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BLAST SUPPRESSING BOMB TRANSPORT
VEHICLES

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Bomb Transport

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Samuel G. Thomas, Richard G. Brannum, Arthur C. Hert, and William E. Domning

Abstract. For the safe removal of a bomb or other explosive devices from an industrial plant, two transport vehicles have been designed and tested. These vehicles consist of a cart and a trailer. A device consisting of 8 sticks of 40% dynamite may be safely destroyed in the trailer. An explosion of 25 sticks of 40% dynamite should not seriously damage the trailer.

The transport cart resisted the effects of one stick of 40% dynamite under test. Approximately 4 sticks of dynamite would be required to destroy the cart.

INTRODUCTION

Bomb threats by extremist factions within the United States have become more frequent. These threats pose hazards to life and property; therefore, a program for protection from bomb threats is necessary. Such a program was initiated at the Rocky Flats Division of Dow Chemical U.S.A. early in 1970. The program consists of a bomb threat plan, bomb search teams, and bomb scene officers trained to remove and disarm bombs.

To facilitate removal and disposal of bombs, two transport vehicles were necessary: a small vehicle which could be used inside buildings, and a larger transporter to be used to remove the bomb to a safe area.

After a survey of vehicles which have been built for this type of service, none satisfied the criteria for safe disposal of a device without removal from the transport vehicle. The use of vermiculite as a blast suppressing material has been reported,¹ and a trailer design which would allow *in situ* disposal of a device was developed using this material.

This report describes the construction and testing of two vehicles; a bomb trailer and a bomb cart designed to suppress bomb blasts, as well as transport explosive devices to "safe" areas.

CONSTRUCTION OF BOMB TRAILER

The proposed use for a blast-suppressing vehicle is to transport an explosive device to a safe area and either allow

the device to explode or explode an additional charge to destroy the device. A device consisting of from 3 to 5 sticks of 40% dynamite was postulated;² therefore, the design of the bomb trailer was developed to contain this size explosion. Other criteria considered were: shrapnel from a blast should not endanger the driver of a towing vehicle, the amount of shrapnel leaving the trailer should be minimized, the trailer should contain the equipment necessary to remove a device to it.

Figure 1 shows the completed bomb trailer and bomb cart. The trailer unit was constructed on a surplus military transport trailer chassis. The stock number for the trailer is FSN 2330-141-8049, nomenclature: trailer, transport water, 400 gallons M-107A2. A tool box was mounted on the front section to contain the bomb removal equipment. Extra sacks of vermiculite are stored behind the tool box.

The bomb-carrying section is essentially a large mortar in that the force of the blast is directed upward. Downward venting was not chosen because of possible shrapnel recoil from a hard surface.

The outer box is 6-feet square by 4-feet high and is constructed of $\frac{3}{16}$ -inch thick mild-steel plate. The purpose for the steel box is to contain vermiculite and provide a final barrier for shrapnel. A tank, 53.5 inches in diameter located in the center of the steel box serves as a secondary barrier for shrapnel. Figure 2 shows the $\frac{3}{16}$ -inch-thick stainless steel tank welded to the box top. The tank was also welded to the floor of the box. The space between the tank and the outer box has been filled with vermiculite through the covers shown in Figure 2. Also shown in Figure 2 are four 9:00 X 20 truck tires filled with vermiculite which serve as the primary shrapnel barrier. These four tires have three 11-inch-high supports welded to the floor of the trailer. The area under the tires and between the tires and tank walls has been filled with vermiculite. Two-inch by $\frac{1}{2}$ -inch steel bars hold the tires in place.

The placement of the bomb-holding cavity, as shown in Figure 3, is directly over the axle to equalize the loading on the suspension. The cavity is about 27-inches deep and 20 inches in diameter.

Additional vermiculite is added to the cavity after a device has been placed into it. Also, sacks of vermiculite may be piled on top of the trailer body for added blast suppression.

¹ Patent Application 239,762, "Method for Mitigating Blast and Shock Transmission Within a Confined Volume," Los Alamos Scientific Laboratory, March 30, 1972

² "Technical Bulletins," National Bomb Data Center, Washington, D.C., U.S. Department of Justice.

Figure 1. Bomb Trailer.

Figure 2. Top View of Trailer.

Figure 3. Holding Cavity.

Access to the bomb cavity is provided by ladders and a stairway. In addition, a small boom crane can be used to place a device as well as lift the bomb cart from its carrier.

Sixty-five sacks of vermiculite were required to fill the 6,720 pound trailer unit.

CONSTRUCTION OF BOMB CART

This smaller vehicle, shown in Figure 4, is designed for transportation of a device from the interior of a building to the larger bomb trailer. Use of the bomb cart as a means for disposing of a device is not anticipated; its function is to protect personnel during transport. The bomb cart has a secondary function; that is in the transport of potentially explosive chemicals from a laboratory to the bomb trailer.

The design of the cart is similar to that used at Lawrence Livermore Laboratories.³ Figure 4 shows the cart which is made from a cut-off size A-3 carbon dioxide cylinder (34.5-inches high, $\frac{5}{16}$ -inch-thick sidewall) inserted into a

³J. Young, H. J. Jelonek, R. W. Gribben, "Design and Tests of a Portable Cask for Explosive Chemicals," UCRL-19331, August 1969.

Figure 4. Bomb Cart.

55-gallon drum. The bottom of the cylinder is 6 inches above the bottom of the drum, this space and the annulus between the cylinder and the drum is filled with vermiculite. The interior of the cylinder is lined with $\frac{1}{2}$ -inch-thick urethane foam. A dolly, handle, and lifting lugs complete the assembly.

The interior of the cavity, shown in Figure 5, is filled with vermiculite to a depth of about 16 inches. In use, additional vermiculite would be added to the cavity and bomb blankets placed on top of the cart.

Figure 5. Bomb Cart Cavity.

COST

The construction costs for building the trailer and bomb cart are summarized in Table 1. Much of the material used to construct this trailer was salvage or was located in a scrap yard. Therefore, the column "salvage" in Table 1 shows the additional cost that would be incurred if all of the material had been purchased.

Table 1. Construction Costs.

	Actual	Salvage
Material Purchased	\$ 149	\$ —
Salvaged Material	—	384
Surplus Tank (new cost)	—	1,150
Surplus Trailer (new cost)	—	1,290
Labor	2,926	—
TOTAL	\$3,075	\$2,824

The out-of-the-pocket costs were \$3,075, while the undepreciated value for the salvaged material was \$2,824, or a total identifiable cost of \$5,899. No engineering time was charged to this project since design of vehicles of this type is usually done on an empirical basis.

Testing costs were not accumulated because time and materials were furnished by Sandia Corporation on a no-charge basis.

Vehicles of this type and equal capability cost in the \$13,000 to 15,000 range.

TESTING

The objective of the tests performed was to determine the effectiveness of explosion suppression or safety of either the bomb trailer or bomb cart. The tests were designed to show the effects of devices that have been used in past instances.⁴ All devices were initiated with electric caps. Timing devices and other means for ignition of the explosives were not tested.

BOMB TRAILER TESTS

A pipe bomb using 6 inches of Schedule 40, 2-inch pipe was loaded with one pound of composition C-4 plastic explosive with a burning rate of 24,000 feet per second. The device was placed in the center of the cavity and was covered with 1 $\frac{1}{4}$ bags of loose vermiculite. Upon detonation, three tires were blown up about 2 feet, twisting and bending the hold-down bars which had not been welded to the floor of the trailer. None of the shrapnel produced in this explosion reached witness boards placed next to the stainless steel tank; however, some fragments of shrapnel were found between the tires and the stainless steel tank. No movement of the trailer because of recoil was noted.

Five sticks of 40 percent dynamite, 8,500 feet per second burning rate, were placed inside a lunch box. This charge was placed on the vermiculite inside the cavity about 18 inches from the floor of the trailer, and the cavity was filled with vermiculite. The force of the detonation threw three tires outside of the stainless steel tank leaving them on the top of the trailer. (The bent straps from the previous test had been discarded.) As in the past test, no fragments were found in the witness boards located at the interior of the stainless steel tank. The fragments of shrapnel found after this test are shown in Figure 6. Again, the trailer remained stable during the blast.

Figure 6. Lunch Box Shrapnel.

The tires were removed from the trailer and eight sticks of 75 percent dynamite with a burning rate of 17,500 feet per second were detonated in the center of the vermiculite-filled steel tank. The force of this blast split a weld in the $\frac{3}{16}$ -inch thick floor plate creating a $\frac{1}{2}$ -inch gap between floor sections. The trailer frame was bent about one inch, shearing eight, $\frac{1}{2}$ -inch bolts. A minor up-and-down motion was imparted to the trailer.

A large pipe bomb was fabricated from an aluminum reaction vessel 10-inches long, 4 inches in diameter, and $\frac{1}{2}$ -inch thick. The explosive consisted of eight sticks of 40-percent dynamite with a burning rate of 8,500 feet per second. The tires were re-installed in the unit and the charge located in the center of the cavity. The charge was buried in loose vermiculite and 10 bags of vermiculite were placed on top of the cavity. The purpose for the additional vermiculite was to attempt to contain the shrapnel fragments and suppress the upward blast effect. This test was the most impressive of all attempted. Three tires were thrown about 20 feet from the trailer and vermiculite shot about 60 feet into the air. Greater than 90% of the fragments shown in Figure 7 from the aluminum can remained in the bomb trailer. Two pieces hit the sides of the tank causing $\frac{1}{2}$ -inch and $\frac{1}{4}$ -inch deep dents in the tank wall. Small fragments were found outside of the trailer at distances of 10, 12, 30, and 60 feet. The bottom of the trailer bulged downward another 1 $\frac{1}{2}$ inches. Again, the trailer had a slight up-and-down motion during the blast.

A black powder (burning rate 1,312 feet per second) pipe bomb was fabricated using 10 inches of 2-inch Schedule 40 pipe with standard pipe caps. The charge was detonated in the center of the vermiculite-filled cavity with the tires in place. No damage and little blast effect was noted from this test. The fragments found after the test are shown in Figure 8.

⁴Op. Cit. (2)

Figure 7. Aluminum Fragmentation.

Figure 8. Fragmentation of Black Powder Pipe Bomb.

A pipe bomb using 2 pounds of ammonium nitrate fertilizer-diesel fuel mixture was fabricated from 10 inches of 3-inch Schedule 40 pipe and two pipe caps. To explode the ammonium nitrate slurry, one stick of 40% dynamite was used as an initiator. The explosion was of very low order. The end of one of the pipe caps was found 12 feet from the trailer, the remainder of the fragments (Figure 9) were found inside the vermiculite.

Figures 10 and 11 show the damage to the $\frac{3}{16}$ -inch thick steel plate located in the bottom of the tank after conclusion of all the foregoing tests. The major damage was a bent

Figure 9. Pipe Fragmentation From Ammonium Nitrate - Diesel Fuel Slurry.

Figure 10. Cavity Floor Damage After Testing.

trailer frame (about one inch) and the split seam in the tank floor. The effectiveness of the tires to absorb shrapnel is shown by the torn and shredded tires in Figure 12.

BOMB CART TESTS

A U.S., MK-2 Fragmentation Hand Grenade was loaded with 0.125 pound of Composition C-4 and placed in the center of the cavity of the bomb cart. The cavity was

Figure 11. Underside of Cavity Floor Showing Damage After Testing.

Figure 12. Shrapnel-Riddled Tires.

filled with vermiculite. After detonation, the urethane foam liner in the cart cavity was blown out and a shrapnel impact pattern 9-inches wide and about $\frac{1}{16}$ -inch deep was noted on the inside of the steel container. No other damage was noted.

A U.S., M-26 Hand Grenade (ball fragment) was loaded with 0.125 pound of Composition C-4. The grenade was placed in the bomb cart on top of vermiculite. No vermiculite was added above the grenade. Again, a fragmentation pattern was noted on the inside of the steel container but no damage was done to the cart. Without the vermiculite cover, the blast was louder and sharper and a burst of flame shot upward about 5 feet.

One stick of 40% dynamite was buried in vermiculite in the center of the bomb cart cavity. No damage was sustained by the cart after detonation. The cart remained stable.

One stick of 75% dynamite was detonated in the center of the vermiculite-filled cavity. The cart jumped slightly

and the steel tank was forced down bending the bottom of the cart slightly as shown in Figure 13.

Figure 14 shows the interior of the steel tank of the bomb cart after testing. No damage or bulging of the tank is noted.

To determine the effectiveness of the 53-inch-diameter vermiculite-filled steel tank, a comparison test was run with a 30-inch-diameter vessel. A section of 30-inch mild-steel pipe 5-feet high with a $\frac{1}{2}$ -inch-thick sidewall was tested with 10 sticks of 40% dynamite placed in the center of a 10-bag vermiculite fill. After detonation, the diameter of the pipe had increased by one-half inch.

Figure 13. Bottom of Bomb Cart After Testing.

Figure 14. Interior of Bomb Cart After Testing.

DISCUSSION

A versatile unit for transport and disposal of a bomb, explosive chemical, or other threat type device has been demonstrated. The advantage of this trailer is that a device can be destroyed *in situ*, by the addition of a separate explosive. Therefore, personnel are not exposed to the potential explosive force of a device during the removal from a transport vehicle.

That the vehicle will withstand the blast and shrapnel effects from typical bombs was demonstrated by the tests performed. The tests and results are recapitulated in Table 2.

Table 2. Tests Performed.

BOMB TRAILER

Pipe bomb — 1 lb C-4	Shrapnel contained.
5 sticks 40% dynamite in lunch box	Shrapnel contained.
8 sticks 75% dynamite	Split floor seam.
Pipe bomb — 8 sticks 40% dynamite aluminum pipe	90% shrapnel contained, maximum distance thrown 60 feet. Tank walls dented.
Pipe bomb — 1 lb black powder	Shrapnel contained.
Pipe bomb — 2 lbs NH_4NO_3	One piece of shrapnel 12 feet from trailer.

BOMB CART

MK-2 grenade	Shrapnel contained.
M-26 grenade	Shrapnel contained.
Stick of 40% dynamite	No damage.
Stick of 75% dynamite	Steel tank forced down. No damage.

The fact that only on one occasion did shrapnel penetrate to the tank walls demonstrates the ability of the vermiculite to break up the shock wave and therefore the rate of acceleration of shrapnel. Only in one test, eight sticks of 40% dynamite, did an appreciable amount of shrapnel leave the trailer cavity. In this case, none of the shrapnel was found beyond 60 feet from the trailer. Also, the action of the trailer suspension is such that the force of the blast forces the trailer downward, throwing material to the rear of the trailer. This is important should a device explode while the trailer is being towed. Also, this 60-foot radius is probably all that is necessary for safe removal, which means that a device could be exploded in the trailer near a populated area.

Neither the trailer nor the cart were tested to destruction; therefore, the maximum charges that can be handled by either are not known. Maximum load for the trailer is

estimated to be 25 sticks of 40% dynamite without destroying the trailer. The bomb cart might contain the blast from 4 sticks of 40% dynamite.

The damage done to the bottom of the trailer is not unexpected when the results of the experiment using 10 sticks of dynamite in the 30-inch pipe is considered. The 10-stick charge was placed in the center of the pipe with 7 inches of vermiculite surrounding it. The resulting blast stretched the tank, which meant that a pressure of the order of 1,000 pounds per square inch was developed at the pipe walls. In the case of the bomb trailer, 22 inches of vermiculite surrounded the charges. The 53.5-inch tank would probably withstand 400 pounds per square inch before stretch occurred. Assuming pressure absorption is proportional to distance, only 300 pounds per square inch would be developed at the tank walls; therefore, little damage to the tank. Three hundred pounds per square inch should tear and distort the $\frac{3}{16}$ -inch steel plate beneath the trailer.

Pressure absorption as a function of distance in vermiculite is probably logarithmic rather than the linear as postulated above. Therefore, the pressure at the tank walls may have been less than 300 psi. To minimize the structure and weight of a bomb trailer, the thickness of vermiculite should be maximized.

Therefore, to prevent damage to the floor of the trailer, additional height could be added to the tank to give a greater thickness of vermiculite. Either a thicker plate, or a conical head added to the tank would strengthen the floor. This is probably not necessary with the present trailer since a device having explosive energy in excess of the amounts tested is not expected.

The trailer suspension is very important to the stability of the unit during detonation. Although definite data are not available, it appears that the stronger the frame, the less likelihood of damage. Therefore, it is preferable to build upon a chassis designed to carry heavy loads.

The bomb cart, while not offering the amount of protection as that of the trailer, does appear to offer sufficient protection against the typical device that might be fabricated, should it need to be removed.

The tool box mounted on the forward section of the trailer contains protection equipment to be used for bomb removal. This equipment is shown in Figures 15 and 16 and consists of body armor, bomb blankets, and protective head gear.

Construction of the bomb transport and disposal unit has completed implementation of the Dow, Rocky Flats' bomb threat plan.

Figure 15. Body Armor.

Figure 16. Bomb Blankets and Protective Head Gear.