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ESTIMATED BLAST PRESSURES FROM TNT CHARGES OF 2 TO 10,000 TONS

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ABSTRACT

Estimates of peak blast pressure and impulse from TNT charges of 2 to 10,000 tons have been made on the basis of much data on blasts from Comp. B charges of 67 to 550 pounds. These estimates are believed to be better than those presented in LAMS-247, which were based only on data of 67-lb Comp. B charges. The Bethe-Kirkwood formula was used to extrapolate the peak pressure and impulse up to large distances. Because of lack of experimental data, this extrapolation is very rough.

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ESTIMATED BLAST PRESSURES FROM TNT CHARGES OF 2 TO 10,000 TONS

In a previous note (LAMS-247) estimates were made of the expected peak pressures from amounts of TNT ranging from 100 tons to 5000 tons. These estimates were based mainly on RRL measurements on 67-lb charges of Comp. B. There is, however, a considerable amount of other data from bare charges of Comp. B which show a wide spread in observed peak pressures. The present estimates are an attempt to obtain a good mean representation of these data.

The results on which the present estimates are based are contained in the following reports.

1) RRL Report MOS/255 (BM-940). 67-lb charges of Comp. B.

2) ARD Explosives Report 16/45 (BM-1027). 67-lb charges of Comp. B.

3) ARD " " 22/44 67-lb charges of Comp. B.

4) ARD " " 147/44 (BM-978). 67-lb, 230-lb, and 550-lb charges of Comp. B.

The results from rounds 5, 6, and 8 of ARD Explosives Report 24/44 have been omitted because the charges were fired in rain or fog. Some further results from 50-lb, 100-lb, and 200-lb charges of Comp. B given in RRL report ARP/408 have not been used, because they give peak pressures which are very low compared with the average values from the sources given above. The charges were all cylindrical in form, with a length to diameter ratio of 2 or less. They were all fired with their axis vertical, resting in the ground, and the measurements were made in an approximately horizontal direction, a few feet above ground. Over the range of pressures considered (about 15 psi downwards) however, the blast wave would be expected to be approximately spherical, so that the expected pressures would not differ greatly in different directions, apart from any effects due to variations in atmospheric pressure.

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To obtain a mean curve over the range covered by the observations quoted, the following procedure was adopted. For each set of charges reported, the mean value of peak pressure at each distance at which measurements were made was determined. [The 60-ft and 80-ft distances in RRL Report MOS/255 (BM-940) were omitted since very few readings were obtained at these distances, and these appeared to be low in comparison with the other results from these charges.] The mean results from the various charges were then all scaled to apply to a charge weight of 2 tons (4000 lbs), and the pressures were multiplied by a factor of 0.91 to allow for the difference between Comp. B and TNT. This factor is based on a large number of British and American comparisons of TNT and Comp. B.

An equation of the form

$$p = \frac{a}{r} + \frac{b}{r^2} + \frac{c}{r^3} \qquad (1)$$

was fitted to the scaled mean values of peak pressure obtained as above. Each mean point was given the same weight, in spite of the fact that the numbers of observations on which the points were based were not all equal. The extra labor involved in giving the points unequal weights was not considered justifiable. To reduce still further the labor of fitting the curve, the mean points were considered in groups, each group having an approximately constant value of r, and containing approximately the same number of points. The mean p and r for each group were determined, and the curve was then fitted to these mean values. For 4000 lbs of TNT, the equation obtained was

$$p = \frac{611}{r} + \frac{20.2 \times 10^3}{r^2} + \frac{23.04 \times 10^6}{r^3} \qquad (2)$$

where p is in lb/sq.in. and r in feet. A plot of this curve, in the form pr against r, is shown in Fig. 1, with the points from which it was determined.

The formula may be applied to TNT charges of any weight by writing it in the form:

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$$p = \frac{38.5\ w^{1/3}}{r} + \frac{85\ w^{2/3}}{r^2} + \frac{5760\ w}{r^3} \qquad (3)$$

where w is the weight of the charge in lbs.

This equation enables expected pressure/distance curves from any weight of TNT fired <u>on the ground</u> to be determined. For the present purposes, however, estimates are required for charges fired 100 ft above ground. The correction can be made on the basis of the results given in ARD Explosives Report 16/45 (BM-1027), which gives data from 67-lb charges of Comp. B fired at heights from 0 to 30 ft with gauge heights 9 inch and 7 ft. The data for the 9-inch gauges have been used, as being more nearly comparable with the height of 6 ft on the scale of the present tests.

For the 2-ton charge, the corrections to be applied for charge height amount to some 50 to 60 percent and may be in error by 10 to 15 percent on account of the limited data in this region. For the larger charges the corrections range from about 25 percent down to 4 percent, and are more accurately determined, so that the pressures estimated for these charges are not likely to be in error from this cause by more than a few percent.

The final curves obtained are shown in Fig. 2. No correction has been applied for the effect of reduced atmospheric pressure due to the altitude. The formula given by Sachs in BRL-466 (AM-640), based on dimensional analysis, is not strictly applicable, since it neglects possible differences in the amount of energy put into the blast, and differences in the amount of energy dissipated in the early stages of the expansion of the blast wave. It seems preferable, therefore, not to attempt to correct for altitude until the experimental data on this effect are available.

<u>ESTIMATES OF POSITIVE IMPULSE.</u> Estimates of the expected positive impulses from various weights of TNT fired 100 ft above ground have been prepared and are shown in Fig. 3.

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These estimates are based on the results from 4000-lb H.C. bombs filled with TNT reported in MOS/360, AC-6600 (BM-645). The reasons for using these results rather than the bare-charge results used for estimating peak pressures are: a) it is known that the positive impulses from 66-lb charges of Comp. B and those from 4000-lb H.C. bombs with Comp. B filling do not scale, those from the bombs being considerably higher when allowance is made for charge/weight ratio. In view of this it seems preferable to base the estimates on results from as large charges as possible. b) The correction for charge/weight ratio is much more accurately known for positive impulses than for peak pressures, so that results from H.C. bombs can be used with fair confidence to predict impulses from bare charges.

The positive impulses from the 4000-lb H.C. bombs were corrected for charge/weight ratio on the basis of the results reported in MOS/193 (BM-1017), and the correction for charge height was made on the basis of the results in ARD Explosives Report 16/45 (BM-1027).

EXTRAPOLATION TO LARGE DISTANCES. The data on which the above estimates of peak pressure and positive impulse are based extend only down to peak pressures of the order of 2 psi.

Large errors can be made in extrapolating the peak pressure and impulse curves to distances where the peak pressure is of the order of 0.1 psi since no experimental data exist in this region. However, for the sake of making rough estimates, we have fitted the Bethe-Kirkwood (see LA-165) asymptotic equations to the experimental data for $R/W^{1/3} = 24.5$ and 15.1 and obtained:

$$p = \frac{35.0}{(R/W^{1/3})\sqrt{\log_{10}(R/W^{1/3}) - 0.928}} \text{ psi} \qquad (4)$$

$$I = 87\, W^{2/3}/R \quad \text{psi-millisec} \qquad (5)$$

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Comparing these results with Kirkwood's calculations for cast pentolite (NDRC A-318) it would appear that the fraction of the energy of the explosion still in the blast wave is approximately:

$$E_{blast}/E_{released} = .0843/\sqrt{\log_{10}(R/W^{1/3}) - 0.928} \qquad (6)$$

In these equations R is the distance in feet, W is the charge weight in pounds and no correction has been made for the height of the charge above the ground.

No data on the effect of charge height on the peak pressures and impulses at very large distances from the charge are available, but the results given in ARD Explosives Report 16/45 (BM-1027) suggest that at such distances the corrections would be substantially the same for all charge weights and would not exceed 5 percent.

Approximate estimates of peak pressure and positive impulse at a number of distances have been made from the above formulae, and are given in Table I. It must be emphasized that the estimates represent considerable extrapolation from the observed data, and are without any experimental backing.

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TABLE I

Estimated pressures and impulses at large distances

Distance (yds)	100 tons		500 tons		1,000 tons		2,000 tons		5,000 tons		10,000 tons	
	Press. lb/ sq.in.	Imp. lb ms/ sq.in.	Press. lb/ sq.in.	Imp. lb ms/ sq.in.	Press. lb/ sq.in.	Imp. lb ms/ sq.in.	Press. lb/ sq.in.	Imp. lb ms/ sq.in.	Press. lb/ sq.in.	Imp. lb ms/ sq.in.	Press. lb/ sq.in.	Imp. lb ms/ sq.in.
3,000	0.21	35	0.40	102	0.54	160	0.72	254	1.06	472	1.45	752
5,000	0.12	21	0.22	61	0.29	96	0.38	153	0.57	283	0.74	451
10,000	0.05	10	0.10	30	0.13	48	0.17	76	0.24	142	0.32	226
80,000	0.005	1.3	0.010	3.8	0.013	6.1	0.016	9.6	0.023	18	0.029	28

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AIRBORNE MEASUREMENTS. To correct the peak pressure and the impulse for the effect of change of density and pressure with altitude it is necessary to multiply the results that we would expect for measurements on the ground by the factor:

$$f = (p_o/760)^{1/2.8} (T_o/T_g)^{1/4}$$

Here p_o is the static pressure at the gauge in mm of Hg; T_o is the temperature at the gauge height and T_g is the temperature at ground level. Using the standard "U.S. Atmosphere" (AM-345, NACA Report No. 538 by Brombacher (1942))

Altitude (feet)	f
0	1.0000
15,000	.7931
20,000	.7299
25,000	.6695
30,000	.6117

There was an airborne gauge 14,500 feet directly above the 100 ton Trinity shot. The results may be compared with our expectancy

	peak pressure (psi)	positive impulse (psi-milliseconds)
Observed	0.095	17.4
Expected (not corrected for height of charge)	0.093	16.4
Expected (corrected for height of charge)	0.098	17.2

The excellence of this agreement is not to be interpreted as a vindication of our extrapolation formulae. These must be checked with reliable blast measurements at low pressures before they can be regarded as trustworthy.

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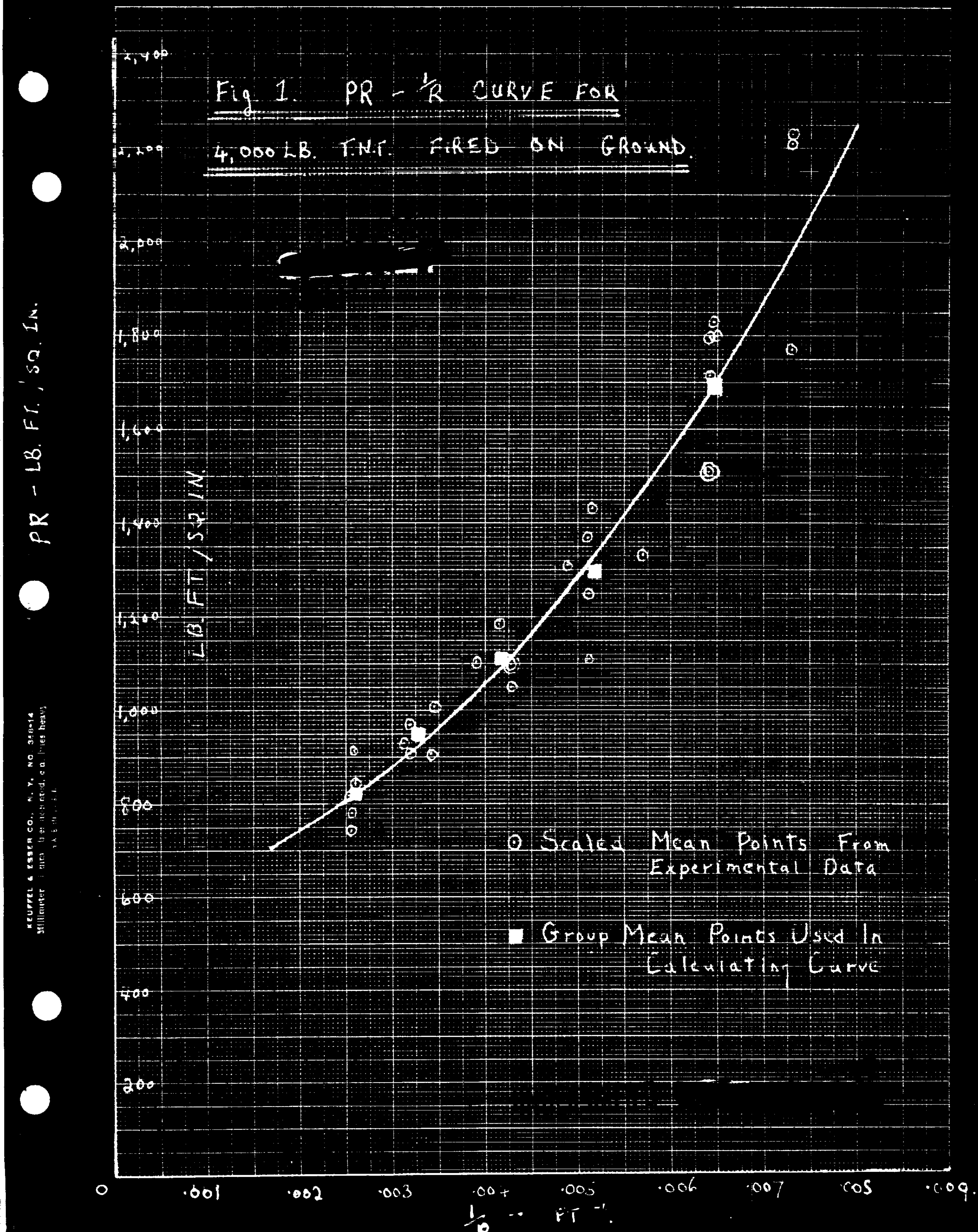

Fig. 1. PR - 1/R CURVE FOR 4,000 LB. T.N.T. FIRED ON GROUND.

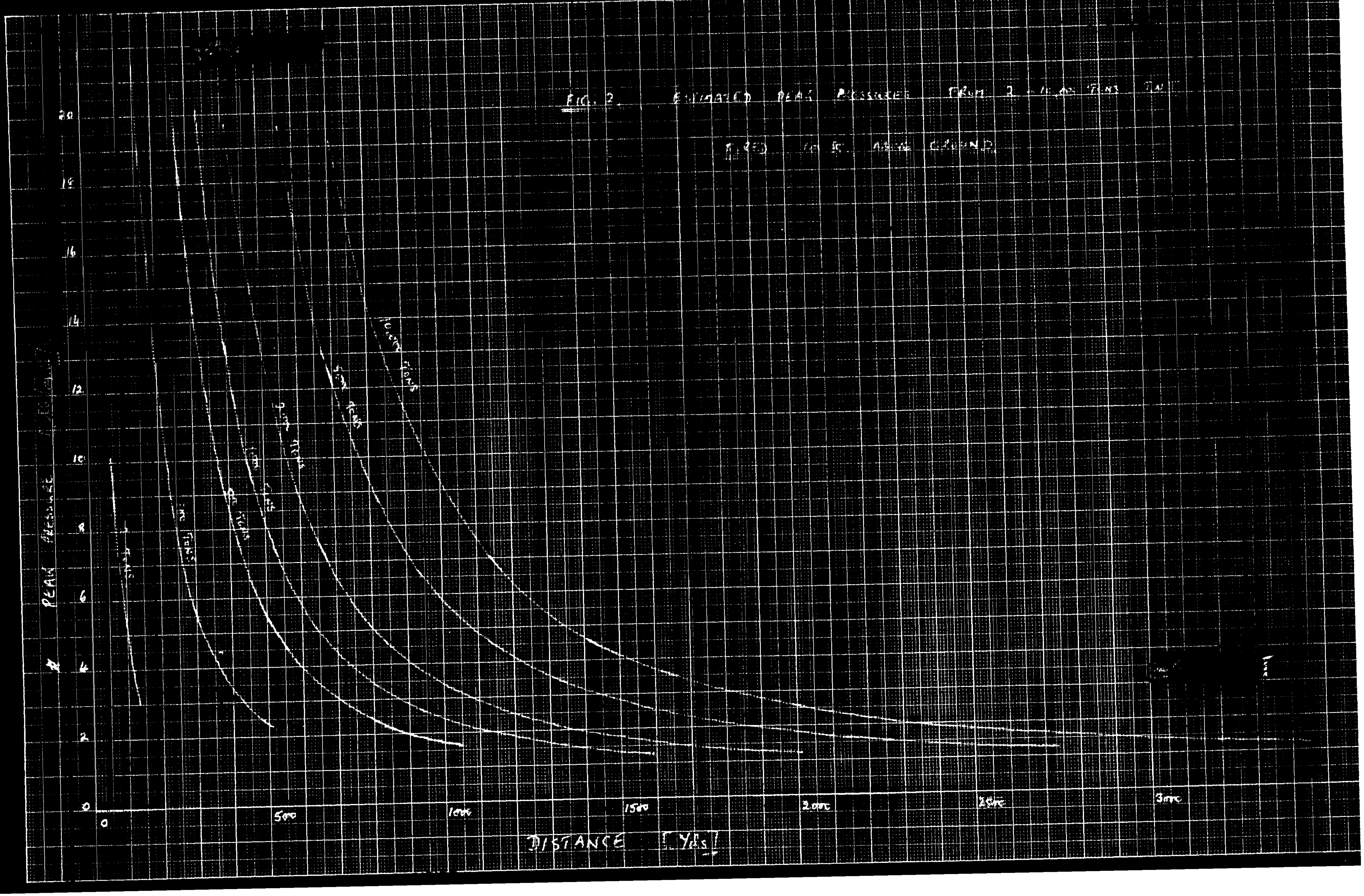

FIG. 2. ESTIMATED PEAK PRESSURES FROM 2 - 10,000 TONS TNT

FIRED 40 FT. ABOVE GROUND.

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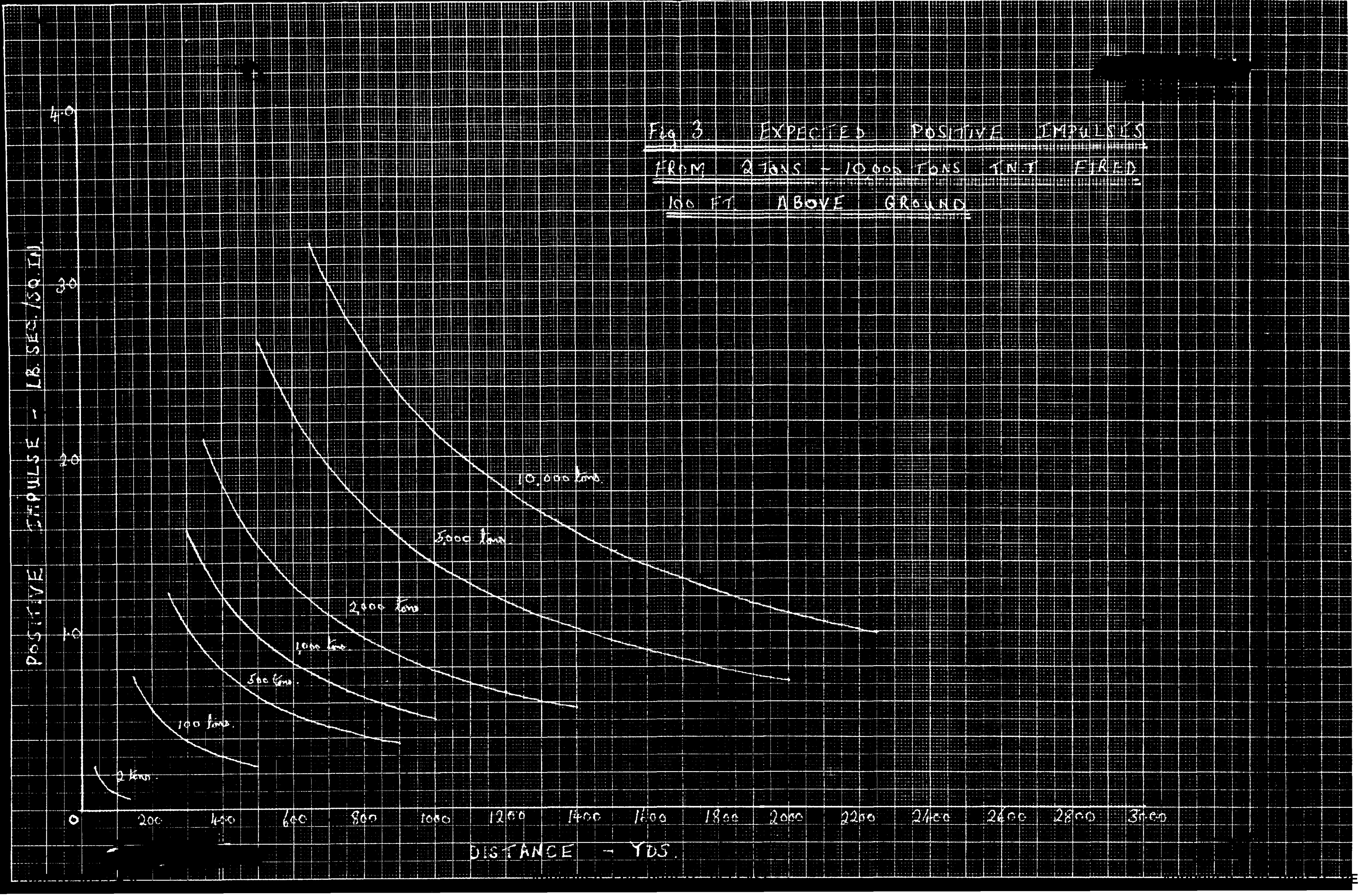

Fig 3 EXPECTED POSITIVE IMPULSES FROM 2 TONS - 10,000 TONS T.N.T FIRED 100 FT. ABOVE GROUND

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