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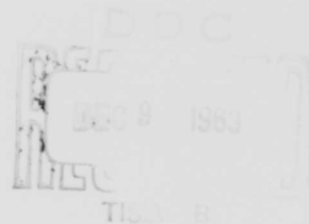
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SENSITIVITY CHARACTERISTICS OF LIQUID EXPLOSIVE SYSTEMS

PROGRESS REPORT NO. 7
July 1, 1963 to September 30, 1963



BUREAU OF MINES, PITTSBURGH, PA.

UNITED STATES
DEPARTMENT OF
THE INTERIOR

**SENSITIVITY CHARACTERISTICS OF LIQUID
EXPLOSIVE SYSTEMS**

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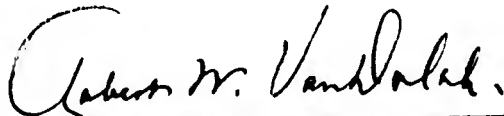
Prepared for:

**Bureau of Naval Weapons
U. S. Department of the Navy
Contract No. IPR 19-63-8029-WEPS**

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SENSITIVITY CHARACTERISTICS OF LIQUID
EXPLOSIVE SYSTEMS

Progress Report No. 7

INTRODUCTION

This is the seventh 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.

The evaluation of the shock sensitivity of liquid explosives was continued with 50-50 nitroglycerin-ethyleneglycol dinitrate (NG-EGDN), Metriol trinitrate (TMETM), and nitromethane. With the NG-EGDN system the gap thicknesses at which 50 percent of the trials gave high velocity detonations and 50 percent gave low velocity reactions^{1/} were determined in various containers to improve the approximate values reported earlier.^{2/} Metriol trinitrate was observed to be slightly less sensitive to shock initiation than NG-EGDN but to yield both low and high velocity detonations. In the projectile impact test NG-EGDN was observed to be initiated into a low velocity reaction with a shock pressure of approximately 3 kilobars. An attempt was made to obtain low velocity reactions in increased diameters in nitromethane.

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/ μ sec and damage to the container is restricted to large fragments.

2/ Mason, C. M., and J. Ribovich. Sensitivity Characteristics of Liquid Explosive Systems. BuMines Progress Rept. No. 6, April 1, 1963 to June 30, 1963.

EXPERIMENTAL RESULTS

Nitroglycerin-Ethyleneglycol Dinitrate

Studies on 50-50 NG-EGDN were with the modified card gap arrangement (combination gap-rate experiment) described in previous reports,^{2,3/} in aluminum, steel, copper lead, Lucite, and polyethylene containers.

The results are in general agreement with the values obtained earlier.^{2/} The gaps increase from steel through copper, aluminum, Lucite, and polyethylene to lead, in the order named. The difference in the values for lead, polyethylene, and Lucite are not too significant, however, since large changes in gap thickness, when the gap is in excess of three inches, represent only small changes in applied shock pressure.^{4/} The data are given in Table 1 and the relationship between gap and wall thickness is shown in the figure.

Previously, 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. To completely evaluate the sensitivity of 50-50 NG-EGDN, an attempt was made to determine the gap values for the threshold between low velocity reaction and no initiation. At 70, 80, 90, 100 and 110-inch gaps with 50-50 NG-EGDN in aluminum containers (1.05-inch id by 0.133-inch wall by 16-inch length), all trials resulted in low velocity detonations.

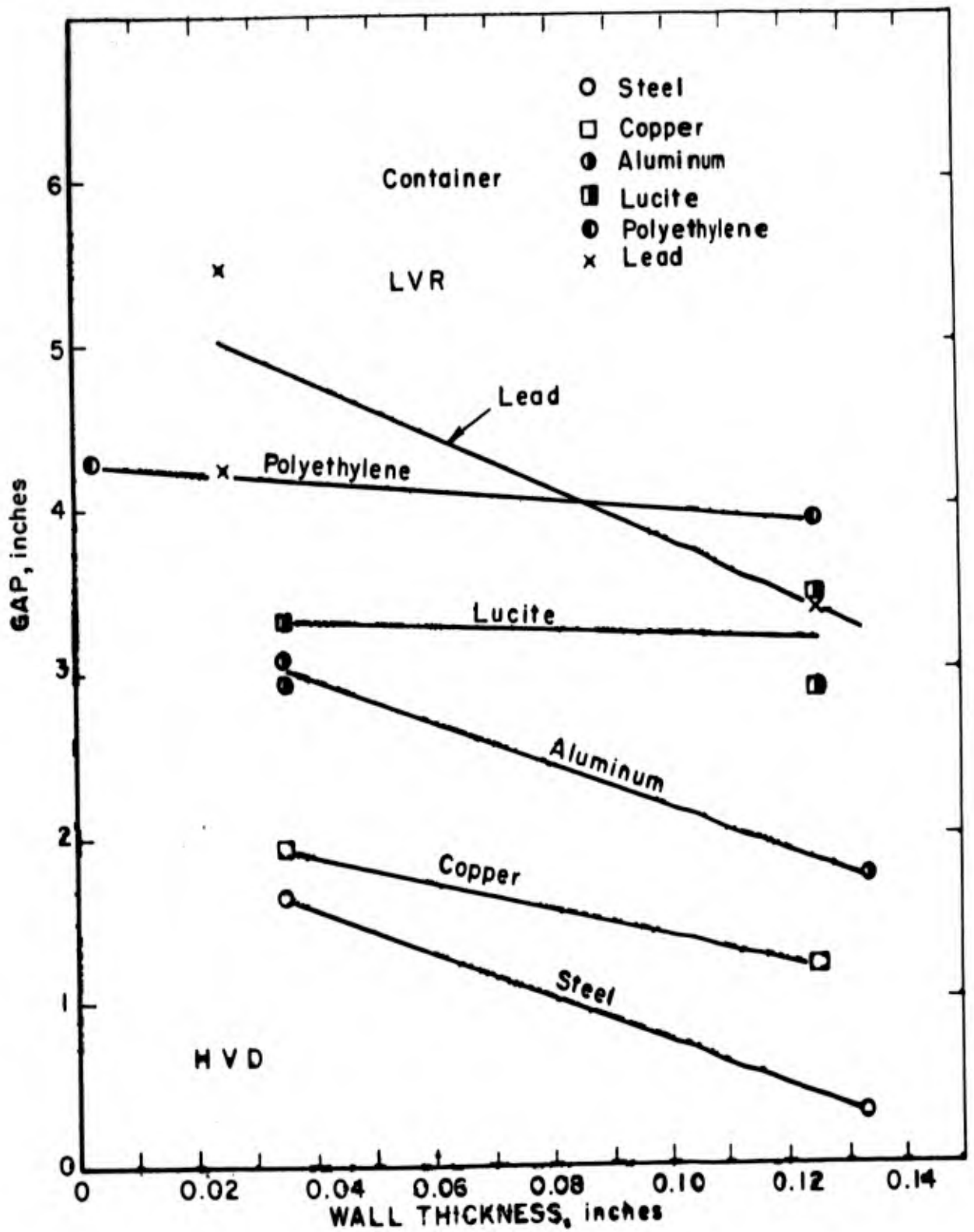
^{3/} Mason, C. M., and J. Ribovich. Sensitivity Characteristics of Liquid Explosive Systems. BuMines Progress Rept. No. 3, July 1, 1962 to September 30, 1962 (Confidential).

^{4/} Jaffe, I., B. Beauregard, and A. Amster. Determination of the Shock Pressure Required to Initiate Detonation of an Acceptor in the Shock Sensitivity Test. J. Am. Rocket Soc., v. 32, 1962, pp. 22-25.

Table 1. - Shock sensitivity data on 50-50 NG-EGDN at 25°C

<u>Container</u> <u>id x wall x length, inches</u>	<u>Card gap value, inches</u> <u>(50 percent points)</u>
Steel, 1.055 x 0.035 x 16	1.62
" 1.050 x 0.133 x 16	0.30
Copper, 1.055 x 0.035 x 16	1.93
" 1.063 x 0.126 x 16	1.20
Aluminum, 1.055 x 0.035 x 16 ^{1/}	2.93
" 1.055 x 0.035 x 16 ^{1/}	3.08
" 1.050 x 0.133 x 16	1.75
Lucite, 1.0 x 0.035 x 16	3.30
" 1.0 x 0.125 x 16	3.46
" 1.0 x 0.125 x 16 ^{1/}	2.88
Polyethylene, 1.0 x 0.003 x 16	4.28
" 1.0 x 0.125 x 16	3.91
Lead, 1.0 x 0.035 x 16	5.45
" 1.0 x 0.035 x 16	4.25
" 1.0 x 0.125 x 16	3.38

1/ Paper tube around the cup.



Gap sensitivity (50 percent) of 50-50 NG-EGDN between high velocity detonation and low velocity reaction at 25°C.

Projectile Impact Studies

The gap test has little meaning for sensitive materials which yield low velocity reactions at large gaps. In order to obtain a more quantitative determination of the shock needed to initiate low velocity reactions in sensitive materials, a projectile impact method being developed in a concurrent investigation was used.^{5,6/} A Mauser 50 caliber antitank action was rebarreled with a smooth-bore barrel and chambered for standard 50 caliber ammunition. The muzzle velocity of a given projectile is found to vary with the square root of the weight of propellant used to drive the projectile. Results are recorded as the velocity necessary for initiation in 50 percent of the trials.

Brass and duraluminum projectiles (0.500-inch diameter by 0.500-inch length) and 50-50 NG-EGDN contained in 1.5-inch diameter by 2-inch long aluminum tubes of 0.125-inch wall thickness, whose ends were sealed with 3 mil polyethylene sheet were employed. The projectiles were fired at the end with the line of flight on the axis of the tube.

The low velocity reaction was initiated by projectiles in the range of 100 to 200 m/sec. The square root relationship between propellant weight and muzzle velocity becomes somewhat erratic at velocities as low as 200 m/sec, and therefore, it was not efficient to use the "up and down" technique to determine the velocity for a 50 percent detonation probability. Instead, projectiles were fired

- 5/ Mason, C. M., and J. Ribovich. Safety and Combustion Characteristics of Homogeneous and Heterogeneous Monopropellant Systems. BuMines Semi Annual Summary Rept. No. 3897, January 1, 1963 to June 30, 1963 (Confidential).
- 6/ Eldh, D., B. Persson, B. Ohlin, C. H. Johansson, S. Ljungberg and T. Sjolín. Shooting Test with Plane Impact Surface for Determining the Sensitivity of Explosives. Explosivstoffe, v. 5, May 1963, pp. 97-102.

at random velocities and the 50 percent velocity determined from the measured velocities.

Analyses of 16 trials with brass projectiles gave a 50 percent velocity of 135 m/sec. This was found to correspond to a shock pressure of about 3 kilobars^{7,8/} in the NG-EGDN. Analyses of 22 trials with duraluminum 2024 projectiles gave a 50 percent velocity of 160 m/sec. This was also found to correspond to a shock pressure of 3 kilobars. A low-order reaction was indicated by the damage to the containers.

Metriol Trinitrate

Gap sensitivity of Metriol trinitrate (trimethylol ethane trinitrate, TMEIN-100 percent assay) in steel cups 1.05-inch id by 0.133-inch wall by 16 inches long was determined. The oily, slightly turbid, amber colored liquid, density 1.46 g/ml at 60°F, melting point of +2°C, exhibits both low velocity reaction (approximately 1,500 m/sec) and high velocity detonation (approximately 7,000 m/sec). The gap value separating the high and low velocities appears to fall between 0.05-inch and 0.10-inch (Table 2). The limiting gap value separating the low velocity detonation and no initiation regime appears to be in excess of 12 inches.

Nitromethane

It has been observed that many liquid explosives detonate at both low and high velocities. Nitromethane is an exception, but

7/ Majowicz, J. M. and S. J. Jacobs. Initiation to Detonation of High Explosives by Shocks. Navord Rept. 5710, March 1, 1958, 27 pp. (Confidential).

8/ McQueen, R. G., and S. P. Marsh. Equation of State for Nineteen Metallic Elements from Shock-Wave Measurements to Two Megabars. J. Appl. Phys., v. 31, July 1960, pp. 1253-1269.

Table 2. - Shock sensitivity data on TMETM at 25°C

Container id x wall x length, inches	Card Gap, inches	Results
Steel, 1.05 x 0.133 x 16	zero	6940-7140 ^{1/}
" 1.05 x 0.133 x 16	zero	7200 --
" 1.05 x 0.133 x 16	0.05	6990 --
" 1.05 x 0.133 x 16	0.10	960 --
" 1.05 x 0.133 x 16	0.15	1060-1730
" 1.05 x 0.133 x 16	0.25	1770-1750
" 1.05 x 0.133 x 16	0.50	1740-1730
" 1.05 x 0.133 x 16	2.00	1410-1500
" 1.05 x 0.133 x 16	12.00	1360-1550

^{1/} Detonation rate in meters per second.

it is possible the negative results to date have resulted from using charge diameters that were too small for a low velocity reaction. To resolve this question 1-1/2 to 4-inch charges were fired. In both 1-1/2-inch and 2-inch schedule 40 steel pipe, 16 inches long, either high velocity detonation or incomplete reaction was obtained depending on the gap employed. In 3-inch schedule 40 steel pipes, 12 to 16 inches long, nitromethane detonated at the high rate when initiated with a 475 gram pentolite booster (3-inch diameter by 2-1/2 inches long) with a 0.4-inch gap. In a similar container, an apparent low rate of approximately 1,500 m/sec was observed with a 0.6-inch gap. With an 0.8-inch gap an incomplete reaction resulted, only 9 inches of the container being destroyed. Water, in a similar container, driven by a 475-gram pentolite donor at zero gap, damaged the steel container for a distance of approximately 9 to 10 inches. In 4-inch schedule 40 steel pipe 72 inches long, with gaps ranging from 0.5 inch to 0.9 inch (1,040 gram pentolite booster), nitromethane detonated at the high rate (approximately 6,300 m/sec). With a 1.0-inch gap, an incomplete reaction resulted in two trials which destroyed only the 12 inches of container next to the booster. The data obtained in these preliminary shots are given in detail in Table 3. Thus, in diameters up to 4 inches nitromethane does not appear to undergo low velocity reaction at ambient temperature.

Table 3. - Shock sensitivity data for nitromethane (99% grade) at 25°C

Steel container, Schedule 40 size	Inside diameter and length, inches	Booster, grams	Card gap, inches	Results
1-1/2 inches	1.61 x 16	50 tetryl	0.150	HVD
1-1/2 inches	1.61 x 16	50 tetryl	0.300	INC 5 inches
1-1/2 inches	1.61 x 16	50 tetryl	0.300	INC 5 inches
1-1/2 inches	1.61 x 16	50 tetryl	0.350	INC 5 inches
2 inches	2.07 x 16	215 pentolite	0.200	HVD
2 inches	2.07 x 16	215 pentolite	0.250	HVD
2 inches	2.07 x 16	215 pentolite	0.300	INC 9 inches
2 inches	2.07 x 16	215 pentolite	0.400	INC 8 inches
3 inches	3.07 x 12	475 pentolite	0.400	HVD _{1/}
3 inches	3.07 x 12	475 pentolite	0.600	UD ₋
3 inches	3.07 x 16	475 pentolite	0.600	UD (1660-1440)
3 inches	3.07 x 16	475 pentolite	0.800	INC 9 inches
4 inches	4.03 x 72	1040 pentolite	0.500	6270-6300
			0.700	6280-6270
			0.830	6270 --
			0.900	6320-6300
			1.000	INC 12 inches
			1.000	INC 12 inches

1/ In this short length the result would indicate an unstable detonation.

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