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MILITARY HANDBOOK

DESIGN GUIDELINES FOR PHYSICAL SECURITY OF FIXED LAND-BASED FACILITIES

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ABSTRACT

This manual provides guidance to assure appropriate physical security considerations are included in the design of Naval shore facilities. Design philosophy and physical security threats are initially discussed. Specific technical sections include building physical security, exterior physical security, hardening existing arms, ammunition and explosive facilities, ballistic hardening, vaults and strong rooms, and vehicle barriers. Procedures are also presented for performance and cost requirements assessment and for data collection.

FOREWORD

This military handbook has been developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other Government agencies, and the private sector. It uses to the maximum extent feasible, national professional society, association, and institute standards. Deviations from this criteria, in the planning, engineering, design, and construction of Naval shore facilities, cannot be made without prior approval of NAVFACENGCOMHQ Code 04.

Design cannot remain static any more than can the functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged and should be furnished to the Naval Civil Engineering Laboratory, Code L30, Port Hueneme, CA 93043, telephone (805) 982-5743.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCE DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGN (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

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SECTION 1: INTRODUCTION

1.1 Scope. This handbook shall be used for the engineering design of Defense facilities to assure that appropriate and economical physical security is included in a facility design. At present, this handbook is based upon the analysis of actual barrier penetration test data. The physical security data in this handbook will be revised or expanded as additional research results become available. The contents include identification of design philosophies, threat considerations, delay time and cost relationships, construction options, and design procedures to apply for appropriate and economical physical security at defense facilities.

This military handbook shall not be used as a reference document for procurement purposes. Further, it shall not be referenced in military or federal specifications or other procurement documents.

1.2 Cancellation. This handbook supersedes NAVFAC DM-13.1, PHYSICAL SECURITY (March 1983), in its entirety.

1.3 Definitions.

1.3.1 Delay Time. As used in this handbook, delay time is the total time an intruder is prevented from gaining access to a secured resource. Delay time includes the penetration time provided by one or more structural barriers separating an intruder from a secured resource, and the ingress time required for travel from barrier to barrier to get to the secured resource. Delay time can also include egress time required to load the secured resource and exit the facility. Penetration time is the actual time it takes an intruder to successfully create a man-passable opening through a barrier by means of forced entry. Ingress and egress times account for the transfer of tools and personnel through barriers and are influenced by the complexity of the facility interior; size of the facility; and weight, size, and shape of the tools used or the assets to be acquired, etc. Penetration, ingress, and egress times are defined in more detail below. It is important to note that high delay times are not useful. The delay time must be related to threat detection and response time if security is to be assured. The time, or "clock," can only be regarded as starting upon detection and stopped at restraint of the intruder. As Appendix A points out, types and locations of intrusion detection systems (IDS), structural barriers, and security personnel bear directly upon the overall effectiveness of the physical security system. Moreover, since a facility consists of several different components--such as floors, walls, roofs, doors, windows, and utility openings--each of these elements can be regarded as links in a physical security chain. Delay time is no greater than the delay time of the weakest link in this chain. Therefore, the design process must reach consistent and cost-effective delay times for each facility element. If a technology limitation applies to one facility component (e.g., a 5-minute door penetration time), there is little benefit in hardening walls with a penetration time above 5 minutes. For example, it might become necessary to meet a 10-minute delay requirement by using two

5-minute doors in series together with a 10-minute wall. This handbook, therefore, specifies that the delay time provided by a structure is the minimum total delay time of any path through the sum of barriers on that path.

1.3.1.1 Barrier Penetration Time. Barrier penetration time is defined as the time interval during which an intruder succeeds in creating a man-passable opening through a barrier (i.e., a wall, roof, floor, door, window, etc.) by forced entry. This penetration time definition is based on the working time rather than elapsed time. Working time only accounts for the interval that an attack tool is actually used by an intruder against a wall, roof, floor, or other building component. This measurement excludes the time required to change tools, change operators, rest operators, transfer tools, and enable personnel to pass through the barrier. In not accounting for these interruptions, this penetration time definition is inherently conservative. The penetration times presented in this handbook apply to single barriers only. In the case of multiple barriers, the total penetration time is the sum of the individual penetration times provided by all barriers. All data adhere to standardized testing methods.

1.3.1.2 Ingress Time. Ingress time is defined as the sum of all time intervals required for an intruder to traverse from barrier to barrier in a facility. This includes the time required to climb (up or down) through horizontal barriers (e.g., roofs or floors) and the time to traverse through vertical barriers (e.g., walls or fences). Also, if a thermal attack is made, this time also includes the time required for the barrier to cool. In general, ingress time increases with increasing facility size, number of barriers separating the secured area from the exterior, and size and types of tools and equipment that must be transported between barriers. The facilities engineer can increase ingress time by properly laying out the exterior and interior of the facility.

1.3.1.3 Egress Time. Egress time is defined as the interval required for an intruder to load and carry stolen assets from a secure area when theft is the purpose of the penetration. The egress time may be short or long depending upon the interior layout of the facility; the availability of doors, windows, and utility ports that can be opened; and the weight and volume of the assets that are being stolen. In general, egress time increases with layout complexity and limitation of the number of doors, windows, and utility openings available as exits. Egress time should not, however, be relied upon as one of the key time intervals in determining delay time unless: (1) the security level of the facility is limited to preventing threats from acquiring multiple-unit, high-volume assets (e.g., a warehouse storing television sets) that are not essential to military readiness; and (2) the interior layout of the facility encloses large areas that require significant time for an intruder to traverse. The facilities engineer can affect egress time to the extent that he can make access to secured facility spaces difficult by means of interior layout and limitations of the number of doors, windows, and utility openings that facilitate rapid exit. For facilities housing key resources that may involve sabotage, political, or national security related considerations, the threat should be stopped before gaining access to the resource. In such cases, accounting for egress time is not appropriate.

1.3.2 Man-Passable Opening. A man-passable opening is defined as the minimum area required for an intruder to physically pass through a barrier and enter a secured area. Department of Defense Manual 5100.76-M defines man-passable as an opening of 96 square inches [0.06 square meters (m^2)], which has its least dimension equal to or larger than 6 inches [150 millimeters (mm)]. This follows the DOD definition of man-passable. As the above restriction suggests, a 96-square inch (0.06-m^2) opening is a relatively small aperture for an adult person of average height and weight. In limiting the definition of a man-passable opening to 96 square inches (0.06-m^2), the definition is inherently conservative, particularly where the avenue of physical entry involves passage through a thick barrier, such as an 18-inch (450-mm) reinforced concrete wall, or a long passageway, such as a 20-foot (6-m) ventilation duct. To avoid confusion between what is considered man-passable and not man-passable, the following examples are provided:

a. Man-Passable Openings:

Square Opening	10 by 10 inches (250 by 250 mm) (100 sq in (0.06 m^2))
Rectangular Opening	6 by 16 inches (150 by 400 mm) (96 sq in (0.06 m^2))
Circular Opening	12-inch (300 mm) diameter (113 sq in (0.077 m^2))

b. Not Man-Passable Openings:

Square Opening	9 by 9 inches (225 by 225 mm) (81 sq in (0.05 m^2))
Rectangular Opening	5 by 60 inches (125 by 1,525 mm) (300 sq in (0.19 m^2))
Circular Opening	11-inch (275-mm) diameter (95 sq in (0.06 m^2))

Many assets to be protected may be smaller or larger than 96 square inches (0.06 m^2) or may not be critical for readiness. Therefore, the facilities engineer should decide whether a 96-square-inch (0.06-m^2) opening is sufficient to prevent assets from being stolen.

1.3.3 Relative Cost Index. A relative cost index (RCI) value is indicated for each construction option presented in this handbook. The RCI value is defined as the ratio of cost of a particular construction option relative to the cost of a predetermined base for each building component type (i.e., walls, roofs, floors, doors, windows, and utility openings). For example, in the case of walls, the predetermined base is the cost [$4.10 per square foot

($44.09 per square meter)] of 12-inch (300-mm) hollow concrete masonry unit construction and in the case of roofs and floors, the base is the cost [$3.00 per square foot ($32.26 per square meter)] of 1/2-inch (13-mm) panelized plywood on 2-by-4-inch wood joist systems 12 inches (300 mm) on center (see Figure 1). The RCI has been introduced in this handbook as a preliminary cost parameter for identifying significant cost tradeoffs among construction options. However, it should not be relied upon as the only cost guideline for performing preliminary cost-effectiveness tradeoffs among construction options. The RCI values that are presented in this handbook relate to individual construction components and costs, such as walls, floors, and roofs. These components, while representing significant cost elements of a total facility cost, do not necessarily constitute the major costs in new construction. Other costs, such as site preparation, plumbing, electrical and mechanical systems, finished interior work, etc., can also be major cost elements in new construction. For this reason, the RCI values are not intended to serve as a substitute for determination of actual comparative construction costs for a specified facility in a given locality. A more detailed cost analysis is necessary to verify and supplement the preliminary tradeoffs that can serve to "flag" important security-related structural costs.

1.3.4 Intrusion Detection System. This is a system designed to detect and alarm the approach, intrusion, or presence of an intruder by reaction of a mechanical or electronic detector.

1.3.5 Restricted Area. This is any area in which special security measures are used to prevent unauthorized accessibility to classified information or matter. Types of restricted areas may vary, depending upon sensitivity and vulnerability of the materials being protected, their location, and the surrounding physical facilities.

1.3.5.1 Controlled Area. This is a restricted area, adjacent to or encompassing limited or exclusion areas, where uncontrolled movement does not permit detection of a security interest. It is designed for the principal purpose of providing administrative control and safety and a buffer zone of security restrictions for limited and exclusion areas.

1.3.5.2 Limited Area. This is a restricted area, surrounding one or more exclusion areas, where uncontrolled movement does permit detection of a security interest but within which detection can be prevented by escorts or other physical safeguards.

1.3.5.3 Exclusion Area. This is a restricted area where access to the area constitutes access to the security interest.

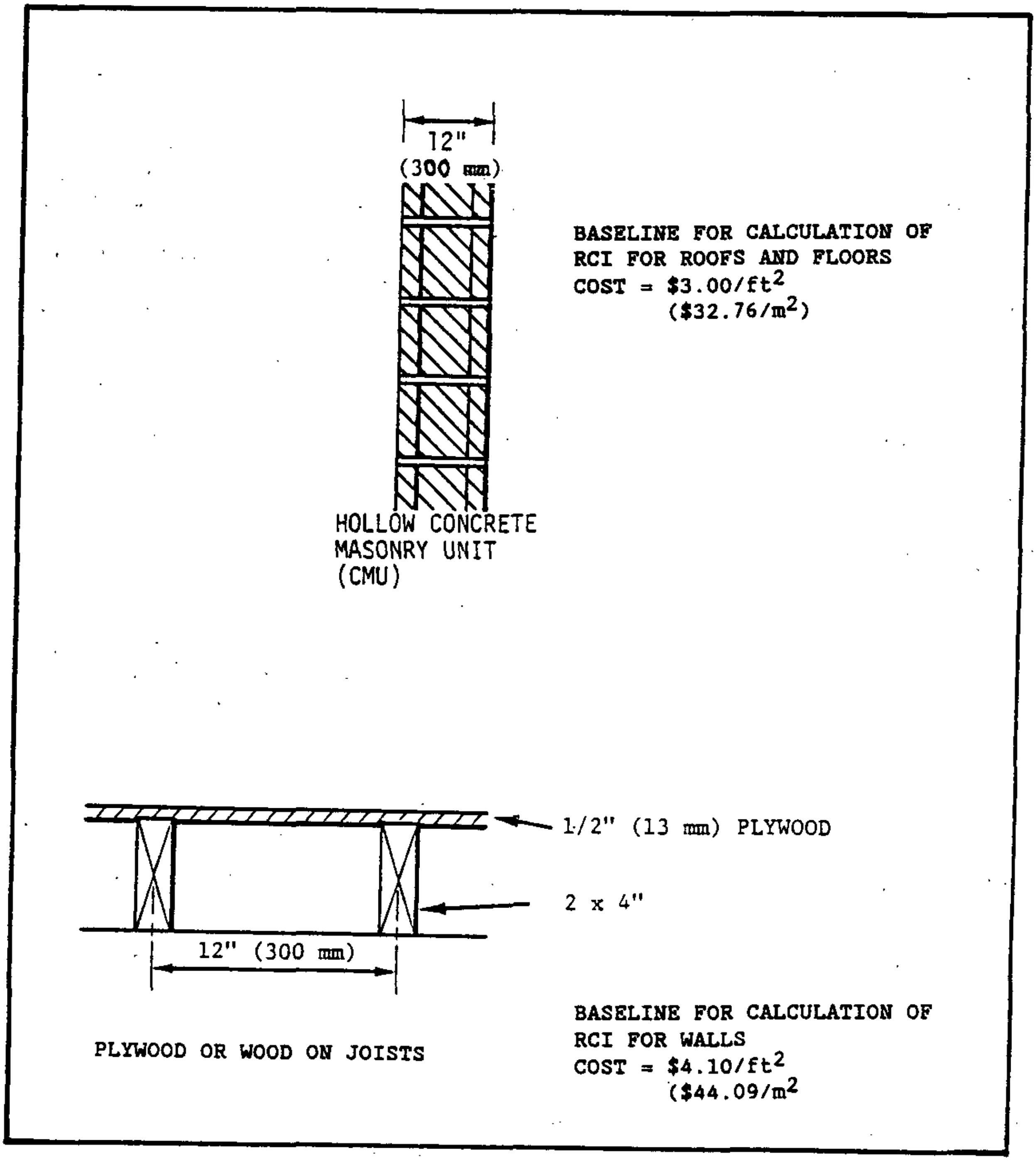


FIGURE 1. Construction options used for calculation of RCI values for walls, roofs, and floors.

1.3.6 Security System. This system is a composition of electronic, electrical, mechanical, and architectural equipment together with guard forces, policies procedures, obstacles, and intelligence activities that as a whole effectively deters sabotage, espionage, armed assault, burglary, disruption of operations, harassment, and vandalism.

1.3.7 Definition of Acronyms. The following acronyms listed in this Military Handbook are defined as follows:

AA&E	- Arms, Ammunition, and Explosives.
AISI	- American Iron and Steel Institute.
ANSI/UL	- American National Standards Institute/Underwriters Laboratories.
AP	- Armor Piercing.
ASTM	- American Society for Testing and Materials.
CCTV	- Closed Circuit Television.
CMU	- Concrete Masonry Unit.
DM	- Design Manual.
DNA	- Defense Nuclear Agency.
DoD	- Department of Defense.
GPBTO	- General Purpose Barbed Tape Obstacle.
HPR	- High Power Rifle.
HPSA	- High Power Small Arms.
IDS	- Intrusion Detection System.
LLLTV	- Low Light Level Television.
MPSA	- Medium Power Small Arms.
NAPEC	- Naval Production Engineering Center.
NATO	- North Atlantic Treaty Organization.
NAVFAC	- Naval Facilities Engineering Command.
NAVFACINST	- Naval Facilities Engineering Command Instruction.
NBS	- National Bureau of Standards.
NCEL	- Naval Civil Engineering Lab.
NILECJ	- National Institute of Law Enforcement and Criminal Justice.
O&M	- Operations and Maintenance.
OPNAVINST	- Office of the Chief of Naval Operations Instruction.
PVC	- Polyvinyl Chloride.
RCI	- Relative Cost Index.
RDT&E	- Research, Development, Test, and Evaluation.
RF	- Radio Frequency.
SAMIT	- Small Arms Multiple Impact Threat.
SFR	- Steel-Fiber-Reinforced.
SPSA	- Super Power Small Arms.

1.4 Related Technical Documents. Generally field personnel will use this handbook to address design problems relative to specific subject areas (i.e., doors, vehicle barrier, etc.). Because of this usage, related technical documents are provided within the text for each unique subject area.

SECTION 2: GENERAL REQUIREMENTS

2.1 Design Philosophy. Physical security includes both active and passive measures to protect assets against acts of burglary, theft, sabotage, espionage, and attack. The purpose of physical security is to make unauthorized access to assets so difficult that an intruder will hesitate to attempt a facility penetration or will, in the course of his penetration efforts, be forced to take actions which will assist in his detection and apprehension. From a practical standpoint, it must be recognized that absolute security can never be obtained. With sufficient resources and time, a determined adversary can gain entry to a protected area regardless of the measures used to protect it. The objective of physical security is to make access so difficult that an intruder will be unwilling to devote the necessary time and resources at the level of risk attendant to penetration of a protected area. The types of facilities that may require security system protection are as follows:

Munitions/Armament
Magazines
Arms storage
Missile sites
Weapons assembly

Data Center
Classified storage
Computer rooms
Classified conference and work rooms
Map rooms

Stores
Exchange
Commissary
Liquor sales
Jewelry stores
Camera shop
Sporting goods

Clubs
Service
Senior enlisted
Officers
Golf
Rod and gun

Operational Areas
Communication center
Operations center
Cryptographic rooms
Critical utilities

Finance and Records
Finance offices
Bank
Credit Union
Imprest fund offices
Commander's office

Warehouses and Storage
Consumer-goods warehouse
Food stuffs warehouse
Household goods storage
Hospital drug storage
Shipping/receiving areas
Medical instrument storage

Miscellaneous
Museums/libraries
Laboratories
Maintenance shops
Confinement facilities
General offices

Security, from an engineering point of view, is achieved by delay of an intruder as measured by delay time. The information presented in this handbook focuses principally on those factors that affect the delay time of a facility, namely, the penetration resistance or hardness of its floors, walls, roofs, doors, windows, and utility openings. Exterior layout, security lighting, and perimeter fencing are additional factors that affect a facility's apparent hardness. Section 3 presents data and techniques for designing and selecting cost-effective facility components that meet specified delay time and budget goals. However, the specification of a facility delay time requirement is a complex task. Physical security depends upon the intersection of many physical security and cost factors (e.g. threat, deterrence, detection, assessment, delay, apprehension, and the value and operational criticality of stored assets), only two of which, delay and building costs, are controllable by a security engineer. This handbook, therefore, recognizes that the security engineer should analyze these other physical security and cost factors as part of the process of advising local commands with respect to specification of an optimal facility delay time and determination of an acceptable physical security budget. For security design applications requiring protection against ballistic threats, a final paragraph presents information related to ballistic attack hardening. The security engineer's job is to advise a local command on how best to specify its security requirements to a facilities engineer. The key security parameters relate to both performance (especially facility delay time) and cost. The facilities engineer's job is to design a facility that meets a delay time goal in a cost-effective manner. The material in this handbook has been prepared on the assumption that the security engineer already has done his job thoroughly and has determined the facility delay time and budget constraints that must be met. However, if that planning job has not been completed, Appendix A presents a procedure describing how to determine delay time and acceptable cost criteria. It also discusses the key physical security factors related to delay time and costs.

2.2 Need For a Security System. The need to install a security system, or to expand or upgrade an existing system, on a military installation stems from a variety of circumstances including the following:

o Regulations requiring the protection of specific types of military material or operations.

o National, regional, or local intelligence data indicating a need to enhance protective measures.

o Increase in the security-sensitivity, importance, or value of operations or material on the installation.

o Increase or decrease in size of an installation or facility (in terms of personnel or real estate).

o Reduction in security guard forces.

o Relocation of material, personnel, or operations that could increase vulnerability or probability of attack.

o Indications of attempted intrusion into a facility.

o Increase in the crime rate, especially burglary and robbery, on the installation or in the area.

o Changes in intrusion tactics/technology that could increase the vulnerability of facilities.

o An analysis of local crime records maintained by military and civil police.

o The identification of places that have a prior history of burglary or robbery.

2.3 Security System Components. A security system is a composite of people, equipment, and procedures. Functionally, these resources break down into six categories of security components that involve intelligence, personnel security clearance, entry control, physical structures and barriers, guard forces, and intrusion detection systems.

2.3.1 Component Role. Each of these components plays its own supporting role in the achievement of physical security. Intelligence activities provide a variety of data that are essential to the planning and design of a security system. These data include intelligence estimates of the relative skills of potential adversaries, the capabilities and availability of new penetration measures, and the anticipated attack patterns and tactics that may be used. Personnel security clearances provide screening of both military and civilian personnel. Entry controls provide a means of establishing and maintaining control over the movement of personnel to achieve security compartmentalization. Physical structures form barriers that the intruder must penetrate to perform his mission. Guard forces perform many of the functions that keep the overall physical security plan in operation. Intrusion detection systems permit efficient use of guard forces by allowing available manpower to be shared in the protection of a number of areas.

2.3.2 Component Interrelationship. It is evident that there are symbiotic interrelationships among the elements that physical security comprises. The interrelationship between an intrusion detection system and a guard force is fundamental. An intrusion detection system not only requires mandatory response by the guard force to all alarms, but also requires guard force protection of an area if the intrusion detection system becomes inoperative. An interrelationship exists among an intrusion detection system, guard forces, and structures. Where physical security protection is to be provided by an intrusion detection system and guards, it is essential that an attempted intrusion be impeded by physical structures to allow time for guard forces to respond to alarms. It should be noted that intrusion detectors generally provide no protection against a rapid, violent attack aimed at the destruction of facilities or material. Entry controls also support the role of intrusion detection systems. Often, intrusion detectors must be deactivated and placed in a nondetecting mode during normal working hours. During these periods, entry controls provide a means to prevent unauthorized persons from entering a protected facility. An intrusion detection system using interior detectors designed to detect an intruder's presence will generally stop any unauthorized person who stays behind after working hours. Entry controls also restrict free access by persons whose intent may be to tamper with intrusion detection system components or circuits. The effectiveness of an intrusion detection system depends on the interaction of personnel security clearances and intelligence activities. Security clearances provide a measure of assurance that those who work on a security system are not unreliable persons who could compromise the system. It must be recognized that clearances provide no absolute guarantee of a person's reliability and that physical security measures are largely ineffective as a defense against collusion of personnel.

2.4 Physical Security Delay Time and Cost Specification Procedure. The procedure set forth in Appendix A offers the security engineer guidance with respect to the key factors of a physical security system, not all of which can be quantitatively measured at this time. Appendix A discusses the range of physical security threats, the role of deterrence, the role of the administration of criminal justice, the function of intrusion detection systems (IDS), the impact of security personnel performance, and the need for balancing the level of investment in security against expected losses. It outlines the steps required for the specification of a cost-effective delay time. For the user who already knows the delay time and budget requirements that must be met, Appendix A can be bypassed.

2.5 Physical Security Threat.

2.5.1 Overview. The term physical security threat is used in this handbook to define the full range of unauthorized intruders who may seek to penetrate a facility with the use of portable attack tools or explosive laden vehicles. The terms "threat" and "intruder" are used interchangeably in this handbook. The range of possible threat objectives, motives, tools, personnel, tactics, and timing is very diverse and is discussed in more detail in Appendix A. Use of the information in this handbook depends strongly on an understanding of the threat because construction options are based upon resistance to a specific attack tool or combination of attack tools, used by a skilled, experienced operator or team of operators.

2.5.2 Objectives and Motivations. There are several objectives that may motivate a threat to penetrate a facility. For example, an intruder may want to steal the assets stored in a facility for the economic value they represent, to equip a paramilitary unit, to prevent the availability of an item important to warfighting capability, or to embarrass the U.S. Government. In general, an intruder's objectives and motivations may include one or more of the following:

o Burglary. Unlawful entry into the building, including breaking and entering, with intent to commit a criminal offense therein.

o Vandalism. Wrongful, willful, or reckless destruction, loss, or damage of military or nonmilitary property.

o Theft. Felonious taking and removal (i.e. stealing) of military or nonmilitary property with intent to deprive the rightful owner of it.

o Sabotage. Destruction of military property or obstructive action designed to hinder warfighting capability.

o Espionage. Action to obtain classified information about the Government's capabilities and/or intentions.

o Embarrassment. Effects resulting from any of the above, causing doubt about the Government's ability to secure its assets.

2.5.3 Threat Description. The principal threats that are of concern to a designer of an installation or facility security system are those that require actual intrusion of personnel. These threats can be external or internal.

2.5.3.1 External Threat.

(1) Skilled and well-equipped intruder. The intruder could be expected to have the knowledge, skill, and equipment to attempt penetration of substantial physical barriers and to attempt defeat or circumvention of a security system. Only the most technologically and operationally advanced systems can be expected to foil this type of highly skilled and determined adversary.

(2) Semi-skilled intruder. The level of competence of the semi-skilled intruder corresponds to that of a professional burglar. There is every reason to expect that this kind of intruder would be able to defeat or circumvent some types of commercially available alarm systems if afforded an opportunity to learn about the operation of a system and inspect the place where it is installed.

(3) Unskilled intruder. The individuals in this category make up the bulk of common burglars who attack small business establishments. Generally, these persons are deterred if they know that a building has an intrusion detection system. However, unless the fact that an intrusion detection system is well-advertised (by signs or breakfoil on windows), there are those who perennially attempt to burglarize places of business without regard for whether or not a system is present. In only a small percentage of instances will the unskilled intruder attempt to defeat an intrusion detection system.

(4) Armed robbery. The armed intruder intent on robbery poses a threat mainly against installation finance offices, post banks, credit unions, and other similar establishments on the installation. This threat differs from those outlined above in two ways: (1) there is an ever-present threat of violence against the robbery victim, and (2) the time taken to accomplish an armed robbery is short.

(5) Armed assault. This threat differs from armed robbery in that it is not necessarily perpetrated for gain; hence, the time factors involved in the attack vary depending on the motivation of the attacker and the purpose of the attack. This threat arises in any situation where it may be possible for an adversary to gain entry or access by threat or force. Variations of this threat are kidnapping and the taking of hostages.

2.5.3.2 Internal Threat. This threat to security is posed by persons on an installation who work in, or have knowledge of, the facility where a security system is installed. The problem is generally considered to be one of human reliability. The threat can be reduced by the use of personnel security checks and clearances. However, the problem cannot be completely eliminated and, for that reason, the design of a security system has to incorporate measures to prevent its compromise.

2.5.3.3 Interaction Between External and Internal Threats. The security problems produced by the internal and the external threats are not separate and distinct. An attack on a facility can be made easier if those planning the attack can gain information on the protective measures in force. This knowledge can be obtained by close observation or by obtaining information accidentally or intentionally from knowledgeable individuals. In addition, unless precautions are taken, there can be actual collusion in which an attack might be made possible by preparatory internal tampering with the security system during normal working hours.

2.5.3.4 Threat Tactics. The tactics that are employed by an intruder vary with the category type of intruder and the specific nature and design of a particular facility. Presented here are brief descriptions of tactics that are very common and are applicable to a majority of situations.

(1) Intrusion - points of entry. The points most frequently used for entry by intruders are: doors, windows, skylights, roof hatches, vents, transoms, trap doors, raised floors, and suspended ceilings. However, it would be unwise to assume that entry could only occur through these apertures. Intruders have been known to gain entry through openings as small as 8 by 12 inches (200 by 300 mm), and even smaller openings have been used to extract items from a protected area. Moreover, openings can easily be made in most common building materials for this purpose.

(2) Fishing. Fishing is a commonly used term that describes a process by which an intruder extracts items from an area without actually entering it. The tactic requires a small opening and a fishing implement, such as a line or long stick with a hook, magnet, or adhesive tip. Valuables can be fished through mail slots, gaps in intrusion-alarm screens, and numerous other small openings.

(3) Scaling to "inaccessible" entry points. Potential entry points are frequently overlooked because they are considered to be inaccessible. These are often places high on a building or on the roof itself. Determined intruders find these places and devise ways to reach them.

(4) Stay-behinds. Using this tactic an intruder gains entry during a time when a facility is open for normal business, and when the intrusion detection equipment is in the ACCESS mode. The intruder then stays behind (usually by hiding) after the facility is closed. Once an intruder has obtained the information or material, he can probably escape before the guard forces arrive, even if the detectors are activated in the process.

(5) Deception against intrusion detection system. Numerous tactics can be used against an intrusion detection system to deceive operators and guard forces into believing that a system is malfunctioning and that alarms do not require a response. These tactics often involve inducing "false" alarms until guard forces and operators become mentally conditioned and reach the incorrect conclusion that the system is unreliable and response is unnecessary.

(6) Attack on alarm signal lines. It is frequently assumed that an area has the protection of an intrusion detection system simply because sophisticated intrusion detection equipment is installed and connected to an alarm indicator manned by guard forces. What is forgotten is that the entire system can be defeated if the connecting lines are compromised. Although most security systems use some means of detection if these lines are tampered with, there is increasing evidence that clever intruders know how to circumvent these measures and prevent alarms from going through a protected area to a monitoring post. Measures that should be taken to counter this tactic include making alarm signal lines physically inaccessible and using more secure line supervisory equipment.

2.5.4 Attack Tools. This handbook is limited to an analysis of attack tools, which are man-portable, in four categories: hand tools, power tools, thermal tools, and explosive-laden vehicles. The penetration time data presented in this handbook are based upon attacks using one or more of the following attack tools:

o Hand Tools. Hammer, sledgehammer, cutting maul, pry axe, pick head axe, claw tool, carpenter's saw, halligan, hacksaw, Kelly tool, boltcutters (including both ratchet and hydraulic), pliers, spanner wrench, tin snips, wrecking and pry bar, wire cutters, shovel, and pick.

o Power Tools. Electric or gasoline-powered circular or reciprocating saw with steel, diamond, carbide-tipped blade, or abrasive wheel; hydraulic boltcutters; chain saw; sabresaw; drill or chisel rotohammer; rescue tools; and electric drill.

o Thermal Tools. Oxyacetylene, electric arc, or oxygen fed cutting torch; oxygen lance; power lance; burning bar; and rocket torch.

o Explosive-Laden Vehicle. A vehicle with a maximum gross weight of 10,000 pounds loaded with 1,000 pounds of explosives and traveling at 50 miles per hour for a high-speed attack, or the same vehicle traveling at 15 miles per hour for a slow-speed attack.

Figure 2 illustrates some typical attack tools mentioned above. In accordance with the conservative physical security design philosophy of this handbook, the penetration time data are based upon optimal application of an attack tool, or combination of attack tools, by experienced operators. Identification of specific tools, or combinations of tools, is intentionally omitted from the penetration time analyses. In all cases, the penetration time information, including both measured and estimated data, is based upon the most effective attack tactics and tool combinations that were identified during penetration testing.

2.6 Physical Security Construction Options. Table 1 presents the penetration times and RCI values for the principal types of conventional and hardened construction for walls, roofs, floors, doors, and windows.

2.6.1 Conventional Construction. The information in this handbook relating types of construction to penetration times and RCI values indicates that the choices among conventional building materials and design approaches are limited to reinforced concrete if penetration times greater than 10 minutes are required. In short, if a security engineer specifies to a facilities engineer that a facility must withstand a forced entry attack of more than 10 minutes, reinforced concrete is the only available conventional approach known at this time for walls, roofs, and floors. Most of the other conventional options offer either less than 2 minutes or equal to or less than 5 minutes, penetration time, and only one of the nonconcrete alternatives approaches 10 minutes. There are no conventional doors constructed of either wood or metal that are attack-resistant against hand, power, or thermal tools for intervals longer than 5 minutes. Doors, therefore, present special problems to the designer restricted to conventional building materials and designs.

2.6.2 Attack-Hardened Construction. For attack-hardened construction of walls, roofs, floors, and doors, steel-fiber-reinforced (SFR) concrete is the only type of attack-hardened construction for walls, roofs, and floors that yields penetration times equal to or greater than 1 hour. There are no other equivalent types of construction in the 1 hour range. However,

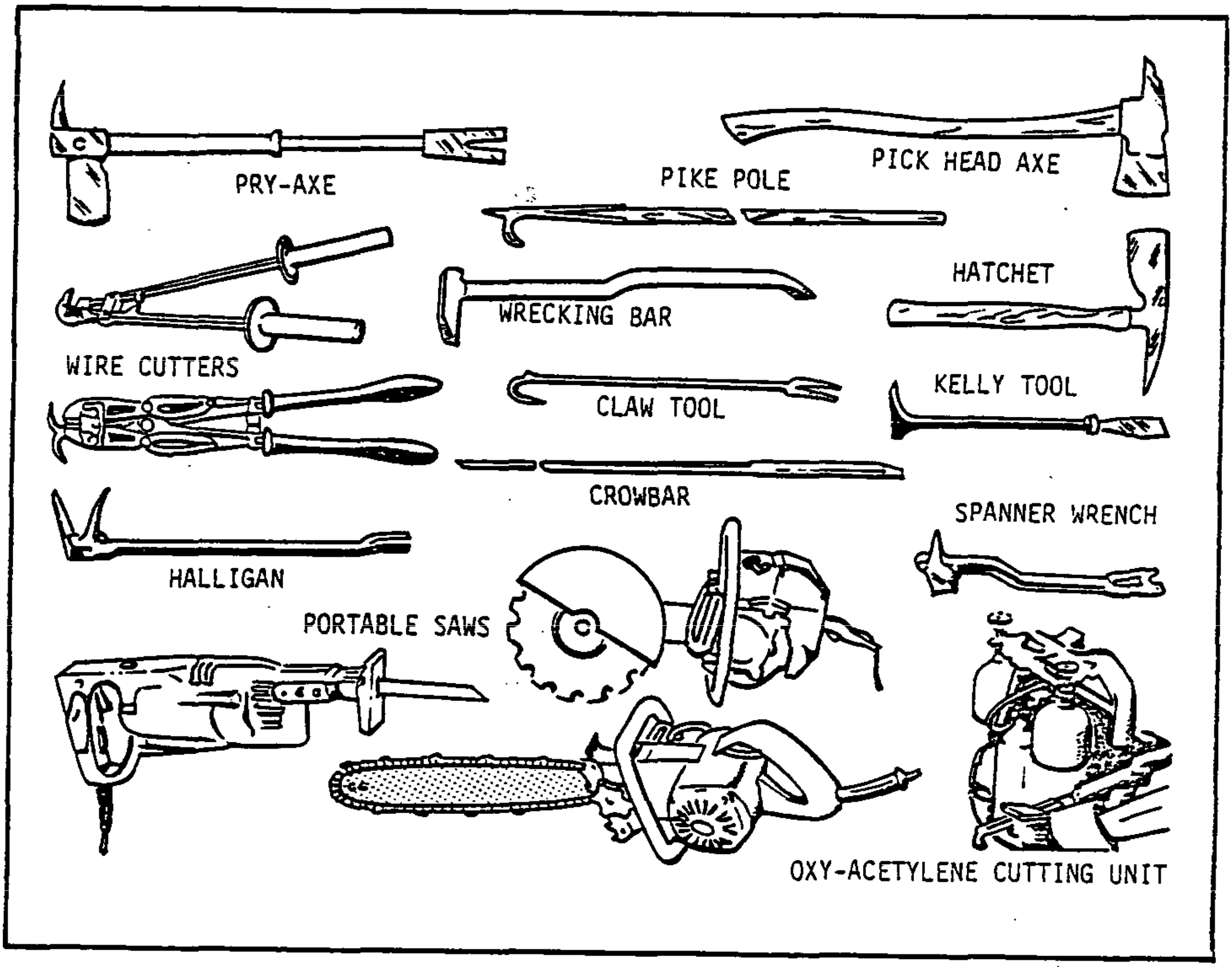


FIGURE 2. Typical attack tools.

TABLE 1.

Conventional and hardened construction options penetration times (minutes) and RCI values.

CONSTRUCTION	WALLS	ROOFS	FLOORS	DOORS	LOCKING DEVICES	WINDOWS	RCI
CONVENTIONAL							
Reinforced Concrete	>60	50-55	>60				0.5-4.2
Masonry	5-10						0.6-3.8
Wood	<2	<2	<2	<2			0.9-2.2
Metal	2-5	2-5	2-5	2-5			0.3-5.4
Industrial Siding	<2	<2					0.7-1.2
HARDENED							
SFR Concrete	>60	55-60	>60				0.6-5.3
Masonry	25-30						1.5-2.0
Wood/Steel Combinations	15-20	15-20	15-20	25-30		10-40	2.0-2.6
Polycarbonate/Steel Combinations				20-25			---
Polycarbonate Materials						2-5	---
High-Security Locking Devices					≤7		---

attack-hardened masonry and wood/steel combinations can yield penetration times in the 30-minute range. Polycarbonate/steel combinations can yield door penetration times in the 20- to 25-minute range. These designs are the only attack-resistant doors that deliver penetration times that approach the hardening of reinforced concrete or steel-fiber-reinforced concrete designs. All of the foregoing choices apply to single barrier designs. To achieve penetration times greater than those shown in Table 1 requires development of a design approach that involves use of multiple barriers and, therefore, careful consideration of interior layouts. These approaches are discussed in greater detail in the sections that follow. Clearly, the key limiting factors are doors, locking devices, windows, and utility openings. The inclusion of these openings in a hardened structure should be minimized. The paragraph on doors, windows, and utility openings (Paragraph 3.2) discusses how these openings can be hardened.

2.7 Designing for Physical Security.

2.7.1 Basic Concepts and Assumptions. The facilities engineer can consider the secured structure he is designing as a six-sided box, and all sides require at least equivalent penetration times to assure the security of what is inside. The value assigned to what is inside determines how secure the box must be in terms of penetration time and what cost for hardening is reasonable. If more delay time is required than can be provided by a single box, then the facilities engineer should consider a "box-within-a-box" concept, where the total delay time is the sum of the penetration times of each box layer, plus the time required to move from layer to layer (i.e. ingress time). In viewing the structure in these terms, it should be kept in mind that the attack direction (upward, downward, or horizontal) may affect the penetration times for some attack tools. The effect of these considerations upon penetration times is summarized below.

2.7.1.1 Wall Construction. Paragraph 3.1 provides penetration time data that assumes a horizontal attack using optimal combinations of hand-held tools.

2.7.1.2 Roof and Ceiling Construction. Paragraph 3.1 provides roof and ceiling penetration time data based upon intruders attempting to penetrate downward through a roof and, where appropriate, a ceiling. In the case of multistory buildings, the same penetration time data can also be used for downward penetration through intermediate floor/ceilings over a secured interior area of a building. In general, conventional finishes used on roofs, floors, or ceilings add very little penetration time and are not included in the data presentations. In general, there are three prevalent types of roof construction geometries: flat, pitched, and arched styles. Flat roofs are among the most common found in warehouses, administrative offices, and industrial/production buildings. Flat roofs are frequently pierced by chimneys, vent openings, shafts, skylights, and other types of fixtures. They may also support air conditioning equipment, antennas, and other structures, which may offer vulnerable points of access. These problems are addressed in

Paragraph 3.2. Pitched roofs are not likely to inhibit a threat's ability to attack efficiently except for very steep angles of slope (greater than 75 degrees). Arched roofs, particularly reinforced concrete arch designs used in the construction of arms, ammunitions and explosives storage magazines, can be covered with earth overburden to enhance attack resistance.

2.7.1.3 Floor Construction. Paragraph 3.1 also includes the floor penetration time data based upon intruders attempting to penetrate upward through a floor in the case of a ground level or basement level floor or upward through a ceiling/floor in the case of an intermediate floor in a multistory building. By definition, the upward attack on a ground or basement level floor also includes digging or tunneling to a position underneath the floor or, perhaps, making use of a tunnel or underground facility already constructed (e.g. an underground parking area, pedestrian tunnel, or utility conduit) that passes beneath the secured area. (Digging times should be included only for overt threats.) In evaluating floor design options, the facilities engineer should be aware that upward attacks through a floor present unique constraints for the use of certain hand, power, and thermal tools because some tools do not work well against gravity. In general upward attacks result in higher penetration times than downward attacks through the same cross section.

2.7.1.4 Doors, Windows, and Utility Openings Construction. Paragraph 3.2 provides penetration time data for facility openings. Facility openings are divided into three major categories:

- o Doors
- o Windows
- o Utility Openings (e.g., pipe chases, vents, ducts, etc.)

Depending upon the orientation of the opening, the attack may be horizontal, upward, or downward. For example, most doors and windows are vertical and should resist horizontal attacks; on the other hand, trapdoors or skylights in a roof should resist downward attacks.

2.7.2 Design Procedure. This subparagraph outlines seven steps to follow in using this handbook to assure a cost-effective design for physical security. A corresponding Delay Time/Cost Worksheet to facilitate the analysis of design alternatives is presented in Paragraph 2.8

2.7.2.1 Step 1--Establish Security Requirements. This step includes establishing:

- o The dimensions of the required area to be secured.
- o The minimum required delay time.

o The maximum allowed security related building cost based upon an analysis of site requirements by the local security engineer (see Appendixes A and B for more details).

2.7.2.2 Step 2--Establish Exterior and Interior Layout. This step includes designing the layouts of the exterior and the interior areas of the facility to maximize:

o The protection of the secured resources.

o The likelihood of detecting, assessing, and tracking a potential threat.

o The likelihood of apprehending the threat before he can either gain access to the secured area or escape with the resource.

This layout should also consider the normal day-to-day operating and functional requirements of the facility. See Section 4 guidelines on the exterior layout (including fencing and lighting). Among others, the following two guidelines apply to the interior layout:

(1) The volume of the secured area. The volume of the secured area should be minimized as much as possible consistent with facility operational and functional requirements.

(2) The location of the secured area. If possible, the secured area should be located in the center of the facility away from exterior walls, etc., consistent with operating requirements. For example, if there is a basement in the facility, the secured area should be located there. If the facility is multistoried, the secured area should be located in the approximate center equally spaced from all exterior walls, roofs, and floors.

2.7.2.3 Step 3--Establish and Evaluate a Preliminary Facility Design. The facilities engineer should complete a preliminary facility design based on components (i.e. walls, floors, roofs, and facility openings) selected according to conventional military design guidelines and the facility functional and structural requirements. An analysis of the delay times and costs associated with this conventional design should then be evaluated with the aid of the Delay Time/Cost Worksheet (hereinafter Worksheet) described in Paragraph 2.8 and the information contained in later paragraphs. If all security delay and cost requirements are met, the facilities engineer need not proceed further with this analysis. If requirements are not met, analyze and compare as appropriate the options presented in steps 4 through 7 below to find the most cost-effective approach. More than one Worksheet may be required.

2.7.2.4 Step 4--Option 1. Design the Secured Areas for Enhanced Hardness. Beginning with the secured area only, redesign the cross sections of the walls, roof, floor, and facility openings using the Worksheet (Paragraph 2.8) and the information in Paragraph 3.1 for walls, roofs, and floors; in Paragraph 3.2 for doors, windows, and utility openings; and Appendix C for guidelines for design of secure conference rooms. This secured area may be, for example, a vault in a finance office or one or more large secure areas in a warehouse. Even if this single barrier approach does meet delay requirements, proceed to the next step.

2.7.2.5 Step 5--Option 2. Harden the Facility Exterior and Compare With Secured Area Hardening. Compare the hardened cross sections required for the secured area developed as a result of Step 4 against the cross sections required for securing the entire exterior of the facility. This comparative analysis is particularly important for facilities containing multiple interior secured areas. For this case the cost of hardening multiple secured areas may be equal to or greater than the cost of hardening the whole "exterior shell" of the facility. It is, therefore, important to compare the engineering feasibility and cost-effectiveness of both approaches.

2.7.2.6 Step 6--Option 3. Design Hardened Multiple Barriers Beyond the Secured Area. Redesign the cross sections of the next set of walls, floors, and facility openings between the secured area and exterior for enhanced hardness. Depending upon the building layout established in Step 2, these barriers may or may not be the exterior walls or roof of the facility. Consider changing this layout as necessary. For example, if a single floor separates the secured area from the ground floor of a multistory building and delay time requirements cannot be made, consider relocating the secured area higher in the building, forcing the intruder to penetrate two or more intermediate floors. It may be that to protect the secure area, one may be able to achieve delay requirements for some components like walls without the use of multiple barriers, while others such as doors may require a multiple barrier approach. A design approach where multiple barriers are placed between the exterior shell of the building and an interior space containing the secured resources is illustrated in Figure 3. If this second layer of hardened barriers is still not adequate to achieve delay time requirements, incorporate additional multiple barriers, as required, consistent with cost constraints. Compare the engineering feasibility and cost of this option with options 1 and 2 above.

2.7.2.7 Step 7--Option 4. If Requirements Cannot Be Met. If, after working through the subsequent paragraphs and various parts of the Worksheet, the required minimum delay time or maximum allowed cost for building security cannot be achieved, the facilities engineer should discuss this problem with the site security officer. Adjustments may be required to other aspects of the security system (e.g., guard response time lines) to ease the building-related delay and cost requirements.

2.8 Delay Time/Cost Worksheet.

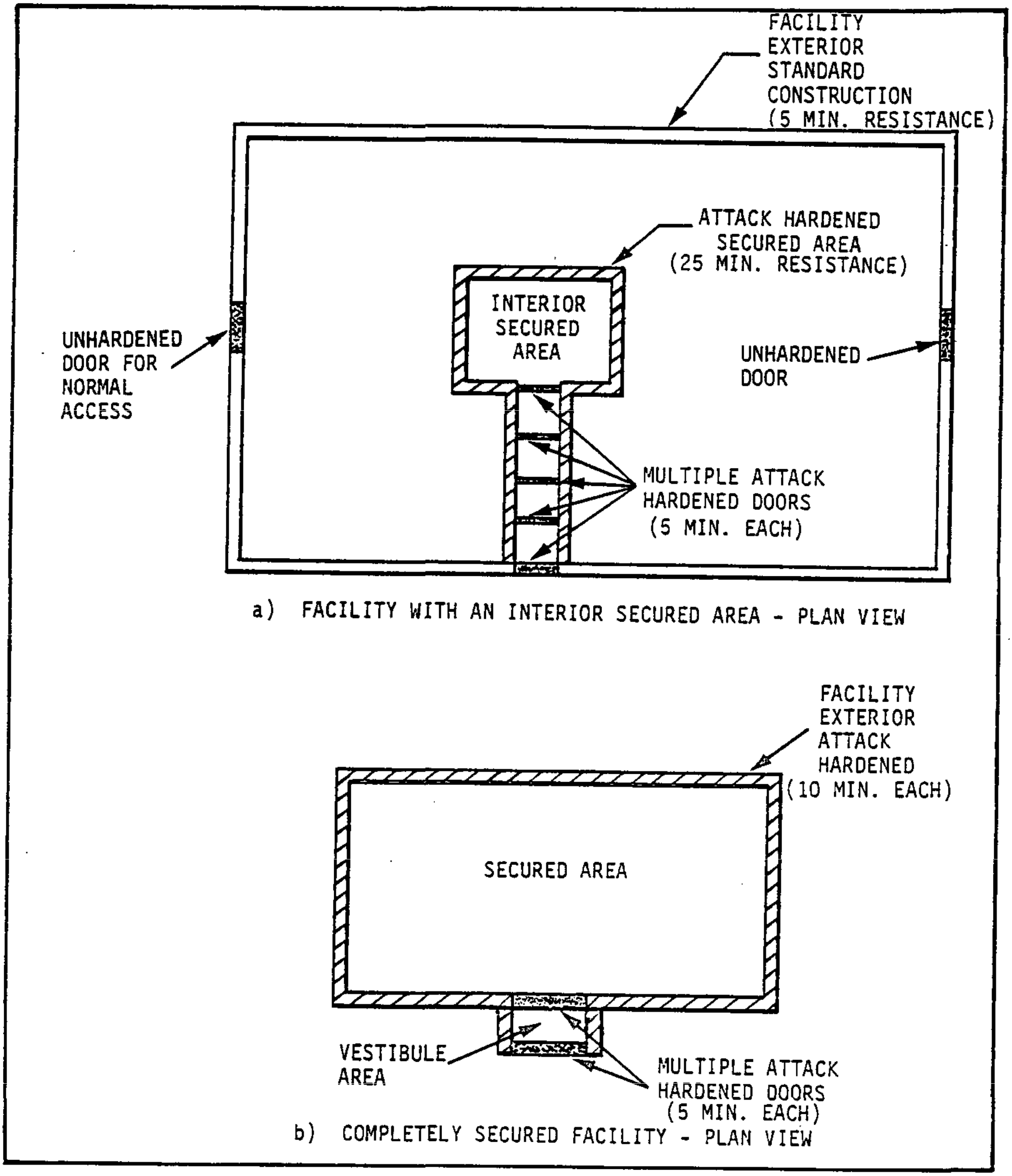


FIGURE 3. Multiple barrier designs.

2.8.1 Overview. Figure 4 is the Delay Time/Cost Worksheet, referenced earlier, to aid the facilities engineer in the selection of cost-effective building components for physical security. In general, this Worksheet provides the user a convenient format for entering and evaluating information obtained from all the other paragraphs of this handbook. By completing this Worksheet and exercising good judgment, all of the facility components should come together coherently, and the most cost-effective design for physical security can be established.

2.8.2 Worksheet Elements. Instructions on how to complete each line or part of the Worksheet follow.

2.8.2.1 Worksheet Number or Identification. The user should identify the Worksheet by number or other identification on Line 1. More than one Worksheet may be required to compare alternative facility designs and layouts and to establish, by iteration, a design or layout that meets overall requirements.

2.8.2.2 Building Identification. Identify the building on Line 2 of the Worksheet. This is particularly important if there is more than one building involved in the design of the facility.

2.8.2.3 Required Volume To Be Secured. Based on the layout plan developed in Step 2 (Subparagraph 2.7.2.2), identify the dimensions of the volume to be secured. This may be the whole building or only a small portion of it. Enter the height on Line 3a, the width on Line 3b, and the length of the secured volume on Line 3c of the Worksheet. Similarly, enter the types, numbers, and dimensions of any facility openings including doors, windows, and utility openings on Lines 3d (1), (2), and (3) of the Worksheet.

2.8.2.4 Required Minimum Delay Time. This requirement is the delay time the building must provide based on an analysis of site requirements by the security engineer. The various factors involved in determining this requirement are discussed in Appendix A. Enter the delay time requirement on Line 4 of the Worksheet.

2.8.2.5 Maximum Allowed Cost of Facility Security. This limitation is the maximum allowed security-related or marginal facility cost based upon an analysis of budget constraints by the facilities engineer. Marginal means penetration hardening related building and site investment, maintenance, and operating costs only. The marginal cost does not include conventional construction costs related to building aesthetic, structural, or functional considerations that would normally be incurred if security were not being considered. The various factors involved in determining this cost are discussed in Appendix A. Enter the maximum allowed cost on Line 5 of the Worksheet.

Page 1

DELAY TIME/COST WORKSHEET

1. Worksheet Number or ID ______ [ ]

2. Building Identification ______ [ ]

3. Required Volume To Be Secured:

   A. Height ______ [ ]

   B. Width ______ [ ]

   C. Length ______ [ ]

   D. Facility Openings

      (1) Type ______ [ ]

      (2) Number ______ [ ]

      (3) Size ______ [ ]

4. Required Minimum Delay Time ______ [ ]

5. Maximum Allowed Cost of Building Security ______ [ ]

FIGURE 4a. Delay time/cost worksheet.

Page 2

Delay Time/Cost Worksheet (Continued)

Part 6

WALL CONSTRUCTION SELECTION

(A) Barrier to secure area	(B) Construction: Type	(B) Construction: Materials	(B) Construction: Dimensions	(C) Delay Time (minutes): Penetration time through	(C) Delay Time (minutes): Ingress time to	(C) Delay Time (minutes): Egress time from*	(C) Delay Time (minutes): Total	(D) Estimated Cost: RCI	(D) Estimated Cost: Unit Cost ($/ft²)	(D) Estimated Cost: Total Units	(D) Estimated Cost: Total Cost ($1000)
6a											
6b											
6c											
						Total time			Total Cost		

*Includes resource loading time, if appropriate

FIGURE 4b. Delay time/cost worksheet (continued).

Delay Time/Cost Worksheet (Continued) Page 3

Part 7

ROOF/FLOOR CONSTRUCTION SELECTION (DOWNWARD ATTACK)

	(B) Construction			(C) Delay time (minutes)				(D) Estimated cost			
(A) Barrier to secure area	Type	Materials	Dimensions	Penetration time through	Ingress time to	Egress time from*	Total	RCI	Unit cost ($/ft^2)	Total units	Total cost ($1000)
7a											
7b											
7c											
					Total time				Total cost		

*Includes resource loading time, if appropriate

FIGURE 4c. Delay time/cost worksheet (continued).

Delay Time/Cost Worksheet (Continued) Page 4

Part 8

FLOOR CONSTRUCTION SELECTION (UPWARD ATTACK)

(A) Barrier to secure area	(B) Construction: Type	(B) Construction: Materials	(B) Construction: Dimensions	(C) Delay time (minutes): Penetration time through	(C) Delay time (minutes): Ingress time to	(C) Delay time (minutes): Egress time from*	(C) Delay time (minutes): Total	(D) Estimated cost: RCI	(D) Estimated cost: Unit cost ($/ft^2)	(D) Estimated cost: Total units	(D) Estimated cost: Total cost ($1000)
8a											
8b											
8c											
						Total time		Total cost			

*Includes resource loading time, if appropriate

FIGURE 4d. Delay time/cost worksheet (continued).

Delay Time/Cost Worksheet (Continued) — Page 5

Part 9

DOOR, WINDOW, AND UTILITY OPENING CONSTRUCTION SELECTION

(A) Barrier to secure area	(B) Construction: Type	(B) Construction: Materials	(B) Construction: Dimensions	(C) Delay time (minutes): Penetration time through	(C) Delay time (minutes): Ingress time to	(C) Delay time (minutes): Egress time from *	(C) Delay time (minutes): Total	(D) Estimated cost: RCI	(D) Estimated cost: Unit cost ($/ft^2)	(D) Estimated cost: Total units	(D) Estimated cost: Total cost ($1000)
9a											
9b											
9c											
						Total time		Total cost			

*Includes resource loading time, if appropriate

FIGURE 4e. Delay time/cost worksheet (continued).

Delay Time/Cost Worksheet (Continued) Page 6

Part 10

IS MINIMUM DELAY TIME ACHIEVED FOR ALL POTENTIAL PATHS?

Total delay time (minutes)	Path 1			Path 2			Path 3		
	Barrier			Barrier			Barrier		
	1	2	3	1	2	3	1	2	3
Penetration time through									
Ingress time to									
Egress time*									
TOTAL									

*Includes resource loading time, if appropriate

FIGURE 4f. Delay time/cost worksheet (continued).

Page 7

Delay Time/Cost Worksheet (Continued)

Part 11

IS MAXIMUM ALLOWED COST EXCEEDED?

11a. Total Wall Construction Cost ____________ [ ]

11b. Total Roof/Floor Construction Cost ____________ [ ]

11c. Total Floor Construction Cost ____________ [ ]

11d. Total Door, Window, and Utility Opening Construction Cost ____________ [ ]

Grand Total Cost ____________ [ ]

FIGURE 4g. Delay time/cost worksheet (continued).

2.8.2.6 Wall Construction. In Part 6 of the Worksheet, construction, delay time, and cost information are entered into Columns B through D, respectively. The objective is to select wall configurations and components that are at least equal to or preferably exceed the minimum delay time on Line 4 for the minimum cost. If the building layout established in Step 2 (Subparagraph 2.7.2.2) identifies multiple walls between the exterior of the building and the secured area, spaces for separate entries (Rows 6a through 6c) are provided in this part of the Worksheet for evaluation of each of these barriers. Based on the information provided in Paragraph 3.1, select the wall construction type, materials, and dimensions for each barrier and enter them into the appropriate subcolumn under Column B. Enter the penetration time for the selected walls from Paragraph 3.1 into the appropriate subcolumn under Column C. Next, estimate and enter the ingress times between barriers using the information presented in Figure 5. Finally, depending upon the facility type, it may be appropriate to enter an allowance for loading of resources onto vehicles, etc., and egress time. (See discussion of egress time in Section 1.) Add the penetration, ingress and, as appropriate, egress times; enter the total for each barrier and the total for all barriers in their respective subcolumns under Column C. If the sum of the times for all barriers does not meet the required minimum delay time shown in Line 4 of the Worksheet, alternative wall construction types or the construction of additional barriers should be evaluated. Once a combination is found that meets delay requirements, its cost should be evaluated using Column D of Part 6. As a preliminary measure of relative cost, the RCI value from Paragraph 3.1 can be inserted into the first subcolumn of Column D to aid in the selection of wall alternatives. Once this initial selection is completed, actual cost data based on the time and location of the specific project should be obtained and used for a more detailed evaluation. Space is provided in Column D for computing total unit wall costs (i.e., dollars per square foot for labor, materials, plant, equipment, etc.) by multiplying the total cost of each barrier by the total units (square feet). It should be noted that the RCI values are intended only for preliminary guidance and are not to be included in any actual cost calculation.

2.8.2.7 Roof/Floor Construction (Downward Attack). Part 7 of the Worksheet is identical in format to Part 6. If the building layout established in Step 2 (Subparagraph 2.7.2.2) locates the secured area in the interior of the building so that a downward attack through the roof or through one or more floors may be possible, space for separate entries (Rows 7a through 7c) is provided in Part 7 for evaluating each barrier based on the information presented in Paragraph 3.1.

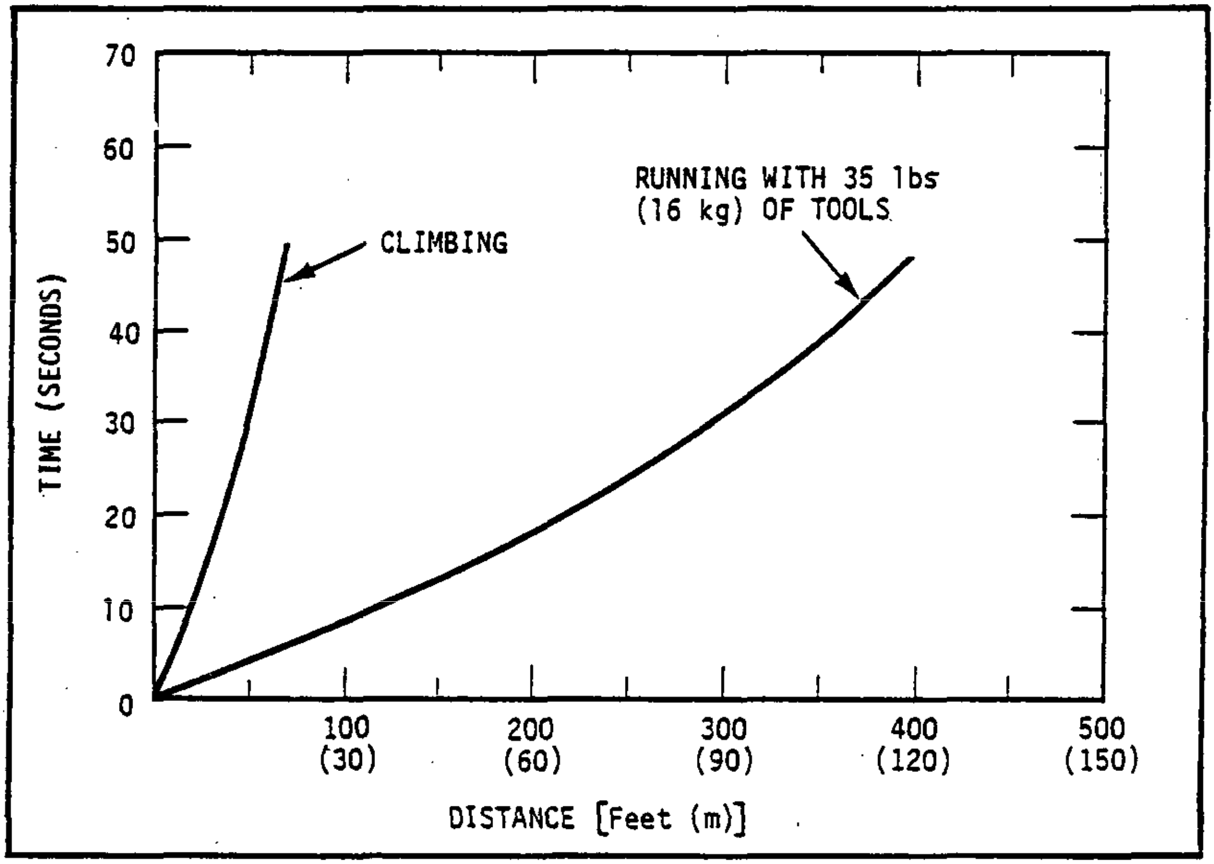


FIGURE 5. Ingress time between barriers. (From Barrier Technology Handbook, Sandia National Laboratories SAND 77-077.)

2.8.2.8 Floor Construction (Upward Attack). Part 8 of the Worksheet is also identical in format to Parts 6 and 7. If the building layout established in Step 2 (Subparagraph 2.7.2.2) locates the secured area in the building so that an upward attack on a basement, ground level, or one or more higher intermediate floors is possible, space for separate entries (Rows 8a through 8c) is provided in Part 8 for evaluating each option, based on the information presented in Paragraph 3.1. For the reasons described in the previous paragraph for the roof/floor design, identified in Part 7, a downward attack may require higher attack resistance than a floor design, selected in Part 8 for an upward attack. Such enhanced hardness is necessary for certain combinations of materials and attack tools because downward attacks work with gravity and are, therefore, easier.

2.8.2.9 Facility Opening Construction. Exterior windows, doors, and utility ports into the building should be identified (using the layout plan) and evaluated using Part 9 of the Worksheet and the information presented in Paragraph 3.2. Most building layout designs include multiple doors, windows, and utility openings. If the building exterior and interior layouts include multiple facility openings, list each door, window, and utility opening between the exterior of the facility and the secured area (Rows 9a through 9c). Use multiple sheets if necessary and prepare separate listings for doors, windows, and utility openings. Each facility opening should be considered with respect to the penetration time it provides. Where a penetration time, combined with the ingress and egress times, does not meet the delay time shown in Line 4 on page 1 of the Worksheet, alternative designs of doors, windows, and utility openings, as appropriate, should be evaluated using the data presented in Paragraph 3.2. The security engineer should recognize that under the current state-of-the-art the most vulnerable point on most doors is its locking device. It should be noted that the penetration time of a locking device is measured by defeat of the locking device itself and not the creation of a man-passable opening through the door surface. Interior doors, windows, and utility openings into the secured area, or between floors, should be treated in the same manner as exterior facility openings. In general, the security engineer should take into account the fact that some doors may have to remain unlocked, e.g. fire doors between floors. Moreover, he should be aware that it is normally wasteful to design an entry or barrier for an opening in a wall that provides greater penetration resistance than the wall.

2.8.2.10 Is Minimum Delay Achieved For All Potential Paths to the Secured Area? At this point in the procedure, designs for all the major building components should have been selected. Part 10 of the Worksheet is provided to check whether all potential paths into (and, if appropriate, away from) the secured area do, in fact, meet the minimum delay requirement. The user should identify on the layout plan (Step 2, Subparagraph 2.7.2.2) a variety of reasonable minimum delay paths that an intruder may take to and from the secured area and estimate the delay times for each, using the delay time information in Parts 6 through 9 of the Worksheet. Note that some paths may involve a combination of walls, roofs, floors, and facility openings. If any path fails to achieve the minimum delay time requirement, adjustments to the building layout or cross section design selected in Parts 6 through 9 of the Worksheet should be made appropriately.

2.8.2.11 Is Maximum Allowed Cost Exceeded? The cost of all building components from Parts 6 through 9 of the Worksheet should be entered into Part 11 of the Worksheet, summed, and the results compared with the maximum allowed cost in Line 5. If the budget is exceeded, adjustments to the building layout or barrier cross-sectional design should be made appropriately.

2.8.2.12 If Requirements Cannot Be Met. See Subparagraph 2.7.2.7

SECTION 3: BUILDING PHYSICAL SECURITY

3.1 Wall, Roof, and Floor Construction.

3.1.1 Summary.

3.1.1.1 Overview. This paragraph presents penetration times for the principle types of conventional wall, roof, and floor construction used in defense facilities. Penetration times for attack-hardened construction are also included where test data are available. Where appropriate, the penetration times are organized into sets of lookup tables, corresponding to specific details for the most common types of construction. The information in the figures will enable the facilities engineer to determine which types of construction yield equivalent penetration times. Penetration time equivalency can be related to cost equivalency by reference to the RCI value indicated for each type of construction. The penetration times are conservative estimates based on the available measured test data. For those designs that are concerned with vaults (i.e., construction of walls, floors, and roofs) Section 7 discusses the different classes of vaults.

3.1.1.2 Evaluation of Construction Design Options. Table 2 summarizes the range of penetration times that can be expected from conventionally constructed, as well as attack-hardened, reinforced concrete walls, roofs/ceilings, and floors. This table also cross-references the tables set forth in Subparagraphs 3.1.2 and 3.1.3 that present design details and penetration times for each specific cross section that has been analyzed. Table 2 also presents the corresponding range of RCI values to facilitate relative cost comparisons among the design options. The following general conclusions can be drawn from a review of Table 2.

First, a reinforced concrete wall is the only design option for those cases where a barrier penetration time requirement exceeds 30 minutes. A conventionally constructed reinforced concrete wall is probably the most cost-effective option to meet these longer penetration times with a single barrier approach. Reinforced concrete, of course, can also be used for single barrier penetration time requirements under 30 minutes. However, in these lower penetration time regimes, equivalent options are limited to attack-hardened cross sections. Conventionally constructed masonry and stud/girt walls are only effective for penetration time requirements below 8 minutes for the former and typically less than 2 minutes, at the most 2 to 5 minutes, for the latter. When equivalent reinforced concrete, masonry, or stud/girt design options are available, the designer should select the option that best satisfies cost, functional, dimensional, and aesthetic objectives. If a single barrier approach is ineffective, the tables outlined in Subparagraph 3.1.2 can be used to evaluate the cost-effectiveness of multiple wall barriers.

TABLE 2.

Penetration time summary and lookup table for walls and roof/floors.

Construction Type	Conventional			Attack Hardened		
	Penetration Time (minutes)	RCI range	Figure/Table Cross Reference Numbers	Penetration Time (minutes)	RCI range	Figure/Table Cross Reference Numbers
WALL CONSTRUCTION						
Reinforced Concrete	2->60	1.4-4.2	Figure 7; Tables III & IV	5->60	1.8-5.3	Figure 8; Tables III & IV
Masonry	<2-8	0.6-3.8	Table II	5-30	1.5-2.0	Figure 9; Tables V & VI
Stud/Girt	≤2	0.9-2.2	Table II	5-20	1.5-11.7	Tables VII & VIII
ROOF/FLOOR CONSTRUCTION						
Reinforced Concrete	2-55	0.5-4.2	Figures 7 & 10; Tables IV & IX	5->60	0.6-5.3	Figure 10; Table IX
Wood	≤2	1.0-1.4	Table II	5-20	1.5-11.7	Table VIII
Metal	<2-5	0.3-5.4	Table II	5-20	2.0-11.7	----

NOTE: The upper RCI value for conventional masonry construction of 3.8 compares unfavorably with the 2.0 value for attack hardened masonry construction. This apparent anomaly is explained by the fact that testing of attack-hardened options has been limited to thicknesses that are narrower than some of the conventional masonry options such as thick stone walls. These thicker masonry wall sections are expensive to build and they deliver lower penetration times.

Second, reinforced concrete is the only design option for those cases where a single barrier penetration time requirement exceeds 20 minutes. A conventionally constructed reinforced concrete roof/floor is probably the most cost-effective option to meet these longer penetration times with a single barrier approach. Reinforced concrete, of course, can also be used for single barrier penetration time requirements below 20 minutes. However, in these lower penetration time regimes, there are wood/metal options that yield equivalent penetration times. Between 2 and 20 minutes these equivalent options are limited to attack-hardened cross sections. Conventionally constructed wood, metal, asbestos cement, and fiberglass roofs and ceilings have only very limited penetration capabilities (typically less than 2 minutes, at most 2 to 5 minutes). As in the case of walls, where equivalent reinforced concrete, wood, or metal options are available, the facilities engineer should select the best option that is compatible with the wall construction selected and also satisfies cost, functional, dimensional, and aesthetic objectives. If there are multiple floors or stories between the roof and the interior space containing the secured resource, the tables outlined in Subparagraph 3.1.3 can be used to evaluate the cost-effectiveness of multiple attack-hardened floors. If the designer is seeking penetration time enhancement against overt threats using earth cover (e.g., an arms, ammunition and explosives (AA&E) storage magazine), the application of earth overburden on a reinforced concrete or corrugated metal roof can enhance penetration times up to intervals approaching 1 hour. Figure 6 indicates incremental penetration times that can be expected from digging to various depths of earth based upon four men using a pick and shovel attack. Figure 6 can also be used to estimate added delay times from digging for an upward attack on basement or ground level floors. For this situation, added intervals of well over 1 hour are possible.

3.1.1.3 Selection of Proper Construction. To use the penetration time and RCI information, the security engineer should follow one or more of the steps outlined in Paragraph 2.7. Table 2 can be used to identify one or more general construction types that fall within the range of delay time requirements. Table 2 can also be used to identify the subsequent tables containing specific details, penetration times, and RCI values for a given construction type.

3.1.2 Walls.

3.1.2.1 Reinforced Concrete. Representative construction options include:

- Cast-in-place walls. The forms are constructed vertically and the concrete poured onsite.

- Tilt-up walls. These are similar to cast-in-place walls except that the walls are constructed in a horizontal direction and then lifted up.

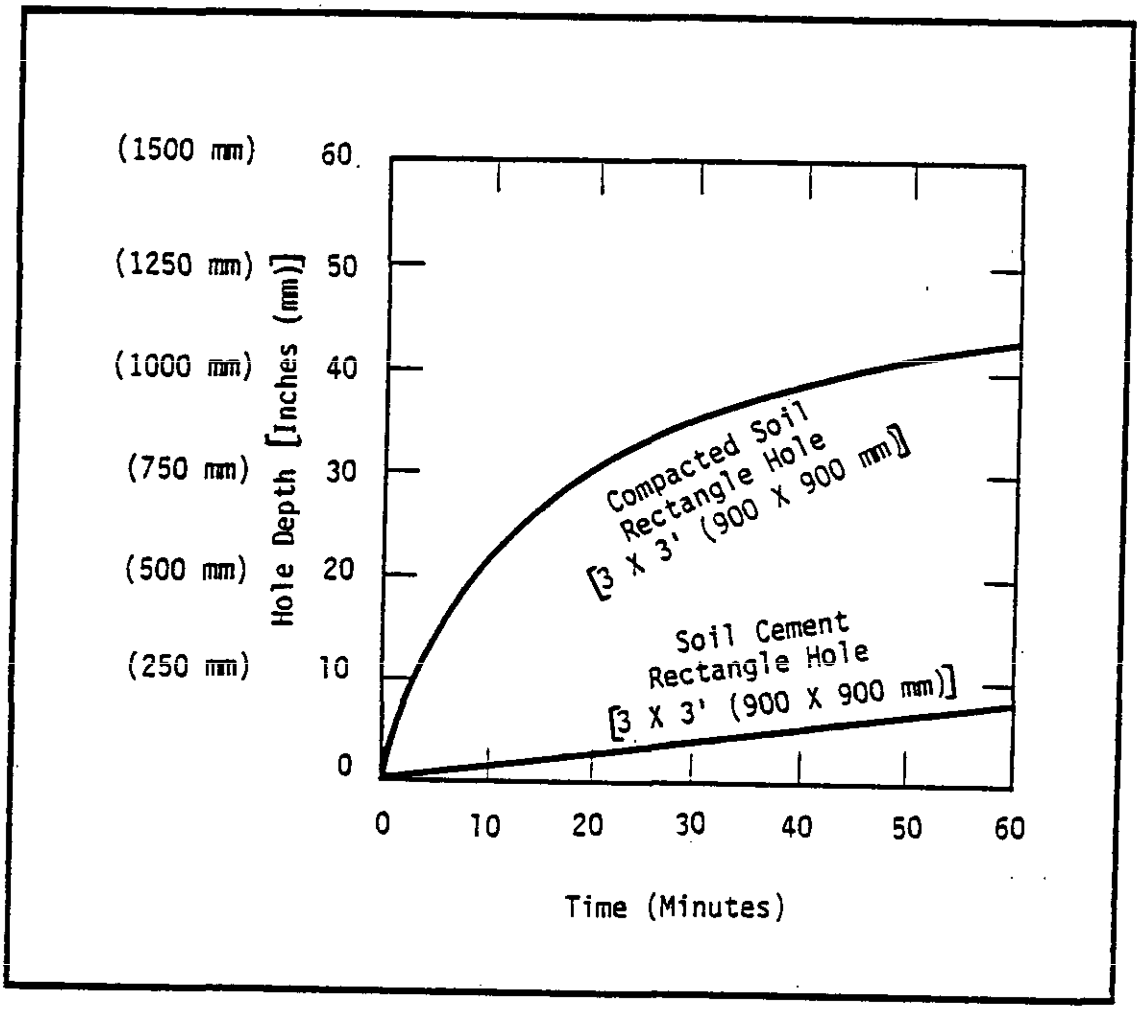


FIGURE 6. Digging rates for various depths of earth, using pick, shovel, four men. (From Barrier Technology Handbook, Sandia National Laboratories SAND 77-077.)

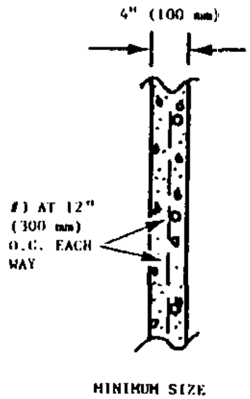
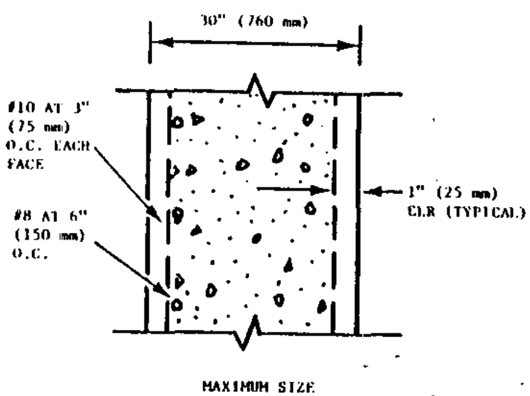
o Precast walls. These are constructed elsewhere and shipped to the site.

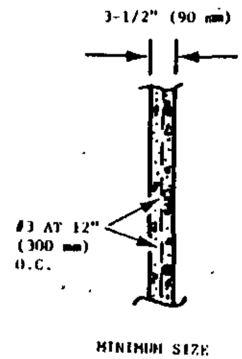
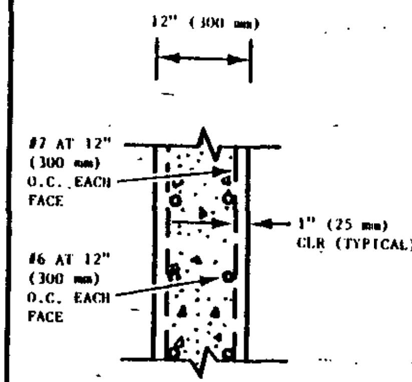
The above options may include both the conventionally constructed walls or the steel-fiber-reinforced (hardened) concrete walls illustrated in Table 3.

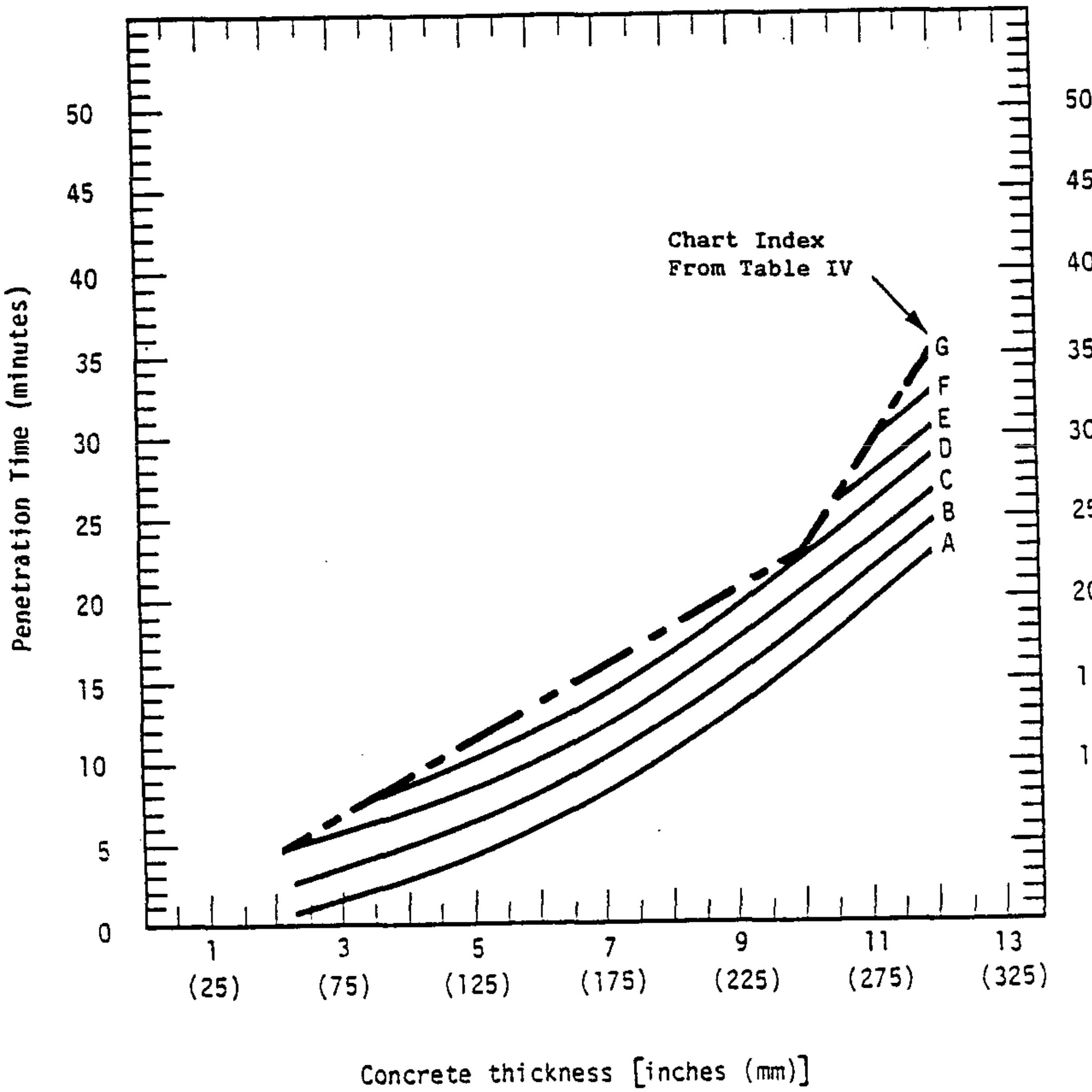
(1) Conventional construction. As illustrated in Table 3, the thickness of typical precast or tilt-up walls may be as low as 3-1/2 inches (90 mm) to as high as 12 inches (300 mm). A cast-in-place wall typically begins at 4 inches (100 mm) and may reach as high as 30 inches (760 mm). The corresponding reinforcement may be as low as a single layer of No. 3 steel bars at 12-inch (300-mm) spacing each way, for the 3-1/2-inch (90-mm) or 4-inch (100-mm) wall, to as high as No. 8 bars at 3 inches (75 mm) each way at each face for the 12-inch (300-mm) wall. Concrete with compressive strengths between 3,000 and 6,000 pounds per square inch (psi) (21 and 42 megaPascal (MPa)) and a steel reinforcing bar (hereinafter, rebar) with a tensile strength between 40,000 and 60,000 psi (275 and 415 MPa) are typically used.

(2) Penetration times for conventional construction. Table 3 gives estimated penetration times for a 3-1/2-, 4-, 12-, and 30-inch (90-, 100-, 300-, and 760-mm) wall against optimal combinations of hand, power, and thermal tools. It should be noted that, for conventional concrete materials, the penetration times range from about 2 minutes to greater than 60 minutes. At the time this handbook was written (1986), no data for hand, power, and thermal tool attacks on concrete walls exceeding 12 inches (300 mm) in thickness were available. However, based on Table 3, one can expect these thicker walls to exceed a 40-to-45-minute penetration time level, with a 30-inch (760-mm) wall well above 1 hour. For walls up to 12 inches (300 mm) thick, Figure 7 and Table 4 can be used to estimate penetration times for thickness and rebar combinations intermediate to those shown in Table 3. In general, reinforced concrete walls provide higher penetration times relative to stud/girt or masonry wall options of comparable thickness. In terms of cost, they are generally comparable to masonry wall construction (RCI between 1.4 and 4.2), but may be up to twice as expensive as stud/girt. Although no specific discussion of 8-inch (200-mm) reinforced concrete walls has been presented in the foregoing information about conventional concrete construction, it should be noted that the data point on Curve C, representing the penetration time (about 15 minutes) for 8-inch (200-mm) reinforced concrete walls (see Figure 7 and Table 4), is equivalent to the expected penetration time of the 8-inch (200-mm) reinforced concrete wall construction mandated for Category II AA&E storage facilities by DOD 5100.76-M and Office of the Chief of Naval Operations Instruction 5530.13.

TABLE 3.
Reinforced concrete walls, conventional and hardened construction.

A. CAST-IN-PLACE	CONVEN-TIONAL PENETRATION TIME (MIN.)	CONVEN-TIONAL RCI	SFR HARDENED PENETRATION TIME (MIN.)	SFR HARDENED RCI
	2.5	1.4	7.5	1.75
	>60	4.2	>60	5.25

B. PRECAST OR TILT-UP	CONVEN TIONAL PENETRATION TIME (MIN.)	CONVEN TIONAL RCI	SFR HARDENED PENETRATION TIME (MIN.)	SFR HARDENED RCI
	2	1.4	6	1.75
	23	2.0	34	2.5



NOTE: If using Table for walls, penetration times based on horizontal attack. If using Table for roofs, penetration times based on downward attack.

FIGURE 7. Penetration times for reinforced conventional concrete walls/roofs.

TABLE 4.

Penetration time chart index for Figures 7 and 8.

Single layer

Spacing each way (inches) (mm)	Bar Number						
	None	3	4	5	6	7	8
3 (75)	A	B	B	C	C	D	E
3-1/2 (90)	A	B	B	C	C	D	E
4 (100)	A	B	B	B	C	C	D
4-1/2 (115)	A	B	B	B	C	C	D
5 to 9 (125 to 225)	A	B	B	B	B	B	C
>10 (250)	A	A	A	A	A	A	A

Double layer

Spacing each way (inches) (mm)	Bar Number						
	None	3	4	5	6	7	8
3 (75)	A	C	C	D	E	G	I
3-1/2 (90)	A	C	C	D	E	F	H
4 (100)	A	B	C	C	D	E	G
4-1/2 (115)	A	B	C	C	D	E	F
5 to 9 (125 to 225)	A	B	B	B	C	C	D
>10 (250)	A	A	A	A	A	A	A

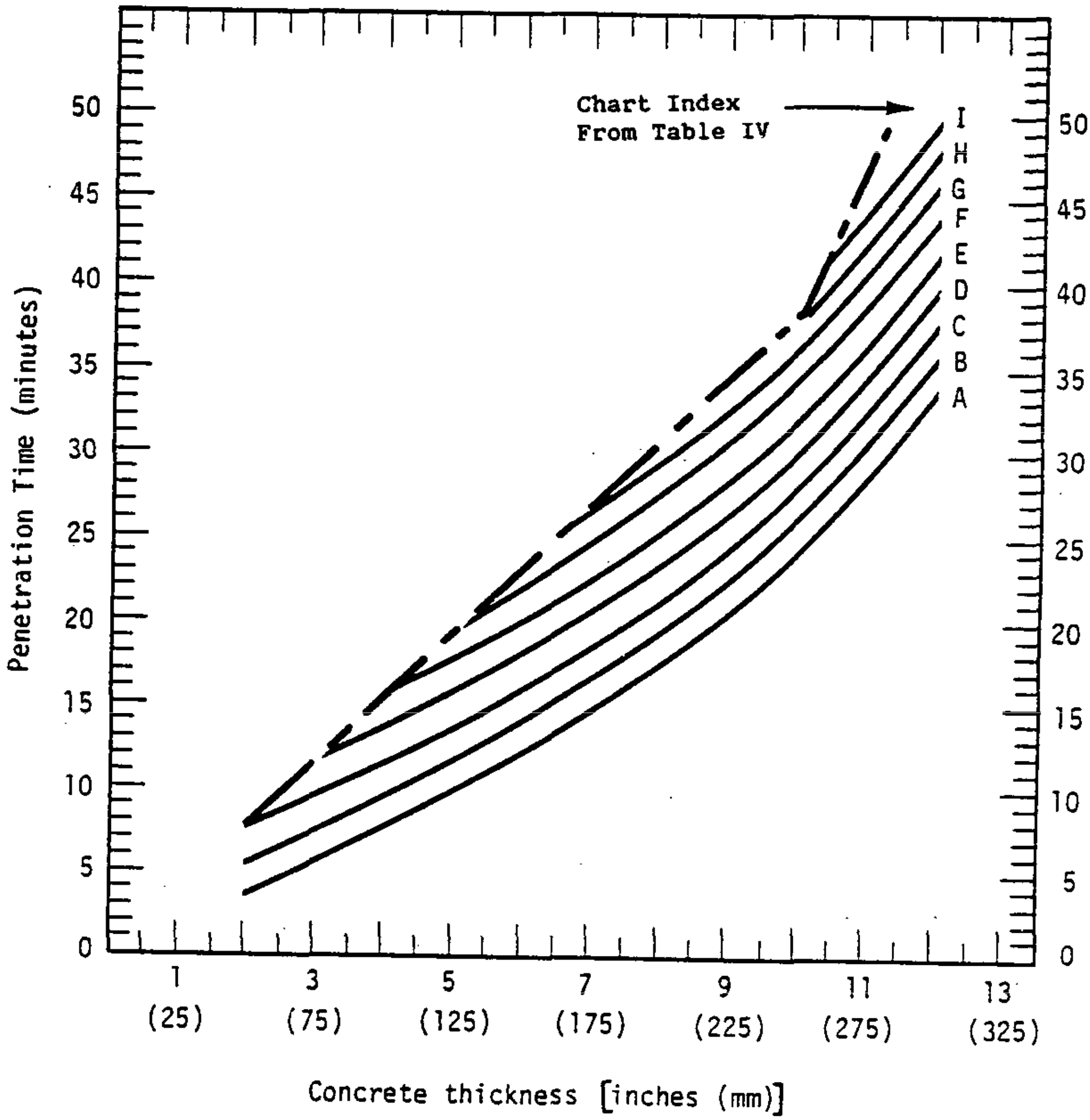
(3) Hardening options. If additional penetration time is required, consider one or more of the following options:

(a) Reinforced concrete. Increase the thickness of the wall or rebar size, number of layers, or decrease the rebar spacing (see Figure 7 and Table 4).

(b) Steel-fiber-reinforced (SFR) concrete. Use steel-fiber-reinforced concrete. For the same wall thickness, SFR concrete generally provides higher penetration times. Table 3 gives penetration time estimates for 3-1/2-, 4-, 12-, and 30-inch (90-, 100-, 300-, and 760-mm) walls using SFR concrete. The amount of steel fiber is about 5 percent by volume weight of the concrete mix design. (For intermediate values, for walls less than 12 inches (300 mm) thick, see Figure 8 and Table 4.) The added penetration time for a given wall thickness gained by this option should be weighed against the added cost of SFR concrete, which has an RCI value at least 25 percent greater than conventional concrete.

3.1.2.2 Masonry Wall Construction. Masonry walls are typically constructed of one or more of the following materials: concrete masonry unit (CMU), brick, structural tile, or stone. These walls may also be reinforced with steel bars. Construction options, penetration times, and RCI values for attack-hardened walls are shown in Table 5.

(1) Conventional construction. Unreinforced masonry wall construction may typically consist of concrete masonry units (CMU), brick, structural tile, stone, or a combination of these materials. CMU may range from 4 to 12 inches (100 to 300 mm) thick and may be left hollow or grouted solid. Single wye brick generally comes in widths of 4 to 12 inches (100 to 300 mm). Structural clay tile will typically range from 4 to 8 inches (100 to 200 mm) wide, and stone will usually vary between 6 and 24 inches (150 and 600 mm). As for combinations of these materials, brick or CMU may range from 8 to 16 inches (200 to 400 mm) with masonry ties every second CMU course. Structural clay tile on CMU may be found in widths from 6 to 16 inches (150 to 400 mm), again with masonry ties every second course. Brick on structural clay tile may vary from 8 to 12 inches (200 to 300 mm) with ties every sixth brick course. Finally, stone on CMU may range from 6 to 16 inches (150 to 400 mm) with ties every second CMU course. Reinforced concrete masonry units (CMU) may vary from 6 to 12 inches (150 to 300 mm) wide, grouted solid with reinforcing ranging from No. 4 rebar at 32 inches (800 mm) on center horizontally and 16 inches (400 mm) on center vertically to No. 5 at 16 inches (400 mm) on center horizontally and No. 8 at 8 inches (200 mm) on center vertically. Brick on stone, double wye ranges from 10 to 16 inches (250 to 400 mm) thick, grouted solid with No. 6 rebar at 12 inches (300 mm) on center horizontally and No. 9 at 12 inches (300 mm) on center vertically. Reinforced CMU with 4-inch (100-mm) stone or brick veneer vary from 10 to 16 inches (250 to 400 mm) wide, grouted solid, with reinforcing ranging from No. 4 rebar at 32 inches (800 mm) on center horizontally and at 16 inches (400 mm) on center vertically to No. 5 rebar at 8 inches (200 mm) on center horizontally and No. 8 at 6 inches (150 mm) on center vertically.



NOTE: If using Table for walls, penetration times based on horizontal attack. If using Table for roofs, penetration times based on downward attack.

FIGURE 8. Penetration times for reinforced fibrous concrete walls/roofs.

TABLE 5-a.
Masonry, wall, hardened construction.

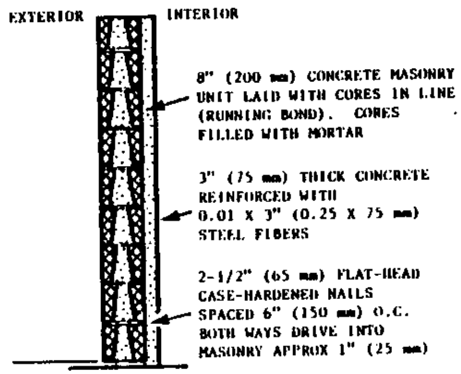
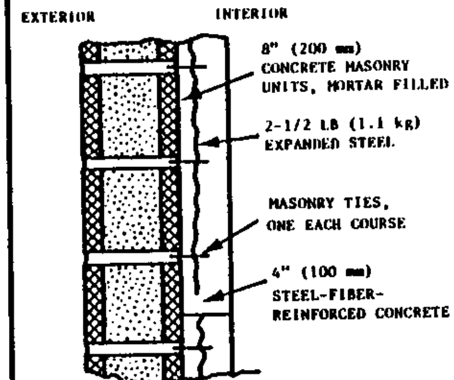
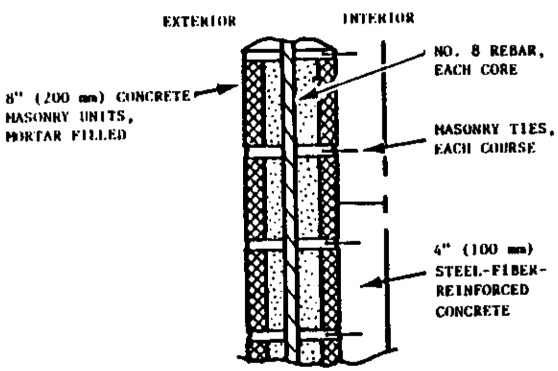
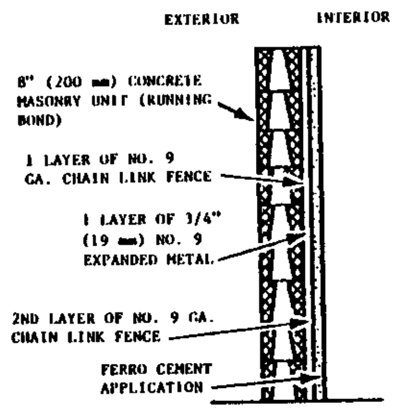
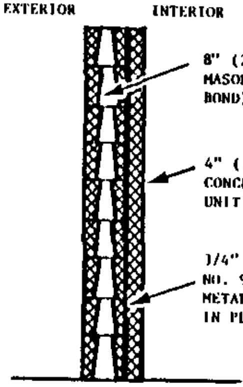
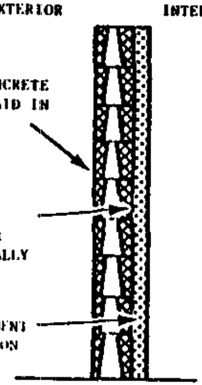
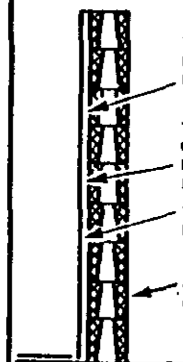
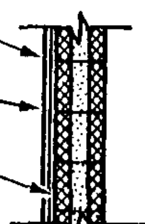
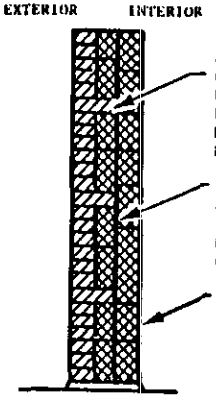
	PENETRATION TIME (MIN.)	RCI		PENETRATION TIME (MIN.)	RCI
 A. CMU/SFR CONCRETE LAYER Source: National Bureau of Standards, NBSTN 837.	25	2.3	 B. CMU/SFR CONCRETE LAYER/EXPANDED STEEL Source: Civil Engineering Laboratory, TN-1508.	30	2.6
 C. CMU/SFR CONCRETE LAYER/STEEL/REBAR Source: Civil Engineering Laboratory, TN-1508.	27	2.5	 D. CMU/FERRO CEMENT LAYER/FENCE/ EXPANDED METAL Source: National Bureau of Standards, NBSTN 837	10	2.9

TABLE 5-b.
Masonry, wall, hardened construction. (continued)

	PENETRATION TIME (MIN.)	RCI		PENETRATION TIME (MIN.)	RCI		PENETRATION TIME (MIN.)	RCI
 E. CMU/EXPANDED METAL/CMU Source: National Bureau of Standards, NBSTN 837	5	1.5	 F. CMU/FERRO CEMENT LAYER/ WIRE FENCING Source: National Bureau of Standards, NBSTN 837	10	2.7	 G. CMU/FOAM/PLYWOOD/ EXPANDED METAL Source: National Bureau of Standards, NBSTN 837.	4	1.3
 H. CMU/PLYWOOD/ASPHALT PAPER Source: VSE Corp., Report 11-RD-80	5	1.2	 I. BRICK/CMU/EXPANDED METAL/CMU Source: National Bureau of Standards, NBSTN 837.	4	2.4			

(2) Penetration times for conventional construction. Conventional masonry walls provide only limited hardness against forced entry attacks using optimal combinations of hand, power, and thermal tools. They typically offer penetration times ranging from less than 2 minutes to 2 to 5 minutes. Even with thicker wall sections, only 8 minutes is achieved. Relative to other forms of construction, masonry walls provide penetration times only slightly greater than stud/girt construction. Specifically, for the same wall thickness, masonry walls provide penetration times that are much less than reinforced concrete. In terms of cost, they are almost twice as expensive as stud/girt.

(3) Hardening options. If additional penetration time is required, consider one or more of the following options:

(a) Hardening with reinforced masonry. Increase the thickness of the wall or the size and number of rebar layers or decrease the spacing of the rebar provided. Figure 9 and Table 6 can be used. These charts assume that all wall cavities are filled with mortar.

(b) Hardening with composites. Use one or more of the nonconventional options summarized in Table 5. These options were specifically designed and tested to provide enhanced attack resistance. With the exception of the option shown in Table 6 which uses a 4-inch (100-mm) layer of brick on a 4-inch (100-mm) layer of concrete block, all the other sections use 8-inch (200-mm) mortar filled CMU blocks as the basic component. The CMU sections vary mostly in the type of reinforcing materials provided. The data in Table 5 show that the only significant improvements in penetration times relative to conventional construction involve using a 3- to 4-inch (75- to 100-mm) layer of steel fiber-reinforced concrete, which is either unreinforced (Table 5) or reinforced with expanded steel grating (Table 5-B), or steel rebar in the CMU cores (Table 5). These construction options provide penetration times between 25 and 30 minutes. These attack-hardened options may be up to twice as expensive as conventional masonry construction of equivalent thickness.

3.1.2.3 Stud/Girt Wall Construction. Stud walls are used in the construction of wood or light metal frame buildings. The basic frame consists of wood or metal vertical supports, usually 2 by 4 inches (50 by 100 mm) or 2 by 6 inches (50 by 150 mm), placed 12, 16, or 24 inches (300, 400, or 600 mm) on center. Metal girts are horizontal framing members used in rigid frame systems. They range in depth from 6-1/2 to 9-1/2 inches (165 to 240 mm) and are spaced 2 to 7-1/2 feet (600 to 2,250 mm) on center. An architectural finish is attached to the exterior side of the stud or girt, and an interior wall finish may be attached to the interior side. It should be noted that wood wall construction for permanent buildings shall be confined primarily to housing and minor structures. Construction options, penetration times, and RCI values for attack-resistant wall systems using stud, wood siding, and steel layering are shown in Tables 7 and 8. Regardless of the degree of security, the choice of wood construction must be in accordance with the fire protection requirements set forth in Department of Defense Military Handbook 1008, Fire Protection for Facilities Engineering, Design and Construction.

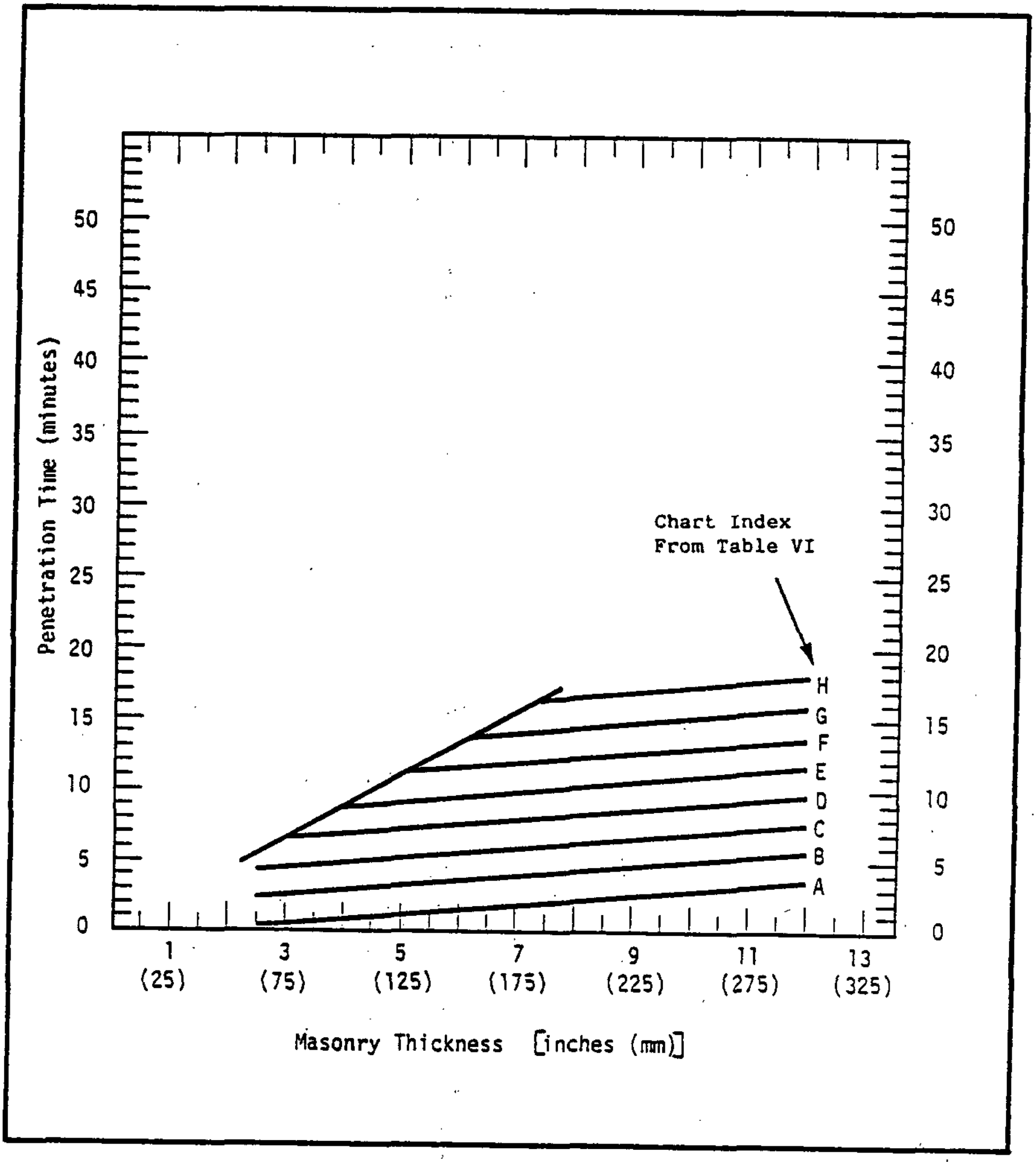


FIGURE 9. Penetration times for reinforced masonry walls.

TABLE 6.

Penetration time chart index for Figure 9, conventional reinforced masonry walls.

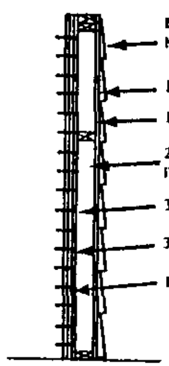
Single layer of rebar in block cavities

Spacing each way (inches) (mm)	Bar Number						
	None	3	4	5	6	7	8
3 (75)	A	B	B	C	C	D	E
3-1/2 (90)	A	B	B	C	C	D	E
4 (100)	A	B	B	B	C	C	D
4-1/2 (115)	A	B	B	B	C	C	D
5 to 9 (125 to 225)	A	B	B	B	B	B	C
>10 (250)	A	A	A	A	A	A	A

Double layer of rebar in block cavities

Spacing each way (inches) (mm)	Bar Number						
	None	3	4	5	6	7	8
3 (75)	A	C	C	D	E	G	H
3-1/2 (90)	A	C	C	D	E	F	H
4 (100)	A	B	C	C	D	E	G
4-1/2 (115)	A	B	C	C	D	E	F
5 to 9 (125 to 225)	A	B	B	B	C	C	D
>10 (250)	A	A	A	A	A	A	A

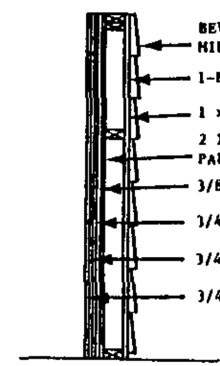
TABLE 7.
Stud and wood siding, hardened. (From National Bureau of Standards, NBSTN 837.)



A. SHEET STEEL LAYERING

ANCHOR TO STUDS USING 10d ANNULAR RING (ANCHORFAST) NAILS SPACED 4" (100 mm) O.C.

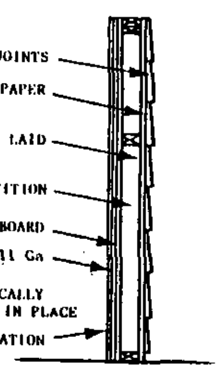
Source: National Bureau of Standards, NBSTN 837.



B. EXPANDED METAL LAYERING

ANCHOR TO STUDS USING 10d ANNULAR RING (ANCHORFAST) NAILS SPACED 4" (100 mm) O.C.

Source: National Bureau of Standards, NBSTN 837.

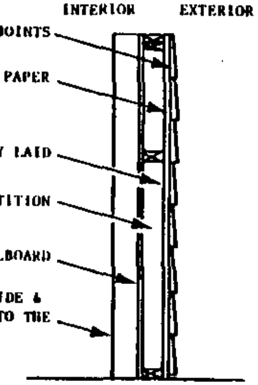


C. FERRO CEMENT APPLICATION

ANCHOR TO STUDS USING 10d ANNULAR RING (ANCHORFAST) NAILS SPACED 4" (100 mm) O.C.

Source: National Bureau of Standards, NBSTN 837.

ANCHOR TO STUDS USING 10d ANNULAR RING (ANCHORFAST) NAILS SPACED 4" (100 mm) O.C.

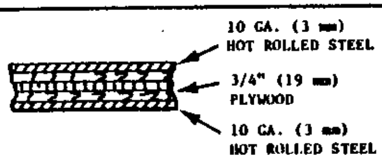
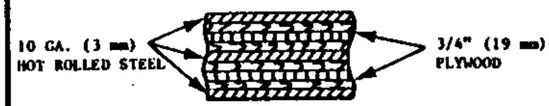
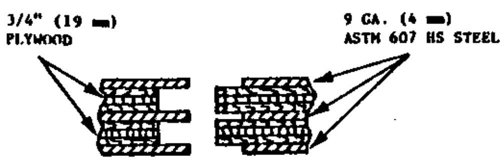
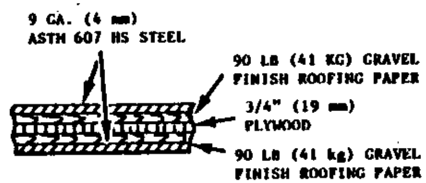


D. 2 x 6 INCH STUDS STACKED AND NAILED

Source: National Bureau of Standards, NBSTN 837.

	PENETRATION TIME (MINUTES)	RCI
A. SHEET STEEL LAYERING	<2-5	1.5
B. EXPANDED METAL LAYERING	<2-5	1.6
C. FERRO CEMENT APPLICATION	<2-5	2.6
D. 2 x 6 INCH STUDS STACKED AND NAILED	<2-5	2.0

TABLE 8.
Wood and steel attack resistant wall system.
(From Civil Engineering Laboratory, TDS 80-02.)

System	Penetration Time (Minutes)	RCI	System	Penetration Time (Minutes)	RCI
 A. TWO-LAYER SYSTEM; TWO LAYERS OF STEEL WITH ONE LAYER OF PLYWOOD IN THE MIDDLE	5-10	2.0	 B. THREE-LAYER SYSTEM; THREE LAYERS OF STEEL WITH A LAYER OF PLYWOOD BETWEEN EACH LAYER	10-15	2.6
 C. TONGUE-AND-GROOVE THREE LAYER PREFABRICATED ASSEMBLY CONSTRUCTION	10-15	2.1	 D. TWO-LAYER SYSTEM WITH GRAVEL FINISH ROOFING PAPER	15-20	2.0

(1) Conventional construction. The seven basic types of stud/girt wall construction include: stud and stucco, stud and wood siding, stud and plywood siding, stud and shingle siding, stud and composition siding, stud/girt industrial siding, and conventional masonry veneer construction.

(2) Penetration Times for Conventional Construction. Estimated penetration times for the seven basic types of stud/girt walls are less than 2 minutes against optimal combinations of hand and power tools. Use of 2- by 6-inch (50- by 150-mm) studs increases the penetration time insignificantly. Conventional masonry veneer walls offer penetration times of 5 minutes or less against optimal combinations of hand and power tools. In terms of cost, stud/girt walls are comparable to hollow CMU unreinforced masonry construction, depending upon the architectural finishes that are selected. In terms of cost, masonry veneer walls have an RCI of 1.4 to 2.2.

(3) Hardening options. Penetration time for stud/girt construction can be significantly increased by using one or more of the following options. Layered sheet steel and wood combinations can double or triple penetration times (see Table 8). The very limited test data indicate that a layer of 3/4-inch (19-mm) plywood sandwiched between two layers of 10-gauge (3.4-mm) hot-rolled steel provides about 5 to 10 minutes of penetration time (see Table 8-A). The penetration time can be increased by about 5 minutes with the addition of another wood/steel layer (Table 8). Presumably, this rule-of-thumb would apply to the addition of more layers until the overall thickness of the wall rendered use of hand and power tools impractical. Better gains in penetration time can be achieved by changing the steel layers to 9-gauge (3.8-mm) American Society for Testing and Materials (ASTM) 607 HS low alloy steel. One layer of 3/4-inch (19-mm) plywood sandwiched between two layers of that steel provides 10 to 15 minutes of penetration time. Adding layers of 90-pound (41-kilogram) gravel finish roofing paper between the plywood and steel further increases the penetration time to about 20 minutes (Table 8). Each layer must be bolted or fastened to the previous layer. Structural adhesives may also be used. It is possible to prefabricate tongue-and-groove panel sections so that individual sheets are off-set (as in Table 8). Adding more wood and steel layers to the sandwich reduces the effectiveness of the optimal mix of attack tools. Increasing the plywood thickness by using a "fire door" design approach would further decrease the effectiveness of an optimal attack. Alternate layers of 3/4-inch (19-mm) plywood and 9-gauge (3.8-mm) ASTM 607 HS low alloy steel, as noted above, also provide significant penetration resistance against optimal attacks. The test program with respect to the above "steel/ply" composites is an ongoing one. The penetration data reported here may be subject to revision as more test results are obtained. Therefore, to take advantage of the most current information about the penetration resistance and cost-effectiveness of these "steel/ply" composites, and to learn what are considered the optimal composites of various materials, layers, and spacings that have been tested, the security engineer should contact:

Naval Civil Engineering Laboratory
Security Engineering Division (Code L56)
Port Hueneme, CA 93043-5003
(AV) 360-4284

3.1.3 Roof/Floor.

3.1.3.1 Reinforced Concrete Roofs and Floors. There are various categories within each option, which are summarized below.

(1) Conventional construction. The five conventional construction categories listed above are discussed below.

(a) Conventional systems that are cast-in-place on structural members.

Slab over open-web steel joists systems range from 2-1/2 inches (63 mm) thick with No. 3 rebar at 7-1/2 inches (190 mm) on center each way up to 6 inches (150 mm) thick with No. 4 rebar at 12 inches (300 mm) on center.

Composite slab/beam systems range from 6 inches (150 mm) thick with No. 5 rebar at 12 inches (300 mm) on center each way up to 12 inches (300 mm) thick with No. 5 rebar at 6 inches (150 mm) on center.

Composite metal deck and slab systems range from 1-1/2-inch (38-mm), 22-gauge (0.8-mm) steel deck with 2-1/2-inch (63-mm) concrete topping [total 4 inches (100 mm)] with 6 x 6 - W 1.4 x W 1.4 wire mesh up to 3-1/2-inch (90-mm), 22-gauge (0.8-mm) steel deck with 4-1/2-inch (115-mm) concrete topping [total 8 inches (200 mm)] with 6 x 6 - W 1.4 x W 1.4 wire mesh.

(b) Conventional systems which are cast-in-place as structural members.

One-way and two-way slab systems range from 6 inches (150 mm) thick with (minimum) No. 4 rebar at 12 inches (300 mm) on center up to 18 inches (450 mm) thick with (maximum) No. 5 rebar at 3 inches (75 mm) on center.

Waffle slab systems penetration resistance should be evaluated on the basis of slab thickness between the reinforcing ribs. The range of normal top slab thickness is between 3 inches (75 mm) and 4-1/2 inches (113 mm) with integral reinforcing ribs 5 to 6 inches (125 to 150 mm) wide spaced 24 or 36 inches (600 or 900 mm) each way. The void spaces between ribs can range between 19 and 30 inches (475 and 750 mm). Total depth of slab plus rib ranges from 11 to 16-1/2 inches (280 to 420 mm) thick. The top slab is reinforced with (minimum) No. 4 rebar at 12 inches (300 mm) on center up to a maximum of No. 7 rebar at 6 inches (150 mm) on center.

(c) Conventional precast prestressed concrete units.

Single tee units range from 3 feet (900 mm) wide by 1-1/2 feet (450 mm) deep up to 10 feet (3,000 mm) wide by 4-1/2 feet (1,400 mm) deep with 6 x 6 - W 1.4 x W 1.4 wire mesh in 2-inch (50-mm) flanges.

Double tee units range from 4 feet (1,200 mm) wide by 1-1/8 feet (350 mm) deep up to 8 feet (2,500 mm) wide by 2-2/3 feet (810 mm) deep with 6 x 6 - W 1.4 W 1.4 wire mesh.

Prestressed deck units range from 8 to 10 inches (100 to 250 mm) thick with tendons at 16 inches (400 mm) on center with 6 x 6 - W 1.4 x W 1.4 wire mesh.

(d) Conventional post-tensioned cast-in-place flat slabs.

One-way slabs range from 4-1/2 inches (113 mm) thick with No. 4 rebar at 36 inches (900 mm) on center and No. 5 at 12 inches (300 mm) on center up to 9 inches (225 mm) thick with No. 4 rebar at 24 inches (600 mm) on center, and No. 6 at 12 inches (300 mm) on center.

Two-way slabs range from 7 inches (175 mm) thick with No. 4 rebar at 36 inches (900 mm) on center up to 10-1/2 inches (265 mm) thick with No. 4 rebar at 24 inches (600 mm) on center and No. 5 rebar at 12 inches (300 mm) on center.

(e) Slabs-on-grade. Slabs-on-grade are used for floors only. The thickness may be as low as 4 inches (100 mm) to as high as 12 inches (300 mm). The corresponding reinforcement may be as low as a single layer of No. 3 rebar at 12 inches (300 mm) on center each way to as high as No. 7 rebar at 6 inches (150 mm) on center each way and on each face, or perhaps wire mesh. Concrete with compressive strengths between 3,000 and 6,000 psi (21 and 42 MPa) are typically used.

(2) Penetration times for conventional construction. Estimated penetration times for both upward and downward attacks on representative major conventional construction types can be estimated using Figure 7 and Table 4 in Subparagraph 3.1.2, and Figure 10 and Table 9. A review of the data in Figures 7 and 10 shows that a wide range of penetration times are possible depending primarily upon the thickness and type of slab, size, and spacing of the reinforcement and the direction of the attack (typical ceiling, roof, and floor covering materials contribute very little to penetration times). The lower bound is less than 2 minutes for very thin, nominally reinforced slabs to greater than 60 minutes for very thick slabs [12 inches (300 mm)] with heavy reinforcements. For a downward attack on roof or floor slabs up to 12 inches (300 mm) thick reinforced with rebar, Figure 7 and Table 4 (see Subparagraph 3.1.2) can be used to estimate penetration times for various thickness and rebar combinations. For an upward attack on floors of various thickness, the conventional concrete family of curves, shown on Figure 10 and cross referenced to Table 9, can be used. For floors, an upward attack is more difficult and requires a different combination of tools than a downward

attack on the same cross section. The result is increased penetration times for the same cross section. The difference is not large--typically only 5 to 10 minutes. For upward attacks on slabs less than 11 inches (275 mm) thick, the primary factor influencing penetration time is the thickness of the slab. Beyond 11 inches (275 mm) the type, size, and spacing of reinforcing also becomes important. This is shown in Figure 7 for slabs up to 12 inches (300 mm) thick reinforced with rebar. For floors, reinforced with mesh rather than rebar (use Curve B in Figures 7 or 8), decreasing the mesh spacing or increasing the quantity or size of wire mesh for slabs reinforced with wire mesh has a small effect on penetration times. In general, reinforced concrete roofs and floors provide higher penetration times than those constructed of wood or metal, at roughly comparable costs.

(3) Hardening options. If additional penetration time is required, consider one or more of the following options:

(a) Reinforced concrete. For roofs, increase the thickness of the slab or rebar size, or number of layers, or decrease rebar spacing using Figure 7 and Table 4 (see Subparagraph 3.1.2). For floors, increase the thickness of the slab or, if greater than 11 inches (275 mm), the rebar size, and decrease spacing (see Figure 10 and Table 9).

(b) Steel-fiber-reinforced concrete. For the same roof or floor thickness, SFR concrete generally provides increased penetration times. For intermediate values for a downward attack on roofs or floors less than 12 inches (300 mm) thick, see Figure 8 and Table 9 in Subparagraph 3.1.2. For an upward attack on floors, see Figure 10 and Table 9. In general, however, the added penetration time for a given slab thickness, when compared to rebar-reinforced concrete, is only 5 to 10 minutes. This should be weighed against the added cost of SFR concrete roofs and floors, which have an RCI of about 25 percent greater than conventional concrete. The amount of steel fiber is about 5 percent by volume weight of the concrete mix design.

(c) Floor slab penetration. For buildings without basements, but with shallow footings and a slab-on-grade floor, the possibility of digging underneath the footing and penetrating upward through the floor should be considered if the threat is overt. Figure 6 provides estimates of digging times. If these times, plus the time for penetrating the slab, are not sufficient to meet requirements, one might consider pouring a reinforced concrete apron around the structure. The intruder will then be forced to attack the apron from above, or tunnel under it. For covert threats, digging times should not be considered, since intruders will use stealth to dig their way to the floor. Therefore, the penetration time through a floor by a covert threat should only be based on the time it takes to penetrate the floor.

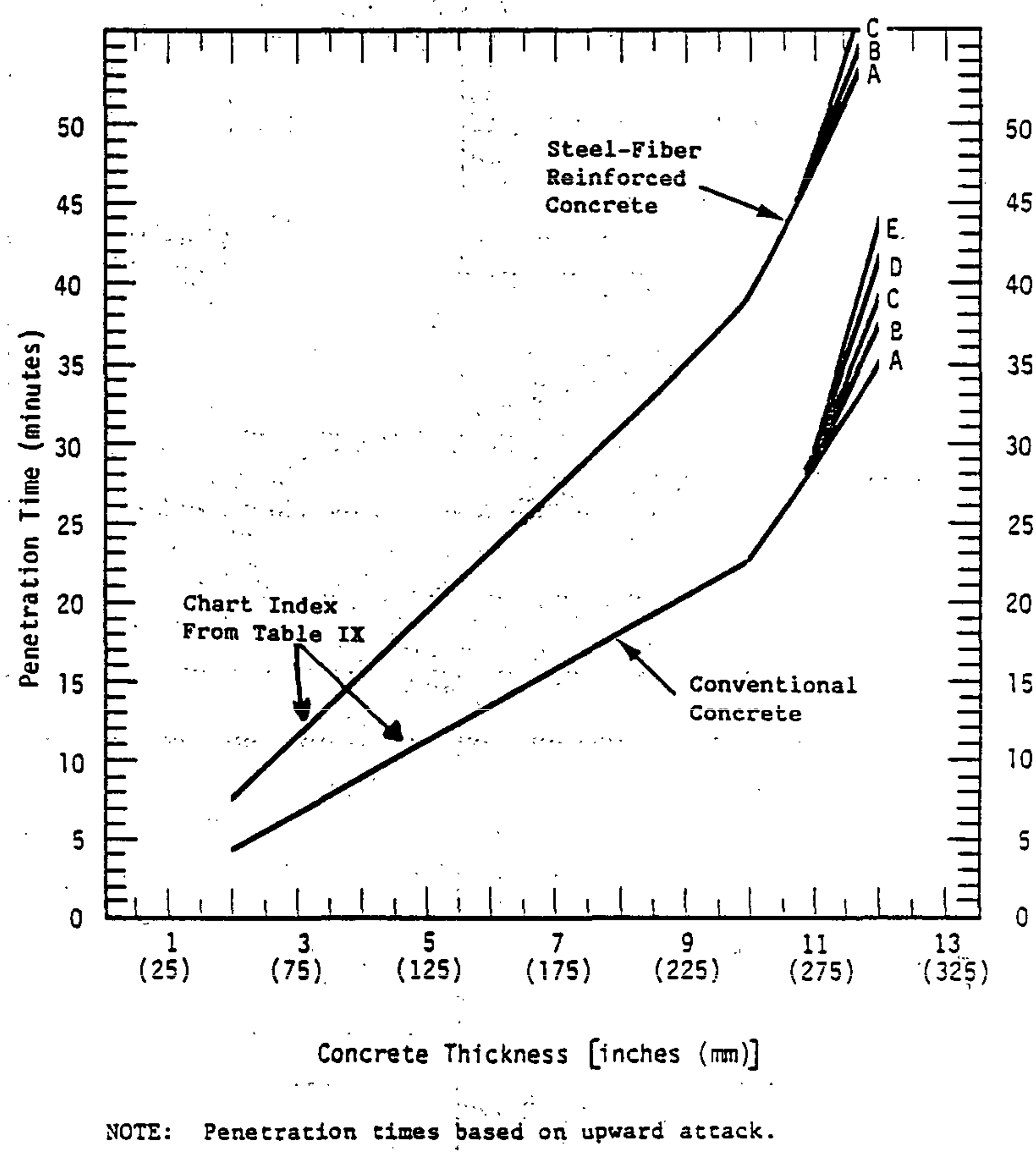


FIGURE 10. Penetration times for reinforced conventional and fibrous concrete floors.

TABLE 9.

Penetration time chart index for Figure 10.

Single layer

Spacing each way (inches) (mm)	Bar Number						
	None	3	4	5	6	7	8
3 (75)	A	B	B	C	C	D	E
3-1/2 (90)	A	B	B	C	C	D	E
4 (100)	A	B	B	B	C	C	D
4-1/2 (115)	A	B	B	B	C	C	D
5 to 9 (125 to 225)	A	B	B	B	B	B	C
>10 (250)	A	A	A	A	A	A	A

Double layer

Spacing each way (inches) (mm)	Bar Number						
	None	3	4	5	6	7	8
3 (75)	A	C	C	D	E	E	E
3-1/2 (90)	A	C	C	D	E	E	E
4 (100)	A	B	C	C	D	E	E
4-1/2 (115)	A	B	C	C	D	E	E
5 to 9 (125 to 225)	A	B	B	B	C	C	D
>10 (250)	A	A	A	A	A	A	A

3.1.3.2 Wood Ceilings/Roofs and Floors. Typical construction for wood roofs and floors includes:

- o Wood or plywood on joists
- o Stressed skin plywood on joists
- o Wood deck on beams

Wood is not normally used for roofs in construction except in housing and minor structures.

(1) Conventional construction. Plywood on joists may include thicknesses from 1/4 to 1-1/8 inches (6 to 28 mm). The plywood is supported on joists ranging from 2 by 4 inches (50 by 100 mm) up to 2 by 14 inches (50 by 350 mm) on 12-, 16-, or 24-inch (300-, 400-, or 600-mm) centers. The stressed skin plywood panels are typically 1/2- to 1-inch (13- to 25-mm) plywood supported on joists of 2 x 4 to 2 x 14 inches on 12-, 16-, or 24-inch (300-, 400-, or 600-mm) centers. The ceiling joists are then covered by 3/8-inch (9-mm) plywood. The wood deck-on-beams option consists of 1-, 1-1/8-, or 1-1/4-inch (25-, 28-, or 32-mm) plywood or 2- by 6-inch (50- by 150-mm) wood decking supported on sawn or glue laminated wood beams on 4- or 8-foot (1,200- or 2,400-mm) centers. Regardless of the degree of security, the choice of wood construction must be in accordance with the fire protection requirements set forth in DOD Military Handbook 1008.

(2) Penetration times for conventional construction. Penetration times for conventional wood floor construction options against optimal combinations of hand and power tools are at less than 2 minutes.

(3) Hardening options. If additional penetration time is required, wood and steel combinations can be useful. As in stud/girt walls in Subparagraph 3.1.2.3, layered wood and sheet steel (see Table 8 in Subparagraph 3.1.2) can significantly increase penetration time against hand and power tools. Limited test data indicate that a layer of 3/4-inch (19-mm) plywood between two layers of 10-gauge (3.4-mm) hot-rolled steel provides about 7 minutes of penetration time (see Table 8). This can be increased by about 5 minutes by adding another wood/steel layer. Additional testing shows that one layer of 3/4-inch (19-mm) plywood sandwiched between two layers of 9-gauge (3.8-mm) ASTM 607 HS low alloy steel, instead of 10-gauge (3.4-mm) hot rolled steel, provides an upper limit of 15 minutes of penetration time (see Table 8). Adding layers of 90-pound gravel finish roofing paper between the plywood and steel further increases the penetration time to about 20 minutes (see Table 8). Adding more wood and steel layers to the sandwich reduces the effectiveness of optimal tool mixes. Increasing the plywood thickness by using a "fire door" design approach would further decrease the effectiveness of a optimal attack. As explained in Subparagraph 3.1.2.3 on wood and steel combinations for wall construction, alternate layers of 3/4-inch (19-mm) plywood and 9-gauge (3.8-mm) ASTM 607 HS low alloy steel provide significant penetration

resistance against optimal attacks. The test program with respect to the above "steel/ply" composites is an ongoing one. The penetration data reported here may be subject to revision as more test results are obtained. Therefore, to take advantage of the most current information about the penetration resistance and cost-effectiveness of these "steel/ply" composites, and to learn what are considered the optimal composites of various materials, layers, and spacings that have been tested, the security engineer should contact:

Naval Civil Engineering Laboratory
Security Engineering Division (Code L56)
Port Hueneme, CA 93043-5003
(AV) 360-4284

3.1.3.3 Metal Roofs and Floors. Typical metal roof construction consists of three types:

- o Steel plate decking
- o Ribbed-steel decking
- o Corrugated metal decking

Typical metal floor construction consists of four types:

- o Steel plate decking
- o Riveted steel grate
- o Welded steel grate
- o Expanded steel grate

These types of construction, penetration times, and RCI values are discussed below.

(1) Conventional construction.

(a) Steel plate decking. Steel plate decking typically ranges from a minimum thickness of 1/4 inch (6 mm) to a maximum of 1 inch (25 mm).

(b) Ribbed-steel decking. This decking consists of long, narrow sections with longitudinal ribs from 1-1/2 to 2 inches (38 to 50 mm) deep, spaced 6 inches (150 mm) center-to-center. Special long-span roof-deck sections may also be used. Common gauges used are No. 22, 20, and 18 (0.8, 0.9, and 1.2 mm), while the deep long-span sections are of heavier gauges, ranging from No. 18 to 12 (1.2 to 2.7 mm).

(c) Corrugated metal decking. This decking is typically made of aluminum, galvanized iron, or protected (rust-inhibited) metal.

Corrugated aluminum may be either corrugated sheets, curved corrugated sheets, V-beam sheets, or concealed clip panels. The corrugated sheets and curved corrugated sheets are typically 0.024 or 0.032 inch (0.6 or 0.8 mm) thick with 2.67-inch (68-mm) corrugations 7/8 inch (22 mm) deep. The V-beam sheet has a 4-7/8-inch (120-mm) pitch with 1-3/4-inch (45-mm) deep corrugations with top and bottom flats of 3/4 inch (19 mm). Thicknesses are 0.032, 0.040, or 0.050 inch (0.8, 1.0, or 1.3 mm). Concealed clip panels are 13.35 inches (340 mm) wide by 3 feet (900 mm) up to 39 feet (12,000 mm) long with thicknesses of 0.032, 0.040, or 0.050 inch (0.8, 1.0, or 1.3 mm).

Protected metal is available in corrugated sheets, mansard sheets, or V-beam sheets. The corrugated sheets have 2.7-inch (69-mm) corrugations 9/16 inch (14 mm) deep. Mansard sheets have 6 beads per sheet. The V-beam sheet has a 5.4-inch (135-mm) pitch with 1-5/8-inch (40-mm) deep corrugations and contains 5 vees per sheet. The thickness of all protected metal sheeting ranges from 18 to 24 gauge (1.2 to 0.6 mm).

(d) Riveted steel grate. Riveted steel grate has a minimum bearing bar size of 3/4 by 1/8 inch (19 by 3 mm) spaced 2-5/16 inches (60 mm) on center and a maximum bearing bar size of 2-1/2 by 3/16 inch (63 by 5 mm) spaced 3/4 inch (19 mm) on center. The spacer bars are riveted about 7 inches (175 mm) on center for average installations or 3-1/2 to 4 inches (90 to 100 mm) for heavy traffic or where wheeled equipment is used.

(e) Welded steel grate. Welded steel grate has minimum and maximum bearing bar sizes of 3/4 by 1/8 inch (19 by 3 mm) and 2-1/2 by 3/16 inch (63 by 5 mm), respectively. The minimum spacing is 15/16 inch (24 mm) on center, and the maximum spacing is 1-3/16 inches (30 mm) on center. Spacer bars are typically welded either 2 or 4 inches (50 or 100 mm) on center.

(f) Expanded steel grate. The expanded steel grate has a minimum diamond size of 1.33 by 5.03 inches (35 by 125 mm) and a maximum diamond size of 1.41 by 5.33 inches (36 by 135 mm).

(2) Penetration times for conventional construction. Penetration times for most conventional metal roof and floor construction are less than 2 minutes when attacked with the optimal combination of hand, power, and thermal tools. In the case of 3/4- to 1-inch (19- to 25-mm) thick steel plates, the penetration time falls into the 2- to 5-minute range.

(3) Hardening options. Layered wood and steel plate combinations can significantly increase penetration times against hand, power, and thermal tool attacks if additional penetration time is required (see Subparagraph 3.1.3.2).

3.1.3.4 Miscellaneous Ceiling and Roof Construction. Miscellaneous construction options for ceilings and roofs include corrugated asbestos cement and corrugated fiberglass. Corrugated asbestos cement sheets have 4.2-inch (106-mm) corrugations with depths of 1/4, 1/2, and 1-1/16 inches (6, 13, and 27 mm), respectively. Thicknesses range from 1/8 to 3/8 inch (3 to 9 mm). No actual test data are available for corrugated asbestos cement or corrugated fiberglass penetration times, but it should be assumed that these materials give less than 2 minutes of penetration time.

3.2 Doors, Windows, and Utility Openings.

3.2.1 Introduction.

3.2.1.1 Overview. Most facilities require doors, windows, and utility openings to provide the internal environmental controls and ready access necessary for their intended use and maintenance. Unless special attention is given to the design of such openings, they can also provide relatively easy access for intruders and, thus, become the weak link in the delay time provided by a facility. Openings are divided into three major categories:

- o Doors
- o Windows
- o Utility openings (e.g. pipe chases, vents, ducts, etc.).

For each category, this handbook:

- o Briefly describes the issues and factors that require special consideration.
- o Summarizes available data on penetration times provided by conventional designs and materials.
- o Describes (and, to the extent possible, quantifies) penetration time enhancements that should be considered by the designer.

As noted earlier, this handbook stresses means of increasing penetration time against well-equipped and determined intruders. However, the user should not lose sight of the fact that many enhancements, which may not significantly increase the penetration time against a determined intruder, can force the use of more sophisticated and heavier tools and equipment and may deter an intruder with less motivation and sophistication.

3.2.1.2 Evaluation of Door, Window, and Utility Opening Design Options. Table 10 summarizes the range of penetration times that can be expected from conventionally constructed as well as attack-hardened doors, windows, and utility openings for which data are available. The table cross-references the

TABLE 10.

Penetration time summary and lookup table for doors, windows, and utility openings.

Construction Type	Conventional		Attack Hardened	
	Penetration Time (minutes)	Figure/Table Cross-Reference Numbers	Penetration Time (minutes)	Figure/Table Cross-Reference Numbers
DOORS	$\leq$2 to 8.70	Figure 11, 12; Tables XI, XII	5 to $\geq$60	Figure 11-12 Tables XIII, XIV
LOCKING DEVICES	$\leq$4	Figure 16; Table XV	$\leq$7*	Figures 13-17: Table XV
WINDOWS	$\leq$2	Tables XVI and XVII	$\leq$2 to 16	Figures 18-20 Tables XVIII-XXII
UTILITY OPENINGS	$\leq$2	Table XXIII	2 to 40	Figures 21-23 Table XXIV

* This penetration time refers to the time interval required for the lock to fail, thus enabling opening of the door and passage of the intruder past the barrier.

figures and tables set forth in Subparagraph 3.1.2, which present design details and penetration times for each specific option that has been analyzed. In general, Table 10 indicates that conventionally constructed doors, windows, and utility openings offer very little attack resistance (typically less than 2 minutes). Attack-hardened single barrier door options for which data are available offer penetration times up to nearly 30 minutes. These door surfaces are constructed of a multilayered wood/steel combination. The facilities engineer should note, however, that these penetration times only apply to door surfaces. They do not apply to locking devices which are integral to any secure door system. There are no locking devices within the current state-of-the-art that provide penetration resistance in excess of 7 minutes. A user, seeking to design a 30-minute door, for example, might consider utilization of multiple locking devices. This approach is discussed in more detail in Subparagraph 3.2.2. Although definitive test data are not available, the use of thick, massive, blast-hardened doors made of reinforced concrete or the use of thick, metallic bank vault-like doors may lead to increased single barrier penetration times estimated to be in excess of 1 hour. Table 10 shows that attack-hardened single barrier window options are available that offer up to approximately 16 minutes of penetration time. These options use steel bar grills. If these grills are used in multiple layer combinations, increased penetration times are possible. Finally, Table 10 shows attack-hardened utility openings with penetration times up to 40 minutes.

3.2.1.3 Selection of Door, Window, and Utility Opening Construction. The remaining subparagraphs present penetration times for the principal types of conventional and attack-resistant doors, windows, and utility openings where test data are available. The penetration times are organized into sets of lookup tables and, where appropriate, figures illustrating the types of construction. The information in the tables and figures will enable the facilities engineer to determine which types of construction yield equivalent penetration times. The penetration times are conservative estimates based on the available measured test data documented in the reports listed in Appendix D. To use the information in this paragraph, the security engineer should follow the two steps outlined below together with Part 9 of the Worksheet described in Subparagraph 2.8.2. In general, doors, windows, and utility openings (e.g., vents, cable trunks, manhole covers, and sewers) should be considered both individually and collectively. The facilities engineer should assess each opening as a separate unit and also as a system of openings, which may be interconnected, for example, by conduits. The facilities engineer should also assume that any skilled, motivated, potential attacker wanting to gain entry may have access to drawings showing the easiest route.

Step 1--Identify doors, windows, and utility openings. Doors, windows, and utility openings (including conduits) into the secured area should be identified and located on a layout plan.

Step 2--Evaluate single barrier door, window, and utility openings options. Review Table 10 to determine which (if any) single barrier construction option meets the delay time requirement. Evaluate the relative cost-effectiveness of each option using Part 9 of the Worksheet. Consideration should also be given to the following:

o It is normally wasteful to design a door, window, or opening for a penetration time greater than that of the wall, roof, or floor.

o Regardless of the degree of security, the securing of doors used as emergency exits must be approved by the fire protection engineer in accordance with NAVFACINST 11012.142, MIL-HDBK-1008, and U.S. Marine Corps MCO P11000.11A.

Step 3--Consider multiple door, window, and utility opening barriers. If Step 2 is unworkable for any opening, consider a design approach where multiple door, window, and utility opening barriers are placed between the exterior shell of the building and an interior space containing the secured resources (see Figure 3 in Paragraph 2.7). The barriers are selected such that the sum of the penetration and ingress times for all barriers meets the required delay time. Examine the cost-effectiveness of these multiple barriers.

3.2.2 Doors

3.2.2.1 General. Doors, because of their functional requirements, construction, and methods of attachment, are normally less attack-resistant than adjacent walls, and frequently provide a "soft spot" in an otherwise attack-resistant structure. Recent studies have confirmed that Government-mandated requirements for secure structures are not uniform from one standard to another and that the mandated door systems do not provide equal penetration resistance compared to the resistance of the wall surrounding the door. In addition, a variety of new and sophisticated attack methods and equipment have rendered present security structures highly vulnerable to forced entry and make existing standards and requirements obsolete. For this reason, the number of doors to a facility should be reduced to an absolute minimum and, in cases where more than one door exists, only one of these should be provided with outside-mounted locks and entry hardware. All others should, as far as practicable, present blank, flush surfaces to the outside to reduce their vulnerability to attack. Exposed locking devices on the exterior (attack side) of the door should be used only on low- (1-minute resistance) or medium- (4-minute resistance) security applications. No matter how secure a door is made, placing the locking device on the exterior of the door cannot provide the level of security required for high-security (16-minute resistance) applications. Doors, as used in this handbook, are divided into four categories: personnel, vehicle, magazine, and vault doors. Although the penetration time through the door surface can usually be increased by use of heavier or composite materials, such hardening may not provide a complete security solution because of weight constraints, conflicts with functional requirements, mounting hardware limitations, or lock vulnerability. There is no point in hardening a door surface beyond the attack resistance of the mounting hardware and locking device technology available. According to available data, with the exception of certain vault doors, no currently used standard or commercial door or door hardware will provide significant penetration time against a determined intruder. The following paragraphs discuss the estimated penetration times for conventional doors summarized in Table 11. Recent tests have also confirmed that certain personnel door designs are suitable for medium- and low-security applications. The penetration times of these doors are listed in Table 12.

3.2.2.2 Conventional Door Penetration Times. Potential attack areas on doors include the door face (surface), hinge, and locking device.

(1) Personnel doors. Exterior personnel doors are commonly 1-3/4 inches (45 mm) thick and typically faced with 16- or 18-gauge (1.5- or 1.2-mm) steel. Although some doors remain hollow, others are commonly filled with a noncombustible foam or slab of polyurethane. Locking devices for personnel doors vary; however, they are typically a five- or six-pin tumbler type. Hinges are of mortised design with nonremovable pins. It should be noted that such features are only furnished when specified (as an extra cost option). Estimated penetration times for standard personnel doors are uniformly low as shown in Table 11. It should be noted that the use of a standard flush hollow-metal (steel) personnel door, vehicle door, or steel plate magazine or vault door is a weak link that can seriously degrade the penetration time of an otherwise substantially hardened facility. Penetration times in most cases will not exceed one minute against a reasonably competent and well-equipped intruder attacking a door with hand-held, power, or thermal tools. The insulated steel plate magazine door offers a slightly higher penetration of up to 2 minutes, as shown in Table 11. All the doors described in Table 12 and shown in Figure 11 are of conventional design but some differ from the hollow-steel doors in general defense facility use that are described in Table 11. These doors are made of heavier gauge metal and have additional reinforcement. Probable application of these doors would be pedestrian access to or egress from any type of secure/sensitive space. In evaluating the penetration times of door surfaces, the facilities engineer should consider doors required to have panic bar hardware as special cases. These doors do not require a man-passable opening to be defeated. The drilling of a small aperture to pass a wire hook through is all that is required to open them. As noted above, the tradeoffs between life safety and security may impact directly upon interior layouts to avoid a design that must be compromised to meet fire protection requirements.

Low-security personnel door panels that provide a penetration resistance of greater than or equal to 1 minute are listed in Table 12. However, cost-effective commercial lock/latch systems that match the low-security rating of the door may not presently be available. The currently specified lock/latch systems do not meet low-security requirements.

TABLE 11.

Doors, conventional construction.

Door Construction	Penetration Time (minutes)
Standard Flush Hollow-Metal (Steel) Swing Door	
16-gauge (1.5-mm) metal face panels, rim applied panic hardware, outside cylinder operation, rim set, butt hinges with removable pins	<1
16-gauge (1.5mm) face panels, narrow glass one side, louvers near bottom	<1
18-gauge (1.2-mm) face panels, hall glass expanded metal 0.11-in. (3-mm) grill	<1
Sheet Metal Vehicle Door	
Hollow steel panel, 16-gauge (1.5-mm)	<1
Roll-up steel, corrugated 16-gauge (1.5-mm)	<1
Sheet Plate Magazine Door	
1/4-in. (6-mm) steel plate, one padlock	<1
Steel Plate-Void-Steel Plate Magazine Door	
Two large hinged hasps for padlocking, 3/4-in. (19-mm) steel, 4-in. (100-mm) air space, 1/2-in. (13-mm) steel	<1
3/8-in. (9-mm) steel, 3-in. (75-mm) air space, 0.036-in. (0.9-mm) steel, two padlocks on door	<1
3/8-in. (9-mm) steel, 3-in. (75-mm) void, 1/4-in. (6-mm) steel plate, two locks	<1
Steel Plate-Insulation-Steel Plate Magazine Door	
3/4-in. (19-mm) steel plate, 3-in. (75-mm) fiberglass, 1/8-in. (3-mm) steel plate	<2
Security Vault Door, GSA Approved, Class 5	
Class 5 Vault	<1

TABLE 12.
Doors, low- and medium-security construction.

Door Construction	Security Level	Penetration Time (minutes)
Sound grade, plain sliced birch, 5/12 inch (12 mm) thick. Outside, 12-gauge (2.7 mm) steel protection plate, ASTM Grade A36 steel through-bolted to door.	Low	3.50
Tempered, S25, 1/8-inch-thick (3 mm) hardboard. Inside, 12-gauge (2.7 mm) steel protection plate, ASTM Grade A36 steel.*	Low	4.50
Tempered, S25, 1/8-inch-thick (3 mm) hardboard. Ouside, 12-gauge (2.7 mm) steel protection plate, ASTM Grade A36 steel.	Low	3.50
16-gauge (1.5 mm) steel with a rigid core of polystyrene foam slab bonded to face panels by a thermosetting adhesive.	Low	2.70
16-gauge (1.5 mm) steel with added 14-gauge (1.9 mm) steel exterior cover plate with a rigid core of polystyrene foam slab bonded to face panels by a thermosetting adhesive.*	Medium	4.00
12-gauge (2.7 mm) steel with face panels supported by 14-gauge (1.9 mm) steel vertical formed sections, spanning the full thickness of the interior space between door face panels.*	Medium	8.70

*Nonmandated door

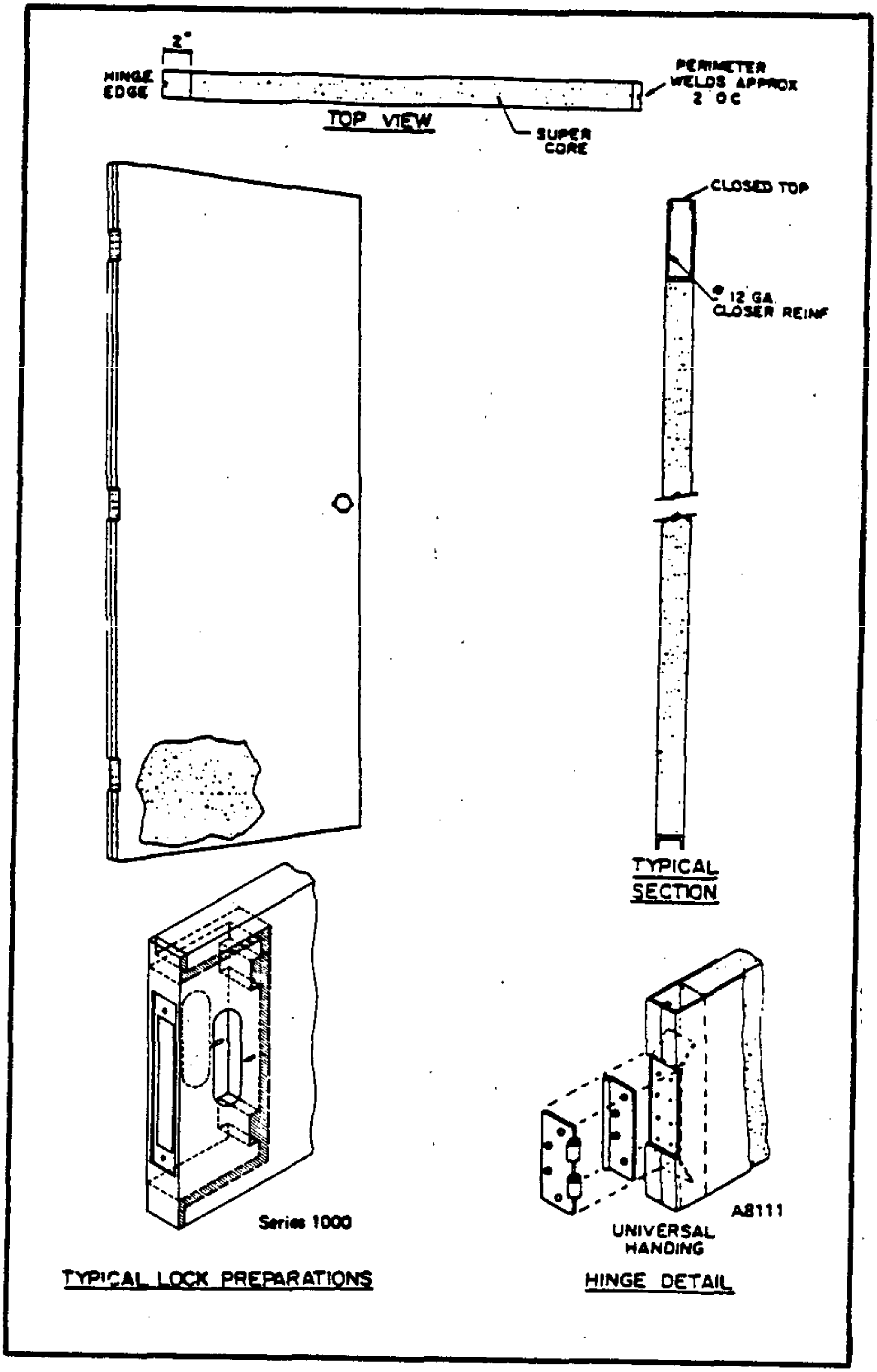


FIGURE 11. Typical hollow metal personnel door.

Medium-security personnel door panels that provide a penetration resistance of greater than or equal to 4 minutes are listed in Table 12. However, cost-effective commercial lock/latch systems that match the medium-security rating of the door may not presently be available. The currently specified lock/latch systems do not meet medium-security requirements. In addition, low- or moderate-cost materials suitable for core materials in heavy gauge commercial, flush, or hollow-steel personnel doors for use in medium-security facilities are currently being investigated. Examples of candidate materials are various types of wood, high-strength plastic and composite materials, and ceramic refactory materials. These materials should exhibit good resistance to both thermal/heat cutting tools and power-operated, abrasive saw-type tools.

For high-security facilities having mandated wall systems that provide penetration resistance equal to or greater than 16 minutes, only a specially designed composite door system can match the wall requirements.

(2) Vehicle doors. Corrugated roll-up and hollow-steel panel doors are commonly used in military buildings. The heights, widths, and thicknesses of these doors vary according to application and specific need. As with personnel doors, these standard doors are likely to provide less penetration time than the surrounding wall construction. Estimated penetration times will not exceed 2 minutes.

(3) Magazine doors. Magazine door designs for AA&E facilities vary in size, shape, and function. Door thickness may range from 1/4-inch-thick (6-mm-thick) sheet steel to an 11-1/2-inch (288-mm) double wall design, depending on the nature of the storage and the site. Magazine designs have evolved from World War II munitions storage depot structures, where explosive safety rather than physical security was the major design objective. In the years since WWII, upgrading has consisted mainly of improved locks and welded hinge pins and, occasionally, some door reinforcements. Estimated penetration times for a successful attack against a typical magazine door lock and mounting hardware may be as short as 1/2 minute. To ensure balanced hardness in door upgrade, attention must be given not only to door cross-sectional construction but also to the hinges, locks, and locking systems.

(4) Vault doors. Vaults are defined as secure spaces used for the storage of classified information or other valuable resources. Currently, there are criteria and standards that form a basis for uniform construction of security vaults within the Department of Defense. Class A and B vaults require a Class 5 vault door. Class C vaults require a Class 6 vault door. However, Class 6 vault doors are no longer available and Class 5 vault doors should be utilized on Class C vaults. Class 5 vault doors are available on the Federal Supply Schedule. The door requirements are specified in Federal Specification AA-D-600, and copies may be obtained from any regional office of the General Services Administration (GSA), or the Naval Publications and Forms Center. In addition to Class A and B vaults, the Class 5 vault door is

authorized for installation in AA&E storage facilities. A typical GSA Class 5 vault door is illustrated in Figure 12. The estimated penetration time for a Class 5 vault door is less than 1 minute against optimal attack tools, as shown in Table 11. Therefore, a facilities engineer, seeking to install a door on a Class A, B, or C vault with a door surface penetration resistance greater than 1 minute, should consider the hardening options indicated in Table 13. If this "customized" approach to door design is followed, the facilities engineer should be careful to ensure a balanced design ensuring commensurable penetration resistance among all the principal elements of a door, including not only the door surface but also the locking device and mounting hardware.

3.2.2.3 Hardening Options. The preceding paragraphs clearly illustrate the need for increased penetration resistance of doors. This subsection presents ideas for improving penetration times for both new construction and retrofit programs. General hardening suggestions are identified that may deter a casual intruder but are not based on specific barrier tests. Penetration times for hardening options are identified and estimated that have either been tested or derived from test results.

General hardening concepts described in Table 14 are the minimal designs that should be considered in constructing a door with enhanced attack resistance. They apply to both new designs and to later upgraded or retrofits. Specific hardening options include the hardening of door face panels and internal construction, door frames, anchoring devices, locking devices, and operating hardware.

(1) Door design/construction. Tests have confirmed that the two types of threats most effective against conventional design hollow-metal (steel) doors are : the power-operated portable circular saw ("Target Quickie") using abrasive blades, and thermal tools such as the oxy-acetylene torch and thermal lance (burn bar) that cut or burn through the door. Either of these methods creates a man-passable opening or allows separation of vital components to allow the door to be opened. None of the conventional doors tested could resist attacks using these two types of attack tools for any appreciable length of time. A prototype personnel door is currently being designed using selected materials shown to have high resistance to both abrasive-cutting and thermal-burning tools. Steel, by itself, does not provide any meaningful delay times or penetration resistance in a door system or assembly. Typical times to make a man-passable opening with an oxy-fuel torch are 2 minutes 1 second for 1/2-inch-thick (13-mm) steel, 3 minutes 5 seconds for 1-inch-thick (25-mm) steel, and 3 minutes 47 seconds for 1-1/2-inch-thick (32-mm) steel.

Factors that increase the penetration resistance of door systems and assemblies include the use of:

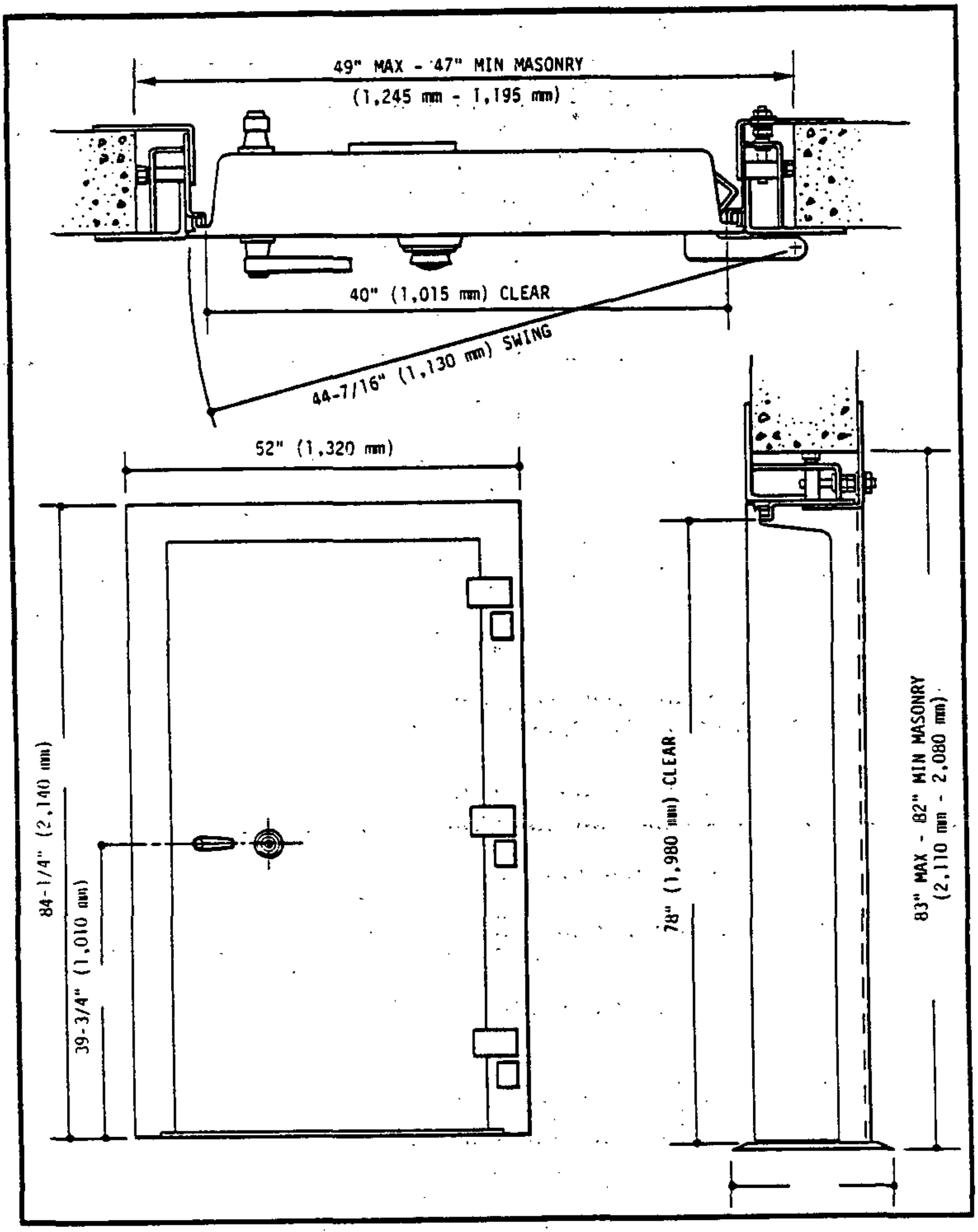


FIGURE 12. Representative GSA Class 5 vault door.

TABLE 13.

General hardening considerations for doors.

DOOR TYPE	VULNERABLE AREA	TECHNIQUE
Large horizontal sliding	Operating system	Protection of electrical system and manual override
	Hanger/Roller assembly	Protect from reversal of installation
	Door bottom	Secure firmly to prevent prying
Roll-up	Entirety	Add other barriers (i.e., grill wire) or horizontal sliding doors
Hinged door	Hinge	Should not be removable from door or frame
	Cane Bolt	Should be at least 1 in. (25-mm) in diameter
	Hinge side of door	Equip with interlocking mechanism to prevent opening if hinges removed
Solid wood, laminated wood, substantial hollow metal	Surface	Clad attack side of door with heavy gauge metal or steel plate 12-gauge (2.7-mm) or greater (prefer 0.15 in. (4-mm))
		Wrap metal around sides to prevent peeling
General	Frames	Steel armor strips or grouting to prevent bullet penetration
		Fabricate from steel one gauge heavier than the door
	Frame jamb and head	Grouting or other reinforcement to prevent jamb from being spread
	Hinge pin	Weld in place
	Lock	Use high-security locks currently available ion the open market Table XIV
		Use multipoint locking (i.e., more than one lock
		Avoid exposing lock hardware
		Flush mount lock to avoid access to external hardware
	Padlock	Replace padlocks with recessed high-security cylinder locks

TABLE 14.

Door surface, hardening options.

Door Construction	Penetration Time (minutes)
Steel Plywood	
2 layers 10-gauge (3.4-mm) hot-rolled steel/1 layer 3/4-in. (19-mm) exterior plywood	6
3 layers 10-gauge (3.4-mm) hot-rolled steel/2 layers 3/4-in. (19-mm) exterior plywood	12
2 layers 9-gauge (3.8-mm) ASTM 607 HS low alloy steel/1 layer 3/4-in. (19-mm) exterior plywood	14
2 layers 9-gauge (3.8-mm) ASTM 60/ HS low alloy steel/1 layer 3/4 in. (19-mm) exterior plywood/ 2 layers of 90-lb (41-kg) gravel finish roof paper	20
9 layers 3/4-in. (19-mm) plywood/8 layers 10-gauge (3.4-mm) steel plate	27
Steel Redwood	
3 layers: 3/8-in. (9-mm) steel, 3-in. (75-mm) redwood, 0.036-in. (0.9-mm) steel	6
Steel Polycarbonate	
3 layers (0.88-in. (22-mm) thick): 1/4-in (6-mm) type 304 stainless steel plate, 1/2-in. (13-mm) polycarbonate, 10-gauge (3.4-mm) ASTM 607 steel sheet	11
5 layers (1.4-in. (35-mm) thick): 3 sheets of 10-gauge (3.4-mm) ASTM 607 steel, 2 sheets of 1/2-in. (13-mm) plexiglass	20
5 layers: 3 sheets of 10-gauge (3.4-mm) ASTM 607 steel, 2 sheets of 1/2-in. (13-mm) lexan	20
Reinforced Concrete	
Blast hardened type doors	up to 60 or more

o Hard materials that resist boring, drilling, sawing, cutting, shearing, and perforating types of attacks.

o High-tensile strength materials that resist bending, breaking, buckling, deforming, separating, or spreading types of attacks.

o High-density materials to provide mass that resists or absorbs large amounts of force, energy, or pressure like that generated by heavy impacts or explosives.

o High melting point materials to resist attacks by thermal tools.

o Materials that interfere with the effective operation of attack tools (such as a soft, sticky material to "gum up" abrasive wheels or saws).

o Materials that generate excessive amounts of flames, heat, or obnoxious smoke or fumes when attacked by thermal tools.

o Door designed with a maximum overall thickness to require the opening on the attack side of the door to be larger than the final man-passable opening made through the protected side of the door.

A door panel using a combination of materials with various thicknesses, each having some specific properties, is needed. Such a composite or laminated door that combines all or most of the properties required will be more penetration resistant and cost-effective than will a door system built using large amounts of only one material. A variety of materials would result in a composite door that would greatly increase penetration resistance by requiring the attack force to have a variety of attack tools available, to face increased logistic problems, to contend with increased environmental disturbance, to cause delays in the attack by frequent tool changes, and to contend with obnoxious smoke or fumes that interfere with the operators of thermal/heat tools.

The composite door is made of 16-gauge (1.5-mm) steel with an internal construction of propitiatory rare earth metals, alloy steel, plastic polycarbonate, and red oak. Such a composite or laminated door will be more penetration resistant and cost-effective than building the door system using large amounts of only one material. This door design will be representative of a class of construction that may be increased or decreased in thickness (amount of core material) to provide a varied range in levels of security and may be utilized in the construction of most all operating types of personnel doors such as swing, sliding, tilt-up, sectional-overhead, bifolding, etc.

(2) Door surfaces. Table 13 provides design and single barrier penetration time information for attack-hardened doors using sandwich combinations of materials that consist of steel and plywood, steel and redwood, and steel and polycarbonate. (The steel/polycarbonate composites can also be used to retro-

fit existing doors.) Depending upon the combination of materials, penetration times of approximately 27 minutes are possible, as shown in Table 13. Other combinations of door materials, including standard steel outer layers with an inner layer composed of cyclone fencing fabric, welded link chain, lightweight conventional concrete or fibrous concrete, barbed tape inserts, metal grating inserts, rubber, etc., are possible. Complete penetration time information on these possibilities is unavailable, and is not included in the handbook at present. Moreover, if it is consistent with the functional requirements of the facility, other options that might be considered (for a smaller, limited volume secured area) are the use of turnstiles, where practicable, e.g., a post with steel arms pivoted on the top, set in a passageway so that persons can pass through on foot one by one; thick, massive, blast-hardened doors made out of reinforced concrete; or the use of thick, metallic, bank vault-like doors. The turnstile approach necessitates cutting enough of the steel arms in the secure mode to offer some delay to intruders. These doors also have yet to be evaluated as barriers and their penetration times have yet to be established. In the case of reinforced concrete doors, the information on reinforced concrete walls in Subparagraph 3.1.2.1 may be of use.

(3) Locking systems. Locking systems can be broadly divided into either externally surface-mounted or internally surface-mounted systems. External systems typically involve some type of lock with an external hasp that is exposed to a potential attack from the outside. Internal locking systems are preferred, particularly for high-security applications. Unfortunately, applicable designs for internal locking systems are under development and recently completed penetration data are not yet available. The best presently available systems recommended in subsequent paragraphs, therefore, emphasize external systems. The types of approved locks and hasps are listed in Table 15. In general, the types of approved locking systems used by the U.S. Government can be divided into low-, medium-, and high-security categories. For attacks involving optimal combinations of tools, one can expect penetration times by forced entry attacks ranging from less than 7 minutes for high-security systems to practically no time for the low-security systems. For less than optimal attacks, penetration times as high as 15 minutes may be possible for the high-security systems. In general, it should be noted that a lock and hasp system offers its maximal potential penetration resistance only when it is properly installed on a strong door with appropriate hardware. The weakest part of the door system is the locking cylinder component of the lock or locking device. Typical delay times or penetration resistance is less than 10 seconds for standard architectural hardware grade locks. The next weakest part of the door system is the lock or locking device, and, on outswing doors, the exposed hinges. Typical delay times or penetration resistance ranges from 9 seconds to 3 minutes. Because it is easier and faster to compromise or defeat the locking cylinder, priority in designing secure door systems must be given to the protection of the locking cylinder. Locking systems under each of the above three security categories are described separately. The installation of multiple locking devices at several points on a door is one method of increasing the penetration resistance of locking devices so that

their combined times are equivalent to the penetration resistance of the door surface. Some commercially available locking systems have multiple dead bolts, locking at a number of points between the periphery of the door panel and the door frame (hinge, top, and lock jambs) or a sliding bar that extends in the locked position to interlock the door panel and the jambs together. A hollow-metal personnel door made of heavy steel, 10 (3.4 mm) to 12 (2.7 mm) gauge, with one of these locking systems provides a penetration resistance equal to or greater than the resistance of the mandated wall systems (greater than 4 minutes) for medium-security facilities when coupled with outswing hinge protection. However, a well-anchored and fully grouted hollow-metal door frame of gauge steel equal to or heavier than the door panels is also required. In general, state-of-the-art developments in locking systems are changing so rapidly that the security engineer should contact qualified RDT&E personnel at the Naval Civil Engineering Laboratory that conducts ongoing RDT&E on high-security locking systems. For information relating to hardening of locking systems, including external locking devices, interior locking devices integral to door systems, and hasps, the security engineer should contact:

Naval Civil Engineering Laboratory
Security Engineering Division (Code L56)
Port Hueneme, CA 93043-5003
(AV) 360-4284

High-security locks and hasps meeting the high-security level requirements are used where the greatest degree of protection is required against forced and surreptitious entry. A high-security level is required, for example, for missiles, conventional arms, ammunition, explosives, and other related spaces. The following describes the various types of high-security locks and hasps.

(a) Shrouded shackle padlock, key operated, high security. Currently, there is only one padlock authorized to be procured under MIL-P-43607 (Figure 13). This padlock is called the shrouded shackle padlock because of its design. The body of the padlock is extended high enough to provide a complete protective cover (shroud) around the shackle, which prevents easy access for attacks directly against the shackle. This padlock is equipped with a 1/2-inch (13-mm) shackle and is keyed individually. When used with a high-security hasp, the high-security padlock provides a high degree of resistance to surreptitious entry and offers the most resistance to forced entry currently available. It should be noted that a high-security padlock provides the specified degree of security when it is used with a high-security hasp. Investment in an expensive high-security padlock is overcome if it is attached to an inexpensive low-security hasp.

TABLE 15.

Summary of locks and hasps.

TYPE OF UNIT/ SECURITY LEVEL	MILITARY/ FEDERAL SPECIFICATION	LOCK/HASP DESCRIPTION	FORCED ENTRY PENETRATION TIME (MINUTES)	SURREPTITOUS ENTRY- PICKING TIME (MINUTES)
HIGH SECURITY				
Key Padlock	MIL-P-43607	Shrouded Shackle Padlock, Key Operated High Security		15
Key Locking Device	MIL-L-29151	Locks and Lock Sets, Exterior, High Security	<7	15
Mounted Combination Lock	MIL-L-15596	Locks, Combination (Safe and Safe Locker)		15
Hasp	MIL-H-29181	Hasp, High Security, Shrouded for High and Medium Security Padlocks		NA
MEDIUM SECURITY				
Key Padlock	MIL-P-43951	Padlock and Padlock Sets, Key Operated, Medium Security, Regular Shackle	<4	15
LOW SECURITY				
Key Padlock	MIL-P-17802	Padlocks and Padlock Sets, Low Security, Key Operated Regular (Open) Shackle	<1	0.67-1

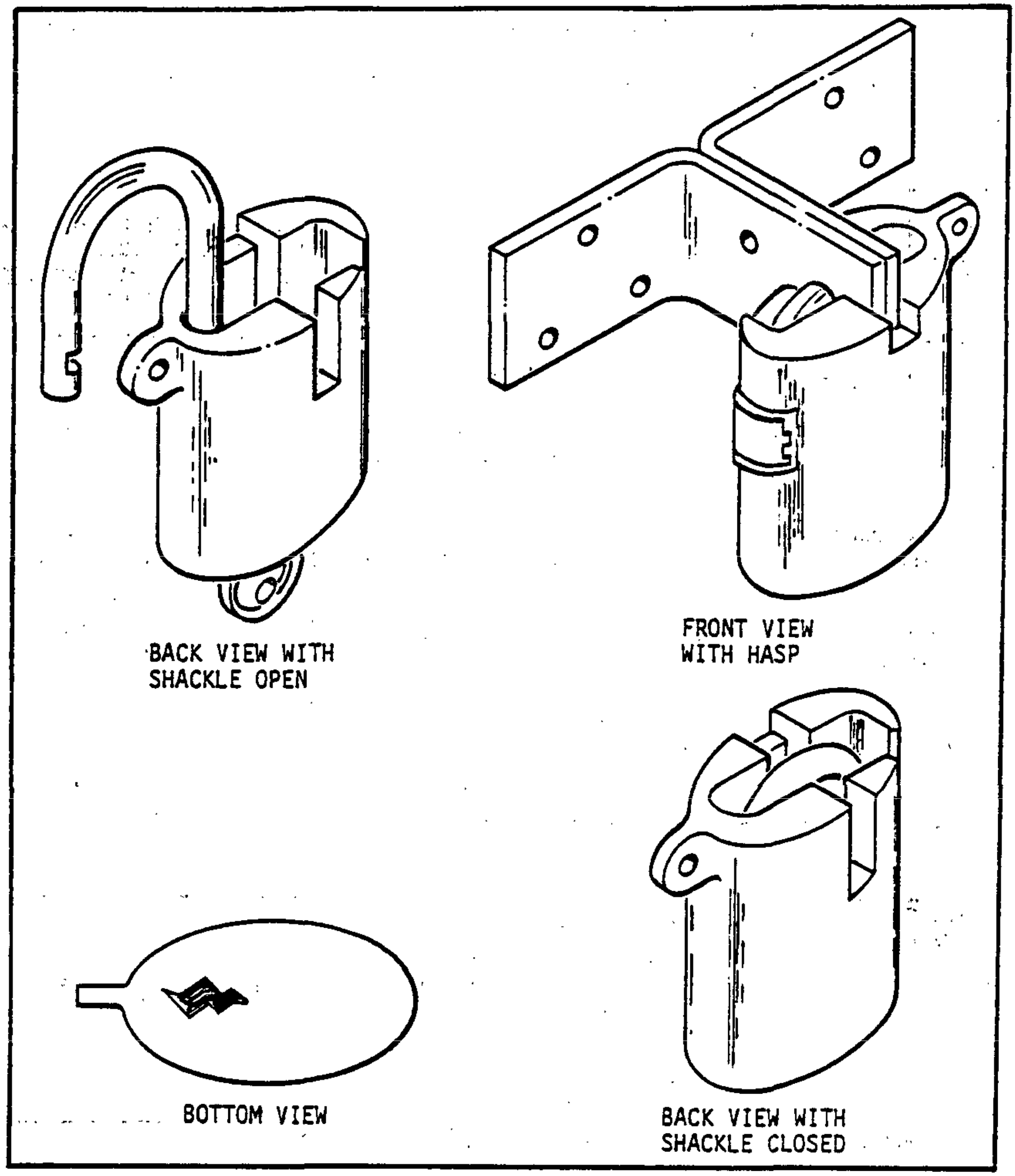


FIGURE 13. **Shrouded shackle padlock, key operated, high security MIL-P-43607 (typical).**

(b) Lock and lock sets, exterior, high security. The high-security locking device, meeting MIL-L-29151, a precision cast, stainless steel lock, is a unique, self-contained, low-profile locking device that provides a high level of security (Figure 14). Its design allows it to be used for outward, double-swinging, sliding, and roll-up doors. This locking device incorporates a durable interlocking cast construction with an integral hasp and a central bolt assembly. The two interlocking wings are mounted directly to the closure, either welded or bolted, and are free of annoying hasps, chains, or other loose parts. This design ensures that the lock cannot be removed for unauthorized use. This unit is keyed individually, and the key retaining function results in a locked open or closed position when the key is removed. The concept allows versatile mounting and is suitable for most security applications.

(c) High-security, shrouded hasp for high and medium padlocks. The hasp approved for high-security applications meeting MIL-H-29181 is the high-security shrouded hasp system. When secured with an approved high-security padlock, this hasp protects the padlock shackle from attack. This system is illustrated in Figure 15.

(d) Locks, combination (safe and safe locker). The mounted combination locking unit, which includes the Group 1R combination lock that meets MIL-L-15596, is specially designed for use on wood and metal doors on secure spaces such as communications and intelligence spaces (Figure 16). It is a reversible, interior surface-mounted lock recommended for use on doors in high-security areas. In essence, it is two locks in one, a deadbolt and a combination lock. The deadbolt section features hardened steel pins and an interlocking strike and frame to prevent jimmying or spreading of the door frame. It has an inside release knob for convenient exiting and an automatic deadlocking trigger. This trigger enables it to be locked while the door is open, but activates the bolt when the door is closed.

Padlocks meeting medium-security requirements must provide protection against forced and surreptitious attacks. Medium-security padlocks may be used in some instances on conventional AA&E spaces when used with high-security hasps, as discussed below. In general, these locks provide a high degree of resistance to surreptitious entry (15 minutes) but only minimal resistance (4 minutes) to forced entry. They are expensive and, therefore, should be used only when prevention of surreptitious entry is essential. There are only two medium-security padlocks currently qualifying under MIL-P-43951 that are in use. They differ in the diameters of their shackles and in the way each model is keyed.

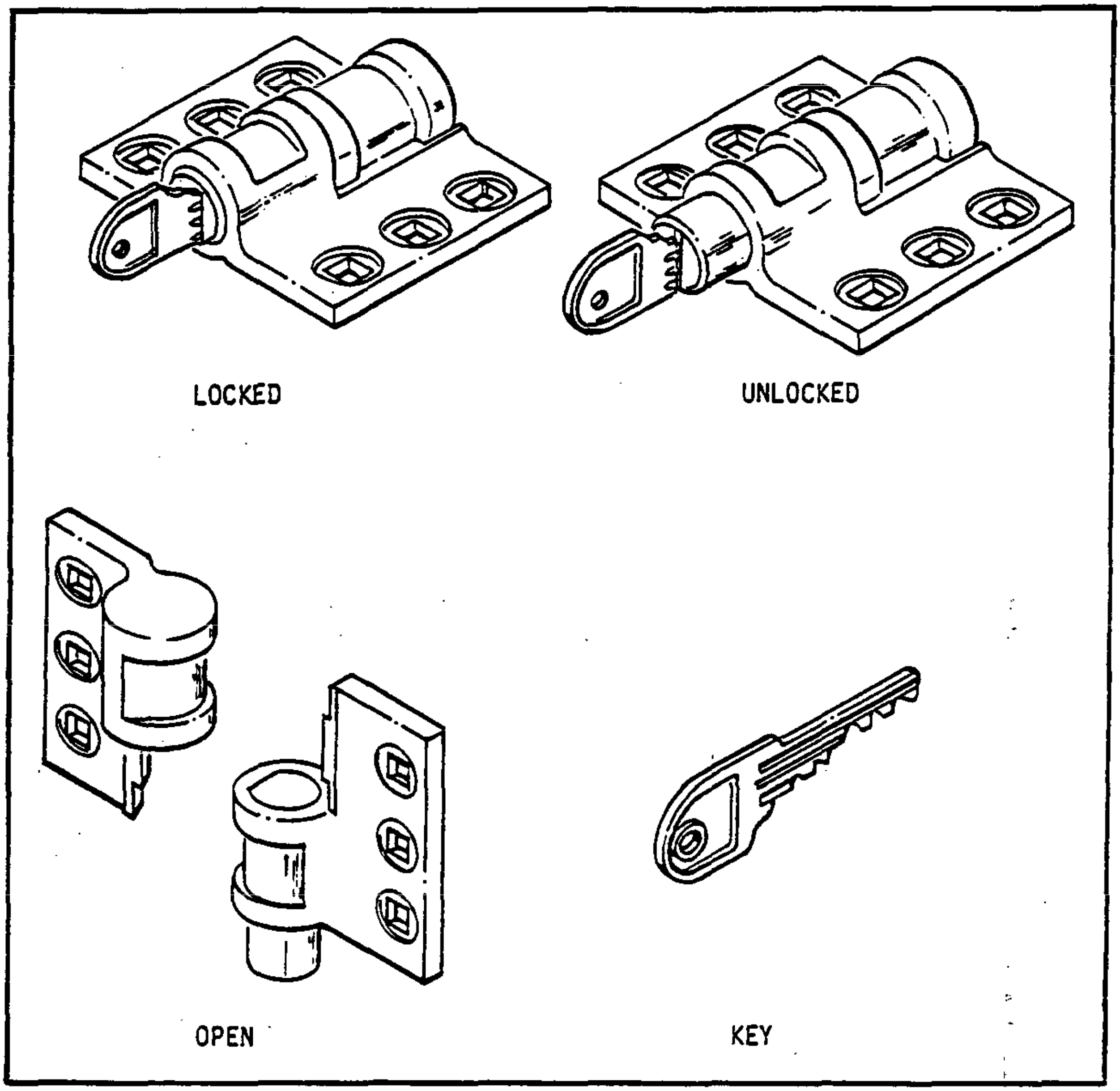
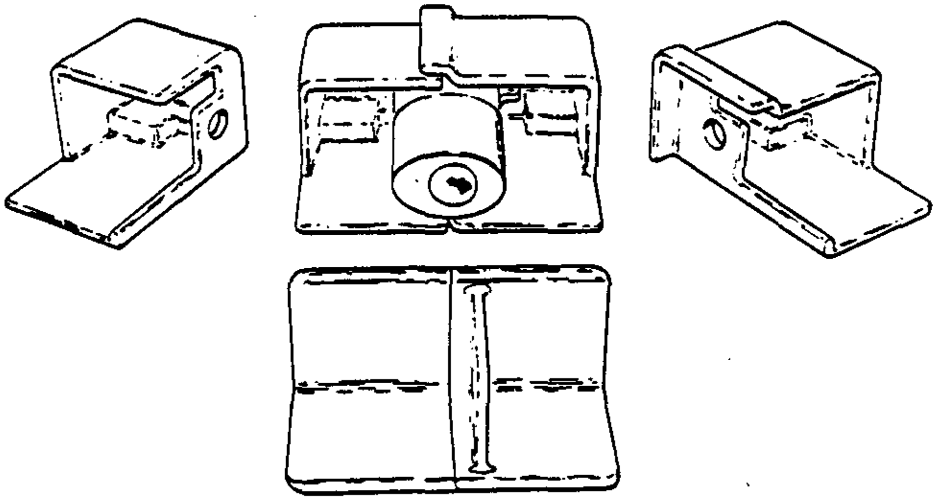
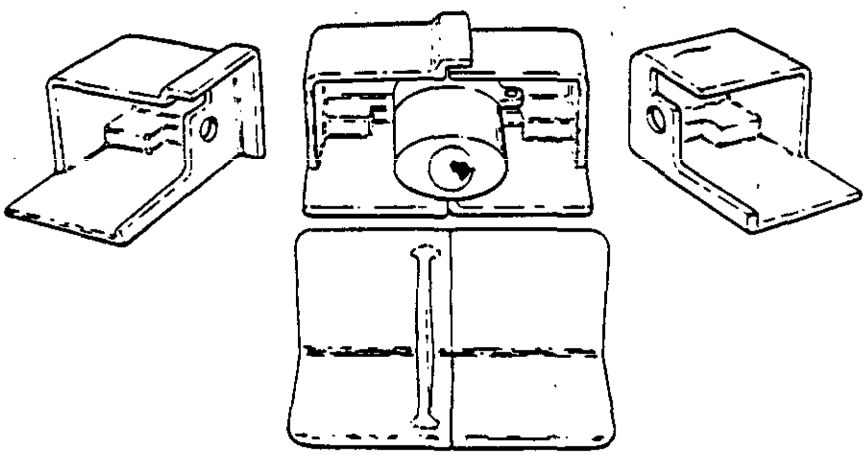


FIGURE 14. Lock and lock sets, exterior, high security MIL-L-29151 (typical).



A) NAPEC 0958: DOOR SLIDES TO RIGHT. CAN ALSO BE USED FOR OUTWARD-OPENING, RIGHT-HAND HINGED DOORS.



B) NAPEC 0957: DOOR SLIDES TO LEFT. CAN ALSO BE USED FOR OUTWARD-OPENING, LEFT-HAND HINGED DOORS.

NOTE: THE BOTTOM ATTACK SHIELD IS IN TWO PIECES SO THAT IT WILL NOT PROJECT INTO THE DOOR OPENING.

FIGURE 15. Hasp, high security, shrouded, for high- and medium-security padlocks MIL-H-29181.

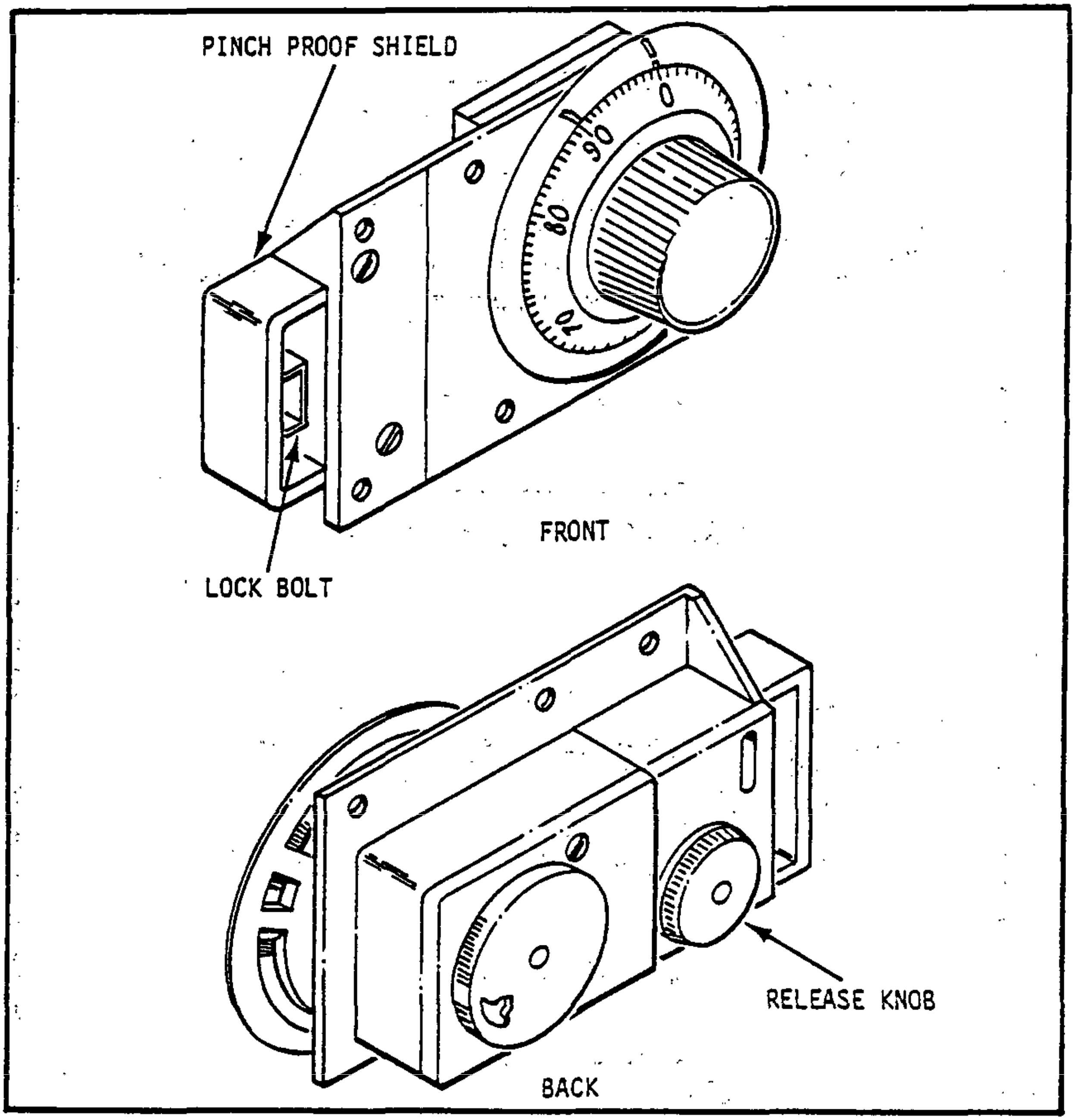


FIGURE 16. **Locks, combination (safe and safe locker) MIL-L-15596.**

Low-security locks and hasps satisfy most access control requirements for offices and other noncritical spaces where hasps and padlocks can be used. Control of access offers protection for records, office equipment, supplies, and personal items and limits accountability to personnel designated for staffing and maintaining these spaces. These locking systems should only be used when their intended purpose is to deter unauthorized entry. They provide no resistance to forced entry and only minimal resistance to surreptitious entry.

(4) Hinges and door/frame interface hardening options. A number of concepts for use on personnel-type doors involving positive interlocking hardware for coupling the hinge sides of the doors to the door frames are illustrated in Figure 17. Hinge side protection options specifically related to AA&E magazine facilities are discussed in Section 5. In the case of installation of hardened doors, the facilities engineer should consider the strength of the door jamb as a part of a secure door system. Hardening the upright surfaces into which the door is fitted (e.g., installing steel uprights) will prevent jamb attacks.

3.2.3 Windows.

3.2.3.1 General. As a general principle, windows present a significant weak point in any balanced physical security design because they provide low penetration times. Conventional window assemblies offer only nominal resistance against even the unskilled intruder. As the test data show, the solutions are limited even among hardening options that offer significant penetration times equivalent to penetration times provided by other building components such as walls, floors, and roofs. The available hardening options impose penalties on functional performance of windows, including reduced light transmission and air flow for ventilation. Hence, in any facility design where there is a penetration time requirement beyond what conventional window assemblies or hardening options can provide, the simplest and most obvious solution is to omit windows, except where there is an overriding operational requirement for them. Such a requirement could be, for example, the necessity for an observation port for security or safety purposes, or for essential business transactions. Even when observation is required, the possibility of substituting a closed circuit television system for windows should receive consideration. When observation ports are essential, they should be kept as small as possible, preferably less than the area [96 square inches (0.06 m^2)] required for man-passable openings.

3.2.3.2 Conventional Window Penetration Times. In general, conventional window assemblies provide penetration times equal to or less than 2 minutes, and usually provide penetration times of 1/2 minute or less. Even bar and grill security enhancements, of the type shown in Table 16 offered as conventional security solutions in general use, add only 1/2 to 1-1/2 additional minutes of penetration time against a skilled, motivated intruder. It is significant that, with the proper choice of tools, only the riveted steel grating (Options No. 9 and 10 in Table 16) provide penetration times of over 1 minute. However, it must also be noted that the actual penetration time is dependent on the method by which such gratings are secured over the window. Most mountings used today allow the gratings to be torn off in less than 1 minute, without an intruder having to resort to cutting. The specimens selected for tests tabulated in Table 16 were designed specifically to match material requirements set forth in the indicated government and industrial security standards. The test data clearly indicate the relatively low penetration times associated with these standards in delaying well equipped intruders. However, possibilities exist for substantial penetration time enhancement with certain bar and grill designs. Table 17 summarizes the available information on estimated penetration times provided by various glazing materials. Again, it should be noted that glazing penetration times are all less than 1 minute against a skilled, motivated intruder. Therefore, any glazing surface covering an area equal to or larger than a man-passable opening is vulnerable.

3.2.3.3 Hardening Options. Many hardening options can be used to increase penetration time. As noted above, in situations where high security is required, windows should not be used. If windows are necessary, they should be smaller than man-passable size [96 square inches (0.06 m^2)], and openings (frames) should be heavily reinforced with steel plate since they provide an avenue for enlargement and wall penetration. Other important factors to be considered in selection among window designs include:

(1) Windows. These comprise a system with at least four components: frame, sash, glazing, lock, and in some cases hinges. Each component should provide the same degree of penetration resistance.

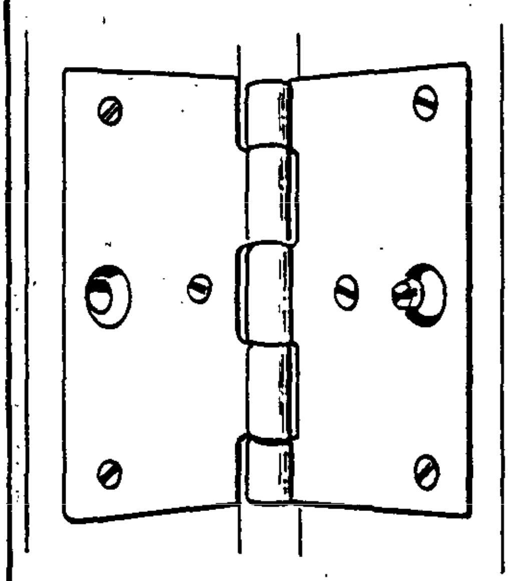
(2) Frames. These should be securely fastened or cemented to the surrounding structure to prevent easy separation and penetration at the interface.

(3) Sashes. These should not be removable from the frame (as is the case with horizontal sliding types).

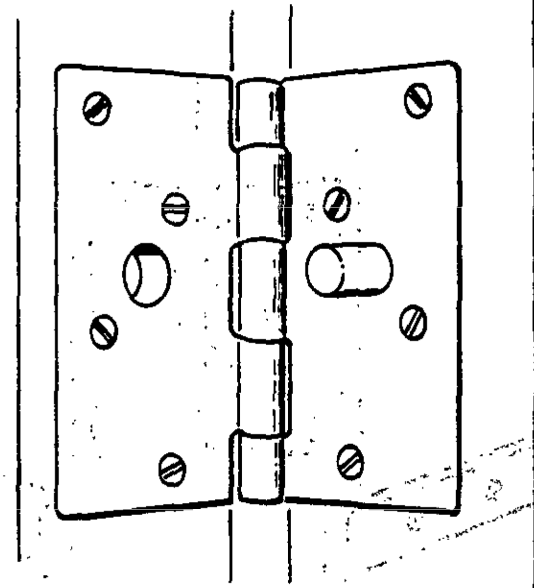
(4) Steel frames, sashes, and muntin/mullions. These can provide some enhancement in penetration resistance.

(5) Glazing. Glazing should not be easily removable from the exterior.

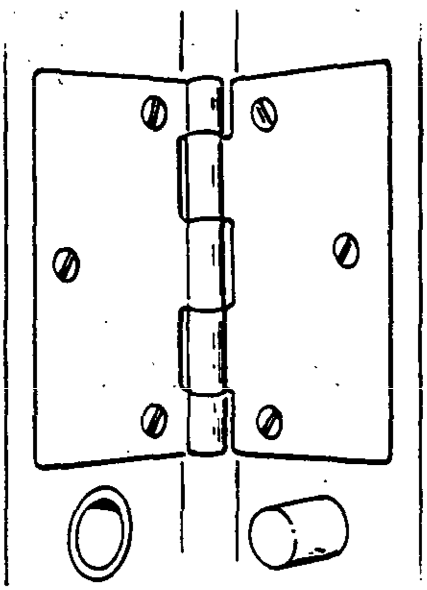
(6) Fixed windows. These generally provide better penetration resistance because the locking component and hinging arrangement are eliminated.



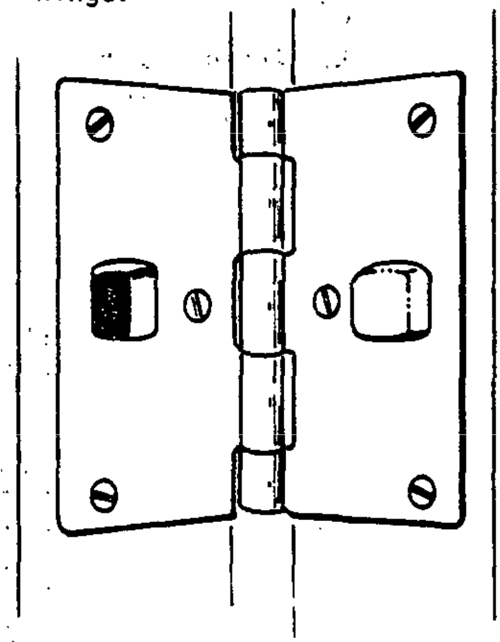
A) Use of a special "stud-end" wood screw that engages in a matching hole when door is closed.



B) Addition of a metal dowel-pin and socket to the existing hinge.



C) Installation of a metal dowel-pin in the door and reinforcing metal cup in the door frame.



D) Hinge with lug and matching socket formed into hinge at factory.

FIGURE 17-a. Hinge and door interface hardening options for personnel doors.

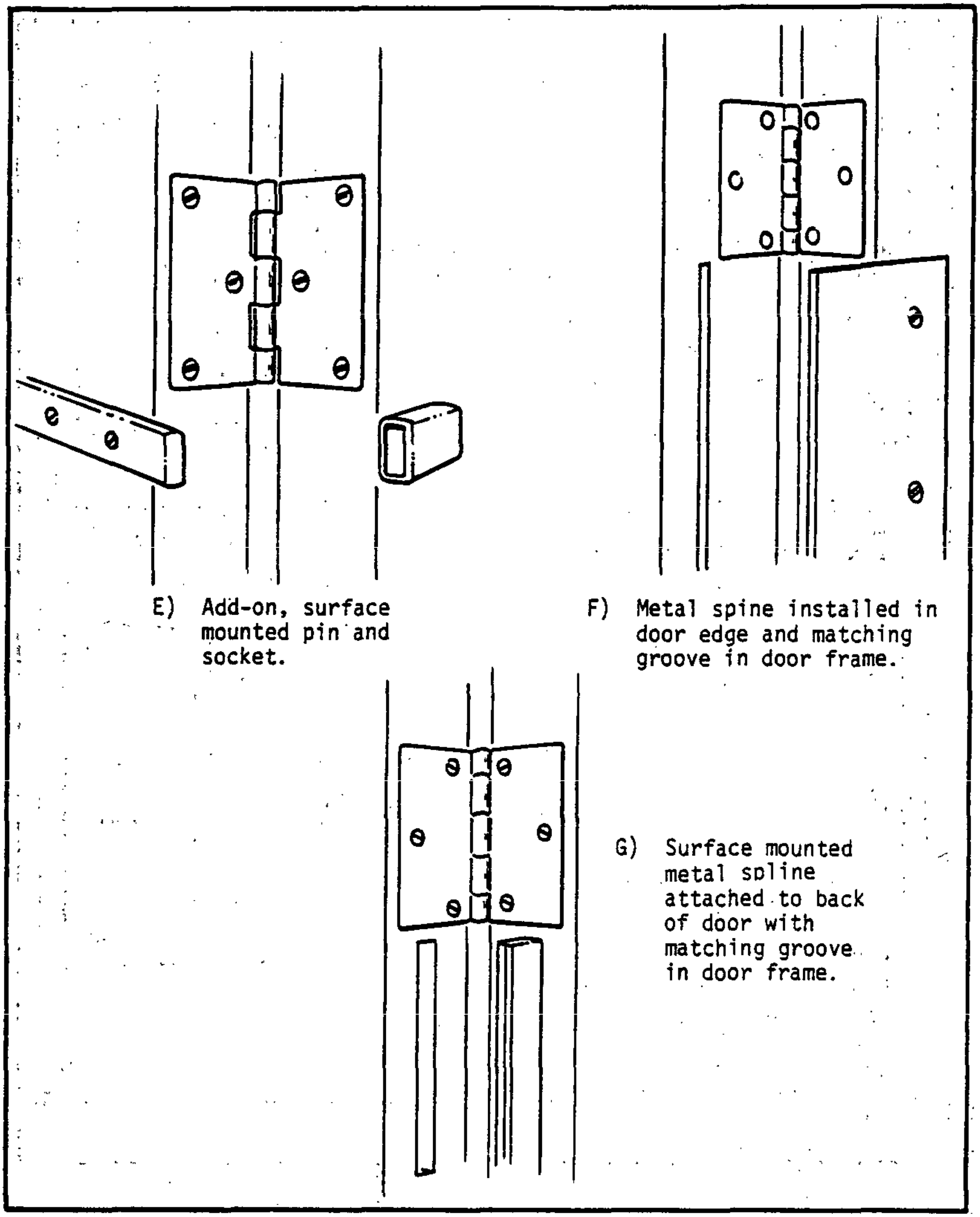
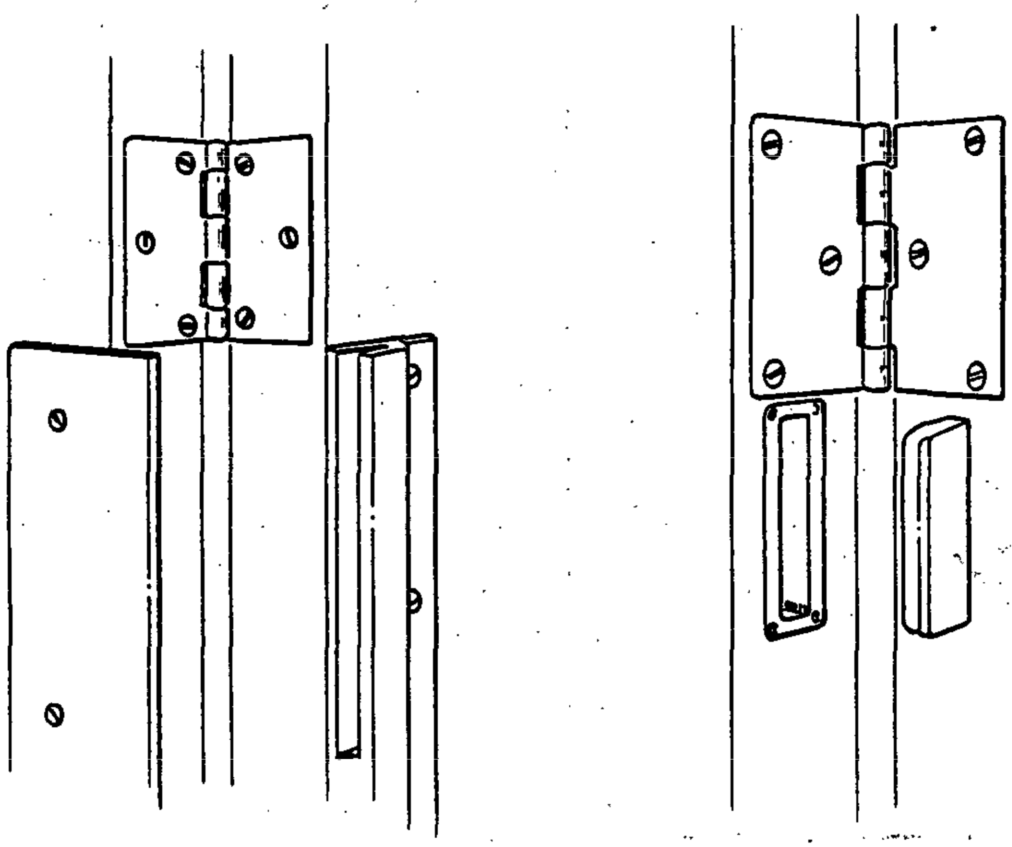


FIGURE 17-b. Hinge and door interface hardening options for personnel doors (continued).



H) Surface mounted metal "spline" and receptacle.

I) Metal lug and receptacle system.

FIGURE 17-c. Hinge and door interface hardening options for personnel doors (continued).

TABLE 16.
Attack resistance of conventional bar-grill security reinforcement.

Option	Sources and Pertinent Excerpt	Materials Used	Penetration Time (seconds)
1	DoD 5100.76M (June 1978), Page 3-2, Paragraph 3-200a. (5)(a) "Three eighths inch (9 mm) or larger hardened steel bars, provided the vertical bars are not more than 4 inches (100 mm) apart with horizontal bars welded to the vertical bars in such a manner that the openings do not exceed 32 square inches (0.02 mm^2)."	3/8-in. (9-mm) HARDENED BARS AISI 1050 heat treated to RC50	14
2	DoD 5100.76M (June 1978), page 3-2, paragraph 3-200a. (5)(a) "Three-eighths inch (9 mm) or larger hardened steel bars, provided the vertical bars are not more than 4 inches (100 mm) apart with horizontal bars welded to the vertical bars in such a manner that the openings do not exceed 32 square inches (0.02 mm^2)."	1/2 in. (13-mm) HARDENED BARS AISI 1050 heat treated to RC50	14
3	DIAM-50-3A (July 1980), page 35, Figure 3. "One-half inch (13-mm) diameter steel bars are used to form a grill work that is to be imbedded into the masonry wall around the window opening. Vertically, the bars must be no more than 6 inches (150 mm) apart; horizontally, no more than 8 inches (200 mm) apart. Horizontally, the bars must be welded to each vertical bar in such a manner that the openings do not exceed 32 square inches (0.02 m^2)."	1/2-in. (13-mm) MILD STEEL BARS ASTM A36	14
4	DNA draft of "Nuclear Weapon Storage Facilities Handbook", 3.9 Window Lines 154 160. "Where security windows and frames are not used, the window opening must be covered by a rod and bar grill constructed of horizontal 1-1/4 inch (32 mm) X 3/8 inch (9 mm) flat steel bars spaced at 8 inch (200 mm) maximum centers, and vertically 1/2 in (13 mm) diameter rods spaced 4 inches (100 mm) on center either welded to or passing through the 1-1/4 inch (32 mm) surface of the flat bars."	1/2-in. (13-mm) MILD STEEL BARS ASTM A36 3/8 X 1-1/4 in. (9 X 32 mm) STEEL BARS ASTM A36	17
5	DNA draft of "Nuclear Weapon Storage Facilities Handbook", 3.9 Window Lines 163-165. "As an alternative to the above grill (Specimen #4), a security screen equivalent to that described in DA OCE Drawing DEF 40-26-01 (Figure 3-23) may be used."	1/2-in. (13-mm) NOMINAL STEEL PIPE ASTM A53, Type S Grade A 1/8 X 1-1/2 in. (3 X 38 mm) FLAT STEEL BARS ASTM A36	22
6	Prison Standard Practice (selected by the Naval Civil Engineering Laboratory to be tested).	7/8-in. (22-mm) TOOL RESISTING DOUBLE-RIBBED BARS ASTM A627 3/8 X 2-1/4 in. (9 X 57 mm) TOOL RESISTING FLAT BARS ASTM A629	28
7	Industry Security Practice (selected by the Naval Civil Engineering Laboratory to be tested).	7/8-in. (22-mm) DOUBLE RIBBED ROUND BARS ASTM A36 3/8 X 2-1/4 in. (9 X 57 mm) FLAT STEEL BARS ASTM A36	39
8	DIAM-50-3A (July 1976) "Physical Security Standards for Sensitive Compartmented Information Facilities", Section D - Air vents and Ducts (8)(b)(1). "Hardened steel bars, 1/2 inch (13 mm) diameter meeting a 600 or 650 Brinell rating, mounted 6 inches (150 mm) center vertically and horizontally and welded at all intersections."	1/2-in. (13-mm) HARDENED BARS AISI 1050 heat treated to RC50	13
9	This grid, currently used by the Navy in structural applications, was selected by the Naval Civil Engineering Laboratory to be tested.	RIVETED STEEL GRATING MIL-G-18014B (SHIPS) Type A, Class B R-18-3 1/2 [3/4 X 3/16 in. (19 X 5 mm)] STEEL	99
10	This grid, currently used by the Navy in structural applications, was selected by the Naval Civil Engineering Laboratory to be tested.	GRID STRUT PANELS Fed Spec #RR-G-1602 Type 1 Para (3.3.1) 14 gauge (1.9 mm) weight - 6.1 lb/ft^2	67

TABLE 17.

Windows, conventional glazing.

Window Glazing	Penetration Time (minutes)
0.09 in. (2.5 mm) annealed glass, single strength (Federal Specification DD-G-451, Latest Edition)	<1
0.12 in. (3 mm) annealed glass, double strength (Federal Specification DD-G-451, Latest Edition)	<1
1/4 in. (6 mm) tempered glass, double strength (Federal Specification DD-G-1403, Latest Edition)	<1
1/4 in. (6 mm) laminated "security glass"	<1
1/4 in. (6 mm) wire glass	<1
1/4 in. (6 mm) polycarbonate*	<1
1/2 in. (13 mm) polycarbonate*	<1
1 in. (25 mm) polycarbonate*	<1
1/4 in. (6 mm) acrylic	<1
1/2 in. (13 mm) acrylic	<1

Note: It should be noted that the thickness of polycarbonate and/or acrylic glazing does not significantly alter its penetration time, at least in 1/4 to 1-inch (6-25 mm) ranges.

(7) Glazing material for fixed windows. This material may be installed directly into the window frame or a sash; however, it is preferable that panes of glazing material be less than 96 square inches (0.06 m^2) in area.

(8) Ventilating system. A separate ventilating system is generally preferable to windows that open.

(9) Locks (latches). These should be located so that they are not easily accessible by breaking out adjacent glazing or using a length of heavy wire. ANSI/ASTM F 588-85 (Standard Test Methods for Resistance of Window Assemblies to Forced Entry, Excluding Glazing) might be consulted; it contains guidelines for estimating window vulnerability to surreptitious forced entry for residential and apartment buildings. It does not, however, directly estimate penetration times and, for the most part, the recommendations provide only nominal security improvements.

Specific hardening options include the use of security glazing, security frames, sashes and muntin/mullions, hardening of bars, screens, and grills, and the installation of shutters or window barriers.

(1) Glazing. Glazing is generally the weak link in providing window penetration time. The best possibilities for penetration-resistant glazing appear to lie with so-called security glass or transparent armor. Extensive tests have been run on such materials to determine their resistance to ballistic penetration; however, very little data are available to base an estimate of penetration time against man-sized openings. In general, glazing material is not necessarily attack-resistant.

(2) Frames, sashes, and muntin/mullions. Use of steel in frames, sashes, and muntin/mullions forces an intruder to use more sophisticated tools but does not otherwise increase penetration time against a well-equipped intruder by more than 1 or 2 minutes--and only if panes are kept well below the roughly 10- by 10-inch (250- by 250-mm) opening required for man entry, so that multiple cuts are necessary. As discussed previously, if possible, windows (observation ports) should be kept at less than man-passable total size [96 square inches (0.06 m^2)]. However, they can provide a convenient opening for the start of wall penetration cuts. Therefore, frames and the surrounding wall interface should be heavily reinforced.

(3) Bars and grills. Data in Table 18 indicate that currently used bars and grills increase penetration times only by 1 to 2 minutes. Table 22 shows, however, that penetration time is directly related to the diameter and spacing of bars, and if, for example, No. 8 [1-inch (25-mm)] bars, spaced 3 inches (75 mm) apart (both vertically and horizontally), are used to form a grill, a penetration time of about 8 minutes can be achieved. Use of a double grill of that type should increase penetration time to over 15 minutes. [It should be noted that a single grillwork as dense as No. 8 bars at 3-inch (75-mm) spacing will block more than 50 percent of the window area. A double grillwork of

TABLE 18.

Penetration times of mandated walls compared to conventional window barriers.

Security Level	Wall Cross-Section	Penetration Time (min)	Penetration Time of Best Prescribed Grating (min)*
High	8-inch (200 mm) reinforced concrete or comparable construction.	16	1.67
Medium	8-inch (200 mm) reinforced filled concrete block or comparable construction.	4	1.67
Low	Wood frame or comparable construction.	1	1.67

*Riveted steel grating

this density will reduce light and ventilation even more. These functional considerations may also deserve consideration in the selection of an appropriate design.] More grill layers would increase the penetration time proportionally. When bars, screens, or grills are used as penetration delay devices, the method of anchoring them to the wall is critical, since it may be easier to tear or pry them loose than to cut them. An appropriate anchoring design should be provided, although there are no test data with respect to what may be optimal at this time.

(4) Shutters. For facilities requiring only intermediate (e.g., nightly) "buttoning up," the designer might consider using one or more shutter assemblies. These can be constructed to either slide into the wall, be attached on the interior surface of the wall, or both, and should include appropriate interior locking devices. If the shutters slide into the wall, the wall cross-section and penetration resistance will be reduced when the barriers are closed. The shutters may be composed of steel polycarbonate composites.

(5) Secure window barriers. Openings of various sizes and configurations are required in the walls of some secure structures for the passage of light, for materials issuance, and for ventilation and observation. It is essential that the barriers protecting these window openings provide forced entry resistance consistent with the resistance of the structure walls. In the past, barriers for windows have usually consisted of bars, grills, or similar elements installed on the outside of the window opening. In this exterior position, these barriers were easily accessible to attack and can be defeated before breaking the glass, thus negating any constructive use of break glass sensors. They also provided very little delay time against attack with common hand tools. Also, these barriers were solidly mounted to the exterior wall, restricting light, observation, and materials issuance. Table 18 shows how the best of these conventional window barriers compares with the three different security levels of wall cross-sections they would be mounted on.

New secure window barrier designs provide specified levels of penetration resistance against specific threat levels as shown in Table 19. Three types of secure window barriers (low, medium, and high security) can be attached to existing walls to protect windows. These barriers vary in the degree of protection provided and cost. The medium- and high-security window barriers provide a solid panel barrier, for installation on the inside of window openings, and can be swung or rolled completely open during times when ventilation, an unobstructed view, or materials issuance through the window are required; yet they provide a barrier to securely seal the window whenever maximum security is needed or the building is unattended.

TABLE 19.

Secure window barrier panel
performance/penetration resistance.

Panel Type	Low Threat (limited handtools)	Medium Threat (unlimited handtools)	High Threat (unlimited hand, power and thermal tools)
Low Security	5.00 (1)	3.00 (1)	N/A
	10.03 (2)	5.52 (2)	
Medium Security	N/A		4.50 (1)
		8.70 (3)	4.30 (2)
High Security	N/A	Not feasible (4)	10.77 (1)
			16 min. (2)

(1) Time to make two handholes.
(2) Time to make a man-passable opening.
(3) Test data for similar panel without fill material.
(4) Forced entry of this panel at this threat level is not considered feasible.

TABLE 20.

Window size ranges for window barriers.

Security Level of Opening	Dimension	Window Size (inches)	
		Min	Max
Medium and High	Vertical	24 (600 mm)	48 (1,200 mm)
	Horizontal	36 (900 mm)	96 (2,400 mm)
Low	Vertical	TBD	TBD
	Horizontal	TBD	TBD

(a) Composite panels. The medium- and high-security designs are based on the attack resistance of specially laminated composite panels similar to the construction used in some vaults or other high-security doors. Elaborate locking mechanisms ordinarily used for high-security doors are not needed for these window barriers because they are never opened from the outside. The barriers are secured with simple latch, bolt, or clamp mechanisms. The low-security window barrier is designed for use on windows that do not require the full protection of the medium- or high-security barriers but still require some measure of protection. These barriers are made of panels of welded steel grating that are mounted on the inside of the window opening.

(b) Other panels. Secure window barriers can be constructed with three types of panels in five different configurations. A horizontal rolling barrier, as shown in Figure 18, can be configured with either a medium- or high-security panel. A double panel hinged-type barrier, as shown in Figure 19, can also be configured with either a medium- or high-security panel. A single-panel hinged-type barrier, as shown in Figure 20, is configured with a low-security panel. Proper selection of the correct window barriers depends on such considerations as the design of the overall security system, the size of the window to be hardened, and the penetration time and spatial conditions of the wall where the window is located. Other specific factors to consider include establishing the minimum delay requirement and the maximum budget; choosing a barrier that provides forced entry resistance equal to or greater than the resistance provided by the structure's walls; and determining the size of the window to be hardened and the spatial conditions of the wall where the window is located. These window barriers provide improved fire safety since all types are mounted inside and all can be opened. This is an improvement over the existing outside rigidly mounted window barriers.

Tables 20 and 21 list the window size ranges and spatial requirements needed for the different types of secure window barriers. The security barriers consist of three types.

First, the low-security barrier is a removable hinged grating. The panel, as shown in Figure 20, is composed of 1-inch x 3/16-inch horizontal bearing bars welded together with 1/4-inch hexagonal bars on 2-inch centers. This grating is a commercial product that is fabricated to Federal Standard RR-G-661. Refer to NCEL drawings 6227000 through 6227003 for more details.

Second, medium-security window shutters can be configured with either a double-panel hinged-type barrier, as shown in Figure 19, or a rolling barrier as shown in Figure 18. The medium-security panel is a 1-3/4-inch-thick hollow sheet metal panel filled with fire-resistant concrete. Refer to NCEL drawings 6227005 through 6227019 for more details.

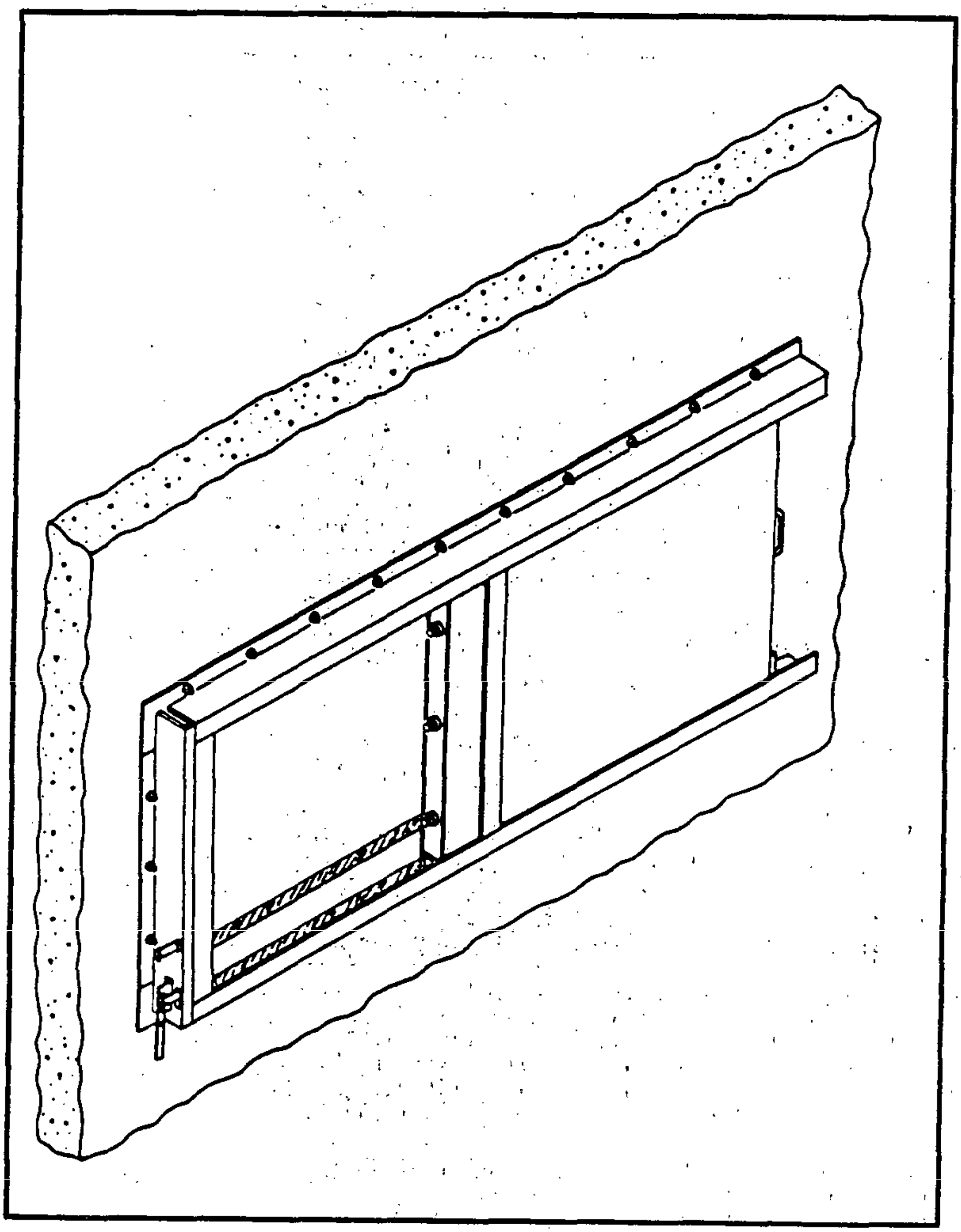


FIGURE 18. Typical horizontal rolling type secure window barrier.

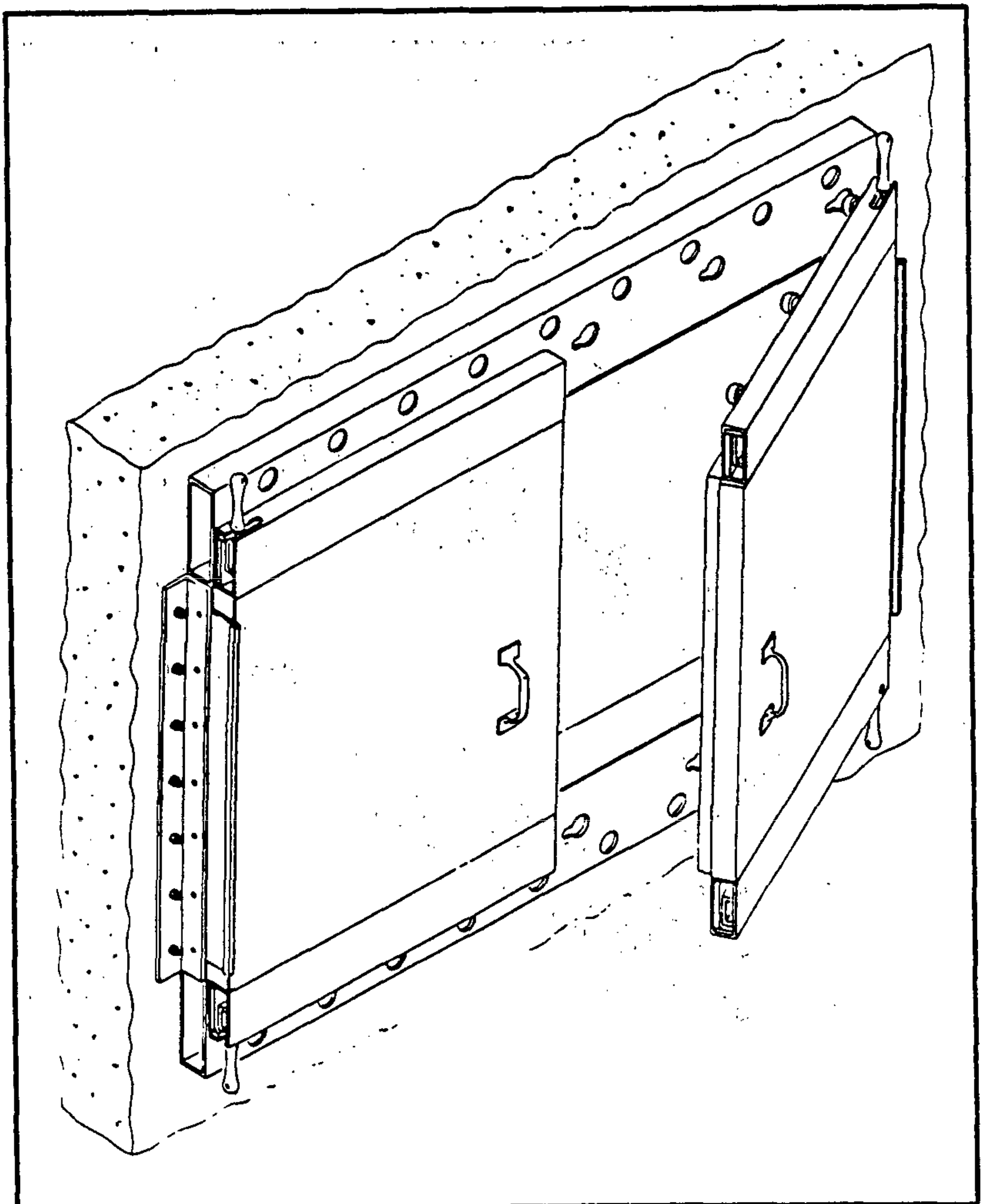


FIGURE 19. Typical double panel hinged type secure window barrier.

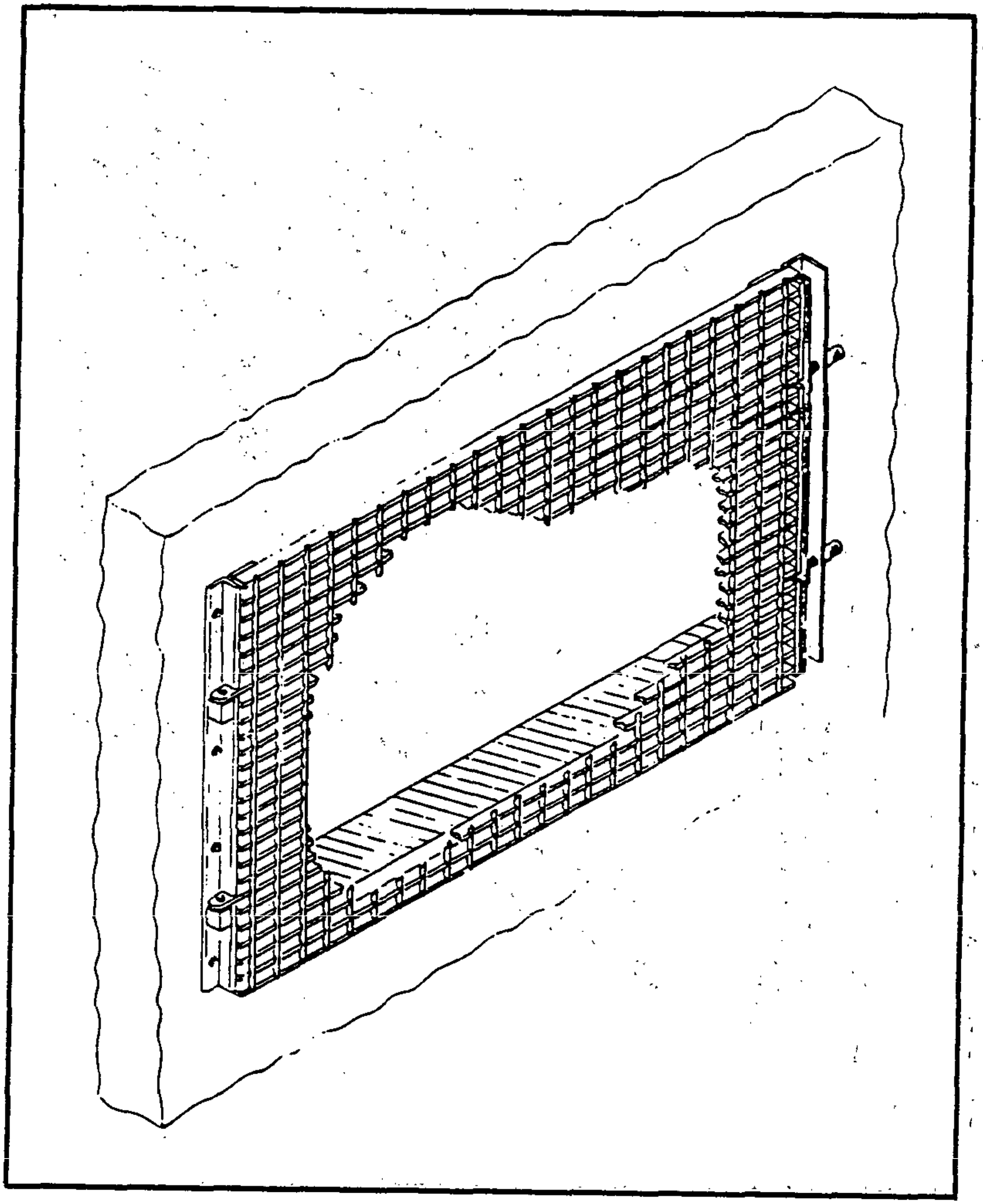


FIGURE 20. Low-security secure window barrier.

TABLE 21.

Wall spatial requirements
for secure window barriers.

Barrier Type	Level of Security	Design Requirement for Walls
Rolling	Medium and High	Horizontal width of the barrier plus 12 inches (300 mm) of clear flat wall space for barrier opening side. 6 inches (150 mm) required at the top, bottom, and side opposite the barrier opening. 2 inches (50 mm) of flat horizontal sill space on top and bottom of window.
Hinged	Medium and High	6 inches (150 mm) clear flat wall space on all four sides of window. 2 inches (50 mm) of flat horizontal sill space on top and bottom of window.
Hinged	Low	2 inches (50 mm) flat clear wall space at top and bottom of window. 4 inches (100 mm) at the hinge side of window and 4-1/4 inches (110 mm) at the latch side of window.

TABLE 22.

Time and number of cuts required to open man-passable entry in grills composed of various size bars and bar spacings.

Bar No.	No. 3		No. 4		No. 5		No. 6		No. 7		No. 8	
Spacing in (mm)	Time	Cuts	Time	Cuts	Time	Cuts	Time	Cuts	Time	Cuts	Time	Cuts
3 (75)	1.2	12	1.7	12	2.5	12	3.5	12	5.1	12	7.9	12
3.5 (90)	0.8	8	1.2	8	1.6	8	2.3	8	3.4	8	5.2	8
4 (100)	0.8	8	1.2	8	1.6	8	2.3	8	3.4	8	5.2	8
4.5 (115)	0.8	8	1.2	8	1.6	8	2.3	8	3.4	8	5.2	8
5-9 (125-225)	0.4	4	0.6	4	0.8	4	1.2	4	1.7	4	2.6	4
>10 (250)	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0

Notes:

1. Estimates are for a single layer grill composed of steel bars of the diameter shown equally spaced, both horizontally and vertically.

2. Times shown are total time measured in minutes required to provide a man-passable entry of at least 96 square inches ($0.06m^2$).

3. Cuts shown are the minimum total number of bars that must be cut to provide the man-passable entry.

4. All bars, grills, security screens, etc. should be located on the "inside" of windows, behind glazing material.

5. Glazing material should be protected by intrusion detection sensors that provide an alarm before the intruder begins penetrating the bars.

Third, high-security window shutters can be configured with either a double panel hinged type barrier as shown in Figure 19 or a rolling type barrier as shown in Figure 18. The high-security panel is made of a 2-3/4-inch-thick panel made of laminate wood, polycarbonate, and bullet-resistant steel sandwiched between front and back sheets of steel. Refer to NCEL drawings 6227020 through 6227033 for more details.

3.2.4 Utility Openings

3.2.4.1 Overview. In conventional building designs, utility openings, manholes, tunnels, air conditioning ducts, filters, or equipment access panels can provide intruders with an attractive entrance or exit route with no significant delay. Such openings must be eliminated, or delay times significantly increased, if consistent physical security integrity of the overall structure is to be provided. The following subparagraphs briefly describe typical utility openings and the factors and issues that require special consideration in determining and enhancing delay times.

3.2.4.2 Conventional Construction. In this subsection, conventional construction methods for electrical system conduits, mechanical system conduits for air conditioning, heating, and venting systems, roof-mounted equipment, filter banks, manholes, and other openings are discussed.

(1) Electrical and mechanical conduits. These conduits consist of tunnels, pipe chases, and sleeves and trays as well as ducts, gravity vents, and exhaust ducts for air conditioning, heating, and ventilating systems.

(a) Tunnels. Tunnels for electrical and mechanical utilities between buildings are seldom well protected. They are typically installed in very large facilities, may be 8 feet (2.4 m) or larger in diameter, and are made of reinforced concrete. They may have lift-off covers or access manholes with no locking devices or interior barriers. The utilities often enter the buildings from such tunnels through a frangible (knockout) panel or through walls or ports that may be easily penetrated because of their construction. Maintenance accessibility, rather than security, has been the primary consideration in some tunnels. When such tunnels exist, they may provide a potential concealed path for an adversary and, thus, may be one of the weak links in the delay system.

(b) Pipe chases. Pipe chases are horizontal or vertical frame-in passageways. These may vary in size from 1 foot square (0.09 m^2) to any desired size and may be constructed of studs and gypsum board. Although they are often quite congested, they still allow space for maintenance work. In some facilities, vertical chases connect adjacent floors, thus providing unlimited access once an intruder is inside the chase system. Similarly, horizontal chases (walk-throughs) are confined spaces; however, there is usually no impedance to movement except that afforded by the internal equipment, piping, cables, and the entrance door(s), which usually use only standard lock sets. Some facilities may have interconnecting vertical and horizontal chase systems, which provide additional paths to an intruder. Maintenance personnel usually require routine or daily access, which further increases the difficulty of control. Entrances to, or exits from, overhead crawl spaces may also be made from some chases. These chases must be provided with barriers, since the path may otherwise be unlimited.

(c) Sleeves and trays. Sleeves are pipe penetrations 1 inch (25 mm) to 8 inches (200 mm) in diameter through walls, floors, or roofs, and are sized one pipe size larger than the penetrating pipe. These require packing for weatherproofing and fire rating. Trays are composed of a sheet metal removable cover conduit, 3 inches square (0.002 m^2) or larger. Pipes, which carry a liquid or gas, present a natural deterrent if they must be cut for entry. Electrical cable trays may also present a natural deterrent; moreover, the free area is usually small, thereby presenting minimal risk. When needed, a closure plate or grid may be installed to close or reduce the opening. The physical size of the cable tray will determine the degree of security enhancements required.

(d) Ducts. Ducts associated with air conditioning, heating, and ventilating systems can be used for surreptitious entrance or exit paths. Ducts are sheet metal or fiberglass, round or square conduits, which may vary from 3 inches (75 mm) on a side, or in diameter up to any required size [e.g., 6 or 8 feet (1,800 or 2,400 mm) on a side]. Ducts constructed of sheet metal, 28 gauge (0.4 mm) through 14 gauge (1.9 mm), can readily be cut with hand tools and light power tools. These ducts do not present a significant barrier to penetration. Penetration resistance is, however, sometimes incidentally enhanced by the use of ducts of less than man-sized cross section and the inclusion of required appurtenances, turning vanes, dampers, pressure plates, or the final air distribution fixture. The standard specification for steel air ventilating grill units for detention units (ANSI/ASTM A 750-84) shows at least one secure design.

(e) Gravity vents. Gravity vents vary in size from 6 inches (150 mm) to 4 by 8 feet (1,200 by 2,400 mm). Since they terminate inside the building, gravity ventilation ducts, such as those used in storage igloos, provide direct entrance when attacked with cutting tools. A typical barrier now used in these ducts is a 3/8-inch (9-mm) thick perforated steel plate welded to an 18-inch-diameter (450-mm-diameter) pipe.

(f) Exhaust ducts. Exhaust ducts through roofs and walls are generally considered to be protected by the equipment used in conjunction with them. However, if the equipment is removed, the entrance is open. Because the duct work, dampers, etc. are usually constructed of light sheet metal, penetration can be accomplished through the use of hand tools. Typical exhaust ducts range in size from 6 inches (150 mm) to 4 by 8 feet (1,200 by 2,400 mm).

(2) Roof-mounted equipment. Roof-mounted equipment, such as air supply fans, exhaust fans, gravity ventilators, and filter banks, is usually welded or bolted to an equipment curb, duct system, or foundation and can be removed with hand tools. Openings uncovered when equipment is removed can provide an adversary path to the interior of the facility. In many installations, the removal of only eight bolts, plus the withdrawal of the equipment, can provide access.

(a) Air supply and exhaust fans. Air supply and exhaust fans are usually constructed of steel sheet metal and vary in size from 12 inches square (0.007 m^2) up to 6 feet square (0.60 m^2).

(b) Filter banks. Filter banks, which are associated with heating, air conditioning, ventilation, and other systems, can be a potential adversary path or point of sabotage. They are usually of sheet metal and wire construction with paper, plastic, or wire mesh elements 12 by 24 inches (300 by 600 mm) in size, several elements wide. Some installations may require hardening to provide suitable penetration time. Filters may be installed in an exterior wall with the holding device exposed. There are some filters that require special attention because of the radiological or toxic materials that could be released or dispersed by a penetration attack involving thermal action, mechanical tampering, or other actions. Such safety issues must not be overlooked in providing increased intrusion delay time. Filters of this type may require installation in locked plenums without exterior access or may be constructed of materials that have a higher resistance to penetration.

(3) Manholes. Manholes may be made of cast iron, concrete, fiberglass, etc. and of course, are large enough for a man access, being 18 inches (450 mm) or larger in diameter. Unless properly protected, manholes for electrical power, communications, and sewers (storm and sanitary) offer an intruder a potential point of entry into a facility. The normal barrier is a cast iron or steel cover, which is occasionally bolted or held in place only by its weight. The estimated time of removal with hand tools is 20 seconds.

(4) Miscellaneous openings. Typical facility openings, such as skylights, roof-hatches, scuttles, elevator shafts, ash dumps, rubbish chutes, equipment penthouses, fire escapes, sidewalk grates, and roof access ladders, offer intruders access to a building's interior. Hardening of these potential penetration avenues should be a consideration when increasing delay times. The approach to upgrading these avenues will be dictated by the building elements involved (i.e. by appropriate design of walls, roofs, floors, doors, and locking mechanisms).

3.2.4.3 Conventional Utility Opening Penetration Times. Table 23 summarizes the very limited penetration time data available on specific types of utility openings. In addition, Table 16 provides penetration data on conventional bar and grill security reinforcements specified in various military directives and standards. In general these penetration times are less than 2 minutes.

3.2.4.4 Hardening Options. In most instances, utility openings must receive different considerations than windows and doors since they offer a variety of routes for the attacker. Table 24 summarizes estimated penetration times for specific hardening options discussed below. However, a note of caution must precede its use: access via utility penetration often can be obtained by multiple routes. Therefore, a barrier may prove less effective than its estimated penetration time if it can be bypassed via a less time consuming assault path. For that reason, the qualitative guidelines provided in the following subparagraphs will generally prove more useful than approximate quantitative values in estimating actual penetration times. This is true for both existing and upgraded utility openings designs.

(1) Electrical and mechanical conduits. These conduits are composed of tunnels, sewers, manholes, pipe chases, and sleeves and trays.

(a) Tunnels/sewers/manholes. Utility and communication tunnels and sewers (including storm sewers) originating outside a secure structure, but either connecting with it or passing close by, can provide a very convenient penetration route for an intruder. They are particularly vulnerable because it may be possible for intruders to work in them undetected for extended periods of time to cut through barriers. Conventional grills, gratings, locked manhole covers, etc. are probably worthwhile to discourage the less dedicated intruder, but they generally offer insignificant increases in penetration time against a determined attack. The lock-on fastening device is usually the weak link. Multiple fixed grills with small interstices can provide significant penetration times (see Table 22 and related discussion in Subparagraph 3.2.3.3); however, they may not be practical in sewers where they may restrict fluid flow or increase the possibility of blockage by debris. It is extremely important to insure that structure walls, floors, or foundations, which are accessible from such underground routes, provide the required penetration time against penetration attempts. Furthermore, actual entry ports from the tunnels/sewers to the structure should, if possible, be constricted to make their expansion into a man-passable opening very difficult and time consuming. Obviously, an effective intrusion detection system capable of detecting preintrusion activities (e.g., a seismic system to detect digging) is very important for high risk situations. Where fluid flow capacity is a limiting factor in constricting tunnel/sewer openings, multiple small openings, or a larger opening filled with 4- to 6-foot (1,200- to 1,800-mm) or longer lengths of steel pipe, welded together and anchored securely in place by a welded structure on the inside (secure side) of the structure may be used (see Figure 21). If possible, such a barrier should be located with a sharp adjacent turn in the tunnel to further restrict the use of cutting tools. This arrangement can also be used for electrical lines, since maintenance personnel can have access to both sides of the impediment (constriction). That is, access is provided from both inside and outside the secure structure, and cables can be threaded through the relatively short constriction. Although there are no available test data giving penetration times for this concept, one can expect 30 minutes or more from barrier depths of 4 to 6 feet (1,200 to 1,800 mm). Construction of this impediment can be undertaken in two ways. One approach is to weld the steel pipes front and back at least 3 inches (75 mm) on each end and at each intersection where the steel pipes intersect. No steel pipe diameter inside the sewer pipe should be greater than 10 inches (250 mm) to insure a smaller than man-passable opening. A second approach is to eliminate the center steel pipe and to connect the remaining six pipes inside the sewer pipe with continuous welds. However, if this approach is taken, the facilities engineer should be careful to insure that the area in the center, which would have been filled by the seventh center pipe, as shown in Figure 21, is not a man-passable opening.

(b) Pipe chases. Pipe chases can be handled in a manner similar to tunnels, sewers, and manholes. The use of conventional grills and locked access doors are a hindrance to maintenance activities and offer very limited penetration times. One potentially cost-effective arrangement is a constriction of the type shown in Figure 22. The constriction should be composed of a series of hardened barriers (or fixed grills, as discussed below), each firmly embedded in or extended beyond the chase wall, to prevent bypassing at the interface. The facilities engineer should recognize that the placement of an obstacle in a pipe chase may not be a final solution because a resourceful intruder may try to cut his way out of the chase. Ideally, constrictions should be located at attack-hardened secure walls. The length of the constriction forces the intruder to attack and remove each barrier separately. Confined working space and the necessity for debris removal further add to penetration time. Penetration times well in excess of 30 minutes should be achievable by use of this method. In lieu of solid barriers, a series of fixed grills (see Table 22) may also serve the purpose and can provide penetration time of up to 1 hour--depending on spacing. Again, the long penetration time is derived from the length of the constriction, which greatly increases the problem if they carry liquids, gas, or steam, of cutting and debris removal. It should be noted that the pipes themselves will provide an inherent deterrent to an attempt to enlarge the opening by removing them.

(c) Sleeves and trays. Sleeves and trays should penetrate security walls at a steep angle, so that the length of the opening will be great enough to forestall its use as a convenient entry for a saber saw or other cutting device. Holes should be angled upward and, to the extent practical, contain sharp turns to prevent the easy introduction of hooks, cables, or explosive devices. They should be kept to the minimum possible dimensions.

TABLE 23.

Utility openings, conventional construction.

Construction Type	Penetration Time (minutes)
Sheet metal magazine vent with grill of rebar at bottom, 1/2-in. (13-mm) diameter, 6-in. (150-mm) O.C.	1.6
36-in. (900-mm) diameter roof exhaust with 1/2-in. (13-mm) diameter security bars	1.1
Air conditioning filter frame bank, 20-X-20-X-2-in.(500-X-500-X-50-mm) filter size with louvers	0.25
36-in. (900-mm) diameter duct, 18- to 24-gauge (1.2- to 0.6-mm) sheet metal	0.65
Air conditioning intake louvers, 22-gauge (0.8-mm) sheet metal, hole size ranging from 10-X-20-in. to 36-X-48-in. (250-X-500-mm to 900-X-1200-mm) with 0.25-in. (6-mm) screen mesh	0.35

TABLE 24.

Utility opening hardening.

Construction Type	Penetration Time (minutes)	Comments
Constriction (Type 1)	30-40	See Figure 21. Estimated penetration time for these constrictions will be a function of vent or tunnel diameter and the diameter, length, wall thickness, and hardness of the internal pipe "honeycomb" used. They must be estimated (and preferably tested) in each case. The times shown on this chart indicate ranges that appear feasible for typical cases.
Constriction (Type 2)	30-40	See Figure 18. Estimated penetration times for these constrictions must be computed in each case, based on choice of materials used in the constriction and the size of the duct or chase. The times shown are the ranges that appear feasible for typical cases.
Bars/Grills	15-25	See Tables XV and XVII. Penetration time will be a function of duct size (i.e.,work space); number and spacing of grills; and number, spacing diameter, and hardness of bar stock used. Estimates can be made for specific cases based on information contained in Tables XV and XVII. The time shown is the range of penetration times that appear feasible.
Vent Frame Hardening	5-10	See Figure 19. Each case must be analyzed (and preferably tested) separately to determine minimum penetration time enhancement. Increases in penetration time will vary depending on roof/wall construction and the thickness, hardness, and extent of the vent fram hardening material used. The time on the chart indicates a range of penetration time enhancements that appear feasible.

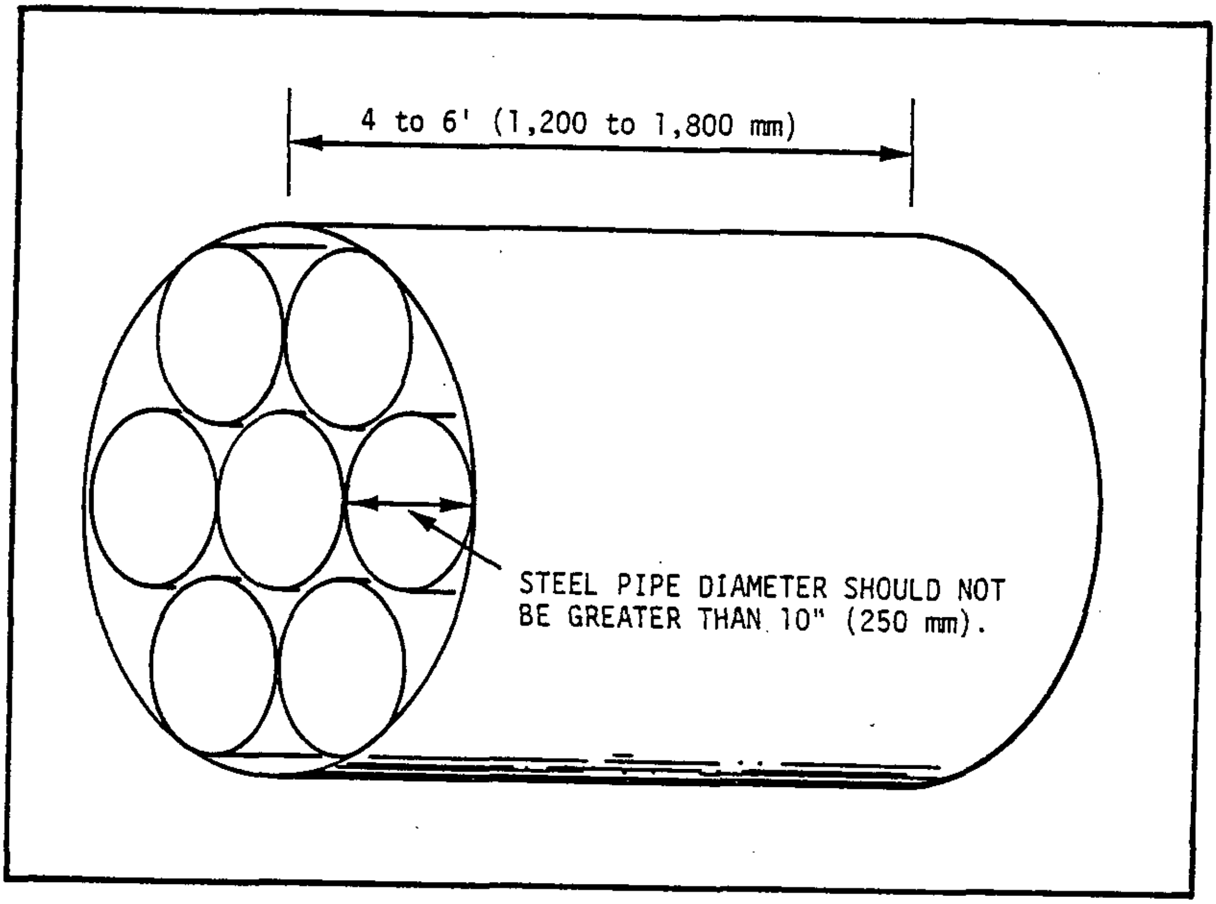


FIGURE 21. Section of large sewer pipe rendered nonman-passable by 4- to 6ft. (1200- to 1800-mm) long sections of honeycomb of welded sections of pipe of nonman-passable diameter.

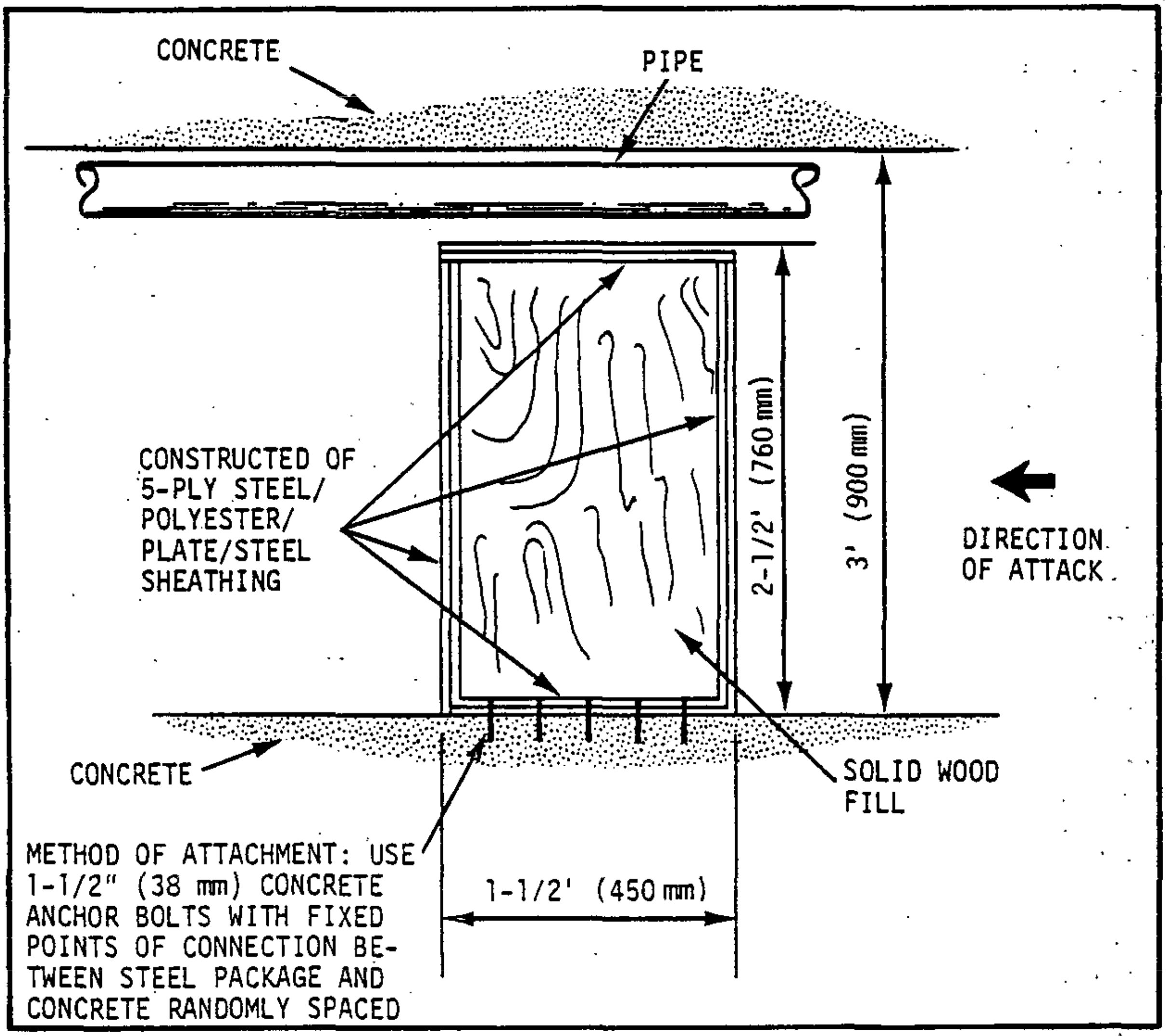
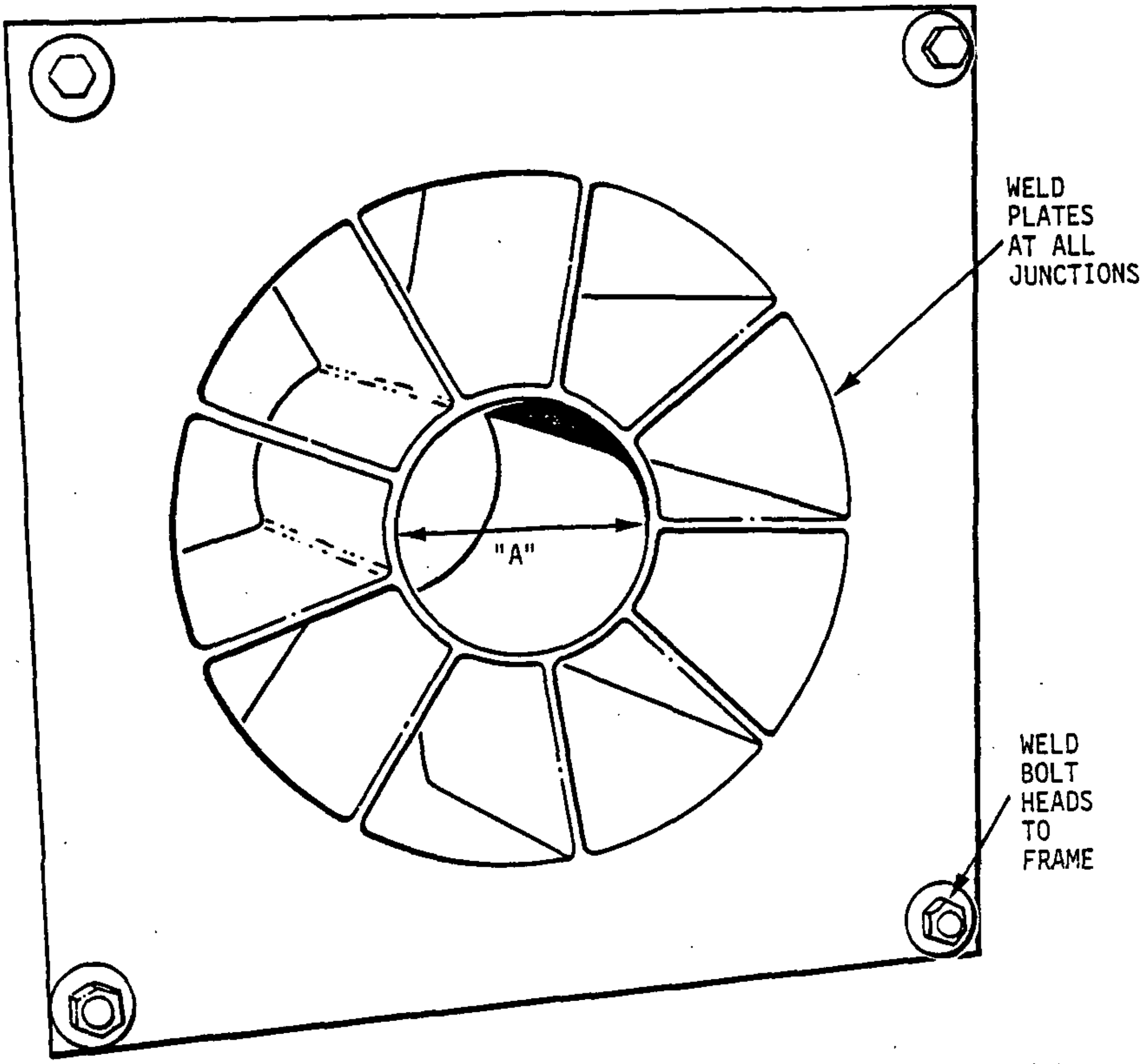


FIGURE 22. Representative constricted pipe chase, cross-sectional elevation view.

(2) Air conditioning, heating, and ventilation systems. These systems are composed of ducts, gravity vents, and exhaust vents.

(a) Ducts. Ducts for air conditioning, heating, and ventilating systems may provide a path for intruders. Ideally, to eliminate that possibility, duct dimensions should be kept at less than a man-passable cross section. However, airflow capacity requirements and cost may make such duct sizes impractical. In these instances, the discussion in this handbook on window grills and gratings should be consulted (see Table 22). The techniques discussed there can also be applied to ducts in, perhaps, an even more effective manner due to confined working spaces and the possibility of using an in-depth barrier of multiple and widely spaced grills. Another possibility is to insert strategically placed honeycomb sections (similar to those shown in Figure 21) to restrict man-passages. Although such sections will require care in design to avoid airflow and noise problems, they are feasible. The honeycomb material should be of a grade of steel reasonably resistant to cutting with hand and thermal tools (at least 1/16 inch thick (1.6 mm)); however, the penetration time will accrue mainly from the length of the honeycomb and the resultant necessity for multiple long cuts and debris removal in the relatively restricted space of the duct. Since duct walls are generally easy to cut through US 18- to 24-gauge (1.2- to 0.6-mm) sheet steel, the honeycomb must be strategically located so that the intruder cannot bypass it by gaining entrance to the crawl space of "soft" ceilings. It may be necessary to reinforce the duct walls at some locations with high resistance materials such as 5-ply steel/plexiglass/steel/plexiglass/steel laminate. The honeycomb sections should be located, if practical, at sharp bends in the ducting. Depending on duct size, cost, and aerodynamics, an alternative approach could be to replace the single duct with a double or triple duct system at selected, strategic points. As previously noted, the inclusion of required appurtenances, turning vanes, dampers, pressure plates, or the final air distribution fixture may also add a few minutes to penetration time. This can be further enhanced by anchoring such fixtures securely and by using grills and bar gratings of a dimension and shape that force the use of large and unwieldy tools and thermal cutting equipment.

(b) Gravity vents. A key in hardening a vent is the depth (i.e. volume of space) available for installation of barriers. If the vent is simply an aperture in a wall or roof, the problem is analogous to hardening a window with grills or bars. Table 22 indicates penetration times that can be achieved in that way. If possible, the vent should be kept to a less than man-passable size. Penetrations through vents smaller than 96 square inches [0.06 m^2 (standard size of man-passable opening)] require attacking the surrounding wall or roof to enlarge the vent. The vent itself may provide an advantage in such an attack since, for example, it eliminates the necessity of drilling a hole for the introduction of tools. That advantage can be reduced by hardening the vent frame. (See Figure 23 for a suggested technique.) If the vent must be kept at a man-passable size, and if space exists behind it, the best approach to increase penetration time is to fill the opening with



DIAMETER "A" MUST NEVER BE LARGER THAN 10 in (250 mm). NO OPENING SHALL BE LARGER THAN 90 SQUARE INCHES (0.6 m^2) IN AREA. PLATE PLACEMENT AND CONFIGURATION MAY BE VARIED TO MEET NEED OF EACH INSTALLATION. UNIT CAN BE FABRICATED, BOLTED AND WELDED IN PLACE OR BUILT INTO EXISTING OPENING. ROUND OPENING WITH STEEL PLACE BARRIERS. ALSO APPLICABLE TO OTHER OPENING CONFIGURATIONS.

FIGURE 23. Vent frame hardening.

lengths of steel pipe welded into a "honeycomb" (see Figure 21). Again, this causes the intruder to have to make cuts in depth, which increases cutting time but also seriously interferes with his use of tools. It also creates problems in removal of debris and working in a confined space. Although not tested, barrier depths of 4 to 6 feet (1,200 to 1,800 mm) are estimated to generate penetration times of 30 minutes or more. An alternative approach is multiple and widely spaced grilled barriers in the shaft or duct leading from the vent. (See Table 22 and related discussion.) These approaches are only effective, however, if the facility mechanical layout is such that the intruder cannot cut his way out of the duct or shaft and gain access to the facility before the grilled barriers are reached. Even very small vents must be protected since they can be an easy route for introduction of explosive charges. Traps or bends at carefully selected locations can often prevent this. In conclusion, any vent, no matter how small, can provide a convenient entry for the blade of a tool used to breach the roof or wall through which the vent passes. Therefore, as a minimum, all vents should be hardened with massive steel collars at the structure interface, as illustrated in Figure 23.

(c) Exhaust vents. The discussion under gravity vents, ventilation ducts, and air distribution fixtures (above) generally applies in the case of exhaust vents. Possibilities for reducing vents to less than man-passable size, by use of multiple honeycombs (Figure 21), should be considered. In some cases, the exhaust system machinery itself may add to penetration time.

(3) Roof-mounted equipment. Although expensive, the only known way of providing extended penetration time for man-passable openings exposed by the removal of roof-mounted machinery is to provide a hardened "penthouse" to house the machinery. Penthouse penetration time will depend on structural components, doors, and openings used. Specific penetration times can be estimated by the same methods described for structures throughout this handbook. Otherwise, the use of multiple, small ports in the penthouse structure in multiple grills (see Table 22) must be considered.

(4) Filter banks. The discussion above regarding roof-mounted equipment applies in general to filter banks, except that the banks themselves are unlikely to offer any significant penetration time. A hardened enclosure, with one of the vent or duct hardening techniques, appears the best approach.

(5) Miscellaneous openings. Structure openings, such as sky-lights, roof-hatches, scuttles, elevator shafts, ash dumps, rubbish chutes, fire escapes, and roof access ladders, offer access to intruders and should be considered in hardening plans. The first step should be to eliminate openings that are not absolutely necessary. The approach to upgrading those that remain will be dictated by the structural elements involved, that is, by appropriate design of walls, roofs, doors, and locking mechanisms.

SECTION 4: EXTERIOR PHYSICAL SECURITY

4.1 Overview. This section presents guidance with respect to three subjects related to the exterior physical security of facilities:

- o Exterior layout
- o Exterior security lighting
- o Exterior barriers

The section on exterior layout provides guidance appropriate to an entire site and an individual facility, and includes considerations related to security support functions. The section on exterior security lighting provides guidance with respect to the function, types, and specifications of security lighting, lighting concepts, lighting as a deterrent, lighting for closed circuit television (CCTV) surveillance, and security-related energy and legal issues. The section on exterior barriers (excluding vehicle barrers, which are discussed in Section 8) provides guidance with respect to the security function of perimeter fences.

4.1.1 Basic Considerations. The guidelines this paragraph provides with respect to exterior layout, security lighting, and exterior barriers are based on the following considerations. First, exterior layout is most important in those cases where a facility's delay time is designed into barriers that depend upon the exterior shell of the building and where continuous or frequent exterior surveillance by security personnel is the primary means of intruder detection and assessment. To be of use, exterior intruder detection must occur before or, at the very latest, at the beginning of an attempted penetration at an exterior barrier exposed to exterior surveillance. Moreover, exterior intruder detection and assessment (e.g., using roving guard patrols or closed circuit television (CCTV)) requires extended clear zones and easy access to all points around the exterior of the facility. Second, the principal value of security lighting is to aid either security personnel directly or to permit an IDS to function properly and to detect and assess an intruder at or near a facility's key barrier. Illuminating a facility at night or other periods of low visibility, without using security personnel for observation, will only deter the nondedicated intruder. Third, the principal value of exterior perimeter barriers, such as fences or walls around a facility, is to deter nondedicated intruders. Because they can be easily scaled, crawled under, or cut through, a dedicated threat will be neither deterred nor significantly delayed by a perimeter barrier. The security engineer should keep these basic considerations in mind when applying the guidelines set forth in this paragraph to a particular physical security situation.

4.1.2 Important Decisions. For all projects, the security engineer should decide, on the basis of economics and effectiveness, whether to devote resources to exterior physical security, or whether to perform the same functions on the interior, nearest the key delay barriers. It is frequently most difficult and expensive to perform access control, detection, and delay outdoors and over large areas.

4.2 Exterior Layout.

4.2.1 Introduction. Recommendations for facility exterior layout, insofar as physical security is involved, are mainly the concern of the security engineer. The facility layout must be compatible with the installation's overall security plan. The security engineer's recommendations will be governed to a large extent by factors such as the following:

- o Location of guard posts and patrols (i.e., facility surveillance).

- o Location of security response forces (i.e., their timely and safe arrival, deployment, and intruder apprehension).

- o Location and characteristics of the current or proposed intrusion detection system.

- o Facility access control (i.e., personnel and vehicle identification and traffic).

- o Natural factors (i.e., location of the facility with respect to installation boundaries; exclusion, limited, critical, and controlled areas; natural barriers; etc.).

The role of the security engineer is not only to assure that physical security requirements are met but also to assure that the facility layout is feasible, practical, and cost-effective. Thus, the purpose of this paragraph is to provide general guidelines on those security factors that drive decisions on facility exterior layout. Only general guidelines can be provided in handbooks of this type. The application of these general principles to a specific facility layout must be governed by site-specific factors, often including classified portions of installation security plans. It should be noted that it is rarely appropriate to react to the results of one security layout consideration. Rather, decisions to provide additional security measures should be made after all available information has been considered. Furthermore, although it is highly desirable that the layout incorporate security considerations from the start, that may not always be possible. In short, the security engineer may likely find himself in situations where an existing site layout will influence security measures, rather than security considerations influencing layout. In general, the exterior layout is as important as interior layout only when the exterior walls and roofs of the building are the crucial delay barriers.

4.2.2 Contributions to Security Made by Exterior Layout. Before the facility design is developed, it should be determined how the exterior layout can assist the overall security mission. In general, there are four security functions that benefit from proper layout of sites and facilities: access control, observation, deterrence and delay, and response. Attention to exterior layout can contribute significantly to their effectiveness.

4.2.2.1 Access Control. Access control is the security function whereby personnel, vehicles, and materials are identified and screened to discriminate authorized from unauthorized personnel and vehicles, and to detect contraband. Access control also includes supervising the flow and routing of traffic, both pedestrian and vehicular. Road networks, entry gates, parking areas, badging systems, parking passes, etc., contribute to exterior access control. Access control is not limited to the site boundary or main gate, but extends to all controlled areas of the activity, e.g., parking areas, controlled roads, building entrances, and even interior rooms and safes. Access control almost invariably involves requiring an easily visible identification to be displayed while in the controlled area. An extreme access control measure may involve prohibiting all privately owned vehicles from parking inside the site perimeter and an onsite shuttle transit system that can be used for onsite travel. A different access control technique is to modify the internal road network to make it time consuming to exit (escape) from the high-security areas.

4.2.2.2 Observation. Exterior observability can be essential if no significant delay time is built into facility structures. Roving patrols and even towers are frequently used options and require a relatively clear field of view to be effective. Site layouts, which place parking and most used entrances on the side of the structure away from patrol roads, defeat efficient observation. Parking and most entrances are best placed in the front of the building facing the roadways.

4.2.2.3 Deterrence and Delay. Effective deterrence and delay of penetration attempts can be greatly enhanced if security is considered in facility exterior layout. The main concern of this handbook is the provision of built-in delay time in the facility itself. A well-designed exterior layout, although adding slightly to delay, is most important in adding early detection of a penetration attempt if the facility is subject to human or IDS surveillance. It is necessary to concentrate on delay times associated with the facility itself, because tests have shown (see Paragraph 4.4) that exterior barriers are generally not very effective in increasing penetration time and will neither deter nor delay a sophisticated and determined intruder. The exception to this general rule occurs when the facility exterior itself is hardened and subject to observation. A well-thought-out exterior layout can force the intruder to make more extensive penetration plans and carry more equipment, and it can definitely increase the probability of his early detection. Moreover, one must not lose sight of the fact that deterrence of penetration attempts by intruders who are not as well-equipped and motivated is also important to facility security.

4.2.2.4 Security Force Response to Intrusion. Improving the ability to respond to intrusion attempts is the fourth major area where site exterior layout can contribute to security. Specifically, three aspects of response must be addressed: timely arrival at the intruder location, safe arrival, and the ability to take necessary actions. The guard forces must therefore possess alternate routes of access that are speedy and are not so channeled as to provide for easy ambush. The security force must also possess a technique for finding the intruders several minutes after their first detection. That is, waiting at the hole in a perimeter fence is not a good tactic. Special access roads closed to all but the security forces are one layout option bearing on this aspect. It should be noted that the ability to take necessary actions implies both the ability of response forces to subdue the intruder under effective restraint and not to injure innocent bystanders. A site layout must be designed without obstructions and with clear access to all points around the facility so that the security force has the greatest opportunity to quickly contain penetration attempts.

4.2.3 Security Layout Considerations. For the purposes of this handbook, facility exterior layout considerations are divided into three subject areas: considerations related to the entire site, considerations appropriate to an individual facility, and considerations that address security support functions. These are discussed separately in the following subparagraphs. As stated earlier in this paragraph, because of the unique function and design of various military sites, only general guidelines can be provided here.

4.2.4 Site Security Considerations. The following considerations relate to the entire site (installation).

4.2.4.1 Areas of Common Risk on the Site. The first consideration, co-locating risks of the same type, is intended to provide related assets with uniform protection. It is necessary to identify the risks, asset values, and potential threats to each facility on the installation. (See Paragraph 1.3 of Appendix A.) The objective of identifying common risks is to co-locate them, if possible, as shown in Figure 24. Appropriate security measures can then be determined and implemented for each risk level. Co-location, if it can be implemented, reduces costs and improves security effectiveness and efficiency by locating facilities requiring comparable security protection within appropriately controlled areas.

4.2.4.2 Routes of Travel. Routes of travel throughout the site must be considered. These routes include pedestrian paths and vehicular road networks. Regulation and direction of traffic must be considered. On the one hand, it is probably desirable to route unauthorized, unofficial traffic away from high-risk protected areas, such as storage magazines. On the other hand, it may be desirable to route as much traffic as possible along main thoroughfares that serve facilities with high traffic densities during duty hours, such as warehouses. In this case, the potential observation of intruders by passersby during non-duty hours might enhance deterrence and

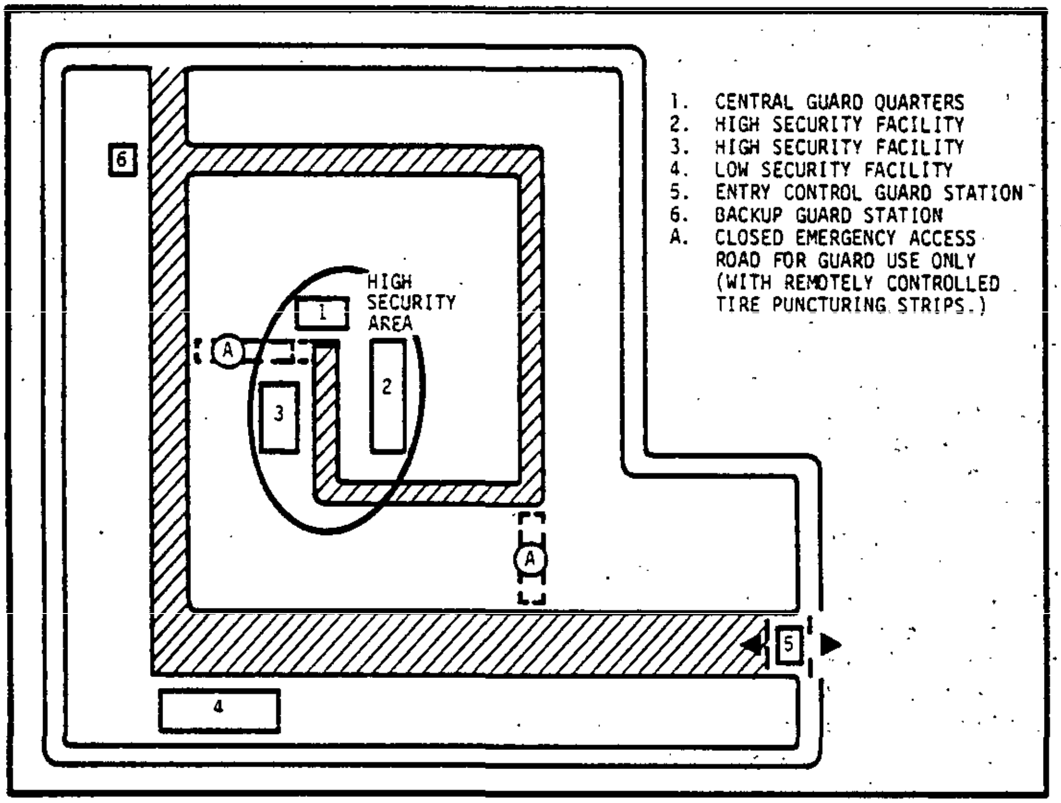


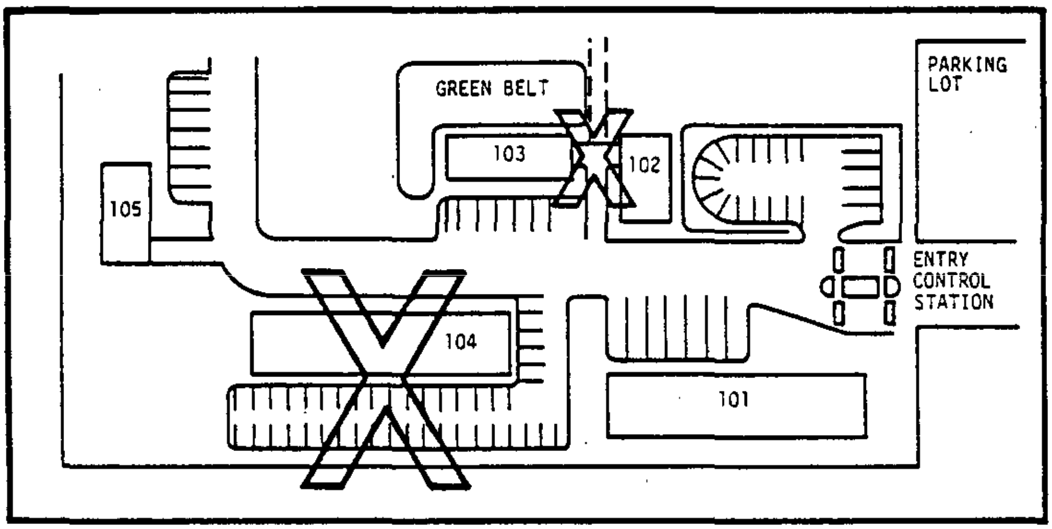
FIGURE 24. Base layout options.

identification of intruders. Road networks and facility layout must also account for the needs of the security roving patrols and response forces. For example, multiple approaches to the facility should be available to minimize the predictability of response forces always using the same route of approach for either surveillance or response. Access paths to all points around the facility should be provided to allow for intruder assessment and interdiction. The paths identified as A in Figure 24 are intended to function in this manner.

4.2.4.3 Points of Observation. The site design should also consider the points of observation to be used for performing security detection, assessment, and interdiction functions. Obviously, the geometric layout can facilitate the security force's ability to observe the site. Surveillance of the entire site, especially its critical areas, is required. Exterior observation posts may vary in kind, such as static and roving patrols on ground level and above ground level and CCTV. It is possible and necessary to ensure that all parts of the facility, including entrances, are easily observed, that pathways are well-lighted, that road networks and parking areas are designed to prevent congestion and assist observation, and that the facility exterior barriers are generally placed in areas free of visual obstructions. For example, Figure 25 indicates how layout of parking areas can assist observation. Normal architectural prerogatives usually "hide" the parking and doorways (except for the main formal entrance) in back of the building and beautify the front. In the figure, these types of decisions are deleted by the large "X's" in favor of forcing all parking to be highly visible to guards patrolling the road. The security engineer should recognize that the foregoing guidance applies primarily to a facility's exterior where observation by security personnel or an IDS is required. An intruder who can penetrate unobserved through a facility's exterior barriers, no matter how they may be hardened, can continue undetected into the secured area. Delay time itself buys very little if it is not coordinated with a detection and assessment system. The security engineer should, therefore, carefully consider the exterior and interior tradeoffs among detection, assessment, and delay to produce a cost-effective system for the site.

4.2.4.4 Points of Entry. Entry ports must be provided for pedestrian and vehicular traffic. Placement of gates should reflect the minimum necessary number. Entry control should occur only at that point on the site where access is limited, rather than at the outer site perimeter. Low-risk area entrance points should be convenient and accessible to general traffic. Entrances to high-risk exclusion and limited areas should be out of the primary traffic pattern.

4.2.4.5 Exterior Barriers. The designer should also consider the effective placement of exterior barriers in his design. The term exterior barrier has typically been limited to fences, vegetation walls, and waterways. If properly situated, exterior fences and wall barriers can create effective obstacles to casual trespassers. Although they offer very limited penetration times against intrusions (see Paragraph 4.4), the use of barriers may deter the



X signifies undesirable plans.

FIGURE 25. Example parking plan.

nondedicated threat and, thus, has a place in site layout design. Section 8 provides detailed information on the types of advanced vehicle barriers (crash-resistant) now available for use in restricting vehicle access to critical facilities. With today's threat, they are essential elements in a security system. The introduction of access road layouts to meet security objectives, such as 90-degree turns to prevent high-speed runs at barriers, also assists in their effectiveness.

4.2.4.6 IDS System Compatibility. The site intrusion detection system must be identified and included during the planning of site layout. Proper layout can enhance both the effectiveness (high probability of correct detections) and efficiency (reduced false and nuisance alarms) of the IDS. Furthermore, IDS needs cannot be completely identified until the proposed site layout plan has been consulted. If the IDS is designed to provide surveillance of a long fence line, then high system costs should be expected as a result of a relatively large number of false alarms and for maintenance of a complex system. Detection and assessment sensors near the exterior of the facility are in general more effective from a performance and cost point of view. On the other hand, if the intrusion detection sensors and fences are located close to the facility building, and if facility delay time is too low, the time available for effective security force response may also be too low. To ensure that resources are wisely spent, the relationship between exterior sensor location, delay times, and security force response times must be carefully examined (see Appendix A for further discussions).

4.2.4.7 Clear Zones. Clear zones serve to improve the ability of guards and the IDS system to observe the facility and to detect or assess intrusions. Clear zones are a useful element of a site layout and, in reference to the Navy, are a requirement.

4.2.4.8 Terrain. The exterior layout must account for site terrain features. If terrain is properly considered during the design phase, it can be used to enhance some security measures. On the other hand, if the characteristics of site terrain are not dealt with, they can significantly limit the effectiveness of the security system. In general, if not properly accounted for, terrain features may provide areas for intruders to hide in, may offer intruders protection from security force weapons, or may serve as assembly points for attacking forces.

4.2.5 Facility Security Considerations.

4.2.5.1 Location With Respect to Other Buildings. It is important to consider a facility's location with respect to other buildings on the site. Specifically, nearby buildings should be identified in terms of both type and function. It may be possible, for example, for a tunnel to be dug from an unsecured building to the secured facility. High traffic areas should also be identified. Finally, the location of high-risk, protected areas should be noted as well as nearby firefighting, public safety, and security teams and equipment capable of dealing with emergency situations.

4.2.5.2 Building Orientation. If parts of the building exterior, especially the access points, are not observable from existing security posts or patrol routes, improved detection and assessment capabilities as well as increased building delay time may be needed. To accomplish this may require the use of IDS hardware, additional security posts, or patrol routes. In addition, it may require more frequent patrols. In the case of the design of a building before its construction, it may simply involve reorienting the building.

4.2.5.3 Building Location With Respect to Exterior Barriers. The relationship between the facility and exterior barriers affects security. Consideration of barriers should not be limited to walls and fences but should also include natural terrain features, such as hill elevation and tree lines. In this manner, potential penetration and ingress times beyond the facility's exterior walls can be identified. In the event a building is difficult to observe and is placed against a natural terrain feature, such as woodlands, additional security measures may be required.

4.2.5.4 Determination of the Facility Intrusion Detection System. Design of the facility IDS must be considered in conjunction with design of the site layout. This is necessary to ensure that layout and security equipment interface as efficiently and effectively as possible.

4.2.6 Security Support Functions. The final exterior layout considerations are those site functions that support facility and related security systems. These include security power supply, general power supply, communications, and actual security control.

4.2.6.1 Security Power Supply. Both regular and standby power sources must be provided for IDS and security lighting. In some cases, dual emergency backup power sources may be required, particularly if power transformer stations are vulnerable. All critical power, communications, and IDS lines should be well-protected, usually by burial. In the case of light poles, cabling should be internal to aluminum or steel poles. Standby power sources must be protected from sabotage by facility hardening and IDS coverage. Standby power sources should be configured for automatic activation when required.

4.2.6.2 General Power Supply. Some of the best tools used for rapid penetration of hardened facilities are electrically powered. Although a sophisticated attacker will probably not let himself be dependent on facility power sources, it is worthwhile to consider arrangements where the general power supply to a facility exterior and just outside any key interior barriers (other than that required for essential services such as IDS) is either normally shut off during nonworking hours or can be shut off remotely by the security forces. Switch and fuse boxes must be protected.

4.2.6.3 Communications. To the extent feasible and practical, consideration should be given to hardening both internal and external communications lines so that security forces will not be easily deprived of their use during emergencies. As mentioned above, communication lines essential to IDS alarm assessment must be hardened and protected with fail-safe features. Phone jacks for security personnel should be provided, as necessary, at external locations. Another possible option is to equip security personnel with hand-held radios.

4.2.6.4 Central Security Control. A central security control (CSC) is established for the purpose of providing a central, continuously manned facility for one or more of the following:

o Alarm annunciation, display, and control.

o Centralized control and communications for base, installation, or facility security operations.

o Cantonment quarters for security alert guard force.

o Monitoring of a remote entry control or surveillance system such as closed circuit television, electronic locking devices and systems, and similar systems.

o Control of entry to restricted area.

o Housing, storage or parking for guard force support equipment including arms, ammunition, portable communications and observation equipment, and vehicles. Depending on the size of a facility or installation, the CSC can vary from an assigned and physically isolated area within a building to a structure designed and constructed especially for the purpose.

4.3 Exterior Security Lighting.

4.3.1 Overview. One function of security lighting is to provide light during periods of darkness and low visibility to aid observation by security personnel. Lighting, generally, also has value as a deterrent to nondedicated intruders. Normally, security lighting uses less candle power than working area lighting, except at ports of entry. Security lighting is used to increase effectiveness of guard systems and closed circuit television by increasing the visual range of the guards and CCTV monitors during periods of darkness or by increased illumination of an area where natural light does not reach or is insufficient. Exterior security lighting is advisable only to ensure a minimal level of visibility when guards are positioned to perform inspection duties properly around the exterior. Guards and CCTV monitors must be able to see badges, people at gates, inspect vehicles, stop attempts at illegal entry, detect intruders inside and outside buildings, and observe unusual or suspicious circumstances. Each facility presents its particular problems based on physical layout, terrain, atmospheric conditions, and security requirements. The remainder of this paragraph discusses standard types of lighting, lighting concepts, lighting as a deterrent, lighting for CCTV and surveillance, and related lighting issues (energy and legal). Exterior lighting should not be routinely specified for physical security but should be considered as an option and compared to other interior lighting for detection and deterrence.

4.3.2 Standard Exterior Lighting Types. The type of lighting system required depends on the overall security requirements of the base concerned. Lighting units of four general types are used for security lighting systems: continuous, standby, movable, and emergency.

4.3.2.1 Continuous Lighting. Continuous lighting (stationary luminaires) is the most common security lighting system. It consists of a series of fixed luminaires arranged to flood a given area continuously during the hours of darkness with overlapping cones of light. The two primary methods of using continuous lighting are glare projection and controlled lighting.

Glare lighting uses luminaires slightly inside a security perimeter and directed outward. The glare projection lighting method is useful where the glare of lights directed across surrounding territory will neither annoy nor interfere with adjacent operations. It is considered a deterrent to a potential intruder because it makes it difficult for him to see the inside of the area being protected. It also protects the guard by keeping him in comparative darkness and enabling him to observe intruders at considerable distance beyond the perimeter.

The controlled lighting method is best used when it is necessary to limit the width of the lighted strip outside the perimeter because of adjoining property or nearby highways, railroads, navigable waters, or airports. In controlled lighting, the width of the lighted strip can be controlled and adjusted to fit a particular need, such as illumination of a wide strip inside a fence and a narrow strip outside, or floodlighting a wall or roof. Unfortunately, this method of lighting often illuminates or silhouettes security personnel as they patrol their routes.

4.3.2.2 Standby Lighting. A standby lighting system is different from continuous lighting since its intent is to create an impression of activity. The luminaires are not continuously lighted but are either automatically or manually turned on randomly or when suspicious activity is detected or suspected by the security force or IDS. Lamps with short restrike times are essential if this technique is chosen. This technique may offer significant deterrent value while also offering economy in power consumption.

4.3.2.3 Movable Lighting. A movable lighting system (stationary or portable) consists of manually operated movable searchlights, which may be lighted during hours of darkness or lighted only as needed. This system normally is used to supplement continuous or standby lighting.

4.3.2.4 Emergency Lighting. An emergency lighting system may duplicate any or all of the above systems. Its use is limited to times of power failure or other emergencies, which render the normal system inoperative. It depends on an alternative power source, such as installed or portable generators or batteries.

4.3.3 Lighting Specification. A lighting specification table for applying proper amounts of light for visual surveillance to specific locations is presented in Table 25. This table provides general guidance for foot-candles as a function of location type. Table 26 provides a guide for the type of area that should be illuminated.

4.3.4 Lighting Concepts. Exterior lighting may be designed for direct illumination, indirect illumination, intermittent illumination, or responsive area illumination.

4.3.4.1 Direct Illumination. This lighting concept is the most widespread and involves directing light down from a structure roof to the ground immediately surrounding the structure. Its goal is to provide a specified intensity of illumination on intruders, facilitating their detection by CCTV or security patrols.

4.3.4.2 Indirect Illumination. An alternative lighting concept involves backlighting the intruders against the structure. This may be done by placing lighting away from the building and directing it back toward the walls so shadows will be cast on the building by the threat. Such applications are most effective if the luminaires themselves are near ground level. This indirect concept is also aesthetically pleasing, illuminating the architecture during darkness.

4.3.4.3 Intermittent Lighting. A deterrent lighting system can be developed to turn lights on at random times. It can use either direct or indirect illumination concepts. Such an intermittent lighting system can involve a duty cycle of 10 to 50 percent although it may increase operational and maintenance costs since this approach may force the use of inefficient lamps or reduce lamp life. Deterrence can actually be higher for such a system because of its appearance of activity. Luminaires may be controlled individually or as a group.

4.3.4.4 Responsive Area Illumination. Rather than randomly activating the luminaries, an IDS sensor can be used to turn on the lights when an intruder is detected. This type of active lighting system provides maximum deterrent value at a low duty cycle. Such a responsive area system, if installed, is subjected to the same nuisance and false alarms of any sensor system. Since the lights will be activated more frequently than intruders will be present, the area should be assessed using CCTV.

TABLE 25.

Lighting specification (foot candles).

Location	Foot Candles on Horizontal Plane at Ground Level
Isolated fenced boundaries	0.15
Semi-isolated fenced boundaries	0.04
Nonisolated fenced boundaries	0.08 [if 40 ft (12 m) outside boundary] 0.10 [if 30 ft (9 m) outside boundary]
Building face boundaries	0.10
Unfenced boundaries	0.04
Waterfront boundaries	0.10
Entrances	2.00 (pedestrian) 1.00 (vehicular)
Industrial throughfares	0.15 (if not bordered by buildings) 0.40 (when bordered by buildings)
Open yards	0.15
Outdoor storage spaces	0.15
Piers and docks	
Land approaches	0.40
Water approaches	0.50 [horizontal out to 50 ft (15 m)] 0.05 [vertical from 50-100 ft (15-30 m)]
Decks of piers	1.00
Underneath piers	0.04
Critical structures	2.00

TABLE 26.

Illuminated area specification.

Type of Area	Width of Lighted Boundary (ft, m)	
	Inside	Outside
Isolated fence boundaries	10 (3 m)	25-200 (8-60 m)
Semi-isolated fence boundaries	10 (3 m)	70 (21 m)
Nonisolated fence boundaries	20-30 (6-9 m)	30-40 (9-12 m)
Building face boundaries	N/A	50 (15 m)
Unfenced boundaries	N/A	80 (24 m) from building
Waterfront boundaries	10 (3 m)	50 (15 m)
Piers and docks (water approaches)		100 (30 m)
Piers and docks (land approaches)		Above as applicable

4.3.5 Lighting as a Deterrent. The Federal Government has sponsored several research investigations to address the issue of lighting as a deterrent. Two agencies, the National Bureau of Standards (NBS) and the National Institute of Law Enforcement and Criminal Justice (NILECJ), have executed or sponsored research studies to determine whether security lighting has a deterrent effect. Two NBS evaluations examined the deterrent effect of perimeter lighting and concluded that security lighting only has a deterrent effect upon the opportunistic intruder (e.g. the vandal or prankster). The NILECJ-sponsored research investigated the relationship between street lighting and crime. The results of this research are uncertain. The lack of reliable and uniform data and the inadequacy of available evaluation studies preclude a definitive statement regarding the relationship between street lighting and crime. There is no statistically significant quantitative evidence that street lighting impacts the level of crime, especially if crime displacement is taken into account. There is a strong indication that increased lighting decreases the fear of crime. (The NBS and NILECJ studies are included in Appendix D). In spite of the lack of a definitive measure for the deterrent value of security lighting, there is a genuine reluctance within the security community to dismiss deterrence as a design objective of security lighting.

4.3.6 Lighting for CCTV and Surveillance. Lighting requirements for CCTV are considerably higher than those required for direct visual surveillance. CCTV cameras must be oriented so that they are not blinded by the rising or setting sun and so that the luminaires do not shine directly into their lenses. The optimal spectrum for CCTV lighting is different than that for human observation.

4.3.7 Related Lighting Issues. There are interactions between a security lighting system and its contiguous, larger environment, which may be relevant to designing a security lighting system. These interactions involve security lighting, its energy demand, its impact on certain legal issues, and the importance of restrike time as a performance parameter. Each one of these interactions may be viewed as placing constraints on the lighting design and operation of the lighting system. These constraints, in turn, cannot be ignored when evaluating the impact of security lighting on crime. The energy, legal, and restrike issues are considered in more detail below.

4.3.7.1 Energy Issues. Since the energy shortage of 1973-74, virtually every system that consumes energy has come under scrutiny for the identification of possible energy savings, and security lighting systems are no exception. In fact, this scrutiny is probably as much related to the conspicuousness of security lighting as to the amount of energy consumed. The only statistics that are available on lighting pertain to the energy required to maintain street lighting systems, which constitutes a negligible amount, 0.18 percent, of the total energy consumed in the United States. Security lighting currently implemented uses considerable less energy than street lighting.

Recently, the direction of the security community to reduce energy costs in security lighting has resulted in replacing luminaires to increase source efficacy by changing to high-pressure sodium lamps because they produce more lumens per watt than either mercury vapor or incandescent lamps, which are the two most widely used lamps in the United States today. Table 27 presents the relative efficacies and restrike times of alternative light sources.

4.3.7.2 Legal Issues. The law is becoming increasingly involved in two areas of street lighting in the civil sector. First, local building security ordinances have extended the concept of building codes to include property owners' obligations to take basic security-oriented steps, including lighting. Second, the possible civil liability of individuals or municipalities for damages incurred as a result of criminal activity following reductions in security lighting may create incentives for better illumination. There have been several cases reported where a city or property owner has been found liable for negligence from the lack of adequate security and outdoor lighting. These types of liability problems may not apply to DOD because of tortuous immunity under the Federal Tort Claims Act. However, prudence may dictate that security lighting should be an element of the security system at or near facilities experiencing high loss rates.

4.3.7.3 Restrike Time. The differences in restrike time among the various lamps (see Table 27) influence the selection of security lighting systems and concepts. For example, high-pressure sodium lamps are the primary light source of most security systems because of their efficiency (140 lumens/watt). However, these lamps are not without deficiencies. From a cold start, a high-pressure sodium lamp warms up to full light output in about 10 minutes. It will usually restrike in less than 1 minute and warmup in 3 to 4 minutes. During this warm-up interval, the lamp cannot be expected to be operating at full light output, and this reduced capacity may be important in many high-security applications. Because of this restrike interval, incandescent lamps are sometimes used as the emergency backup light source because of their short restrike time. The evaluation of any security lighting system, particularly one requiring continuous illumination, requires careful analysis of lamp life, energy consumption, and restrike time. The security engineer, who has determined that a short restrike time is a critical performance parameter, should determine whether the short restrike timeline is economically feasible in relation to increased lamp replacement and energy costs.

4.4 Exterior Barriers

4.4.1 Overview. The use of exterior barriers to enhance the physical security of facilities is the subject of this paragraph. Although barriers can assume a wide range of forms, such as walls, ditches, berms, and barricades, the scope of security guidance provided in this paragraph is limited to fences. See Section 8 for specific information regarding vehicle barriers. The principal point that should be recognized about fences from a security point of view is the negligible penetration time they provide against a determined threat. The same

TABLE 27.

Relative efficacies and restrike times of light sources.
(From IEW Lighting Handbook, edited by J.E. Kaufman)

Lamp Type	Efficacy (Lumens/Watt)	Restrike Time (minutes)
Theoretical Maximum	683	---
Ideal White Light	220	---
Incandescent	10 - 16	fractions of a minute
Tungsten - Halogen	17 - 25	fractions of a minute
Mercury Vapor	30 - 65	3 - 7
Fluorescent	33 - 77	fractions of a minute
Metal Halide	75 - 125	up to 15
High Pressure Sodium	60 - 140	1 (restrike) 3 - 4 (warm-up to full output)
Low Pressure Sodium	180	7 - 15

point, of course, can be made about perimeter security walls that are erected at many facilities. For penetration time information about such walls, see the penetration time tables in Paragraph 3.1 that relate penetration times to attacks through reinforced, CMU, and stone walls. Because of the high penetration times through wall barriers, an intruder will probably go over a wall rather than through it. For attacks that involve penetrations either over or under perimeter fences, the data provided in this paragraph should be used. The user should be careful to use penetration time information that relates to the correct height of a perimeter barrier, whether it is a wall or a fence. The remainder of this paragraph discusses the function of fences, factors to consider in the selection of construction materials, penetration times for the conventional means of constructing fences, and fence hardening options. As the information below demonstrates, fences should not be routinely specified for physical security delay purposes.

4.4.2 Functions. Fences, as used in physical security, serve multiple functions. They are used to accomplish one or more of the following:

o Provide a legal boundary by defining the outermost limit of a facility.

o Assist in controlling and screening authorized entries into a secured area.

o Support detection, assessment, and other security functions.

o Deter "casual" intruders from penetrating into a secured area.

o Cause an intruder to make an overt action that will demonstrate his intent.

o Briefly delay access to a secured area or to facilities under construction.

4.4.3 Selection Factors. The facilities engineer should select the most cost-effective exterior fences, considering the penetration time requirements, cost constraints, and functional requirements.

4.4.3.1 Penetration Time. In general, fences (conventional or hardened) offer less than 2 minutes of penetration time. However, they can be constructed of materials that give the appearance of hardness, which will deter the casual intruder but not the dedicated threat.

4.4.3.2 Cost. Cost must be considered from the viewpoint of fence configuration and maintenance. As pointed out above, fences do not offer much delay time but can be constructed to appear impregnable. This will impact cost considerations since the appearance of impregnability will necessitate new design configurations. Such configurations will probably necessitate the increased use of fencing material (i.e. barbed tape, fabrics, etc.) and, thus, increased cost. The use of added fence materials may also increase the cost of maintenance due to increased material replacement from the effects of inclement weather, unusual environmental conditions, animals, and "pranksters." A double fence, constructed of chain link with one of the fences topped with barbed tape, costs in excess of $55 per foot (300 mm) of perimeter length.

4.4.3.3 Other Considerations. Fences should be designed to complement the other physical security elements. The fences should not produce glare. This is usually accomplished by painting the fabric black, using a fabric with a black polyvinyl chloride (PVC) coating, or an electrogalvanized painted fabric.

4.4.4 Evaluation of Fence Penetration Times. Exterior fence configurations that are being considered for use and have been tested to date offer very limited delay time. At present, the only fences that have received research, development, test and evaluation attention are those made of standard metal fence fabric with various enhancements (see Table 28). The recommendation for a "standard security fence" is consistent with the penetration time information that is known for common chain link fences. Such fences provide penetration times of less than 2 minutes and therefore should not be deployed with the expectation that they contribute significantly to delay of dedicated intruders. The discussion below, relating to fence hardening options, demonstrates that enhancements do not alter this conclusion. Consequently, the security engineer who decides to expend greater resources on fencing configurations of the type described below should only do so either because a military regulation requires him to do so, or because there is a specific determination that such a fencing configuration provides a greater increment of deterrence than the standard security fence. Many different fence configurations have been tested to obtain baseline penetration times. Trained and dedicated intruder teams have demonstrated a consistent ability to quietly penetrate 8-foot (2,400-mm) chain link fences topped with barbed tape within 3 to 8 seconds.

4.4.5 Hardening Options. Since fences alone offer very little deterrent value against dedicated intruders and even less penetration time, a great deal of attention has been given to the development and testing of enhanced fence configurations. Chain link fence enhancements are typically limited to different configurations and combinations of barbed wire outriggers, barbed tape concerting, and General Purpose Barbed Tape Obstacle (GPBTO) developed by the Navy. Figures 26 through 28 identify many of the enhanced fence configurations that have been tested. As in the case of conventional fences, the hardening options and enhancements that are available do not significantly affect penetration times (less than 2 minutes). The height of a fence has proven to add little more than seconds to the penetration time. To increase the difficulty of penetrations under a fence, it is recommended that some form of fabric tiedowns be installed. Tiedowns vary in type from steel wires holding the fabric firmly to anchor posts, to encasing the fabric in a concrete sill. (Imbedding the fence fabric in a concrete sill will effectively preclude any future retensioning of the fabric.) The use of tension wires along the lower portion of the fabric will also hamper, although certainly not stop, a penetration attempt.

TABLE 28.

Common chain link fence materials.

Component	Options
Gauge	#9 (3.8 mm), #11 (3.0 mm),
Mesh	2 in (50 mm), 1.6 in. (40 mm), 2.4 in. (60 mm)
Coating	vinyl, galvanized
Tension Wires	wire, rail, cable (attached at top or bottom)
Support Posts	metal posts (see Federal Specifications RR-F-191H/GEN and RR-F-191/3B)
Height	6 ft (1,800 mm), 7 ft (2,100 mm), 8 ft (2,400 mm)
Fabric Tie Downs	buried, encased in concrete, staked
Pole Reinforcement	buried, encased in concrete
Gate Opening	swing, slide, lift, turnstile

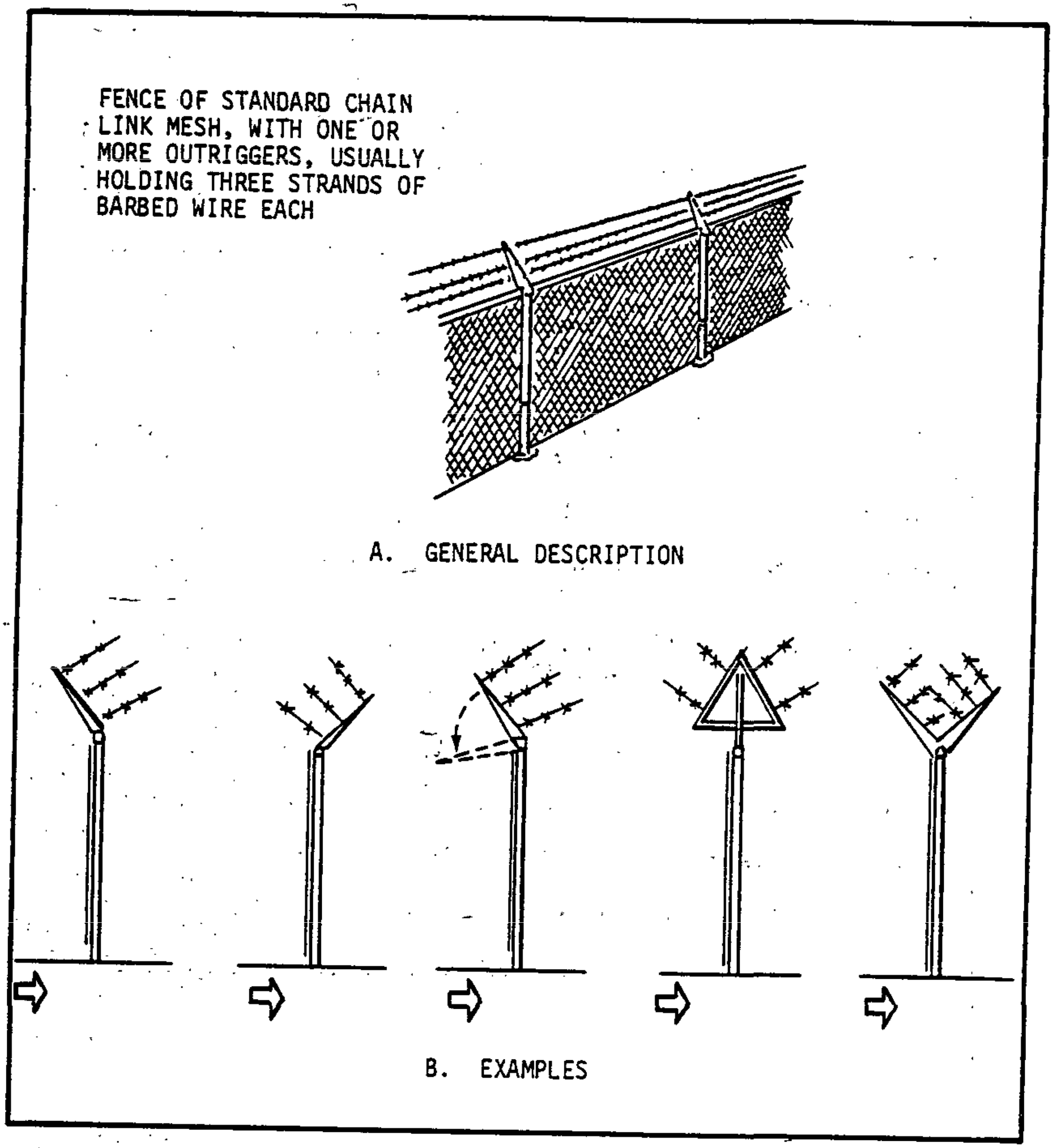


FIGURE 26. Fabric with barbed wire outriggers fence configuration.

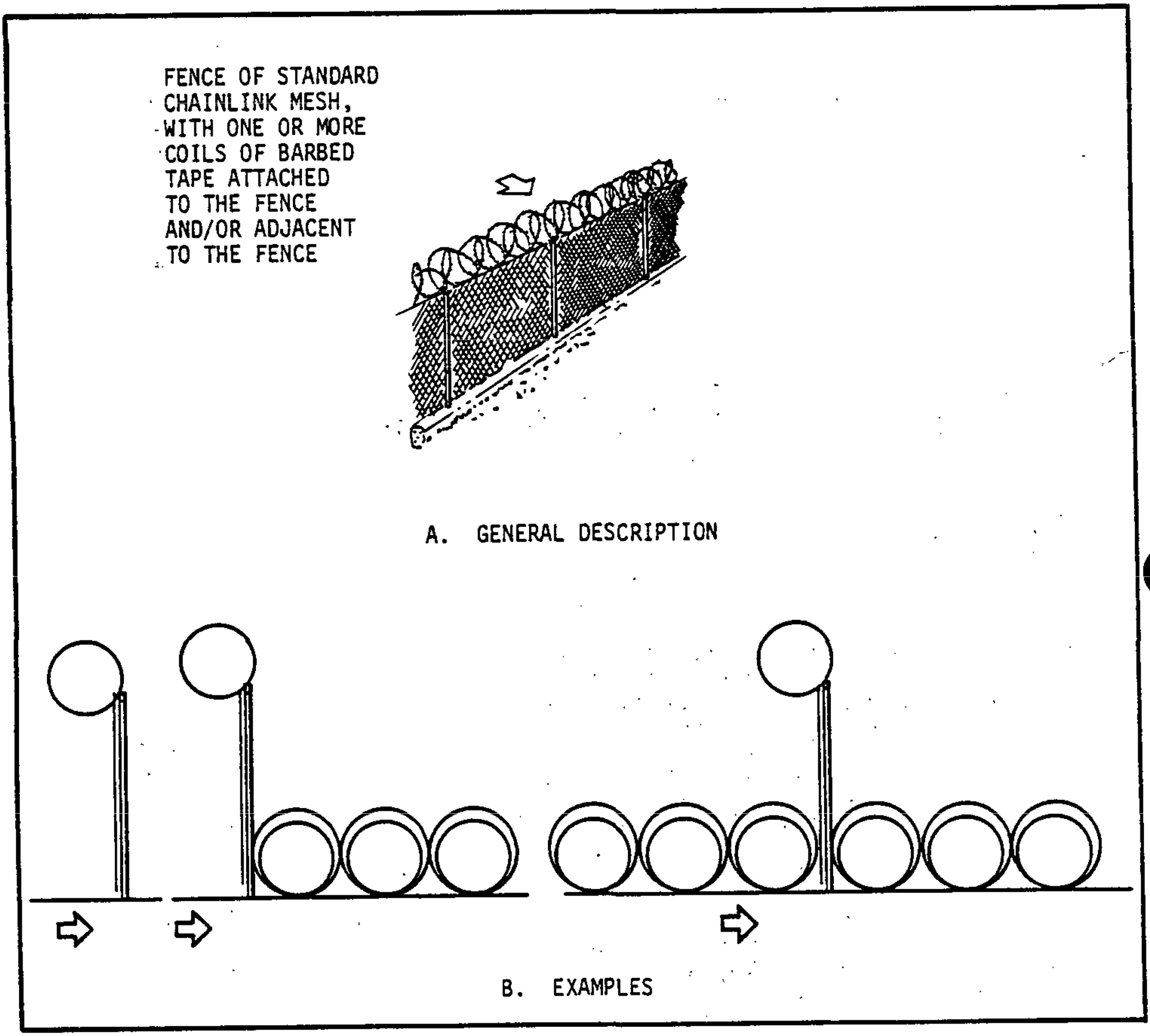


FIGURE 27. Fabric with barbed tape coils fence configurations.

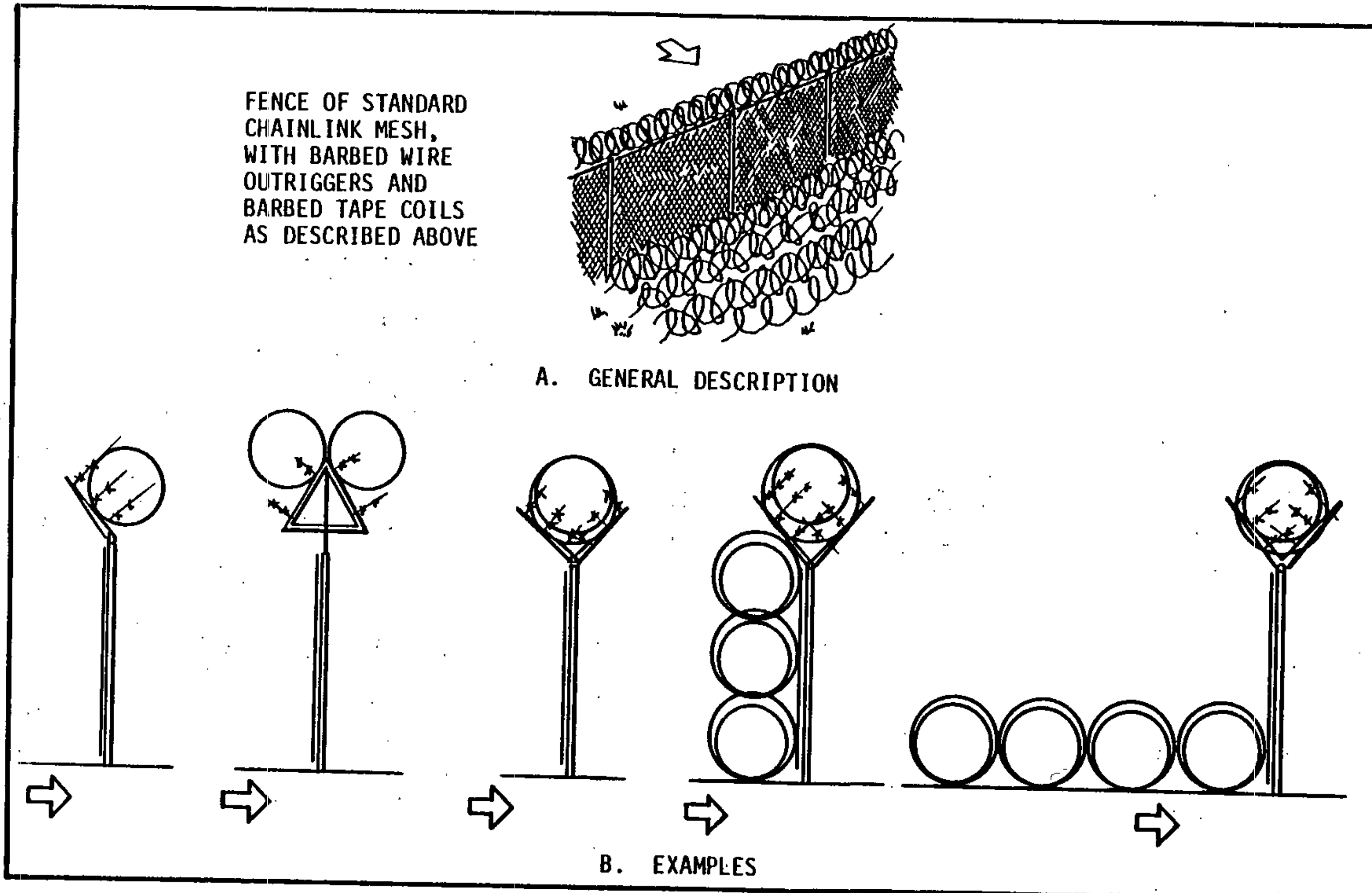


FIGURE 25. Fabric with barbed tape coils and barbed wire outriggers fence configuration.

SECTION 5: HARDENING EXISTING ARMS, AMMUNITIONS, AND EXPLOSIVE FACILITIES

5.1 Use of Design Guidance Information. The retrofit design guidelines presented in this paragraph are intended to establish minimum standards and should not prevent the use of a higher level of physical security, where applicable. Penetration times that are available are summarized in Table 29 for the hardening options discussed in this paragraph.

5.2 Ventilation Openings.

5.2.1 Overview. Door, wall, or roof ventilators in an earth-covered magazine often can provide the best means of penetrating the structure. Any AA&E ventilator that is equal to or exceeds 96 square inches (0.06 m^2) must, therefore, be secured.

5.2.1.1 Door Ventilators. Most magazine door ventilators are shrouded, shrouded and louvered, or simply louvered. These openings can be quickly and easily penetrated because of inherent weaknesses in the external mounting, quality of the mounting, or because, in some cases, the steel of the ventilator is considerably lighter than the door. All external shrouds should be mounted with a continuous bead weld along all edges. Many door ventilators can be readily reinforced on the inside with riveted steel grating, MIL-G- 18014 Type A, Class B, as shown in Figure 29. Where design of the door permits, this cover should be welded flush with the inside of the door. If door stiffeners and ventilator frames do not permit flush mounting, this cover should be offset mounted, using a 1/4-inch (6-mm) flat bar or angle steel at the minimum possible offset. An alternative to the welding of this grate to the door is to mount it with 1/2-inch (13-mm) steel bolts and a 1/4-inch (6-mm) flat bar in the manner shown in Figure 30, with the ends of the grating extending 6 inches (150 mm) beyond the opening and the bolts and nuts welded to prevent removal.

5.2.1.2 Wall Ventilators. All wall ventilators should be externally shrouded using, as a minimum, a 3/8-inch (9-mm) steel plate (see Figure 31). The shroud should extend well below the bottom edge of the ventilator, and the minimum possible distance should be between the wall face and the shroud plate. It should be noted, however, that a solid steel plate placed in front of the ventilator will restrict the air flow because of the blockage in front of the open area. Compensation for this air flow reduction should be made. The security engineer should determine whether the distance between the wall face and the shroud plate and the shroud attachment mechanism permits required air flow. Internally, a cost-effective method of increasing resistance is to use riveted steel grating, MIL-G-18014B, Type A, Class B, cut with a minimum 6-inch (150-mm) overlap on all sides of the ventilator opening. Two installation techniques are shown in Figure 31. One requires welding the steel grating to an existing steel frame surrounding the vent. The other technique requires no welding. Steel flat bars, 1/4 by 2 inches (6 by 50 mm), drilled to accept 1/2-inch (13-mm) expansion fasteners, should be used to hold the grating to the wall. Any concrete anchor meeting the requirements of ASTM or military specifications may be used. To ensure maximum pullout strength, the holes must be drilled carefully to ensure tight fit of the fastener. The fastener must not be installed closer than 4 inches (100 mm) to the edge of the concrete. The bolt should be welded to the frame.

5.2.1.3 Roof Ventilators. Roof ventilators in older magazines may open directly into the magazine ceiling or may open high on the rear magazine wall. These ventilators should be protected through the internally mounted vent covers. The light sheet metal and ceramic tile construction of the older magazine vents precludes reinforcing the roof ventilators at any point other than the inside opening. In concrete arch magazines, use of riveted steel grating mounted as shown in Figure 32, similar to the technique used for wall ventilators, can be used for enhanced penetration resistance.

5.3 Door Surface Protection. The user is referred to Paragraphs 3.1 and 3.2 for retrofitting hardening options applicable to AA&E magazine doors.

5.4 Door Hinge Side Protection. The standard door designs used in existing magazine structures for AA&E storage in almost all cases are vulnerable to physical attack on the hinge side of the door by cutting hinge mounting bolts, by cutting and driving out the hinge pintle pin, or by cutting the hinge assembly. A positive door-to-jamb interlock is, therefore, required. Figures 33 through 36 show the cross sections of hinged doors and door frames, with various options of passive hardware for positive interlocking at the hinge edge to prevent entry by physical attack at the hinge edge. This approach prevents the hinged edge from being pushed in or pulled out when the door is closed and locked. The design options shown have the advantage of not producing a safety hazard by extending the interlocking hardware into the clear door opening.

5.5 High-Security Locks and Hasps. The high security locking device (shown in Figure 14 and described in Subparagraph 3.2.2) and the high-security hasp shown in Figure 37 are both authorized as acceptable systems for securing AA&E storage facilities. The high-security Naval Ammunition Production Engineering Center (NAPEC) 0957 or 0958 hasp shown in Figure 37 consists of a hardened stainless steel shrouded hasp for installation on inactive doors and door frames. The high-security padlock (see Figure 13 in Subparagraph 3.2.2) and the NAPEC 0957 or 0958 hasp (Figure 37) can be used to form a high-security locking system. In addition, the medium-security lock (Table 25) and the NAPEC 0957 or 0958 hasp can form a high-security system if a pair of anti-rotation blocks are added to the hasp. The NAPEC 0957 and 0958 hasps are Government furnished, contractor installed. Figures 38 through 41 illustrate the types of door configurations commonly found in existing AA&E structures and the high-security hasp that is applicable for each particular door style. The following information should be used to determine the correct hasp for the different types of doors.

TABLE 29.

Penetration times for AA&E upgrade hardening.

Construction Type	Penetration Time (minutes)
Wall Construction	
Reinforced Concrete	5 to >60
Masonry	5 to 30
Stud/Girt	≤2 to 20
Roof/Floor Construction	
Reinforced Concrete	5 to >60
Wood	5 to 20
Metal	5 to 20
Doors	≤2 to >60
Windows	≤2 to 8
Utility Openings	2 to 40
Hasps and Locks	≤7

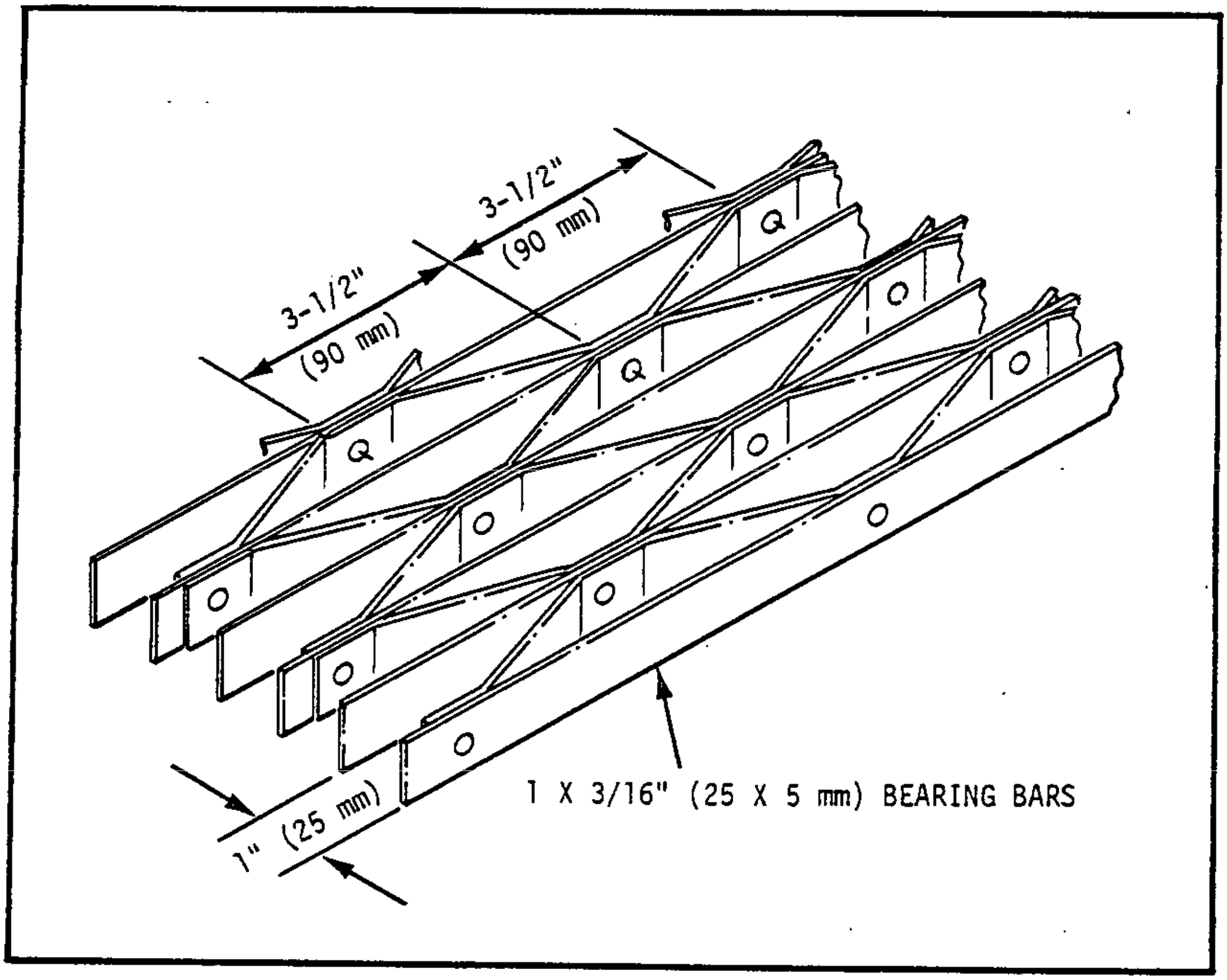


FIGURE 29. Riveted steel grating.

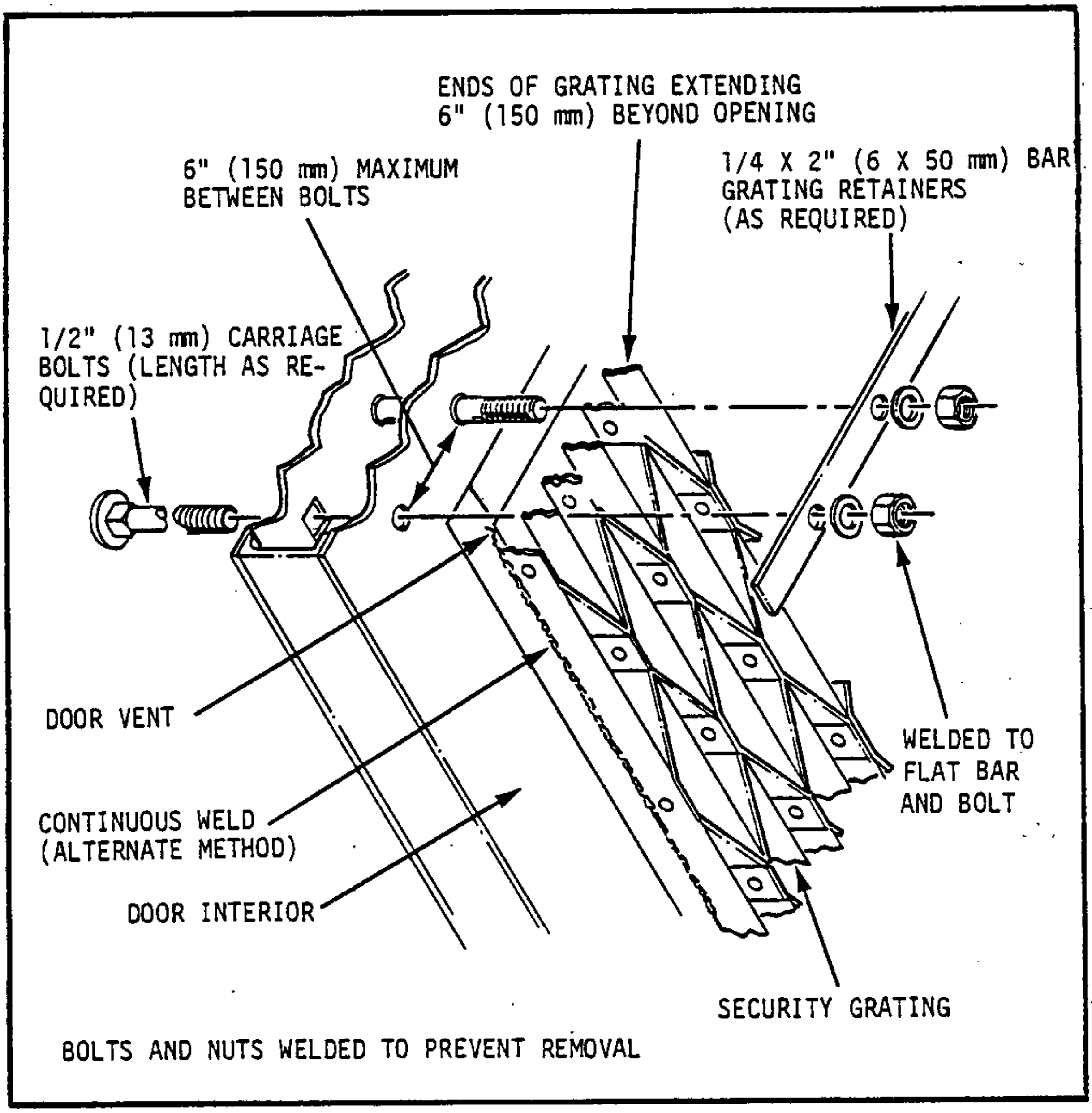


FIGURE 30. Security intrusion protection plan for hardening a typical door ventilator.

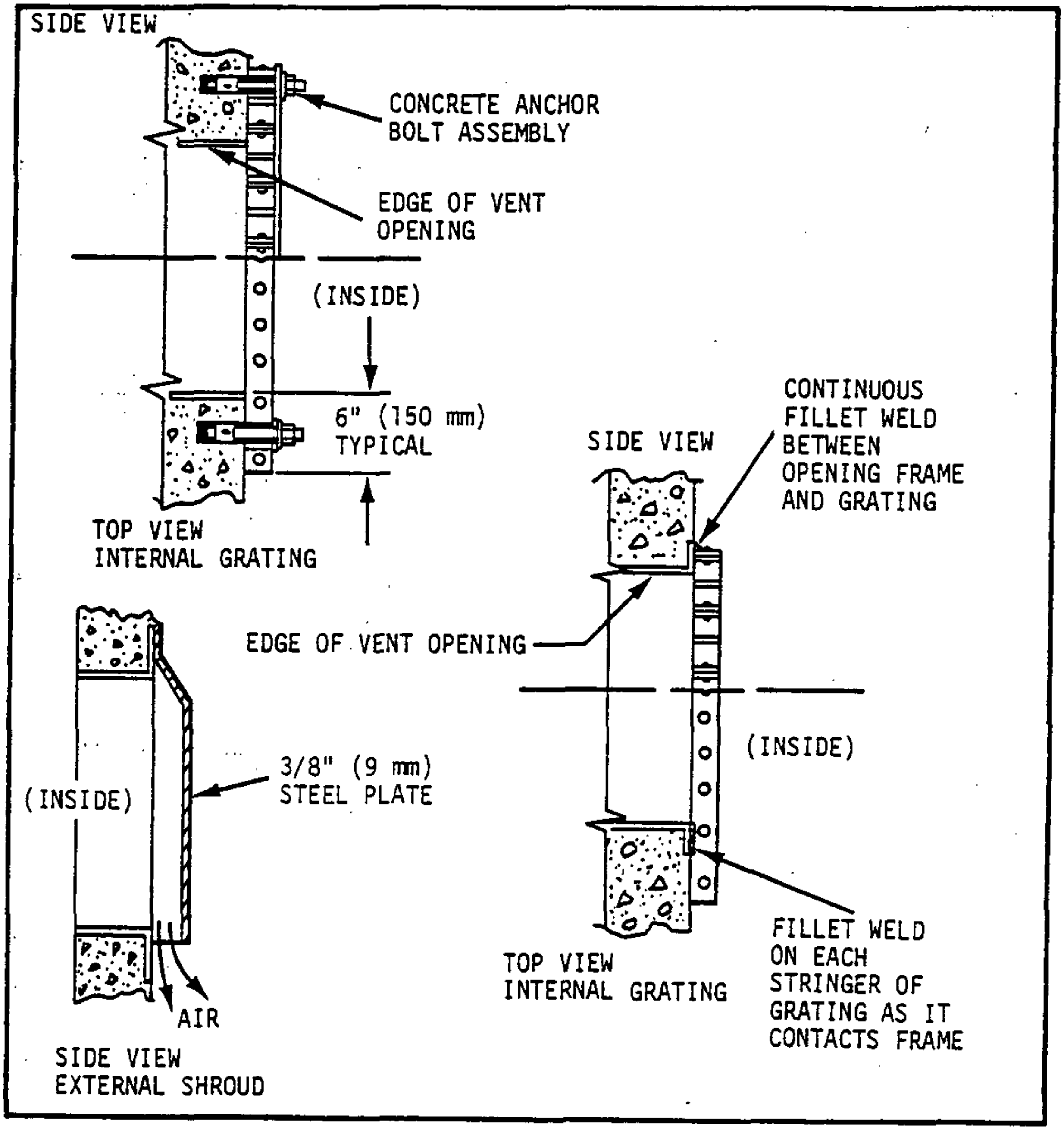


FIGURE 31. Installation details of hardening a typical riveted steel grating and shrouded louver.

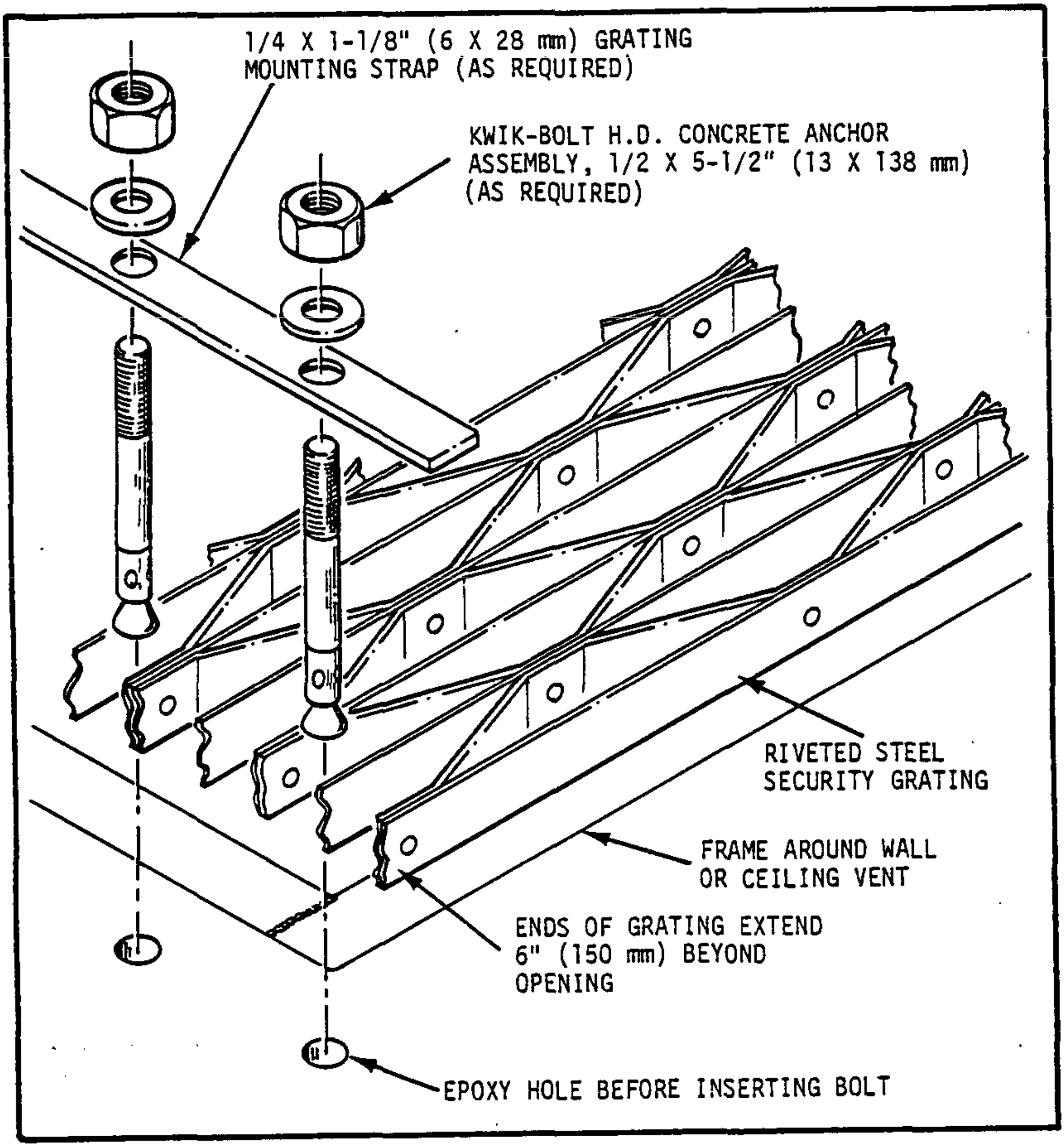


FIGURE 32. Security intrusion protection plan for hardening a typical wall or ceiling.

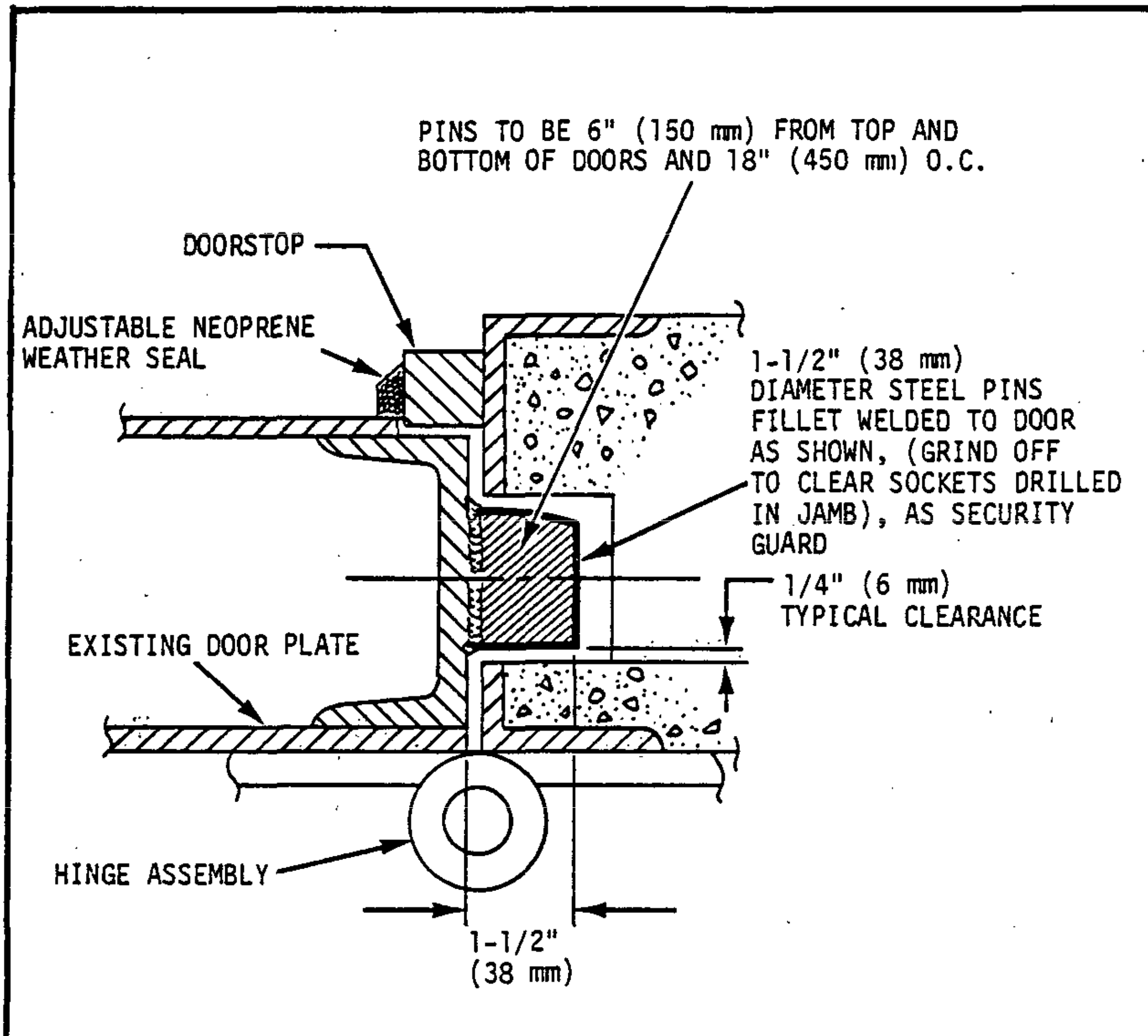


FIGURE 33. **Security plan for doors using a pin-in-socket technique.**

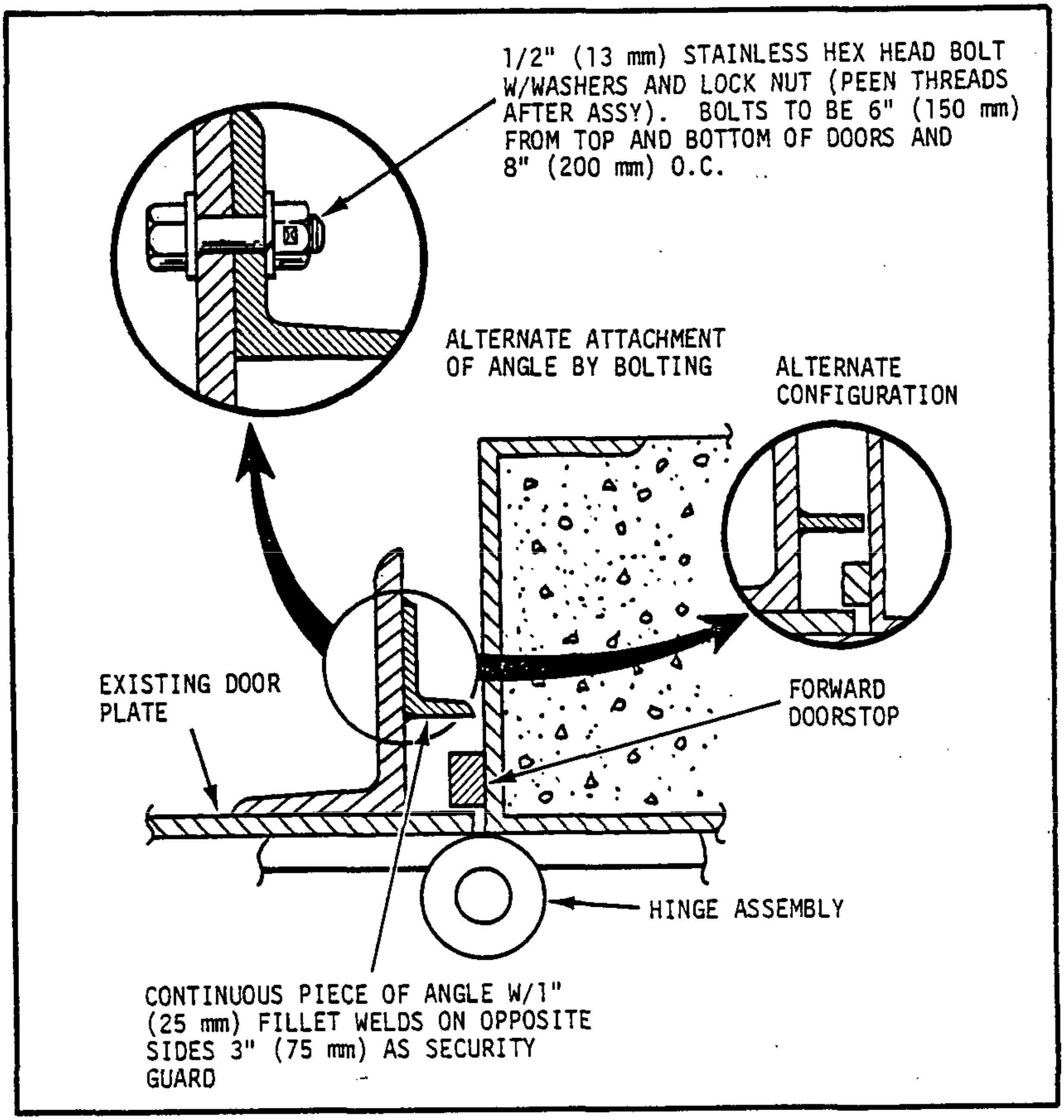


FIGURE 34. Typical hardening plan for doors using a forward doorstop with angle.

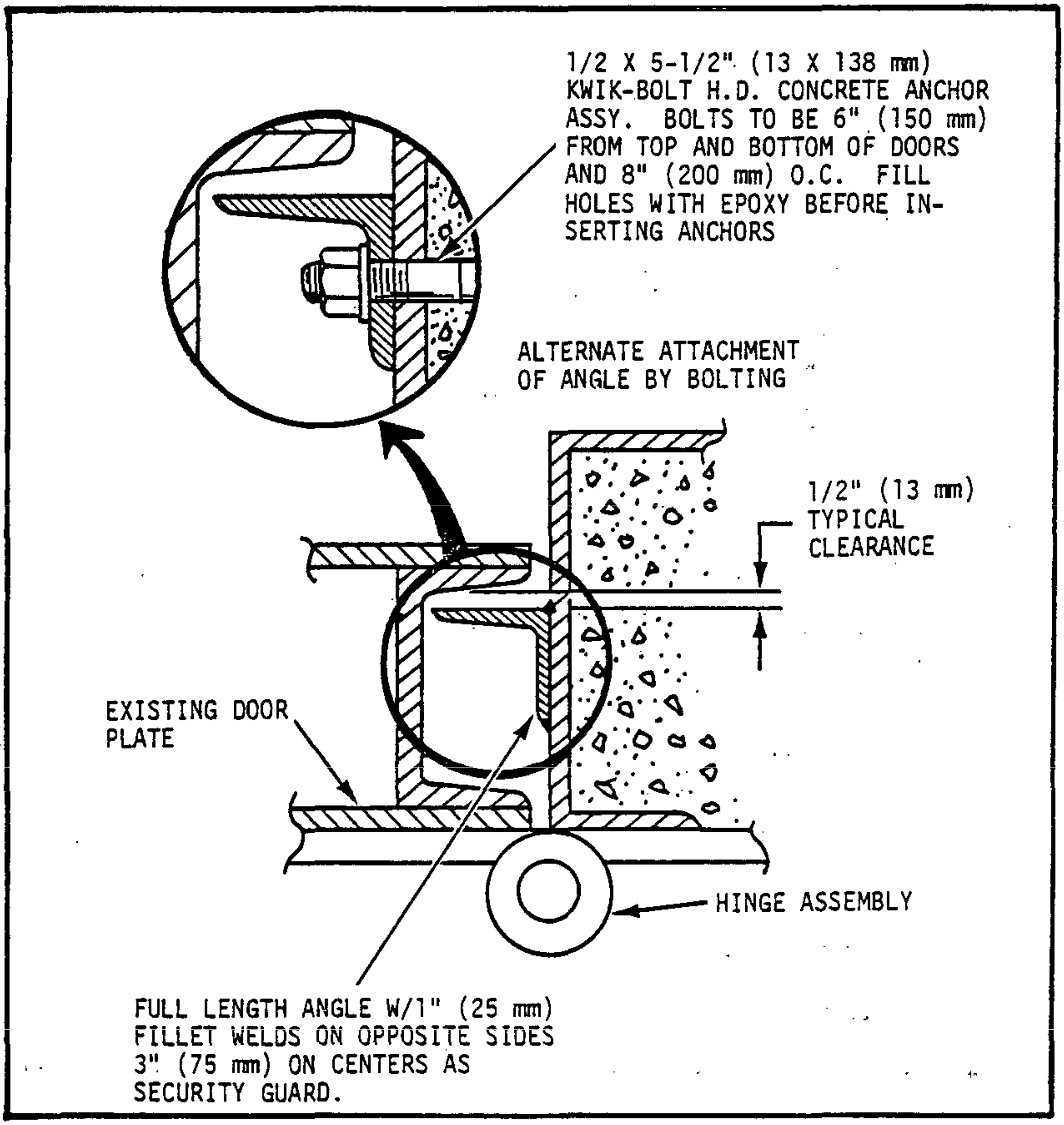


FIGURE 35. Security plan for hardening typical thick doors by using an angle stop.

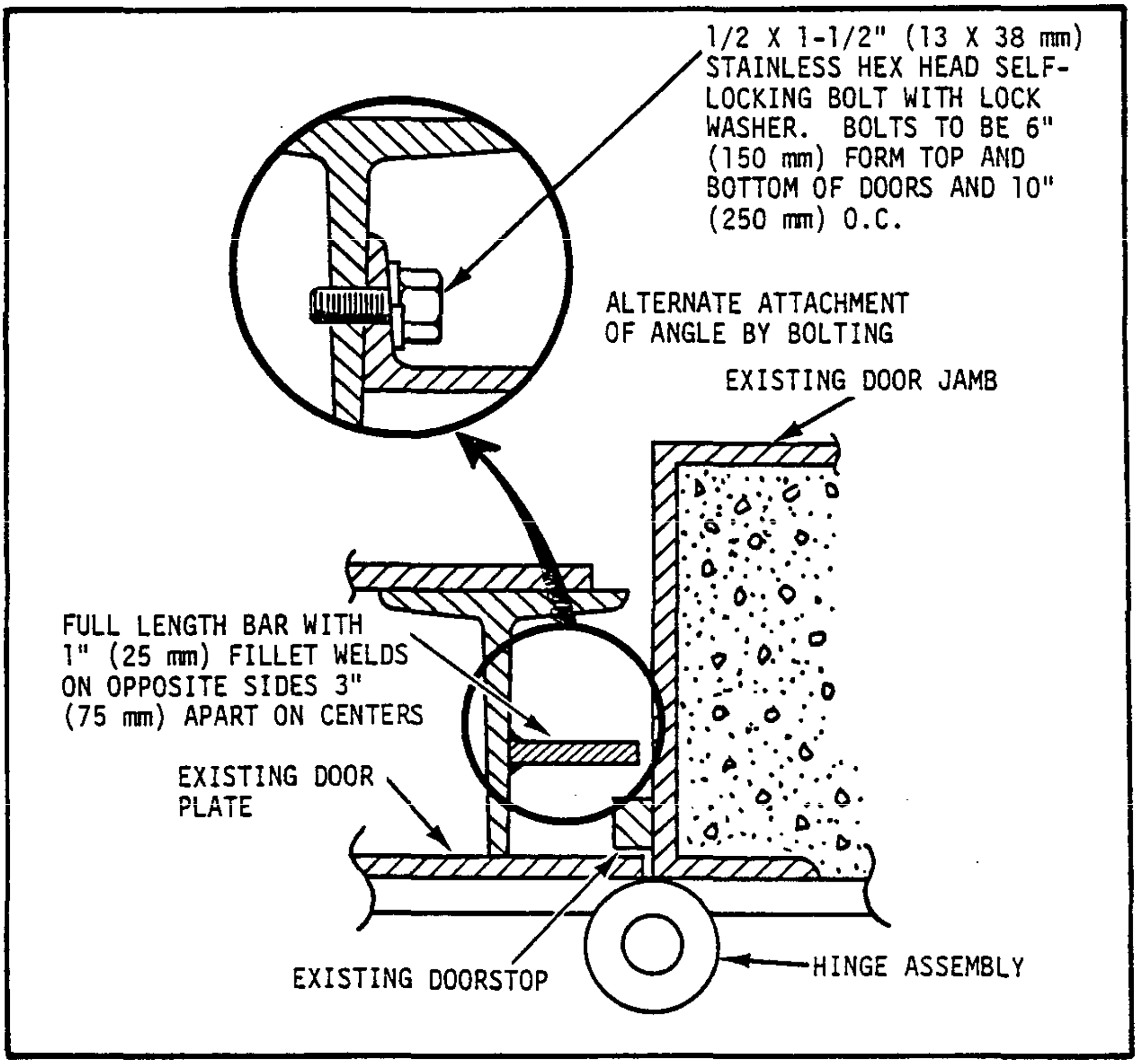
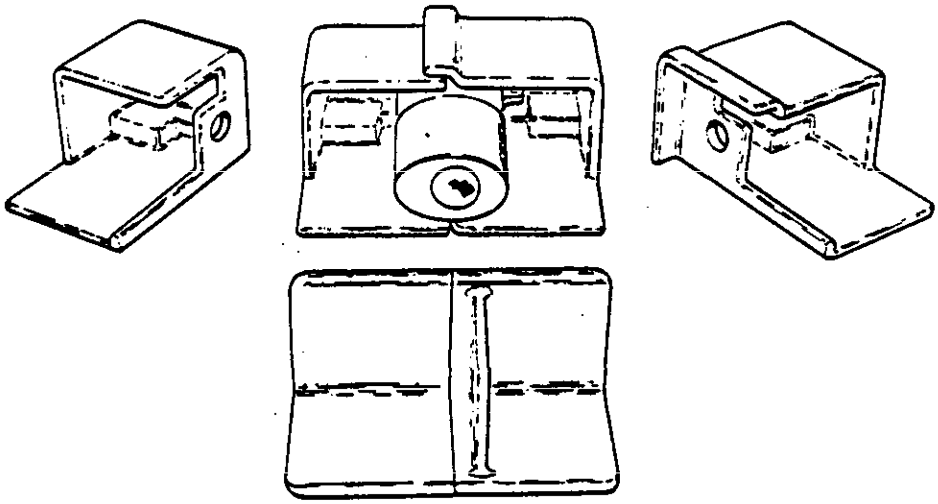
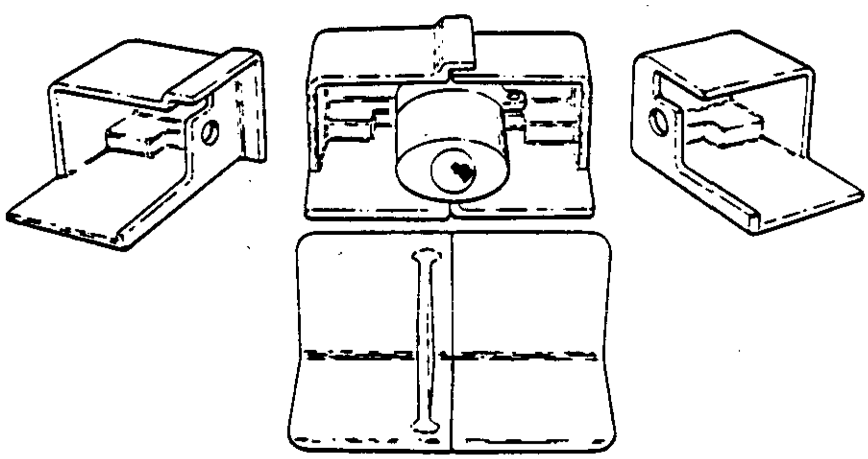


FIGURE 36. Security plan alternative for hardening typical thick doors by using an angle stop.



HIGH-SECURITY HASP NAPEC 0957 STYLE 1 RIGHT-HAND FOR TYPE I, III, IV, IX, XI, AND XIII DOOR CLOSURE ARRANGEMENTS MIL-H-29181 (YD). SHOULD BE INSTALLED WITH A CONTINUOUS WELD. NOTE: AN EARLIER VERSION, THE NAPEC 0955 IS ACCEPTABLE IF INSTALLED PROPERLY.



HIGH-SECURITY HASP NAPEC 0958 STYLE 2 LEFT-HAND FOR TYPE II, IV, V, IX,X AND XII DOOR CLOSURE ARRANGEMENTS MIL-H-29181(YD). SHOULD BE INSTALLED WITH A CONTINUOUS WELD. NOTE: AN EARLIER VERSION, THE NAPEC 0956 IS ACCEPTABLE IF INSTALLED PROPERLY.

FIGURE 37. Acceptable hasps for securing AA&E storage structure.

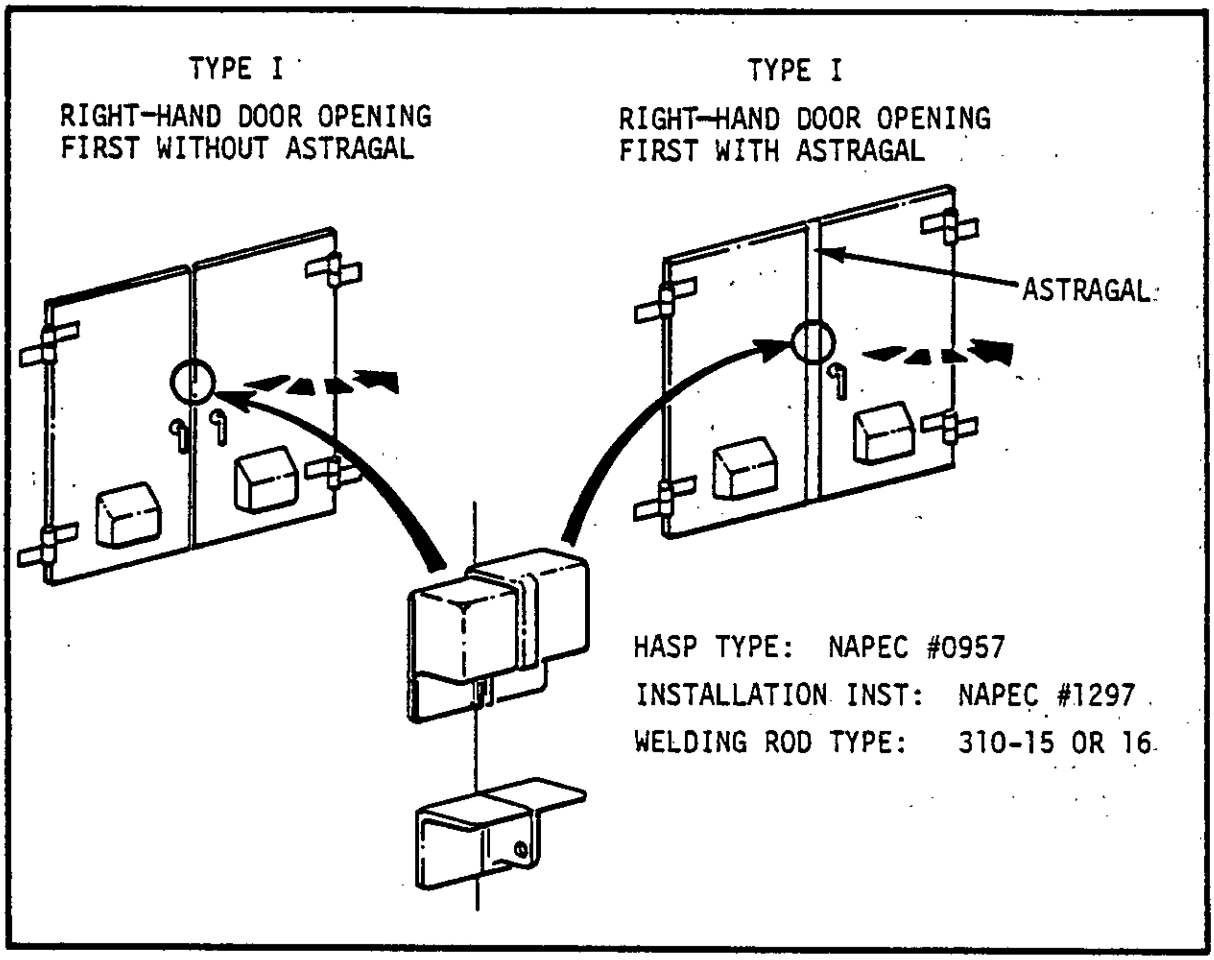


FIGURE 38. High-security hasp installation for double doors.

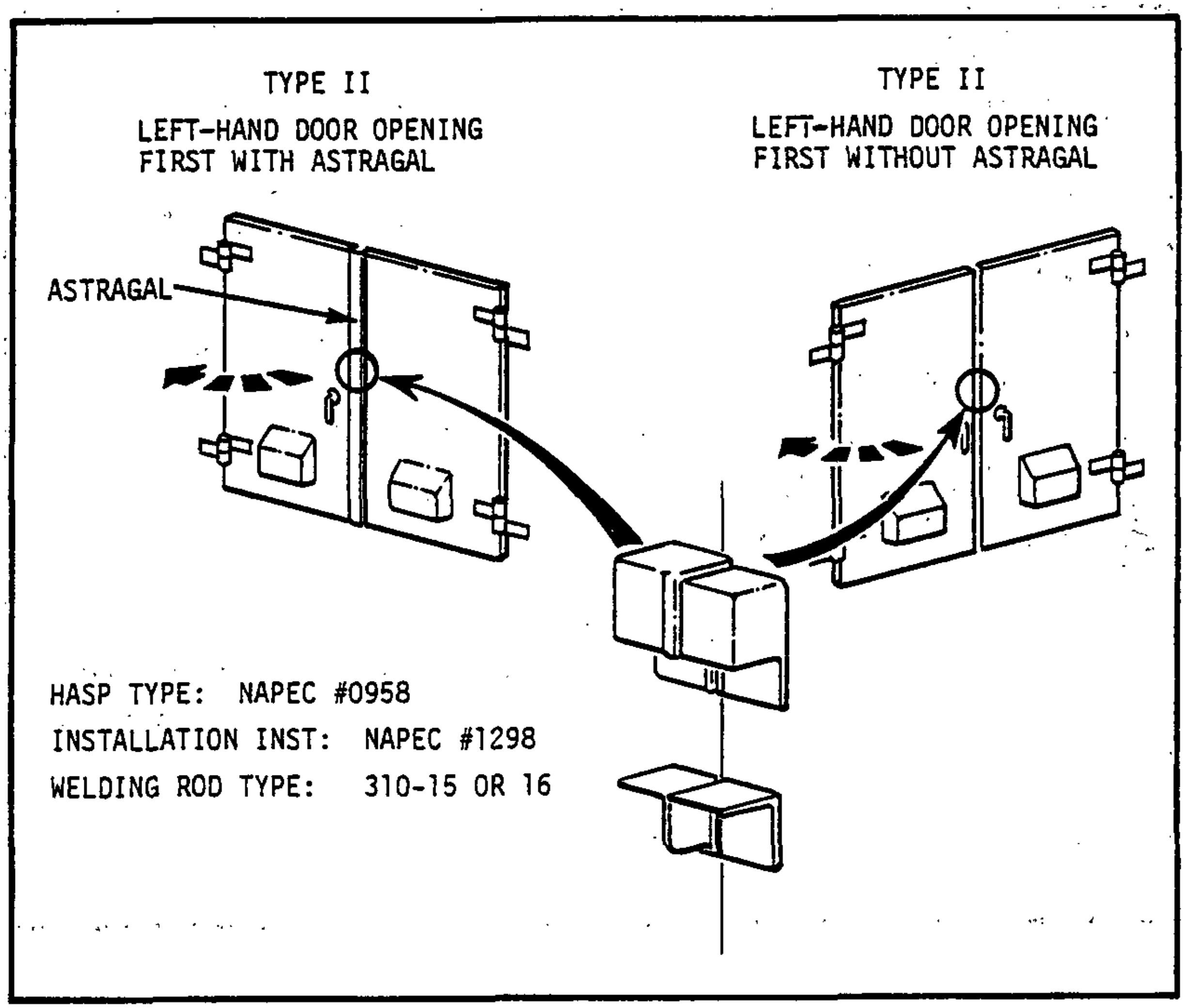


FIGURE 39. Hardening typical, high-security hasp installation by door type.

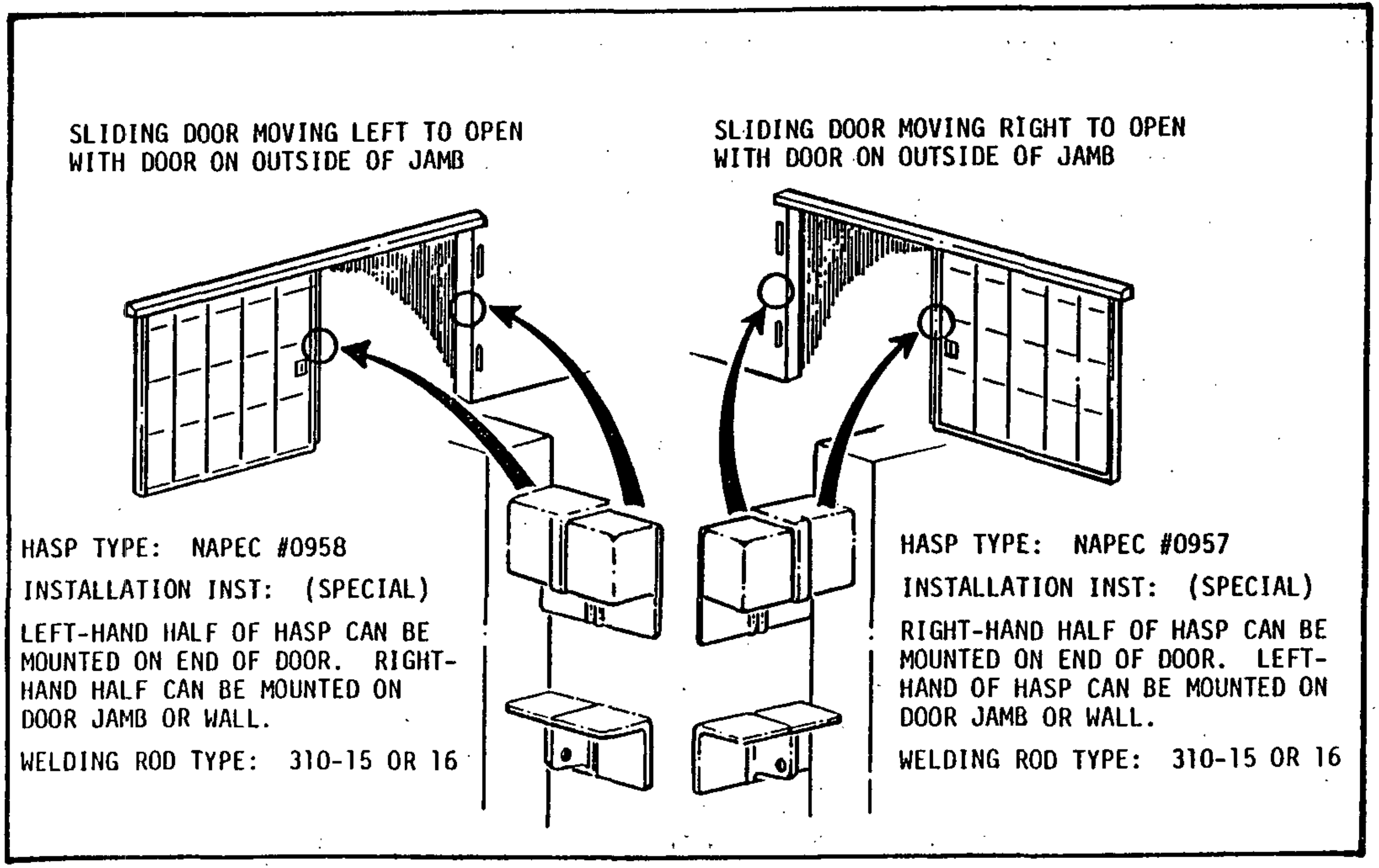


FIGURE 40. High security hasp installation for single external sliding doors.

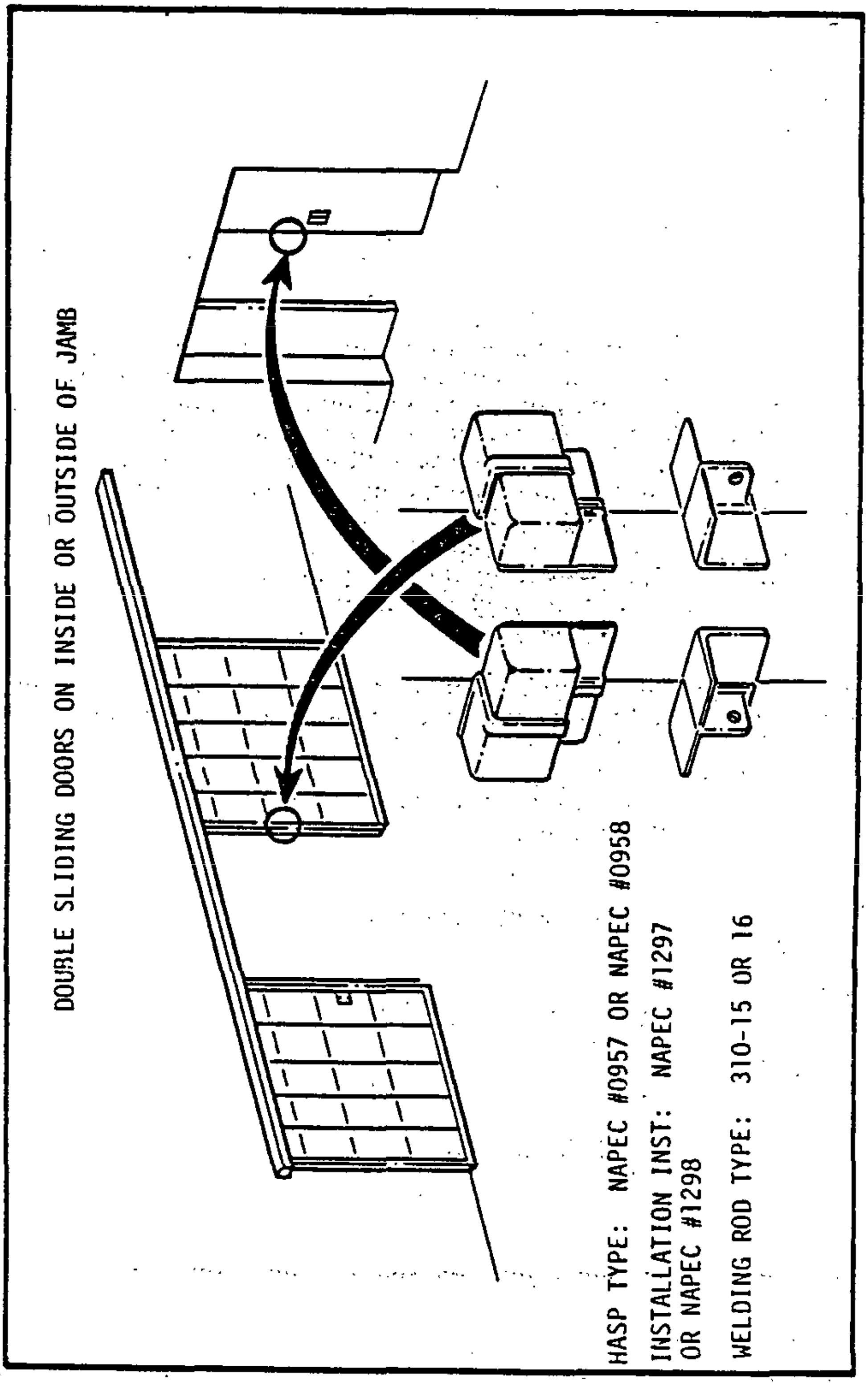


FIGURE 41. High-security hasp installation for double sliding doors.

5.5.1 Double Door Systems. Figures 38 and 39 depict double door systems. One door is secured internally with drop bolts into the floor or header while the active door is secured to the inactive door by the hasp and lock.

5.5.2 Sliding Door Systems. Figure 40 depicts a single sliding door system. The NAPEC 0957 or 0958 hasp may have one-half welded to the end of the door. A larger hasp is available for doors with a thickness greater than 6 inches (150 mm) and is designated NAPEC 1332. Figure 41 depicts double sliding doors. Again, either the 0957 or 0958 hasp may be used to secure these doors. In all cases, however, sliding doors must be equipped with a system to prevent the doors from being lifted off the tracks or pushed or pulled from the structure. Figure 42 illustrates the in-wall or in-jamb box used with a single inside sliding door. Installation instructions for the NAPEC 0957 and 0958 are illustrated in Figures 43 and 44.

5.5.3 Roll-Up Doors. Figure 45 illustrates roll-up doors that may be found on some AA&E storage area structures. These roll-up doors are not capable of being hardened in themselves. A secondary gate system constructed of "jail bar" construction or riveted steel grating must be used as the backup protection and should be secured with a high-security hasp and lock system. This, of course, may eliminate the space saving advantage of a roll-up door and eliminate it from further consideration.

5.6 Electronic Locks. Under certain circumstances electronic locks may be used to control the admission of personnel into protected areas. As such, they can be used as a replacement for manned guard posts. Electronic locks, however, cannot fulfill all the functions of a human sentry because they monitor only a limited portion of the spectrum (e.g. visual, audible, etc.) that can be observed by humans. The degree of security afforded by electronic locks varies with the type of device used. Some electronic locks can only identify a code, which is either encoded on a card or badge carried by the person or is memorized by the individual. The electronic lock that relies on an encoded card or badge offers the least security because cards and badges can be lost or stolen. The more sophisticated types of electronic locks actually identify the person seeking entry on the basis of some physical characteristic, such as fingerprints or dimensions of fingers. Some electronic locks use a combination of code and identification of a personal characteristic, for example, a numerical code and fingerprint identification. Some electronic lock systems may perform such additional functions as initiating alarm or providing automatic personnel entry/exit inventory.

5.6.1 Characteristics. The main requirement of an electronic lock for entry control is the ability to confirm identity of an individual (i.e. authenticate his authorization to enter). The maximum acceptable response time may be as short as 1 second or as long as several minutes, depending on the specific application. No search against a file is required since only authentication of an alleged identity is sought.

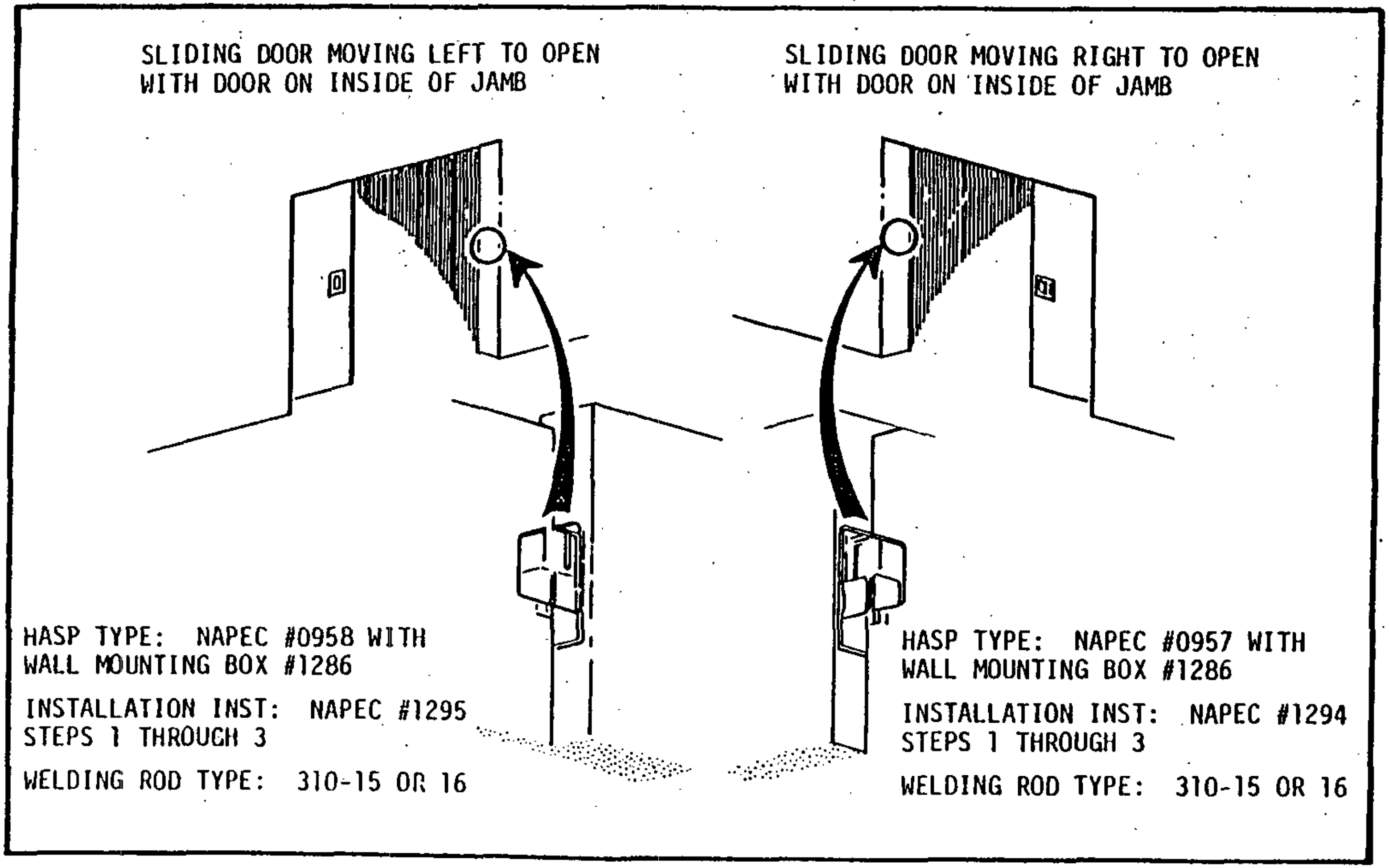


FIGURE 42. High-security hasp installation for single internal sliding doors.

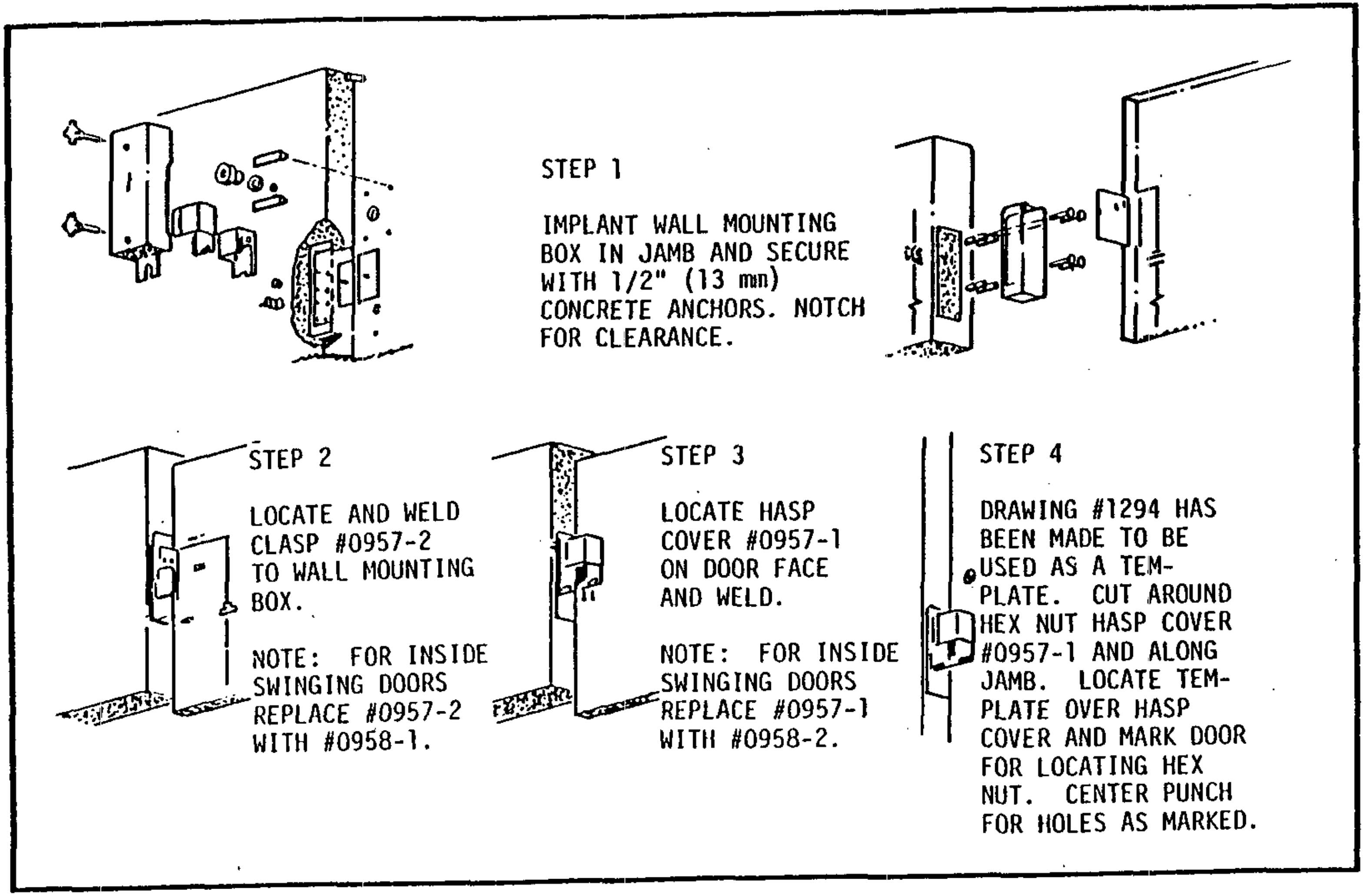


FIGURE 43. High-security hasp installation for single doors sliding left to open. (From NAPEC #1294.)

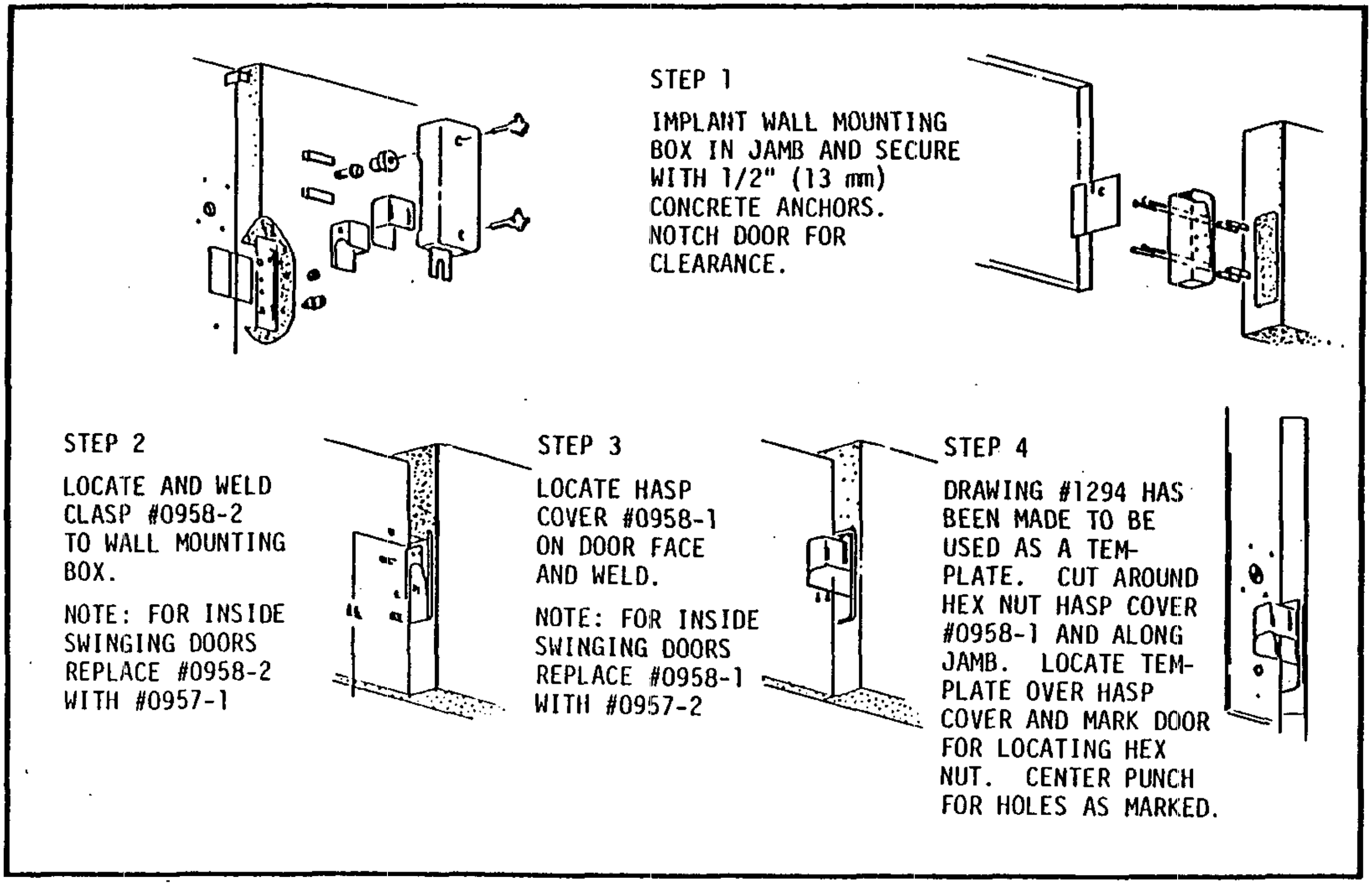


FIGURE 44. High-security hasp installation for single doors sliding right to open. (From NAPEC #1295.)

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5.6.2 Types. The more common commercially available electronic locks and their applications are as follows:

5.6.2.1 Digital Cypher Locks. The principal components of a cypher lock are: switch panel (i.e. digital keyboard), electronic control box, electromechanical lock, various optional monitoring devices (e.g. alarm initiating device), and bypass switches (for controlling entry from within the closed area). The switch panel has 10 digits of which 4 (or 5, depending on the system) in a given preset sequence specify the code. If the same digit cannot be repeated within a code, a four-digit code provides for a maximum of 5,040 combinations and a five-digit code for 30,240 combinations. If digits can be repeated, then the corresponding number of possible combinations approaches 10,000 and 100,000, respectively. In addition, most cypher locks incorporate an "error penalty" delay that can be adjusted from 0 to 45 seconds. This delay following an error prevents an unauthorized person from "running out" or exhausting various combinations. With the maximum 45-second error delay, to try all possible combinations would require nearly 7 hours for a four-digit code (without repetition of digits in the code) and about 55 hours for a five-digit code. The correct code actuates the electric strike latch and allows the door to open. The open door time may be adjusted from 4 to 30 seconds. The system operates on alternating current line voltage and includes an emergency battery power circuit. The switch panel and control box must be shielded to prevent inductive reading. The principal disadvantages of cypher locks are that they identify the code and not the person and that codes can be revealed or obtained by unauthorized persons through illegal means.

5.6.2.2 Card-Locks. The components of a card-lock include a card (or badge) reader, an electrical control system, a plugging-out panel, and a door-lock trip switch. Plastic badges or cards, carried by authorized personnel, are individually coded and may also contain photographic or embossed information. The two principal types of card-locks available today are magnetic and pneumatic; magnetic locks are by far more common. A magnetic key card contains in its memory the specific code and the individual's identity number; thus, it is feasible to exclude individuals who have lost their right access. A punched card is used in a pneumatic card-lock. The card is inserted into the reader, air is applied to the card, and if the punched hole pattern matches the stored pattern, the internal circuit unlocks the door. The principal disadvantage of card-lock systems is that cards can be lost or stolen. The advantages, as opposed to cypher locks, are that individuals can be reclassified and provision can be made to automatically record the entry/exit traffic by number identification.

5.6.2.3 Hand Geometry Comparator Locks. A hand geometry comparator system identifies the individual seeking entry by comparing the specific dimensions of usually the right hand against the encoded data in the file (computer memory) or on a magnetic card carried by the individual, which must be inserted simultaneously into the comparator. Data correlation is performed by either optical or digital means. The measurement parameters usually include the lengths of the four fingers (excluding the thumb); additional parameters, such as palm width, can be included if necessary. The reliability of identification increases with the number of measurement parameters and with decreasing measurement tolerances. For example, the following degrees of identification reliability are obtained with measurements of the lengths of the four fingers: with a measurement tolerance of plus or minus 0.06 inch, identification accuracy is 99.95 percent; with a tolerance of plus or minus 0.03 inch, the accuracy is 99.5 percent. In general, a trade-off exists between the processing time per entry (which depends on the number of measurement parameters and measurement tolerances) and the error rate. For current systems with capacities up to 10,000 individuals, the total identification cycle time is normally about 4 seconds. The principal advantage of the hand geometry comparator lock is that it actually identifies a person and not a code. However, the system could conceivably be spoofed by accurate cut-outs of an authorized person's hand. Therefore, the hand comparator systems are sometimes combined with cypher systems to increase their reliability.

5.6.2.4 Fingerprint Comparison Locks. A fingerprint comparator system uses either digital or optical-correlation techniques to identify a person seeking entry. It compares a fresh fingerprint deposited on the reader with previously encoded data. Such fingerprint data may be stored in a central computer in digitized or holographic form inside the optical correlator or on a film chip contained on the individual's key card. In most automatic fingerprint identification systems, optical scan techniques are used to detect the minutiae, although other schemes are also possible. (Minutiae are the tiny ridge endings or branch points, which are the only legally accepted features of a fingerprint which distinguish one person from another.) Other fingerprint identification schemes include those that measure the core-delta distance, crease length, core-crease distance, core-delta ridge count, and the angle between the core-delta line and the core-crease line. As in the hand geometry comparator, a trade-off exists between the number of features to be compared (and the corresponding process time) and the reliability of identification (error rate). Typical response time of current systems is on the order of 2 seconds per identification with an incidence of class 1 errors (admit an unauthorized person) of less than 0.1 percent. The advantage of the fingerprint comparison system is that it virtually eliminates the problem of forged identity cards. It also identifies a person rather than a code and provides a lock-out capability against persons who have lost access to the area.

5.6.2.5 Hybrid System Locks. Virtually all combinations of the preceding four types of lock systems are possible. Their general advantage is that by redundant means of identification they increase the reliability of the system and make it more difficult for an unauthorized person to penetrate the system.

SECTION 6: BALLISTIC ATTACK HARDENING

6.1 Summary.

6.1.1 Overview. This subparagraph summarizes the available information on the performance of the ballistic resistance of commercial equipment, structural barriers, and glazing materials against small arms and military threats. Six ballistic threat categories are considered in this handbook:

6.1.1.1 Category 1. Threat category 1 is the American National Standards Institute/ Underwriters Laboratories (ANSI/UL) Medium Power Small Arms (MPSA) threat described in ANSI/UL 752-1980. This threat would normally be employed against facilities when the main objective of the attacker is to persuade someone to turn over items of high value such as cash or drugs. This threat may also be employed in a hostage situation.

6.1.1.2 Category 2. Threat category 2 is the ANSI/UL Super Power Small Arms (SPSA) threat described in ANSI/UL 752-1980. This threat would normally be employed when the attacker knows that ballistic-resistant glazing is installed, i.e., teller cages, etc.

6.1.1.3 Category 3. Threat category 3 is the ANSI/UL High-Power Rifle (HPR) threat described in ANSI/UL 752-1980. This threat would normally be employed when the objective is assassination.

6.1.1.4 Category 4. Threat category 4 is the military HPR threat, defined as small arms fire in DOD 5210.41.

6.1.1.5 Category 5. Threat category 5 is the Type III HPR threat defined in National Institute of Justice (NIJ) Standard 0108.01. This threat could be expected to be employed against facilities where several rounds could cause considerable damage.

6.1.1.6 Category 6. Threat category 6 is the Small Arms Multiple Impact Threat (SAMIT) described in Naval Civil Engineering Laboratory (NCEL) Report CR 80.025. This threat would most likely be used during an all out assault to overpower or neutralize a guard or reaction force.

6.1.2 Ballistic Resistance. The term "ballistic resistance" denotes protection against complete penetration, passage of projectiles, or spallation of the protective material to the degree that injury would be caused to a person standing directly behind the bullet-resisting barrier. This definition is set forth in the ANSI/UL Standard for Bullet-Resisting Equipment, ANSI/UL 752-1980. The ANSI/UL definition of bullet-resisting glazing material specifies that there should be no penetration of the projectile, fragments of the projectile, or fragments of the glazing assembly with sufficient force to embed into or damage 1/8-inch (3-mm) thick corrugated cardboard indicators placed a distance of 18 inches (450 mm) behind the protected side of the test sample. Table 30 summarizes the weapon, ammunition, and energy parameters, and the number of rounds fired in each of the six ballistic threats.

TABLE 30.
Ballistic threat levels.

Threat Level	Power Rating	Weapon	Barrel Length		Rounds Fired
			Inches	(mm)	
Level I	Medium-Power Small Arms (MPSA)	Super 38 automatic	5	(125)	3
Level II	Super-Power Small Arms (SPSA)	.44 magnum revolver	6-1/2	(165)	3
Level III	High-Power Rifle (HPR)	30-06 rifle	24	(600)	1
Level IV	High-Power Rifle (HPR)	M-14 rifle			1
Level V	High-Power Rifle (HPR)	M-14 rifle			5
Level VI	Small Arms Multiple Impact Threat (SAMIT)	M-60 machine gun			25

Threat Level	Grain	Ammunition	(g)	Muzzle Velocity		Muzzle Energy	
				fps	(m/s)	ft-lb	(J)
Level I	130	Metal case	(8.4)	1,280	(390)	475	(644)
Level II	240	Soft point or lead	(15.6)	1,470	(448)	1,150	(1,559)
Level III	220	Soft point	(14.3)	2,410	(735)	2,830	(3,837)
Level IV	152	NATO ball	(9.7)				
Level V	152	NATO ball	(9.7)				
Level VI	152	NATO ball	(9.7)				

6.1.3 Design Threat Categories. The determination of the category of security required against ballistic threats is a local command decision. The level of ballistic-resistant hardening required in a facility design depends upon the type of facility and the category of the threat. Table 31 lists the most common types of shore facilities that could be susceptible to ballistic threats and identifies the category of ballistic-resistant hardening that would provide each with adequate protection. These are typical examples only and do not supersede any existing regulations or requirements.

6.2 Ballistic Tests.

6.2.1 Category 1 and 2 ANSI/UL Threats. The tests for categories 1 and 2 threats are conducted at a range of 15 feet (4.6 meters (m)) or less, using weapons and ammunition specified in Table 30 for category 1 and 2. Bullet-resisting materials with a small arms rating for category 1 and 2 should resist three shots spaced 4 ±1/2 inches (100 ±13 mm) apart in a triangular pattern in the approximate center of the test sample. There should be no penetration of the projectile through the test sample, and there should be no spallation of material on the protected side of the test sample to the extent that fragments embed into or damage the cardboard indicators placed 18 inches (450 mm) behind the sample. A glazing material listed for outdoor use is tested for ballistic resistance pursuant to two temperature excursions. One sample is tested immediately after exposure for at least 3 hours on one side at -26 ±5 °F (-32 ±3 °C). The second sample is tested immediately after exposure of the entire sample to a temperature of 120 ±5 °F (49 ±3 °C).

6.2.2 Category 3 ANSI/UL Threat. The category 3 ANSI/UL HPR test is conducted at a range of 15 feet (406 m) or less, using the weapon and ammunition specified in Table 30 for category 3. Bullet-resisting materials assigned a high-power rifle rating (category 3) should resist one shot in the approximate center of the test sample without penetration or spallation. The same temperature excursions specified for indoor and outdoor use in category 1 and 2 tests also apply to category 3 tests, except where limitations are noted on the ANSI/UL listing and product marking.

6.2.3 Category 4 Military High-Power Rifle Threat. The category 4 military HPR test relates to bullet-resisting materials and construction that can withstand one impact by a 7.62 mm NATO (M-80) ball projectile fired from an M-14 rifle located at a distance of 25 yards (23 m) from the test sample without penetration.

6.2.4 Category 5 NIJ High-Power Rifle Threat. The category 5 NIJ HPR test relates to bullet-resisting materials and construction that can withstand five rounds of 7.62 mm NATO (M-80) ball ammunition fired from a distance of 16 feet (5 m) from the test sample without penetration.

TABLE 31.

Design threat levels.

Facility	Ballistic Threat Level					
	I	II	III	IV	V	VI
Arms, Ammunition, and Explosives Storage Facilities(Category I-IV)					xxx	
Alarm Control Centers					xxx	
Armories					xxx	
Cash Transfer Facilities	xxx	xxx				
Communication Facilities					xxx	
Finance Offices	xxx	xxx				
Fleet Command Centers (Executive Protection)			xxx	xxx		
Guard Booths					xxx	
Hazardous Material Storage Facilities					xxx	
Marine Barracks Housing for Backup Alert Force						xxx
Pharmacies	xxx	xxx				
Police Stations			xxx	xxx		
Reaction Force Facilities						xxx
Reaction Force Quarters						xxx

Note: These are typical examples only and do not supersede any existing regulations or requirements.

6.2.5 Category 6 SAMIT. The category 6 SAMIT test is defined as 25 rounds of 7.62 mm NATO (M-80) ball ammunition fired from an M-60 machine gun at a distance of 25 yards (23 m) from the test sample, impacting at zero obliquity within an 8-inch (200 mm) circle with no complete penetration of the test material.

6.3 Ballistic Hardening Options.

6.3.1 Defeating ANSI/UL Threats, Categories 1 Through 3. The design engineer who determines that a facility should be capable of defeating category 1 and 2 small arms threats or category 3 HPR threats should advise the facilities engineer to use only products, structural barriers, and glazing materials that are listed by ANSI/UL as capable of defeating threat categories 1 through 3 as defined in Tables 30 and 31. The facilities engineer evaluating the ballistic resistance of glazing materials for outdoor use should consult the most recent ANSI/UL listing to determine whether any limitation applies with respect to temperature excursions. A glazing material listed for outdoor use is by definition listed for indoor use as well; however, a material listed only for indoor use has not been rated for outdoor use. The facilities engineer should make sure that the ANSI/UL listing applies to outdoor use. Materials proposed for security applications that are not rated to meet ANSI/UL ballistic-resistant requirements should be independently tested by a qualified laboratory pursuant to the ballistic test specifications set forth in ANSI/UL 752-1980.

6.3.2 Defeating Military Threats, Categories 4 Through 6. The design engineer who determines that a facility should be capable of defeating military small arms ballistic threats, categories 4 through 6, should advise the facilities engineer that the published data for ballistic resistance relate principally to common construction materials for opaque barriers. These data are summarized in Table 32. Table 33 summarizes additional data on ballistic resistance to 7.62 mm ball ammunition fired from the M-14 rifle and the AK-47 Soviet assault rifle, and on 7.62 mm armor piercing (AP) ammunition fired from the M-1A1 rifle. Tables 32 and 33 are for weapons that do not fire NATO rounds. The tables present ballistic data for "calibers" not "mm" rounds. In relying upon the data presented in Tables 32 and 33 the security engineer should be aware of the rapid changes that take place in arms and ammunition technology and hardening technology. For example, new high-velocity military small arms ammunitions are under development, including "hot" 7.62 mm rounds as well as 5.56 mm rounds fired from the M-16 rifle. The security engineer who is trying to defend against a military small arms threat other than the 7.62 mm NATO (M-80) ball ammunition tested against the materials referenced in this section should contact qualified research, development, test, and evaluation (RDT&E) personnel at an appropriate laboratory that conducts ballistic testing. For information relative to state-of-the-art developments in arms and ammunition and/or ballistic-resistant materials, including glazing materials and lightweight armor which are not discussed in this section, the security engineer should contact:

TABLE 32.
Test panels capable of defeating 7.62-mm NATO (M-80) ball ammunition at 25 yards (22.9 m).

TEST PANEL	1 ROUND	3 ROUNDS	25 ROUNDS
6 in (150 mm) Cast Concrete, #5 Rebar @ 6 in (150 mm) O.C.	NP	NP	P
8 in (200 mm) Filled Concrete Block, #5 Rebar @ 8 in (200 mm) O.C., Horizontal Joint Reinforcement	NP	NP	P
8 in (200 mm) Hollow Concrete Block, 3 Sheets 10 Gauge (3.4 mm) Steel, 2 Sheets 3/4 in (19 mm) Plywood	NP	NP	NP
6 in (150 mm) Cast Concrete, #5 Rebar @ 6 in (150 mm) O.C., 10 Gauge (3.4 mm) Steel Front and Back	NP	NP	NP
8 in (200 mm) Cast Concrete, #5 Rebar @ 6 in (150 mm) O.C., 10 Gauge (3.4 mm) Steel Front	NP	NP	NP
8 in (200 mm) Concrete Block, #5 Rebar @ 8 in (200 mm) O.C., Horizontal Joint Reinforcement, 10 Gauge (3.4 mm) Steel Front and Back	NP	NP	NP
8 in (200 mm) Hollow Concrete Block, 3 Sheets 10 Gauge (3.4 mm) Steel, 2 Sheets 3/4 in (19 mm) Plywood, 10 Gauge (3.4 mm) Steel Front	NP	NP	NP

Note: Weapon used in testing was a M-60 machine gun

P = Penetration NP = No Penetration NT = No Test

TABLE 33.

Test panels capable of defeating 7.62-mm ammunition fired from M-14 rifle, Soviet AK-47 assault rifle, and M-1 rifle at 25 yards (22.9 m).

	M-14 RIFLE 7.62-mm NATO (M-80) Ball			SOVIET AK-47 ASSAULT RIFLE Soviet 7.62-mm Ball			M-1A1 RIFLE 7.62-mm (M-2) AP		
	1-ROUND	3-ROUND	25-ROUND	1-ROUND	3-ROUND	25-ROUND	1-ROUND	3-ROUND	25-ROUND
8 in (200 mm) Hollow Concrete Block	P	NT	NT	P	NT	NT	P	NT	NT
2 in (50 mm) Precast Concrete T Beam, 8/6 Woven Wire Fabric	P	NT	NT	NP	NT	NT	P	NT	NT
4 in (100 mm) Face Brick, 2 X 4 Studs @ 16 in (400 mm) O.C.	NP	P	NT	NP	NP	NP	P	NT	NT
8 in (200 mm) Grout Filled Block	NP	NP	NT	NP	NP	NT	NP	NP	NT
4 in (100 mm) Concrete, #4 Rebar @ 6 in (150 mm) O.C.	NP	NP	NT	NP	NP	NT	NP	NP	NT
8 in (200 mm) Concrete, #4 Rebar @ 6 in (150 mm) O.C.	NP	NP	NP	NP	NP	NT	NP	NP	NT
12 in (300 mm) Concrete, #4 Rebar @ 6 in (150 mm) O.C.	NP	NP	NP	NP	NP	NP	NP	NP	NP

Note: P = Penetration NP = No Penetration NT = No Test

Department of the Army
Materials and Mechanics Research Center
Watertown, MA 02171

To take advantage of the most current information relative to ballistic testing of unique products and special materials, the security engineer should contact:

Naval Civil Engineering Laboratory
Security Engineering Division (Code L56)
Port Hueneme, CA 93043-5003

6.3.3 Security Levels. There are three levels of security to which a structure may be designed. Each level thwarts a specific design threat, providing the protection required against the tools and force that will be exerted at that threat level. Performance is measured in terms of penetration delay time. Table 34 lists the three security levels, associated design threat, buildings that are typically protected, and the penetration delay time required.

TABLE 34.

Security levels for selected buildings.

Security Level	Design Threat	Type of Building	Penetration Delay Time
Low	Pry Bars, Bolt Cutters, Body Force Unlimited hand,	Commissary, Storage Administration, Shops Exchanges, Warehouses	1 min.
Medium	Tools, Limited power tools	Operations buildings	4 min.
High (Terrorist)	Unlimited tools, Torches, Truck bombs, Rocket propelled grenades, and Light Anti-Tank weapons	Security centers, Nuclear, Command, Aircraft hangers, AA&E, POL	15 min.

SECTION 7: VAULTS AND STRONGROOMS

7.1 Summary.

7.1.1 Overview. A vault is a room or compartment designed to store classified material or other valuable resources. It is designed to provide entrance and working space for one or more persons. Vaults within the Department of Defense (DOD) are categorized by class and purpose. Those required to store classified documents or material are discussed in Paragraph 7.3. Those required for other purposes such as the storage of money, pharmaceuticals, records, or other sensitive resources are addressed in Paragraph 7.4. In many cases the most cost-effective approach to protect DOD assets may be the use of a strongroom as addressed in Paragraph 7.5, rather than the construction of a vault.

7.1.2 Basic Considerations. The most cost-effective method of providing adequate storage for Government resources should always be selected. If, after a thorough analysis, the need for a security vault is validated, attention should focus on the items to be stored. Classified documents, material, and equipment require a Class A, Class B, or Class C vault depending on the classification level of the documents, material, or equipment. If the items to be stored are not classified, a modular vault or strongroom may be the preferred option.

7.1.3 Vaults. Vaults required to store classified items should meet the specific requirements outlined in this handbook. Any deviation, unless approved in writing by appropriate authority, may preclude the utilization of the structure for storage of classified material. Vaults should be periodically inspected and properly maintained. New vaults should be designed and built in accordance with these guidelines. Modular vaults, although not formally approved for the storage of classified items, offer several distinct advantages. They are more quickly constructed, more movable, and cost less than the typical Class A, B, or C vaults. In addition, against some threats, they provide penetration times equal to or greater than the Class A, B, or C security vaults.

7.2 Strongrooms.

A strongroom is a six-sided room, with all sides built of solid materials. Although built with physical security in mind, a strongroom provides little protection against an individual determined to steal or commit other such crimes. Strongrooms should be used, therefore, in areas that are frequently observed by on-duty personnel. A strongroom would be appropriate for storage of highly-pilferable items and property of large bulk, such as office furniture, recreational equipment, office supplies, food items, audio-visual equipment, and musical instruments.

7.3 Class A, B, and C Vaults.

7.3.1 Introduction. The Navy has a document outlining the protection of classified material. Fences, alarms, lights, security containers, vaults, etc., when applied in accordance with procedures explained in OPNAVINST 5510.1G, provide a secure environment for classified material and equipment. Selection of the appropriate vault depends on the classification of the material or equipment to be stored and the value of facility construction supporting physical security equipment or supporting guard forces. Close coordination with the security manager is essential.

7.3.2 General. This section is divided into three distinct subsections applicable to Class A, B, and C security vaults. Each subsection delineates completely the requirements for that particular class of vault. While this causes some duplication, it benefits the reader in that all data for each vault are presented in the subsection pertaining to that vault, negating the necessity to move from one subsection to another.

7.3.3 Class A Vault. A Class A vault offers maximum protection for classified material and equipment. General dimensions are outlined in Table 35 and explained in greater detail below.

7.3.3.1 Floors and Walls. Floors and walls shall be constructed of reinforced concrete in accordance with the requirements imposed by the design dead and live loads. As a minimum, floors and walls shall be 8 inches thick and reinforced. The wall must extend to the underside of the roof or ceiling slab above. When the vault wall is also a part of the exterior wall, that portion of the vault wall that coincides with the exterior wall shall be at least 12 inches thick with the interior portion of the wall being of at least 8 inches of reinforced concrete.

7.3.3.2 Roofs and Ceilings. Roofs and ceilings shall be designed in accordance with the structural requirements dictated by the clear spans between supports to meet dead and live loads and safety factors. A monolithic reinforced-concrete slab shall extend across the entire vault and shall rest on the perimeter vault wall on all sides. Reinforcement shall be the same as for floors and walls above. Roofs and ceilings shall be not less thick than the interior vault floors or walls. Where a roof is not provided, the reinforced ceiling slab shall not be higher than 9 feet above the vault floor.

7.3.3.3 Vault Entrances. Since openings in vaults are more vulnerable to attack than the vault enclosure itself, only one entrance should be provided where possible; however, when a vault exceeds 1,000 square feet in floor space or will have more than eight occupants, it should have a minimum of two exits for safety purposes. When more than one entrance is required, each shall be equipped with an approved vault door (Figure 46) with only one used for normal access. Where continued use of an entry barrier is required at a vault door, a day gate (Figure 46) shall be provided for the primary entrance to preclude undue wear of the door, which could eventually weaken the locking mechanism or cause malfunctioning. Vault doors and frame units shall conform to Federal Specification AA-D-600 for class 5 vault doors. Requirements of this specification are summarized as follows.

(1) Assembly. The door frame shall afford the same security protection as that of the door. Protection for the extended locking bolts shall be built into the door frame. The overall width of the door frame shall not exceed the width of the clear door opening by more than 16 inches. The width of the necessary opening through the structural wall shall not exceed the width of the clear door opening by more than 10 inches. The height of the necessary opening through the structural wall shall not exceed the height of the clear door opening by more than 5 inches. The door shall be assembled in such a manner as to preclude the removal or loosening of any of the door's components when the door is closed and locked. All welding and brazing shall be sound without porosity and shall result in secure and rigid joints in proper alignment. All protruding or depressed welds on the door's exterior surface shall be filled and sanded or ground smooth. The door and frame shall be in perfect alignment to ensure smooth and unrestricted operation of the locking mechanism. The locking bolts shall be smooth and positive without binding or jamming of parts.

(2) Door frame. The door frame shall be of the nongrout type and the frame and door shall be mounted so that there shall be not more than 1/8-inch of clearance between the door and the door frame. The frame shall be designed so that, when attached to the wall, the wall clamping bolts will be exposed only on the inside of the vault. The frame shall have leveling and adjusting screws to compensate for any building sag that may occur in the future.

(3) Door pull and throw-bolt handles. The door pull and throw-bolt handles shall be not less than 4 inches in length and shall be of designs consistent with their intended usages. The handles shall be without burrs, nicks, scratches, and sharp edges. They shall be securely and firmly attached to the door front to withstand loosening resulting from testing or operation during the service life of the door. The door pull handle may be integral with the throw-bolt handle. Removal of the handle arbor shall be controlled only from the inside of the door. The throw-bolt handle shall require not more than 5 pounds to engage or disengage the bolt work mechanism, and the initial force required to swing the unlocked door from any position shall not exceed 10 pounds at the operating handle.

(4) Door stop. A door stop to prevent the door's face hardware from striking wall surfaces shall be furnished with the door. The stop shall be designed to be mounted on a wall or floor and not on the door. The stop shall be able to withstand hard usage and shall not scratch or scar the door's painted finish when the door is swung open against the stop.

TABLE 35.
Minimum vault construction requirements.

		Class	
	A	B	C
Walls	8-in. RC (1-4)	8-in. (2,4,5,)	8-in.(3,4,5)
Floors	8-in. RC (1)	4-in. (6)	4-in. (6)
Ceiling	8-in. RC	(7)	(7)
Roof	8-in. RC	(7)	(7)
Door/Frame	Class 5	Class 5	Class 5
Misc Openings	(96 sq in.)	(96 sq in.)	(96 sq in.)
Lock	UL 768 1-R	UL 768 1-R	UL 768 1-R

Notes:

(1) Determined by structural requirements but not less than 8 inches of reinforced concrete (RC).

(2) Brick, concrete block, or other masonry units. Hollow masonry units shall be vertical cell-type (load bearing) filled with concrete and steel reinforced bars.

(3) Hollow clay tile (vertical cell double shells) or concrete blocks (thick shells). Where hollow clay tiles are used and such masonry units are flush or in contact with facility exterior walls, they shall be filled with concrete and steel reinforced bars.

(4) Walls are to extend to the underside of the roof or ceiling slab above.

(5) Monolithic steel-reinforced walls at least 4 inches thick may be used (recommended for Class B vaults in seismic areas).

(6) Monolithic concrete construction of the thickness of adjacent concrete floor construction, but not less than 4 inches thick.

(7) Monolithic reinforced concrete slab of a thickness determined by structural requirements.

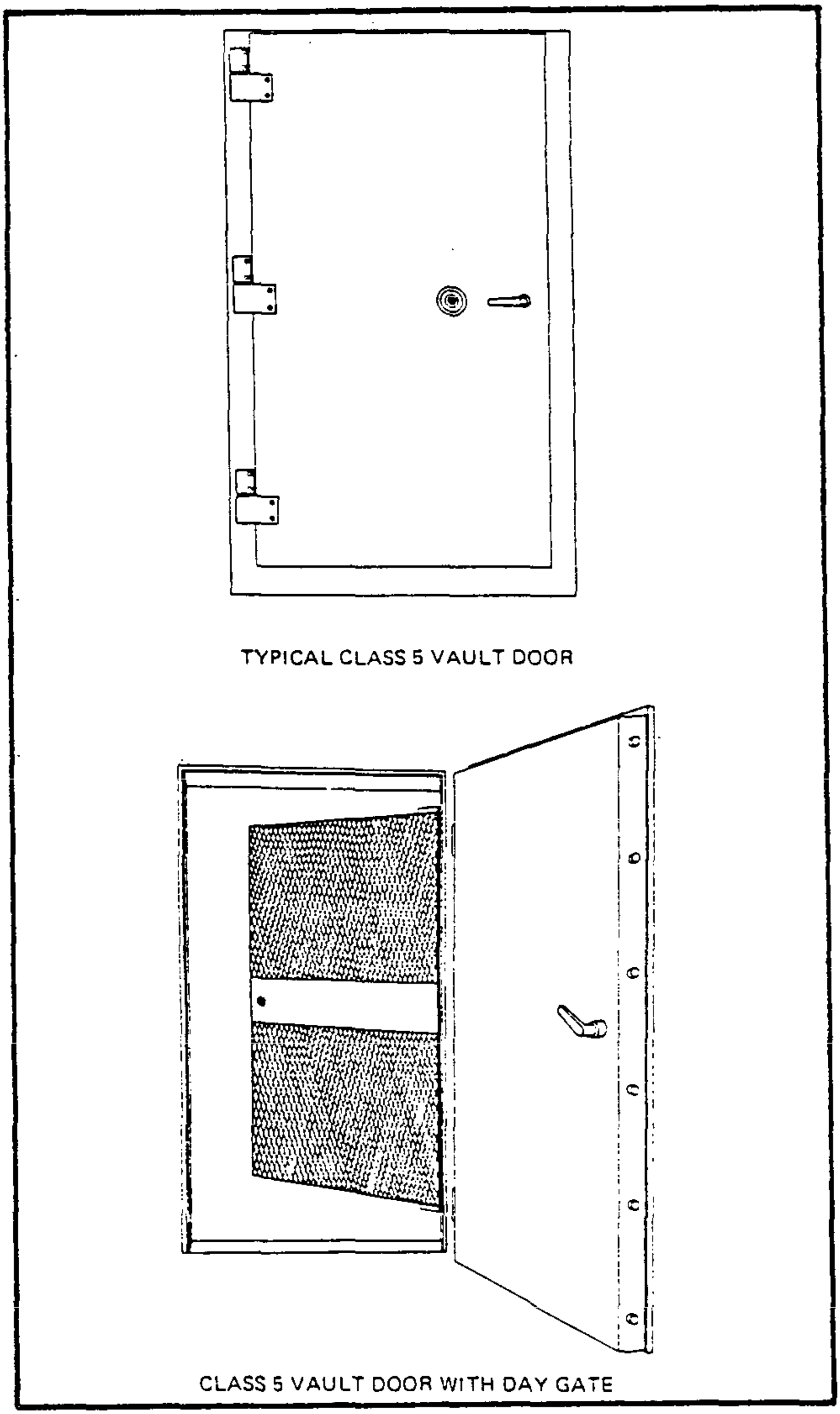


FIGURE 46. Class 5 vault door and day gate.

(5) Door striker. The door shall have a striker on both the front and hinged edges to minimize play or shake in the door when in the locked condition. The fit of the door to the striker on both the front and hinged edges shall be such that there is no more than 1/32-inch of play or shake in the door when the bolts are thrown to the locked position.

(6) Door hinges. The door shall be mounted to the frame by no fewer than three anti-friction bearing hinges, designed to allow the door to be opened approximately 180 degrees. The hinges shall be removable from the outside.

(7) Door threshold. The door threshold shall be designed to provide a ramp of approximately 1/4 inch to permit free swing of the door after its erection. If receptive cups, ports, or grooves are used, they shall be recessed not less than 1/2 inch below the bolt in its extended position to prevent dirt or other substances from obstructing the locking mechanism.

(8) Back cover plate. A back cover plate not less than 16 gauge (0.0598 inch) shall completely enclose the back of the door. The back plate shall be firmly and securely fastened to the door and shall be reinforced or attached by a method to prevent "oil canning." The back plate shall be easily removed for service purposes by the use of common hand tools. The back plate shall have an opening covered by an inspection plate. The opening, with inspection plate removed, shall be large enough and so positioned as to allow maintenance of the door's combination lock and cam assembly.

(9) Combination Lock. The door shall have a changeable combination lock that shall control the door locking mechanism. The lock dial shall be of top-reading design, and the dial ring shall be protected by a standard snap-on dust cover. At the option of the purchaser, the lock shall be a hand change or key change type. The UL Group 1 or 1R label shall be affixed to the lock and will be accepted as evidence of compliance with the UL standard.

(10) Combination Lock Installation. The lock's dial ring shall be mounted so as to be firm and secure without movement or side play. The lock case shall be firmly and securely attached to the door by screws retained by lock washers or other suitable or effective means so that there is no movement or side play to the lock case. The lock's spline key shall not be defaced in any manner and shall be inserted to within 1/32 inch of the top of the lock drive cam. The lock's outer spindle shall be threaded to no more than four threads from the top of the lock drive cam. The formation of the drive cam operating spring shall not be changed or altered in any manner from the formation supplied by the lock manufacturer. Neither the lock bolt nor the drop lever shall be filed, abraided, or otherwise deformed from the formation supplied by the lock manufacturer. No lubricant other than that applied by the lock manufacturer shall be used within the lock case.

(11) Locking Mechanism. The engaging bolts of the locking mechanism shall have a minimum thickness of no less than 1 inch and the attaching linkage shall be channeled, strapped, or welded. The mechanism shall be provided with a detent to lock the bolts in the unlocked position when the bolts are retracted and the door swings open. The detent shall be designed so that it cannot be inadvertently tripped permitting the bolts to be thrown to the closed position.

(12) Locking mechanism and lock mounting drawings. When specified, complete exploded view drawings of the locking mechanism and lock mounting, with individual parts indexed, shall be furnished by the manufacturer.

(13) Escape device. Each vault door shall have an escape device that shall be permanently installed on the inside face of the door. The device shall permit ready escape for persons locked inside the vault area. Access to the device shall be only from inside the vault, and its design shall be such that, under normal operating conditions, it cannot be activated from the outside. A decal shall be permanently affixed to the inside face of the door frame outlining in easily read letters, completely understandable instructions for activating the device to open the door. Neither the design of the device nor its installation shall affect the door's resistance to entry techniques.

(14) Optical device. When specified, the door shall have a wide-angle optical device, and the purchaser should indicate whether the device shall permit observation from inside to outside or vice versa. The optical device shall be installed in such a manner so as not to affect the door's security protection. The device shall be located in the door approximately 5 feet above the bottom of the inside vault door and as close to the center of the door as practicable; however, in no case shall it be closer than 8 inches to the clear opening edge of the door either at the hinged or front edge.

(15) Resistance to entry requirements. The vault door is designed to provide protection for 30 man-minutes against surreptitious entry and 10 man-minutes against forced entry. Federal Specification AA-D-600 discusses test methods in greater detail.

(16) Labels. Each door shall bear the labels as specified below.

(a) General Services Administration label. Affixed to the outside face of the door shall be a label that shall state the following in lettering not less than 1/8 inch in height:

GENERAL SERVICES ADMINISTRATION
APPROVED SECURITY VAULT DOOR
(Manufacturer's Name)

(b) Identification label. Affixed to the inside face of the door frame shall be a label that shall state the door model and serial number, date of manufacture, and Government contract number.

(c) Certification label. Affixed to the inside face of the door frame shall be a label that shall bear the following certificate:

"This is a U.S. Government Class 5 vault door that has been tested and approved by the Government under Fed. Spec. AA-D-600. It affords the following protection:

30 man-minutes against surreptitious entry
10 man-minutes against forced entry
20 man-hours against lock manipulation
20 man-hours against radiology techniques

The protection certified above applies only to the door and not to the vault proper."

(17) Ordering data. Ordering documents should specify the following (Table 36):

(a) Title, symbol, and date of specification.

(b) Class, type, and style required:

- Type IR - Right opening swing: with optical device.
- Type IL - Left opening swing; with optical device.
- Type IIR - Right opening swing; without optical device.
- Type IIL - Left opening swing; without optical device.

(c) Thickness and composition of vault wall. The door assembly will be adaptable to wall thicknesses of 6, 8, 10, or 12 inches. The assembly design shall provide a ±1/2-inch adjustment to allow for variations in the nominal wall thickness.

(d) Request for exploded drawings if desired.

(e) Type of lock. Key change or hand change.

7.3.3.4 Dimensions. The dimensions of the Class 5 vault door and the dimensions of the opening in the vault wall to accept the Class 5 vault door are shown in Figure 47.

7.3.3.5 Ducts, Pipes, and Conduits. Openings through the vault walls, ceilings, and floors will be held to a minimum consistent with security, safety, and adequate personnel health considerations (such as forced air supply fan).

TABLE 36.
Vault doors available through federal supply schedule.

Class	Type	Style	NSN
5	IR	H	7110-00-935-1871
5	IL	H	7110-00-935-1872
5	IIR	H	7110-00-935-1884
5	IIR	H	7110-00-935-1881
5	IR	K	7110-00-935-1885
5	IL	K	7110-00-935-1882
5	IIR	K	7110-00-935-1886
5	IIL	K	7110-00-935-1883

Note:
IR = right opening swing with optical device
IL = left opening swing with optical device
IIR = right opening swing without optical device
IIL = left opening swing without optical device
H = hand change combination lock
K = key change combination lock

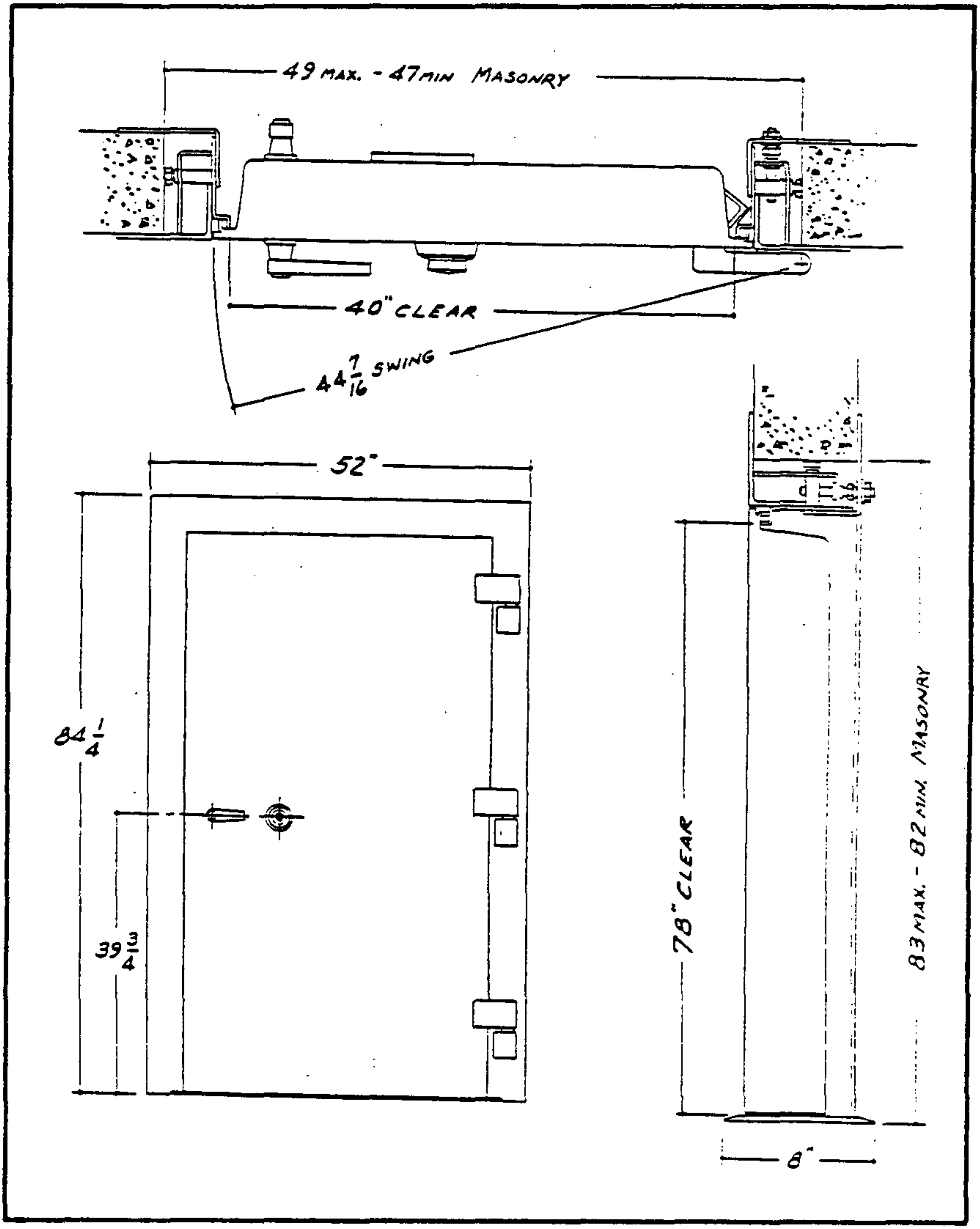


FIGURE 47. Class 5 vault dimensions.

Any openings passing through the protective vault barrier shall not exceed 96 square inches. Preferably, such ducts, pipes, and conduits should be installed and cast in concrete during vault construction. When this is not possible, they shall be carried through snug-fitting pipe sleeves cast in the concrete. After installation, the annular space between the sleeve and the duct, pipe, or conduit shall be caulked solid with lead, wood, waterproof (silicone) caulking, or similar material that will give evidence of surreptitious removal. Ducts, pipes, and conduits shall not be allowed to pass through the vault perimeter or space unless they serve some specific safety, security, or personnel health purpose inside the vault itself. Refer to Subparagraph 1.3.2 for more detail regarding the definition of man-passable openings.

7.3.3.6 Additional Safety Measures. A Class A vault shall be equipped with an interior alarm switch or device (such as a telephone, radio, or intercom) to permit a person in the vault to communicate with the vault custodian or guard post to obtain release. Further, the vault shall be equipped with a luminous type light switch and, if the vault is otherwise unlighted, an emergency light shall be provided.

7.3.3.7 Construction Standards. In addition to the requirements given above, the wall, floor, and roof construction must be in accordance with nationally recognized standards of structural practice. The concrete must be poured in place and have a minimum 28-day compressive strength of 2,500 psi.

7.3.4 Class B Vault. A Class B vault offers adequate protection for classified material and equipment but less protection than a Class A vault. General dimensions are outlined in Table 35 and explained in further detail below:

7.3.4.1 Floor. The floor shall consist of monolithic concrete construction of the thickness of the adjacent concrete floor construction but not less than 4 inches thick. The floor should be reinforced with a minimum of 6- x 6-inch steel mesh, particularly where the slab is not on grade.

7.3.4.2 Walls. Walls shall be constructed of not less than 8-inch thick concrete block, brick, or other similar masonry units in accordance with the requirements imposed by the design dead and live loads. Hollow masonry units shall be of the vertical cell type (load bearing) and will be filled with concrete and steel reinforcement bars. No. 4 or larger reinforcement bars should be placed vertically in each core column. Monolithic steel-reinforced concrete walls at least 4 inches thick may also be considered, and should be considered in seismic areas. As a minimum, reinforcement should be of No. 4 reinforcing bars.

7.3.4.3 Roofs and Ceilings. Roofs and ceilings shall be designed in accordance with the structural requirements dictated by the clear spans between supports to meet dead and live loads and safety factors. A monolithic reinforced concrete slab not less than 4 inches thick shall constitute the roof or ceiling. The slab shall extend across the entire vault and rest on the perimeter vault wall on all sides. Reinforcement should be the same as for a Class A vault. Where a roof is not provided, the reinforced ceiling slab shall not be higher than 9 feet above the vault floor level.

7.3.4.4 Vault Entrances. Since openings into vaults are more vulnerable to attack than the vault enclosure itself, only one entrance should be provided where possible; however, when a vault exceeds 1,000 square feet in floorspace, or when it will have more than eight occupants, it should have a minimum of two exits for safety purposes. When more than one entrance is required, each shall be equipped with an approved vault door (Figure 46), with only one used for normal access. Where continued use of an entry barrier is required at the vault door, a day gate (Figure 46) should be provided for the primary entrance to preclude undue wear of the door, which could eventually weaken the locking mechanism or cause a malfunction. Vault door and frame units shall conform to Federal Specification AA-D-600 for Class 5 vault doors. Requirements of this specification are the same as for Class A vault and are summarized in Subparagraph 7.3.3.3 (1) through (16).

7.3.4.5 Dimensions. The dimensions of the Class 5 vault door and the dimensions of the opening in the vault wall to accept the Class 5 vault door are shown in Figure 47.

7.3.4.6 Ducts, Pipes, and Conduits. Openings through the vault walls, ceilings, and floors will be held to a minimum consistent with security, safety, and adequate personnel health considerations. Any openings passing through the protective vault barrier shall not exceed 96 square inches. Preferably, such ducts, pipes, and conduits should be installed and cast in concrete during vault construction. When this is not possible, they shall be carried through snug-fitting pipe sleeves cast in the concrete. After installation, the annular space between the sleeve and the duct, pipe, or conduit shall be caulked solid with lead, wood, waterproof (silicone) caulking, or similar material that will give evidence of surreptitious removal. Ducts, pipes, and conduits shall not be allowed to pass through the vault perimeter or space unless they serve some specific safety, security, or personnel health purpose inside the vault itself. Refer to Subparagraph 1.3.2 for more detail regarding the definition of man-passable openings.

7.3.4.7 Additional Safety Measures. A Class B vault shall be equipped with an interior alarm switch or device (such as a telephone, radio, or intercom) to permit a person in the vault to communicate with the vault custodian or guard post to obtain release. Further, the vault shall be equipped with a luminous type lightswitch and, if the vault is otherwise unlighted, an emergency light shall be provided.

7.3.4.8 Construction Standards. In addition to the requirements given above, the floor, wall, and roof construction must be in accordance with nationally recognized standards of structural practice. The concrete must be poured in place and have a minimum 28-day compressive strength of 2,500 psi.

7.3.5 Class C Vault. A Class C vault offers minimum protection for classified material and equipment. General dimensions are outlined in Table 35 and explained in further detail below:

7.3.5.1 Floor. The floor shall consist of monolithic concrete construction of the thickness of the adjacent concrete floor construction but not less than 4 inches thick. The floor should be reinforced with a minimum of 6- by 6-inch steel mesh, particularly where the slab is not on grade.

7.3.5.2 Walls. Walls shall be constructed of not less than 8-inch-thick hollow clay tile (vertical cell, double shell) or concrete block (thick shell) in accordance with the requirements imposed by the design dead and live loads. Monolithic steel-reinforced concrete walls at least 4 inches thick may also be used, and should be considered in seismic areas. As a minimum, reinforcement should be of No. 4 reinforcing bars. That portion of the vault wall that coincides with any exterior wall shall be at least of concrete, solid masonry, or hollow masonry units of the vertical cell type (load bearing) filled with concrete and steel reinforcement bars. No. 4 or larger reinforcement bars should be placed vertically in each core column.

7.3.5.3 Roofs and Ceilings. Roofs and ceilings shall be designed in accordance with the structural requirements dictated by the clear spans between supports to meet dead and live loads and safety factors. A monolithic reinforced-concrete slab shall extend across the entire vault and shall rest on the perimeter vault wall on all sides. Reinforcement shall be the same as for floors and walls above. Roofs and ceilings shall be not less than the thickness of the interior vault walls or floor. Where a roof is not provided, the reinforced ceiling slab shall not be higher than 9 feet above the vault floor.

7.3.5.4 Vault Entrances. Since openings into vaults are more vulnerable to attack than the vault enclosure itself, only one entrance should be provided when possible; however, when a vault exceeds 1,000 square feet in floor space, or when it will have more than eight occupants, it should have a minimum of two exits for safety purposes. When more than one entrance is required, each shall be equipped with an approved vault door with only one used for normal access. Where continued use of a barrier to entry is required at the entrance of the vault, a day gate (Figure 46) shall be provided for the primary entrance to preclude undue wear of the door, which could eventually weaken the locking mechanism or cause a malfunction. Vault door and frame units shall conform to Federal Specification AA-D-600 for Class 5 vault doors. Requirements of this specification are the same as for Class A vaults and are summarized in Subparagraph 7.3.3.3 (1) through (16).

7.3.5.5 Dimensions. The dimensions of the Class 5 vault door and the dimensions of the opening in the vault wall to accept the Class 5 vault door are shown in Figure 47. (NOTE: Because Class 6 doors are no longer available through GSA channels, the only way a Class C vault can be authorized for storage of classified material is to be equipped with a Class 5 door. This exceeds standards and may not be the most cost-effective approach to building a security vault. The user should clearly define requirements so that the engineer can design an optimum vault for the least cost.)

7.3.5.6 Ducts, Pipes, and Conduits. Openings through the vault walls, ceilings, and floors will be held to a minimum consistent with security, safety, and adequate personnel health considerations. Any openings passing through the protective vault barrier shall not exceed 96 square inches. Preferably, such ducts, pipes, and conduits should be installed and cast in concrete during construction. When this is not possible, they shall be carried through snug-fitting pipe sleeves cast in the concrete. After installation, the annular space between the sleeve and the duct, pipe, or conduit shall be caulked solid with lead, wood, waterproof (silicone) caulking, or similar material, that will give evidence of surreptitious removal. Ducts, pipes, and conduits shall not be allowed to pass through the vault perimeter or space unless they serve some specific safety, security, or personnel health purpose inside of the vault itself. Refer to Subparagraph 1.3.2, for more detail regarding the definition of man-passable openings.

7.3.5.7 Additional Safety Measures. A Class C vault shall be equipped with an interior alarm switch or device (such as a telephone, radio, or intercom) to permit a person in the vault to communicate with the vault custodian or guard post to obtain release. Further, the vault shall be equipped with a luminous-type lightswitch and, if the vault is otherwise unlighted, an emergency light shall be provided.

7.3.5.8 Construction Standards. In addition to the requirements given above, the floor, wall, and roof construction must be in accordance with nationally recognized standards of structural practice. The concrete must be poured in place and have a minimum 28-day compressive strength of 2,500 psi.

7.4 Modular Vaults.

7.4.1 Introduction. Significant improvement in technology pertaining to vaults has led to the development of a cost-effective alternative to the Class A, B, and C vaults. Although not formally authorized for the storage of classified material, the modular vault may be the optimum choice in selected circumstances.

7.4.2 Advantages of Modular Vaults. Modular vaults are lightweight in comparison to the standard security vault. They are relocatable, easier and quicker to install, have reduced floor loading, and are less expensive. Additionally, they can be custom designed to meet user specifications in terms of size, shape, and weight. Any number of panels of various sizes (Figure 48), can be combined to fit specific space requirements, producing a customized vault (Figure 49) with virtually no design restrictions.

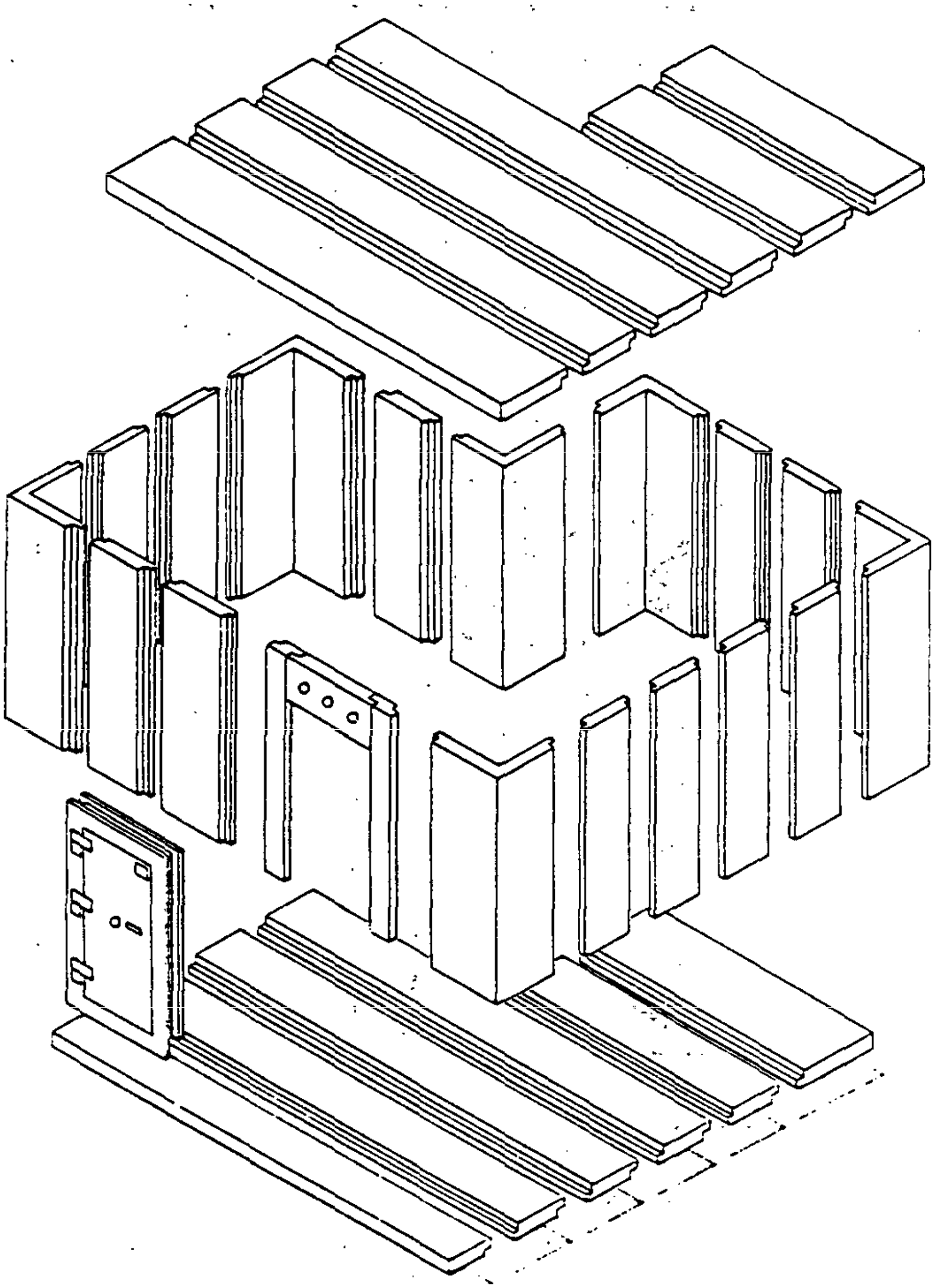


FIGURE 48. Sample modular vault panel arrangement.

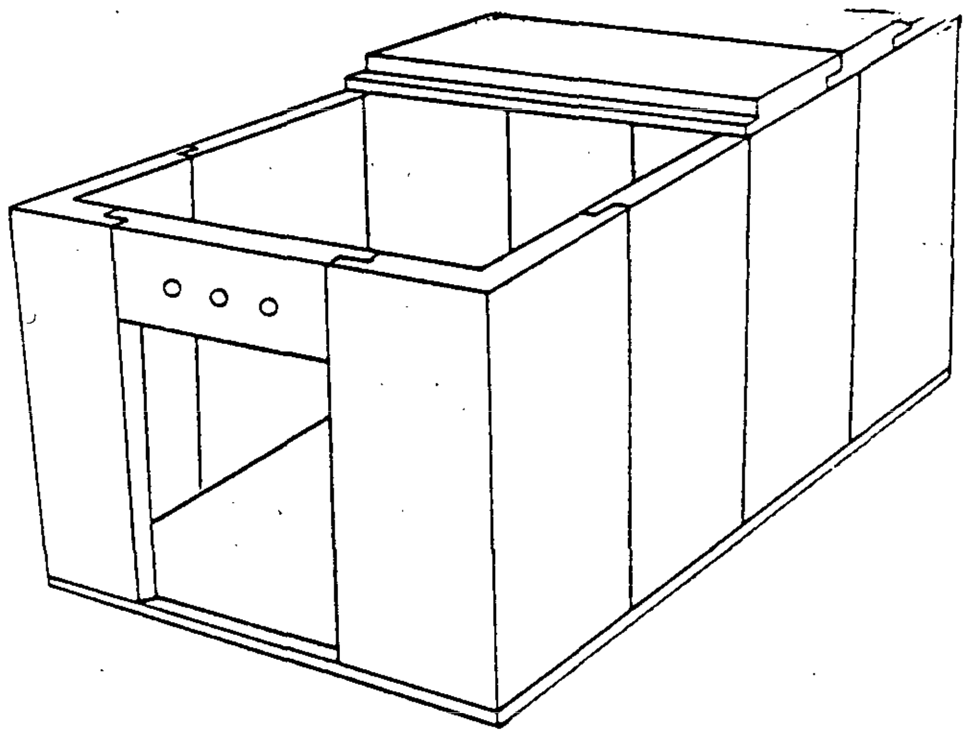


FIGURE 49. Partially assembled modular vault.

7.4.3 Resistance Rating. UL Standard 608, Burglar-Resistant Vault Doors and Modular Panels, establishes ratings of modular panels, some of which equal or exceed those of Class A security vault in terms of penetration resistance. The ratings based on the net working time to effect entry are as follows:

- o Class M - 1/4 hour
- o Class 1 - 1/2 hour
- o Class 2 - 1 hour
- o Class 3 - 2 hours

These ratings are based on attack by common mechanical tools, electric tools, cutting torches, or any combination of these.

7.4.4 Availability. Modular vaults are available from numerous manufacturers throughout the United States. Further information is available in the Navy Physical Security Equipment Manual, Naval Civil Engineering Laboratory, Code L56, Port Hueneme, CA, July 1986.

7.5 Strongrooms.

7.5.1 Overview. A strongroom is an interior space enclosed by or separated from other spaces by four walls, a ceiling, and a floor, all of which shall be constructed of solid materials, or 9 gauge, 2-inch wire mesh as a minimum. Rooms having false ceilings or walls constructed of fabrics, or similar materials do not qualify as strongrooms. If a wall, floor, or ceiling of a strongroom is part of the exterior of a building, separate standards apply as follows:

7.5.1.1 Floors. Floors shall consist of monolithic concrete construction the thickness of the adjacent concrete floor construction but not less than 4 inches thick. The floor should be reinforced with a minimum of 6- by 6-inch steel mesh, particularly where the slab in not on grade.

7.5.1.2 Walls. Walls shall be constructed of not less than 8-inch-thick concrete block, brick, or other similar masonry units in accordance with the requirements imposed by the design dead and live loads. Hollow masonry units shall be of the vertical cell type (load bearing) and will be filled with concrete and steel reinforcement bars. No. 4 or larger reinforcement bars should be placed vertically in each core column. Monolithic steel-reinforced concrete wall at least 4 inches thick may also be used, and should be considered in seismic areas. As a minimum, reinforcement should consist of No. 4 reinforcing bars.

7.5.1.3 Roofs and Ceilings. Roofs and ceilings shall be designed in accordance with the structural requirements dictated by the clear spans between supports to meet dead and live loads and safety factors. A monolithic reinforced-concrete slab not less than 4 inches thick shall constitute the roof or ceiling. The slab shall extend across the entire vault and rest on the perimeter vault wall on all sides. Reinforcement should be the same as for the walls above. Where a roof is not provided, the reinforced ceiling slab shall not be higher than 9 feet above the vault floor level.

7.5.2 Specific Construction Standards. Requirements for the construction of strongrooms are as follows:

7.5.2.1 Walls and Ceilings. Wall and ceiling construction will be of plaster; gypsum board; metal; hardboard; wood; plywood; Number 9 gauge, 2-inch wire mesh or stronger; or other materials offering similar resistance to, or evidence of, unauthorized entry into the area. Insert-type panels will not be used.

7.5.2.2 Floors. Floors will be of solid construction, utilizing materials such as concrete, ceramic tile, wood, etc.

7.5.2.3 Windows. Window openings will be fitted with 1/2-inch bars (separated by no more than 6 inches) plus cross bars (separated by no more than 6 inches) to prevent spreading, or No. 9 gauge mesh fastened by bolts extending through the wall and secured on the inside of the window board. In addition to being kept closed at all times, the windows will be opaqued by any practical means, such as paint, masonite, sheet metal, etc.

7.5.2.4 Miscellaneous Openings. Where ducts, registers, sewers, and tunnels are larger than 96 square inches they will be equipped with man-safe barriers such as wire mesh (No. 9 gauge, 2-inch square mesh) or steel bars at least 1/2 inch in diameter extending across their width, with a maximum space of 6 inches between the bars. The steel bars will be securely fastened at both ends to preclude removal, with cross bars separated by no more than 6 inches to prevent spreading. Where wire mesh or steel bars are used, care will be exercised to ensure that classified material within the room cannot be removed or viewed with the aid of any type of instrument.

7.5.2.5 Doors. Doors shall be of metal construction or solid wood reinforced with a metal panel on the inside as a minimum. When doors are used in pairs, an astregal (overlapping molding) will be used where the doors meet. When the construction is of No. 9 gauge, 2-inch wire mesh, a door constructed of similar material may also be used; however, the wire mesh door will be reinforced with a metal panel at least 36 inches wide from floor to ceiling, welded to the inside of the wire mesh next to the locking device.

7.5.2.6 Door Louvers and Baffle Plates. When door louvers and baffle plates are used, they will be reinforced with wire mesh (No. 9 gauge, 2-inch square mesh) fastened inside the room.

7.5.2.7 Locks. Doors will be secured by a built-in, three-position group I or group IR combination lock. When the construction is No. 9 gauge, 2-inch wire mesh, the locking device will be alarmed to detect attempted tampering with the lock.

7.5.2.8 Hardware. Heavy-duty builder's hardware shall be used in construction. All screws, nuts, bolts, hasps, clamps, bars, hinges, pins, and similar items shall be securely fastened to preclude surreptitious entry and ensure visual evidence of tampering or forced entry. Hardware accessible from outside the area shall be peened, brazed, or spot-welded to preclude removal.

SECTION 8: VEHICLE BARRIERS

8.1 Summary.

8.1.1 Overview. Each Department of Defense (DOD) installation, base, facility, and station is tasked to implement measures necessary to ensure adequate protection for assigned resources. An effective access control system is a vital part of the security effort. In the past the use of gates and guards has been sufficient to control access to all types of DOD areas. However, recent terrorist incidents, involving the use of explosive-laden vehicles in a suicide-type fashion, have forced security managers and security engineers to consider vehicle barriers capable of stopping large vehicles carrying explosives that are traveling at high speed.

8.1.2 Organization of Section. The material in this section will aid the design engineer in meeting this new challenge. Paragraph 8.2 provides a "systems approach" to the selection of vehicle barriers; development of the threat facing the organization; assessment of barrier needs in terms of criticality and vulnerability; and additional considerations that affect the barrier selection process. DOD requirements for vehicle barriers in terms of weight, vehicle speed, and amount of explosives carried in the vehicle and penetration standards are also provided. Paragraph 8.3 defines the five different types of barrier systems and provides examples. Paragraph 8.4 addresses miscellaneous considerations that facilitate the selection, installation, operation, and maintenance of vehicle barriers. Paragraph 8.5 highlights important considerations that pertain to the testing of vehicle barrier systems. A listing of test results is provided to facilitate barrier selection. A comprehensive DOD Users Manual, Entitled "Terrorist Vehicle Bomb Survivability Manual (Vehicle Barriers)," March 1986, for designers, is available from the Security Engineering Division, Code L56, NCEL, Port Hueneme, CA, 93043.

8.2 System Considerations.

8.2.1 Overview. A total "systems approach" to physical security is based on the integration of all security components including fences, lights, alarms, gates, procedures, access control, closed-circuit television (CCTV), blast walls, building components, and personnel. Because of new tactics by terrorists, vehicle barriers are being included as an essential element in a physical security program. When integrated properly into a total system, vehicle barriers can satisfactorily meet the newest threat to sensitive resources. The total systems approach is graphically depicted in Figure 50. This section discusses threat development, security posture assessment (including determination of resource criticality and vulnerability) DOD operational requirements, and general considerations relating to vehicle barrier system selection and utilization.

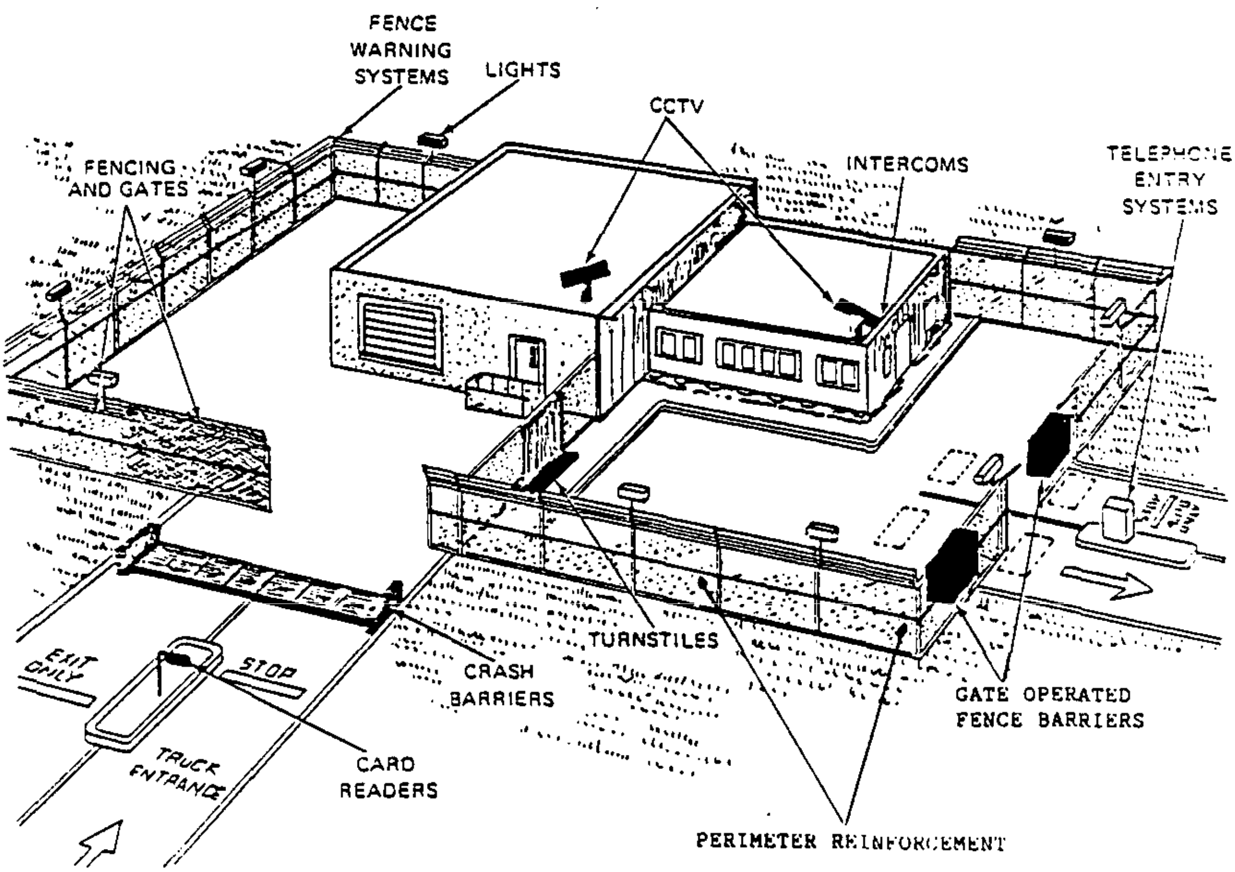


FIGURE 50. Integrated physical security system.

8.2.2 Threat to DOD Installations and Facilities. Threats to DOD installations and facilities may range from minor violations of established rules or procedures to attempted theft of nuclear weapons. Threats can be from individuals with authorized access (military, civilian employees, visitors, or dependents) or from those individuals who have little or no affiliation with the installation. Levels of force, number of personnel involved, tools, and methods used will vary and are determined by the perpetrator. This section is concerned primarily with the threat to sensitive resources located anywhere within the installation.

8.2.3 Threat Assessments. It is the responsibility of the appropriate intelligence agency to provide threat evaluations for each DOD installation, base, and facility. Threat evaluations are based on intelligence information and data furnished by other intelligence activities. This information is used together with locally developed data to determine the local threat assessment. In terms of vehicle barriers, particular attention must be focused on the weights of vehicles that could be used to attempt penetration into a sensitive area, and their velocity.

8.2.4 Security Posture Assessment. Once the security threat has been defined, it is necessary to assess the security posture of the installation. This task is essential to properly counter the potential threat in a cost-effective manner. Failing to use the proper equipment to counter the threat or expending excessive resources to counter the threat creates a false sense of security. This possibility can be avoided by cooperation between the security engineer and the security manager who together should evaluate the criticality and vulnerability of assigned resources.

8.2.4.1 Criticality. Criticality refers to the value of a resource. How important is this resource to the defense of the United States? How important is this resource to the mission of the organization? Weapons (nuclear and conventional), ships, aircraft, and communications facilities are of greater value than gymnasiums, dining facilities, and commissaries. Resources must be considered separately and in total to develop their criticality. Criticality is defined numerically from a low of 1 to a high of 5, for purposes of this handbook.

8.2.4.2 Vulnerability. Vulnerability refers to susceptibility to attack. All facilities have some inherent level of protection. Those located in areas easily accessible to the public are more vulnerable to attack than those located well within a military installation. In determining vulnerability, characteristics such as location, physical security features, environment, and all other factors that relate to the possible success or failure of attack by an aggressor force must be considered. Vulnerability is also numerically defined from a low of 1 to a high of 5.

8.2.4.3 Criticality-Vulnerability Matrix. Table 37 combines the criticality and vulnerability (C-V) ratings into a matrix designed to aid in the determination of barrier needs. Examples of interpretation are furnished to help explain the matrix. It is further delineated into high-, medium-, and low-range classifications to help in determining the types of appropriate barriers. Table 38 categorizes barriers by type and range. The C-V matrix is a tool designed to aid the decision maker in the selection of the best barrier system for the environment where it will be used; however, it is not a decision matrix. Used properly, it will provide an excellent beginning in the deliberation process.

8.2.5 Required Capability. The DOD range of capabilities required for vehicle barriers is outlined in Table 39. Portions of these requirements may not be applicable to all installations due to local site configurations. In general, vehicle barriers should be used at vehicle access points and perimeters to sensitive enclaves. Supplemental gate and fencing reinforcements may also be needed to optimize the effective use of vehicle barriers. Where real estate does not provide adequate standoff protection, or perhaps the likelihood of a parked bomb-laden vehicle with a time detonator exists, blast deflection walls and berms must also be utilized. Maximum weight, weight of explosives, and vehicle velocity requirements may be increased if warranted by local threat conditions.

8.2.5.1 Penetration Standards. One method of evaluating vehicle barriers is to determine the vehicle penetration (in feet) for a given weight and velocity achieved during actual testing. Table 40 lists performance levels used by the Department of State and the U.S. Navy. (Department of State Specification for Vehicle Crash Barriers, SD-STD-0201, April 1985 and Naval Civil Engineering Laboratory, TM M-56-85-01, Vehicle Barriers; and Naval Civil Engineering Laboratory, TM M-56-86-05, Test Plan for Vehicle Crash Testing of Commercial Perimeter Barrier). These ratings serve as a suitable method of comparing the performance of various vehicle barriers. Depending on the location of the resource with respect to the location of the barrier, acceptable penetration distances will vary between installations. An L-1 rated barrier will be acceptable, for example, if the approach road is 200 feet long and the barrier can be located at least 50 feet from the gate or building to be protected (effect of blast from explosives not considered).

8.2.5.2 Blast Walls. In some instances it will be necessary to utilize blast walls to enhance building survivability or to minimize damage caused by detonating an explosives-laden vehicle. The exact placement of these walls must be determined after analyzing the effects of the 1,000 pounds of explosives (minimum referenced in the Navy requirements) detonated. To meet the most restrictive requirement approved by DOD, a blast wall or vehicle barrier must prevent detonation at 400 feet from the resource. This distance is not absolute. An older building with little hardness protection may require increased distance while a newer, hardened building might tolerate a lesser distance.

TABLE 37.

Criticality-vulnerability matrix.

Criticality Value						
5	5-1	5-2	5-3	5-4	5-5	High
4	4-1	4-2	4-3	4-4	4-5	
3	3-1	3-2	3-3	3-4	3-5	Medium
2	2-1	2-2	2-3	2-4	2-5	
1	1-1	1-2	1-3	1-4	1-5	Low
	1	2	3	4	5	

Vulnerability (Threat)

Examples of interpretation:

1-1	Lowest criticality, lowest vulnerability: expend lowest amount of resources.
1-5	Lowest criticality, highest vulnerability: expend low amount of resources.
3-3	Medium criticality, medium vulnerability: expend medium amount of resources.
5-1	Highest criticality, lowest vulnerability: expend only necessary resources, but increase if threat increases.
5-5	Highest criticality, highest vulnerability: expend maximum effort and expense for protection.

TABLE 38.
Barrier effectiveness.

High	Medium	Low
Active Barriers		
Barricade Ramp	Cable Reinforced Gates/ Fences	
Hydraulic or Motorized Barrier	Crash Beams	
Pit Barrier	Sliding Lift/Swing Gates Steel Cable Barriers Wire Rope, Road Block	
Passive Barriers		
Angled Posts	Enhanced Standard Fence	Barbed Wire Fence
Bollards	55-Gallon Drums	Barbed Tape Concertina
Concrete Barriers Circular Highway Median Square Triangular	Guard Posts	General Purpose Barbed Tape Obstacle
Concrete Reinforced Fence	Hedgehogs	Field Perimeter Fence (Cattle Fence)
Dragon's Tooth Concrete Block	Sandbags	Metal Guardrails
Earth-Filled Barrier	V-Fence	
Excavations and Ditches Trapezoidal Triangular V-Cut		
Flowerpot		
Heavy Equipment Tires		
King Tut Block		
Log Cribs		
Masonry Walls		
Tetrahedron		

TABLE 39.

Vehicle crash-resistant barrier requirements.

Parameter	Requirement
Net explosive weight	1,000 pounds
Gross vehicle weight and speed	(1) 10,000-pound vehicle at 50 miles per hour (barrier is at a property boundary or vehicle speed cannot be reduced prior to impact) - 0 to 10 feet penetration (2) 10,000 pound vehicle at 15 miles per hour where real estate is available to slow the vehicle - 50 to 100 feet penetration
Life expectancy	5 to 10 years
Operating time (high-use rate)	0 to 3 seconds
Operating time (low-use rate)	0 to 3 seconds
Operating temperature	-65 to 120°F
Mean-time-between-preventive maintenance (MTBPM)	1 month
Mean-time-for-preventive-maintenance (MTFPM)	2 man-hours
Mean-time-between-repairs (MTBR)	1 year
Mean-time-to-repair (MTTR)	1 working day

TABLE 40.

Penetration standards.

Performance Level	Crash Test Assessment
L3.0	Vehicle and cargo are to be stopped although vehicle partial penetration and/or barrier deflection of up to 3 feet is permitted.
L2.0	Vehicle and cargo are to be stopped although vehicle partial penetration and/or barrier deflection of up to 20 feet is permitted.
L1.0	Vehicle is disabled and does not travel more than 50 feet after impact.

8.2.6 Additional Considerations. There are several additional factors that must be considered prior to the final selection of a particular barrier system. These are addressed to lead to an optimum decision based on the best available information. Without these considerations, selection of a barrier may not be compatible to all of a site's security elements and could be too lethal for the facility or insufficient to a threat. Every security manager strives to achieve sufficient security. However, it can be assured that none would want credit for killing or injuring the innocent due to an over/under rated barrier for the site. With this, the following factors must be considered.

It is essential to begin the barrier selection process with a physical security survey. The purpose of the survey is to identify the resources in terms of criticality and to determine their vulnerability. Deficiencies in other security hardware or procedures should be corrected prior to installing a vehicle barrier system. The facility security manager should thoroughly review existing data relative to penetration delay times developed from actual tests. Much vulnerability information is found throughout this handbook. Additional data is available in appropriate references identified in the Reference section. The following areas should be specifically addressed in the physical security survey:

8.2.6.1 Fencing. Most fences can easily be penetrated by vehicles. Consequently, reinforcement measures may be required to maintain a systems approach to physical security. Table 41 summarizes current evaluation data relative to fixed, in-place vehicle barriers. An analysis of the evaluation data indicates that, unless enhanced by the addition of cables, fences offer little protection against penetration. Fences require enhancement at the same time that vehicle barriers are installed.

8.2.6.2 Windows. Buildings containing critical resources should be analyzed in terms of their survivability from the effects of a given level of blast. The DOD required capability (Table 39) for vehicle barriers and building survivability involves the detonation of 1,000 pounds of explosives. Resources located inside a 400-foot radius should expect slight to severe damage from blast effects. An analysis should be completed based on current explosive effect data to determine what stresses will be imposed upon the structure. Flying glass caused by the effects of blast poses the greatest threat to personnel and damage to equipment and must be addressed. The use of window reinforcement barriers should be considered.

8.2.6.3 Location. Vehicle barriers can be located in different areas: facility entrances, enclave entry points (gates), or at selected interior locations (i.e. entrances to restricted areas). Exact locations will vary from installation to installation; however, in each case the barrier should be located as far from the critical resource as practical. When possible, gates or perimeter boundary fences should be repositioned to a point outside the blast envelope or the resource should be repositioned within the installation to a more secure area. This should be carefully evaluated because consolidation of critical resources into one central area may reduce the number of targets an aggressor must deal with, but at the same time security efforts may be consolidated. Additional studies have shown that it is more cost-effective to secure specific critical resources rather than an entire facility. This technique also provides double envelop security.

8.2.6.4 Vehicle Velocity. Figure 51 relates velocity and distance to vehicle weight. Regardless of the power available to drive a vehicle, its acceleration is limited by the coefficient of friction between the tires and the road surface. A high performance passenger vehicle can maintain an acceleration of approximately 0.35g. A commercial truck (2-1/2 tons) with a reasonable load can be expected to maintain 0.18g. A drag racer with special gum tires can reach acceleration approaching 1.0g. The curves on Figure 51 show the speeds that a car and a 2-1/2-ton truck reach at various distances from a dead start. Formulas are provided for more specific calculations. Using Figure 51, the exact speed at barrier impact can be determined for each installation by using available threat information and existing approach data. Some installations have vehicle approaches that cannot be controlled (i.e. the main entrance begins at the end of a long roadway). Others have approaches that offer a restricted distance when approaching the gate. In the latter case Figure 51 can be used to compute the maximum speed reached by vehicles of different weights.

While a vehicle may have achieved some speed prior to reaching the road leading to an entrance gate, a vehicle's velocity on a curve making a turn is limited by the coefficient of friction between its tires and the roadway. When the centrifugal force of the vehicle exceeds the friction force, the vehicle will start to slide. Figure 52 shows this relationship on a nonbanked turn. A coefficient of friction of 0.60 is used and is based on published test data by various highway study groups. Formulas are provided for calculations unique to special installations.

Figure 52 may also be used to encourage the use of sallyport areas for access control. A sallyport area is a detaining area controlled by two gates. One gate is opened to allow a vehicle to enter the sallyport area. The first gate is then closed, the vehicle and its occupants cleared, and a second gate is opened to allow the vehicle to enter the restricted area. This procedure effectively reduces the vehicle speed to zero prior to approaching the gate affording access to the area containing the critical resource. It also permits selection of a barrier system far less costly and one that offers advantages in such areas as operation, maintenance, and reliability (i.e., nonmechanical wire rope or beam type).

8.2.6.5 Kinetic Energy. Manufacturers normally provide crash test data or calculations in resultant force perpendicular to the barrier, or they provide the total weight of the test vehicle and the velocity of the vehicle at impact. Placing the threat requirement and all test data and calculations in terms of kinetic energy of force will simplify the evaluation and selection process. Kinetic energy is expressed by the equation:

EQUATION: $$KE = 1/2\ mv^2 \qquad (1)$$

TABLE 41.

Results of vehicle barrier tests.

Barrier	Vehicle Weight	Speed	Results (Penetration)
*SNL, Crash Beam	22,000 lbs	36.3 mph	6 feet
8-Inch Bollard System	15,000 lbs	47.0 mph	No penetration
Concrete Planter Box	15,000 lbs	47.0 mph	31.2 feet
8-Inch Bollard System	15,000 lbs	43.5 mph	19.6 feet
Delta, TT 207S	14,815 lbs	49.9 mph	0.75 foot
Concrete-Filled Pipe	4,500 lbs	47.0 mph	72 yards
Delta, TT 212	10,000 lbs	17.0 mph	No penetration
Arrestor	22,000 lbs	36.0 mph	No penetration
Dragnet	1,460 lbs	42.0 mph	10.2 feet
Dragnet	4,300 lbs	60.0 mph	19.4 feet
Dragnet	1,620 lbs	48.0 mph	13.8 feet
Dragnet	4,520 lbs	54.0 mph	23.5 feet
Dragnet	3,760 lbs	56.0 mph	26.3 feet
Dragnet	3,880 lbs	62.0 mph	Greater than 30 feet
Devastator	11,500 lbs	34.0 mph	8.5 feet
Nasatka, MSBII	14,980 lbs	50.3 mph	No penetration
Delta, TT 210	15,000 lbs.	30.0 mph	no penetration
	10,000 lbs.	50.0 mph	no penetration
Chain Link Fence with Top and Bottom Rails	3,300 lbs	48.0 mph	Full penetration
Chain Link Fence with Fabric Buried 2 Feet	4,050 lbs	50.0 mph	Full penetration

*Sandia National Laboratory

TABLE 41.

Results of vehicle barrier tests (continued).

Barrier	Vehicle Weight	Speed	Results (Penetration)
Chain Link Fence with 3/4-Inch-Diameter Cable	3,350 lbs	23.5 mph	7 feet
Chain Link Fence with 3/4-Inch-Diameter Cable	4,050 lbs	50.6 mph	26 feet
Two 3/4-Inch-Diameter Cables with Fence Posts and Deadman Anchors	4,000 lbs	52.0 mph	13 feet
Anchored Concrete Median Barrier, Not Reinforced	4,000 lbs	50.0 mph	20 feet
Buried Tires 36-Ply D-Ft Diameter, 2,000 lbs Each	3,350 lbs	50.5 mph	1 foot
SNL, V-Fence with Rock and Pole Fill	3,800 lbs	52.0 mph	8 feet
Concrete Block Wall, Cores Unfilled	3,000 lbs	42.0 mph	Full penetration
Concrete Block Wall with Rebar and Filled Cores	3,000 lbs	21.3 mph	Full penetration

TABLE 41.

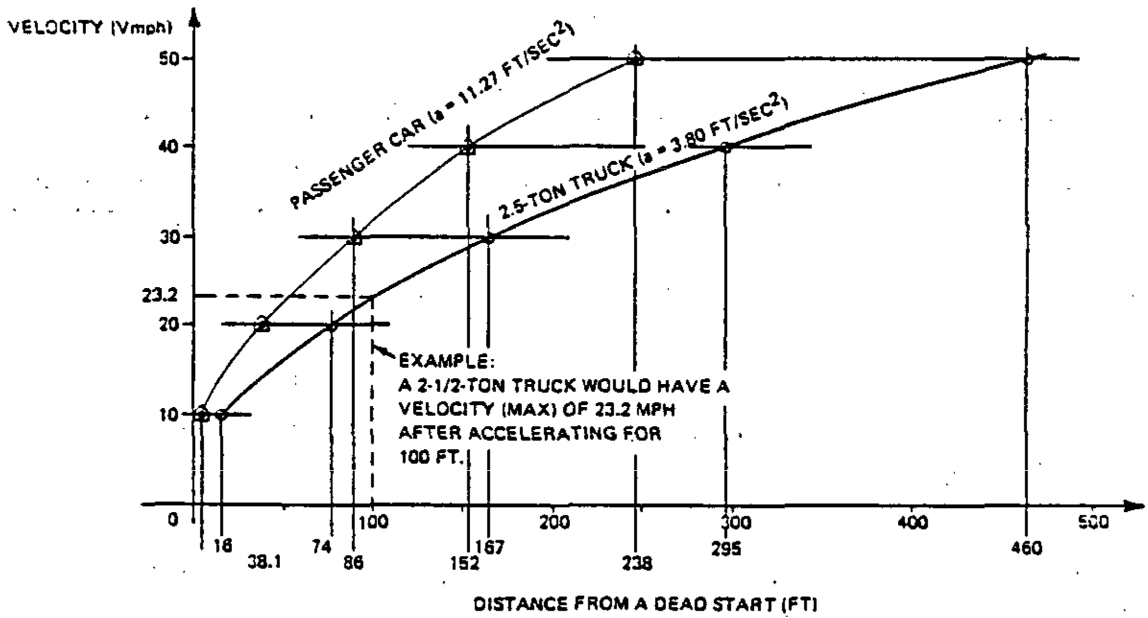
Results of vehicle barrier tests (continued).

Barrier	Vehicle Weight	Speed	Results (Penetration)
Twin T-Beam Wall	3,000 lbs	42.5 mph	Full penetration
Reinforced Concrete Wall, 6 Inches Thick	3,000 lbs	39.6 mph	No penetration
Single Buried Concrete-Filled 8-Inch-Diameter Schedule 40 Pipe	4,500 lbs	30.0 mph	3 feet
Single Swing Gate with Latch and Locked Chain	4,000 lbs	50.0 mph	Full penetration
Double Swing Gate with Latch and Cane Bolt	4,000 lbs	50.0 mph	Full penetration
Dual Post 5/8-Inch Cable	4,500 lbs	20.0 mph	Full penetration
Dual Post 3/4-Inch Cable	4,500 lbs	20.0 mph	2 feet
Dual Post 3/4-Inch Cable	4,500 lbs	39.0 mph	Full penetration
Dual Post 3/4-Inch Cable	4,500 lbs	47.0 mph	Full penetration
Delta, TT207 30 Inches High, 108 Inches Long	6,000 lbs	50.0 mph	27 feet

TABLE 41.

Results of vehicle barrier tests (continued).

Barrier	Vehicle Weight	Speed	Results (Penetration)
Delta, TT207 30 Inches High, 208 Inches Long	18,000 lbs	30.0 mph	29 feet
Delta, TT241 19 Inches High, 17 Inches Wide	6,000 lbs	29.0 mph	82 feet
Frontier, Mac-H10	18,000 lbs	35.0 mph	1 foot
32 Inches High, 120 Inches Long	20,000 lbs	41.0 mph	56 feet
Robot, SCB Crash Beam	4,500 lbs	23.0 mph	4 feet
SNL, Crash Beam	22,000 lbs	43.0 mph	13 feet
Western, Portapungi	14,980 lbs	39.8 mph	40 feet
Entwistle, Dragnet	?	?	Discussed at a Sandia conference.



a = ACCELERATION (FT/SEC^2)

V_f = VELOCITY (FT/SEC)

Vmph = VELOCITY (MPH)

t = TIME (SECONDS)

s = DISTANCE (FT)

SINCE $s = 1/2\ a.t^2$

AND $V = t = \frac{V_f}{a}$

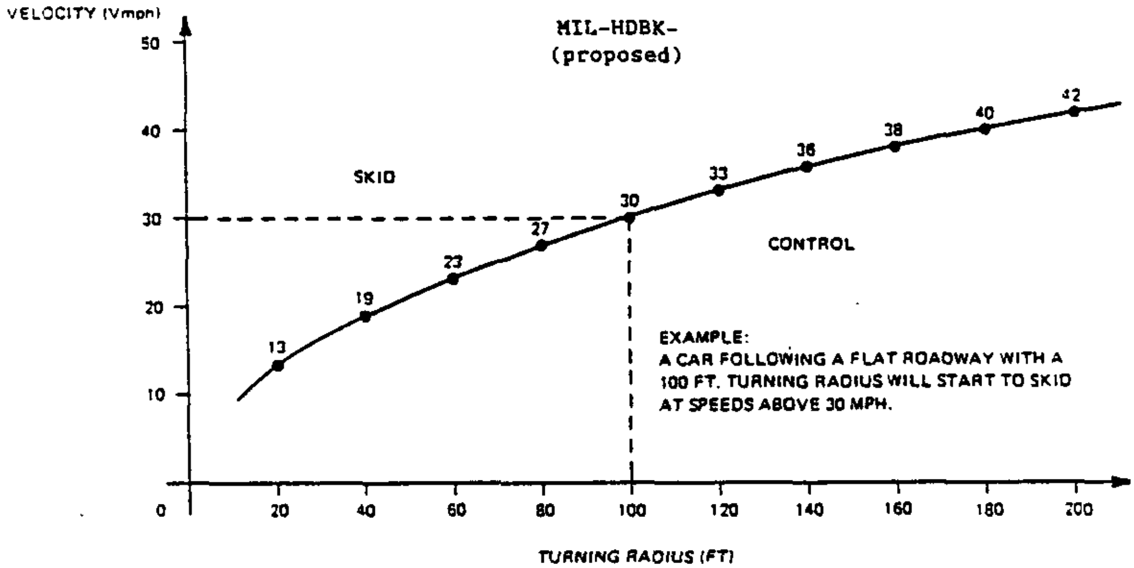
THEN $s = 1/2.a.\ \frac{V^2}{a^2}$

$\therefore s = \frac{0.5.V_f}{a}$ OR $V_f = \sqrt{2sa}$

$$Vmph = \frac{3,600}{5,280} \cdot \sqrt{2sa}$$

$$Vmph = 0.68\ .\ \sqrt{2sa}$$

FIGURE 51. Vehicle velocity.



V_f = VELOCITY (FT/SEC)
Vmph = VELOCITY (MPH)
g = ACCELERATION OF GRAVITY (32.2 FT/SEC^2)
R = RADIUS OF TURN (FT)
μ = COEFFICIENT OF FRICTION
w = WEIGHT (LB)

$$\text{CENTRIFUGAL FORCE} = \frac{w \cdot V_f^2}{g \cdot R}$$

$$\text{FRICTION FORCE} = \mu \cdot w$$

$$\text{THEN} \quad = \frac{w \cdot V_f^2}{g \cdot R} = \mu \cdot w$$

$$\text{AND} \quad = \frac{w \cdot V^2mph}{32.2\ R} = \left(\frac{3,600}{5,280}\right)^2 \mu \cdot w$$

$$Vmph = \sqrt{\left(\frac{3,600}{5,280}\right)^2 (32.2)(\mu \cdot R)}$$

$$= \sqrt{14.96\ \mu R}$$

$$\Rightarrow R$$

$$= \frac{V^2mph}{14.96}$$

FIGURE 52. Turning radius.

where

KE = Kinetic Energy (ft-lb)
m = vehicle mass ($lb\text{-}sec^2/ft$)
v = velocity (ft/s)

This equation can be simplified for vehicle crash threats, requirements, and tests as follows:

EQUATION:

$$KE = 33.44 \times 10^{-3}(wv^2) \qquad (2)$$

where

KE = Kinetic Energy (ft-lbs)
w = vehicle weight (lbs)
v = velocity (mph)

The information about the capabilities required for a vehicle barrier in weight and expected velocity can be converted to the force in kinetic energy that must be absorbed by the barrier. The selection of barrier that will defeat the threat is simplified by having all barrier tests and calculations expressed in terms of kinetic energy. For example, from previous calculations it is determined that the maximum weight of a threat vehicle is 10,000 pounds and the maximum speed it can achieve due to road conditions and configurations is 40 miles per hour. To find the kinetic energy, use the simplified equation above as follows:

EQUATION:

$$KE = 33.44 \times 10^{-3}\ (10{,}000\ lb)\ (40\ mph)^2 = 535{,}040\ ft\text{-}lb \qquad (3)$$

Vehicle barriers that are able to withstand forces greater than 535,040 ft-lb can be assumed to meet the estimated threat shown in the example. Conversely, vehicle barriers that have not demonstrated their capability to absorb 535,040 ft-lb cannot be assumed adequate to contain the threat vehicle. The use of kinetic energy calculations also provides a means of comparing various vehicle barriers with each other.

8.2.6.6 Aesthetics. The overall appearance of a vehicle barrier plays an important role in its selection and acceptance. The "fortress effect" may be a desirable feature, but many barriers are now made with aesthetics in mind. Figure 53 is an excellent example.

8.2.6.7 Safety. An active barrier system should be considered and treated as a tool capable of deadly force. When used for its intended purpose, it will kill or seriously injure individuals who attempt unlawful penetration of a restricted area. It can also kill or seriously injure other individuals as a result of accidental or inadvertent activation caused by either operator error or equipment malfunction. Proper warning lights, bells, and adequate colors

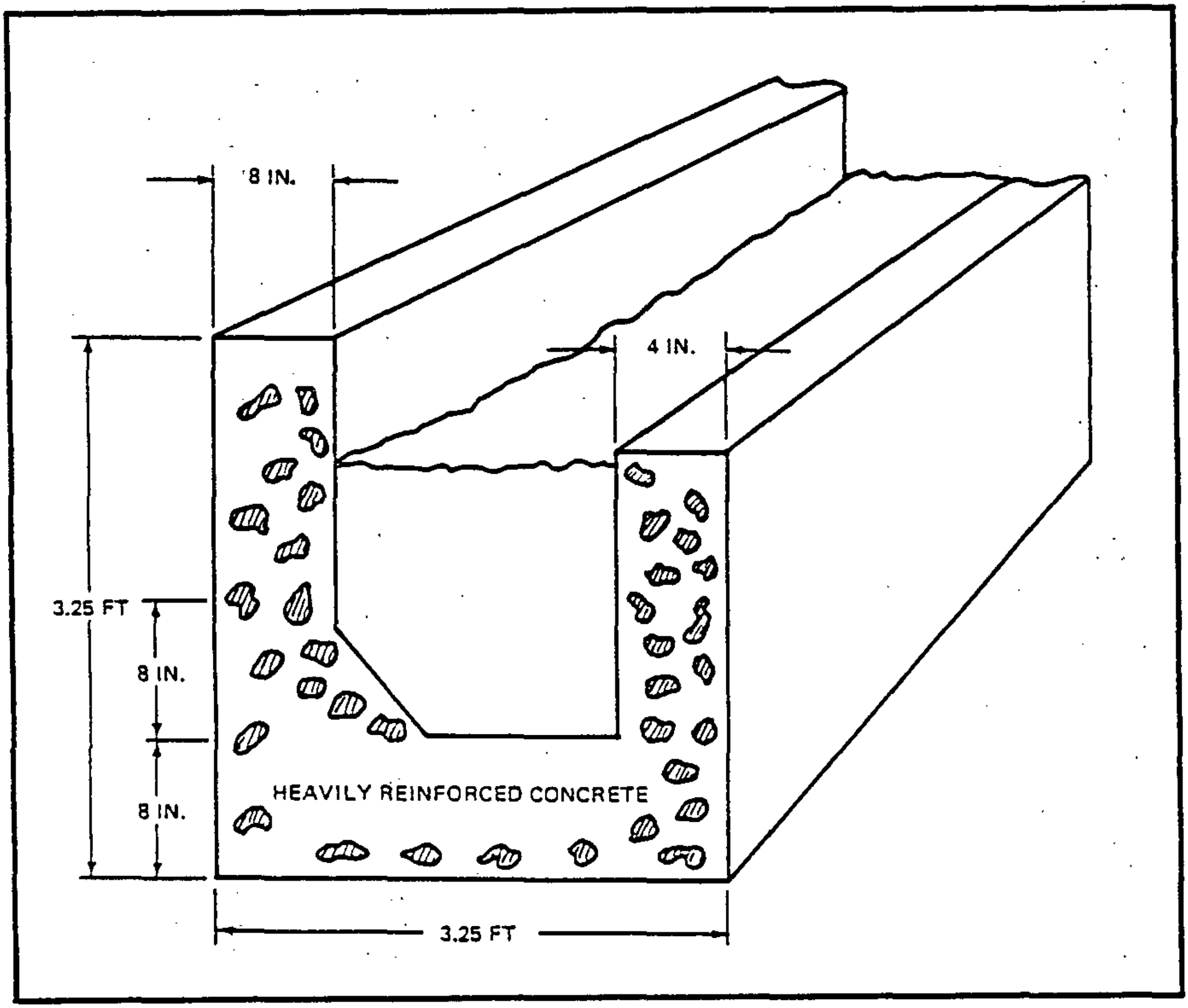


FIGURE 53. Planter barrier.

to identify the barrier must be provided to ensure personnel safety. Questions such as: What happens when power is lost? Is there an emergency stop switch? Is lighting adequate? What safety options are available from the manufacturer? should be addressed to manufacturers and current users to identify potential safety considerations affecting the selection of a barrier system.

8.2.6.8 Reliability. Most vehicle barrier systems have not been in production for a sufficient length of time to have developed an acceptable history of reliability. Some systems are placed in environments not envisioned by the manufacturer while others have developed problems not anticipated by either the manufacturer or user. Several manufacturers have shown a remarkable desire to resolve problems and work effectively with users.

8.2.6.9 Operator Training. Most users surveyed strongly recommend a system of operator training regardless of the simplicity of the system. This will prevent serious injury and equipment/vehicle damage caused by improper operation of the system. Most manufacturers provide schematics and diagrams, but little information on possible operator problems. The owner/user agency may be required to develop its own checklists for normal and emergency operations to avoid experiencing serious problems.

8.2.6.10 Options. All manufacturers offer additional features with their systems in the form of options or optional equipment. Most enhance system performance while others facilitate maintenance or safety. All increase the cost and some increase maintenance requirements. The more common optional features offered by manufacturers are shown on Table 42. Because options vary greatly between manufacturers, consulting with each company is advised to determine which options are offered and their cost.

8.3 Vehicle Barrier Types.

8.3.1 Overview. Vehicle barriers can be categorized as active, passive, fixed, movable, or portable. Definitions used in this section may differ from those used by manufacturers and other agencies since no industry-wide agreement exists. Many barriers can be dual-classified because they meet the requirements for both categories (e.g., fixed-active, portable-passive). A large truck, for example, can be both an active-movable or a passive-movable system: the former if it is moved each time to permit entry after proper identification, or the latter if it is left in place overnight to preclude entry.

8.3.2 Active Barrier Systems. A barrier is considered active if it requires either a personnel or equipment action to permit entry. Systems that move solid masses, impalers, beams, gates, tire shredders, fences, or those that create pits or ramps are active barriers. Vehicles (trucks, bulldozers, etc.) are active barriers if used in that mode in the access control system.

TABLE 42.
Options available for selected vehicle barrier systems.

Options	System									
	Amer. Sec. Fence Devastator	Babcock & Wilcox Arrestor	Delta TT210	Delta TT207S	Delta TT212	Entwistle Dragnet	Frontier Mac-H10	Nasatka NSB II	Robot Model SCB	Western Portapungi
Access Control System	X		X	X				X		
Adjustable Cycle Operating Time			X	X				X		
Automatic Operation		X			X					X
Auto-Read Laser ID System	X							X		
Battery Power Backup	X		X	X			X			
Card Access Control		X	X	X	X			X		X
Cooling for Electrical Systems										
Cushioned Impact (Aesthetics and Safety)						X				
Directional Indicating System	X		X	X					X	
Export Packaging	X		X	X	X		X		X	
Heated Sump and Pump			X	X			X			
Higher Power and Pump Combination			X	X						
High-Speed Monitor Alarm System	X		X	X				X		
Hydraulic Capability			X	X	X		X	X		X
Hydraulic Oil Cooler			X	X			X			
Hydraulic Oil Heater			X	X			X			
Integral/Remote Hydraulics			X	X			X	X		
Interface Modules for Compatibility										
Key Lock Switch			X	X	X					
Lift Gate			X	X			X			
Low-Temperature Protector		X	X	X						
Manual Hydraulic Pump System	X		X	X			X	X		
Master Station With Override Control			X	X			X			
Multiple Station Control	X		X	X			X		X	
Open Barricade Warning Annunciator	X		X	X					X	
Portability Package		X								X
Programmable Controller	X		X	X			X	X		
Radio Control Operation			X	X	X				X	
Red/Green Traffic Lights	X		X	X	X			X	X	
Remote Operation Controls			X	X	X		X		X	
Repetitive Cycle		X								
Self-Priming Sump Pump			X	X			X			
Strip Heater With Thermostat			X	X						
Tamperproof Package								X		
Tiger Teeth on Barrier Front Edge	X									X
Timer/Safety Detector	X							X	X	
Uninterruptible Power System (UPS)		X								
Warning Lights			X	X	X		X			
Water Level Indicator							X			
Wireless Activation			X	X	X					
50-Hz Motors and Controls	X		X	X	X		X	X	X	
60-Hz Motors and Controls	X		X	X	X		X	X	X	

8.3.3 Passive Barrier Systems. A barrier is passive if its effectiveness relies on its bulk or mass, and it has no moving parts. Such systems typically rely on weight to prevent entry into a restricted area. Sandbags, highway medians, angled posts, tires, and guard rails are examples of passive barrier systems. Table 43 lists many barriers divided into active and passive categories.

8.3.4 Fixed Barrier Systems. A system is fixed if it is installed in a permanent fashion or it is of such weight that heavy equipment is required to move or dismantle the barrier. Hydraulically operated rotation or retracting systems, pits, and concrete or steel barriers are excellent examples. Fixed barrier systems can be both active or passive.

8.3.5 Movable Barrier Systems. Movable systems are transferable from place to place. Heavy equipment or a large number of personnel may be required to assist in the transfer. Highway medians, sandbags (large numbers), 55-gallon drums (filled), or vehicles are typical examples.

8.3.6 Portable Barrier Systems. On occasion, a requirement exists to temporarily install a barrier system for a specific purpose or period of time. While it is possible to use a movable system for this purpose, such an action may involve a greater expenditure of time, money, and effort than necessary. A portable system (Figure 54) is ideal for this situation and may provide the necessary security needed. Examples of portable barriers are ropes, chains, vehicles, or tire-puncture systems.

8.4 Miscellaneous Considerations.

8.4.1 Overview. The use of active vehicle barrier systems to meet the growing threat posed by explosive-laden vehicles is a relatively new phenomenon and many installations are learning through trial and error to select, procure, operate, and maintain such systems. The purpose of this section is to relate suggestions from organizations at all levels involved with vehicle barrier systems. They are a set of statements that may be useful to the potential buyer of an active crash-resistant barrier system. Readers are welcome and encouraged to augment this list by directing their input to the Security Engineering Division, Code L56, Naval Civil Engineering Laboratory, Port Hueneme, CA 93043.

8.4.2 Actions That Should be Considered. The following actions are recommended and are based on input from manufacturers, users, and engineers.

- Locate support equipment (i.e., hydraulic power, generator, batteries, etc.) away from the guard posts to lower the threat of sabotage.

- Insist on an operation and maintenance schedule from the manufacturer.

- Have an alternate route plan in the event of either a failure of the barrier to allow traffic to flow, or emergency evacuation.

TABLE 43.
Ten vehicle barriers systems.

Characteristics	System				
	Amer. Sec. Fence Devastator	Babcock & Wilcox Arrestor	Delta TT210	Delta TT207S	Delta TT212
Active	X	X	X	X	X
Passive					
Fixed	X	X	X	X	X
Movable					
Portable					
Cost	$4,950 (2 point)	$30,000	$3,308	$15,826	$3,099
Installation Cost	$850	$9,000	Approx. 40% of unit cost	Approx. 40% of unit cost	Approx. 15% of unit cost
Width (Length)	60 inches (3 point - 92 inches)	12 inches	10.5 inches (Bollard width)	108 inches (Variable)	125 inches (Variable)
Height	26 Inches	40 Inches	30 Inches	38 Inches	30 Inches
Operating Cycle	1/2 second to full height	5 seconds	6 to 8 seconds (adjustable)	3 to 15 seconds (adjustable)	Manual
Emergency Cycle	N/A	0.75 second	0.6 second	Rise in 1.5 seconds	N/A
Backup Power Capability	N/A	Yes	Yes	Yes	N/A
Test Data: Date Results	12-83 0.5-foot penetration 11,500 lbs at 34 mph 2-point manual	2-85 No penetration 22,000 lbs at 34 mph	2-86 No penetration 1500 lbs at 30 mph and 10,000 lbs at 50 mph	9-85 0.75-foot pene tration 14,185 lbs at 50.1 mph	11-85 No pene-tration 10,000 lbs at 17 mph

TABLE 43.
Ten vehicle barriers systems. (continued)

Characteristics	System: Entwistle Dragnet		Frontier Mac-H10	Nasatka MSB II	Robot Model SCB	Western Portapungi
Active	X		X	X	X	X
Passive			X	X	X	X
Fixed	X					X
Movable						X
Cost	$18,500		$26,021 10 feet	$27,500	$16,000 14 feet	$6,900 8-foot manual
Installation Cost	$1,000		$8,000	$2,000 Minimum	Variable	Variable
Width (Length)	Variable		10 feet (Variable)	10 feet (Variable)	Beam is 6 x 15.5 inches Varies by type and size	10 feet Variable
Height	6 feet		32 inches (36 inches available)	31 inches	Variable	23 inches
Operating Cycle	Manual		1.8 seconds (Adjustable)	4 to 8 seconds (Adjustable)	Variable	Less than 2 seconds
Emergency Cycle	N/A		1 second	1 second	N/A	N/A
Backup Power Capability	N/A		Yes	Yes	N/A	N/A
Test Data: Date: Results:	11-86 10.2-foot penetration 1,460 lbs at 42 mph 11-86 13.8-foot penetration 1,620 lbs at 48 mph 11-86 19.4-foot penetration 4,300 lbs at 60 mph	11-86 23.5 ft penetration 4,520 lbs at 54 mph 11-86 26.3-foot penetration 3,760 lbs at 56 mph 11-86 >30-foot penetration 1,880 lbs at 62 mph	2-85 1-foot penetration 18,000 lbs at 35 mph 2-85 56-foot penetration (Debris) 20,000 lbs at 41 mph	9-85 No penetration 14,980 lbs at 50 mph	5-85 4-foot penetration 4,500 lbs at 23 mph	11-85 40-foot pene- tration 14,980 lbs at 39.8 mph

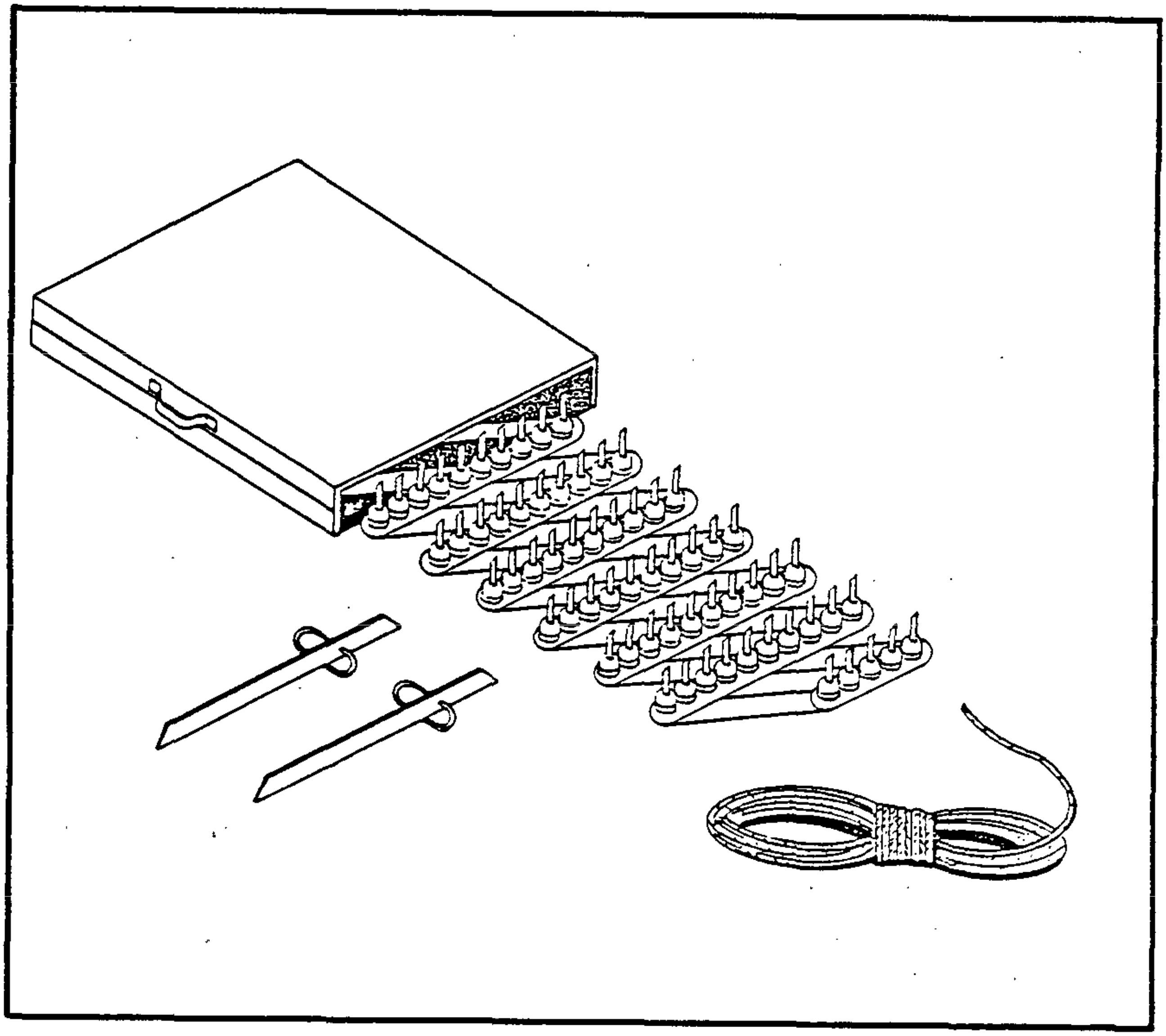


FIGURE 54. Road fangs.

o Provide a thorough training program for operators (including those who operate the system temporarily).

o Provide adequate environmental protection against freezing, dust, and overheating.

o Ensure that the barrier is compatible with other security elements. For example, an active crash-resistant barrier system should not be installed adjacent to chain link fencing that does not provide the same protection.

o Unless desired, avoid a barrier that creates a fortress appearance. Consider aesthetics in terms of image and acceptance.

o Consider installation costs as part of the total package for a barrier system. Installation costs of some commercial systems are the same or greater than the cost of the barrier.

o Ensure that contract guards, unions, and security officers are in agreement on the deployment, use, and responsibility of the barrier system.

o Locate vehicle barriers as far away from the critical resource or asset as practical to provide explosive safety.

o Use active barrier systems (those that must be activated, retracted, or withdrawn to allow a vehicle to pass) whenever possible. Active barrier systems remove the unreliability problem associated with a guard having to activate a barrier under stressful conditions.

o Consider frequency of use carefully in selecting a system. Some systems provide for greater traffic flow than others.

8.4.3 Actions That Should be Avoided. The following actions should be avoided in the selection, installation, and use of barrier systems:

o Avoid installing sunken (underground) barriers unless the excavation can be drained. Collecting water will cause corrosion, and freezing weather may incapacitate the system.

o Avoid providing vehicle barriers at entrance gates without providing equivalent protection at perimeter locations.

o Avoid minimal protection of the perimeter of an installation. Maximum perimeter protection is generally more cost effective for protection of individual buildings and zones within the perimeter.

o Avoid providing perimeter vehicle barriers that are not patrolled or frequently observed. Most types can be overcome quickly with simple tools or ramps.

- o Avoid placing guard posts next to barriers.

- o If separate barriers are used for exits and entrances, avoid controlling only the entrance. Require access control for the exit also.

- o Avoid a long straight-away (greater than 460 feet) road to a crash-resistant barrier system.

- o Avoid use of push button switches.

8.5 <u>Testing</u>.

8.5.1 <u>Overview</u>. No area is more critical in the barrier selection system process than testing. Without adequate testing, there is no assurance that the product will successfully resist the defined threat. Testing is normally accomplished by an independent testing company, by a state agency, or, in some cases, by a manufacturer. Usually Government agencies (Department of State, military departments, etc.) are represented and oversee the testing process for qualification or rating purposes. Comprehensive reports are issued to report test results and should be available from the testing agency or the manufacturer.

8.5.2 <u>General</u>. Table 41 synopsizes current data on vehicle barrier systems that have been tested. More specific information is contained in test reports. Several areas bear additional comment:

8.5.2.1 <u>Manufacturer Tests</u>. Tests conducted by the manufacturer may be suspect unless witnessed by representatives of interested Government agencies or reported by independent testing agencies.

8.5.2.2 <u>Barrier Ratings</u>. Department of State (DOS) and U.S. Navy ratings for vehicle barrier systems are a recent development. Many excellent systems, while adequate to meet defined threats, have never been rated. Some systems may never be rated by these agencies because of their inapplicability to their needs. Systems should not be eliminated from consideration because they do not have an agency rating.

8.5.2.3 <u>Further Information</u>. Barrier testing is a dynamic process. New and existing systems are constantly being evaluated. For the most current information available, contact the Security Engineering Division, Code L56, Naval Civil Engineering Laboratory, Port Hueneme, CA 93043.

8.5.2.4 <u>Performance Trade-Offs</u>. Current testing is to limits set by the military or DOS. Such limits will enable an installation to procure a system to meet projected needs envisioned for most installations. These needs may, however, be greater than required for some areas. For example, a system that allows 50- to 100-foot penetration may be appropriate if sufficient real estate is available. To obtain the best and most cost-effective system, acquire one that meets the defined threat of the installation for which it is purchased.

8.6 Vehicle Barrier Systems.

8.6.1 General. Information on specific vehicle barrier systems that have been tested and are available for purchase is included in this section. Table 43 consolidates data on the 10 selected systems. Table 42 indicates the options available with each system. Manufacturers of the systems included are listed in Figure 55. Diagrams of each system are included to give a concept of operation (Figures 56 through 65).

8.6.2 Additional Comments. Information on vehicle barrier systems described in this section is based on discussions with manufacturers and a review of their product information packages. The fact that a particular system or product is included in this handbook does not imply endorsement by the Department of Defense, the Department of the Navy, or the Naval Civil Engineering Laboratory. They are listed as a service to agencies acquiring a vehicle barrier system. Several additional comments are warranted.

8.6.2.1 Options. Options are those currently offered. Most manufacturers have indicated a willingness to add options needed by the user. Many options provide simple features and can be added with relative ease. All options are at additional cost. Some manufacturers include features in their basic system cost while others add charges for the same features. It is best to plan for the needs of the installation prior to discussing those needs with several manufacturers..

8.6.2.2 Installation Costs. Installation costs depend on soil, site conditions, and labor costs. Estimates included in this section are average costs for systems previously installed.

8.6.2.3 Future Updates. It is the intent of DOD to update system data. Information on new tests and new systems will be added to this handbook as the tests and systems are developed.

8.6.2.4 Prices. Prices are current as of January 1986 (see Table 43), and are included to give the prospective purchaser a range of costs associated with the different types of barrier systems. Manufacturers reserve the right to change their prices at their discretion.

1. American Security Fence Corporation
   P.O. Box 663
   2525 North 27th Avenue
   Phoenix, AZ 85005
   (Distributor)

   Tiretrap, Inc.
   518 Barrymore Street
   Phillipsburg, NJ 08865
   (Manufacturer)

2. Babcock & Wilcox
   Nuclear Power Division
   3315 Old Forest Road
   P.O. Box 10935
   Lynchburg, VA 24506-0935

3. Delta Scientific Corporation, Inc.
   2031 North Lincoln Street
   Burbank, CA 91504

4. Entwistle Company
   Bigelow Street
   Hudson, MA 01749

5. Frontier Machinery Company, Inc.
   20 James Avenue
   Tonawanda, NY 14150

6. Nasatka & Sons, Inc.
   8405 Dangerfield Place
   Clinton, MD 20735

7. Robot Industries, Inc.
   7041 Orchard Street
   Box 219
   Dearborn, MI 48126

8. Western Manufacturing
   1405 Sinclair Street
   P.O. Box 55
   Bottineaw, ND 58318

   Sales Representative
   TSTCO
   1637 Meadowlark Drive
   Fairfield, CA 94533

FIGURE 55. Vehicle barrier manufacturers.

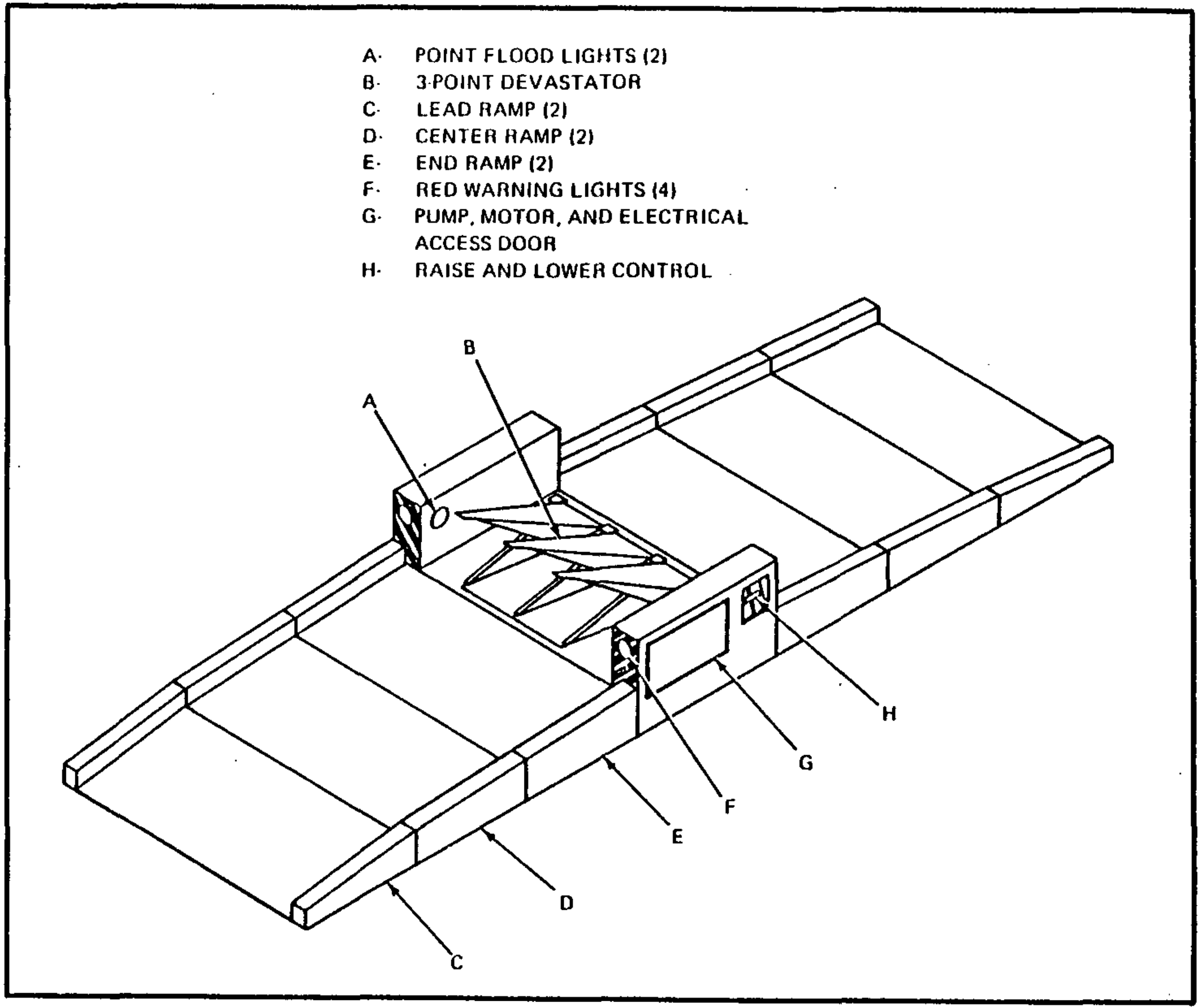


FIGURE 56. American security fence (tiretrap) devastator system.

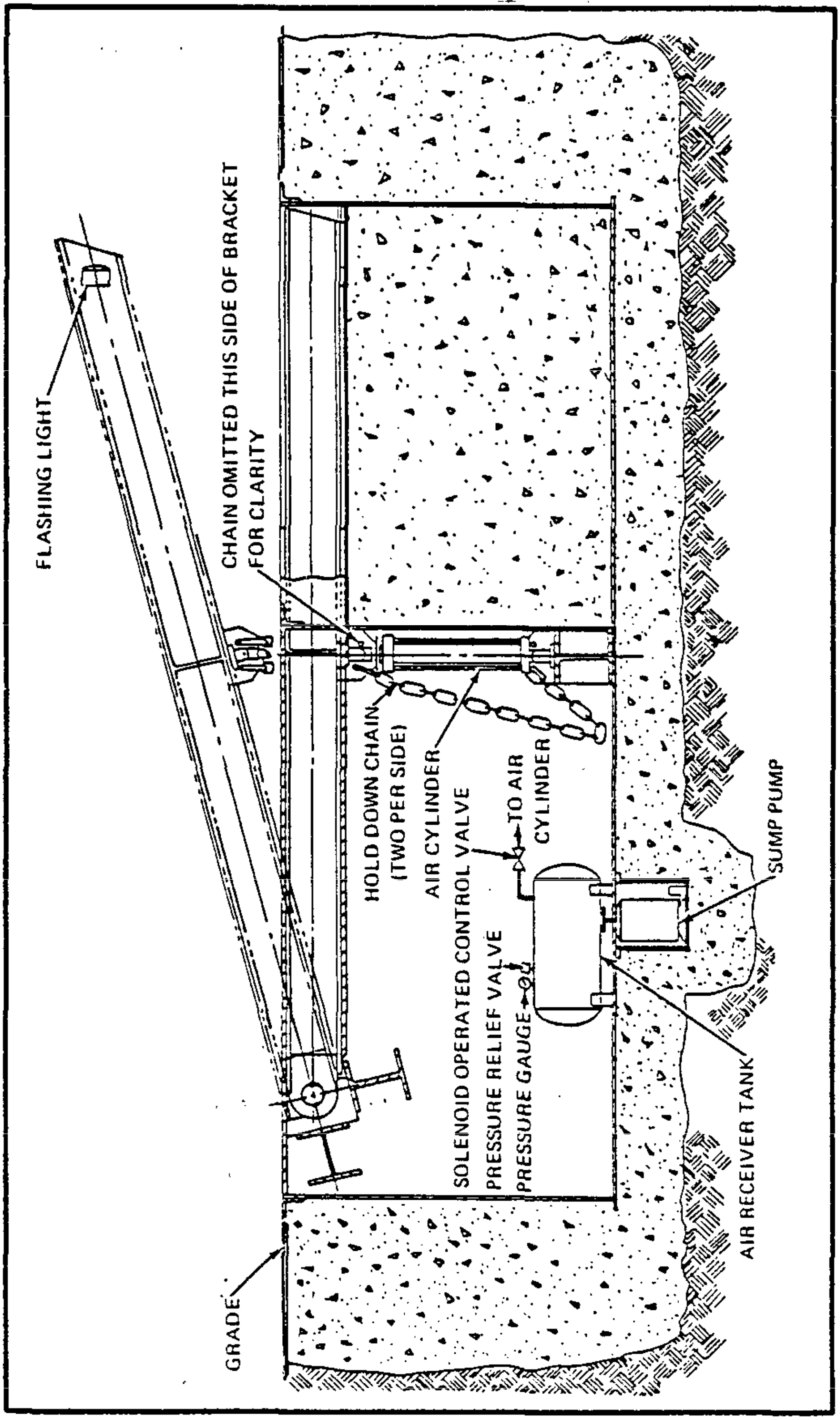


FIGURE 57. Babcock & Wilcox vehicle arrestor.

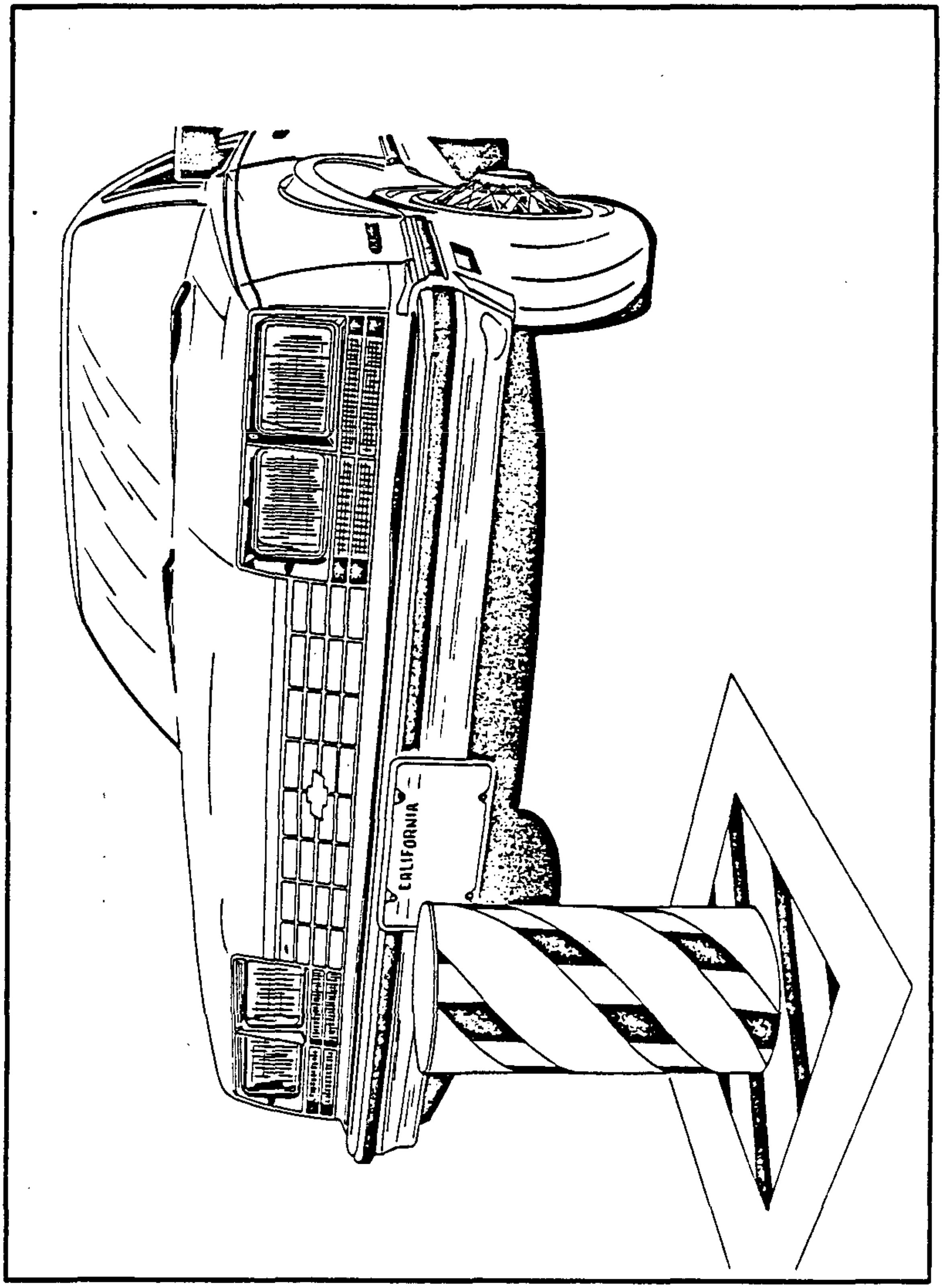


FIGURE 58. Delta TT210 Bollard barrier system.

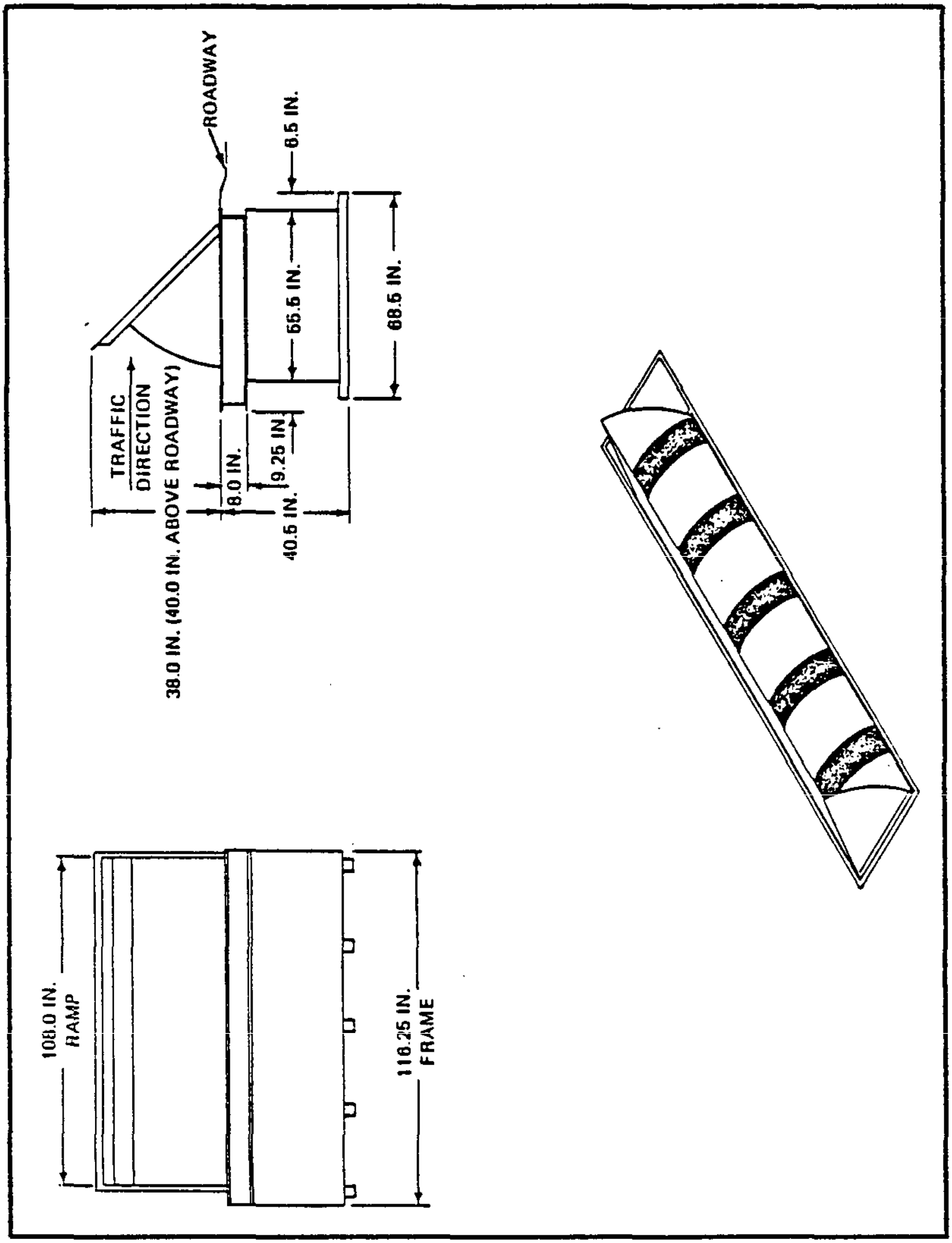


FIGURE 59. Delta TT207S Barrier.

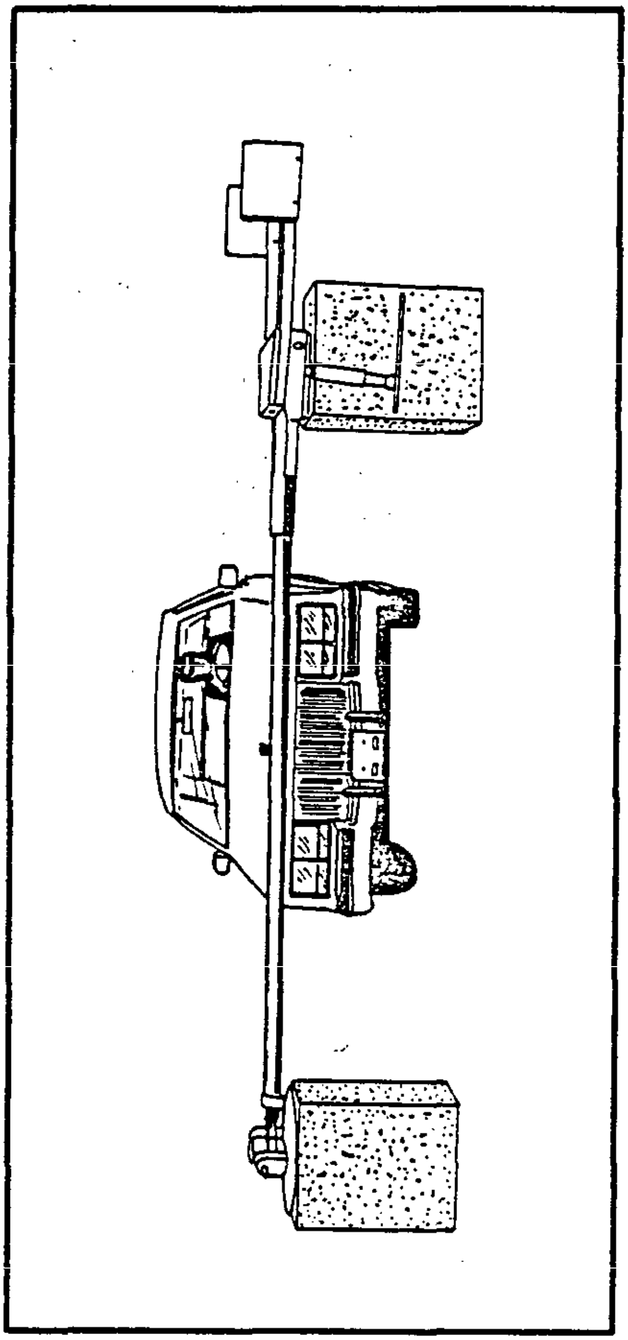


FIGURE 60. Delta TT212 vehicle beam system.

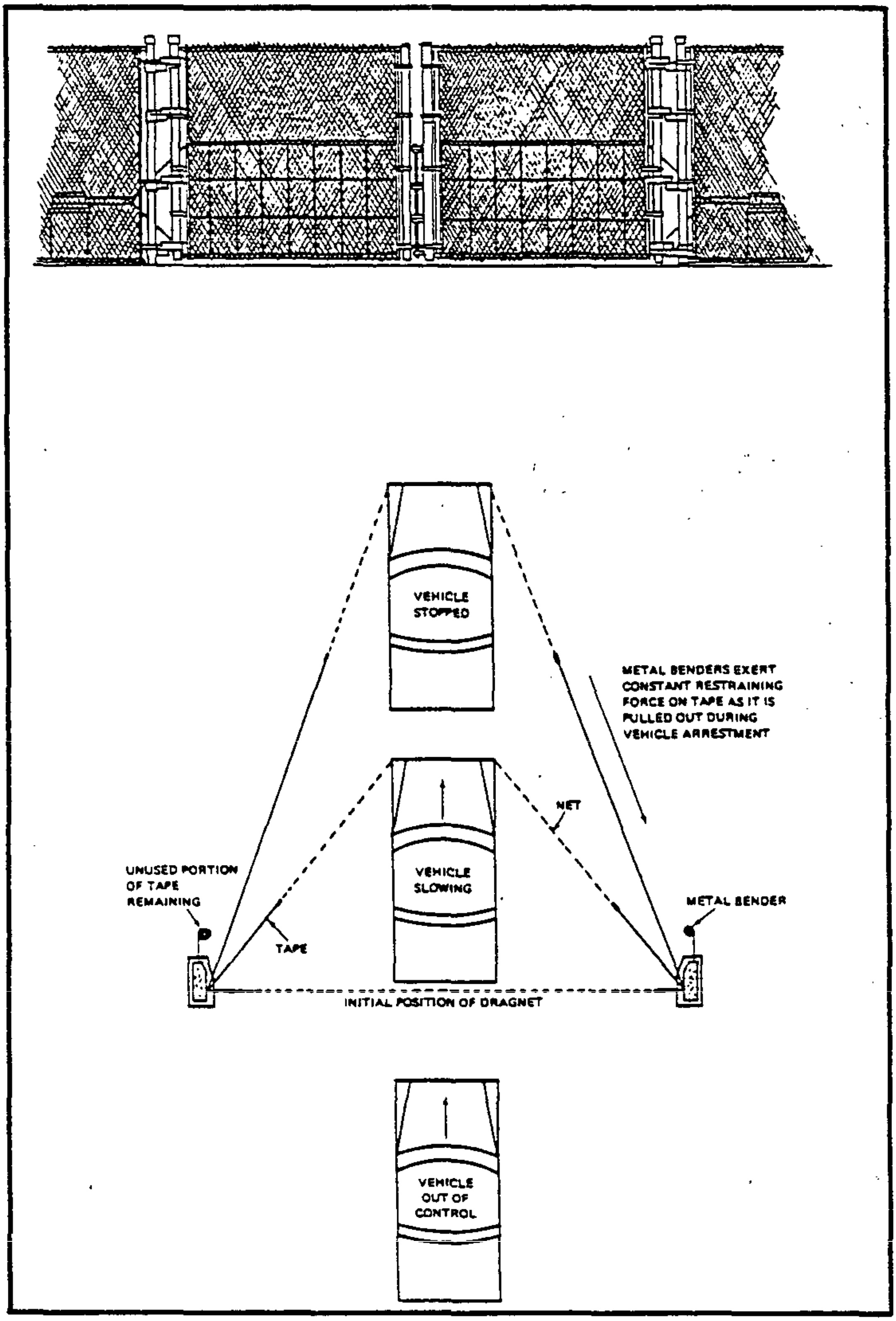


FIGURE 61. Entwistle dragnet system.

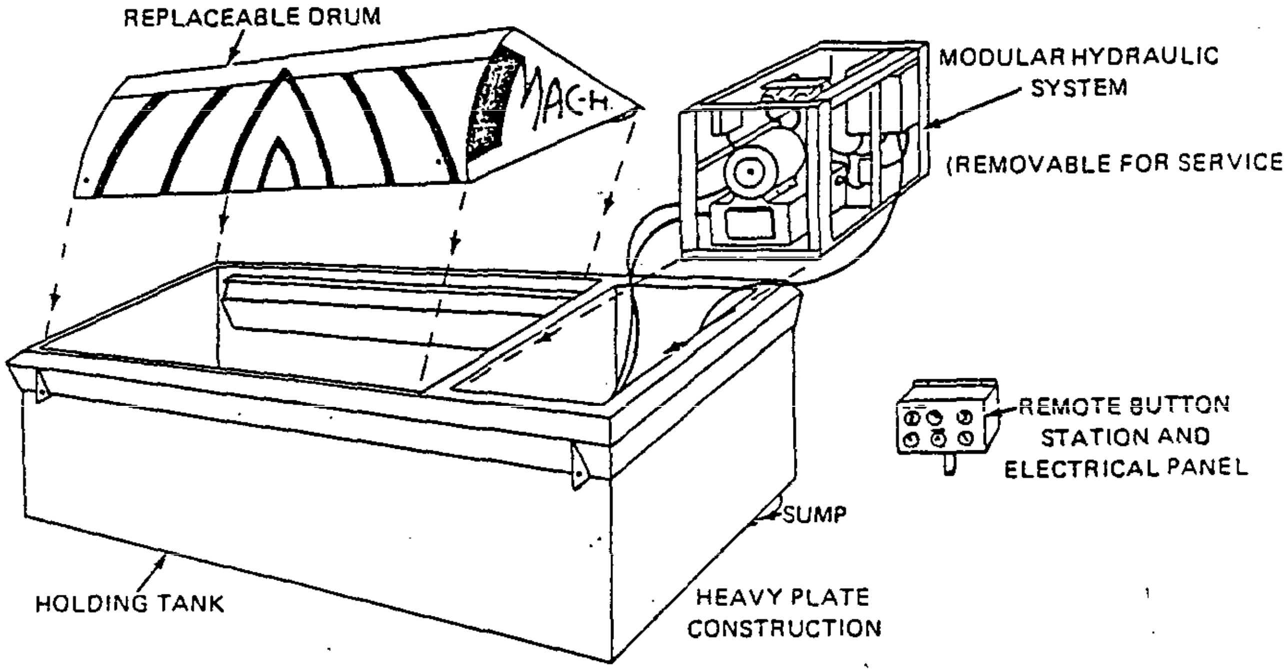


FIGURE 62. Frontier MAC-H10 vehicle barrier system.

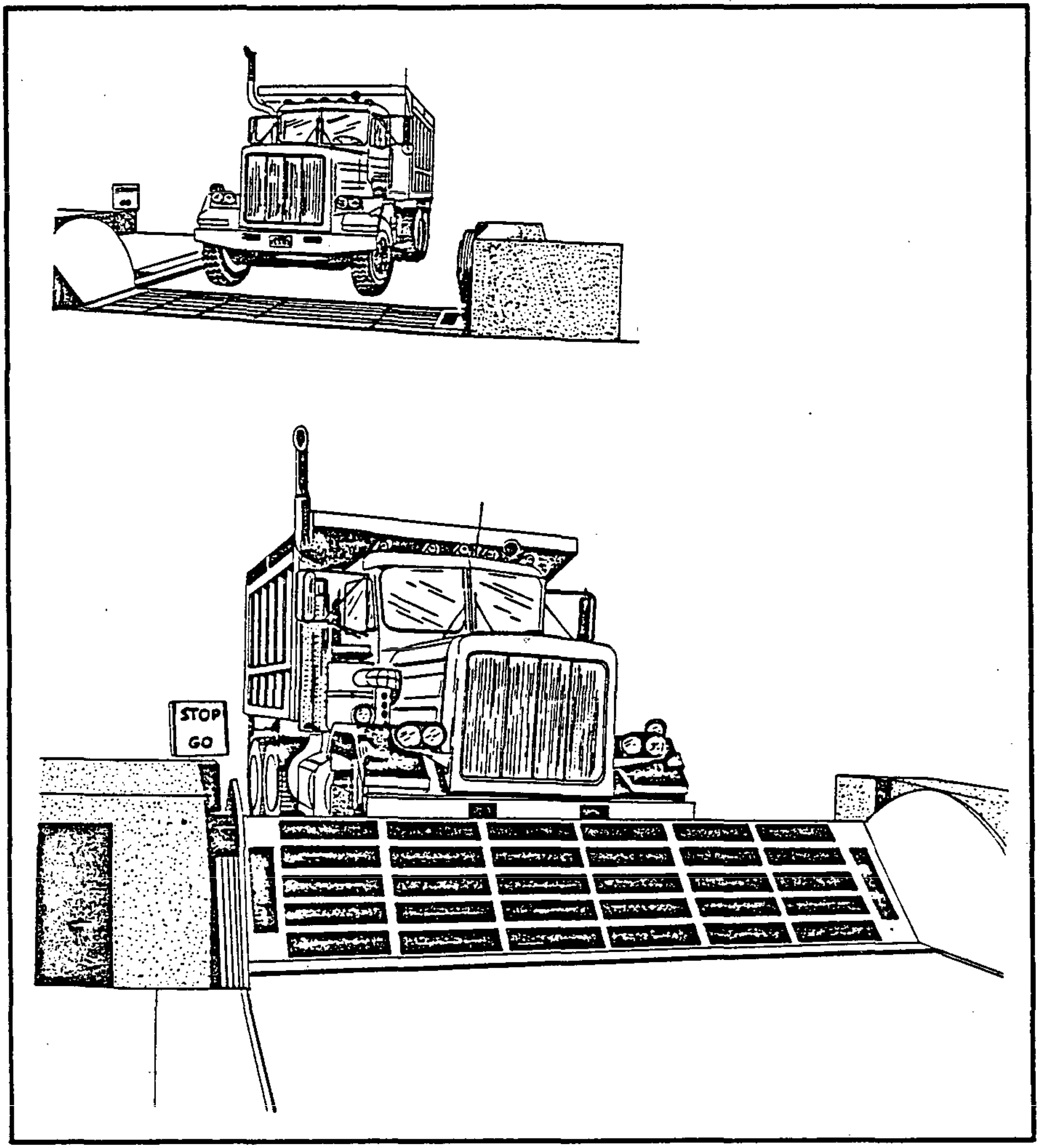


FIGURE 63. Nasatka MSB II vehicle barrier system.

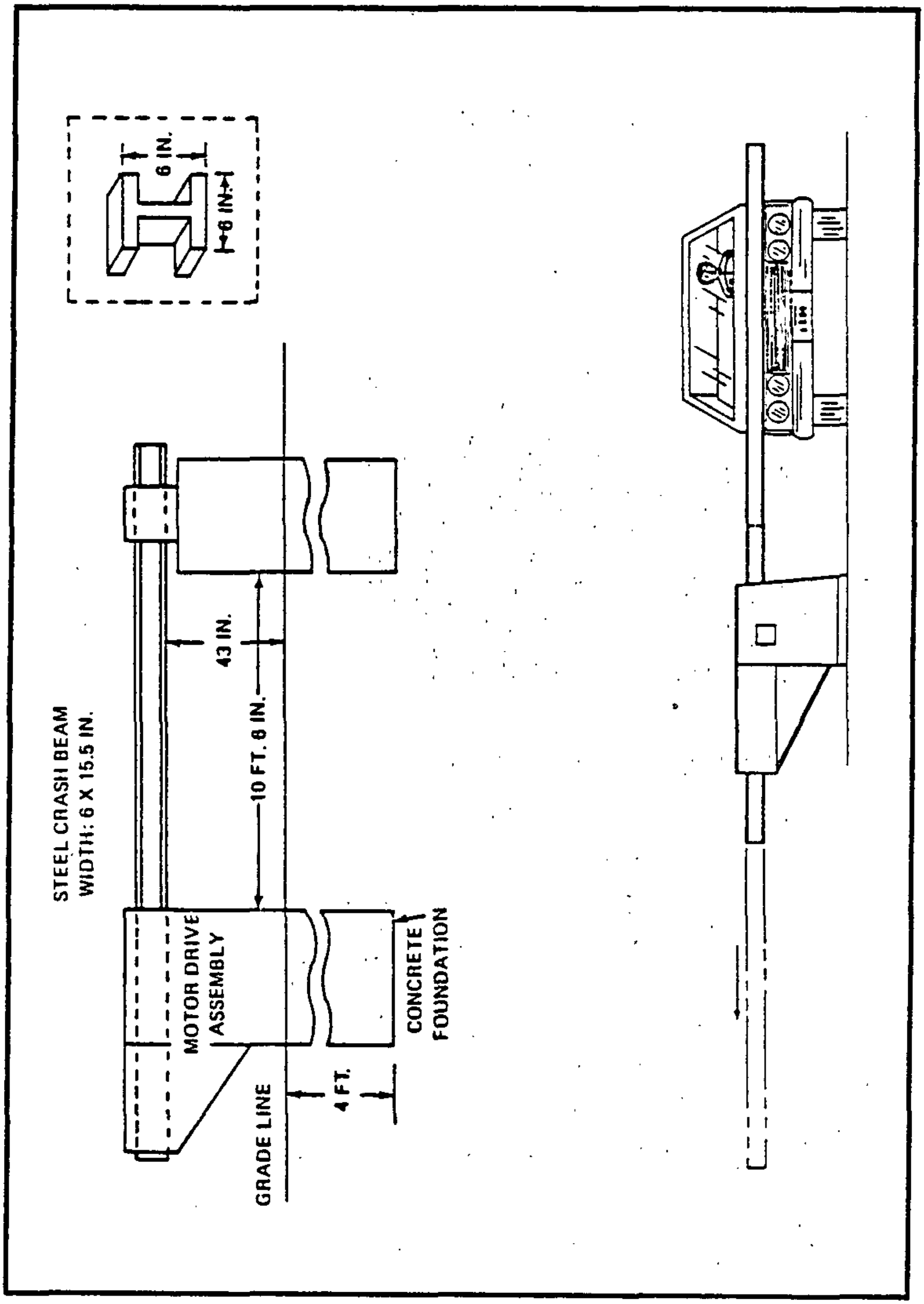


FIGURE 64. Robot model SCB crash beam.

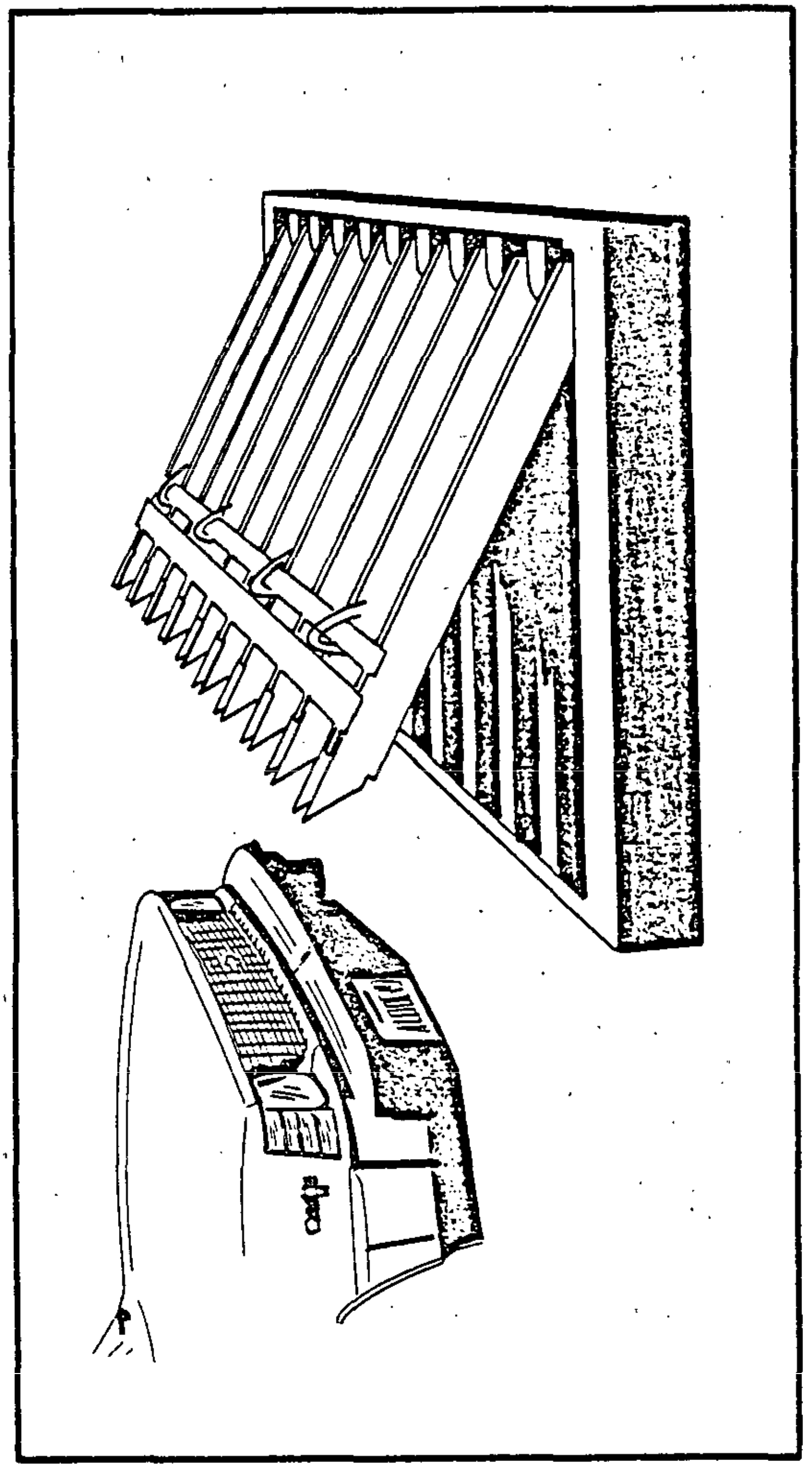


FIGURE 65. Western portapungi system.

APPENDIX A

PERFORMANCE AND COST REQUIREMENTS ASSESSMENT

1.1 Scope. This appendix outlines a general procedure for determining physical security related delay time performance requirements and a cost-effective facility design on the basis of the planning factors.

1.2 Overview of Factors. The most cost-effective delay time and budget specification for a particular facility should be determined by considering the following seven interrelated planning factors:

- o Threats
- o Deterrence
- o Value at risk
- o Criminal justice administration
- o Intrusion detection systems (IDS)
- o Security guards
- o Structural delay options

The first three of these factors relate to the likelihood or frequency of a security loss of a given magnitude occurring. The fourth factor recognizes that physical security is not the only way of handling losses. For example, infrequent, high-loss occurrences may be more economically handled by a criminal justice sequence (investigation, apprehension, recovery, prosecution, and correction) than by building physical security hardening into a facility. Finally, the last three factors are all aspects of the physical security system, which must be coordinated before physical security can be performed cost effectively. All three involve timelines. For example, structural delay time must be specified to be compatible with IDS and guard response times. It is not within the scope of this handbook to provide guidance on how to design a specific IDS or to prescribe the number of personnel and location of the guard force. The primary objective of this handbook is to enable proper design of the facility's walls, roofs, floors, doors, windows, and utility openings consistent with the economics of loss risk, known IDS and security personnel performance, the administration of criminal justice, and the impact of deterrence.

1.3 A Procedure for Determining Cost-Effective Design Requirements.

1.3.1 Overview and Current Limitations. This section outlines a general procedure for determining physical security related delay time performance requirements, and a cost-effective facility design on the basis of the planning factors introduced above. This procedure is presented at a very general level of detail. This section describes what to do without specifying how it is to be done. Further definition requires accumulating and analyzing data for specific facilities.

1.3.2 Procedure, Goals, and Objectives. The overall goals of physical security in general and, therefore, the requirements assessment procedure in particular are fourfold: (1) to save the U.S. Armed Forces and taxpayers the cost of replacing stolen or destroyed property resulting from burglary, larceny, or arson crimes at military installations; (2) to maintain the military readiness of the installation by protecting key weapons or critical weapon system components and parts stored in defense facilities from loss, wrongful destruction, or sabotage; (3) to maintain national security by preventing loss of classified materials; and (4) to reduce the possibility of political embarrassment of the Armed Forces due to any of the above. These goals reduce to the following specific objectives and requirements.

1.3.2.1 Level of Security. The security engineer should identify when a facility is to be considered a "restricted area facility, critical in nature" requiring real time physical security or when deterrence security measures are more appropriate and cost-effective. [As used here, deterrent means simple security measures involving no real response capability and only nominal investment in security (e.g., bars on windows, etc.).] The major factors to be considered in determining the level of security are: (1) the relative costs of investigating and replacing stolen property versus the cost of security; (2) the military readiness, national security, or political embarrassment associated with the stored resources at risk; and (3) the objectives, dedication, and sophistication of potential threats.

1.3.2.2 Real Time Security. Real time security means a 100 percent confidence level of detecting and intercepting an intruder in time. In general this means that the barrier penetration time of all components of the facility are sufficient to delay an intruder, attempting to make a forced entry for an interval at least equal to, or greater than, the sum of the time for an IDS to permit detection and assessment of the intruder and the time for the security force to respond to the scene of the attempted intrusion. When real time security is required, the security engineer should establish the most cost-effective resource balance between structural hardening, intrusion detection systems (IDS), and security guard forces so that the life cycle cost of all resource components and the expected losses are minimized. Expected losses include the replacement costs of the items stolen plus the costs accrued by the investigative service in investigating and apprehending the criminals. Consideration should also be given to the impact that the loss of stored resources may have on military readiness, national security, or political embarrassment. One or more of these may justify higher security related cost. For some assets at risk providing less than 10 percent confidence of detecting and intercepting an intruder in time may be acceptable for budgetary or other reasons. For these cases the security system may have real time functions (detect, assess, delay, and respond) but less than real time response capability.

1.3.2.3 Deterrent Security. The security engineer should decide what specific deterrence measures are appropriate for facilities not categorized as critical but requiring some security. As in the case of real time security, the sum of the life cycle costs of these deterrence measures plus the cumulative expected losses over the life of the building should be minimized.

1.3.2.4 Other Considerations. The practical feasibility and appropriateness of implementing alternative mixes of structural hardness, security forces, IDS, etc. should be evaluated considering such things as: (1) operational use of the building and the impact security measures will have; (2) constraints imposed by existing security resources at the activity (e.g., number of security guards); (3) limits on the security budget allocated; and (4) midstream changes in priorities, missions, etc.

1.3.3 Procedure Overview. Figure A-1 illustrates and highlights the major steps involved in the procedure. Types of data required and various issues involved in their collection are discussed in subsequent paragraphs.

1.3.3.1 Step 1--Review Physical Security Plan for Activity or Installation. The security engineer should review the physical security plan developed for the installation. This plan may provide useful information describing such things as the objectives of the physical security measures that are designed to protect the installation and its facilities; the secure areas that are important; priorities for their protection; the security force organization, etc.

1.3.3.2 Step 2--Plan on Site Survey of Activity or Installation. Meetings should be held with personnel concerned with security at the installation to plan a security related survey of the installation. Specific data requirements should be presented and an approach for obtaining the required information including specific action items and individual assignments agreed upon.

1.3.3.3 Step 3--Determine Characteristics of the New Facility Requiring Security. The security engineer should review available information describing the new facility. Important data includes the location of the facility on the installation; the number and size of the secured area(s) within the facility; description of any structural barrier designs for each building component (doors, windows, walls, roof, floor); description of any intrusion detection sensors systems employed in the design, etc.

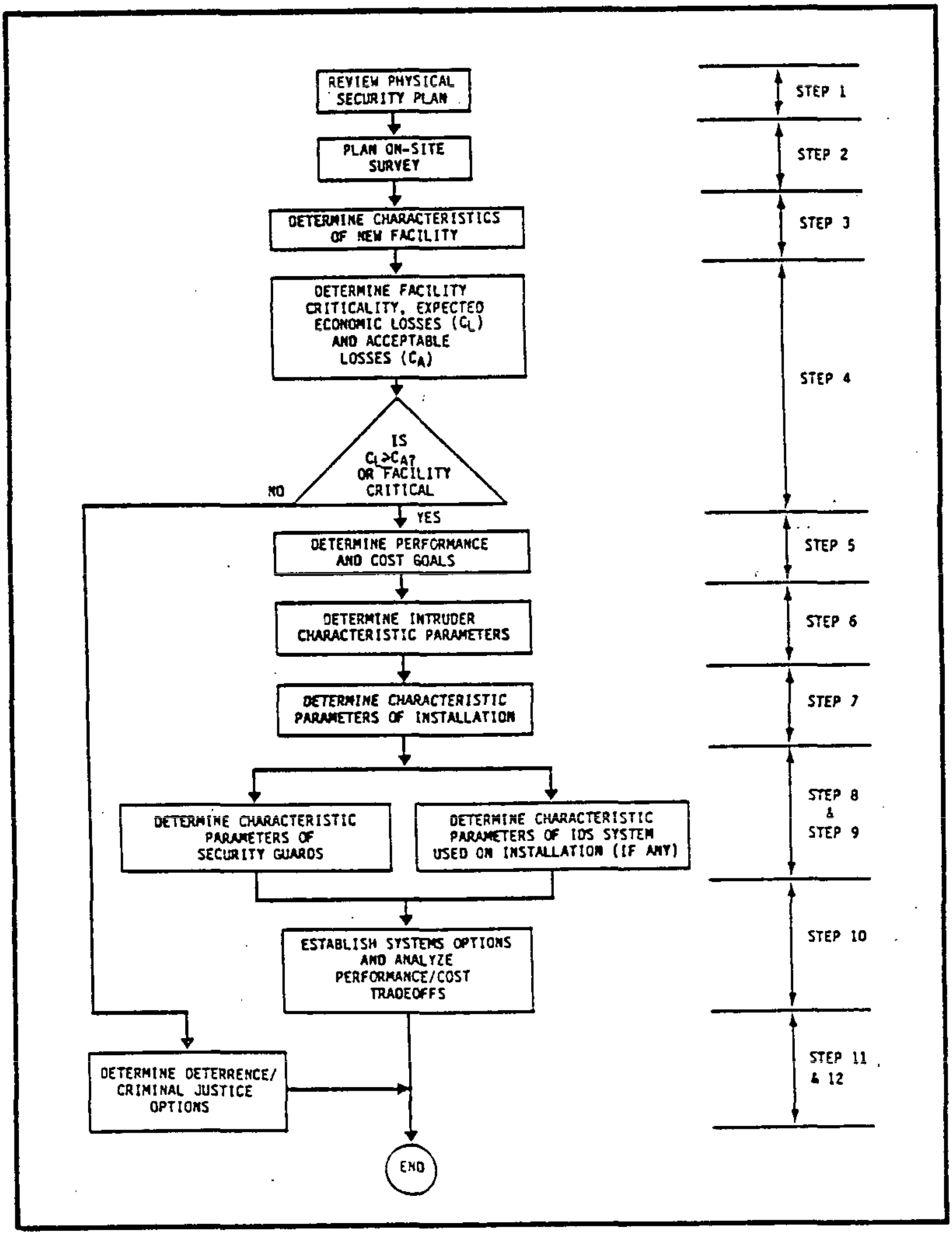


FIGURE A-1. Procedure overview.

1.3.3.4 Step 4--Determine Value at Risk and Facility Criticality. The security engineer should determine who to see and what to ask in order to establish if, during its lifetime, the facility is likely to be used for the production, maintenance, or storage of key weapons, weapon system components, or classified materials whose loss or sabotage would significantly affect the military readiness of the U.S. Armed Forces, compromise national security, or in general cause considerable political embarrassment. If any of these noneconomic conditions apply, the security requirements of the facility should be analyzed from the perspective of considering the facility to be a critical facility requiring real time security. The security engineer should also estimate the economic losses (C_L) which, historically, can be expected over the life of the facility. This should then be compared against some "acceptable" level of economic loss (C_A) (see Figure A-1) determined by policy or other means. If the facility is not considered critical and if the expected economic losses are less than or equal to the acceptable losses ($C_L \leq C_A$), the facility requires only deterrence or criminal justice enforcement security measures, and the security engineer is referred to Step 11 or Step 12. If the facility is critical, the security engineer should proceed to Step 5 (see Figure A-1).

1.3.3.5 Step 5--Determine Security System Performance and Cost Goals. The security engineer should establish what the design goals are for the facility security system being designed. This includes both the level of security performance desired as well as the limitations imposed on security cost because of budget or other considerations. Although security system performance can be measured in a number of ways, here we mean establishing a facility delay time that achieves a desired minimum acceptable confidence level of intercepting an intruder in time consistent with the assets to be stored in the facility and balanced against the available security budget.

1.3.3.6 Step 6--Determine the Intruder Characteristic Parameters. The security engineer should establish the characteristics parameters of the intruder to be considered in the security requirements procedure and design. These include the intruder's objectives and motivation, attack tools (e.g., hand-held, power, thermal, etc.), tactics and timing, and size of the penetration opening. These guidelines will vary depending upon the type of facility and assets at risk. For example, the intruder characteristic parameters for an arms, ammunition, and explosives facility (AA&E) will be significantly more stressful than for a warehouse storing low value noncritical resources.

1.3.3.7 Step 7--Determine Characteristic Parameters of the Installation. Important data describing the activity or installation where the proposed facility is to be built should be assembled. These data, used in subsequent steps of the procedure, should relate to the size of the base, the number of facilities requiring security in addition to the proposed facility, and the general level of security required (i.e., real time, deterrence only, etc.).

1.3.3.8 Step 8--Determine Characteristic Parameters of Security Guards. In this step, important data describing the performance and cost of the base security personnel should be assembled. This information should include the type of guard positions (e.g. gate, central dispatch, roving patrol); the number and cost of billets; roving and incident response speeds; and equipment used (e.g., vehicles, weapons, communication) including numbers, investment, and operations and maintenance (O&M) costs, etc.

1.3.3.9 Step 9--Determine Characteristic Parameters of the Base IDS system (if any). In this step, important data describing the performance and cost of the base IDS system should be assembled. These should include such things as the general type of IDS equipment [e.g., balanced magnetic switches on doors, closed circuit television (CCTV), etc.]; their location; number; coverage area; expected false and nuisance alarm rates; and the cost to install, operate, and maintain the system.

1.3.3.10 Step 10--Establish Security System Options and Analyze Performance and Cost Tradeoffs. In this step, the security engineer should complete a cost effectiveness analysis considering alternative mixes of structural hardness for a given level of security force and type of IDS. The objective is to establish an optimal delay time and physical security budget considering the facility's functional and budgetary constraints established above.

1.3.3.11 Step 11--Determine Deterrence/Security Measures. In this step, the security engineer should establish the most cost-effective deterrence measures for the facility. As noted earlier, these range from very simple security provisions involving no response capability (e.g., bars on windows, locks on doors) to systems having all the real time security functions (detect, assess, delay, respond) but with less than real time response.

1.3.3.12 Step 12--Determine Criminal Justice and Enforceable Loss Limits. Under certain conditions it may be more cost-effective to minimize theft losses without substantial investment in physical security by relying on the administration of criminal justice. In this step the security engineer establishes the conditions under which this applies.

1.3.4 A Computerized Physical Security Requirement Assessment Methodology (PSRAM).

1.3.4.1 Overview. PSRAM is a computerized system currently under development to aid security engineers through many of the steps described above. Specifically, PSRAM identifies security system options, computes the security level (confidence of intercepting an intruder in time) and 25 year life cycle costs for each, and compares these results with security and cost goals. Based on this, the most cost-effective mixture of the major security components, IDS, hardening, and guards, is established. The following briefly describes the user input, processing, and outputs of PSRAM.

1.3.4.2 Inputs. Inputs include data describing the military installation, the new facility to be designed, and intruder threat data. A terminal keyboard and cathode ray tube (CRT) screen display is used for input. Data are inserted on the keyboard interactively as the CRT screen prompts the user for specific inputs. In addition, the security engineer must input the military installation street plan (intersection coordinates), using a digitizer and map, the location of all the secure facilities, as well as the number of guards and their operating procedures (i.e., fixed on site at the facility or roving from facility to facility). Once this general installation data is input, it is recorded on disks for future security system design. Data defining the proposed new facility includes its location on the installation and the size and location of the secured area(s). In addition, the security engineer has the option of specifying a specific security system to be evaluated for the facility, or of having PSRAM automatically search for input which provides: (1) a basis for identifying the most probable forced entry attacks (tools and procedures), (2) a means of determining the size opening required, and (3) the time needed for facility ingress and egress (if appropriate).

1.3.4.3 Processing. Depending upon the processing option selected by the user, either a single specified security system is evaluated or PSRAM automatically identifies and searches for the most cost-effective option. For each security system option identified and/or evaluated, PSRAM determines the probability of detecting the possible attacks and selects the best attack from the intruder's view point, then when appropriate, it computes the time needed to make the size of opening needed (96 square inches is used unless otherwise indicated by the asset) and adds this penetration time to the ingress/egress time allowed. The detectability of the attack by IDS and guards, along with the guards' response time, which depends on their location and the shortest path to the facility, are then computed. These are compared with the total time needed by the intruder to be successful and a confidence of intercept in time is output. Finally the 25-year cycle cost of the complete security system, as well as individual building, IDS, and guard force components is computed. If the user chooses to evaluate a prespecified security system, the confidence of intercept in time for each element of the building is calculated together with the 25-year cycle cost of the complete system. If this cost is excessive or if the confidence of intercept in time is not adequate, then a new design can be input and processed. Multiple trials can be used to find the most cost-effective mix of guards, IDS, and structural hardening. Alternatively, if the automatic optimization option has been specified, the security engineer need only input acceptable bounds on confidence of intercept in time and cost. PSRAM then identifies and evaluates all possible security system options automatically. Options that satisfy performance and cost requirements are output in tabular format ranked with the most cost-effective at the top.

1.3.4.4 Outputs. PSRAM provides tabulated outputs giving security system options ordered, as desired, on minimum cost, maximum confidence of intercept, or minimum cost per level of confidence of intercept. For each security system the construction type, sensors (if any), and the confidence of intercepting the intruder (in percent) for each major building component (doors, walls, etc.) of the facility is tabulated. Also tabulated is the number of fixed onsite or roving vehicle patrol guards, and the 25-year life cycle cost of the security system including cost for hardening the facility against penetration as well as costs for the intrusion detection system (IDS) and security guards.

1.3.4.5 Other Capabilities. PSRAM also allows the security engineer to make recommendations for intrusion detection sensors. Repetitive iterations of building designs that include different types and locations of sensors are possible. In addition, PSRAM also allows the security engineer to determine if the existing guard force (quantities and procedures) is the most cost-effective for protecting the new facility.

1.4 Reviewing the Physical Security Plan for the Activity or Installation.

1.4.1 Overview. At any established military installation a "Physical Security Plan" is likely to exist. This plan should be an important source of guidance on matters relating to physical security. In general a plan is written to define such things as: (1) the purpose and the objectives of the physical security measures that are designed to protect the installation and its facilities; (2) the secure areas that are important and priorities for their protection; and (3) the security force organization and requirements for entry control. Where applicable, the plan may also outline the requirements for mechanical and electrical aids to security such as barriers, protective lighting, communications, and intrusion detection systems. The plan is tailored to each installation to suit the needs imposed by local conditions. A physical security plan may have to be developed for new installations, or adjusted for existing installations to meet changing conditions brought about by construction modifications, or changes in mission or status.

1.4.1.1 Definition of Secure Areas. The Physical Security Plan may designate which areas are restricted, controlled, limited, or excluded. For the security engineer, these designations provide a guide to the sensitivity of the contents of the areas, to the compatibility with operational routines required of the security system, and to the adaptation of a security system to newly designated areas as the installation mission undergoes change.

1.4.1.2 Factors That Influence the Physical Security Plan.

Factors that affect the physical security requirements for an entire installation are: the nature and sensitivity of its mission; vulnerability of equipment; geographic location; economic and political situation in the area; proximity of external support (such as local police); and capabilities and motivation of potential intruders.

Important characteristics of the property within the installation effecting physical security are the vulnerability of the property to theft or damage, attractiveness as an object of sabotage or theft, monetary value, and importance to the primary mission of the installation.

Each installation and activity should continually evaluate its security plan in light of the foregoing factors and devise physical security measures consistent with them. When evaluating the degree and type of physical security required, it must be remembered that the criticality of an installation or activity may vary from time to time as its products or services become more or less important.

1.5 Planning an Onsite Survey of the Activity or Installation.

1.5.1 Information Sources. The origin of a requirement for a security system stems from a variety of sources. In collecting the information necessary to design a security system, the security engineer will find it necessary to conduct interviews with the personnel involved onsite and offsite, and as well as to conduct surveys of the area or facility to be protected. These conferences and surveys can range from a number of meetings and reconnaissance and analysis of an entire installation to one meeting, and one onsite survey of a single area requiring simple security measures. In each case, however, the conferences and surveys must treat all of the pertinent aspects of physical security so that recommendations will be appropriate to the mission of the installation; the environment; the resources available to install, maintain, and operate the security system; and the actual security problem that the system is intended to solve.

1.5.2 Preliminary Meetings and Studies.

1.5.2.1 Initial Conference. The first step in gaining a practical estimate of the nature and scope of the security requirement for the new facility is to meet with the originator of the requirement at the installation. Principal topics of this initial conference should be the degree to which the problem has already been defined; present mission or changes in mission of areas to be protected and their relative importance or criticality; postulated threats to and vulnerability of the area to be protected; physical characteristics and location of the area to be protected; type, nature, and adequacy of the existing security system, (if any); physical and operational environment that may constrain the security system design; capability of the installation to install, maintain, and operate a security system; availability of guard forces, proposed location of central security control, and (if required) remote annunciators; and availability of funds.

1.5.2.2 Plans and Drawings. At this preliminary meeting, the physical security plan, new building floor plans, site plans, and other pertinent written material that might be available should be requested.

1.5.2.3 Notations. Secure areas within the facilities of interest should be noted on these floor and site plans. By working from notes and drawings before actually performing an onsite survey, the security engineer can more quickly identify the nature of the problem to be solved.

1.5.2.4 Checklists. A checklist is a useful way of assuring one obtains the proper information needed for a security system design. The checklists should cover both general and detailed categories of information that can be used as guides during subsequent interviews and during site surveys. Table A-1 presents an example of a checklist.

1.5.3 Onsite Survey Plan.

1.5.3.1 *Arranging for the Onsite Survey*. After the initial study of plans and notes obtained during the preliminary discussion, arrangements should be made to complete the onsite survey of the areas and facilities of interest. Arrangements should include a visit to the facilities during normal working hours and after working hours. It is desirable that the security engineer be accompanied by someone who can provide accurate information on the established mission, who is knowledgeable on routine or special operational activities, and who can ensure access to all areas.

1.5.3.2 Preliminary Site Inspection. Once arrangements have been made for the onsite survey, a preliminary inspection of the areas of interest should be made to gain familiarity with the overall situation. This will establish a mental base of reference in working with the drawings annotated in the initial study.

1.6 Determining Characteristics of the Proposed New Facilities.

1.6.1 Overview. Important security related features for the new building include:

- o Its location on the base

- o The total perimeter of the new facility that is secured and which must be inspected

- o The total surface area of each building component

- o The ingress/egress time of each building component

- o Any limitation on the structural barrier designs to be evaluated for each building component

- o Description of any IDS to be included as part of the new facility

TABLE A-1.
Physical security field data collection
data and documentation checklist.

1. BASE MISSION AND OPERATION
   - Strategic
   - Tactical
   - RDF
   - RDT&E
2. MAP OF INSTALLATION (showing central security facility locations, distances along security routes normally traveled, both day and night, by patrol and response personnel, and topography)
3. SECURITY MANPOWER, EQUIPMENT AND COSTS
   - Security Manpower Listing (by job position and paygrade)
   - Security Personnel Job Descriptions (if available)
   - Officer Billet Salary Schedule
   - Enlisted Billet Salary Schedule
   - Civilian (Civil Service) Billet Salary Schedule
   - Contractor Security Services Data (DOL Register of Wage Determination for San Diego County under the Service Contract Act, including minimum hourly wage and fringe benefits)
   - Security Vehicles (including number, types, purchase cost, operating costs, replacement cycle, etc.)
4. FACILITY INFORMATION
   - List of Mission-Critical and High-Value Asset Facilities
   - Site Plans and Drawings (Public Works Officer)
   - Construction Costs, as Built (Public Works Officer)
5. INTRUSION DETECTION SYSTEMS (IDS)
   - UDS Inventory (indicating all IDSs installed at base that are monitored by security personnel; include host as well as tenant commands/activities)
   - IDS Logs (indicating alarm rates and dispositions per year)
6. TIMELINE INFORMATION
   - Patrol
   - Dispatch to Assess/Inspect
   - Response
   - Inspection
7. LOSS INCIDENCE DATA (NISTRA)
8. STANDARD OPERATING PROCEDURES
   - Patrol Deployment Procedure (including number of vehicles by patrol area/zone, number of personnel/patrol vehicle)
   - Alarm Dispatch Procedure
     - -Single Alarm
     - -Multiple, Simultaneous Alarm
   - Backup Force Procedure
   - IDS Alarm Recordkeeping/Logging Procedure
   - Equipment Backup Procedure (IDS failure, emergency power, etc.)
   - Response Procedure (once assessment confirms presence of a threat)
   - Hostage Procedure

1.6.2 Location and Perimeter. The location of the new facility effects the guard response time and is the X and Y distance in feet from baselines to the center of the new building. The "perimeter to check" is the total walking distance around the secured area(s) that must be inspected by security guards. The "perimeter to check" may be the perimeter of the entire facility, or only that portion of the facility with secure areas. If the facility contains many interior secured areas, the security engineer must decide if it is more cost-effective to harden each individual area as compared to hardening the exterior of the building as a whole.

1.6.3 Ingress/Egress Time. The ingress/egress time is the estimated total time required to successfully complete the theft or destruction of the assets being protected exclusive of the time needed to make the penetration opening. If appropriate, the security engineer should estimate the total ingress/egress time needed by the intruder after the opening is made. If destruction is the anticipated goal of the intruder and the asset is near the barrier, ingress/egress time is not a factor. If theft is the likely goal, the time to crawl through the opening, locate the item or items, and exit the building may be significant. Accounting for facility ingress/egress time can result in a more economical design with less facilities hardening costs. This should be weighted, though, against the criticality of the asset involved. For example, one would not normally account for ingress/egress time in the case of facilities storing arms, ammunitions and explosive assets. In this case one should design barriers of sufficient hardness to completely prevent entrance.

1.6.4 Other Considerations. The security engineer should establish if there are any limitations on the types of structural barriers or intrusion detection sensors that should be considered in the evaluation. For example, operational considerations may limit the choice of door barriers to certain lower weight designs. A checklist of general construction types is presented in Table A-2.

1.7 Determining Value at Risk and Facility Criticality.

1.7.1 Value at Risk. The value at risk is the asset value contained in the facility measured in terms of dollars, time criticality, or political implications. The value at risk depends on the type of asset, its replacement dollar value, its loss expectation, and its loss frequency. Of these considerations, only loss expectation and loss frequency are influenced by guards, IDS, and facility delay time, or deterrence and criminal justice.

1.7.2 Measuring Value at Risk. The economic value at risk (C_{VAR}) may be quantified in terms of the average dollars of the resource replacement or repair cost per unit floor area of the facility (dollars/square foot). Qualitative judgments must be applied to the political or time urgency risks associated with sabotage, espionage, or other threats which potentially affect DOD war fighting responsiveness or create a politically embarrassing environment (such as publicly entering an arms, ammunition, and explosive facility

TABLE A-2.
Checklist of general construction types.

COMPONENT	DESCRIPTION
WALLS	1. Reinforced concrete 2. Fiberous reinforced concrete 3. Concrete masonry units 4. Concrete/metal/wood/foam/plastic composites 5. Metal/wood/foam composites 6. Wood 7. Wood/metal composites 8. Clay tile 9. Brick 10. Asbestos 11. Steel grating 12. Wood/sheetrock composites 13. Stucco sheetrock composite
ROOFS	1. Reinforced concrete 2. Asphalt on concrete 3. Wood 4. Metal 5. Wood/Metal 6. Plaster 7. Overburden 8. Reinforced concrete with overburden
FLOORS	1. Reinforced concrete 2. Reinforced concrete on sheetmetal 3. Wood
DOORS	1. Metal (retrofit) 2. Magazine doors (exiting) 3. Magazine doors (retrofit) 4. Vehicle doors (metal) 5. Personnel doors (metal) 6. Composites (metal) 7. Doors hasps and locks
WINDOWS	1. Glass 2. Plastic 3. Metal bars 4. Expanded metal 5. Louvers 6. Miscellaneous metal shapes

(AA&E) losses). The security engineer should ascertain the planned use of the facility to determine the expected future housed asset inventory including these factors:

- o Replacement cost (i.e., dollar value)
- o Replacement time (criticality)
- o Political impact
- o Military readiness (strategic value)

At a minimum, the physical security design for the building should be based upon the planned first use of the facility. However, the security engineer should recognize that the facility uses change over time; therefore, he may be justified in designing for the most important critical use anticipated in the future.

1.7.3 Effect of Facility Type and Number. This handbook applies to the physical security requirements of any type of military facility. However, there inevitably can arise cases where general requirements and guidelines may need special interpretation by local commands. For example, communications, administrative, industrial, and AA&E facilities may have considerable value because of storage of classified or strategically valued resources. It is also possible that warehouses and administrative offices may contain unique time-urgent supplies, the loss of a "significant" fraction of which may negatively impact military readiness because of a lengthy resupply interval. The security engineer should recognize that the total number of facilities at a site may influence the ability of the security guards to respond in a timely manner. Unique qualities of the facility are important, as the facility is compared to similar facilities at other nearby activities.

1.7.4 Anticipating Losses to be Prevented by Security (C_L). There is normally some fraction of the economic value at risk representing the anticipated losses over the life of the building that a designer intends to prevent or minimize by investment in a physical security system. More specifically, C_L is the total anticipated losses less that recovered by the criminal justice system or protected (deterred from loss) by the physical security system. As an illustration, Figure A-2 presents the likely form of such historical data when they become available. This figure suggests that, for a given facility and resource type, relatively few occurrences involve high losses, while relatively frequent occurrences involve moderate losses. Such data would help in determining the level of losses to be covered by deterrence (C_A), the losses to be prevented by physical security design (C_L), and the losses which apply to criminal justice solutions (C_{ENF}). One such example follows:

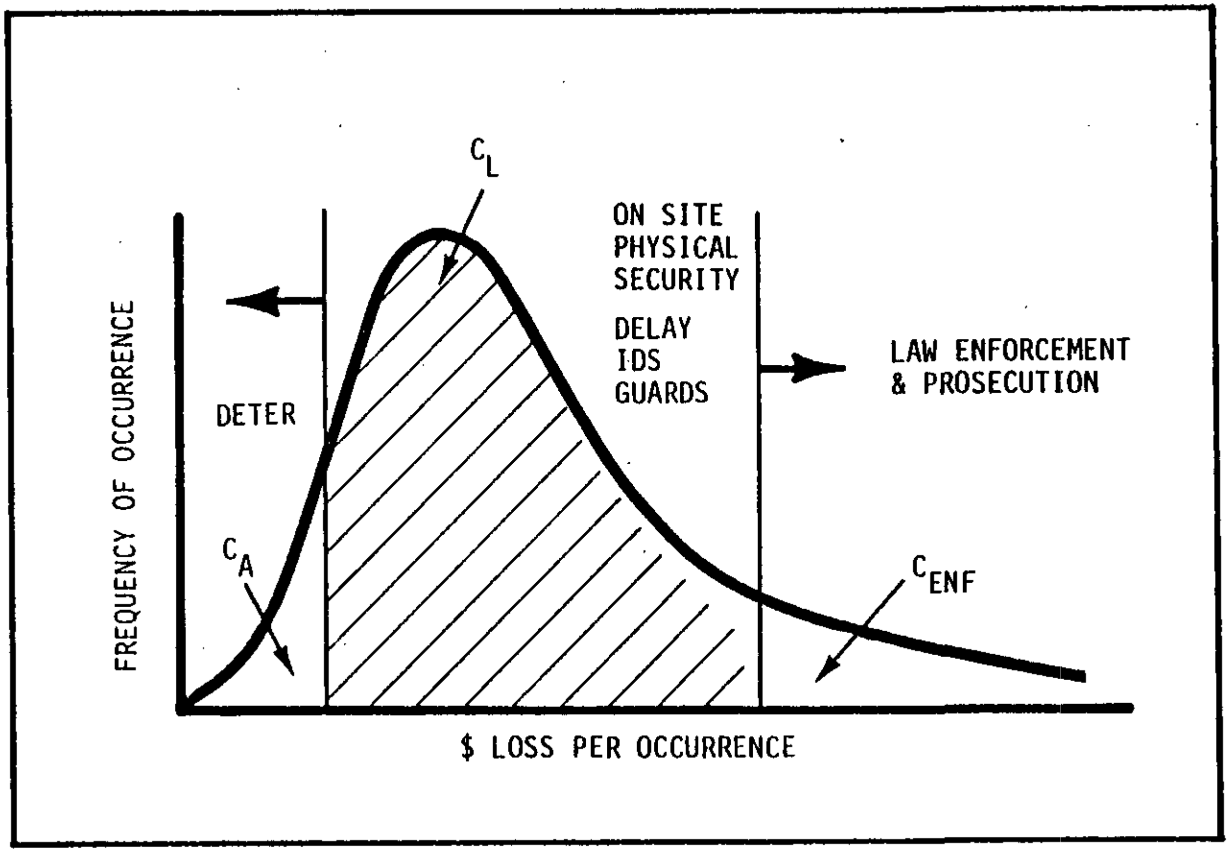


FIGURE A-2. **Frequency distribution of loss occurrences.**

EQUATION: C_L = Loss Ratio x C_{VAR} (A-1)

where

C_{VAR} = Economic value at risk (dollars per square meter)

Loss Ratio (LR) = Fraction of C_{VAR} one can expect to replace because of theft, etc., based on historical date

1.7.5 Loss Expectation. If available, the security engineer should assemble historical data on the losses incurred at similar facilities. The historical data should include enough information to permit calculation of C_L over the life of the planned new facility. It should also include information describing the facility and physical security system. This may include, for example:

- o Facility type
- o Facility location
- o Floor space
- o Economic value at risk (C_{VAR})
- o Years experience
- o Frequency and dollar losses per occurrence
- o Maximum loss occurrence
- o Building delay time (T_{BLDG})
- o Guard response time to building (T_{RF})
- o IDS false alarm rate
- o Deterrent features of facility (i.e., lighting, fences, etc.)

Although the use of historical loss data is useful, it should be remembered that the past may not always be an adequate reflection of the future, particularly if conditions are changing in and around the installation. Figure A-3 provides example data based on 480 cases of unauthorized intrusions into Naval Facilities investigated by the Naval Investigative Services from 1976 to 1981.

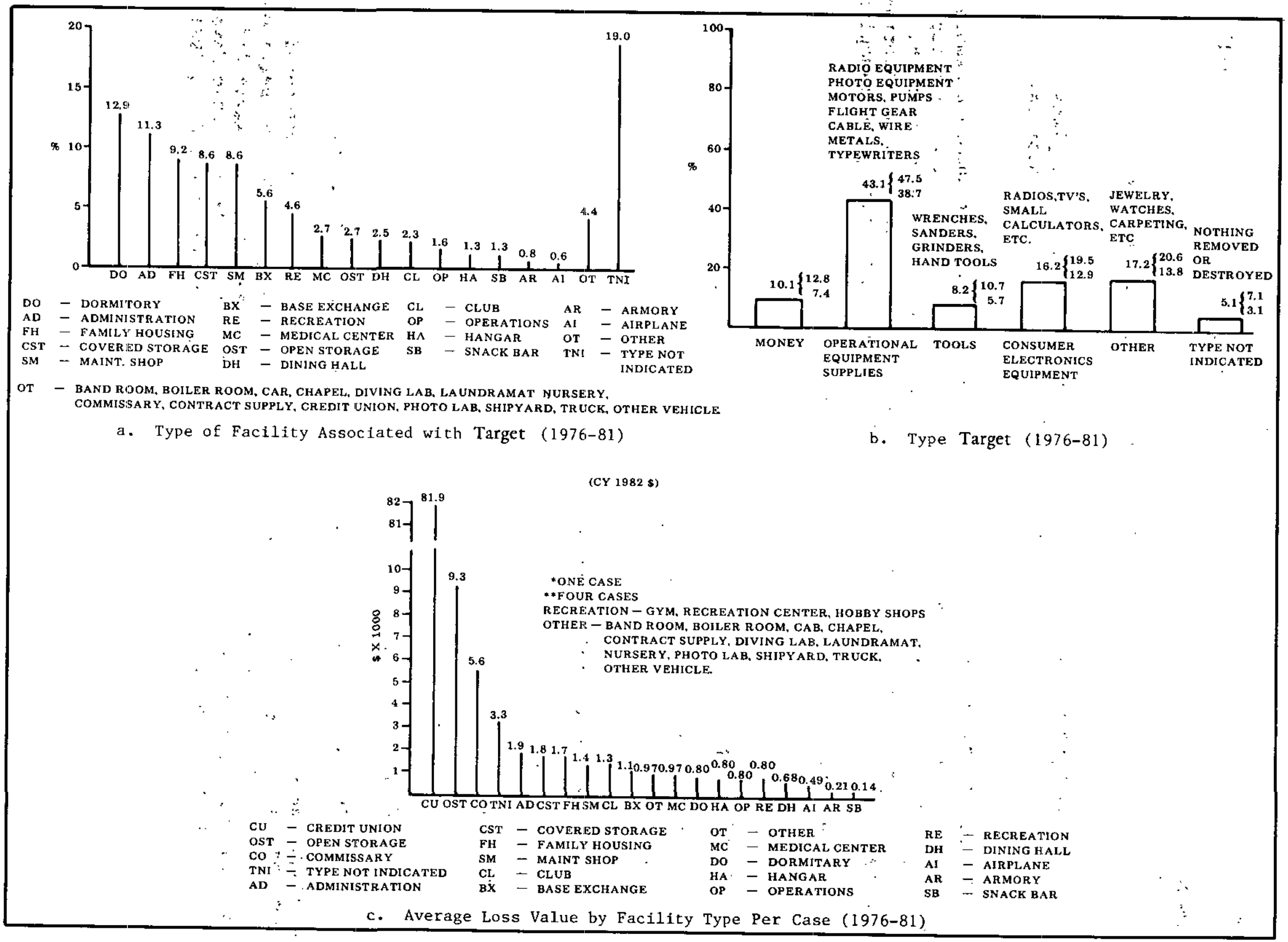
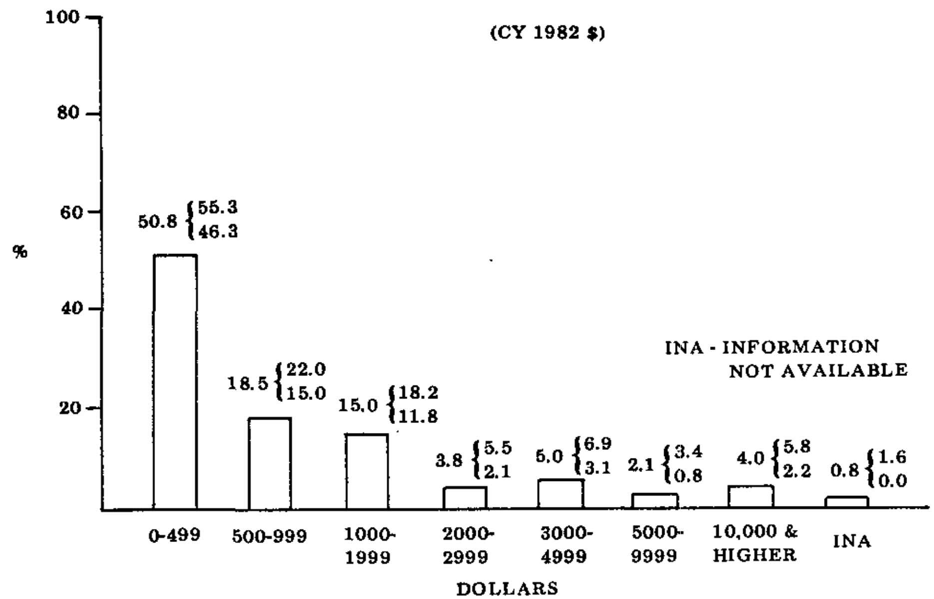
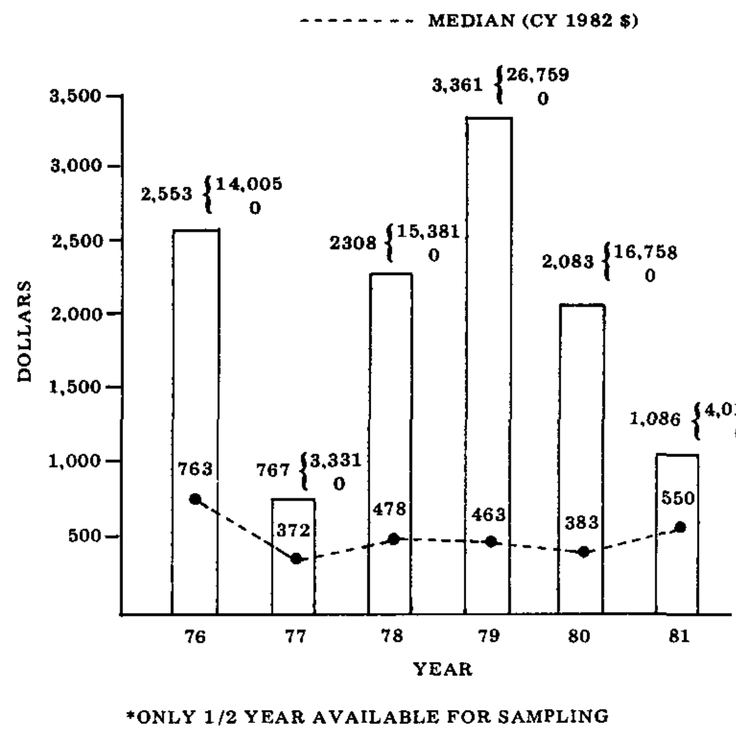


FIGURE A-3. Example of loss expectation.



d. Losses by Grouped Dollar Values



e. Average Loss Value per Incident by Year

Figure A-3. Example of loss expectation (continued).

1.7.5.1 Type of Facility. Figure A-3a shows dormitories and administrative facilities are involved most frequently followed by family housing, maintenance shops, supply storage, base exchange, and other operational type facilities.

1.7.5.2 Type of Asset. Figure A-3b shows the frequency of cases according to type of asset. Operational equipment and supplies lead the list at 43.1% followed by consumer electronics (16.2%), other (17.2%), money (10.1%) and tools (8.2%). The majority of assets were reasonably small, valuable, easy to remove, and salable on the open market.

1.7.5.3 Value Lost. Figure A-3c shows the average loss per facility type per case. Leaders include open storage, administrative, family housing, covered storage, maintenance shops, base exchanges, clubs, etc. Losses per case are reasonably small as shown in Figure A-3d. Over one-half (50.8%) of all cases were less then $500 and 18.5% are between $500 to $999 giving a total of 69.3% of all cases below $1000. Figure A-3e shows that the average loss value per incident by year shows a fairly large variation. The median remains reasonably consistent. The average over 5 years (1976 to 1980) is $2,196 per incident.

1.7.6 Facility Criticality. Based on the above, the criticality of a facility should be determined according to the following criteria:

- o If loss or sabotage of its contents results in a significant adverse impact on military readiness, national security, or political implication then the facility is critical.

- o If the expected economic loss (C_L) over the life of the facility without security is much higher than the cost of providing real time security (C_{RT}), then the facility is critical. If the expected losses are much less, deterrence or criminal investigation measures may be more appropriate.

1.8 Determine Security System Performance/Cost Goals.

1.8.1 Overview. For a critical facility requiring real (or near real) time security, two design goals require specification: (1) the minimum acceptable confidence of detecting and intercepting an intruder in time; and (2) the maximum acceptable life cycle cost of the security system including structural hardening, IDS, and security guards. The security engineer should establish the above design goals with the help of the operational and security personnel at the military installation.

1.8.2 Cost Goal. For losses that are purely economic in nature, one possible limit on security system cost is requiring that it should not exceed the total anticipated losses that are projected over the life of the facility (C_L). On the other hand, what one is willing to spend on security for assets having high military criticality and/or political impact may far outweigh their economic value. In some cases the security engineer may not have a historical base of loss data for estimating C_L. In both of these cases, establishing the cost goal may be dictated by a budgetary process of "give and take."

1.8.3 Performance Goal. The minimum acceptable confidence of intercepting an intruder in time depends on the criticality of the assets at risk. For some assets such as nuclear weapons and Risk Category I and II AA&E, confidence of intercept should be at or near 100%. The protection level for other assets may not be as clearly defined. So long as the level is reasonably high (e.g., 75% or greater) the overall security system cost may be the deciding factor. Practically speaking, in these cases the performance design goal may be dictated by the maximum acceptable security related life cycle cost of the security system.

1.9 Determining Threat Characteristics.

1.9.1 Overview. The physical security threat is very diverse with respect to not only threat objectives, motives, and tools, but also threat personnel, tactics, and timing. A broad range of credible threats is what makes the design of physical security systems difficult. Table A-3 summarizes the most current information on threats.

1.9.2 Personnel. Threat personnel may include unauthorized outsiders who penetrate a military facility as well as authorized site personnel (insiders).

1.9.2.1 Outsiders. Penetration threats may involve casual intruders, vandals, criminals, and/or politically dedicated and motivated agents. The tools, skill level, and tactics that may be employed by such threats are described below.

1.9.2.2 Insiders. Insider threats can include military, civil service, contractor, or visitor personnel who work in, or have knowledge of, the facility in which a security system is installed. The insider security problem is generally considered to be one of human reliability countered through personnel security checks and clearances. However, the insider problem cannot be completely eliminated by these means and, for that reason, the security system has to incorporate measures to prevent its compromise. In this regard, the insider and penetrator threats may not be separate and distinct. An attack on a facility can be made easier if those planning the attack can gain insider information on the protective measures in force or internal tampering with the security system during normal facility access hours.

TABLE A-3.
Threat characteristics summary.

Threat Level	Number of People	Tools	Type of Facilities Affected	Probability of Losses	Total Cost Impact	Operational
Low Level Casual Vandals	1	pry bar bolt cutters body force	commissary administration buildings covered storage open storage family housing maintenance shop dormitory	high	high	low
Mid Level	1-3	pry bar bolt cutters other hand tools	covered storage supply buildings maintenance shops open storage administration Exchange operations buildings	high	moderate	moderate
High Level Terrorist (CONUS)	**	car bombs man carried bombs letter bombs small arms	command facilities security facilities fuel tanks parked aircraft computer facilities AA&E facilities	low (potential threat-no loss history)	moderate	moderate
Terrorist (OCONOS)	**	car bombs man carried bombs letter bombs small arms rockets & grenades hand & power tools	nuclear facilities AA&E facilities computer facilities command facilities fuel tanks parked aircraft	high (immediate threat)	high	high (operational and political impact)
Saboteur (OCONOS)	**	hand & power tools explosives	classified areas communication centers nuclear facilities AA&E facilities utilities fuel tanks	low (in stable peace-time environment threat in place when hostilities commence	moderate	high
Nuclear & Environmental Activists	**	hand tools battering tools	nuclear facilities computing centers shipyards weapon stations command centers	high	low	low

** Defined in OPNAVINST C-5510.838

1.9.2.3 Numbers. Some threats may be single individuals operating spontaneously with negligible preparation. Others may involve a team of several persons with a great deal of preparation in terms of intelligence gathering, rehearsal, and training. The physical security design problem is obviously stressed most by insiders, who might be relatively hard to detect, and by large numbers of penetrators, who might be highly trained and hard to delay.

1.9.3 Threat Level. The security engineer should establish the level of attack the threat is likely to use based on the threat characteristics shown in Table A-3. Four attack levels in ascending order of severity are possible: Attack Level 1 is limited to hand held tools with low observables (e.g., pry-bars); Attack Level 2 allows an unlimited selection of hand tools; Attack Level 3 allows an unlimited selection of hand, power or thermal tools; Attack Level 4 includes hand, power, and thermal tools, as well as explosives. Attack Level 1 applies primarily to low level threats; Attack Levels 2 and 3 to mid-level threats, and Attack Level 4 to high level threats.

1.9.4 Attack Hole Size. The attack hole size effects the penetration time into the facility. Based on the objective of the threat (either theft or destruction), the security engineer can select a penetration opening size. If destruction is the anticipated objective and the asset is visible and located close to the protective barrier, then a small opening may be all that is needed to destroy the asset (i.e., explosives, firearms, or liquid flammables). If theft is the anticipated objective, then either a man-sized opening (96 square inches minimum) is required for access, or an opening large enough to remove the asset is needed when the doors and windows are alarmed. In this regard, fishing is a commonly used term that describes a process by which an intruder may extract items from an area without actually entering it. This requires a small opening and a fishing implement such as a line or long stick with a hook, magnet, or adhesive tip. Valuables can be fished through mail slots, gaps in intrusion-alarm screens, and numerous other small openings.

1.9.5 Skill Level. The security engineer should also be aware of differences in the skill level of the threat in selecting and using the tools. Four levels are possible. In descending order of skill level these are: (1) "skilled"--this implies effective use of the tools; (2) "skilled with tool penalty"--implies that although skilled in using the tools, the intruder nevertheless selects bulky or heavy equipment, or tools requiring an independent power supply that requires added time setting up and using; (3) "unskilled"--implies the threat does not use the tools effectively; and (4) "unskilled with tool penalty"--implies the selection of cumbersome tools, as well as unskilled use. An additional time allowance for skill level and tool penalties can be added to the penetration time given in this handbook if deemed appropriate by the security engineer.

1.9.6 Tactics. There exists a large array of potential threat tactic categories that stress differing aspects of the physical security system. Three tactical factors include stealth, speed, and saturation.

1.9.6.1 Stealth. The threat may attempt to minimize the likelihood of detection by keeping observable signatures low (i.e., quiet and slow threats are typical). As a countermeasure, structural design should attempt to force the use of highly observable (e.g., highly visible and/or audible) tools.

1.9.6.2 Speed. The threat may attempt to minimize the exposure time. These threats may be unconcerned about detection and use brute force tools or high energy devices for entry. The building structure design should lengthen this penetration time by as much penetration resistance as is cost-effective.

1.9.6.3 Saturation. The threat may attempt to create many false alarms to distract or divert the guard force. This problem can be minimized by providing for remote threat assessment (e.g., closed circuit television (CCTV) cameras) or by adding security personnel.

1.9.6.4 Stay-Behind. This tactic involves gaining entry during a time when a facility is open for normal business, and when the intrusion-detection equipment is in the ACCESS mode. The intruder stays behind (usually by hiding) after the facility is closed. Once an intruder has obtained the assets, he may be able to escape before the guard forces arrive, even if the detectors are activated in the process. One countermeasure is to provide hardened limited assess interior vaults for storing critical assets that can only be opened externally.

1.9.6.5 Deception Against Intrusion Detection System. Numerous tactics can be employed against an intrusion detection system to deceive operators and guard forces into believing that a system is malfunctioning and that alarms do not require a response. These tactics often involve inducing "false" alarms until such time as guard forces and operators become mentally conditioned and reach the incorrect conclusion that the system is unreliable and response is unnecessary. One countermeasure is to design the intrusion detection system intergal with the barrier so that only high energy attacks activate alarms.

1.9.6.6 Attack on Alarm Signal Lines. It is frequently assumed that an area has the protection of an intrusion detection system simply because sophisticated intrusion detection equipment is installed and connected to an alarm indicator manned by guard forces. What is forgotten is that the entire system can be defeated if the connecting lines are compromised. Although most security systems employ some means of detection if these lines are tampered with, there is increasing evidence that clever intruders know how to circumvent these measures and prevent alarms from going through from a protected area to a monitoring post. Measures that should be taken to counter this tactic include making alarm signal lines physically inaccessible and utilizing more secure line supervisory equipment.

1.9.7 Timing. Physical security is very sensitive to the degree of readiness of the system. Physical security is often weakest during periods of peak traffic to and from the facility during the normal workday. For example, alarms may be set off when a structure is opened at the start of the day. In this case, the guards may not respond, believing all such alarms to be false. Another example is shipments that are stored in relatively unsecured holding areas for a temporary period before begin relocated to more permanent secure facilities. Bad weather, darkness, and holidays are other times of predictable security difficulty.

1.9.8 Historical Records of Intrusion. The security engineer should obtain, from the appropriate security or police office, records of actual and attempted intrusions or interceptions of unauthorized individuals at the installation or activity for similar facilities as that being designed. The records of attempted and actual penetrations, regardless of intent, should be examined carefully to determine how access was attempted or achieved. The records will aid in assessing the threat and in uncovering likely means and locations of intrusion to be hardened against. Although such historical data is useful, it should be remembered that focusing exclusively on the hardening of these historical weakpoints may simply divert the threat to other previously unidentified weak points. Figure A-4 provides some data based on 480 cases of unauthorized intrusions into Naval facilities investigated by the Naval Investigative Services from 1976 to 1981. Based on these results, one can conclude the facilities involved were largely unhardened with nominal (if any) security.

1.9.8.1 Point of Entry. Figure A-5a shows that the most frequent mode of entry was through a door or window. Of the total of 480 cases, 208 were breaking and entry with 125 (60.1%) through the door and 66 (31.8%) through the window. Entries through walls, roofs and other means accounts for the balance of 8.1%.

1.9.8.2 Method of Entry. Figure A-5b shows the method of entry into the doors and Figure A-5c through the windows. Breaking or disabling the door lock is by far the largest (48%) method of entry. The majority of windows were left unlocked. However, when windows were locked, the method of entry was to break or remove the glass.

1.9.8.3 Tools Used. Figure A-5d shows the tools used for the 208 cases involving breaking and entry. Only 99 of the 208 cases reported the use of tools. Prybars were used in the majority of cases (26.4%) followed by other tools (18.3%) (such as brick, knives, etc.), and bolt cutters (2.9%). No power tools or sophisticated cutting, burning, or explosive devices were reported.

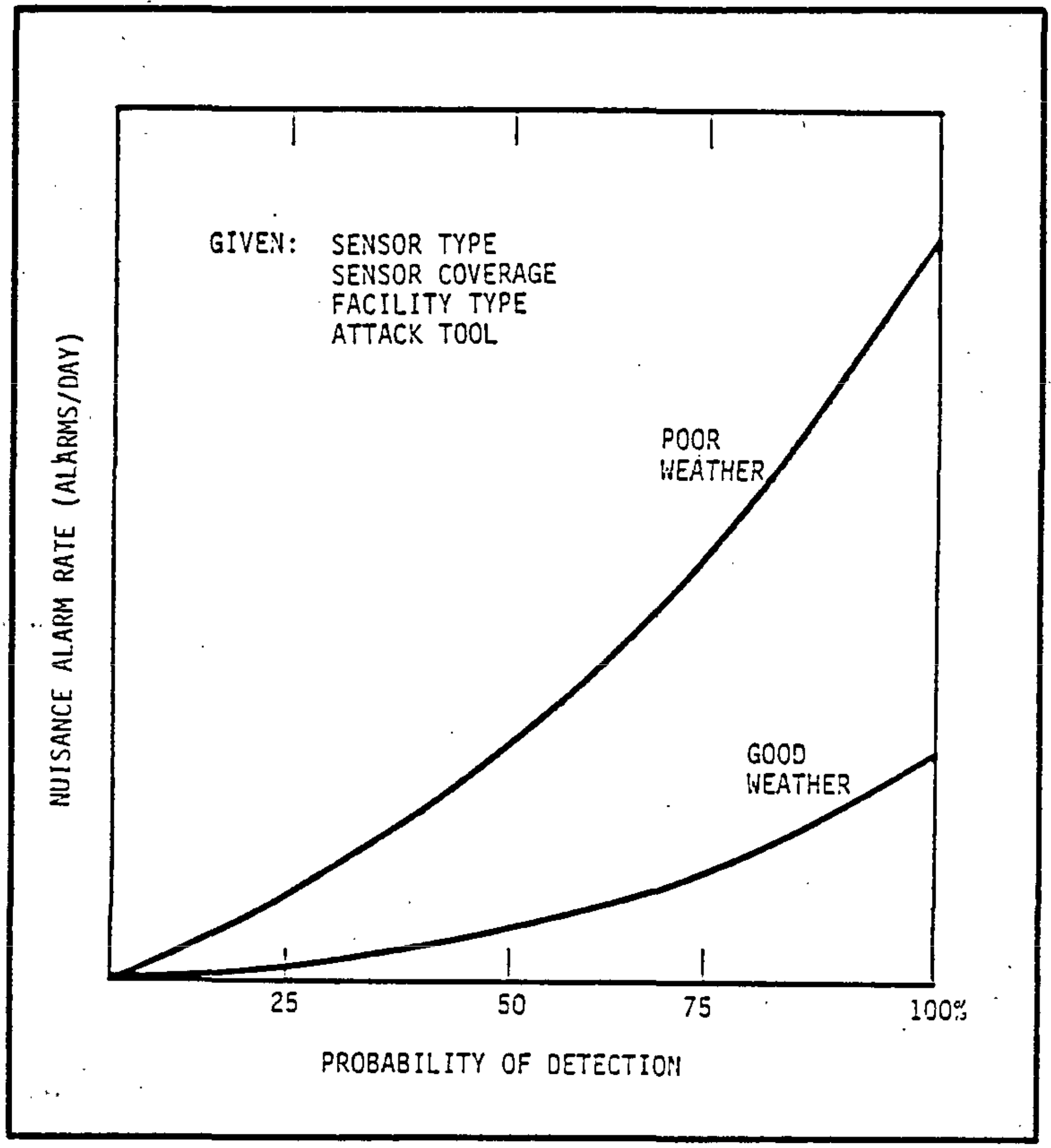


FIGURE A-4. **IDS performance data requirements.**

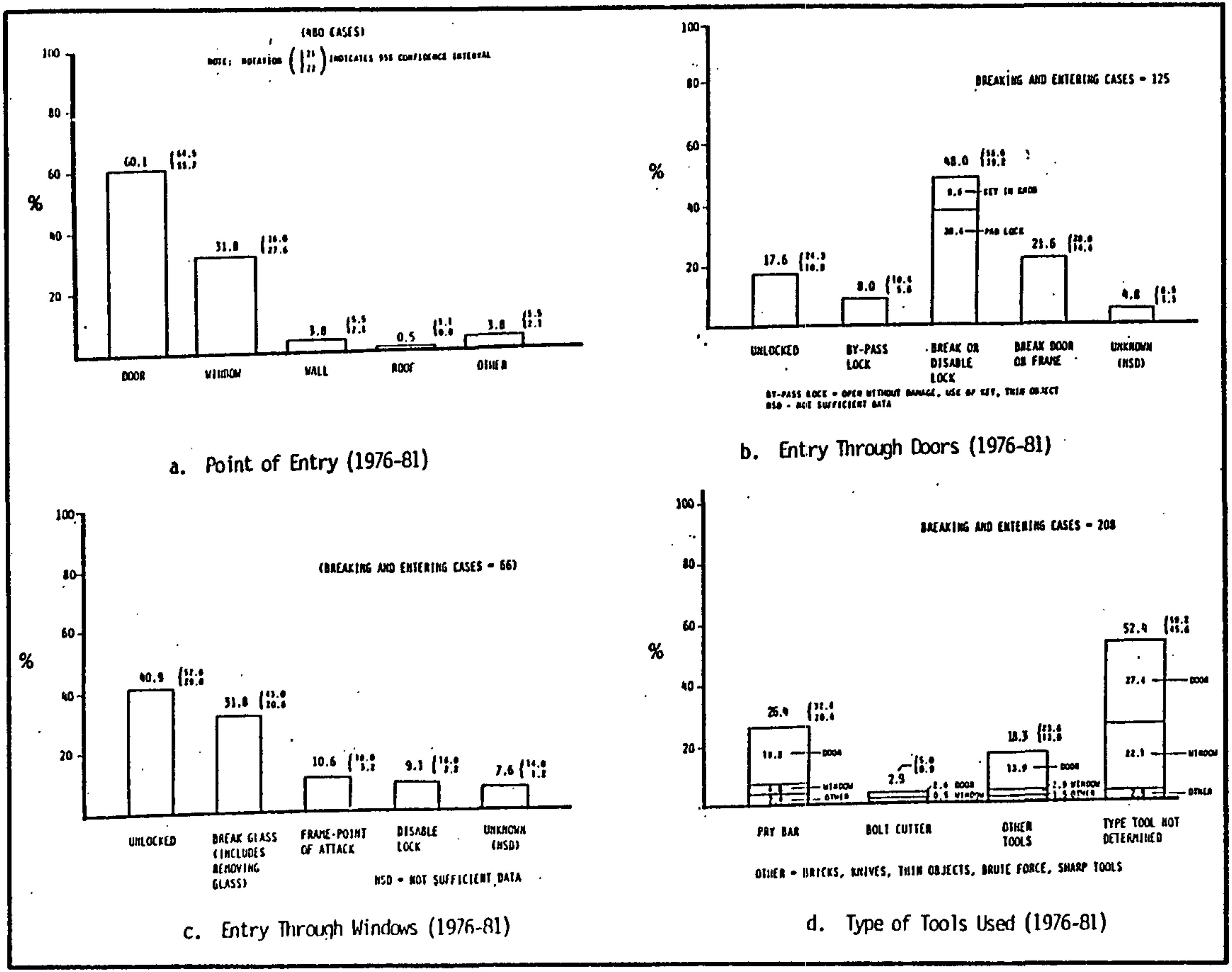
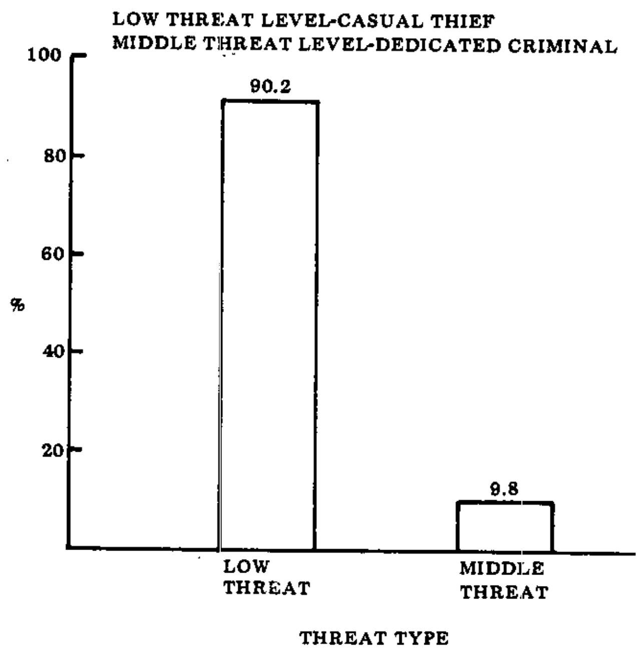
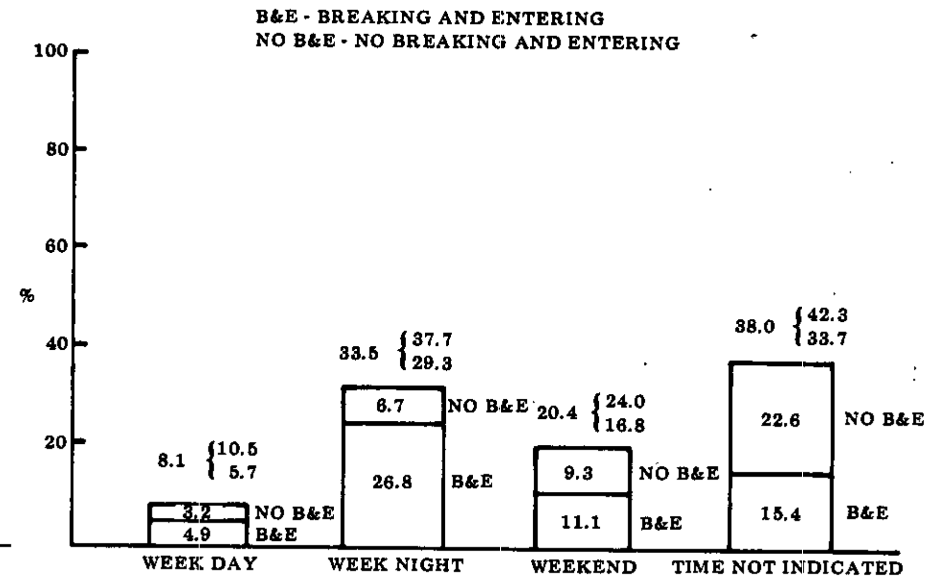


FIGURE A-5. Example historical experience.



e. Percent by Threat Type



f. Frequency by Time of Incident Occurrence per Day

Figure A-5. Example historical experience (continued).

1.9.8.4 Threat and Skill Level. Figure A-5e shows that the majority of the cases could be classified as low threat level crimes of opportunity with intruders of obvious low skills. This is also reflected in minimal to no obvious preplanning and the use of tools of opportunity.

1.9.8.5 Timing. Figure A-5f shows that over the available data most incidents occur at night. The occurrences at night are four times higher than during the week day and 50% higher than the total weekend occurrences. Unfortunately, time of entry for a large portion of the data (38%) was not indicated.

1.10 Determining Security Related Characteristic Parameters of the Installation.

1.10.1 Overview. The design of security for the new facility can not be accomplished without recognizing the impact of other currently existing critical facilities on the installation. Since these other facilities also require security related resources (guards, IDS), the effect is to limit the availability of the same resources for the new facility. For example, the time interval required for roving patrols to periodically check the new facility depends, among other things, on the location and numbers of other critical facilities that must also be checked. Another example--if IDS alarms occur both at the proposed new facility and other critical facilities at about the same time, the overall response time to (and corresponding delay time required of) the new facility may be higher. How much higher depends on the number of alarms and the availability of responding guards.

1.10.2 Other Critical Facilities. The facilities engineer must establish which other facilities on the installation are also critical and require real time security. For these facilities, he should establish the parimeter (in feet) that must be inspected, and the X and Y coordinates of the center of the facility from baselines. The security engineer should also establish whether these other facilities are wired for IDS, whether they are on a roving patrol path with periodic inspection, or both.

1.11 Determining Security Guard Parameters.

1.11.1 Overview. The capability of the security guard response force located on the installation is directly related to the proper investment in facility delay time. The goal of any investment in facility delay time is to resist penetration for the interval of guard response. Therefore, the appropriate structural delay time should consider the worst case of guard response time. The security engineer should obtain data relating to existing security guard performance and economics on the specific military installation where construction is being planned.

1.11.2 Operational Procedures. Information should be compiled regarding guard operating procedures on site, including those related to the following security roles:

- o Roving in one or more vehicle patrols from critical facility to critical facility and conducting walking inspections of each.
- o Dispatched from one central guard facility.
- o Located at one or more critical facilities either in fixed stations, or on walking patrols around the facility.
- o Located at entry control points into the installation.
- o Located offsite as support guards.
- o Combinations of the above.

The security engineer should determine which of the above options are in current use and which are not at the installation.

1.11.3 Guard Numbers and Training. The guard force performance is sensitive to the staffing practices, number, location and size of critical facilities, threat tactics, and degree of training. The security engineer should obtain and evaluate data on the following guard parameters.

1.11.3.1 Hours on Duty Per Guard Per Year. Determine the number of guards required per 24-hour station.

1.11.3.2 Number of Guard Positions Within Each Category. Determine additional guard requirements imposed by the new facility.

1.11.3.3 Saturation Limit of Activity (Fewest Number of Guards on response Duty at Any Time During Year). Determine whether new guards are required to raise the insensitivity to threat-induced, deliberate false alarms.

1.11.3.4 Law Enforcement Skills and Proficiency. Determine whether guard response is likely to be productive under all circumstances.

1.11.4 Guard Costs. The security engineer should obtain data on the current cost to train, equip, and maintain the security guards at the installation, and the total anticipated costs allocated to the new facility over the life of the building (C_{SF}). For example, the cost of guards located onsite at the new facility would be the number of guards required to man one duty station each 24-hours times the cost per guard position over the life cycle of the building. Roving patrol, central dispatch, or gate entry control guard costs should be allocated to all critical facilities on the installation. A cost allocation formulae consistent with budgeting practices should be developed. For example, one may allocate the costs in proportion to the secured perimeter or area of each critical facility. Roving patrol costs should include an allowance for vehicle investment, and operations and maintenance (O&M) costs.

1.12 Determining Intrusion Detection System Related Parameters (IDS).

1.12.1 Use of IDS. For security guards and structural delay to be cost-effective, threat detection and assessment should be provided either by people or by the use of remote sensors. Security personnel, passersby, or sensors are required to announce a possible threat (detect), confirm the existence of a threat (assess), and define the location of the threat (track). IDS may also provide forensic information pertinent to the criminal justice approach and also affect the deterrence features of the facility. The security engineer must develop an appreciation of what an IDS will do for security, criminal justice, and deterrence so the delay time designed into the structure can account for these capabilities.

1.12.2 IDS Performance Parameters. The IDS performance parameters of interest to the security engineer include the following factors:

- Completeness of coverage

- False alarm rate and nuisance alarm rate

- Time for detection and assessment (T_{IDS}) (referenced to initiation of the penetration threat)

- Probability of detection

- Assessment confidence

- Degree of tracking localization

Use of an IDS involves inherent risks. For example, guard requirements for threat assessment may increase because of high false or nuisance alarms rates associated with the detection sensors. For a given sensor there is a relationship between the probability of detection and the number of nuisance alarms. In general, the higher the probability of detecting an intruder, the higher the likely nuisance alarms. This is shown in Figure A-4. One way of minimizing this problem is to design integrated barrier-sensor systems where the disturbance threshold level for actuating the sensor is very high but still within the level of that created by all the attack tools. This is discussed further in what follows.

1.12.2.1 Existing IDS System. The security engineer should establish the IDS performance parameters for both the new facility being designed as well as the IDS system currently operational at the installation (if any). Important basewide IDS information that can effect the cost and level of security at the new facility is the location of other critical facilities with IDS, the IDS coverage area at these facilities, and the historical average and worst case false and nuisance alarm rates experienced. The higher the alarm rate at these facilities the more time will be spent by guards assessing these alarms. This can lead to a higher delay time requirement at the new facility. As a first approximation, one can allocate the estimated alarms per day to the various critical facilities with IDS on the installation in proportion to the IDS coverage area of each.

1.12.3 IDS Cost. The security engineer should also obtain data on the current investment costs of any IDS system, and the anticipated maintenance and other costs over the life cycle of the building (C_{IDS}). In this regard, estimating IDS costs presents a difficult problem. Many of the IDS sensors are discrete in character, wherein one sensor more or less provides detection within a region, but with detection performance degraded as a function of distance from the sensor. Thus, the area of the region protected (and consequently the number of senors) depends on the level of detection sought as well as the corresponding tolerable level of nuisance alarms. In effect, the region protected is operationally defined instead of structurally defined. There is the additional task of allocating the costs of IDS facilities shared with other buildings on the base, such as the command, control and display facilities, the sensor data link facilities, and the annual recurring costs for the command and control operators and maintenance and repair personnel. Thus, costs for a particular building are also dependent on the number of other buildings equipped with IDS.

1.12.4 IDS Detection Issues. The detection function performed by an IDS satisfies the objective of creating a confirmed threat file, which requires further action. There are many problems inherent in any IDS system. Such problems include false and nuisance alarms, vulnerable sensor location, and incomplete sensor coverage. Poor sensors or IDS design or installation will result in a major cost penalty if it results in a large guard force requirement for assessing nuisance alarms.

1.12.4.1 Detector False and Nuisance Alarms. IDS sensors used for detection only may have frequent nuisance alarms because of weather, passersby, or other phenomena. The IDS equipment itself may also produce false alarms (e.g., from internal equipment noise). Since many current IDS applications require guard personnel to respond to the alarm location to assess its validity, a major expense due to an unreliable IDS may be the high cost of assessment guards. To illustrate the above, detectors can operate on any of a wide variety of physical principles and are, therefore, subject to widely different nuisance alarm backgrounds. Some are particularly sensitive to one or more of the following: fog, rain, snow, thunder, aircraft or traffic noise, heat, radio interference, rodents, etc. Generally, detectors possess at least one "Achilles heel" so that selection of the best detector depends upon the application environment. In general, it is also true that as more detectors are needed to complete coverage for an application, more false and nuisance alarms will result over a given period. It should also be noted that detectors deployed outside, and thus subjected to weather, are more prone to high peak alarm rates. To control high false and nuisance alarm rates, sensor systems may require coincident detection by two or more detectors operating on different principles.

1.12.4.2 Detector Location. The detection sensors may be placed in the wrong position relative to the key structural barrier so that the threat is detected only after penetration of the barrier. To be effective, detection sensors must sense in or on the outside of the structural delay barrier at the start of the penetration attempt. When this is not done, the investment in delay barriers is largely wasted (except perhaps as a deterrent). Moreover, in such cases, the IDS functions only as a crime notification system for use in criminal justice enforcement.

1.12.4.3 Detector Coverage. The detection sensor coverage may also be incomplete allowing the IDS to be circumvented along certain paths of approach. There are a myriad of detection options each of which possesses a coverage characteristic. To ensure complete coverage, the detection plan must recognize vertical as well as horizontal planes. For example, in some circumstances, it may be necessary to detect a threat approaching the roof of a secure building from the higher roof of a neighboring insecure building. Detection on the ground plane alone does not provide confidence in threat detection under all circumstances. Specific detection sensors are too numerous to mention here.

1.12.5 IDS Assessment Issues. After a formal detection event, another sensor (either an IDS or a person) must provide confirmation of the existence (designation event) and determination of the threats characteristics (discrimination event). To eliminate the time lost for assessment, as well as the cost of guards dedicated to assessment, it may be desirable to include security sensors that go beyond detection. Assessment sensors confirm the existence of a threat. These can be as crude as a second detection from another detection sensor or as sophisticated as imaging sensors such as CCTV designed to show a remotely located security guard what is actually happening. Some new CCTV sensors include complex microprocessors, which perform detection and do not require a guard viewing the image until some detected change requires attention. Assessment is always required. Due to nuisance alarms, assessment may consume most of the guard force's time when a sensor assessment system is not used. Incorporation of assessment sensors into an IDS may help limit the number of guards required to ensure a secure facility.

1.12.6 Tracking Issues. An IDS can also inform the guards of the location of the threat. Very large sensor zones provide a minimum of location information to guards. Often, when the guard response times are lengthy, the threat may have made significant progress from the position of first detection. Since searching for the threat can be time consuming or prove unsuccessful, in some situations it may be necessary to incorporate tracking sensors that continually update the location of the threat. If the facility is large, tracking sensors become more important.

1.12.7 IDS Communications Issues. Communications lines essential to IDS detection and assessment should be hardened and protected with fail-safe features. The same requirement applies to any radio communications upon which IDS operation depends, such as radio frequency (RF) repeaters and antennas. The operation of the IDS is only as reliable as its weakest point. Either interior or exterior exposure of key communication lines or RF links may provide an informed intruder with the opportunity to defeat the IDS and, therefore, compromise security. The hardening of such lines and links is essential to the reliable performance of any real time security system. As noted under the section on exterior layout in Paragraph 4.2, telephone jacks should be provided as necessary, at external locations, particularly to support security personnel who may be dispatched to assess a sensor for which assessment hardware (i.e., a CCTV camera) has failed and who need access to a telephone. Such jacks should be hardened to prevent a threat from "plugging into" the telephone network and jamming the entire system. A jack with a special key to register contact might be one solution. The alternative is to equip security personnel with hand-held radios.

1.12.8 Display Issues. Security personnel need sufficient technical information about the operation of IDS detection and assessment hardware to understand the information that is symbolically displayed on consoles (e.g., colored lights, annunciators, etc.), particularly during situations when numerous annunciators are alarming simultaneously. A fully lit display panel can easily desensitize even the most energetic security force. Generally, such situations occur during local storms (e.g., wind and rain) and may result from the activation of sensors (e.g., magnetic switches on rattling doors that are not properly set in their jams) thus producing a high nuisance alarm rate and, therefore, reducing the utility of the IDS. In real time security systems, backup provisions must be in place, at least to provide for alternative means of detection and assessment at critical facilities, or the security system can easily and routinely be compromised. Intruders only need to wait for favorable weather or seasonal conditions. Equally important is the precise correlation of detection and assessment hardware, such as motion detectors and CCTV cameras and monitors. For example, security personnel need strong "cues" to look at CCTV monitors because of the decrement in vigilance that occurs during long duty cycles. The important point to remember about alarm displays is that security personnel must be present to immediately react to a detection event, to assess it, and to communicate necessary orders to response personnel, should assessment confirm detection of an intruder.

1.12.9 IDS Related Criminal Justice Issues. Few IDS detection sensors possess characteristics that can contribute to successful criminal justice or an after-the-fact loss recovery program. On the other hand, a CCTV with a videotape recording capability or sequence photography can assist apprehension and prosecution of intruders after a security failure. CCTV sensors may also contribute to detection, assessment, and tracking in a physical security context.

1.12.10 IDS Related Deterrence Issues. IDS sensors are available that are easily visible to the potential threat, and others can be effective while hidden from view (such as buried sensors). Some degree of deterrence results by application of easily viewed sensors. Even inoperable sensors (empty housings) can sometimes be used to enhance deterrence.

1.13 Identifying Hardening Options and Analyzing Performance/Cost Tradeoffs.

1.13.1 Overview. The security engineer should complete a cost-effectiveness analysis considering alternative mixes of structural hardness for a given level of security force and type of IDS. The objective is to establish optimal design options considering the security performance, budgeting, and operational constraints of the facility established above.

1.13.1 Cost Analysis.

1.13.2.1 Overview. The security engineer should begin the process by identifying security system options and evaluating their life cycle costs. This involves using the information in this design handbook to tabulate structural barrier design options for the walls, roof, floors, doors, windows, etc., using the Worksheets in Paragraph 3.2 (shown as Figure 4). A range of delay times should be assumed based on the estimated range of response time ($T_{RF}+T_{IDS}$) of the security system established in previous steps. Next the life cycle costs of these hardening options should be combined with sensor and guard costs to see which are below total security system and/or individual component cost limits.

1.13.2.2 Structural Hardening Costs. Structural hardening costs (C_{BLDG}) are the full-construction costs including general contractor overhead, G&A, and fee. Periodic painting etc., can be assumed to have little to do with maintaining penetration resistance and consequently initial construction costs can reasonably reflect total life cycle costs associated with construction.

1.13.2.3 Intrusion Detection System Costs. IDS costs (C_{IDS}) include hardware procurement for the sensors, command and control (C&C), and wire and cable subsystems. Annual recurring costs for the C&C operators and maintenance and repairs should also be included.

1.13.2.4 Guard Forces Costs. Guard force costs (C_{RF}) involving roving vehicle guards should be allocated to each secured facility on the installation, including the proposed new facility in proportion to the secured area perimeter requiring inspection or other appropriate rules. All the costs should be allocated to the new facility if the guards are located onsite. Vehicle investment and O&M costs should also be considered for the roving cases.

1.13.2.5 Total System Costs. Total system costs ($C_{BLDG}+C_{IDS}+C_{RF}$) for each candidate facility design should be calculated and compared with the maximum cost constraints established previously. Systems that do not meet the constraints should be eliminated accordingly. Since some losses may impact political or replacement time issues in addition to dollars, these parameters should also be considered in the decision. A reasonable physical security expenditure is a complex issue related to many variables as well as to how much delay time is needed and how much is acquired for each increment in cost.

1.13.3 Performance Analysis.

1.13.3.1 Overview. After those security system options meeting the cost limitations have been identified, the confidence or probability of detecting and intercepting an intruder in time (P_I) for each building component (walls, doors, roof, etc.) associated with each option should be then evaluated and compared against the minimum acceptable level specified earlier. Those options not meeting the requirement should be eliminated. The facility structural delay time is a primary factor in estimating P_I. This is discussed further below.

1.13.3.2 Facility Delay Time. Providing adequate structural delay time is a primary factor in physical security, since it takes time for guards to detect and assess a threat and to arrive at the right spot to prevent a loss. Delay of threat progress during this response interval is essential. The facility should provide a cost-effective structural barrier in the path of the intruder consistent with response timeliness of the IDS and guards. All potential paths into the building should be considered. The building delay time should be regarded as no better than the lowest penetration time provided by any one element of the structure, be it doors, windows, utility openings, floors, walls, or roofs. The majority of penetration losses from existing facilities occur through doors, windows, and utility openings. These elements of the structure frequently are the weak links and may not meet physical security delay time goals. Doorjambs, door locking systems, hinges, and window shields require particular attention in order to gain adequate delay time.

1.13.3.3 Probability of Guards Intercepting an Intruder Without an IDS. For systems that rely totally on the guards for detection and interception, the probability of the guards intercepting the intruder in time ($P_I=P_{IG}$) can be estimated using:

EQUATION: $$P_{IG} = P_{DG} \times P_{AG} \qquad (A\text{-}2)$$

where

P_{DG} = Probability of the guards detecting the intrusion attempt

P_{AG} = Probability of the guards assessing which facility is being attacked and arriving in time

The probabilities in Equation A-2 are combined in an "AND-gate" form. This means each of the events must occur for the combined probability to occur.

(1) Probability of detection by guards. P_D involves the possibility of guards hearing attack tool noises, seeing visual observables such as smoke or light generated during a penetration attack, or visually detecting a break-in attempt directly on a normal inspection cycle at the facility. The combined probability of detection (P_{DG}) that accounts for both audible (P_{DA}) and (P_{DV}) visual factors can be calculated by:

EQUATION: $$P_{DG} = 1-(1-P_{DA})\ (1-P_{DV}) \qquad (A\text{-}3)$$

The probability of auditory detection (P_{DA}) is a function of the noise level of the source (attack tools), the background noise level, and the distance the observer or guard is from the source. Attack tool noise data are available from tests and from other sources. Nominal background noise levels of 40 db for a walking or stationary guard and 70 db for roving patrols can be used. Background noise levels for roving patrols is higher because of vehicle and engine noise. The probability of auditory detection is depicted graphically in Figure A-6 for two attack tool noise levels--75 and 105 db. The probability of visual detection (P_{DV}) is a function of attack tool smoke or light luminance levels, background luminance, attentuation due to weather conditions, and the distance of the observer or guard from the source. P_{DV} for a burn bar is depicted graphically in Figure A-7 for various weather conditions. Since the combined probability P_{DG} given by Equation A-3 also depends on the specific locations of the guards away from the noise or light source, the security engineer can calculate an average P_{DG} over all locations by weighing the individual probabilities for each possible location of the guards along the roving path, etc. in proportion to the fraction of the times spent at these locations over the total attack time (which is the same as a given barrier penetration time) when noise or light is being generated.

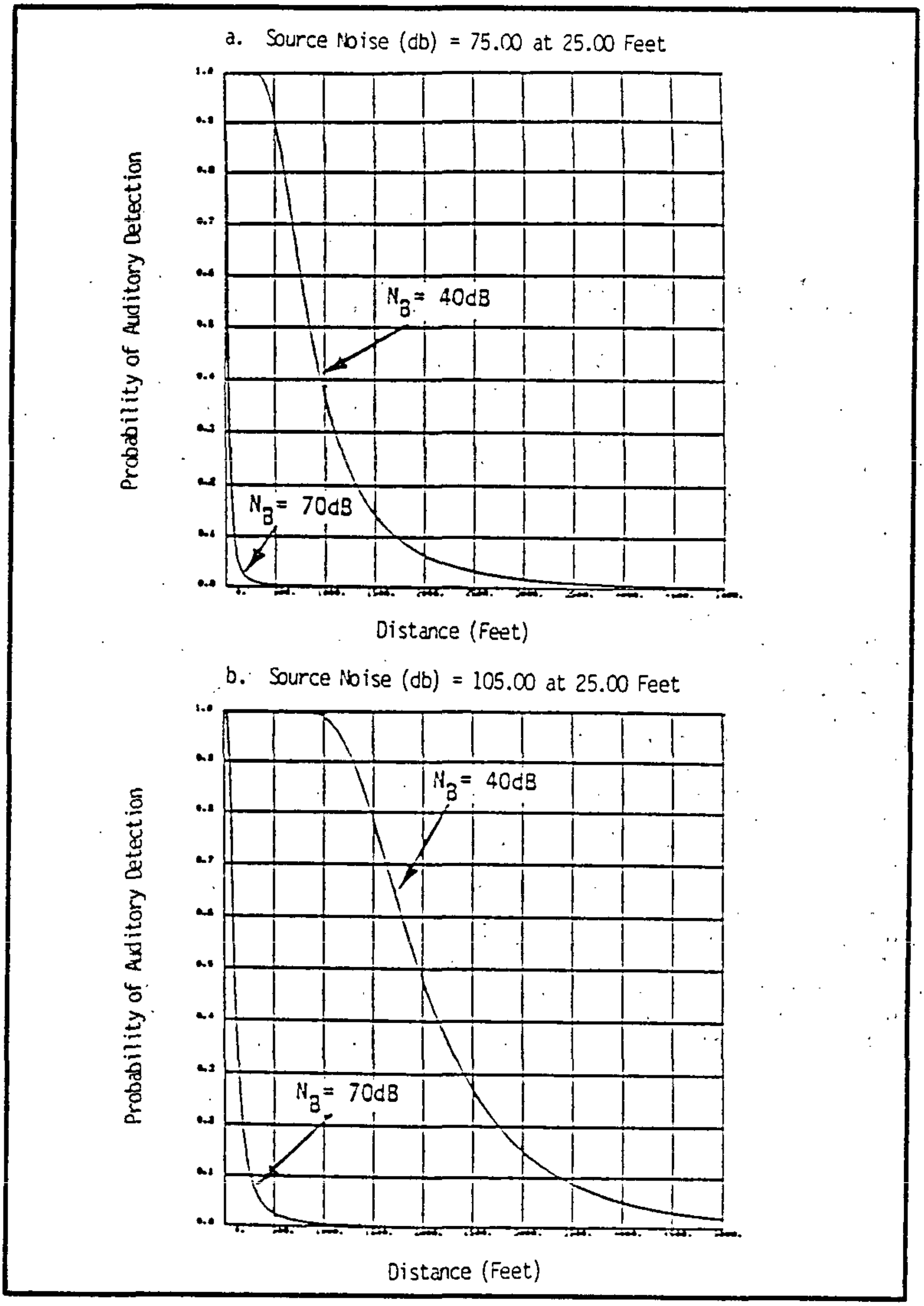


FIGURE A-6. Probability of auditory detection by guards versus range.

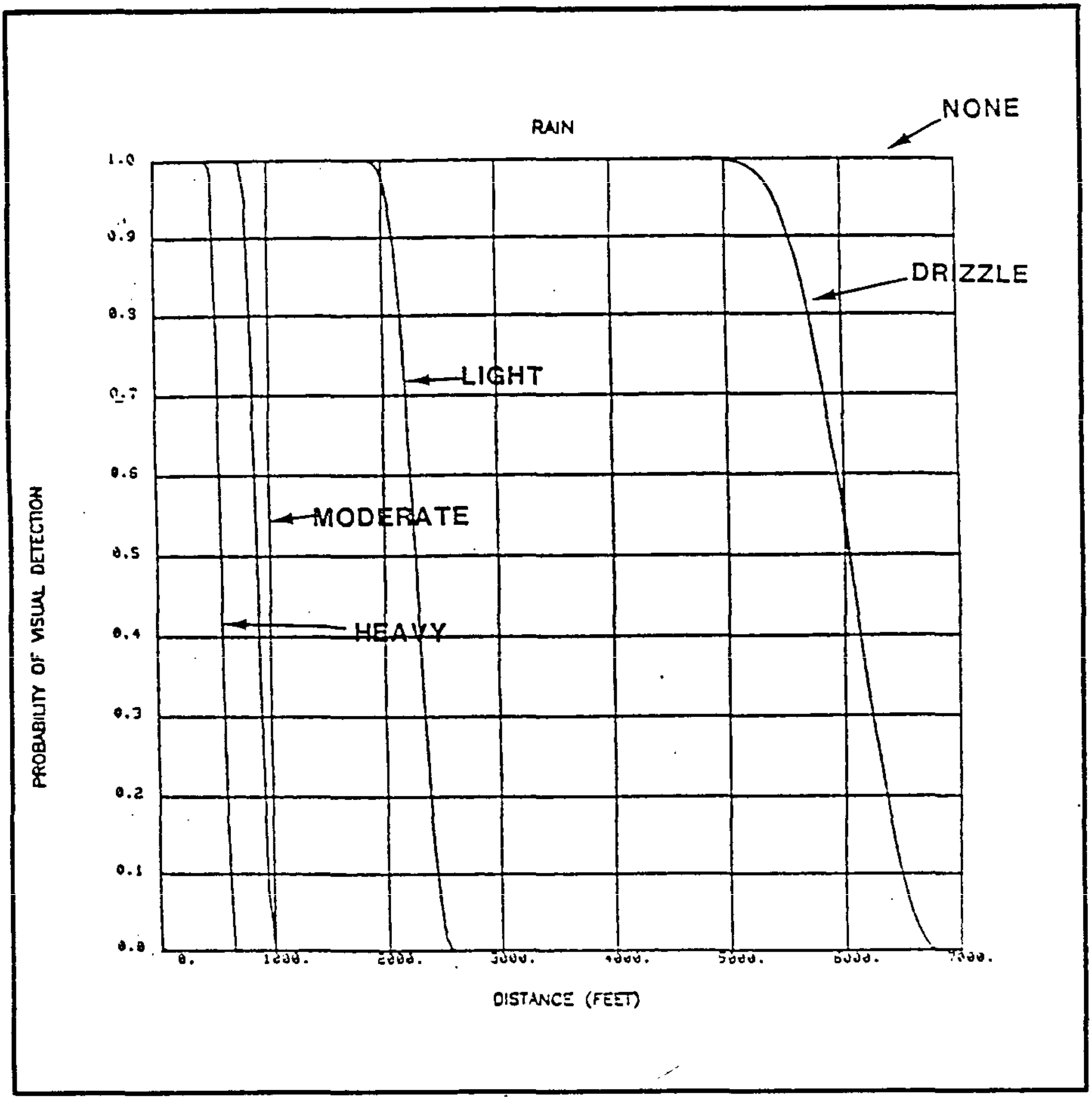


FIGURE A-7. Probability of visual detection by guards versus range and environmental conditions (for a burn bar attack).

(2) Probability of assessing which facility is under attack. The probability of assessing (P_A) depends on the ability of the guards to locate the source of the attack sounds or visual observables. This depends on: the location of the guards at any one time; the fact that there is a 20-degree conical uncertainty of a human observer accurately identifying the location of any sound; and the fact that other secured critical buildings may be located in the 20-degree conical area which would have to be responded to. This angular uncertainty can be taken as zero for attacks involving visual smoke or light observables since the angular direction of these effects can be observed directly. The security engineer can estimate the probability of assessing and arriving in time from the guard locations using:

EQUATION:
$$P_{AG} = \begin{matrix} 0.0 & T_{BARRIER\ PEN} + T_{IN} + T_{OUT} < T_{RF} \\ 1.0 & T_{BARRIER\ PEN} + T_{IN} + T_{OUT} \geq T_{RF} \end{matrix} \quad (A-4)$$

where

T_{RF} = Response force time

$T_{BARRIER\ PEN}$ = Barrier penetration time which varies according to the attack

T_{IN} = Ingress time

T_{OUT} = Egress time

The estimate for T_{RF} should account for an angular uncertainty of 20 degrees regarding the location of the facility if the attack involves only sound observables. Since the guard may be at more than one location (e.g., on a roving path), an average P_{AG} over all possible locations should be established and weighted on the time spent and probability of the detection occurring at a given point.

(3) Response time (T_{RF}). The security engineer can estimate (T_{RF}) in the following manner. He should obtain a large scale road map of the installation and identify: (1) the location of existing critical facilities and the proposed new facility; (2) the locations of vehicle patrol paths followed by roving guards during an inspection cycle; and/or (3) the location of the guard response if an alarm occurs for facilities that depend on IDS guard responding from a central guard house. Based on this information, estimates should be made of the roving patrol path timelines, IDS response time lines, etc. This can be done by actually measuring these times by riding along in a vehicle or estimating them using the distances on the maps and measured values of vehicle patrol and response speed as well as on-foot building inspection rates. Allowance for multiple simultaneous IDS alarms should be made as appropriate.

1.13.3.4 Probability of Guards Intercepting an Intruder With IDS. If IDS is included as part of the protection of one or more components of the new facility, the probability of intercepting an intruder in time for these components can be estimated using:

EQUATION: $$P_I = 1-(1-P_{IG}) \times (1-P_{IDS}) \qquad \text{(A-5)}$$

where

P_I = The combined probability of intercepting the intruder

P_{IG} = The probability of intercept based on the guards hearing or seeing an attack

P_{IDS} = The probability of intercept based on the IDS detecting the attack

The combined "OR-gate" probability expressed by Equation A-5 is used to allow assessment of all possible mixes of fixed guards, roving patrols, and IDS that can occur. The above "OR-gate" expression allows for this in that any one of the combinations can result in an intruder intercept--i.e., all need not occur. P_{IG} in Equation A-5 is estimated using Equation A-2. P_{IDS} can be calculated using Equation A-6:

EQUATION: $$P_{IDS} = (P_D)_{IDS} \times (P_A)_{IDS} \qquad \text{(A-6)}$$

where

$(P_D)_{IDS}$ = The probability of the IDS sensors detecting the observables generated by a given attack tool against the given structural barrier

$(P_A)_{IDS}$ = The probability of guards arriving at the IDS structure in time to intercept the intruder

$(P_D)_{IDS}$ and $(P_A)_{IDS}$ are functions of the probability of the specified IDS sensors on the building component detecting intruder attacks and the nuisance/false alarm rate of these sensors in various environmental conditions. $(P_D)_{IDS}$ is given by Equation A-7:

EQUATION: $$(P_D)_{IDS} = 1 - (1-P_{DN})(1-P_{DS})(1-P_{DH})(1-P_{DL})(1-P_{DV}) \qquad \text{(A7)}$$

where

P_{DN} = Probability of detecting a noise

P_{DS} = Probability of detecting smoke

P_{DH} = Probability of detecting heat

P_{DL} = Probability of detecting light

P_{DV} = Probability of detecting vibration

P_{DM} = Probability of detecting motion.

One or more terms in Equation A-7 apply depending upon the sensors specified for the building component. Values of the detection probabilities depend on the sensor system used and the attack-tool/barrier combination being evaluated.

The probability of arriving at the IDS structure in time to intercept an intruder, $(P_A)_{IDS}$ in Equation A-6, can be calculated as the ratio of the delay time provided by the structure for a given attack divided by the time it takes a guard to respond or service an alarm. The structural delay time in turn is the sum of the penetration delay time of its barriers, plus the ingress/egress time of the intruder entering and leaving. $(P_A)_{IDS}$ is, therefore, expressed as Equation A-8:

EQUATION: $$(P_A)_{IDS} = T_{BARRIER\ PEN} + T_{IN} + T_{OUT} \qquad (A-8)$$

where

$T_{BARRIER\ PEN}$ = Penetration delay time of the structural barrier which varies according to the attack.

T_{IN} = Ingress time

T_{OUT} = Egress time

T_{IDS} = IDS detection time

T_{RF} = Alarm response time

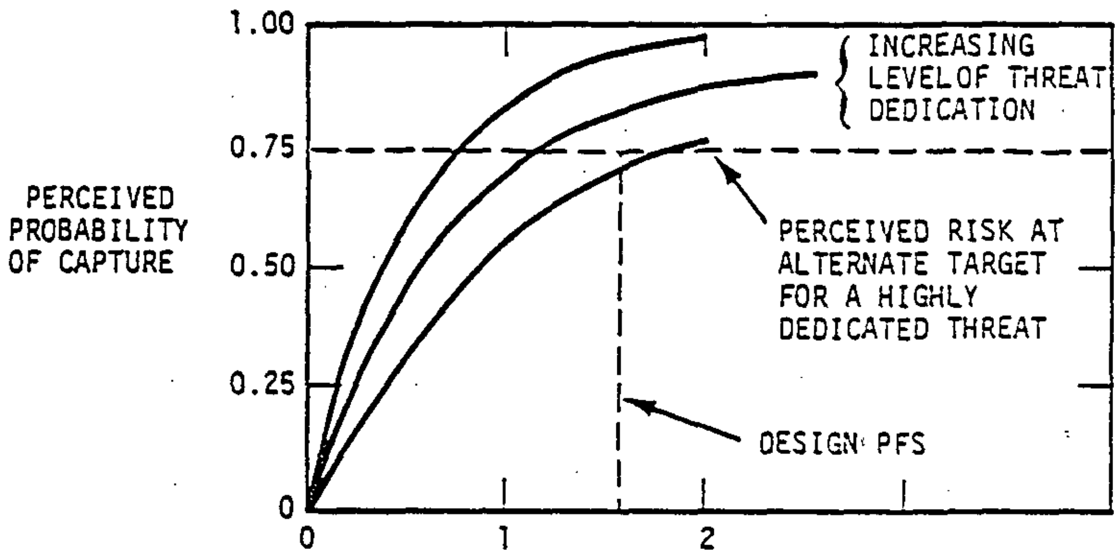
The estimate for T_{RF} is accomplished as discussed previously and should account for the possibility that the guards may be assessing alarms at other critical facilities. The higher the estimated false/nuisance alarm rate for the activity as a whole, the longer T_{RF} for a given fixed number of guards. Since the guards may be at more than one location (e.g., on a roving path), an average $(P_A)_{IDS}$ over all possible locations should be established and weighed based on the time spent at that location.

1.14 Establishing Acceptable Deterrable Measures.

1.14.1 Deterrence. A nominal investment in deterrence measures may be more cost-effective than a large investment in a physical security system. In general, deterrents are intended to create a belief by the threat that the risk incurred by attack is unacceptable. Deterrents are, therefore, compatible with, but not necessarily identical to, physical security options. For example, it may be possible to create a costly system with a high degree of physical security effectiveness, which may, nevertheless, be essentially transparent to the potential threat and result in reduced frequencies of attack and/or less effective intruder tactics (e.g., smash and grab). Conversely, it may be possible to create a low degree of physical security, which appears formidable to the potential threat and results in a small number of successful attacks at much less cost. Each successive attack cannot be guaranteed to occur in ignorance of previous outcomes. However, a "paper tiger" system, when discovered, will be vulnerable.

1.14.2 Deterrence Examples. The apparent structural integrity of the facility can convince some potential threats that it is more work to acquire the tools and is more trouble to break and enter than to attack a nonmilitary facility for the same resource. Visible guardforces with rapid response or frequent patrol intervals are a deterrent because of the perceived probability of capture. High traffic densities in or near a structure may deter by increasing the perceived likelihood of detection or force faster penetrations (e.g. smash and grab thefts). An inventory control system that is updated frequently can deter insider theft. Lighting systems are known to increase the perception of nighttime detection of a potential intruder, whether or not there is an observer to actually perform the detection. Consistently successful prosecution and incarceration of convicted intruders is a deterrent only if these results are widely communicated to potential threats.

1.14.3 Deterrence Cost-Effectiveness. Many deterrents are a side effect of normal physical security and criminal justice practices and, therefore, may be relatively inexpensive. Others require cost-effectiveness justification. For example, the IDS designer may be faced with deciding between a CCTV surveillance with lighting for nighttime performance and a light level television (LLTV), which requires no lighting augmentation. The CCTV with night lighting may be more likely to deter than the LLTV, although they may perform identically for physical security IDS purposes. If there is a cost differential, what it is worth in deterrent performance becomes a question for which limited quantitative data are currently available. Until such data become available, each case should be evaluated on the basis of qualitative judgement. When an alternative physical security option exhibits nearly identical cost and effectiveness, the one with greater deterrent value should be adopted. Figures A-8 and A-9 illustrate how this comparison might be accomplished using the building structural delay time as an example. As shown in Figure A-8 the threat's perceived probability of capture (level of deterrence) is a function of the level of threat dedication, the perceived relative risk of attacking an alternative facility with the same assets, and the perceived performance factor of safety the threat believes is designed into the building. Figure A-9 illustrates that the threat's perceived probability of capture, in turn, influences the actual number of events likely to occur and, ultimately, the losses incurred. It is anticipated that analysis of historical data will lead to a simplified approach for making estimates of the form illustrated in Figures A-8 and A-9.



$$\text{PERFORMANCE FACTOR OF SAFETY (PFS)} = \frac{T_{BARRIER\ PEN}}{[T_{RF} + T_{IDS}] - [T_{IN} + T_{OUT}]}$$

T_{IDS} = IDS DETECTION AND ASSESSMENT TIME

T_{RF} = RESPONSE FORCE TIME

$T_{BARRIER\ PEN}$ = BARRIER PENETRATION TIME

T_{IN} = INGRESS TIME

T_{OUT} = EGRESS TIME

FIGURE A-8. **Quantifying level of deterrence.**

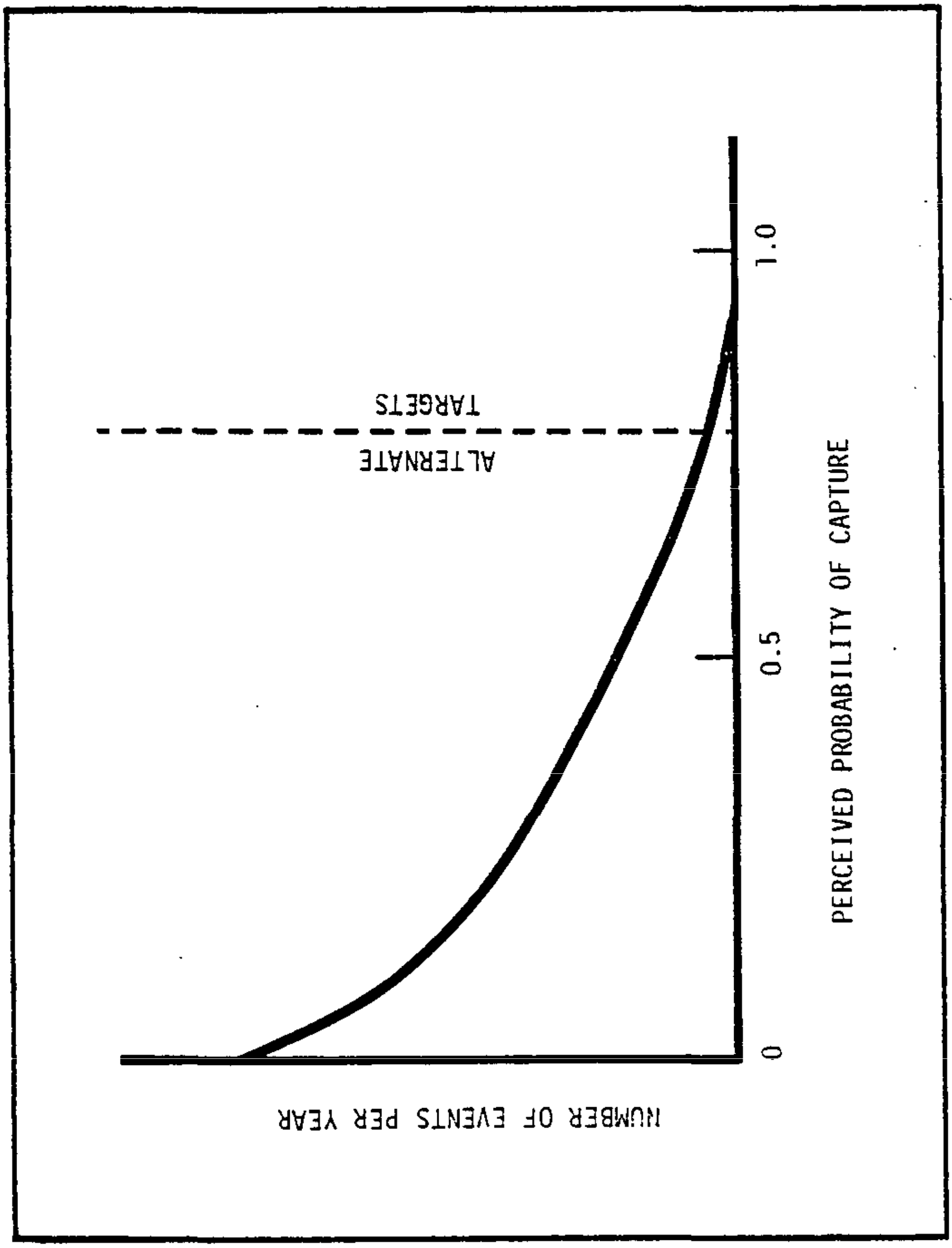


FIGURE A-9. **Interrelationship of perceived probability of capture to number of events.**

1.15 Determining Criminal Justice and Enforceable Loss Limits.

1.15.1 The Criminal Justice Approach. It may be possible to minimize theft losses without substantial investment in physical security by relying on the administration of criminal justice. Although law enforcement and criminal justice functions within DOD and the separate services are "sunk" costs, the allocation of resources for the investigation, apprehension, prosecution, and punishment of intruders who illegally enter military facilities means that fewer resources are available for the enforcement of other, perhaps equally or more important, criminal sanctions. Utilization of investigative and prosecutorial manpower (e.g., Naval Investigative Service, FBI, Judge Advocate attorneys, and related U.S. Department of Justice agencies) is expensive and time consuming. Although all commands and activities are expected to take necessary and cost-effective physical security measures, some commands and activities may not be able to afford extensive physical security resources and may have to rely more on the deterrent effect and operation of the criminal justice system. In order to compare the criminal justice approach against one involving investment in physical security, the security engineer should acquire economic data on the local criminal justice capability at the activity with emphasis upon the differences in costs as a function of these factors:

- o Intruder capture on-site during offense
- o Intruder capture off-site after offense
- o Whether intruder is insider (military, civil service, contractor, or visitor)
- o Whether intruder is outsider (intruder from public at large)

1.15.2 Loss Experience. Anticipated frequency and magnitude of loss based on historical data for similar facilities are also required for each of the above categories. These data should then be analyzed to establish breakpoint levels of loss per occurrence beyond which reliance on the administration of criminal justice is more economical and below which physical security is more economical (see Figure A-1).

APPENDIX B

DATA COLLECTION PROCESS

1.1 General. The scope and character of a particular security system are determined through investigation of the criticality of the installation, facility, or property; vulnerability to potential hazards, damage, or loss; effect of physical security measures on efficiency and operations; practical limitations imposed by the physical characteristics of an installation or activity; availability of funds; probable threat, based on intelligence reports and estimates; alternate measures or approaches to achieving security; and evaluation and appraisal of the physical security capability of all available resources.

1.1.1 Data Assembly Process. Assembling information about the above factors is a step-by-step process. Since security systems are intended to meet the needs of a particular installation, most of the information required is developed at the local level by the designer. The results of the designer's initial investigation form the basis for further investigation to uncover data that clearly defines the requirements. As the process proceeds, the designer should be able to formulate conceptual design approaches and to make tentative judgments of their applicability. It is through this process that the strengths and weaknesses of possible approaches often become apparent. As often occurs, the designer of the physical security system has little or no involvement with the design of the intrusion detection equipment. To insure an optimal security system, it is imperative that the physical security designer coordinate his work with that of the intrusion detection system designer. For example, in new construction, when trying to sense movement with a system that can "see" through wooden walls and when the physical security designer installs wooden walls, a high false alarm rate may be inevitable in the completed installation.

1.1.2 Delineation of Requirements. Only by obtaining information from a variety of sources can the designer develop all of the requirements and constraints that will impact the design. The designer should discuss potential solutions with the representatives of security and user agencies. The designer has to be especially alert and responsive to the operational activities of the user and the possible impact that the implementation of certain kinds of security equipment may have on them, e.g., impairment in the flow of personnel or vehicular traffic, and delays or restrictions of ingress and egress to facilities.

1.2 Physical Security Plan. At an established military installation a "Physical Security Plan" should exist. This plan should be the principal source of guidance on all matters relating to physical security. The plan is normally formulated by the Provost Marshal or comparable officer. The plan defines the purpose and the objectives of the physical security measures that are designed to protect the installation and its facilities, and the areas that are important; establishes priorities for their protection; and defines the security force organization and requirements for entry control. Where applicable, the plan also outlines the requirements for mechanical and electrical aids to security, such as barriers, protective lighting, communications, and intrusion detection systems. The plan is tailored to each installation to suit the needs imposed by local conditions. A physical security plan may have to be developed for new installations or adjusted for existing installations to meet changing conditions brought about by construction modifications or changes in mission or status. Engineering personnel can contribute materially to the formulation of the plan and in the assessment of alternative approaches to achieving its objectives.

1.3 Definition of Areas. The Physical Security Plan should designate that areas are restricted, controlled, limited, or excluded. For the security system designer, these designations provide a guide to the sensitivity of the contents of the areas, to the compatibility with operational routines required of the security system, and to the adaptation of a security system to newly designated areas as the installation mission undergoes change.

1.4 General Factors That Influence Physical Security Requirements.

1.4.1 Overall Installation Security. Factors that affect the physical security requirements for an entire installation are the nature and sensitivity of its mission; vulnerability of equipment, geographic location, and economic and political situation in the area; proximity of external support (such as local police); and capabilities of potential intruders.

1.4.2 Property Within an Installation. Influences on physical security requirements for property within the installation are the vulnerability to theft or damage, attractiveness as an object of sabotage or theft, monetary value, and importance to the primary mission of the installation.

1.4.3 Security Evaluation. Each installation and activity has to continually evaluate its position in light of the foregoing factors and devise physical security measures consistent with them. When evaluating the degree and type of physical security required, it must be remembered that the criticality of an installation or activity may vary from time to time as its products or services become more or less important.

1.5 Data Sources. As seen earlier, the origin of a requirement for a security system stems from a variety of sources. Once the necessity is recognized, the installation engineering staff will be directed to design a system to meet the requirement. In collecting the information necessary to design a security system, the designer will find it useful to conduct interviews with the personnel involved onsite and offsite and surveys of the area or facility to be protected. These conferences and surveys can range from a number of meetings and reconnaissance and analysis of an entire installation to one meeting and one onsite survey of a single area requiring simply a fence. In each case, however, the conferences and surveys must treat all of the pertinent aspects of physical security so that recommendations will be appropriate to the mission of the installation; the environment; the resources available to install, maintain, and operate the security system; and the actual security problem that the system is intended to solve.

1.6 Preliminary Meetings and Studies.

1.6.1 Initial Conference. The first step in gaining a practical estimate of the nature and scope of the security problem is to meet with the originator of the requirement. Principal topics of this initial conference should be: (1) the degree to which the problem has already been defined; (2) present mission or changes in mission of areas to be protected and their relative importance or criticality; (3) postulated threats to and vulnerability of the area to be protected; (4) physical characteristics and location of the area to be protected; (5) type, nature, and adequacy of the existing security system, if any; (6) physical and operational environment that may constrain the security system design or selection of intrusion detectors; (7) capability of installation to install, maintain, and operate a security system; (8) availability of guard forces, proposed location of central security control, and (if required) remote annunciators; (9) requirements for protection of special areas, such as vaults, arm rooms, classified conference rooms, cryptographic facilities, and special weapons storage; and (10) availability of funds.

1.6.2 Plans and Drawings. At this preliminary meeting, the physical security plan, building floor plans, site plans, and other pertinent written material that might be available should be at hand.

1.6.3 Notation. Areas and facilities of interest should be noted on these floor and site plans. By working from notes and drawings before actually performing an onsite survey, the designer can identify the magnitude of the problem to be solved.

1.6.4 Checklists. A checklist is a useful way of acquiring information needed for a security system design. The checklists should cover both general and detailed categories of information that can be used as guides during subsequent interviews and site surveys.

1.7 Onsite Survey Procedure.

1.7.1 Arranging for the Onsite Survey. After the initial study of plans and notes obtained during the preliminary discussion, arrangements should be made for an onsite survey of the areas and facilities of interest. Arrangements should include a visit to the facilities during normal working hours and after working hours. It is desirable that the designer be accompanied on the tour by someone who can provide accurate information on the established mission, who is knowledgeable on route or special operational activities, and who can ensure access to all areas.

1.7.2 Preliminary Site Inspection. Once arrangements have been made for the onsite survey, a cursory inspection of the areas of interest should be made to provide familiarity with the overall site layout. This will establish a mental base of reference in working with the drawings annotated in the initial study.

1.7.3 Detailed Survey. The designer should next address specific details. Building and site drawings should be examined to verify original notations and to correct omissions, overlaps, or illogical designations. The designer should develop and use checklists of specific information required on the individual objects, structures, and areas of interest. It is likely that these inspections, conducted in the company of installation personnel fully acquainted with the specific facility, will reveal additional potentially vulnerable points overlooked on both the drawings and the checklists. If necessary, surveys and discussions should be repeated until all of the desired information is obtained.

1.8 Site Vulnerability. The designer must evaluate the area or facility to be secured against the possible and probable internal and external threats to which the area or facility may be subject.

1.9 Records of Intrusion. The designer should obtain, from the appropriate security or police office, records of actual and attempted intrusions or interceptions of unauthorized individuals in or near the facilities or areas to be protected. The records of attempted and actual penetrations, regardless of intent, should be examined carefully to determine how access was attempted or achieved. These records will aid in assessing the threat and in uncovering likely means and locations of intrusion. Physical inspection of access points used by perpetrators of recorded intrusion attempts should be made to be certain that coverage will be adequate and that a facet of intrusion that may be visually obvious at the access point has not been overlooked in the study of reports and drawings.

1.10 Points of Intrusion. In each area to be protected, the types of entry should be identified as doors used for access; doors used occasionally; doors used for emergency; windows, skylights, or transoms; roof hatches and other access from roof; false ceilings; underfloor crawlspace; steam tunnels; air shafts or vents; ducts and ductwork of all kinds; utility shafts; drainage structures; walls (noting construction, condition, etc.); and areas above, below, and adjacent to the protected area.

1.11 Deterrents to Intrusion. The designer undertaking the detailed inspection of an area to be protected should be aware of certain elements that deter intrusion. The designer should also be aware that the absence of these elements may encourage intrusion. A designer who is alert to these elements will be better able to marshal the appropriate physical security measures to form an adequately protective system. Some of these elements are obvious deterrents, such as strong building construction, the penetration of which requires considerable effort and specialized or heavy tools. Others are more subtle and may not be perceived, or just dimly so, by a would-be intruder, such as strong illumination, high visibility, extensive and controlled activity in the area to be protected, and routes that impede access.

1.11.1 Building Design and Construction. In building design, security is often traded for aesthetic and operational requirements. Retrofitting an existing building to compensate for the lack of architectural features that enhance security is much more costly than if provisions for security from the standpoint of selection of materials and hardware, illumination, and visibility had been originally incorporated into the design. An experienced intruder will seek out weaknesses in construction. If, for example, a wall of a building appears to be strongly constructed and the roof appears to be lightly constructed, the intruder can be expected to exploit that fact. Consequently, in the site survey, the designer should be on the lookout for deterrents to intrusion that will complement the physical protective measures to be applied, and must also take note of weaknesses that can be alleviated by simple construction measures without costly application of alarm systems.

1.11.2 Illumination. Good lighting will act as a psychological deterrent to a potential intruder. However, it is obvious that lighting should not be used alone but that it should be combined with other security measures such as guards, physical protection, and alarm systems. Successful intrusion depends on undetected penetration and escape from the area. The success of these activities is especially affected by the presence or absence of illumination near, on, or inside the facility or building being attacked. However, lighting is seldom used as properly and effectively as it could be. In many instances, lighting is used more for aesthetics than for deterring intrusion. Often lighting is used on the front surfaces of the facility facing thoroughfares and other public areas and only rarely on surfaces that are not normally in view, such as the sides and rear. When lighting is provided on side and rear surfaces, the levels are usually too low and the beams are often disposed to permit deep shadows at ground level. In some cases, when exterior luminaires are sited and directed to illuminate the lower portions of perimeter walls and the surrounding grounds, deep shadows are cast on roof areas, thereby encouraging roof attacks. A comparable deficiency results if exterior lighting is used without recognizing that it may interfere with observation of the interior of a facility from the outside. Lighting acts as a deterrent where the interior is clearly visible from the outside. A structure may be properly illuminated on the outside but lack interior lights. In these situations, once inside, intruders can operate with low risk of detection, and the effectiveness of patrol activity is, thereby, reduced. In other situations, it is important not to have lighting that illuminates activities inside a facility because of the possibility of silhouetting or illuminating guard forces. Therefore, despite the fundamental deterrent effect of lighting, the designer has to be alert to improperly designed lighting that may create conditions that encourage attack. To note these conditions, a designer should always visit a facility at night.

1.11.3 Access Routes. In evaluating vulnerability of a particular installation or facility, the designer should note the existence and characteristics of access routes. When routes are numerous, when they afford easy approach and departure, and when they offer flexibility in their selection, the intruder is encouraged. Routes that are equipped with physical barriers; exceptionally circuitous; or broad, open, and free of opportunities for concealment can serve as deterrents to intrusion.

APPENDIX C

COUNTERINTELLIGENCE SECURITY

1.1 Scope. This appendix provides guidelines for designing secure conference rooms and working areas to thwart counterintelligence efforts.

1.1.2 Referenced Documents.

(a) DOD Directive No. S-5200.17 (M-2)

(b) Pamphlet AFP 88-26, Construction of Secure Conference Rooms

1.1.3 Other Publications. ANSI/UL 768-1984, Combination Locks.

Copies can be obtained from the Underwriters Laboratories, Inc., Publications Stock, 333 Pfingsten Road, North Brook, IL 60062.

1.2 Secure Conference Rooms. These areas require special construction and the use of alarm systems. There are both DOD and Service directives or guidelines that address the topic of securing these areas (e.g., DOD Directive No. S-5200-17 (M-2), Appendix E; and USAF Pamphlet AFP 88-26, "Construction of Secure Conference Rooms"). These areas require soundproofing and other measures related to technical security. In addition, ducts, ventilation grills, and other openings require special treatment. The achievement of adequate security for these rooms requires a blend of acoustical, technical, and physical security measures. In general, secure conference rooms must be constructed so that all elements comprising the physical boundaries of the room have a uniformly high audio transmission loss. No utilities, such as telephone or power, or alarm system components should be allowed to serve as a fortuitous probe to electronic or audio signals emanating from within the room. Unauthorized access must be denied at all times, and in no case should classified conference rooms be constructed adjacent to rooms not under U.S. control. In particular, the designer should give special attention to the following.

1.2.1 Doors. Commercially available, sound-attenuating doors should be used. One such door is a double door; that is, two separately hung doors are mounted on a wide door jamb back-to-back with a dead-air space between. Lead sheets may be added to the inner surfaces to increase sound attenuation. Mounting hardware should be carefully selected and installed so that it does not create a sound leakage path from the room.

1.2.2 Door Jambs. Door jambs should be covered with neoprene or equivalent door gasket material. The manner in which the gasket material is installed should take into account future warping of the door and should not interfere with electronic "metal fingers" where these are used to shield the room electronically. Where double doors are used, the inner edge of each door should be fitted with a gasket.

1.2.3 Door Thresholds. Wooden thresholds (rather than metal) should be used and should be fitted with replaceable neoprene stripping to minimize the air gap and sound leakage path at the bottom of the door.

1.2.4 Expansion Joints. Because expansion joints cannot be effectively soundproofed, a secure conference room should not be located where these form part of, or are immediately against, any portion of the room.

1.2.5 Holes, Crevices, Pipes, and Conduits. These and similar openings should be sealed with elastomeric caulking cement or equivalent mortar. All pipes, ducts, and conduits that are not necessary to provide service to the room should be removed, if possible, and rerouted around the room.

1.2.6 Metal Beams and Posts. Where possible, metal beams and posts should be eliminated from a secure conference room. Where it is not possible to have them eliminated, they should be sound proofed in a manner similar to pipes.

1.2.7 Heating System. Electric heating is preferred in a secure conference room. Radiators for hot water or steam should not be used in new designs. If these exist in an area being converted to a secure conference room, acoustic attenuation treatment must be applied to the pipes and to the radiators themselves.

1.2.8 Air Conditioners. Where possible, secure conference rooms should have an independent air conditioning system because of the difficulty of making a master (building) system sufficiently secure.

1.2.9 Air Ducts and Ventilation Grills. Where these exist, considerable effort should be made to ensure that they are acoustically sealed. This can be accomplished by using fiberglass duct sections and canvas decoupling sections installed to cover all ducts immediately inside the room.

1.2.10 Telephones and Alarm Devices. All devices that may be potentially used to convey classified conversations from a secure conference room should be kept to a minimum or preferably not used at all. Line disconnect jacks on outgoing circuits and isolation amplifiers (where applicable) on incoming circuits are effective in rendering such devices secure. Radio frequency filters should be installed if any equipment is located within a secure conference room that may have possible compromising emanations.

1.2.11 Windows. No windows should be designed into new construction. When an existing area is being converted to a secure conference room and windows are already in place, the windows should be completely sealed to provide the same level of sound attenuation provided by the other parts of the room. This can be accomplished by using venetian blinds and heavy, flameproof drapes (11 ounces per square yard or more) to cover each window.

1.2.12 General Construction. Clean, straightforward construction techniques should be used. Where possible, all utility pipe and conduits (for electrical power, alarm system, or telephone) should be run exposed on interior wall or ceiling surfaces to minimize clandestine exploitation and to facilitate periodic inspection.

1.2.13 Locking Devices. Built-in, manipulation proof, three-position, dial-type combination locks with an interior safety release turn knob should be used. Such locking devices should conform to UL Standard No. 768.

1.2.14 Level of Sound Attenuation. The requirements for the level of attenuation vary depending on the classification level of the information to be discussed in the secure room, the level of acoustic noise outside the room, and whether or not normal or amplified speech is to be used in conversation or for presentations. The minimum attenuation should be at least 30 decibels (dB) for normal speech (e.g. normal speech has an acoustic level equal to about 65 dB or average office sound level) and 55 dB for amplified speech where confidential information is involved. For top secret discussions, the attenuation levels must be increased by 15 dB, and for secret by 5 to 10 dB depending on exterior noise. That is, for a top secret area the sound attenuation between the inside and the outside of the room must be 45 dB for normal speech and 70 dB for amplified speech.

1.3 Secure Working Areas. A secure working area is an accredited area that is used for handling, processing, and discussing classified material. Such an area differs from a secure conference room in that it is not intended for discussion of classified information on a continuous basis and is not specifically accredited for all levels of security or need-to-know. Where information of a certain level is to be discussed within a secure working area, the acoustic safeguards required for that level must be implemented (see DOD Directive S-5200.17 (M-2), Appendix E). General guidelines for secure working areas are given below.

1.3.1 Door. Any door that has sufficient strength to withstand being forcefully entered without leaving evidence of such attempt is acceptable. Such a door may be, for example, a vault type or a metal-clad (16-gauge steel) solid wood door (1-3/4-inch minimum), or a solid wood door backed by 11-gauge expanded steel mesh and tempered masonite.

1.3.2 Construction. New construction should be constructed using concrete, brick, or concrete block at least 4 inches thick. Where existing areas are being converted for this purpose, weaker materials must be reinforced with 11-gauge expanded metal or 16-gauge sheet steel.

1.3.3 Windows. Windows should be protected by 9-gauge expanded metal anchored to the building and protected from outside viewing by fine wire mesh or similar material.

APPENDIX D

BLAST RESISTANT GLAZING

1.1 Scope. This appendix presents guidelines for window design in selected structures so that the windows may survive a design blast overpressure load with a probability of failure of one in 1,000. Tables are provided to choose glass thicknesses for fully thermally tempered glass for charge weights between 10 to 4,000 lb (TNT-equivalent) and standoff distances between 10 and 500 feet. Essential frame design procedures are also presented.

Records of explosions near buildings indicate that glass fragments from failed window panes are a major cause of casualties. Not only are the flying shards and fragments an unacceptable and dangerous hazard, but blasted-out glazing also allows injuries due to blast overpressures that subject personnel to high-pressure jetting, overpressure, secondary debris, and thrown body impact.

1.2 Basic Design Guidelines for Glazing. Tables are provided for determining tempered glass thickness for threats of TNT-equivalent design charge weights of 10 to 4,000 pounds at standoff distances ranging between 10 and 500 feet. Dashed entries indicate design pane thickness is impractical (i.e., thicker than 2.5 inches.) The presented glazing designs limit the maximum principal surface tensile stress to less than 16,000 psi which is correlated to a probability of failure less than one per thousand. When bomb fragments are a threat accompanying blast overpressure, polycarbonate should be placed or laminated on the inside surface of the glass as a fragment guard. Since data are not available on the effects of various sizes, velocities, or shapes of fragments, the exact thickness of the polycarbonate required to protect personnel from fragmentation cannot as yet be determined. Tentatively, 1/2-inch-thick polycarbonate material is considered reasonable for such use as a stop gap design until more research can be accomplished. The Naval Civil Engineering Laboratory, Code L51, Port Hueneme, CA 93043 can be contacted to obtain the latest information concerning ongoing efforts in this regard.

1.2.1 Acceptable Materials for Glazing. Acceptable materials for resistance to blast overpressure are monolithic (single pane) thermally tempered glass and laminated thermally tempered glass. The glass shall be thermally tempered either horizontally or in a basket. Glass with tong marks is not be permitted.

1.2.2 Unacceptable Materials for Glazing. While the designs for monolithic tempered glass are based upon a recently completed research and development program and are validated from blast load tests, the design thicknesses for laminated glass are based upon engineering theory only. While reasonable and conservative engineering assumptions were employed, only a much smaller base of validating blast test data exists. Until research on laminated blast resistant glazing is conducted, the presented design thicknesses for laminated glass should be used provisionally to fulfill immediate and pressing security needs. Test data for polycarbonate materials (such as Lexan or Tuffak) are being generated, collected, and evaluated. Polycarbonate materials should be used as primary glazing until sufficient data is evaluated and appropriate design parameters established. All glass must meet the requirements for ANSI Z97.1 certification. Certification by the Safety Glazing Council constitutes compliance with ANSI Z97.1. Unacceptable materials for resistance to blast pressure are:

- o Annealed glass (plate, float, or polished glass)
- o Heat-treated, semi-tempered glass
- o Wire-reinforced glass
- o Chemically tempered glass (monolithic or laminated)
- o Acrylic (such as Plexiglass or Lucite)

1.2.3 Frame Design Considerations. The frame and fasteners must withstand stress induced by the blast loads. Tables and formulas are provided to calculate the loading imparted to the frame by both the glass and the blast directly. Prescribed design limits for frame stress, deflection, bite, and setting material are mandatory. Windows should not be designed for greater blast-loading effects than can be withstood by the adjacent walls and structure. The wall and framing of the structure must provide a load path for the load applied on the structure by glazing and frame. Table D-1 provides the blast loading for each specified charge weight and standoff distance.

1.3 Window Pane Design.

1.3.1 Pane Thickness From Tables. The proper thickness of a particular pane may be obtained from the top section of Tables D-2 or D-3. The treat charge weight and standoff distance must be defined. Glazing facing the explosive charge must be designed for reflected overpressure. Table D-2 reports design glass thicknesses and frame loadings for reflected overpressures. Glazing around the side and back of the structure can be designed for the incident overpressure. Table D-3 reports design glass thicknesses and frame loadings for incident overpressures. If the explosive threat is credible from all directions, all the glazing should be designed for reflected overpressure. Prescribed monolithic (single sheet) tempered glass should be used for all thicknesses under 0.720 inch. Larger prescribed thicknesses are only available as laminated glazing. Because laminated glass does not behave monolithically under all conditions, a static design load adjustment factor of 0.75, consonant with the design of laminated glass for a windload, is used to limit the static strength of the tempered glass. Factors beneficial to blast capacity, such as longer-than-predicted natural periods and the strengthening effects of strain rate upon the Polyvinyl Butyral (PVB) inner layer are neglected to be conservative. All the design tables and figures for glass thicknesses greater than 0.720 inch, where laminated glass is likely to be used, are based upon these assumptions. Both the reflected and incident blast overpressures for the design charge weights and standoff distances are presented in Table D-1. The entire structure is required to be designed to resist this load.

1.3.1.1 Table Utilization. The required thickness for thermally tempered glass may be obtained from the top section of Tables D-2 or D-3 as follows:

(1) Select the proper table based upon the amount of TNT-equivalent charge weight, and whether the blast loading will be reflected (glazing face-on to the blast) or incident (glazing around the side or back of the structure from the blast). Each table is subdivided by the aspect ratio (the ratio of the longer side divided by the shorter side) of the tempered glass pane. Select the proper section in the table according to aspect ratio.

(2) If the threat charge weight is between the presented charge weights, use the next heavier charge weight.

(3) Enter the selected table in the plate dimension row that matches the two dimensions in inches. If the design dimension is not exactly equal to the ones shown on the table, select the row with the closest dimensions that are at least as large as the design dimensions.

(4) Move across the selected row until the column for the desired stand-off distance is reached, and read the required pane thickness in inches. If the chosen standoff distance is not given in the table, use the column for the closest distance that is less than the design distance.

(5) The thickness value arrived at in the preceding step should be rounded up to the next higher glass thickness normally manufactured. This may be done by consulting Table D-4 where both English and Metric nominal thicknesses are presented. The thickness of a laminated window equals the sum of the composite glass layers. PVB thickness is not considered.

All PVB in laminated glazing shall be at least 25 mils (0.025 inch) thick while architectural grade PVB is acceptable, aircraft grade (AG) is recommended.

1.4 Window Frame Design. Computations can be made to determine the line loading on a window frame's long (V_x) and short (V_y) members as well as the applied corner forces (R) (see Figure D-1). The maximum stress for any frame member must be no greater than the static yield stress for the frame of fastener material divided by 1.65 for frame members and 2.00 for frame fasteners. Frame deflections must be limited to 1/264th of the length of the supported glass.

1.4.1 Line Shear Computation. Distribution of normal loads transmitted by a lite to a frame is shown in Figure D-1. Computation of the load at any point can be performed as shown in the following equations.

1.4.1.1 Line Load, V_x. The line load, V_x, applied to the frame along the long side, a, of the pane is equal to:

EQUATION: $$V_x = C_x r_u \, b \sin(\pi x/a) + r_u \, w \text{ (lb/in)} \qquad \text{(D-1)}$$

where

C_x = design coefficient (see Table D-5)

r_u = static frame design load (see bottom section of Table D-2 or D-3)

b = length of the shorter side of the frame

x = distance from the corner along side a

a = length of the longer side of the frame

w = width of the frame face

1.4.1.2 Line Load, V_y. The line load, V_y, applied to the frame along the short side, b, of the pane is equal to:

EQUATION: $$V_y = C_y r_u \, b \sin(\pi y/b) + r_u \, w \text{ (lb/in)} \qquad \text{(D-2)}$$

where

C_y = design coefficient (see Table D-5)

y = distance from the corner along side b

1.4.1.3 Corner Concentrated Load. The corner concentrated load, R, tending to uplift the corners of the window pane is equal to:

EQUATION: $$R = C_R r_u \, b^2 \qquad \text{(D-3)}$$

where

C_R = the design coefficient (see Table D-5). Both the frame and the retaining strips on the frame must resist this load.

To determine the frame design loads, r_u, select the proper table using the same method used for selecting glazing thickness. The chosen value for r_u should correspond exactly to the charge weight, plate dimensions, and standoff distance parameters used to select glass thickness. The bottom section of

Table D-2 of D-3 reports r_u respectively for reflected and incident blast overpressures.

1.4.2 Design Stresses and Deflections for Metal Frame Members and Fasteners. The allowable design stresses are:

o Design stress of any frame member if $f_y/1.65$, where f_y is the static yield stress of the frame material obtained from its catalogued specification.

o Design stress of any fastener is $f_y/2.00$, where f_y is the static yield stress of the fastener material obtained from its catalogued specification.

o Design deflection in the frame is limited to 1/264th of the span of the supported glass.

1.5 Glazing Details.

o All gaskets and beads are required to be continuous and at least 3/8-inch wide; the elastomeric material must exhibit a shore "A" durameter hardness of 50 and conform to ASTM Specification C 509.

o Minimum frame edge clearance, face clearance, and bite (illustrated in Figure D-2) are defined in Table D-6.

o As the blast resistance of glazing is sensitive to glazing details, a strenuous inspection program during window installation is required.

1.6 Acceptance Test Specification for Windows and Frames. The acceptance test specification is required for quality control blast-resistant windows and frames of monolithic (single pane) tempered glass unless analysis demonstrates that the design is consistent with the above design criteria. All windows with mullions must be tested. While research is required to fine tune and validate the acceptance test specification for laminated tempered glass, it is recommended that it be provisionally used as it will insure quality frame and gasket design, and provide a good orientation to the quality and strength of the laminated tempered glass glazing. The acceptance test specification consists of applying uniform static loads on at least two sample window assemblies until failure occurs in either the tempered glass or frame. Although at least two static uniform load tests until sample failure are required, the acceptance criteria encourage a large number of test samples. The number of samples, beyond two, is left up to the vendor. Results from all tests shall be recorded in the calculations. All testing shall be performed by an independent testing laboratory and signed by a registered professional engineer. The test windows (glass panes plus support frames) shall be identical in type, size, sealant, gasket or bead, and construction to those furnished by the window manufacturer. The frame assembly in the test setup shall be secured by conditions that simulate the adjoining walls. The attending professional engineer shall verify and state this in the test report. Using either a vacuum or a liquid-filled bladder, an increasing uniform load shall be applied to the entire window assembly (glass and frame) until failure occurs in either the glass or frame. Failure shall be defined of either breaking of glass or loss of frame resistance. The load should be applied at a rate not to exceed 0.5 r_u per minute. Tables D-2 and D-3 present the static design resistance, r_u, respectively for reflected and incident blast overpressure. To account for variations such as the increased ceramic fatigue from static load and the assumption of old glass for design, the static load capacity of a glass pane for the acceptance test specification, r_s, is:

EQUATION: $$r_s = 0.876\ r_u \qquad \text{(D-4)}$$

1.7 Acceptance Criteria. The window assembly (frame and glazing) is considered acceptable when the arithmetic mean of all the samples tested, $\bar{r}$, is such that:

EQUATION: $$\bar{r} \geq r_s + s\ \alpha \qquad \text{(D-5)}$$

where

r_s = static load capacity of the glass pane for certification testing

s = sample standard deviation

α = acceptance coefficient (defined in Table D-3)

For n test samples, $\bar{r}$ is defined as:

EQUATION: $$\bar{r} = \frac{\sum_{i=1}^{n} \hat{r}_i}{n} \qquad \text{(D-6)}$$

where

$\hat{r}_i$ = the recorded failure load of the i^{th} test sample. The sample standard deviation, s, is defined as:

EQUATION: $$s = \sqrt{\frac{\sum_{i=1}^{n} (\hat{r}_i - \bar{r})^2}{(n-1)}} \qquad \text{(D-7)}$$

the minimum value of the sample standard deviation, s, permitted to be employed in Equation D-5 is:

EQUATION: $$s_{min} = 0.145\ r_s \qquad \text{(D-8)}$$

This assures a sample standard deviation no better than observed for the general population of tempered glass. The acceptance coefficient, α, is tabulated in Table D-9 for the number of samples, n, tested. The following equation is presented to aid the tester in determining if additional test samples are justified. If:

EQUATION: $$\bar{r} \leq r_s + s\,\beta \qquad \text{(D-9)}$$

then with 90% confidence, the design will not prove to be adequate with additional testing. The rejection coefficient, β, is obtained from the third column of Table D-7.

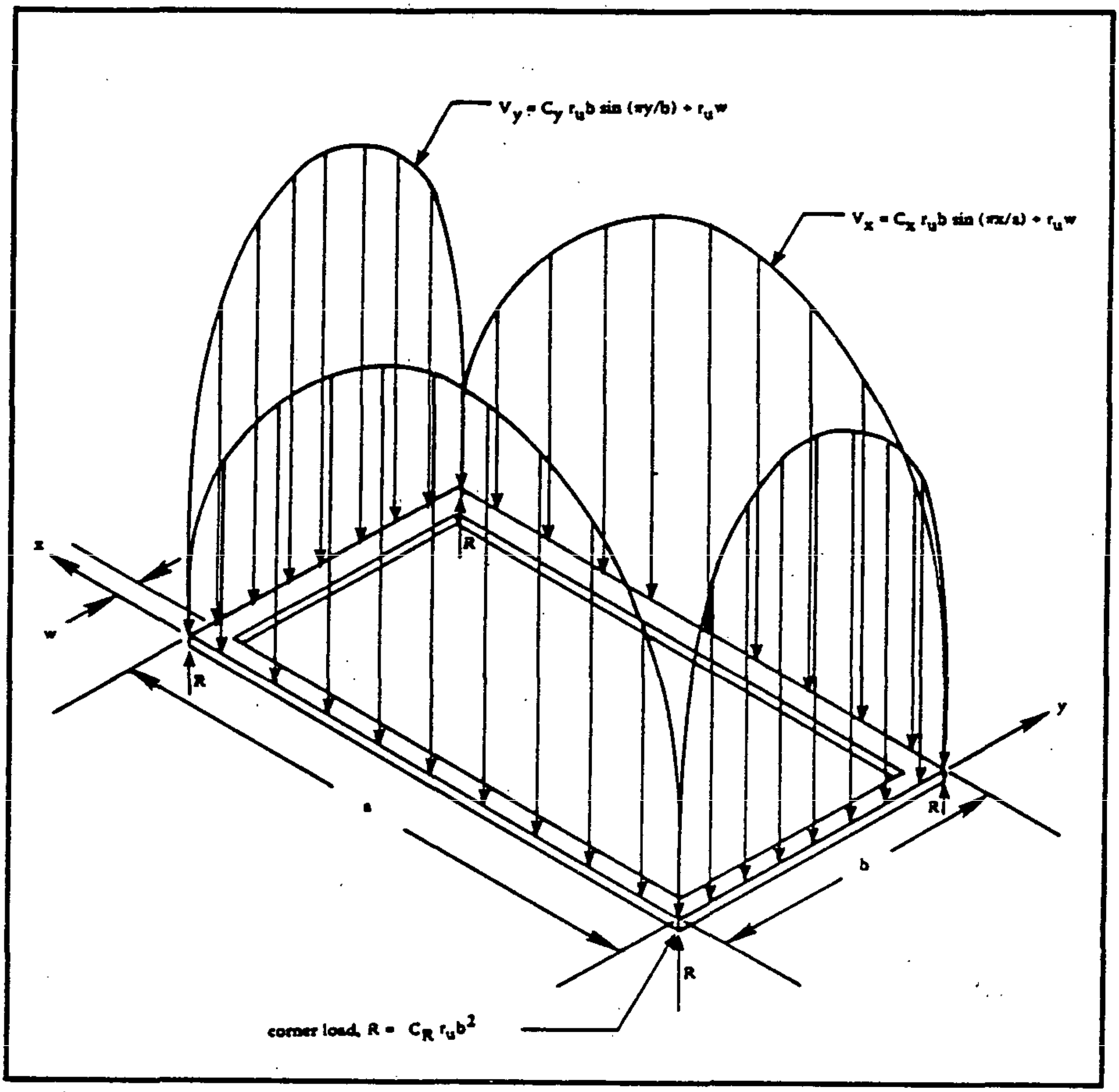


Figure D-1. Distribution of lateral load transmitted by glass pane to the window frame.

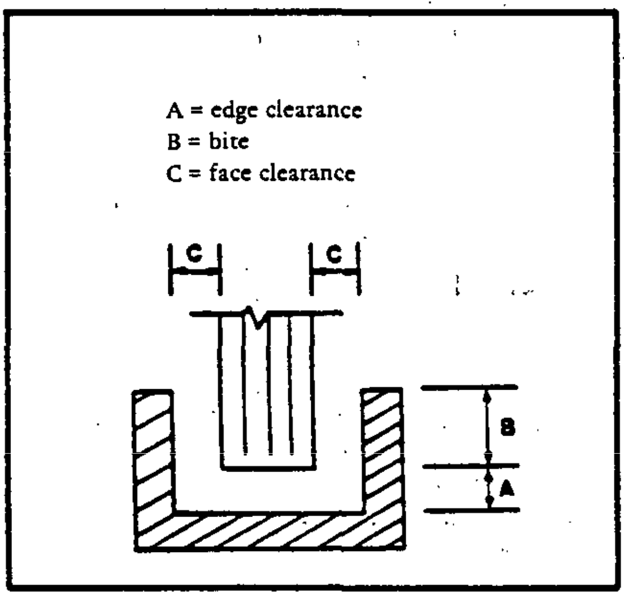


Figure D-2. Edge, face, and bite requirements.

Table D-1. **Pressures and Durations of Specified Bomb Threats**

Charge Weight, W = 4,000 lbs (TNT Equivalency)				
Stand-off Distance	Reflected Pressure		Incident Pressure	
	Peak Pressure	Duration	Peak Pressure	Duration
R (ft)	P_r (psi)	T_r (msec)	P_o (psi)	T_o (msec)
50	646	3.6	122	6.3
75	173	8.0	48.2	10.1
100	74.0	13.3	23.8	16.0
125	42.5	17.8	15.1	20.7
150	27.0	22.6	10.5	25.4
200	14.6	30.3	6.3	32.9
300	7.1	40.3	3.2	44.9
500	3.4	49.6	1.6	54.9

Charge Weight, W = 1,000 lbs (TNT Equivalency)				
Stand-off Distance	Reflected Pressure		Incident Pressure	
	Peak Pressure	Duration	Peak Pressure	Duration
R (ft)	P_r (psi)	T_r (msec)	P_o (psi)	T_o (msec)
50	140	5.7	41.5	6.9
75	48	10.5	16.7	12.3
100	23.4	15.3	9.4	17.0
125	14.9	18.8	6.4	20.5
150	10.3	22.3	4.7	23.8
200	6.4	26.5	3.0	28.6
300	3.7	30.2	1.7	34.1
500	1.7	37.6	0.80	43.7

Table D-1. (continued)

Charge Weight, W = 300 lbs (TNT Equivalency)				
Stand-off Distance	Reflected Pressure		Incident Pressure	
	Peak Pressure	Duration	Peak Pressure	Duration
R (ft)	P_r (psi)	T_r (msec)	P_o (psi)	T_o (msec)
25	391.5	2.0	86.3	3.1
50	49.5	7.0	16.9	8.1
75	18.6	11.4	7.74	12.5
100	10.4	14.9	4.73	15.9
125	7.25	16.8	3.33	18.4
150	5.55	18.2	2.57	20.0
200	3.72	20.2	1.75	22.2
300	2.04	23.7	1.00	26.2
500	1.06	27.3	0.53	30.7

Charge Weight, W = 100 lbs (TNT Equivalency)				
Stand-off Distance	Reflected Pressure		Incident Pressure	
	Peak Pressure	Duration	Peak Pressure	Duration
R (ft)	P_r (psi)	T_r (msec)	P_o (psi)	T_o (msec)
25	114	3.0	34.7	3.6
50	20.2	7.6	8.30	8.4
75	9.14	10.8	4.20	11.6
100	5.86	12.4	2.71	13.7
125	4.29	13.5	2.02	14.8
150	3.30	14.5	1.56	16.0
200	2.16	16.2	1.05	18.0
300	1.27	18.1	0.64	20.2

Table D-1. (continued)

Charge Weight, W = 30 lbs (TNT Equivalency)				
Stand-off Distance	Reflected Pressure		Incident Pressure	
	Peak Pressure	Duration	Peak Pressure	Duration
R (ft)	P_r (psi)	T_r (msec)	P_o (psi)	T_o (msec)
10	606	0.70	117	1.2
25	40.3	3.50	14.6	4.1
50	9.20	7.20	4.21	7.7
75	5.00	8.70	2.33	9.5
100	3.32	9.70	1.57	10.7
125	2.38	10.6	1.14	11.9
150	1.83	11.2	0.92	12.2
200	1.27	12.2	0.64	13.5

Charge Weight, W = 10 lbs (TNT Equivalency)				
Stand-off Distance	Reflected Pressure		Incident Pressure	
	Peak Pressure	Duration	Peak Pressure	Duration
R (ft)	P_r (psi)	T_r (msec)	P_o (psi)	T_o (msec)
10	185	1.0	50.5	1.30
25	17.4	3.70	7.28	4.10
50	5.30	5.90	2.46	6.50
75	2.95	6.90	1.40	7.70
100	1.94	7.70	0.96	8.40
125	1.45	8.20	0.73	9.00
150	1.15	8.60	0.58	9.70
200	0.81	9.40	0.40	10.4

Table D-2.a.1. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 4,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.00**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	2.047	1.084	0.610	0.511	0.368	0.271	0.187	0.115
14.000	14.000	2.382	1.261	0.701	0.596	0.424	0.312	0.214	0.134
16.000	16.000	-----	1.438	0.923	0.671	0.483	0.356	0.244	0.153
18.000	18.000	-----	1.614	1.036	0.870	0.543	0.399	0.274	0.171
20.000	20.000	-----	1.789	1.149	0.965	0.602	0.442	0.304	0.190
22.000	22.000	-----	1.962	1.261	1.060	0.660	0.485	0.333	0.208
24.000	24.000	-----	2.135	1.372	1.154	0.829	0.528	0.362	0.226
26.000	26.000	-----	2.307	1.482	1.247	0.896	0.570	0.391	0.245
28.000	28.000	-----	2.479	1.593	1.340	0.963	0.612	0.419	0.263
30.000	30.000	-----	-----	1.703	1.433	1.030	0.654	0.448	0.280
32.000	32.000	-----	-----	1.811	1.525	1.096	0.696	0.475	0.297
34.000	34.000	-----	-----	1.915	1.617	1.159	0.852	0.502	0.314
36.000	36.000	-----	-----	2.019	1.708	1.222	0.898	0.528	0.332
38.000	38.000	-----	-----	2.123	1.795	1.285	0.944	0.554	0.349
40.000	40.000	-----	-----	2.225	1.882	1.347	0.990	0.580	0.365
42.000	42.000	-----	-----	2.328	1.969	1.409	1.036	0.606	0.382
44.000	44.000	-----	-----	2.430	2.055	1.471	1.081	0.632	0.399
46.000	46.000	-----	-----	-----	2.141	1.532	1.126	0.657	0.417
48.000	48.000	-----	-----	-----	2.227	1.593	1.171	0.684	0.434
50.000	50.000	-----	-----	-----	2.312	1.656	1.217	0.841	0.452
52.000	52.000	-----	-----	-----	2.397	1.720	1.264	0.874	0.469
54.000	54.000	-----	-----	-----	2.482	1.784	1.311	0.906	0.486
56.000	56.000	-----	-----	-----	-----	1.848	1.358	0.938	0.504
58.000	58.000	-----	-----	-----	-----	1.911	1.405	0.971	0.521
60.000	60.000	-----	-----	-----	-----	1.975	1.452	1.003	0.538

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	1671.06	468.61	148.39	104.14	54.01	29.29	15.35	8.61
14.000	14.000	1662.43	465.90	143.98	104.08	52.67	28.52	14.85	8.59
16.000	16.000	----	463.87	191.11	101.00	52.33	28.43	14.79	8.58
18.000	18.000	----	461.72	190.24	134.16	52.26	28.22	14.74	8.48
20.000	20.000	----	459.49	189.54	133.69	52.03	28.07	14.71	8.48
22.000	22.000	----	456.74	188.67	133.32	51.68	27.95	14.63	8.41
24.000	24.000	----	454.45	187.67	132.77	51.39	27.86	14.58	8.36
26.000	26.000	----	452.13	186.58	132.10	68.20	27.69	14.54	8.37
28.000	28.000	----	450.15	185.88	131.53	67.93	27.54	14.48	8.32
30.000	30.000	----	----	185.06	131.03	67.69	27.42	14.45	8.23
32.000	32.000	----	----	183.93	130.42	67.37	27.31	14.38	8.15
34.000	34.000	----	----	182.18	129.89	66.73	36.06	14.31	8.08
36.000	36.000	----	----	180.63	129.27	66.17	35.73	14.23	8.06
38.000	38.000	----	----	179.25	128.14	65.67	35.44	14.15	8.00
40.000	40.000	----	----	177.69	127.13	65.12	35.18	14.09	7.91
42.000	42.000	----	----	176.43	126.21	64.63	34.94	14.03	7.87
44.000	44.000	----	----	175.16	125.27	64.19	34.66	13.97	7.83
46.000	46.000	----	----	----	124.40	63.70	34.41	13.90	7.82
48.000	48.000	----	----	----	123.62	63.25	34.18	13.87	7.79
50.000	50.000	----	----	----	122.79	62.99	34.02	13.14	7.79
52.000	52.000	----	----	----	122.02	62.83	33.93	17.50	7.76
54.000	54.000	----	----	----	121.32	62.68	33.85	17.44	7.73
56.000	56.000	----	----	----	----	62.54	33.77	17.39	7.73
58.000	58.000	----	----	----	----	62.34	33.70	17.38	7.71
60.000	60.000	----	----	----	----	62.22	33.63	17.33	7.69

Table D-2.a.2. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 4,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.25

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	2.367	1.253	0.706	0.592	0.426	0.314	0.204	0.124
14.000	17.500	-----	1.458	0.936	0.681	0.490	0.360	0.237	0.144
16.000	20.000	-----	1.662	1.067	0.896	0.559	0.411	0.270	0.165
18.000	22.500	-----	1.866	1.198	1.006	0.627	0.461	0.303	0.184
20.000	25.000	-----	2.067	1.328	1.116	0.695	0.511	0.335	0.204
22.000	27.500	-----	2.267	1.456	1.225	0.881	0.561	0.366	0.224
24.000	30.000	-----	2.466	1.585	1.333	0.958	0.610	0.398	0.244
26.000	32.500	-----	-----	1.713	1.441	1.035	0.659	0.431	0.263
28.000	35.000	-----	-----	1.840	1.548	1.113	0.708	0.465	0.282
30.000	37.500	-----	-----	1.966	1.655	1.190	0.874	0.498	0.300
32.000	40.000	-----	-----	2.087	1.762	1.263	0.928	0.531	0.319
34.000	42.500	-----	-----	2.207	1.866	1.336	0.982	0.564	0.337
36.000	45.000	-----	-----	2.327	1.968	1.408	1.035	0.597	0.355
38.000	47.500	-----	-----	2.446	2.068	1.480	1.088	0.630	0.374
40.000	50.000	-----	-----	-----	2.169	1.552	1.140	0.663	0.393
42.000	52.500	-----	-----	-----	-----	1.839	1.351	0.912	0.468
50.000	62.500	-----	-----	-----	-----	1.913	1.406	0.949	0.487
52.000	65.000	-----	-----	-----	-----	1.987	1.460	0.985	0.506

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	1668.17	467.46	148.41	104.35	54.03	29.36	13.65	8.54
14.000	17.500	----	465.01	191.65	101.45	52.52	28.35	13.58	8.46
16.000	20.000	----	462.63	190.68	134.46	52.33	28.29	13.53	8.51
18.000	22.500	----	460.77	189.92	133.92	52.02	28.12	13.48	8.36
20.000	25.000	----	457.96	189.04	133.50	51.77	27.99	13.40	8.33
22.000	27.500	----	455.26	187.80	132.93	68.76	27.88	13.28	8.30
24.000	30.000	----	452.66	187.00	132.26	68.31	27.70	13.23	8.28
26.000	32.500	----	----	186.11	131.70	67.94	27.54	13.22	8.20
28.000	35.000	----	----	185.15	131.05	67.75	27.41	13.25	8.13
30.000	37.500	----	----	184.13	130.48	67.46	36.39	13.24	8.02
32.000	40.000	----	----	182.37	129.99	66.79	36.06	13.24	7.97
34.000	42.500	----	----	180.66	129.14	66.20	35.77	13.23	7.88
36.000	45.000	----	----	179.14	128.13	65.59	35.44	13.23	7.81
38.000	47.500	----	----	177.64	126.98	65.04	35.15	13.22	7.78
40.000	50.000	----	----	----	126.07	64.55	34.83	13.22	7.75
42.000	52.500	----	----	----	125.13	64.02	34.59	13.24	7.73
44.000	55.000	----	----	----	124.18	63.55	34.33	12.23	7.71
46.000	57.500	----	----	----	123.32	63.12	34.09	16.27	7.66
48.000	60.000	----	----	----	----	62.93	33.97	16.21	7.64
50.000	62.500	----	----	----	----	62.76	33.90	16.19	7.62
52.000	65.000	----	----	----	----	62.60	33.80	16.13	7.61

Table D-2.a.3. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 4,000 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.50**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	-----	1.402	0.900	0.662	0.471	0.347	0.240	0.155
14.000	21.000	-----	1.631	1.047	0.879	0.548	0.403	0.279	0.180
16.000	24.000	-----	1.859	1.194	1.003	0.625	0.460	0.318	0.204
18.000	27.000	-----	2.086	1.340	1.126	0.702	0.516	0.357	0.227
20.000	30.000	-----	2.311	1.484	1.248	0.898	0.572	0.395	0.251
22.000	33.000	-----	-----	1.628	1.370	0.984	0.627	0.432	0.274
24.000	36.000	-----	-----	1.772	1.490	1.071	0.682	0.470	0.265
26.000	39.000	-----	-----	1.915	1.611	1.158	0.851	0.508	0.284
28.000	42.000	-----	-----	2.057	1.731	1.244	0.914	0.543	0.303
30.000	45.000	-----	-----	2.194	1.850	1.328	0.976	0.578	0.321
32.000	48.000	-----	-----	2.329	1.969	1.410	1.036	0.612	0.339
34.000	51.000	-----	-----	2.463	2.083	1.491	1.095	0.646	0.357
36.000	54.000	-----	-----	-----	2.196	1.571	1.154	0.680	0.377
38.000	57.000	-----	-----	-----	2.308	1.652	1.213	0.835	0.396
40.000	60.000	-----	-----	-----	2.420	1.732	1.272	0.875	0.416
42.000	63.000	-----	-----	-----	-----	1.811	1.330	0.917	0.436
44.000	66.000	-----	-----	-----	-----	1.890	1.389	0.959	0.456
46.000	69.000	-----	-----	-----	-----	1.972	1.450	1.001	0.476
48.000	72.000	-----	-----	-----	-----	2.055	1.511	1.044	0.496

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	----	466.93	192.41	104.10	52.70	28.60	13.68	7.69
14.000	21.000	----	464.27	191.32	134.85	52.41	28.34	13.59	7.68
16.000	24.000	----	461.78	190.50	134.42	52.20	28.27	13.51	7.65
18.000	27.000	----	459.41	189.57	133.86	52.03	28.11	13.46	7.61
20.000	30.000	----	456.72	188.33	133.19	68.96	27.98	13.35	7.60
22.000	33.000	----	----	187.32	132.65	68.43	27.78	13.23	7.57
24.000	36.000	----	----	186.48	131.85	68.12	27.62	13.18	7.81
26.000	39.000	----	----	185.57	131.33	67.86	36.65	13.13	7.77
28.000	42.000	----	----	184.62	130.74	67.52	36.45	12.99	7.74
30.000	45.000	----	----	182.96	130.08	67.03	36.21	12.86	7.70
32.000	48.000	----	----	181.20	129.51	66.41	35.85	12.72	7.67
34.000	51.000	----	----	179.51	128.39	65.78	35.48	12.59	7.64
36.000	54.000	----	----	----	127.28	65.14	35.15	12.48	7.63
38.000	57.000	----	----	----	126.19	64.65	34.86	12.39	7.62
40.000	60.000	----	----	----	125.21	64.13	34.59	16.37	7.61
42.000	63.000	----	----	----	----	63.60	34.30	16.31	7.60
44.000	66.000	----	----	----	----	63.12	34.09	16.25	7.59
46.000	69.000	----	----	----	----	62.87	33.99	16.20	7.57
48.000	72.000	----	----	----	----	62.70	33.90	16.18	7.55

Table D-2.a.4. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 4,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.75**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	-----	1.489	0.956	0.704	0.500	0.368	0.255	0.171
14.000	24.500	-----	1.732	1.112	0.934	0.582	0.428	0.296	0.199
16.000	28.000	-----	1.975	1.268	1.065	0.664	0.488	0.338	0.226
18.000	31.500	-----	2.215	1.423	1.196	0.860	0.548	0.379	0.253
20.000	35.000	-----	2.454	1.576	1.326	0.953	0.607	0.419	0.280
22.000	38.500	-----	-----	1.729	1.454	1.045	0.666	0.460	0.307
24.000	42.000	-----	-----	1.881	1.583	1.137	0.836	0.500	0.332
26.000	45.500	-----	-----	2.033	1.710	1.229	0.904	0.540	0.357
28.000	49.000	-----	-----	2.183	1.838	1.321	0.971	0.579	0.381
30.000	52.500	-----	-----	2.327	1.965	1.408	1.035	0.617	0.405
32.000	56.000	-----	-----	2.470	2.088	1.495	1.098	0.655	0.429
34.000	59.500	-----	-----	-----	2.209	1.581	1.161	0.692	0.454
36.000	63.000	-----	-----	-----	2.328	1.666	1.224	0.842	0.479
38.000	66.500	-----	-----	-----	2.448	1.752	1.287	0.885	0.505
40.000	70.000	-----	-----	-----	-----	1.836	1.349	0.929	0.530
42.000	73.500	-----	-----	-----	-----	1.921	1.411	0.974	0.555
44.000	77.000	-----	-----	-----	-----	2.006	1.475	1.019	0.581

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	----	466.31	192.22	104.24	52.58	28.48	13.68	7.13
14.000	24.500	----	463.54	191.07	134.80	52.34	28.31	13.54	7.11
16.000	28.000	----	461.47	190.21	134.19	52.16	28.17	13.52	7.07
18.000	31.500	----	458.61	189.28	133.71	69.13	28.07	13.43	7.03
20.000	35.000	----	455.97	188.06	133.13	68.77	27.90	13.29	7.00
22.000	38.500	----	----	187.06	132.29	68.33	27.76	13.24	6.97
24.000	42.000	----	----	186.04	131.76	67.97	27.56	13.15	6.91
26.000	45.500	----	----	185.17	131.01	67.67	36.61	13.06	6.85
28.000	49.000	----	----	184.09	130.50	67.41	36.42	12.95	6.79
30.000	52.500	----	----	182.22	129.94	66.71	36.05	12.81	6.73
32.000	56.000	----	----	180.44	128.95	66.10	35.66	12.69	6.68
34.000	59.500	----	----	----	127.84	65.49	35.31	12.55	6.65
36.000	63.000	----	----	----	126.65	64.86	35.01	12.43	6.62
38.000	66.500	----	----	----	125.69	64.38	34.74	16.43	6.61
40.000	70.000	----	----	----	----	63.81	34.45	16.34	6.58
42.000	73.500	----	----	----	----	63.36	34.18	16.29	6.56
44.000	77.000	----	----	----	----	62.95	34.03	16.24	6.56

Table D-2.a.5. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 4,000 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 2.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	-----	1.571	1.009	0.858	0.528	0.388	0.269	0.182
14.000	28.000	-----	1.828	1.174	0.986	0.614	0.452	0.313	0.211
16.000	32.000	-----	2.084	1.338	1.124	0.701	0.515	0.356	0.240
18.000	36.000	-----	2.337	1.501	1.262	0.908	0.578	0.399	0.268
20.000	40.000	-----	-----	1.663	1.399	1.005	0.640	0.442	0.296
22.000	44.000	-----	-----	1.824	1.534	1.103	0.702	0.485	0.323
24.000	48.000	-----	-----	1.985	1.669	1.200	0.882	0.528	0.349
26.000	52.000	-----	-----	2.145	1.804	1.297	0.953	0.569	0.374
28.000	56.000	-----	-----	2.300	1.939	1.392	1.023	0.610	0.398
30.000	60.000	-----	-----	2.452	2.073	1.484	1.090	0.650	0.423
32.000	64.000	-----	-----	-----	2.201	1.575	1.157	0.690	0.447
34.000	68.000	-----	-----	-----	2.327	1.666	1.224	0.842	0.474
36.000	72.000	-----	-----	-----	2.453	1.756	1.290	0.887	0.500
38.000	76.000	-----	-----	-----	-----	1.845	1.356	0.933	0.526
40.000	80.000	-----	-----	-----	-----	1.935	1.421	0.980	0.552
42.000	84.000	-----	-----	-----	-----	2.023	1.487	1.027	0.578

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	----	465.70	192.10	138.91	52.60	28.41	13.65	6.59
14.000	28.000	----	463.25	191.07	134.78	52.26	28.32	13.58	6.54
16.000	32.000	----	460.97	190.02	134.09	52.16	28.15	13.45	6.50
18.000	36.000	----	458.02	188.94	133.56	69.14	28.02	13.35	6.44
20.000	40.000	----	----	187.86	132.95	68.61	27.82	13.27	6.39
22.000	44.000	----	----	186.78	132.11	68.30	27.67	13.21	6.33
24.000	48.000	----	----	185.87	131.40	67.93	36.70	13.15	6.26
26.000	52.000	----	----	184.94	130.81	67.62	36.51	13.01	6.17
28.000	56.000	----	----	183.34	130.30	67.16	36.27	12.90	6.08
30.000	60.000	----	----	181.52	129.74	66.49	35.87	12.76	6.03
32.000	64.000	----	----	----	128.55	65.82	35.52	12.63	5.96
34.000	68.000	----	----	----	127.28	65.24	35.21	12.50	5.94
36.000	72.000	----	----	----	126.16	64.65	34.89	16.50	5.91
38.000	76.000	----	----	----	----	64.05	34.60	16.38	5.89
40.000	80.000	----	----	----	----	63.59	34.29	16.31	5.87
42.000	84.000	----	----	----	----	63.04	34.06	16.25	5.85

Table D-2.a.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 4,000 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 3.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	-----	1.719	1.103	0.927	0.578	0.425	0.294	0.204
14.000	42.000	-----	2.000	1.284	1.078	0.672	0.494	0.342	0.237
16.000	48.000	-----	2.277	1.463	1.230	0.884	0.563	0.389	0.270
18.000	54.000	-----	-----	1.640	1.379	0.992	0.631	0.436	0.303
20.000	60.000	-----	-----	1.816	1.528	1.098	0.699	0.483	0.334
22.000	66.000	-----	-----	1.992	1.676	1.205	0.886	0.530	0.365
24.000	72.000	-----	-----	2.166	1.824	1.311	0.963	0.574	0.396
26.000	78.000	-----	-----	2.333	1.971	1.412	1.037	0.618	0.426
28.000	84.000	-----	-----	2.498	2.112	1.512	1.111	0.662	0.456
30.000	90.000	-----	-----	-----	2.251	1.611	1.184	0.705	0.487
32.000	96.000	-----	-----	-----	2.390	1.710	1.256	0.864	0.518
34.000	102.000	-----	-----	-----	-----	1.808	1.328	0.914	0.549

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	----	463.78	190.95	134.87	52.43	28.35	13.57	6.53
14.000	42.000	----	461.24	190.11	134.00	52.07	28.14	13.49	6.48
16.000	48.000	----	457.73	188.96	133.56	68.99	27.98	13.36	6.44
18.000	54.000	----	----	187.61	132.65	68.64	27.77	13.26	6.40
20.000	60.000	----	----	186.33	131.92	68.12	27.61	13.18	6.30
22.000	66.000	----	----	185.29	131.17	67.80	36.66	13.12	6.22
24.000	72.000	----	----	184.08	130.54	67.44	36.39	12.93	6.15
26.000	78.000	----	----	181.97	129.88	66.66	35.95	12.77	6.07
28.000	84.000	----	----	179.88	128.59	65.90	35.58	12.63	5.99
30.000	90.000	----	----	----	127.24	65.17	35.20	12.48	5.96
32.000	96.000	----	----	----	126.07	64.54	34.82	16.48	5.92
34.000	102.000	----	----	----	----	63.91	34.48	16.33	5.89

Table D-2.a.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 4,000 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	-----	1.777	1.141	0.958	0.597	0.439	0.304	0.211
14.000	56.000	-----	2.066	1.327	1.115	0.695	0.511	0.353	0.245
16.000	64.000	-----	2.352	1.511	1.271	0.913	0.582	0.402	0.279
18.000	72.000	-----	-----	1.694	1.425	1.024	0.652	0.451	0.312
20.000	80.000	-----	-----	1.876	1.578	1.134	0.834	0.499	0.344
22.000	88.000	-----	-----	2.057	1.731	1.244	0.915	0.545	0.376
24.000	96.000	-----	-----	2.229	1.883	1.349	0.991	0.591	0.407
26.000	104.000	-----	-----	2.400	2.030	1.453	1.067	0.636	0.438
28.000	112.000	-----	-----	-----	2.174	1.556	1.143	0.681	0.470
30.000	120.000	-----	-----	-----	2.317	1.658	1.218	0.838	0.503

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	----	462.52	190.69	134.43	52.20	28.23	13.54	6.52
14.000	56.000	----	459.33	189.50	133.79	51.98	28.10	13.41	6.46
16.000	64.000	----	455.78	188.11	133.10	68.68	27.91	13.31	6.41
18.000	72.000	----	----	186.81	132.19	68.26	27.67	13.24	6.34
20.000	80.000	----	----	185.58	131.30	67.81	27.51	13.13	6.24
22.000	88.000	----	----	184.39	130.58	67.44	36.49	12.94	6.16
24.000	96.000	----	----	181.94	129.84	66.64	35.96	12.79	6.07
26.000	104.000	----	----	179.72	128.58	65.87	35.52	12.62	5.99
28.000	112.000	----	----	----	127.15	65.14	35.15	12.48	5.94
30.000	120.000	----	----	----	125.81	64.42	34.77	12.34	5.93

Table D-2.b.1. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 1,000 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	0.948	0.482	0.337	0.269	0.223	0.172	0.119	0.100
14.000	14.000	1.101	0.560	0.391	0.312	0.260	0.200	0.138	0.100
16.000	16.000	1.253	0.637	0.445	0.355	0.296	0.227	0.157	0.104
18.000	18.000	1.405	0.825	0.499	0.398	0.332	0.254	0.176	0.116
20.000	20.000	1.550	0.913	0.553	0.441	0.368	0.280	0.194	0.128
22.000	22.000	1.693	0.997	0.604	0.481	0.401	0.304	0.212	0.140
24.000	24.000	1.834	1.080	0.654	0.521	0.435	0.329	0.229	0.151
26.000	26.000	1.974	1.163	0.704	0.560	0.468	0.353	0.247	0.163
28.000	28.000	2.114	1.245	0.871	0.599	0.501	0.376	0.265	0.174
30.000	30.000	2.259	1.327	0.928	0.637	0.534	0.401	0.283	0.186
32.000	32.000	2.404	1.411	0.986	0.677	0.568	0.426	0.301	0.198
34.000	34.000	-----	1.497	1.046	0.834	0.602	0.451	0.320	0.210
36.000	36.000	-----	1.582	1.105	0.882	0.636	0.476	0.338	0.222
38.000	38.000	-----	1.667	1.165	0.929	0.670	0.502	0.356	0.234
40.000	40.000	-----	1.751	1.224	0.976	0.704	0.527	0.374	0.246
42.000	42.000	-----	1.836	1.283	1.023	0.839	0.552	0.392	0.258
44.000	44.000	-----	1.921	1.342	1.070	0.877	0.576	0.409	0.269
46.000	46.000	-----	2.005	1.401	1.117	0.915	0.601	0.426	0.280
48.000	48.000	-----	2.088	1.460	1.164	0.953	0.622	0.442	0.291
50.000	50.000	-----	2.165	1.515	1.207	0.988	0.644	0.459	0.301
52.000	52.000	-----	2.242	1.569	1.250	1.022	0.664	0.475	0.312
54.000	54.000	-----	2.319	1.622	1.293	1.056	0.685	0.491	0.323
56.000	56.000	-----	2.395	1.676	1.336	1.090	0.698	0.508	0.333
58.000	58.000	-----	2.471	1.729	1.378	1.124	0.704	0.524	0.344
60.000	60.000	-----	-----	1.782	1.420	1.158	0.708	0.540	0.354

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	358.40	92.65	45.29	28.86	20.81	13.94	9.14	6.89
14.000	14.000	355.17	91.88	44.79	28.52	20.79	13.90	9.04	5.32
16.000	16.000	352.19	91.02	44.42	28.27	20.65	13.82	8.97	4.52
18.000	18.000	349.89	90.48	44.13	28.10	20.54	13.76	8.92	4.46
20.000	20.000	344.92	119.67	43.90	27.96	20.46	13.66	8.80	4.40
22.000	22.000	340.08	117.94	43.29	27.56	20.13	13.51	8.70	4.36
24.000	24.000	335.35	116.29	42.64	27.22	19.93	13.41	8.55	4.27
26.000	26.000	331.03	114.90	42.10	26.85	19.70	13.30	8.48	4.25
28.000	28.000	327.35	113.54	55.57	26.54	19.49	13.17	8.43	4.19
30.000	30.000	325.62	112.36	54.95	26.20	19.32	13.12	8.38	4.17
32.000	32.000	324.10	111.65	54.52	26.04	19.23	13.07	8.34	4.15
34.000	34.000	----	111.33	54.35	25.92	19.14	13.03	8.35	4.14
36.000	36.000	----	110.90	54.10	34.47	19.07	12.99	8.31	4.13
38.000	38.000	----	110.52	53.98	34.32	19.00	12.98	8.28	4.12
40.000	40.000	----	110.04	53.77	34.19	18.95	12.95	8.25	4.11
42.000	42.000	----	109.74	53.59	34.07	17.68	12.93	8.23	4.10
44.000	44.000	----	109.46	53.42	33.96	23.49	12.88	8.17	4.07
46.000	46.000	----	109.10	53.27	33.86	23.41	12.86	8.12	4.04
48.000	48.000	----	108.67	53.13	33.77	23.33	12.77	8.04	4.02
50.000	50.000	----	107.67	52.72	33.47	23.14	12.70	8.00	3.97
52.000	52.000	----	106.75	52.28	33.18	22.93	12.60	7.93	3.95
54.000	54.000	----	105.91	51.81	32.93	22.73	12.53	7.87	3.93
56.000	56.000	----	105.04	51.44	32.69	22.54	12.50	7.83	3.89
58.000	58.000	----	104.23	51.03	32.42	22.37	12.55	7.78	3.87
60.000	60.000	----	----	50.66	32.17	22.22	12.61	7.73	3.84

Table D-2.b.2. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 1,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.25**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	1.095	0.557	0.389	0.310	0.257	0.199	0.128	0.100
14.000	17.500	1.272	0.647	0.452	0.360	0.298	0.233	0.148	0.101
16.000	20.000	1.448	0.850	0.514	0.410	0.339	0.265	0.169	0.114
18.000	22.500	1.621	0.953	0.577	0.460	0.380	0.296	0.188	0.127
20.000	25.000	1.786	1.052	0.637	0.508	0.419	0.326	0.207	0.140
22.000	27.500	1.950	1.149	0.696	0.555	0.457	0.355	0.227	0.153
24.000	30.000	2.113	1.245	0.871	0.601	0.494	0.384	0.246	0.166
26.000	32.500	2.275	1.340	0.937	0.647	0.531	0.413	0.266	0.179
28.000	35.000	2.441	1.435	1.003	0.692	0.568	0.442	0.285	0.192
30.000	37.500	-----	1.532	1.070	0.854	0.607	0.472	0.305	0.205
32.000	40.000	-----	1.630	1.139	0.909	0.646	0.502	0.325	0.218
34.000	42.500	-----	1.729	1.208	0.963	0.684	0.532	0.344	0.232
36.000	45.000	-----	1.827	1.277	1.018	0.846	0.562	0.364	0.245
38.000	47.500	-----	1.925	1.345	1.073	0.892	0.592	0.383	0.257
40.000	50.000	-----	2.023	1.414	1.127	0.937	0.622	0.401	0.269
42.000	52.500	-----	2.121	1.482	1.182	0.982	0.652	0.419	0.281
44.000	55.000	-----	2.219	1.550	1.236	1.027	0.679	0.437	0.293
46.000	57.500	-----	2.312	1.617	1.288	1.069	0.706	0.455	0.304
48.000	60.000	-----	2.402	1.680	1.338	1.111	0.836	0.472	0.316
50.000	62.500	-----	2.491	1.742	1.387	1.152	0.866	0.490	0.327
52.000	65.000	-----	-----	1.804	1.437	1.193	0.894	0.507	0.339

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	357.00	92.37	45.06	28.61	19.85	13.23	9.07	5.72
14.000	17.500	353.94	91.57	44.69	28.35	19.64	13.29	8.92	4.45
16.000	20.000	351.16	90.75	44.25	28.15	19.48	13.21	8.91	4.37
18.000	22.500	347.72	120.18	44.06	28.00	19.36	13.08	8.72	4.30
20.000	25.000	341.91	118.63	43.49	27.66	19.11	12.94	8.57	4.24
22.000	27.500	336.85	116.95	42.91	27.29	18.83	12.77	8.52	4.20
24.000	30.000	332.34	115.38	56.47	26.89	18.54	12.63	8.41	4.16
26.000	32.500	328.26	113.89	55.69	26.55	18.29	12.52	8.38	4.13
28.000	35.000	325.86	112.61	55.02	26.19	18.08	12.42	8.30	4.11
30.000	37.500	----	111.81	54.54	34.74	18.00	12.36	8.28	4.08
32.000	40.000	----	111.25	54.32	34.60	17.93	12.32	8.26	4.06
34.000	42.500	----	110.88	54.12	34.40	17.83	12.28	8.20	4.07
36.000	45.000	----	110.43	53.95	34.28	17.76	12.24	8.19	4.06
38.000	47.500	----	110.03	53.71	34.19	23.62	12.21	8.14	4.02
40.000	50.000	----	109.67	53.58	34.04	23.53	12.18	8.06	3.98
42.000	52.500	----	109.34	53.38	33.96	23.44	12.15	7.98	3.95
44.000	55.000	----	109.05	53.21	33.83	23.36	12.04	7.91	3.92
46.000	57.500	----	108.31	52.98	33.61	23.16	11.95	7.85	3.87
48.000	60.000	----	107.37	52.52	33.31	22.97	10.58	7.76	3.85
50.000	62.500	----	106.42	52.04	32.99	22.76	13.99	7.71	3.81
52.000	65.000	----	----	51.60	32.74	22.57	13.85	7.64	3.79

Table D-2.b.3. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 1,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.50**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	1.225	0.623	0.435	0.347	0.289	0.224	0.162	0.100
14.000	21.000	1.422	0.835	0.505	0.403	0.335	0.259	0.188	0.109
16.000	24.000	1.619	0.950	0.575	0.459	0.381	0.295	0.213	0.123
18.000	27.000	1.808	1.065	0.645	0.514	0.427	0.328	0.236	0.137
20.000	30.000	1.993	1.174	0.821	0.567	0.471	0.361	0.259	0.151
22.000	33.000	2.176	1.282	0.896	0.619	0.514	0.393	0.280	0.165
24.000	36.000	2.358	1.389	0.971	0.670	0.557	0.425	0.303	0.180
26.000	39.000	-----	1.495	1.045	0.833	0.599	0.457	0.326	0.194
28.000	42.000	-----	1.602	1.119	0.893	0.643	0.491	0.349	0.209
30.000	45.000	-----	1.712	1.196	0.954	0.687	0.524	0.335	0.223
32.000	48.000	-----	1.823	1.274	1.016	0.844	0.557	0.355	0.237
34.000	51.000	-----	1.933	1.350	1.077	0.895	0.591	0.375	0.251
36.000	54.000	-----	2.043	1.427	1.138	0.946	0.624	0.393	0.264
38.000	57.000	-----	2.152	1.504	1.199	0.997	0.657	0.410	0.277
40.000	60.000	-----	2.262	1.580	1.260	1.047	0.690	0.427	0.290
42.000	63.000	-----	2.371	1.657	1.321	1.098	0.860	0.444	0.303
44.000	66.000	-----	2.476	1.732	1.379	1.145	0.897	0.460	0.316
46.000	69.000	-----	-----	1.802	1.435	1.192	0.933	0.477	0.329
48.000	72.000	-----	-----	1.872	1.491	1.238	0.969	0.496	0.341

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	356.47	92.20	44.95	28.60	19.84	12.26	8.12	5.00
14.000	21.000	352.91	91.26	44.51	28.34	19.59	12.10	8.07	4.39
16.000	24.000	350.24	120.59	44.18	28.15	19.40	12.04	7.98	4.28
18.000	27.000	345.12	119.75	43.92	27.89	19.25	11.83	7.84	4.20
20.000	30.000	339.68	117.87	43.23	27.49	18.97	11.66	7.72	4.14
22.000	33.000	334.65	116.16	56.74	27.08	18.67	11.48	7.64	4.08
24.000	36.000	330.20	114.58	55.99	26.66	18.42	11.33	7.62	4.08
26.000	39.000	----	113.10	55.26	26.33	18.16	11.21	7.59	4.04
28.000	42.000	----	111.98	54.63	34.79	18.04	11.17	7.57	4.05
30.000	45.000	----	111.40	54.37	34.59	17.94	11.10	7.85	4.01
32.000	48.000	----	111.02	54.22	34.48	17.85	11.04	7.82	3.99
34.000	51.000	----	110.57	53.93	34.32	23.70	11.02	7.80	3.96
36.000	54.000	----	110.17	53.75	34.18	23.62	10.97	7.77	3.91
38.000	57.000	----	109.71	53.59	34.06	23.55	10.93	7.73	3.87
40.000	60.000	----	109.39	53.37	33.94	23.44	10.90	7.70	3.83
42.000	63.000	----	109.01	53.24	33.84	23.38	14.34	7.66	3.79
44.000	66.000	----	108.32	53.00	33.60	23.16	14.22	7.63	3.76
46.000	69.000	----	----	52.49	33.29	22.97	14.07	7.60	3.73
48.000	72.000	----	----	52.03	33.01	22.75	13.94	7.55	3.68

Table D-2.b.4. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 1,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.75**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	1.300	0.661	0.462	0.369	0.306	0.241	0.171	0.100
14.000	24.500	1.510	0.886	0.536	0.428	0.356	0.280	0.199	0.112
16.000	28.000	1.719	1.009	0.611	0.487	0.405	0.319	0.228	0.126
18.000	31.500	1.918	1.130	0.684	0.545	0.453	0.355	0.256	0.141
20.000	35.000	2.114	1.245	0.871	0.601	0.499	0.392	0.284	0.156
22.000	38.500	2.308	1.359	0.951	0.656	0.545	0.427	0.310	0.171
24.000	42.000	2.500	1.473	1.030	0.821	0.590	0.463	0.337	0.186
26.000	45.500	-----	1.585	1.109	0.883	0.636	0.500	0.364	0.201
28.000	49.000	-----	1.701	1.188	0.948	0.682	0.537	0.391	0.216
30.000	52.500	-----	1.818	1.270	1.013	0.842	0.574	0.417	0.230
32.000	56.000	-----	1.935	1.352	1.078	0.896	0.611	0.444	0.244
34.000	59.500	-----	2.052	1.434	1.144	0.950	0.648	0.469	0.258
36.000	63.000	-----	2.169	1.515	1.209	1.004	0.684	0.493	0.271
38.000	66.500	-----	2.285	1.597	1.273	1.058	0.833	0.516	0.285
40.000	70.000	-----	2.402	1.678	1.338	1.112	0.873	0.539	0.298
42.000	73.500	-----	-----	1.759	1.402	1.164	0.911	0.562	0.311
44.000	77.000	-----	-----	1.835	1.462	1.214	0.950	0.585	0.324

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	355.44	91.89	44.89	28.64	19.69	12.22	7.13	4.58
14.000	24.500	352.33	121.30	44.39	28.31	19.58	12.11	7.11	4.23
16.000	28.000	349.59	120.44	44.17	28.06	19.41	12.04	7.13	4.11
18.000	31.500	343.87	119.36	43.73	27.76	19.18	11.78	7.12	4.07
20.000	35.000	338.37	117.36	57.44	27.35	18.85	11.63	7.11	4.03
22.000	38.500	333.33	115.57	56.59	26.93	18.59	11.41	7.05	4.01
24.000	42.000	328.63	114.09	55.78	26.58	18.30	11.27	7.02	3.98
26.000	45.500	----	112.55	55.10	34.93	18.12	11.20	7.00	3.97
28.000	49.000	----	111.77	54.52	34.72	17.97	11.14	6.98	3.95
30.000	52.500	----	111.22	54.28	34.53	17.89	11.09	6.94	3.90
32.000	56.000	----	110.74	54.06	34.37	23.74	11.04	6.93	3.86
34.000	59.500	----	110.32	53.87	34.29	23.64	11.00	6.89	3.83
36.000	63.000	----	109.94	53.64	34.16	23.56	10.93	6.83	3.77
38.000	66.500	----	109.51	53.49	33.99	23.48	10.92	6.77	3.74
40.000	70.000	----	109.21	53.30	33.89	23.41	14.43	6.71	3.70
42.000	73.500	----	----	53.12	33.75	23.26	14.25	6.66	3.66
44.000	77.000	----	----	52.68	33.44	23.06	14.12	6.61	3.62

Table D-2.b.5. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 1,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 2.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	1.372	0.697	0.487	0.389	0.323	0.254	0.190	0.100
14.000	28.000	1.593	0.935	0.566	0.451	0.375	0.295	0.220	0.114
16.000	32.000	1.812	1.064	0.644	0.514	0.427	0.336	0.248	0.130
18.000	36.000	2.021	1.190	0.832	0.574	0.477	0.374	0.275	0.145
20.000	40.000	2.227	1.312	0.917	0.633	0.526	0.413	0.301	0.160
22.000	44.000	2.431	1.432	1.002	0.691	0.574	0.450	0.328	0.176
24.000	48.000	-----	1.552	1.085	0.865	0.622	0.488	0.357	0.191
26.000	52.000	-----	1.670	1.168	0.931	0.670	0.527	0.385	0.207
28.000	56.000	-----	1.794	1.254	1.000	0.831	0.566	0.413	0.221
30.000	60.000	-----	1.918	1.340	1.069	0.888	0.605	0.440	0.236
32.000	64.000	-----	2.042	1.426	1.138	0.945	0.644	0.468	0.250
34.000	68.000	-----	2.165	1.513	1.206	1.003	0.683	0.492	0.264
36.000	72.000	-----	2.288	1.598	1.275	1.060	0.834	0.515	0.277
38.000	76.000	-----	2.411	1.684	1.343	1.116	0.878	0.539	0.291
40.000	80.000	-----	-----	1.770	1.412	1.173	0.919	0.561	0.305
42.000	84.000	-----	-----	1.854	1.476	1.226	0.959	0.584	0.318

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	355.19	91.67	44.75	28.55	19.69	12.17	7.01	4.22
14.000	28.000	351.80	121.20	44.41	28.20	19.50	12.06	6.92	4.04
16.000	32.000	348.49	120.16	44.02	28.04	19.35	11.98	6.76	4.02
18.000	36.000	342.54	118.76	43.54	27.63	19.08	11.73	6.65	3.96
20.000	40.000	336.90	116.93	57.12	27.22	18.79	11.59	6.52	3.91
22.000	44.000	331.77	115.12	56.36	26.81	18.50	11.37	6.45	3.91
24.000	48.000	----	113.63	55.53	35.30	18.25	11.23	6.43	3.87
26.000	52.000	----	112.10	54.83	34.84	18.04	11.16	6.40	3.87
28.000	56.000	----	111.54	54.50	34.66	17.95	11.10	6.37	3.81
30.000	60.000	----	111.06	54.21	34.50	23.81	11.05	6.32	3.78
32.000	64.000	----	110.64	53.96	34.36	23.70	11.00	6.30	3.73
34.000	68.000	----	110.17	53.81	34.19	23.65	10.96	6.22	3.69
36.000	72.000	----	109.75	53.54	34.08	23.56	10.94	6.13	3.63
38.000	76.000	----	109.38	53.36	33.94	23.44	14.51	6.07	3.59
40.000	80.000	----	----	53.20	33.86	23.37	14.34	5.99	3.56
42.000	84.000	----	----	52.95	33.56	23.15	14.17	5.92	3.52

Table D-2.b.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 1,000 Pounds TNT at Various Standoff Distances--*Aspect Ratio, a/b = 3.00*

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	1.498	0.880	0.532	0.425	0.353	0.278	0.210	0.138
14.000	42.000	1.740	1.021	0.618	0.493	0.410	0.322	0.243	0.158
16.000	48.000	1.968	1.159	0.702	0.559	0.465	0.365	0.274	0.179
18.000	54.000	2.194	1.292	0.904	0.624	0.518	0.406	0.306	0.201
20.000	60.000	2.417	1.424	0.996	0.687	0.571	0.448	0.338	0.222
22.000	66.000	-----	1.555	1.087	0.866	0.623	0.490	0.371	0.244
24.000	72.000	-----	1.688	1.179	0.940	0.677	0.533	0.403	0.265
26.000	78.000	-----	1.824	1.274	1.016	0.845	0.575	0.436	0.284
28.000	84.000	-----	1.959	1.369	1.092	0.907	0.618	0.468	0.303
30.000	90.000	-----	2.094	1.463	1.167	0.970	0.661	0.499	0.322
32.000	96.000	-----	2.229	1.558	1.242	1.032	0.703	0.528	0.340
34.000	102.000	-----	2.364	1.652	1.317	1.095	0.859	0.557	0.358

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	352.19	121.54	44.42	28.35	19.56	12.13	6.92	3.27
14.000	42.000	349.11	120.20	44.04	28.03	19.38	11.96	6.81	3.17
16.000	48.000	341.93	118.59	43.51	27.59	19.09	11.76	6.63	3.12
18.000	54.000	335.77	116.44	57.00	27.16	18.72	11.50	6.53	3.11
20.000	60.000	330.08	114.57	56.05	26.67	18.42	11.34	6.45	3.08
22.000	66.000	----	112.91	55.17	35.02	18.12	11.21	6.43	3.08
24.000	72.000	----	111.80	54.54	34.67	17.98	11.15	6.37	3.05
26.000	78.000	----	111.23	54.26	34.51	17.90	11.05	6.36	3.00
28.000	84.000	----	110.63	54.03	34.38	23.71	11.01	6.31	2.96
30.000	90.000	----	110.11	53.75	34.20	23.63	10.97	6.25	2.92
32.000	96.000	----	109.66	53.57	34.05	23.51	10.91	6.15	2.88
34.000	102.000	----	109.26	53.36	33.91	23.44	14.43	6.07	2.84

Table D-2.b.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 1,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	1.547	0.908	0.550	0.439	0.365	0.287	0.217	0.143
14.000	56.000	1.790	1.054	0.638	0.509	0.423	0.332	0.250	0.165
16.000	64.000	2.025	1.193	0.834	0.576	0.478	0.375	0.282	0.188
18.000	72.000	2.257	1.330	0.930	0.642	0.533	0.418	0.315	0.210
20.000	80.000	2.488	1.465	1.025	0.707	0.587	0.461	0.349	0.233
22.000	88.000	-----	1.602	1.119	0.893	0.643	0.506	0.383	0.255
24.000	96.000	-----	1.743	1.218	0.971	0.699	0.550	0.416	0.276
26.000	104.000	-----	1.883	1.316	1.049	0.872	0.594	0.450	0.296
28.000	112.000	-----	2.023	1.413	1.127	0.937	0.638	0.481	0.316
30.000	120.000	-----	2.162	1.511	1.205	1.001	0.682	0.512	0.336

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	350.54	120.76	44.31	28.23	19.51	12.06	6.90	3.06
14.000	56.000	344.80	119.55	43.80	27.88	19.26	11.86	6.73	3.00
16.000	64.000	337.86	117.26	42.98	27.34	18.83	11.59	6.55	2.98
18.000	72.000	331.62	115.15	56.30	26.83	18.49	11.37	6.46	2.94
20.000	80.000	326.41	113.17	55.40	26.36	18.17	11.21	6.42	2.93
22.000	88.000	----	111.84	54.57	34.75	18.02	11.16	6.39	2.90
24.000	96.000	----	111.25	54.32	34.53	17.89	11.08	6.34	2.86
26.000	104.000	----	110.63	54.04	34.33	23.72	11.01	6.32	2.81
28.000	112.000	----	110.10	53.71	34.17	23.62	10.95	6.22	2.76
30.000	120.000	----	109.54	53.51	34.03	23.48	10.90	6.14	2.72

Table D-2.c.1. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 300 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	0.479	0.298	0.223	0.184	0.149	0.118	0.100	0.100
14.000	14.000	0.555	0.345	0.258	0.212	0.165	0.136	0.100	0.100
16.000	16.000	0.628	0.390	0.292	0.239	0.187	0.154	0.111	0.100
18.000	18.000	0.699	0.435	0.325	0.266	0.208	0.171	0.124	0.100
20.000	20.000	0.890	0.479	0.358	0.292	0.230	0.189	0.137	0.100
22.000	22.000	0.975	0.525	0.392	0.320	0.252	0.208	0.150	0.106
24.000	24.000	1.060	0.571	0.427	0.348	0.275	0.226	0.164	0.115
26.000	26.000	1.146	0.617	0.461	0.376	0.297	0.244	0.177	0.124
28.000	28.000	1.231	0.663	0.495	0.403	0.319	0.262	0.190	0.133
30.000	30.000	1.316	0.708	0.529	0.431	0.340	0.279	0.202	0.142
32.000	32.000	1.400	0.870	0.563	0.456	0.360	0.296	0.214	0.150
34.000	34.000	1.478	0.919	0.595	0.481	0.380	0.313	0.225	0.158
36.000	36.000	1.555	0.967	0.626	0.504	0.400	0.329	0.237	0.166
38.000	38.000	1.632	1.015	0.656	0.528	0.420	0.345	0.249	0.174
40.000	40.000	1.708	1.062	0.687	0.551	0.440	0.361	0.260	0.182
42.000	42.000	1.783	1.109	0.811	0.573	0.459	0.377	0.272	0.190
44.000	44.000	1.858	1.156	0.844	0.596	0.479	0.393	0.283	0.198
46.000	46.000	1.933	1.202	0.878	0.618	0.498	0.407	0.293	0.205
48.000	48.000	2.007	1.248	0.911	0.638	0.516	0.421	0.304	0.213
50.000	50.000	2.076	1.292	0.942	0.658	0.533	0.436	0.314	0.220
52.000	52.000	2.145	1.334	0.972	0.676	0.551	0.450	0.324	0.227
54.000	54.000	2.212	1.377	1.002	0.695	0.569	0.464	0.334	0.234
56.000	56.000	2.279	1.418	1.039	0.870	0.586	0.477	0.344	0.241
58.000	58.000	2.345	1.460	1.077	0.895	0.603	0.491	0.354	0.248
60.000	60.000	2.410	1.501	1.114	0.706	0.620	0.504	0.364	0.254

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	91.50	35.42	20.81	14.93	12.50	9.00	6.89	6.89
14.000	14.000	90.25	34.87	20.51	14.63	12.61	8.82	5.32	5.32
16.000	16.000	88.47	34.12	20.17	14.46	12.44	8.68	5.06	4.23
18.000	18.000	86.60	33.54	19.80	14.32	12.17	8.48	5.00	3.47
20.000	20.000	113.72	32.94	19.51	14.17	12.06	8.41	4.95	2.91
22.000	22.000	112.79	32.70	19.35	14.13	11.97	8.41	4.91	2.73
24.000	24.000	112.02	32.51	19.30	14.09	11.98	8.36	4.93	2.71
26.000	26.000	111.57	32.34	19.19	14.05	11.91	8.31	4.90	2.69
28.000	28.000	111.00	32.20	19.09	14.00	11.85	8.26	4.87	2.67
30.000	30.000	110.51	31.98	19.01	13.97	11.73	8.18	4.81	2.65
32.000	32.000	109.92	42.45	18.93	13.87	11.56	8.10	4.75	2.61
34.000	34.000	108.52	41.96	18.76	13.79	11.42	8.04	4.66	2.57
36.000	36.000	107.15	41.43	18.56	13.66	11.29	7.93	4.62	2.54
38.000	38.000	105.92	40.97	18.32	13.57	11.18	7.85	4.59	2.51
40.000	40.000	104.71	40.48	18.16	13.47	11.08	7.77	4.52	2.48
42.000	42.000	103.50	40.04	16.68	13.36	10.94	7.70	4.49	2.46
44.000	44.000	102.40	39.64	16.49	13.27	10.86	7.65	4.44	2.44
46.000	46.000	101.41	39.21	21.79	13.18	10.74	7.54	4.37	2.40
48.000	48.000	100.40	38.82	21.58	13.05	10.60	7.44	4.32	2.38
50.000	50.000	99.00	38.34	21.31	12.94	10.43	7.38	4.26	2.35
52.000	52.000	97.72	37.79	21.02	12.80	10.31	7.29	4.20	2.32
54.000	54.000	96.36	37.34	20.76	12.69	10.20	7.22	4.15	2.29
56.000	56.000	95.11	36.82	20.75	15.27	10.06	7.12	4.10	2.26
58.000	58.000	93.87	36.39	20.78	15.10	9.94	7.06	4.06	2.24
60.000	60.000	92.65	35.94	20.78	12.60	9.82	6.97	4.02	2.20

Table D-2.c.2. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 300 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.25

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	0.553	0.344	0.255	0.203	0.181	0.126	0.100	0.100
14.000	17.500	0.639	0.397	0.294	0.233	0.208	0.145	0.108	0.100
16.000	20.000	0.835	0.450	0.332	0.266	0.234	0.164	0.122	0.100
18.000	22.500	0.930	0.501	0.369	0.299	0.261	0.184	0.137	0.100
20.000	25.000	1.027	0.553	0.407	0.332	0.289	0.204	0.151	0.106
22.000	27.500	1.126	0.606	0.446	0.365	0.316	0.224	0.166	0.117
24.000	30.000	1.225	0.659	0.485	0.398	0.344	0.243	0.180	0.127
26.000	32.500	1.323	0.822	0.524	0.431	0.371	0.262	0.194	0.136
28.000	35.000	1.422	0.883	0.563	0.465	0.397	0.280	0.207	0.145
30.000	37.500	1.520	0.944	0.601	0.498	0.422	0.298	0.220	0.155
32.000	40.000	1.610	1.001	0.636	0.528	0.446	0.316	0.233	0.164
34.000	42.500	1.700	1.057	0.671	0.556	0.468	0.334	0.246	0.173
36.000	45.000	1.789	1.112	0.705	0.585	0.490	0.351	0.258	0.182
38.000	47.500	1.877	1.167	0.868	0.613	0.511	0.368	0.271	0.190
40.000	50.000	1.964	1.221	0.908	0.640	0.533	0.385	0.283	0.199
42.000	52.500	2.051	1.275	0.948	0.668	0.552	0.401	0.294	0.207
44.000	55.000	2.137	1.329	0.988	0.693	0.570	0.417	0.305	0.215
46.000	57.500	2.221	1.382	1.026	0.820	0.584	0.432	0.317	0.223
48.000	60.000	2.301	1.431	1.063	0.847	0.581	0.448	0.328	0.231
50.000	62.500	2.379	1.480	1.098	0.874	0.584	0.463	0.339	0.238
52.000	65.000	2.457	1.529	1.133	0.901	0.596	0.479	0.349	0.246

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	91.05	35.23	19.58	13.57	11.65	8.80	5.72	5.72
14.000	17.500	89.32	34.48	19.19	13.29	11.39	8.58	4.99	4.38
16.000	20.000	87.58	33.92	18.80	13.27	11.14	8.41	4.89	3.52
18.000	22.500	114.45	33.22	18.41	13.26	11.00	8.36	4.88	2.87
20.000	25.000	113.05	32.78	18.18	13.24	10.94	8.33	4.81	2.64
22.000	27.500	112.32	32.53	18.06	13.23	10.85	8.30	4.80	2.66
24.000	30.000	111.70	32.33	17.96	13.23	10.81	8.21	4.75	2.64
26.000	32.500	111.01	32.14	17.88	13.22	10.74	8.14	4.71	2.58
28.000	35.000	110.58	42.64	17.81	13.25	10.64	8.02	4.63	2.54
30.000	37.500	110.07	42.45	17.70	13.24	10.52	7.92	4.57	2.53
32.000	40.000	108.53	41.95	17.46	13.14	10.38	7.83	4.52	2.49
34.000	42.500	107.19	41.44	17.25	12.99	10.28	7.75	4.48	2.46
36.000	45.000	105.88	40.91	17.02	12.89	10.21	7.64	4.41	2.43
38.000	47.500	104.61	40.44	22.37	12.77	10.13	7.54	4.37	2.39
40.000	50.000	103.36	39.95	22.09	12.63	10.07	7.45	4.32	2.37
42.000	52.500	102.24	39.51	21.84	12.54	9.98	7.34	4.24	2.33
44.000	55.000	101.14	39.12	21.62	12.38	9.89	7.24	4.18	2.29
46.000	57.500	99.95	38.70	21.33	10.98	9.80	7.12	4.14	2.26
48.000	60.000	98.53	38.11	21.03	10.81	9.78	7.04	4.08	2.23
50.000	62.500	97.06	37.57	20.72	14.20	9.75	6.94	4.03	2.19
52.000	65.000	95.72	37.07	20.44	14.00	9.71	6.87	3.97	2.17

Table D-2.c.3 Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 300 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.50

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	0.618	0.384	0.286	0.238	0.199	0.158	0.100	0.100
14.000	21.000	0.823	0.443	0.330	0.274	0.228	0.181	0.115	0.100
16.000	24.000	0.931	0.501	0.373	0.308	0.257	0.204	0.131	0.100
18.000	27.000	1.038	0.559	0.416	0.343	0.287	0.227	0.147	0.104
20.000	30.000	1.148	0.618	0.460	0.380	0.317	0.224	0.163	0.115
22.000	33.000	1.259	0.677	0.505	0.416	0.348	0.245	0.178	0.126
24.000	36.000	1.369	0.851	0.549	0.452	0.378	0.263	0.193	0.136
26.000	39.000	1.479	0.919	0.593	0.488	0.406	0.281	0.207	0.146
28.000	42.000	1.589	0.987	0.637	0.522	0.429	0.298	0.221	0.155
30.000	45.000	1.694	1.053	0.679	0.553	0.454	0.314	0.235	0.165
32.000	48.000	1.794	1.116	0.830	0.585	0.484	0.331	0.249	0.175
34.000	51.000	1.894	1.178	0.876	0.616	0.515	0.350	0.263	0.184
36.000	54.000	1.993	1.239	0.922	0.647	0.545	0.367	0.276	0.193
38.000	57.000	2.091	1.300	0.967	0.677	0.575	0.385	0.289	0.202
40.000	60.000	2.188	1.360	1.012	0.707	0.605	0.402	0.301	0.210
42.000	63.000	2.284	1.420	1.056	0.874	0.636	0.419	0.313	0.219
44.000	66.000	2.379	1.480	1.099	0.908	0.665	0.435	0.326	0.227
46.000	69.000	2.468	1.536	1.140	0.942	0.687	0.452	0.338	0.236
48.000	72.000	0.000	1.590	1.181	0.975	0.709	0.468	0.350	0.244

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	90.73	35.03	19.43	13.46	10.27	7.88	5.00	5.00
14.000	21.000	88.66	34.25	19.01	13.17	9.99	7.70	4.86	3.72
16.000	24.000	115.82	33.54	18.59	12.84	9.79	7.65	4.83	2.99
18.000	27.000	113.75	32.99	18.27	12.65	9.68	7.61	4.81	2.63
20.000	30.000	112.70	32.66	18.10	12.59	9.60	7.86	4.79	2.60
22.000	33.000	112.03	32.39	18.02	12.50	9.57	7.84	4.72	2.59
24.000	36.000	111.30	43.01	17.90	12.43	9.51	7.78	4.67	2.54
26.000	39.000	110.69	42.74	17.79	12.37	9.42	7.74	4.58	2.50
28.000	42.000	110.17	42.50	17.70	12.24	9.26	7.69	4.50	2.44
30.000	45.000	109.07	42.14	17.52	12.04	9.16	7.63	4.44	2.41
32.000	48.000	107.51	41.60	17.26	11.89	9.16	7.56	4.38	2.39
34.000	51.000	106.15	41.06	22.71	11.73	9.17	7.49	4.33	2.34
36.000	54.000	104.84	40.52	22.44	11.59	9.16	7.35	4.26	2.31
38.000	57.000	103.58	40.03	22.15	11.44	9.16	7.27	4.19	2.27
40.000	60.000	102.35	39.54	21.90	11.30	9.16	7.15	4.11	2.22
42.000	63.000	101.16	39.10	21.62	14.81	9.17	7.05	4.03	2.19
44.000	66.000	100.00	38.70	21.34	14.57	9.15	6.93	3.99	2.15
46.000	69.000	98.47	38.14	21.01	14.35	9.06	6.85	3.93	2.13
48.000	72.000	----	37.53	20.71	14.11	8.97	6.75	3.87	2.10

Table D-2.c.4. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 300 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.75

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	0.656	0.408	0.304	0.253	0.219	0.171	0.103	0.100
14.000	24.500	0.873	0.470	0.350	0.291	0.252	0.199	0.119	0.100
16.000	28.000	0.988	0.532	0.396	0.329	0.284	0.226	0.135	0.100
18.000	31.500	1.101	0.593	0.442	0.368	0.318	0.253	0.151	0.108
20.000	35.000	1.219	0.656	0.489	0.407	0.352	0.279	0.167	0.119
22.000	38.500	1.337	0.830	0.536	0.447	0.386	0.306	0.182	0.129
24.000	42.000	1.454	0.903	0.583	0.486	0.420	0.330	0.197	0.140
26.000	45.500	1.571	0.976	0.630	0.525	0.451	0.353	0.212	0.150
28.000	49.000	1.688	1.048	0.676	0.561	0.481	0.376	0.226	0.160
30.000	52.500	1.795	1.116	0.830	0.597	0.511	0.399	0.241	0.170
32.000	56.000	1.901	1.182	0.879	0.632	0.540	0.422	0.254	0.179
34.000	59.500	2.007	1.248	0.928	0.667	0.569	0.444	0.268	0.188
36.000	63.000	2.111	1.313	0.976	0.701	0.597	0.464	0.281	0.197
38.000	66.500	2.215	1.377	1.024	0.849	0.625	0.483	0.294	0.206
40.000	70.000	2.318	1.441	1.072	0.888	0.649	0.502	0.307	0.215
42.000	73.500	2.420	1.505	1.119	0.924	0.672	0.521	0.319	0.224
44.000	77.000	0.000	1.566	1.162	0.960	0.695	0.539	0.332	0.232

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	90.51	35.01	19.44	13.46	10.16	7.13	4.85	4.58
14.000	24.500	117.77	34.13	18.93	13.09	9.93	7.11	4.76	3.43
16.000	28.000	115.48	33.48	18.55	12.81	9.71	7.07	4.69	2.72
18.000	31.500	113.31	32.87	18.26	12.66	9.63	7.03	4.64	2.54
20.000	35.000	112.51	32.58	18.11	12.54	9.57	6.97	4.60	2.51
22.000	38.500	111.86	32.33	17.98	12.50	9.52	6.95	4.52	2.45
24.000	42.000	111.16	42.87	17.87	12.42	9.48	6.86	4.45	2.43
26.000	45.500	110.57	42.68	17.78	12.35	9.35	6.77	4.39	2.38
28.000	49.000	110.07	42.43	17.65	12.16	9.20	6.69	4.31	2.34
30.000	52.500	108.43	41.91	17.39	11.99	9.08	6.61	4.27	2.30
32.000	56.000	106.88	41.32	22.85	11.81	8.94	6.55	4.17	2.25
34.000	59.500	105.53	40.81	22.56	11.66	8.82	6.47	4.12	2.20
36.000	63.000	104.14	40.29	22.26	11.48	8.69	6.37	4.04	2.16
38.000	66.500	102.90	39.77	21.99	11.34	8.57	6.26	3.97	2.12
40.000	70.000	101.71	39.31	21.75	14.93	8.42	6.16	3.91	2.09
42.000	73.500	100.55	38.89	21.50	14.66	8.26	6.07	3.83	2.06
44.000	77.000	----	38.36	21.12	14.42	8.12	5.98	3.79	2.02

Table D-2.c.5. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 300 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 2.00**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	0.691	0.430	0.320	0.266	0.232	0.184	0.120	0.100
14.000	28.000	0.920	0.495	0.369	0.307	0.267	0.211	0.138	0.100
16.000	32.000	1.040	0.560	0.417	0.347	0.303	0.239	0.155	0.100
18.000	36.000	1.161	0.625	0.466	0.388	0.339	0.267	0.171	0.112
20.000	40.000	1.286	0.692	0.516	0.430	0.375	0.295	0.180	0.123
22.000	44.000	1.410	0.876	0.565	0.471	0.412	0.322	0.193	0.133
24.000	48.000	1.534	0.953	0.615	0.513	0.448	0.346	0.205	0.144
26.000	52.000	1.657	1.029	0.664	0.553	0.481	0.369	0.217	0.154
28.000	56.000	1.777	1.105	0.822	0.591	0.514	0.392	0.231	0.164
30.000	60.000	1.890	1.175	0.874	0.628	0.546	0.414	0.245	0.173
32.000	64.000	2.002	1.245	0.926	0.665	0.578	0.437	0.259	0.183
34.000	68.000	2.112	1.314	0.977	0.702	0.610	0.457	0.272	0.192
36.000	72.000	2.222	1.382	1.028	0.852	0.642	0.483	0.285	0.201
38.000	76.000	2.331	1.450	1.078	0.894	0.672	0.510	0.299	0.210
40.000	80.000	2.440	1.517	1.128	0.933	0.700	0.537	0.312	0.219
42.000	84.000	0.000	1.583	1.176	0.971	0.842	0.559	0.324	0.227

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	90.10	34.89	19.32	13.35	10.16	6.68	4.38	4.22
14.000	28.000	117.34	33.97	18.88	13.07	9.88	6.54	4.36	3.15
16.000	32.000	114.80	33.29	18.46	12.78	9.74	6.47	4.33	2.50
18.000	36.000	113.04	32.76	18.21	12.63	9.64	6.41	4.34	2.48
20.000	40.000	112.34	32.53	18.09	12.56	9.55	6.37	4.37	2.44
22.000	44.000	111.61	43.08	17.92	12.45	9.53	6.31	4.32	2.36
24.000	48.000	111.01	42.84	17.84	12.41	9.47	6.19	4.27	2.33
26.000	52.000	110.36	42.56	17.72	12.29	9.30	6.07	4.23	2.28
28.000	56.000	109.44	42.32	17.56	12.11	9.16	5.97	4.14	2.24
30.000	60.000	107.84	41.68	23.06	11.91	9.00	5.87	4.06	2.18
32.000	64.000	106.35	41.13	22.75	11.73	8.86	5.79	3.99	2.15
34.000	68.000	104.84	40.58	22.44	11.58	8.75	5.68	3.91	2.10
36.000	72.000	103.51	40.04	22.16	15.22	8.64	5.67	3.83	2.06
38.000	76.000	102.24	39.56	21.87	15.04	8.50	5.67	3.78	2.02
40.000	80.000	101.11	39.08	21.61	14.78	8.34	5.67	3.72	1.98
42.000	84.000	----	38.60	21.30	14.52	8.19	5.61	3.64	1.93

Table D-2.c.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 300 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 3.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	0.867	0.467	0.347	0.289	0.252	0.205	0.145	0.102
14.000	42.000	0.999	0.538	0.400	0.333	0.290	0.237	0.168	0.117
16.000	48.000	1.131	0.609	0.454	0.378	0.330	0.270	0.191	0.131
18.000	54.000	1.268	0.682	0.509	0.424	0.370	0.302	0.214	0.144
20.000	60.000	1.404	0.872	0.563	0.469	0.410	0.334	0.237	0.157
22.000	66.000	1.539	0.956	0.617	0.515	0.448	0.363	0.259	0.169
24.000	72.000	1.675	1.040	0.671	0.557	0.484	0.392	0.279	0.181
26.000	78.000	1.799	1.119	0.832	0.598	0.520	0.421	0.299	0.191
28.000	84.000	1.922	1.195	0.889	0.639	0.555	0.450	0.318	0.201
30.000	90.000	2.043	1.271	0.945	0.679	0.590	0.476	0.336	0.208
32.000	96.000	2.164	1.345	1.001	0.830	0.625	0.501	0.354	0.187
34.000	102.000	2.283	1.420	1.056	0.875	0.657	0.526	0.371	0.195

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	117.98	34.23	18.90	13.11	9.97	6.60	3.57	2.09
14.000	42.000	115.08	33.38	18.45	12.79	9.70	6.48	3.52	2.06
16.000	48.000	112.93	32.74	18.20	12.61	9.61	6.44	3.49	2.03
18.000	54.000	112.15	32.44	18.07	12.54	9.55	6.36	3.47	1.99
20.000	60.000	111.38	42.96	17.91	12.43	9.50	6.30	3.45	1.95
22.000	66.000	110.60	42.68	17.78	12.38	9.37	6.15	3.41	1.92
24.000	72.000	110.08	42.44	17.67	12.17	9.19	6.03	3.34	1.89
26.000	78.000	108.20	41.86	17.36	11.96	9.04	5.93	3.27	1.84
28.000	84.000	106.49	41.17	22.78	11.77	8.88	5.84	3.20	1.81
30.000	90.000	104.81	40.57	22.43	11.58	8.74	5.71	3.13	1.79
32.000	96.000	103.36	39.93	22.11	11.40	8.62	5.58	3.06	1.80
34.000	102.000	101.90	39.42	21.80	14.97	8.44	5.47	3.00	1.75

Table D-2.c.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 300 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	0.892	0.480	0.357	0.297	0.259	0.211	0.154	0.111
14.000	56.000	1.028	0.553	0.412	0.343	0.300	0.245	0.179	0.127
16.000	64.000	1.168	0.629	0.469	0.391	0.341	0.279	0.203	0.143
18.000	72.000	1.309	0.704	0.525	0.438	0.382	0.312	0.226	0.159
20.000	80.000	1.450	0.901	0.581	0.484	0.423	0.343	0.247	0.174
22.000	88.000	1.589	0.988	0.637	0.529	0.460	0.373	0.269	0.187
24.000	96.000	1.719	1.069	0.689	0.571	0.497	0.403	0.290	0.201
26.000	104.000	1.847	1.148	0.854	0.614	0.534	0.432	0.310	0.213
28.000	112.000	1.972	1.226	0.912	0.655	0.570	0.460	0.329	0.226
30.000	120.000	2.097	1.304	0.970	0.696	0.605	0.487	0.347	0.237

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	116.54	33.75	18.67	12.92	9.83	6.52	3.53	1.92
14.000	56.000	113.72	32.91	18.27	12.66	9.69	6.46	3.50	1.86
16.000	64.000	112.40	32.60	18.12	12.60	9.58	6.41	3.45	1.82
18.000	72.000	111.55	32.26	17.94	12.49	9.50	6.34	3.38	1.78
20.000	80.000	110.87	42.81	17.80	12.35	9.43	6.20	3.28	1.74
22.000	88.000	110.03	42.54	17.68	12.20	9.22	6.06	3.22	1.68
24.000	96.000	108.21	41.85	17.38	11.94	9.05	5.95	3.14	1.65
26.000	104.000	106.44	41.12	22.76	11.76	8.90	5.82	3.07	1.59
28.000	112.000	104.62	40.44	22.38	11.54	8.74	5.69	2.98	1.56
30.000	120.000	103.06	39.85	22.05	11.35	8.58	5.56	2.89	1.51

Table D-2.d.1. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 100 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	12.000	0.824	0.302	0.203	0.150	0.123	0.108	0.100	0.100
14.000	14.000	0.952	0.349	0.234	0.165	0.142	0.125	0.100	0.100
16.000	16.000	1.083	0.396	0.266	0.188	0.162	0.142	0.113	0.100
18.000	18.000	1.214	0.444	0.298	0.211	0.181	0.159	0.126	0.100
20.000	20.000	1.344	0.491	0.330	0.233	0.201	0.176	0.140	0.105
22.000	22.000	1.468	0.539	0.362	0.255	0.218	0.191	0.152	0.114
24.000	24.000	1.587	0.583	0.391	0.275	0.236	0.206	0.164	0.123
26.000	26.000	1.704	0.626	0.419	0.296	0.254	0.221	0.176	0.132
28.000	28.000	1.820	0.669	0.448	0.316	0.271	0.236	0.188	0.141
30.000	30.000	1.934	0.821	0.476	0.336	0.288	0.251	0.200	0.150
32.000	32.000	2.047	0.869	0.503	0.355	0.305	0.265	0.211	0.158
34.000	34.000	2.152	0.916	0.530	0.374	0.321	0.278	0.221	0.166
36.000	36.000	2.255	0.960	0.555	0.392	0.336	0.290	0.232	0.174
38.000	38.000	2.357	1.004	0.580	0.410	0.352	0.304	0.242	0.182
40.000	40.000	2.457	1.047	0.604	0.428	0.367	0.317	0.252	0.189
42.000	42.000	-----	1.089	0.626	0.445	0.382	0.329	0.262	0.197
44.000	44.000	-----	1.131	0.648	0.463	0.397	0.342	0.273	0.204
46.000	46.000	-----	1.172	0.670	0.480	0.411	0.354	0.282	0.211
48.000	48.000	-----	1.213	0.691	0.495	0.423	0.365	0.291	0.217
50.000	50.000	-----	1.253	0.838	0.510	0.435	0.376	0.300	0.224
52.000	52.000	-----	1.288	0.860	0.524	0.446	0.386	0.308	0.229
54.000	54.000	-----	1.321	0.881	0.538	0.457	0.396	0.316	0.235
56.000	56.000	-----	1.353	0.902	0.552	0.468	0.406	0.324	0.241
58.000	58.000	-----	1.384	0.922	0.565	0.478	0.415	0.332	0.246
60.000	60.000	-----	1.415	0.941	0.578	0.488	0.425	0.339	0.252

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	12.000	203.08	36.37	17.69	12.49	9.67	7.73	6.89	6.89
14.000	14.000	265.54	35.69	17.33	12.61	9.50	7.64	5.32	5.32
16.000	16.000	263.11	35.18	17.17	12.57	9.47	7.57	5.22	4.23
18.000	18.000	261.22	34.94	17.05	12.51	9.36	7.52	5.14	3.47
20.000	20.000	259.33	34.61	16.95	12.36	9.35	7.48	5.14	3.16
22.000	22.000	255.70	34.47	16.87	12.24	9.13	7.33	5.02	3.09
24.000	24.000	251.10	33.89	16.58	11.98	9.00	7.20	4.93	3.03
26.000	26.000	246.67	33.29	16.27	11.83	8.90	7.10	4.85	2.98
28.000	28.000	242.63	32.78	16.07	11.63	8.76	7.01	4.78	2.94
30.000	30.000	238.66	32.26	15.84	11.46	8.64	6.93	4.72	2.91
32.000	32.000	234.99	42.35	15.59	11.26	8.53	6.83	4.63	2.85
34.000	34.000	230.06	41.68	15.36	11.08	8.39	6.70	4.52	2.79
36.000	36.000	225.32	40.84	15.07	10.86	8.23	6.55	4.46	2.75
38.000	38.000	220.94	40.09	14.81	10.67	8.12	6.47	4.36	2.71
40.000	40.000	216.67	39.35	14.60	10.50	7.99	6.37	4.28	2.65
42.000	42.000	----	38.61	14.43	10.31	7.87	6.24	4.21	2.61
44.000	44.000	----	37.94	14.28	10.17	7.76	6.16	4.17	2.56
46.000	46.000	----	37.28	14.14	10.01	7.65	6.05	4.09	2.52
48.000	48.000	----	36.67	14.00	9.79	7.49	5.93	4.02	2.46
50.000	50.000	----	36.06	13.06	9.59	7.35	5.82	3.95	2.42
52.000	52.000	----	35.23	17.02	9.39	7.20	5.69	3.86	2.35
54.000	54.000	----	34.37	16.62	9.21	7.05	5.57	3.78	2.30
56.000	56.000	----	33.52	16.26	9.04	6.92	5.46	3.71	2.26
58.000	58.000	----	32.70	15.89	8.86	6.78	5.34	3.65	2.21
60.000	60.000	----	31.94	15.52	8.69	6.64	5.25	3.57	2.17

Table D-2.d.2. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 100 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.25

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	15.000	0.950	0.348	0.229	0.180	0.132	0.116	0.100	0.100
14.000	17.500	1.100	0.402	0.264	0.209	0.153	0.135	0.109	0.100
16.000	20.000	1.251	0.457	0.299	0.238	0.174	0.154	0.124	0.100
18.000	22.500	1.402	0.513	0.335	0.266	0.194	0.171	0.139	0.104
20.000	25.000	1.551	0.568	0.371	0.293	0.214	0.188	0.152	0.114
22.000	27.500	1.689	0.620	0.403	0.318	0.233	0.205	0.166	0.124
24.000	30.000	1.825	0.670	0.435	0.343	0.252	0.222	0.179	0.134
26.000	32.500	1.960	0.831	0.466	0.367	0.270	0.238	0.192	0.143
28.000	35.000	2.092	0.888	0.497	0.391	0.288	0.254	0.204	0.152
30.000	37.500	2.224	0.943	0.527	0.412	0.306	0.269	0.216	0.161
32.000	40.000	2.345	0.999	0.555	0.430	0.322	0.284	0.227	0.170
34.000	42.500	2.465	1.050	0.580	0.448	0.339	0.298	0.239	0.179
36.000	45.000	-----	1.100	0.605	0.465	0.356	0.313	0.250	0.187
38.000	47.500	-----	1.150	0.630	0.472	0.372	0.327	0.261	0.196
40.000	50.000	-----	1.199	0.663	0.469	0.388	0.341	0.272	0.204
42.000	52.500	-----	1.247	0.697	0.477	0.402	0.354	0.281	0.211
44.000	55.000	-----	1.295	0.847	0.483	0.416	0.365	0.290	0.218
46.000	57.500	-----	1.341	0.875	0.498	0.429	0.377	0.299	0.224
48.000	60.000	-----	1.384	0.897	0.514	0.442	0.388	0.307	0.231
50.000	62.500	-----	1.423	0.918	0.529	0.454	0.398	0.316	0.237
52.000	65.000	-----	1.460	0.939	0.543	0.466	0.408	0.324	0.243

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	15.000	268.71	36.06	16.33	11.55	9.63	7.51	5.72	5.72
14.000	17.500	264.69	35.35	16.02	11.47	9.51	7.48	5.08	4.38
16.000	20.000	262.11	34.98	15.79	11.41	9.42	7.45	5.03	3.52
18.000	22.500	260.11	34.83	15.69	11.31	9.26	7.27	5.00	3.07
20.000	25.000	257.85	34.58	15.60	11.16	9.13	7.13	4.86	3.00
22.000	27.500	252.71	34.05	15.30	10.95	8.95	7.02	4.80	2.94
24.000	30.000	247.92	33.41	15.04	10.77	8.80	6.93	4.71	2.89
26.000	32.500	243.65	32.85	14.77	10.58	8.62	6.79	4.62	2.82
28.000	35.000	239.34	43.12	14.55	10.41	8.46	6.68	4.53	2.76
30.000	37.500	235.63	42.36	14.31	10.26	8.33	6.54	4.44	2.70
32.000	40.000	230.25	41.79	14.02	10.12	8.12	6.42	4.34	2.65
34.000	42.500	225.36	40.89	13.72	10.00	7.97	6.27	4.27	2.61
36.000	45.000	----	40.03	13.45	9.87	7.85	6.18	4.19	2.55
38.000	47.500	----	39.27	13.22	9.79	7.70	6.06	4.12	2.52
40.000	50.000	----	38.52	13.22	9.75	7.56	5.96	4.05	2.47
42.000	52.500	----	37.80	13.24	9.69	7.37	5.84	3.95	2.41
44.000	55.000	----	37.14	12.42	9.59	7.21	5.67	3.85	2.35
46.000	57.500	----	36.44	16.24	9.34	7.03	5.55	3.77	2.28
48.000	60.000	----	35.64	15.79	9.14	6.87	5.42	3.66	2.23
50.000	62.500	----	34.73	15.35	8.93	6.69	5.28	3.59	2.18
52.000	65.000	----	33.80	14.95	8.71	6.53	5.14	3.50	2.12

Table D-2.d.3 Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 100 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.50

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	18.000	1.060	0.389	0.261	0.199	0.170	0.123	0.101	0.100
14.000	21.000	1.229	0.449	0.302	0.230	0.196	0.143	0.117	0.100
16.000	24.000	1.399	0.511	0.344	0.262	0.223	0.162	0.133	0.100
18.000	27.000	1.568	0.573	0.385	0.293	0.248	0.180	0.147	0.111
20.000	30.000	1.729	0.634	0.425	0.320	0.271	0.198	0.162	0.122
22.000	33.000	1.882	0.691	0.463	0.348	0.294	0.216	0.176	0.133
24.000	36.000	2.033	0.862	0.500	0.372	0.316	0.233	0.190	0.143
26.000	39.000	2.183	0.926	0.537	0.395	0.337	0.250	0.204	0.153
28.000	42.000	2.331	0.989	0.573	0.424	0.351	0.266	0.217	0.162
30.000	45.000	2.471	1.051	0.608	0.454	0.326	0.282	0.229	0.171
32.000	48.000	-----	1.110	0.641	0.484	0.340	0.297	0.242	0.181
34.000	51.000	-----	1.166	0.674	0.515	0.353	0.313	0.254	0.189
36.000	54.000	-----	1.222	0.704	0.543	0.370	0.327	0.266	0.197
38.000	57.000	-----	1.277	0.852	0.564	0.385	0.340	0.276	0.205
40.000	60.000	-----	1.331	0.888	0.584	0.400	0.353	0.286	0.212
42.000	63.000	-----	1.384	0.923	0.599	0.414	0.365	0.296	0.219
44.000	66.000	-----	1.437	0.955	0.615	0.428	0.377	0.306	0.226
46.000	69.000	-----	1.485	0.984	0.629	0.441	0.389	0.315	0.233
48.000	72.000	-----	1.527	1.012	0.643	0.454	0.400	0.323	0.240

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	18.000	266.91	35.95	16.18	10.27	8.61	7.43	5.09	5.00
14.000	21.000	263.61	35.18	15.92	10.13	8.49	7.38	5.02	3.72
16.000	24.000	261.52	34.89	15.81	10.08	8.44	7.26	4.97	2.99
18.000	27.000	259.57	34.66	15.65	9.99	8.33	7.09	4.81	2.93
20.000	30.000	255.65	34.37	15.45	9.73	8.16	6.95	4.73	2.88
22.000	33.000	250.33	33.75	15.15	9.57	8.02	6.84	4.62	2.84
24.000	36.000	245.45	44.13	14.85	9.35	7.88	6.70	4.53	2.77
26.000	39.000	241.14	43.39	14.59	9.19	7.73	6.57	4.45	2.71
28.000	42.000	237.07	42.66	14.33	9.17	7.59	6.42	4.35	2.63
30.000	45.000	232.07	41.98	14.05	9.16	7.75	6.29	4.22	2.56
32.000	48.000	----	41.16	13.73	9.16	7.68	6.14	4.15	2.53
34.000	51.000	----	40.23	13.44	9.17	7.60	6.05	4.05	2.46
36.000	54.000	----	39.41	13.15	9.13	7.47	5.89	3.97	2.39
38.000	57.000	----	38.63	17.20	9.01	7.27	5.73	3.84	2.33
40.000	60.000	----	37.88	16.86	8.88	7.09	5.58	3.73	2.26
42.000	63.000	----	37.14	16.52	8.69	6.89	5.42	3.62	2.19
44.000	66.000	----	36.49	16.11	8.47	6.72	5.27	3.53	2.14
46.000	69.000	----	35.65	15.65	8.25	6.54	5.14	3.43	2.08
48.000	72.000	----	34.62	15.21	8.05	6.37	5.00	3.34	2.04

Table D-2.d.4. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 100 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.75

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	21.000	1.125	0.412	0.276	0.220	0.178	0.156	0.104	0.100
14.000	24.500	1.305	0.477	0.321	0.255	0.206	0.181	0.121	0.100
16.000	28.000	1.485	0.543	0.365	0.290	0.233	0.204	0.136	0.104
18.000	31.500	1.664	0.608	0.409	0.323	0.256	0.226	0.151	0.115
20.000	35.000	1.832	0.673	0.451	0.354	0.284	0.247	0.166	0.126
22.000	38.500	1.994	0.846	0.490	0.385	0.313	0.267	0.180	0.136
24.000	42.000	2.154	0.914	0.530	0.415	0.341	0.284	0.194	0.146
26.000	45.500	2.313	0.981	0.569	0.444	0.367	0.299	0.207	0.156
28.000	49.000	2.469	1.047	0.607	0.471	0.388	0.312	0.220	0.165
30.000	52.500	-----	1.113	0.643	0.497	0.409	0.307	0.233	0.175
32.000	56.000	-----	1.173	0.678	0.521	0.429	0.315	0.246	0.183
34.000	59.500	-----	1.233	0.823	0.544	0.449	0.324	0.257	0.191
36.000	63.000	-----	1.292	0.862	0.566	0.467	0.335	0.267	0.199
38.000	66.500	-----	1.350	0.900	0.588	0.482	0.346	0.278	0.206
40.000	70.000	-----	1.407	0.938	0.604	0.495	0.357	0.287	0.213
42.000	73.500	-----	1.463	0.975	0.617	0.507	0.366	0.296	0.220
44.000	77.000	-----	1.518	1.006	0.627	0.511	0.377	0.305	0.226

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	21.000	266.19	35.70	16.02	10.23	7.46	6.43	4.94	4.58
14.000	24.500	263.15	35.16	15.92	10.12	7.38	6.39	4.91	3.43
16.000	28.000	260.89	34.88	15.76	10.04	7.30	6.28	4.76	2.90
18.000	31.500	258.83	34.55	15.64	9.88	7.12	6.17	4.64	2.82
20.000	35.000	254.12	34.29	15.40	9.66	7.11	6.04	4.54	2.75
22.000	38.500	248.80	33.59	15.02	9.48	7.12	5.91	4.42	2.67
24.000	42.000	243.96	43.93	14.77	9.30	7.11	5.82	4.32	2.60
26.000	45.500	239.69	43.12	14.51	9.11	7.06	5.75	4.20	2.54
28.000	49.000	235.49	42.35	14.23	8.89	6.92	5.68	4.09	2.47
30.000	52.500	----	41.69	13.91	8.67	6.80	5.70	4.00	2.43
32.000	56.000	----	40.70	13.60	8.46	6.68	5.67	3.92	2.34
34.000	59.500	----	39.83	13.31	8.26	6.56	5.58	3.80	2.26
36.000	63.000	----	39.01	17.36	8.07	6.42	5.41	3.67	2.20
38.000	66.500	----	38.22	16.99	7.90	6.24	5.26	3.58	2.12
40.000	70.000	----	37.47	16.65	7.64	6.06	5.13	3.45	2.05
42.000	73.500	----	36.75	16.32	7.37	5.88	4.97	3.34	1.99
44.000	77.000	----	36.05	15.83	7.13	5.78	4.83	3.24	1.92

Table D-2.d.5. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 100 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 2.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	24.000	1.186	0.434	0.291	0.233	0.197	0.162	0.124	0.100
14.000	28.000	1.377	0.503	0.338	0.270	0.228	0.188	0.142	0.100
16.000	32.000	1.567	0.573	0.385	0.307	0.259	0.215	0.156	0.107
18.000	36.000	1.755	0.642	0.431	0.343	0.287	0.242	0.163	0.118
20.000	40.000	1.928	0.708	0.474	0.376	0.315	0.266	0.174	0.129
22.000	44.000	2.099	0.890	0.516	0.410	0.342	0.288	0.183	0.139
24.000	48.000	2.268	0.962	0.558	0.442	0.366	0.309	0.197	0.150
26.000	52.000	2.434	1.033	0.599	0.474	0.386	0.329	0.211	0.159
28.000	56.000	-----	1.102	0.639	0.504	0.406	0.348	0.224	0.169
30.000	60.000	-----	1.169	0.676	0.533	0.426	0.366	0.236	0.177
32.000	64.000	-----	1.233	0.823	0.562	0.444	0.384	0.248	0.185
34.000	68.000	-----	1.296	0.865	0.589	0.463	0.398	0.258	0.192
36.000	72.000	-----	1.357	0.905	0.615	0.483	0.410	0.269	0.200
38.000	76.000	-----	1.418	0.946	0.640	0.510	0.417	0.279	0.207
40.000	80.000	-----	1.478	0.985	0.660	0.527	0.423	0.288	0.214
42.000	84.000	-----	1.536	1.021	0.680	0.542	0.424	0.297	0.220

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	24.000	265.41	35.54	15.98	10.24	7.47	5.71	4.45	4.22
14.000	28.000	262.86	35.08	15.84	10.11	7.36	5.68	4.41	3.15
16.000	32.000	260.63	34.85	15.73	10.00	7.29	5.68	4.34	2.81
18.000	36.000	258.30	34.57	15.58	9.87	7.10	5.68	4.37	2.72
20.000	40.000	252.51	34.05	15.26	9.60	6.95	5.61	4.30	2.64
22.000	44.000	247.34	44.47	14.95	9.44	6.79	5.50	4.21	2.55
24.000	48.000	242.65	43.66	14.69	9.22	6.63	5.39	4.10	2.50
26.000	52.000	238.13	42.89	14.42	9.03	6.42	5.28	4.02	2.41
28.000	56.000	----	42.09	14.15	8.80	6.23	5.16	3.91	2.36
30.000	60.000	----	41.26	13.80	8.58	6.08	5.05	3.78	2.27
32.000	64.000	----	40.34	13.48	8.39	5.91	4.95	3.68	2.19
34.000	68.000	----	39.48	17.59	8.19	5.77	4.80	3.53	2.10
36.000	72.000	----	38.61	17.17	8.00	5.67	4.64	3.43	2.04
38.000	76.000	----	37.84	16.84	7.80	5.67	4.56	3.31	1.96
40.000	80.000	----	37.10	16.48	7.53	5.55	4.49	3.20	1.90
42.000	84.000	----	36.34	16.06	7.29	5.41	4.40	3.10	1.82

Table D-2.d.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 100 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 3.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	36.000	1.295	0.473	0.318	0.254	0.217	0.190	0.147	0.110
14.000	42.000	1.504	0.550	0.369	0.295	0.252	0.218	0.169	0.126
16.000	48.000	1.709	0.625	0.420	0.334	0.283	0.245	0.190	0.141
18.000	54.000	1.899	0.697	0.467	0.371	0.315	0.272	0.214	0.155
20.000	60.000	2.085	0.884	0.513	0.407	0.345	0.297	0.233	0.166
22.000	66.000	2.269	0.962	0.558	0.443	0.375	0.320	0.252	0.177
24.000	72.000	2.450	1.039	0.603	0.476	0.402	0.343	0.270	0.186
26.000	78.000	-----	1.114	0.644	0.508	0.429	0.365	0.287	0.193
28.000	84.000	-----	1.185	0.685	0.540	0.456	0.386	0.301	0.197
30.000	90.000	-----	1.253	0.836	0.571	0.481	0.405	0.312	0.174
32.000	96.000	-----	1.321	0.881	0.601	0.503	0.421	0.323	0.182
34.000	102.000	-----	1.387	0.925	0.629	0.521	0.435	0.333	0.191

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	36.000	263.21	35.11	15.87	10.13	7.39	5.69	3.65	2.31
14.000	42.000	260.83	34.88	15.70	10.03	7.32	5.53	3.56	2.24
16.000	48.000	257.85	34.49	15.57	9.85	7.07	5.37	3.46	2.17
18.000	54.000	251.55	33.89	15.21	9.60	6.92	5.25	3.47	2.12
20.000	60.000	245.62	44.15	14.87	9.36	6.73	5.09	3.35	2.05
22.000	66.000	240.40	43.21	14.54	9.16	6.57	4.91	3.25	2.00
24.000	72.000	235.52	42.36	14.27	8.89	6.34	4.77	3.15	1.93
26.000	78.000	----	41.49	13.87	8.63	6.15	4.62	3.05	1.86
28.000	84.000	----	40.48	13.53	8.41	5.99	4.48	2.93	1.80
30.000	90.000	----	39.43	13.16	8.19	5.81	4.32	2.79	1.78
32.000	96.000	----	38.51	17.13	7.97	5.62	4.13	2.66	1.70
34.000	102.000	----	37.61	16.73	7.73	5.38	3.94	2.55	1.62

Table D-2.d.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 100 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	48.000	1.337	0.489	0.329	0.262	0.224	0.196	0.156	0.118
14.000	56.000	1.552	0.567	0.381	0.304	0.258	0.225	0.179	0.135
16.000	64.000	1.755	0.644	0.432	0.342	0.291	0.253	0.201	0.151
18.000	72.000	1.949	0.826	0.479	0.380	0.323	0.281	0.222	0.166
20.000	80.000	2.139	0.907	0.526	0.417	0.354	0.307	0.241	0.180
22.000	88.000	2.328	0.987	0.572	0.452	0.382	0.331	0.260	0.192
24.000	96.000	-----	1.065	0.616	0.486	0.410	0.355	0.279	0.202
26.000	104.000	-----	1.138	0.658	0.519	0.438	0.378	0.295	0.212
28.000	112.000	-----	1.209	0.699	0.550	0.464	0.399	0.312	0.220
30.000	120.000	-----	1.279	0.853	0.582	0.487	0.417	0.327	0.227

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	48.000	261.83	35.02	15.85	10.05	7.35	5.63	3.62	2.14
14.000	56.000	259.21	34.60	15.62	9.95	7.16	5.45	3.50	2.06
16.000	64.000	253.77	34.17	15.38	9.64	6.98	5.27	3.39	1.99
18.000	72.000	247.29	33.31	14.94	9.40	6.79	5.14	3.27	1.91
20.000	80.000	241.26	43.38	14.59	9.17	6.61	4.97	3.13	1.83
22.000	88.000	236.18	42.45	14.26	8.90	6.36	4.79	3.01	1.75
24.000	96.000	----	41.53	13.89	8.65	6.16	4.63	2.92	1.66
26.000	104.000	----	40.41	13.51	8.40	5.99	4.48	2.79	1.58
28.000	112.000	----	39.32	13.14	8.14	5.79	4.31	2.69	1.50
30.000	120.000	----	38.34	17.05	7.94	5.56	4.11	2.58	1.41

Table D-2.e.1. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 30 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	12.000	1.844	0.418	0.200	0.130	0.107	0.100	0.100	0.100
14.000	14.000	2.115	0.485	0.232	0.151	0.123	0.103	0.100	0.100
16.000	16.000	2.381	0.547	0.262	0.170	0.138	0.115	0.100	0.100
18.000	18.000	-----	0.608	0.290	0.189	0.153	0.128	0.111	0.100
20.000	20.000	-----	0.667	0.318	0.207	0.168	0.141	0.122	0.100
22.000	22.000	-----	0.838	0.346	0.225	0.182	0.152	0.132	0.108
24.000	24.000	-----	0.900	0.372	0.242	0.195	0.163	0.142	0.116
26.000	26.000	-----	0.961	0.397	0.259	0.208	0.174	0.151	0.124
28.000	28.000	-----	1.021	0.420	0.275	0.221	0.185	0.161	0.132
30.000	30.000	-----	1.079	0.442	0.291	0.233	0.195	0.170	0.139
32.000	32.000	-----	1.136	0.463	0.306	0.245	0.205	0.178	0.146
34.000	34.000	-----	1.185	0.482	0.320	0.255	0.214	0.186	0.152
36.000	36.000	-----	1.231	0.497	0.333	0.266	0.222	0.193	0.158
38.000	38.000	-----	1.274	0.509	0.345	0.275	0.230	0.200	0.163
40.000	40.000	-----	1.315	0.520	0.357	0.285	0.238	0.207	0.169
42.000	42.000	-----	1.354	0.515	0.368	0.294	0.246	0.213	0.174
44.000	44.000	-----	1.390	0.511	0.378	0.302	0.253	0.219	0.179
46.000	46.000	-----	1.424	0.526	0.388	0.310	0.260	0.225	0.183
48.000	48.000	-----	1.456	0.540	0.397	0.318	0.267	0.231	0.188
50.000	50.000	-----	1.485	0.553	0.405	0.325	0.274	0.236	0.192
52.000	52.000	-----	1.512	0.566	0.414	0.332	0.280	0.241	0.196
54.000	54.000	-----	1.536	0.578	0.422	0.339	0.286	0.246	0.200
56.000	56.000	-----	1.557	0.589	0.430	0.346	0.291	0.251	0.203
58.000	58.000	-----	1.575	0.600	0.438	0.352	0.296	0.255	0.207
60.000	60.000	-----	1.589	0.610	0.445	0.358	0.301	0.259	0.210

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	12.000	1356.06	69.68	17.24	10.76	7.63	6.89	6.89	6.89
14.000	14.000	1310.64	68.92	17.07	10.67	7.46	5.60	5.32	5.32
16.000	16.000	1271.73	67.12	16.73	10.36	7.26	5.38	4.23	4.23
18.000	18.000	----	65.52	16.26	10.13	7.10	5.28	4.13	3.47
20.000	20.000	----	63.87	15.90	9.86	6.97	5.20	4.06	2.91
22.000	22.000	----	62.49	15.60	9.64	6.82	5.02	3.95	2.82
24.000	24.000	----	80.76	15.21	9.40	6.63	4.88	3.85	2.75
26.000	26.000	----	78.45	14.82	9.21	6.47	4.76	3.74	2.69
28.000	28.000	----	76.36	14.51	8.99	6.32	4.65	3.67	2.64
30.000	30.000	----	74.29	14.28	8.80	6.15	4.52	3.59	2.56
32.000	32.000	----	72.37	14.06	8.58	6.00	4.41	3.48	2.49
34.000	34.000	----	69.76	13.81	8.35	5.79	4.28	3.38	2.41
36.000	36.000	----	67.15	13.49	8.10	5.64	4.13	3.27	2.34
38.000	38.000	----	64.55	13.14	7.85	5.44	4.00	3.17	2.25
40.000	40.000	----	62.07	12.80	7.64	5.30	3.89	3.08	2.19
42.000	42.000	----	59.68	12.53	7.43	5.14	3.79	2.98	2.12
44.000	44.000	----	57.31	12.29	7.21	4.97	3.67	2.89	2.06
46.000	46.000	----	55.03	11.93	7.02	4.81	3.57	2.80	1.98
48.000	48.000	----	52.84	11.56	6.81	4.67	3.48	2.73	1.93
50.000	50.000	----	50.66	11.19	6.60	4.52	3.39	2.64	1.87
52.000	52.000	----	48.55	10.85	6.42	4.38	3.29	2.56	1.81
54.000	54.000	----	46.46	10.51	6.22	4.26	3.20	2.49	1.76
56.000	56.000	----	44.39	10.16	6.03	4.14	3.10	2.42	1.70
58.000	58.000	----	42.35	9.85	5.86	4.02	3.01	2.34	1.65
60.000	60.000	----	40.28	9.54	5.68	3.91	2.92	2.27	1.60

Table D-2.c.2. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 30 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.25

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	15.000	2.121	0.482	0.225	0.158	0.115	0.100	0.100	0.100
14.000	17.500	2.432	0.559	0.260	0.179	0.132	0.112	0.100	0.100
16.000	20.000	-----	0.630	0.291	0.189	0.149	0.126	0.109	0.100
18.000	22.500	-----	0.699	0.322	0.205	0.165	0.139	0.120	0.100
20.000	25.000	-----	0.886	0.353	0.219	0.180	0.152	0.131	0.108
22.000	27.500	-----	0.960	0.381	0.238	0.195	0.164	0.142	0.117
24.000	30.000	-----	1.032	0.406	0.255	0.210	0.176	0.152	0.125
26.000	32.500	-----	1.101	0.431	0.273	0.224	0.188	0.162	0.134
28.000	35.000	-----	1.169	0.465	0.289	0.237	0.198	0.171	0.141
30.000	37.500	-----	1.235	0.498	0.304	0.249	0.208	0.179	0.148
32.000	40.000	-----	1.293	0.527	0.318	0.260	0.217	0.187	0.155
34.000	42.500	-----	1.346	0.546	0.332	0.270	0.225	0.195	0.161
36.000	45.000	-----	1.395	0.563	0.345	0.281	0.234	0.202	0.167
38.000	47.500	-----	1.443	0.580	0.357	0.290	0.242	0.209	0.173
40.000	50.000	-----	1.487	0.596	0.369	0.299	0.249	0.216	0.178
42.000	52.500	-----	1.529	0.611	0.380	0.308	0.257	0.222	0.183
44.000	55.000	-----	1.568	0.624	0.391	0.316	0.263	0.229	0.188
46.000	57.500	-----	1.604	0.633	0.402	0.323	0.270	0.234	0.193
48.000	60.000	-----	1.637	0.633	0.411	0.330	0.276	0.240	0.197
50.000	62.500	-----	1.666	0.587	0.421	0.337	0.282	0.245	0.201
52.000	65.000	-----	1.692	0.572	0.429	0.343	0.288	0.250	0.205

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	15.000	1339.45	69.17	15.87	9.99	7.39	5.72	5.72	5.72
14.000	17.500	1293.83	68.36	15.63	9.81	7.17	5.32	4.38	4.38
16.000	20.000	----	66.47	15.12	9.77	7.01	5.18	4.06	3.52
18.000	22.500	----	64.66	14.73	9.70	6.81	5.00	3.93	2.87
20.000	25.000	----	84.14	14.42	9.54	6.58	4.86	3.82	2.73
22.000	27.500	----	81.64	13.99	9.32	6.40	4.70	3.72	2.66
24.000	30.000	----	79.28	13.57	9.01	6.25	4.57	3.60	2.56
26.000	32.500	----	76.88	13.22	8.80	6.08	4.47	3.50	2.52
28.000	35.000	----	74.73	13.25	8.52	5.88	4.31	3.38	2.42
30.000	37.500	----	72.66	13.24	8.23	5.68	4.18	3.25	2.33
32.000	40.000	----	70.00	13.11	7.92	5.47	4.03	3.13	2.26
34.000	42.500	----	67.20	12.69	7.66	5.25	3.88	3.03	2.17
36.000	45.000	----	64.38	12.27	7.39	5.10	3.77	2.92	2.09
38.000	47.500	----	61.83	11.85	7.13	4.90	3.64	2.82	2.03
40.000	50.000	----	59.25	11.44	6.89	4.72	3.50	2.73	1.95
42.000	52.500	----	56.82	11.05	6.65	4.57	3.39	2.63	1.88
44.000	55.000	----	54.45	10.65	6.43	4.42	3.26	2.56	1.81
46.000	57.500	----	52.13	10.28	6.24	4.27	3.16	2.46	1.76
48.000	60.000	----	49.87	10.00	6.01	4.12	3.05	2.39	1.69
50.000	62.500	----	47.60	9.76	5.83	4.00	2.95	2.30	1.63
52.000	65.000	----	45.39	9.63	5.62	3.86	2.85	2.23	1.58

Table D-2.e.3. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 30 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.50

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	18.000	2.363	0.539	0.258	0.182	0.121	0.103	0.100	0.100
14.000	21.000	-----	0.623	0.297	0.211	0.139	0.119	0.104	0.100
16.000	24.000	-----	0.701	0.335	0.236	0.156	0.133	0.117	0.100
18.000	27.000	-----	0.899	0.372	0.259	0.173	0.147	0.129	0.105
20.000	30.000	-----	0.986	0.407	0.281	0.189	0.161	0.141	0.115
22.000	33.000	-----	1.067	0.440	0.302	0.204	0.174	0.152	0.124
24.000	36.000	-----	1.145	0.472	0.322	0.219	0.187	0.163	0.132
26.000	39.000	-----	1.222	0.501	0.341	0.232	0.198	0.171	0.140
28.000	42.000	-----	1.297	0.529	0.305	0.245	0.208	0.180	0.147
30.000	45.000	-----	1.367	0.553	0.312	0.257	0.218	0.188	0.154
32.000	48.000	-----	1.426	0.574	0.326	0.268	0.227	0.195	0.161
34.000	51.000	-----	1.483	0.592	0.340	0.279	0.236	0.203	0.167
36.000	54.000	-----	1.536	0.609	0.353	0.289	0.245	0.210	0.173
38.000	57.000	-----	1.587	0.625	0.365	0.299	0.252	0.216	0.179
40.000	60.000	-----	1.634	0.639	0.377	0.308	0.259	0.223	0.184
42.000	63.000	-----	1.678	0.645	0.387	0.317	0.265	0.228	0.189
44.000	66.000	-----	1.718	0.666	0.398	0.325	0.271	0.234	0.194
46.000	69.000	-----	1.755	0.696	0.407	0.333	0.277	0.239	0.198
48.000	72.000	-----	1.788	0.819	0.416	0.340	0.282	0.244	0.202

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	18.000	1326.41	69.01	15.81	9.18	7.20	5.29	5.00	5.00
14.000	21.000	----	67.74	15.39	9.13	6.99	5.19	4.01	3.72
16.000	24.000	----	65.66	15.00	8.96	6.75	4.97	3.89	2.99
18.000	27.000	----	85.33	14.61	8.77	6.57	4.81	3.74	2.67
20.000	30.000	----	83.14	14.17	8.53	6.36	4.68	3.63	2.60
22.000	33.000	----	80.46	13.68	8.29	6.13	4.52	3.49	2.52
24.000	36.000	----	77.86	13.26	8.06	5.95	4.39	3.39	2.41
26.000	39.000	----	75.56	12.86	7.84	5.70	4.20	3.23	2.32
28.000	42.000	----	73.40	12.49	7.76	5.49	4.01	3.12	2.22
30.000	45.000	----	71.02	12.04	7.61	5.27	3.84	3.00	2.13
32.000	48.000	----	67.93	11.55	7.34	5.04	3.67	2.88	2.06
34.000	51.000	----	65.08	11.05	7.09	4.85	3.52	2.78	1.97
36.000	54.000	----	62.27	10.58	6.82	4.65	3.40	2.67	1.90
38.000	57.000	----	59.66	10.14	6.56	4.48	3.27	2.55	1.83
40.000	60.000	----	57.08	9.71	6.33	4.29	3.15	2.47	1.75
42.000	63.000	----	54.60	9.28	6.06	4.13	3.03	2.36	1.68
44.000	66.000	----	52.15	9.16	5.85	3.97	2.93	2.27	1.62
46.000	69.000	----	49.79	9.16	5.60	3.82	2.82	2.18	1.56
48.000	72.000	----	47.46	8.04	5.39	3.66	2.70	2.10	1.49

Table D-2.e.4. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 30 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.75

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	21.000	-----	0.572	0.274	0.194	0.151	0.106	0.100	0.100
14.000	24.500	-----	0.660	0.315	0.221	0.172	0.121	0.107	0.100
16.000	28.000	-----	0.858	0.355	0.247	0.191	0.136	0.119	0.100
18.000	31.500	-----	0.952	0.394	0.271	0.206	0.150	0.131	0.107
20.000	35.000	-----	1.043	0.431	0.291	0.207	0.163	0.143	0.117
22.000	38.500	-----	1.128	0.466	0.313	0.215	0.176	0.154	0.125
24.000	42.000	-----	1.211	0.500	0.341	0.225	0.188	0.163	0.133
26.000	45.500	-----	1.292	0.533	0.367	0.236	0.198	0.172	0.141
28.000	49.000	-----	1.371	0.566	0.383	0.246	0.208	0.180	0.147
30.000	52.500	-----	1.439	0.592	0.396	0.256	0.218	0.188	0.154
32.000	56.000	-----	1.501	0.618	0.409	0.267	0.227	0.195	0.160
34.000	59.500	-----	1.560	0.641	0.419	0.278	0.235	0.202	0.166
36.000	63.000	-----	1.615	0.663	0.424	0.287	0.243	0.208	0.172
38.000	66.500	-----	1.667	0.680	0.393	0.296	0.250	0.214	0.178
40.000	70.000	-----	1.715	0.696	0.383	0.305	0.256	0.220	0.182
42.000	73.500	-----	1.760	0.710	0.389	0.313	0.261	0.225	0.187
44.000	77.000	-----	1.800	0.853	0.395	0.319	0.266	0.229	0.191

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	21.000	----	68.81	15.79	8.38	6.18	5.06	4.58	4.58
14.000	24.500	----	67.31	15.33	8.11	6.00	4.91	3.88	3.43
16.000	28.000	----	87.09	14.91	7.87	5.85	4.76	3.69	2.72
18.000	31.500	----	84.72	14.51	7.61	5.74	4.58	3.54	2.50
20.000	35.000	----	82.37	14.07	7.30	5.70	4.39	3.43	2.44
22.000	38.500	----	79.62	13.59	7.12	5.67	4.23	3.30	2.31
24.000	42.000	----	77.11	13.15	7.11	5.46	4.07	3.13	2.21
26.000	45.500	----	74.79	12.73	7.06	5.24	3.85	2.98	2.12
28.000	49.000	----	72.61	12.38	6.82	5.02	3.68	2.84	2.00
30.000	52.500	----	69.68	11.79	6.55	4.79	3.53	2.73	1.92
32.000	56.000	----	66.64	11.30	6.30	4.59	3.38	2.61	1.83
34.000	59.500	----	63.76	10.76	6.03	4.42	3.23	2.50	1.75
36.000	63.000	----	60.95	10.31	5.81	4.21	3.09	2.38	1.68
38.000	66.500	----	58.28	9.84	5.70	4.02	2.95	2.27	1.62
40.000	70.000	----	55.67	9.40	5.61	3.86	2.82	2.18	1.54
42.000	73.500	----	53.18	8.96	5.38	3.70	2.69	2.07	1.48
44.000	77.000	----	50.69	11.38	5.16	3.52	2.57	1.97	1.41

Table D-2.e.5. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 30 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 2.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	24.000	-----	0.604	0.289	0.210	0.161	0.128	0.100	0.100
14.000	28.000	-----	0.695	0.332	0.241	0.186	0.143	0.109	0.100
16.000	32.000	-----	0.903	0.373	0.270	0.207	0.150	0.121	0.100
18.000	36.000	-----	1.002	0.414	0.297	0.227	0.156	0.134	0.110
20.000	40.000	-----	1.096	0.453	0.323	0.246	0.165	0.145	0.119
22.000	44.000	-----	1.186	0.489	0.348	0.263	0.177	0.155	0.126
24.000	48.000	-----	1.272	0.525	0.371	0.275	0.188	0.164	0.134
26.000	52.000	-----	1.357	0.560	0.384	0.283	0.199	0.173	0.141
28.000	56.000	-----	1.438	0.592	0.393	0.287	0.209	0.181	0.148
30.000	60.000	-----	1.506	0.620	0.403	0.270	0.218	0.188	0.154
32.000	64.000	-----	1.570	0.646	0.430	0.266	0.226	0.195	0.160
34.000	68.000	-----	1.630	0.670	0.445	0.276	0.234	0.201	0.165
36.000	72.000	-----	1.687	0.693	0.455	0.285	0.241	0.206	0.171
38.000	76.000	-----	1.740	0.825	0.463	0.293	0.247	0.212	0.176
40.000	80.000	-----	1.789	0.848	0.468	0.301	0.252	0.217	0.180
42.000	84.000	-----	1.834	0.869	0.467	0.308	0.257	0.222	0.185

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	24.000	----	68.84	15.76	8.34	5.67	4.51	4.22	4.22
14.000	28.000	----	66.96	15.28	8.10	5.60	4.42	3.71	3.15
16.000	32.000	----	86.55	14.77	7.83	5.42	4.35	3.51	2.50
18.000	36.000	----	84.20	14.37	7.53	5.26	4.30	3.40	2.41
20.000	40.000	----	81.60	13.94	7.26	5.10	4.14	3.24	2.30
22.000	44.000	----	78.97	13.42	7.00	4.92	3.95	3.08	2.15
24.000	48.000	----	76.33	13.00	6.74	4.68	3.75	2.92	2.06
26.000	52.000	----	74.02	12.61	6.38	4.55	3.59	2.79	1.95
28.000	56.000	----	71.67	12.15	5.99	4.43	3.42	2.65	1.85
30.000	60.000	----	68.47	11.61	5.68	4.37	3.25	2.52	1.75
32.000	64.000	----	65.41	11.07	5.68	4.20	3.09	2.40	1.66
34.000	68.000	----	62.45	10.55	5.50	4.02	2.96	2.27	1.57
36.000	72.000	----	59.67	10.07	5.27	3.83	2.82	2.15	1.51
38.000	76.000	----	56.97	9.61	5.04	3.64	2.68	2.05	1.44
40.000	80.000	----	54.35	9.16	4.80	3.47	2.54	1.95	1.37
42.000	84.000	----	51.81	11.63	4.59	3.31	2.41	1.85	1.31

Table D-2.e.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 30 Pounds TNT at Various Standoff Distances--
Aspect Ratio, a/b = 3.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	36.000	-----	0.655	0.313	0.228	0.182	0.149	0.130	0.104
14.000	42.000	-----	0.867	0.358	0.261	0.207	0.168	0.146	0.115
16.000	48.000	-----	0.976	0.403	0.292	0.230	0.190	0.161	0.125
18.000	54.000	-----	1.078	0.445	0.321	0.252	0.209	0.174	0.132
20.000	60.000	-----	1.175	0.485	0.350	0.272	0.224	0.187	0.117
22.000	66.000	-----	1.269	0.524	0.376	0.287	0.236	0.198	0.125
24.000	72.000	-----	1.361	0.561	0.398	0.301	0.246	0.206	0.134
26.000	78.000	-----	1.439	0.592	0.419	0.314	0.255	0.208	0.143
28.000	84.000	-----	1.510	0.621	0.435	0.332	0.265	0.211	0.151
30.000	90.000	-----	1.576	0.648	0.450	0.344	0.273	0.207	0.159
32.000	96.000	-----	1.638	0.673	0.463	0.354	0.280	0.183	0.167
34.000	102.000	-----	1.695	0.696	0.473	0.358	0.277	0.191	0.174

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	36.000	----	67.33	15.38	8.16	5.28	3.74	2.96	2.13
14.000	42.000	----	86.68	14.78	7.85	5.05	3.52	2.80	2.03
16.000	48.000	----	84.10	14.34	7.53	4.81	3.46	2.65	1.94
18.000	54.000	----	81.06	13.81	7.19	4.60	3.33	2.50	1.84
20.000	60.000	----	78.01	13.29	6.92	4.37	3.13	2.38	1.80
22.000	66.000	----	75.20	12.82	6.60	4.07	2.92	2.24	1.70
24.000	72.000	----	72.68	12.35	6.22	3.80	2.73	2.11	1.58
26.000	78.000	----	69.23	11.72	5.87	3.56	2.55	1.99	1.49
28.000	84.000	----	65.73	11.12	5.50	3.45	2.42	1.88	1.38
30.000	90.000	----	62.37	10.54	5.18	3.26	2.28	1.78	1.28
32.000	96.000	----	59.22	10.00	4.87	3.06	2.15	1.74	1.21
34.000	102.000	----	56.17	9.47	4.55	2.84	2.02	1.62	1.12

Table D-2.e.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 30 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	48.000	-----	0.672	0.321	0.234	0.188	0.156	0.135	0.111
14.000	56.000	-----	0.890	0.368	0.267	0.214	0.177	0.154	0.125
16.000	64.000	-----	0.999	0.412	0.298	0.238	0.197	0.171	0.136
18.000	72.000	-----	1.100	0.454	0.328	0.261	0.214	0.185	0.145
20.000	80.000	-----	1.198	0.494	0.356	0.280	0.229	0.197	0.152
22.000	88.000	-----	1.293	0.534	0.379	0.297	0.245	0.207	0.158
24.000	96.000	-----	1.376	0.566	0.401	0.312	0.257	0.215	0.162
26.000	104.000	-----	1.450	0.596	0.420	0.325	0.269	0.222	0.159
28.000	112.000	-----	1.518	0.624	0.438	0.337	0.277	0.226	0.159
30.000	120.000	-----	1.581	0.650	0.453	0.347	0.282	0.228	0.166

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	48.000	----	66.14	15.09	8.02	5.18	3.62	2.74	1.92
14.000	56.000	----	85.24	14.57	7.67	4.93	3.43	2.63	1.81
16.000	64.000	----	82.23	13.99	7.32	4.68	3.26	2.49	1.68
18.000	72.000	----	78.77	13.42	7.00	4.46	3.05	2.31	1.55
20.000	80.000	----	75.68	12.87	6.68	4.17	2.84	2.14	1.42
22.000	88.000	----	72.86	12.43	6.26	3.89	2.69	1.98	1.31
24.000	96.000	----	69.33	11.73	5.89	3.62	2.49	1.82	1.21
26.000	104.000	----	65.60	11.08	5.50	3.36	2.34	1.69	1.10
28.000	112.000	----	61.99	10.48	5.16	3.12	2.16	1.56	1.03
30.000	120.000	----	58.58	9.90	4.82	2.89	1.98	1.42	0.96

Table D-2.f.1. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 10 Pounds TNT at Various Standoff Distances--
Aspect Ratio, a/b = 1.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	12.000	0.993	0.268	0.130	0.100	0.100	0.100	0.100	0.100
14.000	14.000	1.135	0.307	0.149	0.110	0.100	0.100	0.100	0.100
16.000	16.000	1.266	0.344	0.167	0.123	0.100	0.100	0.100	0.100
18.000	18.000	1.393	0.378	0.184	0.135	0.108	0.100	0.100	0.100
20.000	20.000	1.514	0.410	0.201	0.147	0.118	0.101	0.100	0.100
22.000	22.000	1.612	0.441	0.217	0.159	0.127	0.108	0.100	0.100
24.000	24.000	1.703	0.468	0.231	0.168	0.135	0.115	0.101	0.100
26.000	26.000	1.787	0.492	0.244	0.177	0.142	0.121	0.106	0.100
28.000	28.000	1.862	0.520	0.256	0.186	0.149	0.127	0.111	0.100
30.000	30.000	1.929	0.551	0.268	0.194	0.156	0.132	0.116	0.100
32.000	32.000	1.988	0.572	0.278	0.202	0.162	0.137	0.120	0.100
34.000	34.000	2.036	0.590	0.287	0.209	0.168	0.142	0.124	0.102
36.000	36.000	2.073	0.607	0.296	0.216	0.173	0.147	0.128	0.105
38.000	38.000	2.110	0.622	0.304	0.223	0.178	0.151	0.132	0.108
40.000	40.000	2.149	0.634	0.312	0.229	0.183	0.155	0.135	0.110
42.000	42.000	2.178	0.644	0.319	0.234	0.187	0.158	0.138	0.113
44.000	44.000	2.197	0.646	0.326	0.239	0.191	0.161	0.141	0.115
46.000	46.000	2.201	0.652	0.332	0.244	0.194	0.164	0.143	0.119
48.000	48.000	2.194	0.652	0.339	0.249	0.198	0.167	0.146	0.123
50.000	50.000	2.214	0.648	0.345	0.254	0.202	0.170	0.148	0.127
52.000	52.000	2.224	0.604	0.351	0.259	0.205	0.173	0.151	0.131
54.000	54.000	2.223	0.611	0.357	0.263	0.209	0.176	0.153	0.134
56.000	56.000	2.206	0.616	0.362	0.266	0.211	0.178	0.155	0.138
58.000	58.000	2.167	0.623	0.366	0.270	0.214	0.180	0.157	0.141
60.000	60.000	2.135	0.631	0.370	0.272	0.216	0.182	0.159	0.145

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	12.000	393.24	28.64	10.76	6.89	6.89	6.89	6.89	6.89
14.000	14.000	377.44	27.70	10.40	6.27	5.32	5.32	5.32	5.32
16.000	16.000	359.54	26.77	10.02	6.04	4.23	4.23	4.23	4.23
18.000	18.000	343.93	25.70	9.63	5.79	3.95	3.47	3.47	3.47
20.000	20.000	329.09	24.66	9.35	5.59	3.84	2.96	2.91	2.91
22.000	22.000	308.32	23.72	9.05	5.43	3.70	2.82	2.48	2.48
24.000	24.000	289.15	22.62	8.68	5.14	3.54	2.71	2.18	2.14
26.000	26.000	271.28	21.47	8.31	4.90	3.37	2.58	2.07	1.87
28.000	28.000	253.96	20.79	7.94	4.69	3.23	2.47	1.97	1.66
30.000	30.000	237.43	20.39	7.65	4.48	3.11	2.35	1.89	1.47
32.000	32.000	221.64	19.46	7.33	4.30	2.97	2.24	1.80	1.32
34.000	34.000	205.93	18.49	7.03	4.11	2.85	2.15	1.71	1.24
36.000	36.000	190.42	17.59	6.75	3.95	2.72	2.07	1.64	1.18
38.000	38.000	177.06	16.71	6.47	3.80	2.61	1.98	1.58	1.13
40.000	40.000	165.76	15.81	6.20	3.65	2.51	1.90	1.51	1.07
42.000	42.000	154.43	14.93	5.92	3.49	2.39	1.81	1.44	1.03
44.000	44.000	143.18	14.24	5.67	3.34	2.30	1.72	1.38	0.98
46.000	46.000	131.47	13.81	5.42	3.21	2.19	1.65	1.31	0.94
48.000	48.000	119.98	13.30	5.22	3.09	2.11	1.58	1.27	0.91
50.000	50.000	112.60	12.77	5.01	2.99	2.04	1.52	1.21	0.88
52.000	52.000	105.05	12.29	4.83	2.89	1.95	1.47	1.17	0.85
54.000	54.000	97.32	11.69	4.66	2.78	1.89	1.42	1.12	0.80
56.000	56.000	89.12	11.08	4.48	2.67	1.81	1.36	1.08	0.78
58.000	58.000	80.16	10.58	4.30	2.58	1.75	1.31	1.04	0.74
60.000	60.000	72.71	10.16	4.13	2.47	1.68	1.26	1.00	0.72

Table D-2.f.2. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 10 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.25**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	15.000	1.141	0.308	0.155	0.104	0.100	0.100	0.100	0.100
14.000	17.500	1.300	0.353	0.164	0.119	0.100	0.100	0.100	0.100
16.000	20.000	1.450	0.395	0.176	0.133	0.106	0.100	0.100	0.100
18.000	22.500	1.594	0.434	0.194	0.146	0.116	0.100	0.100	0.100
20.000	25.000	1.719	0.473	0.211	0.158	0.125	0.107	0.100	0.100
22.000	27.500	1.828	0.508	0.225	0.168	0.134	0.114	0.101	0.100
24.000	30.000	1.928	0.538	0.239	0.178	0.141	0.121	0.107	0.100
26.000	32.500	2.018	0.564	0.252	0.187	0.149	0.128	0.112	0.100
28.000	35.000	2.097	0.587	0.264	0.195	0.156	0.133	0.117	0.100
30.000	37.500	2.167	0.608	0.276	0.203	0.162	0.139	0.122	0.101
32.000	40.000	2.224	0.627	0.286	0.210	0.168	0.144	0.127	0.105
34.000	42.500	2.267	0.641	0.296	0.216	0.174	0.149	0.131	0.108
36.000	45.000	2.310	0.652	0.305	0.223	0.179	0.153	0.134	0.111
38.000	47.500	2.354	0.659	0.313	0.228	0.184	0.157	0.137	0.114
40.000	50.000	2.387	0.663	0.320	0.233	0.188	0.160	0.140	0.117
42.000	52.500	2.405	0.697	0.328	0.238	0.192	0.164	0.144	0.121
44.000	55.000	2.406	0.708	0.335	0.244	0.197	0.168	0.147	0.125
46.000	57.500	2.408	0.811	0.341	0.249	0.201	0.171	0.150	0.130
48.000	60.000	2.427	0.805	0.347	0.254	0.204	0.174	0.152	0.134
50.000	62.500	2.434	0.829	0.351	0.258	0.208	0.176	0.154	0.138
52.000	65.000	2.425	0.692	0.355	0.262	0.210	0.179	0.156	0.141

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	15.000	387.63	28.25	9.87	6.14	5.72	5.72	5.72	5.72
14.000	17.500	369.69	27.26	9.75	5.93	4.38	4.38	4.38	4.38
16.000	20.000	352.13	26.13	9.63	5.69	3.89	3.52	3.52	3.52
18.000	22.500	336.23	24.93	9.26	5.45	3.71	2.87	2.87	2.87
20.000	25.000	316.74	23.98	8.89	5.21	3.52	2.69	2.39	2.39
22.000	27.500	296.02	22.86	8.37	4.91	3.37	2.54	2.06	2.02
24.000	30.000	276.69	21.55	7.95	4.66	3.16	2.42	1.95	1.74
26.000	32.500	258.29	20.29	7.55	4.43	3.03	2.32	1.84	1.51
28.000	35.000	240.48	19.13	7.17	4.21	2.88	2.18	1.75	1.33
30.000	37.500	223.71	18.05	6.86	4.02	2.73	2.09	1.66	1.20
32.000	40.000	207.10	17.04	6.50	3.83	2.60	1.99	1.60	1.14
34.000	42.500	190.61	16.01	6.19	3.62	2.49	1.90	1.51	1.08
36.000	45.000	176.53	15.02	5.89	3.47	2.36	1.80	1.43	1.03
38.000	47.500	164.53	14.02	5.60	3.28	2.26	1.71	1.35	0.98
40.000	50.000	152.68	13.22	5.32	3.12	2.14	1.62	1.28	0.94
42.000	52.500	140.58	13.24	5.10	2.97	2.04	1.55	1.24	0.89
44.000	55.000	128.20	12.72	4.88	2.86	1.97	1.49	1.18	0.84
46.000	57.500	117.49	10.79	4.66	2.74	1.89	1.42	1.13	0.82
48.000	60.000	109.61	10.06	4.47	2.64	1.80	1.36	1.08	0.78
50.000	62.500	101.60	9.92	4.26	2.52	1.73	1.29	1.02	0.75
52.000	65.000	93.24	10.06	4.08	2.42	1.64	1.24	0.98	0.70

Table D-2.f.3. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 10 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.50

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	18.000	1.271	0.343	0.182	0.110	0.100	0.100	0.100	0.100
14.000	21.000	1.444	0.393	0.205	0.125	0.102	0.100	0.100	0.100
16.000	24.000	1.610	0.438	0.226	0.139	0.113	0.100	0.100	0.100
18.000	27.000	1.768	0.482	0.246	0.152	0.123	0.104	0.100	0.100
20.000	30.000	1.896	0.525	0.261	0.163	0.132	0.112	0.100	0.100
22.000	33.000	2.013	0.560	0.233	0.174	0.140	0.119	0.105	0.100
24.000	36.000	2.119	0.592	0.244	0.185	0.147	0.125	0.111	0.100
26.000	39.000	2.213	0.622	0.257	0.194	0.154	0.132	0.116	0.100
28.000	42.000	2.296	0.649	0.269	0.202	0.161	0.137	0.121	0.101
30.000	45.000	2.364	0.673	0.280	0.210	0.167	0.143	0.126	0.105
32.000	48.000	2.418	0.694	0.290	0.217	0.172	0.147	0.130	0.108
34.000	51.000	2.462	0.823	0.299	0.222	0.177	0.152	0.134	0.111
36.000	54.000	-----	0.840	0.307	0.227	0.182	0.156	0.137	0.115
38.000	57.000	-----	0.852	0.316	0.232	0.187	0.160	0.141	0.120
40.000	60.000	-----	0.869	0.324	0.238	0.192	0.164	0.144	0.125
42.000	63.000	-----	0.883	0.332	0.243	0.196	0.167	0.148	0.129
44.000	66.000	-----	0.893	0.338	0.247	0.200	0.171	0.150	0.134
46.000	69.000	-----	0.895	0.344	0.250	0.203	0.173	0.152	0.138
48.000	72.000	-----	0.885	0.348	0.254	0.206	0.176	0.155	0.142

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	18.000	383.75	27.95	9.18	6.00	5.00	5.00	5.00	5.00
14.000	21.000	363.91	26.96	8.90	5.70	3.86	3.72	3.72	3.72
16.000	24.000	346.36	25.63	8.58	5.41	3.64	2.99	2.99	2.99
18.000	27.000	330.02	24.53	8.24	5.13	3.42	2.63	2.45	2.45
20.000	30.000	307.42	23.57	7.79	4.79	3.25	2.49	2.04	2.04
22.000	33.000	286.39	22.16	7.67	4.52	3.07	2.34	1.87	1.72
24.000	36.000	266.66	20.81	7.31	4.30	2.90	2.19	1.77	1.47
26.000	39.000	247.82	19.58	6.93	4.04	2.74	2.09	1.66	1.27
28.000	42.000	230.01	18.38	6.56	3.79	2.60	1.96	1.57	1.13
30.000	45.000	212.41	17.21	6.21	3.58	2.46	1.87	1.49	1.07
32.000	48.000	195.31	16.09	5.87	3.38	2.32	1.75	1.40	1.00
34.000	51.000	179.36	15.03	5.54	3.19	2.19	1.66	1.33	0.95
36.000	54.000	----	13.97	5.22	3.03	2.08	1.57	1.25	0.89
38.000	57.000	----	17.20	4.98	2.89	1.98	1.49	1.19	0.85
40.000	60.000	----	16.14	4.73	2.76	1.89	1.43	1.13	0.82
42.000	63.000	----	15.12	4.52	2.63	1.80	1.35	1.09	0.76
44.000	66.000	----	14.09	4.27	2.50	1.72	1.29	1.02	0.74
46.000	69.000	----	13.05	4.06	2.36	1.63	1.22	0.97	0.69
48.000	72.000	----	12.04	3.83	2.25	1.55	1.17	0.93	0.66

Table D-2.f.4. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 10 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.75

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	21.000	1.346	0.363	0.191	0.114	0.100	0.100	0.100	0.100
14.000	24.500	1.527	0.415	0.214	0.129	0.103	0.100	0.100	0.100
16.000	28.000	1.701	0.463	0.234	0.141	0.114	0.100	0.100	0.100
18.000	31.500	1.862	0.510	0.256	0.152	0.124	0.105	0.100	0.100
20.000	35.000	1.995	0.554	0.281	0.163	0.132	0.112	0.100	0.100
22.000	38.500	2.116	0.590	0.294	0.174	0.140	0.119	0.105	0.100
24.000	42.000	2.225	0.623	0.306	0.184	0.147	0.125	0.111	0.100
26.000	45.500	2.321	0.653	0.315	0.192	0.153	0.131	0.116	0.100
28.000	49.000	2.403	0.681	0.288	0.200	0.159	0.136	0.121	0.103
30.000	52.500	2.470	0.706	0.282	0.206	0.164	0.141	0.125	0.108
32.000	56.000	-----	0.839	0.287	0.212	0.168	0.145	0.129	0.113
34.000	59.500	-----	0.860	0.293	0.218	0.174	0.150	0.133	0.119
36.000	63.000	-----	0.875	0.302	0.223	0.179	0.154	0.136	0.124
38.000	66.500	-----	0.891	0.309	0.227	0.183	0.158	0.140	0.129
40.000	70.000	-----	0.907	0.316	0.231	0.187	0.161	0.145	0.133
42.000	73.500	-----	0.919	0.322	0.235	0.191	0.164	0.150	0.138
44.000	77.000	-----	0.927	0.326	0.238	0.194	0.166	0.155	0.142

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	21.000	381.04	27.71	8.20	5.56	4.58	4.58	4.58	4.58
14.000	24.500	360.30	26.61	7.77	5.34	3.62	3.43	3.43	3.43
16.000	28.000	342.31	25.36	7.34	5.04	3.41	2.72	2.72	2.72
18.000	31.500	324.09	24.31	7.12	4.70	3.21	2.43	2.22	2.22
20.000	35.000	301.35	23.24	7.02	4.39	2.97	2.25	1.83	1.83
22.000	38.500	280.18	21.78	6.65	4.14	2.80	2.11	1.68	1.53
24.000	42.000	260.30	20.41	6.28	3.90	2.63	1.97	1.58	1.31
26.000	45.500	241.35	19.10	5.90	3.64	2.46	1.85	1.48	1.13
28.000	49.000	223.07	17.92	5.70	3.43	2.31	1.73	1.40	1.03
30.000	52.500	205.30	16.77	5.48	3.19	2.15	1.63	1.31	0.95
32.000	56.000	----	15.61	5.16	2.99	2.00	1.53	1.23	0.88
34.000	59.500	----	19.38	4.88	2.83	1.91	1.45	1.16	0.85
36.000	63.000	----	17.89	4.64	2.68	1.81	1.37	1.09	0.79
38.000	66.500	----	16.65	4.37	2.52	1.71	1.30	1.04	0.75
40.000	70.000	----	15.57	4.13	2.38	1.62	1.23	0.97	0.69
42.000	73.500	----	14.50	3.90	2.25	1.54	1.16	0.92	0.66
44.000	77.000	----	13.44	3.66	2.11	1.45	1.09	0.87	0.61

Table D-2.f.5. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 10 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 2.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	24.000	1.414	0.382	0.207	0.140	0.100	0.100	0.100	0.100
14.000	28.000	1.605	0.436	0.234	0.156	0.105	0.100	0.100	0.100
16.000	32.000	1.787	0.487	0.259	0.165	0.115	0.100	0.100	0.100
18.000	36.000	1.949	0.535	0.281	0.158	0.124	0.105	0.100	0.100
20.000	40.000	2.086	0.580	0.292	0.163	0.132	0.112	0.100	0.100
22.000	44.000	2.210	0.617	0.300	0.173	0.139	0.118	0.105	0.100
24.000	48.000	2.321	0.651	0.322	0.182	0.146	0.124	0.110	0.100
26.000	52.000	2.418	0.682	0.333	0.190	0.151	0.129	0.115	0.102
28.000	56.000	2.499	0.710	0.340	0.197	0.156	0.134	0.119	0.108
30.000	60.000	-----	0.848	0.342	0.203	0.161	0.139	0.124	0.114
32.000	64.000	-----	0.873	0.336	0.209	0.167	0.144	0.130	0.120
34.000	68.000	-----	0.892	0.303	0.214	0.171	0.148	0.136	0.125
36.000	72.000	-----	0.906	0.296	0.218	0.175	0.152	0.142	0.130
38.000	76.000	-----	0.925	0.302	0.221	0.179	0.156	0.147	0.135
40.000	80.000	-----	0.940	0.307	0.224	0.182	0.161	0.152	0.139
42.000	84.000	-----	0.951	0.312	0.228	0.186	0.167	0.157	0.144

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	24.000	377.27	27.53	8.13	4.78	4.22	4.22	4.22	4.22
14.000	28.000	357.12	26.35	7.70	4.59	3.45	3.15	3.15	3.15
16.000	32.000	338.94	25.17	7.29	4.44	3.19	2.50	2.50	2.50
18.000	36.000	318.56	24.00	6.84	4.32	2.96	2.22	2.04	2.04
20.000	40.000	295.59	22.85	6.29	4.05	2.75	2.07	1.66	1.66
22.000	44.000	274.19	21.37	5.78	3.78	2.55	1.90	1.52	1.39
24.000	48.000	254.12	19.99	5.67	3.53	2.39	1.77	1.41	1.18
26.000	52.000	235.01	18.70	5.36	3.28	2.21	1.64	1.32	0.94
28.000	56.000	216.44	17.47	5.02	3.07	2.05	1.53	1.23	0.88
30.000	60.000	----	16.28	4.65	2.87	1.91	1.44	1.16	0.83
32.000	64.000	----	20.22	4.48	2.70	1.81	1.37	1.08	0.78
34.000	68.000	----	18.70	4.35	2.53	1.68	1.28	1.02	0.72
36.000	72.000	----	17.21	4.12	2.37	1.58	1.21	0.96	0.67
38.000	76.000	----	16.10	3.86	2.21	1.49	1.13	0.89	0.63
40.000	80.000	----	15.01	3.61	2.07	1.39	1.04	0.83	0.58
42.000	84.000	----	13.93	3.39	1.95	1.33	0.99	0.77	0.55

Table D-2.f.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 10 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 3.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	36.000	1.516	0.412	0.223	0.157	0.123	0.102	0.100	0.100
14.000	42.000	1.717	0.468	0.252	0.175	0.135	0.108	0.100	0.100
16.000	48.000	1.894	0.521	0.278	0.190	0.146	0.111	0.100	0.100
18.000	54.000	2.042	0.568	0.300	0.206	0.155	0.102	0.100	0.100
20.000	60.000	2.174	0.608	0.318	0.216	0.156	0.111	0.104	0.100
22.000	66.000	2.289	0.644	0.332	0.222	0.153	0.119	0.112	0.103
24.000	72.000	2.386	0.676	0.343	0.227	0.137	0.127	0.119	0.109
26.000	78.000	2.463	0.704	0.351	0.234	0.145	0.134	0.126	0.116
28.000	84.000	-----	0.841	0.355	0.236	0.152	0.141	0.133	0.122
30.000	90.000	-----	0.862	0.361	0.230	0.159	0.148	0.139	0.127
32.000	96.000	-----	0.878	0.374	0.187	0.167	0.155	0.146	0.133
34.000	102.000	-----	0.898	0.377	0.193	0.174	0.161	0.152	0.139

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200.
12.000	36.000	360.71	26.64	7.80	4.09	2.73	2.09	2.06	2.06
14.000	42.000	339.94	25.26	7.32	3.78	2.49	1.92	1.81	1.81
16.000	48.000	316.70	23.96	6.82	3.46	2.29	1.79	1.78	1.78
18.000	54.000	290.86	22.50	6.28	3.25	2.12	1.68	1.55	1.55
20.000	60.000	267.04	20.89	5.73	2.95	1.94	1.54	1.19	1.02
22.000	66.000	244.66	19.37	5.24	2.66	1.79	1.39	1.09	0.78
24.000	72.000	223.38	17.93	4.77	2.42	1.73	1.28	0.98	0.69
26.000	78.000	202.82	16.57	4.32	2.24	1.57	1.15	0.90	0.64
28.000	84.000	----	15.29	3.88	2.08	1.41	1.05	0.83	0.59
30.000	90.000	----	18.66	3.54	1.91	1.28	0.96	0.75	0.52
32.000	96.000	----	17.01	3.37	1.80	1.21	0.90	0.71	0.49
34.000	102.000	----	15.77	3.07	1.69	1.12	0.82	0.65	0.45

Table D-2.f.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Reflected Overpressure from 10 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	48.000	1.546	0.421	0.227	0.164	0.130	0.108	0.100	0.100
14.000	56.000	1.747	0.477	0.256	0.181	0.143	0.117	0.100	0.100
16.000	64.000	1.907	0.530	0.280	0.196	0.153	0.124	0.100	0.100
18.000	72.000	2.049	0.572	0.301	0.209	0.161	0.127	0.101	0.100
20.000	80.000	2.173	0.610	0.319	0.221	0.166	0.128	0.109	0.100
22.000	88.000	2.276	0.644	0.333	0.230	0.169	0.125	0.117	0.107
24.000	96.000	2.357	0.674	0.344	0.236	0.170	0.132	0.124	0.114
26.000	104.000	2.412	0.698	0.352	0.241	0.166	0.139	0.131	0.120
28.000	112.000	2.480	0.828	0.361	0.241	0.158	0.146	0.138	0.126
30.000	120.000	-----	0.846	0.366	0.238	0.166	0.153	0.144	0.132

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	48.000	350.09	25.96	7.55	3.98	2.55	1.83	1.63	1.63
14.000	56.000	328.44	24.49	7.05	3.58	2.28	1.64	1.30	1.30
16.000	64.000	299.63	23.14	6.46	3.23	2.03	1.47	1.12	1.12
18.000	72.000	273.31	21.30	5.90	2.91	1.82	1.28	1.01	0.97
20.000	80.000	248.99	19.62	5.37	2.65	1.62	1.14	0.90	0.64
22.000	88.000	225.74	18.07	4.84	2.38	1.45	1.03	0.82	0.57
24.000	96.000	203.43	16.63	4.36	2.14	1.29	0.93	0.73	0.52
26.000	104.000	181.52	15.20	3.91	1.93	1.14	0.83	0.66	0.46
28.000	112.000	165.46	13.83	3.56	1.72	1.02	0.75	0.60	0.42
30.000	120.000	----	12.58	3.20	1.52	0.96	0.69	0.54	0.38

Table D-3.a.1. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 4,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	1.356	0.646	0.411	0.271	0.226	0.191	0.115	0.100
14.000	14.000	1.578	0.868	0.479	0.315	0.263	0.222	0.134	0.100
16.000	16.000	1.799	0.990	0.546	0.359	0.300	0.253	0.152	0.102
18.000	18.000	2.020	1.110	0.612	0.402	0.336	0.283	0.171	0.114
20.000	20.000	2.238	1.229	0.678	0.445	0.372	0.314	0.189	0.126
22.000	22.000	2.455	1.348	0.858	0.489	0.409	0.344	0.207	0.138
24.000	24.000	-----	1.467	0.934	0.529	0.446	0.374	0.226	0.150
26.000	26.000	-----	1.584	1.009	0.569	0.483	0.404	0.244	0.162
28.000	28.000	-----	1.697	1.080	0.609	0.520	0.432	0.261	0.174
30.000	30.000	-----	1.808	1.151	0.649	0.557	0.460	0.278	0.185
32.000	32.000	-----	1.919	1.222	0.688	0.594	0.488	0.295	0.196
34.000	34.000	-----	2.029	1.292	0.843	0.628	0.516	0.312	0.207
36.000	36.000	-----	2.139	1.362	0.890	0.661	0.543	0.329	0.219
38.000	38.000	-----	2.248	1.432	0.938	0.697	0.570	0.346	0.230
40.000	40.000	-----	2.359	1.502	0.986	0.836	0.597	0.363	0.241
42.000	42.000	-----	2.473	1.574	1.034	0.877	0.626	0.380	0.253
44.000	44.000	-----	-----	1.647	1.081	0.917	0.654	0.398	0.264
46.000	46.000	-----	-----	1.719	1.129	0.957	0.683	0.415	0.276
48.000	48.000	-----	-----	1.791	1.176	0.997	0.834	0.433	0.288
50.000	50.000	-----	-----	1.864	1.223	1.037	0.867	0.450	0.299
52.000	52.000	-----	-----	1.936	1.271	1.076	0.901	0.467	0.311
54.000	54.000	-----	-----	2.008	1.316	1.116	0.934	0.485	0.322
56.000	56.000	-----	-----	2.079	1.359	1.156	0.967	0.502	0.334
58.000	58.000	-----	-----	2.151	1.403	1.192	1.001	0.519	0.345
60.000	60.000	-----	-----	2.223	1.446	1.228	1.034	0.537	0.357

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	733.29	166.43	67.37	29.29	21.30	15.93	8.61	6.89
14.000	14.000	729.58	220.75	67.23	29.07	21.20	15.82	8.59	5.32
16.000	16.000	726.01	219.86	66.87	28.91	21.13	15.75	8.48	4.37
18.000	18.000	723.23	218.38	66.39	28.64	20.97	15.59	8.48	4.32
20.000	20.000	719.08	216.85	66.00	28.43	20.84	15.55	8.41	4.28
22.000	22.000	715.11	215.60	87.35	28.37	20.83	15.44	8.34	4.25
24.000	24.000	----	214.56	86.97	27.95	20.81	15.35	8.36	4.23
26.000	26.000	----	213.15	86.49	27.60	20.80	15.28	8.31	4.20
28.000	28.000	----	210.94	85.44	27.31	20.79	15.09	8.21	4.19
30.000	30.000	----	208.58	84.53	27.06	20.78	14.93	8.13	4.13
32.000	32.000	----	206.52	83.75	26.77	20.77	14.79	8.05	4.08
34.000	34.000	----	204.51	82.92	26.48	20.59	14.67	7.99	4.04
36.000	36.000	----	202.74	82.20	35.10	20.38	14.58	7.93	4.04
38.000	38.000	----	200.97	81.55	34.99	20.35	14.51	7.88	4.00
40.000	40.000	----	199.73	80.97	34.89	19.12	14.45	7.84	3.97
42.000	42.000	----	199.10	80.65	34.81	25.45	14.43	7.80	3.97
44.000	44.000	----	----	80.46	34.66	25.37	14.40	7.80	3.95
46.000	46.000	----	----	80.20	34.59	25.29	14.38	7.76	3.95
48.000	48.000	----	----	79.95	34.47	25.22	13.90	7.76	3.95
50.000	50.000	----	----	79.81	34.36	25.16	18.47	7.73	3.92
52.000	52.000	----	----	79.60	34.31	25.06	18.44	7.71	3.93
54.000	54.000	----	----	79.41	34.11	25.00	18.38	7.71	3.91
56.000	56.000	----	----	79.15	33.82	24.95	18.33	7.69	3.91
58.000	58.000	----	----	78.98	33.60	24.76	18.32	7.67	3.89
60.000	60.000	----	----	78.83	33.35	24.59	18.27	7.67	3.89

Table D-3.a.2. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 4,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.25

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	1.568	0.863	0.476	0.313	0.268	0.213	0.124	0.100
14.000	17.500	1.824	1.004	0.553	0.364	0.311	0.248	0.144	0.100
16.000	20.000	2.080	1.144	0.631	0.414	0.354	0.282	0.164	0.112
18.000	22.500	2.334	1.282	0.707	0.464	0.397	0.316	0.184	0.126
20.000	25.000	-----	1.420	0.904	0.514	0.439	0.350	0.204	0.139
22.000	27.500	-----	1.558	0.992	0.563	0.481	0.383	0.224	0.152
24.000	30.000	-----	1.695	1.079	0.610	0.521	0.416	0.242	0.165
26.000	32.500	-----	1.826	1.163	0.656	0.560	0.447	0.261	0.177
28.000	35.000	-----	1.955	1.245	0.703	0.599	0.477	0.280	0.190
30.000	37.500	-----	2.083	1.327	0.865	0.638	0.507	0.298	0.202
32.000	40.000	-----	2.211	1.408	0.918	0.677	0.536	0.316	0.214
34.000	42.500	-----	2.338	1.489	0.973	0.832	0.565	0.335	0.227
36.000	45.000	-----	2.464	1.569	1.028	0.879	0.597	0.353	0.240
38.000	47.500	-----	-----	1.651	1.084	0.926	0.630	0.372	0.252
40.000	50.000	-----	-----	1.735	1.139	0.973	0.663	0.391	0.265
42.000	52.500	-----	-----	1.819	1.194	1.020	0.697	0.410	0.278
44.000	55.000	-----	-----	1.902	1.249	1.067	0.870	0.429	0.291
46.000	57.500	-----	-----	1.986	1.303	1.114	0.908	0.448	0.303
48.000	60.000	-----	-----	2.069	1.358	1.161	0.946	0.467	0.316
50.000	62.500	-----	-----	2.153	1.412	1.208	0.983	0.486	0.329
52.000	65.000	-----	-----	2.236	1.463	1.255	1.021	0.505	0.341

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	732.04	221.75	67.46	29.17	21.39	14.55	8.54	5.72
14.000	17.500	727.78	220.50	66.90	28.98	21.16	14.50	8.46	4.38
16.000	20.000	724.59	219.19	66.68	28.71	20.99	14.38	8.41	4.24
18.000	22.500	720.88	217.49	66.15	28.49	20.88	14.29	8.36	4.24
20.000	25.000	----	216.13	87.60	28.32	20.70	14.22	8.33	4.20
22.000	27.500	----	215.03	87.17	28.08	20.56	14.10	8.30	4.16
24.000	30.000	----	213.86	86.66	27.70	20.31	14.01	8.15	4.12
26.000	32.500	----	211.48	85.79	27.29	20.04	13.85	8.08	4.06
28.000	35.000	----	209.02	84.77	27.03	19.81	13.69	8.02	4.04
30.000	37.500	----	206.70	83.89	35.64	19.61	13.55	7.92	3.99
32.000	40.000	----	204.68	83.01	35.29	19.44	13.40	7.83	3.95
34.000	42.500	----	202.74	82.23	35.11	19.26	13.26	7.79	3.93
36.000	45.000	----	200.85	81.44	34.96	25.56	13.23	7.72	3.93
38.000	47.500	----	----	80.93	34.89	25.46	13.22	7.70	3.89
40.000	50.000	----	----	80.67	34.76	25.37	13.22	7.68	3.89
42.000	52.500	----	----	80.42	34.65	25.29	13.24	7.66	3.88
44.000	55.000	----	----	80.12	34.55	25.21	17.30	7.64	3.88
46.000	57.500	----	----	79.92	34.40	25.15	17.25	7.62	3.85
48.000	60.000	----	----	79.66	34.32	25.08	17.21	7.61	3.85
50.000	62.500	----	----	79.50	34.19	25.03	17.14	7.59	3.84
52.000	65.000	----	----	79.28	33.94	24.97	17.10	7.58	3.82

Table D-3.a.3. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from *4,000 Pounds TNT at Various Standoff Distances*--
Aspect Ratio, a/b = 1.50

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	1.754	0.965	0.532	0.350	0.299	0.247	0.155	0.100
14.000	21.000	2.041	1.123	0.619	0.407	0.348	0.288	0.179	0.107
16.000	24.000	2.327	1.279	0.705	0.463	0.396	0.328	0.203	0.121
18.000	27.000	-----	1.434	0.913	0.519	0.444	0.367	0.226	0.136
20.000	30.000	-----	1.588	1.011	0.575	0.492	0.407	0.224	0.151
22.000	33.000	-----	1.742	1.109	0.628	0.538	0.446	0.243	0.164
24.000	36.000	-----	1.892	1.205	0.680	0.583	0.484	0.261	0.178
26.000	39.000	-----	2.037	1.297	0.845	0.627	0.521	0.280	0.192
28.000	42.000	-----	2.181	1.389	0.905	0.672	0.558	0.298	0.205
30.000	45.000	-----	2.325	1.480	0.964	0.826	0.594	0.316	0.219
32.000	48.000	-----	2.467	1.571	1.026	0.877	0.630	0.335	0.233
34.000	51.000	-----	-----	1.661	1.088	0.930	0.665	0.355	0.247
36.000	54.000	-----	-----	1.751	1.150	0.983	0.702	0.374	0.261
38.000	57.000	-----	-----	1.846	1.211	1.036	0.857	0.394	0.275
40.000	60.000	-----	-----	1.939	1.273	1.088	0.901	0.414	0.289
42.000	63.000	-----	-----	2.033	1.334	1.141	0.944	0.434	0.303
44.000	66.000	-----	-----	2.127	1.396	1.193	0.988	0.454	0.317
46.000	69.000	-----	-----	2.220	1.457	1.246	1.031	0.474	0.331
48.000	72.000	-----	-----	2.313	1.517	1.298	1.074	0.494	0.344

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	730.82	221.21	67.23	29.10	21.24	14.49	7.69	5.00
14.000	21.000	727.02	220.10	66.87	28.91	21.14	14.48	7.66	4.23
16.000	24.000	723.55	218.58	66.41	28.64	20.95	14.38	7.63	4.15
18.000	27.000	----	217.10	88.01	28.44	20.81	14.22	7.60	4.14
20.000	30.000	----	215.65	87.41	28.27	20.70	14.17	7.86	4.14
22.000	33.000	----	214.47	86.92	27.87	20.46	14.06	7.81	4.04
24.000	36.000	----	212.59	86.23	27.46	20.19	13.91	7.76	4.00
26.000	39.000	----	209.97	85.12	27.10	19.89	13.74	7.72	3.96
28.000	42.000	----	207.54	84.18	35.74	19.70	13.59	7.69	3.90
30.000	45.000	----	205.46	83.25	35.32	19.45	13.41	7.65	3.88
32.000	48.000	----	203.31	82.45	35.17	25.69	13.28	7.63	3.86
34.000	51.000	----	----	81.64	35.03	25.59	13.15	7.62	3.84
36.000	54.000	----	----	80.93	34.91	25.50	13.10	7.61	3.83
38.000	57.000	----	----	80.73	34.74	25.43	17.40	7.60	3.81
40.000	60.000	----	----	80.38	34.65	25.31	17.36	7.57	3.80
42.000	63.000	----	----	80.15	34.51	25.25	17.28	7.55	3.79
44.000	66.000	----	----	79.94	34.43	25.15	17.25	7.53	3.78
46.000	69.000	----	----	79.67	34.32	25.10	17.18	7.51	3.77
48.000	72.000	----	----	79.43	34.17	25.01	17.13	7.49	3.74

Table D-3.a.4. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 4,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.75

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	1.863	1.025	0.565	0.372	0.318	0.263	0.171	0.100
14.000	24.500	2.168	1.193	0.658	0.432	0.369	0.306	0.198	0.110
16.000	28.000	2.471	1.358	0.865	0.492	0.420	0.348	0.225	0.126
18.000	31.500	-----	1.522	0.969	0.551	0.471	0.390	0.252	0.140
20.000	35.000	-----	1.686	1.073	0.610	0.522	0.432	0.279	0.155
22.000	38.500	-----	1.850	1.177	0.666	0.570	0.473	0.304	0.169
24.000	42.000	-----	2.006	1.278	0.833	0.618	0.513	0.328	0.183
26.000	45.500	-----	2.160	1.376	0.897	0.665	0.552	0.353	0.197
28.000	49.000	-----	2.313	1.473	0.960	0.822	0.591	0.377	0.212
30.000	52.500	-----	2.465	1.570	1.023	0.876	0.630	0.401	0.226
32.000	56.000	-----	-----	1.666	1.089	0.931	0.669	0.426	0.241
34.000	59.500	-----	-----	1.761	1.155	0.987	0.708	0.452	0.255
36.000	63.000	-----	-----	1.860	1.221	1.044	0.864	0.477	0.270
38.000	66.500	-----	-----	1.960	1.286	1.100	0.910	0.503	0.284
40.000	70.000	-----	-----	2.059	1.352	1.155	0.956	0.528	0.299
42.000	73.500	-----	-----	2.159	1.417	1.211	1.002	0.553	0.313
44.000	77.000	-----	-----	2.258	1.482	1.267	1.049	0.578	0.327

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	729.98	220.97	67.14	29.11	21.27	14.55	7.13	4.58
14.000	24.500	726.29	219.92	66.90	28.84	21.04	14.47	7.07	4.09
16.000	28.000	722.35	218.18	88.52	28.64	20.87	14.33	7.03	4.11
18.000	31.500	----	216.54	87.77	28.38	20.74	14.22	7.00	4.01
20.000	35.000	----	215.23	87.17	28.17	20.63	14.13	6.97	3.98
22.000	38.500	----	214.16	86.69	27.76	20.33	14.00	6.90	3.92
24.000	42.000	----	211.59	85.88	27.36	20.08	13.84	6.82	3.86
26.000	45.500	----	209.03	84.83	36.05	19.81	13.65	6.77	3.82
28.000	49.000	----	206.67	83.82	35.60	19.58	13.49	6.71	3.81
30.000	52.500	----	204.47	82.95	35.22	25.82	13.36	6.66	3.77
32.000	56.000	----	----	82.09	35.08	25.64	13.24	6.62	3.77
34.000	59.500	----	----	81.25	34.95	25.52	13.13	6.61	3.74
36.000	63.000	----	----	80.85	34.84	25.47	17.44	6.58	3.74
38.000	66.500	----	----	80.57	34.69	25.38	17.37	6.58	3.72
40.000	70.000	----	----	80.25	34.60	25.25	17.30	6.55	3.72
42.000	73.500	----	----	80.03	34.47	25.18	17.24	6.53	3.70
44.000	77.000	----	----	79.76	34.36	25.11	17.21	6.52	3.68

Table D-3.a.5. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 4,000 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 2.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	1.966	1.082	0.596	0.393	0.335	0.277	0.181	0.100
14.000	28.000	2.287	1.258	0.694	0.456	0.390	0.322	0.210	0.114
16.000	32.000	-----	1.433	0.912	0.519	0.443	0.367	0.238	0.129
18.000	36.000	-----	1.606	1.022	0.582	0.497	0.411	0.267	0.144
20.000	40.000	-----	1.779	1.132	0.642	0.550	0.456	0.294	0.159
22.000	44.000	-----	1.951	1.242	0.701	0.601	0.499	0.319	0.173
24.000	48.000	-----	2.114	1.346	0.877	0.651	0.540	0.344	0.188
26.000	52.000	-----	2.276	1.449	0.945	0.701	0.582	0.369	0.203
28.000	56.000	-----	2.437	1.552	1.011	0.866	0.623	0.393	0.218
30.000	60.000	-----	-----	1.654	1.079	0.923	0.664	0.418	0.233
32.000	64.000	-----	-----	1.755	1.149	0.982	0.704	0.445	0.248
34.000	68.000	-----	-----	1.856	1.218	1.042	0.862	0.471	0.263
36.000	72.000	-----	-----	1.962	1.288	1.101	0.911	0.497	0.278
38.000	76.000	-----	-----	2.067	1.357	1.160	0.960	0.523	0.293
40.000	80.000	-----	-----	2.172	1.426	1.219	1.009	0.549	0.307
42.000	84.000	-----	-----	2.277	1.495	1.278	1.057	0.575	0.321

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	729.33	220.91	67.03	29.14	21.18	14.48	6.54	4.22
14.000	28.000	725.09	219.39	66.77	28.83	21.09	14.37	6.50	4.04
16.000	32.000	----	217.96	88.28	28.59	20.83	14.30	6.43	3.97
18.000	36.000	----	216.30	87.59	28.41	20.72	14.17	6.41	3.91
20.000	40.000	----	214.99	87.05	28.00	20.55	14.12	6.34	3.86
22.000	44.000	----	213.69	86.60	27.59	20.28	13.98	6.23	3.78
24.000	48.000	----	210.82	85.46	36.28	19.99	13.76	6.15	3.75
26.000	52.000	----	208.22	84.39	35.90	19.75	13.61	6.07	3.73
28.000	56.000	----	205.83	83.48	35.42	25.99	13.45	5.99	3.71
30.000	60.000	----	----	82.59	35.15	25.72	13.31	5.94	3.69
32.000	64.000	----	----	81.73	35.03	25.59	13.15	5.92	3.68
34.000	68.000	----	----	80.97	34.87	25.52	17.47	5.90	3.66
36.000	72.000	----	----	80.71	34.78	25.41	17.40	5.87	3.65
38.000	76.000	----	----	80.40	34.65	25.32	17.34	5.85	3.64
40.000	80.000	----	----	80.12	34.53	25.24	17.29	5.83	3.61
42.000	84.000	----	----	79.86	34.43	25.16	17.21	5.81	3.58

Table D-3.a.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 4,000 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 3.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	2.151	1.183	0.652	0.429	0.367	0.303	0.204	0.136
14.000	42.000	-----	1.375	0.875	0.498	0.426	0.352	0.237	0.158
16.000	48.000	-----	1.565	0.996	0.567	0.484	0.401	0.269	0.178
18.000	54.000	-----	1.754	1.117	0.633	0.542	0.449	0.301	0.199
20.000	60.000	-----	1.940	1.235	0.697	0.597	0.496	0.332	0.219
22.000	66.000	-----	2.118	1.349	0.879	0.652	0.542	0.362	0.238
24.000	72.000	-----	2.296	1.462	0.953	0.707	0.587	0.393	0.259
26.000	78.000	-----	2.471	1.574	1.026	0.878	0.632	0.423	0.280
28.000	84.000	-----	-----	1.685	1.103	0.943	0.676	0.454	0.300
30.000	90.000	-----	-----	1.796	1.179	1.008	0.834	0.485	0.321
32.000	96.000	-----	-----	1.911	1.255	1.073	0.888	0.516	0.341
34.000	102.000	-----	-----	2.027	1.330	1.137	0.941	0.548	0.362

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	726.17	219.65	66.72	28.88	21.14	14.41	6.53	3.19
14.000	42.000	----	218.01	88.28	28.60	20.93	14.29	6.48	3.17
16.000	48.000	----	216.23	87.58	28.38	20.68	14.20	6.39	3.09
18.000	54.000	----	214.60	87.03	27.95	20.49	14.06	6.32	3.06
20.000	60.000	----	212.65	86.18	27.45	20.14	13.90	6.23	3.01
22.000	66.000	----	209.47	84.98	36.08	19.85	13.72	6.12	2.96
24.000	72.000	----	206.84	83.87	35.64	19.61	13.52	6.06	2.95
26.000	78.000	----	204.14	82.83	35.19	25.77	13.35	5.98	2.94
28.000	84.000	----	----	81.85	35.07	25.63	13.17	5.94	2.91
30.000	90.000	----	----	81.00	34.91	25.52	13.10	5.91	2.91
32.000	96.000	----	----	80.60	34.76	25.41	17.40	5.88	2.89
34.000	102.000	----	----	80.33	34.58	25.27	17.31	5.87	2.89

Table D-3.a.7. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 4,000 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 4.00**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	2.223	1.223	0.674	0.443	0.379	0.313	0.211	0.142
14.000	56.000	-----	1.420	0.904	0.514	0.440	0.364	0.244	0.165
16.000	64.000	-----	1.616	1.029	0.584	0.500	0.414	0.278	0.186
18.000	72.000	-----	1.811	1.153	0.651	0.558	0.463	0.310	0.207
20.000	80.000	-----	1.996	1.271	0.829	0.615	0.510	0.342	0.228
22.000	88.000	-----	2.180	1.388	0.905	0.671	0.557	0.373	0.250
24.000	96.000	-----	2.362	1.504	0.981	0.840	0.604	0.404	0.272
26.000	104.000	-----	-----	1.619	1.060	0.906	0.650	0.436	0.294
28.000	112.000	-----	-----	1.734	1.139	0.973	0.698	0.469	0.316
30.000	120.000	-----	-----	1.854	1.217	1.040	0.861	0.501	0.337

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	723.83	219.08	66.54	28.75	21.04	14.35	6.52	3.02
14.000	56.000	----	216.99	87.94	28.43	20.83	14.26	6.41	3.00
16.000	64.000	----	215.16	87.24	28.10	20.60	14.12	6.37	2.92
18.000	72.000	----	213.51	86.54	27.59	20.27	13.96	6.26	2.86
20.000	80.000	----	210.08	85.18	27.18	19.94	13.72	6.17	2.81
22.000	88.000	----	207.10	83.96	35.69	19.62	13.52	6.06	2.80
24.000	96.000	----	204.29	82.83	35.24	19.38	13.36	5.98	2.78
26.000	104.000	----	----	81.78	35.06	25.61	13.18	5.93	2.77
28.000	112.000	----	----	80.89	34.90	25.47	13.11	5.92	2.76
30.000	120.000	----	----	80.56	34.71	25.35	17.37	5.88	2.73

Table D-3.b.1. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 1,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	0.582	0.341	0.251	0.170	0.138	0.110	0.100	0.100
14.000	14.000	0.676	0.395	0.291	0.198	0.161	0.128	0.100	0.100
16.000	16.000	0.888	0.450	0.331	0.223	0.182	0.146	0.103	0.100
18.000	18.000	0.990	0.503	0.370	0.248	0.203	0.163	0.115	0.100
20.000	20.000	1.091	0.554	0.407	0.272	0.224	0.179	0.127	0.100
22.000	22.000	1.192	0.605	0.444	0.295	0.245	0.195	0.138	0.100
24.000	24.000	1.291	0.655	0.481	0.320	0.265	0.211	0.150	0.100
26.000	26.000	1.394	0.706	0.517	0.345	0.287	0.228	0.162	0.108
28.000	28.000	1.498	0.876	0.554	0.371	0.308	0.245	0.174	0.116
30.000	30.000	1.601	0.936	0.592	0.396	0.329	0.262	0.186	0.123
32.000	32.000	1.704	0.996	0.630	0.421	0.351	0.278	0.198	0.131
34.000	34.000	1.807	1.057	0.668	0.446	0.372	0.295	0.209	0.139
36.000	36.000	1.910	1.117	0.706	0.469	0.393	0.312	0.221	0.147
38.000	38.000	2.012	1.176	0.873	0.491	0.413	0.329	0.233	0.155
40.000	40.000	2.107	1.235	0.918	0.512	0.433	0.344	0.244	0.163
42.000	42.000	2.200	1.290	0.961	0.532	0.452	0.359	0.255	0.170
44.000	44.000	2.293	1.345	1.001	0.542	0.471	0.374	0.266	0.177
46.000	46.000	2.386	1.399	1.042	0.548	0.491	0.389	0.277	0.184
48.000	48.000	2.478	1.453	1.082	0.564	0.510	0.404	0.288	0.191
50.000	50.000	-----	1.507	1.122	0.585	0.529	0.419	0.298	0.198
52.000	52.000	-----	1.560	1.162	0.606	0.547	0.433	0.309	0.205
54.000	54.000	-----	1.613	1.202	0.626	0.566	0.448	0.319	0.212
56.000	56.000	-----	1.666	1.241	0.645	0.585	0.462	0.330	0.219
58.000	58.000	-----	1.718	1.279	0.665	0.603	0.476	0.340	0.226
60.000	60.000	-----	1.770	1.317	0.684	0.620	0.490	0.351	0.233

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	135.08	46.37	25.53	13.80	12.06	7.98	6.89	6.89
14.000	14.000	133.89	45.71	25.25	13.78	12.06	7.94	5.32	5.32
16.000	16.000	176.89	45.43	25.05	13.61	11.81	7.91	4.45	4.23
18.000	18.000	173.72	44.84	24.77	13.47	11.62	7.81	4.39	3.47
20.000	20.000	170.89	44.06	24.35	13.32	11.46	7.67	4.34	2.91
22.000	22.000	168.59	43.43	24.00	13.15	11.34	7.56	4.25	2.48
24.000	24.000	166.17	42.77	23.71	13.09	11.16	7.47	4.23	2.14
26.000	26.000	165.08	42.34	23.39	13.03	11.15	7.44	4.20	2.13
28.000	28.000	164.37	56.21	23.19	13.02	11.08	7.41	4.19	2.12
30.000	30.000	163.55	55.90	23.09	12.98	11.01	7.39	4.17	2.09
32.000	32.000	162.84	55.63	22.99	12.94	11.02	7.33	4.15	2.08
34.000	34.000	162.21	55.50	22.91	12.90	10.96	7.32	4.11	2.08
36.000	36.000	161.65	55.29	22.84	12.83	10.92	7.31	4.10	2.07
38.000	38.000	160.99	55.00	30.31	12.73	10.82	7.30	4.09	2.07
40.000	40.000	159.34	54.74	30.25	12.63	10.74	7.22	4.06	2.06
42.000	42.000	157.57	54.17	30.07	12.52	10.62	7.16	4.03	2.04
44.000	44.000	155.96	53.66	29.72	12.52	10.51	7.10	4.00	2.02
46.000	46.000	154.50	53.12	29.47	12.59	10.45	7.04	3.97	2.00
48.000	48.000	153.05	52.62	29.18	12.57	10.36	6.99	3.95	1.98
50.000	50.000	----	52.17	28.92	12.47	10.28	6.95	3.90	1.97
52.000	52.000	----	51.68	28.68	12.37	10.17	6.88	3.88	1.95
54.000	54.000	----	51.24	28.45	12.25	10.10	6.85	3.84	1.94
56.000	56.000	----	50.83	28.21	12.10	10.03	6.79	3.83	1.93
58.000	58.000	----	50.39	27.97	11.99	9.94	6.73	3.80	1.92
60.000	60.000	----	49.98	27.75	11.86	9.82	6.69	3.78	1.90

Table D-3.b.2. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 1,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.25

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	0.673	0.393	0.292	0.199	0.174	0.119	0.100	0.100
14.000	17.500	0.902	0.457	0.339	0.230	0.201	0.138	0.100	0.100
16.000	20.000	1.024	0.519	0.386	0.260	0.227	0.156	0.113	0.100
18.000	22.500	1.141	0.579	0.430	0.289	0.253	0.174	0.126	0.100
20.000	25.000	1.258	0.638	0.474	0.318	0.277	0.192	0.139	0.100
22.000	27.500	1.373	0.697	0.518	0.347	0.301	0.210	0.152	0.102
24.000	30.000	1.490	0.871	0.561	0.377	0.327	0.229	0.165	0.111
26.000	32.500	1.610	0.942	0.605	0.407	0.353	0.247	0.178	0.120
28.000	35.000	1.730	1.012	0.650	0.437	0.378	0.265	0.191	0.129
30.000	37.500	1.849	1.081	0.695	0.467	0.403	0.284	0.205	0.137
32.000	40.000	1.968	1.151	0.854	0.497	0.429	0.302	0.218	0.146
34.000	42.500	2.087	1.220	0.906	0.525	0.454	0.320	0.230	0.155
36.000	45.000	2.206	1.290	0.957	0.552	0.475	0.337	0.242	0.164
38.000	47.500	2.315	1.357	1.008	0.579	0.496	0.353	0.254	0.172
40.000	50.000	2.423	1.421	1.056	0.605	0.517	0.370	0.266	0.180
42.000	52.500	-----	1.484	1.103	0.631	0.537	0.387	0.278	0.188
44.000	55.000	-----	1.547	1.150	0.657	0.548	0.403	0.289	0.195
46.000	57.500	-----	1.609	1.196	0.683	0.557	0.419	0.301	0.203
48.000	60.000	-----	1.671	1.242	0.708	0.565	0.436	0.312	0.211
50.000	62.500	-----	1.733	1.288	0.829	0.582	0.452	0.324	0.219
52.000	65.000	-----	1.794	1.334	0.862	0.595	0.468	0.335	0.226

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	134.86	45.99	25.39	13.23	11.00	7.89	5.72	5.72
14.000	17.500	177.98	45.69	25.14	13.07	10.84	7.80	4.38	4.38
16.000	20.000	175.62	45.11	24.95	12.89	10.65	7.64	4.31	3.52
18.000	22.500	172.28	44.36	24.47	12.69	10.51	7.51	4.24	2.87
20.000	25.000	169.63	43.63	24.08	12.53	10.32	7.42	4.20	2.39
22.000	27.500	166.99	43.04	23.77	12.40	10.24	7.34	4.16	2.09
24.000	30.000	165.26	56.47	23.43	12.34	10.21	7.33	4.12	2.08
26.000	32.500	164.40	56.28	23.22	12.28	10.19	7.27	4.10	2.08
28.000	35.000	163.68	56.01	23.11	12.24	10.15	7.22	4.07	2.07
30.000	37.500	162.87	55.67	23.01	12.20	10.12	7.23	4.08	2.04
32.000	40.000	162.17	55.47	30.54	12.15	10.11	7.19	4.06	2.03
34.000	42.500	161.54	55.20	30.44	12.05	10.08	7.15	4.02	2.03
36.000	45.000	160.99	55.05	30.30	11.93	10.01	7.08	3.98	2.03
38.000	47.500	159.13	54.68	30.17	11.82	9.94	6.98	3.94	2.01
40.000	50.000	157.32	54.11	29.88	11.69	9.88	6.93	3.91	1.99
42.000	52.500	----	53.53	29.57	11.58	9.81	6.88	3.88	1.97
44.000	55.000	----	53.00	29.29	11.48	9.79	6.80	3.83	1.93
46.000	57.500	----	52.46	28.98	11.38	9.78	6.73	3.81	1.92
48.000	60.000	----	51.96	28.71	11.27	9.76	6.70	3.77	1.91
50.000	62.500	----	51.51	28.45	9.92	9.74	6.64	3.75	1.89
52.000	65.000	----	51.03	28.22	13.22	9.71	6.59	3.71	1.87

Table D-3.b.3. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 1,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.50

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	0.868	0.440	0.326	0.221	0.191	0.127	0.100	0.100
14.000	21.000	1.008	0.511	0.379	0.255	0.221	0.146	0.108	0.100
16.000	24.000	1.142	0.579	0.431	0.288	0.246	0.165	0.122	0.100
18.000	27.000	1.273	0.646	0.480	0.320	0.273	0.184	0.136	0.100
20.000	30.000	1.403	0.822	0.529	0.352	0.303	0.203	0.150	0.101
22.000	33.000	1.532	0.897	0.577	0.385	0.333	0.223	0.165	0.110
24.000	36.000	1.666	0.974	0.626	0.419	0.363	0.242	0.179	0.120
26.000	39.000	1.800	1.053	0.676	0.452	0.394	0.262	0.194	0.129
28.000	42.000	1.934	1.131	0.839	0.485	0.424	0.281	0.208	0.139
30.000	45.000	2.067	1.209	0.897	0.518	0.454	0.301	0.222	0.149
32.000	48.000	2.201	1.287	0.955	0.549	0.484	0.319	0.235	0.158
34.000	51.000	2.333	1.364	1.012	0.579	0.515	0.337	0.248	0.167
36.000	54.000	2.458	1.441	1.070	0.607	0.545	0.355	0.261	0.175
38.000	57.000	-----	1.512	1.124	0.636	0.575	0.372	0.274	0.184
40.000	60.000	-----	1.583	1.177	0.665	0.605	0.390	0.287	0.193
42.000	63.000	-----	1.654	1.229	0.693	0.632	0.407	0.300	0.201
44.000	66.000	-----	1.723	1.281	0.871	0.657	0.425	0.313	0.210
46.000	69.000	-----	1.793	1.333	0.905	0.682	0.442	0.325	0.218
48.000	72.000	-----	1.862	1.384	0.936	0.706	0.458	0.337	0.226

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	178.97	45.99	25.25	12.02	9.66	7.67	5.00	5.00
14.000	21.000	177.33	45.57	25.07	11.82	9.54	7.62	4.31	3.72
16.000	24.000	174.26	44.80	24.82	11.61	9.29	7.52	4.21	2.99
18.000	27.000	171.09	44.06	24.33	11.40	9.18	7.39	4.14	2.45
20.000	30.000	168.33	43.34	23.93	11.23	9.17	7.29	4.08	2.07
22.000	33.000	165.88	56.87	23.53	11.13	9.16	7.27	4.08	2.04
24.000	36.000	164.83	56.34	23.27	11.09	9.16	7.20	4.04	2.04
26.000	39.000	163.95	56.11	23.12	11.02	9.17	7.19	4.04	2.01
28.000	42.000	163.20	55.81	23.03	10.96	9.17	7.14	4.01	2.01
30.000	45.000	162.39	55.56	30.58	10.91	9.16	7.13	3.98	2.01
32.000	48.000	161.83	55.33	30.47	10.81	9.16	7.04	3.92	1.99
34.000	51.000	161.06	55.05	30.31	10.69	9.17	6.97	3.87	1.97
36.000	54.000	159.47	54.81	30.22	10.53	9.16	6.90	3.83	1.93
38.000	57.000	----	54.16	29.93	10.41	9.16	6.80	3.79	1.92
40.000	60.000	----	53.57	29.62	10.31	9.16	6.75	3.75	1.91
42.000	63.000	----	53.05	29.29	10.19	9.12	6.67	3.72	1.88
44.000	66.000	----	52.45	28.99	13.40	9.05	6.63	3.69	1.87
46.000	69.000	----	51.97	28.73	13.27	9.00	6.56	3.64	1.85
48.000	72.000	----	51.47	28.44	13.10	8.94	6.48	3.60	1.83

Table D-3.b.4. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 1,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.75

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	0.922	0.467	0.347	0.239	0.212	0.161	0.100	0.100
14.000	24.500	1.071	0.542	0.402	0.276	0.245	0.185	0.111	0.100
16.000	28.000	1.211	0.615	0.457	0.313	0.276	0.209	0.125	0.100
18.000	31.500	1.350	0.685	0.509	0.348	0.307	0.232	0.140	0.100
20.000	35.000	1.488	0.872	0.561	0.385	0.338	0.256	0.155	0.104
22.000	38.500	1.626	0.951	0.612	0.422	0.370	0.281	0.170	0.114
24.000	42.000	1.769	1.034	0.665	0.459	0.402	0.305	0.185	0.124
26.000	45.500	1.911	1.118	0.829	0.496	0.434	0.329	0.200	0.134
28.000	49.000	2.054	1.201	0.891	0.532	0.466	0.353	0.214	0.144
30.000	52.500	2.195	1.283	0.952	0.569	0.498	0.376	0.228	0.153
32.000	56.000	2.337	1.366	1.014	0.603	0.528	0.398	0.242	0.163
34.000	59.500	2.475	1.449	1.075	0.636	0.556	0.419	0.255	0.172
36.000	63.000	-----	1.527	1.135	0.669	0.583	0.439	0.268	0.181
38.000	66.500	-----	1.603	1.191	0.701	0.610	0.460	0.282	0.190
40.000	70.000	-----	1.678	1.247	0.848	0.637	0.478	0.295	0.198
42.000	73.500	-----	1.752	1.302	0.886	0.663	0.496	0.307	0.207
44.000	77.000	-----	1.826	1.357	0.923	0.689	0.514	0.320	0.216

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	178.79	45.87	25.32	12.01	9.63	6.68	4.58	4.58
14.000	24.500	177.24	45.39	24.97	11.77	9.48	6.56	4.16	3.43
16.000	28.000	173.50	44.75	24.71	11.59	9.26	6.47	4.05	2.72
18.000	31.500	170.36	43.86	24.22	11.32	9.09	6.37	4.01	2.22
20.000	35.000	167.65	57.57	23.83	11.22	8.96	6.31	3.98	1.96
22.000	38.500	165.44	56.59	23.44	11.14	8.89	6.30	3.96	1.95
24.000	42.000	164.54	56.22	23.25	11.08	8.83	6.26	3.94	1.94
26.000	45.500	163.61	56.00	23.09	11.02	8.78	6.22	3.93	1.93
28.000	49.000	162.98	55.72	30.67	10.93	8.74	6.20	3.88	1.93
30.000	52.500	162.13	55.39	30.50	10.89	8.70	6.15	3.84	1.90
32.000	56.000	161.53	55.19	30.41	10.75	8.62	6.09	3.80	1.89
34.000	59.500	160.49	55.01	30.28	10.60	8.51	6.03	3.74	1.87
36.000	63.000	----	54.49	30.10	10.46	8.40	5.95	3.69	1.85
38.000	66.500	----	53.89	29.75	10.34	8.30	5.90	3.67	1.83
40.000	70.000	----	53.30	29.43	10.21	8.21	5.85	3.63	1.79
42.000	73.500	----	52.70	29.11	13.48	8.11	5.82	3.57	1.78
44.000	77.000	----	52.16	28.81	13.33	8.02	5.79	3.54	1.77

Table D-3.b.5. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 1,000 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 2.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	0.973	0.493	0.366	0.252	0.226	0.168	0.100	0.100
14.000	28.000	1.128	0.572	0.425	0.291	0.261	0.192	0.114	0.100
16.000	32.000	1.276	0.647	0.481	0.329	0.295	0.216	0.129	0.100
18.000	36.000	1.423	0.833	0.536	0.367	0.329	0.242	0.144	0.100
20.000	40.000	1.568	0.918	0.591	0.406	0.363	0.269	0.160	0.108
22.000	44.000	1.715	1.003	0.645	0.445	0.398	0.296	0.175	0.119
24.000	48.000	1.866	1.091	0.701	0.484	0.432	0.322	0.191	0.129
26.000	52.000	2.016	1.179	0.875	0.523	0.467	0.349	0.205	0.139
28.000	56.000	2.166	1.267	0.940	0.561	0.502	0.376	0.219	0.148
30.000	60.000	2.316	1.354	1.005	0.599	0.536	0.403	0.233	0.158
32.000	64.000	2.465	1.441	1.069	0.634	0.568	0.428	0.247	0.167
34.000	68.000	-----	1.528	1.134	0.669	0.600	0.451	0.261	0.176
36.000	72.000	-----	1.608	1.195	0.704	0.631	0.474	0.275	0.186
38.000	76.000	-----	1.687	1.254	0.853	0.661	0.497	0.288	0.195
40.000	80.000	-----	1.766	1.313	0.893	0.691	0.520	0.301	0.204
42.000	84.000	-----	1.844	1.371	0.932	0.836	0.542	0.314	0.212

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	178.64	45.86	25.28	11.98	9.64	5.97	4.22	4.22
14.000	28.000	176.39	45.36	25.04	11.74	9.44	5.82	4.04	3.15
16.000	32.000	172.81	44.43	24.56	11.49	9.24	5.71	3.97	2.50
18.000	36.000	169.82	43.64	24.09	11.30	9.08	5.68	3.91	2.04
20.000	40.000	167.01	57.25	23.73	11.20	8.95	5.69	3.91	1.93
22.000	44.000	165.12	56.48	23.36	11.12	8.89	5.69	3.86	1.94
24.000	48.000	164.26	56.15	23.18	11.05	8.80	5.67	3.87	1.91
26.000	52.000	163.36	55.87	30.77	10.99	8.77	5.67	3.80	1.89
28.000	56.000	162.60	55.64	30.62	10.91	8.73	5.68	3.74	1.85
30.000	60.000	161.94	55.35	30.49	10.83	8.67	5.68	3.69	1.84
32.000	64.000	161.23	55.10	30.32	10.67	8.56	5.65	3.65	1.81
34.000	68.000	----	54.88	30.23	10.52	8.46	5.59	3.61	1.78
36.000	72.000	----	54.21	29.94	10.39	8.36	5.54	3.58	1.77
38.000	76.000	----	53.55	29.59	13.69	8.25	5.50	3.52	1.75
40.000	80.000	----	52.96	29.28	13.54	8.15	5.46	3.47	1.73
42.000	84.000	----	52.38	28.95	13.38	8.07	5.41	3.43	1.70

Table D-3.b.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 1,000 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 3.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	1.062	0.538	0.399	0.274	0.246	0.194	0.137	0.100
14.000	42.000	1.225	0.622	0.462	0.316	0.283	0.223	0.157	0.100
16.000	48.000	1.386	0.703	0.522	0.357	0.320	0.252	0.179	0.100
18.000	54.000	1.544	0.905	0.582	0.400	0.358	0.282	0.200	0.105
20.000	60.000	1.708	0.999	0.642	0.443	0.396	0.312	0.222	0.116
22.000	66.000	1.873	1.095	0.704	0.486	0.434	0.342	0.243	0.126
24.000	72.000	2.038	1.191	0.884	0.528	0.472	0.372	0.262	0.137
26.000	78.000	2.202	1.287	0.955	0.570	0.510	0.400	0.281	0.148
28.000	84.000	2.365	1.383	1.026	0.609	0.546	0.427	0.299	0.159
30.000	90.000	-----	1.478	1.097	0.648	0.580	0.453	0.317	0.169
32.000	96.000	-----	1.566	1.164	0.686	0.615	0.480	0.336	0.179
34.000	102.000	-----	1.652	1.228	0.836	0.649	0.505	0.353	0.190

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	177.01	45.43	24.99	11.78	9.50	5.91	3.23	2.06
14.000	42.000	173.04	44.61	24.61	11.51	9.23	5.75	3.13	1.81
16.000	48.000	169.59	43.63	24.06	11.25	9.04	5.64	3.12	1.78
18.000	54.000	166.29	57.13	23.63	11.16	8.94	5.59	3.09	1.80
20.000	60.000	164.83	56.39	23.29	11.09	8.86	5.54	3.08	1.78
22.000	66.000	163.81	55.99	23.14	11.03	8.80	5.51	3.05	1.74
24.000	72.000	162.97	55.66	30.66	10.94	8.74	5.48	3.00	1.73
26.000	78.000	162.11	55.38	30.49	10.86	8.70	5.41	2.95	1.71
28.000	84.000	161.24	55.14	30.35	10.69	8.59	5.33	2.90	1.69
30.000	90.000	----	54.86	30.22	10.54	8.45	5.24	2.85	1.64
32.000	96.000	----	54.13	29.90	10.39	8.35	5.18	2.83	1.59
34.000	102.000	----	53.36	29.48	10.25	8.23	5.09	2.78	1.59

Table D-3.b.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 1,000 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	1.093	0.555	0.412	0.282	0.253	0.199	0.142	0.100
14.000	56.000	1.261	0.640	0.475	0.325	0.291	0.230	0.164	0.110
16.000	64.000	1.425	0.835	0.537	0.369	0.329	0.261	0.187	0.125
18.000	72.000	1.593	0.931	0.599	0.413	0.369	0.292	0.210	0.140
20.000	80.000	1.764	1.031	0.663	0.457	0.409	0.323	0.232	0.154
22.000	88.000	1.934	1.131	0.839	0.501	0.448	0.355	0.253	0.167
24.000	96.000	2.104	1.230	0.913	0.545	0.487	0.385	0.273	0.180
26.000	104.000	2.273	1.329	0.986	0.585	0.524	0.413	0.293	0.193
28.000	112.000	2.433	1.427	1.059	0.625	0.560	0.441	0.313	0.205
30.000	120.000	-----	1.517	1.128	0.665	0.596	0.469	0.334	0.216

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	174.98	45.12	24.86	11.65	9.38	5.80	3.02	1.63
14.000	56.000	171.12	44.08	24.28	11.37	9.11	5.69	2.96	1.50
16.000	64.000	167.31	43.08	23.76	11.22	8.92	5.61	2.95	1.48
18.000	72.000	165.20	56.43	23.36	11.10	8.86	5.55	2.94	1.47
20.000	80.000	164.08	56.05	23.18	11.01	8.82	5.50	2.91	1.45
22.000	88.000	163.00	55.74	23.01	10.94	8.75	5.49	2.86	1.42
24.000	96.000	162.10	55.40	30.52	10.88	8.68	5.43	2.80	1.40
26.000	104.000	161.20	55.11	30.33	10.68	8.57	5.32	2.75	1.37
28.000	112.000	159.25	54.78	30.17	10.51	8.44	5.23	2.71	1.35
30.000	120.000	----	53.93	29.82	10.36	8.32	5.15	2.69	1.31

Table D-3.c.1. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 300 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.00**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	0.276	0.187	0.131	0.111	0.100	0.100	0.100	0.100
14.000	14.000	0.318	0.215	0.151	0.127	0.110	0.100	0.100	0.100
16.000	16.000	0.362	0.244	0.171	0.144	0.125	0.102	0.100	0.100
18.000	18.000	0.406	0.273	0.191	0.161	0.140	0.114	0.100	0.100
20.000	20.000	0.449	0.302	0.212	0.178	0.154	0.126	0.100	0.100
22.000	22.000	0.493	0.331	0.232	0.196	0.169	0.138	0.102	0.100
24.000	24.000	0.533	0.359	0.253	0.213	0.184	0.150	0.111	0.100
26.000	26.000	0.571	0.384	0.271	0.229	0.198	0.162	0.120	0.100
28.000	28.000	0.609	0.409	0.290	0.244	0.212	0.173	0.128	0.100
30.000	30.000	0.647	0.434	0.308	0.260	0.225	0.184	0.136	0.100
32.000	32.000	0.684	0.459	0.327	0.275	0.239	0.194	0.144	0.100
34.000	34.000	0.835	0.483	0.345	0.290	0.252	0.205	0.152	0.106
36.000	36.000	0.876	0.506	0.363	0.305	0.265	0.216	0.160	0.111
38.000	38.000	0.915	0.527	0.380	0.320	0.278	0.226	0.168	0.116
40.000	40.000	0.955	0.547	0.397	0.333	0.290	0.237	0.175	0.122
42.000	42.000	0.993	0.567	0.414	0.347	0.302	0.247	0.183	0.127
44.000	44.000	1.032	0.586	0.430	0.360	0.314	0.256	0.190	0.131
46.000	46.000	1.069	0.605	0.446	0.373	0.326	0.266	0.197	0.136
48.000	48.000	1.107	0.623	0.462	0.386	0.338	0.275	0.204	0.141
50.000	50.000	1.141	0.640	0.478	0.399	0.349	0.285	0.210	0.146
52.000	52.000	1.172	0.655	0.494	0.412	0.360	0.294	0.217	0.150
54.000	54.000	1.202	0.634	0.510	0.424	0.371	0.303	0.224	0.155
56.000	56.000	1.229	0.651	0.525	0.437	0.382	0.312	0.230	0.159
58.000	58.000	1.254	0.667	0.539	0.450	0.393	0.321	0.237	0.164
60.000	60.000	1.278	0.683	0.552	0.461	0.404	0.330	0.243	0.168

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	12.000	30.38	15.35	10.92	8.10	6.89	6.89	6.89	6.89
14.000	14.000	29.63	14.97	10.67	7.83	6.27	5.32	5.32	5.32
16.000	16.000	29.40	14.79	10.48	7.73	6.21	4.37	4.23	4.23
18.000	18.000	29.22	14.65	10.34	7.66	6.16	4.32	3.47	3.47
20.000	20.000	28.94	14.60	10.32	7.61	6.06	4.28	2.91	2.91
22.000	22.000	28.84	14.55	10.21	7.62	6.03	4.25	2.56	2.48
24.000	24.000	28.32	14.48	10.21	7.57	6.01	4.23	2.55	2.14
26.000	26.000	27.77	14.32	9.99	7.49	5.94	4.20	2.54	1.87
28.000	28.000	27.31	14.18	9.87	7.37	5.89	4.14	2.50	1.66
30.000	30.000	26.91	14.06	9.70	7.31	5.79	4.09	2.47	1.47
32.000	32.000	26.50	13.95	9.62	7.22	5.75	4.02	2.44	1.32
34.000	34.000	25.98	13.84	9.51	7.14	5.67	3.98	2.41	1.32
36.000	36.000	34.00	13.71	9.40	7.06	5.61	3.95	2.39	1.29
38.000	38.000	33.30	13.55	9.27	7.00	5.55	3.89	2.37	1.27
40.000	40.000	32.73	13.38	9.15	6.88	5.46	3.86	2.33	1.27
42.000	42.000	32.10	13.23	9.04	6.80	5.38	3.82	2.31	1.25
44.000	44.000	31.59	13.08	8.91	6.70	5.31	3.75	2.28	1.22
46.000	46.000	31.01	12.93	8.79	6.61	5.25	3.71	2.24	1.21
48.000	48.000	30.54	12.78	8.68	6.53	5.19	3.65	2.22	1.19
50.000	50.000	29.91	12.63	8.58	6.44	5.11	3.62	2.17	1.18
52.000	52.000	29.17	12.47	8.48	6.37	5.04	3.57	2.15	1.16
54.000	54.000	28.45	12.55	8.40	6.27	4.98	3.53	2.13	1.15
56.000	56.000	27.74	12.31	8.29	6.20	4.91	3.49	2.09	1.13
58.000	58.000	27.03	12.06	8.17	6.14	4.86	3.45	2.07	1.12
60.000	60.000	26.34	11.83	8.03	6.04	4.81	3.41	2.04	1.10

Table D-3.c.2. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 300 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.25

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	0.318	0.207	0.157	0.118	0.105	0.100	0.100	0.100
14.000	17.500	0.367	0.237	0.179	0.137	0.121	0.100	0.100	0.100
16.000	20.000	0.418	0.269	0.201	0.155	0.137	0.112	0.100	0.100
18.000	22.500	0.468	0.301	0.222	0.174	0.154	0.125	0.100	0.100
20.000	25.000	0.519	0.332	0.243	0.193	0.170	0.139	0.103	0.100
22.000	27.500	0.566	0.365	0.259	0.211	0.186	0.152	0.113	0.100
24.000	30.000	0.612	0.398	0.276	0.228	0.202	0.164	0.122	0.100
26.000	32.500	0.657	0.431	0.293	0.245	0.217	0.176	0.131	0.100
28.000	35.000	0.701	0.465	0.308	0.262	0.231	0.188	0.140	0.100
30.000	37.500	0.860	0.498	0.328	0.279	0.246	0.200	0.149	0.106
32.000	40.000	0.910	0.530	0.348	0.295	0.260	0.211	0.158	0.112
34.000	42.500	0.956	0.557	0.366	0.312	0.275	0.223	0.166	0.118
36.000	45.000	1.002	0.583	0.384	0.327	0.288	0.234	0.175	0.124
38.000	47.500	1.047	0.608	0.402	0.342	0.301	0.244	0.183	0.129
40.000	50.000	1.091	0.632	0.420	0.357	0.314	0.255	0.191	0.135
42.000	52.500	1.135	0.656	0.437	0.372	0.327	0.265	0.198	0.140
44.000	55.000	1.178	0.680	0.454	0.387	0.340	0.275	0.206	0.146
46.000	57.500	1.220	0.704	0.471	0.401	0.352	0.285	0.214	0.151
48.000	60.000	1.256	0.828	0.488	0.415	0.364	0.295	0.221	0.156
50.000	62.500	1.290	0.847	0.504	0.430	0.376	0.305	0.229	0.161
52.000	65.000	1.323	0.863	0.519	0.443	0.388	0.315	0.236	0.166

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	15.000	30.11	13.91	9.95	7.76	6.25	5.72	5.72	5.72
14.000	17.500	29.46	13.58	9.81	7.69	6.11	4.38	4.38	4.38
16.000	20.000	29.26	13.46	9.79	7.55	6.01	4.24	3.52	3.52
18.000	22.500	28.98	13.37	9.79	7.51	6.00	4.19	2.87	2.87
20.000	25.000	28.87	13.24	9.78	7.49	5.93	4.20	2.51	2.39
22.000	27.500	28.38	13.23	9.76	7.40	5.87	4.16	2.50	2.02
24.000	30.000	27.88	13.23	9.72	7.27	5.82	4.08	2.46	1.74
26.000	32.500	27.38	13.22	9.68	7.17	5.73	4.02	2.42	1.51
28.000	35.000	26.87	13.25	9.63	7.07	5.62	3.97	2.39	1.33
30.000	37.500	35.23	13.24	9.51	6.99	5.56	3.93	2.36	1.30
32.000	40.000	34.67	13.21	9.42	6.88	5.47	3.86	2.34	1.28
34.000	42.500	33.90	13.02	9.24	6.82	5.43	3.82	2.29	1.26
36.000	45.000	33.22	12.83	9.07	6.70	5.32	3.77	2.27	1.25
38.000	47.500	32.55	12.63	8.93	6.59	5.23	3.69	2.24	1.21
40.000	50.000	31.90	12.43	8.80	6.48	5.15	3.64	2.20	1.20
42.000	52.500	31.31	12.25	8.65	6.39	5.08	3.58	2.15	1.18
44.000	55.000	30.73	12.07	8.52	6.31	5.01	3.52	2.13	1.17
46.000	57.500	30.16	11.90	8.39	6.21	4.92	3.47	2.11	1.15
48.000	60.000	29.36	10.43	8.28	6.12	4.85	3.42	2.07	1.13
50.000	62.500	28.54	10.19	8.14	6.06	4.77	3.38	2.05	1.11
52.000	65.000	27.75	13.24	7.99	5.95	4.71	3.33	2.02	1.09

Table D-3.c.3. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 300 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.50

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	0.355	0.241	0.182	0.125	0.111	0.100	0.100	0.100
14.000	21.000	0.411	0.279	0.212	0.145	0.128	0.107	0.100	0.100
16.000	24.000	0.467	0.317	0.241	0.165	0.146	0.121	0.100	0.100
18.000	27.000	0.524	0.355	0.270	0.184	0.164	0.136	0.100	0.100
20.000	30.000	0.579	0.392	0.298	0.204	0.181	0.150	0.111	0.100
22.000	33.000	0.631	0.427	0.324	0.222	0.197	0.164	0.121	0.100
24.000	36.000	0.681	0.460	0.349	0.240	0.213	0.177	0.131	0.100
26.000	39.000	0.844	0.492	0.372	0.258	0.229	0.190	0.140	0.101
28.000	42.000	0.902	0.524	0.397	0.276	0.245	0.203	0.150	0.108
30.000	45.000	0.958	0.556	0.421	0.294	0.260	0.215	0.159	0.114
32.000	48.000	1.010	0.586	0.444	0.310	0.275	0.227	0.168	0.121
34.000	51.000	1.062	0.614	0.465	0.327	0.289	0.239	0.177	0.127
36.000	54.000	1.113	0.641	0.485	0.343	0.303	0.251	0.185	0.133
38.000	57.000	1.162	0.668	0.505	0.359	0.317	0.262	0.194	0.139
40.000	60.000	1.211	0.694	0.524	0.374	0.331	0.273	0.202	0.145
42.000	63.000	1.260	0.860	0.543	0.390	0.345	0.284	0.210	0.151
44.000	66.000	1.307	0.893	0.556	0.405	0.358	0.295	0.219	0.157
46.000	69.000	1.347	0.925	0.501	0.420	0.371	0.305	0.227	0.162
48.000	72.000	1.385	0.951	0.509	0.433	0.383	0.314	0.234	0.168

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	18.000	29.94	13.80	9.18	7.61	6.10	5.00	5.00	5.00
14.000	21.000	29.48	13.59	9.17	7.58	5.97	4.23	3.72	3.72
16.000	24.000	29.14	13.43	9.12	7.52	5.95	4.15	2.99	2.99
18.000	27.000	28.99	13.32	9.09	7.39	5.93	4.14	2.45	2.45
20.000	30.000	28.67	13.20	9.04	7.36	5.85	4.08	2.45	2.04
22.000	33.000	28.14	13.00	8.95	7.21	5.73	4.04	2.41	1.72
24.000	36.000	27.54	12.76	8.85	7.09	5.64	3.95	2.38	1.47
26.000	39.000	27.03	12.52	8.72	6.98	5.56	3.88	2.32	1.29
28.000	42.000	35.50	12.31	8.62	6.89	5.49	3.83	2.30	1.28
30.000	45.000	34.88	12.13	8.52	6.82	5.39	3.74	2.26	1.24
32.000	48.000	34.08	11.92	8.40	6.67	5.30	3.67	2.22	1.23
34.000	51.000	33.37	11.67	8.25	6.58	5.19	3.61	2.19	1.21
36.000	54.000	32.70	11.43	8.10	6.46	5.09	3.55	2.14	1.18
38.000	57.000	31.99	11.21	7.97	6.36	5.01	3.47	2.11	1.16
40.000	60.000	31.35	10.99	7.83	6.23	4.93	3.41	2.07	1.14
42.000	63.000	30.79	14.34	7.70	6.15	4.86	3.37	2.04	1.13
44.000	66.000	30.18	14.09	7.62	6.05	4.77	3.32	2.02	1.11
46.000	69.000	29.33	13.83	7.76	5.95	4.69	3.27	1.99	1.08
48.000	72.000	28.48	13.43	7.67	5.82	4.60	3.20	1.94	1.07

Table D-3.c.4. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 300 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.75

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	0.376	0.256	0.194	0.159	0.120	0.100	0.100	0.100
14.000	24.500	0.436	0.296	0.224	0.184	0.137	0.110	0.100	0.100
16.000	28.000	0.496	0.336	0.254	0.209	0.155	0.125	0.100	0.100
18.000	31.500	0.556	0.377	0.284	0.234	0.173	0.140	0.104	0.100
20.000	35.000	0.614	0.417	0.314	0.257	0.190	0.154	0.114	0.100
22.000	38.500	0.668	0.454	0.340	0.279	0.206	0.168	0.125	0.100
24.000	42.000	0.833	0.491	0.365	0.300	0.222	0.181	0.135	0.100
26.000	45.500	0.895	0.527	0.391	0.322	0.238	0.195	0.144	0.105
28.000	49.000	0.955	0.563	0.415	0.342	0.253	0.208	0.154	0.112
30.000	52.500	1.013	0.598	0.438	0.361	0.267	0.220	0.163	0.119
32.000	56.000	1.069	0.631	0.458	0.376	0.280	0.232	0.172	0.125
34.000	59.500	1.123	0.664	0.483	0.390	0.294	0.244	0.181	0.132
36.000	63.000	1.176	0.695	0.511	0.404	0.308	0.255	0.189	0.138
38.000	66.500	1.229	0.839	0.540	0.400	0.322	0.267	0.198	0.144
40.000	70.000	1.280	0.874	0.568	0.403	0.336	0.278	0.206	0.150
42.000	73.500	1.331	0.909	0.591	0.410	0.349	0.289	0.214	0.156
44.000	77.000	1.377	0.943	0.612	0.419	0.361	0.298	0.222	0.162

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	21.000	29.73	13.78	8.38	6.58	5.68	4.58	4.58	4.58
14.000	24.500	29.37	13.54	8.26	6.52	5.67	4.09	3.43	3.43
16.000	28.000	29.11	13.36	8.17	6.47	5.66	4.05	2.72	2.72
18.000	31.500	28.90	13.29	8.11	6.43	5.64	4.01	2.38	2.22
20.000	35.000	28.54	13.17	8.05	6.34	5.56	3.94	2.32	1.83
22.000	38.500	27.92	12.90	7.88	6.24	5.45	3.87	2.31	1.53
24.000	42.000	27.36	12.68	7.71	6.13	5.37	3.78	2.27	1.31
26.000	45.500	35.89	12.44	7.60	6.06	5.30	3.74	2.21	1.23
28.000	49.000	35.23	12.24	7.45	5.96	5.21	3.68	2.18	1.21
30.000	52.500	34.53	12.03	7.32	5.87	5.11	3.59	2.13	1.19
32.000	56.000	33.80	11.78	7.17	5.81	5.00	3.52	2.09	1.16
34.000	59.500	33.04	11.55	7.11	5.75	4.91	3.46	2.05	1.15
36.000	63.000	32.32	11.29	7.10	5.69	4.82	3.37	2.00	1.12
38.000	66.500	31.68	11.07	7.11	5.70	4.73	3.32	1.97	1.10
40.000	70.000	31.01	14.46	7.11	5.69	4.65	3.26	1.93	1.08
42.000	73.500	30.42	14.19	7.04	5.67	4.55	3.20	1.89	1.06
44.000	77.000	29.66	13.91	6.95	5.57	4.44	3.11	1.86	1.04

Table D-3.c.5. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 300 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 2.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	0.396	0.269	0.210	0.165	0.145	0.100	0.100	0.100
14.000	28.000	0.460	0.312	0.243	0.191	0.168	0.113	0.100	0.100
16.000	32.000	0.523	0.355	0.277	0.217	0.191	0.129	0.100	0.100
18.000	36.000	0.587	0.398	0.310	0.242	0.213	0.143	0.107	0.100
20.000	40.000	0.646	0.439	0.342	0.269	0.234	0.158	0.118	0.100
22.000	44.000	0.703	0.478	0.372	0.296	0.253	0.172	0.128	0.100
24.000	48.000	0.877	0.517	0.401	0.322	0.272	0.185	0.138	0.101
26.000	52.000	0.942	0.555	0.430	0.346	0.290	0.199	0.148	0.108
28.000	56.000	1.005	0.592	0.458	0.369	0.305	0.212	0.157	0.116
30.000	60.000	1.065	0.629	0.486	0.390	0.320	0.224	0.166	0.123
32.000	64.000	1.123	0.663	0.511	0.410	0.333	0.236	0.176	0.131
34.000	68.000	1.180	0.697	0.536	0.429	0.345	0.249	0.184	0.138
36.000	72.000	1.236	0.843	0.561	0.448	0.356	0.261	0.193	0.146
38.000	76.000	1.291	0.881	0.582	0.467	0.359	0.272	0.202	0.153
40.000	80.000	1.345	0.918	0.602	0.485	0.353	0.282	0.209	0.160
42.000	84.000	1.397	0.955	0.622	0.501	0.353	0.291	0.217	0.167

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	24.000	29.59	13.65	8.34	5.84	4.99	4.22	4.22	4.22
14.000	28.000	29.33	13.49	8.22	5.79	4.95	3.97	3.15	3.15
16.000	32.000	29.03	13.38	8.18	5.75	4.92	3.97	2.50	2.50
18.000	36.000	28.90	13.28	8.11	5.68	4.86	3.85	2.30	2.04
20.000	40.000	28.35	13.09	8.01	5.69	4.80	3.81	2.27	1.66
22.000	44.000	27.74	12.83	7.86	5.69	4.70	3.74	2.21	1.39
24.000	48.000	36.28	12.61	7.70	5.67	4.63	3.64	2.17	1.20
26.000	52.000	35.67	12.38	7.56	5.61	4.59	3.59	2.13	1.18
28.000	56.000	35.01	12.15	7.42	5.55	4.55	3.52	2.07	1.17
30.000	60.000	34.24	11.94	7.30	5.46	4.51	3.42	2.02	1.12
32.000	64.000	33.46	11.66	7.12	5.36	4.46	3.34	2.00	1.11
34.000	68.000	32.73	11.42	6.96	5.26	4.41	3.30	1.94	1.08
36.000	72.000	32.03	11.17	6.82	5.17	4.36	3.24	1.90	1.07
38.000	76.000	31.36	14.61	6.67	5.09	4.34	3.16	1.87	1.04
40.000	80.000	30.72	14.31	6.52	5.01	4.33	3.08	1.81	1.02
42.000	84.000	30.06	14.05	6.40	4.91	4.24	2.99	1.77	0.99

Table D-3.c.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 300 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 3.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	0.433	0.293	0.229	0.192	0.165	0.136	0.100	0.100
14.000	42.000	0.502	0.341	0.266	0.223	0.192	0.157	0.110	0.100
16.000	48.000	0.571	0.387	0.303	0.253	0.217	0.177	0.124	0.100
18.000	54.000	0.636	0.433	0.338	0.282	0.241	0.197	0.136	0.100
20.000	60.000	0.699	0.475	0.371	0.309	0.264	0.215	0.149	0.102
22.000	66.000	0.878	0.517	0.404	0.336	0.287	0.233	0.159	0.111
24.000	72.000	0.948	0.559	0.437	0.362	0.309	0.250	0.166	0.120
26.000	78.000	1.015	0.600	0.468	0.387	0.329	0.266	0.168	0.129
28.000	84.000	1.079	0.637	0.498	0.410	0.349	0.281	0.162	0.138
30.000	90.000	1.141	0.674	0.527	0.433	0.368	0.296	0.171	0.146
32.000	96.000	1.202	0.821	0.555	0.455	0.387	0.311	0.181	0.155
34.000	102.000	1.262	0.862	0.583	0.477	0.406	0.324	0.191	0.163

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	36.000	29.43	13.47	8.23	5.79	4.46	3.19	2.06	2.06
14.000	42.000	29.06	13.41	8.16	5.75	4.44	3.13	1.95	1.81
16.000	48.000	28.78	13.22	8.11	5.68	4.35	3.06	1.93	1.78
18.000	54.000	28.22	13.08	7.97	5.59	4.26	3.01	1.89	1.55
20.000	60.000	27.61	12.75	7.78	5.45	4.15	2.93	1.87	1.10
22.000	66.000	36.00	12.48	7.62	5.34	4.07	2.86	1.82	1.05
24.000	72.000	35.26	12.26	7.49	5.23	3.98	2.79	1.79	1.02
26.000	78.000	34.44	12.04	7.32	5.11	3.86	2.72	1.77	0.99
28.000	84.000	33.56	11.70	7.15	4.97	3.76	2.64	1.77	0.96
30.000	90.000	32.69	11.41	6.97	4.85	3.66	2.58	1.72	0.91
32.000	96.000	31.89	11.16	6.80	4.72	3.57	2.52	1.67	0.90
34.000	102.000	31.14	14.53	6.65	4.62	3.49	2.44	1.62	0.86

Table D-3.c.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 300 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	0.447	0.303	0.237	0.199	0.174	0.142	0.107	0.100
14.000	56.000	0.519	0.352	0.275	0.231	0.202	0.164	0.122	0.100
16.000	64.000	0.588	0.400	0.312	0.261	0.228	0.185	0.137	0.100
18.000	72.000	0.653	0.444	0.347	0.290	0.253	0.205	0.152	0.100
20.000	80.000	0.828	0.488	0.381	0.319	0.277	0.225	0.166	0.109
22.000	88.000	0.901	0.531	0.415	0.347	0.302	0.245	0.178	0.119
24.000	96.000	0.970	0.573	0.448	0.374	0.324	0.264	0.191	0.129
26.000	104.000	1.036	0.612	0.478	0.399	0.346	0.282	0.203	0.138
28.000	112.000	1.101	0.650	0.508	0.424	0.367	0.300	0.213	0.147
30.000	120.000	1.164	0.688	0.537	0.448	0.387	0.317	0.222	0.156

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	50	75	100	125	150	200	300	500
12.000	48.000	29.27	13.45	8.23	5.80	4.46	3.02	1.81	1.63
14.000	56.000	28.99	13.33	8.14	5.74	4.42	2.96	1.75	1.30
16.000	64.000	28.49	13.18	8.02	5.61	4.31	2.89	1.70	1.12
18.000	72.000	27.76	12.83	7.84	5.47	4.20	2.81	1.67	0.97
20.000	80.000	27.11	12.56	7.65	5.37	4.08	2.74	1.62	0.90
22.000	88.000	35.38	12.29	7.51	5.25	4.02	2.69	1.56	0.87
24.000	96.000	34.45	12.02	7.35	5.12	3.89	2.63	1.53	0.85
26.000	104.000	33.49	11.69	7.13	4.97	3.78	2.56	1.48	0.81
28.000	112.000	32.61	11.37	6.94	4.85	3.67	2.50	1.43	0.78
30.000	120.000	31.75	11.09	6.76	4.72	3.56	2.43	1.37	0.75

Table D-3.d.1. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 100 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	12.000	0.387	0.190	0.121	0.100	0.100	0.100	0.100	0.100
14.000	14.000	0.449	0.220	0.140	0.111	0.100	0.100	0.100	0.100
16.000	16.000	0.505	0.250	0.159	0.127	0.108	0.100	0.100	0.100
18.000	18.000	0.561	0.278	0.178	0.141	0.121	0.106	0.100	0.100
20.000	20.000	0.616	0.305	0.195	0.155	0.133	0.116	0.100	0.100
22.000	22.000	0.668	0.331	0.213	0.169	0.145	0.126	0.102	0.100
24.000	24.000	0.829	0.356	0.230	0.183	0.156	0.137	0.110	0.100
26.000	26.000	0.884	0.380	0.247	0.196	0.168	0.147	0.118	0.100
28.000	28.000	0.939	0.402	0.263	0.209	0.178	0.156	0.126	0.100
30.000	30.000	0.992	0.424	0.279	0.221	0.189	0.165	0.134	0.100
32.000	32.000	1.040	0.444	0.294	0.233	0.199	0.174	0.141	0.106
34.000	34.000	1.083	0.463	0.309	0.245	0.209	0.183	0.148	0.111
36.000	36.000	1.123	0.482	0.324	0.257	0.219	0.192	0.155	0.116
38.000	38.000	1.161	0.497	0.338	0.268	0.229	0.201	0.162	0.121
40.000	40.000	1.197	0.508	0.351	0.280	0.239	0.209	0.168	0.126
42.000	42.000	1.231	0.491	0.363	0.290	0.248	0.217	0.175	0.131
44.000	44.000	1.263	0.507	0.375	0.300	0.256	0.225	0.181	0.136
46.000	46.000	1.292	0.523	0.385	0.309	0.265	0.232	0.187	0.140
48.000	48.000	1.319	0.538	0.396	0.318	0.272	0.238	0.192	0.144
50.000	50.000	1.344	0.552	0.405	0.327	0.280	0.245	0.197	0.148
52.000	52.000	1.365	0.566	0.415	0.335	0.287	0.251	0.202	0.152
54.000	54.000	1.384	0.579	0.426	0.343	0.294	0.257	0.207	0.155
56.000	56.000	1.402	0.591	0.435	0.351	0.301	0.263	0.212	0.159
58.000	58.000	1.417	0.603	0.445	0.359	0.308	0.269	0.217	0.162
60.000	60.000	1.439	0.615	0.454	0.366	0.315	0.274	0.221	0.166

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	12.000	59.73	15.78	9.40	6.89	6.89	6.89	6.89	6.89
14.000	14.000	59.07	15.58	9.27	6.37	5.32	5.32	5.32	5.32
16.000	16.000	57.21	15.43	9.17	6.39	4.83	4.23	4.23	4.23
18.000	18.000	55.78	15.12	9.09	6.24	4.79	3.82	3.47	3.47
20.000	20.000	54.48	14.79	8.87	6.13	4.70	3.73	2.91	2.91
22.000	22.000	52.94	14.55	8.77	6.03	4.63	3.65	2.56	2.48
24.000	24.000	51.39	14.37	8.61	5.96	4.52	3.63	2.51	2.14
26.000	26.000	66.39	14.18	8.48	5.84	4.48	3.57	2.47	1.87
28.000	28.000	64.59	13.96	8.32	5.74	4.35	3.49	2.44	1.66
30.000	30.000	62.79	13.77	8.18	5.61	4.28	3.41	2.41	1.47
32.000	32.000	60.66	13.55	8.01	5.50	4.19	3.35	2.35	1.46
34.000	34.000	58.27	13.33	7.86	5.40	4.11	3.29	2.31	1.42
36.000	36.000	55.88	13.14	7.73	5.32	4.04	3.24	2.26	1.39
38.000	38.000	53.61	12.87	7.60	5.21	3.98	3.20	2.23	1.37
40.000	40.000	51.43	12.54	7.45	5.14	3.92	3.13	2.17	1.34
42.000	42.000	49.33	12.45	7.28	5.02	3.84	3.07	2.14	1.32
44.000	44.000	47.32	12.11	7.13	4.91	3.75	3.02	2.10	1.30
46.000	46.000	45.30	11.80	6.94	4.79	3.69	2.95	2.06	1.27
48.000	48.000	43.36	11.48	6.79	4.67	3.59	2.87	2.00	1.24
50.000	50.000	41.49	11.15	6.60	4.57	3.52	2.81	1.95	1.21
52.000	52.000	39.57	10.85	6.45	4.45	3.43	2.74	1.91	1.18
54.000	54.000	37.72	10.55	6.32	4.35	3.35	2.68	1.86	1.15
56.000	56.000	35.99	10.23	6.15	4.25	3.28	2.62	1.83	1.13
58.000	58.000	34.28	9.94	6.02	4.16	3.22	2.56	1.79	1.10
60.000	60.000	33.03	9.67	5.88	4.06	3.16	2.50	1.74	1.08

Table D-3.d.2. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 100 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.25

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	15.000	0.447	0.211	0.130	0.105	0.100	0.100	0.100	0.100
14.000	17.500	0.516	0.245	0.151	0.122	0.105	0.100	0.100	0.100
16.000	20.000	0.581	0.277	0.170	0.139	0.119	0.103	0.100	0.100
18.000	22.500	0.645	0.306	0.189	0.154	0.132	0.115	0.100	0.100
20.000	25.000	0.708	0.333	0.208	0.169	0.145	0.126	0.103	0.100
22.000	27.500	0.884	0.365	0.227	0.184	0.158	0.137	0.112	0.100
24.000	30.000	0.949	0.398	0.245	0.199	0.170	0.148	0.120	0.100
26.000	32.500	1.012	0.431	0.262	0.213	0.181	0.158	0.129	0.100
28.000	35.000	1.074	0.461	0.278	0.226	0.193	0.168	0.137	0.105
30.000	37.500	1.132	0.486	0.295	0.239	0.204	0.177	0.145	0.111
32.000	40.000	1.181	0.511	0.311	0.252	0.215	0.187	0.153	0.117
34.000	42.500	1.228	0.534	0.326	0.265	0.225	0.196	0.160	0.122
36.000	45.000	1.272	0.553	0.341	0.277	0.236	0.205	0.168	0.128
38.000	47.500	1.314	0.572	0.354	0.288	0.245	0.214	0.175	0.133
40.000	50.000	1.353	0.589	0.367	0.298	0.253	0.222	0.181	0.138
42.000	52.500	1.389	0.605	0.380	0.308	0.262	0.229	0.187	0.143
44.000	55.000	1.422	0.619	0.392	0.317	0.270	0.237	0.193	0.147
46.000	57.500	1.452	0.629	0.404	0.326	0.278	0.244	0.199	0.152
48.000	60.000	1.479	0.633	0.415	0.335	0.285	0.251	0.205	0.156
50.000	62.500	1.503	0.616	0.426	0.343	0.293	0.257	0.210	0.160
52.000	65.000	1.523	0.585	0.437	0.352	0.300	0.264	0.215	0.164

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	15.000	59.49	14.33	9.35	6.25	5.72	5.72	5.72	5.72
14.000	17.500	58.24	14.22	9.27	6.21	4.75	4.38	4.38	4.38
16.000	20.000	56.54	13.98	9.01	6.17	4.68	3.70	3.52	3.52
18.000	22.500	55.05	13.65	8.80	6.00	4.57	3.66	2.87	2.87
20.000	25.000	53.73	13.30	8.64	5.86	4.49	3.57	2.51	2.39
22.000	27.500	69.23	13.23	8.52	5.76	4.42	3.50	2.46	2.02
24.000	30.000	67.04	13.23	8.34	5.67	4.33	3.44	2.39	1.74
26.000	32.500	64.96	13.22	8.14	5.55	4.21	3.35	2.36	1.51
28.000	35.000	63.08	13.11	7.91	5.41	4.14	3.28	2.30	1.45
30.000	37.500	61.05	12.84	7.76	5.28	4.05	3.19	2.25	1.41
32.000	40.000	58.40	12.60	7.59	5.18	3.97	3.13	2.21	1.38
34.000	42.500	55.93	12.34	7.40	5.08	3.88	3.06	2.15	1.34
36.000	45.000	53.53	11.96	7.23	4.97	3.82	3.00	2.12	1.32
38.000	47.500	51.27	11.61	7.02	4.84	3.71	2.94	2.07	1.28
40.000	50.000	49.05	11.25	6.82	4.70	3.59	2.86	2.01	1.25
42.000	52.500	46.89	10.89	6.65	4.57	3.51	2.78	1.95	1.22
44.000	55.000	44.78	10.52	6.46	4.45	3.41	2.72	1.90	1.18
46.000	57.500	42.72	10.24	6.30	4.33	3.32	2.65	1.85	1.16
48.000	60.000	40.71	10.00	6.12	4.22	3.22	2.58	1.81	1.13
50.000	62.500	38.74	9.79	5.95	4.11	3.15	2.51	1.76	1.10
52.000	65.000	36.78	9.68	5.81	4.02	3.07	2.45	1.71	1.07

Table D-3.d.3. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 100 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.50

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	18.000	0.500	0.246	0.166	0.112	0.100	0.100	0.100	0.100
14.000	21.000	0.575	0.285	0.192	0.130	0.113	0.100	0.100	0.100
16.000	24.000	0.648	0.322	0.216	0.147	0.127	0.112	0.100	0.100
18.000	27.000	0.830	0.357	0.238	0.163	0.141	0.124	0.100	0.100
20.000	30.000	0.908	0.391	0.260	0.179	0.155	0.136	0.109	0.100
22.000	33.000	0.982	0.423	0.278	0.194	0.168	0.148	0.119	0.100
24.000	36.000	1.054	0.452	0.261	0.209	0.181	0.158	0.128	0.100
26.000	39.000	1.124	0.481	0.275	0.223	0.194	0.169	0.136	0.106
28.000	42.000	1.192	0.508	0.290	0.238	0.206	0.179	0.145	0.112
30.000	45.000	1.248	0.535	0.307	0.251	0.218	0.189	0.153	0.118
32.000	48.000	1.302	0.561	0.322	0.265	0.229	0.199	0.162	0.125
34.000	51.000	1.352	0.581	0.337	0.277	0.239	0.207	0.169	0.131
36.000	54.000	1.399	0.599	0.351	0.288	0.249	0.216	0.176	0.136
38.000	57.000	1.443	0.617	0.365	0.300	0.258	0.224	0.183	0.141
40.000	60.000	1.484	0.633	0.378	0.310	0.267	0.231	0.190	0.146
42.000	63.000	1.522	0.636	0.390	0.321	0.275	0.239	0.196	0.151
44.000	66.000	1.556	0.666	0.402	0.331	0.282	0.246	0.202	0.155
46.000	69.000	1.586	0.696	0.414	0.340	0.290	0.253	0.208	0.160
48.000	72.000	1.612	0.823	0.425	0.349	0.297	0.259	0.213	0.164

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	18.000	59.39	14.38	8.37	6.21	5.00	5.00	5.00	5.00
14.000	21.000	57.70	14.18	8.28	6.15	4.70	3.72	3.72	3.72
16.000	24.000	56.11	13.85	8.12	6.02	4.55	3.58	2.99	2.99
18.000	27.000	54.55	13.46	7.92	5.86	4.44	3.47	2.45	2.45
20.000	30.000	70.51	13.15	7.76	5.73	4.35	3.39	2.37	2.04
22.000	33.000	68.15	12.82	7.62	5.57	4.23	3.34	2.34	1.72
24.000	36.000	65.97	12.43	7.76	5.44	4.13	3.23	2.29	1.47
26.000	39.000	63.93	12.10	7.66	5.28	4.04	3.17	2.21	1.41
28.000	42.000	61.99	11.75	7.58	5.19	3.94	3.09	2.17	1.36
30.000	45.000	59.20	11.45	7.41	5.04	3.84	3.03	2.11	1.32
32.000	48.000	56.63	11.16	7.17	4.94	3.73	2.97	2.08	1.31
34.000	51.000	54.09	10.74	6.97	4.78	3.61	2.87	2.01	1.27
36.000	54.000	51.66	10.32	6.75	4.62	3.50	2.80	1.95	1.23
38.000	57.000	49.33	9.95	6.56	4.50	3.39	2.72	1.90	1.19
40.000	60.000	47.08	9.57	6.36	4.35	3.30	2.62	1.86	1.16
42.000	63.000	44.92	9.17	6.15	4.23	3.21	2.56	1.80	1.13
44.000	66.000	42.78	9.16	5.96	4.11	3.11	2.48	1.75	1.09
46.000	69.000	40.66	9.16	5.79	3.97	3.03	2.41	1.70	1.06
48.000	72.000	38.58	8.10	5.61	3.85	2.95	2.33	1.64	1.03

Table D-3.d.4. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 100 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.75

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	21.000	0.530	0.261	0.173	0.125	0.100	0.100	0.100	0.100
14.000	24.500	0.609	0.303	0.199	0.140	0.115	0.102	0.100	0.100
16.000	28.000	0.686	0.341	0.228	0.154	0.130	0.115	0.100	0.100
18.000	31.500	0.879	0.378	0.256	0.170	0.145	0.127	0.103	0.100
20.000	35.000	0.960	0.415	0.284	0.186	0.158	0.139	0.113	0.100
22.000	38.500	1.038	0.451	0.307	0.200	0.172	0.151	0.122	0.100
24.000	42.000	1.114	0.484	0.328	0.214	0.184	0.162	0.131	0.102
26.000	45.500	1.188	0.516	0.348	0.227	0.197	0.173	0.139	0.109
28.000	49.000	1.256	0.548	0.368	0.241	0.209	0.183	0.148	0.116
30.000	52.500	1.314	0.579	0.387	0.254	0.220	0.193	0.156	0.122
32.000	56.000	1.369	0.608	0.402	0.266	0.230	0.201	0.163	0.128
34.000	59.500	1.421	0.633	0.415	0.278	0.240	0.209	0.170	0.133
36.000	63.000	1.470	0.653	0.422	0.289	0.249	0.217	0.177	0.138
38.000	66.500	1.515	0.673	0.425	0.300	0.258	0.224	0.184	0.143
40.000	70.000	1.557	0.691	0.396	0.310	0.267	0.231	0.190	0.148
42.000	73.500	1.595	0.707	0.399	0.320	0.275	0.239	0.197	0.154
44.000	77.000	1.628	0.853	0.408	0.330	0.282	0.245	0.203	0.160

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	21.000	59.08	14.33	7.22	5.70	4.58	4.58	4.58	4.58
14.000	24.500	57.31	14.19	7.11	5.68	4.45	3.55	3.43	3.43
16.000	28.000	55.67	13.76	7.13	5.65	4.36	3.46	2.72	2.72
18.000	31.500	72.22	13.36	7.12	5.51	4.29	3.35	2.34	2.22
20.000	35.000	69.78	13.04	7.11	5.41	4.13	3.26	2.29	1.83
22.000	38.500	67.42	12.73	6.97	5.25	4.05	3.19	2.21	1.53
24.000	42.000	65.25	12.32	6.82	5.12	3.90	3.09	2.15	1.36
26.000	45.500	63.23	11.93	6.67	4.98	3.82	3.01	2.07	1.32
28.000	49.000	60.94	11.60	6.52	4.87	3.71	2.92	2.02	1.29
30.000	52.500	58.10	11.28	6.37	4.72	3.59	2.85	1.96	1.25
32.000	56.000	55.43	10.93	6.17	4.56	3.46	2.74	1.89	1.21
34.000	59.500	52.90	10.50	5.96	4.42	3.35	2.64	1.83	1.16
36.000	63.000	50.50	10.06	5.80	4.26	3.23	2.56	1.77	1.12
38.000	66.500	48.14	9.67	5.69	4.13	3.12	2.47	1.72	1.08
40.000	70.000	45.89	9.29	5.67	3.98	3.03	2.38	1.66	1.05
42.000	73.500	43.68	8.90	5.56	3.86	2.93	2.32	1.63	1.02
44.000	77.000	41.46	11.38	5.38	3.74	2.83	2.23	1.58	0.99

Table D-3.d.5. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 100 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 2.00**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	24.000	0.559	0.275	0.193	0.148	0.108	0.100	0.100	0.100
14.000	28.000	0.641	0.318	0.223	0.170	0.120	0.105	0.100	0.100
16.000	32.000	0.834	0.359	0.251	0.190	0.133	0.118	0.100	0.100
18.000	36.000	0.925	0.398	0.277	0.210	0.147	0.131	0.105	0.100
20.000	40.000	1.009	0.437	0.301	0.228	0.161	0.142	0.115	0.100
22.000	44.000	1.091	0.473	0.322	0.243	0.174	0.154	0.124	0.100
24.000	48.000	1.170	0.508	0.341	0.257	0.187	0.165	0.133	0.104
26.000	52.000	1.247	0.543	0.360	0.270	0.200	0.176	0.142	0.111
28.000	56.000	1.314	0.576	0.378	0.279	0.211	0.185	0.150	0.118
30.000	60.000	1.375	0.609	0.403	0.268	0.222	0.194	0.158	0.124
32.000	64.000	1.432	0.636	0.427	0.267	0.232	0.202	0.165	0.131
34.000	68.000	1.485	0.662	0.443	0.278	0.241	0.210	0.171	0.138
36.000	72.000	1.535	0.686	0.456	0.289	0.250	0.218	0.178	0.145
38.000	76.000	1.580	0.709	0.468	0.300	0.259	0.225	0.184	0.151
40.000	80.000	1.622	0.844	0.479	0.310	0.267	0.232	0.190	0.158
42.000	84.000	1.660	0.867	0.488	0.319	0.274	0.238	0.196	0.164

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	24.000	58.96	14.27	7.21	5.12	4.37	4.22	4.22	4.22
14.000	28.000	56.96	14.02	7.09	5.02	4.28	3.45	3.15	3.15
16.000	32.000	55.37	13.68	6.90	4.88	4.20	3.34	2.50	2.50
18.000	36.000	71.76	13.28	6.70	4.78	4.06	3.26	2.22	2.04
20.000	40.000	69.16	12.97	6.52	4.65	3.95	3.12	2.17	1.66
22.000	44.000	66.82	12.56	6.31	4.58	3.82	3.05	2.09	1.39
24.000	48.000	64.58	12.17	6.08	4.52	3.71	2.95	2.03	1.27
26.000	52.000	62.50	11.85	5.89	4.46	3.62	2.87	1.97	1.24
28.000	56.000	59.84	11.50	5.71	4.38	3.48	2.76	1.90	1.21
30.000	60.000	57.08	11.20	5.68	4.35	3.36	2.66	1.84	1.16
32.000	64.000	54.41	10.73	5.63	4.23	3.24	2.55	1.77	1.11
34.000	68.000	51.83	10.30	5.47	4.07	3.11	2.45	1.68	1.08
36.000	72.000	49.40	9.87	5.29	3.93	3.00	2.37	1.63	1.04
38.000	76.000	46.97	9.46	5.11	3.81	2.91	2.28	1.57	0.99
40.000	80.000	44.68	9.07	4.93	3.68	2.81	2.20	1.51	0.97
42.000	84.000	42.45	11.58	4.76	3.54	2.70	2.11	1.46	0.92

Table D-3.d.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 100 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 3.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	36.000	0.605	0.300	0.213	0.167	0.143	0.123	0.100	0.100
14.000	42.000	0.693	0.344	0.245	0.191	0.164	0.140	0.108	0.100
16.000	48.000	0.900	0.388	0.275	0.214	0.184	0.156	0.119	0.100
18.000	54.000	0.992	0.430	0.305	0.236	0.202	0.172	0.129	0.100
20.000	60.000	1.081	0.469	0.333	0.256	0.220	0.187	0.135	0.103
22.000	66.000	1.167	0.507	0.360	0.276	0.236	0.202	0.127	0.112
24.000	72.000	1.247	0.544	0.386	0.295	0.250	0.214	0.136	0.120
26.000	78.000	1.314	0.580	0.410	0.311	0.262	0.224	0.145	0.128
28.000	84.000	1.377	0.612	0.430	0.332	0.273	0.230	0.155	0.136
30.000	90.000	1.436	0.640	0.447	0.347	0.285	0.235	0.163	0.144
32.000	96.000	1.490	0.667	0.464	0.361	0.296	0.240	0.172	0.152
34.000	102.000	1.539	0.691	0.478	0.373	0.306	0.243	0.181	0.159

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	36.000	57.45	14.13	7.12	4.55	3.48	2.73	2.06	2.06
14.000	42.000	55.38	13.65	6.92	4.40	3.38	2.63	1.92	1.81
16.000	48.000	71.51	13.29	6.68	4.25	3.27	2.53	1.86	1.78
18.000	54.000	68.64	12.90	6.49	4.11	3.14	2.45	1.81	1.55
20.000	60.000	66.03	12.43	6.27	3.94	3.03	2.38	1.77	1.15
22.000	66.000	63.59	12.00	6.05	3.81	2.92	2.31	1.77	1.09
24.000	72.000	61.01	11.61	5.85	3.67	2.79	2.21	1.68	1.02
26.000	78.000	57.72	11.25	5.65	3.50	2.66	2.12	1.57	0.96
28.000	84.000	54.66	10.80	5.40	3.45	2.53	2.03	1.53	0.91
30.000	90.000	51.78	10.29	5.12	3.31	2.43	1.95	1.42	0.86
32.000	96.000	49.00	9.82	4.89	3.17	2.34	1.88	1.36	0.83
34.000	102.000	46.31	9.34	4.63	3.02	2.24	1.81	1.31	0.78

Table D-3.d.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 100 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	48.000	0.621	0.308	0.219	0.174	0.149	0.131	0.105	0.100
14.000	56.000	0.821	0.353	0.251	0.200	0.170	0.150	0.119	0.100
16.000	64.000	0.919	0.398	0.282	0.224	0.190	0.168	0.133	0.100
18.000	72.000	1.012	0.439	0.312	0.247	0.209	0.184	0.145	0.100
20.000	80.000	1.102	0.479	0.340	0.269	0.227	0.200	0.156	0.110
22.000	88.000	1.186	0.517	0.367	0.290	0.245	0.214	0.165	0.119
24.000	96.000	1.257	0.555	0.393	0.309	0.262	0.225	0.172	0.127
26.000	104.000	1.322	0.587	0.415	0.325	0.276	0.236	0.179	0.136
28.000	112.000	1.382	0.616	0.436	0.340	0.289	0.245	0.184	0.144
30.000	120.000	1.437	0.644	0.454	0.354	0.301	0.253	0.184	0.152

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	25	50	75	100	125	150	200	300
12.000	48.000	56.49	13.89	7.02	4.46	3.31	2.59	1.76	1.63
14.000	56.000	54.40	13.41	6.78	4.33	3.17	2.50	1.68	1.30
16.000	64.000	69.58	13.05	6.55	4.17	3.04	2.40	1.63	1.12
18.000	72.000	66.67	12.55	6.34	4.01	2.91	2.28	1.55	0.97
20.000	80.000	64.04	12.10	6.10	3.86	2.79	2.20	1.48	0.93
22.000	88.000	61.30	11.65	5.87	3.72	2.69	2.10	1.40	0.87
24.000	96.000	57.86	11.28	5.66	3.55	2.59	1.97	1.30	0.80
26.000	104.000	54.53	10.75	5.37	3.36	2.45	1.86	1.24	0.76
28.000	112.000	51.38	10.21	5.11	3.17	2.32	1.76	1.17	0.71
30.000	120.000	48.39	9.72	4.84	3.00	2.21	1.66	1.10	0.67

Table D-3.e.1. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 30 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	12.000	0.680	0.243	0.119	0.100	0.100	0.100	0.100	0.100
14.000	14.000	0.895	0.278	0.136	0.100	0.100	0.100	0.100	0.100
16.000	16.000	0.998	0.312	0.154	0.113	0.100	0.100	0.100	0.100
18.000	18.000	1.098	0.342	0.170	0.125	0.102	0.100	0.100	0.100
20.000	20.000	1.185	0.372	0.186	0.136	0.111	0.100	0.100	0.100
22.000	22.000	1.261	0.409	0.201	0.147	0.120	0.101	0.100	0.100
24.000	24.000	1.330	0.441	0.216	0.158	0.129	0.108	0.100	0.100
26.000	26.000	1.393	0.465	0.230	0.168	0.137	0.116	0.102	0.100
28.000	28.000	1.448	0.487	0.242	0.178	0.146	0.123	0.108	0.100
30.000	30.000	1.497	0.508	0.254	0.187	0.153	0.129	0.113	0.100
32.000	32.000	1.537	0.527	0.264	0.196	0.160	0.135	0.118	0.100
34.000	34.000	1.569	0.544	0.274	0.204	0.166	0.140	0.123	0.100
36.000	36.000	1.597	0.560	0.284	0.212	0.172	0.146	0.127	0.104
38.000	38.000	1.628	0.572	0.294	0.219	0.178	0.151	0.132	0.107
40.000	40.000	1.653	0.578	0.303	0.226	0.184	0.155	0.136	0.111
42.000	42.000	1.667	0.581	0.312	0.233	0.189	0.160	0.140	0.114
44.000	44.000	1.671	0.578	0.320	0.239	0.195	0.164	0.144	0.117
46.000	46.000	1.667	0.541	0.328	0.246	0.200	0.168	0.147	0.120
48.000	48.000	1.682	0.552	0.335	0.251	0.204	0.172	0.151	0.124
50.000	50.000	1.689	0.562	0.341	0.257	0.209	0.176	0.154	0.129
52.000	52.000	1.685	0.571	0.348	0.262	0.213	0.180	0.157	0.133
54.000	54.000	1.668	0.579	0.353	0.267	0.216	0.183	0.160	0.136
56.000	56.000	1.629	0.586	0.358	0.271	0.220	0.186	0.162	0.140
58.000	58.000	1.627	0.591	0.364	0.275	0.223	0.189	0.165	0.144
60.000	60.000	1.642	0.596	0.370	0.279	0.226	0.192	0.167	0.148

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	12.000	184.40	24.14	9.14	6.89	6.89	6.89	6.89	6.89
14.000	14.000	234.70	23.34	8.82	5.32	5.32	5.32	5.32	5.32
16.000	16.000	223.43	22.62	8.68	5.22	4.23	4.23	4.23	4.23
18.000	18.000	213.69	21.62	8.40	5.07	3.59	3.47	3.47	3.47
20.000	20.000	201.60	20.84	8.18	4.89	3.46	2.91	2.91	2.91
22.000	22.000	188.67	20.83	7.93	4.74	3.36	2.52	2.48	2.48
24.000	24.000	176.36	20.41	7.73	4.62	3.28	2.44	2.14	2.14
26.000	26.000	164.84	19.48	7.54	4.48	3.18	2.40	1.94	1.87
28.000	28.000	153.58	18.56	7.28	4.35	3.12	2.34	1.88	1.66
30.000	30.000	142.99	17.72	7.06	4.21	3.01	2.26	1.81	1.47
32.000	32.000	132.48	16.89	6.79	4.08	2.91	2.19	1.75	1.32
34.000	34.000	122.29	16.07	6.55	3.95	2.79	2.10	1.69	1.20
36.000	36.000	113.01	15.31	6.32	3.82	2.69	2.05	1.62	1.16
38.000	38.000	105.40	14.56	6.11	3.69	2.61	1.98	1.58	1.11
40.000	40.000	98.07	14.04	5.89	3.57	2.53	1.90	1.52	1.09
42.000	42.000	90.47	13.52	5.69	3.46	2.44	1.84	1.47	1.05
44.000	44.000	82.83	12.92	5.49	3.34	2.38	1.78	1.43	1.01
46.000	46.000	75.42	12.59	5.31	3.25	2.30	1.72	1.37	0.98
48.000	48.000	70.52	12.06	5.11	3.13	2.22	1.66	1.34	0.94
50.000	50.000	65.53	11.54	4.91	3.05	2.15	1.62	1.29	0.93
52.000	52.000	60.30	11.04	4.76	2.95	2.08	1.57	1.25	0.90
54.000	54.000	54.79	10.55	4.57	2.85	2.00	1.52	1.21	0.85
56.000	56.000	48.59	10.06	4.39	2.75	1.94	1.47	1.16	0.82
58.000	58.000	45.19	9.58	4.26	2.66	1.87	1.42	1.13	0.80
60.000	60.000	43.01	9.16	4.13	2.58	1.81	1.38	1.09	0.78

Table D-3.e.2. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 30 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.25

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	15.000	0.903	0.283	0.127	0.100	0.100	0.100	0.100	0.100
14.000	17.500	1.026	0.324	0.145	0.109	0.100	0.100	0.100	0.100
16.000	20.000	1.143	0.362	0.163	0.123	0.100	0.100	0.100	0.100
18.000	22.500	1.255	0.399	0.180	0.135	0.109	0.100	0.100	0.100
20.000	25.000	1.345	0.433	0.197	0.147	0.119	0.101	0.100	0.100
22.000	27.500	1.428	0.465	0.213	0.159	0.128	0.109	0.100	0.100
24.000	30.000	1.503	0.491	0.227	0.170	0.138	0.117	0.104	0.100
26.000	32.500	1.570	0.514	0.241	0.180	0.146	0.125	0.110	0.100
28.000	35.000	1.628	0.535	0.253	0.189	0.154	0.131	0.116	0.100
30.000	37.500	1.676	0.553	0.265	0.197	0.161	0.137	0.121	0.100
32.000	40.000	1.714	0.568	0.277	0.206	0.168	0.143	0.126	0.104
34.000	42.500	1.746	0.579	0.288	0.214	0.175	0.149	0.131	0.108
36.000	45.000	1.783	0.597	0.298	0.221	0.181	0.154	0.136	0.112
38.000	47.500	1.810	0.627	0.307	0.228	0.187	0.160	0.140	0.116
40.000	50.000	1.825	0.632	0.316	0.235	0.193	0.164	0.145	0.119
42.000	52.500	1.826	0.639	0.324	0.241	0.198	0.169	0.148	0.123
44.000	55.000	1.828	0.647	0.331	0.247	0.203	0.173	0.152	0.127
46.000	57.500	1.843	0.653	0.337	0.253	0.208	0.177	0.156	0.132
48.000	60.000	1.847	0.646	0.343	0.258	0.212	0.181	0.159	0.136
50.000	62.500	1.837	0.566	0.349	0.263	0.216	0.185	0.162	0.140
52.000	65.000	1.807	0.560	0.356	0.268	0.220	0.188	0.164	0.144

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	15.000	242.78	23.85	8.94	5.72	5.72	5.72	5.72	5.72
14.000	17.500	230.27	22.96	8.58	5.08	4.38	4.38	4.38	4.38
16.000	20.000	218.81	21.95	8.31	4.96	3.52	3.52	3.52	3.52
18.000	22.500	208.42	21.07	8.02	4.75	3.33	2.87	2.87	2.87
20.000	25.000	193.91	20.22	7.79	4.59	3.23	2.43	2.39	2.39
22.000	27.500	180.64	19.40	7.54	4.47	3.11	2.35	2.02	2.02
24.000	30.000	168.15	18.35	7.21	4.33	3.05	2.28	1.86	1.74
26.000	32.500	156.34	17.30	6.95	4.17	2.92	2.23	1.78	1.51
28.000	35.000	144.94	16.36	6.63	4.00	2.82	2.13	1.72	1.33
30.000	37.500	133.82	15.45	6.36	3.83	2.70	2.04	1.64	1.18
32.000	40.000	123.01	14.55	6.13	3.70	2.60	1.96	1.57	1.13
34.000	42.500	113.07	13.68	5.89	3.56	2.51	1.90	1.51	1.08
36.000	45.000	105.17	13.23	5.65	3.41	2.41	1.82	1.46	1.04
38.000	47.500	97.27	13.14	5.42	3.28	2.32	1.77	1.40	1.01
40.000	50.000	89.25	12.43	5.21	3.16	2.24	1.69	1.36	0.96
42.000	52.500	81.04	11.80	4.99	3.04	2.15	1.63	1.30	0.94
44.000	55.000	74.00	11.22	4.78	2.92	2.07	1.57	1.25	0.89
46.000	57.500	68.82	10.66	4.57	2.82	2.00	1.51	1.21	0.87
48.000	60.000	63.48	10.13	4.39	2.71	1.92	1.46	1.16	0.83
50.000	62.500	57.87	9.69	4.23	2.61	1.85	1.41	1.12	0.79
52.000	65.000	51.77	9.24	4.10	2.52	1.78	1.36	1.07	0.76

Table D-3.e.3. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 30 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.50

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	18.000	1.004	0.315	0.159	0.101	0.100	0.100	0.100	0.100
14.000	21.000	1.139	0.361	0.181	0.116	0.100	0.100	0.100	0.100
16.000	24.000	1.268	0.403	0.174	0.130	0.106	0.100	0.100	0.100
18.000	27.000	1.385	0.443	0.188	0.143	0.117	0.100	0.100	0.100
20.000	30.000	1.482	0.482	0.205	0.156	0.127	0.107	0.100	0.100
22.000	33.000	1.571	0.516	0.220	0.168	0.136	0.116	0.103	0.100
24.000	36.000	1.650	0.546	0.234	0.179	0.145	0.123	0.109	0.100
26.000	39.000	1.720	0.573	0.248	0.189	0.153	0.130	0.116	0.100
28.000	42.000	1.778	0.598	0.260	0.198	0.160	0.137	0.121	0.101
30.000	45.000	1.825	0.621	0.272	0.207	0.167	0.143	0.127	0.105
32.000	48.000	1.858	0.641	0.283	0.215	0.174	0.149	0.132	0.109
34.000	51.000	1.902	0.655	0.294	0.222	0.180	0.155	0.137	0.114
36.000	54.000	1.935	0.662	0.304	0.229	0.187	0.160	0.141	0.117
38.000	57.000	1.955	0.666	0.313	0.235	0.192	0.165	0.146	0.122
40.000	60.000	1.958	0.672	0.321	0.241	0.198	0.170	0.150	0.127
42.000	63.000	1.958	0.677	0.329	0.247	0.203	0.174	0.154	0.132
44.000	66.000	1.975	0.670	0.336	0.252	0.207	0.178	0.157	0.136
46.000	69.000	1.979	0.696	0.344	0.256	0.212	0.182	0.160	0.141
48.000	72.000	1.967	0.703	0.351	0.262	0.216	0.185	0.163	0.145

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	18.000	239.45	23.57	7.94	5.09	5.00	5.00	5.00	5.00
14.000	21.000	226.42	22.74	7.70	4.94	3.72	3.72	3.72	3.72
16.000	24.000	214.84	21.70	7.76	4.76	3.26	2.99	2.99	2.99
18.000	27.000	202.52	20.72	7.62	4.56	3.17	2.45	2.45	2.45
20.000	30.000	187.82	19.87	7.43	4.40	3.06	2.30	2.04	2.04
22.000	33.000	174.43	18.82	7.09	4.23	2.94	2.24	1.81	1.72
24.000	36.000	161.68	17.70	6.75	4.04	2.84	2.13	1.71	1.47
26.000	39.000	149.70	16.61	6.47	3.85	2.71	2.04	1.66	1.27
28.000	42.000	137.93	15.60	6.15	3.65	2.58	1.96	1.57	1.13
30.000	45.000	126.59	14.66	5.87	3.48	2.46	1.87	1.51	1.07
32.000	48.000	115.32	13.73	5.60	3.33	2.36	1.79	1.44	1.02
34.000	51.000	107.05	12.86	5.36	3.19	2.26	1.72	1.38	0.99
36.000	54.000	98.83	11.99	5.13	3.07	2.18	1.65	1.31	0.94
38.000	57.000	90.54	11.16	4.89	2.94	2.07	1.58	1.27	0.91
40.000	60.000	81.96	10.47	4.65	2.82	2.00	1.52	1.21	0.87
42.000	63.000	74.34	9.84	4.44	2.71	1.91	1.45	1.17	0.84
44.000	66.000	68.92	9.21	4.23	2.59	1.82	1.39	1.11	0.78
46.000	69.000	63.31	9.16	4.06	2.46	1.76	1.34	1.06	0.76
48.000	72.000	57.44	8.90	3.89	2.38	1.68	1.28	1.02	0.71

Table D-3.e.4. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 30 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.75

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	21.000	1.062	0.333	0.171	0.103	0.100	0.100	0.100	0.100
14.000	24.500	1.204	0.381	0.198	0.118	0.100	0.100	0.100	0.100
16.000	28.000	1.341	0.426	0.219	0.132	0.109	0.100	0.100	0.100
18.000	31.500	1.458	0.468	0.239	0.145	0.119	0.100	0.100	0.100
20.000	35.000	1.559	0.509	0.258	0.158	0.129	0.109	0.100	0.100
22.000	38.500	1.651	0.543	0.273	0.169	0.138	0.117	0.104	0.100
24.000	42.000	1.732	0.574	0.282	0.179	0.145	0.124	0.110	0.100
26.000	45.500	1.802	0.602	0.266	0.189	0.153	0.131	0.117	0.100
28.000	49.000	1.859	0.628	0.266	0.198	0.160	0.137	0.122	0.103
30.000	52.500	1.903	0.651	0.275	0.206	0.167	0.143	0.128	0.109
32.000	56.000	1.943	0.671	0.282	0.214	0.173	0.149	0.133	0.115
34.000	59.500	1.984	0.688	0.290	0.220	0.179	0.155	0.137	0.120
36.000	63.000	2.013	0.702	0.299	0.226	0.184	0.160	0.142	0.126
38.000	66.500	2.025	0.823	0.307	0.231	0.190	0.164	0.145	0.131
40.000	70.000	2.016	0.839	0.315	0.236	0.195	0.169	0.149	0.136
42.000	73.500	2.036	0.852	0.323	0.241	0.199	0.172	0.154	0.141
44.000	77.000	2.047	0.860	0.330	0.247	0.204	0.177	0.159	0.146

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	21.000	237.21	23.32	7.13	4.85	4.58	4.58	4.58	4.58
14.000	24.500	224.00	22.43	7.07	4.68	3.43	3.43	3.43	3.43
16.000	28.000	212.75	21.47	6.83	4.49	3.14	2.72	2.72	2.72
18.000	31.500	198.71	20.47	6.60	4.29	2.98	2.22	2.22	2.22
20.000	35.000	184.03	19.62	6.37	4.13	2.86	2.14	1.83	1.83
22.000	38.500	170.57	18.45	6.08	3.92	2.73	2.05	1.65	1.53
24.000	42.000	157.73	17.32	5.81	3.71	2.57	1.94	1.56	1.31
26.000	45.500	145.48	16.24	5.70	3.54	2.46	1.85	1.51	1.13
28.000	49.000	133.50	15.24	5.56	3.36	2.34	1.76	1.42	1.03
30.000	52.500	121.87	14.26	5.31	3.19	2.23	1.67	1.37	0.98
32.000	56.000	111.66	13.32	5.04	3.04	2.11	1.60	1.30	0.94
34.000	59.500	103.13	12.40	4.79	2.87	2.01	1.54	1.23	0.88
36.000	63.000	94.70	11.52	4.55	2.74	1.90	1.47	1.18	0.85
38.000	66.500	86.01	10.65	4.31	2.60	1.83	1.39	1.11	0.80
40.000	70.000	76.93	9.99	4.11	2.47	1.74	1.34	1.06	0.75
42.000	73.500	71.17	12.46	3.93	2.35	1.66	1.27	1.02	0.72
44.000	77.000	65.55	11.57	3.74	2.26	1.59	1.23	0.96	0.68

Table D-3.c.5. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 30 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 2.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	24.000	1.116	0.351	0.185	0.121	0.100	0.100	0.100	0.100
14.000	28.000	1.265	0.401	0.208	0.126	0.100	0.100	0.100	0.100
16.000	32.000	1.408	0.447	0.228	0.134	0.111	0.100	0.100	0.100
18.000	36.000	1.525	0.492	0.247	0.147	0.121	0.102	0.100	0.100
20.000	40.000	1.630	0.534	0.269	0.159	0.130	0.110	0.100	0.100
22.000	44.000	1.723	0.568	0.290	0.169	0.139	0.117	0.105	0.100
24.000	48.000	1.805	0.600	0.304	0.180	0.146	0.124	0.111	0.100
26.000	52.000	1.875	0.629	0.316	0.189	0.153	0.131	0.117	0.103
28.000	56.000	1.931	0.655	0.326	0.197	0.160	0.137	0.122	0.109
30.000	60.000	1.971	0.678	0.329	0.205	0.166	0.143	0.128	0.116
32.000	64.000	2.018	0.698	0.325	0.212	0.172	0.148	0.133	0.122
34.000	68.000	2.056	0.825	0.293	0.218	0.177	0.154	0.139	0.127
36.000	72.000	2.079	0.839	0.294	0.223	0.182	0.158	0.145	0.133
38.000	76.000	2.082	0.856	0.303	0.228	0.187	0.162	0.151	0.138
40.000	80.000	2.085	0.871	0.311	0.233	0.192	0.167	0.157	0.144
42.000	84.000	2.102	0.882	0.318	0.238	0.197	0.173	0.163	0.149

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	24.000	235.01	23.25	6.72	4.40	4.22	4.22	4.22	4.22
14.000	28.000	221.84	22.29	6.42	4.37	3.15	3.15	3.15	3.15
16.000	32.000	210.42	21.21	6.10	4.23	3.00	2.50	2.50	2.50
18.000	36.000	195.04	20.30	5.83	4.06	2.84	2.11	2.04	2.04
20.000	40.000	180.48	19.37	5.69	3.86	2.68	2.00	1.66	1.66
22.000	44.000	166.66	18.11	5.55	3.61	2.55	1.87	1.52	1.39
24.000	48.000	153.69	16.98	5.29	3.45	2.39	1.77	1.44	1.18
26.000	52.000	141.31	15.90	5.02	3.25	2.26	1.69	1.37	0.98
28.000	56.000	129.23	14.87	4.77	3.07	2.14	1.60	1.29	0.91
30.000	60.000	117.29	13.88	4.56	2.92	2.02	1.52	1.24	0.89
32.000	64.000	108.06	12.93	4.41	2.77	1.91	1.44	1.18	0.84
34.000	68.000	99.36	12.00	4.29	2.62	1.80	1.38	1.11	0.77
36.000	72.000	90.62	11.07	4.06	2.47	1.70	1.30	1.04	0.74
38.000	76.000	81.57	13.79	3.88	2.33	1.61	1.23	0.99	0.69
40.000	80.000	73.83	12.88	3.70	2.22	1.54	1.19	0.94	0.67
42.000	84.000	68.06	11.98	3.52	2.11	1.48	1.14	0.90	0.63

Table D-3.e.6. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 30 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 3.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	36.000	1.195	0.379	0.204	0.143	0.115	0.100	0.100	0.100
14.000	42.000	1.353	0.430	0.231	0.165	0.130	0.104	0.100	0.100
16.000	48.000	1.482	0.478	0.258	0.184	0.144	0.101	0.100	0.100
18.000	54.000	1.595	0.523	0.280	0.198	0.153	0.102	0.100	0.100
20.000	60.000	1.694	0.560	0.298	0.209	0.158	0.112	0.105	0.100
22.000	66.000	1.778	0.594	0.314	0.219	0.164	0.121	0.114	0.104
24.000	72.000	1.846	0.624	0.328	0.228	0.140	0.129	0.121	0.111
26.000	78.000	1.896	0.650	0.339	0.237	0.148	0.137	0.129	0.118
28.000	84.000	1.944	0.673	0.348	0.245	0.156	0.145	0.136	0.125
30.000	90.000	1.987	0.691	0.356	0.241	0.164	0.153	0.144	0.132
32.000	96.000	2.010	0.704	0.370	0.242	0.172	0.160	0.151	0.138
34.000	102.000	2.007	0.831	0.378	0.238	0.180	0.167	0.157	0.144

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	36.000	224.13	22.54	6.53	3.48	2.47	2.06	2.06	2.06
14.000	42.000	211.09	21.32	6.15	3.42	2.35	1.86	1.81	1.81
16.000	48.000	193.90	20.17	5.88	3.27	2.24	1.78	1.78	1.78
18.000	54.000	177.46	19.08	5.52	3.03	2.09	1.68	1.55	1.55
20.000	60.000	162.14	17.72	5.12	2.81	1.96	1.60	1.24	1.02
22.000	66.000	147.62	16.48	4.75	2.61	1.87	1.49	1.17	0.81
24.000	72.000	133.71	15.28	4.41	2.43	1.80	1.36	1.05	0.74
26.000	78.000	120.19	14.13	4.07	2.29	1.71	1.25	0.99	0.69
28.000	84.000	108.94	13.06	3.74	2.15	1.57	1.17	0.91	0.65
30.000	90.000	99.15	11.99	3.46	1.99	1.45	1.10	0.86	0.61
32.000	96.000	89.17	10.94	3.31	1.89	1.36	1.02	0.81	0.56
34.000	102.000	78.75	10.13	3.09	1.80	1.28	0.95	0.74	0.52

Table D-3.c.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 30 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	48.000	1.219	0.387	0.208	0.151	0.124	0.102	0.100	0.100
14.000	56.000	1.368	0.438	0.236	0.171	0.139	0.114	0.100	0.100
16.000	64.000	1.491	0.487	0.263	0.188	0.151	0.123	0.102	0.100
18.000	72.000	1.598	0.527	0.284	0.202	0.162	0.130	0.104	0.100
20.000	80.000	1.689	0.563	0.303	0.218	0.170	0.135	0.111	0.102
22.000	88.000	1.762	0.594	0.320	0.230	0.177	0.137	0.119	0.109
24.000	96.000	1.815	0.622	0.334	0.240	0.181	0.135	0.127	0.117
26.000	104.000	1.865	0.645	0.346	0.246	0.183	0.144	0.135	0.124
28.000	112.000	1.907	0.664	0.356	0.250	0.185	0.152	0.143	0.131
30.000	120.000	1.927	0.677	0.362	0.255	0.179	0.159	0.150	0.137

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	48.000	217.65	21.94	6.34	3.40	2.33	1.68	1.63	1.63
14.000	56.000	201.39	20.64	5.99	3.21	2.17	1.58	1.30	1.30
16.000	64.000	183.16	19.54	5.70	2.98	1.99	1.45	1.14	1.12
18.000	72.000	166.24	18.08	5.25	2.73	1.83	1.32	1.04	0.97
20.000	80.000	150.42	16.71	4.85	2.58	1.68	1.21	0.97	0.69
22.000	88.000	135.30	15.38	4.49	2.38	1.55	1.11	0.87	0.62
24.000	96.000	120.63	14.17	4.12	2.20	1.41	1.02	0.80	0.58
26.000	104.000	108.53	12.98	3.78	2.00	1.28	0.96	0.74	0.53
28.000	112.000	97.84	11.86	3.47	1.81	1.18	0.89	0.69	0.49
30.000	120.000	87.02	10.74	3.14	1.68	1.07	0.81	0.64	0.44

Table D-3.f.1. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 10 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	12.000	0.422	0.160	0.100	0.100	0.100	0.100	0.100	0.100
14.000	14.000	0.475	0.178	0.100	0.100	0.100	0.100	0.100	0.100
16.000	16.000	0.518	0.186	0.109	0.100	0.100	0.100	0.100	0.100
18.000	18.000	0.556	0.203	0.120	0.100	0.100	0.100	0.100	0.100
20.000	20.000	0.588	0.219	0.130	0.100	0.100	0.100	0.100	0.100
22.000	22.000	0.614	0.233	0.139	0.104	0.100	0.100	0.100	0.100
24.000	24.000	0.634	0.246	0.147	0.110	0.100	0.100	0.100	0.100
26.000	26.000	0.652	0.259	0.155	0.116	0.100	0.100	0.100	0.100
28.000	28.000	0.671	0.270	0.162	0.121	0.100	0.100	0.100	0.100
30.000	30.000	0.684	0.281	0.169	0.126	0.101	0.100	0.100	0.100
32.000	32.000	0.685	0.290	0.176	0.131	0.105	0.100	0.100	0.100
34.000	34.000	0.681	0.297	0.182	0.135	0.108	0.100	0.100	0.100
36.000	36.000	0.683	0.304	0.187	0.139	0.112	0.100	0.100	0.100
38.000	38.000	0.700	0.310	0.192	0.142	0.114	0.100	0.100	0.100
40.000	40.000	0.692	0.317	0.196	0.146	0.117	0.103	0.100	0.100
42.000	42.000	0.676	0.323	0.200	0.149	0.119	0.107	0.101	0.100
44.000	44.000	0.686	0.329	0.205	0.151	0.122	0.110	0.105	0.100
46.000	46.000	0.689	0.333	0.209	0.155	0.124	0.114	0.108	0.100
48.000	48.000	0.683	0.336	0.213	0.157	0.126	0.118	0.112	0.101
50.000	50.000	0.667	0.340	0.216	0.160	0.130	0.121	0.115	0.104
52.000	52.000	0.601	0.345	0.219	0.163	0.134	0.125	0.118	0.107
54.000	54.000	0.609	0.350	0.222	0.165	0.137	0.128	0.122	0.110
56.000	56.000	0.619	0.353	0.224	0.167	0.141	0.132	0.125	0.113
58.000	58.000	0.628	0.357	0.226	0.168	0.144	0.135	0.128	0.116
60.000	60.000	0.635	0.360	0.227	0.169	0.147	0.138	0.131	0.118

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	12.000	71.02	13.09	6.89	6.89	6.89	6.89	6.89	6.89
14.000	14.000	66.11	12.56	5.32	5.32	5.32	5.32	5.32	5.32
16.000	16.000	60.19	12.31	4.90	4.23	4.23	4.23	4.23	4.23
18.000	18.000	54.79	11.62	4.72	3.47	3.47	3.47	3.47	3.47
20.000	20.000	49.64	10.98	4.52	2.91	2.91	2.91	2.91	2.91
22.000	22.000	44.73	10.30	4.31	2.65	2.48	2.48	2.48	2.48
24.000	24.000	40.07	9.67	4.08	2.51	2.14	2.14	2.14	2.14
26.000	26.000	36.11	9.21	3.90	2.40	1.87	1.87	1.87	1.87
28.000	28.000	32.98	8.71	3.71	2.28	1.66	1.66	1.66	1.66
30.000	30.000	29.85	8.28	3.55	2.17	1.50	1.47	1.47	1.47
32.000	32.000	26.57	7.82	3.41	2.08	1.44	1.32	1.32	1.32
34.000	34.000	23.69	7.40	3.26	1.98	1.36	1.20	1.20	1.20
36.000	36.000	21.57	7.03	3.10	1.89	1.31	1.09	1.09	1.09
38.000	38.000	20.50	6.67	2.96	1.79	1.24	0.99	0.99	0.99
40.000	40.000	18.39	6.37	2.81	1.72	1.19	0.93	0.82	0.82
42.000	42.000	16.24	6.05	2.68	1.64	1.12	0.89	0.71	0.68
44.000	44.000	15.37	5.76	2.58	1.55	1.08	0.82	0.68	0.56
46.000	46.000	14.49	5.45	2.48	1.50	1.03	0.80	0.64	0.47
48.000	48.000	13.86	5.14	2.38	1.43	0.99	0.77	0.63	0.41
50.000	50.000	13.10	4.89	2.28	1.38	0.96	0.72	0.59	0.39
52.000	52.000	12.18	4.68	2.18	1.33	0.93	0.70	0.56	0.38
54.000	54.000	11.62	4.50	2.10	1.27	0.87	0.67	0.55	0.36
56.000	56.000	11.18	4.29	2.00	1.22	0.85	0.65	0.52	0.35
58.000	58.000	10.75	4.12	1.92	1.17	0.80	0.62	0.50	0.34
60.000	60.000	10.29	3.95	1.82	1.11	0.76	0.59	0.48	0.32

Table D-3.f.2. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 10 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.25

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	15.000	0.483	0.186	0.100	0.100	0.100	0.100	0.100	0.100
14.000	17.500	0.539	0.209	0.106	0.100	0.100	0.100	0.100	0.100
16.000	20.000	0.586	0.231	0.118	0.100	0.100	0.100	0.100	0.100
18.000	22.500	0.627	0.245	0.128	0.100	0.100	0.100	0.100	0.100
20.000	25.000	0.661	0.236	0.138	0.103	0.100	0.100	0.100	0.100
22.000	27.500	0.687	0.239	0.146	0.110	0.100	0.100	0.100	0.100
24.000	30.000	0.705	0.252	0.154	0.116	0.100	0.100	0.100	0.100
26.000	32.500	0.838	0.264	0.162	0.122	0.100	0.100	0.100	0.100
28.000	35.000	0.852	0.274	0.169	0.127	0.103	0.100	0.100	0.100
30.000	37.500	0.854	0.283	0.175	0.132	0.107	0.100	0.100	0.100
32.000	40.000	0.859	0.293	0.181	0.136	0.111	0.100	0.100	0.100
34.000	42.500	0.864	0.302	0.186	0.141	0.114	0.100	0.100	0.100
36.000	45.000	0.856	0.309	0.191	0.144	0.117	0.103	0.100	0.100
38.000	47.500	0.826	0.316	0.196	0.148	0.120	0.108	0.102	0.100
40.000	50.000	0.706	0.321	0.201	0.151	0.123	0.112	0.106	0.100
42.000	52.500	0.703	0.325	0.206	0.155	0.125	0.116	0.110	0.100
44.000	55.000	0.839	0.329	0.210	0.158	0.128	0.120	0.114	0.103
46.000	57.500	0.829	0.335	0.213	0.160	0.133	0.124	0.118	0.106
48.000	60.000	0.803	0.339	0.216	0.163	0.137	0.128	0.121	0.110
50.000	62.500	0.708	0.342	0.218	0.165	0.140	0.131	0.125	0.113
52.000	65.000	0.704	0.345	0.220	0.166	0.144	0.135	0.128	0.116

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	15.000	69.46	12.12	5.72	5.72	5.72	5.72	5.72	5.72
14.000	17.500	63.55	11.47	4.83	4.38	4.36	4.38	4.38	4.38
16.000	20.000	57.51	10.93	4.61	3.52	3.52	3.52	3.52	3.52
18.000	22.500	52.02	10.21	4.35	2.87	2.87	2.87	2.87	2.87
20.000	25.000	46.83	9.76	4.15	2.51	2.39	2.39	2.39	2.39
22.000	27.500	41.81	9.40	3.90	2.39	2.02	2.02	2.02	2.02
24.000	30.000	37.00	8.80	3.68	2.25	1.74	1.74	1.74	1.74
26.000	32.500	33.40	8.26	3.50	2.14	1.51	1.51	1.51	1.51
28.000	35.000	39.70	7.69	3.31	2.01	1.40	1.33	1.33	1.33
30.000	37.500	34.74	7.18	3.12	1.91	1.32	1.18	1.18	1.18
32.000	40.000	30.90	6.80	2.96	1.80	1.26	1.05	1.05	1.05
34.000	42.500	27.69	6.43	2.79	1.72	1.19	0.95	0.95	0.95
36.000	45.000	24.24	6.04	2.65	1.62	1.13	0.86	0.77	0.77
38.000	47.500	15.27	5.70	2.52	1.54	1.07	0.84	0.67	0.62
40.000	50.000	14.42	5.35	2.41	1.46	1.02	0.79	0.63	0.50
42.000	52.500	13.39	5.02	2.31	1.41	0.97	0.75	0.61	0.41
44.000	55.000	12.23	4.73	2.20	1.34	0.92	0.71	0.58	0.39
46.000	57.500	11.18	4.52	2.09	1.27	0.90	0.68	0.56	0.36
48.000	60.000	10.03	4.31	1.99	1.22	0.85	0.65	0.52	0.35
50.000	62.500	10.62	4.09	1.88	1.16	0.79	0.61	0.50	0.34
52.000	65.000	10.17	3.90	1.78	1.09	0.76	0.58	0.47	0.32

Table D-3.f.3. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 10 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 1.50**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	18.000	0.536	0.203	0.100	0.100	0.100	0.100	0.100	0.100
14.000	21.000	0.594	0.228	0.112	0.100	0.100	0.100	0.100	0.100
16.000	24.000	0.645	0.245	0.124	0.100	0.100	0.100	0.100	0.100
18.000	27.000	0.687	0.273	0.135	0.100	0.100	0.100	0.100	0.100
20.000	30.000	0.833	0.290	0.144	0.107	0.100	0.100	0.100	0.100
22.000	33.000	0.861	0.300	0.153	0.114	0.100	0.100	0.100	0.100
24.000	36.000	0.887	0.261	0.161	0.120	0.100	0.100	0.100	0.100
26.000	39.000	0.908	0.265	0.167	0.126	0.103	0.100	0.100	0.100
28.000	42.000	0.916	0.275	0.173	0.131	0.107	0.100	0.100	0.100
30.000	45.000	0.917	0.285	0.179	0.135	0.111	0.100	0.100	0.100
32.000	48.000	0.926	0.294	0.184	0.139	0.114	0.101	0.100	0.100
34.000	51.000	0.921	0.301	0.189	0.143	0.117	0.106	0.100	0.100
36.000	54.000	0.894	0.307	0.194	0.148	0.121	0.111	0.105	0.100
38.000	57.000	0.896	0.312	0.199	0.151	0.124	0.115	0.109	0.100
40.000	60.000	0.906	0.319	0.203	0.155	0.128	0.119	0.113	0.103
42.000	63.000	0.910	0.326	0.207	0.157	0.132	0.124	0.117	0.106
44.000	66.000	0.905	0.331	0.210	0.160	0.137	0.128	0.121	0.110
46.000	69.000	0.883	0.335	0.212	0.162	0.141	0.131	0.125	0.113
48.000	72.000	0.887	0.338	0.216	0.164	0.145	0.135	0.128	0.116

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	18.000	68.25	10.58	5.00	5.00	5.00	5.00	5.00	5.00
14.000	21.000	61.58	9.99	4.62	3.72	3.72	3.72	3.72	3.72
16.000	24.000	55.59	9.26	4.35	2.99	2.99	2.99	2.99	2.99
18.000	27.000	49.83	9.18	4.08	2.45	2.45	2.45	2.45	2.45
20.000	30.000	44.50	8.82	3.78	2.30	2.04	2.04	2.04	2.04
22.000	33.000	52.39	8.22	3.53	2.17	1.72	1.72	1.72	1.72
24.000	36.000	46.72	7.76	3.33	2.04	1.47	1.47	1.47	1.47
26.000	39.000	41.72	7.35	3.12	1.92	1.34	1.27	1.27	1.27
28.000	42.000	36.61	6.85	2.94	1.81	1.26	1.11	1.11	1.11
30.000	45.000	31.96	6.42	2.78	1.68	1.19	0.98	0.98	0.98
32.000	48.000	28.64	6.02	2.60	1.58	1.11	0.85	0.82	0.82
34.000	51.000	25.10	5.61	2.46	1.49	1.04	0.81	0.64	0.64
36.000	54.000	21.10	5.22	2.33	1.43	1.00	0.78	0.62	0.51
38.000	57.000	19.02	4.86	2.21	1.35	0.95	0.72	0.58	0.41
40.000	60.000	17.55	4.59	2.09	1.29	0.90	0.67	0.55	0.38
42.000	63.000	16.06	4.36	1.98	1.21	0.84	0.65	0.52	0.35
44.000	66.000	14.47	4.11	1.87	1.15	0.81	0.61	0.49	0.34
46.000	69.000	12.79	3.86	1.76	1.08	0.76	0.56	0.47	0.31
48.000	72.000	12.08	3.62	1.68	1.03	0.71	0.54	0.43	0.29

Table D-3.f.4. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 10 Pounds TNT at Various Standoff Distances--Aspect Ratio, a/b = 1.75

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	21.000	0.566	0.223	0.100	0.100	0.100	0.100	0.100	0.100
14.000	24.500	0.625	0.251	0.113	0.100	0.100	0.100	0.100	0.100
16.000	28.000	0.677	0.272	0.124	0.100	0.100	0.100	0.100	0.100
18.000	31.500	0.832	0.287	0.135	0.100	0.100	0.100	0.100	0.100
20.000	35.000	0.871	0.297	0.144	0.107	0.100	0.100	0.100	0.100
22.000	38.500	0.897	0.313	0.152	0.113	0.100	0.100	0.100	0.100
24.000	42.000	0.926	0.326	0.159	0.119	0.100	0.100	0.100	0.100
26.000	45.500	0.944	0.329	0.165	0.124	0.103	0.100	0.100	0.100
28.000	49.000	0.946	0.328	0.170	0.129	0.106	0.100	0.100	0.100
30.000	52.500	0.953	0.286	0.175	0.133	0.111	0.103	0.100	0.100
32.000	56.000	0.957	0.288	0.180	0.138	0.116	0.108	0.103	0.100
34.000	59.500	0.944	0.290	0.185	0.142	0.121	0.113	0.108	0.100
36.000	63.000	0.920	0.297	0.189	0.146	0.126	0.118	0.112	0.102
38.000	66.500	0.933	0.304	0.192	0.149	0.131	0.123	0.116	0.105
40.000	70.000	0.940	0.309	0.196	0.151	0.136	0.127	0.120	0.109
42.000	73.500	0.939	0.313	0.200	0.154	0.140	0.131	0.124	0.113
44.000	77.000	0.926	0.315	0.204	0.160	0.145	0.135	0.128	0.116

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	21.000	67.38	10.46	4.58	4.58	4.58	4.58	4.58	4.58
14.000	24.500	60.36	9.87	4.31	3.43	3.43	3.43	3.43	3.43
16.000	28.000	54.22	9.05	3.98	2.72	2.72	2.72	2.72	2.72
18.000	31.500	48.53	8.22	3.74	2.22	2.22	2.22	2.22	2.22
20.000	35.000	57.44	7.47	3.48	2.07	1.83	1.83	1.83	1.83
22.000	38.500	50.35	7.12	3.22	1.92	1.53	1.53	1.53	1.53
24.000	42.000	45.09	6.77	2.99	1.80	1.31	1.31	1.31	1.31
26.000	45.500	39.92	6.22	2.78	1.68	1.19	1.13	1.13	1.13
28.000	49.000	34.57	5.80	2.59	1.57	1.10	0.92	0.92	0.92
30.000	52.500	30.56	5.58	2.43	1.47	1.05	0.78	0.70	0.70
32.000	56.000	27.09	5.18	2.27	1.39	0.97	0.73	0.61	0.54
34.000	59.500	23.35	4.79	2.13	1.31	0.91	0.69	0.57	0.42
36.000	63.000	19.78	4.49	2.00	1.24	0.85	0.65	0.53	0.36
38.000	66.500	18.26	4.23	1.86	1.17	0.80	0.62	0.49	0.33
40.000	70.000	16.73	3.96	1.76	1.09	0.75	0.57	0.46	0.31
42.000	73.500	15.14	3.70	1.67	1.02	0.70	0.53	0.43	0.30
44.000	77.000	13.41	3.44	1.59	0.99	0.67	0.50	0.40	0.27

Table D-3.f.5. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 10 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 2.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	24.000	0.592	0.234	0.105	0.100	0.100	0.100	0.100	0.100
14.000	28.000	0.654	0.265	0.114	0.100	0.100	0.100	0.100	0.100
16.000	32.000	0.707	0.289	0.125	0.100	0.100	0.100	0.100	0.100
18.000	36.000	0.866	0.309	0.135	0.100	0.100	0.100	0.100	0.100
20.000	40.000	0.904	0.325	0.143	0.107	0.100	0.100	0.100	0.100
22.000	44.000	0.932	0.335	0.151	0.113	0.100	0.100	0.100	0.100
24.000	48.000	0.960	0.329	0.157	0.118	0.100	0.100	0.100	0.100
26.000	52.000	0.974	0.344	0.162	0.122	0.105	0.100	0.100	0.100
28.000	56.000	0.971	0.349	0.168	0.127	0.111	0.104	0.100	0.100
30.000	60.000	0.984	0.349	0.172	0.132	0.117	0.109	0.104	0.100
32.000	64.000	0.982	0.326	0.177	0.136	0.122	0.114	0.108	0.100
34.000	68.000	0.955	0.283	0.181	0.140	0.128	0.119	0.113	0.102
36.000	72.000	0.953	0.289	0.183	0.146	0.132	0.124	0.118	0.106
38.000	76.000	0.964	0.294	0.187	0.151	0.137	0.128	0.122	0.110
40.000	80.000	0.968	0.297	0.191	0.157	0.142	0.133	0.126	0.114
42.000	84.000	0.960	0.297	0.195	0.162	0.147	0.138	0.131	0.118

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	24.000	66.13	10.33	4.31	4.22	4.22	4.22	4.22	4.22
14.000	28.000	59.29	9.74	4.04	3.15	3.15	3.15	3.15	3.15
16.000	32.000	53.05	8.86	3.73	2.50	2.50	2.50	2.50	2.50
18.000	36.000	62.89	8.06	3.45	2.04	2.04	2.04	2.04	2.04
20.000	40.000	55.51	7.33	3.16	1.90	1.66	1.66	1.66	1.66
22.000	44.000	48.76	6.62	2.94	1.75	1.39	1.39	1.39	1.39
24.000	48.000	43.47	5.82	2.71	1.61	1.18	1.18	1.18	1.18
26.000	52.000	38.13	5.57	2.49	1.48	1.06	0.87	0.87	0.87
28.000	56.000	32.68	5.18	2.33	1.39	0.98	0.76	0.65	0.65
30.000	60.000	29.23	4.76	2.16	1.31	0.92	0.69	0.57	0.49
32.000	64.000	25.59	4.42	2.02	1.23	0.84	0.64	0.51	0.38
34.000	68.000	21.44	4.21	1.88	1.14	0.80	0.60	0.48	0.32
36.000	72.000	19.04	3.93	1.72	1.07	0.72	0.56	0.46	0.30
38.000	76.000	17.49	3.66	1.61	0.99	0.67	0.51	0.42	0.28
40.000	80.000	15.91	3.39	1.53	0.94	0.63	0.49	0.39	0.26
42.000	84.000	14.20	3.10	1.45	0.88	0.60	0.46	0.38	0.25

Table D-3.f.6. **Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 10 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 3.00**

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	36.000	0.621	0.251	0.139	0.100	0.100	0.100	0.100	0.100
14.000	42.000	0.680	0.278	0.152	0.100	0.100	0.100	0.100	0.100
16.000	48.000	0.840	0.301	0.161	0.100	0.100	0.100	0.100	0.100
18.000	54.000	0.880	0.321	0.170	0.100	0.100	0.100	0.100	0.100
20.000	60.000	0.911	0.337	0.178	0.108	0.100	0.100	0.100	0.100
22.000	66.000	0.935	0.348	0.177	0.116	0.105	0.100	0.100	0.100
24.000	72.000	0.940	0.354	0.177	0.123	0.112	0.105	0.100	0.100
26.000	78.000	0.948	0.358	0.148	0.130	0.118	0.110	0.105	0.100
28.000	84.000	0.949	0.355	0.156	0.137	0.124	0.116	0.110	0.100
30.000	90.000	0.921	0.356	0.164	0.143	0.130	0.122	0.116	0.105
32.000	96.000	0.923	0.363	0.171	0.150	0.136	0.127	0.121	0.109
34.000	102.000	0.933	0.357	0.178	0.156	0.142	0.132	0.126	0.114

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	36.000	60.53	9.89	3.32	2.06	2.06	2.06	2.06	2.06
14.000	42.000	53.32	8.91	2.97	1.81	1.81	1.81	1.81	1.81
16.000	48.000	46.72	8.00	2.65	1.78	1.78	1.78	1.78	1.78
18.000	54.000	54.02	7.19	2.41	1.55	1.55	1.55	1.55	1.55
20.000	60.000	46.89	6.42	2.21	1.38	1.02	1.02	1.02	1.02
22.000	66.000	40.82	5.68	2.00	1.26	0.84	0.69	0.69	0.69
24.000	72.000	34.67	5.03	1.85	1.12	0.77	0.60	0.49	0.49
26.000	78.000	30.05	4.47	1.71	1.02	0.69	0.52	0.43	0.36
28.000	84.000	25.96	3.88	1.57	0.93	0.63	0.48	0.39	0.26
30.000	90.000	21.30	3.46	1.45	0.84	0.57	0.45	0.36	0.24
32.000	96.000	18.80	3.20	1.33	0.79	0.53	0.40	0.33	0.22
34.000	102.000	17.02	2.83	1.22	0.72	0.50	0.37	0.31	0.21

Table D-3.f.7. Minimum Thickness of Thermally Tempered Glass Glazing and Frame Design Load to Survive Incident Overpressure from 10 Pounds TNT at Various Standoff Distances-- Aspect Ratio, a/b = 4.00

Plate Dimensions (in.)		Minimum TTG Glazing Thickness (in.) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	48.000	0.623	0.253	0.142	0.102	0.100	0.100	0.100	0.100
14.000	56.000	0.678	0.279	0.156	0.110	0.100	0.100	0.100	0.100
16.000	64.000	0.831	0.301	0.169	0.114	0.100	0.100	0.100	0.100
18.000	72.000	0.863	0.319	0.178	0.115	0.100	0.100	0.100	0.100
20.000	80.000	0.893	0.332	0.182	0.113	0.102	0.100	0.100	0.100
22.000	88.000	0.901	0.343	0.186	0.120	0.109	0.102	0.100	0.100
24.000	96.000	0.908	0.351	0.186	0.127	0.116	0.108	0.103	0.100
26.000	104.000	0.908	0.353	0.183	0.135	0.123	0.115	0.109	0.100
28.000	112.000	0.874	0.353	0.181	0.142	0.129	0.120	0.114	0.103
30.000	120.000	0.887	0.355	0.168	0.148	0.134	0.126	0.119	0.108

Plate Dimensions (in.)		Frame Design Load (psi) for Standoff Distance (ft) of--							
b	a	10	25	50	75	100	125	150	200
12.000	48.000	56.85	9.38	3.02	1.68	1.63	1.63	1.63	1.63
14.000	56.000	49.47	8.38	2.69	1.50	1.30	1.30	1.30	1.30
16.000	64.000	42.67	7.46	2.43	1.29	1.12	1.12	1.12	1.12
18.000	72.000	48.48	6.62	2.16	1.14	0.97	0.97	0.97	0.97
20.000	80.000	42.05	5.81	1.87	1.02	0.69	0.64	0.64	0.64
22.000	88.000	35.38	5.13	1.67	0.90	0.62	0.47	0.44	0.44
24.000	96.000	30.19	4.53	1.47	0.80	0.56	0.42	0.35	0.31
26.000	104.000	25.72	3.93	1.28	0.74	0.51	0.39	0.32	0.22
28.000	112.000	20.55	3.41	1.15	0.68	0.46	0.34	0.28	0.19
30.000	120.000	18.44	3.02	1.00	0.60	0.41	0.32	0.25	0.17

Table D-4. **Actual Design Thickness and Traditionally Designated Glass Thickness***

Actual Glass Thickness for Design (t) (in)	Traditional Designation (mm)	Metric Designation
0.149	5/32	4.0
0.180	3/16	5.0
0.200	7/32	5.5
0.219	1/4	6.0
0.292	5/16	8.0
0.355	3/8	10.0
0.469	1/2	12.0
0.594	5/8	16.0
0.719	3/4	19.0
0.844	7/8	22.0
0.969	1	25.0

*Glazing over 1 inch thick is laminated from the thicknesses contained in this table.

Table D-5. **Coefficients for Frame Loading**

a/b	C_R	C_x	C_y
1.00	0.065	0.495	0.495
1.10	0.070	0.516	0.516
1.20	0.074	0.535	0.533
1.30	0.079	0.554	0.551
1.40	0.083	0.570	0.562
1.50	0.085	0.581	0.574
1.60	0.086	0.590	0.583
1.70	0.088	0.600	0.591
1.80	0.090	0.609	0.600
1.90	0.091	0.616	0.607
2.00	0.092	0.623	0.614
3.00	0.093	0.664	0.655
4.00	0.094	0.687	0.685

Note: Linear interpolation may be used for aspect ratios, a/b, not presented.

Table D-6. **Minimum Clearance and Bite Requirements***

Glass Thickness		"A" Minimum Edge Clearance (in)	"B" Nominal Bite (in)	"C" Minimum Face Clearance (in)
mm	in			
2.5	3/32	1/8	1/2	1/16
3.0	1/8	1/8	1/2	1/8
4.0	5/32	3/16	1/2	1/8
5.0	3/16	3/16	1/2	1/8
6.0	1/4	1/4	1/2	1/8
10.0	3/8	5/16	1/2	3/16
12.0	1/2	3/8	1/2	1/4
16.0	5/8	3/8	1/2	1/4
19.0	3/4	3/8	1/2	5/16
22.0	7/8	1/2	5/8	5/16
25.0	1	1/2	3/4	3/8

*For thicknesses greater than 1 inch, use the clearance and bite requirements required for 1 inch.

Table D-7. **Statistical Acceptance and Rejection Coefficients**

Number of Window Assemblies	Acceptance Coefficient	Rejection Coefficient
n	α	β
2	4.14	.546
3	3.05	.871
4	2.78	1.14
5	2.65	1.27
6	2.56	1.36
7	2.50	1.42
8	2.46	1.48
9	2.42	1.49
10	2.39	1.52

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NOTES

a. Department of Defense activities may obtain copies of Design Manuals and P-Publications from the following:

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d. Technical society and technical association specification and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.

e. For copies of non-Government publications, contact the agency/organization/publisher directly.

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ANSI/ASTM A629	Tool-Resisting Steel Flat Bars and Shapes for Security Applications
ANSI/ASTM A750	Steel, Air Ventilating Grill Units for Detention Areas
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OPNAVINST 5530.13	Physical Security Instruction for Sensitive Conventional Arms, Ammunition, and Explosives (AA&E)
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AA-D-600	Door, Vault, Security
DD-G-451	Glass, Float or Plate, Sheet, Figured (Flat, for Glasing, Mirrors, and Other Uses)
DD-G-1403	Glass, Float, Sheet, Figured, Coated (Heat-Strengthened and Tempered)
RR-F-191/3	Fencing, Wire and Post, Metal (Chain-Link Fence Posts, Top Rails, and Braces), (Detail Specification)
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TDS 80-02	Steel/Ply Attack-Resistant Wall Systems
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TM-56-86-05	Test Plan for Vehicle Crash Testing of Commercial Perimeter Barrier
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MIL-HDBK 1013/1	Design Guidelines for Physical Security of Fixed Land-Based Facilities

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