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TECHNICAL MEMORANDUM 1337

CHARACTERISTICS OF CONDUCTIVE EXPLOSIVE MIXTURE CONTAINING MODERATE AMOUNTS OF ALUMINUM

HENRY J. JACKSON

JULY 1964

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U.S. ARMY MUNITIONS COMMAND

PICATINNY ARSENAL
DOVER, NEW JERSEY

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by

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Feltman Research Laboratories
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Approved:

H. J. MATSUGUMA
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TABLE OF CONTENTS

Page

Figures

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OBJECT

To study the parameters that influence the electrical initiation of conductive mixtures containing secondary explosives.

SUMMARY

An examination of some of the parameters which affect the electrical initiation of a conductive explosive mixture has been made. The conductive mixture was RDX/aluminum 80/20. Some parameters were arbitrarily held constant, since the effort was concentrated on parameters which were considered most critical in the initiation. The effects of energy, voltage, and power were studied. The tests show that, for a given condition, power is an important factor. Also that, for a given energy, there is a critical voltage and capacitance for effective energy transfer. Secondly, the results show that the diameter and column length of the conducting layer are related to the probability of fire for a given applied energy and loading pressure, and that a mathematical expression of this relationship, when plotted, gives a normal sensitivity curve. Finally, 0.50 joule was found sufficient to initiate a conductive RDX/aluminum 80/20 mixture.

INTRODUCTION

Conductive explosive mixtures are used widely in this country in primers, detonators, and initiating devices (Ref 1). These mixtures contain primary explosives of low energy. Recently, secondary explosives have been used to arrive at a safe in-line detonator (Refs 2 and 3). Many such compositions are used in end items for various purposes. Hence, an understanding of the behavior of these compositions in response to different stimuli is essential. Although we had previously developed several conductive explosive mixtures for service use, we had not studied the parameters involved in the electrical initiation of such mixtures.

It has been suggested, and confirmed by actual tests, that the mass, length of column, diameter of column, loading pressure, particle size, amount of conductor, type of conductor, density, and resistance are of importance in the initiation of conductive explosive mixtures (Refs 4, 5, and 6). Also, there is some indication that the electrical energy is not the only factor involved in the initiation of these compositions (Ref 7). An earlier study of a conductive (RDX/aluminum) mixture has indicated that column length, mass, and density are interrelated (Ref 8). Thus it was postulated that there is some critical length or mass from which it is probable that a self-sustaining reaction can be obtained by using a given input electrical energy (Ref 5). Investigators in this country and in England have further postulated that, for a given electrical energy discharged from a capacitor, there is a critical voltage above or below which the probability of initiation becomes less if the energy is the same (Refs 5 and 9).

These two hypotheses have been investigated and the experimental results indicate that they have some validity.

DISCUSSION

In previous studies of the initiation of explosives and explosive compositions, energy has always been the main concern. In studying the electrical initiation of secondary explosives, investigators have found that the addition of conductive material, such as graphite, metals, and metal oxides, reduces the energy required for initiation.

The conductive mixtures used in this study were RDX and aluminum in a ratio of approximately 4 parts RDX to 1 part aluminum. The two mixtures used, which were designated ER41-14 and ER41-29, contained 20.56% and 17.45% aluminum, respectively.

The results of the series of experiments using conductive mixture ER41-14 are given in Table 1 (p 8). The data in Table 1 shows that, as the input electrical energy from a capacitance discharge circuit is increased, the probability of firing is also increased. The energy varied from 0.12 to 8.00 joules. Some of the energy levels were obtained from several different combinations of voltage and capacitance. The percentage firing at the 1.25 joules/1600 volts level was of interest because a 100% firing probability was obtained.

Table 2 (p 9) gives similar results for 5000 volts and 1600 volts. The data in Table 2 shows that, when the energy is increased, the probability of firing also increases. However, 1600 volts (1.28 joules) gave the same frequency of firings as 5000 volts (3-6 joules).

The data in Table 3 (p 9) shows the relationship of probability of firing to voltage with 0.32 joule input energy. It should be noted that 3500 volts gave the highest probability of firing and further that 100% firing was not attainable with 0.32 joule at 5000 volts.

In Table 1, where the energy level of 1.28 joules is considered over its voltage range, 1400 to 1850 volts represents the critical voltage range. This data lends some credence to the hypothesis that, for a given electrical energy, there is a critical combination of voltage and capacitance which gives maximum probability of firing. Any other combination will give reduced firing probability. Table 1 shows that, for 100% firing at 1.28 joules, the critical voltage is 1600 ± 250 volts and the critical capacitance 1.00 ± 0.25 microfarad.

The percentage of the calculated stored energy that is delivered to the explosive composition (column 1, Table 1) is not known. However, in the case of 1.28 joules, the reaction of the conductive explosive composition varies. It seems reasonable to assume that the quantity of delivered energy is constant under the test conditions. The only other logical explanation for the difference is that power input is a significant factor. Thus, for a given calculated energy, there is a critical voltage and RC time for effective initiation.

In the second series of experiments, the ER41-29 RDX/Al conductive mixture was used. In this series, the mass and the diameter, both of which have effects on the column length, were varied. The input energy was held constant at 0.5 joule and the loading pressure at 10,000 psi. Because the loading pressure was constant, it was assumed that the density would be constant in this series. The density can, however, be calculated for each point since all the required measurements are available.

Some of the results reported in the literature on conductive explosive mixtures (Refs 5 and 6) indicate that both mass and resistance are important in electrical initiation.

In this series of tests, the following diameters were used: 0.10 inch, 0.196 inch, and 0.25 inch. The mass was varied from 25 milligrams to 200 milligrams. Table 4 (p 10) gives the probability of firing with 0.5 joule in 0.10-inch-diameter sleeves for the different masses or sample sizes. It should be noted that the column lengths, as measured, are also given. Similar results for 0.196-inch- and 0.250-inch-diameter sleeves are given in Tables 5 and 6 (pp 11 and 12), respectively. When column 5 is plotted against column 7 for Tables 4, 5, and 6, three distinct curves are obtained, as Figure 2 (p 14) shows. One can immediately conclude that the energy-to-mass ratio is not the predominant controlling factor. If it were, Figure 2 would show only a single curve. It appears that some other properties apparently related to the length and diameter of the column are of considerable importance. These curves are similar to other curves from sensitivity data plots; they are S-shaped. The data also shows that there are critical masses for each of the diameters for 0% and for 100% firing. Also, there is a corresponding critical column length, for 0% and 100% firing, for a given energy and loading pressure.

If a relationship among the mass, column length, and diameter exists, this relationship should result in a single curve for all the data. At the outset of our attempt to correlate the data, let us assume that the probability of firing, % F(x), is some function of the mass (m) and the resistance (R) of the conductive explosive mixture for a given input energy and loading pressure,

$$\% \, F(x) = F(m,R) \qquad (1)$$

Figure 2 shows that, as one would intuitively expect, % F(x) varies as 1/m. Suppose, also, that % F(x) would vary as 1/R. Let X = % F(x) and the relative importance of mass (m) and resistance (R) be designated by the exponents a and b.

$$X = k \left(\frac{1}{m}\right)^{a} \left(\frac{1}{R}\right)^{b} \qquad (2)$$

Since

$$m = \rho v = \frac{\rho \pi D^2 L}{4}, \text{ and } R = \frac{\sigma L}{A} = \frac{4L}{\pi D^2},^*$$

by substituting one gets

$$X = k \left(\frac{4}{\rho \pi D^2 L}\right)^a \left(\frac{\pi D^2}{4L}\right)^b \qquad (3)$$

Combining the constant factors into one constant

$$X = k' \left(\frac{1}{D^2 L}\right)^a \left(\frac{D^2}{L}\right)^b \qquad (4)$$

Since the exponents a and b represent the relative importance to be assigned each term, suppose one assumes a = 3 and b = 1

then

$$X = k'' \left(\frac{1}{D^6 L^3}\right) \left(\frac{D^2}{L}\right) = k'' \frac{1}{D^4 L^4} \qquad (5)$$

For simplicity, X vs $\frac{1}{DL}$ was plotted (i.e., the same weight for both D and L) for all the data in Tables 4, 5, and 6, (pp 10, 11, and 12), and columns 3 and 7 of Figure 3 (p 15). Now, assume that a = 2 and b = 1

$$X = k'' \left(\frac{1}{D^4 L^2}\right) \left(\frac{D^2}{L}\right) = k'' \frac{1}{D^2 L^3} \qquad (6)$$

Plot X vs $\frac{1}{DL^{3/2}}$ for all the data in columns 4 and 7 of Figure 4 (p 16).

These graphs show a grouping which gives the typical S-shape sensitivity curves. Figure 3 does not show as good a correlation of diameter and column length with probability of fire as does Figure 4. Thus, Equation 6 better describes the relative importance of the parameters.

---

*ρ = density, v = volume, D = diameter, L = length, A = area, σ = resistivity, π = constant.

EXPERIMENTAL PROCEDURE

The materials used were:

RDX (specification grade), HOL-SR4-57

Aluminum powder, atomized, Type C, Class D (14.5 microns)

Weighed amounts of the RDX and aluminum were blended for 4 hours in a V-type blender. The composition was then analyzed by washing out the RDX with acetone and weighing the residue to a constant weight.

Weighed amounts of conductive mixtures ER41-14 and ER41-29 were loaded at 10,000 psi into plastic sleeves having a 0.125-inch wall thickness and diameters of 0.100 inch, 0.196 inch, and 0.250 inch. The press used was a Denison Midget one-ton type.

The column lengths were measured by using a pair of brass electrodes and a micrometer.

The firing tests were conducted according to Picatinny Arsenal SOP-ER-20 (April 1959) for Firing Explosive Devices (high and low voltages). The main features of the test firing assembly are shown in Figure 1 (p 13). The electrodes are held firmly against the column of conductive RDX/Al by the spring in the head of the fixture. The firing energy is applied through the electrodes into the conductive RDX/Al. A detonation was recorded when the plastic sleeve was ruptured. Ten tests were conducted for each condition studied.

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TABLE 1

Relationship of energy input to percent fired for conductive RDX/aluminum (80/20) mixture*

Energy, joules	Capacity, μf	Voltage	Percent Fired
0.12	0.01	5000	10
0.12	0.10	1600	0
0.32	0.025	5000	40
0.306	0.05	3500	60
0.312	0.10	2500	30
0.32	0.25	1600	30
0.32	1.00	800	20
0.61	0.10	3500	60
0.64	0.50	1600	60
1.23	0.10	5000	30
1.28	0.50	2240	80
1.28	0.75	1840	100
1.28	1.00	1600	100
1.28	1.25	1400	100
1.28	2.00	1150	60
1.28	3.00	820	70
1.53	0.25	3500	70
2.00	4.00	1000	40
3.12	0.25	5000	70
5.12	4.00	1600	100
6.25	0.50	5000	100
8.00	4.00	2000	100

*ER41-14, 100 mg/10,000 psi/0.25 inch diameter.

TABLE 2

Relationship of energy and voltage to percent fired for conductive RDX/aluminum (80/20) mixture*

Energy, joules	Capacity, μf	Voltage	Percent Fired
0.12	0.01	5000	10
0.32	0.025	5000	40
1.23	0.10	5000	30
3.12	0.25	5000	70
6.25	0.50	5000	100
0.12	0.10	1600	0
0.32	0.25	1600	30
0.64	0.50	1600	60
1.28	1.00	1600	100
5.12	4.00	1600	100

*ER41-14, 100 mg/10,000 psi/0.25 inch diameter.

TABLE 3

Relationship of voltage to percent fired for RDX/aluminum (80/20) mixture at 0.32 joule

Energy, joules	Capacity, μf	Voltage	Percent Fired
0.32	1.00	800	20
0.32	0.25	1600	30
0.312	0.10	2500	30
0.306	0.05	3500	60
0.32	0.025	5000	40

TABLE 4

Relationship of percent fired to weight and column length for conductive RDX/aluminum (80/20) mixture in 0.10-inch-diameter plastic sleeve at 0.50 joule*

Weight, mg	Column Length, mm	1/DL	$1/DL^{1/2}$	1000/m	Density, g/cc	Percent Fired
25	3.164	3.164	1.778	40.00	1.559	100
27	3.333	3.00	1.65	37.03	1.599	100
30	3.538	2.82	1.50	33.33	1.673	100
32	3.398	2.94	1.60	31.25	1.858	100
33	3.6525	2.737	1.576	30.30	1.783	100
34	3.8666	2.586	1.312	29.41	1.736	100
35	4.540	2.20	1.03	28.57	1.522	60
36	4.190	2.386	1.16	27.77	1.696	70
38	4.520	2.21	1.04	26.31	1.659	60
40	4.870	2.07	0.942	25.00	1.638	50
42	5.930	1.69	0.693	23.80	1.398	40
44	5.13	1.949	0.869	22.72	1.693	20
45	4.919	2.03	0.919	22.22	1.805	60
48	5.707	1.752	0.735	20.83	1.659	20
50	5.880	1.700	0.704	20.00	1.678	0
75	9.330	1.07	0.351	13.33	1.586	0
100	12.79	0.78	0.223	10.00	1.543	0

*ER41-29 loaded at 10,000 psi.

TABLE 5

Relationship of percent fired to weight and column length for conductive RDX/aluminum (80/20) mixture in 0.196-inch-diameter plastic sleeve at 0.50 joule*

Weight, mg	Column Length, mm	1/DL	$1/DL^{3/2}$	1000/m	Density, g/cc	Percent Fired
60	2.057	2.481	1.732	16.66	1.502	100
65	2.146	2.377	1.628	15.38	1.559	100
68	2.240	2.278	1.5209	14.70	1.563	100
70	2.316	2.203	1.430	14.28	1.556	80
75	2.480	2.057	1.4322	13.33	1.557	70
76	2.457	2.076	1.331	13.16	1.593	100
78	2.571	1.984	1.240	12.82	1.562	90
80	2.570	1.985	1.240	12.50	1.602	20
85	2.731	1.868	1.132	11.76	1.603	50
90	2.837	1.798	1.070	11.11	1.633	20
100	3.28	1.555	0.8591	10.00	1.570	0
125	3.91	1.305	0.6627	8.064	1.646	0

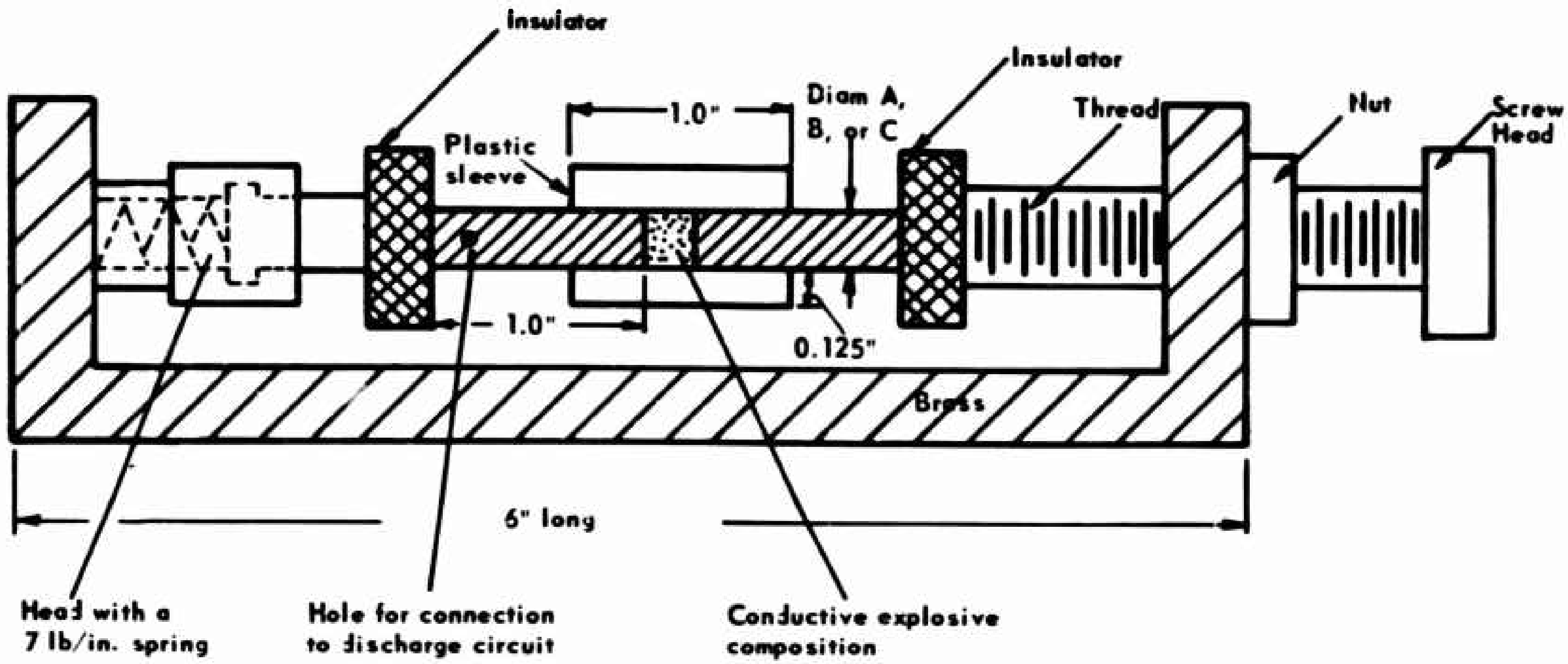
*ER41-29 loaded at 10,000 psi.

TABLE 6

Relationship of percent fired to weight and column length for conductive RDX/aluminum (80/20) mixture in 0.250-inch-diameter plastic sleeve at 0.50 joules*

Weight, mg	Column Length, mm	1/DL	$1/DL^{3/2}$	1000/m	Density, g/cc	Percent Fired
80	1.6258	2.460	1.9379	12.50	1.554	100
90	1.800	2.222	1.6583	11.11	1. [illegible]79	100
100	2.040	1.960	1.508	10.00	1.548	90
100	2.07	1.934	1.344	10.00	1.526	90
100	2.05	1.949	1.3634	10.00	1.540	90
110	2.239	1.786	1.199	9.09	1.551	80
120	2.431	1.6545	1.0616	8.333	1.599	70
125	2.47	1.6207	1.032	8.00	1.598	40
130	2.462	1.6246	1.042	7.692	1.669	40
140	2.70	1.4814	0.9033	7.142	1.637	10
150	2.96	1.3513	0.7862	6.666	1.595	0
150	3.00	1.333	0.7710	6.666	1.579	0
200	3.89	1.005	0.505	5.00	1.623	0
200	3.87	1.034	0.5277	5.00	1.632	0

*ER41-29 loaded at 10,000 psi.



Diameters of Plastic Sleeves and Brass Electrodes (in.)

A = 0.100 in.
B = 0.196 in.
C = 0.250 in.

Fig 1 Test firing assembly

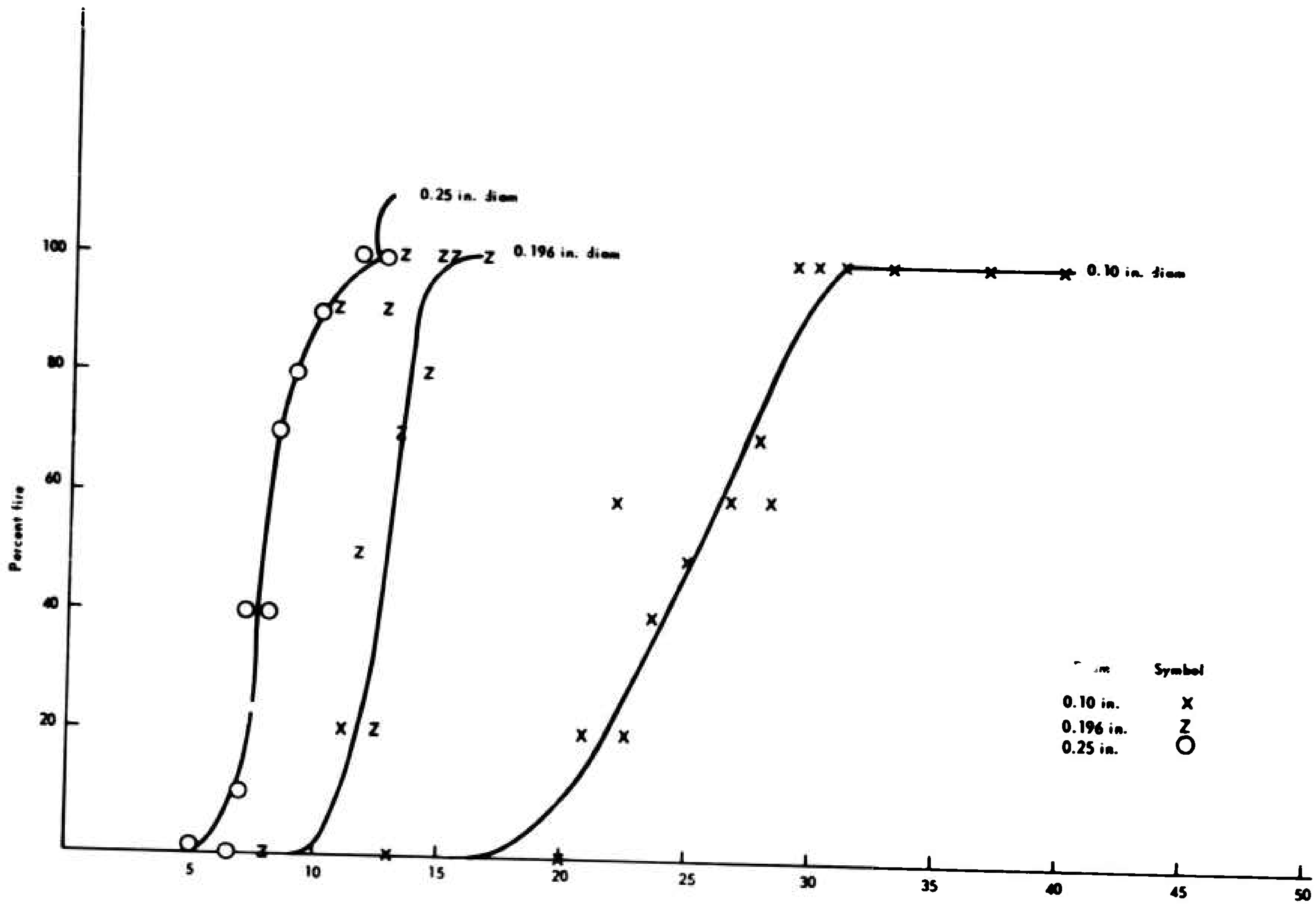


Fig 2 Percent fire vs 1000/m

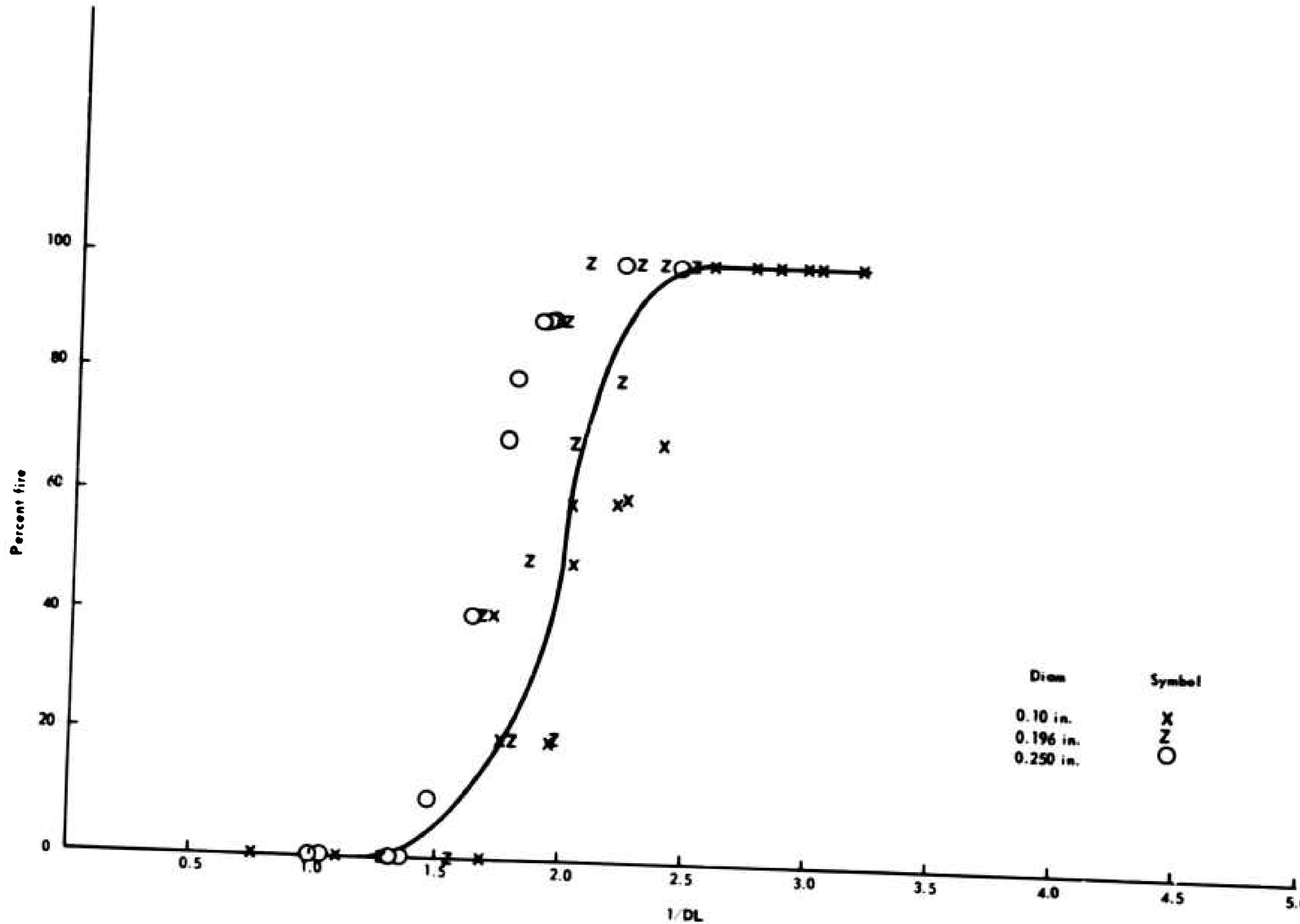


Fig 3 Percent fire vs 1/DL

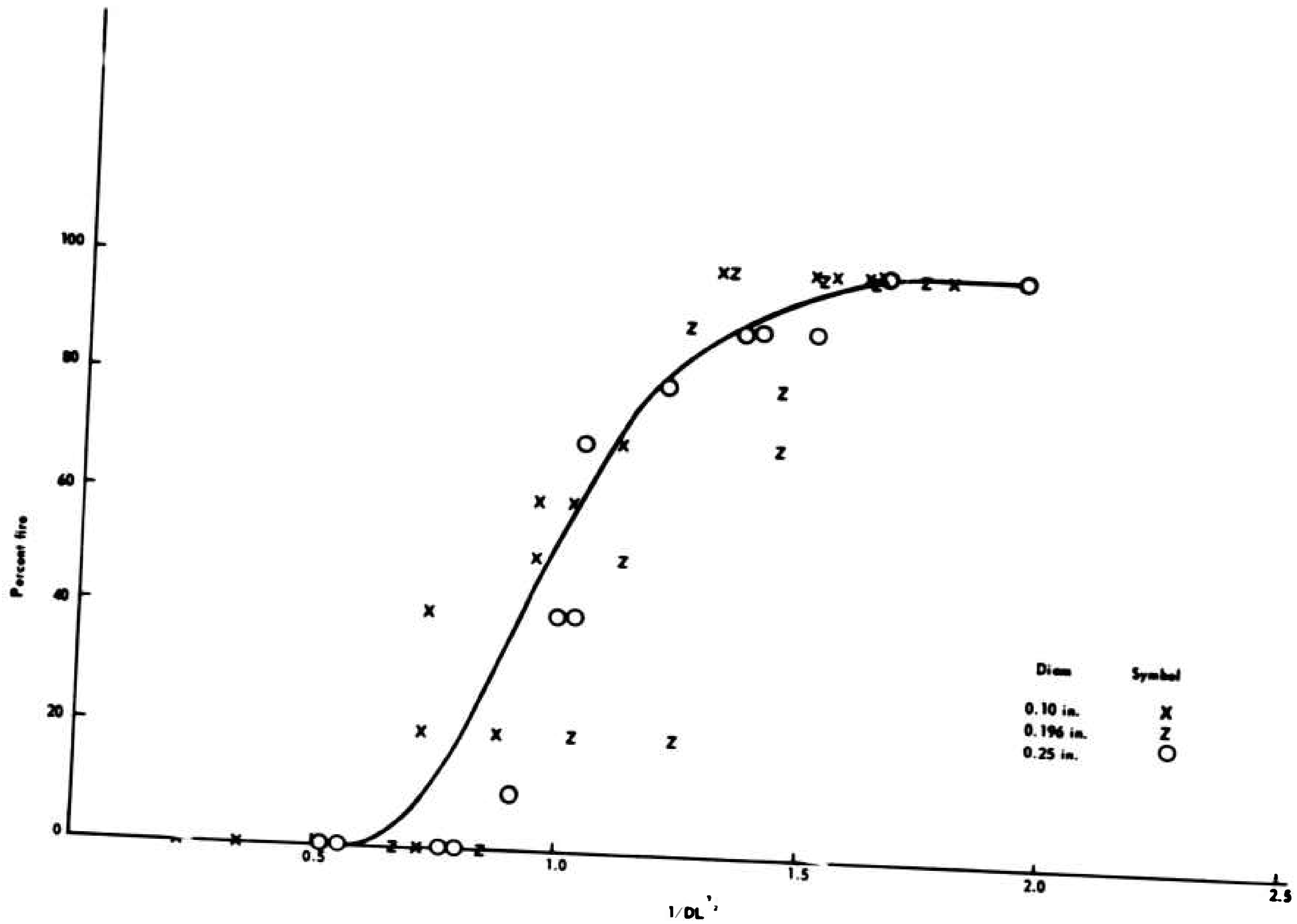


Fig 4 Percent fire vs $1/DL^{3/2}$

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(over)

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2. Conductive mixes

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II. RDX aluminum

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Physics Department	
Brookhaven National Laboratory	
Upton, Long Island	
New York	51
Scientific Information Section	
Research Branch – Research & Development Division	
Office, Assistant Chief of Staff	
Department of the Army	
Washington 25, D. C.	52
U. S. Atomic Energy Commission	
ATTN: Division of Technical Information	53
Oak Ridge Tennessee	