LA-7123-MS

Informal Report

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Special Distribution

Issued: March 1978

Safe-Stationary Detonation Train for Army Ordnance

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UNITED STATES
DEPARTMENT OF ENERGY
CONTRACT W-7405-ENG. 36

This work was sponsored by Harry Diamond Laboratories, Silver Spring, Maryland.

SAFE-STATIONARY DETONATION TRAIN FOR ARMY ORDNANCE

by

J. H. Goforth

ABSTRACT

Experiments were conducted to demonstrate the feasibility of designing safe-stationary detonation trains for Army ordnance. A system is described that required three detonation trains to be fired simultaneously to detonate a PBX 9407 acceptor charge separated physically from the detonation trains by an aluminum barrier. The system detonates the acceptor when a 0.62-mm-thick inert barrier separates the acceptor from three trains. A barrier <0.25 mm thick is required for a single train to detonate the acceptor. The system described involves no moving parts, no physical contact between detonation trains and the acceptor charge, and is practicable for high-volume, low-cost production.

I. INTRODUCTION

To meet safety requirements, the detonation trains of conventional military fusing systems must have movable out-of-line/in-line elements. R. K. Warner of Harry Diamond Laboratories, Silver Spring, Maryland, has proposed the development of safe-stationary detonation trains for Army ordnance.[1] Two possibilities for such detonation systems are discussed in this report. Most of the experiments described here are based on the concept of using the high-pressure interaction of multiple shock waves to initiate an acceptor explosive through an inert barrier. The experimental apparatus, procedures, and results are described for a system that uses three simultaneous shock waves. In addition, results are reported from a small number of experiments based on the corner-turning properties of XTX 8003,* discovered by Parkinson.[2] XTX describes an extrudable explosive often referred to as Extex.

II. XTX 8003 CORNER-TURNING EXPERIMENTS

Parkinson[2] states that the detonation wave in 0.5- by 0.5-mm tracks of XTX 8003 would turn through 135° angles but not through 150° angles. Figure 1 illustrates how this information could be used to build shock-interaction detonation trains. In principle, two interacting shocks will produce a greater pressure than will a single shock. Therefore, it should be possible to find some angle between 135°

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*80 wt% PETN, 20 wt% Sylgard 182.

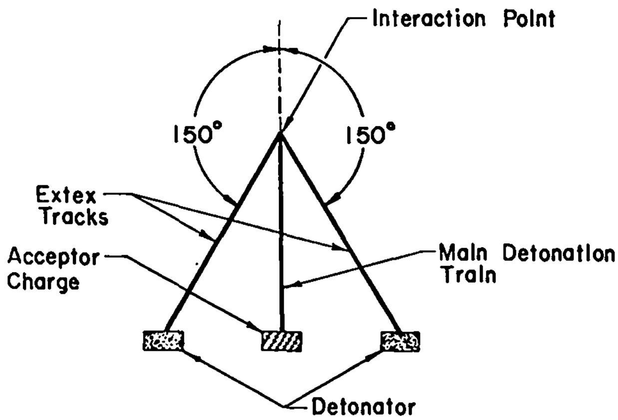

Fig. 1.
Simultaneous arrival of the detonation fronts at the interaction point is necessary for detonation of the main detonation train for some angle of the XTX 8003 tracks. The tests were performed with 150° angles, as shown.

and 150° where a single detonation wave will not turn the corner, but where two detonation waves arriving simultaneously at the interaction point will turn the corner.

To test this concept, we drilled three 1-mm-diam holes into the edge of a 38- by 38- by 13-mm-thick acrylic block and intersected them within the block, as shown in Fig. 1. Two holes were 30 mm long, the third was 25 mm long, and all were loaded with Extex. Detonators and witness blocks were glued to the edge of the acrylic in contact with the appropriate holes.

The initial tests were made to prove single-point safety. One detonator and the acceptor charge (Fig. 1) were replaced by witness blocks, and the remaining detonator was fired. In the three tests performed, the detonation turned the corner and went up the detonation train toward the location for the second detonator, but never turned the corner toward the acceptor charge.

Next, dual-train experiments were run with the same configuration except that the acceptor charge was replaced by a witness block. In the four tests performed, no detonations were observed in the main detonation train; however, burn marks on the witness block indicated that the main detonation train had burned.

At this time, because of significant successes with the "three-shock interaction" concept, the "corner-turning" experiment was discontinued. Future efforts in the corner-turning effort should emphasize three areas: hardware, instrumentation, and correct angle determination.

First, Extex tracks (to replace holes drilled into acrylic blocks) should be milled in plastic surfaces.

Second, the instrumentation should be such that timing differences can be detected between trains. Past failures may have been due either to the lack of a strong interaction or to poor timing.

Third, the correct angle between 150° and 135° should be found for which a two-train interaction provides corner turning. There is little question that such an angle exists, but we do not know how much latitude exists between angles that require two trains to turn the corner and angles that allow only one train to turn the corner.

III. MULTIPLE SHOCK-INERT BARRIER EXPERIMENTS

Two shock waves can interact to produce a shock of higher amplitude than that produced separately by either of the initial shocks.[1] Depending on geometry,[3] the resulting shock amplitude may be two to three times that of the component shocks. By using this principle (illustrated in Fig. 2) one can design safe-stationary detonation trains. Two detonation trains are fired simultaneously into an inert material. The high-amplitude shock formed by the interaction of the two shocks will detonate the acceptor, whereas the shock produced by either train will not.

Figure 3 shows the geometry used for the tests. The selection of three explosive trains rather than two was made to enhance the fail/fire margin. Various types of explosive trains were used and the inert-barrier material and thickness were varied. The acceptor charge was 1.62 g/cm^3 PBX 9407.*

RDX mild detonating fuse (MDF) as well as XTX 8003 were used as explosive trains in some tests. Most experiments were run with Extex because it

*94 wt% RDX, 6 wt% Exon 461.

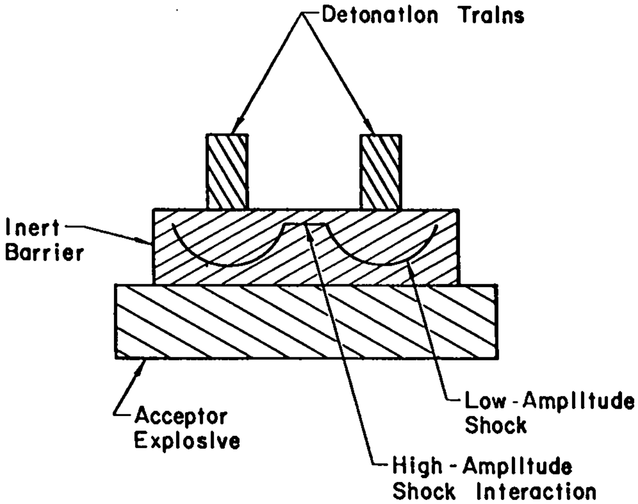

Fig. 2.
The high-amplitude shock interaction formed in the barrier is sufficiently large to cause detonation of the acceptor, but the low-amplitude shocks are not.

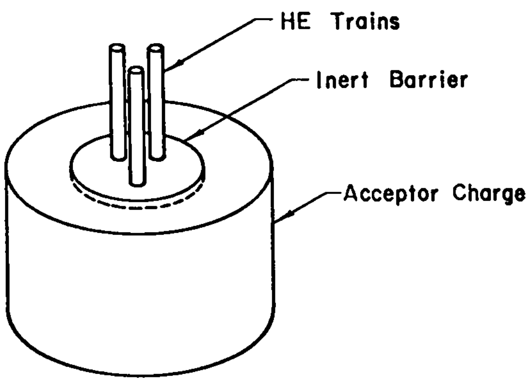

Fig. 3.
Experimental geometry for multiple shock-inert barrier experiments.

had advantages in terms of choosing spacing between explosive trains and explosive train diameter.

The configuration for the preliminary tests with Extex is shown in Fig. 4. A detonator fired one, two, or three trains of Extex that had been hand-loaded into 1-mm-diam holes drilled in 12.7-mm-thick acrylic blocks. The three 1-mm-diam holes were drilled at equal spacing on a 1.7-mm-radius circle. If fewer than three trains were used in a test, special hardware was built with only the desired number of

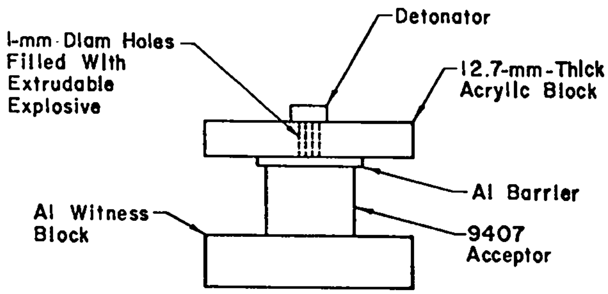

Fig. 4.
Test configuration for preliminary tests.

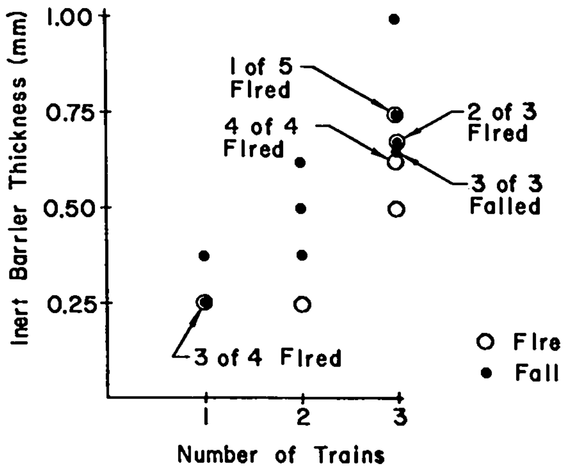

Fig. 5.
Inert barrier thickness vs number of Extex trains. The hole spacing was the same whether one, two, or three holes were drilled for the Extex trains. Data points are for one test unless otherwise indicated.

holes. For two-train tests, the spacing between holes remained the same as for three-train tests. The inert barriers were aluminum disks of various thicknesses and a 1.62-g/cm^3 PBX 9407 pellet was the acceptor. A witness block was glued to the pellet. All pieces were assembled with Eastman Kodak 910 glue.

The variables were the aluminum-barrier thickness and the number of trains. The results, plotted in Fig. 5, show a wide range between the one-point, "no-fire" barrier thickness and the three-point, "fire" barrier thickness.

To determine whether an Extex train adjacent to one or two detonating trains would fire sympathetically, thereby producing the same effect as if all three trains were purposely detonated, another series of tests was run in which the three Extex trains were always present. Extex trains to be detonated intentionally were fired by trains of MDF, as shown in Fig. 6, thus preventing detonation of the remaining train(s) from sources other than the adjacent train(s). Dent block tests showed that the detonation of one train did not cause a sympathetic detonation of the other two, but that when two trains were detonated simultaneously, the third detonated also. Results from this second series of interaction tests are shown in Fig. 7. These data agree well with those of the dent block tests and indicate that when two trains are detonated, the third (or sympathetically detonating) train provides some stimulus but does not produce the full effect of an intentionally detonated train. The result is that the safety window between the "one-train fail" barrier thickness and the "three-train fire" barrier thickness remains the same as in previous tests, but the safety margin decreases between a two-train, "no-fire" and a three-train, "fire." Further testing should provide the engineering data necessary to eliminate this problem.

Other configurations with the same basic geometry were tested. In a number of experiments, RDX MDF trains were used instead of Extex trains. In these tests, equal lengths of MDF were detonated with a single detonator. The inert barrier, acceptor, and witness block were arranged as in the other tests. The results of these experiments and those of the Extex experiments are summarized in Table I.

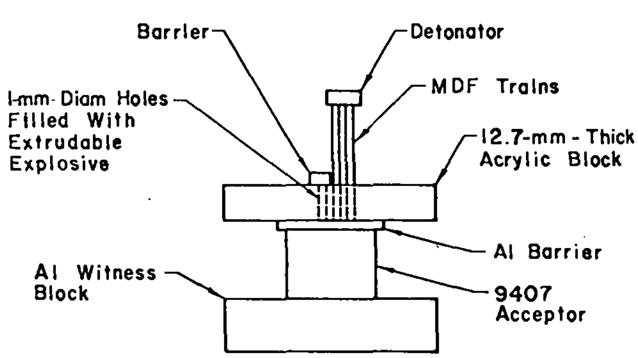

Fig. 6.
Test configuration for sympathetic detonation tests. MDF was used to fire the trains that were intentionally detonated.

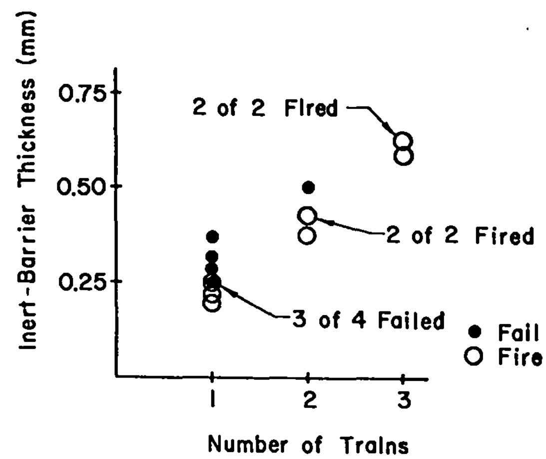

Fig. 7.
Inert barrier thickness vs number of Extex trains purposely detonated. In this test, three Extex trains were used in all experiments, and those trains that were detonated intentionally were fired by MDF trains.

Table I shows the advantages of the Extex system. However, the results from a system using MDF of similar dimensions probably would match those from the Extex system. In addition, an MDF system might eliminate sympathetic firing among the trains. The data in Table I also show that aluminum is more forgiving than brass in regard to dimensional tolerance.

IV. SUMMARY

Safe-stationary detonation trains with an adequate safety margin can be built. The hardware for such a system occupies little space and is readily adaptable to high-volume, low-cost production. An explosive safe-and-arm system could be included in the same manufacturing steps at little or no increase in production cost. The inert-barrier technique prevents physical contact between explosive trains and the acceptor charge so that burning and deflagration are not transmitted to the acceptor explosive. Also, the chance of human error and mechanical malfunction is reduced or eliminated.

TABLE I

RESULTS FROM MDF AND EXTEX INERT-BARRIER TESTS

Explosive Train	Point Spacing (mm)	Inert Barrier	Safety Window[a] (mm)	No. of Trains	One-Point Safe Barrier Thickness (mm)
RDX MDF[b]	1.1	Al	<0.25	3	>0.25
RDX MDF[b]	1.1	Brass	<0.05	2	>0.075
XTX 8003[c]	0.85	Al	<0.23	2	~0.25
XTX 8003[c]	0.85	Al	~0.37	3	~0.25
XTX 8003[d]	0.85	Al	~0.18	2	~0.25
XTX 8003[d]	0.85	Al	~0.37	3	~0.25

[a]Difference in inert-barrier thickness between one-train-failure thickness and thickness at which multiple trains will fire.

[b]MDF had HE content of 5 grain/foot.

[c]Data presented in Fig. 5.

[d]Data presented in Fig. 7.

ACKNOWLEDGMENTS

I wish to thank Ismael Garcia, Gomer Gray, Billy Fisher, Willard Hemsing, Lillie Rico, and Dan Varley for their efforts in fabricating the test components and assemblies and conducting a major portion of the experiments described in this report, and special thanks to Glenn Seay for his guidance and direction.

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