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DDESB

APPROVED PROTECTIVE CONSTRUCTION

Department of Defense Explosives Safety Board

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14. ABSTRACT

Technical Paper 15 is a record of historically significant information about the origin and evolution of protective construction designs, the current approved protective construction, and the associated explosives safety criteria. Content includes standard designs and criteria for earth-covered magazines, barricades, containment chambers, and hardened aircraft shelters.#

15. SUBJECT TERMS

Protective construction, explosives, magazines, earth-covered magazines, barricades, quantity-distance, reduced QD, blast effects

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FOREWORD

Technical Paper (TP) 15 is a record of historically significant information about the origin and evolution of protective construction designs, the current approved protective construction, and the associated explosives safety criteria. The following table highlights the significant changes in this revision:

Summary of Changes

Chapter	Changes
1	Updated general wording and references for clarity and accuracy.
2	Revised early magazine history content for historical accuracy.
3	Added Unified Facilities Criteria 4-420-01, a reference tool to assist in the planning and design of DoD ammunition and explosives storage magazines.
4	• Added modular storage magazine (MSM) to the list of earth-covered magazine (ECM) categories. • Incorporated updated guidance on the siting of legacy flat-roof ECMs and the associated restrictions due to inadequate structural strength.
6	Updated content on the use of sandbags to mitigate blast effects at explosive hazards removal sites based on the latest amendment to the U.S. Army Engineering and Support Center, Huntsville report “Use of Sandbags for Mitigation of Fragmentation and Blast Effects Due to Intentional Detonation of Munitions,” and the permitted use of sand-filled Defencell System Units as an alternative. • Added recently approved intentional detonation chambers to the documented list, including: o Dynasafe DynaSEALR X10, MECV-5L-B3, and DynaSEALR X12 o NABCO Total Containment System models 64-SCS, 64-SCS-GT, 42-SCS, and 42-SCS-GT o Mistral Security models ARC 5 Gas Tight (GT), ARC 6 GT, ARC 9 GT, and ARC 10 GT o DAVINCH USA DV-60 • Updated content on missile test cells (MTCs) to reflect recent documentation and siting restrictions; added a comprehensive list of pertinent MTC documents. • Updated substantial dividing wall (SDW) content in major revision; corrected historical SDW testing information; and revised content on the current status of guidance to reflect reevaluation efforts resulting from recent research.
8	• Incorporated F-22 missile load maximum credible events (MCEs) and reduced quantity-distance. • Incorporated additional F-15 and F-16 configurations that were tested and approved since the publication of Revision 3. • Added reduced debris inhabited building distance for aircraft configurations in light metal structures. • Added recently approved reduced MCE for AIM-120 trailer storage configurations.

Summary of Changes, Continued

Chapter	Changes

AP1	• Updated tables to:
	  o Incorporate new magazine designs approved by the Department of Defense Explosives Safety Board (DDESB) since the previous versions were published.
	  o Move designs between tables as designs are superseded or no longer supported and to reflect new DDESB policy.
	  o Add new information for designs already in Appendix AP1.
	• Consolidated the list of 7-bar and 3-bar ECMs approved for new construction in Table AP1-1, including only ECM designs that are actively maintained and regularly used in new construction.

This document will be kept current and updated as new information becomes available. TP 15 is on the DDESB Website at https://ddesb.altess.army.mil/documents/TechnicalPapers.aspx.

This TP has been reviewed by the DoD Components and the DDESB staff.

Thierry L. Chiapello
Executive Director,
Department of Defense Explosives Safety Board

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CHAPTER 1: INTRODUCTION

1.1. GENERAL.

1.1.1. Department of Defense Explosives Safety Board (DDESB) Technical Paper (TP) 15 provides a comprehensive listing of ammunition and explosives (AE) storage facilities and protective construction facilities and features that have been designed and built over the past several decades. This TP:

1.1.1.1. Provides a historical perspective and clear explanation of how explosives safety criteria developed.

1.1.1.2. Documents approved protective construction designs to provide the explosives safety community common reference information to assist in assessing existing facilities and to aid in the development of new facilities.

1.1.2. TP 15 includes:

1.1.2.1. Information on significant testing that has been performed and that has impacted the development and evolution of explosives safety criteria found in Defense Explosives Safety Regulation (DESR) 6055.09.

1.1.2.2. Past and present protective construction design information.

1.1.2.3. Relevant siting information associated with each protective construction facility and feature.

1.1.3. Throughout TP 15, safety distances are calculated primarily by means of the formula $D = K \bullet W^{1/3}$, where "D" is the distance in feet (ft), "K" is a factor depending on the risk assumed or permitted, and "W" is the net explosive weight (NEW) in pounds. This is further described in Volume 1 of Enclosure 8 of DESR 6055.09. Distance requirements determined by the above formula are sometimes expressed by the value of "K," using the terminology K9, K11, K18, to mean K = 9, K = 11, and K = 18. In certain cases, safety distances have been determined by means of testing, such as with a full or partial containment of explosion effects (e.g., blast, thermal, primary fragments, structural debris). When this is the case, a description of the test and the results of testing has been provided.

1.1.4. TP 15 will be reviewed at least annually and updated periodically by adding information on existing items and addressing newly approved protective construction.

1.1.5. Appendix AP1 will be maintained and kept current without re-issuing TP 15. The updates will be re-published at the DDESB's Website at https://ddesb.altess.army.mil/documents/TechnicalPapers.aspx.

1.2. SUMMARY OF DDESB TP 15 CONTENT. Table 1.1 provides brief summaries of the content of each chapter and the appendix tables.

Table 1.1. Summary of TP 15 Content

Chapter/ Appendix	Content Summary
2	Provides a history of the evolution of magazine design since the Lake Denmark, New Jersey, accident of 1926. It includes the significant testing that was conducted as part of this evolution that has impacted magazine design and magazine siting criteria.
3	Addresses the major differences between 7-Bar, 3-Bar, and undefined earth-covered magazines (ECM) and describes the typical features and structural components associated with each type. It also includes a discussion of storage magazines and transportation containers that have been approved with reduced NEW and/or reduced quantity-distance (QD).
4	Provides information associated with the four magazine tables in Appendix AP1. Those tables list ECMs, identify the magazines and transportation containers that have a reduced QD or reduced maximum credible event (MCE), and include relevant information for each design.
5	Pertains specifically to underground (i.e., tunnel) AE storage facilities and associated criteria.
6	Provides a comprehensive discussion, including pertinent testing information, of available barricade designs, fragment distance-limiting barrier designs, test cells, detonation chambers, suppressive shields, and other similar protective construction that have been approved by the DDESB.
7	Describes the history and testing associated with barricaded module development and the use of barricaded modules for AE storage.
8	Documents the history and testing of hardened aircraft shelters (HASs) and other QD/MCE reductions associated with airfields.
9	Addresses non-storage-related protective construction.
Table AP1-1	Identifies 7- and 3-Bar ECM designs approved for new construction. These are designs that are maintained by the DoD Components and that are kept current with explosives safety criteria.
Table AP1-2	Lists existing 7- and 3-Bar ECM designs that users may find in the field. These designs are no longer maintained and will more than likely not reflect current criteria. These designs can be considered for new construction, if they are approved by the DoD Component and the designs have been thoroughly reviewed and the design drawings updated to reflect current criteria.
Table AP1-3	Lists ECM designs determined to be undefined structures. A design is placed in this category when it is either known to be structurally weaker than a 7- or 3-Bar ECM design (through a structural assessment, analysis, or test), or if insufficient information is available to indicate its strength. These designs can be considered for new construction if they are approved by the DoD Component and have been thoroughly reviewed and updated to reflect current criteria.
Table AP1-4	Lists both ECM and aboveground magazine designs and transportation containers that have reduced QD and/or reduced MCE.

1.3. TP 15 SUPPORT DOCUMENTATION.

1.3.1. As TP 15 was developed, a great deal of supporting documentation (e.g., construction drawings, approval memoranda, Component letters, messages, technical reports (TRs), analyses) was accumulated. Much of the hard-copy information has been digitized and is available from the DDESB on request through the Services' explosives safety agencies.

1.3.2. The Naval Facilities Engineering Command (NAVFAC) established a webpage on the Whole Building Design Guide (WBDG) Website, specifically devoted to AE storage magazines: http://www.wbdg.org/building-types/ammunition-explosive-magazines. The Website:

1.3.2.1. Assists in the planning and design of new AE storage magazines for the DoD and provides definitions, descriptions, requirements, and standard drawings and specifications.

1.3.2.2. Includes Tables AP1-1 and AP1-2 and makes magazine approval documentation and drawings readily accessible to support facility planning and evaluation of existing infrastructure.

1.3.3. Locating drawings for older magazines can be difficult and, in many cases, may no longer be possible. Note that the organizations referred to in this TP as "Designer" reflect the original designer; therefore, in some cases, the listed design organization may no longer be in existence and the location of their drawings may not be known. Drawings for newer magazines, or information pertaining to design drawings, may be obtained from the design and explosives safety agencies in Table 1.2.

Table 1.2. Design and Explosives Safety Agencies

Army	U.S. Army Corps of Engineers Engineering and Support Center, Huntsville (CEHNC) Attn: CEHNC-EDC-S P.O. Box 1600 Huntsville, AL 35807-4301 Defense Ammunition Center Attn: SJMAC-EST 1 C Tree Road McAlester, OK 74501-9053
Navy	Naval Facilities Engineering Command (NAVFACENGCOM) Attn: NAVFAC Criteria Office (Code 15C) 1510 Gilbert Street Norfolk, VA 23511-2699 Naval Ordnance and Security Activity (NOSSA) Attn: N41 23 Strauss Avenue, Bldg D323 Indian Head, MD 20640-5035 Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) Attn: CI7 1000 23rd Avenue, Building 1000 Port Hueneme, CA 93043-4370
Marine Corps	Commander, Marine Corps Systems Command Attn: AM-EES 2200 Lester Street Quantico, VA 22134-5010
Air Force	Air Force Safety Center (AFSEC) Attn: AFSEC/SEW 9750 Avenue G, Suite 264 Kirtland AFB, NM 87117-5670
DDESB	Department of Defense Explosives Safety Board Attn: DDESB-PD 4800 Mark Center Drive, Suite 16E12 Alexandria, VA 22350-3606

1.4. UPDATING AND IMPROVING TP 15.

1.4.1. For TP 15 to be of continuing value to its users, it must be kept current and accurate. The DDESB will maintain this document on its Website at usarmy.pentagon.hqda-dod-esb.mbx.ddesb-tp-15@mail.mil and update it as new protective construction designs are approved and information is received and evaluated. The explosives safety community is asked to provide the DDESB (e-mail: ryan.w.bowers.civ@mail.mil) with copies of:

1.4.1.1. Documents that can be used to correct, update, or enhance this TP.

1.4.1.2. Documents, drawings, and historical or current photographs for structures and barricades listed in this TP, or not listed so that they can be added.

1.4.2. On receipt, all information will be reviewed and, if warranted, added to TP 15 or its supporting database. As new designs are approved or modified, they will be added to the TP and its supporting database.

1.4.3. In order to provide the most current information, the four tables containing the magazine listings are in an appendix at the end of this TP so they can be updated periodically without reissuing the entire TP.

1.5. PROTECTIVE CONSTRUCTION SUBMITTALS TO THE DDESB.

1.5.1. In order to clarify requirements for protective construction that are submitted as part of explosives safety site approval requests, the DDESB issued the 21 October 2009 DDESB-PD Memorandum with pertinent guidance. An explosives safety submission is required to validate compliance with DESR 6055.09 for protective construction. When minimum default separation distances are not satisfied, protective construction may be used in buildings and structures to provide protection against the propagation of explosions, damage to facilities, and loss of life. Accordingly, protective construction may be designed to:

1.5.1.1. Achieve personnel protection,

1.5.1.2. Protect facilities and equipment, and/or

1.5.1.3. Prevent propagation of explosives.

1.5.2. Previous versions of DESR 6055.09 specifically referenced Army Technical Manual (TM) 5-1300/NAVFAC P-397/AFR 88-22 for design procedures for the quantitative protection against the propagation of explosions, damage to facilities, and loss of life. The Joint document has been superseded by Unified Facilities Criteria (UFC) 03-340-02. Therefore, future protective constructions should be designed in accordance with the requirements of UFC 03-340-02. It is recommended that all design assumptions (e.g., blast loading, charge weights/locations) be included in notes on the design drawings.

1.5.3. Of particular importance to the Services is the 21 October 2009 DDESB-PD Memorandum that requires documentation from the DoD Component's explosives safety office verifying that the protective construction design/modifications comply with the requirements of DESR 6055.09 and UFC 03-340-02. This verification must be based on a quality control review (unless a more detailed independent technical review is warranted based on either the lack of experience by the designer or the use of a new, non-validated blast analysis or design approach) by a competent DoD blast design agency, such as the NAVFAC EXWC or CEHNC. Because both of these organizations operate on a cost reimbursable basis, project managers must arrange funding for their services.

1.5.4. The methods of UFC 3-340-01 may be applied in protective construction designs when topics (e.g., isolation of ground shock) are not addressed in UFC 3-340-02. In the event of conflicts between UFC 3-340-01 and UFC 3-340-02, the requirements of UFC 3-340-02 will control.

1.6. DEVELOPMENT OF NEW DRAWINGS. When using a previously approved DDESB protective construction design and site adapting it for construction at a new location, it is strongly recommended that the original, approved structural drawing numbers of the design be captured on the new design drawings. There have been numerous projects where the originally approved design drawing numbers were not captured in a new drawing package, and the lineage of the design was lost. As a result, significant effort and cost was expended when trying to determine the structural capabilities of a protective design, such as determining the structural strength designation of an ECM.

CHAPTER 2: MAGAZINE HISTORY

2.1. EARLY HISTORY OF EXPLOSIVES SAFETY DISTANCES. Throughout this TP:

2.1.1. The American Table of Distances (ATD) is cited. This chapter provides a brief history of the ATD, including its origins and how it was initially used by the Military Services. The historical information in this section was extracted from the sources listed in Table 2.1 and various DDESB records. Source number 3 in Table 2.1 provides a listing and summary discussion for the meetings that were held between 1928 and 1956.

2.1.2. References to the "Board" refer to the DDESB and its various names, which have evolved over the past century. Depending on the time period cited, these are the applicable names of the Board:

2.1.2.1. Joint Army Navy Munitions Board (JANMB) – 1928-1930

2.1.2.2. Joint Army and Navy Board on Ammunition Storage (JANBAS) – 1930-1943

2.1.2.3. Joint Army Navy Ammunition Storage Board (JANASB) – 1943-1945

2.1.2.4. Army Navy Explosives Safety Board (ANESB) – 1945-1948

2.1.2.5. Armed Services Explosives Safety Board (ASESB) – 1948-1971

2.1.2.6. Department of Defense Explosives Safety Board (DDESB) – 1971-current

Table 2.1. ATD Historical Sources

#	**Source**
1	"History of Explosions on which the American Table of Distances was Based," Institute of Makers of Explosives, 1930
2	"Ordnance Safety Manual, Regulations Governing the Manufacture, Storage, Loading and Handling of Military Explosives and Ammunition at Establishments of the Ordnance Department, U.S. Army," O.O. Form No. 7224, Office of Chief of Ordnance, 1931
3	Army-Navy Explosives Safety Board, Technical Paper No. 1, "The Present Status of the American Table of Distances," Washington D.C., July 1, 1945
4	Memorandum for The Joint Army Navy Ammunition Storage Board, "The Functions and Duties of the Board," July 9, 1946
5	Memorandum for The Secretary of War and The Secretary of the Navy, "Recommended Changes in Army and Navy Safety Standard for the Storage of Ammunition and Explosives," Army Navy Explosives Safety Board, April 11, 1947
6	Ilsley, Ralph, "Reappraisal of the American Table of Distances and Recommended Bases for Discussion, Modification, and Final Approval of Minimum Risk Distances for Handling and Storing Military Explosives and Ammunition," Army-Navy Explosives Safety Board, July 1, 1948
7	Letter from J. Howard McGrath (Attorney General) to The Secretary of the Navy, October 27, 1949
8	DoD Directive 4145.17, "Quantity-Distance Standards for Manufacturing, Handling and Storage of Mass-Detonating Explosives and Ammunition," Department of Defense Directive Number 4145.17, December 7, 1956
9	DoD 5154.4S, "DoD Ammunition and Explosives Safety Standards," Department of Defense Office of the Assistant Secretary of Defense for Installations and Logistics, July 1974
10	Freund, David, "Origin and Subsequent Modifications of Explosive Safety Quantity-Distance (ESQD) Standards for Mass Detonating Explosives with Special Reference to Naval Vessels," Volumes I and II (Appendices), David W. Taylor Naval Ship Research and Development Center, Carderock, MD, May 1978
11	DoD 6055.9-STD, "Department of Defense Ammunition and Explosives Safety Standards," Assistant Secretary of Defense for Manpower, Installations, and Logistics, July 1984
12	DoD 6055.9-STD, "Department of Defense Ammunition and Explosives Safety Standards," Assistant Secretary of Defense for Production and Logistics, October 30, 1992
13	DoD 6055.9-STD, "DoD Ammunition and Explosives Safety Standards," Under Secretary of Defense for Acquisition and Technology, August 1997
14	Murphey, J., Packer, D., Savage, C., Peter, D., and Marsha, P. "Final Draft: Army Ammunition and Explosives Storage in the United States, 1775-1945," Geo-Marine Inc. Special Publication No. 7. Fort Worth, TX, July 2000
15	DoD 6055.9-STD, "DoD Ammunition and Explosives Safety Standards," Under Secretary of Defense for Acquisition, Technology, and Logistics, October 5, 2004

2.1.3. Before 1909, there was no recognized rule or table that specified safe distances from AE storage sites in the United States. Because of this, large quantities of AE were stored close to population centers, often leading to disastrous accidents.

2.1.3.1. In July 1909, Colonel B.W. Dunn, Chief Inspector for the Bureau for the Safe Transportation of Explosives, suggested significant changes to the storage conditions associated with railroads and explosives. A Special Committee of Manufacturers of Powder and High Explosives was established.

2.1.3.2. The committee was charged with "compiling and carefully studying all data procurable relating to the area of substantial structural damage resulting from explosions, in order to arrive at some intelligent basis on which to recommend reasonably safe distances at which buildings containing explosives should be located from railroads…."

2.1.3.3. The goal of the committee was to minimize hazards to the public and public property. The first "Report of Committee on Location Magazines, 30 December 1910" included tables of "Proposed American Distances" and compared them to English regulations. The American distances, which would become the ATD, were based on observations from 135 accidental explosions involving up to 900,000 pounds (lbs) NEW.

2.1.3.4. In 1928, the Board adopted the laws of the State of New Jersey as its explosives safety standards. These laws incorporated the ATD.

2.1.3.5. The ATD focuses on QD relations to be maintained to inhabited buildings, public railways, and public highways; it does not consider minimum separation distances between AE storage structures. For cases not considered by the ATD, the Board adopted safety standards that had been developed independently by the Army and Navy (but with almost identical results). These requirements were set forth in the Army's "Ordnance Safety Manual" (O.O. Form No. 7224) and the Navy's Bureau of Ordnance Pamphlet 5.

2.1.4. O.O. Form No. 7224 was first issued in 1931. It divides magazines into four groups: explosives magazines; smokeless powder magazines; primer and fuze magazines; and ammunition magazines and warehouses. The manual recommends that:

2.1.4.1. Design criteria for each group be developed through careful consideration of the unique hazards of the class of materials to be stored.

2.1.4.2. Magazine areas be arranged so that like risks are together.

2.1.4.3. Magazines in each group be constructed in separate areas with separation distances between groups determined based on the risks presented by each class of material stored.

2.1.5. On 9 July 1946, the Board issued a memorandum outlining its functions and duties. In addition to referencing the Army's O.O. Form No. 7224 and the Navy's Bureau of Ordnance Pamphlet 5, the memo summarizes numerous supplementary general policies adopted by the Board. The Board designated earth-covered concrete arch type (igloo) magazines as the preferable type for future construction for the storage of all type of explosives and ammunition except small arms ammunition and adopted a standard 400-ft separation distance between these magazines. The Board also established standard siting criteria for new igloo construction. Igloo magazines were to be constructed in blocks of 100 each with a safety distance of 1,400 ft between adjacent blocks. The maximum number of igloo magazines permitted at one depot was set at 1,000.

2.1.6. On 11 April 1947, the Board proposed a new set of QD relations for the storage of mass detonating high explosives. The proposal significantly changed minimum intermagazine distance (IMD) requirements between Army arch-type ECMs constructed in accordance with the standard series 652-686 through 652-693 design drawings. These changes were based on an extensive series of model and large scale tests (250,000-lbs to 500,000-lbs NEW) made at the U.S. Naval Proving Ground, Arco, Idaho, during 1945 and 1946. The proposal significantly changed minimum IMD requirements between series 652-686 through 652-693 ECMs. At the proposed 500,000-lb storage limit, recommended IMDs were 185-ft (if both the donor and acceptor ECM were considered to be barricaded) and 360-ft (if only the donor or acceptor ECM were considered to be barricaded).

2.1.7. On 27 October 1949, the Attorney General issued an opinion advising that:

2.1.7.1. In executing its statutory duties, the Board had the authority to establish explosives safety standards and make changes to these standards.

2.1.7.2. Standards approved by the Board must be considered binding as minimum safety standards.

2.1.8. Table 2.2 highlights the origins and significant changes to IMD applied by the DoD and the Services. Note that Geo-Marine Inc. Special Publication No. 7 details the historic context and events that led to the building and modification of magazines from 1775 through World War II and offers a classification system of storage magazines.

Table 2.2. Origins of IMD and Significant Changes

Date	Event
10 July 1926	• A catastrophic explosion, ignited by a lightning strike to an explosives storage site, occurred at Lake Denmark Naval Ammunition Depot (NAD), NJ, located adjacent to Picatinny Arsenal and approximately 3-1/2 miles from Dover, NJ. The initial event spread to additional explosives storage sites. This accident virtually destroyed the depot, causing heavy damage to Picatinny Arsenal and the surrounding communities, killing 21 people, and seriously injuring 51 others. • The monetary loss to the Navy alone was $46 million (in 1926 dollars). Injuries occurred out to a distance of 3 miles. Window breakage extended out to a distance of 5 miles. This event caused widespread concern and indignation among the public about the practice of building arsenals and storing dangerous explosives near heavily populated communities.
1927	• In light of the Lake Denmark disaster and the general public's concern with military ammunition storage, the 70th Congress directed that the Secretaries of War and Navy prepare a report on the subject of ammunition storage conditions. The Secretaries subsequently assigned a Joint Board on Ammunition (JBA), consisting of four military officers, "to conduct a survey of points of supplies of ammunition and components thereof for use of the Army and Navy...." This Board convened on 9 January 1928. • In their final report, submitted approximately 2 months later to the Secretaries, the Board made specific recommendations for correcting the storage problems they found. They also recommended the adoption of the New Jersey explosives law, which had incorporated the ATD as its standard of safety. The Secretaries approved the Board's report.
1928	• The Secretaries sent their final report to the House of Representatives on 9 March 1928. The Committee on Appropriations printed the report, and it became known as House Document No. 199. A special subcommittee of the House of Representatives was appointed to investigate the issue of explosives storage. During the hearings, the subcommittee chair suggested that a permanent board of munitions storage, representing both the Army and Navy, be established. The subcommittee also recommended appropriations to carry out the recommendations of House Document No. 199. • Congress approved both the recommendations and the appropriations, and the Joint Army Navy Munitions Board (JANMB) was established on 6 August 1928. This Board used the ATD as its guide for the application of safe separation distances to inhabited buildings, public highways and public railways. IMDs were developed separately by the Services and published in Army's "Ordnance Safety Manual" (O.O. Form No. 7224) and the Navy's Bureau of Ordnance Pamphlet 5.
1931	O.O. Form No. 7224 was published, providing minimum separation distance requirements between explosives storage magazines.
1945	• Army-Navy Explosives Safety Board, TP No. 1, was published. This paper compared accident data (117 events from 1882 to 1909) used to develop the ATD to accident data (66 events from 1910 to 1945) that occurred after the ATD was published. • The data presented indicated that some of the safety distances required by the ATD were inadequate for military explosives, and that increases in these safety distances were warranted.

Table 2.2. Origins of IMD and Significant Changes, Continued

Date	Event
1948	• In a 19 January 1948 letter, the Board documented its concern that the barricaded inhabited building distance (IBD) and public traffic route distance (PTRD) criteria of the ATD did not provide reasonable and practical protection against loss of life, serious injury, and property damage. • The Board recommended that greater barricaded IBD and PTRD QD be used in place of the ATD. This recommendation was a result of Ralph Ilsley's "Reappraisal of the American Table of Distances and Recommended Bases for Discussion, Modification, and Final Approval of Minimum Risk Distances for Handling and Storing Military Explosives and Ammunition."
1950	In a 1 April 1950 letter, the Armed Services Explosives Safety Board (ASESB) again proposed net explosive weight quantity-distance (NEWQD) criteria for mass-detonating materials. These criteria were subsequently accepted by the Navy and the Air Force (USAF), but were not accepted by the Army.
1956	DoD Directive 4145.17 was issued on 7 December 1956 and IMDs were provided only between magazines of the same type. Three types were considered: • Army Standard Igloo Magazines whose construction is at least equivalent in strength to the standard series 652-686 through 652-693 design. • Special type magazines (e.g., igloo magazines with steel or wood arches, Corbetta magazines, dome magazines and earth-covered box-type magazines). • Aboveground magazines (AGM). Minimum IMDs for ECM orientations where both the donor and acceptor ECM were considered to be barricaded continued to be roughly 50% of the IMDs applied when only the donor or acceptor ECM were considered to be barricaded.
1974	DoD 5154.4S was issued in July 1974 introducing standard and non-standard ECM classifications. ECM designs that had been approved for siting as a Standard ECM were listed. A Standard ECM continued to be defined as an arch-type ECM whose construction was at least equivalent in strength to the standard series 652-686 through 652-693 design.
1984	DoD 6055.9-STD was issued in July 1984. The list of approved Standard ECM designs was expanded to include the first two box-type ECMs designed to withstand blast overpressures from an accidental HD 1.1 detonation in an adjacent ECM. These ECM designs were designated as Navy Box-Type A and Navy Box-Type B.
1992	DoD 6055.9-STD was reissued in October 1992. While the revision retained previous explosives limits to standard and non-standard magazines, minimum ECM IMDs were reduced. Between 1974 and 1992, the minimum side-to-side IMD reduced from K4 to K1.25. • Minimum rear-to-front IMDs dropped from K5 to K2 (to a standard magazine) and from K8 to K6 (to a non-standard magazine). • Minimum front-to-rear IMDs reduced from K5 to K2 (from a standard magazine) and from K8 to K6 (from a non-standard magazine).
1997	DoD 6055.9-STD was issued in August 1997 and reclassified ECMs as 7-bar, 3-bar or undefined. IMDs to 7-bar and undefined ECMs were based on previous requirements to standard and non-standard magazines, respectively. IMDs to 3-bar ECMs were introduced. Definitions of expected blast loads on an ECM headwall and doors at 7-bar and 3-bar IMDs were also introduced.
2004	DoD 6055.9-STD was issued on October 5, 2004 and introduced a definition of the expected blast load on the flat roof of box-type ECMs.

2.2. MAGAZINE DESIGN EVOLUTION FROM PRE-1928 THROUGH 1970. The historical information provided in this paragraph was extracted primarily from a December 1950 document (author unknown) and has, except for minor editing changes, been repeated verbatim. It chronicles the evolution of AE magazines from aboveground structures (sometimes barricaded) to the more modern earth-covered structures in existence today. The 1950 document also provides a unique insight into the thought process that drove this evolution. Testing to prove out the theories about QD associated with ECMs and their structural strengths did not begin in earnest until about 1945. The knowledge gained from this testing was responsible for future magazine designs and separation distance criteria. Testing also disproved many magazine designs that were considered standards for many years; and consequently they became unsatisfactory and obsolete. Paragraph 2.3. documents the testing that significantly impacted magazine design and magazine siting criteria.

2.2.1. Magazines: Pre-1928. AE storage facilities were typically of three types. These were aboveground, casemate, and dumps. There was also one other design that was just starting to be constructed in the late 1920s. During the 129th Meeting of the ASESB on 13 May 1953, a discussion was held regarding the Lake Denmark accident of 1926 and the Navy-developed ECM design that withstood nearby major explosions of surrounding facilities. At this meeting, the Navy representative to the Board stated the survival of this particular magazine design at Lake Denmark was what started the Navy's move towards construction of earth-covered igloos. This event also later sparked the Army's interest in the ECM design concepts.

2.2.1.1. AGMs were rectangular, gable-roofed or flat-roofed buildings constructed of masonry (typically tile), corrugated asbestos on a wood frame, or ordinary wood frame construction, with floors at grade or at car-floor level (refers to the presence of a loading dock at railcar floor level). Occasionally, separate barricades were erected around the magazines, so that safety distances could be halved as permitted at that time by the ATD.

2.2.1.2. Casemate magazines were masonry vaults in fortifications (e.g., in hills) and were used only at line stations, such as Coast Artillery and Harbor Defense installations, posts, and seacoast battery emplacements.

2.2.1.3. Dumps were stacks in the open. This type of AE storage was seldom used, except in wartime.

2.2.1.4. The Navy's new ECM design was constructed of either stone masonry walls or of reinforced concrete and had 1 ft of earth cover over the top of the structure. The principle behind development of this design was that the structure itself was designed to be weak; in order to avoid confinement and minimize the effects of an internal explosion, but it would be strong enough to protect its contents from fire, wind pressure, snow loads, and other external forces. The purpose of the earth cover was to provide greater protection against long-range missiles that might drop onto the top of the structure.

2.2.2. Magazines: 1928 Through 1940.

2.2.2.1. Major AE Storage Construction Efforts. During this time period, there were two major efforts to construct ammunition storage structures and ammunition storage depots.

2.2.2.1.1. The first construction effort followed the 1926 Lake Denmark, NJ, accident and continued until approximately 1934. This effort was in response to recommendations made by the JBA in their final report to the Secretaries of War and Navy, which then went to the 70th Congress. In their report, the JBA adopted the ATD for the establishment of safe separation distances and made a number of recommendations for constructing new storage areas and relocating ammunition to safer storage sites. The impact of adopting the ATD was that a number of ammunition storage locations, in use at the time, were not able to meet ATD safe separation distance criteria. In order to bring the storage into compliance with the recommendations that were made by the JBA, Congress appropriated funds to construct new magazines at certain existing installations, to construct new depots, and to relocate ammunition, as necessary. These efforts were coordinated, reviewed, and approved by the JANMB, which was formed after the JBA completed their report. As part of this re-stowage effort:

2.2.2.1.1.1. New magazines were constructed at Ft. Bragg, NC; Savanna Ordnance Depot, IL; Benicia Ordnance Depot, CA: Delaware Ordnance Depot; Ogden Ordnance Depot, UT; and Aberdeen Proving Ground, MD.

2.2.2.1.1.2. Navy installations constructed new magazines at Navy Mine Depot, Yorktown, VA; NAD St. Juliens Creek, VA; NAD Hingham, MA.; NAD Iona Island, NY; NAD Lake Denmark, NJ; NAD Mare Island, CA; and Naval Torpedo Station, Keyport, WA.

2.2.2.1.1.3. New depots were constructed at Hawthorne, NV, and Kuahua, HI, in the Lualualei District.

2.2.2.1.2. The second major ammunition storage expansion effort began in the early 1940s as a result of World War II. This effort constructed 13 new Army Ordnance Depots (see Paragraph 2.2.3.) and 4 new NADs in Burns City, IN; Charleston, SC; Fallbrook, CA; and New Orleans, LA.

2.2.2.2. Continued AGM Construction. AGMs continued to be regarded as the standard and to be constructed. Casemate magazines tended towards obsolescence with the decline in importance of harbor defenses.

2.2.2.3. Origins of Igloo-Type Magazines. The mounded concrete arch magazine was originally designated “underground magazine” and was soon dubbed the “igloo-type magazine” or simply “igloo.” This design appears to have been developed during the 1920s, possibly independently, in different places. The German “Munitionshaus” constructed in 1938 was this type. U.S. NADs had igloos in existence by 1928. Brigadier General Hof of the Ordnance Department, U.S. Army, learned of the Navy igloos, and in light of their survival at Lake Denmark, directed adoption of this concept by the Army. General Hof was one of four military officers assigned to the 1928 JBA that reviewed ammunition storage following the Lake Denmark accident. He was also the first chair of the JANMB.

2.2.2.4. Igloo-Type Construction Features. These igloos consisted of reinforced concrete, approximately semi-circular barrel arch springing from a floor at grade (or occasionally at car-floor level). It was thus above natural grade, but was called "underground," because the arch and rear wall were covered over with earth.

2.2.2.5. Trend Toward Preference for "Underground" Magazines. Factors that led to the preference for the "underground" magazine over the older aboveground types were:

2.2.2.5.1. The thermal insulation qualities of the concrete and earth would eliminate the extreme high temperatures which were experienced in AGMs and which accelerated the deterioration of smokeless powder and other stores.

2.2.2.5.2. The earth cover would facilitate camouflage.

2.2.2.5.3. It was expected that the igloo would be less of a hazard to its environs than an AGM, particularly an unbarricaded, AGM. It was supposed that an explosion of the igloo's contents would be confined by the thick haunches of the concrete arch and by the thick earth fill at the sides, and would be vented upwards through the thin crown. It was expected that the radius of simultaneous ("sympathetic") detonation, the radius of structural damage, and the range of debris would all be reduced.

2.2.2.5.4. IMDs, IBDs, etc., could be halved because of being "barricaded" without the necessity for separate barricades, and land area requirements would be substantially reduced.

2.2.2.5.5. It was supposed that the igloo would be missile-proof and resistant to structural damage, with respect to an explosion at an adjacent igloo. In AGMs, even though barricaded, explosives subject to initiation by missiles or by structural damage had to be separated from missile-forming and mass-detonating ammunition by IBD, rather than by inter-magazine separation distance. With igloos, this requirement could be waived, with a further saving in land requirements, to provide increased flexibility and efficiency in space use.

2.2.2.5.6. The possibility of propagation of an explosion from magazine to magazine would be reduced to practically zero.

2.2.2.6. First Army "Standard" Magazine ("old Savanna type").

2.2.2.6.1. Office of the Quartermaster General (OQMG) Drawings 6379-160 and 6379-161 changed to 652-311 and 652-312 (Ordnance Drawings 19-2-03 and 19-2-04, Magazine Type 30), dated 19 July 1928. This design was referred to as the "Standard Underground Magazine."

2.2.2.6.2. This reinforced concrete magazine had interior dimensions of 25 ft wide, 40 ft 4 inches long, and 10 ft high at the crown. The arch crown was 5 inches thick. The base of the arch was 10 inches thick. The front concrete wall had a thickness of 4 inches and the rear concrete wall was 6 inches thick. The arch and walls had wire mesh reinforcement that was electrically grounded. The magazine had a 6-ft by 8-ft double steel-clad wood door. A full-timber headwall was provided. There was no platform or apron, and the magazine fronted directly onto the road. An optional front barricade, across the road, could be constructed. Vent louvers were provided. Earth cover, at the crown, was 1 ft thick. The term "headwall" is now used to describe a magazine's front wall, and the term "wingwall" describes the wall (located on both sides of the headwall) that supports a magazine's earth cover. In the early years of ECM design, the term "front wall" denoted just the portion that fronted the magazine, with the "headwall" defining the portion supporting the magazine's earth cover.]

2.2.2.6.3. This magazine was constructed at the following military installations: Savanna, Delaware, Benicia, and Aberdeen.

2.2.2.7. "Old Line" Type Magazine.

2.2.2.7.1. OQMG 652-295 and 652-296 (Ordnance Drawings 19-2-107 and 19-2-108, Magazine Type 42), dated 20 June 1933.

2.2.2.7.2. Same as Paragraph 2.2.2.6, except an exterior monorail was added, the doors were changed to steel plate, the headwall was changed to concrete, earth cover was increased to 2 ft thickness, a sand cushion was placed on the magazine's water-proofing, and the concrete front wall's thickness was increased to 6 inches.

2.2.2.7.3. This magazine was intended for use at line stations, such as Coast Artillery and Harbor Defense installations, posts, and seacoast battery emplacements.

2.2.2.8. "Old Depot" Type Magazine.

2.2.2.8.1. Drawings.

2.2.2.8.1.1. 40-ft length: OQMG Drawings 652-317 through 652-320 (Ordnance Drawings 19-2-121 through 19-2-124 and 19-2-130, Magazine Type 48), dated 9 December 1935, "Underground Magazine-Igloo Type" (Type 1).

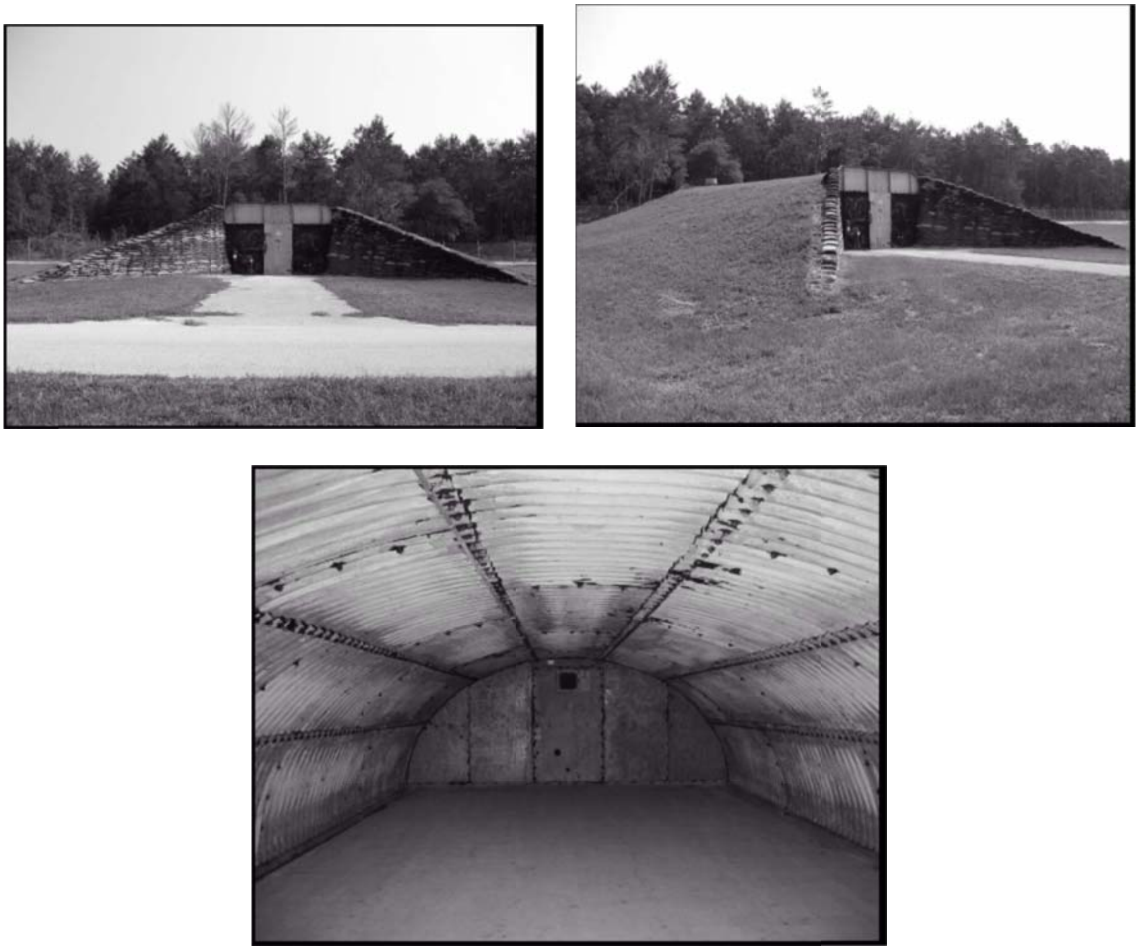
2.2.2.8.1.2. 60-ft length: OQMG Drawings 652-326 through 652-331 (Ordnance Drawings 19-2-125 through 19-2-129, Magazine Type 49), dated 23 July 1937. This magazine had an interior width of 26 ft 6 inches and an interior height of 12 ft 9 inches. A monorail was provided that was supported by pilasters projecting from the end walls. It had a single 4-ft wide door. Arch wire mesh was used for arch reinforcement. The crown thickness was 6 inches and the reinforced concrete front wall thickness was 7 inches.

2.2.2.8.1.3. These types of magazine were constructed at "old ordnance depots" (Raritan and Benicia Arsenal, Charleston, Curtis Bay, Delaware, Nansemond, Ogden, San Antonio, Savanna, and Wingate) and at line stations, such as Coast Artillery and Harbor Defense installations and seacoast battery emplacements. During construction at Ogden, the headwalls were stubbed (shortened) by the elimination of wingwalls.

2.2.2.9. Earliest Known Steel Arch Magazine. The below information and photographs of an early 1940-era, all steel magazine located at Camp Blanding, FL, was provided courtesy of an architectural historian doing research on the installation. He contacted the DDESB as part of his research into 24 similar magazines he was evaluating. "Stamped" on one panel for each of the head wall plates is "Order 3171, Oalvert Iron Wks, Atlanta, Ga." The rip rap walls were added in 1985. Graffiti from the 1940s is written on the majority of the igloos. The earliest is dated 9 April 1940 and the next closest is 24 February 24 1941, with the majority dated from

1943. Based on his research, assuming the 1940 date is correct, these igloos were built for the Florida Army National Guard, before the U.S. Army took over Camp Blanding. The Camp historian thought the 1940 date was a little suspect. He was not aware of the Florida Army National Guard building the ammunition supply point, but believed that the Army did it when the Federal Government took over Camp Blanding on 14 September 1940. The photographs in Figure 2.1 show an exterior and interior view:

Figure 2.1. Earliest Known Steel Arch Magazine at Camp Blanding, FL



2.2.3. Magazines: 1940 Through 1945.

2.2.3.1. "New Depots" Type Magazine.

2.2.3.1.1. OQMG Drawings 652-340 through 652-349, dated 27 September 1940. The drawings were lost and replaced by OQMG Drawings 652-377 through 652-386, dated 30 October 1940. Reference is made in the original documentation to this being a Type 2 magazine. Reinforced concrete headwalls were 7 inches thick and the crown was 6 inches thick.

2.2.3.1.2. This design provided for three optional interior lengths (40 ft 4 inches (1,003 square feet (ft^2)), 60 ft 8 inches (1,528 ft^2), or 81 ft (2,147 ft^2)), deleted the monorail and pilasters, and deleted vents, which were subsequently restored by Revision C, dated 1941).

2.2.3.1.3. This type magazine was constructed at the following new ordnance depots: Anniston, AL; Milan, TN; San Jacinto, TX; Portage, OH; Red River, TX; Seneca, NY; Navajo, AZ; Black Hills, SD; Blue Grass, KY; Sierra, CA; Pueblo, CO; Letterkenny, PN; and Umatilla, OR.

2.2.3.2. World War II-Type Magazine.

2.2.3.2.1. Office, Chief of Engineers (OCE) Drawings 652-686 through 652-692, dated 27 December 1941, “Underground Magazine-Igloo Type.” Magazine Type O. Revised 14 March 1942. This design was available in 60 and 80-ft lengths.

2.2.3.2.2. This design has fully reinforced arch and walls and a full concrete headwall, vents were restored, an alternate concrete door was added, the front wall thickness was increased to 10 inches, and sand fill was deleted.

2.2.3.2.3. This type of magazine was constructed at Army Ordnance Depots and line stations. A 2 December 1944 document lists this magazine type being constructed in 1941 and 1942 in the locations shown in Table 2.3.

Table 2.3. World War II-Type Magazines

Depot/ Line Station	No. of 60 ft Magazines	No. of 80 ft Magazines
Umatilla	652	358
Wingate	550	100
Anniston	200	600
Portage	354	100
Milan	600	100
San Jacinto	146	54
Seneca	400	100
Red River	300	400
Letterkenny	200	600
Sierra	200	600

2.2.3.3. Huntsville-Type Magazine.

2.2.3.3.1. OCE Drawings 652-1012 through 652-1014, dated 29 April 1942, Magazine Type A-O. This design was available in 40-, 60-, and 80-ft lengths.

2.2.3.3.2. This magazine was a redesign of the World War II type magazine with the goal being to conserve critical materials needed for the war effort. Reinforcing was reduced, with the reinforcing bars replaced by 4 inches by 4 inches wire mesh weighing 62 lbs/ft^2 in the extrados (exterior surface of the arch) only; the headwall was stubbed (earth fill spilled around front corners); the door was changed to 6-ft double sheet steel; and the front wall thickness was reduced to 8 inches.

2.2.3.3.3. This magazine type was constructed at Ordnance Department industrial installations. An Ordnance Department industrial installation was an activity operated by the Ordnance Department for the production of ammunition. A 2 December 1944 document states that 40, 60, and 80-ft magazines were constructed at the following depots in 1942: Pueblo (200 - 60 ft, 600 - 80 ft), Black Hills (200 - 60 ft, 600 - 80 ft), Blue Grass (200 – 60 ft, 600 – 80 ft), Navajo (200 - 60 ft, 600 - 80 ft), and Tooele (200 - 60 ft, 600 - 80 ft). Two 40-ft magazines were constructed at each of the following ordnance depots: Umatilla, Wingate, Anniston, Portage, Milan, San Jacinto, Seneca, Red River, Letterkenny, Pueblo, Black Hills, Blue Grass, Navajo, and Tooele.

2.2.3.4. “Corbetta and Beehive” Type Magazines. This has also been called a “dome-type” magazine.

2.2.3.4.1. OCE Drawings 652-1000 through 652-1010, dated 19 February and 23 March 1942, “Underground Magazines 52-ft and 44-ft 7 inches, Corbetta and Beehive Types.”

2.2.3.4.2. This design has a reinforced concrete dome (oblate hemispheroid) and the floor is at grade level. Other features include 2 ft of earth cover, a single 6-ft double sheet-steel door, and a buried counter-poise (ground loop), to which was grounded the magazine’s metallic masses (reinforcing steel, door, ventilator). The ventilator also had an air terminal for lightning protection.

2.2.3.4.3. This type magazine was constructed at Curtis Bay (location for pilot model magazine), Sioux (a 2 December 1944 document lists the following quantities as being constructed: 202 - Corbetta; 600 - Beehive), Susquehanna, and Ordnance Department industrial installations.

2.2.3.5. “Richmond” Type Magazine.

2.2.3.5.1. OCE Drawing 652-1017 and 652-1018, dated 13 May 1942.

2.2.3.5.2. This magazine is not an igloo, but it has been frequently so miscalled. It has massive masonry side and rear walls, which are banked with earth. It has a wood frame front wall, with asbestos shingles, and a wood frame gable roof.

2.2.3.5.3. This type magazine was constructed at Ordnance Department industrial installations.

2.2.4. Magazines: 1945 Through 1970s.

2.2.4.1. Blast Door Developments. The following door design/installation drawings and sketches were provided to the ASESB for review. Prints were furnished to OCE along with ASESB recommendations for their use in lieu of the typical 4-ft, single blast-proof door being used at the time.

2.2.4.1.1. Office of the Chief of Ordnance (OCO) Sketch UD-29, dated 11 February 1946 (revised 14 March 1946), was for a 6-ft double blast-proof door.

2.2.4.1.2. OCO Sketch UD-29A dated 14 March 1946, for installation of Sketch UD-29 6-ft double blast-proof door on existing igloos.

2.2.4.1.3. FP 3a, dated 23 April 1946, for a double blast-proof door, was designed by Mr. Stradley of Code ORDFT, for special projects at Ordnance Depot Wingate.

2.2.4.2. Engineer-Type Magazine.

2.2.4.2.1. OCE Drawing 33-15-01 (7 sheets), dated 27 January 1948.

2.2.4.2.2. This magazine design was similar to the World War II type, except that door was changed to an un-reinforced 6-ft single, steel plate; the headwall was stubbed; the platform and apron were rearranged; the front wall was restored to a 10-inch thickness; full reinforcement was restored; and sand fill was restored.

2.2.4.2.3. This design was issued primarily for line station use, such as Coast Artillery and Harbor Defense installations, posts, and seacoast battery emplacements.

2.2.4.3. Observed Magazine Design Problems.

2.2.4.3.1. The door of the Engineer-type magazine was questioned as to its blast resistance capability.

2.2.4.3.2. The Corbetta and Beehive-type magazines, originally approved by OCO, were considered unsatisfactory following their approval and were officially made obsolete.

2.2.4.3.3. The Huntsville-type magazine had never been approved and was considered unsatisfactory.

2.2.4.3.4. The Richmond-type magazine, a wartime substitute, was never classed as an igloo magazine for QD purposes.

2.2.4.3.5. On 30 July 1940, the Board established general policies for the construction of new AE storage facilities. The earth-covered arch-type magazine was identified as the preferred type for all AE storage except small arms. In 1943, the Board tentatively adopted Army Office of Ordnance Form 7224, "Ordnance Safety Manual." The 3 May 1945 edition of this manual, paragraph 83.b, provides the following guidance on siting older magazines: "Ordnance ammunition depots, manufacturing arsenals, and proving grounds which have the older type of magazines (constructed prior to 1 Dec 1941) or which store only limited quantities of explosives and ammunition and which cannot comply with the regulations set forth herein, shall comply with the spirit of the regulations. If violations in storage exist, approval for their continuance must be obtained from the Chief of Ordnance.".

2.2.4.4. Correction of Design Problems. In 1945, preliminary magazine testing had begun with the goal of proving out magazine designs and the separation distances being used by the Services. As a result of the data obtained from this preliminary testing, the ASESB issued a report, dated 1 April 1950, that called for the front walls of magazines to be increased in strength. This report also recommended that doors be widened to provide for safer handling of AE. On 26 February 1951, the USAF concurred with criteria for a revised magazine design and Drawing DEF-E-33-15-04, Magazine, Mounded Concrete Igloo, Type MA-5, dated 29 May 1951 was created. With this design, magazine designs evolved from those based on theory to magazine designs founded on test results.

2.2.4.5. New Army Magazine.

2.2.4.5.1. OCE Drawing 33-15-06 (6 sheets), dated 1 August 1951.

2.2.4.5.2. This magazine represented a redesign of Drawing 652-686 through 652-692 and Drawing OCE 33-15-01: The headwall thickness was increased to 12 inches; larger diameter and more reinforcing was used; and the door design was changed to two 4-ft wide doors that were 4 inches thick and were provided with vertical stiffeners.

2.2.4.6. Steel Arch Magazine.

2.2.4.6.1. In 1963, three semi-circular, corrugated steel-arch magazines with hinged double-leaf, steel plate doors were developed by Black and Veatch for the USAF and the Defense Atomic Support Agency (DASA). It appears that both of these drawings were each a corrugated steel magazine design that had a 12-inch thick reinforced concrete headwall, a corrugated steel arch, and a reinforced concrete rear wall. A flow-through design also was developed which had two headwalls and no rear wall). Access to the magazine was provided via a hinged double-leaf steel plate door. A minimum of 2 ft earth cover was specified. These magazines were:

2.2.4.6.1.1. AW 33-15-63 (USAF), dated 5 March 1963. Two separate designs were identified as part of this drawing: (1) Flow through design consisting of two headwalls and no rear wall. The magazine measured 11 ft wide by 68 ft long, and (2) a magazine design that measured 11 ft wide by 17 ft long. The door opening for both designs measured 10 ft wide by 8 ft high.

2.2.4.6.1.2. AW 33-15-64 (USAF), dated 10 May 1963. This design measured 25 ft wide by 60 ft long and had a door opening that measured 10 ft wide by 10 ft high.

2.2.4.6.1.3. 33-15-65 (DASA), dated 10 Jan 1963. This drawing also had two separate designs identified on it: (1) 7 ft 6 inches by 11 ft long (min) to 27 ft (max), in increments of 2 ft, and (2) 9 ft wide by 11 ft long (min) to 27 ft (max), in increments of 2 ft. Each design had a door opening that measured 6 ft wide by 6 ft 4 inches high.

2.2.4.6.2. Because these corrugated steel arch designs reflected a major conceptual change to the typical arch design (reinforced concrete) previously tested and on which criteria were based, it was unknown whether existing magazine separation distance criteria could be applied to the semi-circular corrugated steel arch magazine design. Consequently, a series of tests were initiated at Naval Ordnance Test Station (NOTS), China Lake, CA, between January

1962 and December 1963. The results from the testing, which established minimum criteria for semi-circular, corrugated steel-arch magazines are summarized in Paragraph 2.3.6.

2.2.4.6.3. The 3 semi-circular, corrugated steel-arch magazine designs were approved at the 225th ASESB Meeting as Standard designs for 500,000 lbs NEW storage using separation distances determined by the NOTS testing.

2.2.4.6.4. Subsequently, the door and headwall design was further tested during the Explosive Safety Knowledge Improvement Operation (ESKIMO) I test to evaluate the possibility of further reductions of IMD and to develop additional information to indicate the minimum safe distance to use between the concrete headwall of a magazine and the earth-covered side and rear walls and barricaded headwall of another magazine. These tests are summarized in Paragraph 2.3.7. The principal conclusions arrived at from the test were that earth-covered, semi-circular steel-arch magazines, without intervening barricades, could be separated in a face-to-rear orientation by $2.0W^{1/3}$ and in a face-to-side orientation by a distance of $2.75W^{1/3}$. In addition, as a result of ESKIMO I data, the DDESB adjusted the spacing for a face-to-face orientation to $11W^{1/3}$ when unbarricaded, and to $6W^{1/3}$, when barricaded.

2.2.4.7. Modification of Steel Arch Thickness. In response to a Navy query regarding NAVFAC Standard Steel Arch Magazines and an interest by the Navy in moving from a 1 gauge corrugated steel arch to an 18 gauge corrugated steel arch, the 18 June 1971 ASESB-PP Memorandum states that "The ASESB has recommended new standards for separation of earth-covered igloos which provide the same separation distances between earth-covered surfaces of standard types regardless of the material of construction. The results of a number of recent tests including USAF Big Papa series indicate the volume of earth interposed is more important than other factors in preventing communication of detonation. If the headwall and rear wall construction proposed by the Navy are identical to the standard steel arch magazine, and the arch is of sufficient strength to permanently support the standard earth cover, these may be considered standard for the application of the siting criteria."

2.2.4.8. Oval Steel Arch Magazine.

2.2.4.8.1. OCE Drawing 33-15-73, dated February 1975.

2.2.4.8.1. In the period 1972 through 1974, the OCE, contracted for and supervised the design of a new magazine design. The structure was built of a corrugated steel arch having a non-circular (oval) cross section, with a single leaf sliding door mounted on a reinforced concrete headwall. This design was considered optimal for unitized loads of rectangular shape and its relative construction economy (as compared to an all reinforced concrete arch and headwall magazine design).

2.2.4.8.2. Since the design represented a departure from the previously approved semi-circular steel arch design, it was incorporated into a series of tests, known by the acronym ESKIMO, the DDESB was developing and sponsoring to further define magazine separation distance requirements. A full-scale prototype of the oval steel arch magazine was tested at the Naval Weapons Center (NWC), China Lake, CA. The tests demonstrated the safety of the oval arch magazine design at the minimum separation distances permitted by QD standards for side-to-side orientations and for certain permissible headwall exposures. In January 1976, the DDESB approved the oval steel arch magazine (specifically OCE 33-15-73) as a Standard magazine for the storage of up to 500,000 lbs (226,796 kg) NEW at minimum separation distances permitted.

2.2.4.9. Design Enhancements/New Designs. Enhancement of existing designs and development of new designs has been ongoing, and there has been significant testing and data analysis associated with their development. That information has been captured in Paragraph 2.3., which provides full descriptions and results of that work. Descriptions and illustrations of those newer designs can be found in Chapter 4.

2.3. MAGAZINE TESTING.

2.3.1. Magazine Siting (From Laws of New Jersey - 1925). As discussed in Paragraph 2.1.3.4., the JANMB adopted the explosives laws of the State of New Jersey for its standard of safety. These laws, which incorporated the ATD, specified the following with respect to explosives storage:

2.3.1.1. Magazines in which more than 50 lbs of explosives are kept or stored must be detached from other structures and magazines.

2.3.1.2. Magazines where more than 5,000 lbs of explosives are kept or stored must be located a minimum of 200 ft from other magazines.

2.3.1.3. Magazines where quantities of explosives over 25,000 lbs are kept or stored must be located a minimum of 200 ft from other magazines, with an increase of 2-2/3 ft for each 1,000 lbs of explosives in excess of 25,000 lbs.

2.3.1.4. "No quantity in excess of 250,000 lbs of explosives ... shall be had, kept, or stored in any factory building, or magazine in this State."

2.3.2. Magazine Siting (Post 1928). In March 1928, the JANMB established additional AE storage rules to complement the ATD. These rules were:

2.3.2.1. The Army could store up to 250,000 lbs NEW at a minimum IMD of 400 ft.

2.3.2.2. The Navy could store up to 143,000 lbs NEW at a minimum IMD of 500 ft.

2.3.3. Naval Proving Ground, Arco, Idaho, 1945 Testing.

2.3.3.1. During this time period, the Armed Services were limited to an allowable quantity per storage unit of 250,000 lbs, which for strategic and economic reasons was regarded as the maximum quantity whose loss could be risked at one time. However, with the close of World War II, on-hand ammunition tonnage quantities were so vast that the earlier considerations were no longer valid and the question of safety of surrounding populations and structures and the avoidance of major losses became the only impediments to raising the limit. It was out of this concern that the JANASB, in October 1944, recommended to the Secretaries of War and Navy, that testing be conducted to determine if standard IMD might safely be reduced and AE might safely be stored in open stacks midway between existing magazines.

2.3.3.1.1. Successful testing would help alleviate safety concerns, eliminate the need to purchase additional land for the construction of new magazines to handle the influx of returning AE, extend available data on QD relations for storage of high explosives, and provide a check on the inhabited building safety distances for barricaded storage, as prescribed by the ATD. The ATD permitted the reduction of inhabited building safety distances by 50 percent, if a barricade stood between the explosives and the inhabited building.

2.3.3.1.2. In October 1947, the Secretaries of War and Navy approved testing and each service contributed funding to conduct the tests, which required the construction of four test igloo magazines, three revetments, and a wood-frame barracks test building.

2.3.3.2. The 1945 tests are documented in the Army-Navy Explosives Safety Board TP No. 3. The following conclusions were reached from the tests:

2.3.3.2.1. The Army standard inter-magazine spacing of 400 ft (K6.4), clear distance edge-to-edge, between earth-covered, reinforced concrete, arch-type (igloo) magazines that were limited to 250,000 net lbs of high explosives in each, could be reduced to 185 ft (K2.94). This spacing could be reduced without appreciable risk that a detonation of the entire contents of one such magazine would spread to another. This 185-ft clear distance results when an additional magazine is built midway between two existing magazines at the Army standard inter-magazine spacing of 400 ft.

2.3.3.2.2. Structural damage to an igloo when a 250,000-lb charge is detonated in a neighboring igloo at 185-ft (K2.9) clear distance is slight.

2.3.3.2.3. When 250,000 lbs of high explosives are detonated in an open revetment located midway between igloos 400 ft (K6.4) apart, it is improbable that the explosion will spread to either igloo, and they will not suffer severe damage.

2.3.3.2.4. A two-story, wood-frame, standard-type barracks building is not entirely safe from structural damage, and its occupants are likely to suffer severe injury from flying fragments of window glass, when 250,000 lbs NEW of high explosives are detonated within an igloo magazine at a distance of 2,155 ft (K34.2), the safety distance specified by the ATD for inhabited buildings from a barricaded storage of such quantity.

2.3.3.3. In February 1946, the JANASB voted to continue the test program begun in 1945, with the primary interest in further investigating the possibility of safely increasing the potential storage capacities of existing storage facilities, without acquiring additional land, by raising the allowable explosive limit per igloo magazine to 500,000 net lbs of high explosives. In addition, the Board contemplated that it might be safe and feasible to double the quantity of high explosives per igloo magazine (to 500,000 lbs), while reducing by 50 percent the required 400-ft inter-magazine separation distance used between magazines. In order to evaluate this possibility, the Board chose to use a 185-ft (K2.3) side-to-side spacing between test magazines and a 360-ft (K4.5) front-to-rear spacing between test magazines. One other area that the Board decided to evaluate was the effect that increased earth cover might have on the blast phenomena. This would be done using a number of 1/10-scale model igloos, which were already available, and a full-scale igloo magazine remaining from the 1945 test series.

2.3.4. Scale Model Testing at Underwater Explosives Research Laboratory, Woods Hole, MA, 1945 Testing, and Naval Proving Ground, Arco, Idaho, 1946 Testing.

2.3.4.1. Scale model tests of detonations of high explosive charges in igloo magazines and in open storage were conducted at Naval Proving Ground, Arco as a sequel to similar tests by the Woods Hole Oceanographic Institution, in order to further study the effects of such explosions on next-in-line igloos, to investigate whether the model law (i.e., assumed scaling effects) holds for determining various phenomena from explosions, and to determine how increased earth cover on the exploding donor magazine affects these phenomena. In order to investigate the effects of explosions in igloos on adjacent igloos, without going to great expense, the Board arranged for tests to be conducted using 1/10 linear scale models of the standard Army and Navy 27-ft by 80-ft igloo magazine and 1/1000 ratio of charge weights. Eight tests were held, six with 250-lb charges and two with 500-lb charges, simulating certain phases of the 1945 and 1946 full-scale test programs.

2.3.4.1.1. The 1945 Woods Hole scale model testing is recorded in the Underwater Explosives Research Laboratory's "Test on Scale Model Igloo-Type Storage Magazines" while the 1945 Arco scale model test report is provided by the Army-Navy Explosives Safety Board TP No. 4. The following conclusions were reached from this series of tests:

2.3.4.1.1.1. The model law holds for air blast, crater diameters, horizontal earth movement, and damage to structures by air blast.

2.3.4.1.1.2. The model law does not hold for crater depths, vertical ground movement, vertical component of ground shock, or damage to target igloos (which is partially caused by ground shock).

2.3.4.1.1.3. Increased earth cover on a donor igloo magazine reduces air blast and damage to target structures.

2.3.4.1.1.4. Use of standard service igloos does not justify halving the distances specified by the ATD for safety of inhabited buildings from unbarricaded charges. The ATD permitted halving required distances if a barricade was present. Note that use of the term "standard" in 1945 and 1946 to describe an igloo merely indicated that it was typical of what was being constructed by the Services at the time. During this period of magazine design history, the explosives safety community was still trying to determine what the strengths of these magazine designs were and what role these strengths played in preventing propagation. It was a result of these early tests that the term "standard" was revised to describe a magazine that, because of its inherent strength, met specific construction criteria that would permit it to be located closer to adjacent magazines containing up to 500,000 lbs NEW, as compared to those magazine designs that did not meet the more robust construction criteria.

2.3.4.1.1.5. Standard Army revetments around open charges do not reduce air blast generated by detonation of their contents.

2.3.5. Full-Scale Reinforced Concrete, Arch-Type Igloo and Revetment Tests at Naval Proving Ground, Arco, Idaho, 1946.

2.3.5.1. Test Description. This series of tests was the continuation of testing begun in 1945, as described in Paragraph 2.3.3. One of the proposed tests would use the remaining full-scale igloo from the 1945 test series, in order to obtain further data on the effects of augmented earth cover on a donor igloo with respect to blast damage and window breakage in nearby habitation-type buildings. The new facilities constructed in support of the 1946 testing included two reinforced concrete arch, earth-covered igloo magazines, two revetments, and three modified barracks structures. One of the igloos was constructed to Army Drawings OCE 652-687 through 652-693, while the second igloo was constructed to Bureau Yards and Docks' (Y&D) Drawings 357428 through 357430, except an Army-type door was installed. The Army igloo had no barricade, while the Navy igloo was provided a front barricade. These two igloos were tested with 500,000 lbs NEW of high explosives. The igloo used for the increased earth cover test was also of the Army design (Drawings 652-687 through 652-693) and its earth cover at the crown was increased to a depth of approximately 6-1/2 ft. This igloo was tested with 250,000 lbs NEW of high explosives. The revetments were of the standard Army-type in use at the time.

2.3.5.2. Test Conclusions. The report for this series of tests is provided by the Army-Navy Explosives Safety Board TP No. 5. The following conclusions were reached from these tests:

2.3.5.2.1. Clear distances between standard reinforced concrete, arch-type igloos could be reduced to 185 ft (side-to-side), which equates to $2.3W^{1/3}$, for 500,000 lbs NEW.

2.3.5.2.2. The maximum quantity of high explosives permitted in each igloo tested could safely be raised to 500,000 net lbs of high explosives.

2.3.5.2.3. Army magazine design OCE 652-687 through 652-693 and Bureau Y&D magazine design 357428 through 357430, modified with an Army blast door, were qualified as standard magazines for 500,000 lbs of high explosives.

2.3.5.2.4. Based on the damage experienced by the barracks structures from an explosion involving 500,000 lbs of high explosives, the 50 percent reduction of IBDs, as permitted by the ATD when there is a barricade between the explosives and the inhabited buildings, is unwarranted in the case of standard ECMs. Testing showed that only a 20 percent reduction of the unbarricaded IBD is warranted.

2.3.5.2.5. No evidence was produced to support the theory that an increase in earth cover was sufficient to warrant reduction in IBDs.

2.3.5.3. Criteria Change as a Result of Testing. Based on the results of this testing, Bureau Y&D magazine design 357428 through 357430, dated 9 August 1944, and other magazines of equivalent strength, were required to use a side-to-side magazine separation distance of 210 ft (K3.3) for quantities up to 250,000 net lbs of high explosives and a magazine separation distance of 400 ft (K6.3 to K5.0) for quantities over 250,000 lbs and up to 500,000 lbs. When modified by the addition of an Army blast door, these magazines were permitted to store up to 500,000 lbs with a side-to-side inter-magazine separation distance of 185 ft (K2.3). There is a 9-year gap between when the above testing of Bureau Y&D magazine design 357428 through 357430 occurred (1946) and when the Bureau Y&D blast door design, Drawing 626739, dated 19 March 1954, was published. The 1955 ASESB explosives safety standard specified that, in order to qualify as a "standard" magazine, Bureau Y&D magazine design 357428 through 357430, dated 9 August 1944, was required to be modified in accordance with Bureau Y&D Drawing 626739, dated 19 March 1954. Between the years 1946 and 1954 Bureau Y&D magazine design 357428 through 357430, dated 9 August 1944, was considered as a "standard" magazine when it had been modified with an Army blast door. It is therefore concluded that if the blast door being used on an arch-type igloo was equivalent to that being used with approved Army magazine design OCE 652-687 through 652-693, then it qualified the igloo to be considered a "standard" magazine.

2.3.6. Earth-Covered, Steel-Arch Magazine Tests, NOTS, China Lake, CA, 1962 -1963.

2.3.6.1. Test Description. Full-scale and model testing experiments conducted previously had demonstrated that the historical criteria for the storage of high explosives could be substantially improved for standard, reinforced concrete, arch-type igloo magazines. The series of tests conducted between January 1962 and December 1963, at NOTS, had three goals: (1) determine the feasibility of reducing the land area required for high explosives storage by further reducing inter-magazine spacing, (2) establish the minimum safe distance permissible between earth-covered, steel-arch magazines, and (3) compare the inter-magazine protection afforded by the more economical steel-arch magazine with that afforded by the reinforced concrete, arch-type magazine. The steel-arch-type magazine designs to be tested were the USAF's 33-15-63 and 33-15-64.

2.3.6.2. Test Conclusion. The test series are documented in the NOTS TP 3843. The test concluded that steel arch magazine igloos could be safely located at side-to-side separation distance of K1.25; rear-to-rear separation distance of K1.5, and rear-to-front (unbarricaded) of K4.5.

2.3.6.3. Criteria Change as a Result of Testing. Based on the results of this test series, the 225th ASESB of 19 February 1964 approved the siting of earth-covered, steel-arch magazines, constructed per Drawings AW 33-15-63 (5 March 1963), AW 33-15-64 (10 May 1963), and 33-15-65 (10 January 1963), or their equivalent, as standard magazines, using the following criteria:

2.3.6.3.1. Spacing is to be $1.25W^{1/3}$ for side-to-side and side-to-rear orientations.

2.3.6.3.2. Spacing is to be $1.5W^{1/3}$ for a rear-to-rear orientation.

2.3.6.3.3. Spacing is to be $4.5W^{1/3}$ for front-to-rear or front-to-side orientations.

2.3.6.3.4. No magazine will be spaced one from another at less than 7 ft.

2.3.7. ESKIMO Test Series (I through VII), NWC, China Lake, CA., 1971 Through 1985. Testing before the ESKIMO Series confirmed that some selected arch-type magazines, extant at that time, could be sited side-to-side at a scaled distance of 1.25W1/3, and that the separation distances for other orientations were overly safety conservative. Since these earlier tests did not satisfactorily answer questions about necessary separation distances for other orientations, additional testing was necessary. These questions led to the development of the ESKIMO Test Series (ESKIMO I through VII), which was conducted as part of a continuing program to determine more accurately minimum safe separation distances between ECMs storing high explosives. The reports for these tests are provided in NWC TPs 5430, 5557, 5771, 5873, and 6076; Naval Civil Engineering Laboratory (NCEL)-TR R889; Army Ballistics Research Laboratory (ARBRL)TR-02215; NCEL TM 51-86-26; and the 2 March 2001 Naval Facilities Engineering Services Center Memorandum.

2.3.7.1. ESKIMO I, 8 December 1971. Previous testing had demonstrated that earth-covered, steel-arch magazines could be safely spaced side-to-side at a distance of $K=1.25W^{1/3}$. However, little information had been developed to indicate the minimum safe distance to use between the concrete headwall of a magazine and the earth-covered side and rear walls and barricaded headwall of another magazine. The most recent data from the 1962 NOTS Test (NOTS TP 3843) showed that a spacing of $4.5W^{1/3}$ for a front-to-rear orientation appeared to be conservative. ESKIMO I was designed to evaluate the possibility of further reductions of IMD.

2.3.7.1.1. Test Description. The test required the construction of four acceptor steel-arch magazines constructed per OCE Drawing AW 33-15-64 (their lengths were limited to 20 ft) and one barricade. The donor magazine was a remaining structure from earlier 1963 testing. The acceptor magazines were oriented with respect to the donor, so that the desired relationships (e.g., front-to-side) could be tested. The donor charge consisted of 200,000 lbs (90,718 kg) of trinitrotoluene (TNT) contained in 13,696 155-millimeter (mm) projectiles. The test was fully instrumented in order to obtain the data described in the test objectives. High-explosive charges were located in each of the acceptor igloos to provide further evidence of the probability of the explosion propagating to the acceptor magazines. Each magazine contained eight acceptor charges, arranged in two rows of four, across the face of the magazine, one about 18 inches off the floor, and the other above it, about 5 ft off the floor.

2.3.7.1.2. Test Objectives. Principal test objectives for ESKIMO I were: evaluation of igloo inter-magazine spacing; measurement of fragment mass and distribution resulting from the mass detonation of typical high-fragmentation ammunition stored in a standard earth-covered igloo; measurement of air blast in the area surrounding such an explosion; and measurement of the structural motion of an earth-covered igloo in response to the explosion in an adjacent magazine.

2.3.7.1.3. Test Conclusions. The principal conclusions arrived at from the test were that earth-covered, steel-arch magazines, without intervening barricades, could be separated in a face-to-rear orientation by $2.0W^{1/3}$ and in a face-to-side orientation by a distance of $2.75W^{1/3}$. In addition, as a result of ESKIMO I data, the DDESB adjusted the spacing for a face-to-face orientation to $11W^{1/3}$ when unbarricaded, and to $6W^{1/3}$, when barricaded.

2.3.7.2. ESKIMO II, May 1973. This was the second in a DDESB-sponsored series of tests, whose main purpose was the evaluation of the protection afforded by five steel-arch acceptor igloo magazines, against communication of explosion, when their headwalls faced a barricaded donor site (bombs in a revetment).

2.3.7.2.1. Test Description. ESKIMO II was a full-scale proof test of other existing and modified door and headwall designs; in this test, the separation distances from a donor stack of bombs, in a revetment, were approximately the same for all five acceptor igloo magazines facing the stack. The donor stack consisted of 72 M117 bombs, with a TNT equivalency of 24,000 lbs. This explosion source was designed to produce an impulse load of 1100 pounds per square inch milliseconds (psi-ms) on the headwalls of the five acceptor magazines, each located 147 ft away from the explosion source. Two of the five acceptor magazines had no acceptor charges inside them. The remaining three acceptor magazines each contained twelve M15 land mines as acceptor charges. The land mines were positioned in two rows of six, one row approximately 3 ft from the floor, and the second row was located approximately 6 ft from the floor. The rows were located 3 ft from the headwall and door.

2.3.7.2.2. Test Objectives. The objectives of ESKIMO II were:

2.3.7.2.2.1. Evaluation of the resistance of several types of igloo door and headwall designs, and of proposed modifications to existing door and headwall designs, to withstand the blast environment associated with an explosion. The headwall and door designs tested were one Navy Type II magazine (NAVFAC Drawing 649-604), with its hinged, double-leaf doors; one proposed non-circular, steel-arch (oval) Army Stradley magazine (OCE Drawing 33-15-61), with its bi-parting, sliding doors; and three Army steel-arch magazines (OCE 33-15-64), with three different door designs. One was the double-leaf, hinged doors specified on OCE Drawing 33-15-64, the second was a proposed single-leaf, sliding door designed by Black and Veatch and shown on an unnumbered drawing dated 25 October 1972, and the third was a proposed double-leaf, hinged door, with removable steel beam reinforcing, which represented a Black and Veatch modification of the door shown on OCE Drawing 33-15-64.

2.3.7.2.2.2. Investigation of hazards associated with window glass and window frames placed at several distances from explosions, with the emphasis on using window types common in commercial and institutional buildings.

2.3.7.2.2.3. Evaluation of blast damage to both foreign and domestic vehicles placed at distances specified by various authorities for PTRDs.

2.3.7.2.2.4. Acquisition of data regarding fragment hazards associated with an M117 bomb.

2.3.7.2.3. Test Conclusions. This was an over-test, because the near-field blast loading exceeded that planned. The conclusions from testing were as follows:

2.3.7.2.3.1. Though there was a wide range of door and headwall responses, no change to DDESB separation distance standards were considered necessary at that time. In addition, the results provided guidance for the selection of promising types of headwalls and doors to be tested more extensively.

2.3.7.2.3.2. The Black and Veatch single-leaf, sliding door withstood the blast with minor distortion, although the accompanying headwall suffered severe damage. The proposed Stradley-type magazine headwall withstood a face-on impulse of 1,750 psi-ms with only minor damage and its non-circular (oval) steel-arch withstood the blast without breakup or severe distortion. Further, the test reaffirmed a need for achieving a closer balance in the strength of headwalls and doors.

2.3.7.2.3.3. The test supported DDESB IBDs and PTRDs. North Atlantic Treaty Organization (NATO) distances were questionable.

2.3.7.3. ESKIMO III, June 1974. In this third test of the ESKIMO Series, approximately 350,000 lbs of Tritonal explosives (in M117 Bombs) were detonated simultaneously within a steel-arch, earth-covered igloo flanked by two adjacent igloos and near three other igloos located with varying degrees of face-on exposure and at varying distances from the donor magazine. There were no acceptor charges used in this test.

2.3.7.3.1. Test Objectives. The objectives of ESKIMO III were to:

2.3.7.3.1.1. Qualify the redesigned oval steel-arch magazine (OCE 33-15-73), at the minimum side-to-side spacing of $1.25W^{1/3}$, which was permitted for semicircular and other standard ECMs. This was the primary objective of the ESKIMO III test.

2.3.7.3.1.2. Evaluate a less expensive, deeply corrugated, 14-gauge (0.075-inch thickness), semi-circular steel-arch, ECM. At that time, the standard gauge used for steel-arch construction was 1-gauge (0.20-inch thickness).

2.3.7.3.1.3. Test a single-leaf, sliding door installed on an existing headwall remaining from the 1963 test, at a distance of $2.75W^{1/3}$ from the donor, with a face-to-side orientation.

2.3.7.3.1.4. Further investigate inter-magazine separation distances for other than side-to-side orientation.

2.3.7.3.1.5. Investigate the hazards associated with window glass located at varying distances (based on DDESB and NATO IBDs) from the donor magazine.

2.3.7.3.1.6. Evaluate blast damage to highway vehicles placed at PTRDs specified by DDESB and NATO criteria, from magazine structures.

2.3.7.3.2. Test Conclusions. The conclusions resulting from the ESKIMO III test were as follows:

2.3.7.3.2.1. The oval steel-arch igloo (OCE 33-15-73) was qualified, at the minimum side-to-side spacing of $1.25W^{1/3}$ permitted for standard magazines.

2.3.7.3.2.2. The deeply corrugated, 14-gauge, circular steel-arch magazine design survived the minimum side-to-side spacing, as well. Though the degree of damage was more extensive and arch movement greater than that experienced by the oval, steel-arch magazine, it was considered that the arch structure would have provided protection against explosion communication for common explosives stores.

2.3.7.3.2.3. The single-leaf, sliding door experienced little damage or deformation and was found to be effective whether mounted on a new structure or on an existing headwall.

2.3.7.3.2.4. Door and headwall response of the standard magazine OCE 33-15-64 was unsatisfactory at a test separation distance based on $3.7W^{1/3}$. A successful test would have possibly justified a reduction of the required separation distance (based on K6 $W^{1/3}$) for this orientation. However, test results showed that a relaxation of front-to-front criteria (K6 $W^{1/3}$) for this magazine was not warranted. The test consisted of a single barricade between the donor and the acceptor magazines.

2.3.7.3.2.5. Test results supported DDESB criteria for inhabited building and PTRDs. In the final report, no conclusions were provided regarding NATO criteria.

2.3.7.4. ESKIMO IV, September 1975.

2.3.7.4.1. Test Description. In this test, three ECM structures each faced an unbarricaded explosion source, located 147 ft away; the source consisted of 37,000 lbs of TNT contained in a hemisphere built of 8-lb blocks. The donor explosion size was selected to duplicate the free-field peak pressure and impulse observed at a scaled distance of $2.0W^{1/3}$, to the rear of the donor magazine in ESKIMO III, which contained M117 bombs filled with a total of 350,000 lbs of Tritonal at full-scale quantity. The three structures tested included an existing oval, steel-arch magazine used in ESKIMO III, with a single-leaf, sliding door (OCE Drawing 33-15-61); a new circular steel-arch magazine constructed to OCE Drawing 33-15-64, with its specified double-leaf, hinged door; and an existing circular steel-arch magazine used in ESKIMO III, with a rebuilt OCE Drawing 33-15-64 headwall and a single-leaf, sliding door. The second structure described served as the control structure to demonstrate directly the relative strengths of the primary target, which was the oval, steel-arch structure. There were no acceptor charges used in this test.

2.3.7.4.2. Test Objectives. The objectives of ESKIMO IV were:

2.3.7.4.2.1. To demonstrate the resistance of a newly designed headwall and door combination (the oval, steel-arch magazine with a single-leaf, sliding door) to a blast simulating that possible at the minimum front-to-rear spacing permitted for semicircular and other standard ECMs. This was the primary objective.

2.3.7.4.2.2. To test the single-leaf, sliding door installed on a standard headwall (OCE Drawing 33-15-64), at a level of blast loading equal to that experienced by the newly designed headwall and door combination.

2.3.7.4.2.3. To acquire data on the response of a standard headwall and standard double-leaf, hinged door design to blast loading from a hemispherical charge of TNT, which has well-documented blast characteristics.

2.3.7.4.3. Test Conclusions. Based on test results, the following conclusions were arrived at:

2.3.7.4.3.1. The blast produced by the donor stack was essentially as predicted and properly simulated conditions at a scaled distance of $2.0W^{1/3}$, to the rear of the donor magazine in ESKIMO III.

2.3.7.4.3.2. The newly designed headwall and door combination (the oval, steel-arch magazine with a single-leaf, sliding door) responded within acceptable limits and was considered adequate to protect all magazine stores against propagation of explosion under the conditions simulated and blast effects produced in the test.

2.3.7.4.3.3. The response of the control magazine was as expected, with door failure creating a hazard to more sensitive types of explosive stores, that could prove unacceptable.

2.3.7.4.3.4. The response of the test circular steel-arch magazine used in ESKIMO III, with a rebuilt OCE Drawing 33-15-64 headwall and a single-leaf, sliding door, showed significant damage to the reinforced concrete headwall and a marked imbalance in strength between the one-piece, horizontally spanning door and the concrete headwall.

2.3.7.5. ESKIMO V, August 1977.

2.3.7.5.1. Test Description. Test magazines were oriented side-on to the explosion source, at centerline separations of 155 ft. The test was designed to simulate the same loadings on the acceptor magazines as produced by the ESKIMO III donor, where the explosion source consisted of 350,000 lbs of Tritonal (contained in stacked M117 bombs), placed inside an 80 ft long, lightweight, 14-gauge, deeply corrugated, steel-arch magazine. Magazines in ESKIMO III were separated by a scaled distance of $1.25W^{1/3}$. The oval, steel-arch magazine (OCE Drawing 33-15-61) used in ESKIMO II, III (for side-on loading) and ESKIMO IV (headwall loading) was again tested. However, for ESKIMO V, the earth cover was removed, the concrete thrust beams were removed, and the earth cover replaced. ESKIMO V also included a newly constructed magazine of the FRELOC concrete-arch type (Stradley), U.S. Army Engineer Command, Europe, Drawing 33-15-13. Door response was not a concern in the ESKIMO V test; therefore, non-permanent steel doors were spot-welded and/or bolted to the door openings of both test magazines. There were no acceptor charges used in this test.

2.3.7.5.2. Test Objectives. In this test, a hemispherical charge of approximately 75,000 lbs of TNT was detonated with the principal objectives being to justify the removal of concrete thrust beams from an oval, steel-arch igloo and to demonstrate the safety of applying the current side-to-side separation distances to concrete-arch igloos, which had never been tested at those distances.

2.3.7.5.3. Test Conclusions. The ESKIMO V test produced the following conclusions:

2.3.7.5.3.1. The blast produced by the donor stack was essentially as predicted and acceptably simulated conditions at a scaled distance of 1.25 ft/lb$^{1/3}$, to the side of the donor magazine as in ESKIMO III.

2.3.7.5.3.2. Structural response of the FRELOC concrete-arch magazine (U.S. Army Engineer Command, Europe, Drawing 33-15-13) was well within acceptable limits, and the structure was considered to be adequate to protect all magazine stores against propagation of an explosion under the conditions simulated and blast effects produced by the test.

2.3.7.5.3.3. The response of the oval, steel-arch magazine, without concrete thrust beams was also within acceptable limits. Comparison of magazine response from this test to the response of the steel-arch and the concrete thrust beams in ESKIMO III showed that the absence of concrete thrust beams did not significantly affect the response of this type structure under blast loads comparable to, or less than, those of ESKIMO III and ESKIMO V. Based on the test results, thrust blocks were removed from OCE magazine design Drawing 33-15-61.

2.3.7.6. ESKIMO VI, July 1980. This was the sixth in a series of explosives tests involving ECM structures. This test was designed to test and evaluate the safety and performance, under blast loading, of two box-shaped storage magazines. These magazines included the existing Navy Type IIB Smokeless Powder/Projectile Magazine and the newly designed NAVFAC Type A Magazine. Before ESKIMO VI, box magazines in the field had not been tested or specifically designed for overpressure loads. Prior to 1974, DoD Q-D standards designated box-type ECMs as Special Use Magazines. IMDs to Special Use Magazines were K 4.5 (side-to-side) and K9 (front-to-rear and rear-to-front) and the HD 1.1 explosives storage limit to a Special Use Magazine was 250,000 lbs. The 1974 Q-D standards introduced standard/non-standard ECM designations and sited standard box-type ECM designs as non-standard ECMs. In these standards, the HD 1.1 explosives limit to a non-standard ECM was 250,000-lbs and minimum IMDs were K4 (side-to-side) and K8 (front-to-rear and rear-to-front).

2.3.7.6.1. Test Description. In order to keep the costs associated with ESKIMO VI down, one-half scale test structures were proposed. However, because a box magazine's geometry is so different from an arch-type, ECM, it was expected that the blast environment produced by the donor and the effect of the acceptor geometry on loads would be significantly different than those measured for arch-type magazines. Therefore, the U.S. ARBRL conducted 1/50th-scale model tests of box-shaped magazines, to determine the blast environment on the acceptors to the front, side, and rear of a model donor. These are documented in the ARBRL-TR-0221. Pre-shot predictions were developed for nonstandard and standard IMD for box-type magazines. The donor charge consisted of 60 MK 16 torpedo warheads containing the equivalent of 44,000 lbs of TNT, which corresponded to 350,000 lbs of TNT at full scale, the design charge weight of the new NAVFAC Type A magazine. This charge was placed in a donor structure, which was constructed to simulate the mass properties and geometry of the earth-covered Type IIB magazine. There were no acceptor charges used in this test.

2.3.7.6.2. Test Objectives. The objectives of ESKIMO VI were to:

2.3.7.6.2.1. Evaluate the safety of existing box-shaped magazines that used non-standard inter-magazine spacing. The Navy's Smokeless Powder/Projectile Magazine, Type IIB, Bureau Y&D Drawing 749771, was used to meet this objective because they were in abundant use and had dimensions that were identical to those of the blast-resistant Type A magazine. The Type IIB magazine was oriented side-to-side with the donor magazine with a separation distance of 44 ft (1.25$W^{1/3}$).

2.3.7.6.2.2. Demonstrate the safety of the new NAVFAC box-magazine designs for use at standard inter-magazine spacing. The structure that was tested was the new Box Magazine, Type A, NAVFAC Drawing 1404000, which had been designed to resist the blast loads associated with standard inter-magazine separation distances. In the test, the rear of the Type A magazine was oriented to the front of the donor magazine at a separation distance of 70.5 ft (2.0$W^{1/3}$).

2.3.7.6.2.3. Develop improved load criteria, structural performance requirements, and appropriate inter-magazine spacing criteria for box-shaped magazine roofs, walls, and doors. The new NAVFAC Type A magazine and its single-leaf, sliding doors were selected to meet this objective.

2.3.7.6.3. Test Conclusions. The ESKIMO VI test produced the following conclusions:

2.3.7.6.3.1. The safety and performance of the Type A magazine, under “worst-case” standard IMD pressure loads was confirmed. The test report noted that the minor damage experienced by the Type A magazine might imply the possibility of reducing steel and construction requirements while still maintaining satisfactory performance under blast loading. The Type A magazine roof had been designed for a maximum support rotation of 2 degrees, in accordance with the tri-service manual on explosion resistant structures (TM 5-1300/NAVFAC P-397/AFM 88-22, dated June 1969) in use at the time.

2.3.7.6.3.2. It was demonstrated that the roof of the Type IIB smokeless powder/projectile magazine would sustain only light to moderate structural damage when exposed to non-standard side-to-side IMD pressure loads. The door design is inadequate for resisting loads generated by a 350,000-lb NEW charge. The test structure eliminated other penetrations in the headwall (six louvers and three large glass block windows). These elements may also fail in an accidental detonation. A complete redesign of the headwall, including its doors and penetrations, would be needed to adequately withstand the tested blast loads.

2.3.7.6.3.3. Loading criteria were developed for box magazines (full-scale) located to the side and forward of a donor ECM storing 350,000-lbs HD 1.1 AE. A magazine located to the side of a donor at 1.25$W^{1/3}$, as the Type IIB magazine was, can be expected to experience a maximum roof overpressure of 105 psi, with a corresponding impulse of 754 psi-ms. The headwall will experience a peak overpressure of 50 psi and an impulse of 764 psi-ms. A magazine located to the front of a donor at 2.0$W^{1/3}$, as the Type A was, can be expected to experience a peak roof overpressure of 360 psi, with a corresponding impulse of 1,312 psi-ms. The headwall will experience a peak overpressure of 50 psi and an impulse of 1,218 psi-ms.

2.3.7.7. ESKIMO VII, 5 and 12 September 1985.

2.3.7.7.1. Test Description. The existing Type A and Type IIB structures remaining from the ESKIMO VI test were used for ESKIMO VII. ESKIMO VI had demonstrated an ample, possibly excessive margin of safety in the Type A magazine roof. ESKIMO VI also had shown that the door system design of the Type IIB magazine was inadequate to resist the loading resulting from a detonation of 350,000 lbs in a similar magazine located at the minimum side-to-side spacing. To address these two areas, two tests were conducted: TEST A-ROOF and TEST IIB-DOORS. There were no acceptor charges used in these tests. Details of the test and the results are provided in the test report (NCEL TM 51-86-26).

2.3.7.7.2. Test Objectives. The objectives of these two tests were to:

2.3.7.7.2.1. Validate the performance of a redesigned door and headwall system for the Type IIB magazine, under blast loading conditions approximating those at the minimum side-to-side spacing of ECMs.

2.3.7.7.2.2. Evaluate the reserve strength inherent in the Type A magazine design at roof slab deformations corresponding to large rotations at supports.

2.3.7.7.2.3. Provide test data to support improved load criteria, structural performance requirements, and design methods for the roofs, walls, and doors of more economical box-shaped magazines that can be sited at the minimum separation distances permitted by explosives safety standards.

2.3.7.7.3. TEST A-Roof, 5 September 1985. To produce the required airblast loading on the roof, it was necessary to accurately simulate the overpressure component of the airblast generated by a high explosive surface burst. To accomplish this, a test procedure called the High Explosive Simulation Technique (HEST), developed by the Air Force Weapons Laboratory (AFWL) for the Defense Nuclear Agency (DNA), was used to produce the required blast overpressure and impulse on the roof of the Type A magazine. This technique involved distributing a high explosive over a relatively large surface area and covering the explosive with a soil overburden. The HEST charge density used for TEST A-ROOF was designed to produce a peak overpressure of 800 psi and an impulse of 2,300 psi-ms.

2.3.7.7.3.1. TEST A-Roof Results. The average measured impulse was 2,500 psi-ms. Both internal columns catastrophically collapsed, changing the roof configuration from a flat slab (with column supports) to a rectangular two-way slab restrained on only four sides. The permanent center deflection at midspan of the roof was 45.5 inches. Both the back wall and headwall were forced inward by the tensile membrane action of the roof. The maximum inward displacement of these walls, measured at the magazine centerline near the roof elevation, was 8 inches and 2.5 inches for the back wall and headwall, respectively. The performance of the Type A test structure in ESKIMO VII demonstrated an ample, possibly excessive margin of safety in the Type A box magazine roof, which had been initially designed for a maximum support rotation of 2 degrees. Based on ESKIMO VII test results, allowable roof support rotation was subsequently increased to 8 degrees.

2.3.7.7.3.2. TEST A-Roof Conclusions. In summary, because the columns failed, it was not possible to directly assess the inherent ultimate rotational capacity of the box magazine flat slab configuration. What could be concluded was that support rotations of slabs are possible beyond the 8-12 degree range if tensile membrane behavior can be mobilized. It was noted that these large rotations occurred without the presence of any roof shear reinforcement. The NAVFAC box magazines are now designed for maximum support rotation of 8 degrees. Additional information on the test results and conclusions arrived at are provided in the 2 March 2001 Naval Facilities Engineering Services Center Memorandum.

2.3.7.7.4. TEST IIB-Doors, 12 September 1985. As part of this test, the door/headwall combination was redesigned to address problems found as a result of ESKIMO VI. The doors were designed for a maximum allowable support rotation of 12 degrees. The hemispherical donor charge consisted of 13,616 lbs of TNT, located to the side of the Type IIB magazine being tested, at a distance of 108.6 ft from the magazine headwall centerline. This charge and distance was calculated as providing a blast environment similar to that observed in the ESKIMO VI test.

2.3.7.7.4.1. TEST IIB-Doors Results. The donor charge weight and its standoff distance to the retrofitted SP/P door in the one-half scale ESKIMO VII test were determined to simulate the positive impulse of 382 psi-msec measured in the one-half scale ESKIMO VI test. The maximum door responses measured for the two doors were 2.5 and 3.6 degrees, well below the allowable 12 degrees.

2.3.7.7.4.2. TEST IIB-Doors Conclusions. Upgrading the explosives safety integrity of older box type magazines can be accomplished by replacing the double leaf hinged doors with sliding (built-up) single leaf doors supported along the door sides and top by a strengthened reinforced concrete headwall. Additional information on the test results and conclusions are provided in the 2 March 2001 Naval Facilities Engineering Services Center Memorandum.

2.3.7.8. ESKIMO Series Test Summary. The ESKIMO tests:

2.3.7.8.1. Validated the acceptability of using a side-to-side spacing of K1.25 for earth-covered, arch-type magazines, for hazard division (HD) 1.1 NEW up to 350,000 lbs. The DDESB subsequently determined that the results of the ESKIMO Series were valid for HD 1.1 NEW up to 500,000 lbs.

2.3.7.8.2. Showed that the roofs of flat-roofed magazines needed specific design considerations (ESKIMO VI and VII).

2.3.7.8.3. Showed that the headwalls and doors of some of the magazines in use at the time (i.e., the magazine described in OCE Drawing 33-15-61) required strengthening to qualify for storage of 500,000 lbs NEW, at the reduced inter-magazine separation distances eventually approved for “standard” magazines.

2.3.7.8.4. Indicated that several of the magazines in use at the time, and separated by the IMDs at which they were originally built, could safely contain up to 500,000 lbs NEW of HD 1.1 material. Before the ESKIMO tests, Army magazines and unbarricaded Navy magazines were typically separated by 400 to 500 ft.

2.3.8. NAVAJO Depot Activity, Flagstaff, Arizona, 1979 Tests.

2.3.8.1. Test Description. Full-scale field tests were conducted in 1979, by the ARBRL, to characterize the hazards to an exposed site (ES) when either a 150-lb or 450-lb TNT charge, positioned inside earth-covered, reinforced-concrete igloos, were statically detonated. Test results took the form of airblast profiles and concrete fragment distributions in terms of densities, weights, and their locations relative to igloo orientation. These tests were conducted at the Navajo Depot Activity near Flagstaff, Arizona, using igloos constructed in 1942 to Army standards. The tests are described in the ARBRL-MR-03356.

2.3.8.2. Test Objective. The objective of these tests was to demonstrate that the NATO Explosives Safety Manual, which required a minimum of 1,312 ft (400 meters (m)) between inhabited buildings and igloos containing HD 1.1 AE, was overly conservative for small quantities of explosives in magazines. No minimum quantity of AE was associated with this 400-m restriction.

2.3.8.3. Test Conclusions. The conclusions reached in the Flagstaff tests were:

2.3.8.3.1. The 400-m minimum distance requirement between inhabited buildings and igloos containing HD 1.1 AE is excessive for small explosive charges. This was true for both fragment and peak overpressure hazards.

2.3.8.3.2. The use of a barricade in front of the headwall and a redesign of the vent stack at the rear of the igloo would have reduced the density of hazardous fragments to an insignificant level.

2.3.8.3.3. The peak overpressure and fragment hazards to the sides and rear of earth-covered igloos are significantly less than those to the front for relatively small explosive weights. These directional effects should be considered when establishing minimum distance requirements.

2.3.8.4. Test Result. Though these tests were initially conducted to support a hazards analysis for a particular activity, the results of the test were subsequently used to support changes to the NATO Explosives Safety Manual.

2.3.9. Hastings Igloo Hazards Tests for Small Explosive Charges, Hastings, Nebraska, 1984. The Hastings testing was conducted to supplement, with additional full-scale testing, the Flagstaff testing described in Paragraph 2.3.8.

2.3.9.1. Test Description. These tests were conducted at the then Nebraska State National Guard Weekend Training Site near Hastings, Nebraska, using 12 excess, standard-size igloos built to Navy standards. The test igloos were abandoned structures. Before testing, these igloos all had developed hairline cracks on all walls and their arches. There was also erosion of the earth cover that was observed on many of the structures due to lack of maintenance. An earth-backed concrete blast shield (barricade) fronted each test igloo. The igloos' headwall thickness was 8 inches. The test report is provided in ARBRL-MR-03356. Test results are in the form of overall structural response, airblast measurements, and hazardous fragment distribution for explosive charge weights from 12 to 150 lbs (5.4 to 68 kg).

2.3.9.2. Test Objectives. The objectives of the Hastings tests were to:

2.3.9.2.1. Determine the explosive quantity which, when detonated inside a standard-size, earth-covered igloo, produces no significant external effect.

2.3.9.2.2. Evaluate the dispersal of structure debris and measure external airblast for the range of explosive quantities up to 150 lbs (68 kg).

2.3.9.3. Test Conclusions. Test conclusions were:

2.3.9.3.1. The maximum distance requirements between inhabited buildings and standard-size, earth-covered igloo magazines containing small explosive charge weights will be determined by door displacement and not by concrete fragments from the headwall. Blast shields (front barricades) will reduce this distance and change the critical direction of the hazard from the front to the sides, at small charge weights.

2.3.9.3.2. Blast shields are effective in controlling concrete fragment hazards from the headwalls at explosive charge weights up to 39.6 lbs (18 kg). At higher explosive charge weights, significant numbers of fragments will be projected over the blast shield.

2.3.9.3.3. Igloo magazines will suffer severe structural damage when explosive charges as small as 12 lbs (5.4 kg) TNT detonate inside a magazine. An explosive charge weight of 16 lbs (7.3 kg) can completely destroy an igloo.

2.3.9.3.4. There are no significant overpressure hazards, outside of a magazine, associated with the detonation of up to 150 lbs (68 kg) TNT inside a magazine.

2.3.10. Summary of Flagstaff and Hastings Testing. The tests described above that were conducted at Navajo Depot Activity, Flagstaff, Arizona, in 1979 and at Hastings, Nebraska, in 1984, were conducted to determine if the (then current) NATO fragment criteria of 400-m should apply for small amounts of explosive material in ECMs. Based on the results of these tests, DDESB siting criteria for standard ECM containing small quantities of explosives (less than/equal to 450 lbs NEW of HD 1.1) were revised to permit the use of lesser IBDs and PTRDs.

2.3.11. Modular Igloo Tests, 1989 and 1994.

2.3.11.1. Test Description. The Modular Igloo that was tested by the USAF in 1989 at the Utah Test and Training Range was constructed of precast reinforced concrete panels and had a box shape. The intent of the test was to evaluate the design for possible certification as a standard ECM, for allowable storage NEWs up to 500,000 lbs of HD 1.1. The test involved one modular donor igloo with 500,000 lbs NEW of HD 1.1 and four modular acceptor igloos. Three of these acceptor magazines contained explosives-loaded MK 82 (48 each in two magazines) and MK 84 (36 in the remaining magazine) bombs. The fourth acceptor magazine contained empty AGM-65 Missile Containers. The acceptor magazines were sited to the front, sides and rear of the donor magazine, at required minimum separation distances for standard magazines. Data to be collected from the test included blast overpressure, structural and ground acceleration measurements, and limited debris collection. The test is documented in Lewis, Friesenhahn, and Nash (March 1989).

2.3.11.2. Test Results.

2.3.11.2.1. Based on results of this test, the DDESB did not accept the Modular Igloo design as a standard ECM. The primary reason for rejection was that the roof of an acceptor magazine collapsed and a second magazine fell within the crater produced by the donor. Though there was no propagation of any of the acceptor charges in any of the acceptor magazines, the DDESB felt that the damage experienced by the two severely damaged acceptor igloos fell outside the level of acceptable damage to an acceptor standard magazine. The DDESB suggested that the USAF re-design the roof and then use a HEST to validate the modified roof design. This was done and is reported in Roller et al. (January 1994). In 1994 the DDESB applied the results of the HEST-V test to grant final approval to site the modular storage magazine (MSM) (previously called the Modular Igloo or the Hayman Igloo) as a standard ECM. At that time, the MSM design was documented via several separate drawing packages developed by the USAF. In 1999, these separate drawing packages were consolidated by the U.S. Army Corps of Engineers (USACE)-Huntsville into the standard series 421-80-06 drawings. The design was also modified to incorporate a lightning protection system.

2.3.11.2.2. In January 2002, the AFSEC discovered a serious problem with both the original USAF and series 421-80-06 MSM design drawings. On both drawing sets, the MSM's double doors differed markedly from the acceptor door design documented in the 1989 test report. A translation error appears to have occurred during development of the initial USAF drawings, resulting in the depiction of much less robust double doors. As a result, a 2 December 2002 DDESB-KT Memorandum was sent out. AFSEC quickly set up a design engineering team to review the situation and develop a fix. In early April 2002, AFSEC submitted their proposed solution to the DDESB for review, and a 17 April 2002 DDESB-KT Memorandum was issued which approved a modified 421-80-06 design with the correct door and details for retrofitting new hinges onto the headwall for the heavier doors.

2.3.12. Reexamination of Airblast and Debris Criteria, 1991. A reexamination of the airblast and debris produced by explosions inside earth-covered igloos was conducted in 1991, at the request of the DDESB, by the Naval Surface Warfare Center (NSWC). This reexamination reviewed available airblast and fragmentation/debris data produced by explosions within standard ECM. The intent of this review was to recommend possible changes to the standards and to provide the best predictive tools for both fragmentation and airblast. Based on the review of data available at that time, this study determined that the present criteria for airblast appear to be safety conservative. It was discovered that there is a major deficiency in the data relating to the debris/fragmentation produced by explosions in ECM. The report of this reexamination can be found in the NSWC's NAVSWC TR 91-102. Facility debris studies based on data obtained from UK, Australian, and U.S. tests conducted since 1991, indicate that safety criteria based on facility debris distances are not conservative. Additional studies and testing are on-going in the debris arena.

2.3.13. Expected Blast Loads from an ECM. By 2000, the Army and Navy based their design loads for headwalls and roofs of their respective ECM designs on large-scale field tests that had been conducted. For the Army, this was the ESKIMO I test (arch-shaped ECM donor), whereas for the Navy, it was ESKIMO VI and VII (box-shaped ECMs). The predecessor of DESR 6055.09 at that time did not accurately reflect the design loads indicated by field tests and needed to be revised to do so. As a result, the DDESB, in accordance with the 5 July 2000 DDESB-KT Memorandum, approved minimum DoD ECM design considerations and blast loads, which have since evolved to the following in DESR 6055.09:

"V2.E5.5.2. ECMs must be designed to withstand:

V2.E5.5.2.1. Conventional (e.g., live, dead, snow) loads for the barrel of an arch-shaped ECM.

V2.E5.5.2.2. Conventional (e.g., live, dead, snow) and blast-induced loads for the roof of a flat-roofed ECM.

V2.E5.5.2.3. Conventional (e.g., live, dead, snow) loads for the rear wall of an arch-shaped ECM and for the rear and side walls of a flat-roofed ECM.

V2.E5.5.2.4. Expected blast loads, as applicable:

V2.E5.5.2.4.1. On the head wall and door of 3-Bar ES ECMs is a triangular pulse with peak overpressure of 43.5 psi [3 bars, 300 kilopascal (kPa)] and impulse of $11.3W^{1/3}$ psi-ms [100 net explosive quantity (NEQ) in kg $(Q)^{1/3}$ pascal-seconds (Pa-s)].

V2.E5.5.2.4.2. On the head wall and door of 7-Bar ES ECMs is a triangular pulse with peak overpressure of 101.5 psi [7 bars, 700 kPa] and impulse of $13.9W^{1/3}$ psi-ms [$123Q^{1/3}$ Pa-s].

V2.E5.5.2.4.3. On the roof of a flat-roofed undefined, 3-Bar, or 7-Bar ES ECM is a triangular pulse with peak overpressure of 108 psi [7.5 bars, 745 kPa] and impulse of $19W^{1/3}$ psi-ms [$170Q^{1/3}$ Pa-s]."

2.3.14. High Performance Magazine (HPM). The Naval Facilities Engineering Service Center (NFESC), Port Hueneme, CA (now NAVFAC EXWC), developed the HPM design with a primary goal of reducing the encumbered land associated with an explosives storage site. They were able to accomplish this goal through the design of a facility that used non-propagation wall (NPW) technology, developed by NFESC to limit the MCE to the amount of AE in one storage cell plus the amount of AE that might be present in the shipping/receiving area. The MCE associated with the HPM design reduces the IBD by 60 percent and the amount of encumbered land by 80 percent, as compared to a typical ECM containing the total quantity of AE that could be located in all the storage cells of a HPM. Another touted benefit of the HPM design was that it permitted the storage of non-compatible material within the same storage structure, though in different storage cells. The basis of design (BOD) for the HPM is provided in the NFESC TR-2084-SHR. Based on the results of the testing described below, the DDESB granted approval of the HPM as a 7-Bar magazine (and adopted the AE Sensitivity Group (SG) principles discussed later in this chapter) at its 319th Board Meeting on 27 January 2000.

2.3.14.1. The following testing and analyses were conducted to prove the HPM concept:

2.3.14.1.1. In fiscal year (FY) 1993, NFESC conducted two full-scale explosives tests, which demonstrated the explosives safety performance of the NPW concept.

2.3.14.1.2. In FY 1995 and FY 1996, NFESC conducted two full-scale magazine certification tests (CTs) (CT1 and CT3), to certify explosives safety of the prototype design of the HPM. These tests confirmed that the HPM design prevents sympathetic detonation (SD) under the two most critical hazard scenarios. CT1 tested the MCE in a covered storage area (30,000 lbs NEW of HD 1.1) to obtain the maximum cell wall loading. CT3 tested the MCE in uncovered storage/transfer (60,000 lbs NEW of HD 1.1 (total) in the shipping/receiving area, the open storage cell, and the crane load) to obtain the greatest loading on a storage cell. The Test Plan and Debris Density Report for CT1 are provided in the NFESC's Site Specific Report-2127 and "Debris Density US Navy High Performance Magazine Certification Test Number 1." Planning and results of CT3 and CT2 (described below) are provided in DDESB's "High Performance Magazine Certification Test No. 3: Planning and Results."

2.3.14.1.3. CT2 of the pit cover was conducted to certify the required cross section of the storage cell cover for preventing fragment penetration.

2.3.14.1.4. Analytical modeling was used to certify the explosives safety of the prototype design for an MCE fire in either the shipping/receiving area or a storage cell.

2.3.15. NPW Technology. The following summarizes critical areas associated with the HPM's NPW design and the basis for the criteria associated with it, as well as the evolution of that knowledge base to other NPW application. Detailed information about development of NPW SD criteria, the method for classifying munitions into the five SG, and the method for designing composite NPW can be found in the NFESC TR-2221-SHR and TR-2112-SHR. Background information summarizing the knowledge base behind the NPW and SG technology is provided in the NFESC TR-2271-SHR. The preliminary design document developed by NAVFAC for construction of an HPM is provided in the NAVFAC's "Standard High Performance Magazine Preliminary Design."

2.3.15.1. SD Criteria Development. Flyer plate impact tests were conducted to determine reaction thresholds for groups of ordnance items with similar sensitivities. Detailed information on the testing that was conducted can be found in the NFESC TR-2221-SHR. In summary, ordnance tested in the flyer plate impact tests were representative of the ordnance to be stored in the HPM, including the MK 82 bomb, MK103 and MK107 torpedo warheads, the WAU-17 Sparrow missile warhead, the M864 projectile, cluster bomb units (CBUs), and the tube-launched, optically tracked, wire-guided (TOW) II missile. The results of those impact tests were used to establish 5 SGs (Table 2.4) and their associated prompt SD threshold criteria (Table 2.5). All HD 1.1 and 1.2.1 AE are appropriately classified into one of the 5 SGs in accordance with the protocol given in TB 700-2/NAVSEAINST 8020.8C/TO 11A-1-47/DLAR 8220.1. These thresholds limit the applied unit impulse and energy loads on acceptor ordnance in order to prevent SD. SD design criteria are based on allowable unit impulse loads, the unit kinetic energy of the NPW, and the NPW velocity, which must all be less than or equal to the threshold limits of the acceptor ordnance in order to prevent SD.

Table 2.4: SGs and Critical Acceptors

SG		Storage Compatibility Group	Ordnance Description	Critical Acceptor Ordnance
SG #	Description			
1	Robust	C, D, E	Bombs, Projectiles, Thick-Case Munitions	MK82, MK83, MK84 Bombs M107-155-mm Projectile WALLEYE[1]
		J	Ammunition with Both Explosives and Flammable Liquids	HARPOON TOMAHAWK
2	Non-Robust	D, E	Thin-Case Items: Most Missiles, Rockets Underwater Mines and Torpedoes	MK103/MK10 Torpedo Warheads MK55 Underwater Mine
3	Fragmenting	D, E	Fragmenting Missile Warheads	WAU-17 Sparrow Warhead
4	Cluster Bombs/ Dispenser Munitions	D, E	Cluster Bombs, Dispenser Munitions	M483 Bomblet Gator Bomblet
		J	Ammunition with Both Explosives and Flammable Liquids	TOMAHAWK
5	SD Sensitive	B	Detonators and Initiating Devices	#8 Blasting Cap
		F, G	Fireworks, Incendiary, Illuminating, Smoke or Tear-Producing Munitions; Ammunition with Initiation Devices	M106 Grenade M61 Grenade
		C, D, E	Demolition Explosives, Very Thin-Case Items; Sheet Explosives, Sensitive Non-Robust	M118 PETN and MK36 H6 Demo Blocks TOW/HELLFIRE[1]

[1] Directed energy weapon stowage plan must orient the directed energy jet away from the NPW.

Table 2.5: Summary of SD Threshold Criteria for SGs

HP Magazine SGs		Unit Impulse and Energy Loads	
Group No.	Group Description	Impulse, I_{thres} (psi-sec)	Energy, KE_{thres} (ft-k/in^2)
1	Robust	45	24.5
2	Non-Robust	67	24.5
3	Fragmenting	53	8.49
4	Cluster Bombs/Dispenser Munitions	25.6	3.77
5	SD Sensitive	5.23	0.3

2.3.15.2. NPW Criteria Development.

2.3.15.2.1. The most important factor in the improved performance of the HPM is the reduction of the MCE to a detonation involving only a fraction of the total quantity of explosives stored in the HP magazine. This performance is achieved through the use of specially designed NPW and cell covers that prevent prompt SD caused by primary fragment impact, air shock, and heat flux.

2.3.15.2.2. The NPW design eliminates the hazards associated with NPW debris impact and resulting kinetic trauma. The primary hazard to acceptor ordnance in the HPM is the secondary debris generated by NPW and cell covers as they break up under loading. During the design effort, these loads were conservatively estimated by transferring the total impulse of the air shock to the mass-velocity of the wall and cover debris. In addition, the calculated energy and mass-velocity of the debris was not reduced to account for dispersion before it impacted the acceptor munitions. Secondary kinetic trauma hazards occur after the acceptors begin moving under the impact loads from the wall debris. As the acceptor munitions move, they impact other ordnance and magazine components, causing kinetic trauma to the acceptors.

2.3.15.2.3. This kinetic trauma is mitigated by reducing loads on the acceptors (to reduce the free body velocities) and by using “crushable” lightweight concrete in the magazine walls and covers to reduce peak shock loads and create a more uniform loading on the acceptors. The HPM’s NPW cell covers, and magazine storage area external walls have been designed to mitigate loads on the acceptors, as follows: NPW use relatively weak and crushable lightweight concrete external panels with heavy granular fill materials (sand and steel shot). The mass of the wall reduces the energy in the moving debris. The weak lightweight concrete, with a high void ratio, crushes on contact with the acceptors to reduce the peak shock loads on the acceptor when it is impacted by wall debris and when it makes contact with magazine walls. The granular fill materials flow around the acceptors, disperse their energy, and reduce the impulse coupling from the wall debris to the acceptors.

2.3.15.2.4. In addition to the limits on the load environment, a debris velocity limit threshold is applied to non-propagation structural elements. This debris velocity limit is based on the calculated NPW debris velocities from the CT1 and CT3 of the HPM. Because these tests provide the best available data on successful prevention of SD, the velocity limit threshold for the NPW in the HPM were established as follows:

2.3.15.2.4.1. 330 ft-per-second for NPW wall impulse loads of > 10 psi-sec

2.3.15.2.4.2. 500 ft-per-second for NPW wall impulse loads of < 10 psi-sec

2.3.15.2.5. NPW have not been designed to prevent SD of acceptor ordnance from effects of directed energy weapons, therefore, until such time that an NPW is designed to do so, all directed energy ordnance must be oriented toward an exterior wall of the HPM.

2.3.16. NPW Technology and SD Criteria Implementation in New ECM Designs.

2.3.16.1. As previously mentioned, NAVFAC published a preliminary design standard for the HPM (NFESC TR-2271-SHR), which provides an architectural/engineer contractor with guidance to develop a final design which satisfies DoD explosives safety requirements. This preliminary design document states that the first HPM should be considered a prototype facility to resolve any design and construction issues and to establish final standards for future HP magazine construction.

2.3.16.2. Subsequently, NFESC was asked by Atlantic Ordnance Command to determine the feasibility of modifying 7-Bar ECMs, which had been approved by the DDESB, using NPW technology. They determined (NFESC's "Feasibility Study and Basis of Design for Type HP-3B Earth-Covered Magazine") that it was feasible to use NPW technology to create a three-bay ECM with a 135,000 lbs NEW HD 1.1 total storage capacity. The two NPWs separating the three storage bays would prevent propagation of detonation between the bays. The MCE would be based on a single bay storage capacity up to 45,000 lbs NEW. This magazine design was designated the Type HP-3B magazine, where the HP defines an ECM which uses NPWs to separate bays, and the 3B indicates that the ECM is divided into three storage bays. No such ECM have been designed to date.

2.3.16.3. NFESC was then tasked by Marine Corps Air Station (MCAS) Iwakuni and the Corps of Engineers Japan Engineer District to develop and design a new ECM, which reduced the land encumbered by explosive safety quantity-distance (ESQD). This effort supported the Iwakuni Runway Replacement Project. The Iwakuni Runway Replacement Project was a multi-year construction project, which included reclaiming 531 acres of land from the adjacent bay, relocating an existing runway 0.6 miles from its original location onto the reclaimed area, and relocating all of the existing ordnance facilities. Due to the high cost of the reclaimed land, reducing the land encumbered by the ESQD arcs from storage magazines was a critical planning factor. Using the concepts developed for the HP-3B, NFESC developed the Type HP-2B magazine concept (NFESC's "Basis of Design for Type HP-2B Earth-Covered Magazine MCAS Iwakuni"). The Type HP-2B magazine is an earth-covered, reinforced concrete box with two storage bays, which are separated by a NPW. In case of an accidental detonation in a donor storage bay or during handling operations, the NPWs, the magazine roof, the front headwall, and magazine door were designed to prevent propagation of the detonation to the 2nd storage bay within the ECM. On this basis, the magazine was sited for the NEW in a single storage bay. The maximum NEW that can be stored in a single storage bay is 45,000 lbs. The 13 September 2007 DDESB-PD Memorandum approved the HP-2B, with conditions, for use at MCAS Iwakuni, Japan only.

CHAPTER 3: ECM DESCRIPTIONS

3.1. GENERAL.

3.1.1. Original Structural Strength Designations. Before 1997, the terms "Standard" and "Non-standard" were used to designate the structural strengths of ECM and their ability to protect their contents from propagation and damage due to an explosion at an adjacent magazine. Of the two designations, a "Standard" ECM had the greater structural strength and provided a higher level of protection to its contents, while a "Non-standard" ECM was the weaker of the two and provided a lower level of protection to its contents. Consequently, a "Standard" ECM was permitted to be sited at reduced inter-magazine separation distances and to have a higher HD 1.1 storage capacity of 500,000 lbs NEW of HD 1.1, while a "Non-standard" ECM was required to apply greater inter-magazine separation distances and was limited to a smaller HD 1.1 storage capacity of 250,000 lbs NEW of HD 1.1.

3.1.2. Transition to "7-Bar," "3-Bar," and "Undefined" Ratings. In 1997, the terms "Standard" and "Non-standard" were replaced with the terms "7-Bar," "3-Bar," and "Undefined." The terms "7-Bar" and "Standard" designations are synonymous, as are the terms "Undefined" and "Non-standard." The new structural strength designation of "3-Bar" has no pre-1997 equivalent and was established in recognition of the fact that there could be ECM designs that have greater structural strength than an undefined ECM, but less structural strength than a 7-Bar ECM. Due to the additional protection offered to the magazine's contents, as compared to that provided by an undefined ECM, a 3-Bar ECM can be sited using inter-magazine separation distance criteria that are not as stringent as those required for an undefined ECM. These designations are discussed further in Paragraph 3.3. Separation distance criteria and design criteria for all AE storage structures are found in DESR 6055.09.

3.1.3. Additional ECM Information in TP 15. Chapter 4 provides additional information pertaining to ECM designs that have been constructed, and Tables AP1-1 through AP1-4 identify the known magazine designs (ECM and aboveground) that exist, and the structural strength designation assigned to them.

3.1.4. Applicability of Reduced ECM IBD and PTRD to Undefined ECM. In 1990, the Army's Technical Center for Explosives Safety asked the DDESB Secretariat about the applicability of reduced IBD and PTRD in Table 9-1, columns 2, 3, and 4, of DoD 6055.09-STD to non-standard ECM, now termed undefined ECM. [Note: The July 1984 Version of the DoD 6055-STD was in use at that time. Table 9-1 has since been changed to delete the column numbers discussed below from Table 9-1, however, the column titles (i.e., front (column 2), side (column 3), rear (column 4) remained unchanged as compared to the subsequent versions of DoD 6055.09-STD. Following the administrative reissue of the STD as DESR 6055.09, Table 9-1 became Table V3.E3.T1.] The Secretariat's response to the Army's question is documented in the 27 July 1990 DDESB-KT Memorandum. Their response, which remains unchanged to this date, was as follows:

3.1.4.1. Columns 3 and 4 (side and rear) may be used for an undefined ECM, provided the magazine cover is equivalent or better than that of a 7-Bar or 3-Bar ECM, and the ECM's dimensions are 26 ft wide by 60 ft long or larger.

3.1.4.2. Columns 2, 3, and 4 (front, side, and rear) may be used for an undefined ECM with dimensions less than 26 ft wide by 60 ft long, provided the MCE loading density is less than or equal to 0.028 lbs/cubic feet (ft^3), and the earth cover is equivalent to or better than that of a 7-Bar or 3-Bar ECM (or MCE/internal volume).

3.1.4.3. All other default applications of columns 2, 3, and 4 apply only to 7- or 3-Bar ECM with dimensions of 26 ft wide by 60 ft long or longer.

3.2. ECM DESIGN CRITERIA. An ECM's primary purpose is to protect AE. To qualify for the default IMD of DESR 6055.09, an ECM acting as an ES must not collapse. Although substantial permanent deformation of the ECM may occur, sufficient space should be provided to prevent the deformed structure or its doors from striking the contents. ECM design criteria (blast loads) for a 7-Bar, a 3-Bar, and an undefined ECM are specified in DESR 6055.09.

3.3. ECM STRUCTURAL STRENGTH DESIGNATIONS.

3.3.1. 7-Bar ECM. A 7-Bar ECM provides the highest level of asset protection and permits the use of the least restrictive separation distances. A 7-Bar ECM is approved by the DDESB, for a maximum, allowable NEW of 500,000 lbs HD 1.1, unless otherwise noted in Table AP1-1. Most existing 7-Bar magazine designs listed in Tables AP1-1 and AP 1-2 are arch-type or box-type, as defined in Paragraph 4.2.

3.3.2. 3-Bar ECM. The headwall and doors of a 3-Bar ECM are not structurally as strong as those of a 7-Bar ECM but are stronger than the headwall and doors of an undefined ECM. As a result, IMDs to a 3-Bar ECM are generally more restrictive than to a 7-Bar ECM, but not as restrictive as to an undefined ECM. A 3-Bar ECM is permitted to store up to 500,000 lbs NEW of HD 1.1, unless otherwise noted in Table AP1-1 or AP1-2.

3.3.3. Undefined ECM. An undefined ECM is the weakest of the three ECM design types specified in DESR 6055.09. A magazine placed in this structural strength category is either known to be a weak structure or there is insufficient information available for a particular design to prove that it provides greater than "Undefined" protection. Consequently, the undefined ECM generally requires the application of the greatest IMD. An undefined ECM is permitted to store up to 500,000 lbs NEW HD 1.1. This has not always been the case, as discussed in Paragraph 3.1.1. Before January 1996 (312th DDESB Board Meeting), the maximum allowable explosives limit for an undefined (Non-standard) ECM was 250,000 lbs NEW and any quantity over 250,000 lbs required the undefined ECM to be sited as an AGM.

3.4. TYPICAL ECM FEATURES. An ECM has the following typical features:

3.4.1. A semicircular arch or oval arch constructed of reinforced concrete or steel, or a combination of the two. Alternatively, many ECM designs are reinforced concrete box-types with flat roofs. The only design requirement for an arch is that it be capable of supporting conventional (e.g., live, dead, snow) loads. The flat roof of a box-type ECM must meet blast load requirements of DESR 6055.09 and be designed for conventional loads. Neither arches nor box-type ECMs are designed to contain the effects of an internal explosion.

3.4.2. A reinforced concrete floor slab that is sloped for drainage and designed for dead and live loads that account for the expected munitions storage and munitions loading equipment.

3.4.3. A reinforced concrete rear wall. There are existing ECM designs that have no rear wall but are designed instead with two headwalls. These type magazines are known as “flow-through” designs (e.g., standard drawing 421-80-10).

3.4.4. A reinforced concrete headwall that extends at least 2-1/2 ft above the top of the ECM. The headwall is designed to withstand the external blast pressures and impulses resulting from an explosion in an adjacent AE storage facility. This is a critical feature that directly contributes to the strength designation assigned to an ECM. The stronger the headwall, the more protection it can provide to its contents. Some designs have two headwalls, rather than the traditional headwall and rear wall (see Paragraph 3.4.3.). A headwall’s entrance header and pilasters are strengthened to support the loads transferred from the door when an external blast load impacts it. If the door or headwall fails at the door interface, then the design is considered inadequate. However, if the door and headwall survive, but the door in rebound falls to the ground, the magazine is considered to have accomplished its goal. That said, the goal should always be for the door to remain in place following an external explosion at an adjacent AE magazine.

3.4.5. Reinforced concrete wingwalls on either side of the headwall. The wingwalls may slope to the ground or may join wingwalls from adjacent ECM. The wingwalls may be monolithic (of single construction) or separated by expansion joints from the headwall. The purpose of wingwalls is to retain the earth fill along the side slopes of the ECM.

3.4.6. Robust steel entrance doors in the headwall, typically constructed of two thick steel plates with reinforcing elements (e.g., I or C structural steel shapes) placed between them, which are either manually operated or motorized. Approved box-type ECM, to date, have as many as five of these doors in their headwall, while, to date, approved arch-type ECM have as many as two doors on each headwall, though one door is more typical. Doors are either of the swinging (hinged) or sliding type. Sliding doors are generally used on the larger ECM or where a large entrance is needed for the AE being stored, while swinging doors are primarily used on smaller ECM or where it’s not critical to have a large door. Doors are designed to withstand the dynamic loads from an explosion in an adjacent AE storage facility, and are therefore another critical element associated with the structural rating of an ECM design. Doors are not designed to provide resistance to the effects resulting from an internal explosion. Past designs included single and double hinged doors and single or bi-parting sliding doors. The trend is to provide larger doors to accommodate longer munitions in today’s inventory. Many projects have been initiated to expand the entrance into existing magazine structures. The structural hardness must be maintained when modifying magazine headwalls and/or doors, or there may be a significant penalty associated with the modification (e.g., an existing 7-Bar ECM modified for a larger door must have the replacement headwall and door also rated for 7-Bar, or the design will have to be treated as an undefined ECM). DDESB site approval is required for the replacement design before commencing work. Unified Facilities Guide Specifications 08 39 53 should be applied for specifying design and construction of new ECM doors.

3.4.7. Earth cover over the top, sides, and rear of the ECM. A minimum of 2 ft (24 inches) of earth cover is required over the ECM. The requirements for earth cover are specified in Enclosure 5 of Volume 2 of DESR 6055.09. Where allowed by DESR 6055.09 for permissible exposures, the earth covered sides and rear of an ECM can be considered as barricades. Where insufficient earth cover exists on top of an ECM, then the ECM must be sited as an AGM. If earth slope requirements are met, it can be sited as an aboveground, barricaded magazine. The use of 2 ft of earth cover on ECM did not become a standard depth until sometime in the early 1940's. Therefore, unless 2 ft of earth cover is provided over an ECM constructed before 1940, it will have to be sited as an AGM. Earth cover cannot necessarily be added to meet this criterion and qualify the facility as an ECM. It must also be verified that the structure has adequate reserve capacity for the additional dead load in accordance with applicable building codes and, in the case of a box-type magazine, the flat roof blast loading criterion of DESR 6055.09 must also be met.

3.4.8. Lightning protection and grounding systems are installed and integral to the ECM reinforcing. Reinforcing steel in the walls, floor, and arch or box must be interconnected and bonded together and must have a continuous path to ground. For steel arch-type ECMs, the arch is interconnected with reinforcing steel in the floor and walls of the ECM. Continuous bonding of metallic structural components, as described above, produces a faraday-like shield, which shields the contents of the ECM from lightning hazards. Lightning protection criteria are specified in Enclosure 4 of Volume 2 of DESR 6055.09. No specific design information has been found for grounding and lightning protection systems that were associated with ECM designs from 1928 through 1940.

3.4.9. Incoming utilities are installed to meet the construction, installation, grounding, and lightning surge protection criteria of Enclosures 3 and 4 of Volume 2 of DESR 6055.09. In general, electrical, communication, and signal wiring must be placed underground for the last 50 feet to an explosives facility.

3.4.10. When required, internal electrical work and equipment must be rated for the hazardous environments expected within the ECM, in accordance with Enclosure 3 of Volume 2 of DESR 6055.09.

3.4.11. At one time, flappers on ECM ventilators were a standard requirement in ECM design. The flapper is the closure device that is held in the open position with a fusible link. When an ECM is exposed to an external fire, the fusible link melts, allowing the flapper to close and to block off the ventilation openings into the ECM. This action keeps out flames, hot gasses, and burning embers, all of which can threaten the contents of an ECM. For a fusible link to be effective, it has to be located outside the ECM in a location where flames can impinge on it and cause it to function properly. Flappers are no longer required on ECM; however, many ECM still use flappers and fusible links. If used as originally designed, flappers on existing ECM must be secured with a fusible link that complies and is installed in accordance with Underwriters' Laboratory or Factory Mutual Systems. Flappers must also be kept free of corrosion. A temperature rating of 160/165 degrees Fahrenheit is recommended for fusible links used with ECM flappers. If the flappers do not meet these requirements, they should be secured in an open position or completely removed.

3.4.12. In the case of a box-type ECM, the walls and roof may be constructed of reinforced concrete or of prefabricated concrete panels that are assembled in the field. Earth cover, lightning and grounding criteria described above would also apply to box-type ECM. The use of a NPW is a feature found in certain box-type ECM designs used in Japan to limit the MCE and reduce QD.

3.4.13. The only current exception to the typical 7-Bar ECM features described above is the HPM, which consists of multiple barricaded, reinforced concrete storage areas, separated by specially designed non-propagation interior walls, with reinforced concrete covers over the storage areas. Removal of AE from the storage pits involves the use of an overhead crane. Though given a 7-Bar designation, the HPM is not an ECM. The HPM is earth-bermed (except for the truck entrance) and moveable reinforced concrete lids form the roof of each storage cell. The area above the storage cell is enclosed by a lightweight metal panel building, within which is contained the crane used for ordnance movement in the HPM. Additional information about the HPM can be found in Paragraph 2.3.14.

3.4.14. Physical security requirements in accordance with DoDM 5100.76 must be considered in ECM designs. The purpose is to provide a forced entry delay time that exceeds the response force response time. These requirements should be coordinated with the Service and installation security personnel. Note that these requirements often dictate design features and robustness of ECM doors.

3.5. ECM DESIGN APPROVALS.

3.5.1. 7-Bar and 3-Bar ECM Design Approvals.

3.5.1.1. All new 7- and 3-Bar ECM designs must be approved by the DDESB before they can be sited as 7- or 3-Bar ECM. A request for approval must be accompanied by supporting documentation to prove the structural strength being claimed for the design. For example, these data can consist of an ECM test report or a detailed structural analysis. In the past, hybrid 7-Bar ECM have been designed, using component features from other 7-Bar ECM designs. This type of ECM design is not considered pre-approved for construction and would require DDESB approval before it could be sited as a 7-Bar ECM. The design of hybrid ECM offers no clear advantages and is not recommended. Close coordination with the DDESB should be conducted before the start of a new 7- or 3-Bar ECM design in order to avoid problems arising that may prevent obtaining the desired structural strength rating.

3.5.1.2. Once approved, 7- and 3-Bar ECM designs do not have to be re-approved every time they are to be constructed; however, any use of any 7- or 3-Bar ECM design for new construction requires DDESB approval of the site plan, which must clearly identify by drawing number the design being constructed.

3.5.1.3. Changes to approved 7- and 3-Bar ECM designs are not permitted without specific DDESB approval of the proposed changes. If there is any doubt about the impact of a proposed change to the structural integrity of a 7- or 3-Bar ECM, only the DDESB can make a final determination of the change's impact on the design.

3.5.1.4. When using an approved 7- or 3-Bar ECM design and site adapting it for construction at a new location, identify the original, approved drawing numbers of the ECM design selected for construction on the new drawings. There have been numerous construction projects where the original ECM design drawing numbers were not captured in a new drawing package, and the lineage of the design was lost, which by default placed the new design into the "undefined" structural strength category. Significant effort is required to revise a structural strength designation upward from an "undefined" designation.

3.5.15. For ECM designs being constructed overseas, substitution of U.S. materials with locally available materials must be approved by the DDESB. The material specifications must be reviewed to verify they are appropriate substitutes with adequate strength and ductility. It is recommended that either NAVFAC EXWC or CEHNC be consulted on any site-adapted designs with this type of modification.

3.5.2. Undefined ECM Approval. New undefined ECM designs require DDESB approval to ensure minimum design and construction criteria are met (e.g., earth cover depth and slope, grounding, lightning protection, strength of flat roof). In addition, any use of an undefined ECM design for new construction requires DDESB approval of the site plan.

3.5.3. Changes to Undefined ECM Structural Strength Designation. The USACE "Guide for Evaluating Blast Resistance of Existing Arch-Type Earth Covered Magazines" may be used to evaluate the blast resistance of headwalls of existing undefined, steel or concrete arch-type ECM having an internal radius of approximately 13 ft. This reference may also be used for determining the amount of explosives that can be stored in adjacent undefined steel or concrete arch-type ECM (internal radius approximately 13 ft), without creating a blast propagation hazard between ECM. Procedures are provided for determining the adequacy of an undefined ECM headwall to withstand the blast from a known quantity of explosives at a known distance. This is accomplished by comparing the impulse capacities of the various headwall elements (wall, pilaster, and door) to the impulse generated by an imposed blast environment. The results of such an analysis may be used to revise the structural strength designation of an undefined ECM design to another strength designation. DDESB approval of such an analysis is required before an ECM's structural strength designation can be revised.

3.6. FOREIGN ECM DESIGNS.

The DDESB has certified some foreign ECM designs as meeting 7- or 3-Bar criteria of DESR 6055.09. These approvals have typically come through one of the Services as part of a site submission package, such as to construct or site a NATO magazine(s) at a NATO facility jointly operated/shared by U.S. Forces. On occasion, the DDESB has determined that a magazine design was not able to meet 7- or 3-Bar criteria and had to be sited to meet undefined ECM separation distance criteria. In other cases, foreign magazine designs have been given 7- or 3-Bar designations for exposure to a maximum quantity of explosives. In excess of that quantity, the magazine is required to be sited as an undefined ECM.

Foreign ECM designs that have been through this process are included in the magazine tables of Appendix AP1. Restrictions and NEW limitations applicable to use of those designs is also provided by AP1.

3.7. UFC 4-420-01 AMMUNITION AND EXPLOSIVES STORAGE MAGAZINES. UFC 4-420-01 serves as a reference tool to assist in the planning and design of DoD AE storage magazines, including ECMs. It provides definitions and information related to the design, selection, and siting of magazines. The UFC is intended to assist in the selection of a magazine design by providing available options and information related to the use of designs that have been used in the past and have been approved by the DDESB.

CHAPTER 4: MAGAZINE LISTINGS

4.1. GENERAL.

4.1.1. Tables AP1-1 through AP1-3 of Appendix AP1 list all known ECM designs. Table AP1-4 identifies magazines that have been approved with a reduced NEW and/or a reduced QD. Also included in Table AP1-4 are shipping containers that are capable of containing or greatly reducing hazards produced by an explosion of a known quantity of explosives while in the container. For specific shipping containers, this mitigation capability allows the assignment of a hazard classification based on the lesser risk (e.g., MK 663, LD-1000 and LD-2250).

4.1.2. The tables are set up in a manner to preserve the historical structural strength designations assigned to magazine designs. A discussion of those structural strength designations is provided in Chapter 3. As a reminder, “7-Bar” and “Standard” structural strength designations are synonymous, as are the structural strength designations “Undefined” and “Non-standard.”

4.1.3. A numerical-first, alphabetical-second methodology was used for listing magazine designs in Tables AP1-1 through AP1-3. This approach was selected because it is expected that users will typically approach these tables first with a drawing number that they are trying to identify. Magazine designs are first listed by their drawing number(s), in ascending order. Since magazine designs usually have multiple drawing numbers associated with them, the lowest drawing number in the magazine design drawing set was used to determine where the magazine design was placed in the numerical list. Those designs that do not have a drawing number(s) then follow, in alphabetical order, after the numeric listing. Table AP1-4 is an exception to this approach, because of the large number of magazine designs for which no drawing numbers exist and the wide variation of magazine and container types listed. To simplify the use of Table AP1-4, the magazine design’s MCE has been listed. The MCE may be identified as NEW or TNT equivalence.

4.2. ECM DESCRIPTIONS. Figure 4.1 illustrates the various ECM cross-section variations (described below) that exist. The names associated with those cross-sections are also used in the description fields of Tables AP1-1 through AP1-4.

4.2.1. Arch. Also known as a circular arch. A single radius is used to define the interior face of the arch, which may be constructed of reinforced concrete, steel (corrugated, laminate, or single gauge), or a combination of reinforced concrete and steel to form a composite arch (steel interior arch with overlying concrete).

4.2.2. Arch, Oval. This arch is in the shape of an oval, with the lower portion of each sidewall bowing in towards the direction of the centerline. The arch can be constructed of steel, reinforced concrete, or a composite of both. The shape is defined by the use of a single radius for the vast majority of the arch, with a separate radius called out for the lower portions of the arch. The modified FRELOC-Stradley ECM design is an example of an oval-arch ECM.

4.2.3. Arch, Semi-Circular. The sidewalls are elongated with the arch defined by a radius that originates approximately 3 to 5 ft above floor level. A radius originating at the opposite sidewall defines the lower portion of the arch. The arch can be constructed of either reinforced concrete or steel.

4.2.4. Stradley. This reinforced concrete ECM is characterized by vertical sidewalls that blend into the arched roof. Three radii are used to define the arch and the transition from the vertical sidewalls to the roof arch. Another feature of the Stradley ECM is that its walls are significantly thicker at the base of the sidewalls and thinner at the crown of the arch. The Stradley magazine is named after a Mr. Stradley, its designer.

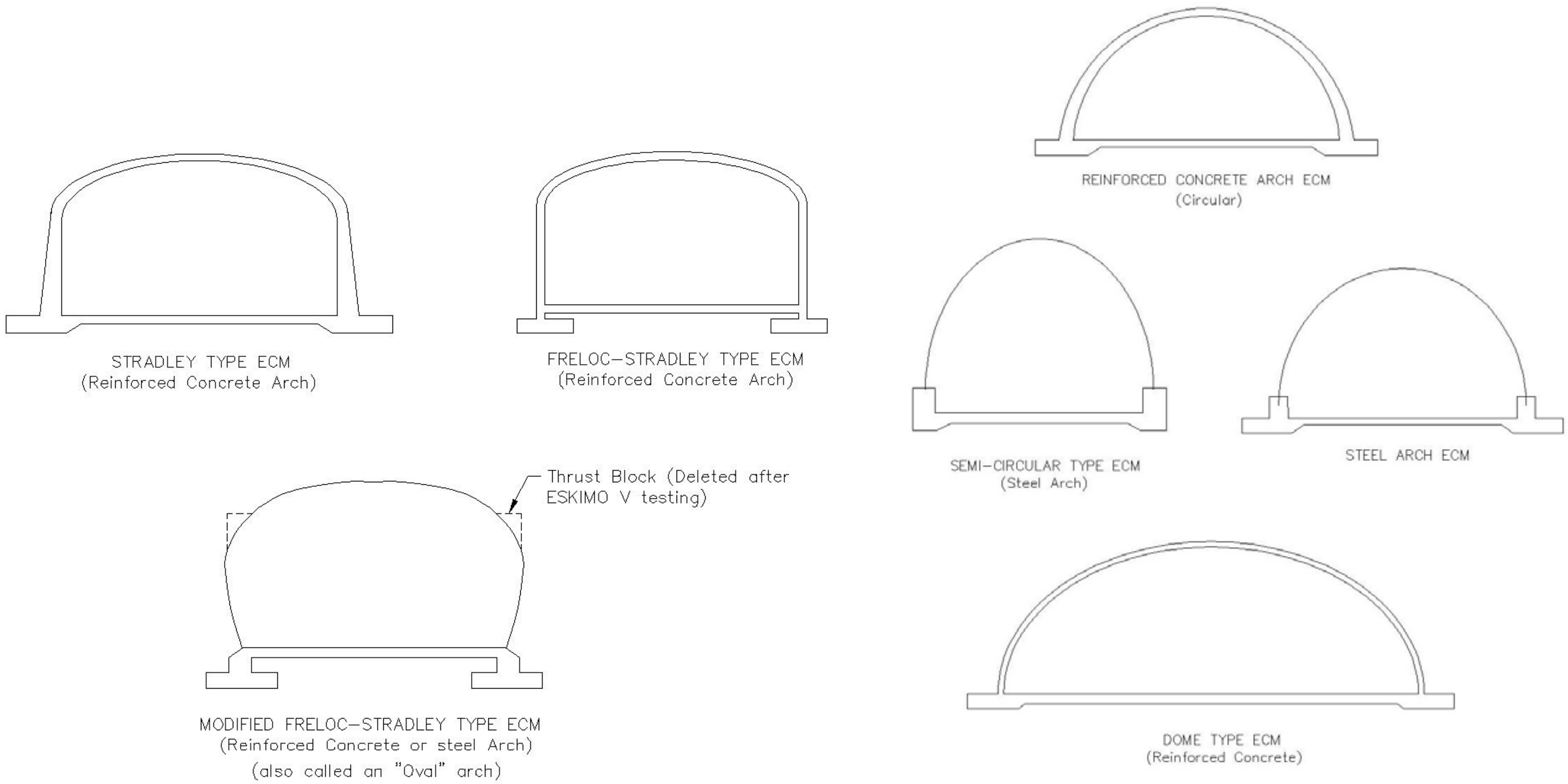
4.2.5. FRELOC-Stradley. The FRELOC-Stradley ECM is constructed of reinforced concrete. Its interior shape is similar to a Stradley ECM, except that the sidewalls and arch have the same uniform thickness. The FRELOC design has its origins in the late 1960s, in Germany, and was developed by the U.S. Army Engineer Command (Europe) to reduce construction costs and improve its constructability.

4.2.6. Modified FRELOC-Stradley. This ECM design was the first ECM constructed with an oval arch. See the information above for the oval arch.

4.2.7. Box. This term describes any ECM that has an internal box shape. Explosives limits can range from less than a pound NEW of HD 1.1 to 500,000 lbs NEW HD 1.1.

4.2.8. Dome. This shape was used only with the Corbetta ECM. The interior wall of the magazine is circular. The magazine roof is convex, and the magazine diameter is approximately three times the height of the magazine.

Figure 4.1. ECM Cross Sections



4.2.9. HP-2B Box Magazine. This design is based on the work described in Chapter 2 about HPM, SD, and NPW criteria development. The Type HP-2B magazine is a flat-roofed, reinforced concrete box ECM containing two 2 AE storage bays separated by a large NPW. In case of an accidental detonation in one of the storage bays or during handling operations, the design of the NPW, magazine roof, headwall, and magazine doors prevent propagation of the detonation from the donor bay to the adjacent storage bay within the magazine. The magazine may therefore be sited for the NEW in a single storage bay.

4.2.10. MSM. This ECM category includes box-type magazines constructed primarily of precast concrete panels comprising the roof and side/rear walls. The front side of these magazines consists of a large steel blast door. These magazines are desirable based on relatively low construction costs and duration, along with the large door size that allows for greater access for loading/unloading. Origins of this magazine type are documented in Paragraph 2.3.11.

4.3. MAGAZINE TABLES (FOUND IN APPENDIX AP1).

4.3.1. Table AP1-1. 7-Bar and 3-Bar ECM Approved for New Construction. This table identifies all 7- and 3-Bar ECM currently approved by the DDESB for new construction. Also included are any foreign-designed ECMs that have been approved for new construction as 7-Bar structures. Notes are provided to identify those ECM that have NEW limitations and/or restrictions associated with their DDESB approval.

4.3.2. Table AP1-2. 7-Bar and 3-Bar ECM No Longer Used for New Construction, But Still in Use. This table identifies all 7- and 3-Bar ECM that are generally no longer constructed but may still be in use. The table's contents either were previously approved by the DDESB as 7- or 3-Bar (Standard) ECM or were placed into this category by the DDESB as a result of an analysis. In most cases, the restriction on the use of the design for new construction is a result of the Service superseding the design with another design. The information in the table can be used for assistance in siting existing magazines that were previously approved for construction. NEW limitations and/or restrictions associated with their DDESB approval must be observed. Because these designs are no longer actively maintained, they may not comply with current explosives safety criteria. If there is a desire to use a design from this table, and DoD Component approval is obtained, the design may be used for new construction, provided it has been completely evaluated for compliance with current criteria of DESR 6055.09 and the design drawings updated. DDESB approval of the revised design is required, and all changes that have been made must be clearly identified on the drawing.

4.3.3. Table AP1-3. Undefined ECM. Table AP1-3 lists magazine designs that are considered to be undefined. This structural strength designation is assigned to an ECM design if it was determined by analysis, testing, or DDESB assessment to be inherently weaker than a 7- or 3-Bar magazine design, or if its structural strength is simply unknown due to a lack of supporting information to prove its ability to meet 7- or 3-Bar criteria. Each DoD Component provides its own guidance as to which of these magazines can be constructed. Note that a flat roof magazine's roof strength must be validated against current DESR 6055.09 criteria for it to be considered an undefined ECM rather than an AGM.

4.3.4. Table AP1-4. Magazines (Earth-covered and Aboveground) and Containers with Reduced NEWs and/or a Reduced QD. Table AP1-4 lists AE storage structures and containers that have been approved by the DDESB for specific NEWs and/or reduced QD. The items in this table were generally designed for a particular application; however, as approved items, they can be used by other DoD Components and for other applications, provided all conditions, restrictions, design elements, etc., are observed. All documentation pertaining to the use of the storage structure or container must be obtained before their use. Table AP1-4 also identifies restrictions/conditions, as applicable, for use of the items listed. Select flat roof magazines that have been evaluated and determined not to be equivalent to an undefined ECM are found in Table AP1-4.

4.4. SPECIAL NOTE ON BOX-TYPE OR FLAT ROOF ECMS.

4.4.1. IMD requirements in DESR 6055.09 are based primarily on explosives testing of arch-type ECMs. These tests indicate that when an arch-type magazine is sited at 7-Bar ECM IMDs, its roof will not collapse under blast overpressure loading from an adjacent donor magazine. This beneficial response is credited to the inherent strength of an arch placed in near-uniform compression from a blast load impinging on adequate soil cover (greater than or equal to 2 ft of earth cover). Box-type or flat roof magazines do not have the same compressive-arch capacity and may fail rapidly and catastrophically in direct-shear under blast loading.

4.4.2. Navy box-type ECMs constructed during the World War II era were designed for storage of non-mass detonating AE. During the planning phases of Eskimo VI, DDESB and the Services concluded that the flat roofs of these magazines would fail catastrophically under the blast load from an adjacent donor magazine. Accordingly, while the Eskimo VI and VII tests were used to determine if specially designed flat roof magazines could be sited at standard IMDs, these tests did not consider World War II era box-type magazine construction.

4.4.3. DESR 6055.09 requires that the roof of an undefined box-type magazine be capable of withstanding the specified flat roof loading. While many box-type or flat roof magazines listed in Table AP1-3 may have been historically treated as undefined ECMs, the roof on these magazines should be checked on a case-by-case basis to verify its adequacy to withstand the flat roof blast loading specified in DESR 6055.09. While the "grandfathering" clause of DESR 6055.09 allows for the continued use of legacy facilities sited under the criteria in place at the time of construction provided the original approval conditions remain in place, flat roof configurations may have, over time, been repurposed (e.g., storage changed from HD 1.3 powders to HD 1.1 AE; allowable NEWs increased (given greater internal, usable volume); or IMDs reduced with the addition of new magazines). Legacy flat roof magazines are, in many cases, unable to withstand potential blast overpressures at undefined ECM IMDs; those magazines that remain in use should be evaluated and replaced, as appropriate.

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CHAPTER 5: UNDERGROUND AMMUNITION STORAGE FACILITY

5.1. GENERAL. USACE Definitive Drawing 421-80-04, dated 18 November 96, was approved by the DDESB on 8 December 1996 and provides general advice and guidance in the planning, siting, and construction of underground ammunition storage facilities. This drawing provides details regarding facility layout, tunnel and chamber dimensions, a frontal barricade, closure blocks, and blast doors, as well as on rock classifications. Copies of this drawing can be obtained from the CEHNC, Code CEHNC-EDC-S, P.O. Box 1600, Huntsville, AL 35807-4301.

5.2. UNDERGROUND MAGAZINE CRITERIA. DoD explosives safety and design criteria for underground ammunition storage facilities can be found in DESR 6055.09.

5.3. NATO CRITERIA. NATO explosives safety and design criteria for underground ammunition storage facilities given in Allied Ammunition Storage and Transport publication (AASTP)-1 are similar to those found in DESR 6055.09, though there are some major differences. The NATO criteria represent the most recent work, but the DDESB has not yet adopted the NATO criteria at this time. NAVFAC ESC, (now NAVFAC EXWC), was asked to do a comparison of NATO versus DoD criteria, and their work is described in "Review of NATO Underground Magazine Criteria and Update Recommendations for DoD 6055.09-STD." The DDESB is currently assessing the differences and evaluating the adoption of NATO criteria.

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Chapter 6: Barricades and Containment Structures

6.1. GENERAL.

6.1.1. Explosives Hazards and Protective Construction. The hazards produced by an external explosives detonation generally consist of airblast overpressure, primary fragments (e.g., fragments from a detonating munition's casing), secondary fragments/debris, and thermal flux. In addition to these hazards, full and partial blast containment cells are exposed to gas pressure loads. If sufficient distance is provided from detonating AE, these hazards may be eliminated. However, the large protective zones typically required for complete protection from blast hazards are not usually feasible due to the vast areas that would be encumbered. Consequently, the explosives safety criteria of DESR 6055.09 define protection requirements to personnel and property and provide minimum default separation distances both to prevent an explosives propagation (prompt and subsequent) and to protect personnel (related and non-related) and assets. These distances vary with the type of explosives operation, the required protection level, the explosives material, the facility type, and other factors. For example, DESR 6055.09 requires a higher level of protection and, in most cases, applies greater default separation distances to personnel exposed to an intentional detonation or a high risk explosives operation (e.g., motor firing in a test cell, a detonation range) than to personnel exposed to a low risk operation where only an accidental (non-intentional) detonation may occur. DESR 6055.09 permits the application of lesser separation distances if DDESB-approved protective construction/mitigation is used that is capable of providing an equivalent level of protection to that required at the minimum default separation distance. Testing and/or analyses are necessary to demonstrate to the DDESB that a protective construction design or mitigation method is adequate.

6.1.2. Protective Construction Records in TP 15. The purposes of this chapter are to consolidate in one document the many protective construction designs and mitigation methods that have been approved by the DDESB; to provide sufficient information for initial assessments of available methods for specific needs; and to provide sources for additional information.

6.1.3. Conditions for Use of Approved Protective Construction. Conditions and restrictions (e.g., maximum NEW, minimum AE standoff distances, minimum barricade heights, required construction materials, inspection requirements) always apply to the use of protective construction designs and blast mitigation methods. These conditions and restrictions ensure that any planned use of a design/method falls within the boundaries and parametric limits of its supporting testing or analyses. Uses outside of these conditions and restrictions may increase explosives hazards and could negate the benefit that was intended. Consequently, before a design/method is selected, all pertinent information and approvals must be read and understood. If a condition or restriction in the approval is violated, additional testing or analyses may be required to validate the design/method for the new application.

6.1.4. Modification of 2-Degree Barricade Height Criteria.

6.1.4.1. The DDESB approved a change to the barricade design requirements of the predecessor to DESR 6055.09, as documented in the 11 December 2006 DDESB-PD

Memorandum, specifically for determining the required height of barricades used for inter-magazine (K6) protection against prompt propagation due to high-velocity, low-angle fragments. The then-existing “2 degree rule” was replaced with a requirement that the barricade’s height must be at least 1 ft above the line-of-sight between explosives stacks, with the line-of-sight determined in the same manner as was previously required. Details regarding this change can be found in the DDESB approval document. This change does not apply to previous approvals where explosion testing was conducted with a barricade (e.g., USAF Big Papa test for barricaded module storage described in Chapter 7), where the tested barricade’s height was determined using the 2-degree requirement.

6.1.4.2. The DDESB subsequently approved an additional change to the barricade design requirements for determining the required height of barricades used for intraline protection when the ES does not contain an acceptor stack, as documented in the 30 April 2014 DDESB-PD Memorandum. In this situation, the height of the barricade will be determined using the height of the highest personnel location in place of the height of the acceptor stacks.

6.2. BARRICADE DESIGNS. Barricades are available in many different types and sizes, and if properly constructed can be very effective in controlling fragments and debris, and, in certain circumstances, airblast effects. The various uses for a barricade are described below:

6.2.1. A barricade can provide an effective means of defeating high-velocity, low-angle fragments, which are the primary cause of prompt propagation of an explosion from one explosives site to another explosives site. In the event of an explosion at an explosives site, the presence of a barricade will not necessarily prevent subsequent explosions from occurring at other nearby sites; however, each explosion may be viewed as a separate event.

6.2.2. A barricade can provide adjacent operations and facilities protection from high-velocity, low-angle fragments, which present a high risk of injury or death to personnel and a high damage potential to facilities and equipment. A barricade will not provide any protection from high-angle fragments, which can pass over a barricade.

6.2.3. A barricade can provide limited protection from blast overpressure in an area immediately behind the barricade. The amount of protection provided by a barricade is governed by the barricade’s height and width and the distance the exposure is from the rear of the barricade. Protection increases as separation distance decreases. A barricade is ineffective in reducing blast overpressure at far-field distances, such as those associated with IBD or PTRD.

6.2.4. In certain situations, explosives safety criteria permit the use of reduced separation distances between explosives sites and from explosives sites to adjacent operations and facilities, when properly constructed, intervening barricades are present.

6.2.5. Some barricades are designed for specific applications, such as to contain fragments or to minimize potential fragment throw distances. Examples where such barricades could be used are at an ordnance environmental (OE) cleanup site to protect from an unintentional detonation of an AE item being worked, or at an explosive ordnance disposal (EOD) site where only limited quantities of explosives material will be detonated/burned. Use of such fragment defeating barricades may permit a reduction in QD by allowing other factors, such as blast overpressure or maximum expected fragment distance, to govern the application of QD.

6.2.6. When there is a need for AE to be in close proximity to other AE, a barricade can be used to limit the MCE to a single AE item, stack, vehicle, etc. As a result, the QD arc emanating from the site can be reduced because it is based on the MCE involved and not all the AE on-site. The DDESB has approved the use of a number of barricade designs, and these are listed below. Barricade design and construction criteria are provided in Enclosure 5 of Volume 2 of DESR 6055.09.

6.2.7. Approved barricade applications are listed below.

6.2.7.1. DEF 149-30-01 Barricades. The Huntsville Center of USACE has developed a definitive drawing, DEF 149-30-01, which provides construction information for numerous barricade designs that can be used to protect facilities and equipment located close to explosives sites from high-velocity, low-angle fragments. The definitive drawing provides details for the construction of a traditional earthen barricade, a sandbag barricade, numerous retaining wall barricades, and other types of barricades. The DDESB originally approved definitive drawing DEF 149-30-01 on 25 February 1992. The most recent version of these drawings to be released is dated 19 August 2011. The various barricade configurations are recognized as effective for the applications shown on the drawings and, consistent with constraints indicated on the drawings, are approved for site-adaptable implementation. Copies of definitive drawing DEF 149-30-01 can be obtained from CEHNC (see Paragraph 1.3 for their contact details).

6.2.7.2. Jungle Growth. Dense vegetation can be effective in preventing prompt propagation of an explosion from one explosives site to another, due to the jungle growth's ability to stop high-velocity, low-angle fragments. The density of jungle growth plays an important role in stopping these fragments. On 27 July 1976, the DDESB approved the use of barricaded, aboveground separation distance (K6) between aboveground, unbarricaded explosives storage sites at Andersen Air Force Base, Guam. Their approval was based on testing which showed that high-velocity fragments could be effectively stopped by a medium that had a gross average density of at least 2000 grains/ft^3, about four times the density of air at standard conditions. The DDESB approved restricted use of jungle growth as an effective barricade for the storage of relatively insensitive, finished ammunition, such as bombs and separate-loaded projectiles, without fuzes or propelling charges. In addition, a regular program of surveillance is required to ensure that the average gross density of the jungle growth is not compromised.

6.2.7.3. Earth-filled, Steel Bin-Type Barricades. These barricades, also known as ARMCO Inc. revetments, are earth-filled, steel bins that have been used to separate munitions awaiting scheduled processing; for example, munitions on flight lines associated with aircraft parking/loading operations, or the temporary positioning of munitions awaiting transfer to preferred, long-term storage. These barricades are also used to separate uploaded aircraft. These barricades are typically formed into cells and are designed to limit the MCE (for QD purposes) to the munitions stored in each cell. Criteria were approved during the 314th DDESB Meeting for siting of munitions in ARMCO revetments during flight line "load and unload operations." The DDESB Secretariat maintains a list of the munitions suitable for storage in revetments and has developed a methodology for adding other munitions to the list in the future. The initial list and methodology are documented in an 18 April 1997 DDESB Memorandum. The Type A ARMCO Inc. revetment has an allowable MCE of 30,000 lbs (13,608 kg) NEW of HD 1.1 (prompt propagation protection), and the Type B ARMCO Inc. revetment has an allowable MCE of 5,000 lbs (2,268 kg) NEW of HD 1.1 (prompt propagation protection). Restrictions associated with the use of these ARMCO Inc. revetments are found in DESR 6055.09. NFESC TR-0259-SHR is the technical report describing the analyses conducted for the ARMCO revetments. These bin-type barricades can also be used around storage sites and operations area, where use of barricaded inter-magazine and barricaded intraline separation distances is allowable by DESR 6055.09.

6.2.7.4. Ammunition Quickload and Safeload Programs. These programs were developed by the U.S. Army Project Manager for Ammunitions Logistics in response to a 1986 DDESB Survey of U.S. Army camps in Korea, which revealed that a number of explosives safety storage violations (primarily involving explosives loaded vehicles) existed in proximity to occupied areas. These programs, through testing, developed barricades to help reduce MCE to smaller NEW that were more manageable and that permitted reductions in QD. These barricades are to be used primarily in Theatres of Operation. The following barricades were developed under these programs:

6.2.7.4.1. AGAN Steel Panel (ASP) Walling System. The ASP walling system consists of formed metal sheets, which are joined together to constitute both the permanent framework for the wall and the reinforcement for the concrete that is then poured into the metal framework and allowed to cure. The DDESB approved the use of this system initially on 18 September 1990 and then approved a revised technical data package (TDP) for the walling system on 25 September 1990. The ARBRL “Ammunition Quickload Program, Barriers for Truck Protection” is the revised TDP for the ASP walling system, and it details the construction techniques that are required to properly assemble the ASP walling system. The system permits the parking of 155-mm loaded trucks carrying up to 160 155-mm projectiles (M107 or M483) and their associated propellant charges, side-to-side with an intervening ASP walling system between trucks. This quantity of 155-mm projectiles equates to about 2,500 lbs (1,134 kg) NEW. A minimum of 15 ft must separate trucks. In this configuration, the MCE is the AE on one truck, and QD can be based on this MCE.

6.2.7.4.2. Sand Grid Wall. The sand grid wall uses commercially available honeycomb grid sections that are expanded and sand-filled, in accordance with the instructions provided in the ARBRL “Quickload Program Technical Data Package, Use of Sand Grid Wall to Prevent Propagation Between Truckloads of 155-mm Artillery Ammunition,” to construct the barricade needed. Once built up to the required height, the sand grid wall can be used as a barricade to separate individual truck or trailer loads of 155-mm artillery projectiles plus their associated propellant charges. Up to 160 155-mm projectiles and their associated propellant charges may be on any truck or trailer, which represents the MCE for QD purposes. A minimum separation distance of 15 ft must be maintained between trucks or trailers. Initial DDESB approval for the sand grid wall was granted on 22 February 1991 for use as a barricade for 21 different projectile types and their associated propellant charges. Subsequent DDESB approval for an additional four projectiles and their propellant charges was granted on 24 June 1991. The total number of projectile types permitted to use the sand grid wall barricade is currently 25.

6.2.7.4.3. Geotextile Stabilized Sand Walls as Barricades. A 6 February 1991 DDESB Memorandum found acceptable the concept of a stand-alone, geotextile stabilized sand wall barricade, which was at least 3 ft thick at its crown, provided it could meet lifetime requirements through validated erosion control techniques. This barricade design had to have side slopes exceeding 1.5 ft horizontal to 1 ft vertical. Based on this DDESB acceptance, the Project Manager, Ammunition Logistics, at Picatinny Arsenal published a TDP which described methods for constructing three different types of geosynthetic reinforced barricades using sandy soil as a backfill, as an improvement to ordinary sandbag walls. The TDP, ARBRL “Safeload Program Technical Data Package, Geosynthetic Reinforced Barricades for Ammunition Storage,” provides detailed instructions for constructing a double-faced geotextile wall, a geotextile-wrapped sandbag wall, and a geocell wall. It was envisioned that these walls would be used in a Theatre of Operation to protect and separate ammunition. However, use of these walls is allowed wherever permitted by DESR 6055.09, for the reduction of separation distances, such as barricaded inter-magazine or barricaded intraline. Painting of exposed portions of the two-geotextile walls has been found to be essential for barricade longevity.

6.2.7.4.4. 4.2-Inch Mortar Rack. The 4.2-inch mortar rack is contained in a Container Express (CONEX) container and is built of wooden modules and steel plates arranged in a specific configuration. Each module can contain one box of two M39A2 Composition B loaded mortar rounds. A steel plate is used to separate rows of modules. A passive fire suppression system is used, which consists of plastic containers filled with a fire suppression liquid that are placed in select spaces in the rack. The sidewalls and roof of the CONEX must be sandbagged, and a door barrier must be constructed in front of the CONEX container. The 4.2-inch mortar rack was approved by the DDESB on 30 December 1991. If constructed and used in accordance with the ARBRL “Quickload Program Technical Data Package, 4.2-Inch Mortar Ammunition Rack and Fire Suppression System,” the MCE is one box of two mortar rounds. The rack requires a front IBD arc of 310 ft within a 30-degree arc (+/-15 degrees from the CONEX centerline) and a 100-ft IBD arc around the remainder of the storage site.

6.2.7.4.5. Improved Loading Configuration for 8-Inch Artillery. A 27 March 1987 DDESB Memorandum approved loading configurations for TNT-filled 8-inch (M106) artillery ammunition, with associated propelling charges and fuzes, aboard transport vehicles. Transport vehicles using these approved spacing and shielding configurations are permitted to be parked near each other within a holding area, with the MCE considered one transport vehicle. The 11 May 1987 Office of the Deputy Chief of Staff for Personnel letter provides details regarding spacing, shielding, and load configurations that were approved.

6.2.7.4.6. 105-mm Tank Rack Design. A rack was developed for the temporary storage of 105-mm tank ammunition in congested areas, such as when a tank has to be downloaded for maintenance. The rack is designed to limit the MCE to one tank round, which permits the application of a 50-ft IBD arc around the facility containing the rack. The facility has soil cover on its sidewalls, rear wall, and roof and uses a front barricade. The rack/facility design was approved by the DDESB on 23 December 1986. A modification of the initial approval to add additional 105-mm ammunition types to those already approved to be placed in the rack/facility was approved by the DDESB on 19 March 1987. ARBRL Special Publication BRL-SP-46 provides construction details for the rack and the facility that contains it and identifies the 105-mm ammunition types permitted to be stored within it.

6.2.7.4.7. 105-MM/120-mm Tank Ammunition Download Rack. Several construction options have been developed for the storage of 105- and 120-mm ammunition in facilities containing ammunition download racks that are designed to limit the MCE to one projectile only. These facilities use soil containment elements for the sidewalls, rear wall, and roof and have a front barricade. The ARBRL "Rack for Temporary Storage of 105-mm Heat Ammunition" provides the specifics for construction and use of the rack designs approved by the DDESB on 21 November 1989. The 105-mm versions of the rack require a 50-ft IBD arc, while the 120-mm versions of the rack require a 75-ft IBD arc. Additional technical information is provided in the ARBRL "Ammunition Quickload Program, 105 MM and 120 MM."

6.2.7.4.8. TOW Missile Rack. A 28 April 1989 DDESB Memorandum approved the use of the TOW missile rack. The rack, which limits the MCE to a detonation involving 50 lbs (22.7 kg) NEW (TNT equivalent), is contained within a CONEX container. The rack is assembled using stacking modules and steel plates between rows, in a manner similar to that described above for the 4.2-inch mortar rack. The CONEX container is sandbagged on the sides, rear, and roof, and a barricade is constructed in front of the door. When assembled and used in accordance with the ARBRL "Ammunition Quickload Program, TOW Missile Rack," the rack requires a front IBD arc of 740-ft within a 60-degree arc (+/-30 degrees from the CONEX centerline) and a 350-ft IBD arc is required around the rest of the container.

6.2.7.4.9. QD Reduction Using Concertainer Barricades.

6.2.7.4.9.1. 28 October 2002 DDESB-KT Memorandum approved a TDP, (TACOM-ARDEC Logistics R&D Activity "Technical Data Package for Ammunition Storage Quantity-Distance Reduction with Concertainer Barricades"), for the use of a HESCO-Bastion™ concertainer barricade, configured as shown in the TDP, for prevention of prompt propagation between munitions storage cells, each containing 8,820 lbs (4,001 kg) NEW of HD 1.1, when separated by less than the required intermagazine (K6) default criteria. For the NEW involved, K6 separation criteria would normally require an intervening barricade and a separation distance of 124 ft. In a full-scale test using worst-case (i.e., SG 5) HD 1.1 and HD 1.3 acceptor munitions, it was demonstrated that an intervening HESCO-Bastion concertainer barricade was capable of preventing prompt propagation of acceptor munitions located at an IMD of 28 ft from the detonation of a donor munition stack containing 8,820 lbs (4,001 kg).

6.2.7.4.9.2. NATO nations have conducted significant testing with these types of sand-filled, fabric, wire-reinforced barricades for the construction/protection of forward operating bases used in deployed operational scenarios. This testing has shown that significant fragment protection (which can be further enhanced with overhead protection), as well as some overpressure mitigation, is provided by using these types of barricades around explosives storage sites in order to reduce both internal (in camp) field distances and external (off-base) QD. Based on this data, NATO has developed AASTP-5, which provides criteria associated with barricaded storage sites for up to 8,820 lbs (4,001 kg) and associated QD. In 2007, the DDESB, with Service agreement, ratified AASTP-5 for use by U.S. Forces in support of NATO operations. NATO Working Paper, PFP(AC/326-SG/6)WP(2008)0001 is an accompanying document for AASTP-5 and was developed to further explain the background data and protection levels associated with the field distances given in AASTP-5.

6.2.7.5. Munitions and Explosives of Concern Removal Sites. CEHNC has been involved with projects that require the dispositioning of explosive hazards on such sites. These sites could be on government, public, or private lands. Actions that can be taken when an explosive hazard is found include treatment on-site or movement of the item to another site for proper treatment. Safety to the public and personnel involved in munitions response actions is of utmost concern. In response to the need to ensure this safety, CEHNC was tasked to develop procedures and barricades for blast and fragment mitigation for use by personnel performing intrusive and/or treatment operations. The barricades that have been approved for this purpose are listed below.

6.2.7.5.1. Minimum QD for OE removal sites. Revision 2 of DDESB TP 16 had applied a 200-ft minimum safe distance when using the methodology contained within it for calculating a munition-specific hazardous fragment distance (HFD) or maximum fragment distance (MFD). Per CEHNC "Hazardous Fragment Distances," the basis for this 200-ft minimum was to keep bystanders from interfering with or being a distraction during munitions response operations. The 200-ft minimum was not based in any way on the hazard from an explosive item to exposed personnel. Because the 200-ft minimum has imposed an undue burden on munitions response operations and was not originally driven by explosives safety concerns, it has been removed from DDESB TP 16; instead, the calculated HFD or MFD for the specific munition being addressed will be used. Although the 200-ft minimum was not based on hazards from the explosives to exposed personnel, it is important to recognize that interference and distraction from bystanders can pose a concern to the safe conduct of munitions response operations. Therefore, as determined by the DoD Component involved, use of larger distances than those calculated is encouraged wherever feasible.

6.2.7.5.2. Minimum Separation Distances (MSD) to Non-Essential Personnel When Using the DDESB-Approved Consolidated Shot Method. The 27 October 1998 DDESB-KO Memorandum approved the procedure given in the CEHNC "Procedures for Demolition of Multiple Rounds (Consolidated Shots) on Ordnance and Explosives (OE) Sites," for intentional detonation of single or multiple munitions and the determination of safe separation distances for unrelated personnel. In summary, using the prescribed procedures, the safe distance is the greater of K328 (using the total NEW and detonation charge as the NEW) or the MFD. The MFD will be the MFD computed for the most probable munition for an OE area at a site, and this will be the MFD for a consolidated shot.

6.2.7.5.3. Use of the Consolidated Shot Method at Collection Sites. The 25 September 2009 DDESB-PD Memorandum approved the use of the consolidated shot method concept to collection sites. For those situations, the MSD (to nonessential personnel) for unintentional detonations from in-grid collection or consolidation points is the greater of: (1) the largest HFD of any item at the collection or consolidation point, or (2) K40 of the total NEW of all the items at the collection or consolidation point.

6.2.7.5.3.1. As described in the CEHNC "Procedures for Demolition of Multiple Rounds (Consolidated Shots) on Ordnance and Explosives (OE) Sites," this procedure orients the rounds horizontally on the ground, in a single layer, and sidewall to sidewall. By doing so, the interaction zone between projectiles points up (vertically), rather than out (horizontally). This orientation limits the effective maximum range of interaction zone fragments since they exit up and therefore at very high launch angles. The MFD can therefore be based on that for a single round rather than on the greater range of interaction zone fragments. This orientation also controls the number (density) of fragments entering the far field such that the HFD remains that based on a single round. MSD for nonessential personnel for intentional detonations (shots) and for collection/consolidation points are as follows:

6.2.7.5.3.1.1. The MSD for intentional detonations for nonessential personnel for a consolidated shot is the greater distance of:

6.2.7.5.3.1.1.1. The largest MFD of any item in the shot, or

6.2.7.5.3.1.1.2. K328 of the total NEW of all items in the shot, including donor charges.

6.2.7.5.3.1.2. The MSD for unintentional detonations for nonessential personnel from in-grid collection or consolidation points is the greater of:

6.2.7.5.3.1.2.1. The largest HFD of any item at the collection or consolidation point, or

6.2.7.5.3.1.2.2. K40 of the total NEW of all the items at the collection or consolidation point.

6.2.7.5.4. Sandbags to Mitigate Fragmentation and Overpressure Effects.

6.2.7.5.4.1. The CEHNC "Use of Sandbags for Mitigation of Fragmentation and Blast Effects Due to Intentional Detonation of Munitions" was originally approved by the DDESB on 23 February 1999. This approval permits use of sandbagging procedures for the intentional detonation of munitions up to 155 mm (M107), at OE sites. Only one munition item can be detonated at a time. Detailed guidelines are provided for the selection and use of sandbag enclosures of various thicknesses to mitigate fragments and blast and for determining minimum withdrawal distances to be used during detonation operations. A methodology is also provided for determining sandbag enclosure thickness and withdrawal distance for a munition item that is smaller than a 155-mm (M107) projectile, but which had not been tested as part of the sandbag test program.

6.2.7.5.4.2. Since the original release of the CEHNC "Use of Sandbags for Mitigation of Fragmentation and Blast Effects Due to Intentional Detonation of Munitions," in 1998, additional testing has been conducted, the results of which are included in Amendment 2 of the CEHNC document. The 200 ft minimum separation distance has been removed and replaced with separation distances based on sandbag throw distances with an applied safety factor. The DDESB approval was accordingly revised in the 22 May 2014 DDESB-PD Memorandum. Use of any means of initiation when conducting an intentional detonation using sandbag mitigation other than the one described by the DDESB requires DDESB approval. Any item classified as "Extremely Heavy Cased" must be reviewed by a subject matter expert and entered into the Fragmentation Database before being permitted. The use of double-thickness sandbags for robust and non-robust munitions items with fragmentation characteristics and

NEWs not exceeding that of the 75-mm M48 is approved by the DDESB; a minimum withdrawal distance of 12.5 ft applies.

6.2.7.5.4.3. As documented in the 20 January 2015 DDESB-PD Memorandum, the DDESB approved the 18 July 2012 REK Associates Report "Use of Defencell System Units for the Mitigation of Fragmentation and Blast Effects Due to Intentional Detonations of Munitions," permitting the use of sand-filled Defencell System Units, as an alternative to sandbags, for the mitigation of fragmentation and blast effects associated with intentional detonation of munitions. Defencell System Units offer the advantage of rapid deployment and easy scaling while offering the same lack of secondary debris and level of protection demonstrated by sandbags.

6.2.7.5.5. Open Front Barricade (OFB). The OFB is designed to defeat the primary fragments of select ordnance, in the event of an accidental detonation that occurs while performing an intrusive operation at an OE removal site. The OFB is not intended for intentional detonations and is not designed for repeated use. The OFB is used by placing it over the unexploded ordnance (UXO) being worked on. The OFB is designed for use with ordnance items that generate an explosives weight-to-OFB internal volume ratio of 0.29 lbs/ft^3 or less. If the weight-to-volume ratio is met, then the "minimum separation distance (MSD) for unintentional detonation" associated with the OFB is 300 ft from the three covered sides, and default distances from DESR 6055.09 must be used from the front of the OFB. The OFB consists of an aluminum frame on which aluminum plates can be mounted to form the three sides and roof. The OFB frame is capable of supporting an aluminum plate thickness of up to 2.75 inches. Sandbags are then used, as necessary, to seal off any gaps under the OFB. The CEHNC "Open Front and Enclosed Barricade" was approved by the DDESB on 9 December 1999 and provides specific guidelines for the use of the OFB and for aluminum plate thickness selection for the ordnance items that might be encountered at the OE removal site. If the OFB is to be used for any ordnance item that has a weight-to-volume ratio that exceeds 0.29 lbs/ft^3, then the appropriate "MSD for unintentional detonation" for that particular munition needs to be determined using an approved analysis method or by testing, or default IBD distances of DESR 6055.09 will apply.

6.2.7.5.6. Enclosed Barricade (EB). The EB serves the same purpose as the OFB described above, except that it has a front barricade associated with it. The conditions/ restrictions for its use are the same as for the OFB and are contained in the CEHNC "Open Front and Enclosed Barricade," as well. The "MSD for unintentional detonation" associated with the EB is 300 ft, all around. The DDESB approved use of the EB on 9 December 1999.

6.2.7.5.7. Miniature Open Front Barricade (MOFB). The MOFB is a smaller version of the OFB described above. The CEHNC "Miniature Open Front Barricade" provides details on the restrictions/conditions pertaining to use of the MOFB. DDESB approval of the CEHNC "Miniature Open Front Barricade" was granted on 14 May 2010. The MOFB defeats primary fragments to its sides, rear, and top and is for use during an intrusive operation at an OE removal site, in the event of an unintentional detonation. Select UXO items for which it is designed are listed in the CEHNC "Miniature Open Front Barricade." It can be used for other items provided the NEW does not exceed 2.4 lbs, and an analysis determines that the thickness of aluminum needed to stop primary fragments does not exceed 1.5 inches. The DDESB approval letter explains what analysis has to be performed. The MSD to the sides and rear of the MOFB is the larger of K40 overpressure distance for the munition with the greatest fragment distance (MGFD), 3 ft if the TNT equivalent NEW of the MGFD is no more than 0.5 lbs, or 74 ft if the TNT equivalent NEW of the MGFD is greater than 0.5 lbs but no more than 2.4 lbs.

6.2.7.5.8. Guide for Selection and Siting of Barricades for Selected UXO. The CEHNC "Guide for Selection and Siting of Barricades for Selected Unexploded Ordnance" was developed to enhance safety to the public and personnel conducting OE removal operations. It provides guidance to field personnel to assist them in controlling the potential primary fragment hazard generated by a suspected buried explosive filled ordnance item being uncovered. These barricades are not designed to control overpressure. A number of barricade designs are presented in The CEHNC "Guide for Selection and Siting of Barricades for Selected Unexploded Ordnance," with guidance given on how to select the best barricade for the job being conducted.

6.2.7.5.9. Buried Explosion Module (BEM). An analytical method to calculate public and operational personnel withdrawal distances for buried munitions disposal has been developed. The method includes cratering calculations and calculations of the velocity of the fragment as it exits the soil and fragment trajectory calculations using an approved trajectory analysis code. The maximum ejecta radii of large soil chunks produced by the cratering are then calculated with an appropriate safety factor. In order to simplify and standardize these calculations, software has been developed. The theory and the software, which is called the BEM, are discussed in CEHNC "Buried Explosion Module (BEM): A Method for Determining the Effects of a Detonation of a Buried Munition." DDESB approval of the BEM methodology was given on 3 November 1998, and it has since been incorporated into DDESB TP 16. In addition, a software version (EXCEL spreadsheet template– now up to Version 7.2), addresses both burial in soil and burial in water, implements the methodologies, procedures and algorithms discussed in Chapter 6 of DDESB TP 16 and calculates the following:

6.2.7.5.9.1. Whether a crater, camouflet or no crater (underwater) is formed.

6.2.7.5.9.2. If formed, either true crater radius or true camouflet radius.

6.2.7.5.9.3. Maximum soil ejecta range.

6.2.7.5.9.4. Fragment exit velocity.

6.2.7.5.9.5. Fragment exit angle.

6.2.7.5.9.6. MFD.

6.2.7.5.9.7. Fragment hazard range.

6.2.7.5.9.8. Airblast at horizontal range entered.

6.2.7.5.9.9. Airblast at fragment hazard range.

6.2.7.5.10. Use of Water for Mitigation of Fragmentation and Blast Effects Due to Intentional Detonation of Munitions. In 1999, the Structural Branch of CEHNC sponsored a test program to evaluate the use of water for fragment and blast mitigation for intentional detonations at OE sites. The program was broken into two phases, with the first phase determining the minimum water depth needed to defeat fragments from four different munitions, and the second phase testing various water containment systems for the four munitions. The 27 February 2001 DDESB Memorandum approved the use of water for mitigation of fragmentation and blast effects due to intentional detonations. The techniques provided in the CEHNC "Use of Water for Mitigation of Fragmentation and Blast Effects Due to Intentional Detonation of Munitions" are approved for field use on OE removal action projects.

6.2.7.6. Buffered Storage.

6.2.7.6.1. From 1986 through 1987, USAF conducted a series of tests to prove out the concept of "buffered storage," which used specific palletized AE material as a buffer between specified quantities (stacks) of Mk 82 or Mk 84 bombs in order to prevent propagation between stacks and thereby reduce the MCE. The MCE was based on the NEW in the largest stack plus the NEW of the buffer material (when HD 1.4 material is used as buffer material, then the HD 1.4's NEW does not need to be included). The QD was determined using the combined NEW. Test results are recorded in the Ogden Air Logistics Center "MK 82 Buffered Storage Test Series: PART I (Technical Report) and PART II (Data Report)" and "MK 84 Buffered Storage Test Series: PART I (Technical Report) and PART II (Data Report)." The tests are documented in Lewis, Friesenhahn, and Nash (December 1988).

6.2.7.6.2. The USAF received DDESB approval for use of the "buffered storage concept" in ECMs and AGMs and at outdoor storage areas. A 30 April 1990 DDESB-KO Memorandum approved 12 buffered storage configurations that were documented on Drawings AFISC 900402A through AFISC 900402L. Initially, the buffer material approved for use consisted of only palletized 20-mm, 30-mm, and CBU 58. The 10 May 1990 DDESB-KT Memorandum authorized palletized CBU 71 to be used as a buffer material, and the 28 November 1990 DDESB-KT Memorandum authorized the use of palletized CBU 52 as buffers.

6.2.7.7. Composite (sand-filled foam panel) Walls for Sub-dividing Magazine MCEs.

6.2.7.7.1. At the 261st meeting (24 April 1972) of the DDESB, there was a discussion regarding the use of sandbag walls, constructed per DNA criteria, which permitted storage igloos to be subdivided by sandbag walls generally 6 ft high by 22 inches wide using a prescribed configuration. At this meeting, a representative of DNA presented a wall system developed by DNA and Dow Chemical Co. to provide equivalent protection as the sandbag wall and to use as a replacement to the sandbag wall. The system consisted of high-density extruded polystyrene (styrofoam) sections that were assembled into walls and were filled with sand as the wall was erected. The DDESB approved the use of the new wall system at this meeting.

6.2.7.7.2. The above concept of using polyurethane type walls is also part of the Blast Tamer Explosive Damping Blast-Wall System used in Air National Guard (ANG) magazine designs listed in Table AP1-4 and defined by drawings ANG-DWG-94-001, ANG-DWG-94-002, ANG-DWG-96-001, ANG-DWG-99-001, and ANG-DWG-00-001. The General Plastics Manufacturing Company, at the request of the Vermont ANG, developed this composite wall system (i.e., polyurethane wall panels filled with sand) to allow the ANG to reduce the

MCE of ECM to the NEW contained in a single cell, rather than all the ordnance contained in the ECM. The wall was approved by the DDESB for a maximum of 425 lbs NEW, with a reduced IBD arc of 700 ft to the front of the ECM and a reduced IBD arc of 250 ft to the side of the ECM. By reducing the MCE to 150 lbs NEW, the required IBD arcs could be reduced further to 500 ft to the front and 250 ft for the side and rear (not just to the side).

6.2.7.7.3. The ability of a composite polyurethane panel/sand wall system (as a non-propagation cell wall) to prevent prompt propagation was analyzed for the ANG by the NCEL, (now NAVFAC EXWC), in January 1993, using AUTODYN-2D analysis. The results of their analysis are documented in NCEL "AUTODYN-2D Analysis of Air National Guard Non-Propagation Wall (Single-Row Cell Configuration)." In addition, personnel from the Vermont ANG and General Plastics Manufacturing Company gave a presentation on the Blast Tamer design at the 28th DDESB Seminar, "Polyurethane Foam and Sand Barriers Extend Munitions Igloo Capacity."

6.2.7.8. QD for Ammunition in International Organization for Standardization (ISO) Containers. A significant study was undertaken in the late 1990s by the DDESB to (1) develop realistic estimates of the safety hazard ranges (e.g., IBD) for accidental explosions of ammunition in ISO shipping containers, and (2) investigate methods for reducing QD for ammunition containers at temporary storage sites. Co-sponsors of the study were the U.S. Transportation Command, the Explosives Storage and Transport Committee of the British Ministry of Defence, and USACE. The study consisted of 2 phases:

6.2.7.8.1. Phase 1 of the study was an analytical effort, in which QD were calculated using accepted analytical methods. The goals of Phase 1 were to:

6.2.7.8.1.1. Review the state-of-the-art for establishing QD for munitions in shipping containers.

6.2.7.8.1.2. Examine the composition of typical container loads of ammunition.

6.2.7.8.1.3. Develop preliminary, revised QD for ammo containers, based on existing data and the best available hazard prediction methods.

6.2.7.8.1.4. Identify the most critical needs for additional test data.

6.2.7.8.1.5. Design a program of experiments to provide the most needed test data and to verify the revised QD.

6.2.7.8.2. Phase 2 was a program of experiments conducted to provide test data on:

6.2.7.8.2.1. The effect of the steel ISO container walls on fragment impact velocities against acceptor munitions,

6.2.7.8.2.2. Safe separation distances between ISO containers to prevent propagation by blast pressures.

6.2.7.8.2.3. The performance of sand-filled barricades for preventing propagation at the proposed minimum separation distances between containers.

6.2.7.8.3. As part of the Phase 1 effort, an extensive survey of available literature was conducted to identify and review previous research related to the objectives of the program. This effort was conducted to extract any information that would be useful to the analysis and to avoid duplicating any work previously performed. This search resulted in 613 references being selected for inclusion in the listings, and data from over 2,500 explosion tests being tabulated in spreadsheets. The results of Phase 1 are documented in the U.S. Army Engineer Research and Development Center (ERDC) "Quantity-Distances for Ammunition in ISO Shipping Containers: Supplemental Report - Literature Survey."

6.2.7.8.4. The remainder of the study is documented in the ERDC "Quantity Distances for Ammunition in ISO Containers." The principal conclusions developed from the analyses and experiments were:

6.2.7.8.4.1. IBD and PTRD for ISO containers with HD 1.1 components are the same as in open storage.

6.2.7.8.4.2. Calculations indicated that IMD between containers with fragment-producing HD 1.1 components may be reduced slightly by the reduction of fragment impact velocities due to the shielding effect of acceptor container walls.

6.2.7.8.4.3. IMD for containers with non-fragmenting HD 1.1 components can be reduced by significant amounts - down to a scaled separation of 3.0 ft/lb$^{1/3}$(1.0 m/kg$^{1/3}$) - if there are no highly sensitive munitions (such as M2 demolition shaped charges) in the container loads.

6.2.7.8.4.4. IBD, PTRD, and IMD values for HD 1.2 munitions in containers (with no HD 1.1 components) are significantly less than indicated by the current standards, according to FRAGPROP calculations. Again, however, the container walls provide only a minor shielding effect, at best, for acceptor munitions.

6.2.7.8.4.5. The IMD for HD 1.3 material is limited to that necessary to prevent initiation by spread of a fire. Since the containers shield their contents against firebrands, the recommended minimum IMD is 8 ft for inspection and fire control access.

6.2.7.8.4.6. "Blast-Tamer" barricades can be easily and quickly constructed by 3 or 4 workers with minimal training. It should also be possible to disassemble this type of barricade and re-construct it elsewhere.

6.2.7.8.4.7. The slope-sided barricade design did not appear to provide any advantage in blast protection over a normal barricade with vertical sidewalls, except for better stability.

6.2.7.8.4.8. The use of sand-filled barricades allows ISO containers of HD 1.1 munitions to be spaced at IMD of 20 ft (6 m).

6.2.7.8.4.9. Barricades with a sand thickness of only 18 inches (0.5 m) are effective in preventing fragment damage between ISO containers of HD 1.1 munitions.

6.2.7.9. Water Barriers to Prevent Prompt Propagation.

6.2.7.9.1. USAF has requirements to park combat aircraft at airfields in order to meet operational readiness requirements. These parked combat aircraft must comply with minimum airfield requirements and must be separated from each other by IMD (unbarricaded IMD is K11). Properly constructed barricades to defeat the low-angle, high velocity fragments may be placed between the aircraft to prevent prompt propagation and reduce the required separation distance to barricaded IMD (K6). The primary material that is used for such barricades is sand, frequently contained in HESCO bastions. While such barricades are effective, the HESCO bastions can deteriorate in harsh environments and must be replaced. Water has been shown to be an effective fragment mitigating material and several manufacturers make prefabricated blocks which can be filled with water and used to build walls.

6.2.7.9.2. The CEHNC "Water Barriers to Prevent Prompt Propagation Test Report" documents a test of a 1.64 ft) (0.5 m) thick and a 3.28 ft (1.0 m) thick water barrier wall to determine if these walls will prevent prompt propagation. The water barriers were constructed of modular blocks that are a commercial off the shelf item manufactured by MRP Systems Ltd. UK. The results of this test, therefore, are applicable only to water barrier walls constructed of the commercial off the shelf modular blocks tested. The donor munitions were two MK 84 bombs, and the acceptors were one MK 84 bomb and one AGM-65 Maverick Warhead on the other side of each wall.

6.2.7.9.3. Although none of the acceptor munitions in the single wall scenario detonated or burned, the evidence of the fragment strikes on the acceptor munitions and witness panel make it inadvisable to use a single wall to prevent prompt propagation without further testing. There was no evidence of fragments from the donor bombs striking the acceptor munitions or witness panel on the double wall side, so it was therefore recommended that water barriers constructed using the MRP Systems Ltd. UK modular blocks in the 5 x 3 block configuration or larger be used in order to prevent prompt propagation between combat aircraft. Additionally, this test shows that the distance between combat aircraft separated by this 1.0 m thick water barrier need only be separated by K5 to prevent prompt propagation.

6.2.7.9.4. DDESB approval, and the conditions/limitations associated with the use of the modular blocks was given by the 27 September 2007 DDESB-PD Memorandum.

6.3. SUPPRESSIVE SHIELDS.

6.3.1. A suppressive shield is a vented steel enclosure, which is used to mitigate hazardous blast overpressure, fragmentation, and thermal hazards from an internal detonation. Conditions and limitations associated with each design must be satisfied to provide the level of protection described.

6.3.2. During the 1970s, an extensive manufacturing technology program was undertaken by the Army to design and proof-test several prototype structures and to develop a technology base for suppressive shield designs. As part of this effort ARBRL, National Aeronautics and Space Administration, Southwest Research, Inc., USACE Huntsville District, and AAI Corporation conducted extensive testing to develop design procedures and analytical techniques for use in suppressive shielding. The CEHNC "Suppressive Shields: Structural Design and Analysis Handbook" is a product of this effort. Because of the interest in suppressive shielding, the DDESB established a Suppressive Shielding Technical Steering Committee, which included Dr. Zaker of the Secretariat, to review test data and subsequent design documentation. This committee approved five basic suppressive shield designs for use in hazardous operations, and the CEHNC "Suppressive Shields: Structural Design and Analysis Handbook" presents design details for these designs (Groups 3, 4, 5, 6 (A and B), and 81mm (prototype and Milan)), along with engineering guidance on their selection and modification to meet operational requirements. The CEHNC "Suppressive Shields: Structural Design and Analysis Handbook" includes information on other groups (1, 2, and 7) that, at that time, either were not funded or had not yet received approval because they were still in preliminary design stages. Approval has since been given for a Group 1 suppressive shield that was installed within a production facility at Indian Head Division, NSWC. The CEHNC "Suppressive Shields: Structural Design and Analysis Handbook" also provides guidelines and techniques for the design and proof testing of new suppressive shields. The Edgewood Arsenal TP EM-TR-76088 is a report that contains descriptions of five groups of DDESB-approved suppressive shields and the engineering data and analysis supporting the safety approval recommendations. Copies of the approval documentation are provided in this report. The following describes each approved group:

6.3.2.1. Group 1. Rated for an NEW of 2,000 lbs. Contains all fragmentation and reduces blast overpressure at unbarricaded intraline distance by 50 percent.

6.3.2.2. Group 3. Rated for an NEW of 37 lbs. Contains all fragmentation and provides K24-equivalent protection at 6.2 ft from the shield.

6.3.2.3. Group 4. Rated for an NEW of 9 lbs. Contains all fragmentation and provides K24-equivalent protection at 19 ft from the shield.

6.3.2.4. Group 5. Rated for an NEW of 30 lbs propellant material or pyrotechnics or 1.84 lbs C-4 explosives. Contains all fragmentation and provides K24-equivalent protection at 3.7 ft from the shield.

6.3.2.5. Group 6A. Rated for an NEW of 0.962 lbs TNT equivalent. Contains all fragmentation and provides K24-equivalent protection at 1 ft from the shield.

6.3.2.6. Group 6B. Rated for an NEW of 0.5545 lbs TNT equivalent. Contains all fragmentation and provides K24-equivalent protection at 1 ft from the shield.

6.3.2.7. Prototype 81-mm Shield. Rated for an NEW of 6.72 lbs C-4 explosives. Contains all fragmentation and provides K24-equivalent protection at 3 ft from the shield.

6.3.2.8. Milan 81-mm Suppressive Shield. This is an adaptation of the Prototype 81-mm Shield and is rated for an NEW of 4.2 lbs C-4 explosives. Contains all fragmentation and provides K24-equivalent protection at 7.3 ft from the shield.

6.4. INTENTIONAL DETONATION CHAMBERS. Structures that contain all effects (blast and fragments) produced by the intentional detonation of AE have been designed for use in locations where open detonation may not be an acceptable or desired method of disposal. Such situations can exist as a result of the proximity of exposed persons or property or where transportation of AE to remote sites may be hazardous, impractical, or economically not feasible. The following containers have been approved by the DDESB:

6.4.1. On-site Demolition Container (ODC). USACE Huntsville District (now CEHNC) designed the ODC for the containment of fragments and overpressure produced by the detonation of UXO up to 81 mm in diameter. The maximum explosives weight is 6 lbs of TNT equivalent explosives. The ODC is a cylindrical steel container that is mounted on an integral support frame and working platform. Inside the container, an innovative system of different materials is used to capture fragments. The system includes a layer of sand surrounding the ordnance item to be destroyed, a set of steel cable blasting mats, and a segmented inner steel liner. Water bags, at a ratio of 5 lbs of water for each pound of TNT equivalent explosives, are used to reduce quasi-static pressures. Water bags, sand, and their containers need to be replaced after every shot. The mats are good for eight to ten shots, while the liner is good for 30 or more shots before they have to be replaced. The CEHNC "Safety Submission for On-Site Demolition Container for Unexploded Ordnance" provides information regarding the ODC and how to obtain safety approval for its use. The 15 September 1998 DDESB-KO Memorandum approved use of the ODC. During a detonation, the minimum withdrawal distance for related personnel is 75 ft. The minimum withdrawal for unrelated personnel and the public is the applicable IBD associated with the ordnance item being destroyed. This distance is specified because of hazards associated with operations leading up to an intentional detonation in the container.

6.4.2. Reduced QD Detonation Chambers/Vessels.

6.4.2.1. T-10 Transportable.

6.4.2.1.1. The CEHNC "Explosive Safety Submission for a Commercially Developed Portable Contained Detonation Chamber for Unexploded Ordnance; T-10 Transportable Donovan Blast Chamber" documents the patented T-10 transportable Donovan blast chamber (DBC), which is capable of containing all pressures and fragmentation resulting from the detonation of UXO up to 81 mm in diameter. DeMil International, based out of Huntsville, AL, designed the DBC (see "Explosive Safety Submission for a Commercially Developed Portable Contained Detonation Chamber for Unexploded Ordnance; T-10 Transportable Donovan Blast Chamber"). The maximum explosives charge (donor weight and NEW of the projectile) approved for the DBC is 10 lbs HMX (13 lbs TNT equivalency). A round with a diameter no greater than 81 mm can be destroyed within the DBC provided its fragment hazard has been determined and falls within specific parameters (i.e., mass, velocity) to ensure that it will not penetrate the chamber walls. The T-10 chamber was not approved for chemical, biological, white phosphorus (WP), or plasticized WP munitions. The following information is provided about the design of a T-10 DBC:

6.4.2.1.2. The DBC design consists of a box within a box. The void between these boxes is filled with silica sand to dampen and absorb detonation shock. The detonation chamber is lined with replaceable 12 inch by 12 inch by 0.5 inch thick armor plates that are used to stop fragments and to mitigate damage to the interior walls of the detonation chamber. Water bags are suspended inside the chamber to reduce temperatures. The design of the DBC permits the chamber to be used repeatedly. The noise level produced by the detonation of 10 lbs of HMX inside the DBC measures approximately 130 decibels at a distance of 30 ft from the DBC. Related personnel are considered to meet all protection criteria of DESR 6055.09 when located at a distance of 18 ft from the DBC during detonation operations. However, hearing protection is still required at this distance. The minimum withdrawal for unrelated personnel and the public is the applicable IBD associated with the ordnance item being destroyed. This distance is specified because of hazards associated with operations leading up to an intentional detonation in the container.

6.4.2.1.2.1. Following an internal detonation, blast pressures, along with detonation byproducts, are vented into a hardened expansion chamber and then through the Air Pollution Control Unit, where the air stream is cleaned before venting to the environment.

6.4.2.1.2.2. In March 2002, an amendment requested by the Defense Ammunition Center was approved (2 July 2002 DDESB-KT Memorandum). The amendment allows the use of the T-10 for detonation of fragmenting munitions with diameters up to and including 105 mm, provided a minimum of 0.75 inch thick armor plating is installed on the interior of the T-10 detonation chamber. The maximum NEW remains unchanged at 10 lbs HMX (13 lbs TNT equivalency).

6.4.2.1.2.3. A second amendment requested by the Defense Ammunition Center was also approved (10 October 2002 DDESB-KT Memorandum). This amendment permits use of the T-10 for destruction of WP-filled munitions with diameters of 81 mm or less. In order to ensure destruction of the WP, the ratio of donor charge (in TNT equivalent weight) to WP is required to be a minimum of 3 to 1, subject to the maximum TNT equivalent explosives limit of 13 lbs. Destruction of munitions containing plasticized WP is currently not permitted.

6.4.2.2. T-25, T-30 and T-60 Transportable Controlled Detonation Chamber (CDC).

6.4.2.2.1. Built along the same concept as described above for the T-10, the transportable CDC Models T-25, T-30, and T-60 were approved for contained intentional detonations with limitations/conditions and with the explosives limits shown in Table 6.1, as documented in a 3 July 2008 DDESB-PD Memorandum. General siting approval was granted for the disposal of conventional warfare material (not including plasticized WP filled munitions). Minimum donor explosive weight is 1 part donor explosive to 1 part energetic fill (1:1) for a munition with energetic fill only; 2:1 for propellant fills; and 3:1 for smoke, riot agent, or incendiary fills. Refer to the DDESB approval memorandum for additional conditions/limitations/restrictions.

Table 6.1. Transportable CDC Maximum Allowable NEW

CDC	T-25	T-30	T-60
NEW Limit (lbs – TNT equivalent)	16.7	40	40
Maximum Allowable Diameter (primary fragmentation hazard)	4.2-inch mortar or 4.5-inch rocket	155-mm projectile	155-mm projectile
See approval memorandum for complete guidance.			

6.4.2.2.2. The T-60 was also approved by the DDESB for use at Schofield Barracks, HI, for the destruction of chemical munitions. This was a site-specific approval, with a maximum TNT equivalent NEW for intentional detonation of 40 lbs, including both the donor and acceptor, as given in Table 6.1. The TC-60 that was used was provided with a large-scale filtration system that was capable of absorbing any toxic vapor that might be emitted from detonation operations. The first bank of the filtration system was required to be monitored for the toxic chemical agent of concern and was required to be changed out at the first confirmed breakthrough. Additional conditions/limitations can be found in the DDESB approval memo for the siting of the T60 and its associated process at Schofield Barracks.

6.4.2.3. Dynasafe Total Containment Vessel.

6.4.2.3.1. The Dynasafe Total Containment Vessels, Models DynaSEALR X10 and DynaSEALR X12, are approved by the DDESB for reduced QD for emergency response detonation and transportation, as documented in the 17 December 2014 DDESB-PD Memorandum. The technical assessment of these systems by the DDESB is documented in the DDESB “Assessment of DYNSAFE X10 and X12 Total Containment Vessels (TCVs).” The containment vessel of the DynaSafe model MECV-5L-B3 and DynaSEALR-X10 are assessed to be structurally identical. Dynasafe Total Containment Vessels, Model MECV-5L-B3, is also approved by the DDESB for reduced QD for emergency response detonation and transportation, as documented in the 30 June 2020 DDESB-PD Memorandum . These systems are intended for use by first responders to provide means of safely transporting and containing/limiting the effects from accidental or intentional detonation of improvised explosive devices (IEDs) and UXO.

6.4.2.3.2. The DynaSEALR X10 and MECV-5L-B3 are authorized for up to 11 lbs (5 kg) of TNT equivalent material and up to 11 consecutive internal detonations. The DynaSEALR X12 is authorized for up to 17.64 lbs (8 kg) of TNT equivalent material and up to 10 consecutive internal detonations.

6.4.2.3.3. Following each consecutive shot, an inspection must be performed in accordance with the 17 December 2014 DDESB-PD Memorandum.

6.4.2.3.4. For both systems, munitions up to 40 mm in diameter are permitted to be placed directly on the internal shelf. Munitions which produce hazards greater than a 40-mm item but not more than those of 105-mm fragmentation may be placed on the internal shelf when the Dynasafe sacrificial fragment defeating shield is installed. No munition larger than 105 mm or other device that produces fragmentation greater than a 105-mm item is permitted to be placed in either system. Neither system is approved for shaped charges.

6.4.2.3.5. During actual emergency response operations, appropriate safety distances from applicable EOD criteria/guidance apply. When in the sealed configuration, a 2-m safety distance is required for all unrelated personnel. If the unsealed configuration is required, a minimum distance of 6 m is required for all unrelated personnel. When the door is open or an explosive device is located outside of the container, on-site emergency response personnel should determine the applicable safe distance for all personnel.

6.4.2.3.6. The Dynasafe systems are also approved for training operations that involve intentional detonations. The K328-equivalent distance to all non-essential personnel is 25 ft in these scenarios.

6.4.2.4. NABCO Total Containment System

6.4.2.4.1. The NABCO, Incorporated, Total Containment System Models 64-SCS, 64-SCS-GT, 42-SCS, and 42-SCS-GT are approved for use by the DDESB, as documented in the 29 June 2010 DDESB-PD Memorandum. The systems are designed to be used by emergency response personnel needing to move explosives to a suitable disposal site. Because of this, there is no DDESB site plan required for their usage, but the operations will be conducted in accordance with appropriate EOD criteria/guidance.

6.4.2.4.2. The allowable capacity is 12.8 lbs TNT equivalent material for the NABCO 42-SCS and 42-SCS-GT and 19.20 lbs TNT equivalent material for the NABCO 64-SCS and 64-SCS-GT.

6.4.2.4.3. NABCO fragment-attenuating tubes must be used for all fragmenting items with outside diameters greater than 40 mm.

6.4.2.4.4. With the doors closed, the minimum exclusion distance for all non-related personnel is 5 ft. An appropriate distance must be determined by on-site emergency personnel if the doors remain open.

6.4.2.5. Mistral Security ARC Series Chamber.

6.4.2.5.1. The Mistral Security Inc., ARC 5 Gas Tight (GT), ARC 6 GT, ARC 9 GT, and ARC 10 GT blast containment chambers are approved by the DDESB for reduced QD for emergency response detonation and transportation, as documented in the 24 August 2011, 17 December 2014, and 21 January 2016 DDESB-PD Memoranda. These systems are intended for use by first responders to provide means of safely transporting and containing/limiting the effects from accidental or intentional detonation of IEDs and UXO. They are not intended for storage or routine destruction of ammunition.

6.4.2.5.2. The ARC 5 GT, ARC 6 GT, ARC 9 GT and ARC 10 GT are authorized for up to 12.92 lbs (5.86 kg), 13.23 lbs (6.00 kg), 19.8 lbs (9.00 kg) and 17.64 lbs (8.00 kg), respectively, of TNT equivalent material. The ARC 6 GT is approved for 10 consecutive internal detonations. The ARC 9 GT is approved for 5 consecutive internal detonations.

6.4.2.5.3. For all four systems, munitions up to 40 mm in diameter and other explosives devices that would produce fragmentation effects similar to 40 mm may be placed directly on the internal shelf. Those munitions that would produce fragmentation effects more hazardous than a 40-mm item, but not more hazardous than an 81-mm outside diameter Schedule 40 pipe bomb, must be placed inside the Mistral-designed fragment attenuating box and on the internal shelf. Munitions which produce more hazardous fragmentation or do not fit in the box are not permitted unless they have been assessed in accordance with DDESB TP 16 to ensure that fragments do not penetrate the chamber wall.

6.4.2.5.4. Applicable EOD criteria/guidance applies during actual emergency response, and appropriate safety distances will be determined in accordance with those criteria. For the ARC 6 GT, when it is in the preferable GT configuration, a minimum safety distance of 3 ft must be applied for all unrelated personnel. If the GT configuration is not possible, a minimum safety distance of 4 ft for all unrelated personnel must be applied. For the ARC 9 GT, when it is in the preferable GT configuration, a minimum safety distance of 5 ft must be applied for all unrelated personnel. If the GT configuration is not possible, a minimum safety distance of 10 ft for all unrelated personnel must be applied. For the ARC 5 GT and ARC 10 GT, a minimum distance of 6 ft must be applied for all unrelated personnel when the doors are sealed. For all four models, if the door is open or explosives are located outside the container, appropriate safe distances must be determined by on-site emergency response personnel in accordance with their work/criteria.

6.4.2.5.5. When being used for training involving intentional detonations, the operation must be conducted at a location with a DDESB–approved explosives site plan, and non-essential personnel must be afforded the K328-equivalent safe separation distance (51 ft for ARC 5 GT and 25 ft for ARC 6 GT, ARC 9 GT, and ARC 10 GT).

6.4.2.6. Explosive Destruction System (EDS).

6.4.2.6.1. The EDS is a trailer-mounted mobile system used to destroy explosively configured chemical munitions that are deemed unsafe to transport and to fully contain all effects. The system has been used to destroy chemical munitions with or without explosive components.

6.4.2.6.2. The EDS is an explosion containment vessel with 2 phases. EDS, Phase 1 was approved by the DDESB for up to 1.5 lbs TNT equivalent material, as documented in the 19 April 2005 DDESB-KO Memorandum. EDS Phase 2 design was approved for use by the DDESB for up to 9 lbs of TNT equivalent material (and items no greater than 10 inches in diameter), as documented in the 13 July 2012 DDESB-PD Memorandum. Any phase 1 or phase 2 unit is approved to handle any chemical agent (except VX) up to the maximum allowable NEW.

6.4.2.6.3. The EDS uses explosive linear shaped charges to access the agent cavity and to destroy any energetics in the munition. After detonation of the shaped charges, reagents appropriate to the agent to be neutralized are pumped into the vessel, and the vessel contents are mixed until the treatment goal has been attained. After the concentration of chemical agent falls below the treatment goal, as determined by sampling the contents of the chamber, the liquid waste solution is transferred out of the chamber into a waste drum. The drummed EDS liquid waste is normally treated further at a commercial hazardous waste treatment, storage, and disposal facility.

6.4.2.6.4. A 19 May 2006 DDESB Memorandum approved the disposal in the EDS Phase 2 of a complete, assembled German Traktor Rocket with a chemical projectile on the basis that the propellant would not contribute to the NEW reaction.

6.4.2.7. Detonation of Ammunition in a Vacuum Integrated Chamber (DAVINCH™ USA DV-60).

6.4.2.7.1. The DDESB approved the use of the DAVINCH™ USA DV-60, as documented in the 2 August 2011 DDESB-PE Memorandum. The chamber is approved for up to 23.4 lbs of H-series (H/HD/HT) chemical agent and a NEW limit of 132 lbs of TNT equivalent material. All changes to the system require DDESB approval.

6.4.2.7.2. The DV-60 detonation chamber consists of two close-fitting outer and inner chambers. The inner chamber is a replaceable vessel designed to protect the outer chamber from fragments. The detonation chamber is cylindrical in shape, with spherical end caps and possesses an interior volume of 1074 ft^3. A hydraulic clamping system acts to seal the chamber before evacuation and detonation.

6.4.2.7.3. The DV-60 includes an off-gas treatment system, consisting of a damper, exhaust gas heater, particulate filter with metallic filter media, vacuum pumps, "cold-plasma" grid-arc oxidizer, cooler, acid scrubber, exhaust blower, off-gas retention tank with a recirculation option through a dedicated carbon filter, and an additional carbon filter.

6.4.2.7.4. The DV-60 includes a control room, which serves as the operations center for the system's processing activities.

6.4.2.7.5. Requirements for chemical agent concentrations and associated corrective actions are documented in the 2 August 2011 DDESB-PE Memorandum.

6.5. NAVY MISSILE TEST CELLS (MTC).

6.5.1. In 1986, NCEL, (now NAVFAC EXWC), was funded by Naval Ship Weapon Systems Engineering Station to develop NAVFAC Standards for Navy MTCs. It was originally envisioned that there would be six types of MTC as described in Table 1.1 of NCEL Technical Note (TN) N-1752. These were as follows:

6.5.1.1. Type I and II (40 ft long by 25 ft wide by 15 ft high) with a 300 lb (136.1 kg) TNT rated capacity.

6.5.1.2. Type III (20 ft long by 15 ft wide by 15 ft high) with a 105 lb (47.6 kg) TNT rated capacity.

6.5.1.3. Type IV (30 ft long by 20 ft wide by 8 ft high) with a 1,231 lb (558.4 kg) TNT rated capacity.

6.5.1.4. Type V (10 ft long by 10 ft wide by 10 ft high) with a 40 lb (18.1 kg) TNT rated capacity.

6.5.1.5. Type VI (6 ft long by 6 ft wide by 8 ft high) with a 10 lb (4.5 kg) TNT rated capacity.

6.5.2. The MTC is a component of an intermediate level maintenance facility, which has the capability to assemble missiles from new or fleet-return sections, test missile all-up-rounds (AURs) or sections, and handle, store, or ship AURs or sections in support of fleet requirements. The missile is tested in the MTC to certify its performance and reliability before delivery to the fleet. The test simulates the actual flight and intercept capabilities of the missile. The test missile is an AUR, which includes the rocket motor, guidance and control sections, warhead, and arming device. The test is remotely controlled by personnel and equipment located outside the MTC in a test control room.

6.5.3. Certain operations, such as an AUR test described above, are considered high risk. The MTCs have been designed to protect assets and personnel from either inadvertent ignition of the rocket motor or inadvertent detonation of the warhead. Mitigation of these hazards is performed through protective construction. Each MTC type is designed to contain/limit the explosion effects associated with specific weapons/items.

6.5.4. Each MTC is a rectangular-shaped, reinforced concrete structure with a covered passageway leading to the main part of the missile processing building (MPB) (or missile maintenance facility (MMF)) and a barricaded area at the opposite end. The barricade is located outside the building and is designed to stop fragments and debris exiting the MTC. The end of the MTC facing the barricade is provided a frangible panel for the venting of explosion byproducts. A typical MPB may have several MTC nested side-by-side along one or two faces of the building. Two MTC are usually dedicated to each variant of the missile. This eliminates the need to change test equipment each time a different variant of the missile is tested. It also increases the production rate by allowing a test to be underway in one MTC while another missile is being set up for test in an adjacent MTC. Table 6.2 lists NAVFAC TM and Basis of Design Documents (BODD) for Navy MTC development.

Table 6.2: NAVFAC TM and BODDs for Navy MTC Development

Document No.	Document Name	Publication Date	Description
NCEL TN N-1752	Basis of Design for NAVFAC Type I Missile Test Cell	June 1986	BODD for NAVFAC Type I Test Cell with a scaled vent area $A/V^{2/3}$ = 0.34.
NCEL TM 51-86-17	Test Plan for Missile Test Cell Variable Vent Area Tests	July 1986	Description of the test program to determine the blast pressure outside MTCs as a function of vent area.
NCELTM 51-86-15	Missile Test Cell Design Load and Safe Siting Criteria	August 1986	Test data with the constant scaled vent area, $A/V^{2/3}$ = 0.34
NCEL TM 51-87-02	External Blast Load Criteria for MTC's with Small Vent Areas	June 1987	Additional test data with the various scaled vent areas, $A/V^{2/3}$ = 0.34, 0.21 and 0.13
NCEL TN N-1770	Basis of Design for NAVFAC Type II Missile Test Cell	June 1987	BODD for NAVFAC Type II Test Cell with $A/V^{2/3}$ = 0.34
NCEL TN N-1752R	Basis of Design for NAVFAC Type I Missile Test Cell	April 1990	Supersedes N-1752. BODD for NAVFAC Type I Missile Test Cell with $A/V^{2/3}$ = 0.13
NCEL TM-2116-SHR	Basis of Design – NAVFAC Type IH-1 Missile Test Cell	April 1995	BODD for NAVFAC Type IH-1 Test Cell with $A/V^{2/3}$ = 0.25
NCEL TM-2174-SHR	Basis of Design – NAVFAC Type IH-2 Missile Test Cell	May 1996	BODD for NAVFAC Type IH-2 Test Cell with $A/V^{2/3}$ = 0.25
NCEL TM-2350-SHR	Basis of Design – NAVFAC Type IS-2 Missile Test Cell	September 2001	Supersedes N-1752R. BODD for NAVFAC Type IS-2 Test Cell with $A/V^{2/3}$ = 0.25
NAVFAC EXWC TR-NAVFAC-EXWC-CI-1501	Proposed siting criteria and external design blast loads for Type I & II Missile Test Cells	October 2014	Revises TM-2174-SHR and TM-2350-SHR for the Type IH-2 and Type IS-2 MTCs

6.5.5. The following MTCs have been approved to date:

6.5.5.1. Type I. Designed to NCEL BOD N-1752 of June 1986 (NCEL TN N-1752). The BOD is used by the Architect and Engineering contractor to guide development of MTC construction drawings and specifications. The BOD specifies that construction drawings, specifications, and design calculations be submitted to NFESC, now NAVFAC EXWC, for their review to ensure compliance with the requirements of the BOD. The drawings, specifications, and calculations will be submitted for 35 and 100 percent design reviews. The maximum NEW for the Type I MTCs built in accordance with NCEL TN N-1752 is 300 lbs TNT or equivalent

NEW. Refer to NCEL TN N-1752 for the weapon types that can be accommodated in the Type I MTC. The BOD was originally approved by the DDESB on 7 Dec 1988, revised by NCEL TN N-1752R, and a number of MTC have since been constructed. This BOD has been superseded by NAVFAC EXWC TR-NAVFAC-EXWC-CI-1501 and is no longer approved for new construction.

6.5.5.2. Type II. Designed per BOD N-1770 for NAVFAC Type II Missile Test Cell developed by NCEL (NCEL TN N-1770). The maximum NEW is 310 lbs TNT or equivalent NEW. Refer to the NAVFAC EXWC TR-NAVFAC-EXWC-CI-1501 for the weapon types that the Type II MTC can accommodate. The BOD was originally approved by the DDESB on 7 December 1988. This BOD has been superseded by the NAVFAC EXWC TR-NAVFAC-EXWC-CI-1501 and is no longer approved for new construction.

6.5.5.3. Type IS-2 (Formerly Type I) and IH-2 (Formerly Type II). The NAVFAC Type IS-2 and IH-2 MTCs were designed to support maintenance of Standard and Harpoon Missile systems, respectively, and DDESB approved by the 4 March 2015 DDESB-PD Memorandum. With respect to the structural design, the IS-2 and IH-2 are identical and approved for a maximum NEW of 310 lbs TNT or equivalent NEW in accordance with the guidance on scaled siting distances for adjacent test cells, the associated missile maintenance facility, IBD, PTRD, and intraline distance (ILD) as provided in Table 6.2 of the NAVFAC EXWC TR-NAVFAC-EXWC-CI-1501. The separation distance from the exterior center of the MTC door to the MMF is 63 ft. This is a greater distance than the 53 ft noted in the NCEL TNs 1752 and 1752R. MTCs constructed under TNs 1752 and 1752R, and other earlier criteria, continue to be used by the Navy.

6.6. SUBSTANTIAL DIVIDING WALLS (SDW). SDWs are 12-inch thick reinforced concrete walls meeting several specific design requirements. SDWs have been used since the World War II era to subdivide explosive quantities, thereby reducing the MCE for explosives siting, and to protect personnel from explosives hazards. During World War II, Service explosives limits to prevent a prompt propagation between explosives separated by a SDW varied widely.

6.6.1. In 1944, the Department of the Army initiated a series of tests under the direction of the Board to evaluate the response of various dividing wall types to explosive detonations. Tests were conducted at the Naval Proving Ground in Arco, Idaho and evaluated SDW responses to external blast loads only. Donor and acceptor charges varied and included bulk explosives, bombs, and torpedoes in general use at the time. Based on these tests, the Board implemented a 5,000-lb explosives limit to prevent a prompt propagation through a SDW.

6.6.2. In 1959, the DDESB established a "Work Group to Determine the Effectiveness of Dividing Walls in the Prevention of Propagation of Explosives." Over the next decade, the DDESB sponsored several series of full and reduced scale tests of typical Service explosives operating and storage cells. In these tests, donor cells had three concrete dividing walls (rear and sides) and were open to the exterior (no front wall or roof). Cell dimensions varied. The NEW and location of donor and acceptor AE also varied. Acceptor AE were placed behind the three donor cell walls, either in adjacent cells or in the open. While the first three series of tests focused heavily on SDWs, later tests evaluated other reinforced concrete wall concepts, including sand infilled reinforced concrete sandwich panels. The extensive blast load, analysis and design data developed by this work group were subsequently incorporated in the blast design manual, Army TM 5-1300/NAVFAC P-397/AFR 88-22.

6.6.3. In 2000 and 2001, NAVFAC EXWC performed three full-scale tests of concrete dividing walls. Data from these tests were used to develop SD criteria for AE exposed to small-sized debris from a concrete dividing wall. Donor charge weights were 425-lbs (440-lbs TNT equivalent) in Tests 1 and 3 and 3,000-lbs in Test 2. Acceptor munitions included MK 82 bombs, CBU-87, M864 projectiles, and TOW and TOW II missiles. The DDESB “Prevention of Sympathetic Detonation with Concrete Dividing Walls” and the NFESC “Prevention of Sympathetic Detonation with Substantial and Large Dividing Walls: Test Report” document the results of these tests.

6.6.4. The 14 May 2001 DDESB-KT Memorandum provided initial guidance regarding design requirements and permissible uses of a SDW to prevent prompt propagation of detonation or burning reactions (involving AE) between adjacent bays and to satisfy personnel protection requirements from remotely controlled operations. This memorandum has been updated; the current version is the 25 June 2020 DDESB-KT Memorandum. The memorandum’s explosives limits to prevent prompt propagation of a detonation are based on acceptor AE in their storage configurations and only consider impact by smaller sized wall debris, such as the debris typically produced by a breached wall section. Recent research indicates that other failure modes may be possible. Parametric limits for these failure modes are being evaluated. Revised SDW guidance will be issued when this evaluation is completed.

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CHAPTER 7: BARRICADED MODULE STORAGE

7.1. HISTORY. The following information was extracted from the AFWL-TR-67-132.

7.1.1. In July 1966, the Commander in Chief, Pacific Air Forces informed the Chief of Staff, USAF, of problems encountered in stockpiling required munitions (bombs) at Southeast Asia (SEA) air bases in compliance with existing explosives QD criteria. The problem was caused by the shortage of land on which the bombs could be stored. Explosives safety criteria required that the separation distance (in feet) between aboveground barricaded storage facilities containing mass-detonating explosives be $6W^{1/3}$, and real estate was not available to accommodate these separation distances for the quantities of explosives in theater. The Explosive Safety Branch of the Directorate of Aerospace Safety, Headquarters (HQ) USAF, Norton Air Force Base, California, was therefore directed to investigate this critical explosives storage problem. A three-step plan was established. The first step taken was to establish an eight-member USAF special study group (AFSSG), augmented by personnel from the ASESB and ARBRL, to research and analyze data on both accidental and planned explosions of large quantities of high explosives and to determine if existing QD criteria could be reduced. The AFSSG expended considerable effort searching for data and evidence, which would identify those parameters pertinent to the propagation of sympathetic simultaneous detonations of adjacent barricaded bomb stacks. They found that very little planned experimentation, which was pertinent to the problem at hand, had been accomplished. They also determined that high-speed fragments impinging on adjacent stacks of bombs would be the most likely cause of sympathetic simultaneous detonations from one bomb stack to another and that barricades would be necessary to stop these fragments if any reductions in separation distances were to be possible.

7.1.2. The AFSSG made a number of recommendations, which are listed below, to the USAF Chief of Staff. The Vice-Chief of Staff, USAF, approved the recommendations on 27 September 1966, for immediate use in combat zones.

7.1.2.1. A modular concept of munitions storage should be used. A module was defined as a barricaded area containing a maximum of five cells separated from one another by an intermediate barricade.

7.1.2.2. The NEW within each cell could not exceed 100,000 lbs. The distance between the nearest edge of the stacks of bombs in adjacent cells would be a minimum of 50 ft. These distance and weight criteria were based on a K factor of 1.1.

7.1.2.3. The distance between the nearest edge of stacks of bombs in adjacent modules could not be less than 200 ft. This value was based on a K factor of 2.5 applied to the total NEW content of the module.

7.1.3. The AFSSG also recommended that a test program be conducted to develop minimum separation distances between single stacks of bombs in the 125,000- to 500,000-lb range, as it was foreseen that the storage of 100,000 lbs per cell would only temporarily alleviate the storage problem being experienced at the time. Conduct of this test program, Explosive Storage (Big

Papa) Test Series, was approved by the USAF Chief of Staff on 28 March 1967 and was directed to proceed as soon as ordnance was available.

7.2. EXPLOSIVES STORAGE (BIG PAPA) TEST SERIES.

7.2.1. Background. The proposed testing was basically required to determine minimum separation distances between single barricaded aboveground stacks of bombs in the 125,000- to 500,000-lb range and optimum barricade geometry and materials to be used in an explosives storage area. Secondly, testing was required to validate the 100,000-lb modular concept, which had been approved for use in combat zones, and also to investigate the possibility of using this concept universally. It was agreed to by representatives from USAF, ASESB, USACE, ARBRL, and NOTS that tests should represent standard barricaded field storage conditions for tritonal-loaded bombs (such as the 750-lb M117), with at least six "samples" of acceptors located at the same separation formula distance of the approved five-cell module (K1.1), or less, from donors containing 250,000 lbs of explosives. Additionally, one of the USAF representatives proposed a barricade comparison test be conducted and agreed to provide complete details for constructing a test array of six barricades around a donor of 100,000 lbs of explosives.

7.2.2. Test Objectives. The primary objectives of the Big Papa Test Series, conducted between 1 June and 15 October 1967, at Hill Air Force Test Range, UT, were as follows:

7.2.2.1. Determine the minimum distance needed between single stacks of barricaded mass-detonating explosives to prevent simultaneous detonation of adjacent stacks and to minimize non-simultaneous propagation.

7.2.2.2. Determine the validity of the criteria being used in the 100,000-lb NEW cell (five cells per module), approved for combat zone use by the Vice Chief of Staff, USAF, on 27 September 1966.

7.2.2.3. Determine if the detonation of a single general-purpose bomb, with current explosives fill, within a stack would project other bombs into the air above the barricade and subsequently detonate the bombs suspended in the air, resulting in the detonation of adjacent bomb stacks by fragment impingement.

7.2.2.4. A secondary test objective was to obtain a substantial amount of airblast and ground-shock data for use in future AFWL QD studies.

7.2.3. Test Phases. Testing was divided into four separate phases.

7.2.3.1. Phases I and II were designed to demonstrate the feasibility of reducing existing, barricaded IMD criteria to the maximum practical extent for barricaded bomb storage in single stacks in the range of 125,000 to 500,000 lbs NEW of high explosives. Phases I and II were also designed to validate the five-cell module concept, which had been approved for use in combat zones.

7.2.3.2. Phase III of this test series was designed to determine optimum barricade geometry and materials for use in munitions storage by comparing the fragment attenuating effectiveness of six different barricades. Four vertical-faced metal-bin barricades, a soil-cement barricade, and a standard earth barricade were tested. A secondary objective of this portion of the test was to obtain a multipurpose barricade, which could be used for aircraft protection, munitions storage, and protection of habitable buildings. At that period in time, metal-bin barricades were not being used in combat zones for the storage of large quantities of mass-detonating explosives.

7.2.3.3. Phase IV was an attempt to determine what would happen when only one bomb in an 80-bomb donor stack was detonated. Two acceptors were placed with centerlines 80 ft from the center of a donor. A standard earth barricade separated the donor from the acceptors.

7.2.4. Test Conclusions. Test conclusions were as follows:

7.2.4.1. A substantial reduction can be made in the then-current DoD barricaded aboveground IMD criteria for mass-detonating explosives in open storage (revetments without structures that would burn or create heavy falling weights or damaging secondary fragments).

7.2.4.2. Bombs located at K1.1 or less from the donor explosions will be covered with earth and unavailable for use until extensive uncovering operations are completed. Bombs at K = 2.5 separations will be readily accessible.

7.2.4.3. The minimum barricaded distance between single stacks of mass-detonating explosives stored in adjacent cells of a module could be based on a K factor of 1.1 with a high degree of confidence since six stacks, located at distances of K1.1 or less (four at 1.1 and one each at 0.9 and 0.8), were tested without causing any sympathetic simultaneous or delayed detonations. However, some possibility of non-simultaneous propagation exists under some circumstances. Dunnage flammability and some possibility of damaging fragments escaping over the barricade are a few of the factors influencing probabilities in this connection.

7.2.4.4. The modular concept, developed by the AFSSG and approved for use in combat zones, is sound for large-quantity munitions storage.

7.2.4.5. Since no sympathetic simultaneous or delayed detonations occurred within the test modules, the spacing between modules could be based on a K factor of 2.5 as related to the net weight of explosives in one cell rather than the entire module, as the AFSSG recommendation specified.

7.2.4.6. The AFSSG recommendation of 100,000 lbs per cell could be increased to 250,000 lbs NEW, provided that the spacing corresponding to a K factor of 1.1 was maintained.

7.2.4.7. Since no sympathetic simultaneous or delayed detonations occurred, the number of cells per module (five recommended by the AFSSG) was determined to be arbitrary.

7.2.4.8. The vertical acceleration delivered to a bomb stack resting on the natural ground surface was about twice the magnitude of one standing on a concrete storage pad.

7.2.4.9. The frontal air pressure was consistently higher than the ground surface pressure at any given distance out from the detonation.

7.2.4.10. The standard earth barricade does, in fact, affect the airblast in the immediate vicinity of the barricade, but the disturbance dissipates rapidly as the blast front moves out from the detonation. The pressure at a given point on the ground beyond the toe of the barricade was the same as to be expected where no barricades were employed.

7.2.4.11. Since very few fragments of significance were found out to the barricaded highway/railway distance, most damage to structures would probably result from airblast effects.

7.2.4.12. The USAF "2-degree" theory for proper barricade height was determined to be sound.

7.2.4.13. The standard earth barricade provides excellent fragmentation protection for adjacent bomb stacks stored within a module, as was the case in Phases I and II of the test series.

7.2.4.14. Cell-to-cell propagation purely by airblast probably will not occur.

7.2.4.15. Metal-bin barricades having many small parts should not be considered for the storage of large quantities of high explosives, because of the production of secondary fragments (barricade components). The secondary fragments, which had sufficient mass, would be hazardous in an explosives storage area.

7.2.4.16. The use of steel beams or pilings as anchoring devices for the metal-bin barricades will create hazards in an explosive storage area in the event of an explosion.

7.2.4.17. Foam concrete, used as a fragment-catching mechanism to obtain energy data, did not function as designed since no fragment penetrations were detected in any of the 10 acceptors. However, the crater that enveloped the front faces of the acceptors precluded analysis of that portion.

7.2.4.18. Based on acceleration data, the standard earth barricade remained in position longer and thus performed the fragment-catching function longer than any of the other five barricades tested.

7.2.4.19. The "high-order" detonation of a single bomb loaded with tritonal or an equivalent fill within a stack can be expected to cause the simultaneous detonation (practically instantaneous) of all bombs in the stack.

7.2.4.20. Stacks of bombs spaced at a K-factor distance of 1.1 will require considerable recovery effort if one of the stacks detonates, whereas stacks spaced at a K-factor distance of 2.5 would require very little recovery effort.

7.2.5. Post-Test Actions.

7.2.5.1. Following the test series, the USAF contacted the ASESB to inform them of the test results and to describe the proposed recommendations that would be made to the Air Staff. An opinion on these recommendations was requested from the ASESB. A 31 October 1967 ASESB letter documented the conversation. This letter stated that, based on the results of testing, recommendations appeared reasonable, however, an opinion could not be offered by the ASESB until the results of the testing and the recommendations were received in writing.

7.2.5.2. A 7 December 1967 ASESB letter, written following review of Interim Change 1 to Air Force Regulation 127-100, which would permit the application of barricaded modules, identifies concerns the ASESB had with the proposed USAF use of barricaded modules. In general, the concerns dealt with a perception that USAF planners were moving towards application of barricaded module criteria for situations other than operational theaters and for more types of munitions than just those tested in Big Papa and that unwarranted capability would be attributed to the Big Papa type storage revetments. The last concern had to do with the fact that a detonation in one of the barricaded cells would not protect the serviceability of other munitions in the same module. With respect to using barricaded modules for other than conventional bombs (or munitions of similar mass-detonating characteristics as bombs), plans to store other munitions that had not been tested could result in simultaneous propagation between cells as a result of having materials of a more sensitive nature. At this point, the ASESB had not yet received the test report and had never formally had the opportunity to review the barricaded module concept.

7.2.5.3. The USAF module concept was placed on the agenda (Item 3i.) for the 257th ASESB meeting that was held 10 March 1970. During this meeting, the Board reviewed the USAF module concept, siting criteria, and use and voted to incorporate this concept into DoD 4145.27M as a standard in connection with bombs and other cased Class 7 (now HD 1.1) munitions and to undertake a series of tests to determine the applicability of this concept to other type munitions. A summary of the 257th Meeting of the ASESB is provided by the 31 March 1970 ASESB Memorandum.

7.2.5.4. Barricaded module criteria never appear to have made it into DoD 4145.27M. However, these criteria were placed in DoD 5154.4S (the predecessor of DESR 6055.09), dated July 1974, which superseded DoD 4145.27M, dated March 1969.

7.2.5.5. CBU testing was completed in September 1972, and recommendations were made to the DDESB for the placement of CBUs in barricaded modules. A 31 October 1972 DDESB-PP letter concurred with USAF's recommendation that mass-detonating CBUs be stored using the same criteria as Class 7 bombs. Subsequent to this DDESB approval, DoD criteria for use of barricaded modules was revised in DoD 5154.4S, July 1974 version, which stated "The items, which may be stored in modules, are limited to high explosives bombs, similarly cased Class 7 ammunition, and CBUs in authorized, non-flammable shipping containers."

7.2.5.6. The DDESB approved USAF's request to change module storage criteria as follows:

> "The items which may be stored in modules are limited to high explosive bombs, similarly cased Class 1 Division 1 ammunition, CBUs in authorized non-flammable shipping containers, and 20/30-mm ammunition in metal shipping containers."

7.2.5.7. The decision for the inclusion of 20/30-mm ammunition in metal shipping containers was based on the similarity of response to CBU munitions. The non-propagating classification and the metal shipping containers assure that the 20/30-mm ammunition will not propagate from cell to cell in a module; therefore, module criteria are adequate to limit the effects of a mishap to a single cell.

CHAPTER 8: AIRFIELD ASSOCIATED PROTECTIVE CONSTRUCTION/MITIGATION

8.1. HAS DEVELOPMENT. This historical information was extracted from AFWL-TR-71-65; DNA 4377P-2; AFWL-TR-77-1; and a 18 February 1977 letter HQ, Air Force Inspection and Safety Center, to the DDESB. In the early 1960s, USAF began an intensive effort to develop a protective arch shelter for tactical aircraft. The impetus for this was the need to protect parked aircraft at SEA installations. Beginning in 1967 with the Concrete Sky test program, USAF began developing and testing various elements of the aircraft shelter in order to optimize the arch and protective cover configuration. A hardened version of the original SEA aircraft shelter was developed as a result of those tests – the tactical air base hardened aircraft shelter (TAB VEE) HAS. This HAS was also known as the 1st Generation TAB VEE. Later, when NATO specified requirements for hardened shelters for use within the European theater, the TAB VEE HAS design was modified and re-named the 1st Generation modified TAB VEE. This design was constructed at NATO installations throughout Europe. The results of the Dice Throw Series of high explosives tests (AFWL-TR-77-1) were used to substantiate the TAB VEE and the modified TAB VEE designs and to obtain test data to support further HAS structural design improvements. Subsequently, the introduction of newer and larger tactical aircraft, such as the F-111 with its wings fully extended, necessitated modification of the basic 48-ft arch shelter, and the 2nd Generation HAS was developed to accommodate this aircraft. A 3rd Generation HAS was later developed for A-10 or F-15 aircraft because the 2nd generation HAS was larger than required for those smaller aircraft. By 1977, USAF had 1st (TAB VEE and modified TAB VEE), 2nd, and 3rd Generation HAS in existence, and they are still in use today. These structures are steel-arch, sheet metal structures with a 2-ft sinusoidal wave covered by a minimum of 18 inches of concrete. Concrete cover on the arch itself ranges from 18 to 42 inches thick. The rear wall is constructed of 24-inch thick reinforced concrete with an internal 1/8th-inch thick steel facing. The sliding door is a steel form filled with concrete. There are three basic sizes: 48 ft width (1st Generation), 82 ft width (2nd Generation), and 71 ft width (3rd Generation).

8.2. HAS SITING AND TESTING.

8.2.1. A letter to the DDESB from HQ Air Force Inspection and Safety Center, dated 18 February 1977, proposed siting criteria for Group I (1st Generation), II (2nd Generation), and III (3rd Generation) HAS relative to ECM. The proposed criteria were based on the results of the Concrete Sky Phase IXB test of explosive propagation between HAS (AFWL-TR-71-65) and the 1/3-scale model HAS testing conducted during Dice Throw (AFWL-TR-77-1). In summary, the USAF proposal suggested that HAS be sited at IMD distance from ECM, based on their perception that HAS provided the same hardness (protection capability) as a standard ECM. An 18 March 1977 DDESB-KT Memorandum disagreed that the testing showed the HAS designs were completely equivalent to standard ECM. However, the DDESB did agree that the testing showed the HAS designs were capable of providing an increased level of protection. As a result, the DDESB approved HAS exposures to adjacent ECM as follows:

8.2.1.1. Unstrengthened Group I (1st Generation TAB VEE) HAS were permitted to be sited side-by-side to one another with no separation distance between them, provided each HAS was limited to one aircraft load containing not more than 4,800 lbs of mass detonating explosives.

8.2.1.2. The sides of unstrengthened Group I (1st Generation TAB VEE) HAS were permitted to be oriented toward the side or rear of an ECM at $2.75W^{1/3}$ or toward the front of the ECM at $6W^{1/3}$, provided the ratio of explosives weight to ECM internal volume did not exceed 6 lbs/ft^3.

8.2.1.3. The sides or ends of strengthened Group I (1st Generation modified TAB VEE) HAS, with strengthened end enclosures, were permitted to be oriented towards the sides or rear of an ECM at $6W^{1/3}$ or the front at5 $W^{1/3}$, provided the ratio of explosives weight to ECM internal volume did not exceed 6 lbs/ft^3.

8.2.1.4. Groups II (2nd Generation) and III (3rd Generation) HAS were permitted to be located side-by-side to one another and to Group I (TAB VEE or modified TAB VEE) HAS, with no minimum separation distance between them, provided each HAS was limited to one aircraft load containing not more than 4,800 lbs of mass detonating explosives. For any other application of QD standards, HAS of Groups II or III were to be treated as barricaded AGMs.

8.2.2. By 1979, USAF was finding it more and more difficult to site HAS in compliance with then-existing explosives safety criteria. Those problems were primarily related to real estate constraints and USAF’s operational need to place HAS closer to taxiways and runways. Though a number of HAS-related tests and analyses had been conducted between 1969 and 1977 (AFWL-TR-71-65 provides a chronology of these), for a number of reasons these tests and analyses only provided limited data capable of supporting further reductions of HAS QD criteria. As a consequence, siting criteria were primarily based on the Concrete Sky Phase IXB Test that was conducted in 1971. That test used a single detonation of 4,632 lbs NEW and a fueled aircraft in an open-ended SEA-type shelter constructed of un-reinforced concrete. By contrast, the HAS constructed in the 1970s were made of reinforced concrete and had reinforced bulkheads and front closure systems. It was felt that these structures were capable of offering more protection, as both explosion donors and acceptors, than criteria acknowledged. By closely working with the DDESB, USAF was able to obtain some relief from the then-current HAS siting criteria. However, in order to obtain further DDESB-approved QD reductions, additional testing was required. In 1979, USAF initiated the Aircraft Shelter Explosive Test (ASET) Program to develop better QD for HAS.

8.2.2.1. The overall goals of the ASET Program were to:

8.2.2.1.1. Assess the capability of HAS to protect internal assets (aircraft, munitions, and personnel) from external weapons effects (airblast and ground shock).

8.2.2.1.2. Assess the capability of HAS to prevent or suppress propagation.

8.2.2.1.3. Assess collateral damage effects to and vulnerability of nearby taxiways and runways.

8.2.2.2. The ASET Program was named DISTANT RUNNER and was separated into two phases. The first phase was to investigate the response of two full-scale 3rd Generation HAS to an external pressure loading, and the second phase was to investigate an internal pressure loading. A total of five tests were conducted and are described below. Preliminary test analyses, test results, and conclusions are recorded in DNA's 5385F and 5964F; POR's 7062 and 7198; NSWC's TR-85-116 and TR-86-114; and the DDESB "DISTANT RUNNER - Debris Recovery and Analysis Program for Events 4 and 5."

8.2.2.2.1. Event 1 exposed a HAS to an internal detonation of 42 lbs NEW (four Sidewinder air intercept missile (AIM-9) warheads). This weapon arrangement was selected to simulate a weapons load for an aircraft loaded with air-to-air weapons. The primary objective of this test was to demonstrate the ability of a 3rd Generation HAS to completely suppress all effects resulting from an internal detonation involving four AIM-9 missiles.

8.2.2.2.2. Event 2 exposed both HAS to an external loading of 15 psi produced by the detonation of 240,000 lbs of ammonium nitrate/fuel oil. One HAS was oriented side-on to the blast, while the second HAS was oriented rear-on to the blast. Obsolete aircraft were located inside the HAS. The primary objectives of this test were to demonstrate that a 3rd Generation HAS could withstand an external pressure loading of 15 psi in rear-on and side-on orientations to the detonation source and to demonstrate that a 3rd Generation HAS could prevent internal pressure buildup in these orientations.

8.2.2.2.3. Event 3 exposed one 3rd Generation HAS to an external loading of 15 psi and the other to an external loading of 7.8 psi produced by the detonation of 240,000 lbs of ammonium nitrate/fuel oil. The HAS exposed to 15 psi was oriented head-on to the detonation source, while the other HAS was oriented at an oblique angle (26 degrees off normal) to the detonation source. Obsolete aircraft were located inside the HAS. The primary objectives of this test were to demonstrate that a 3rd Generation HAS could withstand external pressure loading of 15 psi in a front-on orientation and 7.8 psi in an oblique orientation to the detonation source and to demonstrate that a 3rd Generation HAS could prevent internal pressure buildup in these orientations.

8.2.2.2.4. Event 4 exposed a HAS to an internal pressure loading from the detonation of 2,292 lbs NEW (12-MK 82 bombs) inside the HAS. The primary objectives of this test were to demonstrate the blast attenuation characteristics of a 3rd Generation HAS, exposed to an internal detonation involving 2,292 lbs NEW, to evaluate debris distances, and to determine the structure's failure mode.

8.2.2.2.5. Event 5 exposed a HAS to an internal pressure loading from the detonation of 9,168 lbs NEW (48 MK 82 bombs) inside the HAS. The primary objectives of this test were to demonstrate the blast attenuation characteristics of a 3rd Generation HAS exposed to an internal detonation involving 9,168 lbs NEW, to evaluate debris distances, and to determine the structure's failure mode.

8.2.2.2.6. A common secondary objective for Events 2 through 5 was to assess the damage (from ground motion effects and fragmentation) to the taxiway or runway as a result of each event.

8.2.2.3. DISTANT RUNNER results supported the reduction of QD for:

8.2.2.3.1. Side or rear of an ECM (275,000 lbs NEW TNT) to a 3rd Generation HAS from K30 to K5.

8.2.2.3.2. Open storage (100,000 lbs NEW TNT) to a 3rd Generation HAS from K30 to K8.

8.2.2.3.3. ECM (275,000 lbs NEW TNT) to a taxiway or runway from K18 to K4.

8.2.2.3.4. Open storage (100,000 lbs NEW TNT) to a taxiway or runway from K18 to K4.

8.2.2.4. DISTANT RUNNER results were unable to support a reduction of QD for HAS to occupied (inhabited) structures, but instead demonstrated a need for increased separation distances. Consequently, increased QD was required as follows:

8.2.2.4.1. $D = 50W^{1/3}$ from the front of a HAS.

8.2.2.4.2. $D = 62W^{1/3}$ from the sides of a HAS.

8.2.2.4.3. $D = 40W^{1/3}$ from the rear of a HAS.

8.2.3. At the 283rd Meeting of the DDESB, which met on 19 January 1982, USAF presented their rationale as to why the separation distances between HAS and ECM, approved previously by the DDESB for 3rd Generation HAS, should apply to all HAS, except the door of a 1st generation HAS. DDESB approval of the proposed USAF changes can be found in 1 February 1982 DDESB-IK Memorandum. These changes, as well as those previously approved by the DDESB for HAS siting, were published in DoD 6055.09-STD (now DESR 6055.09).

8.2.4. Additional 3rd Generation HAS siting criteria changes were proposed in 1995. Those changes resulted from U.S. involvement in the NATO AC/258 (Group of Experts on Safety Aspects of Transportation and Storage of Military Ammunition and Explosives) Small Quantities Workshop. USAF subsequently recommended DDESB adoption of these proposed revised third-generation HAS siting criteria, and they were discussed during the 310th Board Meeting; however, they were not put forward as a voting item. The DDESB Secretariat felt that additional analyses and test data were needed before the proposed changes could be presented to the Board as a voting item. Subsequently, based on data presented (DDESB's "Hazard Ranges for Small Net Explosives Quantities in Hardened Aircraft Shelters"; "Quantity-Distance Determination for Third Generation Hardened Aircraft Shelter"; and "Earth-Covered Ammunition Storage Magazines Quantity-Distance Model, DISPRE2") at the 26th DoD Explosives Safety Seminar, and based on DDESB Secretariat and DDESB Steering Group review of the proposed changes, the original proposal was revised and then presented to the 311th Board that met on 19 January 1995 for a vote. The Board unanimously approved the modified changes governing siting of 3rd Generation HAS, which permitted reduced QD for a third-generation HAS, for selected ranges of NEW present within the HAS.

8.2.5. On 3 December 1998, a revised version of Chapter 10 of DoD 6055.09-STD was approved by the Chair, DDESB, based on previous written endorsement of the revision by Board members. As part of this approval, a statement was to be added to Chapter 9 permitting the use of Chapter 10 HAS criteria to peacetime operations as well as to contingency and combat operations. HAS criteria were subsequently moved into Chapter 9 during the DoD 6055.09-STD Rewrite effort. Following the administrative reissue of DoD 6055.09-STD as DoDM 6055.09, and then the reissuance as DESR 6055.09, the HAS criteria are located in Enclosure 3 of Volume 4 of the DESR.

8.3. SIGNIFICANT ENHANCEMENT OF HAS CRITERIA SINCE 1995.

8.3.1. As a result of numerous issues that were coming up related to the application of HAS criteria, the DDESB, with the assistance of AFSEC, began a significant effort to resolve the issues and develop missing criteria. The major issues were that DoD 6055.09-STD did not:

8.3.1.1. Provide QD criteria for Korean TAB VEE, Korean TAB VEE Modified, or Korean Flow-Through HAS.

8.3.1.2. Provide QD criteria from storage area ECM/AGM to any type of HAS.

8.3.1.3. Provide QD criteria from 1st Generation, 2nd Generation, Korean TAB VEE, Korean TAB VEE Modified, or Korean Flow-Through HAS to unhardened ESs.

8.3.1.4. Address siting of HD 1.2, HD 1.3 or HD 1.4 in a HAS.

8.3.2. Korean-type HAS are unique HAS found only at USAF installations in South Korea. There are three different designs and these are the Korean TAB VEE, a hardened Korean TAB VEE (concrete rear wall with the rear vent opening protected by a steel bin barricade and a first generation front closure), and a Korean flow-thru (no front or rear wall). The arches of those Korean HAS are identical to either the first or third generation HAS arch, thus providing significant blast and fragmentation protection.

8.3.3. In order to correct this deficiency, DDESB and AFSEC representatives began working together, starting in 2003, to develop the lacking HAS criteria. Once completed, it was their intent for AFSEC to submit a proposed change to DoD criteria for review/approval at a future Board meeting. This was accomplished as discussed later in this section.

8.3.3.1. As an initial step in this process, DDESB collected historical information about HAS and consolidated it into a "History of the Air Force's Hardened Aircraft Shelter Program."

8.3.3.2. Using the above reference and all available test data and analysis of that data (e.g., Concrete Sky, Dice Throw, Distant Runner, ASET) as a basis for the proposed changes, DDESB and AFSEC developed specific, supporting rationale for each proposed change to address the deficiencies given above. The supporting rationale and proposed changes, which were closely coordinated with AFSEC, are detailed in the Action 4 Attachment to the 21 November 2007 DDESB-PD Memorandum. The six parts of the proposed changes were as follows:

8.3.3.2.1. Change 1 – Revise paragraph C9.6.1.5, now V4.E3.7 in DESR 6055.09, for HAS to address all types of HAS, and siting of HD 1.2, HD 1.3 and HD 1.4 in HAS.

8.3.3.2.2. Change 2 – Revise Table C9.T25, now V4.E3.T3 and V4.E3.T4, (HAS K-factors to prevent simultaneous detonation) to address the various Korean HAS.

8.3.3.2.3. Change 3 – Revise Table C9.T26, now V4.E3.T5 and V4.E3.T6, (HAS K-factors for asset preservation) to address the various Korean HAS, and storage area ECM/AGM.

8.3.3.2.4. Change 4 – Revise Table C9.T27, now V4.E3.T7, (QD from a Third Generation HAS to unhardened ES) to address Second Generation HAS and the sides of a Korean Flow-Through HAS.

8.3.3.2.5. Change 5 – Add Table C9.T27A, now V4.E3.T8, (QD from a First Generation HAS to an unhardened ES), to address First Generation HAS and the sides/rear of a Korean TAB VEE HAS.

8.3.3.2.6. Change 6 – Revise and add new HAS definitions.

8.3.3.3. The 9 January 2008 DDESB-PD Memorandum approved the above criteria with one proposed change, which involved updating Table C9.T24, now V4.E3.T1, to add a HAS column and HAS row.

8.3.3.4. Some minor adjustments to the criteria have since been accomplished.

8.4. REDUCED QD FOR F-15, F-16, AND F-22 AIRCRAFT CONFIGURATIONS INVOLVING AIM-7, AIM-9, AND AIM-120 MISSILES.

8.4.1. USAF conducted significant missile testing and missile-on-aircraft testing to determine associated MCE and QD for a number of F-15, F-16, and F-22 missile configurations. Based on this testing, the DDESB approved revised MCE and QD for those aircraft configurations listed in Table 8.1, as documented in the 5 May 2004 DDESB-KT Memorandum, the 4 June 2014 DDESB-PD Memorandum, and the 22 June 2012 DDESB-PD Memorandum. The rationale on which DDESB approval was based is provided as part of the 11 June 2003 HQ AFSC/SEW Memorandum, the 16 October 2013 HQ AFSC/SEW Memorandum, the 16 April 2014 HQ AFSC/SEW Memorandum, and the 22 May 2012 HQ AFSC/SEW Memorandum.

8.4.2. Table 8.2 provides the individual missile NEWQD used for determining required aircraft configuration MCE.

8.4.2.1. Test Results.

8.4.2.1.1. Table 8.3 shows the single missile HFD determined as part of the Air Force Test Program.

8.4.2.1.2. Tables 8.4, 8.5, and 8.6 show the MCE for each aircraft configuration from Table 8.1. In some cases for the F-15, the configurations are broken down into cases based on missile configurations and/or positions.

8.4.2.2. Initial QD Determinations for Aircraft in the Open.

8.4.2.2.1. Tables 8.7 through 8.17 show the initial QD determinations for aircraft in the open.

8.4.2.2.2. The variations presented in Tables 8.7 through 8.17 have been reduced for purposes of simplification. In many instances, only slight differences in NEWQDs and ILDs existed between some variations. USAF determined these differences were not significant, and elected to apply the worst-case NEWQD and ILD.

8.4.2.2.3. The IMDs presented in Tables 8.7 through 8.17 are superseded by the minimum aircraft separation requirement of 10 ft, per normal flight line criteria. Therefore, USAF has elected to use 10 ft as the default IMD between aircraft in all cases. However, units may request lesser distances (down to those in Tables 8.7 through 8.17) if circumstances require. USAF will approve these on a case-by-case basis.

8.4.2.3. Final QD Determinations for Aircraft in the Open.

8.4.2.3.1. Tables 8.18, 8.19, and 8.20 show the final QD determinations for aircraft in the open. The QD presented in these tables are only for the aircraft and missile configurations described in Tables 8.1 and 8.2.

8.4.2.3.2. The variations presented in Tables 8.7 through 8.17 have been reduced for purposes of simplification. In many instances, only slight differences in NEWQDs and ILDs existed between some variations. USAF determined these differences were not significant, and elected to apply the worst-case NEWQD and ILD.

8.4.2.3.3. The IMDs presented in Tables 8.7 through 8.17 are superseded by the minimum aircraft separation requirement of 10 ft, per normal flight line criteria. Therefore, USAF has elected to use 10 ft as the default IMD between aircraft in all cases. However, units may request lesser distances (down to those in Tables 8.7 through 8.17) if circumstances require. USAF will approve these on a case-by-case basis.

8.4.2.4. Considerations for Aircraft in Buildings. Table 8.21 applies to aircraft configurations of Tables 8.18, 8.19, and 8.20 when located in one of the structures types listed. For structures of heavier construction, conduct a structural analysis using approved methodologies in accordance with DESR 6055.09 to determine the appropriate debris IB distance to apply.

Table 8.1. Aircraft Configurations

F-16	
Configuration 1	4 AIM-120 missiles, 2 AIM-9 missiles
Configuration 2	2 AIM-120 missiles, 2 AIM-9 missiles, 2 AIM-7 missiles
Configuration 3	2 AIM-120 missiles, 4 AIM-9 missiles
Configuration 4	6 AIM-120 missiles
Configuration 5	5 AIM-120 missiles, 1 AIM-9 missiles
F-15	
Configuration 1	4 AIM-120 missiles, 2 AIM-9 missiles, 2 AIM-7 missiles
Configuration 2	4 AIM-9 missiles, 4 AIM 7 missiles
Configuration 3	6 AIM-120 missiles, 2 AIM-9 missiles
Configuration 4	4 AIM-120 missiles, 4 AIM-9 missiles
F-22	
Configuration 1[1]	4 AIM-120 missiles, 2 AIM-9 missiles
Configuration 2	6 AIM-120 missiles, 2 AIM-9 missiles
[1] The AIM-9s will always be on station 3/10 and the AIM-120s can be on (4/5 and 8/9) or (5/6 and 7/8)	

Table 8.2. Missile Configurations

Missile	Missile NEWQD	Basis for Missile NEWQD
AIM-120, WDU-33/B Warhead	16.9 lbs	Warhead NEWQD (15 lbs) plus some motor contribution.
AIM-120, WDU-41/B Warhead	19.0 lbs	Warhead NEWQD (16 lbs) plus some motor contribution.
AIM-9L, WDU-17 Warhead	7.9 lbs	Warhead NEWQD only.
AIM-9M and X, WDU-17 Warhead	9.1 lbs	Warhead NEWQD (7.9 lbs) plus some motor contribution
AIM-9P	10.5 lbs	Warhead NEWQD only.
AIM-7M, WAU-17 Warhead	36.0 lbs	Warhead NEWQD only.
AIM-7F, WAU-10 Warhead	26.1 lbs	Warhead NEWQD only.

Table 8.3. Test Results – Single Missile HFDs

Missile	Single Missile HFD
AIM-120, WDU-33/B Warhead	280 ft
AIM-120, WDU-41/B Warhead	335 ft
AIM-9L, M and X WDU-17 Warhead	400 ft
AIM-9P Warhead	400 ft
AIM-7M, WAU-17 Warhead	280 ft
AIM-7F, WAU-10 Warhead	199 ft

Table 8.4. Test Results – F-16 Aircraft Configuration MCEs

Configuration	MCE[1, 2]
Configuration 1 (4 AIM-120s, 2 AIM-9s)	One AIM-120 and One AIM-9
Configuration 2 (2 AIM-120s, 2 AIM-9s, 2 AIM-7s)	One AIM-9 and One AIM-7
Configuration 3 (2 AIM-120s, 4 AIM-9s)	One AIM-120 and Two AIM-9s
Configuration 4 (6 AIM-120s)	One AIM-120
Configuration 5 (5 AIM-120s, 1 AIM-9s)	One AIM-120 and One AIM-9

[1] For each missile type, the missile configuration present with the largest NEWQD would be used for calculation of the NEWQD of the configuration MCE. For example, in Configuration 4, if 3 AIM-120, WDU-33/Bs and 3 AIM-120, WDU-41/Bs were present, the NEWQD for the MCE would be 19 lbs (the NEWQD of one AIM-120, WDU-41/B).
[2] HFD is based on the largest HFD of any single missile present.

Table 8.5. Test Results – F-15 Aircraft Configuration MCEs

Configuration	MCE[1, 2]
Configuration 1 (4 AIM-120s, 2 AIM-9s, 2 AIM-7s)	
Case 1 – AIM-7s in Rear Fuselage Position	*Use whichever produces largest NEWQD:* One AIM-7 *or* One AIM-120 and One AIM-9
Case 2 – AIM-7s in Front Fuselage Position	One AIM-9 and One AIM-7
Configuration 2 (4 AIM-9s, 4 AIM-7s)	
Case 1 – AIM-7Ms in Front Fuselage Position, and any AIM-9Ps	Two AIM-9s and One AIM-7
Case 2 – AIM-7Fs in Front Fuselage Position	One AIM-7
Case 3 – Only AIM-7Ms, and only AIM-9Ls or 9Ms	One AIM-7
Configuration 3 (6 AIM-120s, 2 AIM-9s)	One AIM-120 and One AIM-9
Configuration 4 (4 AIM-120 missiles, 4 AIM-9 missiles)	One AIM-120 and Two AIM-9s

[1] For each missile type, the missile configuration present with the largest NEWQD would be used for calculation of the NEWQD of the configuration MCE. For example, in Configuration 2, Case 2, if 2 AIM-7Fs and 2 AIM-7Ms were present, the NEWQD for the MCE would be 36 lbs (the NEWQD of one AIM-7M).
[2] HFD is based on the largest HFD of any single missile present.

Table 8.6. Test Results – F-22 Aircraft Configuration MCEs

Configuration	MCE[1, 2]
Configuration 1 (4 AIM-120s, 2 AIM-9s)[3]	*Use whichever produces largest NEWQD:* One AIM-120 or One AIM-9
Configuration 2 (6 AIM-120s, 2 AIM-9s)[4]	*Use whichever produces largest NEWQD:* One AIM-120 or One AIM-9

[1] For each missile configuration, its MCE will be equivalent to the largest missile NEWQD present.
[2] HFD is based on the largest HFD of any single missile present.
[3] The AIM-9s will always be on station 3/10 and the AIM-120s can be on (4/5 and 8/9) or (5/6 and 7/8).
[4] The AIM-9s will always be on station 3/10 and the AIM 120 all stations (4/5/6 and 7/8/9).

Table 8.7. Initial QD Determinations for F-16, Configuration 1, in the Open

Configuration 1 (4 AIM-120s, 2 AIM-9s)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD[5]
a. Only AIM-120, WDU-33/Bs Only AIM-9Ls, 9Ms, or 9Xs	One AIM-120, WDU-33/B and One AIM-9L/M/X	24.8 lbs	400 ft (AIM-9L/M/X)	240 ft	53 ft	100 in
b. Any AIM-120, WDU-41/Bs Only AIM-9Ls, 9Ms, or 9Xs	One AIM-120, WDU-41/B and One AIM-9L/M/X	26.9 lbs	400 ft (AIM-9L/M/X)	240 ft	54 ft	100 in
c. Only AIM-120, WDU-33/Bs Any AIM-9Ps	One AIM-120, WDU-33/B and One AIM-9P	27.4 lbs	400 ft (AIM-9P)	240 ft	55 ft	100 in
d. Any AIM-120, WDU-41/Bs Any AIM-9Ps	One AIM-120, WDU-41/B and One AIM-9P	29.5 lbs	400 ft (AIM-9P)	240 ft	56 ft	100 in

[1] MCE is based on rule from Table 8.4.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE.
[5] Assumes AIM-120s are on the wing tips. IMD is 36 inches if AIM-9s are on the wing tips (to maintain 100 inches between AIM-120s).

Table 8.8. Initial QD Determinations for F-16, Configuration 2, in the Open

Configuration 2 (2 AIM-120s, 2 AIM-9s, 2 AIM-7s)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD[5]
a.1 Only AIM-9Ls, 9Ms, or 9Xs Only AIM-7Fs	One AIM-9L/M/X and One AIM-7F	34.0 lbs	400 ft (AIM-9L/M/X)	240 ft	59 ft	100 in
a.2 Any AIM-9Ps Only AIM-7Fs	One AIM-9P and One AIM-7F	36.6 lbs	400 ft (AIM-9P)	240 ft	60 ft	100 in
b.1 Only AIM-9Ls, 9Ms, or 9Xs Any AIM-7Ms	One AIM-9L/M/X and One AIM-7M	43.9 lbs	400 ft (AIM-9L/M/X)	240 ft	64 ft	100 in
b.2 Any AIM-9Ps Any AIM-7Ms	One AIM-9P and One AIM-7M	46.5 lbs	400 ft (AIM-9P)	240 ft	65 ft	100 in

[1] MCE is based on rule from Table 4.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE.
[5] Assumes AIM-120s are on the wing tips. IMD is 36 inches if AIM-9s are on the wing tips (to maintain 100 inches between AIM-120s).

Table 8.9. Initial QD Determinations for F-16, Configuration 3, in the Open

Configuration 3 (2 AIM-120s, 4 AIM-9s)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD[5]
a. Only AIM-120, WDU-33/Bs Only AIM- AIM-9Ls, 9Ms, or 9Xs	One AIM-120, WDU-33/B and Two AIM-9L/M/Xs	32.7 lbs	400 ft (AIM-9L/M/X)	240 ft	58 ft	100 in
b. Any AIM-120, WDU-41/Bs Only AIM- AIM-9Ls, 9Ms, or 9Xs	One AIM-120, WDU-41/B and Two AIM-9L/M/Xs	34.8 lbs	400 ft (AIM-9L/M/X)	240 ft	59 ft	100 in
c. Only AIM-120, WDU-33/Bs Any AIM-9Ps	One AIM-120, WDU-33/B and Two AIM-9Ps	37.9 lbs	400 ft (AIM-9P)	240 ft	61 ft	100 in
d. Any AIM-120, WDU-41/Bs Any AIM-9Ps	One AIM-120, WDU-41/B and Two AIM-9Ps	40.0 lbs	400 ft (AIM-9P)	240 ft	62 ft	100 in

[1] MCE is based on rule from Table 4.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE.
[5] Assumes AIM-120s are on the wing tips. IMD is 36 inches if AIM-9s are on the wing tips (to maintain 100 inches between AIM-120s).

Table 8.10. Initial QD Determinations for F-16, Configuration 4, in the Open

Configuration 4 (6 AIM-120s)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD
a. Only AIM-120, WDU-33/Bs	One AIM-120, WDU-33/B	16.9 lbs	280 ft (AIM-120, WDU-33/B)	168 ft	47 ft	100 in
b. Any AIM-120, WDU-41/Bs	One AIM-120, WDU-41/B	19.0 lbs	335 ft (AIM-120, WDU-41/B)	201 ft	48 ft	100 in

[1] MCE is based on rule from Table 8.4.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE.

Table 8.11. Initial QD Determinations for F-16, Configuration 5, in the Open

Configuration 5 (5 AIM-120s, 1 AIM-9)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD
a. Any AIM-120, WDU-41/Bs Any AIM-9Ps	One AIM-120, WDU-41/B and One AIM-9P	29.5 lbs	400 ft (AIM-9P)	240 ft	56 ft	120 in

[1] MCE is based on rule from Table 8.4.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE.

Table 8.12. Initial QD Determinations for F-15, Configuration 1, in the Open

Configuration 1 (4 AIM-120s, 2 AIM-9s, 2 AIM-7s)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD[5]
Case 1 – AIM-7s in Rear Fuselage Position						
a.1 Only AIM-7Fs Only AIM- AIM-9Ls, 9Ms, or 9Xs Only AIM-120, WDU-33/Bs	One AIM-7F	26.1 lbs	400 ft (AIM-9L/M/X)	240 ft	54 ft	100 in
a.2 Only AIM-7Fs Only AIM- AIM-9Ls, 9Ms, or 9Xs Any AIM-120, WDU-41/Bs	One AIM-120, WDU-41/B and One AIM-9L/M/X	26.9 lbs	400 ft (AIM-9L/M/X)	240 ft	54 ft	100 in
a.3 Only AIM-7Fs Any AIM-9Ps Only AIM-120, WDU-33/Bs	One AIM-120, WDU-33/B and One AIM-9P	27.4 lbs	400 ft (AIM-9P)	240 ft	55 ft	100 in
a.4 Only AIM-7Fs Any AIM-9Ps Any AIM-120, WDU-41/Bs	One AIM-120, WDU-41/B and One AIM-9P	29.5 lbs	400 ft (AIM-9P)	240 ft	56 ft	100 in
b. Only AIM-7Ms	One AIM-7M	36.0 lbs	400 ft (AIM-9L/M/X/P)	240 ft	60 ft	100 in
Case 2 – AIM-7s in Front Fuselage Position						
a.1 Only AIM-7Fs Only AIM- AIM-9Ls, 9Ms, or 9Xs	One AIM-7F and One AIM-9L/M/X	34.0 lbs	400 ft (AIM-9L/M/X)	240 ft	59 ft	100 in
a.2 Only AIM-7Fs Any AIM-9Ps	One AIM-7F and One AIM-9P	36.6 lbs	400 ft (AIM-9P)	240 ft	60 ft	100 in
b.1 Any AIM-7Ms Only AIM- AIM-9Ls, 9Ms, or 9Xs	One AIM-7M and One AIM-9L/M/X	43.9 lbs	400 ft (AIM-9L/M/X)	240 ft	64 ft	100 in
b.2 Any AIM-7Ms Any AIM-9Ps	One AIM-7M and One AIM-9P	46.5 lbs	400 ft (AIM-9P)	240 ft	65 ft	100 in

[1] MCE is based on rule from Table 8.5.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE.
[5] Assumes AIM-120s are on the wing tips. IMD is 36 inches if AIM-9s are on the wing tips (to maintain 100 inches between AIM-120s).

Table 8.13. Initial QD Determinations for F-15, Configuration 2, in the Open

Configuration 2 (4 AIM-9s, 4 AIM-7s)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD[5]
Case 1 AIM-7Ms in Front Fuselage Position Any AIM-9Ps						
a. AIM-7Fs in Rear	One AIM-7M and Two AIM-9Ps	57.0 lbs	400 ft (AIM-9P)	240 ft	70 ft	22 in
b. AIM-7Ms in Rear	One AIM-7M and Two AIM-9Ps	57.0 lbs	400 ft (AIM-9P)	240 ft	70 ft	22 in
Case 2 AIM-7Fs in Front Fuselage Position Any AIM-9Ps						
a. AIM-7Fs in Rear	One AIM-7F	26.1 lbs	400 ft (AIM-9P)	240 ft	54 ft	22 in
b. AIM-7Ms in Rear	One AIM-7M	36.0 lbs	400 ft (AIM-9P)	240 ft	60 ft	22 in
Case 3 Only AIM-7Ms Only AIM-9Ls, 9Ms, or 9Xs	One AIM-7M	36.0 lbs	400 ft (AIM-9L/M/X)	240 ft	60 ft	22 in

[1] MCE is based on rule from Table 8.5.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE.
[5] For all cases presented for this configuration, the AIM-9s are on the outer stations and the AIM-7s are on the fuselage. Although the IMD between the AIM-9s is 22 inches, the aircraft structure precludes the AIM-9s from being this close.

Table 8.14. Initial QD Determinations for F-15, Configuration 3, in the Open

Configuration 3 (6 AIM-120s, 2 AIM-9s)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD[5]
a. Only AIM-120, WDU-33/Bs Only AIM-9Ls, 9Ms or 9Xs	One AIM-120, WDU-33/B and One AIM-9L/M/X	24.8 lbs	400 ft (AIM-9L/M/X)	240 ft	53 ft	100 in
b. Any AIM-120, WDU-41/Bs Only AIM-9Ls, 9Ms or 9Xs	One AIM-120, WDU-41/B and One AIM-9L/M/X	26.9 lbs	400 ft (AIM-9L/M/X)	240 ft	54 ft	100 in
c. Only AIM-120, WDU-33/Bs Any AIM-9Ps	One AIM-120, WDU-33/B and One AIM-9P	27.4 lbs	400 ft (AIM-9P)	240 ft	55 ft	100 in
d. Any AIM-120, WDU-41/Bs Any AIM-9Ps	One AIM-120, WDU-41/B and One AIM-9P	29.5 lbs	400 ft (AIM-9P)	240 ft	56 ft	100 in

[1] MCE is based on rule from Table 8.5.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE.
[5] Assumes AIM-120s are on the wing tips. IMD is 36 inches if AIM-9s are on the wing tips (to maintain 100 inches between AIM-120s).

Table 8.15. Initial QD Determinations for F-15, Configuration 4, in the Open

Configuration 4 (4 AIM-120s, 4 AIM-9s)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD
a. Any AIM-120, WDU-41/Bs Any AIM-9Xs	One AIM-120, WDU-41/B and Two AIM-9Xs	34.8 lbs	400 ft (AIM-9X)	240 ft	59 ft	120 in

[1] MCE is based on rule from Table 8.4.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE.
[5] Reference 8-18 used an NEWQD for the AIM-9X that was later increased as a result of testing that showed some motor contribution. This MCE of 34.8 lbs is what was approved by 4 June 2014 DDESB-PD Memorandum. The increased NEWQD would actually be 37.2 lbs; however, this would only result in a 1-ft increase of the ILD and thus was determined not to require an update to 4 June 2014 DDESB-PD Memorandum.

Table 8.16. Initial QD Determinations for F-22, Configuration 1, in the Open

Configuration 1 (4 AIM-120s, 2 AIM 9s)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD
a. Only AIM-120, WDU- 33/Bs Only AIM-9Ls or 9Ms	One AIM-120 or One AIM - 9L/M	16.9 lbs	400 ft (AIM-9L/M)	240 ft	46.2 ft	100 in
b. Only AIM-120, WDU-41/Bs Only AIM-9Ls or 9Ms	One AIM-120 or One AIM - 9L/M	19.0 lbs	400 ft (AIM-9L/M)	240 ft	48.0 ft	100 in
c. Only AIM-120, WDU- 33/Bs Only AIM-9P/Xs	One AIM-120 or One AIM - 9P/X	16.9 lbs	400 ft (AIM-9P/X)	240 ft	46.2 ft	100 in
d. Only AIM-120, WDU-41/Bs Only AIM-9P/Xs	One AIM-120 or One AIM - 9P/X	19.0 lbs	400 ft (AIM-9P/X)	240 ft	48.0 ft	100 in

[1] MCE is based on Table 8.4 rules.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE determination.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE determination.

Table 8.17. Initial QD Determinations for F-22, Configuration 2, in the Open

Configuration 2 (6 AIM-120s, 2 AIM 9s)	MCE[1]	NEWQD for MCE	HFD/IBD[2]	PTRD[3]	ILD[4]	IMD
a. Only AIM-120, WDU- 33/Bs Only AIM-9Ls or 9Ms	One AIM-120 or One AIM - 9L/M	16.9 lbs	400 ft (AIM-9L/M)	240 ft	46.2 ft	100 in
b. Only AIM-120, WDU-41/Bs Only AIM-9Ls or 9Ms	One AIM-120 or One AIM - 9L/M	19.0 lbs	400 ft (AIM-9L/M)	240 ft	48.0 ft	100 in
c. Only AIM-120, WDU- 33/Bs Only AIM-9P/Xs	One AIM-120 or One AIM - 9P/X	16.9 lbs	400 ft (AIM-9P/X)	240 ft	46.2 ft	100 in
d. Only AIM-120, WDU-41/Bs Only AIM-9P/Xs	One AIM-120 or One AIM - 9P/X	19.0 lbs	400 ft (AIM-9P/X)	240 ft	48.0 ft	100 in

[1] MCE is based on Table 8.4 rules.
[2] HFD is based on the largest HFD of any single missile present. The HFD is also the IBD, because in all cases it exceeds K40 using the NEWQD for MCE determination.
[3] PTRD is 60 percent of IBD.
[4] ILD is K18, using the NEWQD for MCE determination.

Table 8.18. QD for F-16 Aircraft in the Open

See Notes 1 and 2	NEWQD for MCE	HFD/IBD	PTRD	ILD	IMD[3]
Configuration 1 4 AIM-120s, 2 AIM-9s	29.5 lbs	400 ft	240 ft	56 ft	10 ft
Configuration 2a 2 AIM-120s, 2 AIM-9s, 2 AIM-7Fs	36.6 lbs	400 ft	240 ft	60 ft	10 ft
Configuration 2b 2 AIM-120s, 2 AIM-9s, 2 AIM-7Ms	46.5 lbs	400 ft	240 ft	65 ft	10 ft
Configuration 3 2 AIM-120s, 4 AIM-9s	40.0 lbs	400 ft	240 ft	62 ft	10 ft
Configuration 4a 6 AIM-120, WDU-33/Bs	16.9 lbs	280 ft	168 ft	47 ft	10 ft
Configuration 4b 6 AIM-120s, with one or more being an AIM-120, WDU-41/B	19.0 lbs	335 ft	201 ft	48 ft	10 ft
Configuration 5 5 AIM-120s, 1 AIM-9	29.5 lbs	400 ft	240 ft	56 ft	10 ft

[1] Configuration numbers do not correspond to configuration numbers in AFMAN 91-201.
[2] Unless otherwise specified,
- AIM-120s must be AIM-120, WDU-33/Bs and/or AIM-120, WDU-41/Bs
- AIM-9s must be AIM-9L, WDU-17s, and/or AIM-9M, WDU-17s, and/or AIM-9X, WDU-17s, and/or AIM-9P
- AIM-7s must be AIM-7M, WAU-17s and/or AIM-7F, WAU-10s

[3] This IMD is based on the minimum aircraft separation requirement of 10 ft. If circumstances require locating aircraft at less than this distance, then lesser IMDs may be approved by USAF.

Table 8.19. QD for F-15 Aircraft in the Open

See Notes 1 and 2	NEWQD for MCE	HFD/IBD	PTRD	ILD	IMD[3]
Configuration 1, Case 1a 4 AIM-120s, 2 AIM-9s, 2 AIM-7Fs in Rear Fuselage Position	29.5 lbs	400 ft	240 ft	56 ft	10 ft
Configuration 1, Case 1b 4 AIM-120s, 2 AIM-9s, 2 AIM-7Ms in Rear Fuselage Position	36.0 lbs	400 ft	240 ft	60 ft	10 ft
Configuration 1, Case 2a 4 AIM-120s, 2 AIM-9s, 2 AIM-7Fs in Front Fuselage Position	36.6 lbs	400 ft	240 ft	60 ft	10 ft
Configuration 1, Case 2b 4 AIM-120s, 2 AIM-9s, 2 AIM-7Ms in Front Fuselage Position	46.5 lbs	400 ft	240 ft	65 ft	10 ft
Configuration 2, Case 1 2 AIM-7Ms in Front Fuselage Position, 2 AIM-7Fs or Ms in Rear Fuselage Position, 4 AIM-9s	57.0 lbs	400 ft	240 ft	70 ft	10 ft
Configuration 2, Case 2a 4 AIM-7Fs, 4 AIM-9s	26.1 lbs	400 ft	240 ft	54 ft	10 ft

Table 8.19. QD for F-15 Aircraft in the Open (Continued)

See Notes 1 and 2	NEWQD for MCE	HFD/IBD	PTRD	ILD	IMD[3]
Configuration 2, Case 2b 2 AIM-7Fs in Front Fuselage Position, 2 AIM-7Ms in Rear Fuselage Position, 4 AIM-9s	36.0 lbs	400 ft	240 ft	60 ft	10 ft
Configuration 2, Case 3 4 AIM-7Ms, 4 AIM-9Ls or 9Ms	36.0 lbs	400 ft	240 ft	60 ft	10 ft
Configuration 3 6 AIM-120s, 2 AIM-9s	29.5 lbs	400 ft	240 ft	56 ft	10 ft
Configuration 4 4 AIM-120s, 4 AIM-9s	34.8 lbs	400 ft	240 ft	59 ft	10 ft

[1] Configuration numbers do not correspond to configuration numbers in AFMAN 91-201.
[2] Unless otherwise specified,
- AIM-120s must be AIM-120, WDU-33/Bs and/or AIM-120, WDU-41/Bs
- AIM-9s must be AIM-9L, WDU-17s, and/or AIM-9M, WDU-17s, and/or AIM-9X, WDU-17s, and/or AIM-9P, 10.5lb Warheads
- AIM-7s must be AIM-7M, WAU-17s and/or AIM-7F, WAU-10s

[3] This IMD is based on the minimum aircraft separation requirement of 10 ft. If circumstances require locating aircraft at less than this distance, then lesser IMDs may be approved by USAF.

Table 8.20. QD for F-22 Aircraft in the Open

See Note 1	NEWQD for MCE	HFD/IBD	PTRD[3]	ILD[4]	IMD[2]
Configuration 1 4 AIM-120s, 2 AIM-9s	19.0 lbs	400 ft	240 ft	48.0 ft	10 ft
Configuration 2 6 AIM-120s, 2 AIM-9s	19.0 lbs	400 ft	240 ft	48.0 ft	10 ft

[1] Unless otherwise specified:

- AIM-120s must be AIM-120, WDU-33/Bs and/or AIM-120, WDU-41/Bs
- AIM-9s must be AIM-9L, WDU-17s and/or AIM-9M, WDU-17s and/or AIM-9P/Xs

[2] This IMD is based on the minimum aircraft separation requirement of 10 ft. If circumstances require locating aircraft at less than this distance, then lesser IMDs may be approved with the AFSEC Weapons Safety Division. Request approval through the Major Command's Weapons Safety Division.

[3] PTRD is 60 percent of IBD.

[4] ILD is K18, using the NEWQD for MCE determination.

Table 8.21. QD for Aircraft in Structures for Configurations in Tables 8.18, 8.19, and 8.20

Structure Type	IBD	PTRD	ILD/IMD
Fabric/Tubular Shelter or Light Metal Structure	Aircraft Configuration HFD[1]	Note 2	Note 3
[1]Minimum debris distance of 279 ft applies when in a light metal structure. No minimum debris distance applies to a fabric/tubular shelter. [2]PTRD is 60 percent of HFD. [3] ILD and IMD are the same as determined for "open" in previous section.			

8.5. APPROVAL OF REDUCED MCE FOR AIM-9 AND AIM-120 MIXED TRAILER CONFIGURATION. The 10 February 2004 DDESB-IK Memorandum approved the reduced MCE for mixed storage configurations of two AIM-120 (any model) and two AIM-9 (any model) all-up missiles on an MHU-141/M missile transport trailer. The following conditions apply to this approval for use of a reduced MCE for AIM-9 and AIM-120 missiles on an MHU-141/M missile transport trailer:

8.5.1. The two AIM-120 missiles will be loaded only on the inside stations of the trailer, oriented in alternating directions to prevent warheads being located adjacent to each other. Ensure missiles are centered on trailer.

8.5.2. The two AIM-9 missiles will be loaded only on the outer stations of the trailer. The direction of the AIM-9s is optional. Ensure missiles are centered on trailer. Line-of-sight between the two AIM-9 missiles must be prevented while on the trailer.

8.5.3. The above placement will result in the two AIM-9 missiles (any orientation) being separated by two AIM-120 missiles (oriented in alternating directions).

8.5.4. The MCE for a trailer load meeting the above conditions is one AIM-120 missile and one AIM-9 missile, and the maximum allowable NEWQD for the trailer load, based on this MCE, is 29.5 lbs HD 1.1.

8.5.5. The QD allowed for the subject trailer are as follows:

8.5.5.1. IBD - 400 ft;

8.5.5.2. PTRD – 60 percent of IBD, which equates to 240 ft;

8.5.5.3. ILD - $18*NEWQD^{1/3}$; and

8.5.5.4. IMD - 100 inches.

8.6. APPROVAL OF REDUCED MCE FOR AIM-120 TRAILER CONFIGURATION.

8.6.1. The 22 May 2017 DDESB-PD Memorandum approved the reduced MCE for a storage configurations of a maximum load of six AIM-120 all-up missiles with WDU-33/B or WDU-41/B warheads on a MHU-141/M or MHU-226 missile transport trailer. Table 8.22 presents the reduced MCE and associated QD for each warhead configuration. The approval applies to the following missile configurations:

8.6.1.1. Up to four AIM-120 missiles loaded across the bottom (or deck) of the MHU-141/M trailer; up to six AIM-I 20 missiles loaded across the bottom (or deck) of the MHU-226 trailer. If M-10 Adapter Trees are present, no missiles will be loaded on them across the top of the trailer. The AIM-120 missiles will be alternating with the left inside missile facing forward and alternating all other missiles loaded across the bottom (or deck) of the trailer.

8.6.1.2. Up to six AIM-120 missiles loaded across the top of the trailer on M-10 Adapter Trees with no other missiles loaded on the bottom (or deck). The AIM-120 missiles will be alternating with the left inside missile facing forward and alternating all other missiles loaded across the M-10 Adapter Trees.

8.6.2. The missiles will be loaded nose to tail, and in a single layer. The configurations listed above are intended to ensure there is line of sight separation between warheads of the missiles; specifically, the missiles must be centered on the trailer such that the motor of one missile interrupts the line of sight between the warheads of the missiles on either side of it. The MCE of the trailer will be based on NEWQD of a single missile. The approved AIM-120 trailer configuration, MCEs, NEWQDs, and associated QDs are shown in the attachment to the 22 May 2017 DDESB-PD Memorandum. IMD separation will be maintained between trailers.

8.7. APPROVAL OF MCE FOR MULTIPLE AUR CONTAINERS OF AIM-7 MISSILES WITH WAU-10 WARHEADS. Based on testing results documented in the Ogden Air Logistics Center TR MMWRM-TR-84-M25025C, the 30 September 2004 DDESB-IK Memorandum approved the establishment of the MCE, for stacks of multiple AIM-7 Missile (with WAU-10 Warheads) AUR containers, to be a single AUR container. The following pertain to this approval:

8.7.1. All four AIM-7 Missiles within the AUR container must be oriented in the same direction.

8.7.2. There are no restrictions on the orientation of AUR containers, relative to each other.

8.7.3. The NEWQD associated with an AUR container is 105 lbs HD 1.1. This is determined by using the MCE of a single AIM-7 (with a WAU-10 Warhead) as 26.1 lbs and multiplying it by 4, the number of warheads in an AUR container.

8.7.4. The QD associated with the AIM-7 (with WAU-10 Warhead) AUR container will be in accordance with paragraph V3.E3.1.2.1.1.1 of DESR 6055.09.

8.8. MISSILE CONTAINER STORAGE REDUCED MCE FOR AIR-TO-AIR MISSILES.

8.8.1. The 25 April 2008 DDESB-PD Memorandum approved a single container MCE for a mixed storage configuration of AIM-7, AIM-9 and AIM-120 air-to-air missile containers provided the following conditions are met:

8.8.1.1. Each stack of containers will contain the same type of missile and warhead.

8.8.1.2. Each stack will be no more than three containers high.

8.8.1.3. For containers of AIM-7 missiles with the WAU-10 warhead:

8.8.1.3.1. The missiles must be oriented in the same direction within the container.

8.8.1.3.2. There is no restriction on the orientation of the containers relative to one another within a stack.

8.8.1.3.3. There is no restriction on the orientation of containers between stacks.

8.8.1.3.4. There is no required separation between stacks. MCE of the stack(s) is 105 lbs of HD 1.1 (based on the four warheads a single container).

8.8.1.4. For containers of AIM-7 missiles with the WAU·17 warhead:

8.8.1.4.1. The missiles must be oriented in the same direction within the container.

8.8.1.4.2. The containers within a single stack must be alternated (nose-to-tail).

8.8.1.4.3. There is no restriction on the orientation of containers between stacks.

8.8.1.4.4. There is no required separation between stacks. MCE of the stack(s) is 144 lbs of HD 1.1 (based on the four warheads in a single container).

8.8.1.5. For containers of AIM-9 missiles with the WDU-l7 warhead:

8.8.1.5.1. There is no restriction on the orientation of the missiles relative to one another within a container,

8.8.1.5.2. There is no restriction on the orientation of the containers relative to one another within a stack.

8.8.1.5.3. There is no restriction on the orientation of containers between stacks.

8.8.1.5.4. There is no required separation between stacks. MCE of the stack(s) is 32 lbs of HD 1.1 (based on the four warheads in a single container).

8.8.1.6. For containers of AIM-l20 missiles with the WDU-33/B warhead:

8.8.1.6.1. The missiles must be oriented in the same direction within the container.

8.8.1.6.2. There is no restriction on the orientation of the containers relative to one another within a stack.

8.8.1.6.3. There is no restriction on the orientation of containers between stacks.

8.8.1.6.4. There is no required separation distance between stacks. The stack(s) is HD 1.2.1 with an MCE of 68 lbs (based on the four missiles in a single container).

8.8.1.7. For containers of AIM-l20 missiles with the WDU-41/B warhead:

8.8.1.7.1. The missiles must be oriented in the same direction within the container.

8.8.1.7.2. There is no restriction on the orientation of the containers relative to one another within a stack.

8.8.1.7.3. There is no restriction on the orientation of containers between stacks.

8.8.1.7.4. There is no required separation distance between stacks. The stack(s) is HD 1.2.1 with an MCE of 76 lbs (based on the four missiles in a single container).

8.8.1.8. Stacks of differing missile and warhead configurations will be separated from each other by a horizontal distance of 100 inches. (For example, stacks of AIM-7/WAU-I0 containers will be separated by a horizontal distance of 100 inches from stacks of AIM-7/WAU-17 containers.)

8.8.2. Provided the conditions above are met, the storage of mixed AIM-7, AIM-9 and AIM120 air-to-air missile containers (with the warheads specified above) may be sited based on whichever of the following is more restrictive:

8.8.2.1. Siting the greatest MCE present as HD 1.1 (regardless of whether the greatest MCE is for HD 1.1 or HD 1.2.1), or

8.8.2.2. Siting the total HD 1.2.1 NEWQD present.

Table 8.22. AIM-120 Trailer Configuration Reduced MCEs

Configuration of AIM-120s on a Trailer[1]	MCE[2]	NEWQD for MCE	IBD[3]	PTRD[4]	ILD[5]	IMD[6]
WDU-33/B Warheads Only	One AIM-120, WDU-33/B	16.9 lbs of HD 1.1	280 ft	168 ft	47 ft	100 in
WDU-41/B Warheads Only	One AIM-120, WDU-33/B	19 lbs of HD 1.1	335 ft	201 ft	48 ft	100 in
Mixture of WDU-33/B and WDU-41/B Warheads	One AIM-120, WDU-41/B	19 lbs of HD 1.1	335 ft	201 ft	48 ft	100 in

[1]This approval applies to the MHU-141/M and MHU-226 trailers with a maximum load of six AIM-120 missiles on the trailer. The missiles will be loaded nose to tail and in a single layer. The configurations allowed are intended to ensure there is line of sight separation between warheads of the missiles; specifically, the missiles must be centered on the trailer such that the motor of one missile interrupts the line of sight between the warheads of the missiles on either side of it.
[2]MCE is based on the single missile configuration present with the largest NEWQD. For example, if three AIM-120s with WDU-33/B warheads and three AIM-120s with WDU-41/B warheads were on a trailer, the MCE would be 19 lbs of HD 1.1 (i.e., the NEWQD of one AIM-120 with a WDU-41/B warhead).
[3]IBD is the greater of: 1) K40 of the NEWQD for the MCE, or 2) HFD of any single missile present. For both the AIM-120 with a WDU-33/B warhead and the AIM-120 with a WDU-41/B warhead, the HFD is greater than K40 of the NEWQD. Therefore, the IBDs in the table are based on the HFDs.
[4]PTRD is 60 percent of IBD.
[5]ILD is K18, using the NEWQD for MCE.
[6]IMD must be maintained between AIM-120 trailers and to other potential explosions site.

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CHAPTER 9: OTHER NON-STORAGE RELATED PROTECTIVE CONSTRUCTION

9.1. GENERAL. This chapter will capture non-storage related structures approved by the DDESB that have protective construction features associated with them, but do not fall in the categories associated with the previous chapters.

9.2. SECURITY ALERT FACILITY. The 12 March 1976 DDESB-KT Memorandum provided the following siting guidance for Security Alert Facilities.

9.2.1. Sitings at a risk factor of $9W^{1/3}$ or greater will be approved on the assumption that hardening against attack by sustained small arms fire will be provided. Presence of, or lack of, conventional barricading will not be a factor.

9.2.2. Sitings at a risk factor of less than $9W^{1/3}$ will be disapproved unless the submission clearly shows that the exposed security alert facility has been hardened against blast overpressure so that, at the proposed location, personnel will not be subjected to risks greater than for siting approved at $9W^{1/3}$, in accordance with subparagraph 3a of the DDESB approval memorandum.

9.2.3. Siting of the Security Alert Facilities at the minimum permitted distance of $9W^{1/3}$ would expose the security personnel to maximum incident peak overpressure up to 11 to 11.5 psi, which is sufficient to cause disabling injuries and render personnel militarily ineffective, possible at a critical time. Consider providing distance separation to about $18W^{1/3}$, or an overpressure level of approximately 3.5 psi.

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APPENDIX 1: MAGAZINE LISTINGS

AP1.1. TABLE AP1-1. Table AP1-1 presents current data on 7- and 3-Bar ECM approved for new construction. Note that:

- 7- and 3-Bar ECM are permitted to store up to 500,000 lbs NEW of HD 1.1, unless otherwise noted.
- There are currently no 3-Bar ECM approved for new construction.

Table AP1-1. 7- and 3-Bar ECM Approved for New Construction, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
1	14004689 through 14004720 (without loading dock) and 14005091 through 14005122 (with loading dock)	10-May-17	Reinforced Concrete Box, Type C	NAVFAC	25-Sep-17	7-Bar
	This design supersedes the previous version of 14004689 through 14004720 and 14005091 through 14005122 dated 15 December 2010. Revision dates on drawings vary, so the DDESB approval memo references the drawing date of 10 May 2017. Internal dimensions are 50 ft deep by 94 ft 8 inches wide by 13 ft 8 inches (rear of magazine) to 15 ft 10 inches (front of magazine) high. Three (3) entrances are provided on the headwall. Each of the 3 sliding doors measures 26 ft 6 inches wide by 12 ft high over 25 ft wide by 11 ft high openings. Sited for 350,000 lbs NEW. Original DDESB approval of the Type C magazine was documented in a memo dated 11 May 85. DDESB memo of 2 February 2006 approved an increase of the maximum, allowable NEW to 500,000 lbs of HD 1.1. This revision incorporates lessons learned from recent projects, including increases to rebar splice and development lengths and changing light fixtures to LEDs.					
2	14063806 through 14063858	2-Jul-19	Reinforced Concrete Box, MSM	NAVFAC	18-Jul-19	7-Bar
	This design is commonly referred to as the Navy MSM and supersedes Drawing Numbers 14026988 through 14027031, which was based on the design of the Hill AFB MSM (see Table AP1-2). Internal dimensions are 25 ft wide by 80 ft long by 14 ft 8 inches high. The allowable HD 1.1 explosive limit is 500,000 lbs. The design is presented in metric units. This magazine has higher seismic limits than other MSMs. It also is equipped with a robust sliding steel door with concrete fill, providing a greater level of physical security. The door opening measures 25 ft wide by 14 ft 8 inches high. The design includes an optional air conditioning room with associated equipment. Modifications from the superseded design include enhancements to physical security at the door jamb and trench, minor revisions to the electrical and mechanical systems, and updates to the lightning protection system.					
3	18232899 through 18232936 (without platform) and 18232939 through 18232978 (with platform)	May-17	Reinforced Concrete Box, Type D, Rev. 1	NAVFAC	19-Jul-17	7-Bar
	Superseded NAVFAC 14021368 through 14021404 and 14021406 through 14021444. Internal dimensions are 50 ft deep by 158 ft 8 inches wide by 13 ft 8 inches (rear of magazine) to 15 ft 10 inches (front of magazine) high. Five (5) entrances are provided on the headwall. Each of the 5 sliding doors measures 26 ft 3 inches wide by 12 ft high over 25 ft wide by 11 ft high openings. Sited for up to 500,000 lbs NEW. This revision incorporates lessons learned from recent projects, including increases to rebar splice and development lengths and changing light fixtures to LEDs.					
4	33-15-74 (Korean Version)	August 2000/ modified March 2006	Reinforced Concrete FRELOC Stradley	Korean Ministry of Defense	23 Sep 2003 and 26 July 2006	7-Bar
	This design is the approved version of the Republic of Korea Army (ROKA) drawing for 33-15-74, Igloo Type Storage (63 Pyung). The original basis for the Korean version was USACE 33-15-74. The Korean drawings assure that all reinforcing steel is electrically continuous. The design specifies the use of a single sliding door which measures 10 ft 10 inches wide by 10 ft 3 inches high over an opening that measures 10 ft by 10 ft. The previous version of this drawing was approved by the DDESB as a 7-Bar magazine on 25 May 2002. DDESB-PD Memorandum of 26 July 2006 approved design changes which added a mechanical room and several penetrations for the addition of air conditioning.					

#	Table AP1-1. 7- and 3-Bar ECM Approved for New Construction, June 2019					
	Drawing Number	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
5	421-80-01	5-Feb-88	Steel, Semi-circular Arch	USACE	28-Jun-88	7-Bar
	Replaced 33-15-64. Drawing permits the use of a 2 inch deep or 5.5 inches deep corrugated steel arch. Internal width and height dimensions are approximately 26 ft wide by 13 ft 6 inches high. The minimum internal length is 19 ft, expandable up to the most commonly used magazine length of 89 ft. The magazine has a single entrance with 2 size options with sliding steel doors: a) 8 ft wide by 8ft high (8 ft 10 inches wide by 8 ft 3 inches high door), or b) 10 ft wide by 10 ft high (10 ft10 inches wide by 10 ft 3 inches high door).					
6	421-80-03	30-Oct-92	Steel, Oval Arch	USACE	28-Dec-92	7-Bar
	Replaced 33-15-73. Arch design composed of a 0.280 inch (1 gauge) corrugated steel arch. Internal dimensions are 24 ft wide (measured from base of steel arch) by 21 ft (minimum) to 89 ft maximum length. Arch height is 14 ft 5 inches. The magazine has a single entrance with 2 size options with sliding steel doors: a) 8 ft wide by 8 ft high (8 ft 10 inches wide by 8 ft 3 inches high door), or b) 10 ft wide by 10 ft high (10 ft 10 inches wide by 10 ft 3 inches high door). DDESB approval signature of 28 Dec 1992 on drawings. Thirty-nine ECM based on this design drawing were constructed at Camp Leatherneck, Afghanistan, using the CONTECH SUPER-SPAN Mode1102A15-24 High Profile Arch. DDESB approval memo DDESB-PE of 6 Oct 2010 approved the use of this arch as meeting the arch requirements of 421-80-03, thereby considering the ECM as 7-bar structures.					
7	421-80-05	1-Sep-98	Reinforced Concrete Arch	USACE	8-Sep-98	7-Bar
	Constructed using the Techspan Precast Concrete System, developed by the Reinforced Earth Company, for arch construction. The headwall and door are derived from 33-15-74. Internal dimensions are 25 ft 11 inches wide by 90 ft maximum (normally length is 60 ft or 80 ft) by 14 ft high (largest clearance at center of magazine). The magazine has a single entrance with 2 size options with sliding steel doors: a) 8 ft wide by 8 ft high (8 ft 10 inches wide by 8 ft 3inches high door), or b) 10 ft wide by 10 ft high (10 ft 10 inches wide by 10 ft 3 inches high door).					
8	421-80-07	2-Dec-11	Reinforced Concrete Box, MSM	USACE	27-Dec-11	7-Bar
	This design supersedes 421-80-06 (modified). This series updates the drawings to meet current AEC CAD standards, to improve plan readability and constructability, and to correct omissions within the construction drawings. Internal dimensions are 25 ft wide by 20 ft minimum length to 80 ft maximum length by 11 ft high. The front wall consists of two hinged doors, each measuring 12 ft 2 inches wide by 10 ft 8 inches high. The door opening measures 24 ft wide by 10 ft 4 inches high. The magazine can be sited for 500,000 lbs NEW.					
9	421-80-08	Jun-13	Reinforced Concrete Box, MSM	USACE	15-Jul-13	7-Bar
	This design supersedes the MSM as designed for Hill AFB. This series updates the drawings to meet current AEC CAD standards, and features improved plan readability and constructability and corrects omissions within the construction drawings. Internal dimensions are 25 ft wide by 20 ft minimum length to 80 ft maximum length by 14 ft 8 inches high. The front wall consists of two hinged doors, each measuring 12 ft 1-1/4 inches wide by 14 ft 8-1/2 inches high. The door opening measures 24 ft wide by 13 ft 11 inches high. The magazine can be sited for 500,000 lbs NEW.					

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
	Table AP1-1. 7- and 3-Bar ECM Approved for New Construction, June 2019					
10	421-80-09	Sep-13	Reinforced Concrete FRELOC Stradley	USACE	10-Oct-13	7-Bar
	This design supersedes 33-15-74. This series updates the drawings to meet current AEC CAD standards, improves plan readability and constructability, and corrects omissions within the construction drawings. Headwall components have been re-analyzed under the 7-bar blast loading from DoDM 6055.09 using the methodology of UFC 3-340-02. The remaining components are as originally designed. Internal dimensions are 25 ft wide by 20 ft minimum length to 90 ft maximum length by 14 ft maximum arch height. The magazine has a single entrance with 2 size options with sliding steel doors: a) 8 ft wide by 8 ft high (8 ft 10 inches wide by 8 ft 3 inches high door), or b) 10 ft wide by 10 ft high (10 ft 10 inches wide by 10 ft 3 inches high door).					
11	421-80-10	Mar-19	Reinforced Concrete Box, MSM (Flow-through)	USACE	22-Apr-19	7-Bar
	This design is based on the 421-80-08 standard, with a flow-through configuration. There is a headwall and blast door on either end of the chamber, resulting in two front sides for siting purposes. Internal dimensions are 25 ft wide by 40 ft minimum length to 120 ft maximum length by 14 ft 8 inches high. For lengths exceeding 80 ft, a cast-in-place concrete shear wall is required near mid-length of the chamber for added lateral stability. The front wall consists of two hinged door leafs, each measuring 12 ft 1-1/4 inches wide by 14 ft 8-1/2 inches high. The door opening measures 24 ft wide by 13 ft 11 inches high. The magazine can be sited for 500,000 lbs NEW.					
12	421-80-13	Aug-18	Reinforced Concrete Box, MSM	USACE	24-Aug-18	7-Bar
	This is a modified MSM designed for construction in select locations throughout Europe using locally available materials and in metric dimensions. Specific locations intended for construction are England, Germany, Romania, Poland, and Slovakia. Development of this standard was funded by the United States Air Forces in Europe (USAFE) and the Air Force Civil Engineer Center (AFCEC) to meet United States and NATO explosives safety criteria for a 7-Bar ECM. Internal dimensions are 25 ft (7.62 m) wide by 40 ft (12.19 m) minimum length to 80 ft (24.38 m) maximum length by 14 ft 8 in (4.47 m) high. The front wall is a sliding structural steel blast door. The door slides in a floor trench, which is covered by steel plates when the door is in the open position. The door opening measures 25 ft (7.62 m) wide by 14 ft 8 in (4.47 m) high. The design includes a reinforced concrete topping slab over the roof panels for enhanced seismic resistance.					

AP1.2. TABLE AP1-2. Table AP1-2 presents current data on 7- and 3-Bar ECM no longer used for construction but still in use. Note that:

- Each line represents a separate ECM design. Where UNK appears, it indicates that no information has been found to fill in that particular field. Table AP1-2 lists magazines that have been constructed in the past and are still in use today, though they generally are no longer being used for new construction. However, at the discretion of DoD Components, these designs could be used for new construction, but the designs will need to be closely evaluated to insure current DoD requirements for ECM (e.g., grounding, lightning protection, earth-cover slope and depth, structural hardness) are met.

- The storage capacities of the 7-Bar and 3-Bar ECMs in this table are as permitted in their respective DDESB approval memoranda. These capacities must not exceed 500,000 lbs.

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
1	10400001 through 10400027	5-Jan-04	Reinforced Concrete Box, Type M	NAVFAC	1-Dec-99	7-Bar
	Internal dimensions are 81ft wide by 124 ft long by 24 ft 6 inches high (measured at interior face at each side wall). The design provides for 2 entrances on the headwall. Each door measures 14 ft 8 inches wide by 14 ft 2 inches high over 14 ft by 14ft openings. The design provides for internal magazine access by rail and truck. Sited for 350,000 lbs NEW. This drawing number represents the most recent design of three versions of the Box Type M Magazine that have been constructed. The initial design was approved by DDESB-KO memo of 9 Apr 93 for construction at NAVWPNSTA Seal Beach. Two subsequent design variations were approved by DDESB-KO memo of 1 Dec 99, for construction at NAVWPNSTA Yorktown.					
2	1059128 through 1059132 modifications 1069906, and 1355460 through 1355461	18-Mar-64	Steel Arch	NAVFAC	1964	7-Bar
	Designed for NOTS test of 18 Dec 1963. Listed in DDESB minutes as a STD ECM. NAVFAC MIL-BUL-340 (YD), Jul 93, listed this magazine design as canceled. Drawing 1351905 provided for an optional deeply corrugated, light gauge arch vice the 1 gauge specified on 1059128.					
3	14004689 through 14004720 (without loading dock) and 14005091 through 14005122 (with loading dock)	15-Dec-10	Reinforced Concrete Box, Type C	NAVFAC	4-Jan-11	7-Bar
	This design supersedes 1404430 through 1404444. Internal dimensions are 50 ft deep by 94 ft 8 inches wide by 13 ft 8 inches (rear of magazine) to 15 ft 10 inches (front of magazine) high. Three (3) entrances are provided on the headwall. Each of the 3 sliding doors measures 26 ft 6 inches wide by 12 ft high over 25 ft wide by 11 ft high openings. Sited for 350,000 lbs NEW. Original DDESB approval of 11 May 85 for this magazine design. DDESB memo of 2 February 2006 approved an increase of the maximum, allowable NEW to 500,000 lbs of HD 1.1. This design does not include explosion-proof electrical installation/equipment. If the design is to be used where there is a potential for an internal explosive/flammable hazardous environment, then significant electrical redesign will be required as well as subsequent DDESB review/approval of that redesign before construction/use. This design has been superseded by an updated version of the same drawing numbers dated 10 May 2017.					
4	14021368 through 14021404 (without platform) and 14021406 through 14021444 (with platform)	26-Sep-12	Reinforced Concrete Box, Type D	NAVFAC	13-Mar-13	7-Bar
	Superseded NAVFAC 6448522 through 6448554. This revision corrects minor drafting issues, updates the lightning protection and grounding systems, and creates separate sets of standard drawings with and without loading platforms. Internal dimensions are 50 ft deep by 158 ft 8 inches wide by 13 ft 8 inches (rear of magazine) to 15 ft 10 inches (front of magazine) high. Five (5) entrances are provided on the headwall. Each of the 5 sliding doors measures 26 ft 3 inches wide by 12 ft high over 25 ft wide by 11 ft high openings. Sited for up to 500,000 lbs (226,796 kg) NEW. This design has been superseded by NAVFAC 18232899 through 18232936, revision 1, and 18232939 through 18232978, revision 1.					
5	14026988 through 14027031	31-May-13	Reinforced Concrete	NAVFAC	31-Jul-13	7-Bar

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019						
#	**Drawing Number**	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
			Box, MSM			
	This design is commonly referred to as the Navy MSM. The standard is based on the design of the Hill AFB MSM (see Table AP1-2) with the following changes: The standard includes a sliding door and an option for environmental controls. Internal dimensions are 25 ft wide by 80 ft long by 14 ft 8 inches high. The allowable HD 1.1 explosive limit is 500,000 lbs. The design is presented in metric units. This magazine has higher seismic limits than other MSMs. It also is equipped with a robust sliding steel door with concrete fill, providing a greater level of physical security. The door opening measures 25 ft wide by 14 ft 8 inches high. The design includes an optional air conditioning room with associated equipment. This design was superseded by Drawing Numbers 14063806 through 14063858.					
6	1404000 through 1404007	1-May-78	Reinforced Concrete Box, Type A	NAVFAC	13-Aug-82	7-Bar
	Superseded Drawings 749771 through 749774 and 793751. NAVFAC MIL-BUL-340 (YD), Jul 93, lists these ECM drawings as canceled.					
7	1404018 through 1404025, 952132, through 952134	25-Sep-78	Reinforced Concrete Box, Type B	NAVFAC	13-Aug-82	7-Bar
	Superseded Y & D Drawings 952127 through 952131 and 952135. NAVFAC MIL-BUL-340 (YD), Jul 93, lists these ECM drawings as canceled.					
8	1404026 through 1404034	UNK	Steel, Oval Arch	NAVFAC	27-Jan-76	7-Bar
	Listed in DDESB minutes as STD magazine. NAVFAC MIL-BUL-340 (YD), Jul 93, lists these ECM drawings as canceled.					
9	1404310 through 1404324	12-Sep-83	Reinforced Concrete, Circular Arch	NAVFAC	15-Jul-83	7-Bar
	Superseded NAVFAC's original (1954) Standard Drawings 627954 thru 627957, 649602 thru 649605, 658384 thru 658388, 724368, 751861, 764596 thru 764597, 793746 thru 793748, 803060, and 822978 thru 822989. Magazine internal dimensions are 25 ft wide by 80 ft (maximum) length. The magazine has a single entrance with 2 size options for the entrance. Corresponding optional sliding door sizes are: a)11 ft 10 inches wide by 10 ft high, and b) 17 ft 10 inches wide by 10 ft high. DDESB approval signature of 15 Jul 83 on drawings.					
10	1404328 through 1404342	7-Aug-84	Steel Arch	NAVFAC	15-Jul-83	7-Bar
	Superseded NAVFAC's original (1964) Standard Drawings (1059128 thru 1059130, 1059132, 1069906, and 1355460 thru 1355461).					
11	1404375 through 1404389	31-Oct-85	Composite, Circular Arch	NAVFAC	14-Jan-86	7-Bar
	Composite circular arch design composed of an internal 0.138 inch (10 gauge) corrugated steel arch with reinforced concrete overlay. Magazine internal dimensions are 25 ft wide by 80 ft (maximum) length. Design provides for 2 door sizes: a) 11 ft 10 inches wide by 10 ft high, and b) 17 ft 10 inches wide by 10 ft high. Each door is a single-piece sliding door. DDESB approval signature of 14 Jan 86 on drawings.					
12	1404390 through 1404398	31-Oct-85	Composite, Oval	NAVFAC	14-Jan-86	7-Bar

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
			Arch			
	Composite oval arch design composed of an internal 0.138 inch (10 gauge) corrugated steel arch with reinforced concrete overlay. Internal dimensions are 25 ft 11 inches wide (measured from base of steel arch) by 20 ft (minimum) to 80 ft maximum length. Arch height is 14 ft 5 inches. Design provides for a single sliding door with dimensions 10 ft high by 11 ft 2-1/2 inches wide. DDESB approval signature of 14 Jan 86 on drawings.					
13	1404430 through 1404444	20-Sep-85	Reinforced Concrete Box, Type C	NAVFAC	5-Nov-85	7-Bar
	Internal dimensions are 50 ft deep by 94 ft 8 inches wide by 13 ft 8 inches (rear of magazine) to 15 ft 10 inches (front of magazine) high. Three (3) entrances are provided on the headwall. Each of the 3 sliding doors measures 26 ft 6 inches wide by 12 ft high. Sited for 350,000 lbs NEW. DDESB approval signature of 11 May 85 on drawings. DDESB memo of 2 February 2006 approved an increase of the maximum, allowable NEW to 500,000 lbs of HD 1.1. This design was superseded by upgraded Box Type C designs 14004689 through 14004720 (without loading dock) and 14005091 through 14005122 (with loading dock). The upgrade addressed lightning protection, security, and electrical requirements. NOSSA letter 8020 Ser N511/3015 of 19 October 2010 details the modifications that were made.					
14	1404465 through 1404478	20-Sep-85	Reinforced Concrete Box, Type D	NAVFAC	5-Nov-85	7-Bar
	DDESB (P. Price) approval signature of 5 Nov 85 on drawings. Sited for 350,000 lbs NEW. Superseded by NAVFAC Drawings 6448522 through 6448554 (Standard Box Magazine Type D) and NAVFAC Drawings 6448555 through 6448588 (HSILS Box Magazine Type D), both dated 27 May 97.					
15	1404523 through 1404537	30 June 1987, Rev 1 9 June 1988	Reinforced Concrete Box, Type E	NAVFAC	17 Jul 87; see comment	7-Bar
	Internal dimensions are 50 ft deep by 94 ft 8 inches wide by 13 ft 8 inches (rear of magazine) to 15 ft 10 inches (front of magazine) high. Three (3) entrances are provided on the headwall. Each of the 3 sliding doors measures 17 ft 6 inches wide by 12 ft high. Sited for 350,000 lbs NEW. DDESB approval signature of 30 Jun 87 on drawings. DDESB memo of 2 February 2006 approved an increase of the maximum, allowable NEW to 500,000 lbs of HD 1.1. There is no DDESB approval memorandum associated with Revision 1 of the drawings.					
16	1404541 through 1404555	9-Jun-87	Reinforced Concrete Box, Type F	NAVFAC	17-Jul-87	7-Bar
	Superseded by NAVFAC Drawings 6448589 through 6448621. This magazine design was sited for 350,000 lbs NEW. A site specific site approval was granted to Naval Weapons Station, Seal Beach, for the construction of four Box Type F Magazines with the dehumidification system located on top of the magazine, vice behind the magazines as was shown on the approved design drawings. This modification was not approved by the DDESB as a standard design, since the Navy never came in with a modified standard magazine drawing set to incorporate the addition of the dehunidification system onto the magazine roof.					
17	180-25-694	21-Aug-78	Reinforced Concrete	USACE,	22-Aug-89	7-Bar

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019						
#	**Drawing Number**	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
			Box, Type B, Modified	Sacramento District		
	Hill AFB modified the previously cancelled Navy Box Type B ECM design (NAVFAC Drawings 1404018 through 1404025, to accomodate the storage of large missile motors, by increasing the size of the structure to 102 ft by 117 ft, and going from 3 bays wide and 3 bays deep to 4 bays wide and 5 bays deep. A total of 15 such structures were approved by the DDESB for NEWs of 500,000 lbs each. It appears 13 were initially built, with the remaining 2 being constructed in the late 1990s, with a modified lightning protection system (faraday system with no overhead terminals), as approved by the DDESB on 21 Jan 1998.					
18	180-25-837	6-Feb-07	Updated - Reinforced Concrete Box, Type B, Modified	USACE, Sacramento District	9-May-07	7-Bar
	In 2006, Hill AFB desired to construct 2 additional modified Navy Box Type B ECM (designed per Drawings 180-25-694, but was unsure if they met current criteria at the time. NAVFAC ESC was asked by the DDESB to review the design to validate if it met current criteria of DoD 6055.09-STD. Their analysis determined that the design did comply, but NAVFAC ESC suggested some minor design improvements to enhance their structural capacities further. Those recommendations were adopted and incorporated into a new drawing package (180-25-837), which was approved by the DDESB. The DDESB approval memo identifies the 2 new buildings as 2329 and 2330, whereas the construction drawings list 1360 and 1361.					
19	219-25-321	23-Apr-90	Reinforced Concrete FRELOC Stradley	USACE, Sacramento District	Acceptance based on COE analysis	7-Bar
	This design was constructed at Luke AFB. It was evaluated by CEHNC to determine its structural rating. Their analysis, documented on memo CEHNC-ED-CS-S (210-2b) of 23 January 2002, found that the design shown on the drawings came from existing 7-Bar ECM design 33-15-74.					
20	33-03-0028	20-Jun-88	Reinforced Concrete Stradley	USACE, Pacific Ocean District	Acceptance based on USACE analysis	7-Bar
	This design was constructed at Osan Air Base, Korea and is based on OCE Drawing 33-15-61, 30 Dec 1959, which is considered a 7-Bar ECM. The drawings provides for two different ECM designs. One design is a typical ECM with a single headwall and the ventilator out the rear of the ECM, while the second design includes two headwalls and a ventilator that is centered on the roof of the ECM. Based on a review by CEHNC, the headwall and doors used on 33-03-0028 match the headwall and doors of 33-15-61. The doors of the three designs are all 6-ft wide sliding doors. Two of these doors are required per entrance.					
21	33-03-31	UNK	Reinforced Concrete FRELOC Stradley	U.S. Army Engineer Command (Europe)	1978	7-Bar
	This design is similar to 33-15-61, the DDESB approved Standard Freloc-Stradley Magazine. 33-03-31 was designed for construction at VILSECK ASP-1 (Germany) for USAFE. It measured 26 ft wide by 80 ft long and had a ceiling height of 14 ft at the centerline. The entrance measured approximately 10 ft by 10 ft. It had a reinforced concrete arch of uniform thickness, a heavily reinforced headwall, and bi-parting, double-leaf steel doors. A Sep 1977 dynamic analysis of this Freloc design, performed by Agbabian Associates for the USACE, European Division, determined that the					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019						
#	**Drawing Number**	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
	headwall was sufficiently strong to meet NATO face-on loading criterion, but the door was not. Recommendations were provided in Agbabian Associates Report R-7745-4503 to strengthen the doors by adding additional horizontal and vertical stiffeners on the exterior side of the doors. DDESB-KT Memos of 27 Jan and 4 May 1978 states that the door of the ECM analyzed by Agbabian Associates (33-03-31) met U.S. standard magazine criteria.					
22	33-03-43	1-Apr-76	Reinforced Concrete Arch	USACE, Europe Division	19-Mar-76	7-Bar, See Comment section.
	Known as a Quick Reaction Site (QRS) magazine, which were only constructed in Germany. Permitted to store a maximum of 4,000 kg NEQ. DDESB-KT Memo of 19 March 1976 evaluated this design and compared its structural components to counterpart features of standard ECM, particularly those in 33-15-61 and 33-15-64, which had undergone extensive testing. Based on this review, the design was approved for the storage of 4,000 kg NEQ in each arch uit. In addition, the design of the door was considered to qualify the ECM design for the minimum separation distances permitted.					
23	33-13-02	15-May-51	Reinforced Concrete Stradley	OCE	26-Jan-99	7-Bar
	A CEHNC letter of 13 Apr 98 determined this ECM was a revision of 33-15-06 (a 7-Bar ECM) and recommended it be considerd a 7- Bar ECM as well. A 26 Jan 99 DDESB ltr approved use of ECM constructed in accordance with Drawing 33-13-02, as a 7-Bar magazine. NOTE: A provision of the approval was that the separation distances between the rear or side of these ECMs, as the PES, to the front of one of these ECMs, as an ES, were at least 360 ft. Side to side exposures between the PES and the ES are required to be separated in accordance with the appropriate entries for either 3-bar or 7-bar ECMs in accordance with Table V3.E3.T6 of DoD 6055.09-M.					
24	33-15-01	1-Jul-78	Reinforced Concrete Stradley	CEHNC, Omaha District	Acceptance based on DDESB comparison to existing approved 7-Bar ALCM design.	7-Bar
	A double-headwall (flow-through) design with two sliding door on each headwall. The headwall and door design are consistent with the USACE, Omaha District, ALCM magazine design (AW 33-15-01), a 7-Bar design.					
25	AW 33-15-01	1979	Reinforced Concrete Stradley	USACE, Omaha District	26-Feb-80	7-Bar
	This design was known as the Air Launched Cruise Missile (ALCM) Igloo and is a double-headwall (flow-through) design with two large sliding doors on each headwall. The design provides 7-Bar protection. A 26 Feb 1980 DDESB letter approved AW 33-15-01 as a typical layout for ALCM storage and considered this design equal to a standard ECM. There are two designs in existence, with the only differences being the footings and floor slab. The initial design constructed at Griffis AFB, NY, had wall footings and a floating slab-on-grade. The subsequent design revised the foundation					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019						
#	**Drawing Number**	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
	and flooring to a mat foundation slab. The subsequent design is believed to have been constructed at the following Air Force Bases: Grand Forks, ND; Minot, ND; Fairchild, WA; Ellsworth, SD; Wurtsmith, WI; K.I. Sawyer, MI; Barksdale, LA; Blythville, AR; McConnel, KS; Carswell, TX; and Andersen, Guam. Internal dimensions are 40 ft wide by 112 ft long by 18 ft 6 inches high along the longitudinal centerline. Each of the sliding doors measures 18 ft 10 inches long by 13 ft 7-5/8 inches high.					
26	AW 33-15-02	21-Aug-67	Reinforced Concrete Arch	USACE Los Angeles District	Acceptance based on USACE analysis	7-Bar
	Constructed at Luke AFB. Analyzed by CEHNC to determine its structural rating. Their analysis, documented on memo CEHNC-ED-CS-S (210-2b) of 23 January 2002, found that the design of the headwall and door meets 7-Bar criteria.					
27	33-15-02	1-Jul-78	Steel, Oval Arch	USACE, Omaha District	Acceptance based on DDESB comparison to existing approved 7-Bar ALCM design.	7-Bar
	A double-headwall (flow-through) design with a single sliding door on each headwall. The headwall and door design are consistent with the USACE, Omaha District, ALCM magazine design (AW 33-15-01), a 7-Bar design.					
28	33-15-02	1-May-51	Reinforced Concrete Arch	USACE, Little Rock Division	Acceptance based on USACE analysis	7-Bar
	Constructed at Barkesdale AFB, LA. Analyzed by CEHNC to determine structural rating. Their analysis, documented on memo CEHNC-ED-CS-S of 15 July 2003, found that the design of the headwall and doors met 7-Bar criteria.					
29	33-15-03	1-Jul-78	Reinforced Concrete Stradley	USACE, Omaha District	Acceptance based on DDESB comparison to existing approved 7-Bar ALCM design.	7-Bar
	A double-headwall (flow-through) design with a single sliding door on each headwall. The headwall and door design are consistent with USACE, Omaha District ALCM magazine design. Similar design to Omaha Distrct 33-15-01, but with a larger door opening.					
30	33-15-04	1-Jul-78	Steel, Oval Arch	USACE, Omaha District	Acceptance based on DDESB comparison to existing approved	7-Bar

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
					7-Bar ALCM design.	
	A double-headwall (flow-through) design with a single sliding door on each headwall. The headwall and door design are consistent with USACE, Omaha District ALCM magazine design. Similar design to Omaha District 33-15-02, but with a larger door opening.					
31	33-15-06	1-Aug-51	Reinforced Concrete Arch	OCE	29-Jul-55	7-Bar
	Previously called the "YURT" Magazine. This magazine design superseded Drawings 652-686 through 652-692 and OCE 33-15-01 (1941 design - see Table AP1-3). A 1 Apr 87 COEHQ letter stated that ECM design 33-15-06 was no longer being used for new construction.					
32	33-15-13	16-Jan-68	Reinforced Concrete FRELOC Stradley	U.S. Army Engineer Command (Europe)	19-Aug-75	7-Bar
	A 4 May 78 DDESB letter restated that 33-15-13 was a standard ECM and that variations of this design were acceptable, provided new designs were at least equal to it structurally. This design is known as the "thin-wall" magazine and is known to have been built at Camp Darby, Italy. Similar designs, based on the 33-15-13 design are known to have been constructed in Germany and elsewhere. NOTE: ECM separation distances based in the following criteria: Side-to- side: use $1.5W^{1/3}$; back-to-back: use $1.5W^{1/3}$; front-to-back: use $4.5W^{1/3}$.					
33	33-15-15	UNK	Modified FRELOC Stradley (Steel Oval Arch)	U.S. Army Engineer Command (Europe)	22-Apr-80	7-Bar
	This design includes a double leaf door system, similar to the 33-15-61 two-leaf sliding door tested as aprt of ESKIMO II.					
34	33-15-16	26-Mar-79	Reinforced Concrete FRELOC Stradley	U.S. Army Engineer Command (Europe)	1-Apr-79	7-Bar
	Also known as the "TYPE 16" Magazine. This design corrected strength deficiencies found in ECM design 33-15-14, which was determined to be a non-standard ECM.					
35	33-15-208	UNK	Steel Arch	U.S. Army Engineer Command (Europe)	7-Aug-87	7-Bar
	Replaced design 33-15-28 that was previously approved by DDESB for construction at Larson Barracks, Kitzingen, GE. This design has only one entrance vice the 2 shown on 33-15-28.					
36	33-15-28	UNK	Steel Arch	U.S. Army Engineer Command (Europe)	11-May-83	7-Bar
	Constructed at Larson Barracks, Kitzingen, GE. Based on QRS magazine, which were only constructed in Germany (see 33-03-43 design). This design had 2 front headwalls and doors and no rear wall.					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
37	33-15-58	3-Feb-58	Reinforced Concrete Stradley	OCE	14-Oct-70	7-Bar
	Approved during 259th ASESB meeting of 14 Oct 70 and was considered to be atomic blast resistant. This drawing replaced former drawings YT-1-1 though YT-111. At that meeting, the Chair, ASESB, also read into the record that Stradley (Yurt) magazines, which are constructed in accordance with Standard OCE Drawings 33-15-58 and/or 33-15-61, are considered to be equivalent in strength to the OCE's standard earth covered igloo magazines.					
38	33-15-61	30-Dec-59	Reinforced Concrete Stradley	OCE	14-Oct-70	7-Bar
	Approved during 259th ASESB meeting of 14 Oct 70. This drawing replaced former drawings YT-1-1 though YT-111. At that meeting, the Chair, ASESB, also read into the record that Stradley (Yurt) magazines, which are constructed in accordance with Standard OCE Drawings 33-15-58 and/or 33-15-61, are considered to be equivalent in strength to the OCE's standard earth covered igloo magazines. Two door sizes are shown on the drawing: a 10 ft by 10 ft door and a 12 ft by 12 ft door. DDESB memo of 22 Apr 1980 discusses the successful testing of the two-leaf sliding door of 33-15-61 as part of ESKIMO II.					
39	33-15-61-6	UNK	Reinforced Concrete Stradley	UNK	Acceptance based on USACE analysis	7-Bar
	Very similar to 33-15-61, which is a 7-Bar ECM. Only differences were the use of a 10 ft door and 3,000 psi concrete vice a 12 ft door and 2,500 psi concrete. Doors and headwall were analyzed and were found to meet 7-Bar criteria. CEHNC e-mail of 24 January 2003 to DDESB documents results of review and analysis.					
40	33-15-62	13-Jan-60	N/A	OCE	12-Dec-75	N/A
	This is not an ECM design drawing. This drawing permited installation of larger doors on specific magazines, on the basis that the strength of the modified structures remained unchanged as a result of the door modifications. This drawing applied to ECM 33-15-01, 33-15-06, and 652-686 through 652-692.					
41	AW 33-15-63	5-Mar-63	Steel, Semi-Circular Arch	OCE	19-Feb-64	See note
	Approved during 225th ASESB meeting of 19 Feb 64 as a standard magazine design. A 1 Apr 87 COEHQ letter stated that ECM design AW 33-15-63 was no longer being used for new construction. Drawing AW 33-15-63 had two designs shown on it. One is a traditional magazine with a single 12-inch thick reinforced concrete headwall, while the second is a design with two headwalls and doors (flow through design). USACE structural evaluation of AW 33-15-63 door in 2003 determined the door would not provide 7- or 3-Bar protection. NOTE: The conversion of these designs from Standard magazines to 7-Bar magazines in the early 1990s was in error in that the hinged doors of AW					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
	33-15-63, AW 33-15-64 and 33-15-65 (all similar door designs) are not capable of providing 7- or 3-Bar protection to their contents. This determination was arrived at during ESKIMO III, which tested an AW 33-15-64 design and by a structural analysis of the door design that was conducted by CEHNC at the request of DDESB-KT. Paragraph 2.3.7.3. provides further information regarding this test. If different doors than those shown of AW 33-15-63, AW 33-15-64, and 33-15-65 have been installed, then the headwall and alternate door(s) can be structurally evaluated to determine their strength. As a result of the ESKIMO series tests, Services began moving towards single and bi-sliding doors on hardened headwall pilasters and header. **<u>Siting guidance</u>**: Do not use for new construction. Site existing magazines as "Undefined" structures to provide a higher level of protection to contents. Use of the K4.5 that is permitted for 7-Bar ECM (face-to-face) with intervening barricades or the K6 permitted for 7-Bar ECM (face-to-face) without a barricade provides a very high likelihood of prompt propagation between ECM designed to AW 33-15-63, AW 33-15-64 and 33-15-65. This note also applies to rows 41 through 45.					
42	AW 33-15-64	10-May-63	Steel Arch	OCE	19-Feb-64	See note in row 40
	Approved during 225th ASESB meeting of 19 Feb 64 as a standard magazine design. A 1 Apr 87 COEHQ letter stated that ECM design AW 33-15-64 was no longer being used for new construction. USACE structural evaluation of AW 33-15-64 door in 2003 determined the door would not provide 7- or 3-Bar protection.					
43	AD 33-15-67 R2	8 May 1964, Rev 2 dated 8 Mar 65	Steel, Semi-Circular Arch	AF	See comment	See note in row 40
	This ECM was required to be constructed in accordance with Drawing AW 33-15-63. A 13 Jan 1995 USACE, Huntsville District, ltr stated that since the design drawing calls for it to be constructed in accordance with a standard (7-Bar) design, then, by analogy, it also should be considered a standard. Added to the magazine listing in DoD 6055.9-STD, based on USACE analysis. USACE structural evaluation of AW 33-15-63 door in 2003 determined the door would not provide 7- or 3-Bar protection.					
44	AD 33-15-68 R2	8 May 1964, Rev 2 dated 8 Mar 65	Steel, Semi-Circular Arch	AF	See comment	See note in row 40
	This ECM was required to be constructed in accordance with Drawing AW 33-15-63. A 13 Jan 1995 USACE, Huntsville District, ltr stated that since the design drawing calls for it to be constructed in accordance with a standard (7-Bar) design, then, by analogy, it also should be considered a standard. Added to the magazine listing in DoD 6055.9-STD, based on USACE analysis. USACE structural evaluation of AW 33-15-63 door in 2003 determined the door would not provide 7- or 3-Bar protection.					
45	AD 33-15-69 R2	8-May-64	Steel, Semi-Circular Arch	AF	See comment	See note in row 40
	This ECM was required to be constructed in accordance with Drawing AW 33-15-63. A 13 Jan 1995 USACE, Huntsville District, ltr stated that since the design drawing calls for it to be constructed in accordance with a standard (7-Bar) design, then, by analogy, it also should be considered a standard.					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019						
#	**Drawing Number**	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
	Added to the magazine listing in DoD 6055.9-STD, based on USACE analysis. USACE structural evaluation of AW 33-15-63 door in 2003 determined the door would not provide 7- or 3-Bar protection.					
46	AD 33-15-70 R1	8-May-64	Steel, Semi-Circular Arch	AF	See comment	See note in row 40
	This ECM was required to be constructed in accordance with Drawing AW 33-15-64. A 13 Jan 1995 USACE, Huntsville District, ltr stated that since the design drawing calls for it to be constructed in accordance with a standard (7-Bar) design, then, by analogy, it also should be considered a standard. Added to the magazine listing in DoD 6055.9-STD, based on USACE analysis. USACE structural evaluation of AW 33-15-64 door in 2003 determined the door would not provide 7- or 3-Bar protection.					
47	33-15-73	21 Feb 75, Revised 23 Sep 77	Steel, Oval Arch	OCE	7-Feb-75	7-Bar
	A 1 Apr 87 COEHQ letter stated that ECM design 33-15-73 was no longer being used for new construction. A 25 Feb 1985 OCE ltr had rescinded use of this design, due to excessive deflections that could occur at the crown of the steel arch, due to the weight of the earth cover, and as a result of the collapse of an ECM in the field because of this problem. A 7 Feb 1975 DDESB memorandum approved OCE 33-15-73 (Oval Steel Arch) as a substitute igloo for AW 33-15-64, for use for any application for which a standard igloo is specified. This memorandum was in response to a Ft. Leonard Wood project (Project No. 109, Ammunition Storage Facility). Superseded by 421-80-03.					
48	33-15-74	11 Apr 79, Rev 3, 11 June 98	Reinforced Concrete FRELOC Stradley	USACE	22 July 1980; see comment	7-Bar
	Internal dimensions are 25 ft wide by 90 ft maximum (normally length is 60 ft or 80 ft) by 14 ft high (largest clearance at center of magazine). The magazine has a single entrance with 2 door-size options. Corresponding optional sliding door sizes are: 8 ft 10 inches wide by 8 ft 3 inches high, or 10 ft 10 inches wide by 10 ft 3 inches high. This design was superseded by 421-80-09. There is no DDESB approval memorandum associated with the magazine revisions.					
49	33-31-01	UNK	Reinforced Concrete Arch	UNK	4-May-99	7-Bar
	DDESB letter of 4 May 1999 identifies this magazine as being located at Incirlik AFB, Turkey. Dr. Canada of the DDESB evaluated the strength of this ECM design located at Incirlik AFB.					
50	33-31(JCASE)-01	UNK	Reinforced Concrete Arch	UNK	4-May-99	3-Bar
	DDESB letter of 4 May 1999 identifies this magazine as being located at Incirlik AFB, Turkey. Its blast door was determined to be incapable of providing 7-Bar protection, although the magazine arch and headwall were designed to meet 7-Bar criteria. Dr. Canada of the DDESB evaluated the strength of this ECM design located at Incirlik AFB.					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
51	FI-350 through FI-356	18-Apr-51	Reinforced Concrete Arch	OCE	Acceptance based on USACE analysis	7-Bar
	This Black and Veatch design was constructed at Rapid City Air Force Base (now known as Ellsworth AFB), Rapid City, SD. USACE Huntsville District reviewed this design and determined the design met 7-Bar criteria. Their results are documented on CEHNC-ED-CS-S (210-20b) of 6 March 2003. Some of the magazines were subsequently modified with larger doors, as shown on USACE Omaha District Drawing AW 33-13-01, dated 18 May 1960. The original door measures 9 ft 11-3/4 inches high by 8 ft 5-/2 inches wide (double, hinged, swinging doors), while the modified larger door measures 11 ft high by 10 ft 1-1/2 inches wide and are also double, hinged, swinging door. The magazine with the modified door is treated as an Undefined ECM.					
52	TLDI 350, 355, 356, 359	1-May-54	Reinforced Concrete Arch	USACE, Little Rock Division	Acceptance based on USACE analysis	7-Bar
	Located at Barksdale AFB, LA. CEHNC-ED-CS-S Memorandum of 18 February 2003, Subject: Analysis of Special Igloos applies. This analysis was for 33-15-02. DDESB-PD Memorandum for Record of 24 April 2007 records that this design is similar to 33-15-02, 1 May 51, USACE Little Rock District, an approved 7-Bar design.					
53	357428 through 357430, modified in accordance with OCE Drawing 626739	9 Aug 44, modification 19 Mar 54	Reinforced Concrete Arch	Bureau Y&D	25-Oct-56	7-Bar
	This magazine design, modified with an Army blast door, was successfully tested in 1946 at Naval Proving Ground, Arco, Idaho, with an NEW of 500,000 lbs NEW. Refer to Paragraph 2.3.5. of TP 15 for additional information regarding the test. DoD 4145.27M, March 1969 permitted this ECM to be separated by 210 ft for quantities up to 250,000 lbs NEW and 400 ft for quantities between 250,000 lbs and 500,000 lbs NEW. The 1 December 1955 ASESB QD Standards permitted this ECM design, if it had been modified in accordance with Bureau Y&D Drawing 626739, dated 19 Mar 54, to use a 185-ft separation distance for quantities up to 500,000 lbs NEW. If not, then a minimum separation distance of 210 ft was required for NEW quantities up to 250,000 lbs and a 400-ft separation distance was required for NEW quantities from 250,000 to 500,000 lbs. Paragraph 2.3.5.3. of TP 15 provides additional information to address the door, with respect to the nine year gap between when the 1946 test occurred and 1954, when Bureau Y&D Drawing 626739 was approved. Bureau Y&D Drawing 626739 provided for a 13-inch thick headwall and improved door design.					
54	421-80-02	15-Dec-92	Composite Box	USACE	1-Mar-00	7-Bar
	This magazine uses a Blast and Fragment Resistant (BFR) wall system that is also known as the AGAN Steel Panel (ASP) System. Removed from the authorized new construction list on the advice of USACE, Huntsville District, as the U.S. distributor for this magazine design is no longer in business.					
55	422-80-01	1-Nov-95	Reinforced Concrete Stradley	USACE, Omaha District	Acceptance based on DDESB comparison to existing approved 7-Bar ALCM design.	7-Bar

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
	Constructed at McConnell AFB, KS. This design is based on Air Launched Cruise Missile(ALCM) Igloo AW 33-15-01 and is a double-headwall (flow-through) design with double (2) sliding doors on each headwall. The design provides 7-Bar protection. A 26 Feb 1980 DDESB letter approved AW 33-15-01 as a typical layout for ALCM storage and considered this design equal to a standard ECM. Internal dimensions are 40 ft wide by 112 ft long by 18 ft 6 inches high along the longitudinal centerline. Each of the sliding doors measures 18 ft 10 inches long by 13 ft 7-5/8 inches high.					
56	421-80-06 (modified)	1 October 1999, as modified by USACE Sketches S-9 through S-13, dated Mar 2002	Reinforced Concrete Box	Eglin AFB	17-Apr-02	7-Bar
	This design reflects a modified version of 421-80-06, which had been considered as a 7-Bar ECM until its structural rating was downgraded to undefined due to deficiencies in the door design. The orginal standard had inadvertently incorporated the wrong double door design. The door from the donor magazine was used rather than the acceptor magazine used to valdiate the design. The modified version corrected this error. Modified 421-80-06 meeting the requirements of DDESB memo of 17Apr 2002, and modified per USACE sketches S-9 through S-13, are considered 7-Bar ECM. Internal dimensions are 24 ft wide by 20 ft minimum length to 80 ft maximum length by 11 ft high. The front wall consists of two hinged doors, each measuring approximately 12 ft wide by 11 ft high. This design has been superseded by 421-80-07.					
57	422-264-001	1-Aug-93	Reinforced Concrete Stradley	USACE, Omaha District	26-Feb-80	7-Bar
	Constructed at Whiteman AFB, MO. This design is based on Air Launched Cruise Missile(ALCM) Igloo AW 33-15-01 and is a double-headwall (flow-through) design with double (2) sliding doors on each headwall. The design provides 7-Bar protection. A 26 Feb 1980 DDESB letter approved AW 33-15-01 as a typical layout for ALCM storage and considered this design equal to a standard ECM. Internal dimensions are 40 ft wide by 112 ft long by 18 ft 6 inches high along the longitudinal centerline. Each of the sliding doors measures 18 ft 10 inches long by 13 ft 7-5/8 inches high.					
58	4374567 through 4374578	UNK	M-Type Reinforced Concrete Box	NAVFACNAVFAC, Atlantic Division	1-Dec-99	7-Bar
	This design superseded the inital M-Type magazine design constructed at NWS Seal Beach, CA (see 8027514 through 8027532). The DDESB approved the modified Type M magazine as a “default,” 7-bar structure for storage of up to 350,000 lbs of HD 1 .l explosives and approved the siting of 14 Type M (modified) magazines at WPNSTA, Yorktown. The proposed modification increased the ceiling height by 4 ft and upgraded the magazine's foundation to carry the additional weight of the increased height. Two of the 14 ECMs constructed have foundations with slightly less carrying capacity. This is because their construction was started as the Type M design was evolving.					
59	5167368 through 5167413	21-Aug-87	Reinforced Concrete Arch	NAVFAC	6-May-85	7-Bar
	This is a magazine design developed for storage of Trident rocket motor storage at Kings Bay, GA. The headwall/door design from this magazine was also used to upgrade existing Huntsville-type (drawings 1012 through 1014) constructed at Camp Navajo (formerly Navajo Ammunition Depot), see NAVFAC Drawings 8150953 through 8150971. This same design is shown in NAVFAC drawing numbers 5125093 through 5125142, dated 22					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
	August 1985.					
60	627954 thr 627957, 751861, 764597, 793747	5-Apr-54	Reinforced Concrete Arch, Type 1	Bureau Y&D	7-May-54	7-Bar
	Listed in 1954 DDESB minutes as Standard ECM. This design was an original Bureau Y&D Standard. The 1 Dec 55 ASESB QD Standards listed ECM 627954 through 627957 as a Standard ECM for storage of NEW up to 500,000 lbs. A 185-ft separation distance was required from other magazines. Bureau Y&D Drawing 817104 provides general information regarding this ECM and was used for planning purposes.					
61	6448522 through 6448554	27-May-97	Reinforced Concrete Box, Type D	NAVFAC	UNK	7-Bar
	This design superseded NAVFAC 1404465 through 1404478. Internal dimensions are 50 ft deep by 158 ft 8 inches wide by 13 ft 8 inches (rear of magazine) to 15 ft 10 inches (front of magazine) high. Five (5) entrances are provided on the headwall. Each of the 5 sliding doors measures 26 ft 3 inches wide by 12 ft high. Sited for 350,000 lbs NEW. DDESB approval signature of 30 Jun 87 on original drawings. Sited for 350,000 lbs NEW. DDESB memo of 2 February 2006 approved an increase of the maximum, allowable NEW to 500,000 lbs of HD 1.1. This design has been superseded by NAVFAC 14021368 through 14021404 and 14021406 through 14021444.					
62	6448555 through 6448588	27-May-97	Reinforced Concrete Box, Type D (HSILS)	NAVFAC	UNK	7-Bar
	Sited for 350,000 lbs NEW. This design is identical to NAVFAC 6448522 through 6448554 (superseded by 14021368 through 14021404 and 14021406 through 14021444), Box Type D, except that it incorporates a High Security Integrated Locking System (HSILS). DDESB memo of 2 February 2006 approved an increase of the maximum, allowable NEW to 500,000 lbs of HD 1.1.					
63	6448589 through 6448621	27-May-97	Reinforced Concrete Box, Type F	NAVFAC	2-Feb-06	7-Bar
	Supersedes NAVFAC 1404541 through 1404555. Internal dimensions are 50 ft deep by 158 ft 8 inches wide by 13 ft 8 inches (rear of magazine) to 15 ft 10 inches (front of magazine) high. Five (5) entrances are provided on the headwall. Each of the 5 sliding doors measures 17 ft 6 inches wide by 12 ft high. Sited for 350,000 lbs NEW. DDESB approval signature of 30 Jun 87 on original drawings. Sited for 350,000 lbs NEW. Sited for 350,000 lbs NEW. DDESB memo of 2 February 2006 approved an increase of the maximum, allowable NEW to 500,000 lbs of HD 1.1.					
64	64990	varies	Reinforced Concrete Box	USACE, Mobile District	9-Apr-10	7-Bar
	The number given under the Drawing Number column reflects the project number only. For actual drawing numbers associated with this design, refer to the DDESB approval memo. Constructed at Eglin AFB, Special Forces Complex. Approximate internal dimensions are 12 ft 6 inches wide by 20 ft long by 11 ft high. There is no headwall and the door spans the front opening.					
65	6521000 through 6521010	19 Feb & 23 Mar	Reinforced Concrete	OCE	12-Jul-90	7-Bar if proper

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019						
#	**Drawing Number**	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
		42	Dome			spacing provided, See Comment and Note.
	Called a Corbetta, Beehive, or Dome Magazine. At a 23 Feb 1942 meeting, the Joint Army and Navy Board of Ammunition Storage (predecessor of ASESB) approved the Corbetta Magazine as an alternate type magazine (i.e., Non-Standard). A 12 Jul 90 DDESB ltr approved a 27 Nov 89 USACE ltr, requesting approval to modify doors on Corbetta Type ECM at Volunteer Army Ammunition Plant (AAP) and Holston AAP. Once modified, each ECM can be sited for 500,000 lbs NEW, provided the conditions of the note below were met. If they cannot be met, then the ECM must be treated as a non-standard. NOTE: A Corbetta-type ECM is considered as “Undefined” because its door is inadequate to prevent explosion communication. However, in 1990, the DDESB approved two improved door designs for installation onto Corbetta-type ECM. If modified with the new doors, and provided they meet minimum separation distances of 400 ft, side-to-side or rear-to-front exposures between the donor and acceptor ECM and (K11) front-to-front exposures between the donor and acceptor ECM, then storage of up to 500,000 lbs (226,796 kg) NEW of HD 1.1 is permitted in modified Corbetta-type ECM.					
66	658384 through 658388, modifications 724368, 764596, and 793746	23-Nov-54	Reinforced Concrete Arch	Bureau Y&D	9-May-84	7-Bar
	Listed in 1954 DDESB minutes as Standard ECM. This design was an original Bureau Y&D Standard. The 1 Dec 55 ASESB QD Standards listed ECM 658384 through 658388 as a standard ECM for storage of NEW up to 500,000 lbs. A 185-ft separation distance was required from other ECM. Superseded by NAVFAC Drawings 1404310 through 1404324. Bureau Y&D Drawing 817103 provides general information regarding this ECM and was used for planning purposes.					
67	*718313401 through 718313405	21-Jul-41	Reinforced Concrete Arch	OQMG	10-Dec-04	7-Bar
	Approved as 7-Bar ECM based on DDESB review of 25 February 1998 Huntsville District, Corps of Engineers evalaution of the design that determined it was similar to 652-686 through 652-692. These design was constructed at Milan AAP.					
68	725738 through 725746	9-Sep-56	Reinforced Concrete Stradley	Bureau Y&D	Acceptance based on USACE analysis	7-Bar
	CEHNC memo (CEHNC-ED-CS-S (210-2b) of 27 June 2002, Subject: 7-Bar Magazines, states that the magazines constructed to this drawing at Moron Air Base, Spain, are 7-Bar ECM. The basis for their determination is that this design is identical to 33-13-02, which is a 7-Bar design.					
69	7978204 through 797231	16-Mar-06	Reinforced Concrete Box	NAVFAC	19-Apr-07	7-Bar

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
	Known as the the Type S ECM and designed by the GOJ. The nominal interior dimensions of the storage-bay are 50 ft long by 32 ft wide by 16 ft tall. Access is provided through a single 16 ft wide by 11 ft tall opening in the headwall. This design is rated for a maximum allowable NEW of 500,000 lbs HD 1.1.					
70	7982660 through 7982747	19-Sep-06	Reinforced Concrete Box	NAVFAC	4-Jan-07	7-Bar
	The subject site plans were originally approved for construction of the 7-bar MSM, USACE Drawing 421-80-06, dated 1 October 1999, Sheets S-1 through S-8, Sheets S-14 through S-18, E-1, E-2, and USACE sketches (Air Force MSM, Box-Type, dated March 2002) S-9 through S-13. This design upgraded the design to meet seismic requirements for construction at Anderson AFB, Guam. This designed is referred to as the P-3 105 Version of the MSM. A complete description of the design can be found in NAVFAC ESC Memorandum of 29 September 2006, Subject: Blast Analysis of Modular Storage Magazine Modification Andersen Air Force Base, Guam, with Enclosure “Blast Analysis of Modular Storage Magazine Modification Andersen Air Force Base, Guam,” SSR-3 144-SHR Revision (A), September 2006.					
71	7986314 through 7986342	23-Apr-07	2-Bay, Reinforced Concrete Box with NPW	NAVFAC	13-Sep-07	7-Bar
	Known as the Type HP-2B ECM and designed by the GOJ. The Type HP-2B magazine has two storage-bays separated by a 22-ft thick NPW. The nominal interior dimensions of each storage-bay are 50 ft long by 32 ft wide by 16 ft tall. Access to each storage bay is provided through a single 16-ft wide by 11-ft tall opening in the headwall. Approved by the DDESB (with conditions for use) at MCAS Iwakuni, Japan only, for storage up to 45,000 lbs NEW, dependent on SG being stored in the bays. Refer to DDESB Memorandum. The Japan Maritime Self-Defense Force (JMSDF) Type HP-2B version is identical.					
72	7988502 through 7988531	7-Dec-07	Reinforced Concrete Box	NAVFAC	22-Apr-08	7-Bar
	Known as the Type L ECM and designed by the GOJ. The Type L magazine is a single-bay magazine with nominal interior dimensions of 96 ft wide by 50 ft long by 16 ft tall. The roof is supported by two interior columns. The headwall is nominally 96 ft wide. Access to the magazine is provided by three 25 ft wide by 11 ft tall openings in the headwall. The GOJ used NAVFAC Drawing Nos. 1404430 through 1404444 for guidance in their design of the Type L magazine NAVFAC ESC SSR-3247-SHR, “Blast Analysis of the Type L Magazine MCAS Iwakuni Japan,” of January 2008 documents the blast analysis of the design. The L-Type design was approved by the DDESB at MCAS Iwakuni, Japan only, for storage up to 45,000 lbs NEW.					
73	8027514 through 8027532	1990	Reinforced Concrete Box	NAVFAC SW Division	9-Apr-93	7-Bar
	Initial M-Type Navy magazine designed for and constructed at NWS Seal Beach, CA as part of MILCOM P-137. Approved as a site-adaptable magazine with a maximum NEW of 350,000 lbs NEW. Subsequently modified and constructed at NWS Yorktown. Replaced by NAVFAC Drawings 10400001 through 10400027 for new construction.					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019

#	Drawing Number	Drawing Date	Description	Design Agent	DDESB Approval Date	ECM Designation
74	FE-8101 (Modified)	1-May-10	Reinforced Concrete Arch	US Army Garrison-Redstone Arsenal, AL	24-Jun-10	7-Bar
	This ECM is considered a 7-Bar ECM structure when modified in accordance with DDESB approved drawings D-5732 (Sheets 3 through 8), which can be applied to any ECM that has an interior width at the floor slab of 26 ft 6 inches and an interior height above the floor slab (at the center of the arch) of 12 ft 9 inches. DDESB approval is only applicable to Redstone Arsenal, AL. The modification replaces the headwall and door to meet 7-Bar requirements.					
75	8150917 through 8150988	19 October 2002 (final)	Reinforced Concrete Arch	NAVFAC	26-Dec-96	7-Bar
	As part of FY 2001 MILCON Project P-114, this design modified eight existing Undefined ECM built in the 1940s timeframe (Huntsville Type 652-1012 through 652-1014, with inadequate headwall reinforcing steel) by replacing their headwalls and doors with those that met 7-Bar criteria. This occurred at Army National Guard Training Site, Camp Navajo, AZ. The new headwall and door, a single sliding door, are similar to NAVFAC headwall and door designs (drawings 5167380 through 5167413) previously approved by DDESB at SUBASE Kings Bay, SC.					
76	AF Segregated ECM Design	See Note in Comments	Reinforced Concrete Box	USACE, Mobile District	9-Apr-10	7-Bar, See Comment
	Each reinforced concrete box type ECM has internal dimensions of approximately 12 ft wide by 19 ft long by 11 ft high. The NEW in a singly constructed Segregated ECM will not exceed 30,000 lbs); when three Segregated ECMs are constructed in accordance with Drawings S-S0l and S-S02 to share a common head wall, the maximum NEW in each ECM will be 10,000 lbs NEW; if three Segregated ECMs are constructed in accordance with the expansion joint details of Drawings S-S01 and S-S02 but with a larger side-to-side separation distance between each ECM, the maximum NEW in each ECM will satisfy the minimum Kl.25 side-to-side separation distance between ECM side walls but will not exceed 30,000 lbs. Drawing dates vary. NOTE: Drawing dates vary within the approved set. Approved sheets and associated drawing dates are as follows: A-01 (dated 1/09), A-03 (dated 1/09), A-04 (dated 1/09), S-01 (dated 12/08), S-101 (dated 12/08), S-201 (dated 12/08), S-301 (dated 2/10), S-302 (dated 2/10), S-401 (dated 12/08), S-402 (dated 12/08), S-501 (dated 2/10), S-502 (dated 2/10), E-101, revision 1 (dated 3/10), E-102 (dated 1/09).					
77	B3325 Ready Magazine	24-Jun-08	Reinforced Concrete Box	NAVFAC	25-Aug-08	7-Bar
	Five of these magazines were constructed at NSWC Crane, Indiana, in a unique design that incorporates parts from a number of other 7-Bar designs: (a) The ECM is the same width and height as the original MSM (interior dimensions of 25 ft wide by 11 ft high). The interior length is 96 ft (vice the maximum length of 80 ft as allowed in the original MSM design). (b) The ECM doors will be those approved for the 7-bar version of the 11-ft high MSM design (identified in TP-15 as “421-80-06 (modified).” (c) The side and back wall panel characteristics are most similar to the “421-80-06 (modified)” design. The roof panel characteristics are most similar to the 14-ft high MSM design approved for Hill AFB (identified in TP-15 as “Modular Storage Magazine (MSM).” (d) The connections between the roof panels, between the roof and wall panels, and between the wall panels and foundation, were modified as					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019						
#	**Drawing Number**	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
	approved for Guam (Andersen AFB drawings 7982660 through 7982747) to meet seismic requirements. A topping slab was also added as approved for Guam, but the thickness of the slab is greater, and it will be sloped to aid in water drainage. (e) The front ventilator in the original MSM design (which exited via the side wall and vented vertically) was replaced with two vents (one from each side wall that now vent out of the wing walls) using the ventilator design from the Navy Type-E ECM. The rear ventilator in the original MSM design (which exited via the rear wall and vented vertically) was replaced using the ventilator design from the Navy Type-E ECM (which exits via the real wall and vents vertically). (f) The multiple air terminal system in the original MSM design was replaced with the design from the Navy Type-E ECM, which has only a single air terminal on the rear ventilator.					
78	High Performance Magazine (HPM)	Jan-00	Reinforced Concrete Box (multi-cell)	NAVFAC	27-Jan-00	7-Bar
	Additional information on the Navy's HPM can be found in paragraph 2.3.14. The HPM design concept was granted DDESB approval as a 7-Bar magazine during the 319th Board Meeting of 27 January 2000. A preliminary design document, dated 3 July 2001, is available from NAVFAC. The HPM consists of four separate ordnance storage bays that are treated as independent magazines (i.e., independent MCE). Each storage bay can store up to 30,000 lbs of NEW. Each bay can optionally be subdivided into two separate storage areas with the use of the "Re-locatable" Modular Wall. Each subdivided storage area can also store up to 30,000 lbs of NEW, thereby increasing the total storage capacity of the HPM. The separation of the storage bays or subdivided storage areas also allows for the storage of incompatible ordnance in adjacent bays. The maximum storage capacity of a HPM with no subdivided bays is 120,000 lbs NEW. If all four bays are subdivided, the maximum storage capacity is 240,000 lbs NEW.					
79	Incirlik, Turkey (Cephane Deposu) ECM	UNK	Modifed Reinforced Concrete Stradley	UNK	4-May-96	3-Bar
	DDESB letter of 4 May 1999 identifies this magazine as being located at Incirlik AFB, Turkey. Its blast door was determined to be incapable of providing 7-Bar protection, although the magazine arch and headwall were designed to meet 7-Bar criteria. Dr. Canada of the DDESB evaluated the strength of this ECM design located at Incirlik AFB.					
80	Incirlik Turkey ECM	UNK	Reinforced Concrete Arch	UNK	4-May-96	3-Bar
	DDESB letter of 4 May 1999 identifies four ECM (1995, 2059 (Modified NATO-16), 2323, and 2327) as being located at Incirlik AFB, Turkey. These four ECM were evaluated by Dr. Canada of the DDESB and determined to be as follows: 2059 and 2323 are 3-Bar ECM, and 1995 and 2327 are 7-Bar ECM. The blast doors of the 3-Bar ECM were determined to be incapable of providing 7-Bar protection, although the magazine arch and headwall were designed to meet 7-Bar criteria.					
81	Lone Star AAP ECM	UNK	Reinforced Concrete Arch	UNK	13-Jul-99	3-Bar
	A 23 Sep 89 site visit to Lone Star, by Adib Farsoun of the Huntsville Division, Corps of Engineers (Code CEHND-ED-CS) concluded that the Lone Star magazines were almost equivalent to standard ECM design 33-15-06 with one exception: 33-15-06 had a double leaf door as compared to a single leaf door on the Lone Star magazines. In addition, magazines are sited 400 ft apart. On this basis, DDESB determined that magazines					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019						
#	**Drawing Number**	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
	equivalent to those at Lone Star AAP may be treated as 3-Bar magazines and are authorized to contain up to 500,000 lbs NEW OF HD 1.1.					
82	MSM	May-02	Reinforced Concrete Box	Hill AFB	11-Jul-02	7-Bar
	This 14-ft ceiling height MSM design was developed for construction of magazines 2580 and 2581 at Hill AFB, Ogden, Utah, and is basically a larger version of the MSM (11-ft ceiling height) shown on Drawings 421-80-06 (Undefined) and 421-80-06 (modified) (7-Bar). Internal dimensions are 24 ft wide by 14 ft high by 80 ft long. A total of 40 MSM (14 ft) are planned to be constructed at Hill AFB. Two have been constructed at RAF Lakenheath, United Kingdom, with drawings converted to metric (DDESB-PE memorandum of 5 April 2006, Subject: Expeditious Final Approval Request, Construct Explosives Operating Location and Two Earth-Covered Magazines, RAF Lakenheath, United Kingdom (USAFE-Lakenheath 04-S5 through S7)). This design has been superseded by 421-80-08.					
83	Munitionslagerhause (MLH) 25	UNK	Reinforced Concrete Portal Type	German	2-Dec-77	7-Bar
	DDESB determined that MLH 25, MLH 90, and MLH 180 ECM designs could be equated to a standard igloo. Construction of 19 of these magazines was approved for Forward Storage Site (FSTS) Ottrau, Germany. Maximum explosives limit assigned to this ECM design, as a standard magazine was 82,753 lbs (37,536 kg). The Ottrau ECM were separated at 82 ft (25 m) (side-to-side).					
84	Munitionslagerhause (MLH) 30	UNK	Reinforced Concrete Box	German	18-Aug-87	7-Bar
	Approval was on the basis of the 12 Dec 77 DDESB letter that determined the MLH design could be equated to a standard ECM. Separation distances were d=1.25W1/3 (side to side) and d=2.00W1/3 (front to rear), which were used at the time to site standard magazines. Approved maximum limit for this design is 171,884 lbs (77,965 kg). The minimum side to side distance used was 82 ft (25 m). The site plan to construct 20 magazines at FSTS Seckach (Kuelsheim), GE was approved.					
85	Munitionslagerhause (MLH) 50	UNK	Reinforced Concrete Box	German	10 Feb 82 & 18 Aug 87	7-Bar
	DDESB approved the construction of seventeen MLH 180, six MLH 90, and three MLH 50 at FSTS Grebenhain, Germany. Approval was on the basis of the 12 Dec 77 DDESB letter that determined the MLH design could be equated to a standard ECM. Separation distances were d=1.25W1/3 (side to side) and d=2.00W1/3 (front to rear), which were used at the time to site standard magazines. Approved maximum limit for this design is 171,884 lbs (77,965 kg). The minimum side to side distance used was 82 ft (25 m).					
86	Munitionslagerhause (MLH) 60B	UNK	Reinforced Concrete Box	German	18-Aug-87	7-Bar, See Comment section.
	NATO explosives safety standards limit this magazine to an NEQ of HD 1.1 of 165,000 lbs 75,000 kg (165,000 pounds NEW). For siting at U.S. installations, where encumered land is completely within U.S.-owned or -controlled property, an explosives limit of 250,000 lbs NEW can be used for siting purposes. Considered a standard (7-Bar) ECM for sitings involving 165,000 lbs NEW or less.					

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019						
#	**Drawing Number**	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
87	Munitionslagerhause (MLH) 90B	UNK	Reinforced Concrete Box	German	12 Dec 77/18 Aug 87	7-Bar, See Comment section.
	See comment in row 85.					
88	Munitionslagerhause (MLH) 90S	UNK	Steel, Oval Arch	German	12 Dec 77/18 Aug 87	7-Bar, See Comment section.
	See comment in row 85.					
89	Munitionslagerhause (MLH) 180B	Jul-88	Reinforced Concrete Box	German	12 Dec 77/18 Aug 87	7-Bar, See Comment section.
	See comment in row 85.					
90	Munitionslagerhause (MLH) 180S	Sep-76	Steel, Oval Arch	German	12 Dec 77/18 Aug 87	7-Bar, See Comment section.
	See comment in row 85.					
91	Munitionslagerhause (MLH) 148, Dwg 41214	16-Feb-87	Reinforced Concrete Box	German	28-Jun-88	7-Bar, See Comment section.
	NATO explosives safety standards limit this magazine to an of HD 1.1 NEW=165,000 lbs (NEQ of 75,000 kg). For siting at U.S. installations, where encumered land is completely within U.S.- owned or -controlled property, an explosives limit of 250,000 lbs NEW can be used for siting purposes. Considered a standard (7-Bar) ECM for sitings involving 165,000 lbs NEW or less.					
92	Volkel (Netherlands)	UNK	Reinforced Concrete Stradley	Netherlands	31-Mar-99	7-Bar
	DDESB letter of 31 March 1999 determined that the ECM in Block A at Volkel Air Base (Netherlands) met the criteria of 7-Bar ECM, based on an evaluation of Dr. Canada of the DDESB. The Strengths of the ECM in Blocks B and C could not be determined due to insufficient information.					
93	RAF Base, Welford, UK, 200 Series ECM (Drawing #859249)	see comments	Reinforced Concrete Box	UK	22-Apr-10	7-Bar
	The DDESB approval memo addresses 200 and 600 Series ECM located at RAF Base Welford, UK. Approval is based on structural analysis by USACE-Huntsville. The 200 Drawings are dated October 1986. They have a double sliding leaf door. Twelve 200 series ECMs were considered in the analysis. The allowable NEW of the 200 Series ECMs was reduced to ensure 7-Bar protection to adjacent 200 Series ECMs. Refer to the DDESB approval memo for additional details.					
94	RAF Base, Welford, UK, 600 Series ECM (Drawing #747360)	see comments	Reinforced Concrete Box	UK	22-Apr-10	7-Bar

Table AP1-2. 7- and 3-Bar ECM No Longer Used for New Construction But Still in Use, June 2019						
#	**Drawing Number**	**Drawing Date**	**Description**	**Design Agent**	**DDESB Approval Date**	**ECM Designation**
	The DDESB approval memo addresses 200 and 600 Series ECM located at RAF Base Welford, UK. Approval is based on structural analysis by USACE-Huntsville. Drawings are dated 1975 to 1976. The 600 Series ECMs have a hinged double leaf door. Five 600 series ECMs were considered in the analysis. Refer to the DDESB approval memo for additional details.					
95	RAF Base, Lakenheath, UK	see comments	various - see comments	UK	5-Apr-06	7-Bar
	As part of a project to build 2 new 14-ft MSM (Modified 421-80-06) ECM at RAF Lakenheath, CEHNC performed structural analyses of existing ECM in Areas 1 and 2 to determine their structural hardness for siting purposes. Area 1 consisted of 2 ECM types – a reinforced concrete flat roof and a reinforced concrete arch; while Area 2 contained only a flat-roof ECM. Based on the assessment, the Area 1 ECM are considered as 7-Bar with allowable, maximum NEW of 363,000 lbs HD 1.1 (HNC-ED-CS-S-05-02, Rev 1, July 2005). The ECM in Area 2, is also considered a 7-Bar ECM for an allowable, maximum NEW of 100,000 lbs HD 1.1 (HNC-ED-CS-S-06-1 March 2006). Refer to DDESB-PE memo of 5 April 2006 for specific requirements/conditions.					

AP1.3. TABLE AP1-3. Table AP1-3 presents current data on undefined ECM. Note that:

- Each line represents a separate ECM design. This listing identifies ECM designs that were approved as either “Non-standard” or “Undefined,” and also includes those ECM designs for which no documentation could be found to support a structural designation other than “Undefined.” Where UNK appears in the table, it indicates that no information was found for that particular field.

- “Undefined” ECM are currently permitted to store up to 500,000 lbs NEW of HD 1.1. Before 1992, a Non-standard ECM was only permitted to store a maximum of 250,000 lbs HD 1.1. Note that previously approved ECM site approvals, for NEW not exceeding 250,000 lbs remain valid. However, a DDESB site approval is required for any increase beyond 250,000 lbs HD 1.1.

- Assignment of an ECM to this table does not necessarily mean that it cannot provide 7-Bar or 3-Bar protection. A number of the magazine designs listed could potentially be capable of providing 7-Bar or 3-Bar protection; however, their structural strengths have never been validated through analysis or testing.

Table AP1-3. Undefined ECM, June 2019

#	Drawing Number	Drawing Date	Description	Designer	DDESB Review Date (if known)
1	104260 & 104261	15-Jul-27	Reinforced Concrete Arch	Bureau Y&D	2004
	DDESB review of drawing observed that headwall is only 6 inches thick and that 4-inch by 4-inch wire mesh was used for reinforcement in the headwall. Treat as Undefined ECM. The door is identified as metal covered and a large ventilator is mounted in the headwall over the door. The drawing shows the magazine was constructed at Naval Mine Depot, Yorktown, VA, which is now called NWS Yorktown. An analysis of the stresses on the arch (from dead loads and blast loads) is provided by Bureau Y&D Drawing 104714.				
2	107368	20-Apr-29	Reinforced Concrete Arch	Bureau Y&D	2004
	DDESB review of drawing observed that headwall is only 6 inches thick and that 4-inch by 4-inch wire mesh was used for reinforcement in the headwall. Treat as Undefined ECM. The drawing shows the magazine was constructed at NAD, Hawthorne, NV, which is now an Army Ammunition Depot.				
3	110-25-64	1-May-42	Reinforced Concrete Arch	USACE, Sacramento Office	2004
	Constructed at Sierra Ordnance Depot, Hackstaff, CA. Drawings are marked to indicate the drawing set superseded 652-686 through 652-689 (see below). Drawings show a 10-inch thick headwall and 6-inch by 6-inch wire mesh reinforcing.				
4	130445	5-Jan-39	See Comments	Bureau Y&D	2004
	This is a variation of a reinforced concrete box ECM. The side walls are vertical for approximately 13 ft at which point the roof begins sloping towards the peak at slightly angle. Hoists and racks are provided for moving and storaging warheads. The door consisted of a steel plate. DDESB review of drawing observed that headwall is only 6 inches thick and that 4-inch by 4-inch wire mesh was used for reinforcement in the headwall. Site as an AGM. The drawing shows the magazine was constructed at NAD, Hawthorne, NV, which is now an Army Ammunition Depot.				
5	133959	18-Nov-39	Reinforced Concrete Arch	Bureau Y&D	4-Apr-84
	Headwall is 6 inches thick and uses 4-inch by 4-inch mesh steel for reinforcement. Treat as Undefined.				
6	142199	31-Jul-40	Reinforced Concrete Arch	Bureau Y&D	2004
	DDESB review of drawing observed that headwall is only 6 inches thick and that 4-inch by 4-inch wire mesh was used for reinforcement in the headwall. Treat as Undefined ECM. The drawing shows the magazine was constructed at NAD, Hawthorne, NV, which is now an Army Ammunition Depot.				
7	157457	12-Apr-41	Reinforced Concrete Arch	Bureau Y&D	2004
	DDESB review of drawing observed that headwall is only 6 inches thick and that 4-inch by 4-inch wire mesh was used for reinforcement of the headwall. Treat as Undefined ECM. Drawing indicates that this design was constructed at U.S. Naval Air Station Banana River, FL, which is now called NAS Key West.				
8	158632	UNK	UNK	Bureau Y&D	20-Jun-84

#	Table AP1-3. Undefined ECM, June 2019				
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**DDESB Review Date (if known)**
	DDESB letter of 20 June 1984 determined the magazine could not be considered a standard magazine because its construction was not equivalent to a standard magazine.				
9	163582 & 163583	23-May-41	Reinforced Concrete Box	Bureau Y&D	11-May-53
	Known as the Keyport Magazine. 128th (4 May 1953) and 129th (11 May 1953) ASESB minutes discuss the Keyport Magazine to great length. The 129th ASESB unanimously passed a motion to permit the Keyport Magazine to be sited for 4,000 lbs NEW with a minimum 30-ft separation distance (center to center) between Keyport Magazines. Greater separation distances would be required, if there is an unbarricaded front exposure.				
10	G165-177 & 178	20-Jan-53	Reinforced Concrete Arch	Bureau Y&D	12-Apr-02
	A 12 April 2002 e-mail from CEHNC informed DDESB that this design,located at Andersen AFB, Guam, is an Undefined structure due to the weakness of the headwall and door. Steel mesh was used vice reinforcing steel, similar to the Huntsville magazines built during WWII due to steel shortages.				
11	173658	3-Sep-41	Reinforced Concrete Arch	Bureau Y&D	2004
	DDESB review of drawing observed that headwall is only 6 inches thick and that 4 by 4 wire mesh was used for reinforcement in the headwall. Treat as Undefined ECM. The drawing shows the magazine was constructed at NAD, Hawthorne, NV, which is now an Army Ammunition Depot.				
12	187407 & 187408	UNK	UNK	Bureau Y&D	9-May-84
	The 9 May 1984 DDESB approval letter provided an NEW rating of only 250,000 lbs. Treat as an undefined ECM.				
13	209854 & 209855	24-Jun-42	Reinforced Concrete Arch	Bureau Y&D	UNK
	This ECM measures 25 ft wide by 50 ft long. Its internal height is 12 ft 2 inches. Known to have been constructed at Crane Army Ammunition Plant.				
14	217867	14-Sep-42	Reinforced Concrete Arch	Bureau Y&D	2004
	Headwall is 6 inches thick and uses 4 by 4 wire mesh for reinforcement. Constructed at Hawthorne Army Ammunition Plant. Treat as Undefined.				
15	217869	14-Sep-42	Reinforced Concrete Arch	Bureau Y&D	4-Apr-84
	Headwall is 8 inches thick and uses 4 by 4 wire mesh for reinforcement. Constructed at Hawthorne Army Ammunition Plant. Treat as Undefined.				
16	226166	UNK	Reinforced Concrete Box	Bureau Y&D	UNK
	This design is for a 144 ft^2 Fuze and Detonator Magazine. The design drawing specifies only 18 inches of soil cover. Current explosives safety criteria call for a minimum of 24 inches of earth cover. A magazine constructed to this drawing must be treated as an AGM. Bureau Y&D Drawing 817112 provides general details for this magazine and was used for planning purposes.				
17	33-03-01	9-Apr-81	Reinforced Concrete FRELOC Stradley	USACE, Savannah District	14-Apr-94

Table AP1-3. Undefined ECM, June 2019

#	Drawing Number	Drawing Date	Description	Designer	DDESB Review Date (if known)
	A 2 March 1994 USACE Huntsville District letter determined that the basis for the 33-03-01 magazine design was standard magazine design 33-15-74, however, modifications were made which caused any ECM constructed in accordance with Drawing 33-03-01 to be considered non-standard.				
18	33-03-04	UNK	Reinforced Concrete Arch	UNK	4-May-99
	DDESB letter of 4 May 1999 identifies this magazine as being located at Incirlik AFB, Turkey and belonging to WSA Security. Its blast door was determined to be incapable of providing 7- or 3-Bar protection, although the magazine arch and headwall were designed to meet 7-Bar criteria.				
19	33-03-43	1-Apr-76	Steel Arch	USACE, Europe District	11-May-83
	A 6 December 1982 Dept of Army, HQ, 21st Support Command (Subject: Proposed Construction of New Magazines at Larson Barracks, Kitzingen, Germany) called for the construction of 6 of these magazines. This letter also stated that DDESB-KO approval was granted on 19 April 1976, for construction of EUD-33-03-43 magazines at QRS Bindlach, Germany. The 19 April 1976 DDESB letter has not been located. These magazines were sited at a side-to-side separation distance of 0.5Q1/3 (equates to K1.25). This separation was applicable to standard ECM and to non-standard ECM (for NEWs less than 250,000 lbs HD 1.1.) Treat as an undefined ECM, until receipt of additional information to support some other designation.				
20	33-11-0002	27-Feb-84	Steel Arch	USACE, Japan District	UNK
	This design was constructed at Misawa Air Base, Honshu, Japan. Not all drawings available, but available details appear to be similar to 33-15-63 design.				
21	33-15-01	27-Dec-41	Reinforced Concrete Arch	OCE	29-Oct-02
	This design is different from magazine design AW 33-15-01 and 33-15-01 (USACE Omaha District), listed in Table AP1-2 of TP 15. A 1950 document, which describes the history of magazines from pre-1928 to 1950, identified this magazine design as having an unreinforced steel door which had questionable blast resistance capability. Superseded by 33-15-06 of 1 August 51. Drawing 33-15-62 (13 June 1960) increased door size. An additional issue is that the headwall construction used steel mesh vice reinforcing bars, which was characteristic for that period due to steel shortages. CEHNC e-mail of 29 Oct 2002 to the DDESB identifies headwall design shortcomings and the need to classify the ECM as Undefined.				
22	33-15-01	10-Jan-52	Reinforced Concrete Arch	USACE, Louisville District	UNK
	Constructed at Bluegrass Ordnance Depot. Based on the above information for the 33-15-01 design, and the fact that the first page of the package indicates that it is based on 33-15-06, it's possible an analysis may demonstrate that this ECM could meet 7-Bar criteria.				
23	33-15-01	2-Sep-52	Reinforced Concrete Arch	USACE, Seattle District	UNK
	This drawing number was assigned to an ECM design constructed at Ft Lewis, Washington. Each drawing indicates it was based on OCE 33-15-04, a design whose structural hardness has not been analyzed. This design measures 26 ft wide by 60 ft long and has 2 4-inch thick hinged doors, spanning a 8 ft 6 inches by 8 ft 6 inches opening. The door and headwall would need to be analyzed to determine their structural hardness.				
24	E 33-15-02	UNK	UNK	UNK	UNK

#	Drawing Number	Drawing Date	Description	Designer	DDESB Review Date (if known)
	Table AP1-3. Undefined ECM, June 2019				
	This design was identified in a 29 January 1968 study entitled "A Standard System for Type Classification of Explosives Storage Magazines" as a Type C magazine (i.e., substandard ECM). This design requires a technical analysis on a case-by-case basis to determine the structural hardness of its door(s) and headwall.				
25	E 33-15-03	UNK	UNK	UNK	UNK
	See the comment in row 24.				
26	E 33-15-04	UNK	UNK	UNK	UNK
	See the comment in row 24.				
27	DEF-E-33-15-04	29 May 51, Revised 1 Oct 51	Reinforced Concrete Arch	USACE, Los Angeles District	UNK
	No additional information is available.				
28	EUD 33-15-05	UNK	Reinforced Concrete FRELOC Stradley	USACE, Europe District	UNK
	A 10 April 1979 DDESB Telephone Record states that EUD drawing 33-15-05 is said to be the same as the Standard FRELOC, 33-15-13, except that the footings are similar to those of a steel arch magazine, will be submitted through channels for consideration as a standard magazine. No record was found to show that this was ever accomplished.				
29	33-15-07	UNK	UNK	UNK	UNK
	See the comment in row 24.				
30	33-15-08	UNK	UNK	UNK	UNK
	See the comment in row 24.				
31	E 33-15-09	UNK	UNK	UNK	UNK
	See the comment in row 24.				
32	E 33-15-10	UNK	UNK	UNK	UNK
	See the comment in row 24.				
33	33-15-11 A	1-Sep-76	Reinforced Concrete FRELOC Stradley	USACE, Europe District	UNK

#	Table AP1-3. Undefined ECM, June 2019				
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**DDESB Review Date (if known)**
	No additional information is available. Design appears to be very similar to 33-03-31 design.				
34	AD 33-15-11 R2	29 Dec 61, Rev 2 dated 5 Jan 62	Reinforced Concrete Arch	AF	UNK
	This magazine was listed in a 1968 document, presented by a working group meeting to standardize magazine nomenclature, as a Type B (STD) magazine for Army and Air Force use. No documentation has been found to support anything other than an undefined designation.				
35	33-15-12	UNK	UNK	UNK	UNK
	See the comment in row 24.				
36	33-15-13	UNK	UNK	UNK	UNK
	See the comment in row 24.				
37	33-15-14	5-Sep-52	Steel Arch	OCE	UNK
	Has a width of 25 ft, an arch radius of 15 ft and could have 3 possible lengths: 40, 64, or 80 ft. The design has 2 hinged doors. This design was identified in a 29 January 1968 study entitled "A Standard System for Type Classification of Explosives Storage Magazines" as a Type C magazine (i.e., substandard ECM). This design requires a technical analysis on a case-by-case basis to determine the structural hardness of its door(s) and headwall. Drawings provided by Ft Bragg, NC.				
38	33-15-14	UNK	Modified FRELOC Stradley (Reinforced Concrete Arch)	USACE, Europe District	5-Dec-78
	This design represented a significant modification of standard ECM 33-15-13 (reduced reinforcement), and the DDESB determined it had to be considered a non-standard (undefined) until fully evaluated. No information was found to show an evaluation had ever been completed.				
39	33-15-19	UNK	Reinforced Concrete Arch	AF	29-Nov-84
	The DDESB determined this ECM could not be considered a standard ECM, because the headwall and doors were of weaker design than those of a concrete arch ECM that had been tested successfully. The DDESB review pertained to ECM located at Camp Edwards, Massachusetts, an Army National Guard Training Site.				
40	33-15-28	UNK	Steel Arch	USACE, Europe District	5-Aug-87
	This design was initially approved by the DDESB 11 May 1983, for construction at Larson Barracks, Kitzingen, Germany, with an NEW of 4,000 lbs and a side-to-side separation of K1.25. This separation was applicable to standard ECM and to non-standard ECM (for NEWs less than 250,000 lbs HD 1.1.) Project was subsequently modified to use ECM design 33-15-208, which was almost the same as design 33-15-28 with some minor modifications. Treat as an undefined ECM.				
41	AW 33-15-63	5-Mar-63	Steel, Semi-Circular Arch	OCE	19-Feb-64

Table AP1-3. Undefined ECM, June 2019

#	Drawing Number	Drawing Date	Description	Designer	DDESB Review Date (if known)
	Approved during 225th ASESB meeting of 19 Feb 64 as a standard magazine design. A 1 Apr 87 COEHQ letter stated that ECM design AW 33-15-63 was no longer being used for new construction. Drawing AW 33-15-63 had two designs shown on it. One is a traditional magazine with a single 12-inch thick reinforced concrete headwall, while the second is a design with two headwalls and doors (flow through design). USACE structural evaluation of AW 33-15-63 door in 2003 determined the door would not provide 7- or 3-Bar protection. See note under AW 33-15-63 of Table AP1-2.				
42	AW 33-15-64	10-May-63	Steel Arch	OCE	19-Feb-64
	Approved during 225th ASESB meeting of 19 Feb 64 as a standard magazine design. A 1 Apr 87 COEHQ letter stated that ECM design AW 33-15-64 was no longer being used for new construction. USACE structural evaluation of AW 33-15-64 door in 2003 determined the door would not provide 7- or 3-Bar protection. See note under AW 33-15-63 of Table AP1-2.				
43	33-15-65	10-Jan-63	Steel, Semi-circular Arch	OCE	19-Feb-64
	This ECM was available in four widths: 8 ft, 10 ft, 12 ft, and 14 ft. Approved during 225th ASESB meeting of 19 Feb 64. However, an 18 Dec 89 DDESB ltr identifies problems with this ECM being able to meet standard magazine criteria and states that USACE would be asked to redesign 33-15-65 to strengthen it. The DDESB letter further state that Drawings 33-15-74 or 421-80-01 should be used for new construction of Standard ECM. Based on headwall strength issue, allowable NEW limited to only 250,000 lbs.				
44	AD 33-15-67 R2	5/8/1964, Rev 2 dated 8 Mar 65	Steel, Semi-Circular Arch	AF	See Comments
	This ECM was required to be constructed in accordance with Drawing AW 33-15-63. A 13 Jan 1995 USACE, Huntsville District, ltr stated that since the design drawing calls for it to be constructed in accordance with a standard (7-Bar) design, then, by analogy, it also should be considered a standard. The design was added (at that time) to the magazine listing in DoD 6055.9-STD, based on the above USACE assessment. USACE structural evaluation of AW 33-15-63 door in 2003 determined the door would not provide 7- or 3-Bar protection. See note under AW 33-15-63 of Table AP1-2.				
45	AD 33-15-68 R2	5/8/1964, Rev 2 dated 8 Mar 65	Steel, Semi-Circular Arch	AF	See Comments
	This ECM was required to be constructed in accordance with Drawing AW 33-15-63. A 13 Jan 1995 USACE, Huntsville District, ltr stated that since the design drawing calls for it to be constructed in accordance with a standard (7-Bar) design, then, by analogy, it also should be considered a standard. The design was added (at that time) to the magazine listing in DoD 6055.9-STD, based on the above USACE assessment. USACE structural evaluation of AW 33-15-63 door in 2003 determined the door would not provide 7- or 3-Bar protection. See note under AW 33-15-63 of Table AP1-2.				
46	AD 33-15-69 R2	8-May-64	Steel, Semi-Circular Arch	AF	See Comments
	This ECM was required to be constructed in accordance with Drawing AW 33-15-63. A 13 Jan 1995 USACE, Huntsville District, ltr stated that since the design drawing calls for it to be constructed in accordance with a standard (7-Bar) design, then, by analogy, it also should be considered a				

Table AP1-3. Undefined ECM, June 2019

#	Drawing Number	Drawing Date	Description	Designer	DDESB Review Date (if known)
	standard. The design was added (at that time) to the magazine listing in DoD 6055.9-STD, based on the above USACE assessment. USACE structural evaluation of AW 33-15-63 door in 2003 determined the door would not provide 7- or 3-Bar protection. See note under AW 33-15-63 of Table AP1-2.				
47	AD 33-15-70 R1	8-May-64	Steel, Semi-Circular Arch	AF	See Comments
	This ECM was required to be constructed in accordance with Drawing AW 33-15-64. A 13 Jan 1995 USACE, Huntsville District, ltr stated that since the design drawing calls for it to be constructed in accordance with a standard (7-Bar) design, then, by analogy, it also should be considered a standard. The design was added (at that time) to the magazine listing in DoD 6055.9-STD, based on the above USACE assessment. USACE structural evaluation of AW 33-15-64 door in 2003 determined the door would not provide 7- or 3-Bar protection. See note under AW 33-15-63 of Table AP1-2.				
48	33-15-71	UNK	Steel Arch	USACE, Europe District	UNK
	An informal DDESB magazine listing, dated 26 Aug 80, shows this magazine design having only a 250,000-lb capacity. Treat as an undefined ECM until additional information is provided which supports another designation.				
49	AD 33-15-72	23-Mar-67	See Comments.	AF	UNK
	This drawing identifies two ECM types. The first is a steel, oval arch ECM and the second is a steel arch ECM. Both types must be constructed in accordance with arch requirements of Drawing AW 33-15-64 and are economical open-ended models of the magazine design. Separate barricades may be used where end protection is necessary. These structures were used for covered field storage in austere areas. The design drawing designates these magazines as Combat Zone Type.				
50	33-15-208	UNK	Steel Arch	USACE, Europe District	8/5/1987 message
	This design was initially approved by the DDESB 11 May 1983, for construction at Larson Barracks, Kitzingen, Germany, with an NEW of 4,000 lbs and a side-to-side separation of K1.25. This separation was applicable, at the time, to the siting of standard ECM and to non-standard ECM (for NEWs less than 250,000 lbs HD 1.1.) Project was subsequently modified to use ECM design 33-15-208, which was almost the same as design 33-15-28 with some minor modifications. Treat as an undefined ECM until further information is received to justify a designation change.				
51	E 33-31-01	UNK	UNK	UNK	UNK
	See the comment in row 24.				
52	E 33-31-02	UNK	UNK	UNK	UNK
	See the comment in row 24.				
53	33-33-01	5-Jan-57	Reinforced Concrete Arch	USACE, Tulsa District	UNK
	Drawings provided by Beale AFB, CA.				

#	Table AP1-3. Undefined ECM, June 2019				
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**DDESB Review Date (if known)**
54	33-33-03	UNK	Modified FRELOC Stradley (Reinforced Concrete Arch)	USACE, EUR District	UNK
	A 4 May 1978 DDESB-KT memo to USACE Europe District mentions this design. It appears to be a design variation of 33-15-13, however, no details are available and it must be considered as Undefined until additional details are provided.				
55	E 33-31-04	UNK	UNK	UNK	UNK
	See the comment in row 24.				
56	E 33-31-05	UNK	UNK	UNK	UNK
	See the comment in row 24.				
57	E 33-31-06	UNK	UNK	UNK	UNK
	See the comment in row 24.				
58	FI-350 through FI-356, modified with larger door	18-Apr-51	Reinforced Concrete Arch	OCE	8-Apr-03
	This design reflects FI-350 through FI-356, with a modified door. The larger door was evaluated by CEHNC and determined to be incapable of providing 7-Bar protection. Their determination is documented in an e-mail to the DDESB (8 Apr 2003). The original door design measures 9 ft 11-3/4 inches high by 8 ft 5-1/2 inches wide (double, hinged, swinging doors). The modified larger door design (11 ft high by 10 ft 1-1/2 inches wide) is also a double, hinged, swinging door. Treat as Undefined ECM.				
59	357428 through 357430	9-Aug-44	Reinforced Concrete Arch	Bureau Y&D	UNK
	A WW II Navy Standard design. It was upgraded by Bureau Y&D Drawing 626739 to provide a stronger headwall and door design, which was then accepted as a Standard magazine design.				
60	359870	UNK	Reinforced Concrete Box	Bureau Y&D	UNK
	This is a 68 ft^2 Ready Magazine. The design drawing calls for only 18 inches of soil cover. Current explosives safety criteria call for a minimum of 24-inches of earth cover. A magazine constructed to this drawing must be treated as an AGM. Bureau Y&D Drawing 817112 provided general details for this magazine and was used for planning purposes.				
61	359871	UNK	Reinforced Concrete Box	Bureau Y&D	UNK
	This design provides construction details for both a 192 ft^2 Fuze and Detonator ECM and a 266 ft^2 Black Powder ECM. The design drawing specifies only 18 inches of soil cover. Current explosives safety criteria require a minimum of 24 inches of earth cover. A magazine constructed to this drawing will have to be treated as an AGM. Bureau Y&D Drawing 817112 provided general details for this magazine and was used for planning purposes.				

#	Table AP1-3. Undefined ECM, June 2019				
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**DDESB Review Date (if known)**
62	387744	22-Mar-45	Reinforced Concrete Box	Bureau Y&D	9-May-84
	This design provides construction details for both a 10 ft by 10 ft and a 10 ft by 14 ft Fuze and Detonator ECM. The design drawing specifies only 15 inches of soil cover. Current explosives safety criteria require a minimum of 24 inches of earth cover. A magazine constructed to this drawing will have to be treated as an AGM.				
63	387745	22-Mar-45	Reinforced Concrete Arch	Bureau Y&D	9-May-84
	This design is for a 25 ft by 20 ft Fuze and Detonator Magazine. A 9 May 1984 DDESB memorandum stated that the magazine was rated for only 250,000 lbs NEW. Treat as an undefined ECM.				
64	411428	UNK	UNK	Bureau Y&D	9-May-84
	DDESB letter of 9 May 1984 showed that the magazine was rated for only 250,000 lbs NEW. Treat as an undefined ECM.				
65	421-80-06	1-Oct-99	Reinforced Concrete Box	Eglin AFB	28-Oct-99
	Known as the Air Force "Hayman Igloo." This design represents an upgraded version of the AF Modular Storage Magazine (MSM) that was approved by the DDESB in 1994. 421-80-06 and the MSM design were previously considered as 7-Bar designs. Their rating was downgraded to "Undefined" by the DDESB in Apr 2002 due to identified problems with the door design. In FY 1999, the Air Force funded the development of consolidated CADD drawings of the MSM design. Per the 28 Oct 1999 DDESB-KO approval memo, the CADD drawings incorporated updates dealing with the electrical continuity of rebar between structural elements and waterproofing. Superseded by series 421-80-06 (modified) design.				
66	421-80-06 flow through version	UNK	Reinforced Concrete Box	UNK	14-Sep-00
	DDESB site approval was granted for the construction of 2 modified Hayman igloo (421-80-06 with two headwalls) at Kunsan Air Base, Korea. The structures were required to be treated as Undefined ECM. Doors can be upgraded to meet 7-Bar criteria.				
67	516667	UNK	Steel Arch	Bureau Y&D	UNK
	Superseded by Bureau Y&D Drawing 6027803. No additional information is available.				
68	544839 through 544842	25-Feb-52	Reinforced Concrete Box	Bureau Y&D	UNK
	Smokeless Powder and Ammunition Storage Magazine known to have been constructed at McAlester AAP. Front wall has glass block windows installed approximately 10 ft above floor level to let in natural lighting. Given the limited data on this ECM design, it's unclear if it's a Type I, Type IIA or Type IIB Smokeless Powder/Projectile Magazine. Future siting of this design must verify the magazine type and apply the corresponding minimum intermagazine distances of the 8 March 2016 DDESB-PD Memorandum for Commanding Officer, NOSSA, Subject: Explosives Safety Quantity-Distances for Type I, Type IIA and Type IIB Smokeless Powder/Projectile Magazines.				
69	550-001 & 550-002	2-Sep-41	Reinforced Concrete Arch	Red River Ordance Depot	2004

Table AP1-3. Undefined ECM, June 2019

#	Drawing Number	Drawing Date	Description	Designer	DDESB Review Date (if known)
	Though the door header and pillasters are reinforced and a 10-inch thick headwall is provided, the headwall reinforcing is 6-inch by 6-inch wire mesh, which does not provide the required headwall strength. Door details not available at this time - no drawing. Constructed at Red River Ordnance Depot.				
70	6027801	1-Mar-75	Steel Arch	NCEL	UNK
	This is a 1,200 ft^2 High Explosive Magazine. The design's grounding system does not meet current explosives safety grounding criteria. The magazine was designed by the Civil Engineering Support Office, Naval Construction Battalion Center, Pt. Hueneme, CA.				
71	6027802	1-Mar-75	Steel Arch	NCEL	UNK
	This is a 576 ft^2 High Explosive Magazine. The design’s grounding system does not meet current explosives safety grounding criteria. The magazine was designed by the Civil Engineering Support Office, Naval Construction Battalion Center, Pt. Hueneme, CA.				
72	6027803	1-Mar-75	Steel Arch	NCEL	UNK
	Superseded Bureau Y&D Drawing 516667. This is a 192 ft^2 High Explosive Magazine. The design’s grounding system does not meet current explosives safety grounding criteria. The magazine was designed by the Civil Engineering Support Office, Naval Construction Battalion Center, Pt. Hueneme, CA.				
73	649602 through 649605,793749, and 803060	5-Mar-54	Reinforced Concrete Arch	Bureau Y&D	9-May-84
	DoD 4145.27M, March 1969, identified this magazine as a non-standard structure, permited to store 250,000 lbs NEW at a minimim separation distance of 185 ft. A 9 May 1984 DDESB memorandum confirmed that it was a non-standard ECM.				
74	652-295 and 652-296	20-Jun-33	Reinforced Concrete Arch	OQMG	UNK
	See description information provided in paragraph 2.2.2.6.				
75	652-311 and 652-312	19-Jul-28	Reinforced Concrete Arch	OQMG	UNK
	See description information provided in paragraph 2.2.2.5. Treat as an AGM, unless the required 2 ft of earth cover is provided. The design may need to be evaluated to insure the structure is capable of safely supporting 2 ft of earth.				
76	652-317 through 652-320	9-Dec-35	Reinforced Concrete Arch	OQMG	UNK
	See description information provided in paragraph 2.2.2.7.				
77	652-326 through 652-331	23-Jul-37	Reinforced Concrete Arch	OQMG	UNK
	See description information provided in paragraph 2.2.2.7.				

#	Table AP1-3. Undefined ECM, June 2019				
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**DDESB Review Date (if known)**
78	652-340 through 652-349	27-Sep-40	Reinforced Concrete Arch	OQMG	UNK
	See description information provided in paragraph 2.2.3.1. These drawings were lost shortly after approval and were replaced by Drawings 652-377 through 652-386.				
79	652-377 through 652-386	30-Oct-40	Reinforced Concrete Arch	OQMG	UNK
	See description information provided in paragraph 2.2.3.1.				
80	652-394 & 652-395	UNK	UNK	OQMG	UNK
	Referenced on Red River Ordnance Depot, Texarkana, TX, drawing 550-001.				
81	652-535 through 652-537	13-Feb-41	Steel Arch	OQMG	UNK
	Superseded OQMG Drawing 652-354. The arch is construced of 7-ga. corrugated steel panels. The design provided for 2 ft of earth cover.				
82	652-686 through 652-692	27 Dec 41, Revised 14 Mar 42	Reinforced Concrete Arch	OCE	24-Dec-98
	This ECM design was tested as part of the 1946 Naval Proving Grouns, Arco, Idaho, tests. The 130th ASESB (18 May 53) acknowledged USACE Drawings 652-686 through 652-694, dated 27 Dec 41, revised 14 Mar 42, as a Standard ECM. 1Dec 55 ASESB QD Standards list this ECM as a standard, with 185-ft separation for barricaded, 360-ft separation for unbarricaded. A 24 Dec 98 DDESB ltr states that an ECM constructed to Drawings 652-686 through 652-692 is not robust enough to qualify as a 7-Bar ECM. However, it is robust enough to protect its contents if it is spaced about 400 ft from a detonation of 500,000 lbs NEW in an adjacent ECM. In addition, these ECM constructed with “Medium” or “Rock Only” footings do not satisfy present requirements for electrically continuous reinforcing steel, therefore ECM with these type footings do not meet current lightning protection criteria. Superseded by 33-15-01 listed above. If distances cannot be met, then the ECM must be treated as an undefined ECM.				
83	652-686 through 652-693	27 Dec 41, Revised 14 Mar 42	Reinforced Concrete Arch	OCE	24-Dec-98
	In response to a 2019 USATCES request, DDESB staff evaluated IMD requirements to this design in the absence of grandfathering. DDESB-PD’s 26 Jun 19 reply memo references DDESB Technical Paper 5 and advises that if the Services choose to disallow grandfathering, a minimum rear-to-front IMD of K4.54 may be applied to this design; otherwise, IMDs to an undefined ECM would apply. DDESB Technical Paper 5 includes data from two full-scale ECM tests of the series 652-686 through 652-693 design. Based on these tests, ANESB sent a memo to the Secretary of War and the Secretary of the Navy on 11 Apr 47 requesting approval to increase this design’s HD 1.1 explosives storage limit from 250,000-lbs to 500,000-lbs and to reduce its minimum intermagazine distances to 360-ft if barricaded and 185-ft if unbarricaded. The 1 Dec 55 ASESB QD Standards list this ECM as a standard, with 185-ft separation for barricaded, 360-ft separation for unbarricaded. A 24 Dec 98 DDESB letter states that an ECM constructed to Drawings 652-686 through 652-692 is not robust enough to qualify as a 7-Bar ECM. Superseded by 33-15-01.				
84	6521000 through 6521010	19 Feb & 23	Reinforced Concrete Dome	OCE	12-Jul-90

#	Table AP1-3. Undefined ECM, June 2019				
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**DDESB Review Date (if known)**
		Mar 42			
	Called a Corbetta, Beehive, or Dome Magazine. At a 23 Feb 1942 meeting, the Joint Army and Navy Board of Ammunition Storage (predecessor of ASESB) approved the Corbetta Magazine as an alternate type magazine (i.e., Non-Standard). A 12 Jul 90 DDESB ltr approved a 27 Nov 89 USACE ltr, requesting approval to modify doors on Corbetta Type ECM at Volunteer Army Ammunition Plant (AAP) and Holston AAP. Once modified, each ECM can be sited for 500,000 lbs NEW, provided the conditions of Note4 below were met. If distance cannot be met, then the ECM must be treated as an undefined ECM. NOTE: Storage of up to 500,000 lbs NEW of HD 1.1 is permitted in Corbetta-type ECM, provided it has been modified with one of the two approved door designs and the required separation distances are met, as discussed in the note for 6521000 through 6521010 in Table AP1-2.				
85	652-1012 through 652-1014	29-Apr-42	Reinforced Concrete Arch	OCE	UNK
	Known as the Huntsville Magazine. This was a redesign of the Series 652686 through 652693 magazine, and its purpose was to conserve critical wartime materials. Reinforcing steel was reduced. The headwall stubbed by removal of wingwalls (earth fill spilled around front corners). The door was changed to a 6-ft double-sheet steel. The headwall thickness was reduced to 8 inches.				
86	6579-160 & 6579-161	12-Mar-29	Reinforced Concrete Arch	OQMG	UNK
	This magazine, as shown on the drawing, has insufficient earth cover to qualify as an earth-covered ECM under today's standards. Treat as an AGM, unless earth cover has been increased to meet the minimum required 2 ft of depth.				
87	*7013623 through 7013638	11-Sep-76	Reinforced Concrete Arch	NAVFAC	8-Dec-04
	This design was constructed at Naval Support Activity, Diego Garcia. Based on DDESB review of the magazine design, it is considered an Undefined ECM. The basis for this decision is the headwall reinforcing which used 4 by 4 wire mesh. This reinforcement is not capable of providing 7-Bar protection to magazine contents.				
88	7115-1400	UNK	Reinforced Concrete Arch	OQMG	UNK
	This Lone Star AAP drawing indicates that the details on this drawings were copied from 7115-1400.4. No date was given for the original drawing, though the copy effort was completed on 20 June 1969. Base on the original drawing number, the reinforcing design and door design shown, it is suspected that this an early 1940 era design. The drawing indicates 59 40 ft 2 inches long by 26 ft 6 inches side; 138 60 ft 8 inches by 26 ft 6 inches; and 45 80 ft 8 inches by 26 ft 6 inches were constructed at Lone Star AAP per this drawing.				
89	7120-8101 and 652-538	27 Jan 1942/16 July 1941	Reinforced Concrete Arch	OQMG	UNK
	This design provided the contractor the option of replacing reinforcing bars with wire mesh at his option. The door is a 4-inch thick concrete door reinforced with 6 inches by 6 inches wire mesh on each face. Drawing 652-538 is for a concrete door design that has a bronze copper weatherstrip attached to the inside edge of the door. When the door closes, the copper weatherstrip presses against the steel angle that forms the door frame. This design may provide a ground path for the door, but it needs to be tested. This magazine design is known to have been constructed at Redstone				

Table AP1-3. Undefined ECM, June 2019

#	Drawing Number	Drawing Date	Description	Designer	DDESB Review Date (if known)
	Arsenal, AL.				
90	895065	UNK	Reinforced Concrete Box	Bureau Y&D	UNK
	Type II Missile Magazine. This design had six 11 ft wide by 11 ft high doors.				
91	895066	UNK	Reinforced Concrete Box	Bureau Y&D	UNK
	Type 1 Missile Magazine. This design had three 22 ft wide by 11 ft high doors.				
92	9210827 through 9210832 (Eglin AFB) and 422-264-03 (USACE)	9-Apr-93	Reinforced Concrete Box	Eglin AFB	20-Jul-94
	Superseded by 421-80-06. Its structural rating was downgraded to “Undefined” by the DDESB in Apr 2002 due to identified problems with the door design. (NOTE: Eglin AFB drawing 9484969 is a consolidation of Sheets S-8 and S-9 (doors and doorframe assembly) from Savannah District USACE Drawings 422-264-03, dated 11 May 1990.)				
93	952127 through 952135	13-Dec-61	Reinforced Concrete Box	Bureau Y&D	UNK
	Type I Missile Magazine. This design had three 22 ft wide by 11 ft high doors.				
94	Korean ECM	No number	Steel Arch	Korean	3-Dec-76
	DDESB review this design and determined that the door would not provide the required level of protection to the contents of the ECM, therefore, the design was was not considered equivalent to a standard ECM design. New Korean magazines are constructed to the Korean Version of 33-15-74, a 7-Bar design.				
95	M-30792	4-May-86	Steel Arch	AF	UNK
	This design was developed by Eglin AFB. The ECM is 39 ft deep and has an internal radius of 13 ft. No approval documentation could be found for this design.				
96	Modified Type 16 for Air Force use	UNK	Reinforced Concrete FRELOC Stradley	USACE, Europe District	30-Apr-91
	USACE Europe District developed this modified TYPE 16 magazine design for Air Force use. This design modified the headwall to incorporate a 16-ft door opening. Ten of these modified magazines were to be constructd at Ramstein Air Base, Germany, by FY 1990 MCP, Project PAZY 90372.				
97	Munitionslagerhause (MLH) 30B	UNK	Reinforced Concrete Box	German	UNK
	A 15 September 1986 Department of Army letter from Commander, V Corps (Attn: AETV-GAS) states that the MLH30 is identical to the MLH25, which was approved by the DDESB and constructed in FSTS Ottrau and FSTS Giesel. The letter states that the MLH30 is rated at 7-Bar. Sixteen				

#	Table AP1-3. Undefined ECM, June 2019				
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**DDESB Review Date (if known)**
	MLH30 ECM were constructed at PSP4J, Muenster, Germany. Their separation distances were K=1.25W1/3 (side to side) and K=2.0W1/3 (front to rear), both applicable to the siting of standard magazines. The 15 September 1986 letter applied a 11,023 lb (5,000 kg) peace-time limit to the Muenster MLH30 ECM. Approval documentation has not been found. Site as an AGM until supporting information is provided to change the designation.				
98	Shipping Container, Earth-Covered	UNK	ISO and MILVAN container	DAC	22-May-95
	The DDESB approved the use of earth-covered MILVANs and ISO Containers as undefined ECM, for NEWs up to 8,800 lbs), provided the earth-covering criteria of DAC letter SMCAC-EST (385{A}) of 10 February 1995 were met. Attachment C of this letter provides three methods for insuring the required earth cover is provided. There is no reduction in ESQD as a result of these designs; however, containers meeting these criteria can be sited as undefined ECM with respect to adjacent AE storage structures.				

AP1.4. TABLE AP1-4. Table AP1-4 presents current data on magazines (earth-covered and aboveground) and containers with reduced news or reduced QD. Note that each line represents a separate magazine design. Where UNK appears in the table, it indicates that no information was found for that particular entry.

Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
1	173649 through 173651	28-Aug-41	Reinforced Concrete Box	Bureau Y&D	26-Jun-05	Other	500,000
	This an early version of the Navy Smokeless Powder and Projectile Magazine (Type I) and measures 52 ft by 103 ft. The design provides for glass block windows in the front wall to let in natural lighting. The drawing shows the magazine was constructed at NAD, Hawthorne, NV, which is now an Army Ammunition Depot. Future siting of this ECM will be in accordance with the 8 March 2016 DDESB-PD Memorandum for Commanding Officer, NOSSA, Subject: Explosives Safety Quantity-Distances for Type I, Type IIA and Type IIB Smokeless Powder/Projectile Magazines.						
2	387740	15-Mar-45	Reinforced Concrete Box	Bureau Y&D	UNK	Other	500,000
	Type I Smokeless Powder Magazine. It includes glass blocks in the face to allow natural lighting to enter. Future siting of this ECM will be in accordance with the 8 March 2016 DDESB-PD Memorandum for Commanding Officer, NOSSA, SUBJECT: Explosives Safety Quantity-Distances for Type I, Type IIA and Type IIB Smokeless Powder/Projectile Magazines.						
3	422-15-01	1-Jun-87	Reinforced Concrete, 1-Compartment Mini-Magazines	USACE	4-Mar-88	Other	425
	10'x10'x10' cubicle with single-leaf swinging door (4 ft by 3ft). Approved reduced siting distances listed on sheet 1 of 10 in standard drawings.						
4	422-15-02	21-Feb-96	Reinforced Concrete, 3-Compartment Mini-Magazines	USACE	28-Sep-98	Other	150
	When NEW described on approval letter are met, this ECM can be sited for overpressure (K40) only.						
5	422-15-03	21-Feb-96	Reinforced Concrete, 3-Compartment Mini-Magazines	USACE	28-Sep-98	Other	400
	When NEW described on approval letter are met, this ECM can be sited for overpressure (K40) only.						
6	422-264-03	11-May-90	Reinforced Concrete Box	USACE, Savannah District	2-Apr-02	AG	500,000
	An early version of the Air Force MSM. Unlike MSM design 9210827 through 9210832 (Hill AFB) and 9484969 (Eglin AFB), this design could not be upgraded to a 7-Bar design because it has a weaker roof design. Previously, it had been considered an Undefined ECM, as documented in approval memos. However, all future siting of these magazines must apply AGM criteria due to inadequate roof strength.						

#	Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019						
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**Approval Date**	**Magazine Designation**	**Magazine MCE (lbs of HD 1.1)**
7	544839 through 544842	25-Feb-52	Reinforced Concrete Box	Bureau Y&D	UNK	N/A	N/A
	Smokeless Powder and Ammunition Storage Magazine known to have been constructed at McAlester AAP. Front wall has glass block windows installed approximately 10 ft above floor level to let in natural lighting. Given the limited data on this ECM design, it's unclear if it's a Type I, Type IIA or Type IIB Smokeless Powder/Projectile Magazine. Future siting of this design must verify the magazine type and apply the corresponding minimum intermagazine distances of the 8 March 2016 DDESB-PD Memorandum for Commanding Officer, NOSSA, Subject: Explosives Safety Quantity-Distances for Type I, Type IIA and Type IIB Smokeless Powder/Projectile Magazines.						
8	6037-2-5006 to 6037-2-5018	UNK	Reinforced Concrete Box	Israel	9-Oct-98	AG	500,000
	This design is for a Box Type ECM provided with 2 entrances. The design does not have substantial blast doors. A retaining wall is positioned in front of the front wall, but the magazine is not be to considered barricaded. The magazine was originally approved as a 7- Bar ECM. A DDESB-KO Memo of 9 Oct 1998 provided siting criteria for this design, which was brought back by a DDESB survey team that visited U.S. Forces in Israel. It was specified that USAFE (Dominant User for that AOR) would use this information for preparation of a site plan, which would also have to address other requirements of ECM (e.g., cover slope and depth, grounding, LPS). For a PES with explosives weights up to 100,000 lbs, it could be sited as a 7-Bar ECM (front unbarricaded). When in excess of 100,000 lbs, the siting guidance contained in the DDESB memo could be applied. Subsequent investigations, however, indicated that the flat roof was not capable of resisting ECM roof loads specified in the DESR. For that reason, these magazines must be treated as an AGM in most scenarios. The only possible exception would be site plans where an ECM is exposed to ECM PESs that have unusually low HD 1.1 MCEs. For these scenarios, it can be treated as an undefined ECM.						
9	749767 through 749769, Revision B	28-May-57	Reinforced Concrete Box, Type IIA	Bureau Y&D	UNK	Other	500,000
	The smokeless powder projectile magazine is used for the storage of smokeless powder, pyrotechnics, rocket motors, rocket heads, loaded projectiles, fixed ammunition, small-arms ammunition, and other fire (Class 1 Division 2) or missile hazard material. Type IIA (52 ft by 161 ft). DDESB approval of this design (6 Oct 1976) as a standard magazine design was site specific for NAVWPSTA Yorktown only. In their approval letter, the DDESB encouraged the Navy to pursue designating this ECM as a standard design. No documentation has been found to show if this was ever performed. Original design of this drawing number had glass block windows in the magazine face to allow natural lighting to enter. Change C (dated 5 Jul 61) removed the glass blocks. Original DDESB approval as a Standard magazine was based on an analogous comparison of structural features to OCE 33-15-64. ESKIMO VI tested a similar magazine design (Bureau Y&D 749771 - 749774), which failed to meet Standard Magazine criteria. A model of the Type IIB Smokeless Powder Projectile Design was tested in ESKIMO VI. The Type IIA and Type IIB Smokeless Powder Projectile Magazine designs are very similar, so the same minimum intermagazine distances apply to both designs. These magazines are to be sited in accordance with 8 March 2016 DDESB-PD memorandum for Commanding Officer, NOSSA, Subject: Explosives Safety Quantity-Distances for Type I, Type IIA and Type IIB Smokeless Powder/Projectile Magazines. This design may not be used for new construction.						
10	749771 through 749773, Revision B	28-May-57	Reinforced Concrete Box, Type IIB	Bureau Y&D	UNK	Other	500,000

Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
	The smokeless powder projectile magazine is used for the storage of smokeless powder, pyrotechnics, rocket motors, rocket heads, loaded projectiles, fixed ammunition, small-arms ammunition, and other fire (Class 1 Division 2) or missile hazard material. Type IIB (52 ft by 97 ft). The original design had glass block windows in the magazine face to provide natural lighting within the magazine. Change C (dated 5 July 1961) removed the glass blocks. The acceptor magazines in the one-half scale ESKIMO VI test included a model of a Type IIB Smokeless Powder Projectile Magazine. In the test, the flat roof of the Type IIB magazine withstood an equivalent full-scale detonation of 350,000-lbs at a K1.25 side-to-side intermagazine distance, but the headwall doors failed and were propelled into the magazine. The tested model did not incorporate the design's large glass block 'windows,' so this potential debris source was not considered. The flat roof design does not satisfy UFC 3-340-02 requirements (e.g., some of the top flexural bars are not continuous), so minimum intermagazine distances/NEW limits could not be determined by blast analyses. These magazines are to be sited in accordance with DDESB-PD memorandum dated 8 March 2016. This design may not be used as new construction.						
11	752296 through 752299, Revision A	28-May-57	Reinforced Concrete Box, Type I	Bureau Y&D	UNK	Other	500,000
	The smokeless powder projectile magazine is used for the storage of smokeless powder, pyrotechnics, rocket motors, rocket heads, loaded projectiles, fixed ammunition, small-arms ammunition, and other fire (Class 1 Division 2) or missile hazard material. Type 1 (52 ft by 103 ft). Bureau Y&D Drawing 817109, dated 7 January 1958, provides general details of this magazine and was used for planning purposes. Subsequent investigations of the smokeless powder magazines indicated that the flat roof was not capable of resisting ECM roof loads specified in DoD 6055.09-M, so undefined ECM siting distances cannot be applied. These magazines are to be sited in accordance with DDESB-PD memorandum dated 8 March 2016. This design may not be used for new construction.						
12	A-1 (K9 Explosive Storage Facility)	10-May-94	Reinforced Concrete shell with an internal steel magazine	AF (Hanscom AFB)	7-Apr-95	Undefined	18
	Magazine designed by 66th Support Group, Hanscom AFB, MA., for the storage of explosives training aids used in SPS Detector Dog Training Kits. Reduced QD for this facility was originally approved in a 14 October 1994 DDESB memorandum. NOTE: The ECM's shell is constructed of 8-inch thick reinforced concrete. A 1/4-inch thick steel magazine with wood lining is placed inside the reinforced concrete shell. The ECM must have 38 inches of earth cover, and the sides of the earth cover must have a 2:1 slope. Explosives must be stored 2 ft from the magazine walls. The ECM has a reduced IBD arc of 92 ft and a PTRD arc of 55 ft. A front barricade is required.						
13	Magazine design designated by AF-NGB as ANG-DWG-87-095	N/A	Steel Arch	AF-NGB	9-Apr-90	Undefined	150 0r 450
	Known as the Ellington ECM (40 ft by 80 ft). The design was approved under Site Plan ANG Ellington ANGB-85-S1 and S-2. NOTE: Approved for up to 450 lbs NEW HD 1.1. An IBD arc of 250 ft applies to the sides of these ECM. A 700-ft IBD arc applies to the front sector of these ECM, with one exception. When the MCE is 150 lbs of HD 1.1 or less, a 500-ft IBD arc can be used from the front sector of these						

#	Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019						
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**Approval Date**	**Magazine Designation**	**Magazine MCE (lbs of HD 1.1)**
	ECM. The front sector of the ECM is defined by angles of plus and minus 15 degrees, drawn normal to the door.						
14	Magazine design designated by AF-NGB as ANG-DWG-87-112	N/A	Steel Arch	AF-NGB	9-Apr-90	Undefined	150 or 450
	Known as the Fresno ECM (40 ft by 80 ft). The design was approved under Site Plan NGB-Fresno-85-S3 thru S6. NOTE: See note in row 13.						
15	Magazine design designated by AF-NGB as ANG-DWG-89-115	N/A	Reinforced Concrete Arch	AF-NGB	7-Aug-89	Undefined	150 or 450
	Known as the Fargo ECM (40 ft by 80 ft). Approved under Site Plan ANG Fargo-88-S1 thru S-5 Hector Field, Fargo, ND. NOTE: See note in row 13.						
16	Magazine design designation by AF-NGB as ANG-DWG-94-001	N/A	Reinforced Concrete Arch	AF-NGB	29-Jul-94	Undefined	425
	This design provides construction details for both a 26-ft by 66-ft ECM and a 30-ft by 60-ft ECM containing 5 barricaded cells. The design was approved under Site Plan NGB Des Moines ANG 91-S1 thru S6. NOTE: Approved for a maximum of 425 lbs NEW HD 1.1 of SG 1 through 4 per cell as permitted by DDESB-KT memo of 30 September 2002, subject: Approval of Multi-Barricaded Storage Cell, Magazine Design ANG-DWG-00-001. The conditions and restrictions established for ANG-DWG-00-001 also apply to ANG-DWG-94-001, ANG-DWG-94-002, ANG-DWG-96-001, and ANG-DWG-99-001, ANG-DWG-00-001. Those designs all have layouts that provide for multiple internal cells, separated by sand-filled (2.5-ft sand thickness) Styrofoam walls (Blast Tamer). Those internal walls prevent prompt propagation thereby allowing the ECM's MCE to remain the largest explosive quantity in one cell, not to exceed 425 lbs. An IBD arc of 250 ft applies from the sides of these ECM. A 700-ft IBD arc applies from the front sector of these ECM, with one exception. When the MCE is 150 lbs of HD 1.1 or less, a 500-ft IBD arc can be used from the front sector of these ECM. The front sector of the ECM is defined by angles of plus and minus 15 degrees, drawn normal to the door. When SG 5 munitions are placed inside any cell, a minimum of 3 ft of sand is required to separate the SG 5 from munitions in adjacent cells. A layer of sandbags can be used to augment the existing Blast Tamer wall in order to obtain the additional sand thickness requirement.						
17	Magazine design designated by AF-NGB	N/A	Reinforced Concrete Arch	AF-NGB	29-Jul-94	Undefined	425

#	Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019						
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**Approval Date**	**Magazine Designation**	**Magazine MCE (lbs of HD 1.1)**
	as ANG-DWG-94-002						
	This is a 40 ft by 80 ft ECM containing 8 barricaded cells. The design was approved under Site Plan ANGRC-Dannelly-93-S1 thru S7. NOTE: See note in row 16.						
18	Magazine design designation by AF-NGB as ANG-DWG-96-001	N/A	Reinforced Concrete Arch	AF-NGB	23-Dec-96	Undefined	425
	This is a 40 ft by 80 ft ECM containing 8 barricaded cells. AF-NGB has restricted this design from new construction. NOTE: See note in row 16.						
19	Magazine design designated by AF-NGB as ANG-DWG-99-001	N/A	Steel Arch	AF-NGB	13-Sep-99	Undefined	425
	This is a 26 ft by 60 ft ECM containing 3 barricaded cells. NOTE: See note in row 16.						
20	Magazine design designated by AF-NGB as ANG-DWG-00-001	N/A	Steel Arch	AF-NGB	30-Sep-02	Undefined	425
	This is a 26 ft by 60 ft ECM containing 4 barricaded cells. NOTE: See note in row 16.						
21	40-mm Ammunition Storage	See Comments	Earth covered 55 gallon drum or corrugated steel pipe	USATCES	7-Nov-07	ECM	5
	Constructed of either a steel 55-gallon drum or a 35-inch length of 24-inch diameter, 16-gauge corrugated steel pipe, with the magazine top and sides covered by at least 2 ft of earth or sandbags. Use for M430 40-mm linked grenades or HD 1.4S small arms ammunition. The HD 1.4S small arms ammunition may be stored by itself, or in conjunction with the M430 grenades. The M430 grenades will be stored in either the PA 120 or M548 can. The magazine will be constructed as shown in Joint Munitions Command, Army Peculiar Equipment, drawings ACV00819-1 through 8. The QD with a front barricade is 69 ft. Without a front barricade, the QD is 69 ft out the sides and rear and 452 ft out the front. Refer to DDESB-PD Memorandum of 7 November 2007 for additional conditions and limitations.						

Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
22	Blasting Cap Carrying Box	UNK	Metal box	NRL-USRD	12-Mar-92	AG	N/A
	Capable of fully containing effects from initiation of up to five blasting caps. The ESQD is 0 ft when the container is closed.						
23	Canine Training Aid Explosive Storage Magazine (CETASM)	See Comments	Sand-filled cannisters in a metal box	NOSSA	27-Jul-07	AG	1.25
	NOSSA is responsible for maintaining the CETASM design drawings and specifications as well as the technical report NAWCWD TP 8615, "Limited Arc Magazines for Military Working Dogs, Magazine Tests Final Report," (April 2006). The container is constructed by Armag Corporation per drawings KP00001.01, revision 1, dated 2/22/07; drawing number C-00001.01, revision 1, dated 7/31/06; drawing number C-00003.01, revision 0, dated 8/3/05; drawing number C-00004.01, revision 1, dated 7/31/06; and drawing number C-00005.01, revision 1, dated 7/31/06. The maximum allowable NEW in the CETASM will be 87.5 lbs HD 1.1. The IB distance is 25 ft, PTRD is 15 ft, ILD of 12 ft, and IMD is 4 ft. Subsequent to the initial approval, DDESB on 14 November 2008 approved the modification of the blank container that is inserted into a slot not containing any explosives samples. Refer to DDESB approval memos for additional conditions and limitations.						
24	Class 5 Mosler Security Container	N/A	High security, heavy duty, file cabinet	NCEL	23-Feb-93	AG	0.3
	This container is approved for full containment of an internal explosion involving up to 0.3 lbs NEW of HD 1.1. Approval is based on the condition that the cabinets being used are equivalent in strength to the Mosler safe design that was evaluated by NCEL in 1983.						
25	CONEX, HAZMAT, MILVAN, and ISO Container Storage	N/A	Metal box	USADAC &USABRL	6-Feb-92, mod 6-May-96	AG	500
	Approved for storage of bulk explosives and demolition charge material (e.g., composition C-4, TNT) and select HD 1.3 and 1.4 materials. If conditions are met, a 360-ft ESQD is permitted. NOTE: The concept for using a CONEX container, as an explosives storage container for certain mixed munitions, is described in Quickload Program TDP, dated 25 Nov 91, and was issued by the ARBRL, Aberdeen Proving Grounds, MD. The TDP lists the specific item that can be stored in these containers. Use of a sandbag barricade between CONEX containers allows them to be stored at IMD of 8 ft, allowing the MCE and QD to be based on a single container. Subsequently, DDESB approval was obtained to permit storage of these same AE items in hazardous material (HAZMAT) containers, Military-owned Demountable Containers (MILVAN), and ISO containers. Specific container dimensions apply to the approval and must be met. CONEX containers will have internal dimensions of 92 inches long by 72 inches wide by 70 inches high, 0.125 inch thick corrugated steel walls and floor. HAZMAT containers will have internal dimensions of 222 inches long by 126 inches wide by 84 inches high, 0.100 inch thick corrugated steel floor and 0.125 inch thick epoxy-coated plywood deck. MILVAN containers will have internal dimensions of 232 inches long by 90 inches wide by 85 inches high, 0.0787 inch thick corrugated steel walls and a hardwood floor. ISO containers will have internal dimensions of 231 inches long by 92 inches wide by 92 inches high, 0.0787 inches thick corrugated steel walls and a hardwood floor.						

Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
26	Use of Shipping Containers as ECM	N/A	Metal box, earth-covered	USADAC & CEHNC	22-May-95	Undefined ECM	4,000 kg/8,800 lbs
	Concept for converting shipping containers (e.g., MILVANs and ISO) into undefined ECM was evaluated. Since the skin of the container cannot support 2 ft of earth cover, three alternate methods are identified in USADACS memo SMAC-EST (385[A]) dated 10 Feb 1995, subject: Analysis of Earth-Covered Shipping Containers as Earth-Covered Magazines (ECM), for providing the required earth cover on and around the container. No reduction in QD is permitted.						
27	Container Blasting Cap: MK-663 MOD 0	26-Jul-77	Capped steel pipe	NAVSEA SYSCOM	(1) DOT approved (2) 28-Jan-11	AG	(1) 5 grams (0.011 lbs) (2) 10grams (0.022 lbs)
	Detailed in NAVSEA drawings 5206195 through 5206200, dated 26 July 1977. This container is approved for two uses: (1) Refer to latest revision of DOT-SP 9571 at http://www.phmsa.dot.gov/hazmat/regs/sp-a/special-permits. When packed in this container, explosives can be shipped as HD 1.4S. (2) DDESB approved the use of the container for storage of up to 10 grams of laboratory-sized explosive samples with zero QD.						
28	Explosive Ordnance Disposal Quick Response Ready Stowage Locker (EODRSL)	ARMAG, Inc. Drawing S1495, dated 19-Aug-15	Metal Box with pumice-lined containers	Navy	11-Sep-15	AG	0.5 C-4, 0.625 TNT equivalent
	This design is approved for use only by the EOD community. It is a 5 ft by 5 ft by 5 ft steel magazine produced by ARMAG, Inc. The magazine uses pre-tested pumice-lined containers intended to prevent SD. There is a set of specific, approved loadout configurations that must be adhered to. These loadouts are documented in EOD TM A-2-1-143.						
29	Advanced EOD Magazine (EODMAG)	ARMAG, Inc. Drawing S1494, dated 19-Aug-15	Metal box with pumice-lined containers	Navy	11-Sep-15	AG	1.25 C-4, 1.56 TNT equivalent
	This design is approved for use only by the EOD community. It is a 7 ft by 7 ft by 7 ft steel magazine produced by ARMAG, Inc. The magazine uses pre-tested pumice-lined containers intended to prevent SD. There is a set of specific, approved loadout configurations that must be adhered to. These loadouts are documented in EOD TM A-2-1-140.						
30	Explosives storage	N/A	Reinforced Concrete	USACE	10-Sep-93	AG	50

Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
	building		Box				
	Approved for 1.1 and 1.3 bulk explosives and HD 1.4 ammunition. The ESQD is 147 ft and is based on overpressure (K40) only. A front barricade is required to stop the structures front panel and door.						
31	Explosives storage building	N/A	Reinforced Concrete Box	USACE	10-Sep-93	AG	100
	Approved for HD 1.1 and 1.3 bulk explosives and HD 1.4 ammunition. The ESQD is 186 ft and is based on overpressure (K40) only. A front barricade is required to stop the structures front panel and door.						
32	Explosives storage building	N/A	Reinforced Concrete Box	USACE	10-Sep-93	AG	200
	Approved for HD 1.1 and 1.3 bulk explosives and HD 1.4 ammunition. The ESQD is 234 ft and is based on overpressure (K40) only. A front barricade is required to stop the structures front panel and door.						
33	Explosives storage building	N/A	Reinforced Concrete Box	USACE	10-Sep-93	AG	300
	Approved for HD 1.1 and 1.3 bulk explosives and HD 1.4 ammunition. The ESQD is 268 ft and is based on overpressure (K40) only. A front barricade is required to stop the structures front panel and door.						
34	2-Bay Explosives Storage building	N/A	Reinforced Concrete Box	NCEL	1988 (undated memo)	ECM	250
	This design, as described in NCEL TM 51-86-27, Basis of Design for PE 500R, Ammunition Magazine Mountain Warfare Training Center, Bridgeport, CA, is for a two bay ECM that is front barricaded. The MCE is 250 lbs HD 1.1 (lightly cased), the contents of one bay, since IMD is met between bays. The allowable QD with a front barricade is 320 ft. If the front barricade is not provided, the frontal QD will comply with DoD 6055.9-STD criteria.						
35	Explosive Containment Device (ECD)	Covered by U.S. Patent 6,196,107 B1	Metal Box filled with rigid polyurethane foam	"Samples of Dry Primary Explosives" by Harold K.H.	Patent approval - 6 Mar 2001	AG	5 lbs TNT
	The ECD measures roughly 78 inches long by 48 inches high by 34 inches wide. Designed to fully contain an explosives event involving up to 5 lbs . TNT or equivalent. Initially designed for the FAA as a bomb containment vessel to complement lugagae screening operations, it is suitable for other applications as well. A paper on the ECD was given at the 26th DDESB Seminar in Orlando, FL. The DDESB is currently awaiting the documentation package for review.						
36	GOLAN 5 Protectainer	N/A	Metal cylindrical	Israeli company (see	2-Oct-02	AG	11 lbs TNT

Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
			vessel with elliptical heads, both ends	comments)			equivalent material
	Refer to the DDESB approval memo for restrictions and conditions associated with the use of the GOLAN 5. Manufactured by Koors Metals Ltd of Israel. The U.S. distributor is Mistral Security, Inc. NAVFACENGCOM maintains the design drawings and specifications for this container. The GOLAN 5 Protectainer is designed to contain/limit explosion effects from an internal detonation of 11 lbs (5 kg) TNT equivalent explosives. It has an internal fragment defeating liner, but it has munition diameter limitations associated with it. Internal pressures are vented slowly through 2 vents in the bottom and around the door. A minimum of 19 inches standoff distance must be maintained between explosives and the interior wall/door. The reduced QD are 30 ft IBD, 20 ft PTRD, and 10 ft ILD. IMD requirements provided by DDESB memo. NOTE: The GOLAN 5, 10, 15, and 45 manufactured by Mistral Security, Inc., are approved for storage of fragmenting munitions with diameters up to 1.6 inches (40 mm) and explosives materials weighing up to 11 lbs TNT equivalent explosives (GOLAN 5), 23 lbs NEW (GOLAN 10), 33 lbs NEW (GOLAN 15), and 100 lbs (GOLAN 45). The use of NEW with the GOLAN 10, 15, and 45 containers is intentional and results from testing at 125 percent of the rated TNT equivalence capacities with minimal damage to the containers. A minimum internal standoff for explosives from the nearest inside wall apply (19 inches for the GOLAN 5, 23 inches for the GOLAN 10, 29 inches for the GOLAN 15, and 28 inches for the GOLAN 45). The minimum IMD from a GOLAN 5 container to another exposed explosives site (acting as an ES) is based on K1.25. There is no minimum required IMD from a GOLAN 10, GOLAN 15, or GOLAN 45 as a PES. The minimum IMD from any PES that does not totally contain blast hazards to an ES GOLAN container will be based on K6. There is no minimum IMD from any storage PES that is capable of containing all effects to an ES GOLAN container. Use of these containers will be in accordance with DDESB approval memorandums. Refer to DDESB approval memorandum for specific requirements for each GOLAN design.						
37	GOLAN 10 Protectainer	N/A	Metal cylindrical vessel with elliptical heads, both ends	Israeli company (see comments)	9-Jun-04	AG	23 lbs
	Refer to the DDESB approval memo for restrictions and conditions associated with the use of the GOLAN 10. Manufactured by Koors Metals Ltd of Israel. The U.S. distributor is Mistral Security, Inc. NAVFACENGCOM maintains the design drawings and specifications for this container. The GOLAN 10 Protectainer is designed to contain/limit explosion effects from an internal detonation of 23 lbs (10.4 kg) NEW HD 1.1. It has an optional internal fragment defeating liner, but it has munition diameter limitations associated with it. Internal pressures are vented slowly through a small vent in the bottom and around the door. A minimum 23 inches standoff distance must be maintained between explosives and the interior wall/door. Previously, required QD were 30 ft IBD, 20 ft PTRD, and 10 ft ILD. Based on subsequent testing, the DDESB approved reduced QD of 3 ft IBD, PTRD, and ILD. IMD requirements are provided by DDESB memo. NOTE: See note in row 36.						
38	GOLAN 15 Protectainer	N/A	Metal cylindrical vessel with elliptical heads, both ends	Israeli company (see comments)	30-Sep-04	AG	33

Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
	Refer to the DDESB approval memo for restrictions and conditions associated with the use of the GOLAN 15. Manufactured by Koors Metals Ltd of Israel. The U.S. distributor is Mistral Security, Inc. NAVFACENGCOM maintains the design drawings and specifications for this container. The GOLAN 15 Protectainer is designed to contain/limit explosion effects from an internal detonation of 33 lbs (15 kg) NEW. It has an optional internal fragment defeating liner, but it has munition diameter limitations associated with it. Internal pressures are vented slowly through a small vent in the bottom and around the door. A minimum 29 inches standoff distance must be maintained between explosives and the interior wall/door. Required IBD, PTRD, and ILD is 4 ft. IMD requirements are provided by DDESB memo. NOTE: See note in row 36.						
39	GOLAN 45 Explosive Storage and Blast Containment Chamber	N/A	Metal cylindrical vessel with elliptical heads, both ends	Israeli company (see comments)	27-Jan-14	AG	100
	Refer to the DDESB approval memo for restrictions and conditions associated with the use of the GOLAN 45. Manufactured by Koors Metals Ltd of Israel. The U.S. distributor is Mistral Security, Inc. This chamber is authorized for storage of up to 100 lbs HD 1.1, 1.2, and 1.3 and MEQ of 1.4. Required IBD, PTRD, and ILD are 6 ft, and IMD is 0 ft as both a PES and ES. For less than 55 lbs, IBD, PTRD, and ILD are 5 ft. Fragmenting items can be stored in accordance with the restrictions of the approval. A minimum standoff of 28 inches from the interior walls, floor and door is required. NOTE: See note in row 36.						
40	Military Working Dog Training Aids Storage ECM	N/A	Metal box in an earth-covered reinforced concrete box	NFESC	8-May-91	Undefined	17.9
	This ECM has a reduced QD of 105 ft (maximum fragment throw). Two storage concepts were approved and these are described in NCEL TM Number 51-91-03. Default distances apply if a front barricade is not provided. NOTE: Two storage concepts have been approved. The first storage concept consists of 12-inch reinforced masonry walls with a reinforced concrete roof and floor slab and 3 ft of earth cover. A metal storage locker is located within the cavity. The second storage concept uses railroad ties to form the walls and roof of the structure. Three feet of earth are required on top of this structure. A metal storage locker is located within the cavity. A front barricade is needed with both concepts.						
41	Modular Ready Magazine (MRM)	UNK	Reinforced Concrete Box, with internal non-propagating walls	NFESC	31-Jul-97	Undefined	500
	The allowable NEW for each of the five bays in the MRM is 500 lbs HD 1.1. The internal non-propagating walls limit the MCE to 500 lbs NEW. The ESQD associated with this ECM design is 1,250 ft out the front and 700 ft for the sides and rear. Constructed at MCAS Kaneohe Bay.						

#	Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019						
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**Approval Date**	**Magazine Designation**	**Magazine MCE (lbs of HD 1.1)**
	NOTE: The MRM is a five-cell ECM designed to store one, loaded AERO 51 trailer in each cell. The only ordnance items permitted within the cells are MK50 Torpedoes; GM Tactical Penguin; Sonobuoy HE, SSQ-110; GM Tactical Maverick; Bomb, GP MK 82; Bomb, GP MK 83; Bomb, Rockeye MK 20; MK 46 Torpedo (MK 103 Warhead); and GM Tactical Harpoon Missile. Other limitations are: the maximum height from the floor of any ordnance item is 6.5 ft; a 1.5-ft separation distance is required between weapon and walls; a stand-off of 1 ft is required from the floor; bombs cannot be fuzed while in MRM storage; and the Maverick and MK 50 Torpedo (directed energy weapons) must be oriented so that their directed effects are towards the front or back wall of the MRM. The BOD of the MRM, constructed at Marine Corps Air Station (MCAS) Kaneohe, HI, is found in NFESC Technical Report TR-2056-SHR, May 96.						
42	Multiple Round Container (MRC)	UNK	SS Tube with welded/bolted end caps	Office of the Product Manager for Non-Stockpile Chemical Materiel (PMCD)	16 June 2006/16 Nov 2007	AG	See Comments
	The DDESB has approved two designs (7 inches by 27 inches and 9 inches by 41inches) of the multiple round container (MRC) for non-propagation storage of chemical rounds containing bursters (but no fuzes) with zero (0) QD. The containers are approved for explosively configured RCWM with NEW less than or equal to 105-mm M60. The application of chemical arcs still must be accomplished. Refer to the DDESB memorandums for additional considerations/limitations.						
43	NABCO SV-23	N/A	Metal cylindrical vessel with elliptical heads, both ends	NABCO, Inc.	21-Dec-01	AG	22 TNT equivalent
	Refer to the DDESB approval memo for restrictions and conditions associated with the use of the NABCO SV-23. Manufactured by NABCO, Inc., of Pittsburg, PA. The SV-23 is designed to contain/limit explosion effects from an internal detonation of 22 lbs of TNT equivalent material. The SV-23 is available in two models, one with a fragment defeating liner and one without. Both designs have munition diameter limitations associated with them. Internal pressures are vented slowly through 2 vents in the top and around the door. A minimum of 24 inches standoff distance must be maintained between explosives and the interior wall/door. The reduced QD are 5 ft IBD, 5 ft PTRD, and 2 ft ILD. IMD requirements provided by DDESB memo. NOTE: The SV-23, increased NEW SV-23, SV-50, and SV-80, manufactured by NABCO Inc., are approved for storage of fragmenting munitions with diameters up to 1.6 inches (40 mm) and explosives materials weighing up to 23, 32, 50, and 80 lbs NEW, respectively. A minimum internal standoff distance for explosives separation from the nearest inside wall is required (24 inches for the SV-23, and 30 inches for the increased NEW SV-23, SV-50, and SV-80). Refer to DDESB approval memorandum for specific requirements for each SV version.						
44	NABCO SV-23 (Increased NEW)	N/A	Metal cylindrical vessel with elliptical heads, both ends	NABCO, Inc.	10-Apr-03	AG	32

Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
	Through additional testing, NABCO, Inc. demonstrated that the SV-23 had the capability to contain explosion effects from 32 lbs (plus a 25 percent additional test charge). Based on the results of testing, the DDESB approved the SV-23 for a larger NEW quantity. QD were modified accordingly. Refer to the DDESB approval memo for restrictions and conditions associated with the use of the NABCO SV-23 for storage of explosives quantities up to 32 lbs NEW. A minimum of 30 inches standoff distance must be maintained between explosives and the interior wall/door. The reduced QD are 15 ft IBD, 15 ft PTRD, and 5 ft ILD. IMD requirements provided by DDESB memo. NOTE: See note in row 43.						
45	NABCO SV-50	N/A	Metal cylindrical vessel with elliptical heads, both ends	NABCO, Inc.	16-Apr-04	AG	50
	Refer to the DDESB approval memo for restrictions and conditions associated with the use of the NABCO SV-50. Manufactured by NABCO, Inc., of Pittsburg, PA. The SV-50 is designed to contain/limit explosion effects from an internal detonation of 50 lbs NEW of HD 1.1. The design has munition diameter limitations associated with it. Internal pressures are vented slowly through 2 vents in the top and around the door. A minimum of 30 inches standoff distance must be maintained between explosives and the interior wall/door. The reduced IBD and PTRD are 20 ft to the front and sides, which transitions to a 5 ft IBD and PTRD to the rear. IMD requirements provided by DDESB memo. NOTE: See note in row 43.						
46	NABCO SV-80	N/A	Metal cylindrical vessel with elliptical heads, both ends	NABCO, Inc.	23-Mar-09	AG	80
	Through additional testing, NABCO, Inc. demonstrated that the SV-50 had the capability to contain explosion effects from 80 lbs (plus a 25 percent additional test charge). Based on the results of testing, the DDESB approved the SV-50 for a larger NEW and QD were modified accordingly. Refer to the DDESB approval memo for restrictions and conditions associated with the use of the NABCO SV-80. A minimum of 30 inches standoff distance must be maintained between explosives and the interior wall/door. The reduced IBD and PTRD arc is in the shape of a baseball field and measures 35 ft to the front, 35 ft to the sides (measured from the center of the door), and l0 ft to the rear. The required ILD is 15 ft to the front and sides of the entrance of the SV-80 vessel and 5 ft to the rear. IMD requirements are given in the DDESB memo. NOTE: See note in row 43.						
47	NABCO Portable Total Containment Vessel (PTCV)	N/A	Metal cylindrical vessel with elliptical heads, both ends	NABCO, Inc.	18-Jun-04	AG	2.25

#	Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019						
	Drawing Number	**Drawing Date**	**Description**	**Designer**	**Approval Date**	**Magazine Designation**	**Magazine MCE (lbs of HD 1.1)**
	Refer to the DDESB approval memo for restrictions and conditions associated with the use of the NABCO PTCV. Manufactured by NABCO, Inc., of Pittsburg, PA. The PTCV is a dual-vessel containment system approved for containment of an internal detonation of 2.25 lbs NEW of non-primary fragment producing HD 1.1 (e.g., bulk explosives). After explosives are placed into the PTCV, a lever attached inner vessel is rotated 180 degrees in order to seal off the opening. Pressures from an internal detonation are slowly released from around the door seal. The IBD, PTR, ILD, and IMD is 3 ft. NOTE: See note in row 43.						
48	Non-Propagating Explosives Storage Cabinet	N/A	Reinforced Concrete Box, earth-covered	Bartles, presented at the 12th Symposium of Explosives	UNK	ECM	5 lbs TNT
	Sandia National Laboratories (SNL), Albuquerque, working with New Mexico Engineering Research Institute (NMERI), developed a design for a non-propagating explosives storage cabinet capable of preventing propagation to an adjacent cabinet for 5 lbs TNT. The design was to be incorporated into ECM housing 20 such cabinets (2 rows with 10 back-to-back) with the MCE remaining 5 lbs NEW. A maze is provided to stop the door and other debris and to attenuate blast effects. A description of the development program and testing results can be found in Sandia Report SAND90-1906, dated August 1991, “Development of a Non-Propagating Explosives Storage Cabinet.” Due to insufficient data, the default QD will need to be used, until such time as additional information is made available.						
49	Prosser/Enpo Containment Magazine	UNK	Metal box	AF	1-May-89	AG	N/A
	An aboveground metal magazine capable of completely containing fragments from an explosion involving up to 1,000 DUPONT E-117 detonators when stored in the defined configuration. The ESQD is based on blast only. Use of this magazine was approve for a DCMA contractor who was unable to meet a 670-ft ESQD requirement.						
50	Protectainer Model DROR-1	N/A	Metal box	Israeli company (see comments)	25-June-98	AG	1.1
	Manufactured by Koors Metals Ltd of Israel. The U.S. distributor is Mistral Security, Inc. Called the Protectainer Model DROR-1 and is designed to fully contain the hazardous effects from the detonation of 1.1 lbs HD 1.1. Approved by the DDESB on a site approval for Building 568, Room 8, at Fort Dedrick, MD (U.S. Army Technical Center for Explosives Safety, SIOAC-EST File Number 1258), and on a site approval for the TAIL Laboratory at the Detroit Arsenal (approval dated 18 Nov 99). Contact U.S. Army TCES for information. The ESQD for this container was specifically defined by the approval letters for the rooms they were sited in.						
51	Prototype, Non-propagation 40-mm HEDP Storage Container	N/A	Aluminum box with pumice separated slots for M433 grenades	NWC China Lake	UNK	AG	One M433 grenade

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
	Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019						
	This design was developed by NWC China Lake for Eglin AFB in 1989. The effort involved developing an aluminum, pumice-filled container that would hold M433 grenades and prevent the propogation of one grenade to the remaining grenades in the box. Testing, described in NWC TP 7029, August 1989, proved out the concept, but a DDESB approval memo has not been found yet. This entry is to make Services aware of this work, in the event they might have additional information about this work.						
52	Ready Service Magazine (C-2748)	31950	Reinforced Concrete Box	MCLB Albany	10-Apr-87	Undefined	20
	Constructed at Marine Corps Logistics Base, Albany, GA, in accordance with local Drawing C-2748. ECM has internal dimensions of 5 ft^2. A front barricade is required for application of a reduced ESQD. The IBD is 110 ft, and PTRD is 65 ft. Explosives must be kept a minimum of 1 ft from walls and ceiling.						
53	Ready Storage Magazine for various grenades in pumice-filled containers	N/A	Metal box	Navy	8-Apr-93	AG	One grenade
	This AGM was developed for storage of 40-mm M433 HEDP Grenades, M67 Fragmentation Grenades, and MK3A2 offensive hand grenades in specially designed pumice-filled containers, placed inside a specific, modified Sam Nally magazine. Conditions of 8 Apr 93 DDESB letter must be met. NAWC-WPNS TM 7263, dated February 1992, provides test and design criteria for the pumice containers and the magazine. MCE is one grenade. The grenade containing the largest NEW is the MK3A2 which contains 0.5 lb of explosives. The ESQD for this magazine is 0 ft.						
54	Shipping Container for Transportation of Small Samples of Dry Primary Explosives	N/A	6-inch by 12 to 14-inch Schedule 80 Seamless Pipe with 6-inch dia. Malleable iron end caps	NAVSEA SYSCOM	DOT approved	AG	25 grams (0.055 lbs)
	This shipping container is rated for explosive or pyrotechnic material, including waste containing explosives that has energy density not significantly greater than that of pentaerythritol tetranitrate. Refer to the latest version of DOT-SP 8451. When packed in this container, treat contents as 1.4E.						
55	Shipping Container for Transportation of Small Samples of Dry Primary Explosives	N/A	4-inch by 14-inch Schedule 80 Seamless Pipe with 4-inch dia. forged steel end caps	NAVSEA SYSCOM	DOT approved	AG	25 grams (0.055 lbs)
	This shipping container is rated for explosive or pyrotechnic material, including waste containing explosives that has energy density not significantly greater than that of pentaerythritol tetranitrate. Refer to the latest revision of DOT-SP 8451. When packed in this container, treat contents as 1.4E.						
56	Shipping Container for	N/A	Metal box	Los Alamos National	DOT	AG	15 grams (0.033

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
	Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019						
	Transportation of Small Samples of Dry Primary Explosives			Laboratory	approved		lbs)
	Model LD-1000 explosive or pyrotechnic material, including waste containing explosives that has energy density not significantly greater than that of pentaerythritol tetranitrate. Refer to the latest version of DOT-SP 8451. When packed in this container, treat contents as 1.4E. NOTE: Construction of Models LD-1000 and LD-2250 is described in "Shipping Containers for Small Samples of High Explosives" by Richard A. Hildner and Manual J. Urizar, Los Alamos National Laboratory Report No. LA-9107-MS/UC-71, Hercules Incorporated's application, dated January 14, 1993.						
57	Shipping Container for Transportation of Small Samples of Dry Primary Explosives	N/A	Metal box	Los Alamos National Laboratory	DOT approved	AG	25 grams (0.055 lbs)
	Model LD-2250 rated for explosive or pyrotechnic material, including waste containing explosives that has energy density not significantly greater than that of pentaerythritol tetranitrate. Refer to the latest version of DOT-SP 8451. When packed in this container, treat contents as 1.4E. NOTE: See note in row 56.						
58	Shipping Container for Transportation of Small Samples of Dry Primary Explosives	N/A	Metal box	See comments	DOT approved	AG	25 grams (0.055 lbs)
	The device described in "Handling Procedure and Design of a Shipping Container for Transporting Small Samples of Dry Primary Explosives" by Harold K.H. Bartles, presented at the 12th Symposium of Explosives and Pyrotechnics on March 13, 1984 in San Diego, California, is USA Rated for explosive or pyrotechnic material, including waste containing explosives that has energy density not significantly greater than that of pentaerythritol tetranitrate. Refer to the latest version of DOT-SP 8451. When packed in this container, treat contents as 1.4E.						
59	Small Explosives Magazine, TYPE I	91-11-1F through 91-11-3F	Metal box	NCEL	12-Mar-92	AG	1
	The ESQD is 20 ft. Intraline distance is 12 ft. Operational requirements are contained in NCEL TM M-51-91-07, dated Feb 91.						
60	Suppressive Shields	N/A	Metal containers of various shapes and dimensions	Edgewood Arsenal	See Comments	AG	See Comments

#	Drawing Number	Drawing Date	Description	Designer	Approval Date	Magazine Designation	Magazine MCE (lbs of HD 1.1)
	Table AP1-4. Magazines (Earth-Covered and Aboveground) and Containers with Reduced NEWs and/or Reduced QD, June 2019						
	A suppressive shield is a vented, steel enclosure, which is capable of controlling or confining the hazardous blast, fragment, and flame effects of internal detonations. There are 8 Groups of suppressive shields that have been developed and approved by the DDESB, and these are described in Paragraph 6.3. Allowable NEWs range from 2,000 lbs to approximately 1 lb. These shields were designed to provide very high levels of personnel protection at less than the required default separation distances.						
61	Type 2 Explosive Storage Magazine with Barricades	N/A	Steel box with earthen barricades	Army	16-Jun-15	AG	110
	Two configurations are approved for reduced QD for use in deployed scenarios. Both configurations use a 7 ft by 7 ft by 7 ft ARMAG Inc. Type 2 magazine with Expeditionary Barrier System (EBS) barricades. Configuration 1 includes four 42inches thick EBS walls and a 24 inch thick EBS roof placed over fiberglass decking. Configuration 2 includes only the four 42 inches thick EBS walls. Configuration 1 has an IBD of 200 ft and PTRD of 120 ft. Configuration 2 has an IBD of 410 ft and PTRD of 246 ft. Default IMD and ILD apply.						
62	X8745127 through X8745138, X8745146, and X8851911	UNK	Reinforced Concrete Box	Hill AFB	Apr-02	AG	500,000
	An early version of the Air Force MSM. Unlike MSM design 9210827 through 9210832 (Hill AFB) and 9484969 (Eglin AFB), this design could not be upgraded to a 7-Bar design because it has a weaker roof design. Previously, it had been considered an Undefined ECM, as documented in approval memos. However, all future siting of these magazines must apply AGM criteria due to inadequate roof strength.						

LIST OF ACRONYMS

AASTP	Allied Ammunition Storage and Transport publication
AE	ammunition and explosives
AFM	Air Force manual
AFR	Air Force regulation
AFSEC	Air Force Safety Center
AFSSG	Air Force special study group
AFWL	Air Force Weapons Laboratory
AGM	aboveground magazine
AIM	air intercept missile
ANG	Air National Guard
ARBRL	Army Ballistics Research Laboratory
ARDEC	Armanent Research, Development Engineering Center
ASESB	Armed Services Explosives Safety Board
ASET	Aircraft Shelter Explosive Test
ASP	AGAN steel panel
ATD	American Table of Distances
AUR	all-up-round
BEM	buried explosion module
BOD	basis of design
BODD	basis of design document
CBU	cluster bomb unit
CDC	controlled detonation chamber
CEHNC	U.S. Army Engineering and Support Center, Huntsville
CONEX	Container Express
CT	certification test
D	distance in feet
DASA	Defense Atomic Support Agency
DAVINCH™	Detonation of Ammunition in a Vacuum Integrated Chamber
DBC	Donovan blast chamber
DDESB	Department of Defense Explosives Safety Board
DESR	Defense Explosives Safety Regulation
DLAR	Defense Logistics Agency regulation
DNA	Defense Nuclear Agency
EB	enclosed barricade

ECM	earth-covered magazine
EDS	explosive destruction system
EOD	explosive ordnance disposal
ERDC	Engineer Research and Development Center
ES	exposed site
ESKIMO	Explosive Safety Knowledge Improvement Operation
ESQD	explosive safety quantity-distance
EXWC	Expeditionary Warfare Center
ft	feet or foot
ft^2	square foot or feet
ft^3	cubic feet
FY	fiscal year
GT	gas tight
HAS	hardened aircraft shelter
HD	hazard division
HEST	High Explosive Simulation Technique
HFD	hazardous fragment distance
HMX	high melting explosive
HPM	high-performance magazine
HQ	headquarters
IBD	inhabited building distance
IED	improvised explosive device
ILD	intraline distance
IMD	intermagazine distance
ISO	International Organization for Standardization
JANMB	Joint Army Navy Munitions Board
JBA	Joint Board of Ammunition
K	a factor depending on the risk assumed or permitted
kg	kilogram
kPa	kilopascal
lbs	pounds
m	meter

MCAS	Marine Corps Air Station
MCE	maximum credible event
MFD	maximum fragment distance
MGFD	munition with the greatest fragment distance
mm	millimeter
MMF	missile maintenance facility
MOFB	miniature open front barricade
MPB	missile processing building
MSD	minimum separation distance
MSM	modular storage magazine
MTC	missile test cell
NAD	Naval Ammunition Depot
NATO	North Atlantic Treaty Organization
NAVFAC	Naval Facilities Engineering Command
NAVSEAINST	Naval Sea Systems Command instruction
NCEL	Naval Civil Engineering Laboratory
NEQ	net explosive quantity
NEW	net explosive weight
NEWQD	net explosive weight for quantity-distance
NFESC	Naval Facilities Engineering Service Center
NOTS	Naval Ordnance Test Station
NPW	non-propagation wall
NSWC	Naval Surface Warfare Center
NWC	Naval Weapons Center
OCE	Office, Chief of Engineers
OCO	Office of the Chief of Ordnance
ODC	on-site demolition container
OE	ordnance environmental
OFB	open front barricade
OQMG	Office of the Quartermaster General
Pa-s	pascal-seconds
psi	pounds per square inch
psi-ms	pounds per square inch per millisecond
PTRD	public traffic route distance
QD	quantity-distance

SD	sympathetic detonation
SDW	substantial dividing wall
SEA	Southeast Asia
SG	sensitivity group
TAB VEE	tactical air base hardened aircraft shelter
TACOM	Tank-automotive and Armaments Command
TB	technical bulletin
TDP	technical data package
TM	technical manual
TN	technical note
TNT	trinitrotoluene
TO	technical order
TOW	tube-launched, optically tracked, wire-guided
TP	technical paper
TR	technical report
UFC	Unified Facilities Criteria
USACE	U.S. Army Corps of Engineers
USAF	United States Air Force
UXO	unexploded ordnance
W	net explosive weight
WBDG	Whole Building Design Guide
WP	white phosphorus
Y&D	yards and docks

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