CALIBRATION OF THE NOL LARGE SCALE GAP TEST WITH A PENTOLITE DONOR II

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UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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ABSTRACT: Henceforth the standard donor in the NOL large scale gap test will be 50/50 pentolite pellets pressed to a density of 1.56 g/cc instead of the tetryl pellets previously used. The pentolite donors will be supplied by NAD, Crane, Indiana. This report gives the current calibration curve for the large scale gap test with the pentolite donors.

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The work described in this report was carried out under Task ORD 331-002/092-1/UF19-332-302 (Propellant and Ingredient Sensitivity). It presents the calibration data (pressure vs gap thickness) for the NOL large scale gap test with a standard pentolite donor. This information is of importance to the study of shock sensitivity of explosives and propellants.

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Captain, USN
Commander

ALBERT LIGHTBODY
By direction

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INTRODUCTION

Because NOS, Macon, Georgia, has been closed, there is no longer a satisfactory source of tetryl pellets for use as a standard donor in the large scale gap test (LSGT). Henceforth, the standard donor will be 50/50 pentolite pressed to a density of 1.56 g/cc; pellets will be supplied by NAD, Crane, Indiana, (Federal Stock No. 1375-991-8891). It is the purpose of this report to present the calibration curve, pressure vs thickness of polymethylmethacrylate (PMMA) attenuator, most in accord with our present knowledge of the pentolite/PMMA system in the LSGT.

EXPERIMENTAL

The LSGT is fully described in Reference (1). It consists of a donor, a PMMA gap, a moderately confined test charge (acceptor), and a mild steel witness plate. The gap length is varied until the 50% value is found; it is that length of attenuator at which a hole is punched in the witness plate in 50% of the trials. The 50% gap is, in fact, that length of attenuator which permits transmission of the critical pressure required to initiate the acceptor explosive to detonation. Because the amplitude of the shock transmitted from the donor to the PMMA is complexly related to the gap thickness, the test must be calibrated. We are concerned here with the calibration curve obtained with a 5.08 cm diam x 5.08 cm long donor of 50/50 pentolite at 1.56 g/cc used to shock load a 5.08 cm diam cylinder of PMMA.

The first lot of pentolite pellets was made at NOL[2], and a calibration of the pentolite/PMMA system was carried out with them[2]. Our usual procedure is to follow the shock front in the PMMA with a streak camera. The records give position (X) vs time (t) data which must be differentiated to obtain the desired shock velocity (U) vs X data. Once the U vs X data are obtained, they can be converted to pressure (P) vs X data through the PMMA shock Hugoniot[3]. Among the problems involved are (a) obtaining accurate X vs t data, and (b) differentiating them properly. Of these, the latter is by far the more difficult problem. In the first work, an analytical procedure and a graphical procedure gave values of U which differed by as much as 0.3 mm/μsec at $X \leq 20$ mm[2].

Subsequent calibration work[4] led to a revision of the U vs X curve (obtained from the same X vs t data). It also showed the advantage of working with U vs X rather than P vs X, inasmuch as conversion of U to P magnified differences by a factor of 3 or 4. Finally, it demonstrated, with Record 144A, that three graphical methods of differentiating the same X vs t data (considered equivalent) gave differences in the U vs t data shown in Table 1; the maximum spread is 0.25 mm/μsec. A later numerical treatment of the same X vs t data by use of a spline function gave a U vs X curve below those obtained by the three graphical methods and increased the maximum difference between methods to about 0.4 mm/μsec for

$X < 50$ mm. These different U vs X from the same X vs t data are described to emphasize the difficulty of choosing a method of differentiation. It is not a problem that we can expect to solve, only to minimize. It is one that will be under continuing study because there is no physical basis for choosing a "correct" U vs X curve.

The second lot of pentolite pellets was obtained from Crane. They, too, have been used in a calibration study[5], and from the four shots made, X vs t data were read at much closer intervals than in the first study. The X vs t data of the first study fit into the X vs t data of the second for $X \leq 50$ mm, i.e., there seems no experimentally significant difference between the two sets of position - time data. The more recent set of data has been differentiated numerically[5]. It is not surprising that the U vs X curve differs from the best graphical treatment[4] by 0.4 to 0.05 mm/μsec over the range of 5 to 50 mm in X. Unfortunately, as we indicated above, there is as yet no method of selecting the more accurate curve. Hence, at the present time, and pending the results of continuing studies, the two U vs X curves will be averaged $X \leq 50$ mm; the more recent values (numerical differentiation) will be used at $X > 50$ mm. This choice is also based in part on the results of 2-D flow computations described below.

2-D COMPUTATIONS

We have long needed a hydrodynamic 2-dimensional computation of the complex flow in the shocked PMMA to assist in interpreting the gap test results. Two attempts have now been made, each with variants of the HEMP code. The first[6] used 14 zones per inch of PMMA, which produced a P vs X curve showing a number of oscillations; these might be caused by either the coarse zoning or complex interactions of shock, compression and rarefaction waves or both. The second[7] used 20 zones per inch and showed a smooth U vs X curve. (The zoning does not seem to be sufficiently fine to account for the result; some smoothing of the data must have been a part of deriving the U vs X curve.) Neither computation shows a sharp dip in U for $X \geq 70$ mm shown in the best graphically derived curve for pentolite, Lot 1[4]. It was on this basis as well as a significant difference in the X vs t data ($X > 50$ mm) of Lot 1 from the X vs t data of Lot 2[5] that the former have been discarded.

It is evident that neither of the hydrodynamic calculations seems completely satisfactory, and that they are not completely consistent with each other. Until a better description of the flow can be obtained, we shall assume that the P vs X curve for pentolite (1.56 g/cc) should be similar to that of tetryl (1.51 g/cc). In fact, this pressed pentolite was chosen because of its similarity to tetryl. In other words, the pentolite P vs X curve should be as free of oscillations as the current curve for tetryl.

CHOICE OF CALIBRATION CURVE

As in the case of the calibration with tetryl, values of pressure at small attenuation ($X < 10$ mm PMMA) are considered nominal. Data for $X \geq 10$ mm are extrapolated back to a value at $X = 0$ corresponding to the pressure entering the PMMA if the incident pressure is the C-J pressure for pentolite. /This boundary pressure should actually be that induced by the von Neumann (not the C-J) pressure of the donor. However, we are not yet able to make good pressure measurements at small values of X in the gap test. The electromagnetic method, which measures particle velocity (u) directly,[8] has been used to verify the tetryl calibration curve at X = 10, 20, and 25 mm.[8] The P values obtained from the measured u were well within the expected accuracy (±10%) of the tetryl calibration; they differed from the current calibration values by -4%, 0% and 1% for X's of 10, 20, and 25 mm, respectively.7

Computations of detonation parameters at several densities of both TNT and PETN by a Ruby-like code are given in Reference (9). If these are combined according to the method for mixtures given in Reference (10) and interpolated to the proper density, C-J values for 50/50 pentolite at 1.56 g/cc are:

$$D = 7.2 \text{ mm/}\mu\text{sec},$$

$$u = 1.92 \text{ mm/}\mu\text{sec},$$

and $$P = 216 \text{ kbar}$$

The isentrope from this point was taken approximately parallel to that for cast pentolite (Walker-Sternberg curves[11]) and intersected the PMMA Hugoniot at

$$U = 6.24 \text{ mm/}\mu\text{sec},$$

$$u = 2.28 \text{ mm/}\mu\text{sec},$$

and $$P = 168 \text{ kbar}$$

Hence our nominal values at X = 0 are U_o = 6.24 mm/μsec and P_o = 168 kbar, as shown in Tables 2 and 3.

Table 2 contains the two sets of U vs X data for the pentolite donor and their average for the range X ≤ 50 mm. It also gives the Reference (5) data selected for X > 50 mm and the corresponding calibration data for the tetryl donor. These data are plotted in Figure 1 which shows the U vs X curve (pentolite donor) slightly above that for the tetryl donor as would be expected from the respective computed C-J pressures. The two curves appear to become coincident at X = 35 mm (possibly as early as X = 25 mm). For X ≥ 35 mm, the average difference in the velocities for the two curves is 0.02 mm/μsec; the maximum is 0.05 mm/μsec or less than 2% U. The maximum value is less than the average difference (0.07 mm/μsec) found in differentiating the same X vs t data by different methods (Table 1). Hence it cannot be considered significant, and the two calibration curves will be treated as coincident for X ≥ 35 mm.

For X < 35 mm, only one additional smoothing adjustment was made. The value of U at X = 5 mm was increased by about 1% to make the present curve more similar in shape to the calibration curve for the tetryl donor. This is in the region of nominal values (i.e., X < 10 mm) where we now know, from electromagnetic measurements of particle velocity in PMMA[8], that both calibration curves must eventually be revised.

Table 3 contains the data selected for the present calibration curve of the LSGT with a 50/50 pressed pentolite donor, ρ_o = 1.56 g/cc. The P vs X data* are plotted in Figure 2 where the calibration for the tetryl donor is also shown for comparison. In both cases, for X = 10 to 100 mm, the accuracy is believed to be ±2.5% in U and ±10% in P or better. Largest errors would be expected at the two extremes of the range.

The revised calibration for the pentolite donor can now be used for comparison of P_g measured in the gap test with the two different donors. Table 4 contains the results for such a comparison obtained about five years ago with pentolite pellets from Lot 1. With the present calibration, the value of U at the 50% point is the same for the two donors to ±0.5% and the value of P_g is the same to ±2%. The previous calibration gave differences larger by a factor of five.

The only material that has so far been tested with both pentolite pellets, Lot 2, and tetryl is DATB. The results were:

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Donor	DATB Acceptor		50% Value		
	ρ_o(g/cc)	% TMD	Gap(cards)	Gap(mm)	P_g(kbar)
P	1.667	90.75	139	35.3	35.1
T	1.674	91.13	138	35.0	34.7**

** Becomes 34.9 when corrected to ρ_o = 1.667 g/cc.

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For x ~ 35 mm both the 50% gap value and P_g were the same to within less than 1% and this fact lends support to the coincidence of the two calibration curves of Figure 2 at X ≥ 35 mm. So too does the result for Comp B-3 of Table 4.

The gap test results for both lots of pentolite pellets indicate that the 50% pressure P_g is the same as that measured with the tetryl donor. Inasmuch as the pentolite was chosen to have the same detonation velocity and approximately the same detonation pressure as the standard tetryl donor, it is reasonable to expect that the pressure pulse it produces in the PMMA will be of approximately the same shape and duration as that produced by the tetryl. If so, the measured P_g should be the same in each case, as it appears to be.

* As mentioned earlier, the PMMA Hugoniot[3] was used to convert U vs X data to P vs X.

SUMMARY

The calibration curve for the LSGT with 50/50 pentolite as the donor has been revised in the light of additional data for the pentolite/PMMA system and a better knowledge of the PMMA Hugoniot. Work will be continued and the present curve will be revised when new data indicates that a revision should be made.

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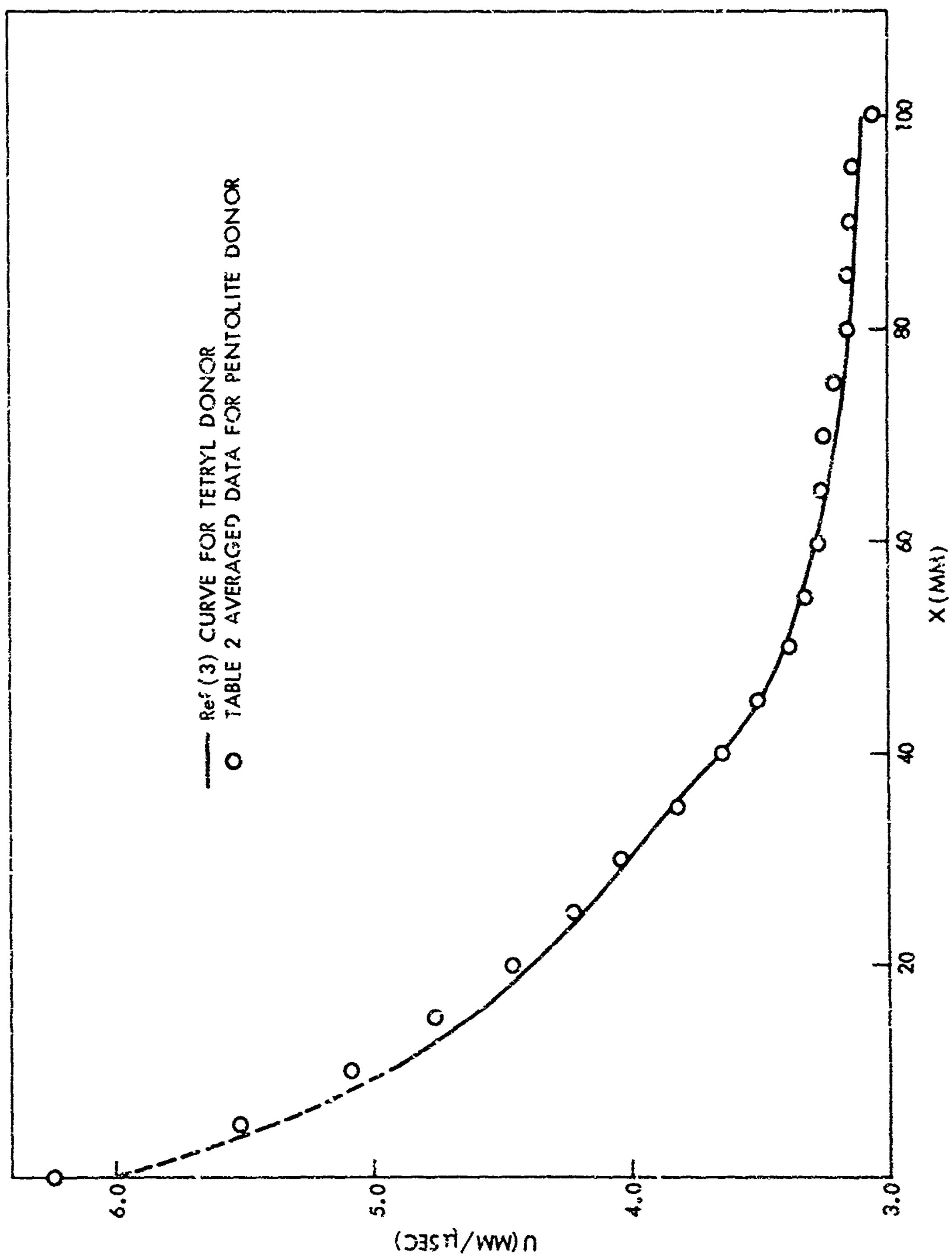

FIG. 1 COMPARISON OF U VS X CURVES FOR TETRYL AND PENTOLITE DONORS

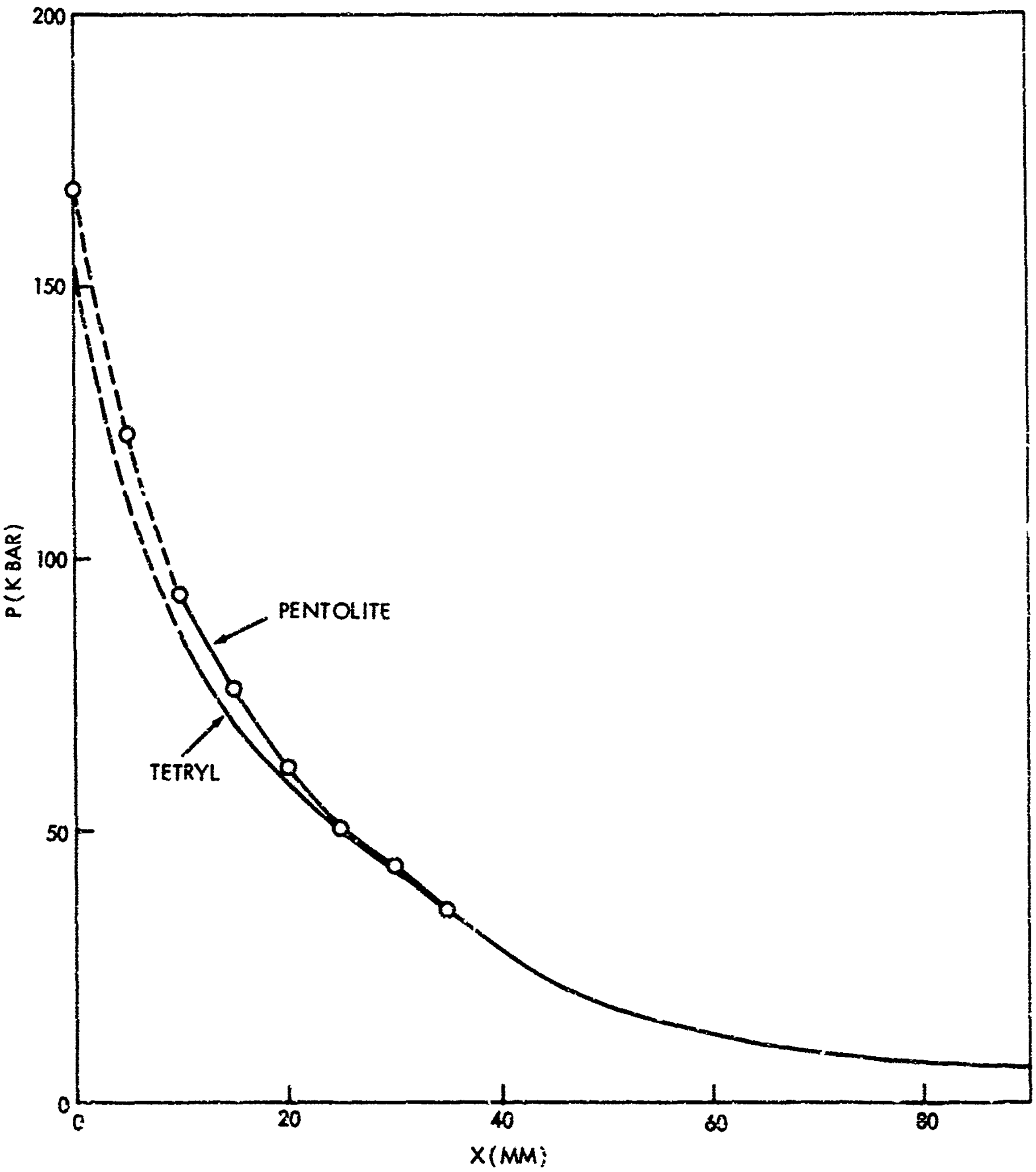

FIG. 2 COMPARISON OF CALIBRATION CURVES FOR TETRYL AND PENTOLITE DONORS

Table 1*

SPREAD IN VELOCITY DATA FOR THREE METHODS OF DIFFERENTIATION

X (mm)	Mean Value U mm/μsec	Spread in U values from three methods, mm/μsec
0	5.62	0.25
5	5.28	0.24
10	4.97	0.22
15	4.66	0.14
20	4.40	0.09
25	4.20	0.02
30	4.05	0.04
35	3.86	0.07
40	3.66	0.09
45	3.47	0.06
50	3.36	0.05
55	3.29	0.04
60	3.23	0.05
65	3.19	0.08
70	3.15	0.09
75	3.14	0.08
80	3.12	0.06

* Data for tetryl/PMMA system. Taken from Table B1 of Reference (4).

Table 2

COMPARISON OF AVERAGE SHOCK VELOCITIES IN PMMA FOR PENTOLITE AND TETRYL DONORS

X (mm)	X (No. Cards)	Pentolite U (Ref 5) mm/μsec	Pentolite U (Ref 4)* mm/μsec	Pentolite U(Av.) mm/μsec	Tetryl(Ref 3) U mm/μsec
0	0	-	-	6.24	6.00
5	19.7	5.34	5.71	5.52	5.39
10	39.4	4.93	5.25	5.09	4.94
15	59.0	4.68	4.84	4.76	4.63
20	78.7	4.43	4.49	4.46	4.39
25	98.4	4.25	4.20	4.22	4.19
30	118.1	4.11	3.96	4.04	4.01
35	137.8	3.90	3.74	3.82	3.84
40	157.5	3.71	3.58	3.65	3.66
45	177.2	3.58	3.44	3.51	3.50
50	196.9	3.42	3.34	3.38	3.40
54.61	215	3.32	*	3.32	3.34
59.69	235	3.27		3.27	3.28
64.77	255	3.26		3.26	
69.85	275	3.25		3.25	3.20
74.93	295	3.21		3.21	
80.01	315	3.16		3.16	3.15
85.09	335	3.16		3.16	
90.17	355	3.15		3.15	3.12
95.25	375	3.14		3.14	
100.33	395	3.06		3.06	3.10

* Table A4 data at X > 50 mm discarded. See text.

Table 3

CALIBRATION DATA CHOSEN FOR LSGT WITH PENTOLITE DONOR*

X(mm)	P_g(kbar)	U(mm/μsec)	u(mm/μsec)
0	(168)	(6.24)	(2.28)
5	(123)	(5.58)	(1.87)
10	93.7	5.09	1.56
15	76.3	4.76	1.36
20	61.6	4.46	1.17
25	50.7	4.22	1.02
30	43.5	4.04	0.913
35	35.7	3.84	0.788
40	28.1	3.66	0.651
45	22.0	3.50	0.533
50	18.0	3.40	0.449
55	14.9	3.34	0.378
60	12.4	3.28	0.320
70	9.2	3.20	0.244
80	7.4	3.15	0.199
90	6.2	3.12	0.168
100	5.3	3.10	0.145

* PETN/TNT, 50/50, ρ_o = 1.56 g/cc. Values shown in parentheses are only nominal.

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