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COMPILED FREE-AIR BLAST DATA ON BARE SPHERICAL PENTOLITE

H. J. Goodman

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P. Ann Brown

P. ANN BROWN
Chief, Security Office

BALLISTIC RESEARCH LABORATORIES

REPORT NO. 1092

FEBRUARY 1960

COMPILED FREE-AIR BLAST DATA ON
BARE SPHERICAL PENTOLITE

H. J. Goodman

ORIGINAL REPORTS SECTION
BALLISTIC RESEARCH
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Department of the Army Project No. 5B03-04-002
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ABERDEEN PROVING GROUND, MARYLAND

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BALLISTIC RESEARCH LABORATORIES

REPORT NO. 1092

HJGoodman/sec
Aberdeen Proving Ground, Md.
February 1960

COMPILED FREE-AIR BLAST DATA ON
BARE SPHERICAL PENTOLITE

ABSTRACT

Free-air blast parameters (peak pressure, positive impulse and positive duration) from the detonation of spherical 50/50 Pentolite charges fired at sea level conditions have been compiled. Analytic expressions for side-on pressure, side-on positive impulse and normally reflected impulse have been determined by fitting least squares polynomials to the data. The function for side-on pressure extends over all scaled distances where pressure might be of military importance, and is of the asymptotic form given by Kirkwood and Brinkley.

SYMBOLS

R = radial distance from center of explosive (ft).

a = charge radius (ft).

W = explosive weight (lb).

X = $\frac{R}{a}$ (numerical value of scaled distance in charge radii).

Z = $\frac{R}{W^{1/3}}$ = scaled distance.
 = 0.1323 X ft/lb^{1/3}.

p = total peak pressure (psi).

p₀ = ambient sea level pressure.

P = p - p₀ = excess pressure (psi).

y = $\frac{P}{p_0}$ = excess pressure ratio.

I = $\int_t^{t+\Delta t} (p - p_0) dt$ = positive impulse (psi msec).

t = time of arrival of shock front (reported in milliseconds).

Δt = positive duration (reported in milliseconds).

c₀ = sound velocity at ambient conditions (ft/sec).

U = shock front velocity (ft/sec).

M = $\frac{U}{c_0}$ = Mach number of shock front.

N = number of observations.

σ = standard deviation of individual measurement.

$\bar{\sigma}$ = standard deviation of mean.

ln = natural logarithm.

INTRODUCTION

Spherical 50/50 Pentolite charges are commonly used as standards in air shock measurements because of the reproducibility of results with this explosive. This report collects available unclassified air shock data, excepting measurements reported before 1945. Earlier measurements are omitted because of improvements in measuring techniques which have been made since 1945 and because so many of the early experiments were carried out under hurried wartime conditions. The consistency of the measurements of peak pressure and of reflected impulse made by widely different techniques is better than the original reports suggest and warrant fitting equations to the results so that smoothed average values would be available for test of instrumentation, planning of experiments, etc. However, side-on impulse and duration measurements are less satisfactory.

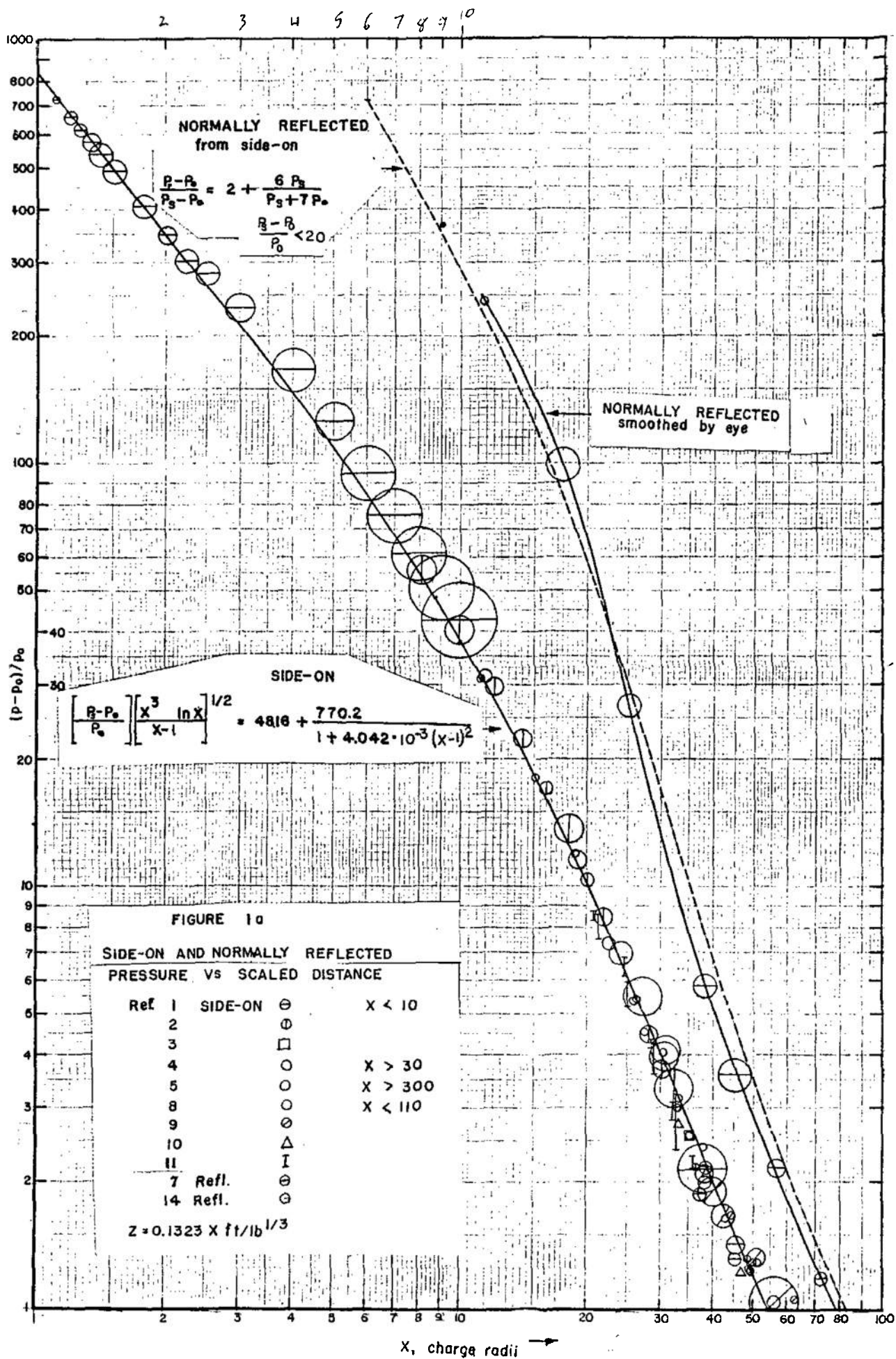
Existing data did not adequately determine the slope of the pressure-distance curve at long distances. Therefore, some new measurements made at pressures lower than those of military interest are reported here. In the region between the charge surface and a scaled distance of $1.5 \text{ ft/lb}^{1/3}$, peak pressure and reflected impulse data are each from a single source; however, the optical and mechanical methods used in this range of data give results which extrapolate well to piezoelectric gage results.

For planning of experiments the time of arrival of a shock is also of interest. Therefore, this parameter was computed and reported with the data, as well as the slope of the peak pressure-distance curve.

COMPILATION OF DATA

Collected data on the more commonly reported parameters are given in Figures 1 - 4 and the tables of the Appendix. The height of each symbol is approximately 3σ except where a larger size is required for visibility. The authors, with the exception of Sultanoff and McVey^{1,2*}, reported standard deviations of their data. The present report estimates the standard deviations of the data of Sultanoff and McVey by averaging data at the same scaled distance over the charge weights used and then computing the standard deviation of the individual from this average. Stoner and Bleakney³ report the standard deviation of their pressure-distance curve. Three peak pressures were computed from their reported formula. Curtis⁴ reports the deviation of the mean for each charge weight and distance. All other authors report the standard deviation of the individual, computed in the same way. The use of only three points from the work of Stoner and Bleakney may appear to give little weight to their extensive measurements. However, the high weight given these points by using the error of the curve at least partially compensates for this. The standard deviation of a measurement in their work was about the same as in most others. Curtis's work is overweighted, but this is of little importance in view of the large number of measurements from other sources. In any case, the information given in reports is not sufficient to make new estimates of error, on a comparable basis, possible. The agreement between optical and gage data is better than would be expected, since measured charge radii are used in reporting optical data while weights only are given in reporting gage data. Thus the effect of detonator wells, explosive density, booster used, etc., on scaling of distance differs. Unpublished data are also reported. Most of these were obtained as control rounds in comparisons of explosives. A few measurements at large distances from the charge were made by Johnson and Schlueter⁵ for this compilation. Atlantic pencil gages⁶ were used because a high sensitivity

* Superscripts refer to references listed at end of report.



X, charge radii

FIGURE 1b

SIDE-ON AND NORMALLY REFLECTED
PRESSURE Vs SCALED DISTANCE
(contd.)

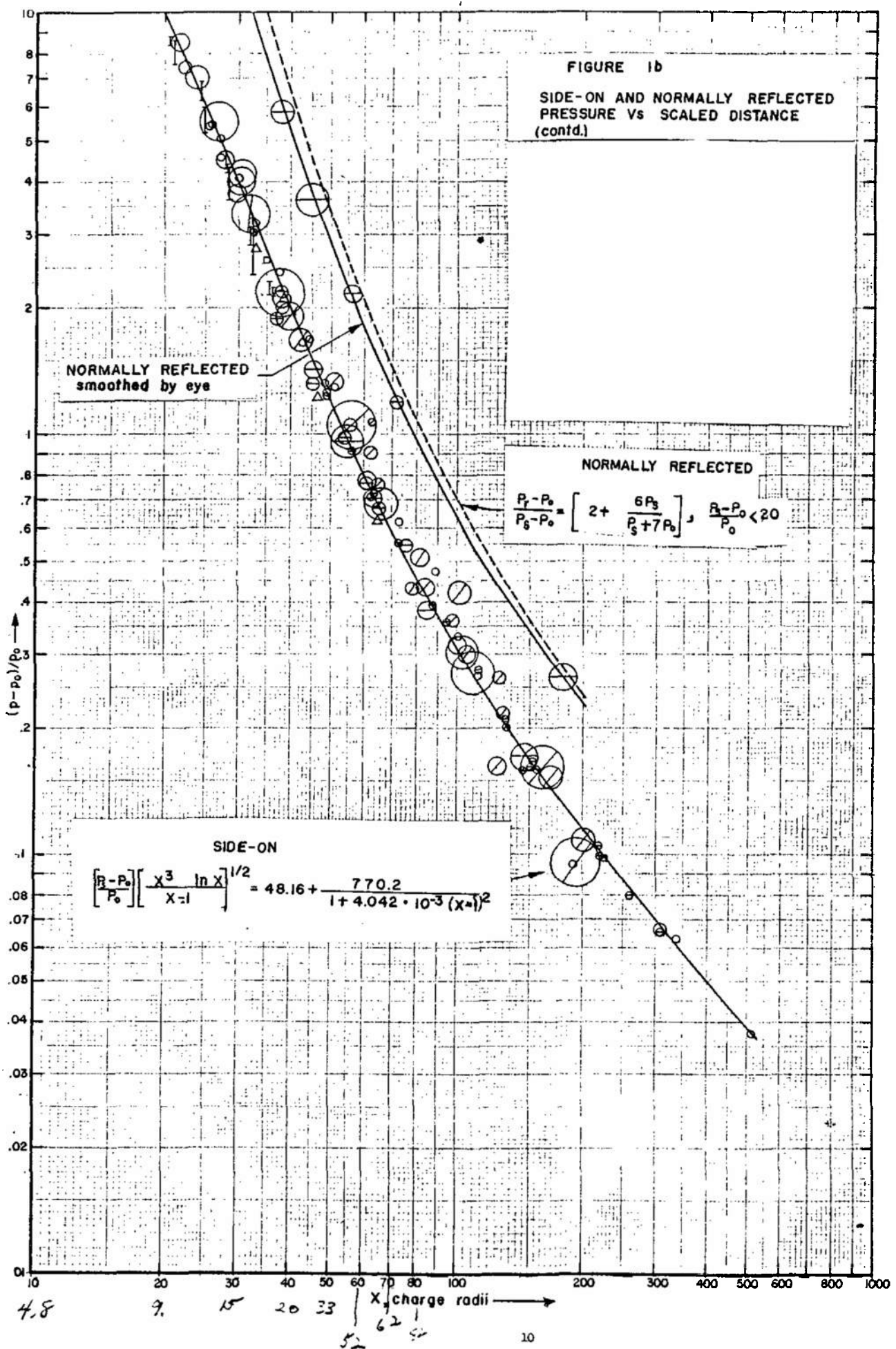
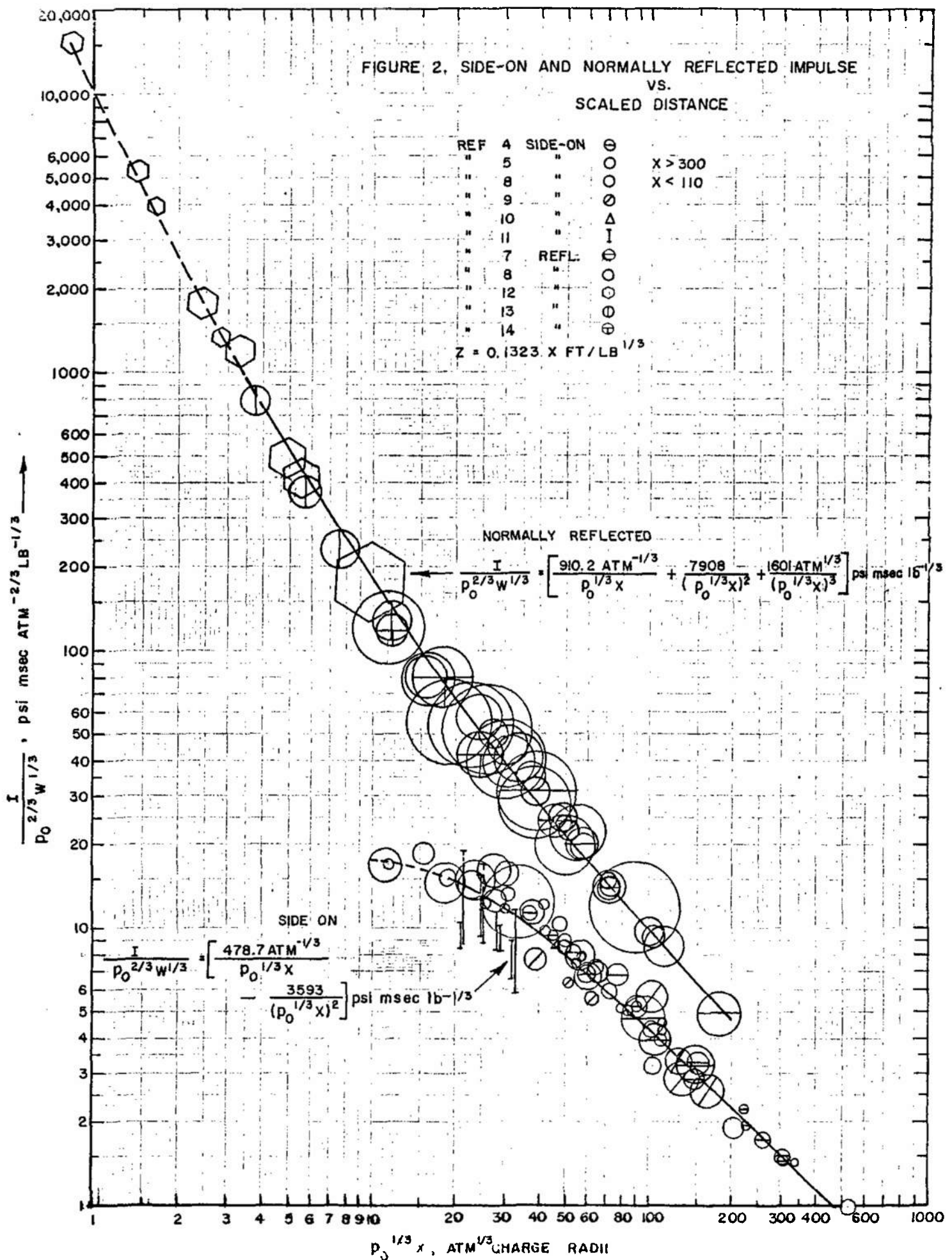
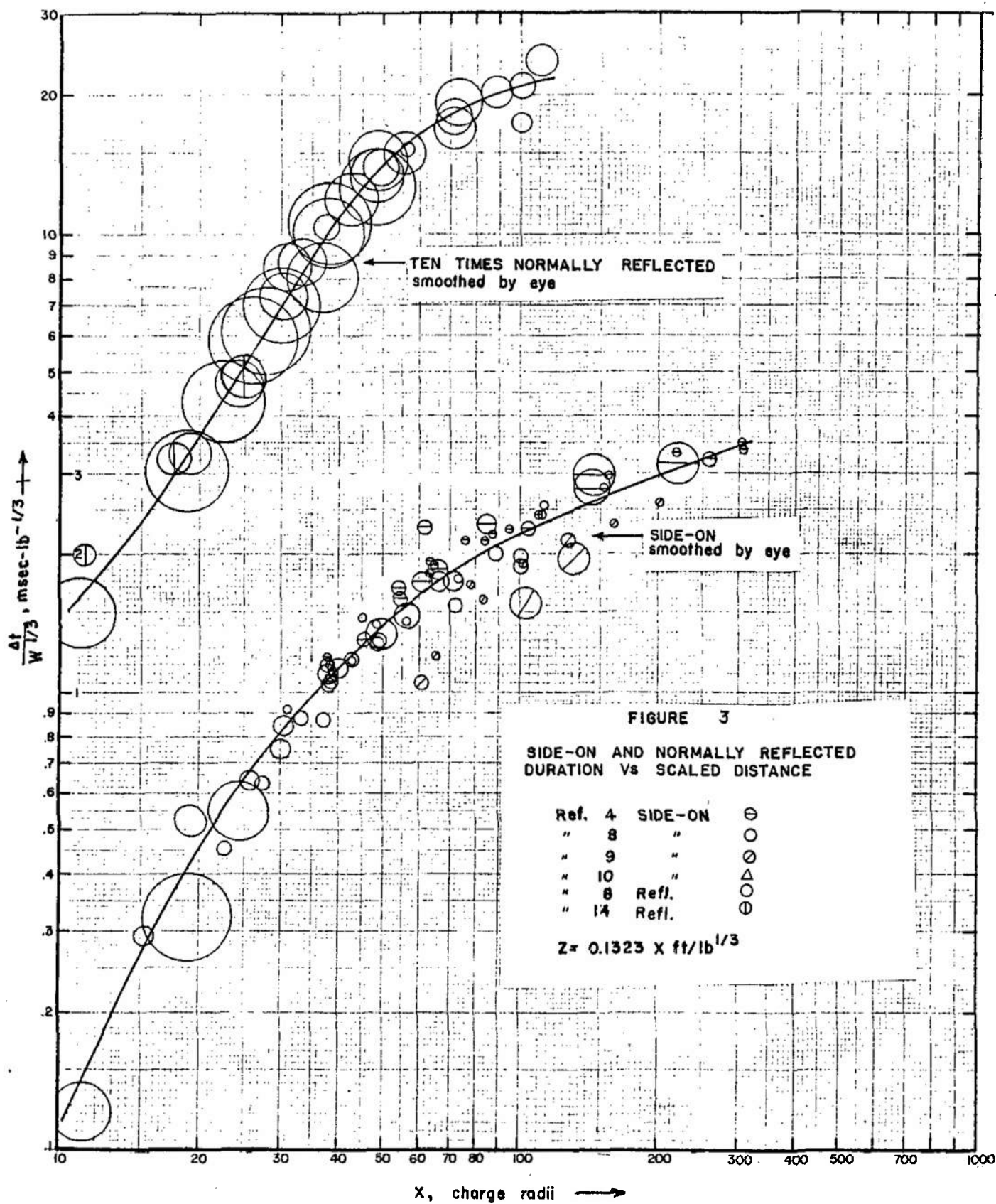
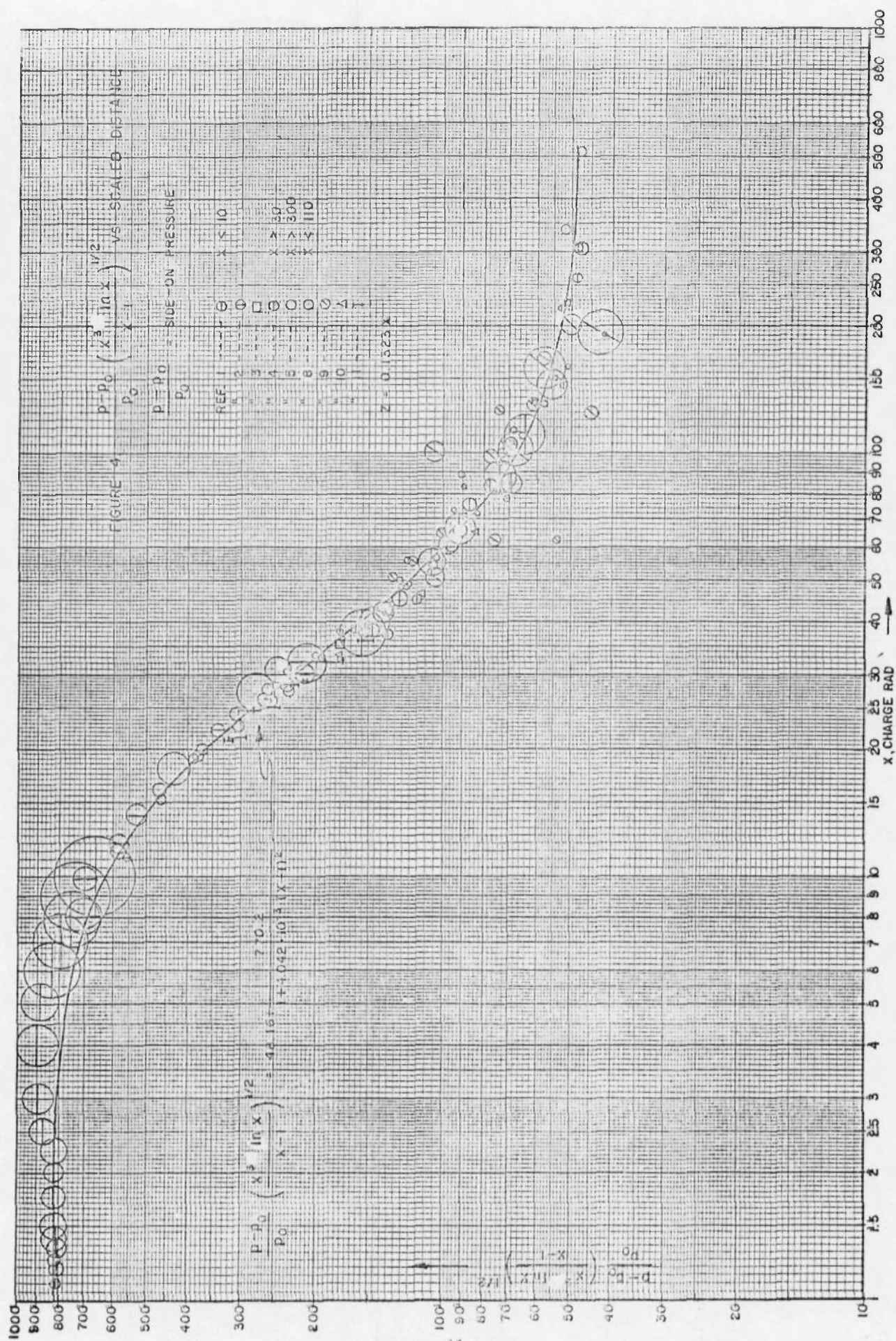


FIGURE 2. SIDE-ON AND NORMALLY REFLECTED IMPULSE
VS.
SCALED DISTANCE







was needed. The relatively poor aerodynamic form of these gages is unimportant at these low pressures. These side-on pressure measurements are shown in Figures 1a, 1b and 4 and tabulated in Table I of the Appendix.

The number of actual measurements of normally reflected pressure⁷ is small, but Mills and Hoffman⁸ have computed a considerable number of reflected pressures from their measured side-on pressures. However, only those reflected pressures which were actually measured are tabulated in Table II of the Appendix.

Mills and Hoffman⁸ made a large number of measurements of side-on positive impulse at distances of 1.48 ft/lb^{1/3} to 14.81 ft/lb^{1/3}. These, along with other available side-on impulse measurements^{9,10,11} are shown in Figure 2 and Table I of the Appendix.

No measurements of normally reflected impulse at distances less than 3.8 charge radii have been reported. Measurements at ambient atmospheric pressures simulating altitudes up to 100,000 feet have been made by Olson, Patterson, and Williams¹² by a mechanical gage, giving higher precision than is obtainable with piezoelectric gages. They have been scaled by Sachs's^{9a} scaling law and combined with sea level measurements^{8,13}.

However, Sachs's scaling is most improbable at the charge surface, since there the peak pressure ratio (p/p_o) is independent of ambient pressure except as the equation of state of air may be changed.¹⁷ It gives the same reflected impulse as the well-founded assumption p/p_o independent of p_o . For, from Sachs's scaling of the data used in Figure 2, we have close to the charge the approximate relation,

$$\frac{I}{W^{1/3} p_o^{2/3}} \approx \frac{AW^{2/3}}{R^2 p_o^{2/3}},$$

or I independent of p_o and varying inversely with the area of the shock front.

From p/p_0 independent of p_0 at shock formation it follows that the material velocity and density of the explosion products are also independent of p_0 . Since the contribution of static impulse to dynamic impulse is negligible close to the charge (Figure 2), the reflected impulse is determined by the outward flow of explosion products until the separation of shock front and contact surface is great enough to include a significant mass of air. Thus the total momentum of the outward flow changes only slowly, giving a reflected impulse independent of pressure and varying inversely as the area of the shock front. This physical picture of the cause of the observed results is at least more reasonable than the application of Sachs' scaling, with time scaling based on invariance of the velocity of sound in the ambient air, to a positive phase still largely in the explosion.

Other unpublished pressure and impulse data half way between two equal charges have been reported.¹⁴

Available reflected and side-on measurements of duration of the first positive phase are shown in Figure 3 and Tables I and II of the Appendix.

The size of the detonation wells, boosting, etc., are seldom fully reported. As neither ambient pressures or temperatures are commonly stated, all measurements are arbitrarily assumed to have been made at 14.7 psi and 300°K with ambient sound velocity 1139.4 ft/sec. The charge density is assumed to be 1.65 gm/cc.

From p/p_0 independent of p_0 at shock formation it follows that the material velocity and density of the explosion products are also independent of p_0 . Since the contribution of static impulse to dynamic impulse is negligible close to the charge (Figure 2), the reflected impulse is determined by the outward flow of explosion products until the separation of shock front and contact surface is great enough to include a significant mass of air. Thus the total momentum of the outward flow changes only slowly, giving a reflected impulse independent of pressure and varying inversely as the area of the shock front. This physical picture of the cause of the observed results is at least more reasonable than the application of Sachs' scaling, with time scaling based on invariance of the velocity of sound in the ambient air, to a positive phase still largely in the explosion.

Other unpublished pressure and impulse data half way between two equal charges have been reported.¹⁴

Available reflected and side-on measurements of duration of the first positive phase are shown in Figure 5 and Tables I and II of the Appendix.

The size of the detonation wells, boosting, etc., are seldom fully reported. As neither ambient pressures or temperatures are commonly stated, all measurements are arbitrarily assumed to have been made at 14.7 psi and 500°K with ambient sound velocity 1139.4 ft/sec. The charge density is assumed to be 1.65 gm/cc.

DISCUSSION

The excellent agreement between pressure measurements made by various methods suggested that a single formula could be fitted to the whole pressure range which had been studied. Previous investigators^{3,4,9} made least squares fits of the side-on peak pressure data to a polynomial in Z^{-1} . This type of function is an adequate empirical representation for $4 \text{ ft} \left[\frac{\text{atm}}{\text{lb}} \right]^{1/3} \leq P_0^{1/3} Z \leq 30 \text{ ft} \left[\frac{\text{atm}}{\text{lb}} \right]^{1/3}$. However, this type of function will not fit over the entire range that is of military importance. Kirkwood and Brinkley^{15,16,17} showed that the asymptotic form of a formula at large distances should be

$$(1) \quad P = P_1 R^{-1} (\ln R/R_1) - 1/2$$

where P_1 and R_1 are constant. The parameter $yX \left[\frac{X \ln X}{X - 1} \right]^{1/2}$ was calculated (Figure 4) from the experimental data, with the factor $[X/(X - 1)]^{1/2}$ introduced to eliminate the zero value at the charge surface. Although the parameter was chosen to be constant at long distances, it is seen in Figure 4 that it is constant close to the charge, but only approaching an asymptote at the longest distances at which measurements are made. The parameter used has the advantage over fitting the pressure directly of a smaller range, thus improving the fit obtained by minimizing the standard deviation of the regression. One group of pressure measurements made by Sultanoff and McVey² is seen as a bulge in the plotted data of their report as well as here. It may result from their selecting a quadratic distance-time curve thus forcing a linear fit to the velocity. This is equivalent to assuming a pressure distance relation of the form

$$P = c(1 - bR)^2$$

where c and b are constants. Close to the charge, a third order distance-time fit was used.

A simple form of function constant at both short and large distances is $A + B / \left[\text{Polynomial in } (X - 1) \right]$. When such a function was fitted to $yX \left[\frac{X \ln X}{X - 1} \right]^{1/2}$ using all data, the value of A was too large for

consistency with data at large distances, which should determine A.

A weighted fit to data for $1.756 \leq X \leq 512$ of a fifth order polynomial in X^{-1} (significant at the 5% level) was therefore used to determine A. Fixing A, the best expression found was

$$(2) \quad y \, X \left[\frac{X \ln X}{X - 1} \right]^{1/2} = A + \frac{B}{1 + c(X - 1)^2}$$

with the values of the constants

$$A = 48.16 \pm 3.8$$

$$B = 770.2 \pm 3.6$$

$$C = 4.048 \times 10^{-3} \pm 4.8 \times 10^{-5}$$

for $1 \leq X \leq 512$.

The standard deviation of the regression is 10.5. No significant improvement in the fit was obtained by using a larger number of constants. The data were weighted in the usual way in computing the best values of the constants, using the standard deviation reported in Table I of the Appendix.

If the scaled distance is expressed in $\text{ft}/\text{lb}^{1/3}$ instead of charge radii, $Z = 0.1323 \, X \, \text{ft}/\text{lb}^{1/3}$, equation (2) becomes

$$(2a) \quad (p - p_0) \, Z \left[\frac{Z \ln \left(\frac{Z}{a} \right)}{Z - a} \right]^{1/2} = A_1 + \frac{B_1}{1 + C_1(Z - a)^2}$$

where

$$A_1 = 93.66 \, \text{psi} \, \text{ft}/\text{lb}^{1/3}$$

$$B_1 = 1498 \, \text{psi} \, \text{ft}/\text{lb}^{1/3}$$

$$C_1 = 0.2309 \, \text{lb}^{2/3}/\text{ft}^2$$

for $a \leq Z \leq 68 \, \text{ft}/\text{lb}^{1/3}$.

The value of "a" used is $0.1323 \, \text{ft}/\text{lb}^{1/3}$ (explosive density, $1.65 \, \text{gm/cc}$). Peak pressures have been computed from Equation (2) and (2a) and tabulated in Table I. Figures 1a, 1b, and 5 are plots of the tabulated pressures.

TABLE I

Side-On Peak Pressure From Equation 2 and Some Derived Quantities

X Charge radii	Z ft/lb ^{1/3}	$t/\sqrt{Z}$ ^{1/3} msec/lb ^{1/3}	y atm	P - P ₀ psi	dy/dx	M Mach Number
1.000	0.1323	0.000000	818.4	12030	-1023.	25.24
1.005	0.1330	0.000023	813.3	11955	-1011.	25.16
1.010	0.1336	0.000046	808.2	11881	-1000.	25.08
1.015	0.1343	0.000069	803.3	11808	- 988.8	25.00
1.020	0.1349	0.000092	798.4	11736	- 977.8	24.93
1.025	0.1356	0.000116	793.5	11664	- 967.0	24.86
1.030	0.1363	0.000139	788.7	11594	- 956.4	24.78
1.035	0.1369	0.000163	783.9	11524	- 945.9	24.71
1.040	0.1376	0.000186	779.2	11454	- 935.6	24.64
1.045	0.1383	0.000210	774.6	11386	- 925.4	24.57
1.050	0.1389	0.000234	770.0	11318	- 915.4	24.50
1.075	0.1422	0.000353	747.7	10991	- 867.7	24.14
1.100	0.1455	0.000474	726.6	10680	- 823.6	23.79
1.125	0.1488	0.000597	706.5	10385	- 782.6	23.46
1.150	0.1521	0.000722	687.4	10105	- 744.5	23.15
1.175	0.1555	0.000848	669.2	9838	- 709.0	22.85
1.200	0.1588	0.000976	651.9	9583	- 676.0	22.55
1.225	0.1621	0.001105	635.4	9341	- 645.1	22.27
1.250	0.1654	0.001237	619.6	9109	- 616.2	22.00
1.275	0.1687	0.001369	604.6	8888	- 589.2	21.74
1.300	0.1720	0.001504	590.2	8676	- 563.9	21.48
1.325	0.1753	0.001640	576.4	8473	- 540.1	21.23
1.350	0.1786	0.001776	563.2	8278	- 517.7	21.00
1.375	0.1819	0.001959	550.5	8092	- 496.7	20.76
1.400	0.1852	0.002056	538.3	7913	- 476.9	20.53
1.425	0.1885	0.002199	526.6	7742	- 458.2	20.31
1.450	0.1918	0.002342	515.4	7576	- 440.6	20.10
1.475	0.1951	0.002487	504.6	7418	- 423.9	19.89
1.500	0.1985	0.002635	494.2	7265	- 408.2	19.69
1.525	0.2018	0.002782	484.2	7117	- 393.2	19.50
1.550	0.2051	0.002932	474.5	6976	- 379.1	19.31
1.575	0.2084	0.003083	465.2	6839	- 365.7	19.12
1.600	0.2117	0.003235	456.2	6707	- 353.0	18.94
1.625	0.2150	0.003389	447.6	6579	- 340.9	18.76
1.650	0.2183	0.003545	439.2	6456	- 329.4	18.59
1.675	0.2216	0.003702	431.1	6337	- 318.4	18.43
1.700	0.2249	0.003860	423.3	6222	- 308.0	18.26
1.725	0.2282	0.004020	415.7	6111	- 298.1	18.10
1.750	0.2315	0.004180	408.4	6003	- 288.6	17.94
1.775	0.2348	0.004343	401.2	5898	- 279.6	17.79
1.800	0.2381	0.004508	394.4	5797	- 270.9	17.64
1.825	0.2414	0.004672	387.7	5699	- 262.7	17.50
1.850	0.2448	0.004838	381.2	5604	- 254.8	17.36
1.875	0.2481	0.005007	375.0	5512	- 247.3	17.22

TABLE I (Cont'd)

Side-On Peak Pressure From Equation 2 and Some Derived Quantities

X Charge radii	Z ft/lb ^{1/3}	$t/w^{1/3}$ msec/lb ^{1/3}	γ atm	P - P _o psi	dy/dx	M Mach Number
1.900	0.2514	0.005176	368.9	5422	- 240.0	17.08
1.925	0.2547	0.005347	363.0	5336	- 233.1	16.94
1.950	0.2580	0.005519	357.2	5251	- 226.5	16.81
1.975	0.2613	0.005692	351.6	5169	- 220.2	16.68
2.000	0.2646	0.005867	346.2	5089	- 214.0	16.56
2.025	0.2679	0.006042	340.9	5012	- 208.2	16.44
2.050	0.2712	0.006220	335.8	4936	- 202.6	16.32
2.075	0.2745	0.006398	330.8	4863	- 197.2	16.20
2.100	0.2778	0.006578	325.9	4791	- 192.0	16.08
2.125	0.2811	0.006759	321.2	4722	- 187.0	15.96
2.150	0.2844	0.006941	316.6	4654	- 182.2	15.85
2.175	0.2878	0.007126	312.1	4588	- 177.6	15.74
2.200	0.2911	0.007310	307.7	4523	- 173.1	15.64
2.225	0.2944	0.007496	303.4	4460	- 168.8	15.53
2.250	0.2977	0.007684	299.3	4399	- 164.6	15.43
2.275	0.3010	0.007874	295.2	4339	- 160.7	15.32
2.300	0.3043	0.008063	291.2	4281	- 156.8	15.22
2.325	0.3076	0.008254	287.4	4224	- 153.1	15.12
2.350	0.3109	0.008447	283.6	4169	- 149.5	15.02
2.375	0.3142	0.008641	279.9	4114	- 146.0	14.93
2.400	0.3175	0.008836	276.3	4061	- 142.7	14.83
2.425	0.3208	0.009032	272.8	4009	- 139.4	14.74
2.450	0.3241	0.009230	269.3	3959	- 136.3	14.65
2.475	0.3274	0.009428	265.9	3909	- 133.3	14.56
2.500	0.3308	0.009628	262.6	3861	- 130.4	14.47
2.525	0.3341	0.009830	259.4	3813	- 127.5	14.38
2.550	0.3374	0.01003	256.3	3767	- 124.8	14.30
2.575	0.3407	0.01024	253.2	3722	- 122.1	14.22
2.600	0.3440	0.01044	250.2	3677	- 119.5	14.13
2.625	0.3473	0.01065	247.2	3634	- 117.0	14.05
2.650	0.3506	0.01085	244.3	3591	- 114.6	13.96
2.675	0.3539	0.01106	241.5	3550	- 112.3	13.88
2.700	0.3572	0.01127	238.7	3509	- 110.0	13.80
2.725	0.3605	0.01148	236.0	3469	- 107.8	13.73
2.750	0.3638	0.01169	233.3	3430	- 105.6	13.65
2.775	0.3671	0.01191	230.7	3391	- 103.6	13.58
2.800	0.3704	0.01211	228.1	3354	- 101.5	13.50
2.825	0.3737	0.01233	225.6	3317	- 99.57	13.43
2.850	0.3771	0.01255	223.2	3280	- 97.60	13.36
2.875	0.3804	0.01277	220.7	3245	- 95.80	13.29
2.900	0.3837	0.01299	218.4	3210	- 94.00	13.22
2.925	0.3870	0.01321	216.0	3176	- 92.24	13.15
2.950	0.3903	0.01343	213.8	3142	- 90.54	13.08
2.975	0.3936	0.01365	211.5	3109	- 88.88	13.01
3.000	0.3969	0.01388	209.3	3077	- 87.26	12.94
3.025	0.4002	0.01411	207.2	3045	- 85.69	12.8

TABLE I (Cont'd)

Side-On Peak Pressure From Equation 2 and Some Derived Quantities

X Charge radius	Z ft/lb ^{1/3}	$t/w^{1/3}$ msec/lb ^{1/3}	Y atm	P - P _o psi	dy/dx	M Mach Number
1.900	0.2514	0.005176	368.9	5422	- 240.0	17.08
1.925	0.2547	0.005347	363.0	5336	- 233.1	16.94
1.950	0.2580	0.005519	357.2	5251	- 226.5	16.81
1.975	0.2613	0.005692	351.6	5169	- 220.2	16.68
2.000	0.2646	0.005867	346.2	5089	- 214.0	16.56
2.025	0.2679	0.006042	340.9	5012	- 208.2	16.44
2.050	0.2712	0.006220	335.8	4936	- 202.6	16.32
2.075	0.2745	0.006398	330.8	4863	- 197.2	16.20
2.100	0.2778	0.006578	325.9	4791	- 192.0	16.08
2.125	0.2811	0.006759	321.2	4722	- 187.0	15.96
2.150	0.2844	0.006941	316.6	4654	- 182.2	15.85
2.175	0.2878	0.007126	312.1	4588	- 177.6	15.74
2.200	0.2911	0.007310	307.7	4523	- 173.1	15.64
2.225	0.2944	0.007496	303.4	4460	- 168.8	15.53
2.250	0.2977	0.007684	299.3	4399	- 164.6	15.43
2.275	0.3010	0.007874	295.2	4339	- 160.7	15.32
2.300	0.3043	0.008063	291.2	4281	- 156.8	15.22
2.325	0.3076	0.008254	287.4	4224	- 153.1	15.12
2.350	0.3109	0.008447	283.6	4169	- 149.5	15.02
2.375	0.3142	0.008641	279.9	4114	- 146.0	14.93
2.400	0.3175	0.008836	276.3	4061	- 142.7	14.83
2.425	0.3208	0.009032	272.8	4009	- 139.4	14.74
2.450	0.3241	0.009230	269.3	3959	- 136.3	14.65
2.475	0.3274	0.009428	265.9	3909	- 133.3	14.56
2.500	0.3308	0.009628	262.6	3861	- 130.4	14.47
2.525	0.3341	0.009830	259.4	3813	- 127.5	14.38
2.550	0.3374	0.01003	256.3	3767	- 124.8	14.30
2.575	0.3407	0.01024	253.2	3722	- 122.1	14.22
2.600	0.3440	0.01044	250.2	3677	- 119.5	14.13
2.625	0.3473	0.01065	247.2	3634	- 117.0	14.05
2.650	0.3506	0.01085	244.3	3591	- 114.6	13.96
2.675	0.3539	0.01106	241.5	3550	- 112.3	13.88
2.700	0.3572	0.01127	238.7	3509	- 110.0	13.80
2.725	0.3605	0.01148	236.0	3469	- 107.8	13.73
2.750	0.3638	0.01169	233.3	3430	- 105.6	13.65
2.775	0.3671	0.01191	230.7	3391	- 103.6	13.58
2.800	0.3704	0.01211	228.1	3354	- 101.5	13.50
2.825	0.3737	0.01233	225.6	3317	- 99.57	13.43
2.850	0.3771	0.01255	223.2	3280	- 97.60	13.36
2.875	0.3804	0.01277	220.7	3245	- 95.80	13.29
2.900	0.3837	0.01299	218.4	3210	- 94.00	13.22
2.925	0.3870	0.01321	216.0	3176	- 92.24	13.15
2.950	0.3903	0.01343	213.8	3142	- 90.54	13.08
2.975	0.3936	0.01365	211.5	3109	- 88.88	13.01
3.000	0.3969	0.01388	209.3	3077	- 87.26	12.94
3.025	0.4002	0.01411	207.2	3045	- 85.69	12.87

TABLE I (Cont'd)

Side-On Peak Pressure From Equation 2 and Some Derived Quantities

X Charge radii	Z ft/lb ^{1/3}	$t/W^{1/3}$ msec/lb ^{1/3}	Y atm	P - P ₀ psi	dy/dx	M Mach Number
3.050	0.4035	0.01433	205.0	3014	- 84.16	12.81
3.075	0.4068	0.01456	202.9	2983	- 82.67	12.74
3.100	0.4101	0.01478	200.9	2953	- 81.22	12.68
3.125	0.4134	0.01501	198.9	2924	- 79.81	12.62
3.150	0.4167	0.01524	196.9	2895	- 78.43	12.56
3.175	0.4201	0.01548	195.0	2866	- 77.09	12.50
3.200	0.4234	0.01571	193.1	2838	- 75.78	12.44
3.225	0.4267	0.01594	191.2	2810	- 74.51	12.38
3.250	0.4300	0.01617	189.3	2783	- 73.26	12.32
3.275	0.4333	0.01642	187.5	2757	- 72.05	12.26
3.300	0.4366	0.01665	185.7	2730	- 70.87	12.21
3.325	0.4399	0.01689	184.0	2704	- 69.71	12.16
3.350	0.4432	0.01713	182.2	2679	- 68.58	12.10
3.375	0.4465	0.01737	180.6	2654	- 67.48	12.04
3.400	0.4498	0.01761	178.9	2630	- 66.41	11.98
3.425	0.4531	0.01786	177.2	2605	- 65.36	11.91
3.450	0.4564	0.01810	175.6	2582	- 64.34	11.85
3.475	0.4597	0.01834	174.0	2558	- 63.34	11.80
3.500	0.4631	0.01859	172.4	2535	- 62.36	11.75
3.525	0.4664	0.01883	170.9	2512	- 61.40	11.70
3.550	0.4697	0.01909	169.4	2490	- 60.47	11.66
3.575	0.4730	0.01933	167.9	2468	- 59.56	11.61
3.600	0.4763	0.01959	166.4	2446	- 58.67	11.56
3.625	0.4796	0.01984	165.0	2425	- 57.80	11.52
3.650	0.4829	0.02009	163.5	2404	- 56.94	11.47
3.675	0.4862	0.02034	162.1	2383	- 56.11	11.42
3.700	0.4895	0.02060	160.7	2363	- 55.29	11.37
3.725	0.4928	0.02085	159.4	2343	- 54.50	11.32
3.750	0.4961	0.02111	158.0	2323	- 53.71	11.28
3.775	0.4994	0.02136	156.7	2303	- 52.95	11.23
3.800	0.5027	0.02163	155.4	2284	- 52.20	11.18
3.825	0.5060	0.02189	154.1	2265	- 51.49	11.13
3.850	0.5094	0.02215	152.8	2246	- 50.75	11.09
3.875	0.5127	0.02241	151.5	2228	- 50.05	11.05
3.900	0.5160	0.02268	150.3	2209	- 49.36	11.00
3.925	0.5193	0.02294	149.1	2191	- 48.69	10.96
3.950	0.5226	0.02321	147.9	2174	- 48.03	10.92
3.975	0.5259	0.02348	146.7	2156	- 47.38	10.88
4.000	0.5292	0.02374	145.5	2139	- 46.75	10.84
4.025	0.5325	0.02401	144.3	2122	- 46.13	10.80
4.050	0.5358	0.02428	143.2	2105	- 45.52	10.76
4.075	0.5391	0.02455	142.1	2089	- 44.92	10.72
4.100	0.5425	0.02482	141.0	2072	- 44.34	10.67
4.125	0.5457	0.02509	139.9	2056	- 43.76	10.63
4.150	0.5490	0.02536	138.8	2040	- 43.20	10.59
4.175	0.5524	0.02564	137.7	2024	- 42.65	10.55

TABLE I (Cont'd)

Side-On Peak Pressure From Equation 2 and Some Derived Quantities

X Charge radii	Z ft/lb ^{1/3}	$t/W^{1/3}$ msec/lb ^{1/3}	y atm	P - P ₀ psi	dy/dx	M Mach Number
4.200	0.5557	0.02592	136.7	2009	- 42.11	10.51
4.225	0.5590	0.02620	135.6	1994	- 41.58	10.47
4.250	0.5623	0.02647	134.6	1978	- 41.06	10.43
4.275	0.5656	0.02674	133.6	1964	- 40.55	10.39
4.300	0.5689	0.02703	132.6	1949	- 40.05	10.35
4.325	0.5722	0.02731	131.6	1934	- 39.55	10.32
4.350	0.5755	0.02759	130.6	1920	- 39.07	10.28
4.375	0.5788	0.02788	129.6	1906	- 38.60	10.24
4.400	0.5821	0.02816	128.7	1892	- 38.13	10.21
4.425	0.5854	0.02845	127.7	1878	- 37.68	10.17
4.450	0.5887	0.02873	126.8	1864	- 37.23	10.14
4.475	0.5920	0.02902	125.9	1850	- 36.78	10.10
4.500	0.5954	0.02931	125.0	1837	- 36.35	10.07
4.525	0.5986	0.02960	124.1	1824	- 35.93	10.03
4.550	0.6020	0.02989	123.2	1811	- 35.51	9.999
4.575	0.6053	0.03018	122.3	1798	- 35.10	9.965
4.600	0.6086	0.03047	121.4	1785	- 34.70	9.931
4.625	0.6119	0.03076	120.6	1772	- 34.30	9.897
4.650	0.6152	0.03105	119.7	1760	- 33.91	9.862
4.675	0.6185	0.03135	118.9	1748	- 33.53	9.828
4.700	0.6218	0.03164	118.0	1735	- 33.15	9.794
4.725	0.6251	0.03194	117.2	1723	- 32.78	9.760
4.750	0.6284	0.03223	116.4	1711	- 32.42	9.728
4.775	0.6317	0.03254	115.6	1700	- 32.06	9.696
4.800	0.6350	0.03284	114.8	1688	- 31.71	9.664
4.825	0.6383	0.03314	114.0	1676	- 31.36	9.633
4.850	0.6416	0.03344	113.3	1665	- 31.02	9.603
4.875	0.6450	0.03374	112.5	1654	- 30.69	9.572
4.900	0.6483	0.03404	111.7	1643	- 30.36	9.541
4.925	0.6516	0.03435	111.0	1632	- 30.04	9.510
4.950	0.6549	0.03466	110.2	1621	- 29.72	9.479
4.975	0.6582	0.03496	109.5	1610	- 29.40	9.449
5.000	0.6615	0.03528	108.8	1599	- 29.10	9.420
5.100	0.6747	0.03651	106.0	1558	- 27.91	9.304
5.200	0.6880	0.03777	103.2	1518	- 26.80	9.185
5.300	0.7012	0.03904	100.6	1480	- 25.75	9.072
5.400	0.7144	0.04033	98.15	1443	- 24.77	8.969
5.500	0.7276	0.04163	95.74	1407	- 23.84	8.864
5.600	0.7409	0.04295	93.42	1373	- 22.96	8.758
5.700	0.7541	0.04428	91.20	1340	- 22.14	8.658
5.800	0.7673	0.04563	89.05	1309	- 21.36	8.561
5.900	0.7806	0.04699	86.98	1279	- 20.61	8.466
6.000	0.7938	0.04837	84.98	1249	- 19.91	8.372
6.100	0.8070	0.04977	83.05	1221	- 19.25	8.281
6.200	0.8203	0.05117	81.19	1194	- 18.62	8.192
6.300	0.8335	0.05260	79.39	1167	- 18.02	8.105
6.400	0.8467	0.05404	77.65	1142	- 17.45	8.020
6.500	0.8600	0.05550	75.97	1117	- 16.90	7.937
6.600	0.8732	0.05696	74.34	1093	- 16.39	7.855

TABLE I (Cont'd)

Side-On Peak Pressure from Equation 2 and Some Derived Quantities

X Charge radii	Z ft/lb ^{1/3}	t/W ^{1/3} msec/lb ^{1/3}	y atm	P - P ₀ psi	dy/dx	M Mach Number
6.700	0.8864	0.05845	72.76	1070	- 15.89	7.776
6.800	0.8996	0.05995	71.23	1047	- 15.42	7.698
6.900	0.9129	0.06147	69.75	1025	- 14.97	7.621
7.000	0.9261	0.06300	68.32	1004	- 14.54	7.545
7.100	0.9393	0.06455	66.92	983.7	- 14.14	7.471
7.200	0.9526	0.06612	65.57	963.8	- 13.74	7.399
7.300	0.9658	0.06768	64.25	944.5	- 13.37	7.328
7.400	0.9790	0.06927	62.98	925.8	- 13.01	7.258
7.500	0.9923	0.07089	61.74	907.6	- 12.66	7.189
7.600	1.005	0.07251	60.53	889.8	- 12.33	7.121
7.700	1.019	0.07415	59.36	872.6	- 12.02	7.056
7.800	1.032	0.07580	58.22	855.8	- 11.71	6.990
7.900	1.045	0.07747	57.11	839.6	- 11.42	6.926
8.000	1.058	0.07915	56.03	823.7	- 11.14	6.863
8.100	1.072	0.08085	54.98	808.2	- 10.87	6.802
8.200	1.085	0.08257	53.96	793.2	- 10.61	6.742
8.300	1.098	0.08430	52.96	778.5	- 10.36	6.682
8.400	1.111	0.08604	51.99	764.2	- 10.11	6.623
8.500	1.125	0.08780	51.04	750.3	- 9.882	6.565
8.600	1.138	0.08959	50.12	736.8	- 9.657	6.509
8.700	1.151	0.09137	49.22	723.5	- 9.441	6.453
8.800	1.164	0.09318	48.34	710.6	- 9.232	6.398
8.900	1.177	0.09500	47.48	698.0	- 9.030	6.343
9.000	1.191	0.09684	46.65	685.7	- 8.835	6.290
9.100	1.204	0.09870	45.83	673.7	- 8.647	6.238
9.200	1.217	0.1006	45.04	662.0	- 8.465	6.187
9.300	1.230	0.1034	44.26	650.6	- 8.289	6.136
9.400	1.244	0.1040	43.50	639.4	- 8.118	6.086
9.500	1.257	0.1063	42.75	628.5	- 7.953	6.036
9.600	1.270	0.1082	42.03	617.8	- 7.794	5.988
9.700	1.283	0.1101	41.32	607.4	- 7.639	5.940
9.800	1.297	0.1121	40.63	597.2	- 7.489	5.892
9.900	1.310	0.1141	39.95	587.2	- 7.344	5.846
10.00	1.323	0.1161	39.29	577.5	- 7.203	5.800
10.40	1.376	0.1242	36.78	540.6	- 6.679	5.622
10.80	1.429	0.1326	34.48	506.8	- 6.213	5.453
11.20	1.482	0.1412	32.36	475.7	- 5.797	5.291
11.60	1.535	0.1501	30.42	447.1	- 5.422	5.139
12.00	1.588	0.1593	28.62	420.7	- 5.084	4.994
12.40	1.641	0.1687	26.95	396.2	- 4.778	4.856
12.80	1.693	0.1785	25.42	373.6	- 4.499	4.723
13.20	1.746	0.1884	23.99	352.6	- 4.245	4.597
13.60	1.799	0.1987	22.66	333.1	- 4.013	4.477
14.00	1.852	0.2091	21.43	315.0	- 3.799	4.361
14.40	1.905	0.2199	20.28	298.1	- 3.603	4.250
14.80	1.958	0.2311	19.21	282.4	- 3.422	4.145
15.20	2.011	0.2423	18.21	267.7	- 3.254	4.044

TABLE I (Cont'd)

Side-On Peak Pressure from Equation 2 and Some Derived Quantities

X Charge radii	Z ft/lb ^{1/3}	$t/W^{1/3}$ msec/lb ^{1/3}	y atm	P - P ₀ psi	dy/dx	M Mach Number
15.60	2.064	0.2540	17.28	254.0	-	3.098
16.00	2.117	0.2659	16.41	241.2	-	2.954
16.40	2.170	0.2781	15.59	229.2	-	2.819
16.80	2.223	0.2905	14.83	218.0	-	2.694
17.20	2.276	0.3033	14.11	207.5	-	2.577
17.60	2.328	0.3164	13.44	197.6	-	2.467
18.00	2.381	0.3298	12.81	188.3	-	2.364
18.40	2.434	0.3433	12.22	179.6	-	2.268
18.80	2.487	0.3573	11.66	171.4	-	2.177
19.20	2.540	0.3716	11.14	163.7	-	2.091
19.60	2.593	0.3861	10.64	156.4	-	2.011
20.00	2.646	0.4008	10.17	149.6	-	1.935
21.00	2.778	0.4391	9.122	134.1	-	1.762
22.00	2.911	0.4793	8.209	120.7	-	1.612
23.00	3.043	0.5214	7.413	109.0	-	1.479
24.00	3.175	0.5652	6.718	98.75	-	1.362
25.00	3.308	0.6109	6.108	89.78	-	1.258
26.00	3.440	0.6564	5.570	81.88	-	1.165
27.00	3.572	0.7077	5.096	74.90	-	1.082
28.00	3.704	0.7588	4.675	68.72	-	1.007
29.00	3.837	0.8116	4.301	63.72	-	.9398
30.00	3.969	0.8661	3.967	58.32	-	.8787
31.00	4.101	0.9222	3.669	53.93	-	.8233
32.00	4.234	0.9799	3.401	50.00	-	.7728
33.00	4.366	1.039	3.160	46.46	-	.7267
34.00	4.498	1.100	2.943	43.27	-	.6844
35.00	4.631	1.163	2.747	40.38	-	.6457
36.00	4.763	1.227	2.569	37.77	-	.6101
37.00	4.895	1.292	2.408	35.40	-	.5772
38.00	5.027	1.360	2.261	33.23	-	.5469
39.00	5.160	1.428	2.127	31.26	-	.5189
40.00	5.292	1.498	2.004	29.46	-	.4929
41.00	5.424	1.569	1.892	27.81	-	.4687
42.00	5.557	1.642	1.788	26.29	-	.4463
43.00	5.689	1.715	1.694	24.90	-	.4253
44.00	5.821	1.789	1.606	23.61	-	.4058
45.00	5.954	1.866	1.525	22.42	-	.3876
46.00	6.086	1.943	1.451	21.32	-	.3705
47.00	6.218	2.020	1.382	20.31	-	.3545
48.00	6.350	2.099	1.317	19.37	-	.3395
49.00	6.483	2.179	1.258	18.49	-	.3254
50.00	6.615	2.261	1.202	17.67	-	.3122
52.00	6.880	2.426	1.102	16.20	-	.2879
54.00	7.1442	2.594	1.015	14.92	-	.2663
56.00	7.409	2.765	.9385	13.80	-	.2470
58.00	7.673	2.939	.8708	12.80	-	.2297

TABLE I (Cont'd)

Side-On Peak Pressure from Equation 2 and Some Derived Quantities

X Charge radii	Z ft/lb ^{1/3}	$t/w^{1/3}$ msec/lb ^{1/3}	y atm	P - P ₀ psi	dy/dx	M Mach Number
60.00	7.938	3.116	0.8108	11.92	- 0.2142	1.3019
62.00	8.203	3.296	0.7574	11.13	- 0.2001	1.2842
64.00	8.467	3.478	0.7097	10.43	- 0.1873	1.2682
66.00	8.732	3.662	0.6668	9.802	- 0.1757	1.2536
68.00	8.996	3.848	0.6282	9.234	- 0.1651	1.2403
70.00	9.261	4.036	0.5932	8.720	- 0.1554	1.2282
72.00	9.526	4.226	0.5615	8.254	- 0.1466	1.2171
74.00	9.790	4.418	0.5327	7.830	- 0.1384	1.2069
76.00	9.005	4.611	0.5063	7.443	- 0.1310	1.1975
78.00	10.32	4.806	0.4822	7.089	- 0.1240	1.1888
80.00	10.58	5.002	0.4601	6.763	- 0.1177	1.1808
82.00	10.85	5.200	0.4397	6.463	- 0.1118	1.1734
84.00	11.11	5.398	0.4209	6.187	- 0.1063	1.1665
86.00	11.38	5.597	0.4035	5.931	- 0.1012	1.1601
88.00	11.64	5.798	0.3874	5.694	- 0.09642	1.1541
90.00	11.91	6.000	0.3724	5.474	- 0.09199	1.1486
92.00	12.17	6.203	0.3584	5.269	- 0.08786	1.1433
94.00	12.44	6.406	0.3454	5.078	- 0.08400	1.1384
96.00	12.70	6.610	0.3333	4.899	- 0.08038	1.1339
98.00	12.96	6.816	0.3219	4.732	- 0.07699	1.1296
100.0	13.23	7.021	0.3112	4.575	- 0.07380	1.1255
105.0	13.89	7.539	0.2873	4.223	- 0.06664	1.1164
110.0	14.55	8.062	0.2666	3.919	- 0.06045	1.1084
115.0	15.21	8.587	0.2486	3.655	- 0.05508	1.1014
120.0	15.88	9.115	0.2328	3.422	- 0.05039	1.09524
125.0	16.53	9.647	0.2189	3.217	- 0.04626	1.08977
130.0	17.20	10.18	0.2065	3.035	- 0.04261	1.08488
135.0	17.86	10.72	0.1954	2.872	- 0.03937	1.08049
140.0	18.52	11.25	0.1854	2.725	- 0.03649	1.07652
145.0	19.18	11.80	0.1764	2.592	- 0.03390	1.07292
150.0	19.84	12.33	0.1682	2.472	- 0.03158	1.06964
155.0	20.51	12.88	0.1607	2.362	- 0.02948	1.06664
160.0	21.17	13.42	0.1538	2.262	- 0.02759	1.06389
165.0	21.83	13.97	0.1476	2.169	- 0.02587	1.06136
170.0	22.49	14.51	0.1418	2.084	- 0.02430	1.05901
175.0	23.15	15.07	0.1364	2.005	- 0.02287	1.05684
180.0	23.81	15.62	0.1314	1.932	- 0.02156	1.05483
185.0	24.48	16.16	0.1268	1.864	- 0.02036	1.05295
190.0	25.14	16.72	0.1225	1.801	- 0.01925	1.05119
195.0	25.80	17.28	0.1185	1.742	- 0.01823	1.04955
200.0	26.46	17.82	0.1147	1.686	- 0.01729	1.04801
205.0	27.12	18.38	0.1112	1.634	- 0.01642	1.04656
210.0	27.78	18.94	0.1078	1.586	- 0.01562	1.04520
215.0	28.44	19.70	0.1047	1.539	- 0.01487	1.04392
220.0	29.11	20.05	0.1018	1.496	- 0.01417	1.04270
225.0	29.77	20.61	0.09897	1.455	- 0.01352	1.04155

TABLE I (Cont'd)

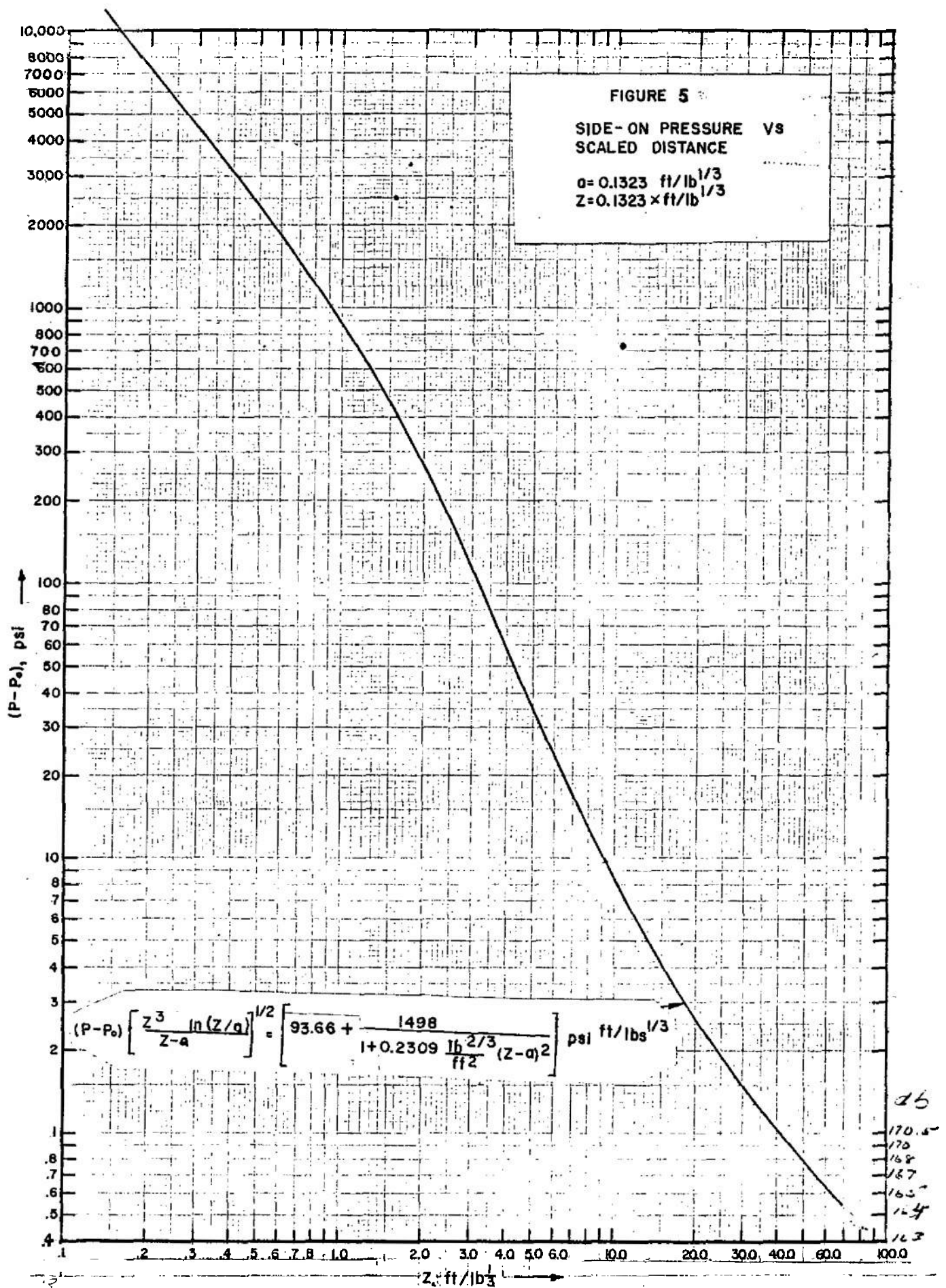
Side-On Peak Pressure from Equation 2 and Some Derived Quantities

X Charge radii	Z ft/lb ^{1/3}	t/W ^{1/3} msec/lb ^{1/3}	y atm	p - p ₀ psi	dy/dx	M Mach Number
230.0	30.43	21.17	0.09633	1.416	- 0.01291	1.04046
235.0	31.25	21.72	0.09382	1.379	- 0.01234	1.03943
240.0	31.75	22.28	0.09144	1.344	- 0.01181	1.03845
245.0	32.41	22.84	0.08918	1.311	- 0.01131	1.03751
250.0	33.08	23.40	0.08702	1.279	- 0.01085	1.03662
255.0	33.74	23.96	0.08497	1.249	- 0.01041	1.03578
260.0	34.40	24.52	0.08301	1.220	- 0.00999	1.03496
265.0	35.06	25.08	0.08114	1.193	- 0.00960	1.03419
270.0	35.72	25.64	0.07935	1.166	- 0.00924	1.03345
275.0	36.48	26.21	0.07764	1.141	- 0.00889	1.03274
280.0	37.04	26.76	0.07600	1.117	- 0.00856	1.03206
285.0	37.70	27.33	0.07442	1.094	- 0.00825	1.03140
290.0	38.37	27.89	0.07291	1.072	- 0.00796	1.03078
295.0	39.03	28.46	0.07146	1.050	- 0.00768	1.03017
300.0	39.69	29.02	0.07007	1.030	- 0.00741	1.02959
305.0	40.35	29.58	0.06873	1.010	- 0.00716	1.02903
310.0	41.01	30.14	0.06744	.9913	- 0.00692	1.02850
315.0	41.67	30.71	0.06619	.9731	- 0.00669	1.02798
320.0	42.33	31.28	0.06499	.9554	- 0.00648	1.02748
325.0	43.00	31.84	0.06384	.9384	- 0.00627	1.02699
330.0	43.66	32.41	0.06272	.9220	- 0.00608	1.02653
335.0	44.32	32.98	0.06164	.9061	- 0.00589	1.02608
340.0	44.98	33.54	0.06060	.8908	- 0.00571	1.02564
345.0	45.64	34.10	0.05959	.8760	- 0.00554	1.02522
350.0	46.30	34.67	0.05861	.8616	- 0.00537	1.02481
355.0	46.97	35.24	0.05767	.8477	- 0.00522	1.02442
360.0	47.63	35.81	0.05675	.8343	- 0.00507	1.02403
365.0	48.29	36.38	0.05587	.8212	- 0.00492	1.02366
370.0	48.95	36.95	0.05501	.8086	- 0.00479	1.02330
375.0	49.61	37.50	0.05417	.7963	- 0.00465	1.02295
380.0	50.27	38.07	0.05336	.7844	- 0.00453	1.02261
385.0	50.94	38.64	0.05258	.7729	- 0.00441	1.02228
390.0	51.60	39.21	0.05181	.7616	- 0.00429	1.02196
395.0	52.26	39.78	0.05107	.7507	- 0.00418	1.02165
400.0	52.92	40.35	0.05035	.7401	- 0.00407	1.02135
405.0	53.58	40.92	0.04965	.7298	- 0.00396	1.02106
410.0	54.24	41.49	0.04896	.7198	- 0.00386	1.02077
415.0	54.90	42.06	0.04830	.7100	- 0.00377	1.02049
420.0	55.57	42.62	0.04765	.7005	- 0.00367	1.02022
425.0	56.23	43.19	0.04702	.6912	- 0.00359	1.01995
430.0	56.89	43.76	0.04641	.6822	- 0.00350	1.01969
435.0	57.55	44.33	0.04581	.6734	- 0.00342	1.01944
440.0	58.21	44.90	0.04522	.6648	- 0.00334	1.01920
445.0	58.87	45.47	0.04466	.6564	- 0.00326	1.01896
450.0	59.54	46.04	0.04410	.6483	- 0.00318	1.01872

TABLE I (Cont'd)

Side-On Peak Pressure from Equation 2 and Some Derived Quantities

X Charge radii	Z ft/lb ^{1/3}	$t/w^{1/3}$ msec/lb ^{1/3}	y atm	P - P ₀ psi	dy/dx	M Mach Number
455.0	60.20	46.61	0.04356	0.6403	- 0.00311	1.01850
460.0	60.86	47.18	0.04303	0.6325	- 0.00304	1.01827
465.0	61.52	47.74	0.04251	0.6249	- 0.00297	1.01806
470.0	62.18	48.33	0.04201	0.6175	- 0.00291	1.01784
475.0	62.84	48.90	0.04152	0.6103	- 0.00284	1.01764
480.0	63.50	49.46	0.04104	0.6032	- 0.00278	1.01743
485.0	64.17	50.03	0.04056	0.5963	- 0.00272	1.01724
490.0	64.83	50.60	0.04010	0.5895	- 0.00267	1.01704
495.0	65.49	51.17	0.03965	0.5829	- 0.00261	1.01685
500.0	66.15	51.74	0.03921	0.5764	- 0.00256	1.01667
505.0	66.81	52.32	0.03878	0.5701	- 0.00250	1.01648
510.0	67.47	52.89	0.03836	0.5639	- 0.00245	1.01631
515.0	68.13	53.46	0.03795	0.5578	- 0.00240	1.01613
520.0	68.80	54.03	0.03754	0.5519	- 0.00236	1.01596



The slope of the peak pressure-distance relation¹⁹, shock velocity and time of arrival computed from Equation 2 and the Hugoniot Tables of Shear and Day²⁰ are given in Table I. The BKR^{2a} Tables were used by Sultanoff and McVey to determine peak pressure and these pressures were used in obtaining Equation 2. The error introduced in using differing tables is less than one percent, hence no adjustment in these values was made. The pressure, time of arrival and shock velocity are reported in the complete tables of Makino and Shear²¹.

No least square fit was made to the normally reflected peak pressure data as the number of measurements is small. However, two smooth curves have been determined for this parameter as shown in Figures 1a and 1b. One is an eye fit to the data. The other is from the side-on peak pressures of Table I using the relation

$$(3) \quad \frac{P_r}{P_s} = 2 + \frac{6y}{y+7}, \quad y < 20,$$

where P_s is side-on excess peak pressure and P_r is normally reflected peak pressure. For side-on peak pressures over 20 atmospheres, the table of Doering and Burkhardt²² was used. The computed results are included in Table II.

Least square polynomials in Z^{-1} were fitted to the product IZ . The side-on impulse is

$$(4) \quad \frac{I}{p_o^{2/3} w^{1/3}} = \frac{a_1}{p_o^{1/3} Z} + \frac{a_2}{(p_o^{1/3} Z)^2}$$

where

$$a_1 = (63.33 + 1.2) \frac{\text{psi msec}}{\text{atm}^{1/3} \text{ lb}^{2/3} \text{ ft}^{-1}}$$

$$a_2 = (-62.89 + 5.6) \frac{\text{psi msec}}{\text{lb ft}^{-2}} .$$

The standard deviation of the regression is $6.7 \frac{\text{psi msec ft}}{(\text{atm lb})^{2/3}}$ for

$$2.380 \text{ ft} \left[\frac{\text{atm}}{\text{lb}} \right]^{1/3} \leq p_o^{1/3} Z \leq 68 \text{ ft} \left[\frac{\text{atm}}{\text{lb}} \right]^{1/3} . \text{ Values for}$$

$p_o^{1/3} Z < 2.380 \text{ ft} \left[\frac{\text{atm}}{\text{lb}} \right]^{1/3}$ were determined by extending the derived curve by eye through the experimental points. However, these eye fit values cannot be relied on because it is impossible to determine the correct extension of the derived impulse due to the limited number of points in this region.

The fit for the normally reflected impulse is

$$(5) \quad \frac{I}{p_o^{2/3} W^{1/3}} = \frac{b_1}{p_o^{1/3} Z} + \frac{b_2}{(p_o^{1/3} Z)^2} + \frac{b_3}{(p_o^{1/3} Z)^3} ,$$

where

$$b_1 = (120.4 + 3.8) \frac{\text{psi msec}}{\text{atm}^{1/3} \text{ lb}^{2/3} \text{ ft}^{-1}} ,$$

$$b_2 = (138.4 + 5.2) \frac{\text{psi msec}}{\text{lb ft}^{-2}} ,$$

$$b_3 = (3.708 + 0.7) \frac{\text{psi msec}}{\text{atm}^{-1/3} \text{ lb}^{4/3} \text{ ft}^{-3}}$$

and the standard deviation of the regression is $22.1 \frac{\text{psi msec ft}}{[\text{atm lb}]^{2/3}}$ for

$$0.1096 \text{ ft} \left[\frac{\text{atm}}{\text{lb}} \right]^{1/3} \leq p_o^{1/3} Z \leq 23.80 \text{ ft} \left[\frac{\text{atm}}{\text{lb}} \right]^{1/3} . \text{ Values from the}$$

above equations are tabulated in Table II and graphed in Figure 2. All coefficients in the equations are significant at the 5% level.

TABLE II

Side-On Positive Impulse and Positive Duration and Normally
Reflected Pressure, Impulse and Duration

X	$P_o^{1/3}$	Z	$P - P_o$	$I/P_o^{2/3} W^{1/3}$	$\Delta t/W^{1/3}$
Charge radii	ft	$\left[\frac{\text{atm}}{\text{lb}}\right]^{1/3}$	psi	psi msec/atm ^{2/3} lb ^{1/3}	(msec)/(lb ^{1/3})
			reflected	side-on	reflected
0.80	0.1058			16,515	
1.00	0.1323			10,354	
1.50	0.1984			4,569	
2.00	0.2646			2,617	
2.50	0.3308			1,722	
3.00	0.3969			1,235	
3.50	0.4630			938.0	
4.0	0.5292			742.9	
4.5	0.5953			607.2	
5.0	0.6615			508.6	
5.5	0.7276			434.4	
6.0	0.7938			376.9	
6.5	0.8600			331.4	
7.0	0.9261			294.7	
7.5	0.9922			264.5	
8.0	1.084			239.4	
8.5	1.124			218.1	
9.0	1.191			200.0	
9.5	1.256			184.5	
10.0	1.323	4234	17.56	170.9	0.1445
12.0	1.588	2969	17.25	131.1	0.1769
14.0	1.852	2087	16.75	105.5	0.2351
16.0	2.117	1514	16.10	87.81	0.3056
18.0	2.381	1110	15.49	74.95	0.3820
20.0	2.646	824.7	14.93	65.22	0.4580
22.0	2.911	632.1	14.31	57.64	0.5380
24.0	3.175	485.1	13.68	51.57	0.6109
26.0	3.440	379.3	13.07	46.62	0.6837
28.0	3.704	301.4	12.49	42.51	0.7541
30.0	3.969	242.6	11.94	39.04	0.8224
32.0	4.234	200.0	11.42	36.08	0.8884
34.0	4.498	164.6	10.95	33.53	0.9524
36.0	4.763	136.0	10.50	31.31	1.014
38.0	5.027	114.7	10.08	29.35	1.074
40.0	5.292	97.76	9.699	27.62	1.132
42.0	5.557	84.53	9.338	26.08	1.200
44.0	5.821	73.50	9.001	24.70	1.243
46.0	6.086	64.24	8.687	23.46	1.295
48.0	6.350	56.89	8.392	22.33	1.346
50.0	6.615	50.72	8.116	21.31	1.395
52.0	6.880	45.28	7.857	20.37	1.442
54.0	7.144	41.16	7.613	19.51	1.488

TABLE II (Cont'd)

Side-On Positive Impulse and Positive Duration and Normally
Reflected Pressure, Impulse and Duration

X	$P_0^{1/3}$	$P - P_0$	$I/P_0^{2/3} W^{1/3}$	$\Delta t/W^{1/3}$		
Charge radii	ft $\left[\frac{\text{atm}}{\text{lb}} \right]^{1/3}$	psi	psi msec/atm ^{2/3} lb ^{1/3}	reflected	side-on	reflected
56.0	7.409	37.19	7.383	18.72	1.533	1.551
58.0	7.673	34.10	7.166	17.99	1.575	1.598
60.0	7.938	31.31	6.962	17.32	1.616	1.640
62.0	8.203	28.81	6.781	16.69	1.657	1.678
64.0	8.467	26.75	6.585	16.10	1.696	1.712
66.0	8.732	24.70	6.402	15.56	1.733	1.742
68.0	8.996	23.08	6.246	15.05	1.770	1.768
70.0	9.261	21.46	6.089	14.57	1.805	1.790
72.0	9.526	20.29	5.939	14.12	1.839	1.809
74.0	9.790	18.96	5.797	13.70	1.871	1.824
76.0	10.05	17.93	5.661	13.30	1.903	1.846
78.0	10.32	16.90	5.531	12.93	1.934	1.875
80.0	10.58	15.88	5.407	12.57	1.964	1.902
82.0	10.85	15.29	5.289	12.24	1.992	1.929
84.0	11.11	14.41	5.175	11.92	2.020	1.953
86.0	11.38	13.82	5.066	11.62	2.047	1.977
88	11.64	13.16	4.962	11.33	2.073	1.997
90	11.91	12.50	4.862	11.06	2.099	2.017
92	12.17	12.13	4.765	10.79	2.123	2.036
94	12.44	11.54	4.673	10.53	2.147	2.052
96	12.86	11.17	4.584	10.31	2.170	2.068
98	12.96	10.73	4.497	10.08	2.193	2.081
100	13.23	10.29	4.415	9.862	2.215	2.093
105	13.89	9.56	4.221	9.357	2.267	
110	14.55	8.75	4.043	8.901	2.316	
115	15.21	8.14	3.880	8.487	2.362	
120	15.88	7.53	3.729	8.109	2.406	
125	16.53	7.08	3.589	7.764	2.448	
130	17.20	6.62	3.460	7.447	2.488	
135	17.86	6.25	3.339	7.154	2.527	
140	18.52	5.85	3.226	6.884	2.565	
145	19.18	5.59	3.121	6.632	2.602	
150	19.84	5.32	3.023	6.400	2.638	
155	20.51	5.07	2.930	6.182	2.675	
160	21.17	4.82	2.843	5.979	2.711	
165	21.83	4.63	2.761	5.789	2.747	
170	22.49	4.41	2.684	5.610	2.783	
175	23.15	4.25	2.610	5.443	2.820	
180	23.81	4.07	2.541	5.284	2.850	
185	24.48	3.92	2.475		2.880	
190	25.14	3.78	2.413		2.915	
195	25.80	3.65	2.353		2.938	
200	26.46	3.53	2.297		2.962	
205	27.12		2.243		2.986	

TABLE II (Cont'd)

Side-On Positive Impulse and Positive Duration and Normally
Reflected Pressure, Impulse and Duration

X	$P_0^{1/3} Z$	$P - P_0$	$I/P_0^{2/3} W^{1/3}$	$\Delta t/W^{1/3}$
Charge radii	ft $\left[\frac{\text{atm}}{\text{lb}} \right]^{1/3}$	psi	psi msec/atm ^{2/3} lb ^{1/3}	(msec)/(lb ^{1/3})
		reflected	side-on	reflected
210	27.78		2.192	3.020
215	28.44		2.142	3.044
220	29.17		2.095	3.080
225	29.77		2.050	3.103
230	30.43		2.007	3.127
235	31.25		1.966	3.150
240	31.75		1.926	3.185
245	32.41		1.888	3.209
250	33.08		1.852	3.232
255	33.74		1.816	3.250
260	34.40		1.783	3.268
265	35.06		1.750	3.303
270	35.72		1.718	3.315
275	36.48		1.688	3.338
280	37.04		1.659	3.362
285	37.70		1.630	3.385
290	38.37		1.603	3.409
295	39.03		1.577	3.432
300	39.69		1.551	3.450
305	40.35		1.526	3.468
310	41.01		1.502	3.491
315	41.67		1.479	3.503
320	42.33		1.456	3.526
325	43.00		1.435	
330	43.66		1.413	
335	44.32		1.393	
340	44.98		1.373	
345	45.64		1.353	
350	46.30		1.334	
355	46.97		1.316	
360	47.63		1.298	
365	48.29		1.281	
370	48.95		1.264	
375	49.61		1.247	
380	50.27		1.231	
385	50.94		1.215	
390	51.60		1.200	
395	52.26		1.185	
400	52.92		1.171	
405	53.58		1.157	
410	54.24		1.143	

TABLE II (Cont'd)

Side-On Positive Impulse and Positive Duration and Normally Reflected Pressure, Impulse and Duration					
X	$p_o^{1/3} z$	$p - p_o$	$I/p_o^{2/3} w^{1/3}$	$\Delta t/w^{1/3}$	
Charge radii	ft $\left[\frac{\text{atm}}{\text{lb}} \right]^{1/3}$	psi	psi msec/atm ^{2/3} lb ^{1/3}	(msec)/(lb ^{1/3})	
		reflected	side-on	reflected	side-on
415	54.90		1.129		
420	55.57		1.116		
425	56.23		1.103		
430	56.89		1.090		
435	57.55		1.078		
440	58.21		1.066		
445	58.87		1.054		
450	59.54		1.043		
455	60.20		1.032		
460	60.86		1.021		
465	61.52		1.010		
470	62.18		.9992		
475	62.84		.9888		
480	63.50		.9787		
485	64.16		.9688		
490	64.83		.9590		
495	65.49		.9495		
500	66.15		.9402		
505	66.81		.9310		
510	67.47		.9220		
515	68.13		.9132		
520	68.80		.9045		

No least square fits have been made to the duration data. Curves drawn by eye (Figure 3) have been determined and the points from the curves tabulated in Table II.

CONCLUSION

Pentolite is recommended as a standard explosive when the side-on peak pressure in a blast wave is considered because of excellent agreement of measurements of various investigators and the large number of observations available. The precision of the measurements shows the excellent reproducibility of results from this explosive.

The measurements of other parameters, side-on impulse and duration, reflected pressure and duration are not as precise as side-on pressure measurements. Recent measurements of normally reflected impulse with a mechanical gage indicate that this parameter can be determined with a high precision over the range where it might be of military importance. Data in the small range of scaled distances in which both mechanical and piezoelectric measurements have been made suggest that the measurements are also of good reliability. It is not a priori obvious that the mechanical measurements integrate over the same time as the piezoelectric but recent studies with plugs of differing masses, as well as overall agreement in the results, indicate that any differences in times are of little importance. Within experimental accuracy, normally reflected impulse approaches a value that is two times the side-on impulse at large distances, as would be expected.^{23,24}

ACKNOWLEDGEMENT

The contributions of Lloyd Campbell of the Computing Laboratory to this work, especially in determining the non-linear analytical functions and their standard deviations by least squares are gratefully acknowledged.

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APPENDIX

Free-Air Measurements on Bare Spherical Pentolite

TABLE I

Experimental Side-On Pressure, Impulse and Duration

Ref. No.	Z ft/lb ^{1/3}	y atm	$\bar{\sigma}$	N	I/W ^{1/3} psi msec/lb ^{1/3}	$\bar{\sigma}$	N	$\Delta t/W^{1/3}$ msec/lb ^{1/3}	$\bar{\sigma}$	N
1	.1323	817.3	3.187	34						
1	.1460	723.5	8.971	34						
1	.1570	660.0	12.01	34						
1	.1669	616.7	15.91	34						
1	.1760	575.0	17.08	34						
1	.1860	536.4	19.10	34						
1	.2000	492.9	20.41	34						
1	.2330	407.6	17.69	34						
1	.2661	348.2	10.59	49						
1	.2990	302.4	13.09	15						
1	.3329	281.3	12.21	15						
1	.3990	231.4	12.80	15						
1	.5311	165.0	13.10	15						
1	.6650	124.8	8.968	15						
1	.7979	94.35	9.435	15						
1	.9300	75.17	7.517	15						
1	1.061	61.40	6.508	15						
2	1.070	56.00	3.332	15						
1	1.196	50.88	6.156	15						
2	1.320	40.48	2.069	15						
1	1.328	42.56	6.044	15						
2	1.480	31.20	.3713	17	16.51	.756	14	.122	.011	13
8	1.510	31.66	.7535	2	16.92	.173	3	.173		1
2	1.590	29.73	.8503	15						
2	1.860	22.38	.7542	20						
8	2.010	18.04	.2039	8	17.42	.457	7	.292	.008	16
2	2.130	16.94	.4167	25						
2	2.401	13.67	.7546	20						
8	2.480	11.99	.1199	17	14.58	.914	8	.321	.047	15
8	2.520	11.61	.0401	7	14.76	.125	9	.526	.028	6
2	2.661	10.41	.1822	25						
11	2.780	8.558	.1249	11	9.50	.417	10			
11	2.830	8.000	.3584	3	12.06	2.400	4			
2	2.950	8.503	.2483	25						

TABLE I (Cont'd)

Experimental Side-On Pressure, Impulse and Duration

Ref. No.	Z ft/lb ^{1/3}	y atm	$\bar{\sigma}$	N	I/W ^{1/3} psi msec/lb ^{1/3}	$\bar{\sigma}$	N	$\Delta t/W^{1/3}$ msec/lb ^{1/3}	$\bar{\sigma}$	N
8	3.010	7.388	.1182	11	14.32	.488	13	.453	.010	16
2,8	3.221	6.965	.2595	25	16.14	.931	3	.545	.059	4
11	3.270	6.490	.2012	11	11.93	1.140	8			
11	3.329	5.558	.1979	3	11.64	2.800	4			
8	3.440	5.388	.0668	7	12.24	.163	6	.644	.028	13
2	3.490	5.415	.0655	20						
8	3.620	5.476	.4102	2						
8	3.640	4.571	.0401	12	12.73	.418	20	0.629	.013	20
8	3.670	5.095	.0361	2	16.23	.721	2	0.579		1
2	3.750	4.476	.1182	20						
11	3.770	4.259	.0384	12	9.869	.548	9			
11	3.830	3.952	.0210	4	9.166	.393	4			
2	4.019	3.741	.1231	25						
8	4.030	4.014	.0189	8	15.71	.506	7	0.744	.024	7
8	4.039	4.068	.0448	8	11.73	.114	13	0.840	.029	13
8	4.110	4.163	.0218	5	13.15	.283	7	0.919	.007	7
11	4.260	2.959	.0080	12	7.73	.511	9			
2	4.290	3.374	.2311	20						
11	4.341	2.803	.0297	4	8.127	1.10	4			
9	4.361	3.088	.0321	4						
10	4.410	2.796	.0294	64						
8	4.420	3.163	.0348	6	12.30	1.43	11	0.879	.021	11
3,10	4.69	2.585	.0427	20	10.50	.212	18			
11	4.760	2.231	.0471	12	8.783	.501	9			
2	4.830	2.469	.0096	10						
11	4.840	2.184	.0295	4	8.244	.259	4			
8	4.930	2.136	.0102	14	9.903	.206	25	0.872	.016	25
4	4.960	1.871	.0299	15	10.66	.150	15	1.190	.014	16
4	4.980	2.150	.1780	33	10.54	.180	32	1.140	.022	33
8	5.000	2.429	.0231	11	11.84	.435	8	1.090	.035	13
8	5.040	2.088	.0549	17	10.95	.169	15	1.030	.017	19
4	5.070	2.000	.0368	4	9.840	.370	4	1.140	.015	4
4,2	5.100	2.172	.0341	13	10.08	.200	3	1.060	.020	3
8,10	5.110	2.102	.0161	47	9.560	.539	45	1.090	.032	7
9	5.289	1.884	.1019	7	7.510	.190	6	0.564	.010	6
9	5.590	1.673	.0639	7						
8	5.640	1.639	.0234	8	12.03	.131	14	1.170	.015	16
8	5.650	1.653	.0095	7	9.721	.131	8	1.170	.028	13
9	5.871	1.673	.0187	10						

TABLE I (Cont'd)

Experimental Side-On Pressure, Impulse and Duration

Ref. No.	Z ft/lb ^{1/3}	y atm	$\bar{\sigma}$	N	I/W ^{1/3} psi msec/lb ^{1/3}	$\bar{\sigma}$	N	$\Delta t/W^{1/3}$ msec/lb ^{1/3}	$\bar{\sigma}$	N
4	5.979	1.306	.0246	16	9.380	.130	16	1.460	.021	16
4	5.990	1.429	.0414	33	9.019	.084	34	1.300	.019	36
10	6.171	1.231	.0129	33	8.300	.074				
8	6.409	1.320	.0095	5	10.40	.157	9	1.414	.019	9
8	6.460	1.265	.0102	8	10.32	.186	9	1.271	.018	10
8	6.500	1.238	.0109	7	8.420	.141	12	1.300	.028	13
8	6.630	1.279	.0136	5	9.161	.139	6	1.340	.066	6
9	6.740	1.041	.0347	7						
9	6.760	1.299	.0156	18	6.250	.053	8	0.875	.014	8
4	7.170	.9796	.0150	14	8.039	.190	15	1.700	.034	16
4	7.271	.966	.0626	36	7.580	.068	39	1.610	.027	40
9	7.399	1.054	.0191	13						
8	7.450	1.061	.0952	6	7.820	.112	11	1.431	.018	12
8	7.470	.9116	.0102	4	7.960	.290	8	1.470	.074	6
4	8.089	.7619		3	6.820	.180	3	1.750	.077	3
4	8.120	.7755		3	6.579	.260	3	2.290	.040	3
9	8.279	.9048	.0190	3						
9	8.290	1.068	.0137	24	5.460	.080	6	1.060	.023	6
9	8.310	.7074	.0061	6						
4	8.420	.7143	.0211	43	6.851	.110	43	1.820	.022	44
4	8.430	.7211	.0067	16	7.220	.120	16	1.921	.027	16
9	8.610	.7619	.0150	7	6.669	.105	7	1.190	.017	7
10	8.640	.6259	.0064	18	5.999	.042	13			
4	8.720	.6741	.0150	6	7.450	.270	6	1.880	.024	6
4	8.770	.6769	.0401	6	7.081	.370	6	1.830	.049	6
8	9.489	.5912	.0009	5	6.070	.159	6	1.740	.056	6
8	9.531	.5993	.0009	5	5.940	.101	10	1.556	.029	10
4	9.570	.5534	.0029	37	6.210	.084	46	2.001	.019	47
8	9.710	.6218	.0044	4	6.590	.141	8	1.780	.029	8
4	10.06	.5476	.0095	12	6.661	.220	12	2.150	.029	12
9	10.40	.4320	.0072	15	5.180	.077	8	1.720	.023	8
9	11.00	.5129	.0128	18	5.019	.080	8	1.590	.013	8
4	11.17	.4197	.0015	4	5.130	.057	4	2.130	.028	4
4	11.20	.4347	.0122	10						
4	11.25	.3837	.0126	4	5.220	.130	4	2.330	.080	4
4	11.63	.3946	.0023	42	5.090	.065	42	2.210	.024	42
8	11.84	.4735	.0044	6	5.201	.130	10	2.010	.039	10
4	12.26	.3605	.0052	16	4.681	.330	16	2.260	.028	16
9	13.10	.3639	.0061	7						

TABLE I (Cont'd)

Experimental Side-On Pressure, Impulse and Duration

Ref. No.	Z ft/lb ^{1/3}	y atm	$\bar{\sigma}$	N	I/W ^{1/3} psi msec/lb ^{1/3}	$\bar{\sigma}$	N	$\Delta t/W^{1/3}$ msec/lb ^{1/3}	$\bar{\sigma}$	N
8	13.42	.3327	.0044	4	4.280	.081	8	1.970	.046	8
8	13.46	.3163	.0082	5	4.380	.143	6	1.880	.029	8
9	13.50	.4741	.0193	27	5.069	.225	5	1.901	.016	5
9	13.60	.3048	.0197	5	3.230	.067	4	1.560	.071	4
4	13.96	.3020	.0029	12	3.900	.180	12	2.270	.044	12
9	14.11	.3000	.0084	15						
4	14.53	.2694	.0205	39	3.939	.056	39	2.430	.019	40
8	14.81	.2660	.0027	12	4.320	.040	16	2.430	.028	17
4	14.93	.2755	.0038	16	4.510	.058	16	2.551	.032	16
9	16.60	.1633	.0041	6						
9	16.80	.2646	.0048	8						
9	17.00	.2170	.0054	8	3.321	.118	7	2.150	.039	7
3	17.34	.2116	.0013	1						
9	17.40	.2007	.0027	5	2.890	.134	5	1.941	.097	5
9	17.60	.2095	.2849	10						
4	19.23	.1599	.0027	6	2.790	.087	6	2.790	.160	6
4	19.36	.1707	.0085	6	3.190	.190	6	2.960	.220	6
4	20.04	.1619	.0013	3	3.300		3	2.960	.220	6
4	20.22	.1660	.0012	46	2.899	.095	46	2.780	.023	46
4	20.62	.1599	.0008	15	2.899	.041	15	0.2970	.023	15
9	21.01	.1422	.0075	7						
9	21.30	.1605	.0116	7	2.590	.124	5	0.2310	.029	5
9	22.20	.1524	.0038	12						
4	25.23	.0952	.0010	3	2.281		3	3.241		3
9	25.70	.0952	.0082	6						
9	26.70	.1082	.0027	7	1.890	.059	7	2.571	.031	6
4	29.07	.1041	.0008	16	2.220	.022	15	3.310	.032	16
4	29.19	.0986	.0005	46	1.950	.024	46	3.080	.023	50
3	30.00	.0980	.0014	1						
4	34.40	.0796	.0010	10	1.730	.033	10	3.210	.060	10
4	40.61	.0654	.0015	42	1.440	.016	44	3.350	.021	46
4	40.73	.0660	.0011	16	1.500	.026	16	3.460		10
5	45.00	.0631	.0009	16	1.450	.019	16			
5	68.00	.0374	.0004	8	0.960	.016	8			

TABLE II

Experimental Values of Normally Reflected Pressure,
Impulse and Duration

Ref. No.	$p_o^{1/3} z$ ft(atm/lb) ^{1/3}	y atm	$\bar{\sigma}$	N	$I/p_o^{2/3} W^{1/3}$ psi msec/atm ^{2/3} lb ^{1/3}	$\bar{\sigma}$ lb ^{1/3}	N	$\Delta t/W^{1/3}$ msec/lb ^{1/3}	$\bar{\sigma}$ lb ^{1/3}	N
12	.1096				15,293.9	426.67	4			
12	.187				5,270.0	148.37	9			
12	.219				3,960.6	92.33	9			
12	.320				1,784.8	77.33	7			
12	.378				1,325.2	45.58	26			
12	.438				1,209.6	86.67	8			
13	.500				795.6	32.20	37			
12	.641				487.8	26.03	7			
12	.741				415.0	29.82	10			
13	.750				374.4	15.70	73			
13	1.00				229.7	13.30	77			
12	1.28				173.8	22.14	7			
8	1.48				119.4	14.20	17	.149	.018	13
14	1.50	243.6	2.925	3	118.6	6.37	3	.200	.006	3
13	1.50				130.9	7.61	124			
8	1.51				119.3		2	.190		3
13	2.00				82.6	5.99	20			
8	2.01				79.3	6.06	4	.280		13
14	2.32	99.05	6.162	4	80.7	8.36	4	.323	.017	4
8	2.48				63.5	13.60	36	.306	.042	36
13	2.50				55.9	7.77	71			
8	2.52				72.8	18.30	11	.334	.023	11
14	3.00	40.79		1	55.8		1	.431		1
8	3.01				54.0	7.77	22	.431	.060	24
8	3.22				56.7	3.77	8	.471	.037	10
14	3.32	26.71	1.469	6	41.9	3.50	6	.491	.035	6
8	3.44				51.9	3.16	6	.584	.086	12
8	3.62				47.9		1	.446		1
8	3.64				44.0	7.36	23	.618	.091	22
8	3.67				49.2	1.89	4	.567		2
8	4.03				44.8	2.70	9	.735	.058	9
8	4.04				40.3	3.42	21	.698	.092	22
8	4.11				40.3	3.43	9	.857	.071	10
8	4.42				40.5	2.72	14	.870	.070	14
8	4.93				28.0	2.58	28	.810	.097	27

TABLE II (Cont'd)

Experimental Values of Normally Reflected Pressure,
Impulse and Duration

Ref. No.	$p_o^{1/3}$ ft(atm/lb) ^{1/3}	γ atm	$\bar{\sigma}$	N	$I/p_o^{2/3}$ psi msec/atm ^{2/3}	$W^{1/3}$ lb ^{1/3}	$\bar{\sigma}$	N	$\Delta t/W^{1/3}$ msec/lb ^{1/3}	$\bar{\sigma}$	N
8	5.00				34.8	1.45	19	1.030	.041	20	
8	5.04				31.2	4.51	24	1.010	.127	29	
7	5.10	5.81	0.244	21	31.0	4.20	21				
8	5.11				30.5	1.51	7	1.110	.153	8	
8	5.64				29.9	1.12	14	1.120	.123	16	
8	5.65				24.2	4.77	15	1.190	.109	15	
7	6.00	3.61	0.211	5	24.4	1.30	5				
8	6.41				25.1	0.90	10	1.350	.125	10	
8	6.46				24.1	0.39	10	1.270	.159	12	
8	6.50				20.1	2.21	12	1.450	.150	13	
8	6.63				22.8	0.71	8	1.410	.084	8	
8	7.45				22.2	2.04	12	1.490	.104	12	
8	7.47				19.9	0.80	7	1.510	.031	5	
7	7.50	2.17	0.061	17	20.5	1.00	17				
8	9.49				14.9	0.29	7	1.780	.106	8	
8	9.53				14.4	0.43	9	1.680	.123	10	
7	9.60	1.18	0.027	21	14.0	0.40	21				
8	9.71				14.0	0.65	8	1.930	.151	8	
8	11.84				11.8	1.89	12	2.020	.101	12	
8	13.41				9.72	0.39	8	2.090	.087	8	
8	13.46				9.29	0.21	8	1.730	.056	8	
8	14.81				8.64	0.52	20	2.370	.125	20	
7	23.80	0.265	0.014	9	4.96	0.40	9				

REFERENCES

1. Sultanoff, M. and McVey, G. "Shock-Pressure at and Close to the Surface of Spherical Pentolite Charges Inferred from Optical Measurements," BRL Report No. 917, Aberdeen Proving Ground, Maryland, August 1954.
2. Sultanoff, M. and McVey, G. "Observations from Spherical Pentolite Charges," BRL Report No. 984, Aberdeen Proving Ground, Maryland, July 1956.
- 2a. Brinkley, S. R., Jr., Kirkwood, J. G. and Richardson, J. M. Tables of Properties of Air Along the Hugoniot Curve and the Adiabatics Terminating in the Hugoniot Curve, OSRD Report No. 3550, April 1944.
3. Stoner, R. G. and Bleakney, W. "The Attenuation of Spherical Shock Waves in Air," Journal of Applied Physics, Volume 19, No. 7, July 1948.
4. Curtis, W. "Free Air Blast Measurements on Spherical Pentolite," BRL Memorandum Report No. 544, Aberdeen Proving Ground, Maryland July 1951.
5. Unpublished Side-on excess pressure data supplied by C. Johnson and D. Schlueter of Special Problems Branch, Terminal Ballistics Laboratory, BRL, Aberdeen Proving Ground, Maryland, April 1958.
6. Fitzgerald, J. W. "Design Considerations for Pencil Type Air Blast Gages." Contract No. DA-36-034-ORD-1860, prepared for BRL by Atlantic Research Corporation, Alexandria, Va., November 1, 1955.
7. Goldstein, H. and Hoffman, A. "Preliminary Face-on Air Blast Measurements," BRL Technical Note No. 788, Aberdeen Proving Ground, Maryland, April 1953.
8. Hoffman, A. J. and Mills, S. N., Jr. "Air Blast Measurements About Explosive Charges at Side-on and Normal Incidence," BRL Report No. 988, Aberdeen Proving Ground, Maryland, July 1956.
9. Dewey, J. and Sperrazza, J. "The Effect of Atmospheric Pressure and Temperature on Air Shock," BRL Report No. 721, Aberdeen Proving Ground, Maryland, May 1950.
- 9a. Sachs, R. G. "The Dependence of Blast on Ambient Pressure and Temperature," BRL Report No. 466, Aberdeen Proving Ground, Maryland, May 1944.

10. Unpublished Data compiled by Air Blast Section, Special Problems Branch, Terminal Ballistics Laboratory, BRL, Aberdeen Proving Ground, Maryland, 1955.
11. Unpublished Data on Spherical Pentolite by R. Hippensteel, Terminal Ballistics Laboratory, BRL, Aberdeen Proving Ground, Maryland, March 1958.
12. Olson, W. C., Patterson, J. D., II and Williams, J. S. "The Effect of Atmospheric Pressure on Normally Reflected Impulse from Air Blast Waves at Small Scaled Distances," BRL Memorandum Report (in preparation).
13. Johnson, O. T., Patterson, J. D., II and Olson, W. C. "A Simple Mechanical Method for Measuring the Reflected Impulse of Air Blast Waves," BRL Memorandum Report No. 1088, Aberdeen Proving Ground, Maryland, July 1957.
14. Unpublished Gage Data on The Pressure Half Way Between Similar Charges by J. Wenig and W. C. Olson, Special Problems Branch, TBL, BRL (in preparation) Aberdeen Proving Ground, Maryland, 1959.
15. Kirkwood, J. G. and Brinkley, S. R., Jr. "Theory of Propagation of Shock Waves from Explosives," NDRC Report No. A318, Munitions Building, Washington, D. C. March 1945.
16. Brinkley, S. R., Jr. and Kirkwood, J. G. "Theory of the Propagation of Shock Waves," The Physical Review, Volume 71, Number 9, May 1947.
17. Makino, R. "The Kirkwood-Brinkley Theory of the Propagation of Spherical Shock Waves, and Its Comparison with Experiment," BRL Report No. 750, Aberdeen Proving Ground, Maryland, April 1951.
18. Osborne, M. F. M. and Taylor, A. H. "Non-Linear Propagation of Underwater Shock Waves," Physical Review, Volume 70, Number 5, March 1946.
19. Carsen, B. and Stanton, J. S. "Journal of Applied Physics, Vol. 19, NAVORD Report No. 1011, and NOTS-1286 (1948).
20. Shear, R. E. and Day, B. D. "Tables of Thermodynamics and Shock Front Parameters for Air," BRL Memorandum Report No. 1206, Aberdeen Proving Ground, Maryland, May 1959.
21. Makino, R. C. and Shear, R. E. "Numerical Integration of Equations of Spherical Unsteady Flow Behind a Known Shock Line," BRL Report (to be published) Aberdeen Proving Ground, Maryland.

22. Doering, W. and Burkhardt, G. "Contributions to the Theory of Detonation" (Translation from German prepared by Brown University), Technical Report No. F-TS-1227-1A (GDAMA9-T-46), Headquarters, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio, May 1949.
23. Courant, R. and Friedrich, K. O. "Supersonic Flow and Shock Waves," Volume I, Interscience Publishers, Inc., New York, 1948.
24. Makino, R. C. and Shear, R. E. "Estimation of Normally Reflected Impulse of Blast Waves," BRL Technical Note No. 1010, Aberdeen Proving Ground, Maryland, May 1955.
25. Scarborough, J. B. "Numerical Mathematical Analysis," Second Edition, The Johns Hopkins Press, Baltimore, Maryland, 1950.
26. Armentdt, B. F., Smith, R. and Wise, R. C. "The Initial Decay of Pressure Behind a Shock Front: Comparison of Experimental and Calculated Results," BRL Memorandum Report No. 997, Aberdeen Proving Ground, April 1956.
27. Makino, R. C. and Goodman, H. J. "Air Blast Data on Bare Explosives of Different Shapes and Composition (U)," BRL Memorandum Report No. 1015, Aberdeen Proving Ground, Maryland, June 1956.

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AD Ballistic Research Laboratories, APG COMPILED FREE-AIR BLAST DATA ON BARE SPHERICAL PENTOLITE H. J. Goodman BRL Report No. 1092 February 1960 DA Proj No. 5803-04-002, OMSC No. 5010.11.815, ORD Proj No. TB3-0112 UNCLASSIFIED Report	UNCLASSIFIED Air blast - Measurement Explosive charges - Blast	AD Ballistic Research Laboratories, APG COMPILED FREE-AIR BLAST DATA ON BARE SPHERICAL PENTOLITE H. J. Goodman BRL Report No. 1092 February 1960 DA Proj No. 5803-04-002, OMSC No. 5010.11.815, ORD Proj No. TB3-0112 UNCLASSIFIED Report	UNCLASSIFIED Air blast - Measurement Explosive charges - Blast
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