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JULY 16th NUCLEAR EXPLOSION: BOX-GAUGE MEASUREMENT OF BLAST PRESSURE

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ABSTRACT

Fifty-two box-type gauges were used to measure the blast pressures as a function of distance from the nuclear explosion of July 16th, Comparison with the May 7th explosion of 108 tons of TNT gives an equivalent tonnage for the nuclear explosion of 9900 ± 1000 tons TNT.

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JULY 16th NUCLEAR EXPLOSION: BOX-GAUGE MEASUREMENT OF BLAST PRESSURE

Box gauges as described in LA-288 were used to measure peak pressure as a function of distance from the July 16th nuclear explosion. Owing to procurement difficulties, the foil (0.65-mil Al) used in the boxes for the nuclear explosion was not identical with the foil (0.70-mil Al) used for the 100-ton shot on May 7th.

Calibrations were carried out on the blast tube as described in LA-288. Measurements by W. T. Reed[1,2] show that the pressures in the shock front in a blast tube are approximately 5 percent lower than those calculated from theory. Consequently, in computing the calibrations of the foil, the calculated blast-tube pressures have been lowered 5 percent. Table I summarizes the results of the calibrations, while Fig. 1 represents them in graphic form. It will be seen that they do not fall on a smooth curve in all regions. It was felt that the calibrations were extensive enough to warrant using the values as given in Table I, rather than values from a smoothed curve such as is shown in Fig. 1.

The calibrations were performed with the plane of the foil perpendicular to the shock-wave velocity; in field use, this plane is parallel to the shock-wave velocity. As discussed in LA-288, the theory of G.I. Taylor (BM-36) is used to calculate breaking pressures for field use from breaking pressures as calibrated. It should be understood that this treatment assumes that the foils in the box gauge break in a time short enough so that they may be considered to be purely peak-pressure meters. LA-288 describes tests designed to check this point for the .7-mil foil used in the 100-ton shot These tests were not repeated for the .65-mil foil. It is felt that any departure from a true peak-pressure-measuring device must be slight.

To measure the peak pressure from the nuclear explosion, 52 box gauges were

1) W.T. Read, Jr.--A method of gauge calibration based on velocity measurements, OSRD-4076

2) W.T.Read, Jr. --Pressures behind a shock wave computed from velocity measurements in the blast tube and correction for humidity. OSRD-4257

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set up along four radii. Table II, columns 1, 4, 7 and 10, shows the locations of the gauges. The angle of the radial line is measured clockwise, looking down on the ground, from the OA line connecting the site of the shot O with the north 10,000 yd-station. Fig. 2 shows photographs of gauges 5, 10, 21, and 53 after the shot.

Table II, columns 3, 6, 9 and 12, gives the smallest hole broken at each location. From this, and the calibrations given in Table I, peak-pressure limits have been calculated for each location. The pressure lies between that required to break the smallest hole broken and that required to break the next smaller hole. These results are summarized in Table III. In Fig. 3, these pressures have been plotted along with the peak pressures from velocity measurements (LA-352), from impulse meters, and from condenser gauges (reports forthcoming). No explanation for the low pressures recorded by the box gauges at about 800 yds and at 1000 yds is apparent. The dotted curve is the expected curve for 10,000 tons TNT equivalent, from LA-316 by Hirschfelder, Littler and Sheard. The solid curve is drawn to fit the experimental data shown.

Comparison of the box-gauge data for the nuclear explosion with those for the 100-ton shot (equivalent to 108 tons of TNT) would be theoretically the most direct method of estimating the equivalent tonnage of the nuclear explosion. The calibrations for the 0.7-mil foil used in the 100-ton shot have been recalculated more carefully. The results are given in Table IV, column 2. They have also been lowered 5 percent to account for the blast-tube correction mentioned earlier. Owing to a shortage of both time and foil before the 100-ton shot, the calibration data were not as extensive as would be desired. Fig. 4 shows the calibration results appearing in Table IV, column 2, and a smooth curve which might be drawn through the data. These smooth curve values appear in Table IV, column 3. It is not clear in this case whether the values in column 2 or column 3 should be used. The 100-ton shot data, as given in LA-288,

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have been reduced to peak-pressure limits using both columns 2 and 3 of Table IV.

It is clear that there are several ways to use the 100-ton data for comparison with the nuclear explosion data. One alternative would be to compare only holes broken in both shots. In the ideal case, this would be the best method, eliminating calibration uncertainties. In practice, however, it is subject to several objections. First, the foils used in the two cases differ appreciably, making a correction involving the calibration necessary. Second, and more serious, it uses information from only 7 out of 26 gauges which gave pressure readings on the 100-ton blast. Of the 26, 20 were gauges used with the plane of the foils parallel to the shock velocity as were all of those used for the nuclear explosion. Selecting only the 7 cases mentioned, the 100-ton average pressure vs. distance curve would be as given in Table V, columns 2 and 3. Fig. 5a shows these selections of data. The second alternative would be to consider the 20 gauges which were in parallel orientation as were those used on the nuclear explosion. This selection of data appears in Table V, columns 4 and 5, and is plotted in Fig. 5b. The third alternative is to include all the data obtained. This appears in Table V, columns 6 and 7 and in Fig. 5c. The curves in Figs. 5a, b, c are averages of the 2 calibration alternatives.

From Table III, giving pressure vs distance data for the nuclear explosion, the average distances for the given pressures ranges were computed and these are plotted in Fig. 6. Assuming the accepted $r/w^{1/3}$ pressure-scaling law[3] the tonnage of the nuclear explosion was calculated from the comparison of Fig. 6 and Figs. 5a, b, c. Table VI gives the ratios of the distances corresponding to four selected pressure levels within the range covered by both explosions. The averages given for each column are unweighted. The resulting equivalent tons of TNT, obtained by multiplying the cube of the average ratio by 108 tons, appear in the next to the last row of Table VI. These have been given a weighting of 1, 2, and 1 for columns 2, 3 and 4 based on the amount and type of 108-ton data involved. The weighted average of the three is 9895 tons of TNT. Hence, we may say that the box gauges give an equivalent tonnage of TNT of 9900 ± 1000 tons where the ± expresses the average deviation of the ratios in Table VI.

3) Where r is distance from the explosion and w is weight of explosive.

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TABLE I

CALIBRATION OF 0.00065" Al FOIL

Diameter of hole in inches	psi to break on blast tube	psi to break in parallel orientation (see text)
1/2	5.24 ± 0.32	12.9
9/16	5.12 ± 0.16	12.5
5/8	4.76 ± 0.20	11.5
11/16	4.38 ± 0.16	10.5
13/16	3.58 ± 0.16	8.42
15/16	3.06 ± 0.25	6.18 - 7.35
1-1/8	3.07 ± 0.24	
1-7/16	2.38 ± 0.23	5.09
1-7/8	1.87 ± 0.23	3.96
2-1/2	1.43 ± 0.10	2.97
3-1/2	1.02 ± 0.10	2.10

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TABLE II

BOX GAUGE LOCATIONS AND SMALLEST HOLE BROKEN BY NUCLEAR EXPLOSION JULY 16, 1945

0°(North)			106°32'(East)			175°.4' (South)			270°(West)		
Distance yards	Box No.	Diameter of smallest hole broken inches	Distance yards	Box No.	Diameter of smallest hole broken inches	Distance yards	Box No.	Diameter of smallest hole broken inches	Distance yards	Box No.	Diameter of smallest hole broken inches
520	39	(7/16)*	814	54	1-1/8	520	12	not found	775	26	(7/16)*
800	38	1-1/8	1190	53	1-7/16	800	11	(7/16)*	1190	25	1-7/16
1000	37	1-1/8	1320	50	1-7/16	1000	10	1-1/8	1320	24	1-7/16
1250	36	1-7/16	1400	49	1-7/8	1250	9	15/16	1400	23	1-7/16
1360	35	1-7/16	1490	48	1-7/8	1360	8	1-7/16	1490	22	1-7/16
1445	34	1-7/16	1620	47	1-7/8	1445	7	1-7/16	1620	21	1-7/8
1550	33	1-7/16	1800	46	2-1/2	1550	6	1-7/16	1800	20	1-7/8
1710	32	1-7/8	2050	45	2-1/2	1710	5	1-7/8	2050	19	2-1/2
1920	31	2-1/2	2550	44	3-1/2	1920	4	1-7/8	2550	18	3-1/2
2250	30	3-1/2	2800	43	none	2250	3	3-1/2	2800	17	none
2675	29	3-1/2	3400	42	none	2675	2	3-1/2	3400	16	none
3100	28	none	4000	41	none	3100	1	none	4000	15	none
3700	27	none	6000	40	none	3700	13	none	6000	14	none

* Plate broken.

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TABLE III

CALCULATED PRESSURES FOR NUCLEAR

EXPLOSION OF JULY 16th

Distance in Yards	Lower Limit psi	Upper Limit psi	Number of Gauges
800	6.18	7.35	1
814	6.18	7.35	1
1000	6.18	7.35	2
1190	5.09	6.18	2
1250	6.18	7.35	1
1250	5.09	6.18	1
1320	5.09	6.18	2
1360	6.18	7.35	1
1360	5.09	6.18	1
1400	3.96	5.09	1
1400	5.09	6.18	1
1445	5.09	6.18	1
1445	6.18	7.35	1
1490	3.96	5.09	1
1490	5.09	6.18	1
1550	5.09	6.18	1
1550	6.18	7.35	1
1620	3.96	5.09	2
1710	3.96	5.09	2
1800	2.97	3.96	1
1800	3.96	5.09	1
1920	2.97	3.96	1
1920	3.96	5.09	1
2050	2.97	3.96	2
2250	2.10	2.97	2
2550	2.10	2.97	2
2675	2.10	2.97	2

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TABLE IV

CALIBRATION OF 0.0007" Al FOIL

Diameter of hole in inches	psi to break on blast tube	Values from smoothed curve	psi to break in parallel orientation	
			From col.2	From col.3
7/16	5.22 ± .32	5.22	12.12	12.12
1/2	-----	4.89		11.25
9/16	-----	4.56		10.35
5/8	4.17 ± .11	4.20	9.42	9.49
11/16	-----	3.87		8.67
13/16	3.63 ± .08	3.30	8.06	7.26
15/16	3.19 ± .02	2.85	6.99	6.18
1-1/8	1.91 ± .13	2.21	4.05	4.71
1-7/16	1.81 ± .16	1.73	3.82	3.63
1-3/4	1.40 ± .03	1.40	2.91	2.91
1-7/8	1.36 ± .04	1.33	2.83	2.75
2-1/2	0.995 ± 0.13	.998	2.05	2.06
3-1/2	0.666 ± 0.037	.665	1.36	1.35

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TABLE V

SELECTION OF DATA FROM 108-TON TNT EXPLOSION

Distance in Yards	7 Gauges: only holes also broken in nuclear explosion		20 Gauges: all gauges used in parallel orientation		26 Gauges: all gauges, both parallel and perpendicular orientation	
	psi from Table IV column 4	psi from Table IV column 5	psi from Table IV column 4	psi from Table IV column 5	psi from Table IV column 4	psi from Table IV column 5
195	--	--	10.54-11.90	11.10-11.78	10.54-11.90	11.10-11.78
220	--	--	9.97-10.81	10.21-11.10	9.97-10.81	10.21-11.20
270	6.99-8.06	6.18-7.26	7.35-8.32	6.54-7.73	7.35-8.32	6.54-7.73
360	3.81-4.04	3.63-4.71	3.81-4.04	3.63-4.71	4.00-4.25	3.92-4.63
520	2.43-3.32	2.40-3.19	2.43-3.32	2.40-3.19	2.06-2.47	2.00-2.60

[redacted]

[redacted]

TABLE VI

Distance corresponding to given psi for nuclear explosion divided by distance for same psi for 108-ton explosion

psi	From Fig. 5a for 108-ton (see text)	From Fig. 5b for 108-ton (see text)	From Fig. 5c for 108-ton (see text)
7.0	4.22	4.27	4.25
5.5	4.57	4.42	4.42
4.0	4.86	4.57	4.69
2.75	4.46	4.59	4.96
average ratio =	4.53	4.46	4.58
equivalent tons TNT =	10,040	9581	10,378

[redacted]

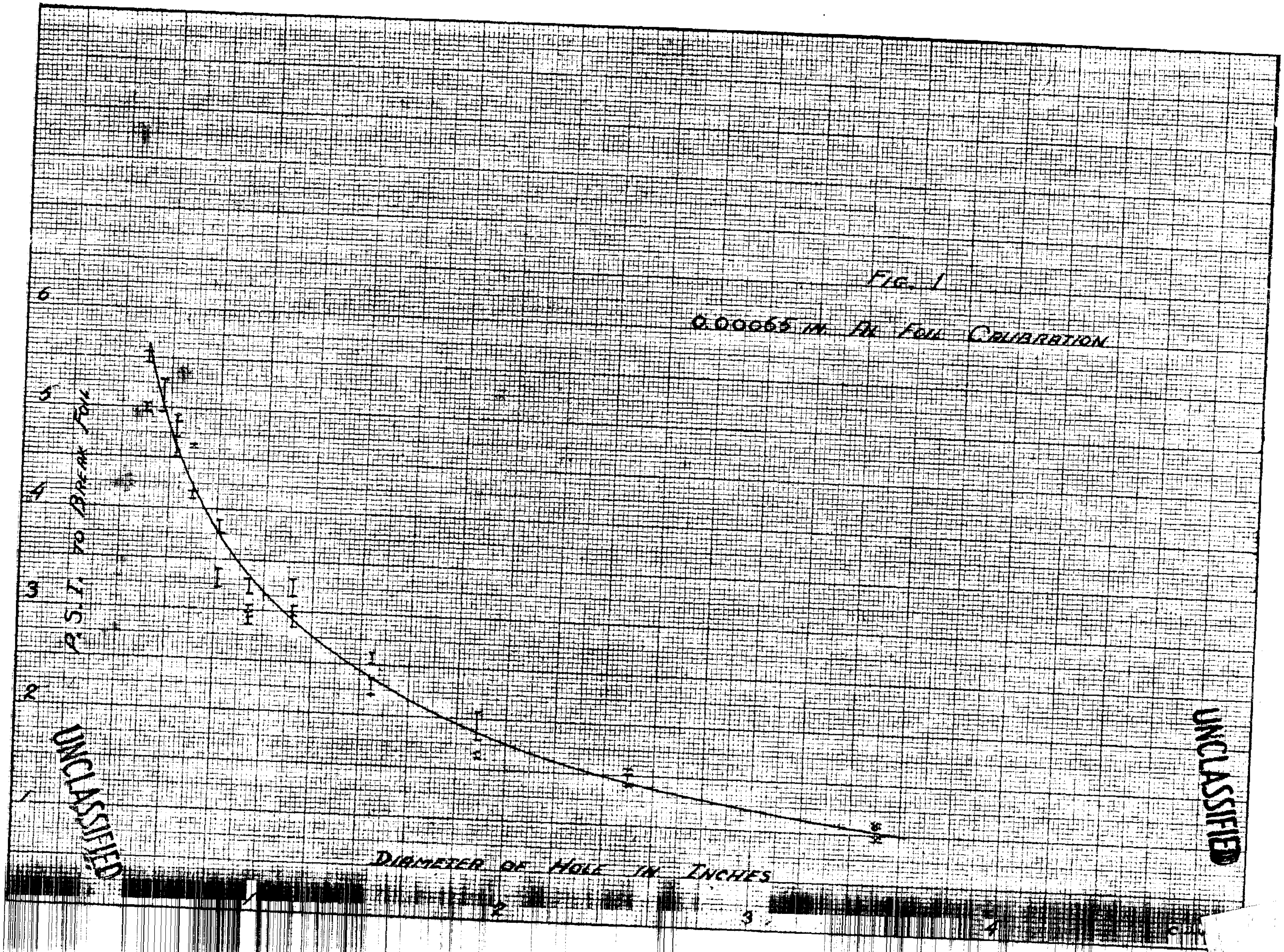
FIG. 1
0.00065 IN. AL FOIL CALIBRATION
P.S.I. TO BREAK FOIL
DIAMETER OF HOLE IN INCHES
6
5
4
3
2
1
2
3
4
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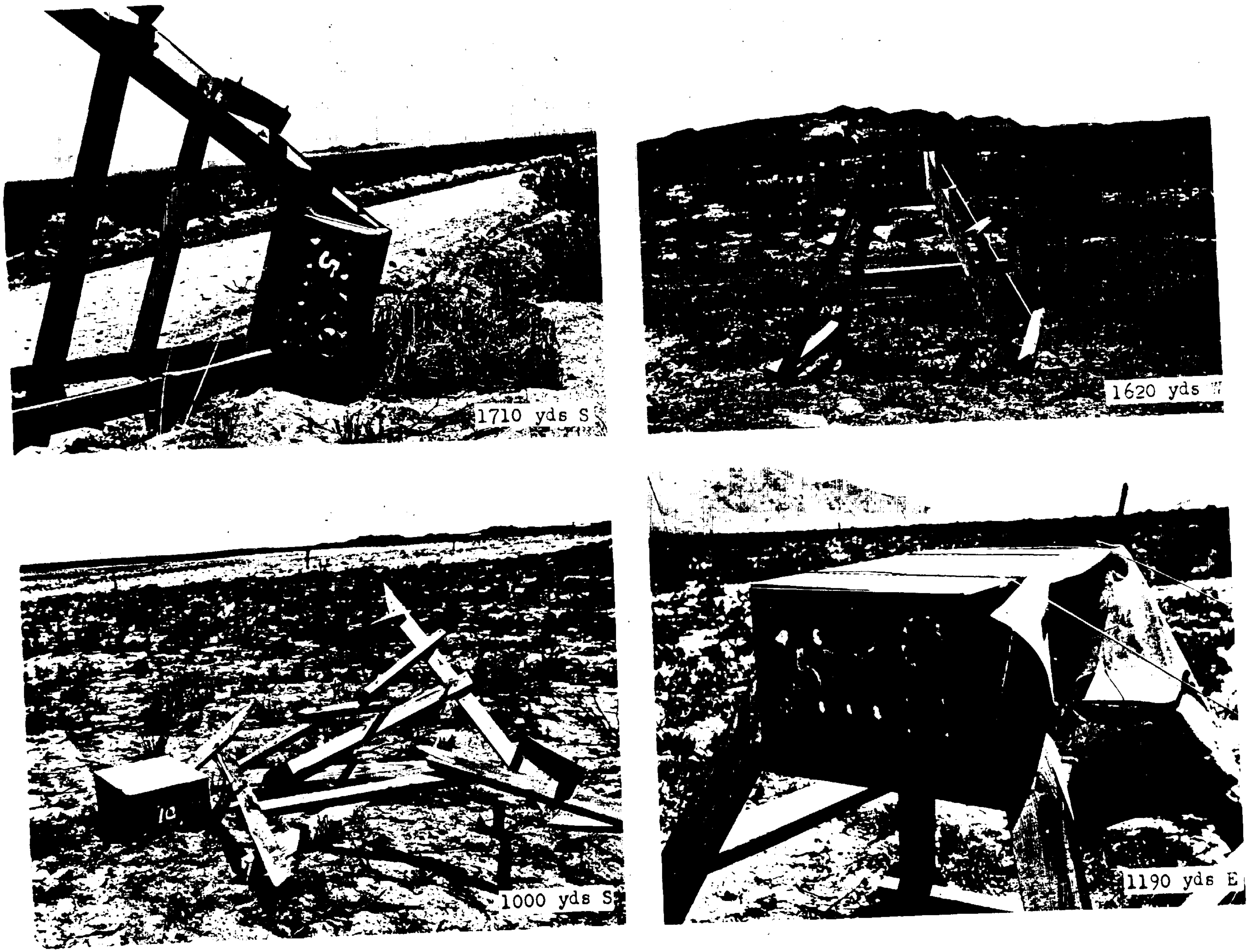


Fig. 2. [illegible] gauges after the nuclear explosion.

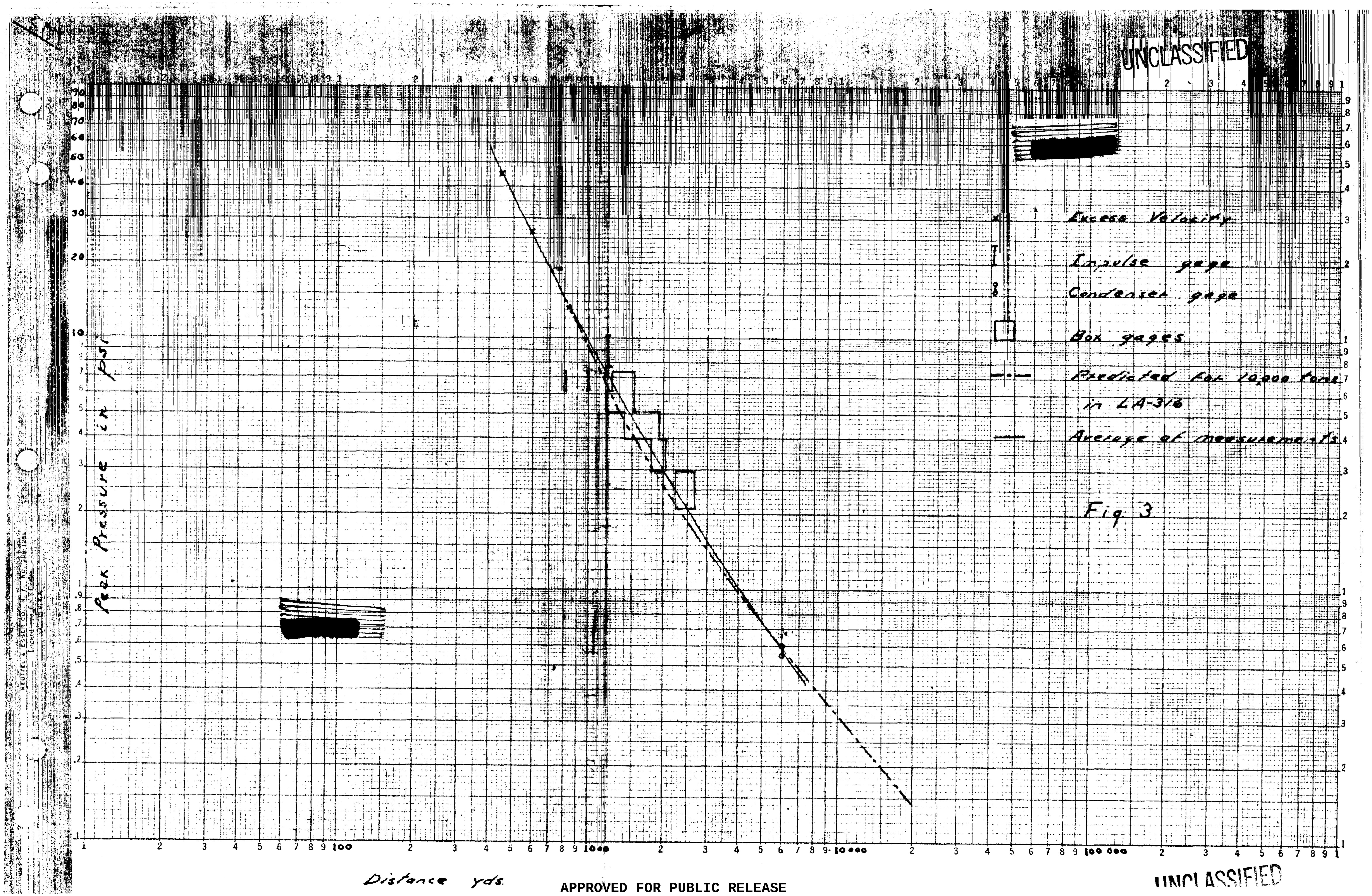

Peak Pressure in psi
Distance yds.
Excess Velocity
Impulse gage
Condenser gage
Box gages
Predicted for 10,000 tons in LA-316
Average of measurements

Fig. 3

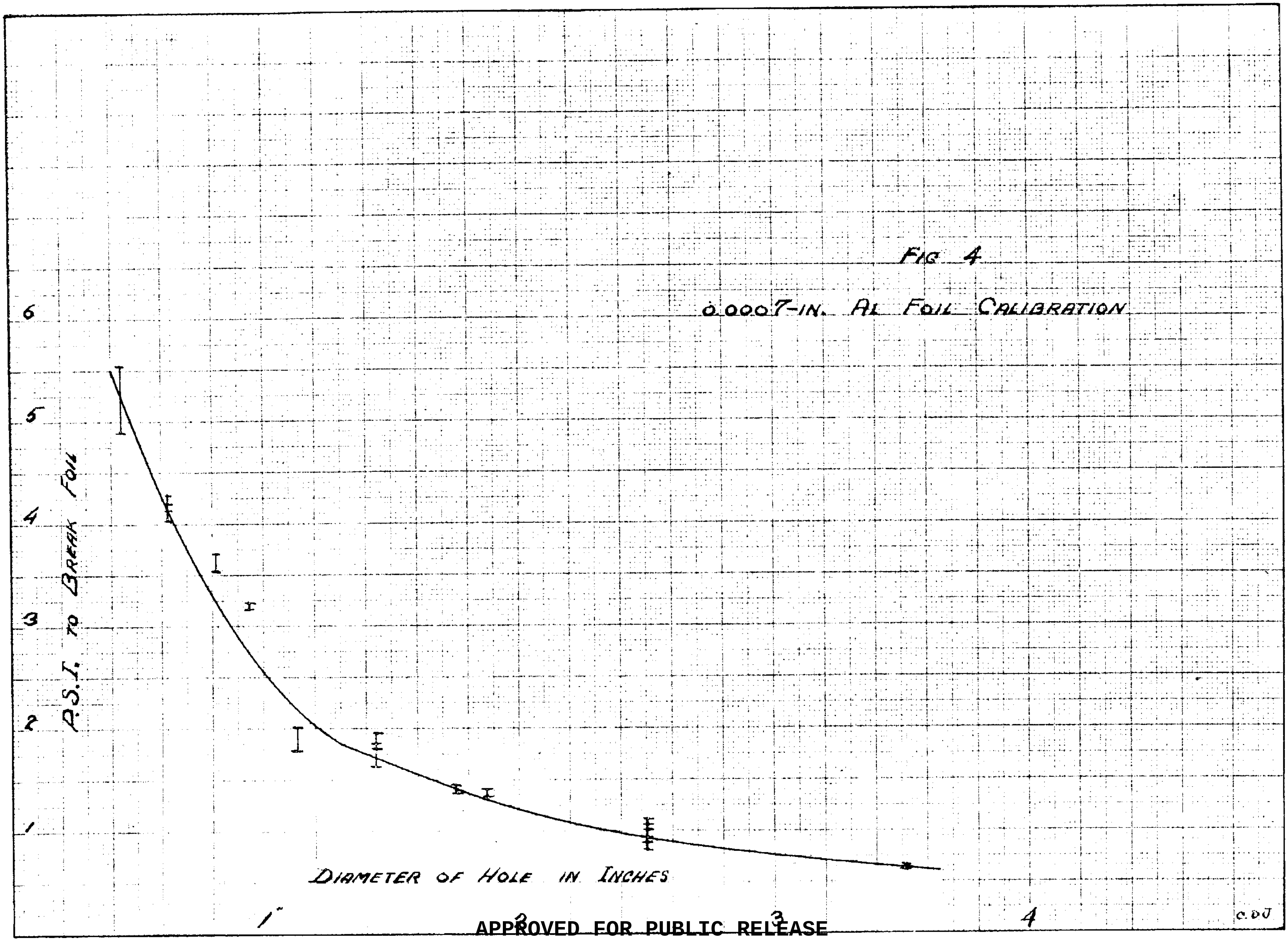
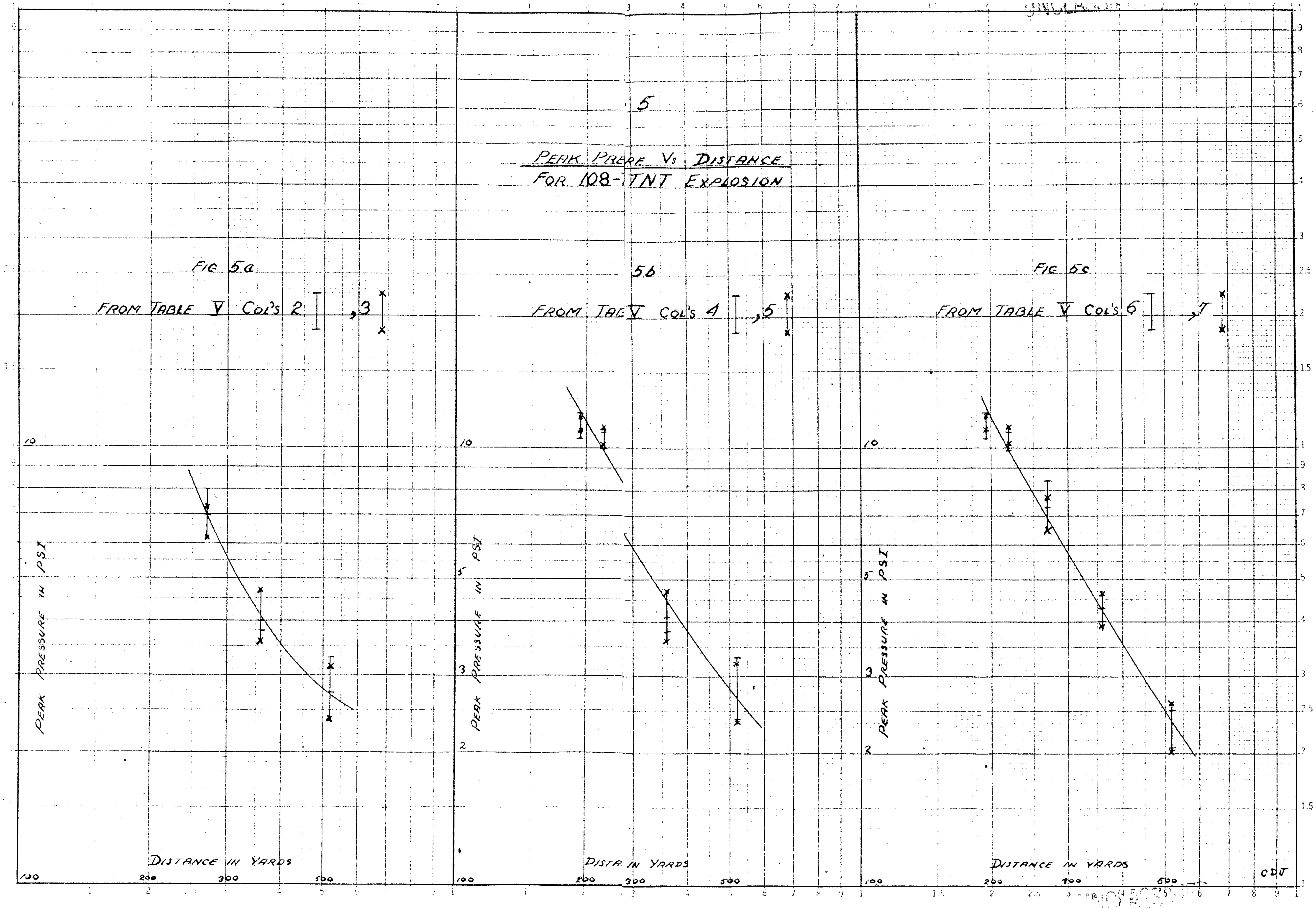


FIG 4
0.0007-IN. AL FOIL CALIBRATION
P.S.I. TO BREAK FOIL
DIAMETER OF HOLE IN INCHES
1
2
3
4
5
6
1"
2
3
4
C.D.J


5
PEAK PRES^RE Vs DISTANCE
FOR 108-TNT EXPLOSION
FIG 5a
FROM TABLE V COL'S 2 , 3
5b
FROM TAB V COL'S 4 , 5
FIG 5c
FROM TABLE V COL'S 6 , 7
PEAK PRESSURE IN PSI
DISTANCE IN YARDS
DISTA. IN YARDS
CDJ

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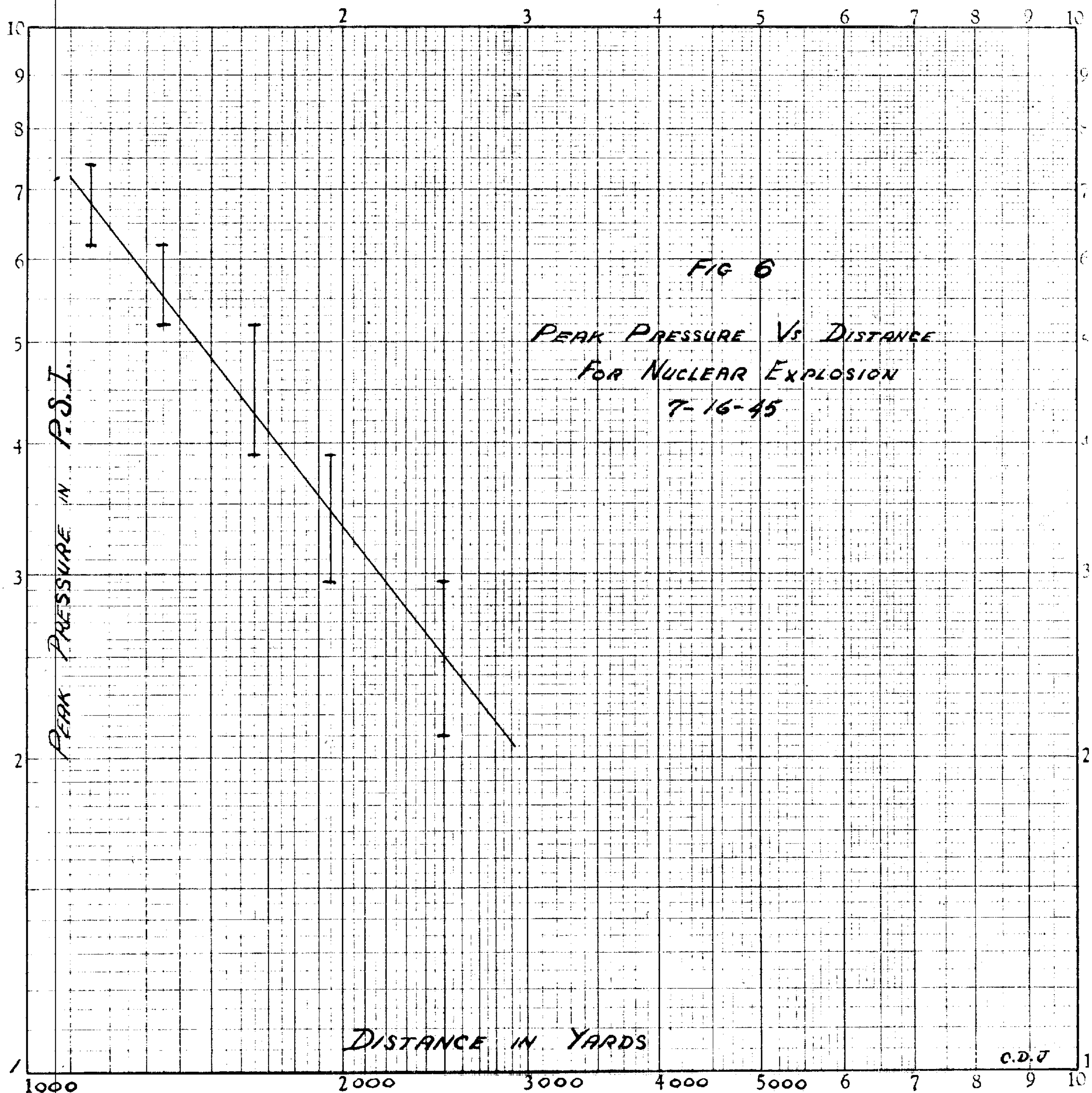

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