FINAL REPORT

on

CAUSES OF CLEAVAGE FRACTURE IN SHIP PLATE
FLAT PLATE TESTS AND ADDITIONAL TESTS ON LARGE TUBES

by

HARMER E. DAVIS, G. E. TROXELL, EARL R. PARKER,
A. BOODBERG AND M. P. O'BRIEN
UNIVERSITY OF CALIFORNIA
Under Navy Contract NObs-31222

COMMITTEE ON SHIP CONSTRUCTION
DIVISION OF ENGINEERING & INDUSTRIAL RESEARCH
NATIONAL RESEARCH COUNCIL

Advisory to

BUREAU OF SHIPS, NAVY DEPARTMENT
Under Contract NObs-34231

Serial No. SSC-8

Copy No. 18

January 17, 1947

ADDRESS NAVY DEPARTMENT,
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1300 E Street, N. W.
Washington 25, D. C.

Dear Sir:

SUBJECT: Final Report on "Causes of Cleavage Fracture in Ship Plate: Flat Plate Tests and Additional Tests on Large Tubes", (SSC-8), Contract NObs-31222

There is enclosed for your information and file one copy of the subject report as follows:

Report Serial No.	Date	Copy No.
SSC-8	January 17, 1947	18

Sincerely yours

L. H. Travis

L. H. Travis
By direction of
Chief of Bureau

Encl: (H.W.)

NATIONAL RESEARCH COUNCIL
2101 Constitution Avenue
Washington, D. C.

January 17, 1947

Chief, Bureau of Ships
Navy Department
Washington 25, D. C.

Dear Sir:

Attached is Report Serial No. SSC-8, entitled "Causes of Cleavage Fracture in Ship Plate: Flat Plate Tests and Additional Tests on Large Tubes". This report has been submitted by the contractor as the final report on one phase of the work done on Research Project SR-92 under Contract NObs-31222 between the Bureau of Ships, Navy Department and the University of California.

The report has been reviewed and acceptance recommended by representatives of the Committee on Ship Construction, Division of Engineering and Industrial Research, NRC, in accordance with the terms of the contract between the Bureau of Ships, Navy Department and the National Academy of Sciences.

Very truly yours,

Frederick M Feiker

Frederick M. Feiker, Chairman
Division of Engineering and
Industrial Research

Enclosure

PREFACE

The Navy Department through the Bureau of Ships is distributing this report to those agencies and individuals that were actively associated with this research program. This report represents a part of the research work contracted for under the section of the Navy's directive "to investigate the design and construction of welded steel merchant vessels".

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Final Report

Navy BuShips Contract NObs-31222

Project SR-92

CAUSES OF CLEAVAGE FRACTURE IN SHIP PLATE
FLAT PLATE TESTS AND ADDITIONAL TESTS ON LARGE TUBES

August 1946

From: University of California, Berkeley, California
M. P. O'Brien, Technical Representative

Report prepared by:

Harmer E. Davis)
G. E. Troxell) Engineering Materials Laboratory
Earl R. Parker) University of California
A. Boodberg)

CONTENTS

ABSTRACT

This report summarizes the test results on wide flat plates to date of termination of U. S. Navy BuShips Contract NObs-31222, August 31, 1946.

The materials used in this investigation were three lots of semi-killed hull quality steels, one lot of nickel alloy, one lot of fully-killed, and one lot of fully-killed quenched and drawn steel.

The specimens used in the principal program were 3/4 inch thick plates containing a narrow transverse slot having a length equal to one fourth of the specimen width. These were tested in tension in widths ranging from 12 inches to 108 inches. Tests were made at each of a number of temperatures in order to determine the temperature at which the mode of failure changed from shear to cleavage type.

In the tests, observations were made of the following: the maximum load, load at development of cracks, fracture load, energy absorbed to maximum load, mode of fracture, strain distribution over the faces of plates and thickness reductions near the lines of fracture.

Results from tests of wide flat notched plates indicated that transition temperatures of semi-killed steels may vary from freezing to well above room temperature. Tests of two lots of steel of essentially the same chemical composition, except for nitrogen content, revealed that the steel with the higher nitrogen content had a considerably higher transition temperature. The microstructure of the steel with the higher transition temperature was also considerably coarser. No appreciable difference in transition temperatures was found when one lot of steel was tested in the "as-rolled" and in the normalized conditions.

Improved metallurgical structure of another lot of steel, accomplished by requenching and redrawing at a lower temperature, resulted in lowering of the transition temperature and an increase in the ability to absorb energy.

The $3\frac{1}{2}$ percent nickel steel was found to be far superior to the mild steel, having a much lower transition temperature and a higher energy absorption.

It was found that the Charpy keyhole-notch impact tests, tension tests of 3 inch wide edge-notched specimens and tension tests of centrally-notched 12-inch and 72-inch wide flat plates are all useful for rating the steels in order of their relative brittleness. However, the transition temperature for any particular steel, as determined by the various tests, differ considerably, with the larger test specimens giving higher and better defined transition temperatures.

The nominal strength of plates was found to decrease slightly as the width of the test specimen was increased, this tendency being more pronounced for specimens failing in shear.

Transition temperatures were found to decrease as the specimen thickness was decreased, an effect introduced by geometry and the additional rolling.

A number of supplemental studies were made to provide additional information on certain questions raised by the principal tests. Results of some of these studies were reported in previous reports,[1,2] while a study of geometrically similar specimens to check the validity of model laws, and results of tests of tension bars at low temperature are given in appendices of this report.

1,2 See Bibliography

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FINAL REPORT

Navy BuShips Contract NObs-31222

Project SR-92

CLEAVAGE FRACTURE OF SHIP PLATE AS INFLUENCED BY DESIGN AND METALLURGICAL FACTORS

Flat Plate and Tube Tests

August, 1946

From: University of California, Berkeley, California
M. P. O'Brien, Technical Representative

Report Prepared by:

Harmer E. Davis)
G. E. Troxell) Engineering Materials Laboratory
Earl R. Parker) University of California
Alexander Boodberg)

INTRODUCTION

The work covered by this report is part of the research program originated by the Office of Scientific Research and Development, to determine the causes of cleavage type failure of ship plate. The work conducted by the University of California was divided into two parts: Part 1 consisted of tests conducted principally on centrally notched large flat plates, and in Part 2 tests were conducted on built up sections simulating a hatch corner structure. This report is concerned primarily with the work on notched flat plates to August 31, 1946, the date of the termination of the contract. Also reported herein are the results of tests on two large tubular specimens fabricated from ship plate, which tests were made to supplement the information obtained in a previous investigation, NRC-75.

The work on Project NRC-92 started in November, 1944, and was conducted under the auspices of the Office of Scientific Research and

Development until August 31, 1945, and was supervised by the War Metallurgy Committee. After that date the program was continued under United States Navy Contract NObs-31222. The chief phase of the investigation was the determination of the temperature at which occurred the transition from ductile, shear type failures to brittle, cleavage type failures for several types of steel and for various widths of plates. The work was confined primarily to 3/4-inch thick plates that had transverse notches at the mid-sections. Six different lots of steel were investigated in this manner, the specimen widths ranging from 3 inches to 108 inches. A program of supplementary tests was also undertaken that included the following: standard tension tests, tension tests on full thickness coupons, Charpy impact tests, hardness tests, chemical analyses, metallographic examinations, and hardness surveys of the fractured plates.

Two previous reports[1,2] covered the progress of the investigation in detail to April 30, 1946. The continuation of the work to August, 1946, and the final results are described in this report.

Test results and the work done in connection with two large tubes are given in Appendix B. These tests complete the work started on NDRC Project NRC-75[3].

Appendix A of this and the previous report[1] contain drawings showing the percent elongations and paths of fracture for all the plates tested. Appendix C gives the results of standard tension tests that were conducted at low temperatures, and Appendix D gives the results of studies on geometrically similar specimens.

[1,2,3] See Bibliography

EXPERIMENTAL WORK

Test Program

The principal phase of the program involved tension tests of wide, 3/4-inch thick flat plate specimens of the various steels, at several temperatures in order to determine the temperature range at which the mode of failure changed from shear to cleavage type. The plates were notched at the mid-section with a transverse slot having a length equal to one quarter of the width of the plate. For most of the steels, plates 12-, 24-, 48-, and 72-inches in width were tested. Two 108-inch wide specimens were also tested, one made of steel B in the as-rolled condition and one made of steel C. The maximum load, the load at development of cracks, the load at failure, the mode of fracture, the amount of energy absorbed to the maximum load, the reduction in thickness near the break, and the strain distribution on the face of the plate were determined for each of the specimens tested.

As an auxiliary program, tension tests under controlled conditions were conducted on 3-inch wide specimens to determine the transition ranges for the various steels. Three 3-inch specimens were easily and cheaply prepared; the four types used in the investigation are shown in Fig. 23.

The description of the steels used and the program of tests are given in Table 1. The summary of physical properties and chemical analyses of the steels are given in Table 2.

Test Procedure

A detailed description of the testing and gaging methods is given in the previous report.[1] Fig. 1 shows a test set-up in the 3-million pound testing machine for a 108-inch wide specimen; the plywood box served as a temperature control chamber. Numerous SR-4 electric strain gages and resistance-wire extensometers were used on the faces of each specimen

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[1] See Bibliography

to measure the elastic and plastic strains. Residual strains were measured by means of a special mechanical gage used on a system of grids that were marked on one face of each specimen tested. The results of these grid measurements are given in Appendix A.

All specimens were loaded until fracture occurred and readings were taken on strain gages at intervals so that a total of at least 10 strain readings were obtained up to a maximum load. From the readings of all resistance-wire extensometers having a length equal to three-fourths of the specimen width, an average elongation for the specimen was computed and plotted, and by integration of the resulting load-strain data the energy absorbed up to a maximum load was determined.

Specimens were maintained at the desired temperature throughout the test by circulating heated or cooled air through a plywood box that enclosed the specimen. A window was provided in this box in order that the formation of cracks and the propagation of the fracture could be observed.

Since the earlier results of wide plate tests indicated that there was a tendency for the nominal strength of the plate to decrease as the width of the plate increased, it was decided to test a few 108-inch wide plates to verify this. As no 108-inch wide plates were immediately available, two 72 by 120-inch plates were welded together along the long edge and then trimmed to the 108-inch width so that the welded joint was along the longitudinal axis of the specimen. In order to make sure that the seam had no effect on the strain distribution, several tests were conducted on 23-, 48-, and 72-inch wide plates that were made up of two narrower plates with a longitudinal unionmelt seam. These were equipped with numerous strain gages to check the strain distribution. No appreciable difference was found between the strain distribution in specimens made of whole plate and those made up with a center seam.

Test Results

The results of chemical analyses of samples from individual plates of the various steels are given in Table 3, and the results of the standard tension and hardness tests are tabulated in Table 4.

Table 5 gives the summary of results for the notched wide-plate tests, and Table 6 summarizes the thickness reductions along fracture lines for the same plates. The complete results of the 3-inch wide plate tests are summarized in Table 7. Residual strains are given in the Appendix A of this and the previous report.[1]

Results of the Charpy keyhole-notch impact tests for the various steels are given in Figs. 2 to 7 inclusive. Notches were machined perpendicular to the plane of the plate for all Charpy specimens.

Table 8 gives a comparison of the transition temperatures for the various types of specimens tested.

Table 9 summarizes the reductions in thickness of plate obtained from samples of fractured plates of ships that failed in service.

Data on the nominal stress in the large flat specimens at which crack started are given in Table 10.

Transition temperatures as defined by the energy absorbed to maximum load are represented in Figs. 8, 9, and 10 for the 72- and 12-inch wide specimens of the various steels.

Figs. 11, 12 and 13 present the transition ranges, as defined by the percent of fracture in the shear mode, for 72-, 12-, and 3-inch wide specimens for the steels used in the investigation.

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[1] See Bibliography

Figs. 14, 15, 16 and 17 show temperature transition ranges for the various types of 3-inch wide specimens.

Figs. 18 and 19 show the variation of nominal stress of a specimen with width, while Fig. 20 shows the variation of the nominal stress with temperature for the 12- and 72-inch wide specimens.

Figs. 21 and 22 show the influence of specimen width on ductility at maximum load and at failure.

Fig. 23 shows the four types of 3-inch wide specimens used in the investigation.

Figs. 27 to 29 inclusive show typical photomocrographs for the various steels.

Discussion of Results

The flat plate tests proved conclusively that it was possible to produce in the laboratory, brittle cleavage fractures identical with those found on sections of fractured steel ships. The thickness reductions for the flat plates are listed in Table 6; these may be compared with similar measurements listed in Table 9 which were made on portions of fractured plates cut from ships. Two types of fractures occurred in the laboratory tests, (1) the normal ductile shear-type fracture and (2) the cleavage-type fracture, which may occur without appreciable ductility but which may also be preceded by a great deal of plastic flow. At high temperatures, shear fractures invariably occurred and at sufficiently low temperatures the steels failed by cleavage. At an intermediate temperature, which is called the transition temperature, the fracture occurred either by shear or cleavage or by a mixture of both. Steels may be rated in a relative order of brittleness by comparing the transition temperatures of the materials and by comparing the energies absorbed by the materials at both high and low temperatures. In the flat plate investigation, transition temperatures were determined by means of Charpy keyhole-notch impact tests and by tension tests on 3-, 12-, 24-, 48-, and 72-inch wide centrally-notched specimens.

One of the most significant results of the investigation is that all of the tests used for determining the relative brittleness of steels rate the steels in approximately the same order. For most steels, the large specimens gave definite transition temperatures. This, however, was not found to be true for the Charpy specimens, which in many cases showed a wide range of temperature over which the transition from shear to cleavage occurred. Figs. 2 to 7 clearly illustrate this effect. The transition temperatures for the Charpy tests, listed in Table 8 are consequently not definitely defined and it is necessary to consider the energy absorptions for the various steels in order to have a clear picture of the merits of the Charpy test in determining the relative brittleness of steels. The Charpy test results reported herein were included primarily to show the variation which can be expected from plate to plate in a single steel. A more complete investigation of the steels by use of the Charpy test has been included in the program of work of Project NObs-31217 conducted at Pennsylvania State College.

The wider specimens usually showed higher transition temperatures. The differences between the transition temperatures of the 12- and the 72-inch wide plates for a particular steel range from 4 to 40°F. The transition temperature of steel C was the highest of all the steels tested and was essentially the same for all plate widths. However, the transition temperatures of the steels with lower transition ranges were invariably lower for the 12-inch specimens than for the 72-inch specimens. Because of the greater spread between transition temperatures of the different steels, the 12-inch wide specimen seems to be more suitable than the wider specimens for rating the steel in order of their relative brittleness.

From theoretical considerations, it is reasonable to expect that the wider notched plates would have higher transition temperatures than the narrower ones. It is somewhat surprising, however, that in several cases there was little effect of plate width on the transition temperature while with other steels large differences in transition temperature were found. There seems to be no simple explanation for these results. The transition temperature very likely is a function of the amount of plastic flow which has occurred prior to the onset of fracture. It is possible that a more detailed study of the conditions of local plastic flow around the notches of the individual plates would disclose the reasons for the differences in behavior of the various steels.

From the theoretical considerations developed in the section "Studies of Formation and Growth of Cracks in Notched Plates" of NDRC Report, OSRD 6452,[2] it follows, that for a notch of a given sharpness, the transition temperature should increase with increasing plate thickness up to a certain thickness after which increasing the plate thickness still further should cause no change in transition temperature. Apparently this is true because the transverse stress developed by restraint is small in thin plates but, with increasing thickness, it gradually increases to a maximum value which would probably remain constant with further increase in plate thickness. To obtain an estimate of the effect of plate thickness, some special tests were conducted. The results of these tests are shown in Figs. 14 and 15. Plate thicknesses ranging from ½- to 1 1/8-inch were tested in the form of 3-inch wide edge-notched bars to determine the transition temperatures

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[2] See Bibliography

of each thickness of plate. Two series were tested: (1) plates from the same heat rolled to each of the various thicknesses and (2) plates from the thickest rolled plate machined to each of the various thicknesses. The first series (results shown in Fig. 14) involved differences in metallurgical structure brought about by the differences in rolling procedures as well as differences in specimen thickness. The second series (results shown in Fig. 15) involved only differences in specimen thickness because all specimens were machined from the same plate. The effect of plate thickness upon the transition temperature is very evident in Fig. 14. The results indicate that when the plate thickness exceeds one inch, the transition temperature is apparently independent of plate thickness. This conclusion is not definite, however, and additional tests on thicker plates and on other steels should be made. It is possible that the thickness effect differs for various steels.

The effect of additional rolling, as shown by comparing Fig. 15 and 14, is to raise the transition temperature of the steel. This effect is in agreement with the known effects of rolling upon the other mechanical properties of steel.

Comparison of Fig. 14 and 16 indicate that the width and depth of notch and minor variations in width of the specimen have little effect on the transition temperature ranges of edge notched narrow specimens.

From examination of results for steel C in Fig. 17, which gives a comparison of the transition ranges for various types of 3-inch wide specimens, it appears that sheared edges of the plates as received from the mill had undergone strain aging and contained small cracks which acted as more severe stress raisers than notches made with hacksaws either at the edges or in the center of the specimen.

The test results for the 3-inch wide plates indicates that the steels can be arranged in approximately the same order by means of these tests as by tension test of wide notched plates, although the actual transition temperatures may differ for the two types of tests.

Tests of 108-inch wide specimens failed to indicate that there is a definite drop in nominal strength as the test specimen width is increased beyond 72 inches. Examination of Figs. 18 and 19 show that there is a considerable drop in nominal strength of notched test specimens, as the width is increased to 24 inches. Further increases in specimen width have little effect on the strength.

The reduction in nominal strength is somewhat more pronounced for specimens failing in shear than for those that break by cleavage.

Variation of nominal stress with temperature is not very evident for "special" steels used in this investigation as can be seen from examination of Fig. 20. The strength of steels N, Q, and QS is not affected by temperature, while that of the semi-killed steel group (steels A, B, and C) tends to be lower at temperatures below the transition temperature for the particular steel. The fully-killed steel H does not exhibit any appreciable decrease in strength with lower temperatures for the 12-inch specimens, but behaves in the same manner as the semi-killed steel group in tests of 72-inch specimens.

Comparisons of the elongation at maximum load and at fracture of plates that behaved in a ductile and a relatively brittle manner are given in Figs. 21 and 22. The elongations are shown in percent, and to compare plates of different sizes, the locations of the gage points on which the measurements were taken are plotted as fractions of the specimen width. A marked difference can be noted between specimens that failed in shear and those that failed by cleavage. For specimens failing by shear, narrower plates exhibited much greater ductility; this, however, was not true for specimens that failed by cleavage.

During the course of the tests, certain specimens exhibited anomalous behaviors. In particular, specimens H8, H10, and H82X which were cut from the same large plate and tested at the same temperature behaved entirely differently. Specimen H10 absorbed more than twice the amount of energy than was absorbed by its supposed duplicate, specimen H82X; specimen H8 absorbed more than three times as much energy as specimen H82X. These specimens were studied in detail to determine the cause for the discrepancy. A study of the surface of the fracture near the base of the notch revealed that the specimens which had absorbed the abnormally high amount of energy had many openings in the metal running perpendicular to the surface of the fracture and perpendicular to the apex of the notch. This effect is shown in Fig. 25a which shows the surface of the fracture adjacent to the base of the notch. Fig. 24 shows the location in the plate specimen of the portion of the fracture shown in Fig. 25. Similar photographs of the portion of the fracture near the base of the notch for specimen H10 and H82X are shown in Figs. 25b and 25c respectively. The openings in the metal perpendicular to the fracture surface were progressively fewer in number and smaller in size for the specimens which fractured with low energy. This superficial examination indicated that the metal was opening along seams of nonmetallic inclusions. The cause for the opening was the Poisson's ratio contraction in the thickness direction brought about by the longitudinal extension of the metal by the load. Sections were then taken through the thickness and perpendicular to the fracture surface for microscopic examination. The results are shown in Figs. 25d, 25e, and 25f. These photomicrographs show the small transverse fractures progressing along lines of nonmetallic inclusions. Specimen H10 had many more lines of nonmetallic inclusions, along which the transverse fractures could occur easily, than did specimen H82X. Specimen H8 had still more lines of nonmetallics than did specimen H10. The extensive separation of the metal in specimen H8 along lines of inclusions prevented the transverse stress from building up to its normal (probably high) value, and thus effectively increased the shear stress and promoted plastic flow; thus a large amount of energy was absorbed although the specimen eventually failed by cleavage. The specimen acted essentially as though it were composed of a number of thinner plates placed face to face to form a composite thick plate. Specimen H82X was cut from a different part of the original large plate which happened to contain fewer nonmetallics and consequently behaved in a more normal manner than did specimens H8 and H10 (see Fig. 10 which gives the energy vs. temperature curve for this steel). The conclusion reached as a result of this study is rather unusual. Nonmetallic inclusions, ordinarily considered undesirable, acted in this case to make the steel less notch-sensitive, and hence improved its performance.

Another unusual result was obtained with the Q steel which had been quenched and drawn. In the original heat treated condition, this steel was not particularly outstanding. However, when requenched from 1600°F and redrawn at 1245°F for 2 hours, its performance was markedly improved. Its transition temperature was lowered slightly, but more important was the improvement obtained in the amount of energy required to rupture the material. The microstructures of this steel are shown in Fig. 26. The microstructure of the QS steel was very much like that of steel Q, but in some of the specimens of steel Q there appeared to be some free ferrite. The worst example of this was found in specimen Q-1 which fractured with low energy at a temperature considerably above the normal transition temperature for this steel. When this specimen was examined microscopically, it was found to have an unusual microstructure. (See Fig. 26c) Much more free ferrite was present in this specimen than in the others of the Q series. The presence of free ferrite in quenched and drawn steels of this type has also been found in other tests to be associated with abnormal brittleness. The brittle behavior of specimen Q-1 thus seems to be in line with the known behaviors of the steels having similar microstructures. The free ferrite could be the result of (1) inadequate quench or (2) reheating slightly above the lower transformation during the tempering treatment.

There is still a deplorable lack of fundamental information about the behavior of steel in the vicinity of a notch. The wide flat plate tests have clearly demonstrated that each steel behaves differently and that even the relative behaviors are different for different plate sizes The need for a fundamental study of the behavior of steels in the notched condition is clearly indicated by the results of the tests performed on wide flat notched plates.

Conclusions

The following conclusions seem justified on the basis of the results of the entire investigation including the work done under References 1 and 2 (see Bibliography) as well as the new work presented for the first time in this report.

1. Fractures were obtained in the laboratory which were identical in appearance and reduction in thickness with those found in sections of fractured ships.

2. All steels tested were arranged approximately in the same order of relative brittleness by Charpy keyhole-notch tests and by tests of notched plates of different widths. Transition temperatures determined by Charpy tests are lower than those determined by notched flat plate tests.

3. Plates failing by cleavage fail with slightly lower nominal stress values than do similar plates which fail entirely by shear.

4. The chemical composition has a marked influence upon the transition temperature of steel. This is well demonstrated by the results of tests on the 3½ percent nickel steel which was far superior to the mild steels both in transition temperature and in energy absorption. The effect of chemical composition was further demonstrated by the results of tests on steels A and C. These steels had essentially the same chemical composition with the exception of the nitrogen content. Steel A contained 0.004 percent nitrogen while steel C contained 0.009 percent. The difference in the behaviors of these two steels may be mainly due to the difference in the nitrogen content. However, the microstructures of these steels also differed slightly and part of the difference in properties was probably due to the difference in metallurgical structure. Apparently a higher rolling temperature had been used for steel C than for steel A. The

transition temperature and energy absorption are apparently affected as much by the metallurgical structure of the steel as they are by the chemical composition. Steel Q, which was quenched and drawn originally, was greatly improved by heat-treating. This treatment eliminated free ferrite from the microstructure.

5. For hull-quality steels of the semi-killed type, produced under ordinary conditions of present commercial practice, the temperatures at which the mode of failure of sharply notched plates changes from a ductile shear to a brittle cleavage type may vary from below freezing to well above room temperature.

6. In these tests it was found that on the basis of the transition temperatures, the steels could be more definitely rated by tests of 12-inch specimens than by tests of wider specimens.

7. With the same sharpness of notch and a fixed ratio of length of notch to width of plate, the nominal strength of plates of the same thickness decreased with increasing width. The decrease in strength is considerable as the plate width is increased from a few inches to one or two feet, but the decrease in strength is relatively small as the plate widths are increased beyond two feet. The nominal strength of steel B is only about 1000 psi less in 108-inch wide plates than it is in 72-inch wide plates.

8. With a given notch geometry and a fixed plate width, the transition temperature was found to increase as the specimen thickness was increased. In specimens cut from plates rolled to different thicknesses from the same heat of steel, two factors influenced the transition temperatures; these were (1) specimen thickness, and (2) metallurgical conditions introduced by the additional rolling given to the thinner plates. Thin

specimens machined from thicker plates had higher transition temperatures than did specimens of the same thickness made from as-rolled plates.

9. Steels can be arranged in the same order of notch sensitivity by tests of edge-notched 3-inch wide specimens as by tests of centrally-notched wider plates, although the actual transition temperature may differ for the two types of tests.

10. For a series of tests conducted on geometrically similar centrally-notched specimens 3, 6, and 12-inches wide it was demonstrated that the model laws apparently do not hold for fracture.

11. For tension tests made on cylindrical un-notched specimens at various temperatures down to liquid-air temperature, both yield and fracture strength were found to increase as the temperature was lowered. As the temperature approached liquid-air temperature, the mode of fracture changed from the shear to the cleavage type, and the fracture stress and ductility decreased. The cleavage strength at low temperatures was found to depend upon the strain history of the material. Bars strained at room temperature were found to have higher cleavage strength when subsequently broken at liquid-air temperature.

12. Tests of two additional tubular specimens, made to complete the research program originated as NDRC Project NRC-75, showed that welding with low hydrogen content electrodes apparently does not improve the ductility and that post heating to 1100°F after welding improves the ductility of the weld.

Organization

The investigations were conducted by the University of California in the Engineering Materials Laboratory. M. P. O'Brien, Dean of the College of Engineering, was the Technical Representative for the Project. The work was under the general direction of Raymond E. Davis, Director of the Engineering Materials Laboratory. G. E. Troxell, Professor of Civil Engineering, Harmer E. Davis, Associate Professor of Civil Engineering, Earl R. Parker, Associate Professor of Physical Metallurgy, and A. Boodberg, Research Engineer, were in charge of the technical phases of the investigation. Special studies were conducted by Charles H. Avery, Joseph D. DeVito, R. Payne, and T. Robinson. The shop work, welding and rigging was under the supervision of Elvin L. Whittier. Other members of the project staff who have served either full or part-time included: P. R. Angell, G. Barringer, D. Behm, Mary E. Bennett, E. Berliner, D. Berner, E. Betts, R. Bousquet, F. Brezee, E. M. Cleave, Winifred Dunlop, C. Glassgow, David E. Gibbs, J. Hancock, Eloise Hornstein, R. Johnsen, Inez Keklak, Ruth Kimball, R. LaForge, S. Lever, J. Logan, E. McLaughlin, J. Mednick, W. Mullins, Jean Neilson, F. Ormsby, D. Peterson, K. T. Rains, Vera Rideout, A. D. Ring, R. F. Schord, Le. Seaborn, D. Unger, T. Yamamoto, and Phebe Zimmerman. Harry E. Kennedy, Research Associate in the College of Engineering, served as consultant on special problems.

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5. Advisory Report, OSRD No. 4060, Serial No. M-345, August 1944, "Suggested Specification for Ferritic Armor-Welding Electrode Type NRC-2A."

6. Office of Production Research and Development, War Production Board, Report No. W-200 - "Study of the Forming Properties of Aluminum Alloy Sheet - Plastic Flow in Metals," May 1945.

7. Progress Report on "Behavior of Steel under Conditions of Multiaxial Stresses - Pilot Tests of Small Tubular Specimens," OSRD Report 4553, Serial No. M-405, January 1945.

APPENDIX A

Residual Strain Distribution in Notched Flat Plate After Fracture

A system of rectangular grids described in a previous report[1] was applied to one face of all the wide notched flat plates that were tested. Readings reproducible to ± 0.002 were taken by means of a special mechanical strain gage prior to the test and after fracture. Percent elongations were calculated for the different gage lengths and the results are presented in Figs. A-68 to A-153 of this report. Residual strain distributions for plates broken in the earlier part of the program were presented in Figs. A-1 to A-67 inclusive of the earlier report.[1] It is to be noted that the values given in the figures do not include elastic elongations nor the amount of separation of the parts of the plate along the fracture line. Also, since the residual elongations were measured only on one face of the plate, the effect of permanent bending of a plate during fracture may be included in the values shown in the figures. In most cases, however, very little bending and distortion occurred during fracture.

Lines of fracture are shown on the drawings for which the overall grid system is plotted. The temperature of test, the nominal stress and the mode of failure are indicated on the figures.

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[1] See Bibliography

APPENDIX B

Additional Tests of Large Tubular Specimens of Mild Steel

To supply additional information, as a result of questions raised by a study of the data obtained from the tests on large tubular specimens included in the program of work of NDRC Project NRC-75,[3] tests were made on two additional tubular specimens at -40°F with a stress ratio of 1:1.

The specimens were hollow cylinders 20-inches in outside diameter, 18½-inches in inside diameter and 10-feet long. The tubes were made by forming two 3/4-inch thick plates into half cylinders and welding them together along two longitudinal seams 180° apart. The same steel was used as for the tubes previously tested (steel A). The plates used in both specimens "L" and "O" were heat treated at 1100°F for about 8 hours after forming operations were completed. For detailed description of the apparatus used and the test procedure reference is made to the original report.[3] Specimen "O" was welded with NRC-2A electrodes[5] and was not stress relieved after welding. Insofar as the fabrication procedure was concerned, specimen "L" was a duplicate of specimen "I" and was welded with E-6020 electrodes and was given a so-called stress-relief heat treatment at 1100°F for 6 hours after the completion of the welding.

Figs. B-1 and B-2 show the nature of the fractures in the two tubes. Figs. B-3 and B-4 show the strain distribution in the fractured tubes as determined from grid measurements. Figs. B-5 and B-6 show the effective-stress: effective-strain[6] curves plotted for all of the tubular specimens

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[3,5] See Bibliography

[6] See Bibliography. Effective-strain and effective-stress are defined as follows:

Effective-strain $= \bar{\epsilon} = \frac{2}{3}\sqrt{\frac{(\epsilon_1-\epsilon_2)^2+(\epsilon_2-\epsilon_3)^2+(\epsilon_3-\epsilon_1)^2}{2}}$

where $\epsilon_1 = \log_e(1+e_1)$; $\epsilon_2 = \log_e(1+e_2)$; $\epsilon_3 = -(\epsilon_1+\epsilon_2)$

(cont'd page 21)

for which load-strain readings were available. Figs. B-7 and B-8 show plots of the strain distributions in the tubes for various stress levels. Some of the results obtained on small tubes of the same steel, tested at Illinois Institute of Technology on NDRC Project NRC-77,[4] are plotted in Fig. B-9 for comparison with Figs. B-5 and B-6. Curves for results obtained from standard .505-inch diameter tension specimens cut from the weld and the plate material near the ends of the large tube and tested at the University of California are shown in Fig. B-10.

Specimen "O", welded with NRC-2A electrodes, did not show any appreciable improvement over tube "F", welded with E-6020 electrodes; both tubes were tested under similar conditions. The two tubes were also similar in method of fabrication with the exception of the electrodes that were used in welding. The same heat treatment prior to welding was used on each tube-plates being first formed, then stress relieved. Neither of the cylinders was preheated prior to welding and neither was stress relieved after welding. The welding of cylinder "O" was done with 1/4-inch diameter NRC-2A type electrodes preheated to 600°F prior to use and used while they were still hot. The longitudinal weld required quite a number of repairs near one of

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[4] See Bibliography

[6] Cont'd

e_1 = measured axial strain and
e_2 = measured circumferential strain

Effective-stress $= \bar{\sigma} = \sqrt{\dfrac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}}$

where σ_1 = average axial true stress, psi
σ_2 = average circumferential true stress, psi
σ_3 = average radial true stress, psi

In these tests, effective-strains were computed from the average strain readings of the 2-in. clip gages located near the mid-section of the specimen away from the welds.

which the fracture originated. No preheat was used in rewelding the areas that were repaired. X-ray pictures of the weld taken after the repairs were made showed no indication of any defect near the origin of the break. Cleavage fracture originated at the longitudinal weld of specimen "O" about 22-inches below mid-section and proceeded in both directions parallel to the weld along the heat affected zone for about 12-inches and then propagated around the specimen in several directions.

Specimen "L" failed to show as good results from post heating to 1100°F as did its counterpart specimen "I". It was more ductile than specimen "F", which was not stress relieved after welding, but did not exhibit as much of a reduction in thickness, as great an elongation, or as large a true stress at fracture as did specimen "I".

The fracture in specimen "L" originated in the plate material well away from the weld, near the upper end of the tube. The fracture apparently started near a defect in the plate shown in Fig. B-11. If it were not for this defect it is possible that somewhat higher strength may have been attained as well as greater elongation and reduction in thickness and thus the results from tube "L" would compare more favorably with those from tube "I". Examination of Fig. B-5 shows that the stress-strain curves for both tubes "L" and "I" do not differ greatly up to an effective-strain of 0.09 at which point tube "L" fractured. The fracture occurred on the section perpendicular to the axis at a true stress of 62,000 psi, which is below the true stress at fracture in a simple tension test.

It may be noted in passing that in the effective-stress:effective-strain curves there are discrepancies large enough to indicate that existing theories of plastic flow are either incomplete or inexact.

Conclusions

The following conclusions may be drawn from the results of large tubular specimen tests described in the final report of NDRC Project NRC-75[3] and the results obtained from the tests of the two additional specimens described in this report. Some of the conclusions are based on results from tests of pilot series on small tubular specimens.[7]

1. Welded 20-inch diameter tubes of hull-quality steel tested under various combinations of internal pressure and axial load exhibited strengths and ductilities considerably less than the tensile strengths and ductilities of standard coupons made of the plate material. This tendency was also exhibited in a number of the smaller, more homogeneous, tubes of the pilot series of tests.

2. The strengths of the tubes as calculated on the "conventional" basis did not vary as widely with different testing conditions as the so-called "true" stresses at failure. Also, for the purposes of interpretation of the phenomena observed in these tests, the true stresses at failure appear to be a more significant index of strength, even though they are computed as average stresses across an entire section rather than stresses at a point.

3. Under certain combinations of temperature, ratio of applied stresses, and conditions of tube as regards heat-treatment, it was possible to attain failures with very low ductilities, approaching those observed in fractured ships, even though there was no mechanical notch in the tubular specimens. The strengths attained under such conditions were correspondingly low as compared with the strengths of the most ductile specimens.

[3,7] See Bibliography

4. All the tubes tested at 70°F, with the exception of those in which the fracture occurred near the ends due to complex stress conditions caused by end restraint and consequent excessive bending, exhibited appreciable ductility prior to fracture.

5. All the tubes tested at -40°F, with the exception of one of the two which were heat-treated after welding, were relatively brittle, i.e., exhibited relatively low plastic strains prior to rupture.

6. Two types of fracture were observed to take place, depending upon the conditions leading up to failure: (a) shear fractures occurring approximately on planes of maximum shear stress, and (b) cleavage fractures occurring normal to the direction of the critical tensile stress.

7. In welded tubes, while the ratio of the principal stresses in a tube wall may have played some part in determining the overall strength and ductility, the orientation of the critical tensile stress with respect to the direction of the welded seam appeared to be a governing factor as regards initiation of failure. It is noteworthy that in the tests at room temperature, in those cases where the circumferential stresses were critical, failure occurred in the plate away from the weld, while in those cases where the longitudinal stresses became critical, the failures occurred in the weld or weld zone.

8. It is believed that the gross residual stresses due to welding contributed relatively little toward causing failure, at least within the range of temperatures at which these tests were conducted, because all tubes in which fracture initiated in the longitudinal weld stretched sufficiently (1.6 percent or more) prior to failure to minimize, if not to eliminate, the influence of residual stress.

9. In tubes in which fracture initiated in the region of a weld, a crack appeared to have started in the weld or weld zone, and then fracture propagated into the plate.

10. Small discontinuities, such as defects, gouges or nicks may be crack-starters, particularly at low temperatures (Tube G and Tube L).

11. In all the tests made in this investigation, wherever fracture started in the weld zone, failure occurred by cleavage and the specimen was brittle.

12. The beneficial results of heat-treatment of tubes after welding is attributed primarily to alteration of the metallurgical structure of the weld zone rather than to relief of residual stress. (See especially Tube I). The so-called "stress relieving" heat-treatment markedly improved the strength and ductility at low temperatures. This heat-treatment reduces the residual stresses and it alters the metallurgical structure of the weld zone, making the material in this region more ductile. The residual stress is also reduced by causing a small amount of plastic flow to occur parallel to the weld. This effect occurs at atmospheric temperatures; consequently, the metallurgical structure remains the same. The plastic flow is sufficient in all of the tubes tested in the "as-welded" condition to produce stress-relief by stretching. The tube "stress-relieved" by heat-treatment had much greater ductility than any of the as-welded tubes. Since stress-relief occurred in all tubes, either by heat-treatment or by stretching, it appears that the main benefit derived from the heat-treatment is the beneficial alteration of the metallurgical structure. It is indicated that appropriate heat-treatments or pertinent changes in

welding technique are means of reducing or eliminating tendencies toward premature brittle cleavage fractures.

13. Bending stresses (such as those which can occur at the end of a closed tube due to radial restraint of the heads) or abrupt changes in wall thickness are likely causes of premature failure at both room and low temperatures. It was found necessary to take special care to provide a very gradual transition at the ends of the tubes in order to obtain failures near the mid-section.

14. A specimen welded with low hydrogen content, NRC-2A electrodes, was apparently no more ductile than similar specimens welded with E-6020 electrodes.

APPENDIX C

Results of Tests on Simple Tension Specimens Tested at Various Temperatures

Tension tests were made on unnotched cylindrical specimens of steels A, B_n, and C at various temperatures ranging from 450°F to liquid-air temperature. Yield strength, fracture stress and reduction of area were determined at each temperature. In addition, the effect of pre-straining at various temperatures on the cleavage fracture stress at liquid-air temperature was determined for steel A. These tests were conducted with the object of obtaining basic data on yield strength and fracture strength, and to determine the temperature of transition from shear to cleavage fracture for the case of simple tension loading.

The results of the tests have been plotted in Figs. C-1, C-2 and C-3. The yield strength increases rapidly as the testing temperature is lowered until it is essentially equal to the fracture stress at liquid-air temperature. The fracture stress (breaking load divided by final area) rises more slowly but continues to increase as the testing temperature is lowered until the cleavage-type fracture begins to occur. At this temperature, the transition temperature in simple tension, the fracture stress reaches a maximum and at lower temperatures drops to considerably lower values. The transition temperatures were found to be about -250°F for all three steels. Thus it was indicated that the simple tension test apparently is not as suitable for rating steels in their relative order of brittleness as are notched-bar tests.

There are several results worthy of further discussion. Steels B_n and C tested at -300°F fractured at stresses lower than the yield stress. When the specimens yielded, the load dropped off as it normally does at room temperature for mild steel, and fracture occurred before the load increased again. This unusual effect was checked by tests on a number of additional specimens.

A series of specimens machined from steel A were strained to a 10, 20, 30, 40, 50 and 60 percent reduction of area at 212, 70, and -105°F, and then the temperature was lowered immediately to -300°F and the specimens broken with no additional plastic flow occurring. The cleavage fracture stress at -300°F was found to increase as the amount of prior strain was increased. These results, shown in Fig. C-4, indicate for these steels how the fracture stress at a low temperature depends upon the strain history of the material. The temperature at which the prestraining was done, however, seems to have little influence upon the fracture stress.

APPENDIX D

Results of Tests on Geometrically Similar Centrally Notched Flat Plate Specimens

Tests were made at several temperatures on a series of geometrically similar specimens. The type of the specimen and the dimensions of the three sizes of specimens are given in Fig. D-1. Table D-1 gives the principal data for each test, and Figs. D-3 and D-4 show the variation of longitudinal strain with distance from the notch of a 3-inch wide size-effect specimen.

Fig. D-2 gives nominal stress-strain curves for longitudinal elements at the base of the notch obtained on gage lengths of 0.01, 0.02, and 0.04 inches for the three sizes of specimens. The specimens do not behave similarly up to strains at which the first crack forms in the root of the notch. Consequently, it is questionable as to the extent to which model laws are valid in the plastic range. After cracks form, similarity in behavior no longer occurs because the specimens are thereafter no longer geometrically similar. The results of these tests contradict a previously reported[2] conclusion that similarly notched samples seem to undergo similar strains within the plastic range.

The fact that the model laws do not hold within the plastic range is surprising, because theoretical considerations lead one to expect similarity in behavior. A possible contribution to the observed differences in behavior is the surface condition of the specimens. After annealing, all specimens were first carefully machined in a shaper, with the final cuts being very light. All specimens were finished in a surface grinder, with the final cuts again being light. Even with light cuts the surface layers of the specimens are cold worked and are consequently stronger than the base plate. The percentage of the total cross-section taken up by the cold-worked surface layers is larger for the smaller specimens and consequently

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[2] See Bibliography

might conceivably explain the results. A rough estimate of the amount of strengthening which could result from such surface hardening indicates that the differences cannot be explained by this factor alone. Additional tests should be made on specimens from which the cold-worked surface layers have been removed completely.

TABLE 1. -- DESCRIPTION OF STEELS USED IN FLAT PLATE TESTS

All steels were tested at temperatures selected so as to define the temperature transition range within reasonable limits.
Steels used in tests of 12-in. specimens (or wider) were furnished in plates 3/4 by 72 by 120 in.

Code Letter for Steel and Manufacturer	Approximate Chemical Analysis		Type of Steel and Condition	Use in Test Program
	% C	% M		
A Carnegie-Illinois	0.25	0.47	Semi-killed as rolled	Large cylinders; 72,48,24,12 and 3-in. notched plates; Charpy impact tests; low temperature tensile bars
B_{ar} Bethlehem	0.18	0.72	Semi-killed as rolled	72,48,24,12 and 3-in. notched plates; Charpy impact tests
B_n Bethlehem	0.18	0.72	Semi-killed normalized	72,48,24,12 and 3-in. notched plates; Charpy impact tests; low temperature tensile bars
C Carnegie-Illinois	0.25	0.49	Semi-killed as rolled	72,48,24,12 and 3-in. notched plates; Charpy impact tests; low temperature tensile bars; size effect studies
D Lukens	0.19	0.52	Fully-killed normalized	One 72-in. plate and 3-in. notched plates
E Lukens	0.23	0.39	Rimmed as rolled	3-in. notched plates
H Bethlehem	0.16	0.85	Fully-killed as rolled	72,12 and 3-in. notched plates; Charpy impact tests
N Lukens	0.13	0.49	3 1/4% Ni as rolled	72,12 and 3-in. notched plates; Charpy impact tests
Q Republic	0.23	1.05	Fully-killed water quenched from 1600°F. and drawn at 1300°F.	12 and 3-in. notched plates; Charpy impact tests
QS Republic	0.23	1.05	Fully-killed water quenched from 1600°F. and drawn at 1245°F.*	12 in. notched plates only

*Six 12-in. specimens of Q steel were reheattreated.

TABLE 2. — PROPERTIES OF STEELS USED IN THE INVESTIGATION.

Steel Code Letter and Manufacturer	Steel A Carnegie - Illinois		Steel B Bethlehem		Steel C Carnegie - Illinois		Steel H Bethlehem		Steel N Lukons		Steel Q Republic	
Chemical Composition	a	b	a	b	a	b	a	b	a	b	a	b
C	0.23	0.26	0.16	0.18	0.24	0.24	0.16	0.18	0.13	0.17	0.21	0.22
Mn	0.47	0.50	0.74	0.73	0.49	0.48	0.75	0.76	0.49	0.53	1.05	1.13
Si	0.02	0.03	0.03	0.07	0.043	0.05	0.17	0.16	0.22	0.25	0.05	0.05
P	0.011	0.012	0.011	0.008	0.015	0.012	0.010	0.012	0.018	0.011	0.011	0.011
S	0.042	0.039	0.030	0.030	0.033	0.026	0.022	0.019	0.027	0.020	0.030	0.030
Ni	—	0.2	—	0.05	—	0.02	—	0.05	3.34	3.39	—	0.05
Al	—	0.012	—	0.015	—	0.016	—	0.053	—	0.077	—	0.008
Cu	—	0.03	—	0.07	—	0.03	—	0.09	—	0.19	—	0.13
Cr	—	0.03	—	0.03	—	0.03	—	0.04	—	0.06	—	0.03
Mo	—	0.006	—	0.006	—	0.005	—	0.006	—	0.025	—	0.006
Sn	—	0.003	—	0.012	—	0.003	—	0.004	—	0.017	—	0.018
N	—	0.004	—	0.005	—	0.009	—	0.004	—	0.005	—	0.006
Type and Heat Treatment	Semi-killed As rolled		Semi-killed As rolled	Normalized.	Semi-killed As rolled		Fully-killed As rolled		Alloy As rolled		Fully-killed Water Quenched from 1625°F Drawn at 1300°F for 1 3/4 hrs.	
Physical Properties												
Yield Point, psi	37,950		35,800	34,800	39,000		39,800		49,800		46,600*	
Ult. Strength, psi	59,910		59,600	58,900	67,400		63,100		78,300		72,450*	
Elong.,% in 2 in.	33.5		—	—	—		—		25.5		49*	
Elong.,% in 8 in.	—		26.0	32.0	25.5		27.0		—		—	
Deoxidation Practice	1-1/3 lb./ton in ladle 1/2 lb./ton Al in the mold		8-1/2 lb./ton of ferro-manganese, 1-1/8 lb/ton ferro-silicon and 2-1/2 lb/ton of Al-Si in Ladle; small amount of Al added in mold		6 lb./ton of 80% ferro-manganese and 2.6 lb./ton of 50% ferro-silicon in ladle; 1/3 lb. per ton of Al in mold.		6.1 lb/ton at 80% ferro-manganese and 7.2 lb./ton of 50% ferro-silicon, 4.3 lb/ton of Alsifer and 2.6 lb/ton of Al in ladle		Not Reported		Not Reported	

Notes: a -- Analysis furnished by the Steel Manufacturer
b -- Analysis performed by Dr. S. Eqstein(Bethlehem Steel Co.) for this investigation.

* Average values for the 10 plates furnished

TABLE 3 -- CHEMICAL ANALYSIS OF SAMPLES FROM INDIVIDUAL PLATES

Plate No.	Condition and Type	Chemical Analysis	
		% C	% Mn
A-1	As rolled, semi-killed	0.27	0.47
A-2	" "	0.25	0.47
A-3	" "	0.22	0.47
A-4	" "	0.25	0.48
A-5	" "	0.24	0.44
B-1	As rolled, semi-killed	0.17	0.71
B-3	" "	0.18	0.70
B-6	" "	0.17	0.73
B-7	" "	0.17	0.68
B-9	" "	0.17	0.71
B-2	Normalized, semi-killed	0.18	0.73
B-4	" "	0.18	0.73
B-5	" "	0.18	0.71
B-8	" "	0.16	0.71
B-10	" "	0.17	0.71
C-1	As rolled, semi-killed	0.25	0.47
C-2	" "	0.26	0.49
C-3	" "	0.23	0.50
C-4	" "	0.25	0.48
C-5	" "	0.26	0.46
C-6	" "	0.25	0.48
D-1	Normalized, fully-killed	0.19	0.52
E-1	As rolled, rimmed	0.20	0.33
H-1	As rolled, fully-killed	0.18	0.76
H-2	" "	0.18	0.75
N-1	As rolled 3.36% N:	0.18	0.48
N-2	" 3.34% N:	0.17	0.48
N-3	" 3.37% N:	0.15	0.50
N-4	" 3.38% N:	0.17	0.50
Q-1	Quenched and Drawn, fully-killed	0.22	1.11
Q-2	" "	0.21	1.13
Q-3	" "	0.22	1.12

TABLE 4. -- RESULTS OF STANDARD TENSION AND HARDNESS TESTS

(Sheet 1 of 3)

Type of Steel	Plate No.	Type of Bar[a]	Orientation[b]	Tensile Properties				Hardness, Rockwell B Numbers
				Yield Point, psi.	Tensile Strength, psi.	Elong. %[c]	Red. in Area, %	
A	A1	.505	T	34,575	57,875	42.0	57.3	61
		.505	L	35,550	58,800	42.8	60.8	
		Square	L	35,070	58,460	50.5	62.0	
		Flat	L	34,510	58,320	34.0	58.4	
	A2	.505	T	35,890	55,700	43.3	59.7	60
		.505	L	36,200	57,630	44.7	62.4	
		Square	L	34,380	58,190	53.2	64.0	
		Flat	L	32,950	57,860	32.4	61.6	
	A3	.505	T	36,500	58,500	42.0	53.7	60-62
		.505	L	35,500	58,400	43.0	60.7	
		Square	L	36,620	58,630	51.0	63.6	
		Flat	L	35,380	58,620	36.6	64.1	
	A4	.505	T	36,180	62,475	38.0	53.0	61
		.505	L	36,680	62,870	42.2	61.5	
		Square	L	35,200	60,900	47.5	58.3	
		Flat	L	34,800	60,900	31.4	57.5	
	A5	.505	T	35,100	57,100	43.2	54.5	58
		.505	L	35,000	57,400	43.0	53.0	
		Square	L	35,100	57,800	50.0	60.0	
		Flat	L	32,800	57,500	32.4	61.5	
B As Rolled	B1	.505	T	34,600	56,950	44.3	63.0	60
		.505	L	32,200	57,050	44.8	65.0	
		Square	L	32,460	57,680	48.8	67.2	
		Flat	L	32,210	56,460	35.0	65.5	
	B3	.505	T	31,230	55,640	44.3	57.9	58
		.505	L	32,050	55,850	42.8	67.5	
		Square	L	32,700	56,350	54.8	66.8	
		Flat	L	31,960	57,680	32.8	64.3	
	B6	.505	T	33,500	56,950	42.0	62.2	60
		.505	L	30,350	56,630	45.3	70.1	
		Square	L	32,410	57,200	54.5	67.7	
		Flat	L	31,960	56,880	33.9	64.3	
	B7	.505	T	33,500	56,500	43.0	60.8	61-63
		.505	L	33,050	57,150	45.7	71.5	
		Square	L	33,000	57,000	53.5	69.8	
		Flat	L	32,300	57,000	33.4	67.5	

a - .505 = A.S.T.M. std. round 0.505-in. dia. bar; square = full thickness of square cross section; flat = A.S.T.M. std. full thickness flat bar.

b - L = axis of bar parallel with direction of rolling.
T = " " " perpendicular to " " "

c - Elongations measured on 2-in. original gage length except on std. flat bars for which gage length was 8 in.

TABLE 4. -- RESULTS OF STANDARD TENSION AND HARDNESS TESTS

(Sheet 2 of 3)

Type of Steel	Plate No.	Type of Bar[a]	Orientation[b]	Tensile Properties				Hardness, Rockwell B Numbers
				Yield Point, psi.	Tensile Strength, psi	Elong. %[c]	Red. in Area, %	
B As Rolled	B9	.505	T	34,600	67,400	43.5	62.0	60
		.505	L	32,400	58,600	43.5	69.0	
		Square	L	30,600	57,000	54.0	70.0	
		Flat	L	30,800	56,900	32.5	68.6	
B Norm.	B2	.505	T	36,370	58,320	41.8	60.4	60
		.505	L	37,100	57,930	46.5	67.2	
		Square	L	34,140	57,440	54.0	65.5	
		Flat	L	35,000	56,880	35.0	63.4	
	B4	.505	T	33,480	56,710	41.8	62.7	59
		.505	L	33,410	57,260	45.5	65.4	
		Square	L	31,080	55,470	54.0	66.0	
		Flat	L	30,900	55,140	35.1	64.9	
	B5	.505	T	37,150	58,530	43.2	60.6	60
		.505	L	35,650	58,700	44.8	66.0	
		Square	L	32,300	56,670	55.0	66.8	
		Flat	L	33,370	56,940	34.8	64.9	
	B8	.505	T	33,600	57,500	43.5	61.0	60
		.505	L	38,800	56,700	49.0	64.0	
		Square	L	31,900	56,700	52.8	68.7	
		Flat	L	32,200	56,200	34.1	67.4	
	B10	.505	T	31,800	56,000	44.5	62.5	60
		.505	L	33,900	55,600	43.5	63.0	
		Square	L	32,400	55,350	54.5	68.0	
		Flat	L	31,800	55,300	33.4	67.9	
C	C1	.505	T	35,500	61,500	40.0	52.2	66
		.505	L	36,330	61,810	41.5	59.6	
		Square	L	35,330	63,000	49.0	59.5	
		Flat	L	35,300	64,600	31.6	57.4	152000
	C2	.505	T	36,000	68,130	35.5	50.1	69
		.505	L	37,130	68,500	38.0	57.0	
		Square	L	36,200	66,540	45.5	54.2	
		Flat	L	35,650	66,170	30.0	53.0	141000
	C3	.505	T	35,650	63,850	38.7	54.5	67-74
		.505	L	34,550	63,850	42.2	60.8	
		Square	L	39,100	65,500	47.7	61.0	
		Flat	L	36,260	64,500	31.7	60.1	161500
	C4	.505	T	35,500	64,200	39.0	53.0	68
		.505	L	37,650	63,750	42.0	59.6	
		Square	L	---	--	--	--	
		Flat	L	--	--	--	--	
	C5	.505	T	36,000	64,000	38.5	55.0	69
		.505	L	34,700	64,200	42.5	61.5	
		Square	L	36,250	66,000	47.0	58.7	
		Flat	L	34,800	65,700	28.0	61.7	171500

35,500　　　150

TABLE 4. -- RESULTS OF STANDARD TENSION AND HARDNESS TESTS

(*Sheet 3 of 3*)

Type of Steel	Plate No.	Type of Bar[a]	Orientation[b]	Tensile Properties				Hardness, Rockwell B Numbers
				Yield Point, psi.	Tensile Strength, psi.	Elong. %[c]	Red. in. Area, %	
H	H1	.505	T	33,900	63,200	41.5	59.0	70
		.505	L	37,000	63,700	43.0	68.6	
		Square	L	34,500	62,600	52.0	68.7	
		Flat	L	34,500	62,100	29.6	68.7	
	H2	.505	T	34,000	63,000	40.5	60.0	70
		.505	L	37,500	63,900	44.0	67.2	
		Square	L	33,700	62,300	51.5	68.7	
		Flat	L	35,500	63,000	30.0	67.0	
N	N1	.505	T	61,000	76,850	37.8	62.0	83
		.505	L	63,000	77,100	37.5	69.7	
		Square	L	59,000	75,600	46.8	70.8	
		Flat	L	60,100	74,700	26.1	69.1	
	N2	.505	T	61,500	77,600	38.2	61.0	83-84
		.505	L	59,000	78,100	38.0	62.1	
		Square	L	53,800	77,500	45.3	69.5	
		Flat	L	59,700	77,100	25.7	66.3	
	N3	.505	T	52,750	83,300	32.5	54.0	85
		.505	L	58,000	82,000	38.0	61.5	
		Square	L	50,600	82,700	41.7	62.1	
		Flat	L	50,300	82,300	26.0	61.2	
	N4	.505	T	61,300	80,000	33.5	59.0	84
		.505	L	60,100	80,100	36.0	65.4	
		Square	L	60,600	78,650	44.0	66.1	
		Flat	L	59,800	78,000	27.0	64.3	
Q Water Quenched and Drawn	Q1	.505	T	49,000	71,800	42.5	61.2	82
		.505	L	48,300	72,500	45.0	65.0	
		Square	L	53,100	73,800	42.0	74.4	
		Flat	L	51,900	71,900	23.5	70.9	
	Q2	.505	T	44,000	70,550	44.2	59.7	83
		.505	L	43,500	70,850	49.0	62.3	
		Square	L	48,400	71,050	43.0	74.0	
		Flat	L	49,600	70,800	22.2	71.8	
	Q3	.505	T	45,200	73,800	42.8	58.3	81
		.505	L	44,800	74,250	47.0	60.2	
		Square	L	53,000	74,000	41.0	73.8	
		Flat	L	50,700	71,600	23.0	71.3	

TABLE 5 - SUMMARY OF PRINCIPAL RESULTS OF TENSILE TESTS AND WIDE - PLATE TESTS

SHEET 1 OF 2

STEEL	3-IN. EDGE-NOTCHED TENSILE BAR (h)				PLATE NO.	STD. 0.505-IN TENSILE BAR			12-INCH TEST PLATE (D SIZE)					24-INCH TEST PLATE (C SIZE)					48-INCH TEST PLATE (B SIZE)					72-INCH TEST PLATE (A SIZE)				
	TEMP. F (b)	Y.S. K.S.I.	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE		TEMP. F. (b)	Y.S. K.S.I.	T.S. K.S.I.	TEMP. F. (b)	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	GAGE LENGTH	ENERGY (c) K-IN (d)	TEMP. F. (b)	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	GAGE LENGTH	ENERGY K-IN	TEMP. F. (b)	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	GAGE LENGTH	ENERGY (c) K-IN (d)	TEMP. F. (b)	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	GAGE LENGTH	ENERGY (c) K-IN (d)
"A" CARNEGIE-ILL. "CHATTANOOGA" C-0.23 Mn-0.47 AS ROLLED SEMI-KILLED	(-19°)-(-15°)	45.9	66.0	3% SH. 97% CL.	A-1	70°	35.6	58.8	86°	46.5	77% SH. 23% CL.(f)	9	98	37°	43.6	72% SH. 28% CL.(f)	18	291	68°	40.7	90% SH. 10% Burn	36 135(e)	935 946(e)	75°	38.5	80% SH 20% Burn	24 54	1034 2081
	30°	43.4	61.6	2% SH. 98% CL.	A-2	71°	36.2	57.6	31°-33°	48.1	26% SH. 74% CL.	9 50 (e)	104 180(e)	84°	42.6	100% SH.	18 65(e)	336 367(e)						30°-34°	38.5	2% SH. 98% CL.	24 54	520 684
	49°-51°	42.5	61.5	10% SH 90% CL.	A-3	72°	35.5	58.4	50°	48.1	100% SH.	9 54 (e)	96 180(e)	(-7°)-(-6°)	38.1	100% CL.	18 94(e)	51 77 (e)	48°	41.1	76% SH. 24% Burn	36 135(e)	981 1062(e)	48°-50°	41.3	73% SH. 27% Burn	24 54 170 (e)	1384 2273 2587 (e)
	69°-73°	42.3	60.2	94% SH. 3% CL.	A-4	70°	36.7	63.1	11°	39.3	100% CL.	9 91 (e)	16.3 25 (e)											10°	35.8	100% CL.	24 54 168 (e)	73 85 219 (e)
	80°	43.1	58.1	97% SH. 3% CL.	A-5				(-9°)-(-8°)	39.9	100% CL.	9 89 (e)	14.4 43 (e)											43°-45°	40.0	90% SH. 10% Burn	24 54 190 (e)	1483 2100 2400 (e)
					A-41X				7°-8°	38.7	100% CL.	9	19															
					A-42X				19°	38.5	100% CL.	9	15															
"B₀r" BETHLEHEM C-0.16 Mn-0.74 AS-ROLLED SEMI-KILLED	(-20°)-(-19°)	38.7	65.8	6% SH. 94% CL.	B-1	73°	31.9	57.1	32°	48.9	83% SH. 17% CL.	9 49 (e)	112 194 (e)	32°	46.3	88% SH. 12% Torn	BROKE AT WELD. WAS RETESTED							32°	38.5	3% SH. 97% CL.	24 54	600 1100(g)
	6°-9°	40.5	65.5	16% SH. 84% CL.	B-3	70°	32.1	55.9	70°-73°	46.1	94% SH. 6% CL.	9 54 (e)	115 181 (e)	72°	43.3	100% SH.	18	566						72°	40.0	74% SH. 26% Torn	24 54	1449 2200(g)
	22	37.8	63.5	39% SH. 61% CL.	B-6	74°	30.4	56.7	50°-51°	49.3	100% SH.	9 46 (e)	114 173 (e)						45°-46°	42.6	83% SH. 17% Torn.	36 135 (e)	1160 1275(e)	48°-51°	40.2	40% SH. 60% CL.	24 54 170 (e)	1262 2288 2494 (e)
	33°-39°	37.7	59.4	100% SH.	B-7	68°	33.1	57.2	(-35°)-(-34°)	40.0	100% CL.	9 43 (e)	21 30 (e)						9°	35.2	100% CL.	36 129 (e)	177 201 (e)	8°-9°	34.6	100% CL.	24 54 158 (e)	209 315 455 (e)
					B-9	78°	33.1	58.6	(-7°)-(-6°)	41.8	100% CL.	9 78 (e)	36 41 (e)															
					B-31X				12°-17°	48.7	20% SH. 80% CL.	9 72 (e)	144 237 (e)											108-INCH TEST PLATE (B1-108)				
					B-32X				20°-23°	50.4	87% SH. 13% CL.	9 72 (e)	158 249 (e)											31°	36.7	75% SH. 25% Burn	36 81	1,316 2,100
					B-33X				(-3°)-(0°)	43.5	100% CL.	9 71 (e)	61 62 (e)															
"Bₙ" BETHLEHEM C-0.16 Mn-0.74 NORMALIZED SEMI-KILLED	(-22°)-(-16°)	43.1	64.8	13% SH. 87% CL.	B-2	72°	37.1	57.9	32°-36°	48.1	78% SH. 22% CL.(f)	9 40 (e)	134 209 (e)	32°-33°	46.3	90% SH. 10% Burn	18 96	405 457(e)						30°	33.2	100% CL.	24 54	140 194(g)
	(-3°)-(0°)	42.8	62.7	31% SH. 69% CL.	B-4	70°	33.5	57.3	89°	45.6	94% SH. 6% CL.	9	133	97°	41.5	100% SH.	18	384						72°	37.9	91% SH. 9% Burn.	24 54	1417 2050
	34°-40°	41.8	60.5	94% SH. 6% CL.	B-5	70°	37.0	58.5	50°-51°	45.9	100% SH.	9 54 (e)	121 192 (e)											49°-52°	39.5	100% SH.	24 54 170 (e)	1138 2100 2366 (e)
	55°	41.5	58.6	100% SH.	B-8	79°	36.7	57.4	(-12°)-(-10°)	38.5	100% CL.	9 47 (e)	22 29 (e)											16°-18°	33.3	100% CL.	24 54 184 (e)	129 288 421 (e)
					B-10	70°	33.9	55.6	10°-15°	48.7	87% SH. 13% CL.	9 76 (e)	116 212 (e)											31°-33°	38.8	79% SH. 21% Burn	24 54 184 (e)	1531 2083 2167 (e)
					B-21X				10°	42.2	100% CL.	9 71 (e)	53 70 (e)															
"C" CARNEGIE - ILL. C-0.24 Mn-0.49 AS ROLLED SEMI-KILLED.	34°-35°	42.9	64.9	2% SH. 98% CL.	C-1	70°	36.3	61.8	32°-33°	40.0	100% CL.	9	13.4	27°-31°	37.0	100% CL.	18 91 (e)	19 43 (e)						30°-31°	37.0	100% CL.	24 54	100 119
	49°	42.5	64.4	3% SH. 97% CL.	C-2	75°	36.0	68.8	84°	42.8	3% SH. 97% CL.	9	20.3	88°	40.4	1% SH. 99% CL.	18	141	80°	37.2	100% CL.	36 135 (e)	56 152(e)	78°	37.8	9% SH. 91% CL.	24 54	102
	75°	41.6	63.2	4% SH. 96% CL.	C-3	68°	34.6	63.9	101°	51.1	51% SH. 49% CL.	9 45 (e)	85 132 (e)						101°	44.9	83% SH. 1% CL. 16% Burn.	36 135(e)	717 820(e)	100°-104°	43.2	100% SH.	24 54 170 (e)	823 1189 1457 (e)
	104°-108°	40.7	62.2	98% SH. 2% CL.	C-4														27°-29°	37.2	100% CL.	36 135 (e)	55 98(e)	80°-82°	35.7	100% CL.	24 54 136 (e)	47 77 314 (e)
	87°	40.7	63.8	6% SH. 94% CL.	C-5	71°	390	69.9	141°-145°	54.7	94% SH. 6% CL.	9 44 (e)	78 119 (e)											152°	43.0	86% SH. 2% CL. 12% Burn.	24 54 167 (e)	472 689 889 (e)
	96°	40.2	61.9	36% SH. 64% CL.	C-6														32°	37.0	100% CL.	36 130 (e)	46 93(e)					
	128°	42.1	63.5	95% SH. 5% CL.	C-51X				120°-123°	48.7	100% SH.	9 83 (e)	93 114 (e)											108-INCH TEST PLATE (C1-108)				
	144°	42.1	61.5	100% SH.	C-52X				90°	46.6	10% SH. 90% CL.	9 77 (e)	72 160											26°-28°	38.4	100% CL.	36 81 237 (e)	126 248 842
					C-11X				132°-136°	53.2	93% SH. 7% CL.	9 62 (e)	83 227															
"D" STEEL ; C-0.17 ; Mn-0.52 , FULLY-KILLED, NORMALIZED																								34°	39.0	100% CL.	24 54	290 310

FOR NOTES SEE SHEET 2

TABLE 5– SUMMARY OF PRINCIPAL RESULTS OF TENSILE TESTS AND WIDE-PLATE TESTS

SHEET 2 OF 2

STEEL	3-IN. EDGE-NOTCHED TENSILE BAR				PLATE NO.	STD. 0.505-IN. TENSILE BAR			12-INCH TEST PLATE (D-SIZE)					PLATE NO.	12-INCH TEST PLATE (D-SIZE)					PLATE NO.	72-INCH TEST PLATE (A-SIZE)				
	TEMP. °F. (b)	Y.S. K.S.I.	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE		TEMP °F (b)	Y.S. K.S.I.	T.S. K.S.I.	TEMP °F (b)	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	GAGE LENGTH	ENERGY (c) K-IN. (d)		TEMP °F (b)	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	GAGE LENGTH	ENERGY (c) K-IN. (d)		TEMP °F (b)	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	GAGE LENGTH	ENERGY (c) K-IN. (d)
"N"– LUKENS C– 0.13% Mn–0.49% Ni –3.25% AS ROLLED	(-39°)-(-36°)	64.0	83.5	5% SH. 95% CL.	N-1	70°	63.0	77.1	(-30°)(-28°)	69.3	84% SH. 16% CL.	9 53 (e)	111 208 (e)	N-42X	(-24°)(-22°)	68.1	100% SH.	9 89 (e)	116 171 (e)	N-1	(-55°)(-51°)	64.2	4% SH. 96% CL.	24 54 195 (e)	717 848 1913 (e)
	(-3°)-(+1°)	64.9	83.2	5% SH 95% CL	N-2	70°	59.0	78.1	(-62°)(-59°)	75.9	6% SH 94% CL.	9 57 (e)	338	N-21X	- 2°	68.4	100% SH.	9 84 (e)	114 208 (e)	N-2	(-35°)(-30°)	60.9	13% SH. 87% CL.	24 54 192 (e)	1500 2277 [illegible] (e)
	15°	64.4	81.9	10% SH 90% CL	N-3	76°	52.8	83.5	72°-73°	66.4	100% SH.	9 49 (e)	94 139 (e)	N-22X	-60°	70.4	35% SH 65% CL.	9 72 (e)	119 146 (e)	N-3	2°	59.8	73% SH. 27% BURN	24 54	1436 2094
	29°	63.0	79.5	98% SH. 2% CL.	N-4	75°	60.4	80.1	(-34°)(-32°)	70.4	100% SH.	9 43 (e)	76 131 (e)	N-13X	(-65°)(-63°)	71.1	17% SH 83% CL.	9 74 (e)	95 131 (e)						
	- 6°	65.0	85.5	11% SH. 89% CL.	N-4X				(-79°)(-78°)	68.9	100% CL.	9 72 (e)	71.7 364 (e)	N- 14X	(-38°)(-36°)	69.6	7% SH 93% CL.	9 74 (e)	115 120 (e)						
					N-41X				(-46°)(-44°)	69.9	81% SH. 19% CL.	9 89 (e)	123 434 (e)	N-15X	-64°	66.7	100% CL.	9 70 (e)	70 72 (e)						
														N-16X	32°- 33°	66.0	100% SH.	9 69 (e)	109 123 (e)						
"Q"–REPUBLIC C–0.21% Mn–1.05% WATER QUENCHED AND DRAWN	-13°	69.3	82.8	8% SH. 92% CL.	Q-1	70°	49.4	73.2	71°	57.3	100% CL.	9 77.5 (e)	33.9 825 (e)	Q-21X	57°- 59°	60.0	100% SH	9 74 (e)	114 121 (e)						
	- 2°	68.6	83.4	5% SH. 95% CL.	Q-2	75°	47.1	72.2	134°	61.0	100% SH.	9 88 (e)	112 402 (e)	Q-22X	32°	62.2	82% SH. 18% CL.	9 78 (e)	117 150 (e)						
	29°	67.4	80.4	93% SH. 7% CL.	Q-3				15°-17°	64.0	100% SH.	9 61.5 (e)	124 144 (e)	Q-13X	0°	58.4	100% CL.	9 71 (e)	32 52 (e)						
	16°	65.3	80.5	6% SH 94% CL.	Q-11X				100°-101°	60.0	100% SH.	9 74 (e)	114 146 (e)	Q-14X	68°	61.9	100% SH	9 70 (e)	131 137 (e)						
	41°	62.2	80.9	26% SH. 74% CL.	Q-12X				85°-87°	60.7	100% SH.	9	115	Q-31X	(-21°)(-20°)	62.2	100% CL.	9 73 (e)	52 85 (e)						
	57°	64.3	81.2	96% SH. 4% CL.										Q-32X	(-51°)(-50°)	59.7	100% CL.	9 52 (e)	38 44 (e)						
"Q"-REPUBLIC C–0.21% Mn–1.05% AFTER SECOND HEAT TREATMENT					Q-1S				(-1°)(1°)	69.0	18% SH. 82% CL.	9 62 (e)	126 158 (e)	Q-4S	(-30°)(-29°)	68.6	100% CL.	9 71 (e)	78 116 (e)						
					Q-2S				31°-34°	66.8	89% SH. 11% CL.	9 57 (e)	152 234 (e)	Q-5S	(-14°)(-13°)	66.7	100% CL.	9 58 (e)	70 110 (e)						
					Q-3S				63°-65°	66.8	100% SH.	9 58 (e)	154 216 (e)	Q-6S	15°	69.3	19% SH 81% CL.	9 58.5 (e)	144 218 (e)						
"H"-BETHLEHEM C– 0.16% Mn–0.85% AS ROLLED FULLY KILLED	71°	41.1	65.2	100% SH	H-1	75°	37.0	63.2	(-1°)(+2°)	53.3	100% CL.	9 69 (e)	91 157 (e)	H-7	98°	52.6	100% SH.	9 58 (e)	134 216 (e)	H-1	67°-69°	44.7	82% SH. 18% BURN	24 54 181 (e)	1725 2236 2672 (e)
	40°	41.6	66.2	88% SH 12% CL.	H-2				23°-27°	53.2	74% SH. 26% CL.	9 69.5 e	120 152 (e)	H-9	(-10°)(-11°)	53.0	100% CL.	9 58 (e)	92.7 169 (e)	H-2	24°-27°	45.6	88% SH 12% BURN	24 54 178 (e)	1904 2480 2610 (e)
	32°	42.2	65.1	3% SH. 97% CL.	H-3				40°-43°	53.4	66% SH. 34% CL.	9 62.5 (e)	129 197 (e)	H-10	(-42°)(-41°)	53.8	100% CL.	9 54	88 139.6 (e)	H-3	15°	38.3	100% CL.	24 54 176 (e)	182 319 406 (e)
	25°	41.4	66.4	95% SH. 5% CL.	H-4				60°-63°	52.7	92% SH 8% CL.	9 72 (e)	130 209 (e)	H-81X	-64°	47.4	100% CL.	9 65 (e)	29.7 46.8 (e)	H-4	(-19°)(-18°)	39.0	100% CL.	24 54 182 (e)	134 239 340 (e)
	25°	42.5	67.9	19% SH. 81% CL.	H-5				(-20°)(-22°)	51.9	100% CL.	9 65 (e)	67 101.3 (e)	H-82X	-40°	47.4	100% CL.	9	38						
	15°	42.5	68.1	30% SH. 70% CL.	H-6				10°-13°	55.0	44% SH. 56% CL.	9 74 (e)	116 236 (e)	H-8	-40°	57.6	3% SH. 97% CL.	9 69 (e)	129 253 (e)						

NOTES:

(a)– NOMINAL STRESS IS COMPUTED ON THE BASIS OF NET SECTION AT THE NOTCH LINE.

(b)– TEMPERATURE RANGE IS THAT OBSERVED DURING THE INTERVAL FROM ZERO LOAD TO MAXIMUM LOAD.

(c)– ENERGY VALUES GIVE THE ENERGY ABSORBED BY THE PLATE UP TO MAXIMUM LOAD.

(d)– ENERGY VALUES ARE CORRECT TO WITHIN PLUS OR MINUS FIVE PERCENT UNLESS OTHERWISE NOTED.

(e)– BASED ON EXTENSION MEASURED BETWEEN PINS OF PULLING HEADS.

(f)– THE PERCENTAGE OF SHEAR AND CLEAVAGE NOTED IS PROBABLY DUE TO A TEARING ACTION CAUSED BY ONE SIDE OF THE PLATE FRACTURING BY SHEAR AND LEAVING THE OTHER TO BE TORN. IT HAS BEEN OBSERVED THAT OTHER TYPE SPECIMENS HAVING A NOTCH ON ONE EDGE ONLY FAIL BY CLEAVAGE AT MUCH HIGHER TEMPERATURES THAN DO SYMMETRICAL SPECIMENS WITH CENTRAL NOTCHES.

(g)– ENERGY ABSORBED IN 54-INCH GAGE LENGTH ESTIMATED FROM DATA FOR OTHER GAGE LENGTHS.

(h)– 3-INCH EDGE NOTCHED TENSILE BAR VALUES DO NOT CORRESPOND TO THE PARTICULAR PLATE NUMBERS. ALL 3-INCH BARS CUT FROM ONE PLATE OF EACH LOT OF STEEL.

TABLE-6

THICKNESS REDUCTION ALONG FRACTURE LINES OF NOTCHED FLAT PLATES

SHEET 1 OF 3

STEEL	PLATE WIDTH IN.	SPECIMEN NO.	TESTING TEMP. °F.	DISTANCE FROM NOTCH, INCHES.																					
				LEFT SIDE OF PLATE											RIGHT SIDE OF PLATE										
				26	16	8	4	2	1	1/2	1/4	1/8	1/16	0	0	1/16	1/8	1/4	1/2	1	2	4	8	16	26
"A"	72"	A-1A	75°	18.5 S	20.0 S	19.5 S	17.0 S	14.0 S	12.5 S	11.5 S	13.0 S	12.5 S		12.0 S	8.0 S		9.0 S	10.5 S	10.0 S	12.0 S	13.5 S	16.0 S	19.0 S	20.5 S	
		A-3A	48°-50°	17.5 S	20.0 S	21.0 S	19.5 S	18.5 S	15.5 S	14.5 S	13.5 S	12.0 S		4.0 S			9.5 S	11.5 S	12.5 S	15.5 S	16.5 S	19.0 S	20.0 S		
		A-2A	30°-34°	14.5 C	25.5 C	25.5 C		5.5 C	11.5 C	17.0 S		14.0 S		11.5 S	6.0 S		15.5 S		18.0 S	10.0 C	5.0 C		3.0 C	3.0 C	2.5 C
		A-4A	10°	2.5 C	3.0 C	2.0 C	2.5 C	2.0 C	2.0 C	3.0 C	5.0 C	5.5 C	6.5 C	7.0 C	6.0 C	5.5 C	5.0 C	4.0 C	3.0 C	2.0 C	1.0 C	1.0 C	1.0 C	1.5 C	2.0 C
		A-5A	43°-45°		17.0 S	20.0 S	18.5 S	15.5 S	15.0 S	11.5 S	11.5 S	10.0 S	7.5 S	2.0 S	3.5 S	6.5 S	9.5 S	12.5 S	12.5 S	13.5 S	16.0 S	19.0 S	19.0 S	20.0 S	19.5 S
	48"	A-1B	68°		18.0 S	18.0 S	19.0 S	17.5 S	16.5 S	14.0 S	13.5 S	10.5 S		5.0 S	5.5 S		8.5 S	11.0 S	12.0 S	15.0 S	16.5 S	19.0 S	19.0 S		
		A-3B	48°		18.0 S	17.5 S	16.0 S	12.0 S	9.5 S	7.5 S	7.0 S	6.0 S		0.0 S	4.0 S		7.0 S	9.5 S	9.5 S	12.0 S	15.0 S		19.5 S		
	24"	A-2C	84°			19.5 S	17.5 S	15.5 S	12.5 S	12.0 S	11.5 S	10.5 S		4.5 S	4.5 S		10.0 S	10.5 S	12.0 S	13.0 S	16.0 S	18.0 S	18.5 S		
		A-1C	37°			3.0 C		16.5 S	14.5 S	12.5 S		8.0 S		5.0 S	3.5 S		7.0 S		9.0 S	10.5 S	13.5 S	15.5 S	18.5 S		
		A-3C	(-7°)-(-6°)			2.0 C	2.0 C	2.5 C	3.0 C	4.5 C	6.0 C	7.0 C	7.5 C	8.5 C	8.0 C	7.5 C	6.5 C	5.5 C	3.5 C	2.5 C	2.5 C	2.0 C	1.5 C		
	12"	A-1D	86°					18.0 S	17.0 S	16.5 S	14.5 S	13.5 S		8.5 S	9.0 S		11.5 S	12.0 S	13.0 S	15.0 S	17.0 S				
		A-3D	50°				4.5 S	14.0 S	17.0 S	14.5 S	12.0 S	10.5 S		6.5 S	11.5 S		15.0 S	16.0 S	18.5 S	21.0 S	16.5 S	17.5 C			
		A-2D	31°-33°				3.0 C	9.5 C	12.5 S	10.5 S	9.5 S	8.0 S		6.5 S	6.0 S		15.0 S	16.5 S	18.0 S	18.0 S	7.5 C	3.0 C			
		A-42XD	19°				1.0 C	2.0 C	2.5 C	2.5 C	4.0 C	4.0 C	4.5 C	1.5 C	2.0 C	4.5 C	4.0 C	4.0 C	3.0 C	2.5 C	2.0 C	1.5 C			
		A-4D	11°				2.0 C	2.5 C	2.5 C	4.0 C	5.0 C	5.5 C	5.5 C	6.0 C	6.5 C	6.0 C	5.5 C	4.5 C	4.5 C	2.5 C	2.0 C	1.5 C			
		A-41XD	7°-8°				0.5 C	1.0 C	1.5 C	2.0 C	3.0 C	3.0 C	3.0 C	3.0 C	3.0 C	3.0 C	3.0 C	2.5 C	2.0 C	1.5 C	1.5 C	1.0 C			
		A-5D	(-9°)-(-8°)				1.5 C	2.5 C	2.5 C	3.0 C	4.0 C	4.5 C	4.0 C	2.5 C	3.0 C	4.5 C	5.0 C	4.5 C	3.0 C	2.5 C	2.5 C	1.5 C			
"B_{ar}"	72"	B-3A	72°		24.5 S	22.5 S	21.0 S	16.0 S	13.5 S	14.0 S	12.0 S	13.5 S		8.5 S	15.5 S		16.0 S	21.0 S	23.5 S	25.5 S	27.5 S	29.0 S	33.0 S		
		B-6A	48°-51°	3.5 C	8.5 C	20.5 S	19.0 S	17.0 S	16.0 S	13.0 S	12.0 S	9.0 S		5.5 S	4.5 S		9.0 S	12.5 S	12.5 S	15.0 S	17.5 S	21.5 S	22.0 S	8.0 C	4.0 C
		B-1A	30°-32°	2.5 C	2.5 C	3.0 C	5.0 C	7.5 C	18.0 S	20.0 S	8.5 S			6.5 S	7.5 S		16.0 S			18.0 S	7.5 C	4.5 C	3.5 C	2.5 C	2.5 C
		B-7A	8°-9°	2.0 C	2.0 C	1.5 C	2.0 C	2.5 C	3.5 C	6.0 C	10.0 C	12.0 C	14.0 C	6.5 C	5.5 C	13.0 C	15.0 C	12.0 C	8.0 C	4.5 C	2.5 C	2.0 C	1.5 C	2.0 C	1.0 C
	48"	B-6B	48°-51°		22.0 S	23.5 S	20.5 S	19.0 S	14.5 S	12.5 S	11.0 S	7.5 S		0.5 S	1.5 S		8.0 S	10.0 S	15.0 S	19.5 S	19.0 S	23.0 S	23.0 S		
		B-7B	9°		2.0 C	3.0 C	2.0 C	2.0 C	3.0 C	4.5 C	7.5 C	9.0 C	11.0 C	7.0 C	2.5 C	9.0 C	9.0 C	7.5 C	5.0 C	3.0 C	2.5 C	1.0 C	2.0 C	2.0 C	
	24"	B-3C	72°				25.0 S	25.0 S	23.5 S	22.0 S	20.0 S	14.5 S		12.0 S	5.5 S		13.5 S	17.0 S	18.5 S	20.5 S	23.5 S	22.0 S	23.5 S		
		B-1C	43°				20.5 S	19.5 S	19.0 S	16.5 S	15.0 S	12.5 S		5.0 S	10.0 S		13.5 S	13.5 S	13.5 S	16.0 S	19.5 S	21.5 S	19.0 S		
	12"	B-3D	70°-73°					25.0 S	24.5 S	22.0 S	19.0 S	16.0 S		7.5 S	8.0 S		15.0 S	18.0 S	20.0 S	23.0 S	20.5 S	13.0 S			
		B-6D	46°				19.0 S	18.5 S	16.0 S	13.5 S	11.0 S	3.5 S		0.5 S	4.0 S		12.5 S	13.0 S	13.0 S	16.0 S	17.5 S	6.5 S			
		B-1D	32°				19.5 S	20.0 S	17.5 S	15.5 S	13.5 S	12.5 S		5.0 S	10.0 S		12.0 S	15.5 S	15.5 S	17.5 S	19.5 S	5.0 C			
		B-32XD	20°-23°				18.5 S	19.0 S	16.0 S	15.0 S	13.0 S	11.0 S	4.0 S	3.5 S	6.5 S	15.0 S	17.5 S	20.0 S	22.0 S	22.5 S	23.0 S	2.0 C			
		B-31XD	12°-15°				3.5 C	8.5 C	20.5 S	22.5 S	20.5 S	17.0 S	14.0 S	3.0 S	3.0 S	8.5 S	11.5 S	16.0 S	18.5 S	19.5 C	8.0 C	3.0 C			
		B-33XD	(-3°)-(0°)				1.5 C	2.5 C	4.0 C	5.0 C	8.5 C	10.5 C	11.5 C	10.5 C	12.0 C	12.0 C	9.5 C	9.5 C	6.0 C	5.0 C	2.5 C	1.5 C			
		B-9D	(-7°)-(-6°)				0.5 C	2.0 C	2.0 C	3.5 C	5.0 C	6.5 C	7.0 C	9.0 C	8.5 C	8.5 C	7.5 C	6.0 C	4.5 C	3.0 C	2.0 C	2.5 C			
		B-7D	(35°)-(34°)				2.0 C	2.0 C	2.5 C	3.0 C	4.0 C	5.5 C	5.5 C	4.5 C	5.5 C	5.5 C	5.0 C	4.5 C	3.0 C	2.5 C	2.0 C	1.5 C			
"B_n"	72"	B-4A	72°	25.0 S	26.0 S	25.5 S	22.5 S	21.0 S	18.0 S	17.0 S	17.0 S	15.5 S		13.5 S	17.0 S	17.5 S	18.0 S	18.0 S	16.5 S	18.0 S	21.0 S	23.5 S	26.5 S		
		B-5A	49°-52°	20.0 S	22.0 S	20.0 S	21.0 S	20.5 S	17.5 S	15.5 S	16.5 S	14.0 S		6.5 S	3.5 S		13.0 S	15.5 S	17.5 S	18.5 S	22.0 S	23.0 S	22.0 S	22.5 S	14.5 S
		B-2A	33°-35°				3.5 C	3.5 C	4.0 C	5.5 C				10.0 C	10.5 C				6.0 C	5.5 C	4.0 C	3.5 C			
		B-10A	31°-33°			24.0 S	21.5 S	26.5 S	24.0 S	20.5 S	18.0 S	15.0 S	14.6 S	6.0 S	2.5 S	13.0 S	17.0 S	19.0 S	17.5 S	17.0 S	19.0 S	21.5 S	23.0 S	24.5 S	21.5 S
		B-8A	16°-18°	1.0 C	2.5 C	0.0 C	3.0 C	3.5 C	4.0 C	5.5 C	8.0 C	10.0 C	10.5 C	12.0 C	16.0 C	13.0 C	12.0 C	9.0 C	6.0 C	4.0 C	2.5 C	1.5 C	0.5 C	0.0 C	1.0 C
	24"	B-4C	97°				19.5 S	19.5 S	16.5 S	14.5 S	13.5 S	13.5 S		10.5 S	16.5 S		19.0 S	22.0 S	23.5 S	23.5 S	25.5 S	25.0 S			
		B-2C	32°-33°			20.5 S	21.0 S	19.0 S	17.0 S	16.0 S	15.0 S	10.5 S		8.5 S	12.0 S		17.5 S	21.0 S	23.5 S	25.0 S	26.0 S	24.5 S			
	12"	B-4D	89°				24.5 S	24.0 S	23.0 S	22.5 S	21.0 S	16.5 S		12.5 S	9.0 S		17.0 S	20.0 S	21.5 S	21.5 S	23.5 S	17.5 S			
		B-5D	50°-51°				15.5 S	21.5 S	23.0 S	23.5 S	21.0 S	18.5 S		9.0 S	5.5 S		11.5 S	14.5 S	16.0 S	17.5 S	19.0 S	24.5 S			
		B-2D	32°-36°				10.5 C	20.5 S	18.0 S	16.0 S	15.5 S	15.0 S		7.5 S	5.5 S		12.5 S	14.0 S	14.5 S	16.0 S	19.5 S	19.0 S			
		B-10D	10°-15°				5.5 C	17.5 S	15.0 S	14.0 S	12.5 S	11.0 S	9.0 S	2.5 S	6.0 S	10.5 S	11.5 S	12.5 S	14.0 S	16.0 S	19.0 S	20.0 S			
		B-21XD	10°				1.5 C	2.5 C	3.5 C	5.5 C	7.5 C	9.0 C	11.0 C	2.0 C	7.0 C	9.5 C	9.0 C	6.5 C	4.5 C	3.0 C	2.5 C	1.5 C			
		B-8D	(-12°)-(-10°)				1.5 C	2.0 C	3.0 C	4.0 C	5.5 C	6.0 C	7.0 C	7.0 C	5.5 C	7.0 C	6.5 C	5.5 C	4.5 C	3.0 C	2.5 C	2.0 C			

✳ VALUES IN TABLE INDICATE PERCENT REDUCTION. LETTER FOLLOWING VALUE INDICATES TYPE OF FRACTURE: S=SHEAR, C=CLEAVAGE.

TABLE - 6

THICKNESS REDUCTION ALONG FRACTURE LINES OF NOTCHED FLAT PLATES *

SHEET 2 OF 3

DISTANCE FROM NOTCH, INCHES

STEEL	PLATE WIDTH, IN.	SPECIMEN NUMBER	TESTING TEMP. °F	LEFT SIDE OF PLATE												RIGHT SIDE OF PLATE											
				39	26	16	8	4	2	1	1/2	1/4	1/8	1/16	0	0	1/16	1/8	1/4	1/2	1	2	4	8	16	26	39
"Bσ"	108	B1-108	31°			24.5 S	20.0 S	17.0 S	13.5 S	14.0 S	13.0 S	11.0 S	7.0 S	5.0 S	2.0 S	5.0 S	12.0 S	13.0 S	15.0 S	17.0 S	17.0 S	18.0 S	21.5 S	22.5 S	25.5 S		20.0 S
"C"	108	C1-108	26°-28°	2.5 C		3.0 C	2.5 C	3.0 C	2.5 C	3.5 C	6.0 C	6.5 C	8.5 C	9.0 C	4.0 C	5.0 C	8.0 C	7.0 C	6.0 C	5.0 C	3.5 C	2.5 C	2.5 C	2.0 C	3.0 C		1.5 C
"C"	72"	C-5A	152°			13.5 S	15.0 S	12.5 S	9.5 S	6.5 S	6.5 S	5.5 S	5.0 S	6.5 S	3.0 S	2.0 C	9.5 C	10.0 C	13.5 C	14.0 C	17.0 C	8.5 S	11.0 S	15.0 S	15.0 S	15.5 S	
		C-3A	100°-104°			17.0 S	17.5 S	17.0 S	14.5 S	13.5 S	10.5 S	9.0 S	8.0 S	5.5 S	3.0 S	2.0 S	6.5 S	7.0 S	10.0 S	12.0 S	13.0 S	14.0 S	16.0 S				
		C-4A	80°-82°			5.0 C	7.0 C	8.5 C	5.0 C	11.5 C	6.5 C	6.0 C	7.6 C		0.5 C	7.0 C		7.5 C	7.0 C	8.5 C	13.5 C	8.0 C	12.5 C	9.5 C	6.0 C	4.0 C	
		C-2A	78°													8.0 C		7.5 C	7.0 C	7.0 C	11.5 C	5.0 C			4.0 C	3.0 C	
		C-1A	30°-31°		1.5 C	2.5 C	1.5 C	1.5 C	1.5 C	1.5 C	2.0 C		3.5 C		4.0 C	4.5 C		3.5 C		2.0 C	1.5 C	1.5 C	1.5 C	2.5 C	2.5 C	1.5 C	
	48"	C-3B	101°			16.0 S	19.0 S	17.0 S	16.5 S	13.0 S	12.5 S	10.0 S	7.0 S		2.5 S	6.0 S		8.0 S	8.0 S	9.0 S	10.5 S	13.0 S	14.5 S	16.5 S			
		C-2B	80°			4.0 C	5.5 C	7.0 C	4.0 C	9.0 C	6.0 C	6.5 C	6.0 C		4.5 C	3.5 C		6.0 C	8.0 C	8.5 C	6.0 C	7.0 C	5.5 C	6.5 C	4.0 C		
		C-6B	32°			2.0 C	2.0 C	2.0 C	2.5 C	2.5 C	3.5 C	4.5 C	5.5 C	6.0 C	3.5 C	4.5 C	5.5 C	5.0 C	4.0 C	3.5 C	2.5 C	2.5 C	2.0 C	2.0 C	2.5 C		
		C-4B	27°-29°			1.5 C	2.0 C	2.0 C	2.0 C	2.5 C	3.5 C	3.5 C	3.5 C	4.0 C	4.0 C	3.5 C	4.0 C	3.0 C	3.0 C	4.0 C	3.0 C	2.5 C	2.0 C	2.0 C	1.0 C		
	24"	C-2C	88°				8.0 C	8.5 C	8.5 C	15.0 C	13.0 C	11.0 C	10.0 C		9.0 C	8.0 C		11.0 C	11.5 C	11.0 C	15.0 C	9.0 C	7.5 C	5.5 C			
		C-1C	27°-31°				2.0 C	2.0 C	2.5 C	3.0 C	3.5 C	4.5 C	3.5 C	3.5 C	4.0 C	4.0 C	3.5 C	3.5 C	3.5 C	3.5 C	2.5 C	1.5 C	2.0 C	2.0 C			
	12"	C-5D	141°-145°					12.5 S	11.5 S	9.5 S	7.5 S	6.5 S	6.0 S		2.5 S	1.0 S		10.0 S	12.0 S	14.5 S	15.5 S	16.0 S	12.5 C				
		C-11XD	132°-136°					14.5 S	13.0 S	10.5 S	8.5 S	7.5 S	8.0 S	5.0 S	2.0 S	7.5 S	7.0 S	7.5 S	8.5 S	11.5 S	11.0 S	12.0 S	18.0 S				
		C-51XD	120°-123°					5.0 S	11.0 S	9.0 S	8.0 S	7.5 S	6.5 S	5.0 S	1.5 S	2.0 S	9.0 S	9.5 S	9.5 S	9.0 S	9.0 S	11.0 S	14.0 S				
		C-3D	101°					7.5 C	11.5 S	10.0 S	9.5 S	8.5 S	5.5 S		4.0 S	8.5 S		13.5 S	15.5 S	16.5 S	16.0 S	10.5 C	2.5 C				
		C-52XD	90°					3.0 C	7.0 C	10.0 S	9.5 C	6.5 C	6.0 C	5.0 C	2.5 C	3.5 C	4.5 C	5.0 C	8.0 C	10.5 C	15.5 S	7.0 C	3.5 C				
		C-2D	80°					1.5 C	4.5 C	10.5 C	6.5 C	6.0 C	6.0 C		4.5 C	5.5 C		6.0 C	7.0 C	8.5 C	11.5 C	4.5 C	2.5 C				
		C-1D	32°-33°					1.5 C	1.0 C	2.0 C	2.0 C	3.0 C	3.5 C		3.5 C	3.5 C		3.5 C	2.5 C	2.5 C	2.0 C	2.0 C	1.0 C				
"D"	72"	D-1A	33°-35°			5.5 C	6.0 C	10.0 C	7.5 C	8.5 C	14.0 C	17.0 C	11.5 C		3.5 C	0.5 C		14.5 C	18.5 C	15.5 C	9.0 C	6.5 C	6.5 C		5.0 C		
"H"	72"	H-1A	67°-69°			20.0 S	23.5 S	21.0 S	18.0 S	15.0 S	16.0 S	19.0 S	17.5 S	12.0 S	5.0 S	4.5 S	8.5 S	9.0 S	11.0 S	12.0 S	14.0 S	17.0 S	20.5 S	23.0 S	23.5 S	20.5 S	
		H-2A	24°-27°			19.0 S	21.5 S	18.5 S	18.5 S	14.0 S	11.5 S	12.0 S	11.5 S	9.0 S	1.0 S	9.5 S	9.5 S	11.5 S	12.5 S	12.5 S	14.0 S	16.5 S	19.0 S	20.5 S	18.5 S		
		H-3A	15°		1.0 C	1.0 C	1.5 C	1.5 C	2.5 C	3.5 C	6.5 C	9.0 C	11.0 C	12.5 C	3.5 C	12.0 C	10.5 C	9.5 C	8.0 C	6.0 C	2.0 C	2.0 C	1.0 C	0.5 C	1.0 C	1.0 C	
		H-4A	(-19°)(-18°)		1.0 C	4.0 C	2.5 C	2.5 C	2.5 C	3.5 C	5.0 C	6.5 C	7.5 C	8.5 C	11.5 C	10.5 C	9.5 C	7.0 C	7.0 C	5.0 C	3.5 C	2.0 C	1.5 C	2.5 C	2.5 C	1.0 C	
	12"	H-7D	98°					7.0 C	18.5 S	15.5 S	14.0 S	11.0 S	9.5 S	8.5 S	2.5 S	4.0 S	8.0 S	11.5 S	12.5 S	13.5 S	16.0 S	18.5 S	19.0 S				
		H-4D	60°-63°					9.0 S	21.5 S	15.5 S	13.5 S	13.0 S	12.0 S	10.5 S	6.5 S	3.5 S	14.0 S	16.0 S	17.5 S	20.0 S	22.0 S	17.5 S	16.0 S				
		H-3D	40°-43°					5.5 C	23.0 S	22.5 S	22.0 S	17.0 S	8.0 S	0.5 S	0.0 S	7.0 S	11.0 S	10.0 S	11.0 S	13.0 S	15.5 S	17.5 S	13.5 C				
		H-2D	23°-27°					9.5 C	17.0 S	15.0 S	13.0 S	10.5 S	10.0 S	6.0 S	3.5 S	6.5 S	7.5 S	9.5 S	11.5 S	13.0 S	16.5 S	18.5 S	6.5 C				
		H-6D	10°-13°					4.5 C	18.5 C	22.5 S	21.0 S	20.0 S	17.0 S	15.5 S	2.5 S	5.0 S	8.5 S	10.5 S	12.5 S	13.5 S	15.0 S	20.5 S	4.5 C				
		H-1D	(-1°)(+2°)					2.0 C	2.5 C	4.0 C	5.0 C	12.5 C	14.5 C	6.5 C	3.5 C	3.5 C	6.0 C	13.0 C	12.5 C	8.5 C	5.0 C	2.0 C	1.5 C				
		H-9D	(-10°)(-11°)					1.0 C	2.0 C	3.5 C	6.5 C	9.0 C	12.0 C	13.0 C	14.0 C	11.5 C	11.5 C	11.5 C	9.5 C	6.5 C	3.5 C	2.5 C	1.5 C				
		H-5D	(-20°)(-22°)					1.0 C	2.0 C	3.5 C	6.0 C	10.5 C	11.0 C	8.0 C	4.0 C	6.0 C	10.5 C	10.0 C	8.0 C	5.5 C	3.0 C	2.0 C	1.5 C				
		H-82XD	-40°					1.0 C	1.5 C	2.0 C	3.0 C	4.0 C	5.5 C	6.0 C	7.0 C	7.0 C	6.5 C	6.5 C	5.0 C	3.5 C	2.5 C	1.5 C	1.5 C				
		H-10D	(-42°)(-41°)					1.5 C	2.5 C	3.5 C	6.5 C	10.0 C	12.0 C	13.0 C	13.0 C	3.0 C	14.0 C	11.5 C	10.0 C	6.0 C	3.0 C	2.5 C	1.5 C				
		H-81XD	-64°					0.5 C	1.0 C	2.0 C	2.5 C	4.0 C	4.5 C	5.0 C	2.0 C	3.0 C	5.0 C	4.5 C	3.5 C	3.0 C	1.5 C	1.0 C	1.5 C				
		H-8D	(-41°)(-39°)					2.5 C	4.0 C	7.0 C	12.5 C	18.0 C	11.5 S	9.5 S	7.5 S	3.5 S	5.5 S	18.0 S	18.5 C	13.5 C	7.5 C	4.5 C	3.5 C				

* VALUES IN TABLE INDICATE PERCENT REDUCTION. LETTER FOLLOWING VALUE INDICATES TYPE OF FRACTURE: S = SHEAR; C = CLEAVAGE.

TABLE-6

THICKNESS REDUCTION ALONG FRACTURE LINES OF NOTCHED FLAT PLATES *

SHEET 3 OF 3

STEEL	PLATE WIDTH, IN.	SPECIMEN NUMBER	TESTING TEMP. °F	DISTANCE FROM NOTCH, INCHES																					
				LEFT SIDE OF PLATE											RIGHT SIDE OF PLATE										
				26	16	8	4	2	1	1/2	1/4	1/8	1/16	0	0	1/16	1/8	1/4	1/2	1	2	4	8	16	26
"N"	72"	N-3A	2°	21.0 S	19.0 S	15.0 S	12.5 S	10.5 S	9.5 S	8.0 S	8.5 S	9.0 S	8.5 S	3.0 S	3.0 S	12.0 S	13.5 S	17.0 S	19.0 S	20.0 S	19.5 S	21.0 S	26.0 S		
		N-2A	(-35°)(-30°)		3.5 C	5.0 C	9.0 C	13.0 S	13.5 S	15.0 S	16.5 S	10.5 S	14.0 S	5.5 S	2.0 S	6.5 S	6.0 S	10.0 S	9.5 S	12.0 S	14.0 S	17.5 C	6.5 C	3.5 C	4.0 C
		N-1A	(-55°)(-51°)	2.5 C	5.5 C	6.0 C	6.5 C	8.5 C	15.0 C	20.5 S	18.5 S	16.0 S	16.5 S	4.5 S	6.0 S	7.0 S	8.0 S	8.5 S	11.0 S	13.5 C	7.5 C	4.5 C	4.0 C	2.5 C	2.0 C
	12"	N-3D	72°-73°				20.0 S	8.5 S	9.0 S	8.0 S	6.5 S	6.0 S	6.0 S	2.5 S	1.5 S	5.5 S	6.5 S	7.5 S	8.5 S	10.0 S	13.0 S	14.5 S			
		N-16XD	32°-33°				8.0 S	13.5 S	11.5 S	9.5 S	9.0 S	8.0 S	6.5 S	3.5 S	4.0 S	5.5 S	8.5 S	8.0 S	9.5 S	11.0 S	12.5 S	12.5 S			
		N-21XD	-2°				6.0 S	14.5 S	12.5 S	11.5 S	10.0 S	7.5 S	6.5 S	3.0 S	2.5 S	5.5 S	7.5 S	9.5 S	10.0 S	12.5 S	13.5 S	16.5 S			
		N-2XD	(-24°)(-22°)				21.5 S	13.5 S	12.0 S	10.5 S	9.0 S	8.5 S	7.5 S	2.0 S	3.5 S	8.0 S	8.5 S	9.0 S	9.0 S	9.5 S	10.0 S	13.0 S			
		N-1D	(-30°)(-28°)				10.0 C	14.0 S	12.5 S	11.0 S	9.5 S	7.0 S		2.5 S	2.0 S	S	5.5 S	9.0 S	9.5 S	11.0 S	14.0 S	6.5 C			
		N-4D	(-34°)(-36°)				12.5 S	10.0 S	9.5 S	8.5 S	8.0 S	7.0 S	5.5 S	2.0 S	2.5 S	6.5 S	7.5 S	8.0 S	8.5 S	9.0 S	10.5 S	5.5 S			
		N-14XD	(-38°)(-36°)				2.5 C	3.5 C	6.0 C	10.5 C	15.5 S	15.0 S	15.0 S	3.0 S	1.5 S	7.5 S	9.0 S	13.5 S	9.5 C	5.5 C	4.0 C	3.0 C			
		N-1XD	(-46°)(-44°)				14.5 S	12.5 S	10.5 S	9.0 S	8.5 S	7.0 S	6.5 S	2.0 S	2.5 S	7.0 S	9.0 S	9.5 S	10.0 S	11.0 S	13.0 S	7.0 C			
		N-2D	(-62°)(-59°)				7.0 C	17.5 C	35.0 S	24.5 S	18.0 S	15.5 S	14.5 S	2.0 S	2.0 S	5.0 S	6.5 S	8.0 S	7.0 S	24.5 S	12.5 C	5.5 C			
		N-2XD	(-62°)(-60°)				3.0 C	7.5 C	18.0 C	20.5 S	18.5 S	19.0 S	18.5 S	1.5 S	3.5 S	6.0 S	7.5 S	8.5 S	9.0 S	11.0 S	13.5 S	4.5 C			
		N-15XD	-64°				3.5 C	6.5 C	5.0 C	7.5 C	9.5 C	11.5 C	12.0 C	12.5 C	2.5 C	11.5 C	11.5 C	11.0 C	7.5 C	5.5 C	5.0 C	3.0 C			
		N-13XD	(-65°)(-63°)				3.5 C	6.5 C	9.5 C	12.0 S	10.0 S	6.5 S	4.5 S	3.5 S	1.5 S	7.5 S	9.5 S	10.0 S	13.0 S	8.5 C	6.0 C	3.0 C			
		N-4XD	(-79°)(-78°)				3.0 C	5.5 C	6.0 C	8.5 C	11.0 C	12.0 C	12.5 C	10.5 C	14.0 C	14.0 C	13.0 C	11.0 C	8.0 C	6.5 C	4.5 C	3.0 C			
"Q"	12"	Q-2D	134°				21.0 S	41.5 S	35.5 S	28.5 S	15.5 S	13.0 S	9.0 S	3.5 S	1.0 S	14.5 S	19.5 S	25.5 S	35.5 S	38.5 S	40.5 S	17.5 S			
		Q-11XD	100°-101°				16.5 S	22.5 S	25.5 S	16.5 S	16.0 S	12.5 S	11.5 S	2.5 S	1.0 S	9.5 S	13.5 S	17.5 S	20.5 S	22.5 S	19.5 S	10.5 S			
		Q-12XD	85°-87°				21.0 S	32.0 S	17.5 S	16.0 S	14.0 S	10.5 S	7.0 S	1.0 S	1.5 S	12.0 S	15.0 S	19.5 S	23.0 S	26.0 S	33.5 S	15.5 S			
		Q-1D	71°				1.5 C	5.5 C	7.0 C	7.5 C	7.5 C	7.0 C	7.5 C	5.5 C	9.0 C	8.5 C	8.0 C	7.5 C	6.0 C	4.5 C	3.5 C	2.0 C			
		Q-14XD	68°				11.5 S	30.0 S	23.0 S	27.0 S	22.0 S	17.0 S	14.0 S	2.5 S	2.5 S	7.0 S	10.0 S	14.0 S	16.5 S	18.0 S	30.5 S	18.5 S			
		Q-21XD	56°-59°				7.5 S	27.5 S	19.5 S	19.0 S	15.0 S	1.0 S	13.5 S	3.0 S	2.5 S	7.5 S	11.0 S	15.0 S	17.0 S	17.0 S	18.0 S	22.0 S			
		Q-22XD	32°				17.5 S	21.0 S	20.5 S	18.0 S	17.0 S	12.0 S	7.5 S	2.0 S	3.0 S	9.0 S	13.0 S	17.5 S	19.5 S	19.5 S	24.0 S	11.0 S			
		Q-3D	15°-17°				9.0 S	17.5 S	20.5 S	19.0 S	16.5 S	13.5 S	11.0 S	1.0 S	1.5 S	6.0 S	9.0 S	10.5 S	12.0 S	13.0 S	15.5 S	17.5 S			
		Q-13XD	0°				1.5 C	1.5 C	2.5 C	3.5 C	5.0 C	5.5 C	6.5 C	7.0 C	5.5 C	6.5 C	6.0 C	5.0 C	3.0 C	3.5 C	1.5 C	1.0 C			
		Q-31XD	(-21°)(-20°)				3.0 C	3.5 C	5.0 C	5.5 C	5.5 C	9.0 C	5.5 C	2.5 C	4.0 C	7.0 C	9.5 C	7.0 C	6.0 C	3.5 C	2.5 C	2.0 C			
		Q-32XD	(-51°)(-50°)				3.0 C	5.5 C	5.0 C	5.0 C	5.5 C	7.0 C	7.0 C	6.0 C	4.5 C	7.0 C	6.5 C		4.5 C	3.5 C	2.0 C	1.5 C			
"Qs"	12"	Q-3SD	63°-65°				24.0 S	18.0 S	18.5 S	17.0 S	14.0 S	9.5 S	8.0 S	1.5 S	3.5 S	9.5 S	11.5 S	16.0 S	18.0 S	18.0 S	18.0 S	8.5 S			
		Q-2SD	31°-34°				13.5 C	20.0 S	16.5 S	15.5 S	13.0 S	10.5 S	6.0 S	1.5 S	7.0 S	7.5 S	12.0 S	16.5 S	27.5 S	27.0 S	20.5 S	18.0 S			
		Q-6SD	15°				4.5 C	6.5 C	15.5 S	14.0 S	14.0 S	13.0 S	11.0 S	3.0 S	3.5 S	10.0 S	11.0 S	13.0 S	15.0 S	13.5 C	6.0 C	3.0 C			
		Q-1SD	(-1°)(+1°)				5.0 C	6.5 C	14.0 C	14.0 S	14.0 S	11.0 S	10.5 S	9.0 S	7.0 S	11.5 S	14.5 S	15.0 S	17.5 S	14.5 C	6.0 C	3.5 C			
		Q-5SD	(-14°)(-13°)				3.0 C	3.0 C	3.5 C	6.0 C	9.5 C	12.5 C	12.0 C	4.0 C	2.5 C	12.5 C	12.0 C	10.0 C	6.5 C	5.0 C	2.0 C	2.0 C			
		Q-4SD	(-30°)(-29°)				2.0 C	3.0 C	3.5 C	6.5 C	8.5 C	10.0 C	10.0 C	10.0 C	7.5 C	11.0 C	11.5 C	9.5 C	6.0 C	3.5 C	2.5 C	1.5 C			

* VALUES IN TABLE INDICATE PERCENT REDUCTION. LETTER FOLLOWING VALUE INDICATES TYPE OF FRACTURE: S = SHEAR, C = CLEAVAGE.

TABLE 7 SUMMARY OF 3-INCH WIDE PLATE RESULTS Page 1 of 3

Steel			Description of test plate					Temperature of Test °F.	Energy Absorbed to Maxim. Load in.-lb.	Yield Point Psi	Nominal Stress (Max.) Psi	Fracture Stress Psi	Type of Fracture % Shear
						Notch							
Code letter, type & Manufacturer	%C	%Mn	Type	Width in.	Thickness in.	Depth in.	Width in.						
A As rolled Carnegie-Illinois	0.25	0.47	Machined Edge	3	3/4	none	none	67	Not Recorded	38,200	64,500	55,200	100
								27		40,900	66,600	58,200	80
								9		37,100	65,000	56,100	37
								- 9		42,900	68,000	58,700	37
								-68		49,300	72,900	61,400	33
A As rolled Carnegie-Illinois	0.25	0.47	Sheared Edge	3	3/4	none	none	51	"	33,570	61,440	7,870	100
								41		32,010	59,720	5,770	100
								28		37,500	65,100	62,300	15
								7		38,300	65,900	65,900	1
A As rolled Carnegie-Illinois	0.25	0.47	Notched Edges	3	3/4	1/4	0.042	95	14,690	34,200	55,500	14,900	100
								80		35,590	57,380	19,125	100
								80		43,100	58,100	26,400	95
								71		42,300	60,200	27,800	95
								70		37,000	51,400	19,100	97
								62	13,600	37,070	56,760	19,200	100
								51		42,500	61,500	60,300	17
								45	13,570	37,490	57,920	50,280	29
								30		43,400	61,600	61,600	8
								21	15,180	38,600	59,700	59,700	4
								-15		45,900	66,000	66,000	6
B As rolled Bethlehem	0.18	0.72	Notched Edges	3	3/4	1/4	0.042	70		36,600	59,600	15,200	100
								49	21,800	37,220	60,800	19,810	100
								38		37,700	59,400	21,300	100
								36		38,200	65,200	17,500	92
								22		37,880	65,500	49,000	17
								20	16,790	36,100	60,000	53,300	16
								6		40,500	65,500	61,200	21
								0		40,800	65,800	65,800	6
								-19		38,700	65,800	65,400	12
								-25	22,850	39,950	66,730	66,730	4
B Normalized Bethlehem	0.18	0.72	Notched Edges	3	3/4	1/4	0.042	60		41,500	58,600	16,500	100
								38		41,800	60,500	25,600	92
								16	20,330	40,700	60,000	20,600	100
								5	16,580	41,205	60,600	19,180	100
								- 1		42,800	62,700	51,400	31
								-16		43,100	64,800	64,800	5
								-21	11,850	40,000	57,[illegible]	57,690	2
								-37	18,200	43,500	63,100	63,100	2
C As rolled Carnegie-Illinois	0.25	0.49	Machined Edges	3	3/4	none	none	106	Not Recorded	34,800	65,400	59,300	100
								76		35,800	66,000	58,500	100
								55		36,760	66,050	55,800	53
								37		38,600	68,900	61,600	48
								22		37,200	70,400	60,100	45
								-43	50,190	41,780	70,440	60,000	36
C As rolled Carneie-Illinois	0.25	0.49	Sheared Edge	2-1/2	3/4	none	none	152	Not Recorded	34,020	64,360	5,210	100
								135		34,710	63,750	4,150	100
								122		34,530	66,850	5,840	100
								119		38,490	64,990	64,990	2
								110		35,670	65,590	65,590	0
								100		35,510	60,180	60,180	0
								99		34,220	64,210	64,210	0
								98		34,950	66,380	8,705	100
								90		34,530	67,120	62,620	11
								74			65,900	65,900	0
								67		30,500	50,500	50,500	0
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges	3	1/2	1/4	0.042	94	Not Recorded	45,700	61,800	16,000	100
								81		47,200	63,400	21,600	100
								74		46,300	62,800	17,200	100
								54		48,700	65,000	19,200	100
								35		47,300	64,100	25,600	97
								25		49,600	66,500	66,500	8
								14		48,300	67,000	67,000	8
								1		50,100	67,500	67,500	8
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges	3	5/8	1/4	0.042	110	12,000	43,510	66,850	26,320	100
								102	10,100	42,500	62,800	21,300	94
								98	9,990	42,730	64,880	25,730	100
								89		41,600	63,500	35,600	98
								73		45,100	65,100	65,100	2
								60	10,220	44,250	65,880	65,880	6
								39		44,000	63,900	63,900	9
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges	3	3/4	1/4	0.042	149	Not Recorded	42,100	61,500	19,300	100
								129		42,100	63,500	33,400	95
								115	13,090	39,200	62,400	25,000	98
								107		40,700	62,200	32,800	97
								101	12,760	40,810	63,000	27,560	96
								91		40,200	61,900	44,800	40
								90	16,080	40,600	63,900	63,900	6
								87		40,700	63,800	63,800	15
								80	9,710	41,220	63,490	63,490	2
								75		41,600	65,200	65,200	8
								71	11,060	41,300	62,900	62,900	4
								61	10,050	41,500	65,400	65,400	2
								49		42,500	64,400	64,400	6
								34		42,900	64,900	64,900	4

TABLE 7 SUMMARY OF 3 INCH WIDE PLATE RESULTS Page 2 of 3

Steel			Description of Test Plates					Temper. of Test °F.	Energy Absorbed to Maxim. Load in-lb.	Yield Point Psi	Nominal Stress (max.) Psi	Fracture Stress Psi	Type of Fracture % Shear
Code letter, type and Manufacturer	%C	%Mn	Type	Width in.	Thickness in	Notch Depth in.	Notch Width in.						
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges	3	1	1/4	0.042	159	Not Recorded	40,960	64,400	36,000	100
								146		39,200	62,800	39,500	94
								142		40,800	61,800	33,600	96
								137		36,800	60,400	60,400	22
								135	16,100	36,640	62,080	62,080	21
								122	18,400	37,600	62,000	61,500	16
								100		42,400	57,800	57,800	11
								80	3,810	38,890	49,960	49,960	0
								41		42,400	63,500	63,500	4
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges	3	1 1/8	1/4	0.042	161		34,600	62,500	45,800	100
								151		38,200	56,100	29,000	94
								139		39,100	57,200	29,800	92
								135		39,600	58,200	32,900	93
								127	17,000	34,300	58,100	34,600	98
								118		40,000	59,300	59,300	11
								111	20,554	35,140	59,460	59,460	11
								77		38,900	55,800	55,800	0
C As rolled Carnegie-Illinois	0.25	0.49	Center Notched	3	3/4	1/2	0.042	111	12,000	38,640	62,490	18,110	100
								89	11,700	44,230	72,040	16,925	100
								70	11,800	43,760	70,490	70,490	8
								60	12,975	41,000	66,000	55,000	6
C As rolled Carnegie-Illinois	0.25	0.49	Center Notched	3	1 1/8	1/2	0.042	139		38,800	61,500	26,200	100
								100	18,860	40,000	63,800	24,700	100
								89	19,320	39,160	64,690	61,400	14
								74	21,500	40,400	64,500	63,800	7
								60	21,810	41,380	66,030	66,030	4
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges, Machined from 1-1/8 stock	3	1/2	1/4	0.042	110	9,000	33,840	57,860	19,680	100
								93	9,000	33,280	59,360	15,200	100
								75	8,200	33,600	59,520	59,520	2
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges, Machined from 1-1/8 stock	3	5/8	1/4	0.042	130	10,900	32,600	59,200	22,300	100
								118	11,500	30,860	58,030	16,825	100
								111	11,160	33,000	56,700	40,700	38
								105	12,220	31,480	60,000	60,000	9
								98	10,550	31,930	58,710	57,420	8
								90	11,770	32,900	58,700	58,500	9
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges, Mashined from 1-1/8 stock	3	3/4	1/4	0.042	151	9,000	32,800	58,500	28,800	100
								140	13,170	30,670	59,630	17,070	100
								132	13,660	31,730	59,310	20,210	96
								123	14,620	31,610	58,630	20,790	100
								121	11,180	31,900	57,800	27,200	96
								102	17,350	31,130	59,360	58,150	19
								91	11,640	33,600	59,980	59,980	3
								83	16,180	32,550	60,440	58,100	12
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges, Machined from 1-1/8 stock	3	1	1/4	0.042	160	14,020	34,460	58,370	29,460	92
								142	14,640	33,800	57,600	56,500	22
								130	15,240	33,500	59,600	49,300	15
								105	14,800	33,900	59,900	59,900	2
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges	2	1/2	5/32	0.027	63	4,470	48,900	67,800	50,600	100
								55	10,080	49,100	64,700		100
								40	5,015	49,900	67,400	30,000	100
								33	6,430	50,100	68,000	68,000	3
								25	4,770	47,900	68,000	68,000	5
								10	5,900	49,100	69,100	69,100	5
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges	2 1/2	5/8	7/32	0.034	106	7,520	42,290	64,070	33,440	97
								93	8,640	44,770	66,920	23,080	100
								80	5,300	44,580	64,730	64,730	1
								66	7,360	45,410	67,420	67,420	0
								55	3,970	44,600	61,220	61,220	1
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges	4	1	5/16	0.058	170	16,390	35,740	57,980	28,400	95
								161	13,920	36,150	60,180	34,190	95
								153	14,030	37,020	59,740	50,330	29
								152	21,860	36,690	61,020	47,400	21
								145	17,250	36,300	58,010	40,360	51
								134	19,310		61,200	61,110	3
								120	13,300	36,600	57,060	57,060	2

TABLE 7 SUMMARY OF 3 INCH WIDE PLATE RESULTS

Steel			Description of Test Plates			Notch		Temper. of Test oF.	Energy Absorbed to Maxim. Load in-lb	Yield Point Psi	Nominal Stress (max.) Psi	Fracture Stress Psi	Type of Fracture % Shear
Code letter, type and Manufacturer	%C	%Mn	Type	Width in.	Thickness in.	Depth in.	Width in.						
C As rolled Carnegie-Illinois	0.25	0.49	Notched Edges	4-1/2	1-1/8	13/32	0.068	151	27,460	33,210	58,620	29,760	98
								139	35,470		56,190	23,920	94
								131	26,350	33,570	55,640	26,860	95
								125	24,790	33,630	56,100	56,100	3
								119	24,540		57,790	57,790	4
								109	28,410	33,509	57,560	57,560	3
D Normalized Lukens	0.19	0.52	Notched Edges	3	3/4	1/4	0.042	66		43,500	65,000	21,200	100
								58		44,700	64,000	21,000	100
								47		41,000	64,500	22,700	100
								36	15,770	37,310	59,100	28,260	97
								28		40,000	63,400	63,400	6
								15	21,750	41,550	65,890	65,470	7
								0	17,160	43,700	67,500	43,500	39
								- 20	19,800	45,230	69,760	69,760	7
E As rolled Lukens	0.23	0.39	Notched Edges	3	3/4	1/4	0.042	160	7,680	34,330	53,950	21,800	100
								151		36,000	55,600	24,700	96
								141	10,740	35,560	56,060	32,340	100
								132	9,520	35,400	53,430	24,860	100
								128	12,160	35,675	56,430	29,730	100
								128		36,300	56,200	56,200	21
								110		35,400	56,500	56,500	13
								90		37,200	57,300	57,300	9
								67		37,700	56,300	56,300	3
								44		39,300	59,700	59,700	2
E As rolled Lukens	0.23	0.39	Sheared Edge	3	3/4	none	none	82		38,400	60,100	6,390	100
								65		31,900	57,100	7,990	100
								53		35,800	62,900	47,800	24
								47		34,880	49,760	49,760	0
								39		33,500	63,200	54,000	8
H As rolled Bethlehem	0.16	0.85	Notched Edges	3	3/4	1/4	0.042	55		41,100	65,300	19,750	100
								71	18,960	41,080	65,180	20,270	100
								40	19,630	41,610	66,200	25,160	88
								33	15,630	42,820	66,960	64,080	14
								32	12,850	42,180	65,100	65,100	3
								25	18,030	42,550	67,950	58,150	19
								20	18,370	42,550	67,500	53,500	25
								15	20,910	42,530	68,120	53,330	30
								1	20,210	43,400	70,600	68,500	15
								- 11	20,200	42,820	70,120	69,200	12
								- 19	18,640	43,640	69,440	64,420	18
								- 33	15,220	44,440	68,280	68,280	1
								-50		45,100	66,800	66,800	3
H As rolled Bethlehem	0.16	0.85	Sheared Edge	3	3/4	none	none	55		40,000	66,950	1,600	100
								28		40,450	67,450	540	100
								23		38,770	67,100	50,620	27
								4			67,080	1,070	100
								- 9		40,000	67,750		2
								- 20		39,470	67,110	67,110	0
								20		42,100	65,900	3,800	100
N As rolled Lukens Nickel Alloy	0.13	0.49	Notched Edges	3	3/4	1/4	0.042	29		63,000	79,500	44,700	96
								24	19,500	66,060	79,500	29,440	96
								16		64,400	81,900	79,200	12
								1		64,900	83,200	83,200	6
								- 6		65,000	85,500	84,300	8
								- 19	22,200	69,850	85,400	57,100	96
								- 20	16,410	69,540	84,080	49,310	98
								- 39	19,690	68,690	84,800	29,330	96
								- 39		64,000	83,500	83,500	4
								- 63	17,500	71,850	84,660	46,560	96
Q Quenched and Drawn Republic	0.23	1.05	Notched Edges	3	3/4	1/4	0.042	57	18,120	64,320	81,180	36,040	96
								50	18,520	56,720	78,720	33,510	100
								42		62,200	80,900	76,600	26
								40	22,430	62,160	79,370	34,590	100
								34	15,925	60,000	79,130	79,130	4
								31	19,765	63,800	81,130	42,870	4
								30	20,680	58,900	78,170	75,690	2
								29		67,600	80,300	31,800	100
								16		65,300	80,500	80,500	4
								1	13,080	67,920	82,960	82,960	3
								- 2		68,700	83,500	82,300	9
								- 13		69,400	82,800	82,400	10
								- 37	15,560	64,000	83,570	83,570	3

TABLE 8 - COMPARISON OF ESTIMATED TRANSITION TEMPERATURES FOR THE VARIOUS TYPES OF SPECIMENS USED IN THE INVESTIGATION, °F.

Steel Code Letter	Charpy Bars		3-in. Tension		Notched Flat Plate Specimens				
	Long.	Trans.	Edge Notched	Sheared Edge	12-in	24-in.	48-in.	72-in.	108-in
A	17	20	45	35	25	-7 to 37	below 48^b	35	---
B_{ar}	0	-8	5	---	5	below 32^a	9 to 45	33	below 32^a
B_n	-17	-8	-5	---	15	below 32	---	31	---
C	22	20	90	120	90	about 88	80 to 100	90	above 32
H	-10	-10	about 20	10	-15	---	---	20	---
N	-120^c	-170^c	---	---	-64	---	---	-45	---
Q	-60	-80	35	---	10	---	---	---	---
QS	---	---	---	---	-5	---	---	---	---

a.- Coldest test at 32°F, resulted in 100 percent shear.
b.- Coldest test at 48°F, resulted in 100 percent shear.
c.- No definite transition temperature.

Note: Transition temperatures for Charpy bars were taken as a point corresponding to a temperature halfway between the maximum and the minimum energy values in Fig. 7 for the particular steel.

Transition temperatures for the 12-in. and 72-in. wide specimens were taken as the value of temperature corresponding to an energy value on the steeply sloping part of the energy-temperature curve approximately one-half way between the maximum and minimum in Figs. 8, 9 and 10.

Transition temperatures for 3-in. wide specimens were taken as the temperature corresponding to a point halfway between a 0 percent and a 100 percent shear fracture in Fig. 13 for the particular steel.

TABLE 9. -- REDUCTIONS IN THICKNESS OF PLATE OBTAINED FROM SAMPLES OF FRACTURED PLATES OF SHIPS THAT FAILED IN SERVICE

Ship	Distance in from Fractured Surface, inches	Percent Reduction in Thickness Measured at Several Locations Along Fracture						
		1	2	3	4	5	6	7
S.S. Sea Bass	0	3.16	2.93	3.09	2.61	----	----	----
	1/16	2.45	2.37	2.29	1.82	----	----	----
	1/8	1.11	1.11	1.27	0.79	----	----	----
	1/4	0.32	0.55	0.40	0.47	----	----	----
	1/2	0.08	0.08	0.24	0.00	----	----	----
	3/4	0.08	0.00	0.00	0.00	----	----	----
S.S. Russell H. Chittenden	0	0.29	1.45	3.48	3.19	2.03	1.16	2.03
	1/16	0.29	0.58	2.61	2.32	2.03	0.87	1.74
	1/8	0.00	0.29	1.45	1.45	2.03	0.87	1.16
	1/4	0.00	0.00	1.16	1.16	1.74	0.58	0.87
	1/2	0.00	0.00	0.87	0.87	1.16	0.58	0.58
	3/4	----	----	0.29	----	----	----	0.29
S.S. James Gunn	0	2.33	2.04	0.58				
	1/16	1.46	0.58	0.00				
	1/8	0.29	0.29	0.00				
	1/4	0.29	0.00	0.00				
	1/2	0.00	0.00	0.00				
	3/4	0.00	0.00	0.00				

All above values were obtained at or near fractures of cleavage type.

TABLE 10 - RECORD OF LOADS AT WHICH CRACKS STARTED
DURING TESTS OF LARGE FLAT PLATES

Specimen Number	Development of Crack			Max. Nominal Stress ksi	Break % Shear
	Temp. °F.	Load, Kips	Nominal Stress ksi		
A3A	49	1320	32.6	40.3	100
A4A	10	1300	32.1	35.8	0
A5A	45	1400	34.6	40.0	90
A1B	68	910	33.7	40.7	100
A3B	48	950	35.2	41.1	100
A3C	-6	505	37.4	38.1	0
A3D	50	250	38.0	48.1	100
A5D	-8	220	32.6	39.9	0
B-108	32	1750	28.8	36.7	100
B7A	9	1250	30.8	34.6	0
B8A	16	1150	28.4	33.3	0
B6B	45	900	33.3	42.6	100
B5D	50	240	35.6	45.9	100
B6D	50	325	48.1	49.3	100
B7D	-34	270	40.0	40.0	0
B9D	-7	240	35.6	41.8	0
B10D	12	265	39.3	48.7	87
C-108	32	1900	31.4	38.4	0
C4A	81	1320	32.6	35.7	0
C5A	152	1350	33.3	43.0	98
C1D	32	257	38.1	40.0	0
C3D	101	270	40.0	51.1	51
C5D	143	275	40.8	54.7	91
C51XD	121	290	43.0	48.7	100
C52XD	90	270	40.0	46.6	10
H1A	68	1640	40.5	44.7	82
H2A	25	1500	37.0	45.6	88
H4A	-18	1450	35.8	39.0	0
N1A	-53	1650	40.7	64.2	4
N2A	-32	2250	55.5	60.9	13
N3A	2	2000	49.4	59.8	73
N1D	-29	385	55.6	69.3	84
N2D	-60	435	64.4	75.9	6
N3D	72	360	53.3	66.4	100
N41XD	-45	430	63.7	69.9	81
Q2D	134	390	57.8	61.0	100
Q12XD	86	385	57.0	60.7	100

TABLE B1 -- SUMMARY OF TEST RESULTS - 20-IN. DIAMETER TUBES

Specimen	Stress Ratio,[a] T/L	Loading Conditions	Test Temp. °F.	Heat Treatment (1100°F)	Conventional Stress psi.[i] Longitudinal	Conventional Stress psi.[i] Transverse	Nominal Stress,[b] psi. Prop. Limit	Nominal Stress,[b] psi. Ultimate	Average True Stress at Fracture,[c] psi. Long.	Average True Stress at Fracture,[c] psi. Trans.	Maximum Percent Elongation in 5 in. Long.	Maximum Percent Elongation in 5 in. Trans.	Reduction in Wall Thickness, %	Potential Energy at Fracture, ft.-lb.[h]	Nature of Fracture
A	2	Internal Pressure	70	Before Welding	26,250	52,500	30,000	59,000	42,500	85,000	1	15.0[j]	30.0	133,000	Initiated by shear in plate about 4 in. from and parallel to weld near midsection; after shearing for about 5 in., crack propagated over considerable length of tube by cleavage.
H	2	"	70	After Welding	24,900	49,800	30,000	62,000	45,000	90,000	1	21.0[j]	32.0	148,500	Practically same as for tube A.
B[d]	2	"	-42	Before Welding	25,650	51,300	40,000	54,000	30,000[e]	60,000[e]	0.2	3.0	3.0	110,000	Cleavage fracture entirely around circumferential end weld.
C[d]	1	Axial load, int.press.	70	Before Welding	55,100	51,300	30,000	55,000	60,000[e]	59,500[e]	4.4	4.4	9.0	109,500	Shear for 6 in. (premature);[f] after repair by welding, shear for 4 in., then cleavage.[g]
D[d]	1	"	70	"	56,800	53,100	30,000	56,500	60,500[e]	56,000[e]	3.5	4.0	7.5	102,000	Cleavage fracture originating in weld about 48 in. from mid-section and propagating spirally around tube.
E	1	"	70	"	56,800	51,000	30,000	61,500	69,000	72,000	9.2	10.6	20.0	143,000	Cleavage fracture originating in weld 2 in. from mid-section and propagating completely around tube. No shattering.
F	1	"	-44	Before Welding	45,400	44,500	40,000	44,500	45,500	45,500	1.6	2.0	3.5	86,500	Cleavage fracture originating in weld 24 in. from mid-section. Specimen shattered into many pieces.
I	1	"	-39	Before and after Welding	62,500	51,400	40,000	65,000	85,500	88,500	17.4	18.7	31.0	201,000	Cleavage fracture originating in weld 4 in. from mid-section. Specimen shattered into many pieces.
J	1	"	-38	None	59,700	59,300	25,000	59,000	61,000	64,500	3.0	3.0	6.7	160,500	Cleavage fracture originating in weld 28 in. from mid-section. Specimen shattered into many pieces.
G	1/2	Axial load, int. press.	-44	Before Welding	50,800	24,700	42,000	49,500	50,000	25,000	2.0	0.3	2.0	38,000	Cleavage fracture originating at defect in plate 90° from weld 44 in. from mid-section and propagating around specimen. No shattering.
O[k]	1	Axial load, int. press.	-40	Before Welding	48,760	48,600	34,000	50,000	49,100	50,600	4.2	3.8	**6.0**	98,000	**Cleavage fracture originating at longitudinal weld 22-in. from mid-section proceeding along the heat affected zone parallel to the weld and then around the tube at both ends.**
L	1	Axial load, int. press.	-42	Before and after welding	58,500	54,300	37,000	56,000	62,000	59,900	5.7	6.3	**10.8**	205,000	**Cleavage fracture originating near top of the tube at the defect in the plate propagating around upper portion and downward parallel to the weld. Specimen shattered into many pieces.**

[a] - T = circumferential stress; L = longitudinal stress.

[b] - Nominal stress computed on basis of original wall thickness but with respect to greatest diameter obtained at the designated load condition.

[c] - Computed as load on a given section divided by actual cross-sectional area, except as noted in footnote e for specimens failing prematurely. Underlined values indicate direction of stress presumed to govern failure.

[d] - Failure occurred at or near ends or end connections, presumably due to high complex stresses caused by bending induced by end restraint. However, results are significant in that they indicate average stress levels attained before localized conditions caused failure.

[e] - Values given are those for mid-section of tube at instant of failure.

[f] - Shear fracture 6 in. long, crossing longitudinal weld at 1/8 in. from circumferential end weld. Fracture started inside of tube, in circumferential weld.

[g] - Fracture 4 in. long (apparently shear) at root of circumferential weld, starting about 8 in. from nearest longitudinal weld; then cleavage fracture extending completely around specimen at angle of about 70° from axis.

[h] - Compression energy in liquid and concrete plugs, and elastic energy in specimen.

[i] - Computed on basis of original diameter and original thickness.

[k] - Welded with **MRC-2A electrodes.**

[j] - Computed from thickness measurements at 1/2 in. intervals over 5 in. length across fracture at point of origin.

TABLE D-1

SUMMARY OF RESULTS OF TESTS ON GEOMETRICALLY-SIMILAR SPECIMENS

Note: All specimens made from a single annealed plate containing 25% carbon

Size Inches	Temp. of Test °F.	Type of Fracture	Stress at formation of first crack Ksi	Nominal Stress at Max. Load Ksi	Reduction in Thickness %	
					Maximum	Minimum
3-in. wide 9-in. long 0.180" thick	75	100% Shear	40.3	45.7	29.8	19.8
	75	100% Shear	42.5	45.7	28.4	20.0
	32 *	100% Shear	x	45.2	26.7	15.6
	0 *	100% Shear	x	47.9	30.0	18.9
	-20	94% Shear	x	45.2	25.1	17.3
	-30	1% Shear	x	47.2	21.0	0
	-40	0% Shear	x	50.3	26.2	1.2
6-in. wide 18-in. long 0.360" thick	90 *	100% Shear	x	44.4	25.6	17.7
	70	100% Shear	37.5	44.5	25.7	15.1
	68	100% Shear	37.5	42.8	20.5	6.9
	50 *	Shear and Cleavage	x	44.2	23.1	7.8
	32 *	0% Shear	x	45.5	22.3	9.0
12-in.wide 36-in.long 0.720" thick	125	60% Shear	32.3	34.4	19.5	2.9
	102 *	0% Shear	x	39.1	19.7	1.7
	70 *	0% Shear	xx	35.2	14.8	0.9
	70	0% Shear	27.5	39.9	17.9	1.4
	32 *	0% Shear	x	40.9	16.2	1.4

* Test results reported in previous report (Bibliography 2)
x Observations not possible in these tests because of type of temperature control housing used.
xx Not observed

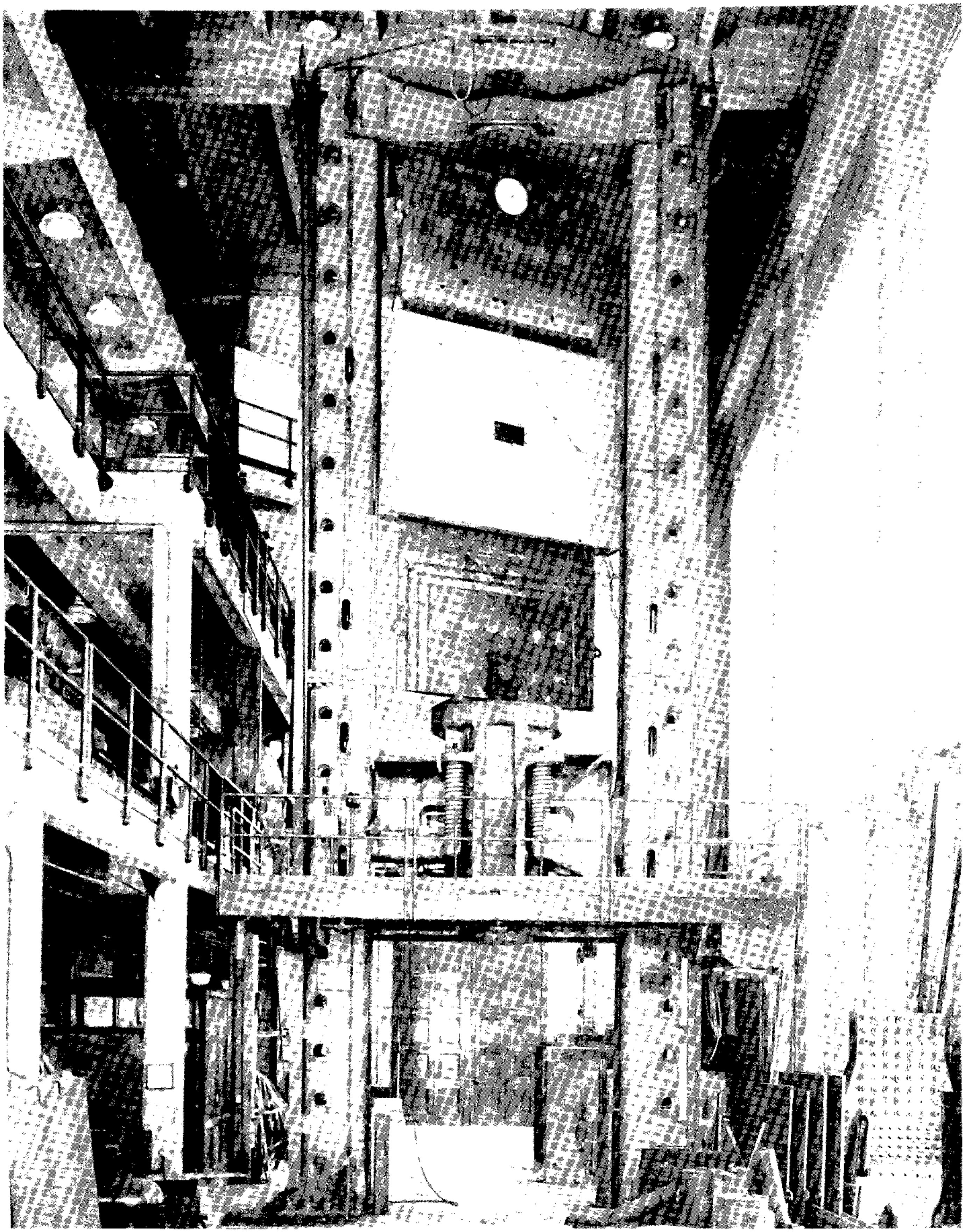


FIG. I VIEW OF 108-INCH SPECIMEN READY FOR TESTING AT 32 °F

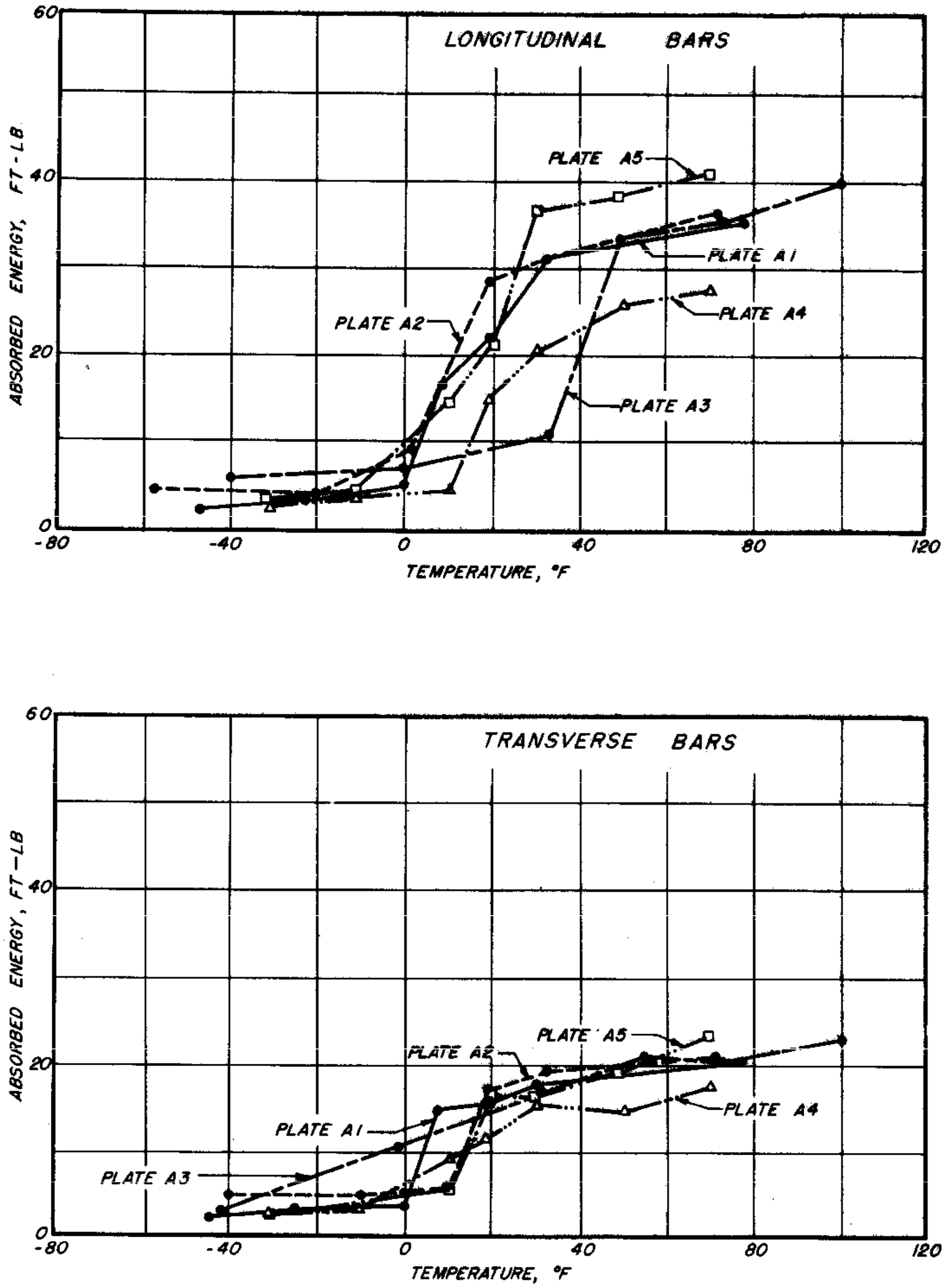


FIG. 2 — RESULTS OF CHARPY IMPACT TESTS — STEEL A.

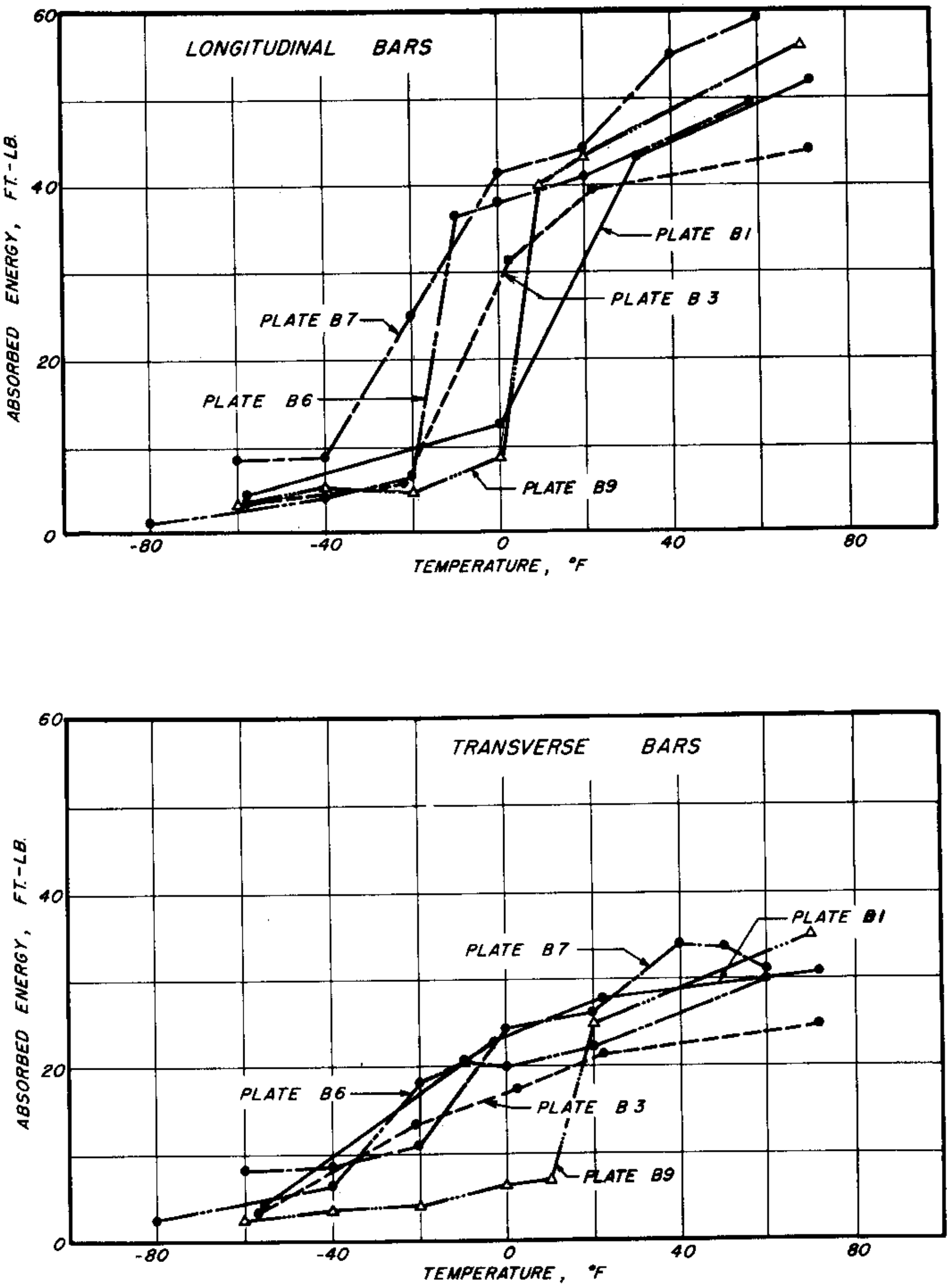


FIG. 3 - RESULTS OF CHARPY IMPACT TESTS - STEEL B IN THE AS-ROLLED CONDITION.

DWG. 44E35

FIG. 3

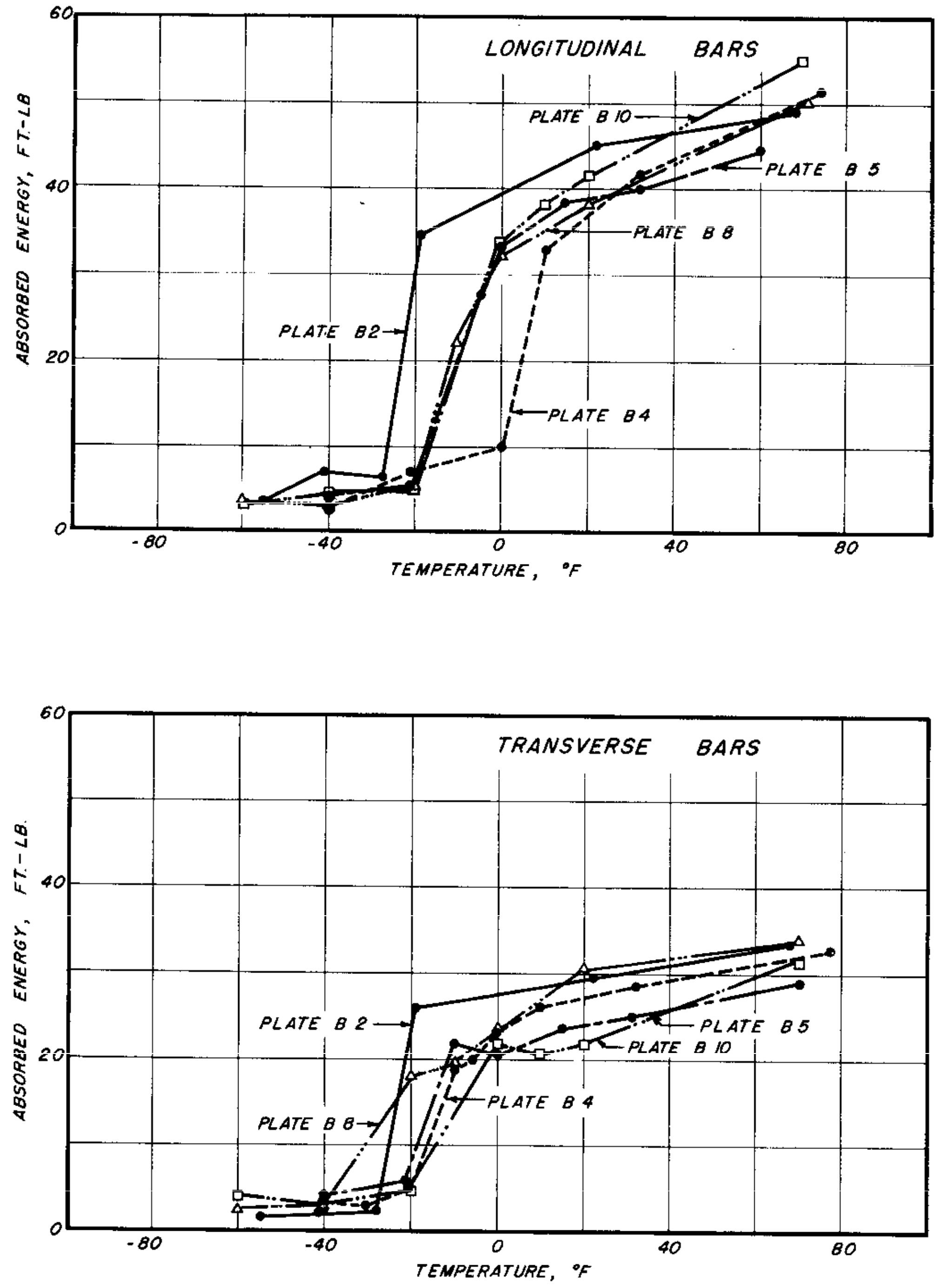


FIG. 4 - RESULTS OF CHARPY IMPACT TESTS - STEEL B IN THE NORMIALIZED CONDITION.

DWG. 44E33

FIG. 4

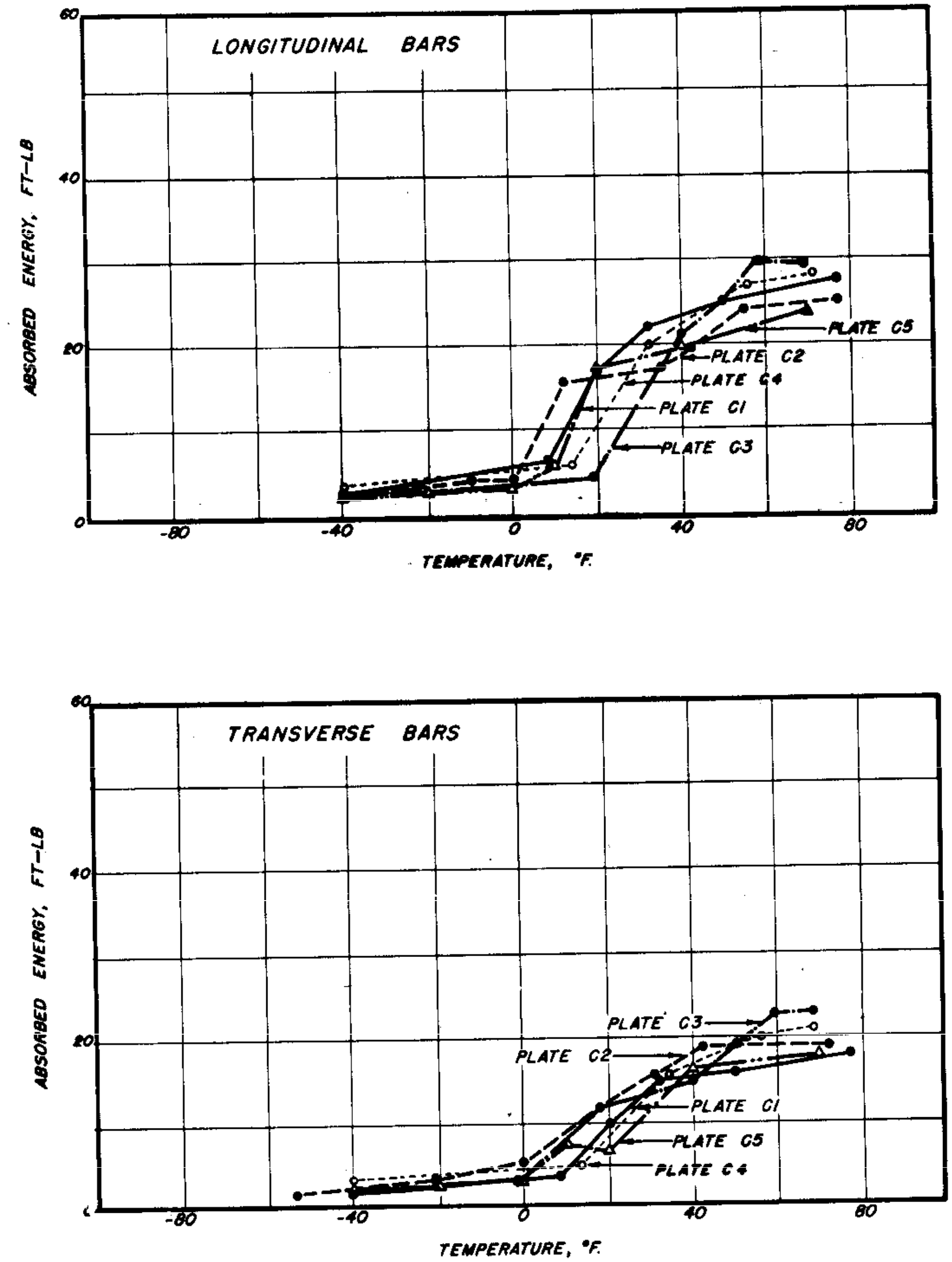
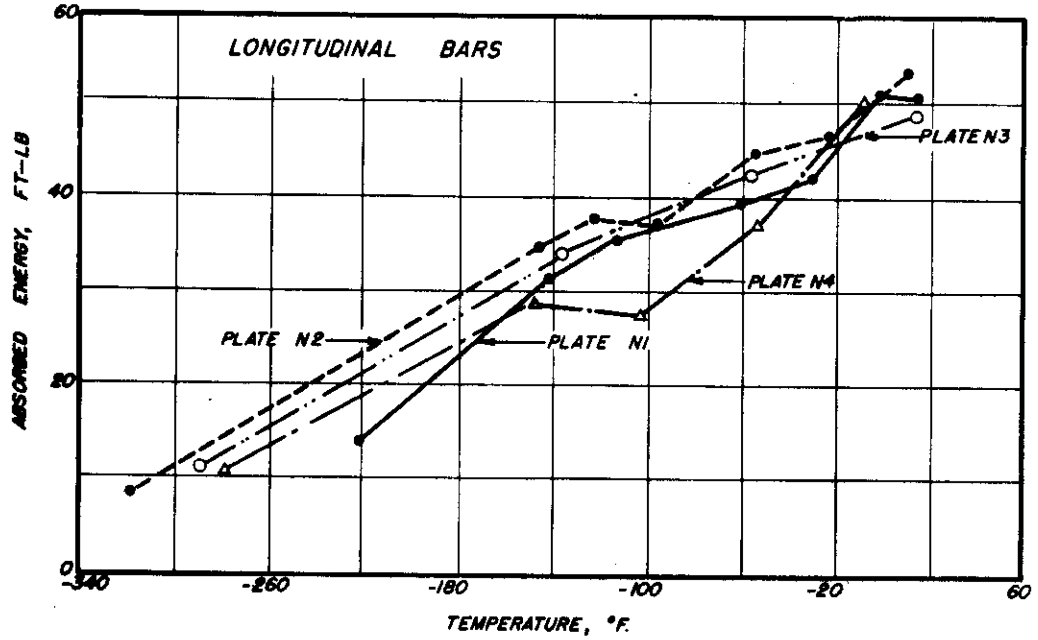


FIG. 5 – RESULTS OF CHARPY IMPACT TESTS – STEEL C

DWG. 44E34

FIG. 5



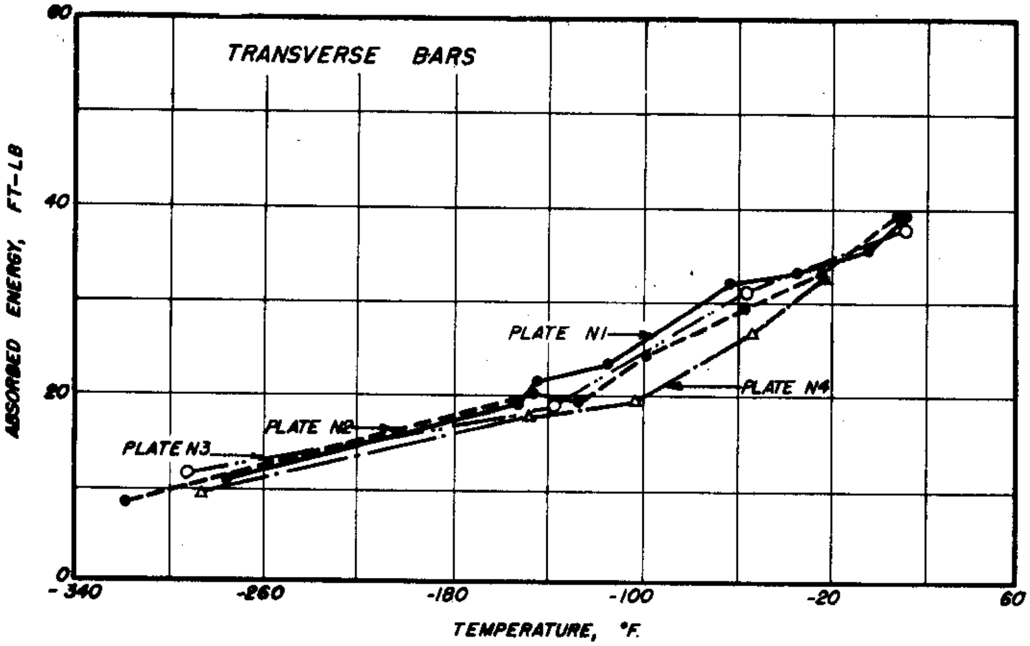


FIG. 6 – RESULTS OF CHARPY IMPACT TESTS – STEEL N

DWG. 44E83

FIG. 6

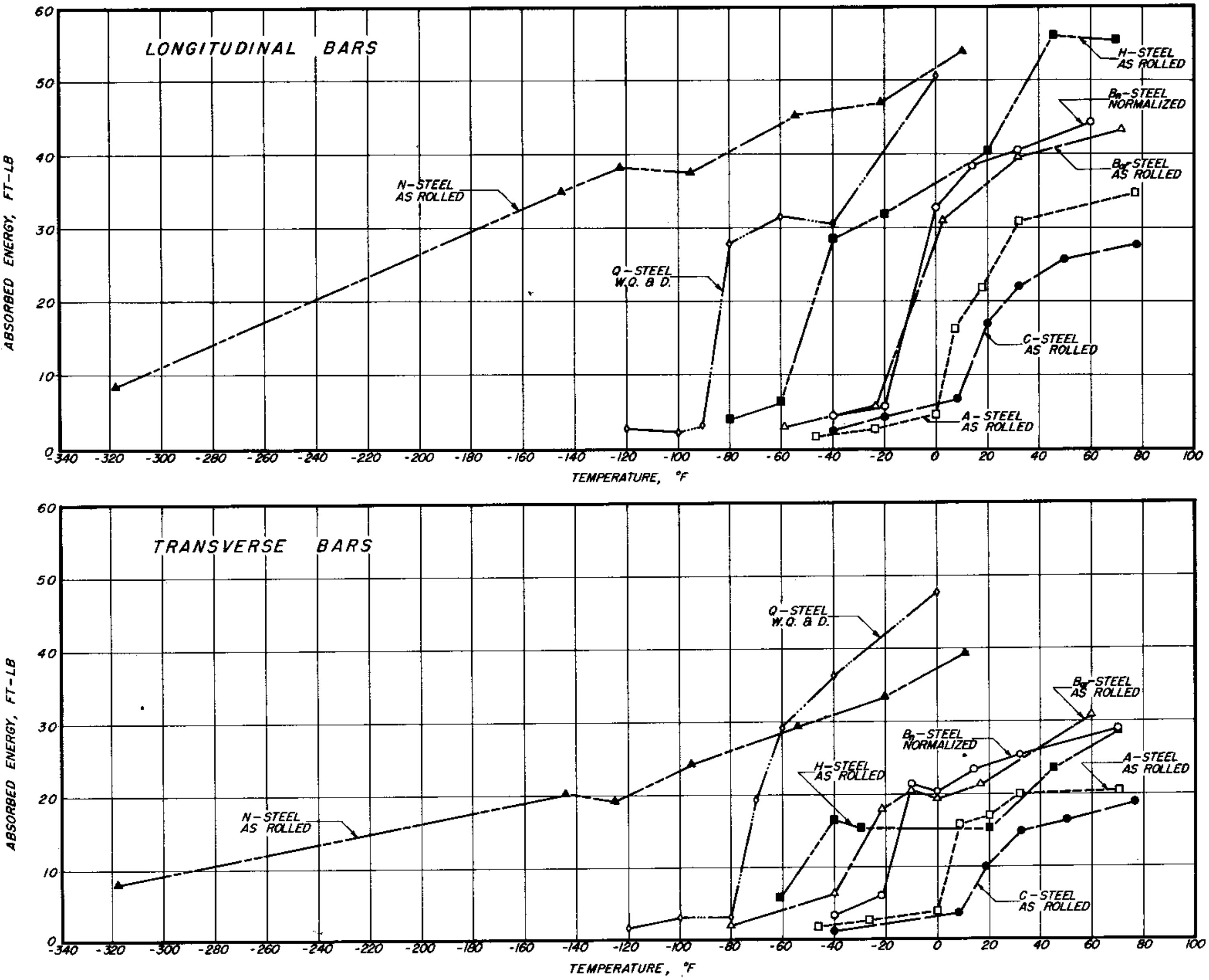


FIG. 7 - COMPARISON OF RESULTS OF CHARPY IMPACT TESTS FOR STEELS A,B,C,H,N AND Q

DIAGRAMS SELECTED TO REPRESENT TYPICAL RESULTS FOR EACH STEEL

FIG 7

DWG. 44E264

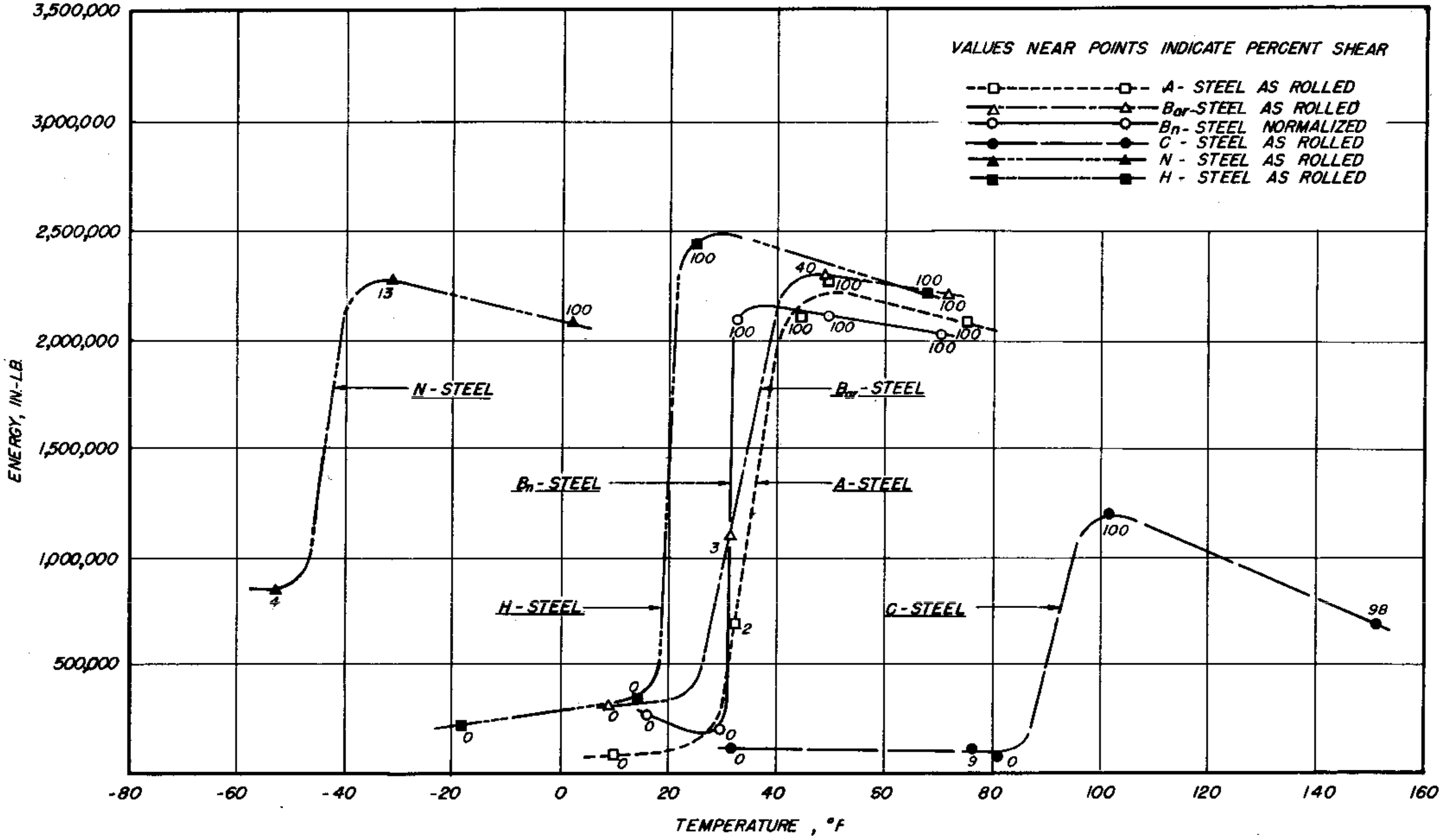


FIGURE 8 —— VARIATION WITH TEMPERATURE OF ENERGY TO MAXIMUM LOAD FOR 72-INCH WIDE SPECIMENS

FIG. 8

DWG. 44E62

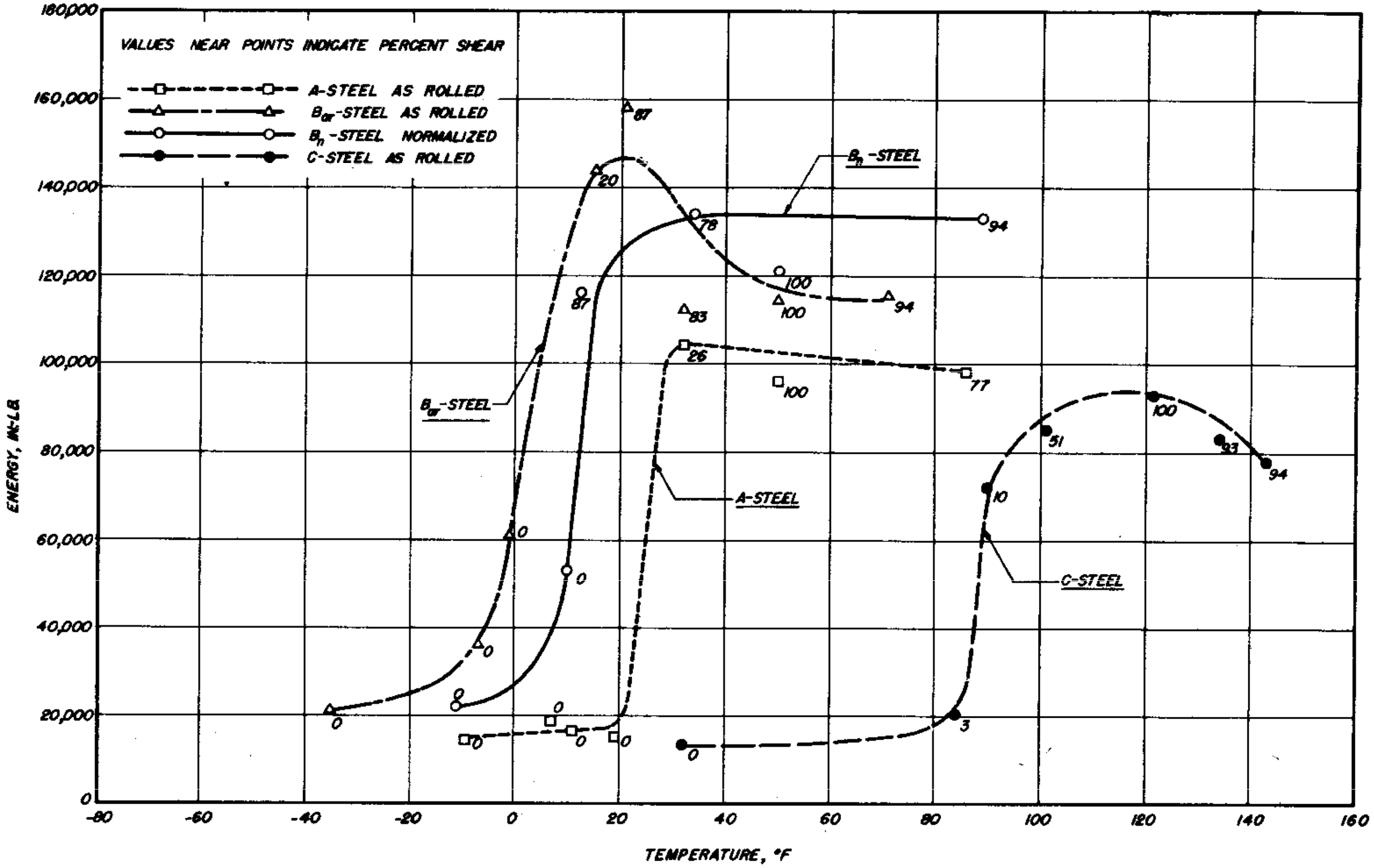


FIGURE 9 — VARIATION WITH TEMPERATURE OF ENERGY TO MAXIMUM LOAD FOR 12-INCH WIDE SPECIMENS SEMI-KILLED STEELS

FIG. 9

DWG. 44E65

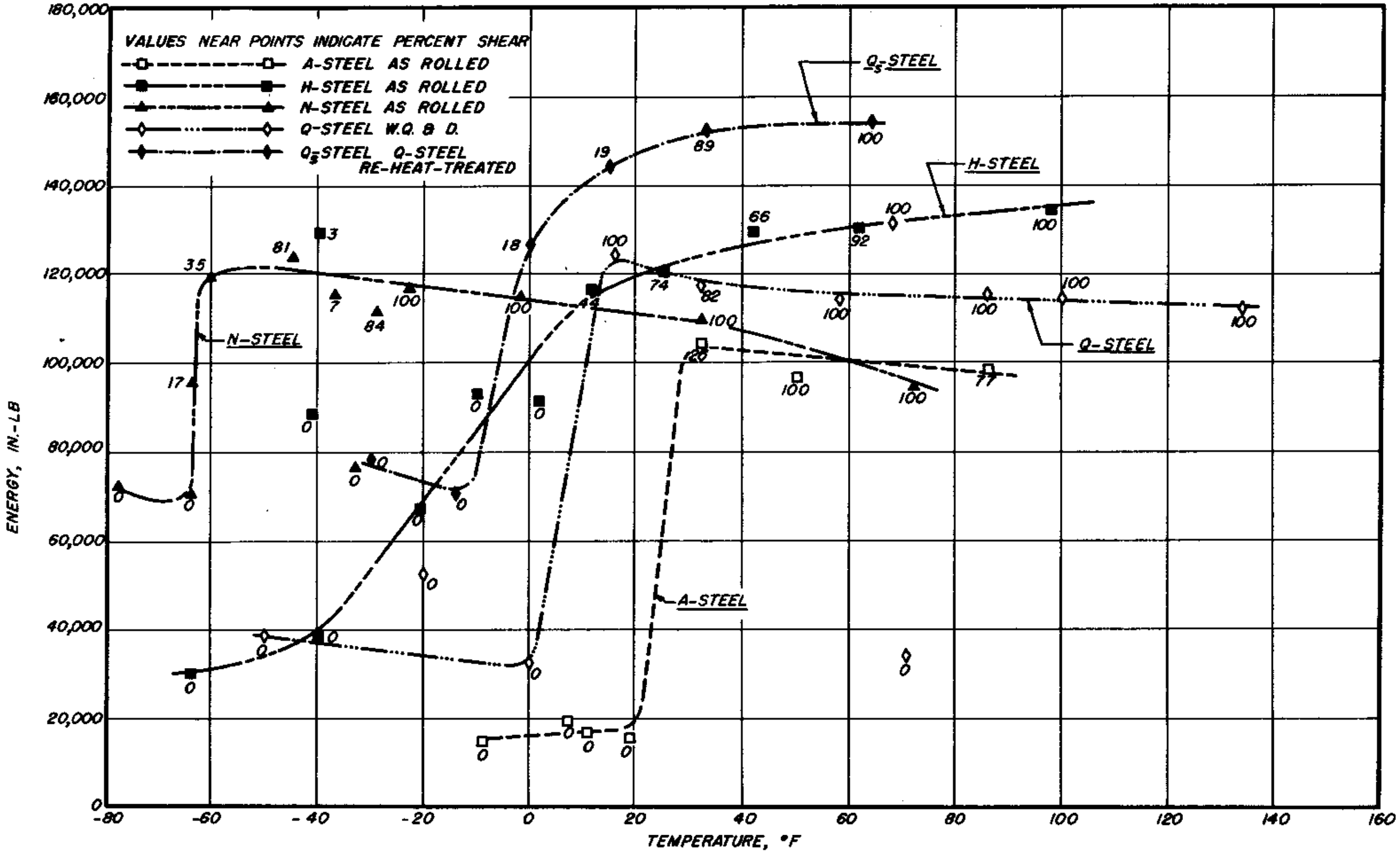


FIGURE 10. — VARIATION WITH TEMPERATURE OF ENERGY TO MAXIMUM LOAD FOR 12-INCH WIDE SPECIMENS, SPECIAL STEELS

FIG. 10

DWG. 44E65-1

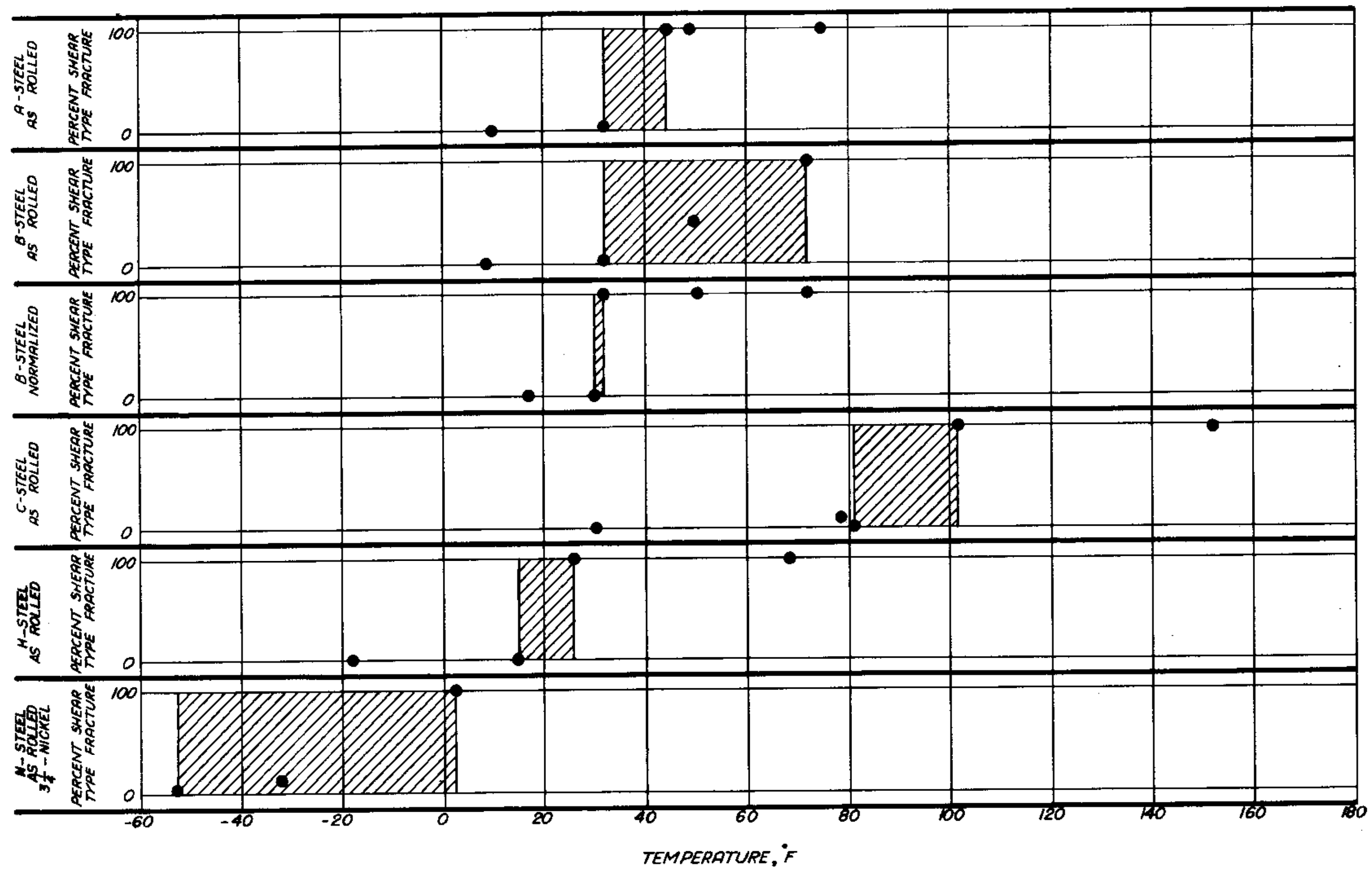


FIG. 11 - TRANSITION TEMPERATURE RANGE, 72-INCH WIDE SPECIMENS

FIG. 11

DWG. 44E66

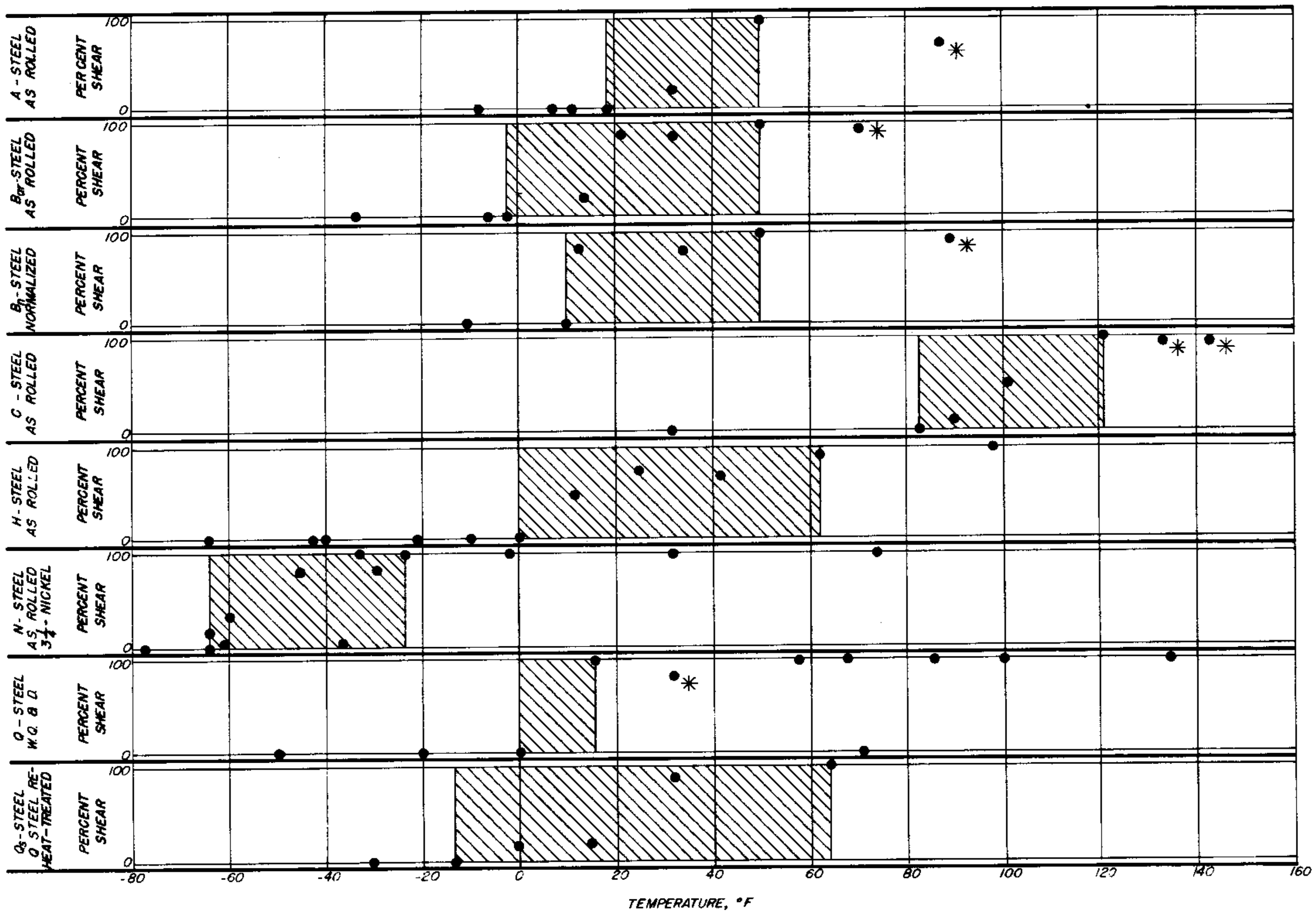


FIG. 12 - TRANSITION TEMPERATURE RANGE 12-INCH WIDE SPECIMENS

✳ — SPECIMENS SHOW SIGNS OF TEARING ACTION OCCURING AT ONE EDGE OF PLATE

FIG. 12

44E69

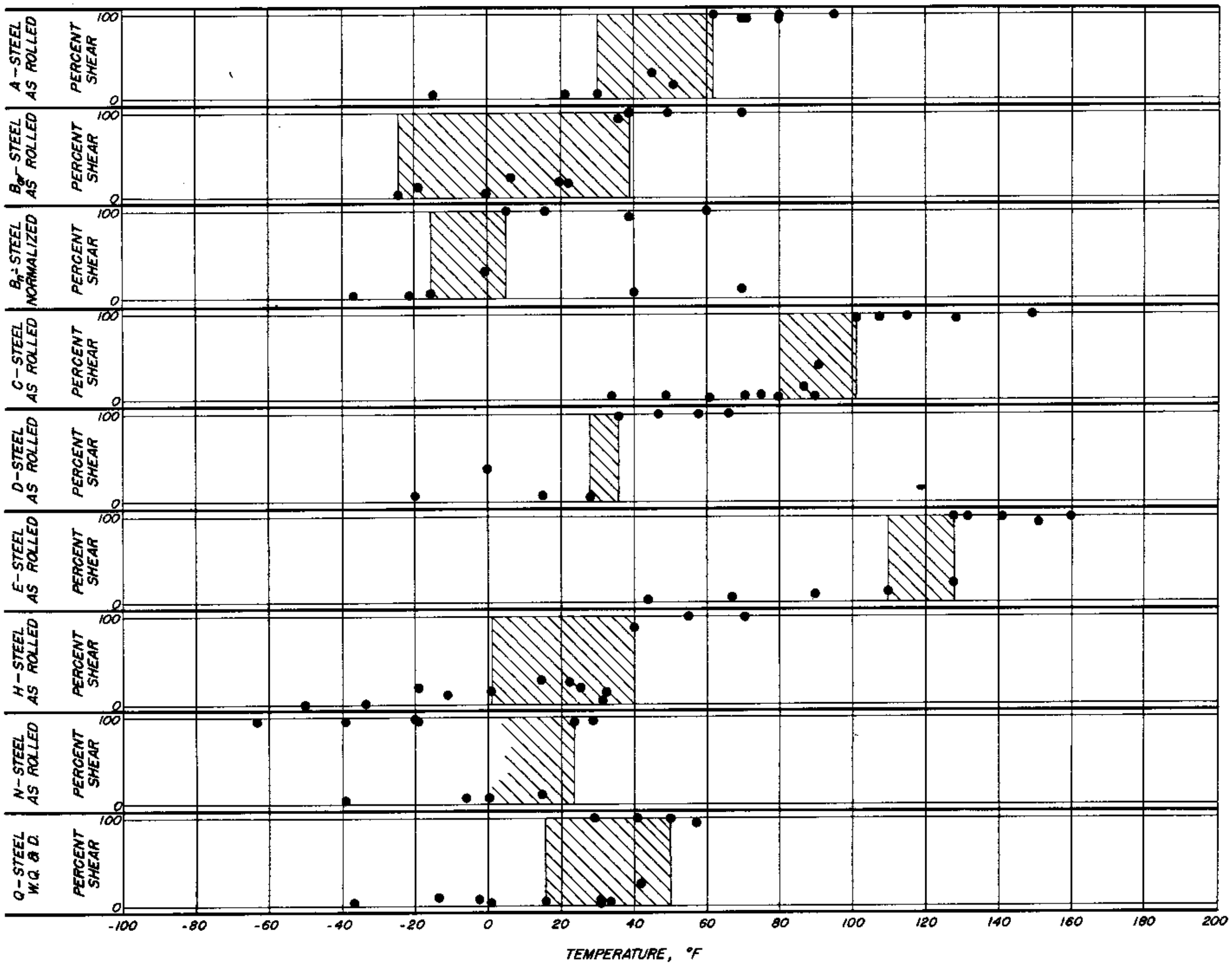


FIG. 13 - TRANSITION TEMPERATURE RANGE 3-INCH WIDE EDGE NOTCHED SPECIMENS $\frac{3}{4}$ - INCH THICK

FIG.13

DWG. 44E266

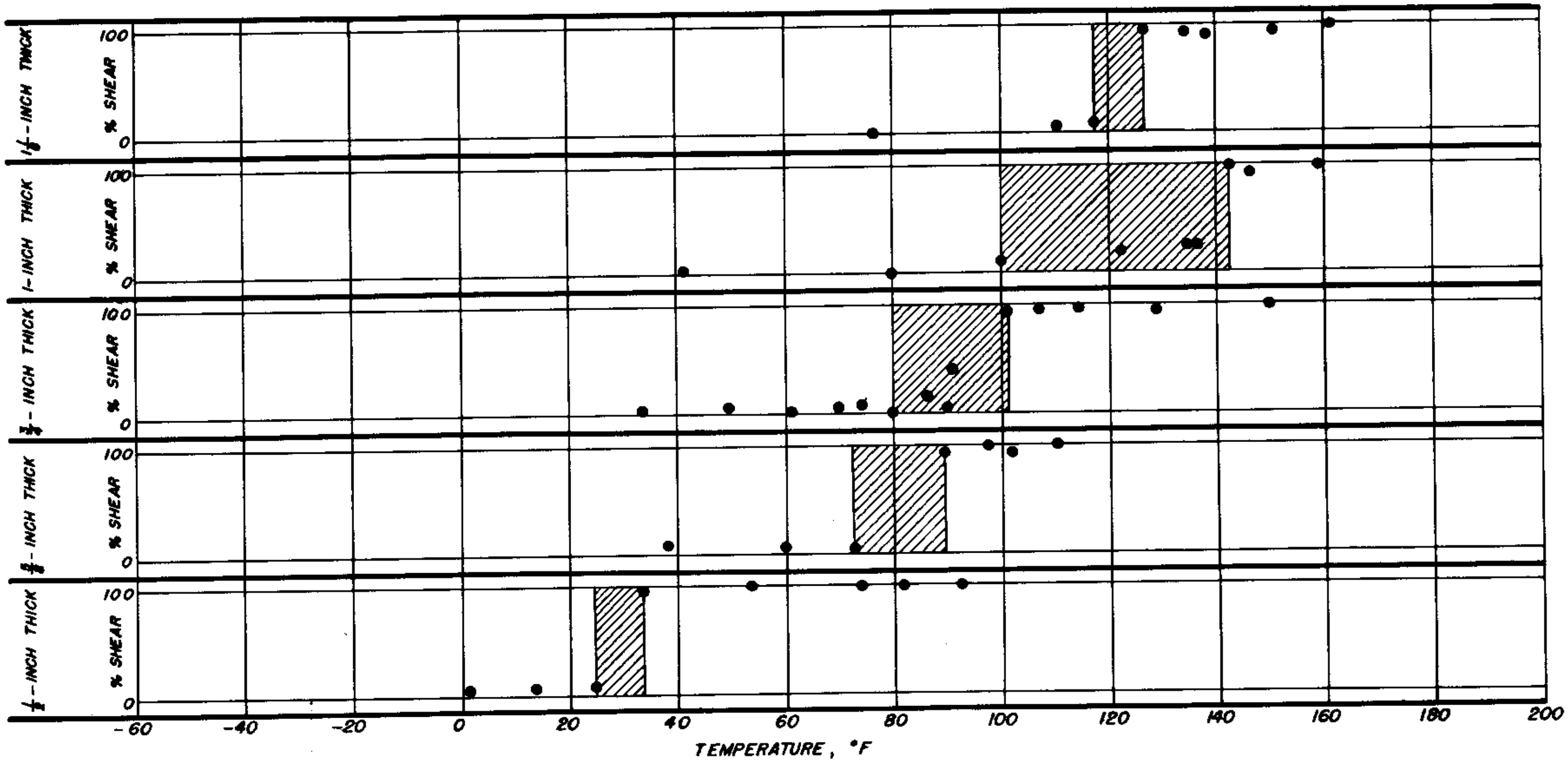


FIG. 14 - TRANSITION TEMPERATURE RANGE, 3-INCH WIDE EDGE NOTCHED SPECIMENS, C-STEEL, CUT FROM PLATES OF VARIOUS THICKNESSES.

FIG. 14

DWG. 44E269

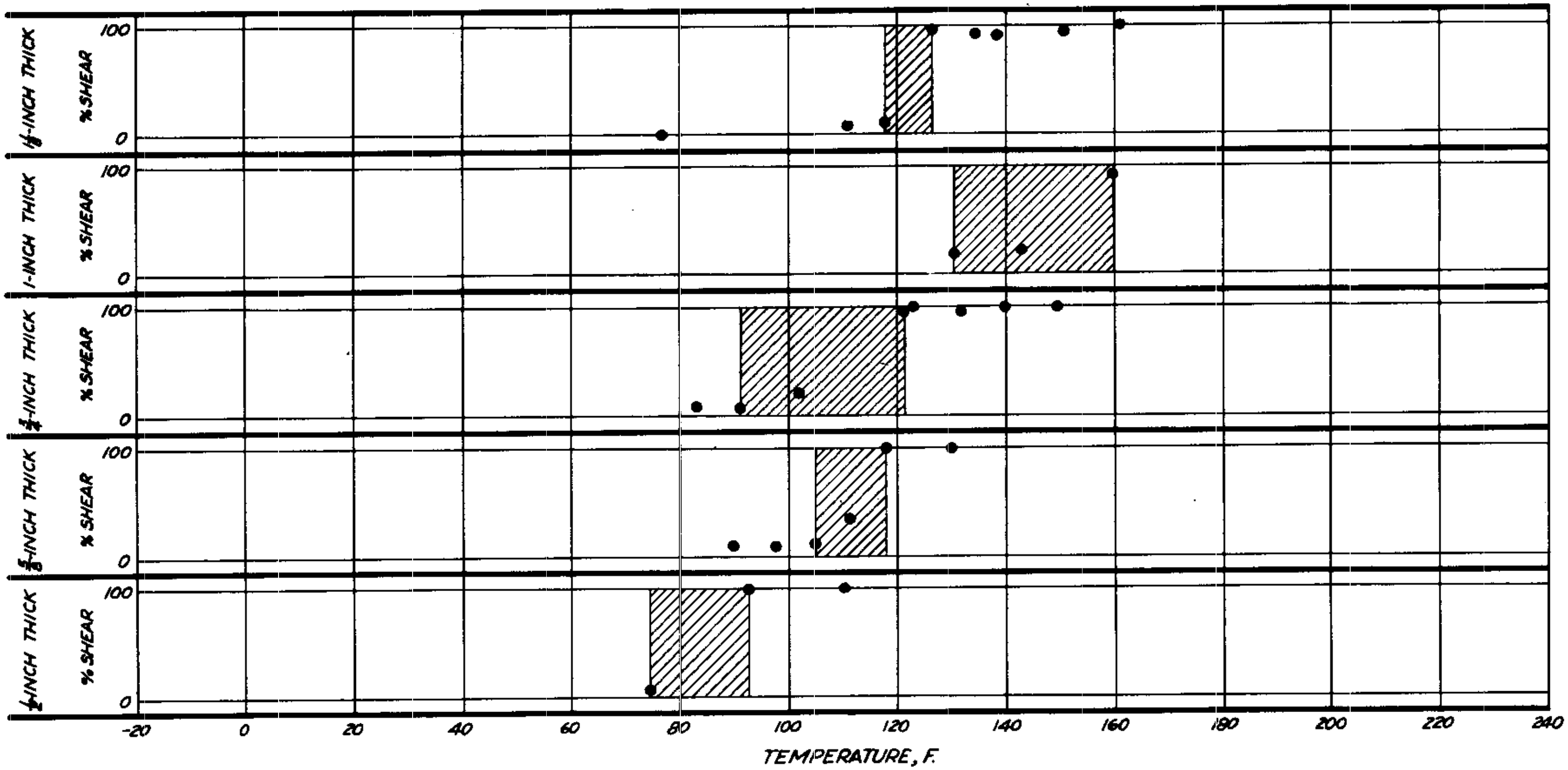


FIG.15 - TRANSITION TEMPERATURE RANGE, 3-INCH WIDE EDGE NOTCHED SPECIMENS, C-STEEL, MACHINED TO VARIOUS THICKNESSES FROM $1\frac{1}{8}$-INCH THICK PLATE

FIG.15

DWG. 44E74

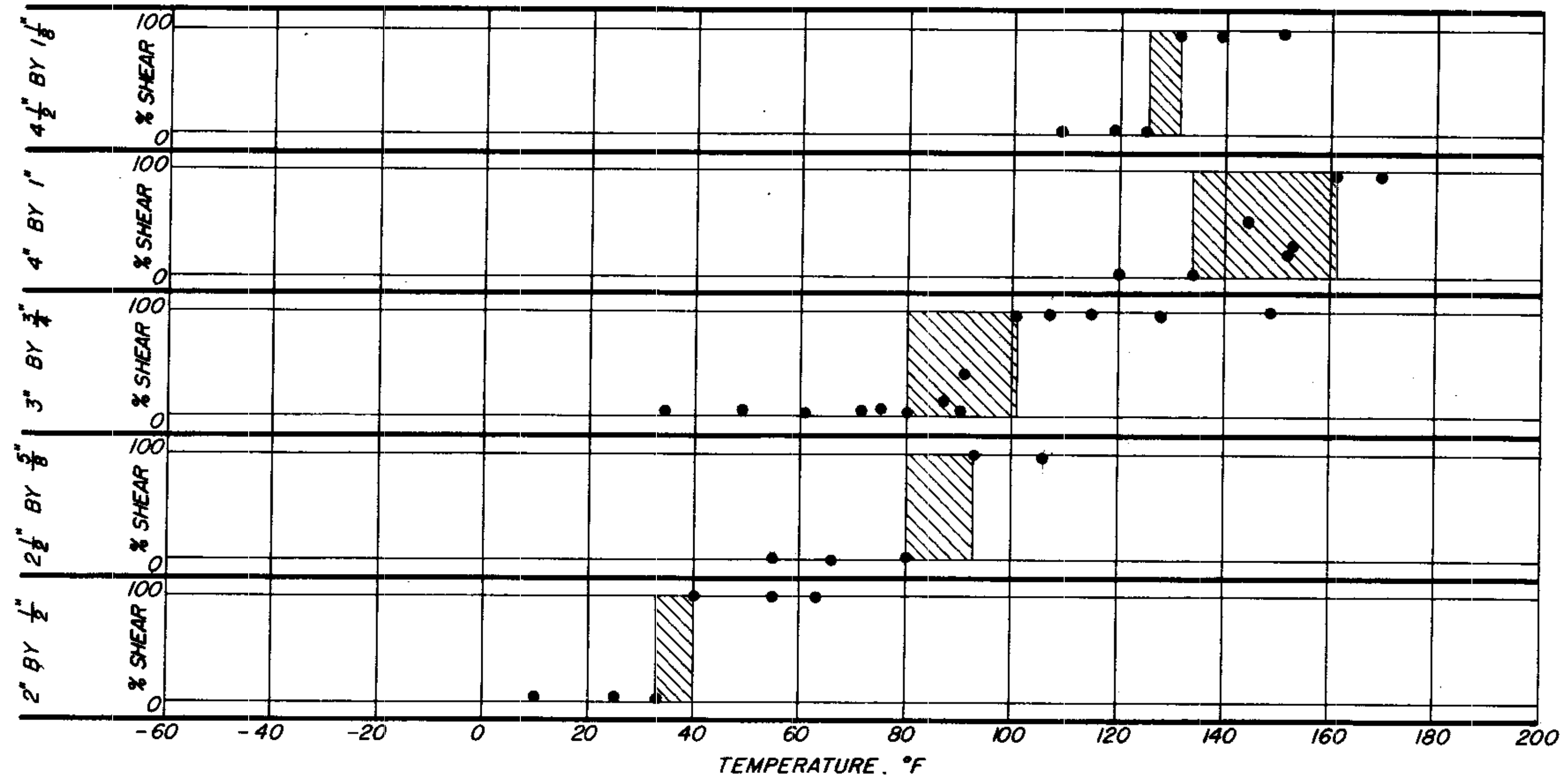


FIG. 16 – TRANSITION TEMPERATURE RANGES FOR PROPORTIONAL EDGE – NOTCHED SPECIMENS, C – STEEL, FROM PLATES OF VARIOUS THICKNESSES.

NOTE: NET SECTION 5/6 OF PLATE WIDTH.
DEPTH OF NOTCH AT EACH EDGE = 1/12 OF SPECIMEN WIDTH.
WIDTH OF NOTCH IS APPROXIMATELLY 1/20 OF SPECIMEN THICKNESS.

DWG. 44E268

FIG. 16

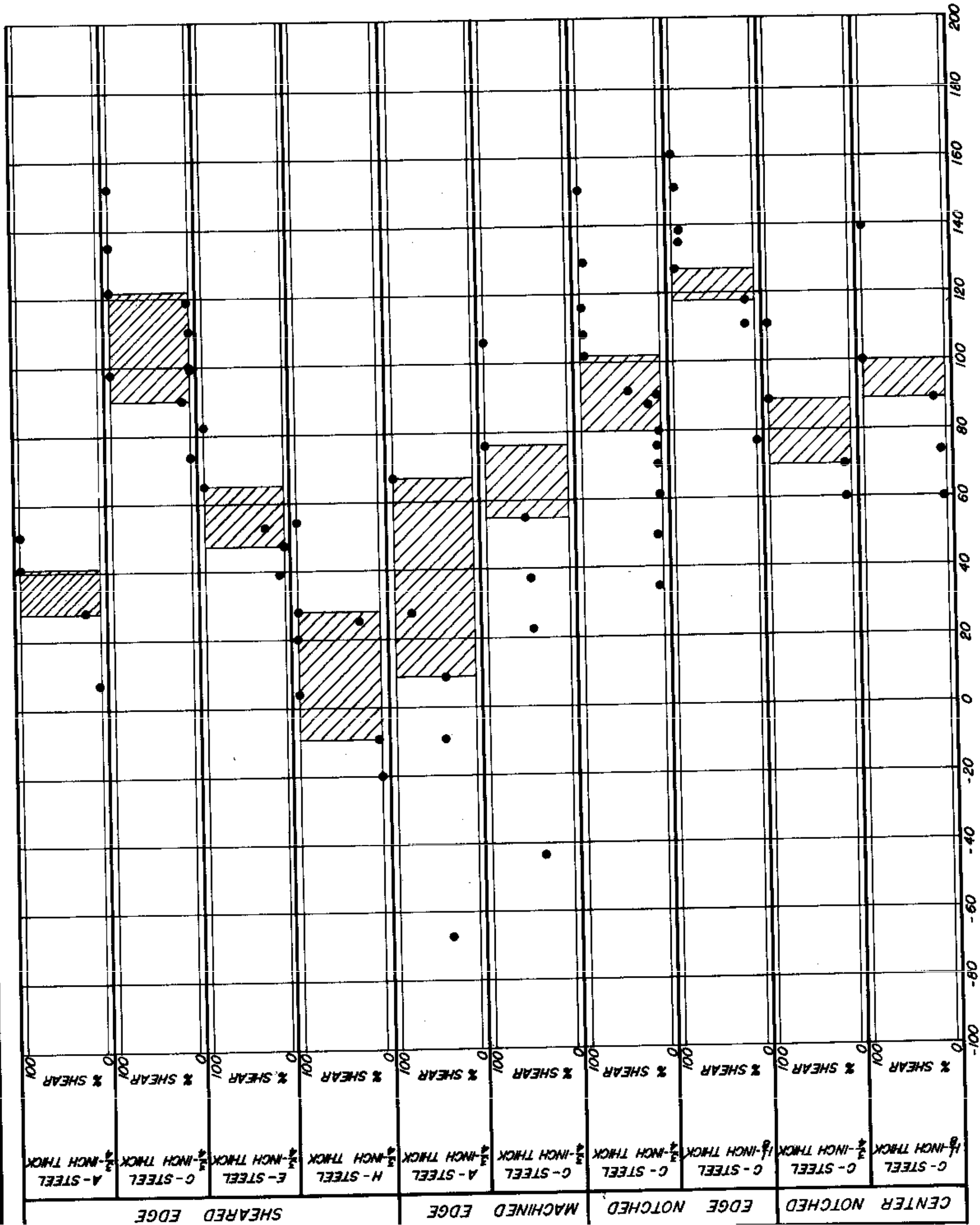


FIG. 17 - TRANSITION TEMPERATURE RANGES FOR 3-INCH WIDE SPECIMENS

DWG. 44E270

FIG. 17

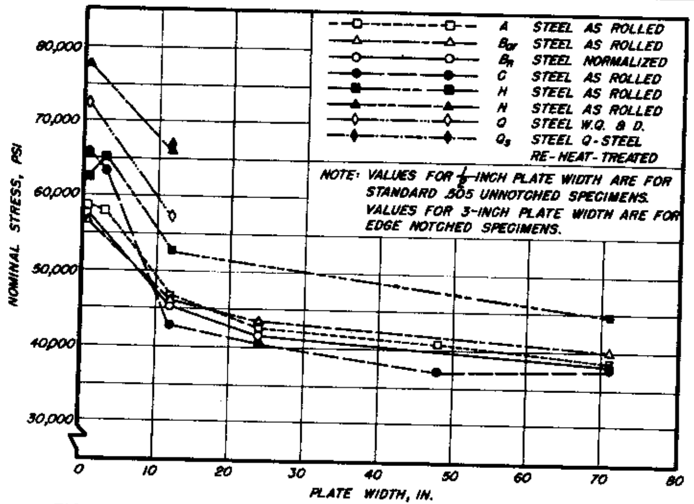


FIG. 18-A- VARIATION IN NOMINAL STRESS WITH WIDTH OF PLATE — TESTS AT ROOM TEMPERATURE.

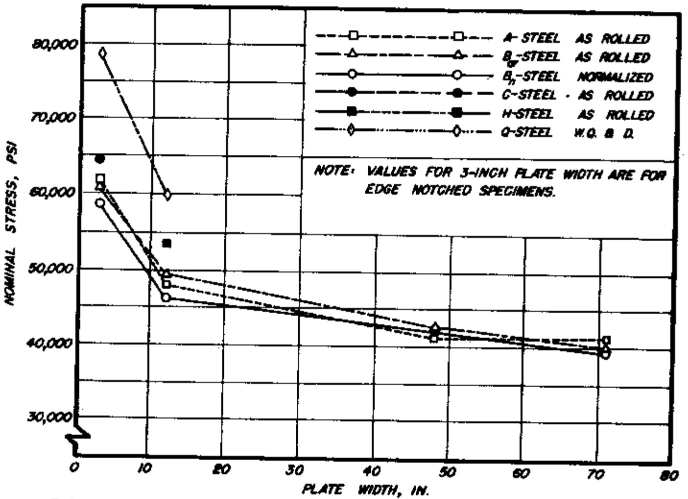


FIG. 18-B - VARIATION IN NOMINAL STRESS WITH WIDTH OF PLATE — TESTS AT 50 °F

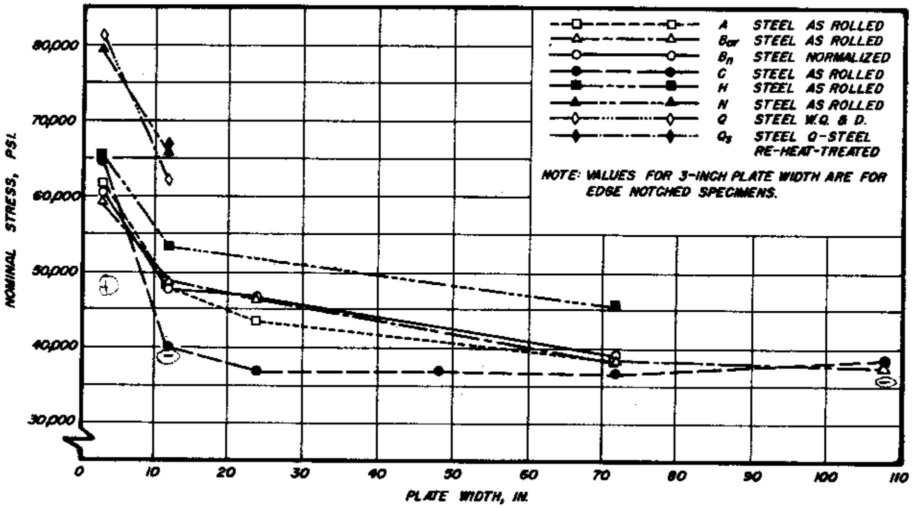
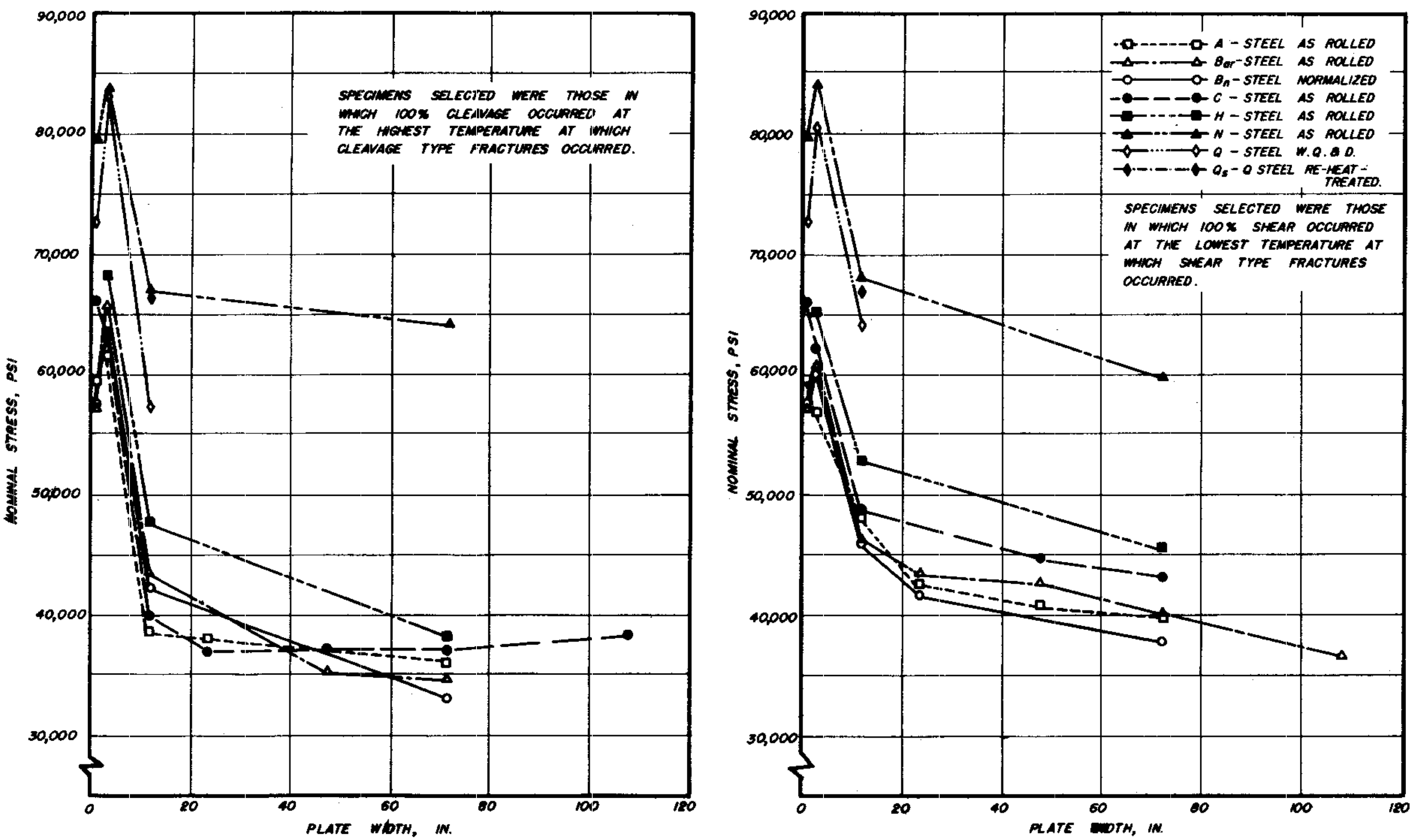


FIG. 18-C - VARIATION IN NOMINAL STRESS WITH WIDTH OF PLATE-TESTS AT 32°F.



SPECIMENS SELECTED WERE THOSE IN WHICH 100% CLEAVAGE OCCURRED AT THE HIGHEST TEMPERATURE AT WHICH CLEAVAGE TYPE FRACTURES OCCURRED.

CLEAVAGE TYPE FRACTURE

SPECIMENS SELECTED WERE THOSE IN WHICH 100% SHEAR OCCURRED AT THE LOWEST TEMPERATURE AT WHICH SHEAR TYPE FRACTURES OCCURRED.

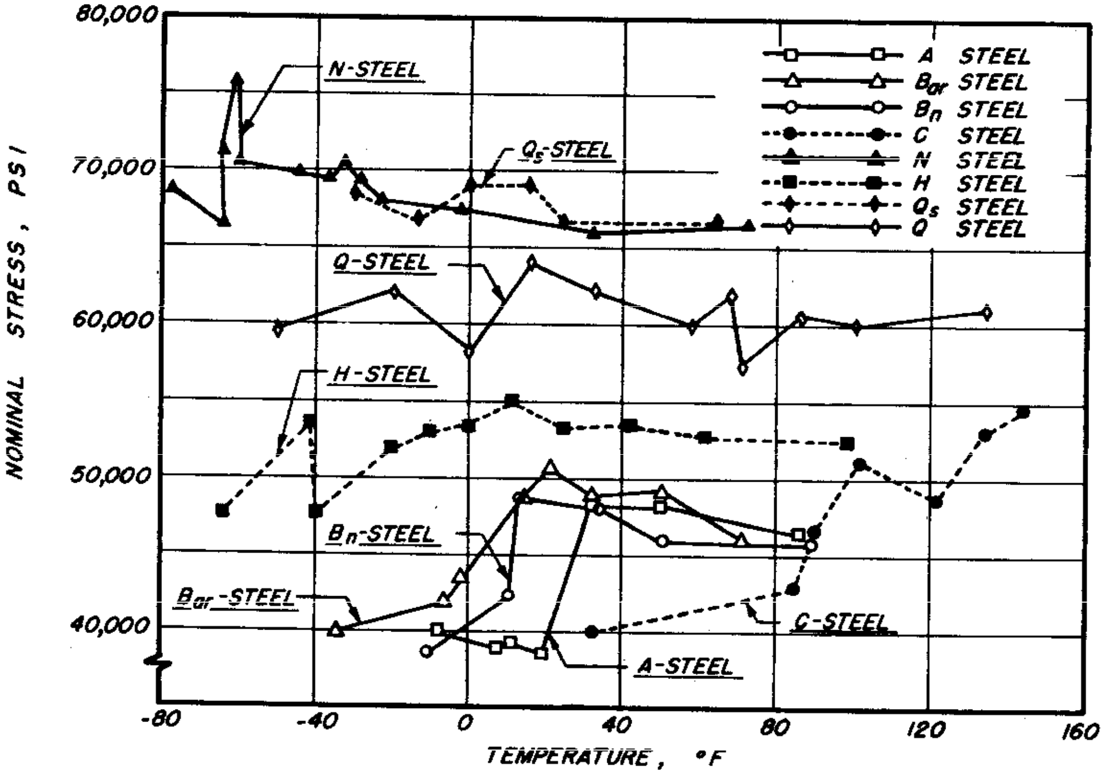
SHEAR TYPE FRACTURE

FIG. 19 - VARIATION IN MAXIMUM NOMINAL STRESS WITH WIDTH OF PLATE

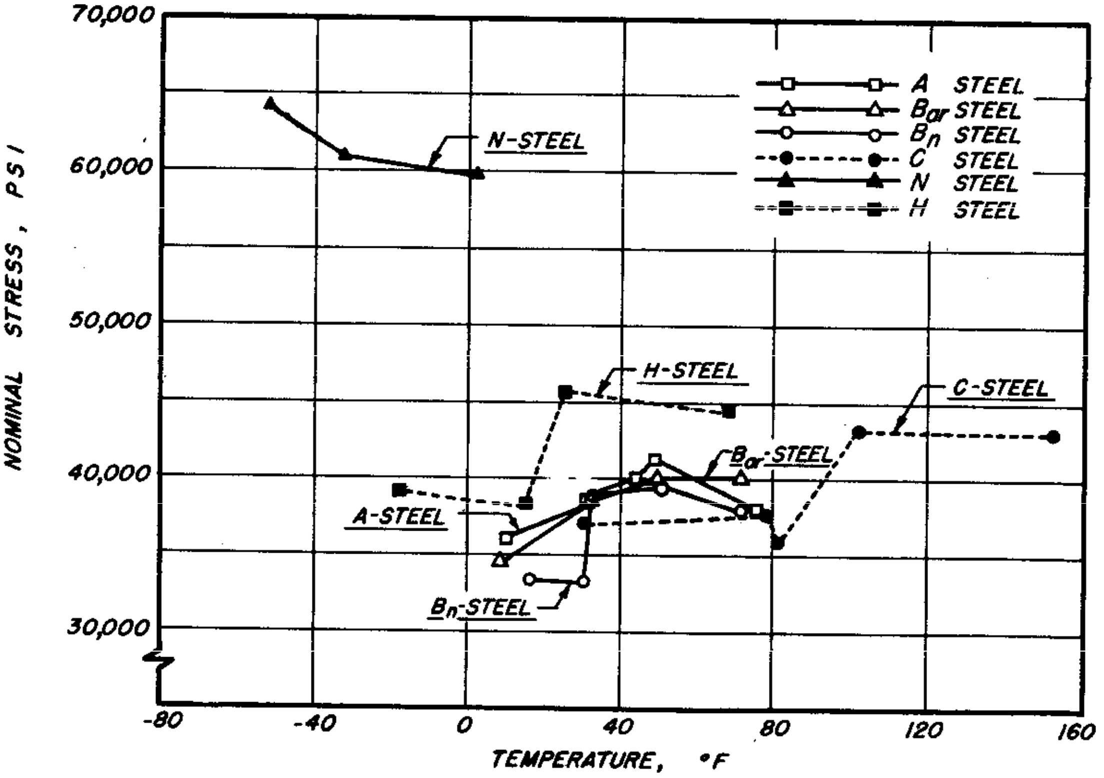
NOTES: VALUES FOR ½-INCH PLATE WIDTH ARE FOR STANDARD 0.505 UNNOTCHED SPECIMENS.
VALUES FOR 3-INCH PLATE WIDTH ARE FOR EDGE NOTCHED SPECIMENS.

DWG. 44E265

FIG.19



12 - INCH WIDE SPECIMENS



72 - INCH WIDE SPECIMENS

FIG20-VARIATION IN NOMINAL STRESS WITH TEMPERATURE FOR FOR FLAT-PLATE SPECIMENS.

DWG. 44E263

FIG. 20

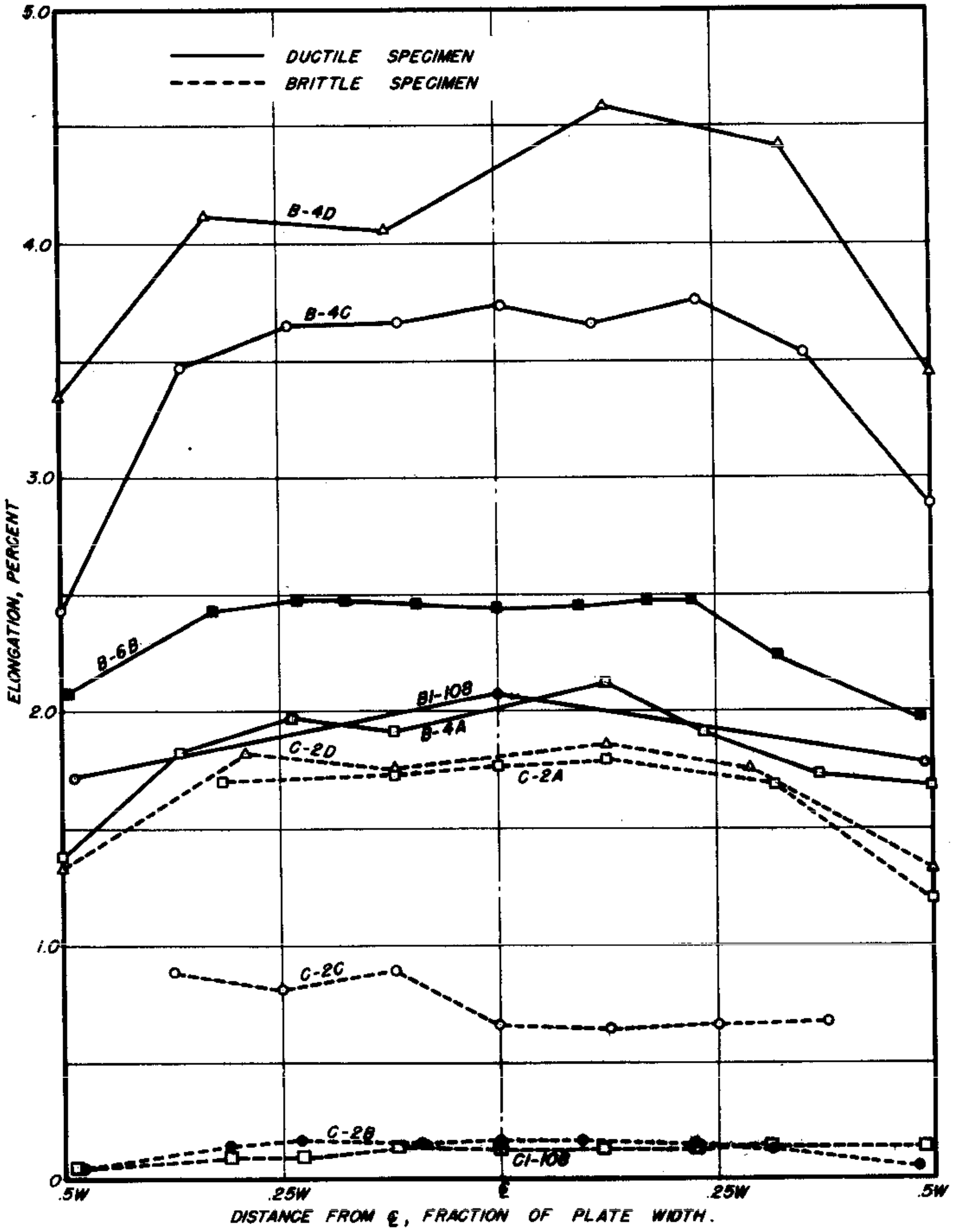


FIG.21- ELONGATION AT MAXIMUM LOAD, ILLUSTRATING INFLUENCE OF PLATE WIDTH ON DUCTILITY AT MAXIMUM LOAD

ELONGATION MEASURED BY RESISTANCE WIRE EXTENSOMETERS

SPECIMENS BI-108 AND CI-108 ARE 108- INCHES WIDE
SPECIMENS B-5A AND C-2A ARE 72- INCHES WIDE
SPECIMENS B-6B AND C-2B ARE 48- INCHES WIDE
SPECIMENS B-4C AND C-2C ARE 24- INCHES WIDE
SPECIMENS B-4D AND C-2D ARE 12 - INCHES WIDE

GAGE LENGTH = $\frac{3}{4}$ OF PLATE WIDTH

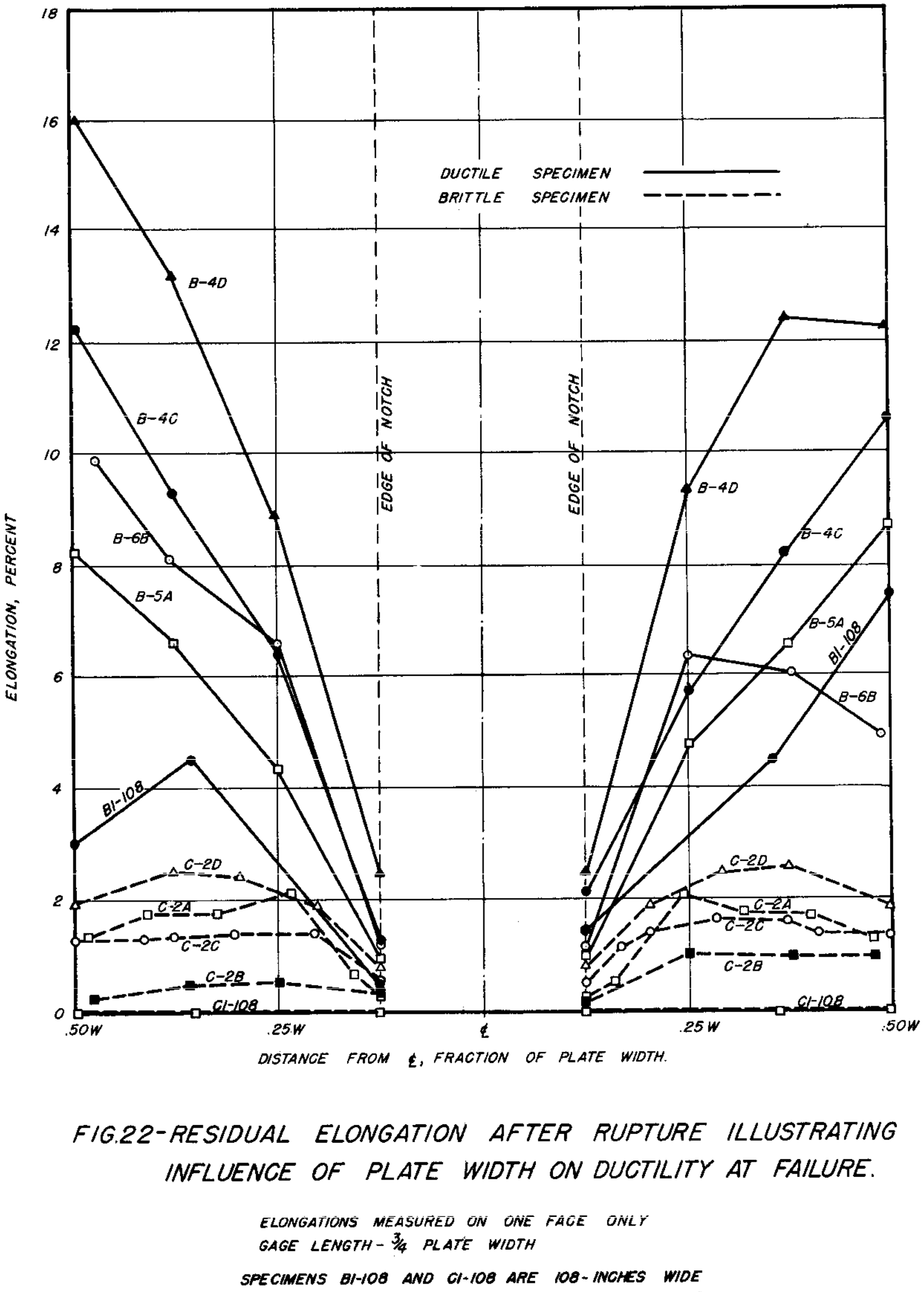


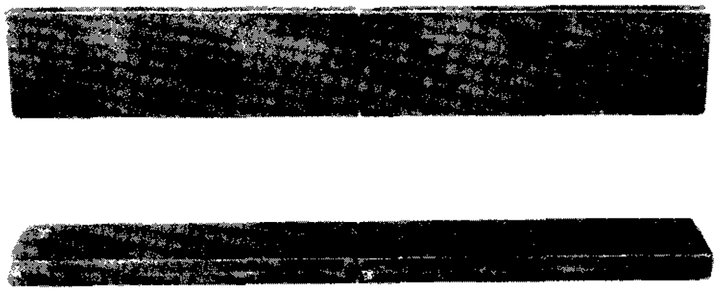
FIG.22-RESIDUAL ELONGATION AFTER RUPTURE ILLUSTRATING INFLUENCE OF PLATE WIDTH ON DUCTILITY AT FAILURE.

ELONGATIONS MEASURED ON ONE FACE ONLY
GAGE LENGTH - 3/4 PLATE WIDTH

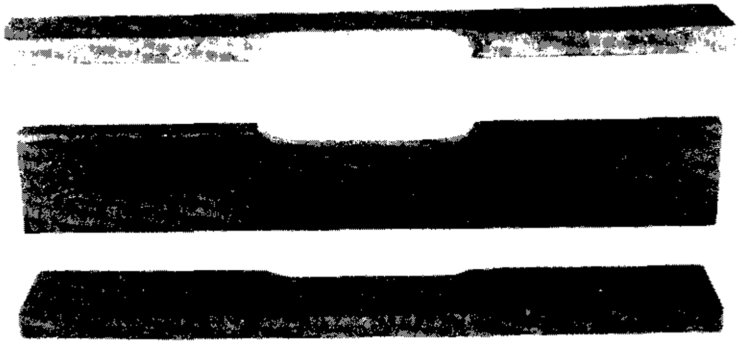
SPECIMENS BI-108 AND CI-108 ARE 108-INCHES WIDE
SPECIMENS B-5A AND C-2A ARE 72-INCHES WIDE
SPECIMENS B-6B AND C-2B ARE 48-INCHES WIDE
SPECIMENS B-4C AND C-2C ARE 24-INCHES WIDE
SPECIMENS B-4D AND C-2D ARE 12-INCHES WIDE

DWG. 44E267

FIG. 22



NOTCHED EDGES



SHEARED EDGE

MACHINED EDGES

CENTER NOTCHED

FIG. 23 - FOUR DIFFERENT TYPES OF 3-INCH WIDE SPECIMENS USED IN THE INVESTIGATION.

DWG 44 E 281

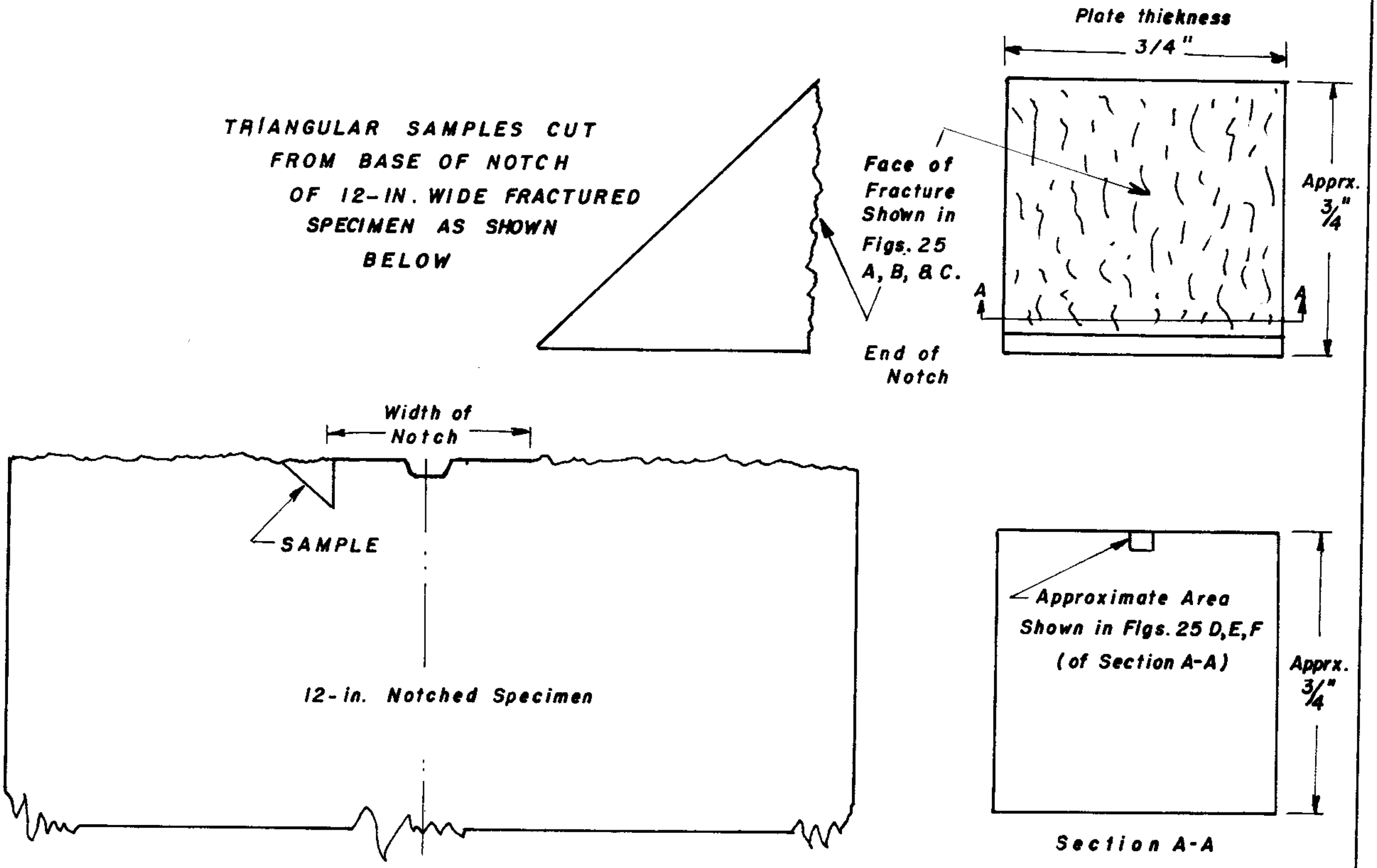


FIG.24 LOCATION OF SAMPLE CUT FROM 12-IN. SPECIMENS.

FIG.24

FIGURE 25A
SPECIMEN H-8D VIEW OF FRACTURE AT NOTCH (5x)

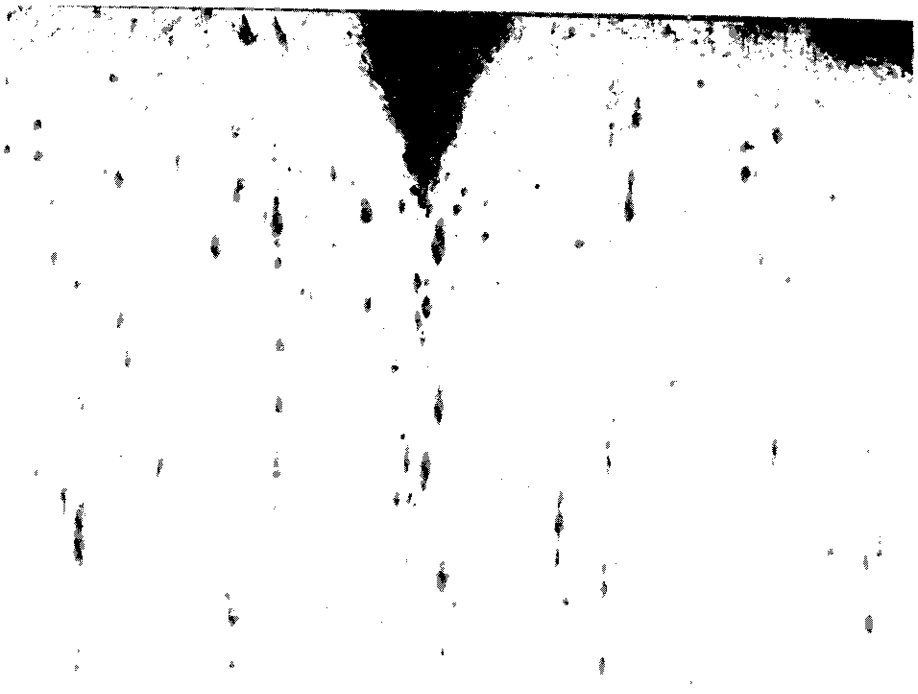


FIGURE 25D (Section DD in Fig. 25A)
SPECIMEN H-8D CUT ACROSS THICKNESS OF SPECIMEN SHOWING OPENNINGS ALONG SEAMS OF NONMETALLIC INCLUSIONS. UNETCHED (50x)

FIGURE 25 B
SPECIMEN H-10D VIEW OF FRACTURE AT NOTCH (5x)

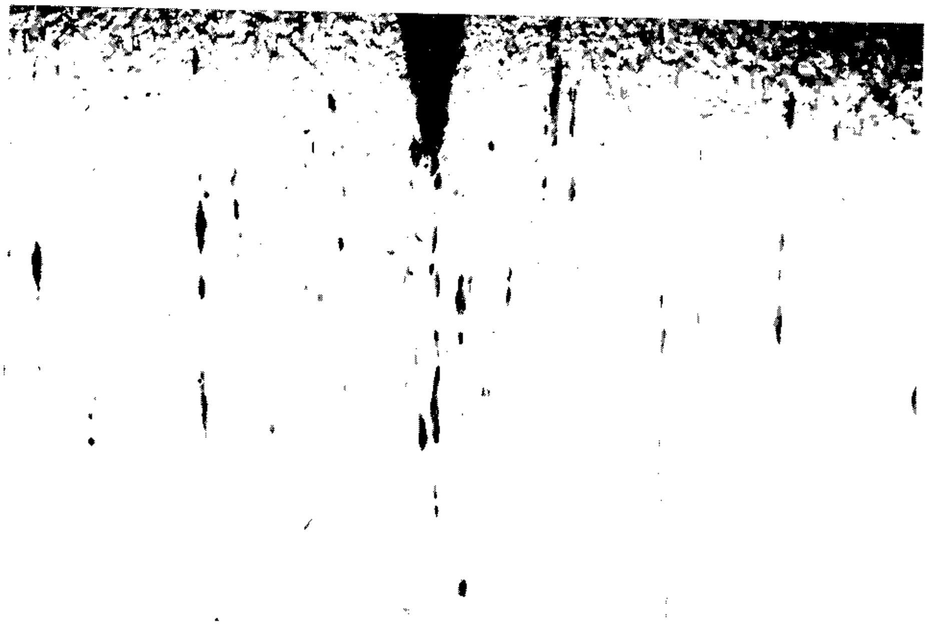


FIGURE 25 E (Section EE in Fig. 25B)
SPECIMEN H-10D CUT ACROSS THICKNESS OF SPECIMEN SHOWING OPENNINGS ALONG SEAMS OF NONMETALLIC INCLUSIONS. UNETCHED (50x)

FIGURE 25 C
SPECIMEN H-82xD VIEW OF FRACTURE AT NOTCH (5x)

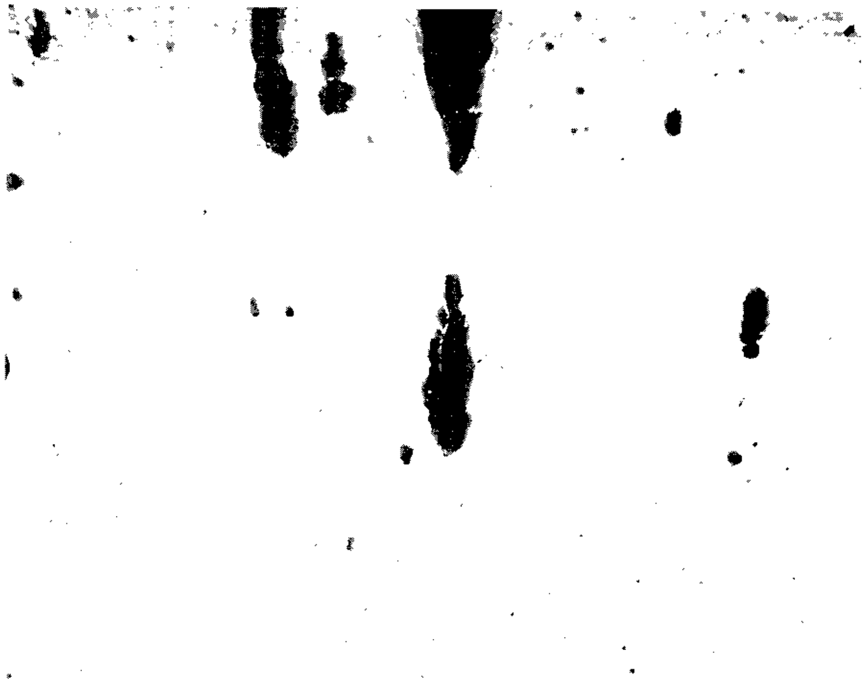


FIGURE 25 F (Section FF in Fig. 25C)
SPECIMEN H-82xD CUT ACROSS THICKNESS OF SPECIMEN SHOWING OPENNING ALONG SEAMS OF NONMETALLIC INCLUSIONS. UNETCHED (50x)

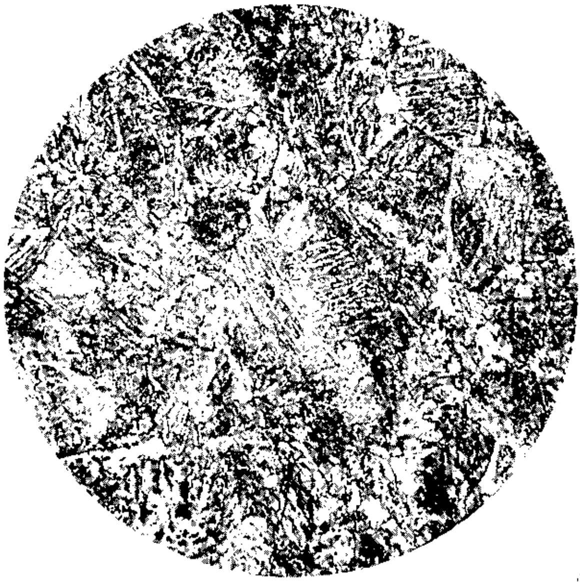
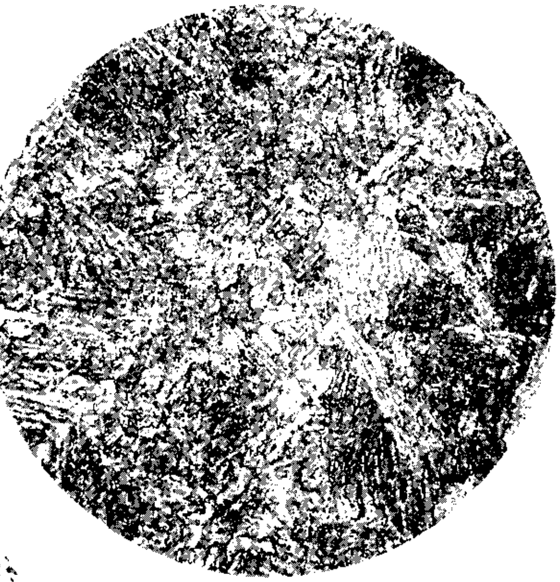
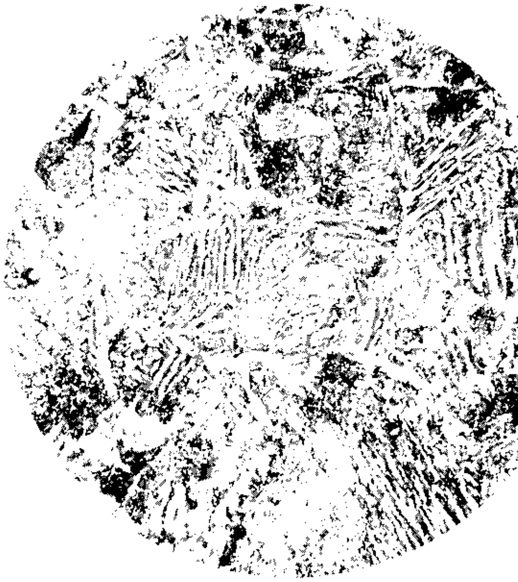


FIG. 26 A
SPECIMEN Q 3S
Quenched from 1600° F.
Drawn at 1300°F for 1-3/4 hrs
Requenched from 1600°F.
Redrawn at 1245°F for 2 hrs.

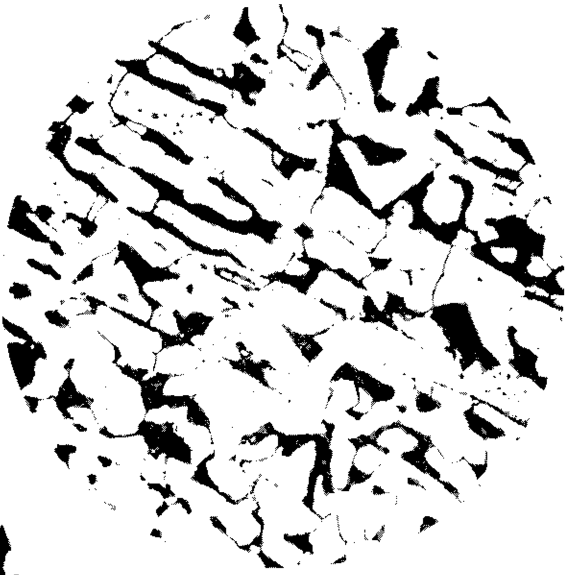
FIG. 26 B
SPECIMEN Q 14
Quenched from 1600°F.
Drawn at 1300°F. for 1-3/4 hrs.





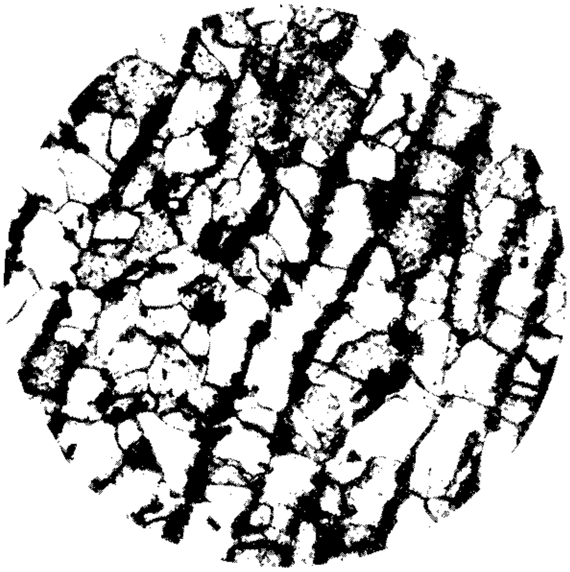
FIG, 26 C
SPECIMEN Q 1
Quenched from 1600°F.
Drawn at 1300°F. for 1-3/4 hrs.

FIGURE 26 PHOTOMICROGRAPHS OF SPECIMENS OF STEEL Q
(Etched for 15 seconds in 2% Nital, 250x)



Steel A

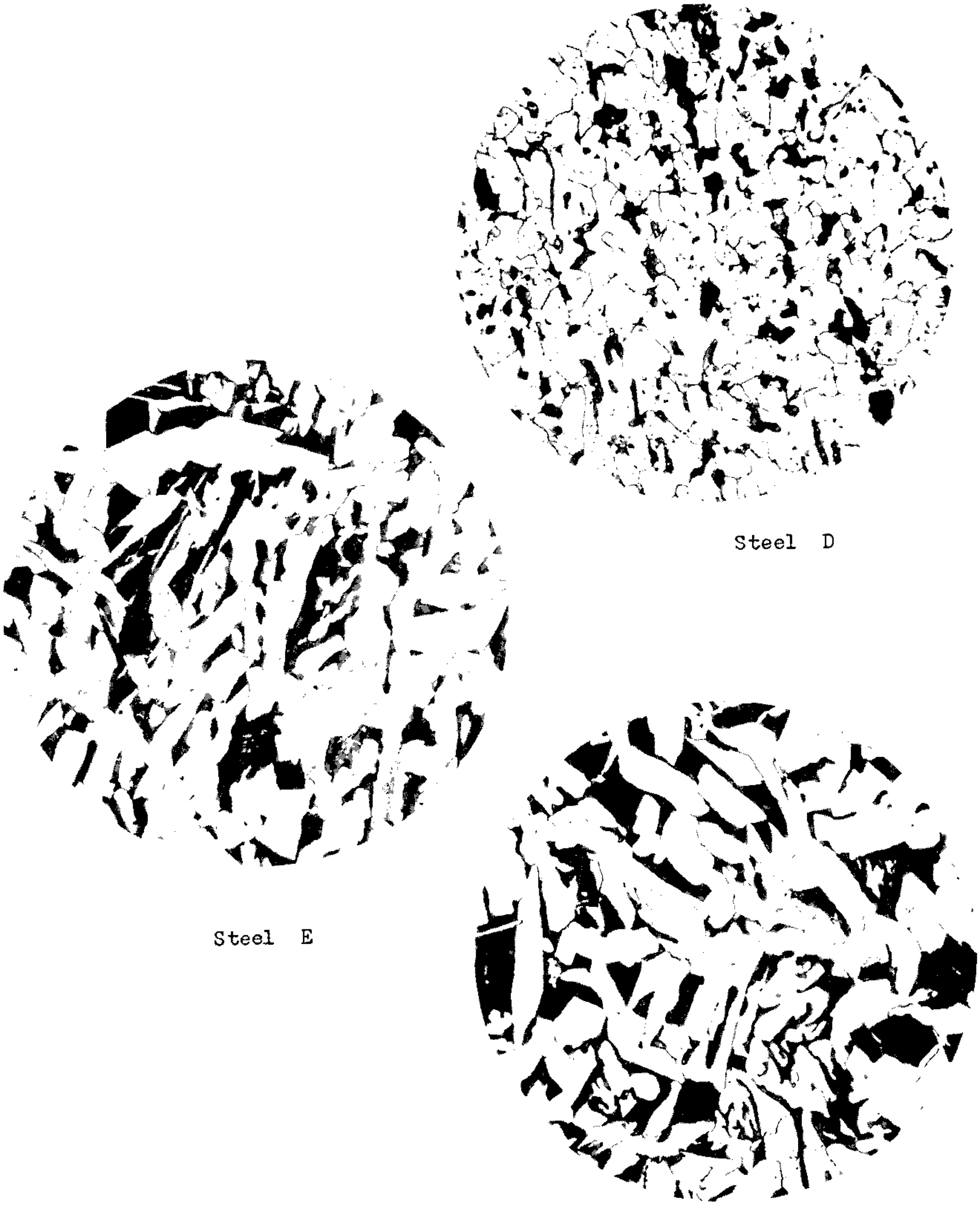
Steel B_{ar}



Steel B_n

Steel C

FIGURE 27 PHOTOMICROGRAPHS OF STEELS A, B_{ar}, B_n, AND C. (100x)



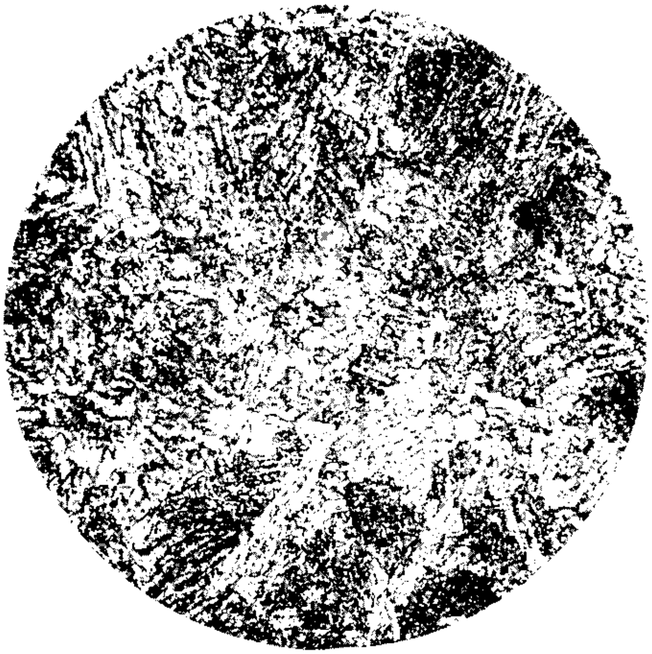
Steel D

Steel E

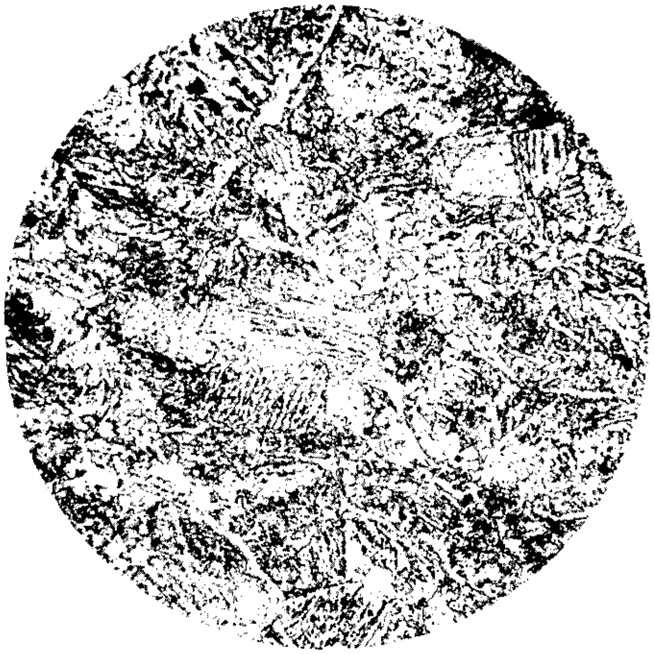
Steel H

FIGURE 28 PHOTOMICROGRAPHS OF STEELS D, E, AND H (100x)

Steel N
(100x)



Steel Q
(250x)



Steel QS
(250x)

FIGURE 29 PHOTOMICROGRAPHS OF STEELS N, Q, AND QS

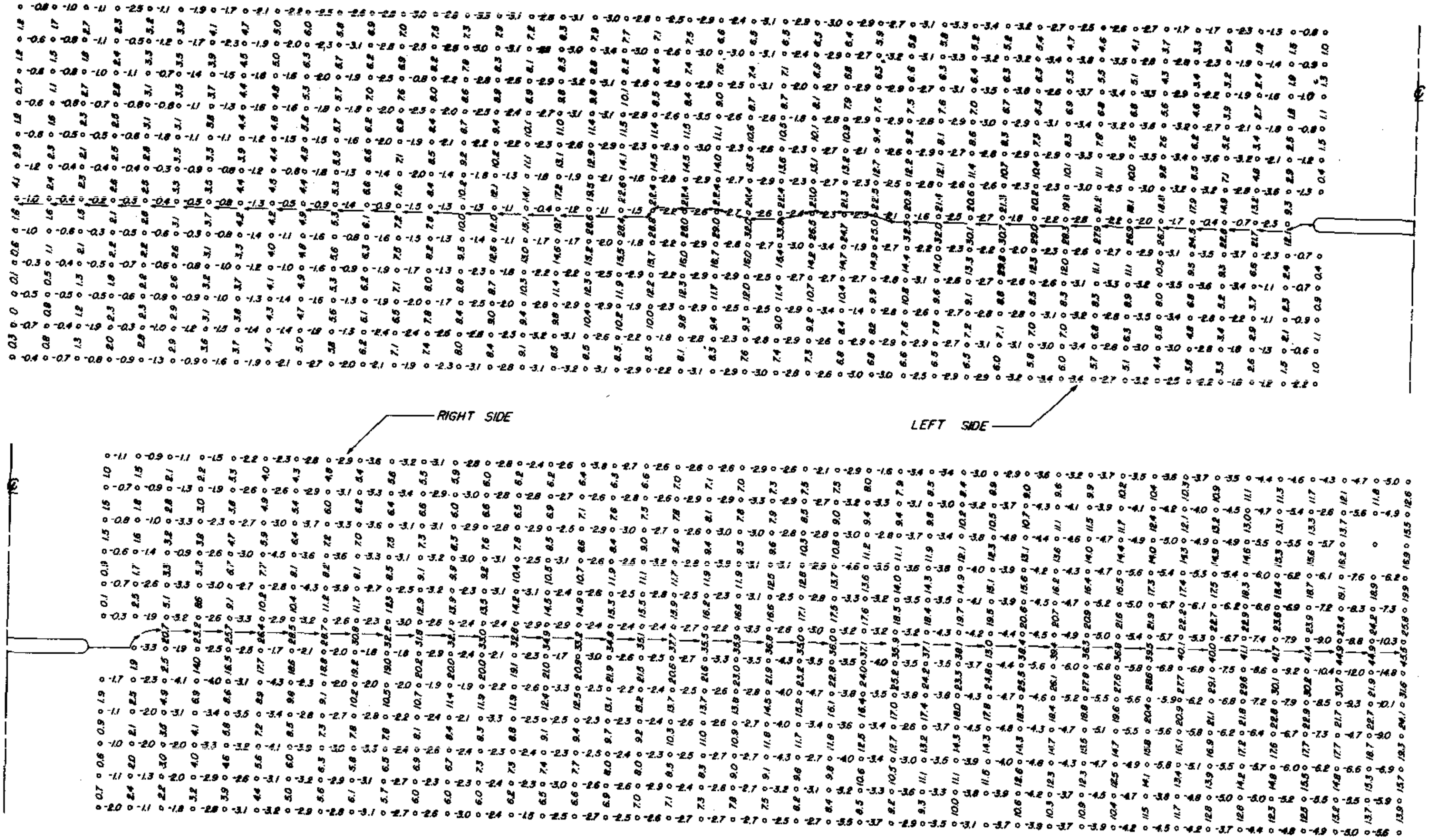


FIG. A-68 PERCENT ELONGATION PLATE B1-108 (1-INCH GRID)

"B"-STEEL, 108-INCH WIDE PLATE
TEMPERATURE 31° F

NOMINAL STRENGTH 36.7 KSI
100% SHEAR

FIG. A-68
DWG. 44E253

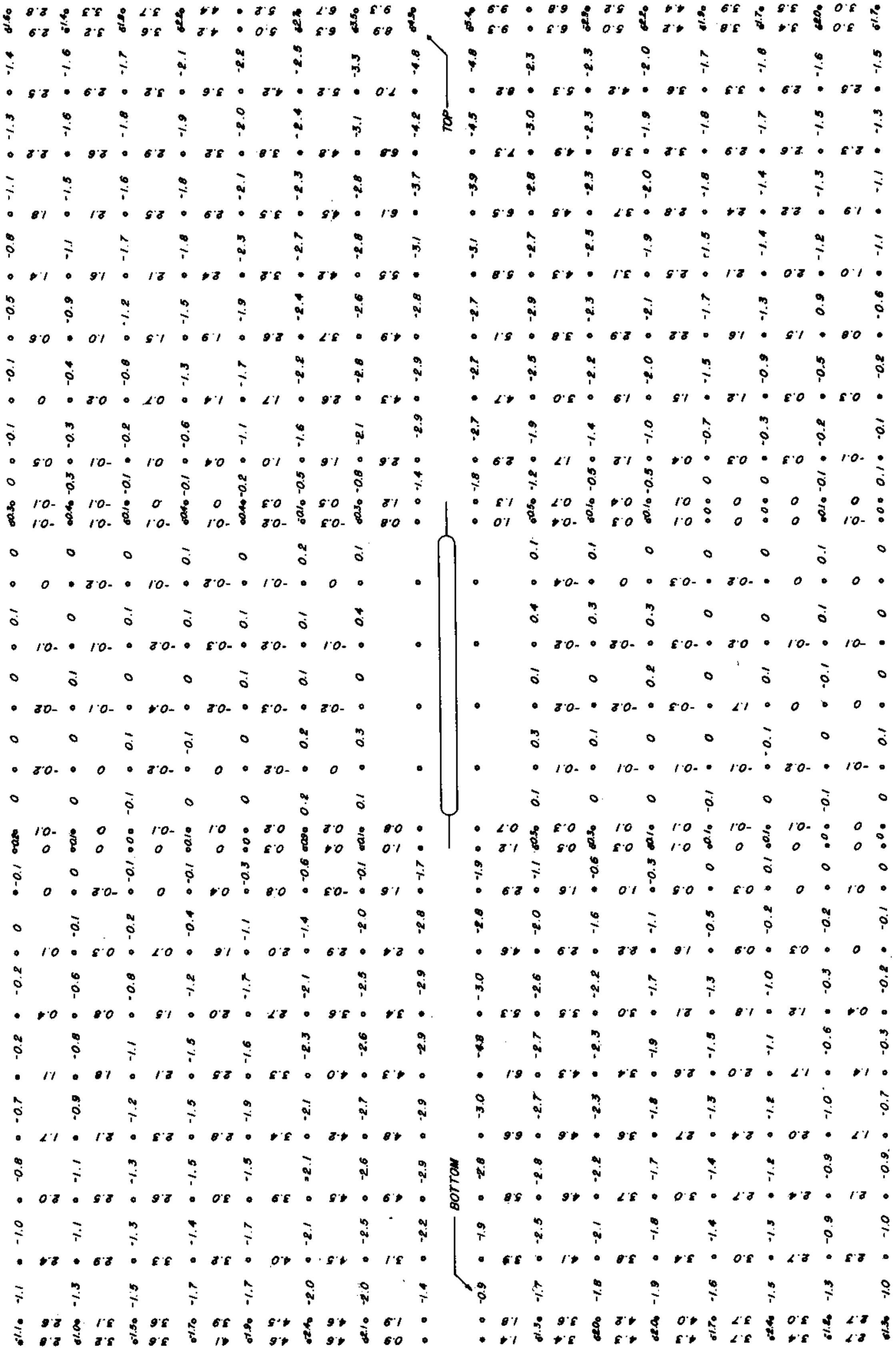


FIG. A-69 PERCENT ELONGATION
"B" STEEL, 108-INCH WIDE PLATE
TEMPERATURE, 31 °F.

PLATE BI-108 (5-INCH GRID)
NOMINAL STRENGTH 36.7 KSI
100% SHEAR

FIG. A-69

DWG. 445853

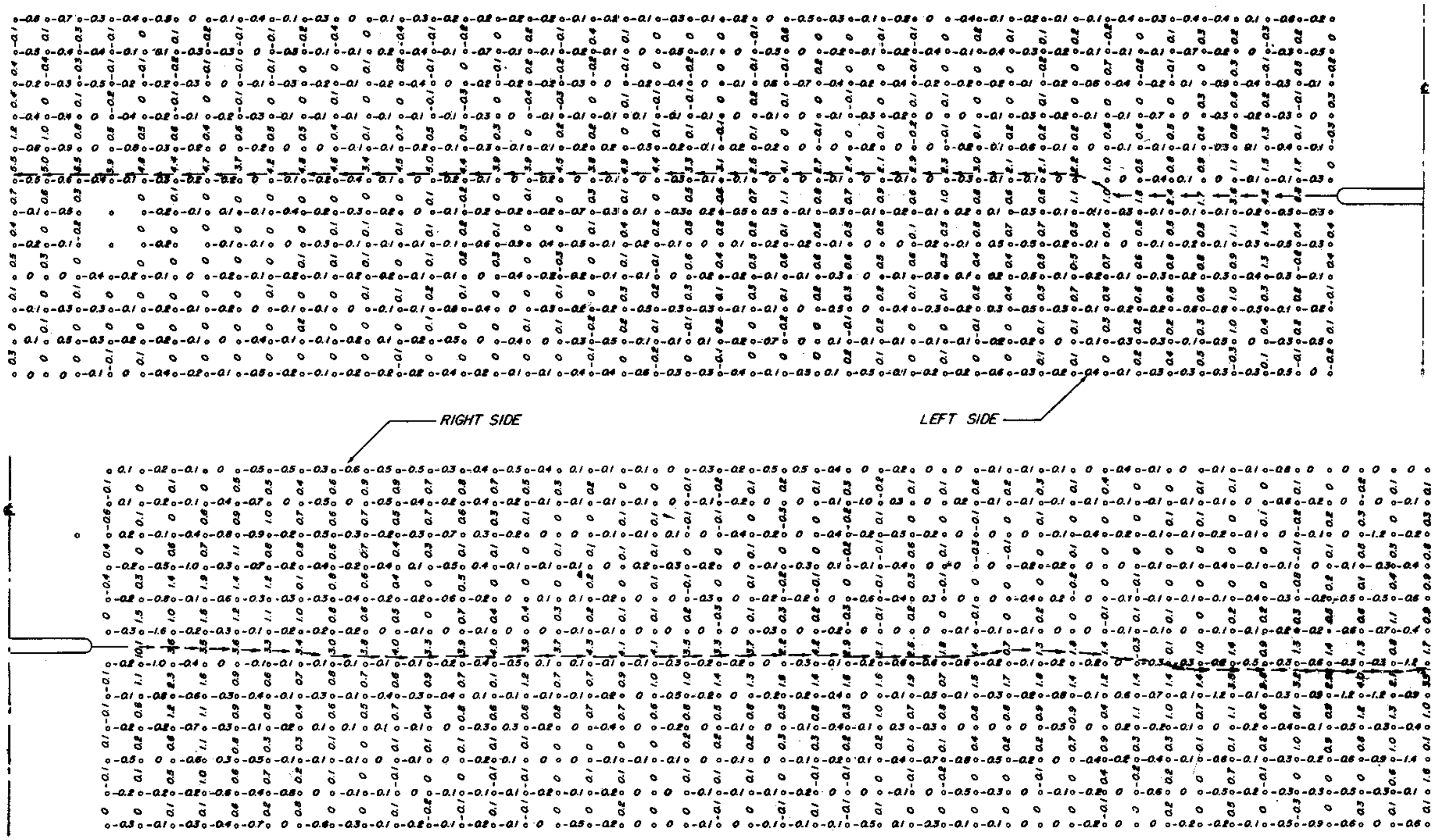


FIG. A-70 PERCENT ELONGATION PLATE C1-108 (1-INCH GRID)

"C"-STEEL, 108-INCH WIDE PLATE
TEMPERATURE 26-28°F.

NOMINAL STRENGTH 38.4 KSI.
0% SHEAR

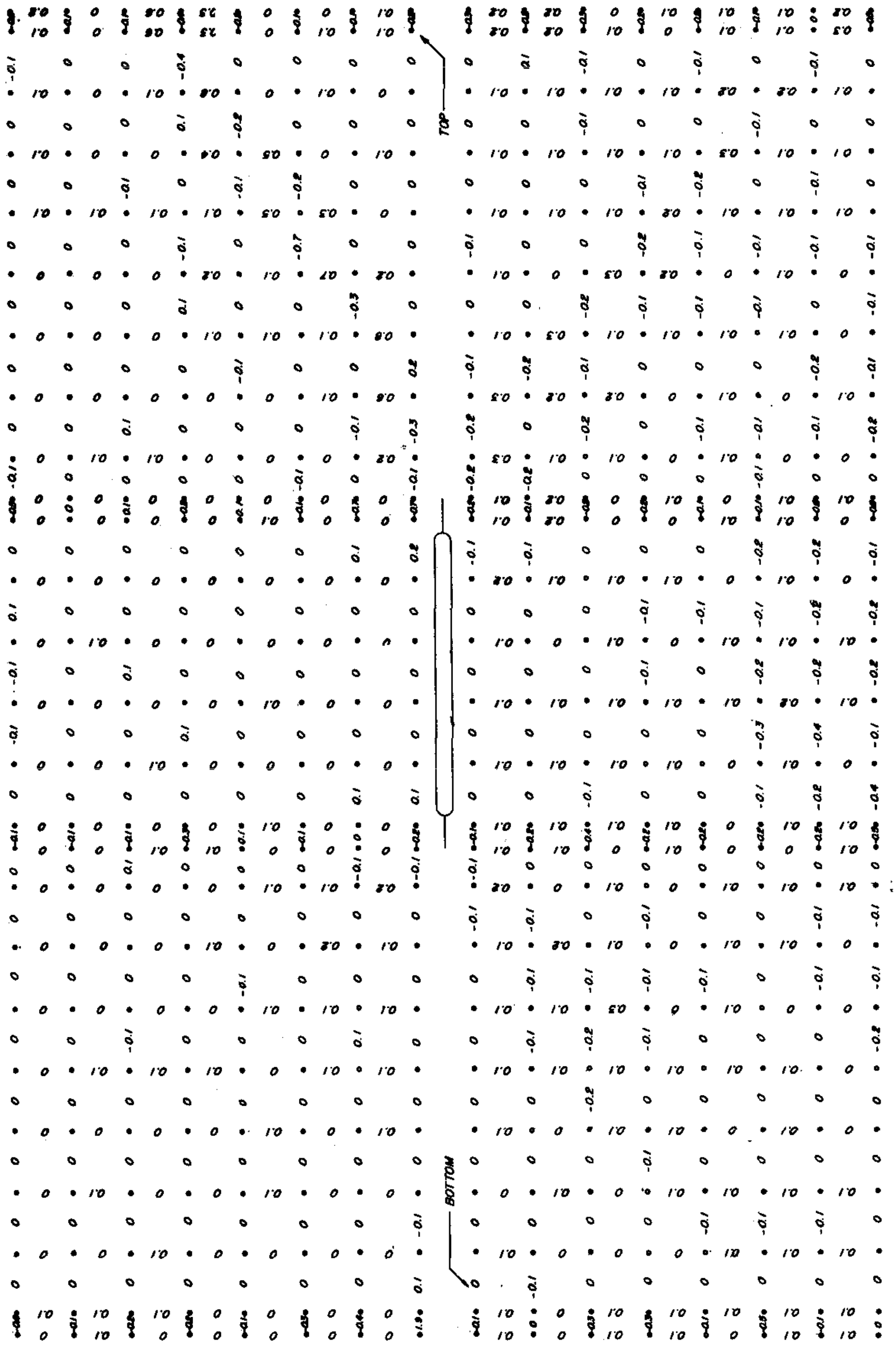


PLATE CI-108 (5-INCH GRID)
NOMINAL STRENGTH 38.4 KSI.
0% SHEAR

FIG. A-71 PERCENT ELONGATION
"C" STEEL, 108-INCH WIDE PLATE
TEMPERATURE, 26-28°F.

FIG. A-71.

DWG. 44E256

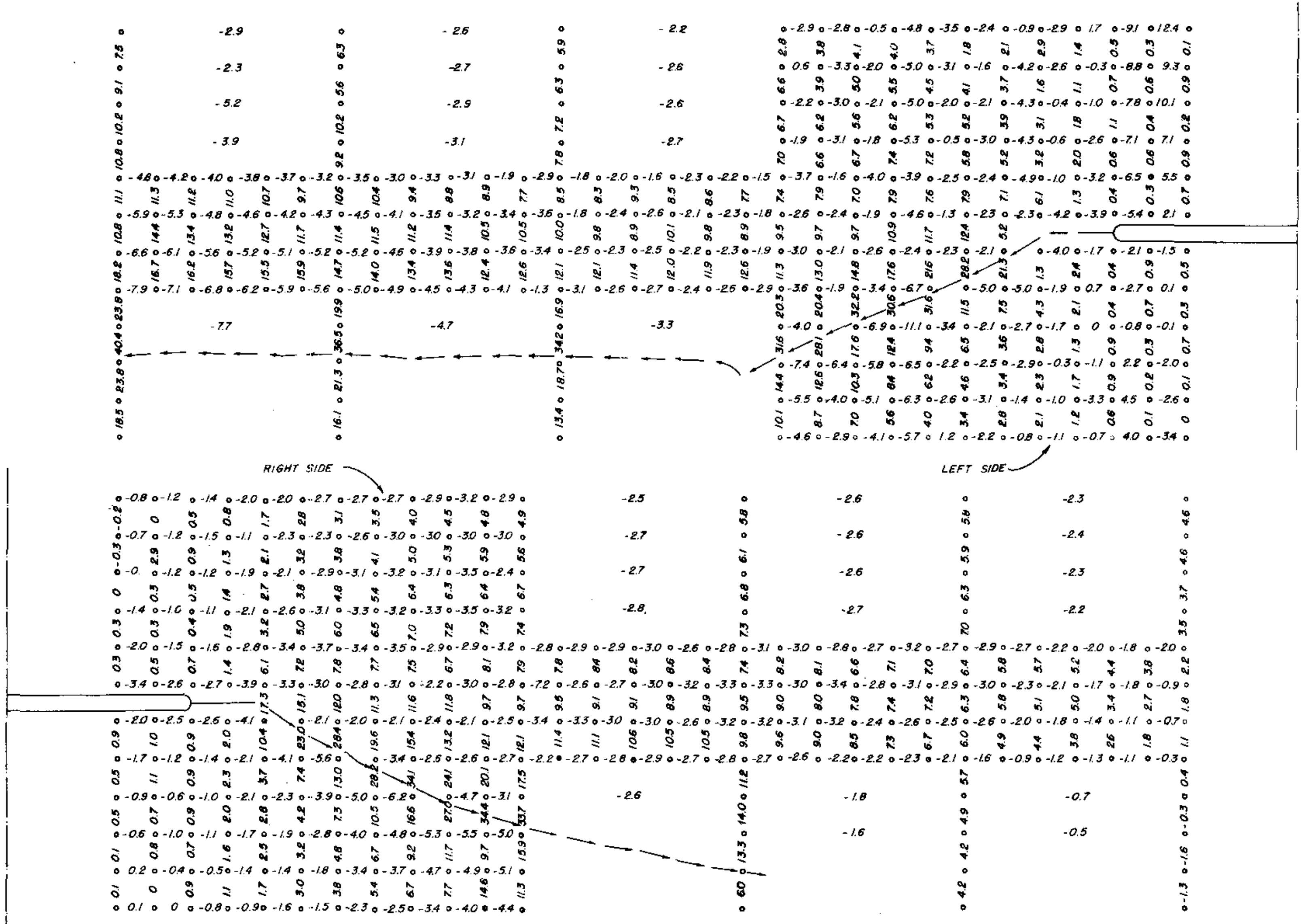


FIG. A-72 PERCENT ELONGATION PLATE A-3A (1-INCH GRID)

"A" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 40.3 KSI

TEMPERATURE 50-48°F 100% SHEAR

FIG. A-72

DWG 44E170

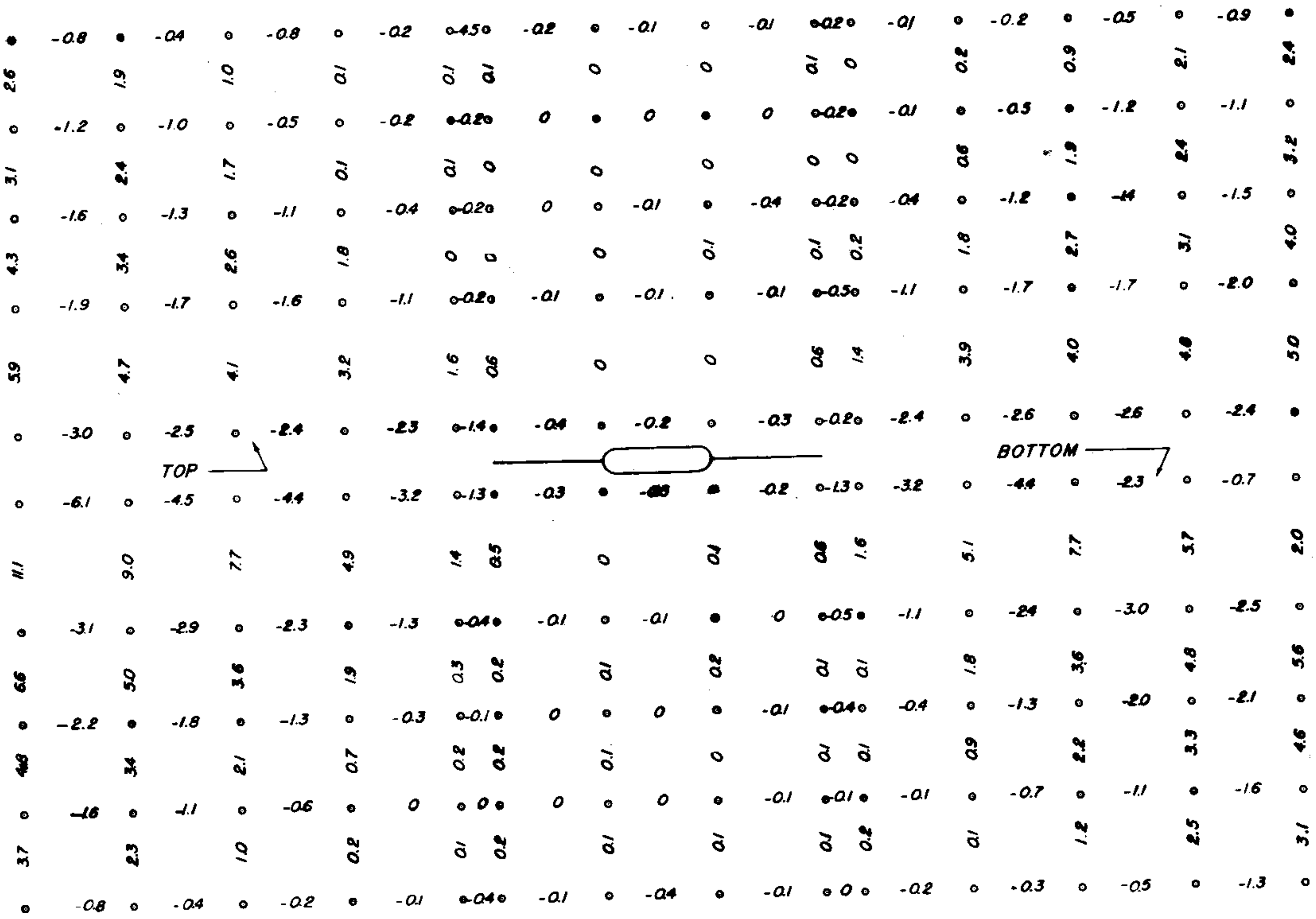


FIG. A-73 PERCENT ELONGATION PLATE A-3A (5-INCH GRID)

"A" STEEL, 72-INCH WIDE PLATE
TEMPERATURE 48-50 °F

NOMINAL STRENGTH 41.3 KSI
100 % SHEAR

FIG. A-73

DWG 44E209

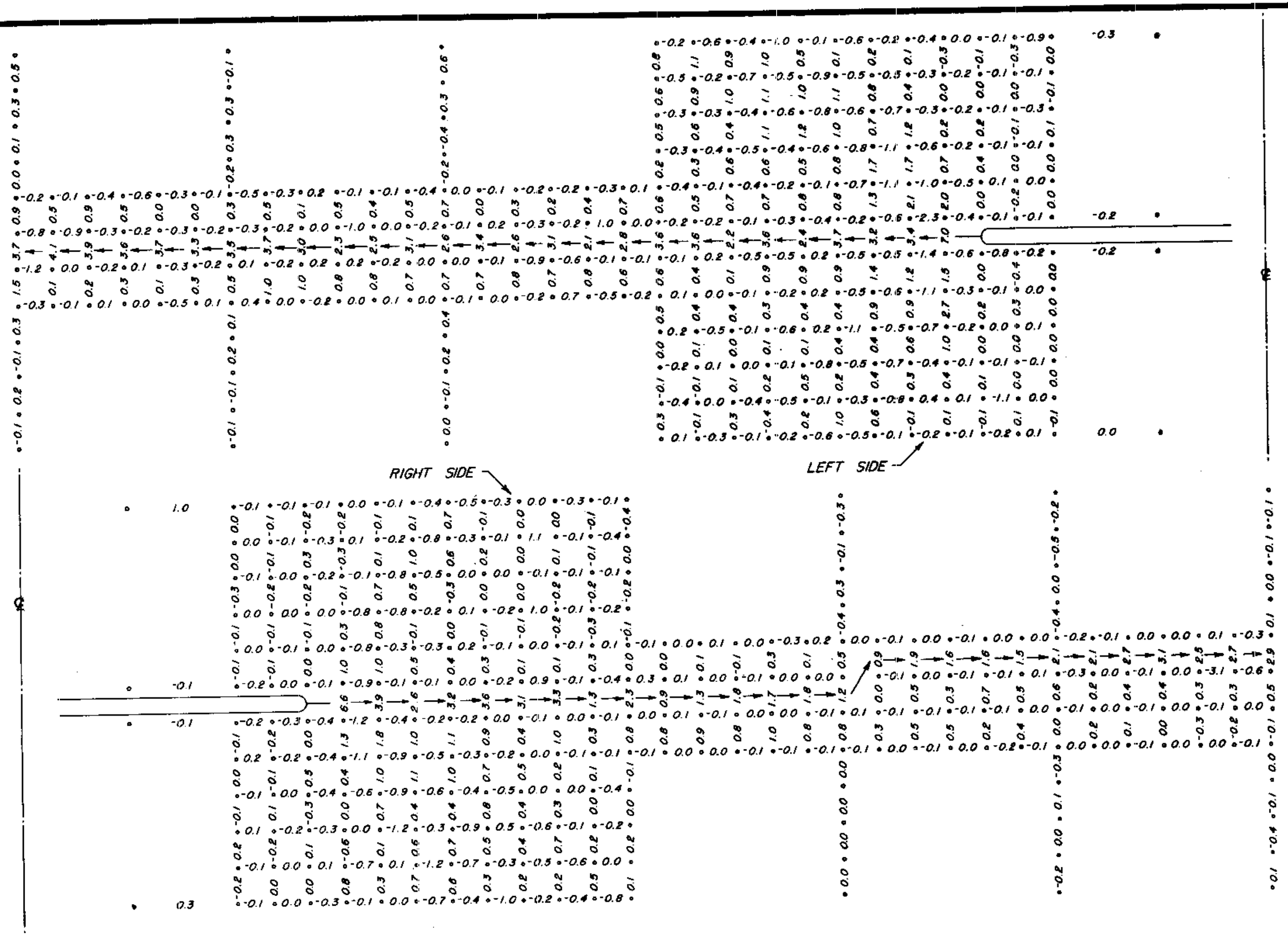


FIG. A-74 PERCENT ELONGATION PLATE A-4A (1-INCH GRID)

"A" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 35.8 KSI

TEMPERATURE 10 °F 0 % SHEAR

DWG. 44E183

FIG. A-74

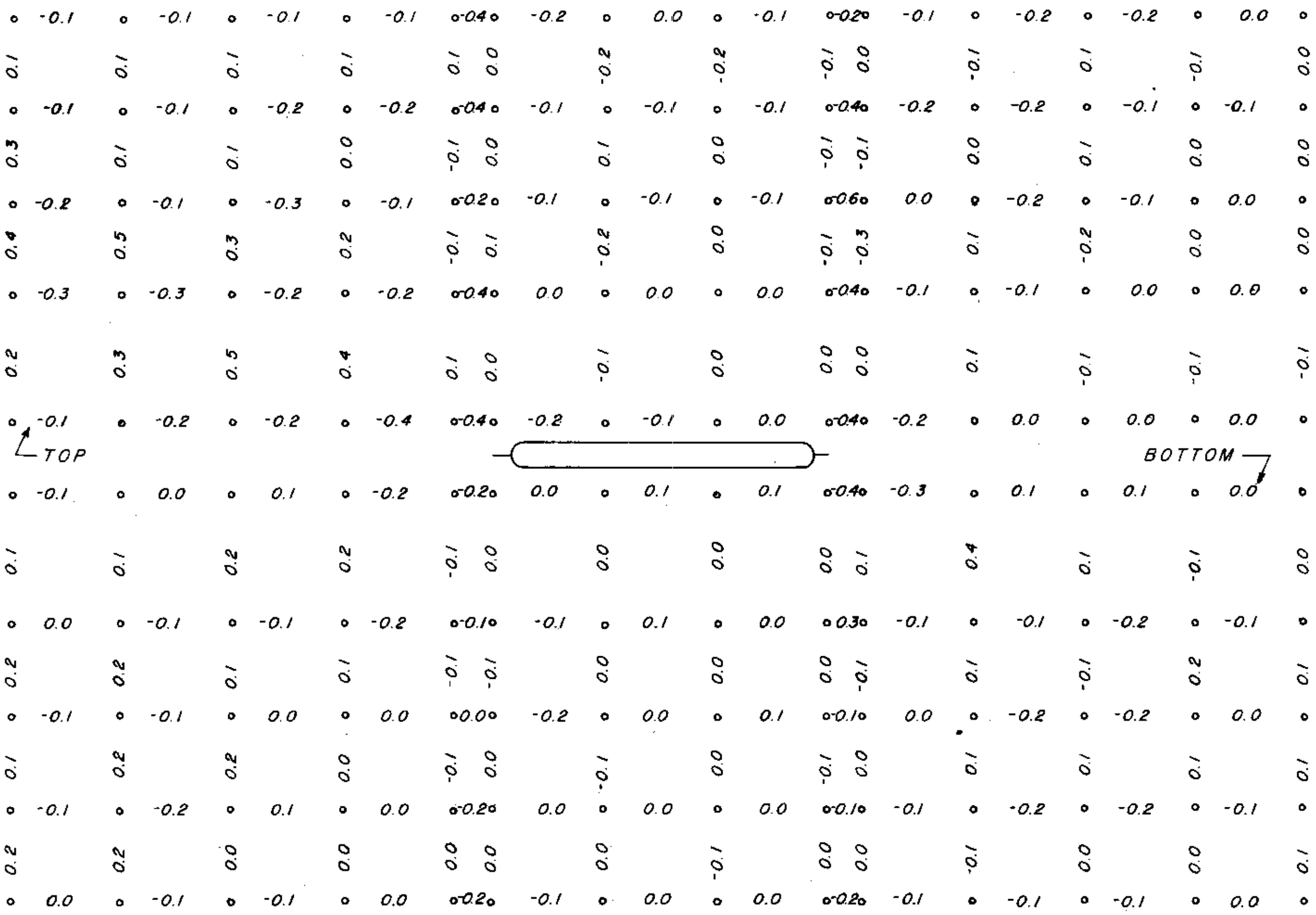


FIG. A-75 PERCENT ELONGATION PLATE A-4A (5-INCH GRID)

"A" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 35.8 KSI
TEMPERATURE 10 °F 0% SHEAR

FIG. A-75

DWG. 44E 216

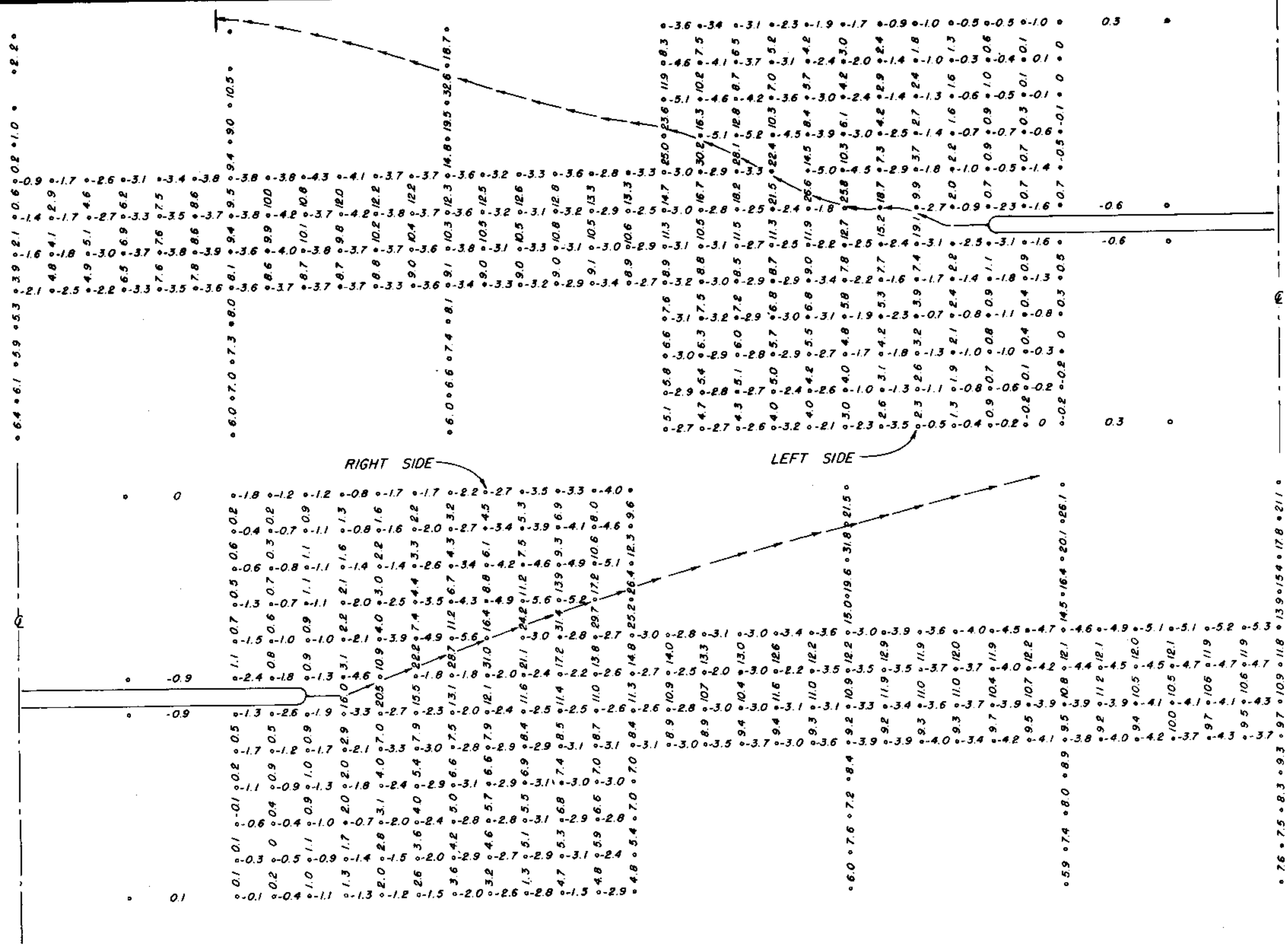


FIG. A-76 PERCENT ELONGATION PLATE A-5A (1-INCH GRID)

"A" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 40.0 KSI

TEMPERATURE 43-45 °F. 100 % SHEAR

DWG. 44E172

FIG. A-76

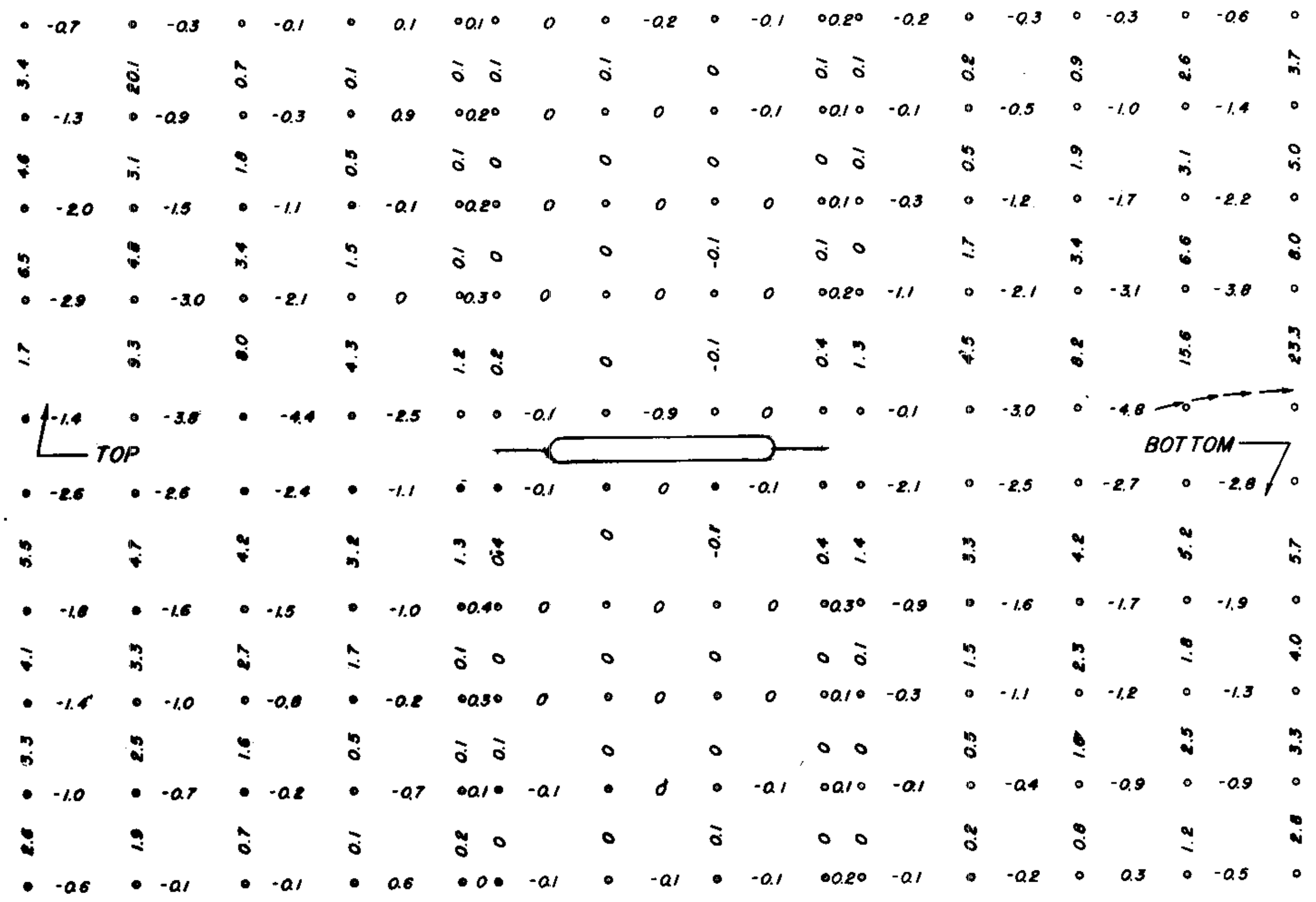


FIG. A-77 PERCENT ELONGATION PLATE A-5A (5-INCH GRID)

"A" STEEL, 72-INCH WIDE PLATE
TEMPERATURE 43-45°F.

NOMINAL STRENGTH 40.0 KSI
100% SHEAR

FIG. A-77

DWG. 4 • E81F

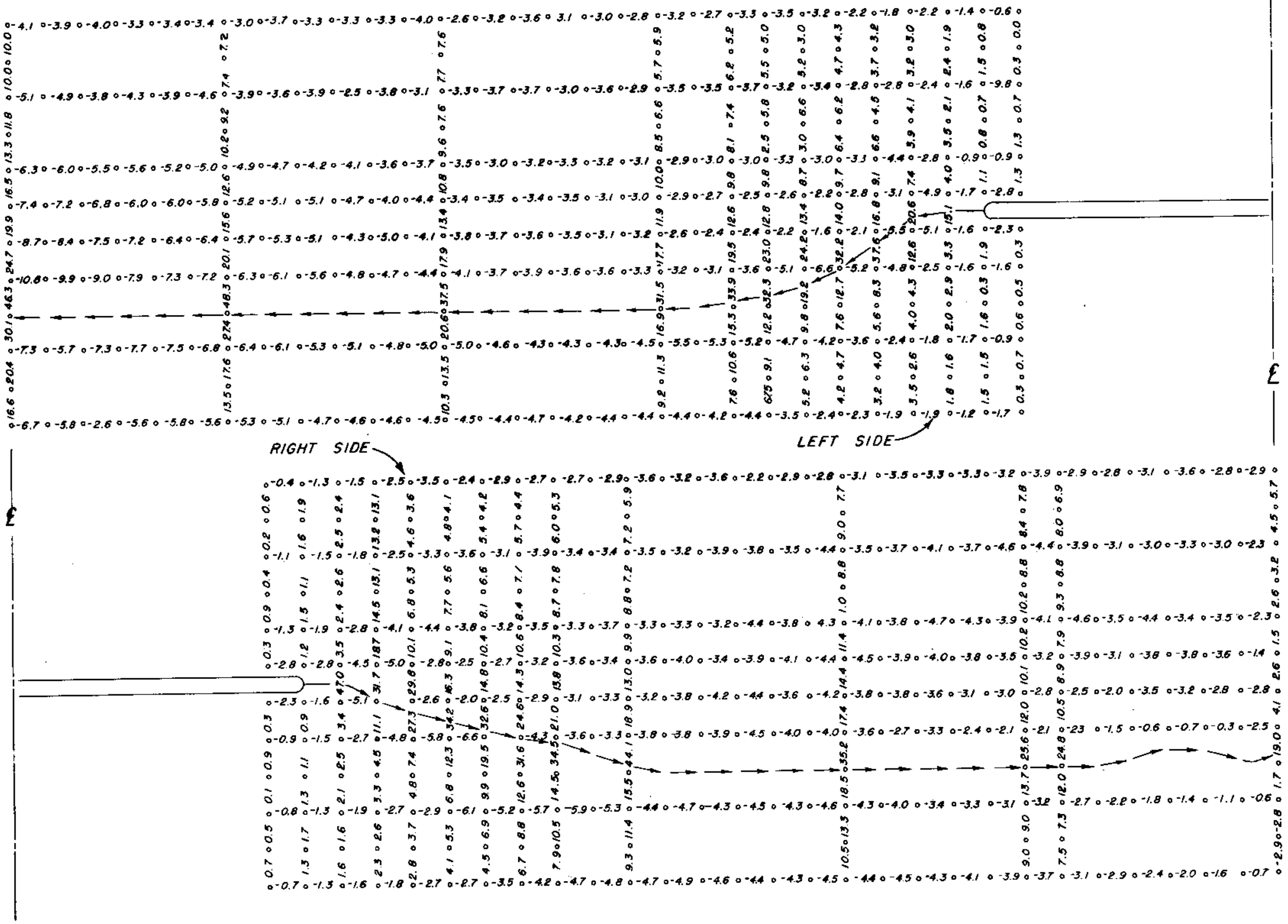


FIG. A-78 PERCENT ELONGATION PLATE B-5A (1-INCH GRID)

"B_n" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 39.5 KSI

TEMPERATURE 49-52 °F 100 % SHEAR

FIG. A-78

DWG. 44E167

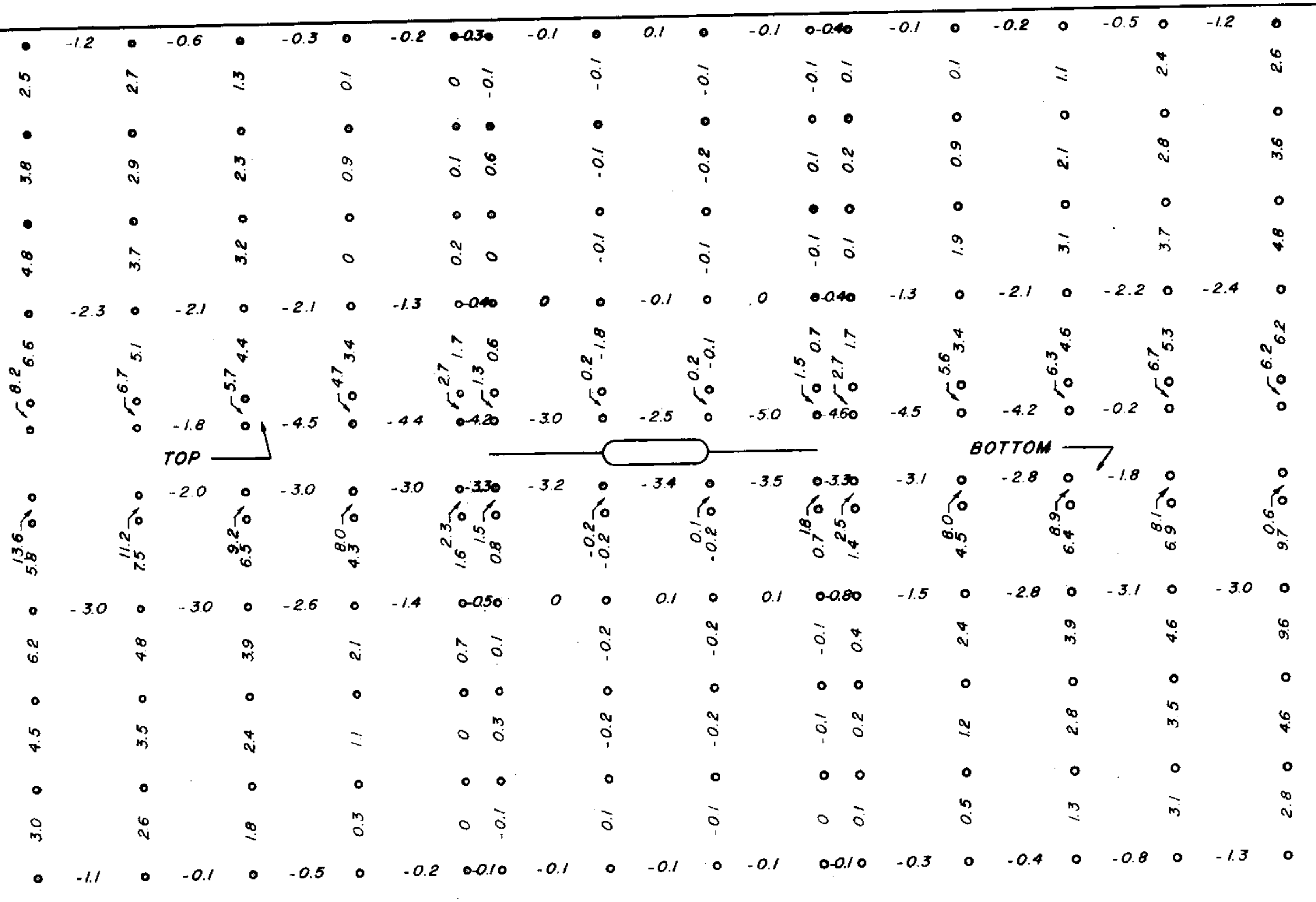


FIG. A-79 PERCENT ELONGATION PLATE B-5A (5-INCH GRID)

"B" STEEL, 72-INCH WIDE PLATE
TEMPERATURE 49-52°F

NOMINAL STRENGTH 39.5 KSI
100% SHEAR

FIG. A-79

DWG. 44E206

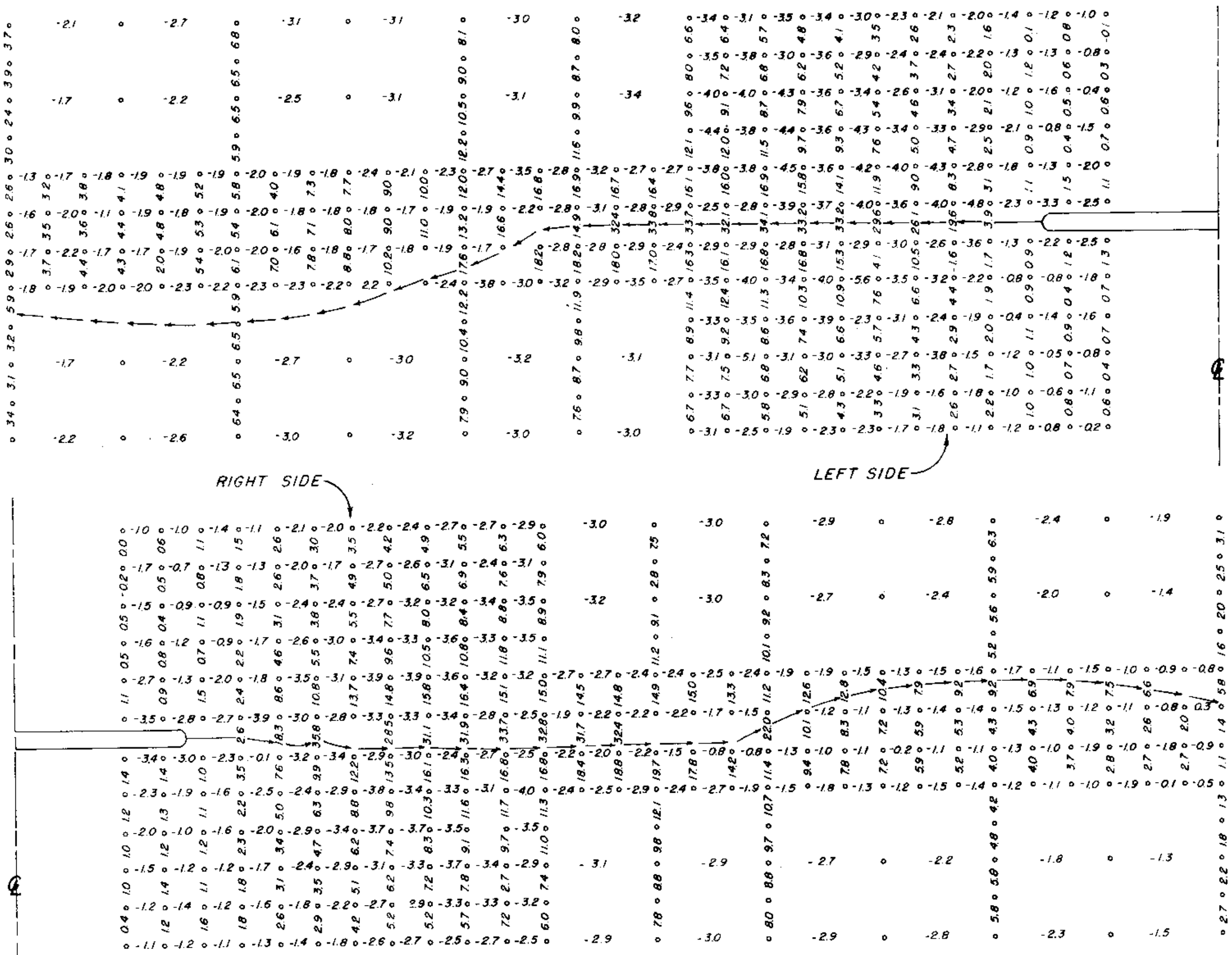


FIG. A-80 PERCENT ELONGATION PLATE B-6A (1-INCH GRID)

"B" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 40.2 KSI

TEMPERATURE 48-51°F 40% SHEAR

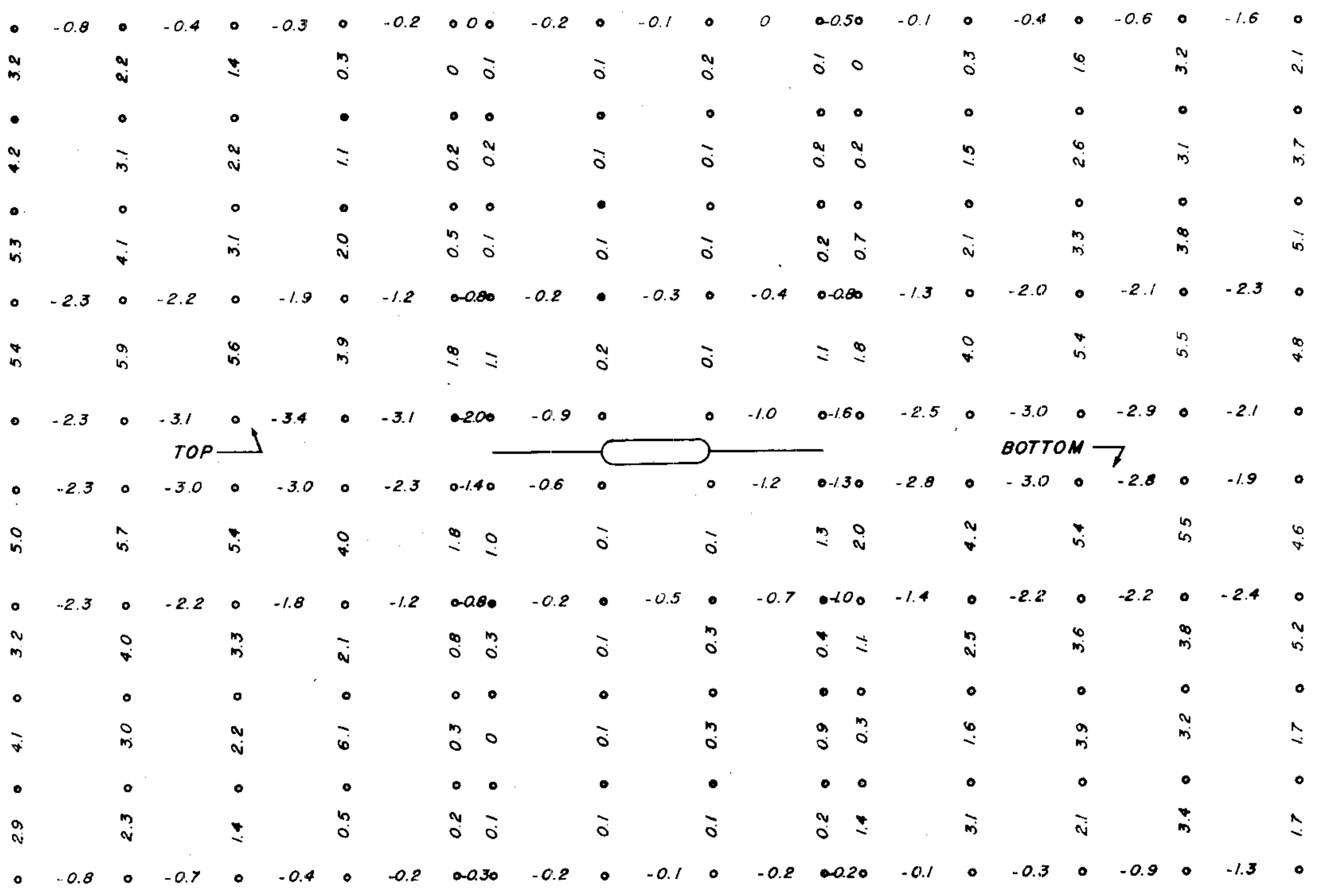


FIG. A-81 PERCENT ELONGATION PLATE B-6A (5-INCH GRID)

"B" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 40.2 KSI

TEMPERATURE 48-51°F 40% SHEAR

FIG. A-81

DWG. 44 E 207

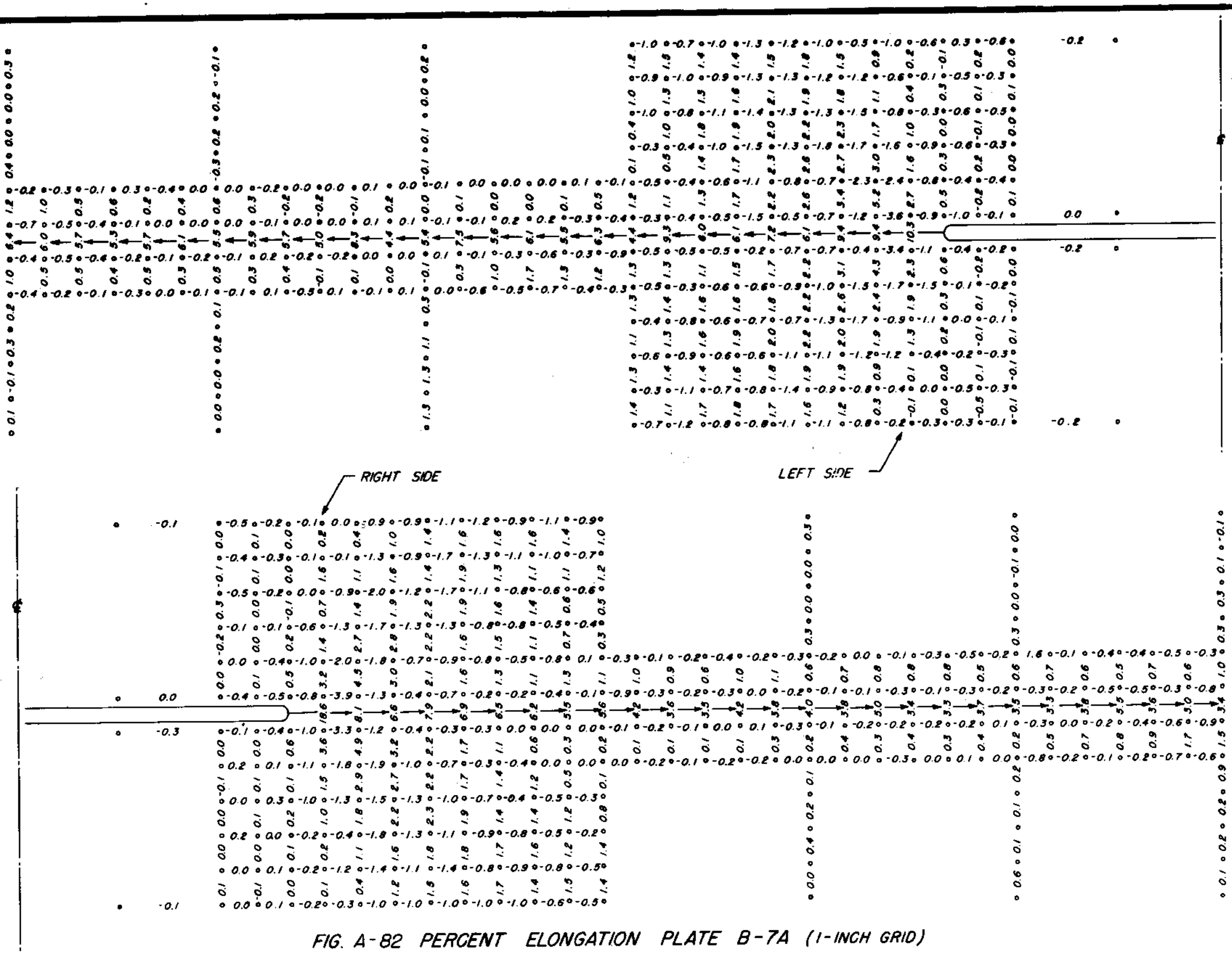


FIG. A-82 PERCENT ELONGATION PLATE B-7A (1-INCH GRID)

"B" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 34.6 KSI

TEMPERATURE 8-9 °F. 0% SHEAR

DWG. 44E 176

FIG. A-82

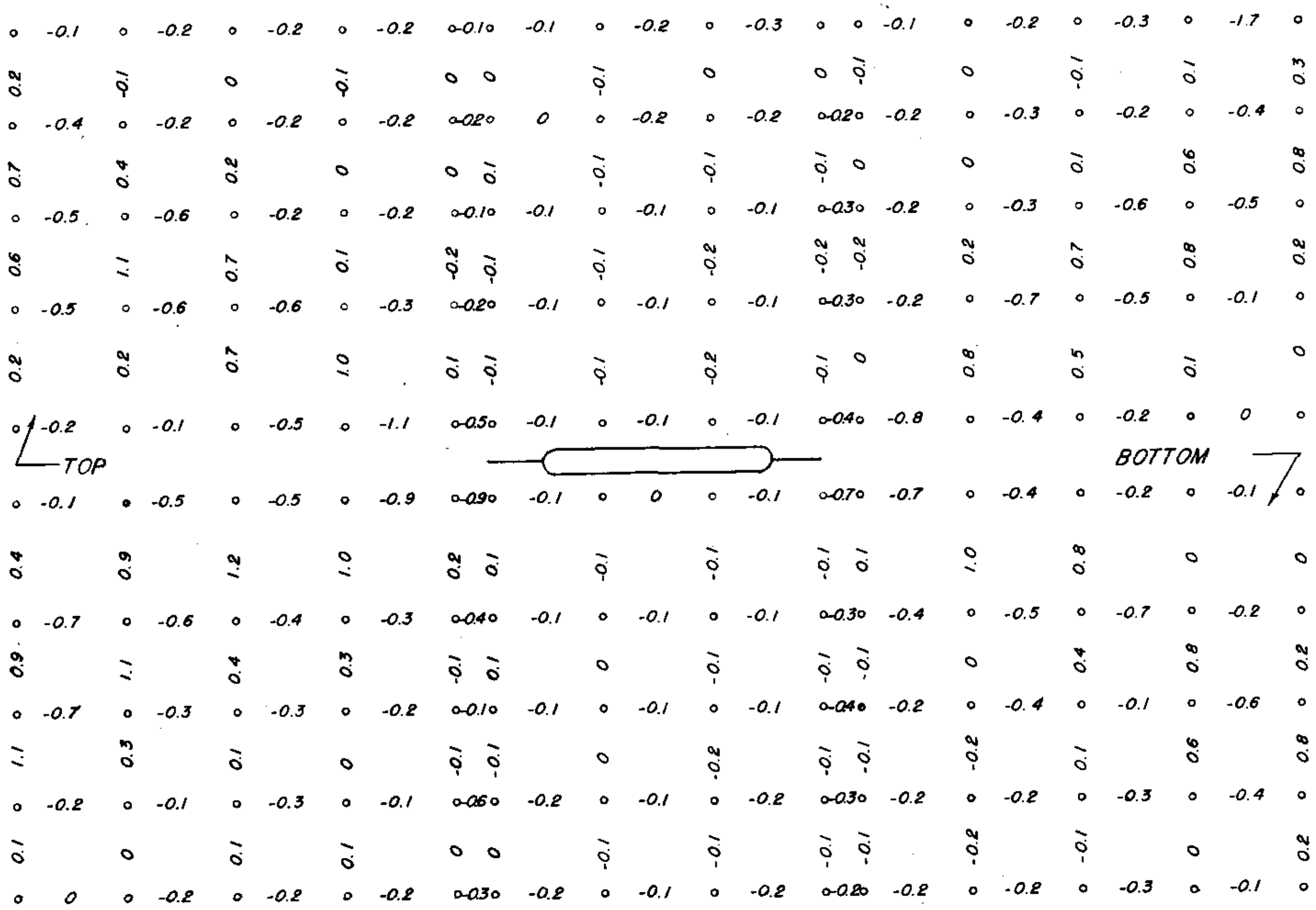


FIG. A-83 PERCENT ELONGATION

"B" STEEL, 72-INCH WIDE PLATE

TEMPERATURE 8-9° F.

PLATE B-7A (5-INCH GRID)

NOMINAL STRENGTH 34.6 KSI

0 % SHEAR

DWG. 44E2M4

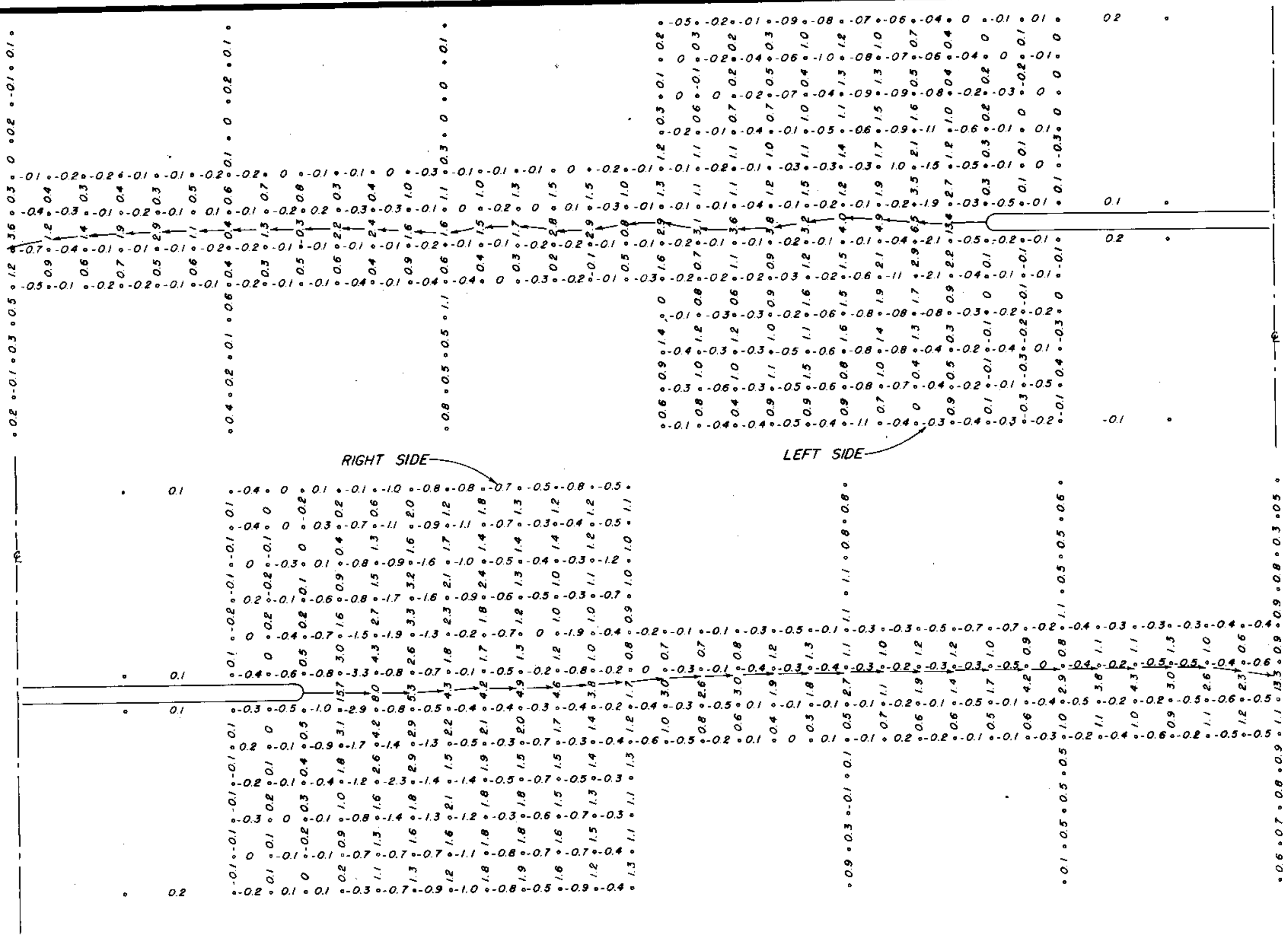


FIG A-84 PERCENT ELONGATION

"B" STEEL, 72-INCH WIDE PLATE

TEMPERATURE 16-18 °F.

PLATE B-8A (1-INCH GRID)

NOMINAL STRENGTH 33.3 KSI

0 % SHEAR

DWG. 44E173

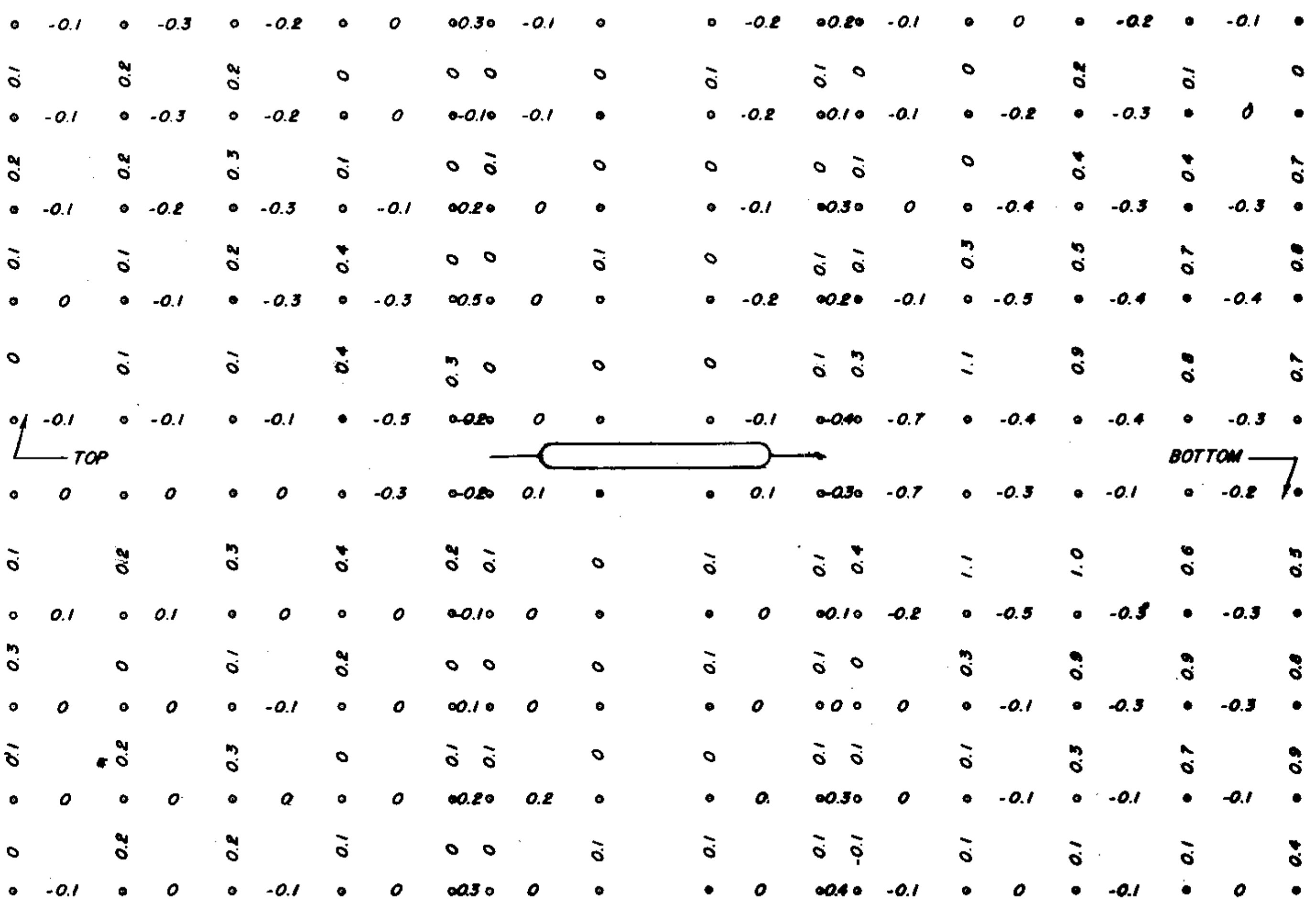


FIG. A-85 PERCENT ELONGATION PLATE B-8A (5 INCH GRID)

"B" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 33.3 KSI

TEMPERATURE 16-18 °F. 0% SHEAR

FIG. A-85

DWG. 44E212

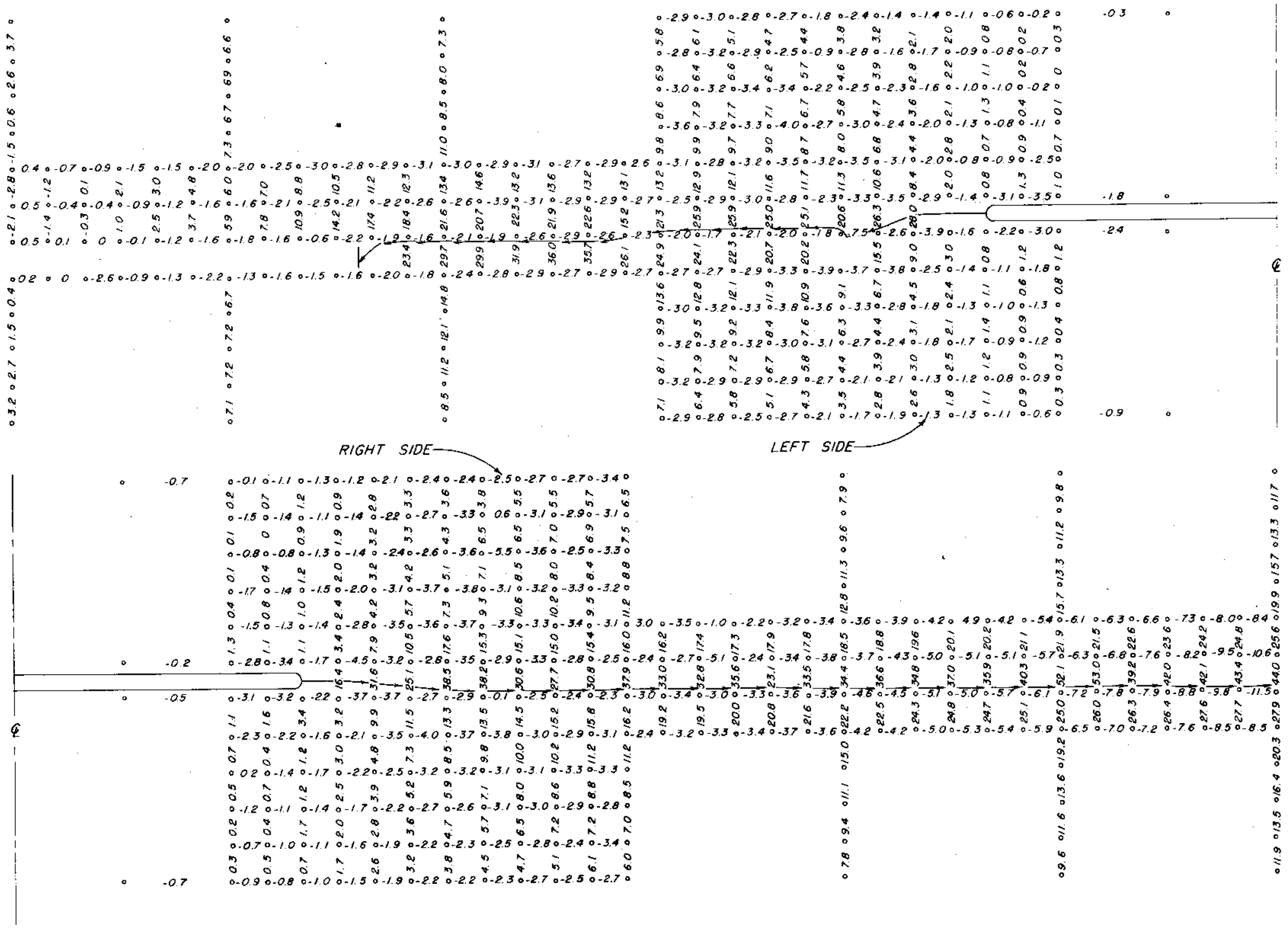


FIG. A-86 PERCENT ELONGATION PLATE B-10A (1 INCH GRID)

"B" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 38.8 KSI

TEMPERATURE 31 - 33 °F 100% SHEAR

FIG. A-86

DWG. 44E235

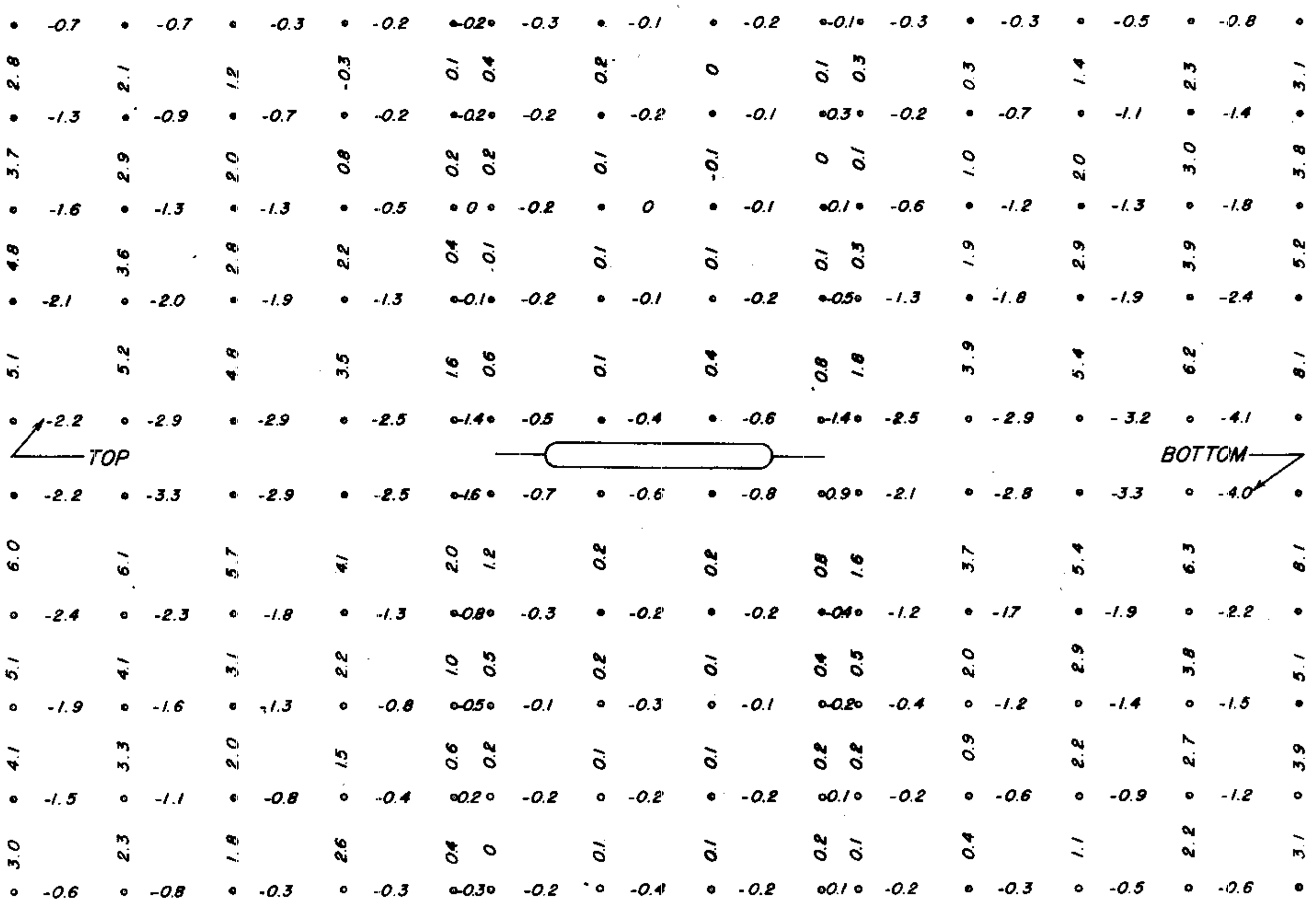


FIG. A-87 PERCENT ELONGATION PLATE B-10A (5-INCH GRID)

"B" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 38.8 KSI

TEMPERATURE 31-33°F. 100 % SHEAR

FIG. A-87

DWG. 44E236

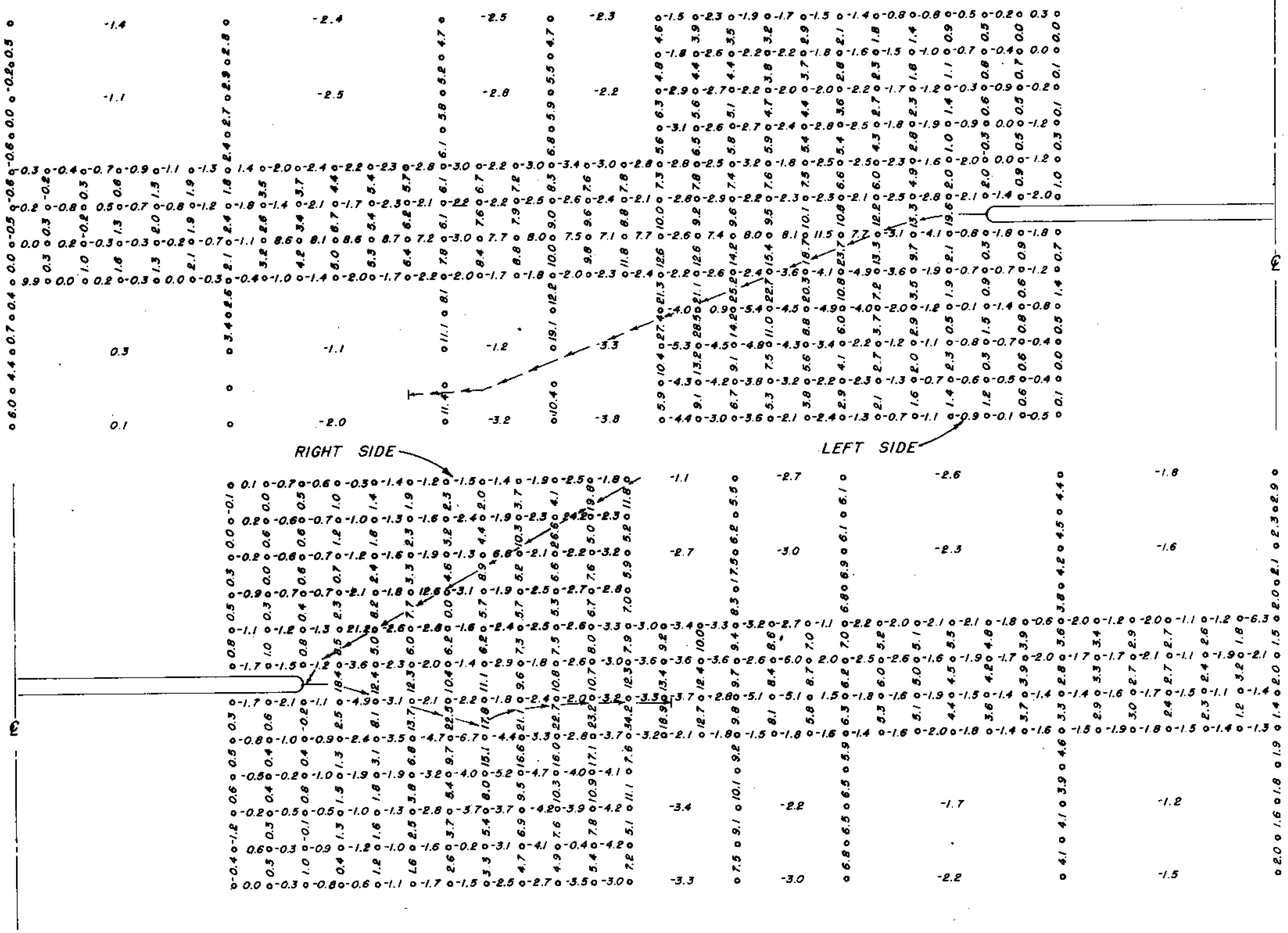


FIG. A-88 PERCENT ELONGATION PLATE C-3A (1-INCH GRID)

"C" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 43.2 KSI

TEMPERATURE 100-104°F 100 % SHEAR

FIG. A-88

DWG 44E169

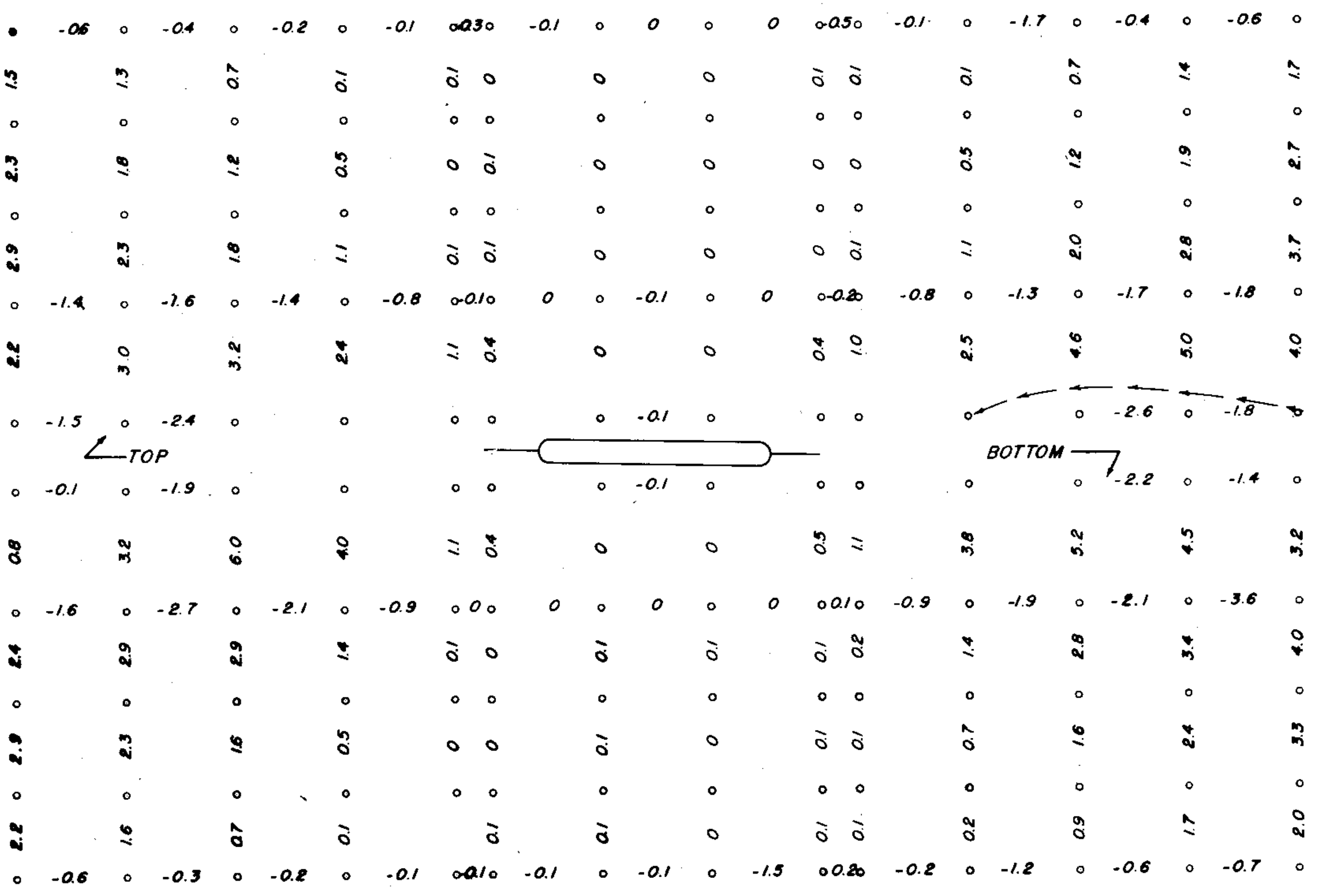


FIG. A-89 PERCENT ELONGATION PLATE C-3A (5-INCH GRID)

"C" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 43.2 KSI

TEMPERATURE 100-104 °F 100 % SHEAR

DWG. 44E208

FIG. A-89

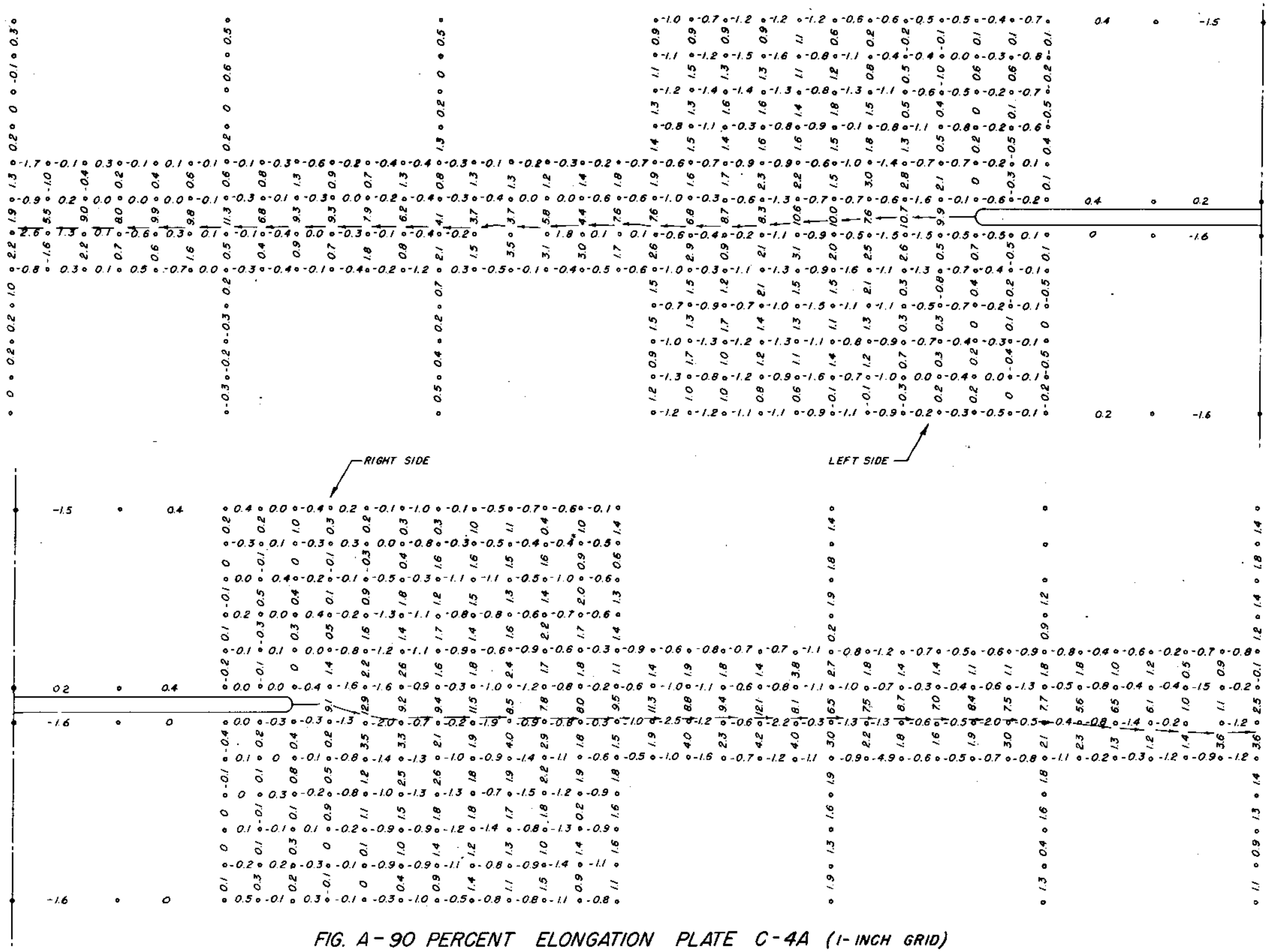


FIG. A-90 PERCENT ELONGATION PLATE C-4A (1-INCH GRID)

"C" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 35.7 KSI

TEMPERATURE 80-82 °F. 0% SHEAR

DWG. 44E171

FIG. A-90

FIG. C-9

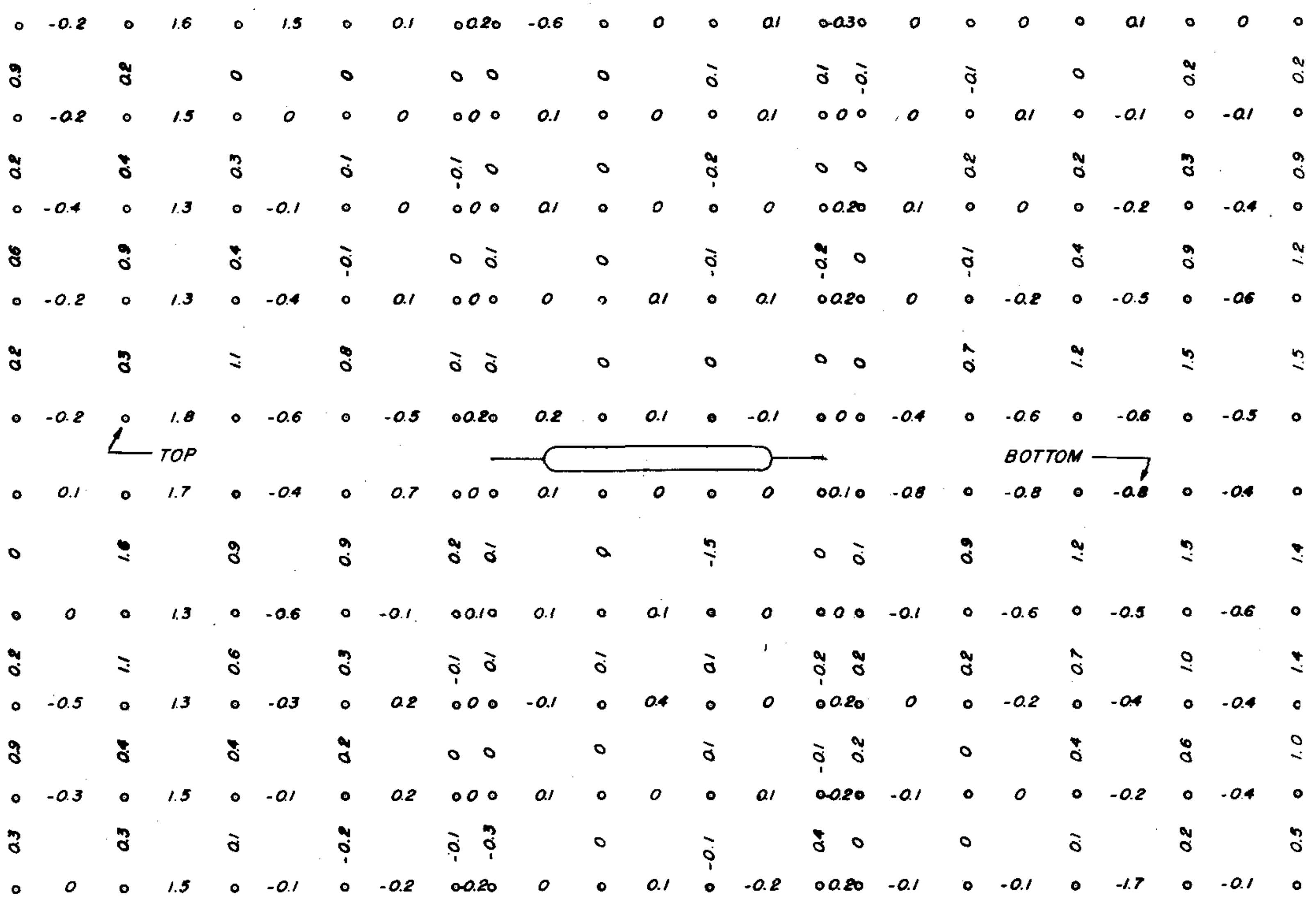


FIG. A-91 PERCENT ELONGATION PLATE C-4A (5-INCH GRID)

"C" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 35.7 KSI

TEMPERATURE 80-82°F 0% SHEAR

DWG. 44E210

FIG. A-91
]

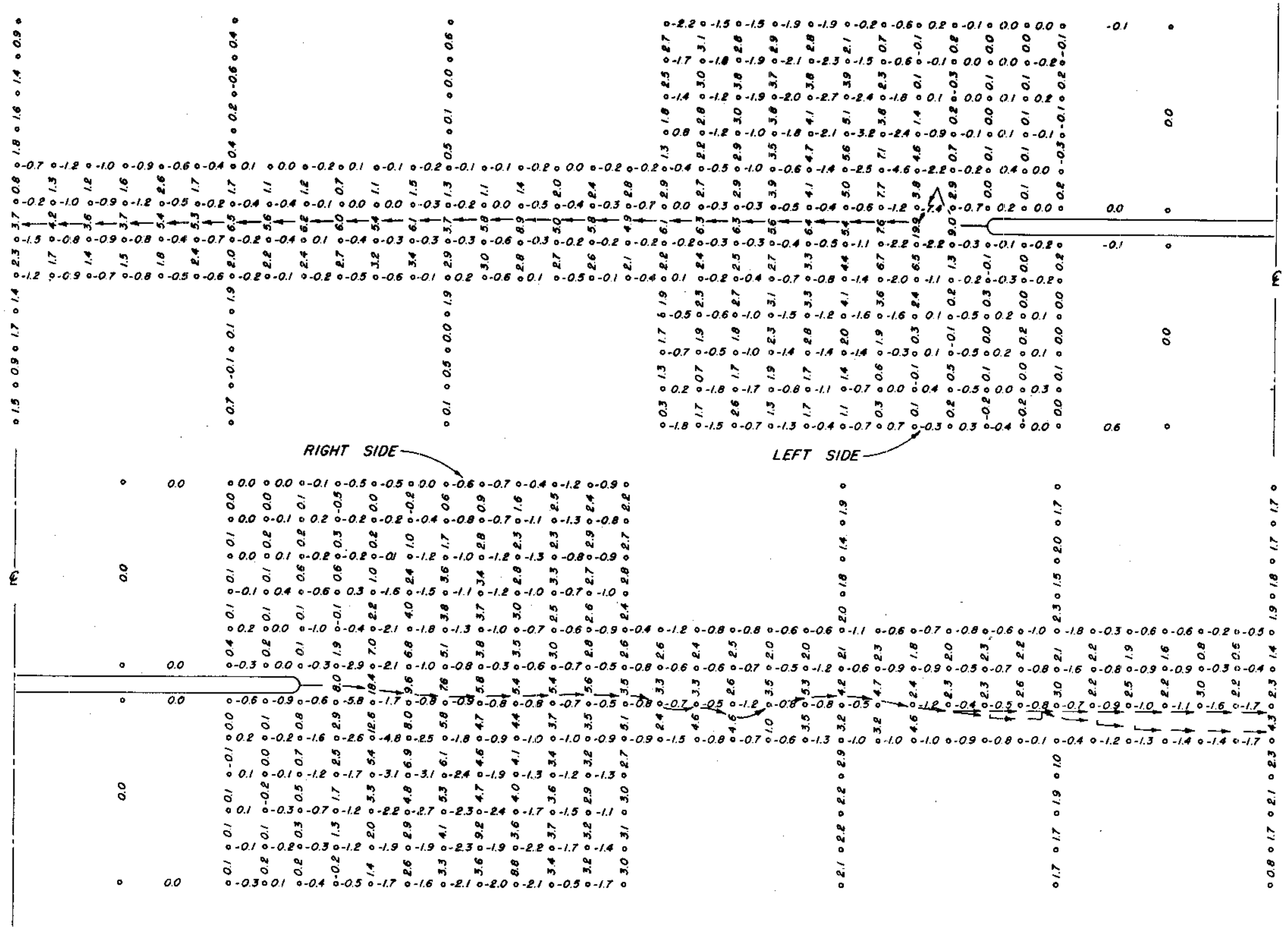


FIG. A-92 PERCENT ELONGATION PLATE N-1A (1-INCH GRID)

"N" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 64.2 KSI

TEMPERATURE (-55) - (-51) °F. 4 % SHEAR

FIG. A-92

DWG. 44E174

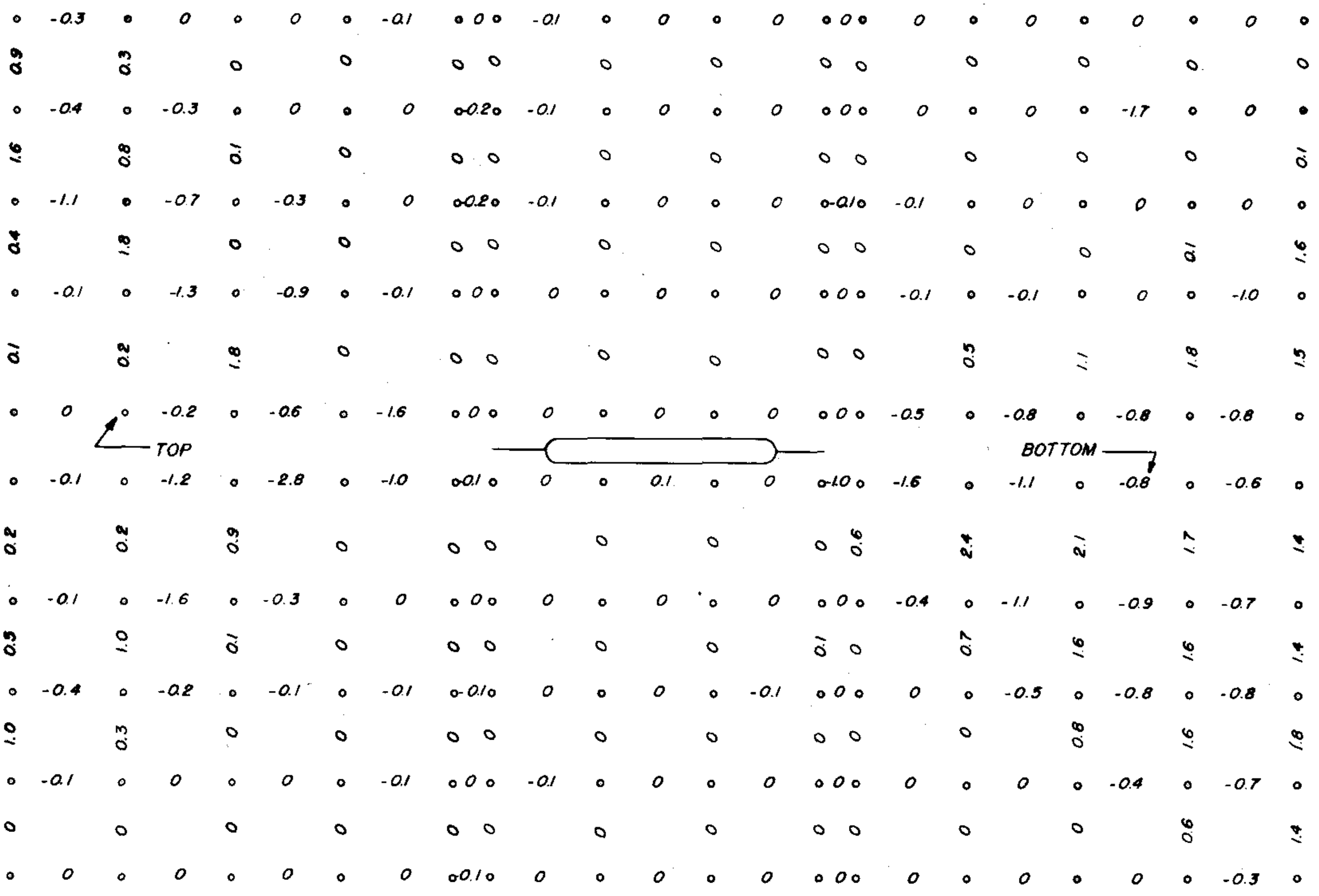


FIG. A-93 PERCENT ELONGATION PLATE N-1A (5-INCH GRID)

"N" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 64.2 KSI

TEMPERATURE (-55)-(-51) °F 4 % SHEAR

FIG. A-93

44E213 DWG

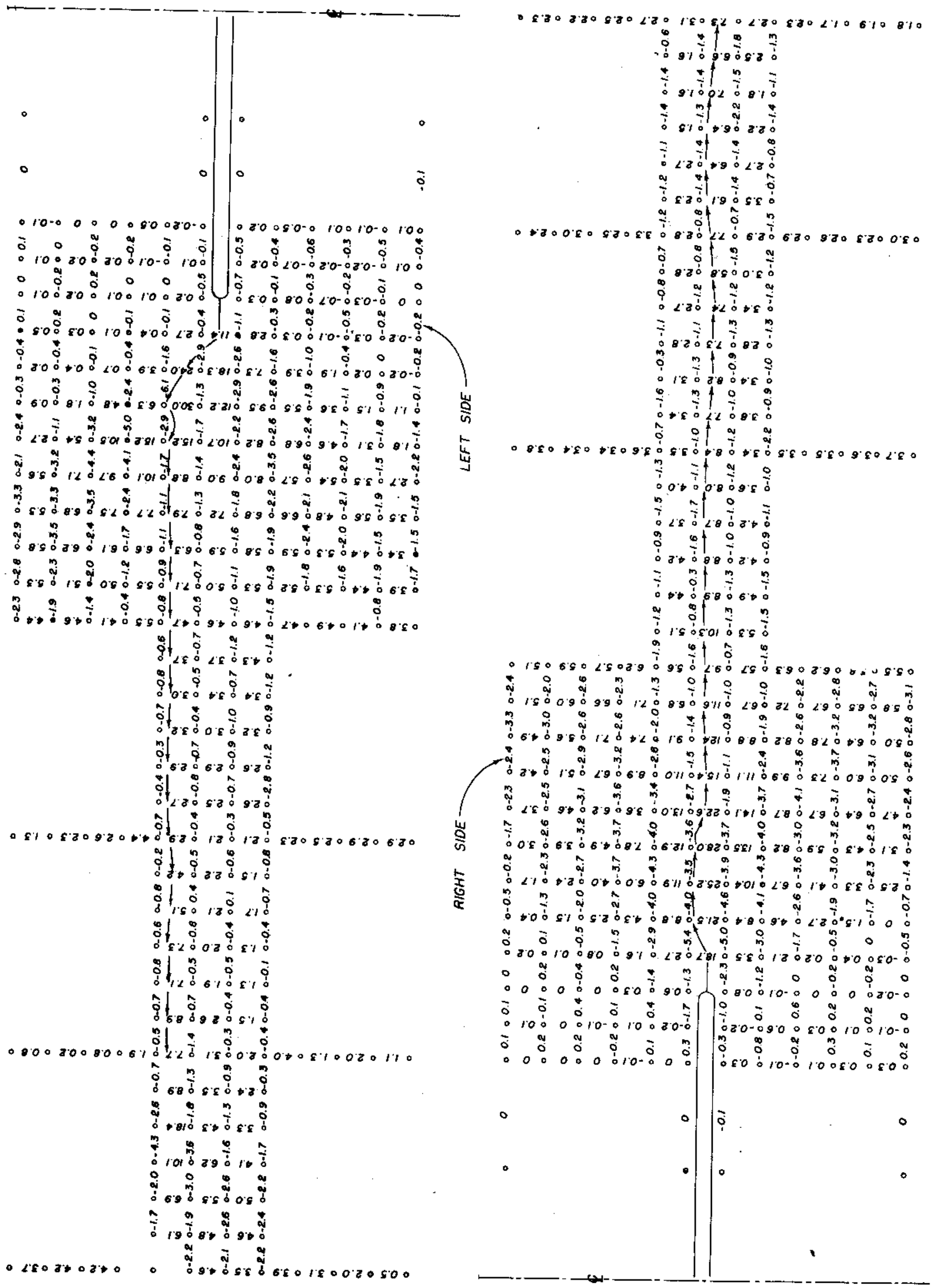


FIG. A-94 PERCENT ELONGATION PLATE N-2A (1-INCH GRID)

"N" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 60.9 KSI

TEMPERATURE (-35)-(-30) °F 13 % SHEAR

DWG. 44E188

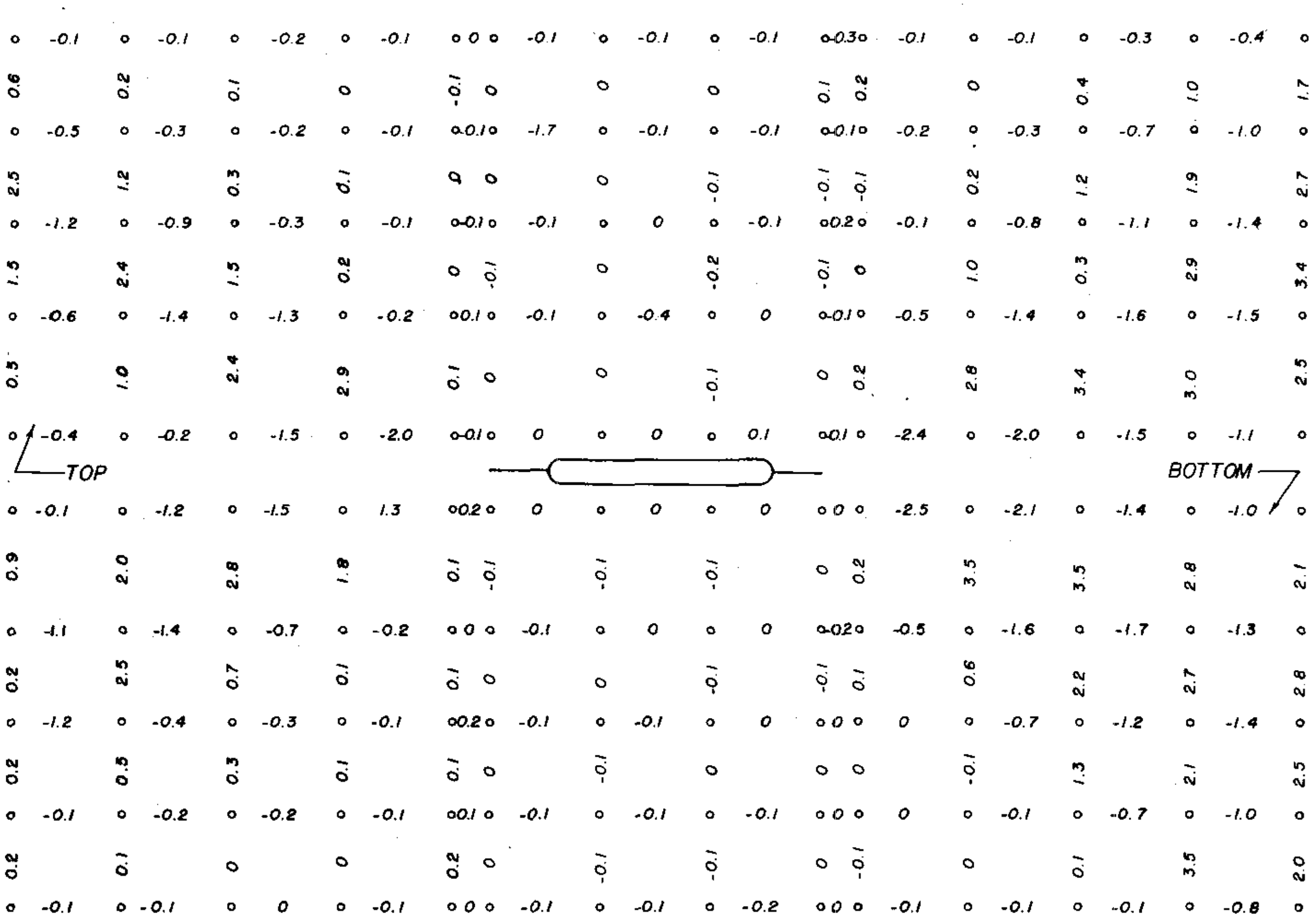


FIG. A-95 PERCENT ELONGATION PLATE N-2A (5-INCH GRID)

"N" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 60.9 KSI

TEMPERATURE (-35)-(-30) °F. 13 % SHEAR

DWG. 44E218

FIG. A-95

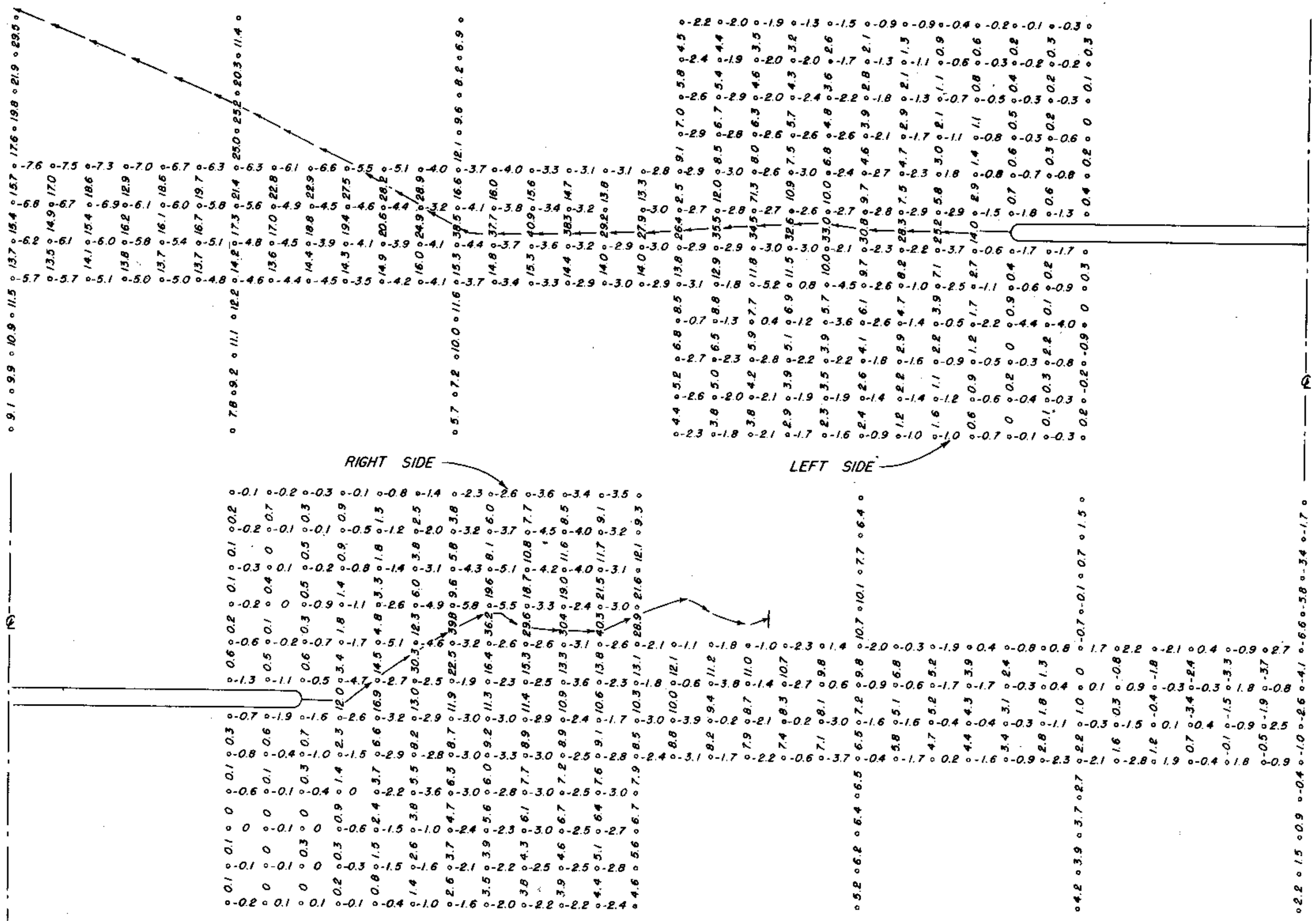


FIG. A-96 PERCENT ELONGATION

PLATE N-3A (1-INCH GRID)

"N" STEEL, 72-INCH WIDE PLATE

TEMPERATURE 2 °F.

NOMINAL STRENGTH 59.8 KSI

100 % SHEAR

DWG. 44E230

FIG. A-96

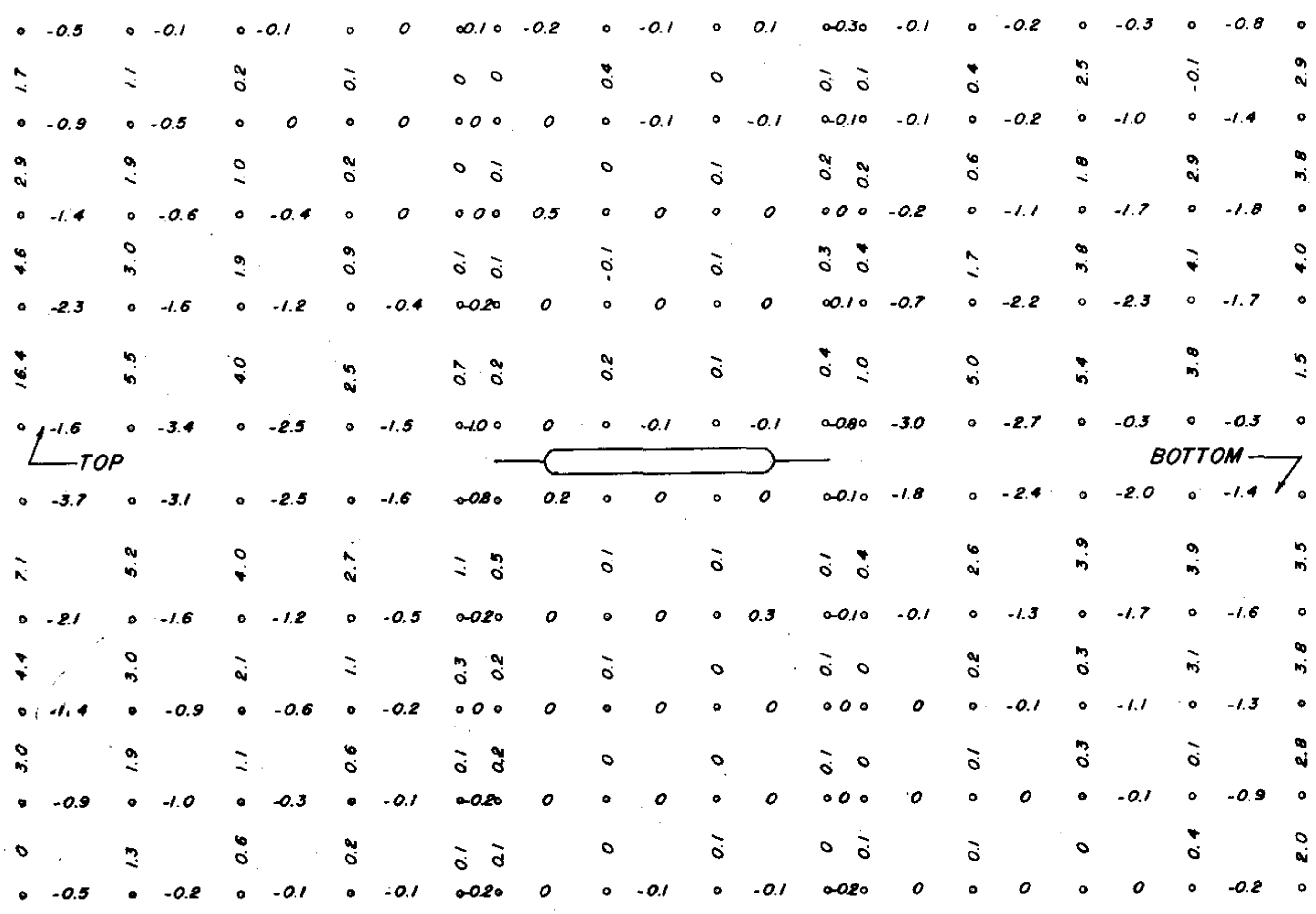


FIG. A-97 PERCENT ELONGATION PLATE N-3A (1-INCH GRID)

"N" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 59.8 KSI
TEMPERATURE 2 °F 100 % SHEAR

FIG. A-97

DWG. 44E231

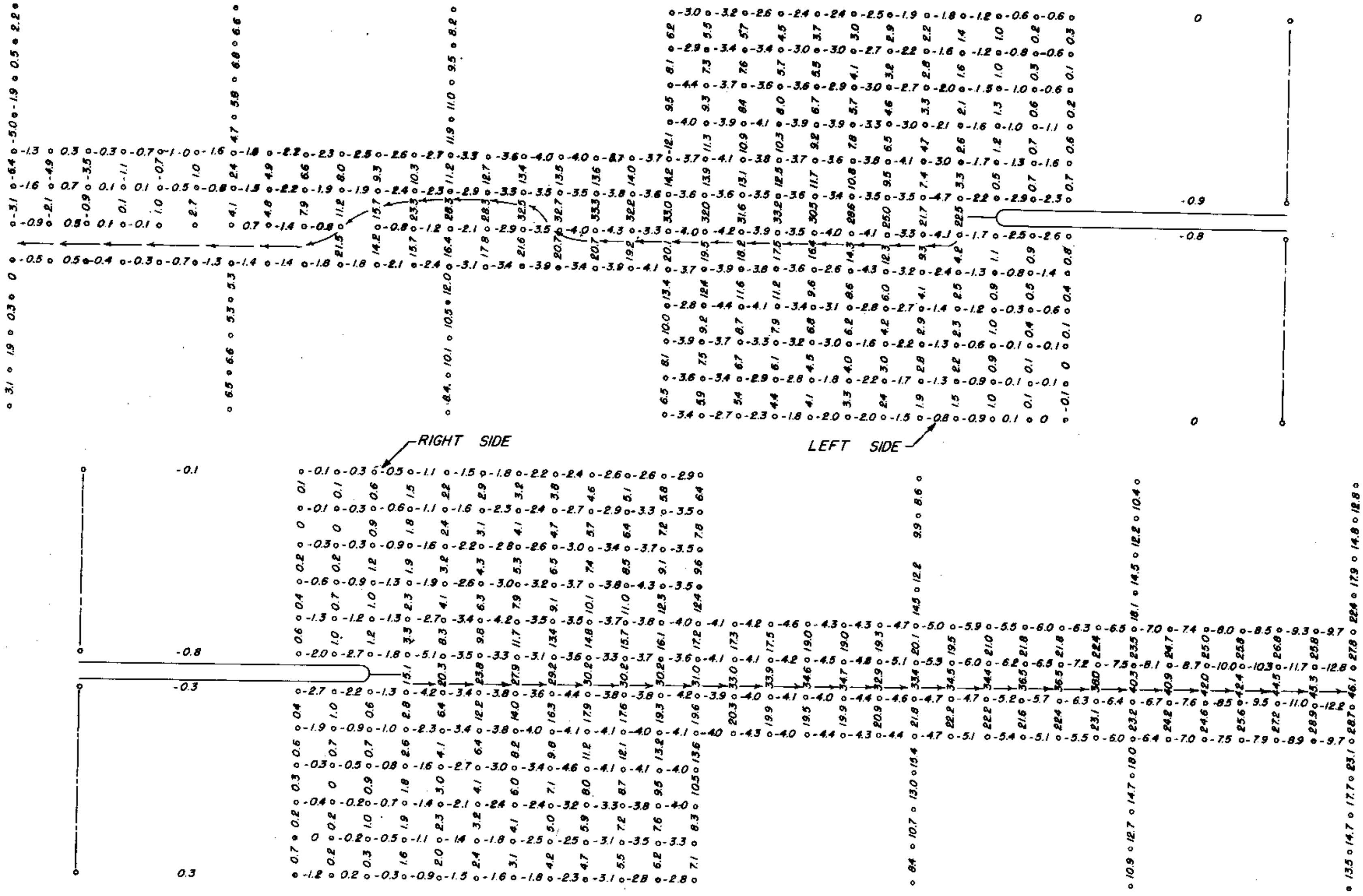


FIG. A-98 PERCENT ELONGATION

"H" STEEL, 72-INCH WIDE PLATE

TEMPERATURE 67 - 69 °F

PLATE H-1A (1 INCH GRID)

NOMINAL STRENGTH 44.7 KSI

100 % SHEAR

DWG. 44E 245

FIG. A-98

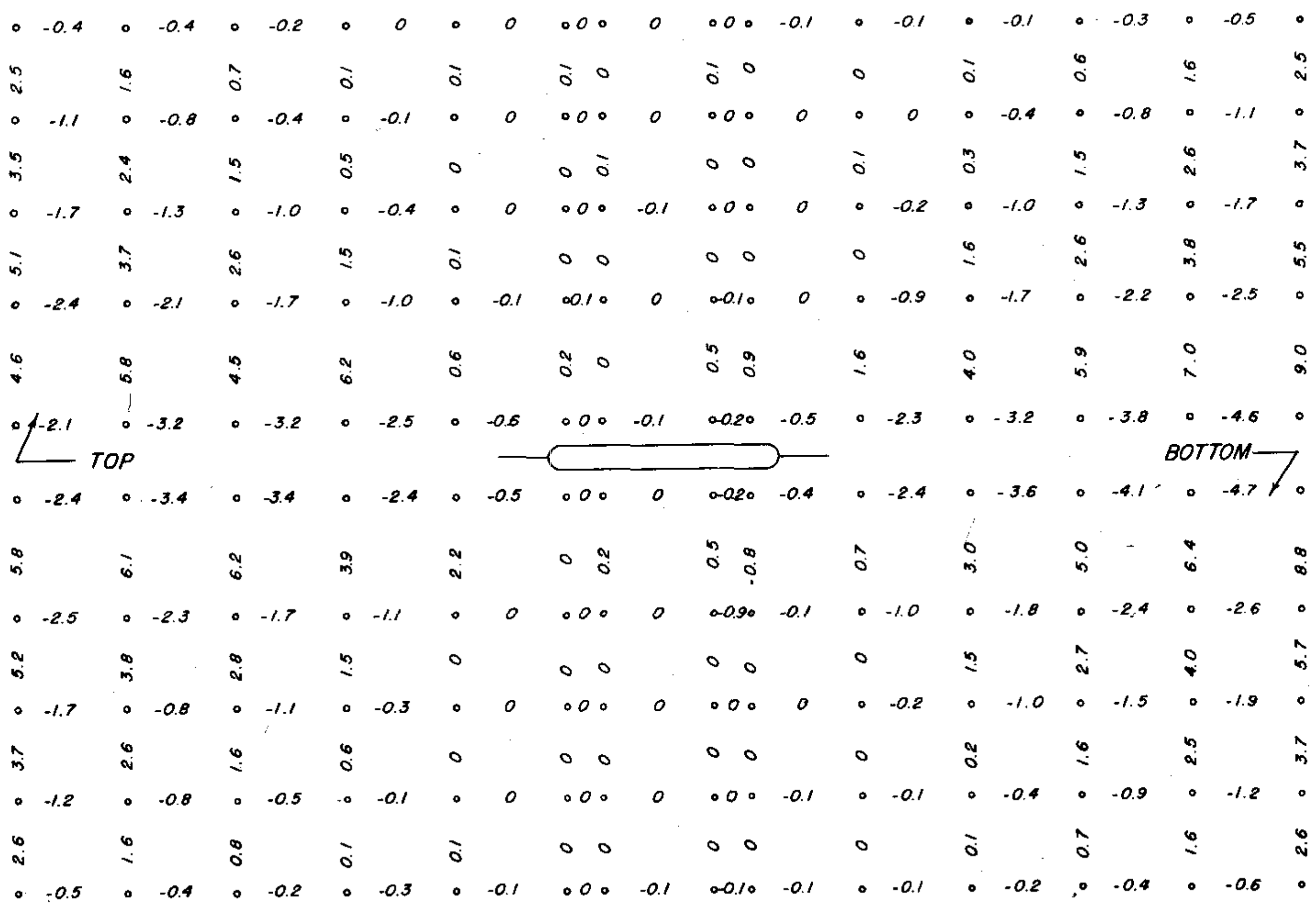


FIG. A-99 PERCENT ELONGATION PLATE H-1A (5-INCH GRID)

"H" STEEL, 72-INCH WIDE PLATE
TEMPERATURE 67-69 °F

NOMINAL STRENGTH 44.7 KSI
100 % SHEAR

DWG. 44E246

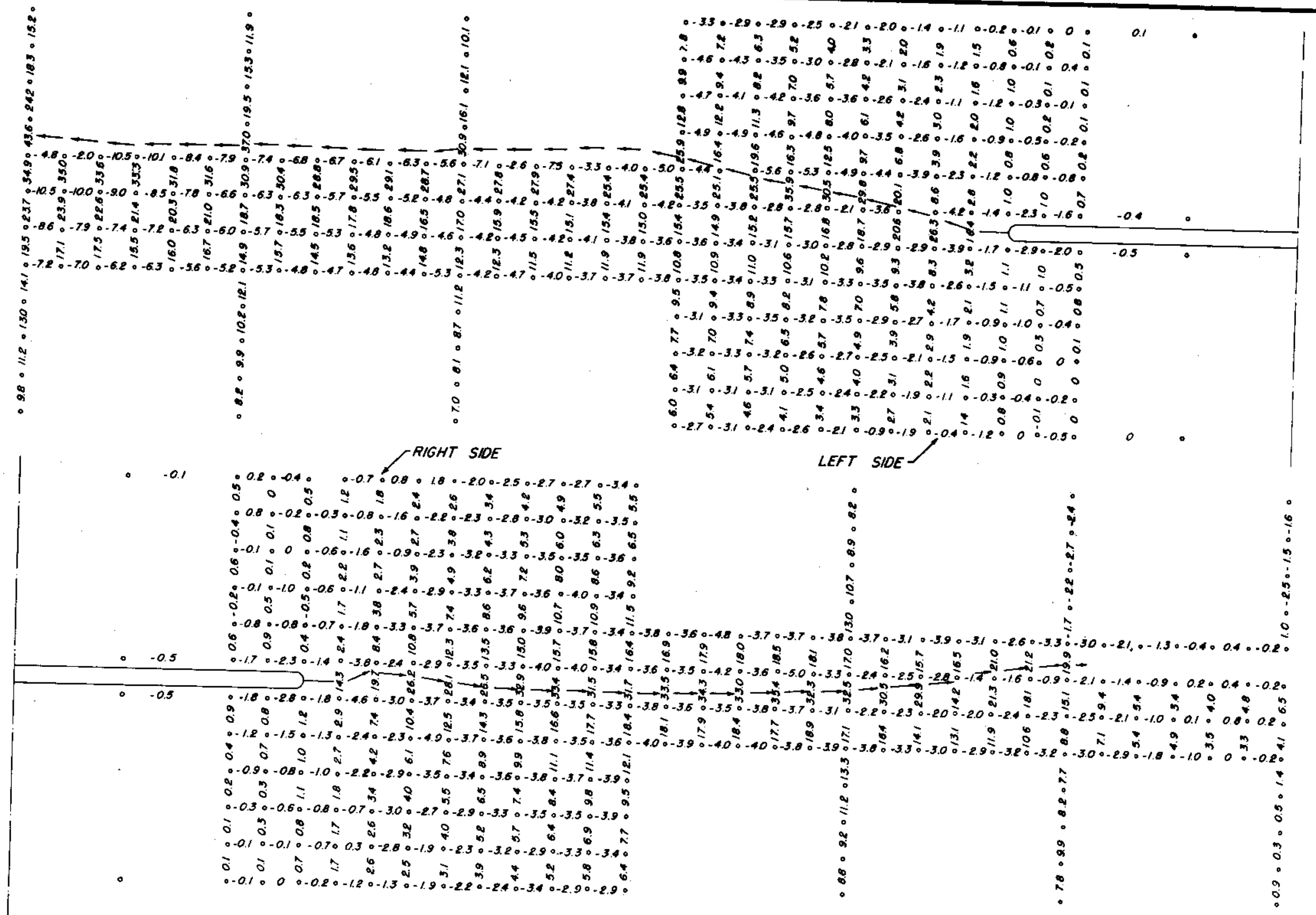


FIG. A-100 PERCENT ELONGATION PLATE H-2A (1-INCH GRID)

"H" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 45.6 KSI

TEMPERATURE 24°-27° F 100% SHEAR

FIG. A-100

DWG. 44E257

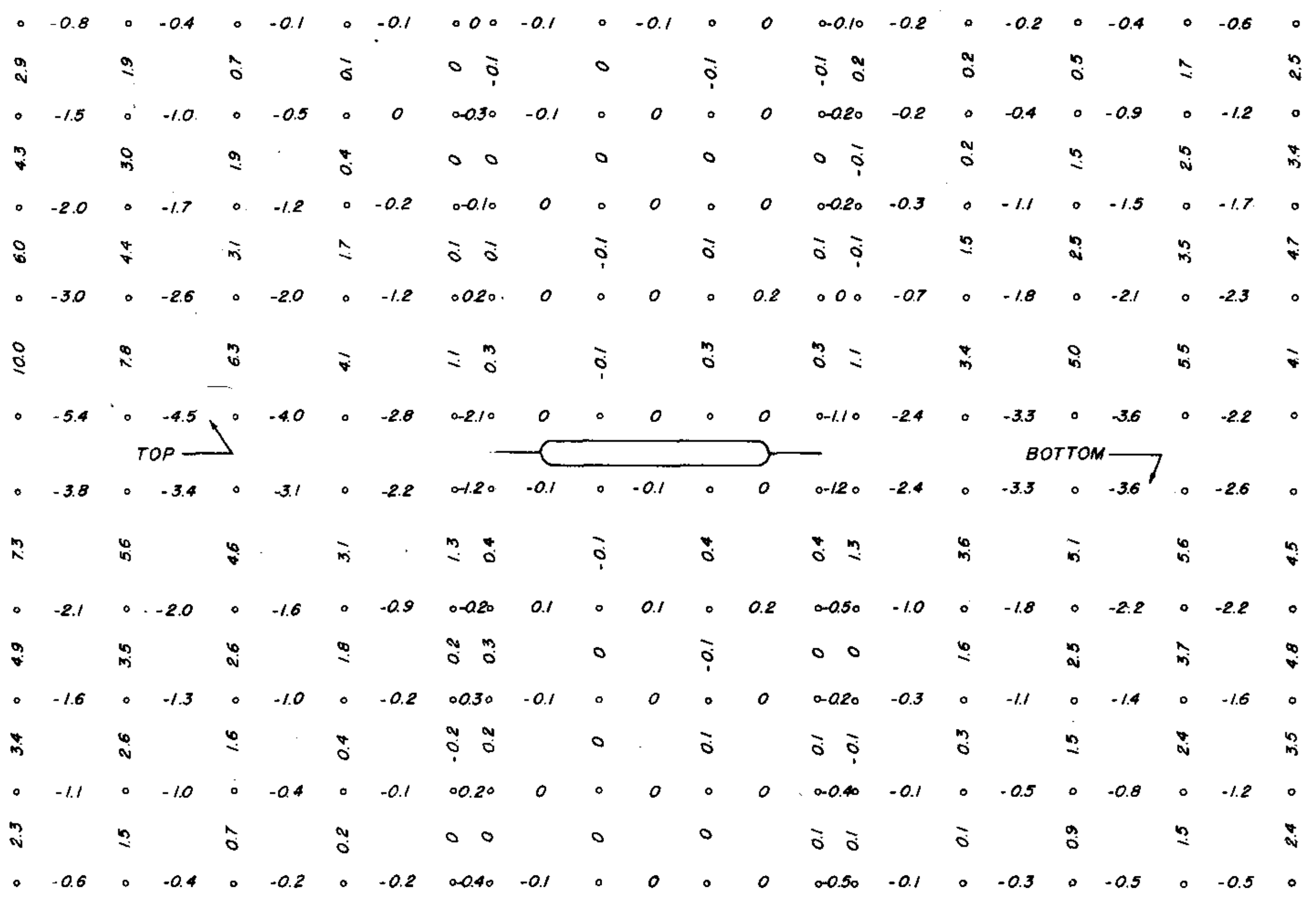


FIG. A-101 PERCENT ELONGATION

"H" STEEL, 72-INCH WIDE PLATE

TEMPERATURE 24°-27°

PLATE H-2A (5-INCH GRID)

NOMINAL STRENGTH 45.6 KSI

100% SHEAR

FIG. A-101

DWG. 44E258

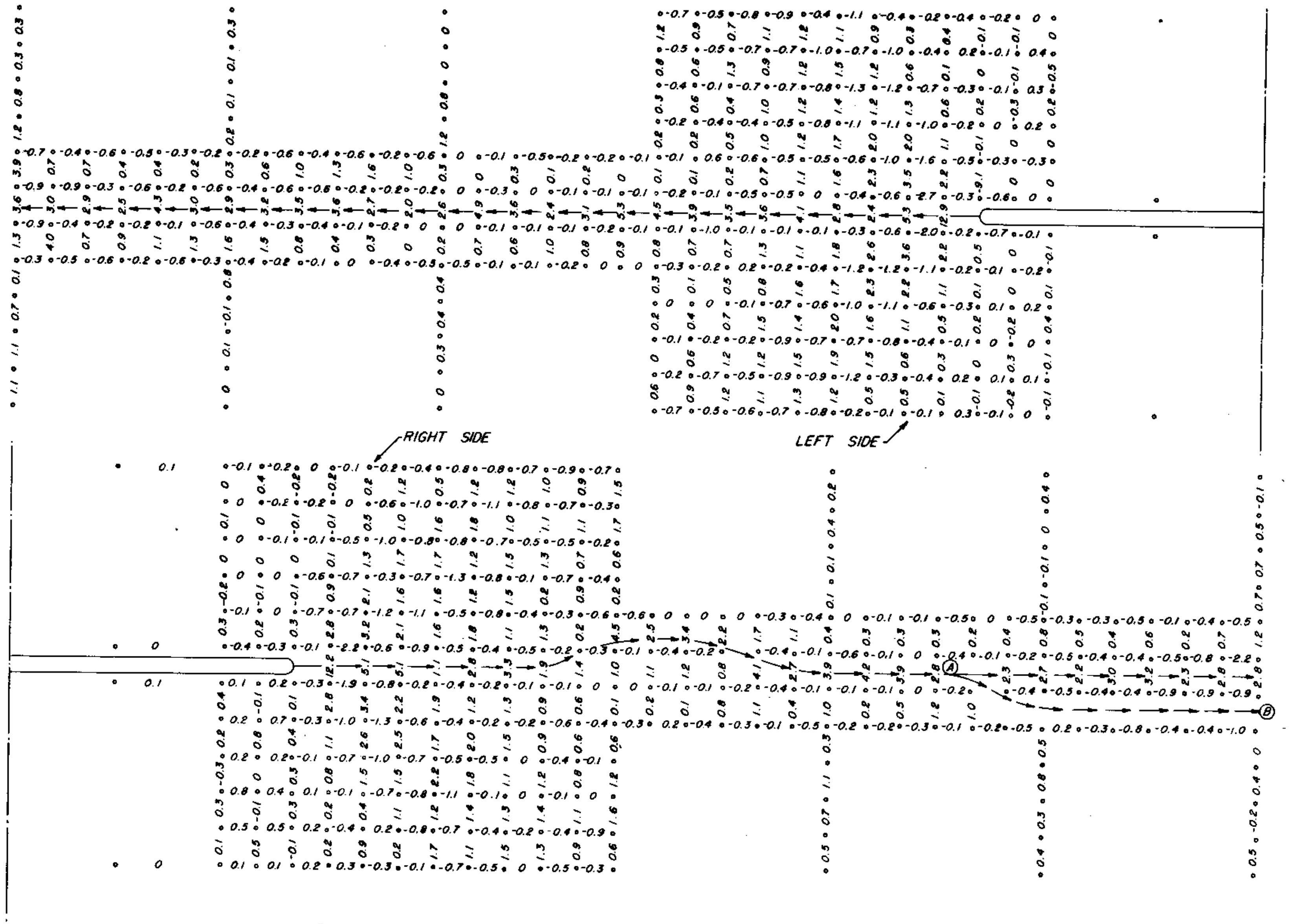


FIG. A-102 PERCENT ELONGATION PLATE H-3A (1-INCH GRID)

"H" STEEL, 72-INCH WIDE PLATE NOMINAL STRENGTH 38.3 KSI

TEMPERATURE 15° F. 0% SHEAR

NOTE: FRACTURE FROM A TO B WAS ONLY PART WAY THROUGH THE THICKNESS OF THE PLATE.

DWG. 44E259

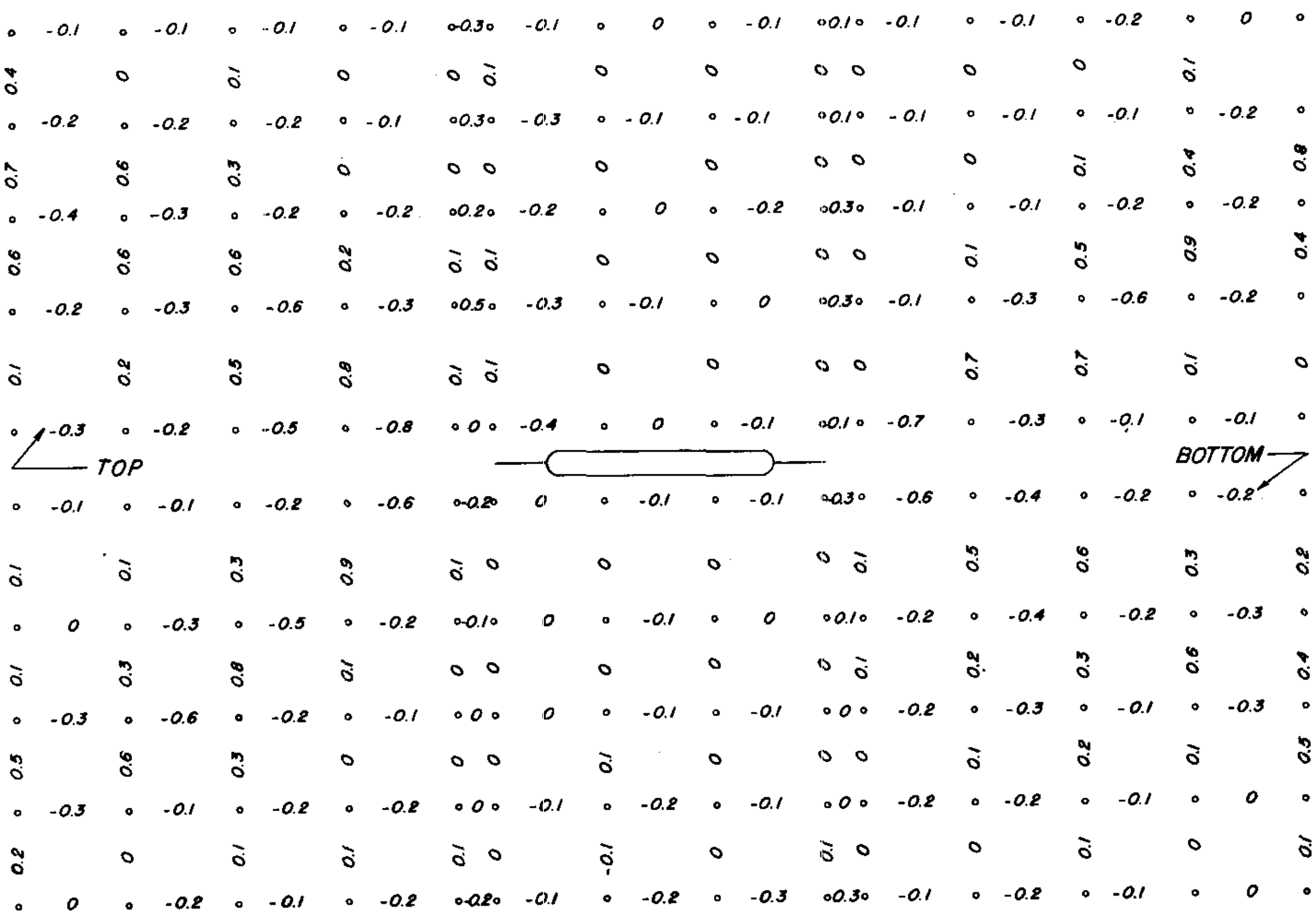


FIG. A-103 PERCENT ELONGATION

"H" STEEL, 72-INCH WIDE PLATE

TEMPERATURE 15 °F

PLATE H-3A (5-INCH GRID)

NOMINAL STRENGTH 38.3 KSI

0 % SHEAR

DWG. 44E260

FIG. A-103

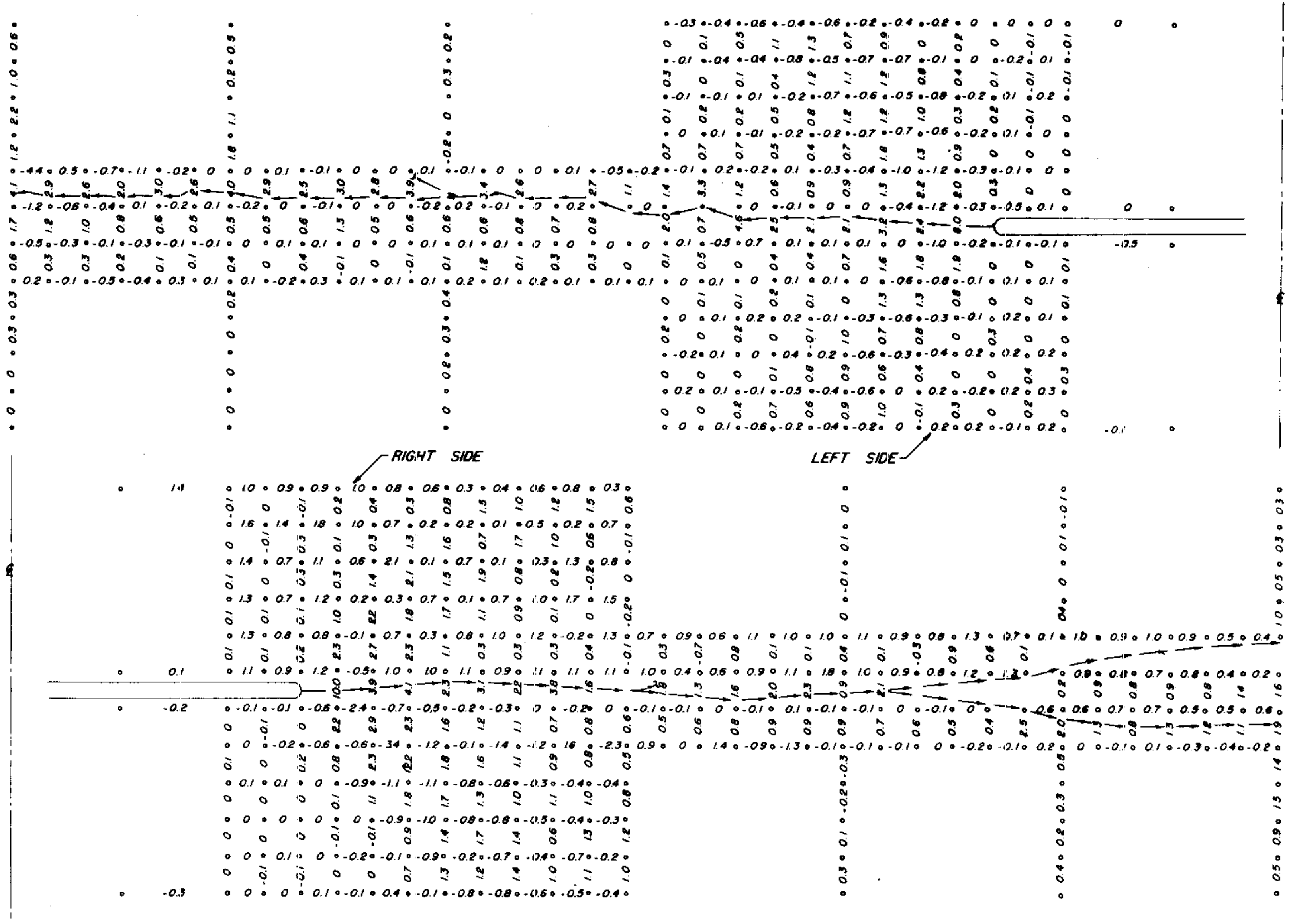


FIG. A-104 PERCENT ELONGATION

PLATE H-4A (1-INCH GRID)

"H" STEEL, 72-INCH WIDE PLATE

NOMINAL STRENGTH 39.0 KSI

TEMPERATURE (-19)-(-18)°F

0 % SHEAR

DWG. 44E261

FIG. A-104

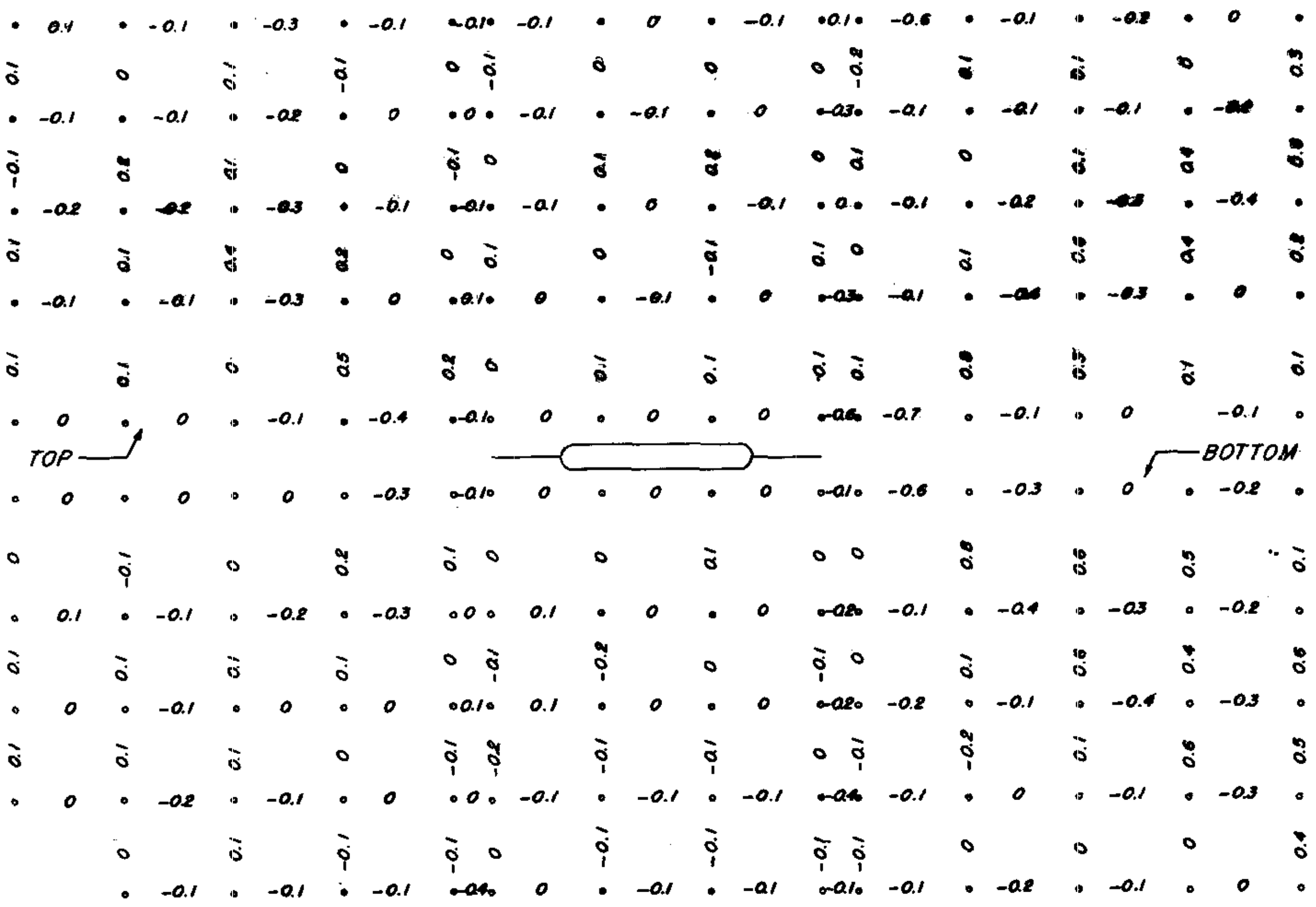


FIG. A-105 PERCENT ELONGATION

"H" STEEL, 72 INCH WIDE PLATE

TEMPERATURE (-19°)-(-18°) F

PLATE H-4A (5 INCH GRID)

NOMINAL STRENGTH 390 KSI

0 % SHEAR

FIG. A-105

44E262

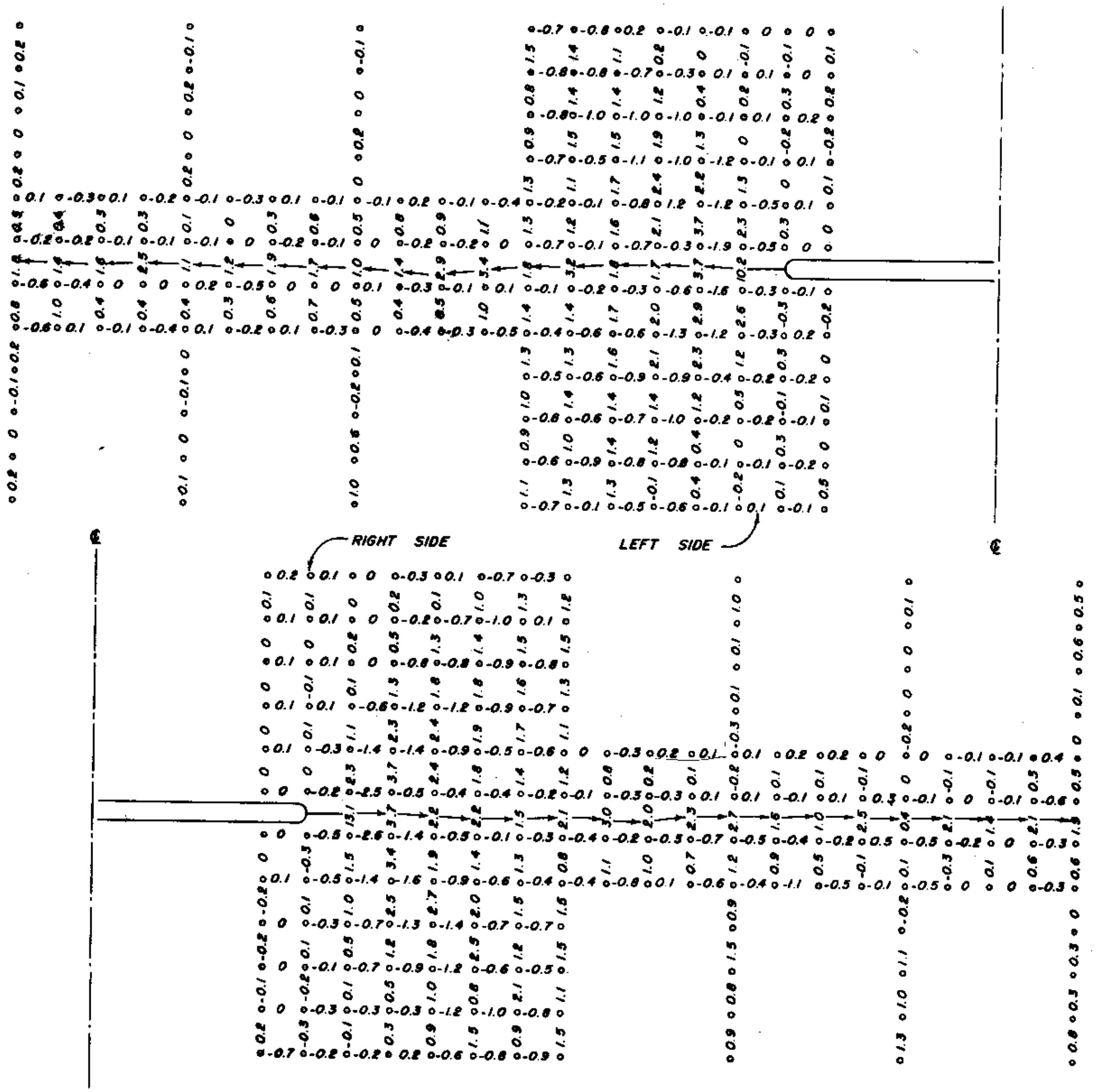


FIG. A-106 PERCENT ELONGATION PLATE B -7B (1-INCH GRID)

"B" STEEL, 48-INCH WIDE PLATE NOMINAL STRENGTH 35.2 KSI

TEMPERATURE 9 °F. 0% SHEAR

DWG. 44E193

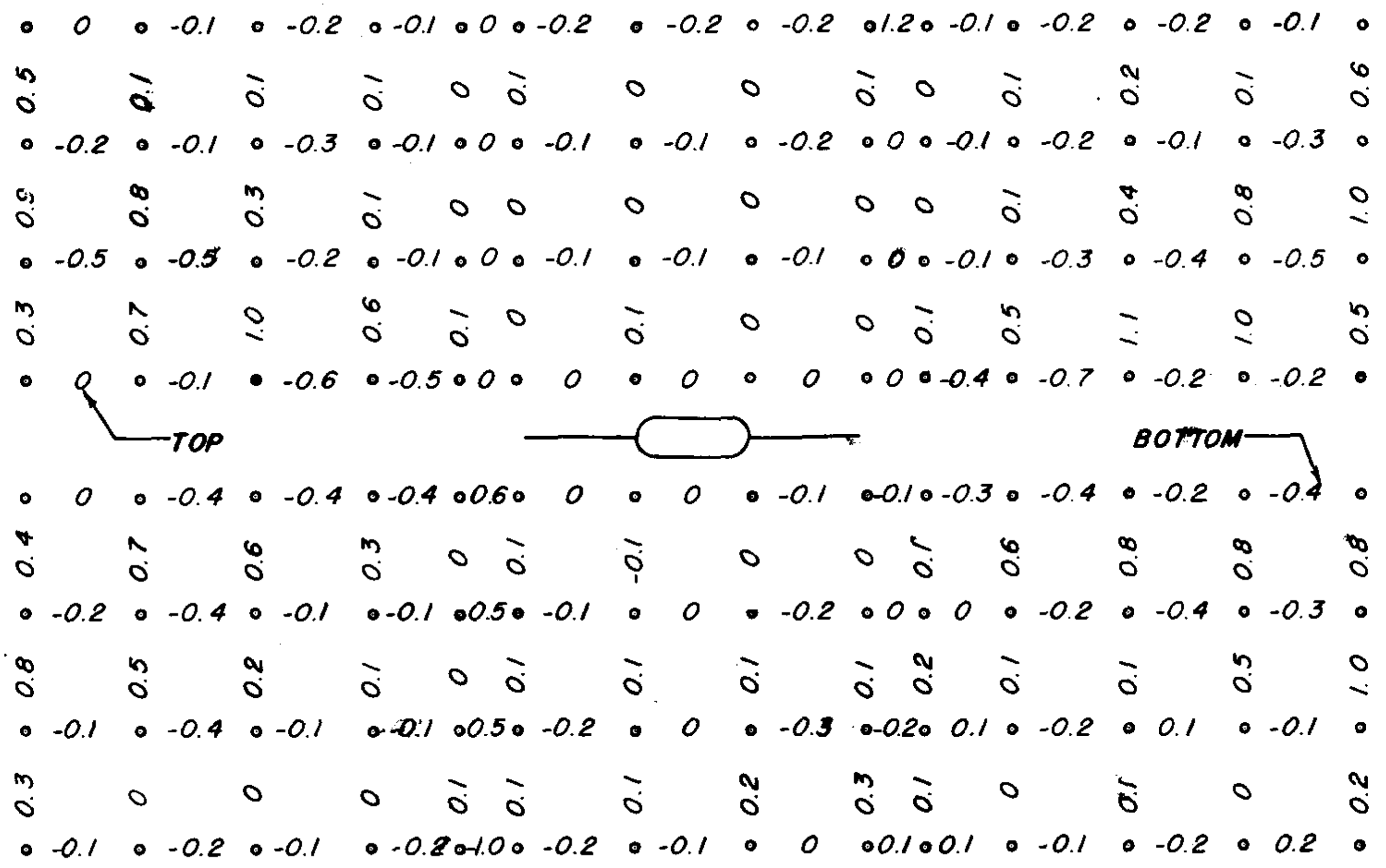


FIG. A-107 PERCENT ELONGATION PLATE B-7B (4-INCH GRID)

"B" STEEL, 48-INCH WIDE PLATE NOMINAL STRENGTH 35.2 KSI

TEMPERATURE 9 °F. 0 % SHEAR

FIG. A-107

DWG. 44E219

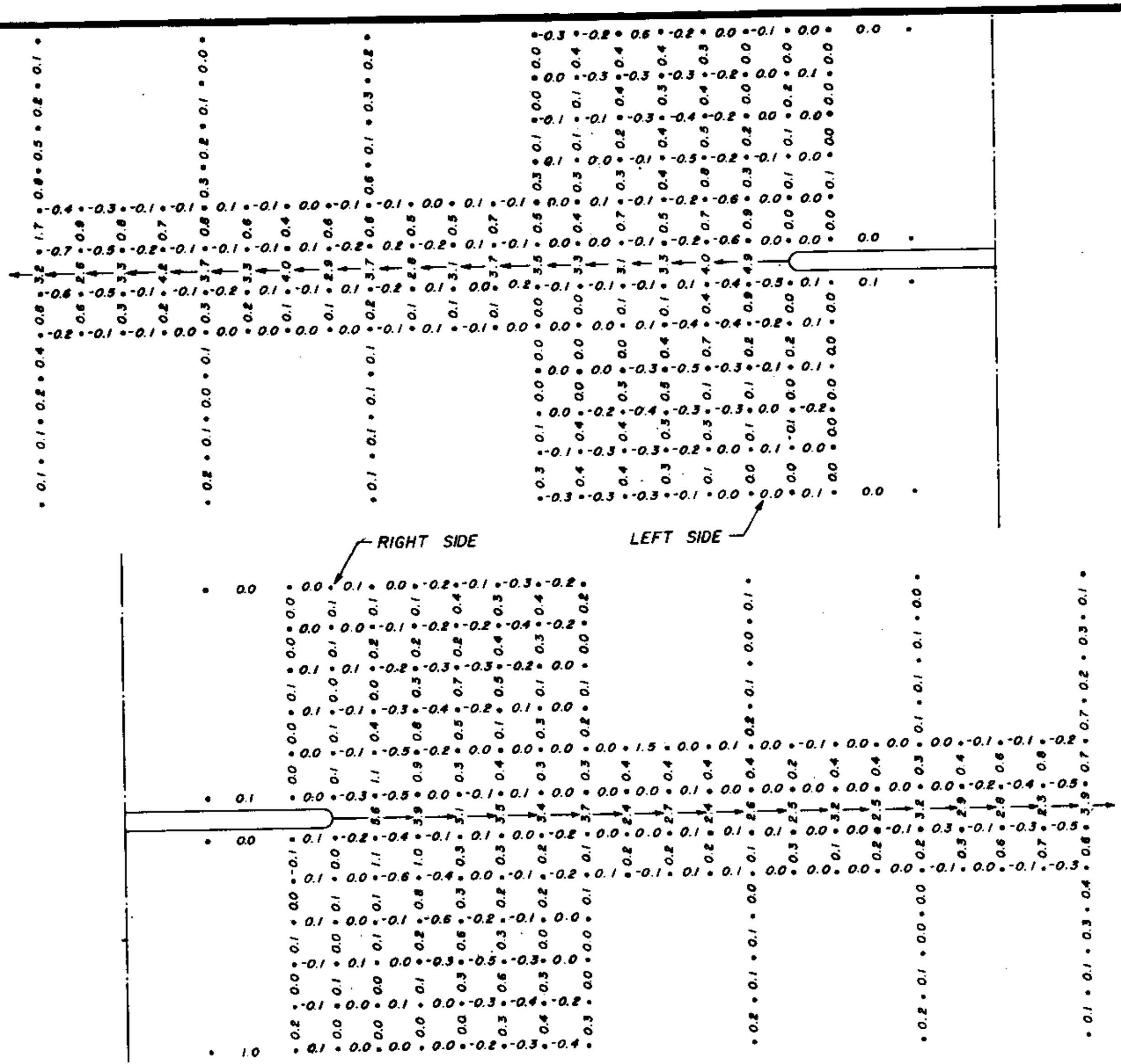


FIG. A-108 PERCENT ELONGATION PLATE C-4B (1-INCH GRID)

"C" STEEL 48-INCH WIDE PLATE NOMINAL STRENGTH 37.2 KSI

TEMPERATURE 27-29° F. 0% SHEAR

FIG. A-108

DWG. 44E179

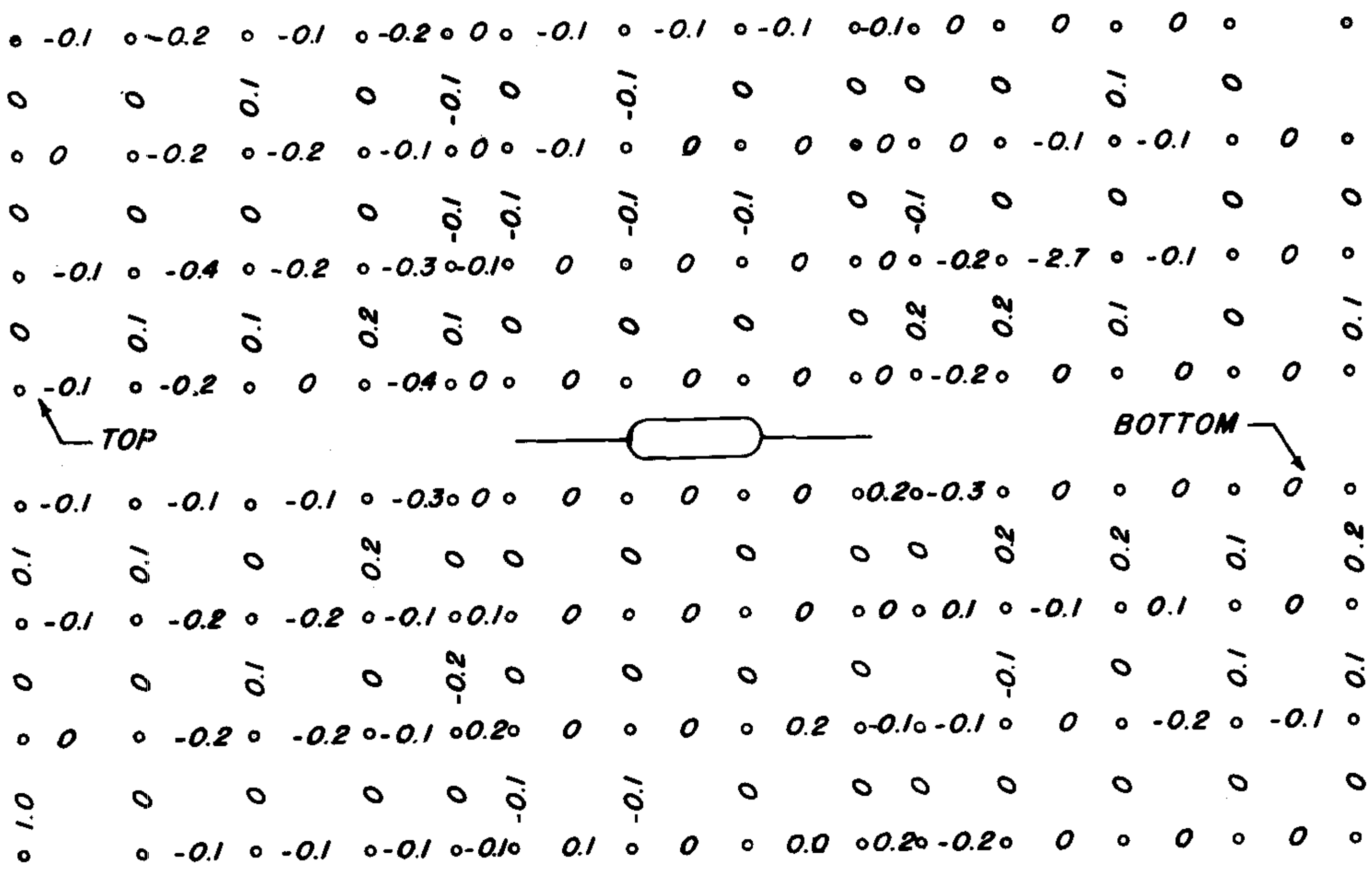


FIG. A-109 PERCENT ELONGATION PLATE C-4B (4-INCH GRID)

"C" STEEL, 48-INCH WIDE PLATE NOMINAL STRENGTH 37.2 KSI

TEMPERATURE 27-29° F. 0% SHEAR

FIG. A-109

DWG. 44E215

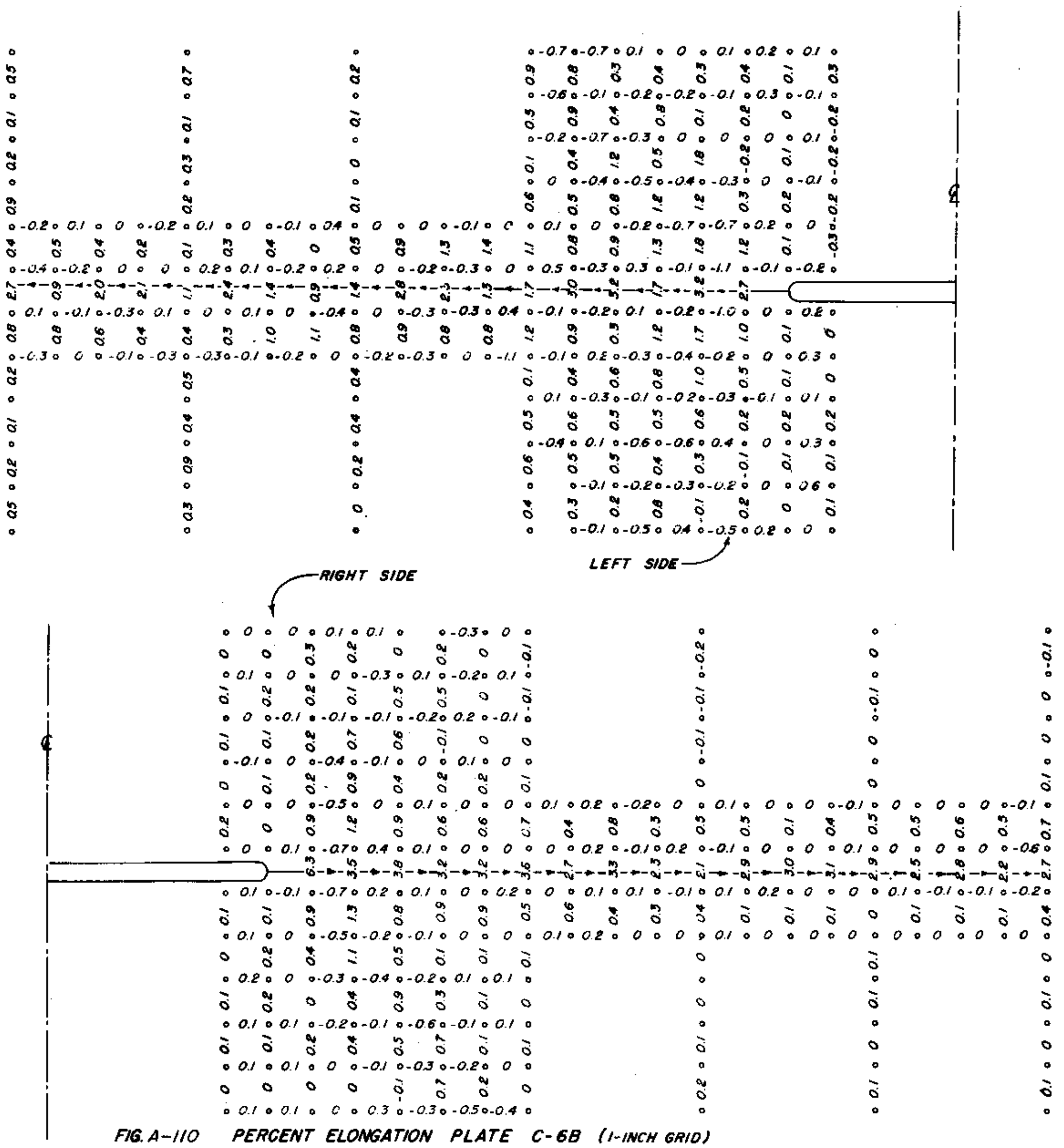


FIG. A-110 PERCENT ELONGATION PLATE C-6B (1-INCH GRID)

"C" STEEL, 48 INCH WIDE PLATE NOMINAL STRENGTH 37.0 KSI

TEMPERATURE 32 °F 0 % SHEAR

DWG. 44E 187

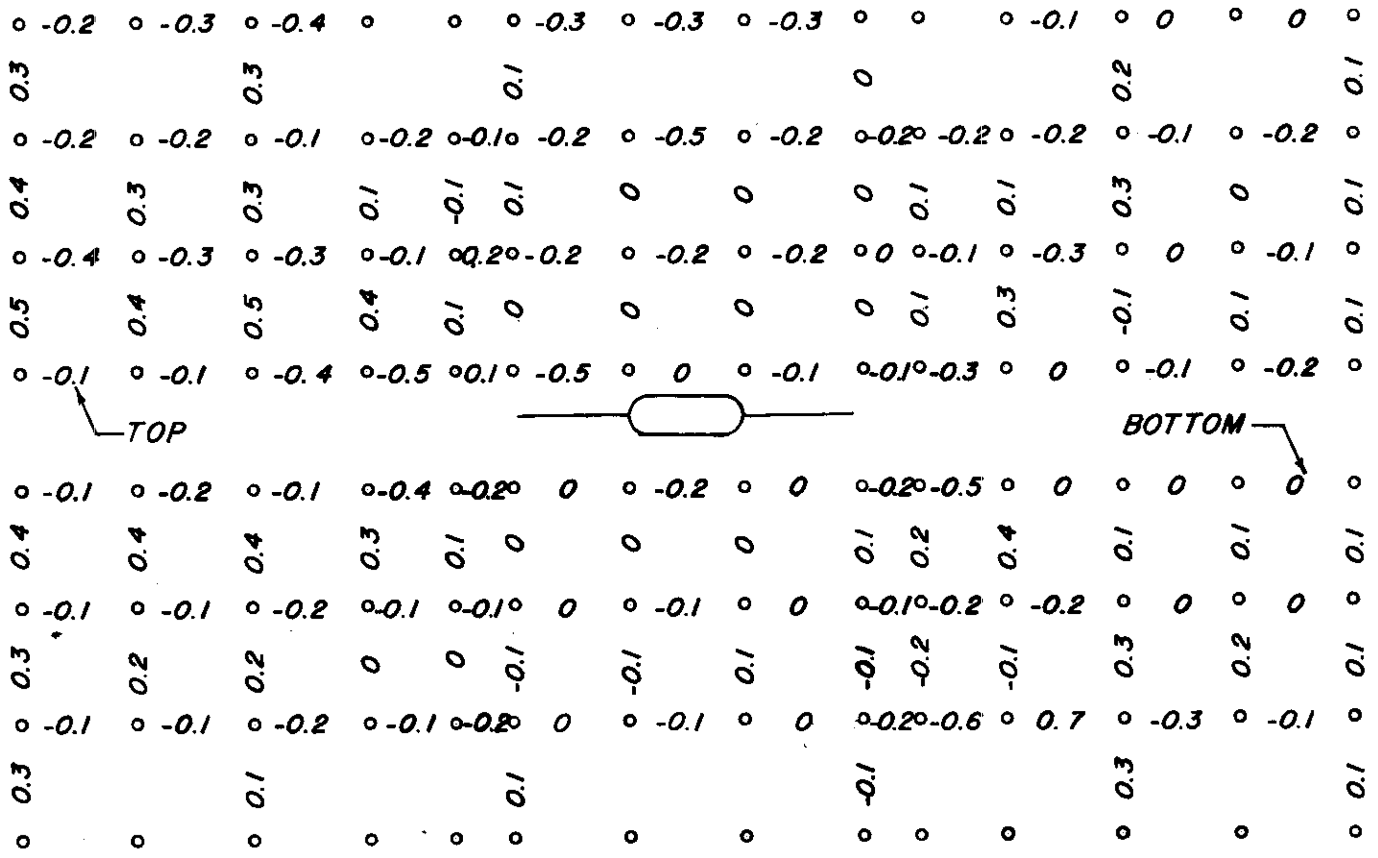


FIG. A-111 PERCENT ELONGATION PLATE C-6B (4-INCH GRID)

"C" STEEL, 48-INCH WIDE PLATE NOMINAL STRENGTH 37.0 KSI

TEMPERATURE 32 ° F. 0% SHEAR

FIG. A-111

DWG. 44E217

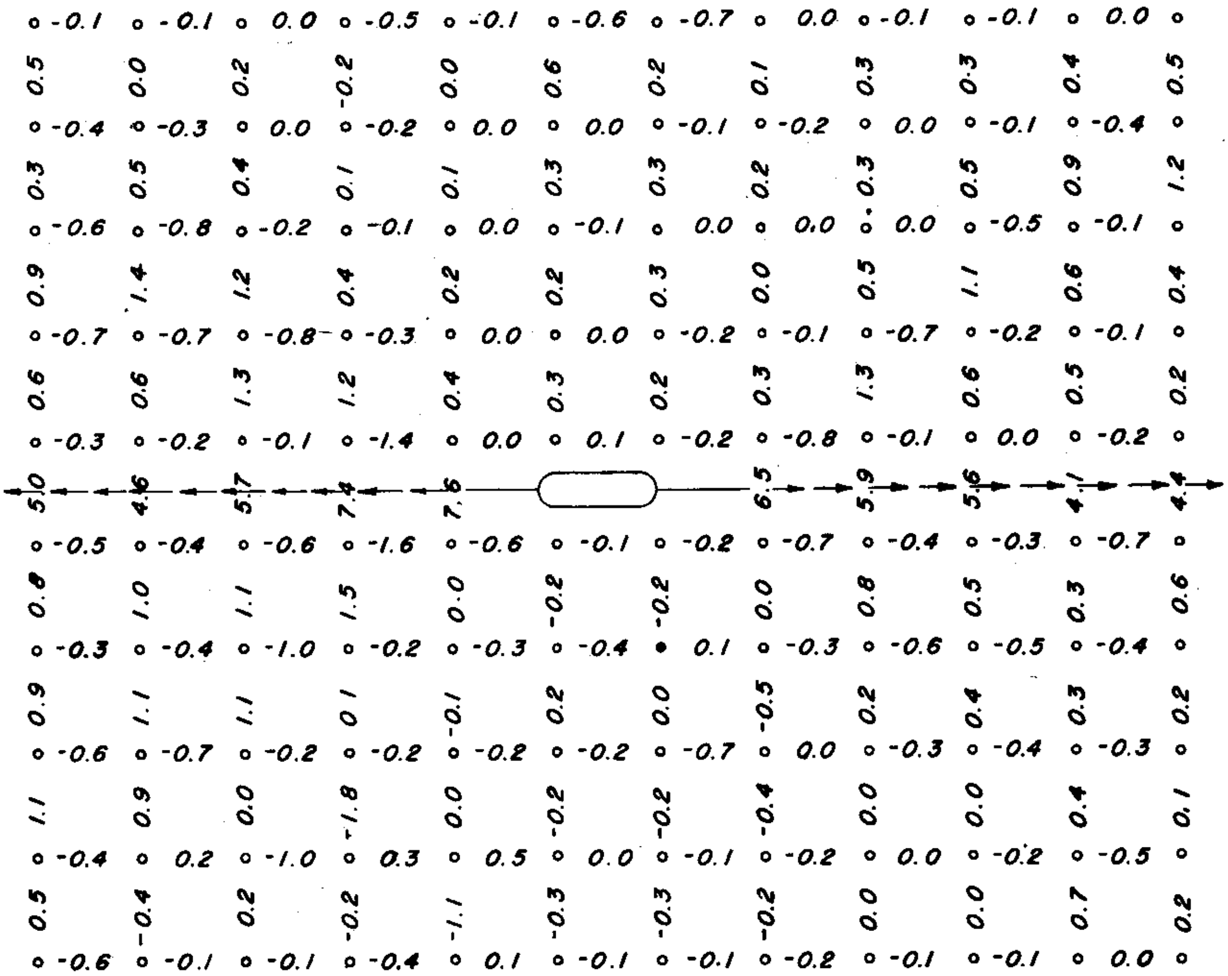


FIG. A-112 PERCENT ELONGATION PLATE A-41XD (1-INCH GRID)

"A" STEEL, 12 INCH WIDE PLATE. NOMINAL STRENGTH 38.7KSI

TEMPERATURE 7 - 8 °F. 0% SHEAR

DWG. 44E182

FIG. A-112

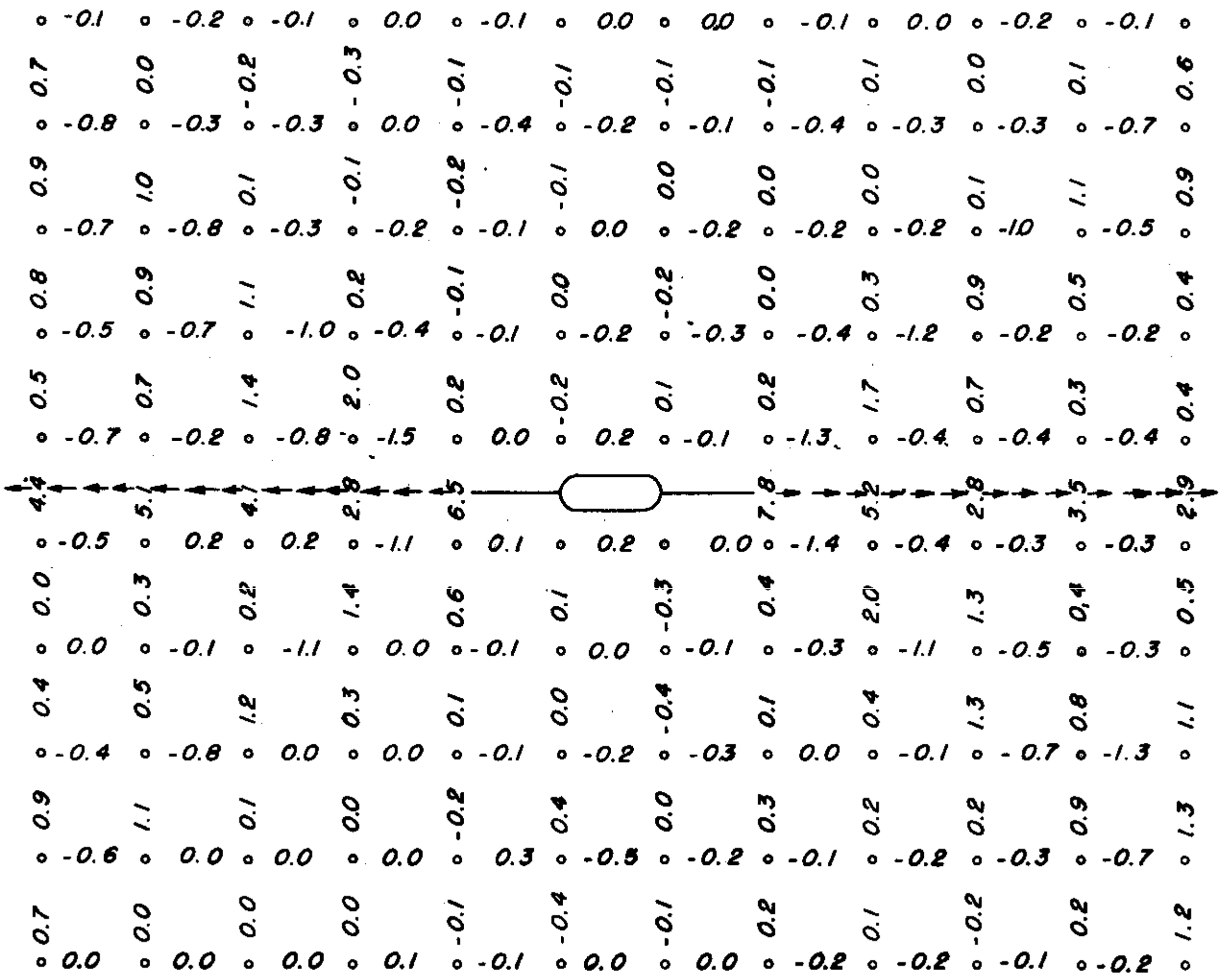


FIG. A-113 PERCENT ELONGATION PLATE A-42XD (1-INCH GRID)

"A" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 38.5KSI

TEMPERATURE 17 °F 0% SHEAR

DWG. 44E184

FIG. A-113

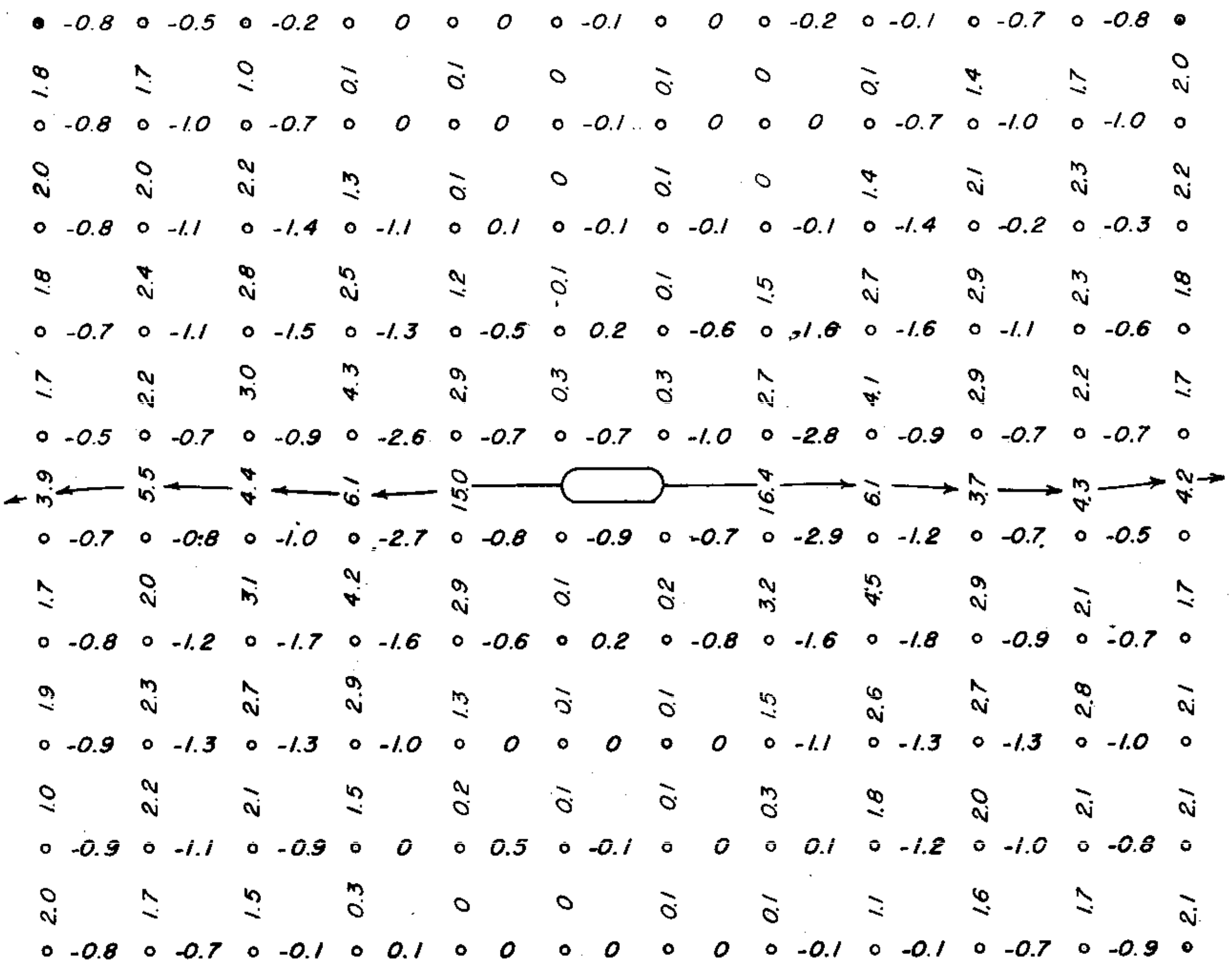


FIG. A-114 PERCENT ELONGATION PLATE B-21XD (1-INCH GRID)

"B" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 42.2 KSI

TEMPERATURE 10 °F. 0 % SHEAR

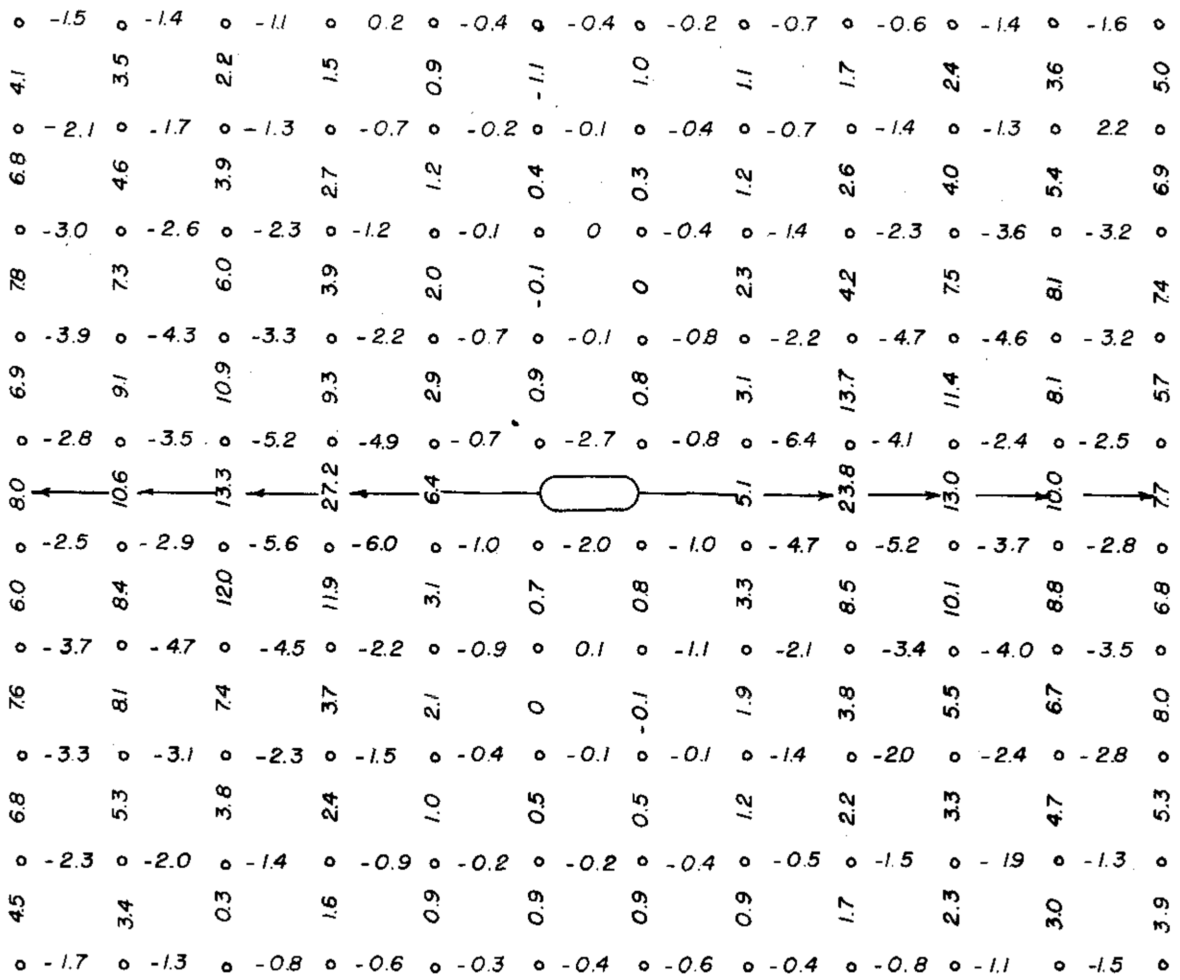


FIG. A-115 PERCENT ELONGATION PLATE B 31 XD (1 INCH GRID)

"B" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 48.7 KSI

TEMPERATURE 12-17 °F 20% SHEAR

DWG. 44E194

FIG. A-115

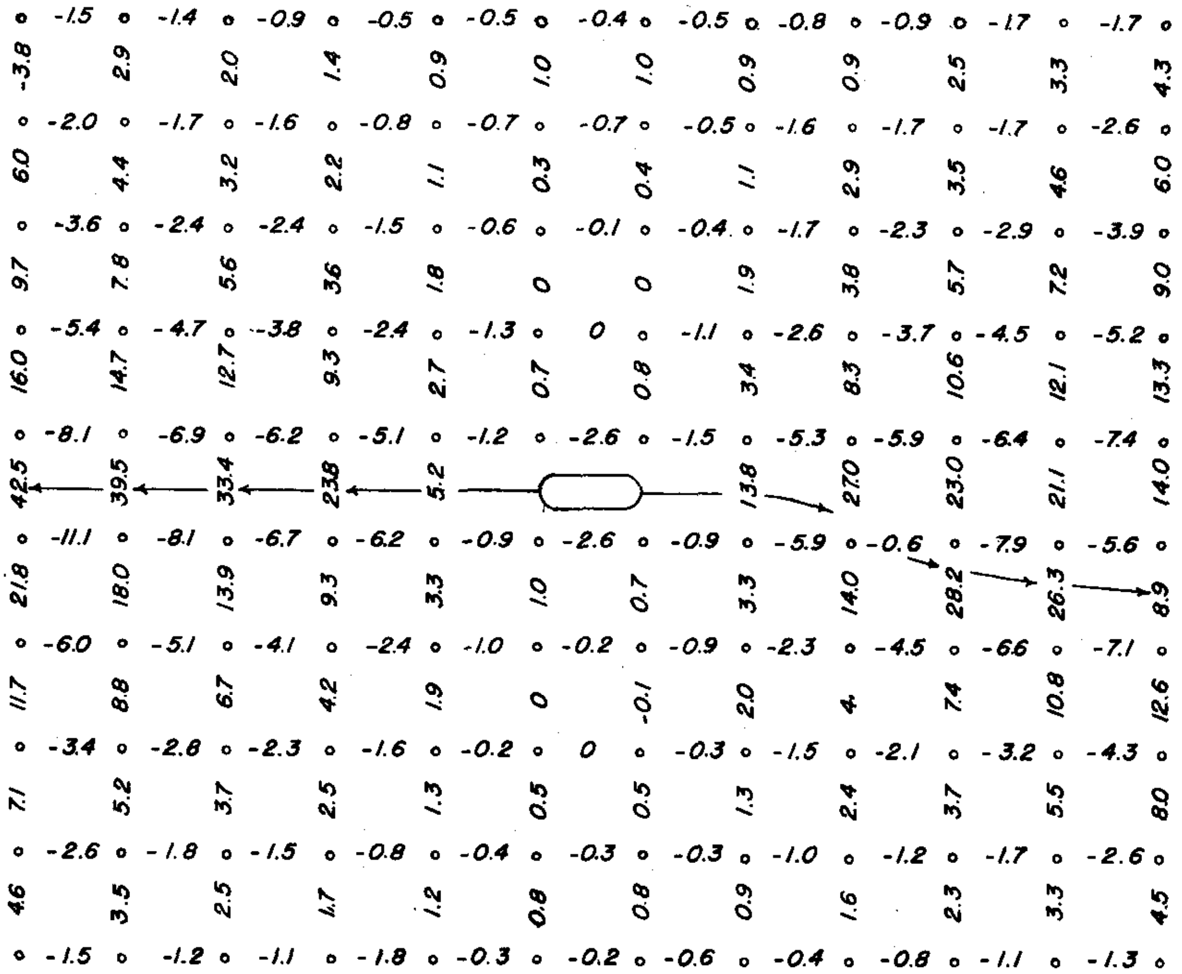


FIG. A-116 PERCENT ELONGATION PLATE B-32XD (1- INCH GRID)

"B" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 50.4 KSI

TEMPERATURE 20-23° F. 87% SHEAR

DWG. 44E203

FIG. A-116

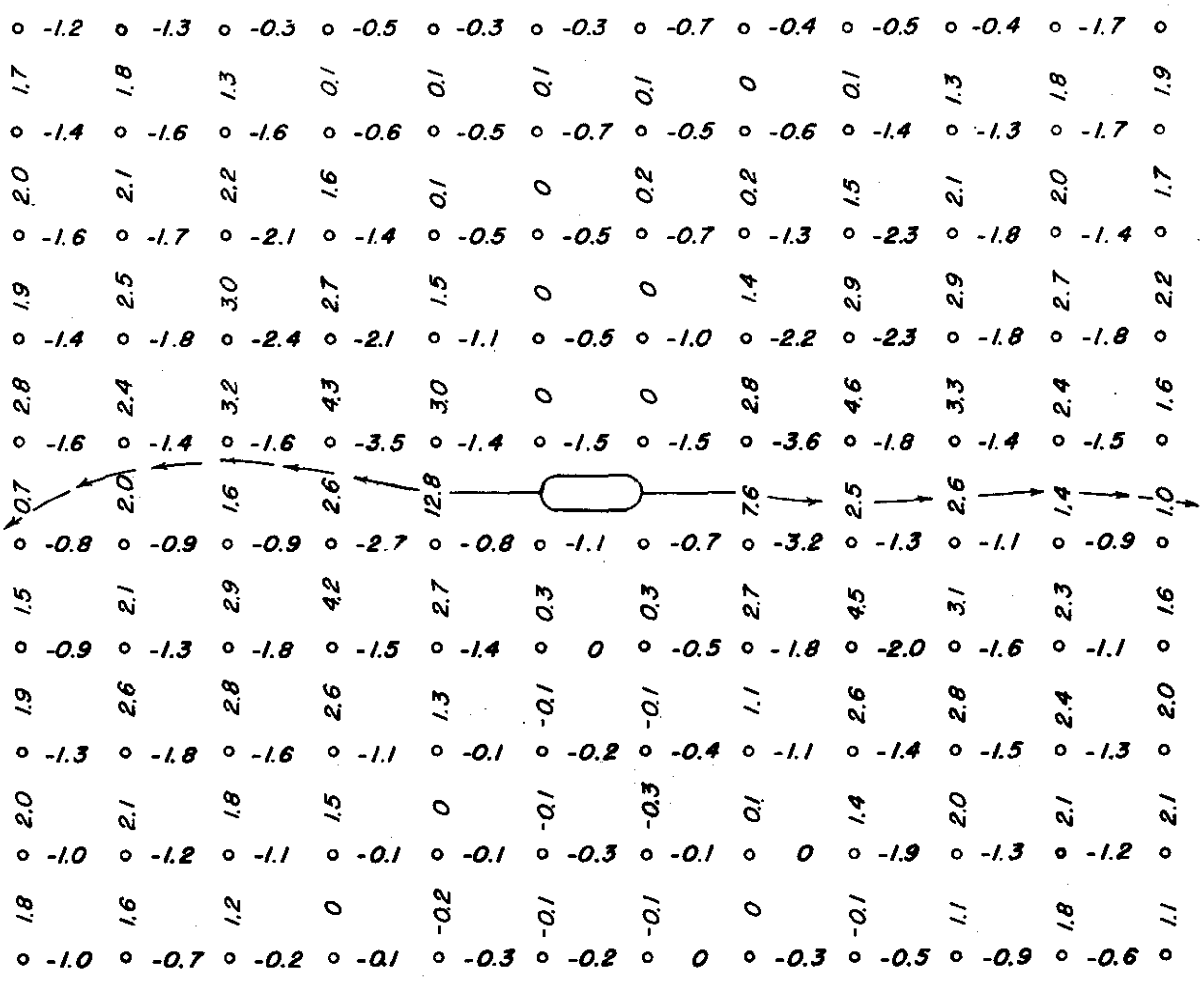


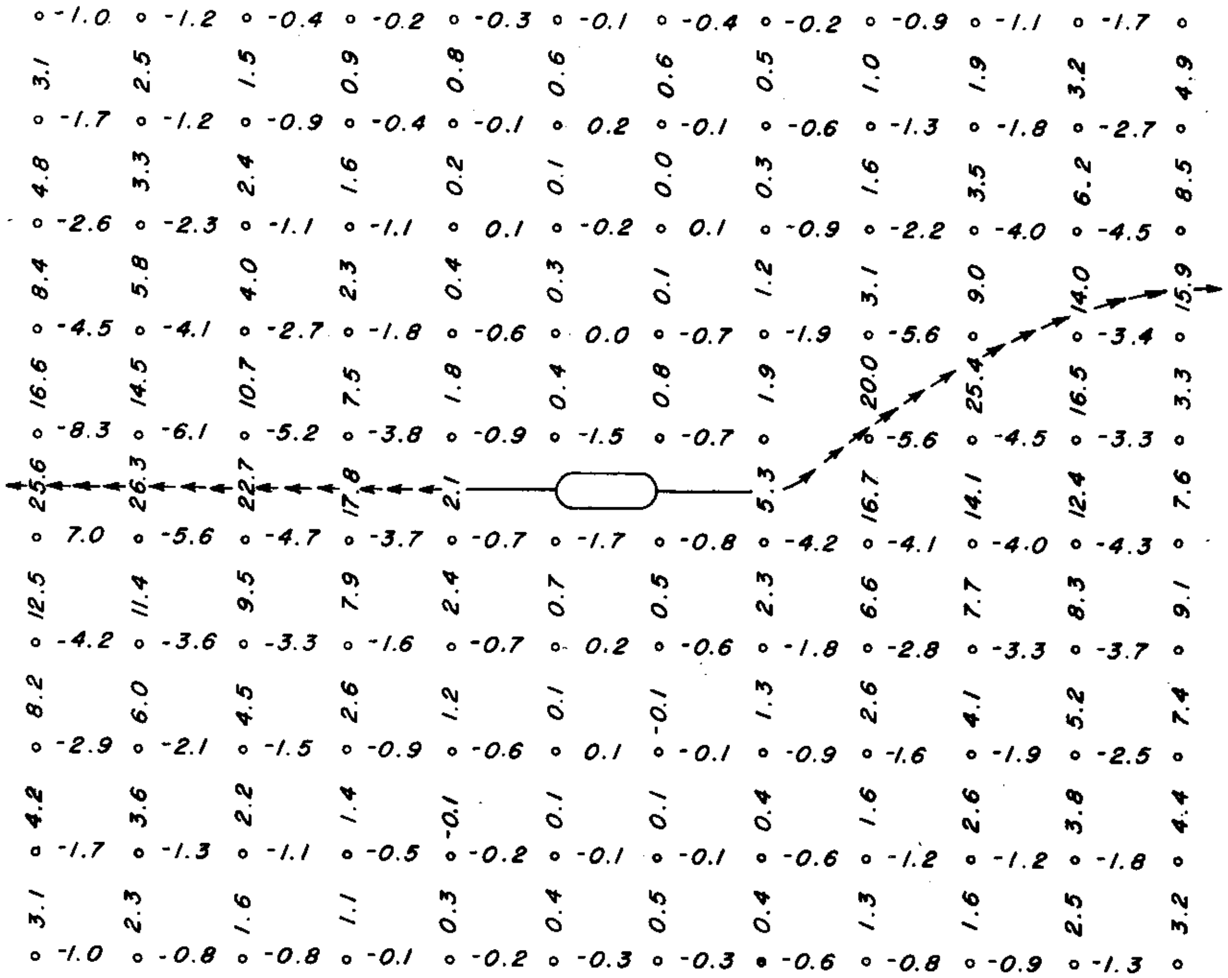
FIG. A-117 PERCENT ELONGATION PLATE B-33XD (1-INCH GRID)

"B" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 43.5 KSI

TEMPERATURE (-3)-(0)° F. 0% SHEAR

DWG. 44E205

FIG. A-117



-1.0 -1.2 -0.4 -0.2 -0.3 -0.1 -0.4 -0.2 -0.9 -1.1 -1.7

3.1 2.5 1.5 0.9 0.8 0.6 0.6 0.5 1.0 1.9 3.2 4.9

-1.7 -1.2 -0.9 -0.4 -0.1 0.2 -0.1 -0.6 -1.3 -1.8 -2.7

4.8 3.3 2.4 1.6 0.2 0.1 0.0 0.3 1.6 3.5 6.2 8.5

-2.6 -2.3 -1.1 -1.1 0.1 -0.2 0.1 -0.9 -2.2 -4.0 -4.5

8.4 5.8 4.0 2.3 0.4 0.3 0.1 1.2 3.1 9.0 14.0 15.9

-4.5 -4.1 -2.7 -1.8 -0.6 0.0 -0.7 -1.9 -5.6 -3.4

16.6 14.5 10.7 7.5 1.8 0.4 0.8 1.9 20.0 25.4 16.5 3.3

-8.3 -6.1 -5.2 -3.8 -0.9 -1.5 -0.7 -5.6 -4.5 -3.3

25.6 26.3 22.7 17.8 2.1 5.3 16.7 14.1 12.4 7.6

7.0 -5.6 -4.7 -3.7 -0.7 -1.7 -0.8 -4.2 -4.1 -4.0 -4.3

12.5 11.4 9.5 7.9 2.4 0.7 0.5 2.3 6.6 7.7 8.3 9.1

-4.2 -3.6 -3.3 -1.6 -0.7 0.2 -0.6 -1.8 -2.8 -3.3 -3.7

8.2 6.0 4.5 2.6 1.2 0.1 -0.1 1.3 2.6 4.1 5.2 7.4

-2.9 -2.1 -1.5 -0.9 -0.6 0.1 -0.1 -0.9 -1.6 -1.9 -2.5

4.2 3.6 2.2 1.4 -0.1 0.1 0.1 0.4 1.6 2.6 3.8 4.4

-1.7 -1.3 -1.1 -0.5 -0.2 -0.1 -0.1 -0.6 -1.2 -1.2 -1.8

3.1 2.3 1.6 1.1 0.3 0.4 0.5 0.4 1.3 1.6 2.5 3.2

-1.0 -0.8 -0.8 -0.1 -0.2 -0.3 -0.3 -0.6 -0.8 -0.9 -1.3

FIG. A-118 PERCENT ELONGATION PLATE C-11XD (1-INCH GRID)

"C" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 53.2KSI

TEMPERATURE 132°-136°F. 93% SHEAR

DWG. 44E204

FIG. A-118

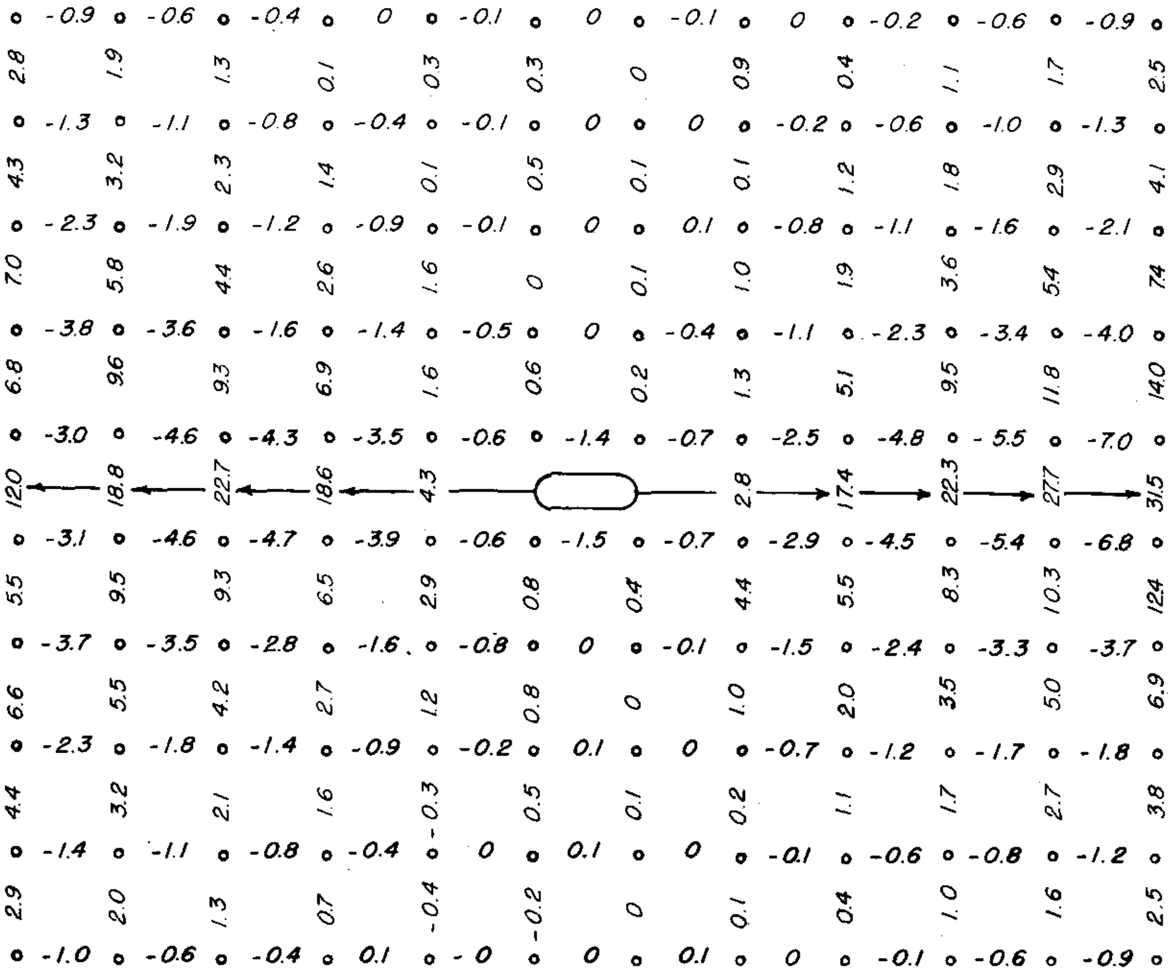


FIG. A-119 PERCENT ELONGATION PLATE C-51XD (1-INCH GRID)

"C" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 48.7 KSI

TEMPERATURE 120-123 °F. 100 % SHEAR

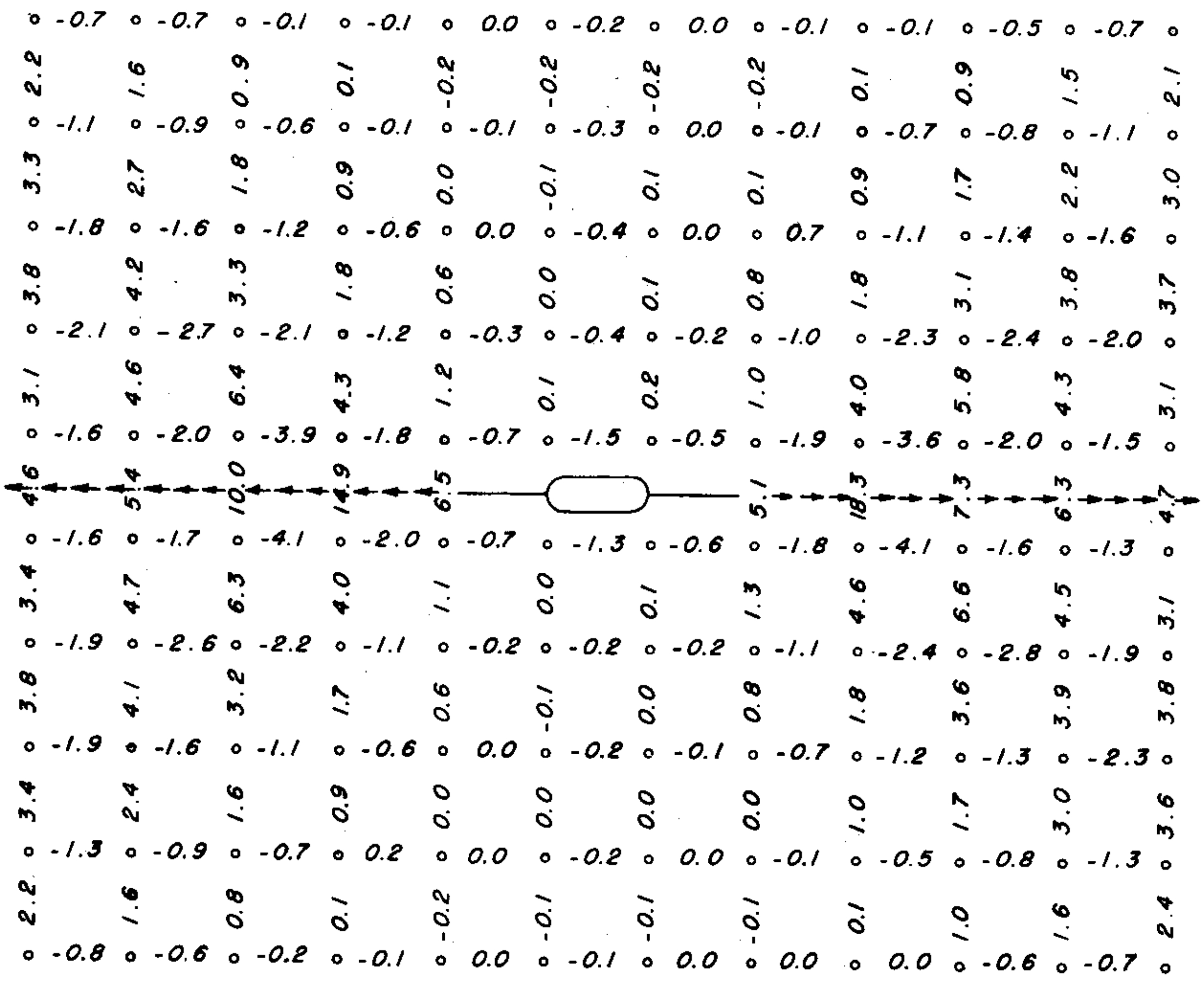


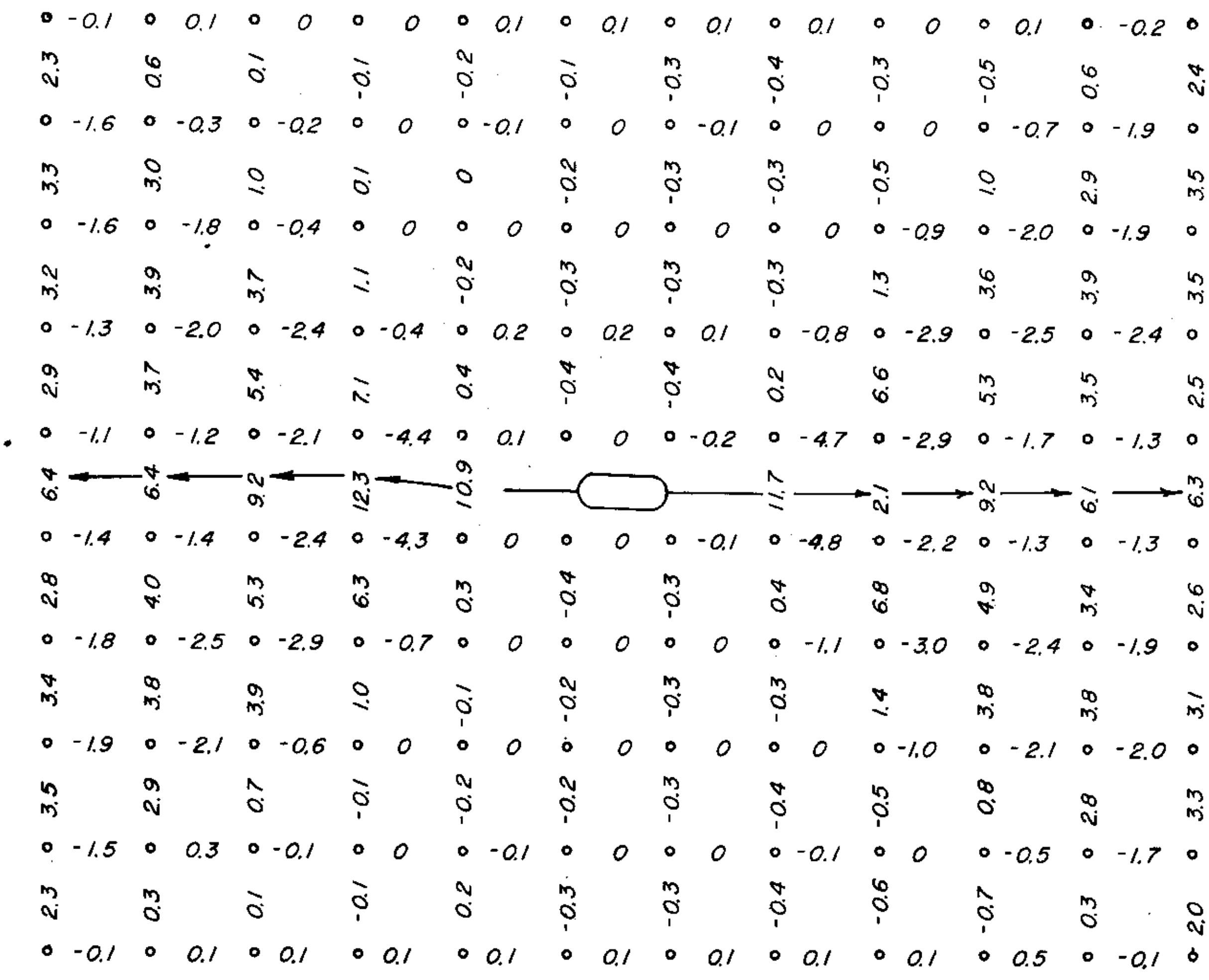
FIG. A-120 PERCENT ELONGATION PLATE C-52XD (1-INCH GRID)

"C" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 46.6KSI

TEMPERATURE 90° F. 10% SHEAR

DWG. 44E185

FIG. A-120



○	-0.1	○	0.1	○	0	○	0	○	0.1	○	0.1	○	0.1	○	0.1	○	0	○	0.1	○	-0.2	○
2.3		0.6		0.1		-0.1		-0.2		-0.1		-0.3		-0.4		-0.3		-0.5		0.6		2.4
○	-1.6	○	-0.3	○	-0.2	○	0	○	-0.1	○	0	○	-0.1	○	0	○	0	○	-0.7	○	-1.9	○
3.3		3.0		1.0		0.1		0		-0.2		-0.3		-0.3		-0.5		1.0		2.9		3.5
○	-1.6	○	-1.8	○	-0.4	○	0	○	0	○	0	○	0	○	0	○	-0.9	○	-2.0	○	-1.9	○
3.2		3.9		3.7		1.1		-0.2		-0.3		-0.3		-0.3		1.3		3.6		3.9		3.5
○	-1.3	○	-2.0	○	-2.4	○	-0.4	○	0.2	○	0.2	○	0.1	○	-0.8	○	-2.9	○	-2.5	○	-2.4	○
2.9		3.7		5.4		7.1		0.4		-0.4		-0.4		0.2		6.6		5.3		3.5		2.5
○	-1.1	○	-1.2	○	-2.1	○	-4.4	○	0.1	○	0	○	-0.2	○	-4.7	○	-2.9	○	-1.7	○	-1.3	○
6.4	←	6.4	←	9.2	←	12.3	←	10.9						11.7	→	2.1	→	9.2	→	6.1	→	6.3
○	-1.4	○	-1.4	○	-2.4	○	-4.3	○	0	○	0	○	-0.1	○	-4.8	○	-2.2	○	-1.3	○	-1.3	○
2.8		4.0		5.3		6.3		0.3		-0.4		-0.3		0.4		6.8		4.9		3.4		2.6
○	-1.8	○	-2.5	○	-2.9	○	-0.7	○	0	○	0	○	0	○	-1.1	○	-3.0	○	-2.4	○	-1.9	○
3.4		3.8		3.9		1.0		-0.1		-0.2		-0.3		-0.3		1.4		3.8		3.8		3.1
○	-1.9	○	-2.1	○	-0.6	○	0	○	0	○	0	○	0	○	0	○	-1.0	○	-2.1	○	-2.0	○
3.5		2.9		0.7		-0.1		-0.2		-0.2		-0.3		-0.4		-0.5		0.8		2.8		3.3
○	-1.5	○	0.3	○	-0.1	○	0	○	-0.1	○	0	○	0	○	-0.1	○	0	○	-0.5	○	-1.7	○
2.3		0.3		0.1		-0.1		0.2		-0.3		-0.3		-0.4		-0.6		-0.7		0.3		2.0
○	-0.1	○	0.1	○	0.1	○	0.1	○	0.1	○	0.1	○	0.1	○	0.1	○	0.1	○	0.5	○	-0.1	○

FIG. A-121 PERCENT ELONGATION PLATE N-13XD (1-INCH GRID)

"B" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 71.1 KSI

TEMPERATURE (-65) - (-63)°F. 17% SHEAR

DWG. 44 E 190

FIG. A-121

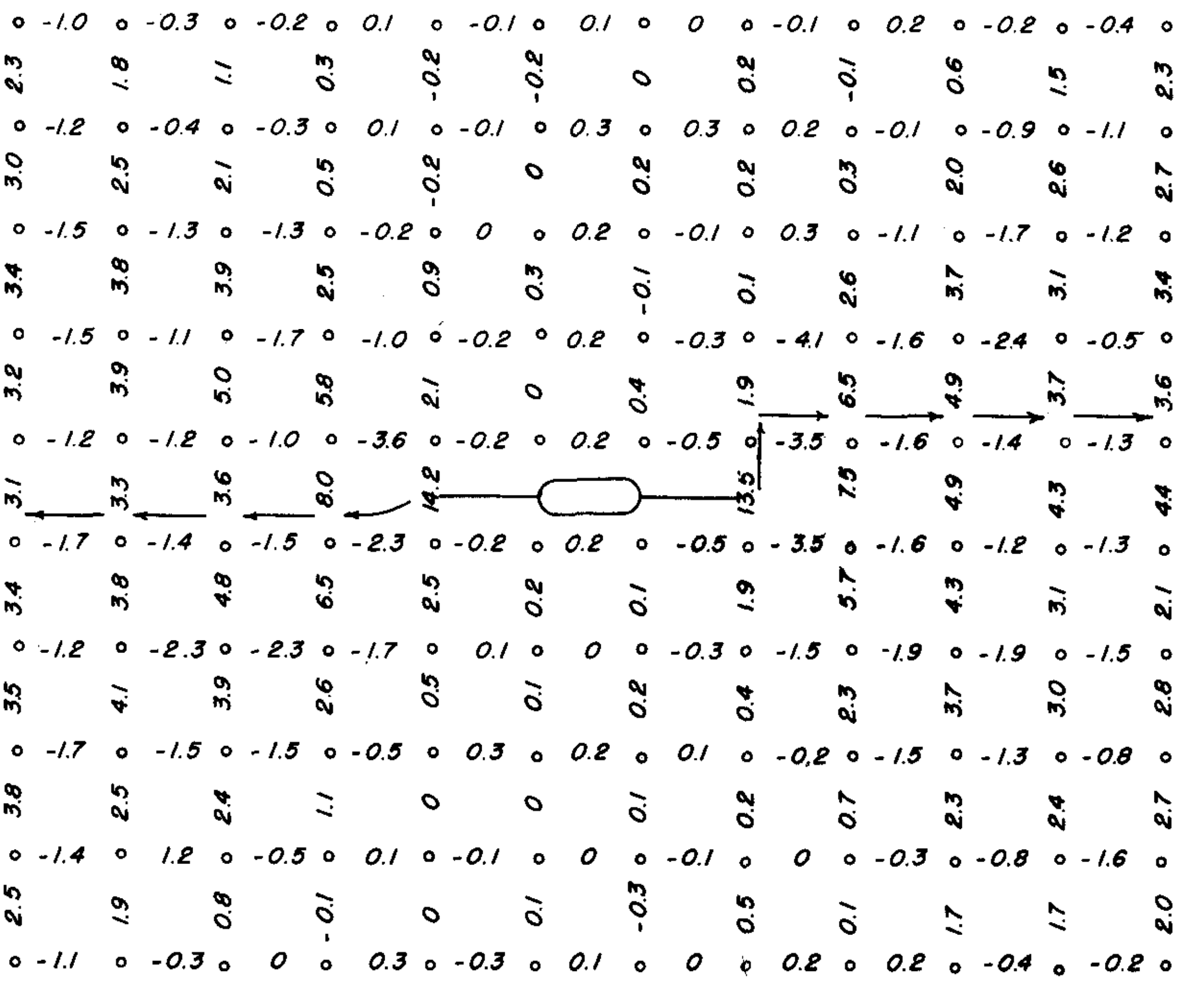


FIG. A-122 PERCENT ELONGATION PLATE N-14XD (1-INCH GRID)

"N" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 69.6 KSI

TEMPERATURE (-38)-(-36)°F. 7 % SHEAR

DWG. 44E191

FIG. A-122

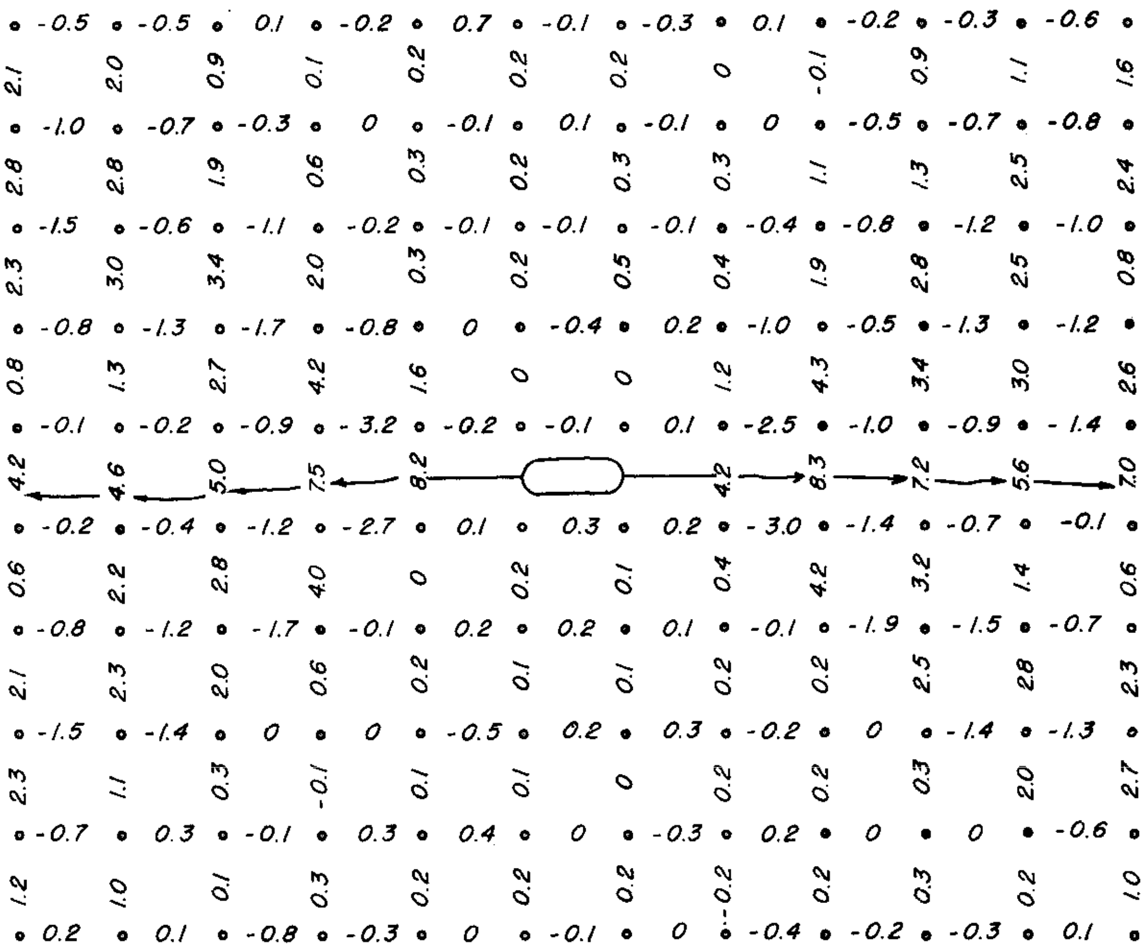


FIG. A-123 PERCENT ELONGATION PLATE N-15XD (1-INCH GRID)

"N" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 66.7 KSI

TEMPERATURE -64 °F. 0 % SHEAR

DWG. 44E192

FIG. A-123

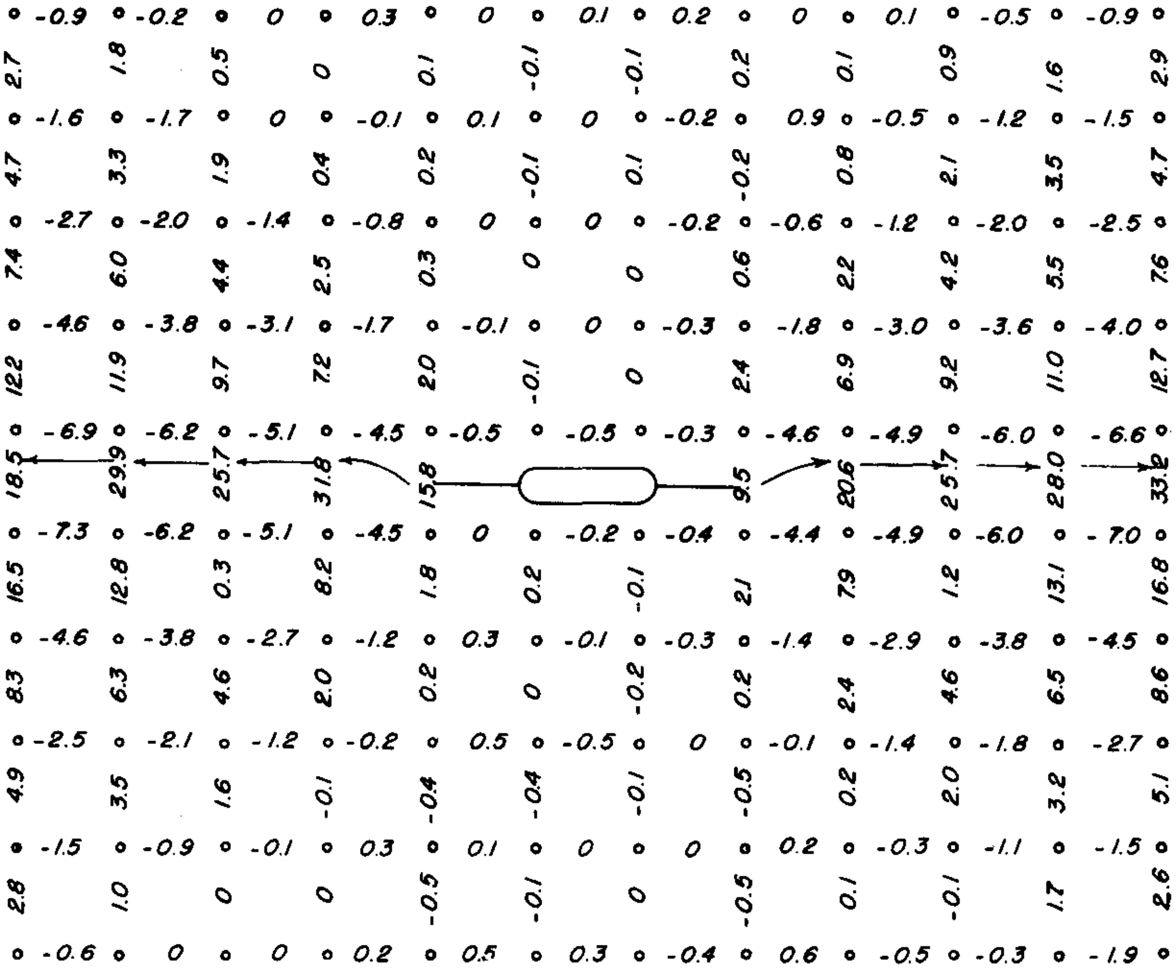


FIG. A-124 PERCENT ELONGATION PLATE N16XD (1 INCH GRID)

"N" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 66.0 KSI

TEMPERATURE 32-33 °F. 100% SHEAR

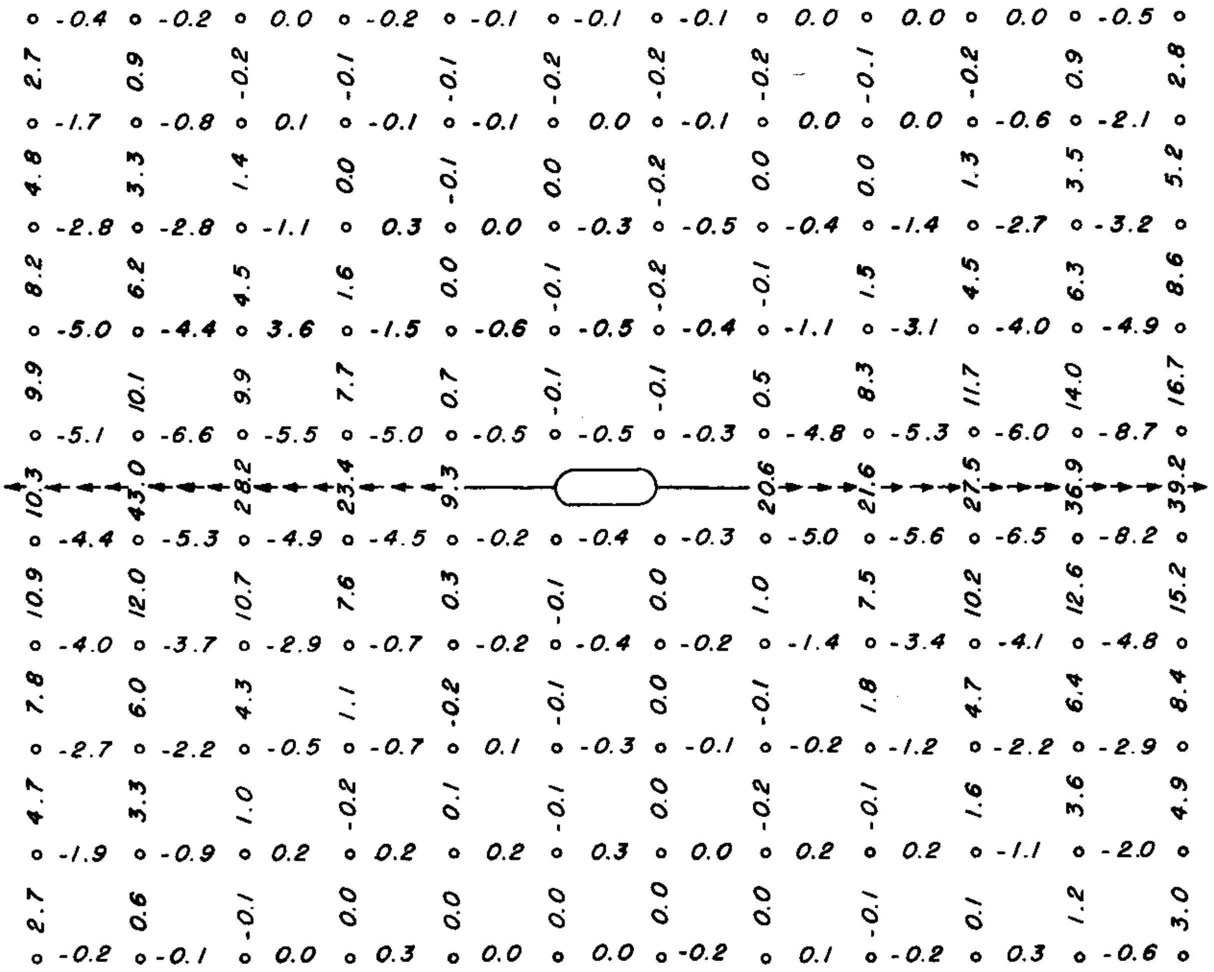


FIG. A-125 PERCENT ELONGATION PLATE N-21XD (1-INCH GRID)

"N" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 68.4 KSI

TEMPERATURE -2 °F. 100% SHEAR

DWG. 44E178

FIG. A-125

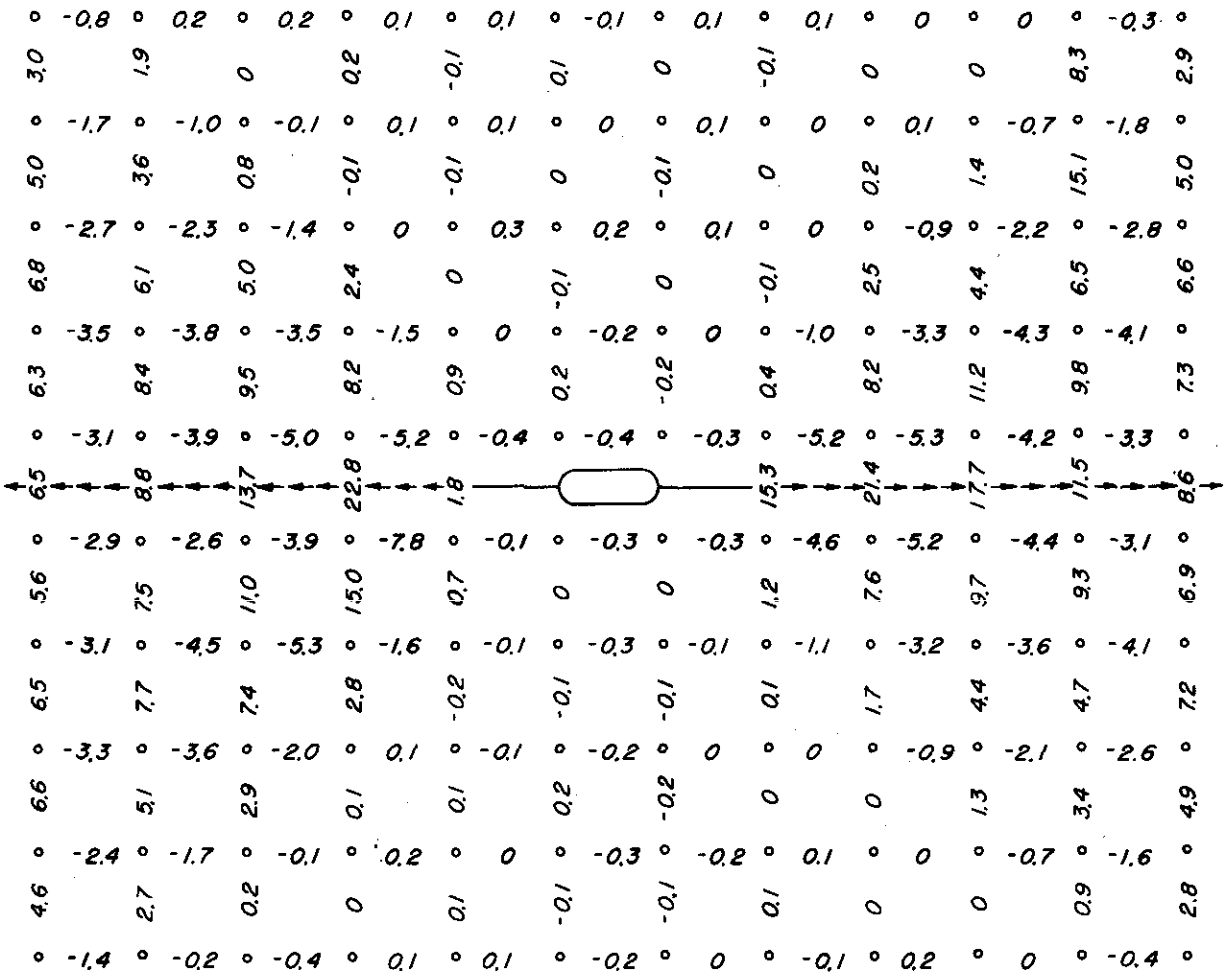
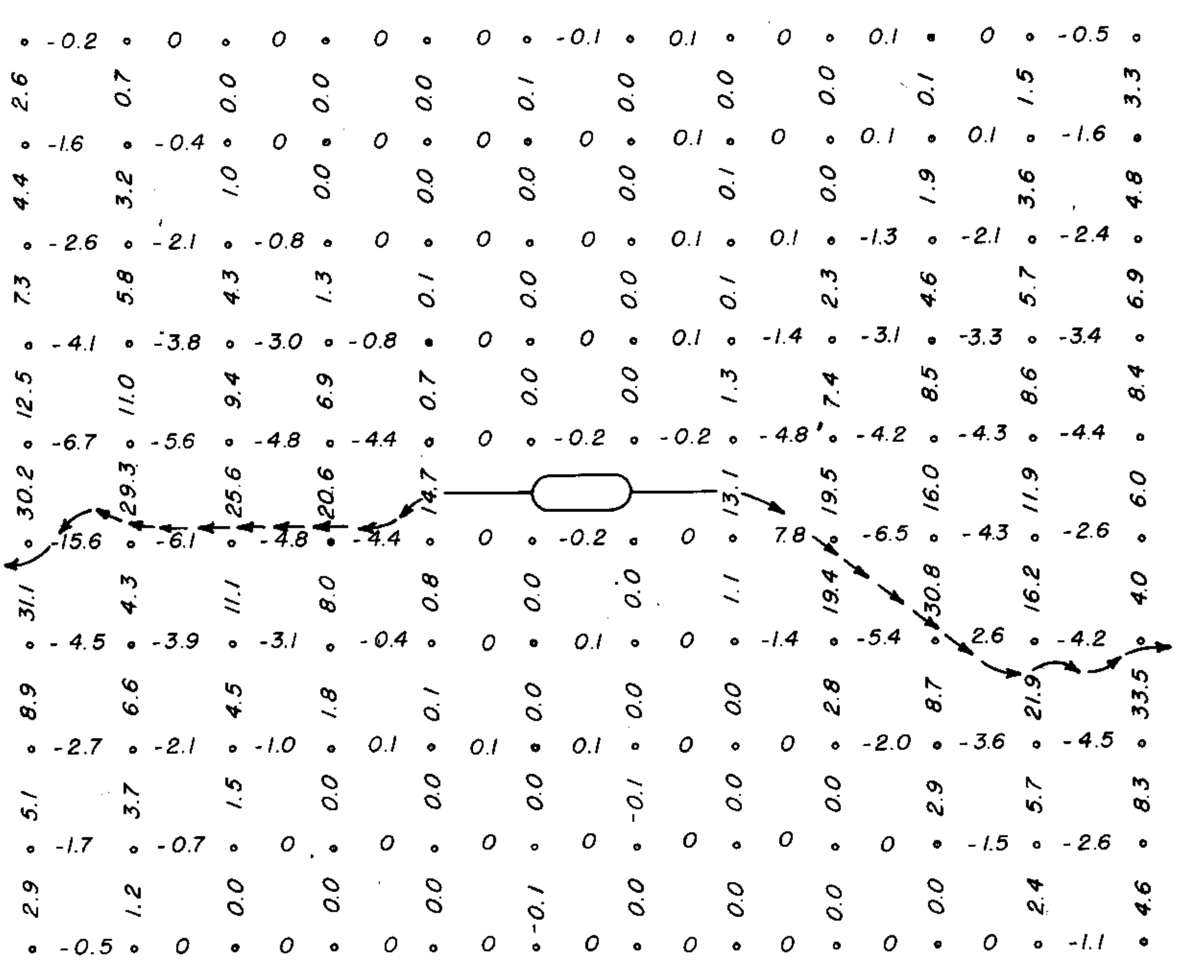


FIG. A-126 PERCENT ELONGATION PLATE N-22XD (1-INCH GRID)

"N" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 70.4 KSI

TEMPERATURE -60 °F. 35% SHEAR



-0.2 0 0 0 0 -0.1 0.1 0 0.1 0 -0.5

2.6 0.7 0.0 0.0 0.0 0.1 0.0 0.0 0.0 0.1 1.5 3.3

-1.6 -0.4 0 0 0 0 0.1 0 0.1 0.1 -1.6

4.4 3.2 1.0 0.0 0.0 0.0 0.0 0.1 0.0 1.9 3.6 4.8

-2.6 -2.1 -0.8 0 0 0 0.1 0.1 -1.3 -2.1 -2.4

7.3 5.8 4.3 1.3 0.1 0.0 0.0 0.1 2.3 4.6 5.7 6.9

-4.1 -3.8 -3.0 -0.8 0 0 0.1 -1.4 -3.1 -3.3 -3.4

12.5 11.0 9.4 6.9 0.7 0.0 0.0 1.3 7.4 8.5 8.6 8.4

-6.7 -5.6 -4.8 -4.4 0 -0.2 -0.2 -4.8 -4.2 -4.3 -4.4

30.2 29.3 25.6 20.6 14.7 13.1 19.5 16.0 11.9 6.0

-15.6 -6.1 -4.8 -4.4 0 -0.2 0 7.8 -6.5 -4.3 -2.6

31.1 4.3 11.1 8.0 0.8 0.0 0.0 1.1 19.4 30.8 16.2 4.0

-4.5 -3.9 -3.1 -0.4 0 0.1 0 -1.4 -5.4 2.6 -4.2

8.9 6.6 4.5 1.8 0.1 0.0 0.0 0.0 2.8 8.7 21.9 33.5

-2.7 -2.1 -1.0 0.1 0.1 0.1 0 0 -2.0 -3.6 -4.5

5.1 3.7 1.5 0.0 0.0 0.0 -0.1 0.0 0.0 2.9 5.7 8.3

-1.7 -0.7 0 0 0 0 0 0 0 -1.5 -2.6

2.9 1.2 0.0 0.0 0.0 -0.1 0.0 0.0 0.0 0.0 2.4 4.6

-0.5 0 0 0 0 0 0 0 0 0 -1.1

FIG. A-127 PERCENT ELONGATION PLATE N-42XD (1-INCH GRID)

"N" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 68.1 KSI

TEMPERATURE (-24)-(-22)°F 100% SHEAR

DWG. 44E175

FIG. A-127

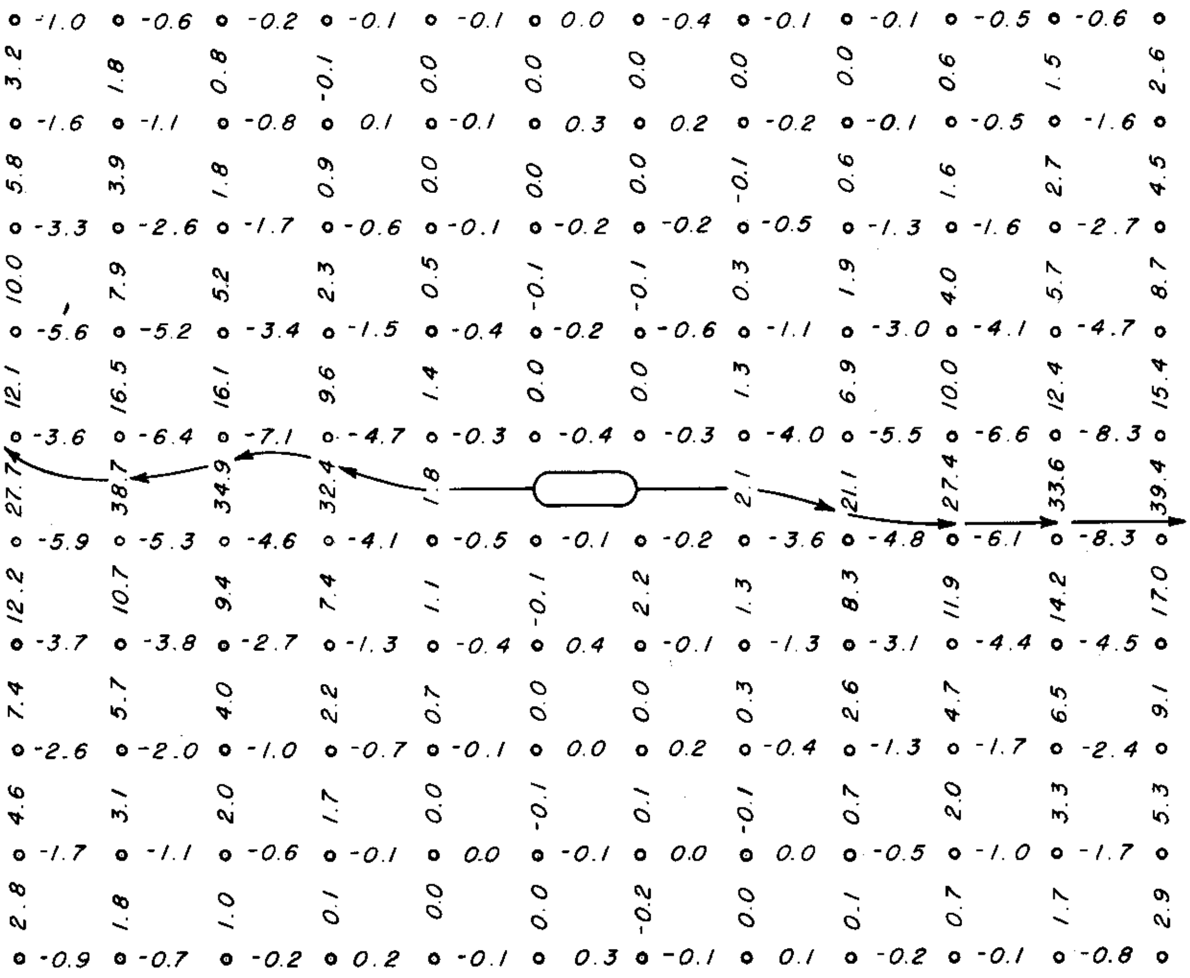


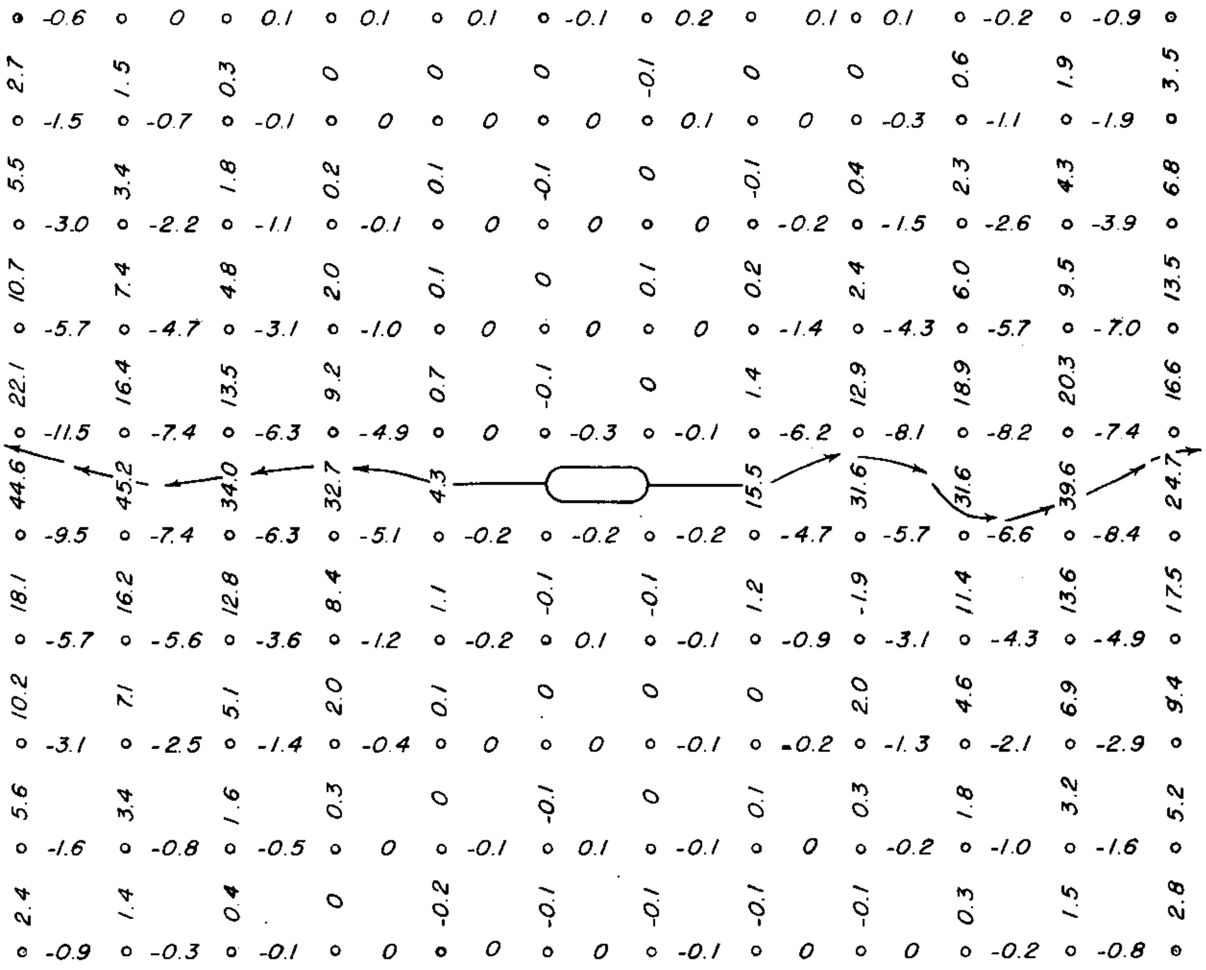
FIG. A-128 PERCENT ELONGATION PLATE Q-3D (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 64.0 KSI

TEMPERATURE 15-17 °F 100% SHEAR

DWG. 44E229

FIG. A-128



-0.6 0 0.1 0.1 0.1 -0.1 0.2 0.1 0.1 -0.2 -0.9
2.7 1.5 0.3 0 0 0 -0.1 0 0 0.6 1.9 3.5
-1.5 -0.7 -0.1 0 0 0 0.1 0 -0.3 -1.1 -1.9
5.5 3.4 1.8 0.2 0.1 -0.1 0 -0.1 0.4 2.3 4.3 6.8
-3.0 -2.2 -1.1 -0.1 0 0 0 -0.2 -1.5 -2.6 -3.9
10.7 7.4 4.8 2.0 0.1 0 0.1 0.2 2.4 6.0 9.5 13.5
-5.7 -4.7 -3.1 -1.0 0 0 0 -1.4 -4.3 -5.7 -7.0
22.1 16.4 13.5 9.2 0.7 -0.1 0 1.4 12.9 18.9 20.3 16.6
-11.5 -7.4 -6.3 -4.9 0 -0.3 -0.1 -6.2 -8.1 -8.2 -7.4
44.6 45.2 34.0 32.7 4.3 15.5 31.6 31.6 39.6 24.7
-9.5 -7.4 -6.3 -5.1 -0.2 -0.2 -0.2 -4.7 -5.7 -6.6 -8.4
18.1 16.2 12.8 8.4 1.1 -0.1 -0.1 1.2 -1.9 11.4 13.6 17.5
-5.7 -5.6 -3.6 -1.2 -0.2 0.1 -0.1 -0.9 -3.1 -4.3 -4.9
10.2 7.1 5.1 2.0 0.1 0 0 0 2.0 4.6 6.9 9.4
-3.1 -2.5 -1.4 -0.4 0 0 -0.1 -0.2 -1.3 -2.1 -2.9
5.6 3.4 1.6 0.3 0 -0.1 0 0.1 0.3 1.8 3.2 5.2
-1.6 -0.8 -0.5 0 -0.1 0.1 -0.1 0 -0.2 -1.0 -1.6
2.4 1.4 0.4 0 -0.2 -0.1 -0.1 -0.1 -0.1 0.3 1.5 2.8
-0.9 -0.3 -0.1 0 0 0 -0.1 0 0 -0.2 -0.8

FIG. A-129 PERCENT ELONGATION PLATE Q-11XD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 60.0 KSI

TEMPERATURE 100-101 °F. 100% SHEAR

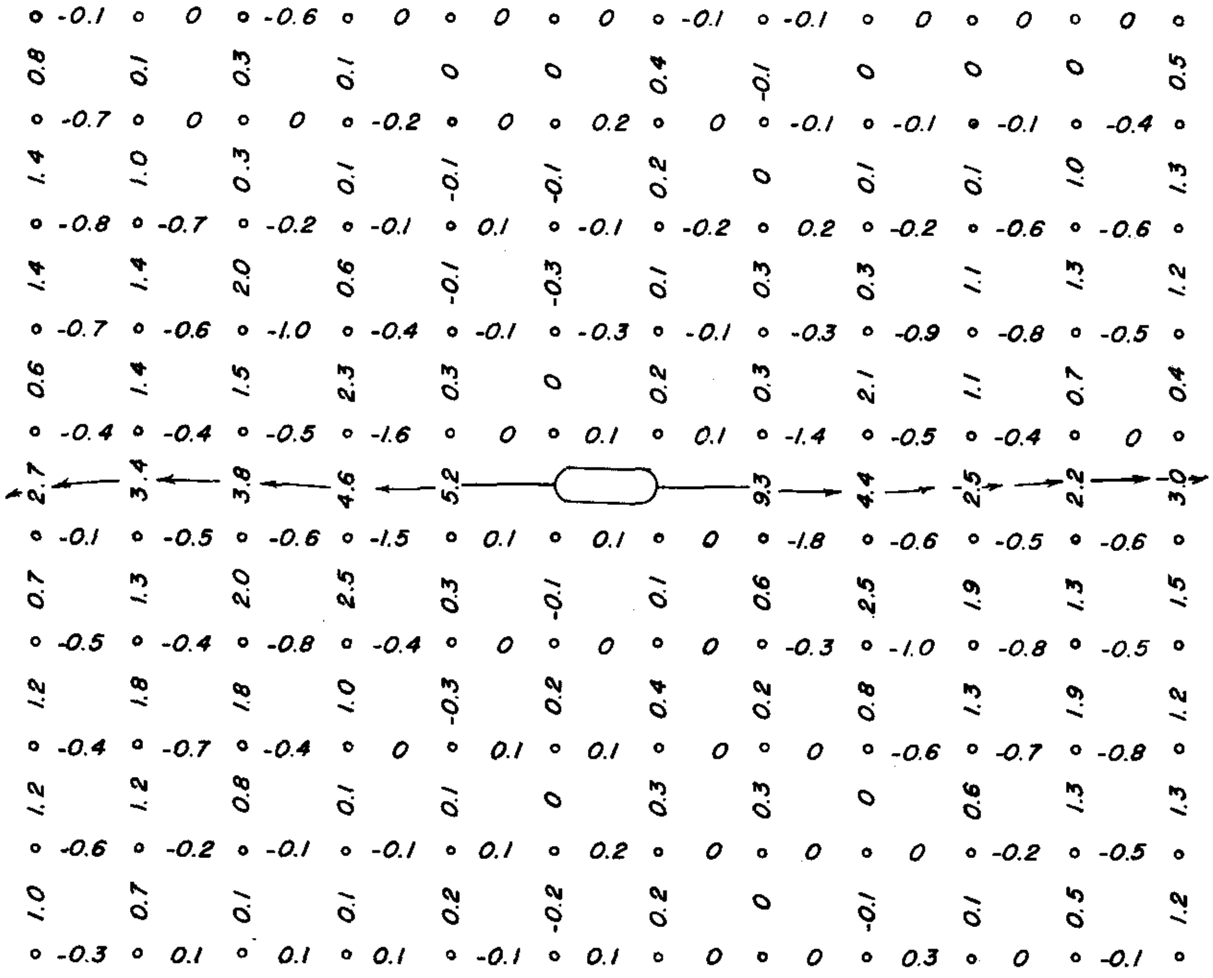


FIG. A-130 PERCENT ELONGATION PLATE Q-13XD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 58.4 KSI

TEMPERATURE 0 °F. 0% SHEAR

DWG. 44E196

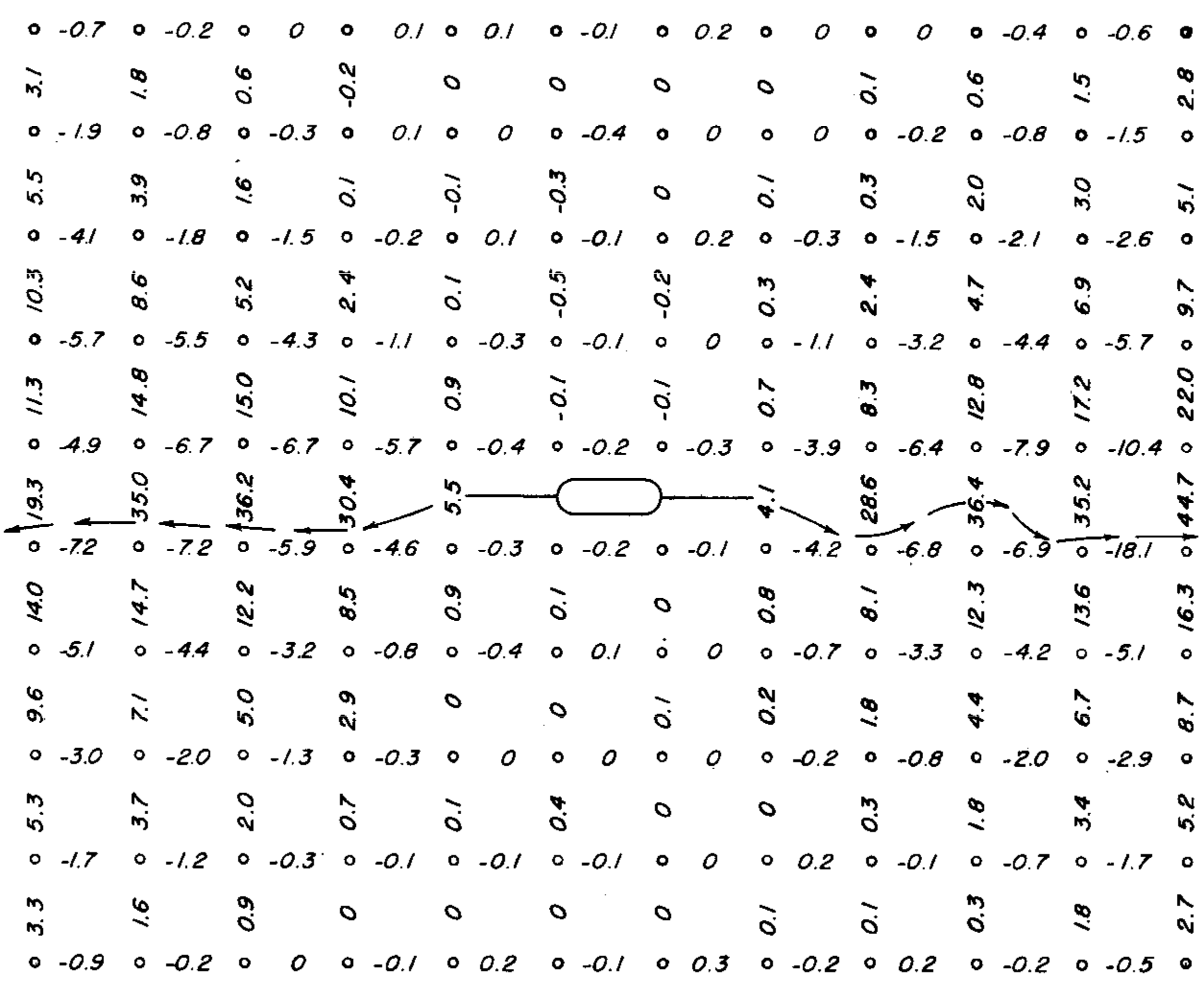


FIG. A-131 PERCENT ELONGATION PLATE Q-14XD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 61.9 KSI

TEMPERATURE 68 °F. 100% SHEAR

DWG. 44E197

FIG. A-131

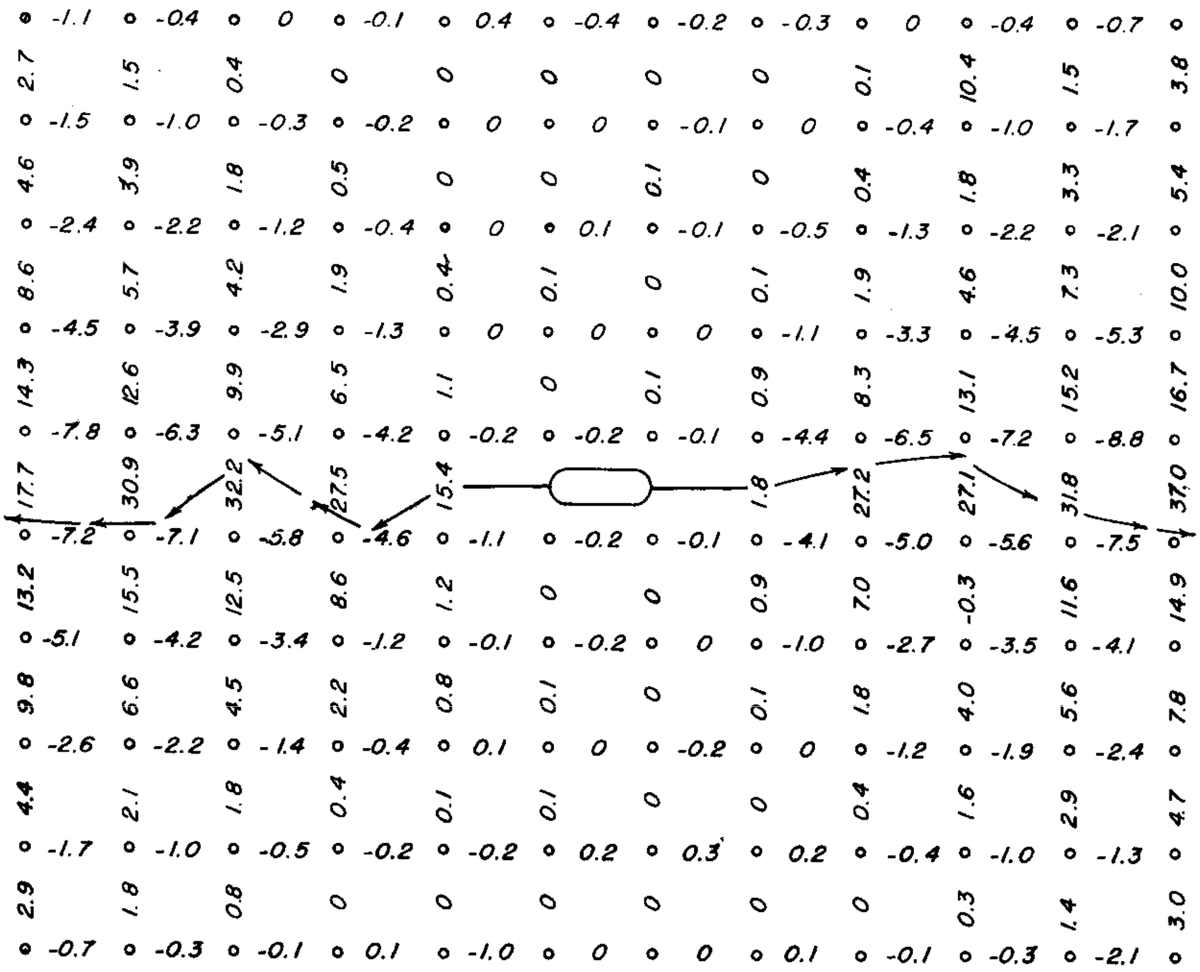


FIG. A-132 PERCENT ELONGATION PLATE Q-21XD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 60.0 KSI

TEMPERATURE 57-59° F. 100% SHEAR

DWG 44E186

FIG. A-132

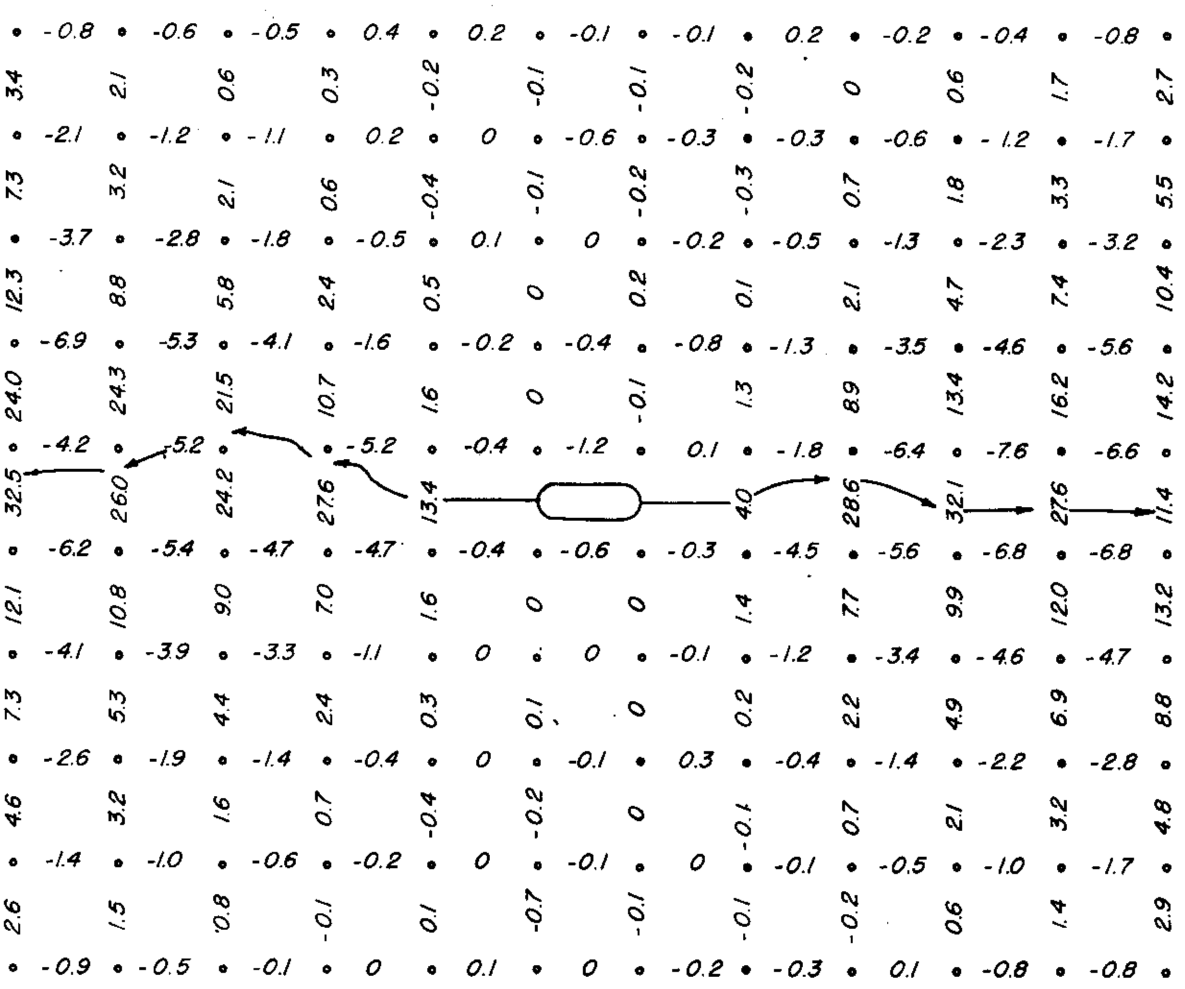
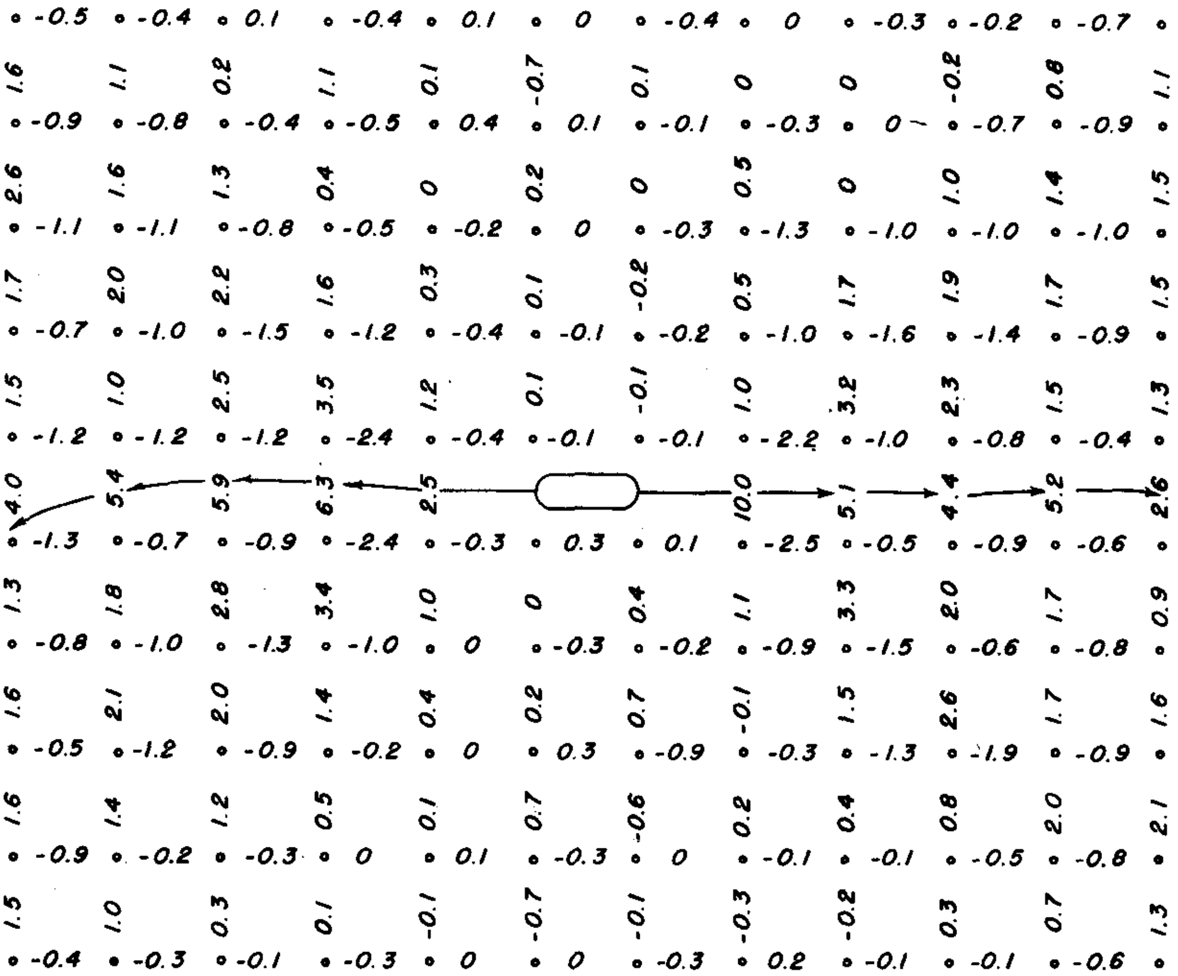


FIG. A-133 PERCENT ELONGATIÓN PLATE Q-22XD (1-INCH GRID)

"Q" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 62.2 KSI

TEMPERATURE 32°F 82 % SHEAR

DWG. 44E189



-0.5	-0.4	0.1	-0.4	0.1	0	-0.4	0	-0.3	-0.2	-0.7	
1.6	1.1	0.2	1.1	0.1	-0.7	0.1	0	0	-0.2	0.8	1.1
-0.9	-0.8	-0.4	-0.5	0.4	0.1	-0.1	-0.3	0	-0.7	-0.9	
2.6	1.6	1.3	0.4	0	0.2	0	0.5	0	1.0	1.4	1.5
-1.1	-1.1	-0.8	-0.5	-0.2	0	-0.3	-1.3	-1.0	-1.0	-1.0	
1.7	2.0	2.2	1.6	0.3	0.1	-0.2	0.5	1.7	1.9	1.7	1.5
-0.7	-1.0	-1.5	-1.2	-0.4	-0.1	-0.2	-1.0	-1.6	-1.4	-0.9	
1.5	1.0	2.5	3.5	1.2	0.1	-0.1	1.0	3.2	2.3	1.5	1.3
-1.2	-1.2	-1.2	-2.4	-0.4	-0.1	-0.1	-2.2	-1.0	-0.8	-0.4	
4.0	5.4	5.9	6.3	2.5			10.0	5.1	4.4	5.2	2.6
-1.3	-0.7	-0.9	-2.4	-0.3	0.3	0.1	-2.5	-0.5	-0.9	-0.6	
1.3	1.8	2.8	3.4	1.0	0	0.4	1.1	3.3	2.0	1.7	0.9
-0.8	-1.0	-1.3	-1.0	0	-0.3	-0.2	-0.9	-1.5	-0.6	-0.8	
1.6	2.1	2.0	1.4	0.4	0.2	0.7	-0.1	1.5	2.6	1.7	1.6
-0.5	-1.2	-0.9	-0.2	0	0.3	-0.9	-0.3	-1.3	-1.9	-0.9	
1.6	1.4	1.2	0.5	0.1	0.7	-0.6	0.2	0.4	0.8	2.0	2.1
-0.9	-0.2	-0.3	0	0.1	-0.3	0	-0.1	-0.1	-0.5	-0.8	
1.5	1.0	0.3	0.1	-0.1	-0.7	-0.1	-0.3	-0.2	0.3	0.7	1.3
-0.4	-0.3	-0.1	-0.3	0	0	-0.3	0.2	-0.1	-0.1	-0.6	

FIG. A-134 PERCENT ELONGATION PLATE Q-31XD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 62.2 KSI

TEMPERATURE (-21)-(-20) °F. 0% SHEAR

DWG. 44E232 FIG. A-134

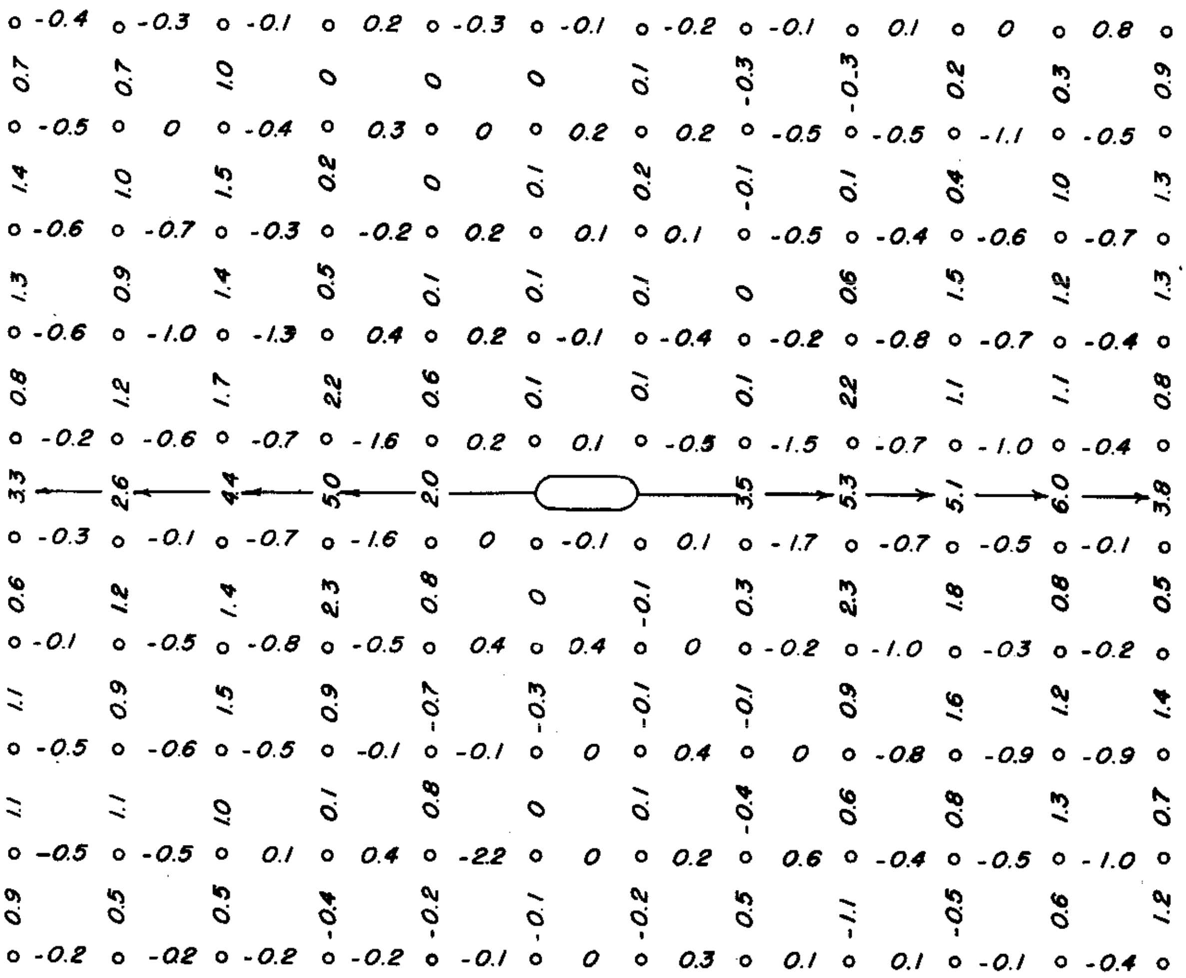
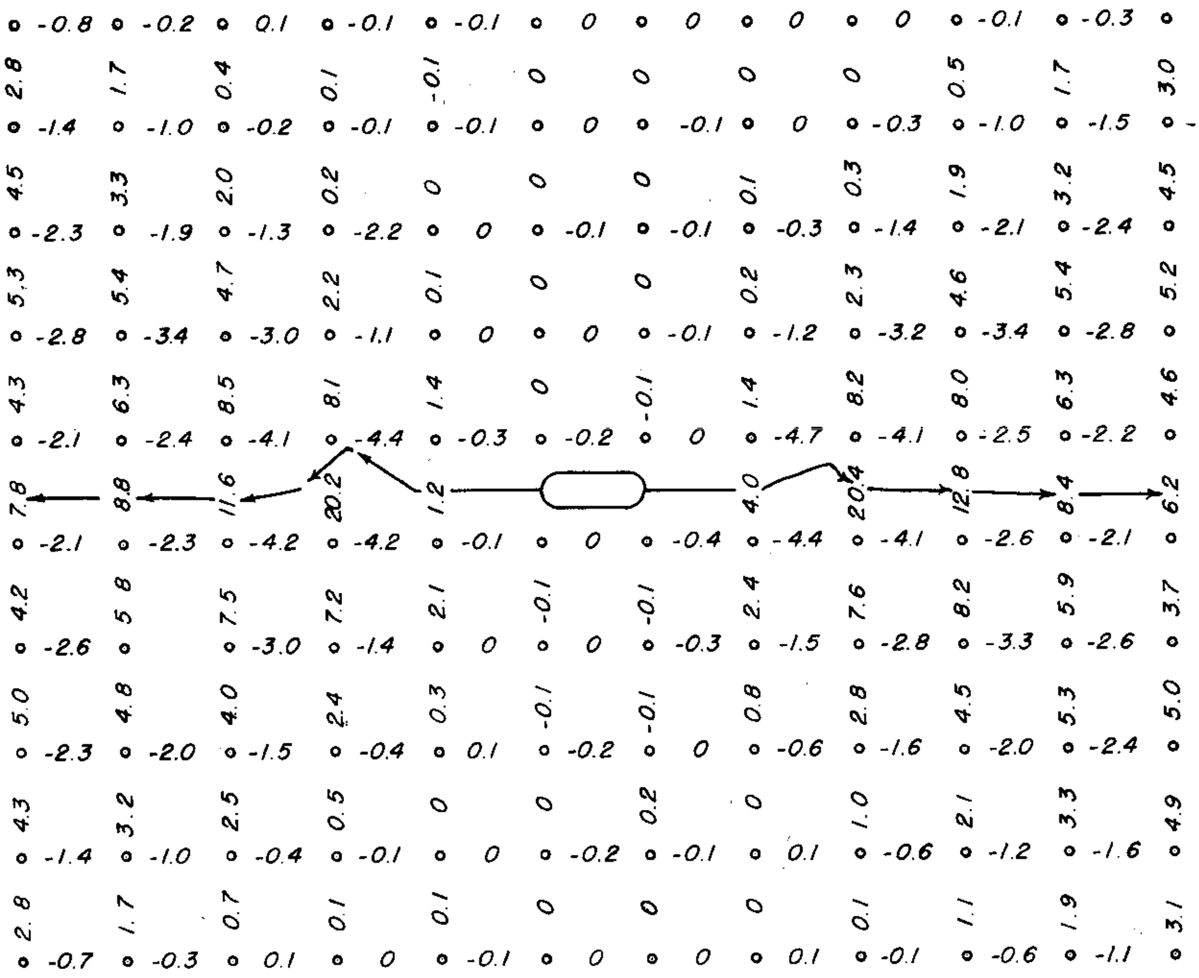


FIG. A-135 PERCENT ELONGATION PLATE Q-32XD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 59.7 KSI

TEMPERATURE (-51)-(-50) °F 0% SHEAR

DWG. 44E250



	-0.8		-0.2		0.1		-0.1		-0.1		0		0		0		0		-0.1		-0.3	
2.8		1.7		0.4		0.1		-0.1		0		0		0		0		0.5		1.7		3.0
	-1.4		-1.0		-0.2		-0.1		-0.1		0		-0.1		0		-0.3		-1.0		-1.5	
4.5		3.3		2.0		0.2		0		0		0		0.1		0.3		1.9		3.2		4.5
	-2.3		-1.9		-1.3		-2.2		0		-0.1		-0.1		-0.3		-1.4		-2.1		-2.4	
5.3		5.4		4.7		2.2		0.1		0		0		0.2		2.3		4.6		5.4		5.2
	-2.8		-3.4		-3.0		-1.1		0		0		-0.1		-1.2		-3.2		-3.4		-2.8	
4.3		6.3		8.5		8.1		1.4		0		-0.1		1.4		8.2		8.0		6.3		4.6
	-2.1		-2.4		-4.1		-4.4		-0.3		-0.2		0		-4.7		-4.1		-2.5		-2.2	
7.8		8.8		11.6		20.2		1.2						4.0		20.4		12.8		8.4		6.2
	-2.1		-2.3		-4.2		-4.2		-0.1		0		-0.4		-4.4		-4.1		-2.6		-2.1	
4.2		5.8		7.5		7.2		2.1		-0.1		-0.1		2.4		7.6		8.2		5.9		3.7
	-2.6				-3.0		-1.4		0		0		-0.3		-1.5		-2.8		-3.3		-2.6	
5.0		4.8		4.0		2.4		0.3		-0.1		-0.1		0.8		2.8		4.5		5.3		5.0
	-2.3		-2.0		-1.5		-0.4		0.1		-0.2		0		-0.6		-1.6		-2.0		-2.4	
4.3		3.2		2.5		0.5		0		0		0.2		0		1.0		2.1		3.3		4.9
	-1.4		-1.0		-0.4		-0.1		0		-0.2		-0.1		0.1		-0.6		-1.2		-1.6	
2.8		1.7		0.7		0.1		0.1		0		0		0		0.1		1.1		1.9		3.1
	-0.7		-0.3		0.1		0		-0.1		0		0		0.1		-0.1		-0.6		-1.1	

FIG. A-136 PERCENT ELONGATION PLATE Q-ISD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 69.0 KSI

TEMPERATURE (-1)-(1) °F. 18 % SHEAR

DWG. 44E240

FIG. A-136

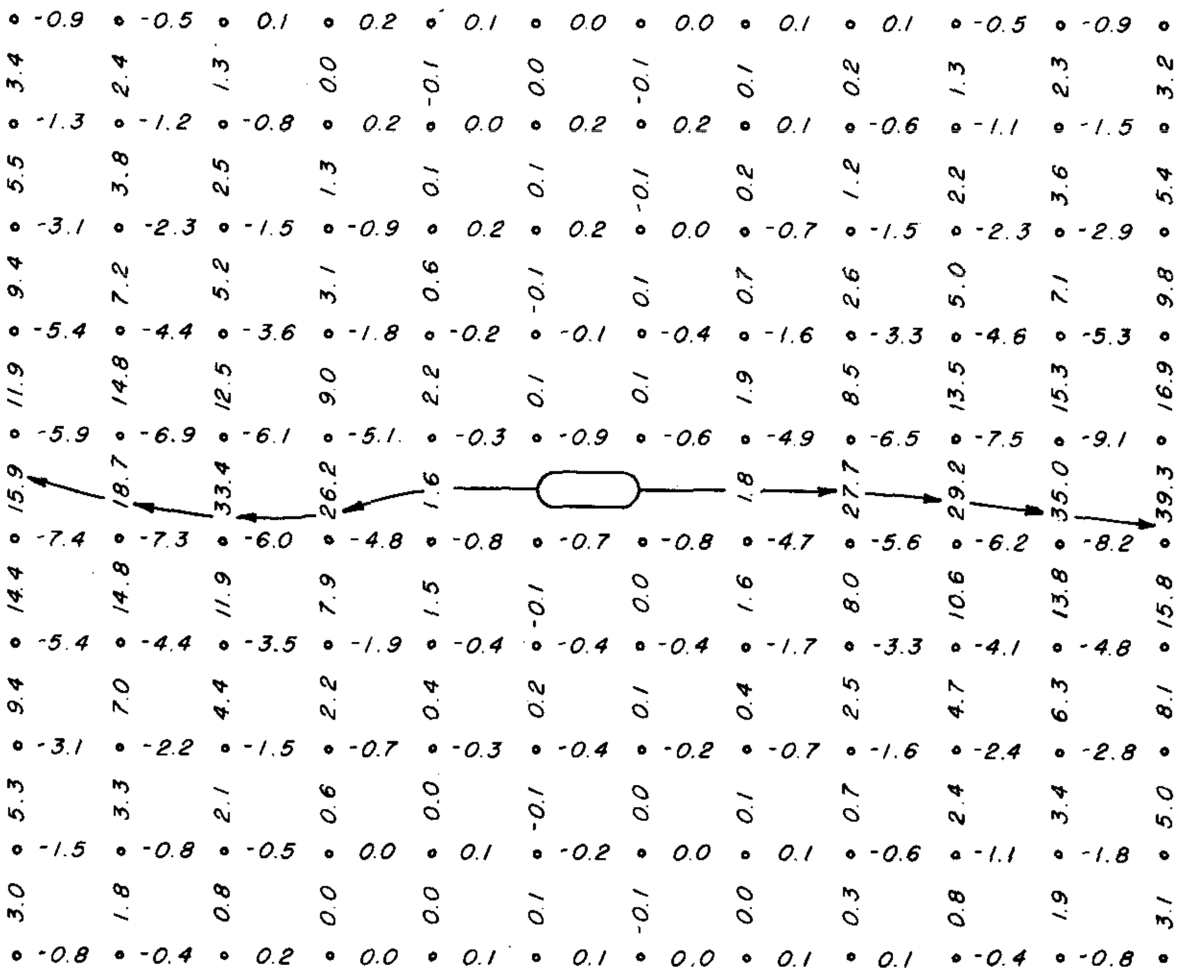


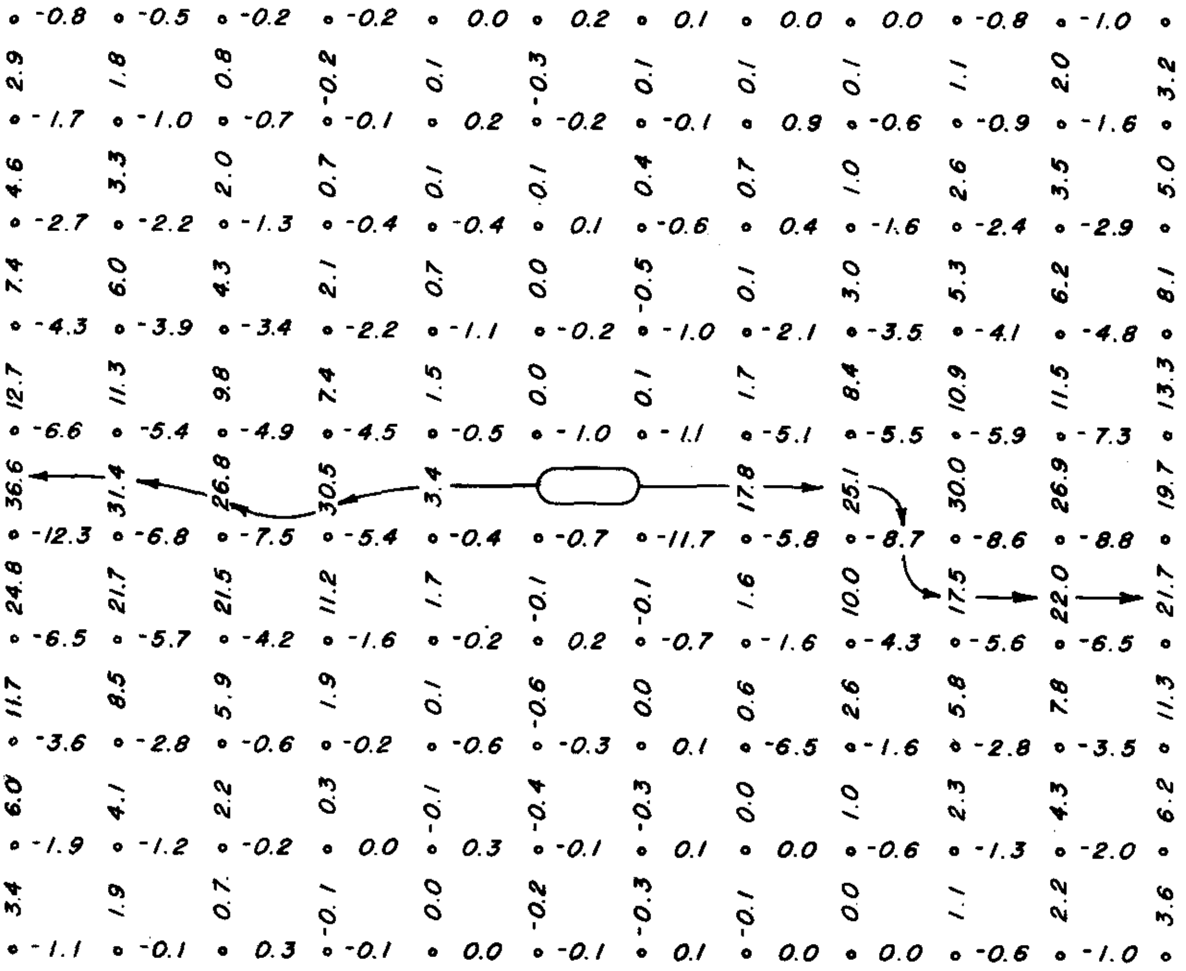
FIG. A-137 PERCENT ELONGATION PLATE Q-2SD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 66.8 KSI

TEMPERATURE 31–34 °F 89% SHEAR

DWG. 44E241

FIG.A-137



-0.8	-0.5	-0.2	-0.2	0.0	0.2	0.1	0.0	0.0	-0.8	-1.0	
2.9	1.8	0.8	-0.2	0.1	-0.3	0.1	0.1	0.1	1.1	2.0	3.2
-1.7	-1.0	-0.7	-0.1	0.2	-0.2	-0.1	0.9	-0.6	-0.9	-1.6	
4.6	3.3	2.0	0.7	0.1	0.1	0.4	0.7	1.0	2.6	3.5	5.0
-2.7	-2.2	-1.3	-0.4	-0.4	0.1	-0.6	0.4	-1.6	-2.4	-2.9	
7.4	6.0	4.3	2.1	0.7	0.0	-0.5	0.1	3.0	5.3	6.2	8.1
-4.3	-3.9	-3.4	-2.2	-1.1	-0.2	-1.0	-2.1	-3.5	-4.1	-4.8	
12.7	11.3	9.8	7.4	1.5	0.0	0.1	1.7	8.4	10.9	11.5	13.3
-6.6	-5.4	-4.9	-4.5	-0.5	-1.0	-1.1	-5.1	-5.5	-5.9	-7.3	
36.6	31.4	26.8	30.5	3.4			17.8	25.1	30.0	26.9	19.7
-12.3	-6.8	-7.5	-5.4	-0.4	-0.7	-11.7	-5.8	-8.7	-8.6	-8.8	
24.8	21.7	21.5	11.2	1.7	-0.1	-0.1	1.6	10.0	17.5	22.0	21.7
-6.5	-5.7	-4.2	-1.6	-0.2	0.2	-0.7	-1.6	-4.3	-5.6	-6.5	
11.7	8.5	5.9	1.9	0.1	-0.6	0.0	0.6	2.6	5.8	7.8	11.3
-3.6	-2.8	-0.6	-0.2	-0.6	-0.3	0.1	-6.5	-1.6	-2.8	-3.5	
6.0	4.1	2.2	0.3	-0.1	-0.4	-0.3	0.0	1.0	2.3	4.3	6.2
-1.9	-1.2	-0.2	0.0	0.3	-0.1	0.1	0.0	-0.6	-1.3	-2.0	
3.4	1.9	0.7	-0.1	0.0	-0.2	-0.3	-0.1	0.0	1.1	2.2	3.6
-1.1	-0.1	0.3	-0.1	0.0	-0.1	0.1	0.0	0.0	-0.6	-1.0	

FIG. A-138 PERCENT ELONGATION PLATE Q-3SD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 66.8 KSI

TEMPERATURE 63-65 °F 100% SHEAR

DWG. 44E238

FIG. A-138

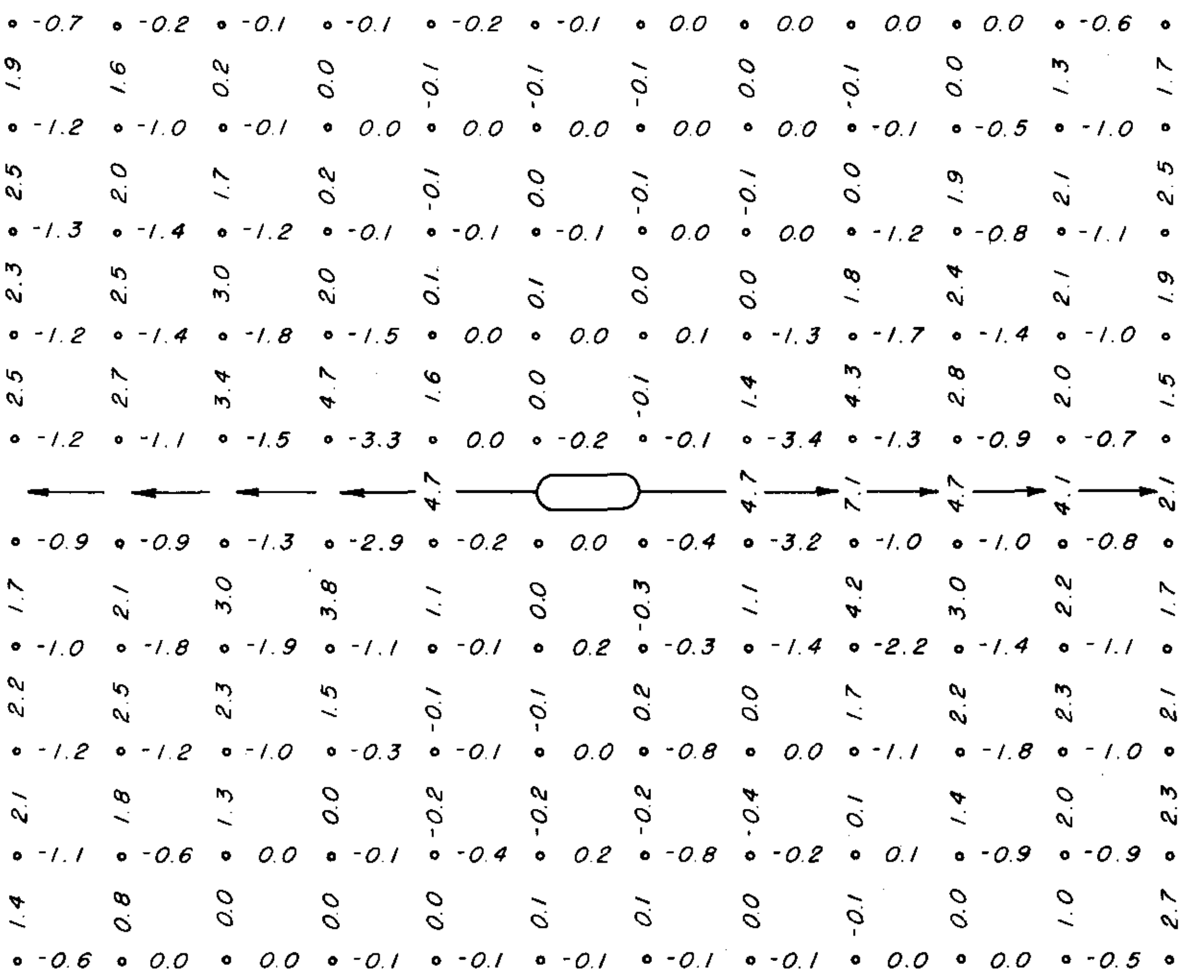


FIG. A-139 PERCENT ELONGATION PLATE Q-4SD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 68.6KSI

TEMPERATURE (-30)-(-29) °F 0% SHEAR

DWG. 44E239

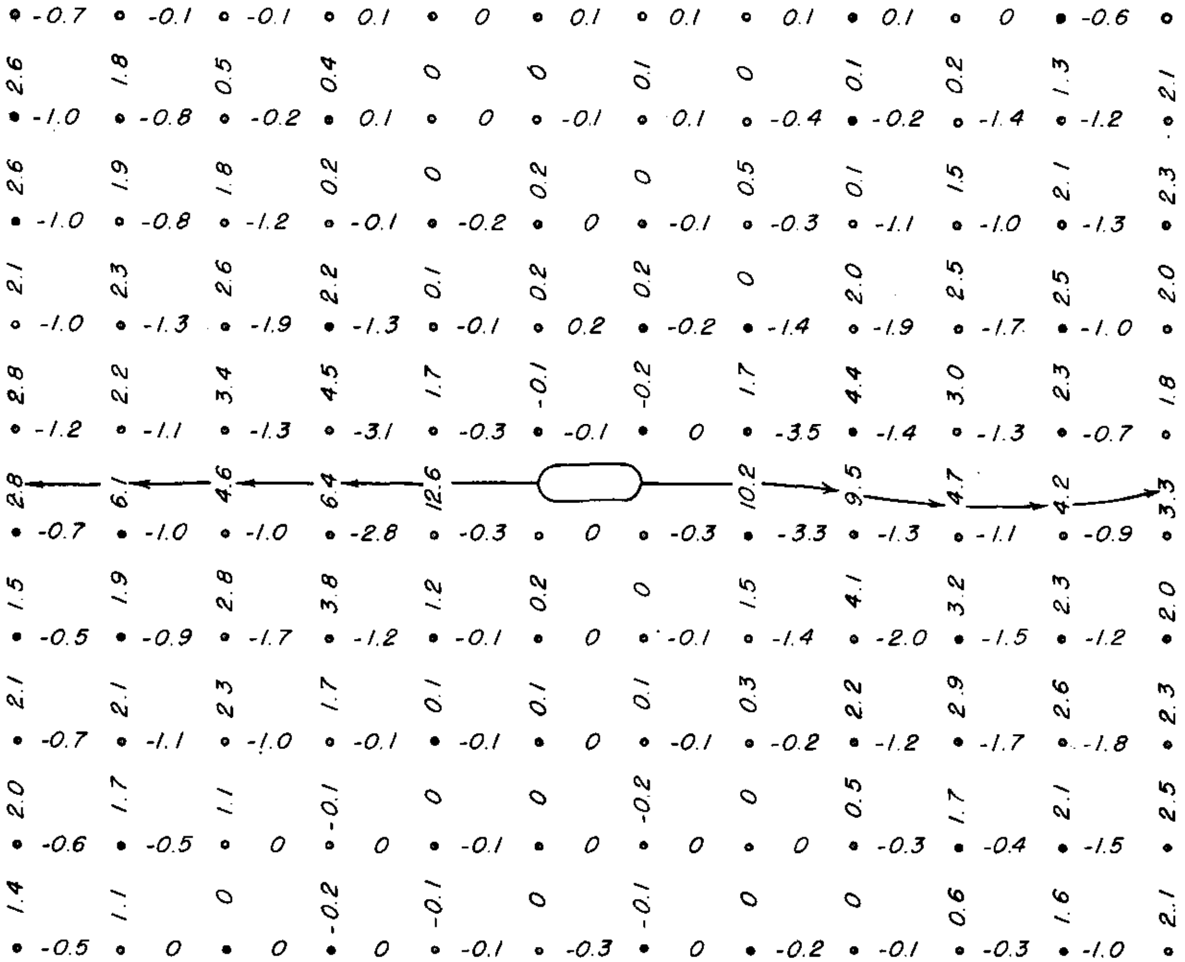


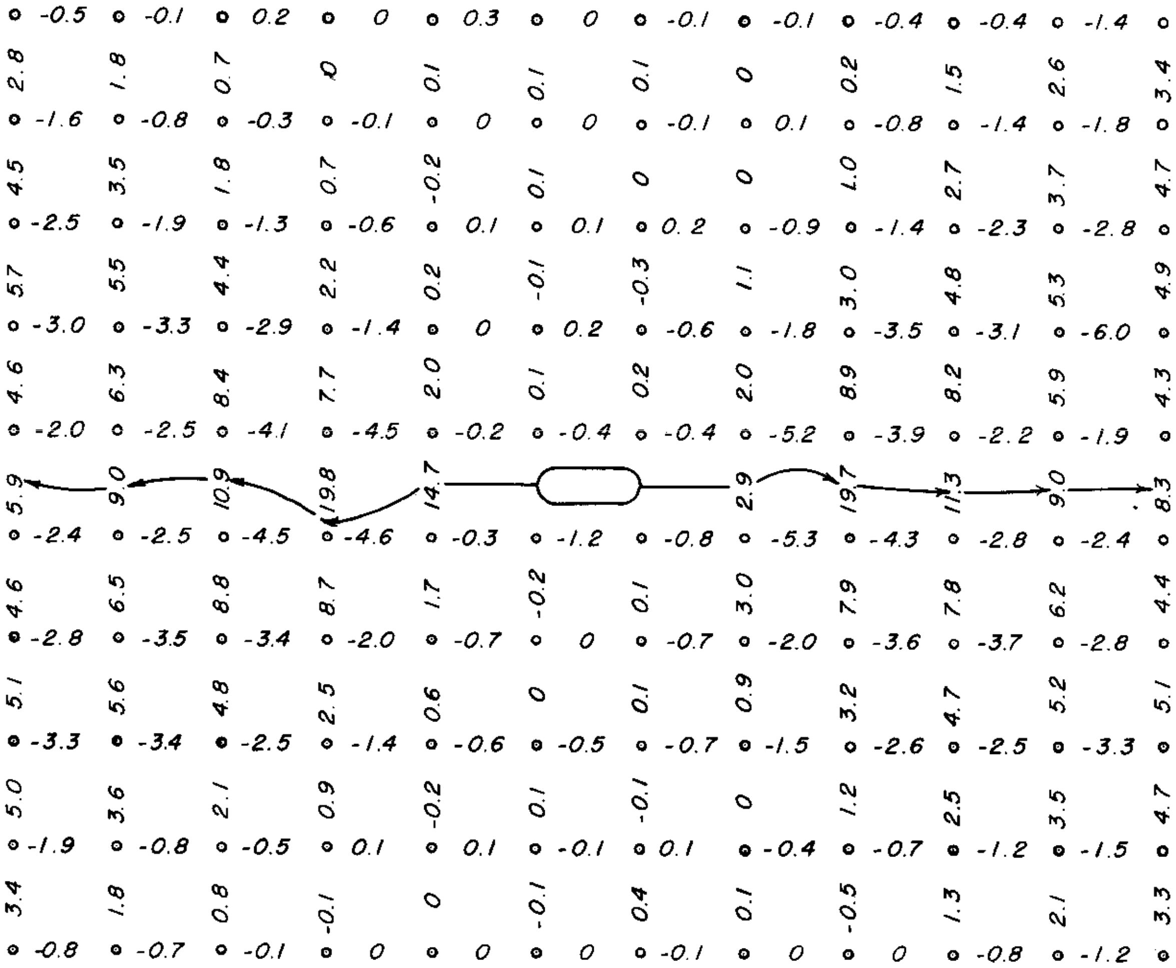
FIG. A-140 PERCENT ELONGATION PLATE Q-5SD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 66.7 KSI

TEMPERATURE (-14)-(-13) °F 0 % SHEAR

DWG. 44E243

FIG. A-140



-0.5	-0.1	0.2	0	0.3	0	-0.1	-0.1	-0.4	-0.4	-1.4
-1.6	-0.8	-0.3	-0.1	0	0	-0.1	0.1	-0.8	-1.4	-1.8
-2.5	-1.9	-1.3	-0.6	0.1	0.1	0.2	-0.9	-1.4	-2.3	-2.8
-3.0	-3.3	-2.9	-1.4	0	0.2	-0.6	-1.8	-3.5	-3.1	-6.0
-2.0	-2.5	-4.1	-4.5	-0.2	-0.4	-0.4	-5.2	-3.9	-2.2	-1.9
-2.4	-2.5	-4.5	-4.6	-0.3	-1.2	-0.8	-5.3	-4.3	-2.8	-2.4
-2.8	-3.5	-3.4	-2.0	-0.7	0	-0.7	-2.0	-3.6	-3.7	-2.8
-3.3	-3.4	-2.5	-1.4	-0.6	-0.5	-0.7	-1.5	-2.6	-2.5	-3.3
-1.9	-0.8	-0.5	0.1	0.1	-0.1	0.1	-0.4	-0.7	-1.2	-1.5
-0.8	-0.7	-0.1	0	0	0	-0.1	0	0	-0.8	-1.2

2.8	1.8	0.7	0	0.1	0.1	0.1	0	0.2	1.5	2.6	3.4
4.5	3.5	1.8	0.7	-0.2	0.1	0	0	1.0	2.7	3.7	4.7
5.7	5.5	4.4	2.2	0.2	-0.1	-0.3	1.1	3.0	4.8	5.3	4.9
4.6	6.3	8.4	7.7	2.0	0.1	0.2	2.0	8.9	8.2	5.9	4.3
5.9	9.0	10.9	19.8	14.7			2.9	19.7	11.3	9.0	8.3
4.6	6.5	8.8	8.7	1.7	-0.2	0.1	3.0	7.9	7.8	6.2	4.4
5.1	5.6	4.8	2.5	0.6	0	0.1	0.9	3.2	4.7	5.2	5.1
5.0	3.6	2.1	0.9	-0.2	0.1	-0.1	0	1.2	2.5	3.5	4.7
3.4	1.8	0.8	-0.1	0	-0.1	0.4	0.1	-0.5	1.3	2.1	3.3

FIG. A-141 PERCENT ELONGATION PLATE Q-6SD (1-INCH GRID)

"Q" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 69.3 KSI

TEMPERATURE 15 °F. 19 % SHEAR

DWG. 44E244

FIG. A-141

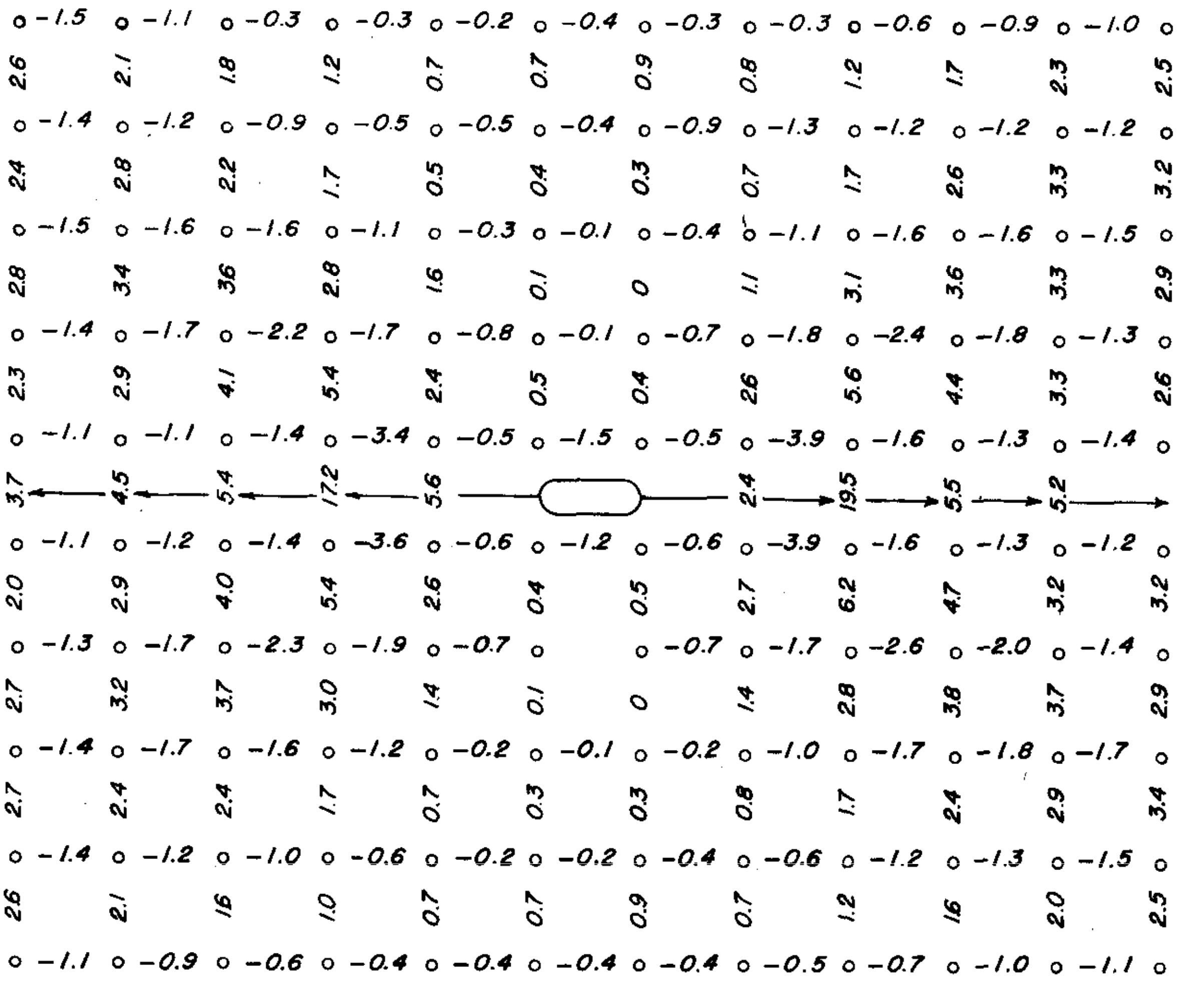


FIG. A-142 PERCENT ELONGATION PLATE H-1D (1-INCH GRID)

"H" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 53.3 KSI

TEMPERATURE (-1)-(2)°F 0 % SHEAR

DWG. 44E198

FIG. A-142

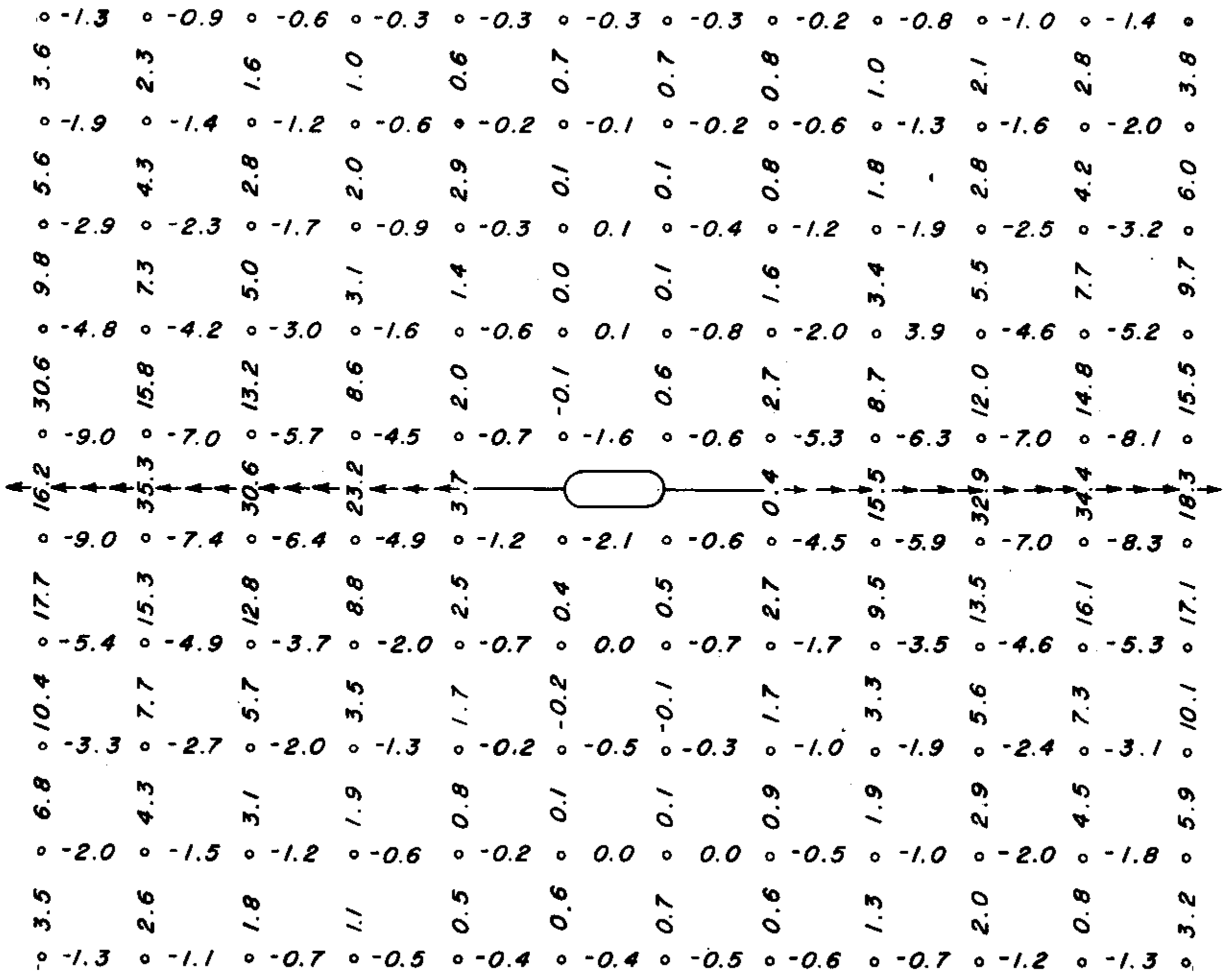


FIG. A-143 PERCENT ELONGATION PLATE H-2D (1-INCH GRID)

"H" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 53.2 KSI.

TEMPERATURE 23°-27° F. 74% SHEAR

DWG. 44E199

FIG. A-143

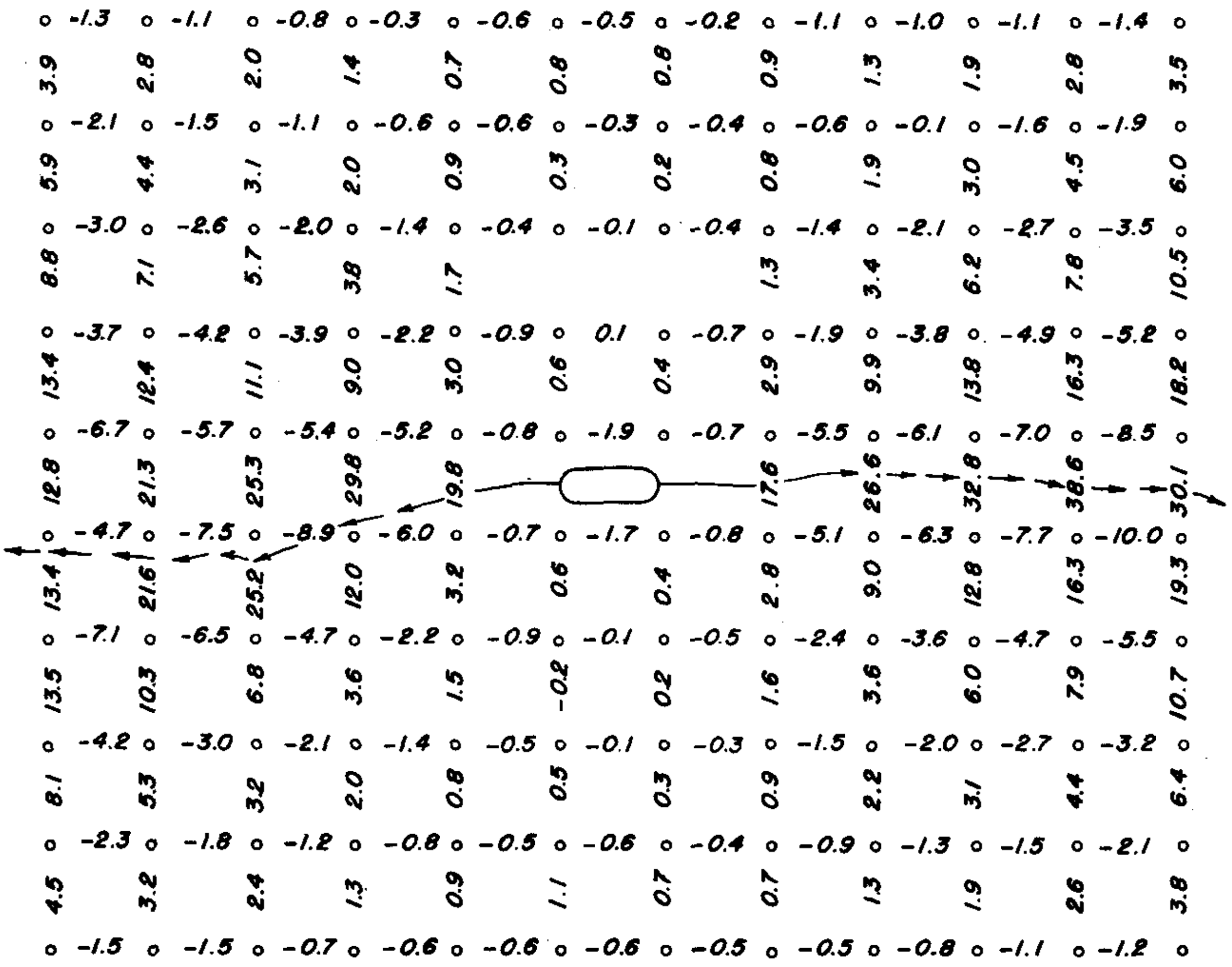

-1.3 -1.1 -0.8 -0.3 -0.6 -0.5 -0.2 -1.1 -1.0 -1.1 -1.4
3.9 2.8 2.0 1.4 0.7 0.8 0.8 0.9 1.3 1.9 2.8 3.5
-2.1 -1.5 -1.1 -0.6 -0.6 -0.3 -0.4 -0.6 -0.1 -1.6 -1.9
5.9 4.4 3.1 2.0 0.9 0.3 0.2 0.8 1.9 3.0 4.5 6.0
-3.0 -2.6 -2.0 -1.4 -0.4 -0.1 -0.4 -1.4 -2.1 -2.7 -3.5
8.8 7.1 5.7 3.8 1.7 1.3 3.4 6.2 7.8 10.5
-3.7 -4.2 -3.9 -2.2 -0.9 0.1 -0.7 -1.9 -3.8 -4.9 -5.2
13.4 12.4 11.1 9.0 3.0 0.6 0.4 2.9 9.9 13.8 16.3 18.2
-6.7 -5.7 -5.4 -5.2 -0.8 -1.9 -0.7 -5.5 -6.1 -7.0 -8.5
12.8 21.3 25.3 29.8 19.8 17.6 26.6 32.8 38.6 30.1
-4.7 -7.5 -8.9 -6.0 -0.7 -1.7 -0.8 -5.1 -6.3 -7.7 -10.0
13.4 21.6 25.2 12.0 3.2 0.6 0.4 2.8 9.0 12.8 16.3 19.3
-7.1 -6.5 -4.7 -2.2 -0.9 -0.1 -0.5 -2.4 -3.6 -4.7 -5.5
13.5 10.3 6.8 3.6 1.5 -0.2 0.2 1.6 3.6 6.0 7.9 10.7
-4.2 -3.0 -2.1 -1.4 -0.5 -0.1 -0.3 -1.5 -2.0 -2.7 -3.2
8.1 5.3 3.2 2.0 0.8 0.5 0.3 0.9 2.2 3.1 4.4 6.4
-2.3 -1.8 -1.2 -0.8 -0.5 -0.6 -0.4 -0.9 -1.3 -1.5 -2.1
4.5 3.2 2.4 1.3 0.9 1.1 0.7 0.7 1.3 1.9 2.6 3.8
-1.5 -1.5 -0.7 -0.6 -0.6 -0.6 -0.5 -0.5 -0.8 -1.1 -1.2

FIG. A-144 PERCENT ELONGATION PLATE H-3D (1-INCH GRID)

"B" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 53.4 KSI

TEMPERATURE 40-43°F. 66 % SHEAR

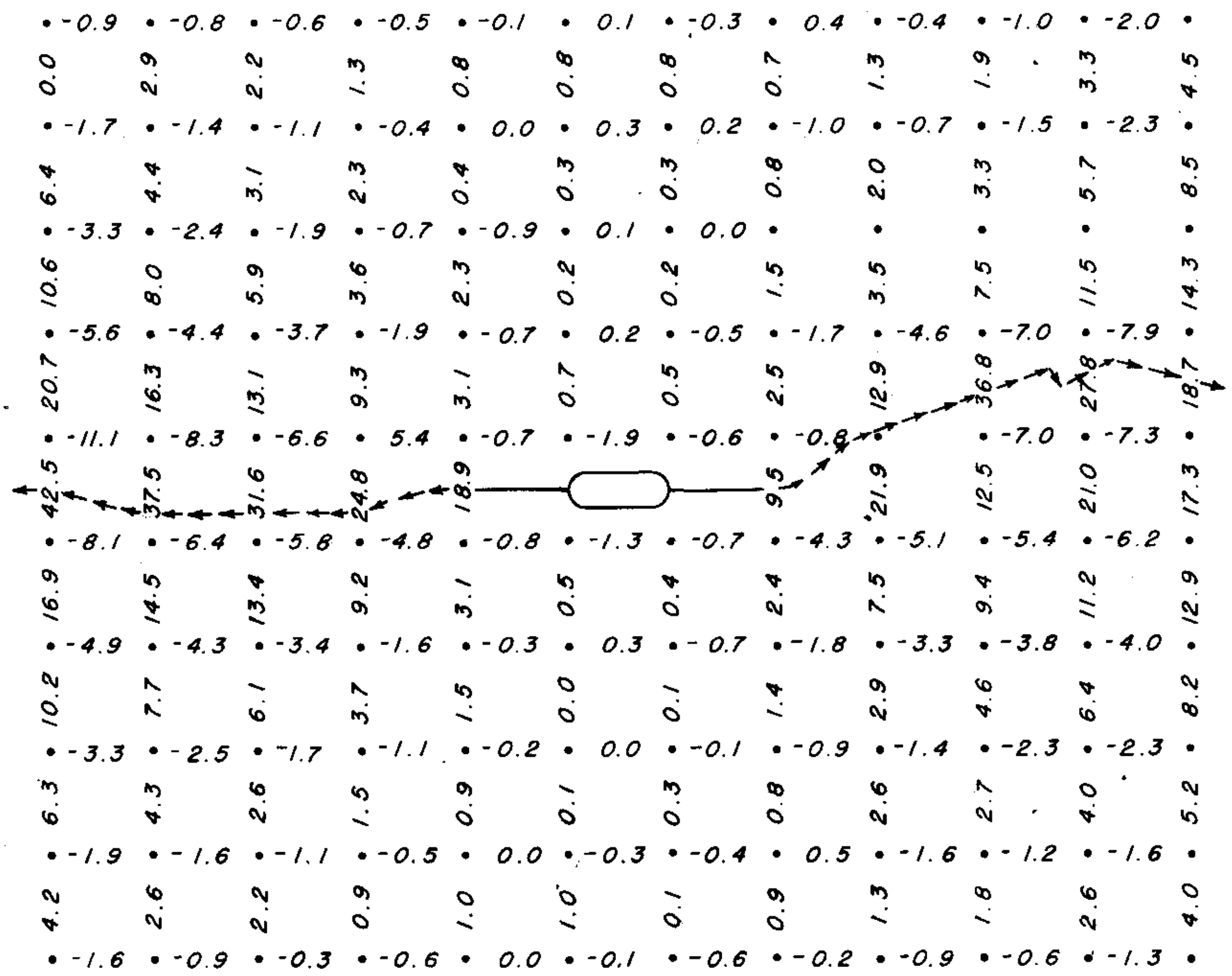


FIG. A-145 PERCENT ELONGATION PLATE H-4D (1-INCH GRID)

"H" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 52.7 K.S.I.

TEMPERATURE 60°-63° F. 92% SHEAR

DWG. 44E202

FIG. A-145

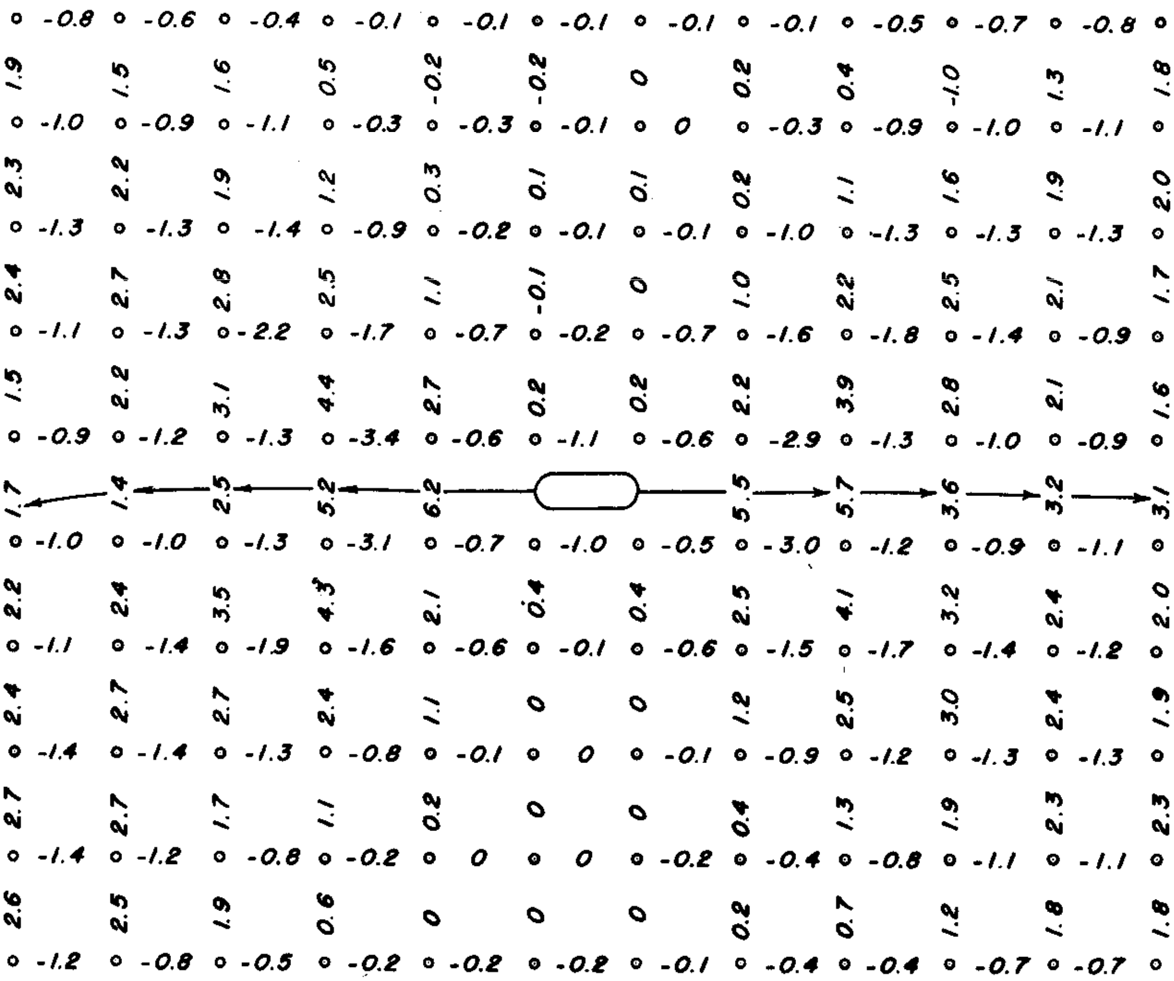


FIG. A-146 PERCENT ELONGATION PLATE H-5D (1-INCH GRID)

"H" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 51.9 KSI

TEMPERATURE (-22 -(-20) °F 0 % SHEAR

DWG. 44E233

FIG. A-146

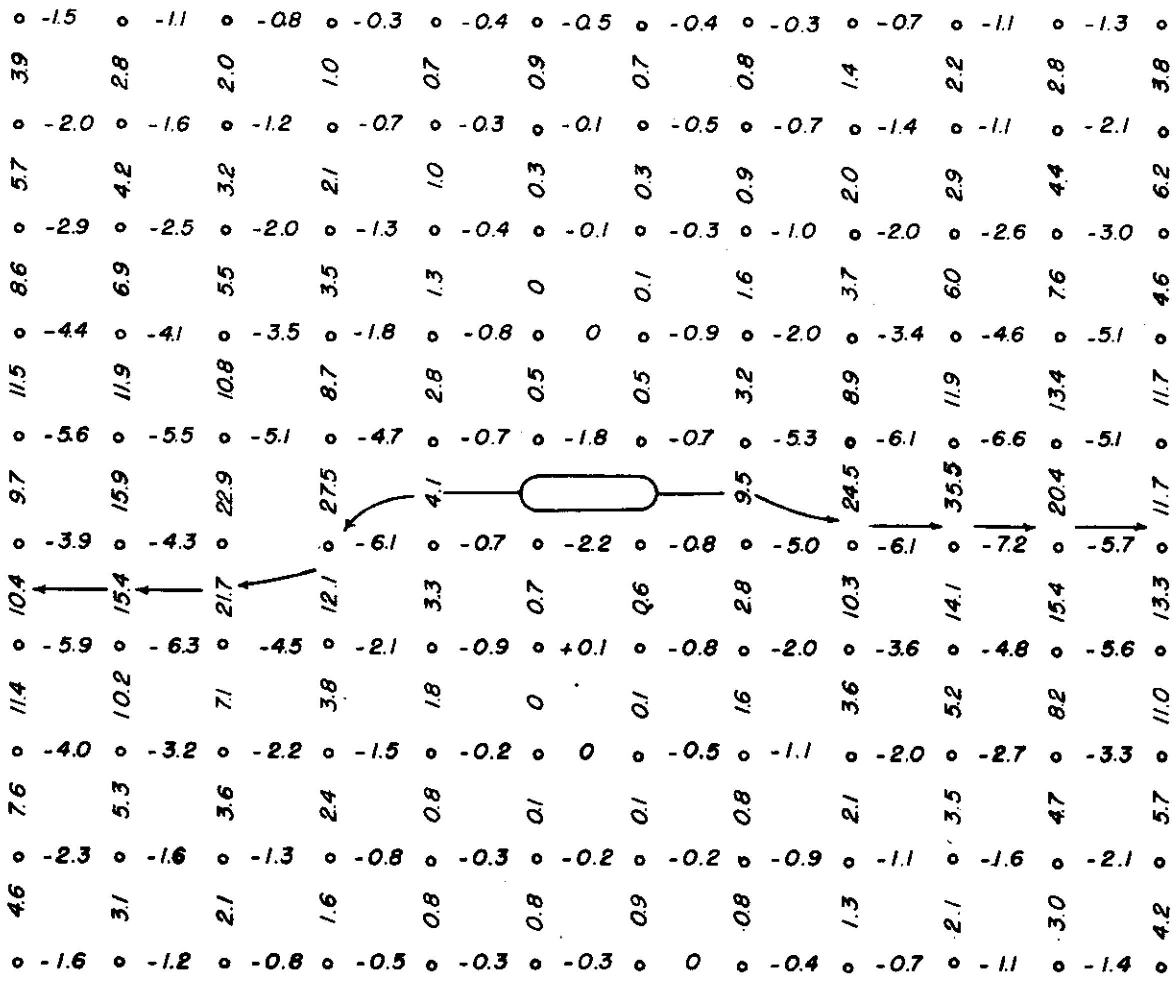


FIG. A-147 PERCENT ELONGATION PLATE H-6D (1-INCH GRID)

"H" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 55.0 KSI

TEMPERATURE 10-13°F 44 % SHEAR

DWG. 44E228

FIG. A-147

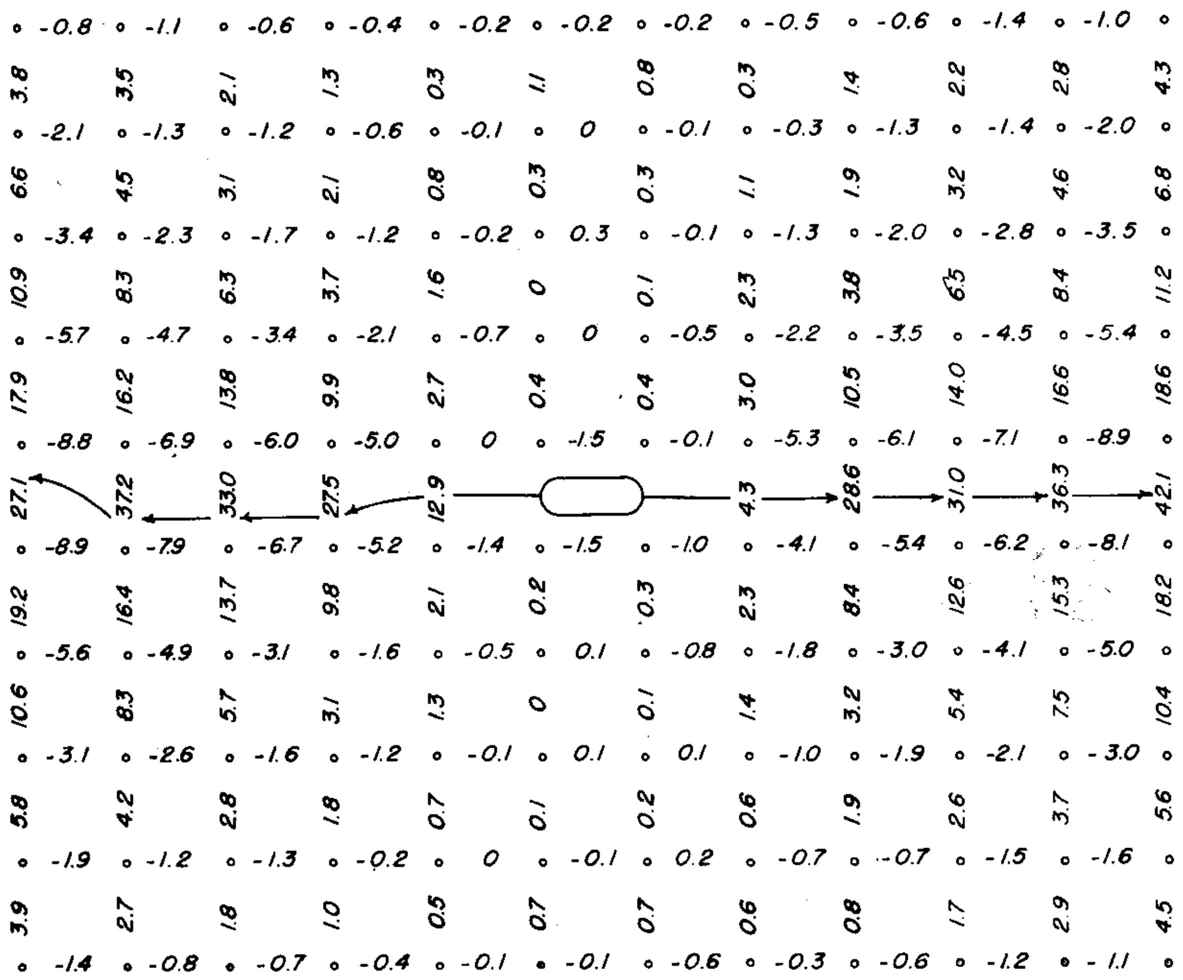


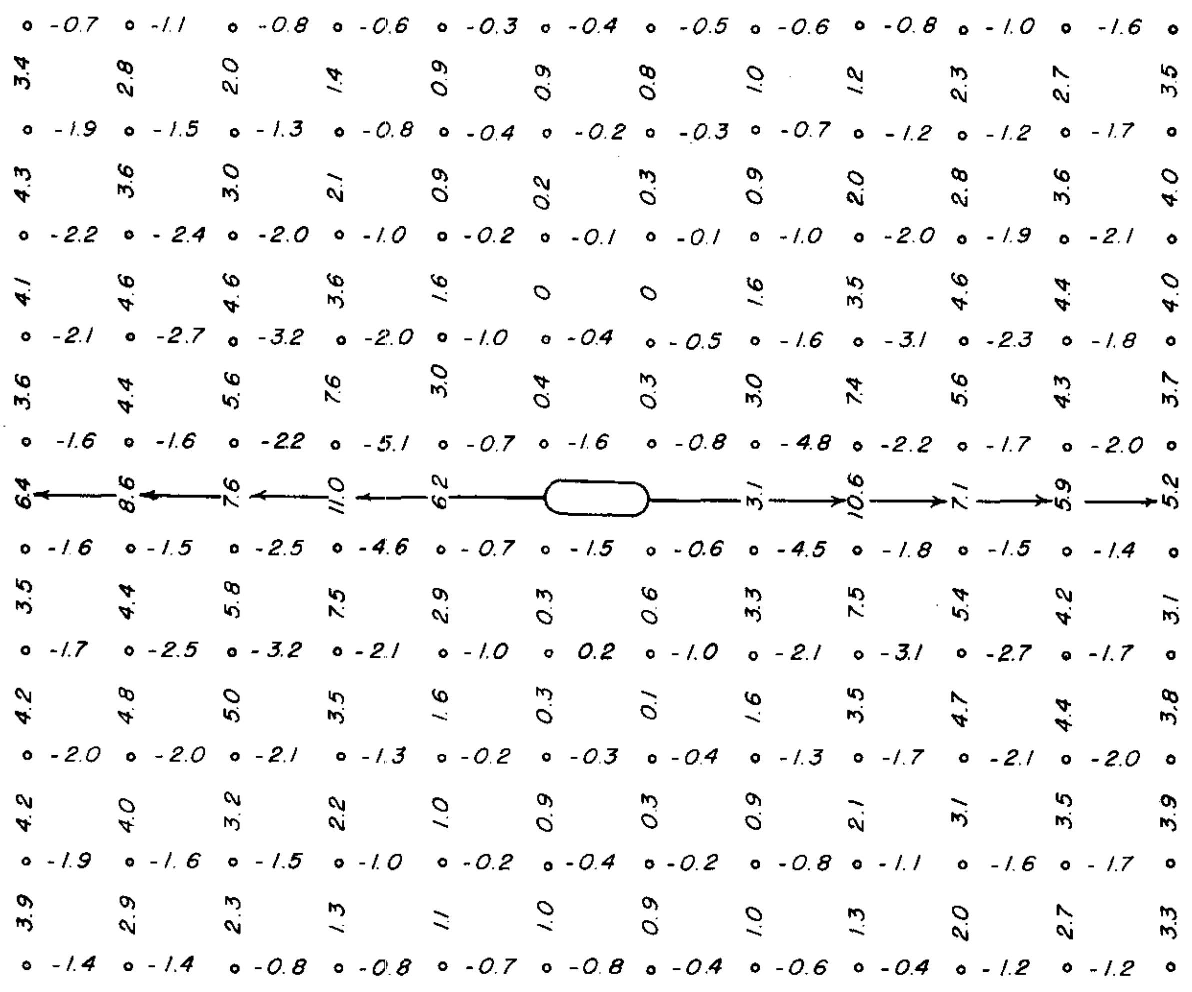
FIG. A-148 PERCENT ELONGATION PLATE H-7D (1-INCH GRID)

"H" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 52.6 KSI

TEMPERATURE 98 °F 100% SHEAR

DWG. 44E237

FIG. A-148



-0.7 -1.1 -0.8 -0.6 -0.3 -0.4 -0.5 -0.6 -0.8 -1.0 -1.6

3.4 2.8 2.0 1.4 0.9 0.9 0.8 1.0 1.2 2.3 2.7 3.5

-1.9 -1.5 -1.3 -0.8 -0.4 -0.2 -0.3 -0.7 -1.2 -1.2 -1.7

4.3 3.6 3.0 2.1 0.9 0.2 0.3 0.9 2.0 2.8 3.6 4.0

-2.2 -2.4 -2.0 -1.0 -0.2 -0.1 -0.1 -1.0 -2.0 -1.9 -2.1

4.1 4.6 4.6 3.6 1.6 0 0 1.6 3.5 4.6 4.4 4.0

-2.1 -2.7 -3.2 -2.0 -1.0 -0.4 -0.5 -1.6 -3.1 -2.3 -1.8

3.6 4.4 5.6 7.6 3.0 0.4 0.3 3.0 7.4 5.6 4.3 3.7

-1.6 -1.6 -2.2 -5.1 -0.7 -1.6 -0.8 -4.8 -2.2 -1.7 -2.0

6.4 8.6 7.6 11.0 6.2 3.1 10.6 7.1 5.9 5.2

-1.6 -1.5 -2.5 -4.6 -0.7 -1.5 -0.6 -4.5 -1.8 -1.5 -1.4

3.5 4.4 5.8 7.5 2.9 0.3 0.6 3.3 7.5 5.4 4.2 3.1

-1.7 -2.5 -3.2 -2.1 -1.0 0.2 -1.0 -2.1 -3.1 -2.7 -1.7

4.2 4.8 5.0 3.5 1.6 0.3 0.1 1.6 3.5 4.7 4.4 3.8

-2.0 -2.0 -2.1 -1.3 -0.2 -0.3 -0.4 -1.3 -1.7 -2.1 -2.0

4.2 4.0 3.2 2.2 1.0 0.9 0.3 0.9 2.1 3.1 3.5 3.9

-1.9 -1.6 -1.5 -1.0 -0.2 -0.4 -0.2 -0.8 -1.1 -1.6 -1.7

3.9 2.9 2.3 1.3 1.1 1.0 0.9 1.0 1.3 2.0 2.7 3.3

-1.4 -1.4 -0.8 -0.8 -0.7 -0.8 -0.4 -0.6 -0.4 -1.2 -1.2

FIG. A-149 PERCENT ELONGATION PLATE H-8D (1-INCH GRID)

"H" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 57.6 KSI

TEMPERATURE -40 °F 3 % SHEAR

DWG. 44E272

FIG. A-149

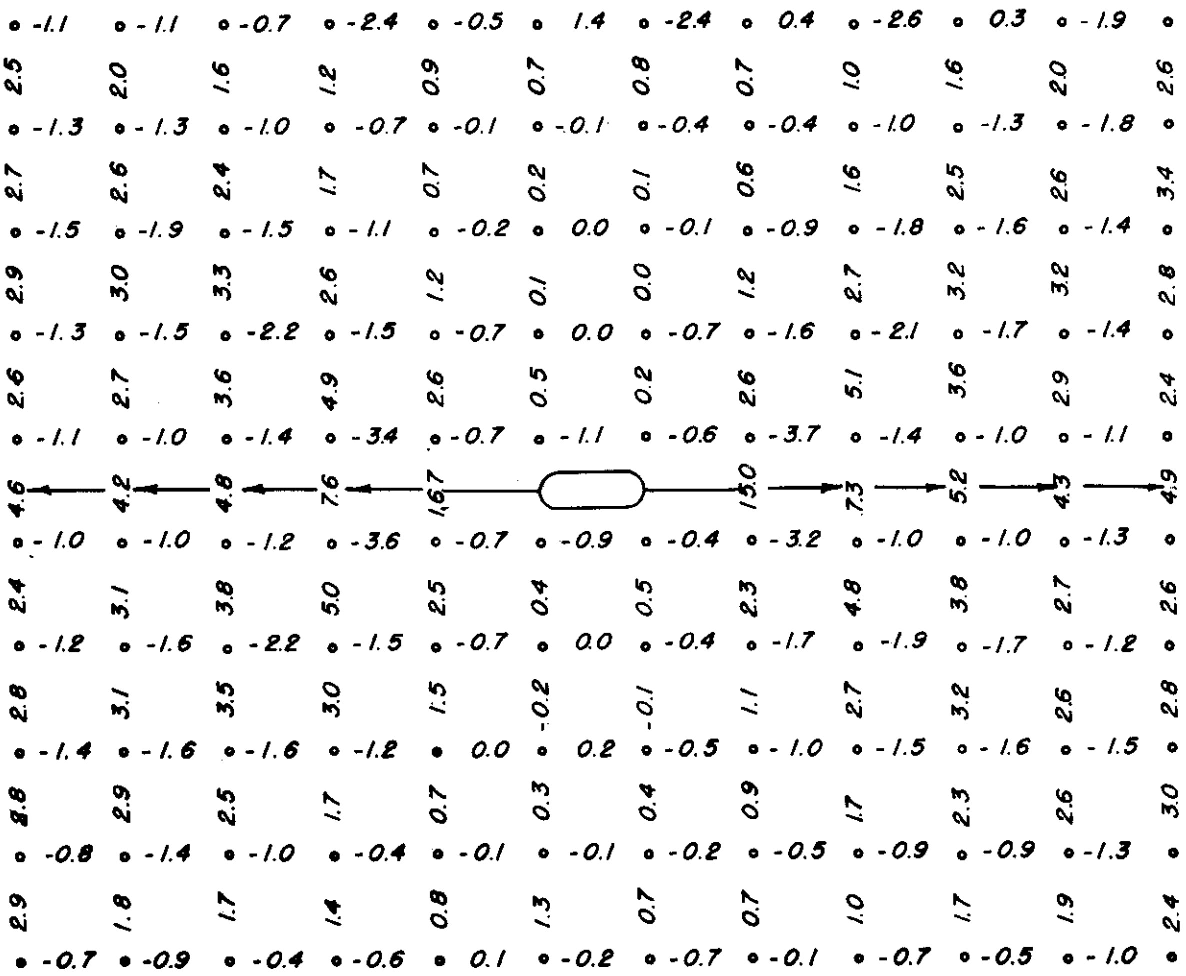


FIG. A-150 PERCENT ELONGATION PLATE H-9D (1-INCH GRID)

"H" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 53.0 KSI

TEMPERATURE (-10)-(-11)° F 0% SHEAR

DWG. 44E 248

FIG. A-150

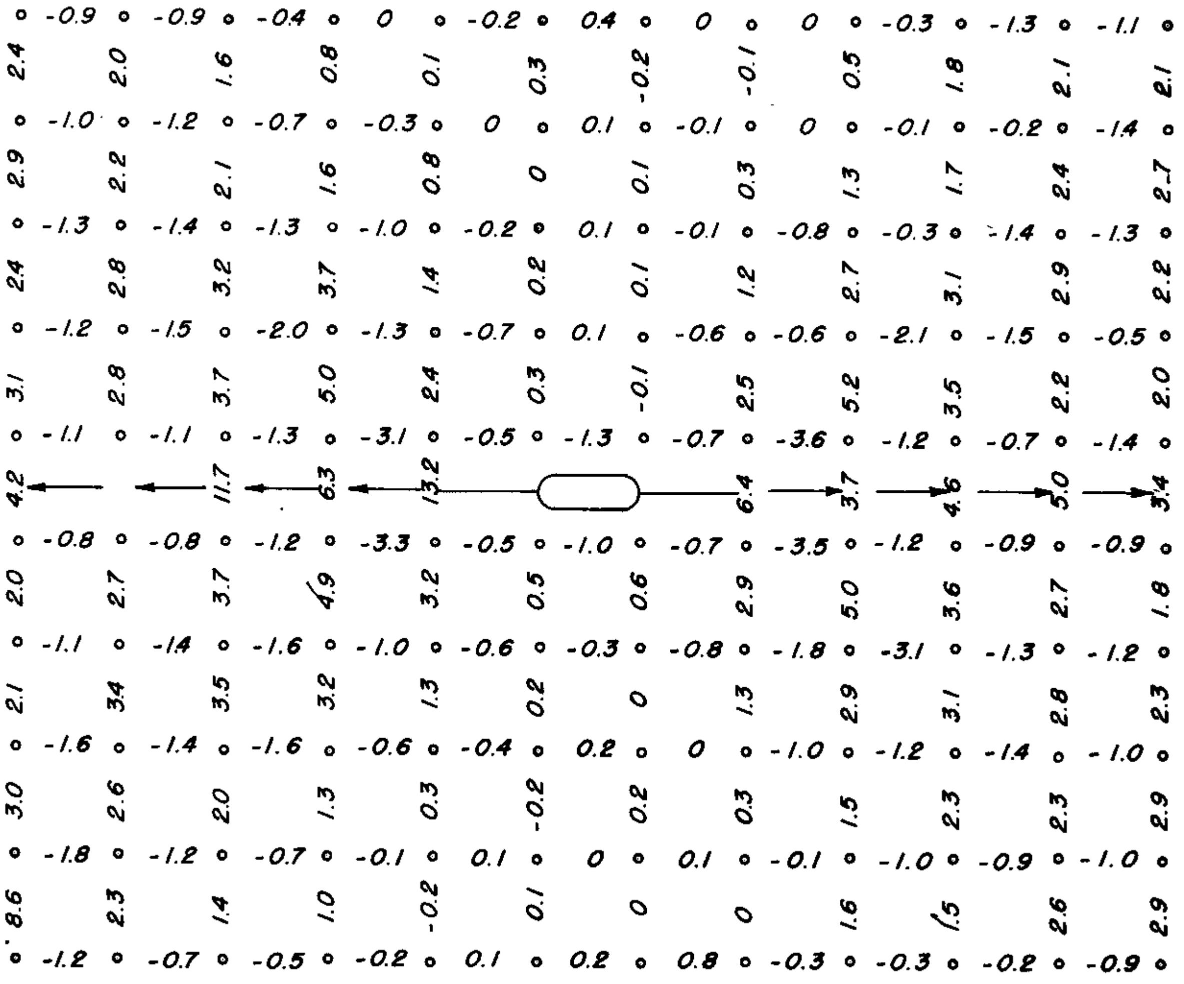


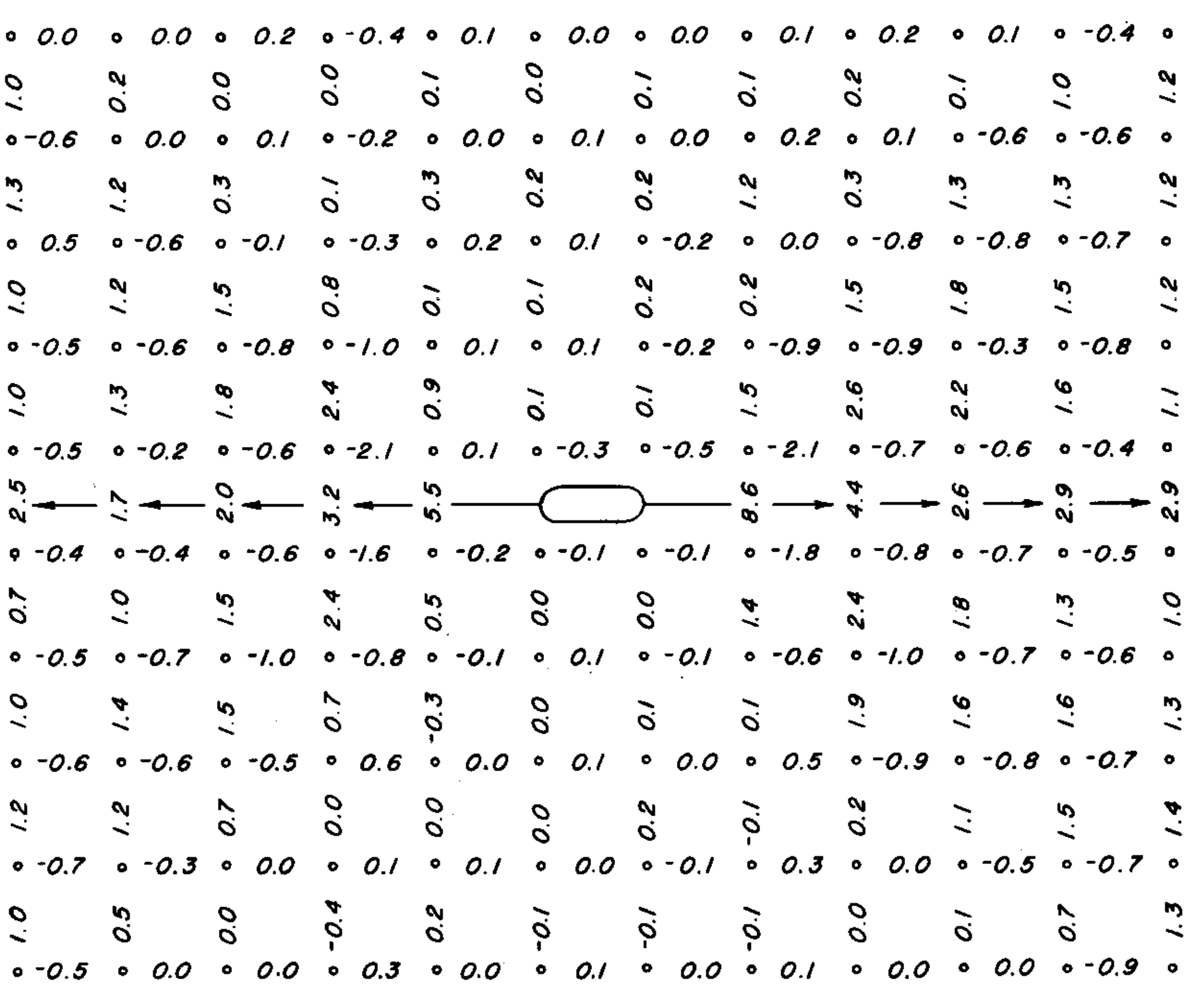
FIG. A-151 PERCENT ELONGATION PLATE H-10D (1-INCH GRID)

"H" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 53.8 KSI

TEMPERATURE (-42)-(-41)°F 0 % SHEAR

DWG. 44E247

FIG. A-151



	0.0		0.0		0.2		-0.4		0.1		0.0		0.0		0.1		0.2		0.1		-0.4	
1.0		0.2		0.0		0.0		0.1		0.0		0.1		0.1		0.2		0.1		1.0		1.2
	-0.6		0.0		0.1		-0.2		0.0		0.1		0.0		0.2		0.1		-0.6		-0.6	
1.3		1.2		0.3		0.1		0.3		0.2		0.2		1.2		0.3		1.3		1.3		1.2
	0.5		-0.6		-0.1		-0.3		0.2		0.1		-0.2		0.0		-0.8		-0.8		-0.7	
1.0		1.2		1.5		0.8		0.1		0.1		0.2		0.2		1.5		1.8		1.5		1.2
	-0.5		-0.6		-0.8		-1.0		0.1		0.1		-0.2		-0.9		-0.9		-0.3		-0.8	
1.0		1.3		1.8		2.4		0.9		0.1		0.1		1.5		2.6		2.2		1.6		1.1
	-0.5		-0.2		-0.6		-2.1		0.1		-0.3		-0.5		-2.1		-0.7		-0.6		-0.4	
2.5	←	1.7	←	2.0	←	3.2	←	5.5						8.6	→	4.4	→	2.6	→	2.9	→	2.9
	-0.4		-0.4		-0.6		-1.6		-0.2		-0.1		-0.1		-1.8		-0.8		-0.7		-0.5	
0.7		1.0		1.5		2.4		0.5		0.0		0.0		1.4		2.4		1.8		1.3		1.0
	-0.5		-0.7		-1.0		-0.8		-0.1		0.1		-0.1		-0.6		-1.0		-0.7		-0.6	
1.0		1.4		1.5		0.7		-0.3		0.0		0.1		0.1		1.9		1.6		1.6		1.3
	-0.6		-0.6		-0.5		0.6		0.0		0.1		0.0		0.5		-0.9		-0.8		-0.7	
1.2		1.2		0.7		0.0		0.0		0.0		0.2		-0.1		0.2		1.1		1.5		1.4
	-0.7		-0.3		0.0		0.1		0.1		0.0		-0.1		0.3		0.0		-0.5		-0.7	
1.0		0.5		0.0		-0.4		0.2		-0.1		-0.1		-0.1		0.0		0.1		0.7		1.3
	-0.5		0.0		0.0		0.3		0.0		0.1		0.0		0.1		0.0		0.0		-0.9	

FIG. A-152 PERCENT ELONGATION PLATE H-81XD (1-INCH GRID)

"H" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 47.4 K.S.I.

TEMPERATURE -64 °F 0% SHEAR

DWG. 44E251

FIG. A-152

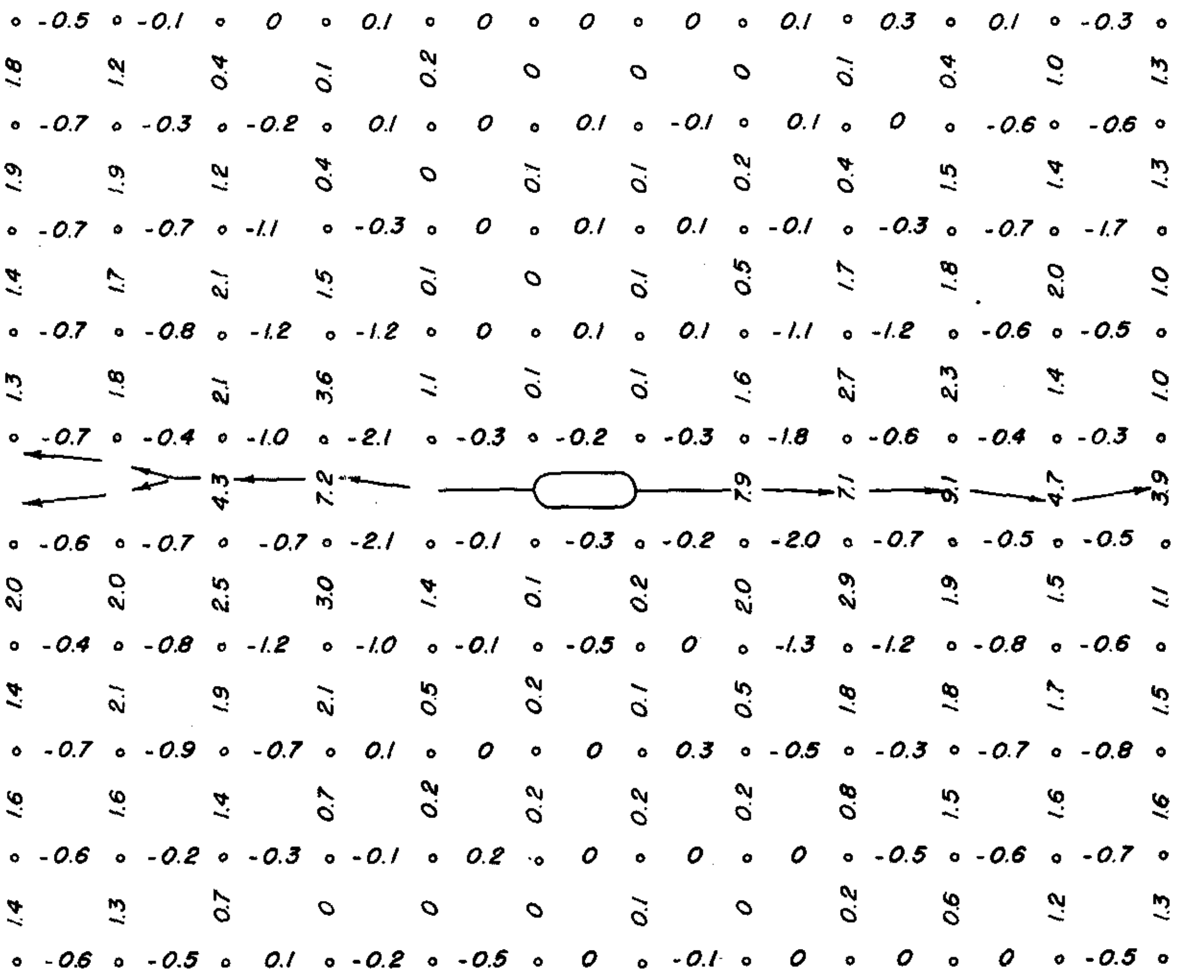


FIG. A-153 PERCENT ELONGATION PLATE H-82XD(1-INCH GRID)

"H" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 47.4 KSI

TEMPERATURE -40°F 0% SHEAR

DWG. 44E252 FIG. A-153

FIG. B-1 VIEW OF TUBE "O" AFTER FRACTURE, TESTED AT - 40° F.

Fig. B-2 VIEW OF TUBE "L" AFTER FRACTURE, TESTED AT -40° F.

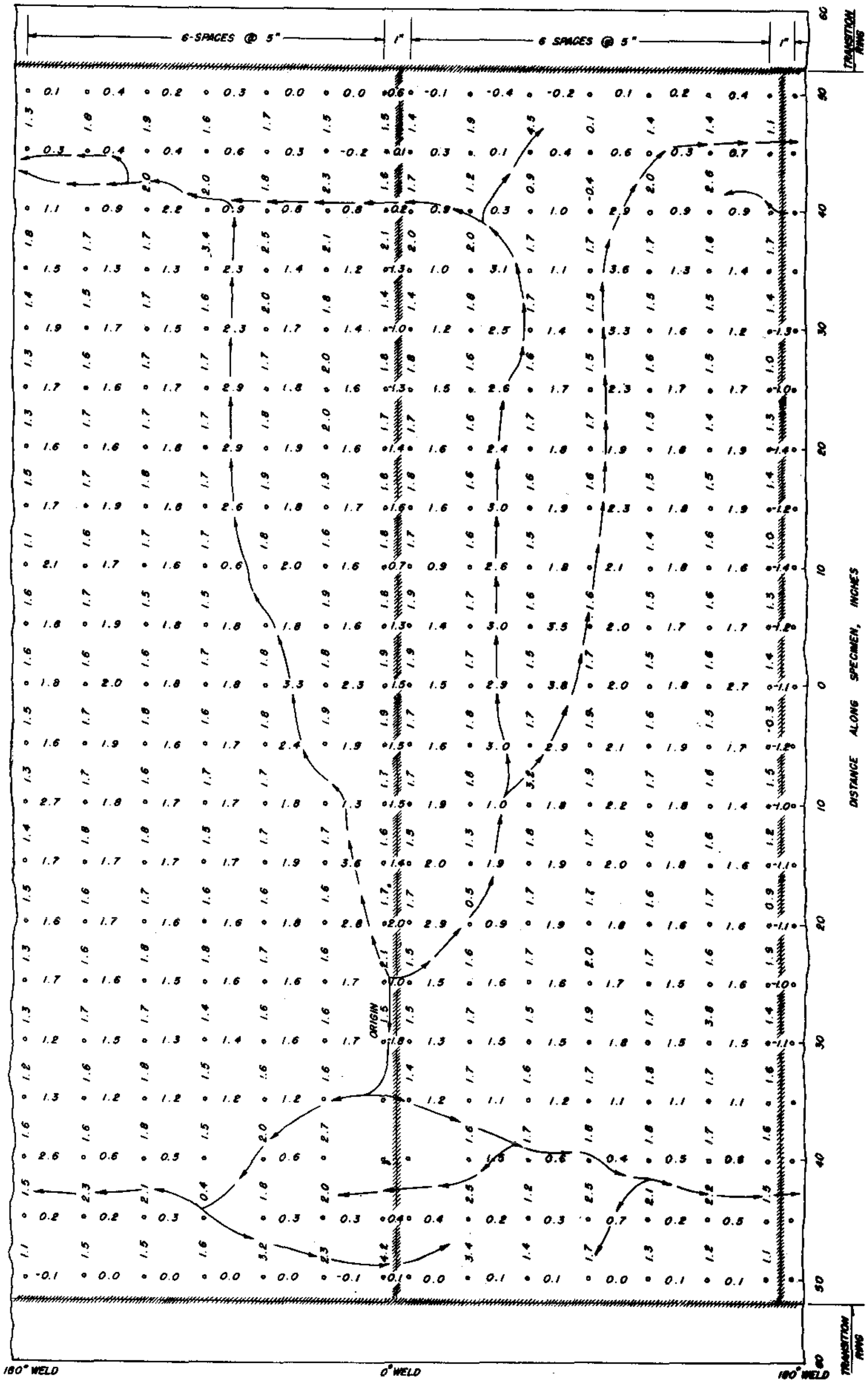


FIG.B-3 PERCENT ELONGATION IN TUBE SPECIMEN "O" AFTER RUPTURE.

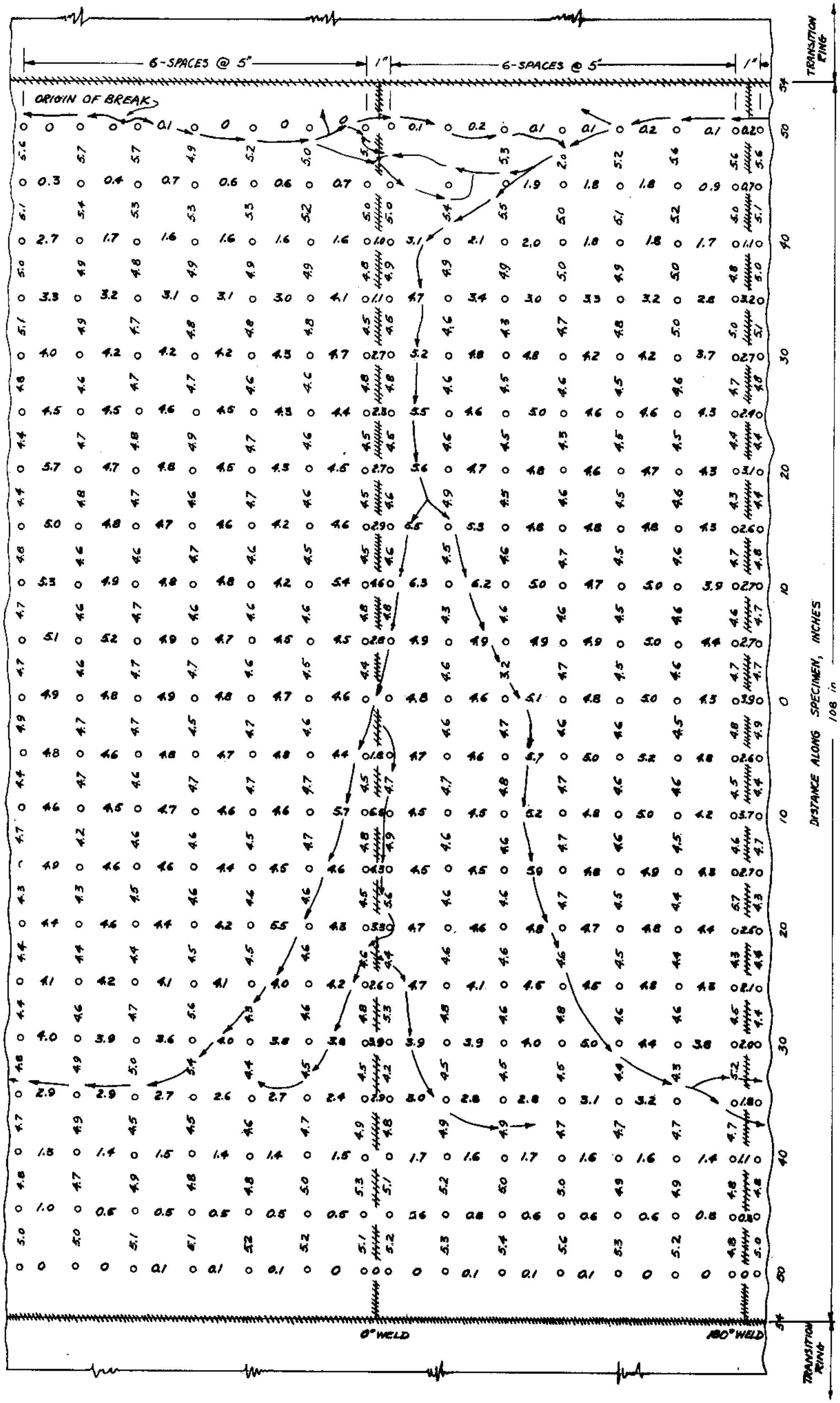


FIG.B-4·PERCENT ELONGATION IN TUBE SPECIMEN "L" AFTER RUPTURE.

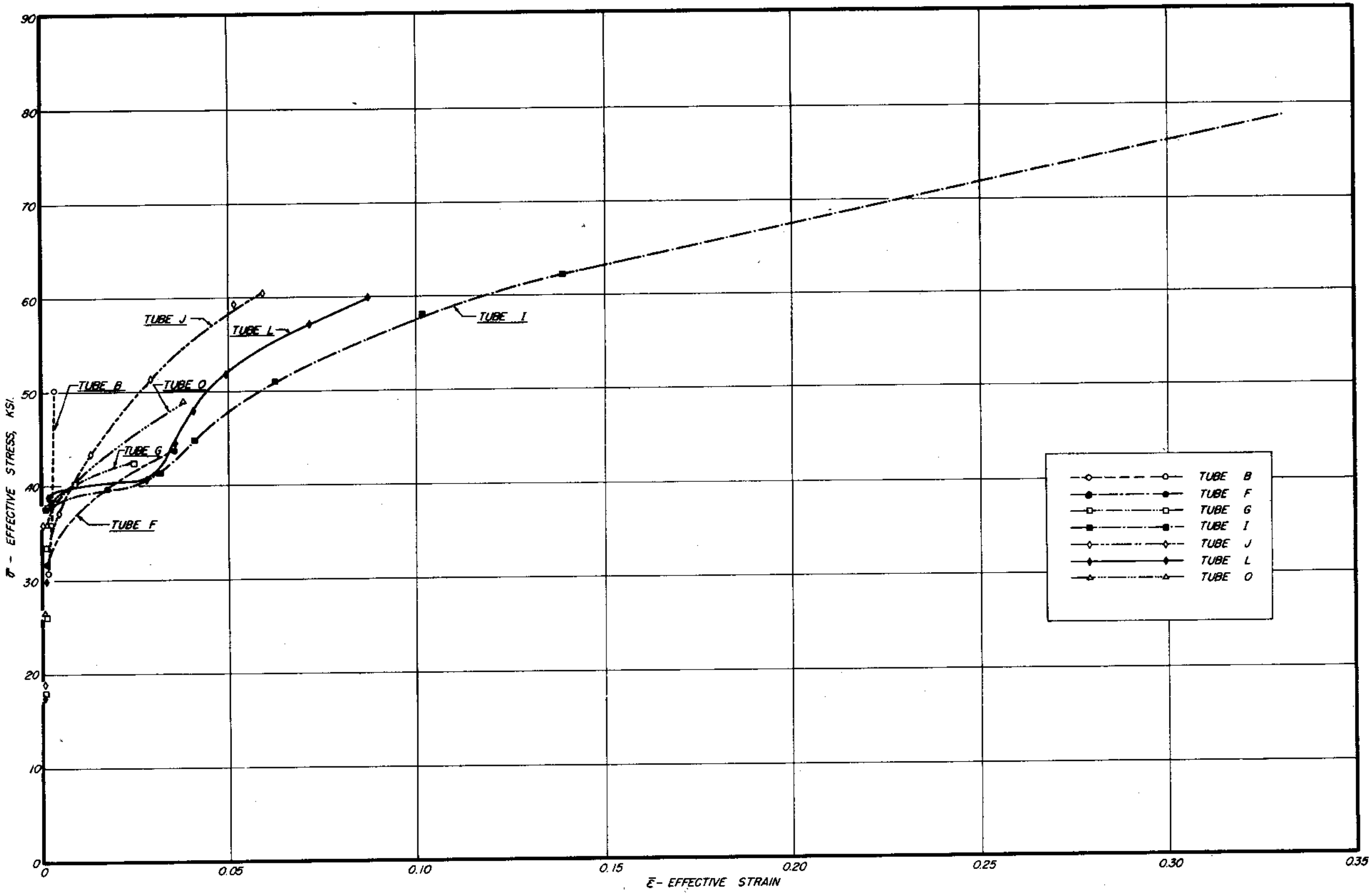


FIG. B-5 - EFFECTIVE STRESS VS EFFECTIVE STRAIN CURVES FOR TUBES B, F, G, I, J, L, AND O TESTED AT APPROXIMATELY -40°F.

FIG. B-5
DWG. 44E285

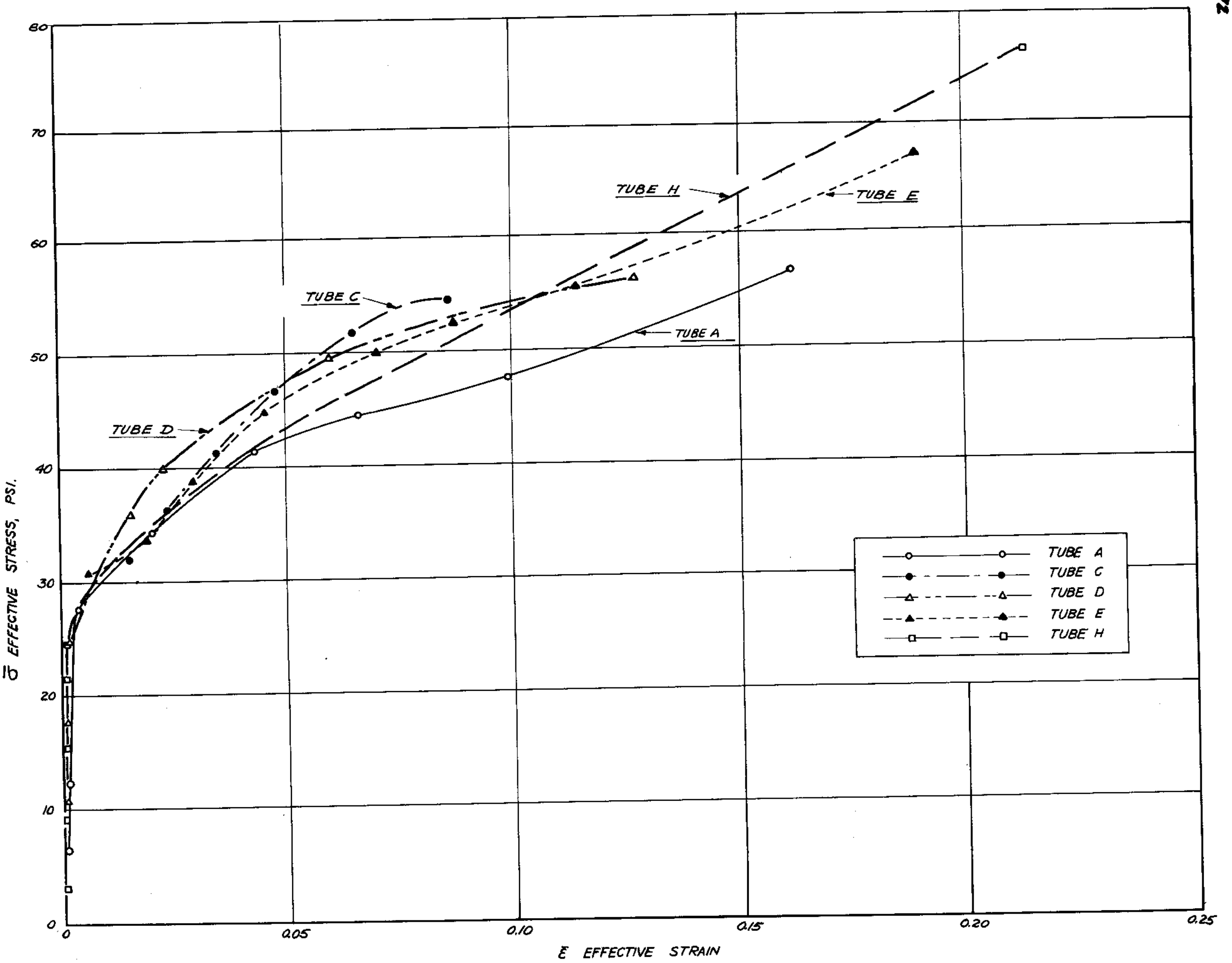
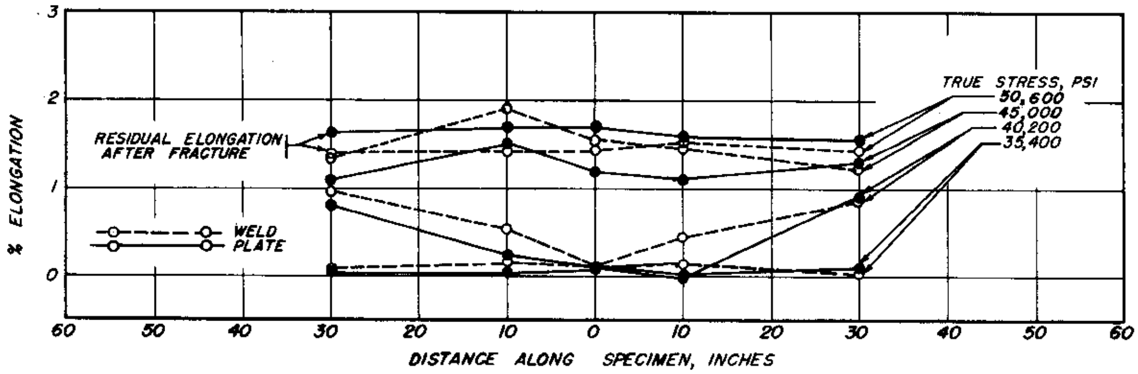
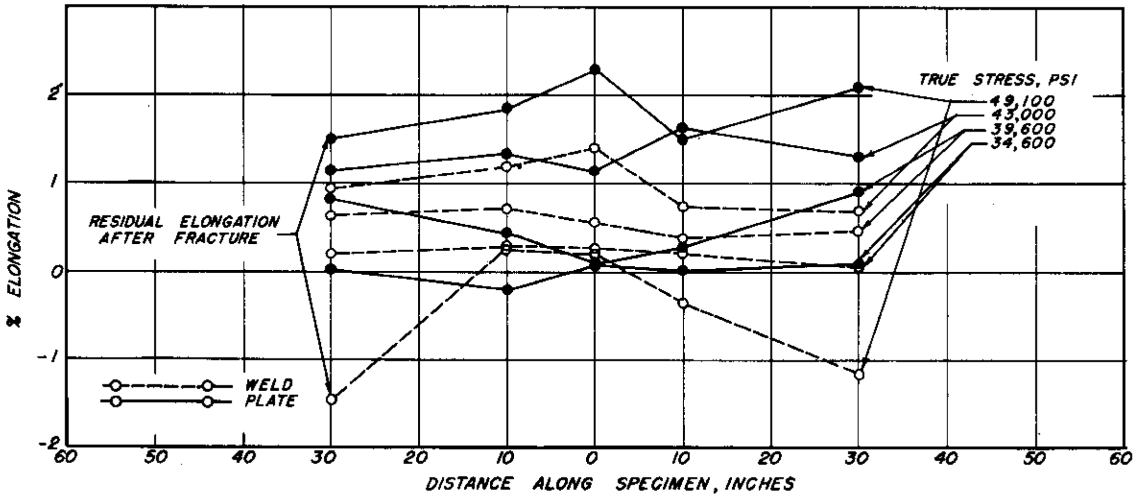


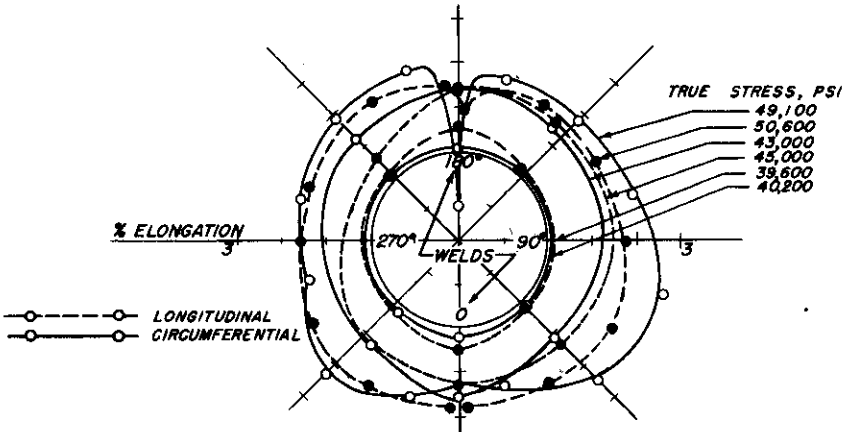
FIG. B-6 - EFFECTIVE STRESS VS. EFFECTIVE STRAIN CURVES FOR TUBES A, C, D, E, AND H TESTED AT APPROXIMATELY 70°F.



LONGITUDINAL ELONGATION IN PLATE AND WELD

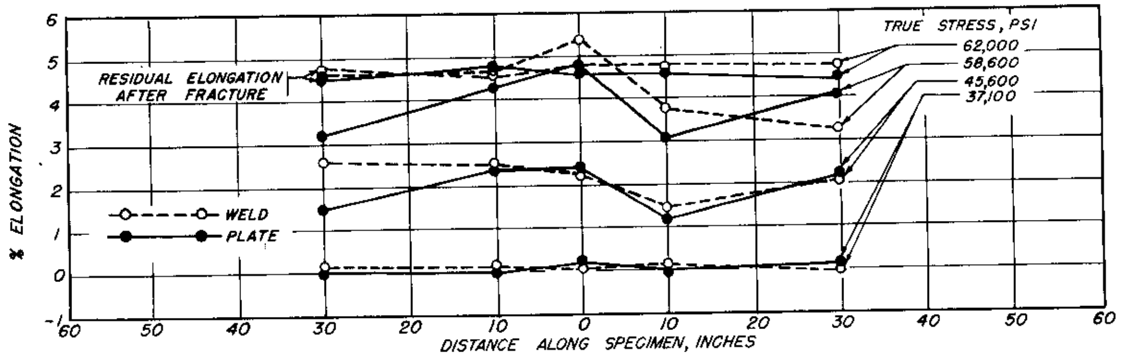


CIRCUMFERENTIAL ELONGATION IN PLATE AND WELD

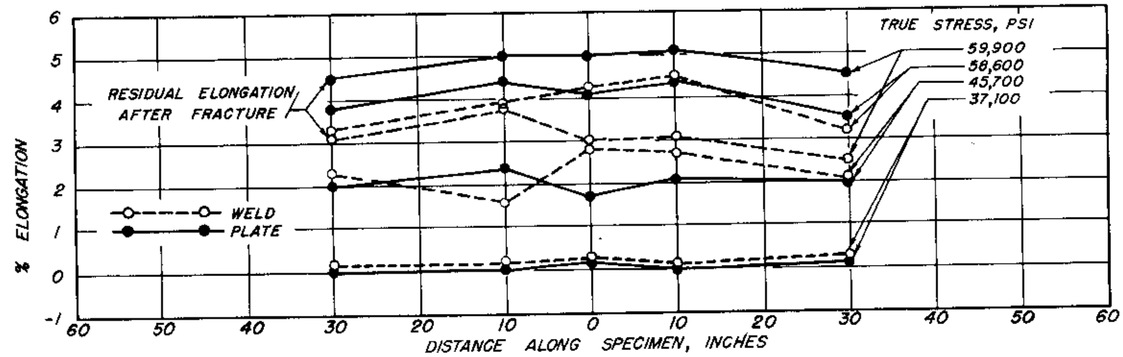


ELONGATION AT MID-SECTION

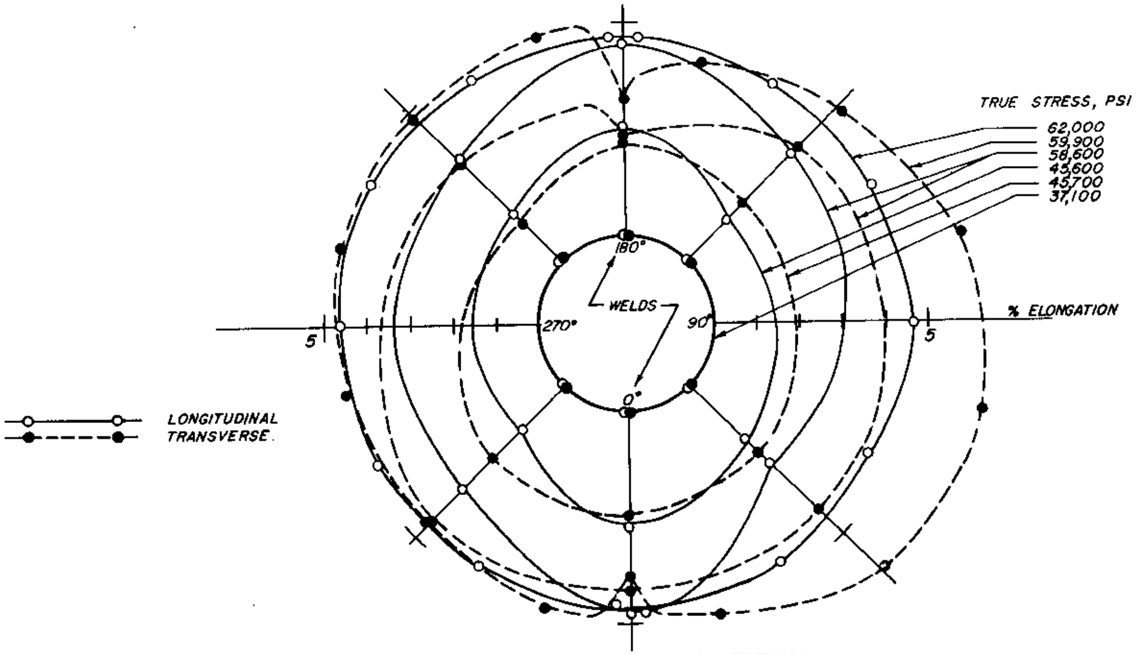
FIG. B-7 - AVERAGE ELONGATION OF SPECIMEN "O", AT VARIOUS LOADS.



LONGITUDINAL ELONGATION IN PLATE AND WELD



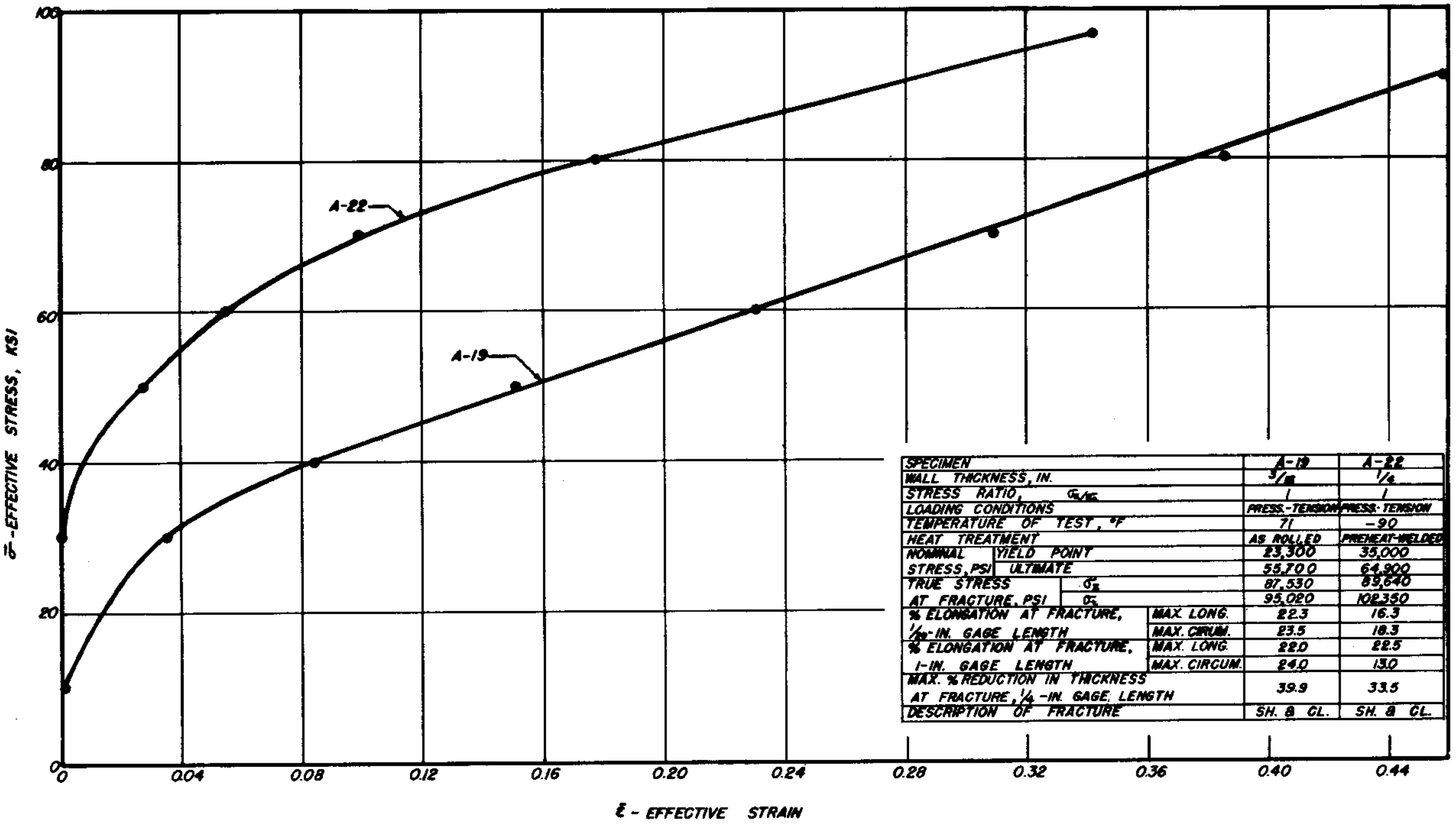
CIRCUMFERENTIAL ELONGATION IN PLATE AND WELD



ELONGATION AT MID-SECTION

FIG. B-8 - AVERAGE ELONGATION OF SPECIMEN "L", AT VARIOUS LOADS.

FIG. B-8



		A-19	A-22
SPECIMEN		A-19	A-22
WALL THICKNESS, IN.		3/[illegible]	1/4
STRESS RATIO, σ_2/σ_1		1	1
LOADING CONDITIONS		PRESS.-TENSION	PRESS.-TENSION
TEMPERATURE OF TEST, °F		71	-90
HEAT TREATMENT		AS ROLLED	PREHEAT-WELDED
NOMINAL STRESS, PSI	YIELD POINT	23,300	35,000
	ULTIMATE	55,700	64,900
TRUE STRESS AT FRACTURE, PSI	σ_2	87,530	89,640
	σ_1	95,020	102,350
% ELONGATION AT FRACTURE, 1/[illegible]-IN. GAGE LENGTH	MAX. LONG.	22.3	16.3
	MAX. CIRUM.	23.5	18.3
% ELONGATION AT FRACTURE, 1-IN. GAGE LENGTH	MAX. LONG.	22.0	22.5
	MAX. CIRCUM.	24.0	13.0
MAX. % REDUCTION IN THICKNESS AT FRACTURE, 1/4-IN. GAGE LENGTH		39.9	33.5
DESCRIPTION OF FRACTURE		SH. & CL.	SH. & CL.

FIG. B-9— EFFECTIVE STRESS VS EFFECTIVE STRAIN CURVES FOR SMALL TUBES TESTED ON NDRC PROJECT NRC-77

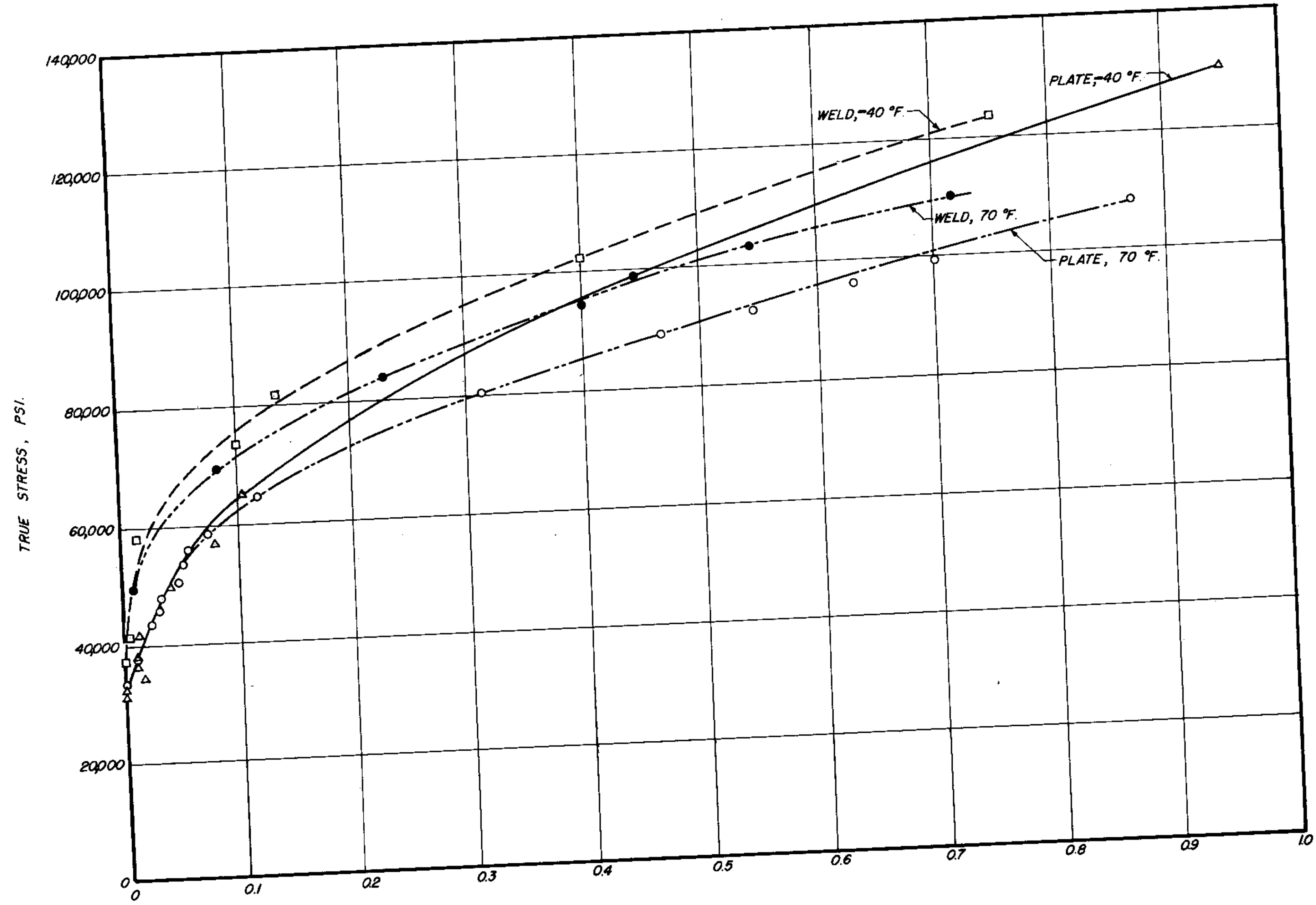


FIG. B-10-RELATIONSHIP BETWEEN TRUE STRESS AND NATURAL STRAIN IN COUPONS CUT FROM PLATE AND WELD OF TUBE J, AT 70 °F AND -40 °F.

View of Internal Surface of Tube at Break (15x)

View of Fractured Edge (15x)

FIG. B-11 - DEFECT IN PLATE AT ORIGIN OF BREAK IN TUBE "L"

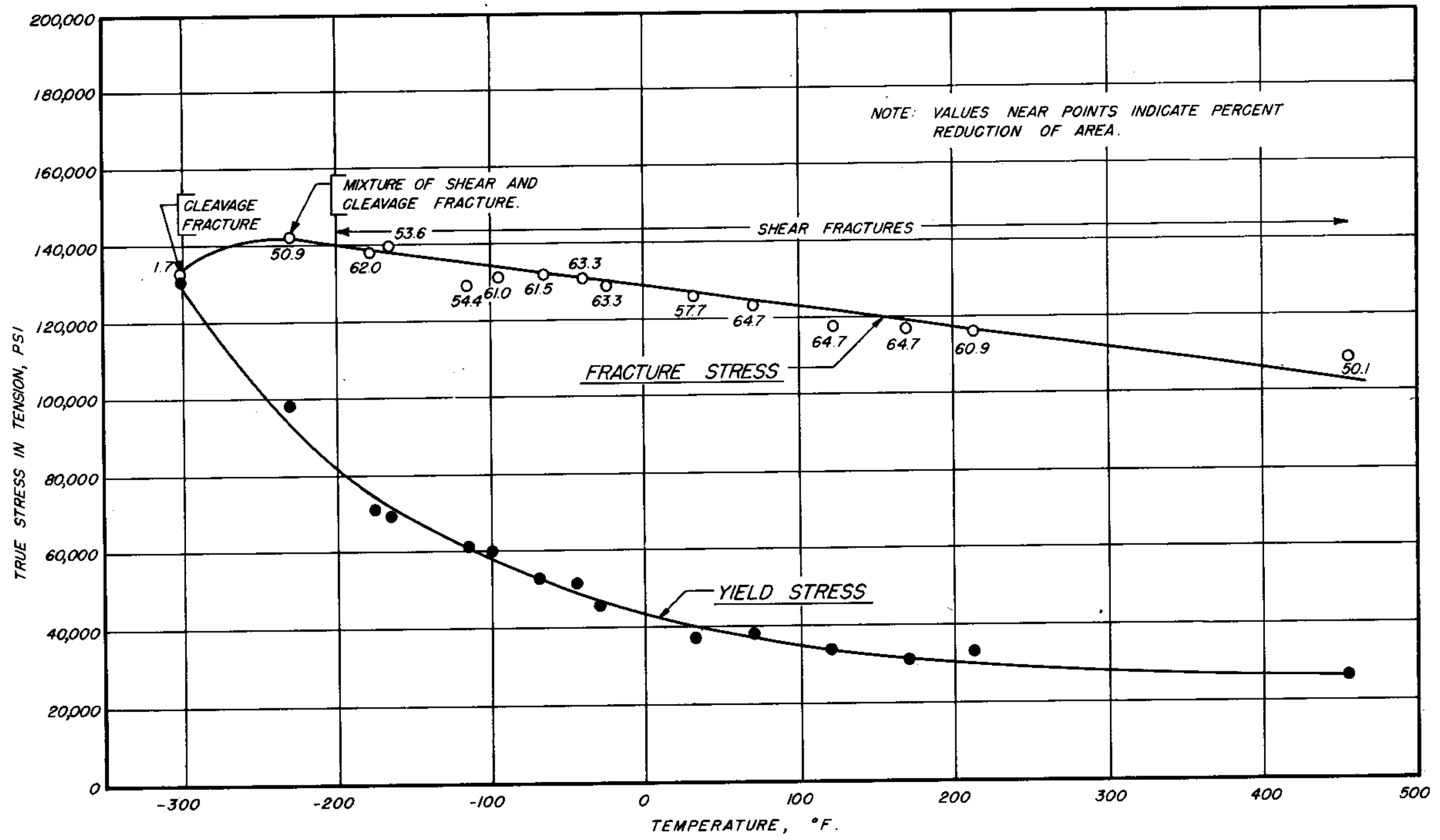


FIG. C-1- EFFECT OF TEMPERATURE ON TENSILE PROPERTIES OF STEEL "A" IN THE "AS ROLLED" CONDITION.

C = 0.25 % Mn = 0.47 %
3/8 - INCH DIAMETER TENSILE BARS.

FIG. C-1

DWG. 44E273

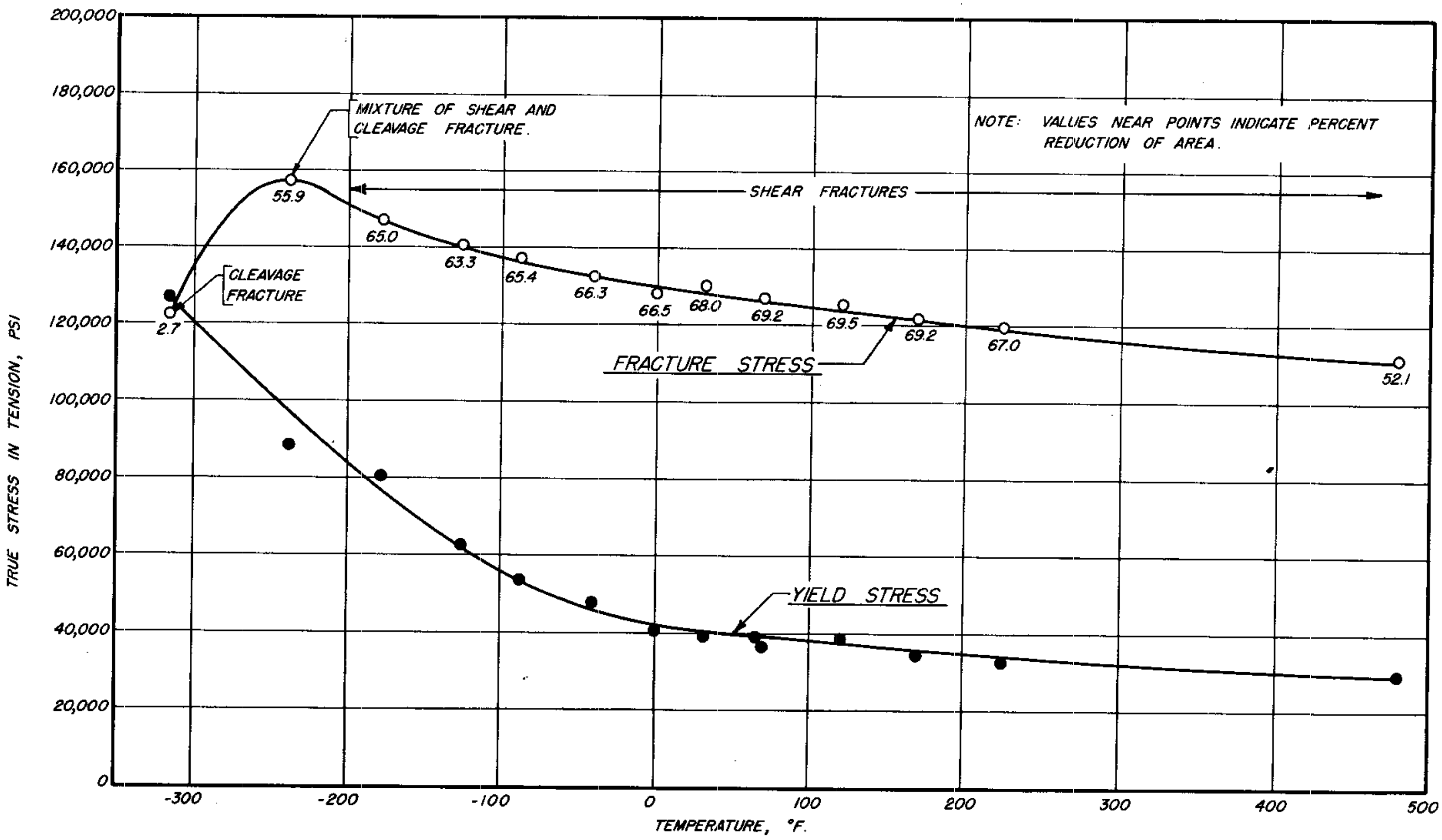


FIG.C-2-EFFECT OF TEMPERATURE ON TENSILE PROPERTIES OF STEEL "B" IN THE NORMALIZED CONDITION.

$C = 0.18\%$ $Mn = 0.72\%$

$3/8$-INCH DIAMETER TENSILE BARS.

FIG. C-2

DWG. 44E277

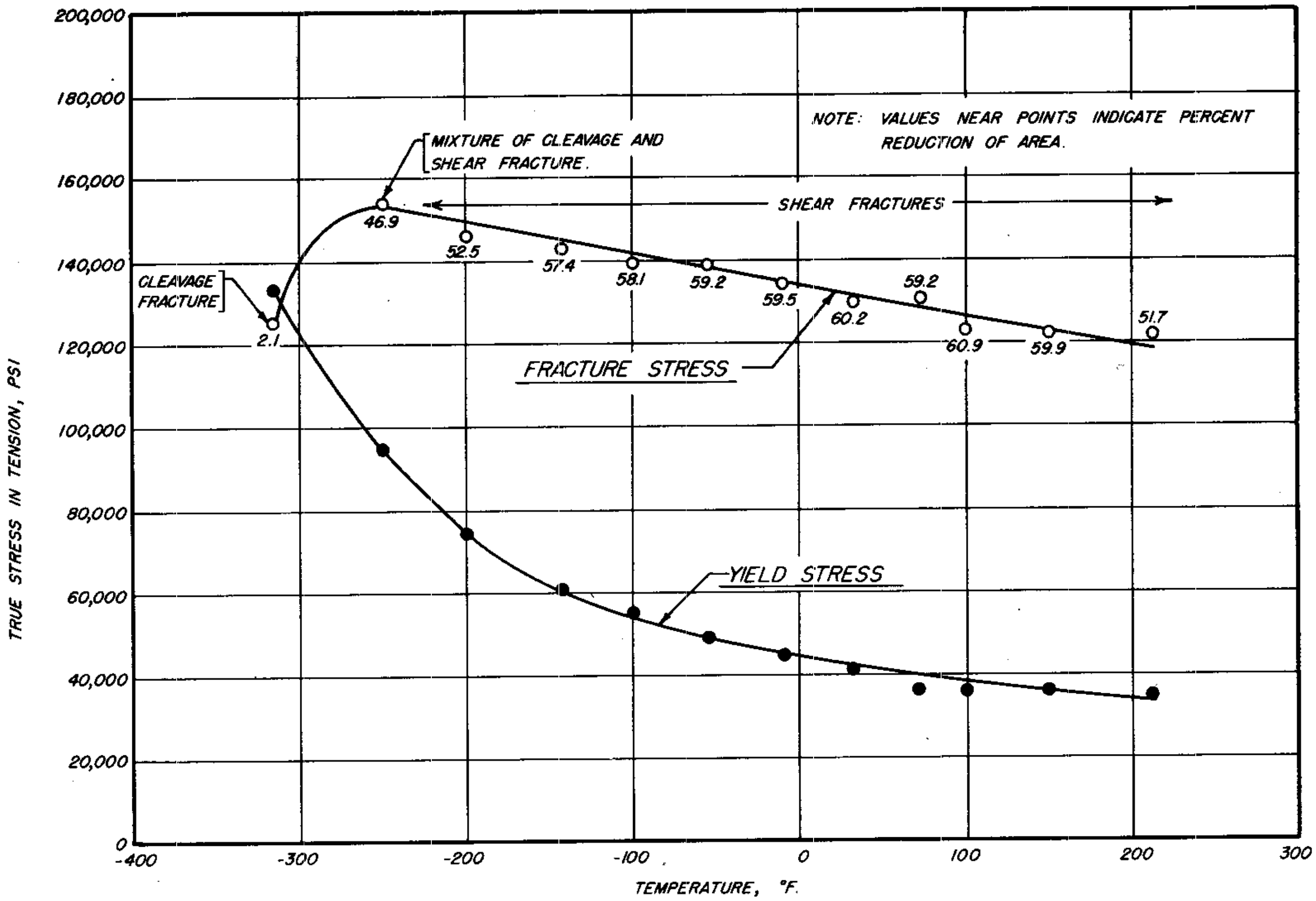


FIG. C-3-EFFECT OF TEMPERATURE ON TENSILE PROPERTIES OF STEEL "C" IN THE "AS ROLLED" CONDITION.

C = 0.25 % Mn = 0.49 %
3/8-INCH DIAMETER TENSILE BARS

FIG. C-3

DWG. 44E278

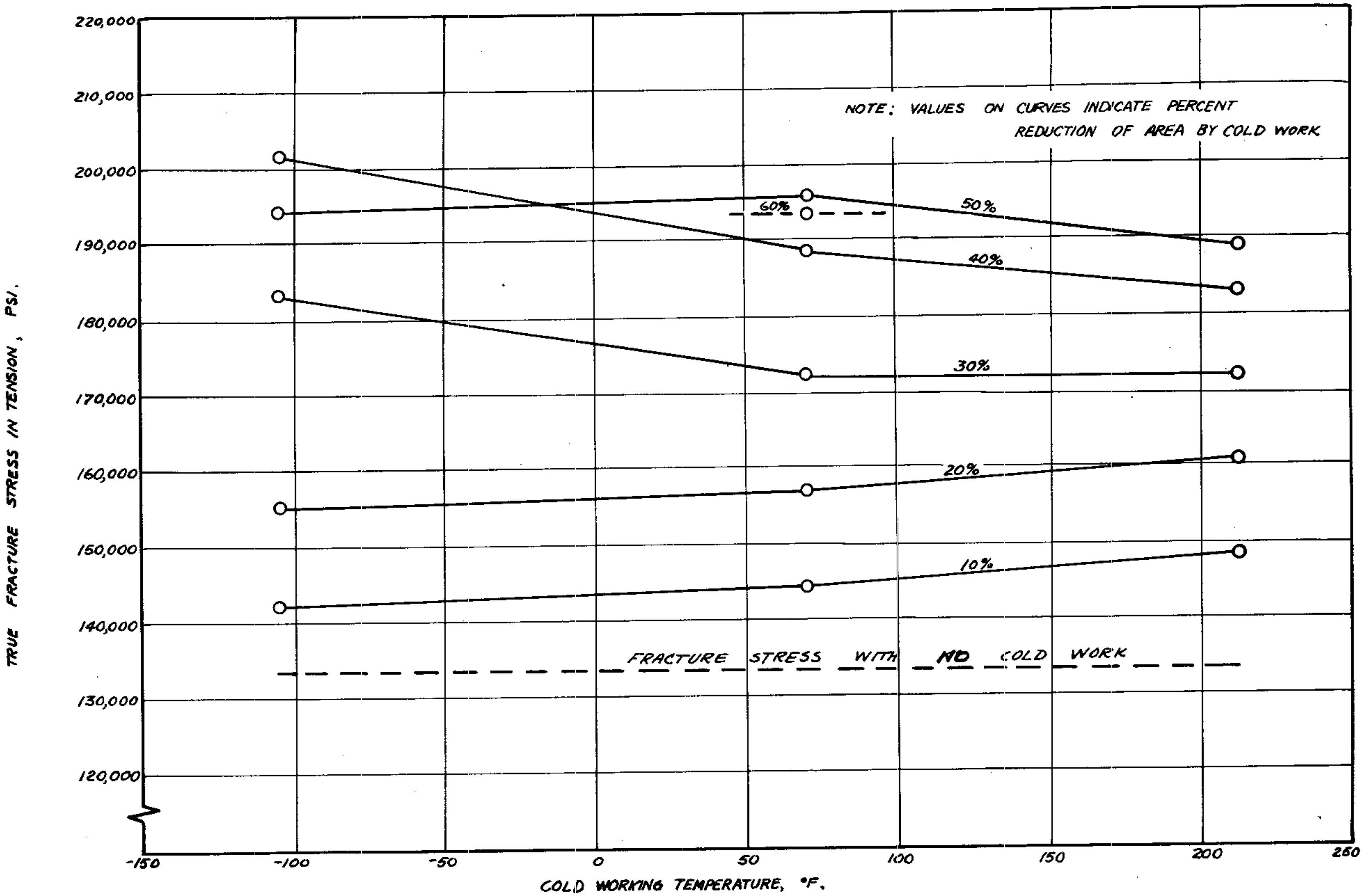
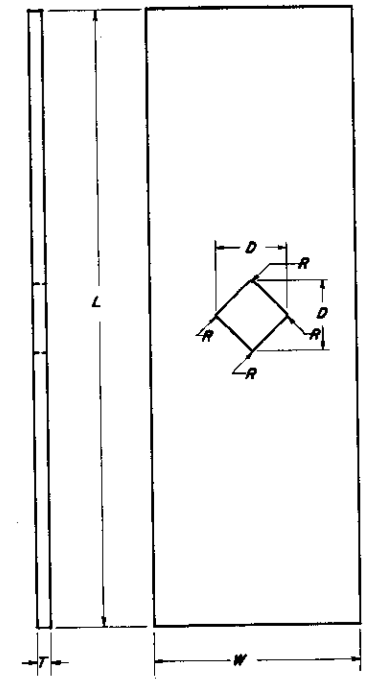


FIG. C-4 - EFFECT OF COLD WORKING AT VARIOUS TEMPERATURES ON CLEAVAGE FRACTURE STRENGTH AT -300 °F. (STEEL "A")



WIDTH, W	LENGTH, L	THICKNESS, T	DIAGONAL, D	RADIUS OF NOTCH, R
3"	9"	0.180"	1"	0.008"
6"	18"	0.360"	2"	0.016"
12"	36"	0.720"	4"	0.032"

FIG. D-1-DIMENSIONS OF GEOMETRICALLY SIMILAR SIZE EFFECT SPECIMENS.

DWG. 44E280

FIG. D-1

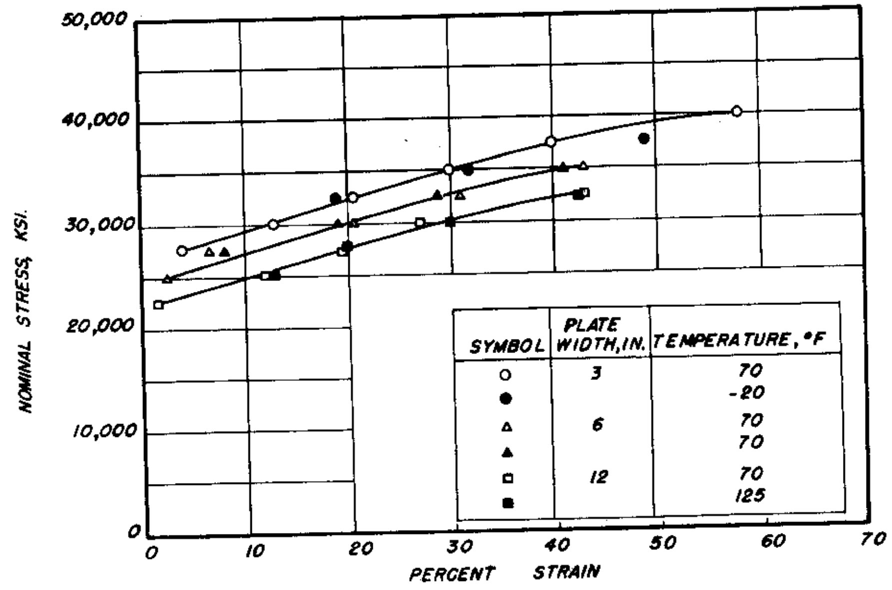


FIG. D-2- DISTORTION CURVE FOR GEOMETRICALLY SIMILAR SPECIMENS

LONGITUDINAL STRAIN VALUES TAKEN AT BASE OF NOTCH.

FIG. D-2

DWG. 44E284

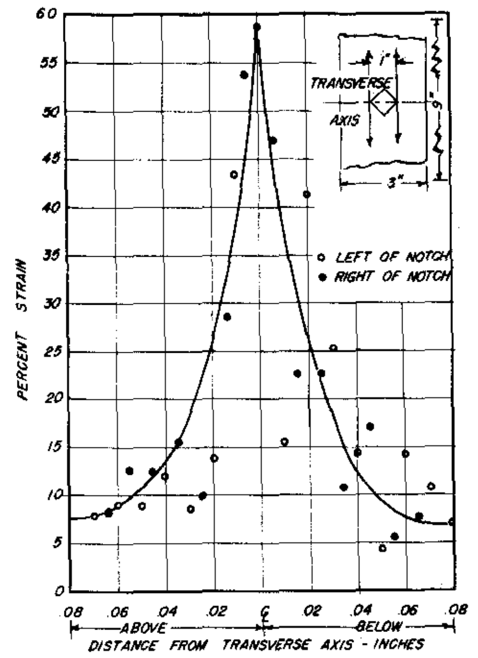


FIG. D-3 VARIATION OF LONGITUDINAL STRAIN WITH DISTANCE FROM TRANSVERSE AXIS FOR 3-INCH SIZE EFFECT SPECIMEN "2" MEASURED AT BASE OF NOTCH; TESTED AT ROOM TEMPERATURE AND 40,000 PSI.

DWG. 44E282 DATA OBTAINED ON ONE FACE OF SPECIMEN FIG. D-3

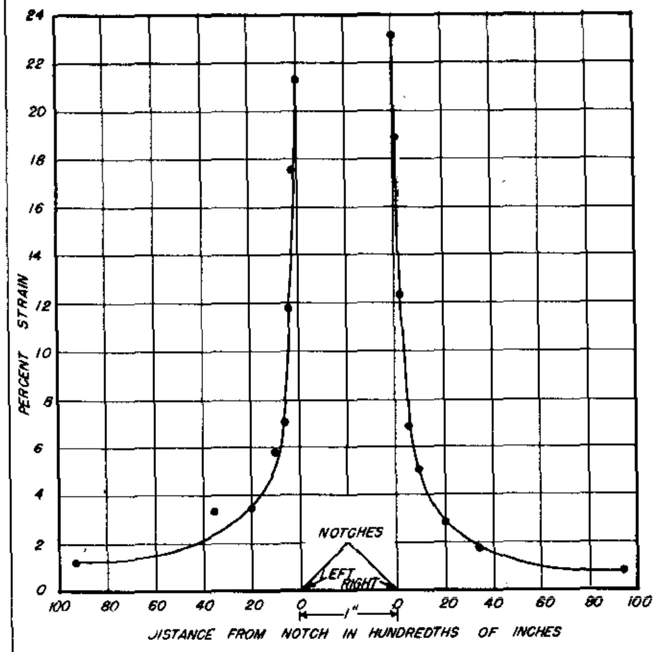


FIG. D-4 VARIATION OF LONGITUDINAL STRAIN WITH TRANSVERSE DISTANCE FROM NOTCH FOR A 3-INCH SIZE EFFECT SPECIMEN. TESTED AT ROOM TEMPERATURE AND 37,500 PSI.

STRAIN VALUES SHOWN ARE AVERAGE OF 4 TO 8 GAGE LENGTHS OF .01 EACH.

DWG. 44E283 DATA OBTAINED ON ONE FACE OF SPECIMEN FIG. D-4

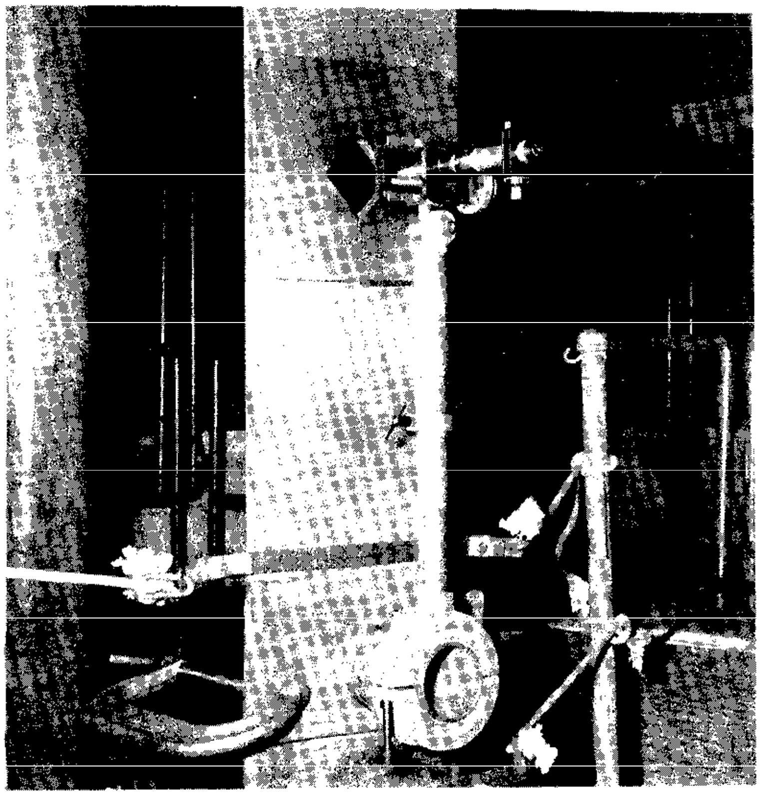


FIG. D-5 -- Apparatus for Measuring Photogrids on Size Effect Specimen