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JULY 16th NUCLEAR EXPLOSION: MECHANICAL IMPULSE GAUGE

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ABSTRACT

The mechanical impulse meter measurements give for the July 16th nuclear explosion, at a point 1200 yards away and 54" above the ground, a peak pressure of 9.4 psi ± 15 percent, an impulse of 1.77 psi-sec ± 6 percent and a positive duration of the blast of .65 sec ± 5 percent.

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JULY 16th NUCLEAR EXPLOSION: MECHANICAL IMPULSE GAUGE

In planning measurements on the first nuclear explosion it was suggested that there was a possibility that electrical disturbances coincident with the explosion might make it impossible to obtain measurements of the blast by the usual piezo-electrical methods. Therefore, mechanical gauges of four types were made ready for the test. These were the aluminum foil boxes, piston pressure gauges, an impulse gauge of English design, of which one was built but not used, and an impulse gauge (squirt gun type). The design and use of this last gauge is the subject of this report.

In the design of this mechanical impulse meter it was assumed that the amount of water flowing through a tube is some function of the pressure difference between the ends of the tube. If a mechanism can be devised to measure the rate at which water flows through a tube as a function of time, and this device can be calibrated, it may be used to measure peak pressure, impulse and duration of the positive phase of the blast. Such a mechanism is a cylinder filled with water, with a piston at one end and a plate with holes at the other. The position of the piston is indicated by a rod from the piston through the plate with holes. The rod carries a stylus which marks a rotating smoked-glass disc. The cylinder is mounted on the side of an air-tight dural box and a motor carrying the glass disc is mounted in the box. Details of the arrangement may be seen in the photographs (Figs. 1, 2, 3, 4, and 5).

Calibration of these instruments was done with a blast tube of two one-foot sections of 6-1/2 inch diameter. There was a cellophane sheet of suitable thickness between the two sections. The compression chamber had a volume of 6300 cc. The

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volume of the expansion chamber was made smaller by a wooden plug which fitted inside the cylinder. The volume of the expansion chamber was 2270 cc. The bulge on the cellophane was measured and a correction was applied to the two volumes. The pressure in the compression chamber before the blast was measured with a mercury manometer and the pressure in the system after the blast was calculated, assuming an isothermal expansion. Actually the expansion is somewhere between an isothermal and an adiabatic expansion. A calculation assuming an adiabatic expansion and compression without mixing gives a result for a compression chamber over-pressure of 30 cm differing by 1.7 percent from the calculation for the isothermal process. Actually, the gas does mix somewhat and also derives heat from the walls of the vessel. The error made by assuming an isothermal process is then definitely less than 1.7 percent for this over-pressure.

The impulse meter to be calibrated was bolted to the side of the expansion tube and constant pressures were suddenly applied to the piston. Traces were thus obtained on the smoked-glass disc which rotated at a known speed. The disc was then placed on a piece of polar-coordinate paper on a film-reading table. Coordinates were read from the trace and a radius-vs-angle (time) graph was drawn on cartesian-coordinate paper for each constant pressure. These graphs were all straight lines showing that the piston moved with constant speed when constant pressure acted on it (see Fig. 6). No curvature was observed at the start of these lines. This showed that the inertia forces were small compared with the blast forces. The slopes of these graphs gave the speeds of the piston for the various constant pressures. The square of the speed was found to be nearly a linear function of the pressure.

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It was found that the impulse gauges would measure impulses with precision only for those impulses for which the instruments were set. Impulses of known peak pressure and duration were applied to the pistons by letting air out of the calibrating blast tube through holes in the expansion chamber. By choosing suitable impulses as scaled from previous shots, gauges were set by adjusting the number of squirt holes to measure impulse from an explosion of 100 ton, 1000 ton, and 5000 ton TNT equivalent. The squirt holes were 1 cm long and .04 inches diameter.

It was decided that twelve gauges should be distributed according to the following table.

Size of Shot tons	Peak Press. psi	Impulse psi x sec.	Time sec.	Radius yards	No. of Holes	No. of gauges at station	Gauge Numbers
100	5	.330	.22-.27	350	29	1	1
100	2.5	.220	.25-.29	520	48	1	3
1000	6	.860	.40-.55	600	11	2	9 and 10
1000	2.5	.500	.46-.57	1000	29	2	4 and 6
5000	8	1.700	.9	900	5	2	7 and 12
5000	5	1.300	.74-.95	1200	8	2	2 and 5
5000	2.5	.800	.90-1.10	2000	9	2	11 and 8

The glass discs were rotated by motors powered by a six-volt storage battery. The motors were windshield-wiper motors remodeled to give a speed of rotation of about one revolution per second. The speed of rotation was determined by counting the revolutions for a five-minute period ending three minutes before the blast by means of a rotating switch in a circuit with a battery and a message register. The motors and counting circuit were turned on by means of a control line and relays. Tests made in the laboratory showed that the speed of rotation was constant enough

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so that no appreciable error would be made by this process.

The dural boxes containing the piston and cylinder, the glass disc, the motor, and the relays were mounted along with the batteries and message register in a plywood box. The box of 3/4" plywood was then supported by screen-door springs on a 1-1/4"-iron-pipe frame. The general arrangement may be seen in the photographs (Figs. 7 and 8). Rough calculation showed that the boxes should not be treated too roughly for the blasts for which the gauges were set.

The motors, relays and revolution counters were tested on each of the dry runs. Thirty-six hours before the nuclear explosion the cylinders were filled with water. The outside of the piston and the stainless-steel shaft were made water-tight with a small amount of silicone stopcock grease. Tests had been run which showed that this grease did not affect the calibration of the gauge. The afternoon before the nuclear explosion, the glass discs were put in place. During the evening before the nuclear explosion, the water level was checked, the splash guards used to keep the water from falling on the smoked-glass discs were put in place, and the lids of the dural boxes were put on.

After the nuclear explosion of July 16th, eight wooden boxes and contents were recovered practically undamaged; only one was on the ground. The gauge closest to the explosion was not recovered. The other three gauges were recovered, but had been treated somewhat roughly. Only parts of these plywood boxes and iron frames could be found. These recovered gauges are shown in photographs (Figs. 9, 10, and 11).

The glass discs of gauges numbers 1, 3, 9 and 10 were not recovered. The record of gauge number 11 showed that the scribe did not move. Investigation disclosed that the splash guard rested against the stainless-steel rod preventing its

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motion. Gauge number 7 gave no record. The glass disc shows evidence of wear, showing that it had been loose on the shaft. This is the gauge that fell to the ground. Gauges numbers 6 and 4 were set for a 1000-ton explosion and these records gave only the duration of the positive phase of the blast. Gauges numbers 5, 12, 8 and 2 gave records.

Preliminary readings of these graphs gave very discrepant peak pressures. Durations of the positive phase of the blast were then plotted against the distance from the nuclear explosion in yards. A point obtained by use of a condenser gauge was also plotted. As will be seen (Fig. 12), the points scatter very much. An extrapolation was made, using blast velocities obtained by use of microphone gauges (LA-352), from the point for gauge number 2 to the point for the condenser gauge. The extrapolation differed from the experimental point by less than 5 percent. This gives some weight to the point for gauge number 2. Gauge number 8 gave too low a value of duration because of faulty action of the relay in series with the motor causing it to run at reduced speed. This trouble with the relay was discovered on inspection after the blast. Gauge number 5 gave too low a value because the piston stuck for the first part of the blast. Gauge number 12 gave a reasonable duration for the blast, but the trace was so irregular that no interpretation could be made.

The records from gauges numbers 5, 12, 8, 2 and 4 are shown in Figs. 13, 14, 15, 16, and 17. The record for gauge number 2 is the only one for which an analysis will be given.

From the record from gauge number 2 the plot of radius vs angle (time) was obtained as shown in Fig. 18. As may be noticed, the record for the first twenty-five degrees is not very smooth. If this is an effect coming from the blast, then

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the peak pressure and impulse should be determined by taking account of the shape of the curve. If the effect is instrumental, then the peak pressure and impulse may be better obtained by extrapolation of the curve occurring after 25 degrees. Both methods have been used. The first method gives a very unlikely pressure time curve (curve A, Fig. 19). The pressure starts out at near 8 psi and, after falling rapidly, rises abruptly to around 13 psi, (this last figure is uncertain because the calibration curve was extrapolated to this pressure) and falls rapidly again. This happens in about 0.1 sec. The impulse determined from this curve 1.68 psi x sec.

The pressure time curve for times greater than .10 seconds is a smooth curve (curves A, B, and C, Fig. 19). Points shown for the same time are independent determinations of that pressure. These points were plotted on semi-log paper (Fig. 20). As may be seen, these points fall about a straight line. Extrapolation on this graph gives a peak pressure in the range 8.5 psi to 10.6 psi. As may be seen, the determination of the peak pressure is somewhat uncertain. It should be in the range, 9.4 psi ± 15 percent.

The impulse is determined by measuring the area under the pressure-time curve. The areas under Curve A, Curve B and Curve C are respectively 1.68, 1.82 and 1.73 psi sec. The impulse from Curve A is not much different from that from Curve C. This means that the impulse can be determined with more precision than the peak pressure. It seems that if less weight is given to the impulse obtained from Curve C, the result may be stated as 1.77 psi sec. ± 6 percent.

The duration of the positive phase was determined directly from the record on the smoked-glass plate and not from the pressure-time curve. The duration is .65 sec ± 5 percent.

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A study was made of the effect of the temperature of the water on the calibration of the instruments. It was found that a cooling of 17° C shifted the speed-squared-vs-pressure curve (Fig. 21) toward higher pressures by about 4 percent for all pressures. Since the air temperature was 19° C at the time of the shot, and by test, the water ran 1° higher than air temperature because of the heating of the interior of the aluminum box by the motor, and since the calibration temperature was 25°C, the temperature correction, assuming a linear relation, is about one percent. This is small compared to other errors and it will be neglected.

The results of this investigation are that at 1200 yards from the nuclear explosion of July 16th, and at 54" above the ground, the peak pressure was 9.4 psi ± 15 percent, the impulse was 1.77 psi x sec ± 6 percent and the duration of the positive phase of the blast was .65 sec ± 5 percent.

When these results are used to estimate the equivalent TNT tonnage of the blast, it turns out that they are not consistent. The impulse measurement gives, according to the results in LA-316 by Hirschfelder, Littler, and Sheard, very nearly 10,000 tons but the peak pressure measurements give nearly twice that figure. The peak pressure for 10,000 tons of TNT at 1200 yards is given as 6.3 psi by their curves.

It is suggested that if apparatus of this kind is ever used again, that somehow the relay controls are done away with, and that a more substantial connection to the storage battery than battery clips be provided.

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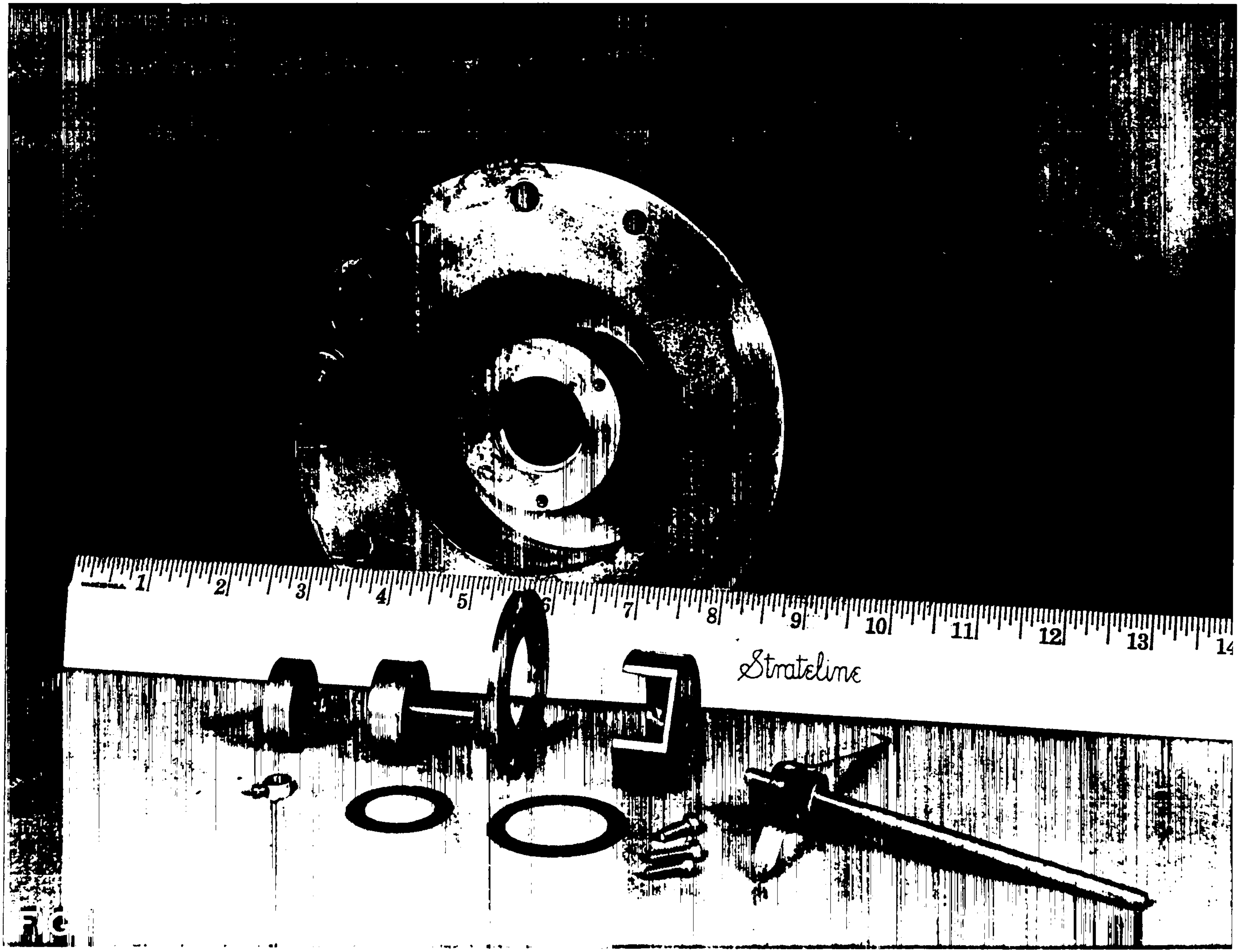


FIG

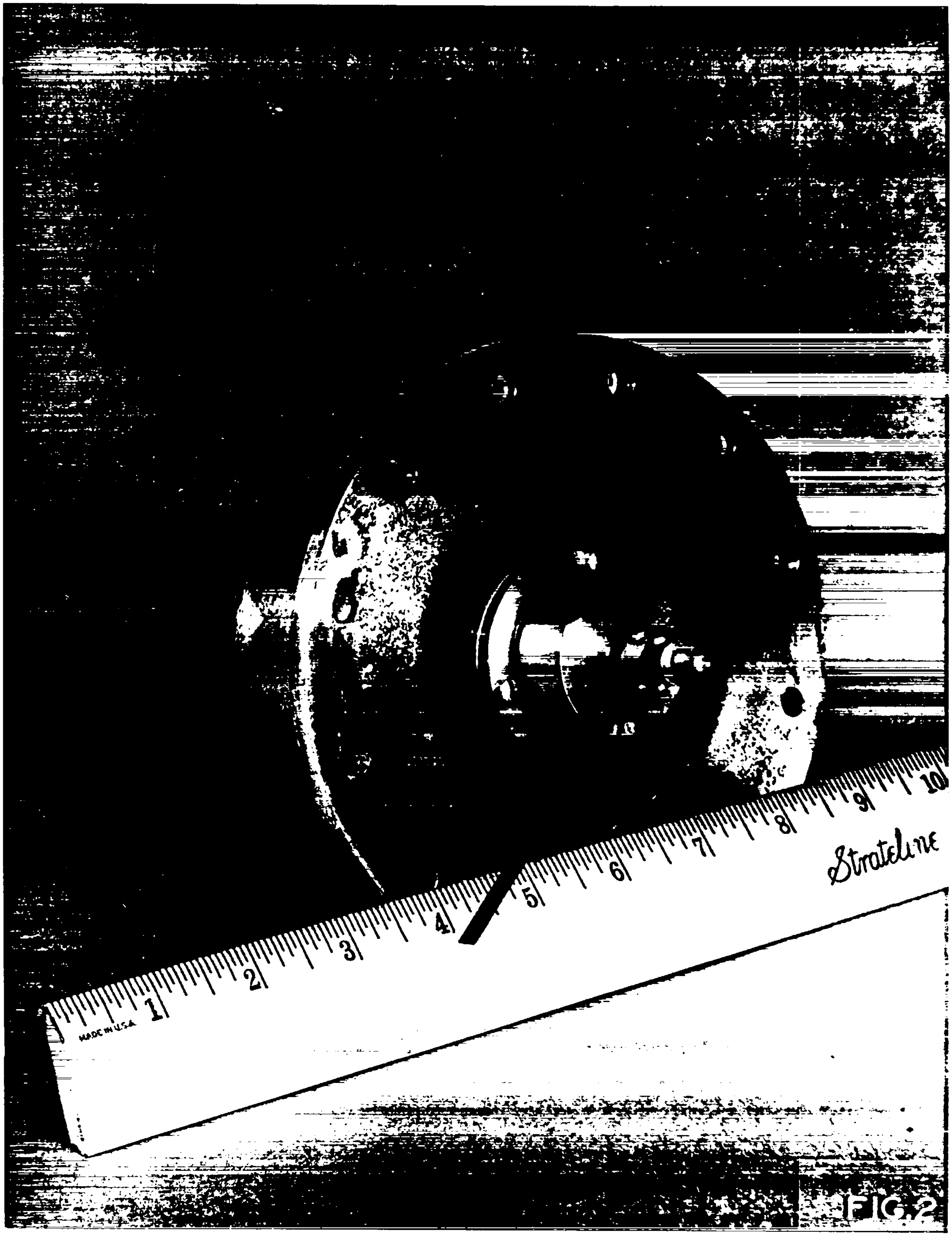
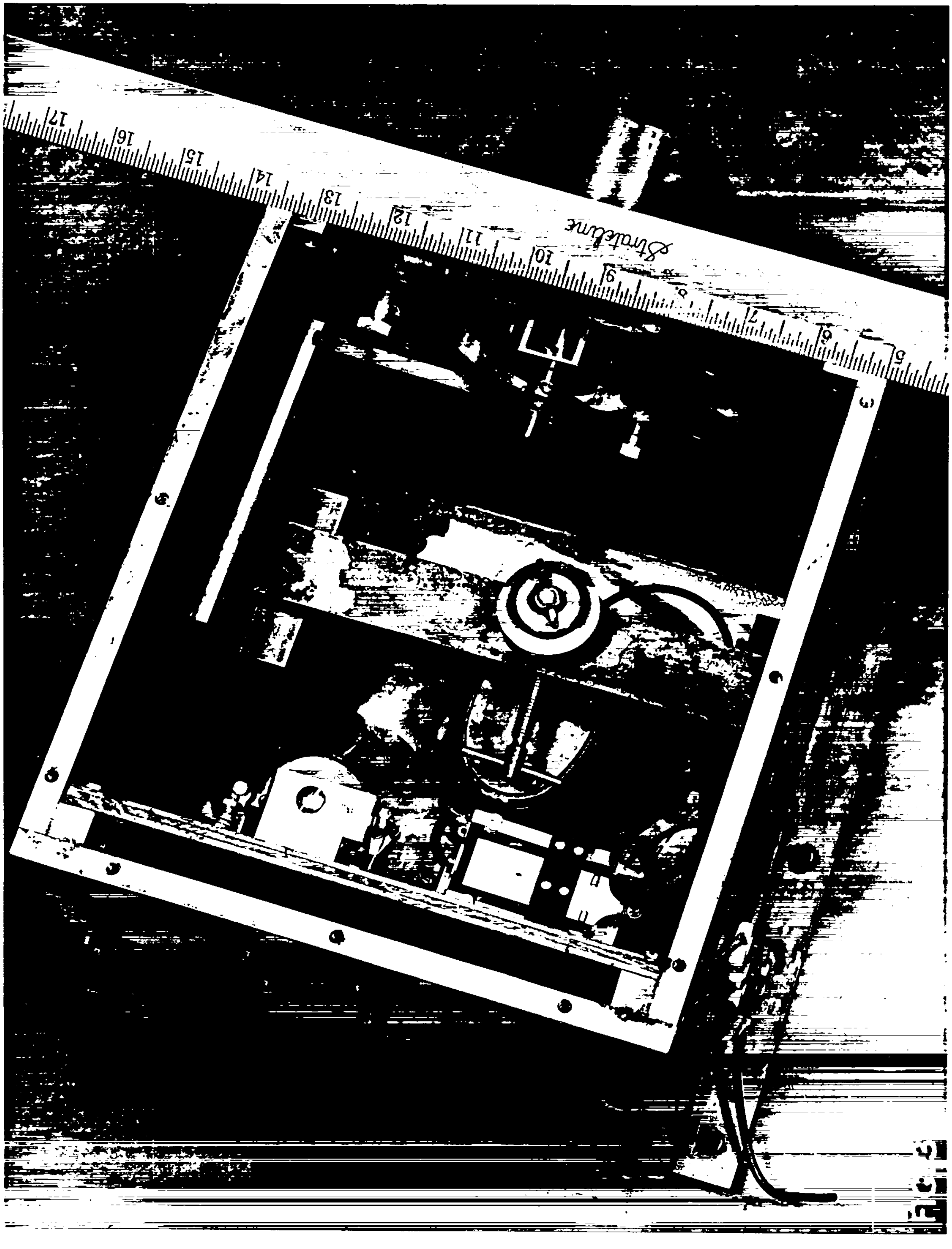
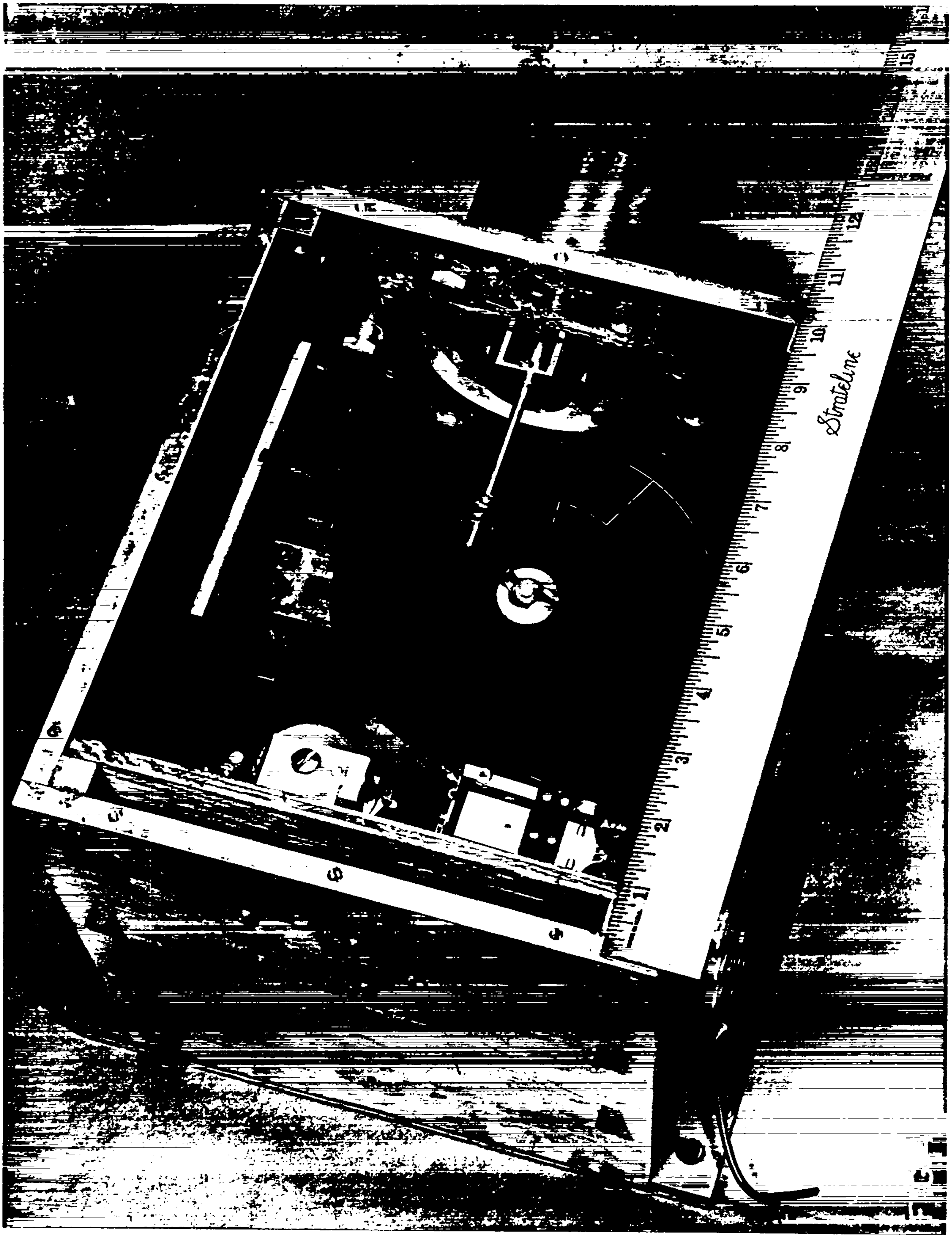


FIG.2



17
16
15
14
13
12
11
10
9
8
7
6
5
Strabine


Straitline
1
2
3
4
5
6
7
8
9
10
11
12
15

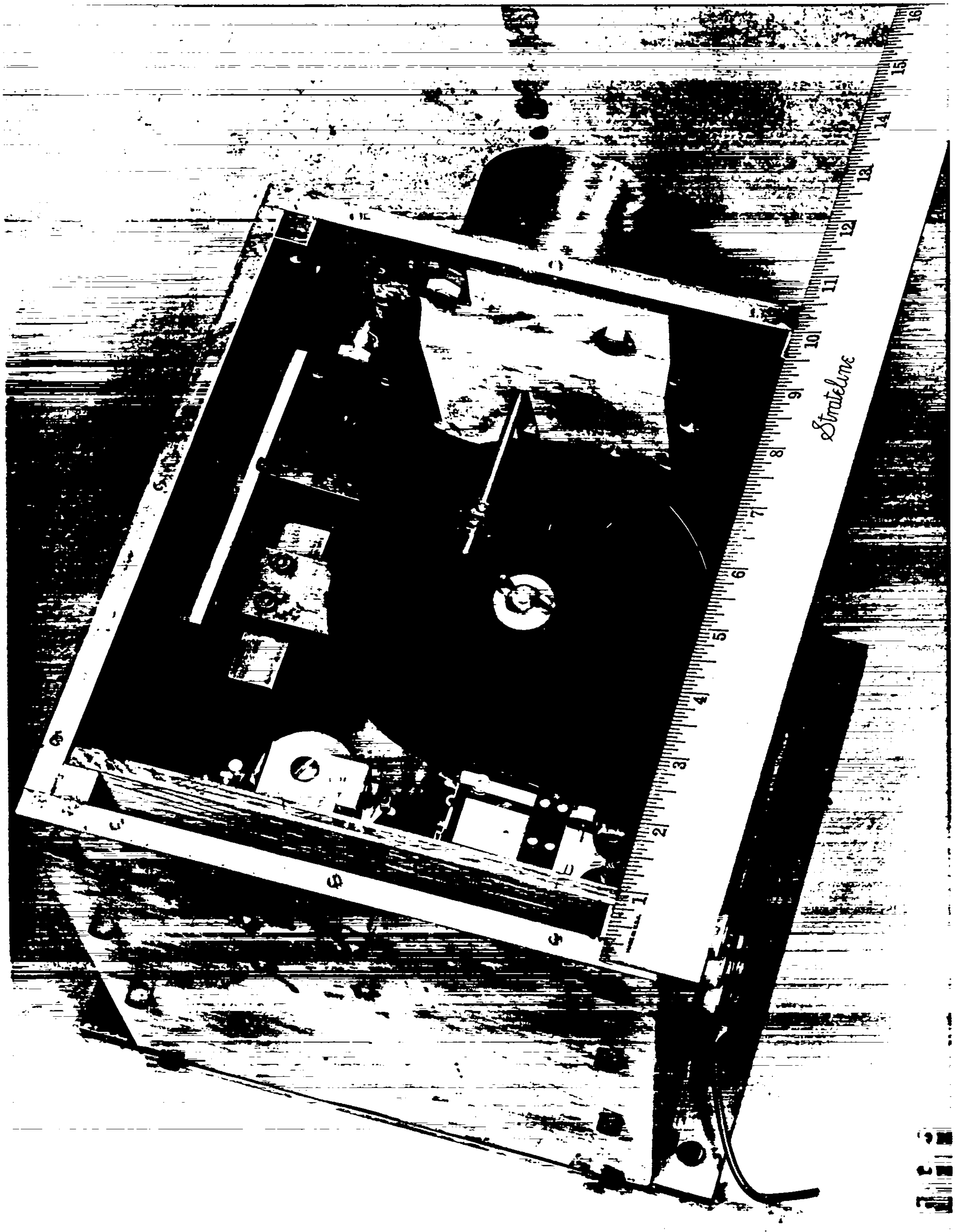
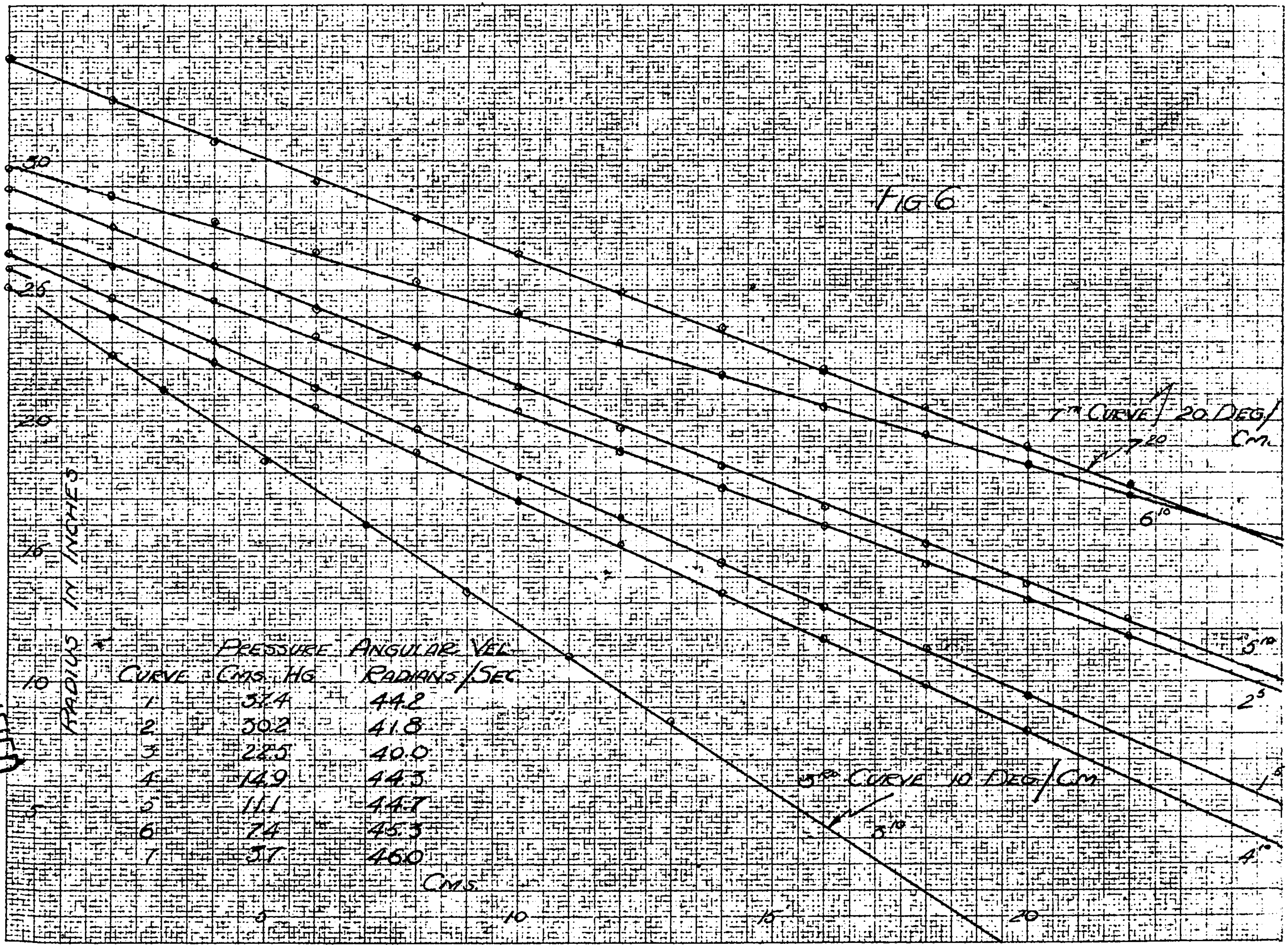

Strateline
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

FIG 6



CURVE	PRESSURE CMS HG	ANGULAR VEL RADIANS/SEC
1	37.4	44.2
2	30.2	41.8
3	22.5	40.0
4	14.9	44.3
5	11.1	44.7
6	7.4	45.3
7	3.7	46.0

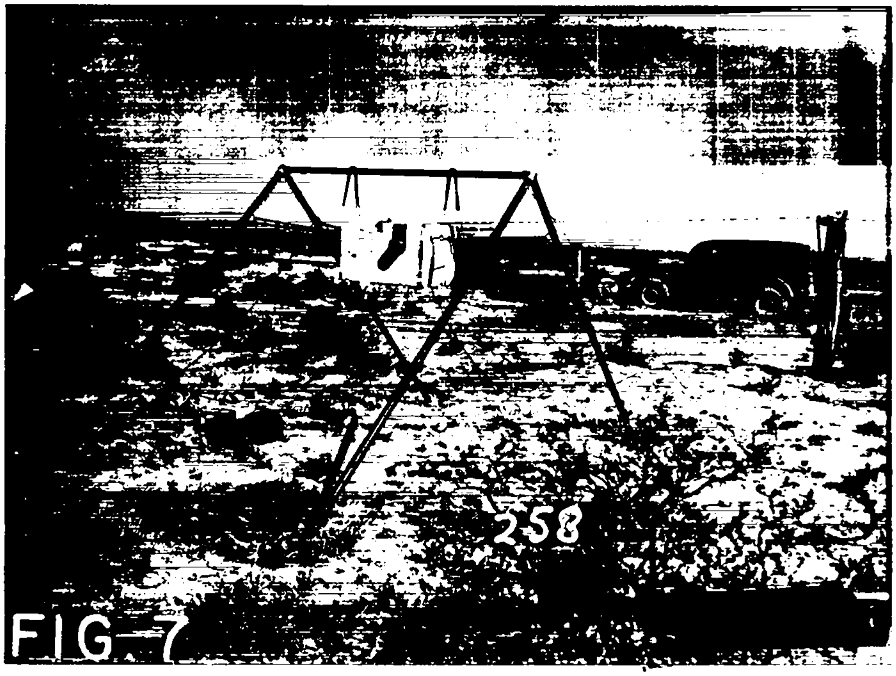


FIG. 7

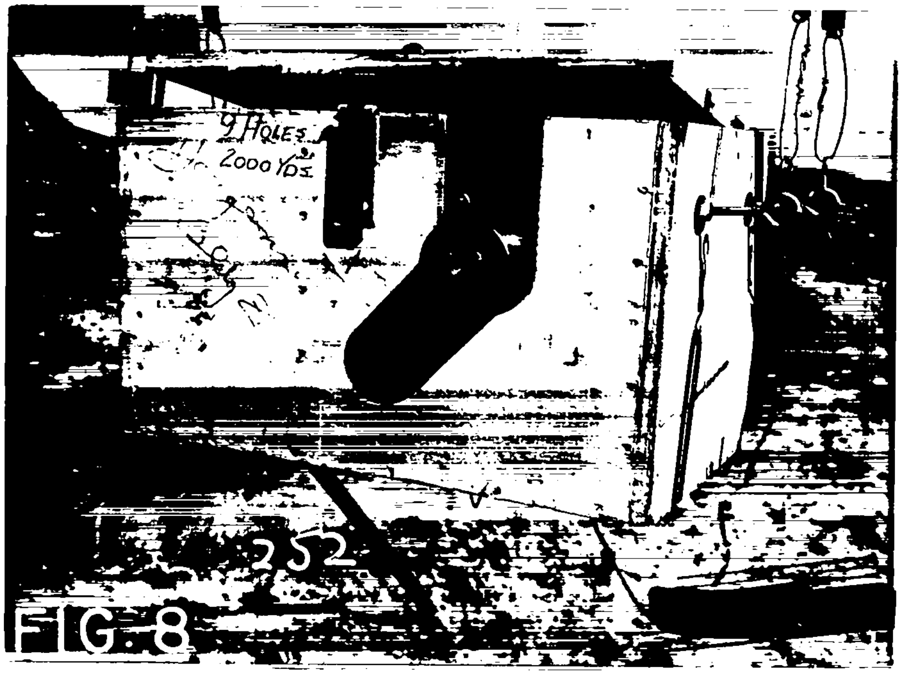


FIG. 8

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FIG. 9

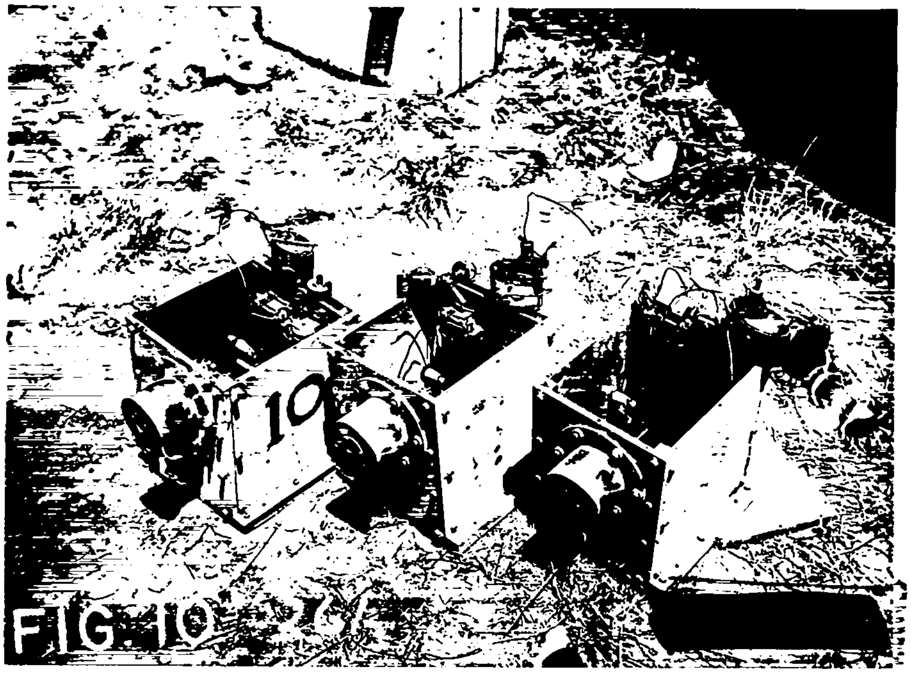

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FIG. 10

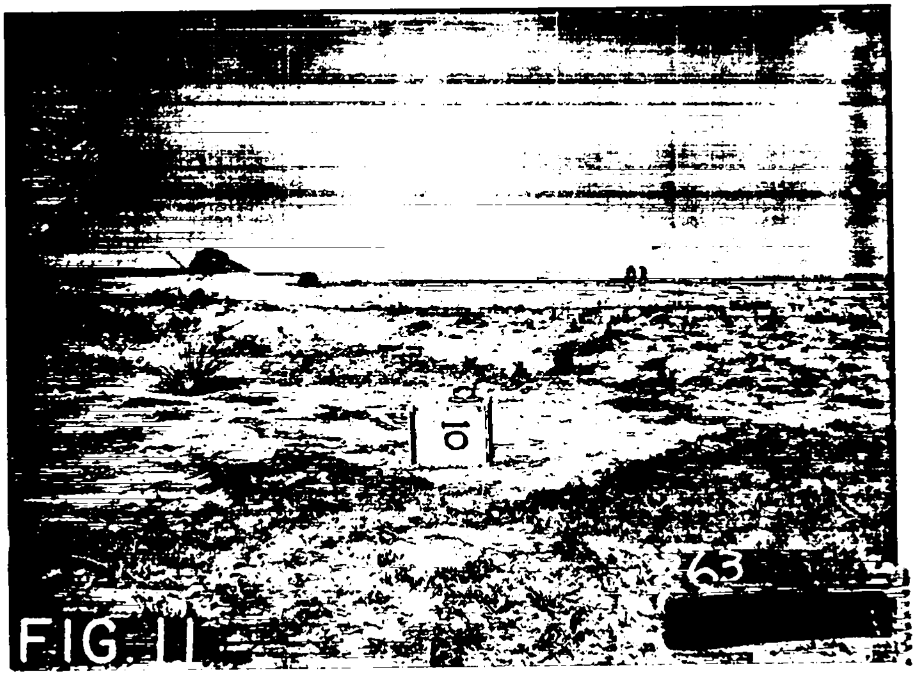

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FIG. 11

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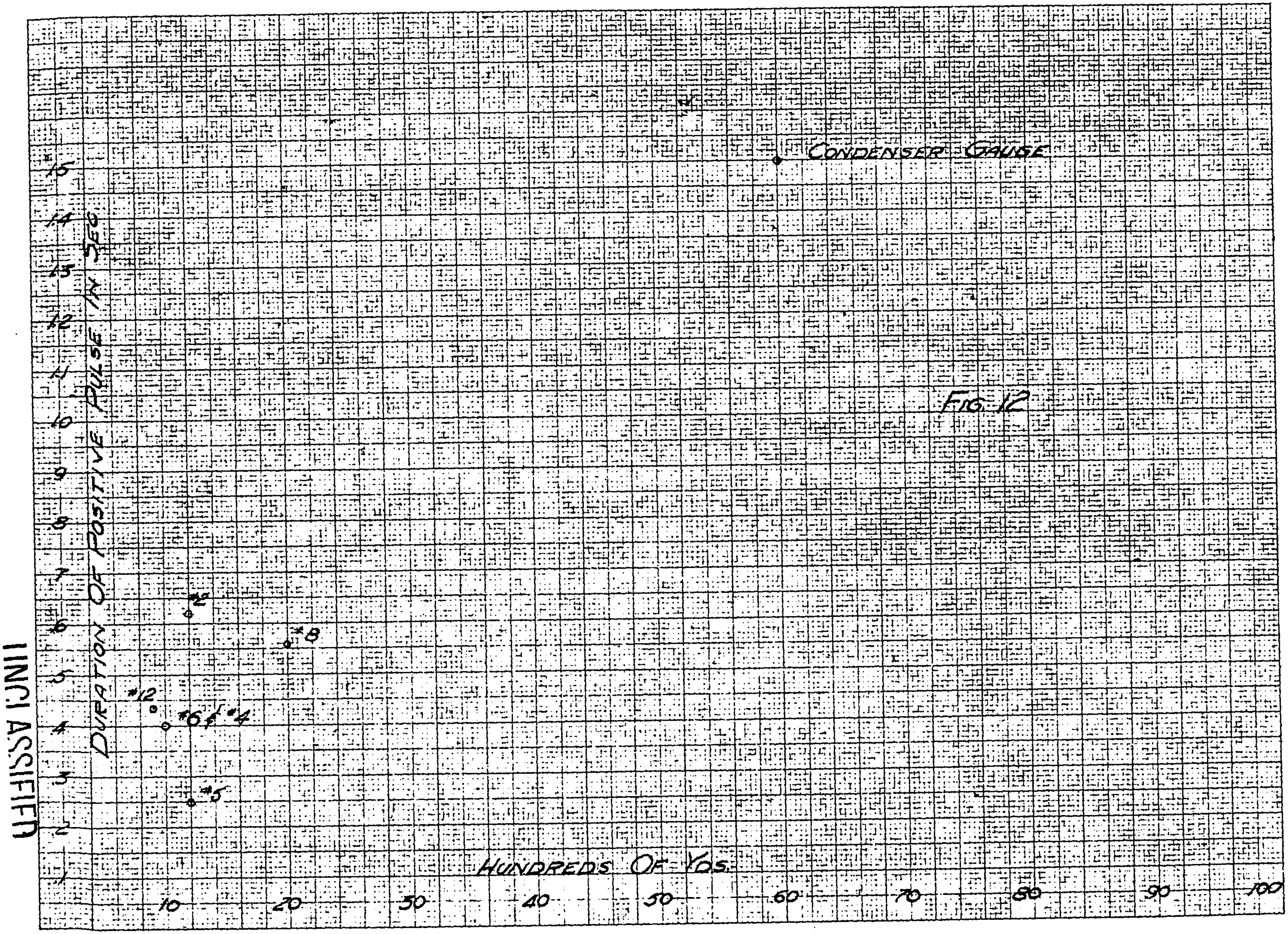
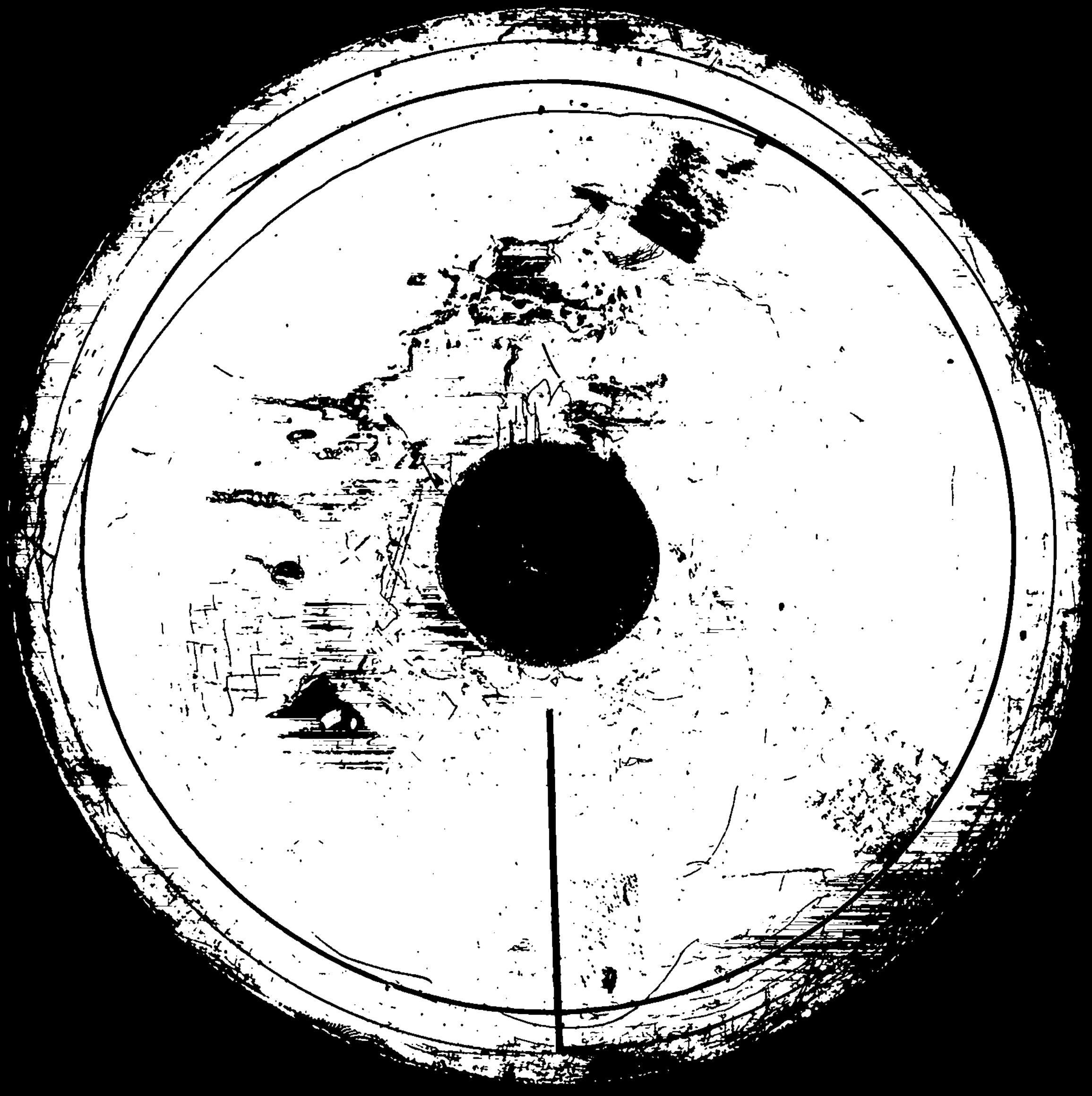
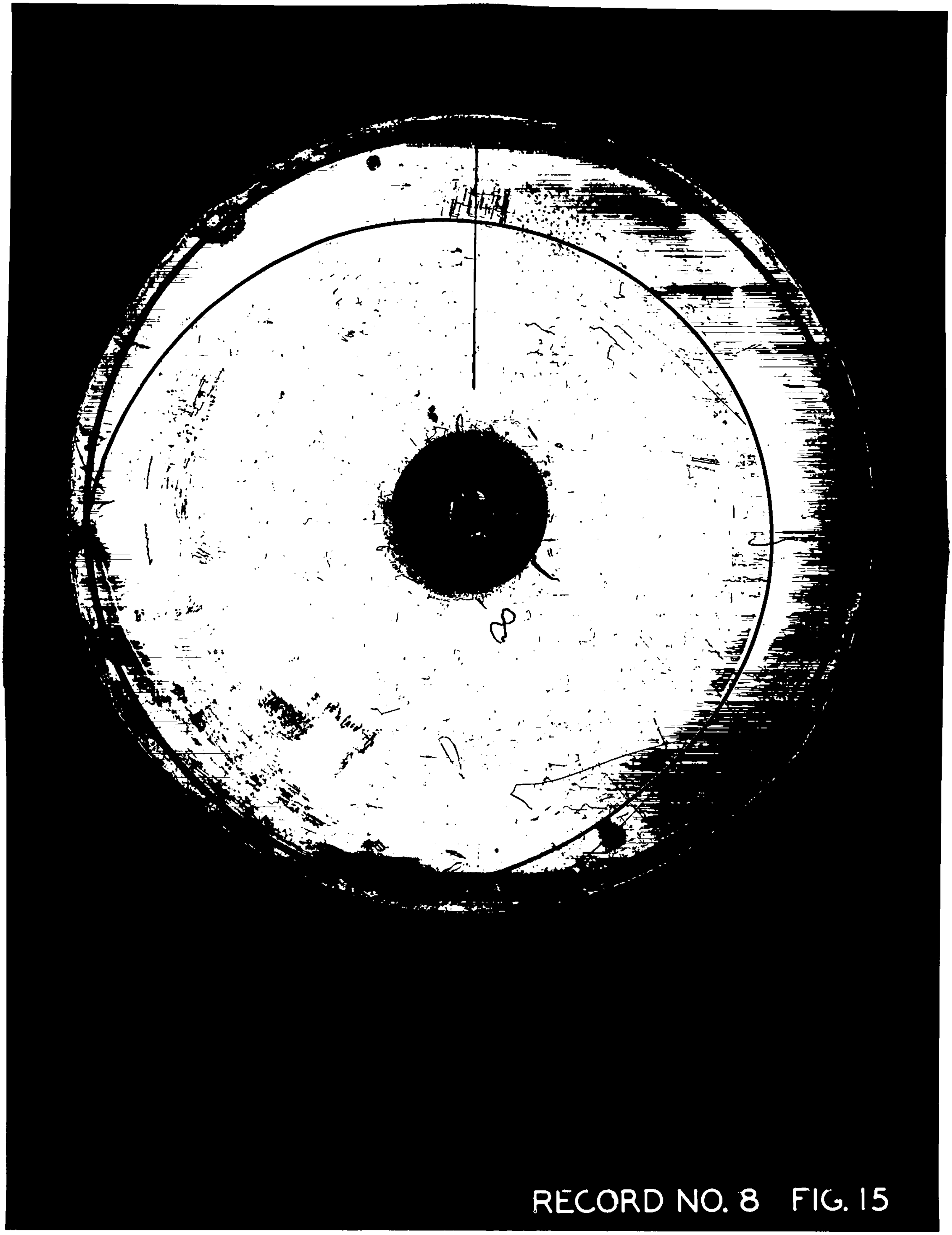

CONDENSER GAUGE
DURATION OF POSITIVE PULSE IN SEC
HUNDREDS OF YDS.
#2
#8
#12
#6
#4
#5
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
10
20
30
40
50
60
70
80
90
100

FIG. 12

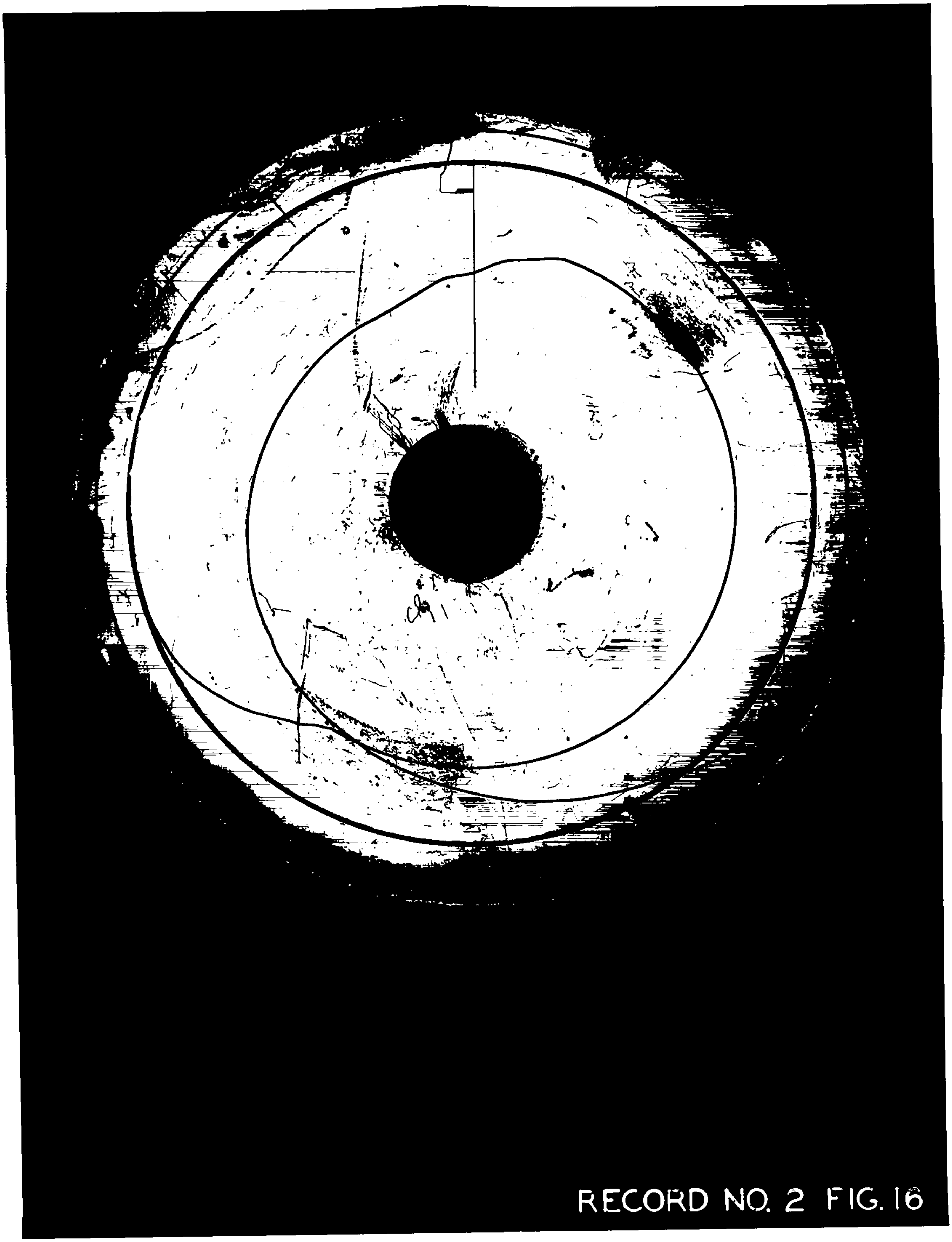


RECORD NO. 5 FIG. 13

RECORD NO.12 FIG.14



RECORD NO. 8 FIG. 15



RECORD NO. 2 FIG. 16

RECORD NO.4 FIG. 17

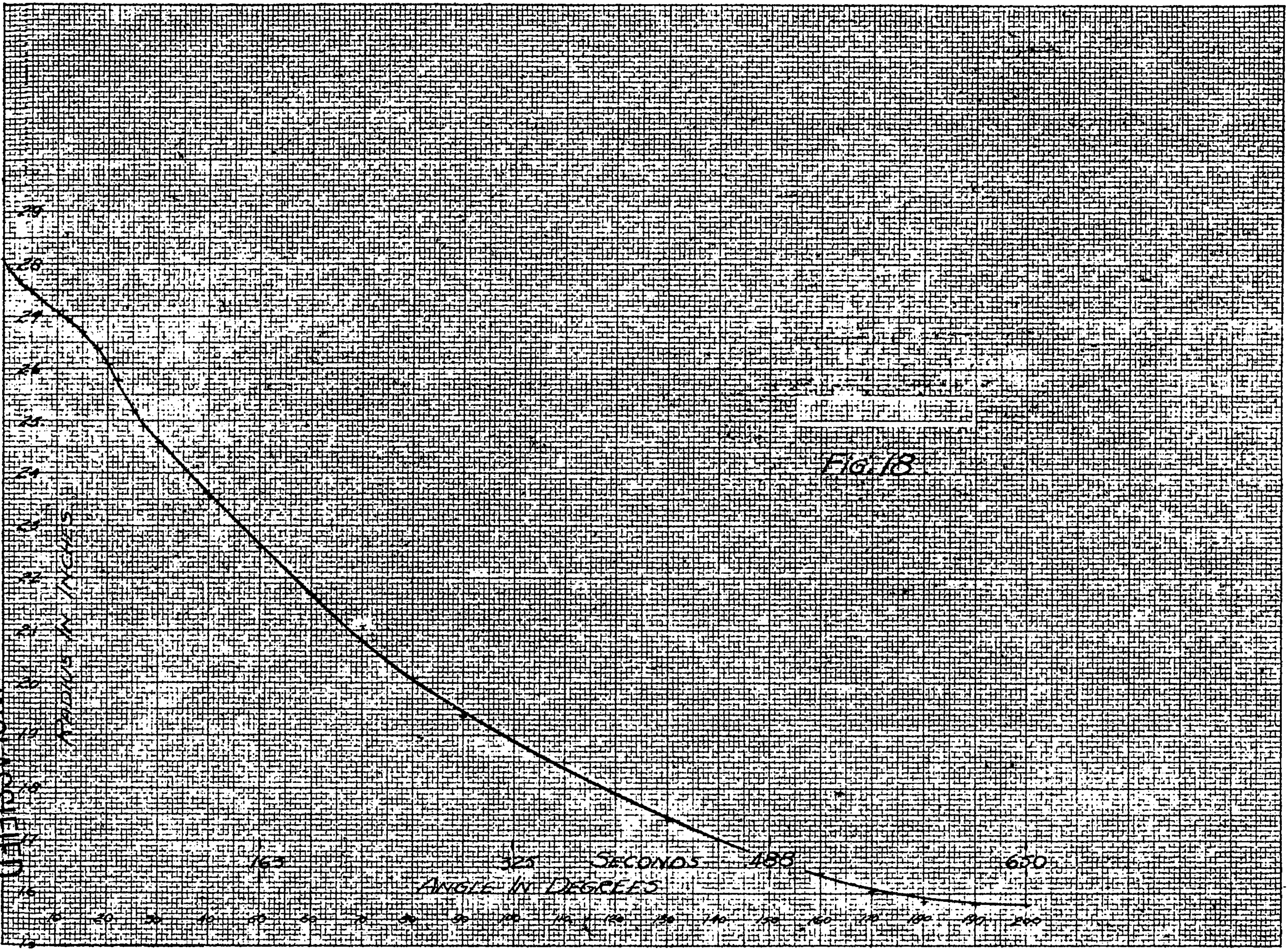
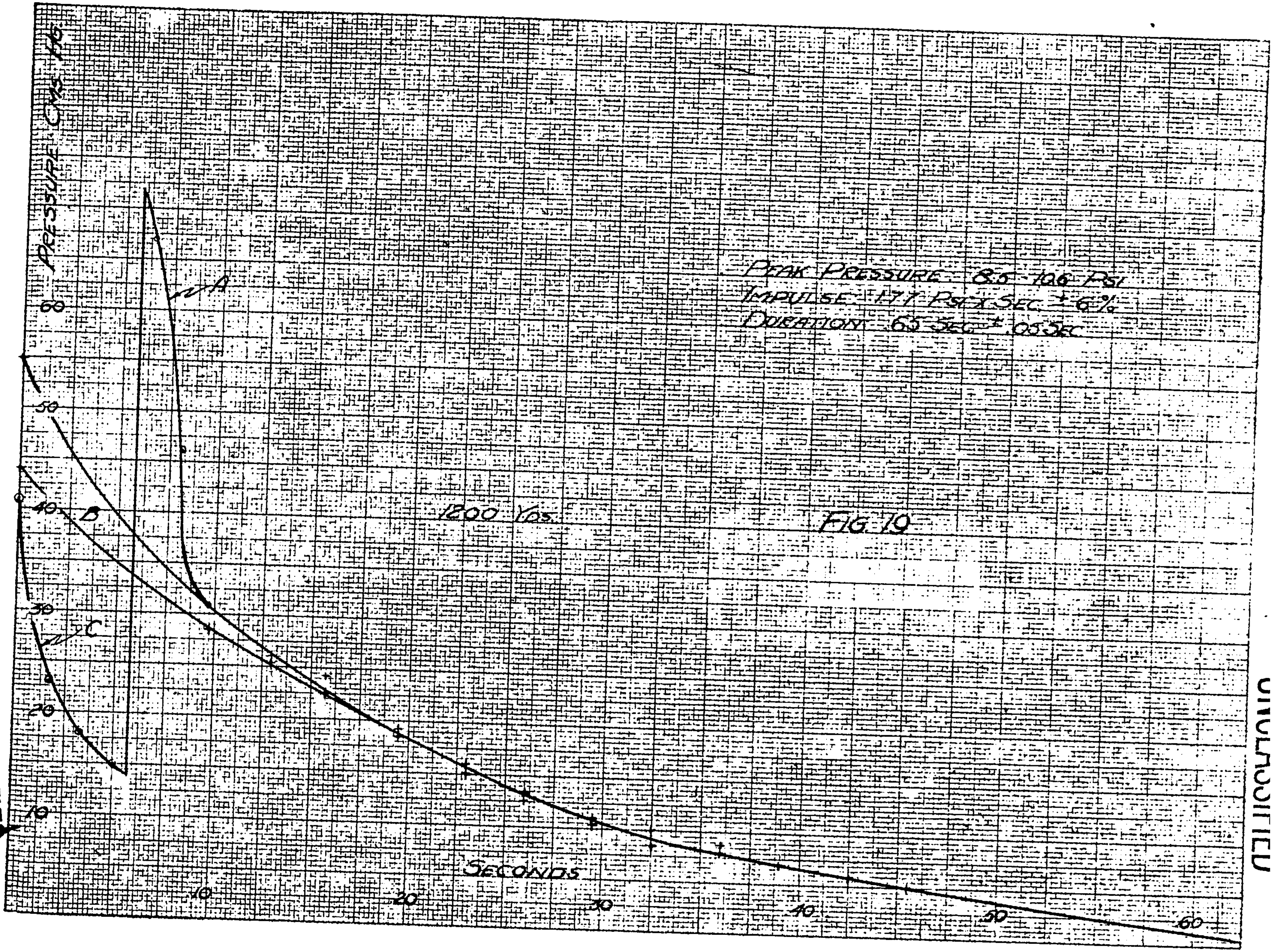

29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
RADIUS IN INCHES
163
325
SECONDS
488
650
ANGLE IN DEGREES
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

FIG. 18



PEAK PRESSURE 8.5-10.6 PSI
IMPULSE .177 PSI X SEC ± 6%
DURATION .63 SEC ± .05 SEC

FIG. 19

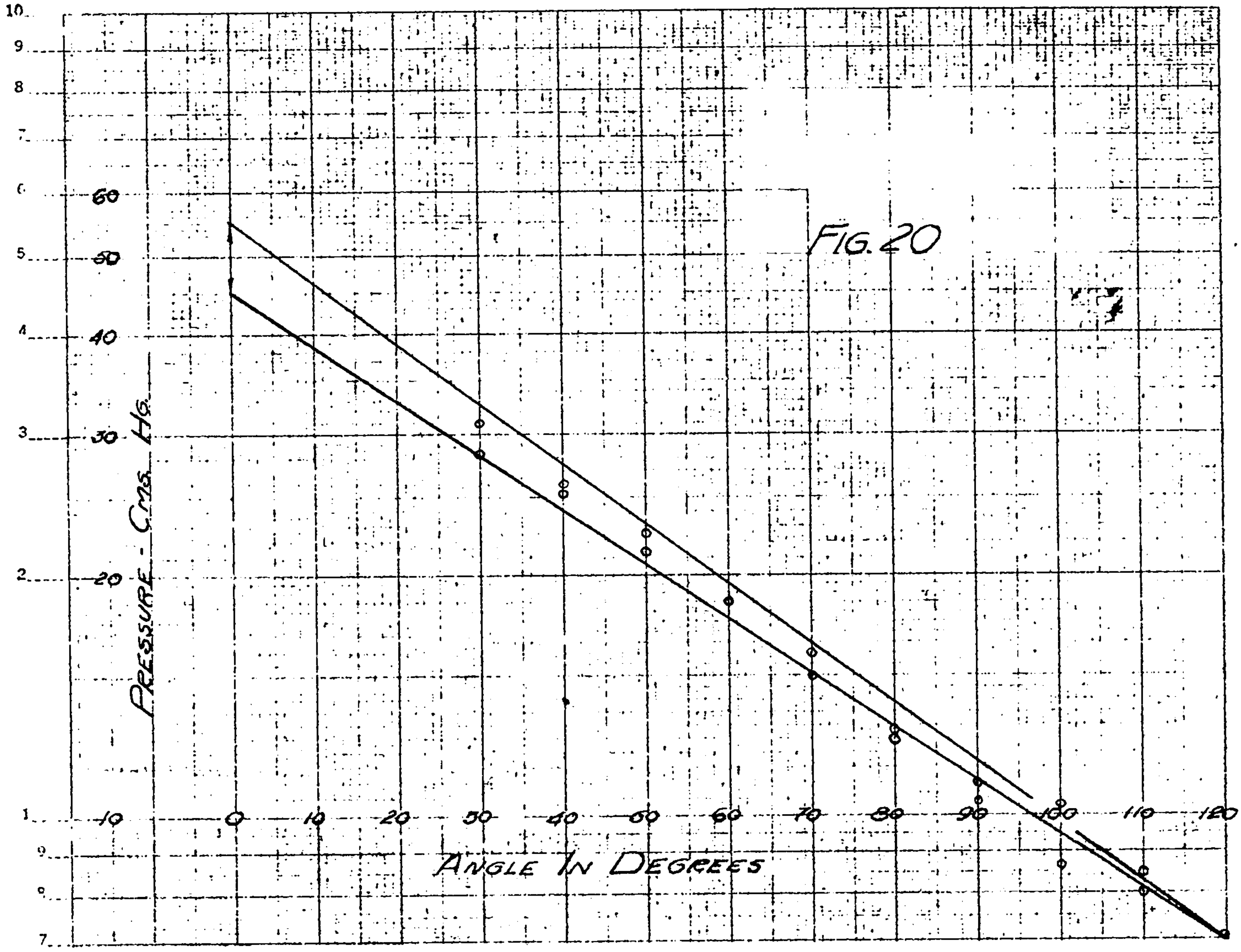


FIG. 20
PRESSURE - CMS. HG.
60
50
40
30
20
10
ANGLE IN DEGREES
0
10
20
30
40
50
60
70
80
90
100
110
120

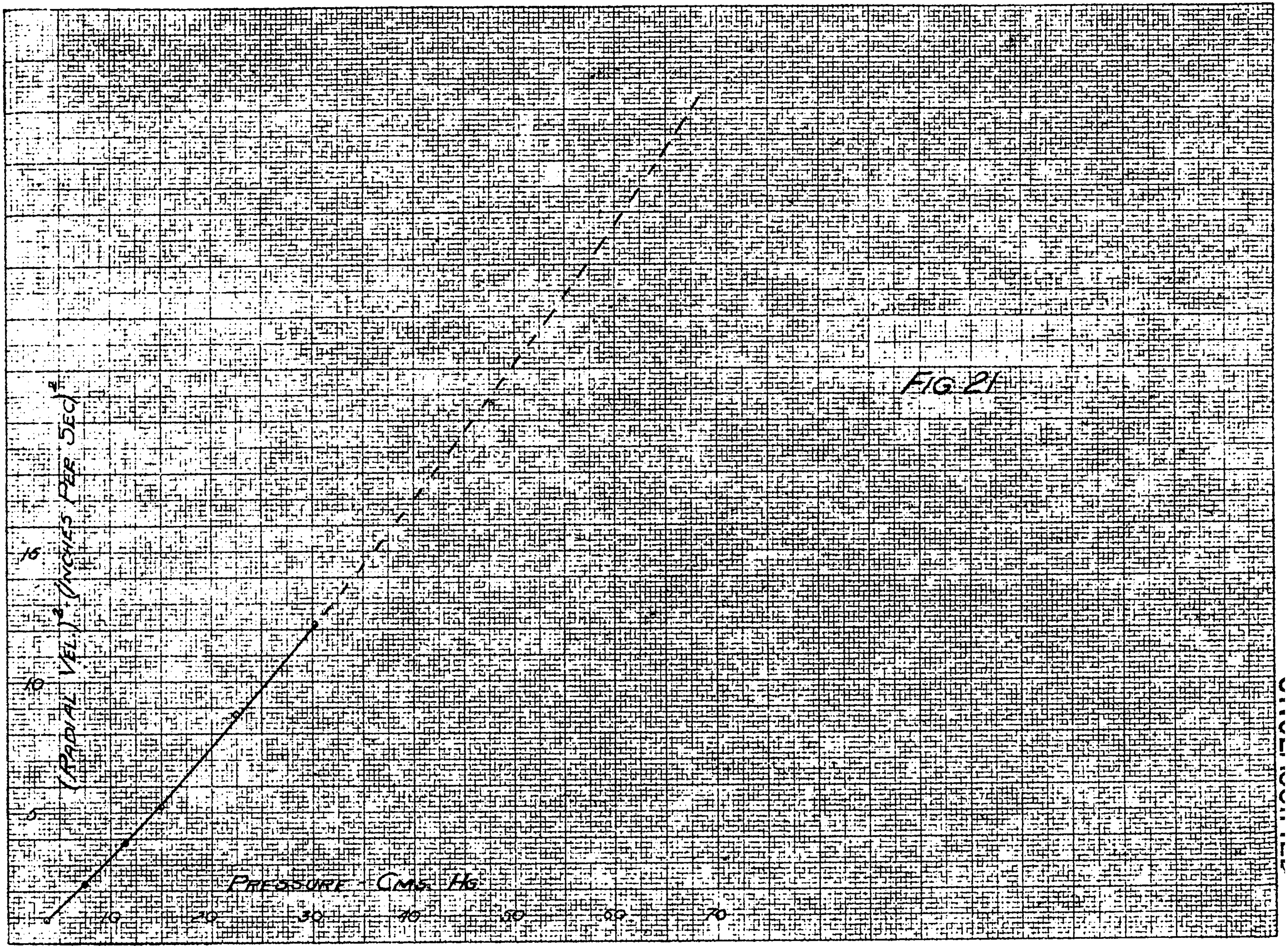

(RADIAL VEL.)² (INCHES PER SEC)²
15
10
5
PRESSURE - CMS. HG.
10
20
30
40
50
60
70

FIG. 21

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