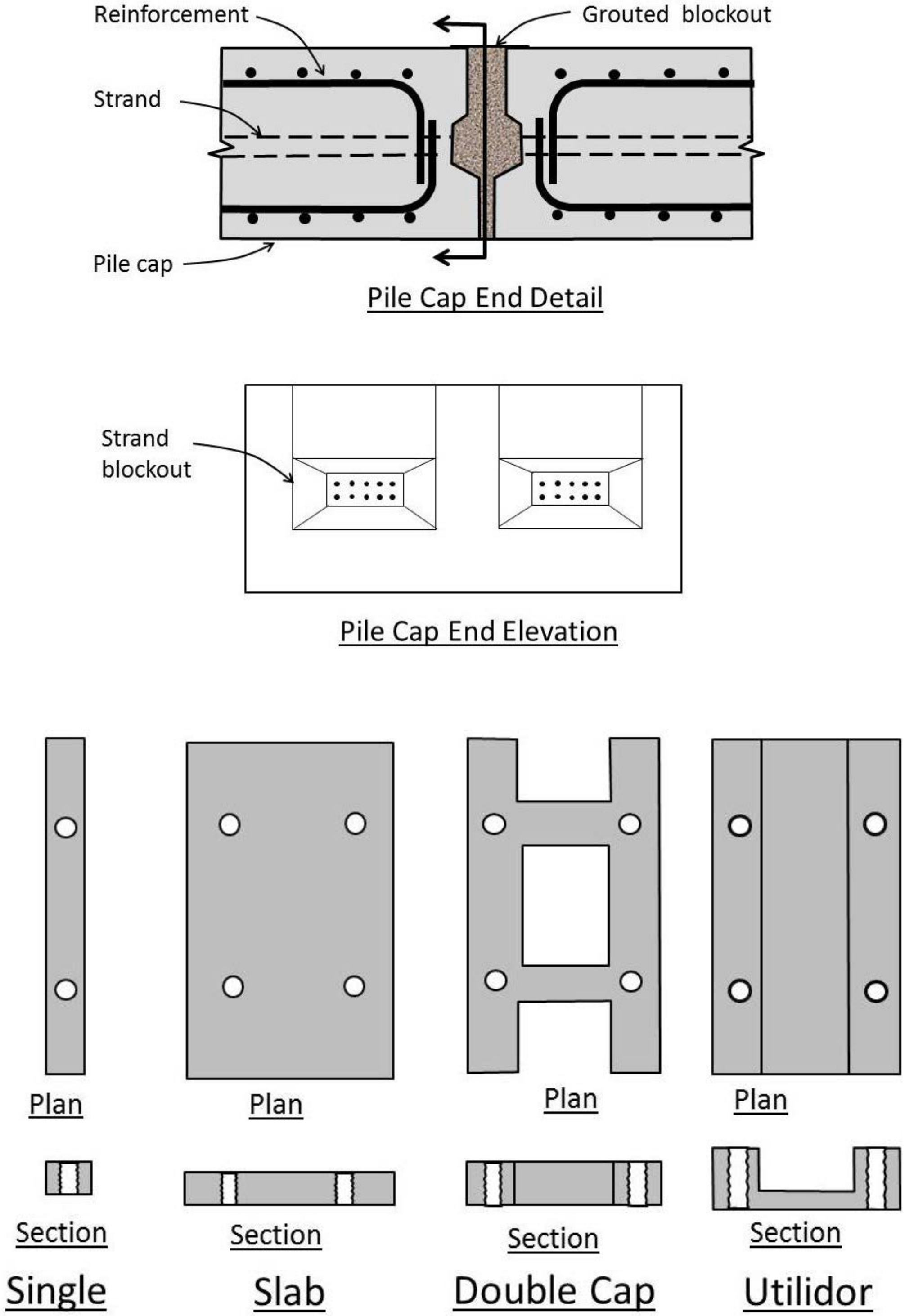
Precast construction is an effective method to enhance durability of waterfront structures while reducing cost; however, one of the challenges of precast construction is integrating individual pieces into a continuous structure. A solution for precast concrete construction is to use tabletop pile caps, which are two-way elements capable of transferring resisted loads to four support piles. Proper implementation will form a self-contained stable platform that when integrated into the deck diaphragm forms a complete lateral load resisting system. Tabletop configuration may vary based on pier requirements, but three potential tabletop variations are the slab, double cap, and utilidor, which are shown in Figure 4-4 along with a single span pile cap beam. Implementation of tabletop pile caps into a pier design is demonstrated in NAVFAC-EXWC-CI-TR-1413, *The Use of Prestressed Concrete for Corrosion Prevention in US Navy Piers.*

Figure 4-3 Conventional versus Gravity Prestressed Pile Caps



Precast Pile Cap Showing End Configurations

Figure 4-4 Tabletop Pile Cap Variations



4-4 SUBSTRUCTURE DESIGN.

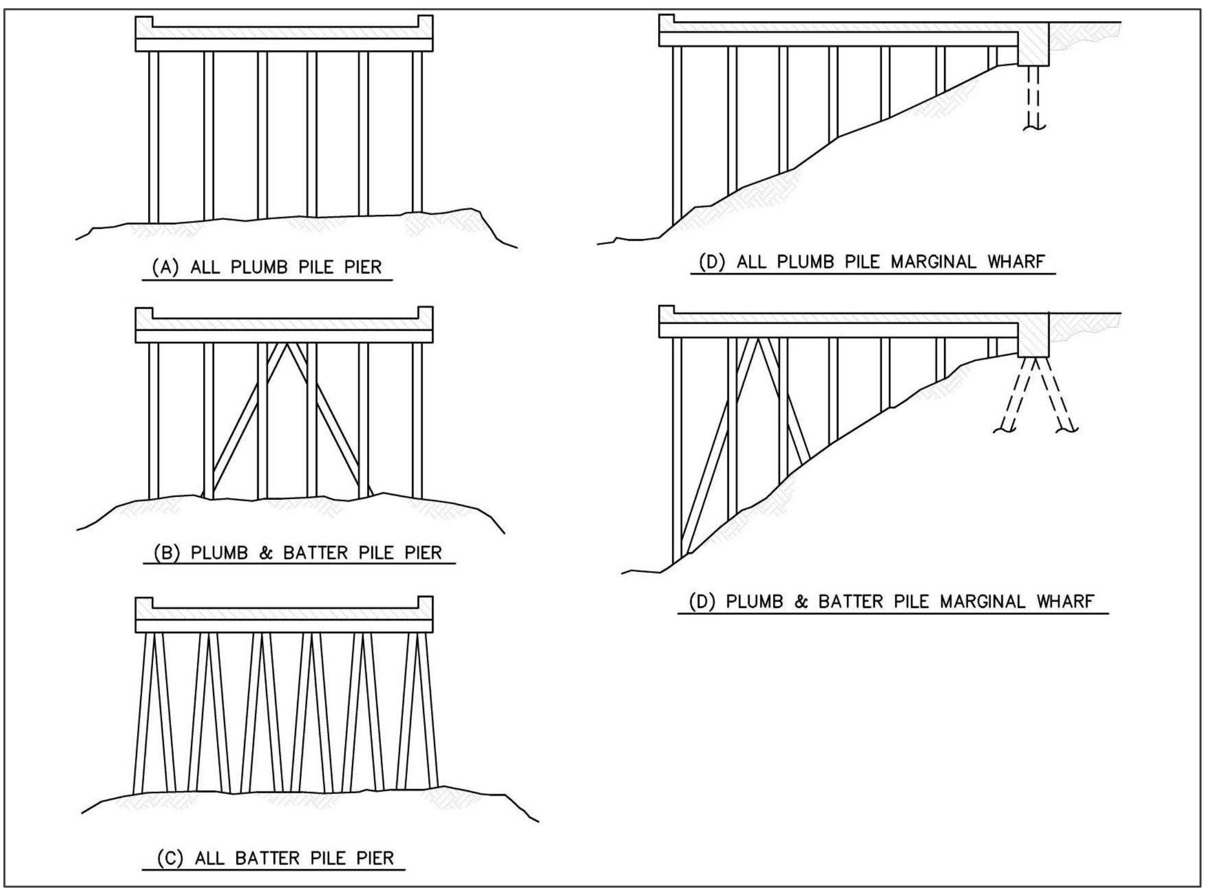
4-4.1 Geotechnical.

General geotechnical guidance and minimum technical requirements for DoD facilities is contained in UFC 3-220-01, *Geotechnical Engineering*. However, given the somewhat unique aspects of marine geotechnical engineering, traditional geotechnical engineering practices need to be supplemented. In this regard, an appropriate reference is *Handbook of Marine Geotechnical Engineering.* This document addresses a variety of structures ranging from piles, moorings, and anchors and the seafloor response whether in shallow or deep water.

4-4.2 Pile Bent Framing.

A pile-supported framing system is the most popular form for substructure design for open piers and wharves. Several framing concepts for open piers and wharves and marginal wharves are illustrated in Figure 4-5. Many variations and combinations of the illustrated concepts are possible.

Figure 4-5 Substructure Framing Concepts



4-4.2.2 All Plumb Pile System.

The lateral loads are resisted by "frame action," whereby the piles and the cap form a moment frame and resist the lateral load primarily by the flexural stiffness of the piles. However, for narrow structures, lateral deflection may be high for even small lateral loads. Also, sidesway is not prevented, which increases the effective length of the pile as a column. If piles vary in unsupported length, the shorter piles will attract a large portion of the lateral load. Because the piles are more efficient for axial loads and less so for bending moments, this framing usually is restricted to shallow waters and light lateral loads. However, for wide structures with a large number of piles, the total stiffness of the system may justify a reduced effective length. A more in-depth stability analysis is needed to validate a reduced effective length. Large diameter steel pipe and precast/prestressed concrete cylinder piles can provide improved lateral stiffness and are attractive for use in areas of high seismic activity.

4-4.2.3 Plumb/Batter Pile Systems.

In this type of framing, all the vertical loads are primarily handled by the plumb piles, and lateral loads are resisted primarily by the batter piles. The behavior of the system is one of "truss action." This system is more cost-effective as the lateral loads are resisted primarily by the axial stiffness of the batter piles. However, very high forces are transmitted to the caps, which will have to be designed and detailed to resist these forces. In areas of high seismic activity, the increased stiffness of the system reduces the period and leads to higher earthquake loads.

4-4.2.4 All Batter Pile System.

This system is a compromise between the two above, and is cost-effective in some circumstances. With this system, the batter slope may be near vertical. Natural periods can be as high as several seconds, making the approach attractive for seismic areas.

4-4.2.5 Batter Pile System with Seismic Isolation.

This system incorporates calibrated isolators or seismic fuses between the wharf deck and batter piles. The system allows for high displacements of the wharf deck once a threshold lateral load causes the isolator slip. Design guidance can be found in ASCE/COPRI 61-14, *Seismic Design of Piers and Wharves* and ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures*. Consider the magnitude of lateral berthing and mooring forces such that they do not exceed the threshold lateral force of the isolator. In this case a separate fendering structure may be required.

4-5 MOORING HARDWARE.

4-5.1 General.

Ships are usually moored to bollards, bitts, and cleats. Occasionally, ships may be tied to a quick-release hook. The position of a ship on a berth is usually controlled by utility hookup and brow location requirements. The crew in charge of tying up the ship will usually tie the lines to whatever mooring hardware is convenient to give the required horizontal angle. This often results in lines tied to a lower capacity cleat while a high-capacity bollard may only be a few feet away. Hence, consider using only one type of high-capacity mooring hardware throughout the facility. When possible, size this mooring hardware for the maximum size vessel that could possibly use the facility. Space hardware to maximize the berth flexibility for use by ships other than the specific vessel the berth was designed to accommodate. In addition, mooring hardware requirements will depend on the mooring service type assigned to the berth as defined in UFC 4-159-03, *Design: Moorings*. For mooring service types III and IV, consider providing additional heavy weather mooring hardware set away from the face of the pier or wharf. Balance the desire to provide the higher capacity hardware with the additional cost of the higher strength hardware and supporting structure. The geometry of the hardware should preclude mooring lines from slipping off, as the mooring angle is often very steep.

4-5.2 Hardware Types.

Additional information (such as tabular data and figures) on mooring hardware is contained in UFC 4-159-03, *Design: Moorings*; UFC 4-150-08, *Inspection of Mooring Hardware;* and TR-6014-OCN**,** *Mooring Design Physical and Empirical Data*. The following are the most commonly used types of mooring hardware:

4-5.2.1 Bollards.

A bollard is a short single-column cast-steel fitting that extends up from a baseplate that is secured to a strong point of a shore structure or berthing facility. Bollards are used in checking the motion of a ship being moored, by tightening and loosening mooring lines that are fastened to them. Bollards are also used for securing a ship that has been placed in its final moored position. Do not use bollards without ears in facilities where a high vertical angle of the mooring line is anticipated, to prevent lines from slipping off.

4-5.2.2 Bitts.

Bitts are short, double-column, cast-steel fittings fastened to the deck of berthing facilities. Bitts are also found on navy vessels. They are used to secure a vessel. The double-columns allow for convenient and rapid tying and releasing of mooring lines, as well as for guiding a line through to other hardware.

4-5.2.3 Cleats.

Currently, available cleats are low-capacity, cast steel deck fittings having two projecting arms that are intended to be used for securing mooring lines of small craft. They are provided at most naval facilities. Given a choice, line-handling crews will use cleats in preference to bollards or bitts, even for large ships, as the possibility of line slippage is remote. However, cleats can easily be overloaded when they are used in lieu of major fittings such as bollards. Because of the low holding capacity of cleats, they should not be used in combination with higher capacity deck fittings.

4-5.2.4 Chocks.

Chocks are either stationary or roller-equipped cast deck fittings on ships that are used to train the direction of a mooring line. Chocks are available either open at the top, permanently closed, or closed by a hinged closing piece.

4-5.2.5 Capstans.

Ships outfitted with winch-mounted wire rope mooring lines require greater pulling power than can be provided by one or two deck hands to draw out the ship's lines. The assignment is handled by capstans mounted along the face of the wharf. The capstans are small electric winches with a drum rotating about a vertical axis. The capstan is used by a deck hand that receives a messenger line at the end of which is fastened the sling of the wire rope hawser. The capstan, receiving several wraps of the messenger line, provides the pulling power needed to draw out the wire rope hawser. The messenger line is then returned to the ship. Capstans are also used as primary guidance (breasting and in-haul) to berth ships in dry docks and slip-type berths (Trident facilities). For these uses, the capstans are of larger capacity and are typically two-speed.

4-5.2.6 Quick-Release Hooks.

The quick-release hook, generally mounted on a swivel base, is a deck fitting used to receive mooring lines. When a ship is required to make a hasty departure from its berth, a tug on the hook's release mechanism unfastens the mooring line. The mechanism can also be tripped from the ship when a tag line is provided. Thus, a ship can make a sudden departure without the assistance of shore personnel. Quick-release mooring hooks with integral power capstans are necessary for securing the steel mooring lines on petroleum tankers at fuel piers, while bollards are needed for the supplementary lines other than steel.

4-5.3 Strength.

The required strength of mooring hardware and its fastenings is determined through mooring analysis. Mooring hardware can and does receive more than one line and as many as three are not unusual. Design anchorage of mooring hardware based on the rated capacity e.g. for the anchorage of a Special Mooring Bollard “A” the working (service level) capacity is either a 660 kip (2,936 kN) horizontal line pull, or a 430 kip (1,913 kN) line pull at an angle of 45 degrees from the horizontal. Line loads are applied just below the horn elevation, and typically from 0 to 180 degrees in plan away from the pier or wharf. For strength level design use the mooring load factor listed in Table 3-7. Capacity design is used for anchorage and local foundation structural design only. Global structural design shall be based on mooring analysis. The sizes of mooring lines are limited to those that can be conveniently handled by deck hands. Thus, wire rope lines generally do not exceed 1-3/4 inch (45 mm) diameter.

4-5.4 Placement.

If a berthing facility were always to receive the same class of ship, each of which had identical arrangements for putting out mooring lines, a specific pattern for mooring hardware spacing, based on the ship's fittings, would be satisfactory. However, most naval berthing facilities require a high degree of flexibility in order to be able to receive several types and sizes of ships. Therefore, a universal pattern for mooring hardware spacing is preferred. Mooring hardware spaced at 60 feet (18.3 m) on centers along the berthing face of a structure will, in most instances, provide the number of fittings required to secure the ships during the periods of time that wind velocities and conditions of sea do not exceed the design criteria established for Mooring Service Types I and II. Mooring Service Types III and IV will likely require additional high capacity storm bollards which are normally set back as far as is practical from the face of the berth to provide a shallow line angle.

a. A berthing facility that will accommodate ships having large wind areas, such as aircraft carriers, should be outfitted with 12 to 100 ton (107 to 890 kN) bollards at 100-feet (30.5 m) centers and 4 to 200 ton (36 to 1779 kN) storm bollards at each end. Locate the storm bollards, which would be used to secure breasting lines, inshore from the face of the wharf, thus reducing vertical angles and permitting the use of longer (safer) mooring lines.

b. At submarine berths where mooring lines go down to the submarine, locate the mooring hardware as close as possible to the waterside edge of the bullrail to minimize chafing of the lines. Where this is not feasible, cast a continuous smooth member, such as a bent plate, in the concrete bullrail.

4-6 MOORING DOLPHINS/PLATFORMS.

4-6.1 Design.

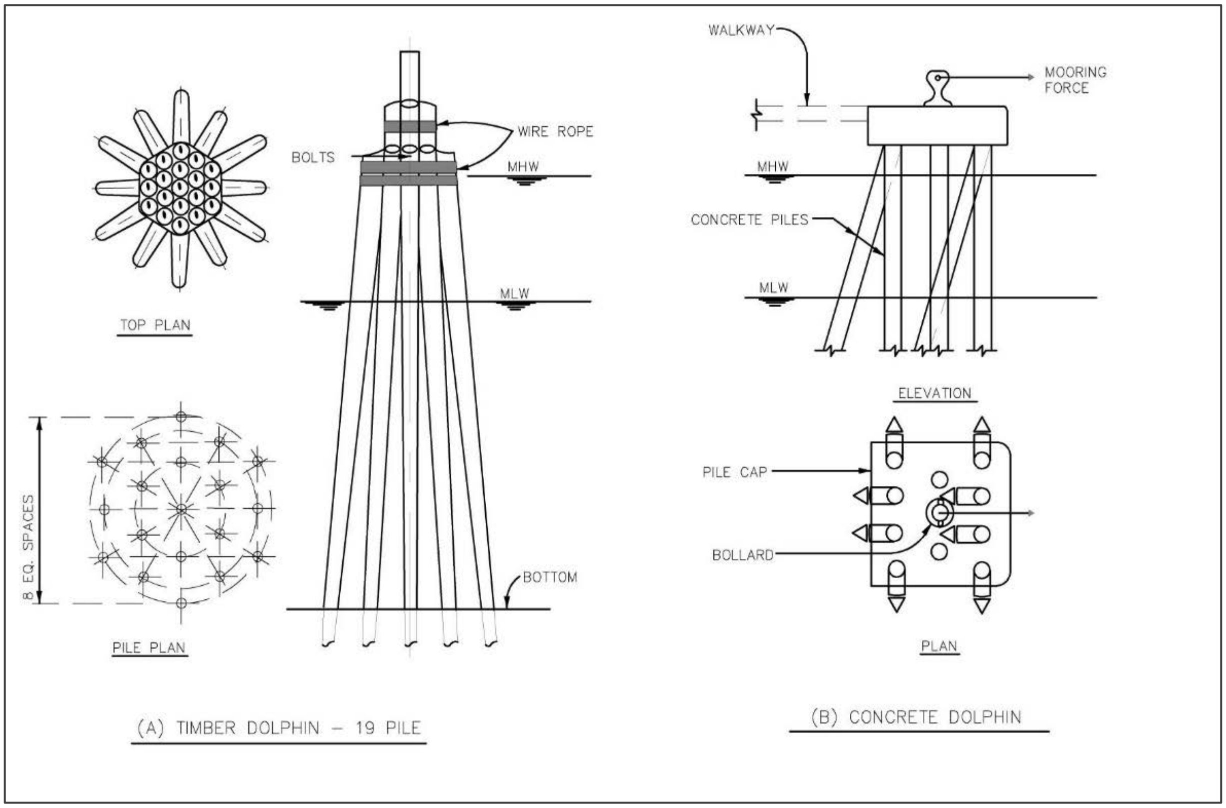
The primary load for a mooring dolphin comes from the tension in the mooring line. It is typically constructed as an open pile supported structure. Where filled (solid) construction is permitted, a single sheet pile cell may be used. When a platform is provided for the dolphin, it should be large enough to allow a 3-foot-wide (1 m) walking space all around the mooring hardware.

4-6.2 Construction.

Timber mooring dolphins can be constructed from 7, 19, or 37 wood piles with a king pile in the center and other piles arranged in a circular pattern around the king pile. A 19-pile dolphin is illustrated in Figure 4-6 (A). Limit the use of timber dolphins to facilities not requiring high capacity mooring points. Timber dolphins may be required for magnetic sensitive facilities. In areas with ready access to timber piles, timber dolphins may be popular for small craft, tugs, patrol craft and barges. For higher loads, a concrete dolphin is preferred, which is illustrated in Figure 4-6 (B). Because both timber and concrete dolphins can be expected to move significantly (1 to 6 inch (25 to

152 mm)) from the lateral load, design and detail the access walkway to allow for this movement.

Figure 4-6 Mooring Dolphins



4-7 MISCELLANEOUS CONSIDERATIONS.

4-7.1 Expansion Joints.

Because expansion joints require frequent maintenance for proper functioning, piers and wharves should use as few joints as possible. The size and number will depend on the temperature range and structural system employed. Provide expansion joints at the junction of an approach with the main structure and such other places where there is a major structural discontinuity. Provide additional expansion joints where necessary to limit buildup of thermal loads. (See also previous section: Thermal Loads) Continue the joint through railroad tracks and crane rail tracks. Recommended details are shown in Figures 4-7 and 4-8. Likewise, detail utilities crossing expansion joints to accommodate the expected longitudinal and lateral movements.

4-7.2 Drainage.

Pier and wharf decks should be sloped in transverse and longitudinal direction to deck drains or scuppers to provide for drainage of storm water. Where permitted, the storm water can be drained off to the water below; however, if fuel, oils, and chemicals are to be handled on the facility, the storm water should be collected and piped off for treatment. A complete review of local jurisdictional requirements for storm water management and treatment required for each facility may vary significantly between locations. It is customary to use subsurface drains in ballasted decks to handle any small amounts of water that may seep through the paving. This water is normally not collected.

4-7.3 Bullrail.

On all waterside edges of piers and wharves, provide a curb or bullrail 10 to 12 inch (254 to 305 mm) high by 12 to 24 inch (305 to 610 mm) wide. Some mooring hardware may be accommodated within the 24-inch (610 mm) width, thus permitting a clear inside face for easy snow removal and line handling. As shown in Figure 4-9, it is also generally possible to house utility vaults within the width of the bullrail. The bullrail should be sufficiently reinforced and anchored to the deck structure. When a continuous bullrail is available, it may be reinforced to serve as chord member for a structural diaphragm.

4-7.4 Utility Trench.

Because the utility services are mostly needed along the pier or wharf edge, the main utility trenches on single deck piers should be kept close to the bullrail. The trench may be underhung or kept above, as shown in Figure 4-10. The trench covers should be removable and made of concrete, steel, or composite construction. Fiberglass reinforced plastic (FRP) trench covers have been used on piers and offer the advantages of light weight and durability in a corrosive marine environment. When using FRP trench covers, give consideration to the proximity of heated steam lines.

Although the trench covers need not be watertight, use a good seal at joints to prevent accidental seepage of spilled liquids. Frequently spaced drains should be placed along the trench to prevent flooding. Provide adequate width and depth to allow access for maintenance of utilities.

Figure 4-7 Railroad Track Support

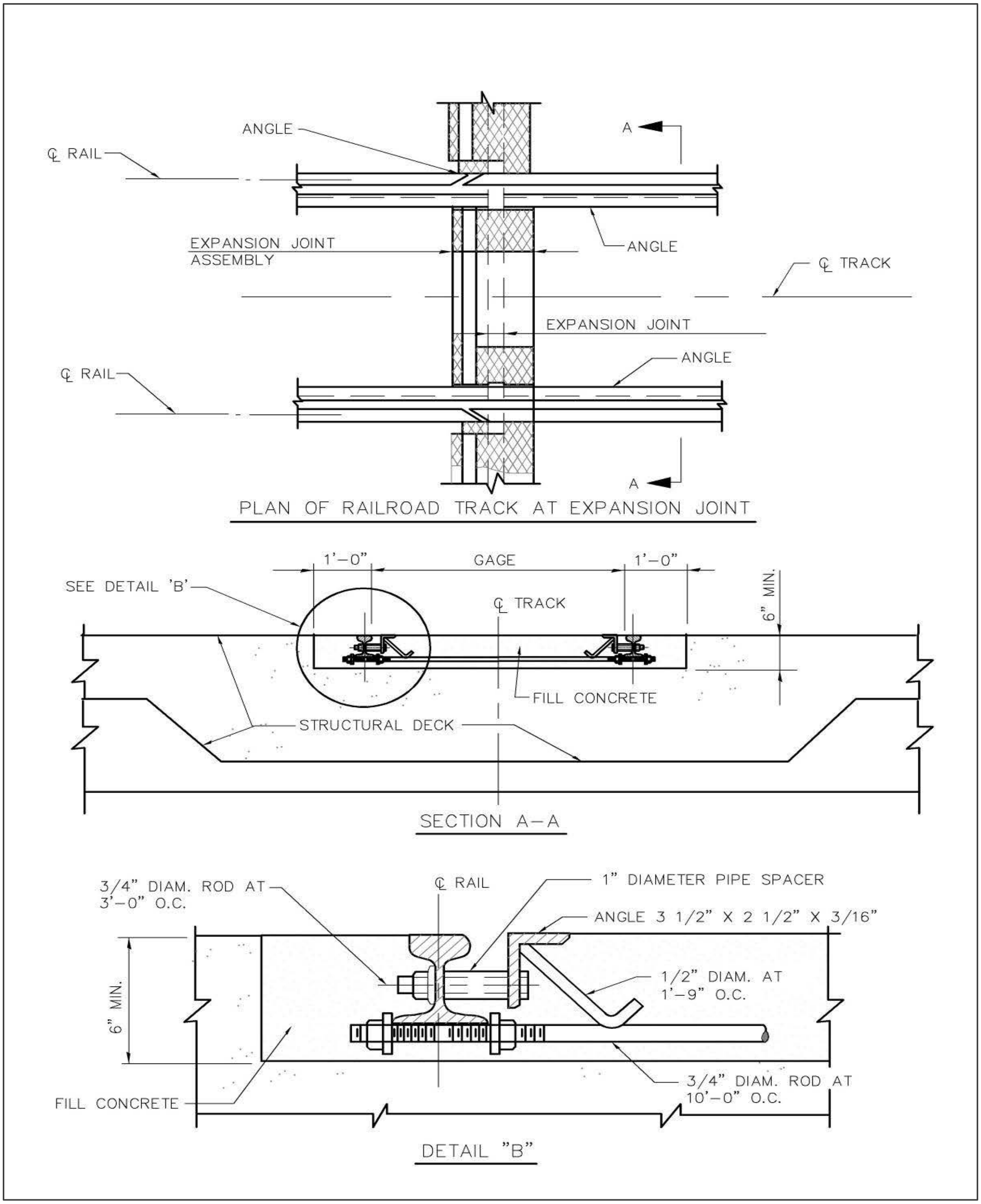


Figure 4-8 Crane Rail Support

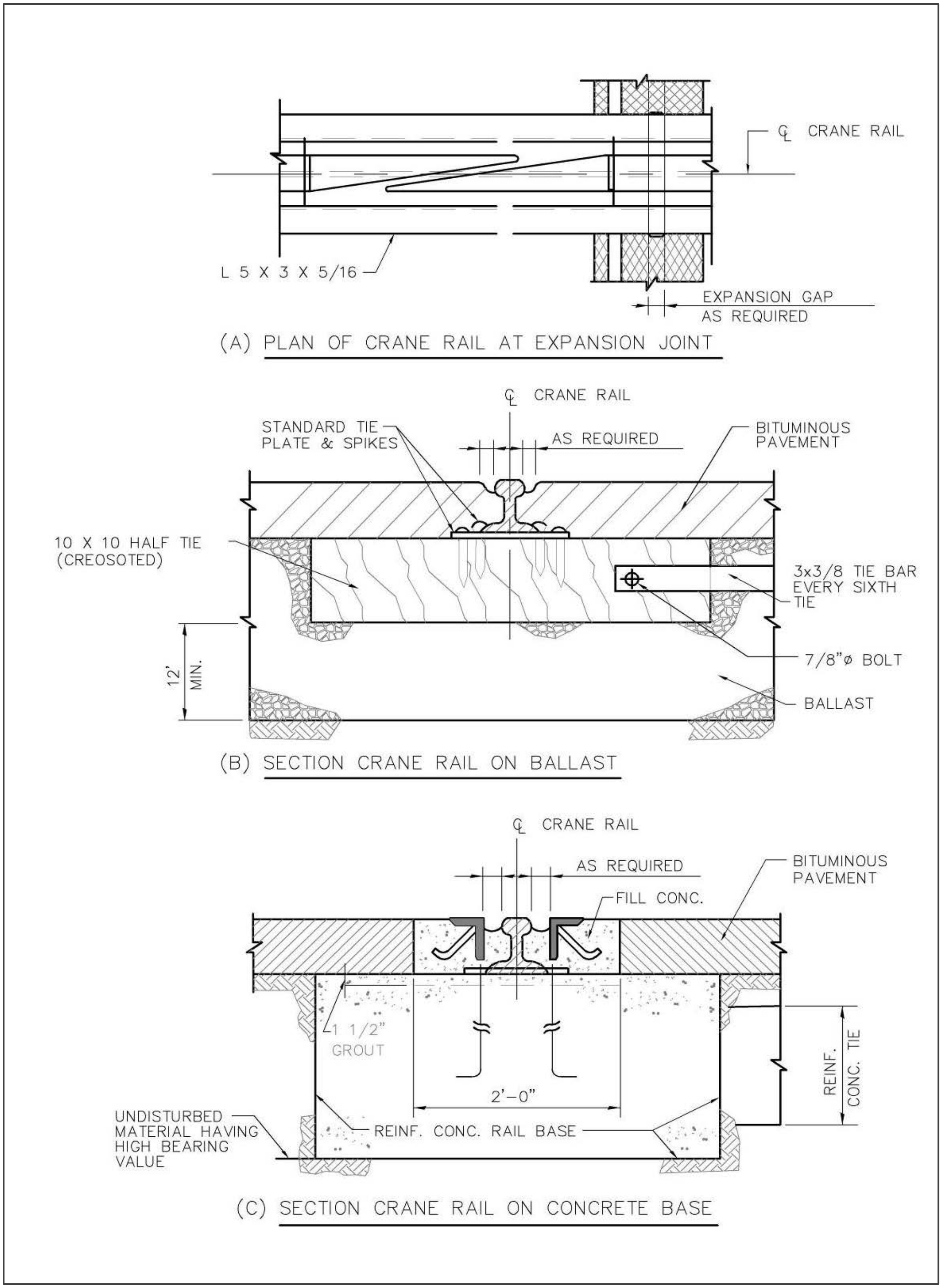


Figure 4-9 Bullrail Details

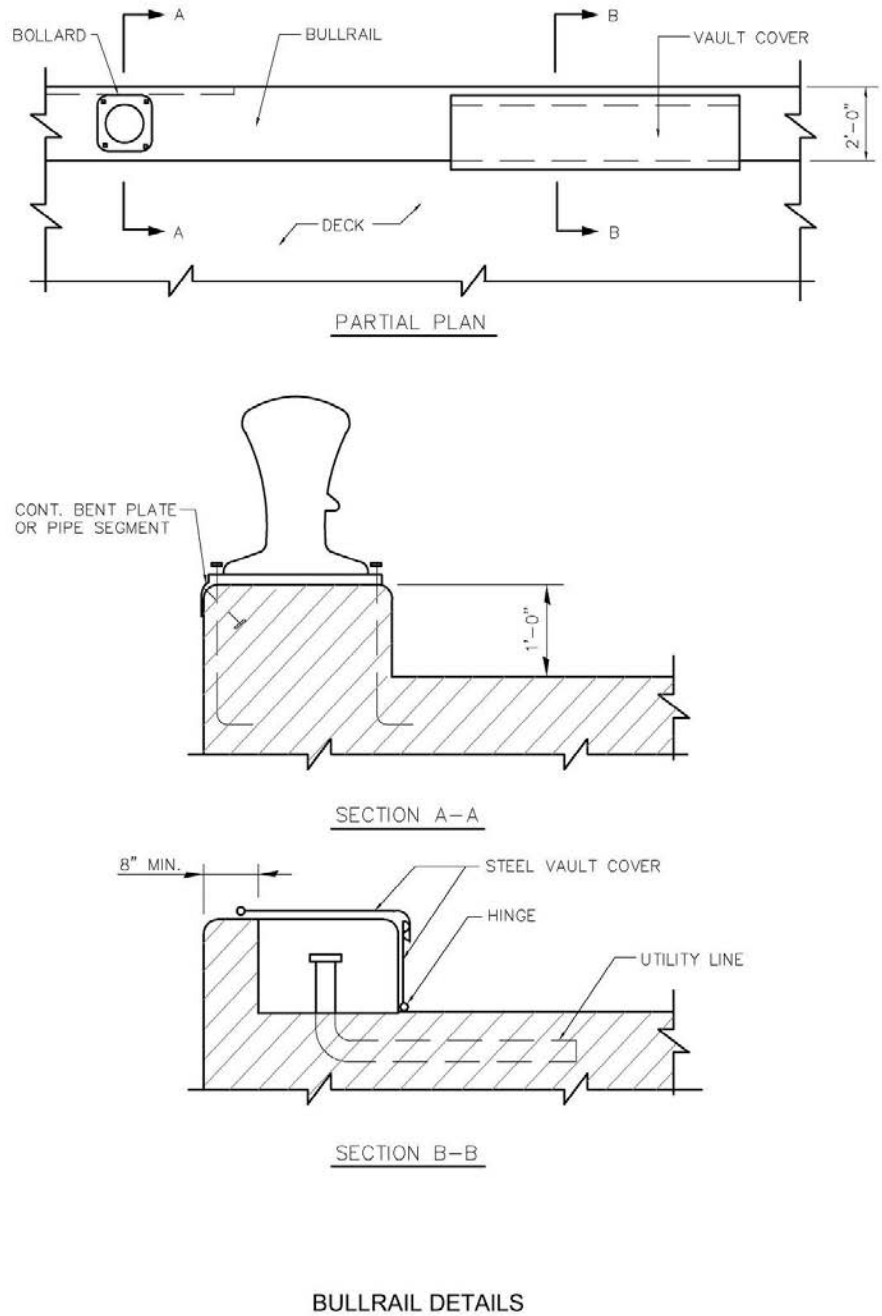
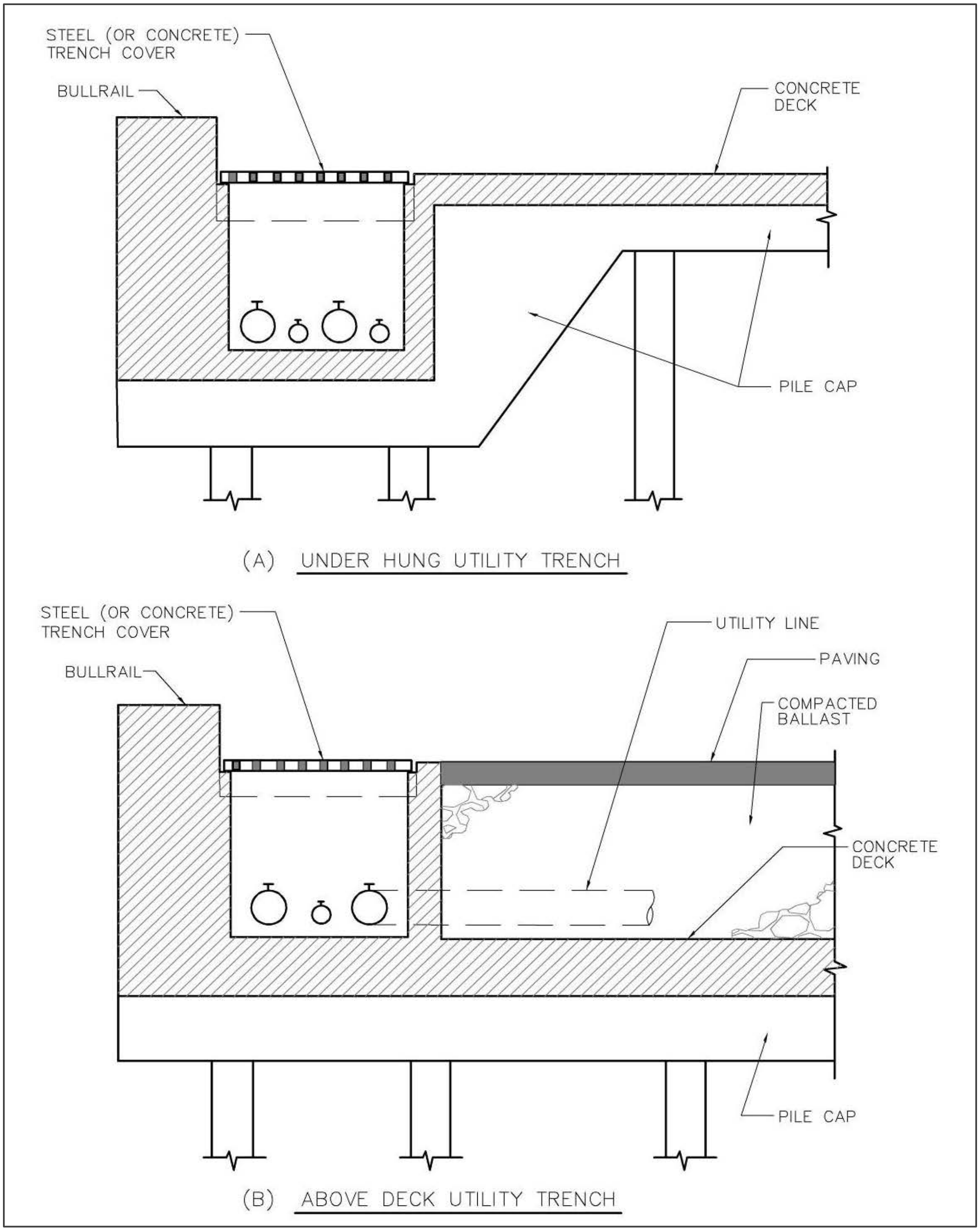


Figure 4-10 Utility Trench Concept



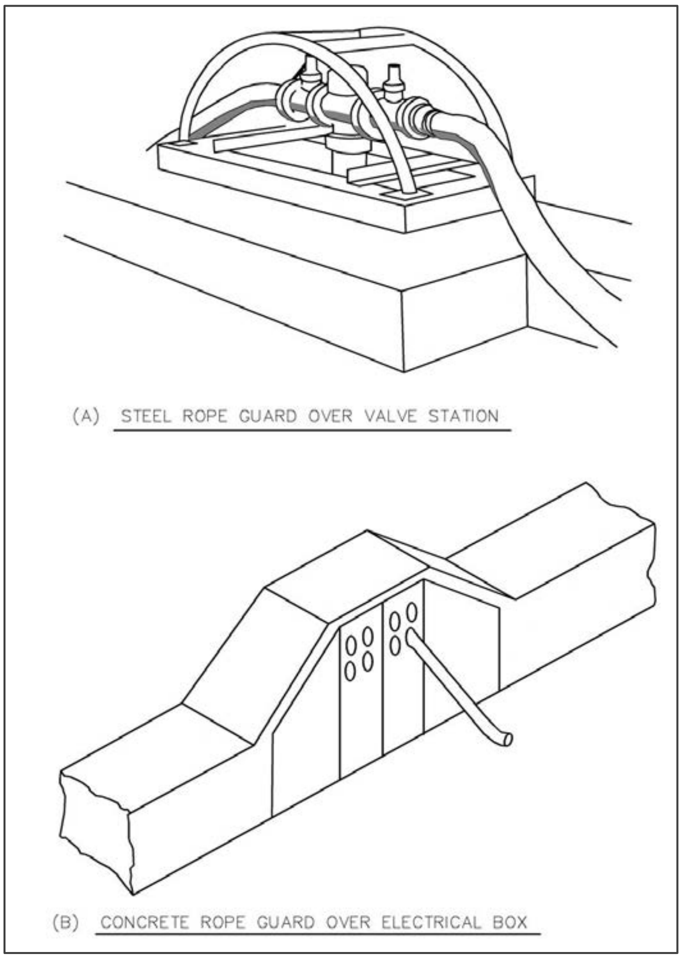
4-7.5 Utility Hoods.

Protect connection points or "utility risers" projecting above deck or bullrail from snagging of mooring lines by pipe rails or concrete hoods, as shown in Figure 4-11. Alternatively, when the bullrail is wide enough, employ hinged utility covers like the one shown in Figure 4-9. For convenience of the users, the risers should not face away from the ship, and should be adequately sized for ease of operation.

4-7.6 Wearing Course.

Generally, a wearing course is not needed for concrete deck structure. However, for precast concrete decks, an asphalt concrete or cement concrete wearing surface may be utilized to provide a slope for drainage. For ballasted decks and for solid (filled) type construction, a wearing course is necessary. For these applications, asphaltic concrete is preferred over cement concrete as the former is easier to repair and maintain and better tolerates substrate movement.

Figure 4-11 Utility Hood



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CHAPTER 5 FENDER SYSTEMS

5-1 GENERAL CONSIDERATIONS.

5-1.1 Description.

The fender system is the interface between the ship and the shore facility. During the berthing of a ship, the fender system is meant to act as a buffer in absorbing or dissipating the impact energy of the ship without causing permanent damage to the ship or the shore facility. Where ships are to be berthed against relatively inflexible solid piers and wharves, protection of the ship is a critical function. When ships are to be berthed against pile-supported piers, wharves, and dolphins (which are relatively flexible), protection of the structure may be the more serious concern. Once the ship is successfully berthed and moored to the shore facility, the fender system continues to provide the interface between ship and shore and transmits the environmental loads (wind, waves, and current) on the ship to the structure. For submarine and other low-profile ship berthing, the fender system also provides a physical barrier to prevent the vessel from going underneath the pier.

5-1.2 Berthing Practice.

The selection and design of a fender system is highly dependent on the berthing practice employed at the particular facility. Typically, two or more tugboats assist large ships into the berth. In some locations, smaller ships may be allowed to come in on their own power. When assisted by tugs, the ship would arrive off the berth and parallel to it. The ship then stops dead in the water and the tugs push and pull the ship transversely toward the berth in an attempt to make contact with as much of the fender system as possible. When unassisted by tugs, the smaller ship will be eased into its berth at some slight angle, referred to as the angle of approach. In both cases, the initial contact is limited to a relatively small portion of the fender system. Assumptions will have to be made regarding the approach angle and contact length.

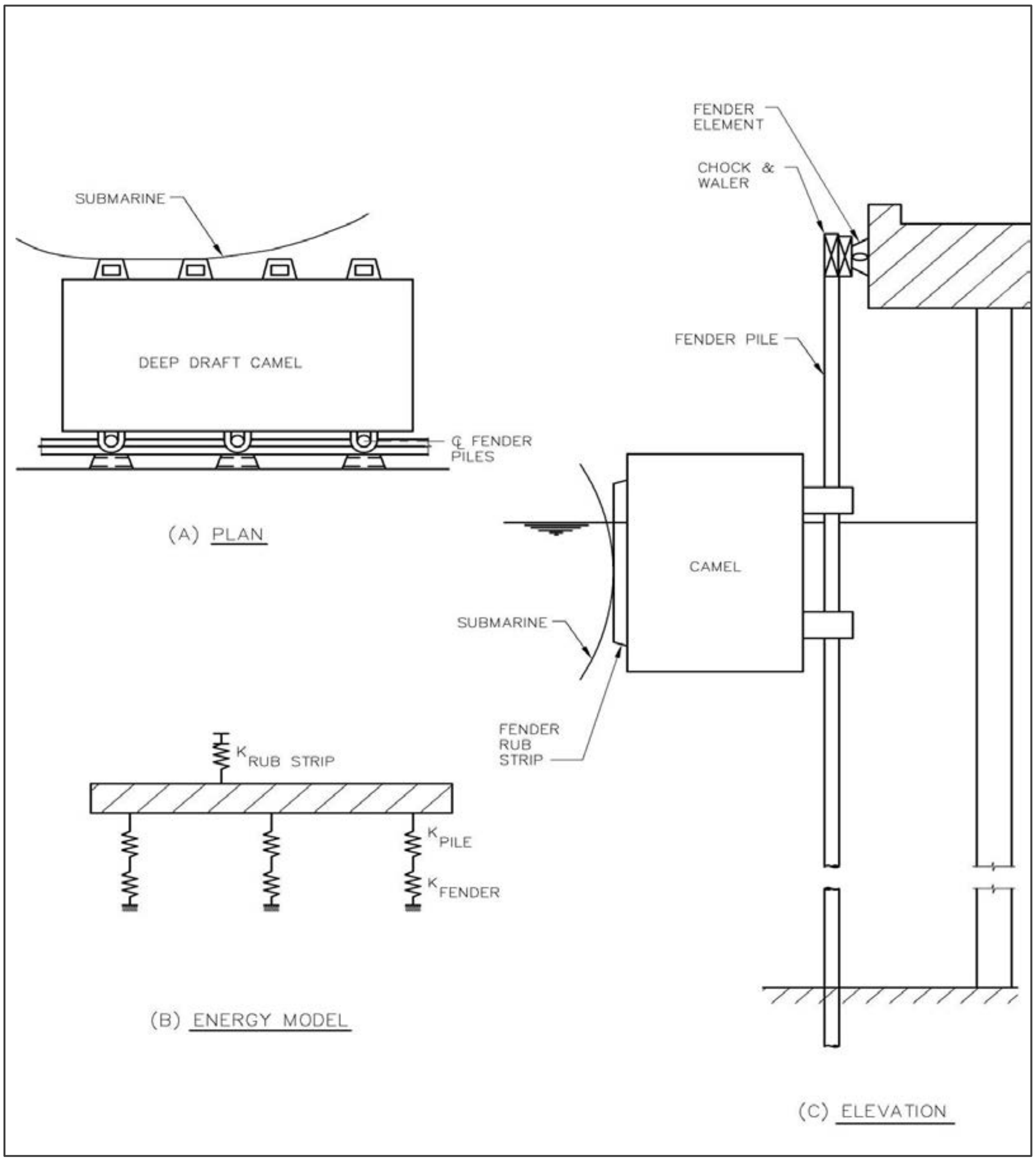
5-1.3 Camels and Separators.

Camels are located between ships and piers or wharves. Separators are located between nested ships. This practice is the most significant difference between commercial ship berthing and naval ship berthing. Berthing against camels concentrates the impact energy to a small length of the fender system as well as applies the energy at some distance below the deck. This is a critical aspect in all fender system design for Navy ships. A fender system designed for commercial ships will, in general, not be satisfactory for Naval applications. The practice of using camels has resulted in a general trend for a minimum of hull protrusions near the waterline. Fender systems with higher fender contact area are more susceptible to damage from longitudinal movement of the vessel due to snags.

5-1.4 Systems Approach.

The impact energy of the berthing ship is absorbed in a complex system of interconnected elements. For the system shown in Figure 5-1, the load passes from the ship's hull to the camel, which is backed by a series of fender piles. The fender piles, in turn, are supported by rubber fender units at the deck level. In this case, the ship's energy is absorbed by the ship's hull, rubbing strips, camel, fender piles, and rubber fenders at deck level. The system can be modeled as shown in Figure 5-1. The energy absorbed and the force developed, by each element can only be solved by an iterative process.

Figure 5-1 Energy Model of a Fender System



5-1.5 Functional Requirements.

5-1.5.1 Energy Absorption.

Design all fender systems for absorption of the ship's berthing energy in all the structural types of piers and wharves.

5-1.5.2 Normal Berthing.

The fender system should be able to absorb the energy from normal berthing operations within the working stress or acceptable deformation range as defined in this section. Most manufacturers indicate a load deflection curve tolerance of plus or minus 10%. If this is determined to be the case, the design normal berthing reaction on the structure should be increased by 10% and the normal energy absorption for design should be decreased by 10%. Variations in the speed of testing of fenders may affect the resulting load-deflection curves. Where the test loads are applied rapidly, i.e., at a speed comparable to the actual ship berthing, the load-deflection will indicate higher reaction and energy than if the test load is applied slowly. Therefore, take care when comparing test results from different manufacturers, and make appropriate adjustments in the factors of safety used in design. Differences on the order of 30% can be expected.

5-1.5.3 Accidental Berthing.

Because the fender system is less expensive than the ship or the berthing structure, some damage to it may be permissible and acceptable. So, in the event of an accidental situation, it is the fender system that should be "sacrificed." Loss of the berth has a much more serious consequence than loss of part or all of the fender system in terms of the cost and time required to restore the facility. The cost and time to repair a damaged ship is of much greater concern than the berth and the fender system. The accidental condition may be caused by increased approach angle or approach velocity or a unique situation that cannot be anticipated. In the absence of any other accident scenario, increase the berthing energy as calculated in this chapter by at least 50% and the fender system should be capable of providing this "reserve" capacity at or near failure of the system materials (including soils).

5-1.5.4 Moored Condition.

All fender systems selected should be capable of safely transferring the environmental loads on the ship to the mooring structure.

5-1.5.5 Hull Damage.

Design all fender systems to prevent permanent deformation of the ship's hull. It is much more expensive to repair a ship's hull than rehabilitate a damaged fender system. The composition of a typical Navy hull is steel plating welded to longitudinal (horizontal) stiffeners. Generally, the stiffeners are of sufficient strength to preclude failure from fender loading. However, the hull plating may yield when subjected to a uniformly distributed overload on the panel. Fender systems with rigid face elements or in combination with rigid camels tend to concentrate the reaction forces on the ships frames versus the hull plating due to the relative stiffness of the frames.

5-2 BERTHING ENERGY DETERMINATION.

5-2.1 Methods.

The following methods can be used in the determination of berthing energy of the ship.

5-2.1.1 Kinetic Method.

The kinetic energy method has been the widely accepted method for piers and wharves of Naval facilities. When the displacement tonnage of the ship is known, the energy equation can be written as:

$$E_{ship} = {}^{1}/_{2}\, W * v^2 \;/\; g$$ **(Equation 5-1)**

where:

- E_{ship} = Berthing energy of ship (foot-lbs)
- W = Weight of the ship in pounds (displacement tonnage, long tons x 2,240)
- g = Acceleration due to gravity (32.2 feet/second^2)
- v = Berthing velocity normal to the berth (feet/second)

However, there are several factors that modify the actual energy to be absorbed by the fender system. The expression can be written as:

$$E_{fender} = C_b * C_m * E_{ship}$$ **(Equation 5-2)**

where:

- E_{fender} = Energy to be absorbed by the fender system
- C_b = Berthing coefficient = $C_e * C_g * C_d * C_c$. Sometimes eccentricity (C_e), geometric (C_g), deformation (C_d), and configuration (C_c) coefficients are combined into a single value called berthing coefficient.
- C_m = Effective mass or virtual mass coefficient

Each of these coefficients is discussed separately below.

a. Eccentricity Coefficient (C_e). During the berthing maneuver, when the ship is not exactly parallel to the berthing line, not all the kinetic energy of the ship will be transmitted to the fenders. Due to the reaction from the fender, the ship will start to rotate around the contact point, thus dissipating part of its energy. Treating the ship as a rigid rod of negligible width in the analysis of the energy of impact on the fenders leads to the simple formula:

$$C_e = k^2 / (a^2 + k^2)$$

where:

- k = Radius of longitudinal gyration of the ship, feet.
- k = $(0.19C_{BL} + 0.11) * L$ (*Guidelines for the Design of Fender Systems*, PIANC, 2002)
- a = Distance between the ship's center of gravity and the point of contact on the ship's side, projected onto the ship's longitudinal axis, feet.
- C_{BL} = Block coefficient

$$C_{BL} = M / (L * B * D * \rho)$$

where:

- M = Displacement of vessel, long tons
- L = vessel length, feet
- B = Beam of vessel, feet
- D = Draft of vessel, feet
- ρ = Density of water (64 lb/ft^3)

Values of C_e typically are between 0.4 and 0.7. The values for C_e may be selected from Figure 5-2.

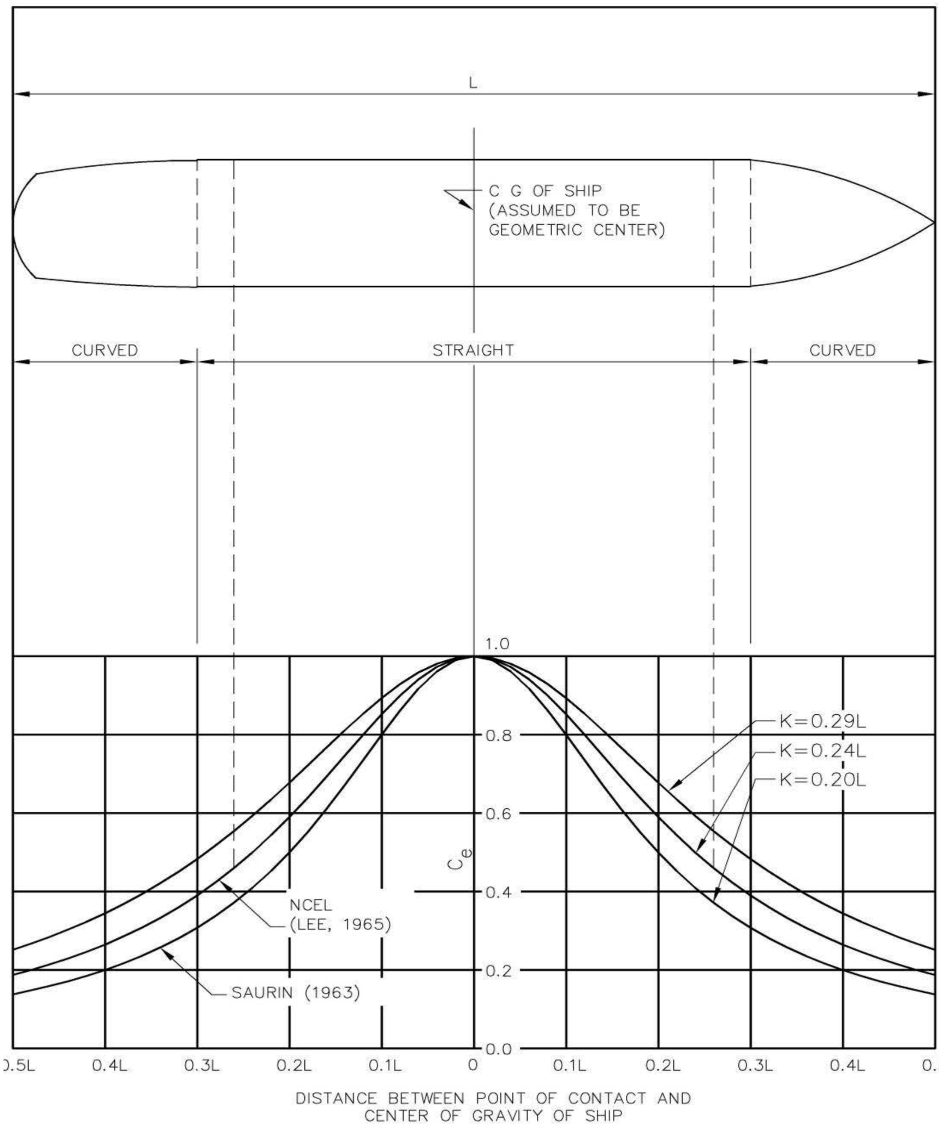
b. Geometric Coefficient (C_g). The geometric coefficient, C_g, depends upon the geometric configuration of the ship at the point of impact. It varies from 0.85 for an increasing convex curvature to 1.25 for concave curvature. Generally, 0.95 is intended for the impact point at or beyond the quarter points of the ship, and 1.0 for broadside berthing in which contact is made along the straight side.

c. Deformation Coefficient (C_d). This accounts for the energy reduction effects due to local deformation of the ship's hull and deflection of the whole ship along its longitudinal axis. The energy absorbed by the ship depends on the relative stiffness of the ship and the obstruction. The deformation coefficient varies from 0.9 for a non-resilient fender to nearly 1.0 for a flexible fender. For larger ships on energy-absorbing fender systems, little or no deformation of the ship takes place; therefore, a coefficient of 1.0 is recommended.

d. Configuration Coefficient (C_c). This factor has been introduced to take into account the difference between an open pier or wharf and a solid pier or wharf. In the first case, the movements of the water surrounding the berthing ship are not (or hardly) affected by the berth. In the second case, the water between the berthing ship and the structure is squeezed, which introduces a cushion effect that represents an extra force on the ship away from the berth and reduces the energy to be absorbed by the fender system. Therefore, a reduction factor has to take care of this effect. Experience has indicated that for a solid quaywall about one quarter of the energy of the berthing ship is absorbed by the water cushion; therefore, the following values for C_c appear to be justified:

- For open berth and corners of solid piers, C_c = 1.0.
- For solid piers with parallel approach, C_c = 0.8.
- For berths with different conditions, C_c might be chosen somewhere between these values.

Figure 5-2 Eccentricity Coefficient, C_e



e. Effective Mass or Virtual Mass Coefficient (C_m). When a ship approaches a dock, the berthing impact is induced not only by the mass of the moving ship, but also by the water mass moving along with the ship. The latter is generally called the "hydrodynamic" or "added" mass. In determining the kinetic energy of a berthing ship, the effective or virtual mass (a sum of ship mass and hydrodynamic mass) should be used. The hydrodynamic mass does not necessarily vary with the mass of the ship, but is closely related to the projected area of the ship at right angles to the direction of motion. Other factors, such as the form of ship, water depth, berthing velocity, and acceleration and deceleration of the ship, will have some effect on the hydrodynamic mass. Procedures for determining added mass are contained in TR-6064-OCN, *Berthing Guidelines for Submarines* and TR-6074-OCN, *Added Mass for Berthing U.S. Navy Vessels*.

The equations for added mass are as follows:

For submarines:

$$C_m = 2.36 + 1.74 * (T/d)^{3.5}$$

where:

T = vessel draft at mid-ships, feet

d = water depth at berth, feet

For all other surface vessels:

$$C_m = C_{M0} + (C_{m1} - C_{M0}) * (T/d)^{3.5}$$

where:

C_{M0} = added mass coefficient for $T/d = 0$ deepwater limit

C_{m1} = added mass coefficient for $T/d = 1$ shallow water limit

T = vessel draft, feet

d = water depth, feet

C_{M0} = $1.3 + 1.5 * (T/B)$

B = vessel beam, feet

C_{m1} = $F * [12.4(T/B)^{0.3} – 50 (T/L)]$

F = $1.5 * C_b$ for $C_b < 0.6$

F = 0.9 for $C_b > 0.6$

(C_b = berthing coefficient as defined previously)

f. Berthing or Approach Velocity (v). It should be noted that the kinetic energy of the berthing ship is a function of the square of the normal component of its approach velocity. Thus, the kinetic energy, as well as the resultant force on the berthing structure, is sensitive to changes in approach velocity. By doubling the design value of the approach velocity, the ship's kinetic energy is quadrupled. Design values used for the approach velocity normal to the berth may vary from 0.25 to 1.50 ft/s (0.08 to 0.46 m/s), depending on the size of the ship being docked and the tug assistance that is employed. Larger vessels with adequate tugboat assistance can generally berth gently and the lower design velocity may be used. Smaller vessels that self-dock may approach the wharf at considerably higher speeds and, accordingly, the higher design velocity should be used. The berthing velocity is also affected by the difficulty of the approach, maneuvering space for tugs (slip width), and location of the pier or wharf facility. Anticipate higher approach velocities when the berth is located in exposed waters where environmental loads cause difficulty in controlling the ship. Also, currents in tidal estuaries in protected waters can be of major concern. Approach velocity normal to the berth may be taken from Figures 5-3 and 5-4. Determining whether a facility is "exposed," "moderate," or "sheltered" depends on the environmental conditions at the site and is a matter for professional judgment by the designer. Most naval facilities in the United States are situated in protected waters and can be taken as "sheltered." Where high currents (0.3 ft/s (0.09 m/s) or more) or strong winds (40 knots (20.6 m/s) or more) occur frequently, a "moderate" condition should be assumed. The "exposed" condition may be used when unusually severe currents and winds are present. However, local experience with ship berthing should control the selection.

Figure 5-3 Berthing Velocity for Small Ships (up to 20,000 tons)

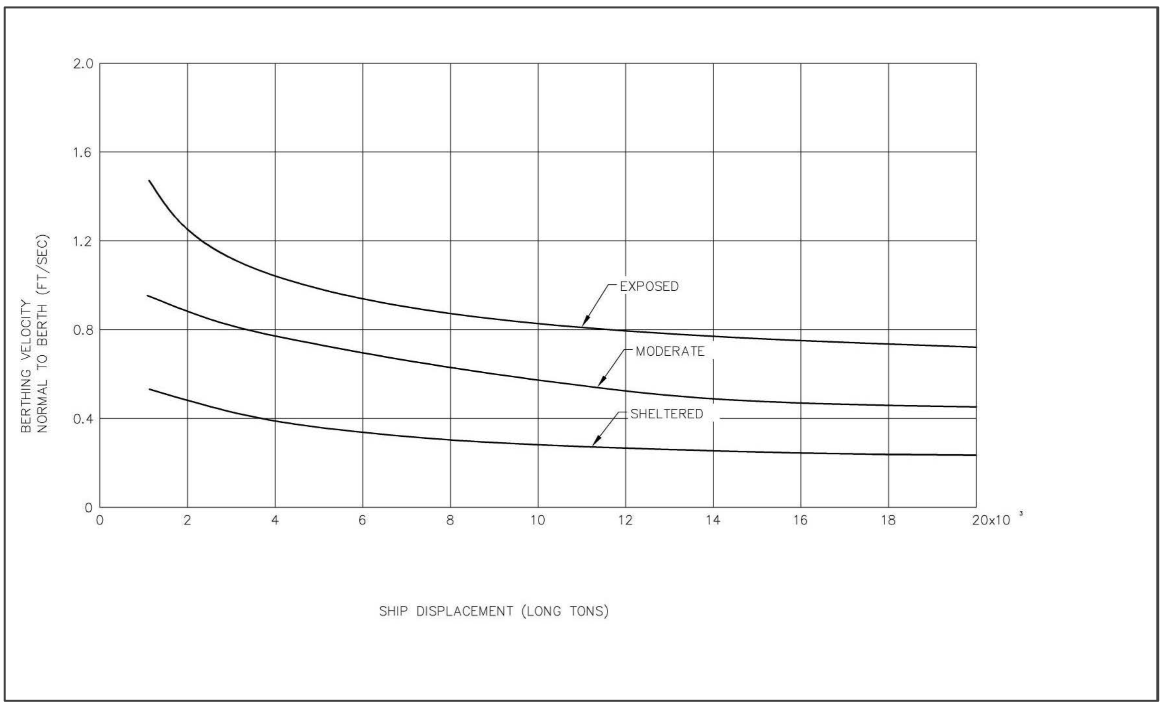
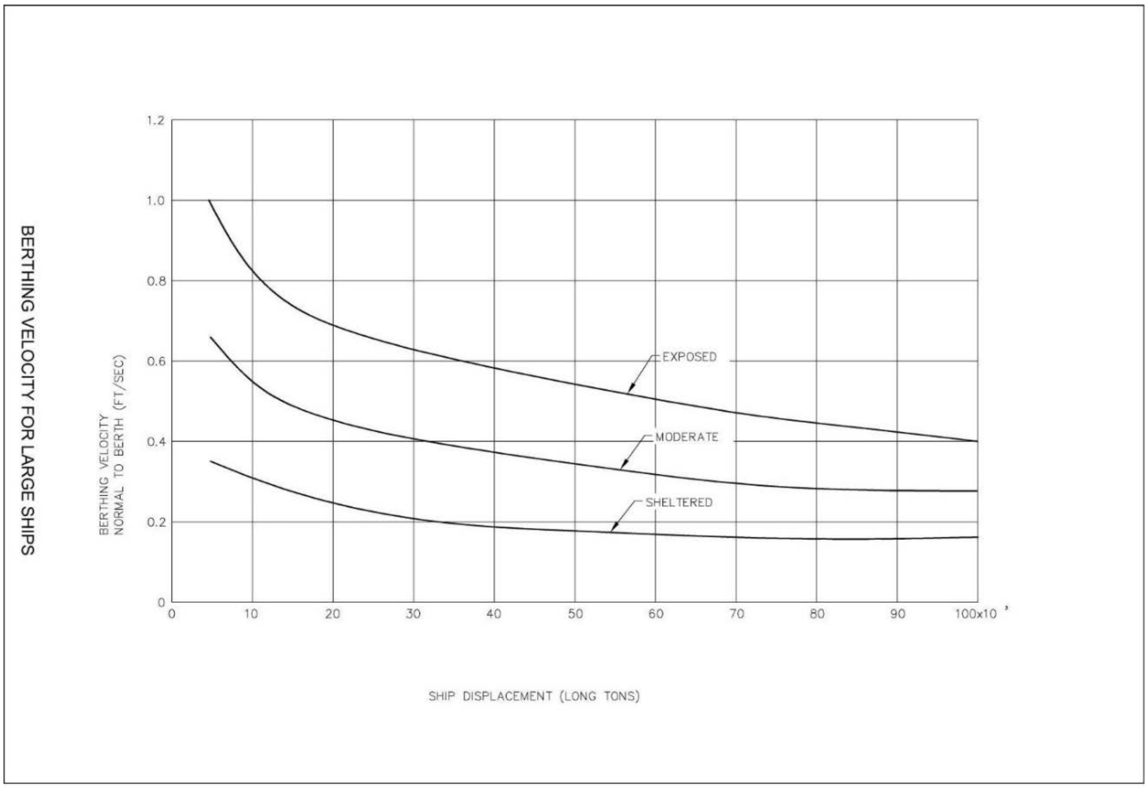


Figure 5-4 Berthing Velocity for Large Ship



5-2.1.2 Berthing Models.

a. Statistical Method. This method is based on actual measurements of the energy of the impact at existing berths. This method is closely related to the conditions of the site where the measurements were taken and is dependent on the fender layout and construction, e.g., distance between piles, and the loading condition of the ship.

b. Scale Model. This method, which makes use of a small-scale model test of the berth to be designed in a well-equipped hydraulic laboratory or ship model basin, suffers from the scale and viscosity effects and requires experienced interpretation.

c. AQWA. NAVFAC EXWC typically uses the COTS AQWA software package to perform a dynamic analysis of berthing through six degrees of freedom in the time domain.

d. Analytical Model. NAVFAC EXWC has developed an analytical model that can accurately predict ship berthing impact forces. The model employs a computational fluid mechanics approach, coupling a Reynolds-Averaged Navier-Stokes (RANS) numerical method with a six-degree-of-freedom motion program for time-domain simulation of ship and fender reactions. The model has been verified with data from small-scale and full-scale tests. Results from the new model for two ship classes yield added mass coefficients close to those calculated by the PIANC formula as long as the depth-to-draft ratio exceeds 1.2. When the underhull clearance becomes small, i.e. for depth-to-draft ratios less than 1.2, predicted added mass coefficients can exceed the PIANC values. Added mass values of 5.0 or higher are predicted for ships berthing against open piers (pile supported) equipped with soft fenders, such as pneumatic or foam-filled cushions. Consider using higher values for the added mass coefficient under these conditions.

5-3 TYPES OF FENDER SYSTEMS.

5-3.1 General.

Fender systems absorb or dissipate the kinetic energy of the berthing ship by converting it into potential energy in the fender materials. This could be in the form of deflection of a fender pile, compression of a column of rubber, deformation of a foam-filled cylinder, torsion of a steel shaft, or pressuring of a pneumatic fender.

5-3.2 Fender Piles.

This is the most commonly used system in existing piers and wharves. This system is stiff and lacks the capacity for large deflection resulting in high reaction loads and frequent breakage of piling and hull damage. This system employs a series of closely spaced fender piles (5- to 10-foot spacing) (1.5 to 3 m) connected together by chocks and wales. A rubber fender unit is mounted between the wale and the berthing structure. A series of diagonal chains from the structure to the waler completes the system. Provide tight-fitting joints between chocks, wales, and pile head, with proper tension splices that provide compression and tension continuity along the face of berth. Ships may be berthed either directly against fender piles or by using additional fenders or camels between the ship and the fender piles. When camels are used, size the fender piling to resist the resulting bending and shear. In the working stress range, there is an approximate linear relationship between reaction force and deflection. When used with floating camels, which tend to cock between the ship and the piles, the ship's energy may become concentrated on just one or two piles. Hence, unless the floating camel is tightly secured to the piles (guided by piles), the system will not work well and frequent damage will occur. The pile-rubber fender unit is not recommended for solid and other types of piers and wharves where full deflection of the piles within the working range will be inhibited. When this system is employed throughout the length of berth, the rubber fender units should be sized for direct berthing of ships (without the use of camels).

5-3.2.1 Timber Fender Piles.

Timber fender piles have historically been the system of choice. Although timber fender piles are still in use, environmental concerns coupled with advances in other fender pile material, have led to a trend in replacement of this type of system. Further, in certain locations, timber fender piles may be susceptible to damage by marine borers.

5-3.2.2 Steel Fender Piles.

Steel HP sections, wide flange sections and pipes have been used for fender elements. These pile sections are typically coated and incorporate a cathodic protection system, a durable rubbing surface is required for fender systems, either UHMW-PE rubbing strips, or HDPE sleeves may be used to protect HP or pipe pile (PP) sections respectively. The typical steel system is comprised of steel HP or PP sections driven vertically and connected to a steel wale. The wale is attached to the supporting structure by a system of rubber fenders and chains.

5-3.2.3 Concrete Fender Piles.

Concrete fender piles are the most prevalent system in use. Square prestressed concrete fender piles have been tested and proven to have high-energy absorption fendering capabilities and greater strain energy at collapse than either timber or steel fender piling. They are typically 18 to 24 inches square (457 to 610 mm) prestressed concrete and have served well as primary fender piles for berthing and mooring. The fender piles are usually connected to a chock and wale system at the deck level and supported by rubber fender units at the bullrail. In the working stress range, there is a linear relationship between reaction force and deflection. Figure 5-5 shows a prestressed concrete fender pile installation. Additional guidance and design aids for concrete fender piles is contained in NCEL TM 53-89-03, *Prestressed Concrete Fender Piling User Data Package* and NCEL CR 89.005, *Prestressed Concrete Fender Piles: Fender System Designs*. In reviewing these documents the following is noted:

- Energy absorbing fender piles. The primary purpose of these piles is to absorb the berthing energy of a vessel and transfer the berthing reaction to the pier or wharf and harbor bottom. These piles were designed to be used with camels, but may be used without camels. Typically these piles are 18 inches (457 mm) square.
- Reaction fender piles. The primary function of these piles is to serve as a backing for foam filled or other marine fender units and to transfer the berthing reactions into the pier or wharf and harbor bottom. The foam filled fender is assumed to absorb all the energy required from vessel berthing. Energy absorption by the concrete piles adds to the system overload capacity. The reaction associated with the berthing energy is transmitted through the foam filled fender either directly into a row of closely spaced concrete reaction piles, or into a rigid bearing panel connected to concrete reaction piles at a greater spacing. The rigid bearing panel acts to distribute the reaction to the piles. Typically these piles are 24 inches (610 mm) square.

Figure 5-5 Foam-filled Fender System

Foam-filled fender, concrete fender piles, steel frame and polyethylene rub strips.
(Marine Fender Systems, by T.E. Spencer, ASCE PORTS 2004).

A test program conducted for concrete fender piles is documented in NCEL R-927, *Laterally Loaded Partially Prestressed Concrete Piles*. Key findings were:

- Partial prestressing to 600 psi (4137 kPa) (was sufficient to close flexural cracks.
- 18-inch (457 mm) square pile with twenty (20) 1/2 inch (13 mm) diameter prestress strands in a rectangular configuration confined by No. 3 ties with a 3-inch (76 mm) pitch performed best.
- 65-foot (19.8 m) lengths can be expected to perform well under cyclic load with an ultimate energy capacity of 30 ft-kips (41 kN-m) and a post ultimate capacity of more than 60 ft-kips (81 kN-m).

5-3.2.4 Composite Fender Piles.

There are two primary types of composite fender piles. One type of composite pile is made of fiber reinforced plastic (FRP) in the form of a tube that can be filled with concrete for greater strength and stiffness. Figure 5-6 shows an FRP fender pile system. Because of a higher susceptibility to abrasion and impact damage, the thermoset FRP tube type pile should have rubberized abrasion strips installed at potential contact points with berthed vessels.

The second type of composite pile is made of thermoplastics (such as high-density polyethylene, HDPE) and reinforced with either steel or FRP strands. Figure 5-7 shows a plastic fender pile system. The reinforced thermoplastic type pile generally exhibit larger load-deflection properties compared to conventional wood, steel or concrete piles.

To ensure uniform loading and avoid premature failure of fender system components, these type piles should not be used in parallel or mixed with conventional type piles in the same system. Relevant work to date on composite fender piles includes TM-2158-SHR, *Study of Recycled Plastic Fender Piles*. Follow on work to this is contained in SP-2005-SHR, *Limited Flexural Tests of Plastic Composite Pile Configurations*, which includes flexural load tests to failure and cyclic tests to determine the stiffness (EI), load/deflection, linearity, hysteresis, energy absorption, degradation, and failure mode. Tests showed that composite piles absorb more energy than timber piles, but are not as stiff. This could pose a problem if the composite fender pile deflects too much. To date, composite piles have been used primarily for corner protection, as secondary fender piles, and as primary fender piles for small craft facilities.

Figure 5-6 Fiberglass Fender Pile System

Fiberglass fender pile, plastic pipe wear surface, top support and cap.
(*Marine Fender Systems*).

Figure 5-7 Plastic Fender Pile System

Plastic piles, plastic block, cylindrical rubber fender, and floating plastic log camel. (*Marine Fender Systems*).

5-3.3 Fenders.

5-3.3.1 General.

The Navy has developed UFGS 35 59 13.16, *Marine Fenders* as the governing specification for selection of marine fenders.

5-3.3.2 Directly Mounted Fender Units.

In this system, individual fender units like the end-loaded, rubber shear, or buckling type, are attached directly to the pier or wharf face. For narrow tidal range in solid piers and wharves, and for narrow vessel size range, this system may be cost-effective for direct berthing of surface ships. Although this system is very popular in commercial piers and wharves throughout the world, it may not be suitable for some DoD facilities. This system is subject to damage from snagging on ship protrusions at levels of 8 to 10 feet (2.4 to 3 m) above the water line and from vertical loads resulting from snags on rails and protrusions during falling tides or from lateral loads due to snags on protrusion during longitudinal movement of the ship.

a. End-Loaded Rubber Fenders. These work by elastic compression of hollow rubber cylinder elements with small length-to-diameter ratios. As shown in Figure 5-8(A), steel fender panels with special rubbing material facing are usually required to minimize wear. The reaction force is an exponential function of the deflection. These fenders are usually attached directly to the pier or wharf structure in the form of a "cell fender."

b. Side-Loaded Rubber Fenders. These are hollow rubber units available in trapezoidal, circular, square, or D-shapes that, when loaded at their side, deform by trying to flatten out. See Figure 5-8(B). The potential energy is stored by a combination of compression and bending of the rubber elements. The reaction force is an exponential function of the deflection and the performance curve is quite similar for all the shapes. Fenders having a curved rather than flat external surface increase in stiffness more gradually as the area of contact increases during deformation. All these fenders experience a sharp and rapid increase in stiffness when the amount of deflection completely collapses the open bore, regardless of their external contour.

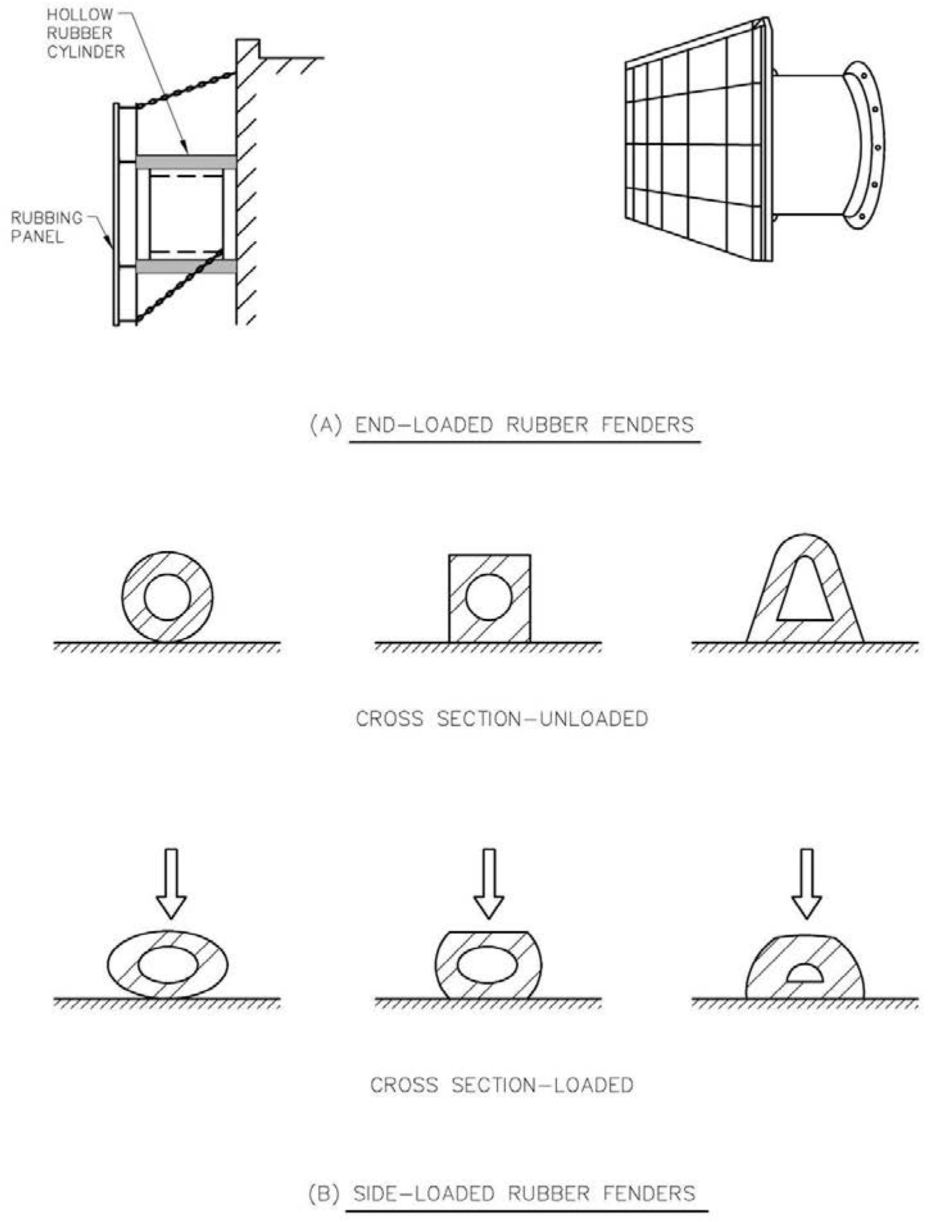
   Side-loaded rubber fenders will not absorb large amounts of energy and generally are not used alone. They are usually provided at the top of fender piles between the wale and berthing structure. A series of diagonal chains from the structure to the wale completes the system. When used with tight fitting joints between chocks, wales, and pile head, and when proper tension splices that provide compression and tension continuity along the face of the berth are used, the system has worked very well in both naval and commercial facilities. Ships may be berthed either directly or a floating camel may be used. When camels are used, size the fender piling to resist the resulting bending.

   Prestressed concrete, steel, and timber have been used successfully with side-loaded rubber fenders. This type of system provides good berthing flexibility. Ships of different sizes, tug boats, submarines, and barges can be accommodated without any modification.

c. Rubber Shear Fenders. The potential energy in these units is stored as elastic shear deformation of the rubber. Usually, a solid rubber block is vulcanized between two metal plates and the force is transferred through a fender frame or panel, as shown in Figure 5-9. These fenders are highly sensitive to proper manufacturing and installation as they depend on the bond between steel plates and the rubber. The force-deflection relationship is essentially linear.

d. Buckling Fenders. These fenders operate on the buckling column principle, in which a molded column of rubber is loaded axially until it buckles laterally. The end-loaded cylinder fenders described earlier are actually a buckling fender in principle. Most buckling fenders are not well suited for direct contact with a moving ship and hence are used with an abrasion or protector panel, as shown in Figure 5-10. The reaction force is linear up to a level when the pure compression behavior changes to the buckling mode. Hence, initially a relatively high reaction is built up with a small deflection, which then stays constant through the rest of the deflection range. Because buckling fenders are intended to buckle in a predetermined direction, any lateral deflection can significantly reduce their effectiveness. When lateral loads in either direction (parallel to length of berth or up/down) are anticipated, a cell-type fender is preferred. These fenders are becoming increasingly popular for berthing very large ships as they can absorb very high energy with a constant reaction force.

Figure 5-8 Side-loaded and End-loaded Rubber Fenders



SIDE-LOADED AND END-LOADED RUBBER FENDERS

Figure 5-9 Shear Fender

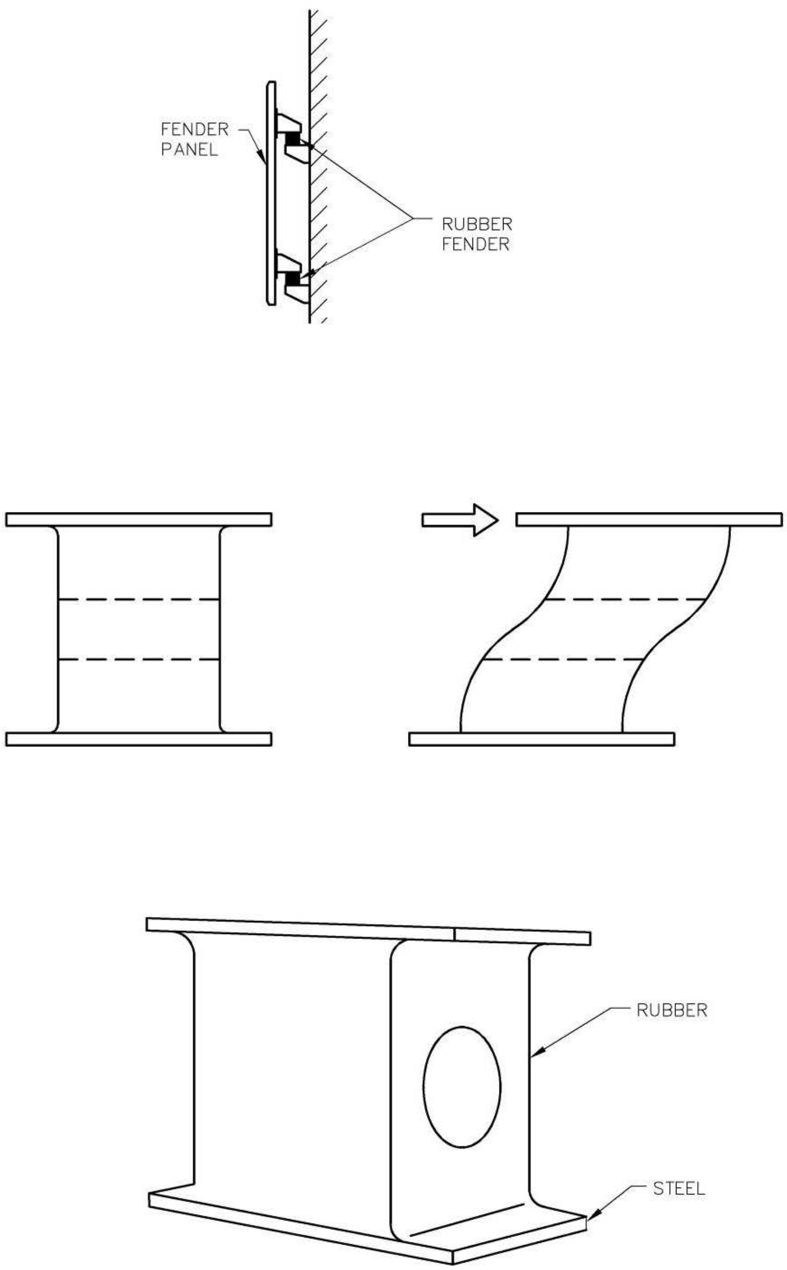
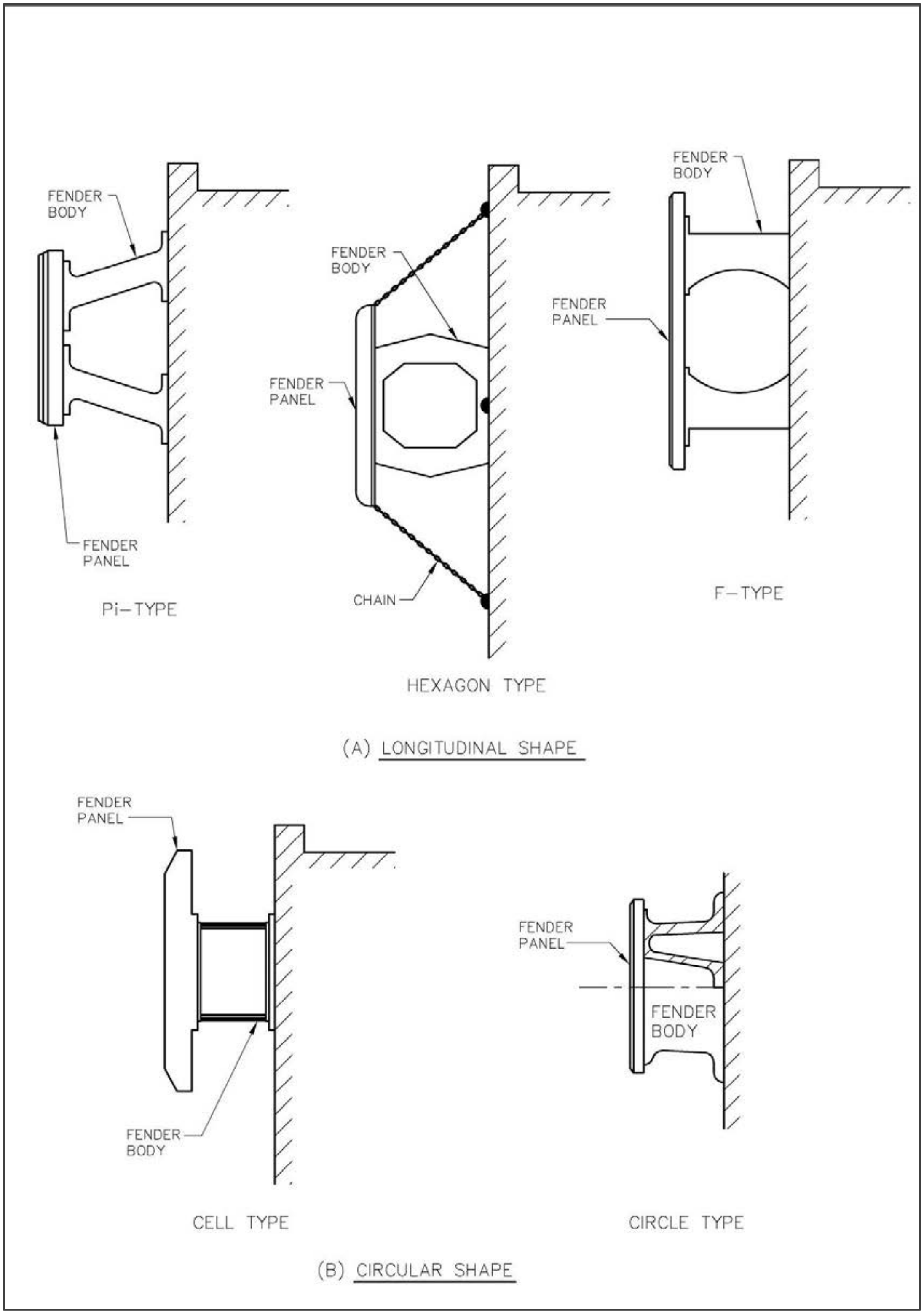


Figure 5-10 Buckling Fender with Contact Panel



5-3.3.3 Floating Fender Units.

This system consists of pneumatic or foam-filled fender units and a backing system. As the fender units can be positioned to float with the tide, most surface ship types can be handled. Design the backing system to work with the fender unit for the full tidal range. Because the floating units are usually rather large, they provide a good standoff. The berthing structure may be designed with the backing system at different points along the length of berth and the fender units moved around as berthing plans change. When clustered piles or sheet piles are used for the backing system, additional energy can be absorbed by the piles and their support systems at the deck level.

a. Pneumatic / Hydro-Pneumatic Fenders. The potential energy in these fenders is stored by the elastic compression of a confined volume of air. By varying the internal pressure of air, the energy-absorption characteristic can be changed. To prevent the air pressure from increasing to a "blowout" level, pneumatic fenders are provided with a relief valve or deflection limiter within the body of the unit. The shell construction for these fenders is similar to an automobile tire with several laminations to provide the high tensile strength required. The surface pressure of these fenders is uniform, resulting in uniform hull pressure. Reaction force is an exponential function of deflection. The basic types of pneumatic fenders in common use are discussed below:

- Air Block and Air Cushion. The shells for these are chemically bonded and mechanically coupled to a rigid mounting plate that can be attached to a solid face of the berthing structure. See Figures 5-11(C) and 5-11(D).
- Floating. The floating type is usually cylindrical in shape with hemispherical ends and is attached to the structure by chains. It floats on the water and rises and falls with the tide. The unit requires a backing system to distribute the load. As shown in Figures 5-11(A) and 5-11(E), large floating pneumatic types are sometimes covered with a net of used automobile tires and cylindrical rubber sleeves to protect the fender from puncture and abrasion. The tire net and chains also form the means for rigging and attaching the fender to the pier.
- Tire. This type consists of a large-diameter tire mounted on an axle and backed by rollers. The unit can be mounted with its axis of rotation vertical or horizontal. This type is particularly suited for pronounced corners of the structure where ships may have approach difficulties. See Figure 5-11(B).
- Hydro-Pneumatic. This type of fender has been developed for use with submarines and consists of a vertically mounted cylindrical pneumatic fender partially filled with water and backed by a closely spaced group of fender piles. A ballast weight is added to adjust the degree of submergence of the fender to coordinate the vertical center of the fender with the horizontal center of the submarine hull; see Figure 5-12. The fender unit floats with the tide and therefore stays in the same relative position with the vessel.

Figure 5-11 Pneumatic Fenders

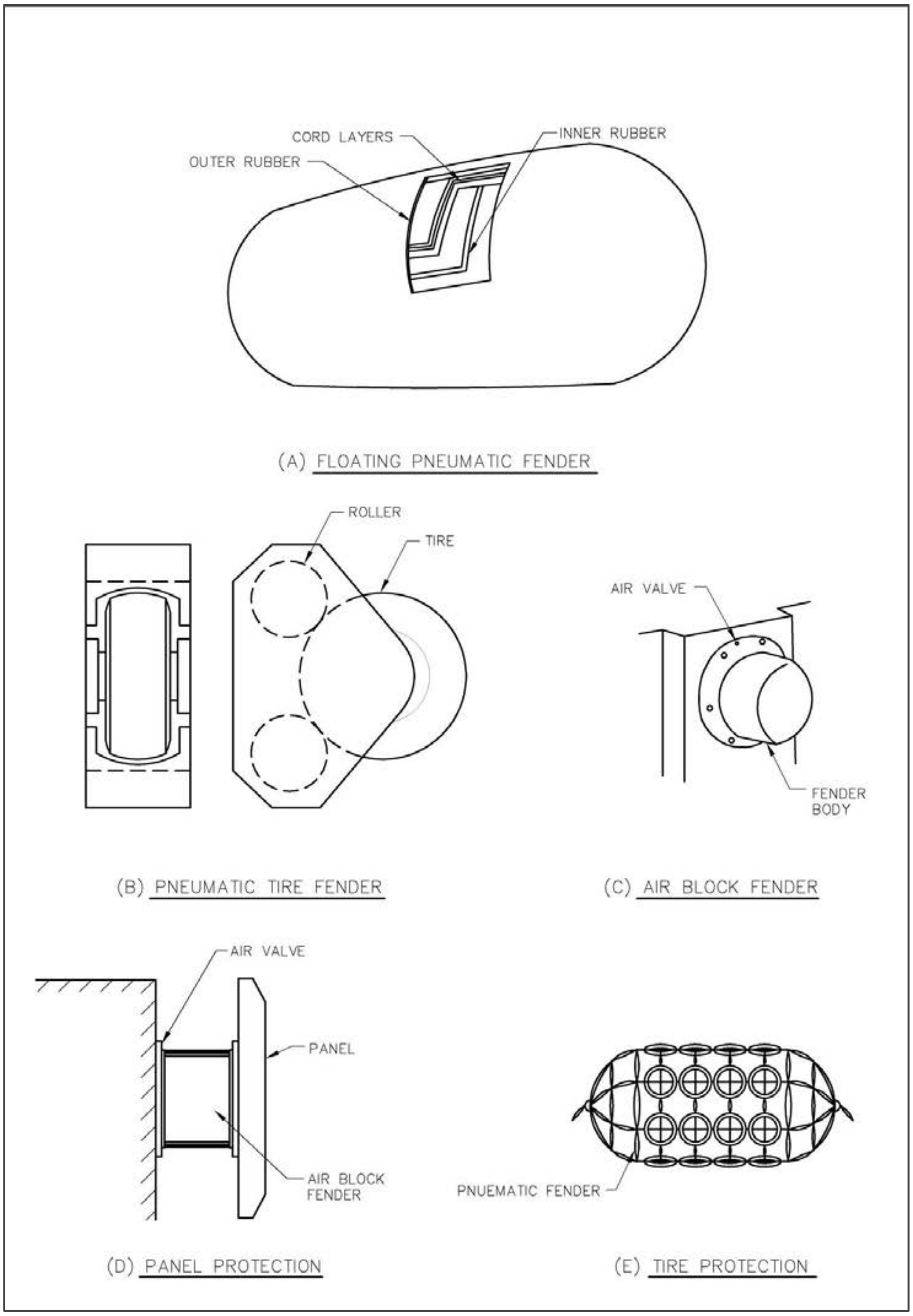


Figure 5-12 Hydro-pneumatic Fender

Hydro-pneumatic fender and counter weight being installed.
(*Marine Fender Systems*).

b. Foam-Filled Fenders. These are constructed of resilient, closed-cell foam surrounded by an elastomeric skin. Provide additional protection against abrasion by thicker elastomeric coatings or an external tire net, similar to the floating pneumatic type. The fender requires a backing system to distribute the load. Netless fenders cost more due to the need for thicker skins and coatings. However, the greater hull marking of the tire net and occasional maintenance need suggest that netless fenders may be preferred. The unit can either be utilized as a floating fender, moving up and down with the tide and held in place with chains or can be suspended from the pier/backing system. The cellular structure of the foam filling reacts like hundreds of millions of individual pneumatic fenders in deforming and absorbing the energy. The foam contains the air within its cellular structure and tends to compress upon itself rather than bulge peripherally. The foam-filled fenders have a high-energy absorption with comparatively small reaction force. Surface pressure of the fender is not quite uniform when it is compressed, so the hull pressure over the contact area is not quite uniform. Where rough concrete surfaces of the backing surface or prestressed concrete piles is a concern, use UHMW pads or strips to protect the skin of the foam filled fender. See Figure 5-5 for a typical foam-filled fender installation.

5-3.3.4 Combination System.

Any of the above-mentioned fender systems may be combined in the same berth. A berth may have either the floating fender units or directly mounted fenders at discrete points, with the in-between spaces filled up by the pile-rubber system designed to work with camels. Floating fenders and directly mounted fenders may be used alternately along solid or open types of piers and wharves.

5-3.3.5 Monopile System.

This fendering system is based on the use of a floating ring-shaped resilient fender unit that rides up and down on a large steel pile driven to the seabed. Special low-friction bearing pads are usually installed on the inner surface of the hull of the ring fender so that the fender unit can rotate and slide freely on the pile. This unique ability makes the monopile system very suitable for corner protection of piers and wharves and entrances to a narrow slip. The units can also work well as breasting and turning dolphins. Energy is absorbed both by the steel monopile in flexure and by the ring-shaped fender unit. This system is illustrated in Figure 5-13.

5-4 SELECTION AND DESIGN OF FENDER SYSTEMS.

5-4.1 General.

The major factors influencing the selection of the best fender system for a particular situation include the following:

5-4.1.1 Energy-Absorption Requirements.

Provide the fender system with sufficient energy-absorption capacity to absorb the kinetic energy of the berthing vessel.

5-4.1.2 Reaction Force.

This is the force that is exerted on the berthing structure during impact. The reaction force has a significant effect on the design of the berthing structure.

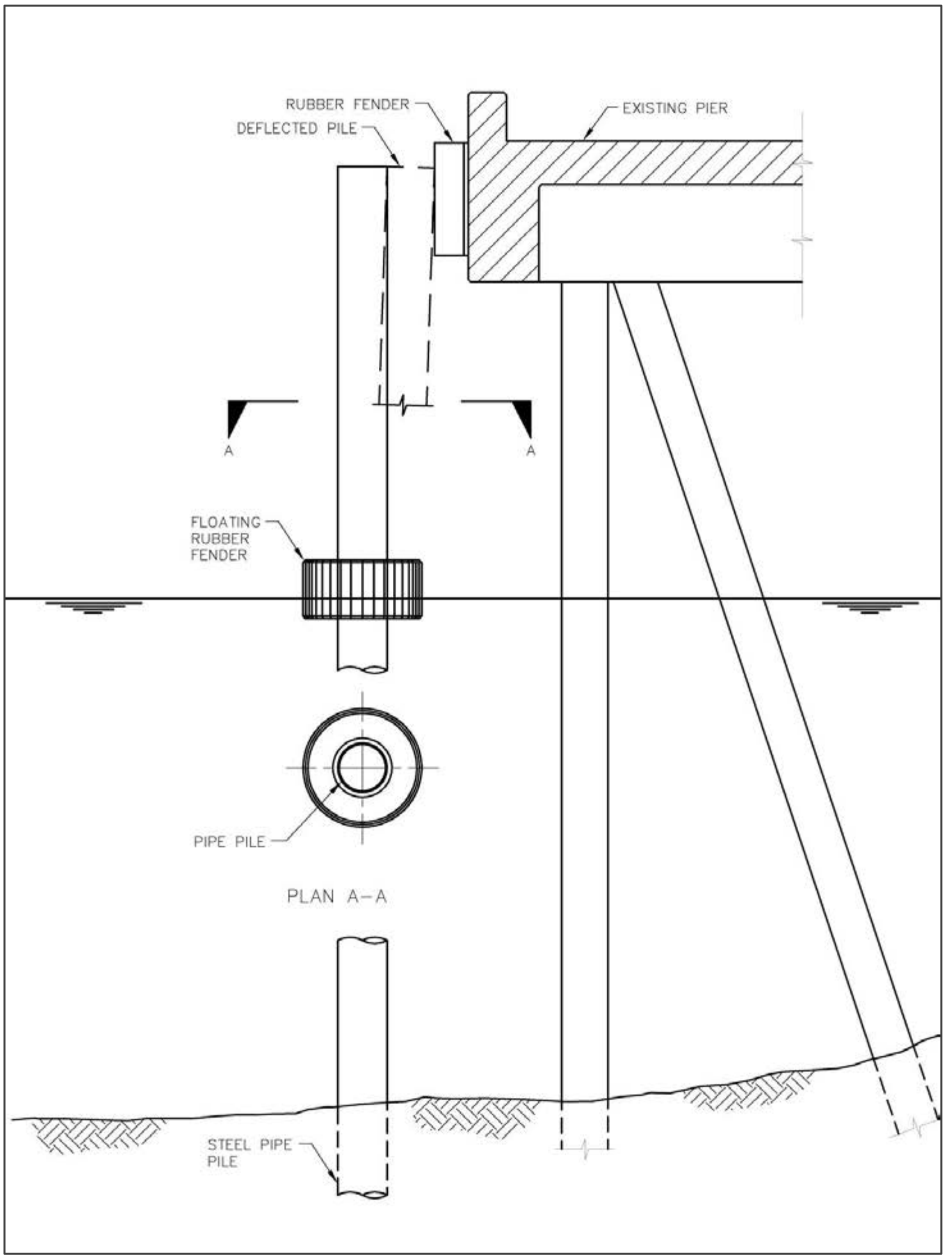
5-4.1.3 Hull Pressure.

This is the pressure exerted on the ship's hull by the fender unit and is derived by dividing the reaction force by the fender area in contact with the ship. Limit hull pressure to levels that will not cause permanent damage to the berthing ship.

5-4.1.4 Deflection.

This is the distance, perpendicular to the line of the berth that the face of the fender system moves in absorbing the ship's kinetic energy. The magnitude of the allowable deflection will be controlled by other protrusions from the berthing face and the ship.

Figure 5-13 Monopile Fender System



5-4.1.5 Reaction/Deflection Relationship.

The nature of the reaction deflection relationship determines the relative stiffness of the fender system.

5-4.1.6 Long-Term Contact.

This includes the changes in environmental conditions (i.e., wind, current, waves, and tide) during loading and unloading at the berth. The fender system should not "roll up," tear, abrade, or be susceptible to other forms of damage when subject to long-term contact.

5-4.1.7 Coefficient of Friction between the Face of the Fender System and the Ship's Hull.

This determines the resultant shear force when the ship is berthing with longitudinal and/or rolling motion and may have a significant detrimental effect on the energy-absorption performance of the fender system. The magnitude of the shear force also may have a significant effect on the cost of the berthing structure.

5-4.1.8 Degree of Exposures.

Where the berth is exposed to severe wind, current, and/or wave action, the fender selection may be governed by the design mooring conditions rather than berthing conditions.

5-4.1.9 Life-Cycle Costs.

Evaluate capital costs for both the fender system and the structure; also evaluate costs for operation, maintenance, and repair.

5-4.1.10 Berthing Practice.

The capability of the crews responsible for berthing the ship will have an effect on the energy-absorption requirement of the fender system. The berthing velocity and angle of approach are affected by the local berthing practice.

5-4.1.11 Maintenance.

Where maintenance is expected to be infrequent, a simple, possibly less efficient, fender system may be preferable to a system requiring a higher degree of maintenance.

5-4.1.12 Local Experience.

Consider fender types already used locally because their performance under actual conditions is known. Also, there may be an advantage in having interchangeability of spares, particularly if the number of new fenders required is small.

5-4.1.13 Frequency of Berthing Operations.

A high frequency of berthings normally justifies greater capital expenditures for the fender system.

5-4.1.14 Range of Ship Sizes Expected to Use the Berth.

While the energy-absorption capacity of the fender system may be selected for the largest ship expected to use the berth, ensure that the fender system is suitable for the full range of ships that the berth will accommodate. The effect of hull pressure and fender stiffness on the smaller vessels may have a significant influence on the selection and arrangement of the fenders.

5-4.1.15 Shape of Ship's Hull in Contact with the Fender System.

Where vessels with unusual hull configurations or protrusions are expected to use the berth or where the berth accommodates barges, pay special attention to the selection and arrangement of the fender system.

5-4.1.16 Range of Water Level to be Accommodated.

Consider the full range of water levels that may occur at the berth. Consider both the largest and smallest vessels, in both the loaded and light conditions, at high and low water levels. Where extreme water level variations occur, consider using floating fender systems.

5-4.1.17 Camels.

The size, type, and number of camels used in berthing operations will seriously influence selection of the fender system.

5-4.2 Fender System Behavior.

The fender systems having the most promise for new installations can be classified into three groups in terms of their behavior:

5-4.2.1 Flexible Pile Types.

The flexible pile types, or various fender piles discussed earlier, have basically a linear force-deflection relationship. Cantilevered piles or “monopile" systems likewise have a basically linear force-deflection relationship.

5-4.2.2 Buckling Column Types.

The buckling column types behave linearly up to a point where the rubber starts to buckle and behave nonlinearly from there on. Because the buckling type fender systems have the highest energy-absorption capacity for a given deflection and reaction, they are in very wide use in commercial piers and wharves. Due to the nature of the reaction/deflection/energy-absorption relationship of these types of fenders, a very high reaction (close to maximum) occurs during virtually every berthing operation. Design the berthing structure with this fact in mind. This fact also causes the fender to be relatively rigid when smaller ships use a berth designed for larger ones.

Many buckling-type fenders cause rather high contact pressures against the ship's hull and consequently require a panel to distribute and thus reduce the pressure. Size and locate the panel to ensure proper contact with both the largest and smallest vessels to use the berth. Another characteristic of these fenders to consider is their lowered performance when impacted by a vessel approaching at an angle to the berth or with a velocity component in the longitudinal direction. The reduction in energy-absorption capacity may be as much as 20 percent when the approach angle is 5 to 10 degrees, with additional reduction when combined with shear strain.

5-4.2.3 Pneumatic, Foam-Filled and Side-Loaded Rubber Fenders.

The pneumatic, foam-filled, and side-loaded rubber fenders exhibit very similar behavior with the reaction force building up more than proportional to increasing deflection. The floating pneumatic and foam-filled fenders have a similar appearance and similar reaction/deflection relationship. Compared to the buckling types, these fenders require greater deflection for a given reaction and energy-absorption capacity. Further, the pneumatic and foam-filled fenders present a relatively larger surface to the ship's hull and consequently have lower hull contact pressures. This eliminates the need for a panel between the ship and the fender. With the pneumatic and foam-filled types of fenders, the maximum reactions will normally occur only a very few times during the life of the facility, permitting the use of higher stress levels in the supporting structure. However, they require a rather large, solid face on the supporting structure, which may increase its costs. The main difference between pneumatic and foam-filled fenders is that the first will lose its strength completely when punctured by ship protrusions and that the latter may lose a significant part of its energy-absorption capacity under repeated heavy loadings.

5-4.3 Evaluation of Fender Systems.

5-4.3.1 Equal Energy and Reaction.

Figure 5-14 (A) illustrates the reaction-deflection characteristics of the three types of fender systems. The area under each of the reaction/deflection curves represents the energy absorbed by that type of fender. Each of the curves in the figure represents fender systems with equal rated reactions and equal energy-absorption capability. It is evident from the figure that, while the fenders of the various types illustrated provide equal energy absorption at equal rated reactions, the energy-absorption capacity is achieved through different deflections, with the buckling type deflecting the least.

5-4.3.2 Equal Reaction and Deflection.

A comparison of the various types of fenders may alternatively be considered on the basis of equal rated reaction and equal deflection, as illustrated in Figure 5-14 (B). This situation often occurs when new fender units are installed in conjunction with, and compatible with, an existing fender system. It may also occur when a replacement fender system is installed in an existing facility with cargo transfer equipment of limited reach. It is evident from the figure that the buckling type fenders have considerably more energy-absorption capacity for the same reaction and deflection than the other types.

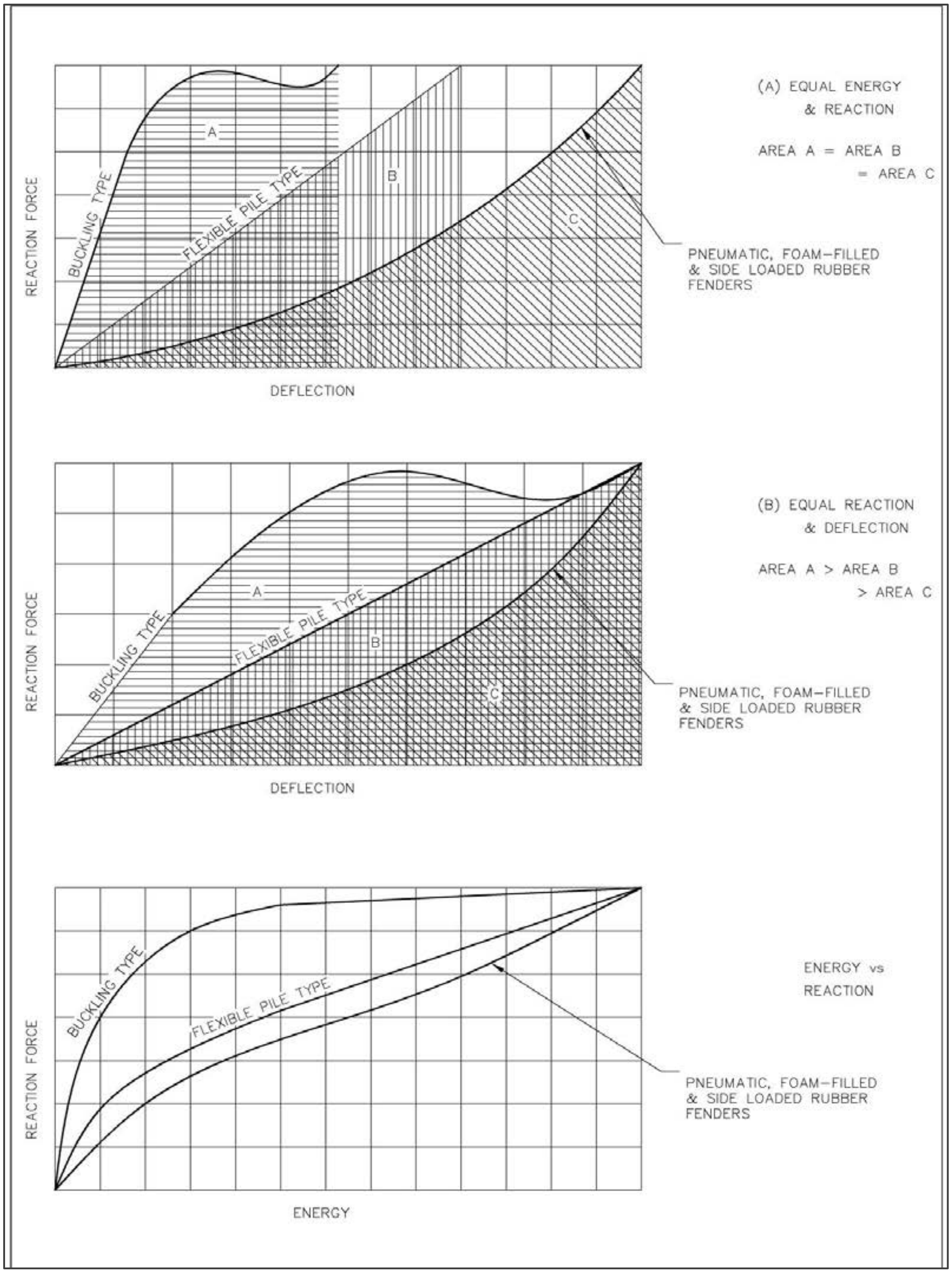
5-4.3.3 Reaction versus Energy Absorbed.

Comparing the various types of fender systems from the point of view of the reaction force that is developed for a given energy-absorption capacity, as illustrated in Figure 5-14 (C), it is evident that the pneumatic, foam-filled, and side-loaded rubber type fender units are the "softest." They have greater energy-absorption capacity at reaction levels less than their maximum rated reaction. This characteristic makes these fenders particularly attractive at berths that expected to accommodate a wide range of vessel sizes because the fenders will deflect significantly even when subjected to relatively small berthing impacts.

5-4.3.4 Accidental Overloads.

Also to be considered in the selection of a fender system is the consequences of an accidental overload of the system. The buckling and side-loaded rubber fenders "bottom out" if compressed beyond their maximum rated deflection, with resultant high reaction forces and the potential for severe damage to the berthing vessel and the support structure. The reaction of flexible pile fender systems will continue to increase at a uniform rate when overloaded until the yield stress of the pile material is reached, at which point continued deflection will occur as the material yields with no appreciable increase in reaction. Foam-filled fenders, when compressed beyond their maximum rated deflection, will exhibit a steadily increasing reaction and will incur permanent deformation and consequent loss of future energy-absorption capacity. The pneumatic fenders are normally fitted with relief valves so that when overloaded they continue to absorb energy with no increase in reaction beyond that which corresponds to the relief valve setting and no permanent damage to the fender unit.

Figure 5-14 Evaluation of Fender System Types



5-4.4 Fender System Design.

5-4.4.1 Ship Contact.

While the ideal berthing process would attempt to engage as many fender units as possible, in reality, at the time of impact, the ship will be at a slight angle to the berth and contact will be made over a small length. Design discrete fender units such as the buckling column type or the floating type, for one unit to absorb the full energy with a minimum of two units installed per berth. For the continuous system using flexible piles and fenders, the length of contact will be a function of the ship's hull radius at the level where contact is made, the flexibility and spacing of fender units, and the stiffness of the chock and wale assembly in the horizontal plane. The problem is analogous to a beam on an elastic foundation. In the absence of more rigorous analysis, the following assumptions for contact length may be made:

- 20 feet (6.1 m) for cruisers, destroyers, and frigates.
- 40 feet (12.2 m) for amphibious warfare ships, and auxiliary ships.

When berthing is made with camels, assume only one camel to be in contact at the time of impact, with a minimum of two camels installed per berth. Where the camels are guided by fender piles, assume all the piles to be effective in sharing the energy. When free-floating camels are used, not all the piles backing the separator will be effective. Local experience should dictate and a more conservative assumption should be made.

5-4.4.2 Allowable Hull Pressure.

When the ship's energy is resisted through foam-filled or pneumatic fenders, the resulting force is concentrated in a small area of the ship's hull. In such cases, the allowable pressure on the ship's hull becomes a critical design issue. Most surface combatants have a thin hull plating with a low allowable hull pressure. For more specific information on the ships being berthed, consult NAVSEA. See TR-6015-OCN, *Foam Filled Fender Design to Prevent Hull Damage*, and note that values in Table 7 are based on yielding of the hull plating and include a 1.5 safety factor. Consequently, when checking for an accidental condition, the allowable value for hull pressure may be increased by up to 50 percent.

5-4.4.3 Allowable Stresses.

Because ship berthing is a short-term impact type of loading, the following increases over previously published values are permitted.

a. Timber. For operating condition, the allowable stress in flexure (tension and compression) may be taken as 0.67 times modulus of rupture or the published allowable values increased by a factor of 2.0, whichever is less. For the accidental condition, the stress-strain curve may be assumed to be linear up to 0.9 times modulus of rupture, which should be taken as the limit.

b. Steel. For operating condition, the allowable stress in flexure (tension and compression) may be taken as 0.8 times yield stress. For the accidental condition, full yield stress may be used. However, the sections used should satisfy compactness requirements or the allowable stress reduced proportionately. Members should be sufficiently braced for development of the yield strength.

c. Concrete. Design reinforced and prestressed concrete members not intended for energy absorption with a load factor of 1.7 over forces developed due to operating condition; they will be satisfactory for the accidental condition. Do not allow further prestressed members to develop tensile stresses in excess of 12 f'_c (f'_c = 28-day compressive strength) in the precompressed zone. Prestressed concrete members specifically designed for energy absorption will have a maximum allowable working energy (E_{wc}) equal to 0.67 times the applied load (P) times the deflection at the point of the applied load. Satisfy the following three criteria to determine the maximum allowable working energy (E_{wc}) in the pile section for a given length:

- Maximum concrete compressive strain equal to or less than 0.0021 inch/inch (0.0021 mm/mm).
- Maximum stress in the prestressing steel at working energy equal to or less than 210,000 psi (1 447 899 kPa).
- The working energy (E_{wc}) no more than 2/3 of the nominal pile energy (E_{nc}). This provides a minimum factor of safety of 1.5 in case of overload of the pile.

5-4.4.4 Coefficient of Friction.

As the ship is berthed against the fender system, there will be force components developed in the longitudinal and vertical directions also. As the coefficient of friction between rubber and steel is very high, special fender front panels have been developed with reduced friction coefficient. Ultra high molecular weight (UHMW) plastic rubbing strips have been successfully used in front of timber piles. The following friction coefficients may be used in the design of fender systems.

- Timber to steel…………… 0.4 to 0.6
- Urethane to steel………… 0.4 to 0.6
- Steel to steel…………….... 0.25
- Rubber to steel…………... 0.6 to 0.7
- UHMW to steel…………… 0.1 to 0.2

5-4.4.5 Temperature Effects.

Fender piles, backing members, etc., are not affected by temperature fluctuations and can be expected to perform normally. However, in colder temperatures, rubber fender units become stiffer and their performance will be affected significantly. Hence, evaluate the energy-absorbing capability of the rubber unit and the fender system as a whole based on the lowest operating temperature expected. Carefully design and detail UHMW rubbing strips which have a significantly higher rate of expansion than steel or concrete to operate effectively.

5-4.5 Corner Protection.

Provide all corners of piers and wharves and entrances to slips with fender piles, rubbing strips, and rubber fenders for accidental contact with ships or routine contact with tugs. Use any of the different types of fender piles mentioned. See Figure 5-15 for typical details.

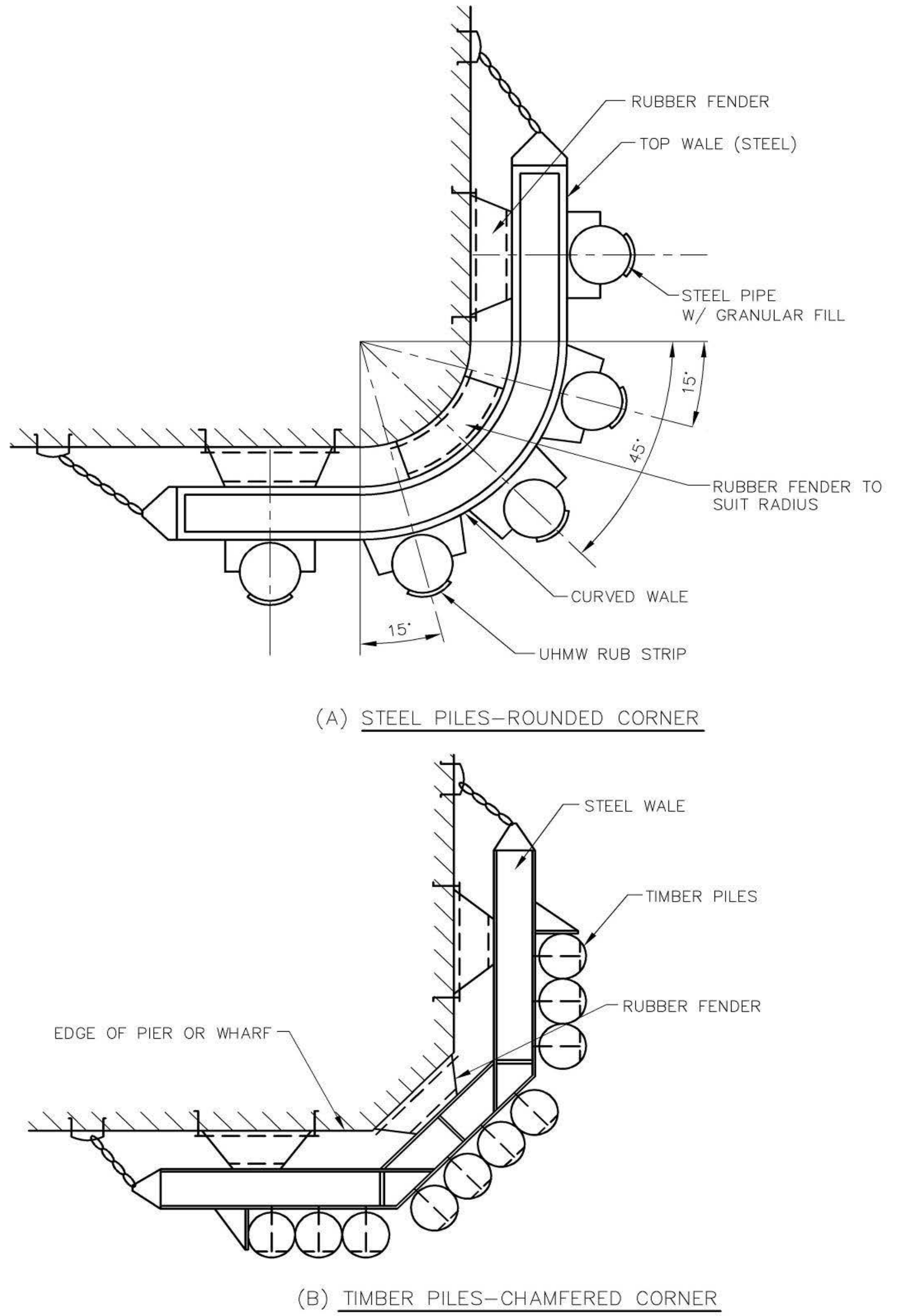
5-4.6 Support Chains.

Chains are commonly used in fender systems when a tension member is needed. Chains are used in continuous fender systems and large buckling and cell type units to resist the sudden energy released. For pneumatic and foam-filled resilient fender units, the chain is used to suspend the units. Chain smaller than 3/8 inch (9.5 mm) is not recommended. For better corrosion resistance, zinc coating is preferred. A common weldless high-test chain is usually more cost-effective than the stud link variety.

5-4.7 Chocks and Wales.

For selection and design of chocks and wales refer to SP-2045-SHR, *Proposed Design Criteria for Chocks and Wales.*

Figure 5-15 Corner Protection



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CHAPTER 6 CAMELS AND SEPARATORS

6-1 FUNCTION AND APPLICATION.

Camels are structures used between the ship and the pier/wharf. Camels are a NAVFAC design responsibility. Separators are structures used between adjacent multiple berthed (nested) ships to provide a "standoff" or separation. Separators are a NAVSEA design responsibility. As mentioned in the previous section, design of fender piles or other backing system is required to provide the structural interface between the camel and the pier/wharf structure. Camels and separators are used at piers and wharves for the following reasons.

6-1.1 Hull Maintenance.

During active berthing, the ship's crew typically performs cleaning, painting, light hull repairs, and other routine maintenance activities on the ship. These activities are best performed when the ship is kept off the structure at discrete points.

6-1.2 Overhangs and projections.

Aircraft carriers that have large overhangs at the flight deck level, and several other ship types having bulges and projections at the side, require camels to prevent damage to the ship at these projections. Other protrusions include air masker bands, soft sonar domes, and stabilizer fins.

6-1.3 Special Hull Treatments.

Some ships are equipped with special hull treatments that can get damaged through constant rubbing against the structure. Camels and separators with rub strips can minimize the contact area and control the damage.

6-1.4 Submarine Berthing.

Navy submarines are typically berthed using camels. The submarines may be moored to the camels or moored directly to the berthing structure. Submarines require the camels to prevent damage to diving planes, screws, fairings, and the special hull treatments. Specifically, camels should not interfere with the Wide Aperture Array (WAA) found on some submarines. Further, special attention may be required for submarines equipped with the Conformal Acoustic Velocity Sonar (CAVES). These systems may require the camels to be located in specific locations. Develop berth specific camel mooring plans and coordinate with SUBFOR.

6-1.5 Multiple Berthing (Nesting).

Separators are required between ships that have to be berthed abreast for ship-to-ship transfer operations or for lack of berthing space at a naval station.

6-1.6 Fender Protection.

When the existing fender system can suffer damage due to motions of moored ships, a camel can be useful in reducing the damage as long as it is properly placed and the ship is properly moored.

6-2 CAMELS.

Experience has shown that camels left unattended in the vacant (no vessel present) condition at a berth can be subjected to damage from action by wind and waves, depending upon the degree to which the berth is sheltered. For this reason, a site specific study should be prepared for each berth where camels are to be utilized. The study should look at: environmental conditions, i.e. wind/wave climatology and vessels expected to utilize the berth. Procedures should be developed detailing how the camels will be moored and secured in place to include measures to buffer the camel face contacting the berth in order to prevent damage to the camel.

6-2.1 Log Camels.

These are large-diameter logs (24- to 36-inch (610 to 914 mm) diameter, 40 to 50 feet (12.2 to 15.2 m) long) held in the desired position from the deck by nylon ropes or chains. They are usually allowed to float with the tide. The longer length is preferred as they can distribute the load to a greater number of piles. Multiple log camels are made from several smaller diameter logs held together by wire rope at ends and at center. They are not as efficient as the single log camels. Plastic coated steel pipes have also been used successfully as camels. The pipe core is generally filled with foam to ensure positive flotation. Log camels fabricated from recycled plastics and composite materials are available. Sometimes a series of used tires may be fitted through the log to provide some energy absorption. Log camels do not provide much of a separation. When a wider separation is needed, other types of camels are more appropriate. Consider marine growth as it relates to log camel buoyancy.

6-2.2 Timber Camels.

These consist of several large timbers connected together by struts and cross braces to form a large crib. Additional flotation units may be inserted between the timbers for a higher freeboard. Wear causes bolt heads to become exposed and thus cause damage to hulls.

6-2.3 Steel Pontoon Camels.

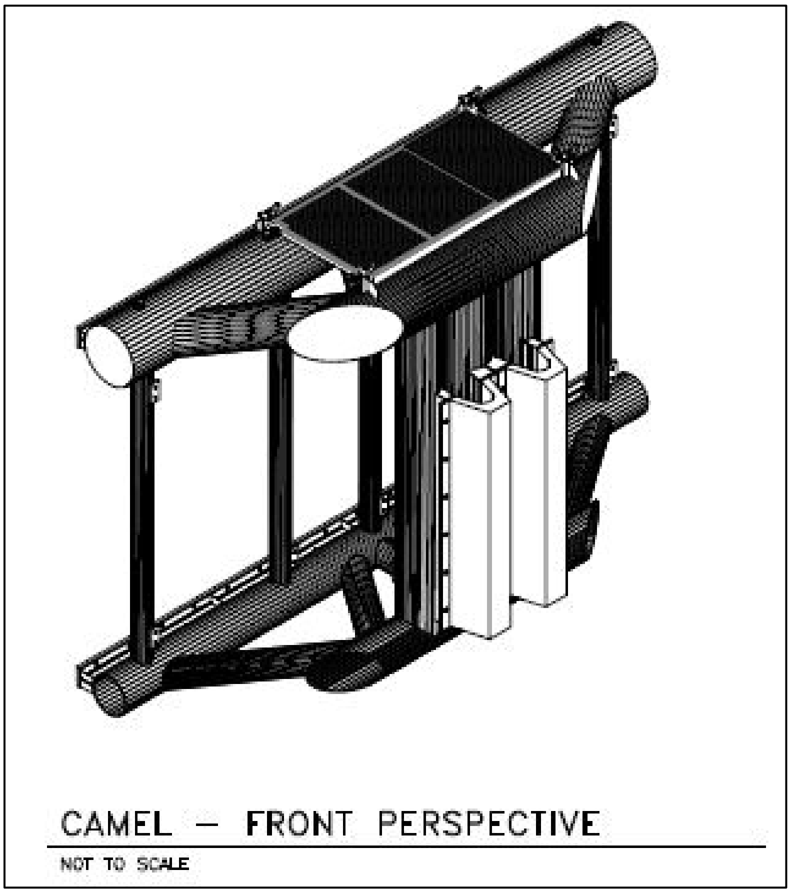
These are made of cubical or cylindrical steel pontoons connected by structural framing. The pontoons should preferably be filled with foam to reduce the risk of losing flotation by accidental puncturing of the units.

6-2.4 Deep-Draft Camels.

For submarine berthing where a good portion of the body is below the waterline, all the above camels are inadequate, as the camel will ride up on the submarine during berthing. Hence, deep-draft camels have been developed. They have limited energy absorption and a narrow working platform. These camels work well when mooring against a tender ship and for multiple berthing. When used against an open pier or wharf, these camels will require solid backing elements (below waterline) from the fender system. A typical deep-draft camel is shown in Figure 6-1.

Figure 6-1 Deep Draft Camel (NAVFAC drawing 100400035)

(Drawing By: B. Deneke)



6-2.5 Hydro-Pneumatic Fenders.

Although discussed previously under the section: Floating Fender Units, this type of fender has been used as a camel for submarines at a number of locations. One of the principle reasons for preparing the report, TR-6064-OCN, *Berthing Guidelines for Submarines,* was to investigate hydro-pneumatic fenders in terms of providing adequate clearance for the submarine's stern planes. Based upon the findings in this report, 14.8

feet (4.5 m) diameter hydro-pneumatic fenders are recommended in lieu of 10.8 feet (3.3 m) diameter hydro-pneumatic fenders.

6-2.6 Composite Camels.

NAVFAC EXWC developed a composite camel for use in berthing submarines. The camels are manufactured from composite materials intended to provide an extended service life over steel construction. The camels were developed and funded under a NAVFAC RDT&E effort and have been successfully used at SUBASE New London since mid-2000. Subsequently, a NAVFAC standard design has been developed and can be obtained at: http://www.wbdg.org/ffc/navy-navfac/cad. Universal composite submarine camels are shown in Figure 6-2.

Figure 6-2 Universal Composite Submarine Camel

6-2.7 Loads.

The camel loads are computed from berthing and mooring analysis of the ship, camel, fender, and structure system resisting the lateral loads. All the ship's berthing reaction loads as well as current and wind loads are transmitted through the camels to the pier or wharf structure. Assume all horizontal loads to be acting uniformly along the length. Design deck elements of large camels for 50 psf (2.4 kPa) vertical live load. Check the camel assembly for fabricated camels for lifting stresses. Where the pick-up points and rigging configurations are critical to control lifting stresses in the camels, provide clearly marked pick-up points or pad-eyes. For complex lifting requirements, provide lifting diagrams on the design drawings.

6-3 GEOMETRY.

The shape and size of fabricated camels are governed by the ship's geometry at waterline.

6-3.1 Length and Width.

Provide adequate length of camels in order to keep the contact pressure between camel and hull and between camel and pier fenders within allowable limits. This is particularly important where compressible fender faces are used that transfer reaction pressure directly to the hull plate versus the frames of the vessel. The length should not be less than the distance between three frames of the ship, three fenders or fender piles on the pier, or 30 feet (9.1 m), whichever is greatest. Minimum camel width is determined by the ship's required standoff; ships roll characteristics and freeboard, the presence of any overhanging projections on a ship and vertical obstructions on the dock such as gantry cranes or light poles.

6-3.2 Depth.

Provide adequate depth for submarine camels and separators to maintain contact with ship and pier/wharf in the full tidal range.

6-4 STABILITY.

There is usually some eccentricity between the horizontal load applied on the ship-side and the horizontal reaction provided on the dock-side. This is due to tilting of the camels (from imperfect flotation, buoyancy tank taking on water, etc.) and tendency of the camel to ride up and down with the vessel due to tidal fluctuations. The camel should have sufficient width, depth, and weight to provide roll stability for counteracting the effect of the load eccentricity and should have means of adjusting for variations in tilt and trim.

6-5 LOCATION.

For fine-lined ships, camels should generally be placed within quarter points of the ship to give strength and to bear on a reasonably straight portion of the hull. For straight-sided ships, camels may be located beyond the quarter points. Provide at least two camels for each class of ship. Camels should not be placed so as to bear directly against structural piles.

6-6 MISCELLANEOUS CONSIDERATIONS.

6-6.1 Protection.

Consider outfitting steel camels with a suitable protective coating or a cathodic protection system, depending on relative costs.

6-6.2 Buoyancy Tanks.

Buoyancy tanks should be compartmented or foam filled. Provide drainage plugs used for pressure testing the buoyancy tanks. Where pontoon camels are assembled in a single line, they should be ballasted for stability through plugged openings provided for this purpose. Consider the buoyancy of framing members and the weight of paint, if any, in the buoyancy and stability computations. Where buoyancy tanks are not foam filled to allow filling with ballast water or weights to adjust trim and freeboard of the camel, provide easily accessible fill/pump out and vent connections. These connections can be used to pump out excess water that leaks into the tanks.

6-6.3 Abrasion.

Camel fenders rubbing against a hull remove its paint. Exposed surfaces are subject to corrosive action, especially at the waterline. For these reasons, it is desirable to have camel fenders rub against hulls above the waterline where the hull can be repainted if necessary.

6-6.4 Service Life.

Service life is an important consideration related to camel selection operation and maintenance. Frequency of inspection, maintenance and overhaul should be determined for the type of camel system used. Life cycle economics should be considered in lieu of just first cost.

6-7 STANDARD CAMEL DESIGNS.

6-7.1 Submarine Camels.

Drawings and information on the camels described below may be obtained from the NAVFAC Atlantic - Engineering Criteria & Programs office.

6-7.1.1 Tapered Submarine Mooring Camel.

(NAVFAC Dwg 1404664-1404666). This tapered camel is framed from steel pipe with timber members on the front of the camel to support the rubber fender elements. This camel is intended for use with the SSN 688 class submarine.

6-7.1.2 Non-Tapered Submarine Mooring Camel.

(NAVFAC Dwg 1404943-1404947). This is a non-tapered version of the camel described above.

6-7.1.3 Attack Submarine Camel.

(NAVFAC Dwg 1404667-1404670). This camel is intended to replace the tapered camel described above. This camel is trapezoidal in shape and is framed from steel pipe. This camel is intended for use with both the SSN 688 and SSN 21 class submarines.

6-7.1.4 Revised Attack Submarine Camel.

(NAVFAC Dwg 10400031-10400034). This camel reflects recent revisions made to the attack submarine camel described above.

6-7.1.5 Trident Submarine Camels.

Specifically designed camels using guide piles along the specific wharves are used for trident submarine homeports at both Kings Bay, Georgia and Bangor, Washington.

6-7.1.6 Composite Camels.

Universal composite submarine camels have been designed and placed in use at numerous submarine bases. These camels were designed to be used with any class of submarine in the U.S. Navy. As a NAVFAC standard design, both drawings and specifications are readily available for use in procurements. Design criteria is provided on the drawings. NAVFAC drawings 14019607-14019615 are available at: http://www.wbdg.org/ffc/navy-navfac/cad. The Universal Composite Submarine Camel was designed with the flexibility to not interfere with the Wide Aperture Array (WAA) and can therefore be located along the length of the submarine with maximum flexibility. However, special attention may be required for submarines equipped with the Conformal Acoustic Velocity Sonar (CAVES). This system may require the camels to be located in specific locations. Develop berth specific camel mooring plans and coordinate with SUBFOR.

6-7.2 Aircraft Carrier Camels.

6-7.2.1 Steel Pontoon CVN Camels.

Aircraft carrier camels designed specifically for CVN 68 class aircraft carriers were available through an indefinite quantity contract (N00189-00-D-0254) which expired in September 2005. Camel design is proprietary. On 2 September 2004 an exercise was conducted in berthing CVN 65 alongside Pier 6 South at Naval Station Norfolk. This was to learn more about CVN berthing at a double deck pier. One significant finding was the need to increase the standoff of the aircraft camel by approximately 5 feet (1.5 m) to give additional standoff. Figure 6-3 shows a CVN camel in plain view (prior to the additional 5-foot (1.5-m) standoff).

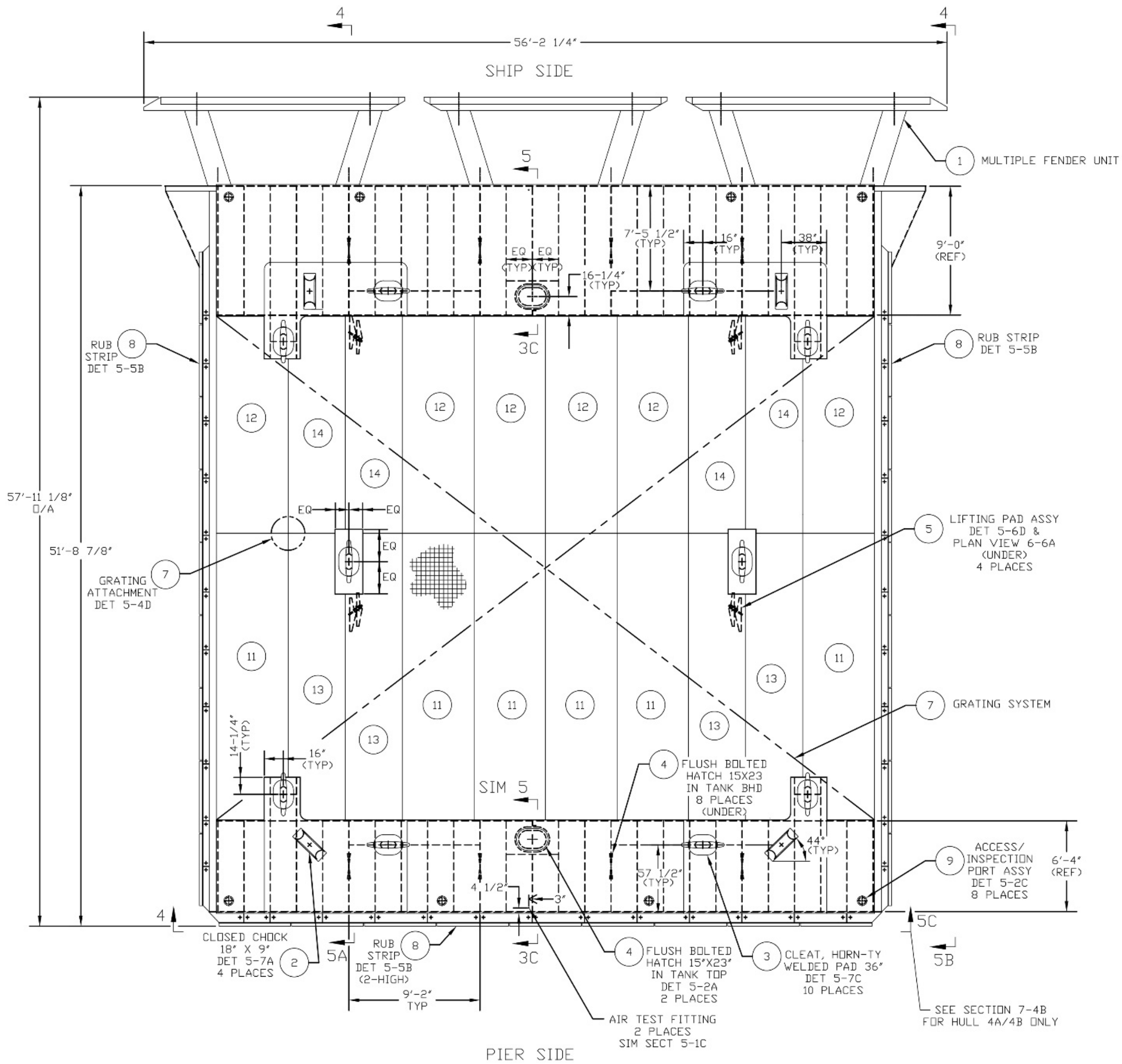
The following pertinent information is provided for the CVN camels:

- Construction – steel floating frame pontoon.
- Loads – 1500 kip (6672 kN) lateral and 500 kip (2224 kN) longitudinal reaction force transmitted to the camel fender system along the length of the camel. Values were based on maximum wind and current forces associated

with heavy weather conditions (95 mph (42.5 m/s) wind, 1 knot (0.51 m/s) current) and breasting reaction associated with CVN berthing assuming a maximum approach velocity of 0.5 feet/second (0.15 m/s).

- Suitable for placement along the flat side of the hull approximately between frames 110 and 190 with an allowable hull pressure of 30 psi (207 kPa).
- Working surface designed for 100 psf (4.8 kPa).
- Size: 56 feet-2 1/4 inch (17.1 m) wide with standoff of 57 feet-11 1/8 inch (17.7 m) (undeflected fender).
- Weight: 95.4 long tons (951 kN).
- Light draft: 3.66 feet (1.12 m); Live load draft: 4.34 feet (1.32 m).
- Light freeboard: 3.3 feet (1 m); Live load freeboard: 2.4 feet (0.73 m).

Figure 6-3 Aircraft Carrier Camel



6-7.2.2 Universal Composite CVN Camel.

Under a design-build procurement, NAVFAC has developed a universal composite CVN camel. Universal composite CVN camel rendering is shown in Figure 6-4.

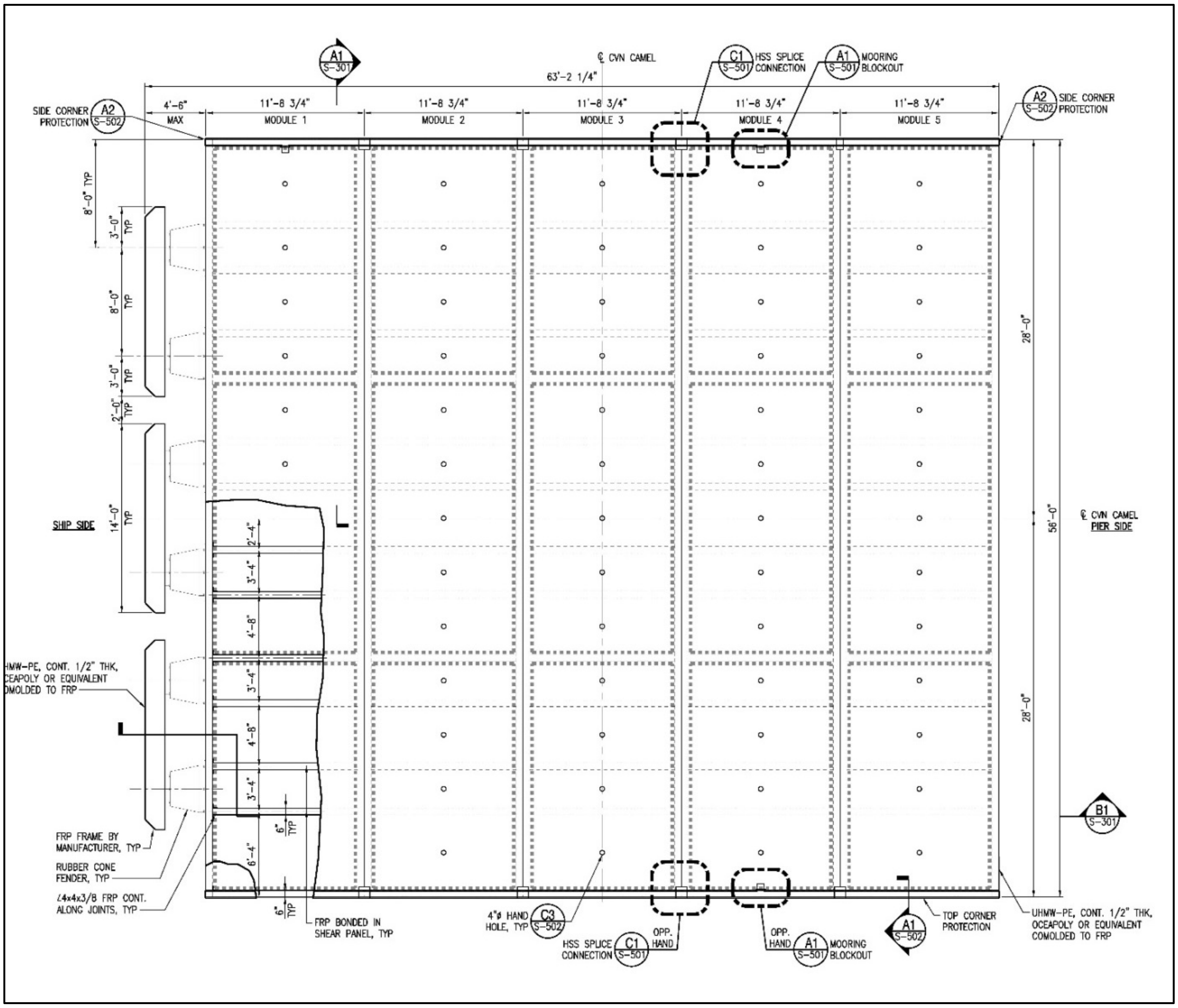
Universal composite CVN camel was developed based upon the following criteria:

- Construction – FRP.
- Loads – 1,500 kip (6,672 kN) lateral and 300 kip (1334 kN) longitudinal reaction force transmitted to the camel fender system along the length of the camel. Values were based on maximum wind and current forces associated with heavy weather conditions (95 mph (42.5 m/s) wind, 30 second gust, 1 knot (0.51 m/s) current) and breasting reaction associated with CVN berthing assuming a maximum approach velocity of 0.3 feet/second (0.09 m/s).
- Suitable for placement along the flat side of the hull approximately between frames 110 and 190 with an allowable hull pressure of 30 psi (207 kPa).
- Uniform live load on overall camel structure ~ 20 psf (1 kPa).
- Uniform live load on individual module top panel ~ 60 psf (3.9 kPa).
- Maximum vertical live load on top panel ~ 20 kips (89 kN) on 6 inch by 6 inch (152 mm by 152 mm) base plate.
- Size: 56 feet (17.1 m) wide with standoff of 63 feet-5 inch (19.3 m) (undeflected fender).
- Weight: 369.1 kips (1642 kN).
- Camel Height: 7 feet-8 inches (2.3 m).

6-8 SEPARATORS.

As mentioned previously, separators are a NAVSEA responsibility. Design for a universal submarine-to-submarine type separator is found on NAVSEA Dwg 6983485. A useful reference from NAVSEA is NSTM 018, Chapter 611, *Fenders and Separator*s.

Figure 6-4 Universal Composite CVN Camel



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CHAPTER 7 ACCESS

7-1 GENERAL.

Several access structures are used in piers and wharves for moving personnel and cargo, and accommodating selected utility lines. They have unique design requirements. Some are of standard design while others are designed and constructed specifically to go with the facility. The access facilities covered by this manual are landing float, brow or gangway, brow platform, walkway or catwalk, and ramp. Utility booms are discussed in UFC 4-150-02, *Dockside Utilities for Ship Service*. Where there is a potential need for access by a physically handicapped person, meet the applicable requirements of the *Americans with Disabilities Act Accessibility Guidelines* and the *Uniform Federal Accessibility Standards*, and when they differ, the one with the greatest accessibility requirement will govern.

7-2 SAFETY.

Safety on piers and in pier design is an important consideration. Consider operational uses and where possible provide safety precautions, protections and warnings to minimize the potential hazards. Double deck piers require additional safety considerations. Potential uses and needs for pier deck space are unlimited and should be evaluated based on the local requirements. It is essential that safety and operators be involved in the pier design, so potential uses can be identified, categorized and policy determined. In particular high-voltage electrical, fall hazards, trip hazards, and access to industrial or mechanical areas are issues that require additional consideration. In light of this, a study was conducted entitled, *Lower Deck Pier Safety Study*. Numerous activities were examined in detail and a matrix developed specifying essential use activities as well as prohibited activities. Although this study was somewhat site specific for Naval Station Norfolk, it should be consulted for details on safety solutions and recommendations. For example, the study provides useful information such as details on all signage required and detailed plan views of both upper and lower decks for the double deck piers at Naval Station Norfolk which show:

- Utility locations
- Activity areas
- Striping
- Transit paths
- Vehicle turn locations
- Curb, fencing, guardrail, handrail, lighting, life ring, fall protection and signage locations

7-2.1 Fall Protection.

In contrast to previous versions of this document, fall protection is now a requirement for mitigating fall hazards on U.S. Navy piers and wharves. Comply with Department of the

Navy Fall Protection Guide, Section 9.13 Work Over Water. This reference provides the relevant information on standards, regulations, criteria, and requirements for fall protections. In particular, fall protection systems, criteria, and design requirements are provided.

7-3 LANDING FLOAT.

When piers and wharves need to be accessed from the waterside by small craft such as patrol boats (which cannot berth directly), a landing float and a brow are required.

7-3.1 Materials.

Flotation units may consist of foams of polystyrene and polyurethane, fiberglass-reinforced polyester resin shells with or without foam cores, metal pontoons, metal pipes, metal drums, and hollow concrete sections. Timber logs, the earliest form of flotation unit and the cheapest, have a tendency to become waterlogged and their use is not recommended. Decks of floats are variously made out of wood planks, plywood, plywood and fiberglass-resin coatings, concrete, and nonskid metal surfaces. Framework for floats is generally of preservative-treated timber, although steel and aluminum are often used. All ferrous metal hardware should be galvanized or otherwise protected from corrosion.

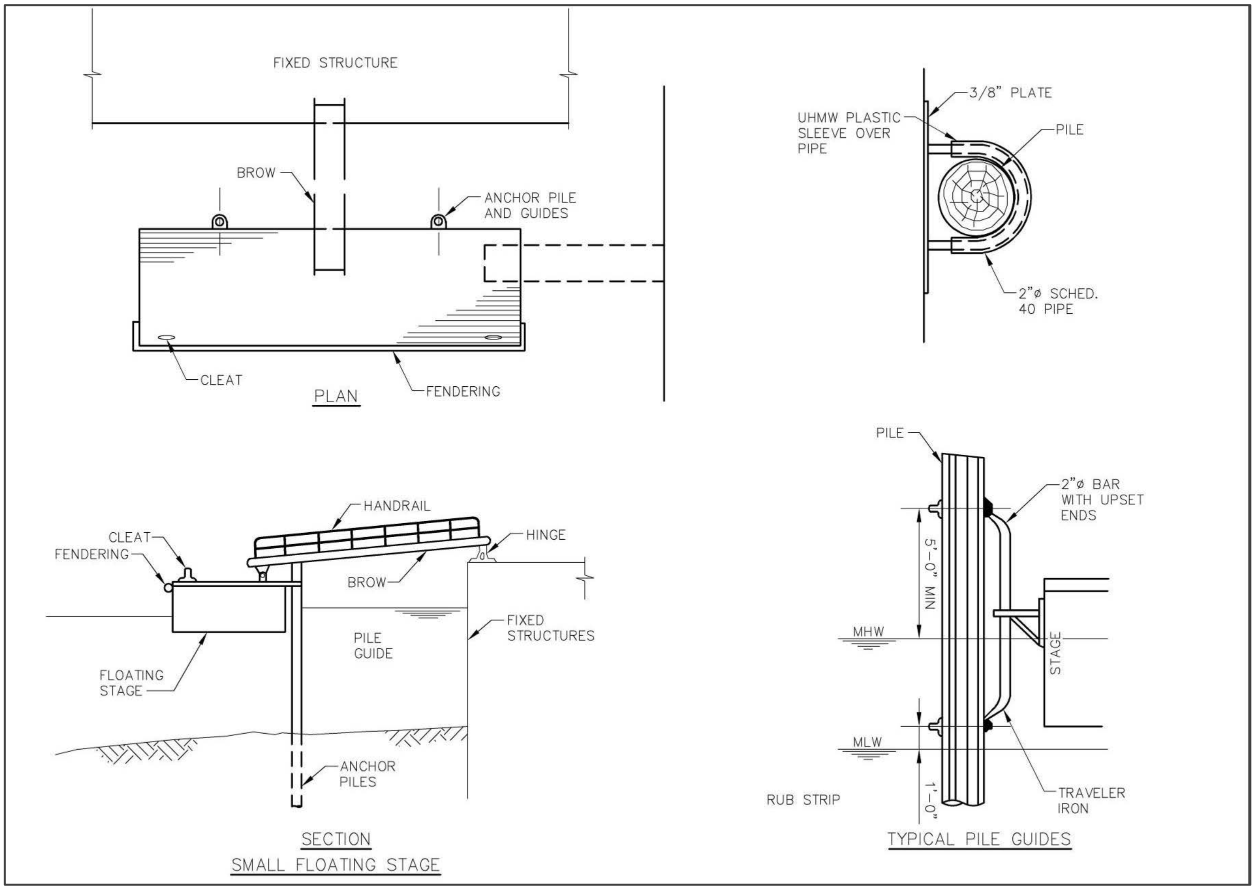
7-3.2 Mooring Systems.

Anchor floats to prevent movement by wind, current, waves and impact from the ships. Anchorage may consist of individual vertical (guide) piles, frames of batter and vertical piles, and cables or chains. When piles are used to anchor small floats, guides are furnished to secure the float to the anchor pile. Commonly used guides are rigidly braced metal hoops of pipes, rollers, or traveler irons. Chains and flat bar guides should not be used as they cause the float to hang up on the piles. See Figure 7-1 for details. This system works well for shallow waters with a large tidal range. In deeper water, the pile head may have to be supported by the structure or pile driven deeper. Anchorage may also be obtained from a cable or chain system attached to the ocean bottom or to the fixed pier or wharf structure.

7-3.3 Live Loads.

Design stages for landing personnel only for a uniform live load of 50 psf (2.4 kPa) or a concentrated live load of 500 pounds (2.2 kN) placed at any point on the deck surface. The float should not tilt more than 6 degrees from the horizontal when applying the concentrated live load of 500 pounds (2.2 kN).

Figure 7-1 Small Floating Stage



7-3.4 Freeboard.

Floating stages for small craft usually ride with the deck from 15 to 20 inches (381 to 508 mm) above the water surface under dead load. Live loads usually lower the float about 8 to 10 inches (203 to 254 mm).

7-3.5 Fendering.

Provide fenders on all floating stages. For small craft berthing, fenders may consist of soft, flexible rubbing strips (rubber tires, sections of hose).

7-3.6 Fittings.

Provide a minimum of three cleats (5,000-pound (22 kN) capacity) for securing small craft.

7-3.7 Finish.

Provide the deck with a nonskid surface. Where wheels or rollers from a brow will be resting on the float, provide guide channels or a skid plate to prevent damage to the float.

7-3.8 Concrete Float Elements.

Concrete encased plastic foam elements designed for use in concrete floating docks for marinas can be connected together in various configurations to be used as work floats. The mass added by the concrete encasement creates a very durable float that is less affected by waves and live loads than more lightweight systems.

7-4 BROW OR GANGWAY.

Brows are used for access to landing floats from the pier or wharf structure, however they are more frequently used to provide personnel access from a pier or wharf to a berthed ship.

7-4.1 Length.

Brows should be of sufficient length so that the slope will not exceed 1.5 horizontal to 1.0 vertical at the worst condition.

7-4.2 Widths.

Widths should be 36 inch (0.9 m) minimum (clear) passage for one-way traffic and 48 inch (1.2 m) minimum (clear) passage for two-way traffic. Provide a 60 inch (1.5 m) minimum (clear) passage for two-way traffic when personnel carry small loads.

7-4.3 Construction.

Use fiberglass, aluminum, steel, timber, or a combination of these materials. Aluminum and fiberglass are generally preferred for the low weight to strength ratio and corrosion protection.

7-4.4 Live Load.

Design the brow structure for a uniform live load of 75 psf (3.6 kPa) and a concentrated live load of 200 pounds (0.9 kN) applied anywhere. A reduction in the live load to 50 psf (2.4 kPa) may be permissible where the brow is to be used in conjunction with a landing float. For calculation of reaction to the landing float, the live load can further be reduced to 25 psf (1.2 kPa).

7-4.5 Handrails.

Design handrails to resist 50 plf (0.73 kN/m), applied in any direction at the top. Design handrails to resist a single concentrated load of 200 pounds (0.9 kN), applied at any direction at any point along the top. It is assumed that the uniform load and the concentrated load do not act concurrently. The handrail may be designed to serve as the top chord of a truss when sufficiently braced.

7-4.6 Safety.

Provide safety devices to keep the brow from rolling off the platform deck and to prevent movement of the platform while in use. Clip safety chains into position for personnel safety. Large tidal variations are a problem because these may cause the brow to roll off the platform. A similar situation exists when high winds, currents, and extreme tides pull a ship away from the pier. Numerous accidents have been associated with brows being supported by pallets either on the ship end or pier end of the brow. Brows are not to be used in conjunction with pallets. If a platform is necessary, properly engineer, design, and build under the technical cognizance of NAVFAC. NAVFAC EXWC had designed a safety gangway ramp as step to alleviate this issue. For additional information, contact NAVFAC Atlantic - Engineering Criteria & Programs.

7-5 BROW PLATFORMS.

Brow platforms are used when a brow from ship deck to pier deck is not practical, or presents an obstruction. Examples are portal crane trackage along repair berths, large tidal variations, and great height from deck to pier. Aircraft carriers (CVNs) usually use one brow forward and two aft. These brows require platforms 20 feet (6.1 m) or higher. This platform is basically a truncated tower, with typical measurements of 12 by12 feet (3.7 by 3.7 m) at the base, while the top deck is 5 feet (1.5 m) wide and 10 feet (3 m) long. If small stair platforms are built alternately opposite hand, the requirement for a large platform can be met by lashing two of the smaller ones together. Sometimes the ship end of the brow can be connected to a rotatable platform which is permanently fixed to the ship by means of pins that lock the brow pivot hooks to the circular rotating portion of the rotatable platform. Construction materials and live load requirements are the same as for brows.

7-6 BROW AND PLATFORM DESIGNS.

Standard designs for brows and platforms are found in NAVFAC Dwg SD1405000-1405041 at: http://www.wbdg.org/ffc/navy-navfac/cad.

7-7 WALKWAY OR CATWALK.

These are permanent personnel access bridges installed between shore and different elements of piers and wharves. One example is a walkway between the pier or wharf structure and a mooring dolphin located some distance away as shown in Figure 2-1.

7-7.1 Width.

For walkways between shore and a U-shaped wharf, a 4-foot (1.2 m) width is recommended. For infrequently used walkways, the minimum width should be 3 feet (0.9 m).

7-7.2 Live Load.

Design all walkway structures for 100 psf (4.8 kPa) live load.

7-7.3 Construction.

Walkway decking should be slip-resistant aluminum or fiberglass grating. Framing may be wood, aluminum, or fiberglass members. In view of the light loads encountered, piles supporting deck stringers can be of treated timber. Where loads and installation difficulty make timber piles inadequate, concrete and steel piles may be used.

7-7.4 Handrails.

Provide handrails on either side of the walkway. Consider handrails for use along edges of approach trestles and along non-berthing extents of docks or wharves.

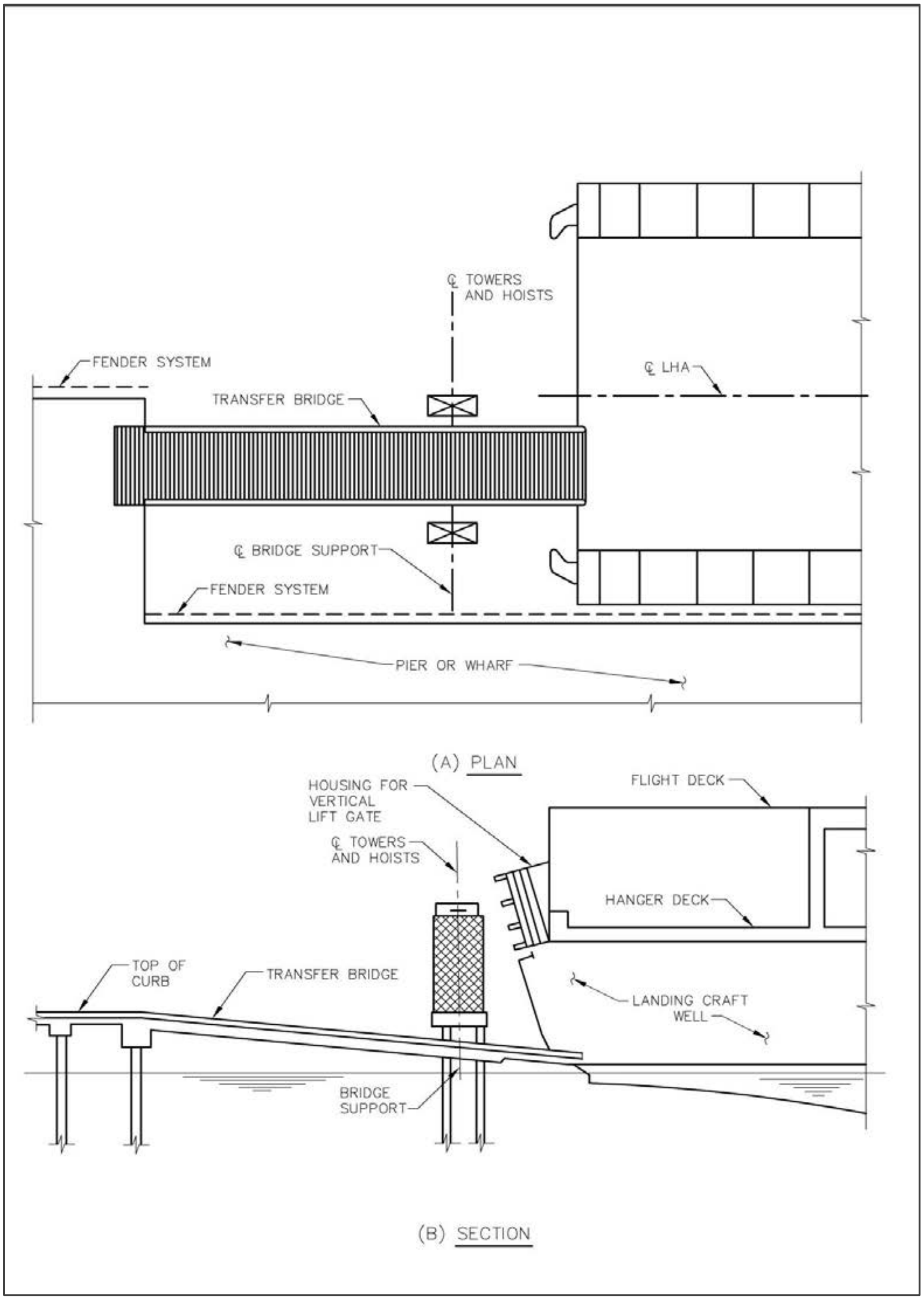
7-8 RAMPS.

Transfer bridges or ramps are sometimes required for moving vehicles or heavy cargo from ships, similar to a roll-on/roll-off (RO/RO) operation. MSC RO/RO ships do not require any special features on existing piers. Sideport ramps are stowed and handled by the ship. Sternport ramps are hinged to the vessel and extend to dockside or floating equipment (lighters, causeways, stages). These ships also have conventional cargo gear.

The LHA-class of amphibious assault ships has vertical lift stern gates, possess RO/RO capability. Installations accommodating vessels of this type should consider the use of a ramp or transfer bridge, as shown on Figure 7-2, to minimize the time required for movement of vehicular equipment and for loading of supplies. Design and construction of ramps should be similar to highway bridges. One key issue regarding ramps is clearance from pier/wharf edge obstructions, i.e. utility risers, cleats, bollards, etc. When designing piers and wharves, consider the specific location for ramp landing as well as structural deck strength.

As discussed previously, sideport loading ramp access for LHA, LHD, and LPD 17 class ships is an important consideration, particularly on double deck piers.

Figure 7-2 Transfer Bridge for LHAs



7-9 SAFETY LADDERS AND LIFE RINGS.

7-9.1 Safety Ladders.

Provide safety ladders from pier or wharf deck to water at a maximum spacing of 400 feet (122 m) or as noted below with regard to life rings. Such ladders should be at least 1 foot-4 inches (0.41 m) wide and should reach the lowest water elevation anticipated. Safety cages are not required. Safety ladders may have grab bars to protect from mooring lines and hinges to protect the ladder from small boat damage in lieu of rail extensions. It is recommended to provide guard timbers/fenders on either side of the ladder, or to protect within the fender system. Locate the ladders on either side for a pier wider than 50 feet (15.2 m). For piers less than 50 feet (15.2 m) wide, insure that an individual could swim under the pier to reach the ladder on the opposite side or provide ladders on both sides. Locate ladders on the waterside for a wharf at places convenient to anyone who might accidentally fall into the water. Figure 7-3 illustrates a safety ladder for a pier or wharf, while Figure 7-4 illustrates a safety ladder with a 3-foot (0.9 m) extension along an unprotected bulkhead, rope guards may be required to protect the ladder extension.

Safety/emergency egress ladders are different than access ladders. Safety regulations may vary from location to location. Coordinate with local safety office on specific ladder requirements, marking, and use.

7-9.2 Life Rings.

29 CFR 1917.26, *First Aid and Lifesaving Facilities* requires that a U.S. Coast Guard approved 30-inch (0.76 m) life ring, with at least 90 feet (27 m) of line attached, shall be available at readily accessible points at each waterside work area where the employees' work exposes them to the hazard of drowning. Provide a readily available portable or permanent emergency egress ladder giving access to the water within 200 feet (61 m) of work areas. Co-locate life rings with permanent ladders.

Figure 7-3 Safety Ladder at Protected Berth

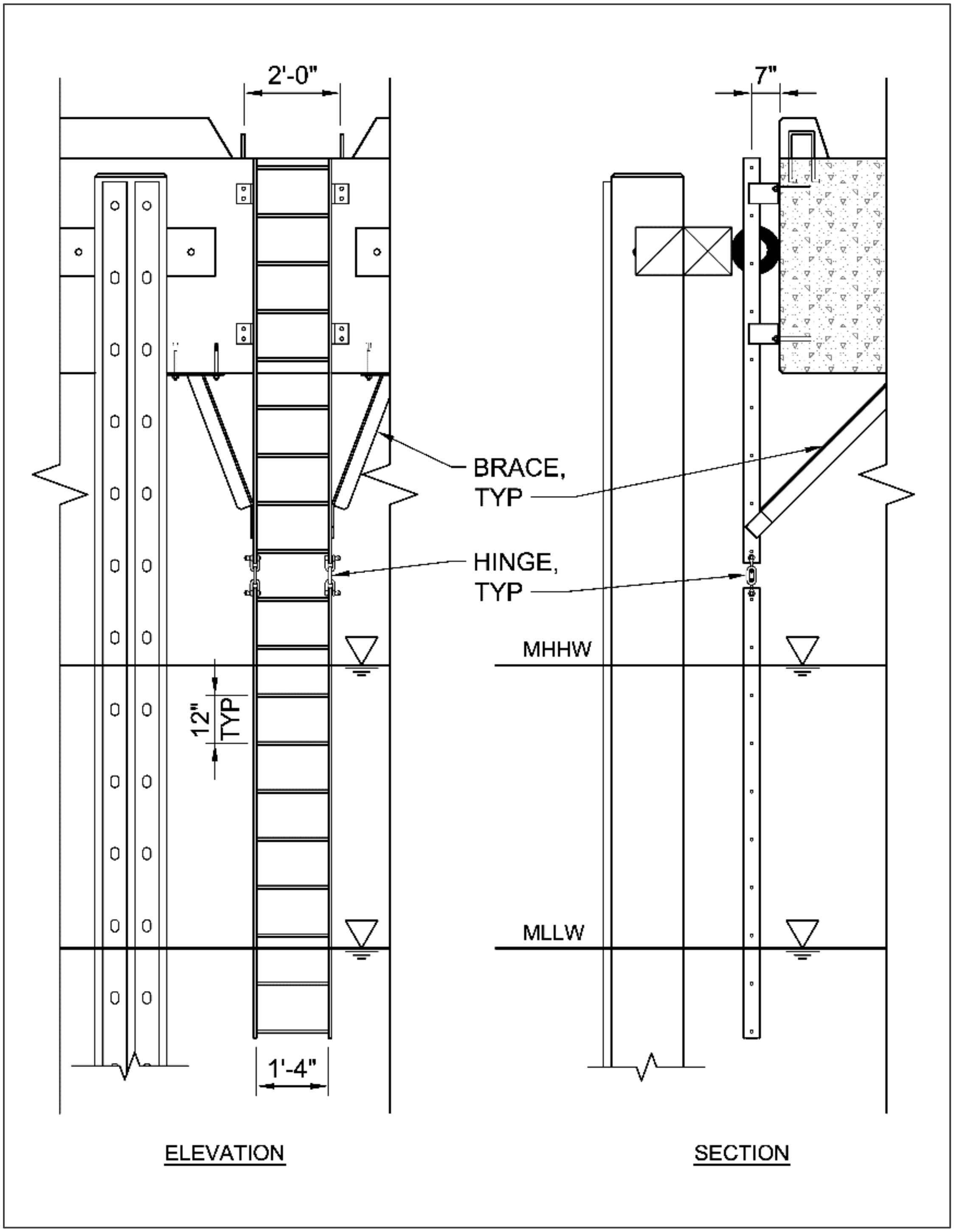
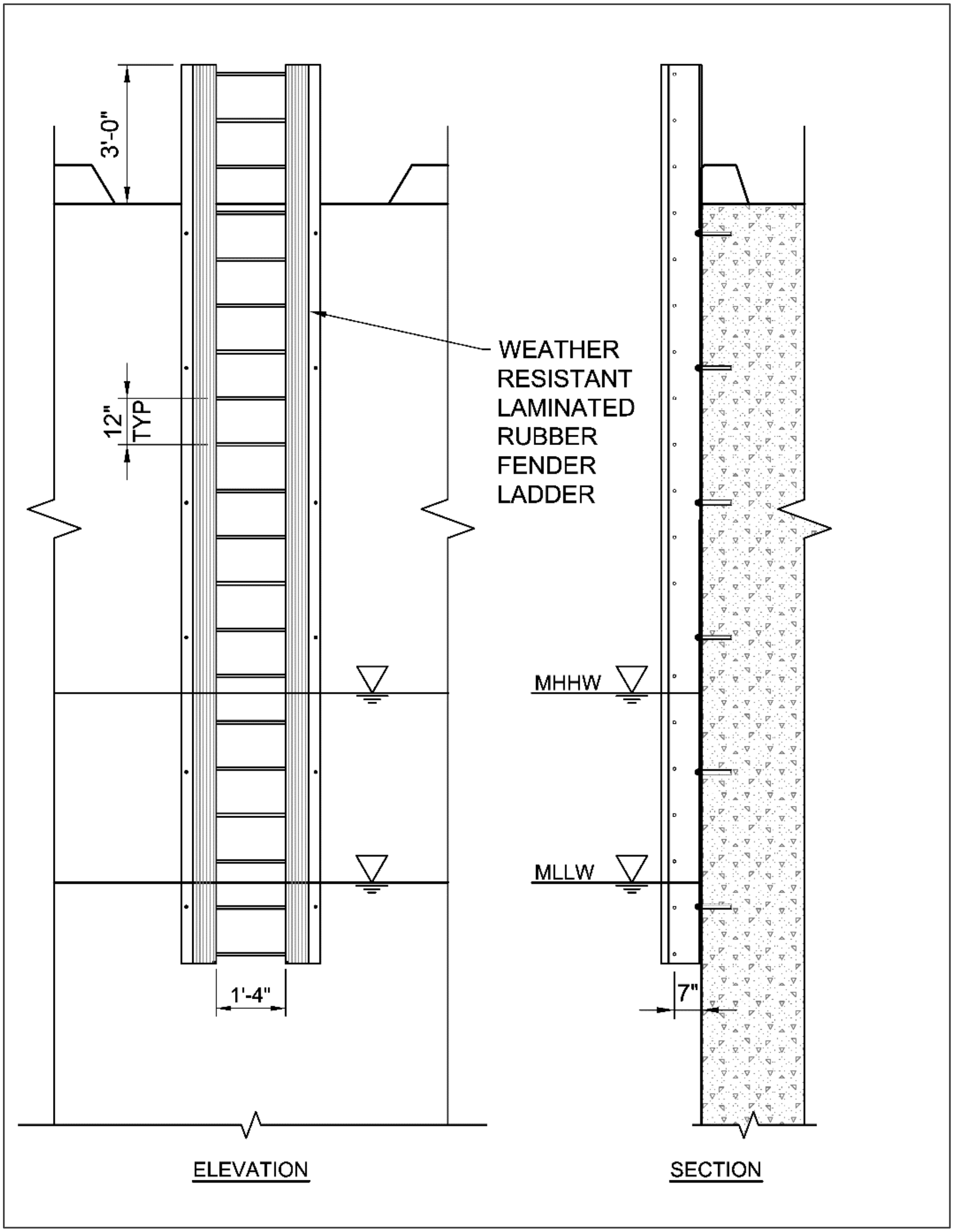


Figure 7-4 Safety Ladder at Unprotected Berth



APPENDIX A REFERENCES

A-1 GOVERNMENT PUBLICATIONS.

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

https://www.fema.gov/media-library/assets/documents/757

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NAVAL FACILITIES ENGINEERING COMMAND, ATLANTIC

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APPENDIX B GLOSSARY

B-1 DEFINITIONS.

Breasting Dolphin – A freestanding independent structure that a vessel will bear against when current, wind or berthing motion moves the ship into the pier or wharf. Breasting Dolphins are typically equipped with energy absorbing fender systems and are pile supported or solid fill structures.

Bulbous Bow – A protruding bulb at the bow (or front) of a ship just below the waterline.

Bullrail – A wide low curb along the outboard edge of the pier or wharf. The bullrail may be cast-in-place concrete, steel or timber. Bullrails may be fixed or removable. Mooring hardware is often mounted on top of the bullrail.

Camel – A floating structure used to separate a moored vessel from the pier or wharf. Camels are used with ships that have hull configurations that do not match well with typical pier or wharf fender systems, such as, submarines or where vessels require an offset from the pier or wharf due to deck or superstructure overhangs such as an aircraft carrier.

Catwalk – A narrow walkway, especially one high above the surrounding area, used to provide access or allow workers to stand or move.

Cold Iron – Used to describe the condition of a ship when all shipboard boilers, engines, and generators are inoperative during repairs or due to intentional shutdown and can furnish none of the ship’s required services.

Degaussing – The degaussing system is installed aboard ship to reduce the ship's effect on the Earth's magnetic field. In order to accomplish this, the change in the Earth's field about the ship's hull is "canceled" by controlling the electric current flowing through degaussing coils wound in specific locations within the hull. This, in turn, reduces the possibility of detection by these magnetic sensitive ordnance or devices.

Dolphins – A free standing pile supported or solid filled structure used for mooring and berthing vessels, protection of the end of piers or wharves, turning ships, or protection of bridge substructure.

Dry docks – A specialized facility used for the repair of ships where the vessel is removed from the water or placed within a lock and the water is removed leaving the ship in the dry to facilitate repairs.

Fenders – Energy absorbing devices used on the face of a pier, wharf or dolphin to protect the ship and shore facility from damage due to contact between the two during berthing and mooring.

Hawser – A thick cable or rope used in mooring or towing a ship.

Homeport – Port for a specific ship that has been identified as such by Commander Fleet Forces Command and is listed in the Naval Register. The homeport is where the ship is assigned and offers all requisite services required by the ship to include the full complement of hotel services.

Hotel Services – Dockside utilities provided for a ship at a berth (also called ships services, utility services, and cold iron services).

Lighterage – Small craft designed to transport cargo or personnel from ship to shore. Lighterage includes amphibians, landing craft, discharge lighters, causeways, and barges. Based on the idea of using use hollow, sheet steel boxes as pontoons and pontoon-assembled structures.

Magnetic Treatment Facility – Due to magnetic fields that are constantly being encountered during normal ship operations, ships and submarines build up a magnetic signature. The earth's natural magnetic fields between the North and South poles are being crossed routinely while the vessels are underway. The traversing of these natural fields, and vessels lying dormant for extended periods of time during scheduled maintenance, result in changes to a vessel's magnetic signature. Correcting those changes requires a thorough treatment process to minimize the level of permanent magnetism. This occurs at Navy Magnetic Treatment Facilities, also known as deperming stations.

Monopile Dolphin – A single pile dolphin usually consisting of a large diameter concrete or steel pipe pile filled with concrete. Monopile dolphins can be used as mooring or breasting dolphins. When used as a breasting dolphin, the monopile dolphin is faced with fendering elements.

Mooring Dolphin – A freestanding pile supported or solid filled structure used for mooring vessels. Mooring dolphins are usually placed at the bow or stern of a moored ship to provide mooring points to attach breasting lines, bow lines and stern lines.

Nesting – Placing vessels alongside one another in a parallel configuration in which they are moored to one another.

Pier – A pier is a structure that projects out from the shore into the water. A pier is oriented either perpendicular to or at an angle with the shore. It may be used on both sides, although there are instances where only one side is used because of site conditions or because there is no need for additional berthing.

Port of Call – Any port where a ship stops along the way other than its homeport, or a stop at a fueling pier, an ammunition pier, a supply pier, or a repair pier. The only real requirements for a port of call would be that it has sufficient dredge depth and that it provides secure mooring. Ship does not go cold iron in port of call and uses its organic systems. However, local determinations and justifications can warrant adding specific features at ports of call. Many of the new classes of ships have concepts of operations and special mission requirements that have resulted in making accommodations at ports in forward operating areas that ordinarily would not be required, i.e. hotel services. These are handled on a case by case basis and driven by operational requirements.

Roll on/Roll off – Also known as RORO. Provision on pier or wharf for vessels designed to carry wheeled cargo, such as cars, trucks, semi-trailer trucks, trailers, and railroad cars, that are driven on and off the ship on their own wheels or using a platform vehicle, such as a self-propelled modular transporter.

Scupper – An opening for the purpose of draining water.

Slip – The space between two approximately parallel piers or the space formed by a cut into the land that provides two approximately parallel mooring faces.

Sonar Dome – Located on the hulls of submarines and surface ships. Their purpose is to house electronic equipment used for detection, navigation, and ranging.

Sponson – A projection extending from the side of a vessel.

Weep Hole – A small opening in a wall which allows water to drain.

Wharf – A wharf is a structure oriented approximately parallel to the shore. Ships can only be moored at the offshore face of a marginal wharf. When water depths close to shore are not adequate to accommodate deep draft ships, the wharf, consisting of a platform on piles, is located offshore in deep water and is connected to shore along its length or at one or more points by pile-supported trestles, usually at right angles to the wharf.

B-2 ABBREVIATIONS.

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
AREMA	American Railway Engineering and Maintenance-of-Way Association
ASCE	American Society of Civil Engineers
ASD	Allowable Stress Design
ASTM	American Society of Testing and Materials
DoD	Department of Defense
ea	each
FEMA	Federal Emergency Management Agency
ft	feet
g	gravity
IBC	International Building Code
ICC	International Code Council
in	Inches
k	Kips (1,000 lbs)
kg	Kilogram
kg/m^3	Kilograms per Cubic Meter
km/h	Kilometers per Hour
kN	Kilonewton
kN/m	Kilonewton per Meter
kN/m^2	Kilonewton per Square Meter
kPa	Kilopascal

ksf	Kips per Square Foot
lbs	Pounds
lb/ft	Pounds per Foot
lb/ft^2	Pounds per Square Foot
lb/ft^3	Pounds per Cubic Foot
lb/in^2	Pounds per Square Inch
LRFD	Load and Resistance Factor Design
m	Meter
m^2	Square Meter
m/s	Meters per Second
mil	0.001 Inches
mm	Millimeter
mm^2	Square Millimeter
MCE$_R$	Risk-Targeted Maximum Considered Earthquake
MPa	Megapascal
MPa/m	Megapascal per Meter
mph	Miles per Hour
MRI	Mean Recurrence Interval
NFPA	National Fire Protection Association
pci	Pounds per Cubic Inch
PGA	Maximum Considered Earthquake Geometric Mean (MCE$_G$) Peak Ground Acceleration
pcf	Pounds per Cubic Foot
plf	Pounds per Linear Foot
psf	Pounds per Square Foot
psi	Pounds per Square Inch

RCSC Research Council on Structural Connections

S_S Risk-Targeted Maximum Consider Earthquake (MCE_R) Ground Motion of 0.2-Second Spectral Response Acceleration

S_1 Risk-Targeted Maximum Considered Earthquake (MCE_R) Ground Motion of 1.0-Second Spectral Response Acceleration

$S_{S,5/50}$ Short-period (0.2-second) spectral response acceleration with a 5% probability of being exceeded in 50 years

$S_{1,5/50}$ Long-period (1.0-second) spectral response acceleration with a 5% probability of being exceeded in 50 years

$S_{S,10/50}$ Short-period (0.2-second) spectral response acceleration with a 10% probability of being exceeded in 50 years

$S_{1,10/50}$ Long-period (1.0-second) spectral response acceleration with a 10% probability of being exceeded in 50 years

$S_{S,20/50}$ Short-period (0.2-second) spectral response acceleration with a 20% probability of being exceeded in 50 years

$S_{1,20/50}$ Long-period (1.0-second) spectral response acceleration with a 20% probability of being exceeded in 50 years

UFC Unified Facility Criteria

V Velocity

APPENDIX C HIGH MAST LIGHTING

Please Post

NAVFAC
Naval Facilities Engineering Command

Safety Alert

Pier high mast lighting structural failure

DESCRIPTION/BACKGROUND:
High mast lighting systems are used for lighting on piers and other structures. Design includes a ring assembly at the "mast" or pole top to support fixtures facilitating lowering of the ring by an internal cable pulley/motor system to access/replace lights or bulbs.

CONCERN: Mast lighting systems at Naval Station Norfolk have experienced an apparent defect where the latching mechanism fractures at the top of the mast light assembly prematurely. These fractured latching arms can then fray associated support cables which support the light ring. Once the support cables fray to a critical point, the entire light ring assembly can fall catastrophically - which has occurred. A subsequent investigation at Naval Station Norfolk pier high mast lighting has revealed additional lights of various designs similarly affected by latching mechanism fracture and cable fray. Many of the latching mechanisms inspected were reported to have a clearly improved design however, and did not exhibit signs of wear or failure.

INDIRECT CAUSE: The cable was incorrectly tightened causing retraction of the cable.

LESSONS LEARNED/RECOMMENDATION: Inspect high mast light systems for latching mechanism fracture/cracking. Visually inspect support cables for signs of wear and fray. While not involved in the failure, it is also recommended that the inspection include (1) a visual examination of the internal master cable for signs of wear as it retracts/coils and (2) a visual examination of the high mast pole splice for any signs of cracking, particularly for systems that have been in operation for a number of years. Any latching mechanism or cable failures noted during inspection should result in the light ring being lowered to ground until repairs can be made (or if pole splice cracking is observed the pole taken down). In some case it may be acceptable to provide temporary safety strapping between the light ring and mast pole with engineering consultation to facilitate continued light use until permanent repairs can be made.

<u>RETROFIT</u>: Where failures are discovered, repairs/retrofit of internal motor/cable assembly and top latching assembly can be performed. Contractor repairs are underway at Naval Station Norfolk. A manufacturer source experienced with retrofitting high mast lights is (www.eaglehighmast.com).

SAFETY ABSTRACT – HIGH MAST PIER LIGHTS

DESCRIPTION OF THE HAZARD:

- A high mast light support cable parted causing the light assembly to be partially suspended at the top of the pole which did not allow for the light to be lowered for maintenance. The plan was to use an aerial work platform and crane to lower the light for maintenance and inspection. The area immediately around the light structure was secured with caution tape and traffic cones. Before coordinated efforts could be made, the supporting mechanisms failed causing the lighting assembly to fall to the pier surface. There were no injuries or damage to property other than the light assembly.

SYSTEM INVOLVED:

- High mast lighting systems are used by the Navy to illuminate piers and other structures. They utilize a light ring assembly supported by a system of wire cables. This light ring is designed to be lowered to the ground mechanically via an internal pulley system so that maintenance can be performed from the ground level.

EVENT:

- The High Mast Light ring assembly fell at a NAVSTA Norfolk double deck pier causing catastrophic damage to the light ring assembly.

SAFETY CONCERN:

- Potential Life Safety Concern related to High Mast Lighting systems on Navy piers and elsewhere.
- Multiple designs at Naval Station Norfolk have been discovered to have a design defect where the latching mechanism fractures at the top of the mast light. These fractures can then cause fraying of the support cables which support the light ring. When the cables fray to a critical point, the light ring can fall catastrophically. Subsequent investigation has revealed additional lights of various designs similarly affected by latching mechanism fracture and cable fraying.

DIRECT CAUSE:

- Stress and fatigue caused the failure of the supporting cables and locking devices which caused the light assembly to fall.

INDIRECT CAUSE:

- Movement of the lighting assembly due to environmental conditions caused chaffing and wearing of the supporting system.

RECOMMENDATION:

- PWDs throughout NAVFAC inspect High Mast Lighting systems for fractures/cracking. Visually inspect support cables for signs of wear. The internal master cable should be inspected. Recommend that the high mast pole splice point be examined for signs of cracking, particularly for systems that have been in operation for several years. Any latching mechanism or cable failures noted should result in the light ring being lowered until repairs effected.

UFC-4-152-07
14 JULY 2009
Change 1, 1 September 2012

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN: SMALL CRAFT BERTHING FACILITIES

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

UNIFIED FACILITIES CRITERIA (UFC)

DESIGN: SMALL CRAFT BERTHING FACILITIES

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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

Change No.	Date	Location
1	1 Sep 2012	Modified 4-1.1.2, 4-2.3, 4-3.5, 5-2.2, 6-3.4.1.1, 6-4.1, 7-3, 7-6, 7-7, App A; added 7-9, “All Purpose Pedestal”; minor editorial changes throughout

This UFC supersedes \1\ UFC 4-152-07N, Design: Small Craft Berthing Facilities, dated June 2005 and /1/ Military Handbook 1025/5, Chapter 2, dated 30 September 1998.

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

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

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

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

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 4-152-07
Superseding: UFC 4-152-07, dated 8 June 2005

Description of Changes:

- Prepared document in proper UFC format
- Expanded/updated references
- Significantly expanded treatment/discussion of types/classes of small boats and craft
- Deleted section on guest docks
- Expanded discussion on aids to navigation
- Abbreviated discussion on fixed versus floating berthing systems
- Added section on covered versus uncovered berths
- Added section on dead loads
- Considerably reduced discussion on floating pier berthing systems
- Added section on floating dock freeboard and stability
- Expanded discussion on environmental (lateral) loading
- Added section on berthing loads
- Deleted section on design criteria for other sheltered basin structures, i.e. slope stabilization/protection, bulkheads as this can be readily obtained from other references
- Deleted section on design criteria for entrance channel and protective structures as this can be readily obtained from other references as well as being briefly addressed in Section 4-3 of new UFC.
- Expanded discussion on hotel services (utilities)
- Revised section on boat launch hoists and lifts and added new methods currently in use
- Expanded section on launching ramps
- Deleted section on administration building
- Expanded section on dry storage facilities
- Expanded section on boat repair/maintenance
- Deleted section on hardware supply store
- Deleted section on transient housing facilities
- Deleted section on layout of utilities
- Deleted section on perimeter fencing
- Deleted section on signs
- Deleted section on environmental factors and protection
- Deleted section on summary of common design problems
- Overall, made document shorter and more concise, relying on other applicable standards where applicable

Reasons for Changes:

- Previous UFC 4-152-07, dated 8 June 2005 was merely a UFC cover sheet applied to MIL-HDBK 1025/5 dated 30 September 1988. Therefore, this new UFC 4-152-07 provides current criteria to replace a document over 20 years old.

Impact: There are negligible cost impacts. However, the following benefits should be realized.

- Over the last several years, NAVFAC LANT has been either directly or indirectly involved with numerous small craft basin projects in various stages of development. Current criteria for small craft berthing was not available. This new UFC will provide the criteria which was been found to be lacking.

Non-Unification Issues: None

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CHAPTER 1

INTRODUCTION

1-1 PURPOSE AND SCOPE

This UFC provides general criteria for the design of small craft berthing facilities.

1-2 APPLICABILITY

This UFC applies to all DOD small craft berthing facilities.

1-3 GENERAL BUILDING REQUIREMENTS

All DoD facilities must comply with UFC 1-200-01, *General Building Requirements*. If any conflict occurs between this UFC and UFC 1-200-01, the requirements of UFC 1-200-01 take precedence.

1-4 SAFETY

All DoD facilities must comply with DODINST 6055.1 and applicable Occupational Safety and Health Administration (OSHA) safety and health standards. NOTE: All NAVY projects, must comply with OPNAVINST 5100.23 (series), *Navy Safety and Occupational Health Program Manual*. The most recent publication in this series can be accessed at the NAVFAC Safety web site: www.navfac.navy.mil/safety/pub.htm. If any conflict occurs between this UFC and OPNAVINST 5100.23, the requirements of OPNAVINST 5100.23 take precedence.

1-5 FIRE PROTECTION

All DoD facilities must comply with UFC 3-600-01, *Fire Protection Engineering for Facilities*. If any conflict occurs between this UFC and UFC 3-600-01, the requirements of UFC 3-600-01 take precedence.

1-6 ANTITERRORISM AND PHYSICAL SECURITY

Installations must focus on threats at the first line of defense – the installation perimeter. Antiterrorism and physical security at the waterfront is extremely important for the protection of waterfront assets and to Installation's security. At a minimum, small craft berthing require landside security, pier access control, and identification of restricted area waterways. Coordinate antiterrorism and physical security requirements with Service and Combatant Commander policies and regulations.

Project documents must provide only the minimum amount of information necessary for the installation of all elements required for force protection and must not contain information on force protection methods, philosophy, or information on design threats, as this information is considered sensitive and for official use only. For further guidance, contact the government reviewer.

1-7 REFERENCES

A complete list of references is contained in Appendix A

CHAPTER 2

APPLICABLE CLASSES AND CHARACTERISTICS OF SMALL CRAFT

Small craft berthing facilities will be designed, constructed and operated according to the type of small craft (boats) to be accommodated and the specific needs of those boats. The primary subject of this manual is the berthing of small craft that are owned and operated by the Armed Forces of the United States (U.S). Accordingly, the first portion of this chapter discusses the characteristics of these vessels currently in use. Following is a general overview of the types of vessels accommodated at a typical boating marina, which reflects the recreational segment of small craft operated and berthed in the U.S.

2-1 MILITARY SMALL BOATS AND CRAFT

A summary of the largest branches of the armed forces and the approximate number of small craft they own and operate is presented in Figure 2-1. The distinction between a ship, boat or small craft is subjective and varies between the branches: some distinctions are by use (warship and service craft by the Navy) and others are by length (small boat is defined as less than 65 feet by the Coast Guard). For this document, small craft are those vessels less than 150 ft in length.

Figure 2-1—Summary of U.S. Military Small Boats and Craft in Use

Branch of Military Armed Forces	Branch Abbreviation	Number of Vessels
Navy	USN	4,760
Coast Guard	USCG	1,445
Marine Corps	USMC	538
Army	USA	334
Military Sealift Command	MSC	57
Air Force	USAF	36
TOTAL =		7,170

The types of small craft owned and operated by the armed forces vary according to the mission of each branch. The following section provides an overview of the classes and general characteristics of these small craft. Figure 2-2 summarizes the primary vessel characteristics including length, displacement, and mission for each vessel classification.

Figure 2-2 U.S. Military Small Craft Characteristics

Vessel Classification	Ship Class	Number Active	Class Length (ft)	Displacement fully loaded (tons)	Mission
USN					
Small Boats and Service Craft	YTB 760	68	109	356	Provide a variety of services. Includes: patrol training craft (YP), tug boats (YTB), torpedo trials craft (YTT), landing craft, barges, transport boats, personnel boats, harbor patrol boats, work boats, utility boats, floating drydocks, and rigid inflatable boats
	YTB 756	3	109	409	
	YTB 752	1	101	375	
	YTT 9	3	187	1,200	
	YP 654	1	--	--	
	YP 676	27	--	--	
	Various others	4,089	12-192		
USCG					
Small Boats and Craft	Various	1,217	22-58	2-32	Used in harbors (drug interdiction, port security, cable repair, harbors and inland waters, navigation aids, illegal dumping, search and rescue, etc.), in rough surf for rescue, for inland river and lake patrol, as transports, and for firefighting
USMC					
RRC	Rigid Raiding Craft	120	18	--	Perform offensive amphibious operations
CRRC	Zodiak (replacing RRCs)	418	15	2	
USA					
Floating Utility	BC	37	120	760	Perform port terminal operations
	BD	10	140	1630	
	BG	8	120	763	
	BK	7	45	33	
	CHI	1	25	--	
	FB	2	75	64	
	HF	1	65	--	
	J-Boat	4	46	12	
	LT-128	6	128	1,057	
	LT-100	16	107	390	
	PB	10	25	--	
	Q-Boat	1	65	37	
	SLWT	4	--	--	
	ST-65	11	71	122	
	ST-45	2	45	29	
	T-Boat	1	65	--	
	Workboats	47	--	--	
Patrol Ships	ABT	7	190-194	1500-1,900	Perform drug interdiction in the Caribbean Sea

2-1.1 **U.S. Navy.** The Navy distinguishes between ships, crafts, and boats (SECNAVINST 5030.1L, 22 Jan 93; OPNAVINST 4780.6E, 24 Jan 06). Vessels applicable to this document would be craft and boats. Characteristics and additional information for service craft can be obtained from both the Craft & Boat Support System (CBSS) http://www.boats.dt.navy.mil/ and the Naval Vessel Register (NVR) http://www.nvr.navy.mil/. Characteristics and additional information for boats can also be obtained from the Craft & Boat Support System (CBSS) http://www.boats.dt.navy.mil/ and S9086-TX-STM-010/CH-583R3, NAVAL SHIP'S TECHNICAL MANUAL CHAPTER 583 BOATS AND SMALL CRAFT.

The Navy owns and operates approximately 4,760 small boats and service craft. The Navy classifies these boats according to the type of service they perform. Types include harbor security and escort boats (HSB or sometimes PB), transport boats, work boats (WB), and utility boats (UB).

In 2006 the Navy established the Navy Expeditionary Combat Command (NECC). NECC has become one of the Navy's largest employers of boats as it conducts Explosive Ordnance Disposal, Maritime Expeditionary Security, and Riverine type missions. Types include riverine patrol boats (RPB), riverine assault boats (RAB) and riverine command boats (RCB).

Many of the service craft are non-self-propelled "lighters," or barges (YC, YFN, YON, and YRBM), used for berthing, office, messing, or repair functions or to carry fuel or equipment. Other boats and service craft include: tugboats of various sizes (YTB, YTM, and YTL), training patrol craft (YP), landing craft (LCU, LCM, CM, and PL), torpedo retrievers (TWR, TRB, and TR), floating drydocks (AFDB, AFDL, AFDM, ARD, and ARDM), and rigid inflatable boats (designated RB or RIB). Boats are often out of the water when not in use to increase the vessels' longevity, for storage or for transiting to operational areas.

Figures 2-3 to 2-5 shows the dimensional characteristics of Navy Boats and Service Craft as a function of their length, as well as a comparison to guidelines for recreational vessels.

Figure 2-3 Vessel Beam vs. Length

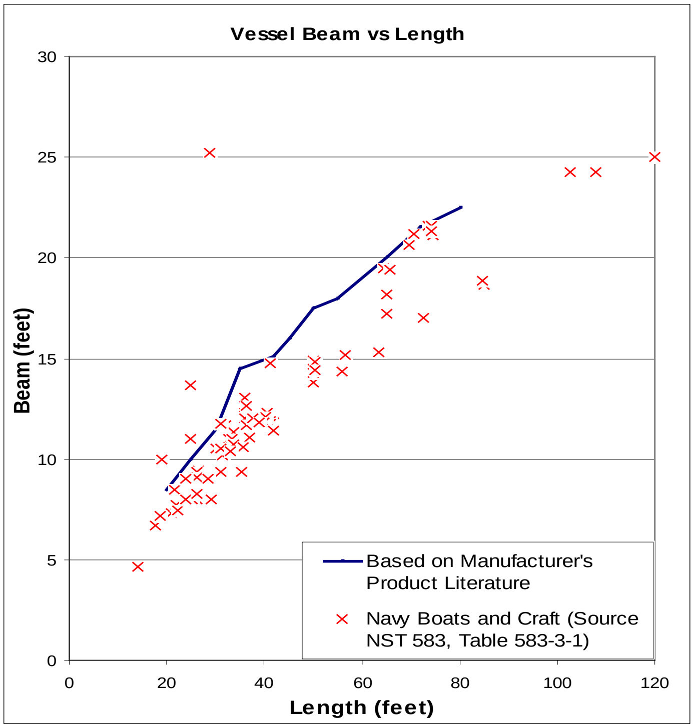


Figure 2-4 Vessel Height vs. Length

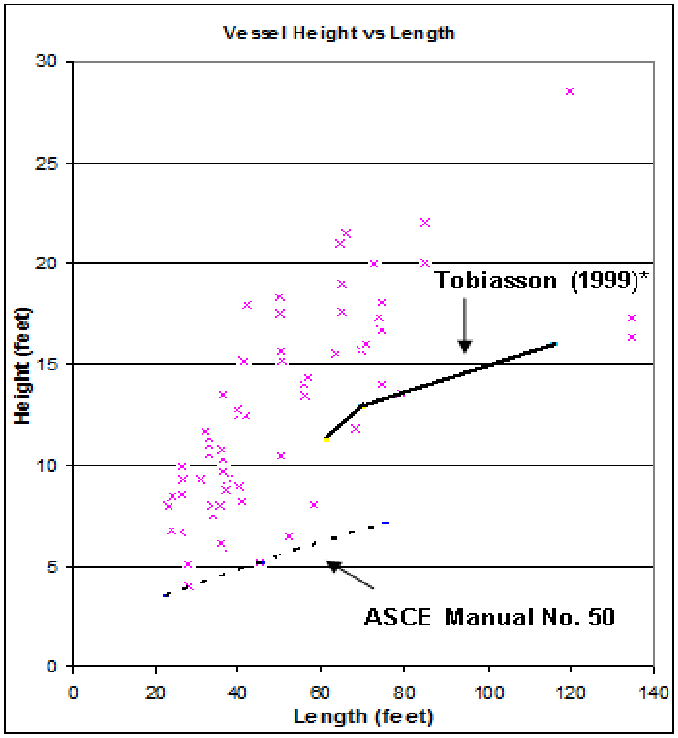
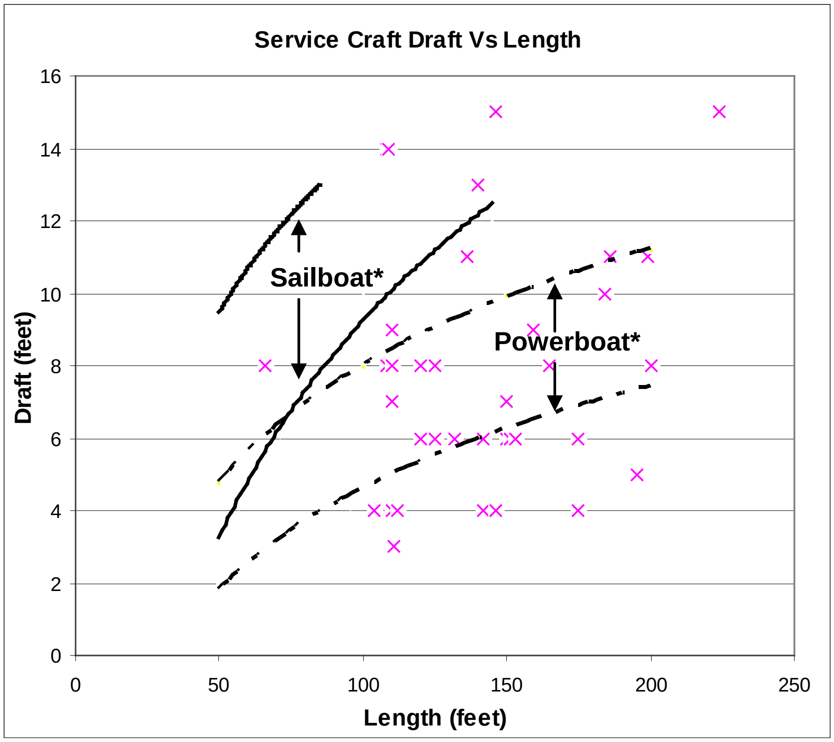


Figure 2-5 Vessel Draft vs. Length



2-1.2 **U.S. Coast Guard.** Small boats and craft are used for various harbor duties, search and rescue, rough surf rescues, inland river and lake patrols, transporting equipment, and firefighting. Some of these vessels can be transported by trailer and used on inland waterways.

2-1.3 **U.S. Army.** The Army's fleet is divided into three sections: the Transportation Corps, the Intelligence and Security (I&S) Command, and the Corps of Engineers (COE). The I&S command operates patrol vessels in the Caribbean sea. The Army Transportation Corps operates lighterage and floating utility vessels. Lighterage are craft used to transport equipment, cargo, and personnel between ships, from ship to-shore, and for operational mission support, and include logistics support vessels, landing craft, and modular powered causeway ferries. Floating utility craft are used to perform port terminal operations and include ocean and harbor tugs, floating cranes, barges, and floating causeways.

The COE operates survey and construction craft, tugs, barges, and other utility craft; these craft are not included in the tables presented herein.

2-1.4 **U.S. Marine Corps.** The Marine Corps operates a large number of watercraft and amphibious craft used during special operations. The watercraft consists of inflatable combat rubber raiding craft (CRRC) and fiberglass rigid raiding craft (RRC). The CRRCs are used for in-port, river, lake, and coastal operations. The RRCs are normally deployed aboard Navy transport dock ships (i.e., LPDs) for transport to the combat area. The CRRCs and RRCs operate exclusively in coastal waters.

2-2 **RECREATIONAL BOATS.** The two primary types of recreational vessels are power boats and sail boats. Power boats can be further classified by the type of use: sport fishing, racing, waterskiing, cruising, etc. In recent years, recreational boats have been outfitted with more electronics and amenities such as refrigeration, complete living facilities and as a result have increased in length and beam. Slip dimensions in marinas have increased to accommodate these larger vessels. Some military boats are of a similar hull design and may be made by the same manufacturer as recreational power boats. Accordingly, manufacturer’s data may be applicable for the design of small craft berthing facilities for military vessels.

Other than for Morale/Recreational Facilities provided by the military, recreational marina berthing guidelines should be carefully considered for applicability when designing for military craft.

CHAPTER 3

SMALL CRAFT HARBOR PLANNING CRITERIA

3-1 BASIN SITING CONSIDERATIONS

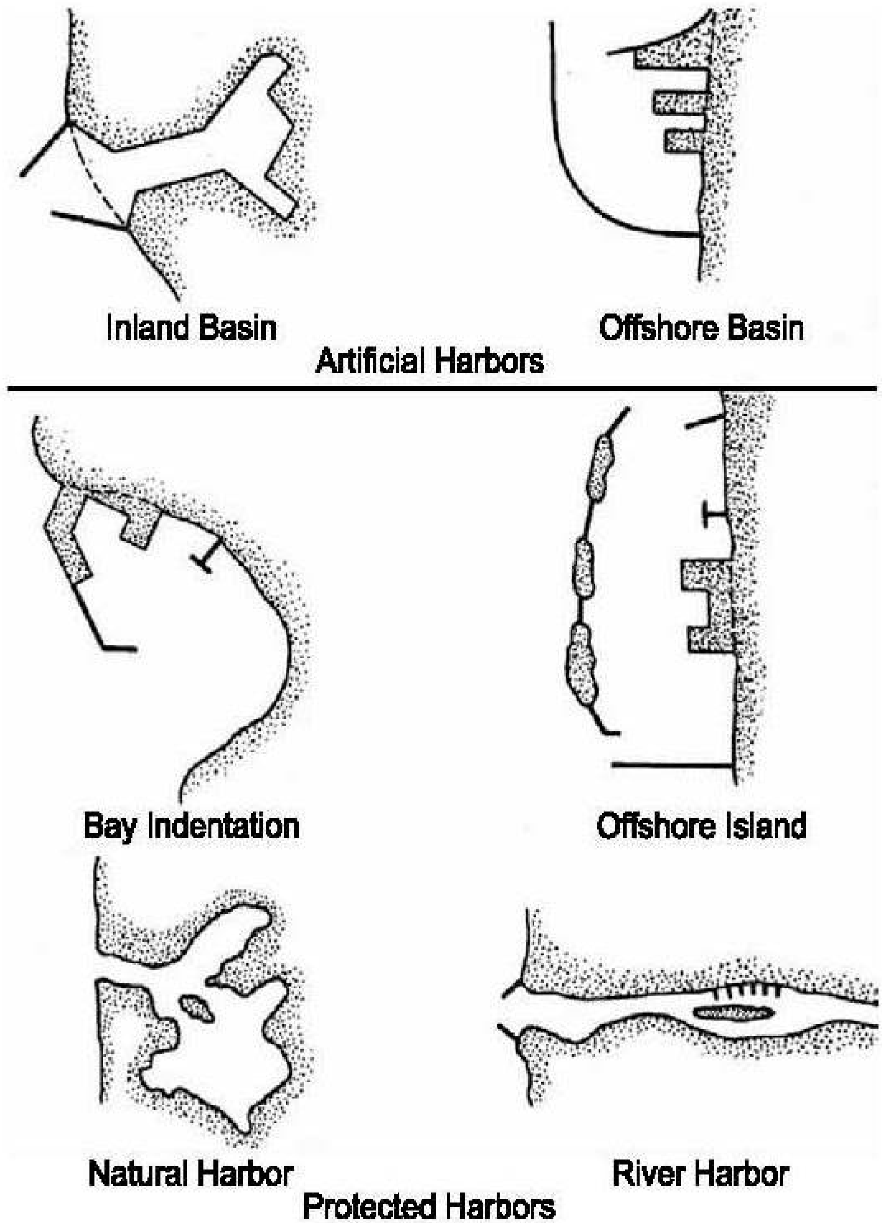
3-1.1 **Siting Considerations.** Small craft berthing facilities should be located in a sheltered harbor. The following key considerations apply for planning the location of the facility:

1. Protection from Winds, Waves and Currents
2. Sufficient Land and Water Area
3. Proximity to Operating Area
4. Adequate Water Depths
5. Limited Exposure to Sedimentation and Shoaling
6. Few Potential Environmental Concerns

Additional considerations include waterside access to the area where the small craft fulfill their mission, and convenient landside access for boat crews and support personnel. The most desirable sites are those that require the least amount of excavation, dredging, filling, breakwater construction, disturbance of sensitive habitat and environmental remediation. Since new sites meeting all criteria are rarely found, feasibility studies of alternative sites to compare the pros and cons of each are often required to identify the most attractive site based on an evaluation of combined engineering, environmental and economic considerations.

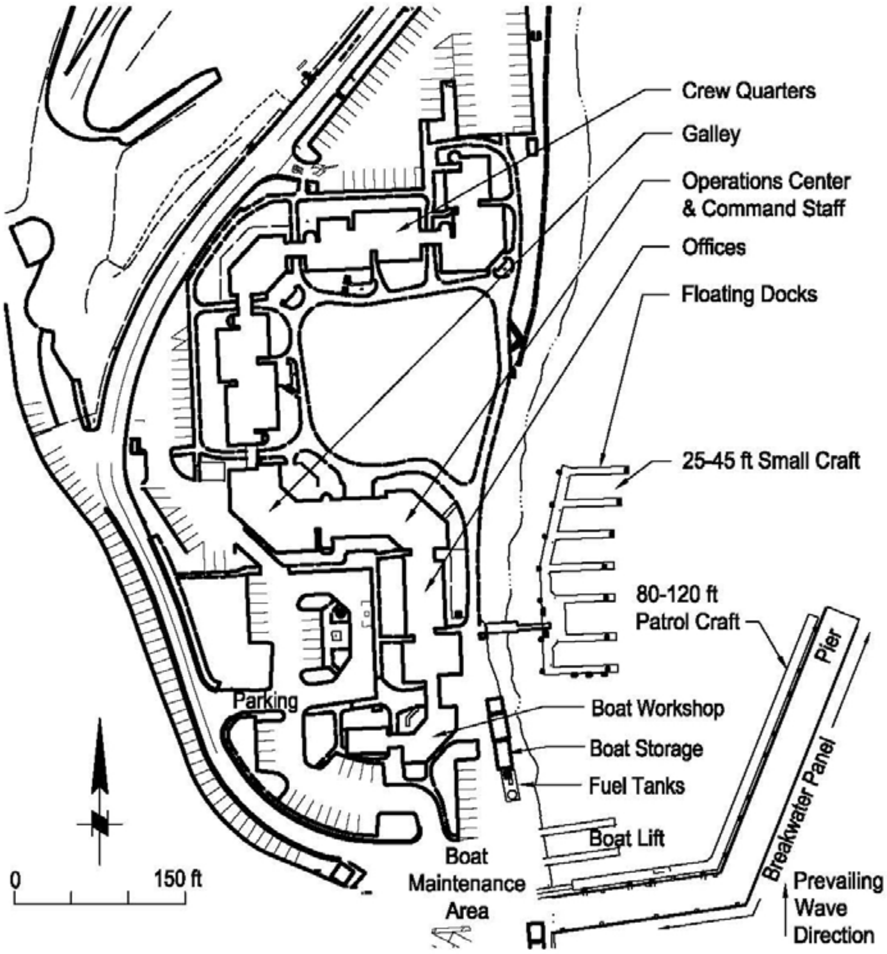
3-1.1.1 **Wave Protection.** The wave protection for the small craft facility is a function of land mass that surrounds the harbor basin to provide a barrier to the incoming waves. Figure 3-1 shows various configurations of landmass and classifications which make up these types of harbors. The source of waves that must be considered are both wind generated waves and vessel generated waves (or wakes). Wind generated waves can be locally generated short period waves (or chop) and longer period waves that are generated far offshore. Protection from waves is more difficult to provide and is a greater concern for small harbors on the coast that are exposed to long fetches than for harbors on inland waterways. When suitable protection is not provided by surrounding land mass, then some means of constructed wave protection must be considered.

Figure 3-1 Small Craft Harbor Site Classifications



3-1.1.2 **Water Area.** The harbor must be of sufficient area to accommodate the berthing facilities, described further in Chapter 5, as well as to provide space for safe maneuvering. There are existing guidelines for the number of boats that can be accommodated per acre of water area for recreational marinas (*ASCE Manual of Practice 50*). Recreational marinas berth relatively large numbers of small craft which leads to large boat/area ratios. In contrast, most military small craft harbors accommodate a much smaller number of craft and the harbor still needs to provide channels and turning areas resulting in smaller boat area ratios than a recreational marina. Figure 3-2 represents a typical layout of a small craft harbor at a DOD installation with associated shore support facilities.

Figure 3-2 Example Military Small Craft Harbor and Shore Facility

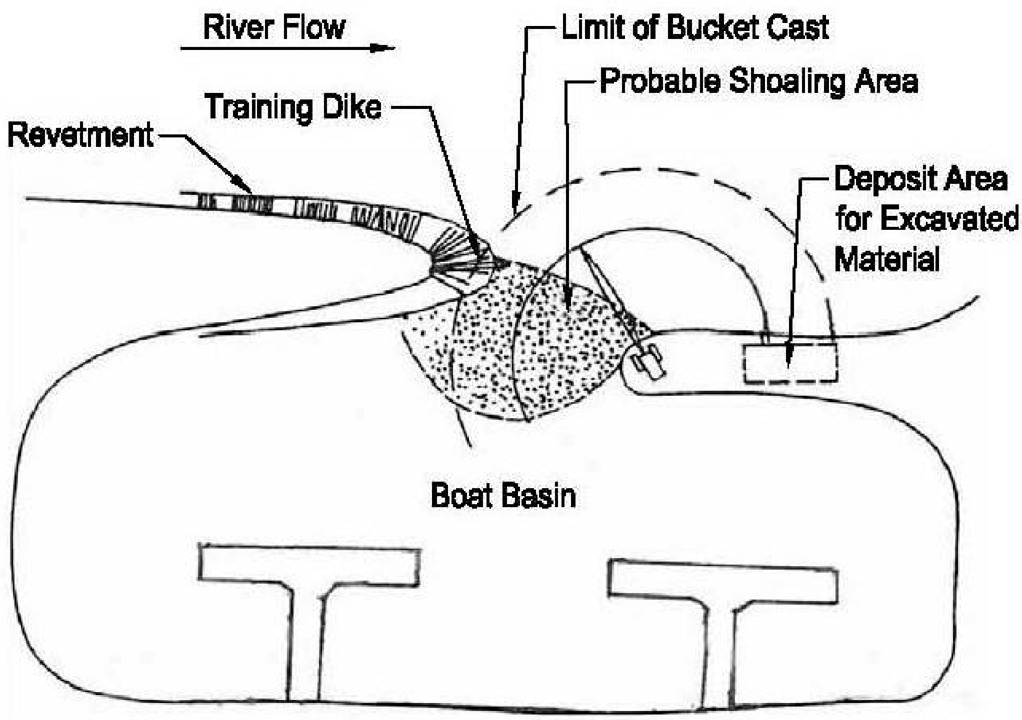


3-1.1.3 **Minimum Depths.** In sheltered harbors, the minimum water depth should extend at least 2 ft (.61 m) for a soft harbor bottom, and 3 ft (.91 m) for a hard bottom below the keel of the deepest draft boat at the design low water level. In tidal waters, the design low water level is typically taken as the Mean Lower Low Water (MLLW) tidal datum. In harbors where wave action causes vessel motion and sedimentation reduces water depths over time, additional under keel clearance should be provided.

3-1.1.4 **Location.** The facility should be located as close as practical to the area where the small craft are intended to operate, depending upon the mission of the craft. For security response or search and rescue missions, time from when the vessel leaves the dock to when it arrives on scene can be critical. For vessels that perform longer term patrols of several days, distance from the facility will be less critical. Where the distance from the facility to the area of operation is great, boats can be trailered from the facility to a boat launching facility close to the area of operation.

3-1.1.5 **Dredging.** Most small craft harbors require dredging to maintain water depths at the facility. Harbors located on the coast often have sediment deposited near the entrance (see Figure 3-3) from alongshore sediment transport (or littoral drift); similarly, harbors on a river often have sediment deposited near the entrance due to sediment transport processes in the river. In addition, suspended sediment can reach far into the harbor as water exchange occurs due to tidal action or river stage fluctuations, and contribute to sediment accumulation within the basin. The extent of this sedimentation can be estimated for a site with the aid of hydraulic models, and the sedimentation rate that will be experienced once a harbor is constructed evaluated for various configurations. Maintenance dredging can be a significant recurring cost due to the environmental concerns that often require disposal of dredged material in distant upland or offshore locations. When considering the minimum required water depth, include over depth to allow for sediment accumulation between maintenance dredging and for a dredging tolerance.

Figure 3-3 Maintenance of Entrance to Off-River Basin with Land-Based Equipment



3-1.2 **Recreational Marina Differences.** There are a number of design guidelines for recreational marinas such as *ASCE Manual of Practice 50*. However, there are important considerations in the layout of a recreational marina that would not apply directly to the design of a military harbor, some of these considerations are:

1. Economic Feasibility

2. Number and Dimensions of Vessels
3. Seasonal and Daily Boat Usage Patterns
4. Walking Distance to Car

Since most recreational marinas are financed by the fees that the boat owners pay to berth their boats in the harbor, cost efficiencies must be realized to make the fees that boaters pay competitive in the market with other marinas. Therefore, one of the primary objectives of the marina design is to accommodate the maximum number of vessels within the minimum water area.

Boat use by the recreational boater is mostly on an occasional basis that tends to occur at regular times: during daylight hours on weekends and holidays in season. In contrast, military small craft will be utilized by personnel who likely live or regularly work at the small craft facility. The military craft will be utilized according to the mission assigned which will likely be at any time and in any weather. Accordingly, layout of the berthing facility must be done to accommodate the unique function of a military facility.

3-2 BERTHING FACILITY LAYOUT

3-2.1 **Berth Location and Orientation.** Within the harbor, vessels that are more difficult to maneuver, usually the larger craft, should be berthed closer to the entrance to the facility. The boat slips should be oriented such that the boats are heading into the prevailing wind when entering the berth (“upwind slip”). When the slip is oriented at 90 degrees to the wind direction (“cross wind slip”), berthing is more difficult.

3-2.2 **Launch Ramps.** Where trailered craft are used, a launch ramp is a convenient method to launch and retrieve the boat. Further, a launch ramp allows water access at a location for a large number of trailerable boats. If a launch ramp is located at a facility where vessels are also berthed, then the launch ramp should be located with sufficient separation from the berths to avoid vessel traffic conflicts. Adequate area must be provided at the top of the launch ramp to allow maneuvering room for the trailer and tow vehicle to align with the ramp. Most guidelines for recreational launch ramp facilities reflect the need to accommodate high volume usage by the public at peak times. As a result, the parking and maneuvering areas for vehicle traffic on the shore, and courtesy docks for boats waiting to be boarded or to be retrieved from the water, may be scaled back at a military facility. Launch ramp layout and design are discussed in greater detail in Chapter 11.

3-2.3 **Marine Fueling.** Where marine fueling facilities are provided, the fuel tanks should be located on shore and the delivery piping and dispensing equipment should be located on a dedicated pier or dock close to the harbor entrance. The dispenser should be located to minimize the length of fuel piping supported on the pier or dock. The fuel tanks should be located to facilitate fuel delivery truck access.

3-2.4 **Dry Boat Storage, Boat Hoists and Lifts.** When necessary to retrieve small craft from the water to address concerns such as reducing saltwater corrosion or marine fouling on the craft, or avoiding ice on the water body, or to perform maintenance and repair on the vessels, a boat hoist or lift should be provided. The main types of retrieval mechanisms are:

1. Straddle Carrier
2. Fork Lift
3. Hoist-jib Crane
4. Floating Lift

The straddle carrier is the most versatile for the larger vessels (over about 33 ft. (10 m) in length). It requires a set of fixed piers over the water upon which a rubber tired straddle carrier with slings drives to retrieve the craft from the water. Once the carrier has lifted the craft in the slings, it can drive and move the craft overland within a fairly level area with suitable surface and then place the craft within a cradle or stands for storage or for work to be performed.

The fork lift is used primarily for placing and retrieving vessels within a dry storage rack system. It will not accommodate as wide a range of vessels as the straddle carrier and requires greater maneuvering area. Fork lifts with “negative” lift are available to enable launching and retrieving small craft, typically over a bulkhead.

A hoist-jib crane is often the simplest and least costly method of launching and retrieving small craft. It is a fixed crane located on a pier or adjacent to a bulkhead over which it lifts the craft from the water. The boats may have lift points built into the hull for slings that attach to the crane hook, though under hull slings can be used when lift points are not provided. Once the craft is lifted, the crane boom revolves in a horizontal plane and lowers the boat onto an awaiting trailer on the shore which is usually towed to a storage area. This method can be adapted for larger craft by using a mobile crane with a spreader and slings sized for the vessel.

Floating lifts and drive-on dry docking are becoming more common to store boats out of the water, but in a slip. Both systems employ pontoons that submerge to permit a boat to enter or leave the slip. The pontoons are equipped with a cradle to retain the boat as the pontoon is filled with air, its buoyancy increased, and the vessel lifted to its dry storage position.

These methods of retrieval are discussed in greater detail in Chapter 10.

3-2.5 **Boat Repair and Maintenance.** Boat repair and maintenance yards should be located close to the area where craft are retrieved from the water. An enclosed work area or high bay building with an overhead crane is desirable if full service to the craft is to be performed at the facility. This facility is usually located as close to the docks as possible at a military facility. Repair and maintenance facilities are discussed in greater detail in Chapter 9.

3-2.6 **Harbor Administration / Command Center.** At most military facilities, there is a shore side component that coordinates the waterfront operations—often a dispatch or command center. This is typically located to provide visual contact with the berthing area and ready boat crew access to the command center once their mission is completed for any follow up briefings or reports.

3-2.7 **Vehicular Parking.** Vehicle parking for the boat crew should be conveniently located no more than 500 ft (152.4m) from the furthermost berth on the pier or dock. If the craft are to be launched from the land at the facility, parking must include spaces for a tow vehicle with boat trailer.

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CHAPTER 4

BERTHING SYSTEM SITING CONSIDERATIONS

4-1 ENVIRONMENTAL

4-1.1 Weather

4-1.1.1 **Precipitation.** Frequency of occurrence and intensity of precipitation should be taken into consideration when siting a facility. They should be evaluated to determine the need for protective structures, such as dock covers, for maintenance activities and may also affect the determination of structure loads. Data on the frequency and intensity of precipitation is readily available from several sources, National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) and United States Geodetic Survey (USGS).

4-1.1.2 **Wind.** Wind is a major factor affecting the design of small craft harbors as it generates waves and loading (pressure) on the berthed craft and structures. The frequency of occurrence of wind direction and speed should be determined. This information is available from the NCDC for most areas around the U.S. If information is not available, data collection should be carried out to determine the wind conditions.

Ideally, berths are oriented upwind to the prevailing wind direction so that vessels enter berths into the wind. If this configuration is impractical then the following configurations may be used in order of priority: downwind and crosswind. The direction of prevailing winds is also to be used to define entrance channel orientation. To the extent possible, vessels should enter the basin upwind. Orienting the entrance with a cross wind condition complicates entrance navigation, and should be avoided to the extent possible.

\1\ Perform a wind wave analysis study to determine design criteria requirements for small craft harbors. /1/

4-1.1.3 **Fog.** Determine the frequency of occurrence of fog and to the extent possible avoid areas of dense fog. Entrance and interior channels in facilities should be as straight as possible so boaters can more easily follow channel-marking devices.

4-1.1.4 **Ice.** Determine the frequency of occurrence of ice formation in the basin and to the extent possible avoid areas where the basin would become ice locked. If the occurrence of ice in the basin is unavoidable, consider boat removal to dry storage during the winter months. If ice formation in the basin is not heavy, the use of bubblers or current inducers can help to keep the berthing area free of ice. Deflecting booms should be used to protect the berthing area from ice flows when there is no breakwater or other structure to provide protection from drifting ice. A more complete discussion of ice and cold weather impact on small craft berthing facilities is given in *ASCE Manual of*

Practice 50.

4-1.2 **Water Level Fluctuations**

4-1.2.1 **Astronomical Tides.** Astronomical tides can affect access during low tides, and create strong currents in and around berthing areas. Tidal predictions for most areas are published. *Coastal Engineering Manual II-5-3* provides a comprehensive discussion of astronomical tides and the appropriate tidal datum for waterfront facility design, usually Mean Lower Low Water (MLLW).

4-1.2.2 **Storm Surge.** Storm surge should be incorporated in the determination of the extreme water level fluctuation and can be significant for sites located on large inland lakes and coastal areas with broad, shallow continental margins. *Coastal Engineering Manual II-5*-5 provides a comprehensive discussion of storm surge and the calculation methodology.

4-1.2.3 **Wave Action.** The berthing facility should be sheltered from waves. Consider the prevailing and storm wave directions and select a site with natural sheltering, if possible. For sites exposed to active shipping channels, consider ship wake as well. If natural shelter is not available, limit wave height by means of structures, such as breakwaters or wave attenuators. The berthing area should meet the wave climate criteria shown in Figure 4-1 adapted from *Design Wave Climate in Small Craft Harbors* to provide generally acceptable levels of dock system performance, vessel wear and tear, and comfort for crew that remain on board (or perform vessel maintenance) while at the berth. The criteria requires a smaller wave height for the more frequent events in the 3rd column of table 4-1, and allows a larger wave for infrequent events in the 2nd column (50 yr exceedence—a wave that occurs only once every 50 years on average). Further, the criteria provides subjective latitude by reducing the height of the allowable waves by 25% (multiple by 0.75) to provide an “excellent” climate, or increasing the wave height by 25% to provide a “moderate” climate.

Figure 4-1: Criteria for a “good” wave climate in small craft harbors

Direction and peak period of significant wave	Significant wave height (H_s) Exceedance	
	50 yrs.	1 yr.
Head seas less than 2 sec	Conditions not likely to occur during this event	Less than 1 ft wave
Head seas greater than 2 sec	Less than 2 ft wave	Less than 1 ft wave
Beam seas less than 2sec	Conditions not likely to occur during this event	Less than 0.5 ft wave
Beam seas greater than 2 sec	Less than 0.8 ft wave	Less than 0.5 ft wave

Note: Criteria for an “excellent” wave climate multiply wave height by 0.75, and for moderate wave climate multiply wave height by 1.25.

Wave climate information should be obtained for the berthing area. Determination of wave conditions will depend on the local bathymetry and exposure to the sources of waves noted above. Facilities should be located to provide protection for vessels entering and exiting the facility and avoid beam seas where possible. Wave transformation due to shoaling, refraction and diffraction within the harbor, and the determination of the potential for wave breaking must be considered as well. For further information on wave mechanics see the *Coastal Engineering Manual II*.

4-1.2.4 **Seiche.** Seiche is a phenomenon in harbors typically associated with long period, low amplitude incident waves, in which the basin geometry and incident wave combine to produce a resonant condition with basin wave heights and oscillatory velocities that are significantly greater than those of the incident wave. *Coastal Engineering Manual II-5-6* provides a comprehensive discussion of seiche, calculation methodology, and long waves.

4-1.2.5 **Tsunamis.** Tsunamis are very long period waves generated by an impulsive disturbance that can cause large water level fluctuations and high velocity currents though the source the disturbance may be thousands of miles away. Reports on the probability of occurrence for the tsunamis for many coastal locations have been prepared by the U.S. Army Corps of Engineers (USACE).

4-1.2.6 **River Stage.** For facilities located on rivers, river stage data is required for the determination of water level fluctuations. Flood stage recurrence intervals should be obtained from the stage data but extreme low river stages should be considered as well because of the impact on minimum water depths. *Coastal Engineering Manual II-5-5* and *II-8-6.f* discuss the importance of river stage and the calculation methodology used to determine the extreme water levels.

4-1.3 **Sediment Movement and Shoaling**

4-1.3.1 **Sediment Transport Processes.** Sediment transport and related deposition and erosion occur on open coasts, in tidal inlets, estuaries, harbors, and rivers, and play an important role in siting a facility. An understanding of sediment transport process at the site is necessary to determine potential for shoreline erosion, sediment deposition and to address needs for dredging over the lifetime of the facility. *Coastal Engineering Manual III-2*, *III-3* and *IV* provide a comprehensive discussion of sediment transport processes, methods for analysis and sources of coastal data.

4-1.3.2 **Effects of Structures on Sediment Transport.** Structures that interfere with the path of sediment transport typically cause deposition and erosion of sediment around the structure. Potential impacts of a structure can be evaluated through modeling or analysis of historical data. Bypassing trapped sediment, or other forms of sediment renourishment are often needed to maintain the natural sediment supply and avoid adverse impacts.

4-1.3.3 **Sedimentation Within Basins.** Protected basins typically experience sedimentation, which should be determined to estimate maintenance dredging requirements in order to avoid access problems related to reduced water depths in the basin. Regular maintenance dredging of the basin or channel is usually required. Sedimentation within existing basins can be determined from analysis of historical dredging records and/or hydrographic data.

4-1.4 **Regulatory Requirements.** Regulatory requirements relate to navigational, environmental and safety issues. The United States Army Corps of Engineers (USACE) and the United States Environmental Protection Agency (EPA) regulate construction activities and dredging in the navigable waters of the United States and its territories and possessions. Facilities within the coastal zone will often require a state water quality certificate and/or a consistency determination for federal projects in order to comply with the state's Coastal Zone Management Act (CZMA) Plan. *ASCE Manual of Practice 50* and *UFC 4-150-06* provide a comprehensive discussion of regulatory requirements in the United States.

4-1.5 Geotechnical Factors

4-1.5.1 **Geotechnical Investigations.** Geotechnical investigations determine the soil characteristics both physical and chemical, at the site. These investigations should include soil borings and soil testing to determine the engineering properties of the soil necessary for the proposed use and constructability of the project. *Coastal Engineering Manual V-2-14* and *ASCE Manual of Practice 50* provide a comprehensive discussion of geotechnical investigations.

4-1.6 **Dredging Projects.** Dredging is often necessary for the construction and maintenance of navigation channels and berthing areas to obtain sufficient water depth. Dredge material must be tested for contaminants to identify proper material handling and disposal methods. *ASCE Manual of Practice 50* provides further information on dredging.

4-2 HARBOR ENTRANCE CHANNEL

4-2.1 **Channel Alignment.** Alignment of the harbor entrance channel, outside of the protective breakwater, should consider the initial construction, long-term maintenance, and safe navigation and utilize natural conditions to the extent possible to minimize shoaling and wave penetration into the harbor. Channels are often aligned to provide the shortest path from the harbor to open water or to utilize an existing natural channel. Other considerations include aligning the channel to account for prevailing winds, waves, and currents.

Appropriate channel alignment allows vessels to transit channels upwind or downwind under the prevailing wind direction, and should not expose vessels to beam seas while in the channel. Channel alignment should also consider prevailing currents. The channel alignment may utilize existing currents to help minimize channel shoaling, but must avoid creating hazardous conditions for small craft. Channel stabilizing structures that constrict the channel area may induce higher current conditions for vessels in the channel. High current speeds can be reduced through channel enlargement.

Longshore sediment transport patterns should be considered in determining channel location because of potential impact on maintenance dredging and the shoreline adjacent to channel. If channel stabilizing structures are used, erosion of the downcoast shoreline may result. Sand bypassing around the channel to nourish the eroding shoreline should be planned using the material dredged from the channel, or from a sand trap provided on the up coast side of the channel.

4-2.2 **Channel Width.** Channel width is defined as the clear width at the design depth, and does not include the channel side slope. Channel width is dependent on the expected vessel types and volume of traffic. Minimum channel widths for 2-way traffic should be the greater of:

- 100 ft (30 m);
- 5B, where B= Beam of the largest vessel expected to use the channel;

Additional width may be warranted to provide allowances for:

- Wind, wave and current exposure that affect vessel maneuverability
- Traffic volume

Widening of the channel may be necessary at channel bends or if immediate turns exist inside the entrance channel. In order to improve the wave climate within the harbor, the channel at the breakwater opening may be narrowed to the greater of 75 ft (23 m) or 3B, where B is as defined above. This criteria includes the restriction to one-way traffic at the opening.

\1\
4-2.3 **Channel Depth and Berthing Basin.** The required channel depth at design low water should be determined by combining the following factors: /1/

- Maximum draft of vessels
- Allowance for under keel clearance
- Wave height (as it relates to vessel motions) outside the breakwater

The maximum draft of vessels should be determined for the type of craft to be berthed regularly at the facility. Where this information is unavailable, see Chapter 2 for typical vessel dimensions.

The "squat" of a vessel is the "drawdown" of the vessel when underway in shallow water when compared to the vessel draft at rest. This is generally a concern for larger vessels but not for small craft.

The minimum allowance for under keel clearance should be 2 ft (0.61m) for soft bottoms and 3 ft (0.91m) for hard bottoms. The overdepth applied for the wave motions outside of the breakwater is a minimum of one-half the significant wave height in the channel. These values should be applied to the design low water elevation.

Additionally, where the area outside of the breakwater is exposed to open sea conditions, the channel should be deep enough for the largest vessels to enter at extreme low tide. If the area outside is sheltered from the open sea, then the channel should be deep enough for the largest vessels to enter at the design low tides, excluding the largest vessels from entering at extreme low tide.

Additional overdepth may be provided in areas where a high rate of sedimentation is experienced to permit shoaling and reduce the frequency of maintenance dredging.

\1\ Either obtain or perform a bathymetric survey to determine design criteria requirements and suitability of site as a small craft harbor or marina. /1/

4-3 PROTECTIVE STRUCTURES

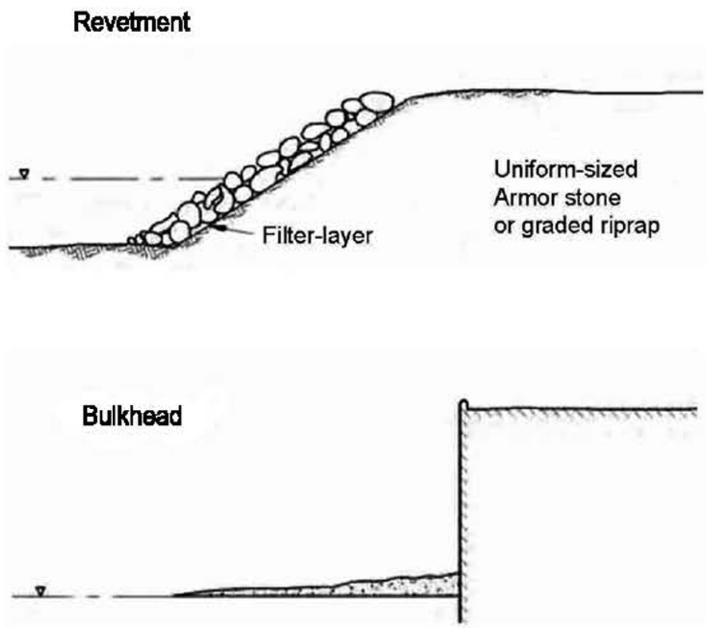
4-3.1 **Jetties.** Jetties stabilize tidal inlets by confining river and tidal currents, and help provide protection for the entrance channel from waves and shoaling. *Coastal Engineering Manual VI-2* provides a comprehensive discussion of Jetties and their application.

4-3.2 **Breakwaters.** Breakwaters provide protection from wave action. *Coastal Engineering Manual VI-2* and *Planning* and *ASCE Manual of Practice 50* provide a comprehensive discussion of breakwaters, their application and design.

4-3.3 **River Current Diverters.** River current diverters provide protection from river currents at an entrance channel and can aid in reducing entrance channel shoaling.

4-3.4 **Bank Protection.** Bank protection stabilizes the berthing basin bank from erosion. *Coastal Engineering Manual VI-2* provides a comprehensive discussion on bank protection systems. Figure 4-2 shows typical structures used for bank or shore protection.

Figure 4-2 Typical Bank Protection Structures



4-3.5 **Wave Attenuators.** Wave attenuators typically consist of floating breakwaters or fixed wave screens and may be used to help protect areas from short period waves (wind waves with a limited fetch, or ship wake). *Coastal Engineering Manual VI-7-5* and *ASCE Manual of Practice 50* provide a comprehensive discussion of wave attenuators and their application. \1\ There have been numerous recent problems associated with wave attenuators and floating structures. It is imperative that a competent coastal engineer perform a wind wave analysis study to properly ascertain design criteria for such floating structures. /1/

4-4 AIDS TO NAVIGATION

4-4.1 **Purpose.** The U.S. Coast Guard operates and administers the United States Aids to Navigation System. The principal purpose of the Aids to Navigation System is to mark channels and other areas of "safe water." In addition, aids to navigation are used to mark hazards to navigation, wrecks and obstructions. To accomplish this, the Coast Guard establishes, operates, and maintains the system in the Federal Channel and major areas of maritime activity in the U.S. In areas of less activity that serve less mariners, private aids are operated and maintained by private parties upon approval from the Coast Guard. The system utilizes audio, visual, radar, or radio methods to mark safe water for navigation. The U.S. marking system is a predominantly lateral system.

4-4.2 Types of Marks

4-4.2.1 **Lateral.** Lateral marks define the port and starboard sides of a route to be followed, usually the sides of channels. Port marks are green in color and indicate the left side of channels when proceeding in the conventional direction of buoyage (returning from seaward). Marks may consist of beacons, buoys or lights. Beacons have green square daymarks, while buoys are green can or pillar buoys. Green lights of various rhythms are used on port hand marks. Starboard marks are red in color and indicate the right side of channels and consist of the same types of marks as port marks

4-4.2.2 **Isolated Danger.** These marks are erected on, moored over, or placed immediately adjacent to an isolated danger that may be passed on all sides by system users. They are black with one or more broad horizontal red bands and will be equipped with a topmark of two black spheres, one above the other. If lighted, they display a white group flashing two light with a period of five seconds.

4-4.2.3 **Safe Water Marks.** Safe water marks indicate that there is navigable water all around the mark. Safe water marks have red and white vertical stripes.

4-4.2.4 **Special.** Special marks are not primarily intended to assist safe navigation, but to indicate special areas or features referred to in charts or other nautical publications. They may be used, for example, to mark anchorages, cable or pipeline areas, traffic separation schemes, military exercise zones, ocean data acquisition systems, etc. Special marks are colored solid yellow, and show yellow lights with a slow-flashing rhythm preferred.

4-4.2.5 **Information and Regulatory.** Information and Regulatory Marks are used to alert the mariner to various warnings or regulatory matters. These marks have orange geometric shapes against a white background.

A complete description of the aids to navigation system is described in Commandant Instruction M16500.7

CHAPTER 5

BERTHING SYSTEM LAYOUT

5-1 BERTHING SYSTEM ARRANGEMENTS

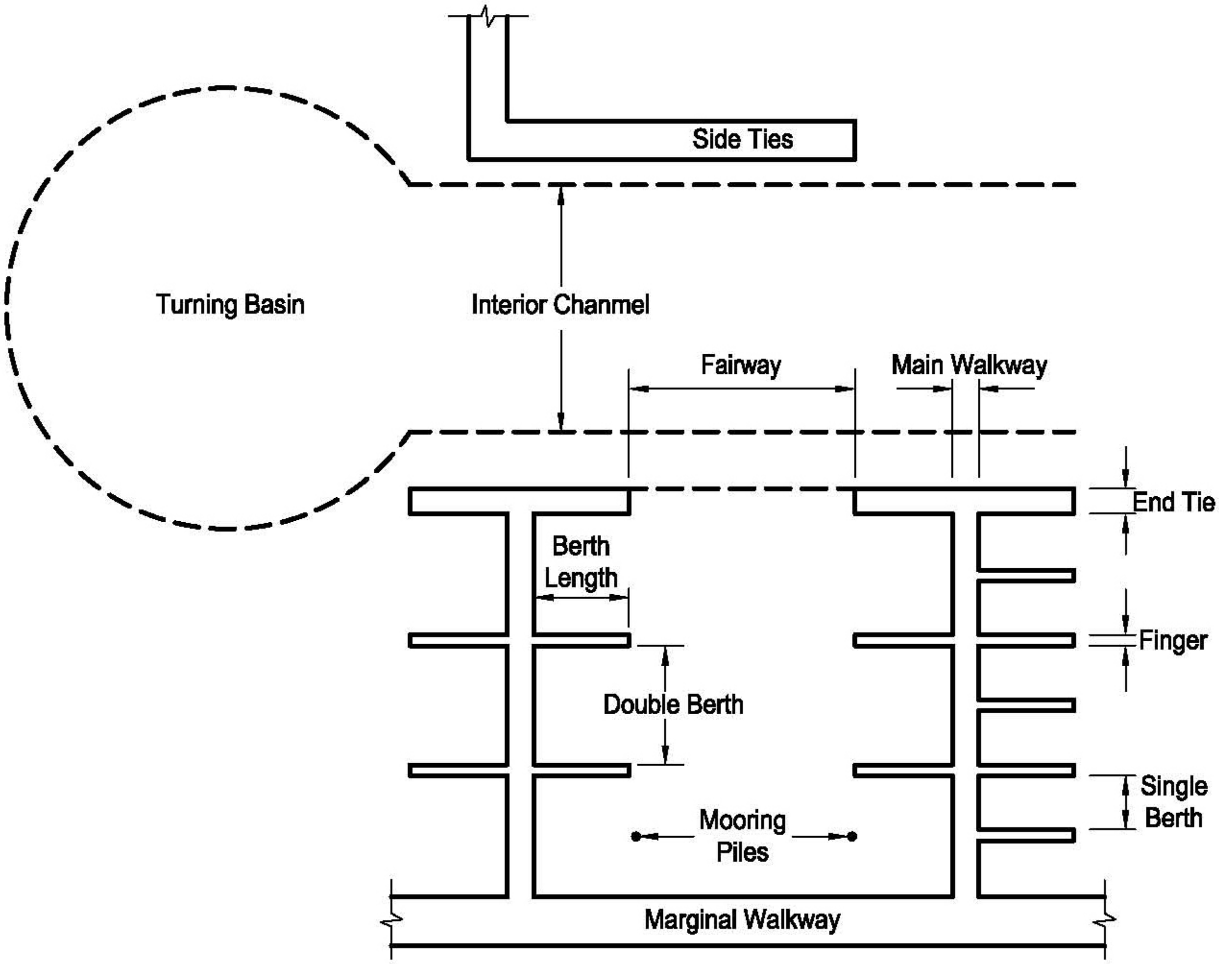
When determining the berthing arrangement, berth orientation should take into consideration the local wind and current conditions to facilitate safe berthing and vessel movements. Common berth arrangements are:

- A series of main walks extending perpendicular from the marginal wharf or dock, with finger piers or floats extending at right angles from the main walks on either side
- Larger vessels should be berthed closer to the entrance channel
- Smaller vessels should be berthed closer to the shore
- Launch and haul out facilities should be located away from other marina activities in quiet water
- Fuel service should be located near the entrance channel to facilitate access for larger vessels and separated from the berthing area.
- Seaward orientation to allow quick response

5-2 BERTHING SYSTEM DIMENSIONAL REQUIREMENTS

Figure 5-1 shows typical features and terms of a berthing system for small craft.

Figure 5-1 Typical Berthing Arrangement



5-2.1 **Interior Channels.** Interior channels connect the entrance channels with the berth fairways.

The minimum clear width of interior channels should be the greater of:

- 1.5 L , where L is the overall length of the longest boat using the channel or
- 75 ft. (23 m)

The preferred width of interior channels should be the greater of:

- 1.75 L, or
- 100 ft. (30 m)

Interior channel depths should be determined using the same considerations as entrance channels. The overdepth allowances for wave height and sedimentation should be included based on the wave and sedimentation patterns within the facility.

Since the minimum interior channel widths in the typical small craft harbor are based on vessel length, turning the vessel within, or at the end of the channel is accommodated without the need for an enlarged turning basin. However, if a situation arises in which a substandard channel width exists, a turning basin should be provided at an appropriate point in the channel; the basin should provide a clear turning circle whose minimum diameter is 1.5 L, where L is as defined above. Where channel currents or winds make turning difficult, this minimum should be increased to 2.0 L.

5-2.2 **Fairways.** Fairways provide vessel access from interior channels to individual berths.

The minimum clear width of fairways should be:

- 1.5 L_b (finger slips) \1\ for power boats and 1.75 L_b for sailboats /1/, where L_b is the length of the longest berth perpendicular to the fairway where vessel are not allowed to overhang the berth.

- 1.5 L_b (with side/end-ties) \1\ for power boats and 1.75 L_b for sailboats /1/, where L_b is the length of the longest berth parallel to the fairway where the fairway width does not include the side-tie berth width. A side/end tie is a berth at the end of the main walkway adjacent to the interior channel (See Figure 5-1).

The preferred clear width of fairways should be:

- 1.75 L, where L is the overall length of the longest boat using the fairway.

Fairway depths should be determined using the same considerations as interior channels.

5-2.3 **Berths.** Berth widths should be based on the particulars of the vessels to be berthed. When this information is not available, see Chapter 2 for typical vessel dimensions. The minimum width of a berth should be:

- Double berth: 2 x Beam of the wider vessels served + clearance for environmental conditions, boater experience, and fendering system

- Single Berth: Beam of the widest vessel served + clearance for environmental conditions, user experience, and fendering system

Typical clearances range from 3 ft (.9 m) to 7 ft (2.1 m), being greater for double berths, for longer berths, and where winds and currents make berthing difficult.

Berth depths should be the same as the fairway depth.

5-2.4 **Walkways.** The minimum clear width of main walkways should be 6 ft. (1.8 m). Depending on the need for dock carts passing each other and emergency access and egress, additional width may be necessary. Main walkways on floating docks should also be increased in width if they are not balanced by fingers on both sides. The width defined above is clear width between obstructions on the pier or dock such as cleats, piles, etc. The minimum clear width of marginal walkways is 8 ft. (2.4 m) to allow for increased pedestrian traffic resulting from the connection to main more than one walkway.

Walkway lengths should be limited to 700 feet for main walkways and 1000 ft for marginal walkways in consideration of:

- Walking distance between berths, parking, and restrooms
- Utility size increases due to distance
- Hauling distance for equipment, supplies and gear

5-2.5 **Fingers.** Finger width should support safe pedestrian use. The minimum clear width of the finger should be the greater of:

- 0.1 L, where L is the length of the slip served by the finger or

- 3 ft

The preferred minimum width to enhance stability of the finger is 5 ft.

Finger length should be sufficient to facilitate the loading and unloading of the vessel, and should not be less than 0.8 times the nominal length of the slip. Typically finger lengths are equal to the slip length and to the length of the boat allowed to occupy the berth. Under certain conditions overlength vessels may be permitted to “overhang” the slip into the fairway, but this practice encroaches on the required clear width of the fairway, and places a greater load on the pier or dock.

CHAPTER 6

BERTHING STRUCTURES

6-1 FIXED VS. FLOATING BERTHING SYSTEMS

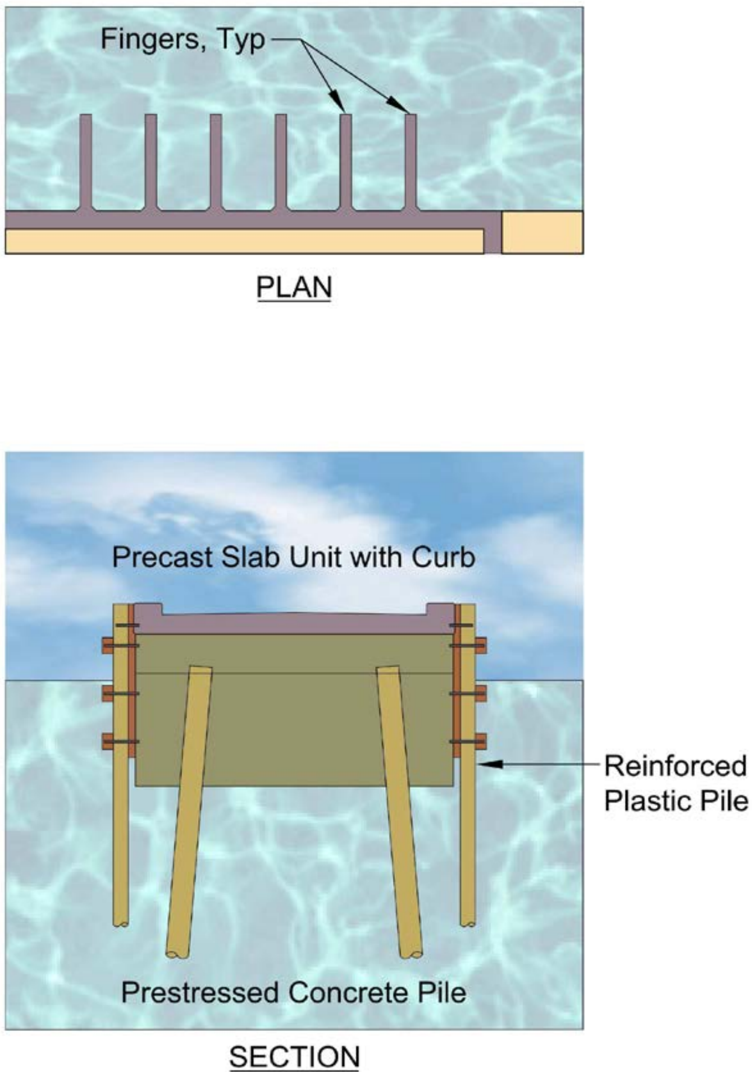
6-1.1 **Selecting a Fixed or Floating Berthing System.** The selection of a fixed or floating Berthing System is primarily determined by the water level fluctuation at the site. The basis for the selection is the requirement that the fixed pier or float deck elevation match as closely as practical the deck freeboard of vessels that use the pier or float, both to facilitate boarding and to reduce the need for mooring line adjustment.

A secondary consideration is wave height at exposed berths; where waves greater than 2 feet can occur and problems due to floating dock motions would over-ride the benefits provided by the floating dock, a fixed system is preferred.

At sites where a fixed pier exists and the water level fluctuation and wave height criteria for a floating system are met, a floating dock with a variable slope gangway to transition from the pier to the float should be provided.

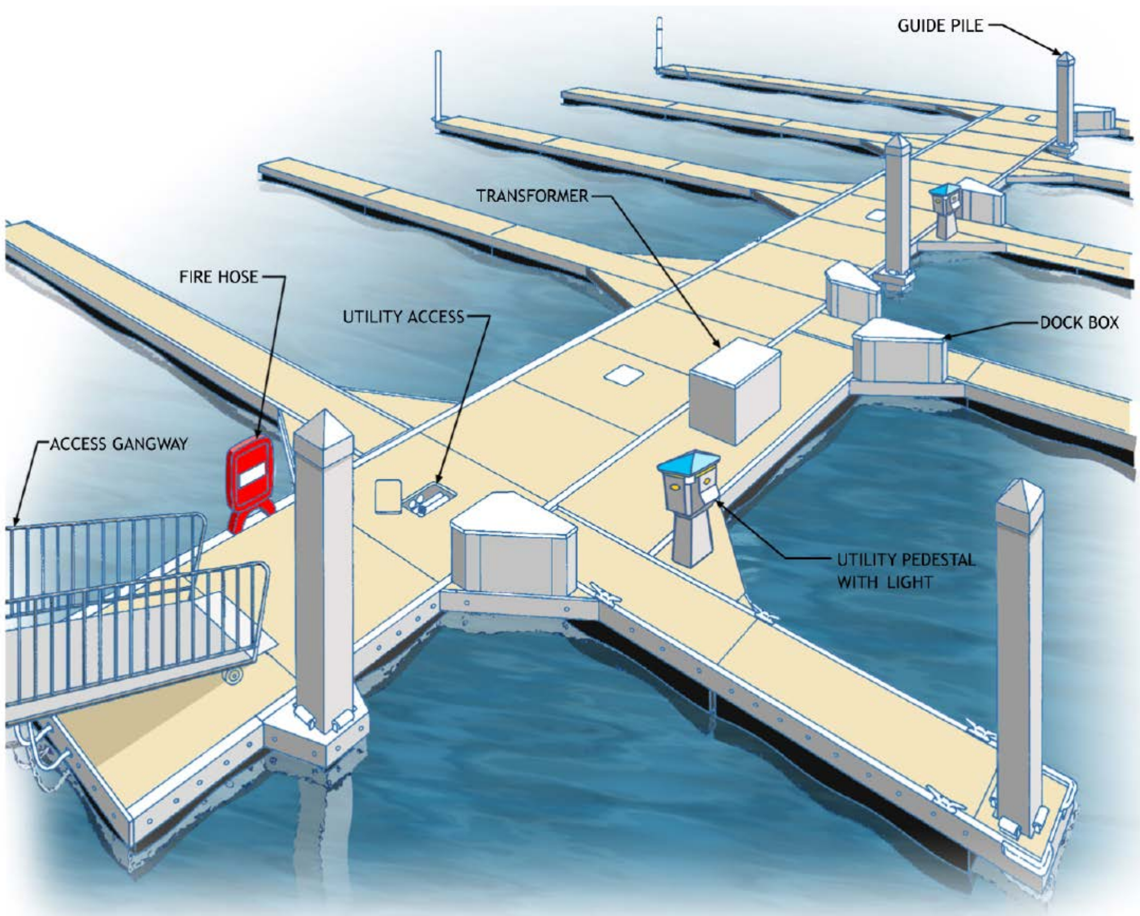
6-1.1.1 **Fixed systems.** Fixed systems are generally selected where the tidal range for coastal sites or the seasonal water level range for inland rivers or lakes is less than 3 feet (0.91m). Figure 6-1 shows a typical fixed pier system.

Figure 6-1 Typical Fixed Finger Pier



6-1.1.2 **Floating systems.** Floating systems are generally preferred where the tidal range or seasonal water level range is 3 feet (0.91m) or more. Figure 6-2 shows a typical floating pier system.

Figure 6-2 Typical Floating Finger Pier System



6-2 COVERED VS. UNCOVERED BERTHS

6-2.1 **Selecting Covered or Uncovered Berths.** Berthing systems are generally uncovered unless adverse weather, in particular precipitation, can be shown to interfere with boat operations, including boarding or essential dockside maintenance. Generally, covers to protect military vessels from exposure to the elements and retard weathering (though common in recreational marinas) are not provided.

Covers for fixed berthing systems are supported on the fixed piers. Covers for floating berthing systems may be supported on the floating dock where wave conditions permit or on fixed pile supports. Berth covers contribute significant additional dead and live loads on the fixed pier or floating dock. Besides the additional dead weight, winds can produce substantial lateral and uplift forces on the dock structure.

Fixed piers or floating docks should not be retrofitted with covers unless the structure (including flotation) was designed for the additional loads produced by the covers, or the berthing structure itself is retrofitted to withstand the additional loads.

6-3 BERTHING SYSTEM LOADING CRITERIA

6-3.1 **Dead Loads.** The dead load should include the self weight of the structure and all permanent attachments such as cleats, fenders, dock boxes, utility pedestals with associated electrical and water lines, fire suppression standpipes and fire lines, light stanchions, power centers, and where fitted, storage lockers, fuel dispensers and fuel lines, sewage pumpout units and sewage lines, etc. The water, fire, fuel and sewage lines should be considered full of liquid. If the berths will be covered, include the superimposed dead load of the cover structure.

The deadload for floating docks should also include the weight of pile guides or anchoring hardware, the superimposed dead load of the gangway reaction on the dock, and an allowance for weight gain due to water absorption in the dock flotation.

6-3.2 **Vertical Live Loads.** The vertical live load may be uniformly distributed or a concentrated point load; both cases should be checked to identify the governing case for design (See Figure 6-3). The restricted access pedestrian application may be used when dock access is controlled and the number of persons on the pier or dock at any one time can be limited to typical recreational marina densities. When it is possible for a large number of persons to congregate on the pier or dock, the unrestricted access pedestrian application should be used. In the case of floating docks, this will impose substantial additional demand on the dock to satisfy freeboard and stability criteria.

Figure 6-3 Vertical Live Loads on Berthing Systems

APPLICATION	UNIFORMLY DISTRIBUTED LOAD	CONCENTRATED POINT LOAD
Fixed Pier – Pedestrian		
▪ Restricted Access	40 psf (8 kPa)	400 lbs at any point on the pier per
▪ Unrestricted Access	100 psf (20 kPa)	
Vehicular	Per UFC 4-152-01	UFC 4-152-01
Floating Dock – Pedestrian		400 lbs at any point on the dock at least 1 ft from the dock edge
▪ Restricted Access	25 psf. (5 kPa)	
▪ Unrestricted Access	100 psf (20 kPa)	

6-3.3 **Floating Dock Freeboard and Stability.**

6-3.3.1 **Freeboard.** Floating docks under dead load only should have a minimum freeboard to the deck of 16 inches (40 cm) and a maximum of 24 (60 cm) inches. For a safe and visually pleasing dock system, the deck cross slope on walkways or fingers should not exceed 2% and the freeboard overall should not depart from the average by more than 1 inch (2.5 cm).

Under full live load plus dead load, floating docks should have a minimum freeboard of 10 in (25 cm).

In the event that a uniform live load of 100 psf (20 kPa) is required, additional dead load freeboard of at least 15 in (38 cm) would be needed to meet the fully loaded minimum freeboard of 10 in (25 cm). As a result, the dock may ride too high under dead load only to satisfy functional requirements. If this occurs, consideration may be given to reducing the fully loaded minimum freeboard if the fully loaded condition is a rare occurrence, provided that the stability requirements can still be satisfied.

The dock freeboard and stiffness requirements (to limit deck slopes) may control the structural and flotation design rather than the minimum live loads, and should be checked.

6-3.3.2 **Stability.** The dock should have a minimum freeboard of 2 in (5.1 cm) to the top of the buoyancy pontoon to provide reserve buoyancy under full live load plus dead load. If the buoyancy pontoons provide full flotation to the top of the deck, the minimum dock freeboard noted above is sufficient to satisfy this requirement. If the width of the pontoon varies (pipe pontoons for instance) with submergence, then the minimum freeboard of the pontoon should be increased to provide reserve buoyancy equivalent to the 2 inch (5.1 cm) requirement.

The dock must also be able to withstand overturning forces and return to a normal freeboard and level condition upon removal of any unbalanced forces. Floating dock systems that consist of interconnected walkway and finger docks will generally satisfy this requirement. However, long and narrow dock modules may not, in which case a metacentric method calculation of stability should be performed. A floating dock is stable if under all conditions of loading, the metacenter is located a safe distance above the center of gravity of the structure.

6-3.4 **Environmental Loads.** The principal environmental loads to consider (not all may apply at a particular site):

- Wind, on berthed vessels as well as the pier or dock structure
- Snow and ice due to accumulation on or against the structure
- Floods, surges and tsunamis that produce both extreme water levels and currents
- Floating debris due to impact or accumulation against the structure

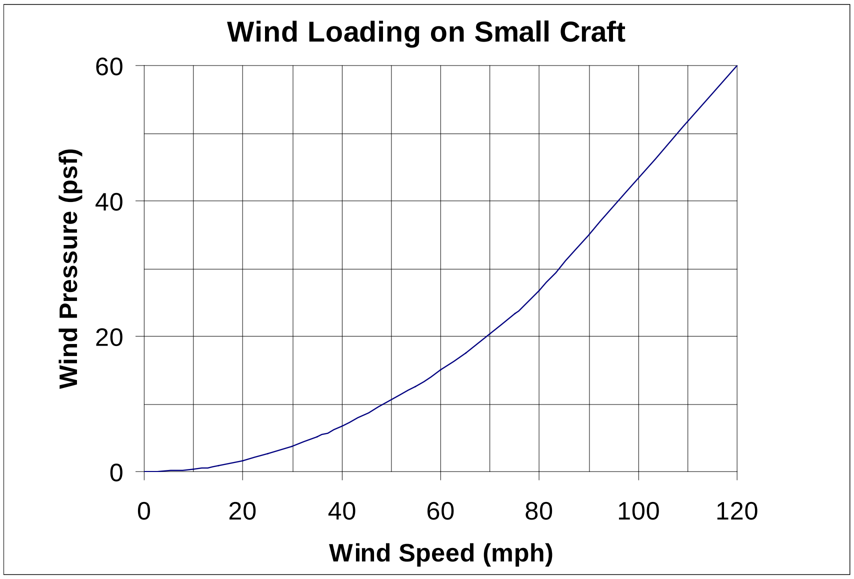
- Waves due to locally generated wind waves and boat wake, or swell arriving from offshore storms
- Currents due to tidal and/or river flows
- Seismic, generally of concern on fixed piers only

6-3.4.1. **Wind Load.** Wind load is based on a wind velocity pressure for steady conditions (neglecting gusts) acting on the above water profile of the berthed vessels and dock system

6-3.4.1.1 For wind velocities at various geographical locations consult \1\ UFC 3-301-01 /1/*.*

6-3.4.1.2 Convert the design wind velocity (in miles per hour) to velocity pressure using Figure 6-4 or other rational method.

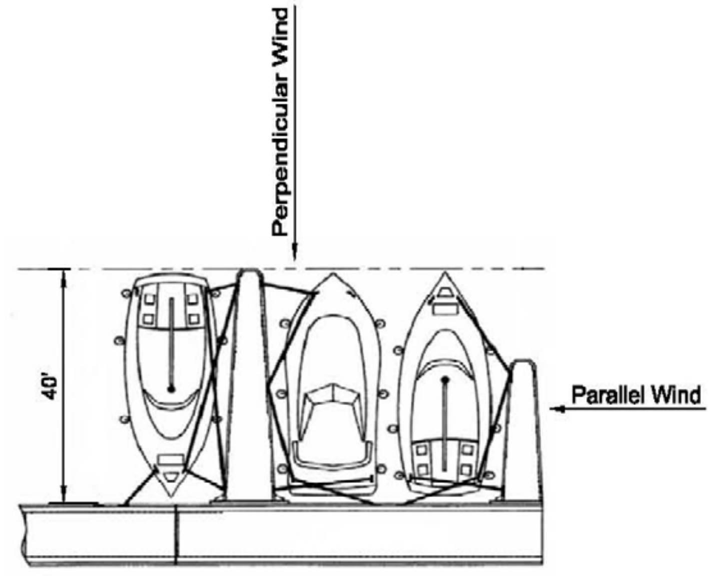
Figure 6-4 Wind Load on Small Craft



6-3.4.1.3 Determine the average profile height for the berthed vessels, generally taken as 15% of the berth length, but other rational method based on the berthed vessel dimensions may be used.

6-3.4.1.4 Compute the wind load, checking both parallel and perpendicular directions to the main axis of the pier or dock. Figure 6-5 shows a sample calculation for total wind load. Assume 100% berth occupancy. For vessels berthed in close proximity to each other, say on either side of a walkway or finger dock, the total force on the structure for each direction should be based on the full wind load applied to the windward (unshielded) vessels, and 20% of the full wind load applied to all leeward (shielded) vessels.

Figure 6-5 Sample Calculation for Windloading on a Floating Pier System



Design Wind Load: 15 PSF

Perpendicular Wind		
40' Boats:	3 Each x 19' Beam x 6.0' Height x 15 PSF	= 5,130 Lbs
Fingers:	2 Each x 4' Beam x 1.5' Height x 15 PSF	= 180 Lbs
	TOTAL PERPENDICULAR LOAD:	= 5,130 Lbs
Parallel Wind		
40' Boats Unshielded:	1 Each x 40' x 6.0' Height x 15 PSF	= 3,600 Lbs
40' Boats Shielded:	2 Each x 40' x 6.0' Height x 3 PSF	= 1,440 Lbs
Headwalk:	1 Each x 6' x 1.5' Height x 15 PSF	= 135 Lbs
	TOTAL PARALLEL LOAD	= 5,175 Lbs

In the case where one of the berthed vessels is larger than the rest, the unscreened part of its profile area should be taken into account. Further, when the above water area of the structure is unshielded, the force on the profile area exposed to the wind should be included in the total.

Individual fingers, however, should be designed to accommodate the full wind load on the berthed craft since the presence of a shielding boat cannot be assured.

6-3.4.2 **Snow and Ice.** Snow and ice loads appropriate to the site as spelled out in local building codes should be considered. Vertical snow and ice loads, resulting from precipitation or wind driven spray, can destabilize a floating dock. Non-moving ice formed on the water surface, or ice drifting against a pier or dock can exert tremendous forces and damage the structure unless counter measures are taken to limit ice formation or accumulation. Ice problems and solutions are discussed in the *ASCE Manual of Practice 50.*

6-3.4.3 **Currents.** Currents in rivers and tidal areas can produce high loads on piers and docks and the berthed vessels through their underwater profile areas. This condition is at its worst when vessels are berthed perpendicular to the current direction, and least when the vessels are aligned with the current direction. Generally, when the current exceeds 3 ft/sec (1 m/s), it could be a significant factor in design, and a rational method should be used to determine the current forces that include consideration of:

- Peak velocities (speed and direction)
- Drag coefficients to determine velocity pressure
- Underwater profile area

Even moderate current velocities passing under floating docks can produce a downward suction on the leading edge of the dock and cause the edge to submerge unless counter measures are taken to reduce the suction force.

6-3.4.4 **Hurricanes (Typhoons), Flood Flows and Tsunamis.** Hurricanes, flood flows and tsunamis are similar in that each can produce dramatic water level rises and destructive waves and currents. If the pier or dock cannot reasonably be designed to withstand such extreme conditions, the berthing system must be relocated to a more protected site, or the consequences of catastrophic failure accepted.

6-3.4.5 **Floating Debris.** Debris mats can form against piers or docks on river or reservoir sites and exert significant loads. The structure should be designed for the drag load produced by a debris mat at least 3 ft. thick (or twice the draft of the flotation for floating docks), or the load controlled by installing a fixed or floating debris boom to deflect the debris around the structure.

6-3.4.6 **Seismic.** Seismic loads appropriate to the site as spelled out in local building codes should be considered in the design of fixed piers. Generally, seismic loads are not significant in the design of floating docks, though seismic events may trigger marina basin oscillations, and the resulting current loads and water level fluctuations can be significant, and should be considered.

6-3.4.7 **Waves and Boat Wake.** Wave heights should be limited by locating the berthing system in a sheltered area. If necessary, additional wave protection may be provided by means of a fixed or floating wave attenuator incorporated in the berthing system design. Areas sheltered from wind waves may still be subject to boat wake, since even “no wake” zones may not succeed in preventing passing vessels from generating large wakes.

6-3.4.7.1. When describing the wave climate, the terms significant wave height (H_s) and maximum wave height (H_1) are generally used. Structural designers often use the maximum wave height to size members and connections, while the significant waveheight is used to estimate floating dock motions and cyclic loads for fatigue analyses.

6-3.4.7.2. Generally, when the design wave height exceeds 1 foot, it could be a significant factor in design and a rational method should be used to determine the wave forces that include consideration of:

- Vertical wave load on a floating dock resulting from hogging (and sagging) of the dock.

- Horizontal and vertical wave forces on the submerged portion of a fixed pier (piling and bracing), or on a floating dock pontoon.

6-3.4.7.3 Wave forces are dependent upon the direction of wave approach to the structure. In particular for floating docks, the vertical loads are greatest when the wave approach is parallel to the long axis of the dock, and the horizontal loads are greatest when the wave approach is perpendicular to the long axis. If the direction of wave approach is limited, then the wave loads may also be limited by appropriate orientation of the floating dock.

For larger vessels dynamic mooring forces under the action of waves can be significant and should be considered if the vessel is to remain at its berth during extreme wave conditions.

6-3.4.8 **Anchorage.** Anchorage forces for floating docks are dependent on the type of anchorage, which can take many forms:

- Piles

- Spuds

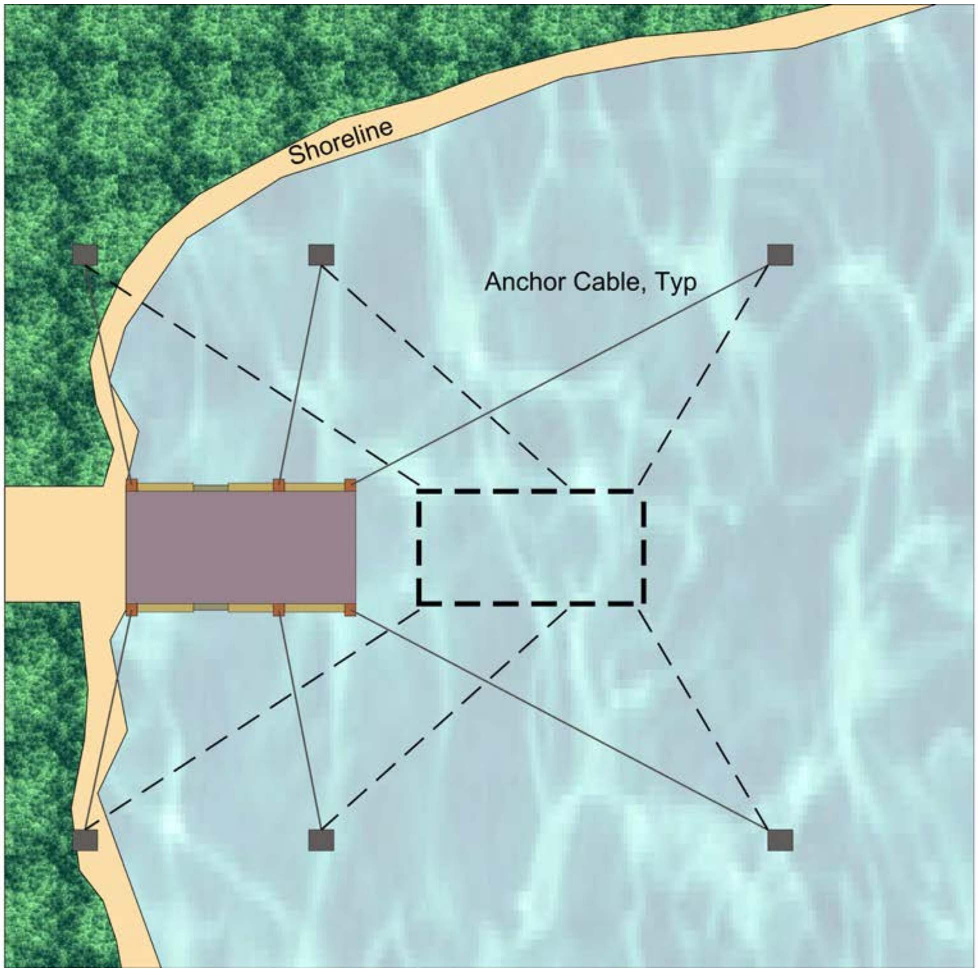
- Cable/Winch/Anchor

- Chain/ Anchor

- Strut-to-Shore

Cable anchor systems are often utilized when water depths are large, or water level fluctuations are large and bottom slope is shallow, requiring the docks to move horizontally to remain floating. Figure 6-6 shows a cable anchorage system that allows horizontal movement.

Figure 6-6 Cable Anchorage System



Specific site conditions should determine the most appropriate option, the principal site considerations being water depth, water level fluctuation, exposure to waves and condition of the submarine bed. An additional consideration is the permanence of the floating dock, as some situations require a system that can be relocated, with an anchorage that can be easily removed and reused.

Anchor loads for floating docks are generally determined by the horizontal live loads, which are additive in many cases. Specific site conditions will vary, but generally wind, wave and current loads are combined to get total loads when they can all arrive simultaneously. The type, number, location and size of the anchorage component are critical aspects of floating dock design. Inadequate anchorage is probably the most frequent cause of failure in floating dock systems. A discussion of anchorage design is presented in *ASCE Manual of Practice 50.*

6-3.5 **Berthing Loads**

6-3.5.1 **Berthing.** Berthing loads due to vessel impact on a pier or dock result from the kinetic energy of the vessel, which is a function of the design vessel's docking (laden) weight and approach velocity generally taken normal to the dock face. For small craft, no allowance is made for the bumpers typically provided on the dock face. However, deflection of the dock system anchorage for floating docks is generally considered to reduce the impact force.

6-3.5.1.1 The docking weight in lbs (w) of recreational craft may be estimated by $W=12L^2$, where L is the vessel length in feet. For military craft, the weight can be considerably greater, and vessel particulars should be obtained.

6-3.5.1.2 The approach velocity (v) generally varies with the vessel size, but the minimum should be:

- v=0.6 ft/sec for L > 60 ft. (0.2 m/s for L > 18 m)
- v=1.0 ft/sec for L < 60 ft. (0.3 m/s for L < 18 m)

The larger value should also be used regardless of length where adverse wind and current conditions create difficulty for pilots maneuvering into the berth.

6-4 BERTHING SYSTEM TYPICAL CONSTRUCTION

6-4.1 **Fixed Piers.** Fixed Piers may be constructed of many types of materials:

- Steel
- Concrete
- Aluminum

\1\
- Timber

/1/
- Combinations of the Above

The basic pier structure consists of piling with caps spanning pairs of piles, and a deck structure spanning between caps. In addition to the basic structure, bumpers, mooring hardware and utility systems (generally power, potable water, fire suppression and communications) are provided. Further, piers may include wastewater reception (pumpout), fuel dispensing and lockers for gear storage. Important safety features include a slip-resistant walking surface, lighting for night operations, guard rails where they do not interfere with vessel berthing requirements, boarding ladders if the deck freeboard exceeds 3 ft (0.9 m) at design low water, and flotation devices for emergency use.

6-4.1.1 Finished Deck Elevation should be a minimum 1 ft (0.3) above design high water, or a height sufficient to prevent deck structure submergence at design high water, including allowance for wave crests, whichever is greater.

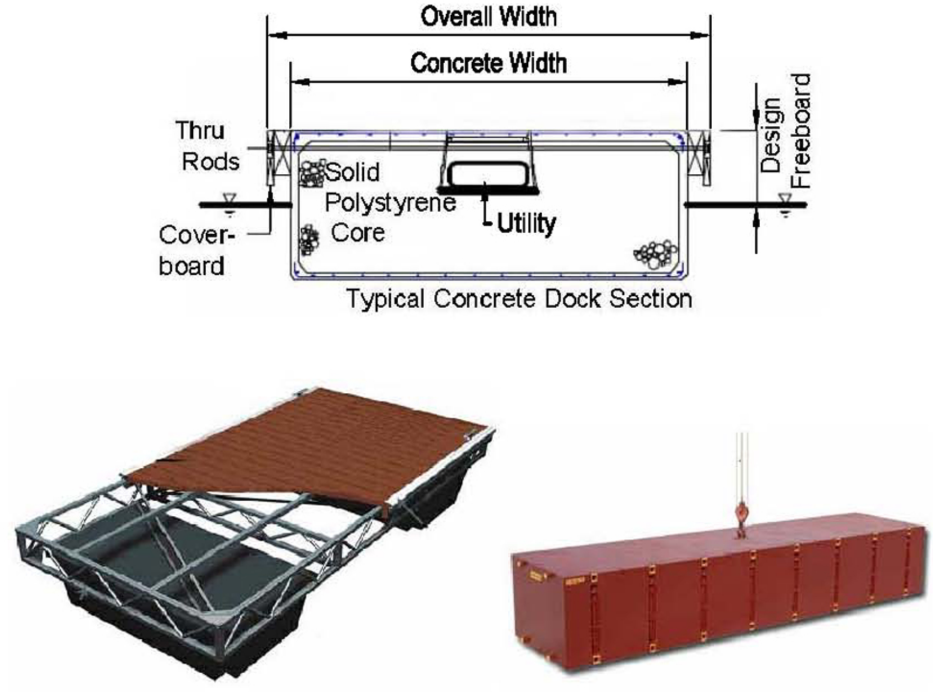
6-4.1.2 Provide bow and stern mooring points appropriately located and sized for the berth length.

6-4.1.3 Provide a bumper system able to accommodate vessels with a low rub rail without 'hanging up' on any structural components of the pier, for the full range of design water levels, and to accommodate vessels with a high gunwale.

6-4.1.4 For other design requirements, refer to UFC 4-152-01.

6-4.2 **Anchoring Floating Docks.** Floating Docks may be constructed of many types of materials, similar to fixed docks. In addition, plastic and fiberglass materials are finding increased use in floating dock construction. Modular factory fabricated floating dock systems are now in common use. Figure 6-7 shows some typical fabricated floating dock systems. Consideration should be given to using an appropriate commercial product, preferably one with a proven track record over many years of experience. The basic dock structure consists of the flotation pontoon, the structural frame, the deck, and the anchorage. In some proprietary systems the flotation, frame and deck are unitized so that system assembly consists essentially of bolting the modular pontoon units together. The basic dock structure should be finished with all of the appurtenances noted previously for fixed piers.

Figure 6-7 Various Types of Floating Docks



Truss
Steel frame pontoon with decking

Steel

6-4.2.1 **Flotation Pontoons.** Flotation pontoons should consist of a foam core completely encapsulated in a protective shell to prevent contact with water or other deleterious elements. The foam generally consists of expanded polystyrene (EPS) closed cell blocks, but other types of foam may be used. Although the foam should be protected by the shell from water contact; certain materials may lose their water-tightness over time. However, a quality foam core will prevent significant loss of buoyancy. This should be acceptable if the maximum water absorption of the EPS core is limited to less than 3% as determined by \1\ ASTM C272/C272M /1/, Method C, the amount of reground material is limited to less than 10%, and the form core is preformed to the interior configuration of the pontoon as a solid block.

6-4.2.2 **Deck Surface.** Deck surface should withstand prolonged exposure to the elements (sunlight, wetting/drying, freezing/thawing etc., unless the berth is covered), severe abrasion by scuffing and dropped objects, and fatigue due to dock motions and flexing. Further, the surface should be non-skid, and resistant to staining by spills and dirt.

6-4.2.3 **Floating Docks.** Floating docks should be anchored against lateral forces.

6-4.2.3.1 **Cantilever Anchor Piles.** Cantilever anchor piles are simple and the most commonly used anchorage. Generally they are preferred when the water depth at the design high water level is less than 30 ft (9 m). The pile should be high enough so that the dock will not float off the top, so allowance must be made for the dock freeboard and motions due to waves and surge in addition to the extreme high water level. Where piles are used, pile guides should be incorporated in the dock structure. Guides generally consist of collars faced with Ultra High Molecular Weight (UHMW) polyethylene rub blocks, which wear and are replaced periodically. In well protected basins, pile guide rollers may be used in lieu of the rub blocks. The anchor piles are generally prestressed concrete or steel pipe; timber marine piles are rarely specified due to concerns over preservative chemicals used to treat softwood piles, or tropical rain forest protection for the naturally resistant species. In situations where dock loads and water depths exceed the capability of simple cantilever anchor piles, multi-pile dolphins may be considered, with the braced vertical pile serving as the guide pile.

6-4.2.3.2 **Anchor Lines.** Anchor lines are generally used where the dock system is constructed in deep water, or where large water level fluctuations occur. For situations where the extreme wave exposure favors a more compliant anchorage to reduce peak loads, anchor lines are often used as well. The anchor lines consist of wire rope, steel cables or chains. Where the floating dock system requires movement through considerable horizontal distance with water level changes, or where large loads are involved, winch systems are used to adjust line tension and control dock position. In most cases the winches are located on the floating dock and the dead load of the winch and anchor line pull must be factored into the design of the dock floatation. A cable guide should extend a sufficient depth below the winch so that the cable leading away from the dock to the anchors will not interfere with the deepest part of the vessels likely to use the dock. Design of cable anchor systems involves complex non-linear analyses to determine cable behavior and the resultant loads on the ground anchors, particularly as the number of cables increase. Design requirements for mooring systems are described in UFC 4-159-03.

6-5 MOORING FITTINGS AND BUMPERS

6-5.1 **Cleats.** Vessel to pier or dock tie up generally utilizes cleats attached to the structure. Since cleat manufacturers do not specify guaranteed minimum holding strengths, the sizing of cleats and their attachment is largely driven by experience.

6-5.1.1 **Number and Location.** Provide a minimum of 3 equally spaced cleats per berth for vessels over 20 ft (6 m) in length and less than 60 ft (18 m); larger vessels will require additional cleats. Single berths (with a finger dock on each side) should have the minimum number of cleats on each side of the berth; double berths (with a finger dock on only one side of the vessel) should have an additional cleat for each berth on the main walk near the center of the slip. The cleats should be located along the edge of the pier or dock to minimize tripping hazard.

6-5.1.2 **Size.** Piers or docks required to hold vessels under extreme wind and wave conditions should receive a rational analyses of peak mooring loads, and an attempt made to obtain data from manufacturers on maximum cleat capacities in order to size the cleats. Generally, however, the following sizes have proven adequate for most situations:

Berth Length L – ft. (m)	Cleat Size – in. (cm)
L< 40 (12)	10 (25)
40 ≤ L < 60 (18)	15 (38)
60 ≤ L < 80 (24)	18 (46)
L ≥ 80	24 (61)

6-5.1.3 **Attachment.** Attach cleats with a minimum of two through bolts into the structural frame of the pier or dock. Plate washers should be used to distribute cleat pull out forces without crushing the structural support. Bolt heads should be recessed into the cleat so lines do not chafe on them; the recess should be filled to prevent water ponding and corrosion.

6-5.2 **Bumpers.** Vessels and piers or docks need protection from each other because of impact and chafing. Hardware used to fasten the various types of bumpers to the pier or dock structural frame should have all exposed heads on the berth face recessed to prevent hull damage. The solutions described below are considered part of the pier or dock, and would be in addition to the portable fenders typically deployed on the vessel itself.

6-5.2.1 **Horizontal Rub Rails.** Generally a continuous recycled plastic lumber, rub rail running the full length of the berth is attached wherever a vessel can contact the pier or dock. Additional protection may be provided by means of a continuous vinyl bumper strip attached to the top edge of the rub rail, largely to reduce marring of the vessel hull, but also to provide some cushioning.

6-5.2.2 **Vertical Rub Strakes.** Generally rub strakes extend below the deck to contact the lowest vessel rub rail at design low water, and prevent the rail from 'hanging up' on the horizontal member at the face of the dock or pier. The top of the rub strakes should extend above the deck far enough to contact the highest vessel rub rail at design high water for the same purpose. Rub strakes are generally fitted to fixed piers as the freeboard variations tend to be greater and the hull rub rail problem arises more often than with floating docks, whose freeboard remains relatively constant. If the berthed vessels are not fitted with rub rails, rub strakes should be avoided on floating docks in particular.

6-5.2.2.1 Rub strakes should be placed at 1/3 points on the berths, starting at the outer end and omitting the strake on the inner end: Do not omit strakes for continuous side tie berthing. Generally, recessed horizontal rub rails are still used between the strakes.

6-5.2.2.2 Rub strakes should be attached to the structural frame of the pier or dock.

Generally, the vessel (due to hull curvature) will lay up against only 2 strakes, and vessel loads are applied to the structure at the level of the vessel rub rail rather than the dock frame, creating a torsional load on the frame.

6-5.2.2.3 Vertical rub strakes may also be fitted with vinyl bumper strips attached on the berth face, similar to the horizontal rub rail.

6-6 ACCESS PIERS AND GANGWAYS

6-6.1 **Accessing Fixed Piers.** Access to a fixed pier berthing system is relatively straight forward, and may be provided by an extension of the berthing system main walkway. For situations where the elevation of the point of access on the shoreline bulkhead or landing is greater than the deck elevation on the fixed pier, a ramp should be provided that conforms to code requirements.

6-6.2 **Accessing Floating Docks.** Access to a floating dock system typically requires a hinged gangway with a variable slope ramp to span between the fixed access point on shore and the floating dock. Design Criteria for the variable slope gangway ramp are discussed in *DBW Layout and Design Guidelines*.

6-6.2.1 **Gangway Ramp Upper Support.** The upper end of the gangway ramp should be supported on the shoreline bulkhead, or on a fixed pier to provide access to a floating dock system that is located a considerable distance from shore. The support should be in the form of a “hinge” that accommodates the vertical swing of the gangway in response to changing water level as well as the horizontal sway in response to floating dock drift.

6-6.2.2 **Gangway Ramp Lower Support.** The lower end of the gangway ramp should be supported on the floating dock, which must be provided with additional flotation to offset the superimposed dead load of the ramp plus 50% of the live load reaction and maintain the required dock dead load freeboard. The remaining 50% of the live load reaction is distributed to the dock system flotation by the dock structure on demand. Experience has shown that providing sufficient flotation for 100% of the live load results in excessive dead load freeboard. The ramp support on the dock consists of HDPE skidplates or rollers to carry the loads and reduce wear on the deck as the ramp adjusts to changing water levels.

6-6.2.3 **Gangway Ramp Structure.** The gangway ramp construction may be of steel or aluminum, with aluminum being the most common because of weight savings. Standardized factory designed aluminum ramps are now in common use to cover a wide range of load requirements, widths and lengths.

6-6.2.3.1 The ramp should have a minimum of 3 ft (0.9 m) clear width.

6-6.2.3.2 The maximum slope at design low water should be 3 (horizontal) to 1 (vertical). The length of the ramp should be the minimum to achieve the slope requirement at design low water. Generally gangway lengths greater than 80 ft are not used; either steeper slopes (2.5 to 1 absolute maximum) or special stair-ramp structures that convert to stair steps at steeper slopes may be used instead.

6-6.2.3.3 The vertical live load on the ramp should be a minimum of 50 psf (10 kPa) if dock access is restricted; use 100 psf (20 kPa) if dock access is unrestricted or public assembly use is permitted.

6-6.2.3.4 The ramps should have guardrails and handrails on both sides in conformance with occupational safety requirements, and an aggressively non-slip walking surface when dry or wet. Raised treads placed transversely are sometimes used for this purpose, but are a potential tripping hazard and are not the preferred solution.

6-6.2.3.5 Generally ramps also support utility feeders for the dock systems, and the added dead load of the utility lines must be considered.

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CHAPTER 7

HOTEL SERVICES (UTILITIES)

7-1 POTABLE WATER

Potable water service is typically provided to individual berths by means of a ¾” hose bibb mounted next to the berth. The hose bibb is supplied by a line on the main walkway. Water demand is estimated to be about 25 gallons (95 L) per berth per day. When potable water is supplied from the public mains system it should be in accordance with the requirements of the local water authority. Piping should be non-corrodible and ultraviolet-stabilized. Flexible hose shall be used when making dock-to-shore connections to allow movements. Rigid lines may be used on piers and docks with the consideration of the expansion and contraction of the material, special consideration of line flexibility should be taken on floating dock systems.

7-2 SEWAGE AND OILY WASTEWATER

7-2.1 **Holding Tanks.** Pumpout facilities should be provided for the emptying of sewage holding tanks to meet the requirements of the local wastewater authority for proper disposal of sewage. Typical small craft sewage pumpout facilities consist of a central pump station with a flex hose that can vacuum out the vessel’s holding tank contents by means of a flex hose connection between the pumpout hydrant on the dock and the holding tank fitting on the vessel. Pumpout hydrants may be located at intervals throughout the marina so boats can be serviced at their berths, or located on a “public” dock for vessels to pull-up for service. Pumpout facilities are typically rated about 40 gals/min (150 L/min). The pumpout facility should include a water hose bibb to permit flushing of the holding tank; the hose bibb should be marked “non-potable water”. If the pumpout station is located near a fueling station, allow space sufficient between the two facilities so that vessels may utilize either facility without interfering with the operation of the other.

7-2.2 **Pump Station.** The pumpout station is connected to a landside sewer system via force main with a sewage pump.

The sewage pump is typically rated at about 40 gals/min (3.79 liter/min) and is a peristaltic or diaphragm type of pump, to reduce clogging from solids being pumped.

7-2.3 **Bilges.** Bilge water if contaminated with oil should be collected and disposed to the oily Waste system. Some marinas now offer bilge water pumpout facilities separate from the sewage pumpout to receive and treat oily wastes.

7-3 ELECTRICAL

Electrical service is provided to individual berths for vessel usage by means of weatherproof receptacles, mounted \1\ in a pedestal /1/ (as with potable water) or with lighting in pedestals. Electrical service is commonly provided at 120/240 vac single phase or 208 vac 3 phase, at currents of 20-100 amps, typically. *ASCE Manual of Practice 50* provides a detailed discussion of small craft berthing facility electrical systems.

7-4 COMMUNICATION

Communication systems include an intercommunication system, such as a public address or paging system with speakers located within easy hearing distance of every berth. Telephone service, though not commonly provided at Naval facilities, may be provided at each slip if desired, often located with lighting and electrical service in one pedestal. Fiber optic and high speed internet service can be included as well. Typically, the service provided installs the required equipment in raceways and cabinets provided for that purpose. *ASCE Manual of Practice 50* provides a detailed discussion of small craft berthing facility telephone service.

7-5 FUEL

Marine fueling stations are often provided in small craft berthing facilities and shall comply with the requirements of NFPA 30A, “Code for Motor Fuel Dispensing Facilities and Repair Garages", unless it is anticipated that some berthing facilities will not be constructed on government property. If berthing facilities will be constructed on private property, then comply with the requirements of the authority having jurisdiction. Determine the fueling requirements (types of fueling, fill rate and quantity) for the classes of vessels to be berthed. Fueling systems should be separated from the berths and landside facilities by required fire separation distances in accordance with UFC 3-600-01. The fueling station is typically located near the harbor entrance in an area that is protected from waves and is often near the sewage pumpout station. The adjacent land area must be suitable for fuel storage tanks and accessible for fuel delivery vehicles and fire fighting equipment. Provide spill containment equipment as required by the local environmental authority.

7-6 LIGHTING

Waterfront areas consist of a defined perimeter (landside and waterside), restricted area, entry control facilities at the entrance into the waterfront area, access control points located at each pier, and pedestrian access control points along the perimeter. In waterfront areas, utilize high mast lighting to reduce the number of poles minimizing obstructions to waterfront operations and maintaining clear paths for equipment and vehicles. Provide full cutoff or fully shielded fixtures mounted in the horizontal plane to limit direct and reflected glare. Lamps should be metal halide (MH) to improve color rendering and nighttime visibility. Refer to UFC 4-152-01 for Pier and Wharf operational lighting requirements and UFC 3-530-01 for lighting design. Note, in some regions, white light sources may interfere with the marine environment. Coordinate marine issues with the local environmental authority.

\1\ For recreational marinas pedestals are provided with lights integral to the units at each slip. If additional lighting is required, low profile bollards or lighting designed more to a pedestrian scale, no taller than 12 ft (4 m) with down lighting is recommended. /1/

7-7 FIRE FIGHTING

Fire protection should be provided through appropriate design and placement of firefighting equipment on the piers and docks in accordance with NFPA 303, "*Fire Protection Standard for Marinas and Boatyards"* and UFC 3-600-01. If any conflict occurs between this UFC, the NFPA 303 and UFC 3-600-01, the requirements of UFC 3-600-01 take precedence.

All firefighting equipment shall comply with the requirements of NFPA 303 and UFC 3-600-01. Firefighting equipment includes, but is not be limited to:

- Portable chemical extinguishers placed at 200 ft (60 m) intervals along each main walkway housed in cabinets painted red. \1\ For recreational marinas, place at 75 ft (23 m). /1/
- Fire-alarm boxes placed at convenient locations on or near piers.
- Fire hydrants or stand pipes located along the shoreline near where the dock/berthing slip meets the shoreline. \1\ For recreational marinas, provide a Class I dry stand pipe system and all related items on the pier. /1/

Firefighting equipment should be maintained and inspected in accordance with \1\ UFC 3-601-02 /1/.

7-8 LOCKER BOXES

Locker boxes provide a place for gear storage on the pier or dock, convenient to the berth. They are typically made of sheet metal, or fiberglass. Locker boxes are typically located in the knee brace of floating dock systems or other similar out-of-the-traveled-way place.

\1\

7-9 ALL-PURPOSE PEDESTAL

All-purpose pedestals may be provided for recreational marine use. The unit housing shall have a white heavy resin housing with a two-part polyurethane coating which is UV resistant. The unit shall have the following features:

- Lockable weatherproof doors
- Bus Bar Rating
- Photocell controlled 13 watt lighting with amber lens
- Dual or single hose bibs and stainless steel handles
- Electrical

- Slips up to 28 feet long – one 20 Amp, 125 VAC outlet and one 30 Amp, 125 VAC twist-lock outlet
- Slips greater than 28 feet long – one 20 Amp, 125 VAC outlet, one 30 Amp, 125 VAC twist-lock outlet, and one 50 Amp, 250 VAC twist-lock outlet

/1/

CHAPTER 8

DRY STORAGE FACILITIES

8-1 DESCRIPTION

Dry storage of small craft is the practice of removing the craft from the water until it is placed in service. Dry storage of boats is performed using two common methods: trailer storage in a yard (yard storage) and rack storage (drystack).

8-2 YARD STORAGE

The most common method of dry storage is storage on trailers within a yard area. In this method, boats are kept on trailers that allow them to be transported on the road (Figure 8-1 shows typical yard storage).

Figure 8-1, Yard Dry Storage

Once the boat is loaded onto the trailer, the trailer is kept in a designated spot within the yard—which is usually paved and enclosed with a locked security fence. The boat gains access to the water either by a ramp, or crane. For the ramp, the boat and trailer are towed, by a vehicle, down the ramp into the water until the trailer is submerged and the boat floats freely, whereupon, the trailer is usually returned to the dry storage yard until the boat is to be retrieved from the water, when the process is reversed. Utilizing a crane, the boat and trailer are towed to the crane location, which is usually close by on a pier or bulkhead adjacent to the water. (Figure 8-2 shows a typical crane). The boat is fitted with a wire rope sling that attaches to fittings on the boat and then to a single pick up point that the crane hook lifts the boat from the trailer. Once the boat is lifted free of the trailer, the crane swivels about a vertical axis to place the boat out above the water, and then it lowers the boat into the water. Again, the trailer is returned to the dry storage yard until the boat returns and the process is reversed.

Figure 8-2, Small Craft Crane Access (Jib-boom)

8-2.1 **Characteristics.** The general characteristics of yard dry storage are summarized as follows:

- Vessel stored on trailer
- Launched from ramp or crane
- Vessels < 35 ft (10.67 m) in length
- Vessel density: 50-80 vessels/acre

8-2.2 **Advantages.** The primary advantages of yard storage are:

- Less costly
- Low height
- Can be performed by boat operator
- Provides destructive weather (hurricanes, deep freeze) haven

8-2.3 **Disadvantages.** The disadvantages of yard storage are:

- Requires greater land area
- Requires time to launch/retrieve vessel

8-3 DRY STACK STORAGE

Figure 8-3, Drystack (rack) Storage

8-3.1 **Characteristics.** The general characteristics of dry stack (rack) storage are summarized as follows:

Vessel Weight:	< 6 tons
Vessel Length	< 35 ft
Rack levels	4-5 Max.
Vessel Density	392 vessels/acre

8-3.2 **Advantages.** The primary advantages of rack storage are:

- Reduced land area required to store a given number of small craft
- Craft are kept dry when not in use, reducing deterioration
- Increased security

8-3.3 **Disadvantages.** The disadvantages of stack storage are:

- Requires trained operator to retrieve and launch the vessel
- Requires landside facility
- Vessel is not immediately ready in the water
- High structure can be objectionable in view corridors
- Heavy structure loads require suitable foundation conditions

8-3.4 **Covered Storage.** The storage rack can be located inside a building, usually a metal building, to provide protection from the weather. The building will usually require sprinklers for fire protection in accordance with NFPA 303. Because these storage facilities are often higher than 35 ft (10.67m), they can be objectionable from a visual perspective along the waterfront.

8-4 APPLICABILITY

Dry storage provides increased security and increased service life of the vessels, as well as reduced maintenance, due to storage out of the water and out of the weather, if covered storage is used. However, yard storage is most probably the preferred method for military facilities.

As discussed above, the primary reason for constructing a stack storage system is to fit as many small craft as possible into a small area—typically done in areas of high real estate values in dense urban settings. This would rarely be the case at most military facilities due to the small number of small craft that need to be accommodated. Further, the advance notice required to launch vessels, may not lend itself to the operational needs of the small craft. For these reason, dry stack storage is generally suited for recreational vessels in urban areas or areas of inclement weather. Several publications provide additional guidance for dry stack storage *ASCE Manual of Practice 50*.

CHAPTER 9

BOAT REPAIR/MAINTENANCE

9-1 GENERAL

Repair and maintenance are required by all small craft during their service life. The location of the facility for repair and maintenance is often determined by the mission of the craft, and the availability of a standby craft to replace the ready boat while it undergoes repair/maintenance. The repair/maintenance facility can be located either at the same facility (onsite), or at a ship yard or another facility (offsite).

9-1.1 **Onsite.** Typically, at least minor maintenance and repair to deck equipment will be performed onsite, usually at the craft moorings, including replacement of broken fittings and tasks that can be performed with hand tools. More involved work can be performed onsite if the facility has a haul out and shoreside repair facilities to perform the work.

9-1.2 **Offsite.** Where onsite facilities do not exist, or do not have the capability to perform the required work, the maintenance and repair work will have to be performed offsite. Offsite facilities can either be boat yards that specialize in small craft repair including hull repair and coatings, or may be facilities that perform general work such as a machine shop or engine repair shop. In regions with large port and marine activities, boat/ship yards are generally available to work on small craft.

9-2 MAINTENANCE SCOPE

9-2.1 **Hull.** Repair and maintenance of the hull requires that either the vessel be hauled out of the water or the work be performed by a diver.

9-2.2 **Deck.** Most minor replacement of deck fittings and equipment (cleats, rails, antenna, etc) can be performed at the slip. For more extensive work, the vessel will usually be removed from the water and placed on land on stands or taken to a dry dock where overhead cranes can lift heavier equipment and where there is access to welding and other power equipment.

9-2.3 **Engine.** Similar to deck work, minor engine work can be performed on the vessel. There is an increased use of outboard engines on small craft under approximately 35 feet (10.67m) in length. This allows quick replacement of the engine if a spare is on hand, for more involved maintenance or repair of the affected engine either on site or at a specialized repair shop.

9-4 MAINTENANCE PROGRAM

All vessels require routine maintenance in order to reduce emergency break downs and required repair. This is particularly true for vessels moored in saltwater where the vessel and its equipment are subject to corrosion when not in use. Maintenance of the vessel is often performed by the boat crew to some extent and greater maintenance tasks are performed by specialized personnel, either on staff at the facility or provided by outside contract services.

9-4.1 **In-House Workforce.** For facilities with larger staff and vessels that perform continuous operations it is preferable to have skilled workers on staff dedicated to performing the maintenance and repair of the small craft equipment (deck, hull and engines). This allows the most control and flexibility to perform the work according to the schedule of the operational needs of the small craft. A scheduled maintenance program should be established in accordance with those established by the manufacturer of the engine, hull and various other equipment (radio, radar, etc.) on the vessel. Having the permanent staff to perform this work will usually increase operating costs which can be compared to costs paid for such work that is contracted out, if such records are available, to see if such staff is cost effective.

9-4.2 **Contract Services.** In larger cities, or where there is a large boating community, there may be skilled maintenance and repair facilities close by that can perform work fairly readily. For scheduled maintenance, skilled personnel often from the manufacturer's staff or trained by the manufacturer can be scheduled in advance to perform the work onsite. For facilities with fewer small craft or multiple standby craft, this may reduce costs or allow a smaller workforce without the requisite skills to perform the maintenance and repair of the vessels.

9-5 FACILITIES

9-5.1 **On Dock.** For minor repair and maintenance, much of the routine maintenance can be performed with the vessel berthed at the dock.

9-5.2 **Covered Mooring.** Where extensive maintenance must be performed on the berthed vessel at the dock by onsite personnel, the cost of a covered mooring may be warranted. In areas of inclement weather (rain, snow, wind) this allows greater time in which the staff can perform this work.

9-5.3 **Haul Out.** If a haul out facility (see Chapter 10) is provided at the facility, the small craft can be transferred to the shore where more extensive maintenance and repair can be performed. Generally, this includes work on the hull or work that requires use of a crane, welding or other powered tools to perform the necessary repairs or maintenance. A straddle type carrier provides the greatest flexibility and speed for retrieving vessels (see Figure 9-1) and is commonly used.

Figure 9-1, Vessel Haul out Facility for Straddle Carrier

9-5.4 **Yard Maintenance.** The vessel can be placed on a trailer or stands in the yard to allow access to the hull for needed repairs. This can be in the outdoors for work that does not require containment. Environmental considerations often require that, depending on the work being performed, that the vessel be fully contained for the work, such as if sand blasting or painting is being performed.

9-5.5 **Enclosed Shop.** An enclosed work shop building provides a facility in which all necessary repairs and maintenance could be performed. Such a building should be furnished with ventilation and filtration to allow painting and sandblasting to be performed, an overhead crane rail for lifting of the engine or similar heavy equipment, and a full supply of power tools including welding capabilities. The building should often be sized to allow a straddle carrier entry to place the vessel on stands or a cradle within the shop. Figure 9-2 shows a typical enclosed shop building.

Figure 9-2, Enclosed Shop Building, with Straddle Carrier

CHAPTER 10

BOAT LAUNCH HOISTS AND LIFTS

10 -1 GENERAL

The ability to remove small craft from the water is essential for any type of major repair or maintenance at a small craft facility. Further, the ability to launch small craft greatly increases the capacity of the facility and the flexibility to operate a greater number of small craft than accommodated at limited spaces on the floating docks or fixed piers. Because of these reasons, most dedicated small craft harbors have some provision to launch small craft. Various systems have been developed over time and the number of such types of systems has varied as technologies and vessel types change.

10-2 FIXED SYSTEMS

Fixed systems typically utilize a lift that is in a set position to retrieve the vessel from the water. Once the vessel is removed from the water, it is transferred to a trailer to be transported and kept at the storage location, or repair facility. Alternatively, if the vessel is the only vessel at the facility, or it is a dedicated system, the vessel will remain on the lift until it is to be placed in service again.

10-2.1 **Jib Boom.** This is the most common type of retrieval system and is comprised of a crane mast that rotates about a vertical axis. The hoist is mounted on a trolley on a fixed arm (jib boom) that is swung over the boat in the water. The boat is fit with a wire rope sling that attaches to fittings on the boat. A crane hook then attaches to a pickup point on the wire rope sling to lift the boat out of the water. Once the boat is lifted above the top of the seawall, the crane rotates about its axis to place the boat onto a waiting trailer. Once the boat is loaded onto the trailer, the trailer is kept in a dry storage yard until the boat is to be placed in service, when the process is reversed.

10-2.2 **Marine Railway.** A marine railway is a set of fixed rails that ramp down from the shore into the water. The rails are typically supported on piles within the water. A cradle with wheels is hauled by a cable and winch system mounted on the railway and runs into the water, sufficiently deep, such that the vessel can float over the cradle. The vessel is lashed to the risers on the cradle and the cradle is winched up the railway to haul the vessel out of the water. Once on shore, the wheeled cradle can be transferred to a rail siding; multiple work bays can be supported by a single inclined railway. This system is best suited to larger vessels and it requires a significant amount of land area. As such, it is not considered practical for most small craft facilities.

10-2.3 **Elevator Lift.** This method consists of a platform that is raised and lowered into the water by a number of synchronized winches mounted on dolphins along the sides of the platform. A cradle with wheels – similar to the marine railway described previously – is located on the platform when it is lowered into the water sufficiently deep such that the vessel can float over the cradle and platform to then be raised out of the water. The platform is fitted with rails that continue to the shore upon which the cradle and vessel are transported once it is out of the water. This system has been developed by the Syncrolift Corp and is best suited to larger vessels.

For small craft, a similar system is used that utilizes a fork lift mounted to a fixed vertical mast that operates similar to a mobile forklift with “negative” lift and is becoming more common. The forklift rotates about the mast to place the forks in the water, or over land where a mobile forklift can access the vessel. This system is more effective for stacked storage in that a conventional forklift can also store and retrieve the vessels.

10-3 MOVEABLE SYSTEMS

10-3.1 **Straddle Carrier.** This is probably the most versatile and cost effective system for small craft retrieval. The system is comprised of a self propelled carrier frame that drives over the water on a set of two fixed piers. The carrier frame supports a set of slings that is lowered into the water between the piers to a depth sufficient to allow the vessel to position itself over the slings. Then the slings are lifted out of the water by lifting mechanisms within the carrier frame. Once out of the water, the carrier drives off the piers and can maneuver to any location with its wheels that can be steered.

10-3.2 **Crane Lift.** This type of haulout can utilized a dedicated fixed crane or a rubber tire boom crane, or similar mobile crane. The crane supports a lifting frame fit with slings that is lowered into the water similar to the straddle carrier described previously. Once the vessel is lifted from the water, the crane swivels to place the boat on an awaiting trailer, or for a limited number of vessels, could place them onto stands within the arc swing of the crane.

10-3.3 **Forklift.** This method utilizes a forklift with “negative” lift. The forklift is positioned at a vertical bulkhead (marginal wharf) where it lowers the forks below the keel depth of the awaiting vessel. The vessel is placed over the forks and the forklift lifts the vessel out of the water. This method is rapid and has the advantage of being able to move the vessel to a storage location on land and to raise the vessel onto a storage rack.

10-3.4 **Trailer.** Various trailer methods are used to retrieve and launch vessels into the water. Trailers are utilized with jib booms, crane lifts or launch ramps, discussed in the following section. This is the most common method of moving vessels.

10-3.5 **Floating Lift.** Floating boat lifts use buoyancy chambers to raise small craft out of the water much like a floating dry dock. The typical floating lift is permanently installed in a single berth and is configured for the vessel that uses that berth. The boat is stored out of (but over) the water with minimal additional load on the dock system. This type of system is used increasingly by the Navy, with capacities up to 13,000 lb (5.897 metric tons).

10-3.6 **Drive On Dock.** The drive on dock is a shallow freeboard platform that floats a few inches above the water surface. Vessels approach the platform from the water and “drive up” onto the platform at low speed. The platform is constructed of multiple plastic blocks that are pinned together to form a flexible platform that yields to the hull when it drives up, sufficient to avoid damage to the hull. The “Jetdock” System (Moose Boats, Inc.) is a drive on dock system currently in use.

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CHAPTER 11

LAUNCHING RAMPS

11-1 GENERAL REQUIREMENTS – WATER AREA

11-1.1 **Fairway.** The Basin or other waterway into which a launching ramp extends should meet the following requirements:

11-1.1.1 Minimum water depth 4 ft (1.2 m) at design low water.

11-1.1.2 Minimum bottom width greater than the combined width of the launch ramp and boarding floats.

11-1.1.3 Minimum length of 50 ft beyond the toe of the ramp, and absolutely clear of obstructions and/or navigation hazards.

11-1.1.4 Mark with navigational aids in accordance with the Waterway Marker System rules per USCG (COMDTINST 16500 series) which identify the proper color and locations of channel markers.

11-1.2 **Launch Ramp.** The launch ramp should meet the following requirements:

11-1.2.1 **Ramp Slope.** Slope between 12% and 15%. Few trailered boats can be launched with slopes flatter than 12% without submerging the wheel hubs of the tow vehicle, which is to be avoided. The slope should be uniform over the entire length of the ramp.

11-1.2.2 **Ramp Toe.** The ramp should extend down to an elevation a minimum of 3 ft (0.9 m) below design low water. The toe of the ramp should be provided with a wheel stop to prevent trailers from backing off the end of the ramp.

11-1.2.3 **Ramp Head.** The ramp should extend up to an elevation 1 ft (0.3 m) minimum above design high water. In addition, the head of the ramp should be provided with a 20 ft (6.1 m) long vertical curve to provide a smooth transition between the steeper ramp slope and the flat slope of the apron/turnaround area.

11-1.2.4 **Ramp Finish.** Ramp surface should be constructed of reinforced concrete, either cast-in-place or pre-cast panels, or a combination of both, and provided with a V-groove surface finish to maximize traction. Typical launch ramp finish details are described in *Layout and Design Guidelines for Marina Berthing Facilities (DBW)*.

11-1.2.5 **Ramp Width.** Standard launching ramp lane width is 15 ft (4.5 m) when 2 or more lanes are provided. When a single lane is provided, the width should be 20 ft. (6.1 m). The number of lanes will be determined by the demand and the site specific conditions. One launching lane should handle up to 25 launch/retrievals (round trips) per day. The total width of the ramp structure is obtained by adding the width of the required number of lanes and boarding floats.

11-1.3 **Boarding Floats and Platforms.** The launch ramp should be fitted with a boarding float (or platform) along the side of the lane (minimum one per lane) meeting the following requirements:

11-1.3.1 **Float Width.** Minimum clear float width is 6 ft. (1.8 m). In cases where guide piles are located inside the boarding float frame on one side, provide a minimum clear distance of 4 ft to the opposite side of the float. Where the guide piles are located in the center of the float, provide a minimum clear distance of 3 ft. (0.9 m) to each side of the float.

11-1.3.2 **Float Length.** Provide a minimum of 50 ft. (15.2 m) in the water (measured from the water line at design low water). Articulated boarding floats are often used to accommodate changes in water level, however, the portion of the boarding float that remains permanently in the water should not be articulated, but be continuous, to enhance stability.

11-1.3.3 **Float Live Load.** Where access is restricted, floats should be designed for a minimum uniform live load of 20 psf 4.1 (kPa); where access is not restricted, the minimum uniform live load should be 40 psf 8.2 (kPa). The floats should also be designed for a live point load of 650 lbs. applied at any point on the float deck not less than 12 in. (0.3 m) from the edge of the float.

11-1.3.4 **Float Freeboard.** Freeboard under dead load only should be between 14 in. (35 cm) and 20 in. (51 cm); the float deck should be level within the following tolerances:

Difference in Freeboard Transverse Direction – 1 in. (2.5 cm) maximum

11-1.3.5 **Other Requirements.** See the discussion for floating docks in Section 6 for other requirements pertaining to floating dock design and construction.

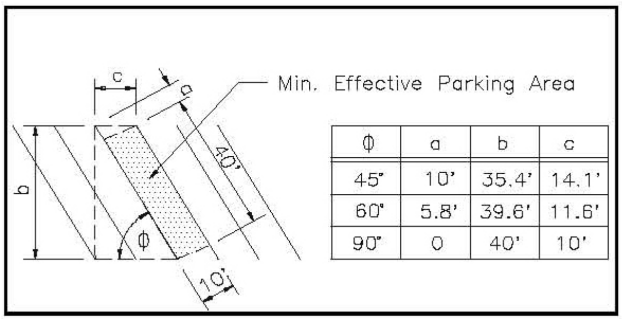
11-1.3.6 **Non-Floating Boarding Platforms.** Non floating boarding platforms generally consist of movable wedge shaped scaffolds that rest on the launching ramp and remain in-place by self weight. Typically constructed of steel, with retractable wheels and fitted with hitches, they may be towed to position on the ramp in response to changing water levels. These are used at sites where water levels do not change rapidly, or where winter conditions dictate removal of the boarding platform to reduce risk of ice damage. Other types of boarding systems are described in the *Layout, Design and Construction Handbook for Small Craft Berthing Facilities*.

11-1.4 **Shoreside Support Facilities.**

11-1.4.1 **Trailer Maneuvering.** Provide sufficient area at the head of the ramp for trailer maneuvering; typically an area 50 ft x 50 ft (15.2 m x 15.2 m) will be sufficient.

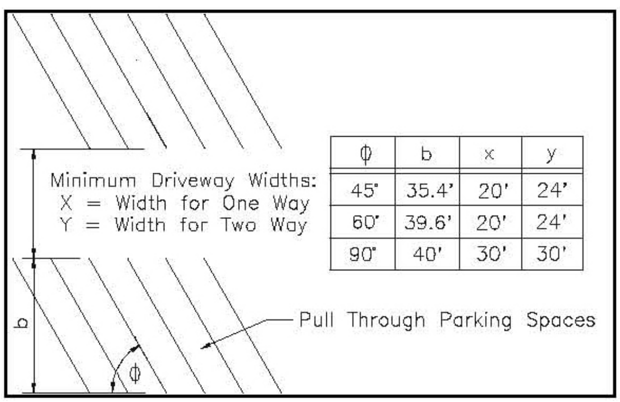
11-1.4.2 **Trailer Parking.** Provide sufficient parking to meet the expected demand for car-trailer spaces; pull through parking spaces should be utilized where practical. See Figure 11-1 for layout of car-trailer parking space and maximum driveway dimensions.

Figure 11-1 Car/Trailer Parking Layout



ϕ	a	b	c
45°	10'	35.4'	14.1'
60°	5.8'	39.6'	11.6'
90°	0	40'	10'

A.



ϕ	b	x	y
45°	35.4'	20'	24'
60°	39.6'	20'	24'
90°	40'	30'	30'

B.

11-1.4.3 **Boat Washdown.** Provide a fresh water boat/engine washdown area for launching facilities in salt water areas. Capture runoff from the washdown area in a separator and direct to wastewater collection system. Locate washdown area away from the head of the ramp to minimize interference with launching and retrieval operations.

11-1.4.4 **Power Lines.** Overhead power lines should not be permitted to cross the launch ramp or its maneuvering or parking area unless minimum overhead clearances prescribed by the authority having jurisdiction are met.

11-1.4.5 **Lighting.** High level lighting for the launching and retrieval area may be required to support night time operations. Avoid glare that can interfere with navigation.

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/1/

UFC 4-159-03
12 March 2020

UNIFIED FACILITIES CRITERIA (UFC)

MOORINGS

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UNIFIED FACILITIES CRITERIA (UFC)

MOORINGS

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U.S. ARMY CORPS OF ENGINEERS

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

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

This UFC supersedes UFC 4-159-03 with Change 2, dated 23 June 2016.

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 is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFCA), 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 HNFCA, and the BIA, as applicable.

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

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: UFC 4-159-03, *Moorings*

Superseding: UFC 4-159-03, *Design: Moorings*, 3 October 2005, with Change 2, dated 23 June 2016

Description: Provide guidance for the analysis and design mooring and berthing systems of ships and watercraft at waterfront facilities.

Reasons for Document:

- To supplement existing Government and commercial standards for design and construction of mooring facilities. Revisions made to update references and verify document refers to most current standards and references.

Impact:

- There are no cost impacts.

Unification Issues:

- There are no unification issues.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This UFC provides design policy and procedures for design of moorings for U.S. Department of Defense (DoD) and other federal agency vessels. The purpose is to ensure quality, consistency, and safety of DoD vessels, mooring hardware, and mooring facilities throughout the world.

1-2 APPLICABILITY.

This UFC applies to the planning, design, construction, sustainment, restoration, and modernization of DoD owned mooring facilities. It is applicable to all methods of project delivery and levels of construction as defined below.

1-3 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 UFC and government criteria referenced herein.

1-4 CYBERSECURITY.

All control systems (including systems separate from an energy management control system) must be planned, designed, acquired, executed and maintained in accordance with UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems*, and as required by individual Service Implementation Policy.

1-5 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and definition of terms.

1-6 REFERENCES.

APPENDIX C 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.

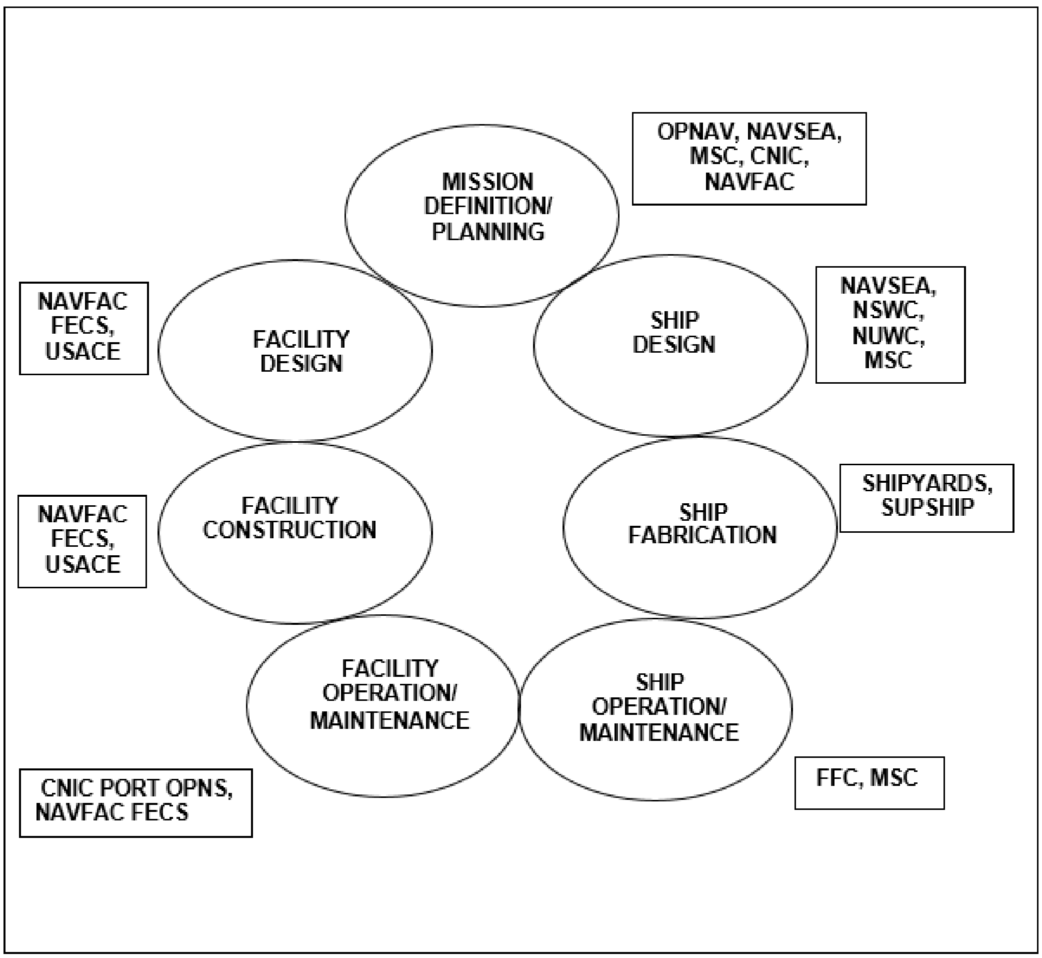
1-7 ORGANIZATIONAL ROLES AND RESPONSIBILITIES.

Over the design life of a mooring facility, many organizations are involved with the various aspects of a facility. Personnel involved range from policy makers, who set the initial mission requirements for vessels and facilities, to deck personnel securing lines. Figure 1-1 illustrates the DoD organizations that must understand the various aspects of moorings. In addition, all these groups must maintain open communications to ensure safe and effective moorings.

Safe use of moorings is of particular importance for the end users (the ship's personnel and facility operators). They must understand the safe limits of a mooring to properly respond to significant events, such as a sudden storm, and to be able to meet mission requirements.

It is equally important for all organizations and personnel shown in Figure 1-1 to understand moorings. For example, if the customer setting the overall mission requirement states, "We need a ship class and associated facilities to meet mission X, and specification Y will be used to obtain these assets" and there is a mismatch between X and Y, the ship and facility operators can be faced with a lifetime of problems, mishaps, and/or serious accidents.

Figure 1-1 DoD Organizations Involved with Ship Moorings



CHAPTER 2 MOORING SYSTEMS

2-1 INTRODUCTION.

The DoD uses several types of mooring systems to moor ships. These systems can be summarized into two broad categories of moorings:

- Fixed Moorings - Fixed moorings are defined as systems that include tension and compression members. Typical fixed mooring systems include moorings at piers and wharves.
- Fleet Moorings - Fleet moorings are defined as systems that include primarily tension members. Mooring loads are transferred into the earth via anchors. Examples of fleet moorings include fleet mooring buoys and ship's anchor systems.

The more common types of moorings are discussed in this chapter.

2-1.1 Purpose of Mooring.

The purpose of a mooring is to safely hold a ship in a certain position to accomplish a specific mission. A key need is to safely hold the vessel to protect the ship, life, the public interest, and to preserve the capabilities of the vessel and surrounding facilities. Ship moorings are provided for:

- Loading/Unloading - Loading and unloading items such as stores, cargo, fuel, personnel, ammunition, etc.
- Ship Storage - Storing the ship in a mooring reduces fuel consumption and personnel costs. Ships in an inactive or reserve status are stored at moorings.
- Maintenance/Repairs - Making a variety of repairs or conducting maintenance on the ship is often performed with a ship moored.
- Mission - Moorings are used to support special mission requirements, such as surveillance, tracking, training, etc.

Most DoD moorings are provided in harbors to reduce exposure to waves, reduce ship motions, and reduce dynamic mooring loads. Mooring in harbors also allows improved access to various services and other forms of transportation.

2-2 TYPES OF MOORING SYSTEMS.

Examples of typical moorings systems are given in this chapter.

2-2.1 Fixed Mooring Systems.

Examples of typical fixed moorings are given in Table 2-1 and illustrated in Figure 2-1 through Figure 2-5.

Table 2-1 Examples of Fixed Moorings

(a) Single Vessel Secured at Multiple Points

Mooring Type	Figure Number	Description
Pier/Wharf	Figure 2-1 Figure 2-2	Multiple tension lines are used to secure a vessel next to a pier/wharf. Compliant fenders, fender piles and/or camels keep the vessel offset from the structure. A T-pier may be used to keep the ship parallel to the current, where the current speed is high.
Spud Mooring	Figure 2-3	Multiple vertical structural steel beams are used to secure the vessel, such as a floating dry dock. This type of mooring is especially effective for construction barges temporarily working in shallow water. Spud moorings can be especially susceptible to dynamic processes, such as harbor seiches and earthquakes.

(b) Multiple Vessel Moorings

Mooring Type	Figure Number	Description
Opposite Sides of a Pier	Figure 2-4	Vessels can be placed adjacent to one another on opposite sides of a pier to provide some blockage of the environmental forces/moments on the downstream vessel.
Multiple Vessels Next to One Another	Figure 2-5	Vessels can be placed adjacent to one another to provide significant blockage of the environmental forces/ moments on the downstream vessel(s).

Figure 2-1 Single Ship, Offset From a Pier with Camels

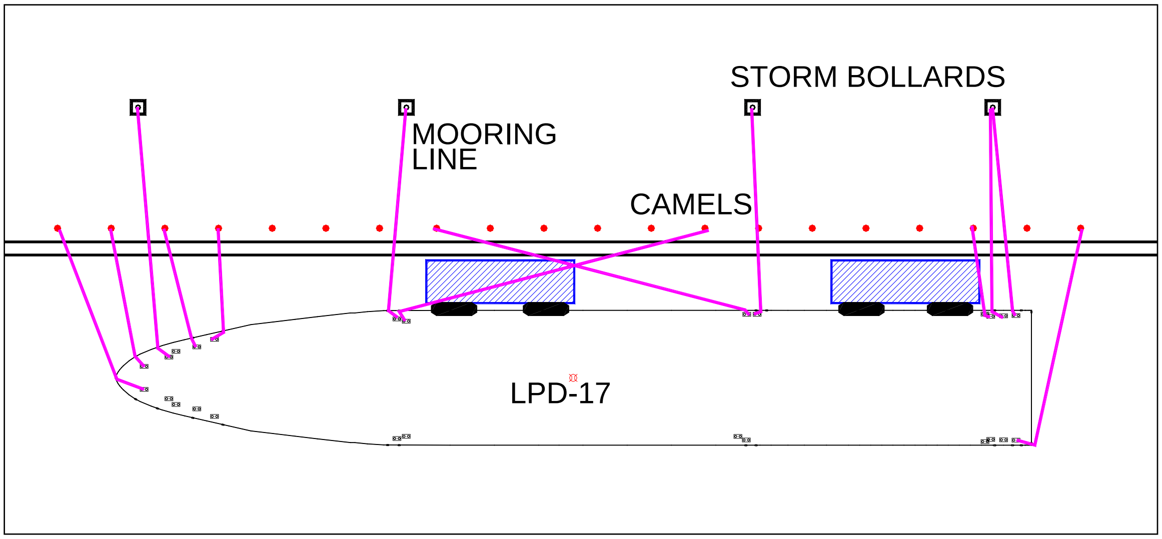


Figure 2-2 Ship at a T-Pier (Plan View)

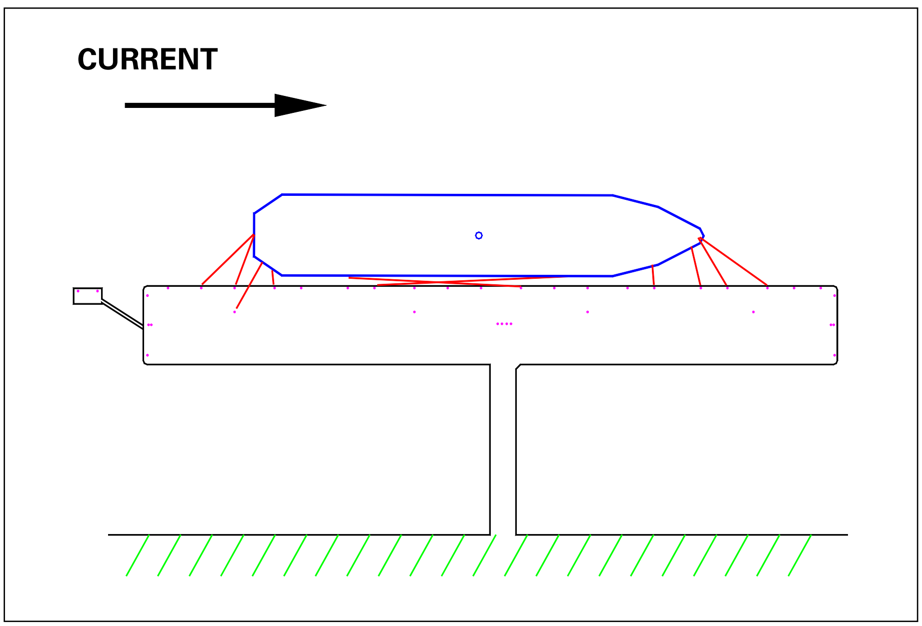


Figure 2-3 Floating Dry Dock Spud Moored

(spuds are secured to a pier, which is not shown, and the floating dry dock rides up and down on the spuds; profile view is shown)

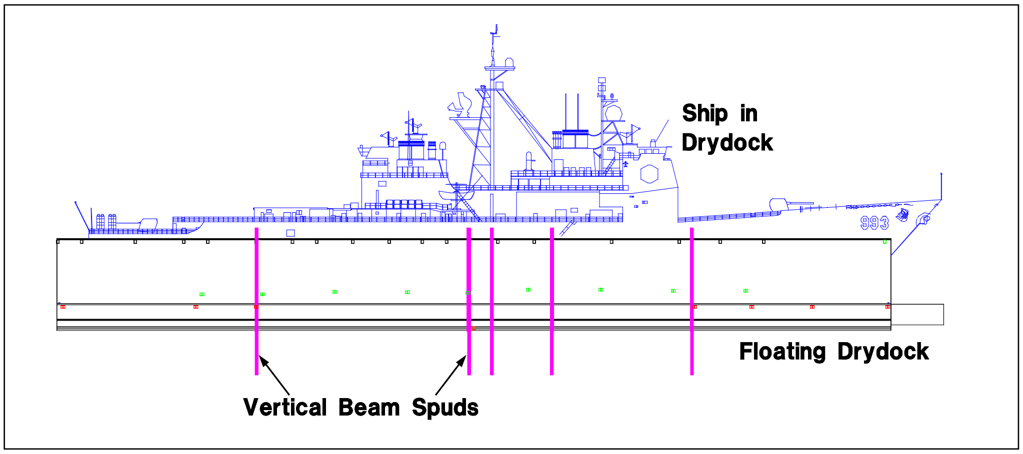


Figure 2-4 Ships on Both Sides of a Pier (plan view)

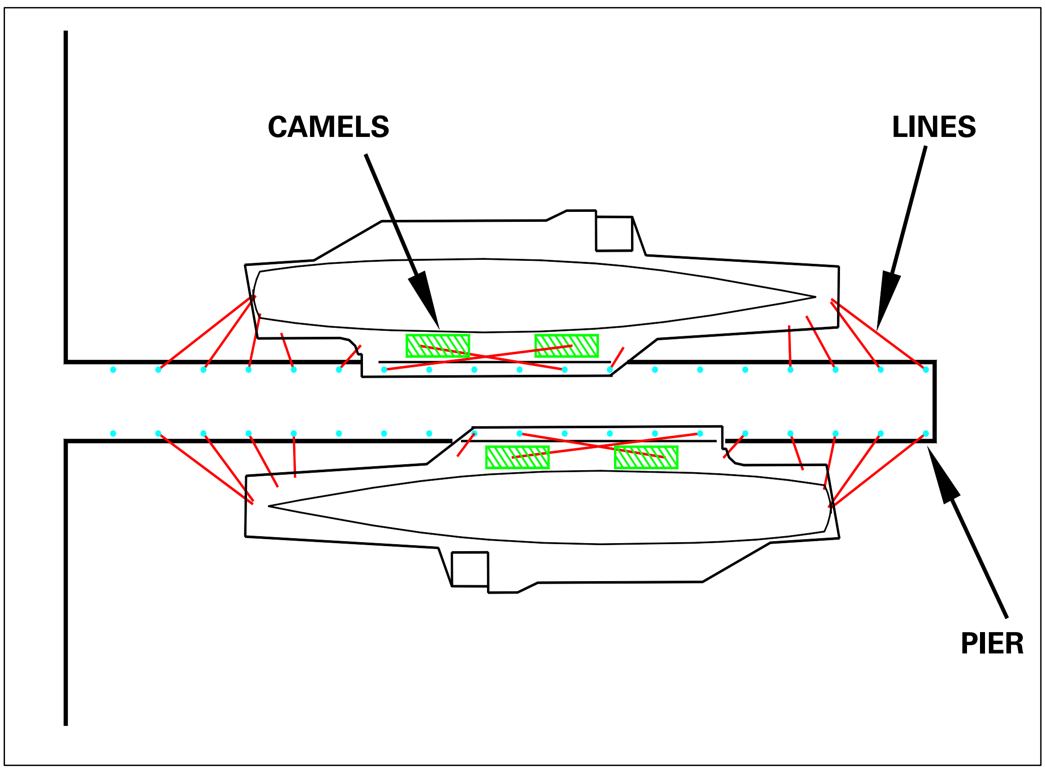
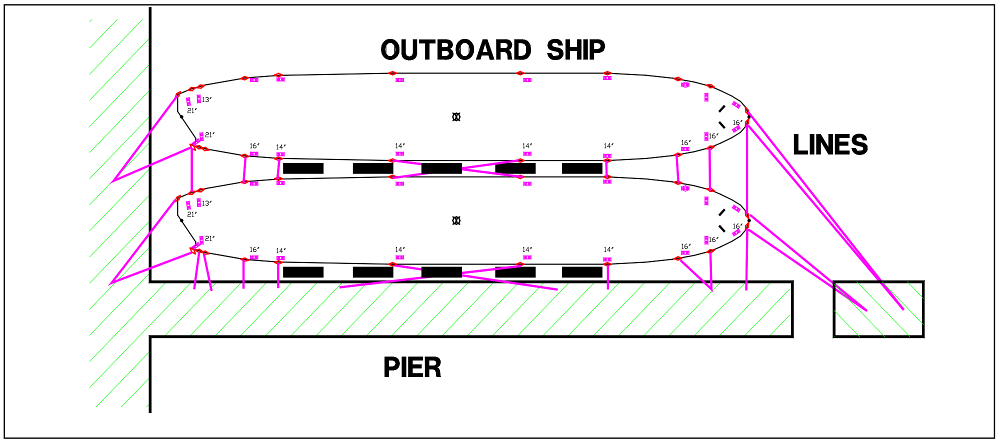


Figure 2-5 Two Ships on One Side of a Pier (plan view)



2-2.2 Fleet Mooring Systems.

Examples of typical fleet moorings are given in Table 2-2 and illustrated in Figure 2-6 through Figure 2-13.

Table 2-2 Examples of Fleet Moorings

(a) Vessel Secured at a Single Point

Mooring Type	Figure Number	Description
At Anchor	Figure 2-6	Typical configuration includes the ship deploying a single drag anchor off the bow. This is usually a temporary mooring used as a last resort in benign conditions. A large amount of harbor room is required for the ship swing watch circle. If the wind changes direction dramatically then the anchor will have to reset. Dynamic fishtailing, even under steady winds and currents, may be a problem. Putting out a second anchor in what is known as a Hammerlock mooring may be required in storm anchoring.
Single Mooring Buoy	Figure 2-7 Figure 2-8	A single point mooring (SPM) buoy is secured to the seafloor typically with 1 to 12 ground legs and either drag or plate anchors. The ship moors to the buoy using an anchor chain or hawser. The vessel weathervanes under the action of forcing, which helps to reduce the mooring load. This type of mooring requires much less room than a ship at anchor because the pivot point is much closer to the vessel. A vessel at a mooring buoy is much less prone to fishtailing than a ship at anchor. Many of the mooring buoys at U.S. Navy facilities around the world are provided under the U.S. Navy's Fleet Mooring Program.

(b) Vessel Secured at Two Points

Mooring Type	Figure Number	Description
Bow-Stern Mooring	Figure 2-9	A vessel is moored with one buoy to the bow and another to the stern. This system has a much smaller watch circle than a vessel at a single mooring buoy. Also, two moorings share the load. However, the mooring tension can be much higher if the winds, currents, or waves have a large broadside component to the ship.

(c) Vessel Secured at Multiple Points

Mooring Type	Figure Number	Description
Med-Mooring	Figure 2-10	The vessel bow is secured to two mooring buoys and the stern is moored to the end of a pier or wharf. This type of mooring is commonly used for tenders or in cases where available harbor space is limited. Commonly used in the Mediterranean Sea. Hence, the term “Med” Mooring.
Spread Mooring	Figure 2-11	Multiple mooring legs are used to secure a vessel. This arrangement of moorings is especially useful for securing permanently or semi-permanently moored vessels, such as floating dry docks and inactive ships. The ship(s) are usually oriented parallel to the current.

(d) Multiple Vessel Moorings

Mooring Type	Figure Number	Description
Nest	Figure 2-12 Figure 2-13	Multiple tension members are used to secure several vessels together. Separators are used to keep the vessels from contacting one another. Nests of vessels are commonly put into spread moorings. Nested vessels may be of similar size (as for inactive ships) or much different size (as a submarine alongside a tender). Advantages of nesting are: a nest takes up relatively little harbor space and forces/moments on a nest may be less than if the ships were moored individually.

Figure 2-6 Ship at Anchor

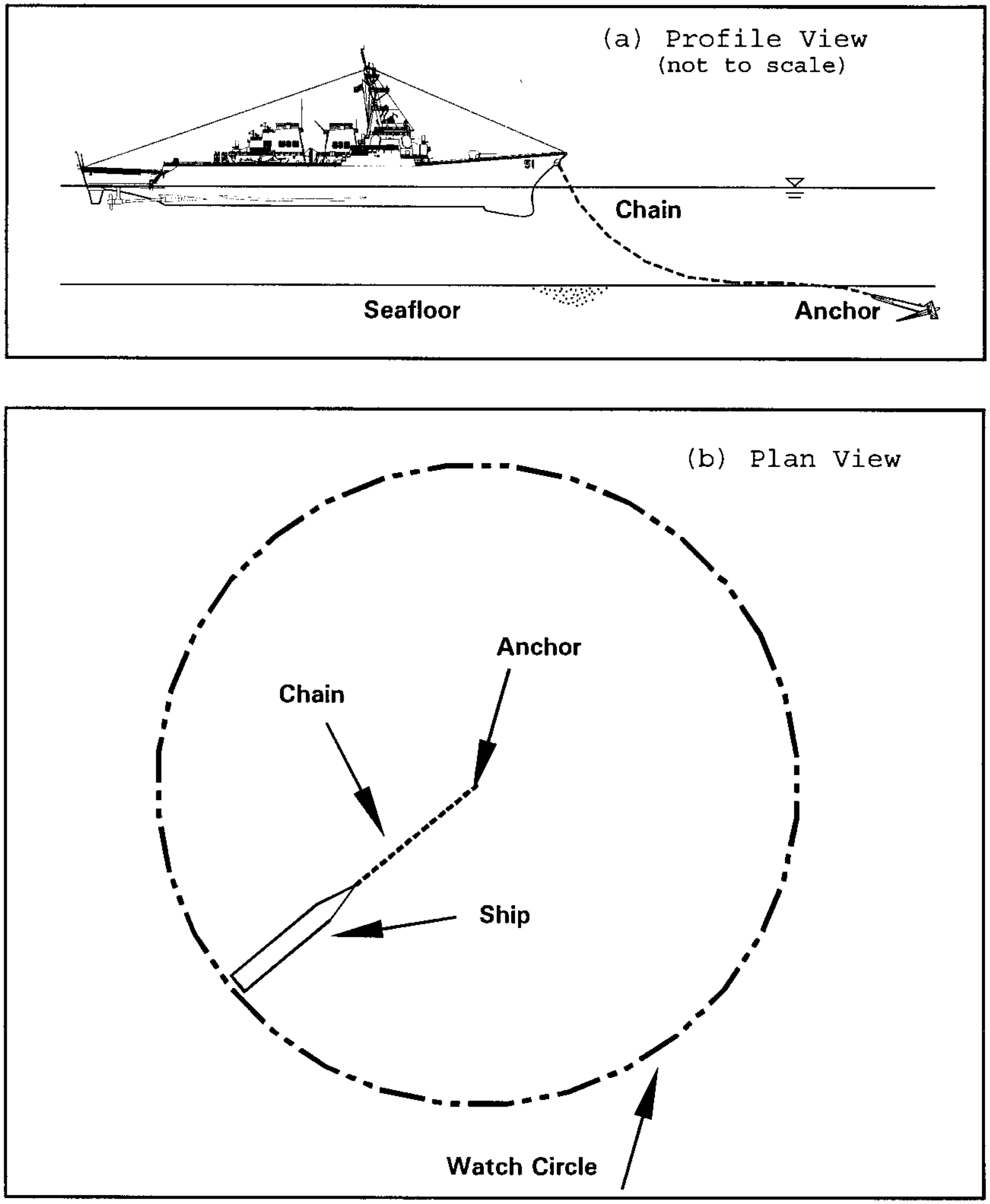


Figure 2-7 Single Point Mooring with Drag Anchors

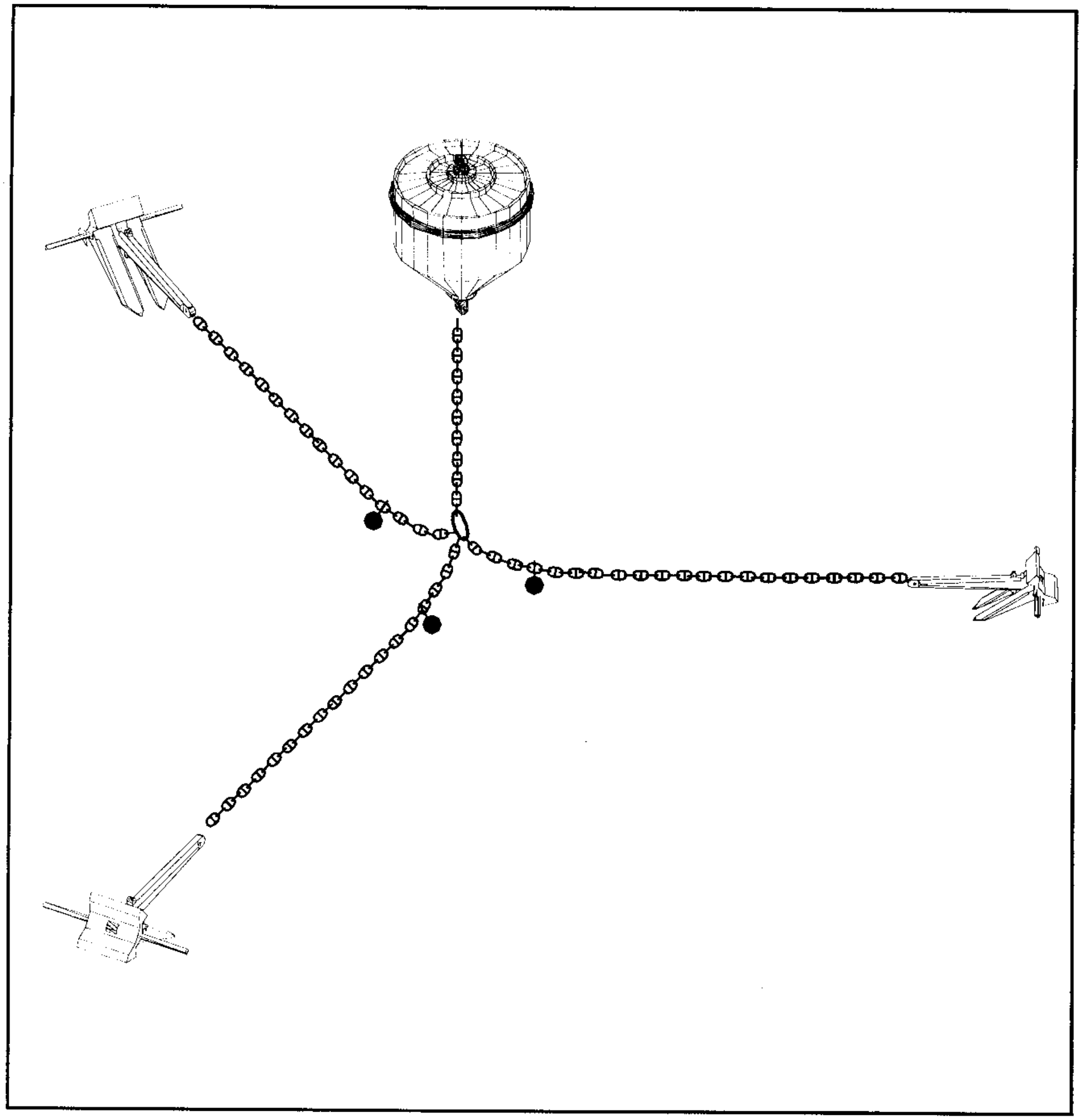


Figure 2-8 Single Point Mooring with a Plate Anchor and a Sinker

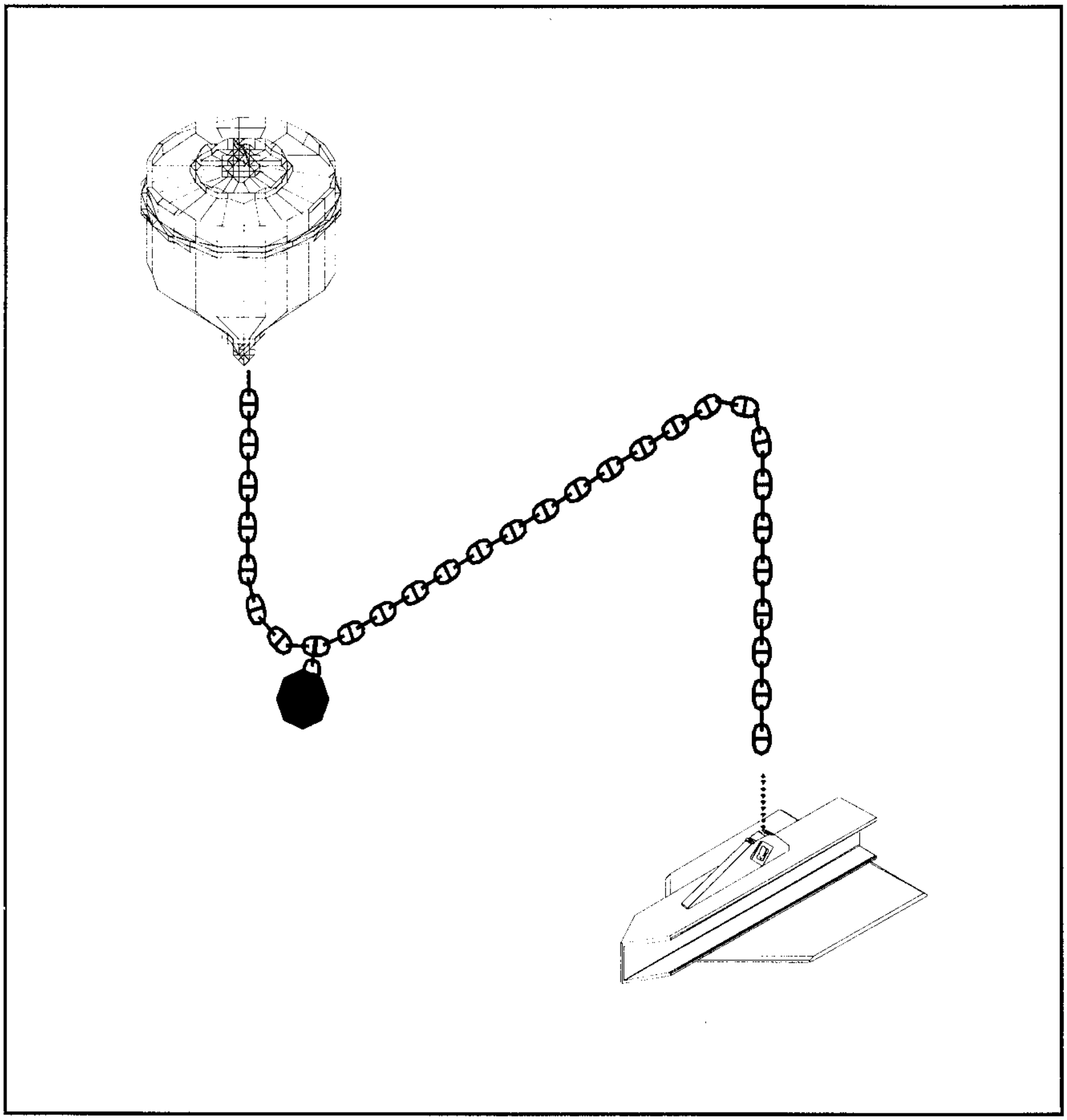


Figure 2-9 Bow-Stern Mooring Shown in Plan View

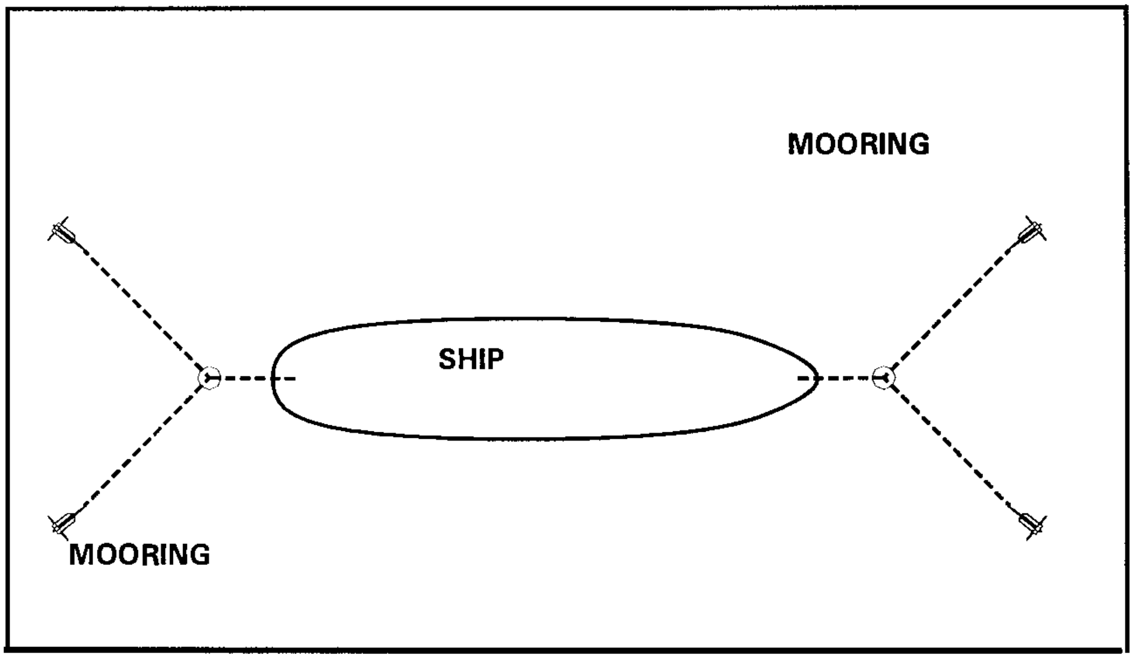


Figure 2-10 Med-Mooring

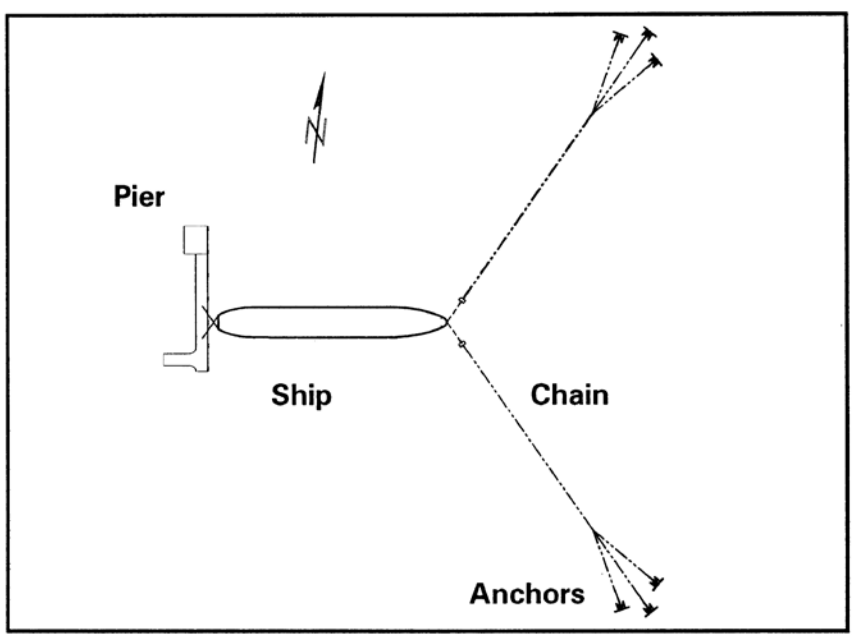


Figure 2-11 Spread Mooring

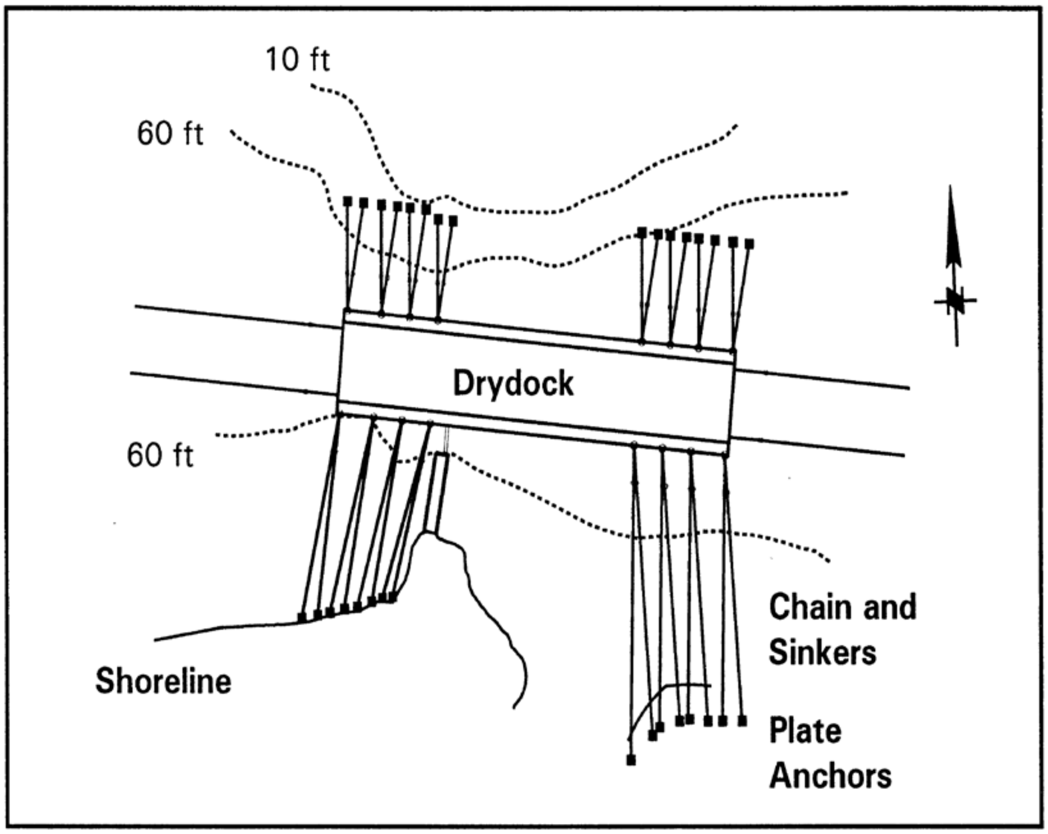


Figure 2-12 Two Inactive Ships Moored at a Wharf

(separators between ships not shown)

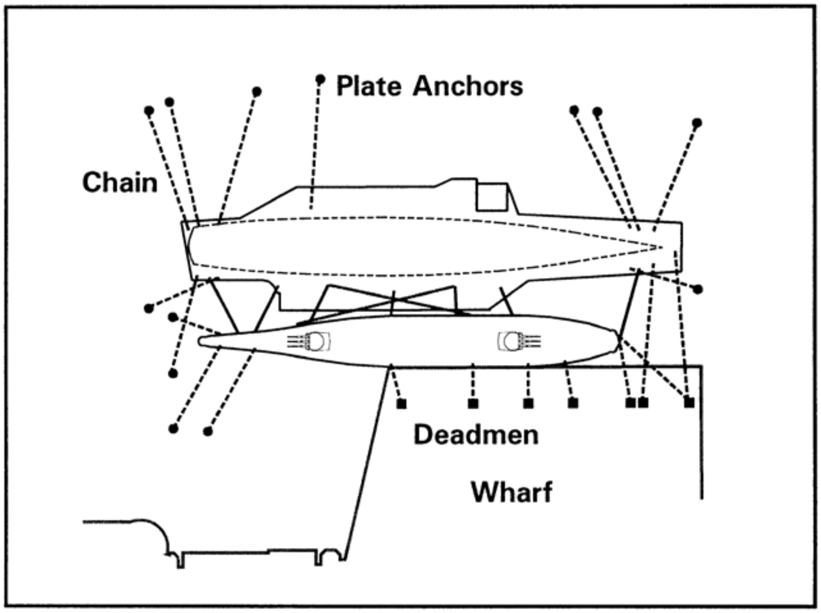
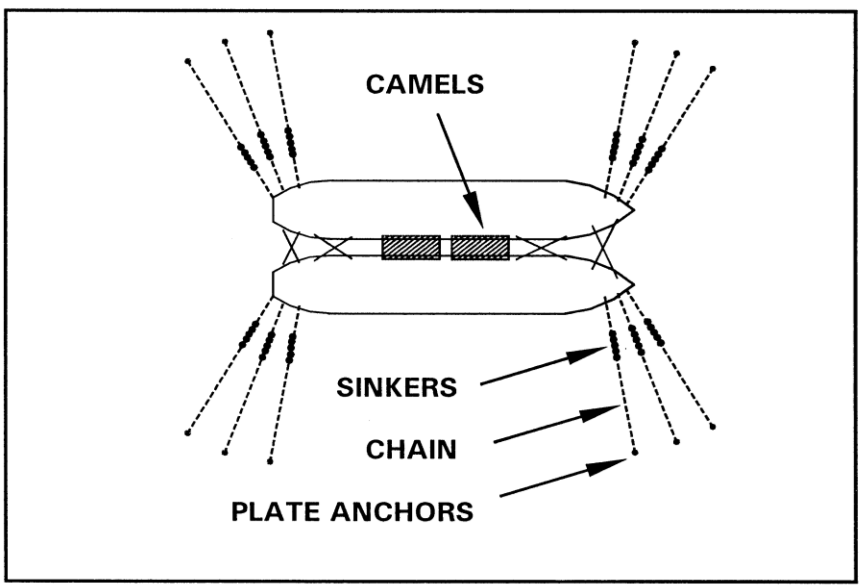


Figure 2-13 Spread Mooring



CHAPTER 3 BASIC DESIGN PROCEDURE

3-1 DESIGN APPROACH.

Use specified parameters and engineering principles throughout the design process. Types of parameters associated with mooring projects are summarized in Table 3-1. The basic approach to performing mooring design with the facility and ship known is given in Table 3-2.

Table 3-1 Parameters in a Mooring Project

Parameter	Examples
1. Operational Parameters	Required ship position, amount of motion allowed
2. Ship Configuration	Basic ship parameters, such as length, beam, draft, displacement, wind areas, mooring fitting locations, wind/current force, mooring fitting safe working loads, allowable hull pressure, and moment coefficients
3. Facility Configuration	Facility location, water depth, dimensions, locations/type/safe working load of mooring fittings/fenders, facility condition, facility overall capacity
4. Environmental Parameters	Wind speed, current speed and direction, water levels, wave conditions and possibility of ice
5. Mooring Configuration	Number/size/type/location of tension members, fenders, camels, etc.
6. Material Properties	Stretch/strain characteristics and breaking strengths of the mooring tension and compression members

Table 3-2 Basic Mooring Design Approach with Known Facility for a Specific Site and a Specific Ship

Step	Examples
1. Define customer(s) requirements	Define the ship(s) to be moored, the type of service required, the maximum allowable ship motions, and situations under which the ship will leave.
2. Determine planning requirements	Define the impact/interaction with other facilities and operations, evaluate explosive arcs and other restricted areas, determine permit requirements, establish how the mooring is to be used, review the budget and schedule.
3. Prepare Environmental Impact Assessments	Prepare any required studies and paperwork.
4. Define site and environmental parameters	See Table 3-1
5. Determine Ship characteristics	See Table 3-1
6. Determine Ship forces/moments	Determine the forces, moments, and other key behaviors of the ship(s).
7. Evaluate mooring alternatives	Evaluate the alternatives in terms of safety, risk, cost, constructability, availability of hardware, impact on the site, watch circle, compatibility, maintenance, inspectability, and other important aspects.
8. Develop Design Calculations	Perform static and/or dynamic analyses (if required) for mooring performance, anchor design, fender design, etc.
9. Issue Notifications	Prepare Notice to Mariners for the case of in-water construction work and notify charting authorities concerning updating charts for the area.

Table 3-2 Basic Mooring Design Approach with Known Facility for a Specific Site and a Specific Ship (*Continued*)

Step	Examples
1. Plans/Specs	Prepare plans, specifications, and cost estimates.
2. Permits [a]	Prepare any required environmental studies and obtain required permits.
3. Installation planning [a]	Prepare instructions for installation, including safety and environmental protection plans.
4. Installation monitoring [a]	Perform engineering monitoring of the installation process.
5. Testing [a]	Perform pull tests of all anchors in mooring facilities to ensure that they hold the required load.
6. Documentation	Document the design and as-built conditions with drawings and reports.
7. Instructions	Provide diagrams and instructions to show the customer how to use and inspect the mooring.
8. Inspection	Perform periodic inspection/testing of the mooring to assure it continues to meet the customer(s) requirements.
9. Maintenance	Perform maintenance as required and document on as-built drawings.

Note:
[a] May not be required for existing berthing facilities

3-2 GENERAL DESIGN CRITERIA.

General design criteria shown in Table 3-3 should be addressed during the design process to help ensure projects meet customers' needs.

Table 3-3 Design Criteria

Criteria	Examples
1. Vessel operating conditions	Under what conditions will the vessel(s) exit? What are the operating mission requirements for the ship? What is the maximum allowable hull pressure?
2. Allowable motions	How much ship motion in the six degrees of freedom will be allowable for the moored ship? This is related to brow positions and use, utilities, ship loading and unloading operations, and other requirements. Many ships have high buoyancy forces, so moorings should be designed to allow for vertical ship motions due to water level changes.
3. User skills	Is the user trained and experienced in using the proposed system? What is the risk that the mooring would be improperly used? Can a design be formulated for easy and reliable use?
4. Flexibility	How adaptable is the design? Can it provide for new mission requirements not yet envisioned? Can it be used with existing facilities/ships?
5. Constructability	Does the design specify readily available commercial products and is it able to be installed and/or constructed using standard techniques, tolerances, etc.?
6. Cost	Are initial and life cycle costs life cycle costs controlled so that the design represents the best value that meets the technical requirements?
7. Inspection	Can the mooring system be readily inspected to ensure continued good working condition?
8. Maintenance	Can the system be maintained in a cost-effective manner?
9. Special requirements	What special requirements does the customer have? Are there any portions of the ship that cannot come in contact with mooring elements (e.g., submarine hulls)?

3-2.1 Mooring Service Types (MST).

Four Mooring Service Types (MST) are defined to help identify minimum design requirements associated with DoD ships and piers, and determine operational limitations. Facility and ship mooring hardware should accommodate the service types shown in Table 3-4.

Table 3-4 Mooring Service Types

Mooring Service Type (MST)	Description
TYPE I Mild Weather Mooring	This category covers moorings for mild weather (sustained winds of less than 35 knots (18 m/s); below gale force) and currents less than 1 knot (0.5 m/s). Mooring situations include ammunition facilities, fueling facilities, deperming facilities, and ports of call. Use of these moorings is normally selected in concert with forecasted weather.
TYPE II Standard/Storm Mooring	This category covers moorings that are used through storm conditions. Moorings include standard, storm and nested configurations. Vessel will normally leave prior to an approaching hurricane, typhoon, surge or other extreme event. Naval ships intend to go to sea if 50 knot (26 m/s) winds are expected, but storms may come up quickly, so higher design winds are recommended.
TYPE IIA Standard Mooring	MST IIA covers mooring in winds of 50 knots (26 m/s) or less in broadside currents of 1-1/2 knots (0.8 m/s) or less. The practice is to provide for full pier operation for MST IIA.
TYPE IIB Storm Mooring	MST IIB covers mooring in winds of 64 knots (33 m/s) or less in broadside currents of 2 knots (1 m/s) or less. This is the intended Navy ship mooring design requirement. It is encouraged for general homeporting because sudden storms can produce high winds on short notice. Pier operations may be impacted for MST IIB if lines must be run across a pier.
TYPE III Heavy Weather Mooring	This category covers moorings of vessels that cannot or may not get underway prior to an approaching hurricane, typhoon, surge or other extreme event. Moorings include fitting-out, repair, dry dock, and overhaul berthing facilities.
TYPE IV Permanent Mooring	This category covers moorings that are used to permanently moor a vessel that will not leave in case of a hurricane, typhoon, surge or other extreme event. Moorings include inactive ships, floating dry docks, ship museums, training berthing facilities, etc.

3-2.2 Facility Design Criteria for Mooring Service Types.

Mooring facilities are designed conforming to the site specific environmental criteria given in Table 3-5. Table 3-5 gives design criteria in terms of environmental design return intervals, R, and in terms of probability of exceedance, P, for 1 year of service life, N=1. The ship usually has the responsibility for providing mooring lines for MSTs I and II, while the facility usually provides mooring lines for MSTs III and IV.

Table 3-5 Facility Design Criteria for Mooring Service Types

Mooring Service Type (MST)	Wind [a]	Current [b]	Water Level	Waves
TYPE I	Less than 35 knots (18 m/s) [c]	1 knot (0.5 m/s) or less	mean lower low to mean higher high	N/A
TYPE IIA	V_w=50 knots (26 m/s) max.	1.5 knot (0.8 m/s) max.	extreme low to mean higher high	P=1 or R=1 yr
TYPE IIB	V_w=64 knots (33 m/s) max.	2.0 knot (1.0 m/s) max.	extreme low to mean higher high	P=1 or R=1 yr
TYPE III [d, e]	P=0.02 or R=50 yr	P=0.02 or R=50 yr	extreme low to extreme high	P=0.02 or R=50 yr
TYPE IV [d, e]	P=0.01 or R=100 yr	P=0.01 or R=100 yr	extreme water levels	P=0.01 or R=100 yr

Note:

a Use exposure D (UFC 1-200-01, *DoD Building Code*; flat, unobstructed area exposed to wind flowing over open water for a distance of at least 1 mile (1.61 km) for determining design wind speeds.) Min. = minimum return interval or probability of exceedance used for design; max. = maximum wind speed used for design.

b Specific site conditions might dictate consideration of a higher current speed. Local current data and information from site personnel should be used to determine appropriate current speed. To define the design water depth for ship current force calculations, use T/d=0.9 for flat-keeled ships. For ships with non-flat hulls (sonar domes or other projections), determine the water depth by adding 2 ft (0.61 m) to the maximum navigation draft of the ship (may vary depending on sonar dome size), and take the ship draft as the mean depth of the keel.

c This is considered an absolute minimum for design, 35 knots (18 m/s) minimum. Specific site conditions might dictate consideration of a higher wind speed. Local wind climatology should be examined to determine appropriate windspeed.

d Refer to UFC 4-152-01, *Piers and Wharves*, Mooring Loads for method to calculate wind speed for recurrence intervals associated with Type III and Type IV mooring service types.

e Refer to NAVFAC EXWC report SSR-NAVFAC ESC-06-2012 *Environmental Conditions Report* for design criteria associated with Type III and Type IV moorings.

3-2.3 Ship Hardware Design Criteria for Mooring Service Types.

Ship mooring hardware needs to be designed to accommodate various modes of ship operation. During Type II operation, a ship may be moored in relatively high broadside current and get caught by a sudden storm, such as a thunderstorm. Type III mooring during repair may provide the greatest potential of risk, because the ship is moored for a significant time and cannot get underway. There are several U.S. shipyards where DoD ships can undergo major repairs. Ship mooring hardware environmental design criteria are given in Table 3-6. For Type IV mooring, special provisions can be made for long-term storage such as extra pad eyes and other modifications to the ship hull.

Table 3-6 Ship Mooring Hardware Design Criteria

(a) Ship Anchor Systems [a]

Vessel Type	Minimum Water Depth ft (m)	Minimum Wind Speed knot (m/s)	Minimum Current Speed knot (m/s)
Ships	240 (73)	70 (36)	4 (2.1)
Submarines	120 (36.6)	70 (36)	4 (2.1)

(b) Ship Mooring Systems [b]

Mooring Service Type (MST)	Minimum Wind Speed knot (m/s)	Minimum Current Speed knot (m/s)
Type I	35 (18)	1 (0.51)
Type II [c]	64 (33)	2 (1.03)
Type III	95 (48.9)	2 (1.03

Note:

[a] Quasi-static design assuming wind and current are co-linear for ship and submarine anchor systems (after NAVSEASYSCOM DDS-581).

[b] Specific site conditions might dictate consideration of a higher current speed. Local current data and information from site personnel should be used to determine appropriate current speed. To define the design water depth for ship current force calculations, use T/d=0.9 for flat-keeled ships. For ships with non-flat hulls (sonar domes or other projections), determine the water depth by adding 2 ft to the maximum navigation draft of the ship (may vary depending on sonar dome size), and take the ship draft as the mean depth of the keel.

[c] Ships need to carry lines suitable for MST IIB.

3-2.4 Strength.

Moorings should be designed and constructed to safely resist the nominal loads in load combinations defined herein without exceeding the appropriate allowable stresses for the mooring components. Normal wear of materials and inspection methods and frequency need to be considered. Due to the probability of simultaneous maximum occurrences of variable loads, no reduction factors should be used.

Throughout this document there are references to Working Capacity, Ultimate Capacity/Strength, Breaking Strength, and other strength, load, and capacities. See APPENDIX B for definition of terms.

3-2.5 Serviceability.

Moorings should be designed to have adequate stiffness to limit deflections, vibration, or any other deformations that adversely affect the intended use and performance of the mooring. At the same time moorings need to be flexible enough to provide for load sharing, reduce peak dynamic loads and allow for events, such as tidal changes.

3-2.6 Design Methods.

All moorings should be designed by skilled and knowledgeable professional personnel. Methods must be used that assure that ships are safely moored. Below are some guidelines.

MST I and II moorings can often be designed using quasi-static tools with three degrees of freedom (surge, sway and yaw). Examples of tools include OPTIMOOR, ANSYS AQWA, etc. Specialized tools need to be considered for cases of high currents, high tidal ranges, passing ship effects, ship waves, multiple/nested ships, situations that are likely to be dynamic and other specialized cases. It is valuable to ships' and port operations personnel to provide generalized mooring designs for MSTs I and II.

MSTs III and IV must be designed on a case-by-case basis using dynamic methods because of the extremely high loading that occurs during extreme storms. It is recommended that NAVFAC EXWC be contacted concerning the design of these types of moorings.

3-2.7 General Mooring Integrity.

For multiple-member moorings, such as for a ship secured to a pier by a number of lines, the mooring system relies on load sharing among several members. If one member is lost, the ship should remain moored. Therefore, design multiple-member moorings to ensure that remaining members maintain a factor of safety at least 75% of the intact mooring factors of safety shown in Table 3-7 with any one member missing.

3-2.8 Quasi-Static Safety Factors.

Table 3-7 gives recommended minimum factors of safety for "quasi-static" design based on material reliability.

Table 3-7 Minimum Quasi-Static Factors of Safety

Component	Minimum Factor of Safety	Notes
Stockless and balanced fluke anchors	1.5	For ultimate anchoring system holding capacity; use 1.0 for ship's anchoring [a]
High efficiency drag anchors	2.0	For ultimate anchoring system holding capacity use 1.0 for ship's anchoring [a]
Fixed anchors (piles and plates)	3.0	For ultimate anchoring system holding capacity [a]
Deadweight anchors	-	Use carefully (see NCEL *Handbook for Marine Geotechnical Engineering*, 1985, Section 4.6)
Chain	3.0 4.0	For relatively straight lengths. For chain around bends. These factors of safety are for the new chain break strength.
Wire rope	3.0	For the new wire rope break strength.
Synthetic line [b]	3.0	For new line break strength.
Ship bitts	See note [c]	Use American Institute of Steel Construction (AISC) code.
Pier bollards	See note [c]	See note [c]

Note:

[a] It is recommended that anchors be pull tested.

[b] Reduce effective strength of wet nylon line by 15%.

[c] Reference UFC 4-152-01, *Piers and Wharves* section on Mooring Loads

3-2.9 Allowable Ship Motions.

Table 3-8 gives recommended operational ship motion criteria for moored vessels.

Table 3-8 (a) gives maximum wave conditions for manned and moored small craft (Permanent International Association of Navigation Congresses (PIANC), *Criteria for Movements of Moored Ships in Harbors; A Practical Guide*, 1995). These criteria are based on comfort of personnel on board a small boat and are given as a function of boat length and locally generated.

Table 3-8 (b) gives recommended motion criteria for safe working conditions for various types of vessels (PIANC, 1995).

Table 3-8 (c) gives recommended velocity criteria and Table 3-8 (d) and (e) give special criteria.

Table 3-8 Recommended Practical Motion Criteria for Moored Vessels

(a) Safe Wave Height Limits for Moored Manned Small Craft

(PIANC, 1995)

		Beam/Quartering Seas			Head Seas	
Vessel Length	Wave Period	Maximum Sine Wave Height, H_s		Wave Period	Maximum Sine Wave Height, H_s	
ft (m)	sec	ft	(m)	sec	ft	(m)
13.1 to 32.8 (4 to 10)	<2.0	0.66	0.20	<2.5	0.66	0.20
"	2.0-4.0	0.33	0.10	2.5-4.0	0.49	0.15
"	>4.0	0.49	0.15	>4.0	0.66	0.20
32.8 to 52.5 (10 to 16)	<3.0	0.82	0.25	<3.5	0.82	0.30
"	3.0-5.0	0.49	0.15	3.5-5.5	0.66	0.20
"	>5.0	0.66	0.20	>5.5	0.98	0.30
65.6 (20)	<4.0	0.98	0.30	<4.5	0.98	0.30
"	4.0-6.0	0.49	0.15	4.5-7.0	0.82	0.25
"	>6.0	0.82	0.25	>7.0	0.98	0.30

Table 3-8 (*Continued*)

(b) Recommended Motion Criteria for Safe Working Conditions [a]

(PIANC, 1995)

Vessel Type	Cargo Handling Equipment	Surge (m)	Sway (m)	Heave (m)	Yaw (º)	Pitch (º)	Roll (º)
Fishing vessels 10-3,000 GRT [b]	Elevator crane Lift-on/off Suction pump	0.15 1.0 2.0	0.15 1.0 1.0	- 0.4 -	- 3 -	- 3 -	- 3 -
Freighters & coasters <10,000 DWT [c]	Ship's gear Quarry cranes	1.0 1.0	1.2 1.2	0.6 0.8	1 2	1 1	2 3
Ferries, Roll-On/ Roll-Off (RO/RO)	Side ramp [d] Dew/storm ramp Linkspan Rail ramp	0.6 0.8 0.4 0.1	0.6 0.6 0.6 0.1	0.6 0.8 0.8 0.4	1 1 3 -	1 1 2 1	2 4 4 1
General cargo 5,000-10,000 DWT	-	2.0	1.5	1.0	3	2	5
Container vessels	100% efficient 50% efficient	1.0 2.0	0.6 1.2	0.8 1.2	1 1.5	1 2	3 6
Bulk carriers 30,000-150,000 DWT	Cranes Elevator/ bucket-wheel Conveyor belt	2.0 1.0 5.0	1.0 0.5 2.5	1.0 1.0 -	2 2 3	2 2 -	6 2 -
Oil tankers	Loading arms	3.0 [e]	3.0	-	-	-	-
Gas tankers	Loading arms	2.0	2.0	-	2	2	2

Note:

[a] Motions refer to peak-to-peak values (except for sway, which is zero-to-peak)

[b] GRT = Gross Registered Tons expressed as internal volume of ship in units of 100 ft^3 (2.83 m^3)

[c] DWT = Dead Weight Tons, which is the total weight of the vessel and cargo expressed in long tons, 2,240 lb (1,016 kg), or metric tons (1,000 kg)

[d] Ramps equipped with rollers.

[e] For exposed locations, loading arms usually allow for 5.0-meter motion.

Table 3-8 (*Continued*)

(c) Recommended Velocity Criteria for Safe Mooring Conditions for Fishing Vessels, Coasters, Freighters, Ferries and Ro/Ro Vessels

(PIANC, 1995)

Ship Size (DWT)	Surge (m/s)	Sway (m/s)	Heave (m/s)	Yaw (°/s)	Pitch (°/s)	Roll (°/s)
1,000	0.6	0.6	-	2.0	-	2.0
2,000	0.4	0.4	-	1.5	-	1.5
8,000	0.3	0.3	-	1.0	-	1.0

(d) Special Criteria for Walkways and Rail Ramps

(PIANC, 1995)

Parameter	Maximum Value
Vertical velocity	0.2 m/s
Vertical acceleration	0.5 m/s^2

(e.) Special Criteria

Condition	Maximum Amplitude Values ft (m)	Notes
Heave	-	Ships will move vertically with any long period water level change (tide, storm surge, flood, etc.). The resulting buoyancy forces may be high, so the mooring must be designed to provide for these motions due to long period water level changes.
Loading/unloading preposition ships	2 (0.6)	Maximum ramp motion during loading/unloading moving wheeled vehicles.
Weapons loading/unloading	2 (0.6)	Maximum motion between the crane and the object being loaded/unloaded.

3-3 DESIGN METHODS.

3-3.1 Quasi-Static Design.

Practical experience has shown that in many situations such as for MSTs I and II, static analysis tools, such as, OPTIMOOR and ANSYS AQWA, etc. can be used to reliably determine mooring designs in harbors. Winds are a key forcing factor in mooring harbors. Winds can be highly dynamic in heavy weather conditions. However, practical experience has shown that for typical DoD ships, a wind speed with a duration of 30 seconds can be used, together with static tools, to develop safe mooring designs. The use of the 30-second duration wind speed with static tools and the approach shown in Table 3-9 is called “quasi-static” design.

Table 3-9 Quasi-Static Design Notes

Criteria	Notes
Wind speed	Determine for the selected return interval, R. For typical ships use the wind that has a duration of 30 seconds at an elevation of 32.8 ft (10 m).
Wind direction	Assume the wind can come from any direction except in cases where wind data show extreme winds occur in a window of directions.
Current speed	Use conditions for the site (speed and direction).
Water levels	Use the range for the site.
Waves	Neglected. If waves are believed to be important, then dynamic analyses are recommended.
Factors of safety	Perform the design using quasi-static forces and moments (see CHAPTER 4), minimum factors of safety in Table 3-7, and design to assure that all criteria are met.

A review of the methodology and available software for the analysis of ship moorings is provided in the Memorandum, *Simplified Mooring Calculation Methodology and Software*.

3-3.2 Dynamic Mooring Analysis.

Conditions during MSTs III and IV and during extreme events can be highly dynamic. Unfortunately, the dynamic behavior of a moored ship in shallow water can be highly complex, so dynamics cannot be fully documented in this UFC. An introduction to dynamics is provided in CHAPTER 8, Table 3-10 contains example conditions when mooring dynamics may be important or when special considerations must be made.

Table 3-10 Conditions Requiring Special Analysis

Factor	Special Analysis Required
Wind	> 39 knots (20 m/s) for small craft > 65 knots (34 m/s) for larger vessels
Wind waves	> 1.5 ft (0.46 m) for small craft > 4 ft (1.22 m) for larger vessels
Wind gust fronts	Yes for SPMs
Current	> 3 knots (20.1 m/s)
Ship waves and passing ship effects	Yes for special cases (see Kizakkevariath, 1989; Occasion, 1996; Weggel and Sorensen, 1984 & 1986)
Long waves (seiches and tidal waves or tsunamis)	Yes
Berthing and using mooring as a brake or to check the motion of the ship being berthed	Yes (see UFC 4-152-01, *Piers and Wharves*)
Parting tension member	Yes. may be static or dynamic
Ship impact or other sudden force on the ship	Yes (if directed)
Earthquakes	Yes, if in a spud moor or stiff system
Explosion, landslide, impact	Yes (if directed)
Tornado (reference NUREG 1974)	Yes
Flood, sudden water level rise	Yes (if directed)
Ice forcing	Yes (if a factor)
Ship/mooring system dynamically unstable (e.g., SPM)	Yes (dynamic behavior of ships at SPMs can be especially complex)
Forcing period near a natural period of the mooring system	Yes; if the forcing period is from 80% to 120% of a system natural period

3-4 RISK.

Risk is a concept that is often used to design facilities, because the probability of occurrence of extreme events (currents, waves, tides, storm surge, earthquakes, etc.) is strongly site dependent. Risk is used to ensure that systems are reliable, practical, and economical.

A common way to describe risk is the concept of 'return interval', which is the mean length of time between events. For example, if the wind speed with a return interval of R = 100 years is given for a site, this wind speed would be expected to occur, on the average, once every 100 years. However, since wind speeds are probabilistic, the specified 100-year wind speed might not occur at all in any 100-year period. Or, in any 100-year period the wind speed may be equal to or exceed the specified wind speed multiple times.

The probability or risk that an event will be equaled or exceeded one or more times during any given interval is determined from:

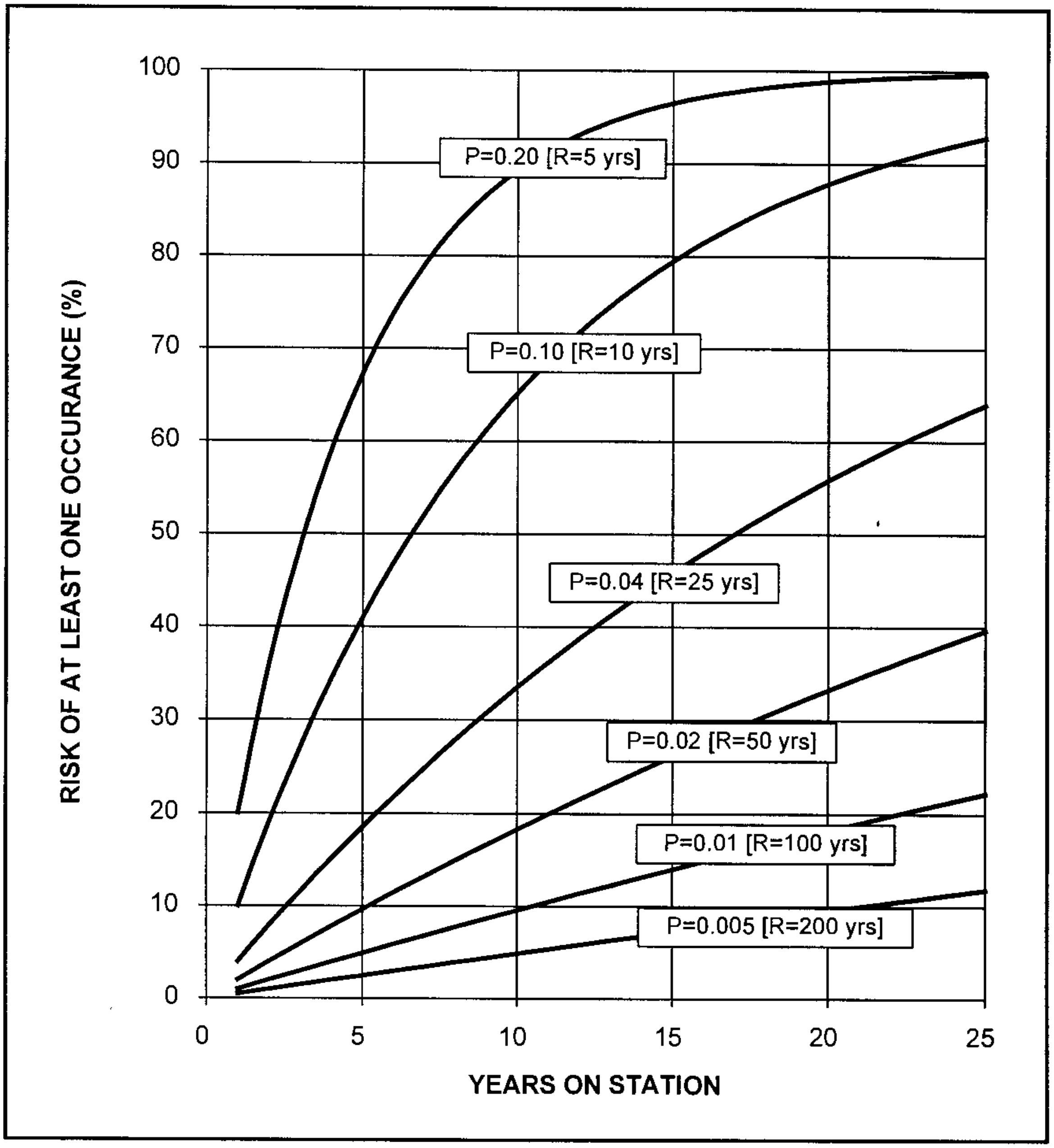
Equation 3-1

$$P = 100\% * \left(1 - \left(1 - \frac{1}{R}\right)^{N}\right)$$

where,
P = probability, in percent, of an event being equaled or exceeded one or more times in a specified interval
R = return interval (years)
N = service life (years)

Figure 3-1 shows risk versus years on station for various selected values of return interval. For example, take a ship that is on station at a site for 20 years (N = 20). There is a P = 18.2% probability that an event with a return interval of R = 100 years or greater will occur one or more times at a site in a 20-year interval.

Figure 3-1 Risk Diagram



3-5 COORDINATE SYSTEMS.

The various coordinate systems used for ships and mooring design are described below.

3-5.1 Ship Design/Construction Coordinates.

A forward perpendicular point (FP), aft perpendicular point (AP), and regular spaced frames along the longitudinal axes of the ship are used to define stations. The bottom of the ship keel is usually used as the reference point or "baseline" for vertical distances. Figure 3-2 illustrates ship design coordinates.

3-5.2 Ship Hydrostatics/Hydrodynamics Coordinates.

The forward perpendicular is taken as Station 0, the aft perpendicular is taken as Station 20, and various cross-sections of the ship hull (perpendicular to the longitudinal axis of the ship) are used to describe the shape of the ship hull. Figure 3-2 illustrates ship hydrostatic conventions.

3-5.3 Local Mooring Coordinate System.

Environmental forces on ships are a function of angle relative to the vessel's longitudinal centerline. A ship tends to move about its center of gravity. Therefore, the local "right-hand-rule" coordinate system, shown in Figure 3-3, is used in this UFC. The midship's point is shown as a convenient reference point in Figure 3-3 and Figure 3-4.

3-5.4 Global Coordinate System.

Plane state grids or other systems are often used to describe X and Y coordinates. The vertical datum is most often taken as relative to some water level, such as mean lower low water (MLLW).

3-5.5 Ship Conditions.

Loading conditions are defined in NAVSEA NSTM 096. There are three common conditions or displacements that a ship has at various stages including:

- <u>Light Condition</u> – This is the ship condition after first launching.
- <u>One-Third Stores Condition</u> – This is the typical ship condition during ship repair, as indicated in SUPSHIP docking/undocking records.
- <u>Fully Loaded Condition</u> – This is the ship condition during operations.

Figure 3-2 Ship Design and Hydrostatic Coordinates

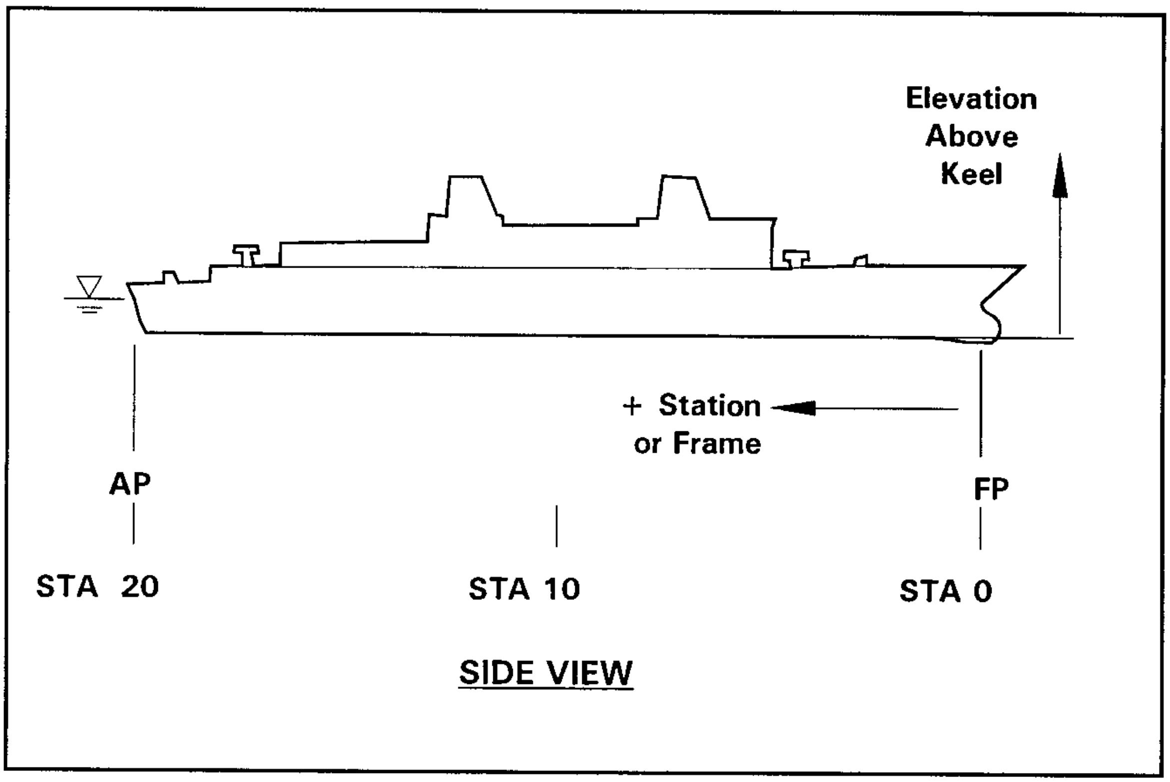


Figure 3-3 Local Mooring Coordinate System for a Ship

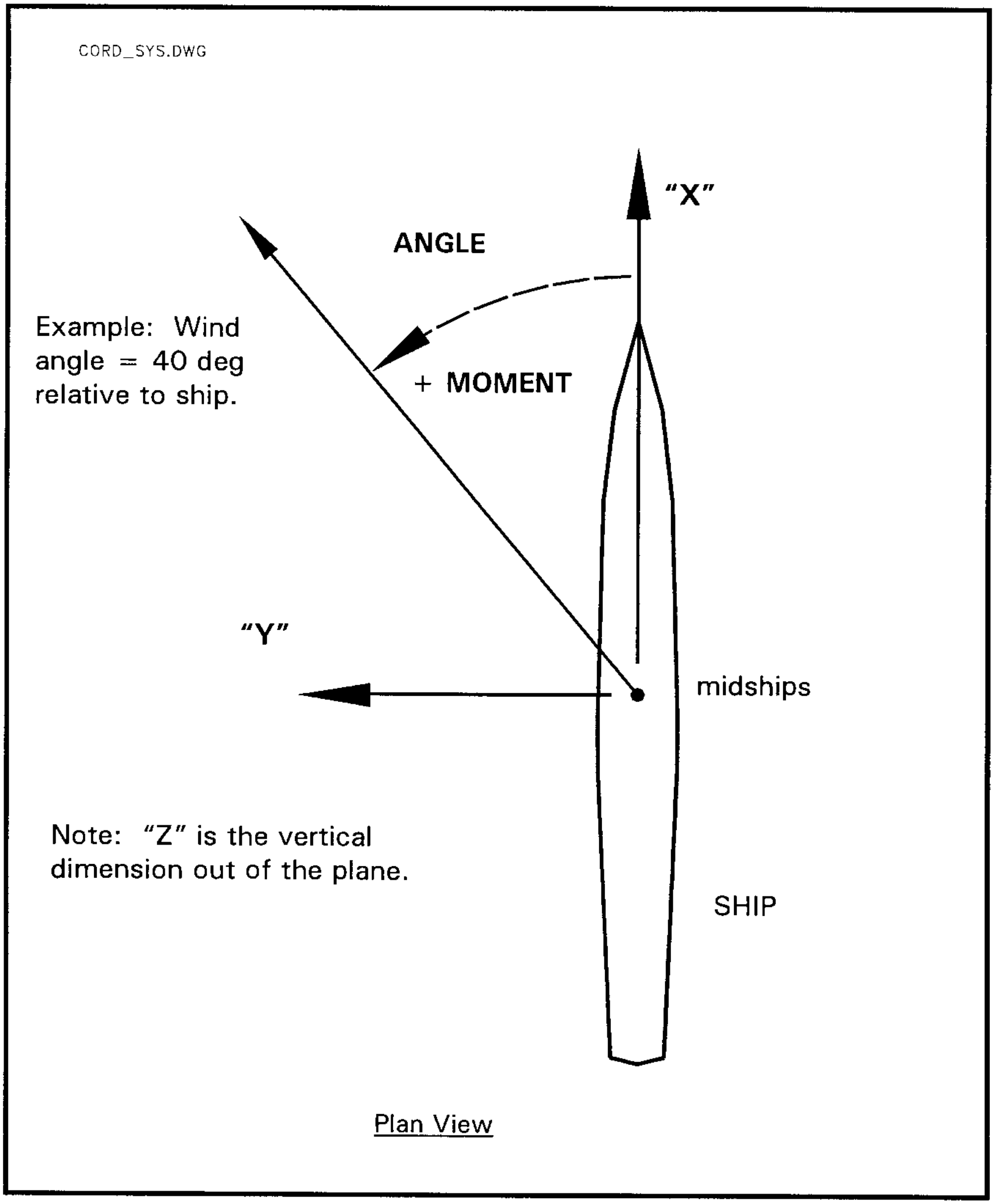
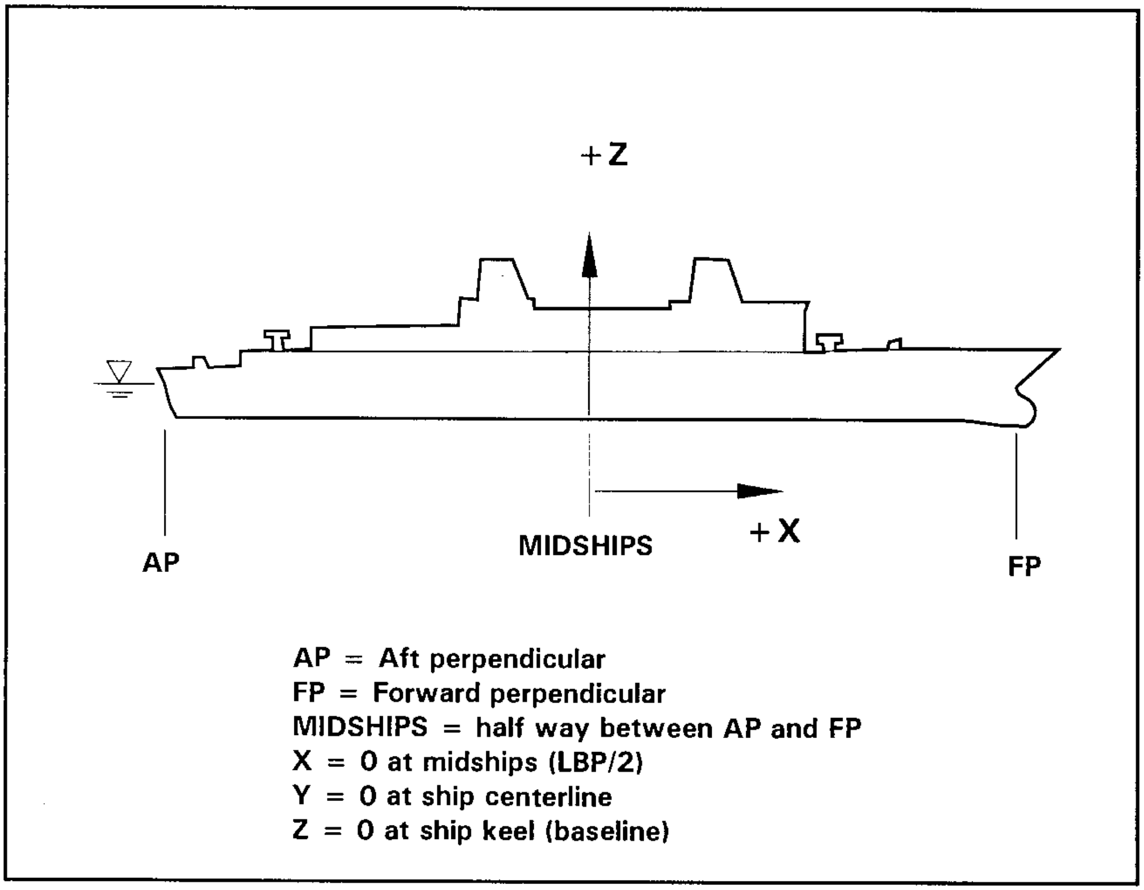


Figure 3-4 Local Mooring Coordinate System for a Ship



3-6 VESSEL DESIGN CONSIDERATIONS.

Some important vessel mooring design considerations are summarized in Table 3-11.

Table 3-11 Design Considerations - Ship

Parameter	Notes
Ship fittings	The type, safe working load, location, and number of mooring fittings on the ship are critical in designing moorings.
Ship hardware	The type, safe working load, location, and number of other mooring hardware (chain, anchors, winches, etc.) on the ship are critical.
Buoyancy	The ship's buoyancy supports the ship up in the heave, pitch, and roll directions. Therefore, it is usually undesirable to have much mooring capacity in these directions. A large ship, for example, may have over a million pounds of buoyancy for a foot of water level rise. If an unusually large water level rise occurs for a mooring with a large component of the mooring force in the vertical direction, this could result in mooring failure.
Hull pressures	Ships are designed so that only a certain allowable pressure can be safely resisted. Allowable hull pressures and fender design are discussed in NFESC TR-6015-OCN, *Foam-Filled Fender Design to Prevent Hull Damage*.
Personnel access	Personnel access must be provided.
Cargo Loading	Ramps/sideport locations
Hotel services	Provision must be made for utilities and other hotel services.
Ship condition	Ships are typically in the "Light", "One-Third Stores" or "Fully-Loaded" condition or displacement.

3-7 FACILITY DESIGN CONSIDERATIONS.

Some important facility mooring design considerations are summarized in Table 3-12.

Table 3-12 Design Considerations - Facility

Parameter	Notes
Access	Adequate ship access in terms of channels, turning basins, bridge clearance, etc. needs to be provided. Tugs and pilots must be available.
Mooring fittings	The number, type, location and capacity of mooring fittings or attachment points have to meet the needs of all vessels using the facility.
Fenders	The number, type, location, and properties of marine fenders must be specified to protect the ship(s) and facility.
Water depth	The water depth at the mooring site must be adequate to meet the customer's needs. Refer to UFC 4-150-06 for required underkeel clearances for military ships.
Shoaling	Many harbor sites experience shoaling. The shoaling and possible need for dredging needs to be considered.
Permits	Permits (Federal, state, environmental, historical, etc.) are often required for facilities and they need to be considered.

3-8 ENVIRONMENTAL FORCING DESIGN CONSIDERATIONS.

Environmental forces acting on a moored ship(s) can be complex. Winds, currents, water levels, and waves are especially important for many designs.

3-8.1 Winds.

A change in pressure from one point on the earth to another causes the wind to blow. Turbulence is carried along with the overall wind flow to produce wind gusts. If the mean wind speed and direction do not change very rapidly with time, the winds are referred to as "stationary."

Practical experience has shown that wind gusts with a duration of approximately 30 seconds or longer have a significant influence on typical moored ships with displacements of about 1000 tons or larger. Vessels with shorter natural periods can respond to shorter duration gusts. For the purposes of this UFC, a 30-second wind duration at a 33-foot (10-meter) elevation is recommended for the design for "stationary" winds. The relationship of the maximum wind speed averaged over t(s) to hourly mean wind speed is shown in Figure 3-5.

If wind speed and/or direction changes rapidly, such as in a wind gust front, hurricane or tornado, then winds are “non-stationary”. Figure 3-6, for example, shows a recording from typhoon Omar in 1992 at Guam. The eye of this storm went over the recording site. The upper portion of this figure shows the wind speed and the lower portion of the figure is the wind direction. Time on the chart recorder proceeds from right to left. This hurricane had rapid changes in wind speed and direction. As the eye passes there is also a large-scale change in wind speed and direction.

Figure 3-5 Ratio of Wind Speeds for Various Gusts

(after ASCE 7-16)

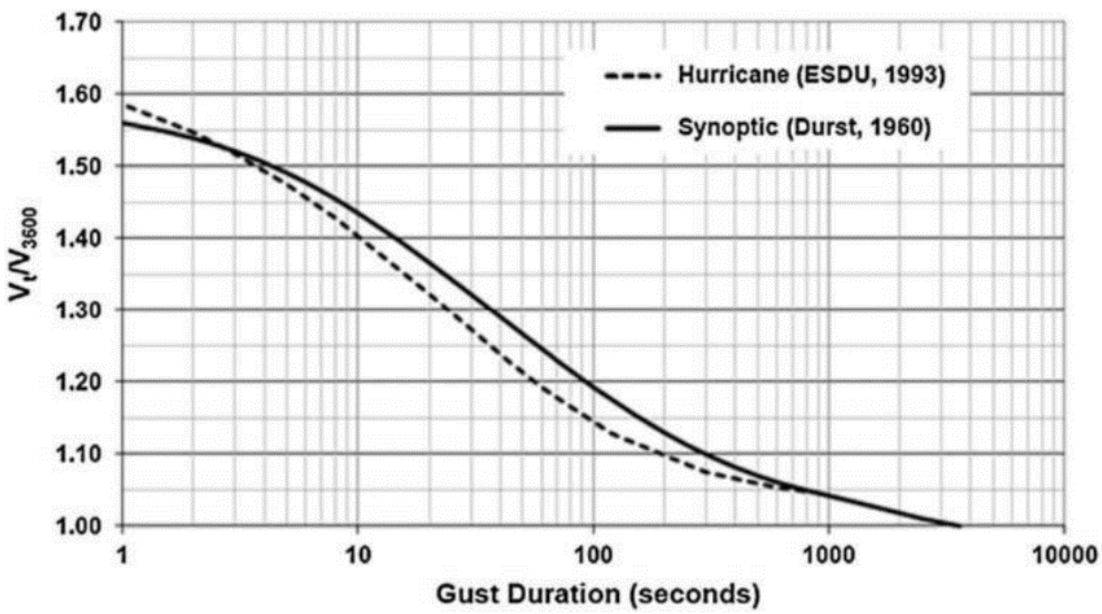
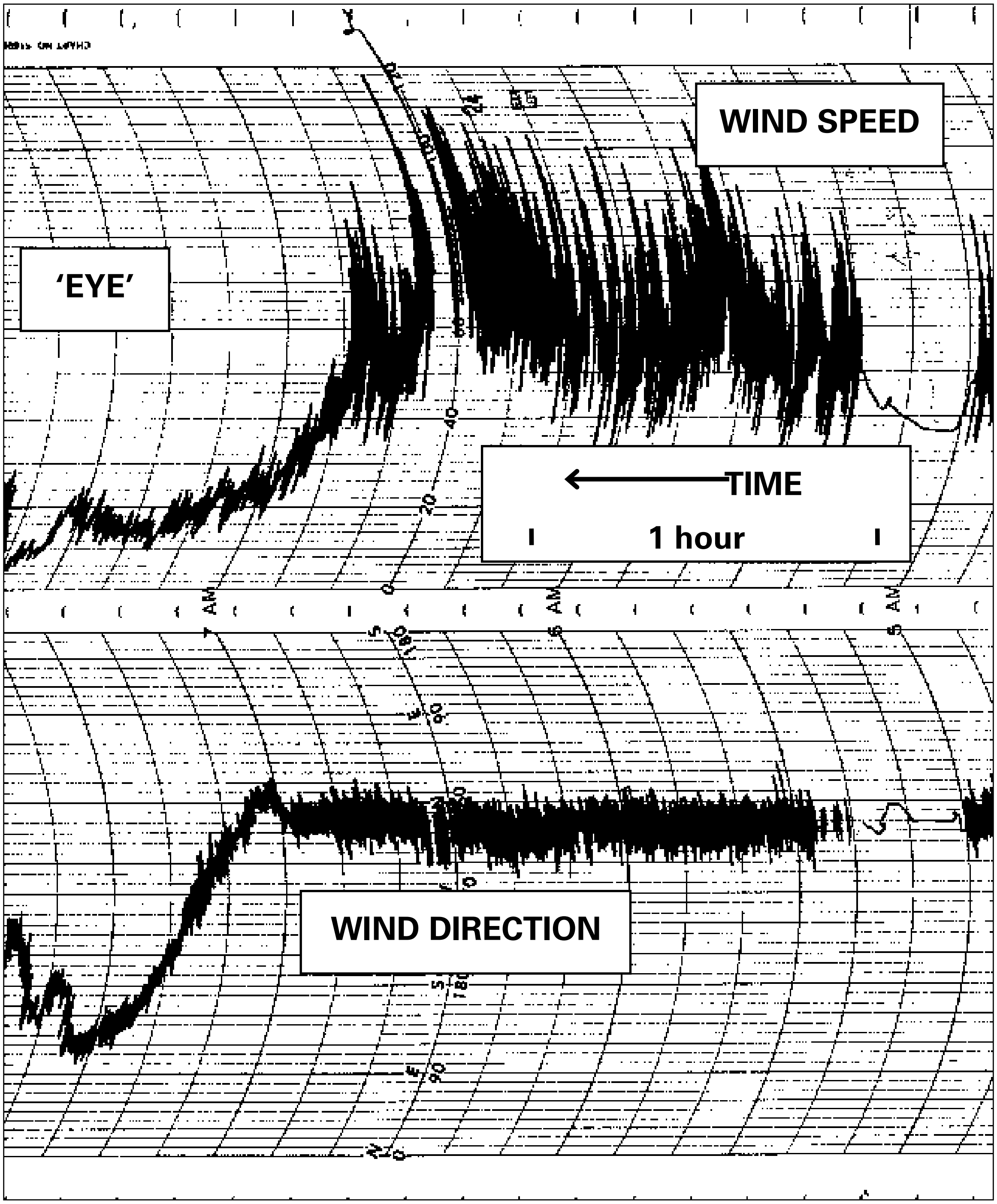


Figure 3-6 Typhoon Omar Wind Chart Recording



3-8.2 Wind Gust Fronts.

A particularly dangerous wind condition that has caused a number of mooring accidents is the wind gust front *(Mooring Dynamics Due to Wind Gust Fronts*, Seelig and Headland, 1998 and CHESNAVFACENGCOM, FPO-1-87(1), *Failure Analysis of Hawsers on BOBO Class MSC Ships at Tinian on 7 December 1986*). This is a sudden change in wind speed that is usually associated with a change in wind direction (*Wind Effects on Structures*, Simiu and Scanlan, 1996). The key problems with this phenomena are: (1) high mooring dynamic loads can be produced in a wind gust front, (2) there is often little warning, (3) little is known about wind gust fronts, and (4) no design criteria for these events have been established.

A study of Guam Agana Naval Air Station (NAS) wind records was performed to obtain some statistics of wind gust fronts (National Climatic Data Center (NCDC), Letter Report E/CC31:MJC, 1987). The 4.5 years of records analyzed from 1982 through 1986 showed approximately 500 cases of sudden wind speed change, which were associated with a shift in wind direction. These wind shifts predominately occurred in 1 minute or less and never took longer than 2 minutes to reach maximum wind speed. Figure 3-7 shows sudden changes in wind speed and direction that occurred over a 2-1/2 day period in October 1982. These wind gust fronts seemed to be associated with a nearby typhoon.

Table 3-13 gives the joint distribution of wind shifts in terms of the amount the increase in wind speed and the wind direction change. Approximately 60% of the wind gust fronts from 1982 through 1986 had wind direction changes in the 30-degree range, as shown in Figure 3-8.

Based on the Guam observations, the initial wind speed in a wind gust front ranges from 0% to 75% of the maximum wind speed, as shown in Figure 3-9. On the average, the initial wind speed was 48% of the maximum in the 4.5-year sample from Guam (NCDC, 1987).

Simiu and Scanlan (1996) report wind gust front increases in wind speed ranging from 3 m/s to 30 m/s (i.e., 6 to 60 knots). Figure 3-10 shows the distribution of gust front winds from the 4.5-year sample from 1982 through 1986 on Guam. This figure shows the probability of exceedance on the x-axis in a logarithmic format. The square of the wind gust front speed maximums was plotted on the y-axis, since wind force is proportional to wind speed squared. Figure 3-10 provides a sample of the maximum wind gust front distribution for a relatively short period at one site. Those wind gust fronts that occurred when a typhoon was nearby are identified with an “H.” It can be seen that the majority of the higher gust front maximums were associated with typhoons. Also, the typhoon gust front wind speed maxima seem to follow a different distribution that the gust front maxima associated with rain and thunderstorms (see Figure 3-10).

Effects of winds and wind gusts are shown in the examples in CHAPTER 8 of this UFC.

Figure 3-7 Sample Wind Gust Fronts on Guam, 2-4 October 1982

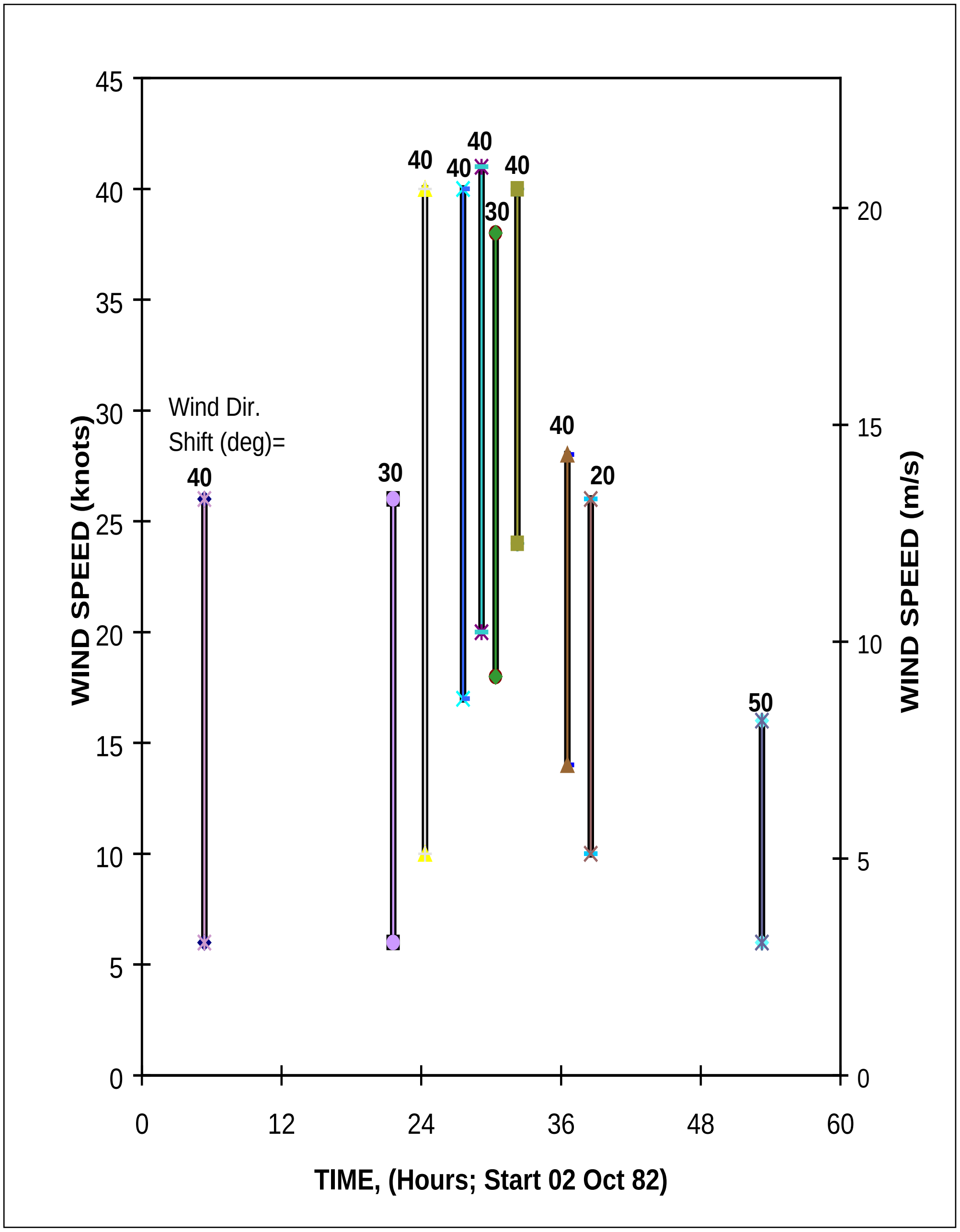


Table 3-13 Sample Distribution of Wind Gust Fronts on Guam (NAS Agana) 1982-1986

Wind Speed Change		Number Of Observations							
knot (m/s)		Wind Direction Change							
min.	max.	20°	30°	40°	50°	60°	70°	80°	90°
6 (3.1)	10 (5.1)	28	241	66	30	4		2	
11 (5.7)	15 (7.7)	8	42	18	13	5	3	1	1
16 (8.2)	20 (10.3)	6	7	3	2	2			
21 (10.8)	25 (12.9)		3	2		1			
26 (13.4)	30 (15.4)			1					

Figure 3-8 Distribution of Guam Wind Gust Front Wind Angle Changes

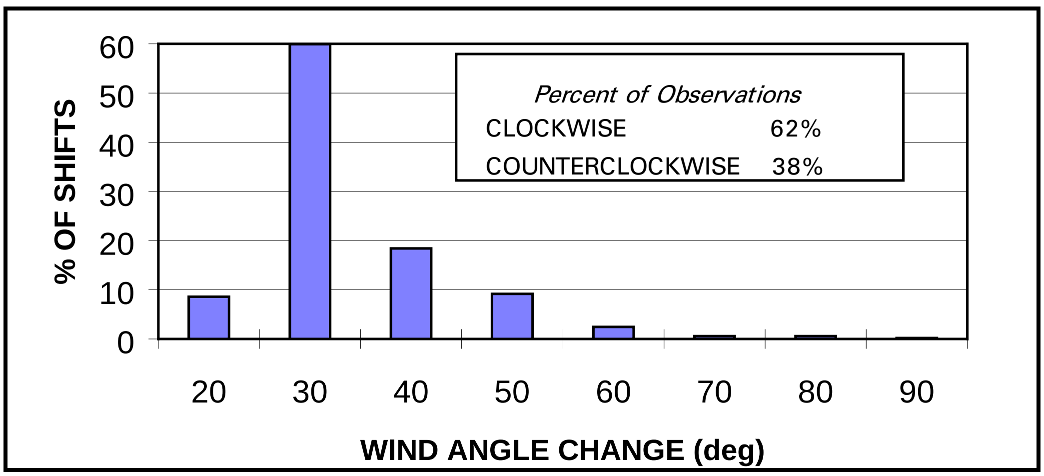


Figure 3-9 Initial Versus Maximum Wind Speeds for Wind Gust Fronts

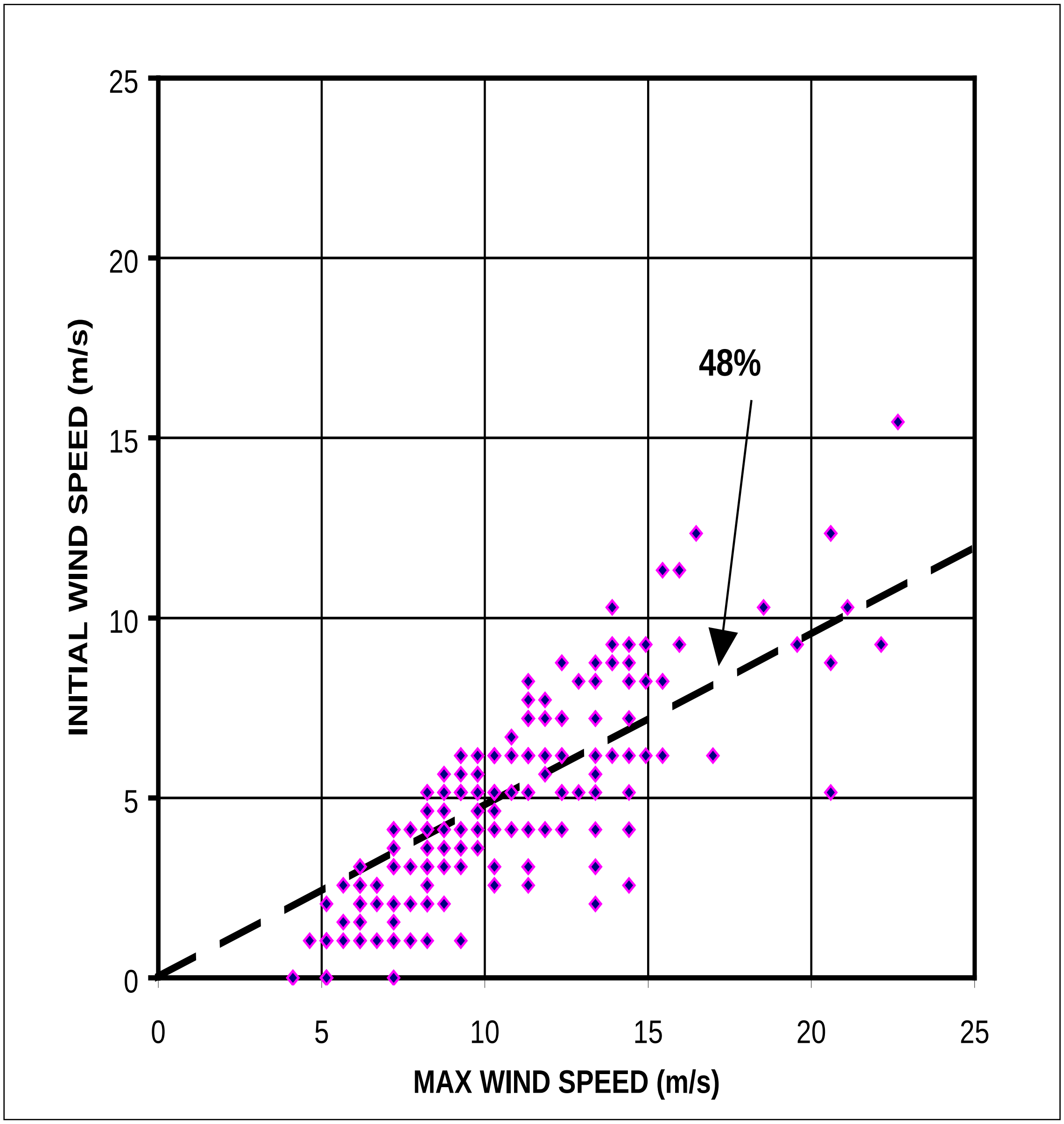
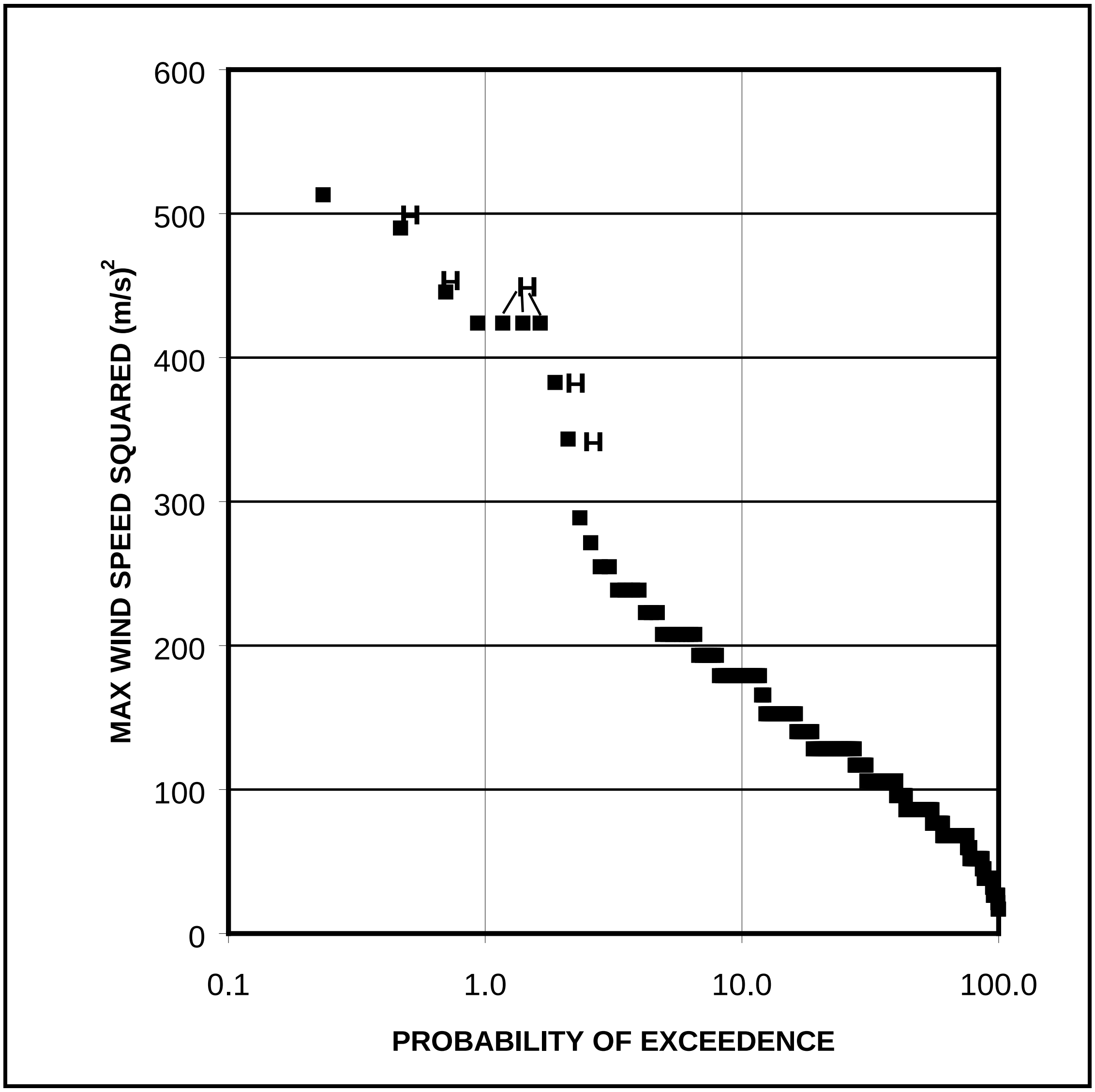


Figure 3-10 Wind Gust Front Maxima on Guam 1982-1986



3-8.3 Storms.

Table 3-14 gives environmental parameters for standard storms. Wind speeds are maximum sustained surface winds (one-minute average).

Table 3-14 Storm Parameters

(a) Tropical Storms

	Lower Wind Speed			Upper Wind Speed		
Storm	**(mph)**	**(knots)**	**(m/s)**	**(mph)**	**(knots)**	**(m/s)**
Tropical Depression	22	19.1	9.8	38	33	17
Tropical Storm	39	33.9	17.4	73	63.4	32.6
Hurricane	74	64.3	33.1	-	-	-

(b) Saffir-Simpson Hurricane Scale

	Wind Speed Range			
	Lower		Upper	
Category	**(mph)**	**(m/s)**	**(mph)**	**(m/s)**
1	74	33.1	95	42.5
2	96	42.9	110	49.2
3	111	49.6	129	57.7
4	130	58.1	156	69.7
5	157	70.2	-	-

Table 3-14 Storm Parameters (*Continued*)

(c) Beaufort Wind Force [a]

		Lower Wind Speed			Upper Wind Speed		
	Beaufort Wind Force/ Description	**(mph)**	**(knots)**	**(m/s)**	**(mph)**	**(knots)**	**(m/s)**
0	Calm	0	0	0.0	1	1	0.5
1	Light Airs	1	1	0.5	4	3	1.5
2	Light Breeze	5	4	2.1	7	6	3.1
3	Gentle Breeze	8	7	3.6	12	10	5.1
4	Moderate Breeze	13	11	5.7	18	16	8.2
5	Fresh Breeze	20	17	8.8	24	21	10.8
6	Strong Breeze	25	22	11.3	31	27	13.9
7	Moderate Gale	32	28	14.4	38	33	17.0
8	Fresh Gale	39	34	17.5	46	40	20.6
9	Strong Gale	47	41	21.1	54	47	24.2
10	Whole Gale	55	48	24.7	63	55	28.3
11	Storm	65	56	28.8	73	63	32.4
12	Hurricane	74	64	32.9	82	71	36.6

Note:

[a] *Handbook of Ocean and Underwater Engineers*, Myers et al. (1969). The above table should be used with caution because design conditions for a specific site could vary from the values shown.

(d) World Meteorological Organization Sea State Scale [a]

	Sea State	**Sign. Wave Height**	**Sustained Wind Speed**	**Modal Wave Period Range**
		ft (m)	**knot (m/s)**	**seconds**
0	Calm/Glassy	-	-	-
1	Rippled	0-0.3 (0-0.1)	0-6 (0-3)	-
2	Smooth	0.3-1.6 (0.1-0.5)	7-10 (3.6-5.1)	3-15
3	Slight	1.6-4.1 (0.5-1.2)	11-16 (5.7-8.2)	3-15.5
4	Moderate	4.1-8.2 (1.2-2.5)	17-21 (8.7-10.8)	6-16
5	Rough	8.2-13.1 (2.5-4.0)	22-27 (11.3-13.9)	7-16.5
6	Very Rough	13.1-19.7 (4.0-6.0)	28-47 (14.4-24.2)	9-17
7	High	19.7-29.5 (6.0-9.0)	48-55 (24.7-28.3)	10-18
8	Very High	29.5-45.5 (9.0-13.9)	56-63 (28.8-32.4)	13-19
9	Phenomenal	>45.5 (13.9)	>63 (32.4)	18-24

Note:

[a] Sea States are representative of fully developed open ocean conditions and are not to be used for harbors or sheltered waterways.

3-8.4 Currents.

The magnitude and direction of currents in harbors and nearshore areas are in most cases a function of location and time. Astronomical tides, river discharges, wind-driven currents, and other factors can influence currents. For example, wind-driven currents are surface currents that result from the stress exerted by the wind on the sea surface. Wind-driven currents generally attain a mean velocity of approximately 3% to 5% of the mean wind speed at 33 ft (10 m) above the sea surface. The magnitude of this current decreases with depth.

Currents are site specific, so it is recommended that currents be measured at the design site and combined with other information available to define the design current conditions.

3-8.5 Water Levels.

At most sites some standard datum, such as mean low water (MLW) or mean lower low water (MLLW), is established by formal methods. Water levels are then referenced to this datum. The water level in most harbors is then a function of time. Factors influencing water levels include astronomical tides, storm surges, river discharges, winds, seiches, and other factors.

The design range in water levels at the site must be considered in the design process.

3-8.6 Waves.

Most DoD moorings are wisely located in harbors to help minimize wave effects. However, waves can be important to mooring designs in some cases. The two primary wave categories of interest are:

- <u>Wind waves</u> – Wind waves can be locally generated or can be wind waves or swell entering the harbor entrance(s). Small vessels are especially susceptible to wind waves.
- <u>Long waves</u> – These can be due to surf beat, harbor seiching, or other effects.

Ship waves may be important in some cases. The response of a moored vessel to wave forcing includes:

- A steady mean force, and
- First order response, where the vessel responds to each wave, and
- Second order response, where some natural long period mode of ship/mooring motion, which usually has little damping, is forced by the group or other nature of the waves.

If any of these effects are important to a given mooring design, then a six degree of freedom dynamic analysis of the system generally needs to be considered in design. Guidance on safe wave limits for moored manned small craft is given in Table 3-8 (a).

3-8.7 Water Depths.

The bathymetry of a site may be complex, depending on the geology and history of dredging. Water depth may also be a function of time, if there is shoaling or scouring. Water depths are site specific, so hydrographic surveys of the project site are recommended.

3-8.8 Environmental Design Information.

Some sources of environmental design information of interest to mooring designers are summarized in Table 3-15.

Table 3-15 Some Sources of Environmental Design Information

(a) Winds

ASCE 7, Minimum Design Loads and Associated Criteria for Buildings and Other Structures; Wind Maps
UFC 1-200-01, *DoD Building Code* UFC 3-301-01, *Structural Engineering*
National Bureau of Standards (NBS), Series 124, *Hurricane Wind Speeds in the United States,* 1980
Nuclear Regulatory Commission (NUREG), NUREG/CR-2639, *Historical Extreme Winds for the United States – Atlantic and Gulf of Mexico Coastlines*, 1982
Hurricane and Typhoon Havens Handbooks, NRL (1996) and NEPRF (1982), https://www.nrlmry.navy.mil/port_studies/tr8203nc/0start.htm
NUREG/CR-4801, *Climatology of Extreme Winds in Southern California*, 1987
NBS Series 118, *Extreme Wind Speeds at 129 Stations in the Contiguous* United States, 1979

(b) Currents

NOAA Tides and Currents website; https://tidesandcurrents.noaa.gov/
National Ocean Survey records
U.S. Army Corps of Engineers records

(c) Water Levels

NOAA Tides and Currents website; https://tidesandcurrents.noaa.gov/
Federal Emergency Management Agency records
U.S. Army Corps of Engineers, Sea Level Calculator, http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html
National Ocean Survey records

Hurricane and Typhoon Havens Handbooks, https://www.nrlmry.navy.mil/port_studies/tr8203nc/0start.htm
U.S. Army Corps of Engineers records

(d) Waves

NOAA Tides and Currents website*; https://tidesandcurrents.noaa.gov/*
Hurricane and Typhoon Havens Handbooks, https://www.nrlmry.navy.mil/port_studies/tr8203nc/0start.htm
U.S. Army Corps of Engineers, *Coastal Engineering Manual* (current version) gives prediction methods https://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/u43544q/636F617374616C/

(e) Bathymetry

NOAA website for charts: https://www.charts.noaa.gov/
From other projects in the area
National Ocean Survey charts and surveys
U.S. Army Corps of Engineers dredging records

3-9 OPERATIONAL CONSIDERATIONS.

Some important operational design considerations are summarized in Table 3-16.

Table 3-16 Mooring Operational Design Considerations

Parameter	Notes
Personnel experience/ training	What is the skill of the people using the mooring?
Failure	What are the consequences of failure? Are there any design features that can be incorporated that can reduce the impact?
Ease of use	How easy is the mooring to use and are there factors that can make it easier to use?
Safety	Can features be incorporated to make the mooring safer for the ship and personnel?
Extreme events	Extreme events can occur unexpectedly. Can features be incorporated to accommodate them?
Future use	Future customer requirements may vary from present needs. Are there things that can be done to make a mooring facility more universal?

3-10 INSPECTION.

Mooring systems and components should be inspected periodically to ensure they are in good working order and are safe. Table 3-17 gives inspection guidelines.

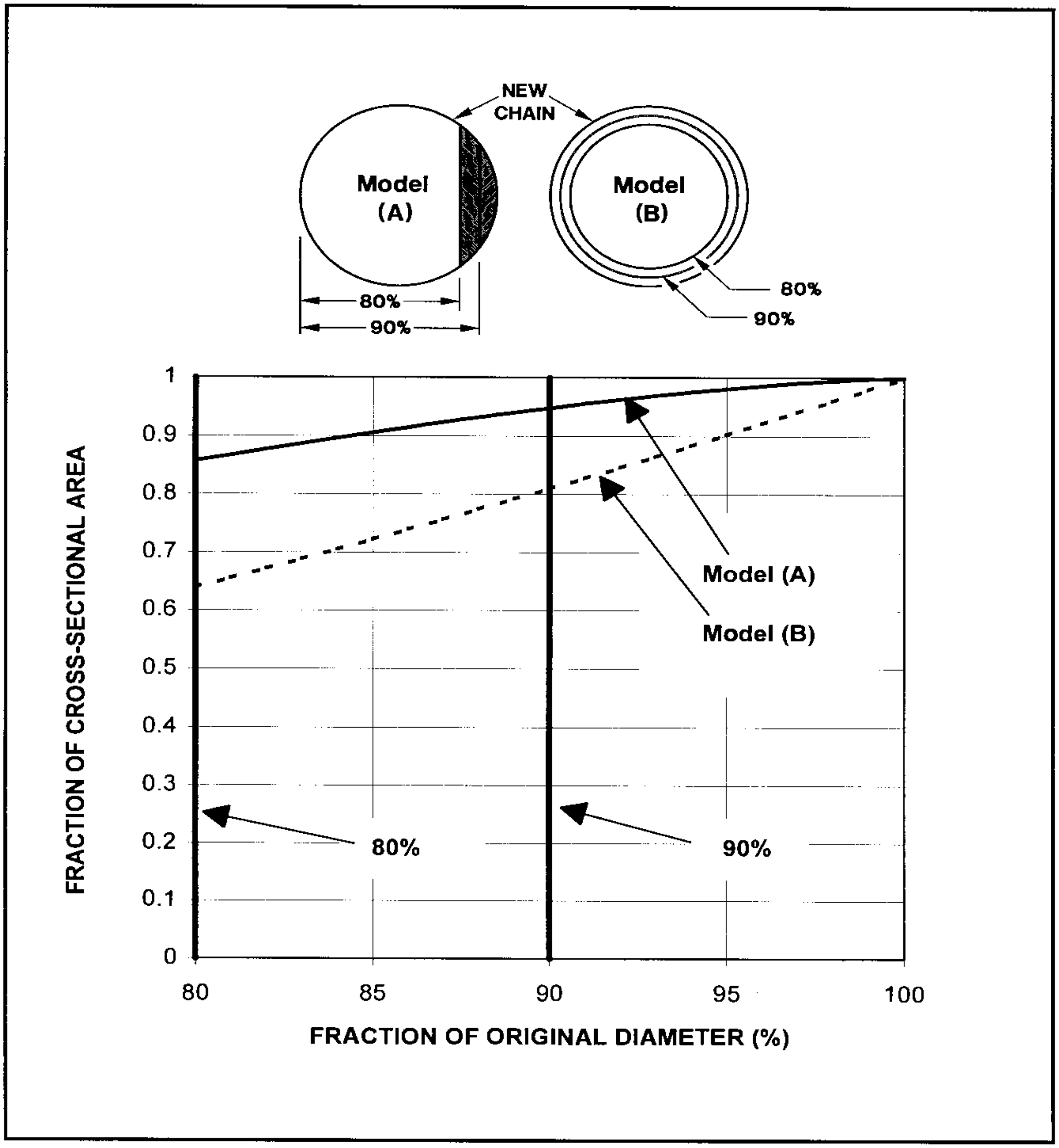
Table 3-17 Inspection Guidelines

Mooring System or Component	Maximum Inspection Interval	Notes
Piers and wharves	1 year 3 years 6 years	Surface inspection Complete inspection - wood structures Complete inspection - concrete and steel structures See UFC 4-150-07, *Waterfront Facilities: Maintenance and Operation* and NAVFAC MO-104.2, *Specialized Underwater Waterfront Facilities Inspections*; If the safe working load/condition of mooring fittings on a pier/wharf is unknown, then pull tests are recommended to proof the fittings.
Fleet Moorings	3 years	See CHESNAVFACENGCOM, FPO-1-84(6), *Fleet Mooring Underwater Inspection Guidelines*. Also inspect and replace anodes, if required. More frequent inspection may be required for moorings at exposed sites or for critical facilities.
Synthetic line	6 months	Per manufacturer's recommendations
Ship's chain	36 months 24 months 18 months	0-3 years of service 4-10 years of service >10 years of service (American Petroleum Institute (API) RP 2T, *Recommended Practice for Planning, Designing, and Constructing Tension Leg Platforms*)
Wire rope	18 months 12 months 9 months	0-2 years of service 3-5 years of service >5 years of service (API RP 2T)

3-11 MAINTENANCE.

If excessive wear or damage occurs to a mooring system, then it must be maintained. Fleet mooring chain, for example, is allowed to wear to a diameter of 90% of the original steel bar diameter. As measured diameters approach 90%, then maintenance is scheduled. Moorings with 80% to 90% of the original chain diameter are restricted to limited use. If a chain diameter reaches a bar diameter of 80% of the original diameter, then the mooring is condemned. Figure 3-11 illustrates some idealized models of chain wear.

Figure 3-11 Idealized Models of Chain Wear



3-12 GENERAL MOORING GUIDELINES.

Experience and practical considerations show that the recommendations given in Table 3-18 will help ensure safe mooring. These ideas apply to both ship mooring hardware and mooring facilities.

Table 3-18 Design Recommendations

Idea	Notes
Allow ship to move with rising and falling water levels	The weight and buoyancy forces of ships can be very high, so it is most practical to design moorings to allow ships to move in the vertical direction with changing water levels. The design range of water levels for a specific site should be determined in the design process.
Design mooring system so any failure will have minimal impact	A system is only as strong as its weakest segment; a system with components of similar strength can be the most economical. The mooring system should be designed such that the mooring lines fail before the ship or shore fitting.
Ensure load sharing	In some moorings, such as at a pier, many lines are involved. Ensuring that members will share the load results in the most economical system.
Bridle design	In cases where a ship is moored to a single point mooring buoy with a bridle, ensure that each leg of the bridle can withstand the full mooring load, because one member may take the full load as the vessel swings.
Provide shock absorbing in mooring systems	Wind gusts, waves, passing ships, etc., will produce transient forces on a moored ship. Allowing some motion of the ship will reduce the dynamic loads. ‘Shock absorbers’ including marine fenders, timber piles, synthetic lines with stretch, chain catenaries, sinkers, and similar systems are recommended to allow a moored ship to move in a controlled manner.
Limit the vertical angles of lines from ship to pier	Designing ships and piers to keep small vertical line angles has the advantages of improving line efficiency and reducing the possibility of lines pulling off pier fittings.
Select drag anchors to have a lower ultimate holding capacity than the breaking strength of chain and fittings	Design mooring systems that use drag anchors so that the anchor will drag before the chain breaks.
Limit the loading on drag anchors to horizontal tension	Drag anchors work on the principle of ‘plowing’ into the soils. Keeping the mooring catenary angle small at the seafloor will aid in anchor holding. Have at least one shot of chain on the seafloor to help ensure the anchor will hold.
Pull test anchors whenever possible to the full design load	Pull testing anchors is recommended to ensure that all facilities with anchors provide the required holding capacity.

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CHAPTER 4 STATIC ENVIRONMENTAL FORCES AND MOMENTS ON VESSELS

4-1 SCOPE.

In this chapter design methods are presented for calculating static forces and moments on single and multiple moored vessels. Examples show calculation methods.

4-2 ENGINEERING PROPERTIES OF WATER AND AIR.

The effects of water and air at the surface of the earth are of primary interest in this chapter. The engineering properties of both are given in Table 4-1.

Table 4-1 Engineering Properties of Air and Water

(a.) Standard Salt Water at Sea Level at 15 °C (59 °F)

Property	English Units	SI Units
Mass density, ρ_w	1.9905 slug/ft^3	1026 kg/m^3
Weight density, γ_w	64.043 lbf/ft^3	10.06 kN/m^3
Volume per long ton (LT)	34.977 ft^3/LT	0.9904 m^3/LT
Kinematic viscosity, ν	1.2817 x10^{-5} ft^2/s	1.191 x10^{-6} m^2/s

(b.) Standard Fresh Water at Sea Level at 15 °C (59 °F)

Property	English Units	SI Units
Mass density, ρ_w	1.9384 slug/ft^3	999.0 kg/m^3
Weight density, γ_w	62.366 lbf/ft^3	9,797 N/m^3
Volume per long ton (LT)	35.917 ft^3/LT	1.0171 m^3/LT
Volume per metric ton (ton or 1,000 kg or 1 Mg)	35.3497 ft^3/ton	1.001 m^3/ton
Kinematic viscosity, ν	1.2817 x10^{-5} ft^2/s	1.141x10^{-6} m^2/s

(c.) Air at Sea Level at 20 °C (68 °F) [a]

Property	English Units	SI Units
Mass density, ρ_a	0.00237 slug/ft^3	1.221 kg/m^3
Weight density, γ_a	0.07625 lbf/ft^3	11.978 N/m^3
Kinematic viscosity, ν	1.615 x10^{-4} ft^2/s	1.50 x10^{-5} m^2/s

Note:

[a] Humidity and heavy rain has relatively little effect on the engineering properties of air (personal communication with the National Weather Service, 1996)

4-3 PRINCIPAL COORDINATE DIRECTIONS.

There are three primary axes for a ship:

X – Direction parallel with ship's longitudinal axis
Y – Direction perpendicular to a vertical plane through ship's longitudinal axis
Z – Direction perpendicular to a plane formed by "X" and "Y" axes

There are six principal coordinate directions for a ship:

Surge – Linear in "X"-direction
Sway – Linear in "Y"-direction
Heave – Linear in "Z"-direction
Roll – Angular about "X"-axis
Pitch – Angular about "Y"-axis
Yaw – Angular about "Z"-axis

Of primary interest are: (1) forces in the surge and sway directions in the "X-Y" plane, and (2) moment in the yaw direction about the "Z"-axis. Ship motions occur about the center of gravity of the ship.

4-4 STATIC WIND FORCES/MOMENTS.

Static wind forces and moments on stationary moored vessels are computed in this chapter. Figure 4-1 shows the definition of some of the terms used in this chapter. Figure 4-2 shows the local coordinate system.

4-4.1 Static Transverse Wind Force.

The static transverse wind force is defined as that component of force perpendicular to the vessel centerline. In the local ship coordinate system, this is the force in the "Y" or sway direction. Transverse wind force is determined from the equation:

Equation 4-1

$$F_{yw} = 0.5\,\rho_a\,V_w^2\,A_y\,C_{yw}\,f_{yw}\,(\theta_w)$$

where,
F_{yw} = transverse wind force (N)
ρ_a = mass density of air (from Table 4-1)
V_w = wind speed (m/s)
A_y = longitudinal projected area of the ship (m^2)
C_{yw} = transverse wind force drag coefficient
$f_{yw}(\theta_w)$ = shape function for transverse force
θ_w = wind angle (degrees)

The transverse wind force drag coefficient depends upon the hull and superstructure of the vessel and is calculated using the following equation, adapted from Naval Civil Engineering Laboratory (NCEL), TN-1628, *Wind-Induced Steady Loads on Ships.*

Equation 4-2

$$C_{yw} = C\left[\left(0.5\frac{(h_s + h_h)}{h_r}\right)^{\frac{2}{7}} A_s + \left(0.5\frac{h_h}{h_r}\right)^{\frac{2}{7}} A_h\right]/A_y$$

where,
C = empirical coefficient, see Table 4-2
h_r = reference height, 10 m (33 ft)
h_h = A_H/L_{wL} ;average height of the hull, m
A_H = longitudinal wind area of hull, m^2
L_w = ship length at waterline, m
h_s = height of superstructure above waterline, m
A_s = longitudinal wind area of superstructure, m^2

A recommended value for the empirical coefficient is C = 0.92 ± 0.1 based on scale model wind tunnel tests (NCEL, TN-1628). Table 4-2 gives typical values of C for ships and Figure 4-4 illustrates some ship types.

Table 4-2 Sample Wind Coefficients for Ships

Ship	C	Notes
Hull Dominated	0.82	aircraft carriers, submarines, drydocks, LHA/LHD
Typical	0.92	ships with moderate superstructure
Extensive Superstructure	1.02	destroyers, cruisers

Note: Wind coefficients are based on older ship profiles. Validation of current profiles is necessary. Professional judgement must be used regarding the appropriate coefficient to use for ship profile.

The shape function for the transverse wind force (NCEL, TN-1628) is given by:

Equation 4-3

$$f_{yw}(\theta_w) = +\frac{(\sin(\theta_w) - 0.05\ \sin(\theta_w))}{0.95}$$

Equation 4-3 is positive for wind angles $0° < \theta_w < 180°$ and negative for wind angles $180° < \theta_w < 360°$. Figure 4-5 shows the shape and typical values for Equation 4-3.

These two components were derived by integrating wind over the hull and superstructure areas to obtain effective wind speeds (NCEL, TN-1628). The following example illustrates calculations of the transverse wind force drag coefficient. The coefficients shown in Table 4-2 are based on the following ship hull profiles.

Figure 4-1 Definition of Terms

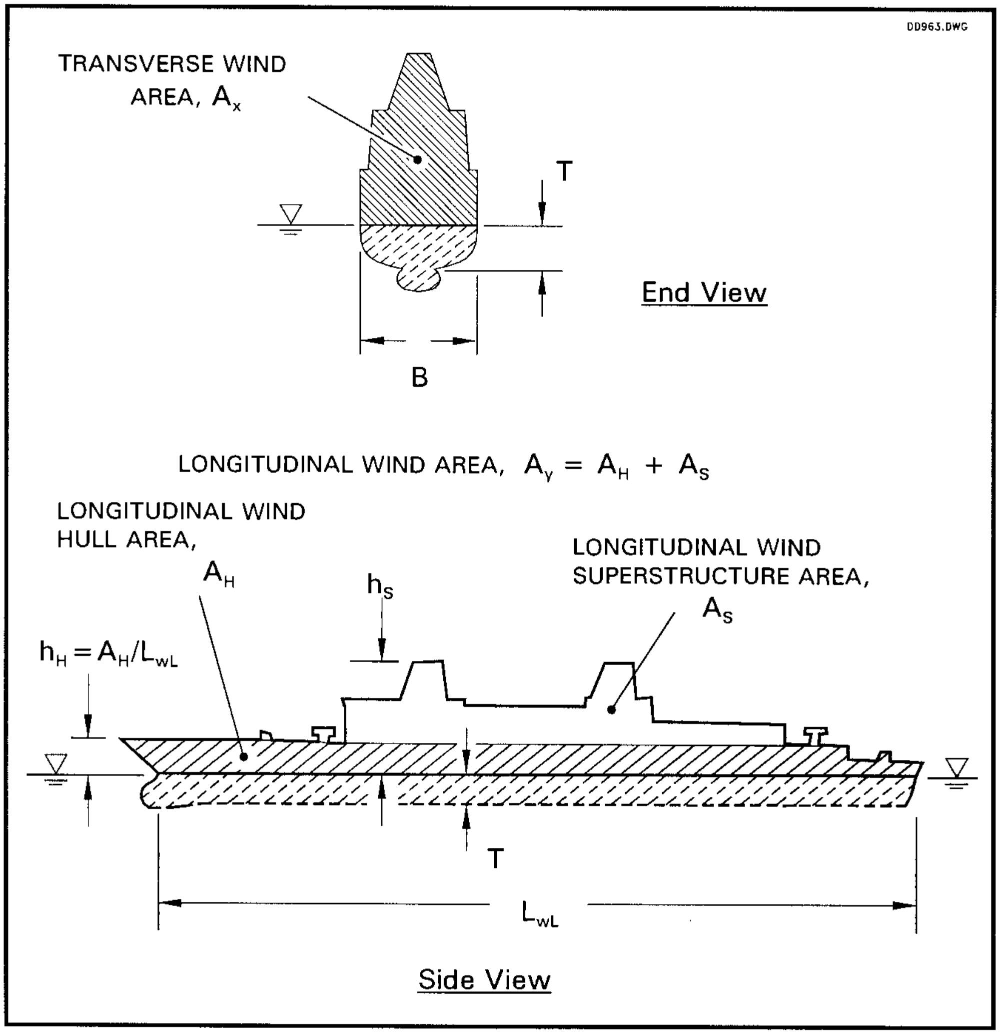


Figure 4-2 Local Coordinate System for a Ship

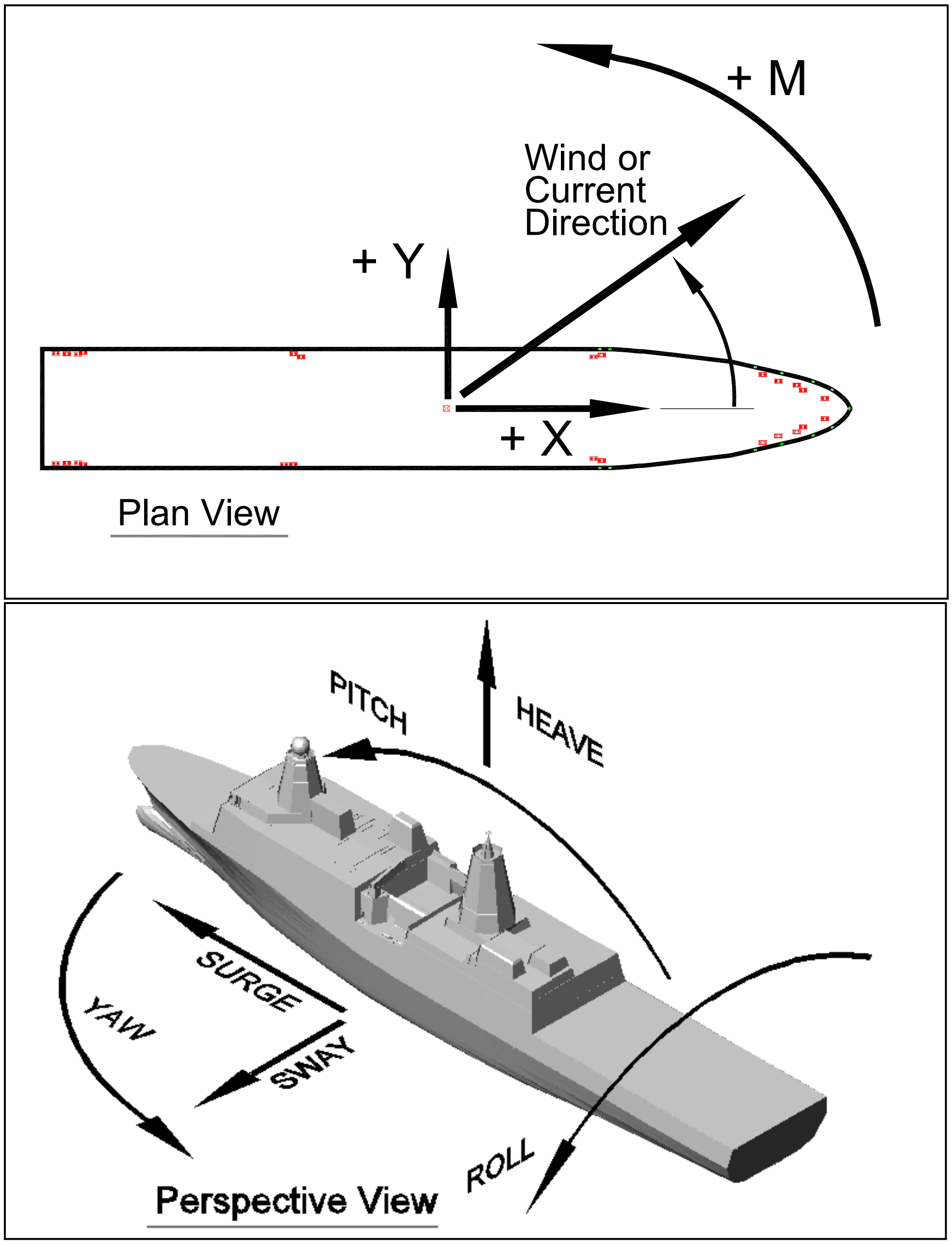


Figure 4-3 Sample Ship Profiles

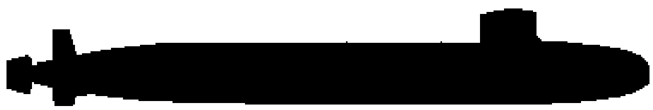
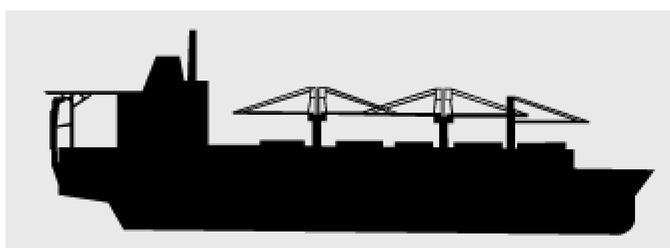
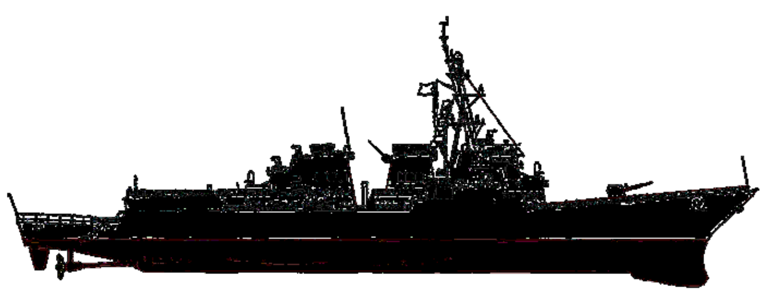
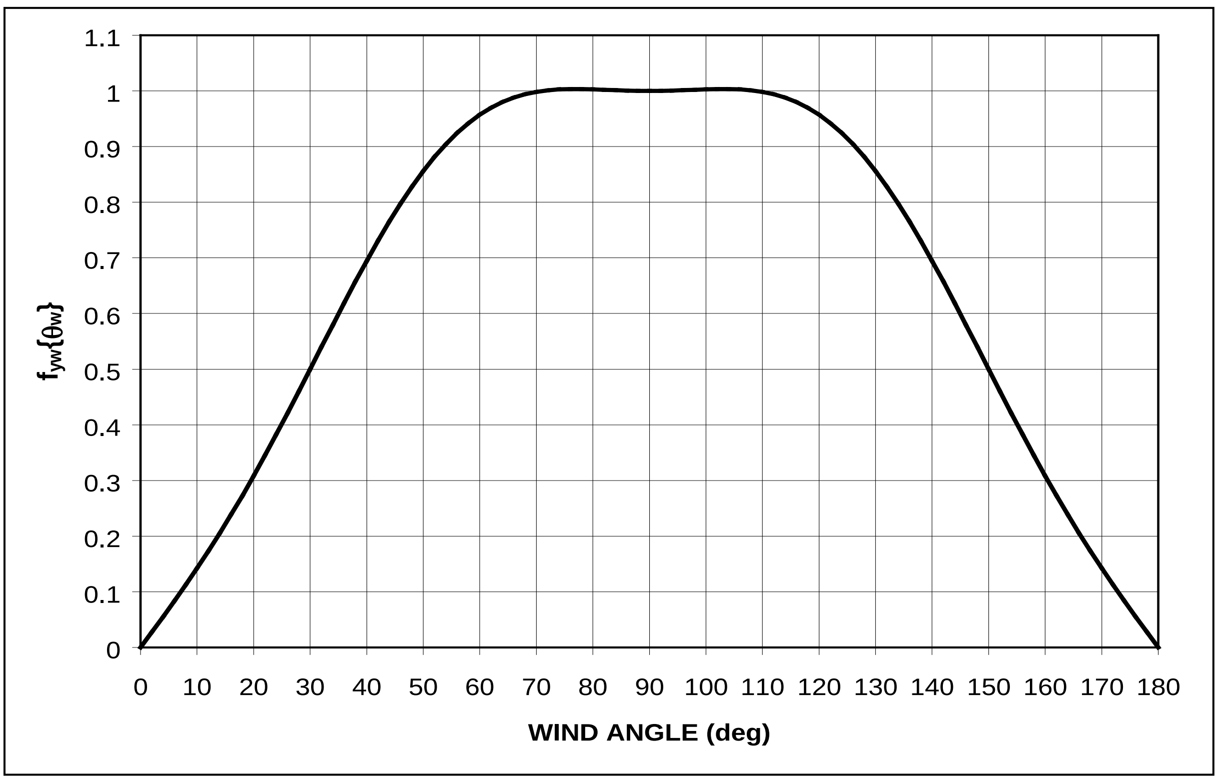
Hull Dominated
 **Aircraft Carrier (CVN)** single superstructure, aft of midships
 **Submarine (SSN, SSBN/SSGN)** single superstructure, forward of midships
Typical
 **Cargo** single superstructure, aft of midships
Extensive Superstructure
 **Destroyer, Cruiser (DDG, CG)** extensive superstructure, distributed

Figure 4-4 Shape Function for Transverse Wind Force

θ_w (deg)	$f_{wy}\{\theta_w\}$	θ_w (deg)	$f_{wy}\{\theta_w\}$
0	0.000	50	0.856
5	0.069	55	0.915
10	0.142	60	0.957
15	0.222	65	0.984
20	0.308	70	0.998
25	0.402	75	1.003
30	0.500	80	1.003
35	0.599	85	1.001
40	0.695	90	1.000
45	0.782	-	-



EXAMPLE: Find the transverse wind force drag coefficient on the destroyer shown in Figure 4-5.

SOLUTION: For this example, the transverse wind force drag coefficient from Equation 4-2 is:

$$C_{yw} = C\,\frac{\left[\left(\frac{0.5\,(23.9\,m + 6.43\,m)}{10\,m}\right)^{\frac{2}{7}}\,1203\,m^2 + \left(\frac{0.5\,(6.43\,m)}{10\,m}\right)^{\frac{2}{7}}\,1036.1m^2\right]}{2239\,m^2}$$

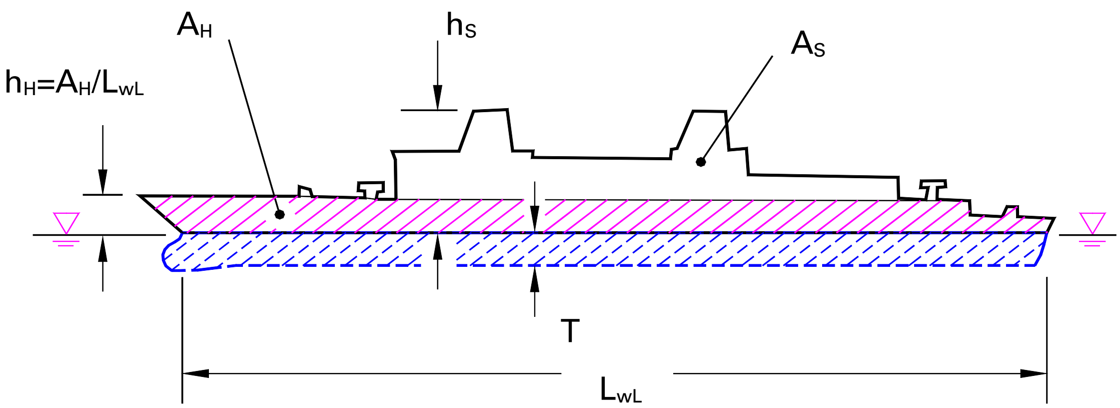
$$C_{yW} = 0.940\,C.$$

Destroyers have extensive superstructure, so a recommended value of C = 1.02 is used to give a transverse wind force drag coefficient of C_{yw} = 0.940 x 1.02 = 0.958.

For cases where an impermeable structure, such as a wharf, is immediately next to the moored ship, the exposed longitudinal wind area and resulting transverse wind force can be reduced. Figure 4-6 shows an example of a ship next to a wharf. For Case (A), wind from the water, there is no blockage in the transverse wind force and elevations of the hull and superstructure are measured from the water surface. For Case (B), wind from land, the longitudinal wind area of the hull can be reduced by the blocked amount and elevations of hull and superstructure can be measured from the wharf elevation.

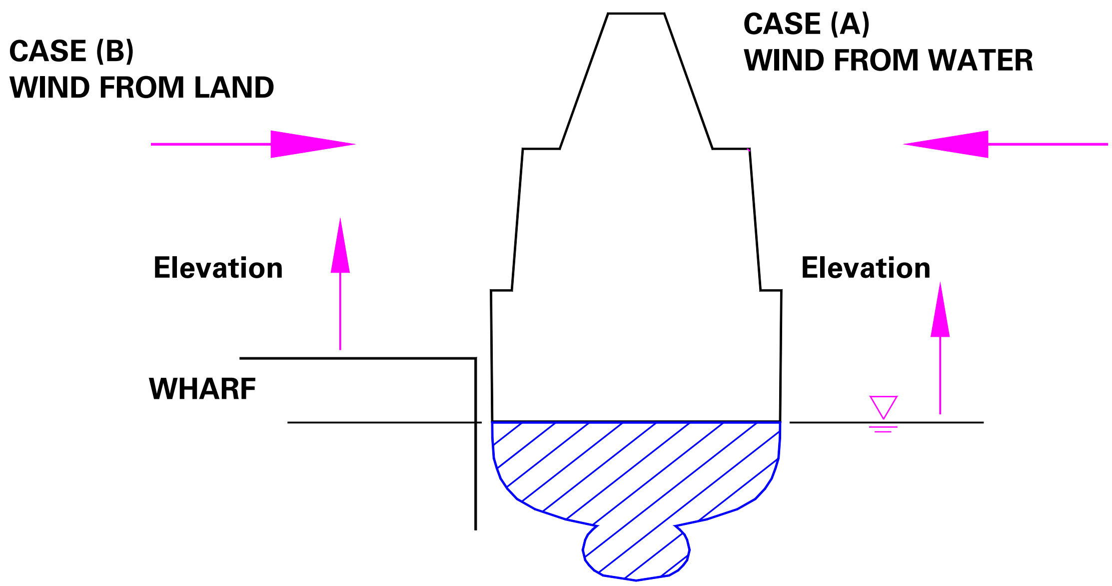
Cases of multiple ships are covered in Section 4-6, *Wind and Current Forces and Moments on Multiple Ships*.

Figure 4-5 Example Destroyer for Transverse Wind Coefficient Calculator



Parameter	Value	
	(English Units)	(SI Units)
L_{wL}	529 ft	161.2 m
A_Y	24,100 ft^2	2,239 m^2
A_H	11,152 ft^2	1,036 m^2
A_S	12,948 ft^2	1,203 m^2
$h_H = A_H/L_{wL}$	21.1 ft	6.43 m
h_S	78.4 ft	23.9 m

Figure 4-6 Blockage Effect for an Impermeable Structure Next to a Moored Ship



END VIEW

4-4.2 Static Longitudinal Wind Force.

The static longitudinal wind force on a vessel is defined as that component of wind force parallel to the centerline of the vessel. This is the force in the “X” or surge direction in Figure 4-2. Figure 4-1 shows the definition of winds areas.

The longitudinal force is determined from NCEL, TN-1628 using the equation:

Equation 4-4

$$F_{xw} = 0.5\, \rho_a\, V_w^2 A_x\, C_{xw}\, f_{xw}\, (\theta_w)$$

where,
F_{xw} = longitudinal wind force (N)
A_x = transverse projected area of the ship (m^2)
C_{xw} = longitudinal wind force drag coefficient
$f_{xw}(\theta_w)$ = shape function for longitudinal force

The longitudinal wind force drag coefficient, C_{xw}, depends on specific characteristics of the vessel. Additionally, the wind force drag coefficient varies depending on bow (C_{xwB}) or stern (C_{xwS}) wind loading. Types of vessels are given in three classes: hull dominated, normal, and excessive superstructure. Recommended values of longitudinal wind force drag coefficients are given in Table 4-3.

Table 4-3 Recommended Ship Longitudinal Wind Force Drag Coefficients

Vessel Type	C_{xwB}	C_{xwS}
Hull Dominated (aircraft carriers, submarines, passenger liners)	0.40	0.40
Normal [a]	0.70	0.60
Center-Island Tankers [a]	0.80	0.60
Significant Superstructure (destroyers, cruisers)	0.70	0.80

Note:
[a] An adjustment of up to +0.10 to C_{xwB} and C_{xwS} should be made to account for significant cargo or cluttered decks.

The longitudinal shape function also varies over bow and stern wind loading regions. As the wind direction varies from headwind to tailwind, there is an angle at which the force changes sine. This is defined as θ_x and is dependent on the location of the superstructure relative to midships. Recommended values of this angle are given in Table 4-4.

Table 4-4 Recommended Values of θ_x

Location of Superstructure	θ_x (deg)
Just forward of midships	100
On midships	90
Aft of midships (tankers)	80
Warships	70
Hull dominated	60

Shape functions are given for general vessel categories below:

CASE I: SINGLE DISTINCT SUPERSTRUCTURE:

The shape function for longitudinal wind load for ships with single, distinct superstructures and hull-dominated ships is given below (examples include aircraft carriers, submarines, tankers, and cargo vessels):

Equation 4-5

$$f_{xw}(\theta_W) = \cos(\phi)$$

$$\phi^- = \left(\frac{90^0}{\theta_x}\right)\theta_w \ \ for\ \theta_w < \theta_x$$

$$\phi^+ = \left(\frac{90^0}{180^0 - \theta_x}\right)(\theta_w - \theta_x) + 90^0 \ for\ \theta_w > \theta_x$$

θ_x = incident wind angle that produces no net longitudinal force (Table 4-4)

Values of $f_{xw}(\theta_w)$ are symmetrical about the longitudinal axis of the vessel. So when $\theta_w > 80^o$, use $360^o - \theta_w$ as θ_w in determining the shape function.

CASE II: DISTRIBUTED SUPERSTRUCTURE:

Equation 4-6

$$f_{xw}(\theta_w) = \frac{\left(\sin(\gamma) - \frac{\sin(5\gamma)}{10}\right)}{0.9}$$

$$\gamma^- = \left(\frac{90^0}{\theta_x}\right)\theta_w + 90^0 \;\; for\ \theta_w < \theta_x$$

$$\gamma^+ = \left(\frac{90^0}{180^0 - \theta_x}\right)(\theta_w) + \left(180^0 - \left(\frac{90^0\ \theta_x}{180^0 - \theta_x}\right)\right) \;\; for\ \theta_w > \theta_x$$

Values of $f_{xw}(\theta_w)$ are symmetrical about the longitudinal axis of the vessel. So when $\theta_w > 180^o$, use $\theta_w > 360^o$ as θ_w in determining the shape function. The maximum longitudinal wind force for these vessels occurs for wind directions slightly off the ship's longitudinal axis.

EXAMPLE: Find the longitudinal wind drag coefficient for a wind angle of 40° for the destroyer shown in Figure 4-5.

SOLUTION: For this destroyer, the following values are selected:

$\theta_x = 70^o$ from Table 4-4
$C_{xwB} = 0.70$ from Table 4-3
$C_{xwS} = 0.80$ from Table 4-3

This ship has a distributed superstructure and the wind angle is less than the crossing value, so Equation 4-6 is used to determine the shape function:

$$\gamma^- = \left(\frac{90^0}{70^0}\right)40^0 + 90^0 = 141.4^0$$

$$f_{xw}(\theta_w) = \frac{\left(\sin(141.4^0) - \frac{\sin(5 * 141.4^0\ )}{10}\right)}{0.9} = 0.72$$

At the wind angle of 40°, the wind has a longitudinal component on the stern. Therefore, the wind longitudinal drag coefficient for this example is:

$$C_{xw}\ f_{xw}\ (\theta_w) = 0.8 * 0.72 = 0.57$$

4-4.3 Static Wind Yaw Moment.

The static wind yaw moment is defined as the product of the associated transverse wind force and its distance from the vessel's center of gravity. In the local ship coordinate system, this is the moment about the "Z" axis. Wind yaw moment is determined from the equation:

Equation 4-7

$$M_{xyw} = 0.5\, \rho_a\, V_w^2\, A_y\, L\, C_{xyw}\,(\theta_w)$$

where,
A_y = longitudinal projected area of the ship (m^2)
L = length of ship (m)
C_{xyw} (θ_w) = normalized yaw moment coefficient
θ_w = wind angle (degrees)

The normalized yaw moment coefficient depends upon the vessel type. Equation 4-8 gives equations for computing the value of the yaw moment coefficient and Table 4-5 gives empirical parameter values for selected vessel types. The normalized yaw moment variables are found from:

Equation 4-8

$$C_{xyw}\,(\theta_w) = -a1 * \sin\left(\frac{\theta_w * 180°}{\theta_z}\right) \quad for\ 0 < \theta_w < \theta_z$$

$$C_{xyw}\,(\theta_w) = a2 * \sin[(\theta_w - \theta_z) * \lambda] \ for\ \theta_z \leq \theta_w < 180°$$

where,
C_{xyw} (θ_w) = normalized wind yaw moment coefficient
a1 = negative peak value (from Table 4-5)
a2 = positive peak value (from Table 4-5)
θ_w = wind angle (degrees)
θ_z = zero moment angle (degrees) (from Table 4-5)
λ = (180°) / (180° - θ_z)

Table 4-5 Normalized Wind Yaw Moment Variables

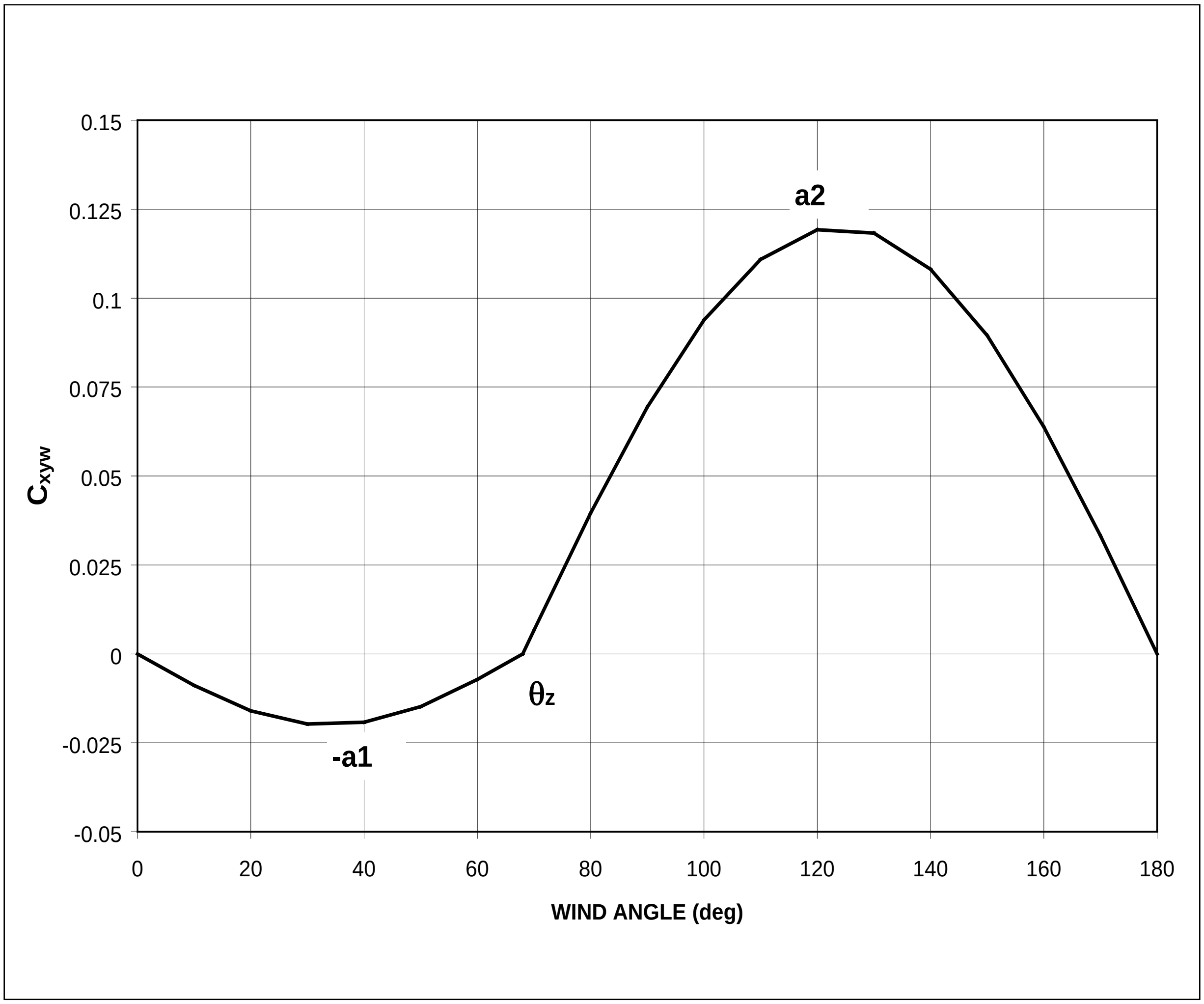
Ship Type	Zero Moment Angle (θ_z)	Negative Peak (a1)	Positive Peak (a2)	Notes
Liner	80°	0.075	0.14	
Carrier	90°	0.068	0.072	
Tanker	95°	0.077	0.07	Center island w/ cluttered deck
Tanker	100°	0.085	0.04	Center island w/ trim deck
Cruiser [a]	90°	0.064	0.05	outdated
Destroyer	68°	0.02	0.12	
Others:	130°	0.13	0.025	stern superstructure
	102°	0.096	0.029	aft midships superstructure
	90°	0.1	0.1	midships superstructure
	75°	0.03	0.05	forward midships superstructure
	105°	0.18	0.12	bow superstructure

Note:

[a] Modern Cruisers (CG) should be analyzed using the normalized wind yaw moment variables for the Destroyer (DDG) ship type.

A plot of the yaw normalized moment coefficient for the example shown in Figure 4-6 is given as Figure 4-7.

Figure 4-7 Example Normalized Yaw Wind Moment Coefficient



4-5 STATIC CURRENT FORCES/MOMENTS.

Methods to determine static current forces and moments on stationary moored vessels in the surge and sway directions and yaw moment are presented in this section. These planar directions are of primary importance in many mooring designs. Preferably, obtain current velocity from direct measurement at the specific site or from reliable local data. In the absence of this, refer to TR-NAVFAC-EXWC-CI-1901, *Revised Environmental Conditions for Mooring Service Types III and IV* to obtain current velocities at various installations.

4-5.1 Static Transverse Current Force.

The transverse current force is defined as that component of force perpendicular to the vessel centerline. If a ship has a large underkeel clearance, then water can freely flow under the keel, as shown in Figure 4-9 (a). If the underkeel clearance is small, as shown in Figure 4-9 (b), then the ship more effectively blocks current flow, and the transverse current force on the ship increases. These effects are considered and the transverse current force is determined from the equation:

Equation 4-9

$$F_{yc} = 0.5\, \rho_w\, V_c^2\, L_{wL}\, T\, C_{yc} \sin\theta_c$$

where,
ρ_w = *mass density of water (from Table 4-1)*
V_c = *current velocity (m/s)*
L_{wL} = *vessel waterline length (m)*
T = *average vessel draft (m)*
C_{yc} = *transverse current force drag coefficient*
θ_c = *current angle (degrees)*

The transverse current force drag coefficient as formulated in *Broadside Current Forces on Moored Ships*, Seelig et al. (1992) is shown in Figure 4-11. This drag coefficient can be determined from:

Figure 4-8 Examples of Ratios of Ship Draft (T) to Water Depth (d)

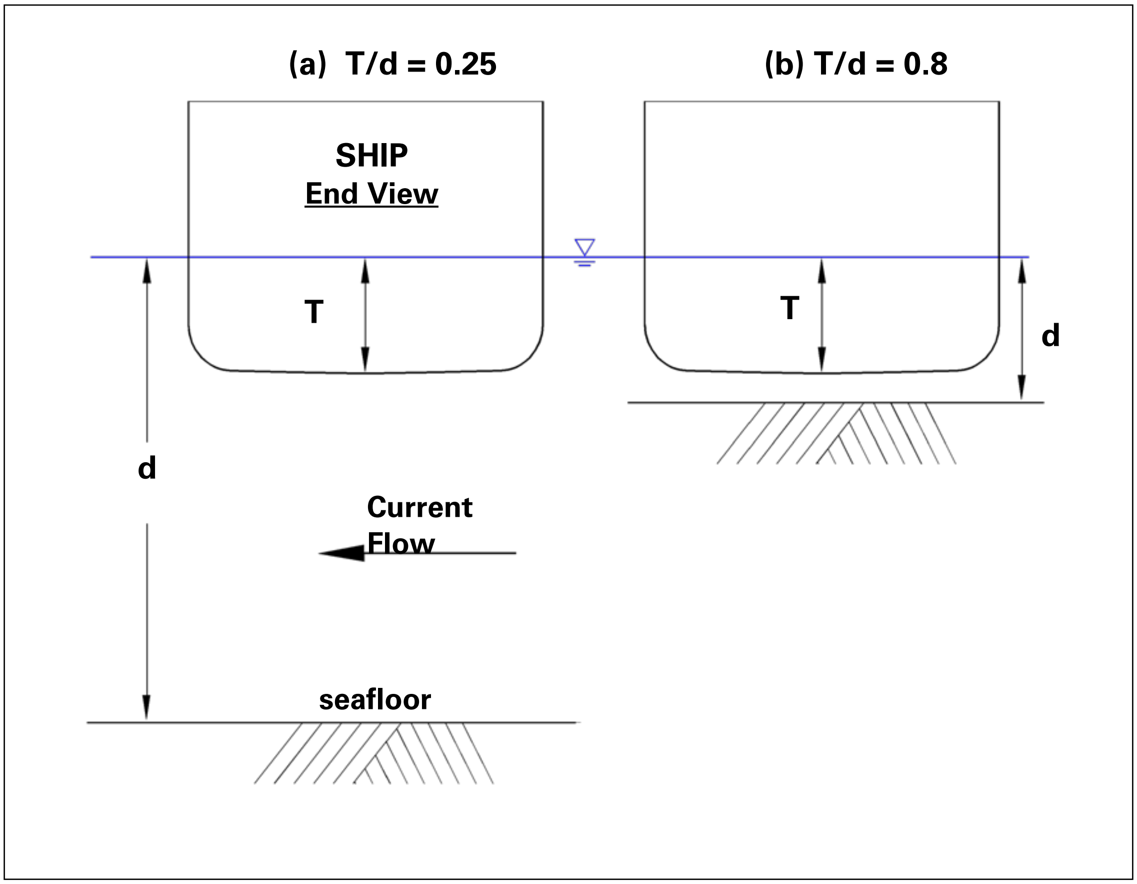
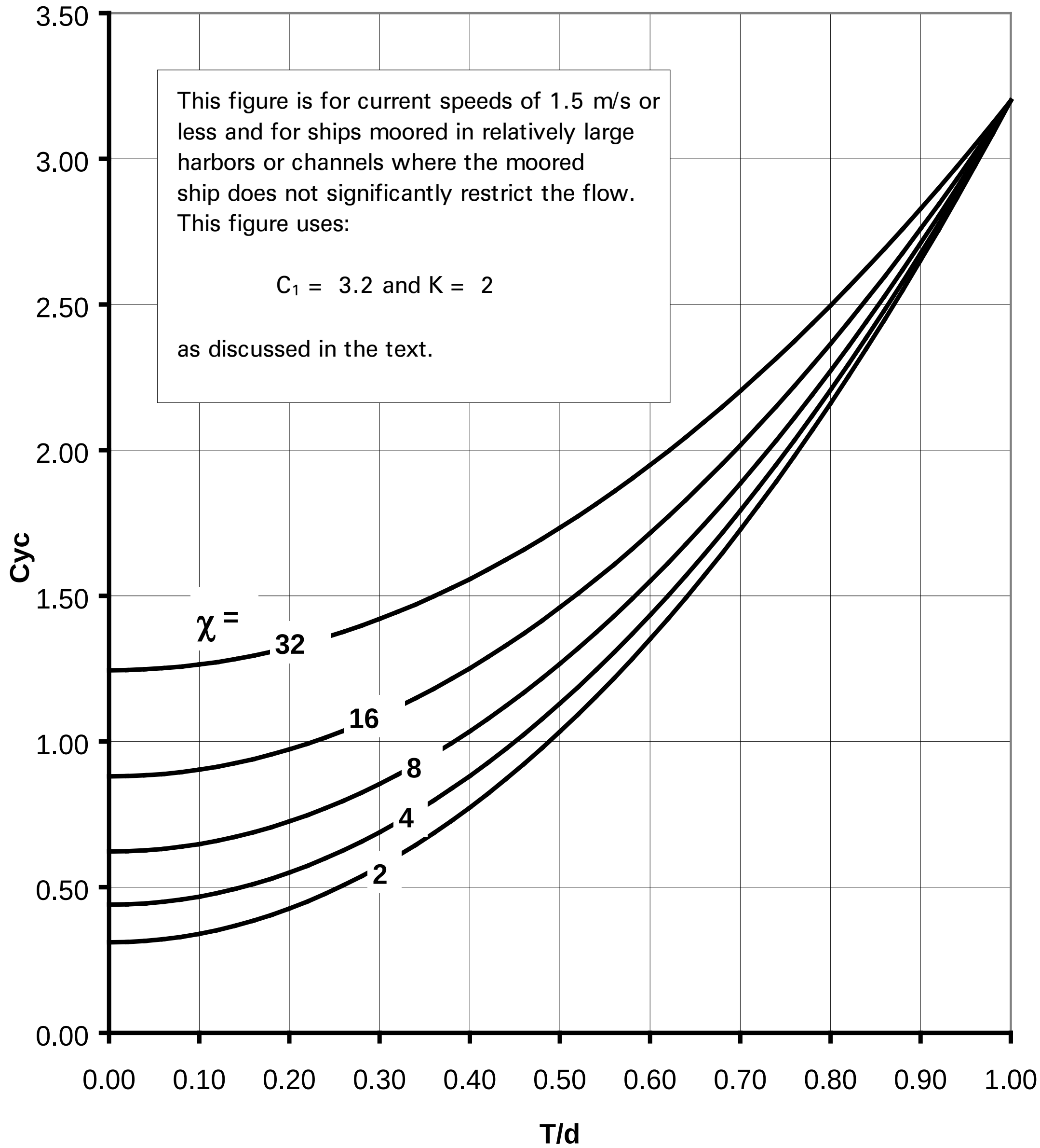


Figure 4-9 Broadside Current Drag Coefficient



Equation 4-10

$$C_{yc} = C_0 + (C_1 - C_0)\left(\frac{T}{d}\right)^K$$

C_0 = deepwater current force drag coefficient for T/d ≈ 0.0; this deepwater drag coefficient is estimated from:

Equation 4-11

$$C_0 = 0.22 * \sqrt{\chi}$$

χ is a dimensionless ship parameter calculated as:

Equation 4-12

$$\chi = L_{wL}^2 * \frac{A_m}{(B * V)}$$

where,
L_{wL} = is the vessel length at waterline (m)
A_m = is the immersed cross-sectional area of the ship at midsection (m^2)
B = is the beam (maximum ship width at the waterline) (m)
V = is the submerged volume of the ship, (m^3)
(which can be found by taking the displacement of the vessel divided by the unit weight of water, given in Table 4-1)
C_1 = shallow water current force drag coefficient
where T/d = 1.0; for currents of 4.9 ft/s (2.9 knots or 1.5 m/s) or less; C_1 = 3.2 is recommended
T = average vessel draft (m)
d = water depth (m)
K = dimensionless exponent; laboratory data from ship models shows:
K = 2 Wide range of ship and barge tests; most all of the physical model data available can be fit with this coefficient, including submarines
K = 3 from a small number of tests on a fixed cargo ship and for a small number of tests on an old aircraft carrier, CVE 55
K = 5 from a small number of tests on an old submarine hull, SS 212

The immersed cross-sectional area of the ship at midships, A_m, can be determined from:

Equation 4-13

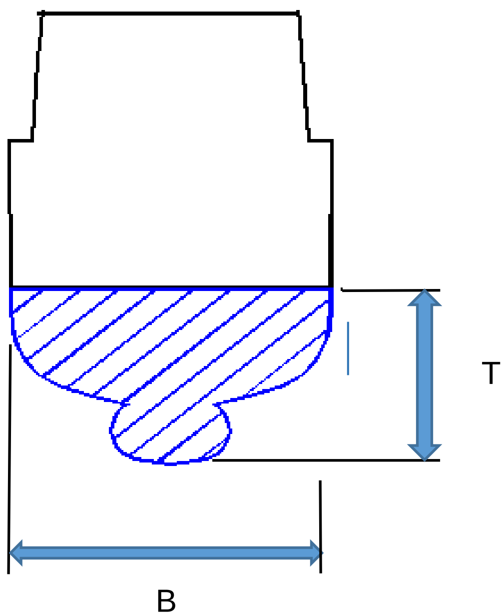
$$A_m = C_m * B * T$$

Midship coefficient, C_m is computed as follows:

Equation 4-14

C_m = Transverse area of vessel below waterline / (T*B), see Figure 4-10.

Figure 4-10 Midship Coefficient Diagram



The above methods for determining the transverse current force are recommended for normal design conditions with moderate current speeds of 4.9 ft/s (2.9 knots or 1.5 m/s) or less and in relatively wide channels and harbors (see Seelig et al., 1992).

If the vessel is moored broadside in currents greater than 4.9 ft/s (2.9 knots or 1.5 m/s), then scale model laboratory data show that there can be significant vessel heel/roll, which effectively increases the drag force on the vessel. In some model tests in shallow water and at high current speeds this effect was so pronounced that the model ship capsized. Mooring a vessel broadside in a high current should be avoided, if possible.

Scale physical model tests show that a vessel moored broadside in a restricted channel has increased current forces. This is because the vessel decreases the effective flow area of a restricted channel, which causes the current speed and current force to increase.

For specialized cases where:

- vessels are moored in current of 5 ft/s (3 knots or 1.5 m/s) or more, and/or
- for vessels moored in restricted channels then the designer should contact NAVFAC EXWC.

Full-scale measurements with a floating dry dock show the transverse current force equations should also be used to compute the longitudinal drag forces for vessels with a high block coefficient.

EXAMPLE: Find the current force on an FFG 7 vessel produced by a current of θ_c = 90 degrees to the ship centerline with a speed of 4.9 ft/s (2.9 knots or 1.5 m/s) in salt water for a given ship draft. At the mooring location, the harbor has a cross-sectional area much larger than the submerged ship longitudinal area, $L_{wL} * T$.

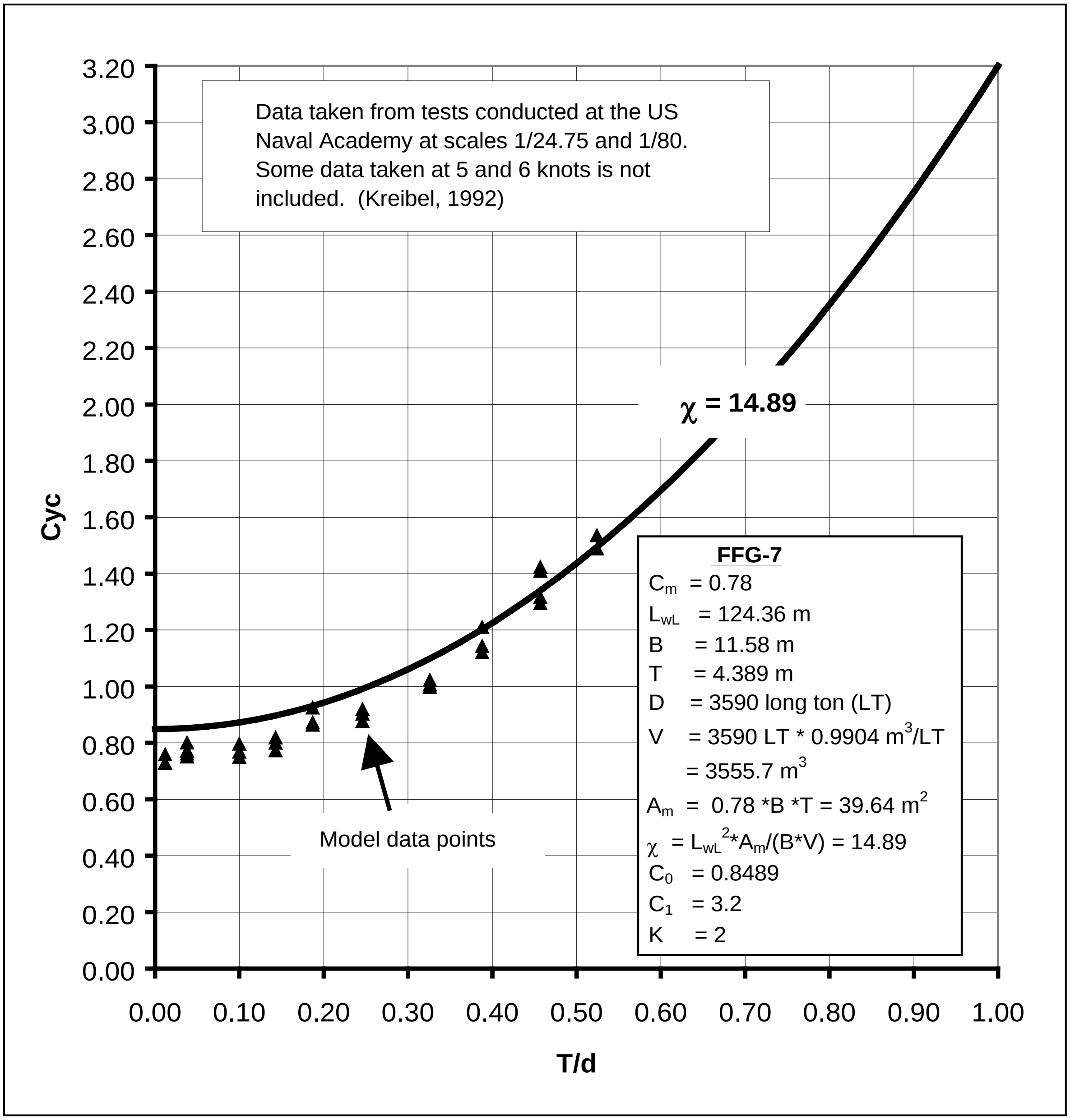
SOLUTION: Dimensions and characteristics of this vessel are summarized in the lower right portion of Figure 4-11. Transverse current drag coefficients predicted using Equation 4-10 are shown on this figure as a solid bold line. Physical scale model data (U.S. Naval Academy (USNA), EW-9-90, *Evaluation of Viscous Damping Models for Single Point Mooring Simulation)* are shown as symbols in the drawing, showing that Equation 4-10 provides a reasonable estimate of drag coefficients. Predicted current forces for this example are given in Table 4-6.

Table 4-6 Predicted Transverse Current Forces on FFG 7 for a Current Speed of 1.5 m/s (2.9 knots)

T/d	d ft (m)	F_{yc} kips (kN)
0.096	150 (45.7)	123 (547)
0.288	50 (15.2)	148 (658)
0.576	25 (7.6)	231 (1,028)
0.72	20 (6.1)	293 (1,303)
0.96	15 (4.6)	427 (1,899)

This example shows that in shallow water the transverse current force can be three times or larger than in deep water for an FFG 7.

Figure 4-11 Example of Transverse Current Drag Coefficients



4-5.2 Static Longitudinal Current Force for Ships.

The longitudinal current force is defined as that component of force parallel to the centerline of the vessel. This force is determined for streamlined ship-shaped vessels from the following equation (Naval Civil Engineering Laboratory (NCEL), TN-1634, *STATMOOR – A Single-Point Mooring Static Analysis Program)*:

Equation 4-15

$$F_{xc} = F_{xForm} + F_{xFriction} + F_{xProp}$$

where,
F_{xForm} = *longitudinal current load due to form drag (N)*
$F_{xFriction}$ = *longitudinal current load due to skin friction (N)*
F_{xProp} = *longitudinal current load due to propeller drag (N)*

Equation 4-16

$$F_{xFORM} = 0.5\, \rho_w\, V_C^2\, B\, T\, C_{xcb} \cos(\theta_c)$$

where,
ρ_w = *mass density of water, from Table 4-1*
V_c = *current speed (m/s)*
B = maximum vessel width at the waterline (m)
T = average vessel draft (m)
C_{xcb} = *longitudinal current form drag coefficient = 0.1*
θ_c = *current angle (degrees)*

Equation 4-17

$$F_{xFriction} = 0.5\, \rho_w\, V_C^2\, S\, C_{xca} \cos(\theta_c)$$

where,
S = wetted surface area (m^2); estimated

Equation 4-18

$$S = 1.7\, T\, L_{wL} + \left(\frac{D}{T\, \gamma_w}\right)$$

where,
T = average vessel draft (m)
L_{Wl} = *waterline length of vessel (m)*
D = ship displacement (N)
γ_w = *weight density of water, from Table 4-1*
C_{xca} = *longitudinal skin friction coefficient, estimated using:*

Equation 4-19

$$C_{xca} = \frac{0.075}{\left((\log_{10} R_N\,) - 2\right)^2}$$

Equation 4-20

$$R_N = \left| \frac{V_c \, L_{wL} \cos(\theta_c)}{\nu} \right|$$

where,
R_N = Reynolds Number
ν = kinematic viscosity of water, from Table 4-1

Equation 4-21

$$F_{xProp} = 0.5 \, \rho_w \, V_C^2 \, A_p \, C_{Prop} \cos(\theta_c)$$

where,
ρ_w = mass density of water, from Table 4-1
A_p = propeller expanded blade area (m^2)
C_{Prop} = propeller drag coefficient = 1.0

Equation 4-22

$$A_p = \frac{A_{Tpp}}{0.838}$$

A_{Tpp} = total projected propeller area (m^2) for an assumed propeller pitch ratio of p / d = 1.0

Equation 4-23

$$A_{Tpp} = \frac{L_{wL} \, B}{A_R}$$

A_R is a dimensionless area ratio for propellers. Typical values of this parameter for major vessel groups are given in Table 4-6. For vessels using water jets or other propulsors that are built into the hull, use A_R = 99999, or eliminate the longitudinal current load due to propeller drag F_{xPROP} from Equation 4-15.

Table 4-7 A_R for Major Vessel Groups

Ship	Area Ratio, A_R
Destroyer	100
Cruiser	160
Carrier	125
Cargo	240
Tanker	270
Submarine	125

In these and all other engineering calculations discussed in this UFC, the user must be careful to keep units consistent.

EXAMPLE: Find the longitudinal current force with a bow-on current of θ_c=180 degrees with a current speed of 3 knots (1.544 m/s) on a destroyer in salt water with the characteristics shown in Table 4-8.

SOLUTION: Figure 4-11 shows the predicted current forces. These forces are negative, since the bow-on current is in a negative "X" direction. For this destroyer, the force on the propeller is approximately two-thirds of the total longitudinal current force. For commercial ships, with relatively smaller propellers, form and friction drag produce a larger percentage of the current force.

Table 4-8 Example Destroyer

Parameter	English Units	SI Units
L_{wL}	529 ft	161.2 m
T	21 ft	6.4 m
B	55 ft	16.76 m
D, ship displacement	7810 long tons	7.93E6 kg
$C_{m;}$ estimated	0.83	0.83
S; est. from Equation 4-18	31,897 ft^2	2,963 m^2
A_R; from Table 4-8	100	100
R_N; from Equation 4-20	2.09×10^8	2.09×10^8
C_{xca}; est. from Equation 4-19	0.00188	0.00188
Ap; est. from Equation 4-22	347.2 ft^2	32.256 m^2

Table 4-9 Example Longitudinal Current Forces on a Destroyer

Force	English Units (kip)	SI Units (kN)	Percent of Total Force
F_{xForm}; Equation 4-16	-2.95	-13.1	22%
$F_{xFriction}$; Equation 4-17	-1.53	-6.8	12%
F_{xProp}; Equation 4-21	-8.87	-39.4	66%
Total F_{xc} =	-13.4	-59.4	100%

4-5.3 Static Longitudinal Current Force for Blunt Vessels.

The methods in Section 4-5.2, *Static Longitudinal Current Force for Ships* are inappropriate for very blunt-bow vessels, such as floating dry docks. For blunt-bow vessels use the methods and equations in the paragraph entitled "Static Transverse Current Force" for the longitudinal current force on the hull. In this case use the appropriate parameters as input.

For example, take the case of a floating dry dock 180 ft (55 m) wide with a draft of 67 ft (20.4 m) moored in a water depth of 70 ft (21.3 m). A current of 1.2 knots (2.33 m/s) is predicted (using methods in the paragraph entitled "Static Transverse Current Force") to produce a longitudinal current force of 144.9 kips (72.45 Tons) on this floating dry dock. Full-scale measurements were made on the actual dry dock for this case and the measured longitudinal force was 143 kips (71.5 Tons), approximately 1% lower than predicted.

4-5.4 Static Current Yaw Moment.

The current yaw moment is defined as that component of moment acting about the vessel's vertical "Z"-axis. This moment is determined from the equation:

Equation 4-24

$$M_{xyc} \qquad = F_{yc} \left(\frac{e_c}{L_{wL}}\right) L_{wL}$$

where,
F_{yc} = transverse current force (N)
e_c/L_{wL} = ratio of eccentricity to vessel waterline length
e_c = eccentricity of F_{yc} (m)
L_{wL} = vessel waterline length (m)

The eccentricity ratio e_c/L_{wL} is calculated by choosing the slope and y-intercept variables from Table 4-10 which are a function of the vessel hull. The eccentricity ratio is a dimensionless moment arm that is dependent upon the current angle to the vessel, as shown in Equation 4-25 and Equation 4-26:

Equation 4-25

$$\frac{e_c}{L_{wL}} = a + b * \theta_c \ \ for\ \theta_c = 0^0\ to\ 180^0$$

Equation 4-26

$$\frac{e_c}{L_{wL}} = a + (b * (360^0 - \theta_c)\,)\ for\ \theta_c = 180^0\ to\ 360^0$$

where,
a = y-intercept (refer to Table 4-10) (dimensionless)
b = slope per degree (refer to Table 4-10)
θ_c = current angle (degrees)

The above methods for determining the eccentricity ratio are recommended for normal design conditions with moderate current speeds of less than 1.5 m/s (3 knots or 5 ft/s). Values provided in Table 4-10 are based upon least squares fit of scale model data taken for the case of ships with level keels. Data are not adequately available for evaluating the effect of trim on the current moment.

Table 4-10 Current Moment Eccentricity Ratio Variables

Ship	a, Y-Intercept	b, Slope per Degree	Notes
SERIES 60	-0.291	0.00353	Full hull form typical of cargo ships
FFG	-0.201	0.00221	“Rounded” hull typical of surface warships
CVE 55	-0.168	0.00189	Old attack aircraft carrier
SS 212	-0.244	0.00255	Old submarine

4-6 WIND AND CURRENT FORCES AND MOMENTS ON MULTIPLE SHIPS.

If ships are moored in close proximity to one another then the nearby ship(s) can influence the forces/moments on a given ship. The best information available on the effects of nearby ships is results from physical model tests, because the physical processes involved are highly complex. NFESC Report TR-6003-OCN provides scale model test results of wind and current forces and moments for multiple identical ships. From two to six identical ships were tested and the test results were compared with test results from a single ship. Data are provided for aircraft carriers, destroyers, cargo ships, and submarines.

Cases included in NFESC Report TR-6003-OCN include: individual ships, ships in nests and ships moored on either side of piers. Results are provided for the effects of winds and currents in both tabular and graphical form.

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CHAPTER 5 DESIGN PROCEDURES ANCHOR SYSTEM

5-1 GENERAL ANCHOR DESIGN PROCEDURE.

Anchor systems ultimately hold the mooring loads in fleet mooring systems. Anchors are used on both ships and in mooring facilities, so selection and design of anchors are included in this section.

The type and size of anchor specified depends upon certain parameters, such as those shown in Table 5-1.

The most commonly used anchors in DoD moorings are drag-embedment anchors and driven-plate anchors, so they will be discussed here. Other types of specialized anchors (shallow foundations, pile anchors, propellant-embedment anchors, rock bolts, etc.) are discussed in the NCEL *Handbook for Marine Geotechnical Engineering*.

Figure 5-1 and Figure 5-2 illustrate typical drag-embedment anchors. Figure 5-3 illustrates a driven-plate anchor. Some characteristics of these two categories of anchors are given in Table 5-2.

Table 5-1 Anchor Specification Considerations

Parameter	Description
Holding capacity	The size/type of anchor will depend on the amount of anchor holding required.
Soils	Engineering properties and sediment layer thickness influence anchor design.
Use	If anchors will be relocated, then drag anchors are most commonly used.
Weight	The amount of weight that can be handled or carried may control anchor specification.
Equipment	The size and characteristics of installation equipment are important in anchor specification.
Directionality	Drag anchors may provide little uplift capacity and primarily hold in one direction; driven plate anchors provide high omni directional capacity.
Performance	Whether anchor will be allowed to drag or not, as well as the amount of room available for anchors systems, will influence anchor specification.

Figure 5-1 Example of a Drag-Embedment Anchor (Stabilized Stockless Anchor)

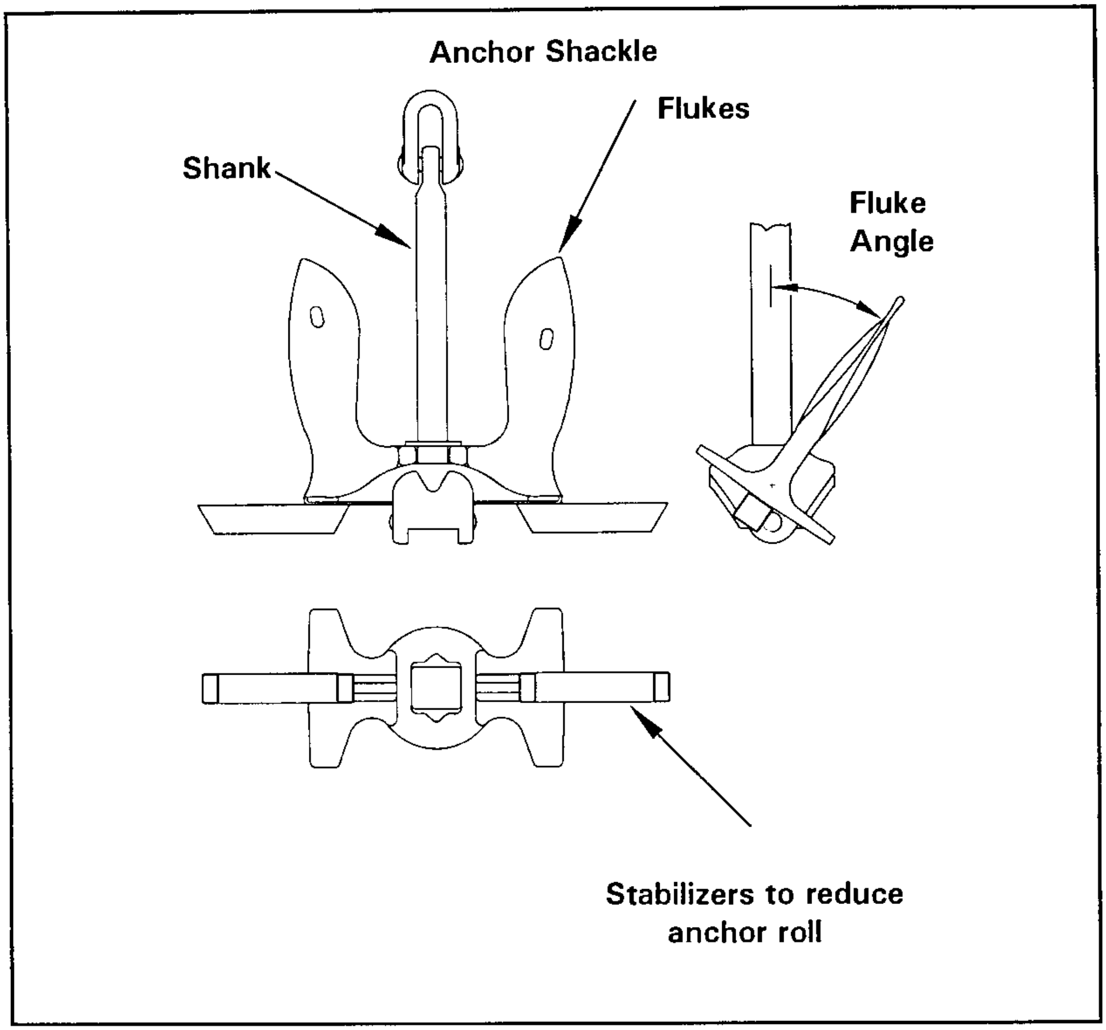


Figure 5-2 Example of a Drag-Embedment Anchor (NAVMOOR Anchor)

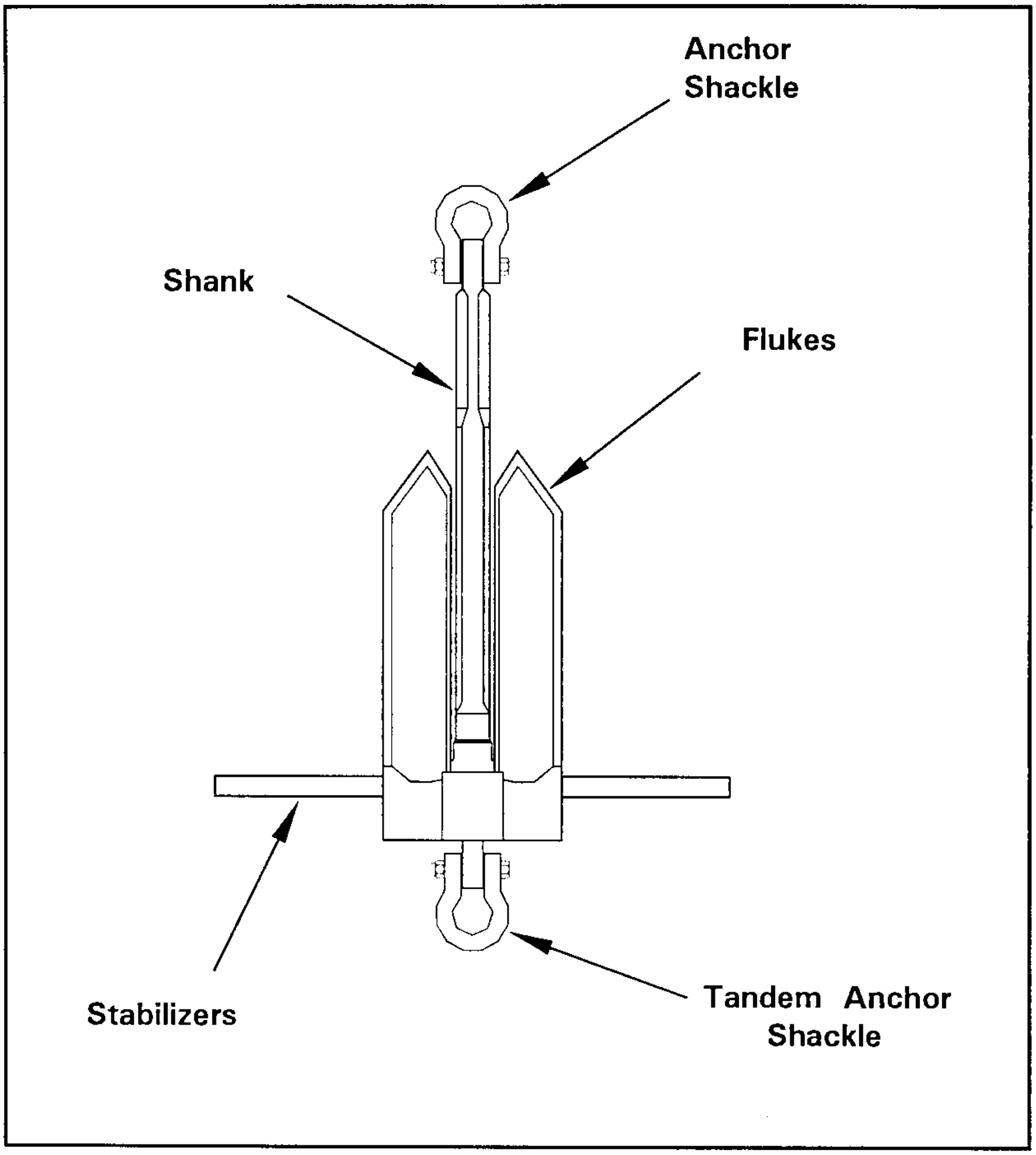
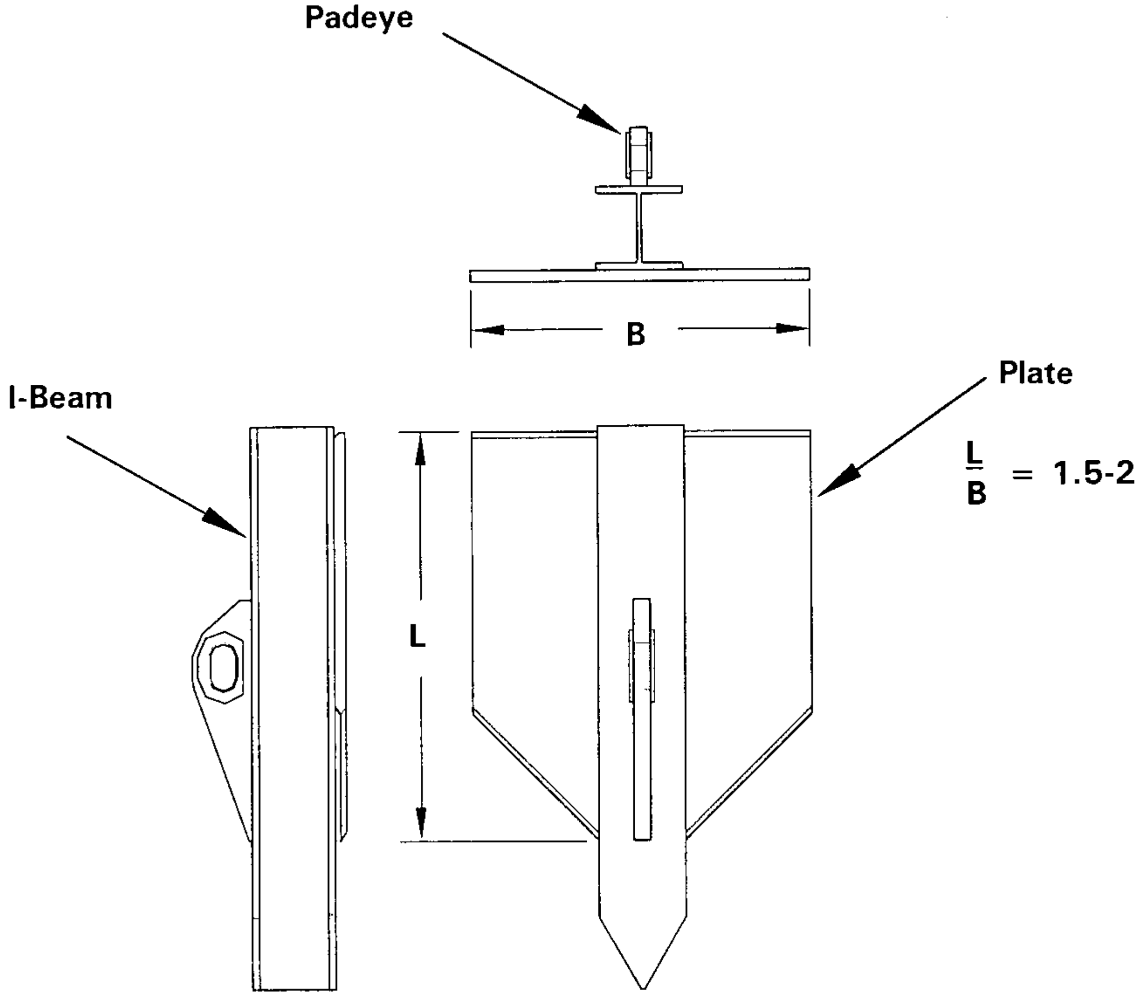


Figure 5-3 Driven-Plate Anchor



Keying flaps (not shown) can be added to the back of the anchor, opposite the padeye, to decrease the keying distance in cohesive soils (mud).

Table 5-2 Anchor Characteristics

(a) Drag-Embedment Anchors

Characteristics	Notes
Many basic designs and sizes are available from manufacturers.	NAVMOOR-10 & -15 and stockless of 20 to 30 kips (89 to 133.5 kN) are stocked by NAVFAC EXWC.
Works primarily in one horizontal direction.	Enough scope of chain and/or wire rope needs to be provided to minimize uplift forces, which can pull the anchor out. If a load is applied to a drag anchor at a horizontal axis off the centerline of the anchor, then the anchor may drag and reset.
Flukes should be set for the soil type.	Anchor performance depends on the soil type. Fixing the maximum angle of the fluke will help ensure optimum performance. For mooring installations, the flukes should be fixed open and stabilizers added for stockless anchors to help prevent overturning.
Adequate sediment required.	Sand layer thickness needs to be approximately one fluke length and mud needs to be 3 to 5 fluke lengths thick.
May not work in all seafloor types.	May be unreliable in very hard clay, gravel, coral, or rock seafloors; and in highly layered seafloors.
May not work well for sloping seafloors.	If the seafloor has a slope of more than several degrees, then the anchor may not hold reliably in the down-slope direction.
Anchor can drag.	If the anchor is overloaded at a slow enough rate, then the anchor can drag, which reduces the peak load. Anchor dragging can be a problem if the room for mooring is restricted. If adequate room is available, then anchor drag can help prevent failure of other mooring components.
Anchors can be reused.	Drag-embedment anchors can be recovered and reused.
Proof loading recommended.	Pulling the anchor at the design load in the design direction will help set the anchor and assure that the soil/anchor interaction provides adequate holding.

(b) Driven-Plate Anchors

Characteristics	Notes
Size and design of anchor are selected to provide adequate holding, to allow driving, and to provide adequate structural capacity.	These anchors have been used in a variety of soils from soft mud to hard coral. A driving analysis is recommended for hard soil, because the anchor must be able to be driven in order to work.
Multi-directional.	Can be used on short scope, since the anchor resists uplift forces. One plate anchor may be used to replace several drag anchor legs, since the anchors are multi-directional.
Anchors designed for the soil type.	Anchors designed for the soil engineering characteristics at the site.
Adequate sediment required.	A minimum of several fluke lengths of sediment is required to provide for keying and allow the anchor to hold (NFESC TR-2039-OCN, *Design Guide for Pile-Driven Plate Anchors*).
Anchor is fixed.	The anchor will not drag, so this type of anchor is well suited to locations with limited mooring area available. The anchors cannot be recovered or inspected.
Proof loading recommended.	Pulling the anchor at the design load in the design direction will help key the anchor and assure that the soil/anchor interaction provides adequate holding.
Installation equipment.	Mobilization can be expensive, so installing a number of anchors at a time reduces the unit installation cost.

5-2 DRAG-EMBEDMENT ANCHOR SPECIFICATION.

Drag-embedment anchors are carried on ships and used in many fleet-mooring facilities. Key considerations in selecting an anchor are: soil type, anchoring holding capacity, anchor weight, anchor stowage, cost, availability, and installation assets. In SI units the anchor mass is used to characterize anchor size, while in U.S. customary units the anchor weight as a force is used.

Drag-embedment anchor holding capacities have been measured in full-scale tests, modeled in the laboratory, and derived from soil analyses. Empirical anchor holding curves were developed from this information (Naval Civil Engineering Laboratory (NCEL), TDS 83-08R, *Drag Embedment Anchors for Navy Moorings*). Predicted static ultimate anchor holding is given by:

Equation 5-1

$$H_M = H_R \left(\frac{W_A}{W_R}\right)^b$$

where,
H_M = ultimate anchor system static holding capacity (kips or kN)
H_R = reference static holding capacity
W_A = weight of the anchor in air (for SI units use anchor weight in kilograms; U.S. units use anchor weight in pounds force)
W_R = reference anchor weight in air (for SI units use 4,536 kg; U.S. units use 10,000 lbf)
b = exponent

Values of H_R and b depend on the anchor and soil types. Values of these parameters are given in U.S. customary units in Table 5-3 and for SI units in Table 5-4.

Figure 5-4 and Figure 5-5 give holding capacities of selected anchors for mud and sand seafloors.

Table 5-3 Drag Anchor Holding Parameters U.S. Customary

Anchor Type (*a*)	SOFT SOILS (Soft clays and silts)		HARD SOILS (Sands and stiff clays)	
	H_R (kips)	b	H_R (kips)	b
Boss	210	0.94	270	0.94
BRUCE Cast	32	0.92	250	0.8
BRUCE Flat Fluke Twin Shank	250	0.92	*(c)*	*(c)*
BRUCE Twin Shank	189	0.92	210	0.94
Danforth	87	0.92	126	0.8
Flipper Delta	139	0.92	*(c)*	*(c)*
G.S. AC-14	87	0.92	126	0.8
Hook	189	0.92	100	0.8
LWT (Lightweight)	87	0.92	126	0.8
Moorfast	117	0.92 *(i)*	60 100 *(d)*	0.8 0.8
NAVMOOR	210	0.94	270	0.94
Offdrill II	117	0.92 *(i)*	60 100 *(d)*	0.8 0.8
STATO	210	0.94	250 *(e)* 190 *(f)*	0.94 0.94
STEVDIG	139	0.92	290	0.8
STEVFIX	189	0.92	290	0.8
STEVIN	139	0.92	165	0.8
STEVMUD	250	0.92	*(g)*	*(g)*
STEVPRIS (straight shank)	189	0.92	210	0.94
Stockless (fixed fluke)	46	0.92	70 44 *(h)*	0.8 0.8
Stockless (movable fluke)	24	0.92	70 44 *(h)*	0.8 0.8

(a) Fluke angles set for 50 deg in soft soils and according to manufacturer's specifications in hard soils, except when otherwise noted.
(b) "b" is an exponent constant.
(c) No data available.
(d) For 28-deg fluke angle.
(e) For 30-deg fluke angle.
(f) For dense sand conditions (near shore).
(g) Anchor not used in this seafloor condition.
(h) For 48-deg fluke angle.
(i) For 20-deg fluke angle (from API 2SK effective March 1, 1997).

Table 5-4 Drag Anchor Holding Parameters SI Units

Anchor Type (*a*)	SOFT SOILS (Soft clays and silts)		HARD SOILS (Sands and stiff clays)	
	H_R (kN)	b	H_R (kN)	b
Boss	934	0.94	1201	0.94
BRUCE Cast	142	0.92	1112	0.8
BRUCE Flat Fluke Twin Shank	1112	0.92	*(c)*	*(c)*
BRUCE Twin Shank	841	0.92	934	0.94
Danforth	387	0.92	560	0.8
Flipper Delta	618	0.92	*(c)*	*(c)*
G.S. AC-14	387	0.92	560	0.8
Hook	841	0.92	445	0.8
LWT (Lightweight)	387	0.92	560	0.8
Moorfast	520	0.92 *(i)*	267 445 *(d)*	0.8 0.8
NAVMOOR	934	0.94	1201	0.94
Offdrill II	520	0.92 *(i)*	267 445 *(d)*	0.8 0.8
STATO	934	0.94	1112 *(e)* 845 *(f)*	0.94 0.94
STEVDIG	618	0.92	1290	0.8
STEVFIX	841	0.92	1290	0.8
STEVIN	618	0.92	734	0.8
STEVMUD	1112	0.92	*(g)*	*(g)*
STEVPRIS (straight shank)	841	0.92	934	0.94
Stockless (fixed fluke)	205	0.92	311 196 *(h)*	0.8 0.8
Stockless (movable fluke)	107	0.92	311 196 *(h)*	0.8 0.8

(a) Fluke angles set for 50 deg in soft soils and according to manufacturer's specifications in hard soils, except when otherwise noted.
(b) "b" is an exponent constant.
(c) No data available.
(d) For 28-deg fluke angle.
(e) For 30-deg fluke angle.
(f) For dense sand conditions (near shore).
(g) Anchor not used in this seafloor condition.
(h) For 48-deg fluke angle.
(i) For 20-deg fluke angle (from API 2SK effective March 1, 1997).

Figure 5-4 Anchor System Holding Capacity in Cohesive Soil (Mud)

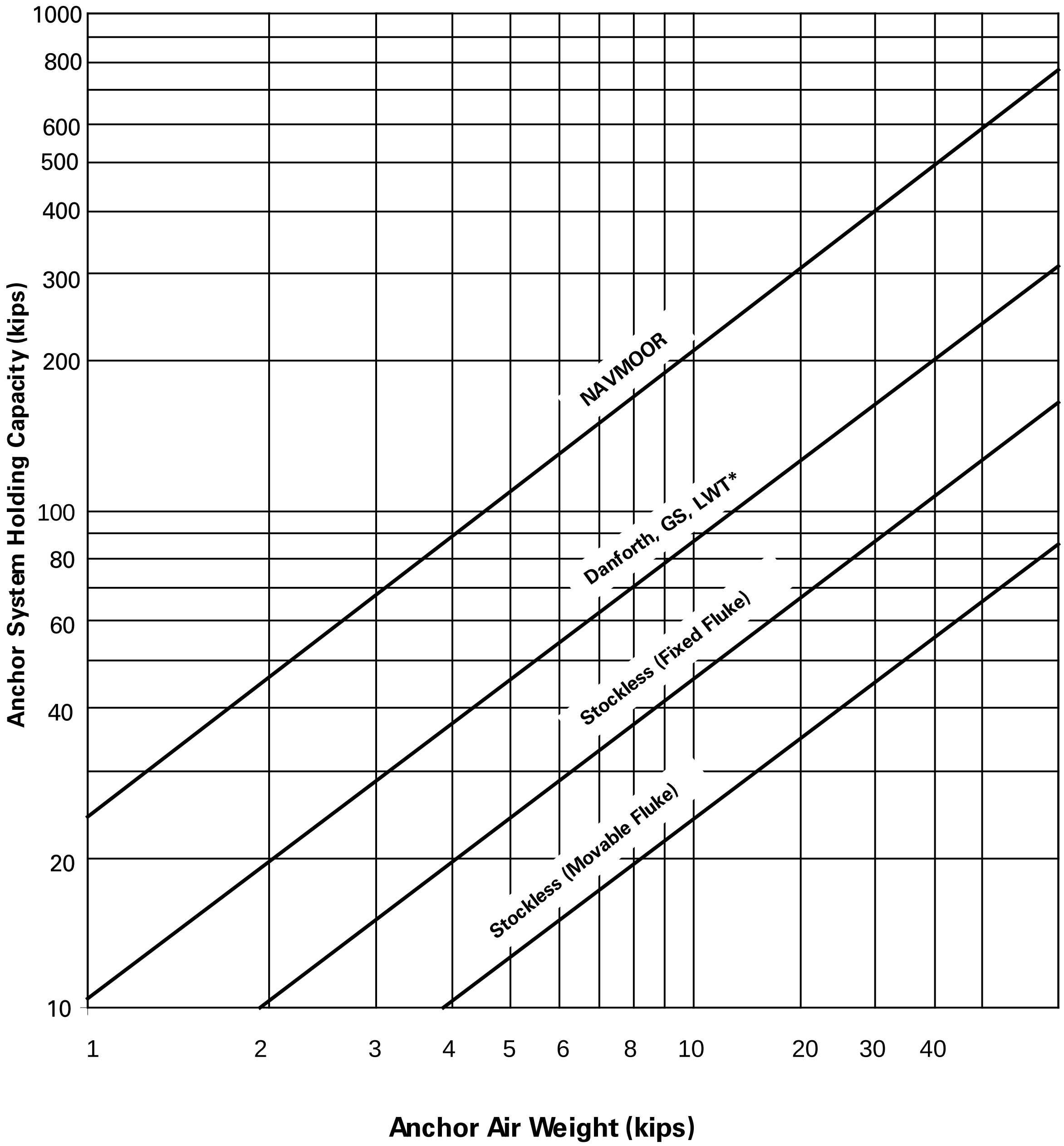
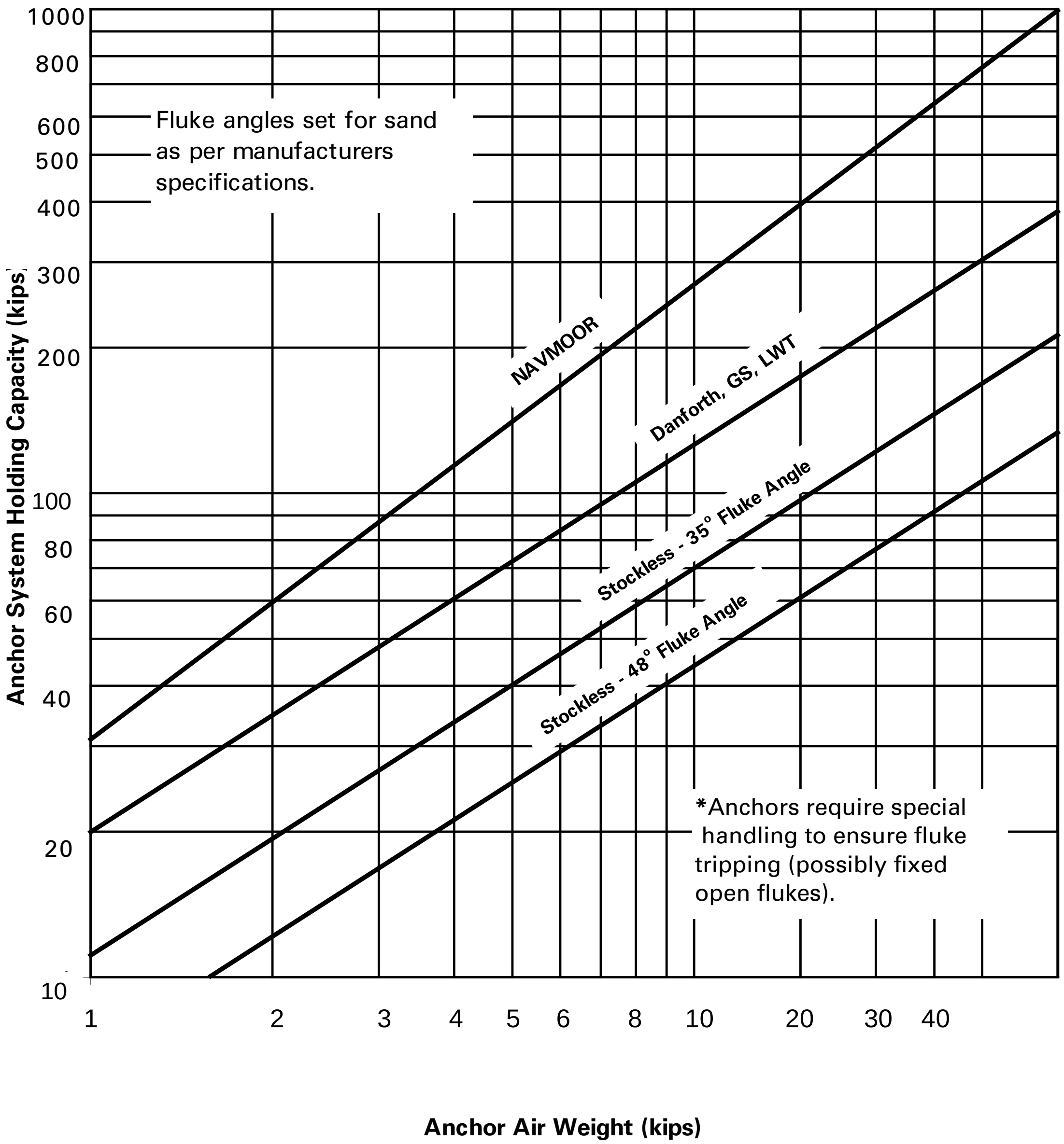


Figure 5-5 Anchor System Holding Capacity in Cohesionless Soil (Sand)



5-3 DRIVEN-PLATE ANCHOR DESIGN.

NAVFAC EXWC has found that various types of plate anchors are an efficient and cost effective method of providing permanent moorings. Detailed design procedures for these anchors are given in NFESC TR-2039-OCN, *Design Guide for Pile-Driven Plate Anchors*. Additional information is given in NCEL *Handbook for Marine Geotechnical Engineering*. An overview of plate anchor design is given here.

A driven-plate anchor consists of the components shown in Figure 5-3 and discussed in Table 5-5.

Table 5-5 Driven-Plate Anchor Components

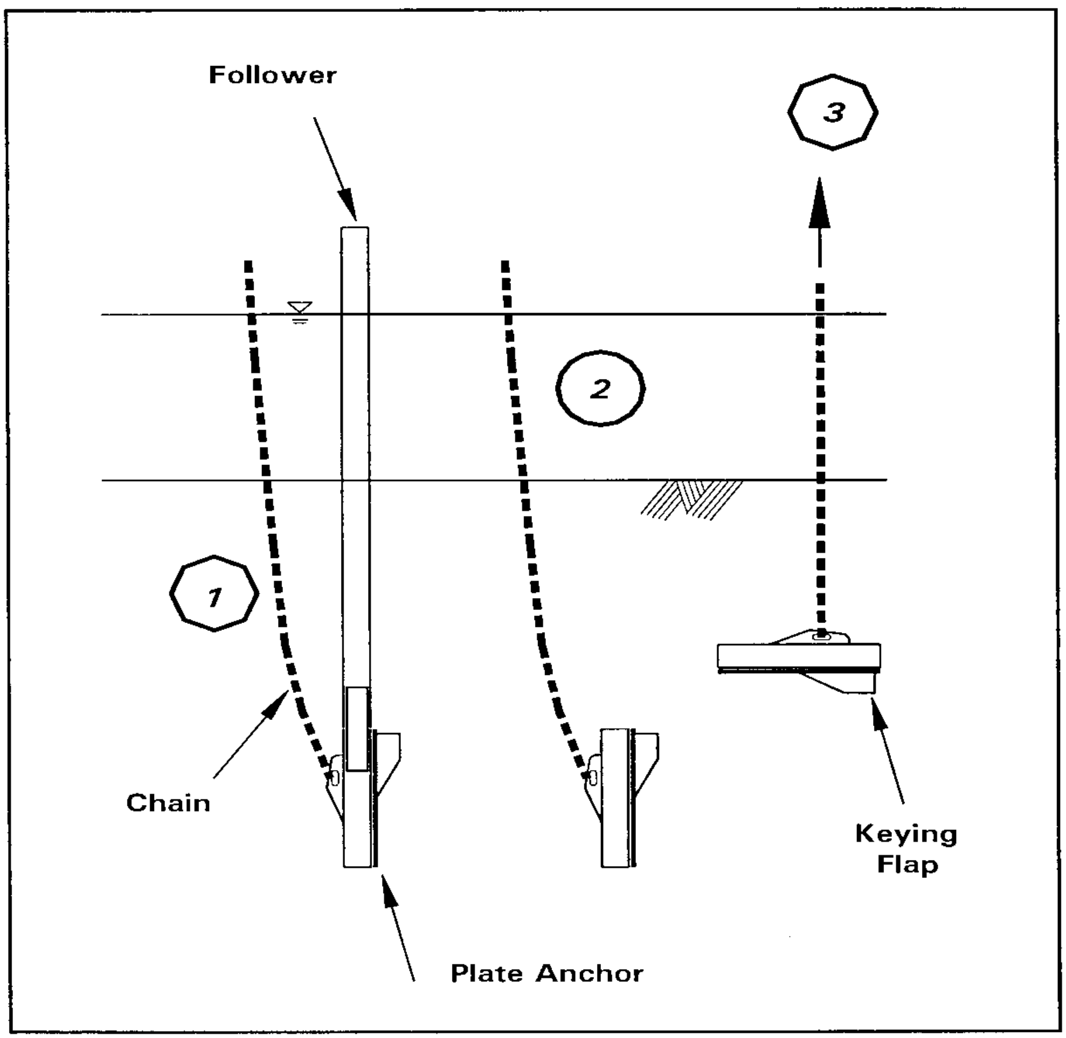
Component	Notes
Plate	Size the area and thickness of the plate to hold the required working load in the given soils. A plate length-to-width ratio of L/B = 1.5 to 2 is shown by practical experience to give optimum performance.
I-Beam	Size the beam to provide: a driving member; stiffness and strength to the anchor; and to separate the pad eye from the plate to provide a moment that helps the anchor key during proof testing.
Padeye	Size this structure as the point where the chain or wire rope is shackled onto the anchor prior to driving.
Follower	Length and size specified so assembly can safely be picked up, driven, and removed.
Hammer	Sized to drive the anchor safely. In most cases it is preferable to use an impact hammer. A vibratory hammer may be used in cohesionless soils or very soft mud. A vibratory hammer may also be useful during follower extraction.
Template	A structure is added to the side of the driving platform to keep the follower in position during setup and driving.

Installation of a plate anchor is illustrated in Figure 5-6. Installation consists of three key steps, as outlined in Table 5-6.

Table 5-6 Major Steps in Driven-Plate Anchor Installation

Step	Description
1.	Moor installation platform, place anchor in follower, shackle anchor to chain, place the follower/anchor assembly at the specified anchor location and drive the anchor to the required depth in the sediment (record driving blow count).
2.	Remove follower with a crane and/or extractor.
3.	Proof load the anchor. This keys the anchor, proves that the anchor holds the design load, and removes slack from the chain.

Figure 5-6 Major Steps of Driven-Plate Anchor Installation



Examples of plate anchors that have been used at various sites are summarized in Table 5-7.

Table 5-7 Typical Driven-Plate Anchors

Size/Location	Seafloor Type	Driving Distance Into Competent Sediment	Proof Load
0.91 m x 1.22 m (3 ft x 4 ft) Philadelphia, PA	Hard Clay	9 m (30 ft)	670 kN (150 kips) Vertical
0.61 m x 1.22 m (2 ft x 4 ft) San Diego, CA	Sand (Medium)	8 m (27 ft)	890 kN (200 kips) Vertical
m x 1.83 m (5 ft x 6 ft) Guam	Coral Limestone	12 m (40 ft)	1000 kN (225 kips) Vertical
m x 3.35 m (6 ft x 11 ft) Pearl Harbor, HI	Mud	21 m (70 ft)	890 kN (200 kips) Horizontal

The recommended minimum plate anchor spacing is five times the anchor width for mud or clay and 10 times the anchor width for sand.

CHAPTER 6 FACILITY MOORING EQUIPMENT GUIDELINES

6-1 INTRODUCTION.

Equipment most often used in mooring facilities is discussed in this section.

6-2 KEY MOORING COMPONENTS.

A mooring is a structure that holds a ship in a position using tension and compression members. The resulting mooring loads are transferred to the earth via anchors or some other members, such as pier piles or a wharf structure.

6-2.1 Tension Members.

The most commonly used tension members in moorings are:

- Chain
- Synthetic line
- Wire rope
- Tension bar buoys

6-2.2 Compression Members.

The most commonly used compression members in moorings are:

- Marine fenders
- Fender Piles
- Camels
- Mooring dolphins
- Piers
- Wharves

6-3 ANCHORS.

Anchors are structures used to transmit mooring loads to the earth. Anchors operate on the basis of soil structure interaction, so their behavior can be complex. Fortunately, the U.S. Navy has extensive experience with full-scale testing of a number of different anchor types in a wide variety of soils and conditions (NCEL *Handbook for Marine Geotechnical Engineering*). This experience provides a strong basis for design. However, due to the complex nature of structure/soil interaction, it is strongly recommended that anchors always be pull tested to their design load during installation. Design and illustration of some of the common anchor types routinely used are discussed in CHAPTER 5 of this UFC, and in NCEL *Handbook for Marine Geotechnical Engineering.*

A brief summary of some anchor experience is given in Table 6-1.

Table 6-1 Practical Experience with Anchors

Anchor Type	Description
Low Efficiency Drag Embedment Anchors (i.e., Stockless)	Reliable if stabilizers are added (see Figure 5-1). Not very efficient, but reliable through 'brute force'. Extensive experience. A large number available in the U.S. Navy Fleet Mooring inventory. Efficiency increased by fixing the flukes for the type of soil at the site. Should be set and proof tested during installation. Can be used in tandem in various configurations (NCEL TDS 83-05, *Multiple STOCKLESS Anchors for Navy Fleet Moorings*). Vertical angle of tension member should be approximately zero at the seafloor.
High Efficiency Drag Embedment Anchors (i.e., NAVMOOR)	Very efficient, highly reliable and especially designed so it can easily be used in tandem (NCEL TN-1774, *Single and Tandem Anchor Performance of the New Navy Mooring Anchor*). Excellent in a wide variety of soil conditions. These are available in the U.S. Navy Fleet Mooring inventory. Should be set and proof tested during installation. Vertical angle of tension member should be approximately zero at the seafloor in most cases.
Driven-Plate Anchors	Extremely efficient, can be designed to hold extremely high loads and will work in a wide variety of soils from mud to limestone (NFESC TR-2039, *Design Guide for Pile-Driven Plate Anchors*). Can take loads at any angle, so short scope moorings can be used. Extensive experience. Requires a follower and driving equipment. Most cost effective if a number are to be installed at one site at one time. Should be keyed and proof tested during installation.
Deadweight Anchors	Very low efficiency. Full-scale tests (NCEL, *Fleet Mooring Test Program – Pearl Harbor*) show anchor-holding capacity dramatically decreases after anchor starts dragging, just when the anchor capacity required may be most needed. As a result, use of this type of anchor can be dangerous. Deadweight anchors should be used with caution. NFESC TR-6037-OCN provides an Improved Pearl Harbor Anchor design.
Other anchor types	NCEL *Handbook for Marine Geotechnical Engineering* gives extensive technical and practical information on a wide variety of anchors and soil/structure interaction.

A summary sheet describing the stockless anchors in the U.S. Navy Fleet Mooring inventory is given in Table 6-2. NAVMOOR anchors in inventory are described in Table 6-3.

Table 6-2 Stockless Anchors in the U.S. Navy Fleet Mooring Inventory

ANCHOR IN AIR WEIGHT (1000 lbf)	20	25	30
LENGTH *(inches)*	127.25	137	145.63
STABILIZER EXTENSION *(inches)*	45	48	50
FLUKE LENGTH *(ft)*	7.65	8.24	8.94
FLUKE AREA *(sq. ft)*	35.1	40.7	46.9
SAFE HOLDING CAPACITIES WITH FS = 1.5*			
MUD SEAFLOOR Fluke Angle = 48 deg			
Minimum MUD Thickness (ft)**	22 ft	24 ft	25 ft
Typical Anchor Drag (ft)***	31 ft	33 ft	36 ft
Single Holding (x1000 lbf)	58	71	84
Tandem Holding (x1000 lbf)	116	142	169
SAND SEAFLOOR Fluke Angle = 35 deg			
Minimum SAND Thickness (ft)**	8 ft	8 ft	9 ft
Typical Anchor Drag (ft)***	33 ft	36 ft	39 ft
Single Holding (x1000 lbf)	81	97	112
Tandem Holding (x1000 lbf)	163	194	225

* design mooring properly ** for ultimate holding*** fix flukes open

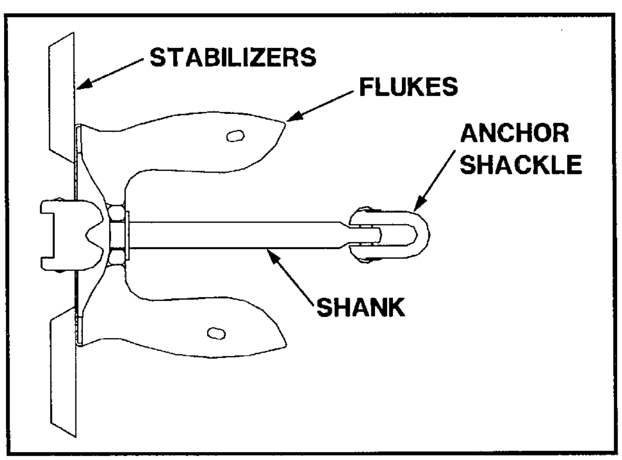
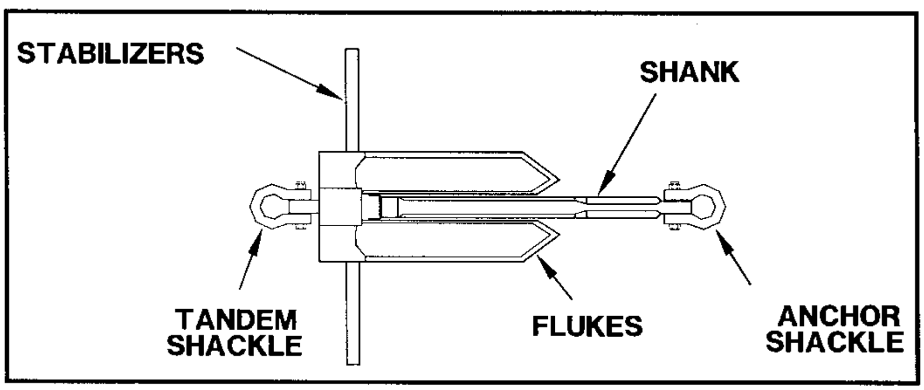


Table 6-3 NAVMOOR Anchors in the U.S. Navy Fleet Mooring Inventory

ANCHOR SIZE =	NAVMOOR-12	NAVMOOR-15
IN AIR WEIGHT *(pounds)*	12400	19200
LENGTH OVERALL *(inches)*	192	219
STABILIZER WIDTH *(inches)*	192	219
FLUKE LENGTH *(ft)*	8.54	9.73
FLUKE AREA *(sq. ft)*	38.54	50.07
SAFE HOLDING CAPACITIES FS=2*		
MUD SEAFLOOR Fluke Angle = 50 deg		
Minimum MUD Thickness (ft)**	38 ft	44 ft
Typical Anchor Drag (ft)***	30-35 ft	35-40 ft
Single Holding (x1000 lbf)	125	168
Tandem Holding (x1000 lbf)	310	420
SAND SEAFLOOR Fluke Angle = 32 deg		
Minimum SAND Thickness (ft)**	9 ft	10 ft
Typical Anchor Drag (ft)***	25 ft	30 ft
Single Holding (x1000 lbf)	160	215
Tandem Holding (x1000 lbf)	400	535



* design mooring properly ** for ultimate holding *** fix flukes open

6-4 CHAIN AND FITTINGS.

Chain is often used in fleet moorings because chain:

- Is easy to terminate.
- Can easily be lengthened or shortened.
- Is durable.
- Is easy to inspect.
- Is easy to provide cathodic protection.
- Has extensive experience.
- Is available.
- Is cost effective.
- Provides catenary effects.

DoD commonly uses stud link chain, with each chain link formed by bending and butt-welding a single bar of steel. Chain used in fleet moorings is Grade 3 stud link chain specifically designed for long-term in-water use (Naval Facilities Engineering Service Center (NFESC), FPO-1-89(PD1), *Purchase Description for Fleet Mooring Chain and Accessories*). This chain is designated as FM3. Properties of FM3 carried in stock are shown in Table 6-4 and in UFC 4-150-09, *Permanent Anchored Moorings, Operations and Maintenance*. Anodes for use on each link of FM3 chain, designed for diver replacement, are described in Table 6-4. Oversized anodes may be used to extend the anode life and increase the time interval required for anode replacement.

Older ships may use Die-Lock chain (not shown), which was made by pressing together male and female parts to form each link. Die-Lock is not recommended for long-term in-water use, because water may seep in between the male and female parts. The resulting corrosion is difficult to inspect.

Chain routinely comes in 90-foot (27.4-meter) lengths called ‘shots’. A number of other accessories are used with chain, as shown in Figure 6-1. For example, shots of chain are connected together with chain joining links. Anchor joining links are used to connect chain to anchors. Ground rings provide an attachment point for multiple chains. Buoy swivels are used to connect chain to buoys. Refer to NFESC TR-6014-OCN, *Mooring Design Physical and Empirical Data* and NFESC FPO-1-89(PD1) for additional information on chain and fittings.

Table 6-4 FM3 Mooring Chain Characteristics

Nominal Size (inch)	1.75	2	2.25	2.5	2.75	3.5	4
Number of Links per Shot	153	133	119	107	97	77	67
Link Length (inch)	10.6	12.2	13.7	15.2	16.7	21.3	24.3
Weight per Shot in Air (lb)	2,525	3,276	4,143	5,138	6,250	10,258	13,358
Weight per Link in Air (lb)	16.5	24.6	34.8	48	64.4	133.2	199.4
Weight per Foot Sub. (lb/ft)	26.2	33.9	42.6	52.7	63.8	104.1	135.2
Breaking Strength (1,000 lb)	352	454	570	692	826	1,285	1,632
Working Strength (FS=3) (1,000 lb)	117.2	151.2	189.8	230.4	275.1	427.9	543.5

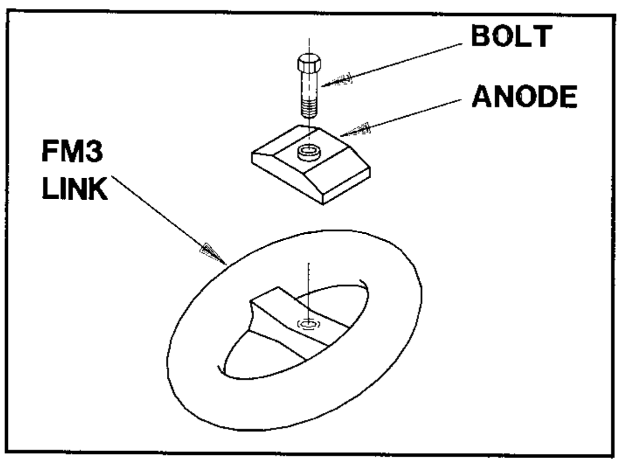


Table 6-5 Properties of FM3 Chain Anodes

Nominal Size (inch)	1.75	2	2.25	2.5	2.75	3.5	4
Anode Weight (lb)	0.80	1.10	1.38	1.70	2.04	3.58	4.41
Screw Length (inch)	1.25	1.50	1.75	1.75	2.00	2.25	2.25
Anode Width (inch)	1.50	1.62	1.75	1.94	2.06	2.38	2.69
Link Gap (lb)	3.74	4.24	4.74	5.24	5.74	7.48	8.48
Anodes per Full Drum	1106	822	615	550	400	158	122
Weight per Full Drum (approx. lb)	976	979	917	993	869	602	550

Notes:

1. all screws are .375-16unc-2a, grade 5, hex cap
2. 4.00 inch anodes fit all chain sizes
3. all screw heads are 9/16 inch

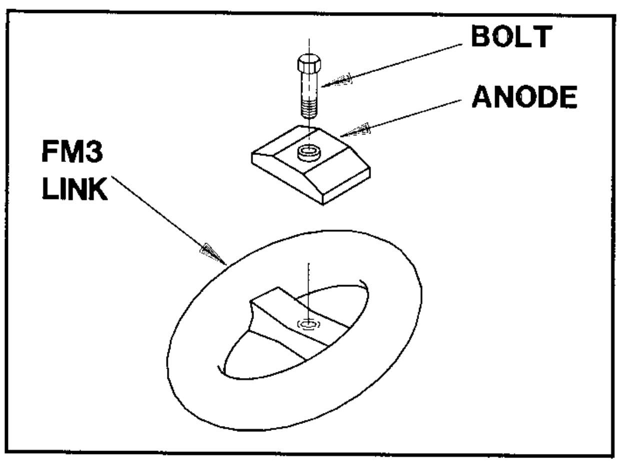
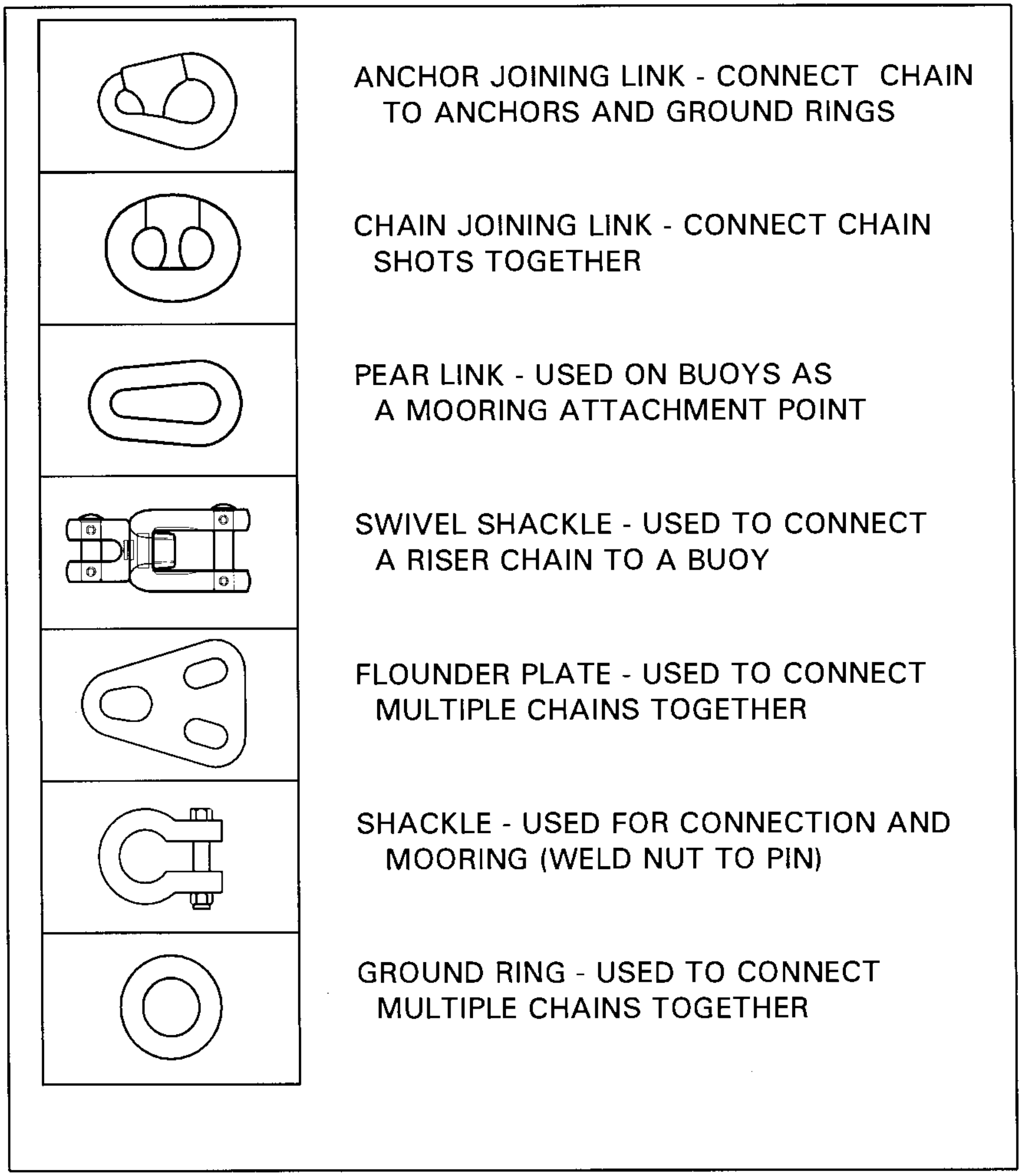


Figure 6-1 Chain Fittings



6-5 BUOYS.

There are two buoys commonly used on U.S. Navy Fleet moorings: an 8-foot (2.44 m) diameter buoy and a 12-foot (3.66 m) diameter buoy. These buoys have a polyurethane shell, are filled with foam, and have a tension bar to transmit mooring loads to the chain. Properties of these buoys are given in Table 6-6. Some of the key features of these buoys are that they require little maintenance and they are self-fendering. A variety of older steel buoys in use are being phased out, due to their relatively high maintenance cost. Some of the factors to consider in selecting the type of mooring buoy to use are: availability, size, cost, durability, maintenance, inspection, disposal and similar factors.

6-6 SINKERS.

Sinkers are placed on fleet moorings to tune the static and dynamic behavior of a mooring. Sinkers are usually made of concrete or low cost metal. Key sinker parameters that can be specified in design include:

- Mass
- Weight
- Location
- Number
- Size
- Design

Special care needs to be taken in the design and inspection of lifting eyes and attachment points on sinkers to ensure that they are safe.

6-7 MOORING LINES.

The most common tension member lines used are synthetic fiber ropes and wire rope. Synthetic lines have the advantage of easy handling and some types have stretch, which can be used to fine tune static and dynamic mooring behavior and aid in load sharing between tension members. Wire rope has the advantage of durability.

6-7.1 Synthetic Fiber Ropes.

Mooring lines are formed by weaving a number of strands together to form a composite tension member. Lines are made of different types of fiber and various constructions. Stretch/strain properties of selected lines are shown in Table 6-7 and Figure 6-2. Engineering characteristics of some double braided nylon and polyester lines are given in Table 6-8 and Table 6-9. Additional information is provided in NFESC TR-6014-OCN, *Mooring Design Physical and Empirical Data*. The size and type of synthetic line specified in a given design will depend upon parameters such as those shown in Table 6-10. A discussion of the use of various mooring line types is given in APPENDIX A.

Table 6-6 Foam-Filled Polyurethane Coated Buoys

Parameters	8-Foot Buoy	12-Foot Buoy
Weight in Air	4,500 lb (2041 kg)	10,400 lb (4,717 kg)
Net Buoyancy	15,000 lb (6804 kg)	39,000 lb (17,690 kg)
Working Buoyancy (24" FB)	6,150 lb (2790 kg)	20,320 lb (9,217 kg)
Proof Load on Bar (0.6 f_y)	300 kips (1334 kN)	600 kips (2,669 kN)
Working Load of Bar (0.3 f_y)	150 kips (667 kN)	300 kips (1,334 kN)
Diameter Overall (w/fenders)	8 ft 6 in (2.6 m)	12 ft (3.66 m)
Diameter of Hull	8 ft (2.44 m)	11 ft 6 in (3.5 m)
Length of Hull Overall	7 ft 9 in (2.36 m)	8 ft 9 in (2.7 m)
Length of Tension Bar	11 ft 4 in (3.45 m)	13 ft 1 in (3.97 m)
Height of Cylindrical Portion	4 ft 4 in (1.22 m)	5 ft 7 in (1.7 m)
Height of Conical Portion	3 ft 5 in (1.05 m)	3 ft 2 in (0.95 m)
Bar Thickness (top/bottom)	4.5/3.0 in (114/76 mm)	5.0/3.5 in (127/89 mm)
Top Padeye ID (top/bottom)	3.5/3.0 in (89/76 mm)	4.5/5.0 in (114/127 mm)
Shackle on Top	3.0 in (76 mm)	4.0 in (102 mm)
Maximum Chain Size	2.75 in (0.07 m)	4.0 in (102 mm)
Min. Recommended Riser Wt	1,068 lb (485 kg)	7,500 lb (3,401 kg)
Riser Wt for 24" freeboard	8,850 lb (4,014 kg)	18,680 lb (8,473 kg)
Max. Recommended Riser Wt	7,500 lb (3,401 kg)	21,264 lb (9,645 kg)
Moment to Heel 1 deg:		
Min Riser Wt	108 ft-lb (14.9 kg-m)	1,183 ft-lb (163.5 kg-m)
Max Riser Wt	648 ft-lb (89.6 kg-m)	2,910 ft-lb (402.3 kg-m)

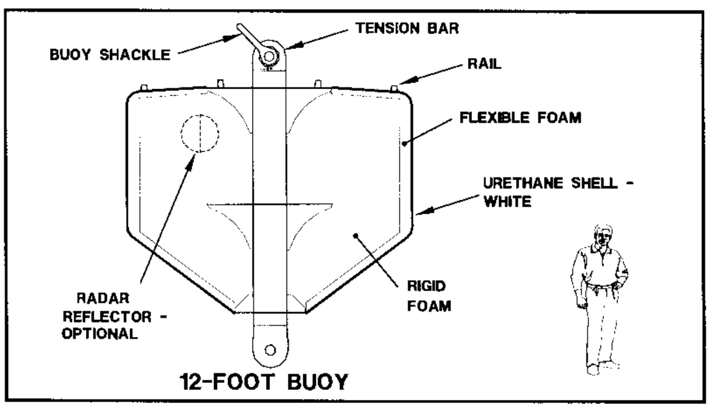


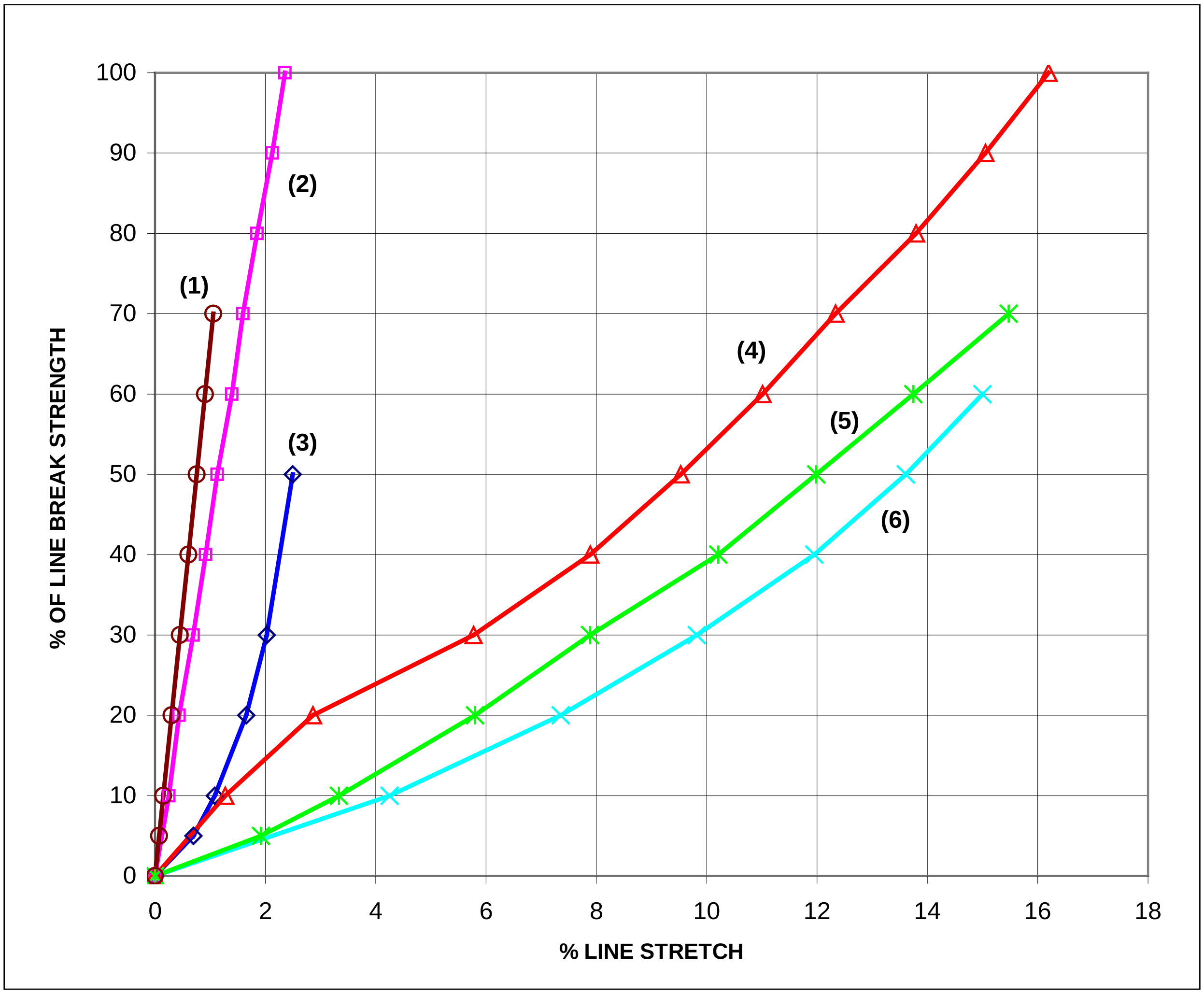
Table 6-7 Stretch of Synthetic Lines

% Break Strength	Wire Rope & Steel Core % Stretch	12-Strand HMWPE % Stretch	Kevlar 4-Strand % Stretch	Double Braided Polyester % Stretch	Nylon 8- Strand % Stretch	Double Braided Nylon % Stretch
(T/Tb)	(1)	(2)	(3)	(4)	(5)	(6)
0	0.000	0.000	0.000	0.000	0.000	0.000
5	0.076		0.697		1.922	
10	0.151	0.250	1.084	1.275	3.335	4.250
20	0.302	0.434	1.656	2.863	5.798	7.353
30	0.453	0.691	2.025	5.776	7.886	9.821
40	0.605	0.915		7.890	10.210	11.950
50	0.756	1.126	2.495	9.528	11.987	13.610
60	0.907	1.395		11.012	13.745	14.999
70	1.058	1.593		12.338	15.472	
80		1.850		13.793		
90		2.126		15.054		
100		2.356		16.197		

Notes:

1. From Tension Technology, Inc.
2. High Molecular Weight Polyethylene; Sampson Ropes
3. VETS 198 Rope; Whitehill Mfg.
4. Double Braided; Sampson Ropes; Mean of 10 & 11 in. cir. Data “2-in-1 Stable Braid”
5. Broken in line; from Tension Technology, Inc.
6. Double Braided; Sampson Ropes; Mean of 7, 10 & 12 in cir. Data; “2-in-2 Super Strong”

Figure 6-2 Synthetic Line Stretch



Notes:

1. From Tension Technology, Inc.
2. High Molecular Weight Polyethylene; Sampson Ropes
3. VETS 198 Rope; Whitehill Mfg.
4. Double Braided; Sampson Ropes; Mean of 10 & 11 in. (0.25 & 0.28 m) cir. Data “2-in-1 Stable Braid”
5. Broken in line; from Tension Technology, Inc.
6. Double Braided; Sampson Ropes; Mean of 7, 10 & 12 in (0.18, 0.25 & 0.3 m) cir. Data; “2-in-2 Super Strong”

Table 6-8 Double Braided Nylon Line [a]

Dia.	Cir.	Single Line				Three Parts Line			
		Av F_b		A·E		Av F_b		A·E	
(in)	(in)	(kips)	(kN)	(kips)	(kN)	(kips)	(kN)	(kips)	(kN)
1.0	3	33.6	149.5	118.9	529	100.8	448	356.8	1,587
1.1	3.5	45	200.2	159.3	709	135	601	477.9	2,126
1.2	3.75	52	231.3	184.1	819	156	694	552.2	2,456
1.3	4	59	262.4	208.8	929	177	787	626.5	2,787
1.4	4.5	74	329.2	261.9	1,165	222	988	785.8	3,496
1.6	5	91	404.8	322.1	1,433	273	1,214	966.4	4,299
1.8	5.5	110	489.3	417.0	1,732	330	1,468	1168.1	5,196
1.9	6	131	582.7	463.7	2,063	393	1,748	1391.2	6,188
2.1	6.5	153	680.6	541.6	2,409	459	2,042	1624.8	7,227
2.2	7	177	787.3	626.5	2,787	531	2,362	1879.6	8,361
2.4	7.5	202	898.5	715.0	3,181	606	2,696	2145.1	9,542
2.5	8	230	1,023.1	814.2	3,622	690	3,069	2442.5	10,865
2.7	8.5	257	1,143.2	909.7	4,047	771	3,430	2729.2	12,140
2.9	9	285	1,267.7	1008.8	4,488	855	3,803	3026.5	13,463
3.2	10	322	1,432.3	1139.8	5,070	966	4,297	3419.5	15,211
3.5	11	384	1,708.1	1359.3	6,046	1152	5,124	4077.9	18,139
3.8	12	451	2,006.1	1596.5	7,101	1353	6,018	4789.4	21,304
4.1	13	523	2,326.4	1851.3	8,235	1569	6,979	5554.0	24,705
4.5	14	599	2,664.5	2120.4	9,432	1797	7,993	6361.1	28,295
4.8	15	680	3,024.8	2407.1	10,707	2040	9,074	7221.2	32,122

Note:

[a] Sampson, dry, cyclic loading; reduce nylon lines by 15% for wet conditions

Dia. = diameter
Cir. = circumference
Av F_b = average break strength
A·E = cross-sectional area times modulus of elasticity (this does not include the highly nonlinear properties of nylon, shown in Figure 6-2)

Table 6-9 Double Braided Polyester Lines [a]

Dia.	Cir.	Single Line				Three Parts Line			
		Av F_b		A·E		Av F_b		A·E	
(in)	(in)	(kips)	(kN)	(kips)	(kN)	(kips)	(kN)	(kips)	(kN)
1.0	3	37.2	165.5	316.6	1,408	111.6	496	949.8	4,225
1.1	3.5	45.8	203.7	389.8	1,734	137.4	611	1,169.4	5,202
1.2	3.75	54.4	242.0	463.0	2,059	163.2	726	1,388.9	6,178
1.3	4	61.5	273.6	523.4	2,328	184.5	821	1,570.2	6,985
1.4	4.5	71.3	317.2	606.8	2,699	213.9	951	1,820.4	8,098
1.6	5	87.2	387.9	742.1	3,301	261.6	1,164	2,226.4	9,903
1.8	5.5	104	462.6	885.1	3,937	312	1,388	2,655.3	11,811
1.9	6	124	551.6	1,055.3	4,694	372	1,655	3,166.0	14,083
2.1	6.5	145	645.0	1,234.0	5,489	435	1,935	3,702.1	16,468
2.2	7	166	738.4	1,412.8	6,284	498	2,215	4,238.3	18,853
2.4	7.5	190	845.2	1,617.0	7,193	570	2,535	4,851.1	21,579
2.5	8	212	943.0	1,804.3	8,026	636	2,829	5,412.8	24,077
2.7	8.5	234	1,040.9	1,991.5	8,859	702	3,123	5,974.5	26,576
2.9	9	278	1,236.6	2,366.0	10,524	834	3,710	7,097.9	31,573
3.2	10	343	1,525.7	2,919.1	12,985	1,029	4,577	8,757.4	38,955
3.5	11	407	1,810.4	3,463.8	15,408	1,221	5,431	10,391.5	46,224
3.8	12	470	2,090.7	4,000.0	17,793	1,410	6,272	12,000.0	53,379
4.1	13	533	2,370.9	4,536.2	20,178	1,599	7,113	13,608.5	60,534
4.5	14	616	2,740.1	5,242.6	23,320	1,848	8,220	15,727.7	69,960
4.8	15	698	3,104.9	5,940.4	26,424	2,094	9,315	17,821.3	79,273

Note:

[a] Sampson, dry, cyclic loading

Dia. = diameter
Cir. = circumference
Av F_b = average break strength
A·E = cross-sectional area times modulus of elasticity

Table 6-10 Factors to Consider when Specifying Synthetic Line or Wire Rope

Parameter
Safety
Break strength
Diameter
Weight
Buoyancy and hydrodynamic properties
Ease of handling
Equipment to be used
Stretch/strain properties
Load sharing between lines
Dynamic behavior
Reliability
Durability
Fatigue
Exposure
Chaffing/abrasion
Wet vs. dry condition
Experience
Ability to splice
Ability to provide terminations
Inspection
Cost
Availability

6-7.2 Wire Ropes.

Wire rope is composed of three parts: wires, strands, and a core. The basic unit is the wire. A predetermined number of wires of the proper size are fabricated in a uniform geometric arrangement of definite pitch or lay to form a strand of the required diameter. The required number of strands are then laid together symmetrically around a core to form the rope. Refer to NAVSEA NSTM 613, USACE EM 1110-2-3200, and *Wire Rope User's Manual* and for additional information. Some factors to consider when specifying wire rope are listed in Table 6-10.

6-8 FENDERS.

Fendering is used between ships and compression structures, such as piers and wharves, in fixed moorings. Fenders act to distribute forces on ship hull(s) and minimize the potential for damage. Fendering is also used between nested ships. A wide variety of types of fenders are used including:

- Wooden piles
- Cylindrical marine fenders
- Hard rubber fenders
- Mooring dolphins
- Specially designed structures
- Composite fender piles
- Plastic fender piles
- Pre-stressed concrete fender piles

Camels are wider compression structures used, for example, to offset a ship from a pier or wharf.

The pressure exerted on ship hulls is a key factor to consider when specifying fenders. Allowable hull pressures on ships are discussed in NFESC TR-6015-OCN, *Foam-Filled Fender Design to Prevent Hull Damage*.

Refer to UFC 4-152-01, NAVSEA NSTM 611, and manufactures data for detailed information on fenders.

6-9 PIER FITTINGS.

Standard pier and wharf mooring fittings, as shown in Figure 6-3, include:

- Bollards
- Bitts
- Cleats

Cleats are not recommended for ships, unless absolutely necessary, because they are low capacity.

Some of the fittings commonly used on U.S. Navy piers are summarized in Table 6-11. Guidance for placing pier fittings in pier/wharf design is given in UFC 4-152-01, *Piers and Wharves*. Guidance for inspecting pier fittings is given in UFC 4-150-08, *Inspection of Mooring Hardware*.

Figure 6-3 Pier and Wharf Mooring Fittings Shown in Profile and Plan Views

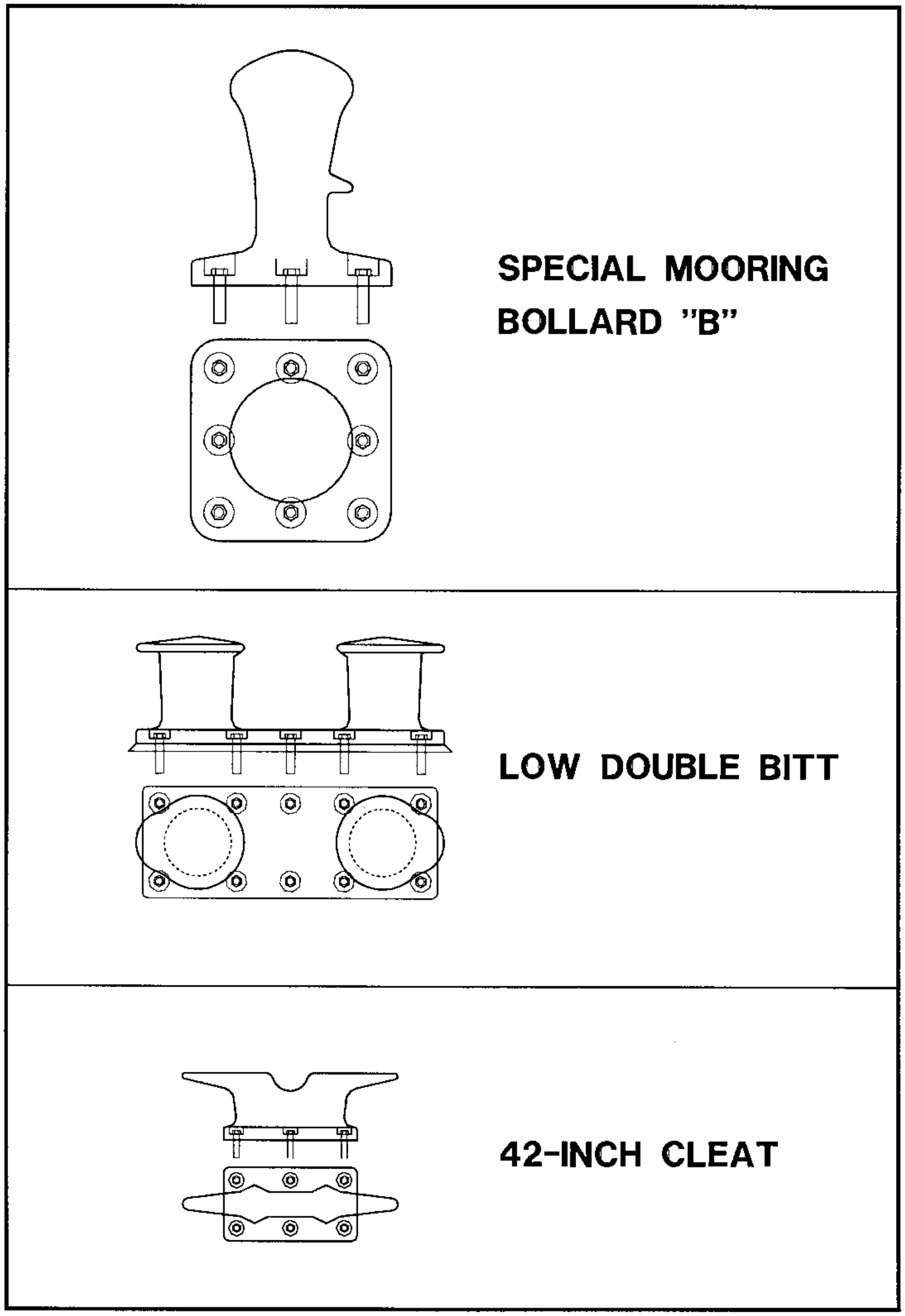


Table 6-11 Commonly Used U.S. Navy Pier Mooring Fittings

Description	Size		Bolts		Working Capacity		
	Height	Base	#	Dia.	Horz.	@ 45°	Nominal
	inch	inch		inch	kips		
Special Mooring Bollard "A"	48	48 x 48	12	2.75	660	430	450
Special Mooring Bollard "B"	44.5	39 x 39	8	2.25	270	216	200
Large Bollard with Horn	44.5	39 x 39	4	1.75	104	66	70
Large Double Bitt with Lip	26	73.5 x 28	10	1.75			75 [a]
Low Double Bitt with Lip	18	57.5 x 21.5	10	1.625			60 [a]
42 Inch Cleat	13	26 x 14.25	6	1.125			40
30 Inch Cleat	13	16 x 16	4	1.125			20

Note:
[a] Working capacity per barrel; NAVFAC Drawing No. 1404464

It is recommended that all mooring fittings be clearly marked with their safe working capacities on a plate bolted or welded to the base of the mooring device. Additional information concerning the sizes and working capacities of pier and wharf mooring fittings is found in NFESC TR-6014-OCN, *Mooring Design Physical and Empirical Data* and in UFC 4-152-01, *Piers and Wharves*. Also, NAVFAC EXWC assesses the condition of all mooring fittings during its routine pier/wharf inspections U.S. Navy waterfront facilities as part of their comprehensive Waterfront Inspection Program.

NAVFAC EXWC also has the capability to perform pull tests to proof the fittings if needed.

6-10 CATENARY BEHAVIOR.

It is not desirable or practical to moor a ship rigidly. For example, a ship can have a large amount of buoyancy, so it usually must be allowed to move with changing water levels. Another problem with holding a ship too rigidly is that some of the natural periods of the ship/mooring system can become short, which may cause dynamic problems.

A ship can be considered a mass and the mooring system as springs. During mooring design, the behavior of the mooring 'springs' can be controlled to fine tune the ship/mooring system behavior to achieve a specified performance. This can be controlled by the weight of chain or other tension member, scope of chain, placement of sinkers, amount the anchor penetrates the soil, and other parameters. The static behavior of catenaries can be modeled using the computer program CSAP2 (NFESC CR-6108-OCN, *Anchor Mooring Line Computer Program Final Report, User's Manual* *for Program CSAP2*). This program includes the effects of chain and wire rope interaction with soils, as well as the behavior of the catenary in the water column and above the water surface.

As an example, take the catenary shown in Figure 6-4. This mooring leg consists of four sections. The segment next to the anchor, Segment 1, consists of wire rope, followed by three segments of chain. Sinkers with the shown in-water weight are located at the ends of Segments 2 and 3. In this example, a plate anchor is driven 55 ft (16.8 m) into mud below the seafloor. The chain attachment point to the ship is 64 ft (19.5 m) above the seafloor. The mooring leg is loaded to its design horizontal load of H = 195 kips (867 kN) to key and proof load the anchor soon after the anchor is installed. The keying and proofing correspond to a tension in the top of the chain of approximately 210 kips (934 kN). Figure 6-5 shows the shape of the chain catenary predicted by CSAP2 for the design load.

The computed load/deflection curve for the design water level for this mooring leg, after proofing, is shown in Figure 6-5. The shape of this and the other mooring legs in this mooring, which are not shown, will strongly influence the static and dynamic behavior of the ship/mooring system during forcing.

Figure 6-4 Sample Catenary

Segment	Type	Dia. (inch)	Weight (lb/ft)	Length (ft)	Sinker (kips)
1	W	3.00	13.15	30	0
2	C	2.75	62.25	156	13.35
3	C	2.75	62.25	15	17.8
4	C	2.75	62.25	113	0

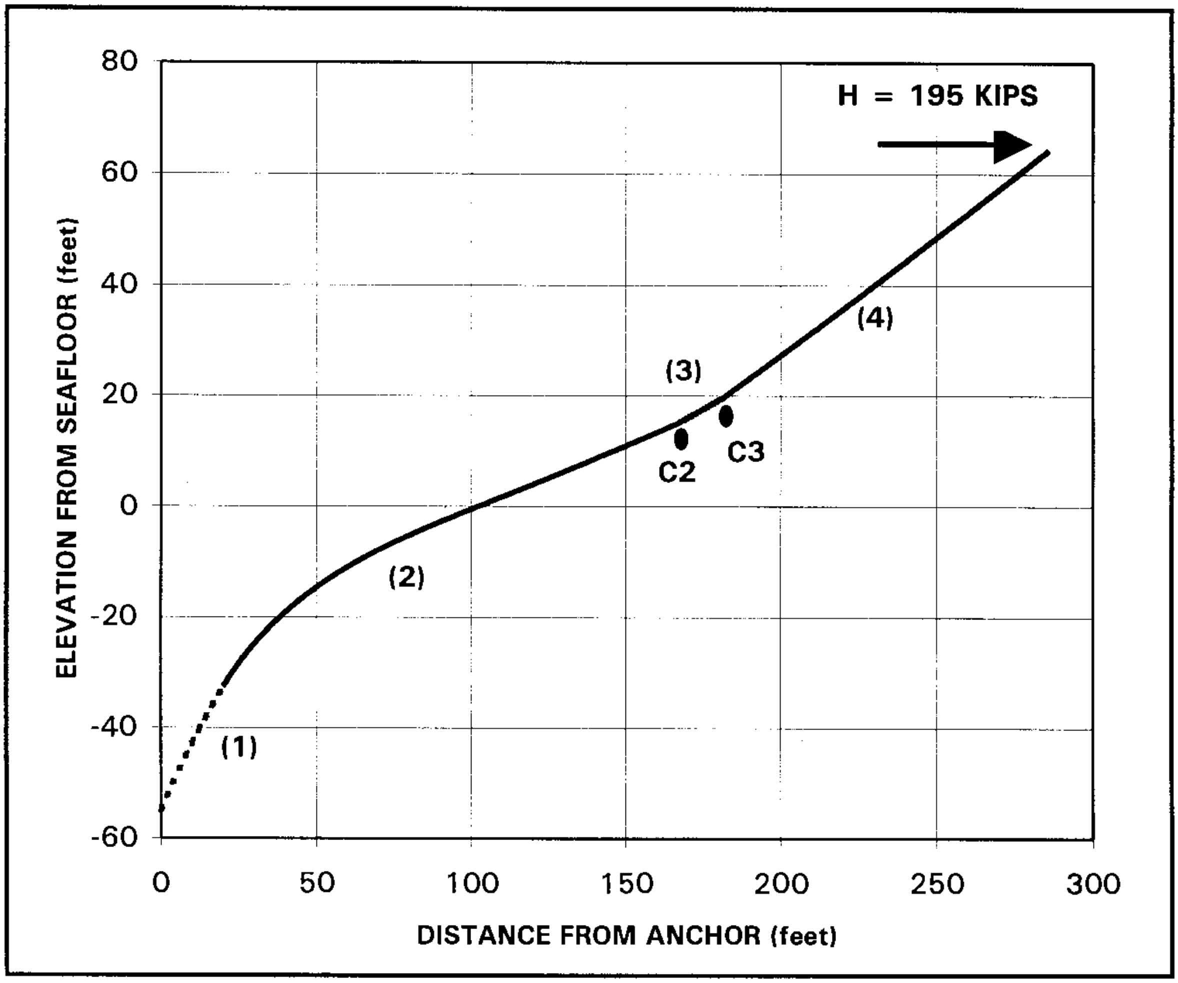
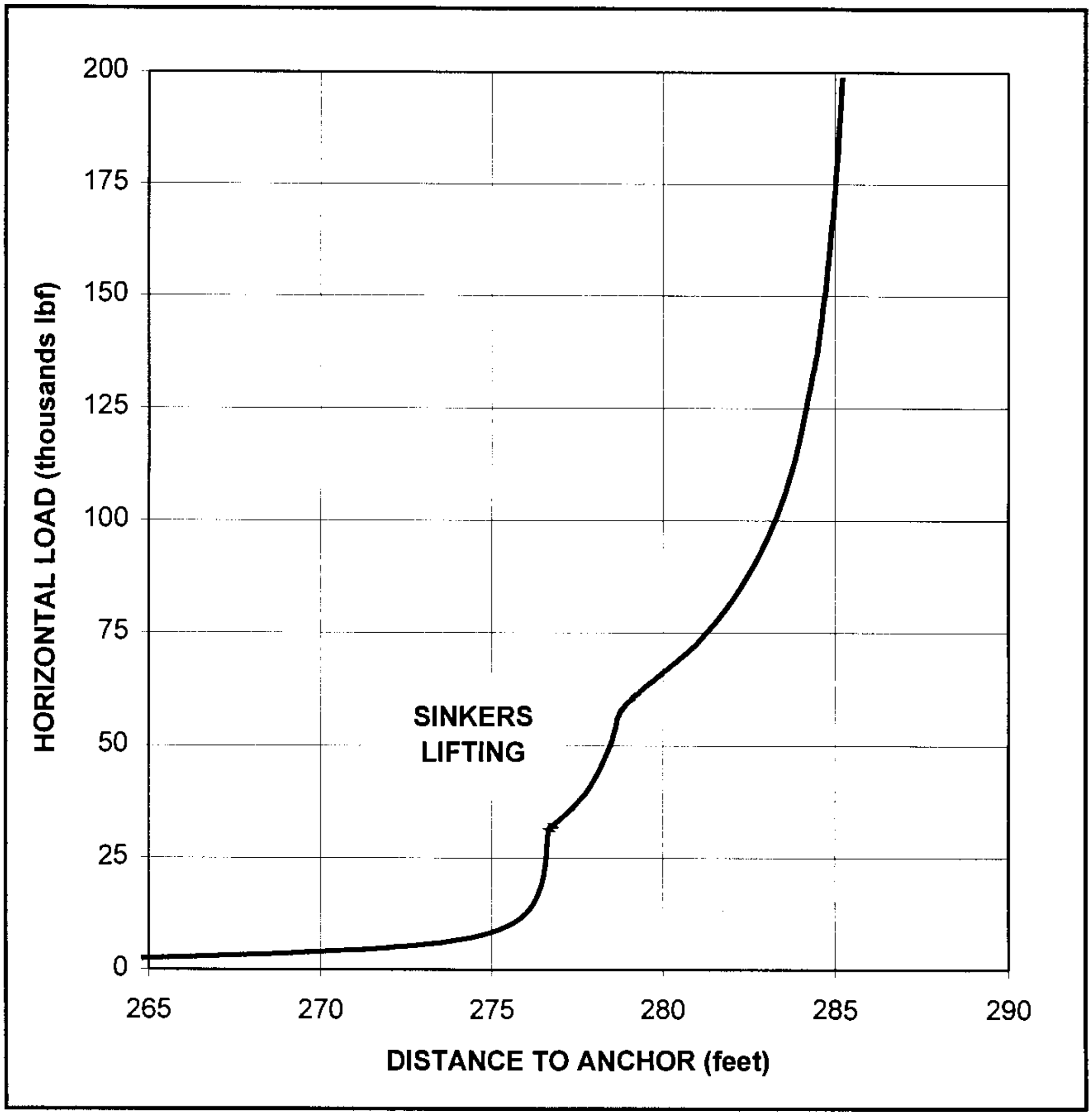


Figure 6-5 Load/Deflection Curve for the Example Mooring Leg



6-11 SOURCES OF INFORMATION.

Detailed NAVFAC information, including drawings, specifications, and manuals, is available in the Whole Building Design Guide (https://www.wbdg.org/). Further information can be obtained from the NAVFAC Engineering Criteria and Programs Office and the NAVFAC EXWC Moorings Center of Expertise. A list of sources for information on facility mooring equipment is provided in Table 6-12.

Table 6-12 Sources of Information for Facility Mooring Equipment

Item	Source
Standard fittings for waterfront structures	NAVFAC Drawing No. 1404464
Marine fenders	UFC 4-152-01, *Piers and Wharves*
Camels	UFC 4-152-01, *Piers and Wharves*
Mooring lines	Cordage Institute Technical Manual
Foam buoys	NFESC purchase descriptions of Mar. 1988, Dec. 1989 and May 1990.
Stud link chain and fittings	NFESC purchase description of Mar. 1995.
NAVMOOR anchors	NFESC purchase description of Nov. 1985 and drawing package of July 1990.
Stud link chain anodes	NFESC purchase description of June 1990.

CHAPTER 7 VESSEL MOORING EQUIPMENT GUIDELINES

7-1 INTRODUCTION.

A vessel must be provided with adequate mooring equipment to meet its operational and design requirements. This equipment enables the ship to anchor in a typical soil under design environmental conditions. In addition, the ship can moor to various piers, wharfs, fleet moorings, and other facilities. Equipment on board the ship must be designed for MSTs I, II, and III, as discussed in Section 3-1 entitled, *Design Approach*. Additional mooring hardware, such as specialized padeyes, mooring chains, wire ropes, and lines, can be added for MST IV situations.

7-2 TYPES OF MOORING EQUIPMENT.

Basic shipboard mooring equipment is summarized in Table 7-1. Additional information is provided in NAVSEA NSTM Chapters 581, 582, 611 and 613; from Naval Sea Systems Command drawings and publications; Cordage Institute, *Modeling the Long-Term Fatigue Performance of Fibre Ropes*, Hearle et al. (1993); Oil Companies International Marine Forum (OCIMF), *Mooring Equipment Guidelines* (2018); OCIMF *Recommendations for Equipment Employed in the Bow Mooring of Conventional Tankers at Single Point Moorings* (2007); OCIMF *Single Point Mooring Maintenance and Operations Guide* (2015); and *Fatigue of SPM Mooring Hawsers*, Parsey (1982), *Handbook of Fibre Rope Technology*, McKenna et al. (2006) and Tension Technology International Publications, https://www.tensiontech.com/papers.

7-3 EQUIPMENT SPECIFICATION.

Whenever possible, standard equipment is used on board ships as mooring equipment. The specification, size, number, and location of the equipment is selected to safely moor the ship. Some of the many factors that need to be considered in equipment specification are weight, space required, interaction with other systems, power requirements, reliability, maintenance, inspection, strength of supporting structures and cost.

7-4 FIXED BITTS.

Bitts provide a termination for tension members. Fixed bitts, Figure 7-1, are typically placed in pairs within a short distance forward or aft of a chock location. They are often placed symmetrically on both the port and starboard sides, so that the ship can moor to port or starboard. Capacities of the bitts are based on their nominal diameter. Table 7-1 provides fixed bitt sizes with their associated capacities. The basic philosophy for bitts use is that mooring lines should part well below the structural yield of the double bits in MSTs I and II to minimize the chance that ship’s mooring fittings need to be repaired. In MST III ‘Heavy Weather Mooring’ is designed to keep the ship moored as safely as possible, so the working capacities of the mooring lines can approximately equal the working capacities of the ship’s double bitts.

7-5 RECESSED SHELL BITTS.

Recessed shell bitts, Figure 7-2, are inset into ships' hulls well above the waterline. These bitts are used to moor lighterage or harbor craft alongside. They also assist in mooring at facilities. The standard NAVSEA shell bitt has a total working capacity of 92 kips (409 kN) with two lines of 46 kips (205 kN) maximum tension each.

7-6 EXTERIOR SHELL BITTS.

Aircraft carriers have exterior shell bitts, NAVSEA Drawing No. 600-6601101, that are statically proof loaded to 184 kips (818 kN). This proof load is applied 11 inches (280 mm) above the base. This testing is described in the Newport News Shipbuilding testing report for USS HARRY S TRUMAN *Bitts, Chocks and Mooring Rings.*

7-7 CHOCKS.

There are many types of chocks, such as closed chocks, Panama chocks, roller chocks, and mooring rings. Closed chocks are often installed on military vessels and characteristics of these fittings are shown in Table 7-3.

7-8 ALLOWABLE HULL PRESSURES.

As a ship berths or when it is moored, forces may be exerted on the hull by structures such as fenders, camels, and dolphins, on the ship hull. NFESC TR-6015-OCN, *Foam-Filled Fender Design to Prevent Hull Damage* provides a rational design criteria to prevent yielding of vessel hull plating. Additional information on a vessel's allowable hull pressures is available from the naval architect or ship builder.

7-9 SOURCES OF INFORMATION FOR SHIPS' MOORING EQUIPMENT.

Additional information is available from the Naval Sea Systems Command (NAVSEA 03P), NSWCCD-SSES, Military Sealift Command (MSC), and the U.S. Coast Guard (USCG). Table 7-4 provides a list of selected referenced materials.

Table 7-1 Types of Ship Based Mooring Equipment [a]

Equipment	Description
Drag embedment anchors	One or more anchors required. See CHAPTER 5 for anchor information.
Anchor chain	Stud link grade 3 chain (see the paragraph entitled “Chain and Fittings”) is used.
Anchor windlass/wildcat and associated equipment	Equipment for deploying and recovering the anchor(s), including the windlass(s), hawse pipe(s), chain stoppers, chain locker, and other equipment.
Mooring Attachment Points	Bitts and cleats for securing mooring lines.
Chocks, mooring rings and fairleads	Fittings through which mooring lines are passed.
Padeyes	Padeyes are provided for specialized mooring requirements and towing.
Mooring lines	Synthetic lines for mooring at piers, wharfs, and other structures. See the paragraph entitled, “Mooring Lines” for information.
Wire ropes	Wire rope is sometimes used for mooring tension members.
Fenders	Marine fenders, as discussed in the paragraph entitled, “Fenders”, are sometimes carried on board.
Winches and Capstans	Winches of various types can support mooring operations. Some ships use constant tension winches with wire rope automatically paid out/pulled in to adjust to water level changes and varying environmental conditions. Fixed-length synthetic spring lines are used in pier/wharf moorings that employ constant tension winches to keep the ship from ‘walking’ down the pier. A capstan is a form of winch mounted on a vertical axis used to aid in line handling.
Other	Various specialized equipment is carried to meet needs (such as submarines).

Note:

[a] See NAVSEASYSCOM Naval Ships’ Technical Manual for additional information and in the paragraph entitled, “Design Approach” for design criteria.

Figure 7-1 Ship's Fixed Double Bitts

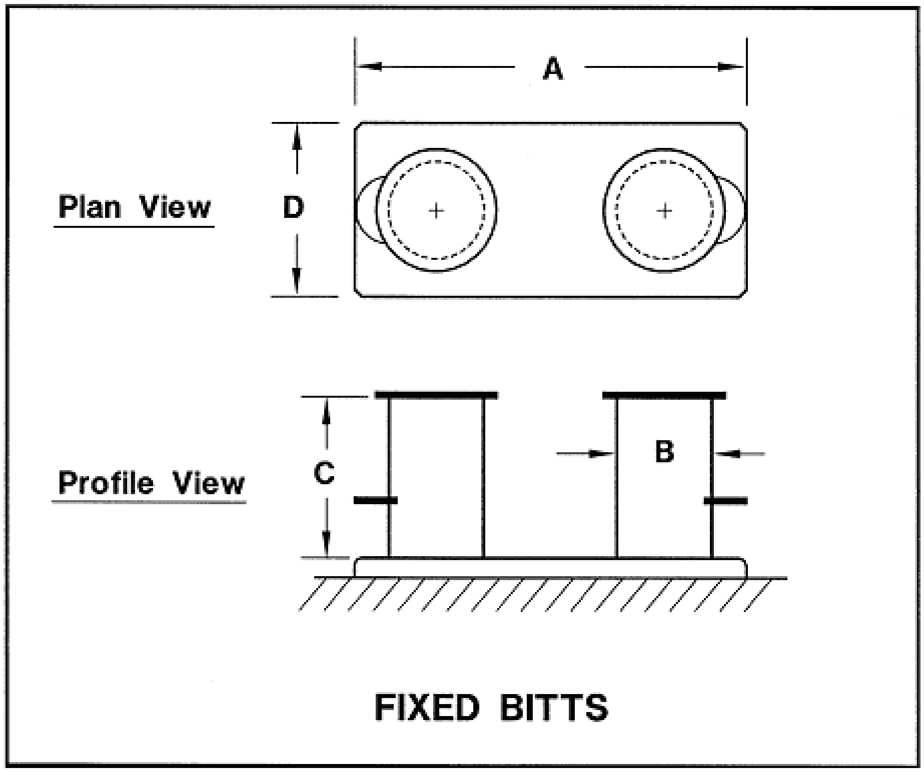
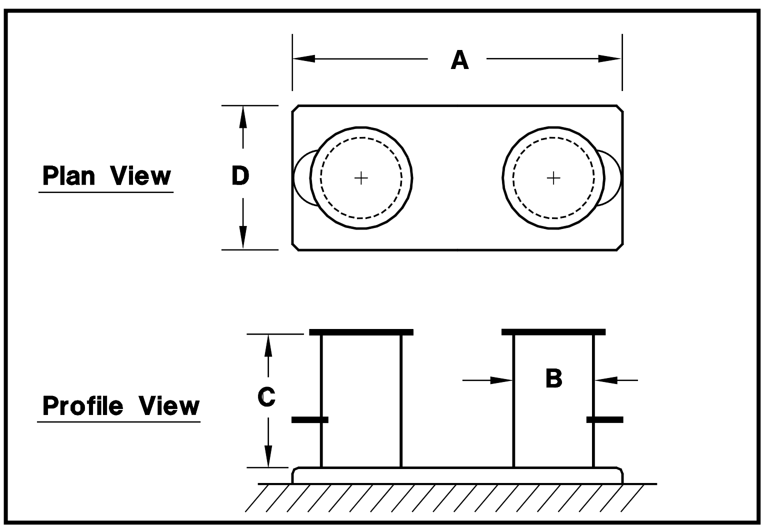


Table 7-2 Fixed Ships' Bits (minimum strength requirements) [a]

NAVSEA FIXED BITTS (after 804-1843362 REV B OF 1987)

NOMINAL SIZE (inches)	4	8	10	12	14	18
MAX. LINE CIR. (inches)	3	5	6.5	8	10	12
MAX. LINE DIA. (inches)	1.0	1.6	2.1	2.5	3.2	3.8
MAX. MOMENT (lbf-in x 1000)	134	475	1046	1901	3601	6672
*MAX. CAPACITY (lbf x 1000)**	26.8	73.08	123.1	181	277	417
A - BASE LENGTH (inches)	16.5	28.63	36.75	44.25	52.5	64
B - BARREL DIA. (inches)	4.5	8.625	10.75	12.75	14	18
C - BARREL HT. (inches)	10	13	17	21	26	32
D - BASE WIDTH (inches)	7.5	13.63	17.25	20.25	22.5	28
MAX. LINE CIR. (mm)	76	127	165	203	254	305
*MAX. CAPACITY (newton x 100000)**	1.19	3.25	5.47	8.05	12.32	18.55
A - BASE LENGTH (inches)	419	727	933	1124	1334	1626
B - BARREL DIA. (inches)	114	219	273	324	356	457
C - BARREL HT. (inches)	254	330	432	533	660	813
D - BASE WIDTH (inches)	191	346	438	514	572	711

* force applied at half the barrel height



Note:

[a] The design of these bitts has changed over the years, so different classes of ships may have different designs. The way the bitts are used may also influence their working capacity. Contact NAVSEASYSCOM for additional information.

Figure 7-2 Recessed Shell Bitt (minimum strength requirements)

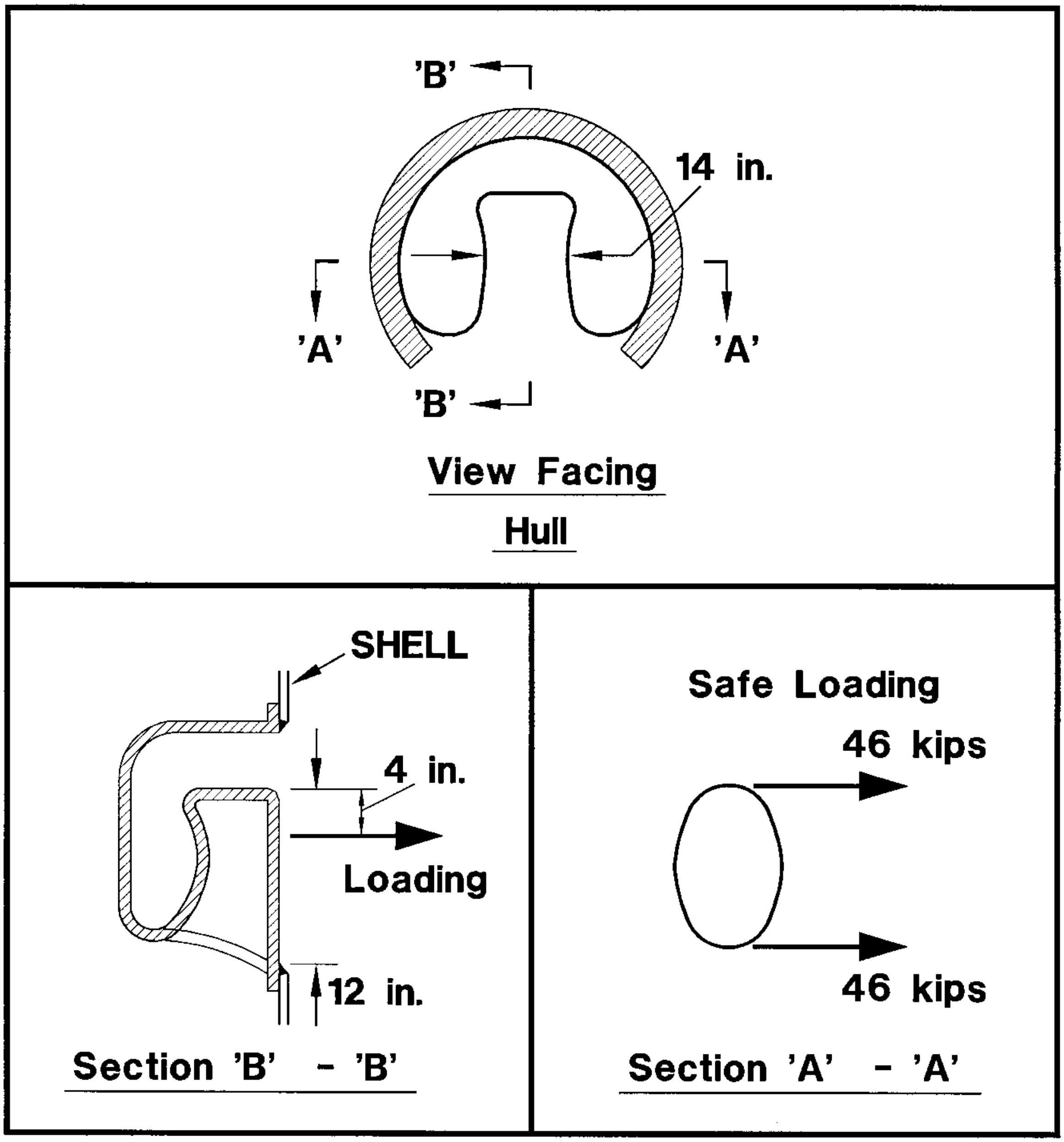
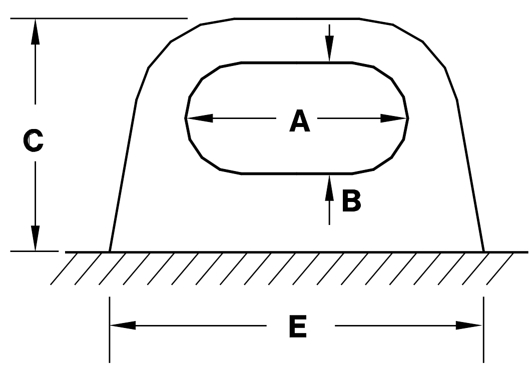


Table 7-3 Closed Chocks (minimum strength requirements)

NAVSEA CLOSED CHOCKS (from Drawing 804-1843363)

CHOCK SIZE (inches)	6	10	13	16	20	24
MAX. LINE CIR. (inches)	3	5	6.5	8	10	12
LINE BREAK (lbf x 1000)	26.8	73	123	181	277	417
A - HOLE WIDTH (inches)	6	10	13	16	20	24
B - HOLE HEIGHT (inches)	3	5	6.5	8	10	12
C - HEIGHT (inches)	8.5	11.25	13.88	16.75	25.75	25.25
D - BASE THICKNESS (inches)	5.25	6.5	7.5	9	16	13.5
E - LENGTH (inches)	13	19	23	28	38.75	40
MAX. LINE CIR. (mm)	76	127	165	203	254	305
LINE BREAK (newton x 100000)	1.19	3.25	5.47	8.05	12.32	18.55
A - HOLE WIDTH (mm)	152	254	330	406	508	610
B - HOLE HEIGHT (mm)	76	127	165	203	254	305
C - HEIGHT (mm)	216	286	352	425	654	641
D - BASE THICKNESS (mm)	133	165	191	229	406	343
E - LENGTH (mm)	330	483	584	711	984	1016



Note: D = thickness at the base

Table 7-4 Sources of Information for Ships' Mooring Equipment

Item	Source [a]
Chocks	NAVSEA Drawing No. 804-1843363 & S1201-921623 (Roller Chock)
Panama chocks	NAVSEA Drawing No. 804-1843363
Fixed bitts	NAVSEA Drawing No. 804-1843362
Recessed shell bitts	NAVSEA Drawing No. 805-1841948
Exterior shell bitts	Newport News Shipbuilding Drawing No. 600-6601101
Cleats	NAVSEA Drawing No. 804-2276338
Capstans/gypsy heads	NAVSEA Drawing No. S260-860303 & MIL-C-17944
Hawser reels	NAVSEA Drawing No. S2604-921841 & 42
Mooring lines	*Cordage Institute Technical Manual; NSTM Chapter 613*

Note:
[a] Contact Naval Surface Warfare Center, Carderock Division for drawings and additional information on ship's mooring equipment.

CHAPTER 8 EXAMPLE PROBLEMS

8-1 INTRODUCTION.

The design of mooring systems is illustrated through the use of several examples in this section. The emphasis of this UFC is on statics, so static results are shown. However, the marine environment can be dynamic, so dynamic effects are illustrated in the examples.

8-2 SINGLE POINT MOORING - BASIC APPROACH.

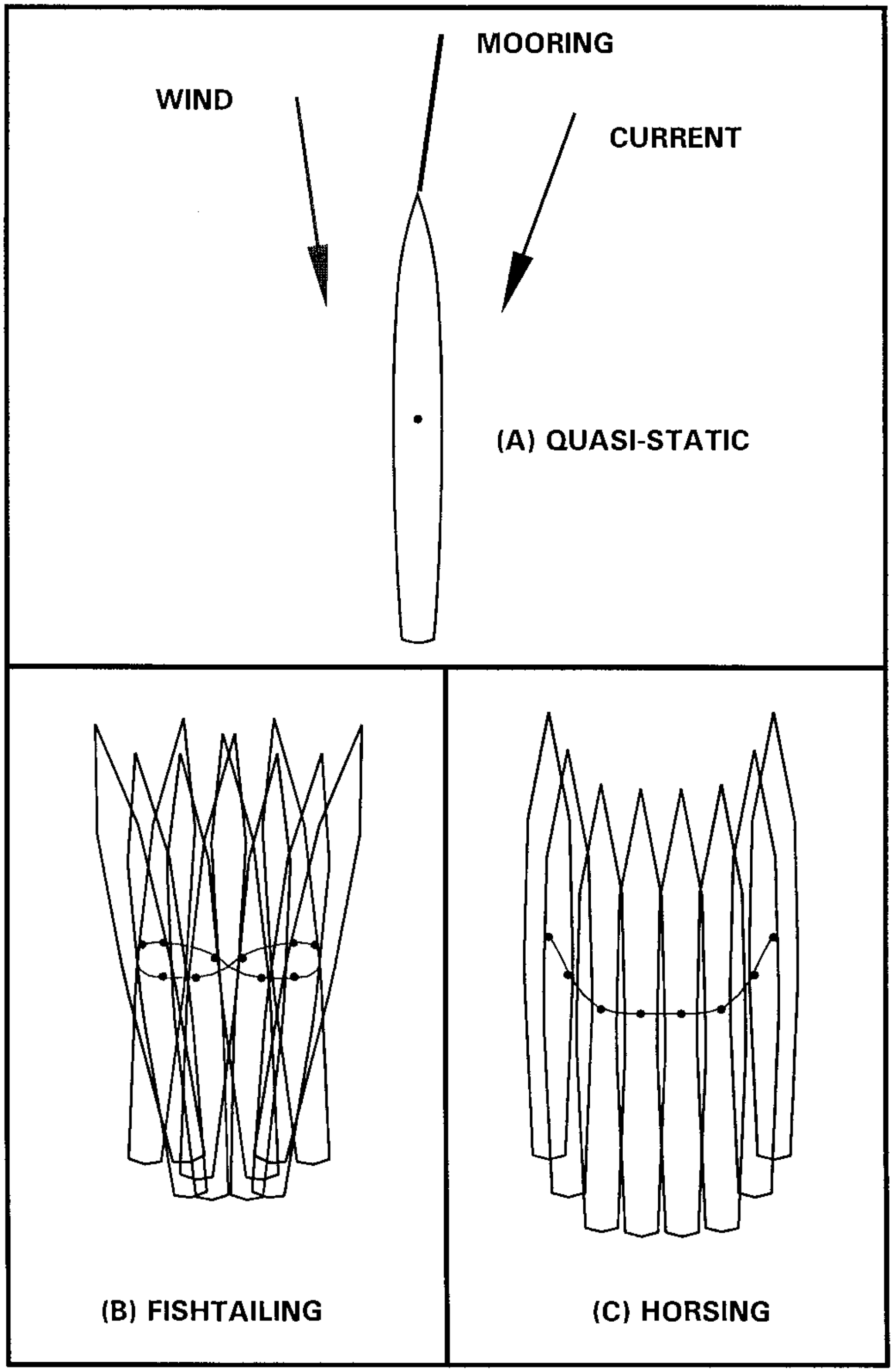
Design of single point fleet moorings (SPMs) is illustrated here.

Assuming the wind is coming from a specified direction and has stationary statistical properties. The current speed and direction are constant. In this case there are three common types of ship behavior, shown in Figure 8-1, that a vessel at a single point mooring can have:

- Quasi-static: In this case the ship remains in approximately a fixed position with the forces and moments acting on the ship in balance. For quasi-static behavior, the tension in the attachment from the ship to mooring will remain approximately constant. Quasi-static analyses can be used for design in this case.
- Fishtailing: In this case the ship undergoes significant surge, sway, and yaw with the ship center of gravity following a butterfly-shaped pattern. The mooring can experience high dynamic loads, even though the wind and current are constant.
- Horsing: In this case the ship undergoes significant surge and sway with the ship center of gravity following a U-shaped pattern. The mooring can experience high dynamic loads.

These cases show that the type of behavior of a given ship at a given single point mooring in a given environment can be very complex (Wichers, 1988), even though the wind and current are steady. It is recommended that a dynamic stability analysis first be conducted (Wichers, 1988) at the early stages of single point mooring design. Then the type of analysis required can be determined. The results from this analysis will suggest what type of method should be used to design a single point mooring. These methods are complex and beyond the scope of this UFC. Behavior of single point moorings is illustrated by example.

Figure 8-1 Some Types of Behavior of Ships at Single Point Moorings



8-2.1 Background for Example.

In this example two moorings were designed and installed. The original designs were based on quasi-static methods. Ships moored to these buoys broke their mooring hawsers when a wind gust front struck the ships. In this example, the design and hawser failures are reviewed. The effects of wind dynamics on a single point mooring are illustrated.

8-2.2 Ship.

A single 2nd LT JOHN P. BOBO (T-AK 3008) class ship was moored at each of two fleet mooring buoys. Table 8-1 gives basic characteristics of the ship.

Table 8-1 2nd LT JOHN P BOBO Parameters (Fully Loaded)

Parameter	Design Basis (English Units)	Design Basis (SI Units)
Length Overall	633.76 ft	193.2 m
Length at Waterline	614.58 ft	187.3 m
Length Between Perpendiculars	614.58 ft	187.3 m
Beam at Waterline	32.15 ft	9.80 m
Draft	32 ft	9.75 m
Displacement	46,111 LT	4.69 x10^7 kg
Line Size (2 nylon hawsers)	12 in.	300 mm

8-2.3 Forces/Moments.

In this case the design wind speed is 45 knots (23 m/s). Currents, waves, and tidal effects are neglected for these ‘fair weather’ moorings. The bow-on ship wind drag coefficient is taken as the value given for normal ships of 0.7, plus 0.1 is added for a clutter deck to give a drag coefficient of 0.8. Methods in Section 4 are used to compute the forces and moments on the ship. The computed bow-on wind force is 68.6 kips (300 kN) for 45 knot (23 m/s) winds, as shown in Figure 8-2.

8-2.4 Quasi-Static Design.

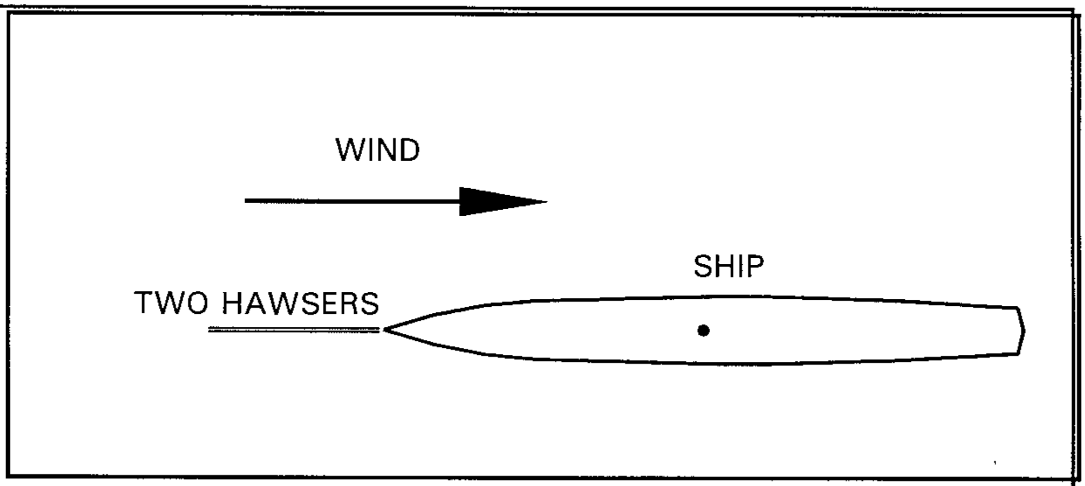
Quasi-static design procedures place the ship parallel to the wind for this example, because in this position the forces and moments on the ship are balanced out. Two mooring hawsers were specified for this design. Extra factor of safety was specified for the two 12 inch nylon mooring hawsers, which had a new wet breaking strength of 406 kips (180 kN), to account for poor load sharing between the two hawsers.

8-2.5 Mooring Hawser Break.

The ships were moored and faced into 15 knot (7.71 m/s) winds. The weather was unsettled, due to two nearby typhoons, so the ships had their engines in idle. A wind gust front struck very quickly with a wind speed increase from 15 to 50 knots (23 to 25.7 m/s). As the wind speed increased, the wind direction changed 90 degrees, so the higher wind speed hit the ships broadside. The predicted peak dynamic tension on the mooring hawsers was 1,140 kips (507 kN), (Seelig and Headland, 1998). Figure 8-3 is a simulation predicting the dynamic behavior of the moored ship and hawser tension. In this case, the mooring hawsers broke and the predicted factor of safety dropped to less than 1. In this event, the peak dynamic tension on the mooring hawser is predicted to be 13.5 times the bow-on wind force for 50 knot (25.7 m/s) winds.

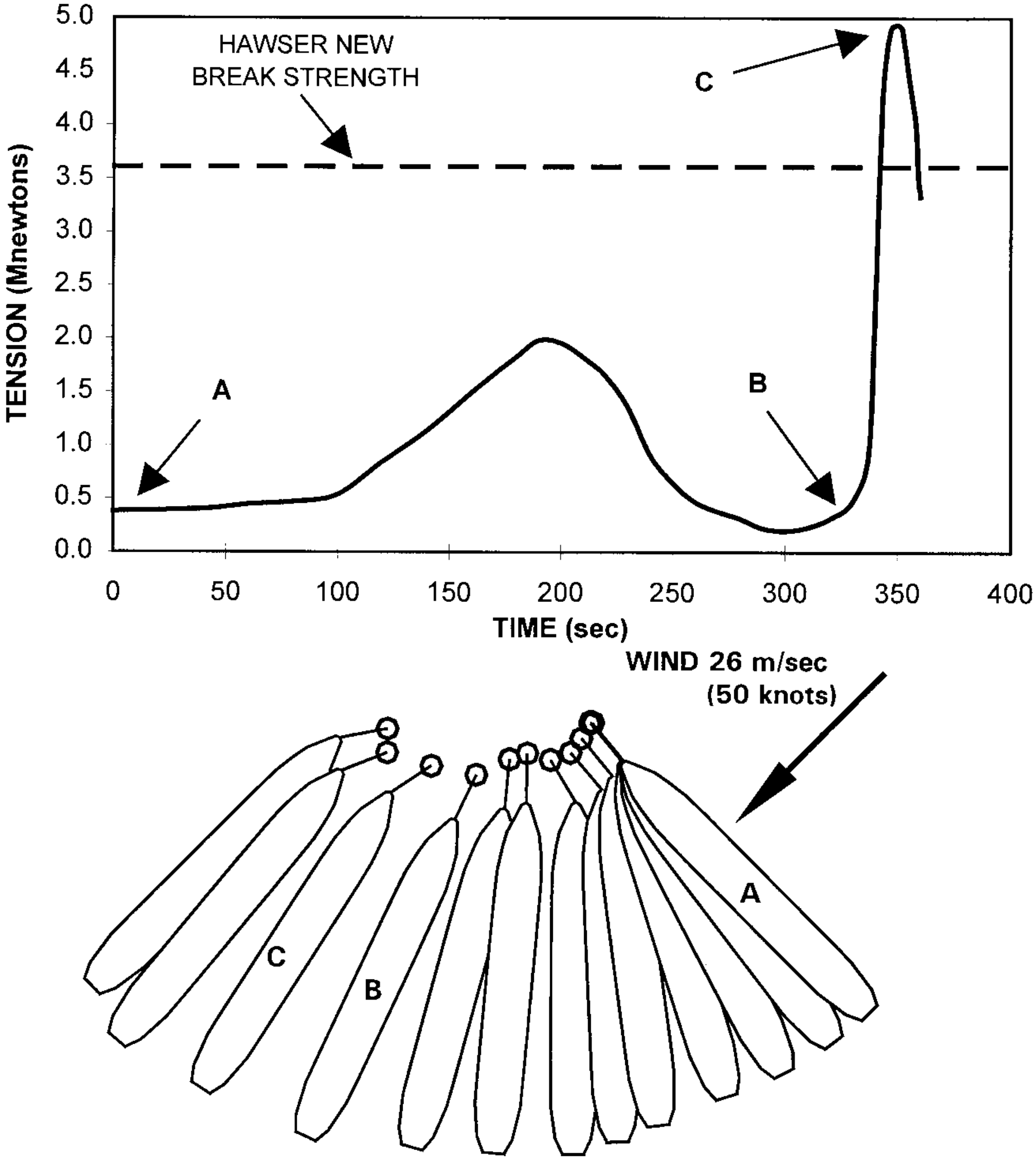
This example shows that single point moorings can be susceptible to dynamics effects, such as those caused by wind gust fronts or other effects.

Figure 8-2 Example Single Point Mooring



CONDITION	*BOW-ON SHIP WIND LOAD*	*F.S. FOR 1 HAWSER*	*F.S. FOR 2 HAWSERS*
45-KNOT WIND	68.5 KIPS	5.9	11.9
50-KNOT WIND	84.5 KIPS	4.8	9.6

Figure 8-3 Example Mooring Failure Due to a Wind Gust Front



Predicted ship positions at 30 second intervals.

8-3 FIXED MOORING - BASIC APPROACH.

Development of a design concept for a fixed mooring, a mooring that includes both tension and compression members, is illustrated here.

8-3.1 Background for Example.

Several new aircraft carrier berthing wharf facilities are being programmed. Users expressed concerns regarding the possibility of excessive ship movement. Wind is the major environmental parameter of concern. Assume the proposed sites have small tidal ranges and tidal currents.

8-3.2 Goal.

Develop a concept to moor USS NIMITZ (CVN 68) class ships at newly constructed wharves. Assume the Mooring Service Type is II and the design wind speed is 75 mph (33.5 m/s).

8-3.3 Ship.

Fully loaded USS NIMITZ (CVN 68) class ships are used in this example. Table 8-2 gives some ship parameters. Refer to UFC 4-152-01, *Piers and Wharves* for additional ship data.

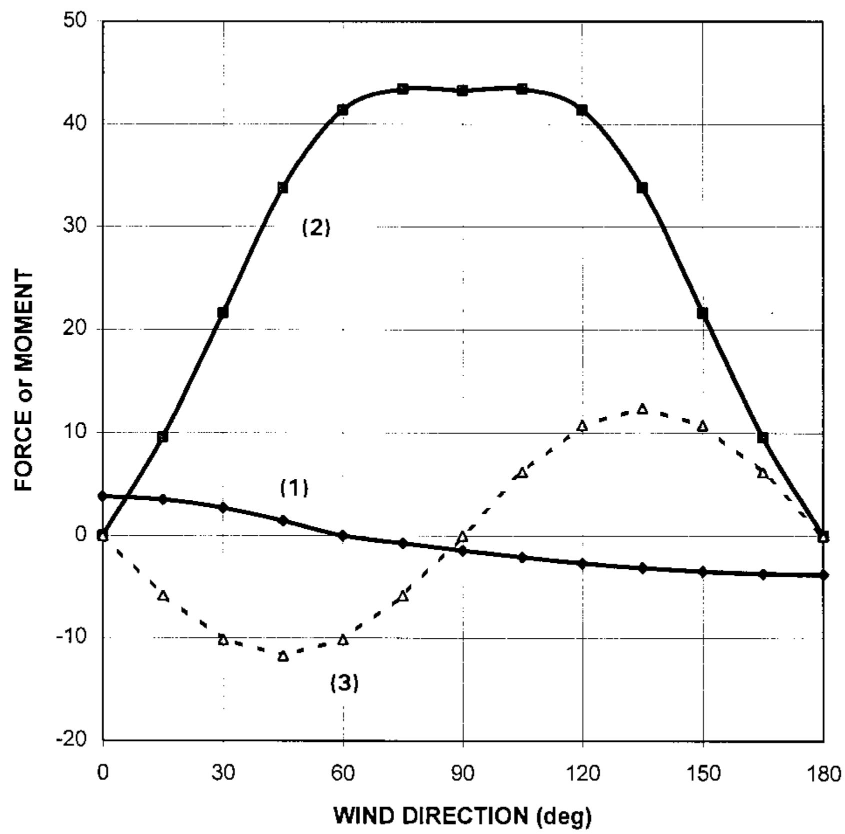
Table 8-2 CVN 68 Criteria (Fully Loaded)

Parameter	Design Basis (English Units)	Design Basis (SI Units)
Length Overall	1,092 ft	332.8 m
Length at Waterline	1,040 ft	317.0 m
Beam at Waterline	134 ft	40.8 m
Draft	37.91 ft	11.55 m
Displacement	91,700 LT	93,171,502 kg
Bitt Size	12 inch	305 mm
Line Size (nylon)	8 and 9 inch	203 and 229 mm

8-3.4 Forces/Moments.

Methods in CHAPTER 4 are used to compute the forces and moments on the ship. These values are summarized in Figure 8-4.

Figure 8-4 Wind Forces and Moments on a Single Loaded CVN 68 for a 75 mph Wind



PARAMETER	*CURVE*	*GRAPH UNITS*	*MAX. VALUE*
F_{xw}	(1)	E5 N	84.6 kips
F_{yw}	(2)	E5 N	975.5 kips
M_{xyw}	(3)	E7 N-m	91421 kip-ft

8-3.5 Definitions.

In this example we define a global coordinate system with “X” parallel to the wharf, as shown in Figure 8-5. Then “Y” is a distance perpendicular to the wharf in a seaward direction and “Z” is a vertical distance. Let “Pt 2” be the ship chock coordinate and “Pt 1” be the pier fitting. A spring line is defined as a line whose angle in the horizontal plane is less than 45 degrees and a breasting line whose angle in the horizontal plane is greater than or equal to 45 degrees, as shown in Figure 8-5.

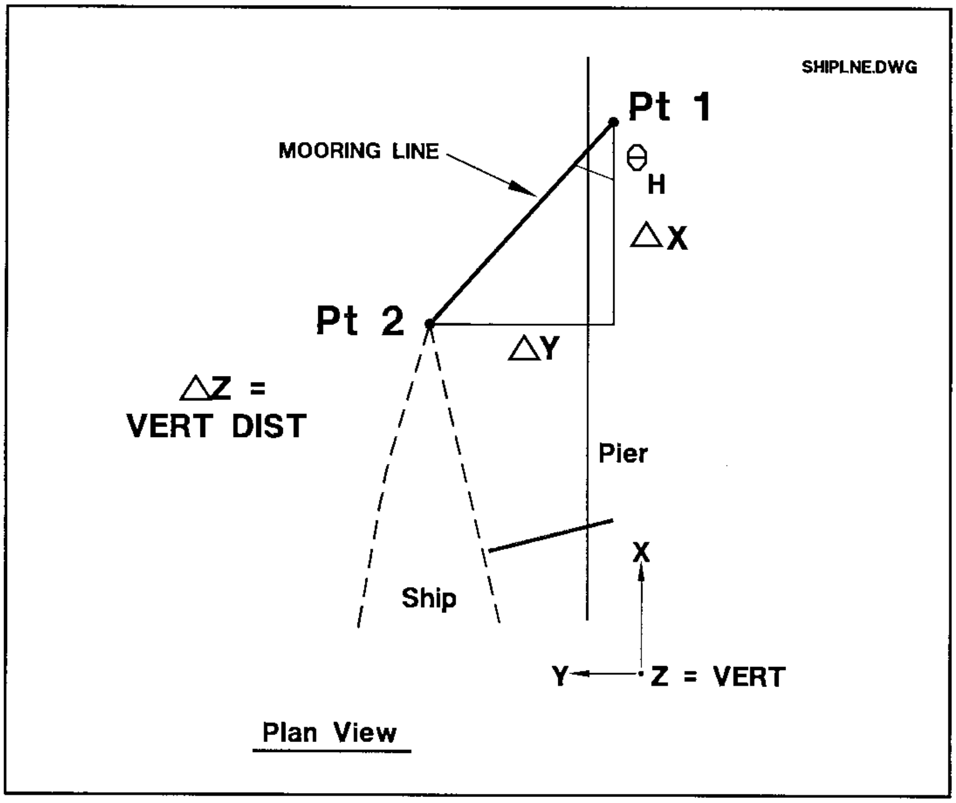
8-3.6 Preliminary Analysis.

The first step for fixed mooring design is to analyze the mooring requirements for the optimum ideal mooring shown in Figure 8-6. Analyzing the optimum ideal arrangement is recommended because: (1) calculations can be performed by hand and; (2) this simple arrangement can be used as a standard to evaluate other fixed mooring configurations (NFESC TR-6005-OCN, *EMOOR - A Planning/Preliminary Design Tool for Evaluating Ship Mooring at Piers and Wharves.)*

The optimum ideal mooring shown in Figure 8-6 consists of two spring lines, Lines 1 and 4, which are assumed to resist longitudinal forces. There are two breast lines, Lines 2 and 3, which are assumed to resist lateral forces and moments for winds with directions from 0° to 180°. Fenders are not shown. All lines are assumed to be parallel to the water surface in the ideal mooring.

A free body diagram is made of the optimum ideal mooring for a loaded CVN 68 in 75 mph (33.5 m/s) winds. It is found that the sum of the working mooring capacity required for Lines 1 and 4 is 174 kips (774 kN) and the sum of the working mooring capacity required for Lines 2 and 3 is 1,069 kips (4,760 kN), as shown in Figure 8-7. No working line capacity is required in the ‘Z’ direction, because the ship’s buoyancy supports the ship. The sum of all the mooring line working capacities for the optimum ideal mooring is 1,243 kips (5,529 kN).

Figure 8-5 Definitions



DEFINITIONS:

$$\Theta_H = \tan^{-1} \left| \frac{\Delta Y}{\Delta X} \right|$$

$$\Theta_V = \tan^{-1} \left| \frac{\Delta Z}{\Delta Y} \right|$$

IF $|\Theta_H| < 45$ deg → SPRING LINE

IF $|\Theta_H| \geq 45$ deg → BREASTING LINE

Figure 8-6 Optimum Ideal Mooring

(Lines are parallel to the water surface and breasting lines are spaced one-half ship's length from midships)

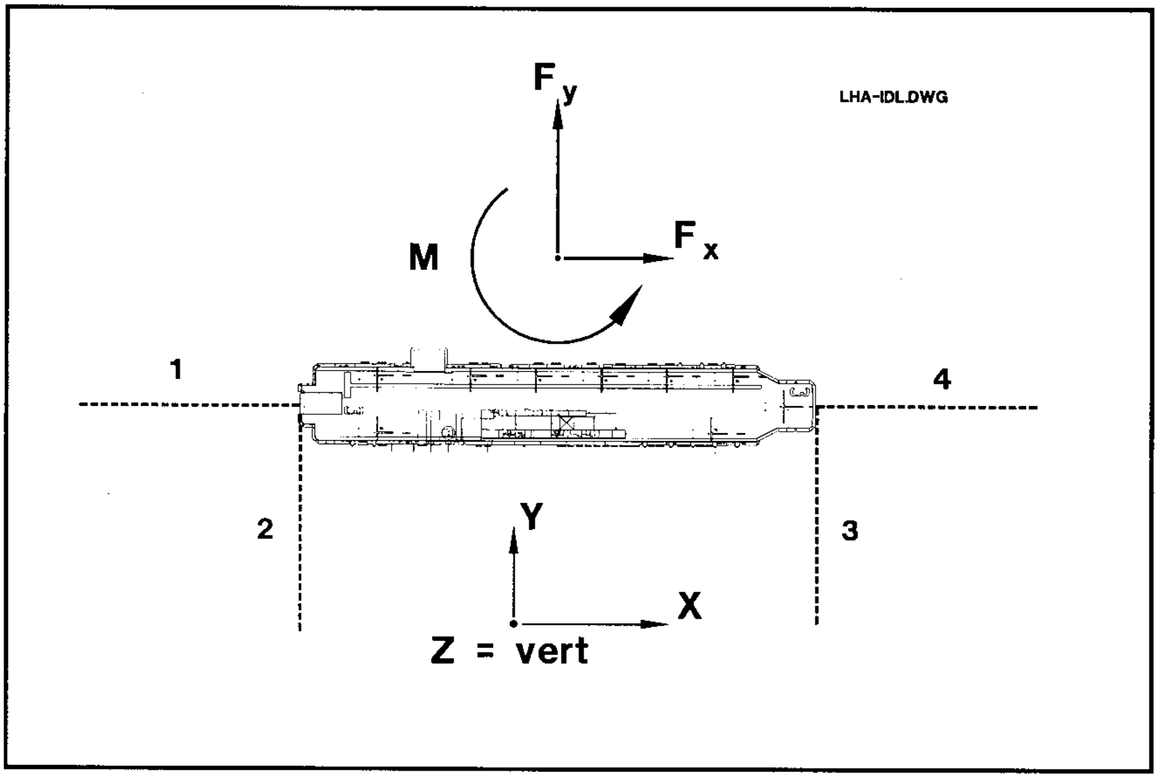
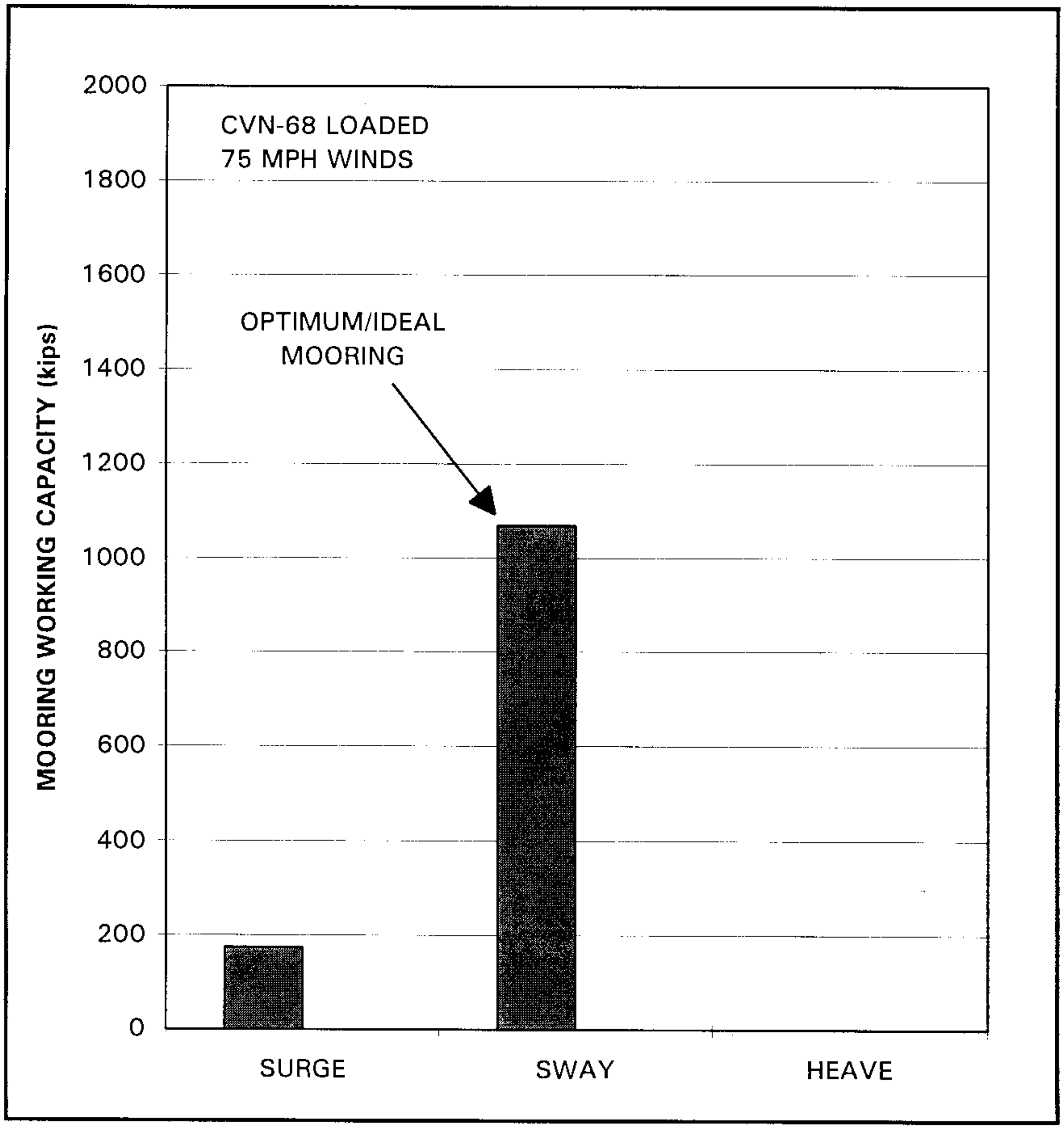


Figure 8-7 Required Mooring Capacity Using the Optimum Ideal Mooring



8-3.7 Wharf Mooring Concept.

Camels and fenders are located between the wharf and ship to offset the ship in this design. Also, the wharf breasting line bollards are set back from the face of the wharf, so that the vertical angles of the breasting lines are approximately 10 degrees. Figure 8-8, from a study of a number of ship moorings at piers and wharves (NFESC TR-6005-OCN) is used to estimate that a mooring system using synthetic lines will have an efficiency of approximately 0.67 for the case of breasting lines with a 10-degree vertical angle. The estimated total required working mooring line capacity is the working line capacity of the optimum ideal mooring divided by the efficiency. In this case, the estimated working line capacity required is 1,243 kips/0.67 or approximately 1,855 kips (8,250 kN).

For extra safety, the selected concept 'Model 2' is given 11 mooring lines of three parts each of aramid mooring line, as shown in Figure 8-9. A single part of line is taken as having a break strength of 215 kips (920 kN). These lines have a combined working strength of 11 lines x 3 parts x 215 kips / 3 = 2,365 kips (10,520 kN) with a factor of safety of 3. These lines are selected to provide extra safety. A component analysis, Figure 8-10, suggests that this mooring concept has adequate mooring line capacity in the surge and sway directions.

Quasi-static analyses are performed by computer using a fixed mooring software program (ANSYS, *ANSYS-AQWA Reference Manual*). Analyses are performed for various wind directions around the wind rose. Results show that the mooring line factors of safety are larger than the required minimum of 3 (i.e. line tensions divided by the new line break strength is less than 0.33), as shown in Figure 8-11. In this concept the spring lines are especially safe with a factor of safety of about 10. These analyses show ship motions of approximately 1 foot (0.3 m) under the action of the 75 mph (33.5 m/s) design winds.

Further quasi-static analyses show this concept is safe in up to 87-mph (38.9-m/s) winds with a factor of safety of 3 or more on all the mooring lines. The computed mooring efficiency for 'Model 2' at this limiting safe wind speed is 0.705, which is slightly higher than the estimated value of 0.67, as shown in Figure 8-5.

These preliminary calculations show that this fixed mooring concept could safely secure the ship. Figure 8-12 illustrates the mooring concept in perspective view. Further information on this example is provided in NFESC TR-6004-OCN, *Wind Effects on Moored Aircraft Carriers.*

Figure 8-8 Efficiency of Ship Moorings Using Synthetic Lines at Piers and Wharves

(after NFESC TR-6005-OCN)

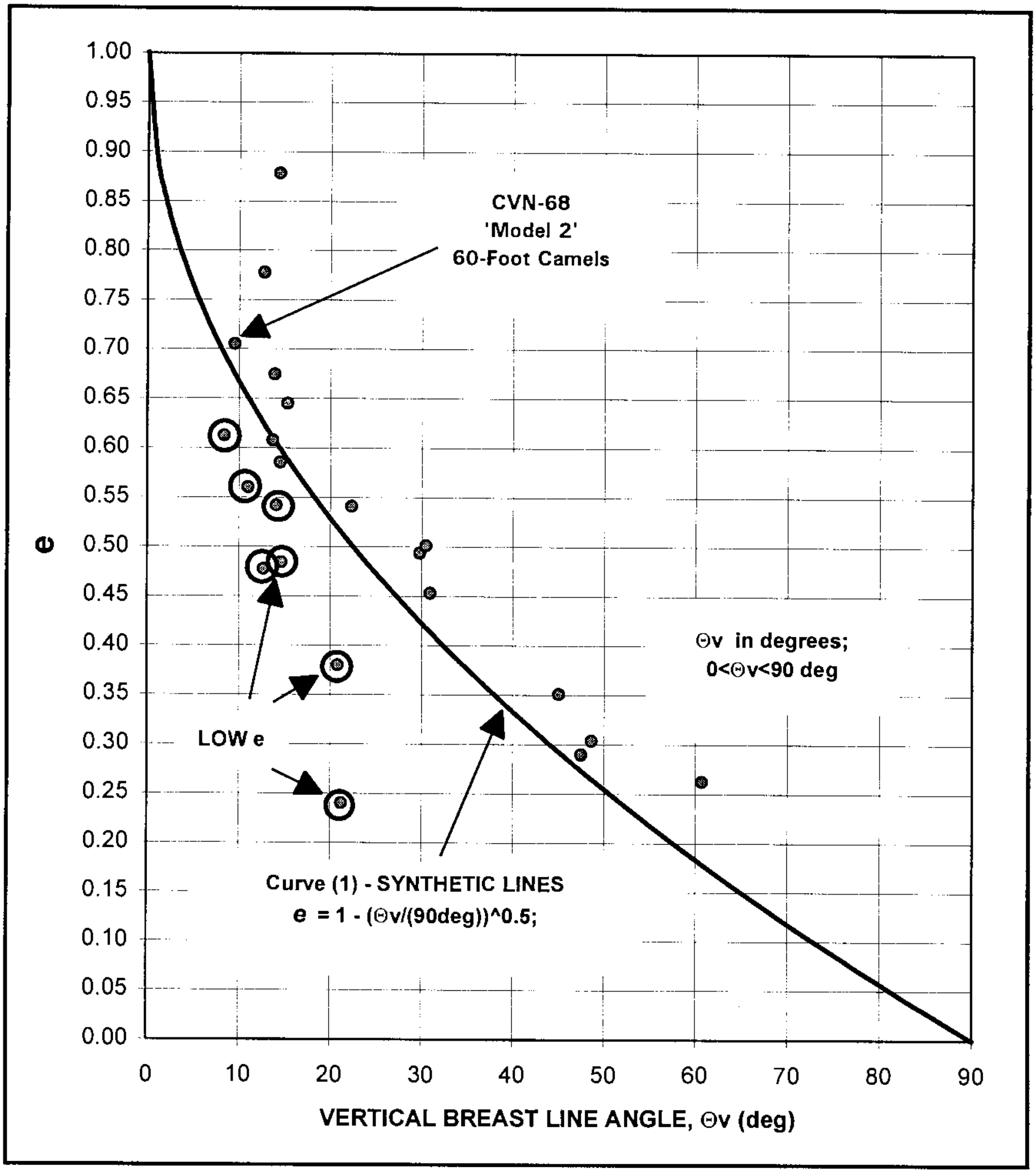


Figure 8-9 CVN 68 Wharf Mooring Concept ('Model 2')

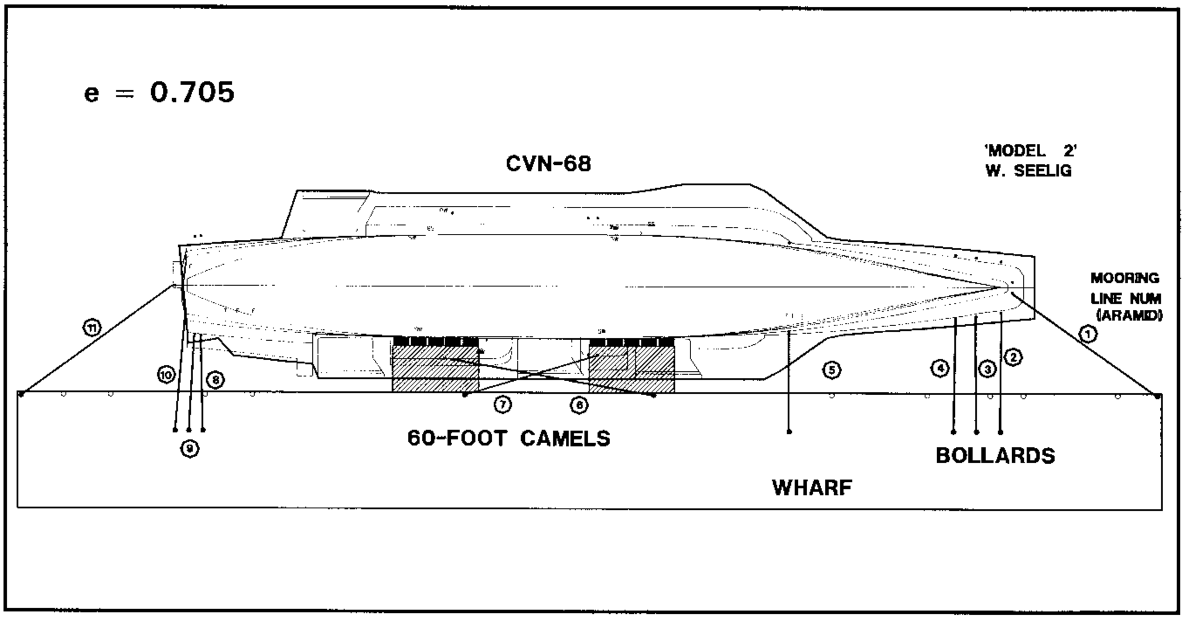


Figure 8-10 Component Analysis of Mooring Working Capacity

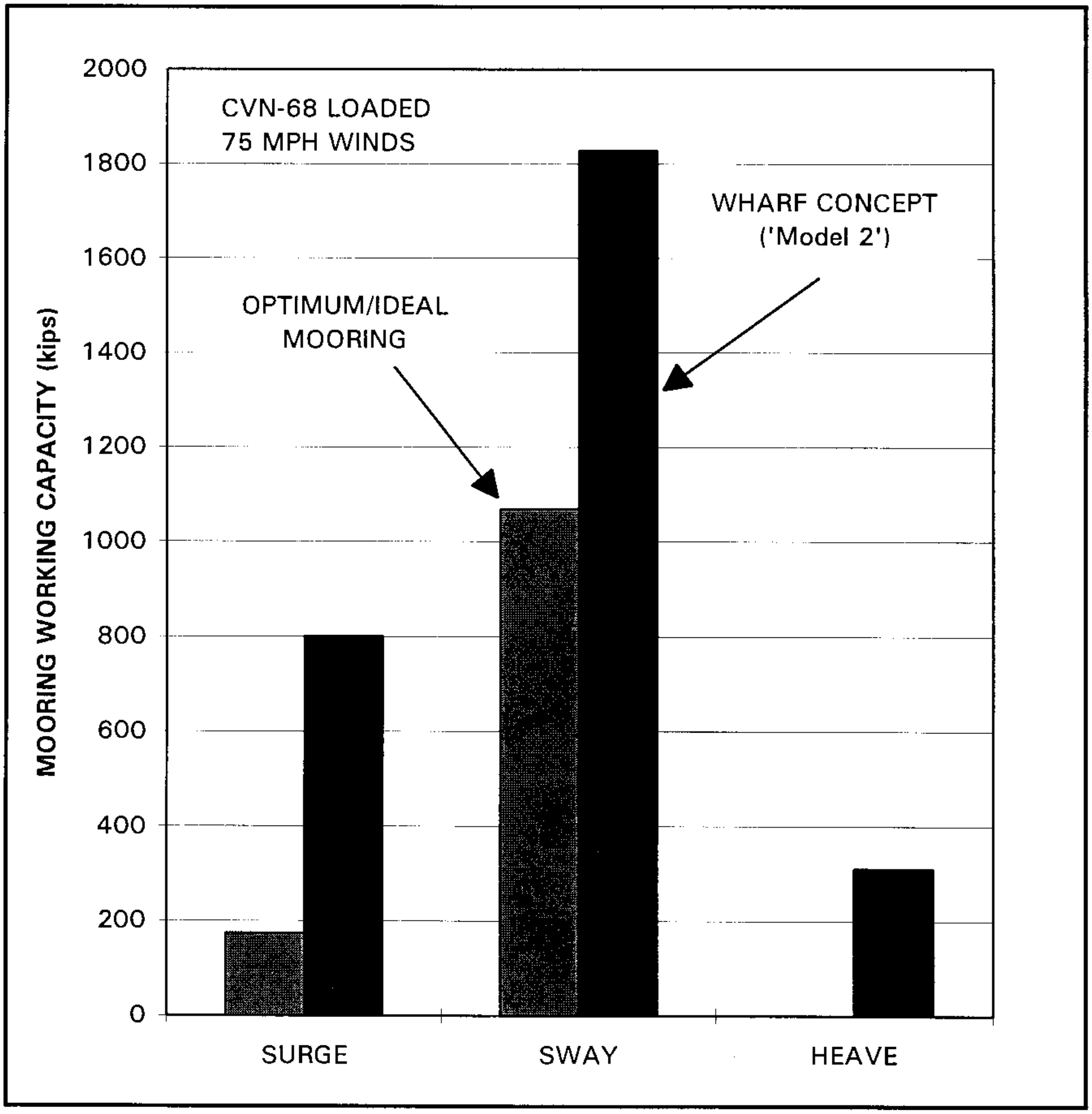


Figure 8-11 Mooring Line Tensions for a CVN 68 Moored at a Wharf with 75 mph Winds ('Model 2')

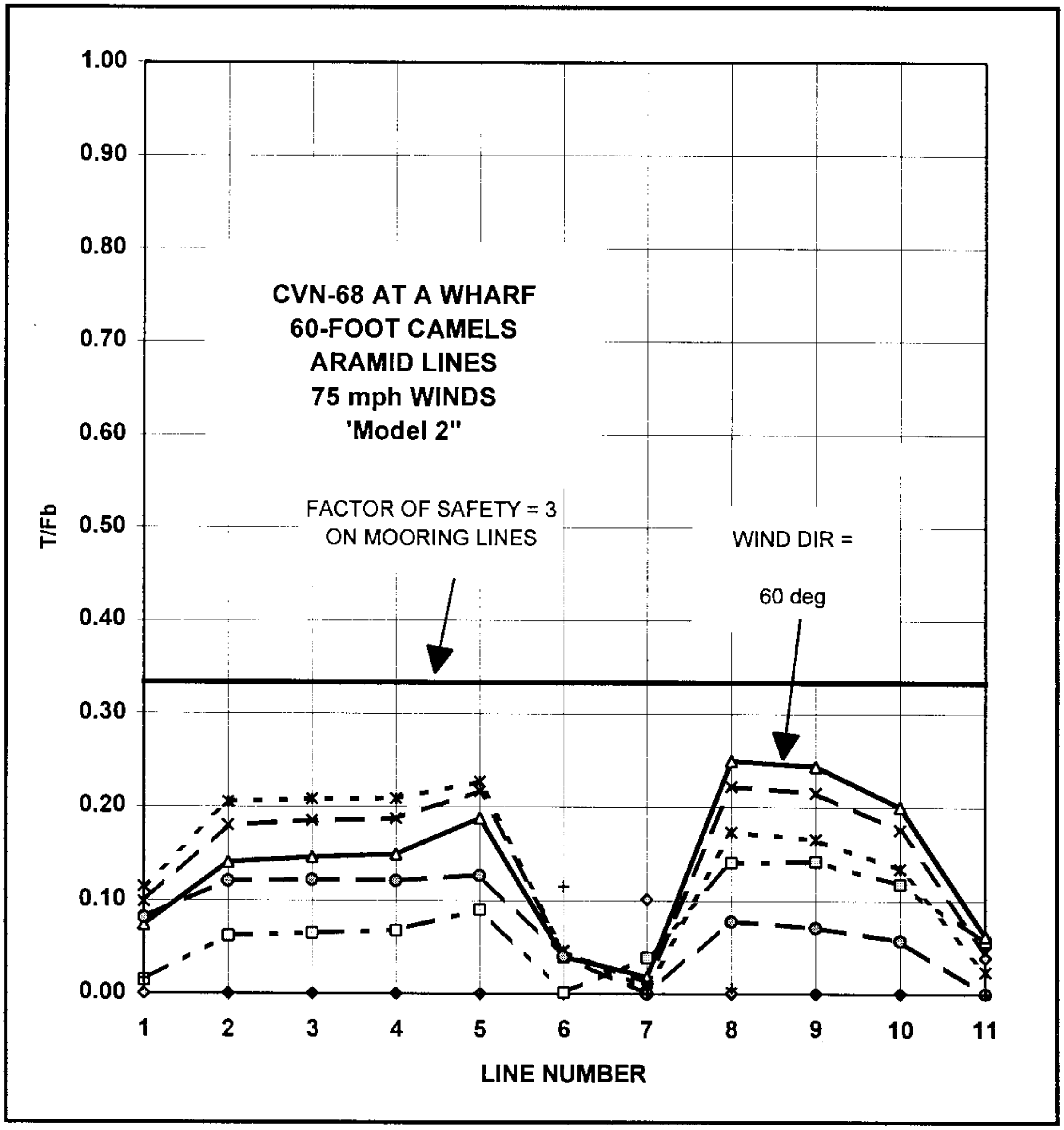
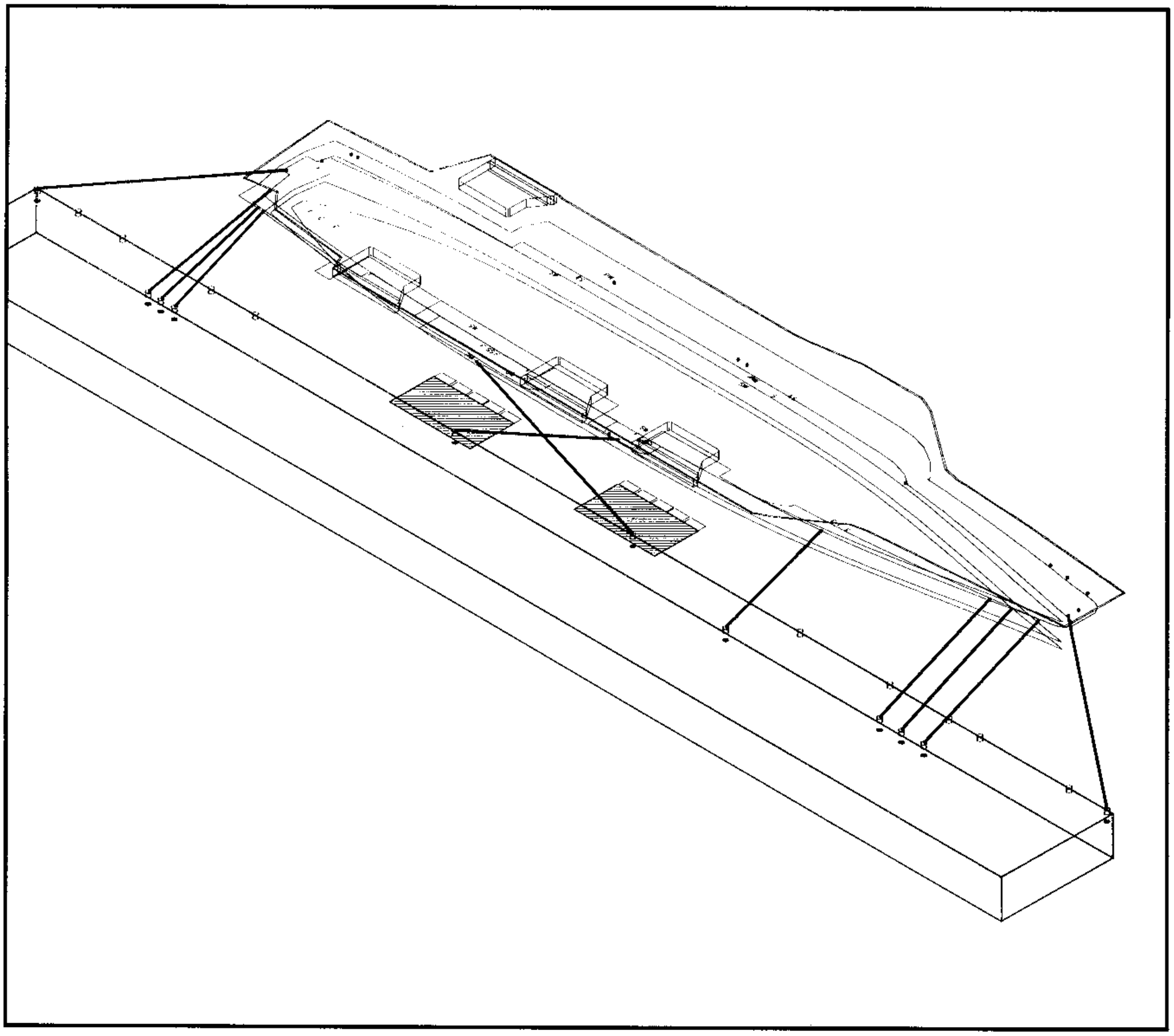


Figure 8-12 Aircraft Carrier Mooring Concept (perspective view)



8-4 SPREAD MOORING - BASIC APPROACH.

Design of a spread mooring for a nest of ships is illustrated in this section.

8-4.1 Background for Example.

SPRUANCE class (DD 963) destroyers are scheduled for inactivation and a mooring is required to secure four of these vessels (NFESC SSR-6119-OCN, *D-8 Mooring Upgrade Design Report*). These ships are inactive and cannot go out to sea, so the mooring must safely secure the vessels in a hurricane using Mooring Service Type IV design criteria. At this location, wind is the predominant environmental factor of concern. At this site the tidal range and tidal current are small. Soil conditions at the site consist of an upper soft silty layer between 50 to 80 ft (15 to 24 m) in depth over a stiff clay underneath. Water depth at the site ranges between 31 to 35 ft (9.4 to 10.7 m) MLLW.

8-4.2 Goal.

Develop a concept to moor four DD 963 class destroyers in a spread mooring. Use MST IV criteria and a design wind speed of 78.3 mph (68 knots or 35 m/s).

8-4.3 Ship.

The ships are assumed to be at one-third stores/cargo/ballast condition, since DD 963 vessels are unstable in the light condition. Table 8-3 gives some ship parameters.

Table 8-3 DD 963 Criteria (1/3 Stores)

Parameter	Design Basis (English Units)	Design Basis (SI Units)
Length Overall Length at Waterline	564 ft 529 ft	171.9 m 161.2 m
Beam at Waterline	55 ft	16.8 m
Average Draft Draft at Sonar Dome	21.2 ft 29 ft	6.5 m 8.8 m
Displacement	8,928 LT	9.07×10^6 kg
Chock Height from Baseline	35 ft 52 ft	10.7 m stern 15.9 m bow

8-4.4 Forces/Moments.

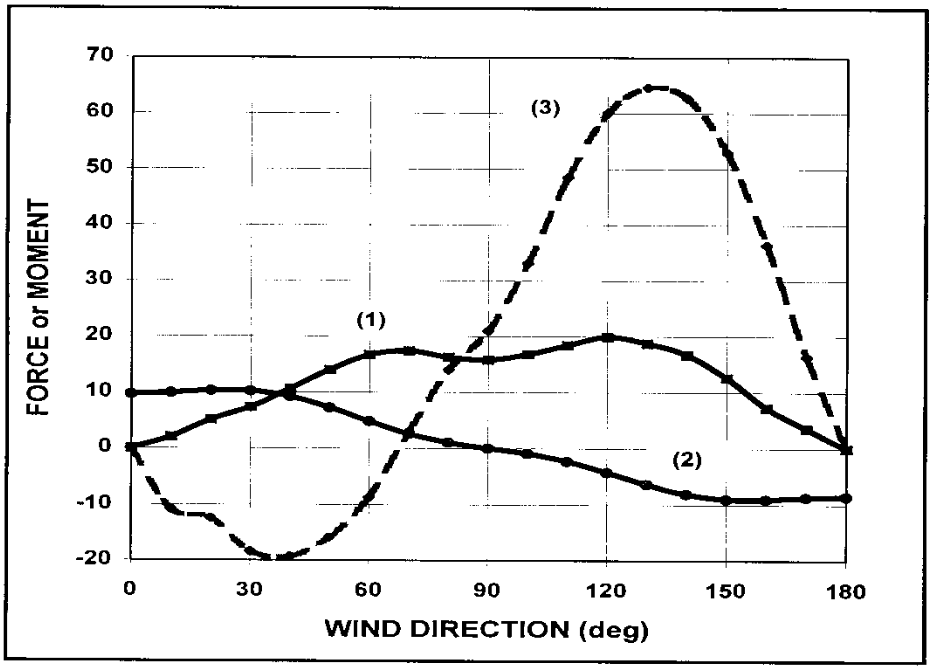
Methods in CHAPTER 4, as well as data in NFESC Report TR-6003-OCN, are used to compute the forces and moments on the ships. These values are summarized in Figure 8-13. Wind angles are based on the local coordinate system for a ship shown inFigure 4-2.

Wind tunnel model tests show that there is significant sheltering in the transverse direction of downwind ships in this nest of identical ships, as shown in NFESC Report TR-6003-OCN. However, there is little wind sheltering in the longitudinal direction. Table 8-4 summarizes the environmental force calculations used for this example.

Table 8-4   Environmental Forces

Condition	Parameter	Load (English Units)	Load (SI Units)
Single DD 963	Transverse Wind	374 kips	1,663.8 kN
	Longitudinal Wind	57.82 kips	257 kN
	Wind-Yaw Moment	26,531 ft-kips	35,972 kN-m
	Transverse Current	23.4 kips	104.2 kN
	Longitudinal Current	0.56 kips	2.5 kN
	Current Yaw Moment	863.1 ft-kips	1,216 kN-m
4 ea DD 963	Transverse Wind	447.4 kips	1,989.9 kN
	Longitudinal Wind	231.3 kips	1,028.7 kN
	Wind-Yaw Moment	47,643 ft-kips	64,595 kN-m
	Transverse Current	42.8 kips	190.6 kN
	Longitudinal Current	2.2 kips	9.8 kN
	Current Yaw Moment	2,372.7 ft-kips	3,342 kN-m

Figure 8-13 Wind Forces and Moments on a Nest of Four DD 963 Class Vessels for a Wind Speed of 78 mph



8-4.5 Anchor Locations.

Driven-plate anchors are selected as a cost-effective method to safely moor the nest of ships. The soils at the site are soft harbor mud of depths between 50 to 80 ft (15 to 24 m), so a chain catenary will form below the seafloor (in the mud) as well as in the water column, as illustrated in Figure 6-4 (Section 6-10). A horizontal distance of 100 ft (30 m) between the anchor location and the chain daylight location (point where the anchor leg chain exits the seafloor) is estimated based on Chain Soil Analysis Program (CSAP) modeling of the chain catenary in the soil and in the water column.

To ensure the mooring legs are efficient in resisting the imposed environmental horizontal forces, a target horizontal distance of 170 ft (52 m) is chosen between the predicted daylight location (where the chain exits the soil) and the attachment point on the ship for each of the mooring legs. Therefore, anchor locations are established at a horizontal distance of 270 ft (82 m) away from the vessel.

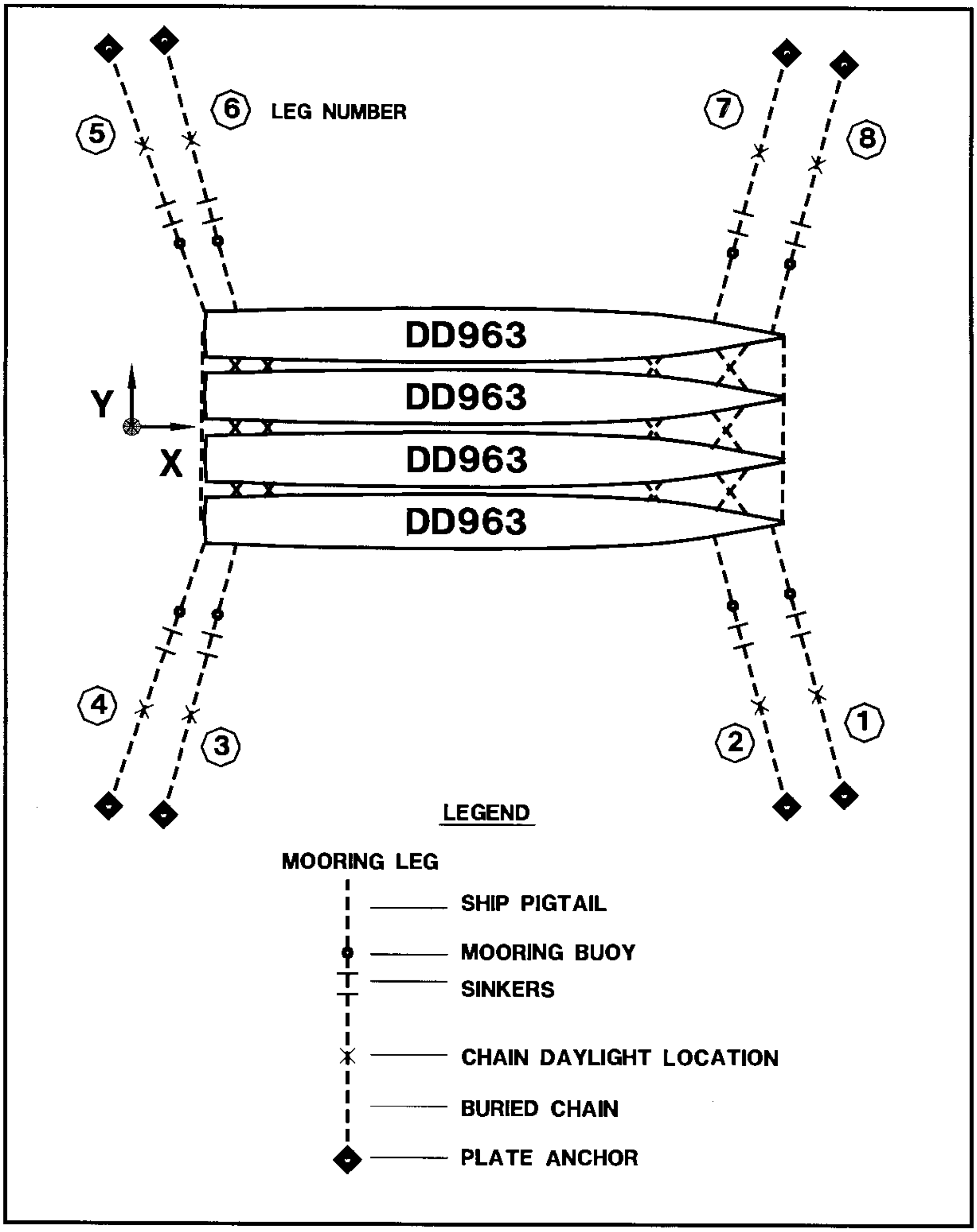
8-4.6 Definitions.

In this example, a local ship and a global coordinate system are defined. The local ship coordinate system is used to determine environmental loads at the various wind and current attack angles, as shown in Figure 4-2, with the origin of the “Z” direction at the vessel keel. A global coordinate system for the entire spread mooring design is selected with the point (0, 0, 0) defined to be at a specific location. For this example, the origin is selected to be in the middle of the vessel nest and 164 ft (50 m) aft of the stern of the vessels. The origin for the “Z” direction in the global coordinate system is at the waterline. This global coordinate system is used by the various analysis programs to define the “chain daylight” locations and the location of the vessel center of gravity within the spread mooring footprint.

8-4.7 Number of Mooring Legs.

It is estimated that eight 2.75 inch (70 mm) chain mooring legs are required, based on the safe working load of the chain (289 kips or 129 kN) and the applied environmental forces and moments on the nest of ships. Four legs are situated on both sides of the nest and each mooring leg is angled to be effective in resisting the longitudinal wind forces, as well as lateral wind forces and moments, from winds approaching at angles other than broadside. Legs are also placed toward the ends of the nest to be effective in resisting the yaw moment. To help control ship motions, two 20 kip (89 kN) sinkers are placed on each mooring leg approximately midway between the vessel attachment point and the predicted chain daylight location. A schematic of the planned spread mooring arrangement is shown in Figure 8-14.

Figure 8-14 Spread Mooring Arrangement for a Nest of Four Destroyers



8-4.8 Static Analysis.

A quasi-static analysis is performed on the mooring system using a mooring analysis program (ANSYS, *ANSYS-AQWA Reference Manual;* other approved mooring analysis programs could have been used). Each mooring leg is initially pretensioned to a tension of 10 kips (4.4 kN). Quasi-static analysis is performed for various combinations of wind and current directions. Quasi-static results for various wind directions in conjunction with a 60-degree flood tidal current of 0.6 knots (0.31 m/s) are shown in Table 8-5.

Table 8-5 Quasi-Static Leg Tensions for Spread Mooring at Various Wind Directions with a Flood Tidal Current

Wind Direction							
Leg	**0°**	**30°**	**60°**	**90°**	**120°**	**150°**	**180°**
kips							
1	11.8	48.33	100.49	136.91	212.45	194.69	121.62
2	-	14.05	78.23	109.26	172.88	208.4	128.37
3	155.79	211.55	189.74	132.19	125.89	77.33	21.02
4	150.17	181.65	137.36	87	57.33	10.25	-
5	139.83	110.16	19	-	-	-	-
6	126.57	102.06	14.55	-	-	-	-
7	-	-	-	-	-	49.68	100.94
8	-	-	-	-	-	69.47	126.79
kN							
1	52.49	214.99	447.01	609.02	945.05	866.04	541.00
2	-	62.50	347.99	486.02	769.03	927.03	571.03
3	693.00	941.04	844.02	588.02	560.00	343.99	93.50
4	668.00	808.04	611.02	387.00	255.02	45.60	-
5	622.01	490.03	84.52	-	-	-	-
6	563.02	454.00	64.72	-	-	-	-
7	-	-	-	-	-	220.99	449.01
8	-	-	-	-	-	309.02	564.00

- Indicates that the leg does not get loaded

A maximum load of 212 kips (943 kN) occurs on Leg 1 at a wind direction of 120 degrees. This provides a quasi-static factor of safety of approximately 4 to the breaking strength of 2.75 inch (70 mm) FM3 chain.

8-4.9 Dynamic Analysis.

A dynamic analysis is performed on the mooring system to evaluate peak mooring loads and vessel motions using a mooring analysis program (ANSYS, *ANSYS-AQWA Reference Manual*). The initial location of the vessel nest is based on the equilibrium location of the vessel nest determined in the quasi-static analysis. An Ochi-Shin wind spectrum is used to simulate the design storm *(Wind Turbulent Spectra for Design Consideration of Offshore Structures*, Ochi-Shin, 1988). This simulation is performed for a 60-minute duration at the peak of the design storm.

Figure 8-14 shows that the four vessels in the nest are close together and Figure 8-15 shows that the ships have a large ratio of ship draft to water depth. In this case it is estimated that the ships will capture the water between them as the ships move. Therefore, the nest of moored ships was modeled as a rectangular box having a single mass with the dimensions of 529 ft (161.2 m) (length of each ship at the waterline), 235 ft (71.62 m) wide (four ship beams + 5 ft spacing between ships), and 21.32 ft (6.5 m) deep (average vessel draft). Added mass for sway and surge was computed as if the nest was cylindrical in shape with a diameter equal to the average draft. Damping as a function of frequency was estimated from a diffraction analysis (ANSYS, *ANSYS-AQWA Reference Manual*).

Dynamic analyses were performed for various combinations of wind and current directions using a wind speed time history that simulated the design storm. Results showing the instantaneous peak tensions for various wind directions in conjunction with a flood tidal current of 0.6 knots (0.31 m/s) are shown on Table 8-6.

Figure 8-15 End View of DD 963 Mooring Nest

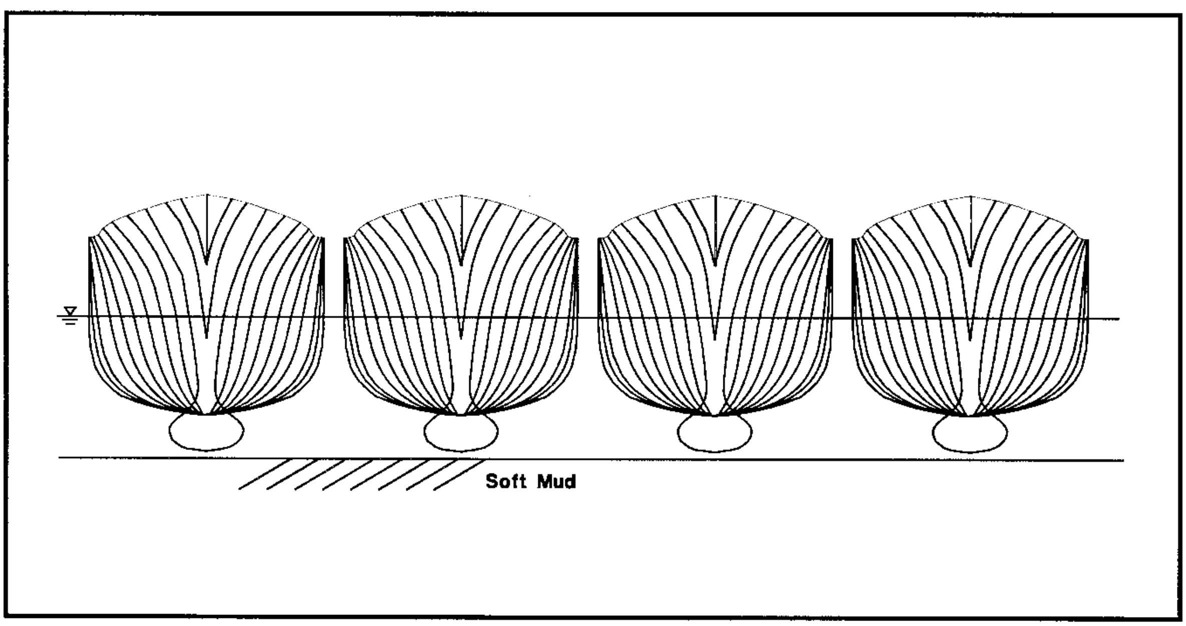


Table 8-6 Peak Dynamic Chain Tensions for DD 963 Nest for Various Wind Directions and a Flood Tidal Current

Wind Direction							
Leg	**0°**	**30°**	**60°**	**90°**	**120°**	**150°**	**180°**
kips							
1	37.55	64.95	142.53	186.29	504.95	415.55	164.50
2	12.38	39.25	96.74	122.58	239.91	259.00	161.98
3	270.33	365.31	223.90	184.07	307.98	145.62	47.35
4	306.23	371.31	146.98	108.09	109.43	54.08	-
5	288.69	304.92	49.26	-	-	-	-
6	210.88	202.74	48.79	-	-	-	-
7	-	-	-	-	12.37	84.28	115.61
8	-	-	-	-	38.34	109.13	187.61
kN							
1	167.05	288.9	634.03	828.68	2246.2	1848.5	731.73
2	55.089	174.58	430.31	545.27	1067.2	1152.1	720.54
3	1202.5	1625	995.98	818.81	1370	647.78	210.62
4	1362.2	1651.7	653.82	480.82	486.77	240.56	-
5	1284.2	1356.4	219.12	-	-	-	-
6	938.06	901.87	217.04	-	-	-	-
7	-	-	-	-	55.019	374.91	514.26
8	-	-	-	-	170.54	485.43	834.54

Modeling shows that the instantaneous peak chain tension of 505 kips (2246 kN) is predicted on Leg 1 as the moored vessel nest responds to wind gusts. This provides a peak instantaneous factor of safety of 1.5 on the breaking strength of the selected chain size. For this example, the peak dynamic chain tension during the 1 hour at the peak of the design storm is 2.4 times the quasi-static tension in the mooring leg with the highest tension, Leg 1.

Nest motions for surge, sway, and yaw are provided in Table 8-7. This table shows that the maximum surge of the vessel nest is approximately 24.3 ft (7.4 m) from its equilibrium condition at no loading. Maximum sway and yaw of the vessel nest is 10.5 ft (3.2 m) and 1.59 degrees clockwise, respectively. During a dynamic analysis simulation, nest motions oscillated up to 17.7 ft (5.4 m) in surge (for a wind direction coming from the stern), 6.2 ft (1.9 m) in sway (for a wind direction 30 degrees aft of broadside), and 2.1 degrees in yaw (for a wind direction 30 degrees off the stern).

8-4.10 Anchor Design.

Using the quasi-static design mooring leg tension, anchor capacity and loads on the embedded plate anchor are calculated using procedures outlined in NFESC TR-2039-OCN, *Design Guide for Pile-Driven Plate Anchors* and NFESC CR-6108-OCN, *Anchor Mooring Line Computer Program Final Report, User's Manual for Program CSAP2*. Due to the lower shear strengths of the soft silty upper layers at the site, a 6-foot by 11-foot

(1.83 m by 3.35 m) mud plate anchor is specified (this anchor is summarized in the lower line of Table 8-7). A design keyed depth of 55 ft (16.76 m) is selected for the plate anchor. This will provide an estimated static holding capacity of 430 kips (1,913 kN).

CSAP is used to predict the mooring leg tension at the anchor. Input requirements of CSAP include: (1) mooring leg configuration between the anchor and the buoy or chock; (2) water depth or height of chock above the seafloor; (3) soil profiles and strength parameters; (4) location and size of sinkers; (5) horizontal tension component of the mooring leg at the buoy or chock; (6) horizontal distance or total length of the mooring leg between anchor and buoy or chock; and (7) anchor depth.

Output provided by CSAP includes: (1) chain catenary profile from the anchor to the buoy or chock attachment point; (2) angle of the mooring leg from the horizontal at the anchor, the seafloor, and the buoy or chock; (3) tension of the mooring leg at the anchor, seafloor, and at the buoy or chock; (4) predicted daylight location for the mooring leg; and (5) length of mooring leg required or horizontal distance between anchor and buoy or chock.

Table 8-7 DD 963 Nest Motions for Surge, Sway, and Yaw at Various Wind Directions with a Flood Tidal Current

Wind Direction							
Motion	**0°**	**30°**	**60°**	**90°**	**120°**	**150°**	**180°**
Surge (m)							
Origin	98.17	98.17	98.17	98.17	98.17	98.17	98.17
Start	105.6	105.4	103.6	98.1	93.7	89.2	88.1
Max	106.9	106.8	103.9	98.8	95.1	93.4	93.5
Min	102.3	102.3	102.4	98.1	93.7	89.2	88.1
Diff	4.6	4.5	1.5	0.7	1.4	4.2	5.4
Sway (m)							
Origin	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Start	0.84	1.49	2.39	2.97	1.27	2.02	1.14
Max	0.84	1.49	2.65	3.13	3.22	2.50	1.45
Min	0.52	0.83	0.93	1.35	1.27	1.43	1.11
Diff	0.32	0.66	1.72	1.78	1.93	1.07	0.34
Yaw (degrees)							
Origin	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Start	0.76	1.09	1.43	0.64	-0.08	-0.74	-0.89
Max	0.76	1.18	1.59	0.80	-1.22	-1.49	-1.12
Min	0.38	0.27	0.43	-0.25	0.76	0.54	-0.83
Diff	0.38	0.91	1.16	1.05	1.96	2.03	0.29

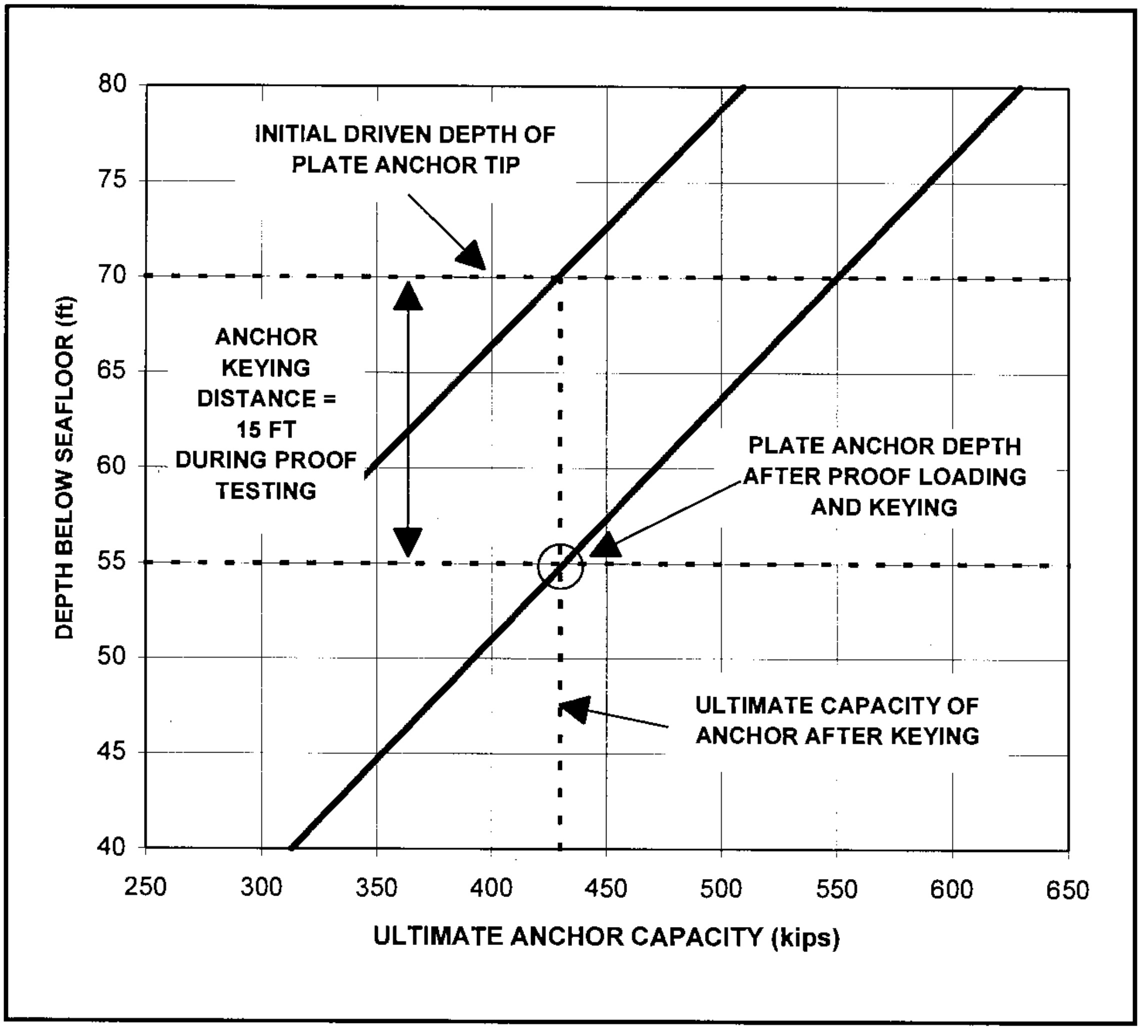
For this example, a keyed anchor depth of 55 ft (16.76 m) was selected. Input data included: (1) configuration of the mooring leg (30 ft (9.14 m) of 3 inch (76.2mm) wire attached to 2+ shots of 2.75 inch (70 mm) chain); (2) height of seafloor to vessel chock (46 ft (14 m) stern and 64 ft (19.5 m) bow); (3) soil profile and strength for the site (shear strength increases linearly at 10 pounds per ft^2 per foot of depth); (4) information on the sinkers (2 each 20-kip (89 kN) sinkers placed a horizontal distance of 170 ft (51.8 m) away from the anchor; (5) horizontal tension component of the mooring leg from the quasi-static results (195 kips); (6) horizontal distance between anchor and chock (280 ft (85 m)) from the quasi-static results; and (7) depth of anchor (55 ft (16.8 m)).

CSAP results for this design leg at this anchor depth indicate that the predicted daylight location of the mooring leg is approximately 99 ft (30 m) from the anchor location and the leg tension at the anchor is 166 kips (738.4 kN). A profile of this leg is shown in Figure 6-5. The interaction between the chain and the soil accounts for a 25% reduction in tension on the mooring leg at the anchor. This gives a predicted quasi-static anchor holding factor of safety of 2.6.

Based on the CSAP results, 6-foot by 11-foot plate anchors are specified. Based on predicted keying distances required for this anchor, as outlined in NFESC TR-2039-OCN, *Design Guide for Pile-Driven Plate Anchors*, the anchors should be installed to a tip depth of 70 ft (21 m) below the mudline to ensure that the anchor is keyed at a minimum depth of 55 ft (16.8 m). Figure 8-16 provides a comparison between tip depth, keyed depth and ultimate capacity for this size anchor.

Further information concerning this design is provided in NFESC SSR-6119-OCN.

Figure 8-16 Plate Anchor Holding Capacity (6-foot x 11-foot anchor with keying flaps in soft mud)



8-5 MOORING LPD 17, LHD 1 AND LHA 1.

As funding and time permit we are preparing general guidelines and recommendations for mooring and/or anchoring various classes of U.S. Navy ships. Work to date includes:

Reference	Title
NFESC TM-6010-OCN	*Some LHA(R) Mooring Concepts*
NFESC TR-6020-OCN	*Mooring USS WASP (LHD 1) Class Ships*
NFESC TR-6028-OCN	*Mooring USS TARAWA (LHA 1) Class Ships*
NFESC TR-6045-OCN	*LPD 17 USS SAN ANTONIO Class Berthing, Mooring and Anchoring*

Detailed information on mooring these three classes of ships is provided in the reports listed above.

8-5.1 MOORING LHD 1, Fully Loaded.

Examples of mooring LHD 1 (Figure 8-17 and Table 8-8) are illustrated in this section.

Figure 8-18 is a summary of the estimated safe mooring limits for LHD 1 based on the NFESC TR-6020-OCN for the ship moored with 32 parts of ship's lines. Figure 8-19 is a summary of the estimated safe mooring limits for LHD 1 based on the NFESC TR-6020-OCN for the ship moored with 28 parts of ship's lines.

Figure 8-17 Proposed Breasting Lines for LHD 1 Heavy Weather Mooring at NNSY Berths 42/43

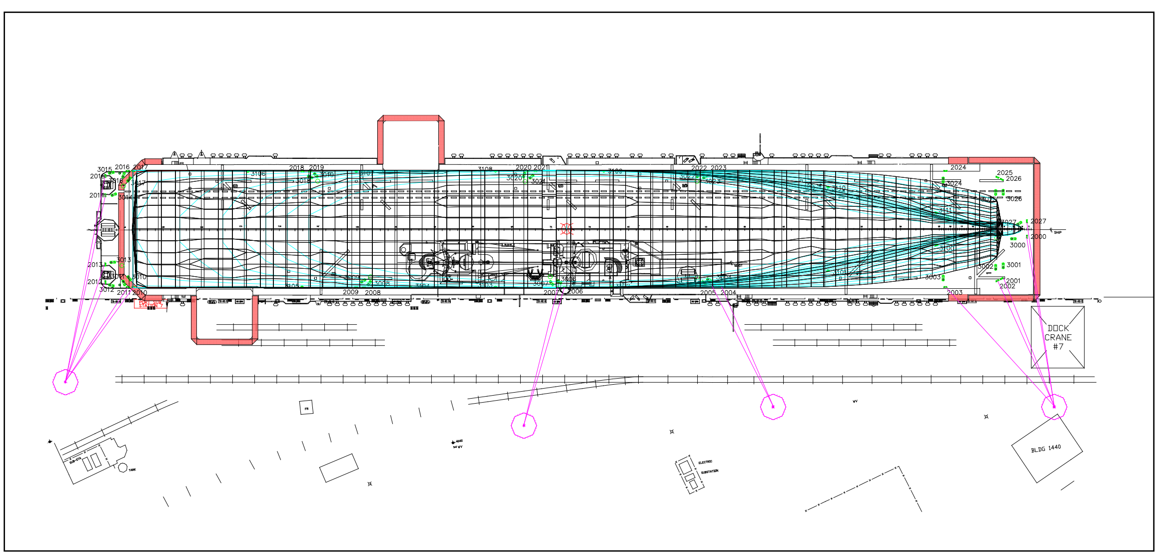


Table 8-8 LHD 1 CLASS CHARACTERISTICS, FULLY LOADED

Parameter	Design Basis (English Units)	Design Basis (SI Units)
LHD 1 through LHD 7 Ingalls Shipbuilding Launched 1987 through 1999		
Length Overall At Waterline Between Perpendiculars	 844 ft 788 ft 778 ft	 257.3 m 240.2 m 237.1 m
Width at Waterline	106 ft	32.3 m
Draft	26.7 ft	8.15 m
Buoyancy	4.43 $x10^6$ lb/ft	64.7 $x10^6$ N/m
Longitudinal Area Above Waterline	61075 ft^2	5675 m^2
Transverse Area Above Waterline	8,800 ft^2	817.6 m^2
Vessel Block Coefficient	0.637	0.637
Midships Section Coefficient	0.958	0.958
Wetter Surface Area	89,028 ft^2	8721 m^2
Roll Period	17.14 sec	17.14 sec
Displacement	40,674 LT	4.053 $x10^7$ kg
KG	40.41 ft	12.32 m
GM	13.42 ft	4.090 m
Double Bitts	12 inch 540 kips	305 mm 2,402 kN
Recessed Bitts	92 kips [a]	409 kN [a]

Note:
[a] Working capacity from Ingalls Shipbuilding Records for LHD 5

Figure 8-18 LHD 1 Safe Mooring Limits from 32 Part Line

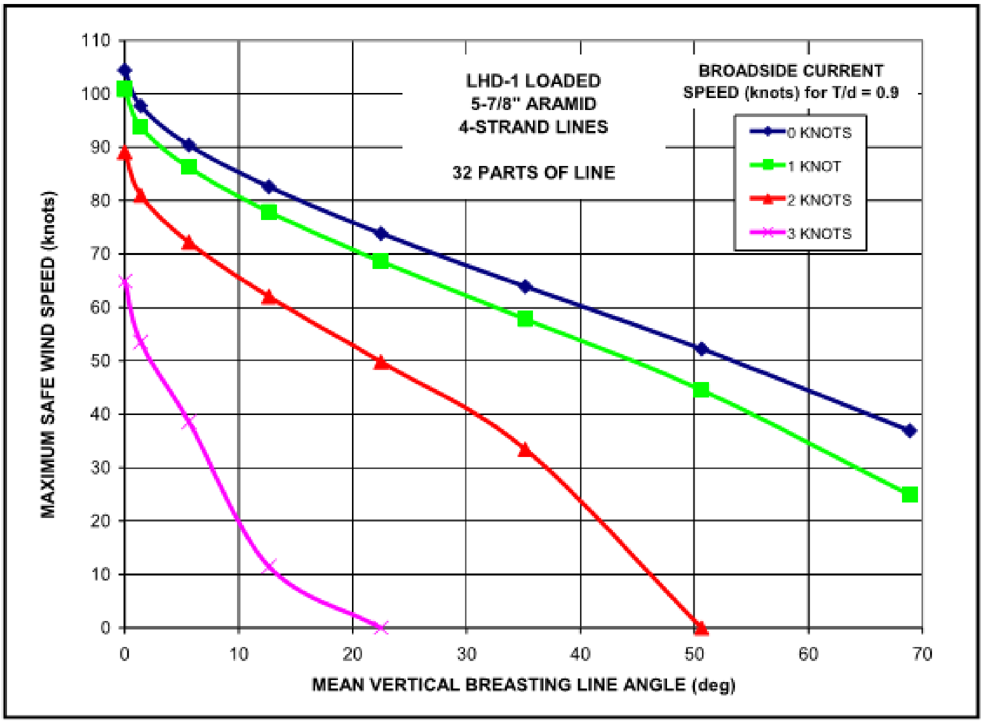
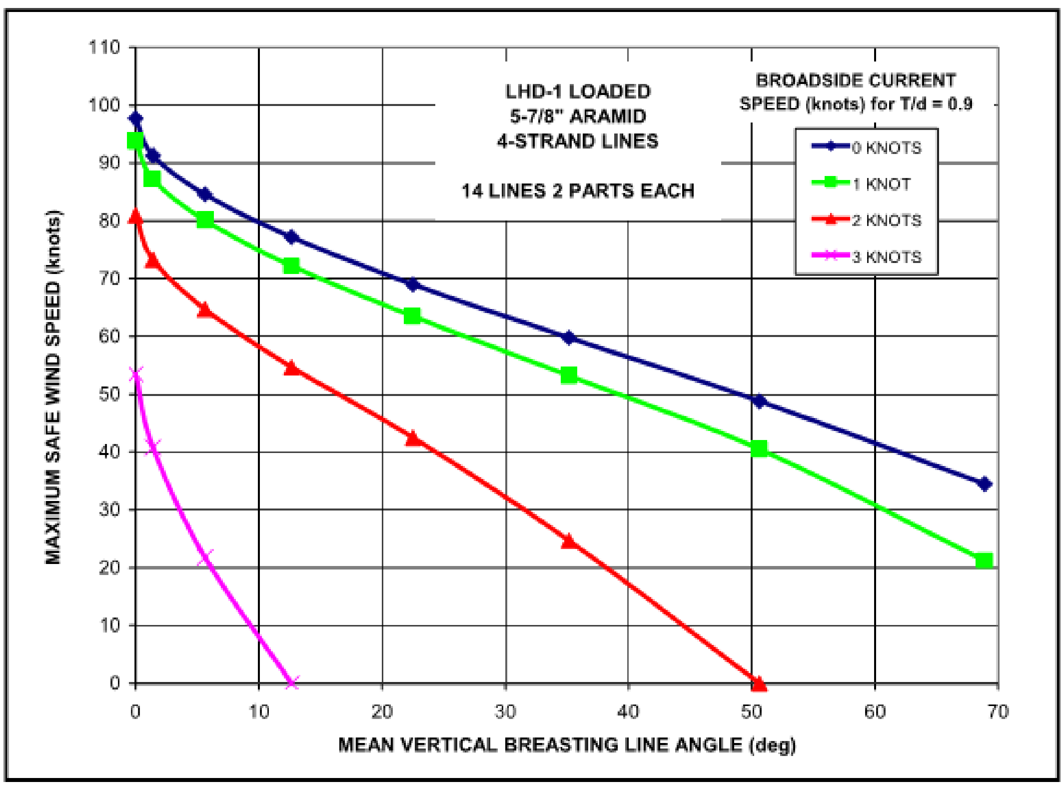


Figure 8-19 LHD 1 Safe Mooring Limits from 28 Part Line



8-5.2 Mooring LPD 17.

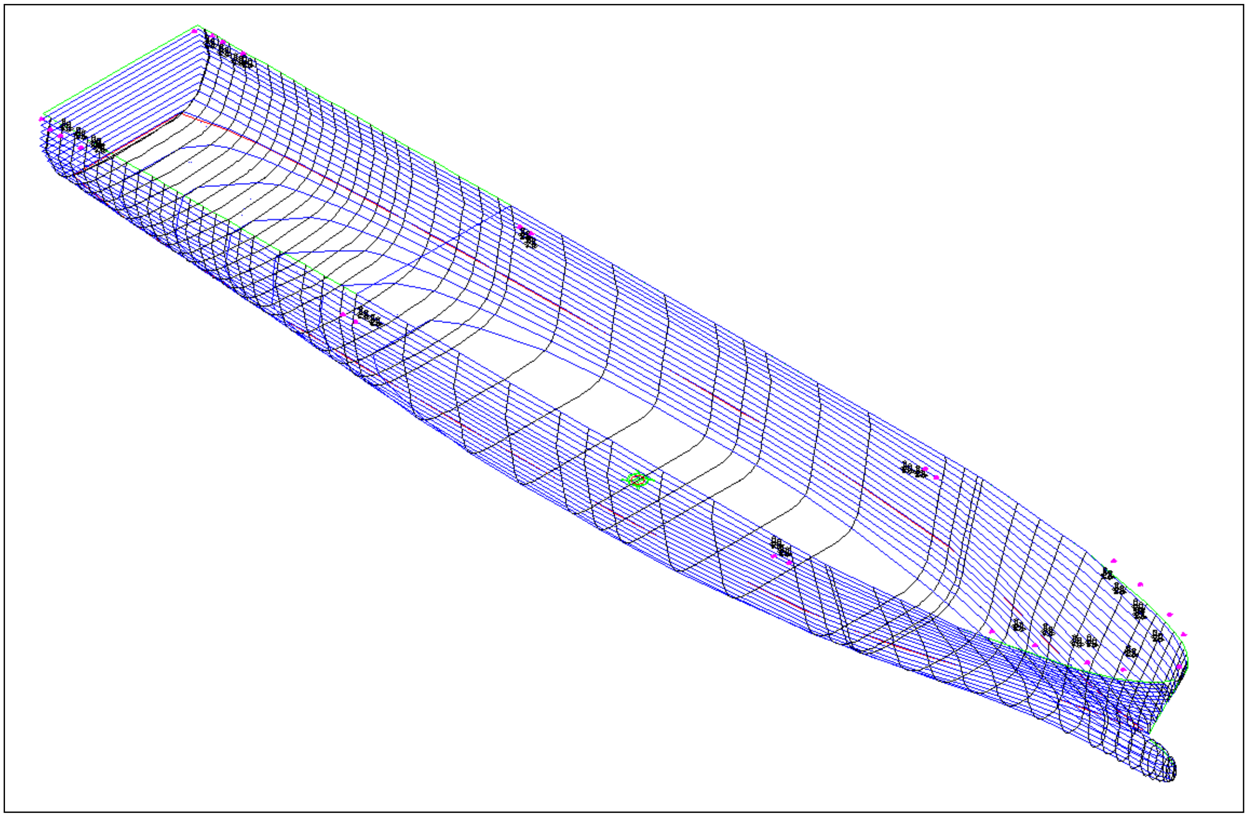
Examples of mooring LPD 17 (Figure 8-20 and Table 8-9) are illustrated in this section.

Figure 8-21 is a summary of the estimated safe mooring limits for LPD 17 based on the EMOOR planning tool for the ship moored with 28 parts of ship's lines. Figure 8-21 (upper) is for a water depth of 45 ft (13.72 m) (i.e. T/d = 0.5) and Figure 8-21 (lower) is for a water depth of 25.2 ft (7.7 m) (i.e. T/d = 0.9). The diagonal lines on the graph correspond to various broadside current speeds, *Vc*. The dashed horizontal lines are for the cases of 50 knot (25.7 m/s) and 64 knot (32.92 m/s) winds. The X-axis on each diagram is the mean vertical angle of the breasting lines. The Y-axis is the estimated maximum safe wind speed.

For example, take the case of the ship moored at a berth with a water depth of 25 ft (7.62 m) and a broadside current of 1.5 knots (0.77 m/s). For a mean vertical breasting line angle of 30 degrees, the maximum estimated safe wind speed from Figure 8-21 (lower) is 53 knots (27.3 m/s)

Figure 8-20 LPD 17 USS SAN ANTONIO

(Upper – hull form and mooring fitting locations, Lower – profile view)



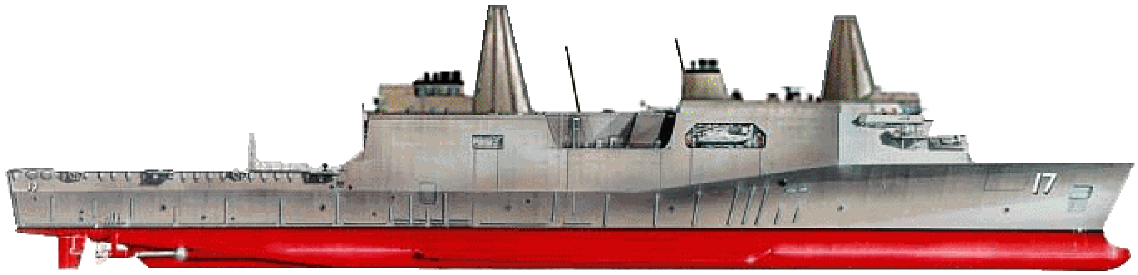


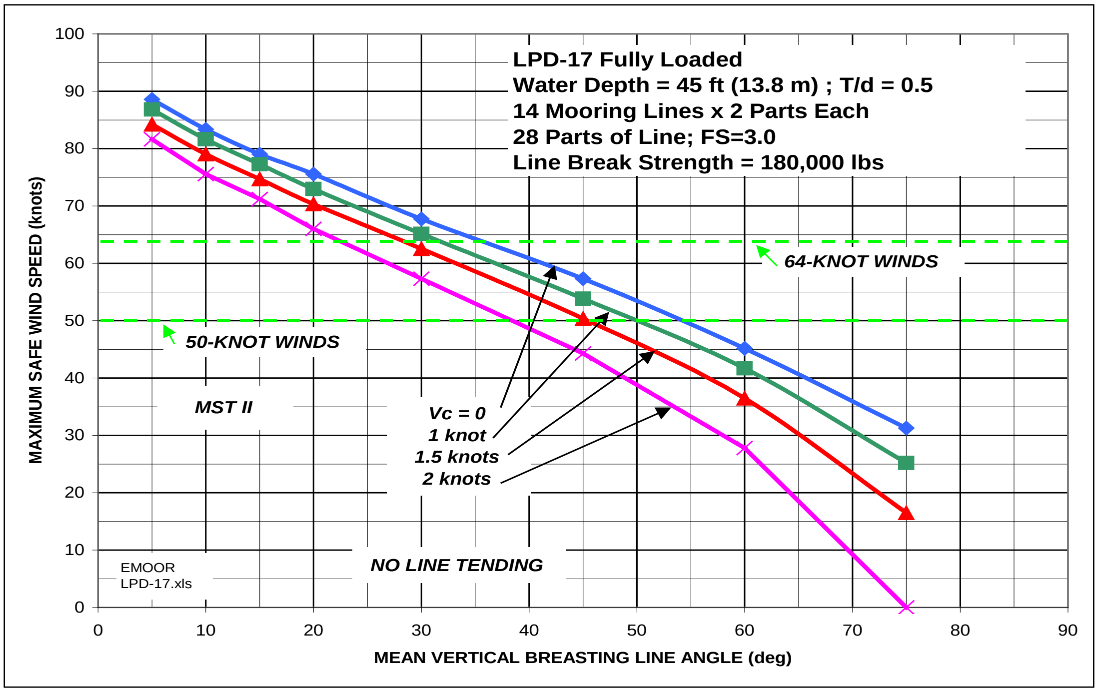
Table 8-9 LPD 17 Characteristics

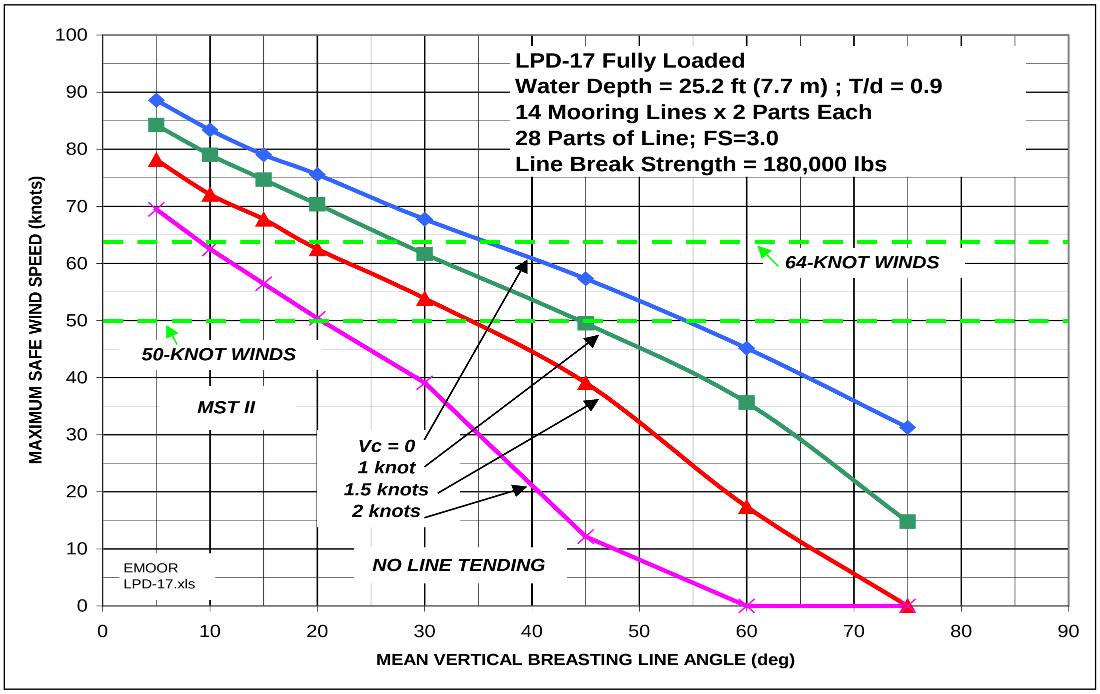
Parameter	English Units	SI Units
Displacement (Full Load)	26,750 US tons 23,880 LT	2.43 x10^7 kg
Draft (Full Load)	22.64 ft	6.9 m
Length Overall	684 ft	208.5 m
Length at Design Waterline	661 ft	201.5 m
Bow Overhang from DWL Perpendicular	19.68 ft	6 m
Stern Overhang from DWL Perpendicular	6.52 ft	2 m
Breadth, Molded Maximum	104.67 ft	31.9 m
Breadth, Amidships at DWL	96.67 ft	29.46 m
Lowest Projection above DWL	22.33 ft	6.81 m
Highest Projection above DWL	158 ft	48.16 m
Deck Elevation (01 Level) above DWL	39.33 ft	12 m
C_m = C_x Midships Coefficient	0.937	0.937
C_b Block Coefficient	0.601	0.601
C_p Prismatic Coefficient	0.641	0.641
Wetted Surface Area	68,246 ft^2	6,340 m^2
Waterplane Area	50,830 ft^2	4,722 m^2
Vertical Center of Gravity [d]	36.5 ft	11.13 m
Natural Period in Roll	13.37 sec	13.37 sec
Vertical Center of Pressure [d]	40.4 ft	12.32 m
Anchors (two-fluke, balanced fluke type)	30,425 lb [b]	13,800 kg [b]
Chain (ABS Grade 3 stud link) [c]	3-3/8 in	85 mm
Ship's Mooring Lines: 18 with length of 600 ft; break = 3 with length of 600 ft; break =	 180 kips 280 kips	 801 kN 1,246 kN
Main Double Bitt Size	12 in	305 mm
Secondary Double Bitt Size	14 in	356 mm
Maximum allowable hull pressure	21 psi	145 kN/m^2

Note:

[a] nominal size
[b] delivered weight, min. specified 27,550 lb, one port and one starboard
[c] 11 shots port and 13 shots starboard
[d] above baseline

Figure 8-21 Approximate Safe Mooring Limits for LPD 17 with 28 Parts of Mooring Line





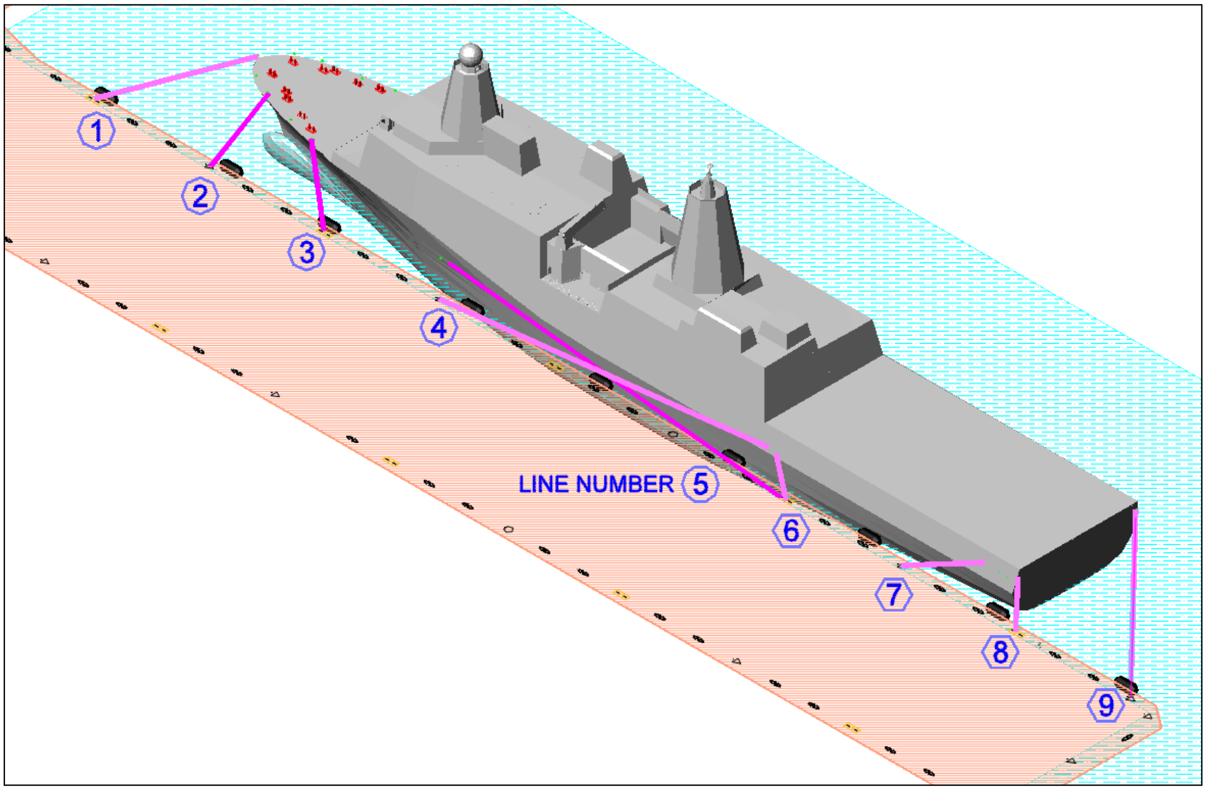
Six degree of freedom quasi-static analyses using the program ANSYS AQWA are performed on various LPD 17 mooring configurations to determine safe mooring limits as follows:

Figure 8-22 shows a sample Standard Mooring (MST IIA) for the ship broadside to a current pushing the ship off the pier. In this example the water depth is 45.3 ft (13.8 m) for a ship draft to water depth ratio of T/d = 0.5. The maximum safe wind speed for various current speeds is illustrated with a factor of safety of 3.0 or higher on all mooring lines.

Figure 8-23 shows a sample Storm Mooring (MST IIB) for the ship broadside to a current pushing the ship off the pier. For the case of a major approaching storm the lines are run across the pier to the bollards on the opposite side to significantly improve mooring efficiency. In this example the water depth is 30.2 ft (9.2 m) for a ship draft to water depth ratio of T/d = 0.75. The maximum safe wind speed for various current speeds is illustrated with a factor of safety of 3.0 or higher on all mooring lines.

Figure 8-24 shows a sample Heavy Weather Mooring (MST III) for the ship broadside to a current pushing the ship off the pier. For the case of a major approaching storm or hurricane the lines are run across the pier to the bollards on the opposite side to significantly improve mooring efficiency. Ship's lines are not adequate for heavy weather mooring. Therefore, double braided polyester lines are used because they have excellent fatigue resistance and some stretch to help improve load sharing. In this example the water depth is 40 ft (12.19 m) for a ship draft to water depth ratio of T/d = 0.57. The maximum safe wind speed for various current speeds is illustrated with a factor of safety of 2.5 or higher on all mooring lines. These dynamic analyses were performed with the six degree of freedom ANSYS AQWA. Figure 8-25 illustrates LPD 17 mooring at a double-deck pier.

Figure 8-22 Sample LPD-17 Standard Mooring (MST IIA)



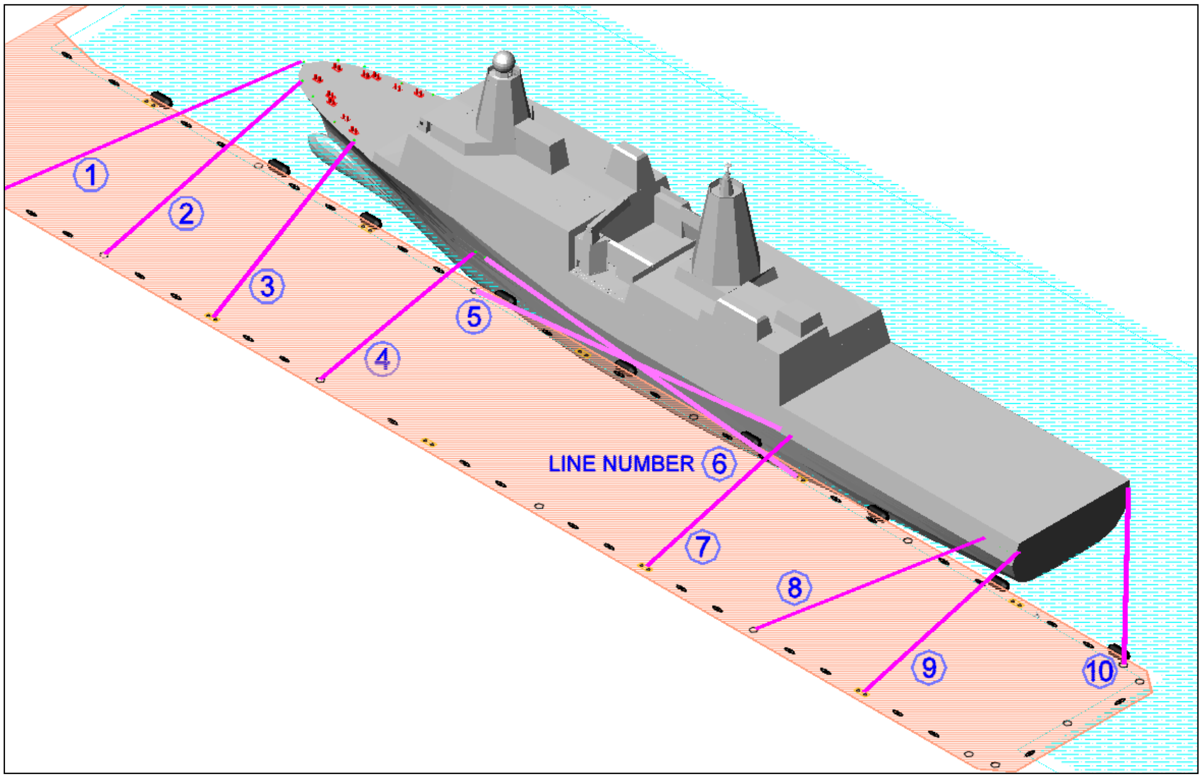
Ship's Mooring Lines
9 Lines of 2 Parts Each = 18 parts of line
1-Foot Slack Added to Lines 2, 7 & 8
Factor of Safety = 3.0 [a]
Water Depth = 45.3 ft (23.3 m/s) (T/d = 0.5)
Maximum Safe Wind Speed for:

Broadside

Current Speed	Maximum Safe Wind Speed
0 knot	55 knot (28.29 m/s)
1 knot (0.51 m/s)	48 knot (24.69 m/s)
1.5 knot (0.77 m/s)	44 knot (22.64 m/s)
2 knot (1.03 m/s)	37 knot (19.03 m/s)

Note:
[a] Factor of safety on new lines with all lines intact. With the most heavily loaded line broken, the factors of safety will likely be reduced.

Figure 8-23 Sample LPD 17 Storm Mooring (MST IIB)

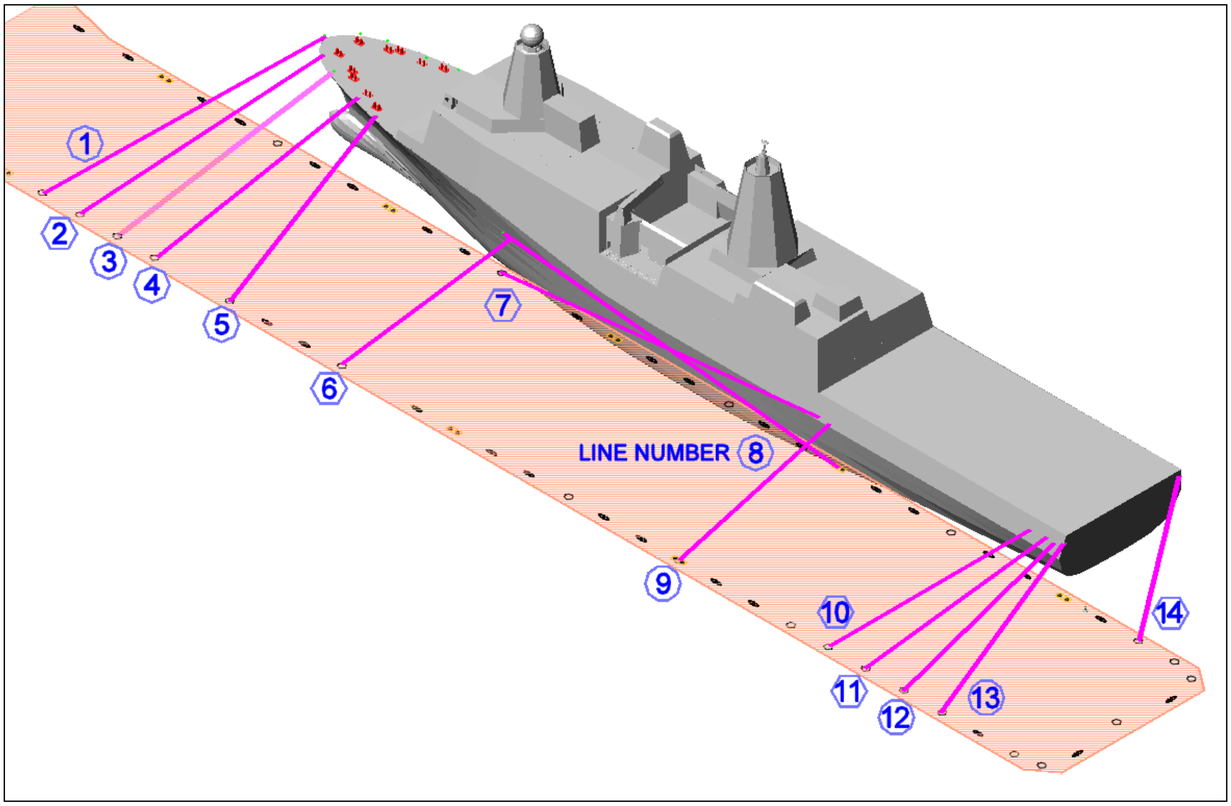


Ship's Mooring Lines
10 Lines of 3 Parts Each = 30 parts of line
Factor of Safety = 3.0 (see note on Figure 8-21)
Water Depth = 30.2 ft (9.2m) (T/d = 0.75)
Maximum Safe Wind Speed for:

Broadside

Current Speed	Maximum Safe Wind Speed
0 knot	85 knot (43.73 m/s)
1 knot (0.51 m/s)	81 knot (41.67 m/s)
1.5 knot (0.77 m/s)	76 knot (39.1 m/s)
2 knot (1.03 m/s)	68 knot (35 m/s)

Figure 8-24 Sample LPD 17 Heavy Weather Mooring (MST III)

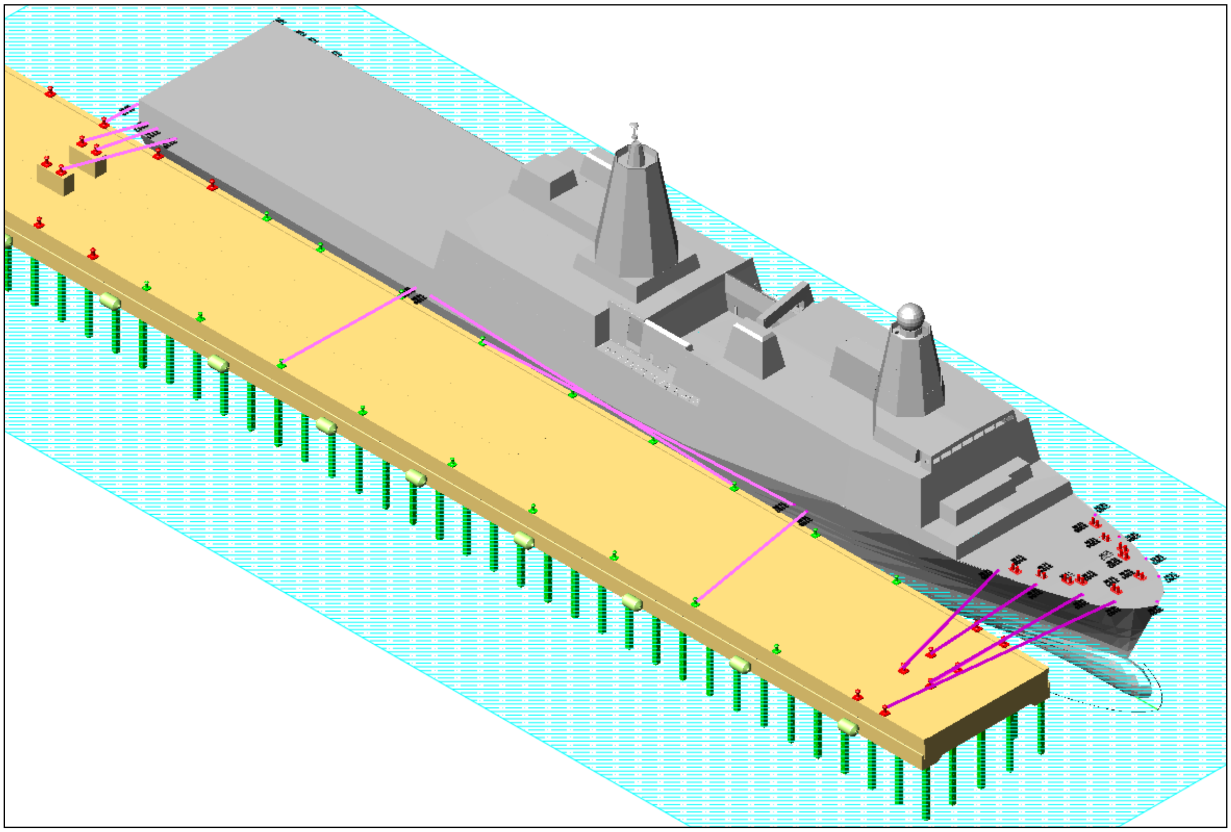


Double Braided Polyester Lines Fb=180 kips
14 Lines of 3 Parts Each = 42 parts of line
Factor of Safety = 2.5 (see note on Figure 8-21)
Water Depth = 40 ft (T/d = 0.57)
Maximum Safe Wind Speed for:

Broadside

Current Speed	Maximum Safe Wind Speed
0 knot	118 knot (60.7 m/s)
1 knot (0.51 m/s)	117 knot (60.19 m/s)
1.5 knot (0.77 m/s)	115 knot (59.16 m/s)
2 knot (1.03 m/s)	113 knot (58.13 m/s)

Figure 8-25 Sample LPD-17 Mooring at a Double-Deck Pier



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CHAPTER 9 PASSING SHIP EFFECTS ON MOORED SHIPS

9-1 INTRODUCTION.

A ship moving through the water generates several types of waves that may have an effect on moored ships, structures, shoreline erosion, etc. One type of wave generated is a long-period pressure wave that may be very small. However, this long wave (together with Bernoulli effects) may have a major influence on moored ships.

9-2 PASSING SHIP EFFECTS ON MOORED SHIPS.

A ship navigating in a harbor or channel can produce major forces/moments on a nearby moored ship. The moored ship is forced through a combination of wave, long-wave and Bernoulli effects (NFESC TR-6027-OCN). NSTB Marine Accident Report, PB91-916404, NSTB/MAR-91/04, for example, discusses a case where a nearby passing ship caused a moored tanker to break its mooring and fuel lines. The resulting fire caused loss of life, in addition to total loss of the pier and tanker.

The forces and moments acting on the moored ship depend upon a great number of parameters including, relative size of the two ships, water depth, as well as passing ship speed and separation from the moored ship. Figure 9-1 shows an example passing ship case for parallel ships. This figure shows that the forces and moments acting on the moored ship are highly time-dependant. Therefore, dynamic programsare used to determine the response of the moored ship to the passing ship.

Parallel passing ships are discussed in detail in NAVFAC EXWC TR-6056-OCN, and perpendicular passing ships are discussed in detail in NAVFAC EXWC TR-6069-OCN. An associated spreadsheet PASS-MOOR.xls is available that aids in predicting passing ship forces and moments. Figure 9-2 illustrates example predictions. These examples show that peak forces and moments applied to the moored ship in various degrees of freedom occur at different times and highly dynamic. NAVFAC EXWC has capability of providing this type of analysis on a reimbursable funding document for any U.S. government or military agency.

Figure 9-1 Sample Passing Ship Situation

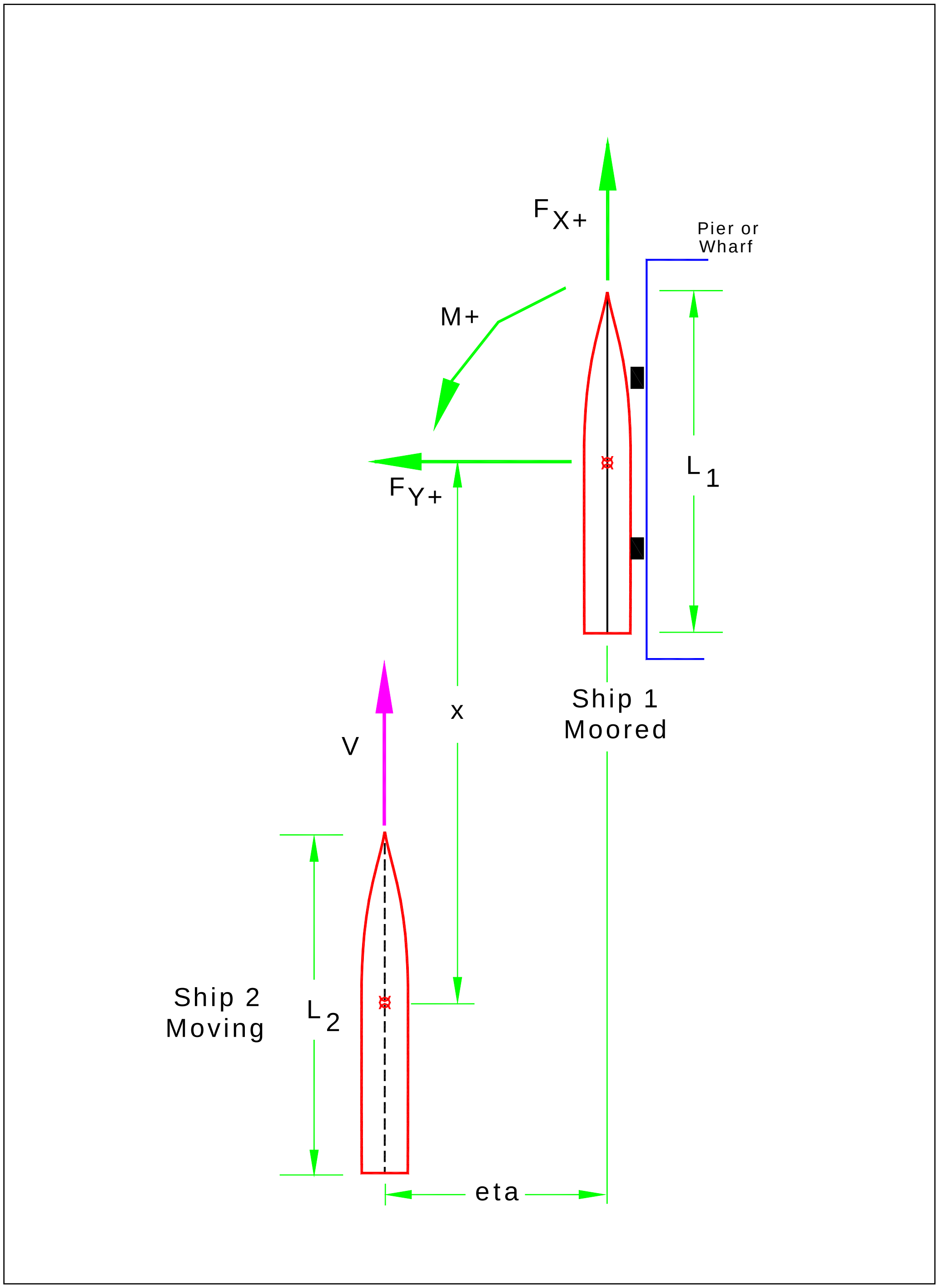
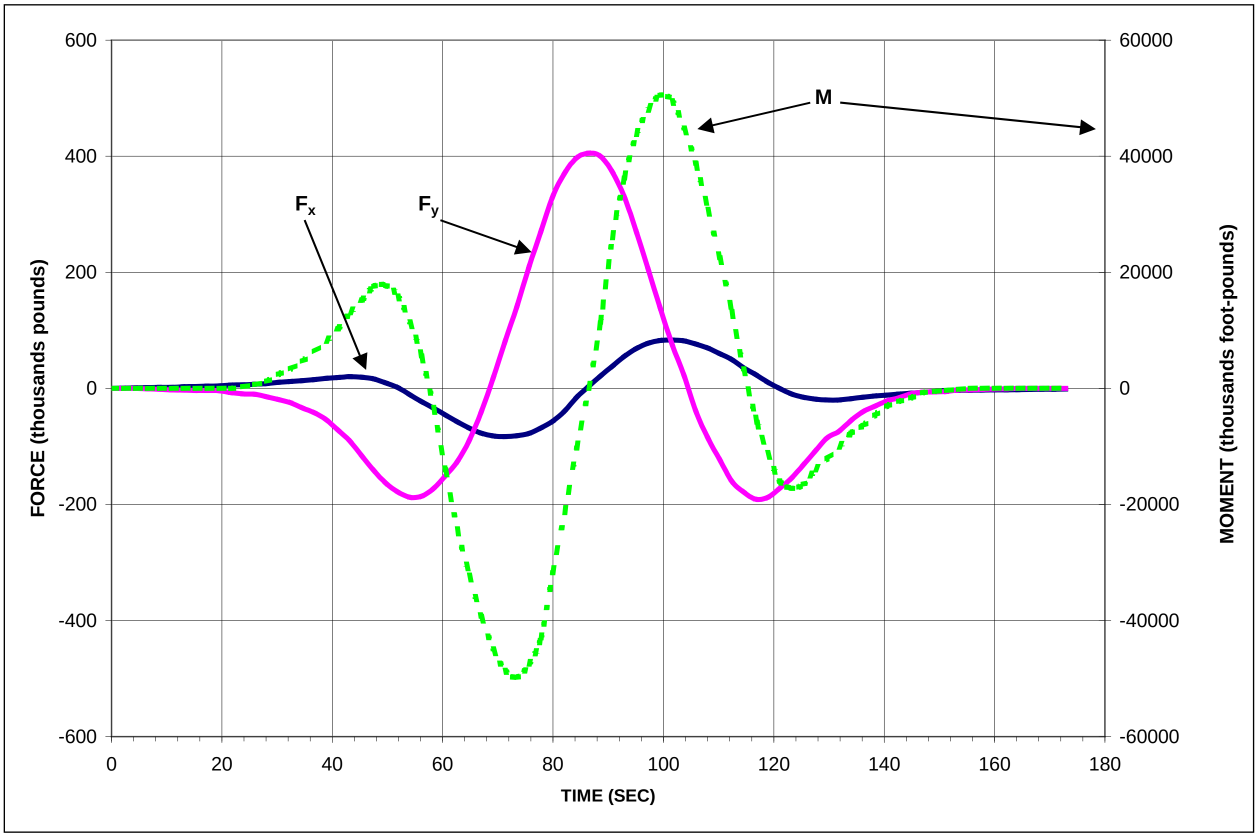


Figure 9-2 Example of Passing Ship Predictions



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CHAPTER 10 SHIP WAVES

10-1 INTRODUCTION.

A ship moving through the water generates several types of waves that may have an effect on moored ships, structures, shoreline erosion, etc.

10-2 SHIP WAVES.

Two of the most noticeable waves generated by moving ships are the diverging (or bow wave) and transverse wave (Figure 10-1). These waves intersect to form a cusp locus line and then the size of the highest generated wave tends to decrease as the distance from the sailing line increases. Characteristics of the ship-generated waves is a complex function of ship shape, water depth, ship speed, etc. NFESC TR-6022-OCN summarizes measurements and recent findings on ship waves for ship hull-forms, such as those illustrated in Figure 10-2.

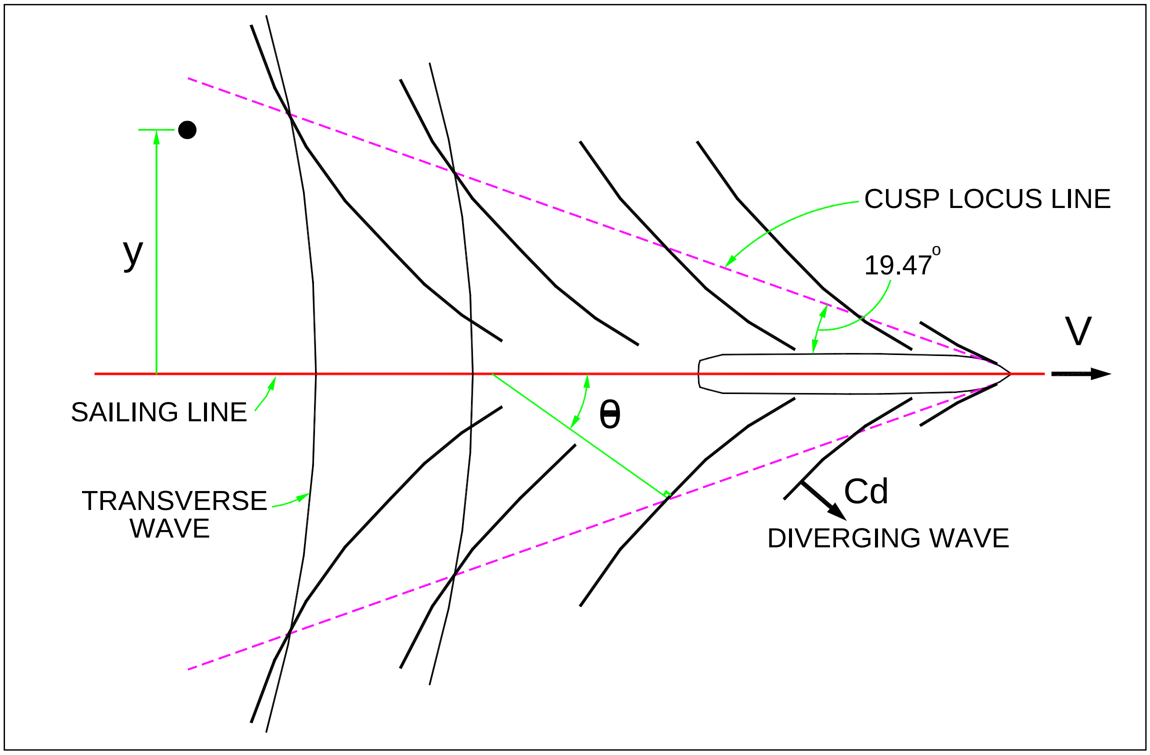
A spreadsheet SHIP-WAVE.xls is available for making ship wave predictions. This spreadsheet takes the measurements from a wide range of physical ship wave measurements and uses one type of Froude scaling to predict maximum wave height one wavelength away from the ship sailing line for a ship of interest.

Figure 10-3, for example, shows the minimum ship speed required to generate a given maximum wave height one wavelength away from the ship sailing line. The X-axis of this figure is water depth. The Y-axis of this figure is ship speed. Contours are for selected maximum wave heights. For deep water (the right side of this figure), the wave height generally increases as the ship speed increases for the range of conditions shown. In shallow water the wave height contours are much closer together at higher speeds. This shows that in shallow water a small increase in ship speed produces a dramatic increase in wave height.

The spreadsheet SHIP-WAVE.xls and report TR-6022-OCN provides additional information on waves generated by surface ships.

Figure 10-1 Ship Waves

(Sorenson, 1997)



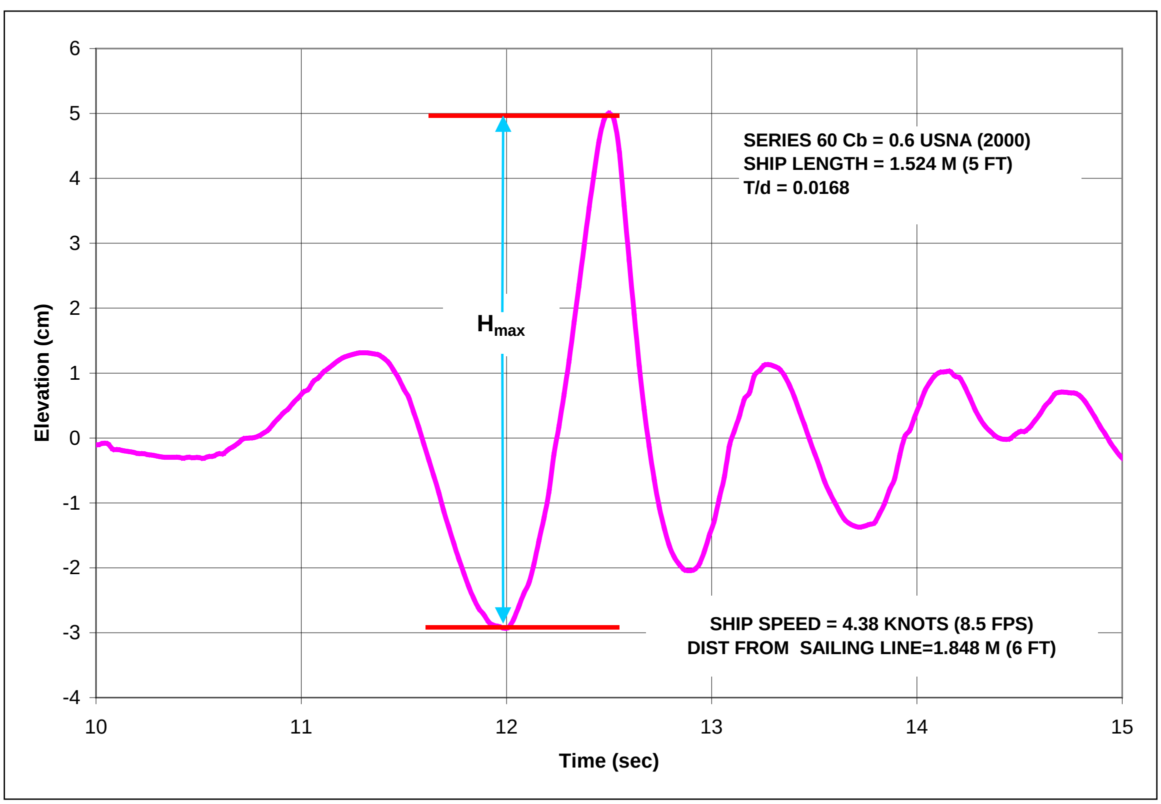


Figure 10-2 Ship Hullforms Tested

(Sorenson, 1997)

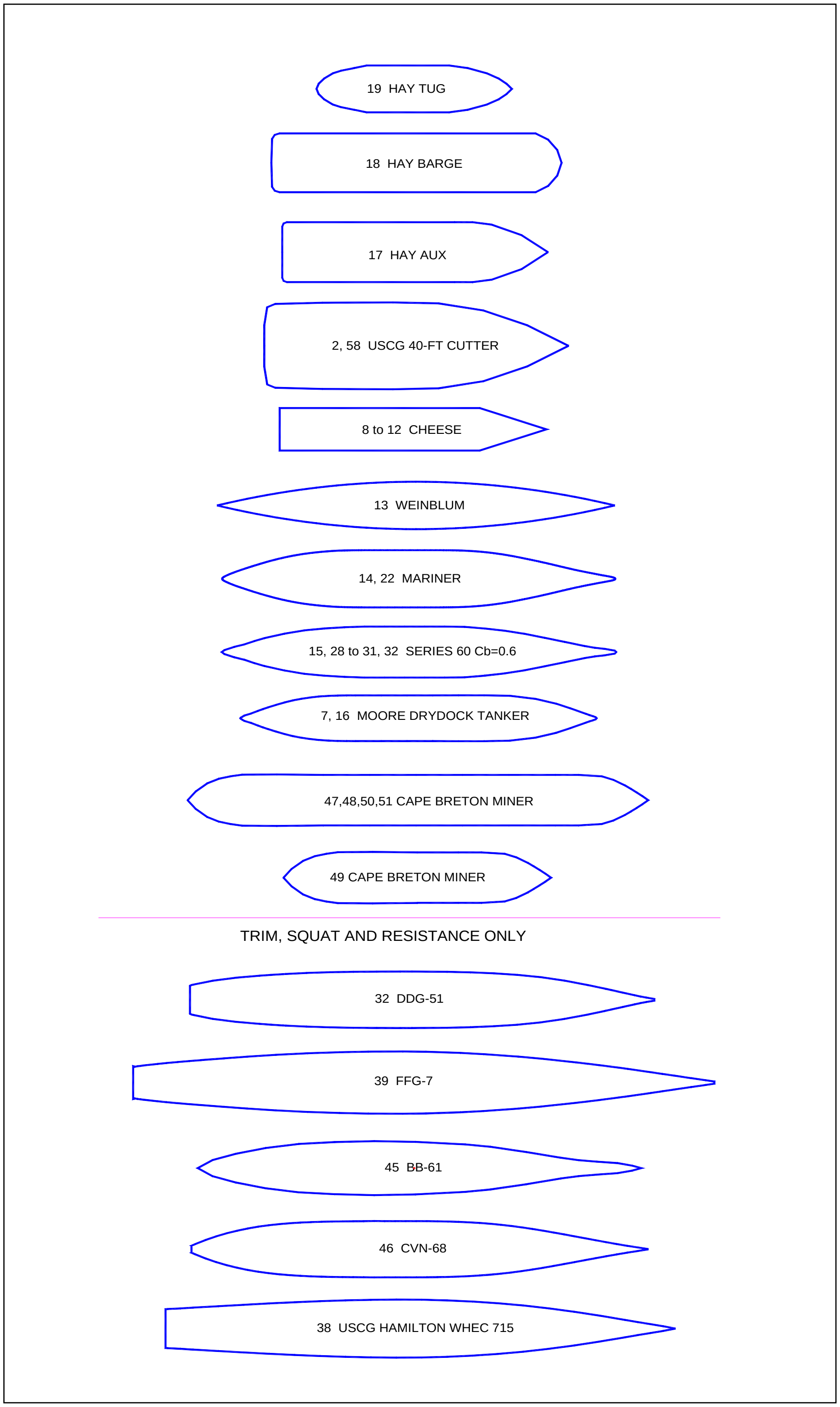
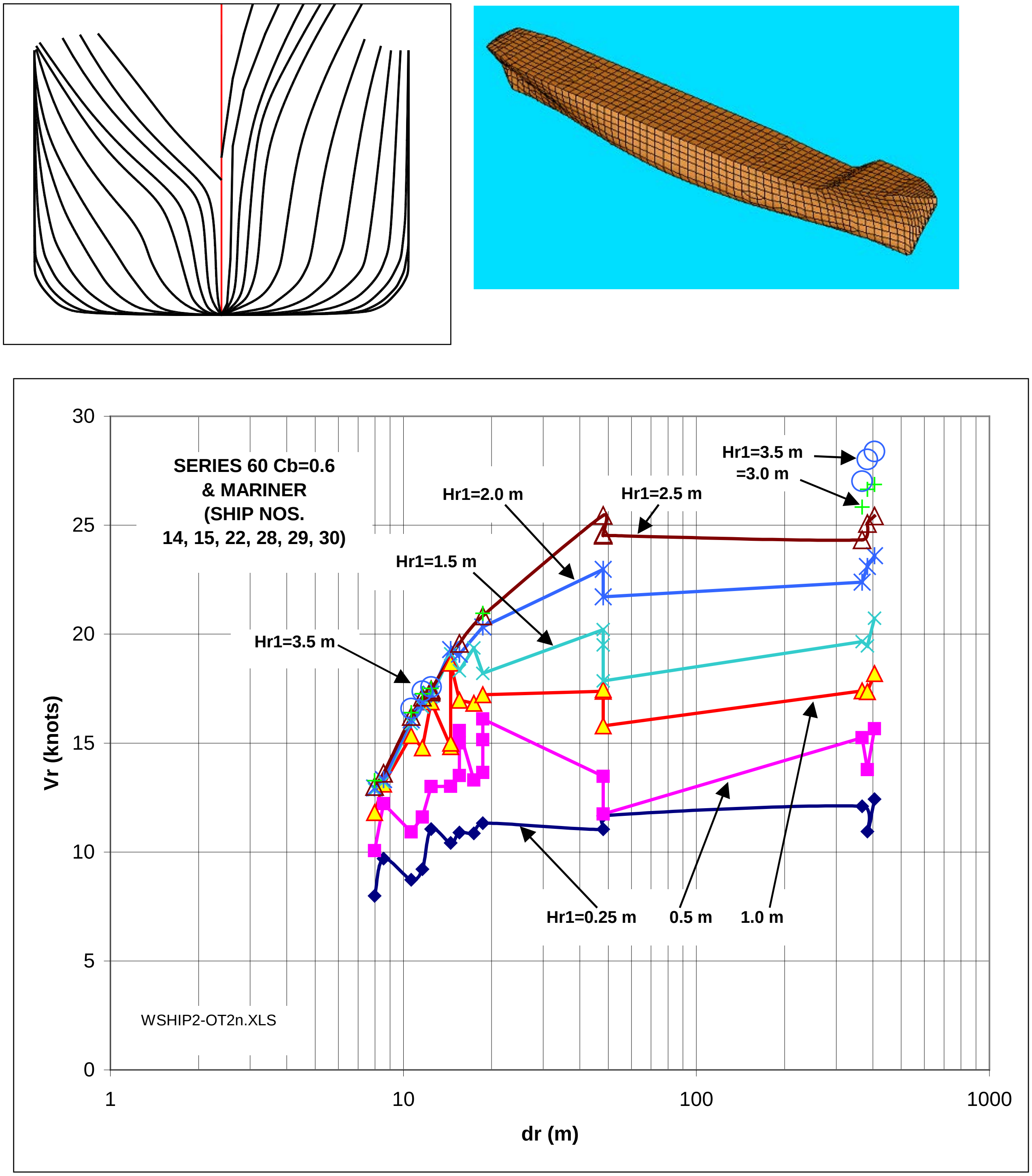


Figure 10-3 Maximum Wave Height One Wavelength Away from the Sailing Line for a SERIES 60 Hull



CHAPTER 11 HEAVY WEATHER MOORING GUIDELINES

11-1 INTRODUCTION.

The purpose of this guidance is to advise facility engineers, planners, and maintenance personnel of minimum facility planning and design criteria necessary to ensure safe mooring of naval vessels during MST III (Heavy Weather). Use this UFC to validate existing sites for heavy weather use and to design new or modified facilities and moorings for heavy weather. Existing facilities and moorings should not be used for heavy weather if they do not meet all criteria noted herein unless provisions are made according to COMNAVSEASYSCOM msg R 130351Z Jul 95 YZB. Since no Building Code or non-government standard exists for MST III design, this UFC provides the relevant safety requirements and criteria for facility aspects of ship mooring.

11-2 DISCUSSION.

This criterion is a compilation of lessons learned from heavy weather mooring studies for COMNAVSURFLANT by COMNAVFACENGCOM, NAVFAC EXWC, and COMNAVSEASYSCOM. This criterion has been extensively coordinated with COMNAVSEASYSCOM and internally within NAVFACENGCOM, COMNAVSURFLANT, CINCLANTFLT N37, N46, and CINCPACFLT N37, N46. It includes state of the art technology in vital facility areas such as mooring and risk assessment. Congressional support for all new construction is dependent on specific planning and design criteria applied consistently throughout the Navy - hence, the need to formalize this criteria. Upgrades to existing facilities likewise require documentation of new “code” requirements. A great deal of work has been performed to ensure that ships are safely moored in Heavy Weather conditions. For example, below is a list of some of the NAVFAC EXWC reports on heavy weather mooring.

NFESC Report	Title
SSR-6078-OCN	*A Preliminary Assessment of Hurricane/Severe Storm Mooring at Naval Station Mayport/Jacksonville, FL*
SSR-6107-OCN	*Heavy Weather Mooring of USS Inchon (MCS-12) at U.S. Naval Station, Ingleside, Texas*
SSR-6112-OCN	*Heavy Weather Mooring of Ships Under Repair in the Hampton Roads Area in 1997*
SSR-6137-OCN	*Heavy Weather Mooring Analyses of Selected Ships Under Repair*, 1998
SSR-6145-OCN	*Heavy Weather Mooring of USS INCHON (MCS-12) at U.S. Naval Station, Ingleside, Texas*
SSR-6148-OCN	*Heavy Weather Mooring Design Report of Avenger and Osprey Class Vessels, U.S. Naval Station, Ingleside, TX*
SSR-6150-OCN	SURFLANT *Heavy Weather Mooring Program, Phase I Completion Report*

SSR-6176-OCN	*Heavy Weather Mooring of FFG-7 and DDG-51 Ships at Subase Kings Bay, Ga*
SSR-6183-OCN	*Concept Study – Mooring Service Type III For a CVN 68 at Naval Station Mayport, Fla*
SSR-6260-OCN	*Hurricane Mooring of Ships and Craft at Naval Coastal Systems Center, Panama City, FL*
SSR-6266-OCN	*Plate Anchor Concept for Heavy Weather Mooring of CVN, LHD and LHA, Berth 42/42 Norfolk Naval Shipyard, Portsmouth, VA*
SSR-6282-OCN	*Heavy Weather Mooring, NAVSTA Pascagoula, MS*
SSR-6342-OCN	*Heavy Weather Mooring of USS JOHN F KENNEDY (CV 67) Naval Station, Mayport, FL*
SSR-6368-OCN	*Heavy Weather Mooring and Berthing-Findings/Recommendations for Selected Berths*
TM-6001OCN	*Risk Analysis for Ships Moored at Piers – Generalized Evaluation of USS Tarawa (LHA-1) Mooring*
TM-6015-OCN	*DD(X) Mooring Concepts*
TR-6004-OCN	*Wind Effects on Moored Aircraft Carriers*
TR-6012-OCN Rev B	*U.S. Navy Heavy Weather Mooring Safety Requirements*
TR-6020-OCN	*Mooring USS WASP (LHD-1) Class Ships*
TR-6023-OCN	*Dynamic Analyses of a CVN 68 in a Heavy Weather Mooring*
TR-6028-OCN	*Mooring USS TARAWA (LHA 1) Class Ships*
TR-6045-OCN	*LPD-17 USS SAN ANTONIO Class Berthing, Mooring and Anchoring*

11-3 HEAVY WEATHER MOORING GUIDELINES.

Ships under repair in graving docks may be relatively safe, since the ships are relatively protected from the potentially high wind forces and are out of current and waves effects. However, ships at piers and wharves may be subjected to high winds, wind gusts, wind gust fronts, currents, waves, storm surges, etc. It is common practice for U.S. Navy ships to exit port prior to arrival of hurricanes and other forecasted extreme weather conditions. This practice is normally executed when destructive winds (sustained wind speed above 50 knots) are expected in the local area. However, ships in availability (i.e. under repair) may not be able to go to sea. Therefore, these ships must be moored safely during heavy weather or be moved to nearby safe facilities before storm arrival. COMNAVSEASYSCOM msg R 130351Z Jul 95 YZB provides operational recommendations to mitigate many effects of heavy weather. The effectiveness of these mitigation measures is difficult to quantify. Therefore, facilities are often relied upon to resist the loads. In each homeporting region, only a portion of all berthing facilities must be capable of heavy weather mooring, since only a portion of the ships cannot go to sea. Ships carry enough lines to moor in MST II as defined below, but not for Type III. Also, facilities are generally designed for Type II and not Type III.

This section provides some general guidelines on heavy weather mooring. For additional information, see the publications listed above. For safe heavy weather mooring:

Ensure that the facility, mooring fittings and fenders are adequate (see UFC 4-150-07, *Waterfront Facilities: Maintenance and Operation*, UFC 4-150-08, *Inspection of Mooring Hardware*, UFC 4-151-10, *General Criteria for Waterfront Construction*, UFC 4-152-01, *Piers and Wharves, etc*.).

Identify alternative piers or wharves that the ship could be towed to that may be safer and work out ahead of time all the logistics necessary to ensure that the needed berth would be available and that the ship could arrive and be safely moored in adequate time.

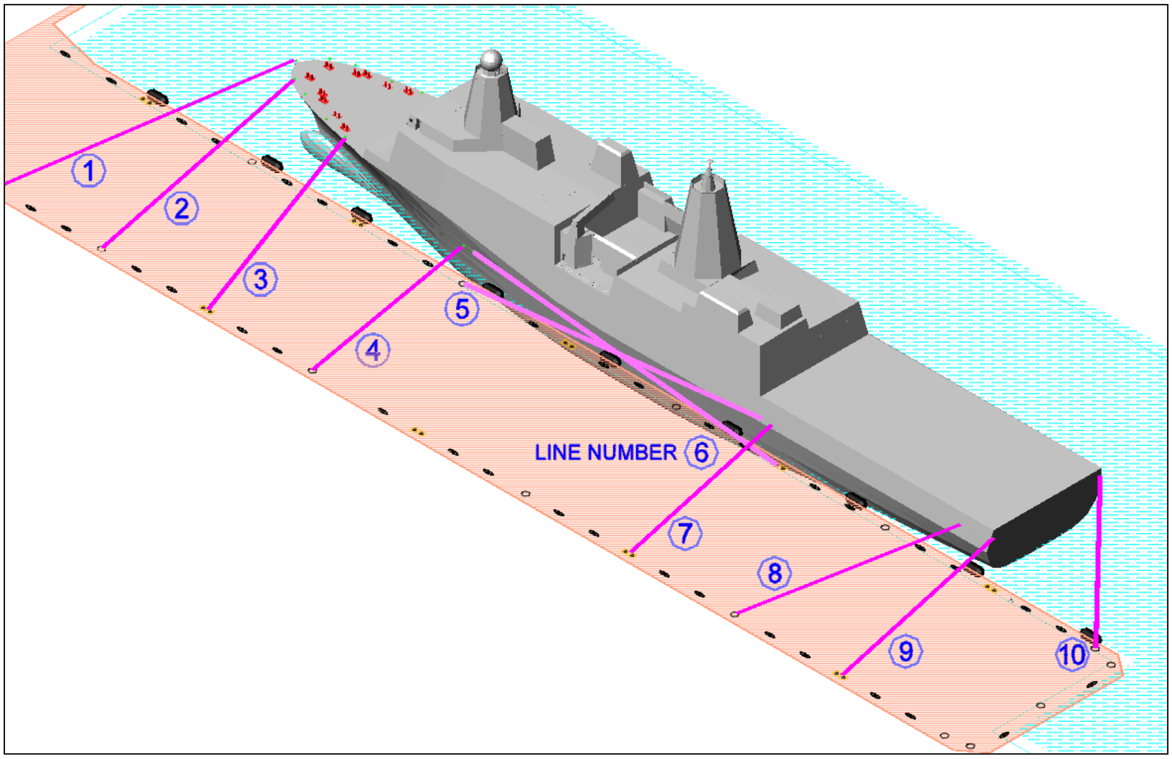
The facility needs to provide heavy weather mooring lines, since ship's lines are generally inadequate. Double braided polyester lines are recommended for heavy weather mooring, because the lines have excellent fatigue resistance. These lines also have some stretch which aids in load sharing between lines and helps accommodate water level changes.

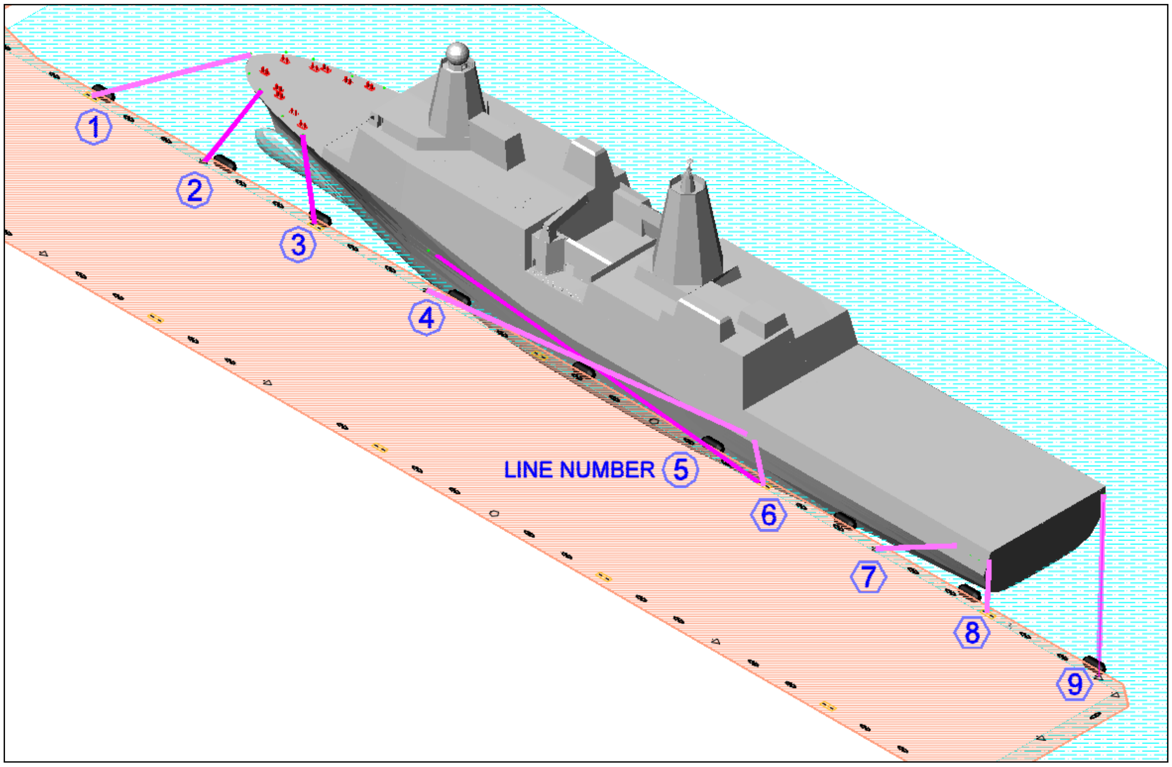
It is standard practice to first put the ship in a Standard or Storm Mooring (i.e. MST IIA or IIB) when a ship comes to a facility for repair (Figure 11-1 upper). These types of moorings are used since the mooring lines can be secured to mooring fittings near the ship, so the mooring lines have minimum interference with repair work.

It is then standard practice to put the ship in a heavy weather mooring (i.e. MST III) if storms, hurricanes or other threatening conditions are expected (Figure 11-1 lower). In heavy weather mooring, for example, mooring lines may be run across the pier to improve mooring efficiency and increase the number of mooring lines that are used.

Detailed structural analyses show that ship's double bitts have the maximum safe working capacity when equal load is applied to each of the two barrels of the bitts. It is recommended that methods be used to provide for equal loading to the barrels in heavy weather mooring.

Figure 11-1 Example of a Heavy Weather LPD 17 Mooring (Upper) and Standard Mooring (Lower)





In the case of using one line in two parts:

- Place eye of mooring line around inner bitt on ship (Figure 11-2 top)
- Place round turnabout pier bollard (Figure 11-2 bottom)
- Place round turnabout inner bitt on ship (Figure 11-2 top)
- Figure 8-1 at least 3 times to engage both barrels on ship's bitt (Figure 11-2 top)
- Bitter end of mooring line remains on ship for line tending
- In the case of using one line in three parts (doubling up).
- The eye is placed over the bollard first (Figure 11-3)
- The line is then run back to the ship and around the bitt
- The line is run directly back to and around the bollard
- The line is run back to the bitt
- The free end is figure-eighted at least 4 times before being tied off and bird nested atop the bitt

Anytime multiple parts of mooring line are used, check the capacity of the ships bitts and piers bollard with respect to being able to handle the Safe Working Load (SWL) of each part of the mooring line.

Detailed heavy weather mooring designs need to be prepared for each ship at each berth. These designs need to consider the site-specific design criteria and special circumstances. As a general rule-of-thumb:

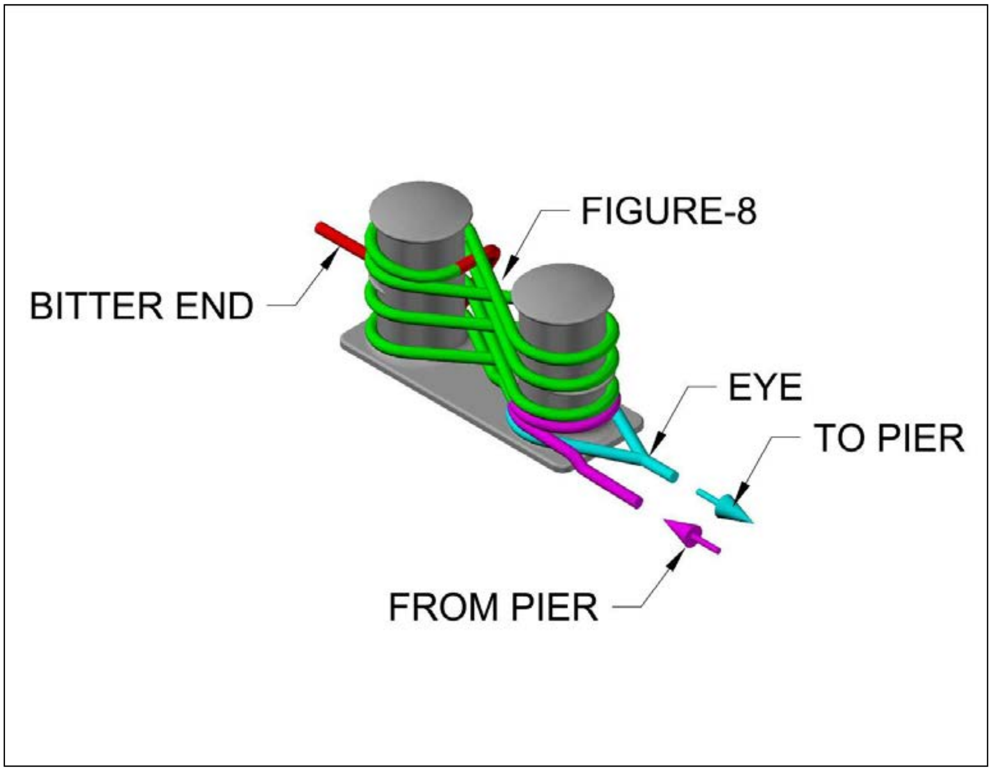
Provide adequate numbers of breasting lines to safely secure the ship. Place the lines towards the bow and towards the stern so they resist both lateral loads and moments.

Breasting lines should be approximately perpendicular to the ship's centerline (to resist loads and moments), be of similar length (to help improve load sharing) and should all have low vertical angles (to improve mooring efficiency and help account for water level changes).

Provide adequate numbers of spring lines, which are approximately parallel to the ship's centerline. Equal numbers of spring lines should be run towards the bow and stern. These lines should have rather low vertical angles to account for water level changes.

It is recommended that preliminary designs be developed with quasi-static designs and factors of safety of 2.5 or higher on all components. Dynamic methods can then be used to refine and verify the designs. The various references cited in this section provide examples of heavy weather mooring designs. CHAPTER 8 of this UFC also provides heavy weather mooring examples.

Figure 11-2 Securing Two Parts of Heavy Weather Mooring Line



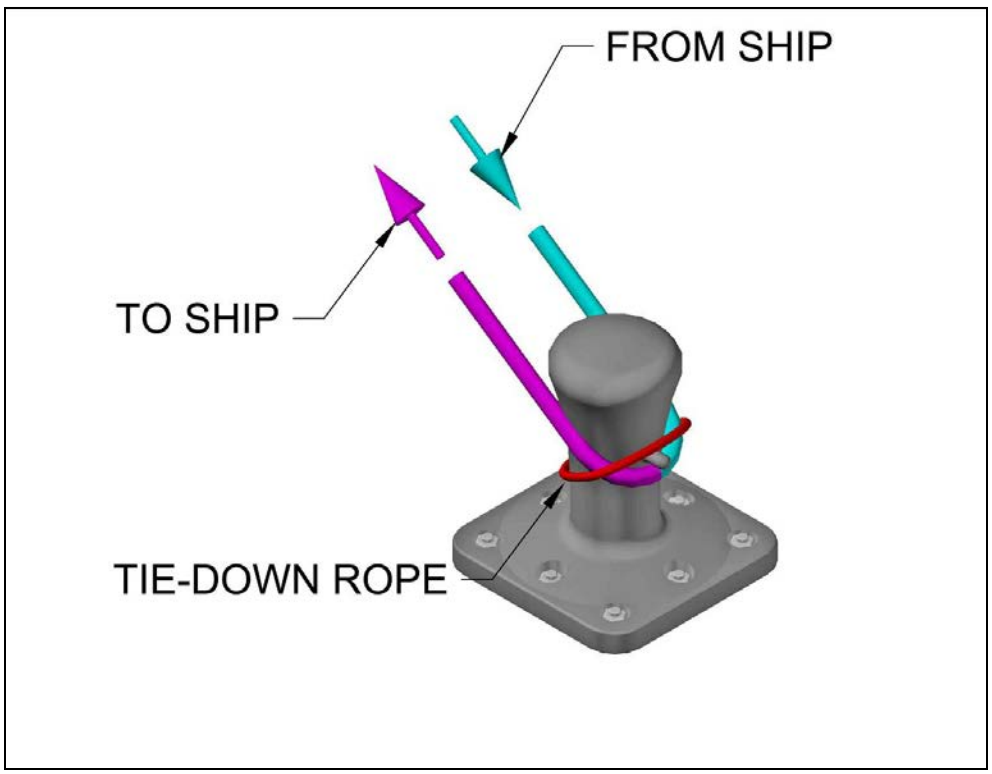
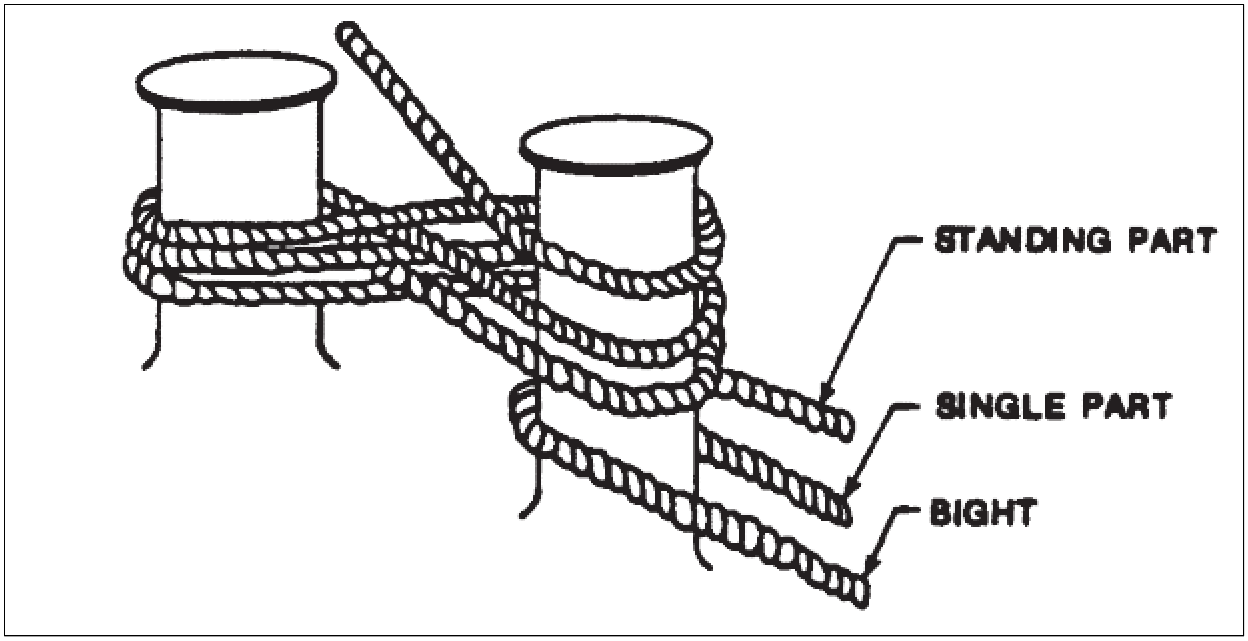


Figure 11-3 Securing Three Parts of Heavy Weather Mooring Line



11-4 ACTION.

11-4.1 Planning.

NAVFAC Field Components and Activities should assist Claimants, Regional Commanders, and Shipyards to determine the number, location, and critical ship class requirement for moorings used locally during MST III. Mooring Service Type should be identified during the planning phase of waterfront structures. Recommendations are provided in TR-6012-OCN Rev B U.S. *Navy Heavy Weather Mooring Safety Requirements*.

11-4.2 Analysis and Design.

Engineers at NAVFAC Field Components should work with NAVFAC EXWC moorings engineers to analyze moorings according to climatological criteria stated in TR-6012-OCN Rev B *U.S. Navy Heavy Weather Mooring Safety Requirement*s. Commercial enterprises providing mooring for U.S. Navy ships should likewise conform to the criteria contained herein. Lines should provide a factor of safety against breaking of 2.5. Design pier and wharf fittings for a working load equal to the break strength of the largest lines expected to use the fitting. Moorings used for Type III service are subjected to significant dynamic wind loads and should be analyzed accordingly. NAVFAC EXWC has capability of providing this type of analysis on a reimbursable funding document for any U.S. government or military agency.

Stiff lines (such as aramid) respond differently to dynamic loads than elastic lines (such as nylon) and should be properly modeled in the analysis. Engineers should also verify the capacity of ship fittings for Type III Moorings. Dynamic analyses may indicate that in order to moor large ships in heavy weather, a ship alteration (SHIPALT) is required as well as facility upgrades. A SHIPALT, if required, is coordinated by NAVSEA.

11-4.3 Maintenance.

Maintenance personnel should inspect moorings to ensure acceptable performance during heavy weather. UFC 4-150-07, *Maintenance and Operation of Waterfront Facilities* and UFC 4-150-08, *Inspection of Mooring Hardware*, provide inspection guidance.

11-4.4 Operations.

Activities should provide additional mooring lines to supplement ship mooring lines for use during MST III.

11-5 ENVIRONMENTAL DESIGN CRITERIA FOR SELECTED SITES.

A risk-based approach is used in heavy weather mooring design to help ensure that ships are safe no matter where they are moored. Site-specific design criteria (i.e. winds, water levels, waves, etc.) associated each berth are used to help ensure that all ships are safely moored. See Section 3-2 for General Design Criteria.

APPENDIX A NOTES ON VARIOUS TYPES OF MOORING LINES

A-1 PURPOSE.

The purpose of this appendix is to describe the use and implications of various mooring line types. Each mooring line in a mooring configuration should be the same line type, size, and break strength. This does not preclude the use of mooring pennants / pig tails, which are an acceptable method of incorporating elasticity into a mooring arrangement.

A-2 MOORING LINE TYPES.

A-2.1 Nylon.

Nylon synthetic lines of various constructions have been used by U.S. Navy vessels. Some of the key features of nylon lines include:

- Nylon has relatively large amounts of elasticity (stretch) for a given applied tension (i.e. the stiffness of these lines are relatively low).
- Moorings using nylon tend to have good load sharing between lines due to the high elasticity.
- Nylon mooring lines require relatively little tending due to the high amount of stretch.
- Nylon loses approximately 15% of its strength when wet.
- Nylon has poor fatigue resistance, so the lines lose strength as the lines undergo cyclic loading.
- Nylon lines are bulky, thus considerable manpower is required to deploy.
- Nylon lines have a large snap-back when they fail under load, which has resulted in serious injury and death.

A-2.2 Polyester.

Polyester Lines:

- Polyester lines have a moderate amount of elasticity (stretch) for a given tension, which enables relatively good load sharing between lines for a well-designed mooring.
- Polyester lines require relatively little tending due to the moderate amount of elasticity.
- Polyester lines retain their strength when wet.
- Polyester lines have excellent fatigue resistance, so are well suited to dynamic situations.

- Polyester lines are not as bulky as nylon lines, thus less manpower is required to deploy.
- Polyester lines snap-back when they fail under load, so care must be taken when using them.
- Polyester lines are very well suited for use as heavy weather mooring lines (MST III), due to their combination of characteristics.

A-2.3 High Modulus Synthetic Fiber (HMSF) Lines.

Aramid, Liquid Crystal Polymer (LCP), and High Modulus Polyethylene (HMPE) (and other High-Modulus Synthetic Fibers):

- Have very little elasticity (stretch) for a given tension, so these lines are very stiff.
- It may be difficult to get good load sharing between HMSF lines, because the mooring lines are so stiff.
- HMSF lines are lighter per foot and have a smaller diameter compared to similar strength nylon or polyester, making them easier to handle and store.
- Chafe protection is important as HMSF lines are particularly vulnerable to chafe.
- HMSF lines require considerable tending, especially at berths with high tidal ranges.
- HMSF lines retain their strength when wet.
- HMSF lines are not be well suited for dynamic conditions. The mooring lines are relatively stiff, which reduces the natural periods of a ship-mooring system, which may result in higher peak dynamic tensions in the mooring lines. ‘Snap loads’ may also occur.
- HMSF line mooring may require a good deal of line tending. A standard ship mooring with HMSF lines may not be compatible with high rate of tidal change, so the lines may need to be tended. IF the lines are not tended then mooring lines may break, mooring fittings may fail and/or the ship could list toward the pier/wharf as the tide rises.
- HMSF lines store relatively little energy, so do not snap back as violently as other lines when they break. Lines can be fitted with tattletales to indicate that the lines may be overloaded.
- Due to their unique properties, HMSF lines are carried on ships for mild weather, standard and storm moorings (MST IIA and IIB).
- Due to their low elasticity, limited load sharing ability, and susceptibility to shock loads in dynamic environments, HMSF lines are generally not recommended for Heavy Weather Mooring.

APPENDIX B GLOSSARY

B-1 ACRONYMS.

ABS	American Bureau of Shipping
AISC	American Institute of Steel Construction
AP	Aft Perpendicular Point
ASCE	American Society of Civil Engineers
API	American Petroleum Institute
CSAP	Chain Soil Analysis Program
CVN	Aircraft Carrier
DDS	Design Data Sheet
DoD	Department of Defense
EXWC	Engineering and Expeditionary Warfare Center
FB	Freeboard
FM	Fleet Mooring
FP	Forward Perpendicular Point
FS	Factor of Safety
HMSF	High Modulus Synthetic Fiber
HNFCA	Host Nation Funded Construction Agreements
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HWM	Heavy Weather Mooring
MBL	Minimum Breaking Load
MHW	Mean High Water
MHHW	Mean Higher High Water
MLW	Mean Low Water
MLLW	Mean Lower Low Water

MSC	Military Sealift Command
MST	Mooring Service Type
NAS	Naval Air Station
NAVFAC	Naval Facilities Engineering Command
NAVSEA	Naval Sea Systems Command
NBS	National Bureau of Standards
NCDC	National Climatic Data Center
NCEL	Naval Civil Engineering Laboratory
NFESC	Naval Facilities Engineering Service Center
NOAA	National Oceanic and Atmospheric Administration
NSTM	Naval Ships Technical Manual
NUREG	Nuclear Regulatory Commission
OCIMF	Oil Companies International Marine Forum
PIANC	Permanent International Association of Navigation Congresses
SHIPALT	Ship Alteration
SPM	Single Point Mooring
SOFA	Status of Forces Agreement
SUPSHIP	Supervisor of Shipbuilding,
SWL	Safe Working Load
UFC	Unified Facilities Criteria
USACE	U.S. Army Corps of Engineers
USNA	U.S. Naval Academy
USCG	United States Coast Guard

B-2 ABBREVIATIONS AND SYMBOLS.

Av	average
AE	cross-sectional area
cir.	circumference
deg	degree
dia.	diameter
DWT	dead weight tons
E	modulus of elasticity
ea	each
Fb	breaking strength
ft	foot
ft^2	square foot
ft^3	cubic foot
ft^3/LT	cubic foot per long ton
ft^3/min	cubic foot per min
ft-lb	foot-pound
ft/s	feet per second
ft^2/s	square foot per second
ft^3/ton	cubic foot per ton
f_y	yield stress
g	gravity
GRT	gross registered tons
H_s	significant wave height
in.	inch
k	kip, kips (1,000 lb)

kg	kilogram (force)
kg-m	kilogram-meter
kg/m^3	kilogram per cubic meter
km/h	kilometer per hour
kN	kilonewton
kN-m	kilonewton-meter
kN/m	kilonewton per meter
kN/m^2	kilonewton per square meter
kN/m^3	kilonewton per cubic meter
lb	pound
lb/ft	pound per foot
lb/ft^2	pound per square foot
lb/ft^3	pound per cubic foot
LT	Long Ton (2,240 lb)
m	meter
m^2	square meter
m^3	cubic meter
m/s	meter per second
m^2/s	square meter per second
m^3/LT	cubic meter per long ton
m^3/ton	cubic meter per ton
mm	millimeter
mph	miles per hour
N	newton
N-m	newton-meter

N/m^3	Newton per cubic meter
P	port (left side of vessel when facing forward)
P	probability of exceedance
psi	pound per square inch
R	return interval
S	starboard (right side of vessel when facing forward)
sec	second
$slug/ft^3$	slug per cubic foot
ST	short ton (2,000 lb)
t	tonne = metric ton = 1000 kg
V	velocity
V_w	velocity of water
Wt	weight
yr	year

B-3 DEFINITION OF TERMS.

Breaking Strength: maximum force developed in an item prior to failure, similar to ultimate capacity.

Minimum Breaking Strength (MBS): often stated as Minimum Breaking Load (MBL) for mooring lines and chain, is the minimum load or capacity an item must be able to support without failure.

Nominal Load: unfactored service load exerted on an item.

Working Capacity, Working Strength: often stated as **Safe Working Load (SWL)** - is the maximum load an item is rated to resist. It contains a factor of safety (FS) applied to the breaking strength and is used during mooring design to ensure that the predicted loads are below breaking strength.

Working Load Limit (WLL): maximum load an item can support, factored or rated capacity.

Ultimate Capacity: maximum load an item can support without failure.

APPENDIX C REFERENCES

C-1 GOVERNMENT PUBLICATIONS.

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NAVAL RESEARCH LABORATORY (NRL)

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SSR-6107-OCN, *Heavy Weather Mooring of USS Inchon (MCS-12) at U.S. Naval Station, Ingleside, Texas*

SSR-6112-OCN, *Heavy Weather Mooring of Ships Under Repair in the Hampton Roads Area in 1987*

SSR-6119-OCN, *D-8 Mooring Upgrade Design Report*

SSR-6137-OCN, *Heavy Weather Mooring Analyses of Selected Ships Under Repair, 1998*

SSR-6145-OCN, *Alternative Heavy Weather Mooring of USS INCHON (MCS-12) at U.S. Naval Station, Ingleside, TX*

SSR-6148-OCN, Heavy Weather Mooring Design Report of Avenger and Osprey Class Vessels, U.S. Naval Station, Ingleside, TX

SSR-6150-OCN, *SURFLANT Heavy Weather Mooring Program, Phase I Completion Report*

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SSR-6260-OCN, *Hurricane Mooring of Ships and Craft at Naval Coastal Systems Center, Panama City, FL*

SSR-6266-OCN, *Plate Anchor Concept for Heavy Weather Mooring of CVN, LHD and LHA, Berth 42/42 Norfolk Naval Shipyard, Portsmouth, VA*

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TR-6003-OCN, *Wind and Current Forces/Moments on Multiple Ships*

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TR-6005-OCN (Rev B), *EMOOR – A Planning/Preliminary Design Tool For Evaluating Ship Mooring at Piers and Wharves*

TR-6012-OCN (Rev B), *U.S. Navy Heavy Weather Mooring Safety Requirements*

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TR-6022-OCN, *Ship-Generated Waves*

TR-6023-OCN, *Dynamic Analyses of a CVN 68 in a Heavy Weather Mooring*

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