RESIDUAL STRESSES IN BUTT-WELDED STEEL PLATES.

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THESIS

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Submitted in partial fulfillment of the requirements for the degree of Master of Engineering

By

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To

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TABLE OF CONTENTS.

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I N T R O D U C T I O N.

During the past decade great advances have been made in the art of welding, so much so, that it has superceded many other methods of making joints and assembling parts. The resulting products have become more satisfactory in every respect as many of the detrimental characteristics have been brought under control and taken care of by changes in the welding details or in the design of the parts. However, it is upon these characteristics that continued study must be made with the object in view of formulating practical procedures to overcome them. Since there are so many variables in the problem and so much depending upon the personal element with regard to the welder, it will be only by well planned and continued research and strict qualification tests that reasonable agreement between the designed and resulting product will be obtained. When all is said and done the joints are the elements of a structure which require most consideration and all types of joints (weld, rivet, etc.) are limited by certain properties of which mere mention of some is included:

1. Stress concentration due to shape of the joint;
2. Shrinkage stresses arising from the joining process;
3. Heterogeneity of structure and composition of plate and added metal (weld, rivet, etc.) in the joint.
4. Workmanship.

The outstanding drawback of welding is the very high temperatures to which the joint must be subjected in order to bring about the fusing of the parent and weld metals. Moreover, heat of any degree causes deformation, and if this deformation is restrained stresses sufficient to surpass the yield point of the metals are quickly set up, resulting in a plastic strain. This plastically deformed material upon cooling will, if restrained against compressing, develop tensile stresses in itself.

Applying the above principle to a welded butt joint it becomes obvious how the stresses, synonymously termed, residual, locked-up, shrinkage and thermal, are set up longitudinally. The weld metal is usually a very small percentage of the parent metal and so its thermal effect is necessarily confined to a narrow limit along the length of the weld. On the application of the weld metal to the plates there is a very great difference in temperature between them resulting in an expansion of the plates and a sudden cooling of the weld metal. Since the yield point of a metal is quite low at high temperatures and the fusion of the two metals very good, the bead will, in cooling, be greatly restrained and consequently yield plastically. Thus there is a residual tensile stress developed in the bead but rapidly changing to compressive in the plates. Since the weld metal also contracts transverse to its length, residual tensile stresses will be set up in the weld and adjacent plates in that direction.

Considerable research has been done both locally and in Europe on the magnitudes and distributions of these stresses but, as yet, a satisfactory conclusion has not been evolved. Various magnitudes have been set forth, some of which are obviously far in excess of those developable by the physical properties of the metals but reported as such because the investigators have neglected to differentiate between plastic and elastic strains. The proposed distributions of the maximum longitudinal stresses are more or less in agreement, indicating a tensile concentration at the weld and a lower compressive concentration in the plates; the reversal taking place in the plates adjacent to the weld. The transverse stresses are also a maximum in tension at the weld.

Everyone who has had contact with welding recognizes the existence of these stresses but many wish to dismiss them as inconsequental on account of so many investigations having shown a sufficiency of the joint when made by accepted procedures of welding. Such an attitude may well be adopted after further experiments have corroborated the conclusion. However, this would be an acceptable answer to their existence, and it is to such an end that those interested are working.

REVIEW OF CURRENT LITERATURE.

During the past several years considerable investigation has been carried on at McGill University in an attempt to prescribe on the control of residual stresses. Much of the work has been the measurement of the plastic and elastic strains set up in the plates by welding and again after they have been stress-relieved. Considerable investigation of the tensile properties of butt joints loaded longitudinally has been made and also the temperature distribution in the plate during welding.

D. E. Evans studied the distribution and magnitude of the longitudinal residual stresses in various widths of opposite edge-welded plates. Stress relieving of the specimens was accomplished by sawing the plates parallel to the weld into one inch strips.

L. Jehu did work more or less along the same line with the main object in view of examining the effects of different welding procedures. His general conclusions were that the use of covered electrodes result in higher shrinkage stresses than are found by using bare electrodes, and that a double layer of beads result in a higher stress parallel to the weld than a single bead. He further found that stress relieving by annealing at 1200°F. reduced the residual stresses to a magnitude of about 5000 psi.

D. M. Hamilton followed up this work with an investigation into the effects of preheating the specimens to various temperatures before starting to deposit the bead. He came to the conclusion that preheating helped to reduce the stresses, having found their magnitudes by the subdivision method.

M. Lupton also made some tests upon the preheating effect together with a study of the longitudinal tension properties of butt welds having been made up by various welding procedures. He found little difference in the magnitudes of the residual stresses created by the various procedures.

C. Craig, besides investigating the temperatures occurring in the plates during welding, studied the residual stresses set up in both the transverse and longitudinal directions of a single edge-welded plate. For the latter case he found that the residual stresses parallel were about twice those transverse to the weld.

Professor R. E. Jamieson made a study of the effect of the residual stresses upon the yield point of opposite edge welded plates and showed that when stressed above the elastic limit the plates behaved as ordinary unwelded plates do. Thus the release of the external load permits a uniform elastic recovery over the entire cross section with the residual stresses reduced to the extent of the inelastic action. He found that the sum of the maximum residual stress and the stress at the elastic limit due to the external load equalled, very closely, the yield point of the parent metal.

Besides the work done at McGill much has been accomplished on residual stress analysis in Europe:-

Perhaps the work which follows closest to the local line of attack has been executed by Lance Martin, and N. S. Boulton and Lance Martin in England. Martin found that for a single edge welded plate that the difference between gauge lengths parallel to the welded edge, measured before and after welding, varied linearly across its width. Qualitatively this was in agreement with the results found in co-operation with Boulton. On the gauge lengths perpendicular to the weld the greatest variation was found in the vicinity of the weld and he concluded that the residual stresses were confined to a two inch limit transverse to the weld. On comparing the elongations perpendicular to the weld with the shortenings parallel to the weld multiplied by Poisson's ratio he found remarkable agreement and inferred that the perpendicular stresses were of zero magnitude. This, of course, does not substantiate the results of Craig who found the transverse stresses to be more of the order of one-half the parallel stresses.

As the knowledge of residual stresses and distortions was extended various methods were proposed and tried to overcome them. Following is a brief resumé of the conclusions arrived at by the different experimenters as they directly apply to the present paper, together with short descriptions of the methods.

Residual stresses are not constant for any technique of welding, but vary considerably with thickness of plate, shape of joint, type of metal, cooling rate and other obvious variables. With so many conditions to be considered for each joint it is apparent that a method is desirable that will reduce the locked-up stresses to values which will not impair the strength nor dimensions of the product and at the same time, be applicable to a large variety of structures.

Before considering these methods it is desirous to review the relationship between the shrinkage stresses and the distortion caused by welding. It is reasonable to assume that, in the face of some contradictory reports, the stresses caused by welding a joint in which the plates are held rigidly in place will be much higher than those created when the plates are free to move and distort during the procedure. Up to now there has been found no relationship between the amount of distortion and the magnitude and distribution of the residual stresses. However, the amount of distortion is is affected by the electrical energy input and so are the residual stresses. For arc welds the extent of the heat disturbed area is directly related to the electrical input. Penetration as measured by the depth of the fusion line below the welded face does not necessarily increase with the increased heat affected area since the area usually increases in width.

Stress-relieving by annealing has been used very extensively and has been found most effective in reducing the stresses. In operation close watch must be kept on the temperature to obtain best results. In treating structural steel, the structure is placed in the furnace at not above 300°F., and the heat applied at a rate of about 200°F. per hour, up to a temperature of 1200°F. This temperature is maintained for at least one hour per inch of thickness of steel, after which the structure is allowed to cool slowly in the furnace down to not more than 300°F. when it may be removed. The temperature 1200°F. has been chosen as that best for stress-relieving for many reasons, among which are; that the yield point and ultimate strength have almost equal values of around 5000 psi; that large structures heated to higher temperatures would be subject to distortion under their own weight. The method is, of course, limited in use to concerns of sufficient means to economically own a furnace. Stress-relief by localized torch heating has been attempted with detrimental results.

Peening or mechanical hammering is used extensively, although its main usefulness is in reducing distortion. Experimenters have shown that there is very little to choose from between hot and cold peening, except that the former does not require a continual moving of the welder so that each pass may cool prior to being peened. Single pass beads are only peened when a minimum of distortion is more important than an unimpaired tensile strength.

Overstraining the structure is another method of stress-relieving, finding its greatest use for vessels which may be subjected to pressure. Residual stresses occur in concentrations or peaks and a uniform stress in the same sense has the effect of creating a plastic deformation at these points, if the sum of the two stresses is above the yield point of the material. On removing the external load these particular spots behave similar to unwelded metal stressed above its yield point, resulting in a reduction of the residual stresses corresponding to the inelastic deformation. Residual stresses are greatest at the junction of the weld and plate metal and it is in this zone that the plastic deformation takes place.

Various investigations have been made into the results obtainable by preheating the parent metal. The general conclusion of local investigators has been that heating to 200° or 300°F. shows marked signs of reducing the residual stresses. Preheating is known to reduce the tendency of the welds to crack, providing the temperature does not coincide with the brittle range of the material to be welded (500° to 600°F. for structural steel). Consideration has also to be given to the comfort of the welder.

Besides considering the methods of reducing the stresses after welding, one has to lay out a sequence of connecting the various parts that will minimize both the stresses and the distortion. By losing sight of this phase, effects of such magnitudes would result that the product would be of little practical use.

In welding so much depends upon the personal element that it is desirable to X-ray each joint to locate any defects so that they may be chipped out and the section rewelded. The defects which are most prevalent are:-

1) Slag inclusions;

2) Porosity;

3) Cracks;

4) Incomplete fusion between weld and base metal or between two layers of weld metal.

OBJECT OF THIS INVESTIGATION.

In the above paragraphs a brief outline of the work done on Residual Stresses at McGill University has been set out. Most of this has been on edge-welded plates giving information about the longitudinal and transverse stresses for that type of specimen. The present investigation was concerned with the stresses which were created at right angles to a butt-weld in 5/8" steel plate and their effect upon the physical properties of the plate when the joint was transversely loaded in tension. In making up the specimens different procedure of welding were used so that comparisons could be drawn between each as well as with the unwelded plate metal.

The various procedures of welding and treatments were:

a) plates welded using high currents;

b) plates welded using low currents;

c) plates welded as in a) and b) and stress-relieved after welding.

d) plates welded using normal currents.

e) plates welded using normal currents and peened while hot.

f) plates welded using small electrodes throughout;

g) unwelded plates to determine the physical properties of the plate metal.

Besides the above series of plates another plate was welded using fairly high currents and was used to determine the residual stress distribution transverse to the weld by the subdivision method.

The U-groove was used for all the plates.

PROCEDURE OF WELDING.

The investigation involved work on a total of seventeen welded plates and two test coupons of the plate metal alone, all taken from the same stock. The plates were stress-relieved at 1150°F. for at least one hour before machining and welding. In order not to cloud the results by the effects of rolling, the grooves were all cut at right angles to that direction. All the welding was done by the same operator at the plant of the Dominion Bridge Co. Ltd., Lachine, Que. so that the personal element was reduced to a minimum.

COUPONS A and B.

The Coupons consisted of pieces of plate approximately 5/8" x 3" x 18", sheared along the edges before stress-relieving. After relief the 3-inch dimension was machined down to approximately $2\frac{1}{4}$" for five inches on either side of the centre line.

PLATES A and B.

These two plates were drawn up as pilots for the remainder of the investigation and for that reason were somewhat different. Their dimensions after welding were 5/8" x $4\frac{1}{2}$" x 48". See Figure 1.

In making them up a backing strip was tacked on the back of the plates to prevent the arc from burning through at the bottom of the groove. This strip extended for $2\frac{1}{2}$" on either side of the $4\frac{1}{2}$" dimension of the plates and aided in completely filling the grooves. After welding it was sawn off flush with the edges of the plates and the tacks chipped for its removal. The plates were not restrained in any way during welding and hence showed a great deal of distortion when completed; even, to such an extent that each pair of plates forming a joint were askew both transversally and longitudinally. This feature was partially taken care of by machining both faces of the plates for a distance of five inches on either side of the weld. The total metal take off the two sideswas about an eighth of an inch. However, this procedure did not help to reduce the bent appearance of the plates, the depth of the concavity at the centre of the 10-inch machined section being about 0.04 inches. While such a bend may be taken care of when measuring the elongations due to load by the extensometers, the straightening of the bend undoubtedly causes a great rearrangement of the residual stresses; a point which must be considered when making comparisons with the results found by the sub-division method.

PLATES C to K.

This series consisted of seven pairs of plates, (I and J omitted), each pair being cut from the same welded plate and so being duplicates of one another. In making up this series, two plates 5/8" x 12" x 18" were butt-welded along the 12" side. After welding or heat treatment the 5/8" x 12" x 36" plate was sawn into two plates 5/8" x 6" x 36", following which each of the 36" edges were machined down to give specimens 5/8" x $4\frac{3}{4}$" to 5" x 36". In order to bring the two plates forming a joint into a single plane, as much as possible, they were clamped to the table during welding as shown in Figure 2. While this procedure did not entirely overcome the difficulty it did yield much straighter specimens than were obtained in Plates A and B, particularly along the 12" dimension. Upon arriving at the laboratory each weld was machined flush with the plate metal, involving the removal of about an eighth of an inch from each side. It was not possible to obtain perfect flushness, due to the many depressions left in the plate during rolling. Chill bars were used during welding.

PLATES N.

Plate N was made up under the same general procedures used for Plates C to K, except that it was not sawn up from the 5/8" x 12" x 36" dimensions until later on in the investigation as explained below.

WELDING DETAILS.

COUPONS A and B.

Stress-relieved at 1150°F.

No welding.

PLATES A and B.

Annealed at 1650°F.

Groove -- U., 9/32" radius, 7° slope, 1/8" lip.

Electrodes -- Murex "Cresta" (Covered).

First two passes with 3/16" diameter.

Next four passes with 1/4" diameter.

Back chipped followed by two passes of 3/16" diam.

Further treatment --None.

PLATES C to K and N.

Stress - relieved at 1150°F.

Groove -- U., 9/32" radius, 4° slope, 1/8" lip.

Direct Current, Reverse Polarity.

Electrodes -- Murex "Cresta". (Covered).

X-ray photographs taken after welding and before cutting.

PLATES C-1 and C-2.

Welded using HIGH CURRENTS.

Electrodes --

First pass with 3/16" diam., 230 amps., 30 volts.

Second to fifth passes with $\frac{1}{4}$" diam., 380 amps.

32 volts.

Back of joint chipped, followed by two passes of 3/16" dia.

Further treatment -- None.

PLATES D-1 and D-2.

Identical to Plates C-1 and C-2.

Stress-relieved after welding.

PLATES E-1 and E-2.

Welded using LOW CURRENTS.

Electrodes --

First pass with 3/16" dia. 155 amps. 28 volts.

Second to fifth passes with 1/4" dia. 270 amps 30 volts.

Back of joint chipped followed by two layers of 3/16' diam.

Further treatment -- None.

PLATES F-1 and F-2.

Identical to Plates E-1 and E-2.

Stress relieved after welding.

PLATES G-1 and G-2.

Welded using NORMAL CURRENTS.

Electrodes --

First pass with 3/16" dia. 190 amps., 29 volts.

Second to fifth passes, $\frac{1}{4}$" diam., 300 amps., 30 volts.

Back of joint chipped followed by two passes of 3/16" diam.

Further treatment -- None.

PLATES H-1 and H-2.

Identical to Plates G-1 and G-2.

Each layer of deposited metal peened.

PLATES K-1 and K-2.

Welded using SMALL ELECTRODES throughout.

Electrodes - -

Seven layers of 3/16" diam. 230 amps., 29 volts.

Back of joint chipped followed by two layers of 3/16" diameter.

Further treatment -- None.

PLATE N.

Welded using fairly HIGH CURRENTS

Electrodes - -

First pass with 3/16" diam. 225 amps., 29 volts.

Second to fifth passes with $\frac{1}{4}$" diam. 350 amps., 34 volts.

Back of joint chipped and welded with two passes of 3/16" diameter.

Further treatment --None.

Previous to machining, Plates C to K and N were X-rayed and all found to be in first class condition, typical examples of which are shown on a following page.

PROCEDURE OF TESTING.

COUPONS A and B.

The coupons were tested in tension in the 100,000 pound Wicksteed Testing Machine applying the load in increments of 1400 p.s.i. The elongations after each loading were measured with two modified Martens extensometers, placed back and front of the specimen over gauge lengths of eight inches. The yield point was determined by the "drop of the beam" method, and the ultimate stress calculated on the basis of the original cross-section.

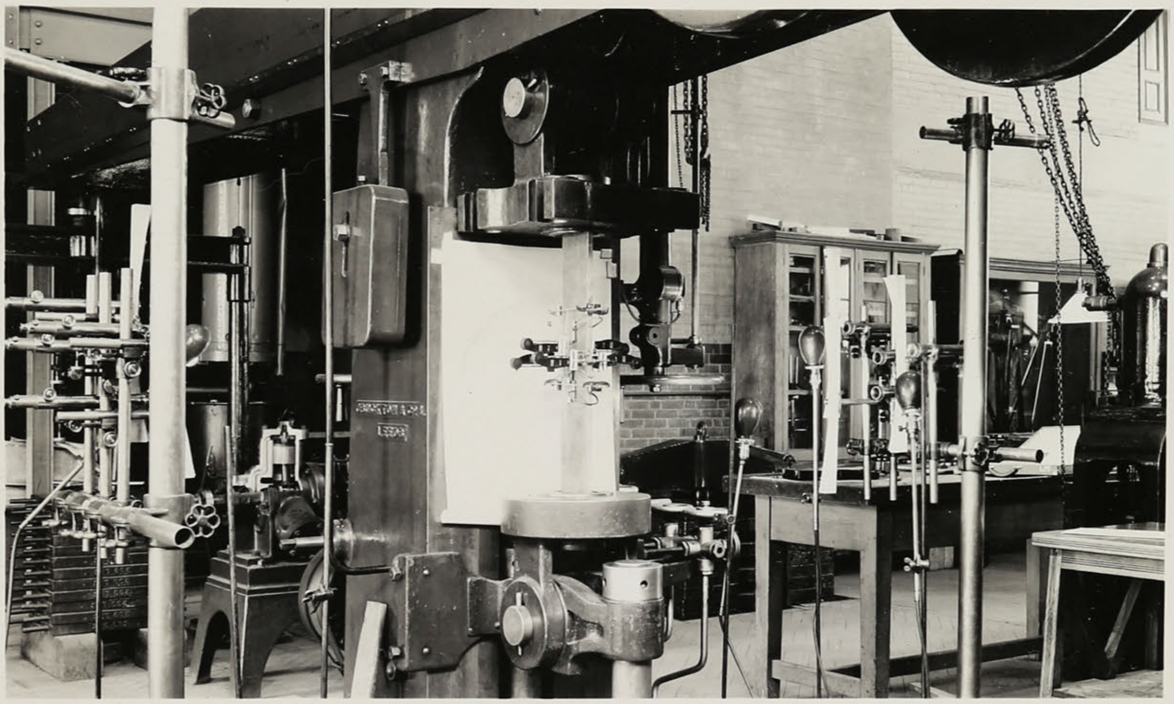
PLATES A and B.

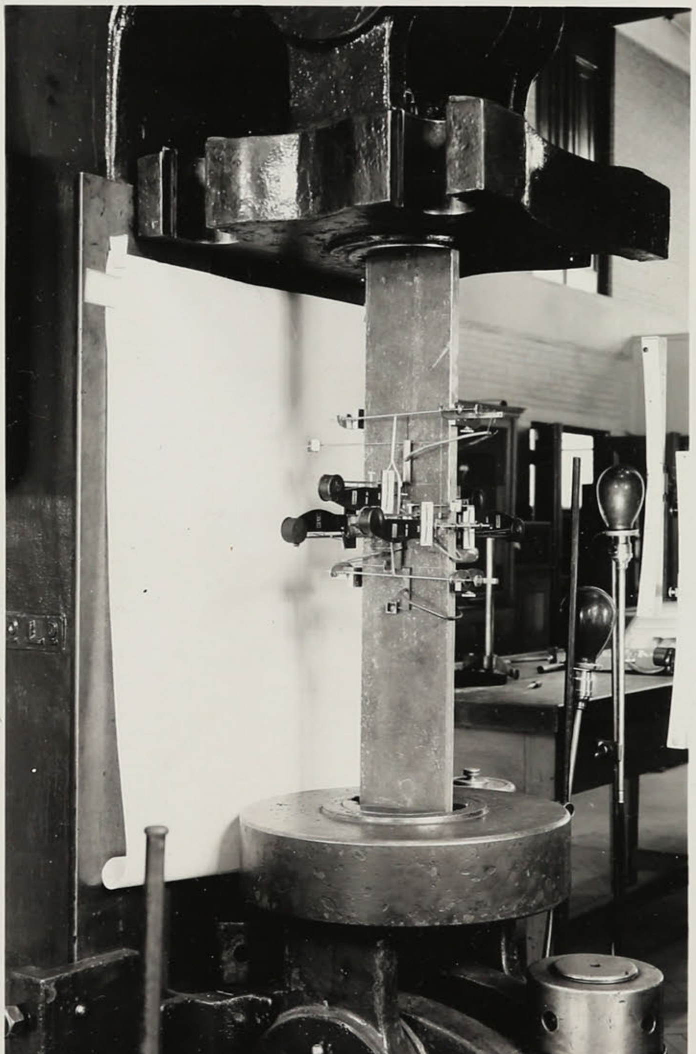
These two plates were tested in the 200,000 pound Wicksteed Testing Machine applying the load in increments of 800 p.s.i. The stress-strain relations of various parts of the plate about the joint were investigated by three pair of modified Martens extensometers and two pair of Huggenberger Tensometers. The arrangement of the extensometers is shown in Figure 1.

This arrangement of the extensometers was so chosen to indicate any marked effects of the residual stresses as the load was applied to the specimen. The concave and convex sides of the plates were identified by the letters "a" and "b", respectively. Each position of the extensometers was referenced by a Roman Numeral, the side being identified by the letter after this Numeral. The side pairs of Huggenbergers were intended to indicate the load carrying characteristics of the joint itself, any eccentricity of loading, as well as the effect of the residual stresses on the edges of the specimen. The pairs of extensometers on either side of the centre line (111 and 1V) served somewhat the same purposes in their respective positions. The pair of extensometers (V) along the centre line of the plate was to indicate the net effects of any local residual stresses which might have existed within its length. The extensometers (Vl) were so placed in an attempt to study the stress-strain characteristics of the plate alone. Admittedly, this set should have been balanced by another on the other side of the centre line, but as originally planned these plates were intended to serve as pilots for the remainder of the investigation.

PLATES C to K.

The procedure of testing of these plates was similar to that used for Plates A and B. The most important change was the rearrangement of the extensometers. Compare Figures 1 and 3. In dividing the eight inch centre line distance up into three two inch distances and two one inch, it was hoped to localize any effects of residual stresses and at the same time have sufficient data to calculate their effects over the total length. It was further hoped that corresponding pairs of distances on either side of the weld would reveal the same results. The accompanying photographs on the next page show the complete set-up.





The yield point reported for these plates was determined after an increment of load was applied and at which the beam of the testing machine immediately began to drop. Previous to this load it was often necessary to wait for twenty or so minutes to allow the extensometers to come to rest and during the time to relevel the beam. This creep was allowed to dissipate itself before continuing with another increment of load. However, these phenomena only occurred after the stress had reached 20,000 p.s.i. so that the procedure was not so time-consuming as it, at first, may appear.

The percentage elongations reported were measured across the fracture between any two gauge lines which were originally eight inches apart. Following this method, it was possible on only one plate (F-2) to include the weld metal in the percentage. No subtraction was made for the distance on the centre line between the ragged edges of the fracture.

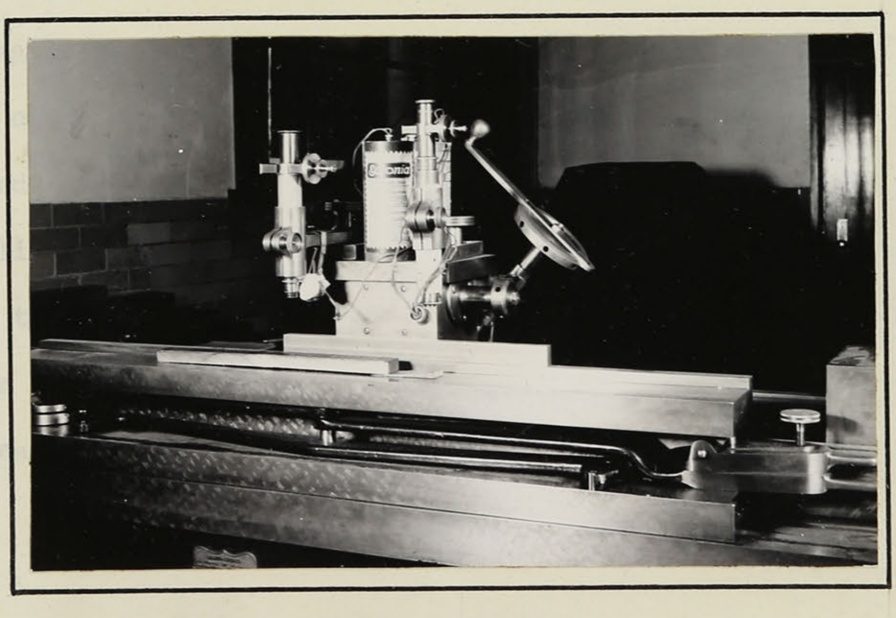
PLATE N.

The work done on this plate was the making of a study of the distribution and magnitudes of the residual stresses perpendicular to the weld, by the subdivision method. The basic principle of the method was to find, very accurately, the change in a known distance on a welded plate caused by stress-relieving. Any change in length was converted into a stress value through Young's Modulus and Hooke's Law, and considered as that produced in the plate by the welding process and known as the Residual Stress. To stress-relieve the plate, it was cut up into a number of narrow strips parallel to the known distances, which, in this case, was perpendicular to the weld. An increase in the distance was indicative of a compressive residual stress and a decrease, of a tensile. Incidentally, the stress reported is an average over the gauge length and considered as being at the centre of that distance.

After machining off the superfluous weld metal a gridwork of polished spots was laid out on the plate. These spots were so placed that on measuring the distance between scribed lines on them which were parallel to the weld, the accuracy of the measurement would yield results comparable to the work involved and at the same time agree with distances laid off on a standard bar within the limit of movement of the micrometers of the measuring device.

The spots were polished with a fine emery wheel in such a direction that the scratches left by the abrasives would not be mistaken for the scribed lines. These lines were drawn with a glass-hard needle, sharpened to a wedge-shaped point on an oil stone, using a straight-edge for a guide. After scribing the plate was allowed to remain in the Constant Temperature Room of the Geodetic Laboratory for forty-eight hours before starting to measure any distances.

For measuring the distances between scribe-lines the Linear Comparator was used. Essentially, this consists of two microscope micrometers mounted on a movable block as shown in the accompanying photograph.



The two microscopes are clamped to the block and for any set of measurements the distances between the fixed cross-hairs of the micrometer part of them remains the same. With one of these microscopes focussed on the scribe-line of the plate and the other on the graduations of a standard bar placed parallel to the distance to be measured, readings are taken with both micrometers, referencing the two points to the fixed cross-hairs. Repeating this procedure at another scribe-line and graduation the difference between the two sets gives the amount to be added to or subtracted from the known distance between the graduations.

The distances on the plate were so laid out and with such accuracy that they were readily comparable to a standard bar marked off in tenths of feet, the limit of motion in the micrometers being the required accuracy. In leveling up the plate when set in the Comparator it was necessary to rely on the focus of the microscopes, that is, as long as two points, about six inches apart, were in focus in the microscope they were considered as being at the same level. This method had to be relied on due to the unevenness and warpage of the plate which precluded the use of an ordinary level.

With the standard bar and plate in place and focus the measurement of the distances between scribe lines was begun. The procedure was to take four readings with the micrometer on the standard bar and then four readings with the one focussed on the plate. In each set of four readings no reading was allowed to differ from the others by more than two divisions of the micrometer drum. Having one scribed line referenced to the standard bar, the block of the Comparator was moved along until the next scribed line and graduation were in the field of view of the microscopes, at which time the procedure of readings was repeated. Four distances bounded by five points could be measured at one focussing of the microscopes. Each set of four readings was repeated another three times so that for the five points eighty readings were taken on the plate and eighty on the bar. This procedure was followed for each distance requiring about six thousand readings before relief and another six after relief.

Each scribe line was identified in a co-ordinate system by a figure and a letter. See Figure 4. The rows of polished spots perpendicular to the weld were called strips, each strip being designated by a number. By numbering Side A from left to right with Figures 1, 2, etc., to 9 and Side B similarly, from right to left, each strip was designated by a single number. The rows parallel to the weld were lettered A, B, C and D, on one side of the weld, and a, b, c and d, on the other side, the D or d being farthest from the weld. The line along the weld was called N - the plate letter.

Thus, as shown in Figure 4 the plate consisted of seven strips of equal width (1.20 inches) and two side strips (1.80 inches in width). After stress-relieving the plate these strips were only about 1.1 inches and 1.75 inches, respectively, due to the saw cuttings.

The set of measurements taken before stress-relief was on the full sized plate 5/8" x 12" x 36". To save time in cutting the strips, the ends of the plate were cut off leaving a plate 5/8" x 12" x 14". Next the edge strips were cut off, followed by alternate ones from each side towards the middle. In all the sawing there was only a tendency for the saw to bind when removing the edge strips. This was overcome by inserting wedges in the saw-cut as the blade advanced.

DISCUSSION OF RESULTS.

Unwelded plate metal upon being loaded shows a sudden elongation without an increase in load, the value of the stress at which this phenomenon takes place being known as the Yield Point. Welded and unwelded plate metal show duplicatable ratios between the stress and strain up to a stress known as the Elastic Limit, but upon removing the load from specimens loaded above this point a permanent set will be found in the metal. The stress at which this occurs is known to be considerably lower for welded than for unwelded specimens, and the difference between the stresses of the Elastic Limit of the welded plate and the yield point of the unwelded plate is the effect of welding referred to as the Residual Stress. Moreover, the yield point of a welded plate is sometimes difficult to detect due to the creep which appears after the elastic limit has been exceeded. It is upon the above basis that the residual stresses for Plates A to K were computed.

The procedure of cutting each pair of specimens from a welded plate obviously destroyed the residual stress system, and the values reported are to be understood with this stipulation. The procedure would have removed the high compressive stresses set up along the edges of the as-welded plate, values of which will be found in the results for Plate N.

Following is a discussion of the results obtained for the specimens with special reference to the stress-strain curves shown in Figures 5 to 21 inclusive.

COUPONS A & B.

The results found for the yield points of the coupons were rather low for the type of plate and being the values to which the rest of the investigation was compared naturally influenced the magnitude of the residual stresses. The moduli of elasticity and ultimate strengths were normal values and served as reasonable figures for comparisons.

PLATES A & B.

These plates were not used in the general interpretation of results along with Plates C to K since the data obtained for them were not of the same order. The differences were probably due to the extra amount of machining required in their preparation,together with the fact that they were not clamped during welding. The clamping of plates during the making of a butt-joint may well be expected to increase the residual stresses; furthermore, the machining of the surface should remove any skin stresses, but, the results of these plates did not substantiate these expectations. In defence of the results when compared to Plates C to K it is to be noted that both A and B were separate welding jobs and not cut after from the same plate as were Plates C to K.

During the testing of Plate A the load was dropped off from a stress of 19200 p.s.i. and showed a permanent set to have taken place in the specimen although there was no change in the modulus. The plate metal was found to have a larger set than the weld.

Fluctuating the load on Plate B at 12400 p.s.i. indicated the possibility of a permanent set. From 20600 p.s.i. a permanent set and an increase in the modulus of elasticity from 25×10^6 p.s.i. to 28.7×10^6 p.s.i. were found. The joint showed the same values as the plate.

PLATES C - HIGH CURRENTS.

The results of these plates were in good agreement both indicating the maximum residual stresses in the vicinity of extensometers 1V, the average value being 11600. Notice is drawn to the remarkably low value at extensometer V (across the junction of the plate and weld metals) also how the average values of lV and V agree with Vl. A fluctuation of the load at 9800 p.s.i. on Plate C-2 showed that no permanent set nor change in stiffness had taken place.

PLATES D. HIGH CURRENTS - STRESS RELIEVED.

These plates showed very conclusively the beneficial effects to be obtained by stress-relieving. Plate D-1 acted at the Yield Point very much like an ordinary unwelded specimen and required the immediate removal of the tensometers. The residual stresses were found to be below 3000 p.s.i. which magnitude would put them in the same class as a rolling stress.

PLATES E. - LOW CURRENT.

The residual stress results for these plates were not in such close agreement as most of the pairs but they both indicate a similar distribution. Again, extensometers lV revealed the maximum stress of 13800 p.s.i. as an average value between the plates. A probable explanation for the difference in the results was the continued slippage of the plates in the wedge-grips of the testing machine. After each slip it was necessary to return to the last load for which the extensometer readings were known and retake them, the difference in the two sets to be applied as a correction. This procedure was rather doubtful after passing the Elastic Limit, due both to the energy load from the testing machine and the dropping off of the load to regain continuity in the strain readings where plastic elongation may have taken place.

PLATES F - LOW CURRENTS - STRESS-RELIEVED.

Besides Plates E, Plate F-1 was the only other in which slippage in the grips occurred. During the loading of this plate it was necessary to retake extensometer readings after every second or third increment. The stress-strain curves plotted quite readily but slippage probably accounts for the detached appearance of the curve for extensometers V. Again the beneficial effects of stress-relieving were quite apparent though not to the same degree as shown by Plates D.

Plate F-2 broke at the weld with a dull third. Breaking here was probably due to it being 0.03 inches thinner than the plate. Impurities in the weld were quite evident having pulled away from the surrounding metal.

PLATES G. - NORMAL CURRENTS.

The stress strain curves for the extensometers lV and V on Plate G-2 revealed the effects of a local disturbance. Extensometer lV recorded a rather high residual stress of 19000 p.s.i. but which, on being averaged out with comparable values, yields a value in accordance with those of the rest of the series.

Fluctuating the load on Plate G-1 at 20400 p.s.i. indicated both a permanent set and a small increase in the modulus (29.9×10^6 p.s.i. to 30.4×10^6 p.s.i.) over the eight inch gauge distance. There was no change in the modulus for the weld metal but the set was greater here than in the plate.

Plate G-2 showed somewhat of a hysteresis effect when the load was dropped but sufficient readings were not taken.

PLATES H - NORMAL CURRENTS - PEENED.

A comparison of the results for this pair with that of Plates G revealed that peening was beneficial. A rather interesting feature of this pair was the finding of Elastic Limits with the same value for so many positions of the extensometers. The reverse appearance of the stress-strain curves of lV and V for Plate H-1 indicated a plastic yielding outside their boundaries, mainly in Vl. This was apparent in other plates where the curves are not completed although the relation of stress to strain was more often a straight line than a reverse curve.

PLATES K - SMALL ELECTRODES.

The procedure of welding used in making up the joints on these plates was the most productive of residual stresses. Extensometer lV on Plate K-2 showed a rather queer stress-strain relation from the start and after passing the elastic limit displayed plastic yielding, discernable by the curve for Extensometer V. The residual stresses in the plates were in the neighborhood of 13000 p.s.i.

A fluctuation of the load on K-2 at 19300 p.s.i. revealed a permanent set in both the plate and weld metals, the latter being the greater. The moduli of elasticity were substantially the same at 30.0 x 10^6 p.s.i. and 30.4 x 10^6 p.s.i., respectively, a small increase over the original values of 29.0 x 10^6 p.s.i. The data showed the greatest set at lV but the oddness of the stress-strain relations precluded it from consideration.

From the graphs shown in Figures 5 to 21 the values of the Elastic Limits and Moduli of Elasticity are taken and the average for each pair of plates tabulated in the table below. The averages between the values for lV and V are inserted to show the relation between those found by localized determinations as compared with those over the same total distance by a single evaluation, namely, Vl. The averages of lV, V and Vl are also given since they represented comparable parts of the specimen. The values under the column headed lll to Vll indicate the combined effects of the localized determinations.

Residual stresses calculated for positions of the extensometers involving some weld metal by using the value of the Yield Point for the plate metal may be open to some controversy, but it is doubtful whether a more correct value would have been obtained by using that of the weld metal since the distances covered were a combination of both metals.

Average values of the Elastic Limit, Residual Stress and Modulus of Elasticity Determined from Corresponding Extensometer Readings of Related Plates.

Plates		1&11	111&1V	V1	V
A & B	E.L.	14900	18900	14300	14600
	R.S.	14500	10500	15100	14800
	E.	28.3	27.3	27.0	27.3

Plates		1&11	111	1V	V	V1	V11	111&V11	1V&V	1V,V&V1	111toV11.
C	E.L.	18300	20800	17800	26000	20800	19800	20300	21900	21400	18300
	R.S.	11100	8600	11600	3400	6000	9600	9100	7500	8000	11100
	E.	29.2	29.8	30.0	29.5	29.5	29.8	29.8	29.7	29.6	29.6
D	E.L.	26600x	-	26600x	26600x	26600x	-	-	26600x	26600x	27300
	R.S.	2800	-	2800	2800	2800	-	-	2800	2800	2100
	E.	29.9	29.5	29.3	27.3	3.12	28.9	29.2	28.3	29.7	29.4
E	E.L.	19600	24000	15600	26000x	17200	21000	22500	20800	19000	20000
	R.S.	9800	5400	13800	3400	12200	8400	6900	8600	10400	9400
	E.	30.2	30.1	28.6	30.1	30.0	30.4	30.2	29.3	29.6	30.1
F	E.L.	23000x	24800x	22800x	22400	22000x	24800x	24800x	22600	22300	23000
	R.S.	6400	4600	6600	7000	7400	4600	4600	6800	7100	6400
	E.	29.4	30.7	29.9	30.1	29.6	30.7	30.7	30.0	29.8	30.7
G	E.L.	18000	21200x	15200	21000x	17100	20000x	20600x	18100	17600	20000
	R.S.	11400	8200	14200	8400	12300	9400	8800	11300	11800	9400
	E.	29.3	30.4	29.6	26.3	29.6	31.0	30.7	28.0	28.8	29.1
H	E.L.	19500	20000x	19500	19000x	19500	19000x	19500x	19300	19400	19500
	R.S.	9900	9400	9900	10400	9900	10400	9900	10100	10000	9900
	E.	30.0	30.0	28.5	29.2	29.6	30.0	30.0	28.9	29.3	29.6
K	E.L.	15700	16500	16500x	-	16500	18500	17500	-	16500x	16500
	R.S.	13700	12900	12900	-	12900	10900	11900	-	12900	12900
	E.	29.2	29.6	29.4	29.6	29.6	30.0	29.8	29.5	29.6	29.6

Values marked x represent those for only one of the pair of plates. In the case of the values for the Elastic Limit for the other plate the curve remained a straight line, generally, indicating the increased rate of elongation to have taken place outside the bounds of the extensometers under consideration.

In order to make a comparison between the magnitude of the residual stresses produced by the various procedures, Figure 22 was drawn up. It is a graphical representation of the average residual stresses for each pair of plates at the various positions of comparable extensometers. The lines joining the points and the line at 10000 p.s.i. are in no way necessary other than as aids to the representation.

A study of the figure reveals that the greatest residual stresses occurred when small electrodes were used exclusively in the making of the joints (Plates K). The values found were in the neighborhood of 13000 p.s.i. for all the positions surveyed.

Normal Currents (Plates G) produced the residual stresses of the next highest magnitude of about 11000 p.s.i. The peak appears to have been in the distance, one to two inches from the centre line of the weld.

A more or less uniform distribution is indicated in Plates C, made up with high currents, of magnitudes in the vicinity of 10500 p.s.i.

Plates made up with low currents (E) and normal currents peened after each layer during welding (H) showed somewhat similar values of around 10000 p.s.i. Plates E showed a high stress (averaged 13800 p.s.i.) at a distance of one to two inches from the centre line of the weld.

The figure shows, very conclusively, the beneficial effects of stress-relieving on the residual stress magnitudes and distributions. Plates D showed a maximum value of 2800 p.s.i. throughout, while Plates F showed a peak of 7100 p.s.i. over a distance of four inches across the joint.

The figure further shows that the greatest residual stresses occurred, not at the junction of the plate and weld metals, but in the distance of one to two inches from the centre line of the weld. At the junction, surveyed by extensometer V, there seems to have been comparatively small residual stresses, except in the case of the averages for Plates H. Also the residual stresses are almost identical on both the eight inch gauge length and the one inch across the weld, for all the plates.

Mechanical Properties and Residual Stresses (Continued)

PLATES	Y.P. (p.s.i.)	U.S. (p.s.i.)	% Elong. in 8 ins.	% Reduc. in area	Redidual 111toV11	Stresses 1 & 11
A & B	25700	51200	30.6	46.0	14800(V)	14500
C	30400 x	54000	42.0	46.0	11100	11100
D	29800	54900	-	53.5	2100	2800
E	30100	53900	41.7	50.4	9400	9800
F	30000	54000	-	-	6400	6400
G	30000	54800	42.2	51.8	9400	11400
H	29600	54800	40.0	56.0	9900	9900
K	30000 x	54900	38.2	51.5	12900	13700
Coupons	29400	55700	34.1	55.0	0	-

x One plate only.

From an examination of the yield points and ultimate strengths presented in the above table it is quite apparent that variations in welding procedures had no effect upon them. The slight reduction in both values for all the plates is really of no importance. There does seem to be somewhat of an increase in the percentage elongation in eight inches and a decrease in the percentage reduction of area. The different magnitudes of the residual stresses have not influenced the above mechanical properties in any way.

Plate F-2 having broken at the weld showed values for the percentage elongation in 8 inches of 21.0%, and a percentage reduction in area of 22.6% indicating that the usual measure of ductility does not apply. Incidentally, the values for the other plates do not include the weld metal but one end of the measurement was influenced by the columnar effect of the weld (See photographs of fractured plates).

PLATE N.

Before proceeding to a discussion of the results, consideration will be given to the probable error of the residual stresses to be reported.

From the procedure used of four sets of four readings in the same direction at every scribed line on both the plate and the bar before and after relief, the probable error in any stress was below 1500 p.s.i. over the gauge length of 1.2 inches except for strip 4 on Side B where it amounted to as high as 1700 p.s.i. before relief and 850 p.s.i. after relief. The 850 p.s.i. was a typical value for the rest of the strips after relief which were chosen at random and the errors calculated.

On the following page are the results as calculated for Sides A and B and the average of the two sides. The value of 30.3×10^6 p.s.i., (coupon value) for Young's Modulus, was used in the calculating of the stresses on the gauge distances involving plate metal only. The average of the results from extensometers 1 and 11 for Plates C to K of Young's Modulus was used for distances combining both weld and plate metal, namely, 28.8×10^6 p.s.i.

The magnitudes and distribution of the residual stresses are perhaps more easily grasped by reference to the Contour Plans of them shown in Figures 25, 26 and 27. From these it is seen that there were four zones of concentrations, namely, the two edges of the plate at the weld and the two central portions of the plate back about two inches from the centre-line of the weld. The two edges showed higher compressive stresses than were present in the central zones of tension; due to the narrow limits in which the former were present because for equilibrium the tensile forces must balance the compressive. Also the stresses in

RESIDUAL STRESSES
PLATE N.

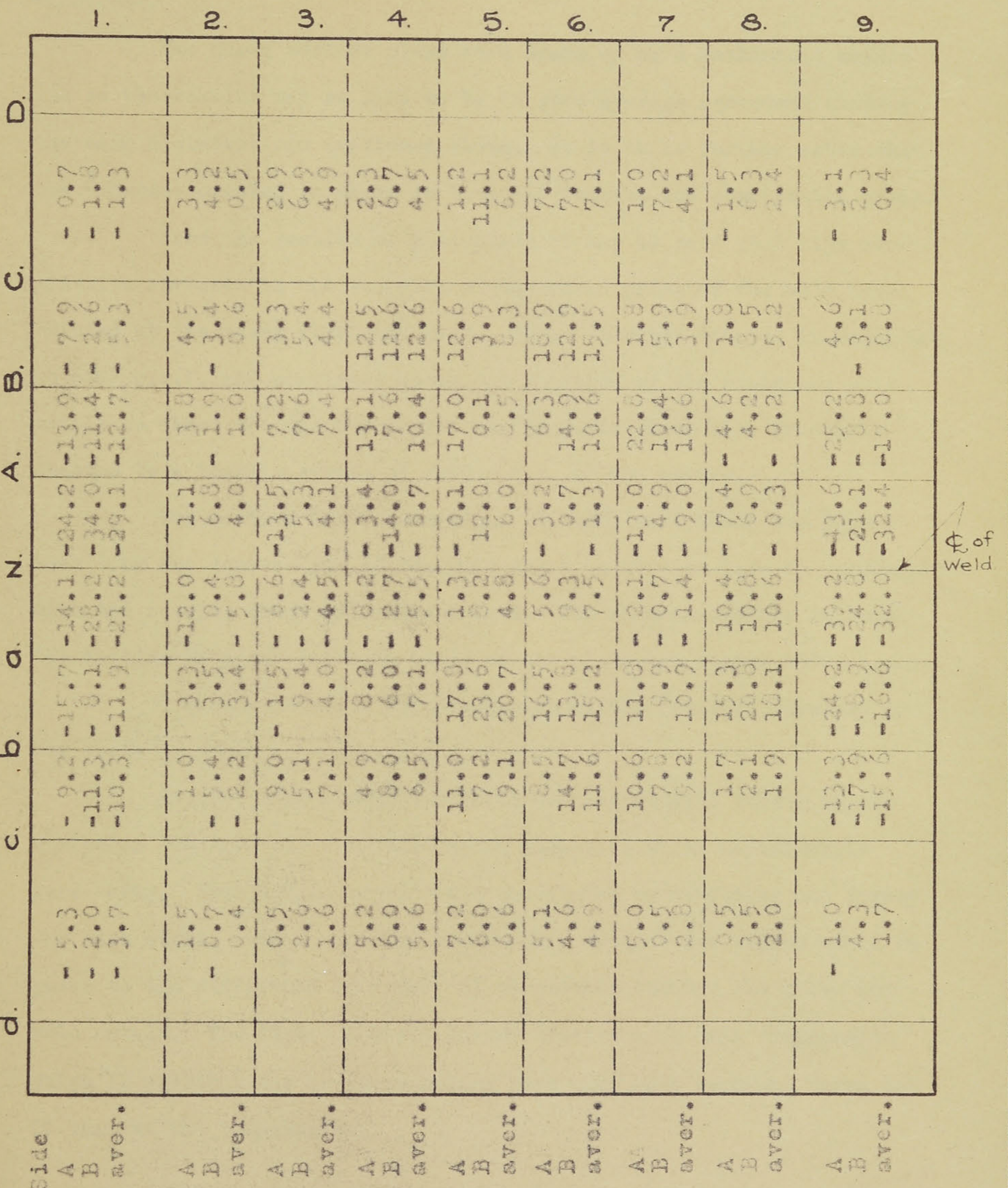


FIG.

Strip 9 of Side A were considerably higher than those in Strip 1. The appearance of the joint indicated that the former was the finishing edge of the last bead on top, showing about one and half inches from the last electrode.

The three contour plans were drawn up by a mechanical method and so the results may be said to be in good average agreement showing the main distributions mentioned above. It is to be further noted that the stresses existed in peaks in both the tension and compression areas.

From the results of this plate it may be said that high compressive stresses in the vicinity of the yield point of the weld metal existed at the edges about the weld. These stresses dropped in magnitude to 5000 p.s.i. and continued along the junction of the plate and weld metals to about the quarter points of the plate where they gradually changed to a tensile stress of 5000 p.s.i. at the centre.

The maximum tensile residual stresses were about two inches back from the centre line of the weld which is more or less in agreement with the results found in Plates C to K. The maximum average value of the tension stresses for both sides of the plate ran around 20000 p.s.i.

A cross-sectional representation of the residual stresses in the plate is given in Figure 23.

Figure 24 is a representation of the residual forces in the strips as they existed over the twelve inches in which measurements were taken. The plotted values were calculated by summating the forces for each strip, rather than the recoveries, so that due weight would be given to the difference in moduli of elasticity between the plate and weld metals. The figure shows a larger tension area than compression which is probably due to there having been many more readings taken on it than on the compression.

CONCLUSIONS FROM THIS INVESTIGATION.

(1) Residual stresses of magnitudes from 10000 p.s.i. to 15000 p.s.i. may be expected to transverse to joints made up under the welding procedures investigated when stress-relieved by the removal of the edges of the plate.

(2) Stress-relieving by heating in a gas furnace at 1150°F may be expected to reduce the residual stresses to below 7500 p.s.i.

(3) Residual Stresses have their greatest values in tension at a distance of one to two inches away from the centre line of the weld.

(4) Residual stresses have no detrimental effects upon the ductility of the plate metal (where percentage elongation and reduction of area are considered as the measure).

(5) Residual stresses have no effect upon the ultimate strength of the plate.

(6) The stiffness of the joint is substantially the same as the plate. (Modulus of Elasticity).

(7) The ductility of the weld metal is much less than that of the base metal.

(8) Nothing can be concluded from these results as to where the greatest permanent set occurred due to stresses in the neighborhood of the elastic limit though they show the weld metal as the most likely.

(9) Literature dealing with the stresses perpendicular to butt joints relate to various distributions, the consensus of opinion being that they may be either tension or compression with locations dependent upon many factors involving the geometry of the plate and joint, procedure, speed of welding and items of like nature. The stresses found in this investigation were fairly symmetrical and so might be said to be representative of the type of specimen. (Plate N).

(10) A welded butt-joint in which a permanent set has been introduced by overstrain will behave as ordinary unwelded metal up to stresses required to cause the permanent set.

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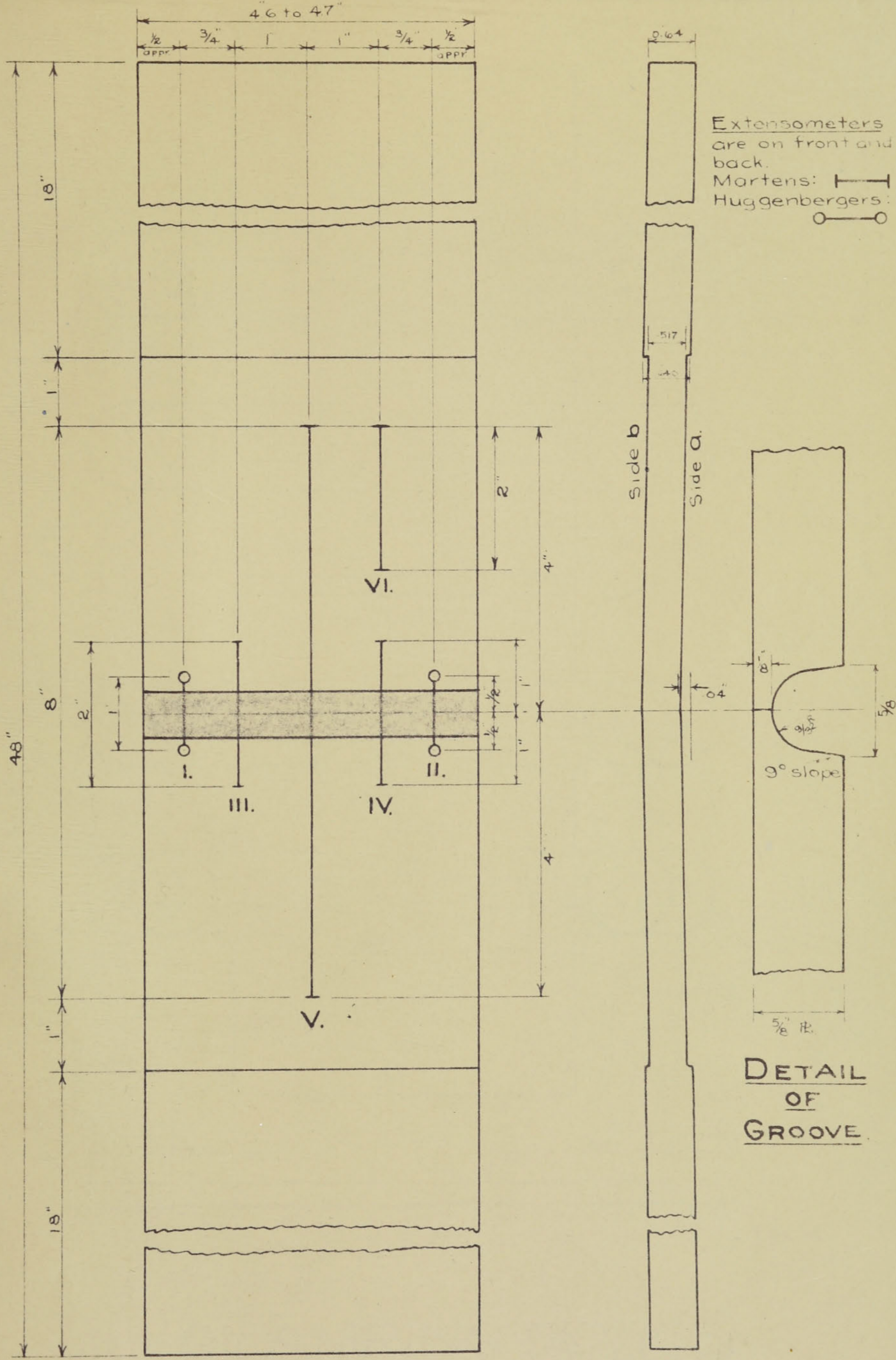
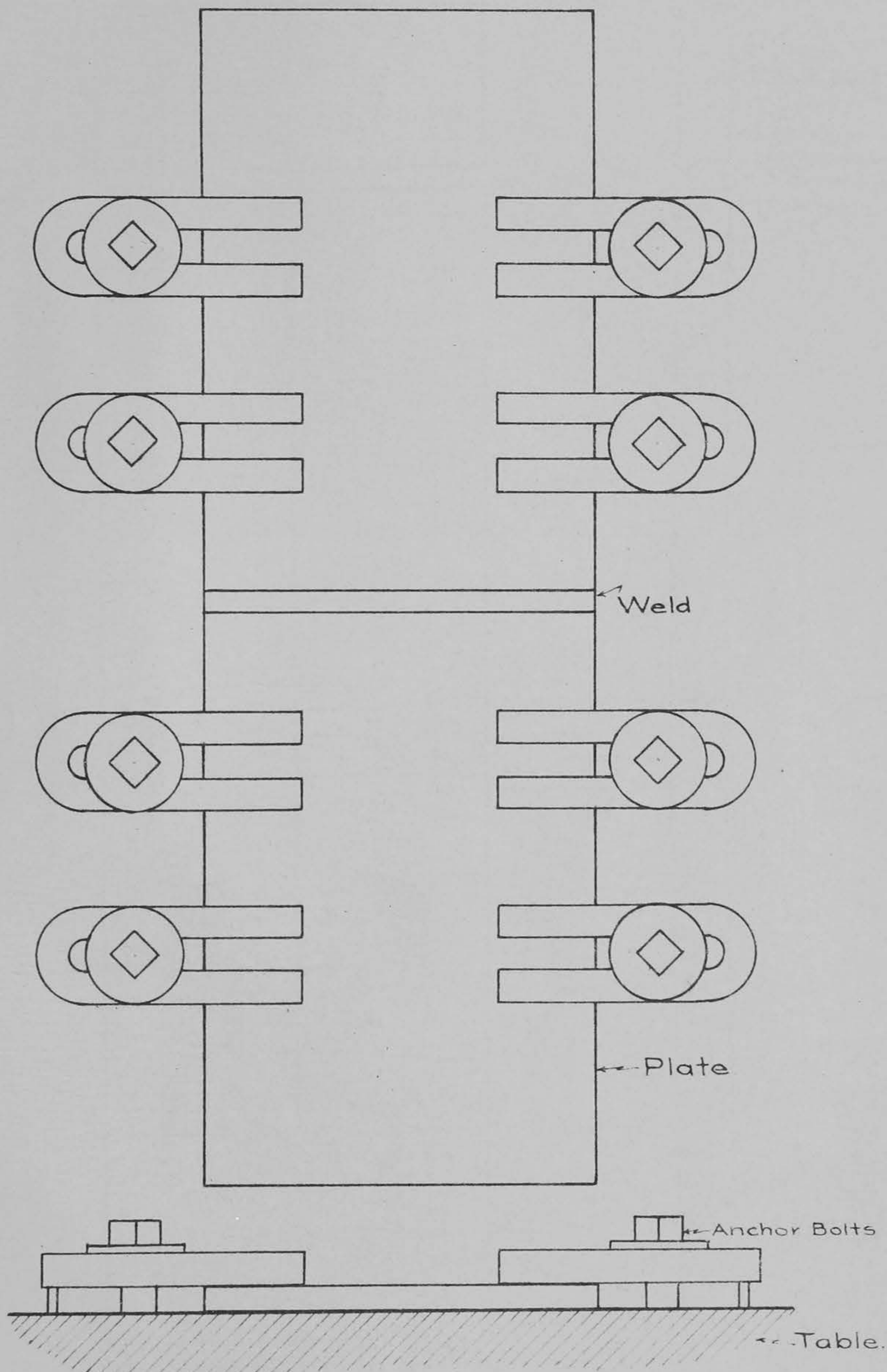


DETAILS OF PLATES A AND B.

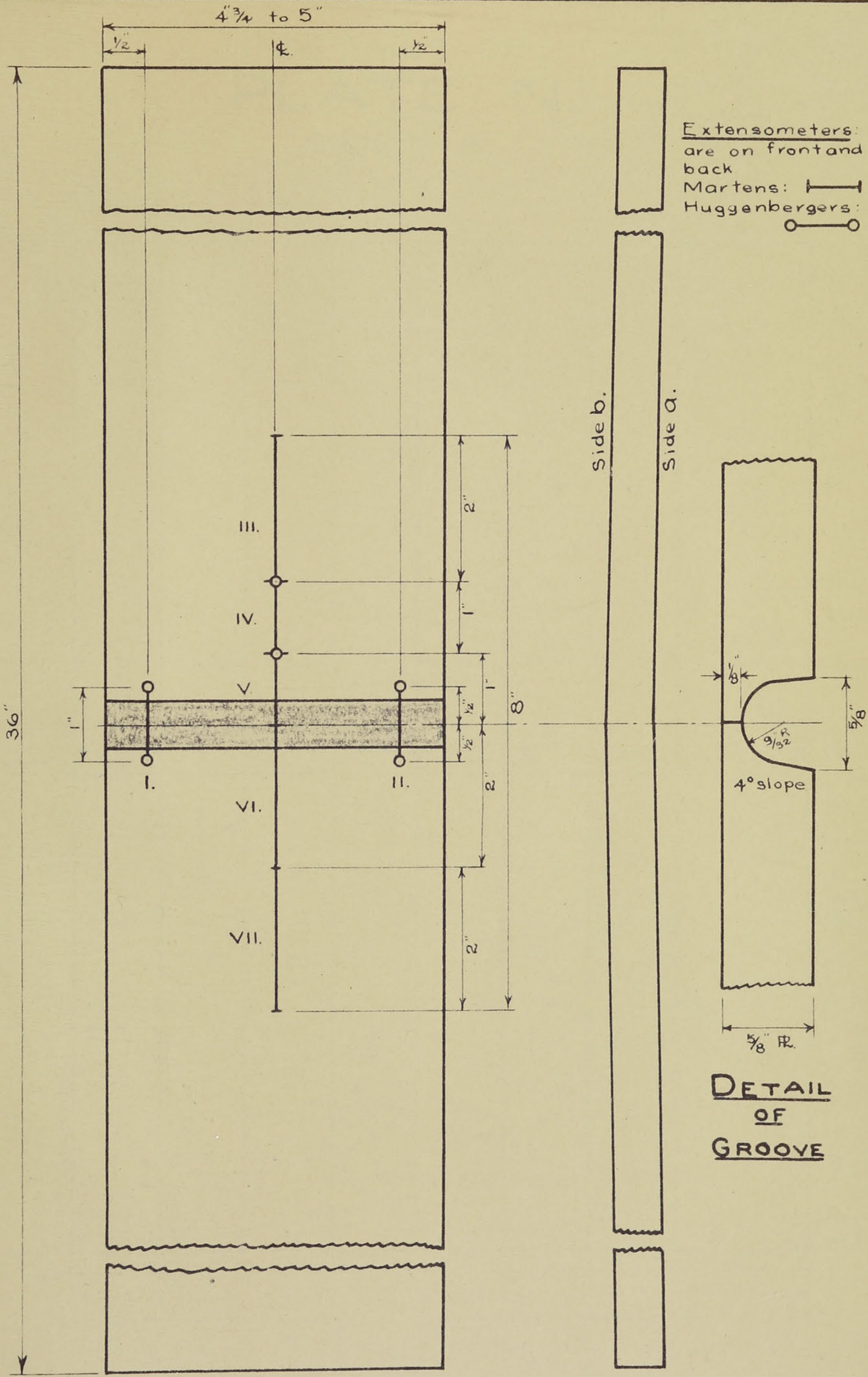
Fig I.



CLAMPING DEVICE

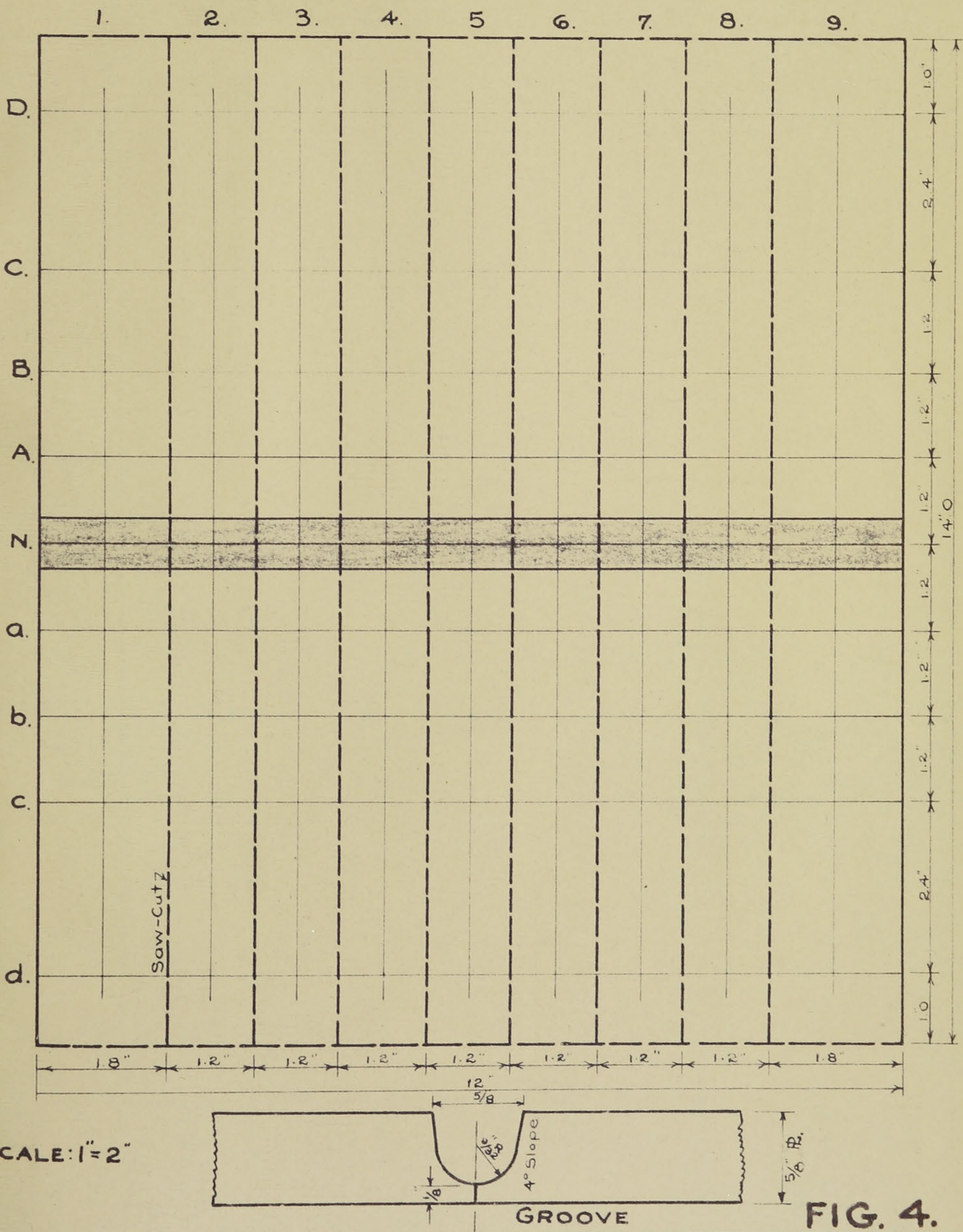
PLATES C. TO N.

Fig. 2.



DETAILS OF PLATES C. TO K. Fig. 3.

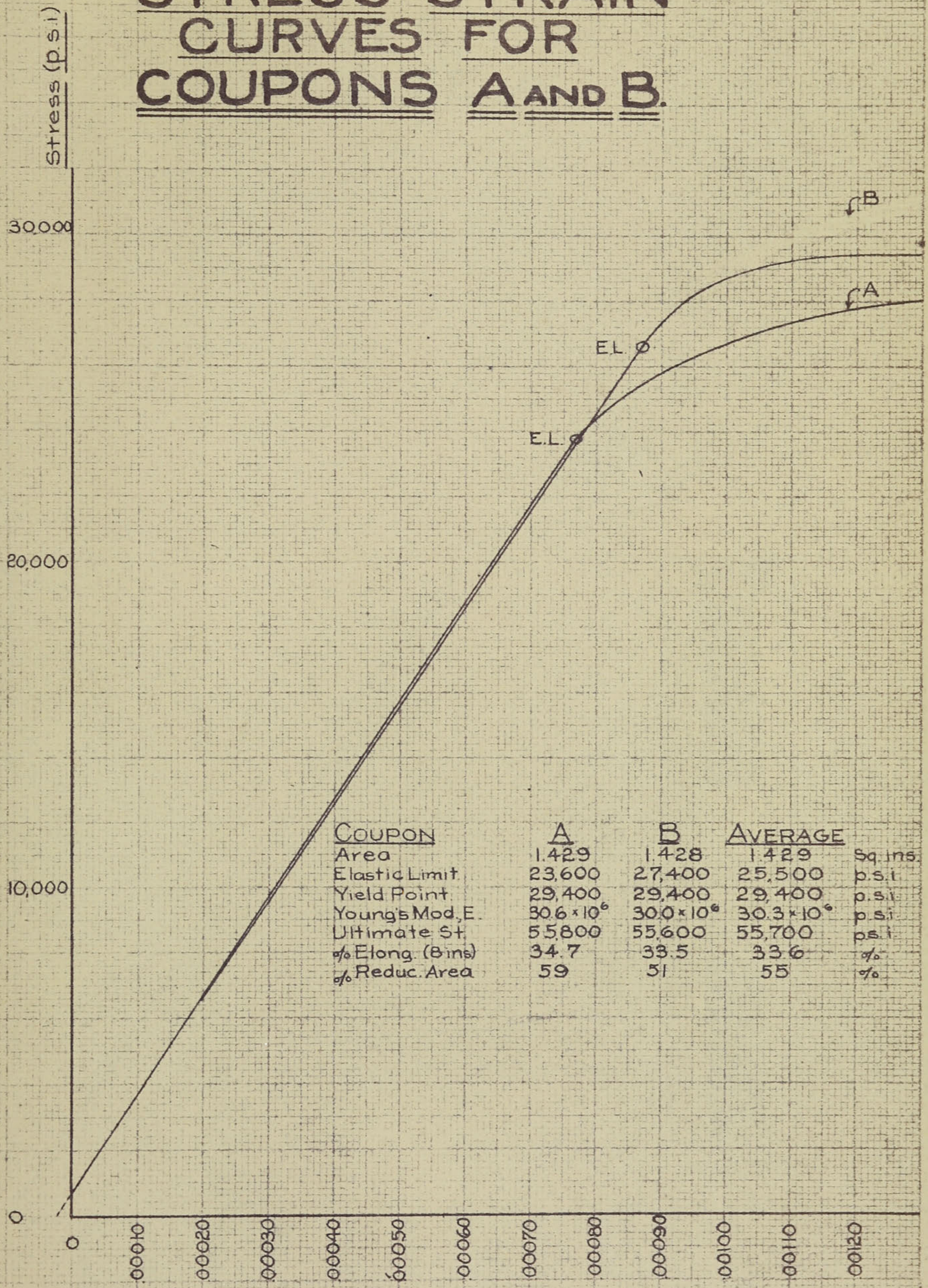
DETAILS OF
PLATE N.
SIDE A.



SCALE: 1"=2"

FIG. 4.

STRESS-STRAIN CURVES FOR COUPONS A AND B.

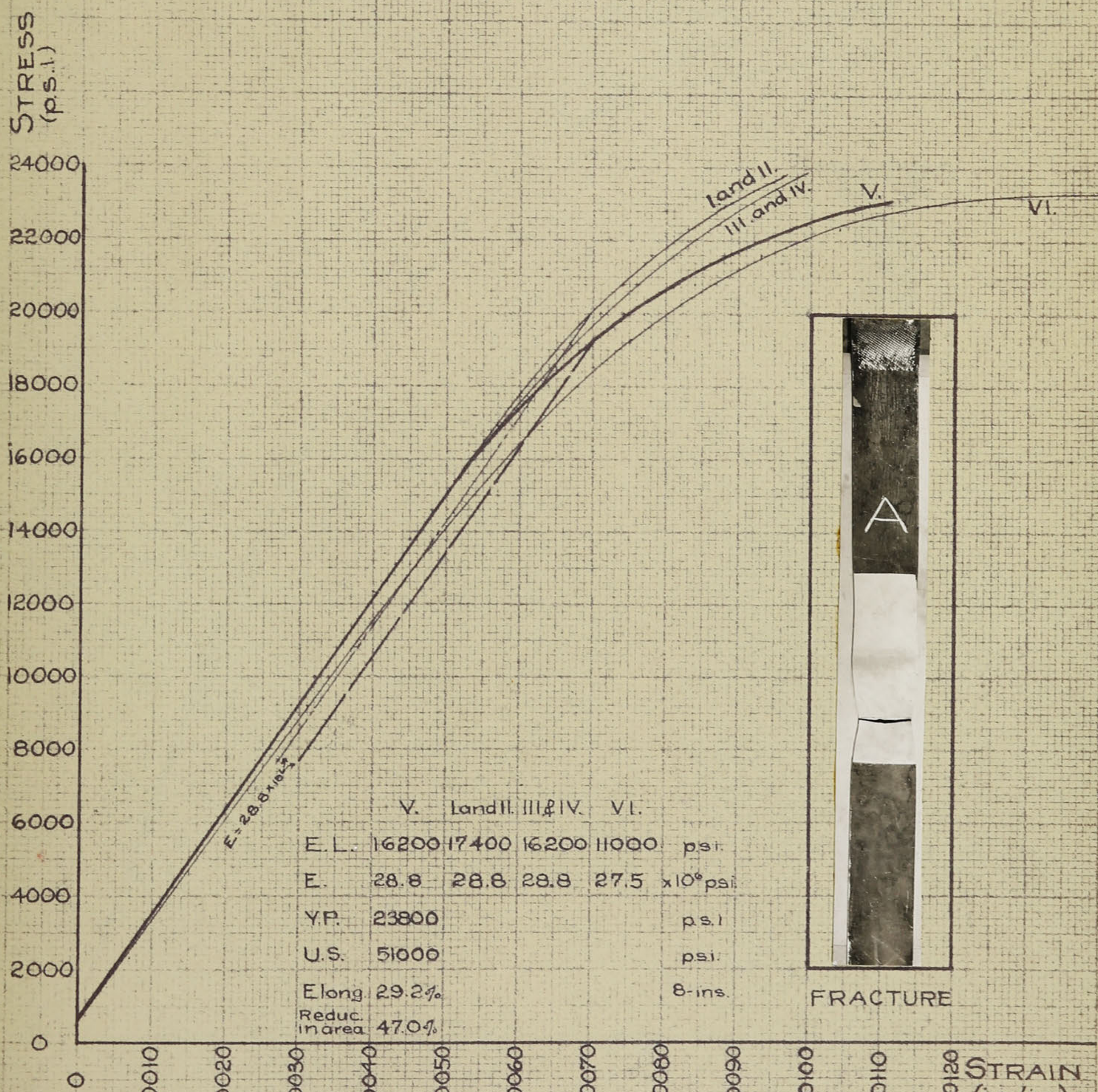


COUPON	A	B	AVERAGE	
Area	1.429	1.428	1.429	Sq. ins.
Elastic Limit	23,600	27,400	25,500	p.s.i
Yield Point	29,400	29,400	29,400	p.s.i
Young's Mod., E.	30.6×10^6	30.0×10^6	30.3×10^6	p.s.i
Ultimate St.	55,800	55,600	55,700	p.s.i
% Elong. (8 ins)	34.7	33.5	33.6	%
% Reduc. Area	59	51	55	%

Add .00002 to all unit strains to correct for initial load.

FIG. 5

STRESS-STRAIN CURVES FOR PLATE A.

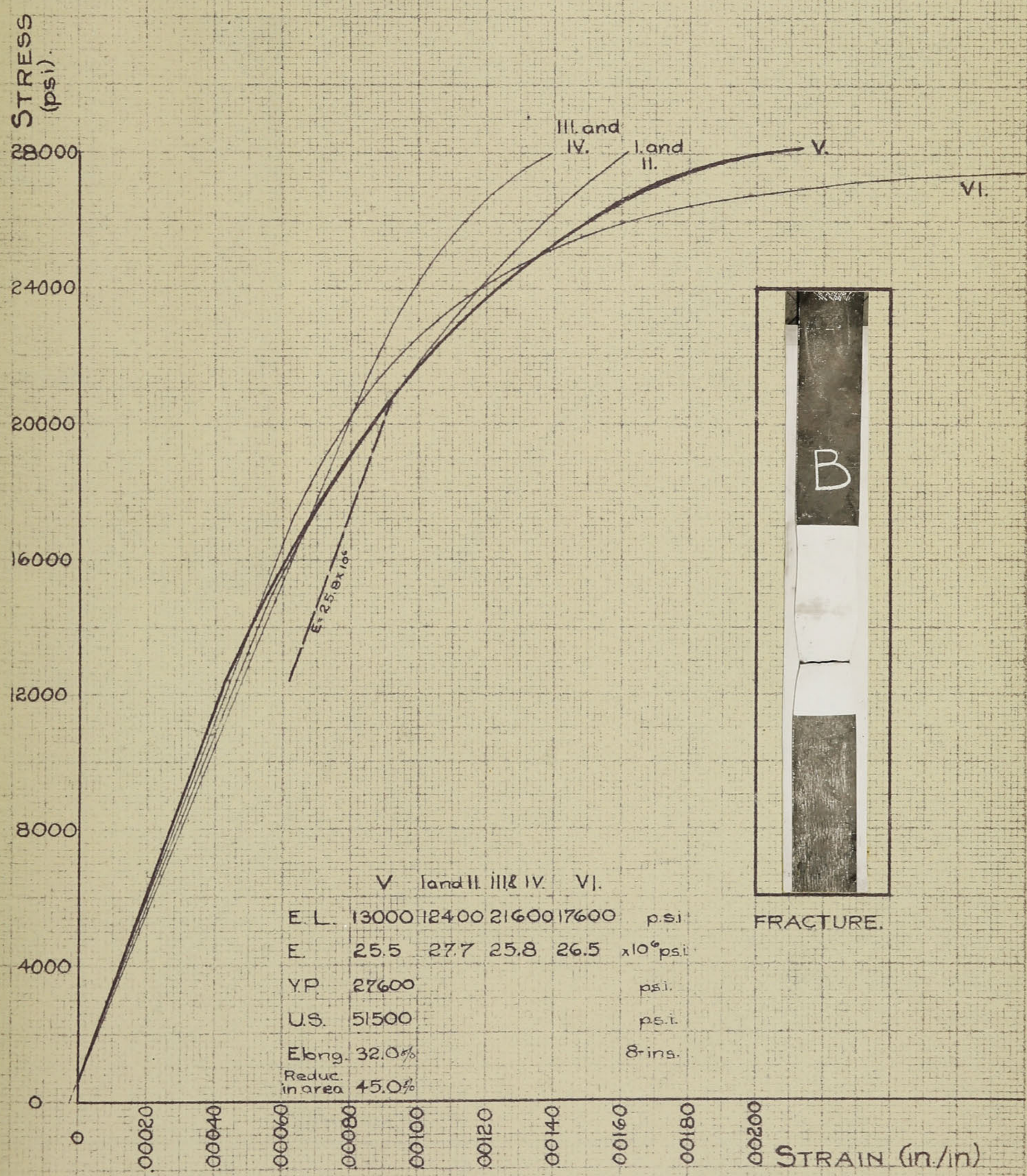


	V.	I and II.	III & IV.	VI.	
E.L.	16200	17400	16200	11000	p.s.i.
E.	28.8	28.8	28.8	27.5	$\times 10^6$ p.s.i.
Y.P.	23800				p.s.i.
U.S.	51000				p.s.i.
Elong.	29.2%				8-ins.
Reduc. in area	47.0%				

Add .00002 to all unit strains to correct for initial load.

FIG. 6.

STRESS-STRAIN CURVES FOR PLATE B.



	V	I and II.	III & IV.	VI.	
E. L.	13000	12400	21600	17600	p.s.i
E.	25.5	27.7	25.8	26.5	$\times 10^6$ p.s.i.
Y.P.	27600				p.s.i.
U.S.	51500				p.s.i.
Elong.	32.0%				8-ins.
Reduc. in area	45.0%				

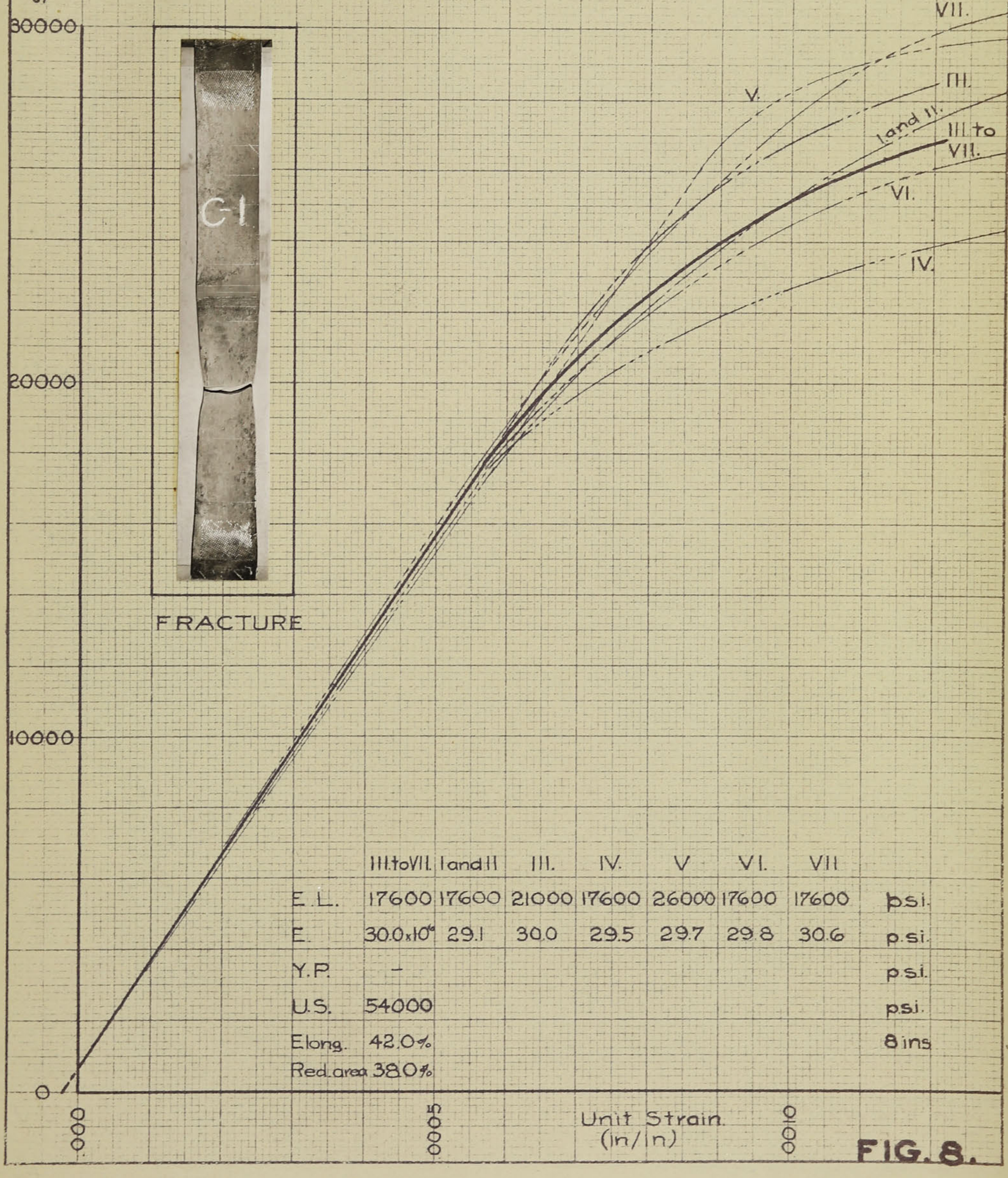
FRACTURE.

Add .00002 to all unit strains to correct for initial load

FIG. 7.

STRESS-STRAIN CURVES FOR PLATE C-1.

HIGH CURRENTS.

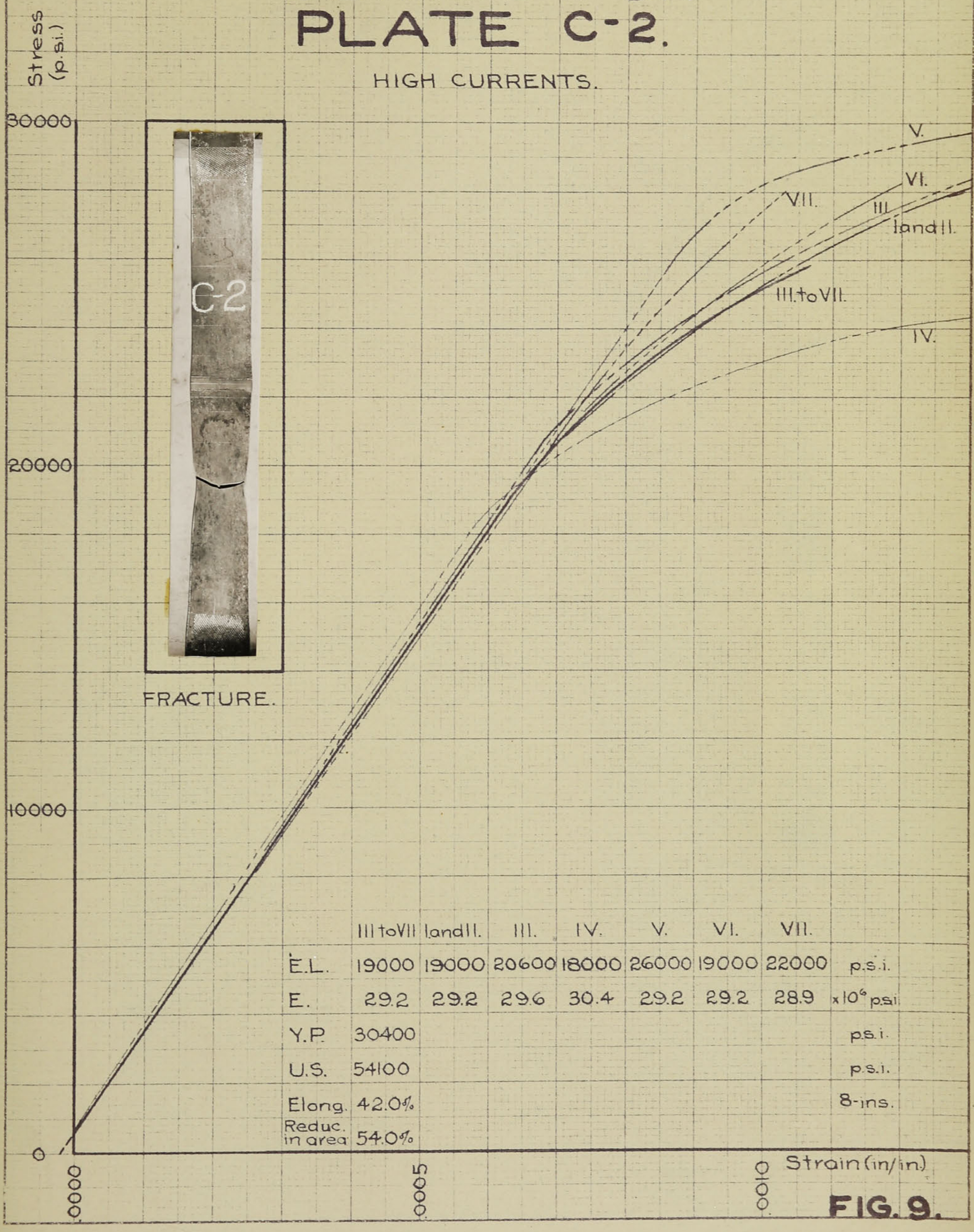


	III to VII.	I and II	III.	IV.	V	VI.	VII	
E.L.	17600	17600	21000	17600	26000	17600	17600	psi.
E.	30.0×10^6	29.1	30.0	29.5	29.7	29.8	30.6	p.si.
Y.P.	–							p.si.
U.S.	54000							p.si.
Elong.	42.0%							8 ins.
Red. area	38.0%							

FIG. 8.

STRESS-STRAIN CURVES FOR PLATE C-2.

HIGH CURRENTS.

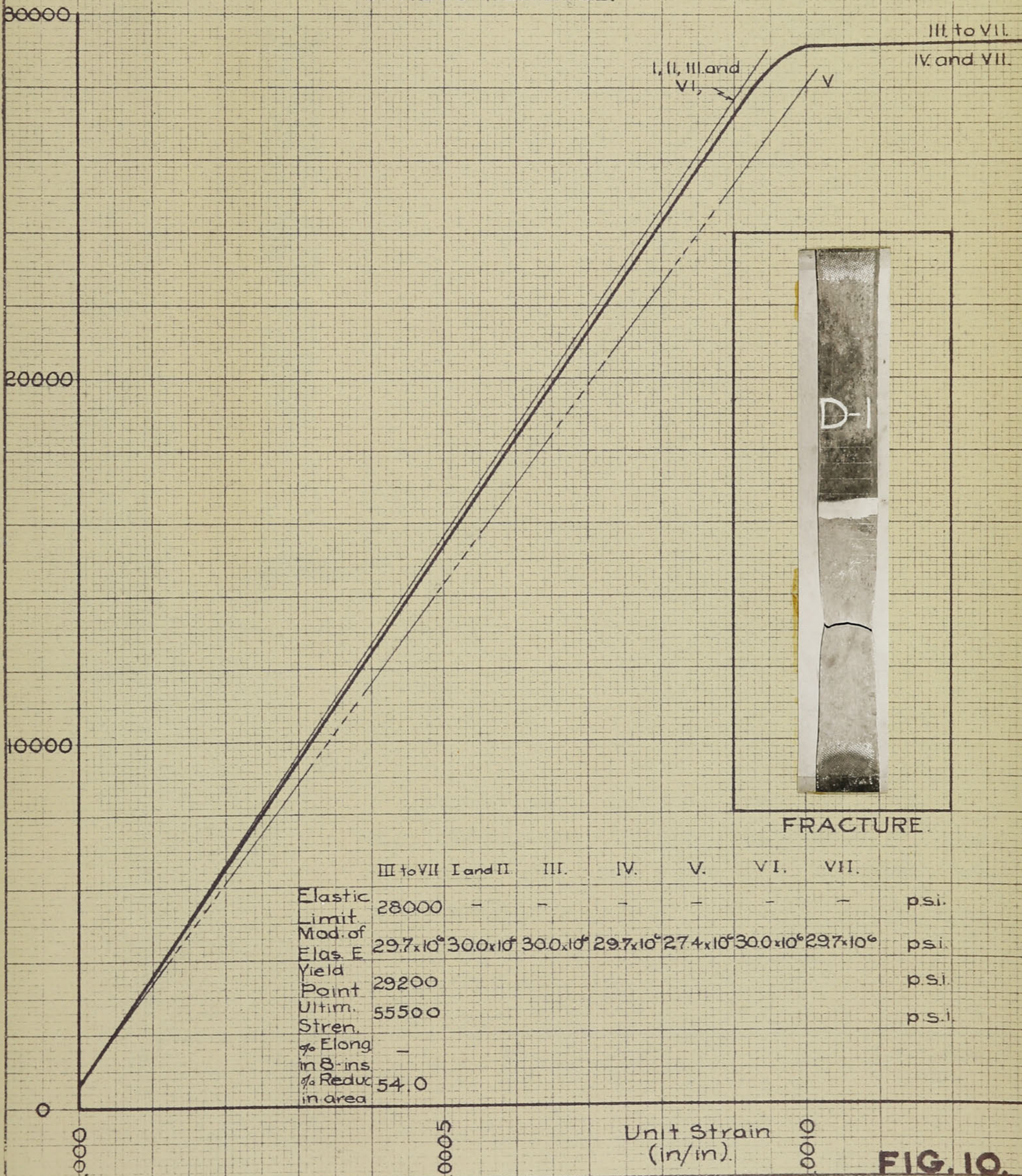


	III to VII	I and II.	III.	IV.	V.	VI.	VII.	
E.L.	19000	19000	20600	18000	26000	19000	22000	p.s.i.
E.	29.2	29.2	29.6	30.4	29.2	29.2	28.9	x10⁶ p.s.i.
Y.P.	30400							p.s.i.
U.S.	54100							p.s.i.
Elong.	42.0%							8-ins.
Reduc. in area	54.0%							

FIG. 9.

STRESS-STRAIN CURVES FOR PLATE D-1.

HIGH CURRENTS.
STRESS-RELIEVED.

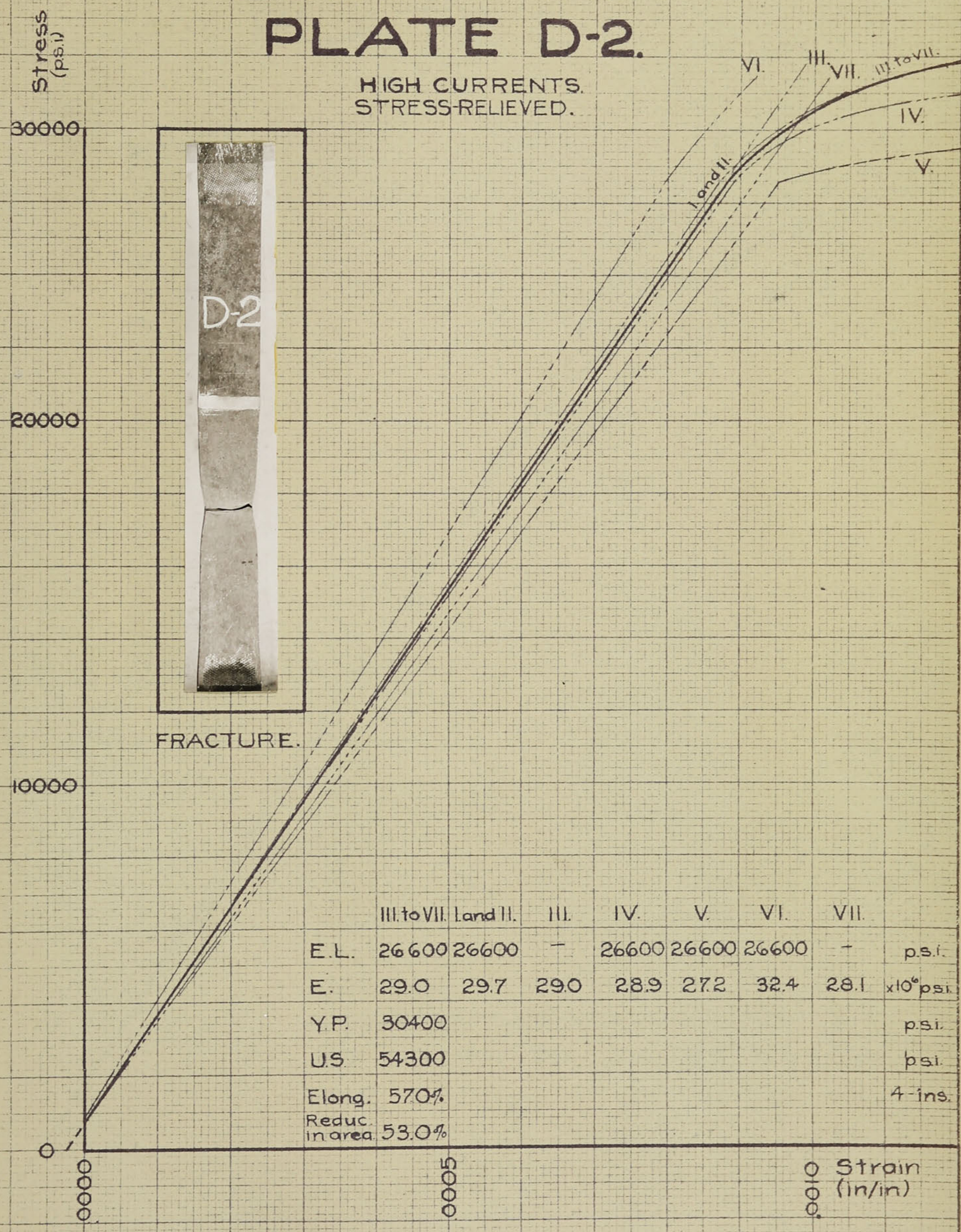


	III to VII	I and II	III.	IV.	V.	VI.	VII.	
Elastic Limit	28000	–	–	–	–	–	–	p.s.i.
Mod. of Elas. E	29.7×10^6	30.0×10^6	30.0×10^6	29.7×10^6	27.4×10^6	30.0×10^6	29.7×10^6	p.s.i.
Yield Point	29200							p.s.i.
Ultim. Stren.	55500							p.s.i.
% Elong in 8-ins.	–							
% Reduc in area	54.0							

FIG. 10.

STRESS-STRAIN CURVES FOR PLATE D-2.

HIGH CURRENTS.
STRESS-RELIEVED.

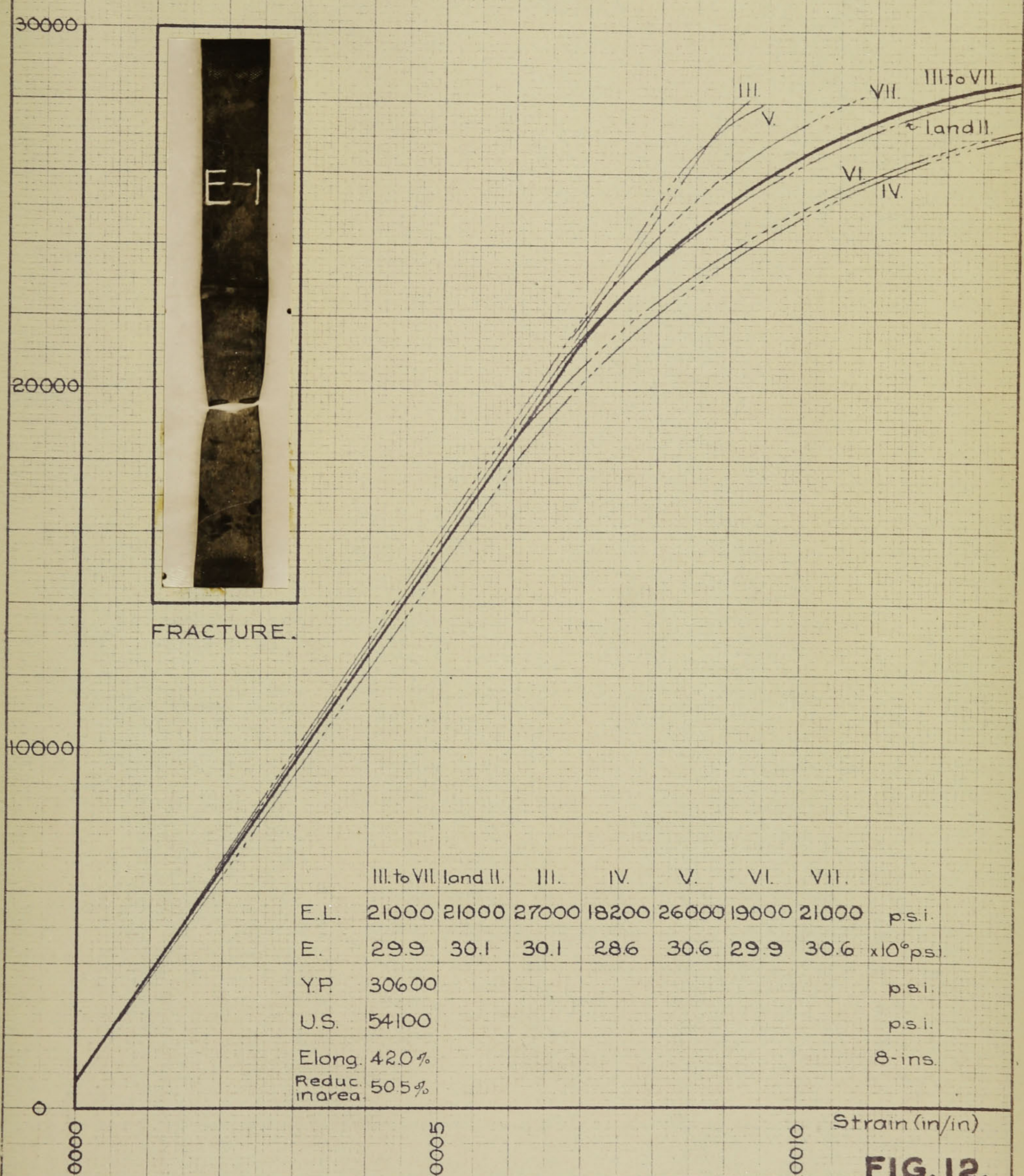


	III. to VII.	I and II.	III.	IV.	V.	VI.	VII.	
E.L.	26600	26600	–	26600	26600	26600	–	p.s.i.
E.	29.0	29.7	29.0	28.9	27.2	32.4	28.1	$\times 10^6$ p.s.i.
Y.P.	30400							p.s.i.
U.S.	54300							p.s.i.
Elong.	57.0%							4-ins.
Reduc. in area	53.0%							

FIG. 11.

STRESS-STRAIN CURVES FOR PLATE E-1.

LOW CURRENTS

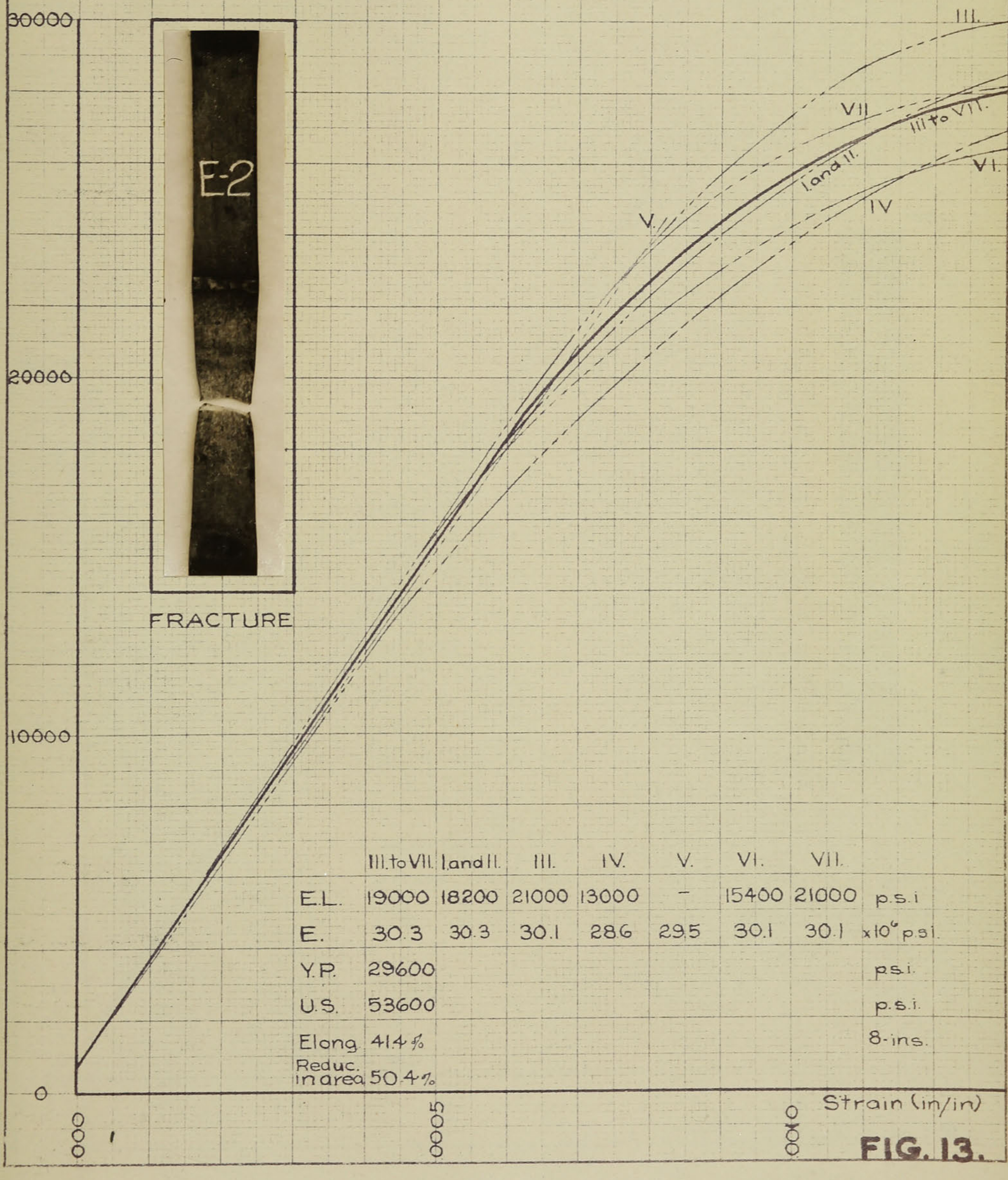


	III. to VII.	I and II.	III.	IV.	V.	VI.	VII.	
E.L.	21000	21000	27000	18200	26000	19000	21000	p.s.i.
E.	29.9	30.1	30.1	28.6	30.6	29.9	30.6	$\times 10^6$ p.s.i.
Y.P.	30600							p.s.i.
U.S.	54100							p.s.i.
Elong.	42.0%							8-ins.
Reduc. in area.	50.5%							

FIG. 12.

STRESS-STRAIN CURVES FOR PLATE E-2.

LOW CURRENTS.

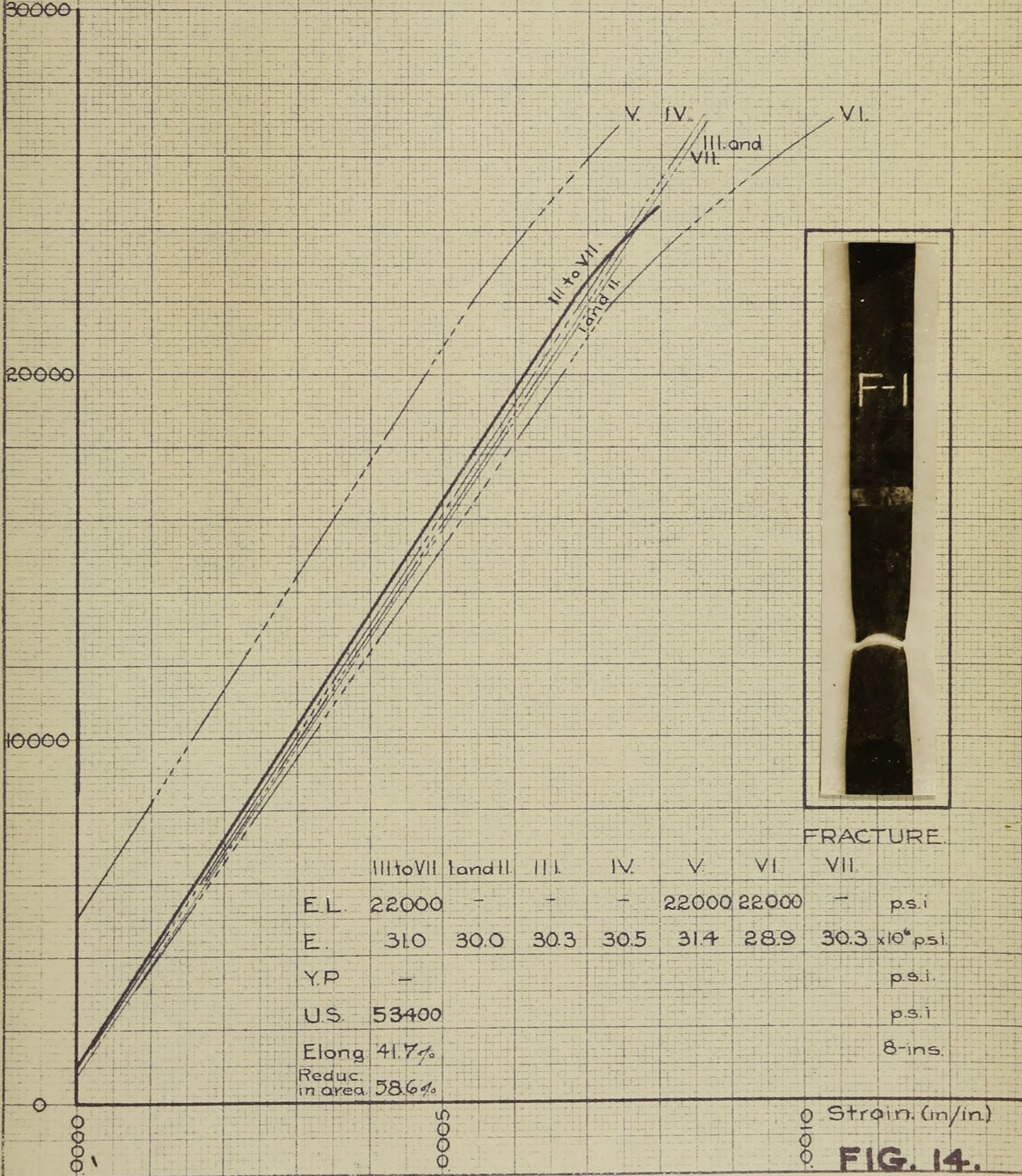


	III. to VII.	I and II.	III.	IV.	V.	VI.	VII.	
E.L.	19000	18200	21000	13000	–	15400	21000	p.s.i
E.	30.3	30.3	30.1	28.6	29.5	30.1	30.1	x10⁶ p.s.i.
Y.P.	29600							p.s.i.
U.S.	53600							p.s.i.
Elong.	41.4 %							8-ins.
Reduc. in area	50.4 %							

FIG. 13.

STRESS-STRAIN CURVES FOR PLATE F-1.

LOW CURRENTS.
STRESS-RELIEVED.

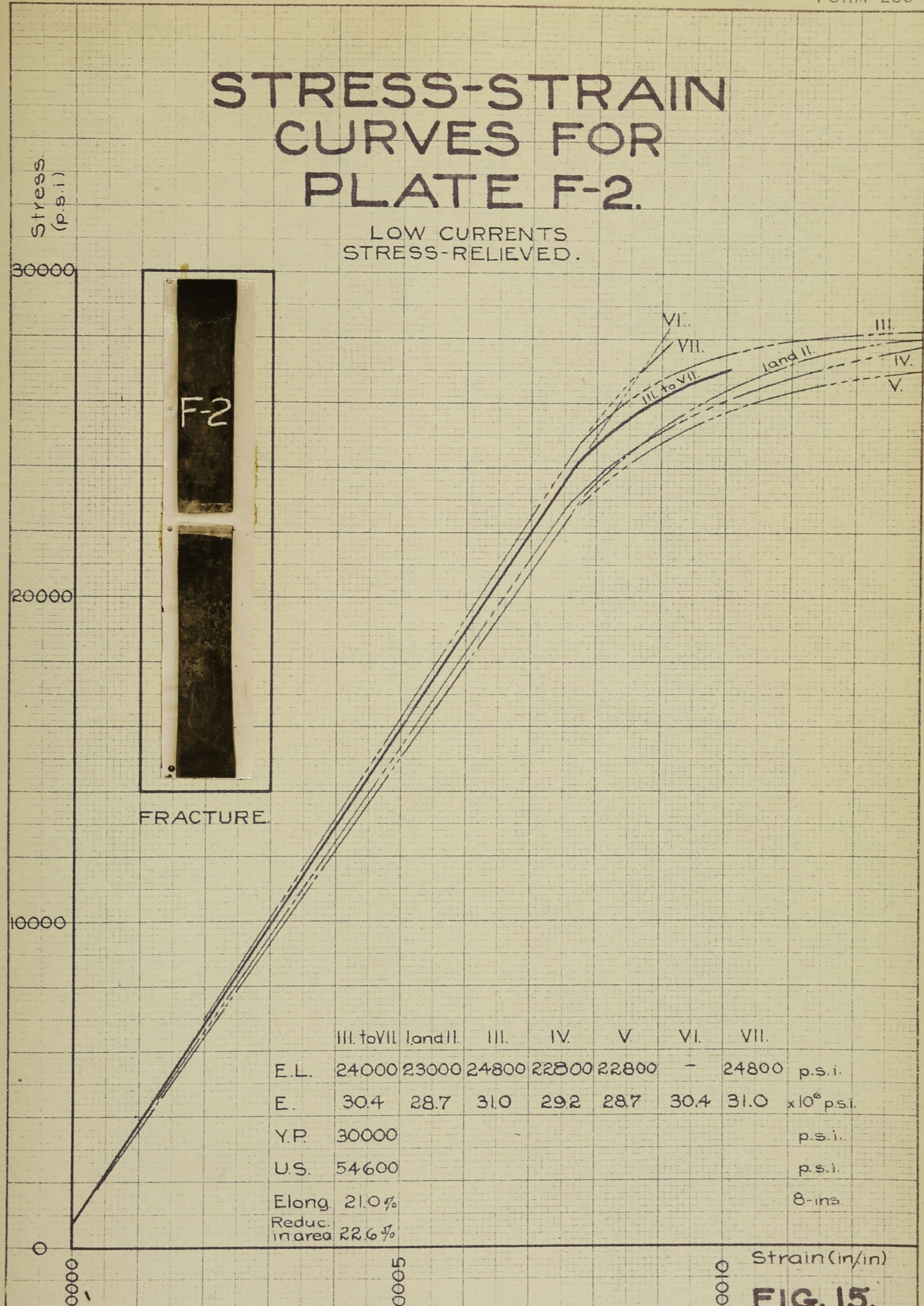


	III to VII	I and II	III.	IV.	V.	VI.	VII.	
E.L.	22000	–	–	–	22000	22000	–	p.s.i.
E.	31.0	30.0	30.3	30.5	31.4	28.9	30.3	x10⁶ p.s.i.
Y.P.	–							p.s.i.
U.S.	53400							p.s.i.
Elong.	41.7%							8-ins.
Reduc. in area	58.6%							

FIG. 14.

STRESS-STRAIN CURVES FOR PLATE F-2.

LOW CURRENTS
STRESS-RELIEVED.

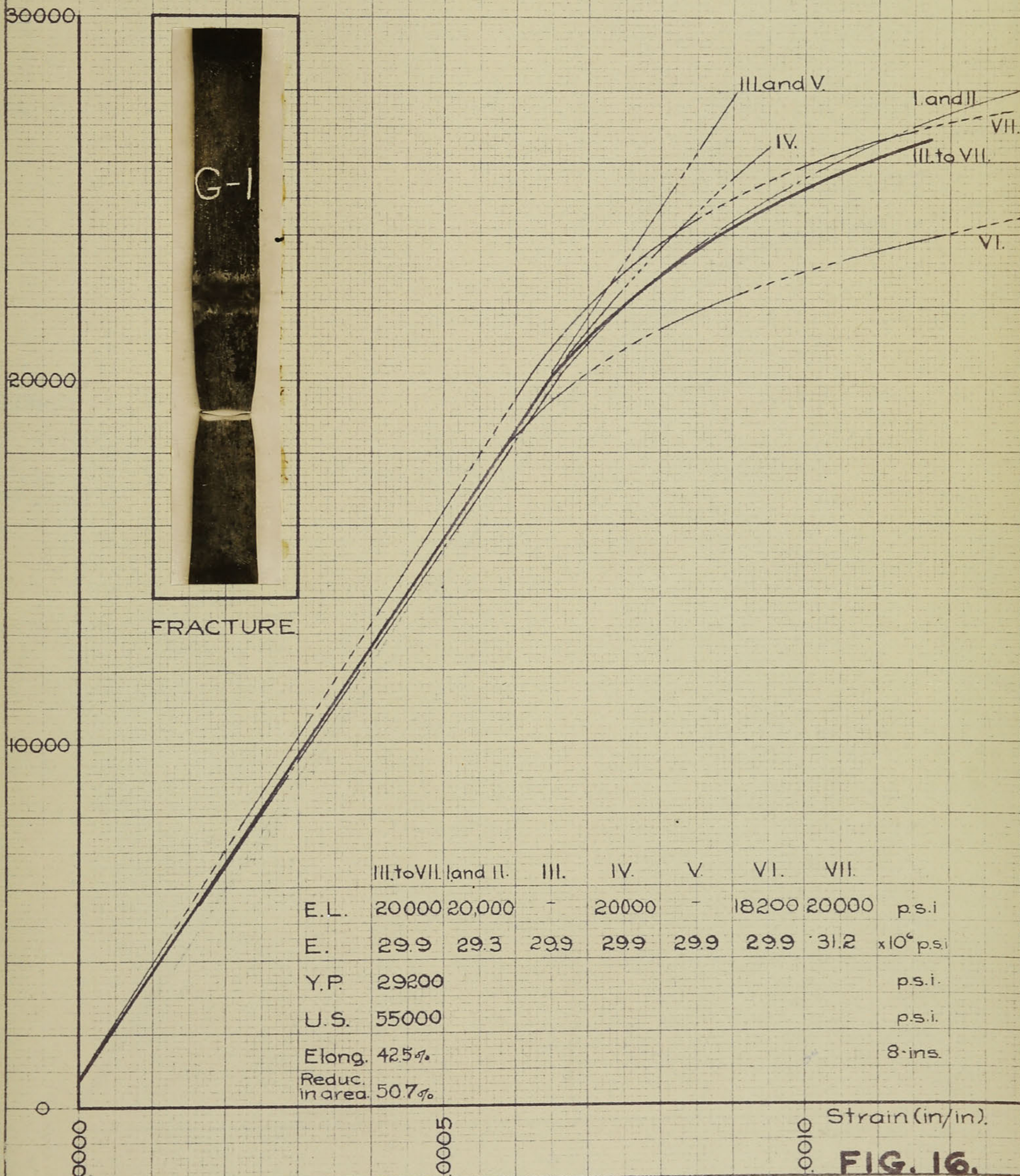


	III. to VII.	I and II.	III.	IV.	V.	VI.	VII.	
E.L.	24000	23000	24800	22800	22800	-	24800	p.s.i.
E.	30.4	28.7	31.0	29.2	28.7	30.4	31.0	$\times 10^6$ p.s.i.
Y.P.	30000							p.s.i.
U.S.	54600							p.s.i.
Elong.	21.0%							8-ins.
Reduc. in area	22.6%							

FIG. 15.

STRESS-STRAIN CURVES FOR PLATE G-1.

NORMAL CURRENTS

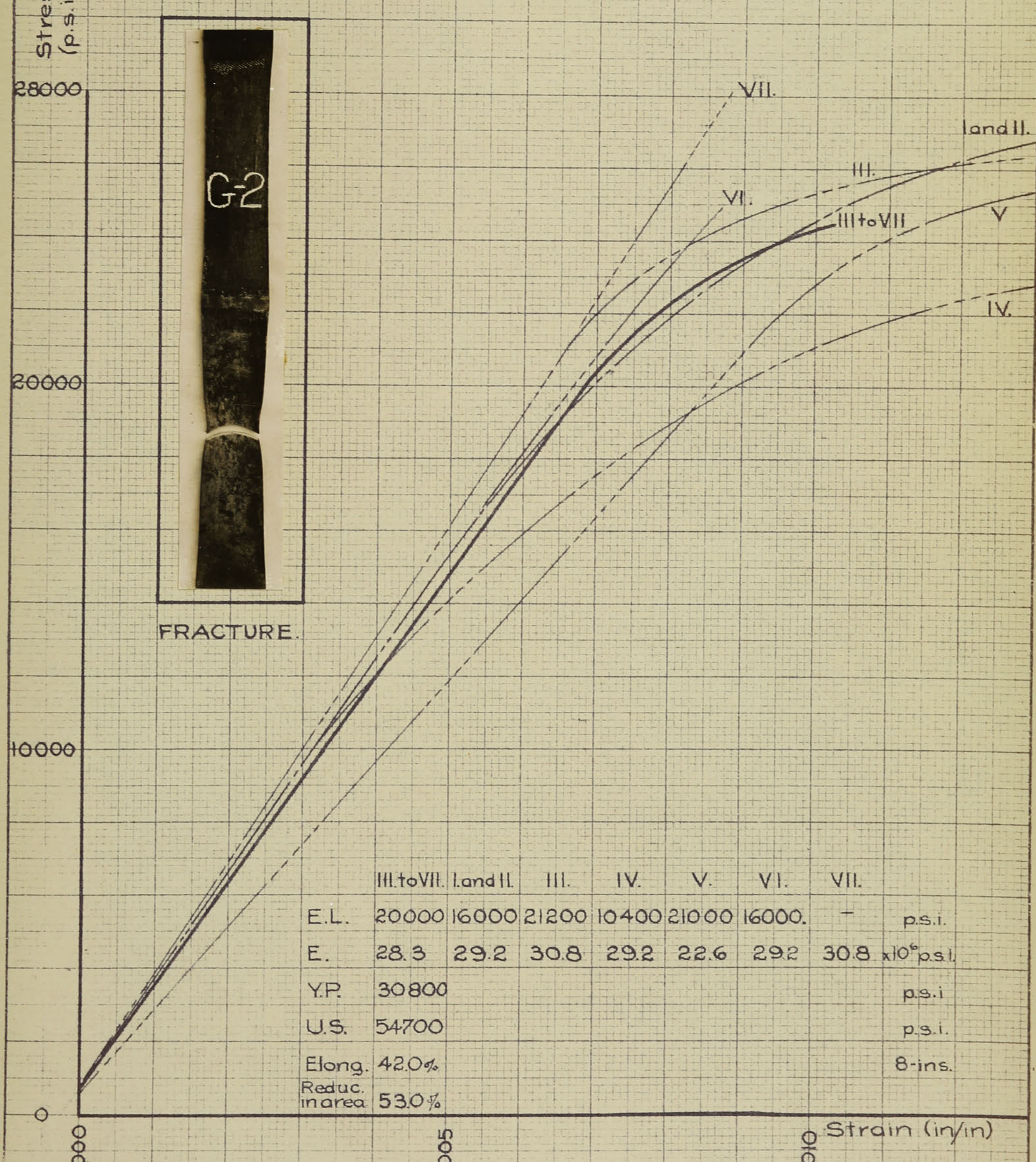


	III.to VII.	I and II.	III.	IV.	V.	VI.	VII.	
E.L.	20000	20,000	-	20000	-	18200	20000	p.s.i
E.	29.9	29.3	29.9	29.9	29.9	29.9	31.2	$\times 10^6$ p.s.i
Y.P.	29200							p.s.i.
U.S.	55000							p.s.i.
Elong.	42.5%							8-ins.
Reduc. in area.	50.7%							

FIG. 16.

STRESS-STRAIN CURVES FOR PLATE G-2.

NORMAL CURRENTS

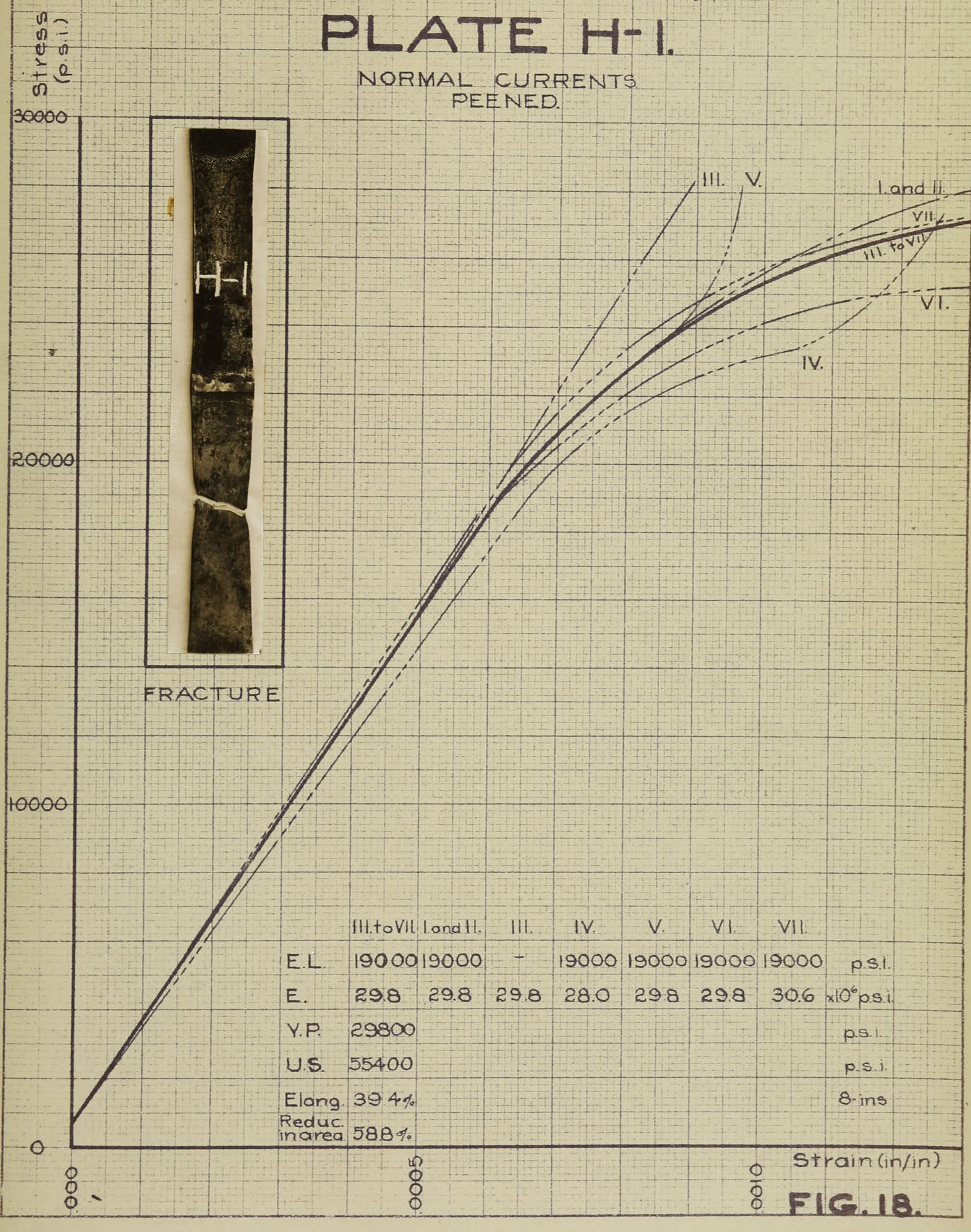


	III. to VII.	I. and II.	III.	IV.	V.	VI.	VII.	
E.L.	20000	16000	21200	10400	21000	16000.	–	p.s.i.
E.	28.3	29.2	30.8	29.2	22.6	29.2	30.8	x10⁶ p.s.i.
Y.P.	30800							p.s.i.
U.S.	54700							p.s.i.
Elong.	42.0%							8-ins.
Reduc. in area	53.0%							

FIG. 17.

STRESS-STRAIN CURVES FOR PLATE H-1.

NORMAL CURRENTS
PEENED.

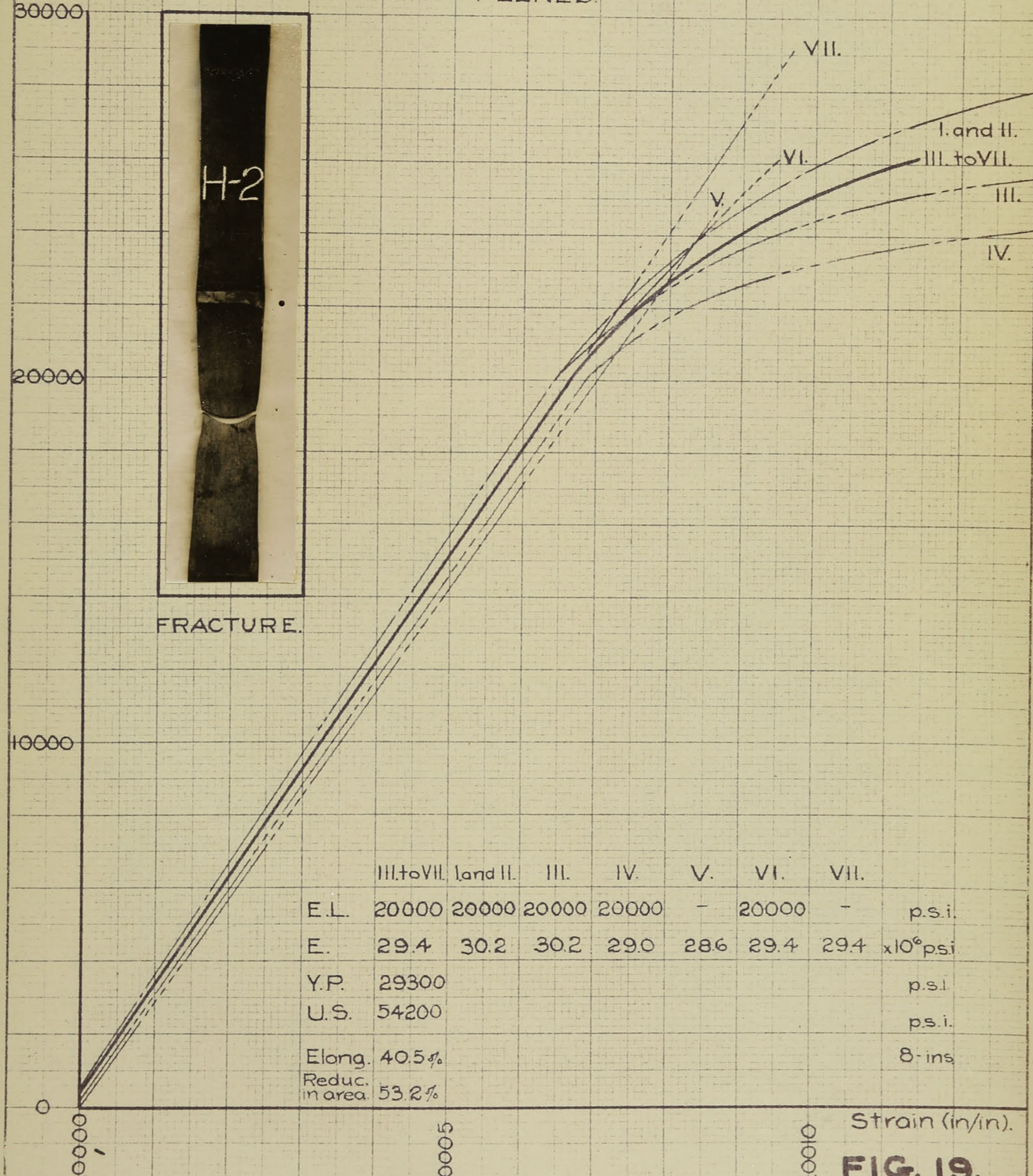


	III. to VII.	I. and II.	III.	IV.	V.	VI.	VII.	
E.L.	19000	19000	-	19000	19000	19000	19000	p.s.i.
E.	29.8	29.8	29.8	28.0	29.8	29.8	30.6	$\times 10^6$ p.s.i.
Y.P.	29800							p.s.i.
U.S.	55400							p.s.i.
Elong.	39.4%							8-ins
Reduc. in area	58.8%							

FIG. 18.

STRESS-STRAIN CURVES FOR PLATE H-2.

NORMAL CURRENTS.
PEENED.

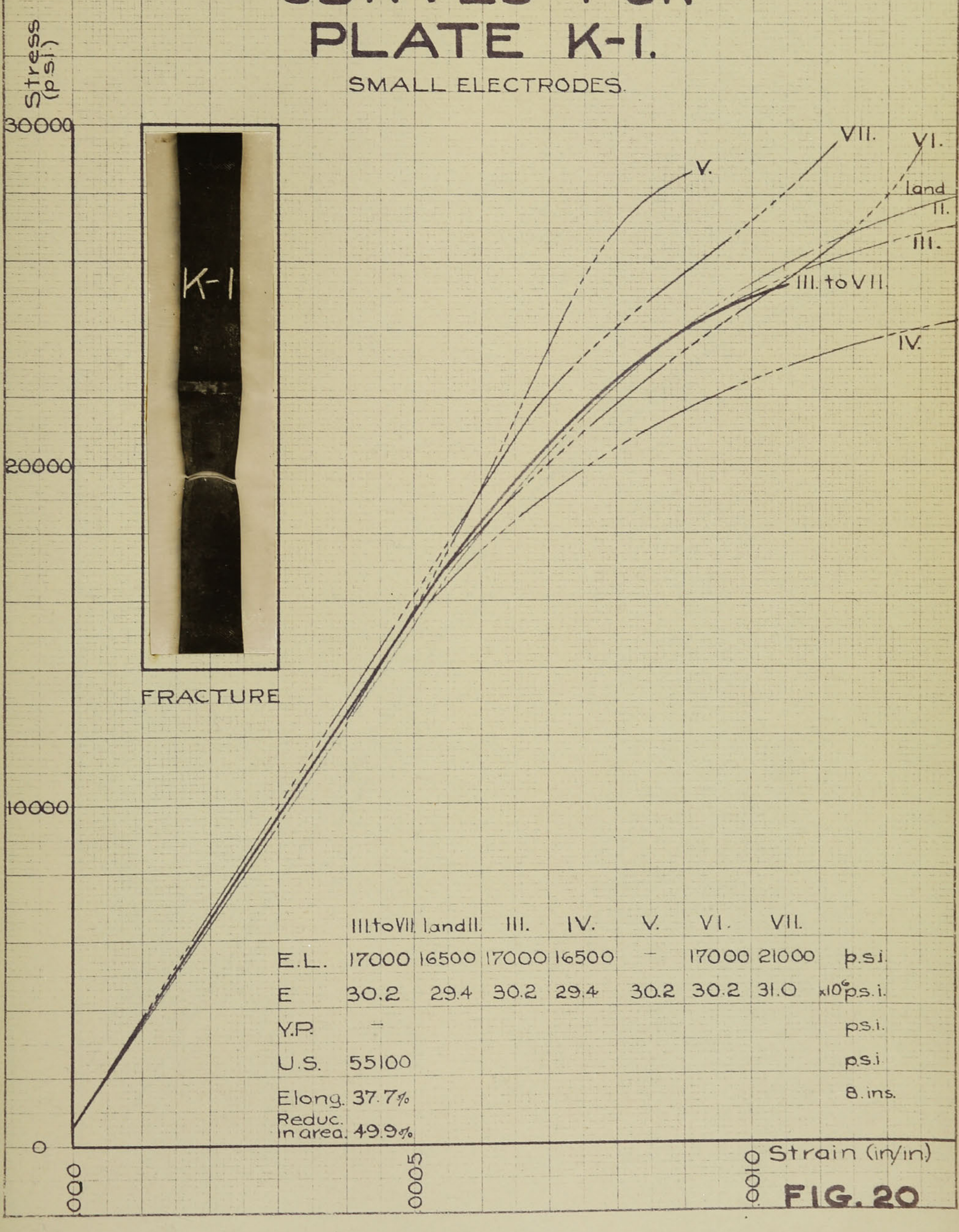


	III. to VII.	I. and II.	III.	IV.	V.	VI.	VII.	
E.L.	20000	20000	20000	20000	–	20000	–	p.s.i.
E.	29.4	30.2	30.2	29.0	28.6	29.4	29.4	x10⁶ p.s.i.
Y.P.	29300							p.s.i.
U.S.	54200							p.s.i.
Elong.	40.5%							8-ins.
Reduc. in area	53.2%							

FIG. 19.

STRESS-STRAIN CURVES FOR PLATE K-1.

SMALL ELECTRODES.

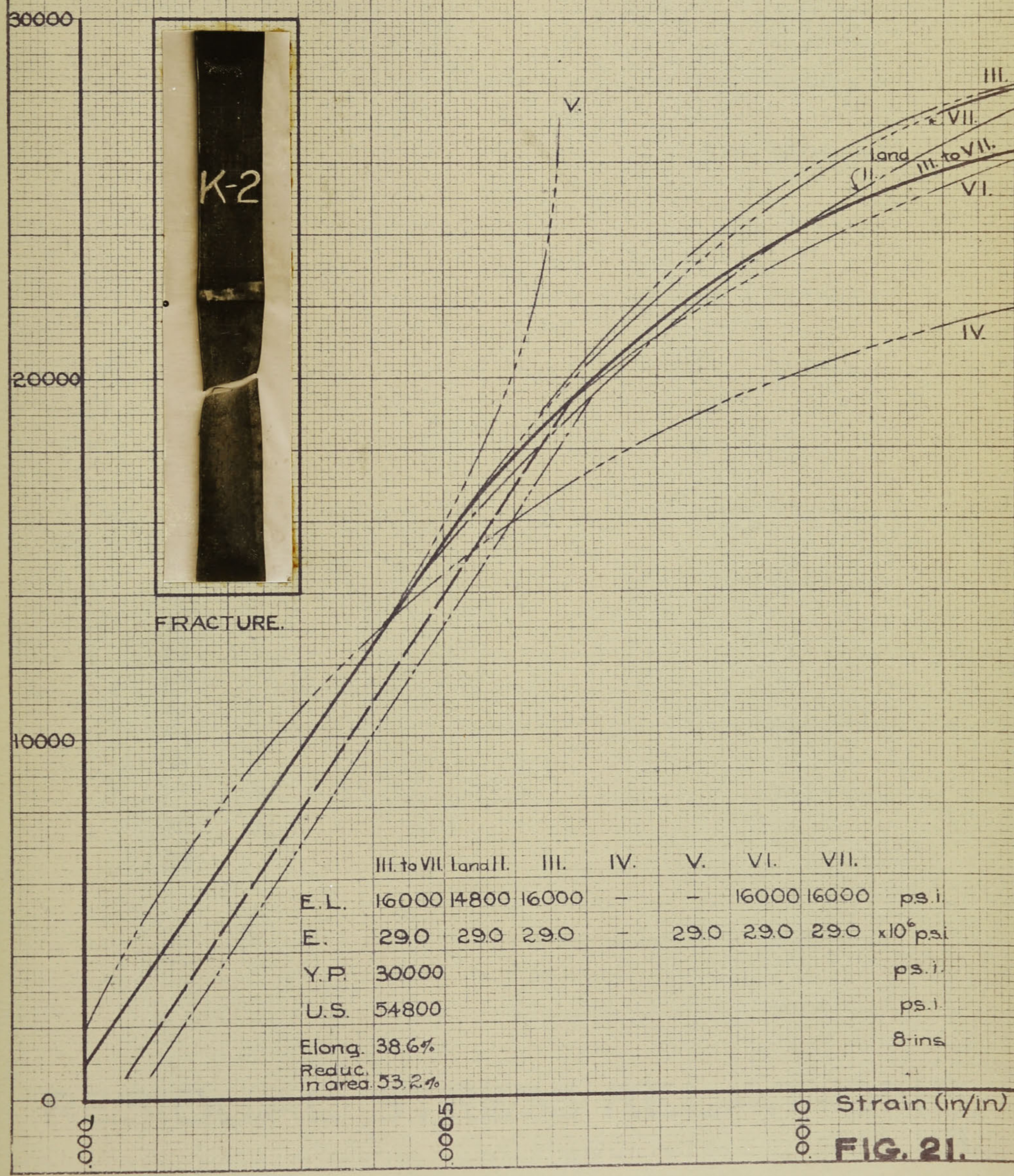


	III.toVII.	I.andII.	III.	IV.	V.	VI.	VII.	
E.L.	17000	16500	17000	16500	–	17000	21000	p.s.i.
E	30.2	29.4	30.2	29.4	30.2	30.2	31.0	x10⁶ p.s.i.
Y.P.	–							p.s.i.
U.S.	55100							p.s.i.
Elong.	37.7%							8. ins.
Reduc. in area.	49.9%							

FIG. 20

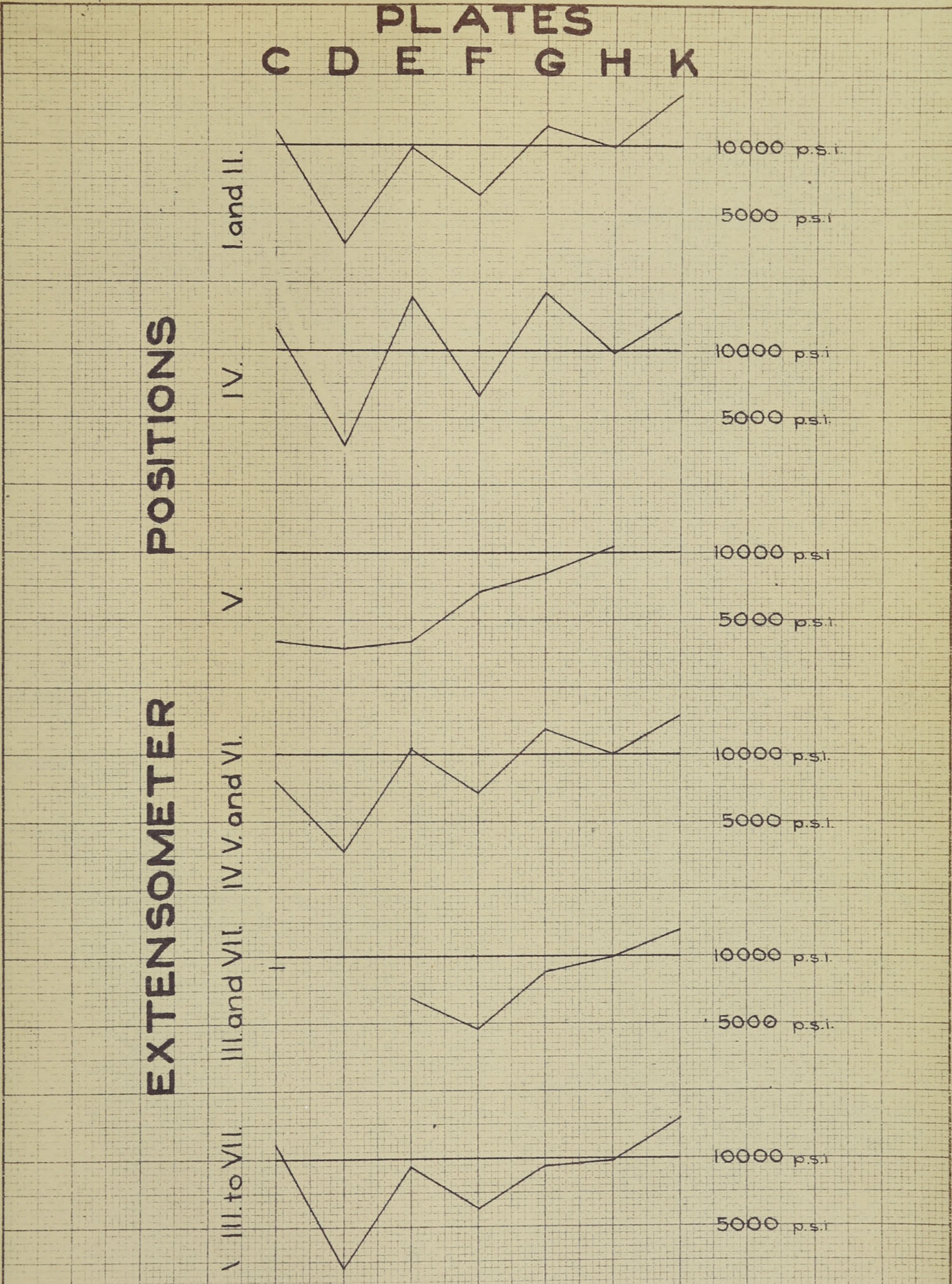
STRESS-STRAIN CURVES FOR PLATE K-2.

SMALL ELECTRODES.



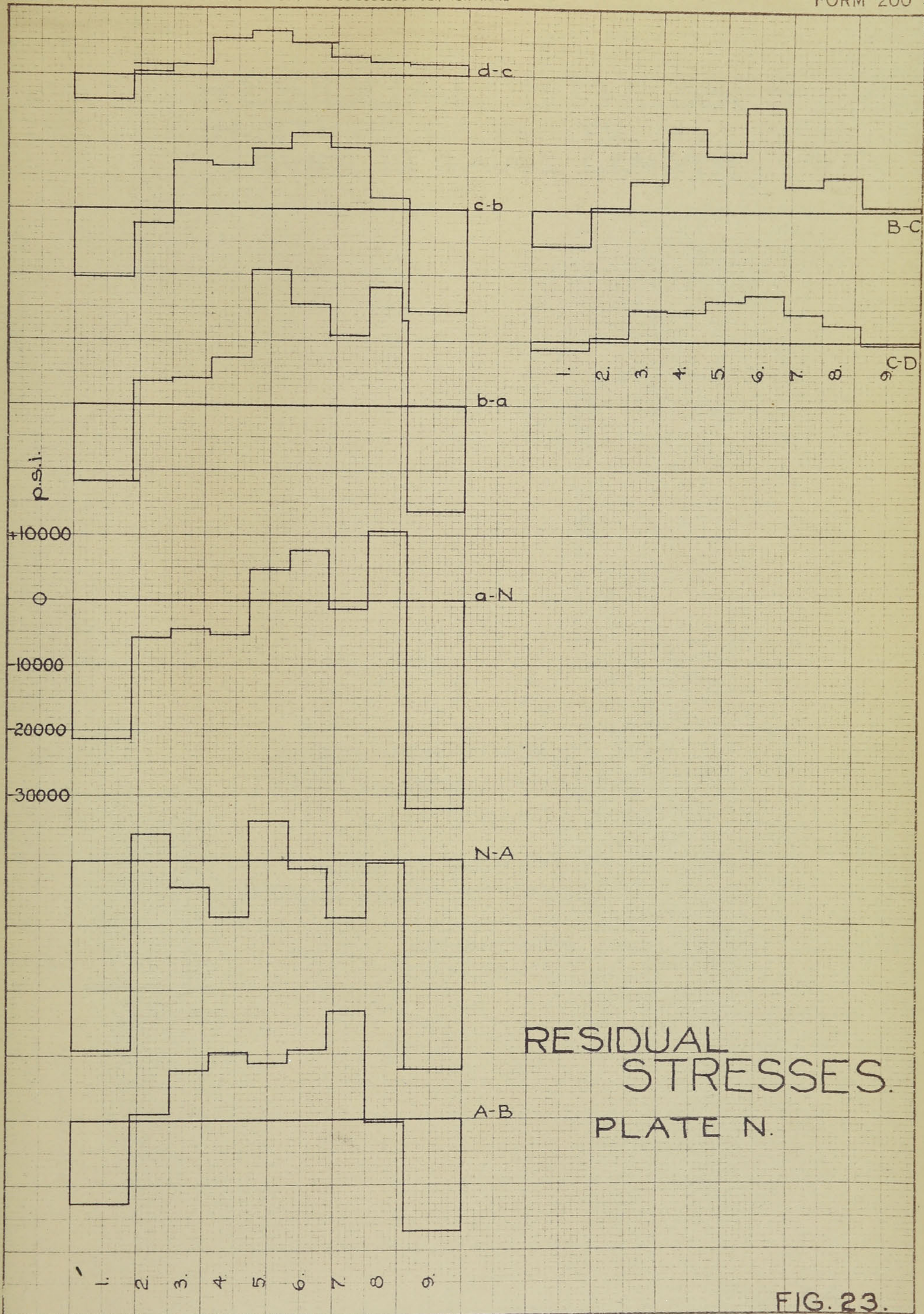
	III. to VII.	I and II.	III.	IV.	V.	VI.	VII.	
E.L.	16000	14800	16000	–	–	16000	16000	p.s.i.
E.	29.0	29.0	29.0	–	29.0	29.0	29.0	$\times 10^6$ p.s.i.
Y.P.	30000							p.s.i.
U.S.	54800							p.s.i.
Elong.	38.6%							8 ins.
Reduc. in area	53.2%							

FIG. 21.



RESIDUAL STRESS RELATIONS.

PLATE TO POSITION. **FIG. 22.**



RESIDUAL STRESSES.

PLATE N.

FIG. 23.

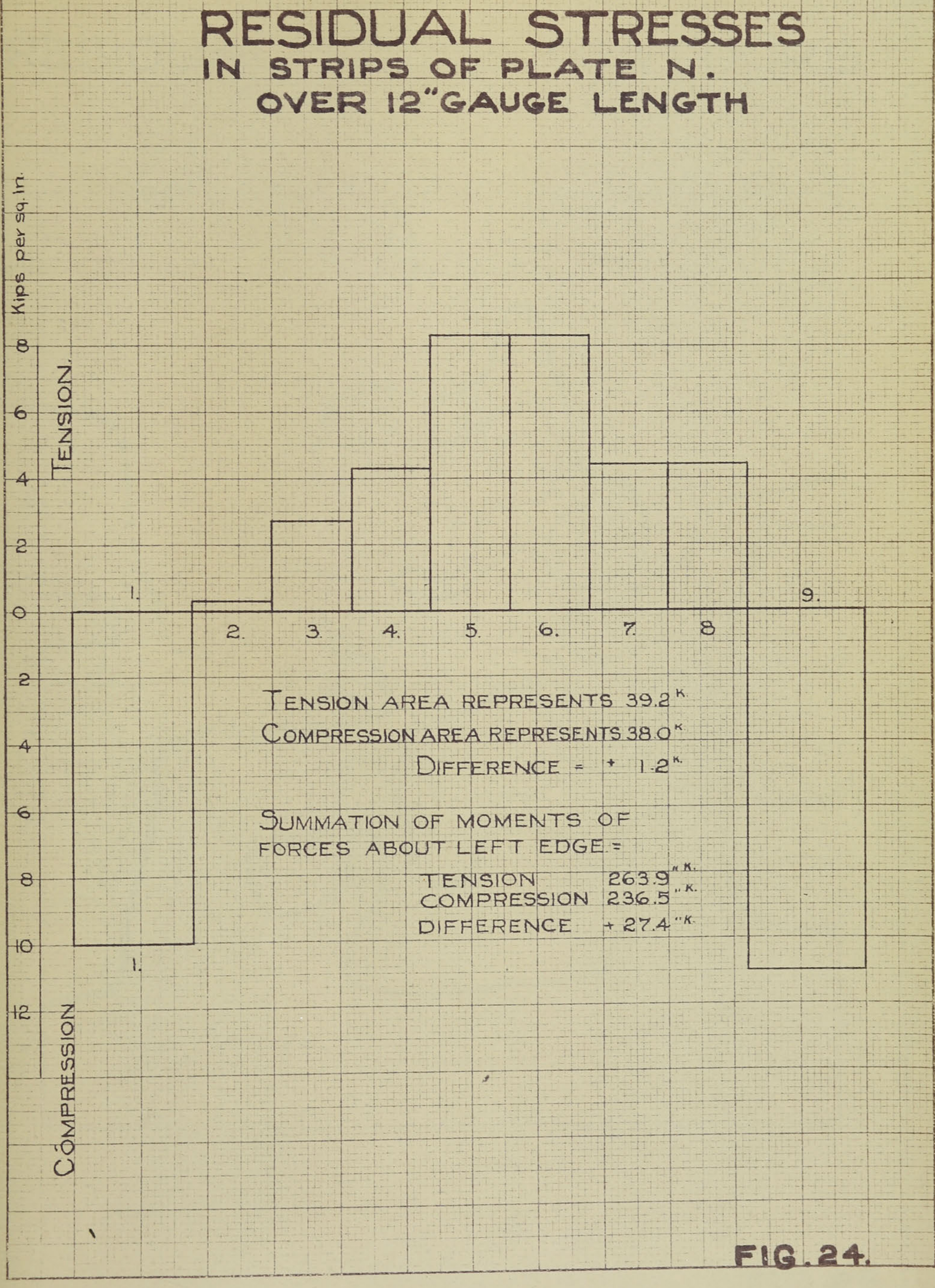

RESIDUAL STRESSES
IN STRIPS OF PLATE N.
OVER 12" GAUGE LENGTH
Kips per sq. In.
TENSION.
COMPRESSION
8
6
4
2
0
2
4
6
8
10
12
1.
2.
3.
4.
5.
6.
7.
8
9.
TENSION AREA REPRESENTS 39.2 K.
COMPRESSION AREA REPRESENTS 38.0 K.
DIFFERENCE = + 1.2 K.
SUMMATION OF MOMENTS OF
FORCES ABOUT LEFT EDGE =
TENSION 263.9 "K.
COMPRESSION 236.5 "K.
DIFFERENCE + 27.4 "K.

FIG. 24.

RESIDUAL STRESS CONTOURS.
PLATE N - SIDE A.

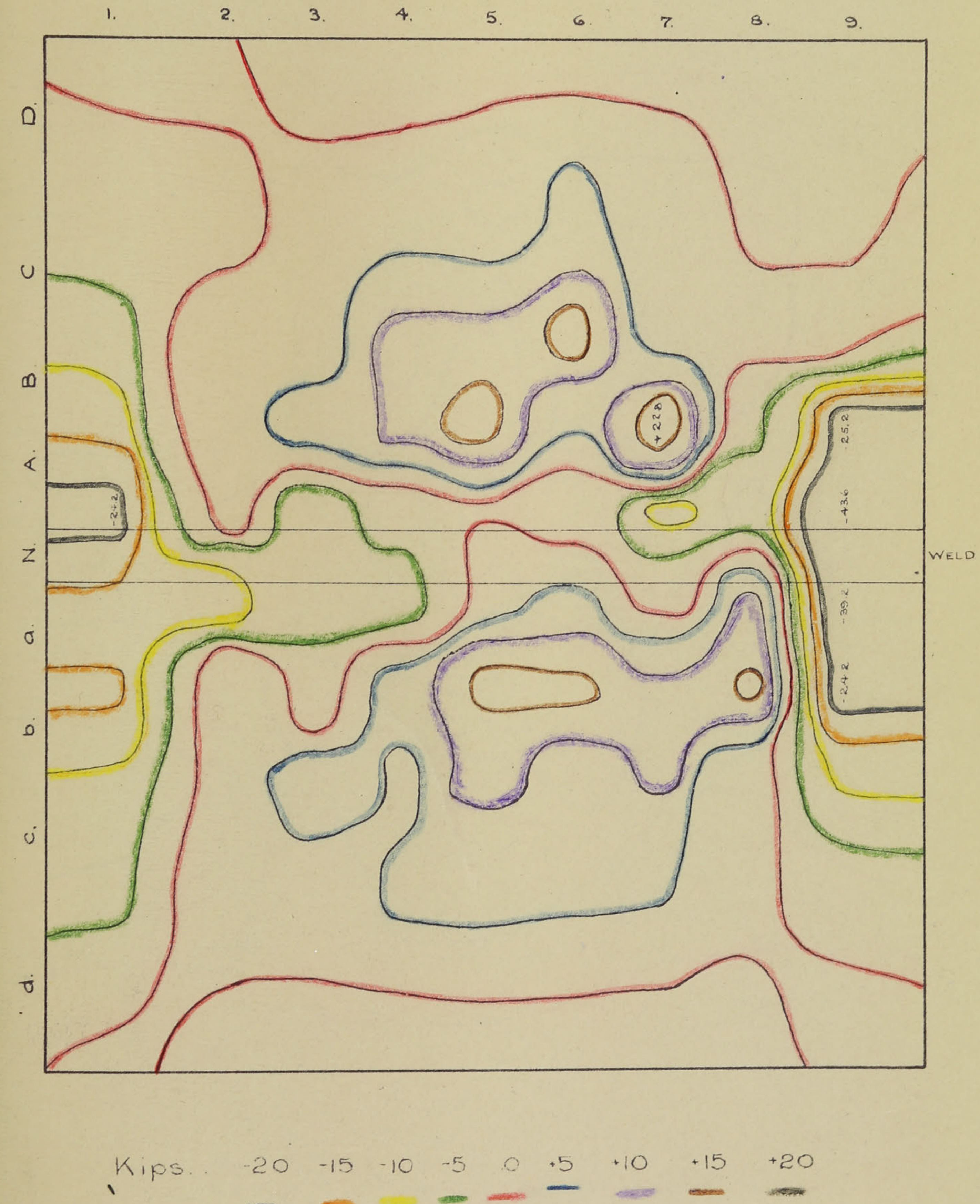


FIG. 25.

RESIDUAL STRESS CONTOURS.
PLATE N. - SIDE B.

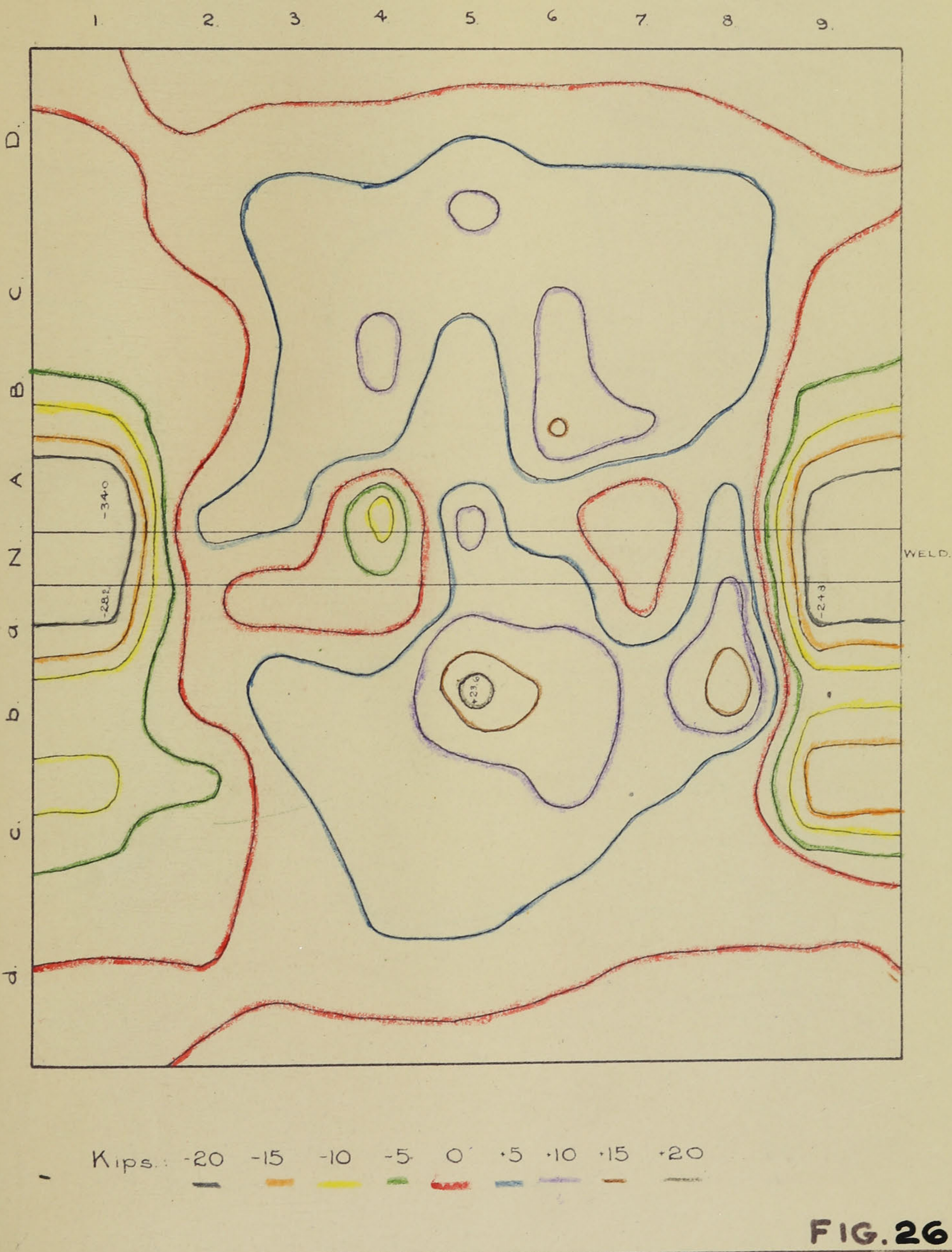


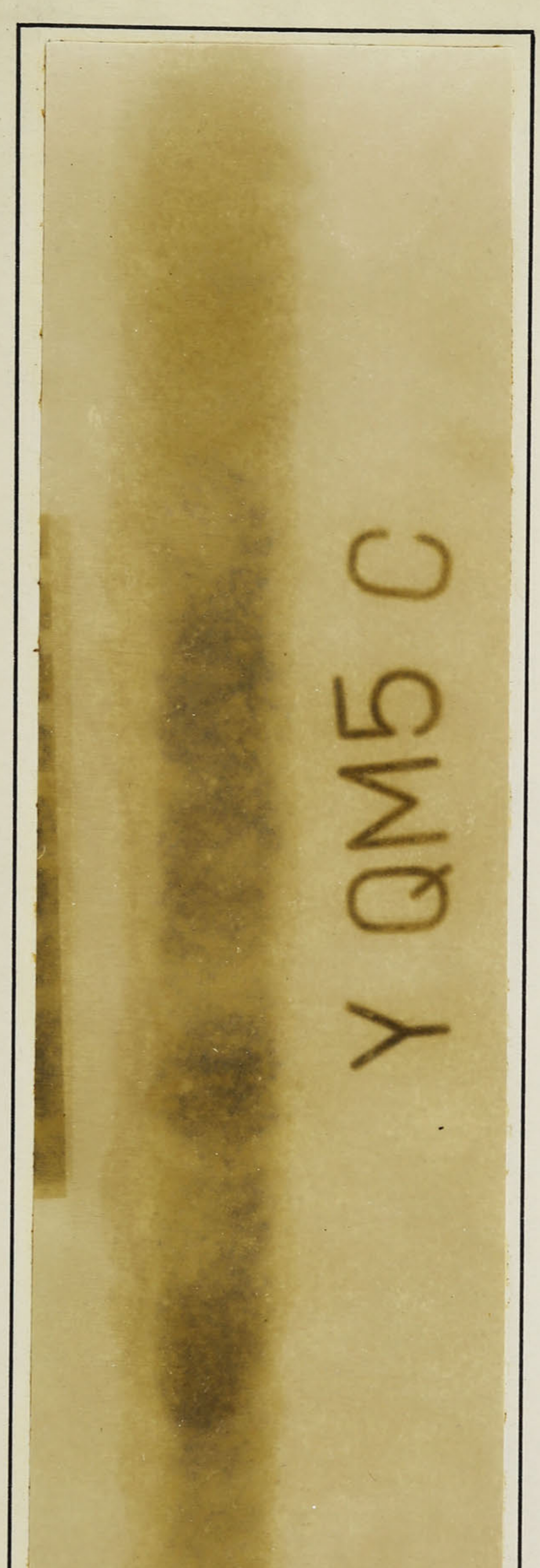
FIG. 26.

RESIDUAL STRESS CONTOURS.

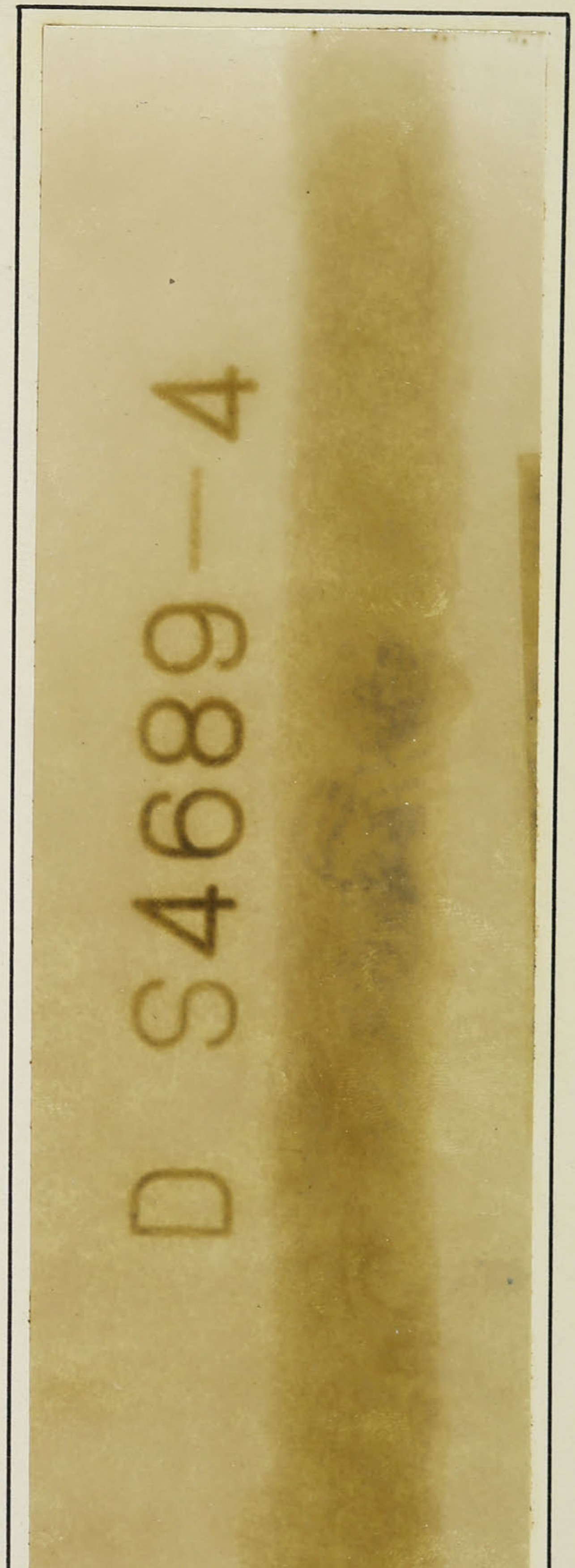
PLATE N - SIDES A AND B.

Kips.: -20 -15 -10 -5 0 +5 +10 +15 +20

FIG. 27.



X-Ray Photo. Plates C.



X-Ray Photo. Plates D.

DATA AND CALCULATIONS

COUPON A.

Area = 2.315 x 0.617 = 1.429 sq. ins.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Front	Elongation ins/ 100,000 Back	Average Elongation ins/ 1,000,000 ----	Average Unit Elongation ---- ----
0	-	-	-	-	-
1	700	0	0	0	0
4	2800	56	55	555	.00007
7	4900	114	110	1120	.00014
10	7000	170	161	1655	.00021
12	8400	211	192	2015	.00025
14	9800	252	225	2385	.00030
16	11200	298	254	2760	.00035
18	12600	339	289	3140	.00039
20	14000	376	322	3490	.00044
22	15400	416	360	3880	.00049
24	16800	455	394	4245	.00053
26	18200	495	430	4625	.00058
28	19600	535	463	4990	.00062
30	21000	569	498	5385	.00067
32	22400	627	529	5780	.00072
34	23800	678	561	6195	.00077
36	25200	762	604	6830	.00085
38	26600	915	669	7920	.00099
40	28000	1190	810	10000	.00125
42	29400	Yield Point			
79.6	55800	Ultimate Stress			

Add 0.00002 to all unit elongations to correct for initial load.

Elastic Limit = 23600 psi.

E = 30.6×10^6 psi.

Elongation = $\frac{2.75}{8.00}$ = 34.75% in 8 ins.

% Reduction in area = $\frac{1.429 - 0.59}{1.429}$ 59%.

COUPON B.

Area = 2.315 x 0.616 = 1.428 sq. ins.

Load (kips)	Stress (psi)	Elongation ins/ 100,000 Front	Elongation ins/ 100,000 Back	Average Elongation ins/ 1,000,000	Average Unit Elongation
0	-	-	-	-	-
1	700	0	0	0	0
4	2800	59	51	550	.00007
7	4900	115	108	1115	.00014
10	7000	170	164	1670	.00021
12	8400	206	202	2040	.00025
14	9800	241	241	2410	.00030
16	11200	280	280	2800	.00035
18	12600	318	318	3180	.00040
20	14000	353	353	3530	.00044
22	15400	391	391	3910	.00050
24	16800	429	429	4290	.00054
26	18200	469	466	4675	.00058
28	19600	508	501	5045	.00063
30	21000	548	538	5430	.00068
32	22400	588	592	5800	.00072
34	23800	628	608	6180	.00077
36	25200	669	642	6555	.00082
38	26600	710	678	6940	.00087
41	28800	822	769	7955	.00099
42	29400	Yield Point			
79.4	55600	Ultimate Stress			

Add 0.00002 to all unit elongations to correct for initial load.
Elastic Limit = 27,400 psi.
E = 30.0×10^6 psi.

Elongation $\frac{2.68}{8.00}$ = 33.5% in 8 in.

% Reduction in area = $\frac{1.428 - .70}{1.428}$ = 51%

Average Values of Coupons A and B.

Average Elastic Limit = 25500 p.s.i.

Average Yield Point = 29400 p.s.i.

Average E. = 30.3×10^6 p.s.i.

Average Ultimate Stress = 55700 p.s.i.

Average % Reduction in area = 55%.

Average % Elongation in 8 ins = 34.1%

PLATE A.

EXTENSOMETERS 1a, 1b, 11a & 11b.

Load (kips)	Stress (psi.)	Elongation ins/ 100000 1a	1b.	Average Unit Strain ins/ 100,000 1a & 1b.	Elongation ins/ 100,000 11a	11b	Average Unit Strain ins/ 100,000 11a & 11b	Average Unit Strain ins/ 100,000 1 & 11
0	0	-	-	-	-	-	-	-
1.5	580	0	0	0	0	0	0	0
2	770	2	1	1	2	0	1	1
4	1500	7	1	4	7	0	4	4
6	2300	11	2	7	11	1	6	7
8	3100	15	2	9	15	1	8	9
10	3800	19	4	10	19	2	11	11
6	2300	11	1	7	11	0	6	7
1.5	600	1	-1	0	1	-3	0	0
4	1500	6	1	4	6	-1	3	4
6	2300	11	2	7	11	-1	5	6
8	3100	15	2	9	15	2	8	9
10	3800	19	3	11	19	2	11	11
12	4600	23	5	14	23	4	14	14
14	5400	26	6	16	26	5	16	16
16	6200	20	7	18	30	7	19	19
18	6900	34	10	22	34	9	22	22
20	7700	37	11	24	37	10	24	24
22	8500	41	13	27	41	13	27	27
24	9200	44	15	29	44	14	29	29
26	10000	48	17	32	48	16	32	32
28	10800	52	18	34	52	18	35	35
30	11500	55	20	37	55	20	38	38
20	7700	37	11	24	37	10	24	24
10	3800	22	4	12	22	3	13	13
1.5	600	2	-1	1	2	-3	0	0
4	1500	7	1	5	7	-1	3	4
8	3100	15	2	9	15	1	8	9
16	6200	31	7	19	31	7	19	19
24	9200	44	14	29	44	14	29	29
30	11500	56	20	37	56	21	39	38
32	12300	59	22	39	59	23	41	40
34	13100	63	23	42	63	24	44	43
36	13800	65	25	44	65	26	46	45
38	14600	69	27	47	69	29	49	48
40	15400	73	30	50	73	31	52	51
42	16200	77	32	53	77	34	56	55
44	16900	81	34	55	81	36	59	57
46	17700	85	37	58	85	39	62	60
48	18500	89	39	61	89	42	66	64
50	19200	93	42	65	93	45	69	67
30	11500	59	23	39	59	23	41	40
20	7700	41	15	27	41	13	27	27
28	10800	55	22	37	55	22	39	38
36	13800	68	29	47	68	29	49	48
44	16900	83	37	57	83	39	61	59
50	19200	93	42	65	93	45	69	67
52	20000	97	45	68	97	49	73	71
54	20800	101	49	71	101	53	77	74
56	21600	105	53	75	105	56	81	78
58	22300	109	61	80	109	60	85	83
60	23000	114	68	87	114	67	91	89

PLATE A.

EXTENSOMETERS Va, Vb, Vla & Vlb.

Load (kips)	Stress (p.s.i.)	Elongation ins/100,000 Va	Elongation ins/100,000 Vb	Average Elongation ins/1000,000 Va & Vb.	Average Unit Strain ins/100,000 Va & Vb.	Elongation ins/100,000 Vla	Elongation ins/100,000 Vlb.	Average Elongation ins/1,000,000 Vla & Vlb.	Average Unit Strain ins/100,000 Vla & Vlb.
0	0	-	-	-	-	-	-	-	-
1.5	600	0	0	0	0	0	0	0	0
2	800	9	2	55	1	1	0	5	1
4	1500	45	9	270	3	4	9	65	3
6	2300	76	20	480	6	10	13	115	6
8	3000	105	32	685	9	15	19	170	9
10	3800	135	48	915	12	20	25	225	11
6	2300	80	19	495	6	10	18	140	7
1.5	600	7	-1	30	1	0	5	25	1
4	1500	43	11	270	3	2	11	65	3
6	2300	80	19	495	6	11	13	120	6
8	3100	109	31	700	9	18	19	185	9
10	3800	137	47	920	12	21	22	215	11
12	4600	162	61	1115	14	29	29	290	15
14	5400	190	78	1340	17	32	34	330	17
16	6200	218	92	1550	19	40	40	400	20
18	6900	242	109	1755	22	46	45	455	23
20	7700	270	125	1975	25	51	50	505	25
22	8500	298	141	2195	28	59	55	570	29
24	9200	321	158	2395	30	65	60	625	31
26	10000	349	178	2635	33	71	66	685	34
28	10800	374	191	2825	35	79	71	750	38
30	11500	400	209	3045	38	85	77	810	41
20	7700	280	121	2005	25	51	51	510	26
10	3800	146	48	970	12	29	31	300	15
1.5	600	11	-1	50	1	1	9	50	2
4	1500	51	11	310	4	8	15	115	6
8	3100	118	31	745	9	21	21	210	11
16	.6200	225	91	1580	20	41	41	410	21
24	9200	328	158	2430	30	67	61	640	32
30	11500	401	210	3055	38	85	78	815	41
32	12300	428	227	3275	41	91	82	865	43
34	13100	452	244	3480	44	91	89	900	45
36	13800	480	261	3705	46	104	95	995	50
38	14600	508	281	3945	49	110	101	1055	53
40	15400	538	300	4195	52	119	107	1130	57
42	16200	570	320	4450	56	125	115	1200	60
44	16900	600	341	4705	59	131	121	1260	63
46	17700	635	363	4990	62	138	130	1340	67
48	18500	671	389	5300	66	142	139	1405	70
50	19200	705	411	5580	70	155	145	1500	75
30	11500	470	231	3505	44	98	99	985	49
20	7700	349	148	2435	30	68	71	695	35
28	10800	442	217	3295	41	88	90	890	45
36	13800	540	287	4135	52	110	109	1095	55
44	16900	635	359	4970	62	133	130	1315	66
50	19200	712	416	5640	71	150	148	1490	75
52	20000	750	441	5955	74	154	152	1530	77
54	20800	813	478	6455	81	173	162	1675	84
56	21600	881	522	7015	88	193	178	1855	93
58	22300	968	579	7735	97	218	199	2085	104
60	23000	1070	650	8600	108	242	220	2310	116

PLATE A.

EXTENSOMETERS 111a, 111b, 1V & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000		Average Elongation ins/ 1,000,000	Average Unit Strain ins/ 100,000	Elongation ins/ 100,000		Average Elongation ins/ 1,000,000	Average Unit Strai[n] ins/ 100,000
		111a	111b	111a&111b.	111a&111b.	1Va	1Vb	1Va & 1Vb	1Va & 1Vb.
0	0	-	-	-	-	-	-	-	-
1.5	580	0	0	0	0	0	0	0	0
2	770	2	0	10	1	2	0	10	1
4	1500	8	2	50	3	10	1	55	3
6	2300	18	7	125	6	19	3	110	6
8	3100	25	10	175	9	27	7	170	9
10	3800	32	12	220	11	22	9	205	10
6	2300	1.8	8	130	6	19	4	115	6
1.5	600	-1	2	5	0	0	1	5	0
4	1500	9	4	65	3	9	2	55	3
6	2300	20	7	135	6	20	4	120	6
8	3100	29	9	190	9	29	5	170	9
10	3800	35	10	245	12	36	9	225	11
12	4600	41	13	270	14	42	11	265	13
14	5400	49	18	335	17	50	14	320	16
16	6200	56	20	380	19	58	19	385	19
18	6900	62	24	430	22	63	21	420	21
20	7700	71	28	495	25	71	25	480	24
22	8500	79	30	545	27	80	29	545	27
24	9200	86	32	590	30	87	31	590	30
26	10000	92	38	650	33	93	34	635	32
28	10800	100	40	700	35	10[illegible]	39	700	35
30	11500	109	42	755	38	109	41	750	38
20	7700	.75	26	505	25	73	22	475	24
10	3800	38	11	245	12	37	9	230	11
1.5	600	0	1	5	0	0	1	5	0
4	1500	11	8	95	5	10	2	60	3
8	3100	31	8	195	10	30	5	175	9
16	6200	59	20	395	20	60	19	395	20
24	9200	89	31	600	30	89	31	600	30
30	11500	109	42	755	38	109	41	750	38
32	12300	115	48	815	41	115	45	800	40
34	13100	122	50	860	43	122	50	860	43
36	13800	129	54	915	46	130	53	915	46
38	14600	137	59	980	49	137	59	980	49
40	15400	142	64	1030	52	142	63	1025	51
42	16200	150	69	1095	55	150	68	1090	54
44	16900	159	72	1155	58	157	71	1140	57
46	17700	165	80	1225	61	162	79	1205	60
48	18500	171	88	1295	65	170	85	1275	64
50	19200	180	92	1360	68	179	91	1350	68
30	11500	119	58	885	44	111	51	810	41
20	7700	84	40	620	31	79	32	555	28
28	10800	110	52	810	41	105	49	770	39
36	13800	138	68	1030	52	132	61	965	48
44	16900	162	81	1215	61	160	81	1205	60
50	19200	182	93	1375	69	179	91	1350	68
52	20000	190	100	1450	73	185	99	1420	71
54	20800	199	108	1535	77	198	103	1505	75
56	21600	210	119	1645	82	210	112	1610	81
58	22300	222	128	1750	88	220	121	1705	85
60	23000	232	142	1870	94	228	132	1800	90
62	23800	Y.P.							
132.4	51000	U.S.							

PLATE A

EXTENSOMETERS 111a, 111b, 1Va & 1Vb. (cont'd).

Add .00002 to all unit strains to correct for initial load.

Area = .567 x 4.58 = 2.60 sq. ins.

Elastic Limit = 16200 p.s.i.

E = 28.8 x 10^6 p.s.i.

% Elongation in 8 ins. = 29.2%

% Reduction in area = 47.0%

PLATE B.

EXTENSOMETERS 1a, 1b, 11a, & 11b.

Load (kips)	Stress (psi.)	Elongation ins/100,000 1a.	Elongation ins/100,000 1b.	Average Unit Strain ins/100,000 1a. & 1b.	Elongation ins/100,000 11a.	Elongation ins/100,000 11b.	Average Unit Strain ins/100,000 11a & 11b.	Average Unit Strain ins/100,000 1. & 11.
0	0	-	-	-	-	-	-	-
1.5	600	0	0	0	0	0	0	0
2	800	2	-1	1	2	-1	1	1
4	1700	10	-2	4	10	-2	4	4
6	2500	18	-2	8	17	-4	7	8
8	3300	25	-3	11	22	-6	8	10
10	4100	32	-3	15	28	-7	11	13
6	2500	19	-2	8	17	-5	6	7
1.5	600	1	0	0	1	0	0	0
2	800	2	0	1	2	-1	1	1
4	1700	11	-2	4	10	-2	4	4
6	2500	24	-3	10	17	-5	6	8
8	3300	25	-3	11	22	-6	8	10
10	4100	31	-3	14	27	-7	10	12
12	4900	37	-2	18	32	-7	13	16
14	5800	43	-2	21	38	-7	16	19
16	6600	49	-2	24	42	-7	18	21
18	7400	55	-1	27	48	-6	21	24
20	8200	60	0	30	52	-5	24	27
22	9100	64	2	33	56	-4	26	30
24	9900	70	2	36	61	-4	29	33
26	10700	76	5	41	66	-3	32	37
28	11500	81	7	44	72	-2	35	40
30	12400	88	8	48	76	0	38	43
20	8200	63	3	33	54	-4	25	29
10	4100	35	0	18	29	-5	12	15
1.5	600	5	2	4	2	0	1	2
4	1700	15	1	8	12	-3	5	7
8	3300	30	-1	15	24	-5	10	13
16	6600	52	0	26	45	-5	20	23
24	9900	73	4	39	64	-3	21	35
30	12400	88	8	48	76	0	38	43
32	13200	93	10	52	81	1	41	47
34	14000	100	15	58	86	3	45	52
36	14800	108	18	63	93	5	49	56
38	15700	114	21	68	98	7	53	61
40	16500	120	26	73	103	9	56	65
42	17300	124	28	76	107	12	60	68
44	18100	132	33	83	114	15	65	74
46	19000	138	39	89	120	17	69	79
48	19800	142	45	94	129	21	75	85
50	20600	148	51	100	136	26	81	91
30	12400	105	35	70	96	12	54	62
40	16500	126	43	85	116	19	68	77
44	18100	136	46	91	125	21	73	82
48	19800	145	50	98	133	25	79	89
50	20600	149	52	100	137	26	82	91
52	21400	154	56	105	143	30	87	96
54	22200	160	63	112	153	37	95	104
56	23000	166	71	119	161	42	102	111
58	23800	170	80	125	170	49	110	118
60	24700	175	90	133	178	58	118	126
61	25100	176	92	134	181	63	122	128
62	25600	178	97	138	184	69	127	133
63	26000	180	103	142	187	77	132	137
65	26800	178	122	150	190	93	142	146

PLATE B.

EXTENSOMETERS Va, Vb, Vla, & Vlb.

Load (kips)	Stress (psi.)	Elongation ins/100,000 Va	Elongation ins/100,000 Vb	Average Elongation ins/1,000,000 Va & Vb	Average Unit Strain ins/100,000 Va & Vb	Elongation ins/100,000 Vlb	Elongation ins/100,000 Vla.	Average Elongation ins/1,000,000 Vla & Vlb.	Average Unit Strain ins/100,000 Vla & Vlb.
0	0	-	-	-	-	-	-	-	-
1.5	600	0	0	0	0	0	0	0	0
2	800	18	-4	70	1	4	0	20	1
4	1700	90	-21	345	4	22	-8	70	4
6	2500	152	-30	610	8	39	-10	145	7
8	3300	206	-30	880	11	50	-6	220	11
10	4100	259	-30	1145	14	62	-5	285	14
6	2500	155	-29	620	8	39	-4	175	9
1.5	600	12	-8	20	0	-5	-1	-30	-1
2	800	30	-11	95	1	10	-2	40	2
4	1700	98	-24	370	5	27	-8	95	5
6	2500	156	-30	630	8	39	-8	155	8
8	3300	208	-31	885	11	51	-7	220	11
10	4100	253	-28	1125	14	61	-5	280	14
12	4900	303	-25	1390	17	75	-8	335	17
14	5800	348	-19	1645	21	85	-5	400	20
16	6600	389	-12	1885	24	98	-5	465	23
18	7400	432	-6	2130	27	107	-3	520	26
20	8200	471	2	2365	30	118	-2	580	29
22	9100	511	12	2615	33	128	-1	635	32
24	9900	551	22	2865	36	138	1	695	35
26	10700	592	35	3135	39	148	3	755	38
28	11500	630	49	3395	42	157	8	825	41
30	12400	668	62	3650	46	165	11	880	44
20	8200	492	14	2530	32	120	1	605	30
10	4100	286	-20	1330	17	71	-6	325	16
1.5	600	48	-7	205	2	16	-5	55	3
4	1700	132	-25	535	7	35	-9	130	7
8	3300	238	-28	1050	13	.58	-4	270	14
16	6600	410	-2	2040	26	98	1	495	25
24	9900	565	35	3000	38	137	9	730	37
30	12400	670	70	3700	46	161	14	875	44
32	13200	708	82	3950	50	171	17	940	47
34	14000	750	100	4250	53	181	19	1000	50
36	14800	799	124	4625	58	191	21	1060	53
38	15700	835	140	4875	61	201	24	1125	56
40	16500	891	170	5305	66	210	30	1200	60
42	17300	925	188	5565	70	219	32	1255	63
44	18100	978	211	5945	74	231	39	1350	68
46	19000	1028	240	6340	79	242	43	1425	71
48	19800	1085	271	6780	85	258	50	1540	77
50	20600	1135	300	7175	90	270	59	1645	82
30	12400	855	151	5030	63	201	22	1115	56
40	16500	1009	225	6170	77	238	40	1390	70
44	18100	1068	258	6630	83	252	48	1500	75
48	19800	1125	291	7080	88	266	55	1605	80
50	20600	1156	311	7335	92	272	60	1660	83
52	21400	1193	338	7655	96	283	68	1755	88
54	22200	1260	380	8200	103	301	80	1905	95
56	23000	1350	440	8950	112	328	92	2100	105
58	23800	1440	492	9660	121	352	105	2285	114
60	24700	1540	570	10550	132	399	121	2600	130
61	25100	1591	629	11100	139	422	130	2760	138
62	25600	1690	672	11535	144	449	142	2955	148
63	26000	1840	725	12075	151	480	158	3190	160
65	26800	2128	975	14075	176	592	198	3950	198

PLATE B.

EXTENSOMETERS 111a, 111b, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 111a,	111b.	Average Elongation ins/ 1,000,000 111a.&111b.	Average Unit Strain ins/ 100,000 111a.&111b.	Elongation ins/ 100,000 1Va.	1Vb.	Average Elongation ins/ 1,000,000 1Va.& 1Vb.	Average Unit Strain ins/ 100,000 1Va. & 1Vb
0	0	-	-	-	-	-	-	-	-
1.5	600	0	0	0	0	0	0	0	0
2	800	7	-2	25	1	8	-2	30	1
4	1700	32	-16	80	4	35	-15	100	5
6	2500	56	-22	170	9	60	-25	175	9
8	3300	71	-25	230	12	79	-29	250	13
10	4100	90	-28	310	16	95	-32	315	16
6	2500	56	-21	175	9	58	-21	175	9
1.5	600	9	-5	20	1	-2	-1	-15	0
2	800	15	-8	35	2	11	-7	20	1
4	1100	31	-18	65	3	38	-18	100	5
6	2500	57	-22	175	9	59	-23	180	9
8	3300	72	-25	235	12	78	-29	245	12
10	4100	89	-28	305	15	92	-31	305	15
12	4900	106	-31	375	19	111	-37	370	19
14	5800	120	-32	440	22	122	-38	420	21
16	6600	133	-33	500	25	139	-39	500	25
18	7400	149	-35	570	29	152	-40	560	28
20	8200	161	-35	630	32	165	-41	620	31
22	9100	173	-36	685	34	180	-41	695	35
24	9900	187	-36	755	38	191	-41	750	38
26	10700	196	-36	800	40	202	-40	810	41
28	11500	205	-33	860	43	213	-38	875	44
30	12400	215	-32	915	46	222	-36	930	47
20	8200	157	-33	620	31	160	-31	645	32
10	4100	90	-29	305	15	90	-21	345	17
1.5	600	10	-10	0	0	9	- 1	40	2
4	1700	40	-21	95	5	41	-15	130	7
8	3300	71	-28	215	11	78	-23	275	14
16	6600	127	-32	475	24	135	-29	530	27
24	9900	178	-31	735	37	188	-31	785	39
30	12400	209	-29	900	45	220	-30	950	48
32	13200	220	-29	955	48	231	-30	1005	50
34	14000	231	-26	1025	51	245	-27	1060	53
36	14800	240	-22	1090	55	259	-21	1190	60
38	15700	249	-21	1140	57	270	-19	1255	63
40	16500	259	-20	1195	60	282	-11	1355	68
42	17300	269	-19	1250	63	294	-9	1425	71
44	18100	280	-15	1325	66	301	-7	1470	74
46	19000	289	-14	1375	69	313	-1	1560	78
48	19800	298	-13	1425	71	328	5	1665	83
50	20600	308	-11	1485	74	340	10	1750	88
30	12400	220	-14	1030	52	248	-11	1185	59
40	16500	267	-29	1190	60	297	-1	1480	74
44	18100	282	-21	1305	65	315	2	1585	79
48	19800	300	-15	1425	71	331	9	1700	85
50	20600	308	-12	1480	74	340	12	1760	88
52	21400	317	-9	1540	77	352	18	1850	93
54	22200	327	-5	1610	81	368	22	1950	98
56	23000	340	0	1700	85	385	29	2070	104
58	23800	352	1	1765	88	402	34	2180	109
60	24700	369	3	1860	93	425	43	2340	112
61	25100	378	5	1915	96	432	49	2405	120
62	25600	381	8	1945	97	442	55	2485	124
63	26000	388	11	1994	100	452	60	2560	128
65	26800	407	12	2095	105	481	71	2760	138
67	27600	YP							
125	51500	US							

PLATE B.

EXTENSOMETERS 111a, 111b, 1Va & 1Vb. (cont'd)

Add .00002 to all unit strains to correct for intial load.

Area = 0.517 x 4.70 = 2.43 sq. ins.

Elastic Limit = 13000 p.s.i.

E = 25.5×10^6 p.s.i.

% Elongation in 8 ins. = 32%

% Reduction in area = 45%

PLATE C-1

EXTENSOMETERS 1a, 1b, 11a & 11b.

Load (Kips)	Stress (psi.)	Elongation ins/ 1,000,000 11b.	Elongation ins/ 1,000,000 11a.	Average Unit Strain ins/ 1,000,000 11a & 11b.	Elongation ins/ 1,000,000 1b.	Elongation ins/ 1,000,000 1a.	Average Unit Strain ins/ 1,000,000 1a. & 1b.	Average Unit Strain ins/ 1,000,000 1a, 1b, 11a & 11b.
0	0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0
4	1300	0	33	16	8	41	24	20
6	2000	0	66	33	17	83	50	42
8	2600	8	99	53	17	125	71	62
10	3300	16	132	74	33	158	95	90
12	3900	25	164	94	41	191	116	105
14	4600	41	206	123	58	224	141	132
16	5200	49	238	143	66	257	161	152
18	5900	66	263	164	75	290	182	173
20	6500	82	296	189	91	324	207	198
22	7200	90	329	209	108	356	232	221
24	7800	107	362	234	125	390	257	246
26	8500	123	386	254	141	415	278	266
28	9100	140	419	279	158	448	303	291
30	9800	164	452	308	166	481	323	316
33	10800	181	493	337	191	523	357	347
36	11800	206	534	370	216	564	390	380
39	12700	230	584	407	232	614	423	415
42	13700	255	625	440	257	647	452	446
45	14700	288	674	481	282	696	489	485
48	15700	312	715	513	307	730	518	516
51	16600	337	765	551	324	780	552	552
54	17600	370	805	587	348	821	584	586
57	18600	386	864	625	373	864	618	622
60	19600	419	929	674	398	921	659	667
63	20600	470	1011	740	431	988	709	725
65	21200	493	1043	768	456	1029	742	755
67	21900	526	1086	806	481	1062	721	763
69	22500	559	1135	847	514	1102	808	828
71	23200	592	1185	888	539	1152	845	867
73	23800	641	1232	936	564	1193	878	907
75	24400	658	1282	970	606	1229	917	944
77	25200	674	1340	1007	664	1295	979	993
79	25800	724	1399	1061	714	1337	1025	1043
81	26400	780	1457	1118	763	1386	1074	1096
83	27100	855	1530	1192	839	1460	1149	1170
85	27700	905	1602	1253	905	1501	1203	1228
87	28400	1002	1685	1343	1020	1585	1302	1323
89	29000	1135	1760	1447	1152	1627	1389	1418
91	29700	1275	1832	1553	1278	1642	1460	1507
93	30400	1480	1840	1660	1378	1670	1524	1592

PLATE C-1.

EXTENSOMETERS 111a & 111b, V11a & V11b.

Load (kips)	Stress (psi.)	Elongation $\frac{1}{100,000}$ ins 111b	111a	Average Elongation $\frac{1}{1,000,000}$ ins 111a & 111b	Av. Unit St. over 2" $\frac{1}{1,000,000}$ ins 111a & 111b	Elongation $\frac{1}{100,000}$ ins V11b	V11a	Average Elongation $\frac{1}{1,000,000}$ ins V11a & V11b	Average Unit Strain $\frac{1}{1,000,000}$ ins V11a & V11b
0	0	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0	0
4	1300	2	5	35	17	5	2	35	17
6	2000	9	8	85	42	9	10	95	47
8	2600	15	10	125	62	11	14	125	62
10	3300	20	12	160	80	15	20	175	87
12	3900	27	18	225	112	19	24	215	107
14	4600	31	20	255	127	21	30	255	127
16	5200	39	21	300	150	25	35	300	150
18	5900	43	25	340	170	29	40	345	172
20	6500	50	29	395	197	31	45	380	190
22	7200	56	30	430	215	36	50	430	215
24	7800	61	32	465	232	39	56	475	237
26	8500	69	37	530	265	41	61	510	255
28	9100	74	39	565	282	45	68	565	282
30	9800	80	41	605	302	49	71	600	300
33	10800	89	47	680	340	52	79	655	327
36	11800	98	50	740	370	59	86	725	362
39	12700	105	55	800	400	64	92	780	390
42	13700	112	60	860	430	70	100	850	425
45	14700	121	65	930	465	77	108	925	462
48	15100	130	70	1000	500	81	112	965	482
51	16600	139	75	1070	535	88	120	1040	520
54	17600	145	80	1125	562	92	128	1100	555
57	18600	153	84	1185	592	100	132	1160	580
60	19600	162	86	1240	620	108	140	1240	620
63	20600	173	90	1315	657	114	145	1295	647
65	21200	181	95	1380	690	120	153	1365	682
67	21900	188	99	1435	717	125	164	1445	722
69	22500	193	101	1470	735	131	170	1505	752
71	23200	200	105	1525	762	138	177	1575	787
73	23800	206	110	1580	790	142	180	1610	805
75	24400	214	115	1645	822	150	185	1675	837
77	25200	227	120	1735	867	160	191	1755	877
79	25800	240	123	1815	907	169	195	1820	910
81	26400	259	127	1930	965	179	201	1900	955
83	27100	283	129	2060	1030	191	203	1970	985
85	27700	305	130	2175	1087	202	204	2030	1015
87	28400	350	139	2445	1222	219	200	2095	1047
89	29000	419	175	2970	1485	237	190	2135	1067
91	29700	549	280	4245	2122	266	182	2240	1120
93	30400	770	Yielded	-	-	328	232	2800	1400

PLATE C-1.

EXTENSOMETERS Va, Vb, 1Va & 1Vb.

Load (kips)	Stress (p.s.i.)	Elongation $\frac{1}{100,000}$ ins Vb.	Elongation $\frac{1}{100,000}$ ins Va.	Average Unit Strain $\frac{1}{1,000,000}$ ins Va. & Vb.	Elongation $\frac{1}{1,000,000}$ ins 1Vb.	Elongation $\frac{1}{1,000,000}$ ins 1Va.	Average Unit Strain $\frac{1}{1,000,000}$ ins 1Va & 1Vb.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	0	4	20	0	42	21
6	2000	1	8	45	0	84	42
8	2600	3	9	60	8	118	63
10	3300	7	10	85	25	143	84
12	3900	9	12	105	33	177	105
14	4600	10	14	120	41	210	125
16	5200	12	17	145	58	244	151
18	5900	18	19	185	74	270	172
20	6500	20	20	200	83	303	193
22	7200	21	21	210	99	337	218
24	7800	25	22	235	124	362	243
26	8500	29	25	270	140	387	263
28	9100	30	28	290	157	421	289
30	9800	33	29	310	165	455	310
33	10800	39	30	345	198	496	347
36	11800	41	33	370	223	531	377
39	12700	45	38	415	248	572	410
42	13700	49	40	445	272	615	443
45	14700	51	42	465	288	656	472
48	15700	56	48	520	322	699	510
51	16600	60	50	550	346	741	543
54	17600	62	52	570	371	783	577
57	18600	65	60	625	404	825	614
60	19600	68	65	665	454	952	703
63	20600	70	69	695	486	1129	807
65	21200	72	70	710	504	1189	846
67	21900	75	72	735	536	1265	900
69	22500	78	73	755	569	1408	988
71	23200	79	76	775	602	1525	1063
73	23800	80	79	795	651	1743	1197
75	24400	81	80	805	700	1938	1319
77	25200	82	85	835	800	2258	1529
79	25800	83	89	860	866	2482	1674
81	26400	88	90	890	982	2610	1796
83	27100	89	94	915	1239		
85	27700	89	100	945	1410		
87	28400	89	112	1005	1672		
89	29000	88	138	1130	1725		
91	29700	88	174	1310	1725		
93	30400	91	205	1480	1725		

PLATE C-1.

EXTENSOMETERS Vla & Vlb and
SUMMATION OF EXTENSOMETER READINGS 111, 1V, V, Vl & Vll.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000		Average Elongation ins/ 1,000,000	Average Unit Strain ins/ 1,000,000	Total Elongation in 8 ins. ins / 1,000,000	Unit Strain over 8 ins. ins/ 1,000,000
		Vlb	Vla	Vla & Vlb.	Vla & Vlb.	111 to Vll	111 to Vll
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	1	6	35	17	146	18
6	2000	2	12	70	35	337	42
8	2600	5	20	125	62	498	62
10	3300	8	28	180	90	684	86
12	3900	10	32	210	105	860	108
14	4600	11	40	255	122	1010	126
16	5200	12	48	300	150	1196	150
18	5900	17	52	345	172	1387	173
20	6500	19	60	395	197	1563	195
22	7200	21	67	440	220	1728	216
24	7800	22	71	465	232	1883	235
26	8500	28	79	535	267	2108	264
28	9100	29	86	575	287	2284	286
30	9800	31	90	605	302	2430	304
33	10800	36	100	680	840	2707	338
36	11800	40	109	745	372	2957	370
39	12700	45	118	815	407	3220	403
42	13700	50	126	870	435	3468	434
45	14700	55	133	940	470	3732	467
48	15700	60	141	1005	502	4000	500
51	16600	65	150	1075	537	4258	532
54	17600	70	160	1150	575	4522	565
57	18600	78	168	1230	615	4814	602
60	19600	85	181	1330	665	5178	647
63	20600	92	192	1420	710	5532	692
65	21200	100	205	1525	762	5826	728
67	21900	108	217	1625	812	6140	768
69	22500	118	229	1735	867	6448	806
71	23200	126	200	1830	915	6768	846
73	23800	132	250	1910	955	7092	887
75	24400	144	262	2030	1015	7474	936
77	25200	158	272	2150	1075	8004	1001
79	25800	173	289	2310	1155	8479	1060
81	26400	192	313	2525	1262	9041	1130
83	27100	219	340	2795	1397	-	
85	27700	239	355	2970	1485	-	
87	28400	260	360	3100	1550	-	
89	29000	280	343	3115	1557	-	
91	29700	312	324	3180	1590	-	
93	30400	342	337	3395	1697	-	
165.	54000	U.S.					

Add .000022 to all unit strains to correct for initial load

Area = .613 x 5000 = 3.065 sq. ins.

Elastic Limit 17600 p.s.i.

$E = 30.0 \times 10^6$ p.s.i.

$\% \text{ Elongation in 8 inches} = \frac{(11.34 - 8.00)}{8.00} 100 = 42\%$

$\% \text{ Reduction in area} = \left(\frac{3.065 - 1.91}{3.065}\right) 100 = 38\%$

PLATE C-2.

EXTENSOMETERS 1a, 1b, 11a & 11b.

Load (kips)	Stress (psi.)	Elongation ins/ 1,000,000		Average Unit Strain ins/ 1,000,000	Elongation ins/ 1,000,000		Average Unit Strain ins/ 1,000,000	Average Unit Strain ins/ 1,000,000
		11a	11b	11a & 11b	1a	1b	1a & 1b	1a,1b 11a & 11b.
0	0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0
4	1300	0	25	13	33	16	24	18
6	2000	8	58	33	66	25	45	39
8	2600	16	99	58	99	41	70	64
10	3300	25	132	79	133	49	91	85
12	3900	33	165	999	165	66	115	107
14	4600	49	197	123	198	82	140	131
16	5200	58	222	140	223	91	157	148
18	5900	82	255	169	256	115	185	175
20	6500	90	279	185	281	132	206	195
22	7200	115	312	214	306	157	231	222
24	7800	123	395	234	314	165	239	236
27	8800	148	386	267	355	198	276	271
30	9800	189	427	308	404	222	313	310
33	10800	206	468	337	437	247	342	339
36	11800	230	510	370	479	280	379	374
39	12700	263	542	403	512	304	408	405
42	13700	288	584	436	559	338	448	442
45	14700	312	625	479	595	370	482	480
48	15700	337	666	502	635	395	515	508
51	16600	362	706	534	685	428	556	545
54	17600	394	748	571	726	462	594	582
57	18600	427	789	608	768	486	627	617
60	19600	452	831	642	816	518	667	654
63	20600	495	888	687	884	560	722	704
66	21600	526	954	740	942	592	767	753
69	22500	576	1020	798	1008	650	829	813
72	23500	632	1086	859	1081	707	894	876
75	24400	690	1160	925	1148	774	961	943
79	25800	805	1259	1032	1256	874	1065	1048
81	26400	855	1300	1078	1296	898	1097	1087
83	27100	921	1366	1144	1352	956	1159	1151
85	27700	1020	1430	1225	1438	1048	1243	1234
87	28400	1182	1512	1347	1528	1146	1337	1342
89	29000	1348	1588	1468	1618	1268	1443	1455
91	29700	1512	1628	1570	1668	1418	1543	1556
93	30400							

PLATE C-2.

EXTENSOMETERS 111a, 111b, V11a & V11b.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 111b	111a	Average Elongation ins/ 1,000,000 111a &111b	Average Unit Strain over 2" ins/ 1,000,000 111a & 111b	Elongation ins/ 1,000,000 V11b	V11a	Average Elongation ins/ 1,000,000 V11a &111b	Average Unit Strain over 2" ins/ 1,000,000 V11a & V11b.
0	0	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0	0
4	1300	-2	12	50	25	11	-2	45	22
6	2000	-1	19	90	45	19	0	95	47
8	2600	2	22	120	60	22	4	130	65
10	3300	9	28	185	92	29	10	195	97
12	3900	12	31	215	107	31	13	220	110
14	4600	19	34	265	132	37	19	280	140
16	5200	22	39	305	152	40	23	315	157
18	5900	29	41	350	175	42	29	355	177
20	6500	34	45	395	197	49	33	410	205
22	7200	40	50	450	225	51	39	450	225
24	7800	44	52	480	240	57	46	515	257
27	8800	52	59	555	277	61	53	570	285
30	9800	61	63	620	310	68	59	635	317
33	10800	69	70	695	347	75	67	710	355
36	11800	76	74	750	375	79	76	775	387
39	12700	83	80	815	407	87	83	850	425
42	13700	92	86	890	445	90	89	895	447
45	14700	100	91	955	477	98	97	975	487
48	15700	109	98	1035	517	105	106	1055	527
51	16600	114	101	1075	537	109	112	1105	552
54	17600	122	108	1150	575	117	118	1175	587
57	18600	131	112	1215	607	123	126	1245	622
60	19600	140	118	1290	645	129	133	1310	655
63	20600	150	121	1355	677	138	138	1380	690
66	21600	159	128	1435	717	147	148	1475	737
69	22500	170	139	1545	772	155	153	1540	770
72	23500	186	153	1695	847	162	158	1600	800
75	24400	199	161	1800	900	170	166	1680	840
79	25800	227	177	2020	1010	185	182	1835	917
81	26400	242	183	2125	1062	190	186	1880	940
83	27100	263	195	2290	1145	198	188	1930	965
85	27700	299	-	-	-	224	180	2020	1010
87	28400	410	-	-	-	237	176	2065	1032
89	29000	-	-	-	-	248	169	2085	1042
91	29700	-	-	-	-	267	162	2145	1072
93	30400								

PLATE C-2.

EXTENSOMETERS Va, Vb, 1Va, & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/ 1,000,000 Vb,	Va.	Average Unit Strain ins/ 1,000,000 Va & Vb.	Elongation ins/ 1,000,000 1Vb	1Va	Average Unit Strain ins/ 1,000,000 1Va & 1Vb.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	-7	11	20	8	25	16
6	2000	-9	17	40	17	66	41
8	2600	-6	20	70	25	99	62
10	3300	-2	22	100	42	132	87
12	3900	-1	25	120	59	165	112
14	4600	0	28	140	67	190	128
16	5200	2	30	160	84	214	149
18	5900	6	31	185	110	248	179
20	6500	9	32	205	118	272	195
22	7200	10	37	235	143	288	215
24	7800	14	38	260	152	297	229
27	8800	16	40	280	185	348	266
30	9800	22	46	340	210	380	295
33	10800	25	47	360	236	412	324
36	11800	28	49	385	270	454	362
39	12700	34	51	425	294	495	394
42	13700	36	56	460	320	536	428
45	14700	42	58	500	354	570	462
48	15700	45	59	520	379	611	495
51	16600	47	62	545	404	652	528
54	17600	53	66	595	438	694	566
57	18600	55	67	610	472	735	603
60	19600	57	69	630	505	800	652
63	20600	63	76	695	539	1031	785
66	21600	65	78	715	606	1140	873
69	22500	68	83	755	674	1222	84
72	23500	70	88	790	749	1371	1060
75	24400	73	89	810	918	1692	1305
79	25800	.75	97	860	1184	2242	1713
81	26400	76	98	870	1350	Limit	-
83	27100	77	106	915	1550		-
85	27700	77	116	965	1896		-
87	28400	75	131	1030	1946		-
89	29000	74	148	1110	Limit		-
91	29700	76	178	1270,	of		
93	30400				Extension		

PLATE C-2.

EXTENSOMETERS Vla & Vlb and
SUMMATION OF EXTENSOMETER READINGS 111, 1V, V, Vl & Vll.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Vlb.	Vla.	Average Elongation ins/ 1,000,000 Vla & Vlb.	Average Unit Strain ins/ 1,000,000 Vla & Vlb.	Total Elongation in 8 ins. ins/ 1,000,000 Ill to Vll	Unit Strain over 8 ins. ins/ 1,000,000 Vl to Vll.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	11	-1	50	25	181	23
6	2000	17	2	95	47	361	45
8	2600	19	10	145	72	527	66
10	3300	21	18	195	97	762	95
12	3900	25	22	235	117	902	113
14	4600	29	30	295	147	1108	139
16	5200	30	35	325	162	1254	157
18	5900	32	41	365	182	1434	179
20	6500	37	49	430	215	1635	203
22	7200	40	52	460	230	1810	226
24	7800	42	59	505	252	1989	249
27	8800	47	68	575	267	2246	281
30	9800	52	77	645	322	2535	317
33	10800	58	83	705	352	2794	349
36	11800	61	91	760	380	3032	379
39	12700	67	101	840	420	3324	416
42	13700	71	110	905	452	3578	447
45	14700	71	118	975	487	3867	483
48	15700	81	126	1035	517	4140	518
51	16600	88	132	1100	550	4353	544
54	17600	92	141	1165	582	4651	581
57	18600	99	150	1245	622	4918	615
60	19600	102	158	1300	650	5182	648
63	20600	111	160	1355	677	5570	696
66	21600	121	170	1455	727	5953	744
69	22500	132	199	1655	827	6443	805
72	23500	142	211	1765	832	6910	864
75	24400	151	229	1900	950	7495	937
79	25800	167	241	2040	1020	8468	1059
81	26400	173	249	2110	1055	-	-
83	27100	181	250	2155	1077	-	-
85	27700	190	251	2205	1102	-	-
87	28400	200	233	2165	1082	-	-
89	29000	211	223	2170	1085	-	-
91	29700	230	209	2195	1097	-	-
93	30400	Y.P.					
167	54100	U.S.					

Add .000022 to all unit strains to correct for initial load.
Area = .6137 x 5.000 = 3.068 sq. ins.
Elastic Limit 19000 p.s.i.
E = 29.2 x 10^6 p.s.i.

$$\% \text{ Elongation in 8 ins.} = \frac{(11.32 - 8.000)}{8.000} 100 = 42\%$$

$$\% \text{ Reduction in area} = \left(\frac{3.068 - 1.415}{3.068}\right) 100 = 54\%.$$

PLATE D-1.

EXTENSOMETERS la, lb, lla & llb.

Load (kips)	Stress psi.	Elongtn 1/1000000 ins llb	Elongtn 1/1000000 ins lla	Average Unit Strain 1/1000000 ins lla & llb.	Elongat'n 1/1000000 ins lb	Elongt'n 1/1000000 ins la	Average UnitStrain 1/1000000 ins la & lb.	Average Unit Strain for both edges 1/1000000 ins la,lb,lla,llb.
0	0	-	-	-	-	-	-	-
1.5	500	0	0	0	0	0	0	0
2	700	0	8	4	0	0	0	2
4	1400	8	41	25	17	25	21	23
6	2000	33	66	50	34	51	43	47
8	2700	44	90	70	41	76	59	65
10	3400	66	132	99	50	100	75	87
12	4100	82	164	123	66	126	96	110
14	4800	99	197	148	83	160	122	135
16	5400	123	230	177	99	185	142	159
18	6200	140	263	202	124	210	167	185
20	6800	164	288	226	132	244	188	207
22	7500	181	321	251	149	270	209	230
24	8200	197	353	275	165	295	230	253
26	8800	222	378	300	190	328	259	280
28	9500	238	410	324	198	346	272	298
30	10200	254	436	345	214	370	292	319
32	10900	271	460	365	240	396	318	342
34	11600	288	494	391	256	430	343	367
36	12200	312	526	419	272	454	363	391
38	12900	328	550	439	289	480	385	412
41	13600	353	575	464	314	506	410	437
42	14300	370	608	489	330	540	435	462
44	15000	394	632	513	346	546	446	480
46	15600	410	656	533	371	581	476	505
48	16300	426	690	558	388	598	493	526
50	17000	452	714	583	404	632	518	550
52	17700	468	740	604	429	665	547	576
54	18400	494	772	633	446	690	568	600
56	19000	510	796	653	462	708	585	619
58	19700	534	822	678	486	732	609	644
60	20400	542	854	698	512	758	635	667
62	21100	566	880	723	528	792	660	692
64	21800	584	904	744	544	808	676	710
66	22400	608	936	772	570	842	706	739
68	23100	624	954	789	594	868	731	760
70	23800	650	986	818	610	894	752	785
72	24500	664	1020	842	626	918	772	807
74	25200	682	1034	858	652	944	798	828
76	25800	698	1068	883	676	968	822	852
78	26500	722	1092	907	694	1002	848	877
80	27200	734	1118	926	718	1020	869	898
82	27900	764	1142	953	744	1044	894	924
84	28600	780	1172	976	750	1088	919	948

PLATE D-1.

EXTENSOMETERS 111a, 111b, V11a & V11b.

Load (kips)	Stress (psi)	Elongation $\frac{1}{100,000}$ ins 111b	Elongation $\frac{1}{100,000}$ ins 111a	Average Elongation $\frac{1}{1,000,000}$ ins 111a & 111b	Average Unit Strain over 2" $\frac{1}{1,000,000}$ ins 111a&111b.	Elongation $\frac{1}{100,000}$ ins. V11b	Elongation $\frac{1}{100,000}$ ins. V11a	Elongation $\frac{1}{1,000,000}$ ins V11a&V11b.	Average Unit Strain over 2" $\frac{1}{1,000,000}$ ins V11a&V11b.
0	0	-	-	-	-	-	-	-	-
1.5	500	0	0	0	0	0	0	0	0
2	700	-1	1	0	0	2	-1	5	3
4	1400	-4	15	55	28	17	-2	75	38
6	2000	5	14	95	48	17	7	120	60
8	2700	14	15	145	73	18	13	155	78
10	3400	18	18	180	90	19	19	190	95
12	4100	26	20	230	115	21	26	235	118
14	4800	32	22	270	135	26	29	275	138
16	5400	38	25	315	158	29	37	330	65
18	6200	46	28	370	185	31	41	360	180
20	6800	53	30	415	208	35	48	415	208
22	7500	57	32	445	223	39	55	470	235
24	8200	65	37	510	255	41	59	500	250
26	8800	71	39	550	275	45	66	555	278
28	9500	76	41	585	293	50	69	595	298
30	10200	81	47	640	320	53	76	645	323
32	10900	87	49	680	340	59	80	695	348
34	11600	94	51	725	363	61	86	735	368
36	12200	97	55	760	380	68	89	785	393
38	12900	104	59	815	408	70	96	830	415
40	13600	108	62	850	425	76	99	875	428
42	14300	115	68	915	458	80	106	920	465
44	15000	119	70	945	473	82	109	955	478
46	15600	126	71	985	493	88	116	1020	510
48	16300	131	77	1040	520	91	119	1050	525
50	17000	136	80	1080	540	96	125	1105	553
52	17700	144	83	1135	568	100	129	1145	573
54	18400	147	88	1185	593	105	136	1205	603
56	19000	150	90	1220	610	110	138	1240	620
58	19700	157	94	1255	628	112	144	1280	640
60	20400	165	99	1320	660	118	148	1300	650
62	21100	170	101	1355	678	121	153	1370	685
64	21800	176	105	1405	703	128	158	1430	715
66	22400	180	109	1445	723	130	163	1465	733
68	23100	186	111	1485	743	134	168	1510	755
70	23800	193	115	1540	770	140	172	1560	780
72	24500	196	120	1580	890	142	178	1600	800
74	25200	204	122	1630	815	149	182	1655	828
76	25800	207	128	1675	838	151	187	1690	845
78	26500	215	130	1725	863	155	190	1725	863
80	27200	218	132	1750	875	160	197	1785	893
82	27900	226	138	1820	910	163	200	1815	908
84	28600	231	140	1855	928	170	204	1870	935

PLATE D-1.

EXTENSOMETERS Va, Vb, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation 1/100,000 ins Vb	Elongation 1/100,000 ins Va	Average Unit Strain 1/1,000,000 ins Va and Vb	Elongation 1/1,000,000 ins 1Vb.	Elongation 1/1,000,000 ins 1Va	Average Unit Strain 1/1,000,000 ins 1Va & 1Vb.
0	0	-	-	-	-	-	-
1.5	510	0	0	0	0	0	0
2	680	-1	-1	0	0	8	04
4	1360	-9	12	15	16	25	20
6	2040	-2	11	45	33	58	45
8	2720	1	11	60	49	91	70
10	3400	6	12	90	66	116	91
12	4080	9	15	120	90	141	115
14	4760	11	18	145	107	174	140
16	5440	15	19	170	132	199	166
18	6220	19	20	195	148	224	186
20	6800	21	21	210	164	258	211
22	7480	26	22	240	189	282	236
24	8160	29	25	270	206	307	256
26	8840	32	28	300	230	340	285
28	9520	35	30	325	246	365	305
30	10200	38	31	345	263	382	322
32	10900	40	32	360	280	424	352
34	11600	42	37	395	304	440	372
36	12200	46	39	435	321	465	393
38	12900	49	40	445	345	490	418
40	13600	50	42	460	362	515	438
42	14300	52	46	490	386	548	467
44	15000	55	49	520	403	565	484
46	15600	60	50	550	427	598	512
48	16300	61	51	560	444	623	534
50	17000	64	54	590	460	648	554
52	17000	68	58	630	494	672	583
54	18400	70	60	650	510	696	603
56	19000	71	61	660	526	723	625
58	19700	75	63	690	551	748	650
60	20400	79	67	730	576	772	674
62	21100	80	69	745	592	798	695
64	21800	82	70	760	617	823	720
66	22400	86	72	790	641	839	740
68	23100	89	75	820	658	872	765
70	23800	91	79	850	683	897	790
72	24500	93	80	865	700	922	811
74	25200	97	81	890	724	948	836
76	25800	100	84	920	740	970	855
78	26500	101	87	940	765	1005	885
80	27200	104	90	970	781	1021	901
82	27900	109	91	1000	806	1046	926
82	28600	111	91	1010	822	1062	942

PLATE D-1.

EXTENSOMETERS Vla, Vlb and
SUMMATION OF EXTENSOMETER READINGS 111, 1V, V, V1 & V11.

Load (kips)	Stress (psi.)	Elongation $\frac{1}{100,000}$ ins Vlb	Elongation $\frac{1}{100,000}$ ins Vla	Average Elongation $\frac{1}{1,000,000}$ ins Vla & Vlb.	Average Unit Strain $\frac{1}{1,000,000}$ Vla & Vlb	Total Elongation in 8" $\frac{1}{1000000}$ ins 111,1V,V,V1&V11.	Average Unit Strain 8 ins. $\frac{1}{1000000}$ ins 111,1V,V,V1&V11.
0	0	-	-	-	-	-	-
1.5	500	0	0	0	0	0	0
2	700	2	0	10	5	19	2
4	1400	15	-2	65	33	230	29
6	2000	13	7	100	50	380	48
8	2700	14	15	145	73	576	72
10	3400	16	21	185	93	737	92
12	4100	19	29	240	120	940	11
14	4800	20	36	290	145	1120	140
16	5400	21	42	315	158	1297	162
18	6200	24	50	370	185	1465	183
20	6800	28	57	425	213	1677	210
22	7500	29	62	455	228	1846	231
24	8200	31	70	505	253	2041	255
26	8800	33	78	555	278	2245	281
28	9500	38	81	595	298	2405	301
30	10200	41	88	645	323	2597	325
32	10900	42	92	670	335	2757	345
34	11600	48	100	740	370	2967	371
36	12200	50	105	775	388	3148	394
38	12900	54	110	820	410	3328	416
40	13600	59	116	875	437	3498	442
42	14300	61	121	910	455	3712	464
44	15000	65	128	965	483	3869	484
46	15600	68	132	1000	500	4067	508
48	16300	71	139	1050	525	4234	529
50	17000	75	142	1085	543	4414	552
52	17700	79	150	1145	573	4638	580
54	18400	81	155	1180	590	4823	603
56	19000	87	160	1235	618	4980	623
58	19700	90	166	1280	640	5155	644
60	20400	92	170	1310	655	5334	667
62	21100	98	178	1380	690	5545	693
64	21800	100	181	1405	703	5720	715
66	22400	103	188	1455	728	5895	737
68	23100	109	192	1505	753	6085	761
70	23800	111	199	1550	775	6290	786
72	24500	116	202	1590	795	6446	806
74	25200	120	210	1650	825	6661	833
76	25800	122	214	1680	840	6820	853
78	26500	128	220	1740	870	7015	877
80	27200	130	226	1780	890	7186	898
82	27900	132	231	1815	908	7376	922
84	28600	139	249	1940	970	7617	952
86	29200	Yield Point					
163	55500	Ultimate Load.					

EXTENSOMETERS Vla, VlB and
SUMMATION OF EXTENSOMETER READINGS lll, lV, V, Vl & Vll (cont'd)

Add .000022 to all unit strains to correct for initial load

Area = .618 x 4.755 = 2.940 square inches.

Elastic Limit = 28000 psi.

$E = 29.7 \times 10^6$ psi.

Elongation (Broke outside gauge lines)

Reduction in area = $\left(\frac{2.940 - 1.360}{2.940}\right)$ 100 = 54%.

PLATE D-2.

EXTENSOMETERS la, lb, lla & llb.

Load (kips)	Stress (psi.)	Elongation $\frac{1}{1,000,000}$ ins llb.	Elongation $\frac{1}{1,000,000}$ ins lla.	Average Unit Elongation $\frac{1}{1,000,000}$ ins lla. & llb.	Elongation $\frac{1}{1,000,000}$ ins lb.	Elongation $\frac{1}{1,000,000}$ ins la.	Average Unit Strain $\frac{1}{1,000,000}$ ins la & lb.	Average Unit Strain $\frac{1}{1,000,000}$ ins la,la,lla,llb.
0	0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0
4	1400	8	25	17	8	33	21	19
6	2000	25	49	37	25	66	46	47
8	2700	41	82	62	42	91	67	64
10	3400	41	107	74	58	133	96	85
12	4100	66	132	99	83	166	125	112
15	5100	82	181	132	100	216	158	145
18	6100	107	214	161	124	257	191	176
21	7200	131	263	197	158	307	233	215
24	8200	156	296	226	191	357	274	250
27	9200	181	337	259	216	398	307	283
30	10200	206	370	288	249	448	349	318
33	11300	230	411	321	274	489	382	351
36	12300	263	452	358	307	539	423	390
39	13300	287	493	390	332	581	457	423
42	14300	312	534	423	365	622	494	458
45	15400	337	575	456	390	664	527	491
48	16400	370	608	489	415	705	560	524
51	17400	394	649	522	448	746	597	559
54	18400	419	690	555	473	788	631	593
57	19400	462	723	593	498	830	664	628
60	20400	476	764	620	531	872	702	661
63	21400	510	805	658	556	913	735	696
66	22500	542	846	694	589	954	772	733
69	23500	575	879	727	622	996	809	768
72	24600	600	929	765	646	1038	842	803
75	25600	624	962	793	672	1080	876	834
78	26600	657	1002	830	705	1120	913	871
81	27600	698	1042	870	714	1320	1017	943
83	28300	731	1069	900	746	1392	1069	984
84	28600	756	1060	908	763	1443	1103	1005
85	29000	855	1042	949	805	1501	1153	1051
86	29400	789	1042	916	839	1535	1187	1051
87	29700	896	1028	962	864	1570	1217	1089
88	30000	904	1028	1016	896	1592	1244	1130
89	30400							

PLATE D-2.

EXTENSOMETERS 111a, 111b, V11a, & V11b.

Load (kips)	Stress (psi.)	Elongation $\frac{1}{100,000}$ ins 111b	111a	Average Elongation $\frac{1}{1,000,000}$ ins 111a & 111b.	Average Unit Strain over 2 ins. $\frac{1}{1,000,000}$ ins 111a & 111b	Elongation $\frac{1}{100,000}$ ins V11b	V11a.	Average Elongation $\frac{1}{1,000,000}$ INS V11a & V11b	Average Unit Strain over 2" $\frac{1}{1,000,000}$ ins V11a & V11b.
0	0	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0	0
4	1400	6	2	40	20	2	6	40	20
6	2000	11	7	90	45	8	11	95	46
8	2700	18	11	145	73	11	18	145	73
10	3400	21	17	190	95	18	21	195	98
12	4100	27	20	235	118	22	28	250	125
15	5100	32	28	300	150	30	34	320	160
18	6100	41	32	365	183	39	41	400	200
21	7200	49	40	445	223	45	50	475	238
24	8200	58	46	520	260	51	58	545	273
27	9200	68	50	590	295	58	68	630	315
30	10200	77	54	655	328	61	76	685	343
33	11300	86	59	725	363	69	84	765	383
36	12300	94	63	785	393	72	92	820	420
39	13300	102	69	855	428	80	101	905	453
42	14300	111	73	920	460	85	110	975	468
45	15400	120	79	1000	500	91	119	1050	525
48	16400	130	83	1065	533	98	128	1130	565
51	17400	139	89	1140	570	102	135	1185	593
54	18400	148	94	1210	605	109	142	1255	628
57	19400	155	100	1275	638	116	150	1330	665
60	20400	162	105	1335	668	121	159	1900	700
63	21400	171	110	1905	703	129	168	1485	743
66	22500	180	117	1495	143	135	173	1540	770
69	23500	188	121	1545	773	141	181	1610	805
72	24600	197	129	1630	815	149	190	1675	848
75	25600	202	133	1675	838	157	199	1780	890
78	26600	210	140	1750	875	165	208	1865	933
81	27600	225	139	1820	910	180	203	1915	958
83	28300	238	136	1870	935	190	202	1960	980
84	28600	248	132	1900	950	198	201	1995	998
85	29000	260	125	1925	963	204	193	1985	993
86	29400	270	122	1960	980	211	195	2030	1015
87	29700	290	102	1960	980	225	180	2025	1012
88	30000	300	102	2010	1005	235	176	2060	1030
89	30400								

LATE D-2.

EXTENSOMETERS Va, Vb, 1Va & 1Vb.

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oad ips)	Stress (psi.)	Elongation 1/100,000 ins Vb.	Va.	Average Unit Strain 1/1,000,000 ins Va. & Vb.	Elongation 1/1,000,000 ins 1Vb	1Va.	Average Unit Strain 1/1,000,000 ins 1Va. & 1Vb.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1400	1	1	10	8	25	17
6	2000	5	3	40	25	558	42
8	2700	7	9	80	51	83	67
10	3400	9	11	100	59	132	96
12	4100	9	16	125	76	149	113
15	5100	10	21	155	110	190	150
18	6100	13	26	195	136	231	183
21	7200	18	30	240	169	272	221
24	8200	20	33	265	194	314	254
27	9200	25	39	320	228	355	292
30	10200	30	40	350	261	388	325
33	11300	35	42	385	295	429	362
36	12300	39	48	435	320	470	395
39	13300	42	50	460	354	512	433
42	14300	48	52	500	387	544	466
45	15400	51	58	545	413	577	495
48	16400	57	60	580	446	619	533
51	17400	60	62	610	480	660	570
54	18400	63	68	655	514	693	609
57	19400	68	71	695	548	734	642
60	20400	71	74	725	581	767	674
63	21400	75	79	770	615	808	712
66	22500	79	82	805	649	850	750
69	23500	81	88	845	682	892	787
72	24600	86	90	880	716	925	821
75	25600	89	95	920	749	966	858
78	26600	91	99	950	783	1000	892
81	27600	87	142	1145	843	1058	951
83	28300	81	168	1245	868	1108	988
84	28600	79	178	1285	860	1339	1100
85	29000	78	208	1430	843	1670	1257
86	29400	72	212	1420	843	1950	1397
87	29700	58	262	1600	860	Yielded	
88	30000	51	280	1655	903		
89	30400						

PLATE D-2.

EXTENSOMETERS Vla & Vlb, and
SUMMATION OF EXTENSOMETER READINGS 111, 1V, V, V1 & V11.

Load (kips)	Stress (psi.)	Elongation $\frac{1}{100,000}$ ins Vlb.	Vla.	Average Elongation $\frac{1}{1,000,000}$ ins Vla.& Vlb.	Average Unit Strain $\frac{1}{1,000,000}$ ins Vla & Vlb.	Total Elongation in 8 ins. $\frac{1}{1,000,000}$ ins 111 to V11	Unit Strain over 8 ins. $\frac{1}{1,000,000}$ 111 to V11.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1400	1	5	30	15	137	17
6	2000	5	10	75	37	347	43
8	2700	9	15	120	60	557	70
10	3400	12	20	160	80	741	93
12	4100	18	22	200	100	923	115
15	5100	22	30	260	130	1185	136
18	6100	30	38	340	170	1485	186
21	7200	35	43	390	195	1771	221
24	8200	40	51	455	227	2039	255
27	9200	45	59	520	260	2352	294
30	10200	49	69	590	295	2605	326
33	11300	52	77	645	322	2882	360
36	12300	59	83	710	355	3145	393
39	13300	61	91	760	380	3413	426
42	14300	68	100	840	420	3701	463
45	15400	71	108	895	447	3985	498
48	16400	78	115	965	482	4273	534
51	17400	82	122	1020	510	4525	566
54	18400	89	130	1095	547	4824	603
57	19400	92	138	1150	575	5092	636
60	20400	99	145	1220	610	5354	669
63	21400	104	151	1275	637	5647	706
66	22500	110	159	1345	672	5925	741
69	23500	116	167	1415	707	6202	775
72	24600	121	172	1465	732	6491	811
75	25600	129	180	1545	772	6778	847
78	26600	135	187	1610	805	7067	883
81	27600	150	185	1675	837	7506	938
83	28300	160	185	1725	862	7788	974
84	28600	169	185	1770	885	8050	1006
85	29000	179	180	1795	897	8387	1048
86	29400	186	180	1830	915	8637	1080
87	29700	203	170	1865	932		
88	30000	215	169	1920	960		
89	30400	YP.					
159	54300	US.					

Add .000026 to all unit strains to correct for initial load.
Area = .617 x 4.752 = 2.932 sq. ins.
Elastic Limit 26600
E = 29.0 x 10^6
Elongation in 4 inches $= \frac{(6.28 - 4.00)}{4.00} 100 =$ 57%

Reduction in area $= \left(\frac{2.932 - 1.405}{2.932}\right) 100 =$ 53%.

PLATE E-1.

EXTENSOMETERS 1a, 1b, 11a & 11b.

Load (kips)	Stress (psi.)	Elongation ins/1,000,000 11b.	Elongation ins/1,000,000 11a.	Average Unit strain ins/1,000,000 11a. & 11b.	Elongation ins/1,000,000 1b.	Elongation ins/1,000,000 1a.	Average Unit Strain ins/1,000,000 1a. & 1b.	Average Unit Strain ins/1,000,000 1a,1b,11a,& 11b.
0	0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0
4	1300	8	33	20	33	0	17	18
6	2000	8	66	37	74	17	46	41
8	2600	16	99	57	107	25	66	61
10	3300	25	123	74	132	33	83	78
12	3900	41	156	99	165	58	112	105
15	4900	66	197	132	214	83	149	140
18	5900	90	246	168	255	108	182	175
21	6800	117	280	199	296	133	215	207
24	7800	132	320	226	338	150	244	235
27	8800	156	362	259	378	174	276	267
30	9800	181	403	292	420	200	310	301
33	10800	206	444	325	461	224	342	333
36	11800	222	484	353	502	250	376	364
40	13000	254	542	398	551	291	421	409
44	14400	280	592	436	601	323	462	449
48	15700	320	650	485	658	356	507	496
52	17000	345	707	526	708	390	549	537
56	18300	378	756	567	757	423	590	578
60	19600	402	814	608	822	456	639	623
64	20900	427	889	658	882	490	686	672
68	22200	477	971	724	955	524	740	732
72	23500	517	1077	797	1052	580	816	806
75	24400	542	1192	867	1088	597	843	855
78	25400	608	1308	958	1178	656	917	937
80	26100	641	1381	1011	1235	697	966	988
82	26800	665	1463	1064	1282	730	1006	1035
84	27400	715	1585	1150	1359	771	1065	1107
86	28000	780	1770	1275	1432	830	1131	1203

PLATE E-1.

EXTENSOMETERS 111a, 111b, 1Va & 1Vb.

Load kips)	Stress (psi.)	Elongation ins/ 100,000 111b.	Elongation ins/ 100,000 111a.	Average Elongation ins/ 1,000,000 111a.& 111b.	Average Unit Strain over 2" ins/ 1,000,000 111a.&111b.	Elongation ins/ 100,000 V11b.	Elongation ins/ 100,000 V11a.	Average Elongation ins/ 1,000,000 V11a.& V11b.	Average Unit Strain over 2" ins/ 1,000,000 V11a.& V11b.
0	0	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0	0
4	1300	8	1	45	22	1	7	40	20
6	2000	12	3	75	37	3	12	75	37
8	2600	19	8	135	67	8	19	135	67
10	3300	24	10	170	85	11	22	165	82
12	3900	30	13	215	107	18	28	240	120
15	4900	38	18	280	140	21	33	270	135
18	5900	48	21	345	172	29	41	350	175
21	6800	57	26	415	207	32	50	410	205
24	7800	67	29	480	240	38	59	405	242
27	8800	78	31	545	272	41	69	550	275
30	9800	88	33	605	302	44	78	610	305
33	10800	98	38	680	340	49	86	675	337
36	11800	108	40	740	370	52	94	730	365
40	13000	120	44	820	410	56	104	800	400
44	14400	131	49	900	450	61	114	875	437
48	15700	144	54	990	495	67	125	960	480
52	17000	158	57	1075	537	75	135	1050	525
56	18300	173	63	1180	590	83	145	1140	570
60	19600	185	66	1255	627	91	155	1230	615
64	20900	197	72	1345	672	98	166	1320	660
68	22200	209	73	1410	705	105	180	1425	712
72	23500	225	75	1500	750	115	194	1545	772
75	24400	234	77	1555	777	122	198	1600	800
78	25400	246	76	1610	805	127	216	1715	857
80	26100	255	77	1660	830	135	226	1805	902
82	26800	263	79	1710	855	142	236	1890	945
84	27400	274	80	1770	885	148	248	1980	990
86	28000	285	83	1840	920	156	265	2105	1052
94	30600	Y.P.							
166	54100	U.S.							

PLATE E-1.

EXTENSOMETERS Va, Vb, 1Va, & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000		Average Unit Strain Va. & Vb.	Elongation Ins/ 1,000,000		Average Unit Strain Ins/ 1,000,000 1Va. & 1Vb.
		Vb.	Va.		1Vb.	1Va.	
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	3	0	15	8	42	25
6	2000	7	2	45	16	76	46
8	2600	9	4	65	33	101	67
10	3300	10	8	90	49	135	92
12	3900	12	9	105	66	168	117
15	4900	17	11	140	91	202	141
18	5900	20	12	160	124	252	.188
21	6800	24	15	195	148	294	221
24	7800	30	17	235	173	328	250
27	8800	36	18	270	198	370	284
30	9800	41	19	300	222	404	318
33	10800	48	19	335	256	446	351
36	11800	51	20	355	288	480	384
40	12000	58	22	400	321	539	430
44	14400	62	24	430	355	589	472
48	15700	70	25	475	396	648	522
52	17000	78	28	530	430	706	568
56	18300	86	30	580	470	766	618
60	19600	92	30	610	512	834	673
64	20900	98	34	660	554	910	732
68	22200	104	37	705	603	995	799
72	23500	113	39	760	676	1102	889
75	24400	115	43	790	718	1220	969
78	25400	123	38	805	785	1339	1062
80	26100	126	38	820	850	1414	1132
82	26800	132	41	865	933	1499	1216
84	27400	142	40	910	1032	1626	1329
86	28000	146	42	940	1180	1810	1495

PLATE E-1.

EXTENSOMETERS Vla & Vlb, and
SUMMATION OF EXTENSOMETER READINGS 111, 1V, V, V1 & V11.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Vlb.	Elongation ins/ 100,000 Vla.	Average Elongation ins/ 1,000,000 Vla & Vlb.	Average Unit Strain ins/ 1,000,000 Vla. & Vlb.	Total Elongation over 8 ins. ins/ 1,000,000 111 to V11.	Unit Strain over 8 ins. ins/ 1,000,000 111 to V11.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	0	10	50	25	175	22
6	2000	0	18	90	45	331	41
8	2600	1	23	120	60	522	65
10	3300	5	30	175	87	692	87
12	3900	9	37	230	115	907	113
15	4900	12	45	285	142	1116	140
18	5900	17	53	350	175	1393	174
21	6800	19	63	420	210	1661	208
24	7800	21	74	475	237	1925	241
27	8800	22	86	540	270	2189	274
30	9800	26	97	615	307	2448	306
33	10800	29	108	685	342	2726	341
36	11800	30	118	740	370	2949	369
40	13000	33	130	815	407	3265	408
44	14400	37	144	915	457	3592	459
48	15700	42	157	995	497	3942	493
52	17000	48	169	1085	542	4308	539
56	18300	54	184	1190	595	4708	589
60	19600	58	203	1305	652	5073	634
64	20900	64	221	1425	712	5482	685
68	22200	68	242	1550	775	5889	736
72	23500	77	271	1740	870	6434	804
75	24400	83	280	1815	907	6729	841
78	25400	97	321	2090	1045	7282	910
80	26100	107	349	2280	1140	7697	962
82	26800	115	369	2420	1210	8101	1013
84	27400	130	399	2645	1322	8634	1082
86	28000	149	435	2920	1460	9300	1163
94	30600	Y.P.					
166	54100	U.S.					

Add .000022 to all unit strains to correct for initial load
Area .616 x 4.980 = 3.068 sq. ins.
Elastic Limit 21000 psi.
E = 29.9×10^6 psi.

& Elongation in 8 ins $= \frac{(11.35 - 8.00)}{8.00} 100 = 42\%$

% Reduction in area $= \frac{(3.068 - 1.519)}{3.068} 100 = 50.5\%$

PLATE E-2.

EXTENSOMETERS 1-a, 1-b, 11-a & 11-b.

Load (kips)	Stress (psi.)	Elongation ins/ 1,000,000 11b	11a.	Average Unit Strain ins/ 1,000,000 11a & 11b.	Elongation ins/ 1,000,000 1b.	1a.	Average Unit Strain ins/ 1,000,000 1a & 1b.	Average Unit Strain ins/ 1,000,000 1a,1b,11a & 11b.
0	0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0
4	1300	0	33	16	0	50	25	20
6	2000	8	82	45	8	83	45	45
8	2600	8	115	62	16	124	70	66
10	3300	16	140	78	25	166	95	86
12	3900	33	173	103	33	199	116	109
15	4900	41	213	127	49	249	149	138
18	5900	58	254	156	73	299	186	171
21	6800	82	304	193	91	349	220	204
24	7800	107	327	217	115	399	257	237
28	9100	131	403	267	140	456	298	282
32	10700	164	452	308	173	514	343	325
36	11700	189	501	345	206	590	398	371
40	13000	222	558	390	238	638	438	414
44	14300	254	606	430	272	696	484	457
48	15600	288	666	477	304	764	534	505
52	16800	328	738	533	338	830	589	561
56	18100	361	796	578	370	914	642	610
60	19400	402	854	628	402	972	687	657
64	20800	444	928	686	452	1062	757	721
68	22000	493	1027	760	502	1130	816	788
72	23400	558	1110	834	560	1230	895	864
75	24300	607	1173	890	616	1302	959	925
78	25200	665	1249	957	675	1369	1022	989
80	25900	682	1306	994	716	1402	1059	1026
82	26600	722	1348	1035	749	1443	1096	1065
84	27200	796	1404	1100	824	1502	1163	1132
87	28200	920	1530	1225	939	1585	1262	1243
90	29200	1150	1690	1420	1136	1678	1407	1414

PLATE E-2.

EXTENSOMETERS 111-a, 111-b, 1V-a & 1V-b.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 111-b	Elongation ins/ 100,000 111-a	Average Elongation ins/ 1,000,000 111a & 111b.	Average Unit Strain over 2" ins/ 1,000,000 111a & 111b.	Elongation ins/ 100,000 V11-b	Elongation ins/ 100,000 V11-a	Average Elongation ins/ 1,000,000 V11a & V11b	Average Unit Strain over 2" ins/ 1,000,000 V11a & V11b.
0	0	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0	0
4	1300	1	8	45	22	8	1	45	22
6	2000	8	10	90	45	10	8	90	45
8	2600	12	12	120	60	12	12	120	60
10	3300	19	17	180	90	17	19	180	90
12	3900	24	19	215	107	20	22	210	105
15	4900	32	22	270	135	25	31	280	140
18	5900	41	28	345	172	30	39	345	172
21	6800	50	31	405	202	35	48	415	207
24	7800	59	38	485	242	40	53	465	232
28	9100	70	42	560	280	48	65	565	282
32	10700	82	49	655	327	53	75	640	320
36	11700	94	54	740	370	61	86	735	367
40	13000	106	60	830	415	69	96	825	412
44	14300	119	67	930	465	76	106	910	455
48	15600	130	70	1000	500	82	114	980	490
52	16800	141	73	1070	535	91	122	1065	532
56	18100	152	79	1155	577	100	131	1155	577
60	19400	163	88	1255	627	110	138	1240	620
64	20800	176	96	1360	680	121	146	1335	667
68	22000	191	102	1465	732	132	156	1440	720
72	23400	204	110	1570	785	142	170	1560	780
75	24300	217	117	1670	835	151	185	1680	840
78	25200	231	124	1775	887	167	200	1835	917
80	25900	237	126	1815	907	176	202	1890	945
82	26600	244	133	1885	942	187	212	1995	997
84	27200	260	139	1995	997	206	235	2205	1102
87	28200	284	153	2185	1042	246	272	2590	1295
90	29200	336	162	2490	1245	378	403	3905	1952

PLATE E-2.

EXTENSOMETERS V-a, V-b, 1V & 1V-b.

Load (kips)	Stress p.s.i.	Elongation ins/ 100,000 V-b	V-a	Average Unit Strain ins/ 1,000,000 V-a & V-b.	Elongation ins/ 1,000,000 1V-b	1V-a	Average Unit Strain ins/ 1,000,000 1V-a & 1V-b.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	-2	8	30	0	25	13
6	2000	0	9	45	8	83	46
8	2600	1	10	55	17	116	67
10	3300	4	12	80	25	157	91
12	3900	8	15	115	34	190	112
15	4900	11	19	150	59	239	149
18	5900	15	21	180	76	280	178
21	6800	20	23	215	101	330	216
24	7800	23	28	255	118	372	245
28	9100	29	30	295	160	438	299
32	10700	36	32	340	194	486	340
36	11700	41	37	390	227	545	386
40	13000	48	40	440	261	611	436
44	14300	52	42	470	295	669	482
48	15600	59	48	535	328	768	548
52	16800	62	49	555	370	842	606
56	18100	70	50	600	412	942	677
60	19400	74	57	655	446	1022	734
64	20800	80	59	695	588	1122	850
68	22000	85	60	725	522	1230	876
72	23400	91	60	755	573	1397	985
75	24300	97	60	785	615	1485	1050
78	25200	100	60	800	699	1635	1167
80	25900	101	60	805	724	1660	1192
82	26600	104	60	820	756	1710	1233
84	27200	110	59	845	842	1816	1329
87	28200	118	52	850	976	1990	1483
90	29200	135	32	835	1094	2116	1605

PLATE E-2.

EXTENSOMETERS Vl-a & Vl-b, and
SUMMATION OF EXTENSOMETER READINGS lll, lV, V, Vl & Vll.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Vl-b	Elongation ins/ 100,000 Vl-a	Average Elongation ins/ 1,000,000 Vl-a& Vl-b	Average Unit Strain ins/ 1,000,000 Vl-a & Vl-b	Average Elongation over 8 ins ins/ 1,000,000 lll to Vll	Unit Strain over 8 ins ins/ 1,000,000 lll to Vll.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	3	5	40	20	173	22
6	2000	5	12	85	42	356	45
8	2600	6	21	135	67	497	62
10	3300	8	29	185	92	716	89
12	3900	10	34	220	110	872	109
15	4900	12	45	285	142	1134	142
18	5900	16	53	345	172	1393	174
21	6800	19	62	405	202	1656	207
24	7800	22	72	470	235	1920	240
28	9100	28	85	565	282	2284	286
32	10700	31	98	645	322	2620	328
36	11700	38	110	740	370	2991	374
40	13000	41	121	810	405	3341	418
44	14300	49	133	910	455	3702	463
48	15600	52	147	995	497	4058	507
50	16800	61	166	1135	567	4431	554
56	18100	69	180	1245	622	4832	604
60	19400	78	193	1355	677	5239	655
64	20800	88	213	1505	752	5745	718
68	22000	99	232	1655	827	6161	770
72	23400	110	260	1850	925	6720	840
75	24300	125	274	1995	997	7180	898
78	25200	142	314	2280	1140	7857	982
80	25900	155	335	2450	1225	8152	1019
82	26600	173	363	2680	1340	8613	1077
84	27200	194	406	3000	1500	9374	1172
87	28200	240	499	3695	1847	10803	1350
90	29200	320	666	4930	2465	13765	1721
91.5	29600	Y.P.					
165.6	53600	U.S.					

Add .000025 to all unit strains to correct for initial load
Area = .620 x 4.990 = 3.094 sq. ins.
Elastic Limit 19,000 pps.i.
$E = 30.3 \times 10^6$ p.s.i.

$$\% \text{ Elongation in 8 inches} = \frac{(11.31 - 8.00)}{(8.00)} 100 = 41.4\%$$

$$\% \text{ Reduction in area} = \frac{(3.094 - 1.53)}{(3.094)} 100 = 50.4\%$$

PLATE F-1.

EXTENSOMETERS 1a, 1b, 11a & 11b.

Load (kips)	Stress (psi.)	Elongation ins/1,000,000 11b.	Elongation ins/1,000,000 11a.	Average Unit Strain ins/1,000,000 11a. & 11b.	Elongation ins/1,000,000 1b.	Elongation ins/1,000,000 1a.	Average Unit Strain ins/1,000,000 1a. & 1b.	Average Unit Strain ins/1,000,000 1 & 11.
0	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0
4	1400	8	57	32	0	41	21	26
6	2100	16	107	62	0	83	42	52
8	2700	16	156	86	0	108	54	70
10	3400	16	197	107	8	149	79	93
12	4100	25	246	136	16	182	99	117
15	5100	41	304	173	25	224	125	149
18	6100	49	361	205	41	266	154	179
21	7200	66	418	242	58	315	187	214
24	8200	66	476	271	66	365	216	243
27	9200	82	534	308	99	415	257	282
30	10200	107	591	349	115	455	285	317
33	11300	123	649	386	132	498	315	350
36	12300	148	698	423	148	548	348	385
40	13700	164	780	472	173	605	389	430
44	15000	197	855	526	206	672	439	482
48	16400	238	936	587	222	730	476	531
52	17800	279	1011	640	255	795	525	582
56	19200	304	1076	690	272	854	563	626
60	20500	336	1150	743	304	914	609	676
64	21900	370	1264	817	329	979	654	735
68	23200	394	1330	862	354			
72	24600	435	1405	920				
75	25600							
78	26700							
79	27000							

PLATE F-1.

EXTENSOMETERS 111a, 111b, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 111b	111a	Elongation ins/ 1,000,000 111a&111b.	Average Unit Strain over 2" ins 1,000,000 111a&111b.	Elongat'n ins/ 1000,000 -- V11b.	V11a.	Average Elongt'n ins/ 1,000,000 V11a&V11b	Average Unit Strain over 2" ins/ 1,000,000 V11a&V11b.
0	-	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0	0
4	1400	10	-1	45	22	-0	9	45	22
6	2100	19	0	95	47	1	17	90	45
8	2700	25	2	135	67	4	21	125	62
10	3400	31	5	180	90	9	28	185	92
12	4100	38	9	235	117	11	32	215	107
15	5100	48	14	310	155	16	40	280	140
18	6100	57	17	370	185	24	48	360	180
21	7200	64	24	440	220	31	51	410	205
24	8200	72	28	500	250	35	59	470	235
27	9200	81	34	575	287	43	64	535	267
30	10200	89	37	630	315	50	71	605	302
33	11300	98	44	710	355	55	79	670	335
36	12300	106	47	765	382	63	85	740	370
40	13700	117	55	860	430	72	94	830	415
44	15000	128	62	950	475	82	102	925	462
48	16400	139	68	1035	517	92	111	1015	507
52	17800	147	76	1125	562	101	120	1105	552
56	19200	161	84	1225	612	109	129	1190	595
60	20500	171	90	1305	652	118	139	1285	642
64	21900	183	96	1395	687	128	148	1380	690
68	23200	194	104	1490	745	136	158	1470	735
72	24600	209	106	1575	787	153	160	1565	772
75	25600	218	114	1660	830	162	169	1655	827
78	26700	228	117	1725	862	171	172	1715	857
79	27000								

PLATE F-1.

EXTENSOMETERS Va, Vb, 1Va & 1Vb.

Load (kips)	Stress (psi)	Elongation ins/ 100,000 Vb	Elongation ins/ 100,000 Va	Average Unit Strain ins/ 1,000,000 Va & Vb	Elongation ins/ 1,000,000 1Vb	Elongation ins/ 1,000,000 1Vb	Average Unit Strain ins/ 1,000,000 1Va & 1Vb.
0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1400	4	-1	15	8	33	20
6	2100	-1	1	0	33	67	50
8	2700	-8	3	-25	41	101	71
10	3400	-12	7	-25	58	135	97
12	4100	-10	9	-5	74	160	117
15	5100	-8	11	15	99	194	147
18	6100	-5	14	45	132	228	180
21	7200	-4	15	55	149	261	205
24	8200	1	19	100	173	295	234
27	9200	4	23	135	198	329	263
30	10200	6	25	155	223	371	297
33	11300	10	30	200	248	414	331
36	12300	13	33	230	272	466	369
40	13700	16	37	265	305	505	405
44	15000	20	43	315	355	557	456
48	16400	25	45	350	396	598	497
52	17800	28	52	400	437	649	543
56	19200	34	52	420	479	709	594
60	20500	36	61	485	520	750	635
64	21900	42	65	535	570	810	690
68	23200	45	72	585	610	860	735
72	24600	55	72	635	660	900	780
75	25600	60	75	675			
78	26700	67	77	720			
79	27000						

PLATE F-1.

EXTENSOMETERS Vla & Vlb and
SUMMATION OF EXTENSOMETER READINGS 111, lV, V, Vl & Vll.

Load (kips)	Stress (psi.)	Elongation ins/100,000 Vlb	Elongation ins/100,000 Vla	Average Elongation ins/1,000,000 Vla & Vlb.	Average Unit Strain ins/1,000,000 Vla & Vlb.	Total Elongation over 8 ins. ins/1,000,000 111 to Vll	Unit Strain over 8 ins. ins/1,000,000 111 to Vll.
0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1400	-2	11	45	22	170	21
6	2100	-3	22	95	47	330	41
8	2700	-2	31	145	72	451	56
10	3400	-1	40	195	97	632	79
12	4100	0	48	240	120	802	100
15	5100	2	59	305	152	1057	132
18	6100	6	70	385	192	1340	168
21	7200	10	80	450	225	1560	195
24	8200	13	90	515	257	1819	227
27	9200	19	100	595	297	2103	263
30	10200	22	110	660	330	2347	293
33	11300	27	120	735	367	2646	331
36	12300	31	130	805	402	2949	369
40	13700	38	142	900	450	3260	408
44	15000	42	154	980	490	3626	453
48	16400	49	169	1090	545	3987	496
52	17800	54	180	1170	585	4343	543
56	19200	61	192	1265	632	4694	587
60	20500	68	204	1360	680	5070	634
64	21900	73	220	1465	732	5465	683
68	23200	81	231	1560	780	5840	730
72	24600	81	274	1775	887	6350	793
75	25600	89	284	1865	932		
78	26700	93	301	1970	985		
156	53400	U.S.					

Due to much slippage of the grips holding the specimen in the Testing Machine it was considered necessary to remove the Huggenberger Extensometers before they reached their limit of measurement.

Add .000033 to all unit strains to correct for initial load.
Area = .6165 x 4.745 = 2.925 sq. ins.
Elastic Limit = 22000 psi.
E = 310×10^6 psi.

% Elongation in 8 ins. = $\left(\frac{11.25 - 8.00}{8.00}\right) 100 = 41.7\%$

% Reduction in area = $\left(\frac{2.925 - 1.210}{2.925}\right) 100 = 58.6\%$

PLATE F-2.

EXTENSOMETERS 1a, 1b, 11a & 11b.

Load (kips)	Stress (psi.)	Elongation ins/ 1,000,000 11b	11a	Average Unit Strain ins/ 1,000,000 11a & 11b.	Elongation ins/ 1,000,000 1b	1a	Average Unit Strain ins/ 1,000,000 1a & 1b.	Average Unit Strain ins/ 1,000,000 1 & 11
0	0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0
4	1400	8	33	20	8	0	4	12
6	2100	25	66	45	25	8	16	30
8	2800	41	107	74	33	58	45	60
10	3500	58	140	99	49	100	74	86
12	4100	66	189	127	58	133	95	111
15	5200	90	246	168	74	191	132	150
18	6200	115	296	205	90	246	165	180
21	7200	140	345	242	107	282	194	218
24	8300	164	402	283	132	332	232	257
27	9300	189	451	315	148	390	269	292
30	10300	206	500	353	173	431	32	327
33	11400	238	558	398	198	480	339	368
36	12400	262	606	434	214	532	373	403
39	13500	287	657	472	238	590	414	443
42	14500	312	706	509	255	631	443	476
45	15500	337	763	550	280	672	476	513
48	16600	361	805	583	304	722	513	548
51	17600	394	854	624	329	763	546	585
54	18700	419	905	662	354	812	583	622
57	19700	452	962	707	378	854	616	661
60	20700	476	1020	748	404	904	654	700
63	21800	501	1059	780	428	954	691	735
66	22700	534	1110	822	452	996	724	773
70	24200	616	1208	912	452	1102	777	844
72	24800	649	1231	940	452	1186	819	830
75	25900	722	1272	997	460	1342	901	949
78	27000	854	1290	1072	518	1586	1052	1062
81	28000	1020	1356	1188	716	2180	1448	1318
83	28700	1159	1371	1265	930	2480	1705	1485
85	29400	1272	1602	147				
87	30000							

PLATE F-2.

EXTENSOMETERS 111a, 111b, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongat'n ins/ 100,000 111b	111a	Elongat'n ins/ 1000000 111a&111b.	Average Unit Strain over 2" ins/ 1000000 111a&111b.	Elongat'n ins/ 100000 V11b	V11a	Average Elongt'n ins/ 1000000 V11a& V11b	Average Unit Strain over 2" ins/ 1000000 V11a&V11b.
0	0	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0	0
4	1400	2	4	30	15	7	2	45	22
6	2100	8	10	90	45	11	7	90	45
8	2800	11	13	120	60	18	10	140	70
10	3500	18	19	185	92	21	13	170	85
,12	4100	21	22	215	107	28	19	235	117
15	5200	30	28	290	145	31	27	290	145
18	6200	39	31	350	175	39	32	355	177
21	7200	49	35	420	210	40	40	420	210
24	8300	58	40	940	245	50	49	495	247
27	9300	64	44	540	270	58	54	650	280
20	10300	72	50	610	305	63	61	620	310
33	11400	80	55	675	337	70	69	695	347
36	12400	89	61	750	375	79	75	770	385
39	13500	96	69	825	412	85	80	825	412
42	14500	102	73	875	437	91	87	890	445
45	15500	110	80	950	475	100	91	955	477
48	16600	118	88	1030	515	108	99	1035	517
51	17600	123	93	1080	540	115	102	1085	542
54	18700	131	100	1155	577	121	110	1155	577
57	19700	139	108	1235	617	130	115	1225	612
60	20700	145	112	1285	642	138	120	1290	645
63	21800	151	120	1355	677	147	127	1370	685
66	22800	159	124	1415	707	152	131	1415	707
70	w4200	174	129	1515	757	170	133	1515	757
72	24800	181	130	1555	777	179	136	1575	787
75	25900	200	130	1650	825	195	134	1645	822
78	27000	230	135	1825	912	220	121	1720	860
81	28000	337	207	2720	1360	210	91	1505	752
83	28700					23w	78	1550	775
85	29400					255	75	1650	825
87	30000								

PLATE F-2.

EXTENSOMETERS Va, Vb, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/100,000 Vb	Elongation ins/100,000 Va.	Average Unit Strain ins/1,000,000 Va & Vb	Elongation ins/1,000,000 1Vb	Elongation ins/1,000,000 1Va	Average Unit Strain ins/1,000,000 1Va 1Vb.
0	0	-	-	-	-	-	- -
2	700	0	0	0	0	0	0 0
4	1400	0	4	20	8	33	20
6	2100	0	9	45	25	66	45
8	2800	1	11	60	42	99	70
10	3500	2	17	95	51	140	95
12	4100	5	19	120	67	173	120
15	5200	9	21	150	93	223	158
18	6200	12	25	185	109	264	186
21	7200	18	29	225	135	314	224
24	8300	21	31	260	160	364	263
27	9300	25	35	300	185	413	299
30	10300	29	40	345	210	454	332
33	11400	31	42	365	236	496	366
36	12400	34	48	410	261	545	403
39	13500	38	51	445	294	586	440
42	14500	40	57	485	320	636	478
45	15500	42	60	510	345	677	511
48	16600	47	64	555	370	718	544
51	17600	49	69	590	396	760	6
54	18700	51	73	620	430	800	615
57	19700	53	79	660	455	843	649
60	20700	58	82	700	480	884	682
63	21800	60	89	745	514	924	719
66	22800	61	91	760	547	967	757
70	24200	55	110	825	556	1130	843
72	24800	52	129	905	614	1198	906
75	25900	44	160	1020	648	1352	1000
78	27000	31	231	1310	716	2070	1393
81	28000	31	437	2340	918		
83	28700	103	520	3115			
85	29400	149	580	3645			
87	30000						

PLATE F-2.

EXTENSOMETERS Vla, & Vlb, and
SUMMATION OF EXTENSOMETER READINGS 111, 1V, V, Vl & Vll.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Vlb.	Vla.	Average Elongation ins/ 1,000,000 Vl a Vlb.	Average Unit Strain ins/ 1,000,000 Vla & Vlb.	Total Elongation over 8 ins. ins/ 1,000,000 111 to Vll.	Unit Strain over 8 ins. ins/ 1,000,000 1V to Vll.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1400	6	4	50	25	165	21
6	2100	9	10	95	47	365	46
8	2800	12	14	130	65	520	65
10	3500	18	20	190	95	635	79
12	4100	20	27	235	117	925	116
15	5200	22	37	295	147	1183	148
18	6200	29	45	370	185	1446	181
21	7200	31	54	425	212	1714	214
24	8300	37	62	495	247	2002	250
27	9300	41	71	560	280	2259	282
30	10300	47	80	635	317	2547	318
33	11400	51	90	705	352	2806	351
36	12400	58	98	780	390	3113	389
39	13500	61	105	830	415	3365	421
42	14500	69	112	905	457	3633	454
45	15500	73	120	965	482	3891	486
48	16600	80	128	1040	520	4204	526
51	17600	87	136	1115	557	4448	555
54	18700	91	142	1165	582	4710	589
57	19700	99	150	1245	622	5014	627
60	20700	104	159	1315	657	5272	659
63	21800	111	166	1385	692	5574	696
66	22800	118	172	1450	725	5797	725
70	24200	133	178	1555	777	6253	782
72	24800	141	178	1595	797	6536	817
75	25900	160	178	1690	845	7005	876
78	27000	189	162	1755	877	8003	1000
81	28000	243	119	1810	905		
83	28700	260	99	1795	897		
85	29400	275	80	1775	888		
87	30000	Y.P.					
158	54600	U.S.					

Add .000025 to all unit strains to correct for initial load.
Area = .609 x 4.760 = 2.898 sq. ins.
Elastic Limit = 24000 psi.
E = 30.4×10^6 psi.

% Elongation in 8 inches = $\frac{(9.66 - 8.00)}{(8.000)} 100 =$ 21%

% Reduction in area = $\frac{(2.898 - 2.245)}{2.898} 100 =$ 22.6%

PLATE G-1.

EXTENSOMETERS 1a, 1b, 11a & 11b.

Load (kips)	Stress (psi.)	Elongation ins/ 1,000,000 11b.	11a.	Average Unit Strain ins/ 1,000,000 11a. & 11b.	Elongation ins/ 1,000,000 1b.	1a.	Average Unit Strain ins/ 1,000,000 1a. & 1b.	Average Unit Strain ins/ 1,000,000 1 & 11.
0	0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0
4	1300	0	33	16	8	41	26	21
6	2000	8	74	41	8	82	45	43
8	2600	16	107	62	17	107	62	62
10	3300	33	140	87	33	124	79	83
12	3900	41	164	103	50	172	111	107
14	4500	58	198	128	58	198	128	128
16	5200	82	222	152	75	222	149	150
18	5800	99	255	177	91	255	173	175
20	6500	115	288	202	100	272	186	194
22	7100	140	312	226	125	304	215	220
24	7800	156	336	246	133	329	231	238
27	8800	181	378	280	166	362	264	272
30	9800	214	420	317	191	395	293	305
33	10800	246	468	357	216	436	326	341
36	11700	280	510	395	249	477	363	379
39	12700	304	550	427	266	510	388	407
42	13600	336	592	464	298	544	421	442
45	14600	370	634	502	324	584	454	478
48	15600	402	674	538	348	626	487	512
51	16500	436	706	571	382	658	520	545
54	17500	468	748	608	406	692	549	578
57	18500	494	780	637	432	724	578	607
60	19500	534	830	682	465	765	615	649
63	20400	575	871	723	498	806	652	687
48	15600	394	656	525	374	642	508	516
30	9700	238	402	320	224	428	326	323
12	3900	58	148	103	75	189	132	117
30	9700	230	402	316	216	428	322	319
39	12700	328	534	431	298	536	417	424
48	15600	394	658	526	374	642	508	517
63	20400	575	871	713	498	806	652	682
66	21400	624	912	768	524	840	682	725
70	22700	706	978	842	590	922	756	789
72	23400	756	1010	883	614	956	785	834
74	24000	805	1051	928	656	1012	834	881
76	24600	855	1093	974	696	1060	878	926
78	25300	904	1126	1015	746	1102	924	969
81	26200	1070	1182	1126	830	1202	1016	1071
84	27200	1076	1240	1158	1004	1310	1157	1157
87	28200	1272	1348	1310	1394	1522	1458	1334
90	29200							

PLATE G-1.

EXTENSOMETERS 111a, 111b, 1Va & 1Vb.

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Load kips	Stress psi.	Elongation ins/ 100,000 111b.	Elongation ins/ 100,000 111a.	Average Elongation ins/ 1,000,000 111a.&111b.	Average Unit Strain ins/ 1,000,000 111a.&111b.	Elongation ins/ 100,000 V11b.	Elongation ins/ 100,000 V11a.	Average Elongation ins/ 1,000,000 V11a.&V11b.	Average Unit Strain ins/ 1,000,000 V11a.&V11b.
0	0	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0	0
4	1300	-1	10	45	22	11	-1	50	25
6	2000	1	15	80	40	15	1	80	40
8	2600	7	19	130	65	19	7	130	65
10	3300	11	21	160	80	21	11	160	80
12	3900	19	24	215	107	24	18	210	105
14	4500	24	28	260	130	28	22	250	125
16	5200	30	30	300	150	30	29	295	147
18	5800	37	31	340	170	31	33	320	160
20	6500	42	34	380	190	34	40	370	185
22	7100	49	38	435	217	38	46	420	210
24	7800	54	40	470	235	40	50	450	225
27	8800	65	43	540	270	43	59	510	255
30	9800	74	48	610	305	49	68	585	292
33	10800	82	52	670	335	52	73	625	312
36	11700	91	58	745	372	59	81	700	350
39	12700	99	61	800	400	63	89	760	389
42	12600	108	68	880	440	70	96	830	415
45	14600	115	71	930	465	75	102	885	442
48	15600	122	78	1000	500	81	109	950	475
51	16500	130	82	1060	530	88	116	1020	510
54	17500	139	88	1135	567	91	122	1065	532
57	18500	146	92	1190	595	99	130	1145	572
60	19500	152	99	1255	627	102	138	1200	600
63	20400	161	101	1310	655	110	146	1280	640
48	15600	127	73	1000	500	79	115	970	485
30	9700	79	45	620	310	48	72	600	300
12	3900	30	18	240	120	15	30	225	112
30	9700	80	42	610	305	44	74	590	295
39	12700	103	58	805	402	61	95	780	390
48	15600	127	73	1000	500	79	115	970	485
63	20400	161	101	1310	655	110	148	1290	645
66	21400	171	106	1385	692	115	152	1335	667
70	22700	182	114	1480	740	125	171	1480	740
72	23400	189	112	1505	752	130	180	1550	775
74	24000	194	116	1550	775	137	191	1640	820
76	24600	201	118	1595	797	145	202	1735	867
78	25300	208	120	1640	820	152	221	1865	932
81	26200	219	121	1700	850	172	243	2075	1037
84	27200	231	119	1750	875	215	281	2480	1240
87	28200	258	105	1815	907				
90	29200								

PLATE G-1.

EXTENSOMETERS Va, Vb, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Vb.	Va.	Average Unit Strain ins/ 1,000,000 Va. & Vb.	Elongation ins/ 1,000,000 1Vb.	1Va.	Average Unit Strain ins/ 1,000,000 1Va. & 1Vb.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	7	10	15	8	41	24
6	2000	6	14	40	17	74	45
8	2600	2	18	80	25	99	62
10	3300	1	19	90	42	124	83
12	3900	2	20	110	59	157	108
14	4500	7	20	135	76	182	129
16	5200	10	21	155	93	207	150
18	5800	12	22	170	110	232	171
20	6500	17	23	200	135	248	191
22	7100	20	23	215	143	272	207
24	7800	23	26	245	168	298	233
27	8800	29	28	285	194	330	262
30	9800	33	29	310	228	372	300
33	10800	39	30	345	261	413	337
36	11700	46	31	365	286	446	366
39	12700	49	34	415	320	480	400
42	13600	51	38	445	354	512	433
45	14600	56	40	480	379	537	458
48	15600	60	41	505	413	569	486
51	16500	62	45	535	446	604	525
54	17500	68	48	580	480	636	558
57	18500	71	50	605	514	676	595
60	19500	77	51	640	539	709	624
63	20400	80	52	660	564	744	654
48	15600	62	37	495	422	560	491
30	9700	39	21	300	236	354	295
12	3900	12	9	105	59	157	108
30	9700	40	21	305	228	364	296
39	12700	51	30	405	320	462	391
48	15600	62	38	500	422	560	491
63	20400	80	52	660	565	743	654
66	21400	84	58	710	606	776	691
70	22700	89	54	715	632	800	716
72	23400	90	53	715	656	810	733
74	24000	92	51	715	691	941	816
76	24600	95	52	735	716	992	854
78	25300	98	45	715	734	1032	883
81	26200	101	38	695	750	1064	907
84	27200	109	28	685	758		
87	28200	130	25	775	775		
90	29200						

PLATE G-1.

EXTENSOMETERS Vla. & Vlb. and
SUMMATION OF EXTENSOMETER READINGS. 111, 1V, V, Vl & Vll.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Vlb.	Elongation ins/ 100,000 Vla.	Average Elongation ins/ 1,000,000 Vla.& Vlb.	Average Unit Strain ins/ 1,000,000 Vla.& Vlb.	Total Elongation ins/ 1,000,000 111 to Vll.	Unit Strain ins/ 1,000,000 111 to Vl.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	9	1	50	25	184	23
6	2000	11	7	90	45	335	42
8	2600	13	12	125	62	527	66
10	3300	16	20	180	90	673	84
12	3900	18	27	225	112	868	108
14	4500	20	32	260	130	1034	129
16	5200	21	39	300	150	1200	150
18	5800	23	45	340	170	1341	168
20	6500	27	51	390	195	1531	191
22	7100	29	58	435	217	1712	214
24	7800	30	63	465	232	1863	233
27	8800	33	72	525	262	2122	265
30	4800	38	82	600	300	2405	301
33	10800	41	91	660	330	2637	330
36	11700	48	100	740	370	2916	365
39	12700	51	108	795	397	3170	396
42	13600	57	117	870	435	3458	432
45	14600	61	122	965	482	3718	465
48	15600	68	131	995	497	3936	492
51	16500	72	140	1060	503	4200	525
54	17500	79	149	1140	570	4478	560
57	18500	85	157	1210	605	4745	593
60	19500	91	170	1305	652	5024	628
63	20400	104	188	1460	730	5364	671
48	15600	78	152	1150	575	4106	513
30	9700	50	102	760	380	2575	322
12	3900	22	52	370	185	1048	131
30	9700	48	104	760	380	2561	321
39	12700	61	130	955	477	3336	417
48	15600	78	152	1150	575	4011	501
63	20400	104	191	1475	737	5389	674
66	21400	112	199	1555	777	5676	710
70	22700	149	249	1990	995	6381	795
72	23400	165	269	2170	1085	6673	834
74	24000	186	291	2385	1192	7106	888
76	24600	209	320	2645	1322	7564	946
78	25300	232	361	2965	1482	8068	1008
81	26200	270	437	3535	1767	8912	1114
84	27200	318	540	4290	2145		
87	28200	393	765	5795	2897		
90	29200	YP					
170	55000	US.					

Add .000023 to all unit strains to correct for initial load.
Area = .617 x 5.000 = 3.085 sq. ins.
Elastic limit 20,000p.s.i.
E 29.9 x 10^6 p.s.i.

% Elongation in 8 ins. = $\left(\frac{11.40 - 8.00}{8.00}\right) 100 = 42.5\%$

% Reduction in area = $\left(\frac{3.08 - 1.52}{3.08}\right) 100 = 50.7\%$

PLATE G-2.

EXTENSOMETERS 1-a, 1-b, 11-a & 11-b.

Load (kips)	Stress (p.s.i.)	Elongation ins/ 1,000,000 11-b.	11-a.	Average Unit Strain ins/ 1,000,000 11a & 11b.	Elongation ins/ 1,000,000 1-b	1-a.	Average Unit Strain ins/ 1,000,000 1-a & 1-b.	Average Unit Strain ins/ 1,000,000 1 & 2
0	0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0
4	1300	8	33	20	0	41	21	20
6	2000	16	74	45	0	74	37	41
8	2600	25	115	70	0	99	50	60
10	3300	41	148	95	8	132	70	82
12	3900	58	181	120	25	165	90	105
14	4500	82	206	144	33	181	107	125
16	5200	99	247	173	50	214	132	152
18	5800	115	271	193	58	238	148	170
20	6500	140	296	218	75	264	170	194
22	7100	156	328	242	91	288	190	216
24	7800	172	362	267	100	312	206	236
27	8800	205	403	304	125	346	236	270
30	9800	238	444	341	141	386	264	302
33	10800	271	493	382	166	428	297	339
36	11700	296	534	415	174	460	317	366
39	12700	328	576	452	216	502	359	405
42	13600	370	624	497	240	544	392	442
45	14600	394	664	529	258	584	421	475
48	15600	418	722	570	282	626	454	512
51	16500	460	764	612	298	666	482	547
54	17500	493	813	653	332	708	520	586
57	18500	534	864	699	357	749	553	626
60	19500	566	910	738	382	806	594	666
63	20400	616	970	793	424	864	644	718
48	15600	452	772	612	324	716	520	568
36	11700	320	606	463	232	592	412	437
24	7800	172	444	308	133	452	292	300
12	3900	49	279	164	41	296	169	166
24	7800	181	435	308	133	444	289	298
36	11700	312	606	459	216	576	396	427
48	15600	452	764	608	307	708	507	557
63	20400	625	969	797	432	872	652	724
66	21400	665	1019	842	456	914	685	763
69	22400	739	1059	899	506	986	746	822
72	23400	813	1109	961	556	1044	800	880
75	24300	912	1168	1040	639	1161	900	970
78	25300	1028	1208	1118	746	1282	1014	1066
81	26200	1175	1249	1212	888	1432	1160	1186
84	27200	1340	1314	1327	1138	1588	1463	1395
86	27900	1448	1354	1401	1370	1644	1507	1454

PLATE G-2.

EXTENSOMETERS 111-a, 111-b, 1V-a & 1V-b.

Load (kips)	Stress (psi.)	Elongation ins/100,000 111-b	Elongation ins/100,000 111-a	Average Elongation ins/1,000,000 111a & 111b.	Average Unit Strain ins/1,000,000 111a & 111 b.	Elongation ins/100,000 V111b	Elongation ins/100,000 V11a.	Average Elongation ins/1,000,000 V11a &V11b.	Average Unit Strain ins/1,000,000 V11a & V11b.
0	0	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0	0
4	1300	7	2	45	22	1	8	45	22
6	2000	11	7	90	45	5	11	80	40
8	2600	15	10	125	62	9	17	130	65
10	3300	19	15	170	85	12	20	160	80
12	3900	22	20	210	105	19	23	210	105
14	4500	28	24	260	130	22	29	255	127
16	5200	31	29	300	150	28	32	300	150
18	5800	37	31	340	170	31	38	345	172
20	6500	41	37	390	195	35	41	380	190
22	7100	48	39	435	217	39	48	435	217
24	7800	51	41	460	230	41	51	460	230
27	8800	61	45	530	265	47	60	535	267
30	9800	71	49	600	300	50	69	595	297
33	10800	80	51	655	327	53	78	655	327
36	11700	88	55	715	357	59	85	720	360
39	12700	99	59	790	395	62	92	770	385
42	13600	108	62	850	425	69	100	845	422
45	14600	115	68	915	457	73	108	905	452
48	15600	123	70	965	482	80	112	960	480
51	16500	130	76	1030	515	87	119	1030	515
54	17500	140	79	1095	547	90	127	1085	542
57	18500	149	82	1155	577	99	132	1155	577
60	19500	155	88	1215	607	103	139	1210	605
63	20400	160	91	1275	637	110	145	1275	637
48	15600	129	64	965	482	84	110	970	485
36	11700	98	43	705	352	61	81	710	355
24	7800	61	28	445	222	42	49	455	227
12	3900	25	11	180	90	28	15	215	107
24	7800	61	26	436	217	42	50	460	230
36	11700	95	39	670	335	61	81	710	355
48	15600	128	59	935	467	81	110	955	477
63	20400	162	85	1235	617	110	145	1275	637
66	21400	171	91	1310	655	118	151	1345	672
69	22400	183	103	1430	715	123	155	1395	697
72	23400	197	115	1560	780	130	160	1450	725
75	24300	219	131	1750	875	139	161	1500	750
78	25300	244	155	1995	997	150	160	1550	775
81	26200	292	192	2420	1210	166	153	1595	797
84	27200	400	320	3600	1800	219	139	1790	845
86	27900	730	600	6650	3325	237	127	1820	910

PLATE G-2.

EXTENSOMETERS V-a, V-b, 1V-a & 1V-b.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 V-b.	V-a.	Average Unit Strain ins/ 1,000,000 V-a & V-b	Elongation ins/ 1,000,000 1V-b	1V-a.	Average Unit Strain ins/ 1,000,000 1V-a & 1V-b.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	2	2	20	0	34	17
8	2600	8	10	90	16	101	58
10	3300	9	15	120	25	135	80
12	3900	10	20	150	41	168	105
14	4500	11	24	175	68	194	131
16	5200	12	29	205	74	228	151
18	5800	15	31	230	91	252	172
20	6500	18	37	275	99	278	189
22	7100	20	39	295	124	312	218
24	7800	22	41	315	140	336	238
27	8800	29	45	370	165	379	272
30	9800	34	49	415	190	420	305
33	10800	40	51	455	222	464	343
36	11700	45	55	500	256	546	401
39	12700	50	59	545	280	598	439
42	13600	54	62	580	314	666	490
45	14600	59	68	635	346	732	539
48	15600	62	70	660	380	800	590
51	16500	66	76	710	421	851	636
54	17500	71	79	750	471	935	703
57	18500	76	82	790	536	1010	773
60	19500	79	88	835	626	1170	898
63	20400	80	91	855	710	1262	986
48	15600	61	64	625	596	1088	842
36	11700	43	43	430	470	935	702
24	7800	24	28	260	346	784	565
12	3900	2	11	65	239	631	435
24	7800	25	26	255	346	784	565
36	11700	45	39	420	462	926	694
48	15600	61	59	600	578	1070	824
63	20400	80	85	825	718	1262	985
66	21400	87	91	890	759	1321	1040
69	22400	90	103	965	892	1500	1196
72	23400	91	115	1030	1040	1750	1395
75	24300	95	131	1130	1418	2540	1979
78	25300	99	155	1270			
81	26200	102	192	1470			
84	27200	102	320	2110			
86	27900	100	600	3500			

PLATE G-2.

EXTENSOMETERS Vl-a & Vl-b. and
SUMMATION OF EXTENSOMETER READINGS 111, 1V, V, Vl & Vll.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Vl-b	Elongation ins/ 100,000 Vl-a	Average Elongation ins/ 1,000,000 Vl-a & Vl-b.	Average Unit Strain ins/ 1,000,000 Vl-a & Vl-b.	Total Elongation over 8 ins ins/ 1,000,000 111 to Vll.	Unit Strain over 8 ins. ins/ 1,000,000 111 to Vll.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	-1	10	45	22	172	22
6	2000	0	17	85	42	351	45
8	2600	2	22	120	60	523	65
10	3300	6	29	175	87	705	88
12	3900	10	33	215	107	890	111
14	4500	12	39	255	127	1076	135
16	5200	17	44	305	152	1261	158
18	5800	20	50	350	175	1437	180
20	6500	21	56	385	192	1619	202
22	7100	25	61	430	215	1813	227
24	7800	28	69	485	242	1958	245
27	8800	30	79	545	272	2252	282
30	9800	32	89	605	302	2520	315
33	10800	35	99	670	335	2778	347
36	11700	39	109	740	370	3076	385
39	12700	41	118	795	397	3339	417
42	13600	46	128	870	435	3635	454
45	14600	50	137	935	477	3929	491
48	15600	52	149	1005	502	4180	523
51	16500	59	157	1080	540	4486	561
54	17500	61	168	1145	572	4778	595
57	18500	68	176	1220	610	5093	637
60	19500	71	184	1275	637	5433	679
63	20400	78	196	1370	685	5761	720
48	15600	55	155	1050	525	4452	557
36	11700	38	121	795	397	3342	418
24	7800	21	84	525	262	2250	281
12	3900	10	45	275	137	1170	146
24	7800	20	86	530	265	2245	281
36	11700	35	121	780	390	3274	409
48	15600	52	156	1040	520	4354	544
63	20400	79	197	1380	690	5700	713
66	21400	82	203	1425	712	6010	751
69	22400	90	211	1505	752	6491	811
72	23400	100	220	1600	800	7035	879
75	24300	110	221	1655	827	8014	1002
78	25300	121	213	1670	835		
81	26200	132	200	1660	830		
84	27200	170	172	1710	855		
86	27900	180	152	1660	880		
95	30800	Y.P.					
169	54700	U.S.					

Add .000025 to all unit strains to correct for initial load.

Area = .619 x 4.990 = 3.088

Elastic Limit = 20000[1] p.s.i.

E = 28.3×10^6 p.s.i.

% Elongation in 8 ins = $\left(\frac{11.35 - 8.00}{8.00}\right) 100 = 42\%$

% Reduction in area = $\frac{(3.09 - 1.45)}{3.09}\ 100 = 53\%$.

PLATE H-1.

EXTENSOMETERS 1a, 1b, 11a & 11b.

Load (kips)	Stress (psi.)	Elongation ins/1,000,000 11b	11a	Average Unit Strain ins/1,000,000 11a. & 11b.	Elongation ins/1,000,000 1b	1a	Average Unit Strain ins/1,000,000 1a & 1b	Average Unit Strain ins/1,000,000 1 & 11
0	0	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0
4	1300	16	33	24	8	33	20	22
6	2000	33	57	45	25	66	45	45
8	2600	41	82	62	41	91	66	64
10	3300	49	123	86	49	124	86	86
12	3900	66	156	111	66	158	112	111
14	4500	82	189	135	74	190	132	133
16	5200	99	214	156	82	216	149	152
18	5800	115	246	180	99	249	174	177
20	6500	123	279	201	107	281	193	197
22	7100	140	312	226	123	315	219	222
24	7800	156	345	255	132	340	236	245
27	8800	172	386	279	148	390	269	274
30	9800	205	435	320	173	431	302	311
33	10800	222	484	353	189	473	331	342
36	11700	246	534	390	206	524	365	377
39	12700	262	574	418	230	564	397	408
42	13600	288	616	452	246	606	426	439
45	14600	320	656	488	272	646	459	473
48	15600	336	705	521	288	688	488	504
51	16500	370	754	562	304	730	517	539
54	17500	394	804	599	321	781	551	575
57	18500	402	962	632	337	829	583	607
60	19500	452	920	686	362	880	621	654
63	20400	485	978	732	378	946	662	697
66	21400	526	1034	780	395	987	691	735
69	22400	566	1116	841	420	1046	733	787
72	23400	616	1200	908	444	1110	777	842
75	24300	656	1272	964	468	1178	823	893
78	25300	748	1402	1075	518	1288	903	989
81	26200	822	1510	1166	552	1368	960	1063
84	27200	928	1658	1293	608	1460	1034	1163
87	28200	1110	1854	1482	700	1610	1155	1319
90	29200	1380	1980	1680	946	1810	1378	1529
92	29800							

PLATE H-1.

EXTENSOMETERS 111a, 111b, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 111b	Elongation ins/ 100,000 111a	Elongation ins/ 1,000,000 111a & 111b	Average Unit Strain ins/ 1,000,000 111a & 111b	Elongation ins/ 100000 V11b	Elongation ins/ 100000 V11a	Elongat'n ins/ 1,000,000 V11a&V11b	Average Unit Strain ins/ 100,000 V11a&V11b.
0	0	-	-	-	-	-	-	-	-
2	700	0	0	0	0	0	0	0	0
4	1300	11	-2	45	22	-1	10	45	22
6	2000	19	-1	90	45	0	18	90	45
8	2600	22	1	115	57	2	21	115	57
10	3300	29	4	165	82	8	27	175	89
12	3900	33	9	210	105	11	31	210	105
14	4500	40	11	255	127	15	35	250	125
16	5200	45	15	300	150	20	40	300	150
18	5800	50	19	345	172	22	45	335	167
20	6500	56	21	385	192	28	49	385	192
22	7100	60	26	430	215	31	52	415	207
24	7800	66	30	480	240	35	58	465	232
27	8800	72	35	535	267	41	64	525	262
30	9800	80	41	605	302	49	71	600	300
36	11700	94	51	725	362	61	83	720	360
39	12700	101	59	800	400	69	90	795	397
42	13600	109	62	855	427	72	98	850	425
45	14600	118	69	935	467	80	103	915	457
48	15600	125	72	985	492	86	111	985	492
51	16500	131	79	1050	525	91	118	1045	522
54	17500	140	82	1110	555	99	123	1110	550
57	18500	148	89	1185	592	105	130	1175	587
60	19500	155	92	1235	617	112	135	1235	617
63	20400	162	99	1305	652	120	140	1300	650
66	21400	169	102	1355	677	131	147	1390	695
69	22400	178	107	1425	712	143	153	1480	740
72	23400	184	110	1475	737	158	160	1590	795
75	24300	193	112	1525	762	172	167	1695	847
78	25300	201	115	1580	790	210	180	1950	975
81	26200	211	120	1655	827	236	191	2135	1067
84	27200	220	122	1710	855	278	229	2535	1267
87	28200	231	122	1765	882	259	336	2975	1487
90	29200								
92	29800								

PLATE H-1.

EXTENSOMETERS Va, Vb, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Vb	Elongation ins/ 100,000 Va	Average Unit Strain ins/ 1,000,000 Va & Vb	Elongation ins/ 1,000,000 1Vb	Elongation ins/ 1,000,000 1Va	Average Unit Strain ins/ 1,000,000 1Va & 1Vb.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	8	-2	30	17	25	21
6	2000	10	-2	40	33	51	42
8	2600	12	0	60	50	76	63
10	3300	15	1	80	66	110	88
12	3900	18	4	110	83	151	117
14	4500	19	8	135	91	185	138
16	5200	20	9	145	107	211	159
18	5800	22	11	165	124	244	184
20	6500	25	13	190	132	278	205
22	7100	28	17	225	149	311	230
24	7800	29	20	245	165	345	355
27	8800	31	22	265	182	396	289
30	9800	32	28	300	206	446	326
33	10800	37	31	340	231	489	360
36	11700	39	35	370	256	530	393
39	12700	41	39	400	280	580	420
42	13600	45	41	430	305	625	465
45	14600	49	46	475	330	666	498
48	15600	51	48	495	347	725	536
51	16500	54	50	520	372	766	569
54	17500	59	52	555	396	834	615
57	18500	61	59	600	421	885	653
60	19500	66	61	635	437	935	686
63	20400	70	68	690	454	1010	732
66	21400	73	71	720	478	1070	774
69	22400	80	80	800	586	1170	878
72	23400	81	88	845	726	1366	1046
75	24300	88	91	895	776	1448	1112
78	25300	92	90	910	800	1558	1179
81	26200	98	91	945	816	1618	1217
84	27200	101	91	960	816	1692	1254
87	28200	112	81	965	794	1678	1236
90	29200				794	1678	1236
92	29800						

PLATE H-1.

EXTENSOMETERS Vla & Vlb and
SUMMATION OF EXTENSOMETER READINGS 111, 1V, V, Vl & Vll.

Load (kips)	Stress (psi)	Elongation ins/ 100,000 Vlb	& Vla	Average Elongation ins/ 1,000,000 Vla & Vlb.	Average Unit Strain ins/ 1,000,000 Vla & Vlb.	Total Elongation over 8 ins. ins/ 1,000,000 111 to Vll	Unit Strain over 8 ins. ins/ 1,000,000 111 to Vll.
0	0	-	-	-	-	-	-
2	700	0	0	0	0	0	0
4	1300	-2	10	40	20	181	23
6	2000	-1	19	90	45	352	44
8	2600	1	22	115	57	468	59
10	3800	3	30	165	82	673	84
12	3900	8	35	215	107	862	108
14	4500	10	41	255	127	1033	129
16	5200	11	48	295	147	1199	150
18	5800	15	51	330	165	1359	170
20	6500	19	59	390	195	1555	194
22	7100	21	63	420	210	1720	215
24	7800	24	69	465	232	1910	239
27	8800	30	78	540	270	2154	269
30	9800	34	85	595	297	2426	303
33	10800	40	92	660	330	2705	338
36	11700	44	101	725	362	2933	367
39	12700	50	110	800	400	3215	402
42	13600	55	119	870	435	3470	434
45	14600	60	127	935	467	3758	480
48	15600	63	133	980	490	3981	498
51	16500	69	141	1050	525	4234	529
54	17500	72	151	1115	557	4505	563
57	18500	79	159	1190	595	4803	600
60	19500	89	172	1305	652	5096	637
63	20400	98	190	1440	720	5467	683
66	21400	106	199	1525	762	5764	721
69	22400	116	215	1655	827	6238	780
72	23400	128	231	1795	897	6751	844
75	24300	148	262	2050	1025	7277	910
78	25300	203	344	2735	1317	8354	1044
81	26200	242	403	3225	1612	9177	1147
84	27200	315	502	4085	2042	10544	1318
87	28200	443	688	5655	2827	12596	1575
90	29200	720	975	8475	4237		
92	29800	Y.P.					
171	55400	U.S.					

Add .000025 to all unit strains to correct for initial load
Area = .617 x 5.000 = 3.085 sq.ins.
Elastic Limit = 19000 psi.
$E = 29.8 \times 10^6$ psi.

$\%$ Elongation in 8 ins = $\left(\frac{11.15 - 8.00}{8.00}\right) 100 = 39.4\%$

$\%$ Reduction in area = $\left(\frac{3.08 - 1.27}{3.08}\right) 100 = 58.8\%$

PLATE H-2.

EXTENSOMETERS 1a, 1b, 11a & 11b.

Load (kips)	Stress (psi.)	Elongation ins/1,000,000 11b	Elongation ins/1,000,000 11a	Average Unit Strain ins/1,000,000 11a & 11b.	Elongation ins/1,000,000 1b.	Elongation ins/1,000,000 1a.	Average Unit Strain ins/1,000,000 1a & 1b.	Average Unit Strain ins/1,000,000 1 & 11.
0	0	-	-	-	-	-	-	-
2	600	0	0	0	0	0	0	0
4	1300	0	25	12	8	33	20	16
6	1900	16	58	37	17	66	41	39
8	2600	25	90	67	33	107	70	68
10	3200	41	123	82	41	140	90	86
12	3900	49	156	103	50	172	111	107
15	4800	66	197	132	66	222	144	138
18	5800	82	246	164	91	271	181	172
21	6800	99	288	193	108	312	210	201
24	7700	123	329	226	125	362	243	234
27	8700	131	378	254	141	411	276	265
30	9700	156	418	287	166	452	309	298
33	10600	173	469	321	174	494	334	327
36	11600	197	509	353	199	535	367	360
39	12600	214	558	386	216	584	400	393
42	13600	238	600	419	240	624	432	425
45	14500	262	650	456	257	675	466	461
48	15500	288	690	489	282	706	494	491
51	16500	312	730	521	298	748	523	522
54	17400	337	781	559	324	796	560	559
57	18400	362	822	592	340	838	589	590
60	19500	386	872	629	374	880	627	628
63	20300	410	930	670	390	922	656	663
66	21300	435	985	710	406	962	684	697
69	22200	494	1052	723	440	1020	730	727
72	23200	534	1118	826	473	1079	776	801
75	24200	575	1191	883	506	1142	824	853
78	25200	649	1291	970	522	1250	886	928
81	26100	764	1406	1085	672	1380	1026	1055
83	26800	822	1478	1150	722	1448	1085	1117
85	27400	904	1552	1228	816	1538	1177	1202
87	28100	1028	1634	1331	922	1652	1287	1309
89	28700	1208	1718	1413	1102	1776	1439	1426
91	29300							

PLATE H-2.

III VII
EXTENSOMETERS 111a, 111b, 1Va & 11Vb.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 111b	111a	Average Elongation ins/ 1,000,000 111a &111b.	Unit Strain ins/ 1,000,000 111a & 111	Elongation ins/ 100,000 V11b	V11a	Average Elongation ins/ 1,000,000 V11a &V11b	Average Unit Strain ins/ 1,000,000 V11a & V11b.
0	0	-	-	-	-	-	-	-	-
2	600	0	0	0	0	0	0	0	0
4	1300	-4	12	40	20	13	-3	50	25
6	1900	-2	20	90	45	20	-1	95	47
8	2600	1	23	120	60	27	1	140	70
10	3200	6	29	175	87	31	7	190	95
12	3900	10	31	205	102	35	10	225	112
15	4800	18	38	280	140	41	18	295	147
18	5800	25	41	330	165	49	23	360	180
21	6800	32	48	400	200	52	31	415	207
24	7700	41	51	460	230	60	39	495	247
27	8700	49	58	535	267	65	46	555	277
30	9700	58	61	595	297	71	52	615	307
33	10600	66	68	670	335	77	61	690	345
36	11600	73	71	720	360	81	69	750	375
39	12600	81	77	790	395	89	75	820	410
42	13600	89	81	850	425	94	81	875	437
45	14500	98	88	930	465	101	89	950	475
48	15500	105	91	980	490	108	96	1020	510
51	16500	112	98	1050	525	112	102	1070	535
54	17400	120	101	1105	552	120	109	1145	577
57	18400	128	109	1185	592	128	115	1215	607
60	19300	134	112	1230	615	132	121	1265	632
63	20300	142	119	1305	652	140	129	1345	672
66	21300	150	123	1415	707	148	136	1420	710
69	22200	181	140	1605	802	152	141	1465	732
72	23200	199	156	1775	.887	161	148	1545	772
75	24200	219	168	1935	967	169	155	1620	810
78	25200	260	201	2305	1152	178	159	1685	842
81	26100	309	249	2790	1395	185	159	1720	860
83	26800	341	279	3100	1550	190	161	1755	877
85	27400	398	340	3690	1845	198	162	1800	900
87	28100	540	485	5125	2562	209	160	1845	922
89	28700					230	150	1900	950
91	29300								

PLATE H-2.

EXTENSOMETERS Va, Vb, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Vb.	Va.	Average Unit Strain ins/ 1,000,000 Va & Vb	Elongation ins/ 1,000,000 1Vb	1Va.	Unit Strain ins/ 1,000,000 1Va & 1Vb.
0	0	-	-	-	-	-	-
2	600	0	0	0	0	0	0
4	1300	1	11	60	8	84	46
6	1900	1	18	95	16	118	67
8	2600	2	21	115	33	152	93
10	3200	2	22	120	49	177	113
12	3900	5	28	165	49	211	130
15	4800	8	30	190	74	252	163
18	5800	10	33	215	99	295	197
21	6800	12	38	250	124	346	235
24	7700	18	40	290	140	388	264
27	8700	20	42	310	173	429	301
30	9700	23	47	350	190	472	331
33	10600	28	49	385	214	514	364
36	11600	31	51	410	239	555	397
39	12600	34	55	445	264	598	431
42	13600	38	59	485	288	640	464
45	14500	40	61	505	314	682	498
48	15500	43	64	535	338	724	531
51	16500	48	69	585	371	759	565
54	17400	50	71	605	396	800	598
57	18400	52	75	635	421	835	628
60	19300	58	79	685	437	885	661
63	20300	60	81	705	462	918	685
66	21300	62	85	735	495	961	728
69	22200	63	89	760	808	1020	914
72	23200	67	98	825	940	1140	1040
75	24200	69	102	855	1080	1248	1164
78	25200	65	106	855	1342	1660	1501
81	26100	59	107	830	1674	2180	1927
83	26800	59	109	840	1808	2382	2095
85	27400	49	111	800			
87	28100	45	120	825			
89	28700	40	148	940			
91	29300						

PLATE H-2.

EXTENSOMETERS Vla & Vlb and
SUMMATION OF EXTENSOMETER READING 111,1V, V, Vl & Vll.

Load (kips)	Stress (psi.)	Elongation ins/100,000 Vlb	Vla	Average Elongation ins/1,000,000 Vl & Vlb.	Average Unit Strain ins/1,000,000 Vla & Vlb.	Total Elongation over 8 ins ins/1,000,000 1111 to Vll	Unit Strain over 8 ins ins/1,000,000 111 to Vll.
0	0	-	-	-	-	-	-
2	600	0	0	0	0	0	0
4	1300	11	-2	45	22	241	30
6	1900	18	1	95	47	442	55
8	2600	20	7	135	67	603	75
10	3200	22	11	165	82	763	85
12	3900	28	18	230	115	955	119
15	4800	30	27	285	142	1213	152
18	5800	35	36	355	177	1458	182
21	6800	39	44	415	207	1715	214
24	7700	41	52	465	232	1974	247
27	8700	47	62	545	272	2246	281
30	9700	50	71	605	302	2496	312
33	10600	52	81	665	332	2774	347
36	11600	58	91	745	372	3022	378
39	12600	61	100	805	402	3491	436
42	13600	68	109	885	442	3559	445
45	14500	71	118	945	472	3828	479
48	15500	78	127	1025	512	4091	511
51	16500	81	134	1075	537	4345	543
54	17400	88	142	1150	575	4603	575
57	18400	91	151	1210	605	4873	609
60	19300	98	161	1295	647	5036	630
63	20300	102	172	1370	685	5410	676
66	21300	109	182	1455	727	5753	719
69	22200	111	199	1550	775	6294	787
72	23200	118	202	1600	800	6785	848
75	24200	127	215	1710	855	7284	911
78	25200	132	225	1785	892	8131	1016
81	26100	132	218	1750	870	9017	1127
83	26800	135	217	1760	880	9550	1191
85	27400	136	220	1780	890		
87	28100	137	209	1730	865		
89	28700	147	185	1660	830		
91	29300	Y.P.					
168	54200	U.S.					

Add .000017 to all unit strains to correct for initial load
Area = .620 x 5.000 = 3.100 sq. ins.
Elastic Limit = 20.000 psi
E = 29.4 x 10^6 psi.

$$\% \text{ Elongation in 8 ins} = \left(\frac{11.24 - 8.00}{8.00}\right) 100 = 40.5\%$$

$$\% \text{ Reduction in area} = \frac{(3.10 - 1.45)}{3.10} 100 = 53.2\%.$$

PLATE K-1.

Load (kips)	Stress (psi.)	Elongation ins/ 1,000,000 11b	11a.	Average Unit Strain ins/ 1,000,000 11a & 11b.	Elongation ins/ 1,000,000 1b	1a.	Average Unit Strain ins/ 1,000,000 1a & 1b	Average Unit Strain ins/ 1,000,000 1 & 11
0	0	-	-	-	-	-	-	-
2	600	0	0	0	0	0	0	0
4	1300	-8	49	20	-8	58	25	22
6	1900	-8	82	37	-8	100	46	41
8	2600	0	123	61	0	133	66	63
10	3200	16	148	82	16	158	87	84
12	3900	25	172	98	33	191	112	105
15	4800	41	213	127	66	240	153	140
18	5800	58	246	152	82	290	186	169
21	6800	82	288	185	123	333	228	206
24	7700	115	329	222	148	374	261	241
27	8700	131	369	250	181	423	302	276
30	9700	156	402	279	206	464	335	307
24	7700	99	329	214	156	390	273	243
18	5800	41	263	152	82	316	199	175
12	3900	-8	230	111	25	241	133	122
2	600	--66	82	8	-82	83	0	4
12	3900	8	180	94	33	224	128	111
18	5800	58	246	152	91	299	195	173
24	7700	99	329	214	148	382	265	239
30	9700	156	402	279	206	464	335	307
33	10600	181	443	312	247	507	377	344
36	11600	205	467	336	280	540	420	378
39	12600	222	510	366	304	590	447	406
42	13600	246	542	394	338	622	480	437
45	14500	279	575	427	370	664	517	472
48	15500	296	616	456	412	696	554	505
52	16800	336	674	505	453	763	608	556
56	18100	378	730	554	502	814	658	606
60	19400	426	788	607	568	872	720	663
64	20700	460	862	661	626	930	778	719
68	22000	509	945	727	708	988	845	786
72	23300	575	1043	809	798	1046	922	865
75	24300	632	1108	870	865	1095	980	925
78	25300	706	1190	948	955	1153	1054	1001
81	26200	780	1272	1030	1046	1202	1124	1077
84	27200	904	1364	1134	1170	1254	1212	1173
87	28200	1060	1494	1277	1640	1294	1467	1372
90	29200	1400	1710	1555	1770	1370	1570	1562

PLATE K-1.

EXTENSOMETERS 111a, 111b, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/100,000 111b	Elongation ins/100,000 111a	Average Elongation ins/1,000,000 111a & 111b	Average Unit Strain ins/1,000,000 111a & 111b.	Elongation ins/100,000 V11b	Elongation ins/100,000 V11a	Elongation ins/1000,000 V11a&V11b	Average Unit Strain ins/1000000 V11a&V11b.
0	0	-	-	-	-	-	-	-	-
2	600	0	0	0	0	0	0	0	0
4	1300	-6	11	25	12	11	-1	50	25
6	1900	-10	25	75	37	22	-3	-95	47
8	2600	-11	33	110	55	31	-2	145	72
10	3200	-9	40	155	77	37	-1	180	90
12	3900	-8	48	200	100	41	1	210	105
15	4800	-2	56	270	135	50	7	285	142
18	5800	1	63	320	160	58	11	345	172
21	6800	7	72	395	197	64	17	405	202
24	7700	11	81	460	230	71	21	460	230
27	8700	16	89	525	262	79	27	530	265
30	9700	21	98	595	297	87	31	590	295
24	7700	10	81	455	227	73	21	470	235
18	5800	1	67	340	170	60	11	355	177
12	3900	-11	49	190	95	47	2	245	122
2	600	-11	11	0	0	8	0	40	20
12	3900	-12	50	190	95	47	1	240	120
18	5800	-2	68	330	165	60	10	350	175
24	7700	8	81	445	223	73	20	465	232
30	9700	19	98	585	292	87	31	590	295
33	10600	23	103	630	315	92	37	645	322
36	11600	29	111	700	350	100	41	705	352
39	12600	35	120	757	378	108	48	780	390
42	13600	41	128	845	422	115	52	835	427
45	14500	48	137	925	462	121	58	895	447
48	15500	52	144	980	490	129	62	955	477
52	16800	62	157	1095	547	141	69	1050	525
56	18100	71	162	1165	582	151	76	1135	567
60	19400	81	179	1300	650	164	74	1190	595
64	20700	91	191	1410	705	175	80	1275	637
68	22000	104	202	1530	765	189	89	1390	695
62	23300	119	217	1680	840	202	100	1510	755
75	24300	130	237	1835	917	215	110	1625	812
78	25300	147	265	2060	1030	232	119	1755	877
81	26200	162	287	2295	1147	248	124	1860	920
84	27200	189	336	2625	1312	268	128	1980	990
87	28200	221	367	2940	1470	288	130	2090	1045
90	29200					309	128	2185	1092

PLATE K-1.

EXTENSOMETERS Va, Vb, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/100,000 Vb	Elongation ins/100,000 Va	Average Unit Strain ins/1,000,000 Va & Vb.	Elongation ins/1,000,000 1Vb	Elongation ins/1,000,000 1Va	Average Unit Strain ins/1,000,000 1Va & 1Vb.
0	0	-	-	-	-	-	-
2	600	0	0	0	0	0	0
4	1300	-8	11	15	-17	50	16
6	1900	13	22	45	-17	91	37
8	2600	-18	30	60	-8	132	62
10	3200	-18	34	80	8	157	82
12	3900	-18	39	105	17	190	103
15	4800	-17	45	140	51	239	145
18	5800	-16	50	170	67	281	174
21	6800	-13	57	220	93	322	207
24	7700	-12	61	245	118	356	237
27	8700	-11	68	285	143	396	269
30	9700	-10	71	305	177	429	303
24	7700	-15	62	235	118	372	245
18	5800	-19	52	165	59	289	174
12	3900	-20	42	110	0	214	107
2	600	-10	11	5	-76	86	3
12	3900	-21	44	115	8	206	107
18	5800	-19	52	165	59	289	174
24	7700	-14	62	240	118	364	241
30	9700	-10	71	305	177	429	303
33	10600	-9	77	340	202	470	336
36	11600	-7	81	370	228	504	366
39	12600	-3	87	420	261	545	403
42	13600	-2	91	445	294	586	440
45	14500	0	95	475	320	626	473
48	15500	1	99	500	345	677	511
52	16800	3	102	525	396	800	598
56	18100	8	108	580	446	876	661
60	19400	10	110	600	506	966	736
64	20700	12	114	630	556	1080	818
68	22000	18	118	680	624	1280	952
72	23300	19	121	700	742	1468	1105
75	24300	20	122	720	910	1732	1321
78	25300	19	128	735	1198	2238	1718
81	26200	20	134	770	1440	-	-
84	27200	27	142	845	1802	-	-
87	28200	18	152	850			
90	29200	19	178	985			

PLATE K-1.

EXTENSOMETERS Vla & Vlb and
SUMMATION OF EXTENSOMETER READINGS 111, 1V, V, Vl & Vll.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000 Vlb	Elongation ins/ 100,000 Vla	Average Elongation ins/ 1,000,000 Vla & Vlb	Average Unit Strain ins/ 1,000,000 Vla & Vlb.	Total Elongation ins/ 1,000,000 111 to Vll.	Unit Strain over 8 ins. ins/1,000,000 111 to Vll.
0	0	-	-	-	-	-	-
2	600	0	0	0	0	0	0
4	1300	8	1	45	22	151	19
6	1900	18	2	100	50	352	44
8	2600	23	3	130	65	507	63
10	3200	29	8	185	92	682	85
12	3900	32	11	215	107	833	104
15	4800	40	18	290	145	1130	141
18	5800	48	22	350	175	1359	170
21	6800	55	29	420	210	1647	206
24	7700	61	33	470	235	1872	234
27	8700	69	40	545	272	2154	269
30	9700	77	46	615	307	2408	301
24	7700	62	33	475	237	1880	235
18	5800	49	22	355	177	1389	174
12	3900	31	13	220	110	872	109
2	600	-5	8	15	7	63	8
12	3900	35	11	230	115	882	110
18	5800	50	21	355	177	1374	172
24	7700	62	33	475	237	1866	233
30	9700	77	46	615	307	2398	300
33	10600	82	52	670	335	2621	327
36	11600	90	59	745	372	2886	361
39	12600	98	63	805	402	3165	396
42	13600	102	70	860	430	3425	428
45	14500	110	77	935	467	3703	463
48	15500	118	82	1000	500	3946	493
52	16800	129	91	1100	550	4368	546
56	18100	139	107	1230	615	4771	596
60	19400	149	119	1340	670	5166	646
64	20700	171	132	1515	757	5648	706
68	22000	177	148	1625	812	6177	772
72	23300	193	163	1780	890	6775	847
75	24300	207	180	1935	967	7436	930
78	25300	223	192	2075	1037	8343	1043
81	26200	240	200	2200	1100		
84	27200	263	203	2830	1165		
87	28200	287	199	2430	1215		
90	29200	318	170	2440	1220		
170	55100	U.S.					

Add .000020 to all unit strains to correct for initial load
Area = .618 x 5.000 = 3.090 sq. ins.
Elastic Limit = 17000 psi.
$E = 30.2 \times 10^6$ psi.

% Elongation in 8 ins. = $\frac{(11.01 - 8.00)}{(8.00)}$ 100 = 37.7%.

% Reduction in area = $\frac{(3.09 - 1.46)}{(3.09)}$ = 49.9%.

PLATE K-2.

Load (kips)	Stress (psi.)	Elongation ins/ 1,000,000 11b	Elongation ins/ 1,000,000 11a	Average Unit Strain ins/ 1,000,000 11a & 11b.	Elongation ins/ 1,000,000 1b	Elongation ins/ 1,000,000 1a	Average Unit Strain ins/ 1,000,000 1a & 1b	Average Unit Strain ins/ 1,000,000 1 & 11.
0	0	-	-	-	-	-	-	-
2	600	0	0	0	0	0	0	0
4	1300	0	33	16	8	42	26	21
6	1900	8	74	41	16	83	50	45
8	2600	8	107	58	25	116	70	64
10	3200	16	140	78	33	149	91	84
12	1900	25	164	94	49	182	115	104
14	4500	33	197	115	58	216	137	126
16	5200	41	222	131	74	250	162	146
18	5800	58	246	152	91	281	186	169
20	6500	74	280	177	115	307	211	194
22	7100	90	304	197	132	332	232	214
24	7700	107	329	218	148	366	257	237
27	8700	123	369	246	173	415	294	270
30	9700	148	402	275	198	456	327	301
33	10600	172	436	304	230	498	364	334
36	11600	197	475	336	255	539	397	366
39	12600	222	516	369	288	580	434	401
42	13600	262	558	410	314	630	472	441
45	14500	288	608	448	354	680	517	482
48	15500	312	650	484	378	730	554	519
51	16500	345	699	522	412	788	600	561
54	17400	386	764	575	452	846	649	612
57	18400	419	813	616	494	904	699	657
60	19300	460	870	665	535	955	745	705
48	15500	345	731	538	428	830	629	583
36	11600	230	584	407	321	680	500	453
24	7700	123	443	283	206	540	373	328
12	3900	33	304	168	91	373	232	200
2	600	-25	189	82	-8	206	99	90
12	3900	41	295	168	99	365	232	200
24	7700	131	427	279	214	522	368	323
36	11600	250	574	412	330	590	460	436
48	15500	353	731	542	428	822	625	583
60	19300	468	880	674	544	954	749	712
63	20300	500	928	714	576	1004	790	752
66	21300	558	1010	784	642	1080	861	822
69	22200	607	1076	842	700	1130	915	878
72	23200	674	1150	912	774	1196	985	948
75	24200	702	1230	966	848	1262	1055	1010
78	25200	730	1320	1025	921	1311	1116	1070
81	26100	838	1442	1140	1020	1360	1190	1165
84	27100	949	1579	1264	1120	1410	1265	1265
87	28100	1108	1700	1404	1242	1460	1351	1377
90	29000	1520	1810	1665	1381	1493	1437	1600

PLATE K-2.

EXTENSOMETERS 111a, 111b, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/100,000 111b	Elongation ins/100,000 111a	Average Elongation ins/1,000,000 111a & 111b	Average Unit Strain ins/1,000,000 111a & 111b	Elongation ins/100,000 V11b	Elongation ins/100,000 V11a	Average Elongat'n ins/1000000 V11a&V11b	Average Unit Strain ins/1,000,000 V11a & V11b
0	0	-	-	-	-	-	-	-	-
2	600	0	0	0	0	0	0	0	0
4	1300	3	4	35	17	3	2	25	12
6	1900	9	9	90	45	9	7	80	40
8	2600	15	12	135	67	11	12	115	57
10	3200	21	13	170	85	12	19	155	77
12	3900	28	17	225	112	16	25	205	102
14	4500	33	19	260	130	19	31	250	125
16	5200	40	21	305	152	21	38	295	147
18	5800	48	23	355	177	22	43	325	162
20	6500	52	26	390	195	25	50	375	187
22	7100	60	29	445	222	28	58	430	215
24	7700	67	30	485	242	30	63	465	232
27	8700	77	32	545	272	33	73	530	265
30	9700	87	38	625	312	38	84	610	305
33	10600	96	40	680	340	41	95	680	340
36	11600	107	41	740	370	45	105	750	375
39	12600	117	43	800	400	50	112	810	405
42	13600	127	48	875	437	54	120	870	435
45	14500	138	51	945	472	61	128	945	477
48	15500	148	57	1025	512	67	135	1010	505
51	16500	157	61	1090	545	71	141	1060	530
54	17400	167	65	1160	580	78	151	1145	572
57	18400	176	70	1230	615	83	163	1230	615
60	19300	188	74	1310	655	89	174	1315	657
48	15500	152	58	1050	525	70	149	1095	546
36	11600	119	41	800	400	51	120	855	427
24	7700	79	29	540	270	38	85	615	307
12	3900	38	19	285	142	22	45	335	167
2	600	9	3	60	30	9	12	105	52
12	3900	38	19	285	142	23	37	300	150
24	7700	79	29	540	270	37	70	535	267
36	11600	119	41	800	400	51	107	740	360
48	15500	154	58	1060	530	69	141	1050	525
60	19300	189	73	1310	655	88	176	1320	660
63	20300	199	79	1390	695	92	184	1390	695
66	21300	210	84	1470	735	101	199	1500	750
69	22200	221	91	1560	780	110	210	1600	800
72	23200	236	102	1690	845	120	221	1705	852
75	24200	251	108	1795	897	131	238	1845	922
78	25200	268	115	1915	957	142	245	1935	967
81	26100	290	117	2035	1017	158	269	2135	1067
84	27100	319	121	2200	1100	172	291	2315	1157
87	28100	370	150	2600	1300	198	311	2545	1277
90	29000	499	237	3680	1840	242	327	2845	1422

PLATE K-2.

EXTENSOMETERS Va, Vb, 1Va & 1Vb.

Load (kips)	Stress (psi.)	Elongation ins/100,000 Vb	Elongation ins/100,000 Va	Unit Strain ins/1,000,000 Va & Vb	Elongation ins/1,000,000 1Vb	Elongation ins/1,000,000 1Va	Unit Strain ins/1,000,000 1Va & 1Vb.
0	0	-	-	---	-	-	-
2	600	0	0	0	0	0	0
4	1300	0	3	15	0	0	0
6	1900	0	9	45	8	17	12
8	2600	1	10	55	8	25	16
10	3200	7	11	90	25	51	38
12	3900	9	12	105	41	76	58
14	4500	12	12	120	50	84	67
16	5200	16	14	150	74	93	83
18	5800	19	16	175	83	101	92
20	6500	22	18	200	101	135	121
22	7100	27	18	225	124	160	142
24	7700	29	18	240	140	194	169
27	8700	34	19	265	173	227	200
30	9700	40	20	300	206	278	242
33	10600	47	21	340	221	321	271
36	11600	51	22	365	272	404	338
39	12600	56	23	395	305	471	388
42	13600	61	23	420	338	540	439
45	14500	64	25	445	396	614	505
48	15500	70	28	490	445	691	568
51	16500	72	29	505	520	774	647
54	17400	78	30	540	595	867	731
57	18400	80	30	550	668	860	764
60	19300	83	31	570	751	1071	911
48	15500	67	22	445	635	935	785
36	11600	48	17	325	512	784	648
24	7700	24	12	180	380	640	510
12	3900	0	11	55	248	488	368
2	600	-15	2	-65	173	337	255
12	3900	0	10	50	256	472	364
24	7700	24	12	180	388	614	501
36	11600	48	17	325	512	776	644
48	15500	68	21	445	635	925	780
60	19300	83	29	560	760	1078	919
63	20300	90	31	605	808	1120	964
66	21300	92	31	615	956	1327	1139
69	22200	98	30	640	1040	1430	1235
72	23200	99	31	650	1202	1650	1426
75	24200	101	29	650	1230	1994	1612
78	25200	102	29	655	1710	2350	2030
81	26100	109	23	660	2030	2780	2405
84	27100	113	21	670	2360	3280	2820
87	28100	124	29	765	2900	4300	3600
90	29000	130	51	905			

PLATE K-2.

EXTENSOMETERS Vla & Vlb and
SUMMATION OF EXTENSOMETERS READINGS 111, 1V, V, Vl & Vll.

Load (kips)	Stress (psi.)	Elongation ins/ 100,000		Average Elongation ins/ 1,000,000	Average Unit Strain ins/ 1,000,000	Total Elongation ins/ 1,000,000	Unit Strain over 8 ins ins/ 1,000,000
		Vlb	Vla	Vla & Vlb.	Vla & Vlb.	111 to Vll	111 to Vll.
0	0	-	-	-	-	-	-
2	600	0	0	0	0	0	0
4	1300	2	7	45	22	120	15
6	1900	3	12	75	37	302	38
8	2600	3	20	115	58	436	55
10	3200	3	29	160	80	613	77
12	3900	5	37	210	105	903	113
14	4500	7	42	245	122	1042	130
16	5200	9	50	295	147	1128	141
18	5800	9	57	330	165	1277	160
20	6500	10	62	360	180	1446	181
22	7100	11	71	410	205	1652	207
24	7700	13	78	455	227	1814	227
27	8700	17	88	525	262	2065	258
30	9700	19	98	585	292	2362	295
33	10600	21	108	645	322	2616	327
36	11600	22	118	700	350	2893	362
39	12600	28	128	780	390	3173	397
42	13600	30	138	840	420	3444	431
45	14500	33	152	925	462	3765	471
48	15500	39	162	1005	502	4098	512
51	16500	41	175	1080	540	4382	548
54	17400	49	188	1185	592	4761	595
57	18400	51	199	1250	625	5024	628
60	19300	58	212	1350	675	5456	682
48	15500	40	182	1110	555	4485	561
36	11600	23	149	860	430	3488	436
24	7700	11	109	600	300	2445	306
12	3900	2	69	355	177	1398	175
2	600	-5	37	160	80	515	64
12	3900	5	67	360	180	1359	170
24	7700	12	109	605	302	2361	295
36	11600	25	148	865	432	3374	422
48	15500	39	182	1105	552	4440	555
60	19300	56	219	1375	687	5484	686
63	20300	61	230	1455	727	5804	726
66	21300	69	250	1595	797	6319	790
69	22200	78	280	1790	895	6825	853
72	23200	89	301	1950	975	7421	927
75	24200	100	330	2150	1075	8052	1007
78	25200	110	352	2310	1155	8845	1106
81	26100	129	402	2655	1327	9890	1236
84	27100	150	452	3010	1505	11015	1277
87	28100	172	498	3350	1675	12860	1608
90	29000	192	502	3470	1735	-	-
93	30000	Y.P.					
170	54800	U.S.					

Add .000032 to all unit strains to correct for initial load

Area = .620 x 5.000 = 3.100 sq. ins.

Elastic Limit = 16000 psi.

E = 29.0×10^6 psi.

% Elongation in 8 ins = $\frac{(11.08 - 8.00)}{8.00} 100$ = 38.6%

% Reduction in area = $\left(\frac{3.100 - 1.450}{3.100}\right) 100$ = 53.2%

CALIBRATION OF MICROMETERS.

All the micrometers were calibrated using the 1.2 foot standard bar. Different parts of the bar and screws were used for each set of readings.

Micrometer A.

Four sets of eight readings were taken with the cross-hairs moving to the right, and again with them moving to the left, over a distance of 0.003 feet. The cross-hairs were in each case carried for 0.005 feet in the opposite direction to that in which the calibration was being made so that the play in the screw was entirely taken up on the return motion.

The average of the two groups of four sets of eight readings:

. = 789.15 divisions = 0.003 feet.
. . 1 division = 0.000003801 feet = 0.00004561 inches
and 200 divisions = 1 revolution of the micrometer.
.˙. 1 revolution = 0.000760 feet = 0.009122 inches.

Micrometer B.

The procedure of calibration for this micrometer was similar to the above except that there were three sets of eight readings in each direction over a distance of 0.005 feet.

The average of the two groups of three sets of eight readings:

= 13.101 revolutions of micrometer = 0.005 feet,
and 100 divisions = 1 revolution.
.˙. 1 division = 0.000003817 feet = 0.00004580 inches
1 revolution = 0.000382 feet = 0.004580 inches.

Micrometer C. (used on plate).

Same procedure as used on Micrometer B. over distance of 0.003 feet — 0.036 inches.

.˙. 7.8083 revolutions of micrometer = 0.036 inches.
100 divisions = 1 revolution.
.˙. 1 division = .00004610 inches.

Micrometer D. (used on bar).

Same procedure as used on Micrometer B.
over distance of 0.002^1 = 0.024 inches.

11.7333 revolution = 0.024 inches.
100 divisions = 1 revolution
1 division = .00002041 inches.

PLATE N. - Side A.

Corrections to 1.2" or 2.4"

Before Stress-Relief
After Stress-Relief
Recovery due to Stress-Relief.

	d - c	c - b	b - a	a - N	N - A	A - B	B - C	C - D
	-3226	-2823	-952	-2238	1843	-521	53	-1881
1	-2809	-2458	-332	-1650	2850	30	365	-1827
	417	365	620	588	1007	551	312	54
	-306	-3721	-1738	-880	1203	-821	-496	-2315
2	-428	-3761	-1870	-380	1159	-971	-675	-2051
	-122	- 40	- 132	500	- 44	-150	-179	264
	- 65	-3479	-2409	-598	1376	-1228	-181	-2545
3	-104	-3836	-2351	-324	1938	-1514	-311	-2771
	- 39	- 357	58	274	562	- 286	-130	- 226
	44	-3205	-3234	658	734	-1214	450	-3450
4	-367	-3400	-3557	1000	877	-1733	- 45	-3635
	-411	- 195	- 323	342	143	- 519	-495	- 185
	2067	-3436	-4530	2018	-492	- 471	95	-3803
5	1496	-3869	-5233	1965	-487	-1144	-403	-3896
	-571	- 433	- 703	- 53	5	- 673	-498	- 93
	4106	-4303	-4229	2160	-777	-1138	797	-3947
6	3704	-4641	-4883	1926	-645	-1388	50	-4517
	-402	- 338	- 654	-234	132	- 250	-747	- 570
	4209	-3899	-4260	1862	-982	- 104	810	-3810
7	3813	-4320	-4705	1951	-441	-1003	739	-3887
	-396	- 421	- 465	85	541	- 899	-71	- 77
	2440	-2911	-4807	-1282	3642	- 676	903	-3653
8	2397	-2979	-5411	-1717	3951	- 495	833	-3533
	- 43	- 68	- 604	- 435	309	181	- 70	120
	-24154	26540	-6577	-1662	3610	373	-345	-2793
9	-24073	27067	-5617	- 29	5425	1370	-529	-2548
	- 81	527	960	1633	1815	997	-184	245

Values are in millionths of inches, thus: - 0.003226.

PLATE N. - Side B.

Corrections to 1.2" or 2.4"

Before Stress-Relief
After Stress-Relief
Recovery due to Stress-Relief.

	d - c	c - b	b - a	a - N	N - A	A - B	B - C	C - D
	-7876	477	2209	-6910	996	-35	4853	2325
1	-7714	885	2528	-5735	2414	417	4955	2465
	162	408	319	1175	1418	452	102	140
	-6260	-148	2352	-5733	1615	-1508	4601	3222
2	-6105	74	2215	-5751	1331	-1432	4736	2892
	55	222	-137	- 18	-284	76	135	-330
	-4853	-1534	2693	-3964	1930	-3767	5193	3044
3	-5060	-1734	2322	-3864	1710	-4067	4980	2498
	- 207	- 200	-371	100	-220	-300	-213	-546
	4614	-1041	2109	-4196	3286	-3411	4339	2181
4	-5090	-1358	1871	-4085	3869	-3700	3840	1652
	- 476	- 317	-238	111	583	- 289	-499	-529
	-3550	-1243	1417	-2320	3541	446	- 1178	830
5	-4012	-1549	481	-2663	3042	442	- 1332	- 51
	- 472	- 306	-936	- 343	-499	- 4	- 154	-881
	-2624	-1323	381	- 9	3351	646	- 2067	673
6	-2990	-1903	-165	- 397	3323	54	- 2577	123
	- 365	- 580	-546	- 388	- 28	-592	- 510	-550
	-2374	-1987	652	- 367	3213	2115	-3035	-531
7	-2410	-2296	260	- 336	3415	1704	-3267	-1099
	- 36	- 309	-392	31	202	-411	- 232	- 568
	-2042	-2591	338	1522	3609	2150	-3279	- 436
8	-2322	-2673	-484	1074	3320	1982	-3615	- 935
	- 280	- 82	-822	- 448	-289	-168	- 336	- 499
	- 554	-3449	1083	2911	3339	1358	-3607	- 590
9	- 891	-2742	1436	3946	4215	1706	-3485	- 770
	- 337	707	353	1035	876	348	122	- 180

Values are in millionths of inches, thus - 0.007876.