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U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA
REPORT NO. 950
BOMBS AND ASSOCIATED COMPONENTS
32nd Partial Report

PLATE PENETRATION TESTS OF THE
2000 LB. BOMB, G. P. (LOW DRAG),
TYPE EX-11, MOD. O

Task Assignment: NG-Resc-321-1-52
Copy No. 4
Classification: CONFIDENTIAL
SECURITY INFORMATION
Plate Penetration Tests of the 2000 lb. Bomb, G.P. (Low Drag), Type EX-11, Mod 0

PART A

SYNOPSIS

1. The tests reported herein were conducted to determine (a) the maximum armor (STS) plate thickness which the 2000 lb. G.P. Low Drag Type EX-11 Mod 0 bomb body will penetrate and remain in an effective bursting condition, (b) the degree of acceptable deformation of the bomb body resulting from impact, and (c) the conditions under which the bomb will fail. Further, a metallurgical study was made of the recovered bomb bodies in order to determine any points of weakness or causes of failure and to suggest any corrective measures that should be taken to improve the bomb performance or facilitate production.

2. It is concluded that:

a. The maximum STS armor plate thickness the inert loaded 2000 lb. G.P. Low Drag Type EX-11 Mod 0 bomb will penetrate and remain in effective bursting condition when fired at 1000 ft./sec. velocity at 20° obliquity is 1-7/8".

b. The firing condition which caused failure of the 2000 lb. G.P. Low Drag Type EX-11 Mod 0 bomb occurred when the bomb was fired at 20° obliquity against 2-35 STS armor using a striking velocity of 1000 ft./sec.

c. No quantitative figures can be given for the amount of acceptable deformation resulting from impact. Deflagration tests were not conducted and thus it cannot be estimated what conditions would be critical as far as deflagration is concerned. From the manner in which the bomb broke up when fired against 2-35 STS armor at 20° obliquity at 1000 ft./sec. it may be reasonable to assume that deflagration would occur at these conditions. The bomb becomes ineffective when cracking occurs which takes place when bomb is fired at 2-30 STS armor at 20° obliquity at 1000 ft./sec. velocity.
Plate Penetration Tests of the 2000 lb. Bomb, G.P. (Low Drag), Type EX-11, Mod. O

The primary cause for the failure of Bomb #20 was the segregated condition of the steel in the area 180° from the weld. The other two bombs examined, #3 and #7, were satisfactory metallurgically with the possible exception that the ductility was somewhat low.

3. The A. O. Smith Co. is experimenting with a boron steel for the manufacture of this type of bomb. Also, the National Tube Co. is redesigning the nose section and is modifying its N-80 steel by substituting a small percentage of chromium for the molybdenum content; both of these changes being made for strengthening purposes. Consequently, no recommendation will be made at present pending the outcome of the above mentioned experiments.
Table of Contents

Page

Synopsis .......................... 1
Table of Contents .................... 3
Authority ............................ 4
References .......................... 4
Background .......................... 4
Object of Test ....................... 5
Period of Test ....................... 5
Description of Item Under Test .... 5
Description of Test Equipment ....... 5
Procedure ......................... 6
Results and Discussions ............. 6
Conclusions ........................ 8
Recommendations ..................... 9

Appendix A - Summary of Firing Conditions and Test Results .... TABLE I 1-2 (Incl)
Appendix B - Butt Impact Records ..... TABLES II-XII (Incl)
Appendix C - NPG Photographs ........ FIGURES 1-10 (Incl)
Appendix D - Photomacrographs and Photomicrographs ...... FIGURES 11-18 (Incl)
Appendix E - Charpy Impacts .......... TABLE XIII
Appendix F - Distribution ............ FIGURES 19-20 (Incl)

Confidential
Security Information 3
Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

PART B

INTRODUCTION

1. AUTHORITY:

This test was conducted by authority of references (a) and (b). The test was conducted in accordance with enclosure (2) of reference (a).

2. REFERENCES:

a. BUORD Conf ltr Re3c-REN:mt, NP9/ Serial 18721 of 28 March 1951
b. Task Assignment NPG-25-Re3c-321-3
c. NPG Report No. 646 of 21 September 1950
d. NPG Report No. 694 of 29 December 1950
e. NPG Report No. 748 of 3 April 1951
f. NPG Report No. 878 of 20 October 1951

3. BACKGROUND:

Presently existing AN standard G.P. bombs, because of excessive drag, materially reduce the maximum performance of high speed aircraft when these bombs are suspended externally. The Bureau of Ordnance, therefore, has developed a new family of bombs designed to reduce the drag when they are suspended externally from aircraft. This new family of bombs is called collectively the Low Drag bomb. The first test of this family involved the 1000 lb. Low Drag bomb, Type EX-10. The results of this test were reported in reference (c). The second test was of the 250 lb. Low Drag, G.P. Bomb, Types EX-1 Mod 0, EX-1 Mod 1, and EX-2 Mod 0. The results of this test were reported in reference (d). The third test involved the 1000 lb. Low Drag G.P. bomb, Type EX-10 Mod 3. The results of this test were reported in reference (e). The fourth test was a further study of the 250 lb. Low Drag G.P. bomb, Type EX-2 Mod 0. Results of this test were reported in reference (f). The present test is the first investigation of the 2000 lb. Low Drag G.P. bomb group. The bomb type is EX-11 Mod 0.
Plate Penetration Tests of the 2000 lb. Bomb, G.P. (Low Drag), Type EX-11, Mod 0

4. OBJECT OF TEST:

The tests were conducted (a) to obtain the maximum STS armor plate thickness the 2000 lb, (Low Drag) G.P. bomb, Type EX-11 Mod 0 will penetrate and remain in an effective condition, (b) to determine the conditions which will cause bomb failure, (c) to determine the degree of acceptable deformation resulting from impact and, (d) to determine by metallurgical study any causes of failure in design and suggest any corrective measures pertaining thereto.

5. PERIOD OF TEST:

<table>
<thead>
<tr>
<th>Date Project Letter</th>
<th>Date Material Received</th>
<th>Date Commenced Tests</th>
<th>Date Tests Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>28 March 1951</td>
<td>27 June 1951</td>
<td>27 July 1951</td>
<td>17 August 1951</td>
</tr>
</tbody>
</table>

PART C

DETAILS OF TEST

7. DESCRIPTION OF ITEM UNDER TEST:

A. O. Smith Corp. Dr. MV-9048-A shows the experimental 2000 lb, Low Drag G.P. bomb, Type EX-11 Mod 0, as modified for gun firing. The bomb bodies were inert loaded with vermiculite cement having a specific gravity of 1.55.

8. DESCRIPTION OF TEST EQUIPMENT:

a. Gun: 13\(^\circ\)/47 Rifled Gun Mk A Mod 0 No. 1 L

b. Charge: 50 lbs. of SPDN-3369 powder used with 3 - 5 lb. powder boosters

c. Targets: Various thickness of STS armor plate.
9. PROCEDURE:

a. Eleven (11) EX-11 Mod 0, 2000 lb. Low Drag G.P. bombs were inert loaded with vermiculite cement of specific gravity 1.55. These bombs were fired against various thickness (1.25 through 2.35) of STS armor plate at a velocity of approximately 1000 ft./sec. The targets were set at 20° obliquity to the line of fire. The armor plate targets were backed up by a large sandpile which was used as the recovery medium. The back half of the sandpile was covered with large steel plates to assist in holding the fired bombs in the sandpile. Each bomb was recovered and examined prior to firing the next round. Velocities were measured by using coils and counter chronographs.

b. Method of Metallurgical Sampling

Samples for metallurgical examination were cut from the fractured side walls of Bomb #20, (impact No. 39191) which broke up and from the least deformed side walls of bombs #3 (impact #39196) and #7 (impact #39204) which were intact and only moderately flattened when recovered after firing.

10. RESULTS AND DISCUSSION:

a. Table I, Appendix (A), summarizes the firing conditions and test results. Appendix (B), Tables II through XII, includes the butt impact records. Figures 1 through 10, Appendix (C), show the condition of the bombs after firing.

b. Metallurgical Examination

Metallurgical examination consisted of chemical and spectrographic analyses, tensile, Brinell hardness, Charpy impact, hot acid etch tests and microscopic examination.
The results of chemical and spectrographic analyses were as follows:

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Si</th>
<th>Cr</th>
<th>Ni</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bomb #20</td>
<td>.29</td>
<td>1.32</td>
<td>.012</td>
<td>.034</td>
<td>None</td>
<td>.10</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Bomb #3</td>
<td>.31</td>
<td>1.17</td>
<td>.020</td>
<td>.031</td>
<td>Trace</td>
<td>.07</td>
<td>.06</td>
<td>.07</td>
</tr>
<tr>
<td>Bomb #7</td>
<td>.32</td>
<td>1.07</td>
<td>.022</td>
<td>.031</td>
<td>Trace</td>
<td>.07</td>
<td>.06</td>
<td>.07</td>
</tr>
</tbody>
</table>

These analyses represent a medium high manganese carbon steel. The copper, nickel and chromium contents are incidental.

Due to the bent and fractured condition of Bomb #20 no tensile test specimens were taken. The results of triplicate longitudinal tensile tests of Bombs 3 and 7 and of transverse Brinell hardness tests are shown below:

<table>
<thead>
<tr>
<th></th>
<th>Yld. Str.</th>
<th>Ult. Str.</th>
<th>Elong.</th>
<th>R.A.</th>
<th>Brinell</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% 2% B.S.I.</td>
<td>B.S.I.</td>
<td>% 2%</td>
<td>% 2%</td>
<td>3000 Kg.</td>
</tr>
<tr>
<td>Bomb #20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>303</td>
</tr>
<tr>
<td>Bomb #3</td>
<td>104000</td>
<td>126300</td>
<td>10.0</td>
<td>44.1</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td>99000</td>
<td>123500</td>
<td>11.4</td>
<td>43.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>104000</td>
<td>127400</td>
<td>11.4</td>
<td>42.8</td>
<td></td>
</tr>
<tr>
<td>Bomb #7</td>
<td>97100</td>
<td>120100</td>
<td>14.3</td>
<td>50.8</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>94000</td>
<td>118000</td>
<td>15.0</td>
<td>48.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100000</td>
<td>121200</td>
<td>14.3</td>
<td>49.1</td>
<td></td>
</tr>
</tbody>
</table>

Transverse sections of the three bombs were etched in 50% HCl - 50% H2O solution at 160°F for twenty minutes and the results are shown in Figures 11 and 12, Appendix (D). Two sections of Bomb No. 20 are shown in Figure 12. At the top is the area of the electric butt weld showing sound steel and a good weld. At the bottom is shown a section 180° from the weld, showing a highly segregated condition in the fractured area. Figure 11 shows sections of Bombs 3 and 7 which are satisfactory although Bomb 3 shows considerable segregation and slight laminations.
Plate Penetration Tests of the 2000 lb. Bomb, G.P., (Low Drag), Type EX-11, Mod 0

Figures 13 through 18 show photomicrographs of the three bombs taken at magnifications of 250X and 1000X, and are indicative of quenched and drawn heat treatment. Figures 13 and 14 were taken near the fracture in Bomb #20 and show oxides and other indications of segregation.

Table XIII and Figures 19 and 20, Appendix (E) show the values of impact tests obtained from standard V-notch Charpy specimens. On Bomb #20 the impact values obtained from the specimens cut away from the fracture area compare with values obtained on Bombs 3 and 7 at room temperature while the impacts from the fracture area show somewhat more brittleness. On Bombs #3 and #7 impacts were made at temperatures ranging from 100°C to minus 70°C and the results were plotted as shown in Figures 19 and 20. On the basis that the transition from toughness to brittleness is taken to be the point on the curve where the fracture is 50% granular and 50% fibrous, the transition temperatures for Bombs #3 and #7 are +30°C and +25°C respectively which is approximately room temperature or slightly above. This is rather a high temperature for the transition but it may be accounted for in part by the fact that the steel was tested after firing which may have caused some work hardening.

PART D

CONCLUSIONS

11. It is concluded that:

a. The maximum STS armor plate thickness that the inert loaded 2000 lb. Low Drag G.P., bomb Type EX-11, Mod 0 will penetrate and remain in effective bursting condition when fired at 1000 ft./sec. velocity with target set at 20° obliquity is 1-7/8".

b. The firing condition which will cause failure of the 2000 lb. Low Drag G.P. bomb Type EX-11, Mod 0 occurs when the bomb is fired at 20° obliquity against 2"0 STS armor plate using a velocity of 1000 ft./sec.
Plate Penetration Tests of the 2000 lb. Bomb, G.P. (Low Drag), Type EX-11, Mod 0

---

c. No quantitative figures can be given for the amount of acceptable deformation resulting from impact. It is conclusive that when cracking occurs the bomb becomes ineffective but the amount of deformation which will cause a bomb to become ineffective has not been determined.

d. The primary cause for the failure of Bomb #20 was the segregated condition of the steel in the area 180° from the weld. The other two bombs examined, No. 3 and No. 7, were satisfactory metallurgically with the possible exception that the ductility was somewhat low.

PART E

RECOMMENDATIONS

12. The A. O. Smith Co. is experimenting with a boron steel for the manufacture of this type of bomb. Also the National Tube Co. is redesigning the nose section and is modifying its N-80 steel by substituting a small percentage of chromium for the molybdenum content, both of these changes being made for strengthening purposes. Consequently, no recommendations will be made at present pending the outcome of the above mentioned experiments.

CONFIDENTIAL SECURITY INFORMATION 9
Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EK-11, Mod C

The tests upon which this report is based were conducted by:
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Terminal Ballistics Department

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Commander, Naval Proving Ground

Captain, USN
Ordnance Officer
By direction
Thirty-Second Partial Report
on
Bombs and Associated Components

Final Report
on
Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

NAVY RESEARCH SECTION
SCIENCE DIVISION
REFERENCE DEPARTMENT

APR 28 1952

Project No.: NPC-Re3a-321-1-52
Copy No.: 4
No. of Pages: 10

CONFIDENTIAL
SECURITY INFORMATION
### Table 1

**Summary of Firing Conditions and Test Results**

<table>
<thead>
<tr>
<th>Impact No.</th>
<th>Date Fired</th>
<th>Type of Bomb</th>
<th>No.</th>
<th>Weight (lbs)</th>
<th>Target Thickness (in.)</th>
<th>Through Opening (in.)</th>
<th>Obs.</th>
<th>Powder Charge</th>
<th>Striking Velocity (ft/sec)</th>
<th>Chamber Pressure (psi)</th>
<th>Gun</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>39176</td>
<td>7/27</td>
<td>IX-11 Mod 0</td>
<td>5</td>
<td>1919</td>
<td>17/62</td>
<td>18 x 19</td>
<td>20°</td>
<td>70 lbs, SPDN 3369</td>
<td>1123</td>
<td>1.3</td>
<td>18”/47</td>
<td>Bomb in river - appeared to be intact and in good shape, Mod 0</td>
</tr>
<tr>
<td>39177</td>
<td>7/31</td>
<td>IX-11 Mod 0</td>
<td>18</td>
<td>1998</td>
<td>17/90</td>
<td>18 x 18-3/4</td>
<td>20°</td>
<td>15 lbs, black powder booster</td>
<td>943</td>
<td>1.4</td>
<td>18”/47</td>
<td>Bomb effective and intact - Moderate to severe flattening, Mod 0 Nose plug sheared off.</td>
</tr>
<tr>
<td>39181</td>
<td>8/3</td>
<td>IX-11 Mod C</td>
<td>20</td>
<td>1910</td>
<td>21/35</td>
<td>19 x 20</td>
<td>20°</td>
<td>70 lbs, SPDN 3369</td>
<td>1120</td>
<td>1.6</td>
<td>18”/47</td>
<td>Bomb completely broken up, Mod 0</td>
</tr>
<tr>
<td>39182</td>
<td>8/6</td>
<td>IX-11 Mod 0</td>
<td>6</td>
<td>1969</td>
<td>24/15</td>
<td>18 x 19</td>
<td>20°</td>
<td>60 lbs, SPDN 3369</td>
<td>523</td>
<td>1.3</td>
<td>18”/47</td>
<td>Bomb cracked open on nose section - Severely flattened and bent, Mod 0</td>
</tr>
<tr>
<td>39183</td>
<td>8/7</td>
<td>IX-11 Mod 0</td>
<td>15</td>
<td>1953</td>
<td>22/0</td>
<td>15 x 19</td>
<td>20°</td>
<td>55 lbs, SPDN 3369</td>
<td>817</td>
<td>1.1</td>
<td>18”/47</td>
<td>Bomb effective and intact - Moderate to severe flattening on sides, Mod 0</td>
</tr>
<tr>
<td>39184</td>
<td>8/7</td>
<td>IX-11 Mod 0</td>
<td>12</td>
<td>1959</td>
<td>22/0</td>
<td>17-1/2 x 19</td>
<td>20°</td>
<td>60 lbs, SPDN 3369</td>
<td>960</td>
<td>1.4</td>
<td>18”/47</td>
<td>Bomb cracked open around fuse hole - Severely flattened, Mod 0</td>
</tr>
<tr>
<td>39196</td>
<td>8/10</td>
<td>IX-11 Mod 0</td>
<td>3</td>
<td>2937</td>
<td>18/64</td>
<td>18-1/2 x 18</td>
<td>20°</td>
<td>60 lbs, SPDN 3369</td>
<td>914</td>
<td>1.5</td>
<td>18”/47</td>
<td>Bomb effective and intact - Moderate flattening, Mod 0</td>
</tr>
</tbody>
</table>
Butt Firing
U.S. Naval Proving Ground
Dahlgren, Va. 7-27-51

Impact No. 39176
Impact Date 21 July 1951

Object: Ballistic Test of 2000 lb. Low Drag G.P. Bomb
Type EX II Mod. 0 vs. 1/2" Sts Plate at 0° obl.

Reference N.P.G. Letter Report No. 950 Dated

PLATE

Caliber 2000 lb.
Maker A. O. Smith
Type Low Drag G.P.
Lot No. - Year of Specification 1951
Mark EX II Mod. 0 No. 5
Date received

G.P. Bomb PROJECTILE

Capped or uncapped
Weight (capped)
Weight (uncapped) 1919.0#
Length (uncapped)

Fuzes None
Filler Vermiculite
Flights by screen
Condition after firing:

EFFECTIVE or INEFFECTIVE
Bomb in river - Appears to be intact and in good shape.

Ballistic Data

Note: All limits are for this plate and this obliquity only.

<table>
<thead>
<tr>
<th>Striking velocity (f.s.)</th>
<th>Desired</th>
<th>Oscillograph</th>
<th>Chronograph</th>
<th>Limit, estimated for this thickness of impact.</th>
<th>Actual, adjusted to nominal gauge.</th>
<th>Limit for nominal gauge, based on this impact only, (Adjusted from column 4)</th>
<th>Limit, for nominal gauge, established from column 8 and previous impacts.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks:

7 LBS. F.C. SFU-336.9 Powder Used. W/3.5# Black Pk. Boosters

Limit shots only

Acceptance or Rejection recommended

N.P.G. Photo No.

U.S. Navy

GUN: 1947 MK. A MOD. 0 #1 L. Appendix B
**Butt Firing**

**U.S. Naval Proving Ground**

**Dahlgren, Va. 7-31-51**

**OBJECT**

**EXPERIMENTAL BALLISTIC TEST OF 2000 Lb. G.P. LOW D.R.A.G. BOMB VS. 2.5" PLATE AT 20° OBLIQUITY**

**REFERENCE N.P.G. LETTER REPORT No. 960**

**G.P. Bomb**

**PROJECTILE**

<table>
<thead>
<tr>
<th>Gauge</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>STS</td>
</tr>
<tr>
<td>Maker</td>
<td>N.S. STEEL</td>
</tr>
<tr>
<td>No.</td>
<td>016,358</td>
</tr>
<tr>
<td>Group</td>
<td>U-526-780</td>
</tr>
<tr>
<td>Contract</td>
<td>N600-1575-928</td>
</tr>
<tr>
<td>Date received</td>
<td>7-31-51</td>
</tr>
<tr>
<td>Dimensions</td>
<td>23&quot; X 250&quot;</td>
</tr>
<tr>
<td>No. of impact on plate</td>
<td>4</td>
</tr>
<tr>
<td>Thickness at impact</td>
<td>1.97</td>
</tr>
<tr>
<td>OBLIQUITY</td>
<td>20°</td>
</tr>
<tr>
<td>Impact dimensions</td>
<td>21&quot; X 2.3&quot;</td>
</tr>
<tr>
<td>PENETRATION</td>
<td>COMPLETE</td>
</tr>
<tr>
<td>Flaking front</td>
<td>C</td>
</tr>
<tr>
<td>Flaking back</td>
<td>0</td>
</tr>
<tr>
<td>Dist. from top, bottom</td>
<td>33&quot;</td>
</tr>
<tr>
<td>Dist. from right, left</td>
<td>63&quot;</td>
</tr>
<tr>
<td>Dist. from nearest impact</td>
<td>170&quot;</td>
</tr>
<tr>
<td>Dish</td>
<td>4&quot;</td>
</tr>
<tr>
<td>Spur</td>
<td>10&quot;</td>
</tr>
<tr>
<td>Cracks - Bulge</td>
<td>0</td>
</tr>
<tr>
<td>Button (Thrown)(Started)</td>
<td>Through Opening 18&quot; X 18 3/4&quot;</td>
</tr>
</tbody>
</table>

**BALLISTIC DATA**

| Note: **All limits are for this plate and this obliquity only.** |
|-------------------|-----------------|-----------------|-----------------|---------------|-----------------|-----------------|
| Desired | Oscillograph | Chronograph | Limit, estimated | Actual adjusted | Limit, for nominal range, based on this impact only, (Adjusted from column 6) | Limit, for nominal gauge, established from column 6 and previous impacts. |
| Striking velocity (f.s.) | **MEAN** | 943 |

**REMARKS**

**PRESS - 1.4 Tons/in²**

**USED .551" SPIN 3269 WITH 3.5" B.C. FOR BOOSTERS.**

**Accepted or Rejected Recommended**

**Confidential**

**Table III**

**N.P.G. Photo. No.**

**Note:**

- Limit shots only
- F(e/d, e)
- Year of Specification
- No. of impact on plate
- Date received
- Capped or uncapped
- Weight (capped)
- Weight (uncapped)
- Length (uncapped)
- Fuze
- Filler
- Flight by screen
- Condition after firing:
  - EFFECTIVE or INEFFECTIVE
  - Intact - Moderate to severe flattening - Nose plug sheared off

**N.G. Photo. No.**

**U.S. Navy**

**Appendix B**
Butt Firing
U.S. Naval Proving Ground
Dahlgren, Va. 5-3-51

PROJECTILE

Caliber 17.99
Type M-328-8.5A
Lot No. 511001
Year of Specification 1952
Mark EX 11
Mod. M

Date received

Dimensions
9.75" x 10.75"

No. of impact on plate 6
Thickness at impact

OBLIQUITY

Impact dimensions 31 x 5.5

PENETRATION

Flaking front

Flaking back

Dist. from top, bottom

Dist. from right, left

Dist. from nearest impact 54"

Dish

Spur

Cracks - Bulge

Button (Thrown) (Starter)

Through Opening 19.5 x 0.5

BALLISTIC DATA

<table>
<thead>
<tr>
<th>Notes</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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</thead>
<tbody>
<tr>
<td>All limits are for this plate and the obliquity only.</td>
<td>1177A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Striking velocity (f -1)</td>
<td>1177</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

REMKS

Li the .30-cal. 3360 Powder - 15 lbs Black Powder in

Limit shots only

C.P. (d-19)

X.P.G. Phone, No.

Confidential

Appendix B
**Plate Impact Test**

**G.P. Bomb** Type EXII Mod. 0, 1 3/4" S.T.P. PLATE

**DATE**

**U.S. Naval Proving Ground** Dahlgren, Va. 8-6-51

**Object** Ballistic Test of Inert Loaded 2000 lb. Low Drag G.P. Bomb Type EXII Mod. 0, 1 3/4" S.T.P. PLATE

**Reference N.P.G. Letter** Report No. 950

**Date**

**G.P. Bomb** Projectile

**Caliber** 17" 99

**Maker** A.O. Smith

**Type** Low Drag

**Lot No.** Year of Specification

**Mark** EXII Mod. - No. #6

**Date received**

**Capped or uncapped**

**Weight (capped)**

**Weight (uncapped)** 1963.0 lbs

**Length (uncapped)** 103.65 in.

**Fuse** None

**Filler** Verticality

**Flight by screen**

**Condition after firing:**

**Effective or Ineffective**

**Penetration** Complete

**Flaking front**

**Flaking back** 0

**Dist. from top, bottom** 39" 61"

**Dist. from right, left** 61"

**Dist. from nearest impact** 50"

**Dish** 5"

**Spur** 7"

**Cracks - Bulge** 0

**Button (Thrown) (Started)**

**Through Opening** 18" x 19"

**Ballistic Data**

<table>
<thead>
<tr>
<th>Note</th>
<th>Desired</th>
<th>Geasograph</th>
<th>G-Measure</th>
<th>A-lhant, corrected for this thickness of impact</th>
<th>Actual, adjusted to nominal gauge</th>
<th>Limit for nominal gauge based on this impact only</th>
<th>Limit from (Nominal)</th>
<th>Limit, for nominal gauge, established from column C and previous impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Striking velocity (I.a.)</td>
<td>923</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks**

These 13 shots only. The SPG-3369 Powder is 15 lbs. Black Powder BBASTED. Limit shots only. Confidential. Acceptance or rejection recommended.

**N.P.G. Photo. No.**

**GUN:** 18" 97 HK. 0 MOD. 0 #1 L. Appendix B.
Butt Firing
U.S. Naval Proving Ground
Dahlgren, Va. 8-7-51

Object: BALL TEST OF INERT LOADED 2000 lb. LOW DRAG G. P.
Bomb Type: EX II Mod. 0 15" 2" STS PLATE
Reference N.P.G. Letter Report No. 950 Dated

Caliber: 17.99
Maker: A.O. Smith
Type: G. P. low Drag
Lot No.: — Year of Specification —
Mark: EX II Mod. — No. 15
Date received: —
Capped or uncapped Weight (capped): —
Weight (uncapped): 1954#
Length (uncapped): 103.65
Fuze: None
Filter: VERMICULITE
Flight by screen
Condition after firing:
EFFECTIVE or INEFFECTIVE
Intact = Moderate to severe Flattening on sides

Dimensions
98" x 288"

No. of impact on plate 14
Thickness at impact 2"

OBLIQUITY 20°

Impact dimensions 17" x 22"

PENETRATION Complete
Flaking front 0
Flaking back 0
Dist. from top, bottom 34"
Dist. from right, left 59"
Dist. from nearest impact 36"

Disch 4"
Spir 8"

Cracks - Bulge 0

Button (Thrown) (Sagged)

Through Opening 15" x 19"

BALLISTIC DATA

Note:
All limits are for this plate and this obliquity only.

Steelhead velocity (f.s.): 817

Note:

REMARKS:
5 x 10 JPDN - 3369 Tandem - 15. No. Black Vorder Booster

Limit shots only
e/d:
F (e/d 0)
N.P.G. Photo No. 275183

Acceptance or Rejection recommended

D.W. Meyer
U. S. Navy
Appendix B
**Butt Firing**

U.S. Naval Proving Ground
Dahlgren, Va. 8-7-51

**OBJECT**
Ball Test of 2000 lb. G.P. Low Drag Bomb Vs.

**2" STE Plate at 20° Oph.**

**REFERENCE N.P.G. LETTER Report No. 956 DATED**

---

**PLATE**

<table>
<thead>
<tr>
<th>Gauge</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>STE</td>
</tr>
<tr>
<td>Maker</td>
<td>CARNEGIE</td>
</tr>
<tr>
<td>No.</td>
<td>061221 Group -</td>
</tr>
<tr>
<td>Contract</td>
<td>10280</td>
</tr>
<tr>
<td>Date received</td>
<td>-</td>
</tr>
<tr>
<td>Dimensions</td>
<td>98&quot; X 358&quot;</td>
</tr>
<tr>
<td>No. of impact on plate</td>
<td>15</td>
</tr>
<tr>
<td>Thickness at impact</td>
<td>2&quot;</td>
</tr>
<tr>
<td>OBLIQUITY</td>
<td>20°</td>
</tr>
<tr>
<td>Impact dimensions</td>
<td>19 X 23&quot;</td>
</tr>
<tr>
<td>PENETRATION</td>
<td>Complete</td>
</tr>
<tr>
<td>Flaking front</td>
<td>0</td>
</tr>
<tr>
<td>Flaking back</td>
<td>0</td>
</tr>
<tr>
<td>Dist. from top, bottom</td>
<td>68&quot;</td>
</tr>
<tr>
<td>Dist. from right, left</td>
<td>65&quot;</td>
</tr>
<tr>
<td>Dist. from nearest impact</td>
<td>64&quot;</td>
</tr>
<tr>
<td>Dish</td>
<td>6&quot;</td>
</tr>
<tr>
<td>Spur</td>
<td>7&quot;</td>
</tr>
<tr>
<td>Cracks - Bulge</td>
<td>0</td>
</tr>
<tr>
<td>Button (Thrown)(Started) Through Opening</td>
<td>17/2&quot; X 19&quot;</td>
</tr>
</tbody>
</table>

---

**BULLET DATA**

| Caliber | 17.99 |
| Maker | A.O. SMITH |
| Type | G.P. Low Drag |
| Lot No. | - |
| Year of Specification | - |
| Mark Ex11 | Mod. | No. 12 |
| Date received | - |
| Capped or uncapped | - |
| Weight (capped) | - |
| Weight (uncapped) | 1967 lbs |
| Length (uncapped) | 103.66 |
| Fuze | NONE |
| Filler | VERMICULITE |
| Flight by screen | - |
| Condition after firing: | EFFECTIVE or INEFFECTIVE |

**Cracked open around Fuze hole - Severely Flattened**

---

**BALLISTIC DATA**

| Note: All limits are for this plate and this obliquity only. |
|---|---|---|---|---|
| 1. Desired | Oscillograph | Chronograph | - | - |
| 2. | - | MEAN | - | Limit, estimated for this thickness of impact. |
| 3. | - | - | Actual, adjusted to nominal gauge. |
| 4. | - | - | Limit, for nominal gauge, based on this impact only. |
| 5. | - | - | Limit for nominal gauge, established from column 4 and previous impacts. |
| 6. | - | - | - |
| 7. | - | - | - |

---

**60/62 SPREAD 3369 Powder - Is the Black Powder Booster**

Limit shots only

**CONFIDENTIAL**

Acceptance or Rejection recommended

---

**FILE No.**

N.P.G. Photo No. 1077

---

**FILE No.**

N.P.G. File No. 1078

---

**FILE No.**

N.P.G. Report No. 956

---

**FILE No.**

N.P.G. Letter Report No. 956
**Buff Firing**

**U.S. Naval Proving Ground**

**Dahlgren, Va. 8-10-51**

**OBJECT** BALLISTIC TEST OF 2000 LB. LOW DRAG G.P. BOMB VS. 1.34" PLATE AT 20° OBLIQUITY

**REFERENCE N.P.G. LETTER** Rep. 241 No. 950

**IMPACT No.** 39196

**IMPACT DATE** 8-12-51

**LETTER No.** E

---

**PLATE**

- **Caliber:** 17.983
- **Maker:** A. O. Smith
- **Type:** LOW DRAG G.P. Bomb
- **Lot No.:** 1937
- **Weight (uncapped):** 103.65 lbs

**PROJECTILE**

- **Caliber:** 17.983
- **Gauge:** 1.049
- **Class:** 5.5
- **Mark:** EX II
- **Date received:** 9-16-50
- **Dimensions:** 95" x 254"
- **Thickness at impact:** 1.84"  
- **OBLIQUITY:** 20°

**Impact dimensions:**

- PENETRATION: Complete
- Flaking front: 7
- Flaking back: 7
- Dist. from top, bottom: 6.3"
- Dist. from right, left: 4.0"
- Dist. from nearest impact: 4.2"
- Dish: 8"  
- Spur: 8"  
- Cracks - Bulge: 0
- Button (Thrown): 0
- Through Opening: 18 1/2" x 18 1/2"

**BALLISTIC DATA**

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**REMARKS**

- **Gun:** 15 time
- **Powder:** 3369 Powder / K. S. Black Powder Booster
- **Limit shots only:** Confidential

---

**APPENDIX B**
**Butt Firing**

U.S. Naval Proving Ground

Dahlgren, Va. 9-10-51

**OBJECT** BALLISTIC TEST OF 2,000 LB. LOW DROG. G.P. BOMB VS. 1/32" PLATE AT 30° OBLIQUITY

**IMPACT No.** 37/197

**IMPACT DATE** 9-10-51

**BUTT No.** G

---

**PLATE**

<table>
<thead>
<tr>
<th>Gauge</th>
<th>1.549</th>
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</thead>
<tbody>
<tr>
<td>Class</td>
<td>575</td>
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<tr>
<td>Maker</td>
<td>CARNEGIE</td>
</tr>
<tr>
<td>No.</td>
<td>091460 Group C-526-736</td>
</tr>
<tr>
<td>Contract</td>
<td>C-N6205-3-5815</td>
</tr>
<tr>
<td>Date received</td>
<td>7-14-51</td>
</tr>
<tr>
<td>Dimensions</td>
<td>95&quot; x 250&quot;</td>
</tr>
<tr>
<td>No. of impact on plate</td>
<td>4</td>
</tr>
<tr>
<td>Thickness at impact</td>
<td>1.84</td>
</tr>
<tr>
<td>OBLIQUITY</td>
<td>20°</td>
</tr>
</tbody>
</table>

**IMPACT dimensions** 20" x 20.25"

**PENETRATION** CAPPED

Flaking front

Flaking back

Dist. from top, bottom | 3/4"

Dist. from right, left | 62"

Dist. from nearest impact | 26"

Dish | 4"

Spur | 7"

Cracks - Bulge | 0

Button (Thrown)(Started) Through Opening 18" x 18%/20"

---

**BALLISTIC DATA**

| Note: | All limits are for this plate and this obliquity only.
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Striking velocity (f.s.)</td>
<td>Desired</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| | | | | | |
| Striking velocity (f.s.) | 928 |

**REMARKS:**

- Press. 1st time.

60.00 SPDX. 3569. Powder: 15 lbs. Clock Fused.

**Acceptance or Rejection recommended:**

- Confidential

- Appendix B

- U.S. Navy

- L. L. Gagne
**Butt Firing**

U.S. Naval Proving Ground
Dahlgren, Va. 8-17-51

**OBJECT** BALL, 7C TEST OF 2000 LB. LOW DRAG G.P. BOMB

**EXH. VERMICULITE LOAD, VS. 1.74" PLATE**

**REFERENCE** N.P.C. HTEST Report 20,950

**PLATE**

<table>
<thead>
<tr>
<th>Gauge</th>
<th>1.849</th>
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<tr>
<td>Class</td>
<td>57.5</td>
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<tr>
<td>Maker</td>
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<tr>
<td>No.</td>
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<tr>
<td>Contract</td>
<td>C-N6005-5-5615</td>
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<td>Dimensions</td>
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<tr>
<td>No. of impact on plate</td>
<td>5</td>
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<tr>
<td>Thickness at impact</td>
<td>0.54</td>
</tr>
<tr>
<td>OBLIQUITY</td>
<td>30°</td>
</tr>
<tr>
<td>Impact dimensions</td>
<td>18&quot; X 19&quot;</td>
</tr>
<tr>
<td>PENETRATION</td>
<td>COMPLETE</td>
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<tr>
<td>Flaking front</td>
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</tr>
<tr>
<td>Flaking back</td>
<td>0</td>
</tr>
<tr>
<td>Dist. from top, bottom</td>
<td>32&quot;</td>
</tr>
<tr>
<td>Dist. from left</td>
<td>86&quot;</td>
</tr>
<tr>
<td>Dist. from nearest impact</td>
<td>40&quot;</td>
</tr>
<tr>
<td>Dish</td>
<td>2&quot;</td>
</tr>
<tr>
<td>Spur</td>
<td>8&quot;</td>
</tr>
<tr>
<td>Cracks - Bulge</td>
<td>0</td>
</tr>
<tr>
<td>Button (Thrown)</td>
<td>0</td>
</tr>
<tr>
<td>Through Opening</td>
<td>16&quot; X 18&quot;</td>
</tr>
</tbody>
</table>

**PROJECTILE**

| Caliber    | 17.966 |
| Maker      | A.D. SMITH |
| Type       | LOW DRAG BOMB |
| Lot No.    | - |
| Year of Specif. | - |
| Mark       | EX II Mod. - No. 10 |
| Date received | - |
| Capped or uncapped | - |
| Weight (capped) | - |
| Weight (uncapped) | 1956.00 |
| Length (uncapped) | 103.65 |
| Fuze       | VERNICULITE |
| Filler     | NONE |
| Flight by screen | - |
| Condition after firing: | EFFECTIVE or INEFFECTIVE |
| Intact - Moderate Flattening |

**BALLISTIC DATA**

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<tr>
<th>Notes:</th>
<th></th>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>All limits are for this plate and this obliquity only.</td>
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<td></td>
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</tr>
<tr>
<td>Flaking velocity (ft.)</td>
<td>MEAN</td>
<td>932</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**REMARKS**

60 lbs. SPAN 3367 Powder + 15 lbs. Black Powder

Confidential

Acceptance or rejection recommended

F (cd, ea)

N.P.C. Photo. No.

GUN: 18/41 MK A MOD 0 # 11 Appendix B
Butt Firing
U.S. Naval Proving Ground
Dahlgren, Va. 8-17-51

OBJECT: BALLISTIC TEST OF 2000 LB. LOW DRAG G.P. BOMB EX II VERNICULIZE LOADED VS. 1/34" PLATE

REFERENCE N.P.G. LETTER Report 720, 95/8

PROJECTILE

Gauge .1849
Class S-3
Maker CARRIE
No. 091460 Group 0-526-726
Contract H-N6005-S-5615
Date received 8-11-50
Dimensions 95" X 2.50"
No. of impact on plate 6
Thickness at impact 1.84
OBLIQUITY 20°

IMPACT DIMENSIONS

Flaking from 0
Flaking back 0
Dist. from top, bottom 32.0"
Dist. from right, left 140.0"
Dist. from nearest impact 46.0"
Dish 2.0"
Spur 8.0"
Cracks - Bulge 0

Condition after firing: EFFECTIVE or INEFFECTIVE

BOTTON (THROWN)(STARTED)
Through Opening: 17" X 24"

BALLISTIC DATA

Penetration
Flaking

Firing velocity (ft.)

Remarks

BARROWS SPAN 3367
Barrel 15 In. Black

Limit shots only

Confidential

Assistant Project

N.P.G. Photo. No. 18-47 M.K.A. MOD. 12 APPENDIX B
## Butt Firing

U.S. Naval Proving Ground
Dahlgren, Va. 8-17-51

**OBJECT**
BALLISTIC TEST OF 2000 LB. LOW DRAG G.P. BOMB EX II VERMICULITE LOADED VS. 1.74" PLATE

**REFERENCE**
N.P.G. Report No. 72-950

**IMPACT NO.**
39204

**DATE**
8-17-51

**LOT NO.**
F

### PLATE

<table>
<thead>
<tr>
<th>Gauge</th>
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<tr>
<td>Class</td>
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<td>No.</td>
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<tr>
<td>Contract</td>
<td>C-16008-S-5615</td>
</tr>
</tbody>
</table>

**Date received**
8-16-51

**Dimensions**
95" x 3.52"

**No. of impact on plate**
7

**Thickness at impact**
1.84

**OBLIQUITY**
30°

**Impact dimensions**
19" x 20"

**PENETRATION**
COMPLETE

- **Flaking front**
- **Flaking back**
- **Dist. from top, bottom**
- **Dist. from right, left**
- **Dist. from nearest impact**
- **Dish**
- **Spur**
- **Cracks - Bulge**
- **Button (Thrown) Started**
- **Through Opening**

**Caliber**
17.981

**Maker**
A. D. SMITH

**Type**
LOW DRAG BOMB

**Lot No.**

**Year of Specification**

**Mark** EX II Mod. No. 1

**Date received**

**Capped or uncapped**

**Weight (capped)**

**Weight (uncapped)**
1968.0#

**Length (uncapped)**
130.163

**Fuze**
NONE

**Filler**
VERMICULITE

**Flight by screen**

**Condition after firing**:

- **EFFECTIVE or INEFFECTIVE**
- **Intact - Moderate Flattening**

### BALLISTIC DATA

<table>
<thead>
<tr>
<th>Notes</th>
<th>Desired</th>
<th>Oscillograph</th>
<th>Chronograph</th>
<th>Limit, estimated for true thickness of impact</th>
<th>Actual adjusted to nominal gauge before this impact only</th>
<th>Actual, for nominal gauge established from column 5 and previous impacts, adjusted from volume IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

**Remarks**

64 lbs. SPDN - 3369 Powder + 15 lbs. Black Powder Booster

Limit shots only

Confidential

Table XIII

E. Lewis

U.S. Navy

N.P.G. Photo. No.

B&W 18/41 MKA MOD 0 #14 Appendix B
Figure 5
Impact 39187, L.O.D. 11, L.P. about 16 in. above 21-1/2 in. No. 0 after impact with 1/4 in. plate at 26° obliquely. Striking velocity was 17.1 ft/s.
Impact 39196; 2000 lb. u.p. bomb (low drag) EX-11 Mod 0 after impact against 1424 steel plate at 20° obliquity. Striking velocity was 914 f.p.

Appendix C
Figure 1

Impact test 36197, 2000-lb C.P. bomb (low drag) at 11,060 f.p.s., after impact against 1484 ft. plate at 0° obliquity. Striking velocity was 11,060 f.p.s.

Appendix C
Transverse Section of 2000# Low Drag G.P. Bomb, Type Ex-11, Mod.O.
Etched in 50% HCl-50% H₂O for 20 Min. at 160°F.  Magn. 1X.

Top:- Weld Area - Sound Steel - Good Weld.
Bottom:- 180° from weld showing fracture in segregated area.

NP9-45699  Figure 12.  APPENDIX D.
CONFIDENTIAL.
Plate Penetration Tests of the 2000 lb. Bomb, G.P. (Low Drag), Type EX-11, Mod. 0

Figure 13 250X Figure 14 1000X
Bomb No. 20 - Impact No. 39181 - Nital-Picral Etch.

Figure 15 250X Figure 16 1000X
Bomb No. 3 - Impact No. 39196 - Nital-Picral Etch.

NP9-45701

CONFIDENTIAL
SECURITY INFORMATION
APPENDIX D
Plate Penetration Tests of the 2000 lb. Bomb, G.P. (Low Drag), Type EX-11, Mod. 0

Figure 17 250X  Figure 18 1000X
Bomb No. 7 = Impact No. 39204 - Nital-Picral Etch.
Plate Penetration Tests of the 2000 lb. Bomb, G,P, (Low Drag), Type EX-11, Mod 0

**TABLE XIII**

CHARPY IMPACT TESTS AT VARIOUS TEMPERATURES

<table>
<thead>
<tr>
<th>Testing Temp, °C</th>
<th>Bomb No. 20</th>
<th></th>
<th>Bomb No. 3</th>
<th></th>
<th>Bomb No. 7</th>
<th></th>
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<tbody>
<tr>
<td>-78</td>
<td>See Note No. 1</td>
<td>10</td>
<td>G</td>
<td>11</td>
<td>G</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>15</td>
<td>G</td>
<td>10</td>
<td>G</td>
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Note 1: On Bomb No. 20 Charpy impact tests were made only at room temperature (25°C). The first four values shown were from an area away from the fracture in the bomb. The last two values were from specimens taken near the fracture.

* F denotes 100% Fibrous Fracture.
* 60F " 60% Fibrous and 40% Granular.
* G " 100% Granular Fracture.

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APPENDIX E
CHARPY IMPACT TESTS

at

VARIOUS TEMPERATURES

Bomb No. 3

Testing Temperature in °C

Code:
- F = 100% Fibrous Fracture
- G = 100% Granular Fracture
- 10F = 10% Fibrous Fracture
- 90G = 90% Granular Fracture
CHARPY IMPACT TESTS

at

VARIOUS TEMPERATURES

Tomb No. 7

Clicks:

F = 100% Fibrous Fracture
G = 100% Granular Fracture
50F = 50% Fibrous Fracture
50G = 50% Granular Fracture

Testing Temperature in °F

FIGURE 20

APPENDIX E
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Plate Penetration Tests of the 2000 lb. Bomb,
G.P., (Low Drag), Type EX-11, Mod 0

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