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ADVANCES IN EXPLOSIVE TRAIN TECHNOLOGY

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Picatinny Arsenal
Dover, New Jersey

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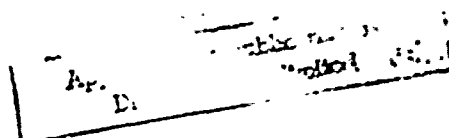
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INTRODUCTION

The proper functioning of any munition system depends on the reliable initiation of successive elements in an explosive train and on the transfer of sufficient energy from one element to another so that the fuze ultimately detonates a main charge. Some of the recent investigations made on explosive train technology by the Explosives Division of the Feltman Research Laboratory at Picatinny Arsenal will be discussed. The purpose of this work was to develop a better understanding of how explosive trains function, provide the basis for improved quality control, and define and determine the parameters needed for new and improved designs. Use was made of new high speed transient recording equipment, and computer programs were developed and used for data reduction and analysis.

DISCUSSION

A typical fuze train contains a detonator, an explosive lead, a booster, and a main explosive charge. The detonator is held out of line by a safe-arm mechanism until just before functioning is desired, since it is the most prone to accidental initiation. After the detonator has been brought into firing position, a small energy input is sufficient to start the reaction in the detonator. This is rapidly built up to high order detonation then transferred across a gap to cause detonation of the explosive lead. Assuming the arming system functions correctly, most duds are caused by failure to initiate the detonator or in the transfer of detonation to the lead, since as the energy output progressively increases the probability of failure decreases.



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Studies began with an investigation of the functional characteristics of the M-55 stab detonator since the majority of Army fuzes (127 million/year) use them. The first slide shows a sketch of this detonator. It is only a little over an eighth of an inch in diameter and height and contains three elements: a stab sensitive NOL 130 mixture, a lead azide booster charge, and a RDX output charge. The second slide shows a gamma-ray density scanner developed to measure detonator and lead column heights and densities nondestructively.¹ A radioactive isotope source of Cobalt-57, which produces a 122 kilovolt gamma ray, is optimum for NOL 130 and lead azide. A Cadmium-109 radioactive source, which produces a 22 keV gamma ray is optimum for RDX and tetryl. The gamma rays pass through a narrow slit approximately 10 mils axially (in the direction of the height of the detonator) and a tenth of an inch across the diameter of the detonator. The rays passing through the detonator are detected by a thallium activated sodium iodide scintillation crystal. The size of the slit is determined by the thickness of the shims placed on the outside of the collimator blocks, as shown on the left. This concept has been incorporated into a semi-automated instrument for routine measurements. A typical record for an M-55 detonator is shown on the third slide. This information is also punched on paper tape, so that average densities and column heights can be calculated by computer.

Once we know the detonator is made correctly, it is necessary to know its stab sensitivity. An instrumented stab tester has been developed for this purpose and is shown in the fourth slide.² The needle is mounted as an integral part of the falling mass to avoid energy losses that occur in the standard ball drop test. In addition, with this new method, it is possible to record needle motion by use of a LVDT (linear velocity differential transformer). The photodiode next to the sample detects the flash of light produced when the stab mixture fires. The insulated block holding the detonator sample provides a starting pulse when the needle first contacts the surface of the detonator. A typical record is shown on the fifth slide. The upper trace shows the needle position. Each major graduation is 5 mils so that the needle position can be measured to an accuracy of a thousandth of an inch. The first pulse on the lower trace is produced when the needle contacts the face of the detonator. The second pulse is produced by the light flash. In this case, the needle penetrated a distance of 8 mils and the NOL 130 mixture fired in 310 microseconds. The pin velocity can be obtained from the slope of the upper curve. The sixth slide shows some of the data obtained with this test on the effect of pin mass on the velocity required to fire the detonator. It also shows the high degree of precision obtainable by this test method.

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Based on the data and correlations from this work, a computer code has been developed which now allows calculation of penetration by any needle shape or mass.³

Once initiation is achieved, the buildup to high order detonation inside the detonator is of interest. This phenomena was studied by use of flash x-ray, streak camera, and pin switches as shown in the seventh slide.⁴ These studies indicated that high order detonation was not achieved until approximately the center of the lead azide layer. Variability in the point where high order detonation begins could account for the variations observed in output. Because of the small dimensions, steady state detonation is never reached and therefore factors such as confinement, particle size, and density of explosive are also important. The detonation velocity measurements with foil switches sandwiched between washers containing the explosive were used to compare lead and silver azide in a range of diameters to provide the data for design of miniature detonators. The eighth slide shows the effect of diameter on the observed detonation velocity in both lead and silver azide. The results for lead azide agree quite well with the results obtained by Dr. Chaudri at Cambridge University for single crystals.⁵

A series of tests in miniature detonator cups of 68 and 96 mil diameters were made to provide the data necessary to design a miniature stab detonator. The cups were loaded first with 20 mils of NOL 130 and the remaining 110 mils were filled with azide and RDX in various ratios as indicated in the ninth slide. The sudden increase in output of lead azide loaded units when the RDX column height was increased above 50 mils indicates that use of silver azide would allow the length of the detonator to be reduced, or conversely, produce higher output by use of a larger RDX charge. Although silver azide is more resistant to hydrolysis than lead azide, it is not compatible with the antimony sulfide and tetrazene used in NOL 130 stab mix. Therefore, stab detonators made with silver azide must utilize primer mixes that are compatible but unfortunately less sensitive.

The work of Walker and Wasley has indicated that both peak pressure and pressure duration are important in the shock initiation of a lead by a detonator.⁶ To measure these parameters a miniature manganin gage was developed by SRI on contract which is only 40 mils square as shown in the tenth slide.⁷ The electrical connections allow a constant current to be passed through the outer two leads while the change in resistance of the gage is measured by the voltage developed across the inner two leads. As a result, stretching of the leads does not influence the gage record and the small sensitive area allows the diverging wave from a detonator to be measured until the pressure drops

to about a half of its peak value. The manganin foil is only 0.0002" thick and is mounted on an inexpensive glass plate which has about the same shock impedance as the detonation products from the detonator. A 3 mil thick glass cover plate electrically insulates the detonator from the gage but produces a minimum of attenuation. A gage coefficient of .0022 ohms per ohm per kilobar has been obtained from gas gun shots. The gage is now in use in studies of detonator designs and detonation transfer.

For routine quality control, a less costly and more precise test was desired. Since most detonators fire over an air gap, a test was developed to measure fragment velocity as shown in the eleventh slide.⁸ A flight distance of one inch was chosen to provide a long enough time for accurate time measurements and still assure the fragments would hit the stop switch. A critical development in this test was the addition of a 20 mil thick aluminum filter over the stop switch. This prevented premature switch closure from blast or small fragments arriving ahead of the main fragments. The 3 mil aluminum closure disc in the M-55 detonator broke up into a spray of small particles and resulted in a large variation in velocity measurements as shown in the twelfth slide. By addition of a thin steel flyer plate which did not break up, the precision of the test was increased by an order of magnitude. This also provides a measure of integrated impulse rather than of peak pressure. The presence of a small air gap or layer of lacquer between the detonator and the flyer plate was found to be unimportant. A comparison of the precision of the flyer plate test compared to the gamma gage is shown on the thirteenth slide. At the 90% confidence level, both tests appeared to be about equal. The gamma gage has the advantage of telling where the defect occurred, while the fragment velocity test provides an overall measure of performance. The fourteenth slide shows the accuracy of the test method with various thickness of flierplates, as compared to hydrodynamic calculations made using the SIN code, and flash x-ray measurements. The flash x-ray velocities are a little higher because the fragments did not have to penetrate the stop switch cover plate.

The next step in the explosive train is the transfer of detonation from the detonator to an explosive loaded lead cup. A test was developed to measure the response of the lead cup to the detonator by determining the time between initiation and output of the lead as shown in the fifteenth slide. In addition to overall function time, a detonation electric pickup was placed underneath the lead cup to measure the details of the initiation process.⁹ A typical record from this probe is shown in the sixteenth slide. From these records, the shock velocity, the fragment velocity, and the time that detonation began

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can be determined. Some interesting observations from this test are shown on the seventeenth slide. The first set of data at 11,000 psi loading pressure indicates that low density fine particle size RDX is easier to initiate than larger particle size, higher density RDX. When the loading pressure is increased to 40,000 psi, the crystal strength of the RDX is exceeded so that all the particles are compacted to about the same density and sensitivity. The excess transit times calculated from both fragment and shock velocity also indicate that shock initiation occurred in the case of the high density and small particle size material rather than initiation by fragments. A further confirmation of this was obtained in tests where increased closure disc thicknesses on M-55 detonators resulted in less efficient initiation of lead cups over short gaps even though they had proved to be beneficial in long gaps.¹⁰

Currently, work is underway on determining design parameters for explosive logic and multipoint initiation systems. The explosive logic is based on using one explosive train to prevent subsequent detonation in another train by destroying a portion of its path. The multipoint systems depend on branching trains of equal length to simultaneously detonate a series of booster pellets. Studies have begun using an off the shelf extrudable explosive developed by the AEC (XTX 8003). A less costly extrudable explosive is also being developed for the Army's large volume requirements. In addition, a longer range study is being made which may significantly reduce the size and cost of these systems by starting with a photengraved pattern of silver film a few thousandths of an inch thick, and then converting this to silver azide electrolytically in a sodium azide solution. Detonation of this film has already been demonstrated.

CONCLUSION

The studies described above have led to improved quality controls for detonators and are currently being used in design studies on improved explosive trains. An example of the way this information can be used is shown in the last (eighteenth) slide showing the M42 grenade explosive train. In this case, the cause of duds was found to be failure to initiate the lead cup explosive properly. The problem was solved by using a more sensitive explosive mixture (99.5% RDX/0.5% graphite), by better control of the thickness of the metal in the cup bottom, and by increasing its diameter to compensate for misalignment. More information is available in the referenced reports for those who desire it.

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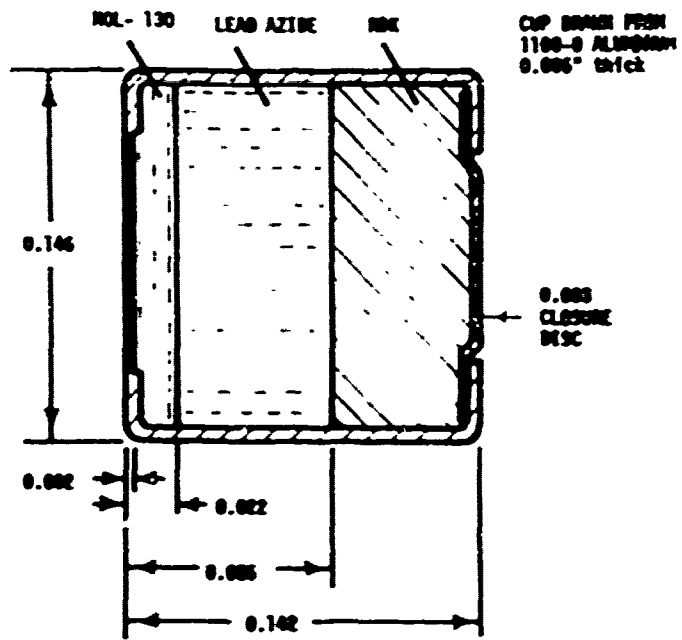


FIGURE 1 M-55 Detonator

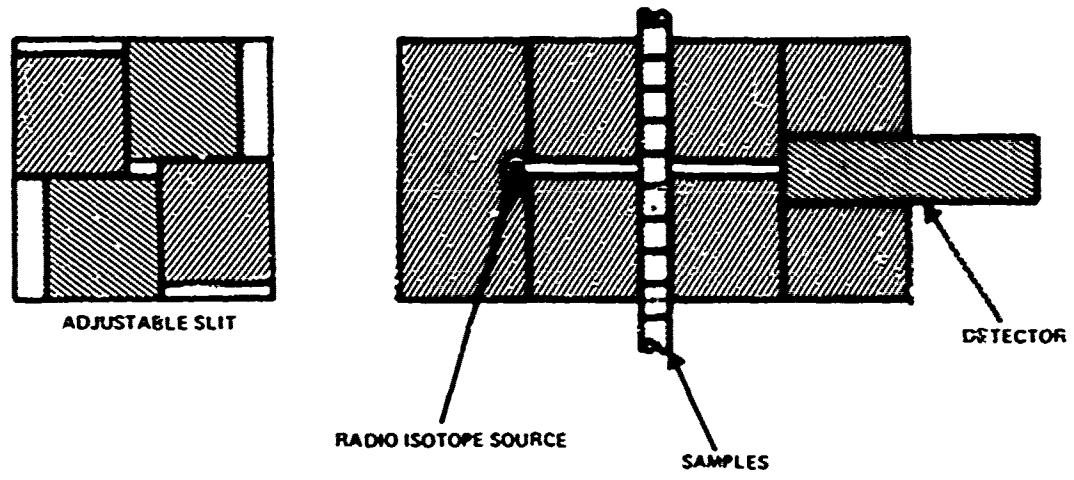


FIGURE 2 Gamma Ray Density Scanner Schematic

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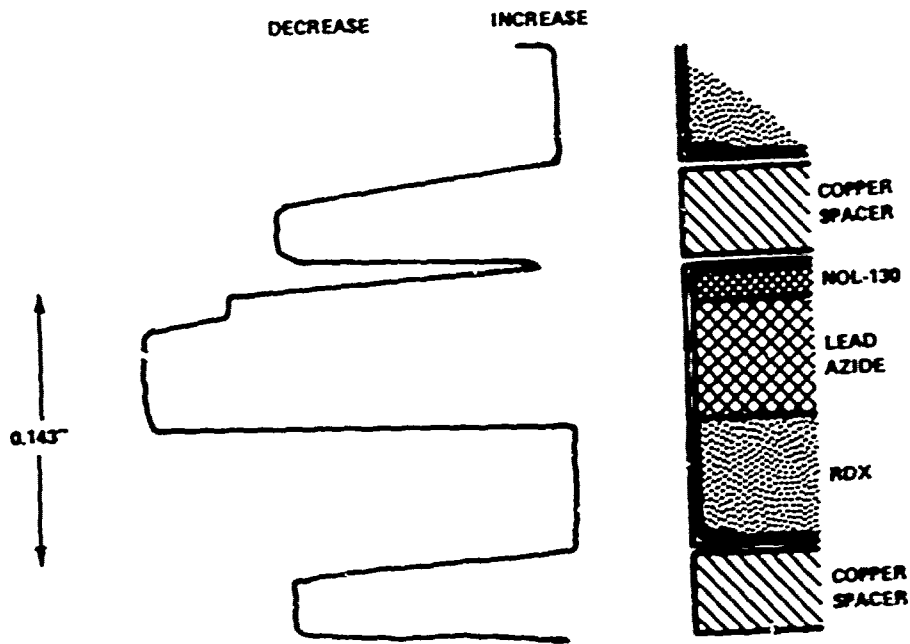


FIGURE 3 M-55 Detonator Gamma Ray Scan

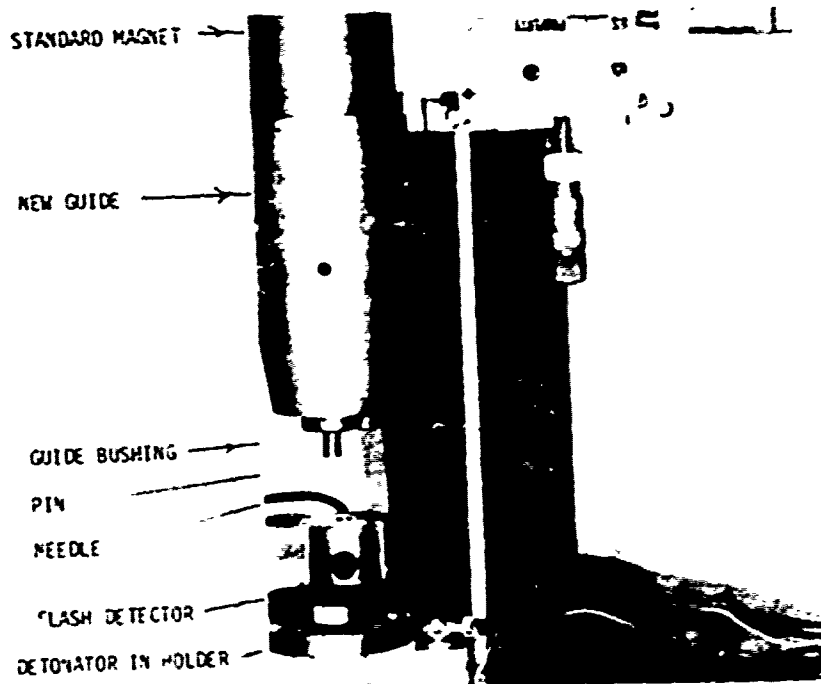
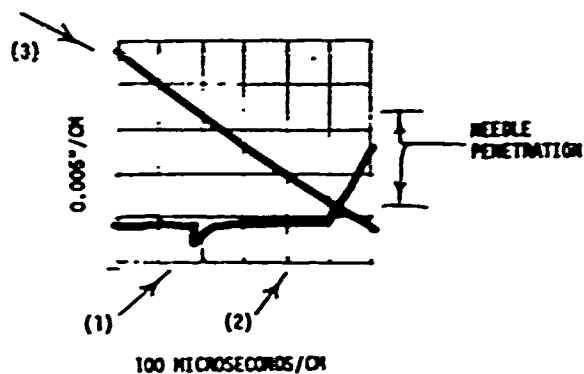


FIGURE 4 Instrumented Stab Tester



- (1) Time needle contacts detonator (negative)
- (2) Time explosion starts (light output positive)
- (3) Needle position vs. time

FIGURE 5 Typical Stab Record

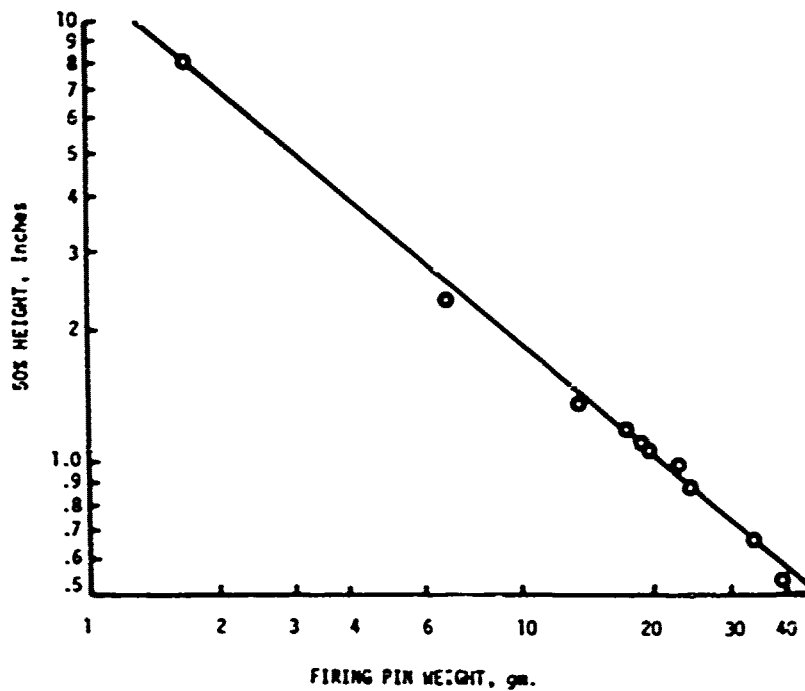


FIGURE 6 Effect of Firing Pin Mass on Stab Sensitivity

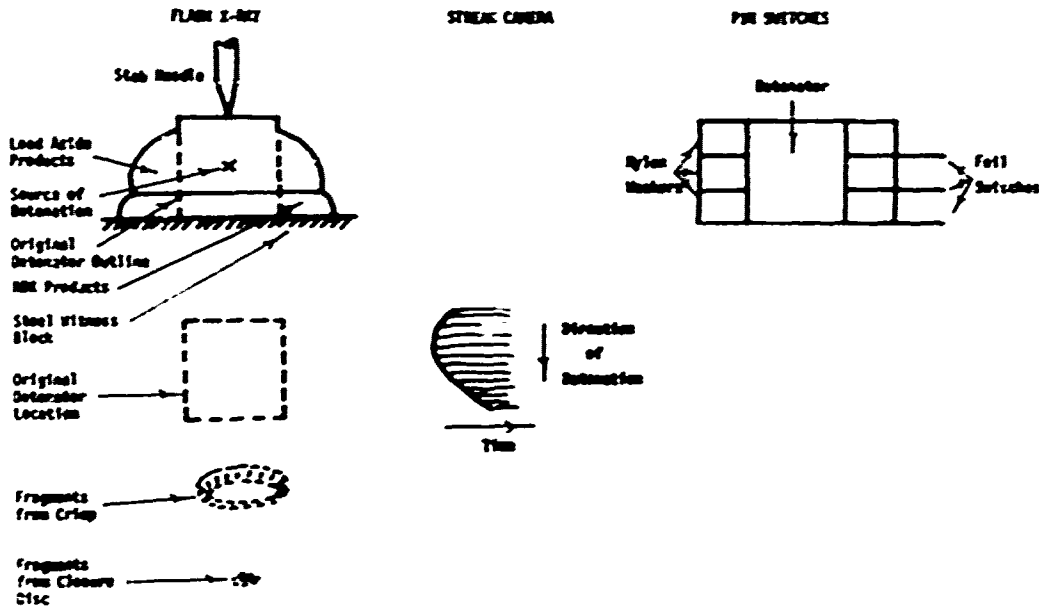


FIGURE 7 Methods of Measuring Detonation Buildup

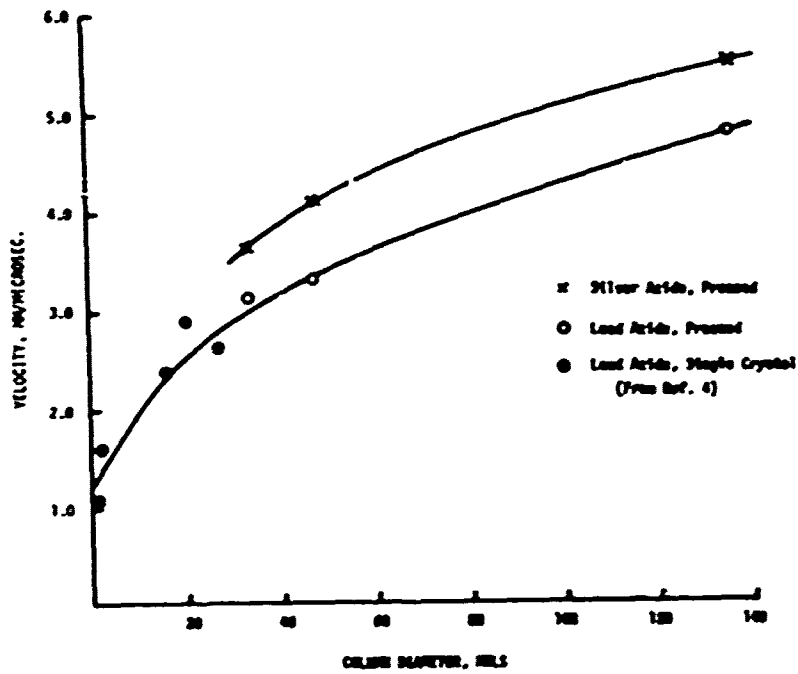


FIGURE 8 Detonation Velocity vs Diameter for Lead and Silver Azide

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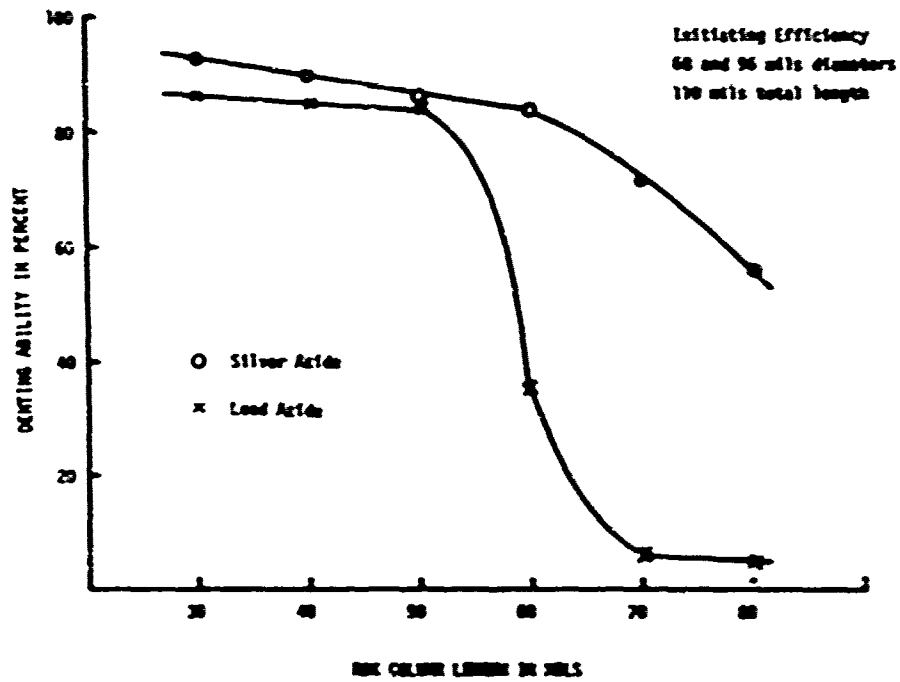


FIGURE 9 Initiating Efficiency of Lead and Silver Azides

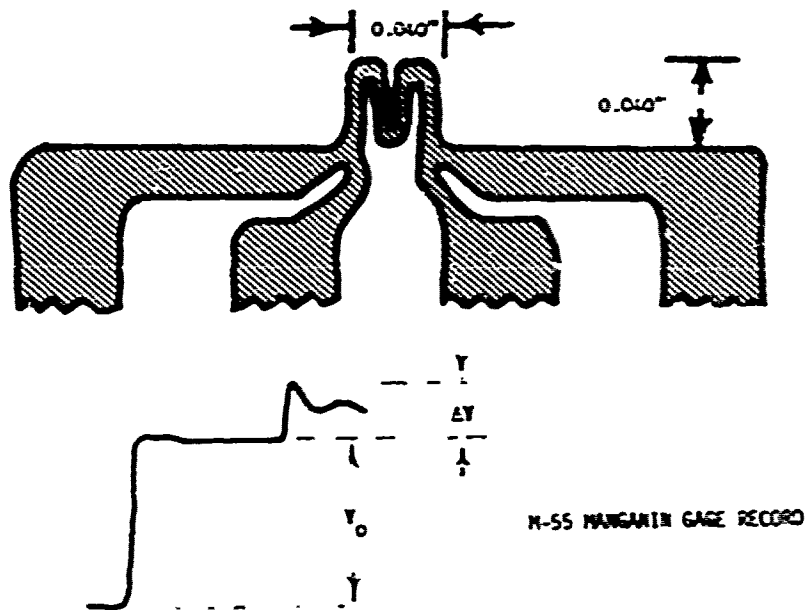


FIGURE 10 Manganin Gage for Shock Pressure Measurements

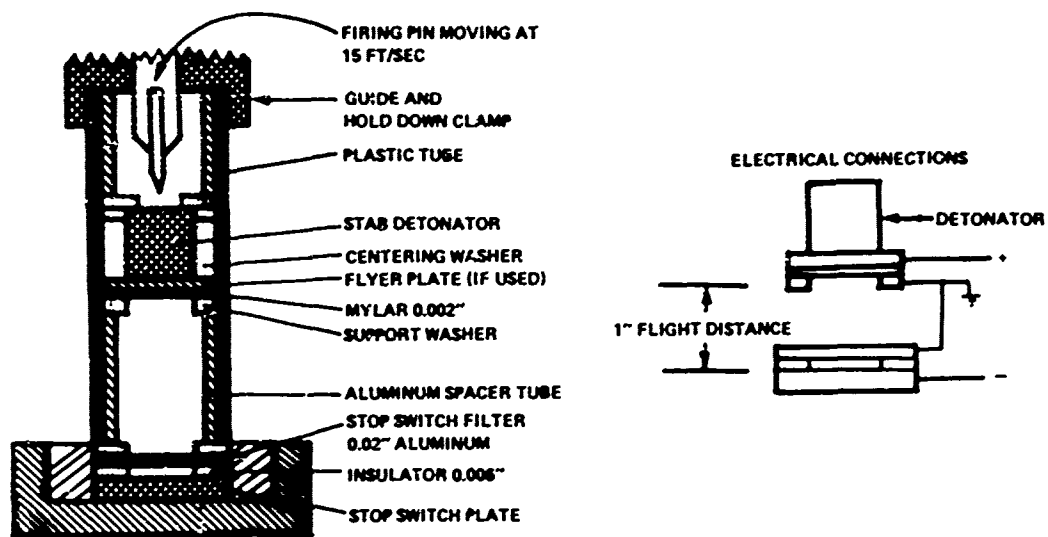


FIGURE 11 Detonator Fragment Velocity Assembly

<u>Variable</u>	<u>Type Detonator</u>	<u>Mean Velocity</u> <u>mm/μs</u>	<u>n</u>	<u>90% C.L. of Mean</u>
Effect of Flyer Thickness	M-55			
3 mil aluminum	"	3.617	7	0.164
3 mil aluminum plus 2 mil steel flyer	"	2.958	9	0.030
3 mil aluminum plus 5 mil steel flyer	"	2.024	13	0.010
Air Gap Between Detonator & 5 Mil Flyer				
4 mil (paper)	"	2.028	6	0.018
Loading Pressure				
15 kpsi (RDX @ 1.69 gm/cc)	"	2.324	13	0.010
30 kpsi (RDX @ 1.77 gm/cc)	"	2.132	12	0.028
RDX Quantity				
12 mg (30 mil)	"	2.064	10	0.019
28 mg (69 mil)	"	2.228	10	0.019
Type Detonator				
10 mil Al Closure, double M-55 length	M-59	1.958	10	0.022
10 mil Cu Closure, and confinement	M-63	2.043	10	0.072
10 mil Cu Closure 0.239" dia.	M-42	2.663	10	0.068

FIGURE 12 Fragment Velocities from Detonators

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Variable	Typical in M-55	90% C.L.		
		Gamma Gage #	Flyer Plate*	
			Measured	Calculated
RDX Length, mils	57	± 4.9	± 5.8	± 1.0
RDX Density, gm/cc	1.67	± 0.03	± 0.01	± 0.01

* Avg. of 10, assuming $0.02 \text{ mm}/\mu\text{s} = 90\% \text{ C.L. on avg. velocity.}$

One measurement

FIGURE 13 Comparison of Precision of Gamma Gage vs Flyer Plate Velocity on M-55 Detonators

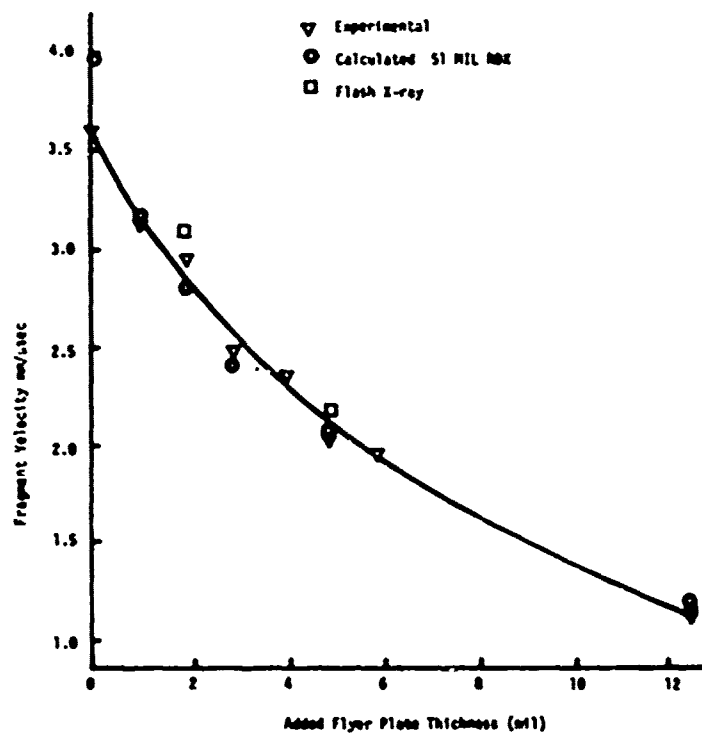


FIGURE 14 Effect of Flyer Plate Thickness on Velocity

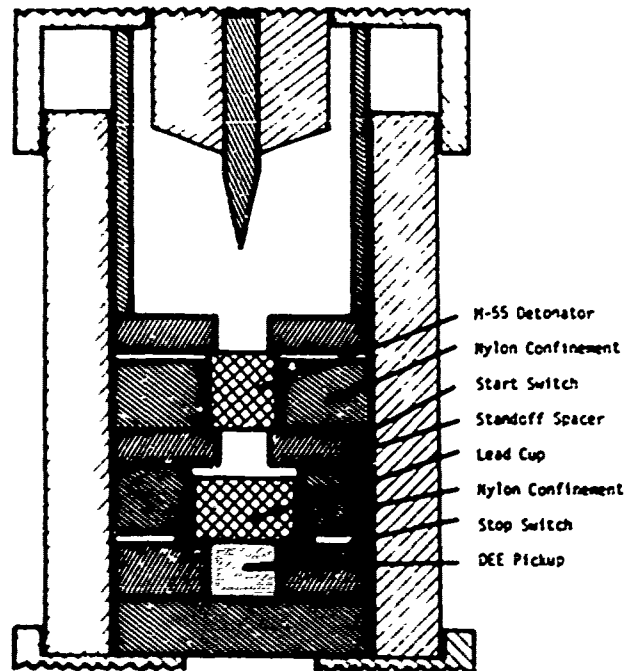


FIGURE 15 Detonation Transfer and Detonation Electric Assembly

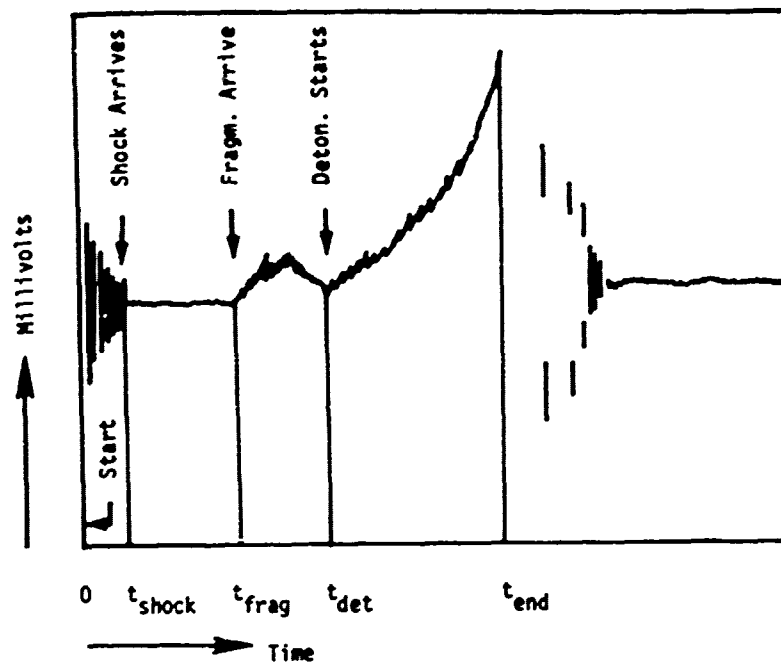


FIGURE 16 Typical Detonation Electric Record

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Loading Pressure (psi)	11,000			40,000		
RDX Class	C	A	E	C	A	E
Mean Particle Size (microns)	498	224	20	498	224	20
Pressed Density (g/cm ³)	1.62	1.60	1.48	1.73	1.73	1.70
Excess Transit Times, μ s						
Fragment Initiation Assumed	25	9	-103	-49	-83	-29
Shock Initiation Assumed	214	198	86	140	106	160
90% Conf. Interval of Mean	<u>+22</u>	<u>+20</u>	<u>+ 29</u>	<u>+30</u>	<u>+38</u>	<u>+42</u>

FIGURE 17 Effect of Density and Particle Size of RDX on Excess Transit Time in 40mm Leads

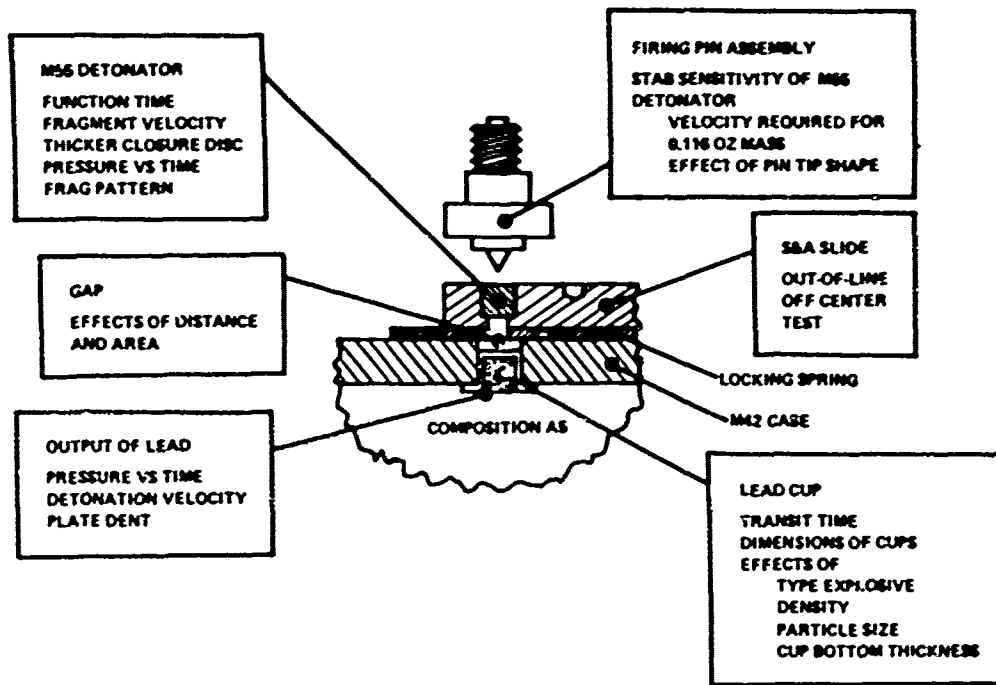


FIGURE 18 Applications of This Program to M-42 Dud Problem