# Dichotomy of Legacy Explosive Cubicle Designs and DoD 6055.09 Personnel Protection Requirements from an Accidental Detonation

**William H. Zehrt, Jr., PE**
**US Department of War - Explosives Safety Office**

**International Explosives Safety Summit**
**Phoenix, AZ – January 22, 2026**

# Presentation Outline

- Introduction and Terminology
- Great Expectations
  - Definition, Design, and Siting of 12-inch SDWs
  - A Complication: Operational Shields and the Expanded Use of 12-inch SDWs
- Reality Strikes
  - Damages Sustained by 12-inch SDWs in Accidental Detonations of Low HD 1.1 NEWs
  - Internal Detonation Tests and Development of Blast Design Requirements for Cubicles
- Introduction of Personnel Protection Requirements and their Application to Legacy Cubicles

# Introduction and Terminology

**Introduction** - The 12-in SDW design was developed in response to the unexpectedly severe damage and debris hazards observed in accidental detonations of small quantities of explosives in brick and masonry buildings/cubicles in the early years of WWII.

**Terminology**

- DDESB
  - Joint Army-Navy Ammunition Storage Board (1928-1945)
  - Army-Navy Explosives Safety Board (1945-1948)
  - Armed Services Explosives Safety Board (1948-1971)
  - Dep't. of Defense Explosives Safety Board (1971-2025)
  - Dep't. of War Explosives Safety Board (2025 to present)

# Terminology

- UFC 3-340-02, “Structures to Resist the Effects of Accidental Explosions” – Previous editions were designated as the tri-service manuals:
  - Army TM 5-1300/NAVFAC P-397/AFR 88-22 (1969)
  - Army TM 5-1300/NAVFAC P-397/AFR 88-22, revision 1 (1990)
- SDW – Substantial Dividing Wall
- AE – Ammunition and Explosives
- HD 1.1 – Hazard Division 1.1 (mass detonating AE)
- MCE – Maximum Credible Event

# Definition, Design and Siting of 12-inch SDWs

***"Ordnance Safety Manual," O. O. Form 7224, 1 Dec 1941***

- Definition: A SDW may be used to subdivide HD 1.1 AE into two rooms. If an accidental MCE detonation occurs in one room, the SDW will prevent the sympathetic detonation of HD 1.1 AE in the other room.
- Design: "A substantial dividing wall must extend to the roof and the side walls of the building or room which it divides into separate rooms. It must consist of concrete at least 12 inches thick, reinforced on both sides by rods [reinforcing bars or rebars] at least ½ inch in diameter, located at maximum centers of 12 inches both vertically and horizontally."
- June and October 1942 supplements allowed 20,000-lbs HD 1.1 NEW on each side of a SDW; WWII Field Director of Ammunition Plants allowed up to 65,000-lbs HD 1.1 NEW in each room.

# Definition and Design of 12-inch SDWs

***"Ordnance Safety Manual," O. O. Form 7224, 3 May 1945***

- Definition: "An interior wall in a building designed to prevent simultaneous detonation of quantities of explosives on opposite sites of the wall."
- Additional Design Requirements: Rebars must be interlocked with footing bars and secured to prevent overturning. Rebars in one face be must staggered with regard to the rebars on the opposite face.
- No HD 1.1 NEW limit defined for rooms separated by a 12-inch SDW.

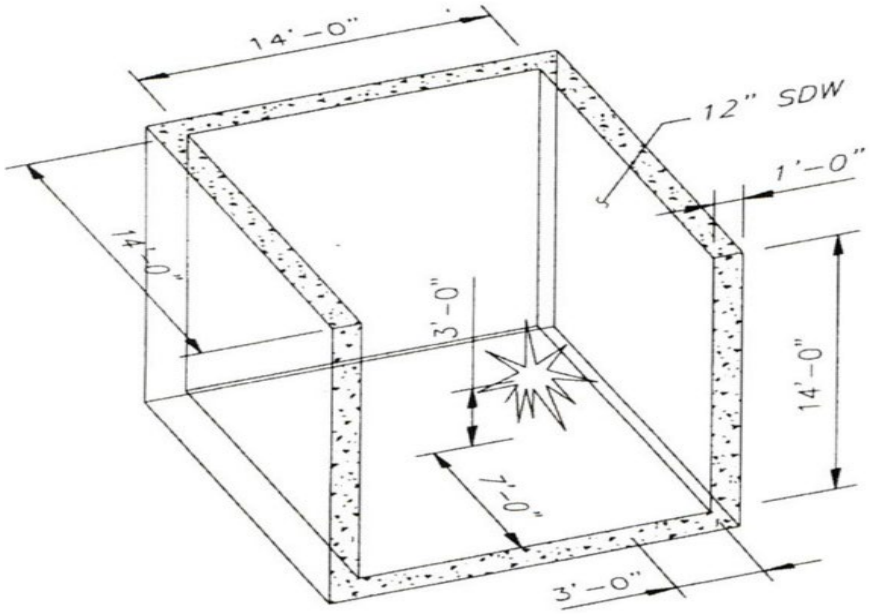
*In 1951, DDESB and the Services applied data from 1944-45 exterior detonation tests to approve a 5,000-lb HD 1.1 NEW limit in each of the two rooms separated by a 12-inch SDW.*

# Definition and Design of 12-inch SDWs

***"Ordnance Safety Manual," ORD-M 7-224 Change 7, 1958***

- Definition (section 271) – "An interior wall designed to prevent simultaneous detonation of quantities of explosives on opposite sides of the wall.'
- Design (section 506a) – Supplements previous requirements with two recommendations
  - Rebars should be approximately 2 inches from each face.
  - Concrete should have a minimum design compressive strength of 2,500 psi.
- Introduces two alternate SDW configurations
  - 5-ft thickness of packed sand or earth, held between concrete, masonry or wooden retaining walls.
  - 6-ft thickness of sandbags (least desirable except for strictly temporary operations).

# Legacy Explosives Cubicle




- Typical interior cubicle dimensions range from 8-ft to 25-ft
- Wall footings typically used for foundation in lieu of floor slab.
- Exterior wall and roof are inset and constructed of lightweight/frangible materials to facilitate venting of blast overpressures.
- Access provided through a door in the exterior wall.

# A Complication: Operational Shields

***"Ordnance Safety Manual," O. O. Form 7224, 3 May 1945***

- Introduced operational shield concept.
- Definition: "A ***barrier*** within an operating building constructed to protect personnel, materiel, or equipment from the effects of a fire or explosion occurring at a particular location." *[emphasis added]*
- No design guidance or NEW limits provided for operational shields.

***"Ordnance Safety Manual," ORD-M 7-224, 4 Sep 1951`***

- Operation shield definition unchanged.
- Over time, though, 12-inch SDWs were increasingly used to provide some undefined – and varying - level of protection from an accidental detonation of an also often undefined, HD 1.1 NEW.

# ORDM 7-224 – Change 3 (1954)

- **Section 2003 – Temporary Storage in Shipping and Receiving Rooms** – "Special rooms shall be provided for the temporary storage of ammunition and explosives awaiting shipment, and for their preparation for shipment before assembling, crating, marking, etc. The rooms shall be separated from each other by ***substantial dividing walls*** and shall be separated from offices and rooms in which inert operations such as the preparation of stencils, packing, and crating are performed, by ***substantial dividing walls*** so constructed that they comply with the requirements for fire walls also." *[emphasis added]*

# ORDM 7-224 – Change 3 (1954)

- **Section 2619 – Concurrent Operations in Loading Plants –** "*e.* Some explosives operations are inherently more hazardous than others. The ***personnel exposure*** in locations where concurrent operations must be performed should be controlled by installation of ***dividing walls*** so that the number exposed is no greater than if a single type of ammunition were worked on." *[emphasis added]*

# ORDM 7-224 – Change 4 (1955) and Change 7 (1958)

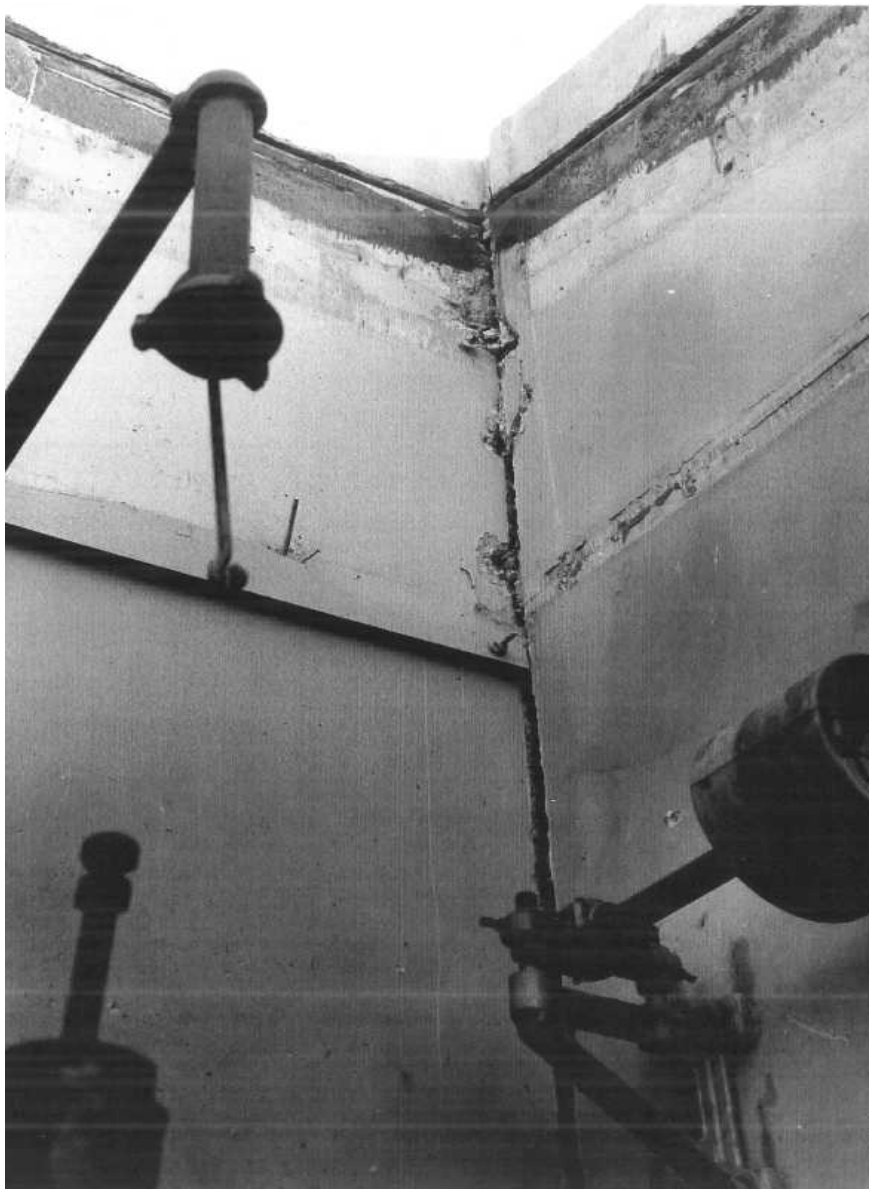
- **Section 2511 – Sand or Shot Blast Operations within a Building in an Operating Line** *[Changes 4 and 7]* – "*a.* The actual sand or blast operating must be separated from the preceding and/or succeeding operations by means of a ***substantial dividing wall to protect all other personnel*** in an unusual incident occurring at this location. Openings in the dividing wall shall be limited to the minimum size requirements to facilitate the handling of items to and from the operation…" *[emphasis added]*
- **Section 1621 – Maintenance and Repairs to Equipment and Buildings** *[Change 7]* – "*i.* Maintenance and tool rooms in an operating line should be separated from explosives by intraline distance. When ***intraline distance*** cannot be provided, protection equivalent to that afforded by a ***substantial dividing wall*** must be provided*." [emphasis added]*

# ORDM 7-224 – Change 7 (1958)

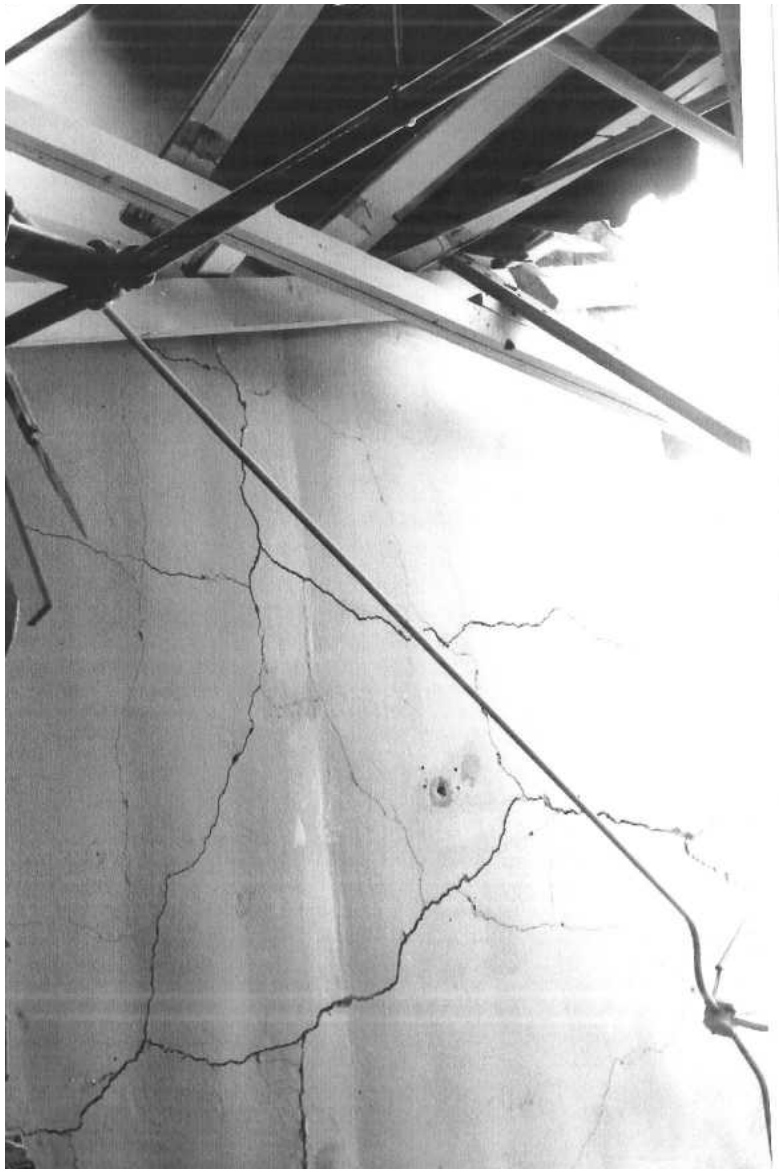
- **Section 2804 – Loading and Assembly Building** - "*a.* The building or buildings used for the assembly and loading of ammunition shall be designed and constructed in accordance with established explosives safety principles. ***Personnel and explosives or ammunition*** shall be kept at the minimum consistent with safe and efficient operations. ***Substantial dividing walls*** shall be used to **limit exposures** and to separation operations involving dissimilar hazards…" *[emphasis added]*

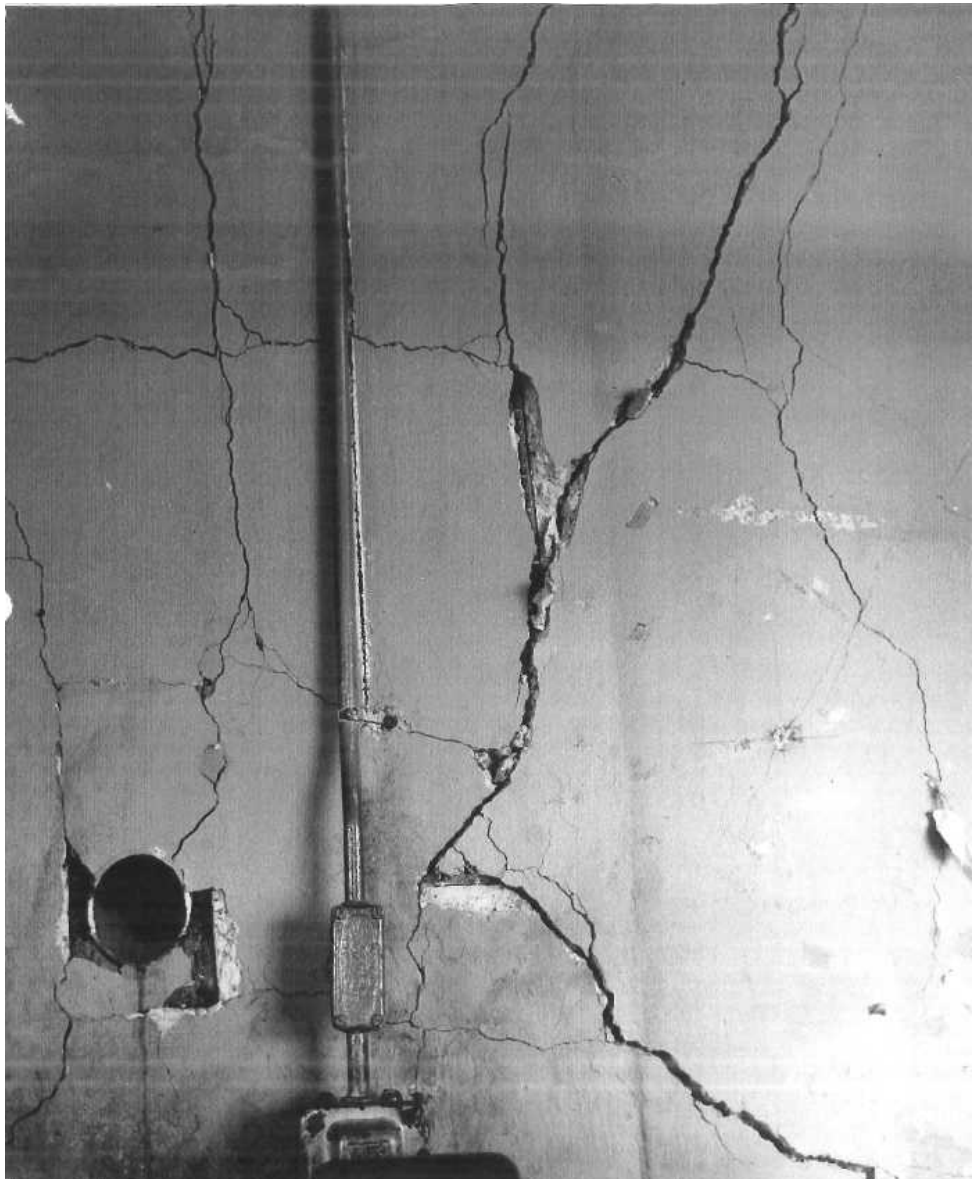
# Accident 1 – Damage to WWII Era Cubicles

# Accident 1 – Concrete Disengagement at Wall Joints



# Accident 1 – Damage to Donor Cubicle Walls





# Accident 2 – Damage to WWII Era Cubicles

# Accident 2 – Damage to Donor Cubicle Walls

Side Wall

Rear Wall

# Accident 3 – Enhanced Damage from Common Roof

# Accident 4 – Basis of HD 1.1 NEW limit in SDW Memos

# Accident 4 – Damage to Donor Cubicle

Inside Cubicle

Outside Cubicle

# Accident 4 – Concrete Disengagement at Wall Joint

# Internal Detonation Tests (1960 to present)

In 1959, DDESB established a “Work Group to Determine the Effectiveness of Dividing Walls in the Prevention of Propagation of Explosions.”

- Between 1960 and 1962, DDESB and the Servies funded 21 full-scale detonation tests in open, 3-wall cubicles; the blast loads measured in these tests made us aware of shock wave reflections inside a cubicle in an internal detonation and the resulting enhancement o shock loads.
- In subsequent tests, the development of longer duration blast overpressures – commonly referred to gas pressures – inside cubicles with covered vent surfaces underscored the importance of incorporating lightweight/frangible vent surfaces in cubicle designs to facilitate the venting of blast overpressures to the exterior.

# Blast Cubicle Design IAW UFC 3-340-02 (1969 onward)

- These and subsequent detonation tests alerted us to premature failure mechanisms – direct shear, diagonal tension, breaching, etc. - which may limit the protection afforded by a reinforced concrete dividing wall.
- Similar to ACI 318, UFC 3-340-02 and its predecessors apply supplementary blast design requirements to prevent premature failures of wall and roof elements, ensuring that they fail in flexure (bending) after undergoing large deflections/support rotations.
- Since 12-inch SDWs are reinforced only in flexure (bending), they may fail prematurely in other failure modes (direct shear along supports, diagonal tension, breaching, etc.); these failure modes have been observed in detonation tests and explosive accidents.

# Introduction of Personnel Protection Requirements

"***DoD Ammunition and Explosives Safety Standards***," **DoD 6055.09-STD (1984)** introduced the following personnel protection requirements:

- Hazard Assessment – Assessment of risk shall be performed on all new or modified industrial operations and facilities involving ammunition and explosives.
- When a hazard assessment indicates that the probability of an accidental explosion is above an acceptable risk level, personnel protection must limit exposures to:
  - Incident blast overpressure ≤ 2.3 psi [15.9 kPa].
  - Fragment energy < 58 ft-lb [79 joules]
  - Thermal flux ≤ 0.3 calorie per $cm^2$ [12.56 kW per $m^2$] (subsequently revised)
- These personnel protection requirements remain in effect.

# Personnel Protection and Siting of Legacy Cubicles

- In general, a 12-inch SDW – or any other legacy dividing wall not designed IAW UFC 3-340-02 - should not be used to satisfy personnel protection requirements to cubicles/hallways immediately adjacent to a HD 1.1 donor cubicle.
- The 25 Jan 2020 SDW policy memo provides an empirical approach for evaluating 12-inch SDWs in well-vented cubicles.
- If a cubicle satisfies the memo's requirements, other sources of overpressure, fragmentation and thermal hazards must be evaluated and mitigated, as necessary. Examples:
  - Personnel exposures behind openings in/under cubicle walls.
  - Personnel exposures under a shared/common roof.
- If a legacy cubicle cannot be sited using the 25 Jan 2020 SDW policy memo, a shelter approach (e.g., a hardened control room) may provide the required personnel protection.

# Status of Services' High Priority Prot. Const. Projects

**Update of UFC 3-340-02's gas pressure model and calculation procedure/software (FRANG code)**

- UFC 3-340-02's gas pressure model was developed from blast load measurements in small rooms ($V_{int} \leq 7$ ft$^3$) with small vent areas in one surface ($A_V/V^{2/3} \leq 0.182$).
- This model proved to be very conservative for typical, well-vented cubicles, greatly reducing their HD 1.1 NEW limits.
- In 2018, DDESB funded full-scale detonation tests in cubicles with one and two vent surfaces (wall and wall/roof), confirming the undue conservative of the UFC's model.
- DDESB then funded Dr. Chuck Oswald to use the blast load data from these tests to develop a new gas pressure model.
- Status: Subject matter expert reviews of Oswald's final documentation report, calculation spreadsheet, and user's manual are ongoing. *POC: Dr. Serdar Astarlioglu*

# Status of Services' High Priority Prot. Const. Projects

**Investigation of thermal hazards behind openings in a donor cubicle's walls from an accidental Hazard Division 1.3 (mass fire) initiation**

- DDESB is funding an ERDC research program to measure the thermal hazards behind a donor cubicle's interior doors and penetrations in HD 1.3 initiations; if/when possible, a thermal prediction model/procedure will be developed from these data. *POCs are Josh Payne and Denis Rickman*
- In FY 25, DDESB funded USACE-Huntsville, Structural Branch to design the test cubicle and NAVFAC EXWC to provide technical expertise on the cubicle's design and instrumentation. P*OCs are Michael Pickett and Brad Durant*
- *Co*nstruction of the test cubicle is underway at ERDC's Fort Polk, Louisiana test facility.
- Initial tests are planned for late 2026/early 2027.