

**DESIGN OF A LARGE DOOR
FOR AN EXPLOSION-CONTAINMENT STRUCTURE**

by

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**Presented at the
25th DoD Explosives Safety Seminar
Anaheim, California**

August 20, 1992

Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE AUG 1992		2. REPORT TYPE		3. DATES COVERED 00-00-1992 to 00-00-1992	
4. TITLE AND SUBTITLE Design of a Large Door for an Explosion-Containment Structure				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Black and Veatch, 800 Wilshire Blvd, Los Angeles, CA, 90017				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADA261116, Volume IV. Minutes of the Twenty-Fifth Explosives Safety Seminar Held in Anaheim, CA on 18-20 August 1992.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	unclassified	unclassified	Same as Report (SAR)	10	

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I. BACKGROUND

A. FACILITY DESCRIPTION

The facility addressed in this paper was built during the 1980's to provide for destructive testing of various types of munitions. These types of munitions include: large caliber, kinetic energy (KE) projectiles of up to 155 mm; advance chemical energy (CE) munitions; self-forging fragment (SFF) munitions; and reactive armors (RA). The principal structures at the facility are a Target Room and a Range Tunnel (See Figure 1).

The Range Tunnel is a 340 feet long reinforced concrete box type structure, 20 feet wide by 16 feet tall. The purpose of the tunnel is to enclose the trajectory of test projectiles between launch and entry into the Target Room. It was designed to remain within the dynamic elastic range when subjected to a muzzle blast loading.

The Target Room, located at the down-range end of the Range Tunnel, is the place of projectile impact. Any one of several types of targets can be located within the room during test firing. The Target Room structure is a vertical truncated cone fabricated from ASTM A572, Grade 60, steel plate. Above this cone is a hemispherical dome, fabricated from ASTM A516, Grade 70, steel plate. The reinforced concrete floor of the Target Room is protected by a cover of armor plate. See Figure 2 for a cross sectional view through the Target Room.

The inside diameter of the conical section at floor level is 59 feet. The clear height inside the Target Room is 29'-6". A three-foot diameter opening in the shell wall adjacent to the Range Tunnel provides for the shot line access. A 14 feet wide by 18 feet high opening was provided in the steel shell for transfer of targets in and out of the room. The original closure for this opening consisted of a horizontally-rolling steel, manually operated door. This original door is now in the process of being replaced, and its replacement is the subject of this paper.

Dust from munitions interactions with the target is controlled by exhaust fans and filters connected to the Target Room. Outside air is introduced through the shot line access opening in the Target Room shell. A high pressure air handling unit forces air and other gases through pre-filters, secondary filters, and high efficiency particulate filters. Blast attenuators, located between the Target Room and filters, minimize sudden pressure differences across the filters. For ease of maintenance, exhaust fans and filters are enclosed in an adjacent structure.

B. EQUIPMENT DOOR DEFICIENCIES

The original door weighed approximately 18,000 pounds. It was designed to operate by rolling laterally across the door opening and then being pulled tight against the shell by a number of peripheral bolts to effect an air seal. Access to these bolts was inconvenient, and tightening the bolts was found to be a time-consuming operation. Over a period of time, the blast pressure impulse on the door and fragment impacts had irreparably damaged the door so that it could no longer be opened and closed manually.

After the door could no longer be manually operated, a fork lift had to be used to position the door before and after each test firing. The time required to move the door by this method, the uncertainty of fork lift availability, and the inconvenience of sealing by a bolted connection all contributed to the decision to investigate possible modifications to the door.

II. INITIAL STUDY

A study was performed to determine the most appropriate action. The study considered economic, reliability, firing range operation, and constructability factors. Criteria for the study were as follows:

- Subsequent repairs to the door would not be required.
- Construction must be phased to coordinate with the range firing schedule.

Two basic options were considered. The first was to modify the existing door and the second was to provide a new door. Eight different variations of the basic options were developed. When all factors were considered, the decision was made that the best course of action would be to replace the door.

III. DESIGN OF THE DOOR REPLACEMENT

A. DESIGN OBJECTIVES

1. Criteria for the original door included provisions for:
 - Containment of pressure within the Target Room,
 - Containment of explosion fragments,
 - Adequate size for passage of targets, and

2. Criteria for the door replacement encompassed all requirements for the original door, plus:
 - Ease of door operation.

B. ESTABLISHMENT OF THE DOOR CONFIGURATION.

Design of the new door configuration was influenced by several inter-related factors that were considered both individually and in concert. These factors were:

1. **Transfer of Blast Pressure at Reaction Points.** The original blast door was positioned inside the Target Room and remained within that room during its opening and closing travels. This inside position allowed bearing against the internal faces of its jambs, a rather simple arrangement. However, experience showed that projectiles created during test firings tended to damage operating mechanisms that were exposed to the interior.

2. **Direction of Motion.** A basic step in design of the door replacement was the definition of its opening and closing motions. Each of twelve singular directions of motion (six ways of translation and six way of rotation) were theoretically possible. By combination of translational and rotational modes, 36 additional travel motions were possible.

3. **Support of Gravity Load.** The completed door replacement was estimated to weigh about ten tons. Support of this ten-ton weight during its travel and while at its terminal positions was considered in parallel with door motion studies. Several schemes involving suspension devices, underneath rollers, and hinges were studied.

4. **Precision of Motion.** Because of it requirement for air containment, little tolerance was permitted in fitting of the door replacement to the door opening. The small tolerance permitted by criteria for air-tightness was reduced to an even lower degree when means for locking into place were considered.

After study of these factors, the basic configuration of the door replacement was established to be:

- The door would be positioned outside the Target Room structure.
- The door would be designed to rotate about a vertical axis that was offset from the door opening.
- Weight of the door would be resisted by rigid connection to an overhead truss. The truss, in turn, was to be

supported on one end by a trolley system that travelled on a curved monorail and on the other end by a steel post with a jib-like connection.

- The internal blast load on the door was to be resisted by multiple locking lugs on its exterior surface.

See Figure 3 for the design configuration of the new door.

C. DETAILS OF DESIGN.

Sizing the door structure to resist an internal blast pressure was straightforward, with the behavior of steel under dynamic loading taken into account. The spring-action rebound of the door after loading was also considered.

The inside plate of the door was designed to be fabricated of Type HY80 steel to provide greater resistance to damage by projectiles emanating from test firings. This type of steel is more normally used for submarine hulls.

A pneumatic hose gasket were designed to seal doors edges for containment of air pressure within the Target Room. This gasket was shielded against damage from projectiles. Accurate fitting of the door to the door frame was made necessary to allow gaskets to function. For this reason, the door replacement was designed for adjustable positioning in horizontal and vertical directions.

The locking mechanism consisted of six latch-bars on both ends of the door; these bars were designed to be electrically inserted and withdrawn (See Figure 4). An annunciator light was designed to prominently display evidence when all latch-bars were not in place, and in this way, prevent test firing while the door was unlocked.

IV. INSTALLATION OF THE DOOR REPLACEMENT

A. PROCUREMENT

Drawings and specifications were prepared for the door replacement, stipulating that the supplier must satisfactorily demonstrate operation of the door upon completion of his work. Purchasing documents also required erection work to be performed only during periods of non-testing at the site.

Although much interest was shown by prospective door suppliers during the design period, this interest narrowed when construction bids for the door were sought. Only a few bids were received, and bid amounts were disappointingly high.

B. CONSTRUCTION

Work preparatory to installation of the door replacement is still underway. Construction problems to date have been (1) a need to repair damage to the existing door frame, and (2) coordinating the contractor's work with the facility operations schedule for testing. Onsite construction work is not permitted during test firing at the facility because of the hazards involved.

V. CONCLUSIONS

The Equipment Door, after its replacement, will likely be one of the most complex and most expensive components of the facility. This complexity and expense resulted from a need for custom-design, a need for precision installation, and other factors that normally attend retrofit of an existing and operating facility.

The primary conclusion of this paper is, then, to emphasize the need for convenient operation of large doors in a containment structure, particularly if doors are to be frequently used. Convenient operation is not easy to achieve and can be even more difficult when the construction budget is strained.

A secondary conclusion may be inferred from the primary one. That is, costs for such doors must be recognized and carefully estimated during the planning phase for a containment structure. Thoroughly detailed estimation of costs for large doors is essential because such costs cannot be found simply by consulting a handbook nor by use of rule-of-thumb estimating guides.

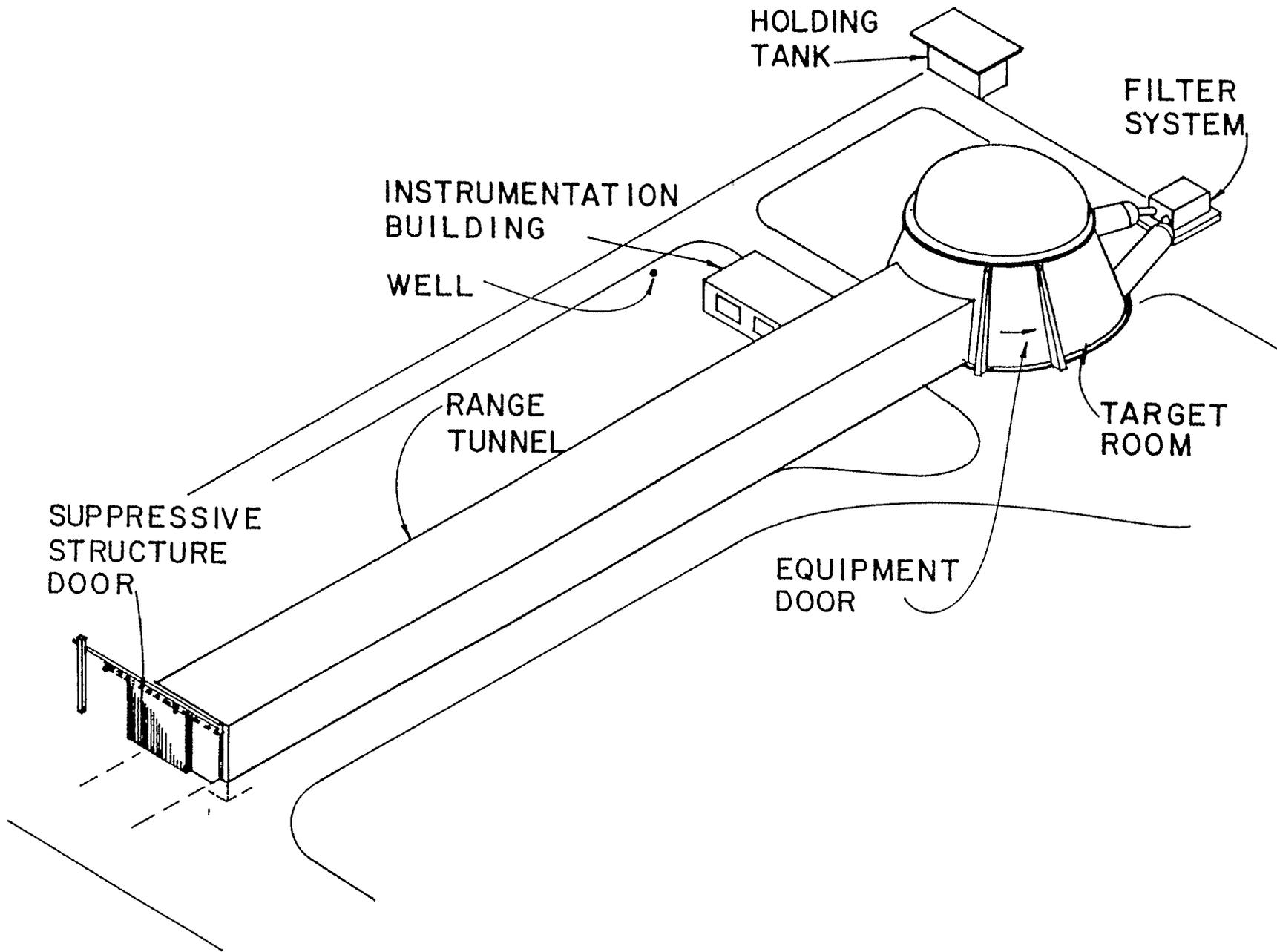
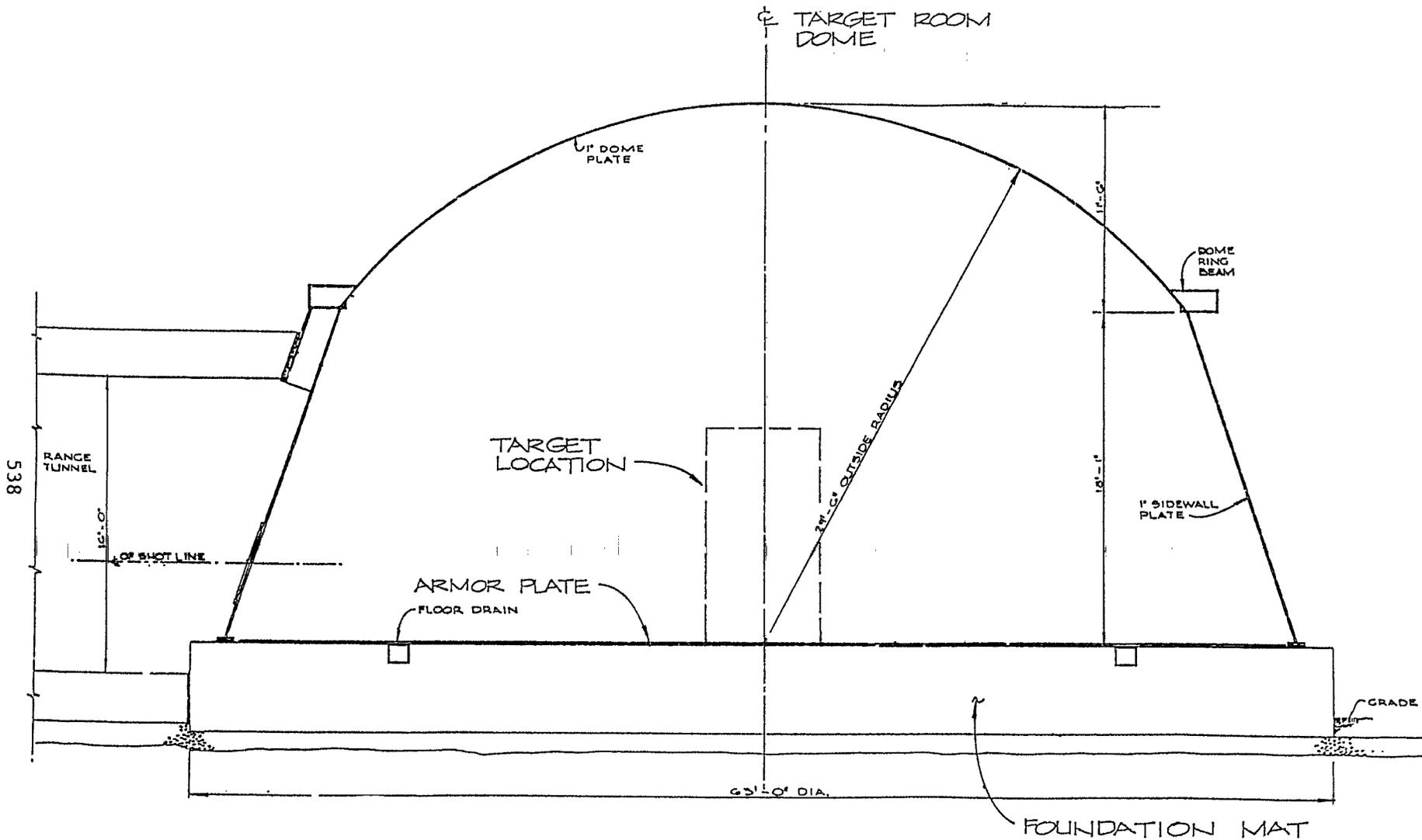


FIGURE 1
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FIGURE 2



TARGET ROOM CROSS SECTION

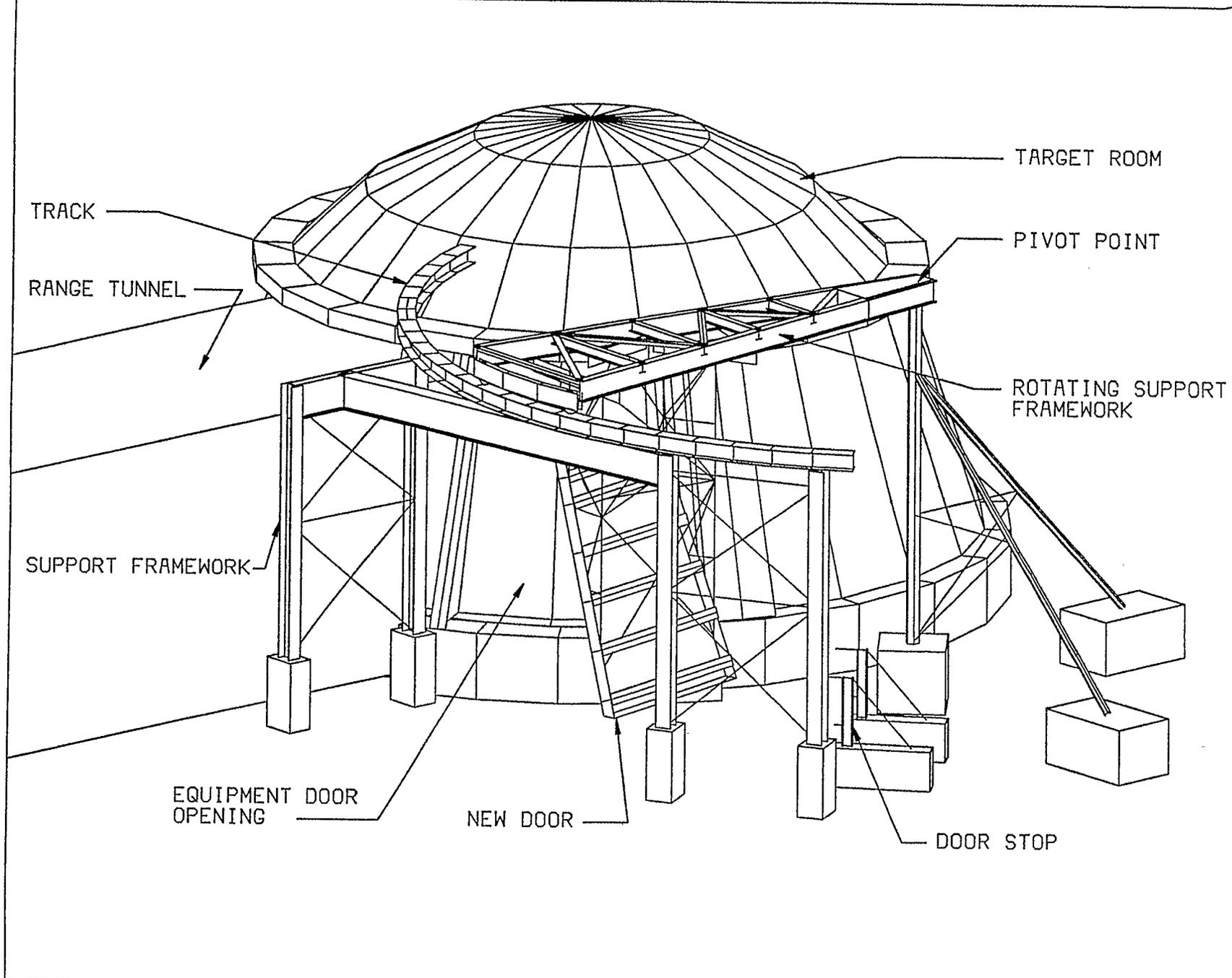


FIGURE 3
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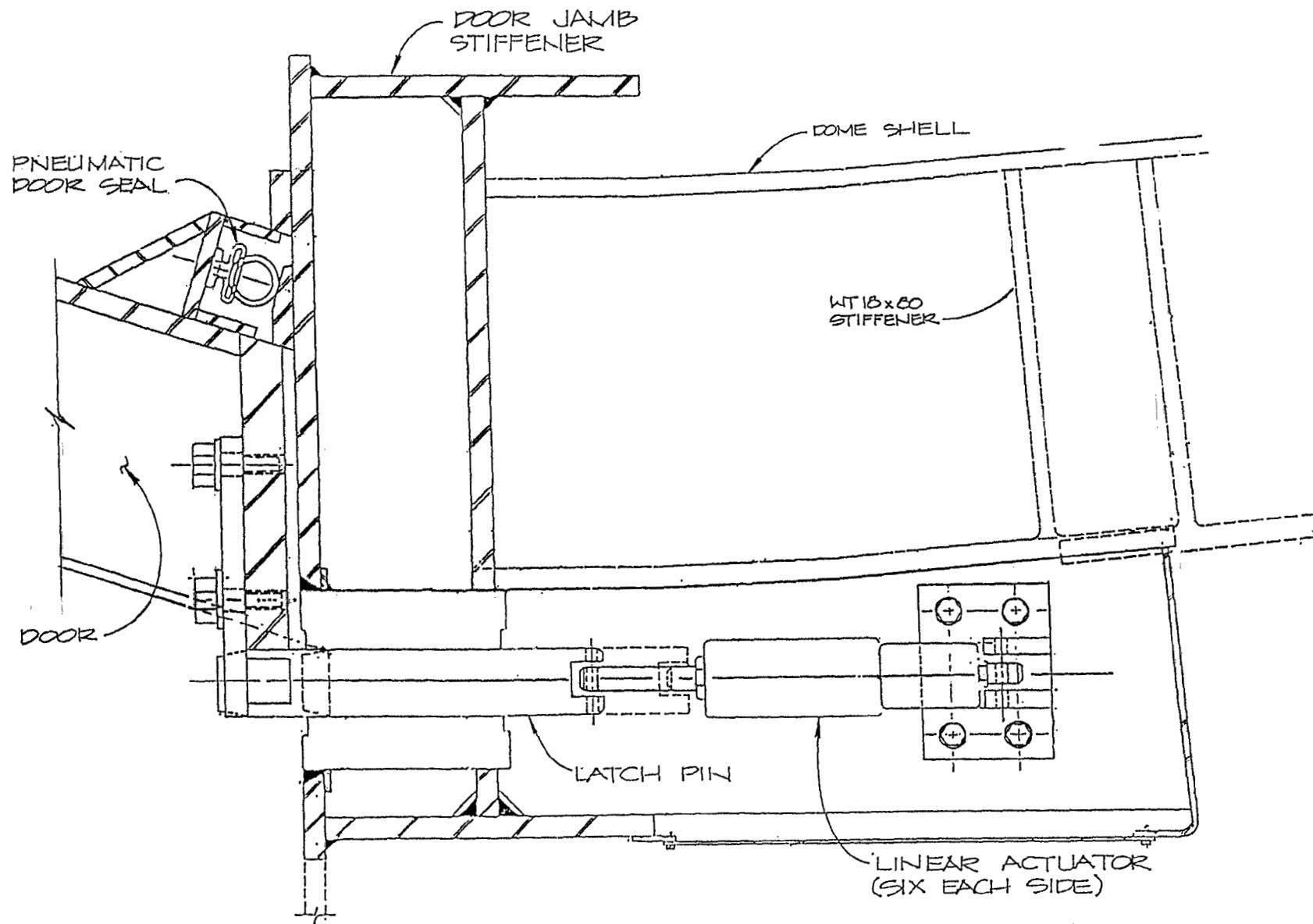


FIGURE 4

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DOOR LATCH DETAIL