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EXPLOSIVES RESEARCH CENTER

SENSITIVITY CHARACTERISTICS OF LIQUID EXPLOSIVE SYSTEMS

PROGRESS REPORT NO. 6
April 1, 1963 to June 30, 1963

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SENSITIVITY CHARACTERISTICS OF LIQUID EXPLOSIVE SYSTEMS

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SENSITIVITY CHARACTERISTICS OF LIQUID EXPLOSIVE SYSTEMS

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INTRODUCTION

This is the sixth report describing experimental results obtained in the research program established to evaluate the safety hazard associated with high-energy liquid explosives. The program is sponsored by the Bureau of Naval Weapons, U. S. Department of the Navy.

Studies continued on the determination and evaluation of the shock sensitivity of liquid explosives. Recent work in this area, from this laboratory on this project, demonstrated that container material and physical dimensions are decisive factors in affecting the results obtained in gap testing. The observation that relatively sensitive liquid explosives may, depending on the applied shock strength, readily detonate either high or low order under the conditions of gap testing, served as the basis for an extensive examination of the variables affecting initiation. Threshold gap values were determined for the difference between high and low order detonation in the nitroglycerin-ethyleneglycol dinitrate (NG-EGDN) system.[1/]

EXPERIMENTAL RESULTS

NG-EGDN

Shock sensitivity studies were continued on 50-50 NG-EGDN with a modified card gap arrangement[2/] (Figure 1) in lead, copper,

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1/ In previous reports we have used the term "low velocity reaction" to replace the indefinite term "low order detonation," and we shall continue to use this term to describe results where the detonation rate is of the order of 1.5 to 2.0 mm/μsec and damage to the container is restricted to large fragments.

2/ Mason, C. M., and J. Ribovich. Sensitivity Characteristics of Liquid Explosive Systems. Bureau of Mines Progress Report No. 3, July 1, 1962 to September 30, 1962 (Confidential).

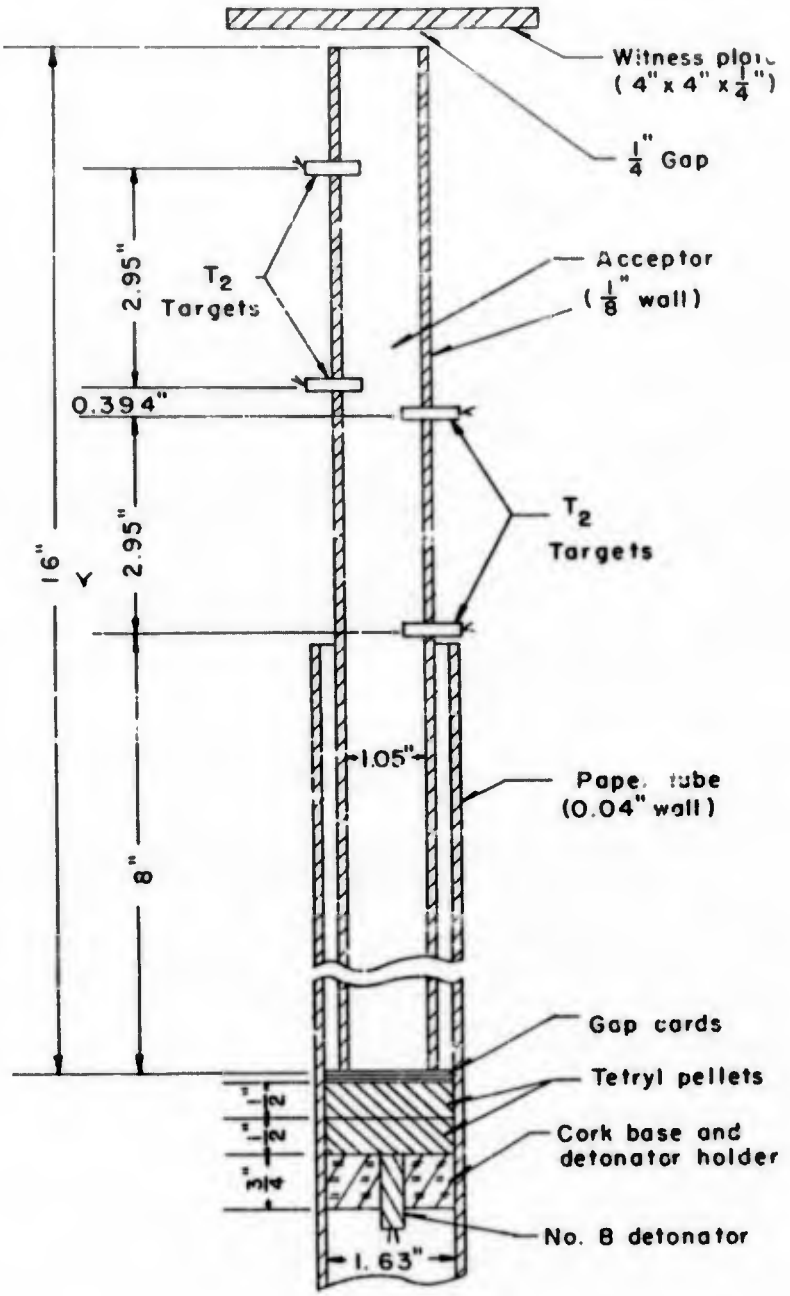

Fig. 1. - Card-gap arrangement.

Lucite, and polyethylene containers. Either high velocity detonation (approximately 7500 m/sec) or low velocity reaction (approximately 1000 to 2000 m/sec) could be obtained in the sample in all containers by varying the input energy by attenuating the shock using Lucite barriers.

A summary of the results obtained to date for 50-50 NG-EGDN is shown in Figure 2. For each material studied, the threshold gap value separating the initiation of high velocity detonation from the initiation of low velocity reaction decreases with an increase in wall thickness. This behavior is in contrast to the usual concept that confinement enhances the initiation of high velocity detonation. Low velocity reactions or detonations were observed in 50-50 NG-EGDN in each of the containers, at gaps up to and including 12 inches of Lucite.

Detailed results for 50-50 NG-EGDN in 1-inch id x 16-inch length lead, copper, and Lucite containers of various wall thicknesses, at 25°C, are given in Tables 1, 2, and 3 and illustrated in Figures 3, 4, and 5, respectively. Results obtained in 1-inch id x 0.003-inch wall x 16-inch length polyethylene containers are given in Table 4.

The effect of the shock wave propagating up along the outside of the acceptor cup in influencing the test was investigated. The paper tube normally used around the lower half of the acceptor cup (Figure 1) was removed with this arrangement. Little or no change in the threshold values between high velocity detonation and low velocity reaction was observed for thin wall aluminum, lead, or polyethylene containers. Similarly, a felt shield (6 inches x 6 inches x 1/2 inch) placed around the lower end of the acceptor cup just above the cards appeared, except for 0.0015-inch wall aluminum containers,

Table 1. - Shock sensitivity data at 25°C
Sample: 50-50 NG-EGDN
Container: Lead, approx. 1-inch id x 16-inch length

Card gap, inches	Results.[1] numerical values in m/sec Container, id x wall, inches				
	1.0 x 0.010	1.0 x 0.025	1.0 x 0.065	1.0 x 0.080	1.0 x 0.125
1.0				HVD	
1.5				[illegible]	HVD 8720-7350
1.8				HVD	1500 --- HVD
2.0		HVD	HVD	1540-1480	LVR HVD
2.2			HVD	LVR	3710-3890 LVR
2.5		HVD	LVR		
3.0		HVD		LVR	
3.5		4520-7430			
4.0	LVR HVD	HVD HVD			
4.5	HVD LVR	HVD HVD			
5.0	LVR	LVR LVR		LVR	
5.5		LVR			
6.0	LVR				
12.0		1560-1210		1810-1370	

1/ Rates measured using T-2 targets at 8-inch and 11-inch, and 11-3/8-inch and 14-3/8-inch positions (7-1/2 cm apart) on same charge.

HVD - high velocity detonation as indicated by a clean hole in the 1/4-inch thick steel witness plate.

LVR - low velocity reaction as indicated by total fragmentation of container and a dome in the 1/4-inch thick witness plate.

Table 2. - Shock sensitivity data at 25°C
Sample: 50-50 NG-EGDN
Container: Copper, approx. 1-inch id x 16-inch length

Card gap, inches	Results,[1/] numerical values in m/sec Container, id x wall, inches			
	1.055 x 0.020	1.055 x 0.035	1.063 x 0.080	1.063 x 0.126
0.8				HVD HVD
1.0				HVD LVR
1.2			HVD HVD	LVR 7430-7500
1.4			LVR	
1.5		HVD	LVR	LVR
1.6		7430-7500		
1.8	HVD	LVR 1320-1530		1610-1740
2.0	HVD HVD	LVR		
2.2	LVR LVR			
2.5	LVR			
12.0	1270-1200		1090-1350	

1/ See footnote 1/, Table 1.

Table 3. - Shock sensitivity data at 25°C
Sample: 50-50 NC-EGDN
Container: Lucite, approx. 1-inch id x 16-inch length

Card gap, inches	Results,[1/] numerical values in m/sec Container, id x wall, inches		
	1.0 x 0.020	1.0 x 0.060	1.0 x 0.125
1.0			7350-7650
1.5			7430-7500
1.6			HVD
1.8	HVD		HVD LVR
2.0	--- 7650	7280 ---	HVD 2010-1960
2.2	HVD	HVD	HVD LVR
2.4	--- 7810	7280-7430	
2.5	1330-2090 LVR	1600-1530	LVR 2040-1940
2.6		HVD	
2.8		1450-1520	HVD
3.0	LVR	HVD	
3.5		LVR	
5.0			LVR
10.0	990-3090		
12.0	LVR		LVR

1/ See footnote 1/, Table 1.

Table 4. - Shock sensitivity data at 25°C
Sample: 50-50 [illegible]
Container: Polyethylene, approx. 1-inch id x 0.00?-inch [illegible] x 16-inch length

Card gap, inches	Results[1/]
2.5	HVD
2.5	HVD
2.8	HVD
3.0	HVD
3.0	LVR
3.2	HVD
3.5	HVD
3.5	HVD
4.0	LVR
4.0	HVD
4.5	LVR
5.0	LVR
5.0	LVR
12.0	LVR

1/ See footnote 1/, Table 1.

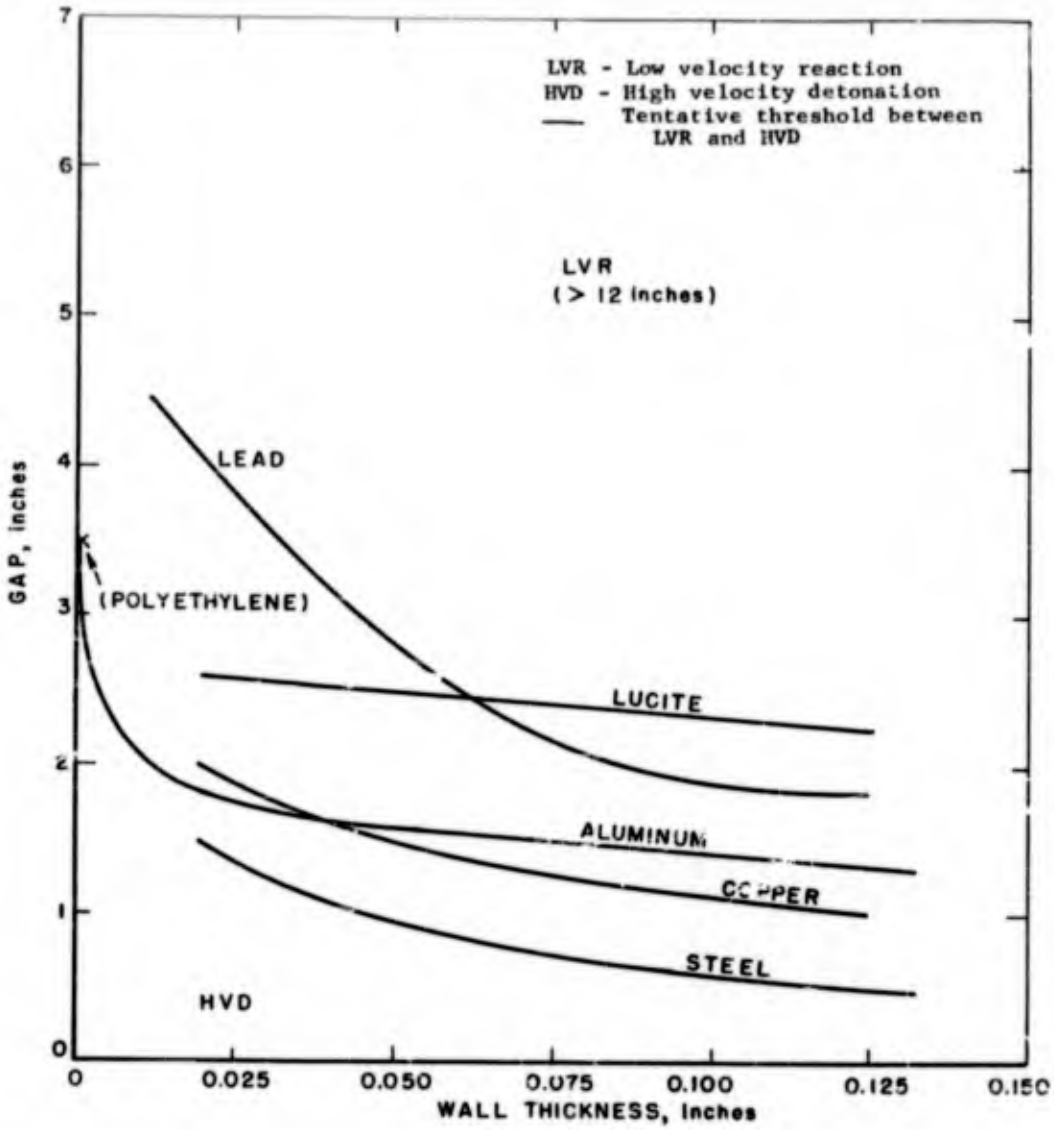

Figure 2. - Gap sensitivity of 50-50 NG-EGDN in 1- x 16-inch containers at 25°C.

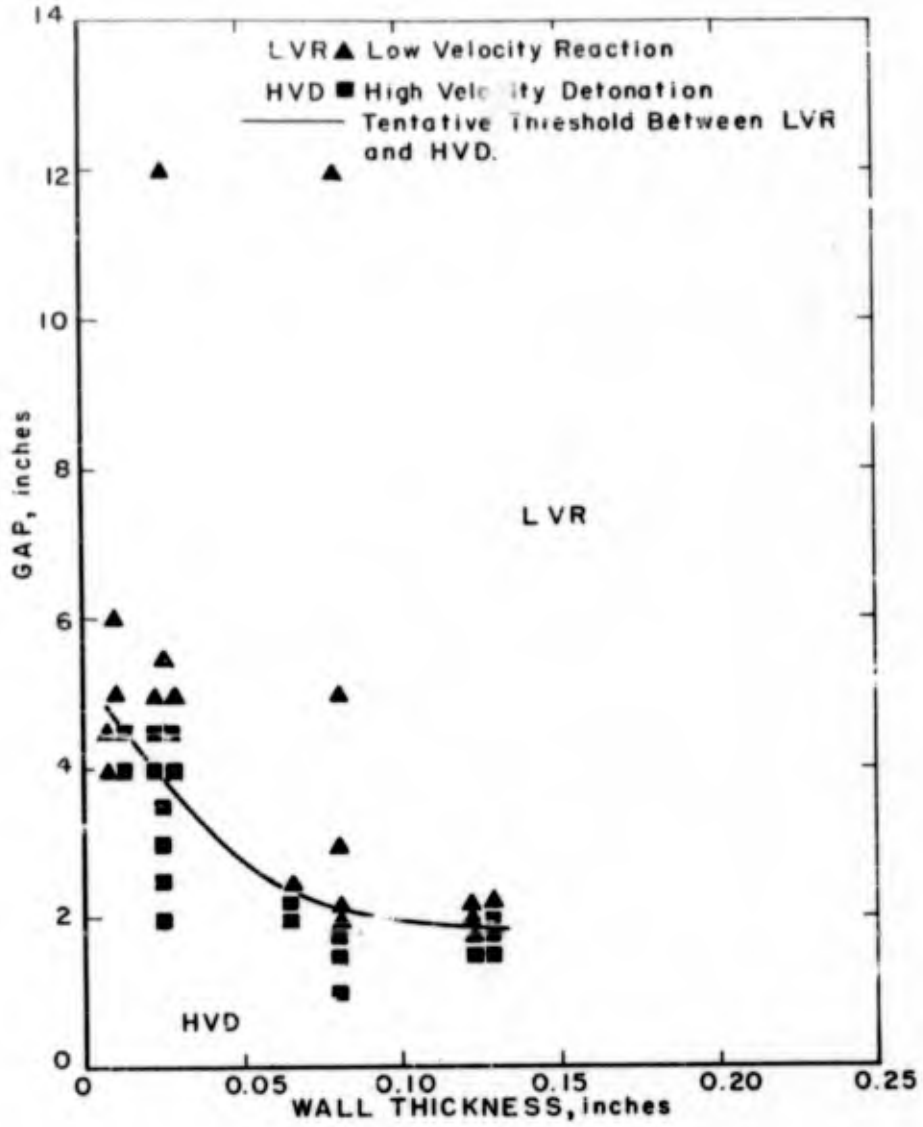

Figure 3. - Gap sensitivity of 50-50 NC-EGDN in 1 x 16-inch lead containers at 25°C.

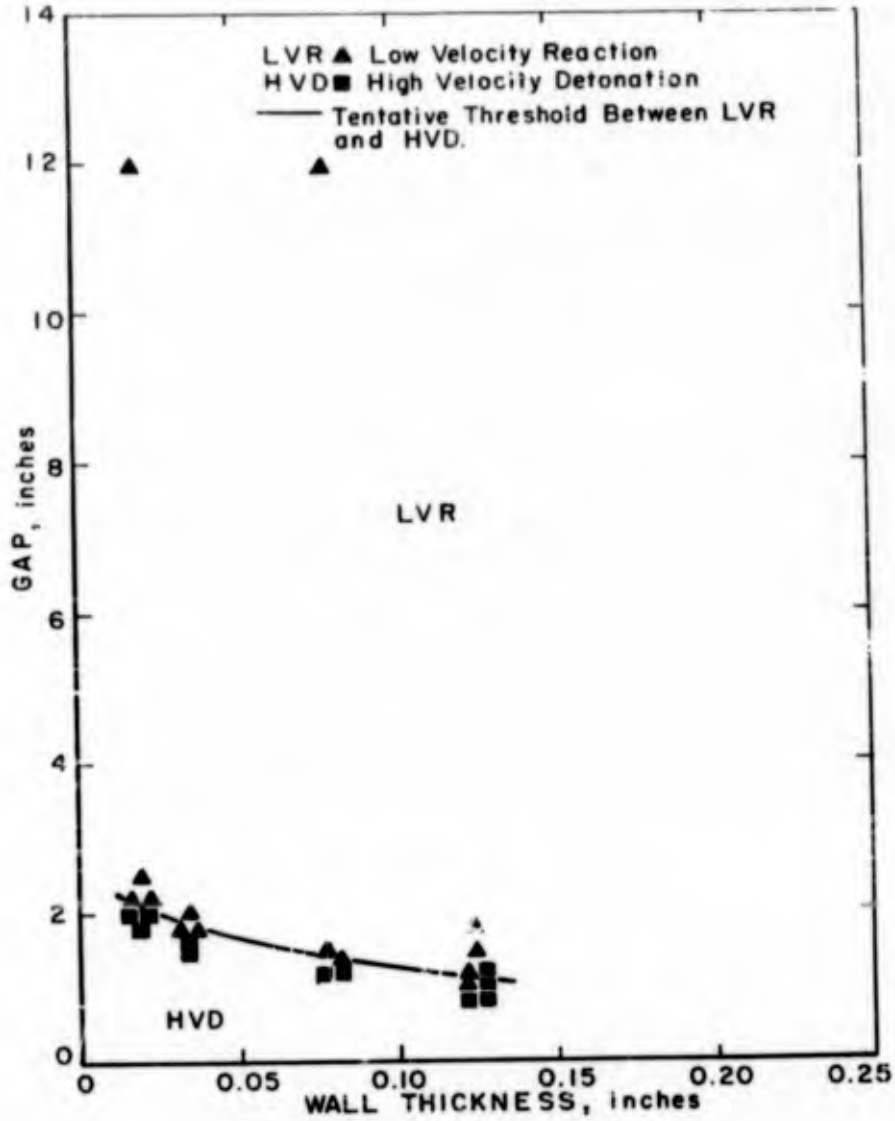

Figure 4. - Gap sensitivity of 50-50 NG-EGDN in 1 x 16-inch copper containers at 2[illegible]°C.

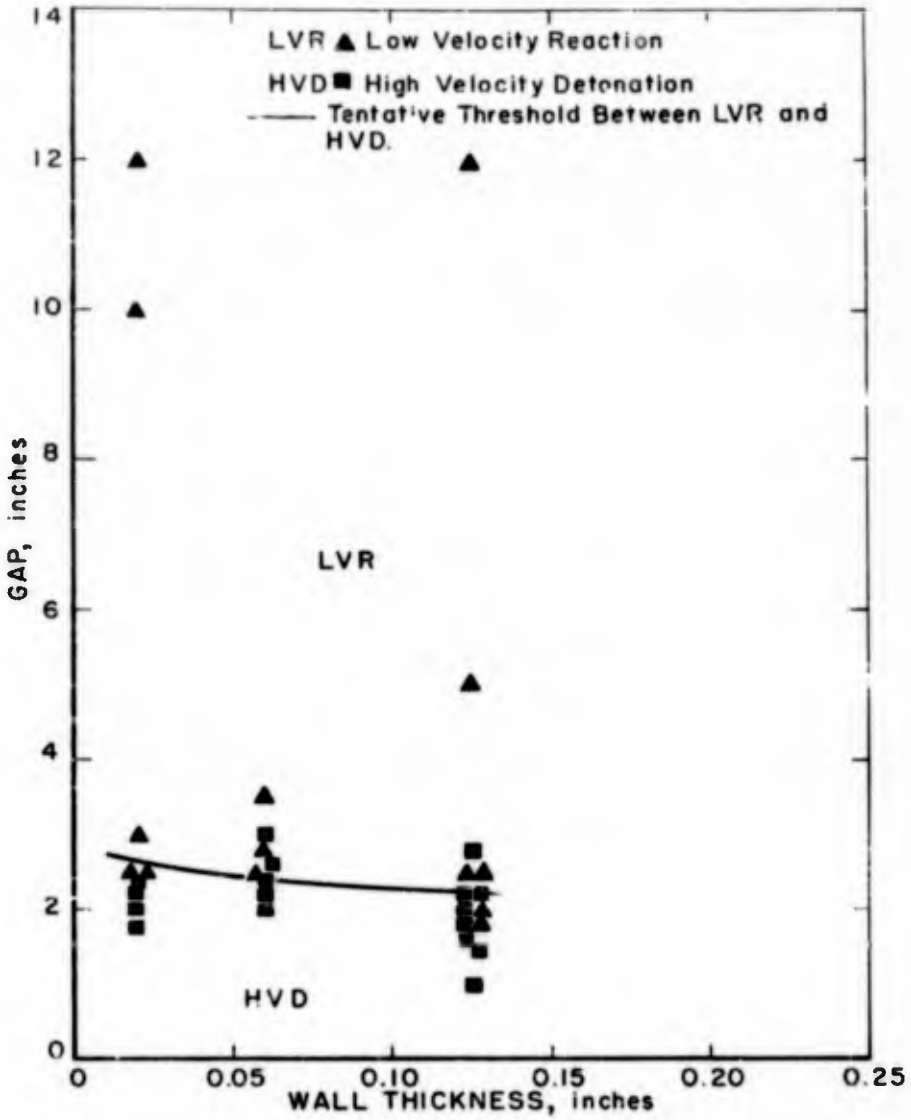

Figure 5. - Gap sensitivity of 50-50 NG-EGDN in 1 x 16-inch Lucite containers at 25°C.

to have little or no effect on the threshold values. Thus, external blast effects, from the donor in this experimental configuration, do not appear to effect ease of initiation of detonation on NG-EGDN in thin-wall containers to a measurable degree. These results are illustrated in Figure 6.

Critical diameters[2/] were determined for 50-50 NG-EGDN in 0.035-inch wall aluminum tubing using the step-down arrangement. A large section of 1-inch diameter x 16-inch length aluminum pipe was attached by a rubber sleeve to a smaller diameter tube 30 inches long. Either high or low velocity regimes were established in the larger section by means of a suitable donor and card gap. Critical diameters were found to be <0.06 inch and between approximately 0.06 and 0.12 inch for high velocity detonations and low velocity reactions, respectively (Table 5).

H_2O_2 (90.7%) - Glycerine

A stoichiometric mixture containing 74.1 percent H_2O_2 (90.7 percent) and 25.9 percent glycerine was employed to extend the studies to other explosives. Passivated[3/] 1-inch id x 16-inch length aluminum (61ST6) cups of various wall thicknesses at 25°C were used as containers. Either high velocity detonation (approximately 6900 m/sec) or low velocity reaction (approximately 1500 to 2000 m/sec) was established in the sample by suitable variation of the shock intensity. As in the case of 50-50 NG-EGDN, the threshold gap value separating the gap-wall thickness high velocity from low velocity detonations decreases with an increase in wall thickness. Likewise, low velocity detonations were obtained in the H_2O_2-glycerine-H_2O system at gaps up to and including 12 inches of Lucite discs. The results obtained are given in Table 6 and illustrated in Figure 7.

3/ The cups were degreased with 5 percent NaOH solution (5 minutes) and then passivated by soaking in 35 percent HNO_3 (24 hours) and in 30 percent H_2O_2 solution (1 to 2 hours).

Table 5. - Critical diameter of 50-50 NG-EGDN at 25°C (Single step-down device)

Container Assembly[1] id x wall x length, inches	Card gap inches	Number of trials	Average Detonation Velocity m/sec[2]
A - Aluminum, 1.05 x 0.133 x 16 B - Aluminum, 0.06 x 0.035 x 30	zero	2	7350 HVD
A - Aluminum, 1.05 x 0.133 x 16 B - Aluminum, 0.43 x 0.035 x 30	2	1	1950 LVR
A - Aluminum, 1.05 x 0.133 x 16 B - Aluminum, 0.31 x 0.035 x 30	2	1	LVR LVR
A - Aluminum, 1.05 x 0.133 x 16 B - Aluminum, 0.18 x 0.035 x 30	2	2	1880 LVR
A - Aluminum, 1.05 x 0.133 x 16 B - Aluminum, 0.12 x 0.035 x 30	2	3	1970 LVR
A - Aluminum, 1.05 x 0.133 x 16 B - Aluminum, 0.06 x 0.035 x 30	2	2	1950 INC - 1.5 inches Irregular

1/ Stable detonation was first obtained in section A (16-inch length) attached to section B (30-inch length).

2/ HVD - high velocity detonation
LVR - low velocity reaction
INC - incomplete reaction - value in inches indicates distance of decay in section B.
Irregular - intermittent ruptures along length of section B.

Table 6. - Shock sensitivity data for stoichiometric mixture of 74.1% H_2O_2 (90.7%) and 25.9% glycerine at 25°C
Container: Aluminum (61ST6), approx. 1-inch id x 16-inch length

Card gap, inches	Results,[1/] numerical values in m/sec Container, id x wall, inches			
	1.055 x 0.020	1.055 x 0.035	1.084 x 0.083	1.05 x 0.133
0.10		HVD		
0.15		6940-7080	6880-7080	
0.20		6940 ----	LVR	6880-6880
0.20				HVD
0.25			HVD	6760-7010
0.25			2310-2190	
0.30		LVR	LVR	LVR
0.30			2150-2140	2160-2150
0.40		6880-7010		
0.50	HVD	HVD		
0.50		LVR		
0.60		HVD		
0.70		1260-2110		
0.90	HVD			
1.00	HVD	LVR		
1.10	HVD			
1.20	6940-6820			
1.20	1630-1650			
1.30	1800-1590			
2.00				2230-2190
4.00				1370-1570
6.00				1780-1520
10.00				1490-1630
12.00	1460-1920			1060-1430

1/ See footnote 1/, Table 1.

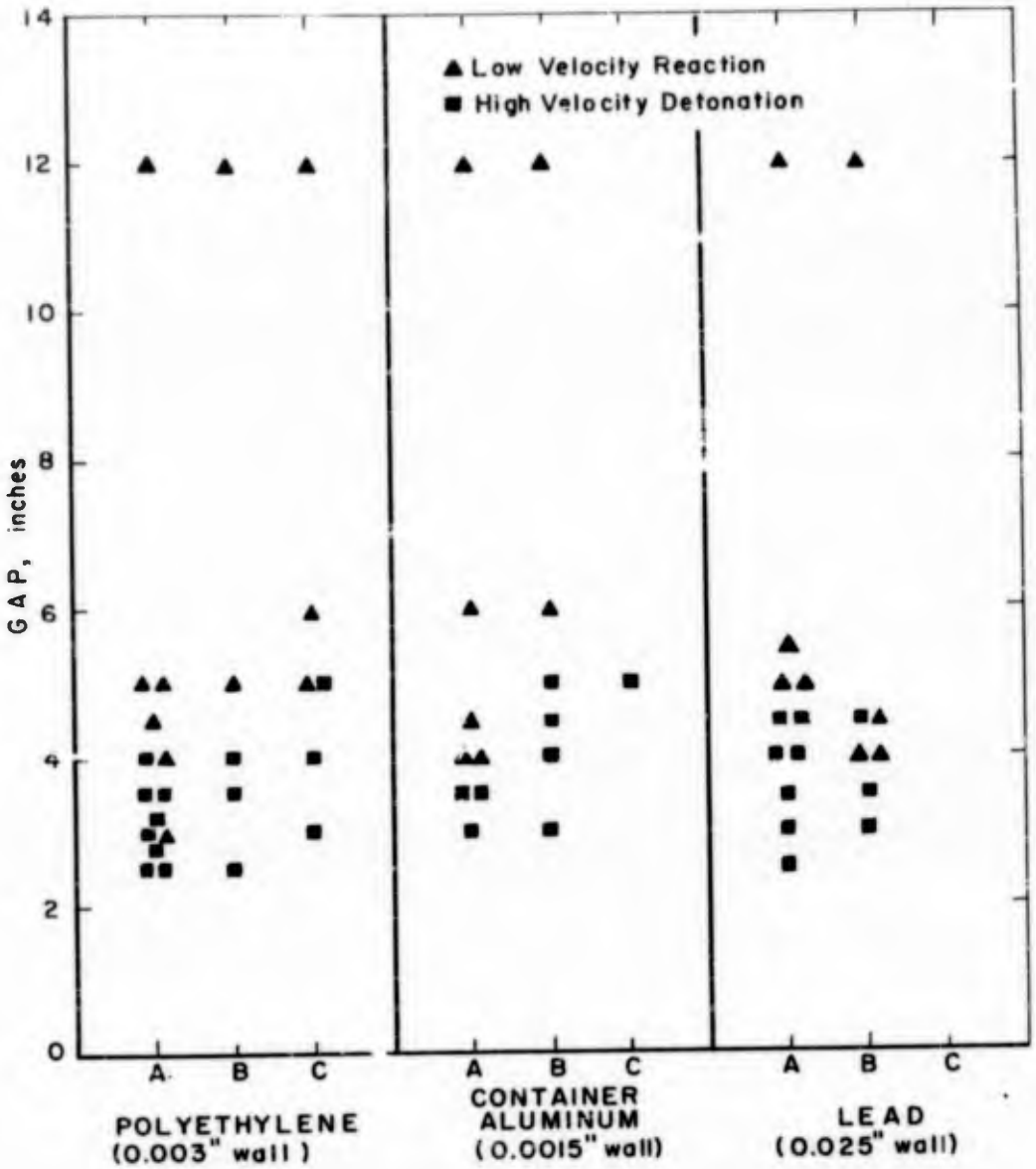

Figure 6. - Effect of external lateral shock wave on gap measurement of 50-50 NG-EGDN at 25°C.
A - paper tube around acceptor cup
B - no paper tube around acceptor cup
C - blast shield and no paper tube around acceptor cup.

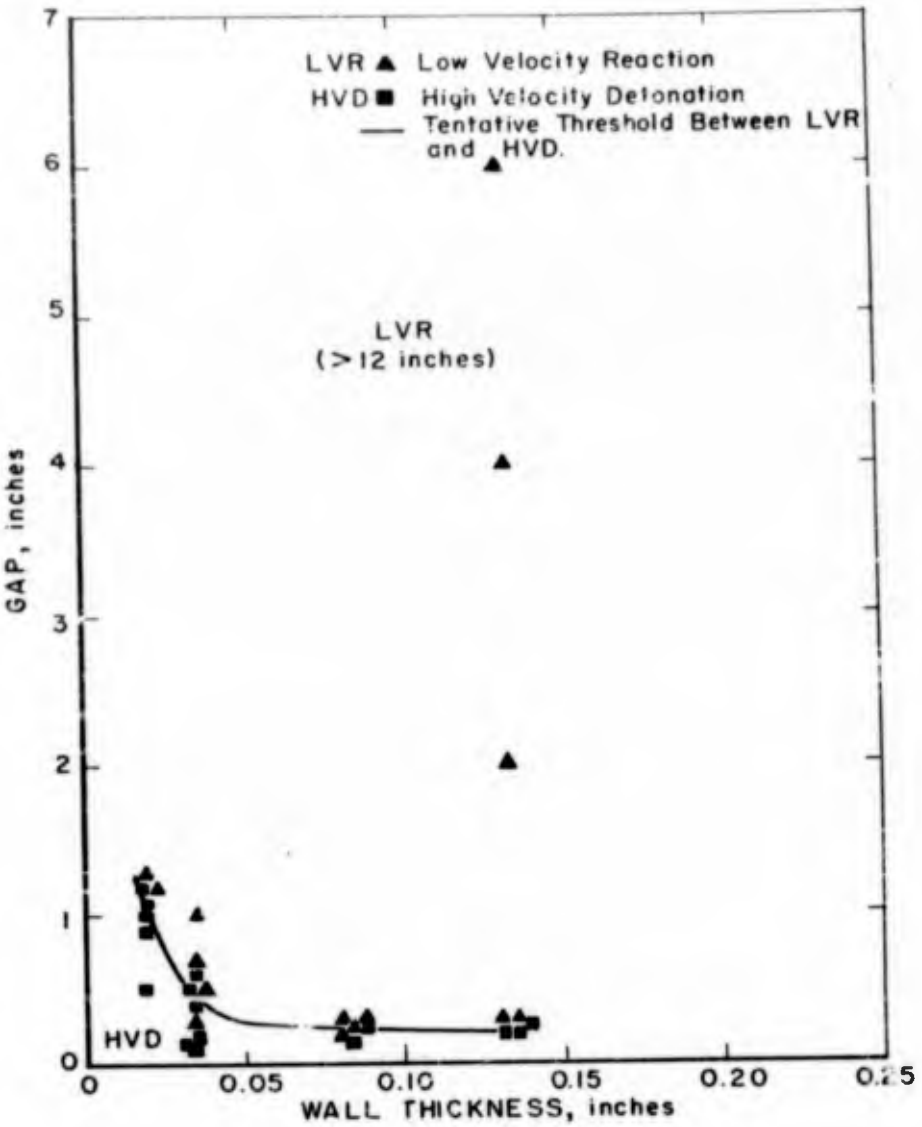

Figure 7. - Gap sensitivity of stoichiometric H_2C_2 (90.7%) - glycerine system in 1 x 16-inch aluminum containers at 25°C.

FUTURE WORK

The curves in Figure 2 are based on a limited number of individual experiments and represent only roughly the threshold between high velocity detonation and low velocity reaction. To adequately define the threshold curve and to determine with a certain degree of precision the minimum card gap where low velocity reactions are initiated would entail a large number of experiments. In order to keep the number of experiments to a minimum, card gaps will be determined at the 50 percent level, that is, the level at which there is a 50 percent likelihood that high velocity detonations and 50 percent low velocity reactions occur. This level is readily obtained using the Bruceton "up-and-down" method.[4/] Curves drawn through the 50 percent gap values will be on a common measurable basis and thus more comparable. This does not mean, of course, that low velocity reactions will not occur at lower than 50 percent gaps nor that high velocity detonations will not occur at higher than 50 percent gaps.

Studies are planned to determine the analogous gap values for the threshold between low velocity reaction and no initiation. A "self destruct" technique will have to be developed to destroy the NG-EGDN sample in case of no initiation to avoid contaminating the bombproof.

4/ Dixon, W. J. and F. J. Massey, Jr. Introduction to Statistical Analysis. McGraw-Hill, New York, 1951, pp. 278-86.

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