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REPORT NO. 111/3

INVESTIGATION OF THE RELATION BETWEEN THE
DYNAMIC TENSILE TEST AND THE STATIC
TENSILE TEST

INDEXED

By

HAROLD ALBERT NISLEY
Capt., Ordnance Department, U.S.A.

Submitted in Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE IN MECHANICAL ENGINEERING

1923

WATERTOWN ARSENAL
WATERTOWN, MASS.

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Signature of Author

Certification by the Department of

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Fig. 1 - Diagram showing location of specimens.

" 2 - Drawing of specimens used.

Figs. 3 to 21 inclusive - Photographs.

Table I - Data from Dynamic Test.

Table II - " " Static Test.

Load Elongation Curves.

Table III - Comparative data from the two methods
of testing.

Figs. 22 and 23 - Graphical Representation of
Comparative Data.

I.

HISTORICAL OUTLINE.Development of the Static Testing Machine.

A knowledge of the mechanical properties of the materials to be employed has always been necessary to the rational designing of any kind of structure or machine. Thus the question of testing the materials of construction has been under consideration from the early ages.

The simplest method of testing materials is by direct loading, and the earlier researches were carried out by this method. Galileo (1638) made many tests on a small scale by this means. But this method is suitable only for weak materials and small sizes, because of the difficulty of handling heavy loads. From the time of Galileo eminent physicists and mathematicians have made endless experiments, largely from a purely scientific and theoretical viewpoint, to determine the physical properties of materials. From these investigations, carried on during the latter quarter of the 17th Century, and during the 18th Century, were deduced the various laws of elasticity which constitute the basis of later scientific research.

When, at the beginning of the 19th Century, the demand came for tests on a large scale, it was necessary to devise other means of applying the force than by direct loading. Within a few years there were devised testing machines employing the three arrangements now found in modern testing machines.

These arrangements are:

- (1) Load applied by hydraulic press - no weighing device but load calculated by pressure on ram.
- (2) Load applied by gearing at one end and measured by weighing lever at other end.
- (3) Load applied by hydraulic press at one end and measured by weighing lever at other end.

As early as 1813 method (1) was used by an English concern, Brunton and Co., in building a cable testing machine.

Method (2) was used by Major Wade, of the U. S. Army, in building one of the first machines for making physical tests. This first machine was built in 1856, and was later remodeled and improved by Captain Rodman.

Method (3) is always associated with the name of David Kirkaldy, who in 1866 built his famous testing machine of this type in London. In 1879 Mr. A. H. Emery constructed a machine of this type of 800,000 lbs. capacity, which is still in daily use at the Watertown Arsenal.

All these machines mentioned above are for so-called static testing, that is, where the applied load is grad-

ually increased. This is not, strictly speaking, a static test, and results will vary with the rate of application of the load. However, Bauschinger has shown that the time element is of no consequence within the ranges of practicability, for the velocity of moving parts is inappreciable for all practical purposes. The term "static" test will be used throughout this discussion to denote this method of testing.

The Impact or Dynamic Testing Machine.

With the increase in speed of machine parts, the desire to test a material under approximately actual service conditions led to the introduction of impact or dynamic testing. The application of shock tests to materials has also been practiced to a limited extent from the early ages. It was only natural, where a material was ultimately to be subjected to rough usage in a structure or machine, to first test out the material by subjecting it to rough usage. But until comparatively recent years no attempt was made to measure the energy required to rupture the specimen. Impact testing has in general followed industrial development. Up to about 1850, impact was studied by investigators more as a phenomenon and without regard to its probable application as a practical means of testing materials. During the next forty years impact testing development followed in a way the development of railroads and railroad materials. In 1849 an English

Commission, appointed to inquire into the use of iron in railroad structures, published a report which was one of the earliest published accounts of the consideration of the practical application of previous theoretical knowledge of impact.

In 1857 Captain Rodman devised a drop weight machine for experiments on guns. A little later the drop test machine began to be widely used in testing railroad materials. In 1881 the U.S. Board for Testing Iron and Steel published results of tests on wrought iron and steel, using a drop test machine.

About this time, 1890, impact testing began to have a wider application. Many investigators took up the problem of measuring the energy absorbed by the specimen under test, and devised various apparatus for this purpose to be used in connection with the drop impact machine.

In 1897 S. B. Russel designed a pendulum machine similar to the later Charpy machine, but the practical application of the pendulum principle was made by Charpy in 1901. About the same time Fremont produced his falling weight machine, in which the work of rupture was measured by a calibrated spring which was struck by the falling weight after striking the specimen. The Izod pendulum machine appeared in 1903, and in 1904 the Guillery rotary machine was introduced.

The four machines last mentioned are representative

of the three classes of impact or dynamic testing machines in actual use in testing laboratories today. The Fremont machine is an example of the vertical ram type. The Charpy and Izod represent the pendular ram type. The Charpy machine is described in more or less detail below. The principle of the Izod machine is the same as that of the Charpy, but it differs chiefly in that the specimen is gripped at one end only as a cantilever beam. The third or rotating ram type is represented by the Guillery machine. Here the striking edge is attached to the periphery of a flywheel rotating about a horizontal axis with sufficient velocity to rupture the specimen. The specimen, on horizontal supports, is introduced suddenly in the path of the striking edge. The loss in kinetic energy of the flywheel is measured by the displacement of a column of water connected to a small vertical water turbine, the turbine serving as a tachometer.

II.

OBJECT OF THIS INVESTIGATION.

With the recent development of impact testing and the almost universal adoption of the impact test for routine work to supplement the static test, the question has arisen as to just what is the relationship between the static and the impact or dynamic test.

The results usually recorded in the static test are: the elastic limit, the ultimate strength, the total elongation over a specified gauge length, and the reduction of area. Whereas in the dynamic test, for all the various kinds of testing machines in present use, the results are obtained in units of energy. It is obvious that any comparison of the two methods must be made between units of the same kind. No relationship could be expressed between a linear quantity, such as force or linear distance, and a two dimensional quantity, as energy, which is the product of force and distance. It would seem, then, that if sufficient data were taken in the static test to determine the total energy or work required for deformation and rupture of the specimen, any relationship between the two methods of testing would be shown on a comparison of the total energy required in each case.

Much attention has been given by able investigators to the comparing of the amounts of energy absorbed by

specimens of a given material when ruptured under static and dynamic conditions. A number of attempts have been made to develop a definite percentage relationship between the results obtained by the two methods. The conclusions arrived at in the various cases have been more or less conflicting.

It was believed that this relationship was dependent upon the nature of the material undergoing comparison; that by changing the structure of the material, the value of the percentage relationship would also be changed, at least to a certain extent.

In this investigation a particular steel was selected, and its structure made to vary over a wide range by widely differing heat treatments. In the case of the static tests, the corresponding loads, elongations, and reductions of area were recorded for each specimen through the ultimate up to the point of rupture. The total work done was then determined in each case by integrating the plotted results. Thus it was possible to make a direct comparison of the total energy required for rupture of specimens when tested statically and when tested dynamically.

The object of the investigation was to determine just what relationship existed between the results of the static and dynamic tests for each heat treatment, and to show whether this relationship did, or did not, vary as a function of the structure of the material.

III.

DESCRIPTION OF MACHINES USED.

Before taking up in detail a discussion of the procedure followed during the investigation, it would seem advisable to include at this point a brief description of the testing machines used. The dynamic tests were carried out on a Charpy machine of 300 Kgm. capacity, while for the static tests a Richle machine was used.

The Charpy Machine (300 Kgm.)

The Charpy machine was selected for the dynamic tests, for the following reasons:

- (1) It is the machine in most general use for routine impact testing.
- (2) It is one of the few impact machines designed for tension tests, and in this investigation it was desired to conduct the dynamic tests upon tensile test pieces of exactly the same size and shape as those used for the static tests.

The large machine was used in preference to the smaller one of 30 Kgm. capacity because the size of test pieces used for tensile testing is more nearly the size of the standard static tensile test piece.

As the machine itself is quite well known, it will be described only briefly here, particular attention being paid to the giving certain constants of the machine, such as weights and dimensions. A photograph of the machine used is exhibited in the Appendix, Fig. 3, which shows clearly the method of attaching a tensile specimen. The pendulum hammer is tapped and threaded at the back for holding one end of the

test piece. On the other threaded end of the test piece is screwed a hardened steel block. When the pendulum drops, this block strikes against prolongations of the anvil and is stopped. The pendulum is suspended to swing about a horizontal axis on roller bearings, and an index hand is mounted on this axis with an easy friction fit and travels over a graduated circular dial with the hammer when this rises after fracturing the test piece.

The hammer is raised by means of a small motor and held up at its maximum starting angle by a catch which may be released by pulling the cord shown in the photograph. The angle of rise of the hammer after fracture of test piece is read off from the graduated circle.

The kinetic energy "K" available at the time of impact is equal to the product of the weight of the striking mass "P" by the height of fall of the center of gravity, ("d" being radius to center of gravity)

$$P \times d (1 - \cos a) \quad (a \text{ being the starting angle})$$

less the kinetic energy absorbed by mechanical friction and the air resistance of the fall.

The kinetic energy "K" left after shock is equal to the product of the weight of the striking mass by the height of ascent of the center of gravity,

$$P \times d (1 - \cos b) \quad ("B" \text{ being the angle of rise})$$

plus the energy absorbed by friction and air resistance during the ascent.

The total energy absorbed is then equal to

$$\underline{k - k}$$

In order to determine the energy absorbed by friction and air resistance the pendulum is allowed to swing freely and the decrease in amplitude of swing noted; this gives a table of corrections to be applied for each angle of ascent.

Where tensile specimens are used for the impact test, in making calculations the weight "P" of the pendulum is increased by the weight of the broken end of the specimen carried away. And the starting angle is that angle which the line through the axis and the resultant center of gravity of the pendulum, with the test piece and tup attached, makes with the vertical. For since the effect of the tup and test piece is to increase the height through which the center of gravity falls, the pendulum has a greater striking velocity than it otherwise would have.

Characteristics of the Charpy Machine.

Machine Used - No. 180, Type No. 2, Monton Pendule
Systeme Charpy.

	<u>Metric Units</u>	<u>English Units.</u>
Weight of Pendulum - - - - -	96.370 Kg.	212.4592 lbs.
Radius to center of gravity - -	1.627 m.	5.3379 ft.
Radius to center of Percussion	1.9045 m.	6.2483 ft.
Maximum Starting Angle - - - -	160 degrees	
Free return angle corresponding to maximum starting angle -	158 degrees	
Velocity of Impact (Max.start- ing angle)	8.733 m/sec.	28.6512 ft/sec
Capacity - - - - -	304.6 Kgs.	2203.2 ft.lbs.
Distance from center of specimen to axis of rotation - - - -	2.000 m.	6.5616 ft.
Period of Oscillation - - - -	2.7691 sec.	
Weight of block or tup - - - -	2.300 Kg.	5.0706 lbs.

The Richle' Machine.

For the static tests the Richle testing machine of 100,000 lbs. capacity was used, chiefly because this type of machine is most generally used for static tests, especially in routine work.

The machine is representative of type (2) mentioned under the discussion of static machines above. It is too well known to merit a detailed description here. The power is applied to the lower end of the test piece by means of three vertical screws, which pass through the weighing table. These vertical screws are connected to the motor by a system of screw and spur gearing. The upper end of the test piece is attached to a frame which is fixed to the weighing table. The force applied to the test piece by the three strain screws is transmitted through this frame to the weighing table, and thence by a compound system of levers to the graduated weighing beam.

IV.

DESCRIPTION OF MATERIAL AND METHODS
OF TESTING.

Steel Selected.

The particular steel selected for this investigation was a plain carbon steel, which upon analysis was found to have the following composition:

Constituent	Percent
Carbon	0.39
Manganese	0.70
Phosphorous	0.048
Sulphur	0.043
Silicon	0.265
Nickel	0.34
Chromium	0.11

This steel was available in square bars 1-3/8" x 1-3/8" and of lengths varying from 39" to 52". Original length of rods had been approximately 10 feet, but all had previously been given a normalizing treatment, and each of the 10 foot bars had been cut in three pieces because of the limited size of the annealing furnace. See Appendix, Fig. 1 for schematic diagram showing location of specimens in the bars from which they were taken. The markings, 3801, 3802, 3803, etc., indicate the markings originally placed on the bars

in the testing laboratory at the Watertown Arsenal, and have been preserved in this sketch for identification from the records of that laboratory. Each horizontal group of three bars in the sketch indicates the three bars that were cut from one 10 foot bar, and also shows their relative position in the longer bar.

Heat treatments.

To obtain a wide range of variation of internal structure, six different heat treatments were applied. Throughout the remainder of this discussion they will be indicated as heat treatments A, B, C, D, E and F. For each heat treatment five dynamic and five static test specimens were taken. In marking the specimens, the first letter of each group indicates the heat treatment. The middle letter of each group, "S" or "R" identifies the specimen as to static or dynamic test; "C" indicating a dynamic or Charpy test piece, and "R" indicating a static or Richle test piece. The numeral following the "C" or "R" of each group indicates the number of the specimen in that group. Having thus indicated the method of marking, a glance at the diagram will show how alternate dynamic and static test pieces were taken, and how correspondingly numbered specimens under any heat treatment occupied adjacent positions in the original bar.

The heat treatments given were as follows:

"A" - Held at 1100° C. for six hours and furnace cooled.

- "B" - Held at 1000° C. for six hours and furnace cooled.
- "C" - Held at 900° C. for six hours and furnace cooled.
- "D" - Held at 850° C. for six hours and furnace cooled.
- "E" - Held at 850° C. for one hour and quenched in water at 21° C. - drawn at 600° C. for one hour and air cooled after the draw.
- "F" - Held at 850° C. for two hours and air chilled - drawn at 600° C. for one hour and furnace cooled.

In heat treating, all of the ten specimens of each group were placed in the same furnace, and great care was exercised to insure absolute uniformity of heating. Attention is invited to the photo micrographs appearing in the Appendix, which show the resulting structures obtained by the six different heat treatments.

Specimen Adopted.

It was desired that the specimens used for the dynamic and static tests should be as nearly identical as to form and dimensions as possible. For a drawing showing all dimensions of the specimen selected see Appendix, Fig. 2. This specimen, of 0.543 in. diameter, is standard, at the Watertown Arsenal Testing Laboratory, for all tests on un-notched tensile bars by the 300 Kgm. Charpy machine. The specimen for the Riehle machine was made of the same dimensions throughout as the Charpy specimen. The only difference between the specimens for the two machines was in the number of threads per inch. The Charpy machine required a metric thread, whereas an English thread was used on the Riehle machine.

The Dynamic Test.

For the results obtained on the Charpy machine, see Appendix, Table I. A two inch gauge length was marked on each specimen before being placed in the machine. The angle of ascent, elongation, and reduction of area were recorded in every case. The last few threads on each end of the test pieces were flattened to limit the whip of the specimen upon the tup's striking the anvil. For unless the threads fit exceptionally tight it was noticed that the specimen with the heavy tup attached tended to sag slightly, thus preventing the tup from striking the anvil squarely. The weight of that portion of the specimen remaining in the pendulum, as well as that portion attached to the tup, are also recorded in table I for every case. For photographs showing appearance of fracture see Appendix, Figs. 5, 6 and 9 to 14 inclusive.

The Static Test.

On the Riehle machine the elongations were measured up to the yield point by means of a Berry Strain gage. The photograph, Appendix, Fig. 4, shows the machine with specimen and strain gage attached. Here also, a two inch gauge length was marked on each specimen by a prick punch gage, before insertion of the specimen in the machine. After the yield point was reached in each case the strain gage was removed, the elongations being measured thereafter by a vernier. As but one man operated the machine the rate of

loading was unusually slow. The load was applied in increments of 1,000 lbs. After each increment of load the beam was left balanced while a reading was taken of the elongation, and, after removal of the strain gage, of the diameter also. The results of the static test for each specimen are recorded in the appendix, Table II.

From the data of Table I, there was plotted for each specimen a Load-Elongation curve. These curves were integrated by means of a planimeter, and the work absorbed in each case thus determined. The Load-Elongation curves for the static test are to be found in the Appendix immediately following Table II. It is to be noted that in the case of heat treatments "E" and "F", there was no falling off of the load at the yield point. While in the other heat treatments there were numerous instances where a decided reduction of load was noticed at the yield point.

As stated at the beginning of this discussion, what is customarily known as the static test is not, strictly speaking, a static test. If the rate of application of the load is increased to such an extent that the moving parts of the testing machine acquire an appreciable velocity, the test then becomes a dynamic one. It is thus seen that there is no definite boundary line between the dynamic test and the so-called static test. It is not intended here to do more than call attention to the above limitations of the terms used, and to give the relative velocities of the moving parts of the machine used in this investigation. In the Charpy tests the

striking velocity of the pendulum was 28.65 feet per second. While in the Richle tests the rate of application of the load varied from 0.01 to 0.14 inches per minute.

In the preparation of the test pieces for this investigation the machinist was particularly carefully as regards the dimensions specified. By referring to the diameters as given in Tables I and II it is noted that in but four cases was the variation more than .0005 inches from the specified diameter.

V.

COMPARISON OF RESULTS.

For a comparison of the type of fracture produced by the two methods of testing, attention is invited to the photographs included in the Appendix. Views normal to the section of fracture are shown in figures 5 to 8 inclusive, and figures 9 to 20 inclusive show the fractured specimens in an upright position. It is to be noted that the fractures for the dynamic test are in general of a more ragged contour and more nearly fibrous appearance than is the case for the static test. While for the static test the plane of fracture is approximately a plane section, for the dynamic test, on the other hand, there is a partial cup and cone effect, or a ragged drawing out of the material at the section of fracture.

In table III of the Appendix has been tabulated side by side for the dynamic and static tests, for each correspondingly numbered specimen, comparative values of total work done, percentage elongation, and percentage contraction of area.

It is interesting to note how very much more nearly uniform are the static results as compared to the dynamic results. In this connection it is seen by turning to table II, that for each heat treatment all five of the static specimens gave very approximately the same yield point, the same ultimate load, and the same breaking load. While in the dynamic tests the lack of uniformity of results for specimens of the same heat treatment is much greater, however the results are nearly uniform as

would be expected from a dynamic test.

In Fig. 21 is shown graphically for the average of each heat treatment, the same comparative data as given in table III. In Fig. 22 is plotted the percentage relationship of the average static results to the average dynamic results for each heat treatment.

We note that in every case the total work done, the elongation, and the contraction of area is greater for the dynamic than for the static test. The difference between the corresponding functions for the two methods of testing is greatest for work done and in least for contraction of area. The ratio of work done statically to work done dynamically varies from 61.3% for heat treatment "A" to 76.2% for heat treatment "E", giving a difference of 15.1% over the range of heat treatments used. The ratio of contraction of area in static tests to contraction of area in dynamic tests varies from 87.3% for heat treatment "A" to 99.5% for heat treatment "E", a difference of 12.2% over the range included. And the ratio of elongation varies from 81.9% for heat treatment "A" to 92.7% for heat treatment "E", giving a variation of 10.6% over the range included.

Referring to Fig. 21, it is interesting to note that the ratio of contraction of area for the two methods of testing varies very much in the same manner as the ratio of work done for the different conditions of structure. That is, it would seem that the contraction of area as recorded in the usual static test would serve fairly well as a criterion of the shock

resisting properties of the material, on bars or structural members of uniform section.

VI.

CONCLUSIONS.

In the light of the above observations, within the limits of this investigation, there appears to be no fixed percentage relationship between the results obtained upon a particular steel by so-called static and dynamic tensile tests. This relationship is apparently a function of the structure imparted to the steel by different treatments. However, the variation of the relationship is not large and seems to be confined to a certain limited range. It must be noted that this investigation has been limited to one particular steel of 0.39% carbon content, and to unnotched tensile test specimens for both the static and dynamic tests.

From the various data obtainable from a static tensile test on this particular steel, the reduction of area seems to be the best criterion of the shock resisting qualities of the material.

APPENDIX.

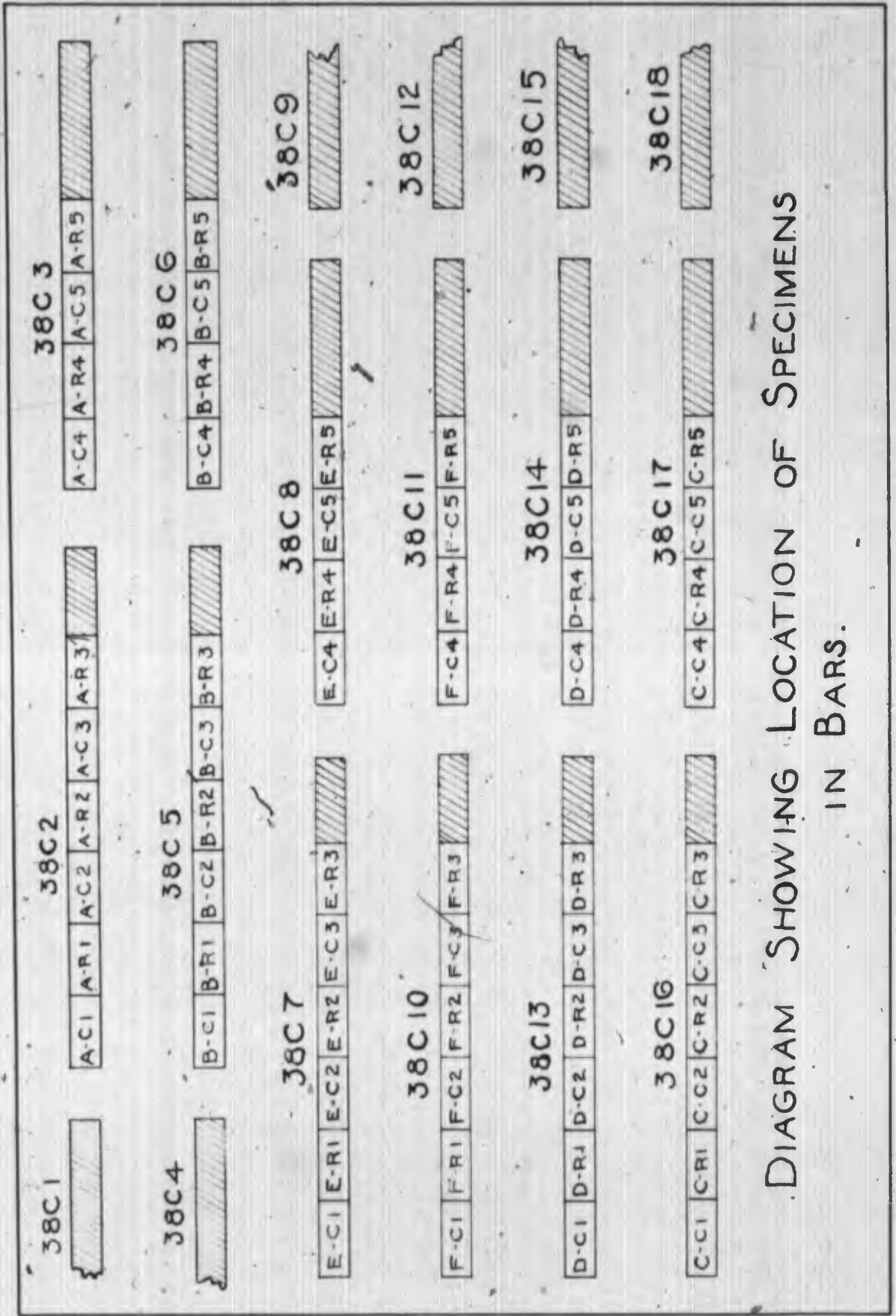
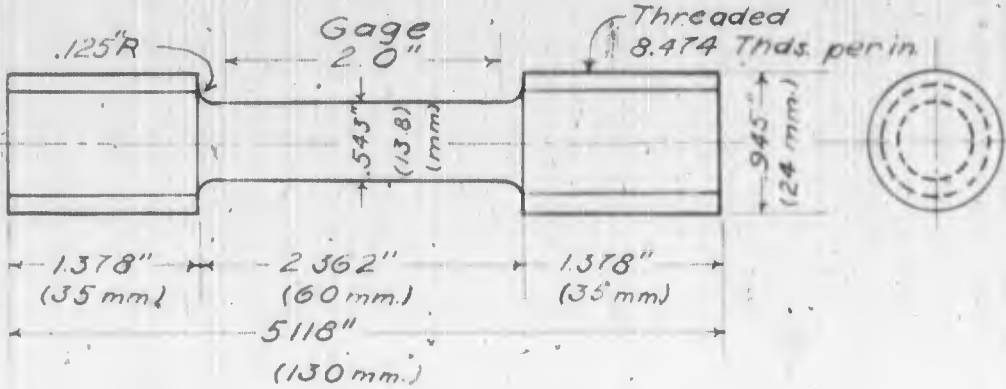


DIAGRAM SHOWING LOCATION OF SPECIMENS
IN BARS.

CHARPY TEST SPECIMEN
DYNAMIC TENSILE TEST



RIEHLÉ TEST SPECIMEN
STATIC TENSILE TEST

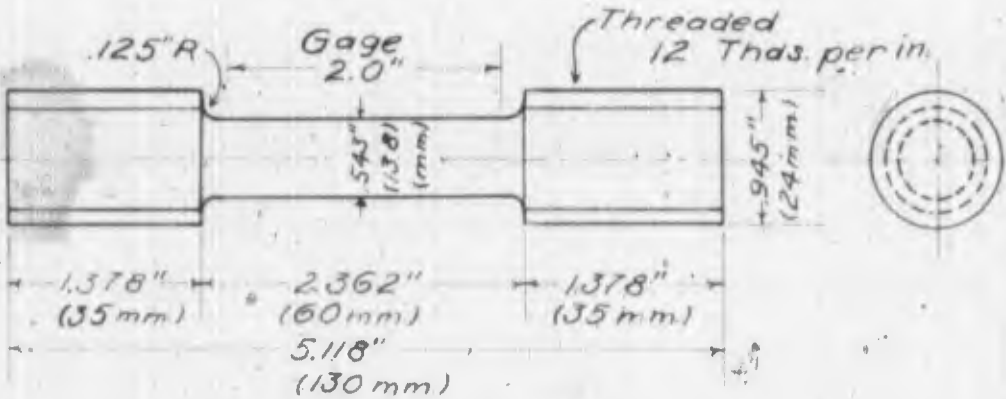
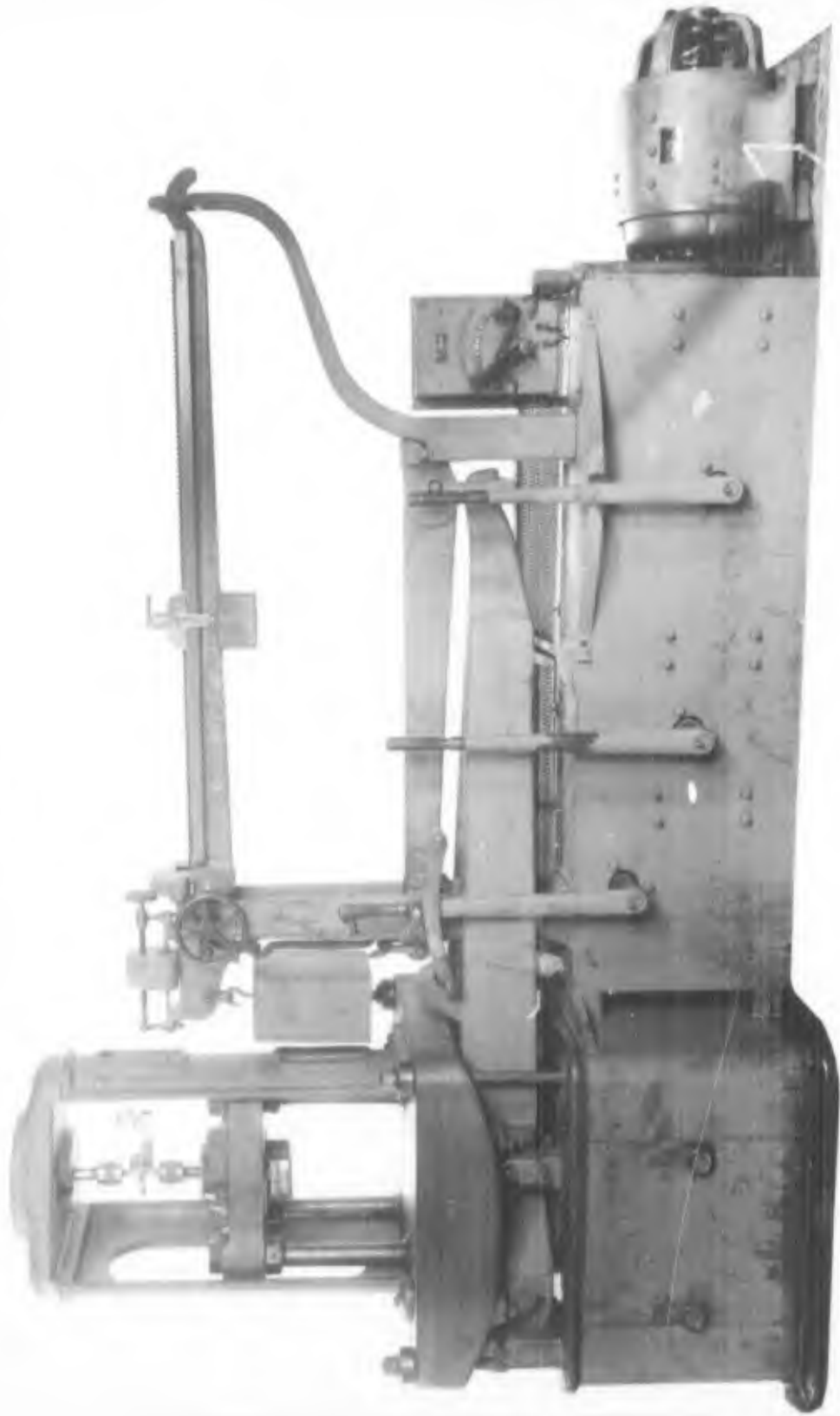


FIGURE 2.



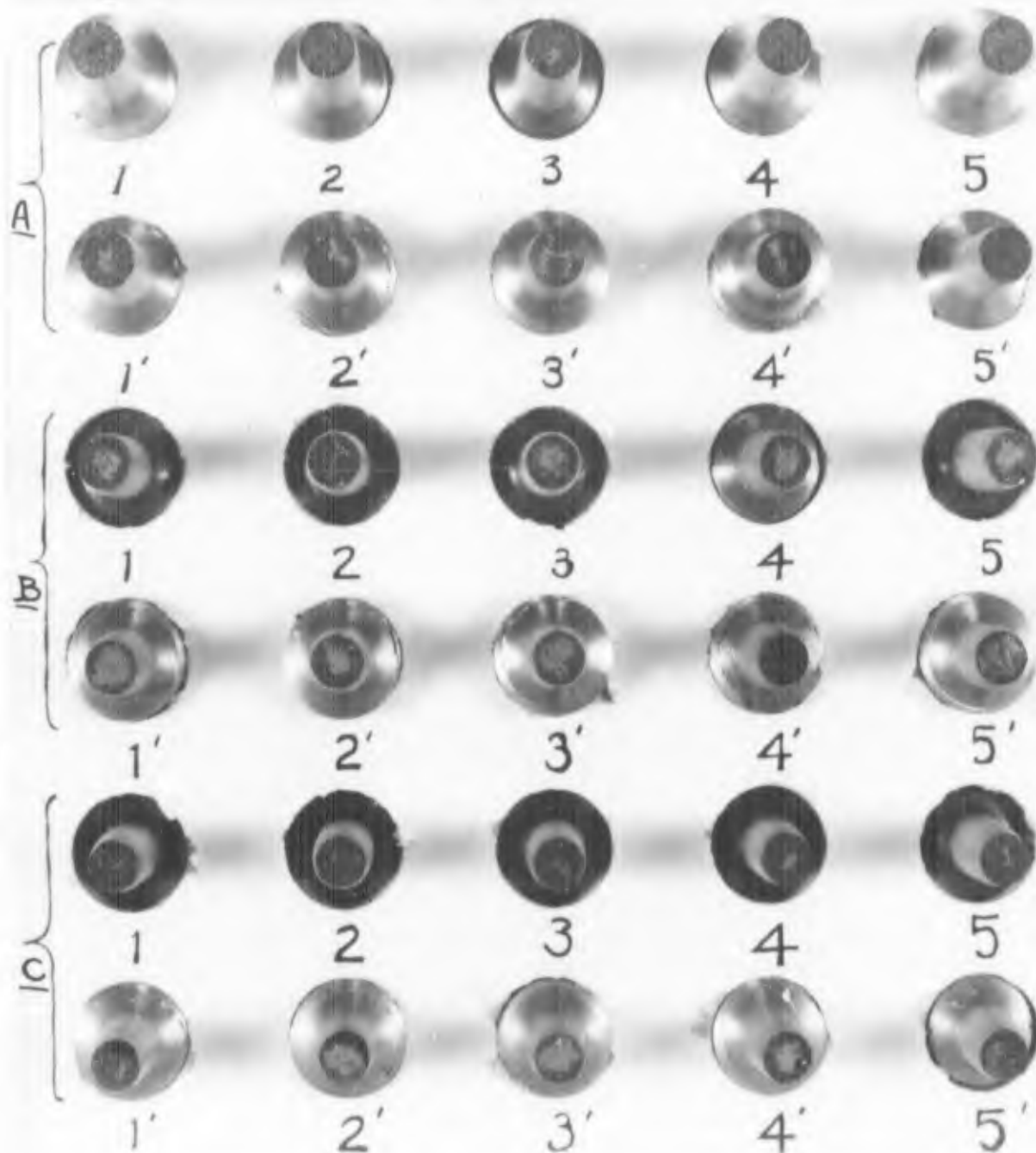
CHARPY TESTING MACHINE. (300 KGM.)

FIGURE 3.



68723

SPINNING MACHINE •
FIGURE 4.

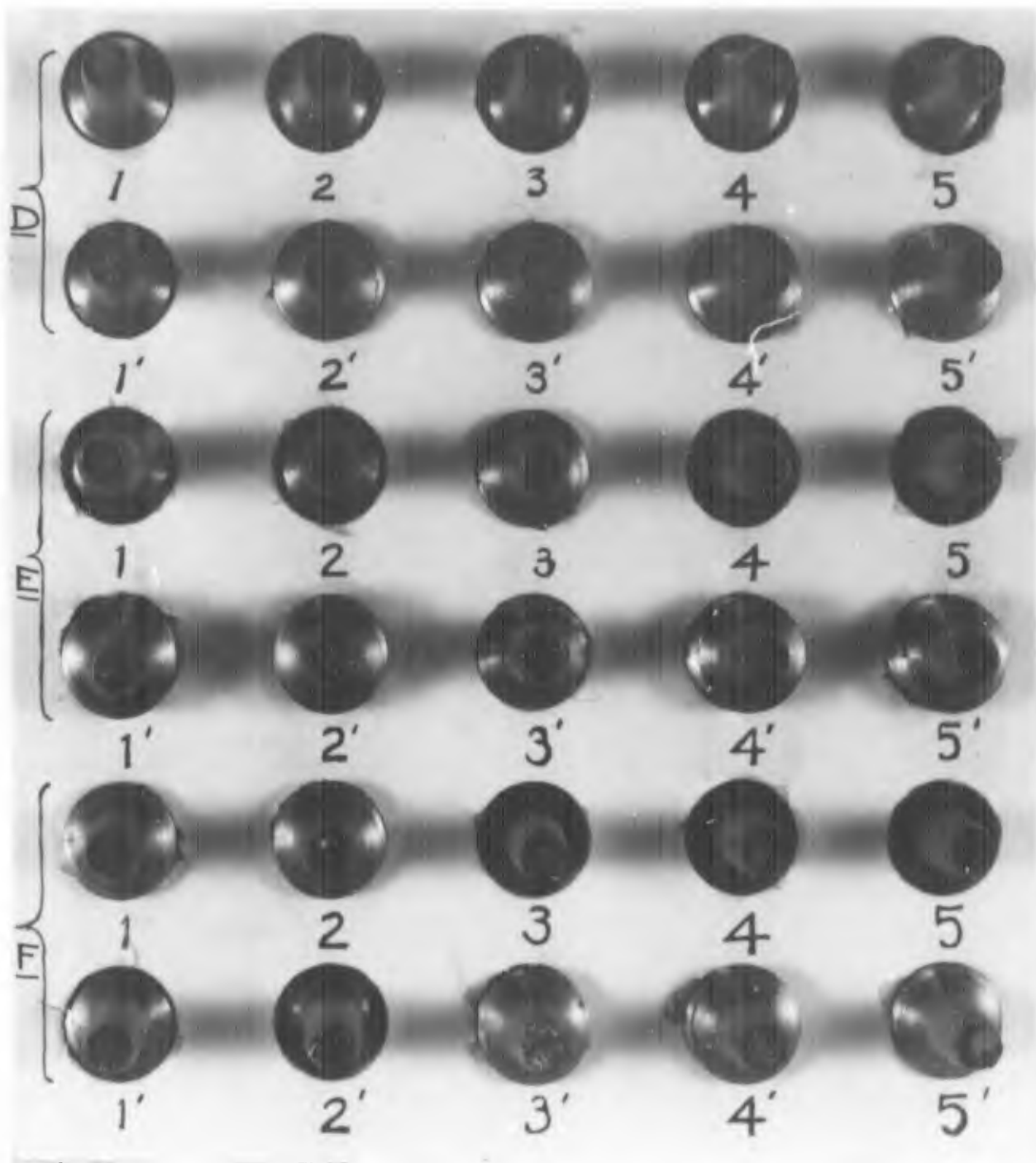


APPEARANCE OF FRACTURE, DYNAMIC TENSILE SPECIMENS.

HEAT TREATMENTS "A", "B", AND "C" .

(Primes indicate end of specimen to which tup was attached.)

FIGURE 5.

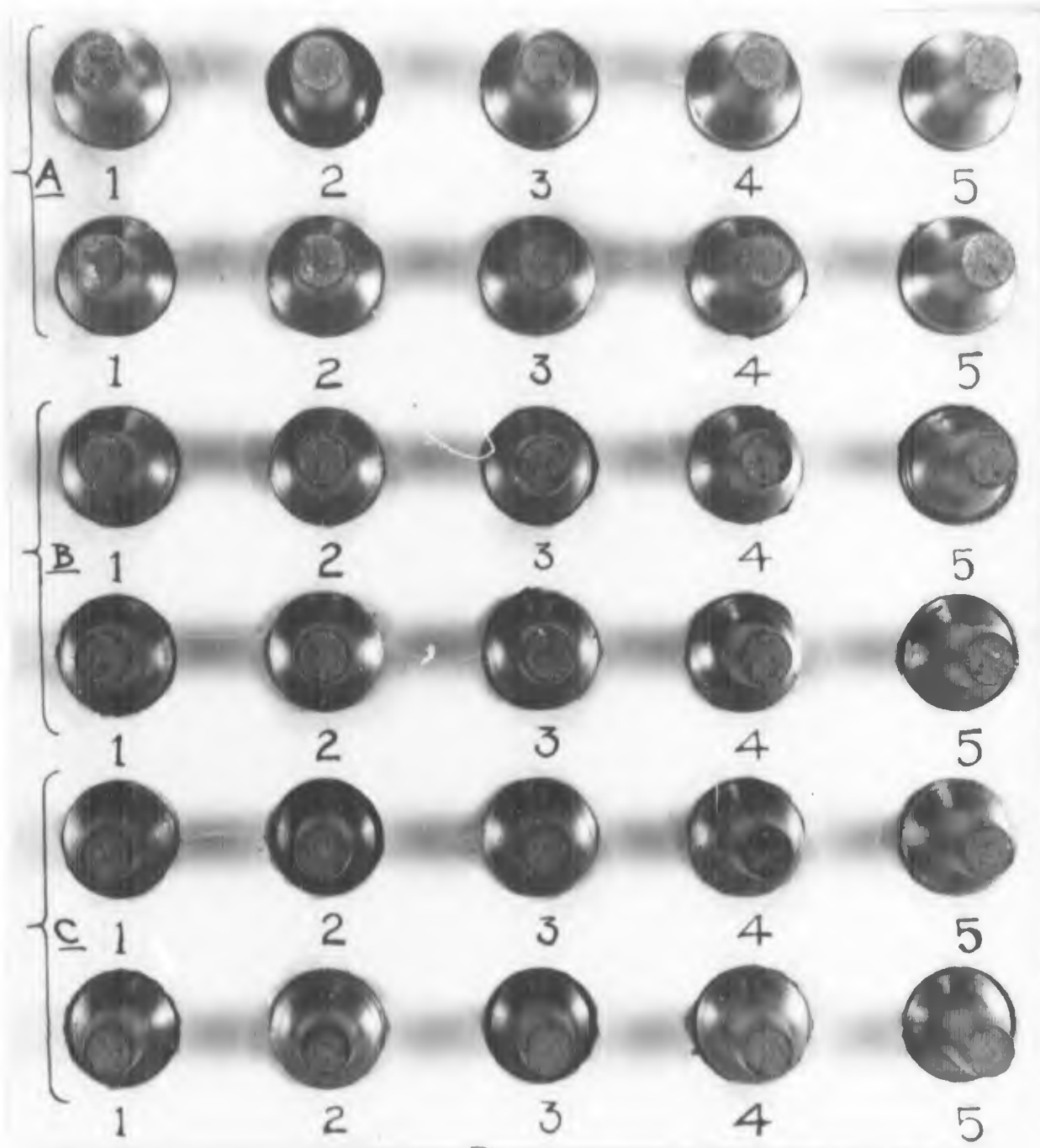


APPEARANCE OF FRACTURE, DYNAMIC TENSILE SPECIMENS.

HEAT TREATMENTS "D", "E" AND "F".

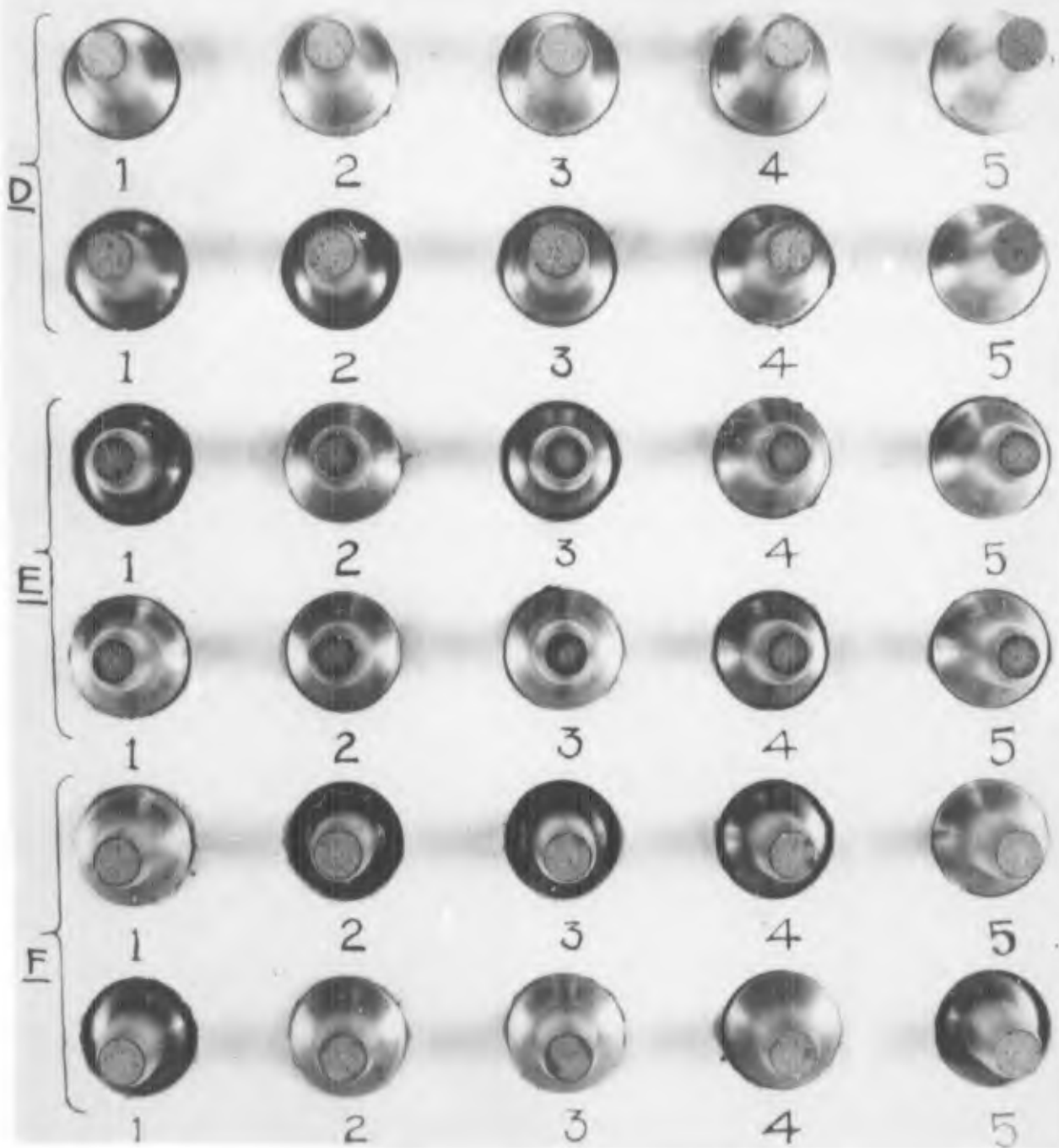
(Primes indicate end of specimen to which tup was attached).

FIGURE 6.



APPEARANCE OF FRACTURE, STATIC TENSILE SPECIMENS.
HEAT TREATMENTS "A", "B", AND "C".

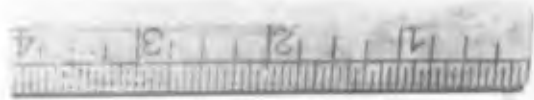
FIGURE 7.



APPEARANCE OF FRACTURE, STATIC TENSILE SPECIMENS.

HEAT TREATMENTS "D", "E", AND "F".

FIGURE 8.



1 1' 2 2' 3 3' 4 4' 5 5'

CHARPY SPECIMENS. USAF WAREHOUSE, "A".
FIG. 9.



1 1' 2 2' 3 3' 4 4' 5 5'

HEAT TREATMENT. "B".

FIG. 10.



1 1' 2 2' 3 3' 4 4' 5 5'

CHIRPY SPECIMENS. HEAT TREATMENT "C".

FIG. 11.



1 1' 2 2' 3 3' 4 4' 5 5'

CHARPY SPECIMENS. HEAT TREATMENT. "D".

FIG. 12.



1 1' 2 2' 3 3' 4 4' 5 5'

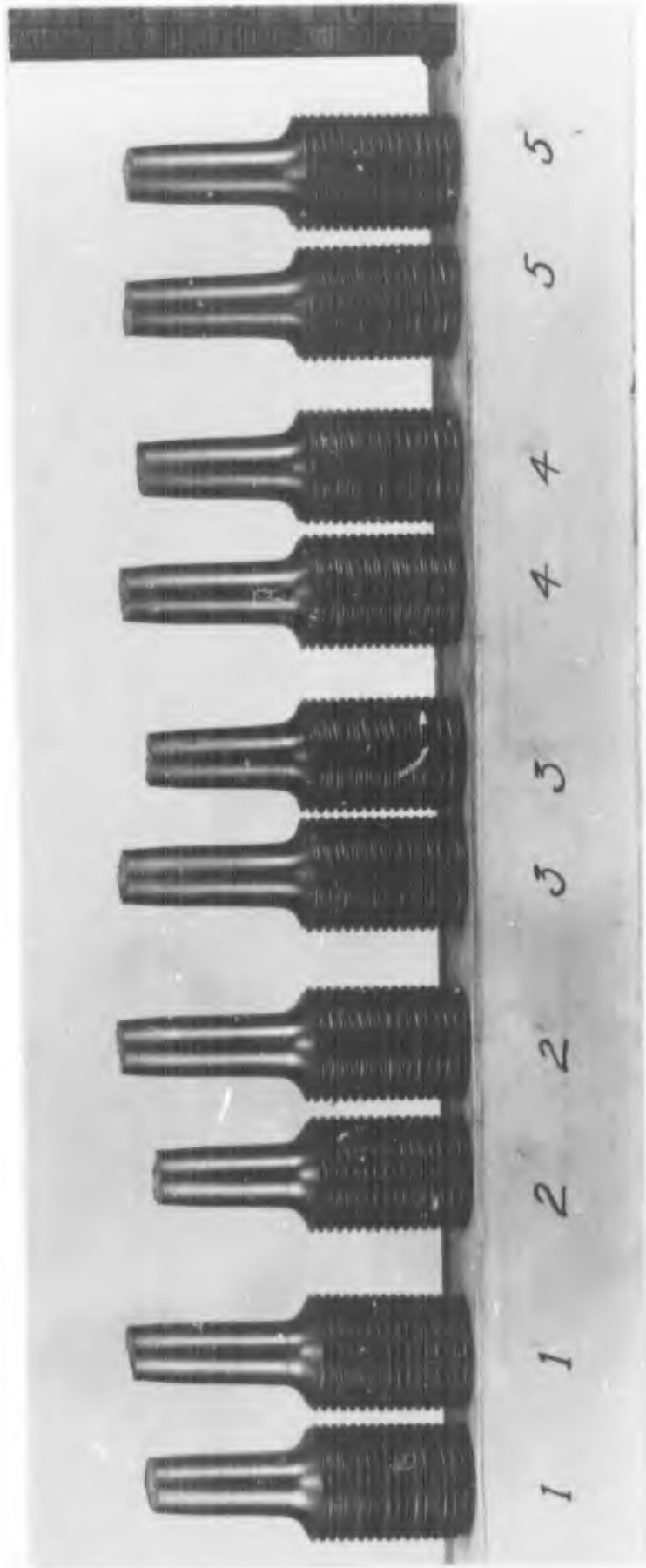
CRACKY SPECIMENS. HEAT TREATMENT. "2"
FIG. 13.



1 1' 2 2' 3 3' 4 4' 5 5'

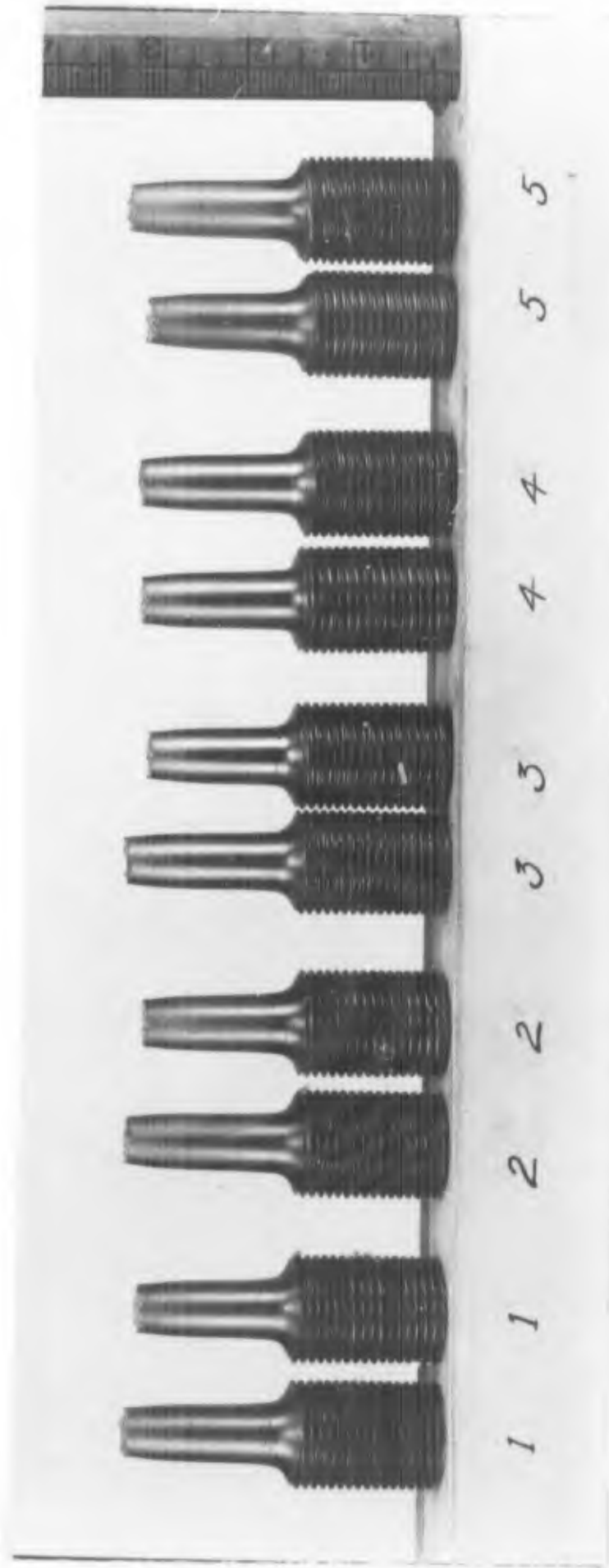
CHARPY ABSOLUTES. HEAT TREATMENT, "P"

FIG. 14.



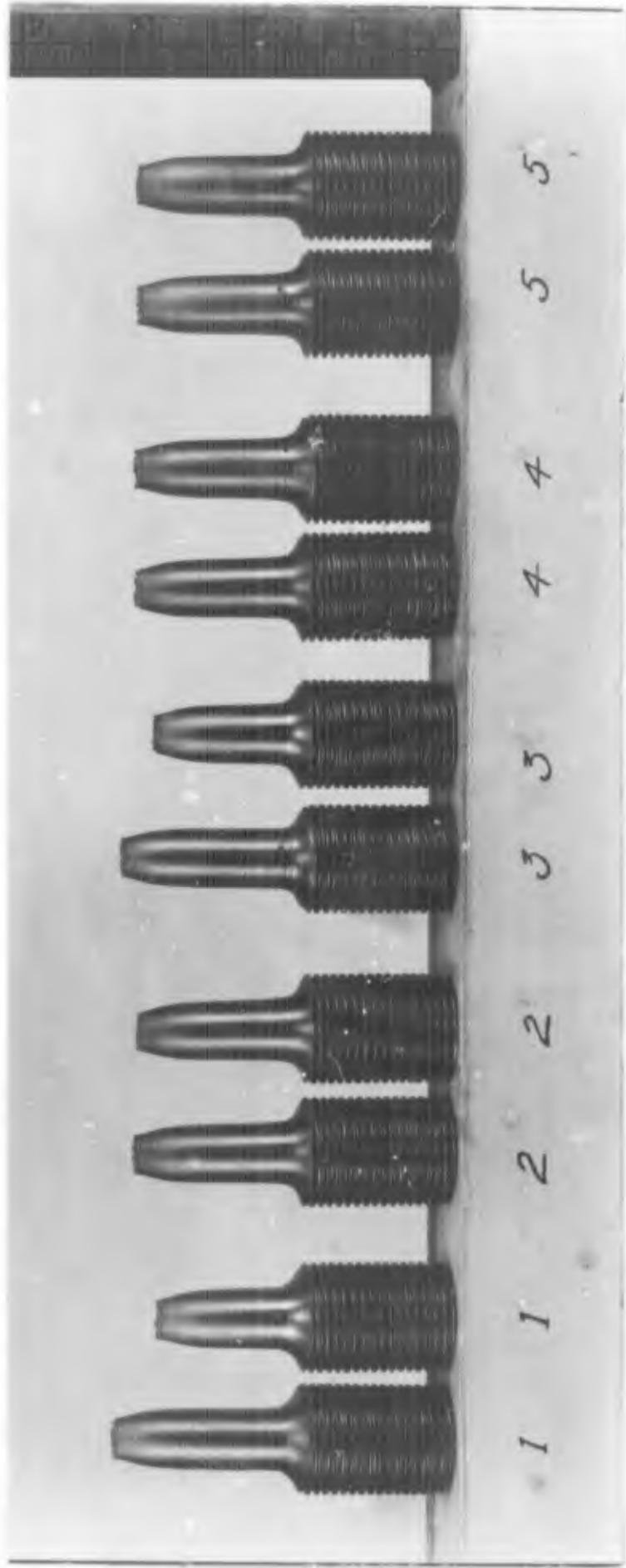
PIPE SECTIONS • HEAT TREATMENT "A"

FIG. 15.

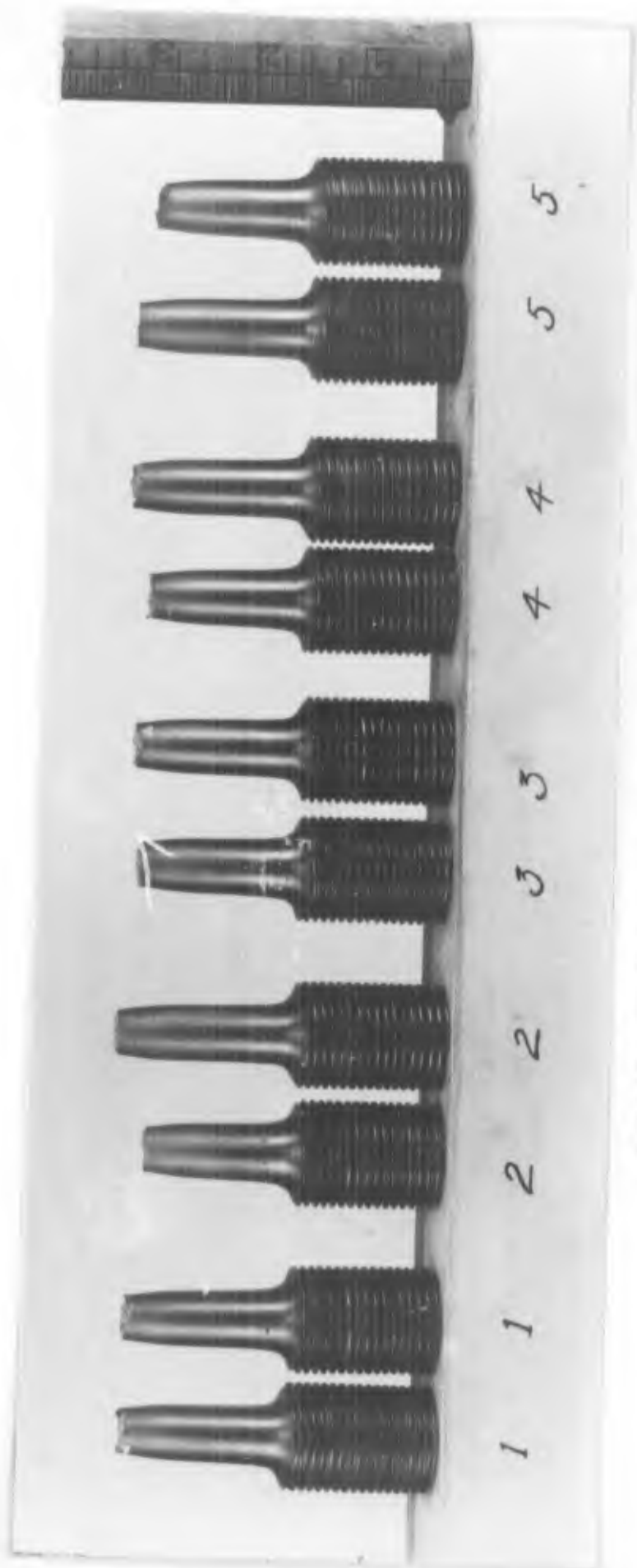


RIBBLE SPECIMENS. HEAT TREATMENT. "B".

FIG. 16.

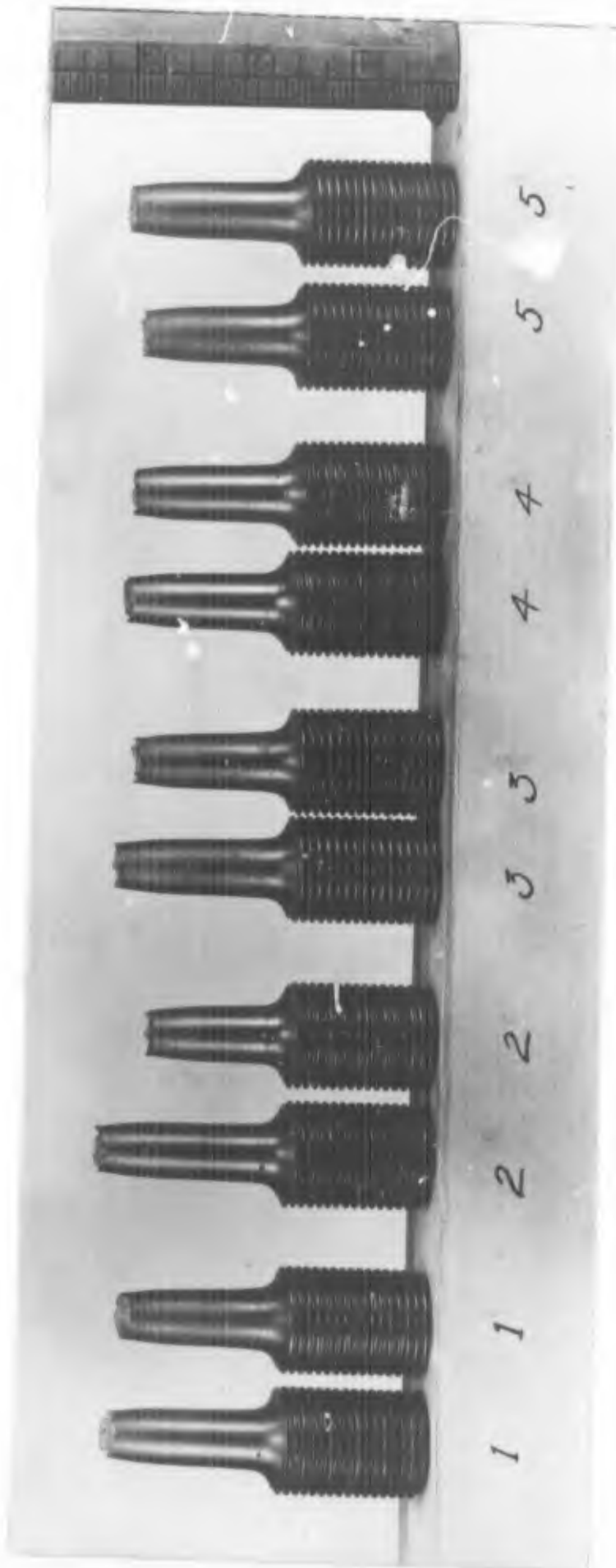


RIBBLE SPECIMENS. HEAT TREATMENT. B.
FIG. 17.



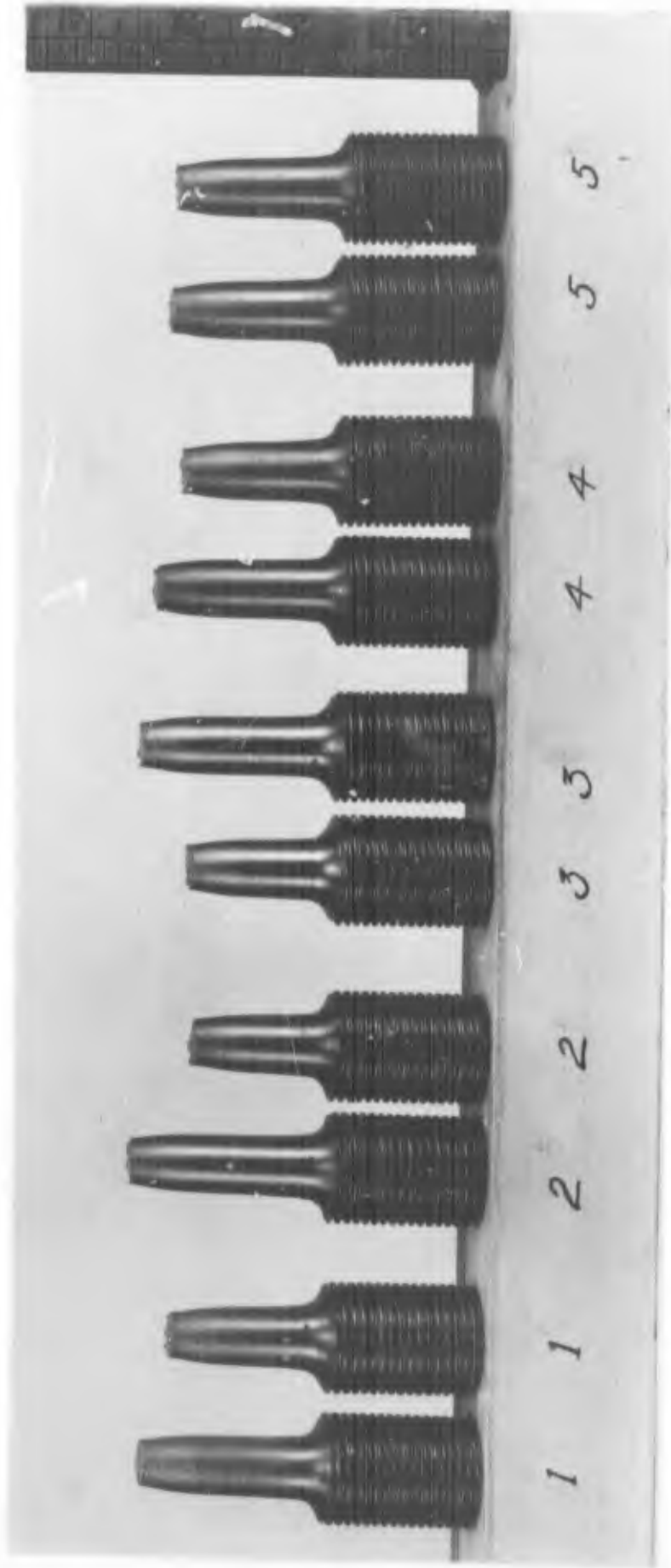
RIEHLER SPECIMENS. HEAT TREATMENT. "D".

FIG. 18.



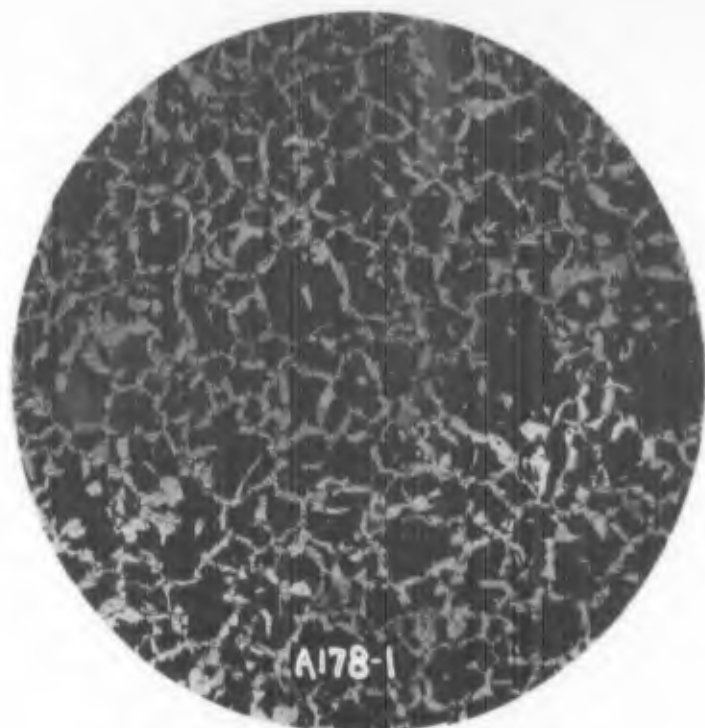
NICKLE SPECIMENS. HEAT TREATMENT. "C".

FIG. 19.

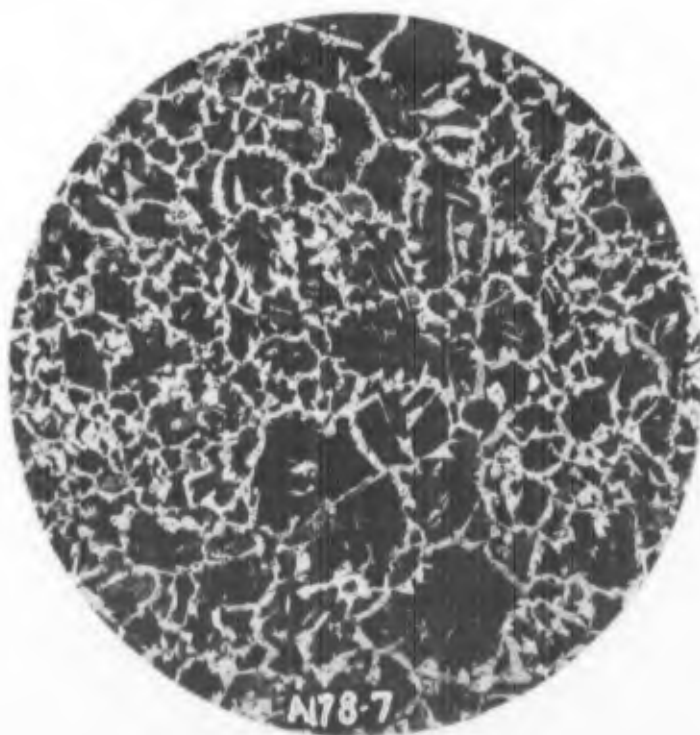


RIBBLE SPECIMENS. HEAT TREATMENT, "P".

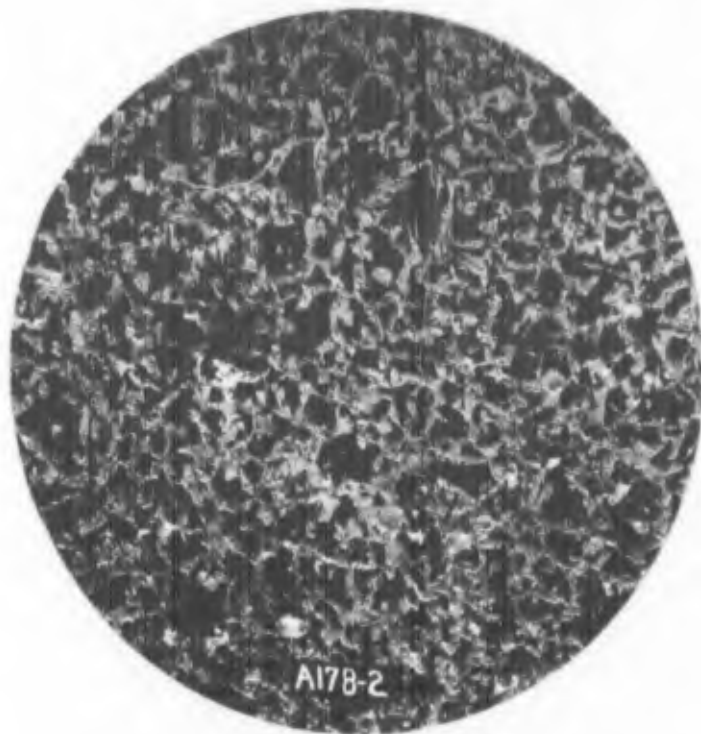
FIG. 20.



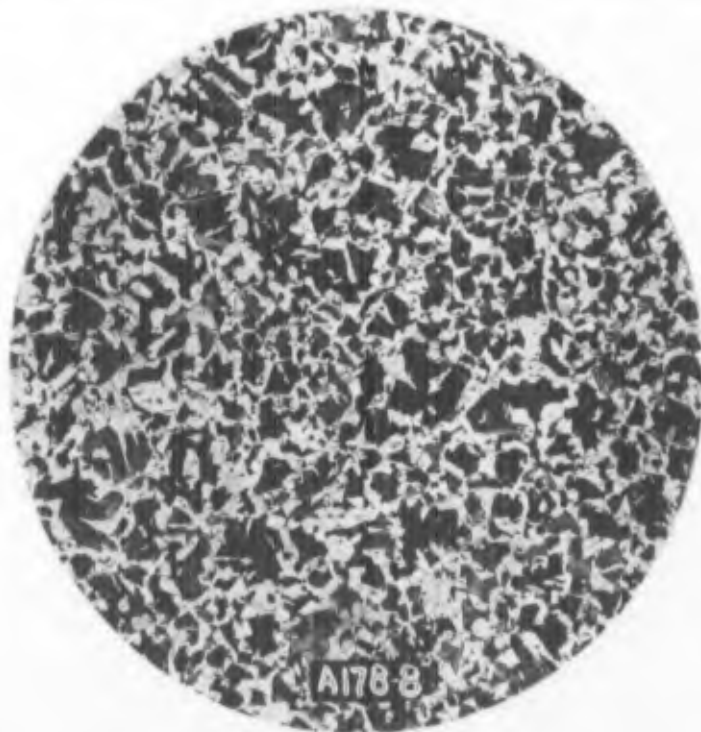
Specimen A-02. Magnification 50.
Etched with a 4% solution of Nitric Acid in Alcohol.



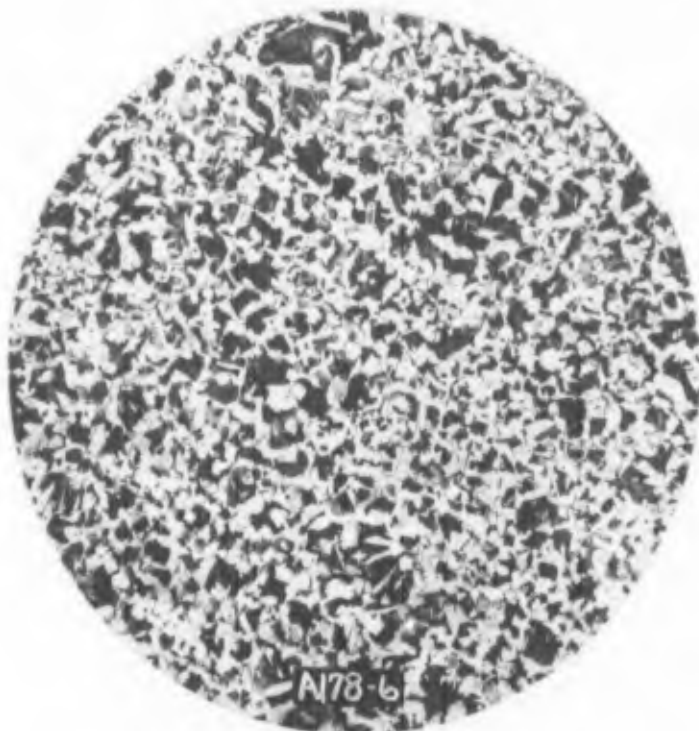
Specimen A-02. Magnification 50.
Etched with a 4% solution of Nitric Acid in Alcohol.



Specimen B-81. Magnification 50.
Etched with a 4% solution of Nitric Acid in Alcohol.

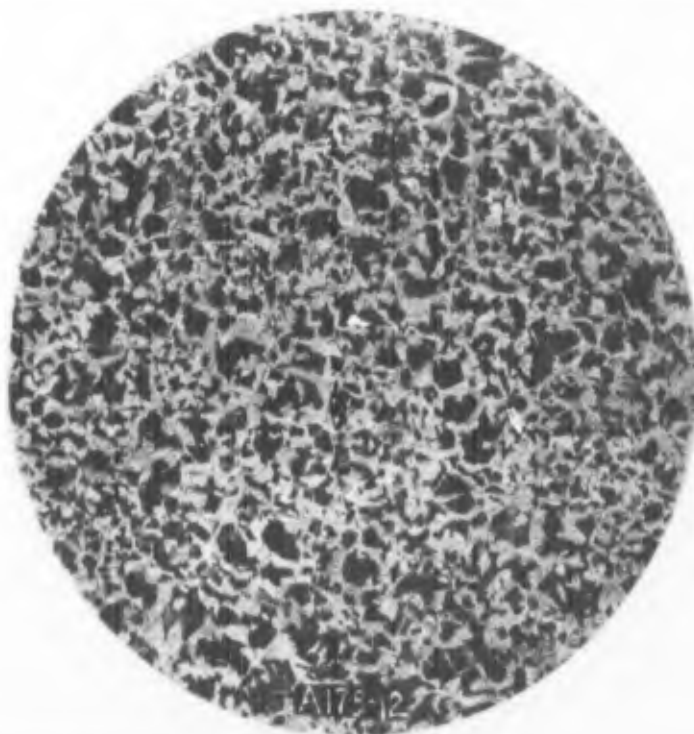


Specimen B-82. Magnification 50.
Etched with a 4% solution of Nitric Acid in Alcohol.



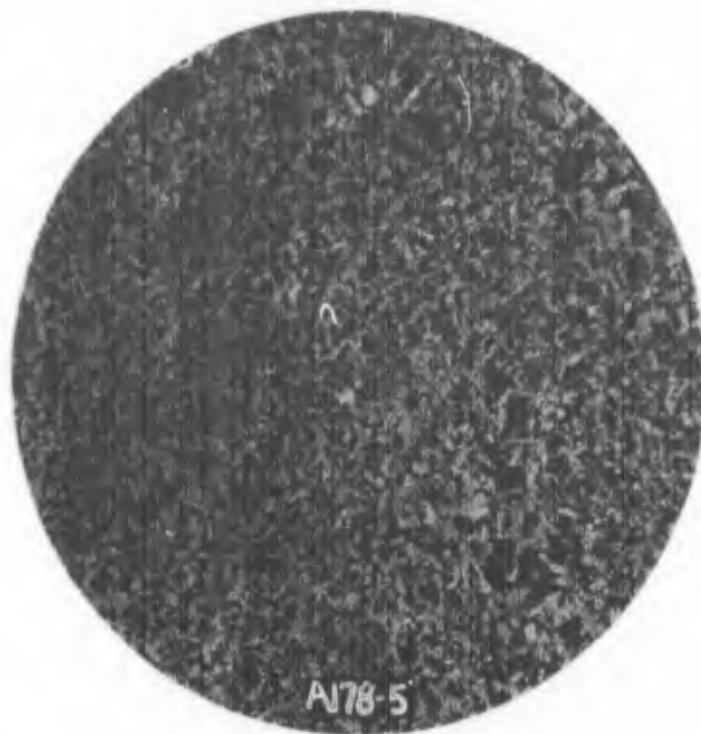
Specimen C-C2. Magnification 50.

Etched with a 4% solution of Nitric Acid in Alcohol.



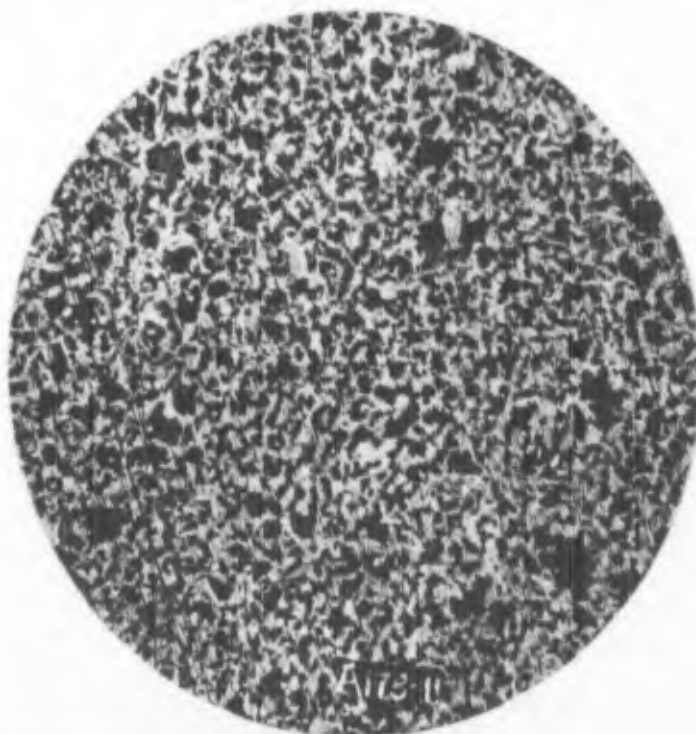
Specimen C-R2. Magnification 50.

Etched with a 4% solution of Nitric Acid in Alcohol.



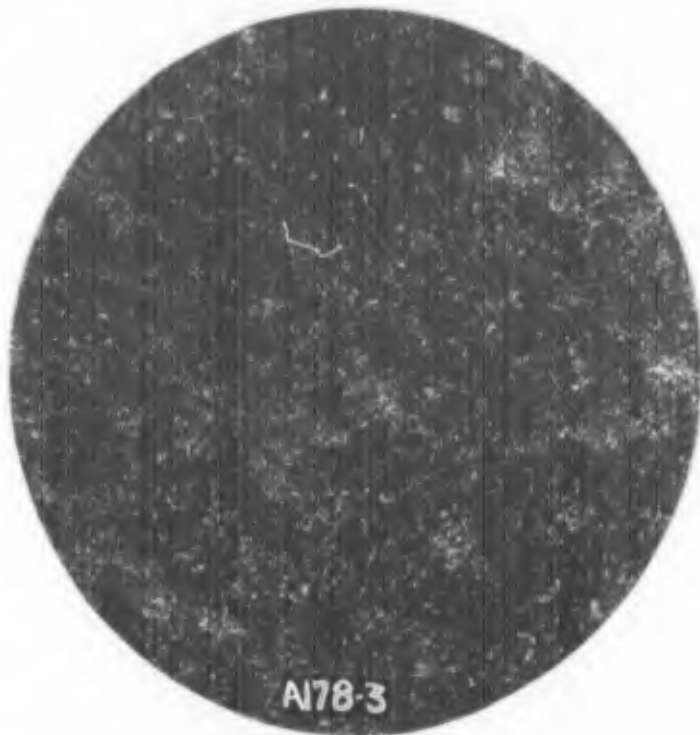
Specimen D-C2. Magnification 50.

Etched with a 4% solution of Nitric Acid in Alcohol.



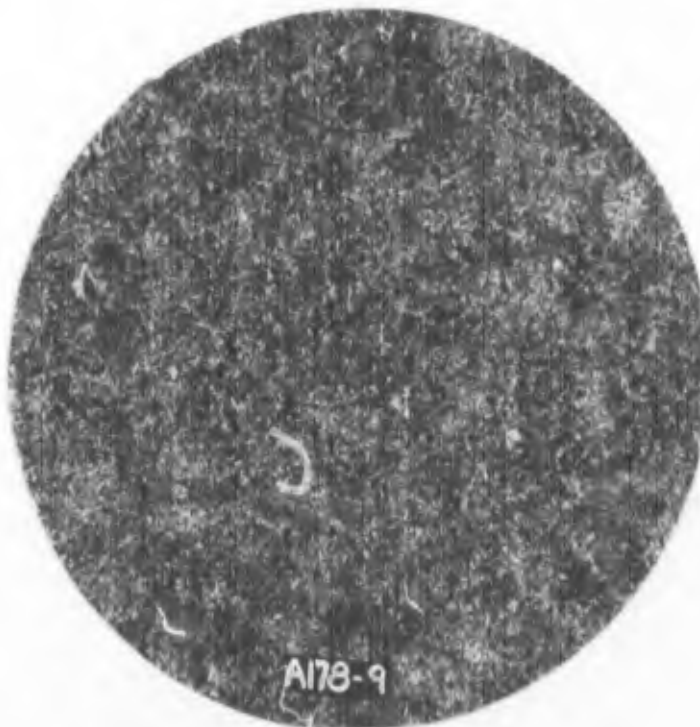
Specimen D-R2. Magnification 50.

Etched with a 4% solution of Nitric Acid in Alcohol.



Specimen E-C2. Magnification 50.

Etched with a 4% solution of Nitric Acid in Alcohol.



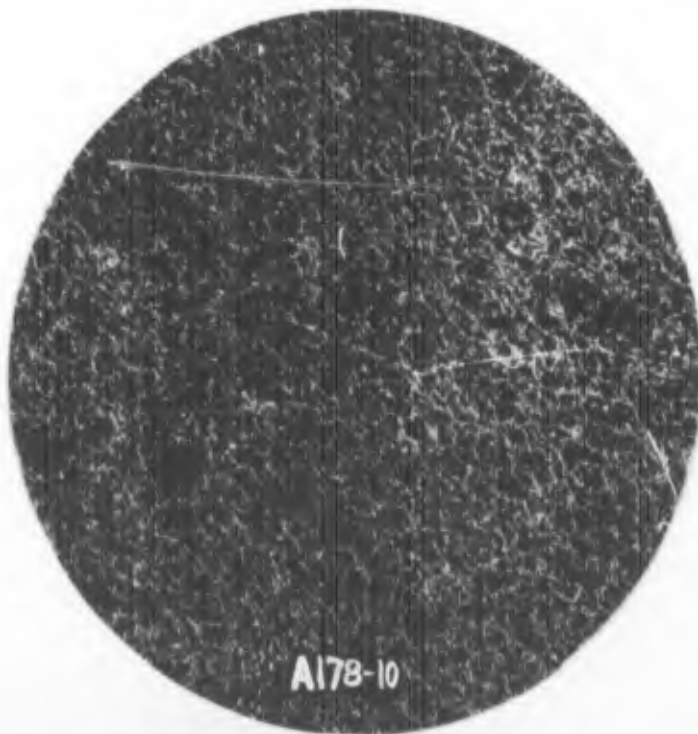
Specimen E-R2. Magnification 50.

Etched with a 4% solution of Nitric Acid in Alcohol.



Specimen F-02. Magnification 50.

Etched with a 4% solution of Nitric Acid in Alcohol.



Specimen F-03. Magnification 50.

Etched with a 4% solution of Nitric Acid in Alcohol.

T A B L E I.

PAGES 1 - 4 to 1 - 2.

T A B L E I-A

CHARPY TEST - HEAT TREATMENT "A"

Date Tested, Nov. 3, 1922; Room Temperature, 24° C.

Date Heat Treated, Sept. 6, 1922.

Constant Starting Angle, 16J°

Specimen No.	Excess Angle (Deg.)	Work done (Ft.-Lbs.)	Diam. (In.)	Diam. after Fract. (In.)	Extens. in 2" Length (In.)	Elongation Percent	Contraction of Area Percent	Weight of Fragments (gm.)	Brinell No.	Appearance	
A-C1	85.0	1154.7	.543	.423	.555	27.75	39.3	139	143	187	Rough, dull silky no cup.
A-C2	89.0	1075.1	.543	.424	.532	26.6	39.0	147	135	187	Ditto
A-C3	88.4	1086.6	.543	.424	.530	26.5	39.0	149	130	183	Ditto
A-C4	87.8	1098.7	.543	.424	.540	27.0	39.0	148	129	187	Ditto
A-C5	86.6	1122.9	.543	.419	.570	28.5	40.4	139	143	187	Ditto
Average		1107.6				27.5	39.3				

T A B L E I-b

CHARPY TEST - HEAT TREATMENT "B"

Date Tested, Nov. 3, 1922: Room Temperature.

Date Heat Treated, Sept. 8, 1922.

Constant Starting Angle, 160°

Specimen No.	Excess Angle (Deg.)	Work done (Ft. Lbs.) (in.)	Diam. after Fract. (in.)	Exten. in 2" Length (in.)	Elongation Percent	Contract-ion of Area Percent	Height of Fragments and End (gm.)	Bris- tle No.	Frac- ture	
B-C1	86.0	1134.8	.408	.600	30.0	43.5	154	148	171	Rough dull
B-C2	86.6	1122.8	.408	.590	29.5	43.7	131	150	171	Ditto
B-C3	89.0	1074.5	.407	.570	28.5	43.3	131	151	171	"
B-C4	86.1	1133.7	.403	.600	30.0	44.9	134	147	171	"
B-C5	88.7	1080.6	.405	.585	29.3	44.4	130	150	171	"
Average		1109.3			29.5	44.0				

TABLE I-c

CHARPY TEST - HEAT TREATMENTS "C"

Date Tested, Nov. 3, 1922; Room Temperature, 24° C.

Date Heat Treated, Aug. 25, 1922.

Constant Starting Angle, 160°.

Speci- men No.	Excess Angle (Deg.)	Work done (Ft.-Lbs.) (In.)	Diam. after Fract. (In.)	Exten. in 2" Length (In.)	Elongu- tion Percent	Contra- ction of Area Percent	Weight of Fragments Pend. Cup End. Lad. (Gm.) (Gm.)	Brin- nell Mo.	Fracture				
C-01	82.7	1200.3	.542	.393	.665	33.3	47.6	146	136	167	167	Rough. dull silky.	1/2"
C-02	87.2	1110.9	.5435	.397	.620	31.0	46.6	150	132	167	167	"	1/2"
C-03	88.2	1090.7	.5435	.396	.595	29.8	46.8	144	135	167	167	"	1/2"
C-04	87.0	1100.2	.543	.396	.620	31.0	46.6	150	133	167	167	"	1/2"
C-05	85.8	1136.1	.543	.394	.630	31.5	47.4	145	132	167	167	"	1/2"
Average		1127.6				31.3	47.0						

T A B L E 4-d

CHARPY TEST - HEAT TREATMENT "D"

Date Tested, Nov. 9, 1922: Room Temperature, 22° C.

Date Heat Treated, Aug. 25, 1922.

Constant Starting Angle, 160°.

Specimen No.	Excess Angle (Deg.)	Work done (Ft.-Lbs.)	Diam. after Fract. (In.)	Diam. after Fract. (In.)	Extension in Length (In.)	Elongation Percent	Contraction of Area Percent	Weight of Brinell Pend. Cup mill End. (Gm.)	Weight of Brinell Pend. Cup mill End. (Gm.)	Fracture
D-01	79.0	1273.5	.543	.384	.690	34.5	50.1	136	139	Dull silky, $\frac{1}{2}$ cup
D-02	82.0	1213.6	.543	.389	.655	32.8	48.8	145	133	" " $\frac{2}{3}$ "
D-03	82.6	1202.1	.543	.393	.655	32.8	47.8	145	130	" " $\frac{2}{3}$ "
D-04	83.5	1184.4	.543	.394	.636	31.8	47.5	147	131	" " $\frac{1}{2}$ "
D-05	86.2	1128.5	.543	.390	.635	31.8	48.5	148	134	" " $\frac{2}{3}$ "
Average		1200.4				32.7	48.5			

T A B L E I-O

CHARPY TEST - HEAT TREATMENT "B"

Date Tested, Nov. 24, 1922; Room Temperature, 21° C.

Date Heat Treated, Aug. 29, 1922.

Constant Starting Angle, 160°.

Speci- men No.	Excess angle (Deg.)	Work done (Ft.-Lbs.)	Diam. after Fract. (In.)	Diam. after Fract. (In.)	Exten- sion in 2" Length (In.)	Elonga- tion Percent	Contrao- tion of Area Percent	Weight of Fragments Pend. Tup End. End (gm.)	Brin- nell Hard No.	Fracture	
E-01	64.6	1162.7	.5435	.336	.565	28.3	61.8	151	128	207	Dull silky.
E-02	85.7	1141.0	.543	.337	.545	27.3	61.4	148	132	212	" " " "
E-03	82.2	1210.0	.543	.337	.585	29.3	61.4	139	142	207	" " " "
E-04	82.8	1198.1	.543	.333	.580	29.0	62.2	148	132	207	" " " "
E-05	80.8	1237.7	.5425	.330	.595	29.8	62.6	146	132	212	" " " "
Average		1189.9				28.7	61.9				

T A B L E I-2

CHARPY TEST & HEAT TREATMENT "P"

DATE TESTED, Nov. 24, 1922; Room Temperature, 21° C.

Date Heat Treated, Aug. 29, 1922.

Constant Starting Angle, 160°

Speci- men No.	Excess Angle (Deg.)	Work done (Ft. Lbs.)	Diam. after Fract. (In.)	Diam. after Fract. (In.)	Exten. in 2" Length (In.)	Elonga- tion Percent	Contra- ction of Iron Percent	Weight of Fragments Pend. Cup and End (Gm.)	Weight of Fragments Pend. Cup and End (Gm.)	Fracture	
F-01	79.7	1259.9	.543	.373	.641	32.2	52.7	137	141	175	Full alloy, $\frac{1}{2}$ cup
F-02	83.4	1186.2	.543	.375	.605	30.3	52.2	137	143	171	" " $\frac{1}{4}$ "
F-03	82.3	1208.0	.541	.379	.624	31.2	51.0	146	137	175	" " $\frac{1}{4}$ "
F-04	82.3	1208.0	.543	.375	.629	31.5	52.2	150	127	175	" " $\frac{1}{4}$ "
F-05	80.0	1233.3	.543	.376	.656	32.7	52.1	143	142	175	" " $\frac{1}{4}$ "
Average		1223.2				31.6	52.0				

TABLE II.

T A B L E II-a-1

SPECIMEN A-81

Date Tested, Dec. 27, 1922; Room Temperature, 25°C.

Date Heat Treated, Sept. 8, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	14,000	.050	.538
1,000	.00025		15,000	.055	.536
2,000	.00050		16,000	.070	.535
3,000	.00075		17,000	.080	.533
4,000	.00100		18,000	.100	.530
5,000	.00125		19,000	.135	.527
6,000	.00150		19,600	.150	.524
7,000	.00172		20,000	.170	.521
8,000	.00200		20,400	.200	.516
9,000	.00220		20,600	.220	.512
9,500	.00230		20,800	.225	.504
10,000	.00250		20,600	.350	.492
10,500	.00755	.542	20,400	.380	.483
11,000	.028	.541	20,200	.395	.478
12,000	.034	.540	20,000	.420	.470
13,000	.039	.539	19,800	.430	.465
			19,200	.440	.450

Yield Point, 10,500 Lbs.

Maximum Load, 20,800 Lbs.

Load at Rupture, 19,200 Lbs.

Elongation, 22%

Contraction of Area, 31.3%

Fracture - granular surrounding silky center; no cup.

Brinell Number, 187

T A B L E II-a-2

SPECIMEN A-R2

Date Tested, Dec. 27, 1922; Room Temperature, 25° C.

Date Heat Treated, Sept. 8, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	16,000	.065	.534
1,000	.00016		17,000	.080	.532
2,000	.00047		18,000	.100	.530
3,000	.00080		19,000	.126	.526
4,000	.00110		19,500	.150	.523
5,000	.00125		20,000	.180	.519
6,000	.00160		20,200	.205	.516
7,000	.00140		20,400	.240	.511
8,000	.00220		20,450	.260	.506
9,000	.00250		20,450	.330	.446
9,600	.00270		20,400	.350	.494
10,000	.00760	.5415	20,200	.380	.491
11,000	.030	.540	20,000	.394	.475
12,000	.035	.539	19,800	.410	.470
13,000	.040	.538	19,400	.435	.450
14,000	.045	.537	19,000	.440	.444
15,000	.055	.536	18,600	.442	.442

Yield Point, 10,000 Lbs.

Maximum Load, 20,450 Lbs.

Load at Rupture 18,600 Lbs.

Elongation 22.1%

Contraction of Area, 33.8%

Fracture - No cup - granular surrounding silky center.

Brinell Number, 187

T A B L E II-7-3

SPECIMEN A-123

Date Tested, Dec. 27, 1922; Room Temperature, 25° C.

Date Heat Treated, Sept. 8, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	16,000	.060	.535
1,000	.00016		17,000	.075	.533
2,000	.00040		18,000	.045	.530
3,000	.00076		19,000	.120	.527
4,000	.00100		19,500	.145	.524
5,000	.00132		20,000	.180	.519
6,000	.00164		20,200	.200	.516
7,000	.00200		20,400	.230	.512
8,000	.00240		20,500	.260	.508
9,000	.00278		20,500	.320	.448
10,000	.00318		20,400	.350	.442
10,200	.00800	.5425	20,200	.370	.482
10,500	.015	.5415	20,000	.400	.475
11,000	.017	.541	19,800	.410	.469
12,000	.020	.540	19,600	.430	.461
13,000	.030	.539	19,200	.440	.450
14,000	.040	.5375	18,800	.450	.437
15,000	.050	.536			

Yield Point, 10,200 Lbs.

Maximum Load, 20,500 Lbs.

Load at Rupture, 18,600 Lbs.

Elongation, 22.5%

Contraction of Area, 36.2%

Fracture - no cup- granular surrounding silky center.

Brinell Number, 187

T A B L E II-a-4

SPECIMEN A-R4

Date Tested, Dec. 27, 1922; Room Temperature, 25° C.

Date Heat Treated, Sept. 8, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	15,000	.054	.536
1,000	.00030		16,000	.060	.535
2,000	.00060		17,000	.080	.532
3,000	.00096		18,000	.100	.529
4,000	.00120		19,000	.130	.525
5,000	.00160		19,500	.160	.522
6,000	.00148		20,000	.200	.516
7,000	.00230		20,200	.250	.511
8,000	.00260		20,250	.293	.502
9,000	.00296		20,200	.326	.446
10,000	.00440	.5425	20,000	.370	.485
9,500	.010	.5415	19,800	.400	.478
10,000	.015	.5412	19,400	.425	.462
11,000	.020	.541	19,200	.440	.455
12,000	.025	.540	19,000	.445	.451
13,000	.030	.539	18,300	.455	.438
14,000	.042	.537			

Yield Point, 10,000 Lbs.

Maximum Load, 20,250 Lbs.

Load at Rupture, 18,300 Lbs.

Elongation, 22.75%

Contraction of Area, 35.0%

Fracture - square, no cup; granular surrounding silky center.

Brinell Number, 187.

T A B L E II-a-5

SPECIMEN A-R5.

Date Tested, Dec. 27, 1923; Room Temperature, 25° C.

Date Heat Treated, Sept. 8, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	14,000	.045	.537
1,000	.00020		15,000	.055	.536
2,000	.00060		16,000	.070	.534
3,000	.00080		17,000	.085	.532
4,000	.00100		18,000	.105	.529
5,000	.00138		19,000	.140	.524
6,000	.00160		19,500	.170	.520
7,000	.00190		20,000	.232	.512
8,000	.00220		20,150	.285	.503
9,000	.00245		20,100	.340	.494
9,500	.00260		20,000	.354	.492
10,000	.00300		19,600	.405	.475
9,300	.00600	.5425	19,400	.420	.466
10,000	.015	.542	19,200	.432	.461
11,000	.020	.541	19,000	.444	.454
12,000	.030	.5395	18,800	.452	.449
13,000	.035	.539	18,200	.464	.434

Yield Point, 10,500 Lbs.

Maximum Load, 20,150 Lbs.

Load at Rupture, 18,200 Lbs.

Elongation, 23.2%

Contraction of Area, 36.1%

Fracture - broken contour, no cup; granular surrounding silky center.

Brinell Number - 187

T A B L E II-b-1

SPECIMEN B-R1

Date Tested, Dec. 27, 1922; Room Temperature, 25° C.

Date Heat Treated, Sept. 8, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.5435	13,000	.050	.537
1,000	.00024		14,000	.060	.536
2,000	.00046		15,000	.075	.534
3,000	.00074		16,000	.100	.531
4,000	.00098		17,000	.130	.527
5,000	.00122		18,000	.160	.522
6,000	.00148		19,000	.300	.504
7,000	.00180		18,800	.340	.497
8,000	.00210		18,600	.390	.485
9,000	.00256		18,400	.420	.475
9,400	.00270		18,200	.440	.467
8,600	.00580	.543	18,000	.465	.454
9,000	.012	.542	17,600	.475	.447
10,000	.022	.541	17,000	.500	.432
11,000	.030	.540	16,600	.510	.418
12,000	.040	.539			

Yield Point, 9,400 lbs.

Maximum Load, 19,000 lbs.

Load at Rupture, 16,600 lbs.

Elongation, 25.5%

Contraction of Area, ~~50.6%~~ 41.0%

Fracture - Granular, surrounding silky center; no cup.

Brinell Number, 173

T A B L E II-b-2

SPECIMEN B-R2

Date Tested, December 27, 1922; Room Temperature, 27° C.

Date Heat Treated, Sept. 8, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.5435	13,000	.050	.537
1,000	.00026		14,000	.060	.535
2,000	.00052		15,000	.078	.533
3,000	.00080		16,000	.095	.531
4,000	.00100		17,000	.120	.527
5,000	.00130		18,000	.160	.521
6,000	.00138		18,800	.300	.503
7,000	.00188		18,800	.342	.496
8,000	.00218		17,600	.400	.482
9,000	.00248		16,400	.440	.473
9,400	.00270		18,200	.464	.465
8,600	.0096	.542	18,000	.470	.457
9,000	.011	.5415	17,600	.495	.446
10,000	.020	.541	17,000	.520	.430
11,000	.030	.540	16,600	.550	.417
12,000	.039	.5385			

Yield Point, 9,400 Lbs.
 Maximum Load, 18,800 Lbs.
 Load at Rupture, 16,600 Lbs.
 Elongation, 26.4%
 Contraction of Area, ~~30.8%~~ 41.2 %
 Fracture - Granular surrounding silky center; no cap.
 Brinnell Number, 171

T A B L E II-b-3.

SPECIMEN B-23

Date Tested, Dec. 28, 1922; Room Temperature, 24° C.

Date Heat Treated, Sept. 8, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	12,000	.031	.539
1,000	.00016		13,000	.040	.537
2,000	.00040		14,000	.050	.5355
3,000	.00060		15,000	.070	.534
4,000	.00080		16,000	.080	.532
5,000	.00100		17,000	.100	.529
6,000	.00134		18,000	.134	.525
7,000	.00166		19,000	.190	.514
8,000	.00200		19,400	.250	.509
9,000	.00240		19,500	.4310	.500
9,400	.00280		19,400	.860	.493
8,800	.00480	.5425	19,800	.610	.475
10,000	.015	.541	18,800	.448	.461
11,000	.024	.540	17,000	.515	.415

Yield Point, 9,400 Lbs.

Maximum Load 19,500 Lbs.

Load at Rupture, 17,000 Lbs.

Elongation, 25.75%

Contraction of Area, ~~30.9%~~ 41.5%

Fracture - Ragged edges, no cup; granular surrounding silky center.

Brinell Number, 171

T A B L E II-b-4

SPECIMEN B-R-4

Date Tested, Dec. 28, 1922; Room Temperature, 24° C.

Date Heat Treated, Sept. 8, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam. eter (In.)
0	0	.5435	13,000	.045	.538
1,000	.00020		14,000	.052	.5365
2,000	.00040		15,000	.065	.535
3,000	.00060		16,000	.082	.532
4,000	.00090		17,000	.100	.529
5,000	.00116		18,000	.140	.525
6,000	.00140		19,000	.190	.517
7,000	.00180		19,400	.278	.506
8,000	.00204		19,800	.340	.498
9,000	.00244		19,400	.380	.490
9,400	.00260		19,000	.448	.469
9,600	.00270		18,600	.490	.448
9,000	.014	.542	17,600	.530	.431
10,000	.020	.541	17,000	.555	.411
11,000	.030	.5405			
12,000	.038	.539			

Yield Point, 9,600 Lbs.

Maximum Load, 19,800 Lbs.

Load at Rupture, 17,000 Lbs.

Elongation, 26.75%

Contraction of Area, 42.9%

Fracture - Ragged, no cup; granular around large silky center.

Brinell Number, 171

T A B L E II-b-5

SPECIMEN B-R5.

Date Tested, Dec. 28, 1922; Room Temperature, 24° C.

Date Heat Treated, Sept. 8, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (in.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	12,000	.040	.538
1,000	.00018		13,000	.048	.5365
2,000	.00040		14,000	.060	.535
3,000	.00062		15,000	.070	.533
4,000	.00084		16,000	.095	.530
5,000	.00120		17,000	.130	.526
6,000	.00144		18,000	.186	.518
7,000	.00184		18,400	.240	.512
8,000	.00220		18,600	.350	.444
9,000	.00254		18,500	.390	.433
9,500	.00270		18,200	.428	.472
8,500	.0052	.5415	17,600	.480	.449
9,000	.010	.541	17,000	.510	.432
10,000	.020	.540	16,100	.530	.408
11,000	.028	.539			

Yield Point, 9,500 Lbs.

Maximum Load, 18,600 Lbs.

Load at Rupture, 16,100 Lbs.

Elongation, 26.6%

Contraction of Area, 43.7%

Fracture - No cup, slightly ragged, granular.

Brinell Number, 171.

T A B L E II-0-1

SPECIMEN C-RI

Date Tested, Dec. 28, 1922; Room Temperature, 24° C.

Date Heat Treated, Aug. 25, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	11,000	.023	.539
1,000	.00018		12,000	.030	.538
2,000	.00038		13,000	.040	.5365
3,000	.00060		14,000	.056	.535
4,000	.00080		15,000	.074	.532
5,000	.00100		16,000	.095	.530
6,000	.00120		17,000	.124	.526
7,000	.00160		18,000	.175	.518
8,000	.00196		18,650	.325	.497
9,000	.00240		18,500	.420	.479
9,200	.00300		18,200	.490	.444
9,000	.005	.421	17,000	.536	.414
10,000	.015	.540	16,000	.646	.400

Yield Point, 9,200 Lbs.

Maximum Load, 18,650 Lbs.

Load at Rupture, 16,000 Lbs.

Elongation, 27.3%

Contraction of Area 45.6%

Fracture - Rough, granular, slight cup.

Brinnell Number, 167

T A B L E II-a-2

SPECIMEN C-42

Date Tested, Dec. 28, 1922; Room Temperature, 24° C.

Date Heat Treated, Aug. 25, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.5435	14,000	.056	.536
1,000	.00020		15,000	.070	.534
2,000	.00040		16,000	.090	.532
3,000	.00060		17,000	.115	.528
4,000	.00080		18,000	.160	.522
5,000	.00110		18,500	.205	.516
6,000	.00120		18,800	.250	.509
7,000	.00160		18,950	.300	.510
8,000	.00190		18,900	.360	.491
9,000	.00240		18,800	.400	.491
9,400	.00260		18,400	.455	.461
10,000	.015		18,000	.485	.447
11,000	.020		17,600	.500	.437
12,000	.030	.538	16,200	.550	.401
13,000	.044	.537			

Yield Point 9,400 Lbs.

Maximum Load, 18,950 Lbs.

Load at Rupture, 16,200 Lbs.

Elongation, 27.5%

Contraction of Area, 45.5%

Fracture - Rough, granular, slight cup.

Brinnell Number, 167

T A B L E II-c-3

SPECIMEN C-125

Date Tested, Dec. 28, 1922; Room Temperature, 24° C.

Date Heat Treated, Aug. 25, 1922.

Load (Lbs.)	Extension in 2' Length (In.)	Diana- stor (In.)	Load (Lbs.)	Extension in 2' Length (In.)	Diana- stor (In.)
0	0	.5435	13,000	.045	.537
1,000	.00022		14,000	.055	.535
2,000	.00040		15,000	.070	.533
3,000	.00060		16,000	.090	.531
4,000	.00080		17,000	.115	.527
5,000	.00110		18,000	.170	.520
6,000	.00140		18,400	.210	.514
7,000	.00170		18,600	.245	.510
8,000	.00210		18,800	.350	.494
9,000	.00240		18,600	.410	.481
9,600	.00264		18,400	.444	.465
9,800	.00280		18,000	.480	.452
9,600	.010	.5430	17,600	.505	.439
10,000	.015	.541	17,200	.525	.428
11,000	.020	.540	16,600	.540	.416
12,000	.025	.539	16,000	.560	.398

Yield Point, 9,800 lbs.

Maximum Load, 18,800 lbs.

Load at Rupture, 16,000 lbs.

Elongation, 28.0%

Contraction of Area, 46.4%

Fracture - Rough granular, slight cup.

Brinell Number, 167

T A B L E II-c-4

SPECIMEN C-R4

Date Tested, Dec. 28, 1922; Room Temperature, 24° C.

Date Heat Treated, Aug. 25, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.5435	13,000	.040	.537
1,000	.00018		14,000	.050	.536
2,000	.00030		15,000	.070	.534
3,000	.000046		16,000	.085	.523
4,000	.00070		17,000	.120	.520
5,000	.00092		17,000	.165	.522
6,000	.000120		17,600	.250	.511
7,000	.00055		18,800	.335	.497
8,000	.00190		18,600	.420	.479
9,000	.00220		18,200	.465	.462
9,300	.00235	.543	17,800	.494	.447
10,000	.014	.542	17,200	.520	.432
11,000	.020	.540	16,600	.540	.418
12,000	.030	.539	16,000	.550	.403

Yield Point, 9,300 Lbs.

Maximum Load, 18,800 Lbs.

Load at Rupture, 16,000 Lbs.

Elongation, 27.5%

Contraction of Area, 45.0%

Fracture - High granular, slight cup.

Brinnell Number, 167.

T A B L E II-0-5

SPECIMEN C-85

Date Tested, Dec. 29, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 25, 1922.

Load (Lbs.)	Extension in 2' Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.5435	12,000	.035	.539
1,000	.00020		13,000	.045	.537
2,000	.00040		14,000	.060	.536
3,000	.00060		15,000	.070	.534
4,000	.00084		16,000	.085	.532
5,000	.00106		17,000	.120	.527
6,000	.00130		18,000	.160	.523
7,000	.00150		18,600	.230	.512
8,000	.00180		18,950	.330	.496
9,000	.00230		18,800	.420	.480
9,500	.00270		18,200	.480	.450
9,500	.010	.542	17,400	.525	.433
10,000	.015	.541	17,500	.530	.422
11,000	.023	.540	16,100	.550	.401

Yield Point, 9,500 Lbs.

Maximum Load, 18,950 Lbs.

Load at Rupture, 16,100 Lbs.

Elongation, 27.5%

Contraction of Area, 45.5%

Fracture - High granular, slight cup.

Brinell Number 167.

T A B L E II-d-1

SPECIMEN D-11

Date Tested, Dec. 29, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 25, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	12,000	.035	.538
1,000	.00020		13,000	.045	.537
2,000	.00040		14,000	.060	.535
3,000	.00060		15,000	.070	.533
4,000	.00084		16,000	.090	.531
5,000	.00108		17,000	.120	.527
6,000	.00130		18,000	.160	.522
7,000	.00150		19,000	.290	.504
8,000	.0020		19,100	.360	.493
9,000	.00232		19,000	.400	.484
9,500	.00256		18,400	.485	.458
10,000	.00258		17,600	.530	.431
10,500	.00300		17,200	.540	.421
9,500	.0070	.5425	16,600	.565	.407
10,000	.015	.542	16,000	.580	.390
11,000	.025	.540			

Yield Point, 10,500 Lbs.

Maximum Load, 19,100 Lbs.

Load at Rupture, 16,000 Lbs.

Elongation, 29.0%

Contraction of Area, 48.3%

Fracture - Rough, dull silky, incipient cup.

Brinnell Number, 163.

T A B L E II-d-2

SPECIMEN D-R2

Date Tested, Dec. 29, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 25, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.5435	15,000	.040	.538
1,000	.00020		14,000	.060	.536
2,000	.00030		15,000	.070	.534
3,000	.00050		16,000	.080	.532
4,000	.00060		17,000	.110	.529
5,000	.00100		18,000	.150	.524
6,000	.00124		19,000	.225	.514
7,000	.00144		19,200	.310	.496
8,000	.00190		18,800	.480	.469
9,000	.00226		18,200	.510	.439
10,000	.00260		17,800	.530	.428
10,000	.010	.542	17,000	.550	.410
11,000	.020	.541	16,100	.560	.400
12,000	.030	.539			

Yield Point, 10,000 Lbs.

Maximum Load, 19,200 "

Load at Rupture, 16,100 "

Elongation, 28.0%

Contraction of Area, 45.7%

Fracture - Rough, dull silky, incipient cup.

Brinnell Number, 163.

T A B L E II-d-3

SPECIMEN D-R3

Date Tested, Dec. 29, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 25, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	14,000	.060	.535
1,000	.00020		15,000	.080	.535
2,000	.00040		16,000	.095	.530
3,000	.00075		17,000	.130	.525
4,000	.00086		18,000	.170	.520
5,000	.00108		18,600	.250	.508
6,000	.00130		18,800	.340	.496
7,000	.00150		18,200	.455	.463
8,000	.00200		17,800	.500	.449
9,000	.00234		17,400	.520	.438
10,000	.00270	.5425	17,000	.540	.423
10,000	.010	.541	16,500	.500	.411
11,000	.030	.539	16,000	.565	.399
12,000	.040	.538			

Yield Point, 10,000 Lbs.

Maximum Load, 18,800 Lbs.

Load at Rupture, 16,000 Lbs.

Elongation, 28.25%

Contraction of Area, 45.8%

Fracture - Dull silky, no cup.

Brinell Number, 163.

T A B L E II-4-4

SPECIMEN D-84

Date Tested, Dec. 29, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 25, 1922.

Load (lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	13,000	.050	.536
1,000	.00020		14,000	.060	.534
2,000	.00040		15,000	.080	.532
3,000	.00060		16,000	.095	.530
4,000	.00080		17,000	.130	.525
5,000	.00100		18,000	.180	.519
6,000	.00124		18,650	.370	.493
7,000	.00148		18,400	.460	.465
8,000	.00196		18,000	.500	.447
9,000	.00230		17,500	.520	.442
10,000	.00250	.5425	17,000	.530	.429
10,000	.010	.542	16,600	.550	.418
11,000	.030	.539	15,800	.570	.397
12,000	.040	.538			

Yield Point, 10,000 lbs.

Maximum Load, 18,650 lbs.

Load at Rupture, 15,800 lbs.

Elongation, 28.5%

Contraction of Area, 46.5%

Fracture - Still silky, rather coarse, no cup.

Brinell Number, 163.

T A B L E II-d-5

SPECIMEN D-R5

Date Tested, Dec. 23, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 25, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" length (In.)	Diam- eter (In.)
0	0	.543	14,000	.075	.534
1,000	.00030		15,000	.091	.531
2,000	.00080		16,000	.132	.527
3,000	.00118		17,000	.172	.521
4,000	.00144		17,500	.200	.516
5,000	.00170		17,800	.255	.509
6,000	.00210		18,000	.310	.500
7,000	.00240		17,800	.430	.478
8,000	.00260		17,600	.455	.470
9,000	.00300		17,400	.475	.463
9,600	.00900	.542	17,200	.500	.454
10,000	.029	.540	16,600	.530	.438
11,000	.035	.538	16,200	.545	.425
12,000	.044	.537	16,000	.555	.418
13,000	.055	.535	15,500	.570	.416

Yield Point, 9,600 Lbs.

Maximum Load, 18,000 Lbs.

Load at Rupture, 15,500 Lbs.

Elongation, 28.5%

Contraction of Area, 41.3%

Fracture - Dull, silky, 1/2 cup.

Brinnell number, 165

T A B L E II-e-1

SPECIMEN B-11

Date Tested, Dec. 29, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 29, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.5435	14,600	.010	.542
1,000	.00016		15,000	.020	.541
2,000	.00024		16,000	.025	.540
3,000	.00040		17,000	.035	.539
4,000	.00064		18,000	.040	.538
5,000	.00092		19,000	.055	.536
6,000	.00110		20,000	.070	.534
7,000	.00135		21,000	.090	.532
7,500	.00148		22,000	.110	.528
8,000	.00176		23,000	.170	.518
9,000	.00200		23,200	.230	.509
9,800	.00224		23,000	.290	.495
10,000	.00238		22,500	.330	.476
11,000	.00260		22,000	.355	.462
12,000	.00288		21,500	.375	.449
12,500	.0030		20,500	.420	.425
13,000	.0032		19,500	.445	.401
14,000	.0035		19,000	.460	.392
14,400	.0040		18,500	.470	.383
14,600	.0044		16,400	.520	.339

Yield Point, 14,600 Lbs.

Maximum Load, 23,200 Lbs.

Load at Rupture, 16,400 Lbs.

Elongation, 26.0%

Contraction of Area, 61.2%

Fracture - silky; star fracture.

Brinnell Number, 207

T A B L E II-8-2

SPECIMEN K-R-2

Date Tested, Dec. 29, 1922; Room Temperature 25° C.

Date Heat Treated, Aug. 29, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	15,000	.020	.541
1,000	.00014		16,000	.030	.539
2,000	.00020		17,000	.040	.538
3,000	.00040		18,000	.050	.537
4,000	.00060		19,000	.060	.535
5,000	.00080		20,000	.070	.533
6,000	.00100		21,000	.100	.530
7,000	.00130		22,000	.135	.525
8,000	.00164		22,750	.220	.512
8,500	.00180		22,600	.300	.491
9,000	.00200		22,000	.370	.463
10,000	.00220		21,500	.390	.456
11,000	.00244		21,000	.405	.444
12,000	.00274		20,000	.445	.420
13,000	.00300		19,000	.474	.348
13,800	.00330		18,000	.500	.377
14,000	.00360		17,000	.520	.357
14,200	.0040		16,000	.540	.336
14,300	.010	.542			

Yield Point, 14,300 lbs.
Maximum Load, 22,750 lbs.
Load at Rupture, 16,000 lbs.
Elongation, 27.0%
Contraction of Area, 61.7%
Fracture- silky; star fracture.
Brinnell number, 207

TABLE II-a-3

SPECIMEN K-R3

Date Tested, Dec. 29, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 29, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.5432	17,000	.030	.5385
1,000	0		18,000	.040	.537
2,000	0		19,000	.060	.535
4,000	.00040		20,000	.075	.534
5,000	.00060		21,000	.090	.532
6,000	.00080		22,000	.110	.527
7,000	.00100		22,500	.140	.524
8,000	.00136		23,000	.200	.515
9,000	.00158		23,150	.230	.508
10,000	.00182		23,000	.260	.500
11,000	.00270		22,000	.355	.484
12,000	.00250		21,000	.400	.430
13,000	.00280		20,000	.440	.416
14,000	.00340		19,000	.460	.394
14,400	.00400		18,000	.490	.374
14,700	.010	.545	17,000	.515	.355
15,000	.015	.541	16,200	.530	.337
16,000	.020	.5395			

Yield Point, 14,400 Lbs.

Maximum Load, 23,150 Lbs.

Load at Rupture, 16,200 Lbs.

Elongation, 26.5%

Contraction of Area, 61.5%

Fracture - silky; star fracture.

Brinnell Number, 207

T A B L E II-a-4

SPECIMEN R-R4

Date Tested, Dec. 29, 1922; Room Temperature 25° C.

Date Heat Treated, Aug. 29, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	15,000	.020	.540
1,000	0		16,000	.028	.539
2,000	0		17,000	.035	.538
3,000	.00020		18,000	.045	.536
4,000	.00040		19,000	.060	.535
5,000	.00064		20,000	.070	.533
6,000	.00080		21,000	.090	.530
7,000	.00110		22,000	.130	.525
8,000	.00144		22,500	.165	.520
9,000	.00180		22,800	.210	.512
10,000	.00200		22,500	.300	.490
11,000	.00230		22,000	.345	.477
12,000	.00260		21,500	.380	.459
13,000	.00294		21,000	.400	.445
13,400	.0032		20,000	.440	.421
13,800	.0035		19,000	.470	.399
14,000	.0040		18,000	.500	.379
14,200	.0044	.542	17,000	.525	.359
14,400	.010	.541	16,100	.535	.335

Yield Point, 14,200 Lbs.

Maximum Load, 22,800 Lbs.

Load at Rupture, 16,100 Lbs.

Elongation, 26.75%

Contraction of Area, 61.8%

Fracture - silky; star fracture.

Brinnell Number, 207

T A B L E II-e-5

SPECIMEN R-R5

Date Tested, Dec. 29, 1922; Room Temperature 25° C.

Date Heat Treated, Aug. 29, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	15,000	.020	.540
1,000	0		16,000	.030	.539
2,000	0		17,000	.037	.538
3,000	.00010		18,000	.044	.537
4,000	.00030		19,000	.055	.535
5,000	.00050		20,000	.070	.533
6,000	.00078		21,000	.090	.530
7,000	.00100		22,000	.130	.526
8,000	.00120		22,900	.200	.514
9,000	.00155		22,500	.320	.485
10,000	.00180		22,000	.560	.472
11,000	.00210		21,500	.890	.453
12,000	.00240		21,000	.410	.439
13,000	.00265		20,000	.450	.416
13,800	.00320		19,000	.480	.395
14,000	.00350		18,000	.500	.374
14,200	.00400	.5425	17,000	.520	.356
14,400	.010	.541	16,200	.530	.356

Yield Point, 14,200 Lbs.

Maximum Load, 22,900 Lbs.

Load at Rupture, 16,200 Lbs.

Elongation, 26.5%

Contraction of area, 61.6%

Fracture - silky; star fracture.

Brinnell Number, 207

T A B L E II-f-1

SPECIMEN F-R1

Date Tested, Dec. 29, 1922; Room Temperature 25° C.

Date Heat Treated, Aug. 29, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	15,000	.0500	.5360
1,000	0		16,000	.0650	.534
2,000	0		17,000	.080	.532
3,000	.00020		18,000	.100	.529
4,000	.00040		19,000	.130	.525
5,000	.00070		20,000	.200	.516
6,000	.00100		20,500	.310	.498
7,000	.00130		20,500	.390	.478
8,000	.00160		20,000	.425	.467
9,000	.00190		19,500	.460	.449
10,000	.00220		19,000	.490	.431
11,000	.00260	.5425	18,500	.515	.419
11,000	.0100	.541	18,000	.540	.407
12,000	.0200	.540	17,500	.546	.396
13,000	.0300	.539	17,200	.555	.387
14,000	.0400	.5375			

Yield Point, 11,000 Lbs.

Maximum Load, 20,500 Lbs.

Load at Rupture, 17,200 Lbs.

Elongation, 27.75%

Contraction of Area, 49.1%

Fracture - Silky, surrounding dull silky center, incipient cup.

Brinell Number, 175

TABLE II-f-2

SPECIMEN 7-12

Date Tested, Dec. 29, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 29, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	15,000	.050	.536
1,000	0		16,000	.065	.534
2,000	0		17,000	.080	.532
3,000	.00030		18,000	.100	.529
4,000	.00040		19,000	.130	.526
5,000	.00070		20,000	.200	.516
6,000	.00100		20,500	.310	.498
7,000	.00130		20,200	.390	.478
8,000	.00160		20,000	.425	.467
9,000	.00180		19,500	.460	.449
10,000	.00220		19,000	.490	.434
11,000	.00260	.5425	18,500	.515	.419
11,000	.010	.541	18,000	.540	.407
12,000	.020	.540	17,500	.546	.396
13,000	.030	.5385	17,200	.555	.387
14,000	.040	.5375			

Yield Point, 11,000 Lbs.

Maximum Load, 20,500 Lbs.

Load at Rupture, 17,200 Lbs.

Elongation, 27.85%

Contraction of Area, 49.1%

Fractures - Silky surrounding dull silky center; incipient cup.

Brinnell Number, 175

T A B L E II-f-3

SPECIMEN F-23

Date Tested, Dec. 30, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 29, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.5435	13,000	.030	.540
1,000	.00008		14,000	.040	.5385
2,000	.00020		15,000	.050	.537
3,000	.00042		16,000	.065	.535
4,000	.00070		17,000	.080	.533
5,000	.00100		18,000	.100	.530
6,000	.00124		19,000	.120	.525
7,000	.00160		20,000	.225	.515
8,000	.00190		20,300	.320	.500
9,000	.00220		20,300	.355	.492
10,000	.00250		20,000	.420	.473
10,200	.00260		19,500	.470	.462
10,500	.00270		19,000	.495	.457
11,000	.00300	.5432	18,500	.520	.422
11,000	.010	.543	18,000	.540	.409
12,000	.020	.541	17,000	.560	.380

Yield Point, 11,000 Lbs.

Maximum Load, 20,300 Lbs.

Load at Rupture, 17,000 Lbs.

Elongation, 27.0%

Contraction of Area, 51.1%

Fracture - Silky surrounding dull silky center; incipient cup.

Brinell Number, 175

TABLE XI-1-4

SPECIMEN F-84

Date Tested, Dec. 30, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 29, 1922.

Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" Length (In.)	Diam- eter (In.)
0	0	.543	15,000	.050	.5355
1,000	.00010		16,000	.060	.534
2,000	.00030		17,000	.080	.532
3,000	.00048		18,000	.110	.529
4,000	.00070		19,000	.145	.523
5,000	.00090		19,500	.250	.508
6,000	.00120		20,000	.250	.508
7,000	.00150		20,300	.300	.500
8,000	.00180		20,000	.380	.481
9,000	.00270		19,500	.450	.456
10,000	.00240		19,000	.500	.437
10,600	.00320	.5425	18,500	.515	.425
11,000	.015	.541	18,000	.535	.413
12,000	.020	.540	17,000	.560	.389
13,000	.030	.539	16,600	.565	.380
14,000	.040	.537			

Yield Point, 10,600 Lbs.

Maximum Load, 20,300 Lbs.

Load at Rupture, 16,300 Lbs.

Elongation, 28.25%

Contraction of Area, 50.9%

Fracture, Silky surrounding dull silky center; incipient cup.

Brinell Number, 171

T A B L E II-2-5

SPECIMEN F-16

Date Tested, Dec. 30, 1922; Room Temperature, 25° C.

Date Heat Treated, Aug. 29, 1922.

Load (Lbs.)	Extension in 2" length (In.)	Diam- eter (In.)	Load (Lbs.)	Extension in 2" length (In.)	Diam- eter (In.)
0	0	.543	15,000	.055	.536
1,000	.00010		16,000	.070	.534
2,000	.00024		17,000	.085	.532
3,000	.00048		18,000	.110	.529
4,000	.00076		19,000	.150	.524
5,000	.00100		19,500	.170	.520
6,000	.00140		20,000	.230	.512
7,000	.00160		20,200	.320	.499
8,000	.00200		20,000	.400	.480
9,000	.00230		19,500	.460	.458
10,000	.00260		19,000	.490	.440
11,000	.0030		18,500	.520	.424
11,600	.0033	.5425	18,000	.545	.410
12,000	.025	.540	17,500	.560	.399
13,000	.035	.538	17,000	.570	.389
14,000	.045	.537	16,400	.576	.374

Yield Point, 11,600 Lbs.

Maximum Load, 20,200 Lbs.

Load at Rupture, 16,400 Lbs.

Elongation, 28.8%

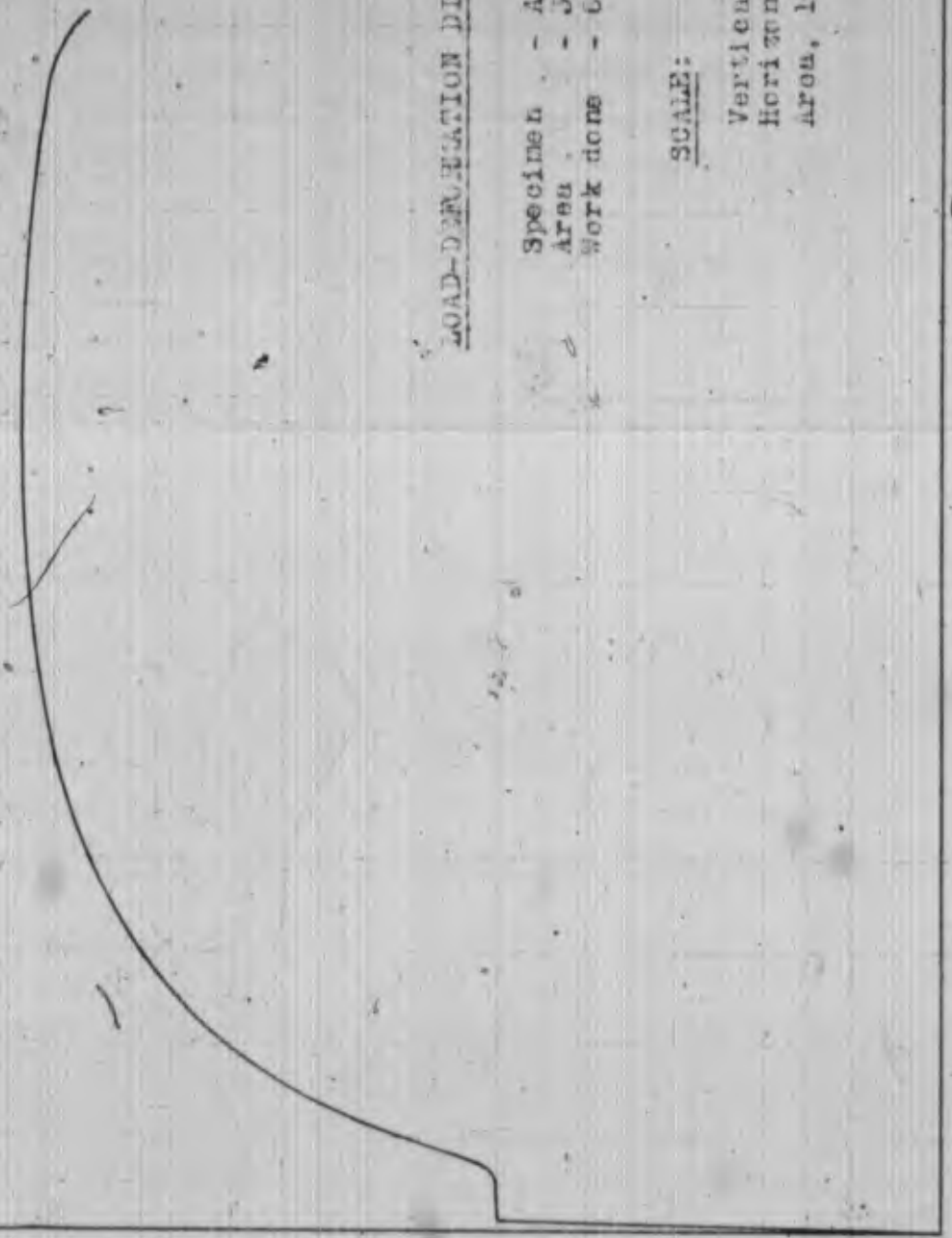
Contraction of Area, 52.5%

Fracture - Silky with duller core; incipient cup.

Brinnell Number - 175.

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



LOAD-DEFLECTION DIAGRAM

Specimen - A-41
Area - 30.84 Sq. in.
Work done - 678.67 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22.322 Ft. Lbs.

ELONGATION

0 0.1 0.2 0.3 0.4 0.5 (Inches)

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

LOAD-DEFORMATION DIAGRAM

Specimen - A-R2
Area - 30.35 Sq. In.
Work done - 674.43 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. lbs.

ELONGATION

(Inches)

0.5

0.4

0.3

0.2

0.1

0



(Lbs.)

LOAD

3,000

2,000

1,000

0

0

0

0

0

0

0

0

0

0

0.1

0.2

0.3

0.4

0.5

ELONGATION

(Inches)

LOAD-DEFORMATION DIAGRAM

Specimen - A-163

Area - 28.51 Sq. In.

Work done - 648.50 Ft. Lbs.

SCALE:

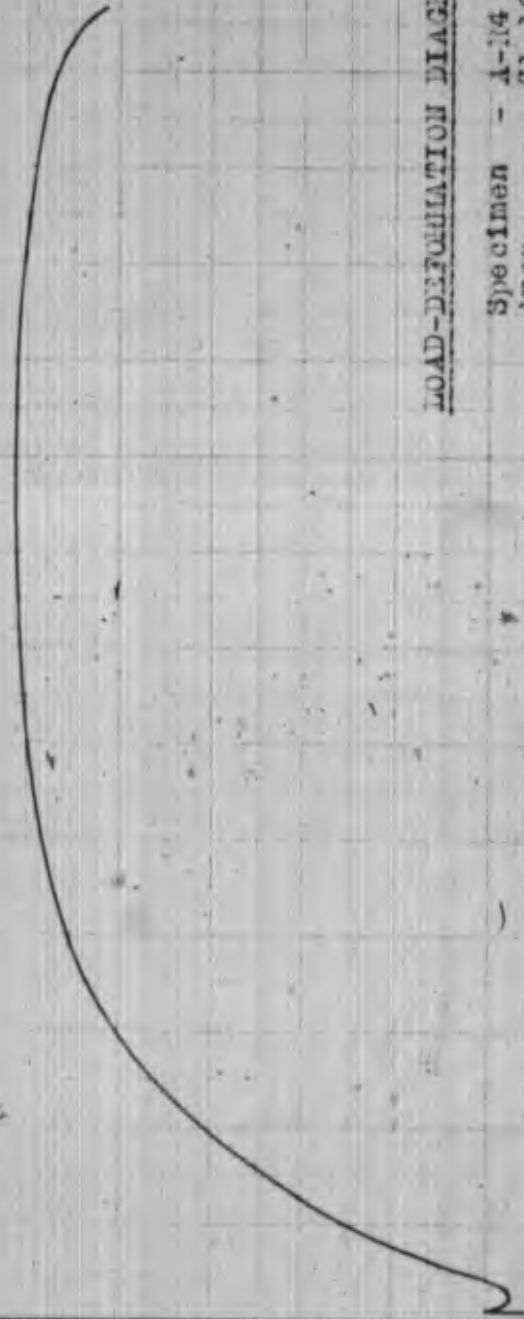
Vertical, 1 In. = 4,000 Lbs.

Horizontal, 1 In. = 1/16 In.

Area, 1 Sq. In. = 22,232 Ft. Lbs.

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



LOAD-DEFORMATION DIAGRAM

Specimen - A-114
Area - 31.16 Sq. In.
Work done - 692.43 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. lbs.

ELONGATION

(Inches)

0.5

0.4

0.3

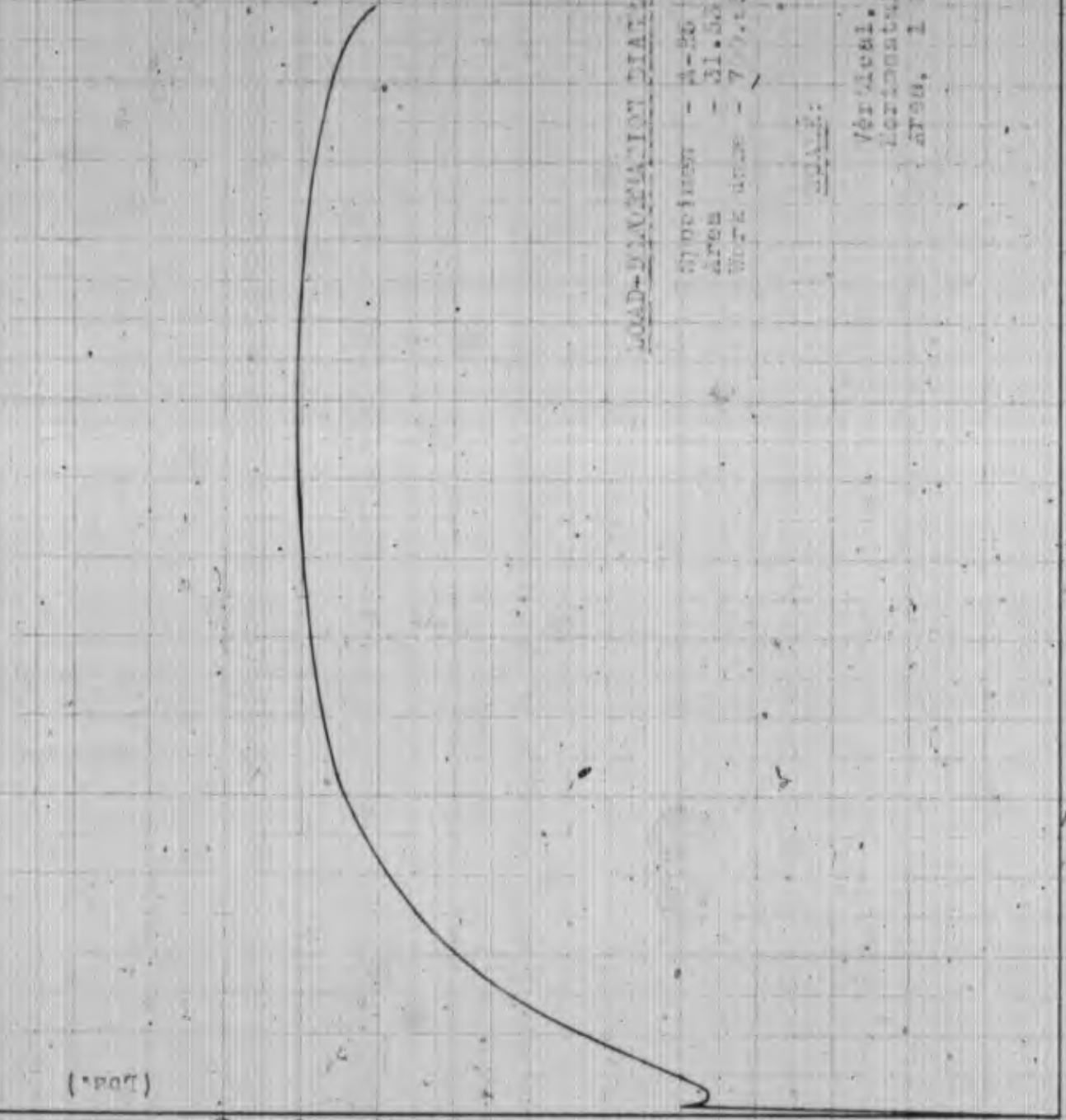
0.2

0.1

0

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



LOAD-ELONGATION DIAGRAM

Specimen - A-26
Area - 31.53 sq. in.
Work done - 7,715 ft. lbs.

NOTE:

Vertical, 1 in. = 4,000 lbs.
Horizontal, 1 in. = 1/10 in.
Area, 1 sq. in. = 11,342 ft. lbs.

ELONGATION

(Inches)

0.5

0.4

0.3

0.2

0.1

0

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

0.1

0.2

0.3

0.4

0.5

ELONGATION

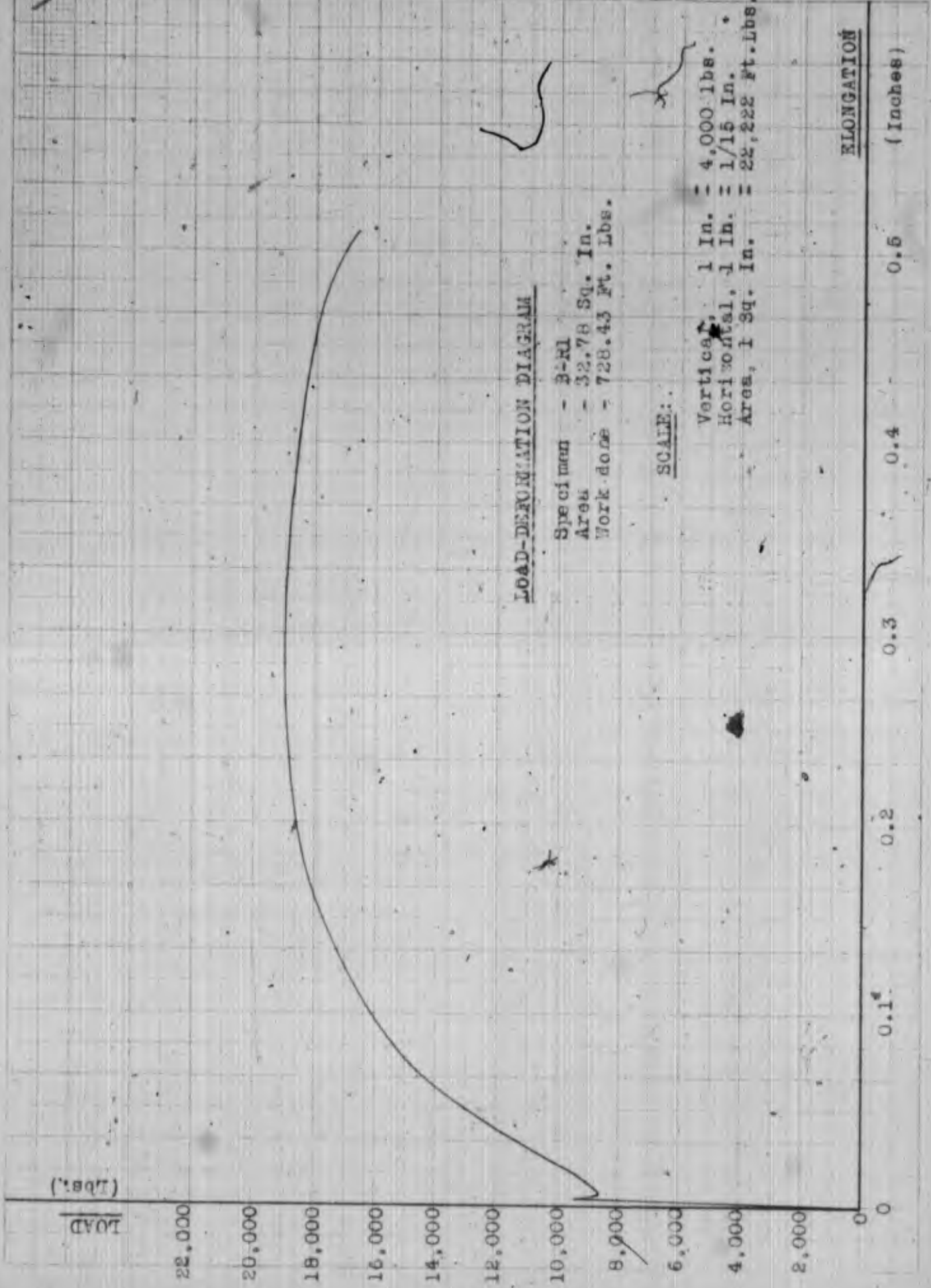
(Inches)

LOAD-DEFORMATION DIAGRAM

Specimen - 3-R1
Area - 32.78 Sq. In.
Work done - 728.43 Ft. Lbs.

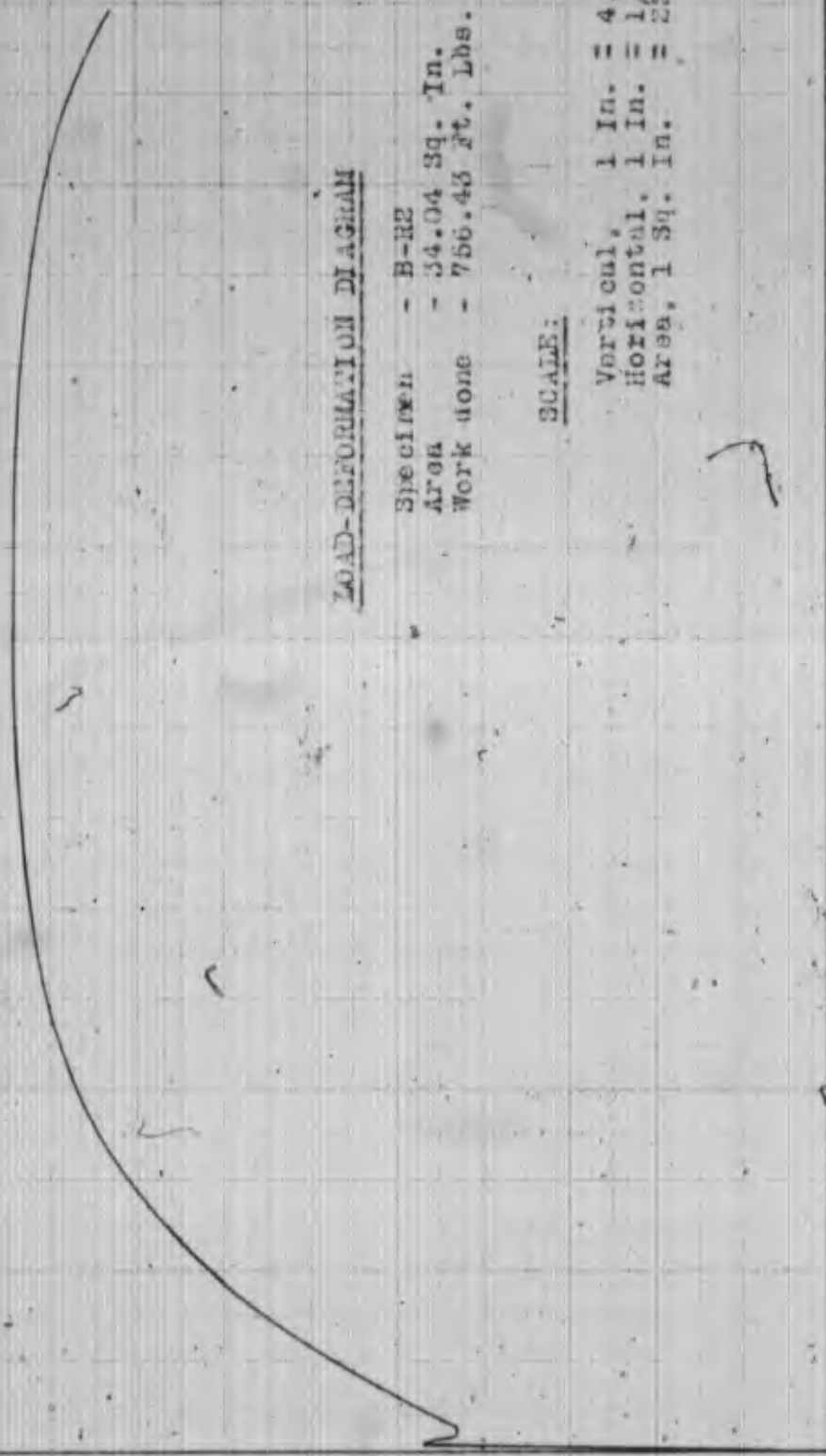
SCALE:

Vertical, 1 In. = 4,000 lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.



LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



LOAD-DEFORMATION DIAGRAM

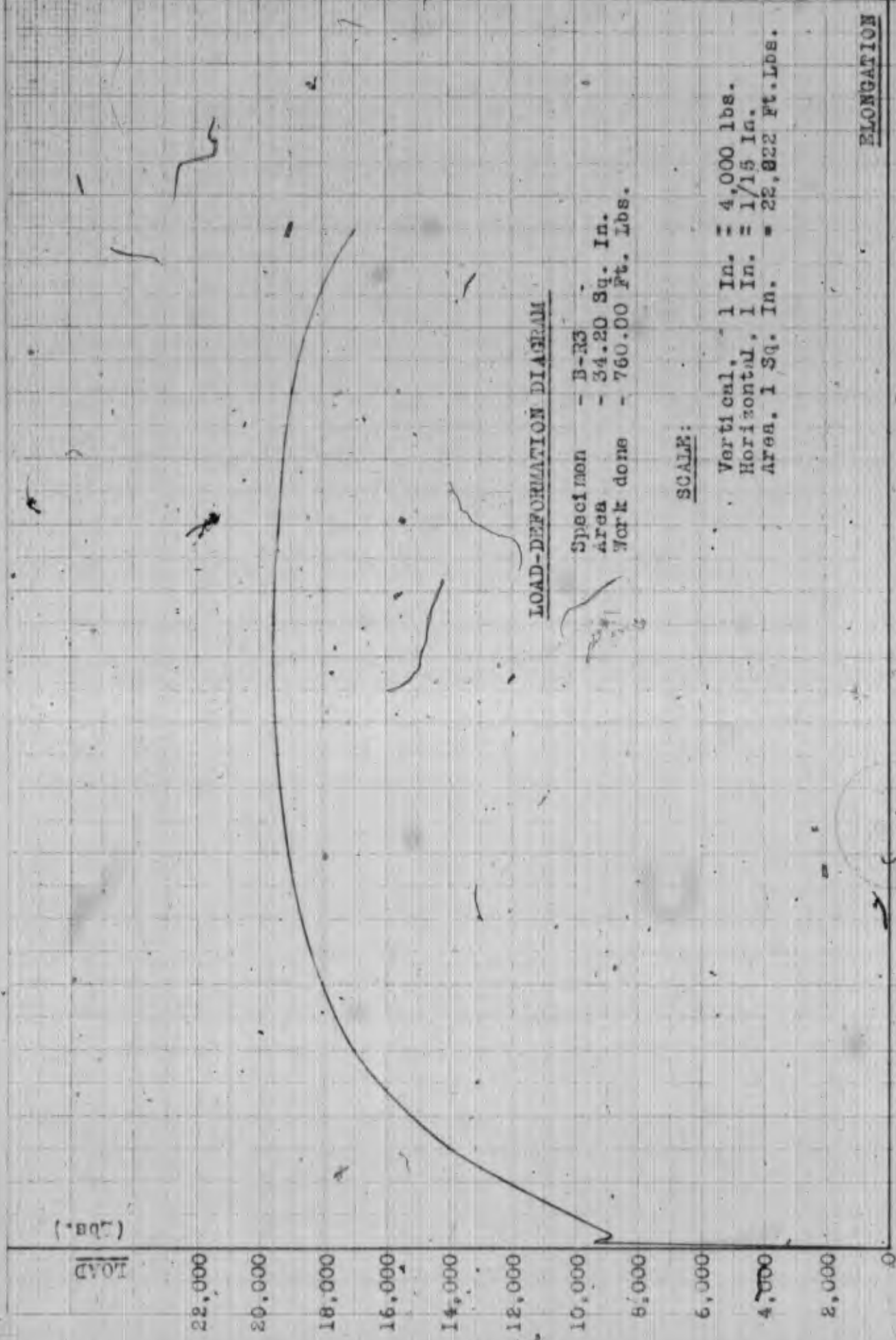
Specimen - B-RE
Area - 34.04 Sq. In.
Work done - 756.43 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION

(Inches)



LOAD-DEFORMATION DIAGRAM

Specimen - B-23
 Area - 34.20 Sq. In.
 Work done - 760.00 Ft. Lbs.

SCALE:

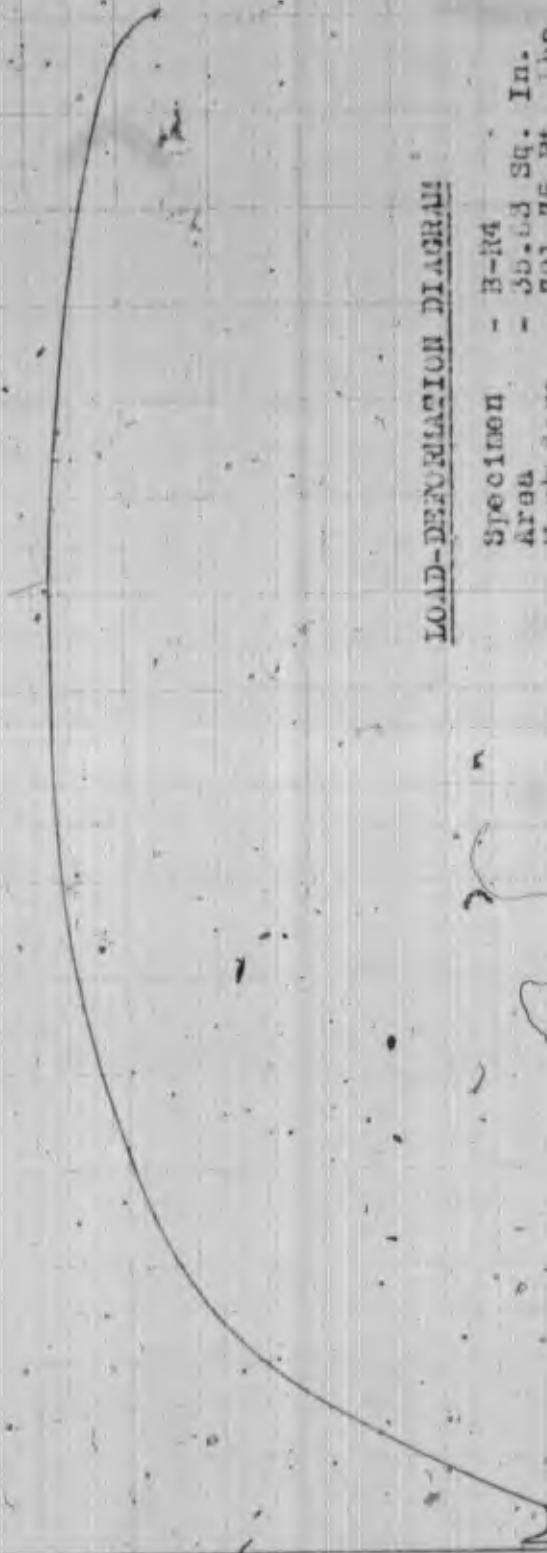
Vertical. 1 In. = 4,000 lbs.
 Horizontal. 1 In. = 1/15 In.
 Area. 1 Sq. In. = 22,922 Ft. Lbs.

ELONGATION

(Inches)

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



LOAD-DEFORMATION DIAGRAM

Specimen - B-N4
Area - 35.63 Sq. In.
Work done - 791.75 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION

(Inches)

0.5

0.4

0.3

0.2

0.1

0

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

LOAD-DEFORMATION DIAGRAM

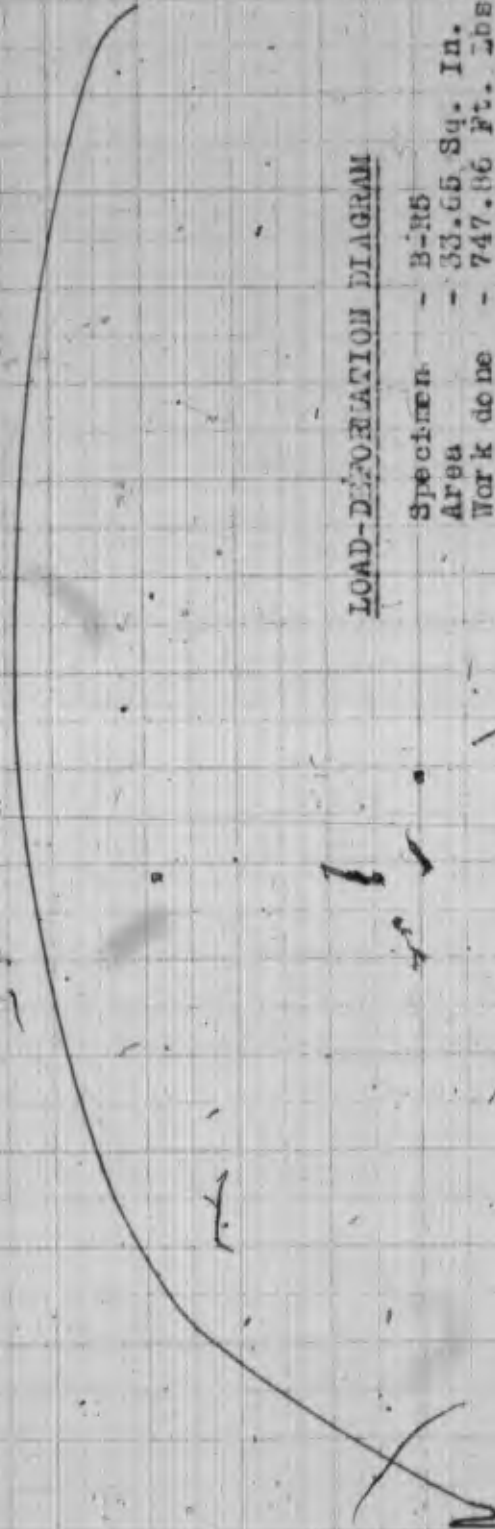
Specimen - B-15
Area - 33.65 Sq. In.
Work done - 747.86 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 lbs.
Horizontal, 1 In. = 1/16 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION

0.1 0.2 0.3 0.4 0.5
(Inches)



LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

LOAD-DEFORMATION DIAGRAM

Specimen - C-RL
Area - 34.95 Sq. In.
Work done - 776.66 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION

(Inches)

0.1 0.2 0.3 0.4 0.5

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

LOAD-DEFORMATION DIAGRAM

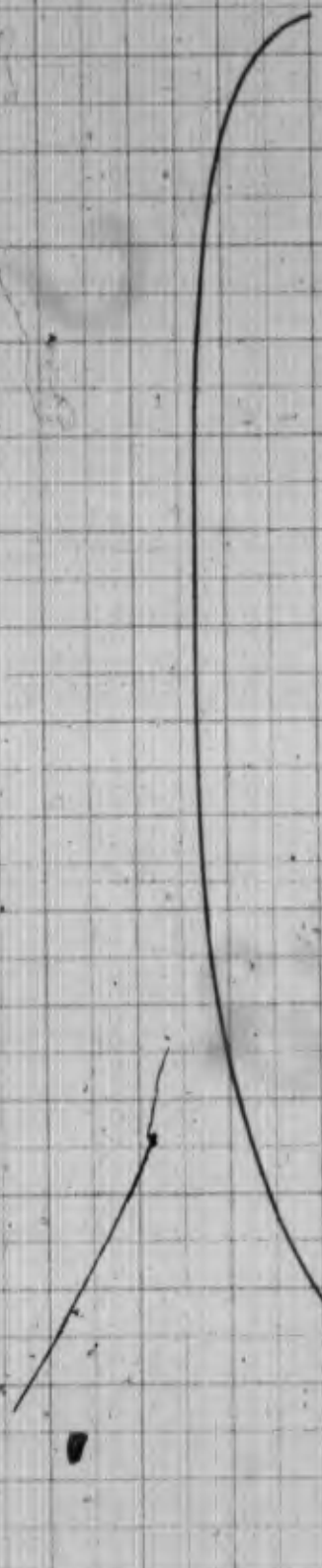
Specimen - C-RI
Area - 34.95 Sq. In.
Work done - 776.66 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION

0 0.1 0.2 0.3 0.4 0.5 (Inches)



LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

0

0.1

0.2

0.3

0.4

0.5

ELONGATION
(Inches)

LOAD-DEFORMATION DIAGRAM

Specimen - C-122,
Area - 35.39 Sq. In.
Work done - 786.43 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

0.1

0.2

0.3

0.4

0.5

ELONGATION

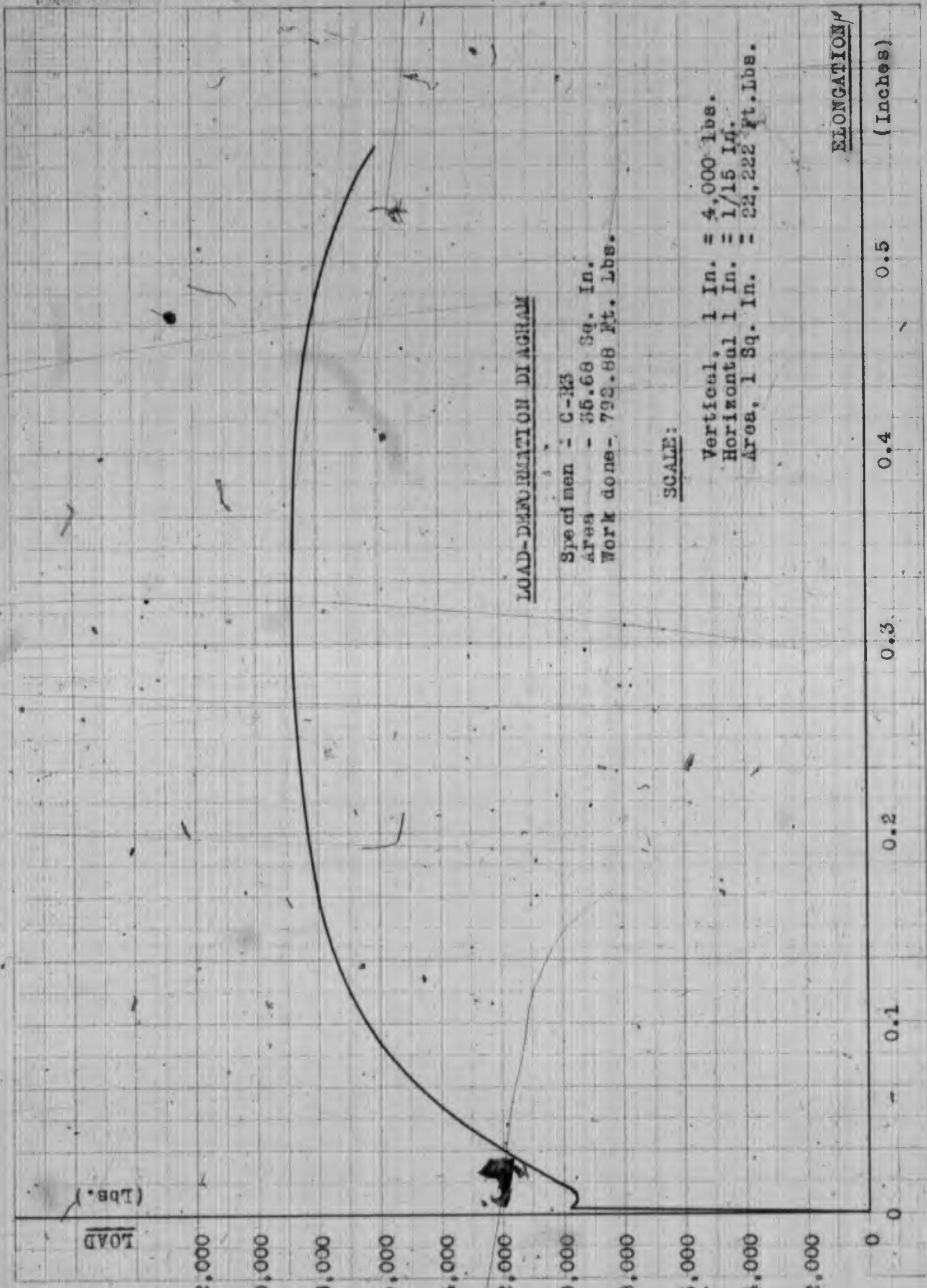
(Inches)

LOAD-DEFORMATION DIAGRAM

Specimen - C-R3
Area - 35.68 Sq. In.
Work done - 792.88 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 Lbs.
Horizontal 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.



LOAD
(Lbs)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

ELONGATION
(Inches)

0.5

0.4

0.3

0.2

0.1

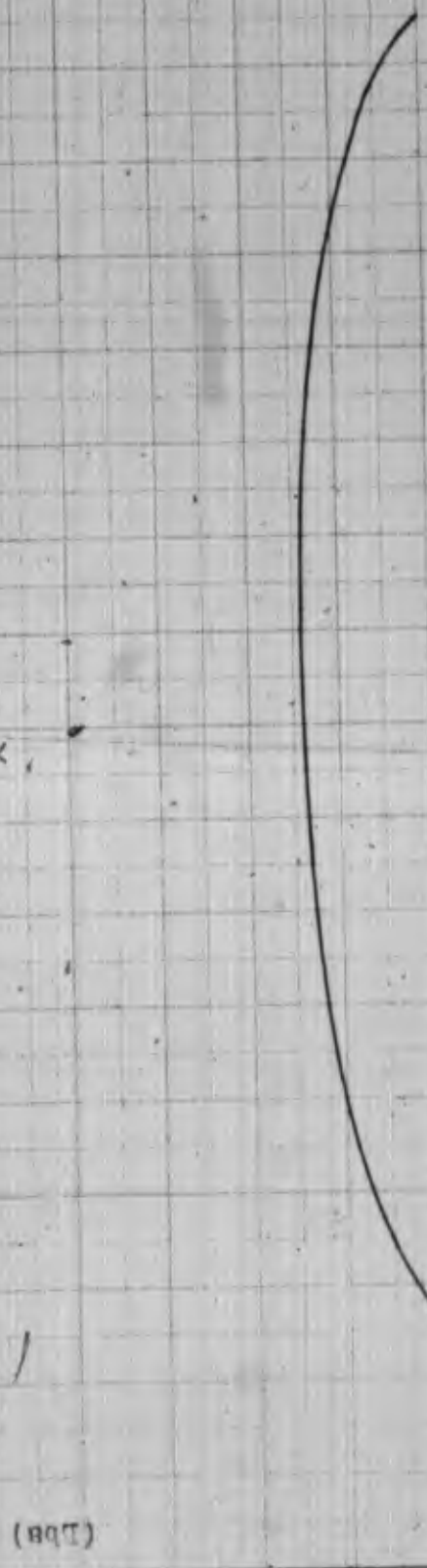
0

LOAD-DEFORMATION DIAGRAM

Specimen - C-R4
Area - 36.22 Sq. In.
Work done - 782.66 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.



LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
9,000
6,000
4,000
2,000
0

0.1 0.2 0.3 0.4 0.5

ELONGATION

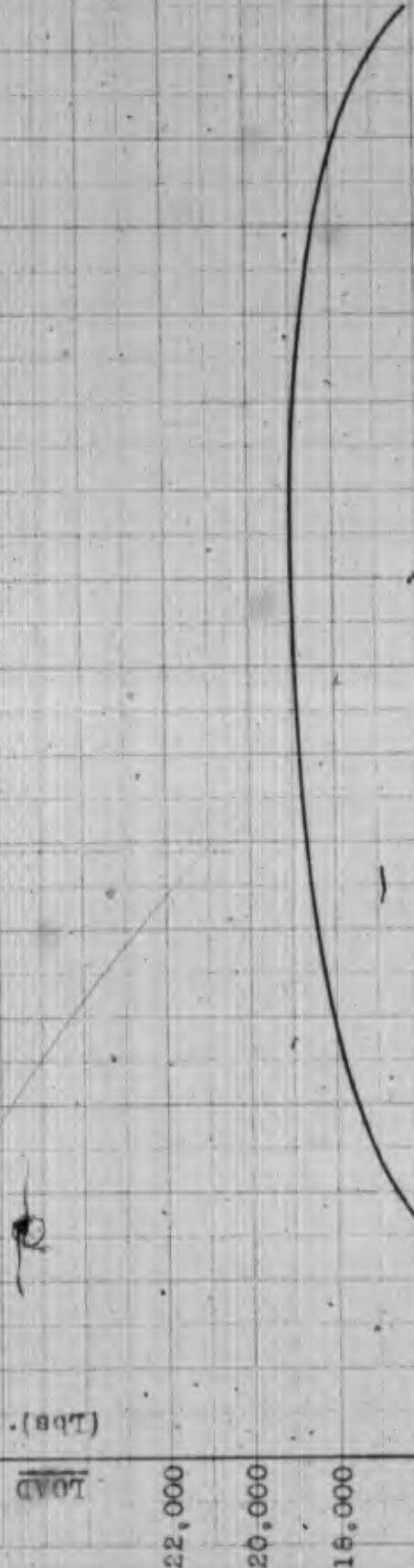
(Inches)

LOAD-DEFORMATION DIAGRAM

Specimen - C-85
Area - 35.43 Sq. In.
Work done - 787.31 Ft. Lbs.

SCALE:

Vertical, 1 Ins. = 4,000 lbs.
Horizontal, 1 Ins. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.



LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

0.1

0.2

0.3

0.4

0.5

ELONGATION

(Inches)

LOAD-DEFORMATION DIAGRAM

Specimen - D-R1
Area - 37.40 Sq. In.
Work done - 831.10 Ft. Lbs.

SCALE:

Vertical 1 In. = 4,000 Lbs.
Horizontal 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



LOAD-DEFORMATION DIAGRAM

Specimen - D-32
Area - 30.68 Sq. In.
Work done - 815.10 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION

(Inches)

0.5

0.4

0.3

0.2

0.1

0

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

0 0.1 0.2 0.3 0.4 0.5

ELONGATION

(Inches)

LOAD-DEFORMATION DIAGRAM

Specimen - D-R3
Area - 36.05 Sq. In.
Work done - 800.63 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
0

LOAD-DEFORMATION DIAGRAM

Specimen - D-R4
Area - 36.26 Sq. In.
Work done - 805.77 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/16 In.
Area, 1 Sq. In. = 22,222 Ft. lbs.

ELONGATION

(Inches)

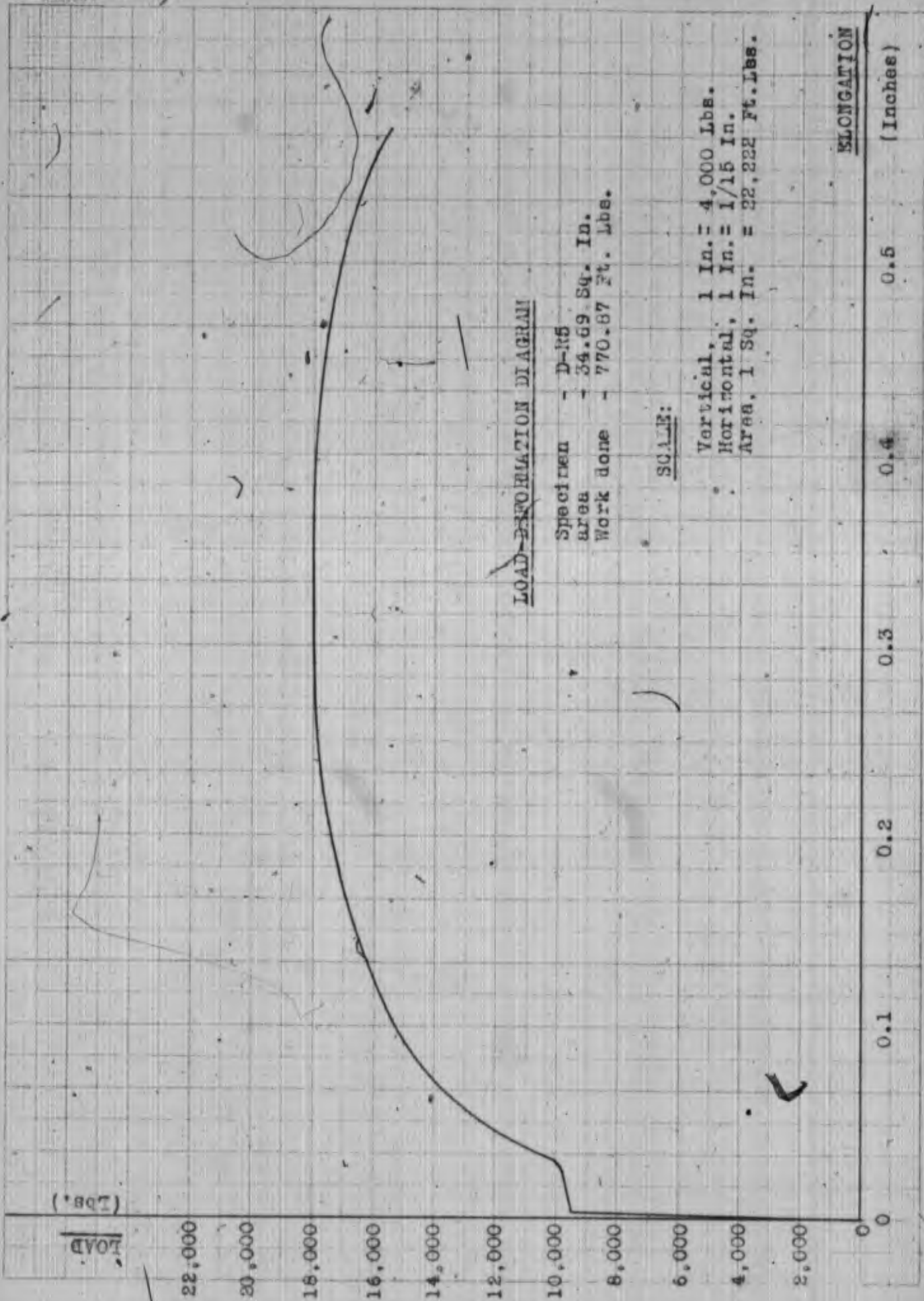
0.4

0.3

0.2

0.1

0



LOAD-ELONGATION DIAGRAM

Specimen - D-115
 Area - 34.69 Sq. In.
 Work done - 770.87 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 Lbs.
 Horizontal, 1 In. = 1/15 In.
 Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION

(Inches)

0.5

0.4

0.3

0.2

0.1

0

LOAD
(Lbs.)

22,000

20,000

18,000

16,000

14,000

12,000

10,000

8,000

6,000

4,000

2,000

0

LOAD
(Lbs.)



LOAD-DEFORMATION DIAGRAM

Specimen - E-R1
Area - 40.19 Sq. In.
Work done - 893.10 Ft. Lbs.

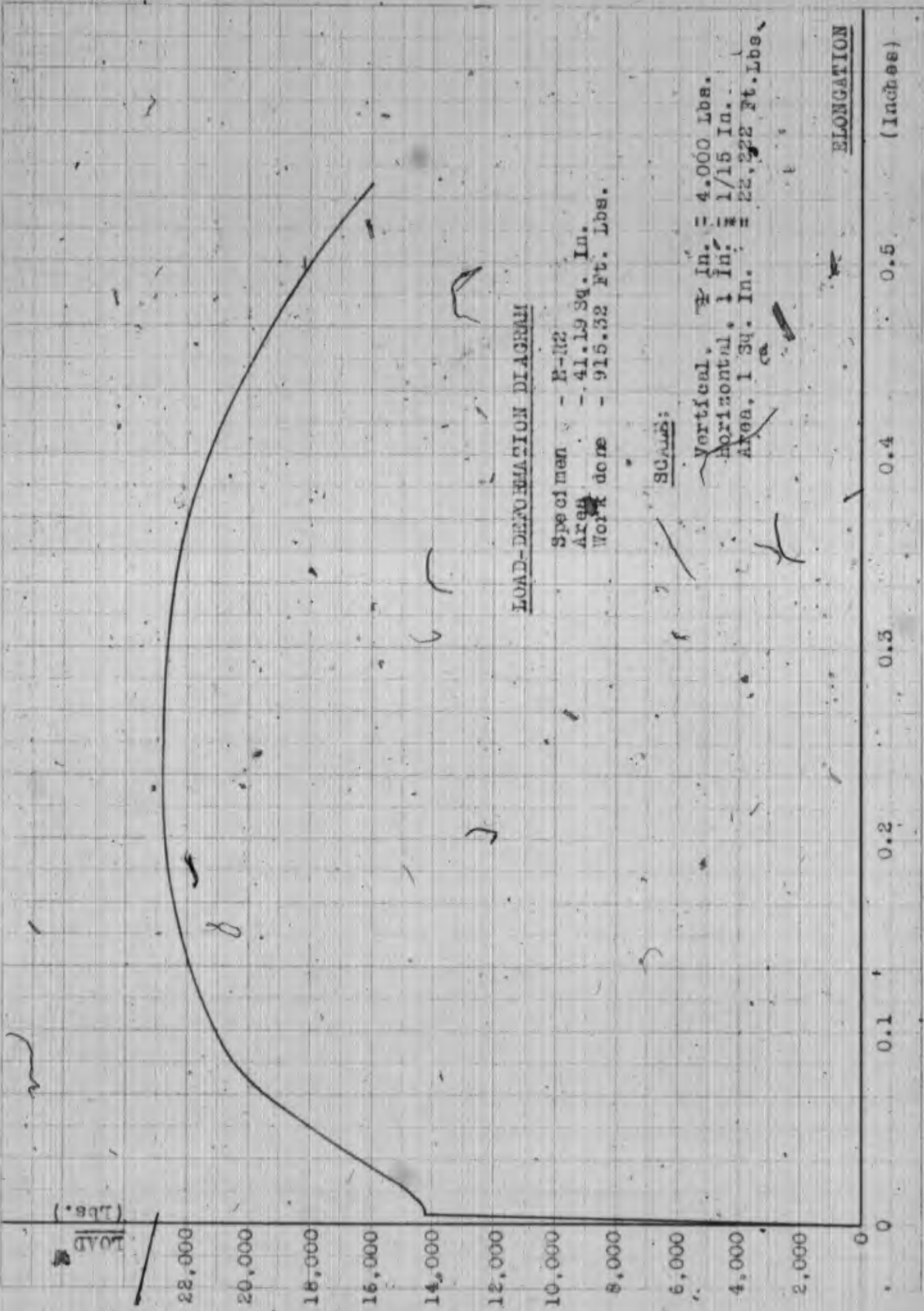
SCALE:

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/16 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION

(Inches)

0 0.1 0.2 0.3 0.4 0.5



LOAD-DEFORMATION DIAGRAM

Specimen - E-112
 Area - 41.19 Sq. In.
 Work done - 915.32 Ft. Lbs.

SCALE:

Vertical, 1 in. = 4,000 Lbs.
 Horizontal, 1 in. = 1/15 in.
 Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION
 (Inches)

0 0.1 0.2 0.3 0.4 0.5

LOAD
(Lbs.)



LOAD-DEFORMATION DIAGRAM

Specimen - E-123
Area - 41.15 Sq. In.
Work done - 914.42 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION

(Inches)

0.5

0.4

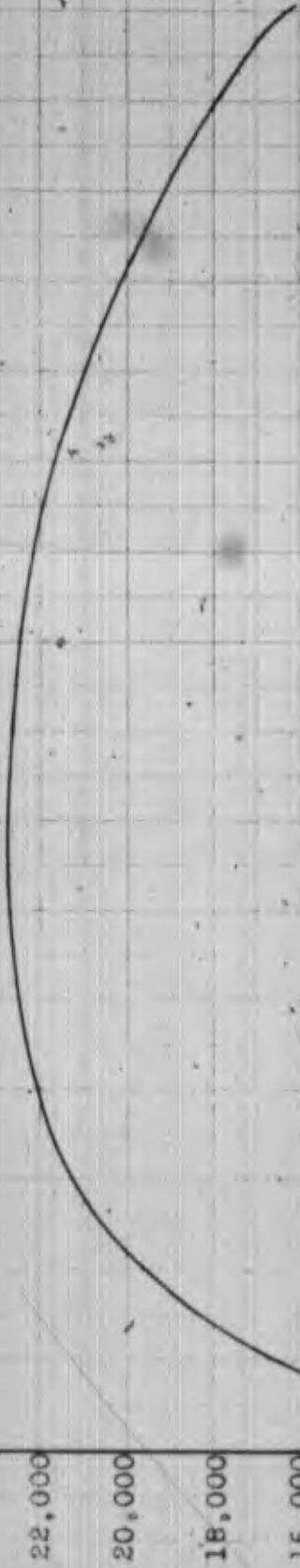
0.3

0.2

0.1

0

LOAD
(Lbs.)



LOAD-DEFORMATION DIAGRAM

Specimen - K-R4
Area - 40.72 Sq. In.
Work done - 904.88 ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22,222 Ft. Lbs.

ELONGATION

(Inches)

0.5

0.4

0.3

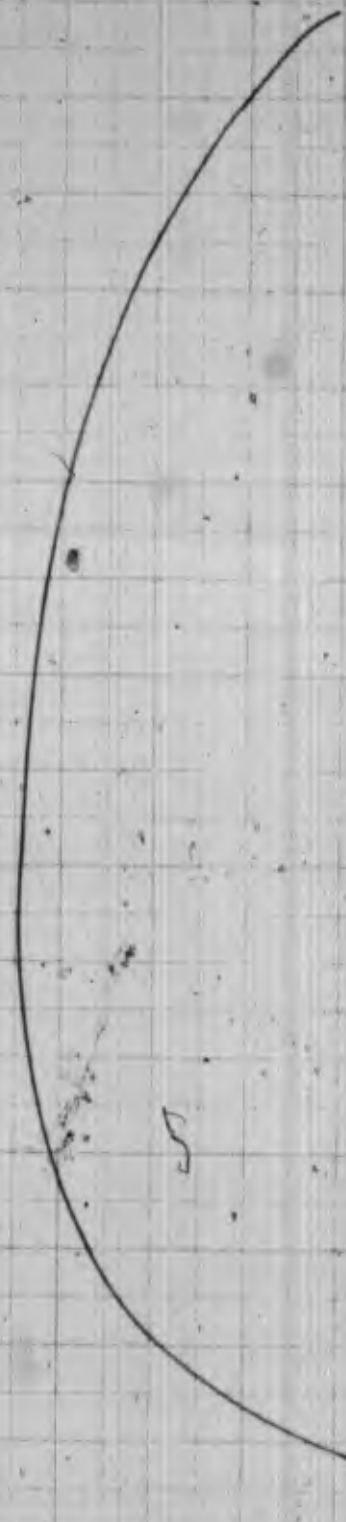
0.2

0.1

0

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



LOAD-DEFORMATION DIAGRAM

Specimen - H-R5
Area - 40.80 Sq. In.
Work done - 900.00 ft. Lbs.

SCALE:

Vertical, 1 in. = 4,000 Lbs.
Horizontal, 1 in. = 1/15 in.
Area, 1 Sq. in. = 22,222 ft. Lbs.

ELONGATION

0 0.1 0.2 0.3 0.4 0.5 (Inches)

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

LOAD-DEFORMATION DIAGRAM

Specimen - 2-11
Area - 39.46 Sq. In.
Work done - 876.88 Ft. Lbs.

SCALE:

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22.222 Ft. Lbs.



ELONGATION
(Inches)

0.5

0.4

0.3

0.2

0.1

0

LOAD

32,000
20,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



LOAD-DEFORMATION DIAGRAM

Specimen - F-RE
Area - 36.60 Sq. In.
Work done - 667.76 Ft. Lbs.

SCALE:

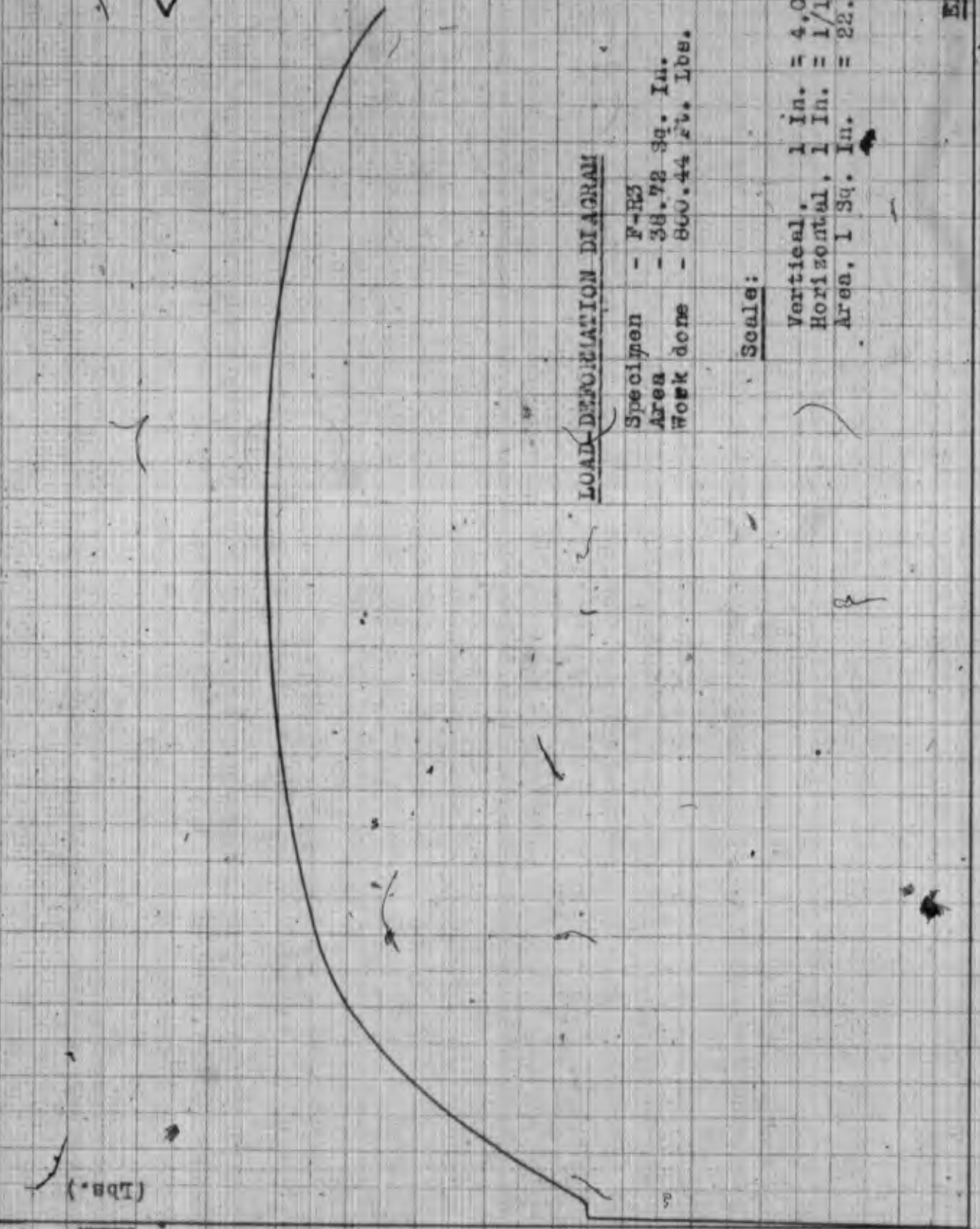
Vertical, 1 In. = 4,000 lbs.
Horizontal, 1 In. = 1/16 In.
Area, 1 Sq. In. = 22.222 Ft. Lbs.

ELONGATION

0 0.1 0.2 0.3 0.4 0.5 (Inches)

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



LOAD-DEFORMATION DIAGRAM

Specimen - F-R3
Area - 38.72 Sq. In.
Work done - 860.44 Ft. Lbs.

Scale:

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22.222 Ft. Lbs.

ELONGATION

0.1 0.2 0.3 0.4 0.5

(Inches)

LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0

0.1

0.2

0.3

0.4

0.5

(Inches)

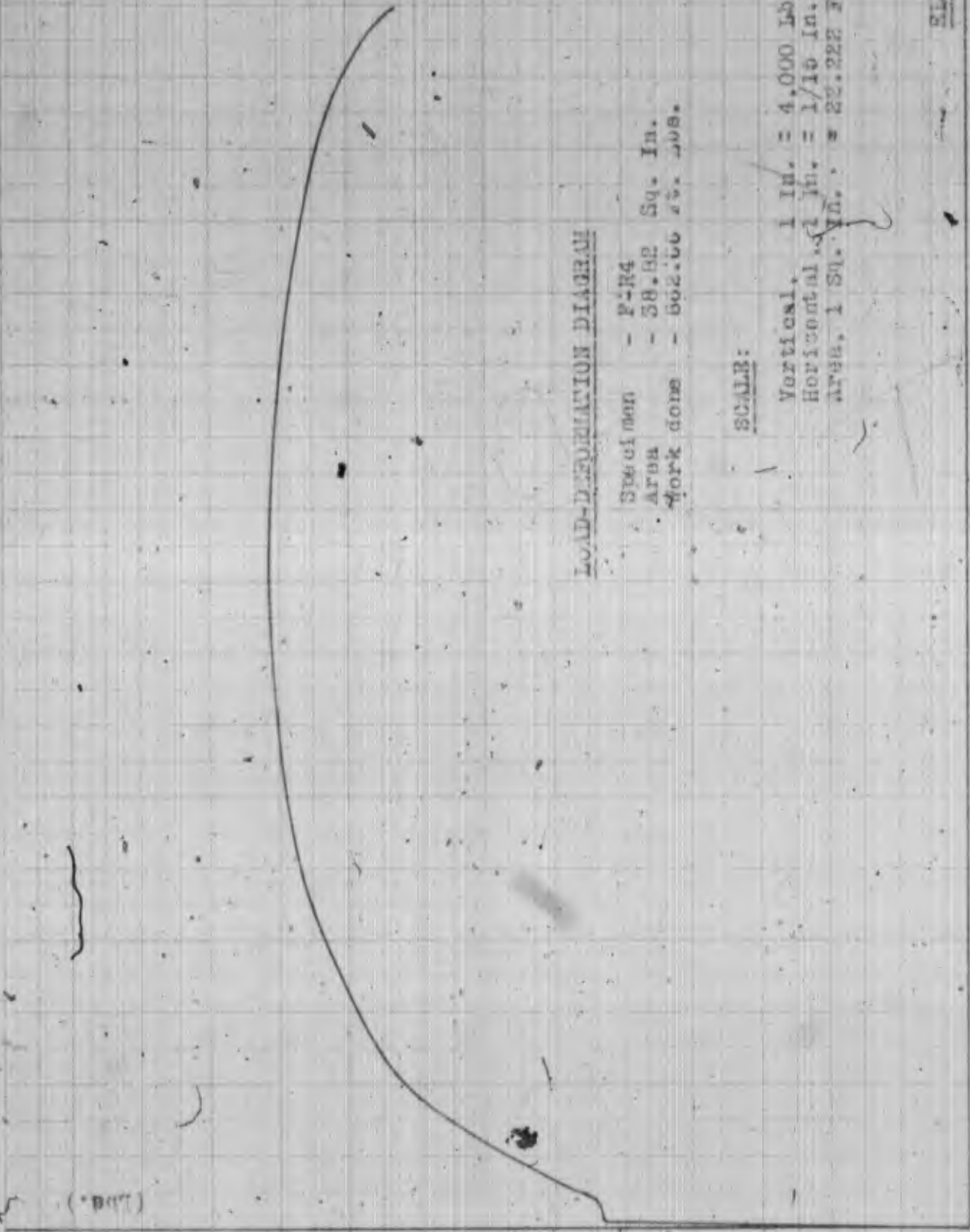
LOAD-DEFORMATION DIAGRAM

Specimen - P-R4
Area - 38.92 Sq. In.
Work done - 602.66 ft. lbs.

SCALE:

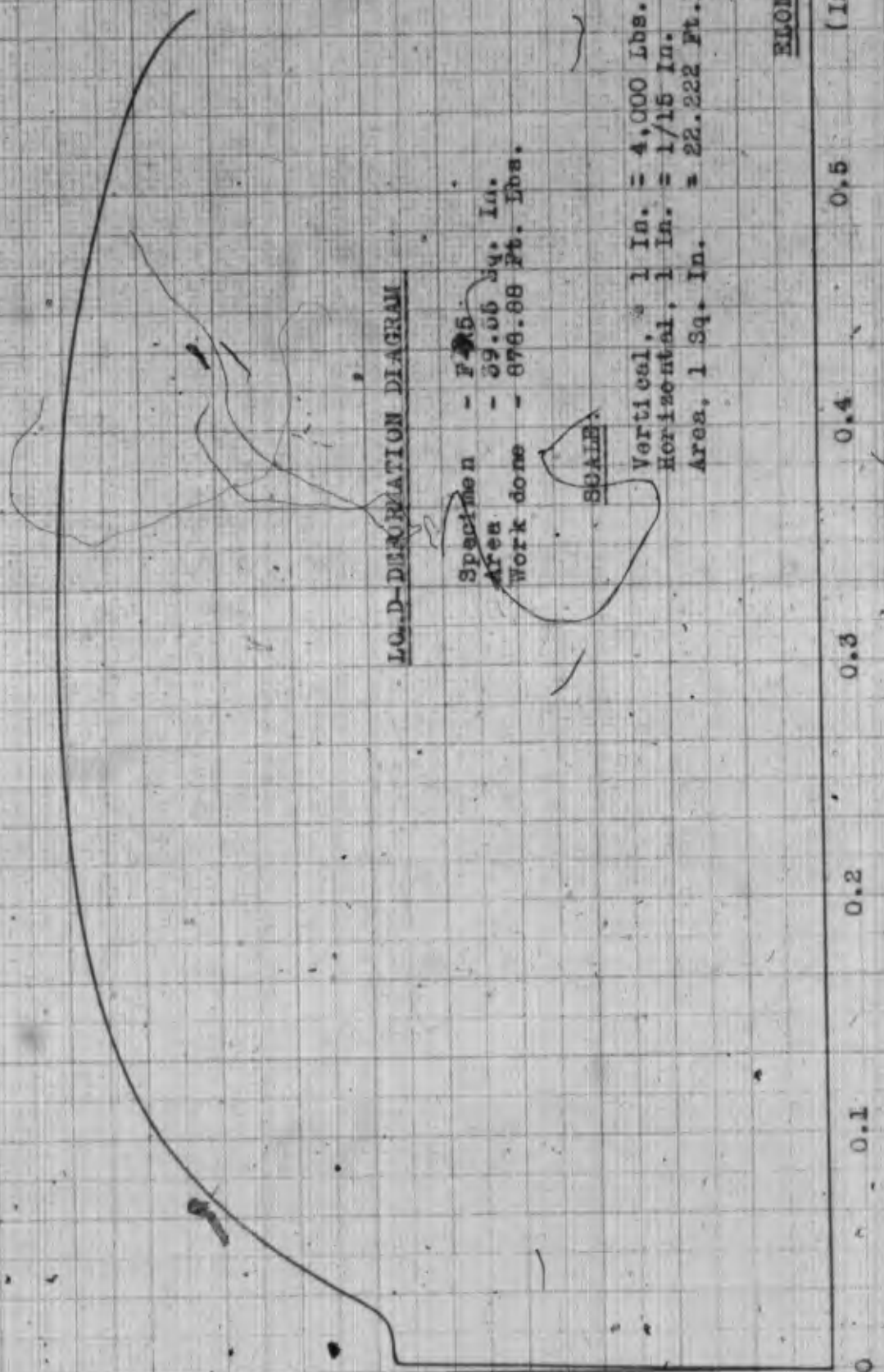
Vertical, 1 in. = 4,000 Lbs.
Horizontal, 1 in. = 1/16 in.
Area, 1 Sq. in. = 22.222 ft. lbs.

ELONGATION



LOAD
(Lbs.)

22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0



LOAD-DEFORMATION DIAGRAM

Specimen - F215
Area - 39.56 Sq. In.
Work done - 876.88 Ft. Lbs.

SCALE

Vertical, 1 In. = 4,000 Lbs.
Horizontal, 1 In. = 1/15 In.
Area, 1 Sq. In. = 22.222 Ft. Lbs.

ELONGATION

(Inches)

TABLE III.

T A B L E III-a

COMPARATIVE RESULTS - CHARPY VS. RIEHLE.

HEAT TREATMENT "A"

(6 hrs. at 1100° C. and furnace cooled)

Specimen No.	Work Done (Ft.-lbs.)		Elongation (Percent)		Contraction of Area (percent)	
	Charpy	Riehle	Charpy	Riehle	Charpy	Riehle
1	1154.7	678.67	27.75	22.0	39.3	31.3
2	1075.1	674.43	26.6	22.1	39.0	33.8
3	1086.6	648.30	26.5	22.5	39.0	35.2
4	1098.7	692.43	27.0	22.75	39.0	35.1
5	1122.9	700.65	28.5	23.2	40.4	36.1
Average	1107.6	678.90	27.5	22.5	39.3	34.3

T A B L E III-b
COMPARATIVE RESULTS - CHARPY VS. RIEHLE.

HEAT TREATMENT "B"

(6 hrs. at 1000° C. and Furnace cooled)

Specimen No.	Work Done (Ft. lbs.)		Elongation (Percent)		Contraction of Area (Percent)	
	Charpy	Riehle	Charpy	Riehle	Charpy	Riehle
1	1134.8 1154.7	728.43 678.67	30.0 27.75	25.5 22.0	43.5 39.2	41.0 41.3
2	1122.8	756.43	29.5	26.5	43.7	41.2
3	1074.5	760.00	28.5	25.75	43.3	41.5
4	1133.7	791.75	30.0	26.75	44.9	42.9
5	1080.6	748.86	29.3	26.5	44.4	43.7
Average	1109.3	756.69	29.5	26.2	44.0	42.1

TABLE III-a

COMPARATIVE RESULTS - CHURPY VS. RIEHLE

HEAT TREATMENT '04

(6 hrs. at 900° C. and furnace cooled)

Specimen No.	Work Done (Ft. Lbs)		Elongation (Percent)		Contraction of Area (Percent)	
	Churpy	Riehle	Churpy	Riehle	Churpy	Riehle
1	1200.3	776.66	35.3	27.3	47.6	45.6
2	1110.9	786.43	31.0	27.5	46.6	45.5
3	1090.7	792.88	29.8	28.0	46.8	46.4
4	1100.2	782.65	31.0	27.5	46.6	45.0
5	1136.1	787.31	31.8	27.5	47.4	45.5
Average	1127.6	785.19	31.3	27.6	47.0	45.6

T A B L E III-d

COMPARATIVE RESULTS - CHARPY VS. RICHELÉ

HEAT TREATMENT "D"

(6 Hrs. at 850° C. and furnace cooled)

Specimen No.	Work Done (Ft. Lbs.)		Elongation (Percent)		Contraction of Area (Percent)	
	Charpy	Richlé	Charpy	Richlé	Charpy	Richlé
1	1273.5	831.10	34.5	29.0	50.1	48.3
2	1215.6	815.10	32.8	28.0	48.8	45.7
3	1202.1	800.63	32.8	28.25	47.8	45.8
4	1184.4	805.77	31.8	28.5	47.5	46.5
5	1128.5	770.87	31.8	28.5	48.5	41.3
Average	1200.4	805.89	32.7	28.5	48.5	45.5

T A B L E III-E

COMPARATIVE TESTS - CHARPY VS. RICHLÉ

HEAT TREATMENT "B"

(1 Hr. at 850° C. and water quenched; drawn 1 Hr. at 600° C. and air cooled)

Specimen No.	Work Done (Ft. Lbs.)		Elongation (Percent)		Contraction of Area (Percent)	
	Charpy	Richlé	Charpy	Richlé	Charpy	Richlé
1	1162.7	893.10	26.5	26.0	61.8	61.2
2	1141.0	915.32	27.5	27.0	61.4	61.7
3	1210.0	914.42	29.5	26.5	61.4	61.5
4	1198.1	904.88	29.0	26.75	62.2	61.8
5	1237.7	906.65	29.8	26.5	62.0	61.6
Average	1189.9	906.87	28.7	26.6	61.9	61.6

T A B L E III-f

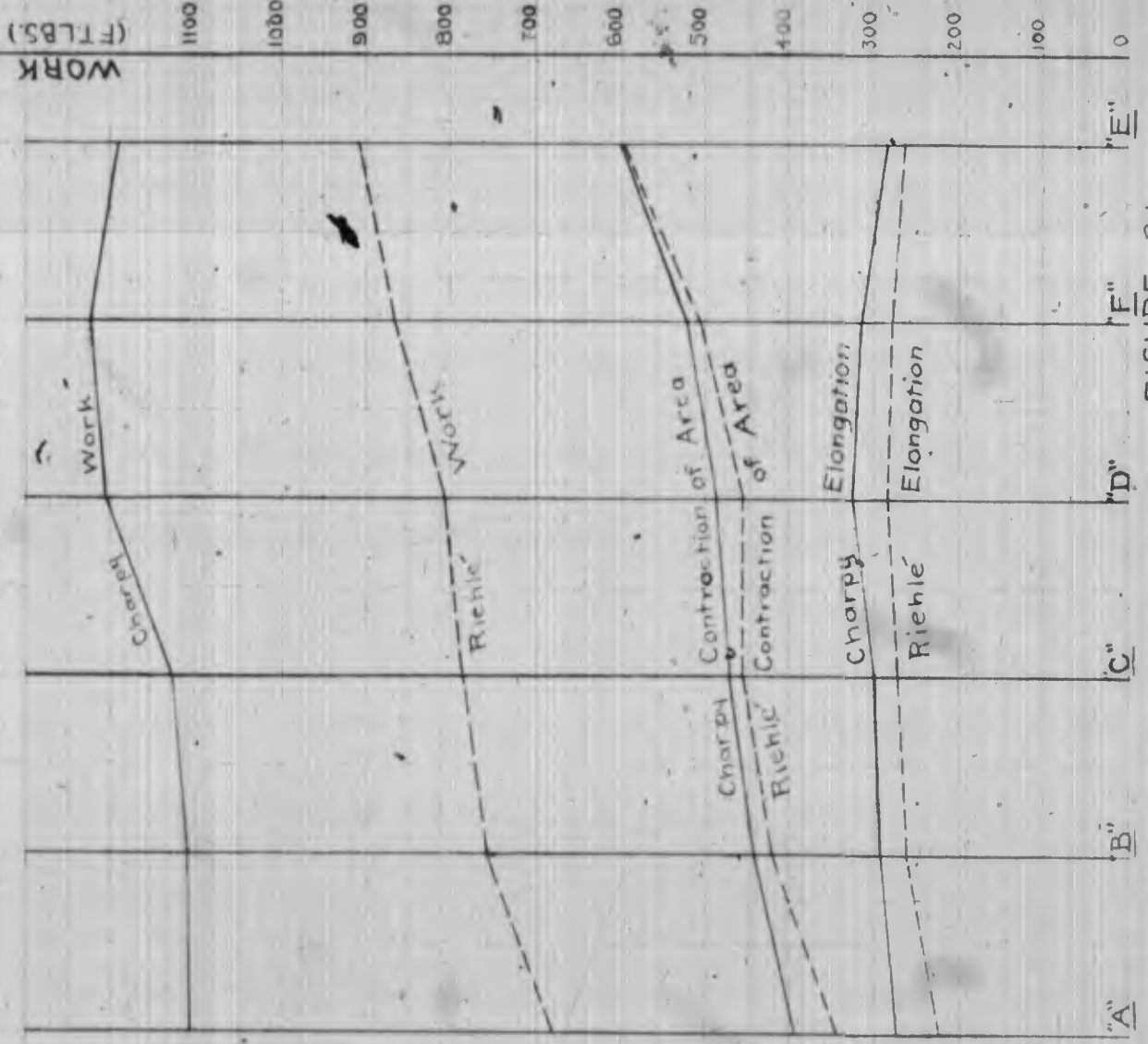
COMPARATIVE RESULTS - CHARPY VS RICHELLE

HEAT TREATMENT "F"

(2 Hrs. at 850° C. and air cooled; drawn 1 hr. at 600° C. and furnace cooled)

Specimen No.	Work Done (Ft.-lbs.)		Elongation (Percent)		Contraction of Area (Percent)	
	Charpy	Richle	Charpy	Richle	Charpy	Richle
1	1259.9	876.88	32.2	27.75	52.7	48.1
2	1186.2	857.76	30.3	27.75	52.2	49.1
3	1208.0	860.44	31.2	27.0	51.0	51.1
4	1208.0	862.66	31.5	28.25	52.2	50.9
5	1253.6	878.88	32.7	28.8	52.1	52.5
Average	1223.2	867.32	31.6	27.9	52.0	50.5

ELONGATION AND CONTRACTION OF AREA (PER CENT)



GRAPHICAL REPRESENTATION OF RELATION BETWEEN WORK OF FRACTURE, TOTAL ELONGATION AND CONTRACTION OF AREA FOR THE STATIC AND DYNAMIC TESTS.

(Plotted values denote the mean of each group of five specimens.)

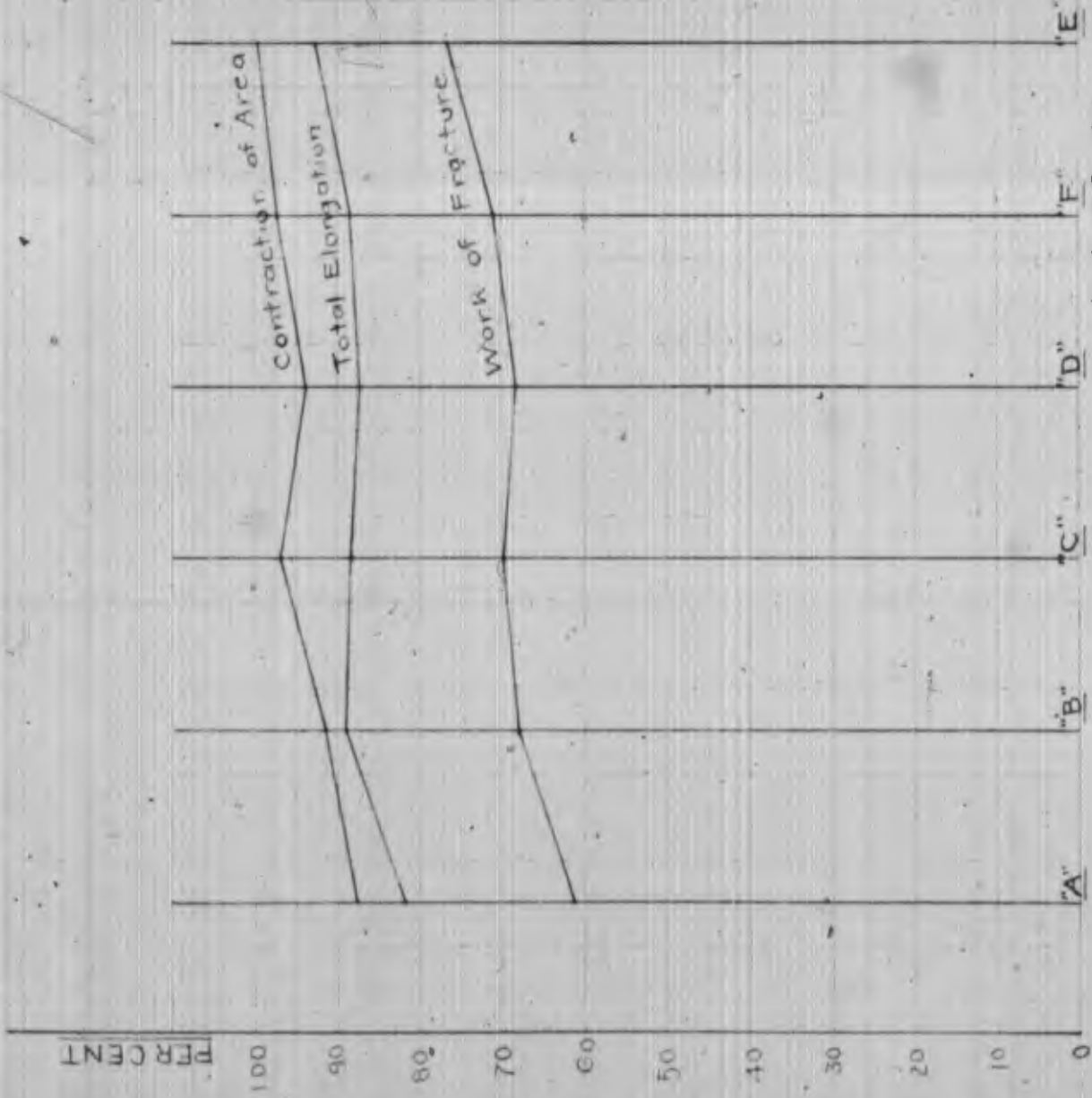
HEAT TREATMENTS:

- "A"-6 hrs. at 1100°C., furnace cooled.
- "B"-6 hrs. at 1000°C., furnace cooled.
- "C"-6 hrs. at 900°C., furnace cooled.
- "D"-6 hrs. at 850°C., furnace cooled.
- "F"-2 hrs. at 850°C., air chilled; drawn 1 hr. at 600°C., and furnace cooled.

"E"-1 hr. at 850°C., water quenched; drawn 1 hr. at 600°C., and air cooled.

(See Table III.)

FIGURE 21:



GRAPHICAL CHART

SHOWING

PERCENTAGE RELATIONSHIP BETWEEN
WORK OF FRACTURE, ELONGATION

AND

CONTRACTION OF AREA

FOR

STATIC AND DYNAMIC TESTS.

(Ordinates represent Riehle values
 Charpy values
 expressed in percent, for the mean
 of each group of five specimens)

FIGURE 22.