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

By
Donna Price

17 MARCH 1970

UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

ATTENTION
This document has been approved for public release and sale, its distribution is unlimited.
CALIBRATION OF THE NOL LARGE SCALE GAP TEST WITH A PENTOLITE DONOR II

Prepared by:
Donna Price

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 MAD, Crane, Indiana. This report gives the current calibration curve for the large scale gap test with the pentolite donors.

Approved by: Carl Boyse, Chief
Advanced Chemistry Division
CHEMISTRY RESEARCH DEPARTMENT
U.S. NAVAL ORDNANCE LABORATORY
White Oak, Silver Spring, Maryland
CALIBRATION OF THE NOL LARGE SCALE GAP
TEST WITH A PENTOLITE DONOR II

The work described in this report was carried out under Task
ORD 331-002/092-1/UF19-332-302 (Propellant and Ingredient Sen-
sitivity). 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.

GEORGE G. BALL
Captain, USN
Commander

ALBERT LIGHTBODY
By direction
MOLTR 70-25

CONTENTS

INTRODUCTION ........................................ 1
EXPERIMENTAL ....................................... 1
2-D COMPUTATIONS ................................. 2
CHOICE OF CALIBRATION CURVE ................. 2
SUMMARY ......................................... 5
REFERENCES ....................................... 6

ILLUSTRATIONS

Figure | Title | Page
---|---|---
1 | Comparison of U vs X Curves for Tetryl and Pentolite Donors | 7
2 | Comparison of Calibration Curves for Tetryl and Pentolite Donors | 8

TABLES

Table | Title | Page
---|---|---
1 | Spread in Velocity Data for Three Methods of Differentiation | 9
2 | Comparison of Average Shock Velocities in PMMA for Pentolite and Tetryl Donors | 10
3 | Calibration Data Chosen for LSOT with Pentolite Donor | 11
4 | LSOT Results with the Two Different Donors | 12
CALIBRATION OF THE NOL LARGE SCALE GAP TEST WITH A PENTOLITE DONOR II

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 WAD, Cran, 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, and a calibration of the pentolite/PMMA system was carried out with them. 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. 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 ≤ 20 mm.

Subsequent calibration work 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, insomuch as conversion of U to P magnified differences by a factor of 3 or 4. Finally, it demonstrated, with Record 1/4A, 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 0.1 mm/μsec for.
X \leq 50 \text{ 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, 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 \text{ 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. It is not surprising that the U vs X curve differs from the best graphical treatment by 0.4 to 0.05 mm/sec 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 \text{ mm}; the more recent values (numerical differentiation) will be used at X > 50 \text{ 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 PMA 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 PMA, 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 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 \text{ mm} shown in the best graphically derived curve for pentolite, Lot 1. It was on this basis as well as a significant difference in the X vs t data (X > 50 \text{ mm}) of Lot 1 from the X vs t data of Lot 2 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 \text{ mm PMA}) are considered nominal. Data for X \geq 10 \text{ mm} are extrapolated back to a value at X = 0 corresponding to the pressure entering the PMA 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, has been used to verify the tetryl calibration curve at X = 10, 20, and 25 mm. 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.

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:

\[
\begin{align*}
D &= 7.2 \text{ mm/\mu sec}, \\
u &= 1.92 \text{ mm/\mu sec}, \\
and \quad P &= 216 \text{ kbar}
\end{align*}
\]

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

\[
\begin{align*}
U &= 6.24 \text{ mm/\mu sec}, \\
u &= 2.28 \text{ mm/\mu sec}, \\
and \quad P &= 168 \text{ kbar}
\end{align*}
\]

Hence our nominal values at X = 0 are \( U_0 = 6.24 \text{ mm/\mu sec} \) and \( P_0 = 168 \text{ kbar} \), 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 \( X \leq 50 \text{ mm} \). It also gives the Reference (5) data selected for \( X > 50 \text{ mm} \) 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 \( X = 35 \text{ mm} \) (possibly as early as \( X = 25 \text{ mm} \)). For \( X \geq 35 \text{ mm} \), the average difference in the velocities for the two curves is 0.02 mm/\mu sec; the maximum is 0.05 mm/\mu sec or less than 2% U. The maximum value is less than the average difference (0.07 mm/\mu sec) 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 \( X \geq 35 \text{ mm} \).

For \( X < 35 \text{ mm} \), only one additional smoothing adjustment was made. The value of U at \( X = 5 \text{ mm} \) 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., \( X < 10 \text{ mm} \)) where we now know, from electromagnetic measurements of particle velocity in PMMA, that both calibration curves must eventually be revised.
Table 3 contains the data selected for the present calibration curve of the LSOT with a 50/50 pressed pentolite donor, \( \rho_0 = 1.56 \text{ g/cc} \). 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 \( X = 10 \text{ to } 100 \text{ mm} \), the accuracy is believed to be \( \pm 2.5\% \) in \( U \) and \( \pm 10\% \) 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 \( P \) 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 \( \pm 0.5\% \) and the value of \( P_g \) is the same to \( \pm 2\% \). 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:

<table>
<thead>
<tr>
<th>Donor</th>
<th>DATB Acceptor</th>
<th>50% Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P )</td>
<td>( 1.667 )</td>
<td>( 90.75 )</td>
</tr>
<tr>
<td>( T )</td>
<td>( 1.674 )</td>
<td>( 91.13 )</td>
</tr>
</tbody>
</table>

** Becomes 34.9 when corrected to \( \rho_0 = 1.667 \text{ g/cc} \).

For \( x \approx 35 \text{ mm} \) 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 \( X \geq 35 \text{ mm} \). 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 PM4A 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 PM4A Hugoniot\(^3\) was used to convert \( U \) vs \( X \) data to \( P \) vs \( X \).
SUMMARY

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


4. T. P. Liddiard and Donna Price, NOLTR 65-43 (20 Aug 1965), particularly the appendices.


FIG. 2 COMPARISON OF CALIBRATION CURVES FOR TETRYL AND PENTOLITE DONORS
Table 1*

SPREAD IN VELOCITY DATA FOR THREE METHODS OF DIFFERENTIATION

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

* Data for tetrol/PMA system. Taken from Table B1 of Reference (4)
### Table 2

**Comparison of Average Shock Velocities in PAMA for Pentolite and Tetryl Donors**

<table>
<thead>
<tr>
<th>X (mm)</th>
<th>X (No. Cards)</th>
<th>Pentalite</th>
<th>Tetrayl (Ref 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>U (Ref 5)</td>
<td>U (Ref 4)*</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>19.7</td>
<td>5.34</td>
<td>5.71</td>
</tr>
<tr>
<td>10</td>
<td>37.4</td>
<td>4.93</td>
<td>5.25</td>
</tr>
<tr>
<td>15</td>
<td>59.0</td>
<td>4.68</td>
<td>4.84</td>
</tr>
<tr>
<td>20</td>
<td>78.7</td>
<td>4.43</td>
<td>4.49</td>
</tr>
<tr>
<td>25</td>
<td>96.4</td>
<td>4.25</td>
<td>4.20</td>
</tr>
<tr>
<td>30</td>
<td>118.1</td>
<td>4.11</td>
<td>3.96</td>
</tr>
<tr>
<td>35</td>
<td>137.8</td>
<td>3.90</td>
<td>3.74</td>
</tr>
<tr>
<td>40</td>
<td>157.5</td>
<td>3.71</td>
<td>3.58</td>
</tr>
<tr>
<td>45</td>
<td>177.2</td>
<td>3.58</td>
<td>3.44</td>
</tr>
<tr>
<td>50</td>
<td>196.9</td>
<td>3.42</td>
<td>3.34</td>
</tr>
<tr>
<td>54.61</td>
<td>215</td>
<td>3.32</td>
<td>*</td>
</tr>
<tr>
<td>59.69</td>
<td>235</td>
<td>3.27</td>
<td>3.27</td>
</tr>
<tr>
<td>64.77</td>
<td>255</td>
<td>3.26</td>
<td>3.26</td>
</tr>
<tr>
<td>69.85</td>
<td>275</td>
<td>3.25</td>
<td>3.25</td>
</tr>
<tr>
<td>74.93</td>
<td>295</td>
<td>3.21</td>
<td>3.21</td>
</tr>
<tr>
<td>80.01</td>
<td>315</td>
<td>3.16</td>
<td>3.16</td>
</tr>
<tr>
<td>85.09</td>
<td>335</td>
<td>3.16</td>
<td>3.16</td>
</tr>
<tr>
<td>90.17</td>
<td>355</td>
<td>3.15</td>
<td>3.15</td>
</tr>
<tr>
<td>95.25</td>
<td>375</td>
<td>3.14</td>
<td>3.14</td>
</tr>
<tr>
<td>100.33</td>
<td>395</td>
<td>3.06</td>
<td>3.06</td>
</tr>
</tbody>
</table>

* Table A4 data at X > 50 mm discarded. See text.
Table 3

CALIBRATION DATA CHOSEN FOR LSGT WITH PENTOLITE DONOR*

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

* PENT/TNT, 50/50, \( \rho_0 = 1.56 \) g/cc. Values shown in parentheses are only nominal.
CALIBRATION OF THE NOL LARGE SCALE GAP TEST WITH A PENTOLITE DONOR II

This document has been approved for public release and sale; its distribution is unlimited.

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 MAD, Crane, Indiana. This report gives the current calibration curve for the large scale gap test with the pentolite donors.
INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (corporate author) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

3a. GROUP: Automatic downgrading is specified in DOD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

7c. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which this report was written.

8a. PROJECT NUMBER: Enter the appropriate departmental identification, such as project number, subproject number, system number, task number, etc.

8b. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (either by the originator or by the sponsor), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

1. "Qualified requesters may obtain copies of this report from DDC."

2. "Distribution and dissemination of this report is controlled. Qualified users shall request through...

3. "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (paying for) the research and development. Include address.

13 ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the security classification of the information in the paragraph, represented as "(1)" or "(2)".

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14 KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.