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Report No. 316/15
Watertown Arsenal

11 April 1933

The Adaptability of Stainless Iron to Manufacture of Recuperator Parts.

Acknowledgment for assistance in obtaining the laboratory data is given to Mr. P. C. Cunnick, Associate Mechanical Engineer, the heat treating data to Mr. J. J. Popalka, Foreman, Heat Treating Department, and the machining data to Mr. Arthur Linnberg, Foreman, Machine Department.

The following is a report of an investigation into the adaptability of stainless iron to the manufacture of recuperator parts.

This material is being considered because it seems to offer a solution to the corrosion problem and at the same time to be a metal with sufficiently high physical properties to properly perform this duty. Some of these recuperators are now being manufactured at Rock Island Arsenal.

Rock Island Arsenal obtained their material from the Rustless Iron Corporation of America, 1001 Edison Highway, Baltimore, Maryland under the following specifications.

> Stainless iron to be annealed but not pickled and to have the following approximate chemical analysis.

Carbon - - - - - - - - - - -	.12 Max.
Manganese- - - - - - - - - -	.35 - .60
Silicon- - - - - - - - - - -	.50 Max.
Phosphorus - - - - - - - - -	.03 Max.
Sulphur- - - - - - - - - - -	.03 Max.
Chromium - - - - - - - - - -	11.5 - 13.00

Brinell hardness that will be furnished in the annealed state 207 Max.

After rough machining, this material will be heat treated at this arsenal to have the following physical properties.

Tensile strength - - - - - -	170,000 Lbs. per Sq. In.
Yield Point - - - - - - - - -	150,000 Lbs. per Sq. In.
Elongation - - - - - - - -	16%
Reduction of Area- - - - - -	50%
Brinell Hardness - - - - - -	350

In this material, it is desired to secure the highest rust and corrosion resisting qualities possible for the manufacture of recoil mechanisms for gun carriages. Material to be furnished and tested in accordance with Ordnance Department Specifications No. 57-107B except where detailed specifications deviate therefrom.

The material furnished was Rustless Iron Corporation's Defirust Rustless Iron. It was furnished in bars of the following sizes.

1-3/4" round
2" "
2-3/4" "
3-5/8" "
5" "

From these bars, cylinders having the following wall thicknesses at the time they were heat treated were manufactured.

Air cylinders, wall thickness 13/16"

Recoil cylinders, wall thickness 11/16"

Oil cylinders, wall thickness 13/16"

Equilibrator cylinders, wall thickness 3/8"

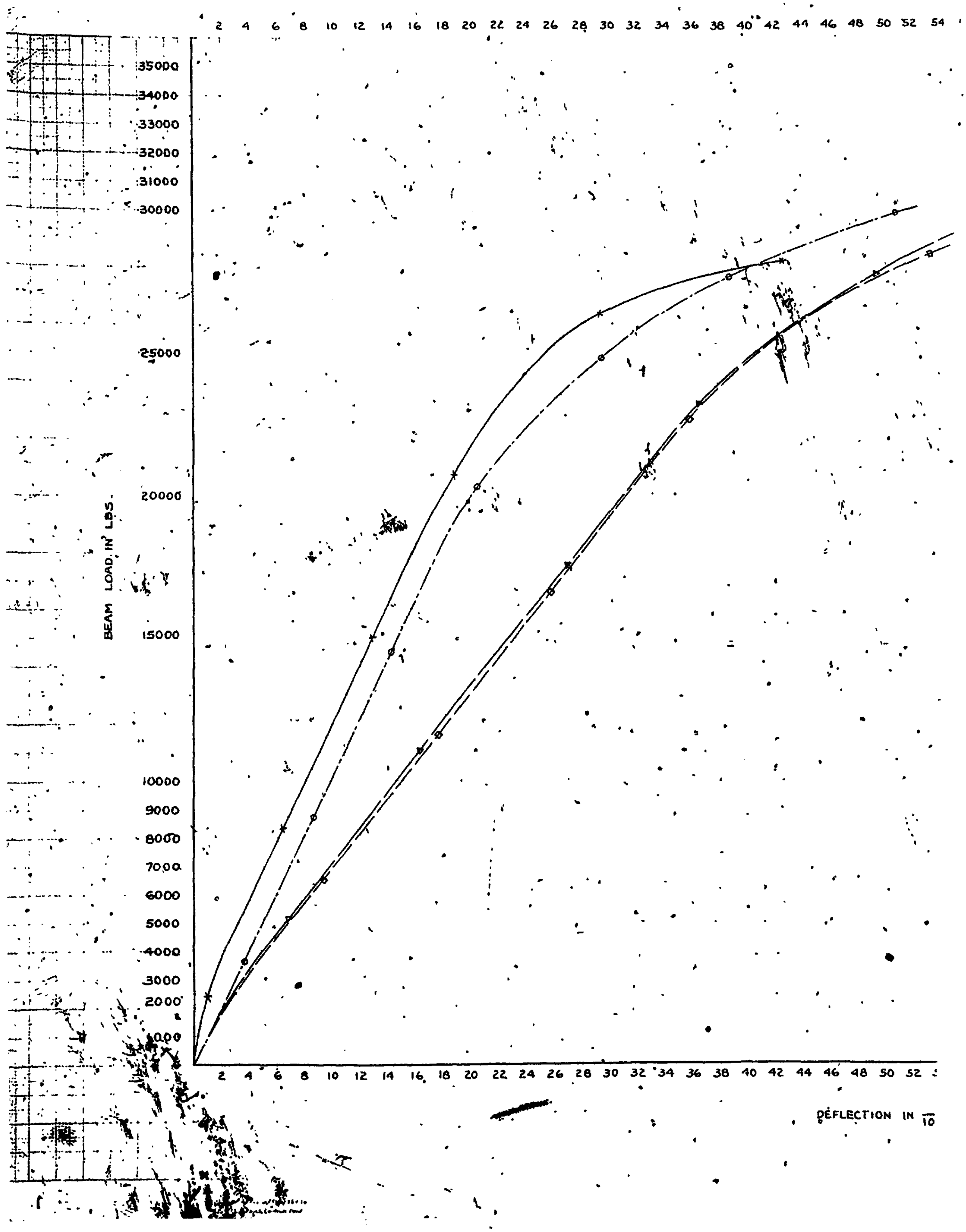
Equilibrator Plungers, wall thickness 9/16"

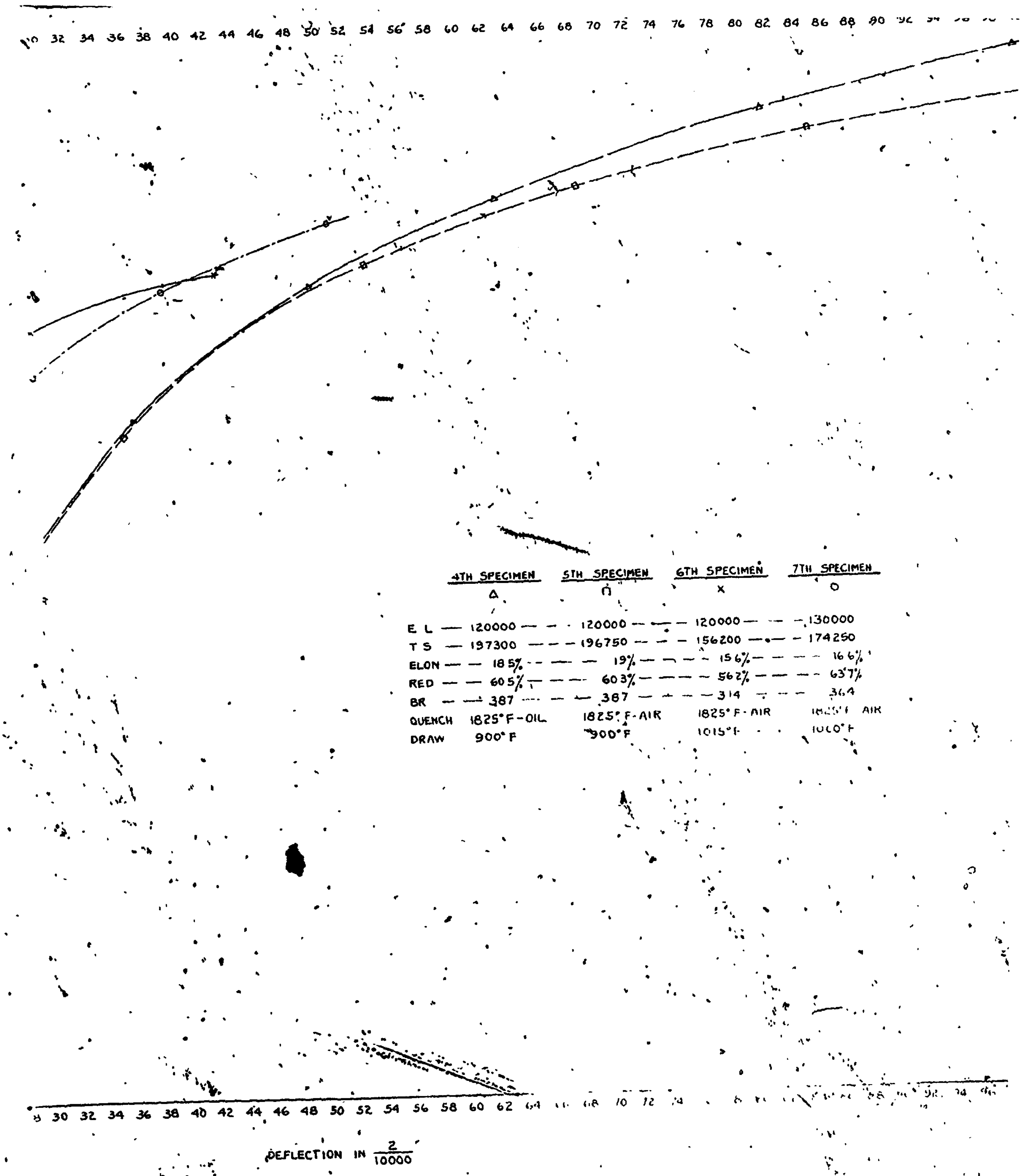
Chemical analysis of the two lots as received gave the following results.

	Lot No. 1	Lot No. 2
C.	.08 - .09	.10
Mn.	.35 - .38	.40 - .42
Cr.	12.60 -13.00	12.40-12.80

The general method of manufacture adapted was to drill out the center of the bar in the Stecher drill to approximately 1/8" less than the finished diameter and to rough turn the exterior of the bar. The tubes thus partially machined were heat treated and then finish machined.

The heat treatment of this material proved rather troublesome. The cylinders, approximately 30 inches in length, were so long that there was no equipment available in which these parts could be oil quenched in a vertical position. Inasmuch as stainless irons and steels are in

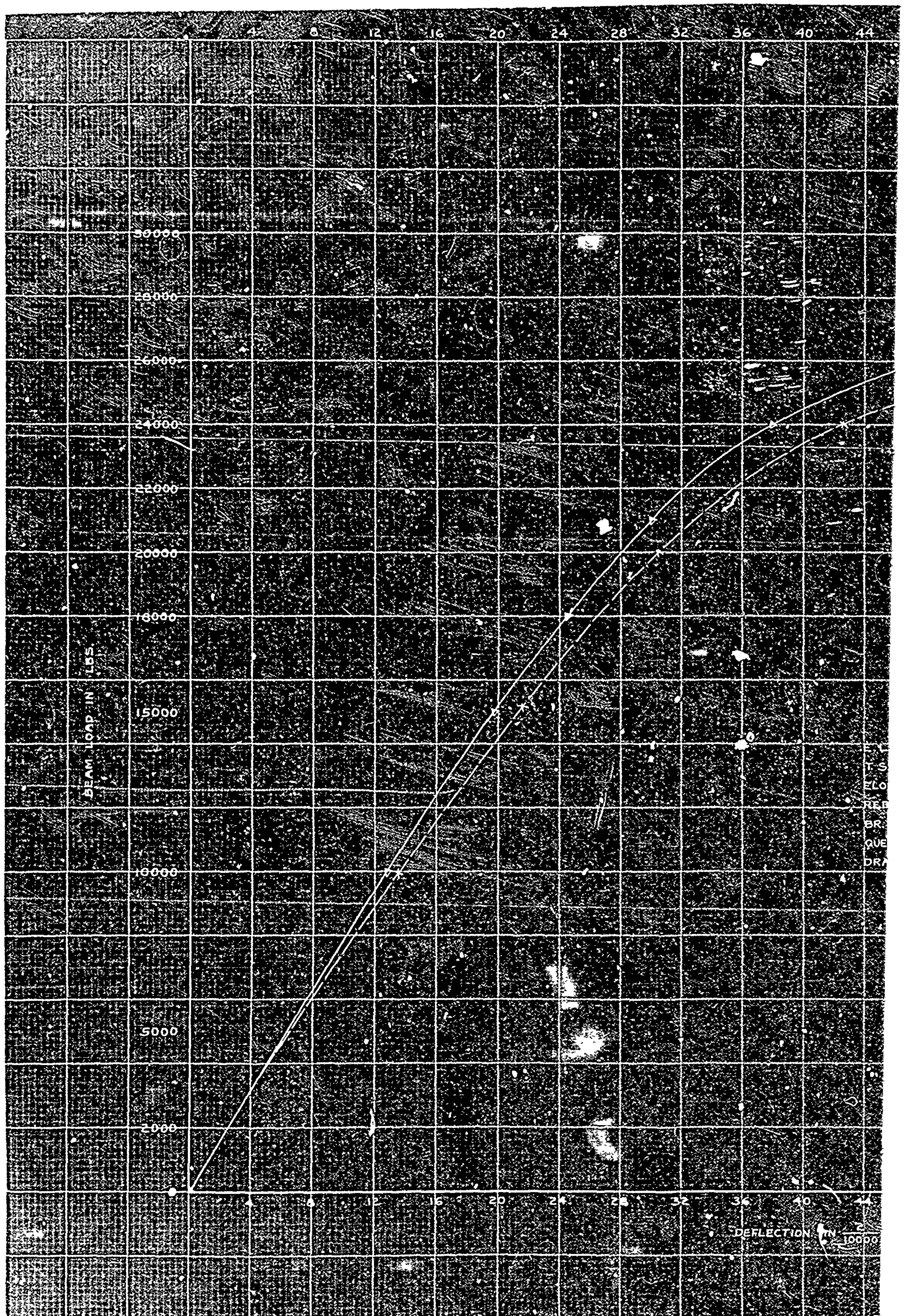

BEAM LOAD IN LBS.
DEFLECTION IN 1/10

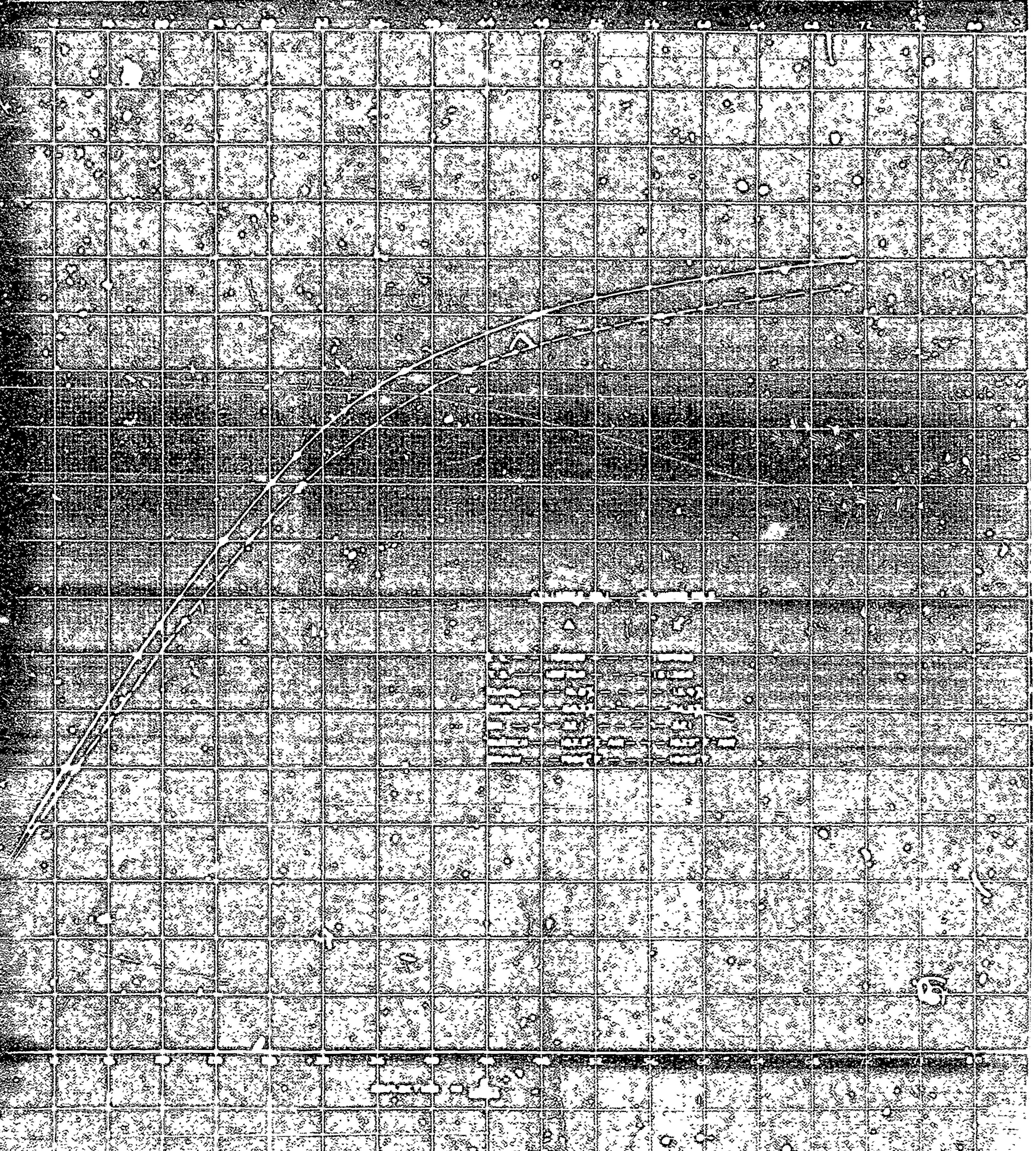

4TH SPECIMEN
5TH SPECIMEN
6TH SPECIMEN
7TH SPECIMEN
E L — 120000 — 120000 — 120000 — 130000
T S — 197300 — 196750 — 156200 — 174250
ELON — 18 5% — 19% — 15 6% — 16 6%
RED — 60 5% — 60 3% — 56 2% — 63 7%
BR — 387 — 387 — 314 — 364
QUENCH 1825°F-OIL 1825°F-AIR 1825°F-AIR AIR
DRAW 900°F 900°F 1015°F 1000°F
DEFLECTION IN $\frac{2}{10000}$

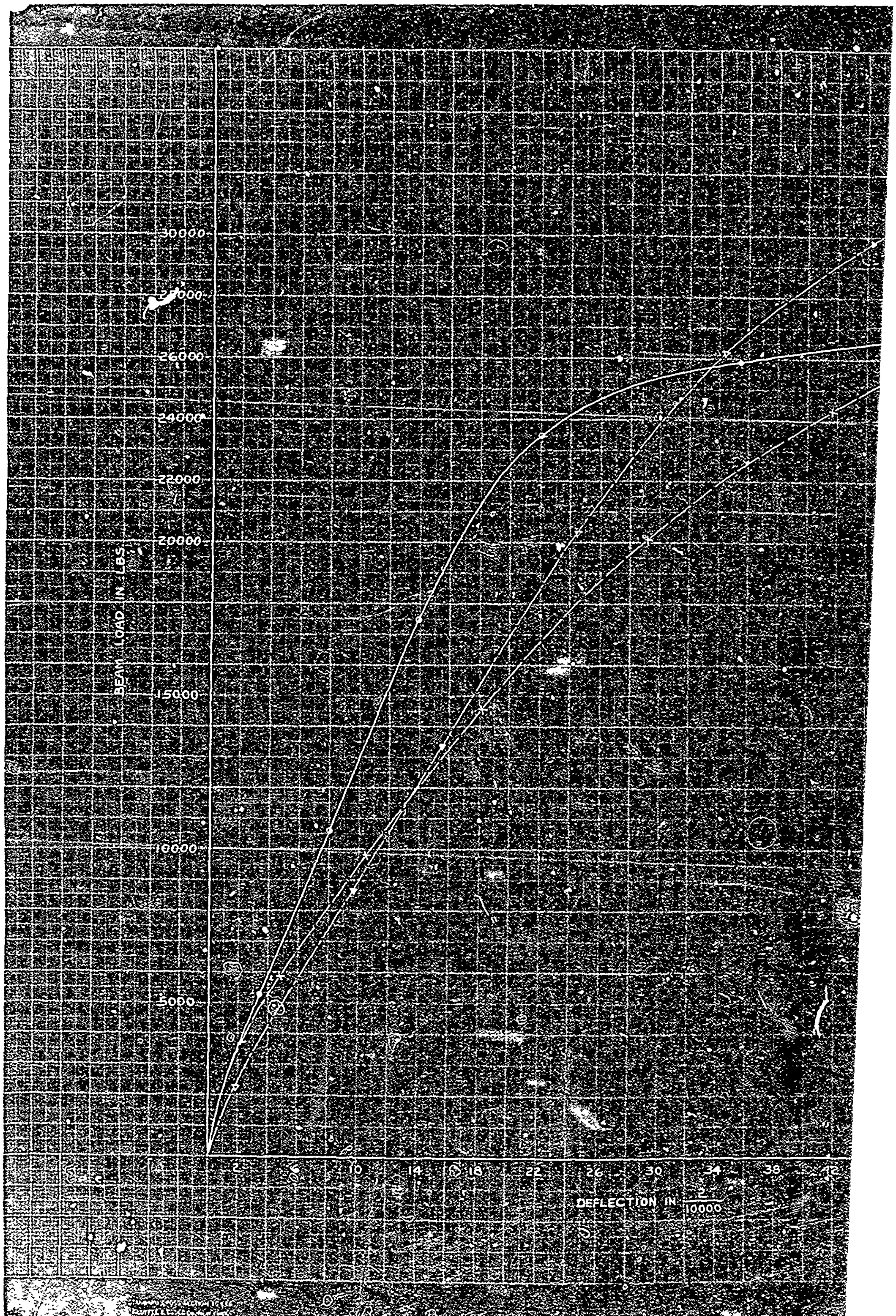
on the side toward the central pipe throughout their length. The cylinder to be quenched was drawn out of the furnace, lifted and dropped down over the central pipe thus giving a positive rapid flow of air on both the interior and exterior of the hot cylinders. The standardized heat treatment adopted was to bring the cylinders to 1825°F, allow them to soak at this temperature for 1-1/2 hours and then to quench in air followed by a draw at 1000°F. The cylinders were held at this temperature for at least two hours. The equilibrator plungers were so small that they could not be quenched on this fixture, therefore, they were oil quenched and given the same draw. The results of this hardening as far as hardness was concerned were as follows.

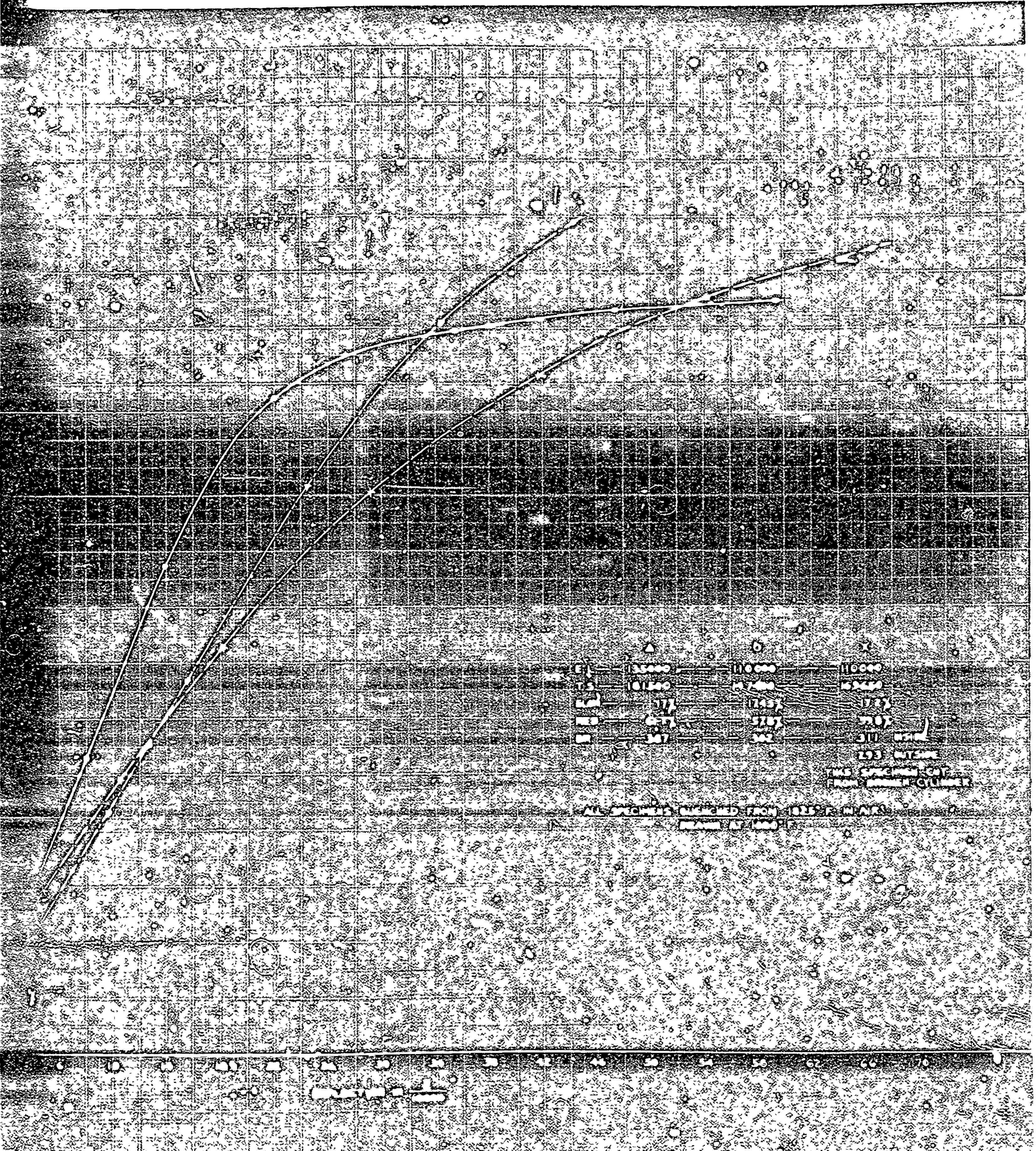
The hardness of the air quenched cylinders as hardened varied from Brinell 364 - 428. The hardness of the oil quenched plungers as hardened was Brinell 364-401. The Brinell obtained on the draw for the air hardened cylinders was 302 - 311 - 321 - 321 - 364 - 387 and for the oil hardened plungers 286 - 321 - 364. In a few cases draw temperatures other than 1000 were found necessary and the following results were obtained.

For the air hardened cylinders drawn at 1015°F, Brinell hardness of 286 - 314 - 321 and for the oil hardened plunger 364. For air hardened cylinders drawn at 1020°F a Brinell hardness of 286 - 293.

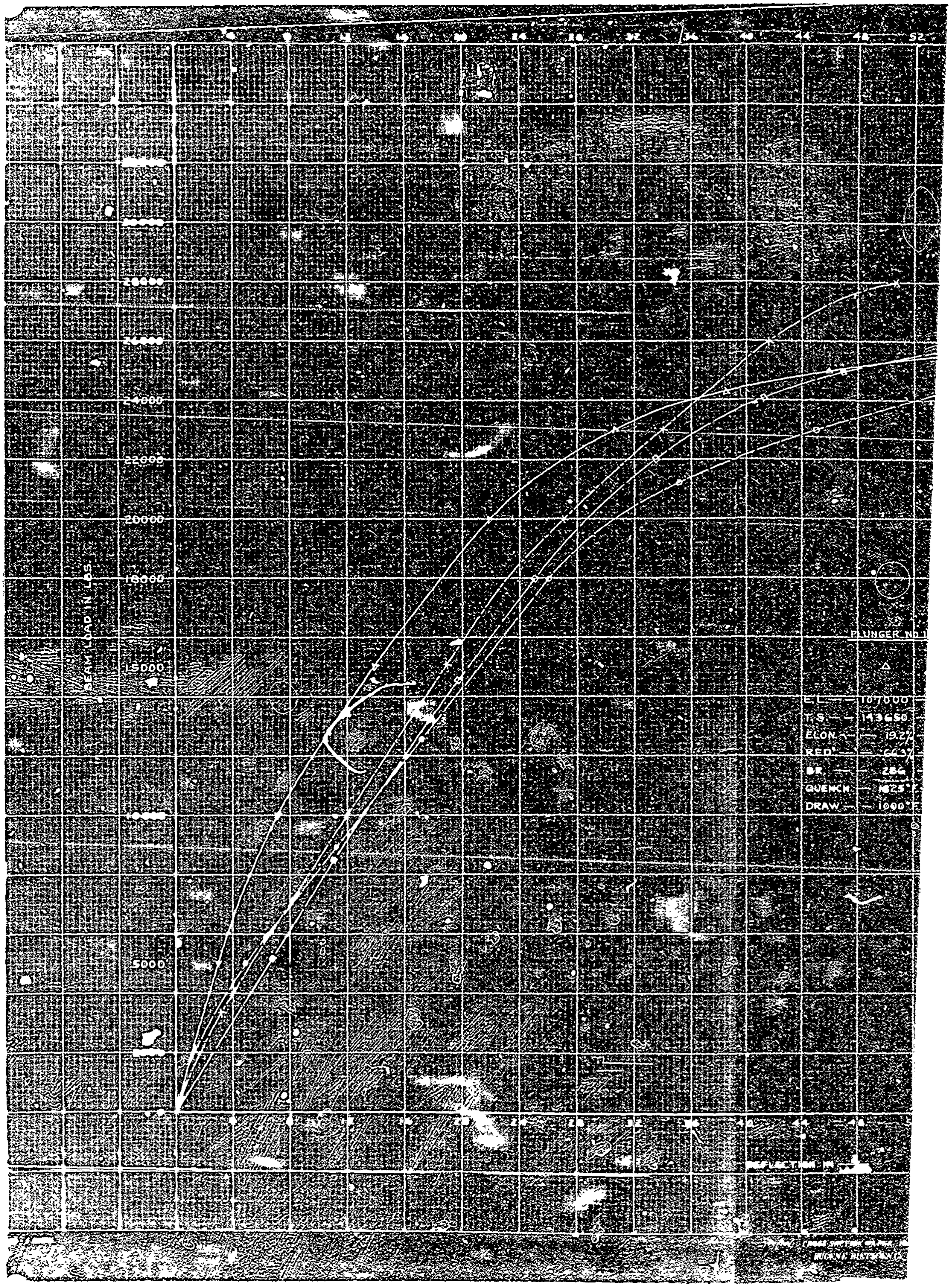

BEAM LOAD IN LBS.
30000
28000
26000
24000
22000
20000
18000
15000
10000
5000
2000
4
8
12
16
20
24
28
32
36
40
44
DEFLECTION IN

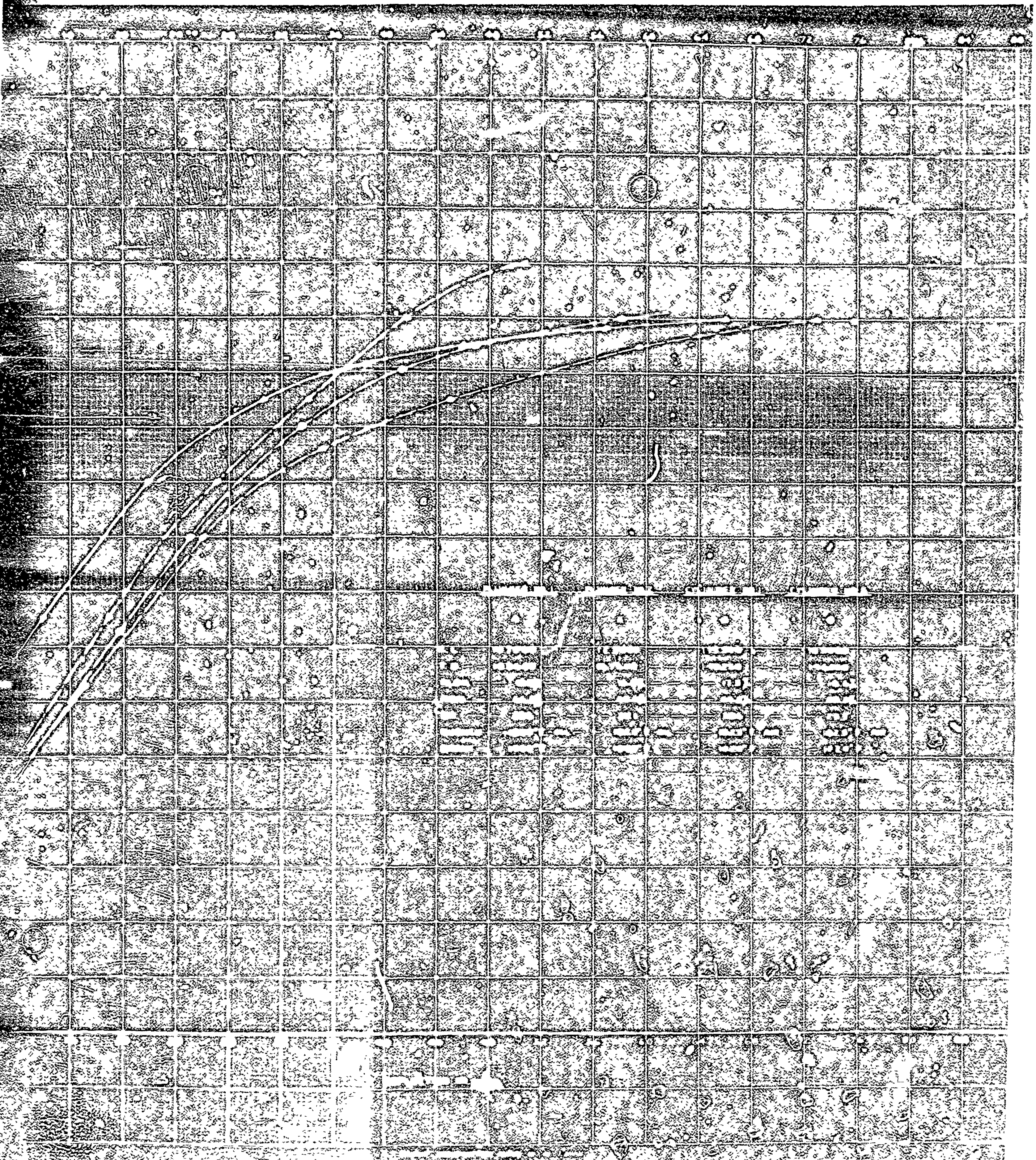


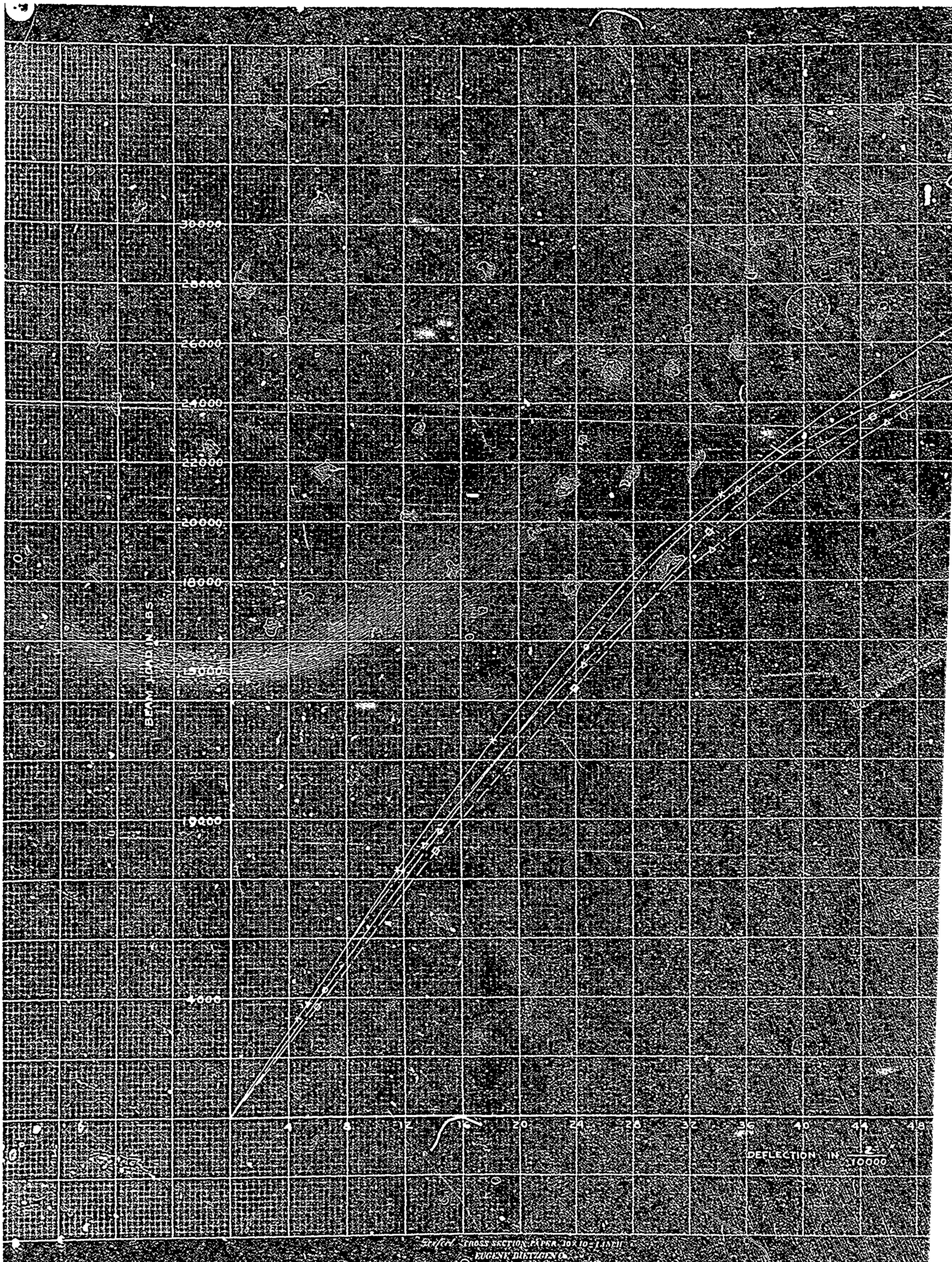

BEAM LOAD IN LBS.
30000
26000
24000
22000
20000
15000
10000
5000
2
6
10
14
18
22
26
30
34
38
42
DEFLECTION IN $\frac{1}{10000}$



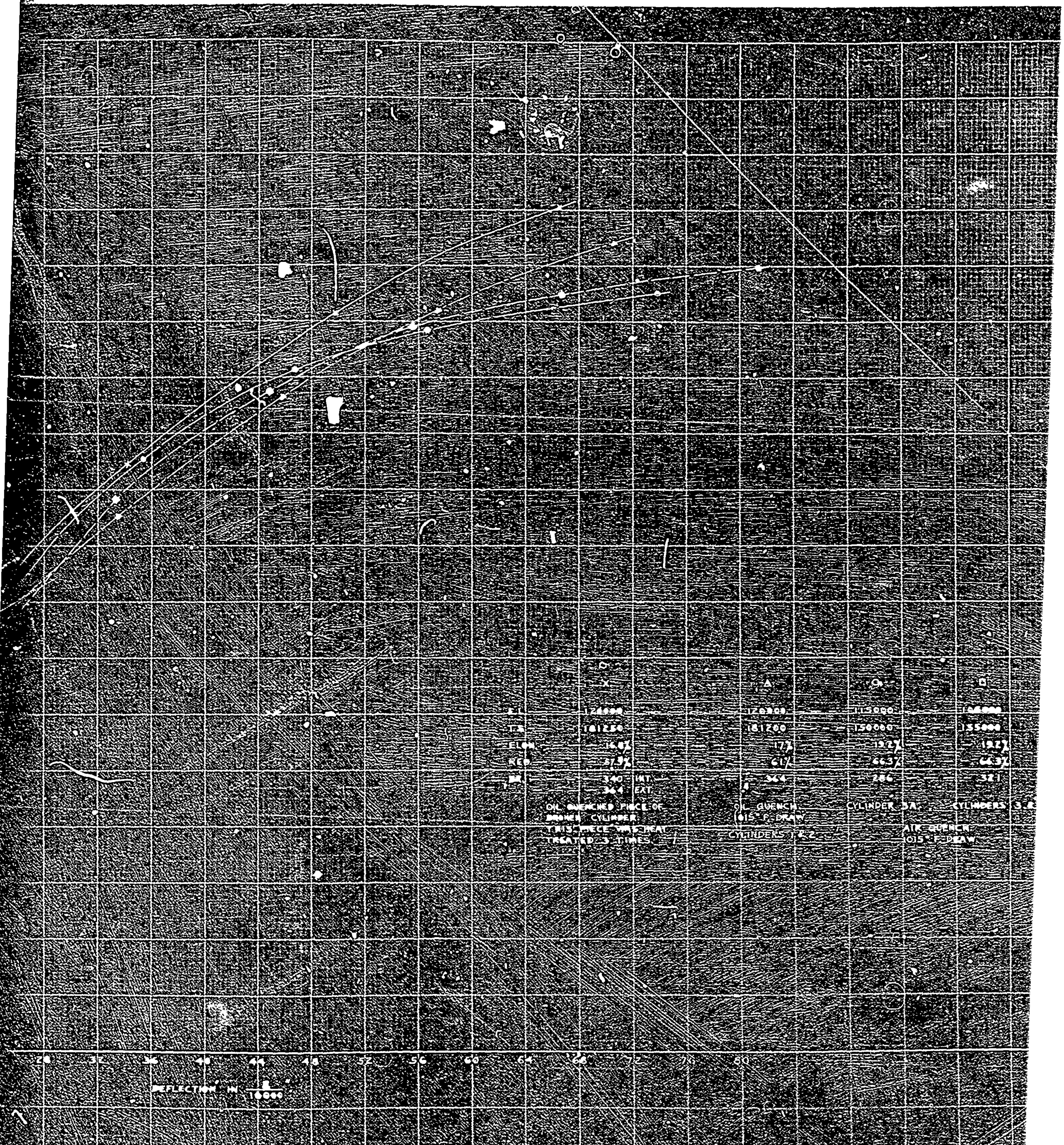
T.S.
110 000
110000
17%
311
293
THIS SPECIMEN CUT
FROM
ALL SPECIMENS
FROM


BEAM LOAD IN LBS.
24000
22000
20000
18000
15000
5000
PLUNGER NO.1
E.L. 107000
T.S. 143650
ELON. 19.2%
RED. 66.3%
BR. 286
QUENCH 1625°
DRAW 1000°
DEFLECTION IN



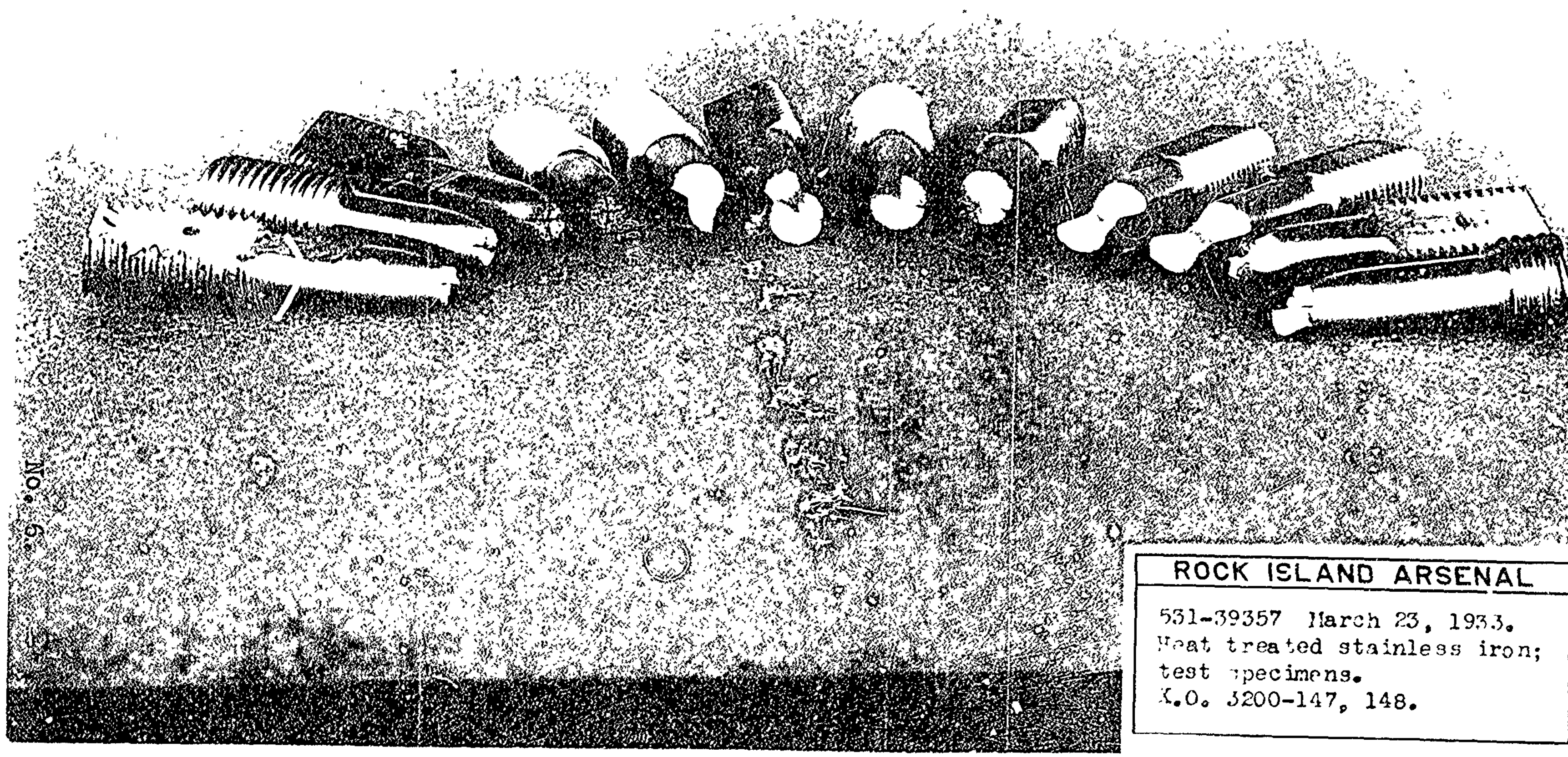


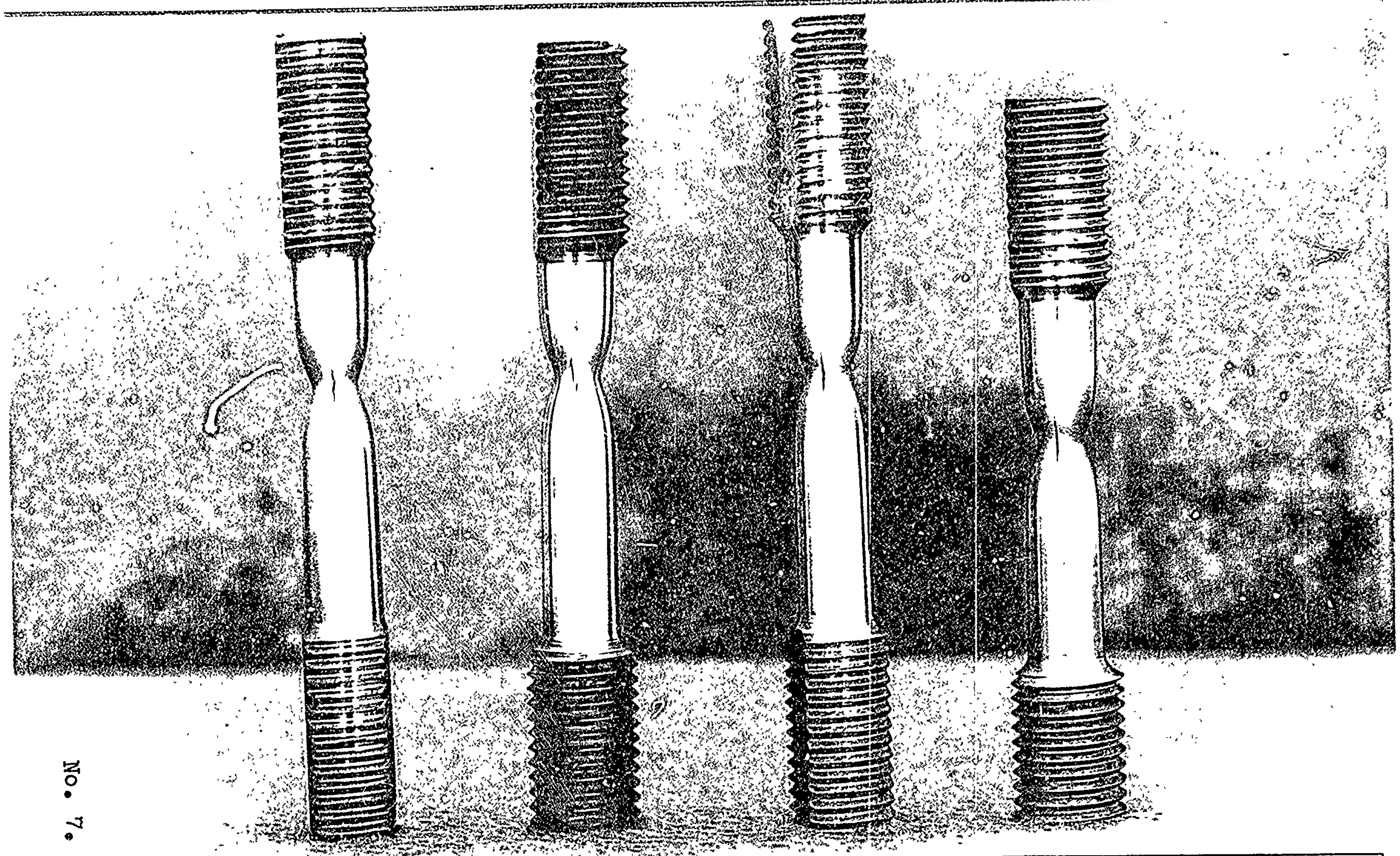
30000
26000
24000
22000
20000
18000
10000
4000
BEAM LOAD IN LBS.
4
8
12
16
20
24
28
32
36
40
44
48
DEFLECTION IN $\frac{2}{10000}$
CROSS SECTION PAPER 10 X 10 = 1 INCH
EUGENE DIETZGEN CO.



X
E.L. 120000
T.S. 181250
ELON. 16.8%
RED. 57.9%
340 INT.
364 EXT.
OIL QUENCHED PIECE OF
CYLINDER
THIS PIECE WAS HEAT
TREATED 3 TIMES.
E.L. 120000
T.S. 181200
ELON. 17%
RED. 61%
364
OIL QUENCH
1015° F. DRAW
CYLINDERS 1 & 2
E.L. 115000
T.S. 150000
ELON. 19.2%
RED. 66.3%
286
CYLINDER 3A
CYLINDERS 3 &
T.S. 135000
ELON. 19.2%
RED. 66.3%
321
AIR QUENCH
1015° F. DRAW
28
32
36
40
44
48
52
56
60
64
68
72
76
80
DEFLECTION IN 1/10000

The physical properties obtained were somewhat erratic. It was originally attempted to determine the elastic limit by the drop of the beam method but this was found impossible as there was no perceptible drop of the beam. It was found necessary to plot the stress strain curves of the specimens and to assume the elastic limit as that point at which the proportion between the stress and the strain greatly increased. It was in fact taken as that point where the curve started to break from a straight line to a curve. The curves for the specimens pulled are shown in charts numbers 1 to 5 inclusive. It will be noticed that these curves show some rather wide variations. This was the cause of considerable question. It was also noted that the test specimens ofttimes broke in a longitudinal direction as shown in the inclosed picture before they broke off laterally. The breaks are shown in two other pictures which illustrate the jagged non-uniform type of fracture with its accompanying longitudinal cracks. Several Charpy impact specimens of this steel were prepared and broken. These specimens showed, with two exceptions, a fairly uniform but very low impact value as follows.

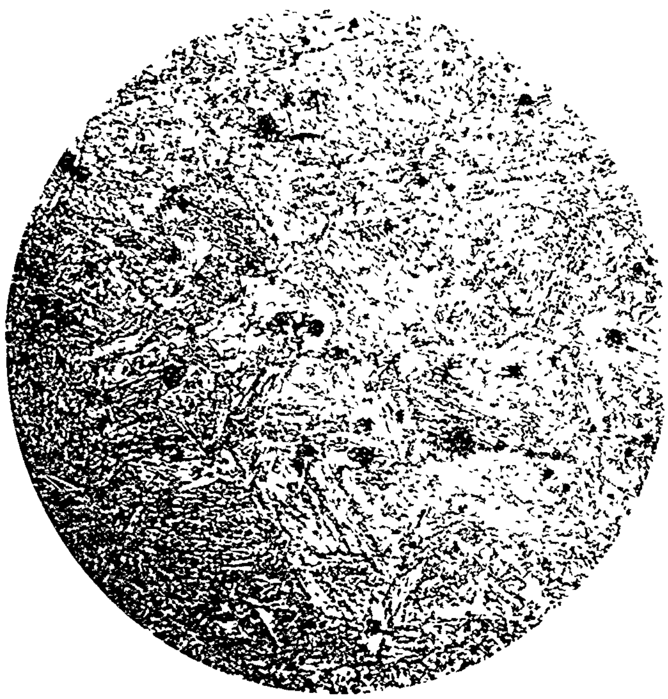

ROCK ISLAND ARSENAL
531-39357 March 23, 1933.
Heat treated stainless iron;
test specimens.
X.O. 3200-147, 148.
No. 6.



No. 7.

ROCK ISLAND ARSENAL

31-39759 April 11, 1933.
hysical test of stainless
ir showing fracture.



Annealed (as received)

Mag. 120X

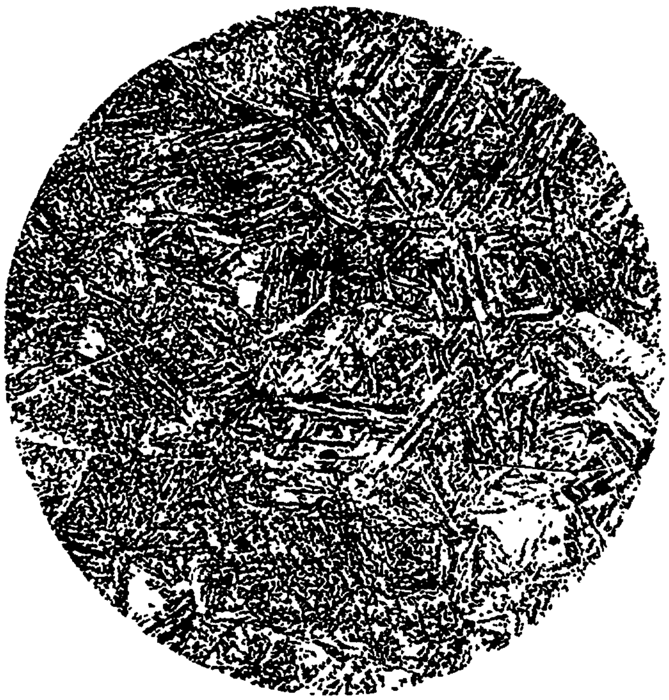
Notice inclusions.

No. 9.

Specimen Mark	Angle	Ft. Lbs.	Brinell Values
1	146	5.99	340
1A	136	20.77	311
1	146	5.99	
1	146.2	6.98	
3	125.5	36.60	
3	144	8.285	
3	147.5	4.39	364-322-364-321-302-340.
3	145.5	6.49	
3	145.5	6.49	
3	147.5	4.39	
2	146	5.99	332
8	146.5	5.19	302-321
8	146	4.99	

Unfortunately these specimens got mixed up in the Laboratory before the Brinell hardnesses could be taken so that it is impossible to say exactly which specimen had any given hardness except for those two specimens 1A and 2 of which there was only one representative Charpy test specimen.

The steel was then examined microscopically. Picture No. 9 is a micrograph of the steel as received in the annealed condition. Magnification 120X. This shows numerous inclusions which gave us our first inkling that the irregularities in the tensile test and the peculiar breaks might be due to dirty steel. Picture No. 10 is a micrograph of an

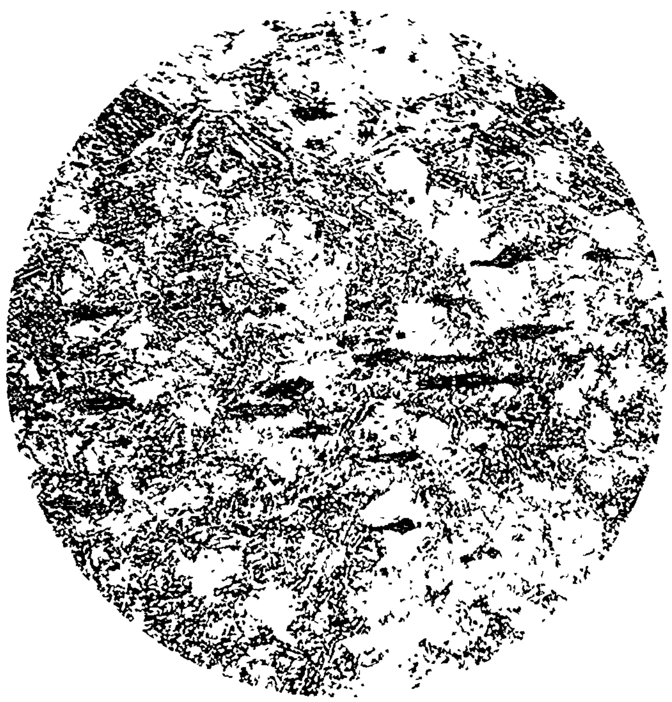


Air quench from 1825°F.

Draw 1000°F.

Mag. 125X.

No. 10.



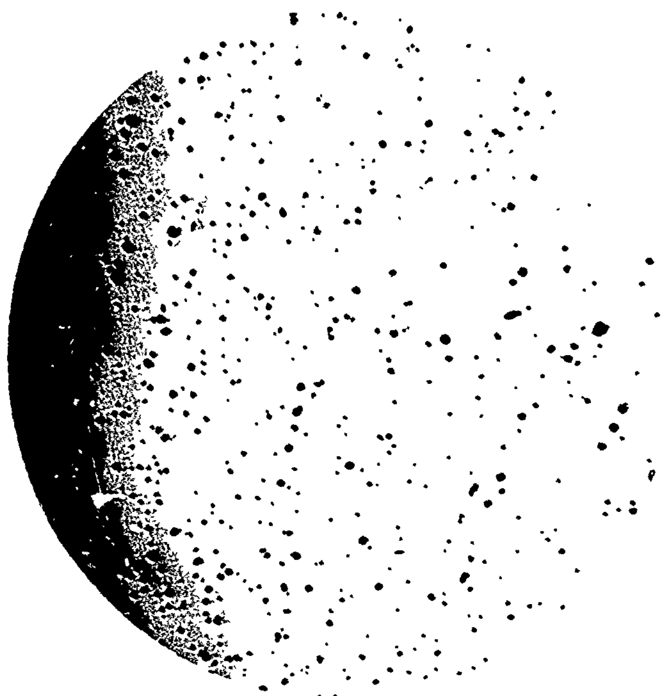
Oil quench from 1825°F.

As hardened structure.

Longitudinal specimen.

Mag. 120X.

No. 11.



Air quench 1825°F.

Draw 1000°F.

Unetched specimen showing inclusions.

Mag. 47X.

air quenched specimen drawn at 1000 degrees, magnification 125X. This shows the almost complete martensetic structure obtained in this steel. It was then questioned as to whether the micro structure of an oil quenched specimen would be any better. A small piece of steel, approximately 3/8" square, was oil quenched and then polished and etched. Micrograph No. 11 shows this piece of steel. It shows the same microscopic structure. This specimen is taken longitudinally of the bar and the inclusions shown in this micrograph are drawn out and elongated. A specimen of this steel was then examined under the microscope in the unetched condition. Micrograph No. 12 shows the condition thus found.

A thin slice of a 3-5/8" bar was given a macro etch. This showed a rather porous center and around the exterior it showed the presence of several elongated string-like inclusions. See picture No. 13.

After heat treatment, it was found necessary to straighten all of the cylinders. Originally it was attempted to do this cold. The first cylinder tried straightened without any trouble. The second cylinder broke under a rather light load. Two specimens were taken from this cylinder and pulled in the Laboratory. See graphs No. 2 and 3. The question of comparative hardness between exterior and interior was also investigated on this broken cylinder and it was found that the interior gave a Brinell hardness of 311 against


1
2
ROCK ISLAND ARSENAL
531-39358 March 28, 1933.
Macroetch of Annealed or
(as received) Stainless
Iron.

No. 13.

a Brinell hardness of 293 on the exterior. The remaining cylinders were all heated to about 900 degrees and straightened hot. There was no difficulty in so straightening them and to date they have exhibited very little tendency to warp.

In the completion of this job, these cylinders will be welded into yokes and heads welded into the air cylinders. Inasmuch as this material had exhibited a high sensitivity to heat, the effect of this welding on the material was investigated. Two flat pieces of metal about 1/2" thick were welded together, after first having taken an average Rockwell C hardness across one of these plates. This hardness, which averaged Rockwell C 37.9 or about 364 Brinell, was reduced by the welding operation to an average Rockwell C of 30.4 or about Brinell 296. The four air cylinders which had the head welded in were also tested for hardness. Cylinder No. 1 showed a hardness of Brinell 401 at the weld and 363 about three inches away from the weld. Cylinder No. 2 showed Brinell 255 in the weld and about 401 three inches from the weld. Cylinder No. 3 showed 363 in the weld and about 415 three inches from the weld. Cylinder No. 4 showed 401 in the weld and about 429 three inches from the weld. The hardness figure for the point three inches from the weld may be questioned inasmuch as the wall thickness of these cylinders is only 5/16 of an inch so that it is probable that the Brinell reading is unreliable. The Brinell reading taken in the weld was taken directly over the welded-in head so that the metal was completely supported at this point. Nevertheless these figures seem to show that the welding operation, depending upon the welder, may either soften or harden this metal. This is readily understandable when thought is given to welding temperatures and to the fact that this is an air hardening steel. It was also found that the welding of the head into the cylinder caused the cylinders to go out of round up to .005 inches. Inasmuch as these cylinders have not yet been welded into the yokes, no information is available as to the result of this operation, but it is anticipated that it may both warp the cylinder and cause it to go slightly out of round.

The following is a partial report on the machining of the stainless iron. It will be several weeks before this work is completed. To date no serious difficulties have been encountered in machining or grinding this material. The shop has successfully handled material with Brinell hardnesses ranging from 302 to 387. This material was originally drilled in the Stecher Drill to interior diameters ranging up to 3-1/8 inches.

Feed .004" per revolution. Speed 58 R.P.M. This is the equivalent of drilling 17-1/4" per hour. The heat treated cylinders were then hognosed with a

Cut .125"

Feed .025" per revolution.

Surface speed 24 ft. per minute.

They were rough turned with a

Cut 3/32"

Feed .027" per revolution.

Surface speed 37 ft. per minute.

They were rough reamed with a

Feed .008" per revolution.

Surface speed 24 ft. per minute.

Cut .05".

They were finish reamed with a wood pack reamer removing .015 to .020" stock with a

Feed .012" per revolution.

Surface speed 24 ft. per minute.

They were finish turned with a

Cut 1/32"

Feed .027" per revolution.

Surface speed 37 ft. per minute.

The exterior surface will be finished by grinding which to date, although only about 10% done, has shown no difficulties.

The wood pack reamer blades used were made of Star Zenith and Rex AA Steel. The turning tools were made of a special Watertown Arsenal Molybdenum Tool Steel, Rex AA and Nasco steels. The interior square thread has been easily cut following ordinary shop routine, The drilling and counterboring of the communicating holes in these cylinders has been accomplished with no trouble following ordinary shop practice. The cutting of the interior keyways has also been accomplished without difficulty following the usual shop practice. Regular shop tools have so far been found satisfactory.

The advisability of adopting this material for general manufacture is questioned. Even though it is readily possible to machine stainless iron, the metallurgical considerations seem to out-weigh its value otherwise. That is, the material shows a very low impact value and no way has been found here to increase this value. The heat treatment of this material is troublesome in that a change of temperature of 10 degrees has changed the hardness by as much as fifty points Brinell. The literature available on the heat treatment and the physical properties to be expected has been found quite inaccurate. The physical properties obtained with any standard heat treatment have been found to give wide variations. The assembly of these parts by welding can also be expected to cause both soft and hard spots in the finished cylinders.

The temperatures at which this material has to be hardened are so high, namely 1825°F, and the soaking time at this temperature so long, approximately two hours, that it is seriously doubted whether any standard type of furnace would stand up in continuous operation without excessive cost for repairs due to continued usage at this high temperature. The soaking time required at the drawing temperature is also approximately two hours. These long periods would tend to slow up a quantity production of this material. It has not been possible for us to harden more than six cylinders in any one day and this only after having set our electric furnaces so that they automatically switched on at about 1:00 A.M. which means that our furnaces were used for approximately fifteen hours in order to get a production of six units. Where power costs are high, this would run the heat treating cost of this material up considerably.

L. S. Fletcher,
Lt., Ord. Dept.,
U.S.A.