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By V. Martinez 2-13-57
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JULY 16th NUCLEAR EXPLOSION

MEASUREMENT OF MAXIMUM BLAST PRESSURE NEAR THE CENTER

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A number of copper-cylinder and copper-ball crusher gauges were disposed at near distances during the explosion of the atomic bomb at Trinity on July 16, 1945. The gauges were protected mechanically by steel containers sunk flush with the ground, the tops of the containers being provided with nozzles which restricted the rate of rise of pressure sufficiently so that the gauges would give reliable readings. Maximum pressures of 1.3 (4 readings) and 5.0 tons per sq. in. were recorded at distances of 324 ft and 208 ft respectively from the center of the base of the 100-foot tower supporting the bomb. When these values are compared with those which would be expected in free air from a bomb having a blast equivalent of 10,000 tons of TNT, it is seen that the multiplication due to the proximity of the ground is 6.0 and 8.0 at 324 ft and 208 ft, respectively. These values relate to the region of Mach reflection where calculation of the multiplication is not at present possible.

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JULY 16th NUCLEAR EXPLOSION

MEASUREMENT OF MAXIMUM BLAST PRESSURE NEAR THE CENTER

INTRODUCTION

It was suggested by G. I. Taylor that maximum blast pressures should be recovered very near the center during the explosion of the atomic bomb at Trinity, as the measurements would be extremely valuable if such a bomb had to be used with a low height of burst against fortifications or other heavy structures. Taylor also suggested that the pressures could be conveniently measured by crusher gauges of the type used in registering pressures in gun barrels during firing. Gauges of this type have the advantage that they do not require synchronization and unlike electrical recording equipment will record in the presence of intense ionization: for this reason it seemed desirable to make use of these gauges in the Trinity trial. Accordingly a number of crusher gauges were obtained and ranged along two lines extending northwards and southwards from the center under the hundred-foot tower on which the bomb was supported, the distances of the furthest gauges being about 300 ft from the center. A description of the gauges and the method of use, together with the results obtained, is given below.

Description of Gauges [redacted]

Two types of gauges were used in these experiments, one utilizing the deformation of a copper cylinder and the other the deformation of a copper ball. The cylinder gauges were of the type used by the Army Ordnance Department and the Navy Bureau of Ordnance, and comprised a copper cylinder 1/2" long and 3/8" in diameter, fitting loosely into a strong hollow steel cylinder provided with a piston and obturating cup. The maximum pressure to which the piston has been subjected is computed from the change in length of the copper cylinder, measured with micrometer calipers before and after the test. Since none of the gauges of this type were recovered, [redacted] [redacted]

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The copper-ball crusher gauges were of the type suggested by C. N. Hickman in NDRC report A-21, and comprised a small spherical copper ball enclosed in a steel cylinder similar to that used with the copper cylinder gauges and provided with a piston and obturating cup. The ball gauges had the advantage that, since the area of the compression member increases with increase in compression, a much larger useful range is attained. A section of the type of gauge used is shown in Fig. I. The ball gauges were supplied and calibrated by the California Institute of Technology, and in the actual gauges used the copper balls were 0.1240" in diameter and were obtained from the Hartford Steel Ball Company, Hartford, Connecticut. The balls were annealed according to the procedure outlined by C. N. Hickman, and were calibrated statically by applying hydraulic pressure to the piston and flattening the ball. A single compression was applied to each ball and the compression was measured after the load had been removed. The average variation between two ball gauges was found to be about 30 psi. The calibration curve obtained was found to be a straight line with a slope of 238 psi/mil compression. This value is somewhat smaller than that given by Hickman probably owing to differences in the copper, which are known to affect the calibration considerably.

Design of Steel Gauge Container

In order to provide adequate anchorage and mechanical protection for the gauges, a steel gauge container of the type shown in Fig. 1 was prepared. This comprises a hollow steel cylinder screwed to the top of a 1-1/4" diameter steel bar 18 inches long. The whole container was driven into the ground before the gauge was inserted so that the top was flush with the surface. After the insertion of the gauge the open end was fitted with a nozzle, the purpose of which was to govern the rate at which pressure was applied to the gauge inside. [redacted]

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sisting medium in which the resistance is proportional to the deflection, if a uniform pressure is suddenly applied the maximum deflection attained is double that which would be produced by the same pressure applied infinitely slowly. Accordingly, reliable readings can only be obtained with crusher gauges of the type described, provided that the pressure is applied gradually. As the time constant of the gauge is extremely short, ($\sim$ 0.02 millisec.), it is sufficient in view of the slow rate of fall of the blast pressure ($\sim$ 25 millisec.) if the maximum pressure in the container is attained in two or three milliseconds and the nozzles used on the containers in the present tests were designed so that the maximum pressure inside was attained in approximately this time. Two types of nozzles were used, one comprising a single 5/8" diameter hole and the other comprising three 1/4" diameter holes, the former type being used at stations A, B, C, D (see Table I), while at stations E and F half the gauges had single-hole nozzles and half had triple-hole nozzles.

Layout of Gauges

The layout of the gauges along each of the two lines extending northwards and southwards from the center is shown in Table I. It will be seen that the cylinder gauges were used only at the nearer stations, and that, in view of the unknown size of the expected explosion, the gauges were well distributed along the two lines. Precise details of the layout are given in Table II for those guages which were recovered after the shot.

Recovery of Gauges

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Four weeks after the shot an attempt was made to recover the gauges, and for this purpose a number of search parties were sent into the area[1]. Only five of the thirty-two gauges were recovered and particulars of the locations and measurements obtained from these gauges are given in Table II, whilst Fig. 2 shows a photograph of a typical station from which gauges were recovered after the shot. All the other

1) The authors wish to thank the various people who helped in the search for the gauges. The names of those participating, together with the radiation dosage received are given in Appendix I.

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stations were located but it appeared that at the nearer distances the earth movement and the stresses involved were such that the upper steel container was torn from the 1-1/4" steel bar and only the steel bar remained (see Fig. 3). The gauges at these stations would accordingly have come out of the steel containers and have been subject to severe accelerations: in view of this and of the radiation hazard it was considered inadvisable to make a further extensive search.

Discussion of Results

It will be seen from Table 2 that maximum pressures of 1.3 (4 readings) and 5.0 tons per sq. in. were recorded at 324 ft and 208 ft from a point on the ground under the center of the tower.

In Fig. 4, a curve is given for the maximum blast pressure in free air as calculated by the IBM's for a gadget having the same blast pressure at somewhat greater distances (e.g., 5 psi level) as 10,000 tons of TNT. When the measured pressures given above are compared with this curve, it is seen that the reflection from the ground apparently causes a multiplication of about six times and eight times at distances of 324 ft. and 208 ft respectively. These values for the multiplication are shown in the figure which also gives the calculated values for the multiplication in the region of regular reflection, assuming $\gamma = 1.25$. This region only extends on the ground to 80 ft from the center, and the measured pressures thus fall in the region of Mach reflection where calculation of the multiplication is not at present possible.

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TABLE I- Layout of Gauges Along Each Line

Station	Nominal distance from center: feet	No. of ball gauges	No. of cyl. gauges
A	50	0	1
B	75	2	1
C	100	2	2
D	150	2	2
E	210	2	0
F	325	2	0

TABLE II- Measurements from Ball Gauges Recovered

Station	Nozzle holes	Dist. from center: feet	Compression mils	Max pressure tons/in^2
N-F1	Triple	327	9.3	1.10
N-F2	Single	328-1/4	11.2	1.34
S-F1	Triple	320-1/4	10.6	1.26
S-F2	Single	322	11.4	1.36
S-E2	Single	208	41.5	4.95

APPENDIX I

The following persons assisted in locating the gauges after the shot, and the amount of radiation received by each is shown below.

J. Ashkin	1.5 R
T. Cuykendall	3.0 R
J. Keck	1.2 R
W. G. Marley	2.0 R
L. G. Parratt	3.0 R
M. Peshkin	4.3 R
F. Reines	0.3 R
T. A. Welton	4.3 R

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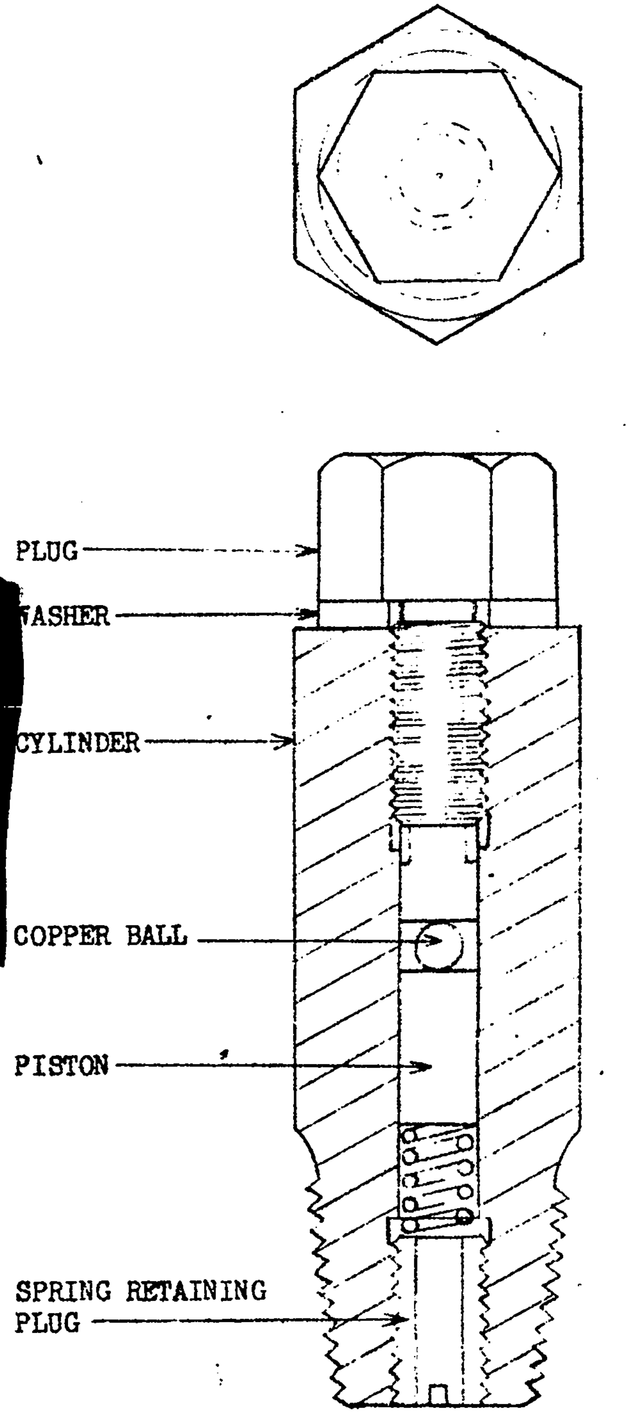
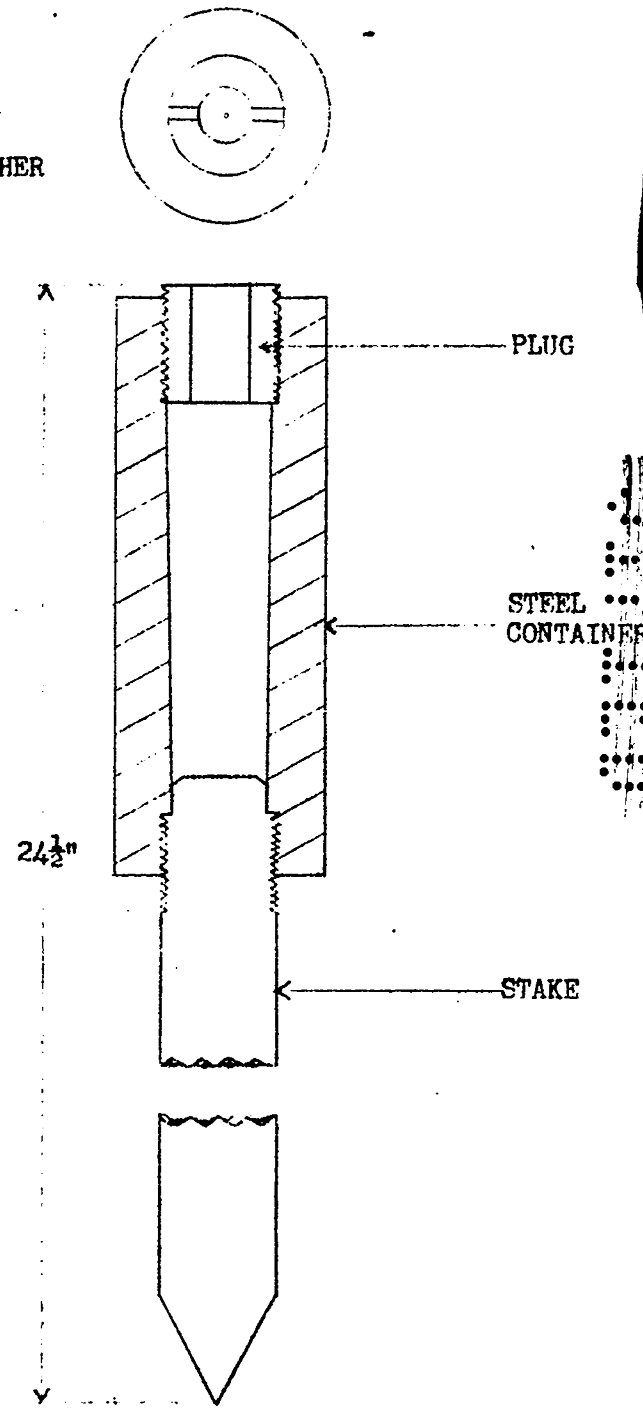
FIGURE 1

SECTION OF BALL CRUSHER GAGE AND OF STEEL CONTAINER.



SCALE 2 x NATURAL SIZE



SCALE ½ NAT.

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Fig. 2. Photograph of station North-F showing position of gauge containers after the shot.

Fig. 3. Photograph of station North-D excavated after the shot, showing ends of three anchor stakes from which containers have been torn.

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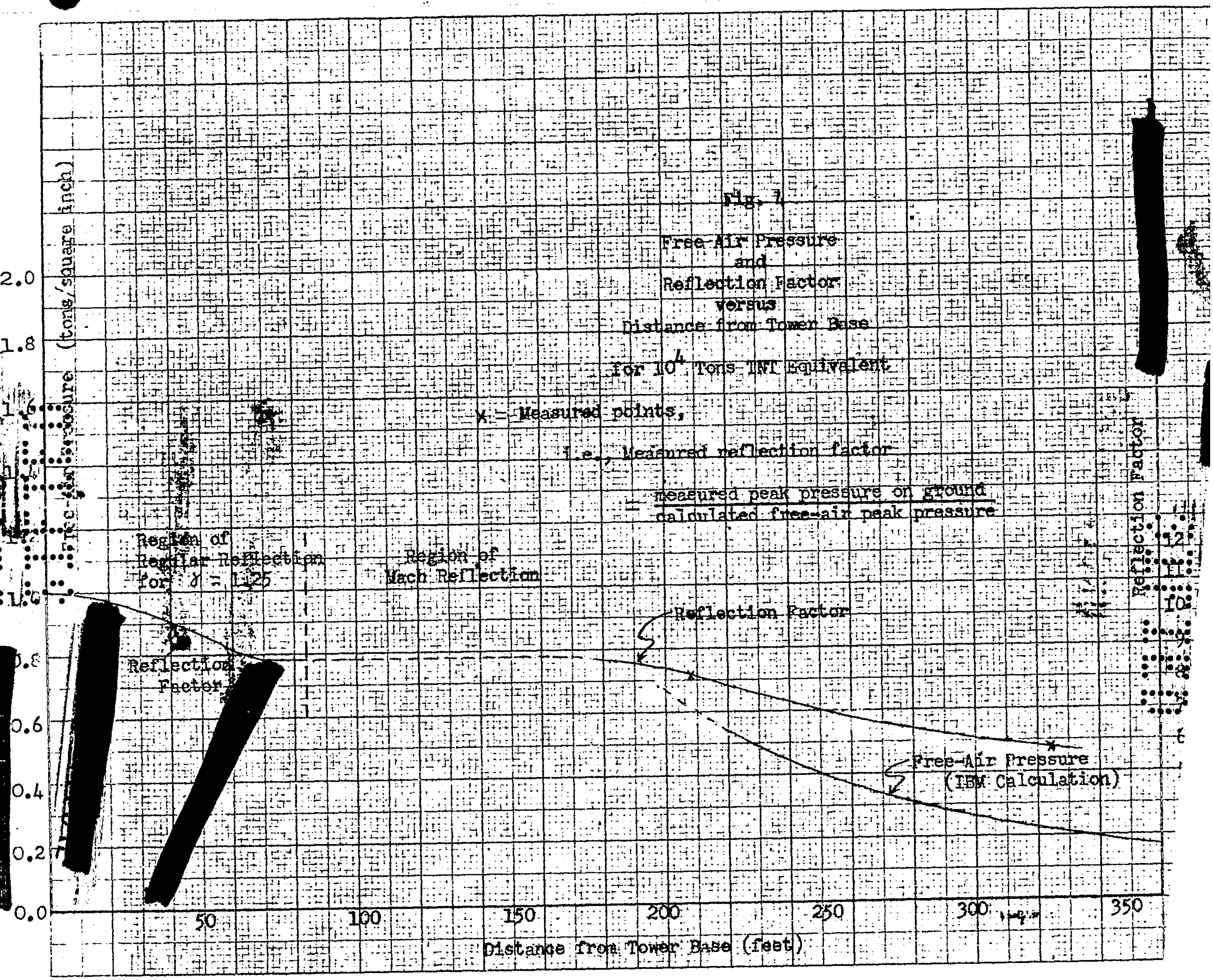
Fig. 1
Free-Air Pressure
and
Reflection Factor
versus
Distance from Tower Base
for 10^4 Tons TNT Equivalent
x = Measured points,
i.e., Measured reflection factor
= measured peak pressure on ground
calculated free-air peak pressure
Region of
Regular Reflection
for γ = 1.25
Region of
Mach Reflection
Reflection Factor
Free-Air Pressure
(IBM Calculation)
Reflection
Factor
(tons/square inch)
Reflection Factor
2.0
1.8
1.0
0.8
0.6
0.4
0.2
0.0
50
100
150
200
250
300
350
Distance from Tower Base (feet)

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