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<tbody>
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THE EFFECT OF THE STEEL CASE ON THE AIR BLAST
FROM HIGH EXPLOSIVES

19 FEBRUARY 1953

U.S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND
THE EFFECT OF THE STEEL CASE ON THE AIR BLAST
FROM HIGH EXPLOSIVES

Prepared by:
E. M. Fisher

Approved by: C. J. Aronson
Deputy Chief,
Explosion Effects Division

ABSTRACT: The formula developed by U. Fano of the Ballistic
Research Laboratories has been revised by new theoretical
and experimental considerations so as to give more reason-
able predictions of the air blast from steel cased charges.

By the use of the same experimental data which was avail-
able to Fano plus new data on bare charges, it has been found
that the ratios of the effective bare charge weights of the
cased charges to the actual charge weights as calculated by
the original Fano formula were about two-thirds as large as
the proper experimental values.

Of the three revised formulae developed for finding bare
charge equivalent weight, \( W' \), the expression which fits ex-
perimental data best is

\[
\frac{W'}{W} = 1 + \frac{M'(1 - M')}{1 + C}
\]

where \( W' \) is the ratio of the bare charge equivalent weight
to the actual charge weight and \( M \) is the case to charge
weight ratio; \( M' \) is equal to \( \frac{M}{C} \) for all weapons with a metal
weight to charge weight ratio less than one. For all values
of \( M' \) greater than one use \( M' \) equal to one.

All the expressions developed correlate with positive im-
pulse. To obtain results that correlate with peak pressure
the right side of the above formula is multiplied by 1.19.

Explosives Research Department
U.S. NAVAL ORDNANCE LABORATORY
White Oak, Maryland
Up until recently a formula derived shortly after the war by U. Fano of the Ballistic Research Laboratories to predict the effect of the bomb case on air blast has been accepted. Experiments conducted at the Ballistic Research Laboratories and this Laboratory have, within the past year, raised the question as to the applicability of the Fano formula as a means of predicting blast effects for cased charges from data measured on bare charges. Since most explosives comparison work has been done on bare charges, the implications of the failure of this formula are extremely important.

The work described in this report, although not completed, presents revised equations based on both experimental and theoretical considerations which enable a more reasonable prediction of air blast parameters from steel cased weapons. This work was performed under NOL task Re25-2-1.

The author wishes to acknowledge the work of Martha J. Bengston and Roy W. Huff for their help in analysis and computations.

EDWARD L. WOODYARD
Captain, USN
Commander

PAUL N. FyE
By direction
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Table I. Peak Pressure Data from Steel Cased TNT Weapons

Table II. Positive Impulse Data from Steel Cased TNT Weapons

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THE EFFECT OF THE STEEL CASE ON THE AIR BLAST FROM HIGH EXPLOSIVES

I. INTRODUCTION

1. All weapons when finally used have some kind of a cover or case, if for no other reason than to make shipping and handling of the explosive charge safer and easier. Steel cases are used when greater fragmentation damage is desired. Stiff wooden cases are used when it is necessary that the weapon penetrate the target without breaking up. In all these cases no matter how heavy and strong the case is made, the explosion of the weapon produces air blast. The amount of this air blast should be known for the assessment of the value of the weapon in comparison with others of different design and in the assessment of a weapon's value against a specific target.

2. It is the purpose of this report to revise the formula developed by Pano in reference (a) on the basis of new experimental data and on the basis of a new treatment of old World War II data and some new theoretical ideas on the partition of the energy of detonation between air blast and fragmentation.

II. DERIVATION OF PANO FORMULA AND COMPARISON OF RESULTS WITH EXPERIMENT

3. The Pano formula has been developed by the extension of the work of Gurney, reference (b), who considered the kinetic energy at the time of rupture as being made up of the kinetic energy of the explosion product gases and the kinetic energy of the case. If one considers a unit length of casesd cylindrical charge the kinetic energy relation at the time of rupture can be written down as follows:

$$ E_C = \frac{1}{2} M v^2 + \frac{1}{2} \left( \frac{1}{2} C v^2 \right) $$ (1)
where $E$ is the total kinetic energy per unit weight
$C$ is the weight of charge or weight of gases prior to rupture of case
$M$ is the weight of metal case per unit length of cylindrical case and charge
$V$ is the velocity of fragments at time of rupture.

It is assumed that the distribution of the velocities of the gas molecules at the time of rupture is not uniform, being zero in the center and $V$ at the metal - gas interface. The $1$ in front of the $\left(\frac{1}{2} M V^2\right)$ is used to take this assumption into account. Solving equation (1) for $E$ and substituting fragment velocity data for $V$, Gurney found that $E$ was about 80% of the total detonation energy. By taking the ratio of the kinetic energy of the fragments $\left(\frac{1}{2} M V^2\right)$ to the total kinetic energy, equation (1), Pano obtained the fraction of the total kinetic energy going into the fragments to be

$$\frac{1}{1 + \frac{C}{2 M}}$$

The fraction of the kinetic energy belonging to the gases after the case has burst is thus

$$1 - \frac{1}{1 + \frac{C}{2 M}} = \frac{1}{1 + \frac{2 M}{C}}$$

This was multiplied by $0.8$ to account for the fraction of the total detonation energy belonging to the gases and case as kinetic energy at the time of rupture of the case. The 20% of the total energy remaining in the gases as potential energy plus the amount of kinetic energy remaining in the gases at the time of rupture is probably mostly spent in the formation of the blast.

4. The equivalent bare charge weight, $W'$, relative to the amount of explosive, $W$, in the cased charge was given as

$$\frac{W'}{W} = 0.2 + \frac{0.8}{1 + \frac{2 M}{C}}$$

The above equation herein referred to as Pano's formula was checked roughly in reference (a) by showing that when the distances from all types of bombs are reduced by the cube
root of \( W \), their equivalent bare charge weight, the data fell approximately on a single curve for peak pressure. The same was found to be true for positive impulse data when the positive impulse value as well as the distance was reduced by the cube root of \( W \) in accordance with the scaling laws. This showed that the Fano formula predicted the relative effect of one case with respect to another but failed to show how \( W \) compared with actual bare charge data. The effective bare charge weights predicted by this formula were low by as much as 40 per cent from the subsequently experimentally determined values.

5. From the data taken from the appendix in reference (a) the effective bare charge replacement value, \( W \), Tables I and II, was determined by methods described in detail in reference (a). Primarily these involved the scaling up of the theoretical free air bare charge data for cast TNT given by Kirkwood and Drinkle in reference (d) as corrected for ground reflection by experimental data obtained in the far field region reference (e). From a study of the ERL cased charge experiments the reflection coefficient was determined to be 1.5 (reference (a)). Reflection coefficient is defined as the ratio of the weight of a charge in free air to the weight of a charge fired near a reflecting surface that will give the same air blast effect (peak pressure or positive impulse) at a given distance.

6. From these results the discrepancy between the Fano formula and the experimental work applying the scaling laws can be seen in the following table:

<table>
<thead>
<tr>
<th>( W' ) = 0.2 + \frac{0.8}{1 + \frac{W}{C}} (Fano Formula)</th>
<th>( W' ) Mean ( \frac{W}{C} ) Experimental Work and Scaling Laws</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Cased Bombs</td>
<td>0.74</td>
</tr>
<tr>
<td>General Purpose Bombs</td>
<td>0.58</td>
</tr>
<tr>
<td>Semi Armor Piercing Bombs</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Fano equation (4) is plotted in Fig. 1.

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7. In the Naval Ordnance Laboratory's 100-pound gun tank experiment, reference (a), \( W' \) is calculated to be 0.31
for positive impulse and 1.03 for peak pressure which is close to results of 0.50 for positive impulse and 0.91 for peak pressure as calculated from HX data, see also Tables I and II. This data tends to show the steel case effect for HMX-1 is not far different from TNT loaded weapons.

III. DERIVATION OF NEW FORMULAE AND COMPARISON OF RESULTS WITH EXPERIMENT

8. An equation was developed for \( W' \) resulting in close agreement with experiment by making the reasonable assumption that nearly all the gas molecules at the time of rupture of the case travel in a cylindrical shell with a velocity \( V \) equal to the freon velocity. When this assumption was put into equation (1) the kinetic energy equation at the time of rupture becomes

\[
EC = \frac{1}{2} MV^2 + \frac{1}{2} CV^2
\]

(5)

which yielded a \( \frac{W'}{W} \) bar charge equivalent to actual charge weight ratio of

\[
\frac{W'}{W} = 0.2 + 0.3 \frac{1}{1 + \delta}
\]

(6)

This equation improves the agreement with experiment as shown in the table below.

<table>
<thead>
<tr>
<th>( \frac{W'}{W} )</th>
<th>( \frac{W'}{W} )</th>
<th>Mean ( \frac{W'}{W} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda ) 0.2 + 0.3 ( \frac{1}{1 + \delta} )</td>
<td>Experimental work and scaling laws</td>
<td></td>
</tr>
</tbody>
</table>

| Light Cased Bombs | 0.85 | 1.99 |
| General Purpose Bombs | 0.74 | 0.91 |
| Steel Armor Piercing Bombs | 0.50 | 0.53 |
|                |      |      |
Equation (6) is plotted on Fig. 1.

9. It has been possible to recalculate, $E$, in equation (5) by making use of the following recent fragmentation data informally supplied by A. D. Salom of the Detonation Division, Explosives Research Department of this Laboratory:

- Fracture Velocity, $V = 3678$ ft/sec.
- Charge-to-Crew Weight Ratio, $C = 0.358$.
- Total Detonation Energy (Cased TNT) = 1050 cal/cm.

The calculation gives a value for $E$, total kinetic energy of the fragments and explosion products at the time of rupture, of 569 calories per gram, or 53 per cent of the total detonation energy. If this factor of 53 per cent is used in equation (6) it becomes:

$$W' = 0.47 + 0.53 \frac{1 + C}{1 + C}$$

(Equation (7))

The agreement of equation (7) with experimental results is shown below:

<table>
<thead>
<tr>
<th>Type</th>
<th>$W' = 0.47 + 0.53 \frac{1 + C}{1 + C}$</th>
<th>Mean $\frac{W'}{W}$</th>
<th>Experimental Work and Scaling Laws</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud</td>
<td>0.90</td>
<td>1.09</td>
<td>Peak Pressure</td>
</tr>
<tr>
<td>Bomb</td>
<td>0.94</td>
<td></td>
<td>Positive Impulse</td>
</tr>
<tr>
<td>General</td>
<td>0.81</td>
<td>0.91</td>
<td>Peak Pressure</td>
</tr>
<tr>
<td>Purpose</td>
<td>0.80</td>
<td></td>
<td>Positive Impulse</td>
</tr>
<tr>
<td>Horns</td>
<td>0.67</td>
<td>0.53</td>
<td>Peak Pressure</td>
</tr>
<tr>
<td>Semi</td>
<td>0.45</td>
<td></td>
<td>Positive Impulse</td>
</tr>
<tr>
<td>Armor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piercing</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Equation (7) is plotted in Fig. 1.

10. An empirical formula that fits experimental impulse data closely is as follows:

$$W' = \frac{1 + \frac{M}{C}(1 - M')}{1 + \frac{M}{C}}$$

(Equation (8))
$M$ is equal to $\frac{M}{C}$ for all weapons with a metal weight-to-charge weight ratio less than one. For all values of $\frac{M}{C}$ greater than one use $M'$ equal to one. For example, $M'$ is equal to 0.23 for light cased weapons and one for semi armor piercing weapons. Multiply equation (8) by 1.19 to obtain $\frac{W'}{W}$ for peak pressure. This in essence implies that the percentage of detonation energy converted into kinetic energy is directly proportional to the percentage of metal weight up to a case having an $\frac{M}{C}$ ratio of one or greater.

The table below shows the agreement of equation (8) with the values obtained from experiment and the scaling laws.

<table>
<thead>
<tr>
<th>$\frac{W'}{W}$</th>
<th>Mean $\frac{W'}{W}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment Work and Scaling Laws</td>
<td></td>
</tr>
<tr>
<td>Light Cased</td>
<td>1.14</td>
</tr>
<tr>
<td>Bombs</td>
<td>0.95</td>
</tr>
<tr>
<td>General Purpose Bombs</td>
<td>0.95</td>
</tr>
<tr>
<td>Light Armor Piercing Bombs</td>
<td>0.46</td>
</tr>
<tr>
<td>Bombs</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Equation (3) is plotted on Fig. 1 showing the difference between it and the Fano equation.

11. Figures 2, 3, 4, and 5 are plots of peak pressure vs reduced radial distance in which the bomb data tabulated in Table I is compared with bare charge data. The source of this bare charge data is mentioned earlier in this report. The bomb data has been scaled by using the cube root of the effective bare charge weight as calculated from the four equations discussed in this report. As can be seen from the graphs the bomb peak pressure data scales poorly for all equations except equation (8) as modified by the factor 1.19 for peak pressure. Figures 6, 7, 8, and 9 are plots of reduced positive impulse vs reduced radial distance in which the bomb data tabulated in Table II are compared with experimental bare charge data. The bomb data has been scaled by use of the cube root of the effective bare charge weight as calculated by the four equations discussed in this report. The bomb positive impulse data scales well for all equations except the Fano equation, Fig. 6 as can be seen from the graphs.
IV. CONCLUSIONS

12. It is concluded that the formulae developed from kinetic energy considerations at the time of rupture correlate best with positive impulse data. Therefore to predict positive impulse results the new formulae developed in this report can be used without modification. The experimental data indicate that to predict peak pressure results the formulae should be multiplied by the factor 1.19.

13. The table below shows the formulae to use that best agree with experimental work and scaling law results for predicting $W'$. 

<table>
<thead>
<tr>
<th>Case Type</th>
<th>*Light Case</th>
<th>*General Purpose</th>
<th>*Semi Armor Piercing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Impulse</td>
<td>$W' = \frac{W}{1 + \frac{M}{C}} \left(1 - M'\right)$</td>
<td>$W' = \frac{W}{1 + \frac{M}{C}} \left(1 - M'\right)$</td>
<td>$W' = 0.2 + \frac{0.8}{1 + \frac{M}{C}}$</td>
</tr>
<tr>
<td>Peak Pressure</td>
<td>$W = \frac{W}{1.19 \left[1 + \frac{M}{C}\right]}$</td>
<td>$W = \frac{W}{1.19 \left[1 + \frac{M}{C}\right]}$</td>
<td>$W = 1.19 \left[0.2 + \frac{0.9}{1 + \frac{M}{C}}\right]$</td>
</tr>
</tbody>
</table>

* Refers to the charge to total weight ratio in the regions of the present type weapons described by light case, general purpose and semi armor piercing.
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REFERENCES


(b) Initial Velocities of Fragments of Rounds, Shells and Grenades; R. W. Gurney, ERL Report 405.

(c) NAVORD Report 2778 - Air Blast effectiveness of "100-pound" General Purpose Steel Cased Bomb as Measured by Piezoelectric and Indenter Gages; Robert R. Garorok, Confidential.

(d) Theoretical Blast Wave Curves for Cast TNT; Kirkwood and Brinkley, OSRD 5401, Confidential.

(e) NAVORD Report 2123 - Experimental Shock Wave Reflection Studies with Several Different Reflecting Surfaces; E. M. Fisher, Confidential.
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TABLE I

Peak Pressure Data From Steel Cased TNT Weapons

<table>
<thead>
<tr>
<th>Weapon Description</th>
<th>Peak Pressure (psi)</th>
<th>Distance (ft)</th>
<th>C/A</th>
<th>Actual Effective Weight of TNT</th>
<th>Weight of TNT (W)</th>
<th>W'</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000 lb GC Bomb</td>
<td>2.95</td>
<td>354</td>
<td>0.82</td>
<td>7050</td>
<td>6300</td>
<td>0.89</td>
</tr>
<tr>
<td>4,000 lb GC Bomb</td>
<td>2.15</td>
<td>300</td>
<td>0.82</td>
<td>3362</td>
<td>3130</td>
<td>1.02</td>
</tr>
<tr>
<td>4,000 lb GC Bomb</td>
<td>6.23</td>
<td>211</td>
<td>0.82</td>
<td>3362</td>
<td>3130</td>
<td>1.27</td>
</tr>
<tr>
<td>4,000 lb GC Bomb</td>
<td>3.09</td>
<td>220</td>
<td>0.82</td>
<td>3362</td>
<td>3130</td>
<td>0.96</td>
</tr>
<tr>
<td>MK 6 Depth Charge</td>
<td>16.30</td>
<td>60</td>
<td>0.77</td>
<td>300</td>
<td>447</td>
<td>1.49</td>
</tr>
<tr>
<td>MK 6 Depth Charge</td>
<td>6.23</td>
<td>90</td>
<td>0.77</td>
<td>300</td>
<td>331</td>
<td>1.10</td>
</tr>
<tr>
<td>MK 6 Depth Charge</td>
<td>3.10</td>
<td>130</td>
<td>0.77</td>
<td>300</td>
<td>271</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Mean | 1.09

1,000 lb GP Bomb | 2.94                | 204.8         | 0.64| 1117                          | 940               | 0.84|
2,000 lb GP Bomb | 2.27                | 242.8         | 0.64| 1117                          | 895               | 0.80|
1,000 lb GP Bomb | 3.97                | 165.0         | 0.64| 1117                          | 869               | 0.78|
500 lb GP Bomb | 2.59                | 165.0         | 0.64| 1117                          | 558               | 0.94|
500 lb GP Bomb | 3.66                | 129.7         | 0.65| 267                           | 265               | 0.99|
500 lb GP Bomb | 1.82                | 167.3         | 0.65| 267                           | 151               | 0.57|
500 lb GP Bomb | 12.94               | 59.7          | 0.65| 267                           | 312               | 1.17|
500 lb GP Bomb | 5.87                | 89.3          | 0.65| 267                           | 298               | 1.11|
500 lb GP Bomb | 3.01                | 129.6         | 0.65| 267                           | 257               | 0.96|
100 lb GP Bomb | 3.23                | 76.3          | 0.65| 55                            | 48.8              | 1.07|
100 lb GP Bomb | 2.02                | 97.9          | 0.65| 55                            | 45.7              | 0.79|

Mean | 0.91

2,000 lb SAP Bomb | 2.18                | 166.2         | 0.36| 556                           | 262               | 0.87|
1,000 lb SAP Bomb | 2.22                | 136.5         | 0.38| 320                           | 148               | 0.46|
500 lb SAP Bomb | 2.55                | 168.4         | 0.38| 161                           | 105               | 0.65|

Mean | 0.53

Note: All weapons fired slightly above ground to avoid cratering.
C/A charge to weight ratio of cylindrical section of weapon.
W' is calculated by scaling up bare charge data.
Peak Pressure values are averages of a number of trials.
<table>
<thead>
<tr>
<th>Weapon Description</th>
<th>Positive Impulse (ft-lb)</th>
<th>Distance (ft)</th>
<th>C/W</th>
<th>Actual Effective Weight Bare Charge of TNT Weight TNT W'</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000 lb LC Bomb</td>
<td>78.2</td>
<td>334</td>
<td>0.82</td>
<td>7030 6490 0.92</td>
</tr>
<tr>
<td>4,000 lb LC Bomb</td>
<td>56.1</td>
<td>100</td>
<td>0.82</td>
<td>3542 2760 0.82</td>
</tr>
<tr>
<td>4,000 lb LC Bomb</td>
<td>120.4</td>
<td>151.3</td>
<td>0.82</td>
<td>3542 3976 1.18</td>
</tr>
<tr>
<td>4,000 lb LC Bomb</td>
<td>62.2</td>
<td>350</td>
<td>0.82</td>
<td>3542 3180 0.95</td>
</tr>
<tr>
<td>4,000 lb LC Bomb</td>
<td>119.7</td>
<td>149.8</td>
<td>0.82</td>
<td>3542 3835 1.14</td>
</tr>
<tr>
<td>MK 6 Depth Charge</td>
<td>43.9</td>
<td>60.0</td>
<td>0.77</td>
<td>300 262 0.71</td>
</tr>
<tr>
<td>MK 6 Depth Charge</td>
<td>23.6</td>
<td>129.6</td>
<td>0.77</td>
<td>300 213 0.71</td>
</tr>
<tr>
<td>2,000 lb GP Bomb</td>
<td>32.66</td>
<td>204.8</td>
<td>0.64</td>
<td>1117 688 0.62</td>
</tr>
<tr>
<td>2,000 lb GP Bomb</td>
<td>59.05</td>
<td>79.5</td>
<td>0.64</td>
<td>1117 906 0.89</td>
</tr>
<tr>
<td>2,000 lb GP Bomb</td>
<td>59.62</td>
<td>120.0</td>
<td>0.64</td>
<td>1117 846 0.76</td>
</tr>
<tr>
<td>2,000 lb GP Bomb</td>
<td>23.2</td>
<td>165.7</td>
<td>0.65</td>
<td>598 394 0.71</td>
</tr>
<tr>
<td>2,000 lb GP Bomb</td>
<td>23.2</td>
<td>165.7</td>
<td>0.65</td>
<td>598 232 0.77</td>
</tr>
<tr>
<td>500 lb GP Bomb</td>
<td>49.17</td>
<td>59.7</td>
<td>0.65</td>
<td>283 264 0.83</td>
</tr>
<tr>
<td>500 lb GP Bomb</td>
<td>50.05</td>
<td>129.7</td>
<td>0.65</td>
<td>267 168 0.83</td>
</tr>
<tr>
<td>100 lb GP Bomb</td>
<td>16.03</td>
<td>76.4</td>
<td>0.65</td>
<td>53 52.5 0.96</td>
</tr>
<tr>
<td>2,000 lb SAP Bomb</td>
<td>20.12</td>
<td>163.2</td>
<td>0.35</td>
<td>556 228 0.81</td>
</tr>
<tr>
<td>2,000 lb SAP Bomb</td>
<td>11.93</td>
<td>297.2</td>
<td>0.35</td>
<td>556 270 0.45</td>
</tr>
</tbody>
</table>

Note: All weapons fired slightly above ground to avoid cratering. C/W charge to weight ratio of cylindrical section of weapon. W' is calculated by scaling up bare charge data. Positive impulse is an average of a number of trials.
FIG. 1
COMPARISON OF EQUATIONS FOR FINDING THE EFFECTIVE BARE CHARGE WEIGHT OF A STEEL CASED WEAPON

\[
W' = 0.47 + 0.53 \frac{M}{1 + M/C}
\]

\[
W' = 0.20 + 0.80 \frac{M}{1 + M/C}
\]

\[
W = 1 + \frac{M}{C} \left(1 - M^2\right)
\]

\[
W = \frac{1}{1 + \frac{2M}{C}}
\]
FIG. 2
PEAK PRESSURE VS REDUCED RADIAL DISTANCE
FOR CAST TNT IN FAR MACH REGION

PEAK PRESSURE (PSI)

REDUCED RADIAL DISTANCE R/W^1/3 (FT/LB^3)

W' FOR STEEL CASED WEAPONS
DETERMINED BY FANO EQUATION

W' = 0.2 + 0.8

C

O LG BOMBS
+ GP BOMBS
X SAP BOMBS

EXP BARE CHG. DATA
REFLECTION COEFFICIENT = 1.8
FIG. 3
PEAK PRESSURE VS REDUCED RADIAL DISTANCE
FOR CAST TNT IN FAR MACH REGION

\[ \frac{W'}{W} = 0.2 + \frac{0.8}{1 + \frac{M}{c}} \]

- O L.C. BOMB
- + G.P. BOMB
- X S.A.P. BOMB

EXP. BARE CHARGE DATA
REFLECTION COEFFICIENT = 1.8

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FIG. 4
PEAK PRESSURE VS REDUCED RADIAL DISTANCE
FOR CAST TNT IN FAR MACH REGION

\[ \frac{W'}{W} = 0.47 + \frac{0.53}{1 + \frac{M}{C}} \]

O L.C. BOOM
+ G.P. BOMB
x S.A.P. BOMB

EXP. BARE CHARGE DATA

PEAK PRESSURE (PSI)

REDUCED RADIAL DISTANCE \( \frac{R}{W^{1/3}} \) (FT/DL^{1/3})
FIG. 5
PEAK PRESSURE VS REDUCED RADIAL DISTANCE
FOR CAST TNT IN FAR MACH REGION

W1 FOR STEEL CASED WEAPONS DETERMINED BY THE FOLLOWING EQUATION:

\[ \frac{W'}{W} = \left( \frac{1 + \frac{M}{1 - M}}{1 + M} \right)^{1.19} \]

○ L.C. BOMB
+ G.P. BOMB
× S.A.R. BOMB

EXP BARE CHARGE DATA

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FIG. 6
REDUCED POSITIVE IMPULSE VS REDUCED RADIAL DISTANCE FOR CAST TNT IN FAR MACH REGION

\[ W = \frac{0.2 + 0.8}{1 + 2M} \]

O-LC BOMB
+G P BOMB
X-SAH BOMB
EXP. BARE CHARGE DATA
REFLECTION COEFFICIENT = 1.8
FIG. 7
REDUCED POSITIVE IMPULSE VS REDUCED RADIAL DISTANCE FOR CAST TNT IN FAR MACH REGION

W' FOR STEEL CASED WEAPONS DETERMINED BY THE FOLLOWING EQUATION:

\[ \frac{W'}{W} = 0.20 + \frac{0.80}{1 + \alpha} \]

- O L.C. BOMB
- + G.P. BOMB
- X S.A.P. BOMB

EXP. BARE CHARGE DATA REFLECTION COEFFICIENT = 1.8

REDUCED POSITIVE IMPULSE \( \frac{T}{W'M} \)

REDUCED RADIAL DISTANCE \( \frac{R}{W'M} \)

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FIG. 8
REDUCED POSITIVE PULSE VS REDUCED RADIAL DISTANCE
FOR CAST TNT IN FAR MACH REGION

$W^1$ FOR STEEL Cased WEAPONS
DETERMINED FROM FOLLOWING
EQUATION: $W^1 = 0.17 + 0.53 \frac{1 + H}{C}$

LC BOMB
PC BOMB
SAP BOMB
EXP. BAR CHARGE DATA
REFLECTION COEFFICIENT = 1.8

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FIG. 9
REDUCED POSITIVE IMPULSE VS REDUCED RADIAL DISTANCE
FOR CAST TNT IN FAR MACH REGION.

W FOR STEEL CASED WEAPONS
DETERMINED FROM FOLLOWING
EQUATION:

\[
W = \frac{t + M}{C} (1 - r^2)
\]

VSAP BOMB
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