HEADQUARTERS
U.S. ARMY CORPS OF ENGINEERS
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DESIGN ANALYSIS

MAGAZINE, STEEL, OVAL-ARCH, EARTH COVERED

(U. S. ARMY CORPS OF ENGINEERS STANDARD DRAWING STD 421-80-03)

1. **Introduction:** The U.S. Army Corps of Engineers maintains a number of Standard Designs. Among the standards, are magazines (igloos). These designs are used throughout the safety community for the storage of explosives and munitions. Several of these magazines are referenced by the DoD 6055.9-STD. Material types vary from concrete to steel, and all have 2'-0" minimum earth covered. The magazines have been approved for the storage of 500,000# net explosive weight when sited IAW DoD 6055.9-STD.

2. **Background:** In 1975, a 25'-1" span steel oval-arch earth covered magazine (33-15-73) was developed and approved by The Department of Defense Explosive Safety Board (DDESB) as a "Standard" magazine. The magazine design contained reinforced concrete thrust beams which ran longitudinally on both sides of the structure. The thrust beams were subsequently removed due to patent infringement. Shortly after, the magazine, minus the thrust beams, was tested during Eskimo V test in 1977. The tested magazine successfully sustained the blast loading that it was designed for without benefit of the thrust beams. Because of the test results and to avoid the royalty payment, the thrust beams were removed from the standard drawings. In 1984, one of eight igloos at Sunflower AAP collapsed and six of the remaining seven exhibited large deflections at the crown. Cause of the collapse and large deflections were attributed construction deficiencies. As a result the magazine was rescinded and no longer approved for new construction.

This design analysis presents a substitute magazine with the same features as the 33-15-73 steel oval-arch. The magazine contains the thrust beams since the patent has now expired.

3. **STD 421-80-03:** This magazine is a steel oval-arch with minimum 2'-0" earth cover. It is an assemblage of components from various sources. Those components that are structurally critical from an explosives safety standpoint are traceable to Department of Defense Explosive Safety Board (DDESB) blast tests and/ or approved magazines. Where dimensional changes in critical components were required, the changes were conservative. A brief discussion of each component follows:

a. Steel Oval-Arch. The oval-arch is of steel construction and 1 gage (0.280 inches) in thickness. The headwall and the rear wall of the magazine is of concrete construction, so is the floor slab. The steel arch is similar to the 33-15-73 magazine with one exception. A concrete thrust beam that runs the length of the magazine was added at the seam between the top plate and corner plates on each side of the structure to provide stability of the oval-arch from the soil loading. Interior dimensions remained the same including anchorage to the arch footings.

b. Door/Headwall. The magazine door/headwall were taken from the concrete, oval-arch, earth covered magazine depicted on Office, Chief of Engineers, Standard Drawing 33-15-74. Drawing 33-15-74 is listed as an approved magazine in DoD 6055.9-STD "Ammunition and Explosives Safety Standards" which is prepared by DDESB. The door and headwall on that drawing were taken from the steel, oval-arch, earth covered magazine depicted on Office, Chief of Engineers, Standard Drawing 33-15-73. That drawing showed the door/headwall that had successfully withstood full-scale explosive forces in DDESB's Eskimo Tests in the the 1970's. The door/headwall were on Test Structure B in both the Eskimo III test (Naval Weapons Center Report TP 5771, Feb 76) and the Eskimo IV test (Naval Weapons Center Report TP 5873, Mar 77).

The pilasters on either side of the door were taken from the Standard Drawing 33-15-74 which is an approved concrete magazine.

c. Arch Footings. The arch footings are identical to the 33-15-73 magazine. The footings are 3'-3" wide by 1'-0" thick, and reinforced with 4-#4 bars. Design adequacy of the footing was demostrated during the Eskimo test series. Site-specific foundation soils data must also be considered in determining the footing size.

d. Rear Wall. The magazine rear wall was taken with modifications from Office, Chief of Engineers Standard Drawing 33-15-74. The modifications were as follows:

(1) The wall thickness was increased from 8" to 12" to allow for anchorage of the steel arch. This is consistent with the approved Standard Design 421-80-01.

(2) All #3 reinforcing bars were increased to #4 bars.

e. Wing Wall. The wing walls are not critical structural components from an explosive safety standpoint. The wing walls are similar to Office, Chief of Engineers, Standard Drawing 33-15-74. Footings are sized for allowable soil bearing pressure of 3,000 pounds per Sq. Ft.

f. Ventilation. The magazine ventilation is identical to Office, Chief of Engineers Standard Drawing 33-15-74. The ventilation system consists of louvered openings in the headwall and a vent stack at the rearwall. The headwall openings are protected by fragmentation plates to prevent detonation of the contents from an accidental explosion or sabotage by unauthorized personnel.