

EVALUATION OF TRENCH STORAGE
OF AMMUNITION TRUCKS

Twenty-Fifth DOD Explosives Safety Seminar
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BACKGROUND

Combat troops are often involved in operations which require temporary storage of fully-loaded ammunition supply trucks at field locations. In peacetime, such temporary storage may be required as a part of training exercises. In wartime, temporary storage sites may be established as a source point for rapid distribution of ammunition to forward-based armor or artillery units.

U.S. safety standards¹ specify separation distances between individual storage units, and between the storage area and troop locations, to minimize the risk of sympathetic explosions and personnel casualties in the event of an accidental explosion of a storage unit. Although the separation distances are less restrictive for temporary storage in "theaters of operations" than for permanent storage sites, they still pose a problem for commanders who want to concentrate a group of ammunition trucks for tactical reasons.

As a possible solution to this problem, the U.S. Army Project Manager for Ammunition and Logistics (PM/AMMOLOG) developed the concept of using trenches for temporary storage of ammo trucks at field sites. Such trenches could be constructed quickly and cheaply, and would, as a minimum, reduce the risk of sympathetic detonations of closely-spaced ammo trucks, in the event that one would accidentally explode. The U.S. Army Engineer Waterways Experiment Station (WES) was tasked to evaluate the feasibility and effectiveness of trench storage.

¹U.S. Dept. of Defense; "Ammunition and Explosives Safety Standards;" DOD 6055.9-STD, July 1984; Office of the Asst. Secretary of Defense (Manpower, Installations, and Logistics).

RESEARCH APPROACH

a. Model Tests.

The evaluation of the trench storage concept was performed in two phases. The first phase was a series of 1:6-scale model tests of four different trench designs to determine their relative effectiveness (see Figure 1). Small explosive charges were detonated in each model trench, simulating explosions of a portion or all of the ammunition in a truckload; i.e., a Unit Basic Load of 1,488 kg (net explosive weight) of artillery ammunition. For each test, two lines of airblast gages were used to record side-on overpressures as a function of distance from the detonation; one line along an extended axis of the trench (0-degree line), and one line extending from the charge in a direction normal to the trench axis (90-degree line). To evaluate the relative debris hazards, small solid metal cylinders were packed around each explosive charge to simulate unexploded projectiles (in model scale). The distribution of the cylinders (and other debris) was surveyed after each test.

An analysis of the model test results clearly showed that the most effective trench design was the timber-framed, earth-covered trench shown in Figure 1(f).

b. Full-scale Experiment.

After selection of the covered trench as the most effective design, a series of three full-scale experiments were conducted to quantify and demonstrate the hazard suppression capabilities of trench storage. The experiments were conducted by WES at the U.S. Army's Dugway Proving Ground, Utah.

The first experiment, called the "Control Data Test," involved the detonation of a full ammo load on an unprotected (i.e., not in a trench) truck to provide a baseline set of airblast and debris data, against which the trench test results could be compared. The ammunition load consisted of 160 TNT-loaded 155 mm projectiles, and 80 propellant canisters, each containing 5 kg of M3A1 propellant. The net explosive weight was 1,488 kg. The load was placed on a surplus M814 cargo truck, with the propellant separated into five groups of canisters, with four groups of projectiles placed in-between (Figure 2). The load was detonated by initiating one projectile at the end of each projectile group. As in the model tests, side-on overpressure measurements were made along two lines extending from the truck; one line extending along the truck axis, and the other normal to the axis. After the detonation, debris was collected and weighed from sampling areas established along four mutually perpendicular radials, at distances of 70 to 550 m from the truck.

For the second experiment, called the Trench Storage Validation Test, a trench 3.7 m wide was excavated to a depth of 1.5 m. The central portion of the trench was 12.8 m long, with ramped excavations extending from each end of the central portion up to the ground surface, at a slope of about five percent. Timber posts, measuring 20 by 20 cm in cross-section, were used to frame the sides and roof of the cover structure in the central portion of the trench. Wooden planks measuring 5 by 20 cm in cross-section were installed against the sides and on the top of the timber frame. The soil excavated from the trench was then placed against the sidewalls and to a depth of 75 cm over the top of the cover structure.

For the Trench Storage Validation Test, a single truck was loaded with projectiles and propellant, as in the Control Data Test, and parked inside the trench cover (see Figure 3). Airblast and debris measurements were made for the Trench Validation Test in the same manner as in the Control Data Test, except that debris samples were taken along only the two radial lines of the airblast gages; i.e., a 0-degree line (along the trench axis), and a 90-degree line (normal to the axis).

The third and final experiment was called the Two-Truck Trench Test, and was designed to see if two trucks could be parked end-to-end in the same trench, without one being sympathetically detonated by an accidental explosion of the other. For this experiment, the covered portion of the trench was about 27 m long. At the center of the trench, a floor-to-ceiling barrier wall was constructed to separate the trucks. The barrier was made of two plywood panels, separated 1.2 m apart at the top and 2.4 m at the base, with sand filled in between them.

As shown in Figure 4, three lines of airblast gages were used for the Two-Truck Trench Test; one normal to the trench axis and one parallel to the axis, both extending from the center of the detonated (donor) truck, and one parallel to the trench axis but extending in the opposite direction, from the undetonated (acceptor) truck. Figure 5 shows the layout of the debris sample areas for the Two-Truck Trench Test.

To provide further information on the detonation process (for the donor ammo load) and the blast environment (for the acceptor ammo truck), two additional sets of measurements were made. Time-of-arrival gages were attached to projectiles around the perimeter of the donor load in an attempt to measure the velocity with which the detonation propagated through the ammo stack. Self-recording gage packages were also used to measure the blast overpressures experienced by the acceptor ammo load.

TEST RESULTS

a. Airblast Effects.

Figure 6 shows the peak airblast pressures, as a function of distance, recorded for the Trench Validation Test. These results are compared with the averaged values (i.e., average for the two radial lines) from the Control Data Test. It is clear that the trench cover suppressed the close-in blast pressures normal to the trench axis. However, the reduction in pressure decreased from a maximum reduction of over 90 percent just outside the trench cover slope, to only about a 30 percent reduction at a distance of 100 m, compared to the pressures measured without a trench.

Figure 7 shows the range of airblast peak pressures recorded on the Two-Truck Trench Test, compared to both the Control Data Test and the Trench Validation Test. For the Two-Truck Trench Test, the peak pressures extending out from the donor truck along the trench axis (0 degrees) were almost identical to those measured along the same axis in the previous tests. In the opposite direction for the Two-Truck Test, however, the pressures along the axis extending from the acceptor truck (180 degrees) were much lower than any previous measurements. At the close-in distances (less than 100 m), the pressures normal to the trench axis (90 degrees) for the Two-Truck Trench Test were also somewhat lower than similar measurements for the Trench Validation Test.

b. Debris Effects.

The fragment and debris sample data from the three full-scale experiments showed a considerable degree of scatter, as can be seen in Figure 8 for the Two-Truck Trench Test. By drawing a curve through the mean of the data, however, the effect of the trench structures on the average debris densities at different ranges could be seen. Figure 9 compares the average debris densities, as a function of distance, for the Two-Truck Trench Test and the Control Data Test. While the trenches produced a greater density of debris impacts at the close-in ranges (less than 100 m), there was a clear reduction at greater ranges. Using the criterion of one hazardous impact per 56 m², the debris hazard distance for the Two-Truck Trench Test was about 270 m, compared to 450 m for the Control Data Test. This represented a Q-D reduction of about 40 percent.

c. Acceptor Truck Damage

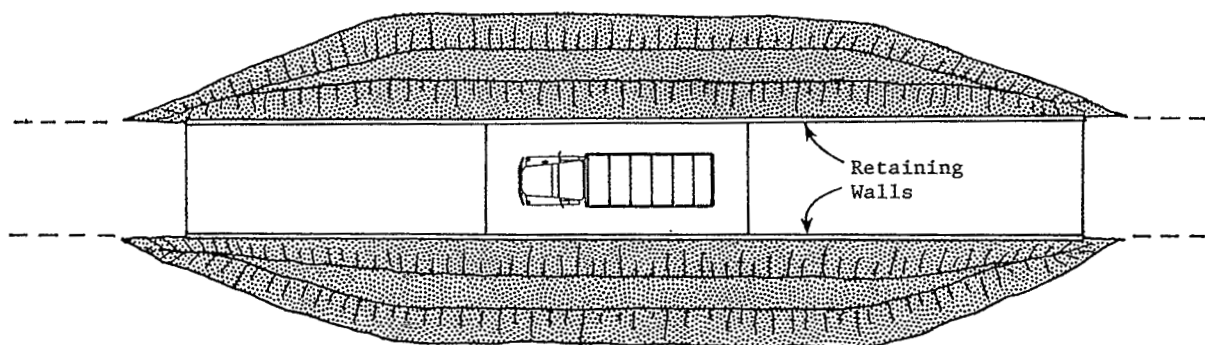
In the Two-Truck Trench Test, peak airblast pressures of about 200 kPa (30 psi) were recorded at the rear of the acceptor ammo truck, just behind the sand wall separating the acceptor truck from the donor truck. A peak pressure of 30 kPa (4.5 psi) was measured on top of the acceptor ammo stack. The force of the blast was sufficient to push the acceptor truck about 10 m forward, and to throw most of the munitions off the truck. Except for a few dents in the propellant canisters, however, there was little damage to the acceptor munitions.

CONCLUSIONS

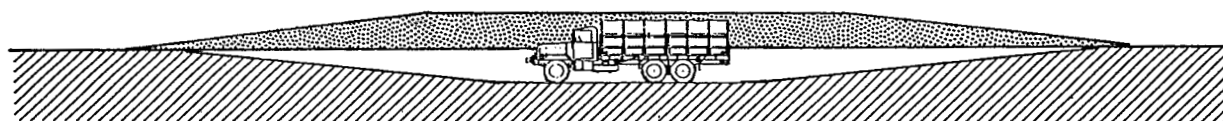
The study indicated that covered trenches are relatively simple to design and easy to construct as an expedient storage method for ammo trucks at field sites. The technique appears to be ideally suited for dry, desert environments, but construction and use may be more difficult in temperate zones, where the soil may be wet.

The explosion hazard measurements indicate that the safe separation distances presently required for open storage of ammo trucks (to prevent sympathetic detonations) can be reduced by 55 to 90 percent using trench storage. There is also a 30 to 40 percent reduction in the Q-D for personnel safety. Table 1 summarizes the Q-D reductions provided by trench storage, compared to the present standards for unbarricaded and barricaded storage.

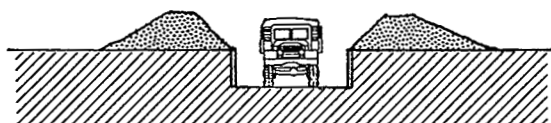
In addition to suppression of explosion hazards, trench storage offers several other benefits in combat areas. In deserts or other regions of long-range visibility, the ammo trucks are extremely difficult to detect by enemy observation. The trench cover also provides excellent protection against direct hits by enemy artillery or mortar fire, and against near-miss detonations of air-delivered weapons.



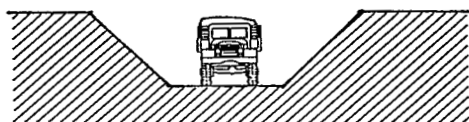
a. Plan view of half-depth trench with adjacent soil embankments.



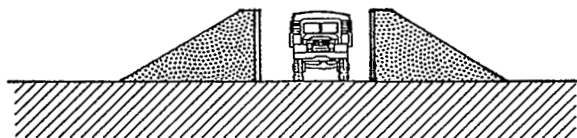
b. Longitudinal cross-section of half-depth trench/half-height berms.



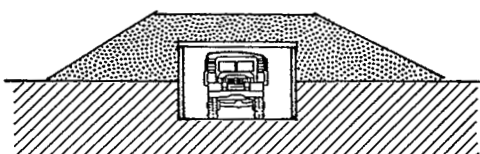
c. Transverse cross-section of half-depth trench/half-height berms.



d. Full-depth trench.



e. Full-height soil embankments.



f. Half-depth trench with timber and soil cover.

Figure 1. Trench design variations identified for evaluation for field storage of ammunition trucks.

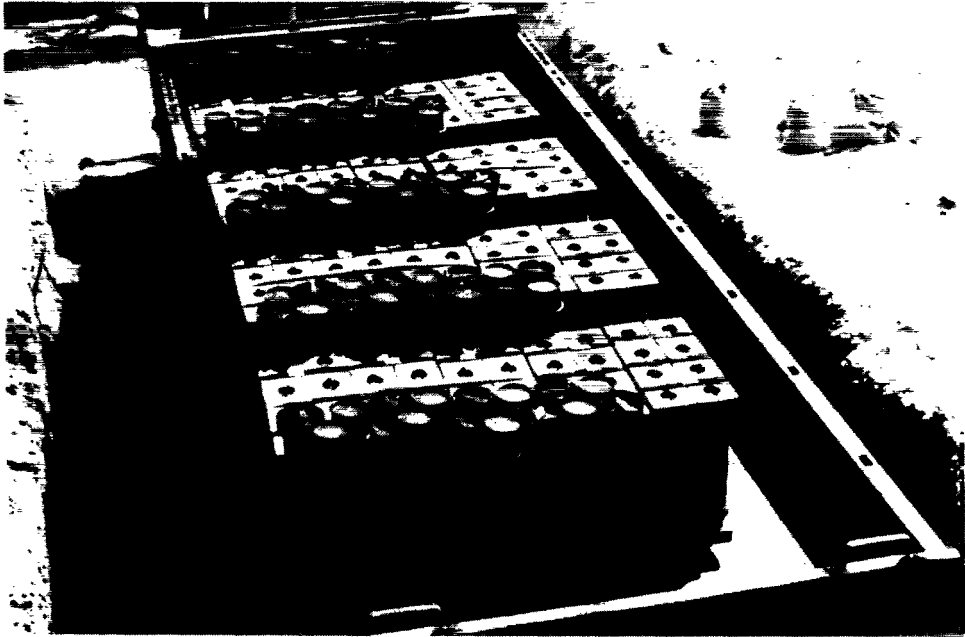


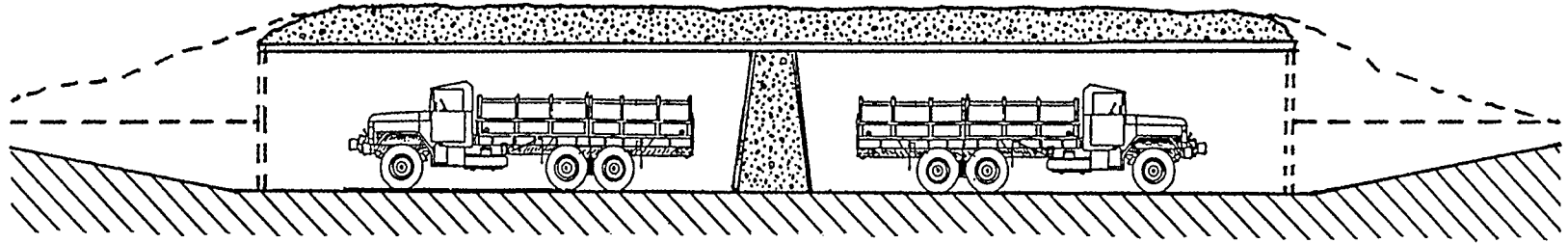
Figure 2. Placement of Unit Basic Load of 155-mm projectile pallets and propellant canisters on truckload for trench storage tests.



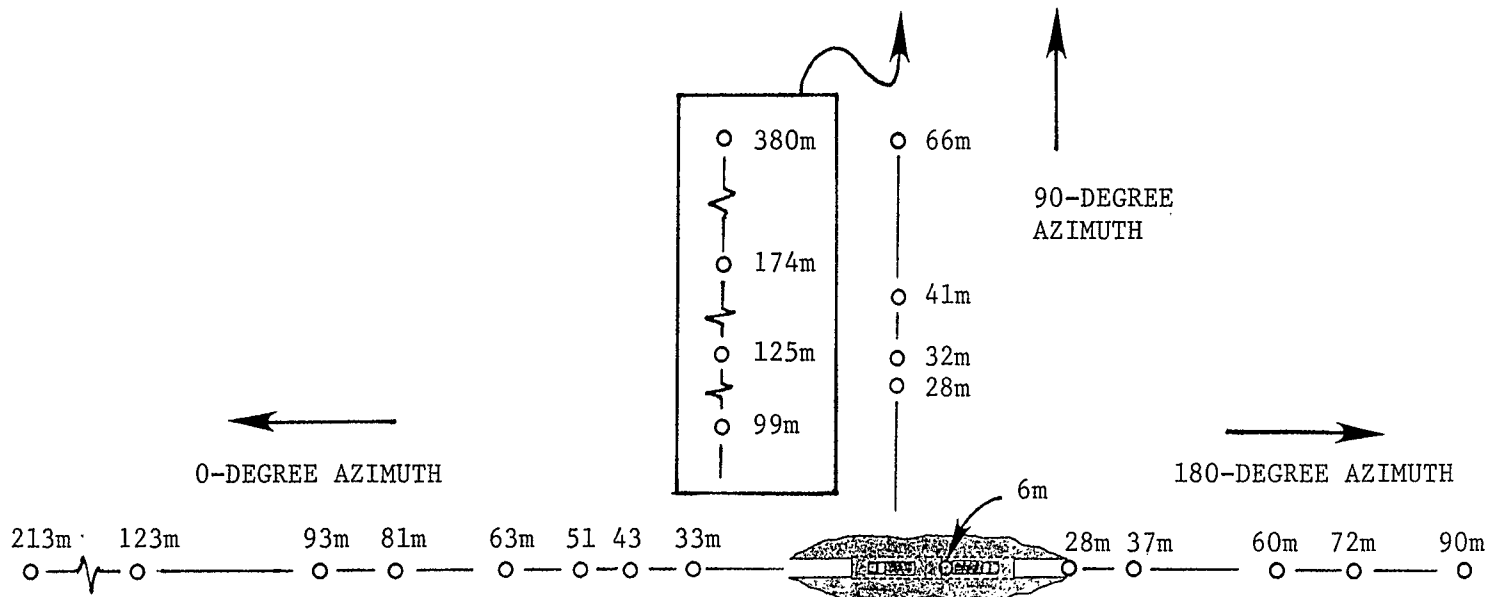
Figure 3. Ammo truck being backed into covered trench structure.

DONOR TRUCK

ACCEPTOR TRUCK



a. Elevation cross-section of truck placement in covered trench.



b. Plan view of airblast gage layout.

Figure 4. Design of Two-Truck Trench Test and airblast gage locations.

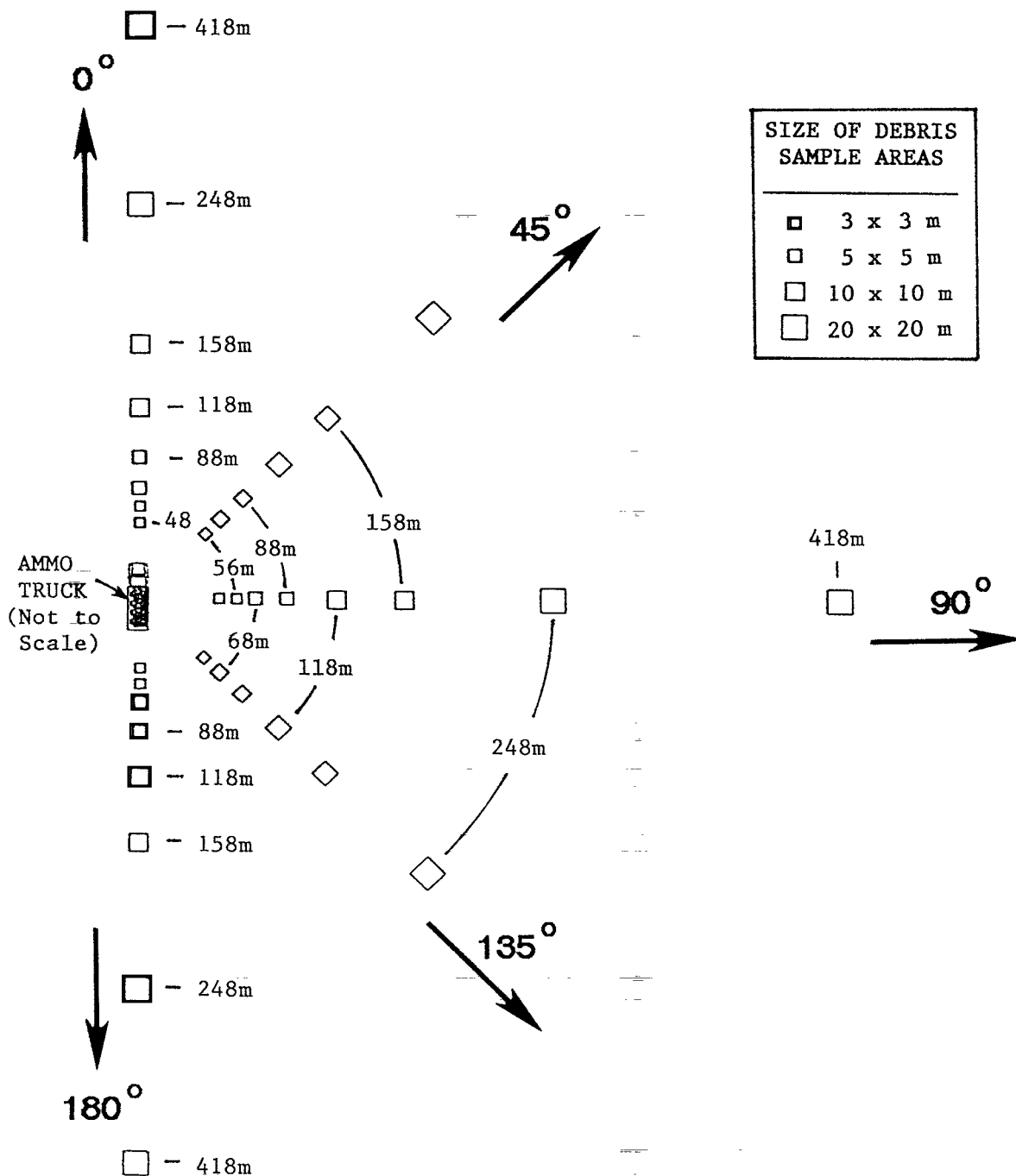


Figure 5. Layout of pre-established fragment/debris sampling areas for the Two-Truck Trench Test.

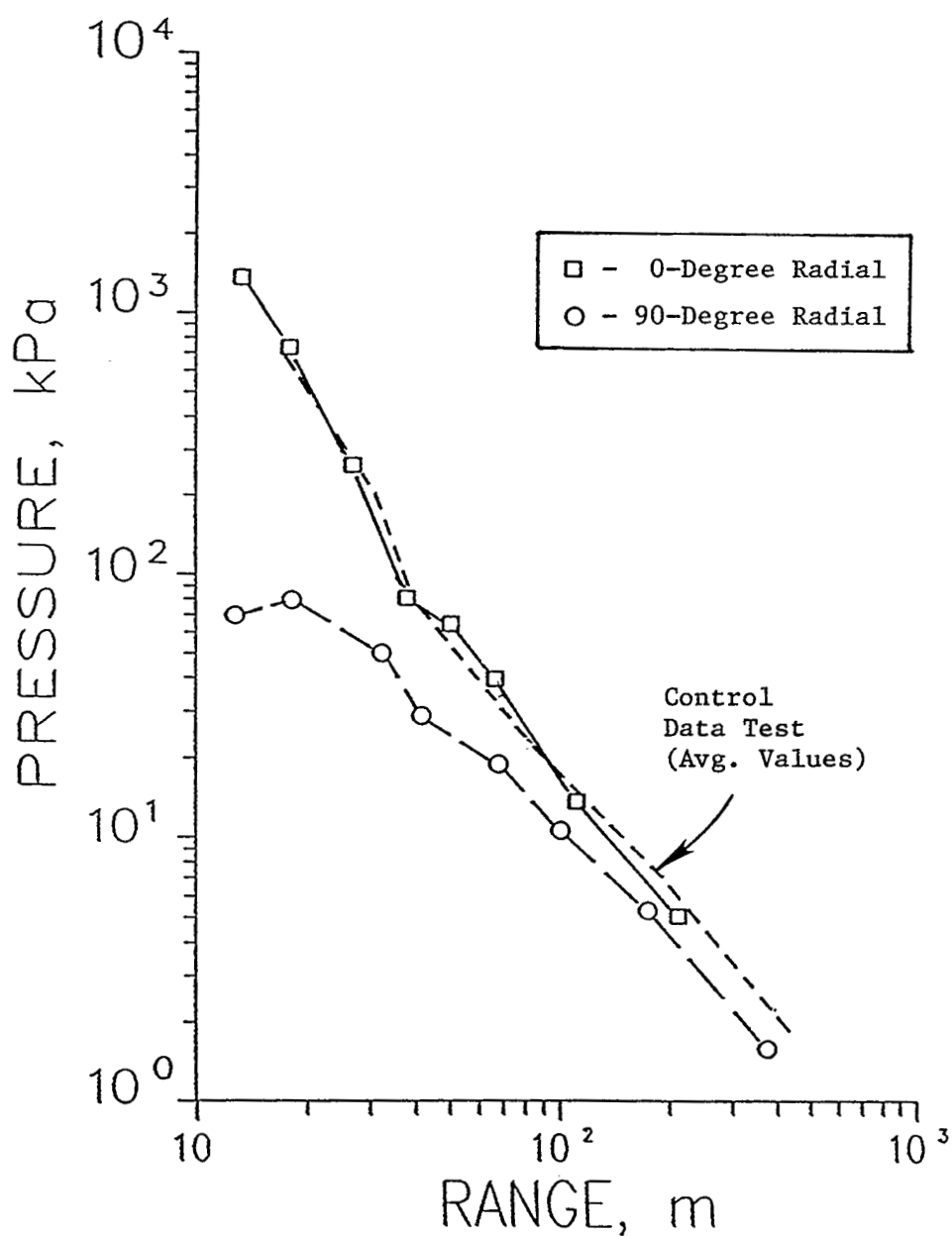


Figure 6. Attenuation of airblast peak pressures with range along the 0-degree (parallel to trench axis) and 90-degree (normal to trench axis) radials for the Trench Validation Test.

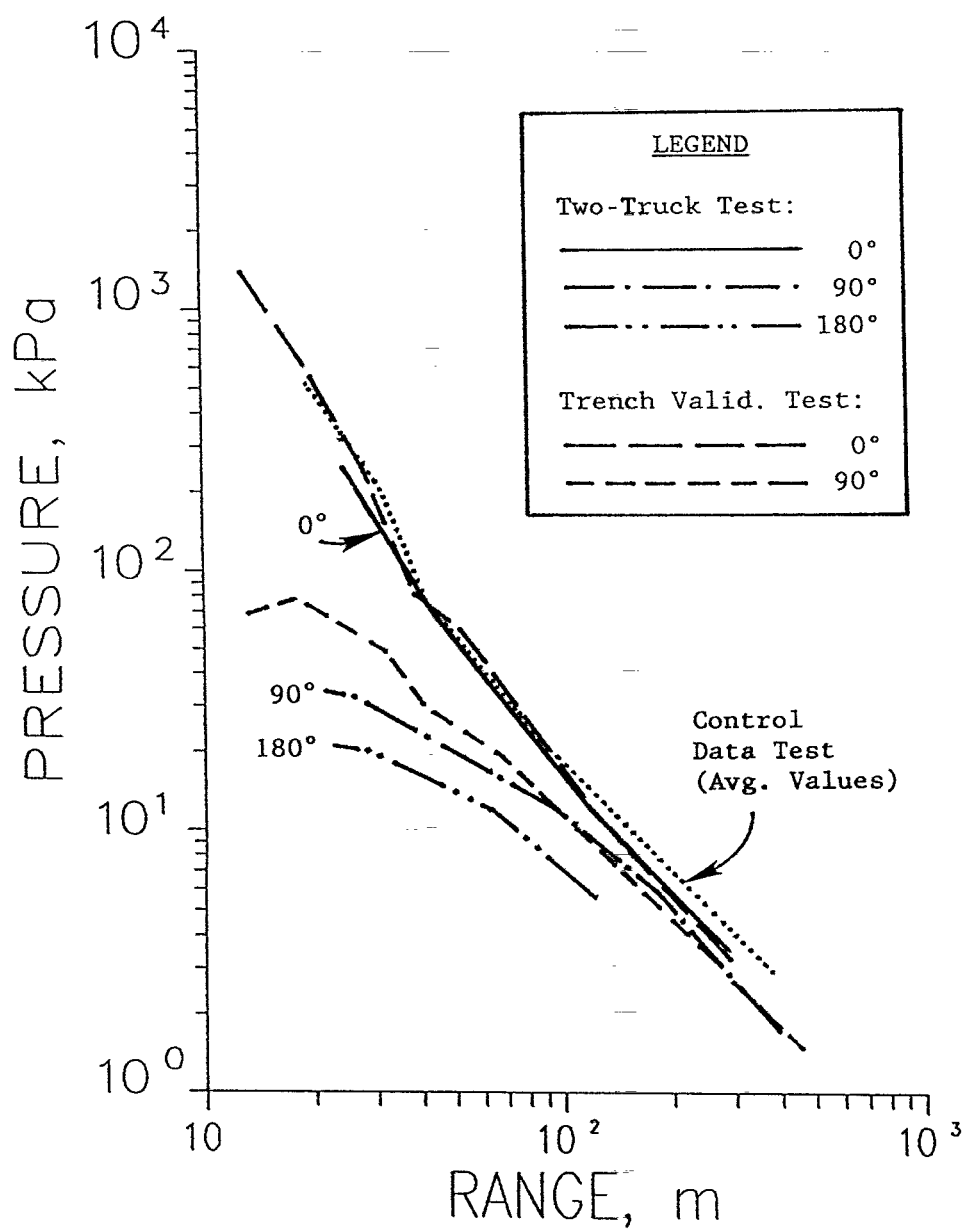


Figure 7. Peak airblast pressures from the Two-Truck Trench Test compared to those from the Trench Validation Test (single-truck trench) and Control Data Test (no trench).

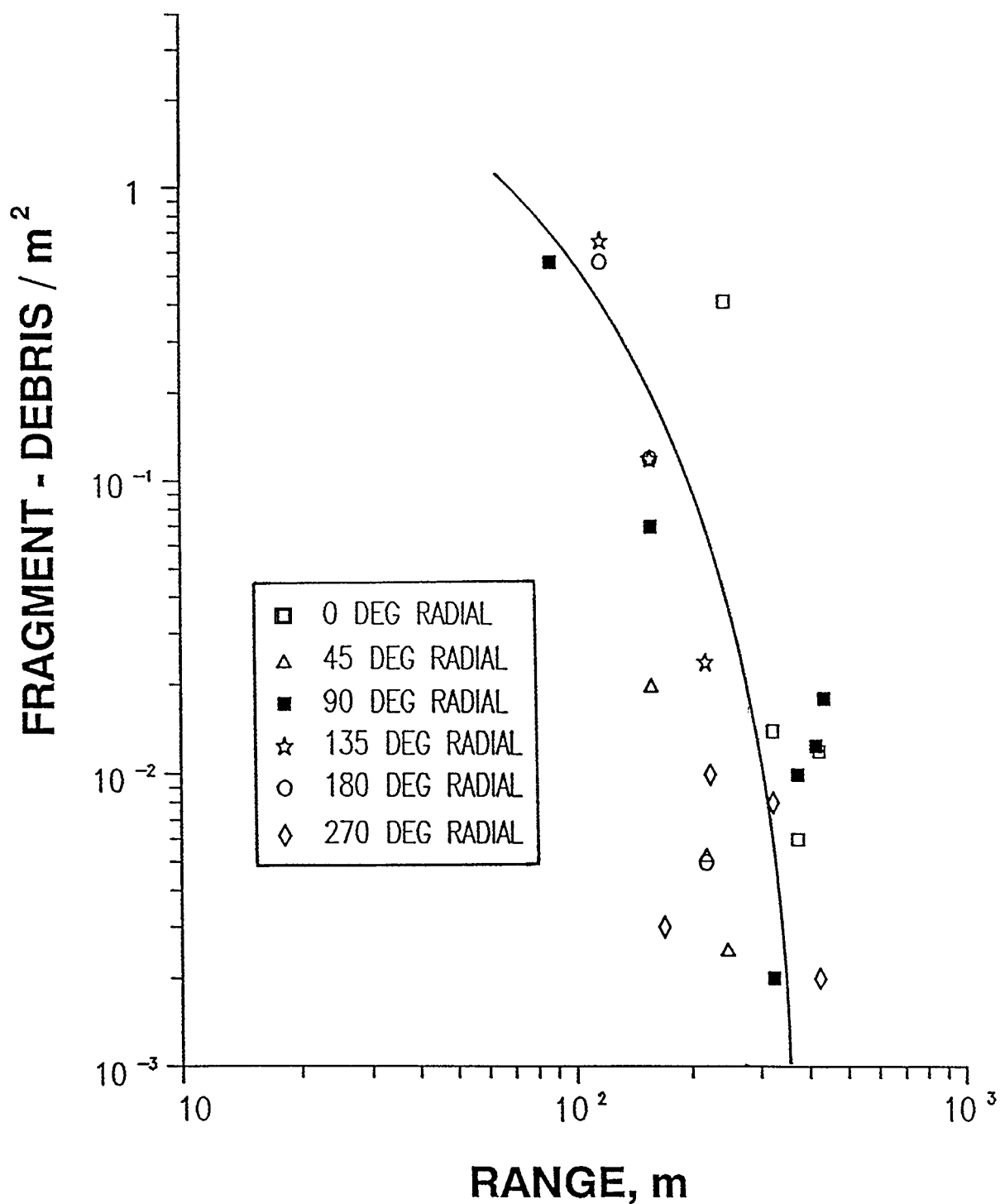


Figure 8. Areal Density (impacts per square metre) of fragments and debris as a function of range for the Two-Truck Trench Test. The curve is drawn through the mean spread of the data points.

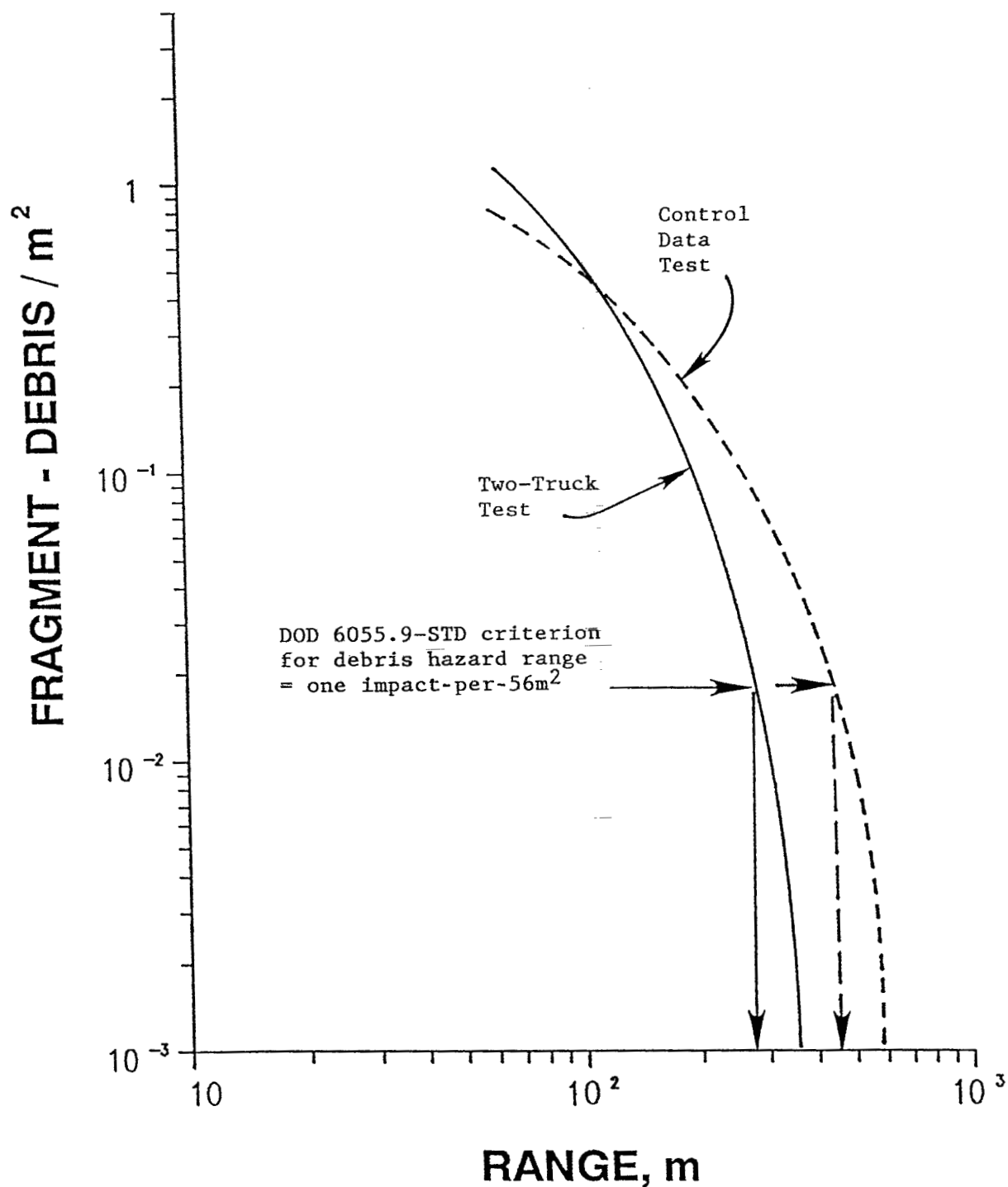


Figure 9. Average debris density versus range for Two-Truck Test compared to Control Data Test. Arrows indicate hazard ranges as defined by current safety standards.

TABLE 1

**QUANTITY-DISTANCE REDUCTIONS
FOR FIELD STORAGE OF UNIT BASIC LOADS
ACHIEVED BY TRENCH STORAGE**

QUANTITY-DISTANCES:

	<u>Unbarricaded Storage</u>	<u>Barricaded Storage</u>	<u>Trench Storage^a</u>
<u>Safe Separation Distance:</u>	187 ft	33 ft	15 ft
Reduction -	92%	55%	
<u>Exposed Personnel - Airblast:</u>	268 ft	268 ft	170 ft^b
Reduction -	40%	40%	
<u>Exposed Personnel - Fragments:</u>	1,480 ft^a	1,480^a	900 ft
Reduction -	40%	40%	
<u>Inhabited Building Distance:</u>	885 ft	885 ft	625 ft
Reduction -	30%	30%	

^a Measured on Trench Storage Tests. All other distances are taken from Chap. 10, DOD 6055.9 - STD.

^b Normal to trench axis.