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UNIFIED FACILITIES CRITERIA (UFC)

DESIGN TO RESIST DIRECT FIRE WEAPONS EFFECTS

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DESIGN TO RESIST DIRECT FIRE WEAPONS EFFECTS

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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**

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.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

Document: UFC 4-023-07, Design to Resist Direct Fire Weapons Effects
Superseding: None

Document Description and Need:

- **Purpose:** 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.
- **Application and Use:** The primary users of this UFC are engineers and architects designing buildings based on design criteria that include direct fire weapons threats against assets within buildings. That design criteria should be developed using the risk and threat analysis process in UFC 4-020-01. This UFC is intended to be used in performing detailed design of countermeasures previously identified during preliminary design using UFC 4-020-02. This UFC may also be used for general reference on building component resistance to direct fire weapons effects.
- **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. 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.
- Separate Service manuals that included conflicting guidance will be disestablished.
- Use of this manual will not result in any adverse impacts on environmental, sustainability, or constructability policies or practices.

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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, Design and Analysis of Hardened Structures to Conventional Weapons Effects.

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.

1-4 REFERENCES.

- 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 (Draft)
- UFC 4-023-04, Design of Blast, Ballistics, and Forced Entry Resistant Windows (Draft)
- ASTM F 1233-98, Standard Test Method for Security Glazing Materials and Systems, Reapproved 2004.
- Australia / New Zealand AS/NZ 2343, 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
- H.P. White Laboratory, Inc. HPW-TP 0500.03, Test procedure: Transparent Materials for Use in Forced Entry or Containment Barriers, 2003
- National Fire Protection Association (NFPA) 101, Life Safety Code
- National Institute of Justice Standard (NIJ) 0108.01, Ballistic Resistant Protective Materials, 1985
- Underwriters Laboratories Standard 752, Bullet Resisting Equipment, 2005
- U.S. Department of State SD – STD-02.01, Ballistic Resistance of Structural Materials (Opaque and Transparent) Test Procedures and Acceptance Criteria, 1986

1-5 DESIGN CRITERIA.

Design criteria in the context of security engineering consists of the assets that require protection, the threat to those assets, the level to which the assets must be protected against the threat (level of protection), and any constraints that need to be accounted for in the design. The threat is described in terms of the tactics aggressors may use in an attack on an asset and the weapons, explosives, tools, or agents that will be used in carrying out those tactics. The levels of protection effectively define the performance of the system of countermeasures that protect assets. The design criteria are established by a planning team during the planning stages of a project. For further information on design criteria development, refer to UFC 4-020-01, the DoD Security Engineering Facilities Planning Manual. The levels of protection provided cannot interfere with or violate the requirements of NFPA 101, Life Safety Code. This UFC assumes the design criteria have already been developed; therefore, it provides guidance on how to implement those criteria for direct fire weapons threats.

1-6 DESIGN PROCESS.

Design criteria will commonly include multiple tactics against which assets are to be protected. Because of the complexity of the interrelationships among countermeasures designed to address different tactics, the design process needs to address the integration of the countermeasures in the overall protective system. The DoD Security Engineering Facilities Design Manual, UFC 4-020-02, was established for that purpose. It provides a preliminary design level treatment of all of the tactics and how to accomplish the necessary integration. This UFC is designed to supplement UFC 4-020-02 to provide for final design level treatment of the direct fire weapons tactic.

1-7 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:

1-7.1 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. Those UFC are for use 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.

1-7.2 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 construction components represented by those cost increases are tabulated for reference, but they represent only representative construction that will meet the requirements of the design criteria and should not be construed to limit designers' options for providing required levels of protection. The manual also includes a means to assess the tradeoffs between cost and risk. UFC 4-020-01 is for use by planners as well as security and antiterrorism personnel with support from planning team members.

1-7.3 DoD Security Engineering Facilities Design Manual.

UFC 4-020-02 provides interdisciplinary design guidance for developing preliminary systems of countermeasures to implement the design criteria established using UFC 4-020-01. Those countermeasures 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 provides 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 countermeasures on risk. The primary audience for the reference UFC 4-020-02 is the design team, but it will also be useful to security and antiterrorism personnel.

1-7.4 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, of which this UFC is one, 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 countermeasures such as vehicle barriers or fences. The Security Engineering Support Manuals are intended for use by the design team during the development of design packages.

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.

Of the ballistic threats in Table 2-1, the weapon associated with the low threat severity level is a handgun. The weapons for the higher threat severity levels are all rifles. Rounds include ball type and armor piercing ammunition. Refer to Appendix A for specific rounds.

The anti-tank weapon is 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 / .308 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. Appendix A 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 Appendix A 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

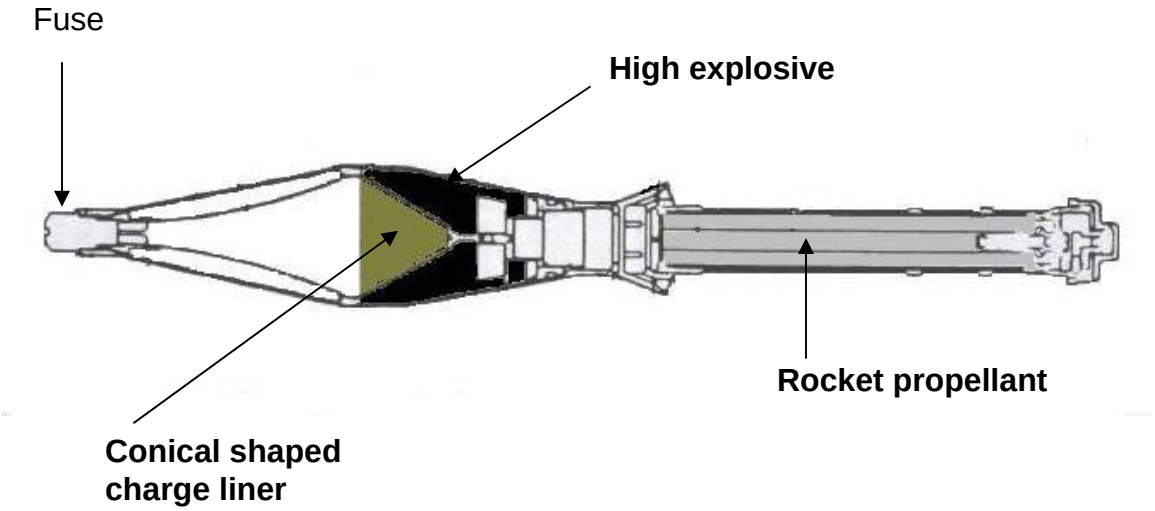

Figure 2-2. Shaped Charge Penetration

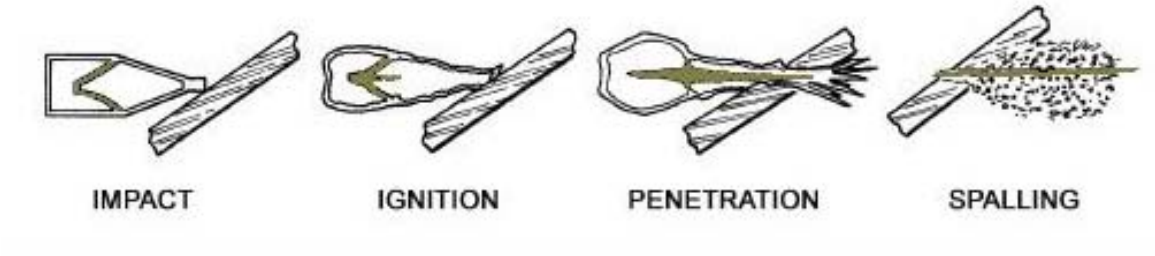

Figure 2-3. Shaped Charge Penetration of Masonry

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. 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 a minimum of 10 meters (33 feet) 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 vegetation 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.

4-4.2 Planting Hedges.

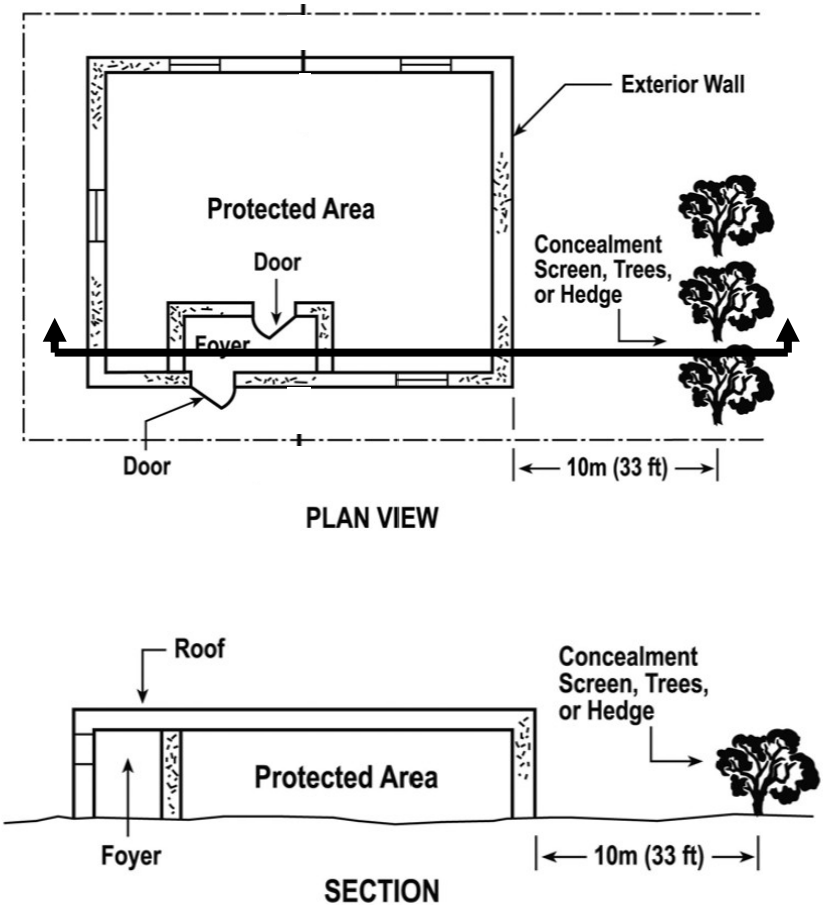
Hedges can be effective at blocking sight lines, but their feasibility and the species available vary by region. Consult a landscape architect to determine the appropriate plants for use in specific areas. Optimally select plants for hedges that retain their foliage year-round and that are typically 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.

There are many types of boxwoods that are historically used for hedges. Boxwood is fast growing and has small leaves that make a dense hedge. Escallonia is another good choice for a hedge that has small leaves and is fast growing. Escallonia, when mature (2 years), will average 1.8 to 2.4 meters (6 to 8 feet) high and 1.2 meters (4 feet) wide. If a higher hedge is required, consider Mock Orange. It will grow to an average of 3 to 3.7 meters (10 to 12 feet) high in 2-3 years and has an easy to control root system. Rhododendron will grow tall and bushy but is very slow growing. Oleander is fast growing but the leaves are long and narrow so they may not be sufficiently effective for obscuration.

Avoid plants such as the Orange Trumpet Vine that will grow to 1.7 to 4.6 meters (5.5 - 15 feet) high and has a very invasive root system. If this variety of shrub is planted near a wood fence it will quickly destroy the fence. There are many new varieties of Bamboo that are not as invasive as the old varieties and will make very sturdy hedges. Select plants that are recommended for the local planting zone.

Figure 4-1. Trees and the Unobstructed Space

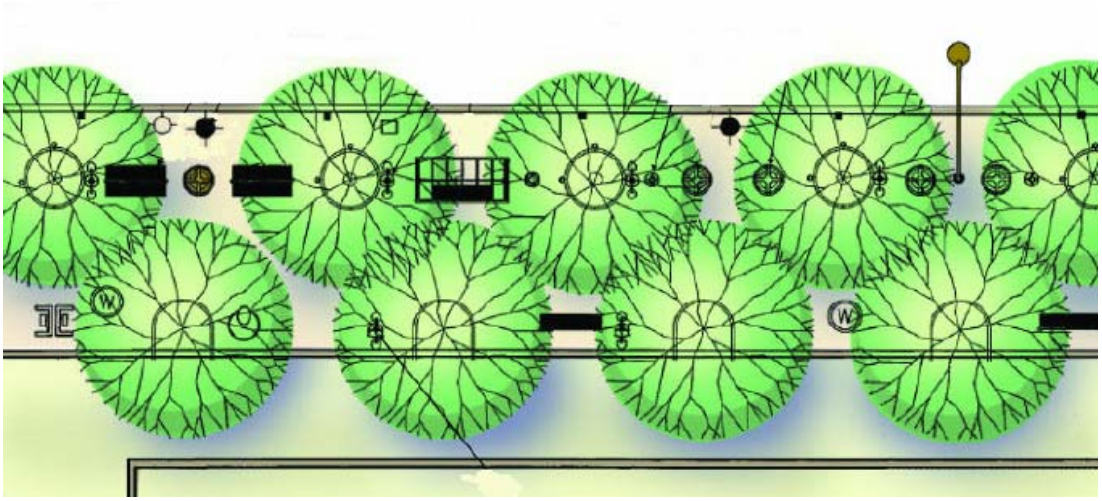


4-4.3 **Planting Trees.**

Select trees that retain their foliage year-round. Pine or fir are adaptable to most planting zones, and will work well if they are varieties that do not grow too tall. 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.

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

For narrow areas such as between unobstructed spaces and paved areas where space for planting trees is limited, soft landscaping that is “fanlike” (wide but not deep) would work best. There are many varieties of Cypress and Cedar that will create a “hedge” of trees in narrow confined areas.

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.

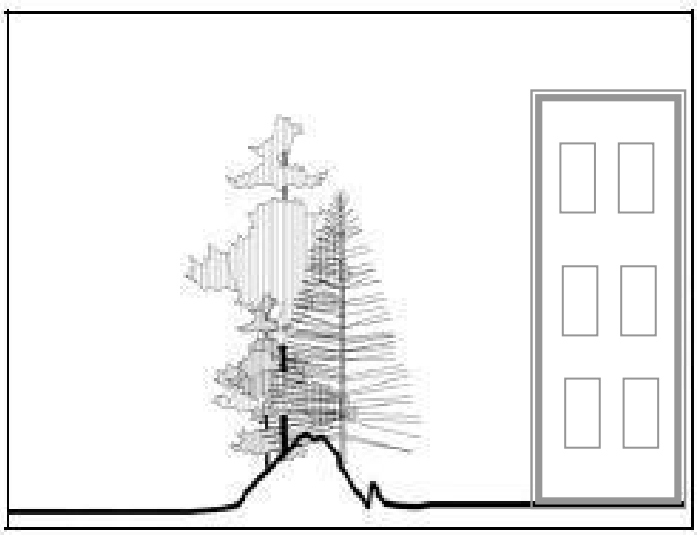
Figure 4-3. Chain Link Fence with Obscuration Material Added

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 10 meter (16 feet) 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.

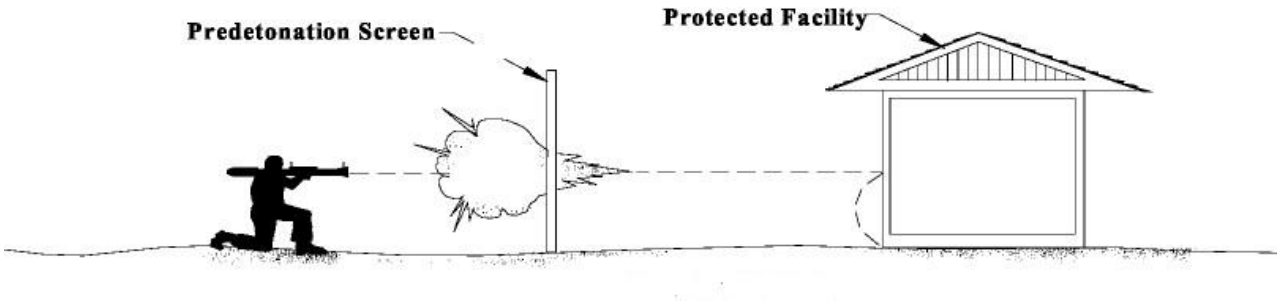
4-5.2 **Predetonation Screen.**

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

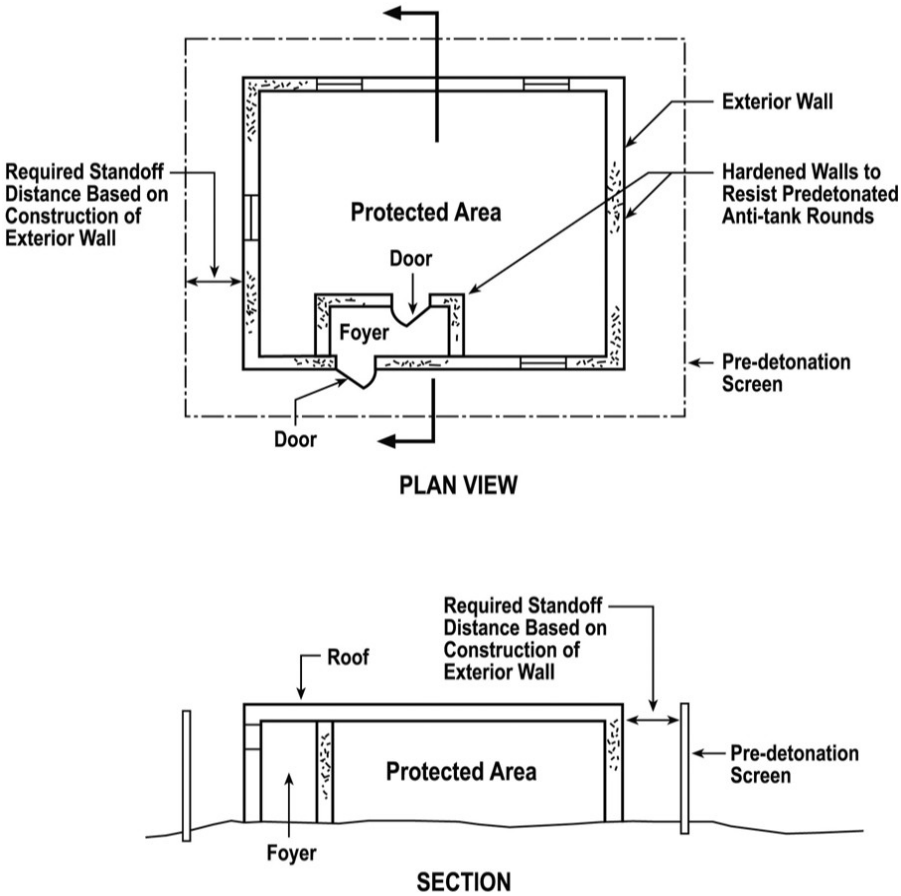


Predetonation screens need to be as high as the portions of buildings they are intended to protect. They may only be practical, therefore, for intercepting anti-tank rounds fired at the lower stories of buildings. Where building predetonation screens high enough to protect upper stories of buildings 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.

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



4-5.2.2 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.

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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.

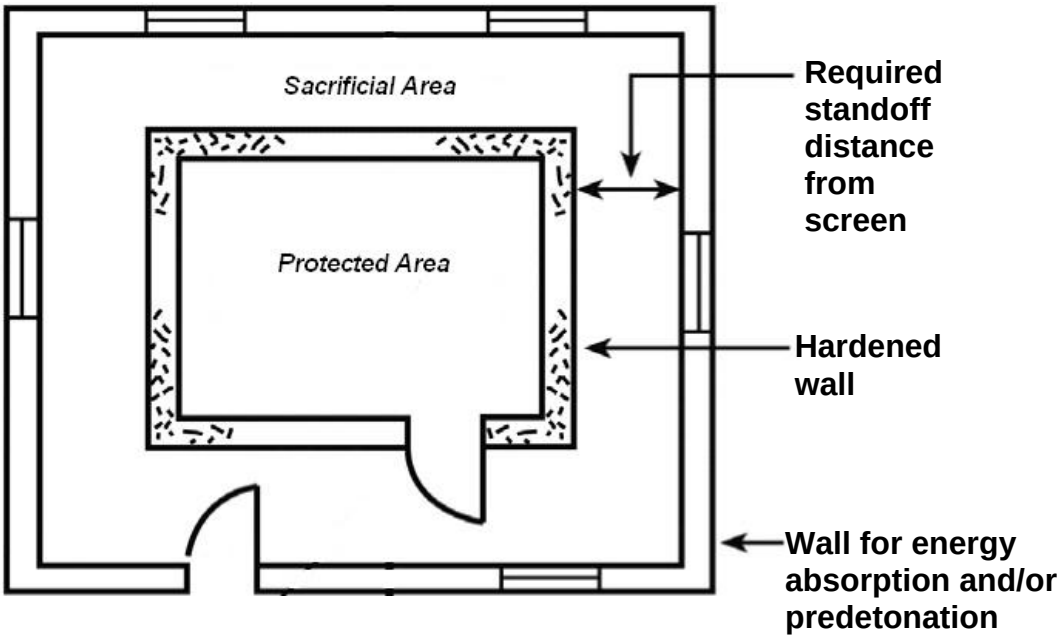
Building orientation can also be used to minimize asset exposure. Where possible, orient buildings so critical areas do not face known vantage points or installation perimeters. Storerooms or other uninhabited areas can be located on those sides of buildings.

Interior room layout can also limit asset exposure. In designing room layouts locate furniture and activity areas to minimize visibility through windows and doors.

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 10 meter (33 feet) 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 10 meters (33 feet), screens should not be located within the 10 meter (33 feet) 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 33 feet (10 meters) where unobstructed space is required in accordance with UFC 4-010-01.

Figure 5-2. Anti-tank Weapon Wall Retrofit Using Sand

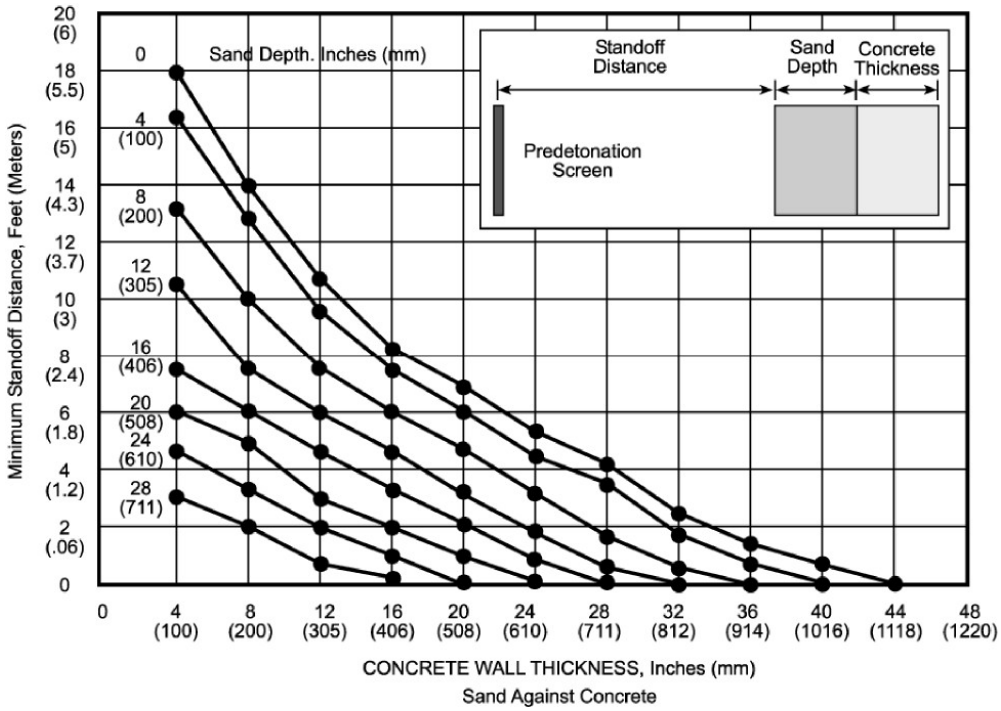
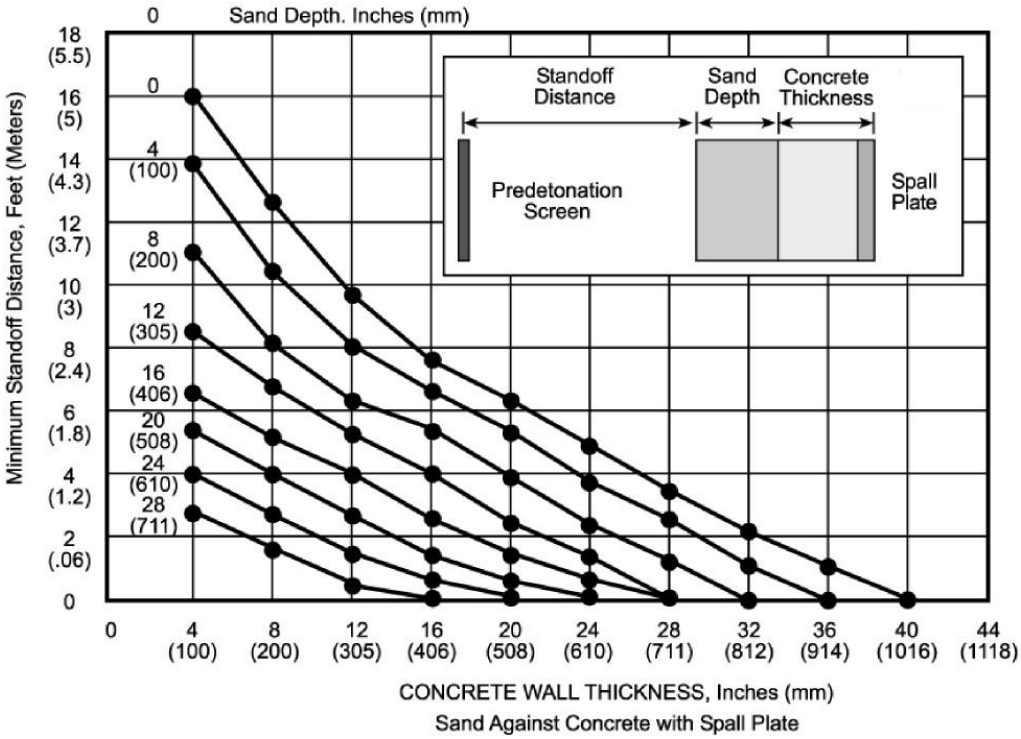


Figure 5-3. Anti-Tank Weapon Retrofit Using Sand and Spall Plate



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[6]	22 inches (560 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. The following construction configurations have also been tested against 0.50 caliber (12.7 mm) rounds:
   - 4-inch (100-mm) solid CMU, 3/4-inch (19-mm) rigid polyether urethane insulation, 8-inch (200-mm) grout-filled CMU.
   - 6-inch (150-mm) grout-filled CMU, 3/4-inch (19-mm) rigid polyether urethane insulation, 6-inch (150-mm) grout-filled CMU.

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, Design and Analysis of Hardened Structures to Conventional Weapons Effects. 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 Appendix A. All velocities in Appendix A 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 A)
w = projectile weight (lbs) (see appendix A)
D = projectile diameter (in^2)
ρ= wood density (lbs/ft^3) (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.

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 A.)
D = projectile diameter (mm) (see appendix A)
T_S = thickness of steel plate to prevent perforation (mm)
θ = angle of obliquity (degrees)(see glossary)
m = mass of projectile (kg) (see appendix A)
BHN = Brinnell Hardness Number (see Table 5-5)

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 A)
m = projectile mass (kg) (see appendix A)
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 A)
$f_C^{'}$ = 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

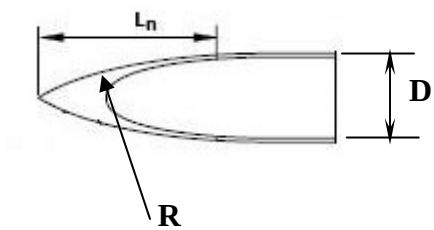
f_{age}	Concrete age (days)
1.0	≥ 360
1.01	180
1.02	66
1.05	≤ 28

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 A-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)*



L_N = nose length of projectile
R = tangent ogive radius

Note: If the tangent ogive is truncated, use the actual LN 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

Equation 5-7. Perforation Limit Thickness for Air Backed Concrete Slabs

$$T_{PL} = D\left[1.239\left(\frac{P_C}{D}\right) + 1.132\right]$$

T_{PL} = perforation limit thickness (mm)

Equation 5-8. Thickness of Concrete Slab to Prevent Backface Damage (Spall)

$$T_{BD} = D\left[1.375\left(\frac{P_C}{D}\right) + 2\right]$$

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 Appendix A 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.

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.

Figure 5-4. Narrow Obliquely Recessed Windows

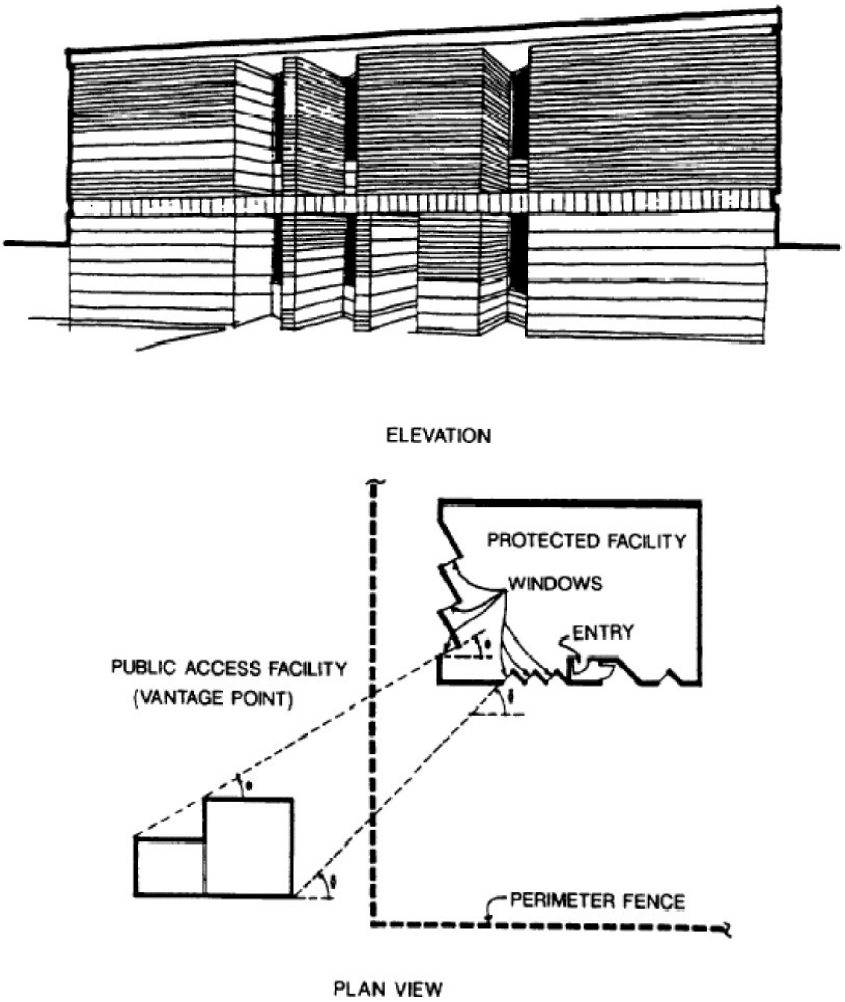


Figure 5-5. Elevated Windows

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 10 meter (33 feet) 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.

Designing windows to resist ballistics is practical and common, however. Ballistic resistant windows are commonly designed based on testing to standards such as those tabulated in Appendix A. 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. Refer to UFC 4-023-04 for more information on ballistics resistant windows.

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, but are available from multiple manufacturers. 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.

5-5 DOORS.

5-5.1 Very Low Level of Protection.

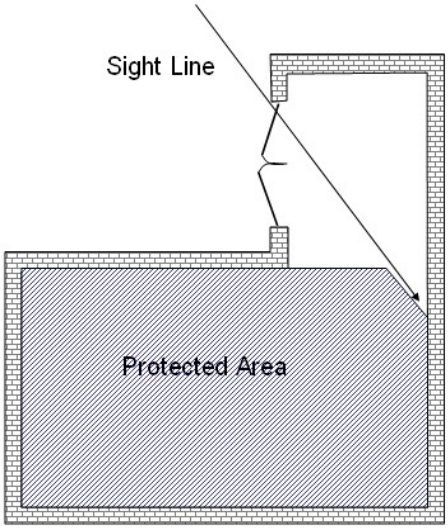
While the design strategy for the very low level of protection is limited to incorporating the minimum standards of UFC 4-010-01, the DoD Minimum Antiterrorism Standards for Buildings, there is a minimum standard that involves doors. It requires main entrances to inhabited buildings to be oriented such 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.

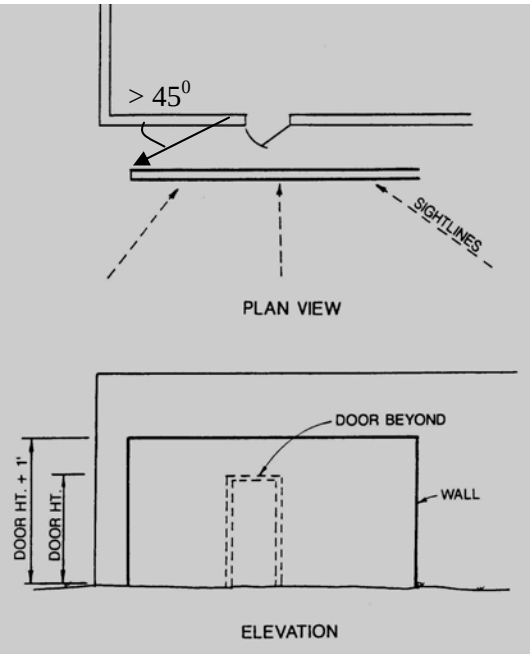
Doors can also be designed to limit sight lines through them by making them opaque (as wood or metal doors would be) or by using translucent or figured glazing for vision panels that allow light in but are not sufficiently transparent for people to be able to see anything through them. Vision panels 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.

Figure 5-6. Entrance Layout to Limit Sight Lines



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.

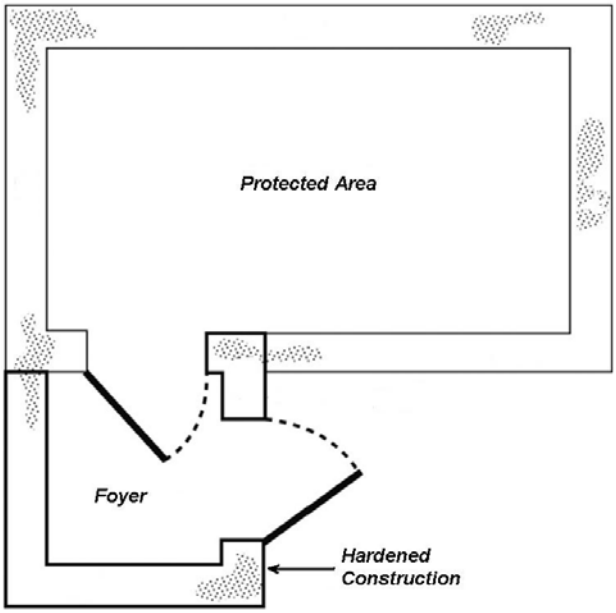
Figure 5-7. Door Shielding



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 A. 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.

Figure 5-9. Bullet Resistant Fiberglass Door Core

Note that bullet resistant doors may be significantly heavier that 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.

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, the DoD Minimum Antiterrorism Standards for Buildings, 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 10 meter (33 feet) 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.

5-6.3.1 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.

5-6.3.2 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, the DoD Minimum Antiterrorism Standards for Buildings, 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.

5-7.1 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.

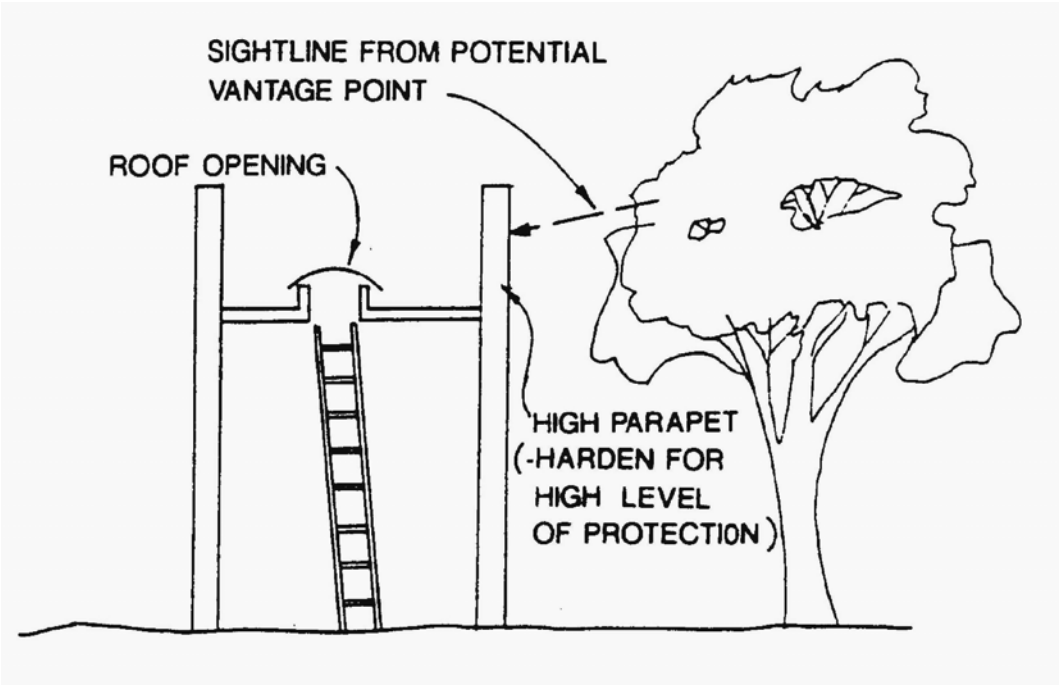
5-7.4 High Level of Protection.

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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GLOSSARY

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

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 (.223 caliber) and 7.62mm (.308 caliber) ammunition for military arms.

Controlled perimeter. For the purposes of this UFC, 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.

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 (e.g., a person, a piece of equipment, or an object, etc.) is protected against injury or damage from an attack.

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 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.

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 A: BALLISTICS STANDARDS

Organization	Standard or Rating	Ammunition	Weight	Diameter	$\overline{N}$	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 (.308 caliber) M-80 NATO	147 gr. 9.53 g	.308 in 7.82 mm	1.26	2750 - 2850 ft/s 838 – 869 m/s	
	.30-'06 Armor Piercing / Rifle	.30-'06 M-2 AP	165 gr. 10.69 g	.308 in 7.82 mm	1.39	2725 - 2825 ft/s 831 – 861 m/s	
	12 Gage 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	.308 caliber, 7.62 mm NATO M80	147 gr. 7.53 g	.308 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	.308 caliber, 7.62 mm NATO M80	147 gr. 9.53 g	.308 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”	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	.308 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	.308 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						
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	.308 caliber, 7.62 mm NATO M80	147 gr. 9.53 g	.308 in 7.82 mm	1.26	2575 – 2608 ft/s 785 – 795 m/s	
	C5-SF and C5-SA, .30, 7.62 NATO	.308 caliber , 7.62 mm NATO M61 AP	150 gr. 9.72 g	.308 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	.308 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	.308 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		.308 caliber, 7.62 mm NATO M80	147 gr. 9.53 g	.308 in 7.82 mm	1.26	> 2800 ft/s > 853 m/s	25
	.30, 7.62 NATO Part 2		.308 caliber, 7.62 mm NATO M61 AP	150 gr. 9.72 g	.308 in 7.82 mm	1.26		
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	.308 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 / .308 Winchester FMJ	150gr. 9.7 g	.308 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	.308 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
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	3
	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	3
	Level 4	.30-06 caliber rifle lead core soft point	180 gr. 11.7 g	.308 in 7.82 mm	1.39	2540 – 2794 ft/s 774 – 852 m/s	1
	Level 5	7.62 mm (.308 caliber) rifle lead core FMCJ , Military Ball	150gr. 9.7 g	.308 in 7.82 mm	1.26	2750 – 3025 ft/s 838 – 922 m/s	1
	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	5
	Level 8	7.62 mm rifle lead core FMCJ, military ball	150 gr. 9.7 g	.308 in 7.82 mm	1.26	2750 – 3025 ft/s 838 – 922 m/s	5
	Level 9	.30-06 caliber rifle, steel core lead point filler, FMJ (APM2)	166 gr. 10.8 g	.308 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	1
	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	3

Organization	Standard or Rating	Ammunition	Weight	Diameter	$\overline{N}$	Velocity	Number of Shots
State Department **SD-STD-02.01**	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)	.308 caliber, 7.62 mm NATO M80	147 gr. 9.53 g	.308 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	.308 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	.308 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

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