PERFORMANCE OF SAND-FILLED BARRICADES FOR PROTECTION OF CONTAINERIZED AMMUNITION IN TEMPORARY STORAGE

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A study was conducted in 1998-99 to develop improved Quantity-Distance (QD) guidelines for ammunition in ISO shipping containers, and to investigate methods for reducing safe separation distances between containers in temporary storage. This paper describes the results of experiments conducted under the Container QD Study to evaluate the effectiveness of Blast-Tamer barricades in preventing propagation of a detonation between donor and acceptor containers of 155-mm M107 projectiles.

BACKGROUND

From depots to deployment in the forward combat areas, stocks of ammunition must be temporarily stored at a number of locations. These range from trans-shipment points (e.g., at dockside) to field storage sites near troop bivouacs on the battle front. The current practice is to ship and store the ammunition in steel ISO containers. The Structures Laboratory of the U.S. Army Engineer Research and Development Center conducted a study in 1998-99 to better define U.S. and NATO Quantity-Distance (QD) guidelines for ammunition in ISO containers, and to investigate methods for reducing the safe separation distances between ammunition containers. The Container QD Study was sponsored by the U.S. DOD Explosives Safety Board, the U.S. Air Force Transportation Command, and the Explosives Storage and Transport Committee of the Ministry of Defence, United Kingdom.

A major part of the study was concerned with evaluating the performance of sand-filled barricades in preventing the propagation of an accidental detonation between containers of ammunition. Various types of barriers have been used in the past to protect ammunition stores from nearby explosions. While concrete or steel barriers are effective shields against fragments, strong blast loads can break these structures up into secondary debris that may be equally hazardous. Loose soil or sand, on the other hand, does not form debris with enough mass to pose a secondary hazard.

Mounded soil berms have long been used as barriers, but they require large "footprint" areas in order to maintain stable slopes. In the 1980s, walls constructed of expandable plastic grids filled with sand were shown to be very effective in preventing propagation

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of a detonation between ammunition trucks. These barricades had base widths of only 4 m or so for a 3-m height, compared to a width of at least 13 m for a 3-m high soil berm. In the 1990s, the use of Hesco-Bastion barricades allowed the base width to be reduced to about 2 m for a 3-m height. The sandgrid, Hesco-Bastion, and the similar Maccaferri barricades also require a fraction of the time and effort that is normally needed to construct a soil berm. The objective of the Container QD barricade test was to evaluate the protection of ammunition containers provided by sand-filled barricades in general, and a new type of barricade, called the Blast-Tamer, in particular.

TEST CONCEPT

One of the advantages of the Blast-Tamer barricade is that allows adjustments in the width and slope of the barricade wall. The wall sections are formed of panels of a rigid, fireproof, polyurethane foam material. Each panel is 3-in. (7.6 cm) thick, 4-ft (1.2 m) wide and 8-ft (2.4 m) high. To form a 2.4 m high barricade, two parallel walls are erected on a plywood platform. Plastic splines are inserted where panel edges meet to link them together. Nylon cords are passed through holes in the two walls and knotted through small plywood plates to hold the wall sections together at the correct separation distance when sand is poured in between them.

Two wall designs were tested in an experiment conducted at the U.S. Naval Weapons Center at China Lake, CA. A "slope-sided" wall was constructed with the two walls leaning towards each other at an angle of 30 degrees from the vertical. The wall was 1.0-m wide at the top, and 2.0 m wide at the base. This design was based on the results of hydrocode calculations performed by the U.S. Army Research Laboratory at Aberdeen, MD. The calculations indicated that a wall surface sloping away from a detonation would reflect much of the blast force upward.

The second design was a "thin" wall, with vertical sidewalls separated only 0.5 m from top to base. Previous research had shown that a sand-filled wall 1-m thick was able to stop fragments from detonations of robust munitions, such as 155-mm M107 artillery projectiles. Other experiments had indicated that such fragments could penetrate no more than 50 to 60 cm of sand. The purpose of the thin barricade test was to confirm an initial conclusion of the Container QD Study that, if a 0.5-m thick sand barricade, together with the 1.5-mm thick steel wall of an acceptor container, would not completely stop heavy fragments, they would be at least reduce the residual impact velocities against acceptor munitions enough to prevent an acceptor reaction.

Figure 1 shows the assembly of the slope-sided barricade, with sand being dumped inside, and an end view of the thin barricade. The walls were placed at a separation distance of 2.5 m from a donor ISO container. The donor contained 400 rounds of M107 projectiles, with a net explosive quantity of 2,820 kg.

Acceptor containers were placed 2.5 m beyond each barricade. Each acceptor contained six pallets (48 rounds) of M107 projectiles. The pallets were stacked two-deep on the side of the container facing the barricade and the donor container. In each acceptor, a stack of inert MK-81 bombs was placed immediately behind the M107 pallets to provide the same resisting mass as a container filled with M107 rounds. Figure 2 shows the arrangement of the donor and acceptor containers and the two barricades.

TEST RESULTS

The detonation sequence is shown in Figure 3. At -2 msecs, the flash of the detonating cord can be seen just before it enters the donor container. Figure 4 follows the motion history of the blast front as it breaks out of the donor container, sweeps over the slope-sided barricade, and displaces the acceptor container. The shape of the blast front and the movement of the front and back sides of the acceptor container clearly show that the blast load had a strong downward component after it bent over the barricade and struck the top of the container.

The post-test condition of the ammunition and container protected by the slope-sided barricade is shown in Figure 5. The barricade itself was completely blown away, with only some of the plywood floor panels left in place. The container was blown about 30 m and badly mangled. The M107-acceptor rounds were scattered from 20 m in front to 20 m behind the container, and many rounds were jumbled around inside the container.

None of the 48 acceptor rounds were seriously damaged. An inspection revealed no dents or gouges--only small scratches from the tumbling of the container. No charring or other evidence of heat effects was found on the container, the munitions, or the wood-munition pallets.

The container protected by the thin barricade suffered much more damage, as expected (Figure 6). The container itself was completely blown apart, with pieces scattered up to 120 m from the original location. The largest piece of the container found was only about 2-m square.

The projectiles from this acceptor were scattered over a distance of 30 to 80 m from the blast. Surface scratches were clearly evident, and the brass rotator bands were crushed at round-to-round contact points. No dents, gouges, or other damage was found. Multiple dents were found, however, on several of the inert MK-81 bombs that were used to back the M107 projectiles. The MK-81s had been stacked horizontally behind the vertically-arranged M107's, and the dent spacings on the MK-81s corresponded to the M107 spacings on their pallets.

ANALYSIS

The Blast-Tamer barricades were quickly assembled by untrained personnel. The only problem encountered was that rapid dumping of sand onto the nylon cords between the sidewalls tended to sag the cords and pull the two walls together, resulting in an uneven face on each side of the barricade.

While the slope-sided barricade may have deflected some of the blast from the donor detonation upward, this effect was not evident in the detonation photography. The average barricade thickness of 1.5 m provided a large inertial resistance to the initial blast front, forcing it to bend over the top of the barricade. The retarding of the blast force, along with the downward component of the blast impact, greatly reduced the dynamic load on the acceptor container. Based on the essentially undamaged condition of the M107-acceptor projectiles, it appeared that this barricade design offers a high degree of protection against propagation when placed in the middle of a 6.5 m separation distance between donor and acceptor containers of robust munitions.

The thin-walled barricade had only half the average thickness and mass of either the slope-sided barricade or a standard Hesco-Bastion barricade. While this was not sufficient to keep the acceptor container from being blown apart, the acceptor munitions received only minor damage at a 5.5 m separation distance between containers.

The results indicate that, for a donor-acceptor scaled separation distance of 0.4 $m/kg^{1/3}$, the thin-walled barricade does not have enough mass to prevent some crushing damage between acceptor rounds. This could pose a risk of a detonation of crush-sensitive munitions. For the vast majority of HD 1.1 and 1.2 munitions, however, a sand-filled barrier only 0.5-mthick appears to be sufficient to prevent propagation between closely-spaced ISO containers of ammunition in temporary storage.

ACKNOWLEDGEMENTS

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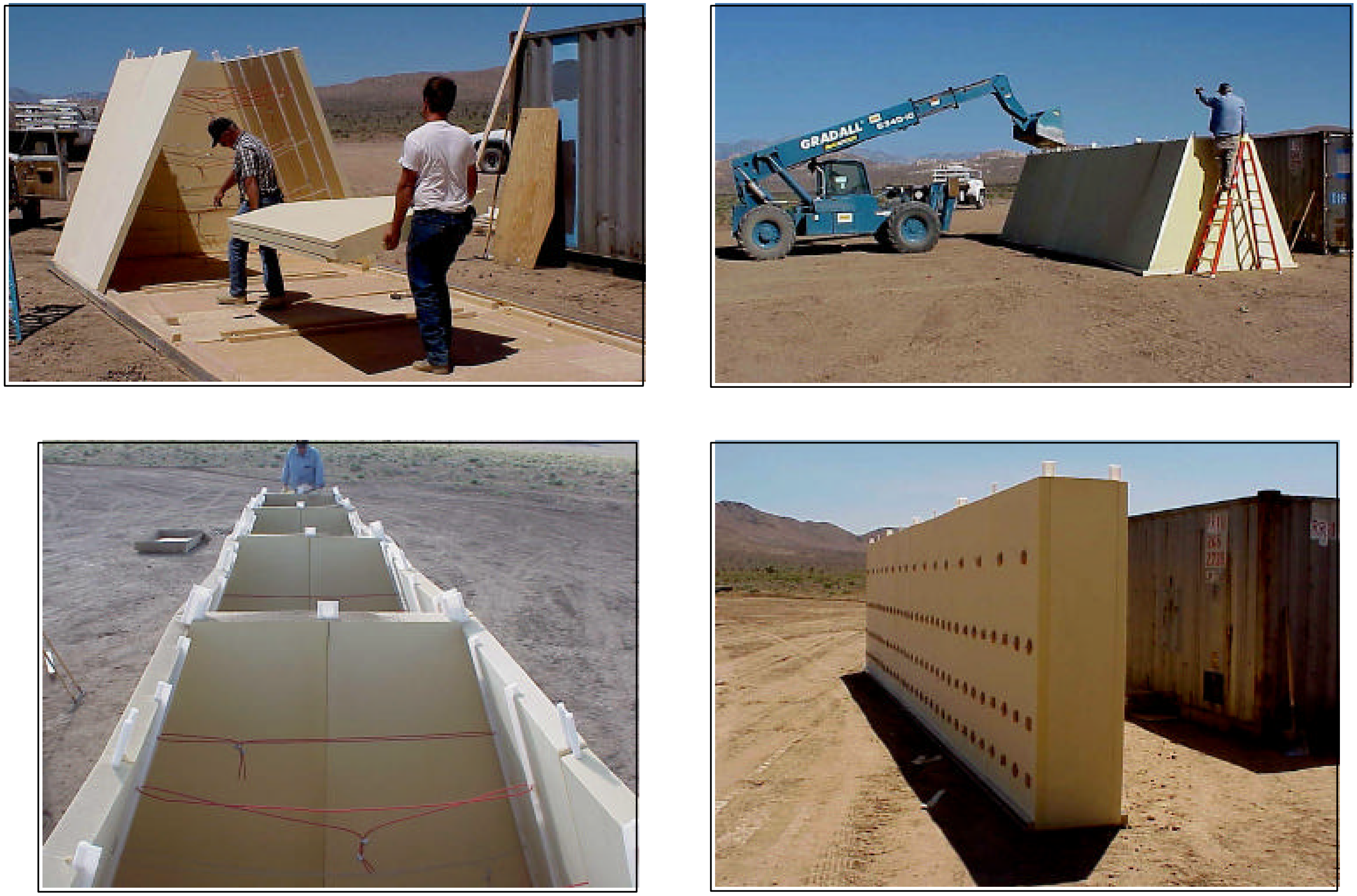
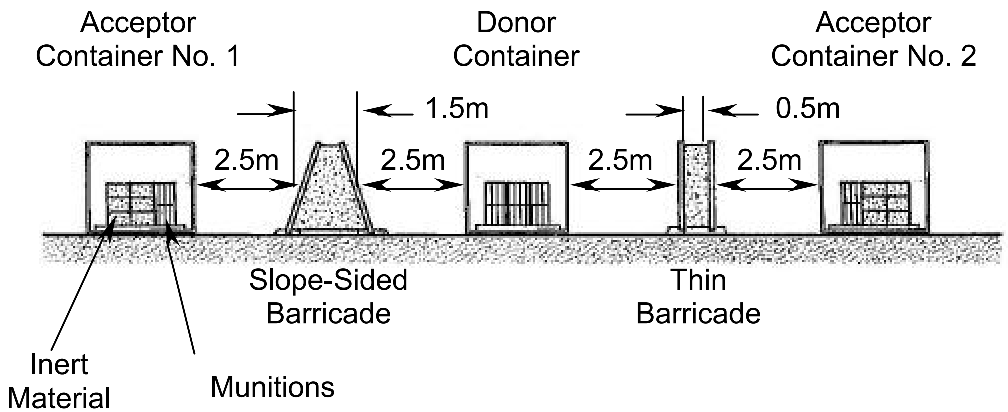


Slope-Sided Barricade

Thin Barricade

Figure 1. Construction of “Blast-Tamer” barricades.



Test Design

Donor Container

Test Set-up

Acceptor Container

Donor: 400 rds, 155mm M107 projectiles (2,820-kg NEQ)

Acceptors: 48 rds, 155mm M107 projectiles, backed by inert MK-81 bombs

Figure 2. Test design and set-up for barricade test.

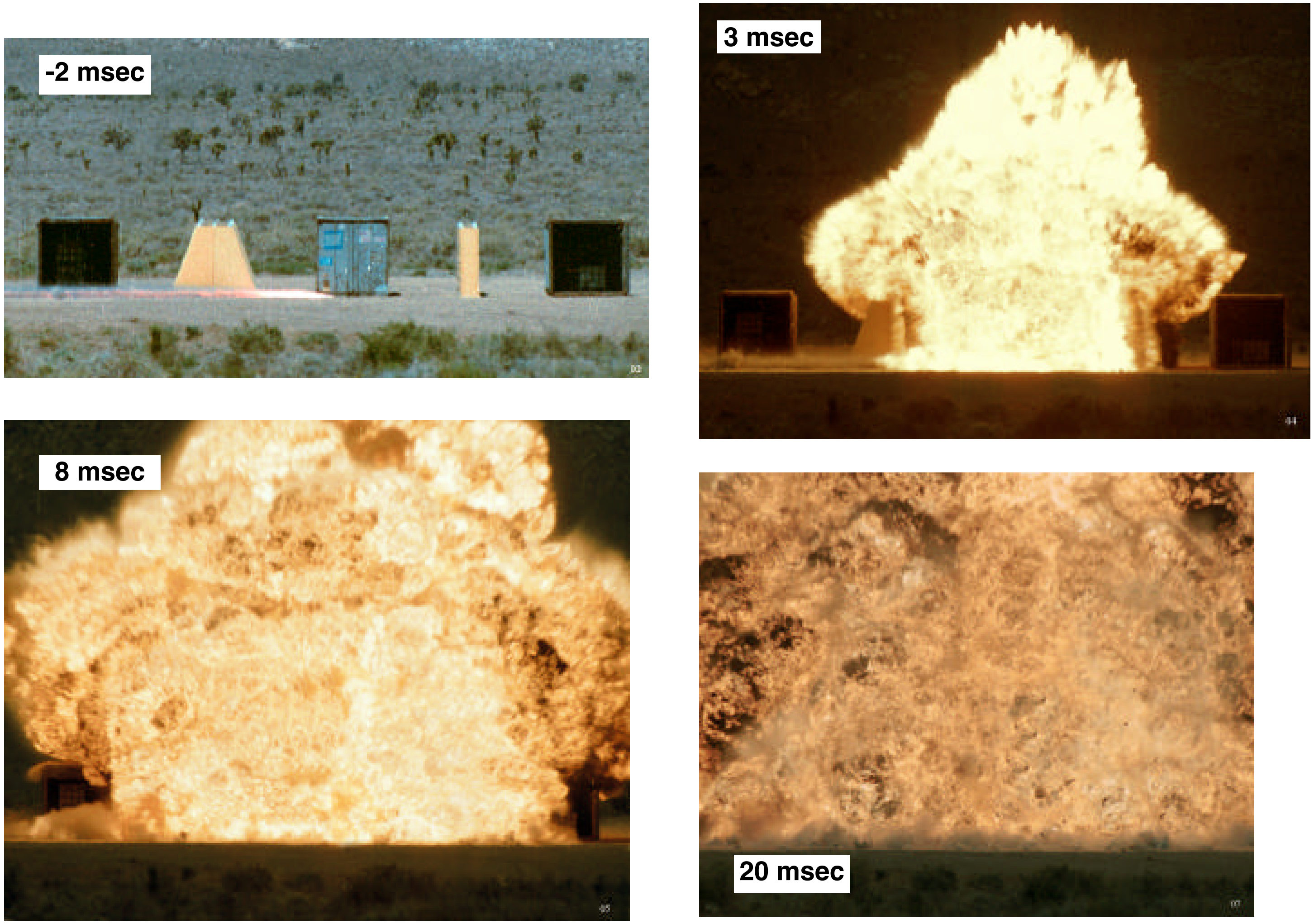


Figure 3. Detonation sequence. Note detcord flash approaching donor container at -2 msec.

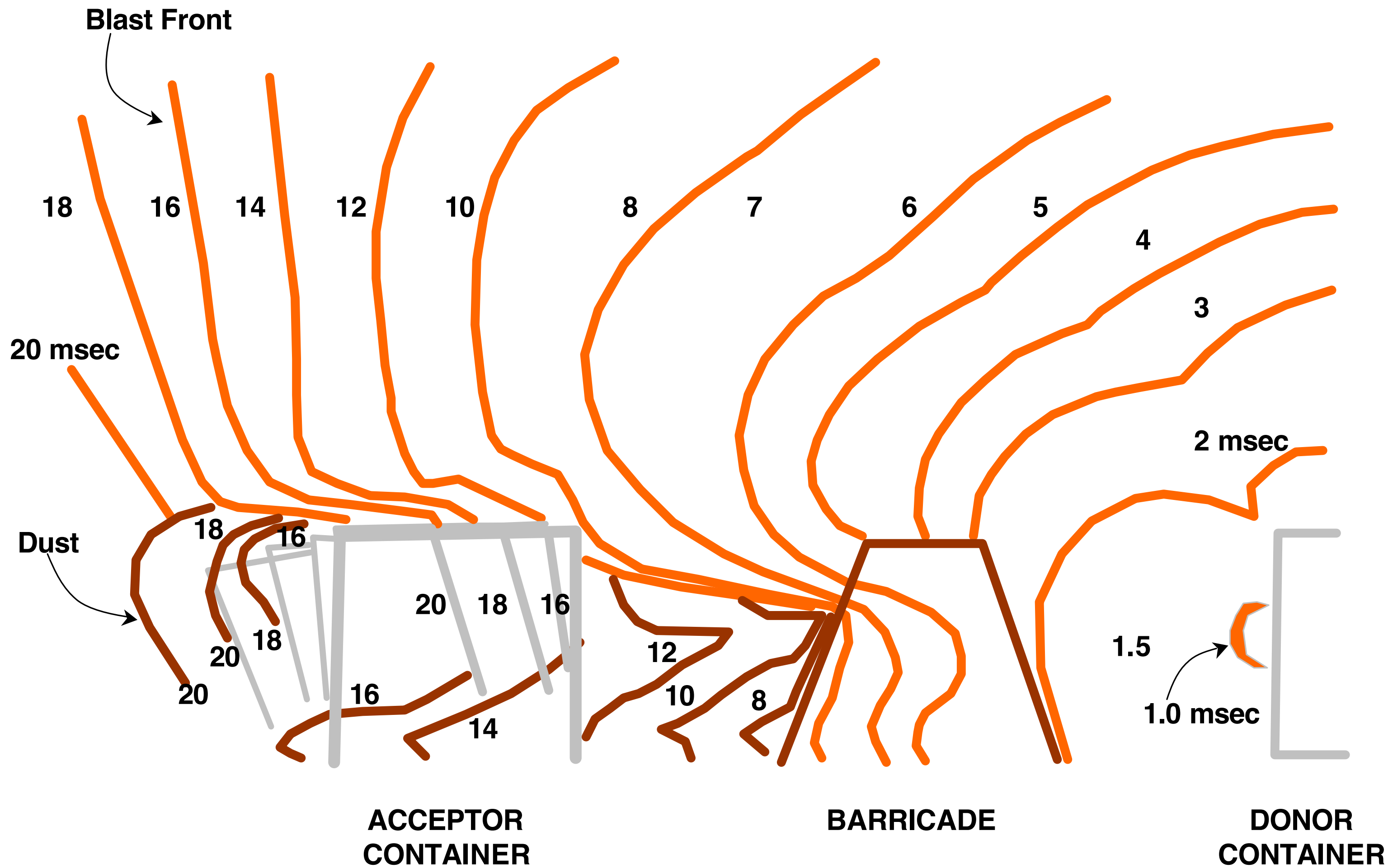
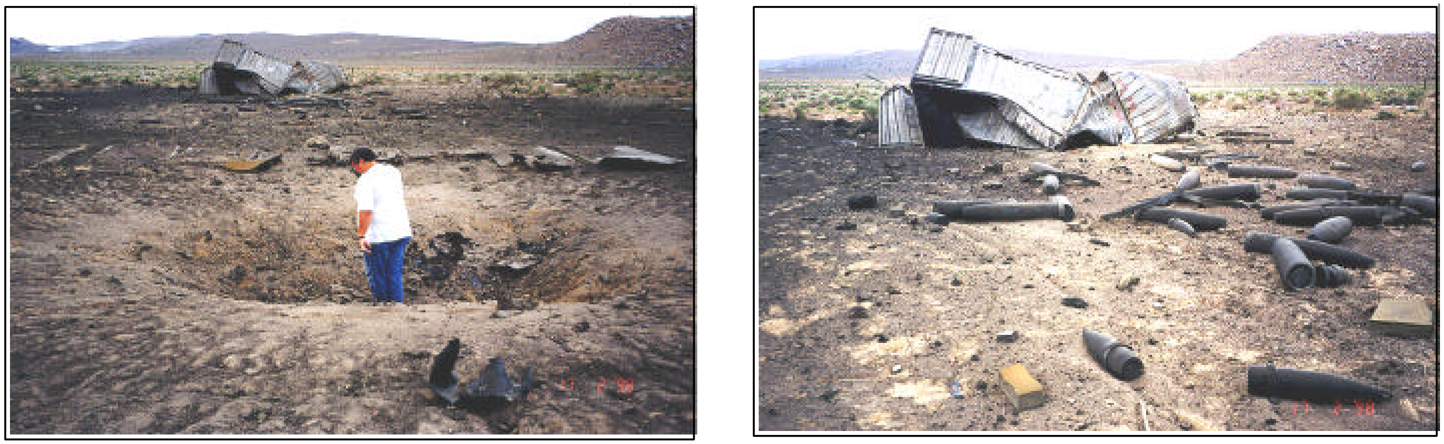


Figure 4. Motion history of blast front, slope-sided barricade, and Acceptor Container No. 1.



View from the donor crater

View from rear of container

Figure 5. Damage to Container No. 1, protected by slope-sided barricade.

Figure 6. Damage to Container No. 2, protected by thin barricade.