SS46/III

FLAT PLATES

PROGRESS REPORT

on

CAUSES OF CLEAVAGE FRACTURE IN SHIP PLATE: FLAT PLATE TESTS

by

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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-2

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August 23, 1946

August 23, 1946

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

Dear Sir:

Attached is Report Serial No. SSC-2, entitled "Causes of Cleavage Fracture in Ship Plate: Flat Plate Tests". This report has been submitted by the contractor as a progress report on 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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Technical Report
Navy BuShips Contract NObs 31222
Project NRC-92A

CAUSES OF CLEAVAGE FRACTURE IN SHIP PLATE

FLAT PLATE TESTS

April 1946

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

Report Prepared by:
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Abstract

This report summarizes the principal results of the tests on wide flat plates completed up to April 15, 1946, under the U.S. Navy Bureau of Ships contract NObs-31222. The program of investigation was begun under OSRD contract OEMsr 1418 and was originally designated as Project NRC 92. The work of this and related investigations has been coordinated with the advice of the War Metallurgy Committee.

The investigational work which is the subject of the report is concerned with the "Causes of Brittle (Cleavage) Fracture in Ship Plate," and specifically pertains to that part of the investigation which has to do with the failure of wide, flat plates at various temperatures.

The principal materials used in the tests were three lots of semi-killed, hull quality steels. Two of these steels were of medium carbon and manganese content, tested in "as-rolled" condition, while the third was of somewhat lower carbon and higher manganese content and was tested in the "as-rolled" condition and also after having received a normalizing treatment.

There were later included in the program of tests one lot of nickel-alloy steel with a nickel content of 3.34 percent, tested in the "as-rolled" condition, one lot of fully killed steel with a 0.16 percent carbon and 0.85 percent manganese content, also tested in "as-rolled" condition, and one lot of fully killed 0.21 percent carbon, 1.05 percent manganese steel that was tested after it had been quenched and drawn. The steels were furnished by the manufacturers in the form of 3/4 in. by 6 ft. by 10 ft. plates.

The specimens in the principal program of tests were tested in tension in widths of 72, 48, 24, and 12 in. The specimens all contained a narrow, central, transverse slot having a length of one-fourth of the plate width. Tests were made at each of a number of temperatures in order to determine the range of temperature within which the mode of failure changed from a ductile, shear type to a brittle, cleavage type.

In these tests, observations were made to determine the maximum load, failure load, strain distribution across the faces of the plates over several gage lengths, energy absorbed to maximum load, the mode of fracture, and the reduction of thickness near the break. Whenever observations could be made, the load at the development of cracks was also recorded.

The tension tests of the severely-notched flat plates indicated that the transition temperatures for the semi-killed steels may vary considerably, although they lay within the range of normal atmospheric temperature. Under the given conditions of test, for one lot of the medium carbon steels the transition range was found to be in the region of freezing temperature while for the other lot, which was almost identical in chemical composition, the transition range was above room temperature. The transition temperature of the low carbon semi-killed steels, both in the normalized and as-rolled conditions, was found to be in the region of freezing temperature. The tests of 12-in. wide plates of fully-killed, quenched and drawn steel indicated that the transition range of this steel also lies in the region of freezing temperature. The transition range for the nickel alloy steel was found to be in the sub-zero region.

It was found that, regardless of the mode of fracture, the nominal strength (average stress on net section of plate at maximum load) of the plate decreased as the width of the plate increased.

For the semi-killed steels the reduction in thickness at the root of the notch for plates that failed either by shear or cleavage was of the same order of magnitude. The reduction in thickness at the edges of the plate, however, differed markedly for the two modes of failure; for specimens failing by shear, the reduction increased to about four times the reduction at the notch while for the plates with cleavage failures the reduction in thickness decreased considerably toward the edges of the plate.

A number of supplemental studies were made to provide additional information on certain questions raised by the principal tests; of these, two are reported herein. One study was concerned with the maximum strains within the plate near the zone of fracture; a microhardness survey on samples sectioned from selected fractured plates was used as the basis for determining the strains. The second study was made by the use of 3-in. wide, edge-notched tensile bars, in order to develop a simple and rapid means for investigating the notch sensitivity of plate steel over a wide range of conditions.

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Technical Report
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Project NRC 92

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

Flat Plate Tests

April 1946

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

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Introduction

The work covered by this report is part of the research program to determine the factors which are responsible for the brittle type failure of ship plate, a program started by the Office of Scientific Research and Development, and now being continued under the auspices of the United States Navy and coordinated with advice of the War Metallurgy Committee. The work undertaken by the University of California is divided into two parts as follows:

Part A: Tests conducted principally on flat plates of different types of steel and of various sizes, containing notches.

Part B: Tests conducted on built up sections, simulating a hatch corner structure.

This report covers the experimental work performed under Part A--the tests conducted on notched flat plates.

The work on this project was started at the University of California in November 1944 upon authorization from the Office of Scientific Research and Development and the general features of the program of investigation have been developed as a result of conferences between the representatives of the War Metallurgy Committee and representatives of the University. At a meeting of the Advisory Committee, held in October 1944, it was pointed out that residual welding stresses in ship steel structures do not appear to be as important a factor in causing the failure of welded ships as had been originally suspected. Consequently it was felt that an investigation of the notch sensitivity of ship steels in the form of large plates offered a promising approach to the ship fracture problem. The investigation proposed was to determine the temperatures at which there occurs the transition from ductile, shear-type failures to brittle, cleavage-type failures, for various steels and for various sizes of steel plates. The investigation was to be confined primarily to 3/4-in. thick plate which would be tested in 72, 48, 24, and 12-in. widths. These specimens were to contain transverse notches at the mid-sections. The steels to be investigated were as follows: a rimmed steel, two semi-killed steels, and a fully-killed steel. The two semi-killed steels were to be of such composition and microstructure as to exhibit different transition temperatures. Subsequently a nickel alloy steel, a quenched and drawn fully-killed steel, and a fully-killed steel of special composition were included in the test program.

The Advisory Committee recommended that the part of the investigation concerned with flat plates be divided into two parts - one to be conducted at the University of California (Project NRC-92), and the other to be conducted at the University of Illinois (Project NRC-93). The University of California was to test the semi-killed steels, and the University of Illinois was to test the rimmed and the fully-killed steels.

To determine the effect of notch geometry, a series of tests were conducted at the David Taylor Model Basin. These tests served as a guide for the design of the large specimens. On the basis of these tests and also a series of preliminary tests at the University of Illinois, the shape of notch and the ratio of notch width to plate width was chosen for the principal tests on the large flat plates.

A previous report (Cleavage Fracture of Ship Plate as Influenced by Design and Metallurgical Factors NS-336, Part II -- Flat Plate Tests: OSRD No. 6452, Serial No. M-608, January 194) covered the progress of the work on the semi-killed steels up to August 31, 1945, under the OSRD contract OEM sr-1418. The results of the continuation of this work to date of April 1946, under United States Navy Contract NObs 31222, are described in this report.

Experimental Work

Test Program

Scope. -- The principal phase of the work on this project involved tension tests on notched flat plates of the several steels, in various widths, each at a number of temperatures, in order to determine the transition temperature ranges at which the mode of failure changed from the ductile shear type to the brittle cleavage type. In these tests the following was determined: the maximum load, load at failure, the mode of fracture, the amount of energy absorbed up to the maximum load, and the reduction of thickness near the break. For a number of the plate specimens the strain distribution across the faces of the plates over each of the several of the gage lengths was determined, and whenever possible the load at development of cracks was recorded.

In conjunction with the principal series of tests, various standard identification tests of the steels were performed, and also to provide a basis for the interpretation and amplification of the data a number of supplementary studies were made which included the microhardness survey of some of the fractured plates, microscopic examination of the metal for several of the specimens, and a complete series of tests on three-inch wide bars which were made from plates of various thicknesses, having edges finished in three various ways: plain flame cut edges, notched flame cut edges, and sheared edges.

Materials. -- Three lots of semi-killed steel, one lot of nickel alloy, one lot of fully killed, and one lot of quenched and drawn steel were used in the principal series of plate tests. These were designated as steels A, B, C, N, H, and Q in the order named. Description of the steels and the general program of tests are given in Table 1.

All plates from each of the six lots of steel obtained for this investigation were made from the same heat. The general nature of the steels as indicated by the abstracts of the mill reports is given in Table 2.

These steels were furnished to the laboratory by the manufacturers in the form of 3/4 in. by 6 ft. by 10 ft. plates; the 10-ft. dimension was in the direction of rolling.

Flat Plate Specimens. -- Plate specimens were tested in widths of 72 in., 48 in., 24 in., and 12 in. All specimens were full thickness as rolled, i.e. 3/4 in.

The plates were notched at the mid-section with a slot having a length equal to one-quarter of the plate width. The form of this notch is shown in Fig. 1. The wider part of the notch was made by flame cutting between two 1/2-in. drilled holes. By use of an ordinary hack saw straight cuts were made outward from the edges of the drilled holes, toward the edges of the plate, for a distance of 1 in. at each side. Each hacksaw cut was then extended for an additional 1/8 in. by means of a jeweler's saw having a blade 0.010 in. thick. For the 72-in. plates the overall length of slot thus made was 18 in.

Identification Tests. -- To accompany the principal tests a program of "identification" tests was undertaken with the following objectives:

1. To obtain a representative description of the materials used, in terms of "standard" tests, all made on comparable basis.

2. To insure that an adequate indication of properties would be provided, so that test results from special experiments might be tied back to accepted indicator tests.

3. To provide a means for detecting variation in the material supplied in any one lot.

The results of the chemical analysis and the standard tension and hardness tests are given in Tables 3 and 4. The results of the Charpy Impact tests are given in Figures 6 to 11.

Methods of Testing.

Loading. -- The flat plate specimens were loaded in a three-million-lb. Baldwin-Southwark testing machine. A typical arrangement for testing is shown in Figure 3. The load increments during the test were usually small so that at least 10 complete sets of strain readings were taken during the loading period. This procedure coupled with the use of six continuous-recording SR-4 strain recorders yielded sufficient data to allow the plotting of a load-elongation curve, shown in Figure 2. By the use of this curve, the energy absorbed by the specimen up to the maximum load (or in some cases to failure) could be calculated.

Gaging Methods, 72-in. Wide Plates. -- Both elastic and plastic strains were measured so as to obtain a load-strain history of the specimens. A strain-gage layout typical of that used for most of the plates tested is shown in Fig. 4. SR-4 electric strain gages were used and readings were taken at a number of loads within the elastic range of the material of the test specimen so that the elastic strain distribution could be calculated. Since the results of many of the earlier tests showed similar stress distributions for the plates of the various steels, in order to conserve time, the SR-4 gages were omitted from several of the plates tested during the latter part of the program.

Plastic strains were measured over 2-in. gage lengths by means of the clip gages developed on Project NRC-75. These strain measurements, however, were omitted for those plates on which no SR-4 gages were used. Plastic strains were also measured over 24-in. and 54-in. gage lengths by means of resistance-wire extensometers. These gages consisted of 0.008-in. diameter manganin wire stretched between insulated terminals located at the ends of the gage lengths. As the specimen stretched, the wires elongated and decreased in diameter, thus causing a change in resistance, which was registered on SR-4 strain indicators. Calibrations were made on a special jig so that the indicator reading could be directly converted to strain.

On one face of each specimen was punched a 1-in. grid in the path of the fracture, as shown in Fig. 5. A similar grid with 5-in. spacing between points was placed on the specimen and extended to the limits of the 54-in. gage length. Measurements with a special mechanical gage were made on the grid before the test and after fracture so that residual strain measurements could be obtained. Readings were reproducible to within ±0.002 in. The results of these grid measurements for the various plates tested are presented in Appendix A.

Gaging Methods, 48 In., 24 In., and 12 In. Wide Plates. -- For the 48, 24 and 12 in. wide plates, strains were measured during the loading by means of resistance wire extensometers having a gage length equal to three-fourths of the plate widths. A few of the plates were equipped with SR-4 gages, laid in a pattern similar to that of the 72 in. plates, in order to check the stress distribution in the elastic range.

Residual strains were determined from a grid system similar to that used on the 72-in. wide plates.

Temperature Control. -- Except for tests made at room temperature, the specimens were enclosed during test in a chamber made of plywood, which extended over the full length of the test plate. The temperature of the air within this chamber was adjusted by circulating through it air which was heated or cooled in a heat exchanger set up near the specimen. Dry ice was used for cooling. A view of a test set-up in which a temperature-control chamber was employed is shown in Fig. 3.

The temperature distribution in a specimen was measured by means of several thermocouples soldered to the surface of the plate. The temperature was regulated manually through operation of a blower in the duct connecting the heat-exchanger with the temperature-control chamber. A typical thermocouple installation for a 72-in. wide specimen is indicated in Fig. 4.

Test Results

General Remarks

Pursuant to the primary purpose of the project, namely, to study the causes of brittle failure of ship-plate, all the steels selected for investigation were tested in tension in the form of notched plates over ranges of temperature so as to define within reasonable limits the transition from the shear to the cleavage mode of fracture. The severity of notch employed in the test plates was such as to cause the transition to occur within the normal range of atmospheric temperatures for the semi-killed steels of normal composition - - the steels that were the principal materials of this phase of the investigation. The subsequent inclusion of additional special steels in the program of tests yielded data the general pattern of which differed somewhat from that obtained from the semi-killed steels.

In the semi-killed class the steels A and C were essentially identical chemically, containing about 0.25 percent carbon and 0.47 percent manganese. The difference in these two heats of steel lies primarily in the metallurgical structure. Steel C had a slightly coarser grain structure than steel A, indicating that steel C had a higher finishing temperature. Steel C was harder, stronger, and less ductile than its chemically similar counterpart, steel A. Since steels A and C were made in different plants, different rolling practices were probably used, contributing to differences in the metallurgical structures of the two steels. It is perhaps fortunate that these differences did exist because it emphasizes the importance of metallurgical structure and minor variations in chemical composition in determining the properties of the steel. Steels A and C were tested only in the as-rolled condition.

Some of the plates of steel B were purposely heat-treated to give two conditions of metallurgical structure for comparison; part of the heat was furnished as-rolled and the other part was normalized. The normalizing treatment resulted in different microstructure. The grain size of the normalized steel was slightly larger than that of the as-rolled steel, but there was otherwise little difference in the microstructure. The properties determined by flat plate tests of the as-rolled and normalized steel B did not differ as much as did those of steels A and C. The normalized steel was slightly lower in strength than the as-rolled steel. Normalizing may sometimes benefit a coarse-grained as-rolled steel by refining the grain structure. If, however, the as-rolled steel has a fine grain size, the normalizing treatment may cause an increase in grain size and thus may be detrimental. In the case of the steel B the as-rolled structure was very fine and was apparently slightly more suitable than the structure obtained by normalizing. Steel A probably would not be improved by normalizing and might even be made slightly worse, whereas the steel C probably would be improved by such a treatment.

One of the secondary purposes of the plate tests was to determine the effect of plate width on relative load-carrying capacity and on notch sensitivity. It should be noted, however, that the test specimens in the various widths do not form a true "size-effect" series because all the plates were of the same thickness and were therefore not geometrically similar.

Another factor which should be considered in the examination of the results is that cracks usually formed at the root of the notch before the maximum load was reached. When the plates failed by shear, the cracks propagated for some distance before the maximum load was reached; in the case of the 72-in. wide plates, the maximum load was reached when the cracks had progressed about 2 to 4 inches from the ends of the notch.

The notch geometry changed when the first crack formed at the base of the saw cut and changed continually as the fracture progressed. In some cases the change in the notch geometry was sufficient to cause the type of fracture to change from shear to cleavage during the progress of the failure. It is also to be noted that not only the notch geometry but the average stress, the local stress and in some cases the temperature at the apex of the crack were continually changing during the test causing changes in the type of fracture.

Nature of Reported Results

Form of Data Presented. -- The test results reported hereinafter show primarily the strength and ductility of the plate specimens at various temperatures and the amounts of energy absorbed by these specimens up to maximum load. The principal results are presented in the form of tables, diagrams, and photographs, as follows:

General Summary of Flat Plate Test Results	Table 5, Figs. 12 through 21
Diagrams of Energy vs. Temperature	Figs. 12 through 14
Diagrams of Temperature Transition Range	Figs. 15 and 16
Maximum Nominal Stress vs. Width and Temperature	Figs. 17 through 21
Typical Strain Distribution Patterns at Various Loads	Figs. 22 through 29
Elongations Measured by Gages at Maximum Load	Fig. 30
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Elongations over 2-in., 24-in. and 54-in. Gage Lengths at Various Loads	Figs. 36 and 37
Photo Diagrams of Micro-Hardness Surveys	Figs. 38 through 54
Results of Supplementary 3 in. Bar Tests	Figs. 55 through 68
Percent Elongations After Fracture	Appendix A

In the data summaries the symbols used to designate the individual test specimens have the following meaning:

First symbol designates lot or source of steel.

A -- Carnegie-Illinois steel obtained in 1944 for manufacture of large tubes on Project NRC-75.

B -- Bethlehem steel manufactured in December 1944 for use on Project NRC-92.

C -- Carnegie-Illinois steel manufactured in February 1945 for use on Project NRC-92.

D -- Lukens fully-killed steel used in University of Illinois investigation.

E -- Lukens rimmed steel used in University of Illinois investigation.

H -- Bethlehem fully-killed steel manufactured in December 1945 for use in this investigation.

N -- Lukens nickel alloy steel.

Q -- Republic quenched and drawn steel manufactured in October 1945 for use in this investigation.

Second symbol following the hyphen is the serial number (up to 10) that was assigned at the laboratory to the 6-ft. by 10-ft. plate of each lot of steel. For numbers above ten, the first digit, as in the preceding case, designates the number of the plate, and the second digit, together with the letter X, designates the number of the extra specimen cut from the plate. Normally only one specimen of each width tested was cut from any one 6-ft. by 10-ft. plate.

Third symbol designates the width of specimen cut from given plate.

A -- 72 in. wide
B -- 48 in. wide
C -- 24 in. wide
D -- 12 in. wide

Examples: 1.) Specimen B-1A is a 72-in. wide test plate of steel B, from a plate that has been assigned serial number 1.

2.) Specimen A-41XD is a 12-in. wide test specimen of steel A, from the plate which had been assigned serial No. 4 and is the first extra 12-in. plate tested.

Basis for Calculations of Strength, Ductility and Energy. -- In order to have a convenient basis for stating the load-carrying ability of the notched plates in various widths, reference is frequently made to the "nominal" stress or "nominal" strength of the plate. By this is meant the average stress on the net section through the notch, i.e. the load divided by the original net cross-sectional area. Due to the stress-concentrating effect of a notch, the actual localized stresses were higher at the base of the notch than at other points along a cross-section through the notch; an indication of this variation may be seen from the strain distributions plotted in Figs. 36 and 37.

In general, by "ductility" is meant the elongation of the plate up to maximum load or to rupture, within a specified gage length. Unless otherwise indicated, the elongation measurements were made at intervals across both faces of a plate specimen over a gage length equal to three-quarters of the gross-width of plate. By plate elongation is meant the average elongation thus determined.

The energy absorbed up to maximum load was computed by integrating graphically the load vs. elongation curves for each of the specimens.

Discussion of Results of Tension Tests of Wide Plates

The principal fracture data, -- strength, energy absorbed to maximum load, mode of fracture, and temperature of test--are summarized in Table 5. Because the program of testing is still in progress, the data are fragmentary for some of the conditions of test.

Not shown in the table are the results of a test on a piece of fully-killed steel (Steel D) on which complete tests are being made in a parallel phase of the investigation at the University of Illinois. This test was made on a 72-in. plate at 33° to 35°F. The plate fractured entirely in cleavage at a nominal stress of 39.0 ksi. and to the maximum load absorbed, 360 k-in. of energy in a 54-in. gage length.

Two criteria for defining the range of transition temperature have been used in this investigation, --energy absorbed to failure (maximum load), and the percentage of fracture in the shear mode, 100 percent shear being at the upper end of the range and 0 percent shear at the lower. The use of the two criteria place the transition temperature in slightly different ranges in some cases. However, it is believed that in the present state of knowledge of the problem, it is desirable to record the results of each method of defining the transition range. From the structural point of view, the energy criterion may be the more significant, but insofar as evidence of physical action (even though localized) is concerned, the type-of-fracture criterion is basic.

Steels A, B (as-rolled), and B (normalized) appear to have about the same notch sensitivity, with steel C, the chemical counterpart of steel A, being the more notch sensitive steel of the semi-killed group. Steel N is, as expected, the least notch sensitive of all, with steel Q having approximately the same transition range as steels A and B. No tests have yet been made on steel H.

Energy vs. Temperature. -- Diagrams showing the estimated variation of the energy absorbed to maximum load with the test temperature are shown in Figs. 12, 13 and 14. Curves for the 48-in. and 24-in. wide plates have not been plotted as insufficient number of plates were tested in these widths. For the 12-in. plates the transition temperature ranges have been fairly well defined for all the steels tested to date. With the exception of two test plates Q-1D and N-4D the results are reasonably consistent. For the 72-in. plates the transition ranges have been established for the semi-killed steels and the nickel alloy steel.

These data place the transition temperatures for both the A and B steels in about the same range, while those for steel C are some 50° to 60°F. higher. This was found to be the case with both the 12-in. and the 72-in. plates. A comparison of Figs. 12 and 13, shows that the transition ranges for 72-in. plates are from 10° to 30°F. higher than the transition ranges for corresponding 12-in. plates.

The transition range for the nickel alloy steel is about -40° to -50°F. for the 72-in. plates and -60° to -70°F. for the 12-in. plates. It is of interest to note that the drop in energy with decrease in temperature is relatively abrupt for this nickel alloy steel, and further, that the energy absorbed in the brittle range is remarkably high as compared with that absorbed in the brittle range by the semi-killed steels.

Attention is directed to the unusual behavior of one specimen of the Q steel (Fig. 14); the only explanation that can be offered at this time is that the sample represented one of the extremes that are encountered from time to time in random selection.

Percent Shear Fracture vs. Temperature. -- Figs. 15 and 16 show by diagram for the various temperatures of test the percentage of the cross-sectional area failing by shear for the several steels. The transition ranges have been blocked as shown, even though some points beyond the range show less than 100 percent shear, because the examination of the breaks for these plates definitely show that the small amount of cleavage resulted from a secondary tearing action that occurred only on one edge of the plate.

Strength vs. Plate Width. -- Figs. 17, 18, and 19 show the variation in the nominal strength at maximum load with the width of the plate for three different temperatures and for the two modes of fracture. The wider plates failed at lower nominal stresses than did the narrower plates, and this difference, with the exception of steel C, becomes more apparent for specimens broken at 32°F. than for specimens broken at higher temperatures. Figs. 20 and 21 show the variation in the nominal strength at maximum load with the test temperature for the 12-in. and 72-in. plates.

Plate Elongations. -- Typical distribution of longitudinal elongation of the plates at various loads are shown in Figs, 22 to 29. Diagrams are given for selected plate specimens in each width tested and for each type of fracture, shear or cleavage. The data represented by open circles were obtained from pairs of wire extensometers placed on opposite faces of the plates, and given the change in distance between two points at the ends of the longitudinal gage lines having, in all cases, lengths equal to three-quarters of the plate width. These elongations are shown for each of several loads (stated in terms of nominal stress), and include the separation of a plate across the notch and the crack, when and if cracking began before maximum load was reached, for example - in some cases the crack may have progressed several inches from the base of the notch before the maximum load was attained, and in case the crack has progressed farther on one side of the plate than on the other, a lack of symmetry of some of the diagrams would result.

In general, at the higher loads, the elongation was greater in the central portion of the plate than at the edges. Thus, since the longitudinal extension was not uniform across the width of the specimen, it was necessary to calculate from the elongation readings an **average elongation** which could be used to estimate the energy absorbed by the specimen. (See Fig. 2).

The data represented by the solid black circles were obtained from measurements on the specimens after failure occured. These values of residual elongation do not include the elastic elongation, nor do they include plate separation due to the opening of cracks; also the residual elongations were measured on one face of the specimens, so that the effect of distortion (if and when any existed) of the plate during rupture is included in the values shown.

It may be noted from the diagrams that the residual elongations of elements traversing the base of the notch are less than the overall elongations determined from the wire gages. The reason was, that as the crack progressed outward from the notch, the stresses were reduced in the longitudinal elements which were severed by the crack, and plastic flow was lessened or completely stopped. In the specimens which failed by shear, during the progress of rupture those portions of the plate outboard from the advancing crack sustained the entire load and continued to yield, so that the residual elongations at the edges of the plate are relatively large. In cleavage type failures there was usually a small amount of shear type fracture near the base of the notch, so that here also, the residual elongations of the elements traversing the base of the notch are less than the elongation indicated by the wire extensometers. However, along elements across a cleavage type of fracture, the residual elongations were much closer to the over-all elongation. It is also to be noted that the magnitude of elongations are much smaller for the specimens that failed by cleavage than those that failed by shear.

A comparison of the residual elongation of specimens that behave in a ductile manner and a relatively brittle manner is given in Fig. 31. The elongations are shown in percent, and to compare specimens of different sizes the locations of the elements on which the measurements were made are plotted as fractions of the specimen width. The marked difference in magnitude and distribution of the residual elongations between ductile and brittle specimens are readily apparent from this figure. It is of interest to note that for the specimens failing by shear, the 12-in. specimens exhibited greater ductility than those of greater width; however, this was not true for the plates where cleavage fracture was predominant.

A comparison of the elongation at maximum load, as determined by the wire extensometers, of specimens which behaved in a ductile manner and in a relatively brittle manner is given in Fig. 30. Trends similar to those just discussed in connection with residual elongations are apparent here.

Figs. 36 and 37 show the elongation at various loads as measured over 2-in., 24-in., and 54-in. gage lengths on two 72-in. specimens. The local elongation near the fracture was very high and decreased as the gage length was increased. This is very pronounced for the ductile specimen B-5A, and less so for the brittle specimen C-1A.

Reduction in Thickness along Line of Fracture. -- As a further aid in judging tendency toward brittle behavior of the plate specimens broken at various temperatures, plate thicknesses were measured after rupture along the line of fracture. By comparison with a set of plate-thickness measurements made before application of load to a specimen, the percentage reductions in thickness were computed in each case. The thickness reductions are summarized in Table 6.

Although there are some exceptions, the general pattern of the data for the semi-killed steels is as follows. For the specimens which fractured entirely by shear the reductions in thickness were of the order of 5 percent at a point a small distance from the notch and increased to about 20 percent at the outside edge of the plate. The thickness reductions at the notch varied considerably, probably being greatly influenced by time of development of the initial crack in the base of the notch.

For the specimens of semi-killed steels which fractured entirely by cleavage, the thickness reduction was generally of the order of 3 to 5 percent at 1/2 in. from the notch and decreased to about 1 or 2 percent at the edge of the plate. The thickness reductions at the notch also varied considerably for plates having this mode of fracture, sometimes being much higher at the notch, and sometimes reaching a maximum for the whole plate at a point between the base of the notch and the 1/2-in. point. It is noteworthy that even for 100 percent cleavage fracture, the minimum reductions in thickness were usually at least 1 percent.

The Q steel appeared to follow a pattern of behavior somewhat similar to that of the semi-killed steels, except that the maximum reductions in thickness attained were appreciably greater.

The N steel did not follow the pattern of behavior described above; compared with the semi-killed steels it tended to exhibit greater thickness reductions where fracture occurred by cleavage, and sometimes showed less thickness reduction than the semi-killed steels where fracture occurred by shear.

Summary of Auxiliary Studies

Hardness Surveys of Fractured Plate Specimens

In attempt to obtain some indication of the localized stress distribution in the wide flat plates at fracture, it was considered desirable to conduct some experiments in which advantage would be taken of the strain-hardening property of steel to indicate maximum stress levels. Accordingly, some specimens were sectioned at intervals along the surface of fracture and hardness surveys were made so as to determine the variation in hardness throughout the metal near the fractured surfaces as described in a previous report (Cleavage Fracture of Ship Plate as Influenced by Design and Metallurgical Factors NS-336, Part II--Flat Plate Tests; OSRD No. 6452, Serial No. M-608, January 1946).

The true stress-natural strain curves for bars cut from specimens B-1A (which failed in a ductile manner), C-1A (which failed in a brittle manner), and C-2A (which failed in a brittle and partly in a ductile manner) are shown in Fig. 52. In Fig. 53 are shown the hardness vs. natural strain curves for the same specimens. From these curves was calculated the energy absorbed per cubic inch of strained material for various strains. The energy in inch pounds per cubic inch is plotted against the Knoop hardness number in Fig. 54.

The locations from which samples for the hardness tests were taken from the plates are indicated in Figs. 38, 39, 40 and 41. The samples used for determining the hardness were pieces about 1 in. long and 1/4 in. thick. The face that was polished and used for measurements was perpendicular to the face or plane of the specimen and parallel to the loading axis. A large number of readings was taken on the face of each sample so that hardness contours could be plotted. About six readings were taken at each point to give an average hardness value for each location. The normal scatter in the Knoop hardness number was ±5. (The Knoop hardness number is very nearly equal to the Brinell hardness number.)

The results of the hardness surveys for plate C-2A are shown in Figs. 42 to 48. These results are shown in the form of hardness "contours" on selected imaginary planes through the plates.

From the Knoop hardness numbers shown in Figs. 42 to 48 it is possible to determine the local distribution of energy at and near the fracture. An example of energy distribution is shown in Fig. 49 for plate B-1A, in Fig. 50 for plate C-1A, and in Fig. 51 for plate C-2A.

Specimen C-2A failed by cleavage for about 4 in. Then the fracture changed to the shear mode for 4 in., and then changed back to the cleavage mode. Large deformations occurred near the notch, then there was little deformation for several inches. In the next few inches extensive shear distortion occurred and then followed a region of cleavage failure with little deformation out to the edge of the plate. At the base of the notch, the microhardness survey indicated that much shear distortion had occurred. The region which failed by shear also showed evidence of great shear distortion, while the region adjacent to cleavage fracture showed much less evidence of plastic flow.

The conclusions that may be drawn from the results of the microhardness tests are:

(1) Extensive deformation occurs at the base of the notch for both shear and cleavage fractures. The strain hardening which occurs in this region is as great as that which occurs near the fracture of a standard tensile test bar.

(2) Some local plastic flow takes place near the fracture during the time that failure occurs. It should be noted that the volume of metal subject to large plastic strain was confined to a relatively localized region, when the fracture was predominently cleavage, while in cases where shear fracture occurred large plastic deformations took place over very extensive regions of the plate.

(3) It appears that more plastic flow occurs near the surfaces of the plate than at points remote from these surfaces.

(4) Cleavage failure may occur after varying amounts of plastic flow have taken place. Cleavage fracture is not necessarily an indication of lack of plastic flow.

Tests of Unnotched, Notched, and Sheared Edge Three-Inch Wide Specimens

An attempt was made to develop a simple, easily-prepared specimen that would behave in the same manner as internally notched wide plates used in the main part of this investigation. The 3-in. specimen flame cut from full thickness plate, does not require any machining and thus might be an inexpensive and fast method for determining the transition ranges of the various steels.

The principal phase of this part of the investigation involved tension tests on three types of flat 3-in. specimensof the various steels in order to determine their transition ranges.

The three different types of bars used in this investigation are shown in Fig. 58. The plain, unnotched bar was flame cut from the test plate to a 4-in. width and the central portion reduced by cutting away 1/2-in. from each edge on a Doall saw. The notched bar was made by flame cutting from a plate and by making a cut, 1/4-in. deep, on each edge of the bar with a hacksaw to produce a net width of 2 1/2 in. at the notch. The shear-edge bar was similar to the unnotched bar except that one edge was made to include the longitudinal sheared edge of the large test plate. The sheared edge bar was used in the tests in order to determine the effect of the sheared edge of plates on the transition range of the steel.

A special cooling unit and a jacket for the specimens were developed so that the temperature could be controlled within very narrow limits. Fig. 67 shows the cooling jacket in place about a specimen in the tensile machine, and Fig. 68 shows a general view of the apparatus used in the 3-in. wide bar tests.

Results of the 3-In. Bar Tests. -- Transition temperatures for the various steels used in this investigation as well as for steel D (fully killed) and steel E (rimmed) are shown in Fig. 55. Transition temperatures for the various thickness of steel C are given in Fig. 56. A comparison of the transition temperatures for the plain, sheared edge and notched edge bars of steels A and C are shown in Fig. 57. Fig. 59 through 66 show the fractures of the test bars for the various steels.

The results of the 3-in. bar tests indicate that the steels tested can be arranged in the same order as by the tension tests of the wider notched plates, although the transition temperatures may differ somewhat.

Tentative Conclusions

Summary of Conclusions

The following statements summarize the principal conclusions that may be drawn from the tests to date. Upon completion of the entire investigation, it is expected that some of the statements may require slight modification and that considerable amplification of the information will be possible.

1. For medium carbon steels of the semi-killed type, produced under the current specifications for hull-quality plate, the temperatures at which the mode of failure of sharply notched plates changes from a ductile, shear-type to a brittle, cleavage-type may vary from below freezing to well above room temperature (65°F to 70°F).

2. Steels of presumably identical chemical composition may have widely different transition ranges, as determined by flat plate test.

3. There was little difference in behavior between steel B as-rolled and steel B normalized. The metallurgical structures of plates for the two conditions were substantially the same.

4. The indications are that the steels can be arranged in approximately the same order by the Charpy impact test as by the tension tests of wide plates, although the transition temperatures were considerably different for the two types of tests.

5. Both shear and cleavage failures in the flat, notch plates begin with the formation of small cracks at the base of the notch midway between the faces of the plate. It appears that both the shear and the tensile stresses are a maximum in this region rather than at the faces or surfaces of the plate. (Note: This was discussed in some detail in a previous report--Cleavage Fracture of Ship Plate as Influenced by Design and and Metallurgical Factors NS336: Part II--Flat Plate Tests OSRD No. 6452 Serial M-608 January 1946.)

6. Microhardness surveys made on samples cut from fractured plates indicate that even the most brittle specimens may undergo large amounts of plastic strain at the base of the notch. Th maximum degree of strain approaches that found adjacent to the fracture in the necked section of a standard tensile test bar. Away from the notch, the amount of plastic strain in the plate may be very small and in some cases may approach zero.

7. Under some conditions, cracks progress from the base of the notch toward the edges of the plate during loading and may lengthen several inches before maximum load is reached. The presence of these cracks rather than the original notch geometry may govern the final failure of the plate.

8. With the same sharpness of notch and a fixed notch-to-width ratio, the nominal strength of plates of constant thickness decreases with increasing plate width. This is true whether the failures are of the shear or cleavage type.

9. The maximum loads are slightly lower for specimens failing by cleavage than are the corresponding loads for similar specimens failing by shear.

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 Technical Representative for the Project, NRC-92. 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, and Earl R. Parker, Associate Professor of Physical Metallurgy, were in charge of technical phases of the investigation. In direct charge of the testing and the general supervision of the work was A. Boodberg. The laboratory work was under direct supervision of F. Brezee and the computing and drafting work was under direct supervision of Joseph D. DeVito. Special studies were conducted by Charles H. Avery and Joseph D. DeVito. The shop work and welding 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, Mary E. Bennett, E. Berliner, D. Berner, E. Betts, E. M. Cleave, W. Dunlop, C. Glassgow, David E. Gibbs, Eloise Hornstein, R. Johnsen, Inez Keklak, Ruth Kimball, G.R. LaForge, S. Lever, J. Logan, E. McLaughlin, J. Mednick, W. Mullins, Jean Neilson, F. Ormsby, R. Payne, D. Peterson, K. T. Rains, Vera Rideout, A. D. Ring, T. Robinson, R. F. Schord, L. Seaborn, D. Unger, T. Yamamoto, Phebe Zimmerman. Harry E. Kennedy, Research Associate in the College of Engineering, served as consultant on special problems.

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

Note: All steels were tested at temperatures selected so as to define the temperature transition range within reasonable limits.

Code Letter for Steel and Manufacturer	Chemical Analysis		Type of Steel	Use in Test Program
	C,%	Mn,%		
A Carnegie-Illinois	0.25	0.47	Semi-killed As rolled	Large cylinders and 72,48,24,12 and 3-in. notched flat plates
B Bethelehem	0.18	0.72	Semi-killed As rolled	72,48,24,12 and 3-in. notched flat plates
B Bethelehem	0.18	0.72	Semi-killed Normalized	72,48,24,12 and 3-in. notched flat plates
C Carnegie-Illinois	0.25	0.49	Semi-killed As rolled	72,48,24,12 and 3-in. notched flat plates
N Lukens	0.13	0.49	3 1/4% Nickel As rolled	72,12 and 3-in. notched flat plates
H Bethlehem	0.16	0.85	Fully-killed As rolled	72,12, and 3-in. notched flat plates
Q Republic	0.23	1.05	Water quenched and drawn	72,12, and 3-in. notched flat plates

TABLE 2. -- PROPERTIES OF PLATE STEEL -- ABSTRACT OF MILL REPORTS

	Steel A Carnegie-Illinois	Steel B Bethlehem		Steel C Carnegie-Illinois	Steel N Lukens	Steel Q Republic	Steel H Bethlehem
hemical Composition							
C	0.23	0.16		0.24	0.13	0.21	0.16
Mn	0.47	0.74		0.49	0.49	1.05	0.75
Si	0.02	0.03		0.043	0.22	0.05	0.17
P	0.011	0.011		0.015	0.018	0.011	0.010
S	0.042	0.030		0.033	0.027	0.030	0.022
Ni	--	--		--	3.34	--	--
Heat Treatment	As rolled	One lot as rolled; one lot normalized at 1650° F.		As rolled	As rolled	Water Quenched and drawn at 1300° F.	As rolled
Physical Tests:		As rolled	Normalized				
Yield point, psi.	37,950	35,800	34,800	39,000	49,800	42,600-50,200*	39,800
Ult. strength, psi.	59,910	59,600	58,900	67,400	77,200-79,400	69,300-75,850*	63,100
Elong., % in 2 in.	33.5	--	--	--	25.5	45-53*	--
Elong., % in 8 in.	--	26.0	32.0	25.5	--	--	27.0
Deoxidation Treatment	1 1/3 lb./ton Si/ton in ladle and 1/2 lb./ton of Al in mold	8 1/2 lb./ton of ferro-manganese, 1 1/8 lb/ton of ferro-silicon and 2 1/2 lb./ton of Al-Si; small amount of Al added in mold		6 lb./ton of 80% ferro-manganese and 2.6 lb./ton of 50% ferro-silicon added in ladle; 1/3 lb/ton of Al in mold	--	--	--

* Maximum and minimum values from tests of 10 different plates.

TABLE 3. -- CHEMICAL ANALYSIS OF SAMPLES FROM INDIVIDUAL PLATES

Plate	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-5	" "	0.26	0.46
C-6	" "	0.25	0.48
D-1	As rolled,fully-killed	0.17	0.52
N-1	As rolled,nickel alloy*	0.18	0.48
N-2	" "	0.17	0.48
N-3	" "	0.15	0.50

*Nickel content - 3.34 percent

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

(Sheet 1 of 2)

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	
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	56,680	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	--	--	--	--	
		Flat	L	--	--	--	--	

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 (continued)

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 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	"	31,080	55,470	54.0	66.0	
		Flat	"	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	33,870	56,940	34.8	64.9	
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	
	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	
	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	
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	--	--	--	--	
		Flat	L	--	--	--	--	
	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	--	--	--	--	
		Flat	L	--	--	--	--	

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

SHEET 1 OF 2

STEEL	PLATE NO.	STD. 0.505-IN TENSILE BAR			3-IN. EDGE-NOTCHED TENSILE BAR (h)				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.	T.S. K.S.I.	TEMP. F. (b)	Y.S. K.S.I.	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	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	A-1	70°	35.6	58.8	(-19°)-(-15°)	45.9	66.0	3% SH. 97% CL.	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
	A-2	71°	36.2	57.6	30°	43.4	61.6	2% SH. 98% CL.	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)	31°-32°					30°-34°	38.5	2% SH. 98% CL.	24 54	520 684
	A-3	72°	35.5	58.4	49°-51°	42.5	61.5	10% SH. 90% CL.	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°	40.3	73% SH. 27% Burn	24 54 170(e)	1584 2273 2387(e)
	A-4				69°-73°	42.3	60.2	94% SH. 3% CL.	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)
	A-5				80°	43.1	58.1	97% SH. 3% CL.	(-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															
"B_or" BETHLEHEM C-0.16 Mn-0.74 AS ROLLED SEMI-KILLED	B-1	73°	31.9	57.1	(-20°)-(-19°)	38.7	65.8	6% SH. 94% CL.	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)
	B-3	70°	32.1	55.9	6°-9°	40.5	65.5	16% SH. 84% CL.	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)
	B-6	74°	30.4	56.7	22	37.8	63.5	39% SH. 61% CL.	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)
	B-7				33°-39°	37.7	59.4	100% SH.	(-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 54 168(e)	209 315 455(e)
	B-9								(-7°)-(-6°)	41.8	100% CL.	9 78 (e)	36 41 (e)															
"B_n" BETHLEHEM C-0.16 Mn-0.74 NORMALIZED SEMI-KILLED	B-2	72°	37.1	57.9	(-22°)-(-16°)	43.1	64.8	13% SH. 87% CL.	32°-36°	48.1	78% SH. 22% CL.(f)	9 40 (e)	134 268(e)	32°-33°	46.3	90% SH. 10% Burn	18 96	405 457						33°-35°	33.2	100% CL.	24 54	140 194(g)
	B-4	70°	33.5	57.3	(-3°)-(0°)	42.8	62.7	31% SH. 69% CL.	89°	45.6	94% SH. 6% CL.	9	133	97°	41.5	100% SH.	18	384						72°	37.9	91% SH. 9% Burn	24 54 170(e)	1417 2050 1713(e)
	B-5	70°	37.0	58.5	34°-40°	41.8	60.5	94% SH. 6% CL.	50°-51°	45.9	100% SH.	9 54(e)	121 192(e)											49°-52°	39.5	100% SH.	24 54 170(e)	1138 2100 2566(e)
	B-8				55°	41.5	58.6	100% SH.	(-12°)-(-10°)	38.5	100% CL.	9 47 (e)	22 29(e)															
	B-10								10°-15°	48.7	87% SH. 13% CL.	9 76(e)	116 212 (e)															
	B-21X								10°	42.2	100% CL.	9 71 (e)	53 70(e)															
"C" CARNEGIE - ILL C-024 Mn-0.49 AS ROLLED SEMI-KILLED	C-1	70°	36.3	61.8	34°-35°	42.9	64.9	2% SH. 98% CL.	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
	C-2	75°	36.0	68.8	49°	42.5	64.4	3% SH. 97% CL.	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
	C-3				75°	41.6	63.2	4% SH. 96% CL.	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	25% SH. 50% CL. 25% Burn	24 54 170(e)	823 1189 1457(e)
	C-4				104°-108°	40.7	62.2	98% SH. 2% CL.											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)
	C-5				87°	40.7	63.8	6% SH. 94% CL.	141°-145°	54.7	91% SH. 9% CL.	9 44 (e)	78 119(e)											152°	43.0	86% SH. 2% CL. 12% Burn	24 54 167(e)	472 689 889(e)
	C-6				96°	40.2	61.9	36% SH. 64% CL.											32°	37.0	100% CL.	36 130(e)	46 93(e)					
	C-51X				128°	42.1	63.5	95% SH. 5% CL.	120°-123°	48.7	100% SH.	9 83 (e)	93 114(e)															
	C-52X				144°	42.1	61.5	100% SH.	90°	46.6	10% SH. 90% CL.	9 77 (e)	72 160															
	C-11X								132°-136°	53.2	93% SH. 7% CL.	9 62 (e)	83 227															

FOR NOTES SEE SHEET 2

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

SHEET 2 OF 2

STEEL	PLATE NO.	STD. 0.505-IN. TENSILE BAR			3-IN. EDGE-NOTCHED 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.	T.S. K.S.I.	TEMP. °F. (b)	Y.S. K.S.I.	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	TEMP. °F. (b)	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	GAGE LENGTH	(c) ENERGY K-IN. (d)		TEMP. °F. (b)	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	GAGE LENGTH	(c) ENERGY K-IN. (d)		TEMP. °F. (b)	NOMINAL STRENGTH K.S.I. (a)	TYPE FRACTURE	GAGE LENGTH	(c) ENERGY K-IN. (d)
"N"- LUKENS C- 0.13% Mn- 0.49% Ni - 3½ % AS ROLLED	N-1				(-39°)-(-36°)	64.0	83.5	5% SH. 95% CL.	(-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)	116 121 (e)	N-1	(-55°)-(-51°)	64.2	4% SH. 96% CL.	24 54 195 (e)	717 848 1913 (e)
	N-2				(-3°)-(+1°)	64.9	83.2	5% SH. 95% CL.	(-62°)-(-59°)	75.9	6% SH. 94% CL.	9 57 (e)	33.8	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 3736 (e)
	N-3				15°	64.4	81.9	10% SH. 90% CL.	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
	N-4				29°	63.0	79.5	98% SH. 2% CL.	(-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)						
	N-4X				-6°	65.0	85.5	11% SH. 89% CL.	(-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)						
"Q"- REPUBLIC C- 0.21% Mn- 1.05% QUENCHED & DRAWN	Q-1				-13°	69.3	82.8	8% SH. 92% CL.	71°	57.3	100% CL.	9 77.5 (e)	33.9 82.5 (e)	Q-21X	(59°)-(57°)	60.0	100% SH.	9 74 (e)	114 121 (e)						
	Q-2				-2°	68.6	83.4	5% SH. 95% CL.	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)						
	Q-3				29°	67.4	80.1	93% SH. 7% CL.						Q-13X	0°	58.4	100% CL.	9 71 (e)	32 52 (e)						
	Q-11X				16°	65.3	80.5	6% SH. 94% CL.	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)						
	Q-12X				41°	62.2	80.9	~~26% SH.~~ 74% CL.	85°-87°	60.7	100% SH.	9	115												
					57°	64.3	81.2	96% SH. 4% CL.																	

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 PRESUMABLY 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 2

DISTANCE FROM NOTCH, INCHES.

STEEL	PLATE WIDTH IN.	SPECIMEN NO.	TESTING TEMP. °F.	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°)			20 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			
"Bar"	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		
	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-31XD	12°-15°				3.5 C	8.5 C	20.5 C	22.5 C	20.5 C	17.0 C	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-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			
"Bn"	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			
	48"																								
	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	6.5 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 2

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	½	¼	⅛	1/16	0	0	1/16	⅛	¼	½	1	2	4	8	16	26
"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	1.0 C	2.0 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		4.0 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	3.0 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-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	9.5 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			
		C-11XD					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			
"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	
"N"	72"	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
		N-3A		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	20.1 S	19.5 S	21.0 S	26.0 S		
	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-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-42XD	(-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		5.5 S	9.0 S	9.5 S	11.0 S	14.0 S	6.5 C			
		N-4D	(-34°)-(-32°)				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-41XD	(-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-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-2D	(-62°)-(-59°)				7.0 C	17.5 C	35.0 C	24.5 C	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 C	24.5 C	12.5 C	5.5 C			
		N-22XD	(-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-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-4X	(-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-21XD	(-59°)-(-57°)				7.5 S	27.5 S	19.5 S	23.0 S	19.0 S	15.0 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 C			
		Q-13XD					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	1.0 C	1.0 C			
		Q-14XD					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			

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

TABLE 7. -- RECORD OF LOADS AT WHICH CRACKS STARTED DURING TESTS OF LARGE FLAT PLATES

Specimen Number	Development of Crack			Max. Nom. Stress, ksi	Break, percent shear
	Temp., °F	Load, Kips	Nominal Stress, ksi		
A3A	49	1320	32.6	40.3	100
A4A	10	1300	32.1	35.8	0
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
B7A	9	1250	30.8	34.6	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
B21XD	10	275	40.8	42.2	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
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

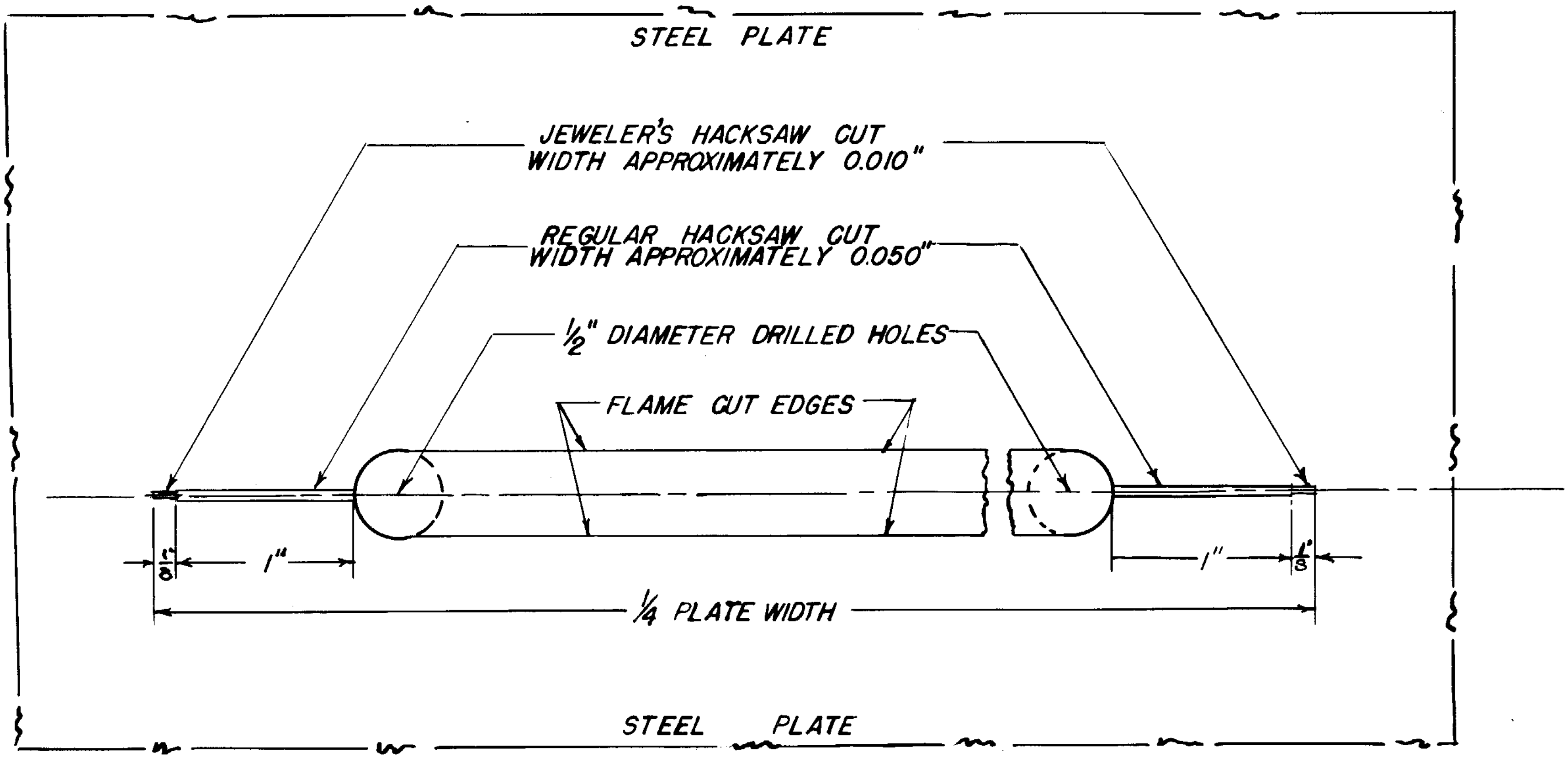
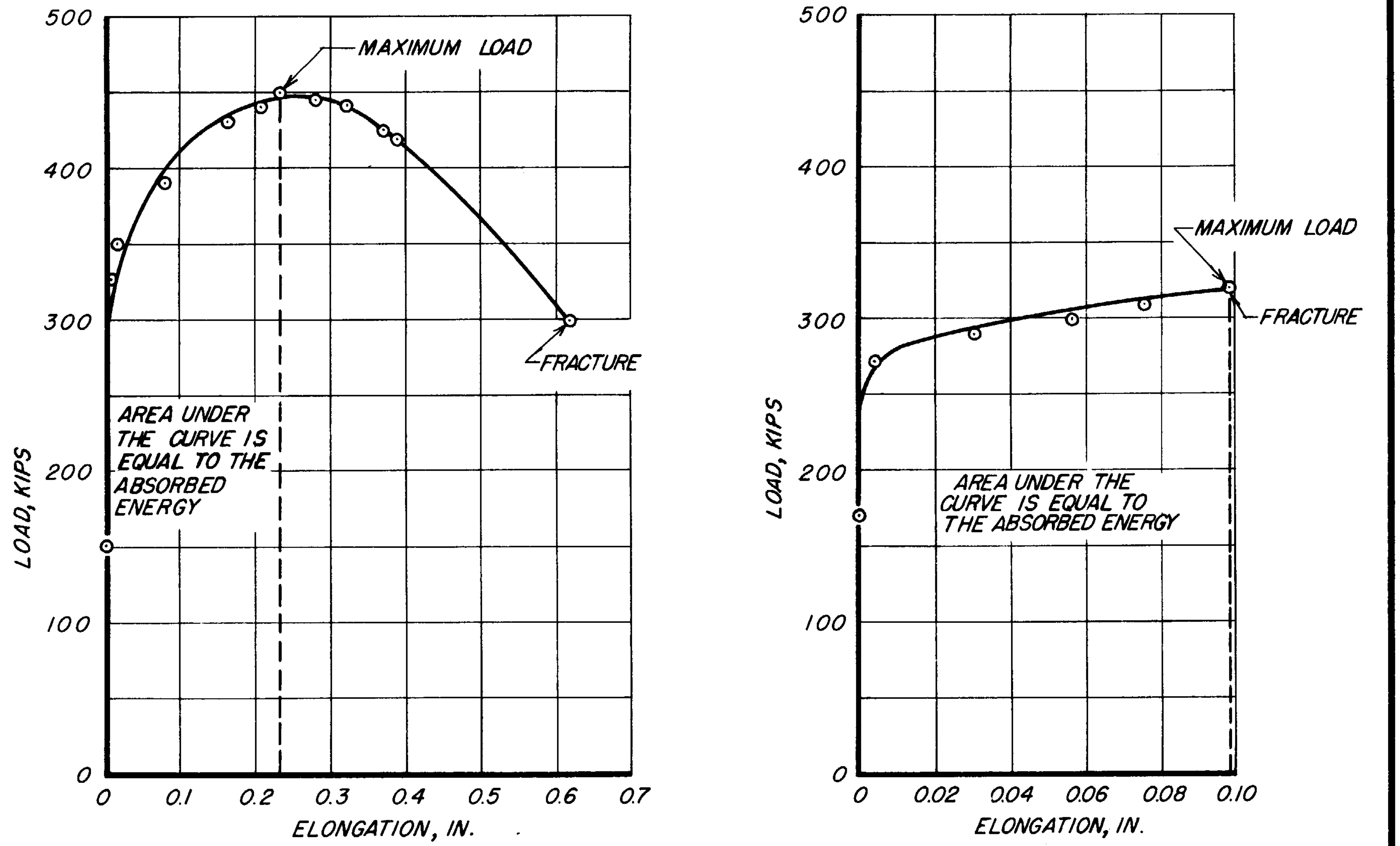


FIG. 1–DIMENSIONS OF NOTCH USED IN FLAT PLATE TESTS

FIG. 1

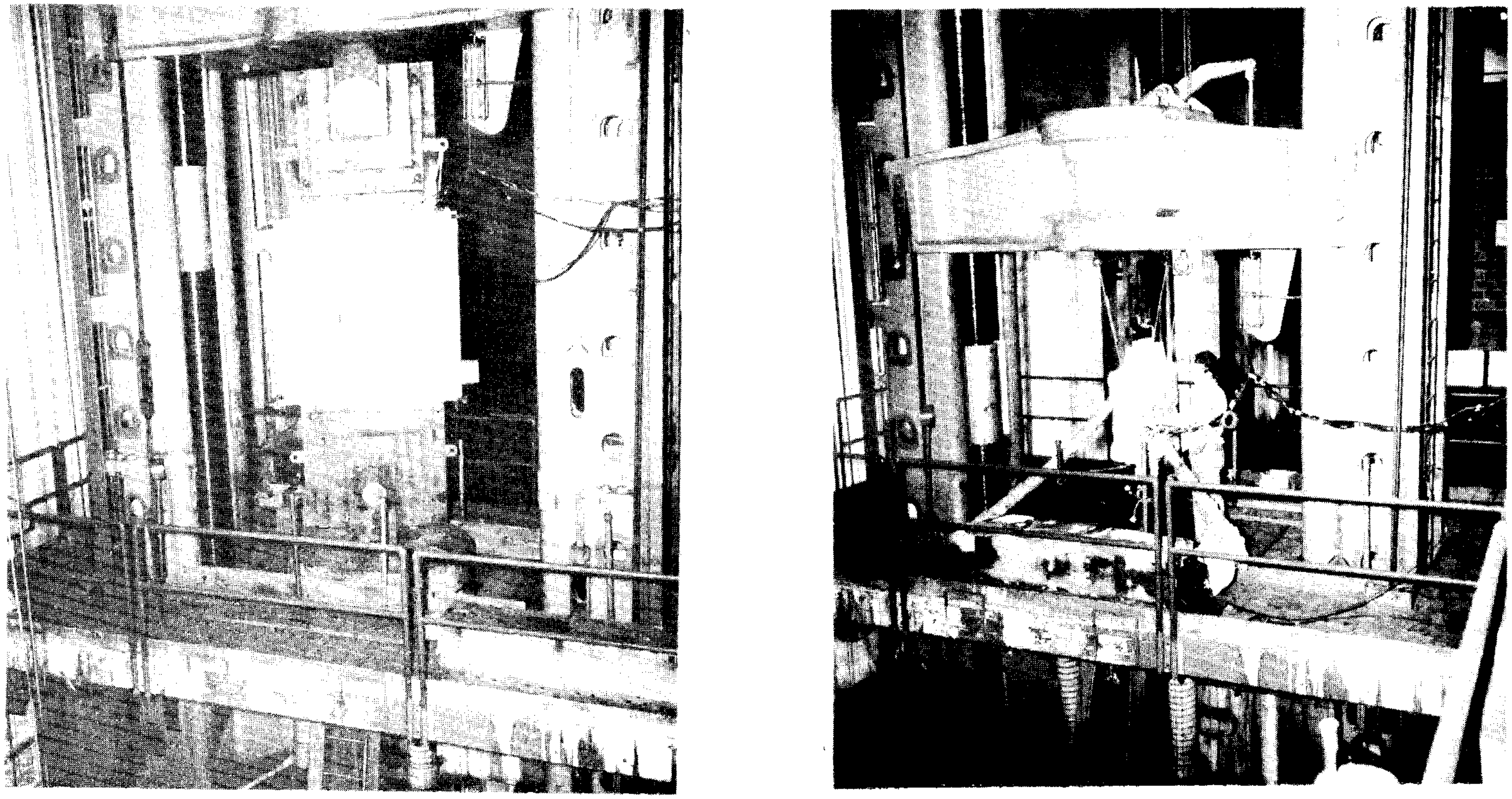
DWG. 44E15



TYPICAL SHEAR TYPE FAILURE

TYPICAL CLEAVAGE TYPE FAILURE

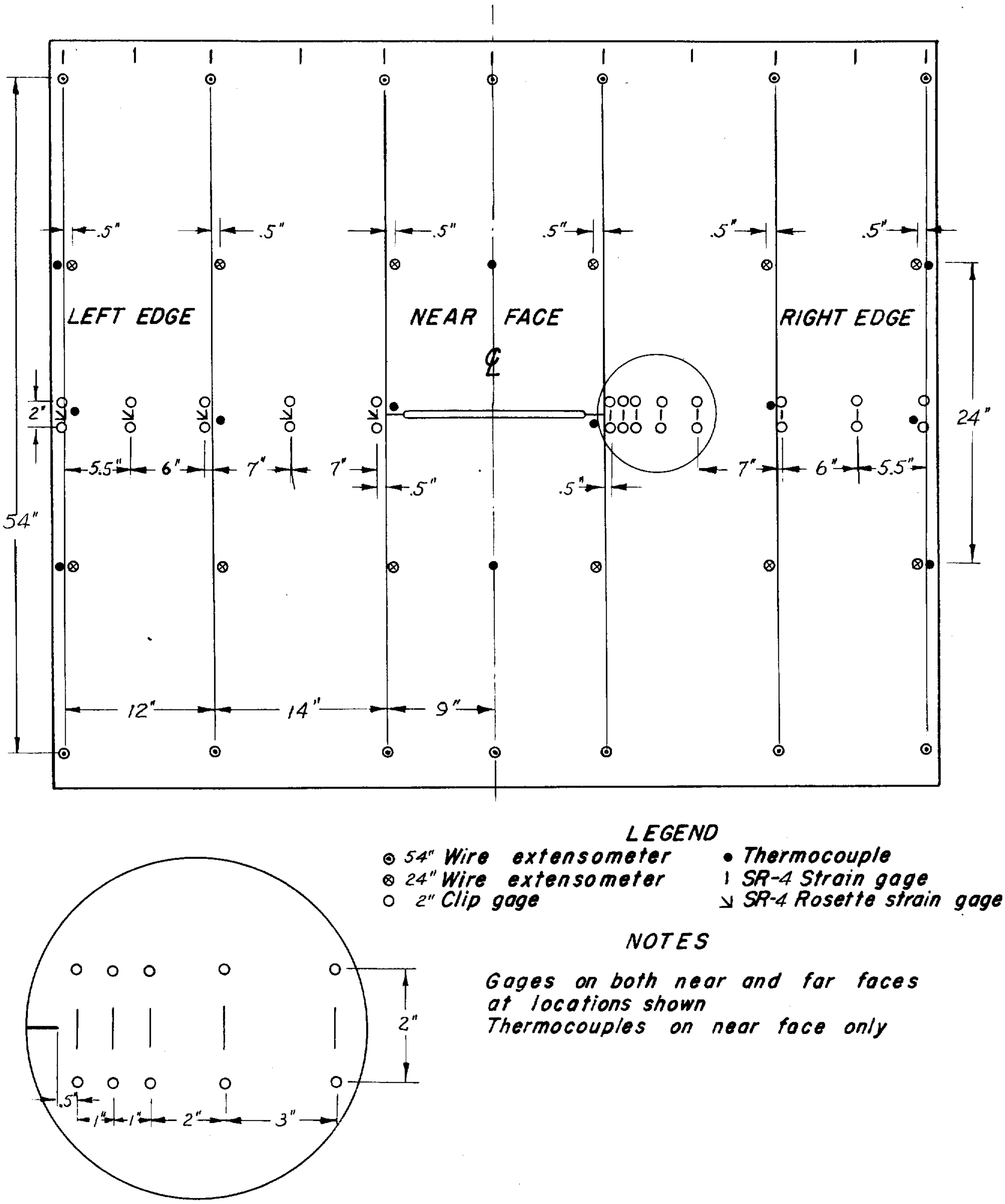
FIG. 2 TYPICAL LOAD-ELONGATION CURVES FOR OBTAINING ENERGY ABSORBED BY THE SPECIMENS UP TO THE MAXIMUM LOAD.



48-INCH SPECIMEN

12-INCH SPECIMEN

FIG. 3 VIEW OF PLATES FOR TESTING UNDER CONTROLLED TEMPERATURE CONDITIONS



LEGEND

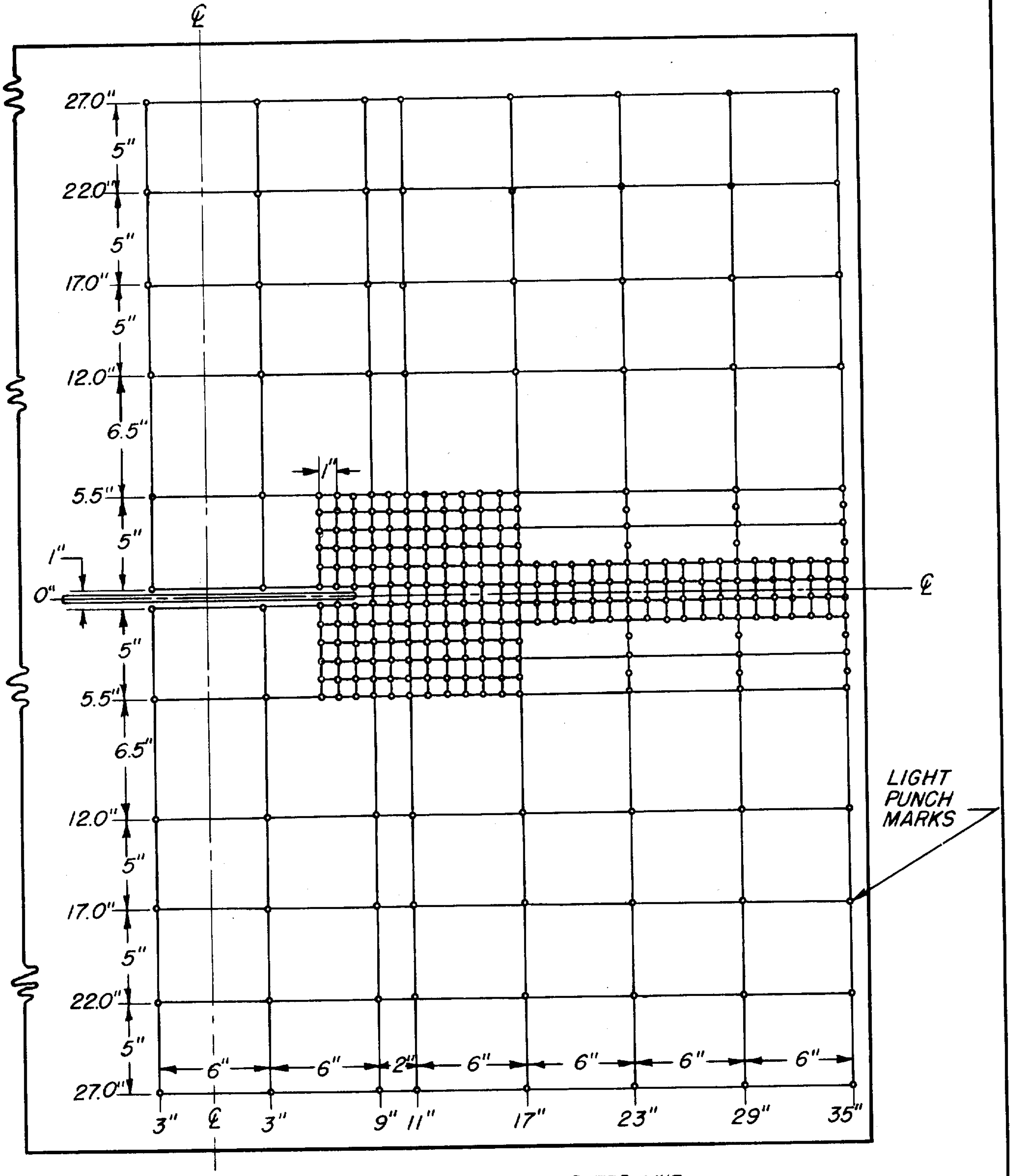
⊙ 54" Wire extensometer
⊗ 24" Wire extensometer
○ 2" Clip gage
● Thermocouple
| SR-4 Strain gage
↘ SR-4 Rosette strain gage

NOTES

Gages on both near and far faces at locations shown
Thermocouples on near face only

FIG. 4-TYPICAL GAGE AND THERMOCOUPLE LAYOUT FOR 72-INCH-WIDE SPECIMEN

DWG. 44E45



NOTE: LAYOUT SYMMETRICAL ABOUT LONGITUDINAL CENTER LINE.

FIG.5-TYPICAL GRID LAYOUT, 72-INCH WIDE SPECIMEN.

DWG. NO. 44E12

FIG. 5

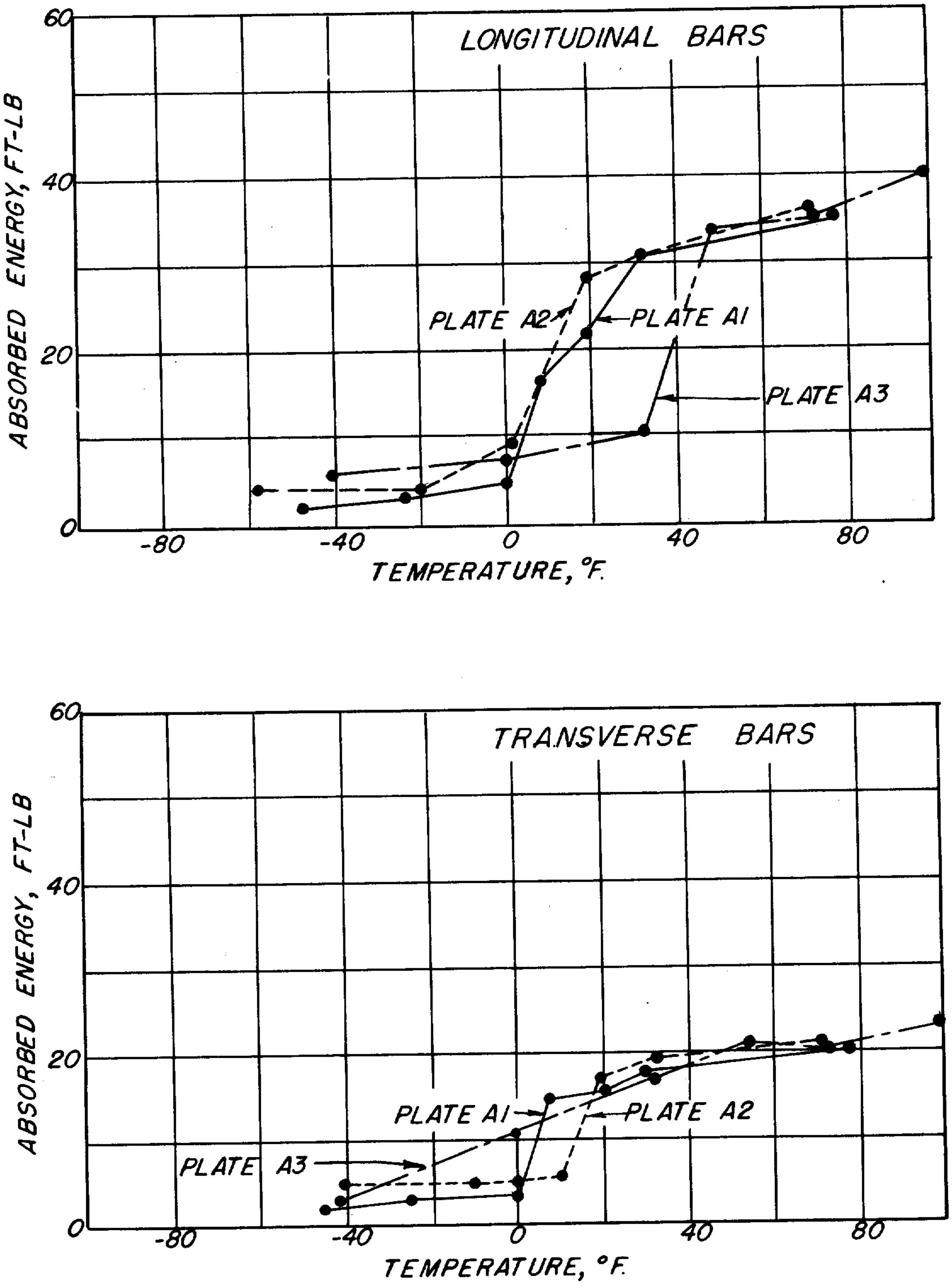
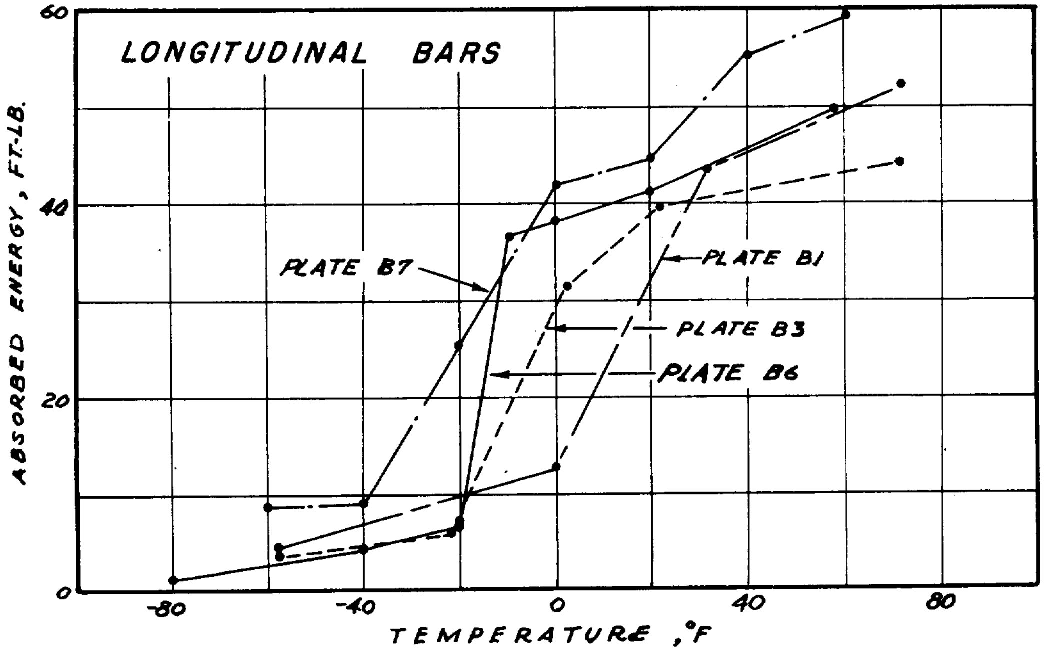


FIG. 6-RESULTS OF CHARPY IMPACT TESTS-STEEL A.



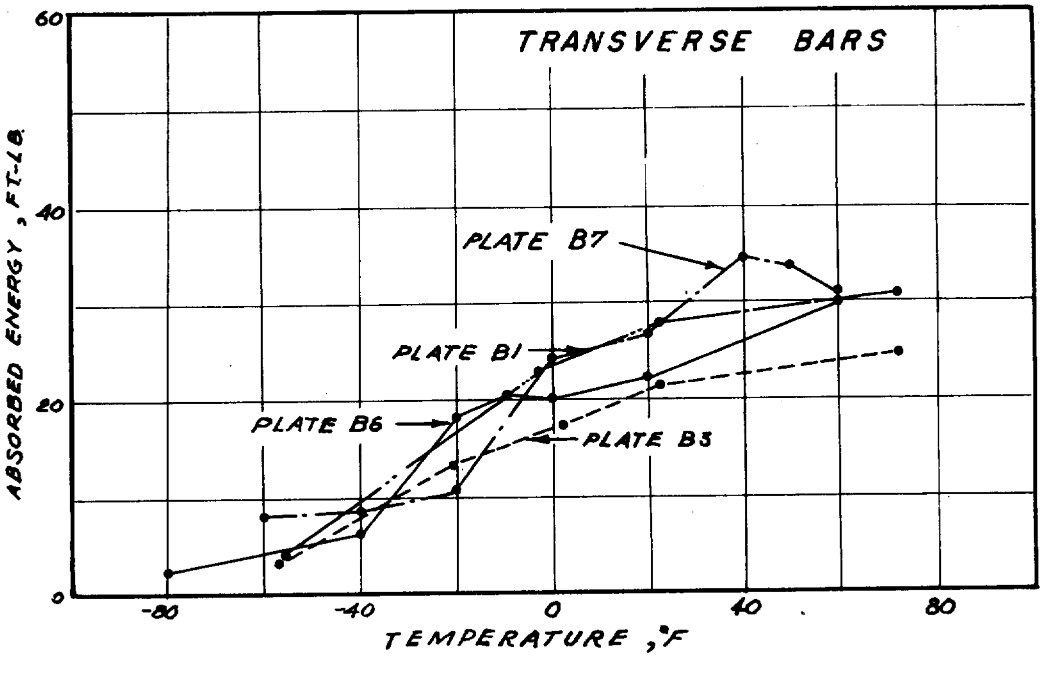
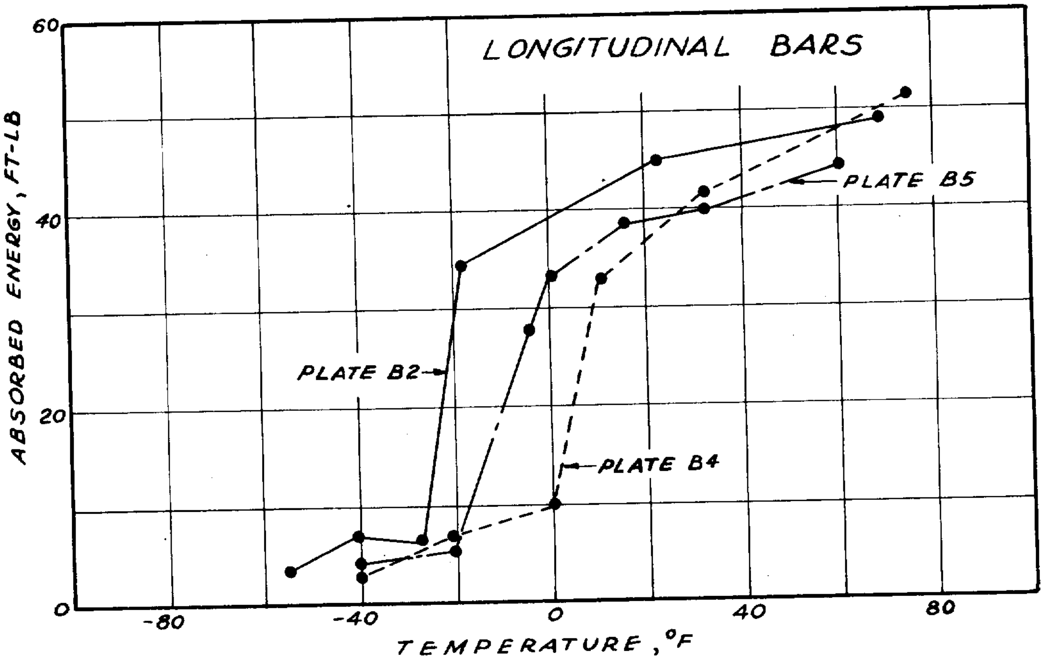


FIG. 7-RESULTS OF CHARPY IMPACT TESTS-STEEL B IN THE AS-ROLLED CONDITION

DWG. 44E36



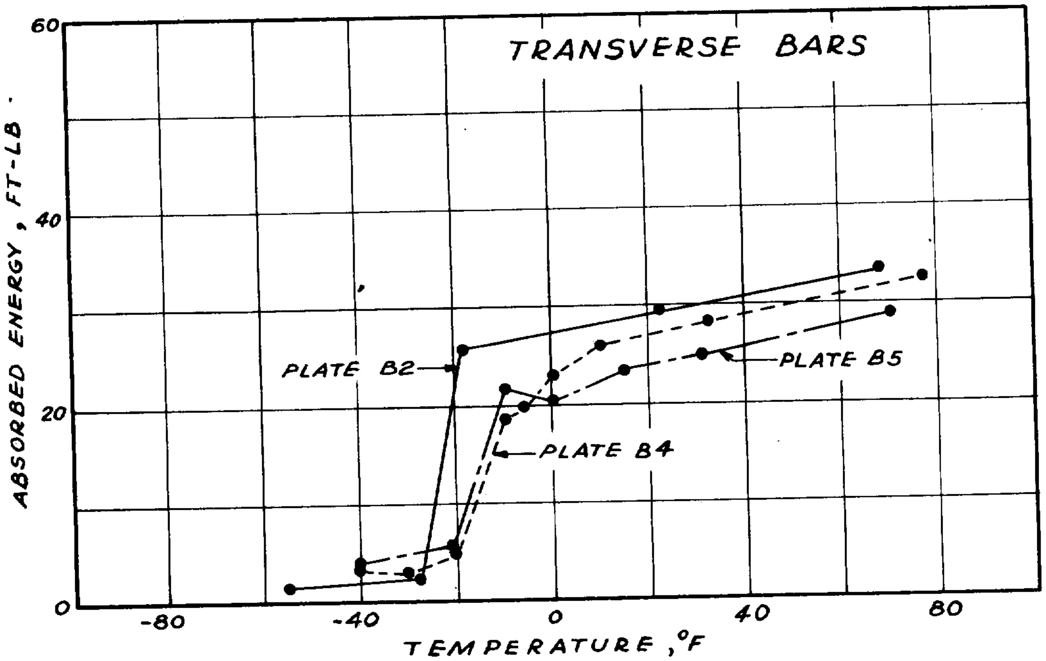
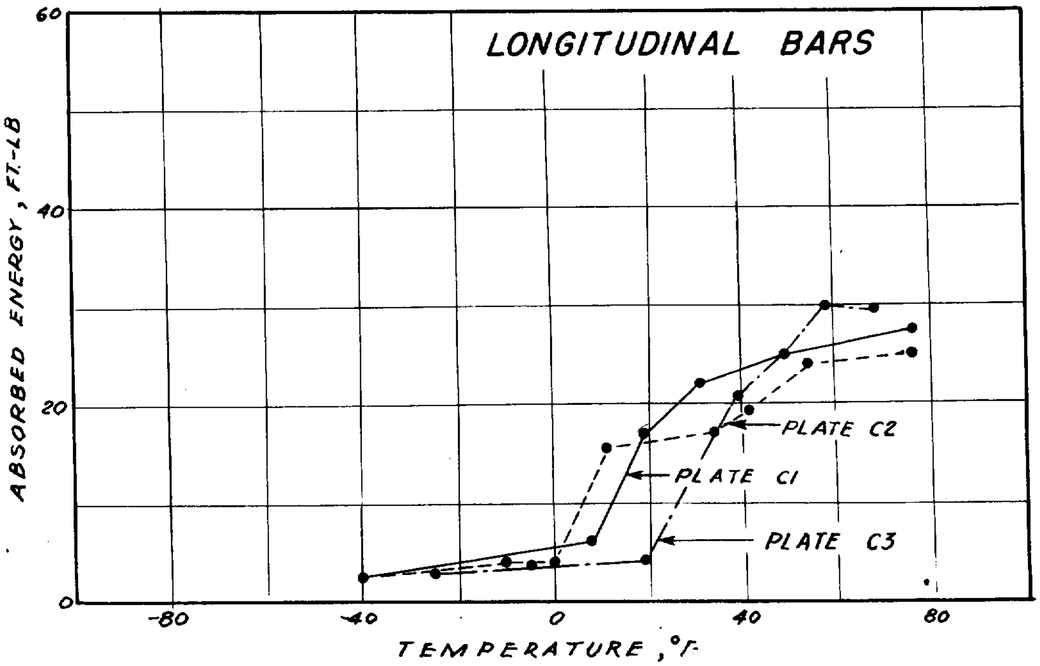


FIG. 8-RESULTS OF CHARPY IMPACT TESTS-STEEL B IN THE NORMALIZED CONDITION.

DWG. 44E33



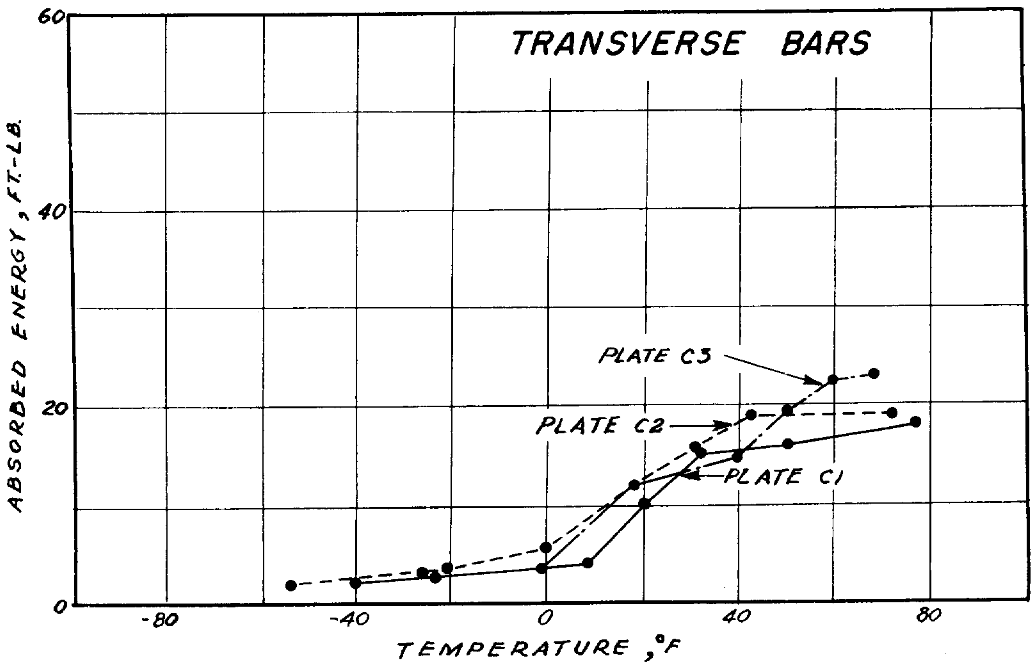


FIG. 9-RESULTS OF CHARPY IMPACT TESTS-STEEL C

DWG. 44E36

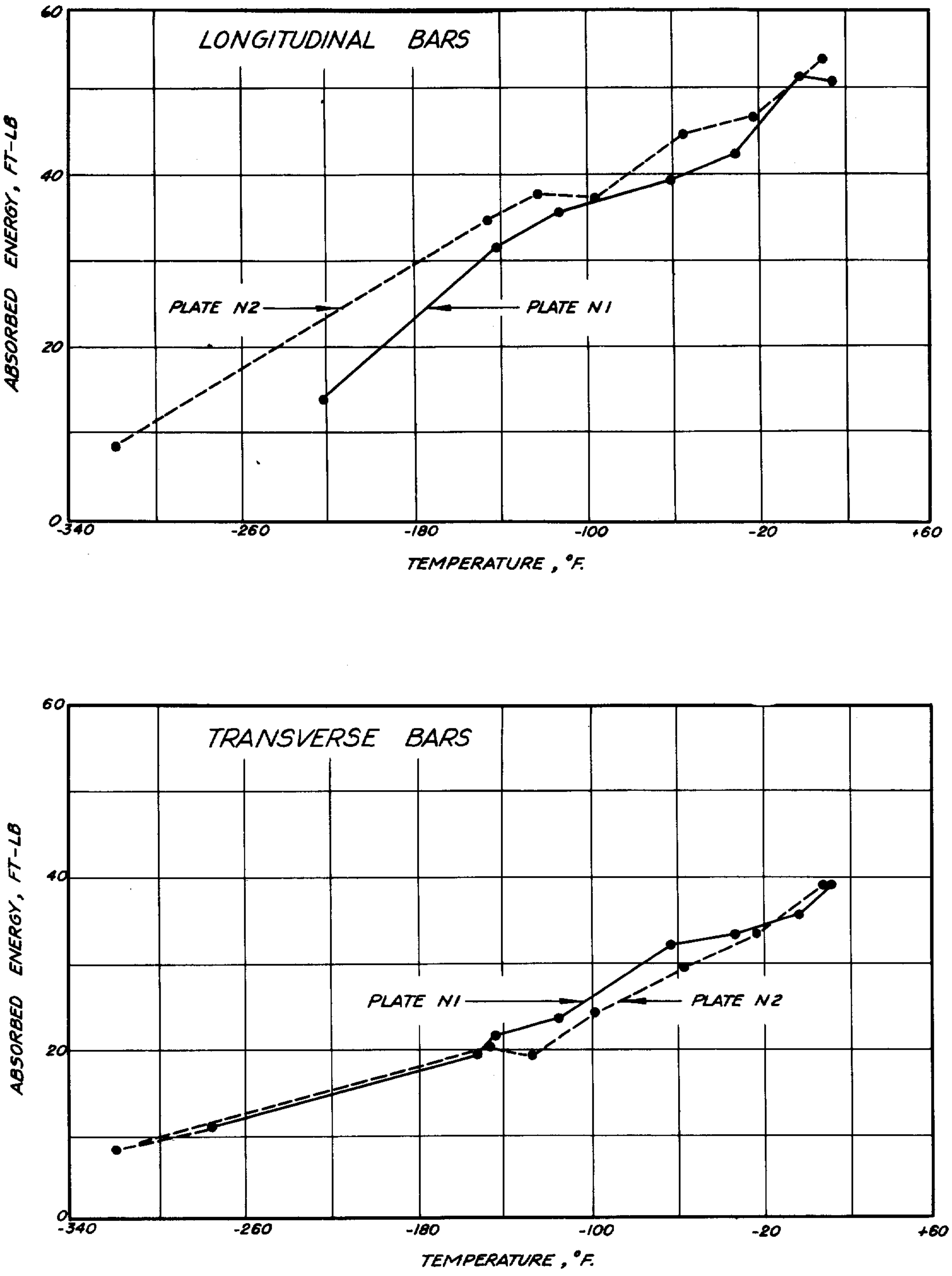


FIG. 10 - RESULTS OF CHARPY IMPACT TESTS - STEEL N

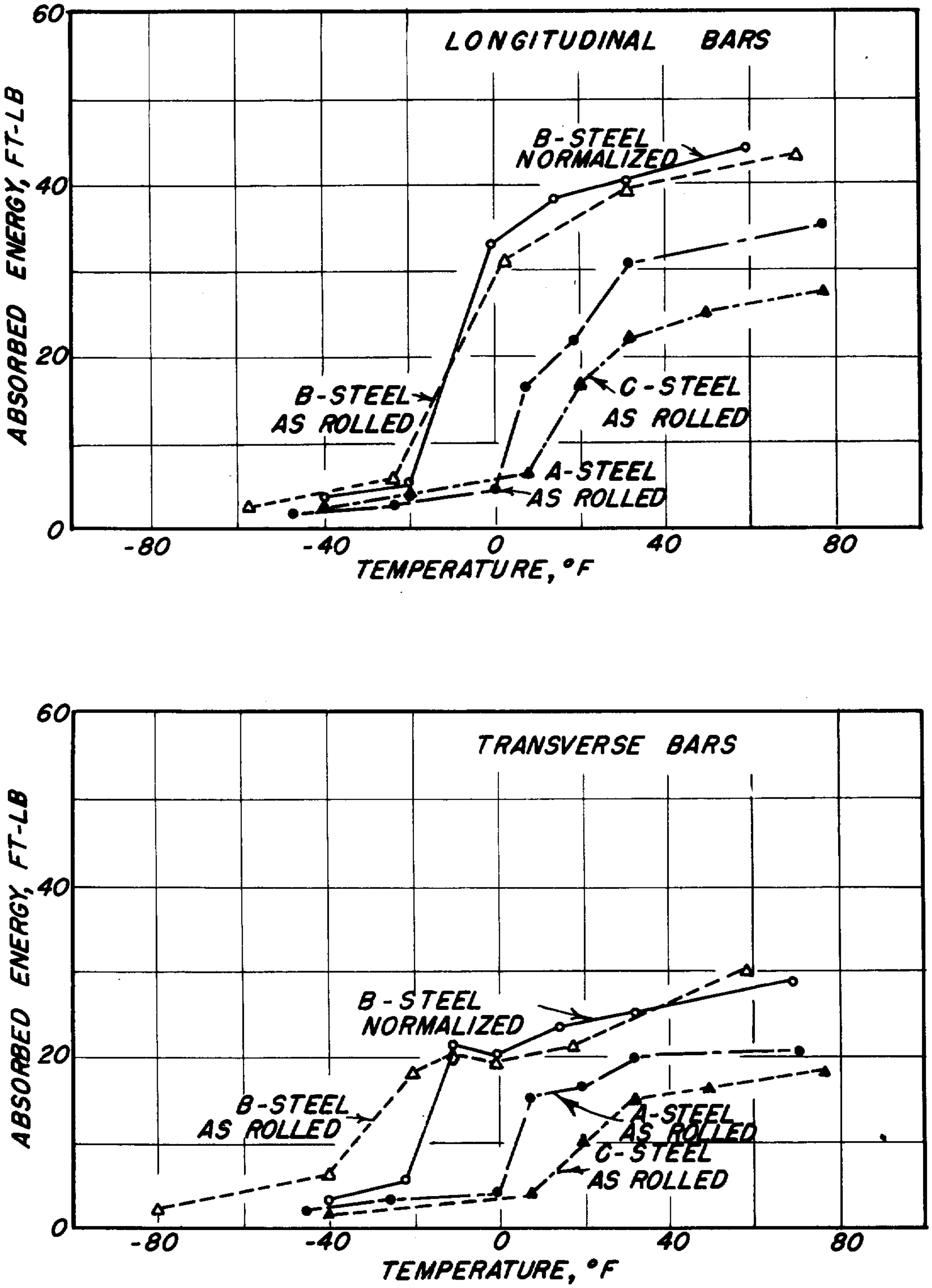


FIG. 11 COMPARISON OF RESULTS OF CHARPY IMPACT TESTS FOR STEELS A, B AND C

DIAGRAMS SELECTED TO REPRESENT TYPICAL RESULTS FOR EACH STEEL.

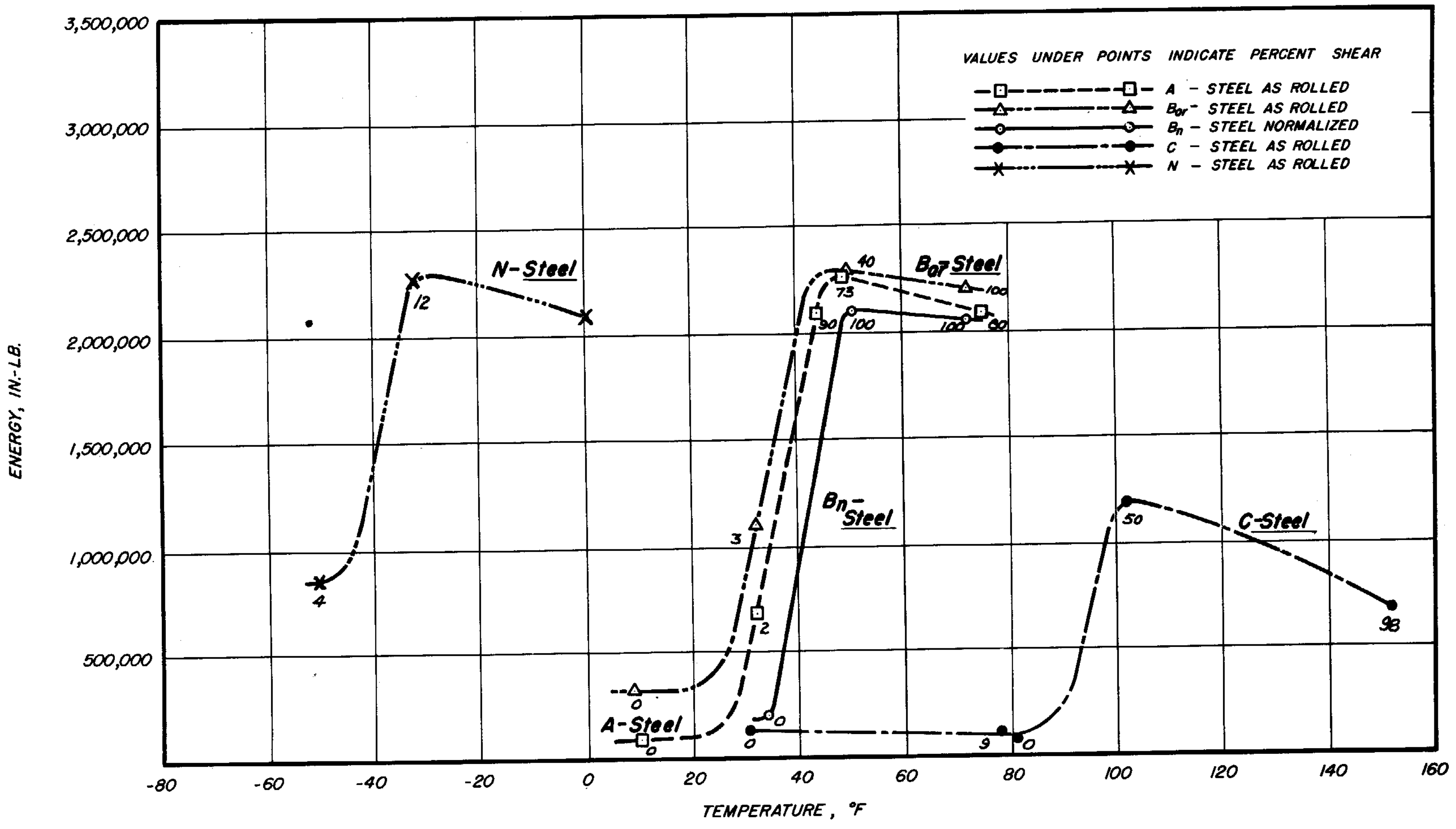


FIG. 12 - ESTIMATED VARIATION WITH TEMPERATURE OF ENERGY TO MAXIMUM LOAD FOR 72-INCH WIDE SPECIMENS.

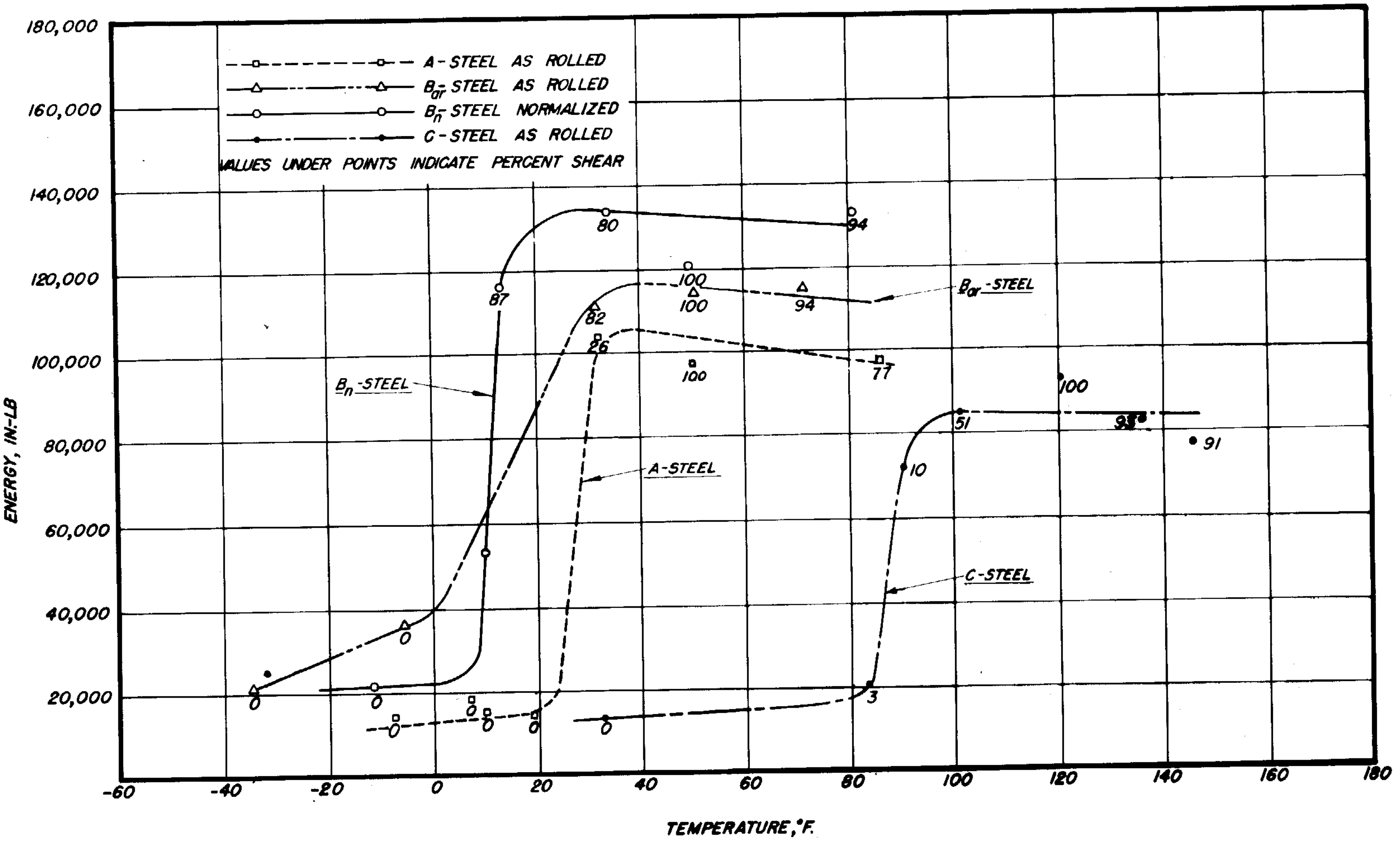


FIG. 13- ESTIMATED VARIATION WITH TEMPERATURE OF ENERGY TO MAXIMUM LOAD FOR 12-INCH WIDE SPECIMENS SEMI-KILLED STEELS

FIG. 13

DWG. 44E65

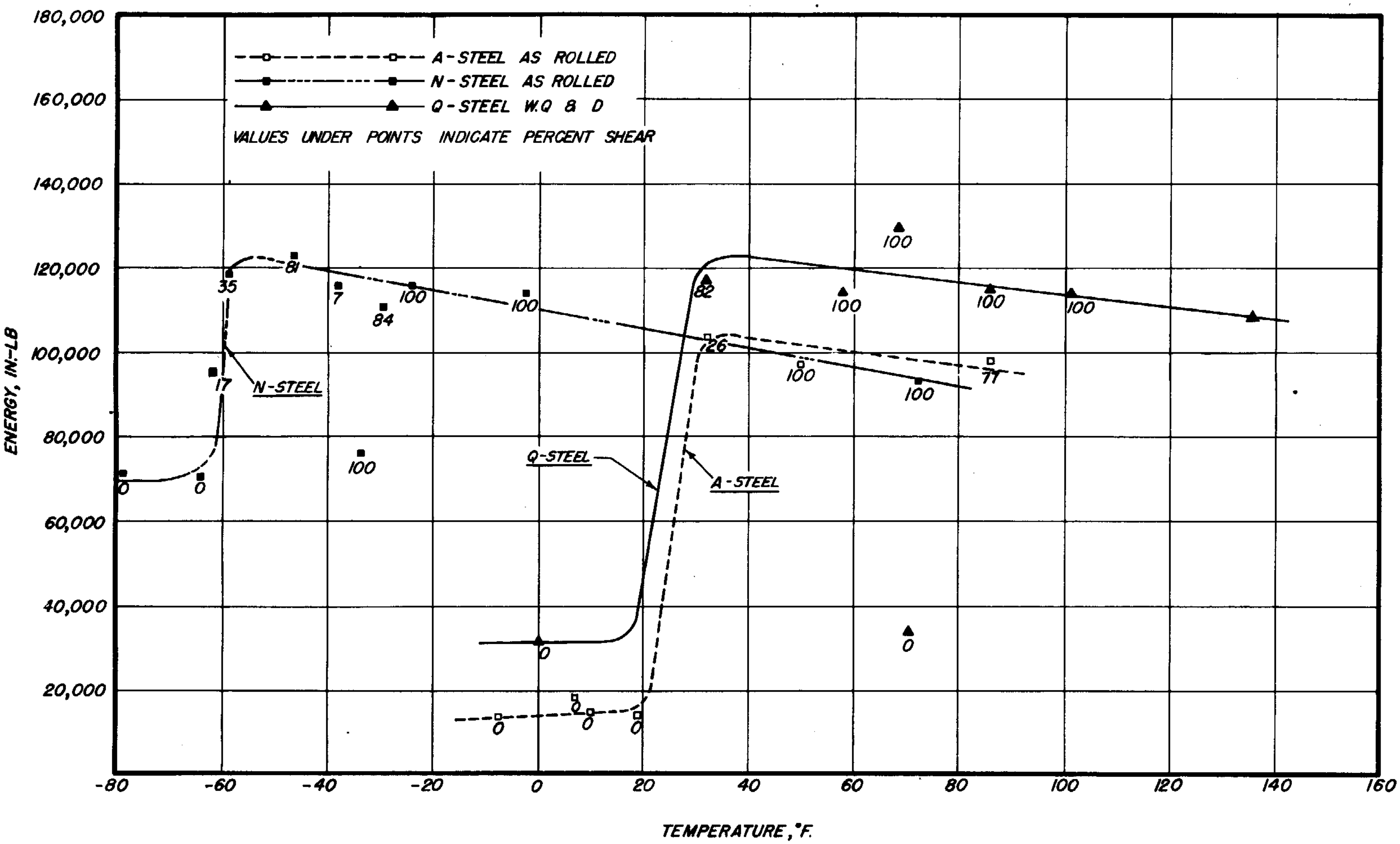


FIG. 14 - ESTIMATED VARIATION WITH TEMPERATURE OF ENERGY TO MAXIMUM LOAD FOR 12-INCH WIDE SPECIMENS

FIG. 14

44E65-1

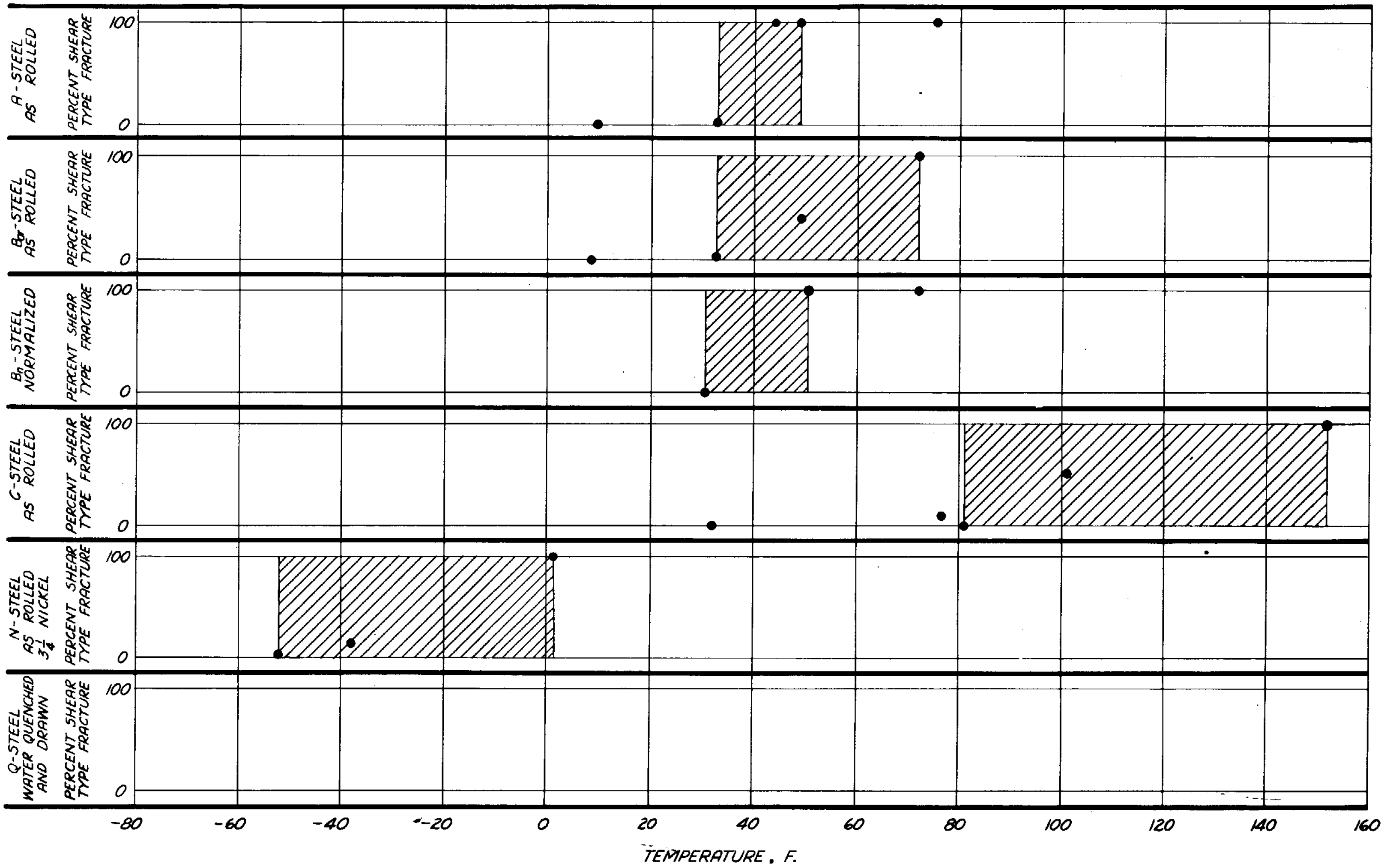


FIG. 15-TRANSITION TEMPERATURE RANGE, 72-INCH WIDE SPECIMENS

FIG. 15

44E66

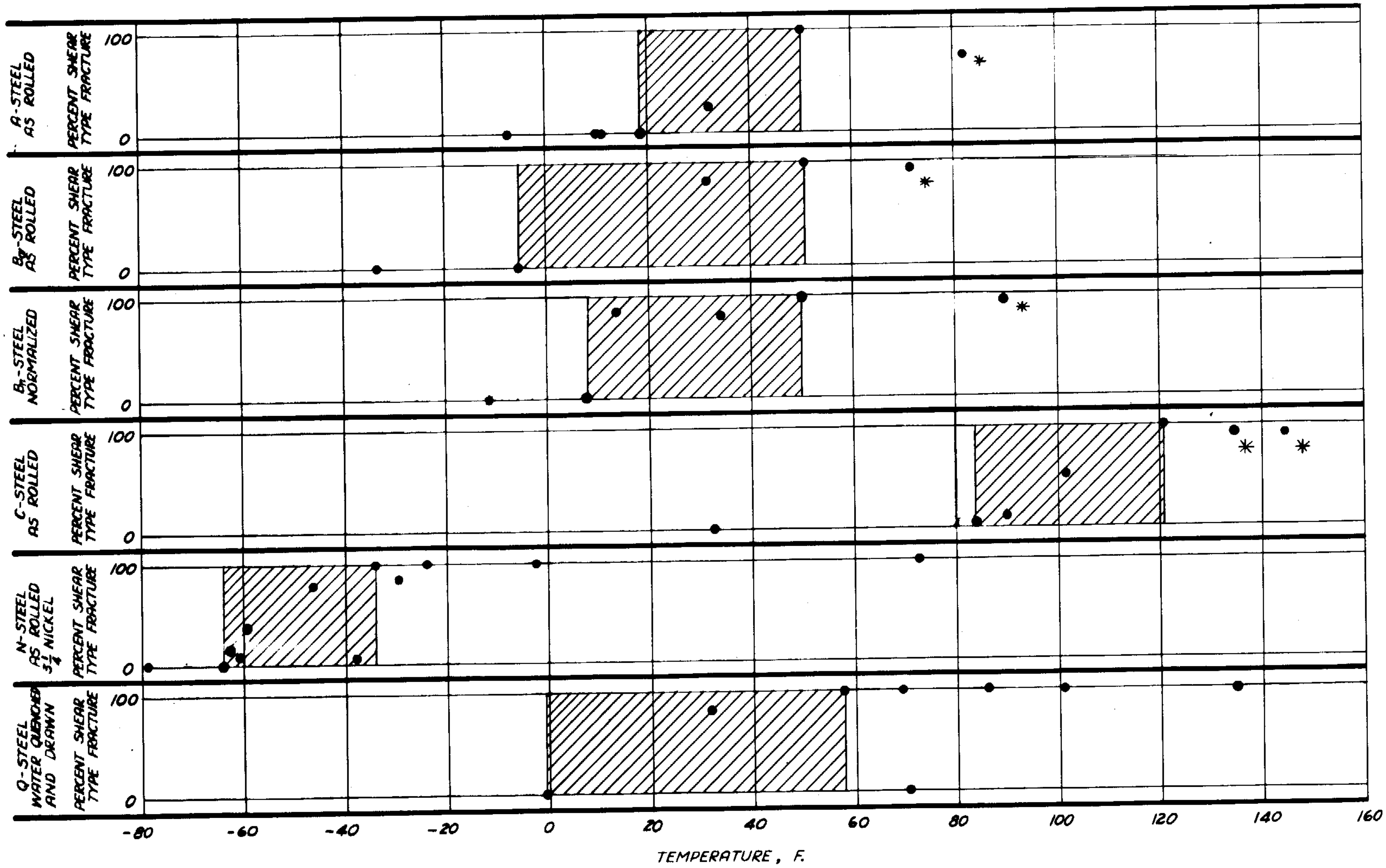


FIG. 16 - TRANSITION TEMPERATURE RANGE 12-INCH WIDE SPECIMENS

*NOTE: SPECIMENS SHOW SIGNS OF TEARING ACTION OCCURING AT ONE EDGE OF PLATE.

FIG. 16

44E69

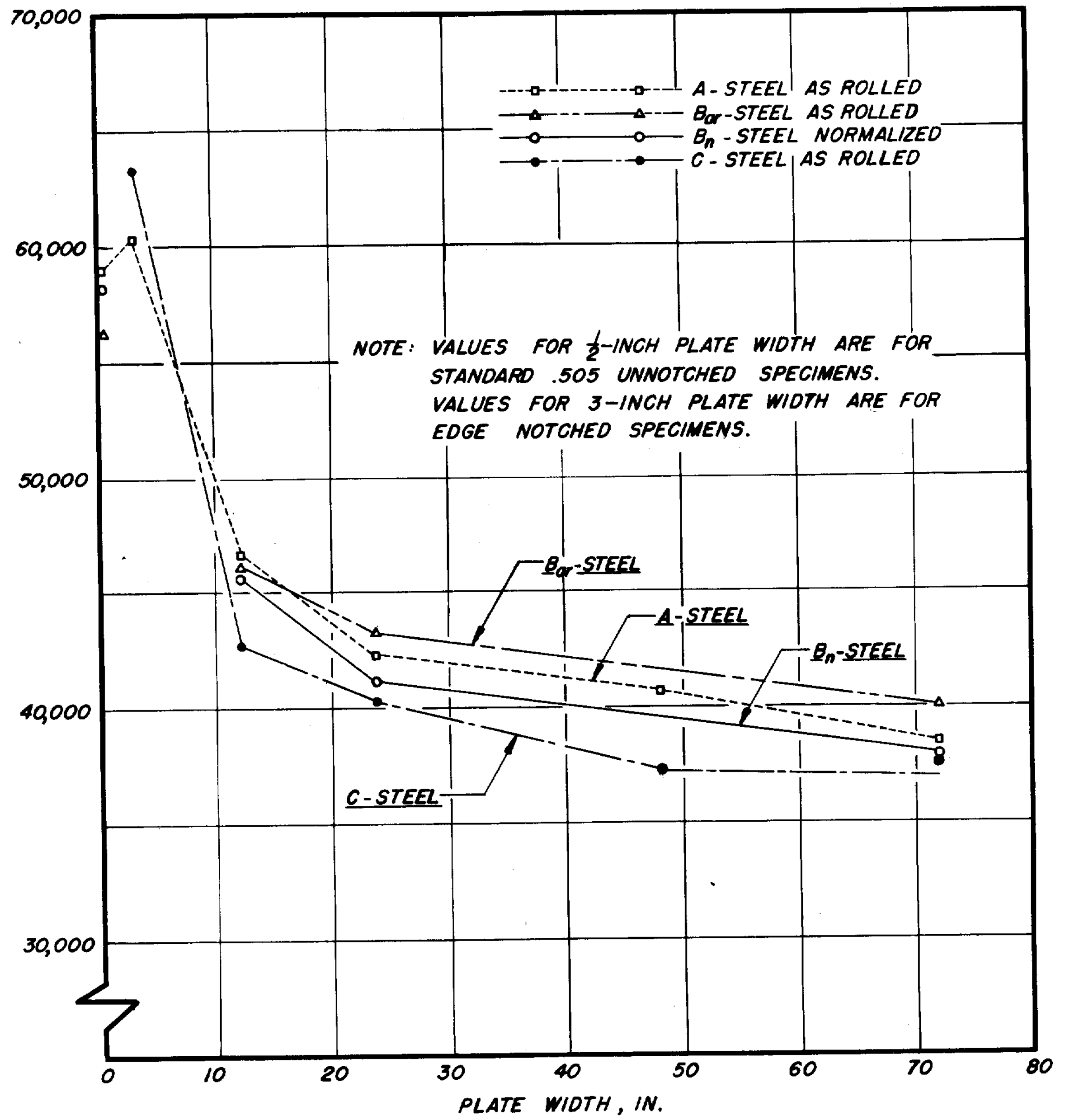


FIG. 17A - VARIATION IN NOMINAL STRESS WITH WIDTH OF PLATE—TESTS AT ROOM TEMPERATURE (70°F.)

44E76

FIG. 17A

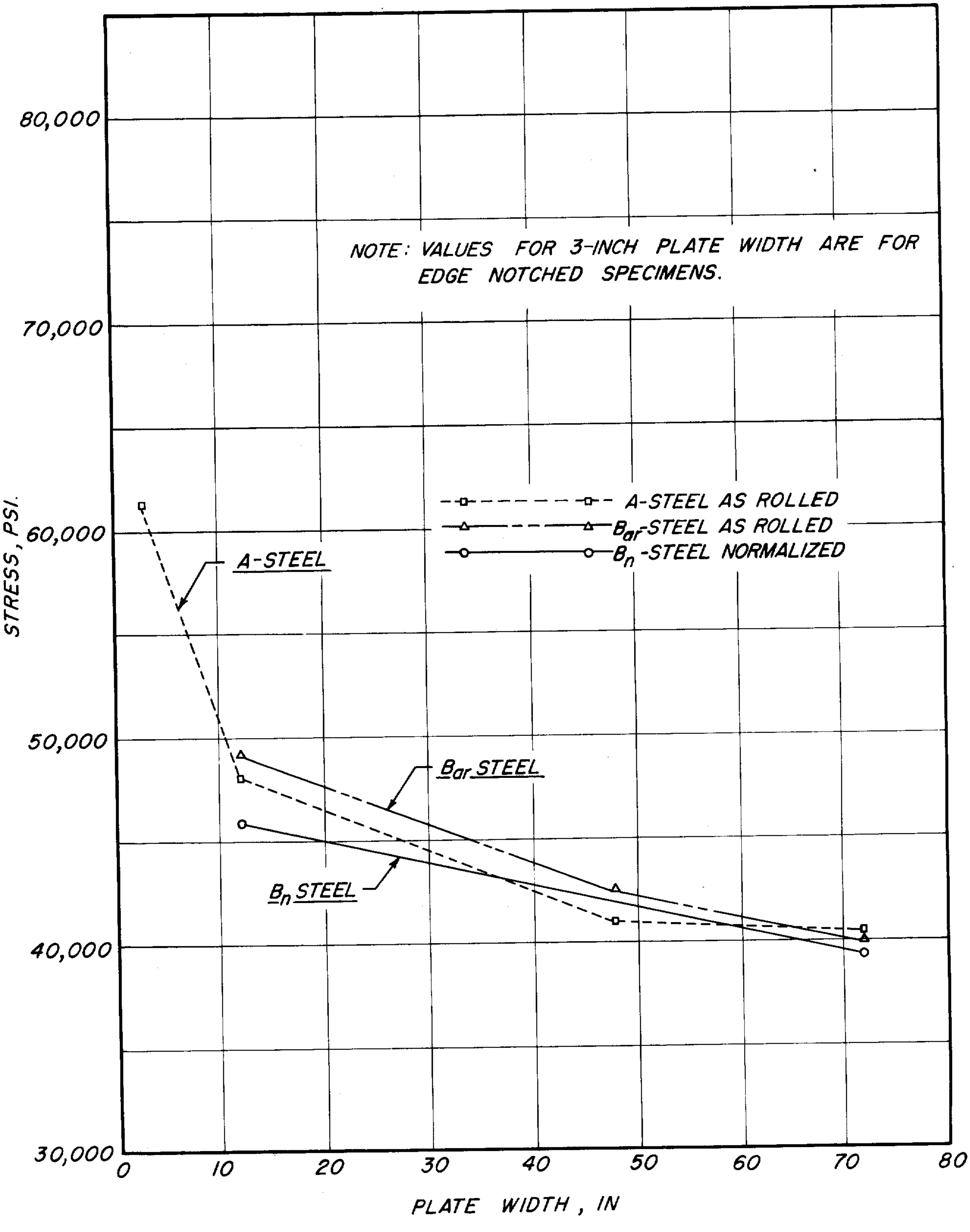


FIG. 17B - VARIATION IN NOMINAL STRESS WITH WIDTH OF PLATE — TESTS AT 50° F.

DWG. 44E78

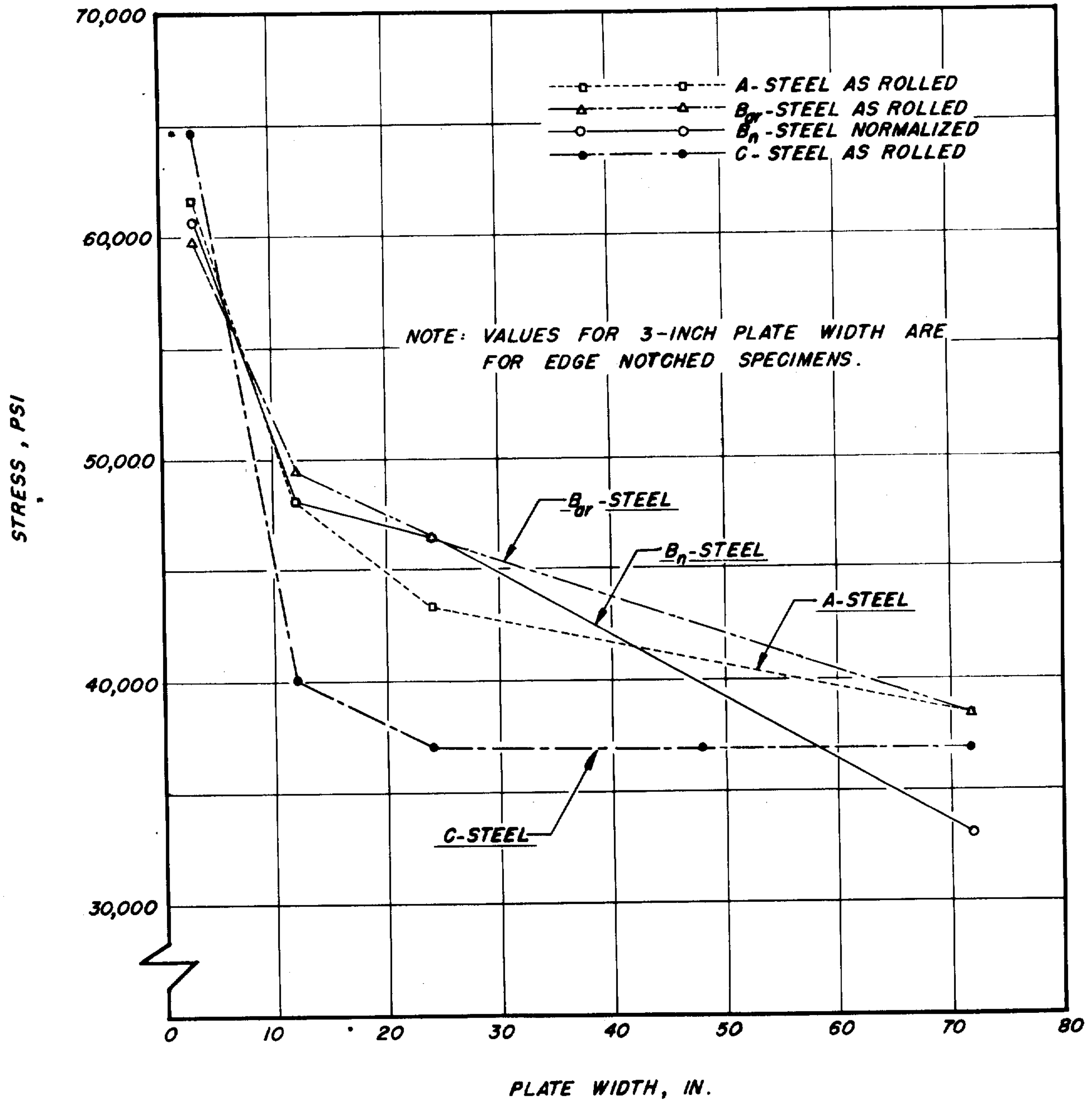


FIG. 17C-VARIATION IN NOMINAL STRESS WITH WIDTH OF PLATE—TESTS AT 32° F.

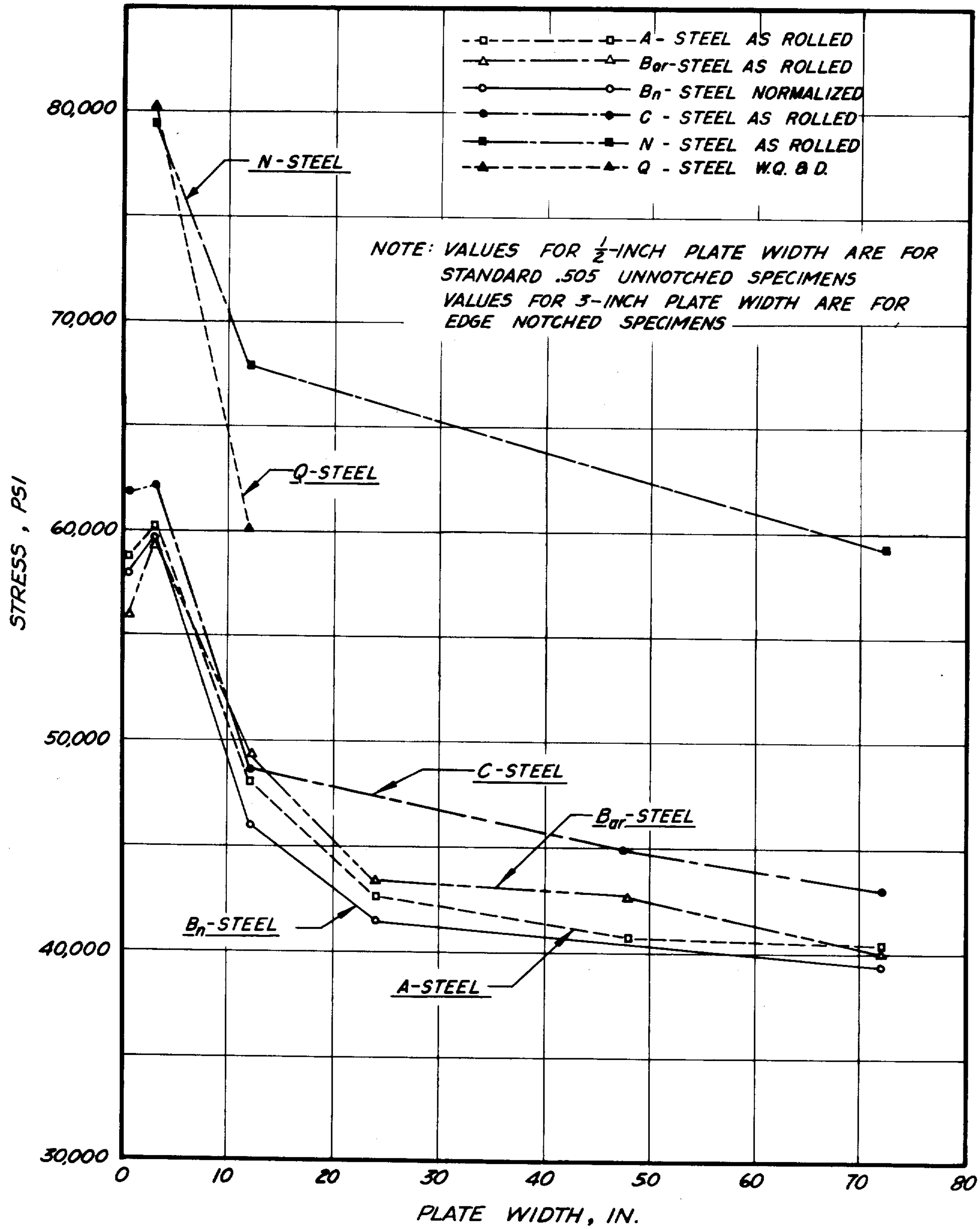


FIG. 18 - VARIATION IN NOMINAL STRESS WITH WIDTH OF PLATE FOR SHEAR TYPE FRACTURE.

THE SPECIMENS WERE TESTED AT THE LOWEST TEMPERATURE THAT GAVE 100% SHEAR FRACTURE.

44E75

FIG. 18

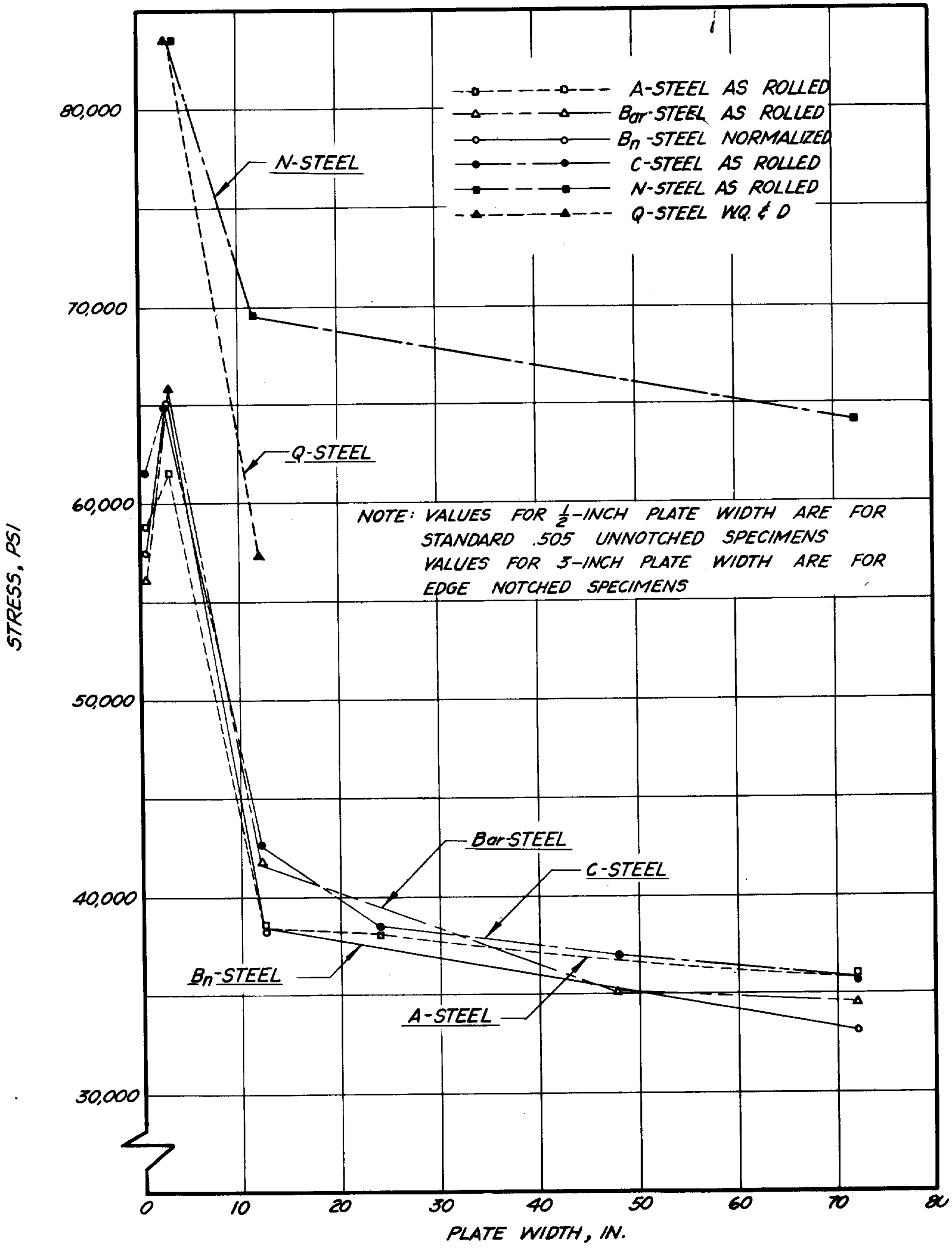


FIG. 19 - VARIATION IN NOMINAL STRESS WITH WIDTH OF PLATE FOR CLEAVAGE TYPE FRACTURE. THE SPECIMENS WERE TESTED AT THE HIGHEST TEMPERATURE THAT GAVE 100% CLEAVAGE FRACTURE.

44E82

FIG. 19

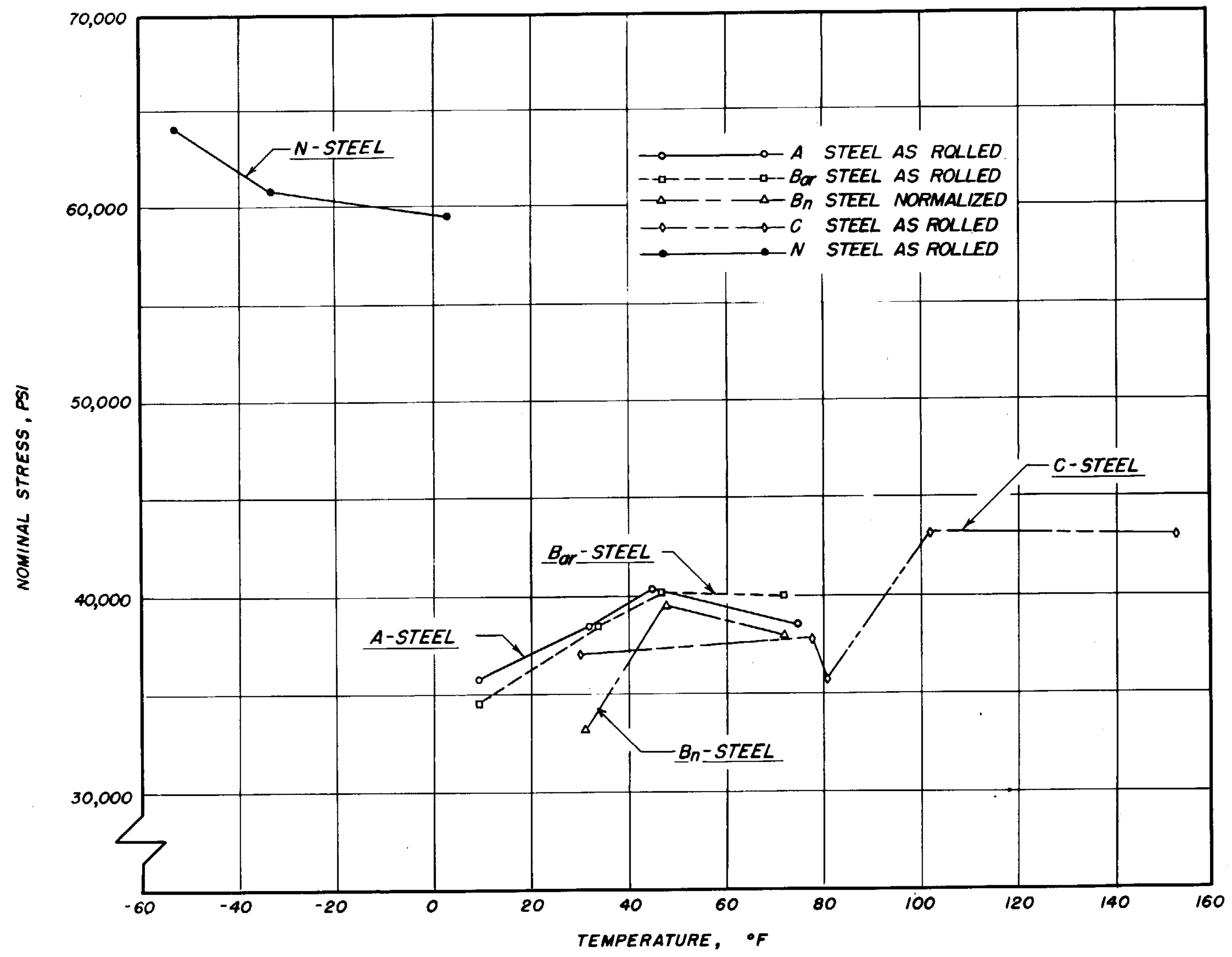


FIG. 20 VARIATION IN NOMINAL STRESS WITH TEMPERATURE FOR 72-INCH WIDE SPECIMENS

FIG. 20

DWG 44E165

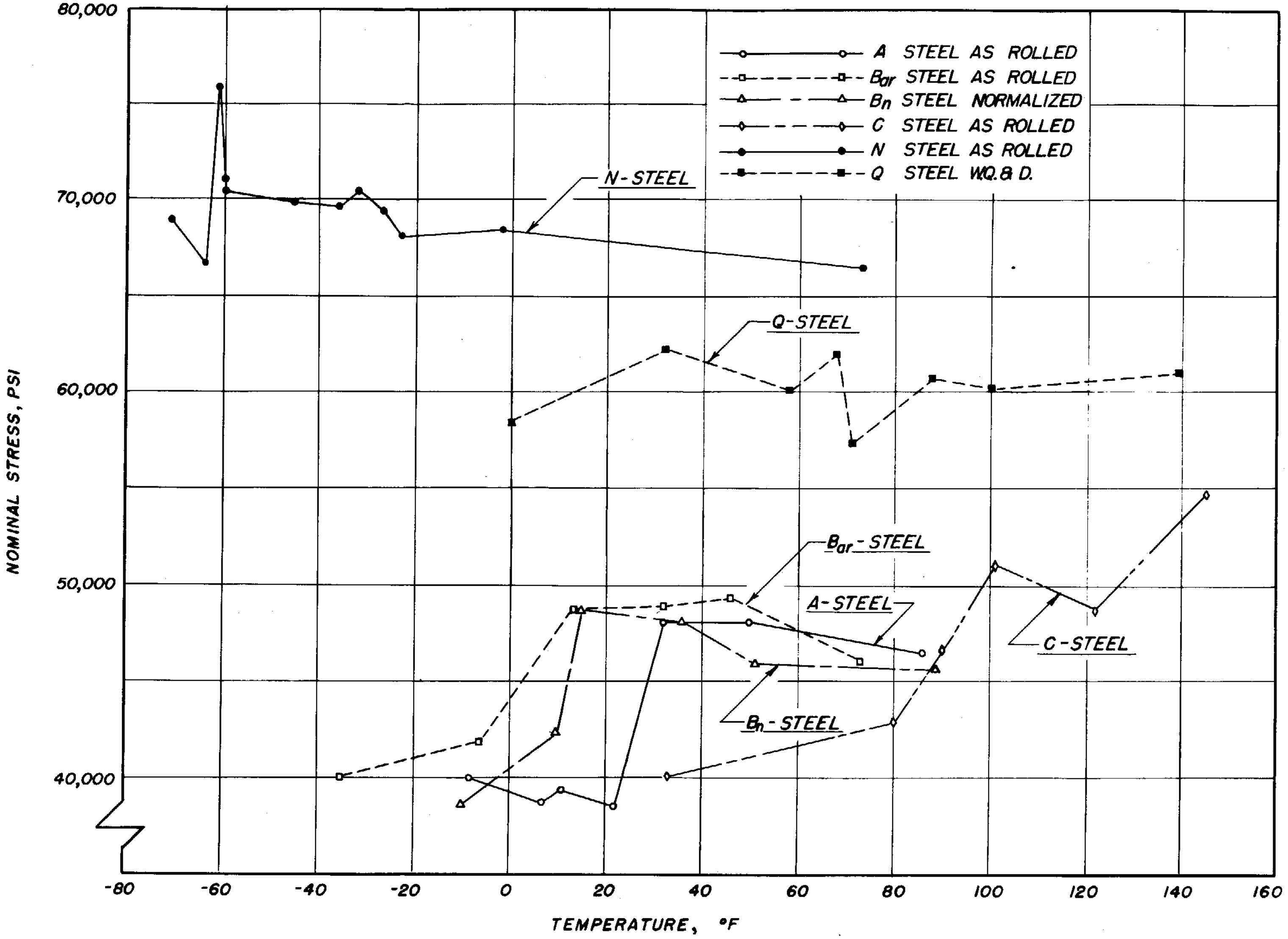


FIG. 21 VARIATION IN NOMINAL STRESS WITH TEMPERATURE FOR 12-INCH WIDE SPECIMENS

FIG. 21

DWG. 44E166

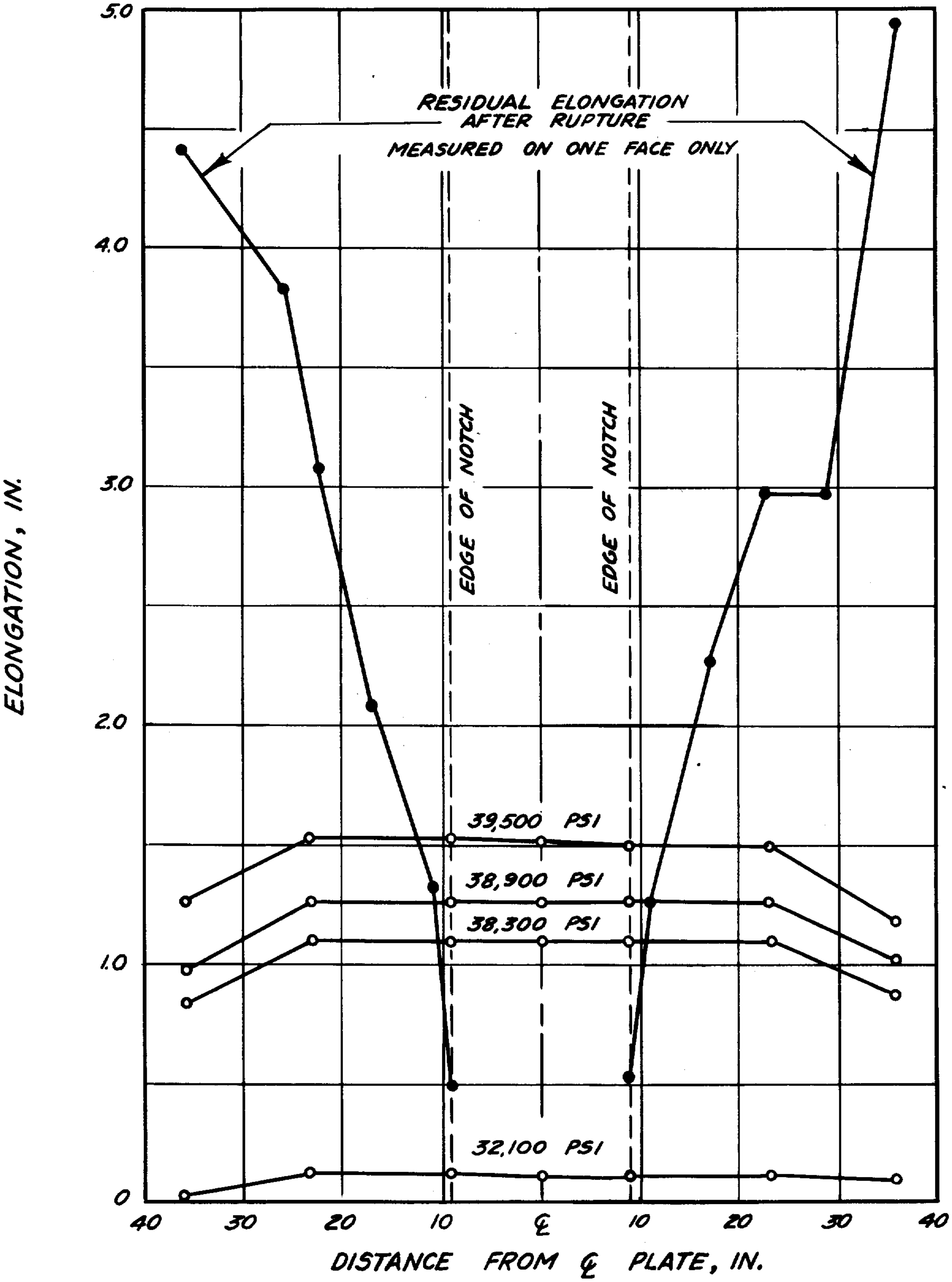


FIG. 22—TYPICAL ELONGATIONS AT VARIOUS STRESS LEVELS, SHEAR TYPE FAILURE, 72-INCH WIDE SPECIMEN

GAGE LENGTH – $\frac{3}{4}$ PLATE WIDTH
(SPECIMEN B-5A)

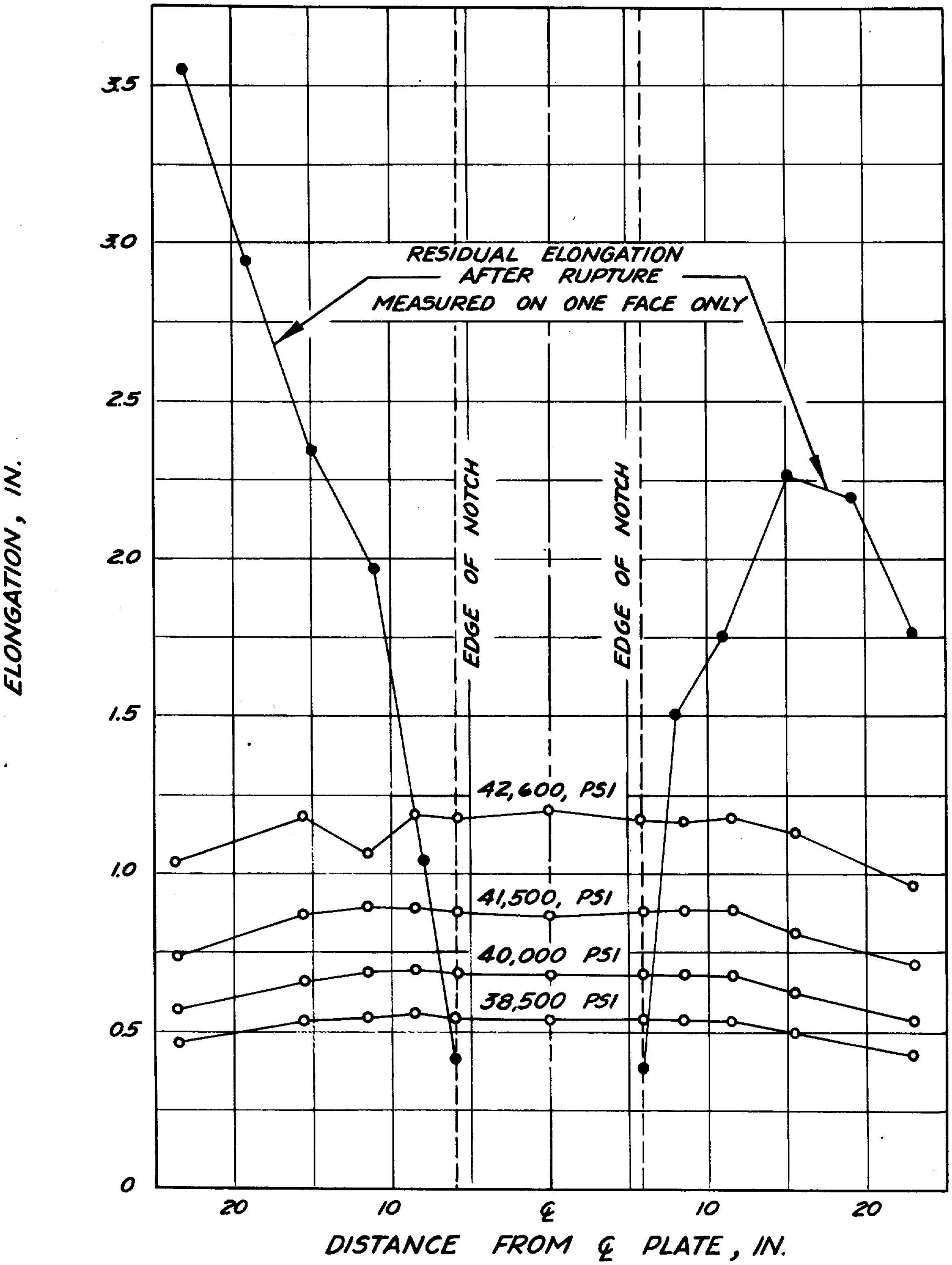


FIG. 23–TYPICAL ELONGATIOMS AT VARIOUS STRESS LEVELS, SHEAR TYPE FAILURE, 48-INCH WIDE SPECIMEN
GAGE LENGTH – $\frac{3}{4}$ PLATE WIDTH
(SPECIMEN B-6B)

44E156

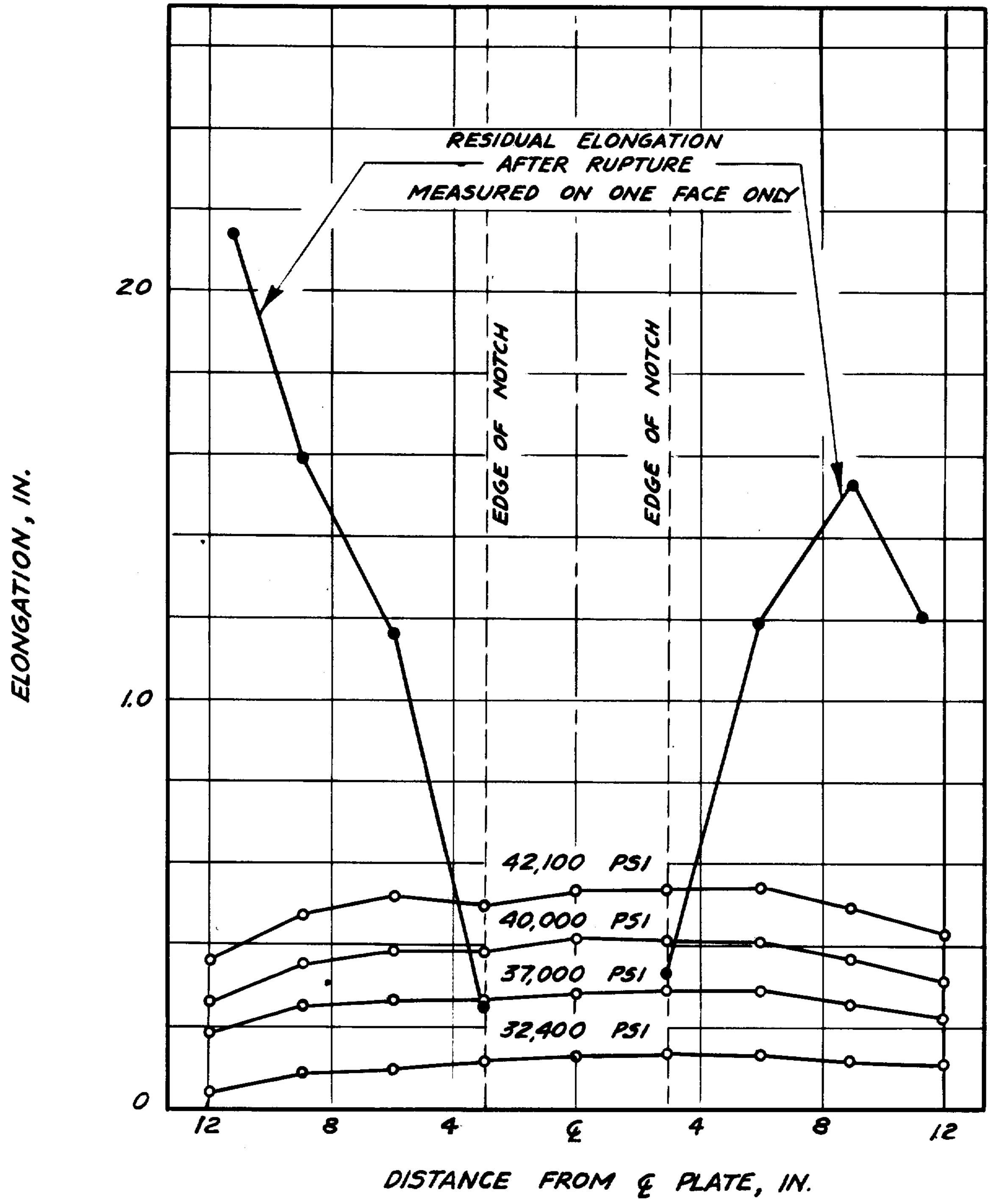


FIG. 24-TYPICAL ELONGATIONS AT VARIOUS STRESS LEVELS, SHEAR TYPE FAILURE, 24-INCH WIDE SPECIMEN
GAGE LENGTH – $\frac{3}{4}$ PLATE WIDTH
(SPECIMEN B-3C)

44E157

FIG. 24

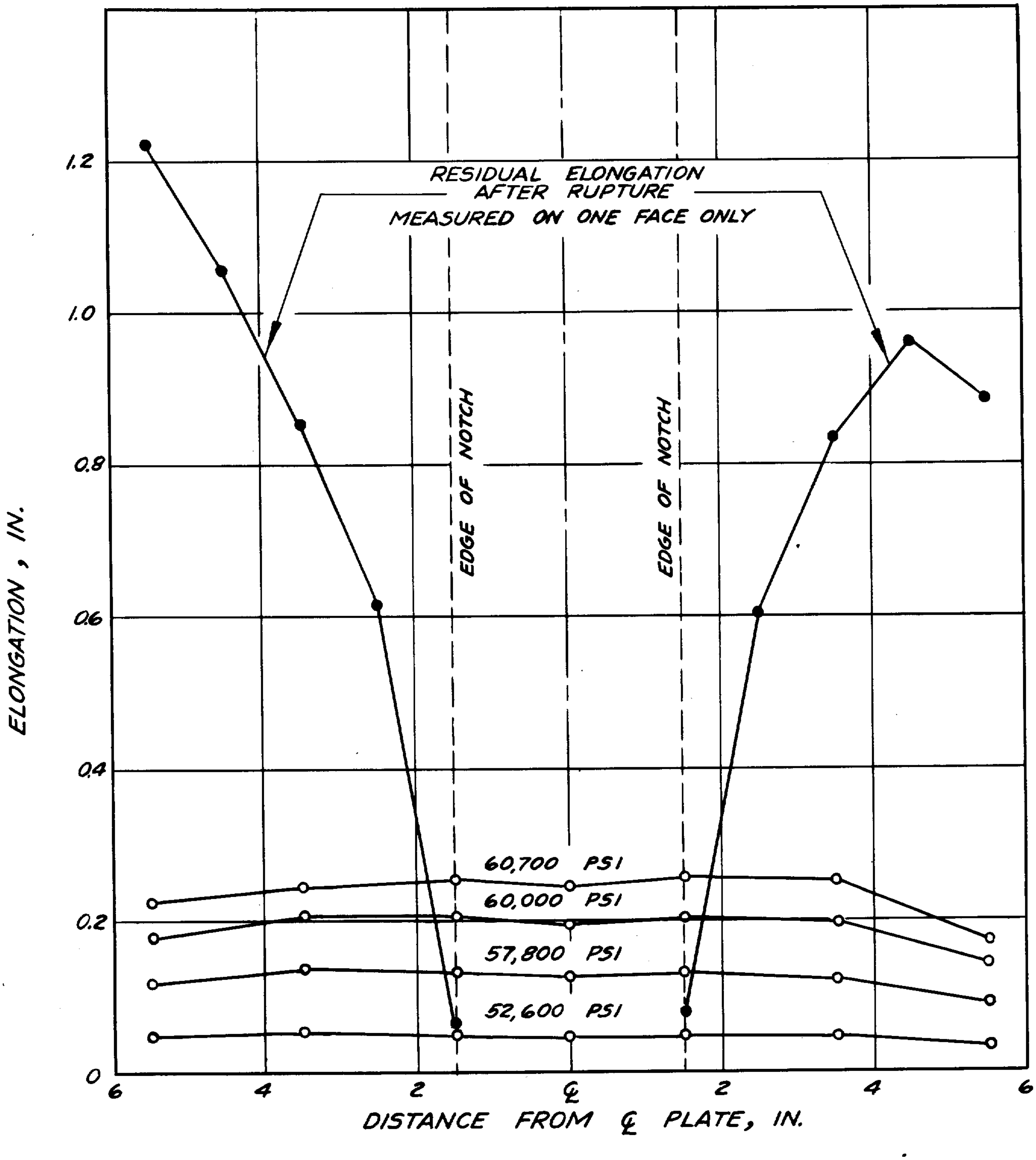


FIG. 25–TYPICAL ELONGATIONS AT VARIOUS STRESS LEVELS, SHEAR TYPE FAILURE, 12-INCH WIDE SPECIMEN GAGE LENGTH-$\frac{3}{4}$ PLATE WIDTH.

(SPECIMEN Q-2D)

DWG. 44E162

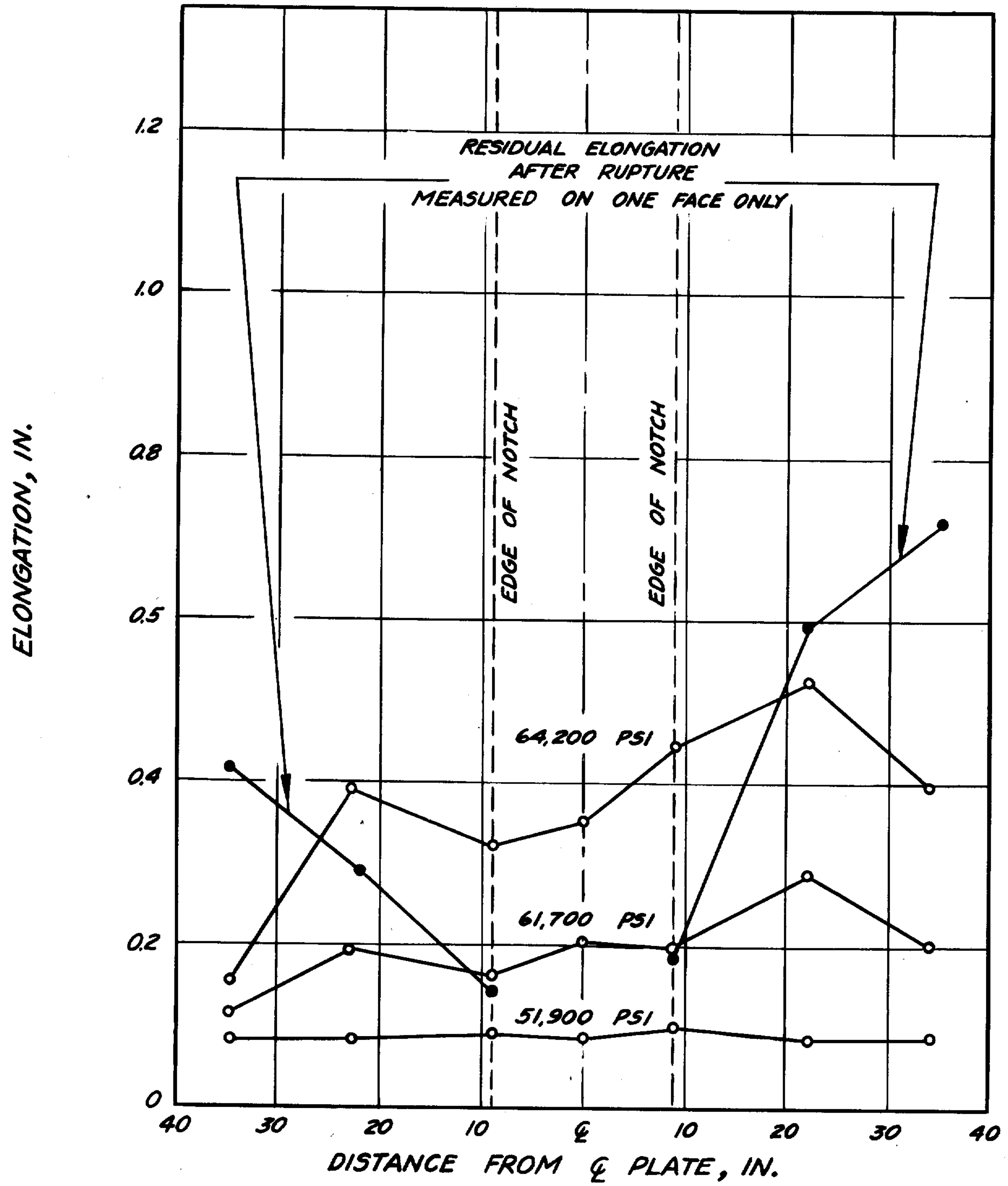


FIG. 26–TYPICAL ELONGATIONS AT VARIOUS STRESS LEVELS, CLEAVAGE TYPE FAILURE, 72-INCH WIDE SPECIMEN

GAGE LENGTH – $\frac{3}{4}$ PLATE WIDTH

(SPECIMEN N-1A)

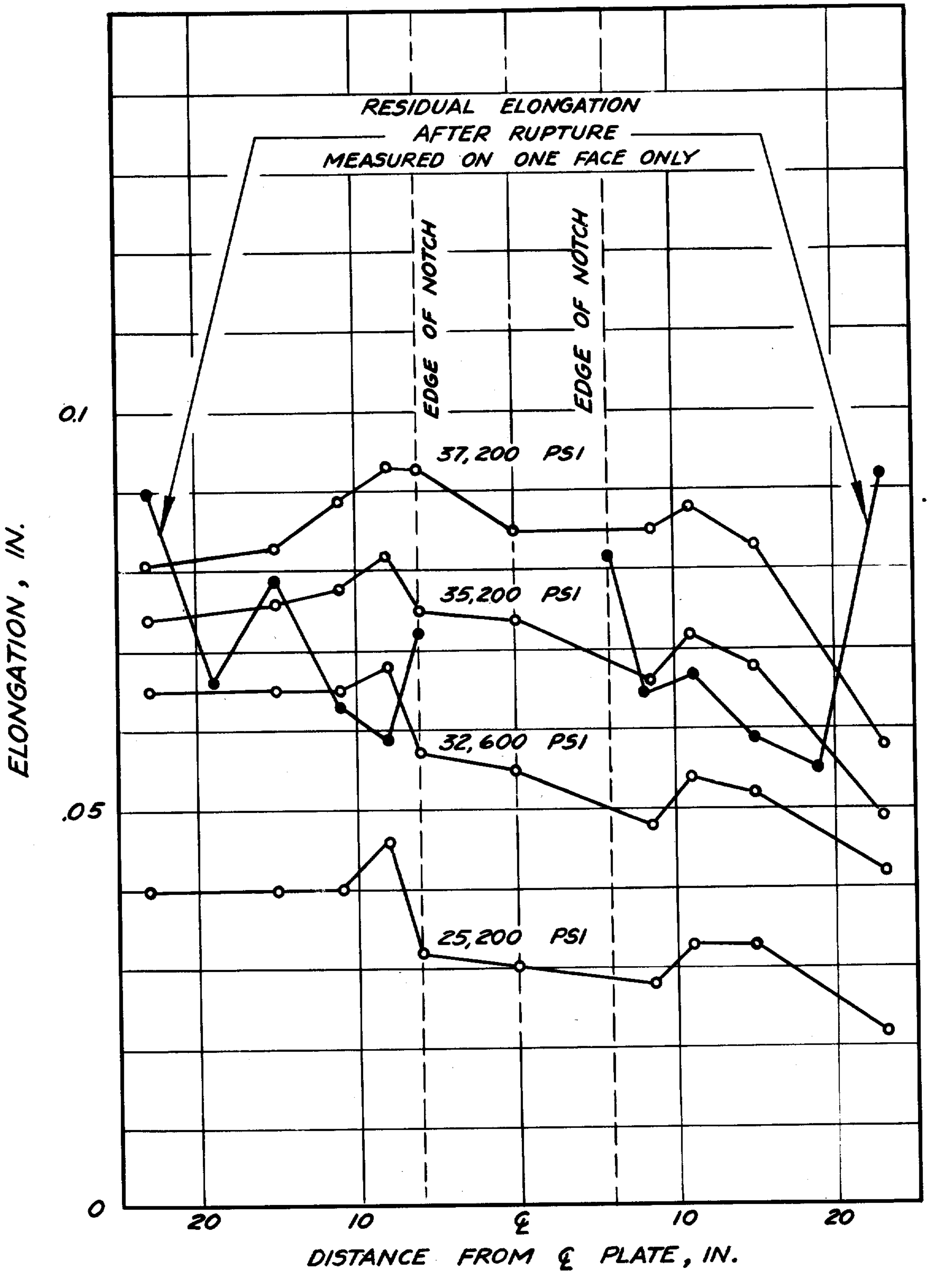


FIG. 27—TYPICAL ELONGATIONS AT VARIOUS STRESS LEVELS, CLEAVAGE TYPE FAILURE, 48-INCH WIDE SPECIMEN
GAGE LENGTH – $\frac{3}{4}$ PLATE WIDTH
(SPECIMEN C-4B)

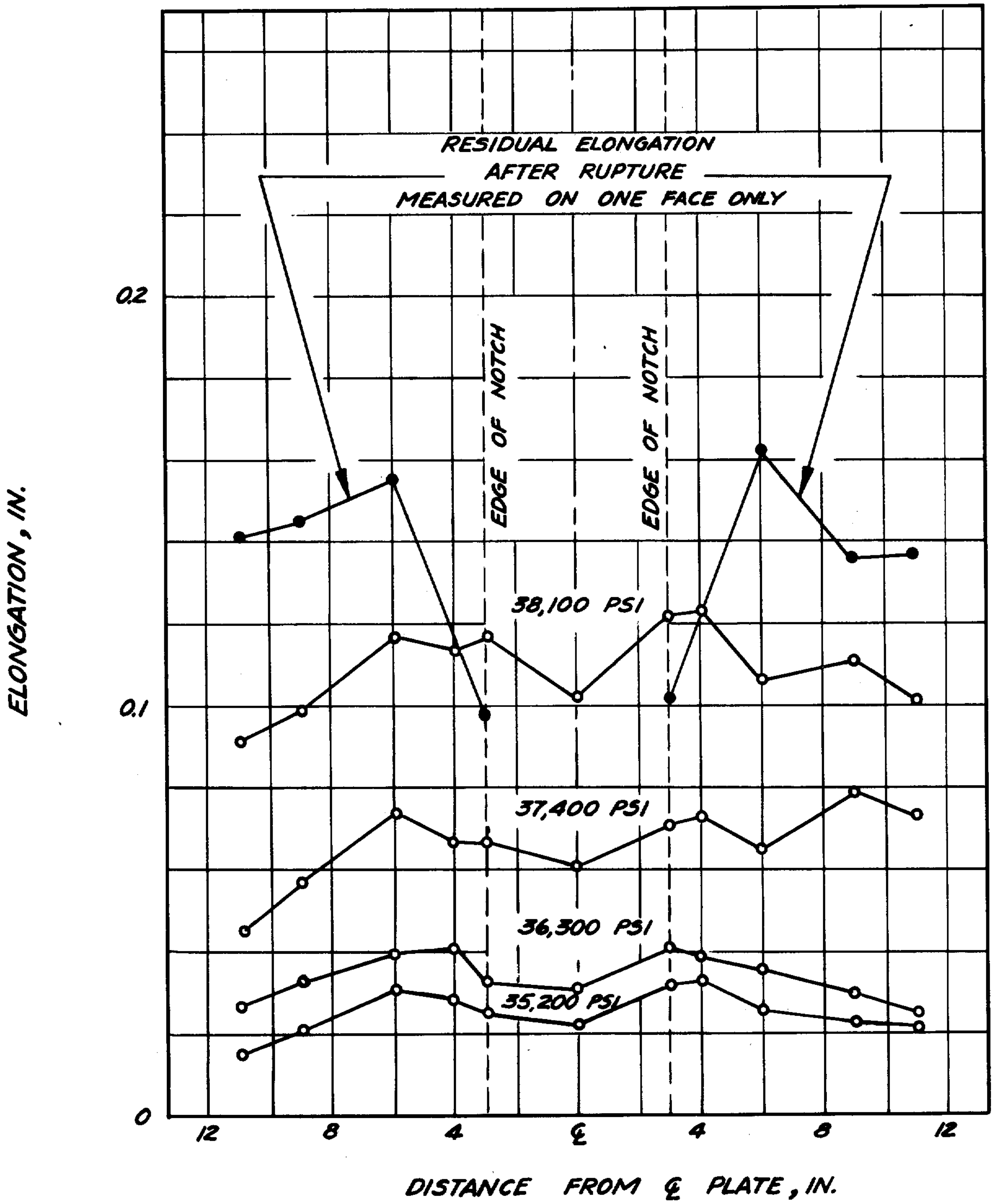


FIG. 28–TYPICAL ELONGATIONS AT VARIOUS STRESS LEVELS, CLEAVAGE TYPE FAILURE, 24-INCH WIDE SPECIMEN

GAGE LENGTH – $\frac{3}{4}$ PLATE WIDTH

(SPECIMEN A-3C)

44E160

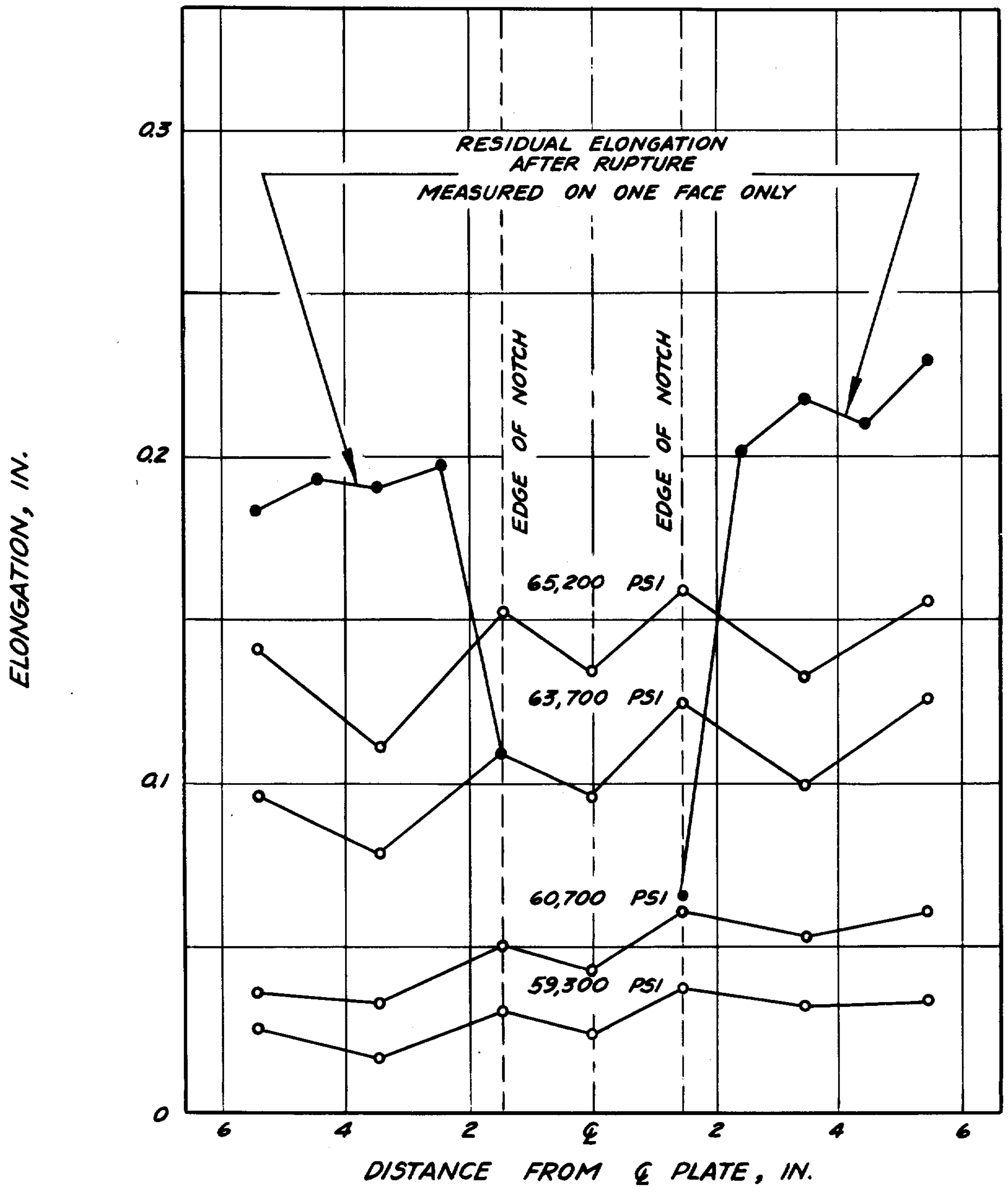


FIG. 29—TYPICAL ELONGATIONS AT VARIOUS STRESS LEVELS, CLEAVAGE TYPE FAILURE, 12-INCH WIDE SPECIMEN

GAGE LENGTH - $\frac{3}{4}$ PLATE WIDTH

(SPECIMEN N-15XD)

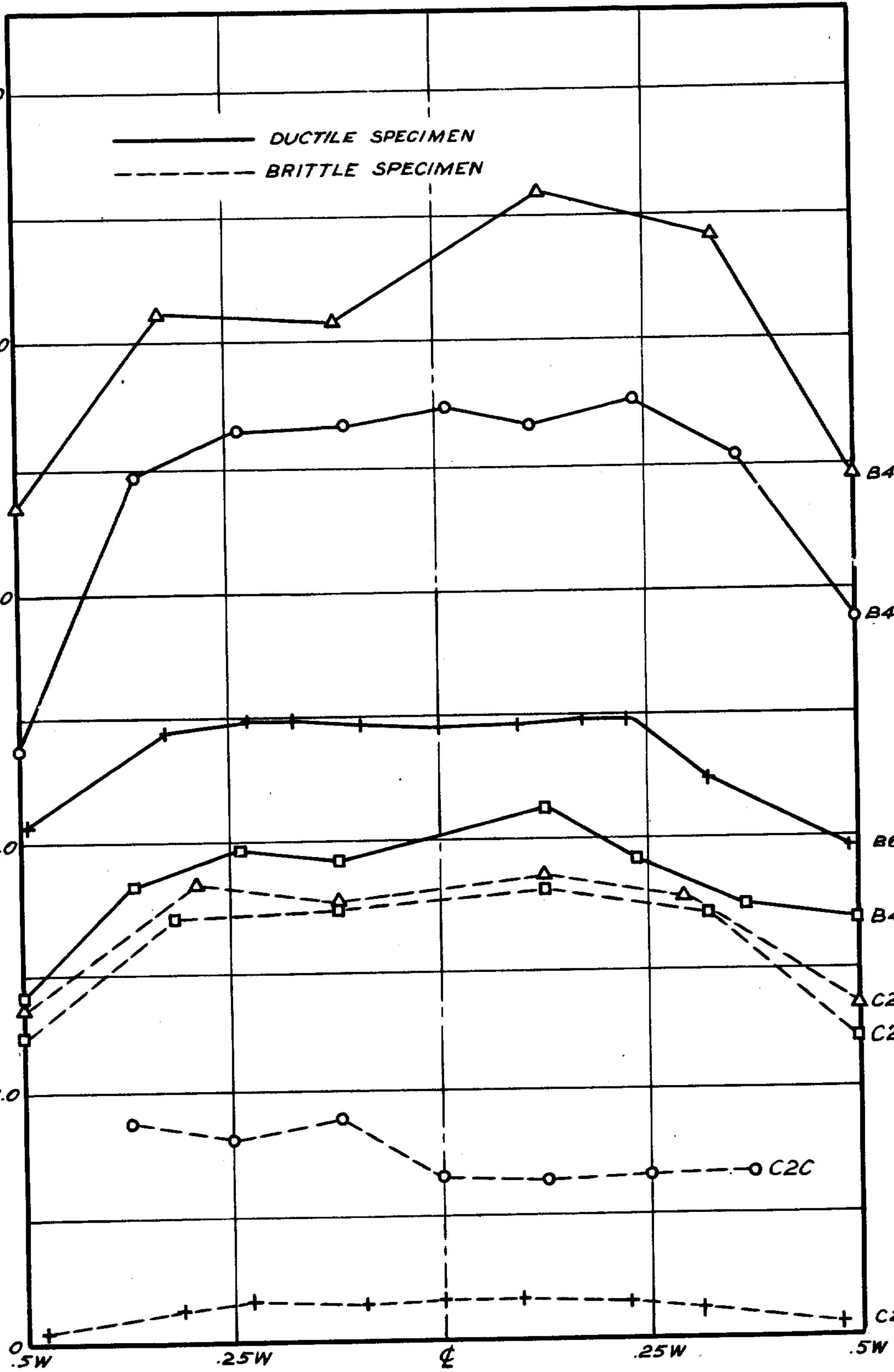


FIG. 30 - ELONGATION AT MAXIMUM LOAD, ILLUSTRATING INFLUENCE OF PLATE WIDTH ON DUCTILITY AT MAXIMUM LOAD

ELONGATION MEASURED BY RESISTANCE WIRE EXTENSOMETERS
SPECIMENS B4A AND C2A ARE 72-IN. WIDE
SPECIMENS B6B AND C2B ARE 48-IN. WIDE
SPECIMENS B4C AND C2C ARE 24-IN. WIDE
SPECIMENS B4D AND C2D ARE 12-IN. WIDE
GAGE LENGTH - $\frac{3}{4}$ PLATE WIDTH

DWG. 44E24

FIG. 30

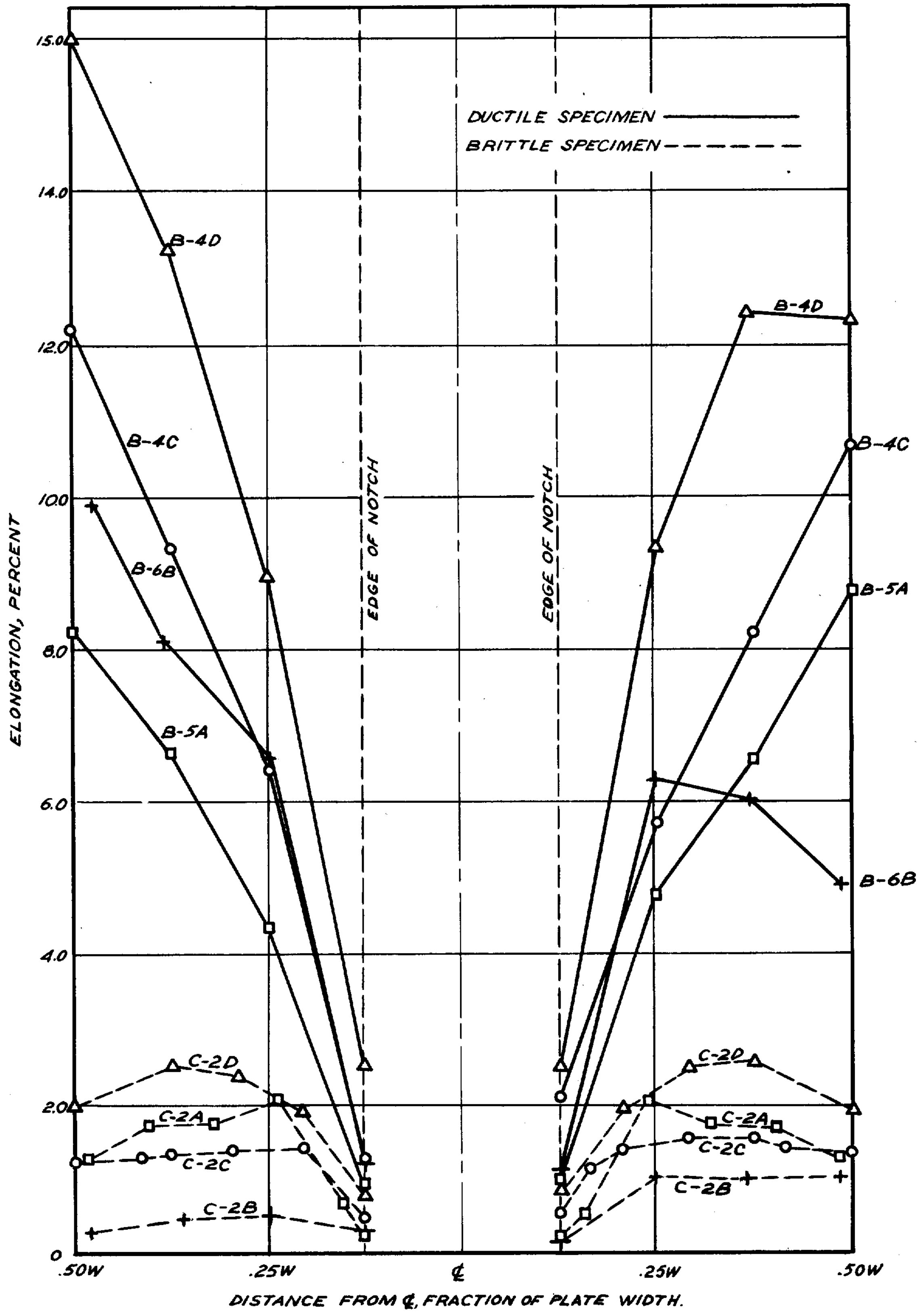


FIG. 31 - RESIDUAL ELONGATION AFTER RUPTURE, ILLUSTRATING INFLUENCE OF PLATE WIDTH ON DUCTILITY AT FAILURE.

ELONGATIONS MEASURED ON ONE FACE ONLY
GAGE LENGTH - $\frac{3}{4}$ PLATE WIDTH

DWG. 44E23

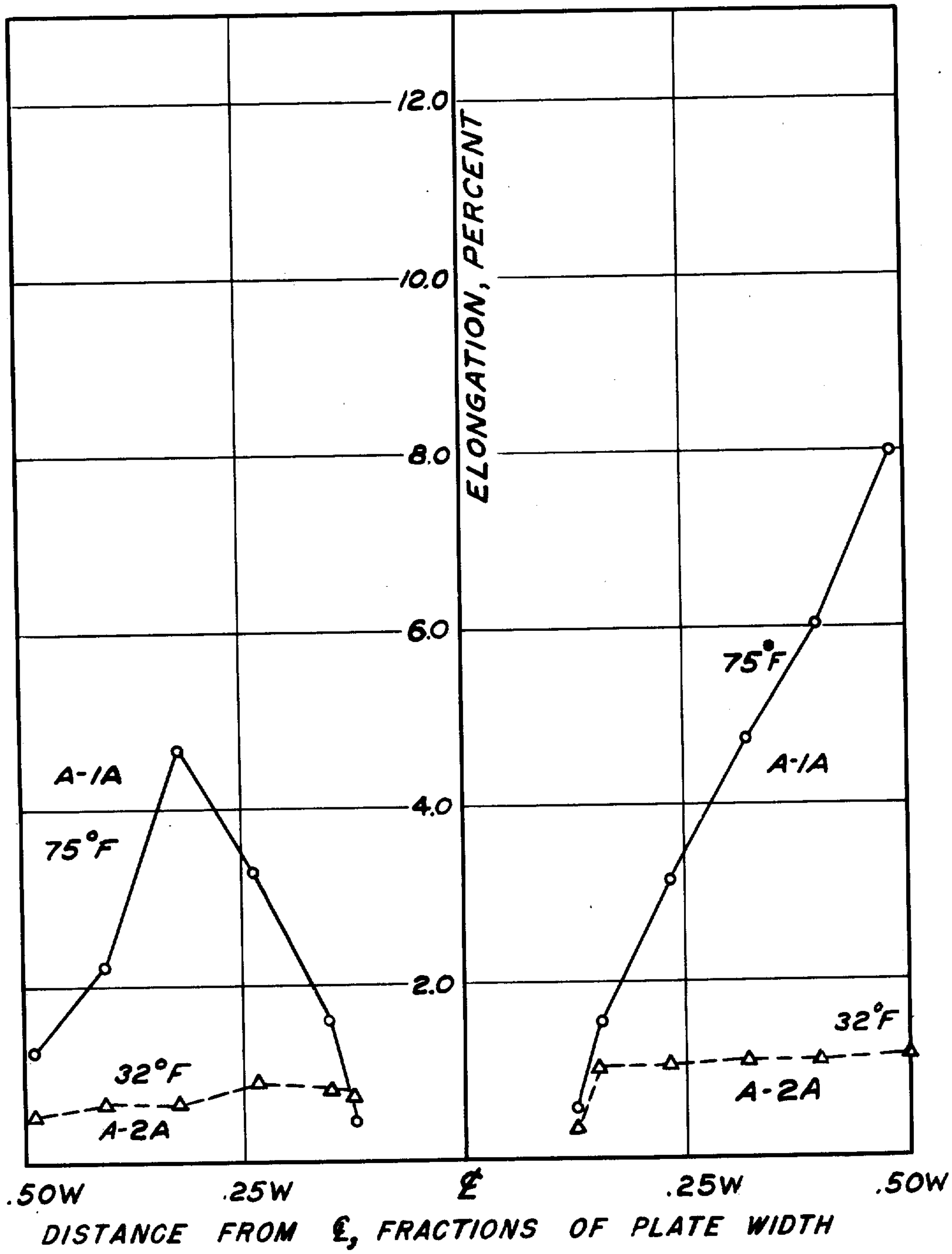


FIG. 32-RESIDUAL ELONGATION AFTER RUPTURE IN 72-INCH WIDE SPECIMEN, ILLUSTRATING EFFECT OF TEMPERATURE ON DUCTILITY AT FAILURE

ELONGATION MEASURED ON ONE FACE ONLY

GAGE LENGTH - $\frac{3}{4}$ PLATE WIDTH

DWG. 44E151

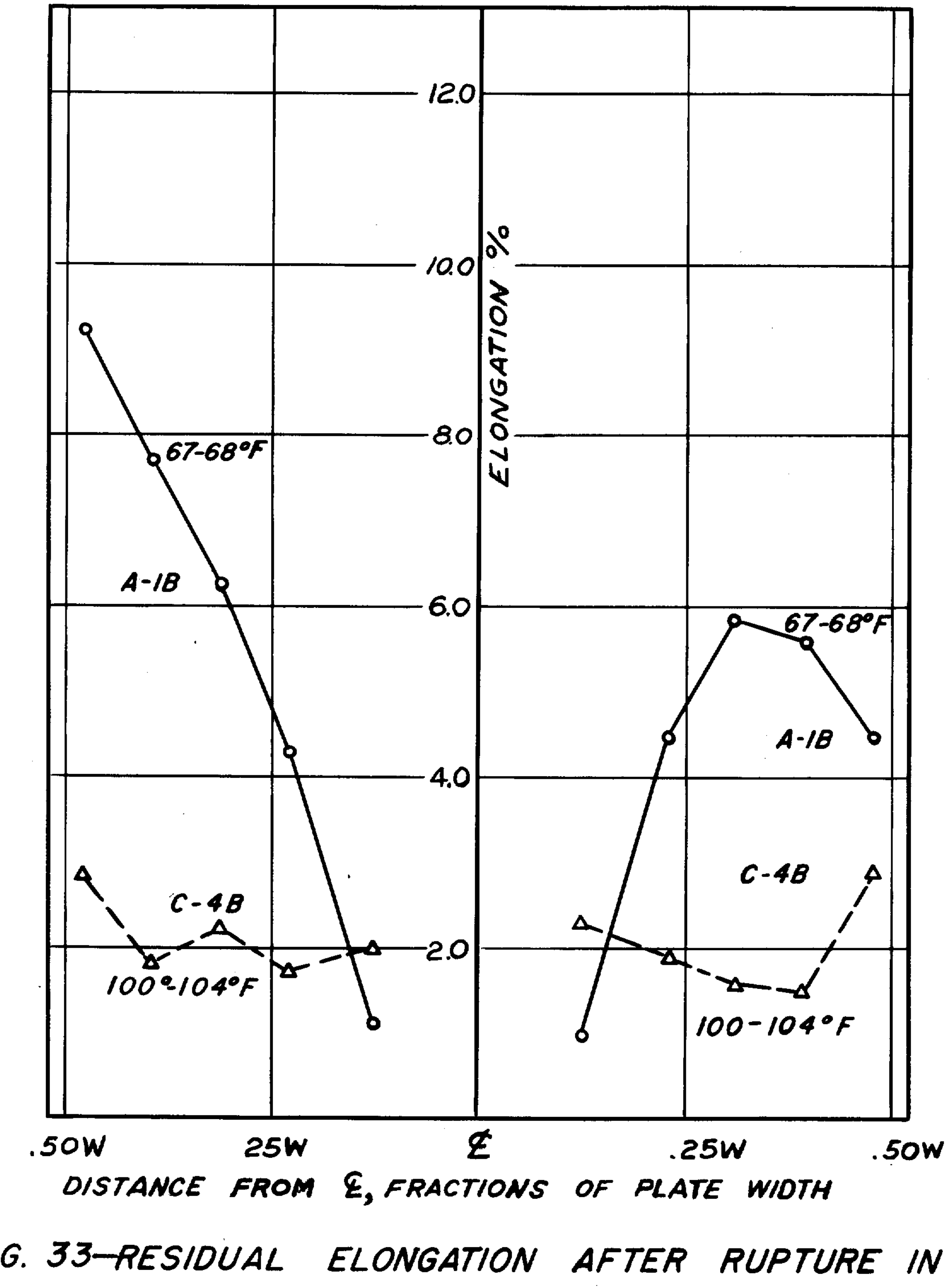


FIG. 33—RESIDUAL ELONGATION AFTER RUPTURE IN 48-INCH WIDE SPECIMEN, ILLUSTRATING EFFECT OF TEMPERATURE ON DUCTILITY AT FAILURE
ELONGATION MEASURED ON ONE FACE ONLY
GAGE LENGTH - $\frac{3}{4}$ PLATE WIDTH

DWG. 44E152

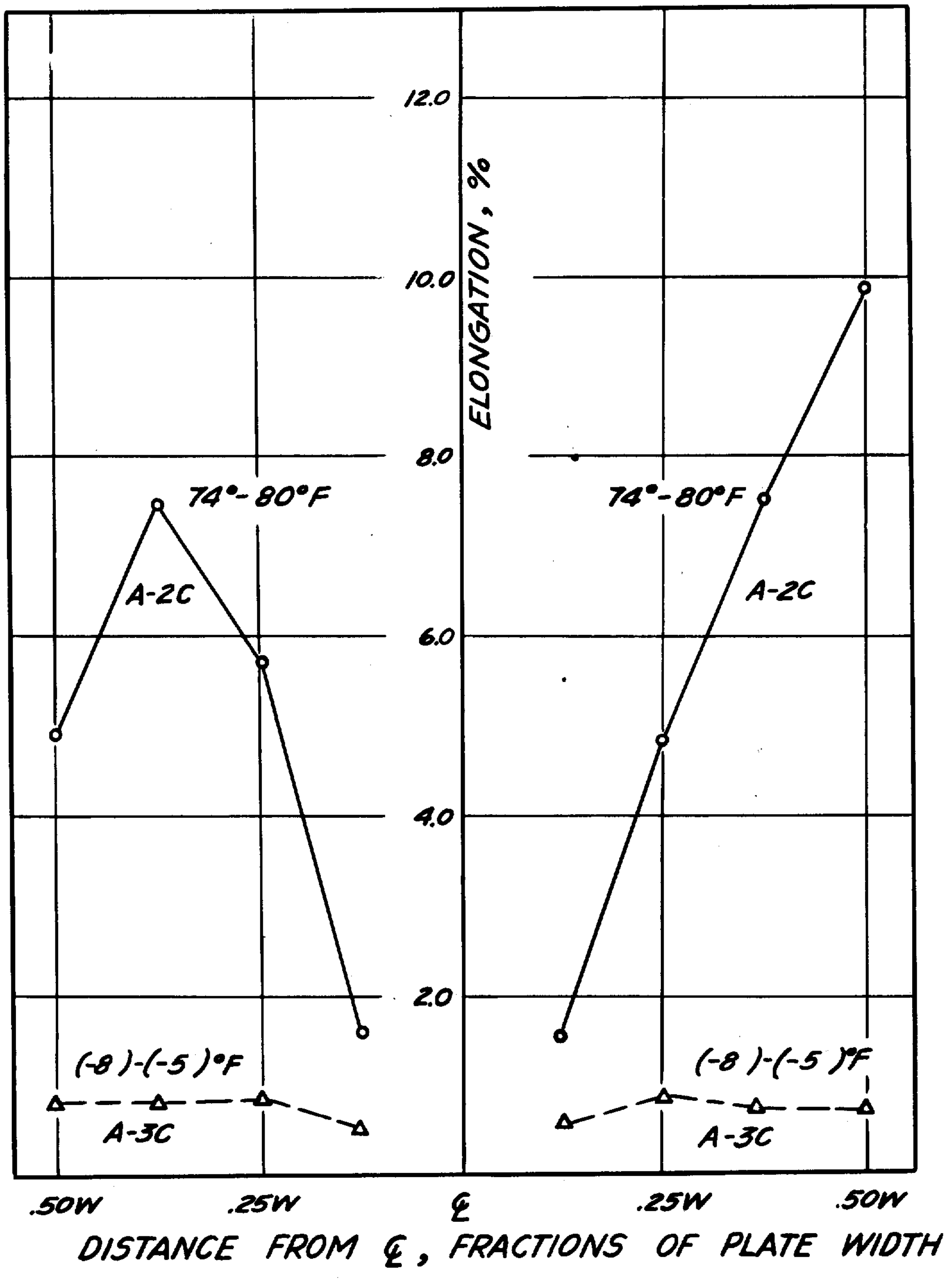


FIG. 34 - RESIDUAL ELONGATION AFTER RUPTURE IN 24-INCH WIDE SPECIMEN, ILLUSTRATING EFFECT OF TEMPERATURE ON DUCTILITY AT FRACTURE
ELONGATIONS MEASURED ON ONE FACE ONLY
GAGE LENGTH - $\frac{3}{4}$ PLATE WIDTH

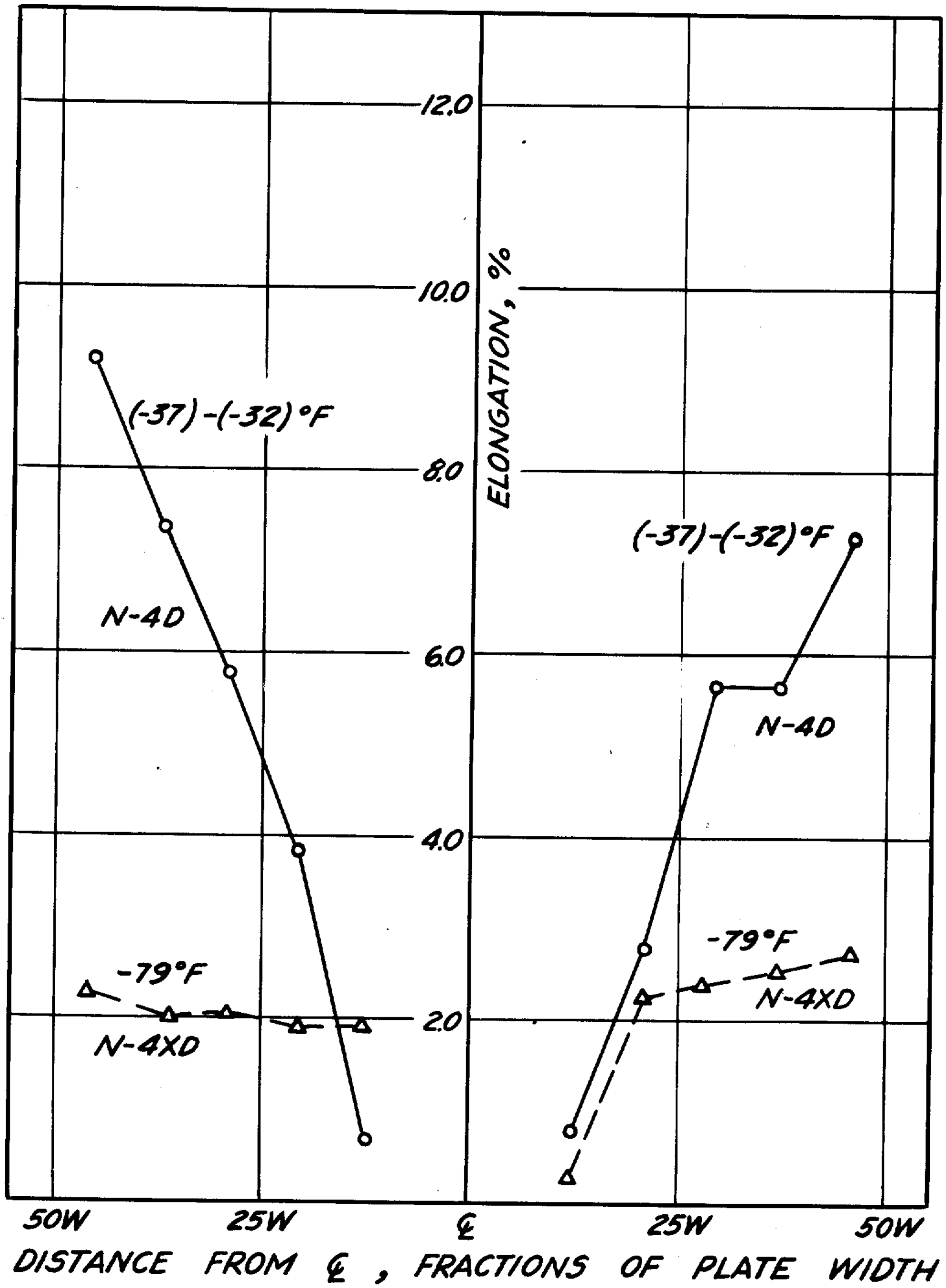
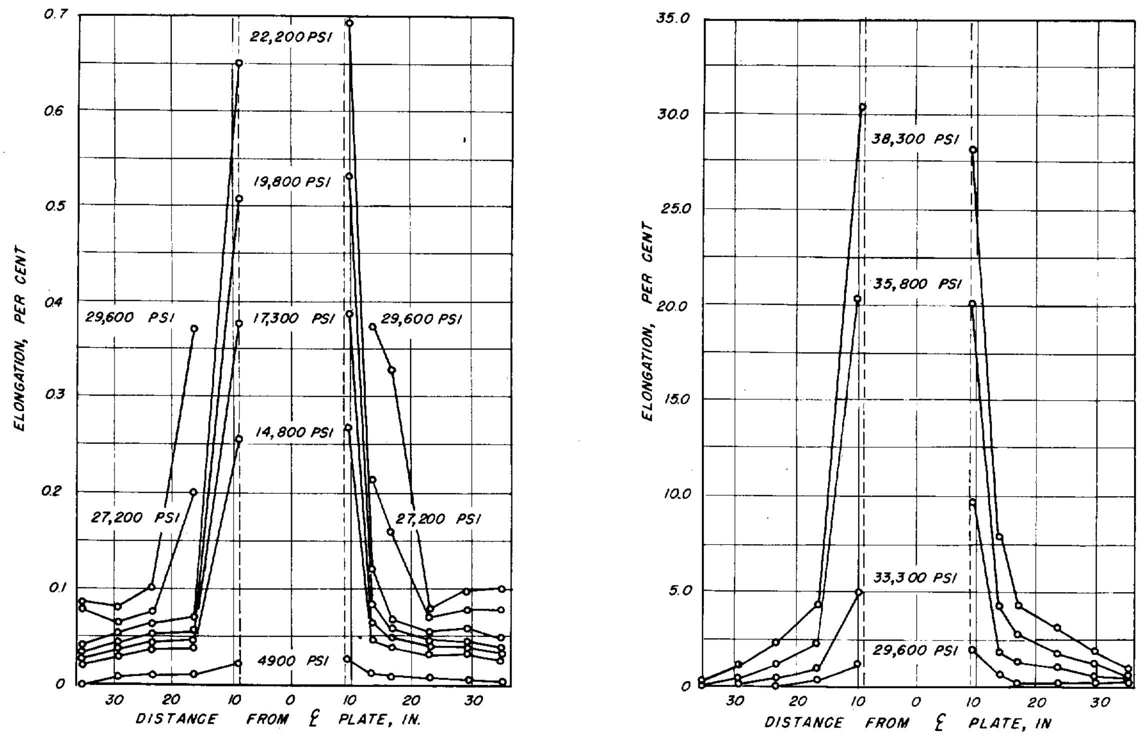


FIG. 35 - RESIDUAL ELONGATION AFTER RUPTURE IN 12-INCH WIDE SPECIMEN, ILLUSTRATING EFFECT OF TEMPERATURE ON DUCTILITY AT FRACTURE

ELONGATIONS MEASURED ON ONE FACE ONLY

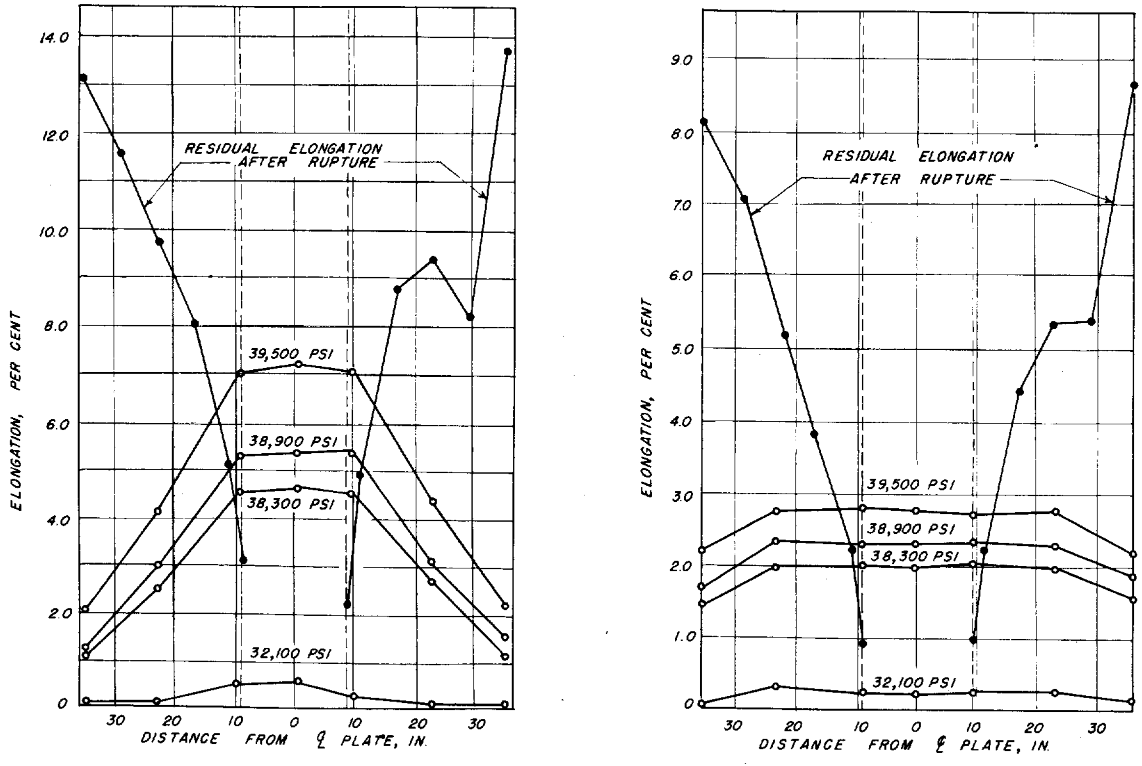
GAGE LENGTH - $\frac{3}{4}$ PLATE WIDTH

44E154



A) SR-4 STRAIN GAGES

B) 2-INCH CLIP GAGES



C) 24-INCH EXTENSOMETERS

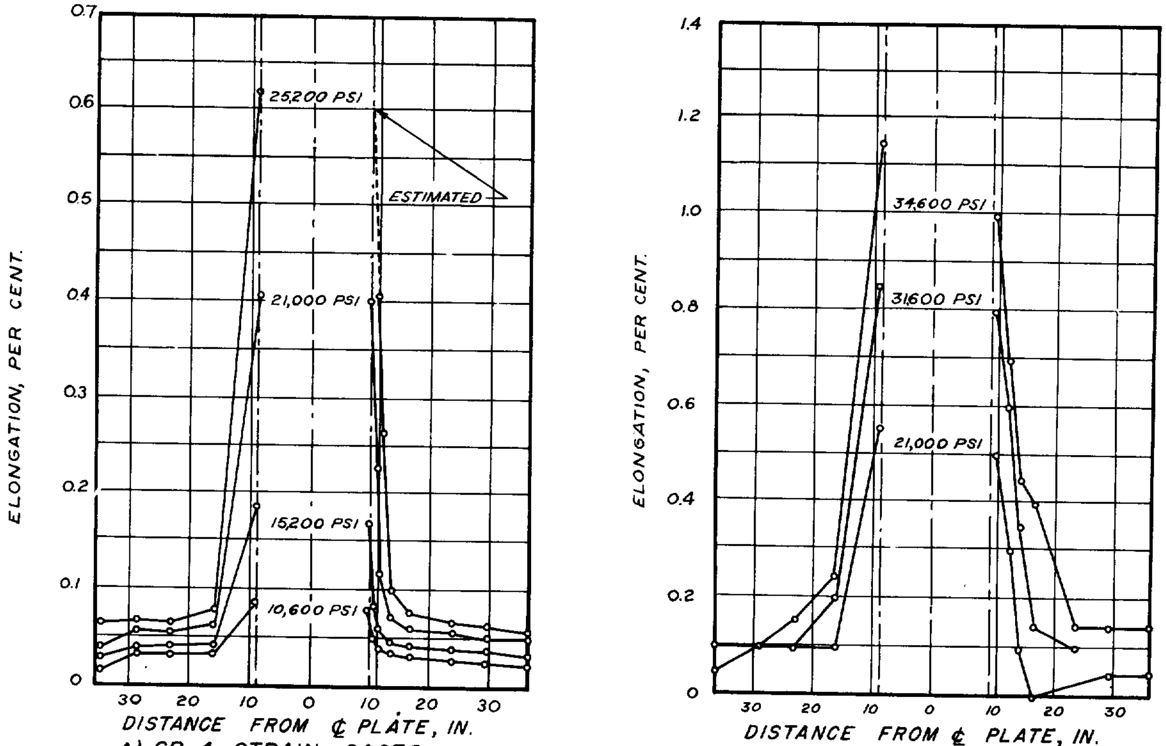
D) 54-INCH EXTENSOMETERS

FIG. 36-COMPARISON OF ELONGATION MEASURED OVER VARIOUS GAGE LENGTHS- DUCTILE SPECIMEN

SPECIMEN B-5A, TEMPERATURE 47 °F
DASH LINE REPRESENTS NOTCH EDGE
RESIDUAL ELONGATION MEASURED ON ONE FACE ONLY.

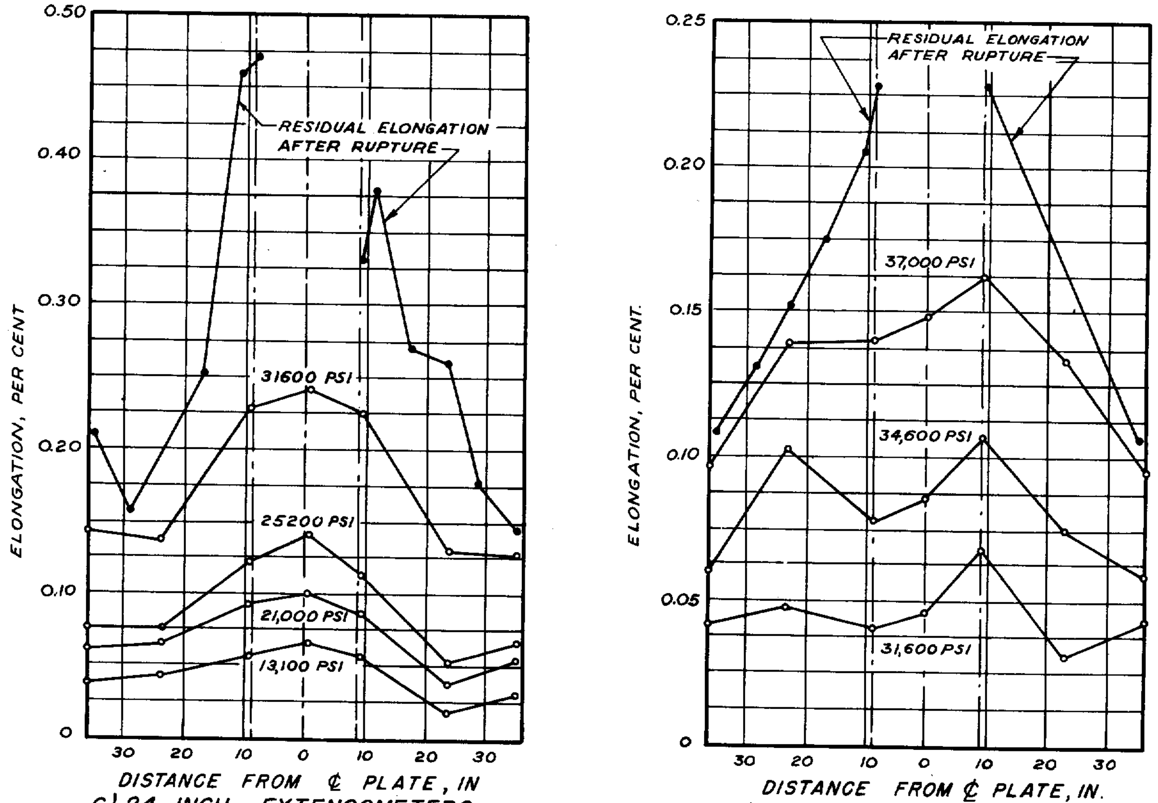
DWG. 44E46A

FIG. 36



A) SR-4 STRAIN GAGES.

B) 2-INCH CLIP GAGES.



C) 24-INCH EXTENSOMETERS.

D) 54-INCH EXTENSOMETERS.

FIG. 37-COMPARISON OF ELONGATION MEASURED OVER VARIOUS GAGE LENGTHS-BRITTLE SPECIMEN

SPECIMEN C-1A, TEMPERATURE 32°F
DASH LINE REPRESENTS NOTCH EDGE
RESIDUAL ELONGATION MEASURED ON ONE FACE ONLY

DWG. 44 E 47A

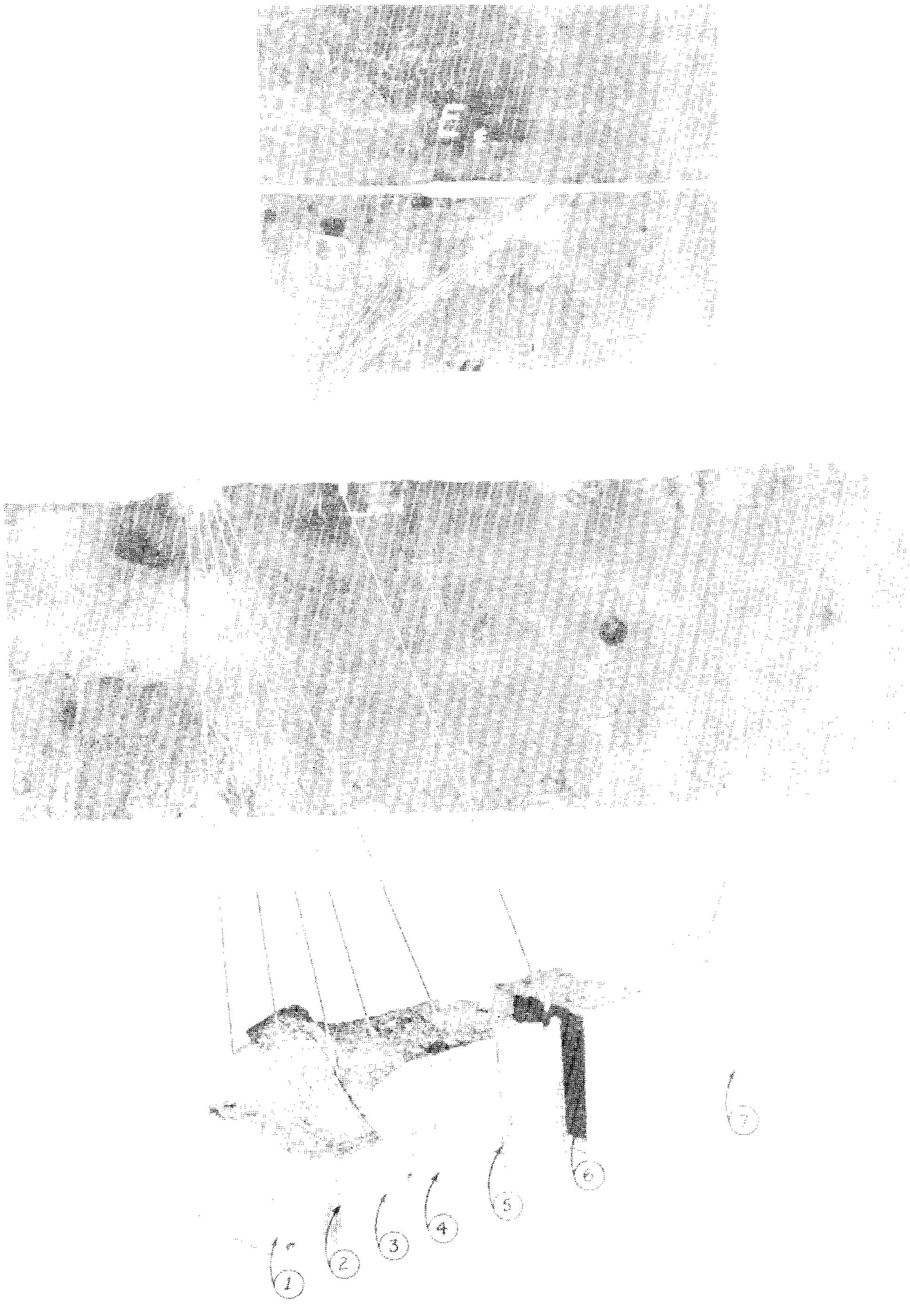


FIG. 38 VIEW OF FRACTURED SPECIMEN B-1A SHOWING LOCATION OF SAMPLES FOR MICROHARDNESS SURVEY

STEEL: 0.17 CARBON, 0.71 MANGANESE, AS ROLLED
SPECIMEN: 72 IN. WIDE BY $\frac{3}{4}$ IN. THICK
FRACTURE: $\frac{3}{4}$ IN. SHEAR, REST CLEAVAGE
TEMPERATURE OF TEST: 32 F
AVERAGE STRESS AT FAILURE: 38,000 PSI

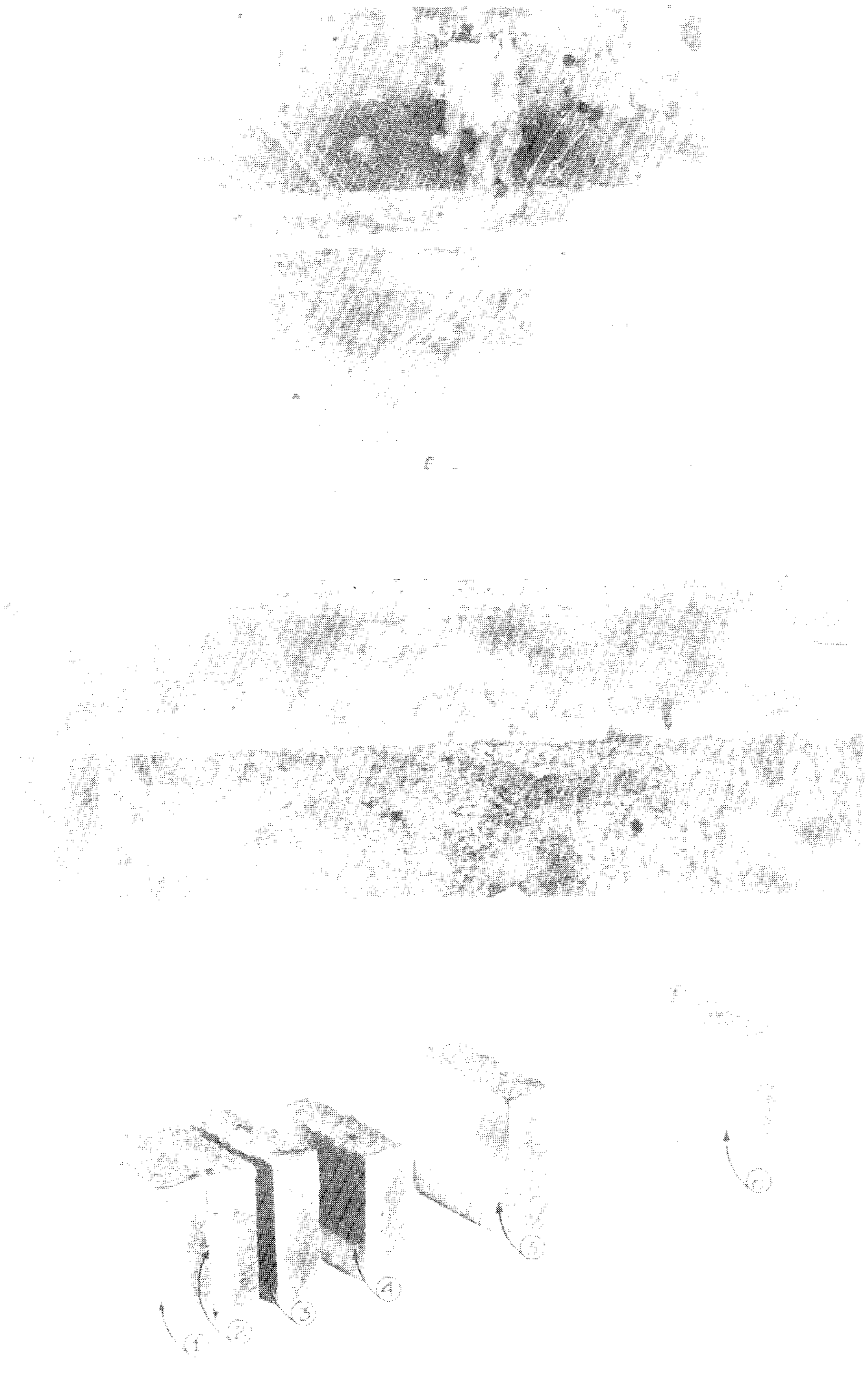


FIG. 39- VIEW OF FRACTURED SPECIMEN C-1A SHOWING LOCATION OF SAMPLES FOR MICROHARDNESS SURVEY

STEEL 0.25 CARBON, 0.47 MANGANESE, AS ROLLED
SPECIMEN 72 IN WIDE BY $\frac{3}{4}$ IN. THICK
FRACTURE CLEAVAGE TEMPERATURE OF TEST 32°F
AVERAGE STRESS AT FAILURE 37,000 PSI

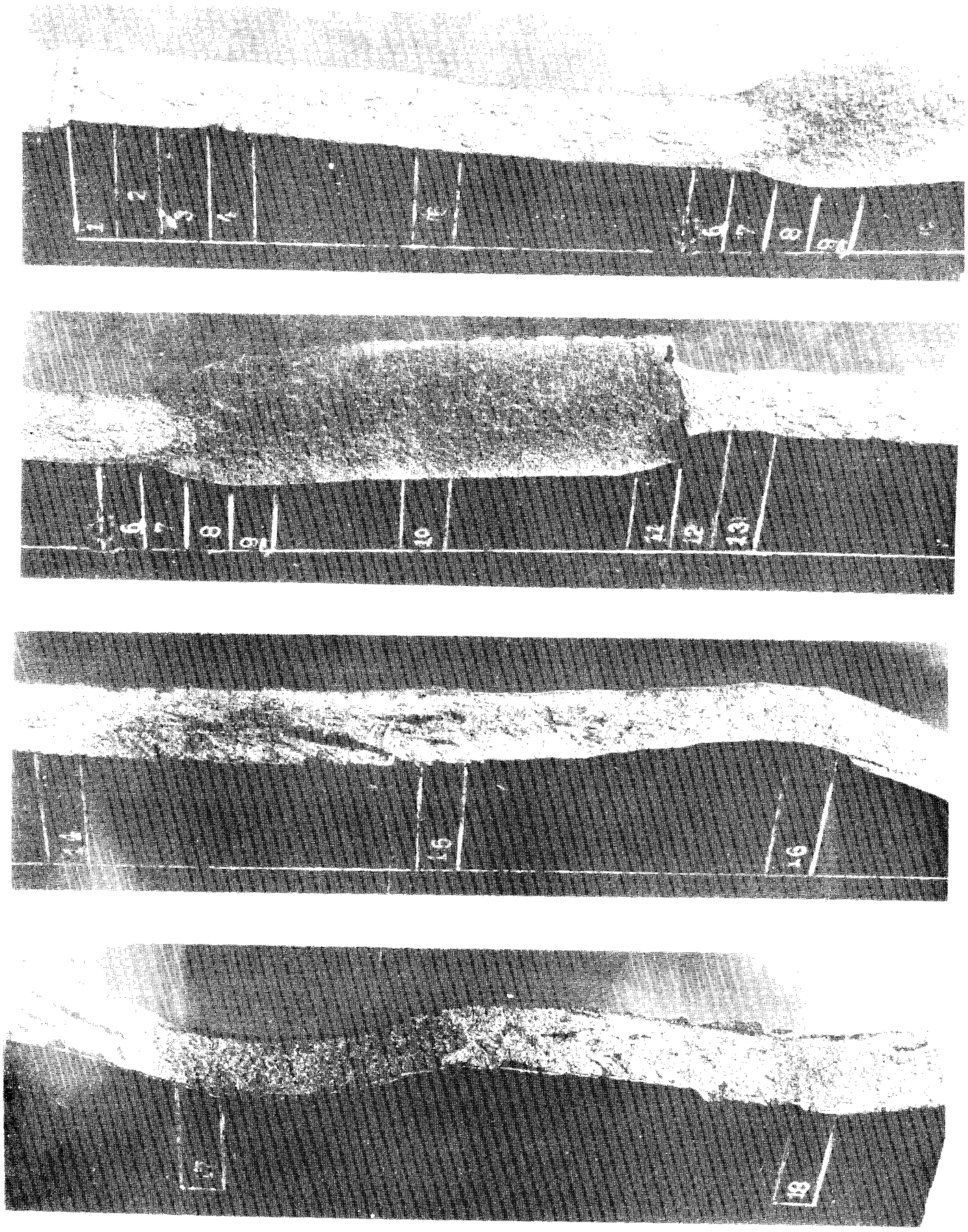


FIG. 41 - VIEWS SHOWING THE FRACTURE OF THE RIGHT SIDE OF THE PLATE C-2A

FIGURES INDICATE THE MICROHARDNESS SPECIMEN NUMBER

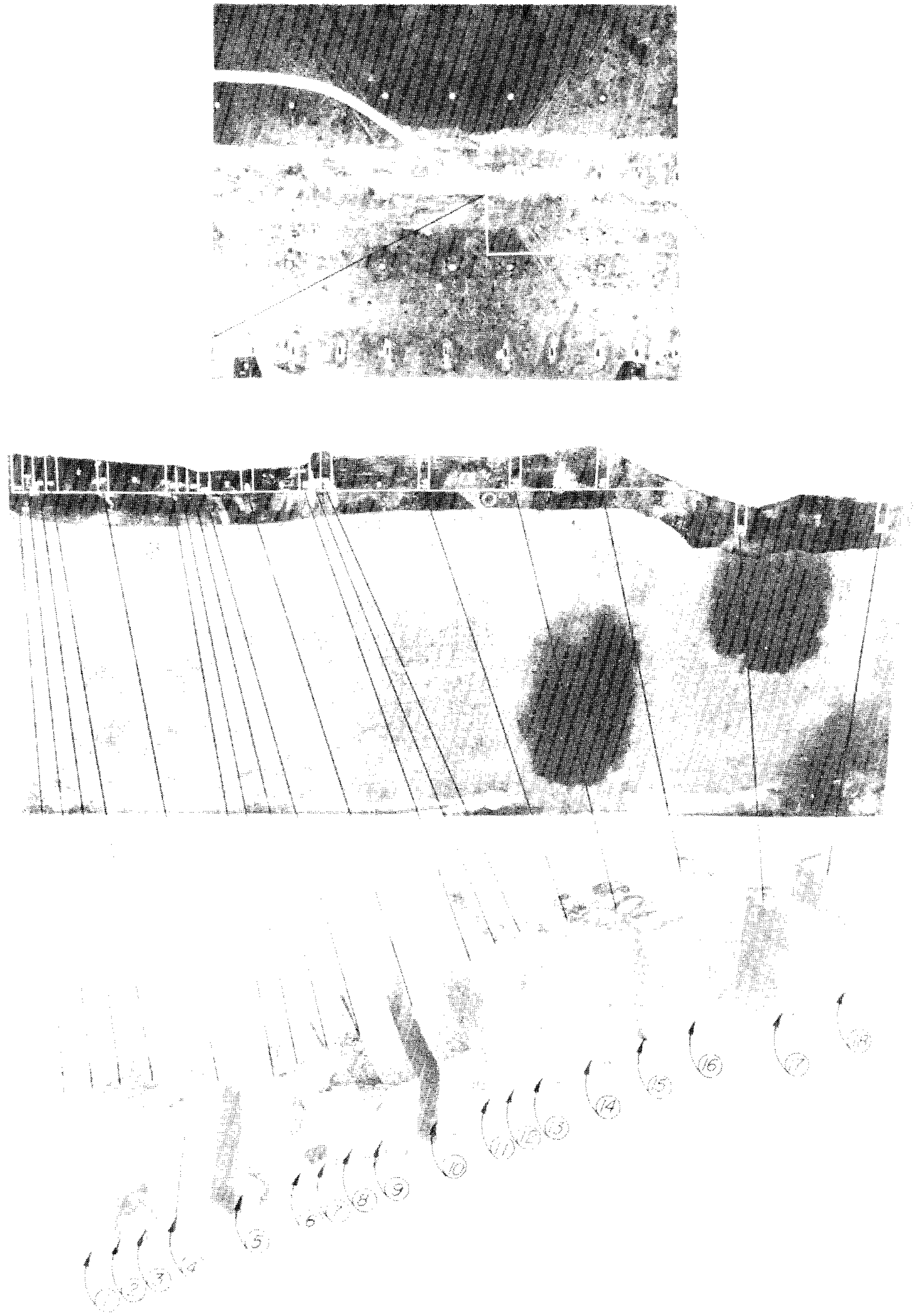


FIG. 40-VIEW OF FRACTURED SPECIMEN C-2A SHOWING LOCATION OF SAMPLES FOR MICROHARDNESS SURVEY

STEEL: 0.26 CARBON, 0.49 MANGANESE, AS ROLLED
SPECIMEN: 72 IN. WIDE BY $\frac{3}{4}$ IN. THICK
FRACTURE: 9.3% SHEAR, 90.7 % CLEAVAGE   TEMPERATURE OF TEST: 76 °F
AVERAGE STRESS AT FAILURE: 37,800 PSI

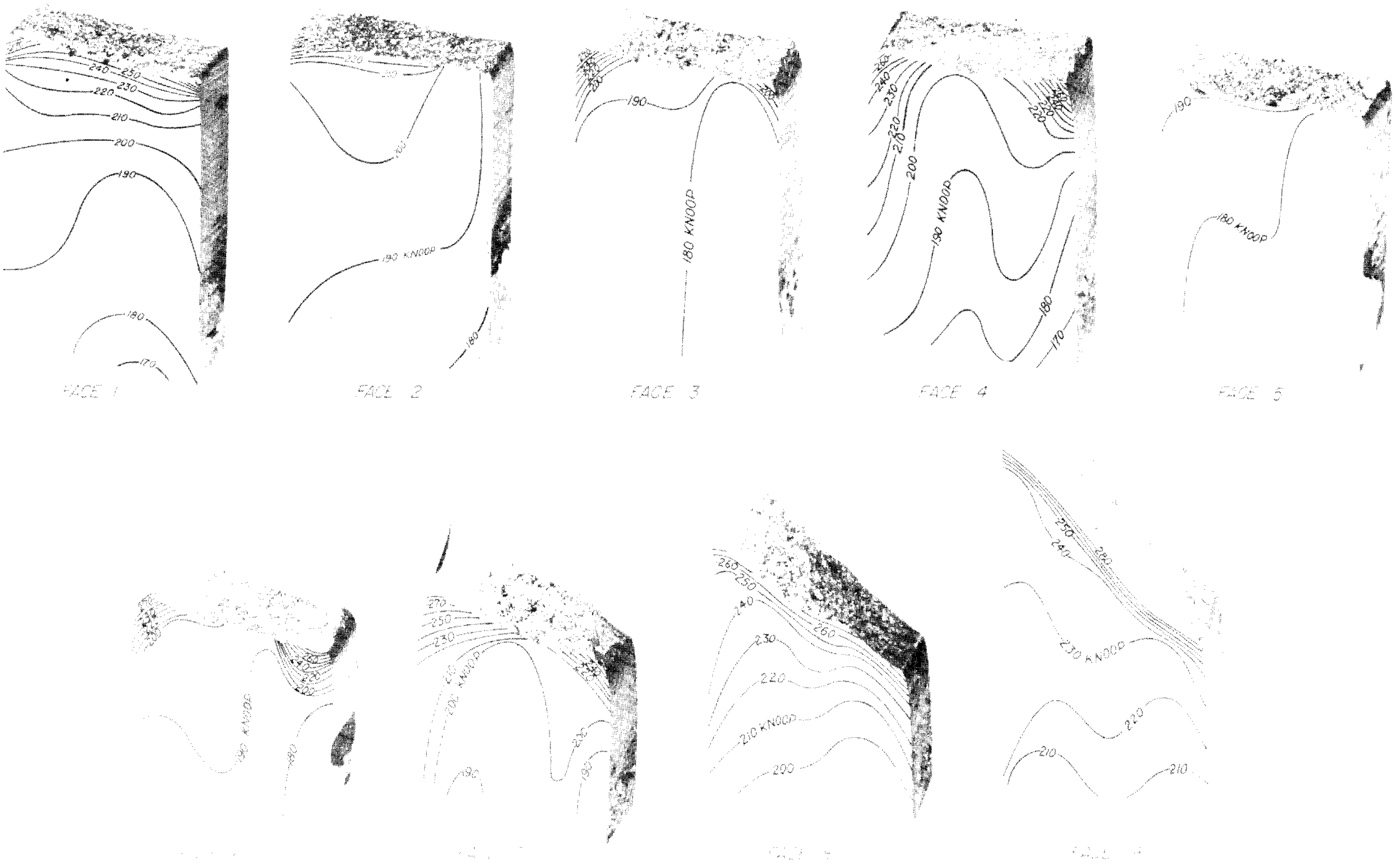


FIG. 42 - HARDNESS CONTOURS-SPECIMEN C-2A
SURFACES 1 THROUGH 9

FIG. 4.3-HARDNESS CONTOURS-SPECIMEN C-2A SURFACES 10 THROUGH 18

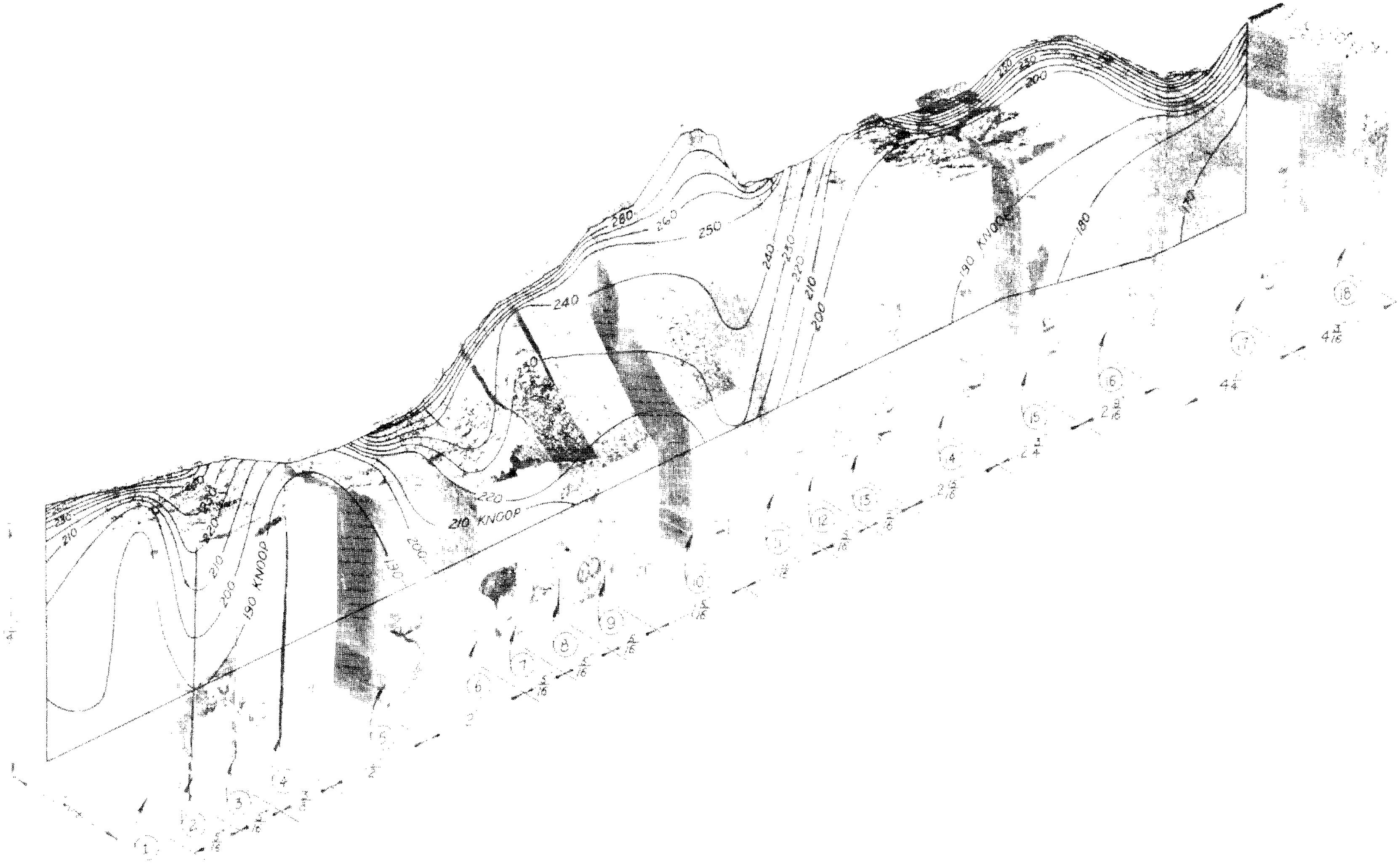


FIG. 44 - HARDNESS CONTOURS - SPECIMEN C-2A, PLANE A

PLANE A IS $\frac{11}{16}$ INCHES FROM "NEAR" FACE OF SPECIMEN
SEE FIG. 40 FOR SECTIONING DIAGRAM

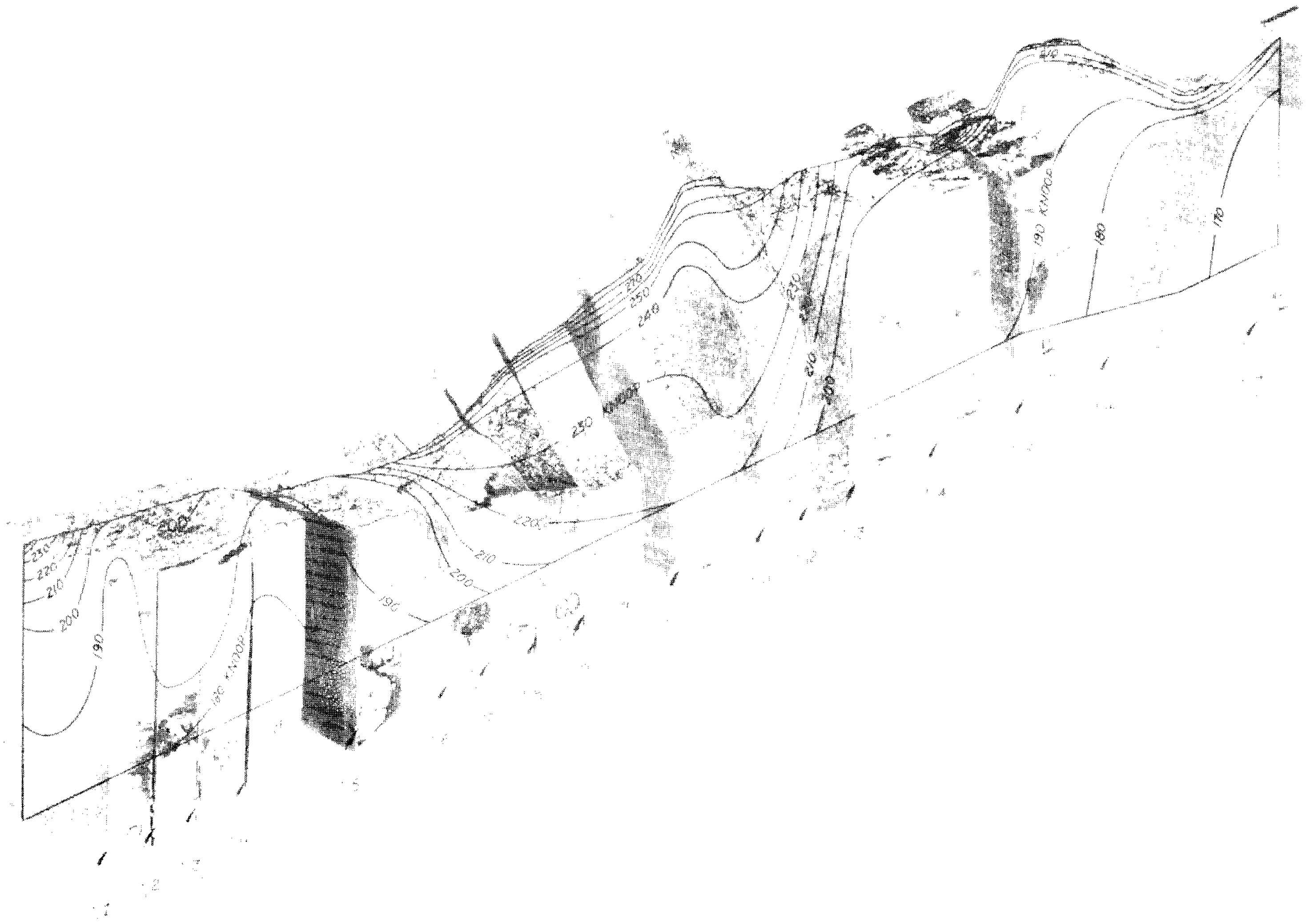


FIG. 45 - HARDNESS CONTOURS—SPECIMEN C-2A, PLANE B

PLANE B IS $\frac{17}{32}$ INCHES FROM "NEAR" FACE OF SPECIMEN

SEE FIG. 40 FOR SECTIONING DIAGRAM

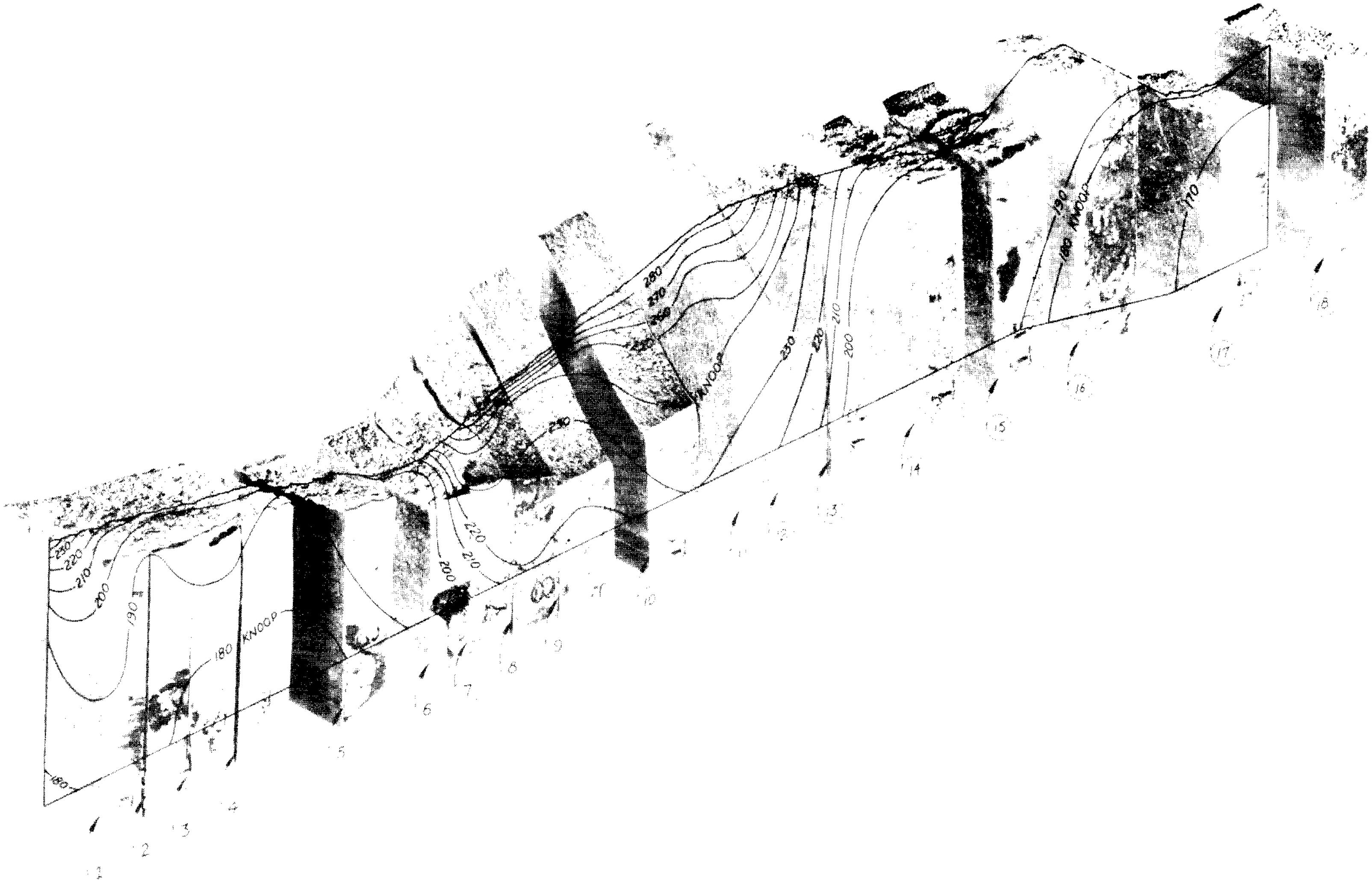


FIG. 46 - HARDNESS CONTOURS - SPECIMEN C-2A, PLANE C

PLANE C IS $\frac{3}{8}$ INCHES FROM "NEAR" FACE OF SPECIMEN

SEE FIG. 40 FOR SECTIONING DIAGRAM

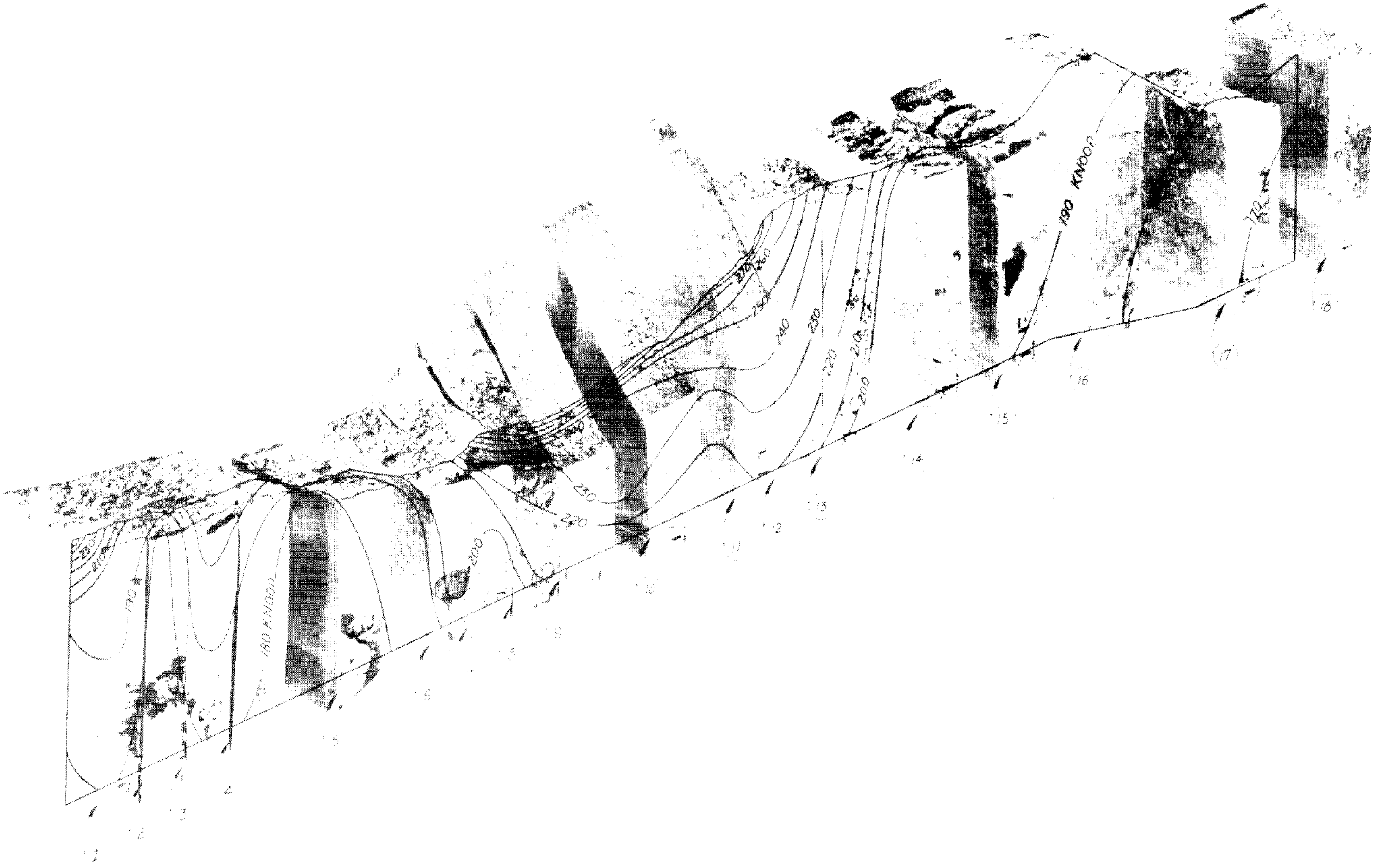


FIG.47- HARDNESS CONTOURS-SPECIMEN C-2A, PLANE D

PLANE D IS $\frac{7}{32}$ INCHES FROM "NEAR" FACE OF SPECIMEN

SEE FIG. 4.0 FOR SECTIONING DIAGRAM

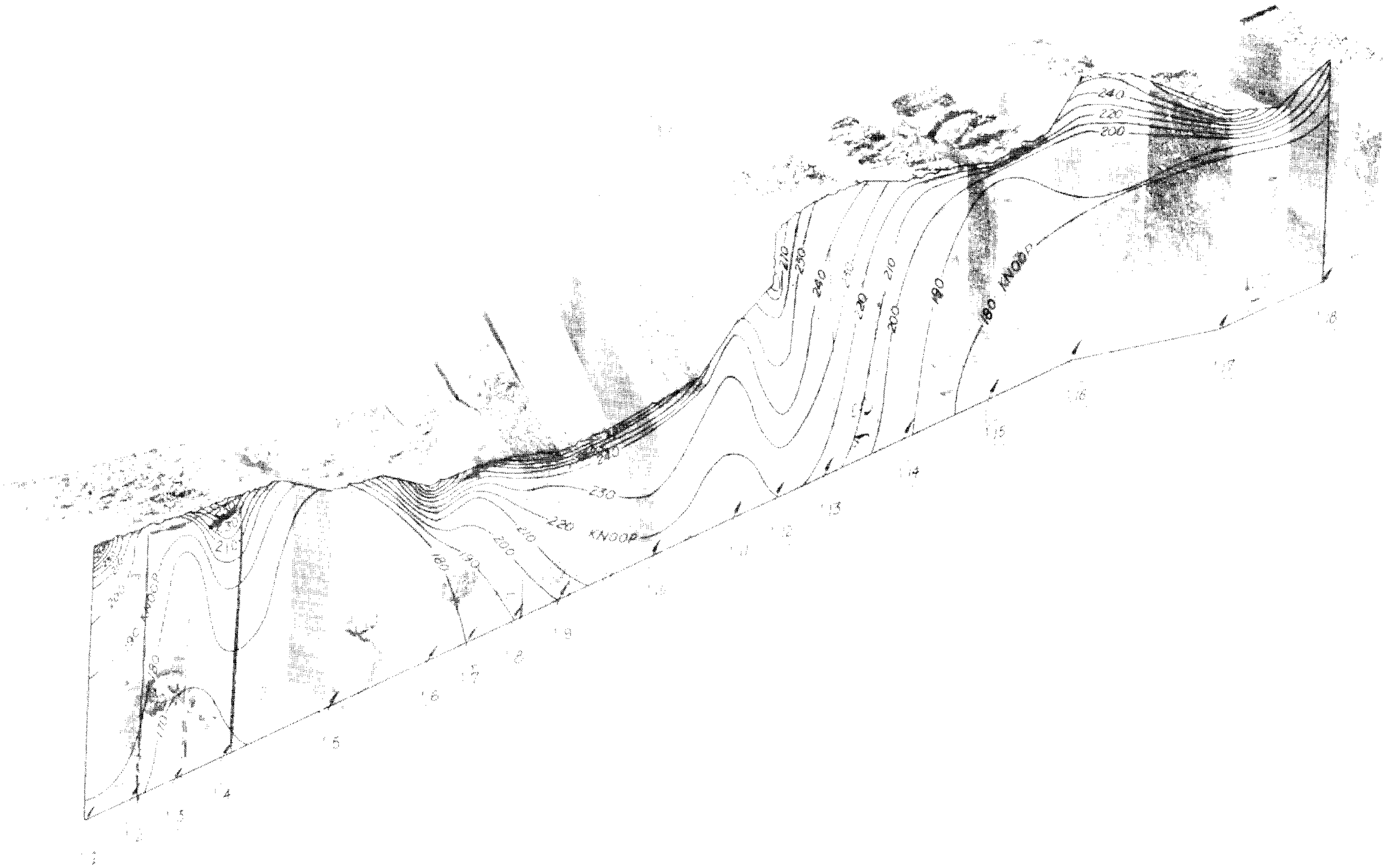


FIG. 48- HARDNESS CONTOURS-SPECIMEN C-2A, PLANE E

PLANE E IS $\frac{1}{16}$ INCHES FROM "NEAR" FACE OF SPECIMEN

SEE FIG. 40 FOR SECTIONING DIAGRAM

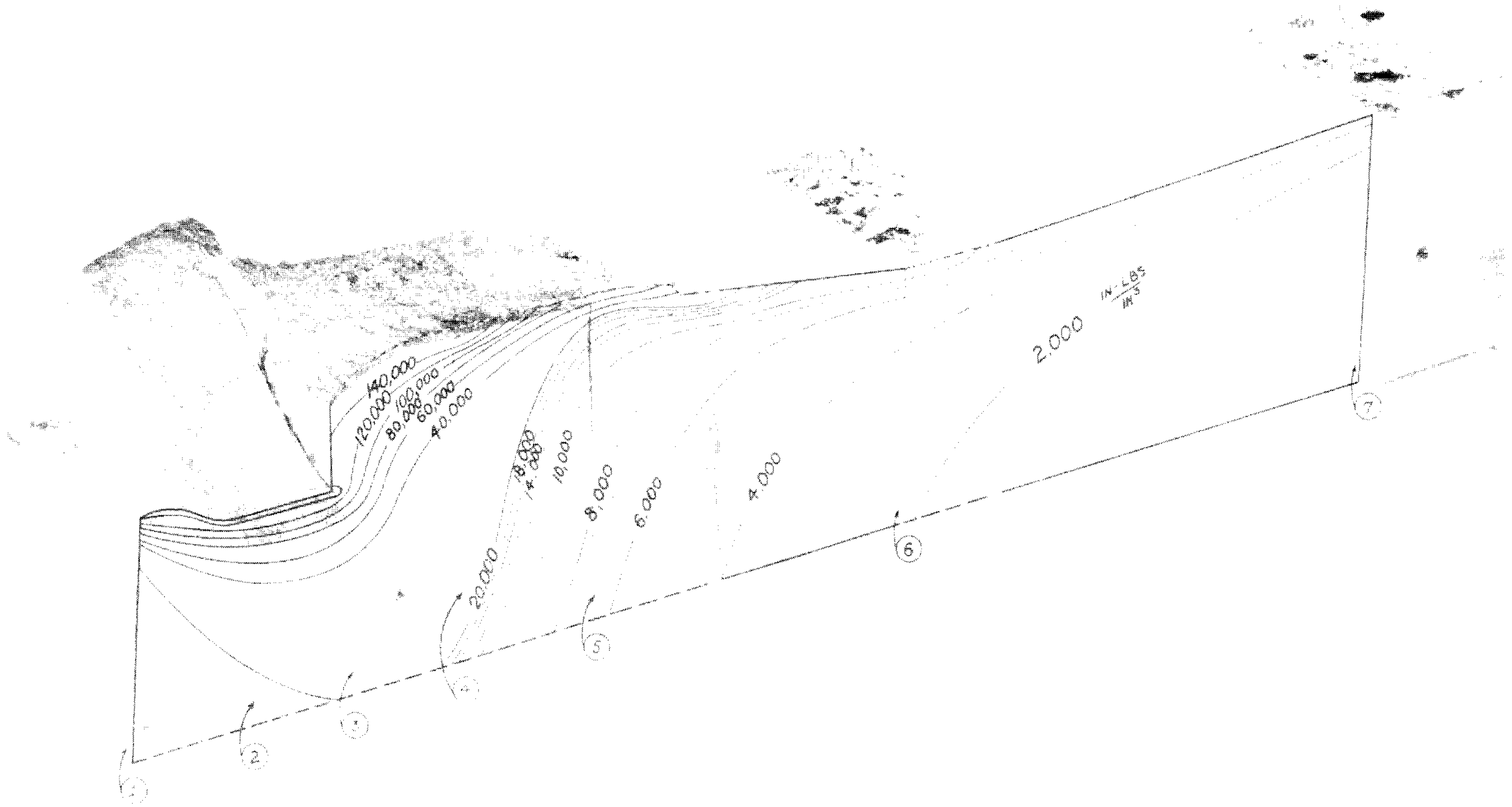


FIG. 49- ENERGY CONTOURS - SPECIMEN B-1A, PLANE E

PLANE E IS $\frac{1}{16}$ INCHES FROM "NEAR" FACE OF SPECIMEN

SEE FIG. 38 FOR SECTIONING DIAGRAM

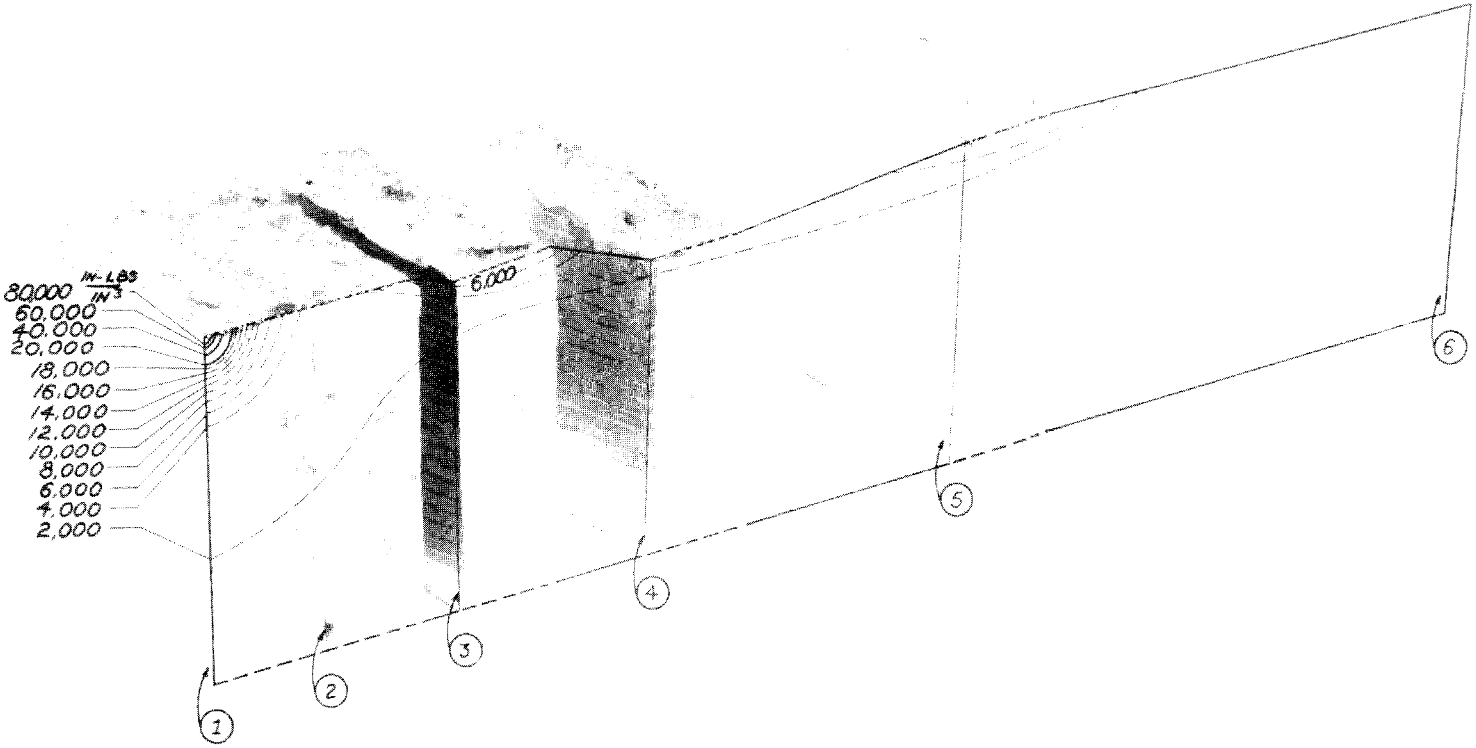


FIG. 50 - ENERGY CONTOURS - SPECIMEN C-1A, PLANE E

PLANE E IS $\frac{1}{16}$ INCHES FROM "NEAR" FACE OF SPECIMEN
SEE FIG. 39 FOR SECTIONING DIAGRAM

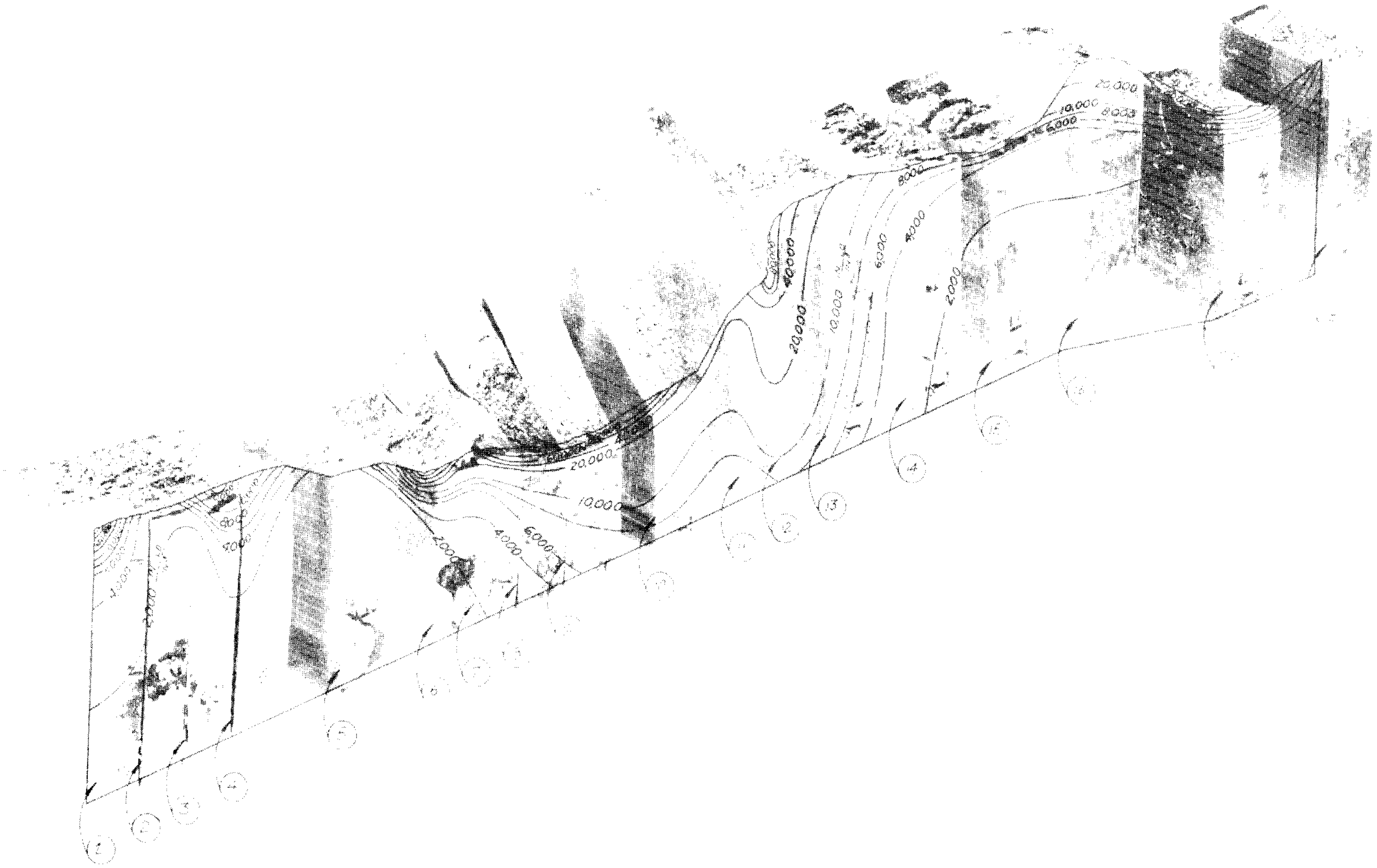


FIG. **51** - ENERGY CONTOURS—SPECIMEN C-2A, PLANE E

PLANE E IS $\frac{1}{16}$ INCHES FROM "NEAR" FACE OF SPECIMEN

SEE FIG. **40** FOR SECTIONING DIAGRAM

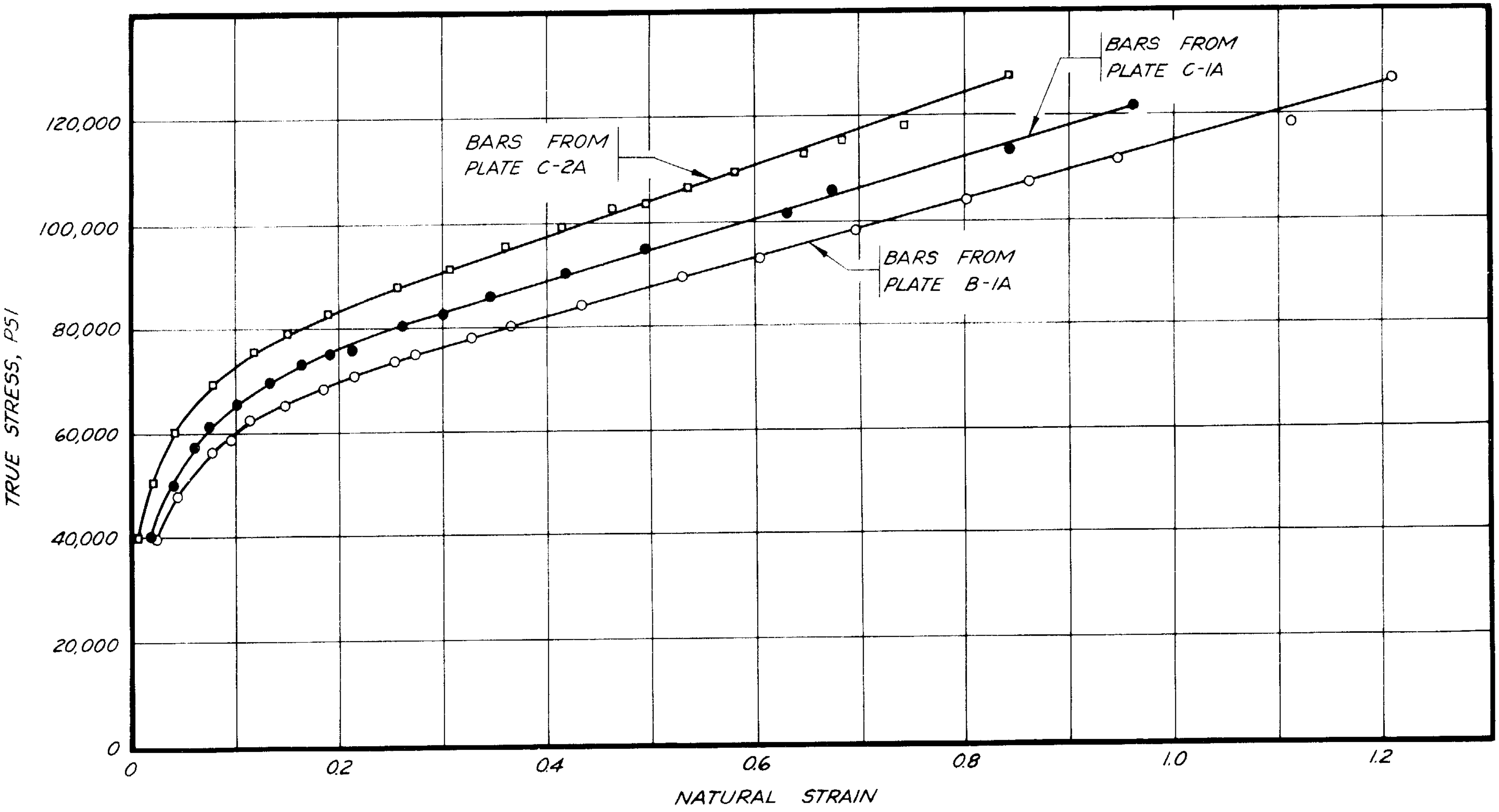


FIG. 52 - TRUE STRESS VS NATURAL STRAIN, TENSILE BARS FROM SPECIMENS C-1A, C-2A AND B-1A

44E79

FIG.52

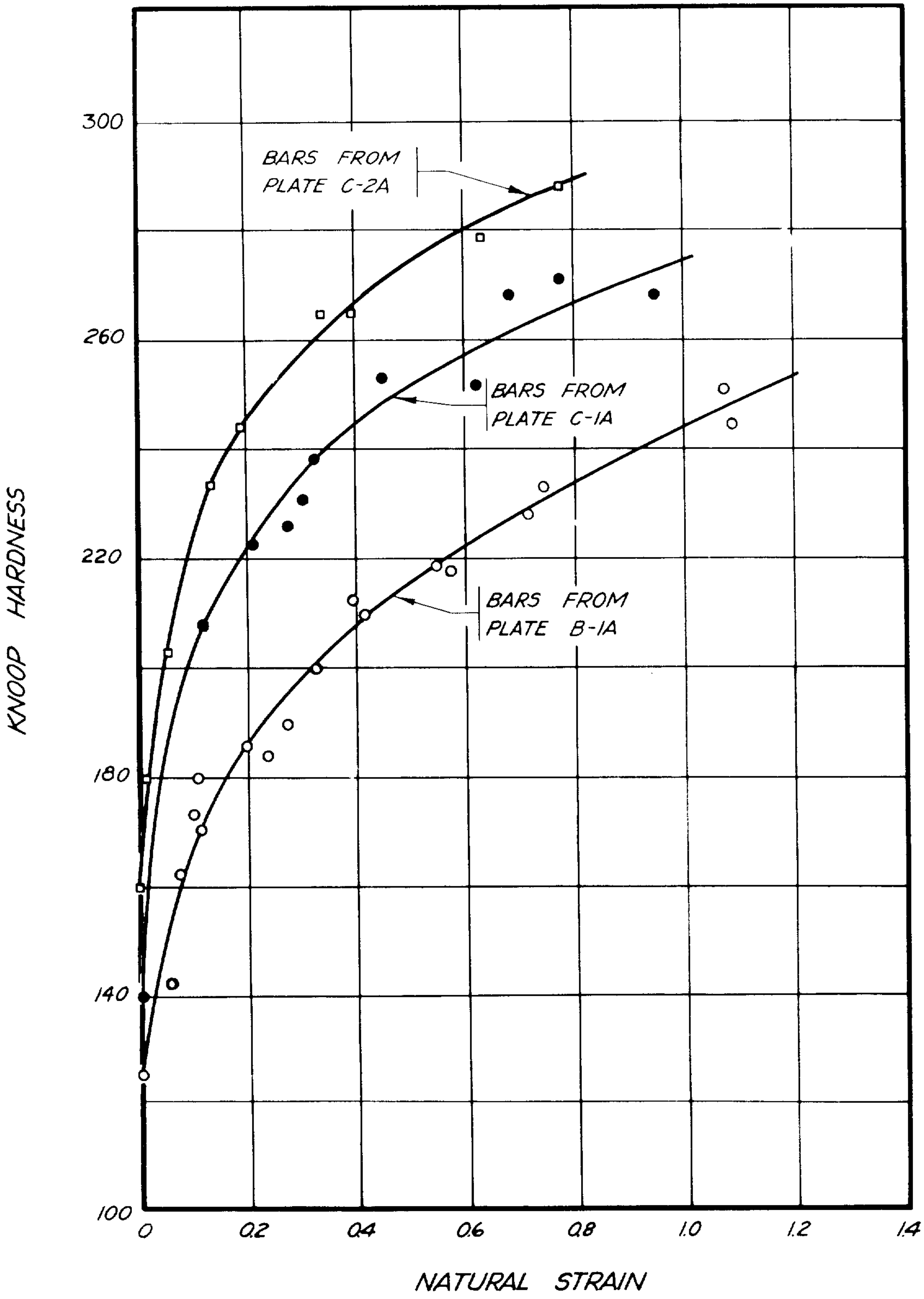


FIG. 53 - KNOOP HARDNESS VS. NATURAL STRAIN, TENSILE BARS FROM SPECIMENS C-1A, C-2A AND B 1A.

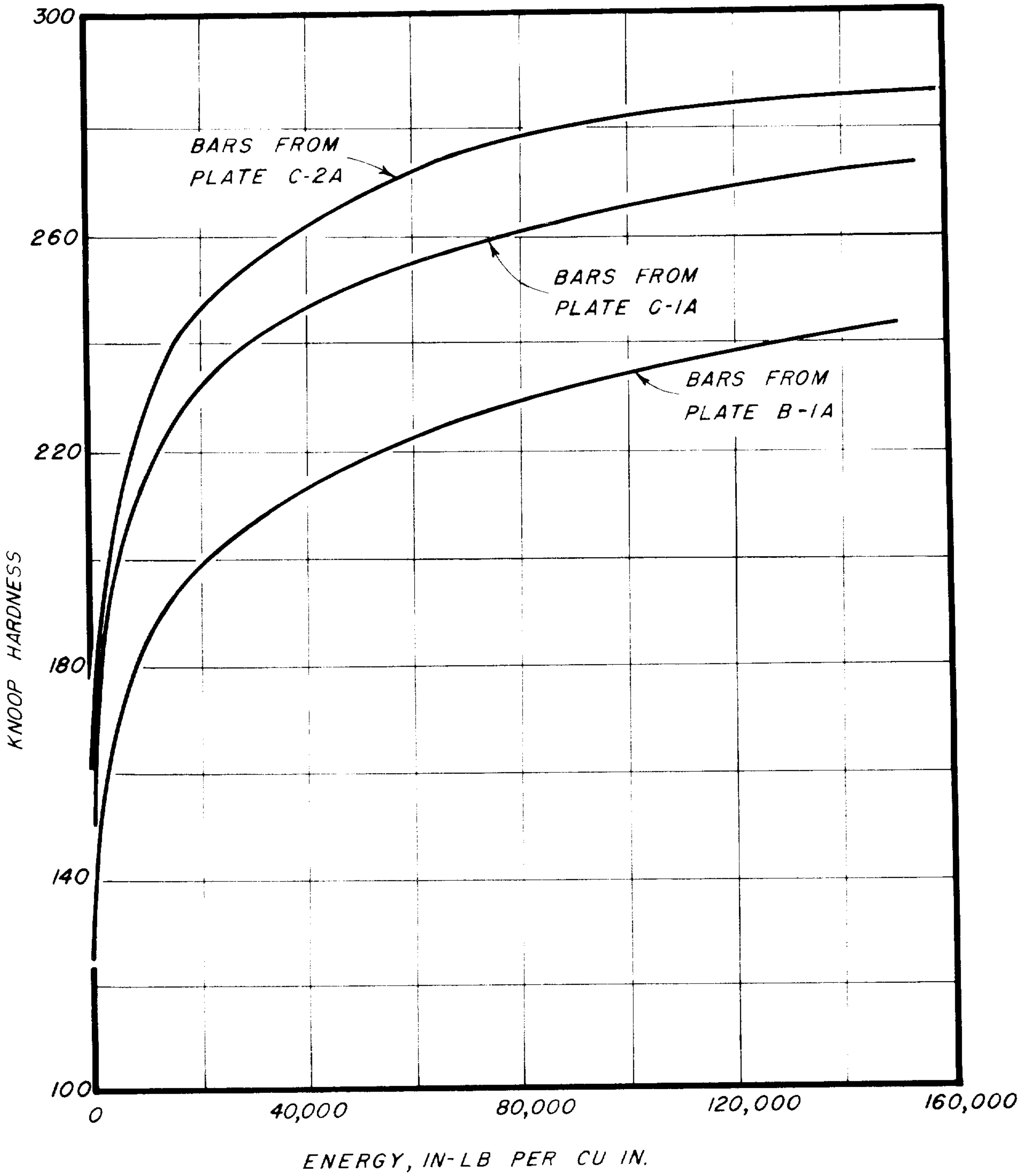


FIG. 54 - KNOOP HARDNESS VS ENERGY ABSORBED DURING STRAINING, TENSILE BARS FROM SPECIMEN C-1A, C-2A AND B 1A.

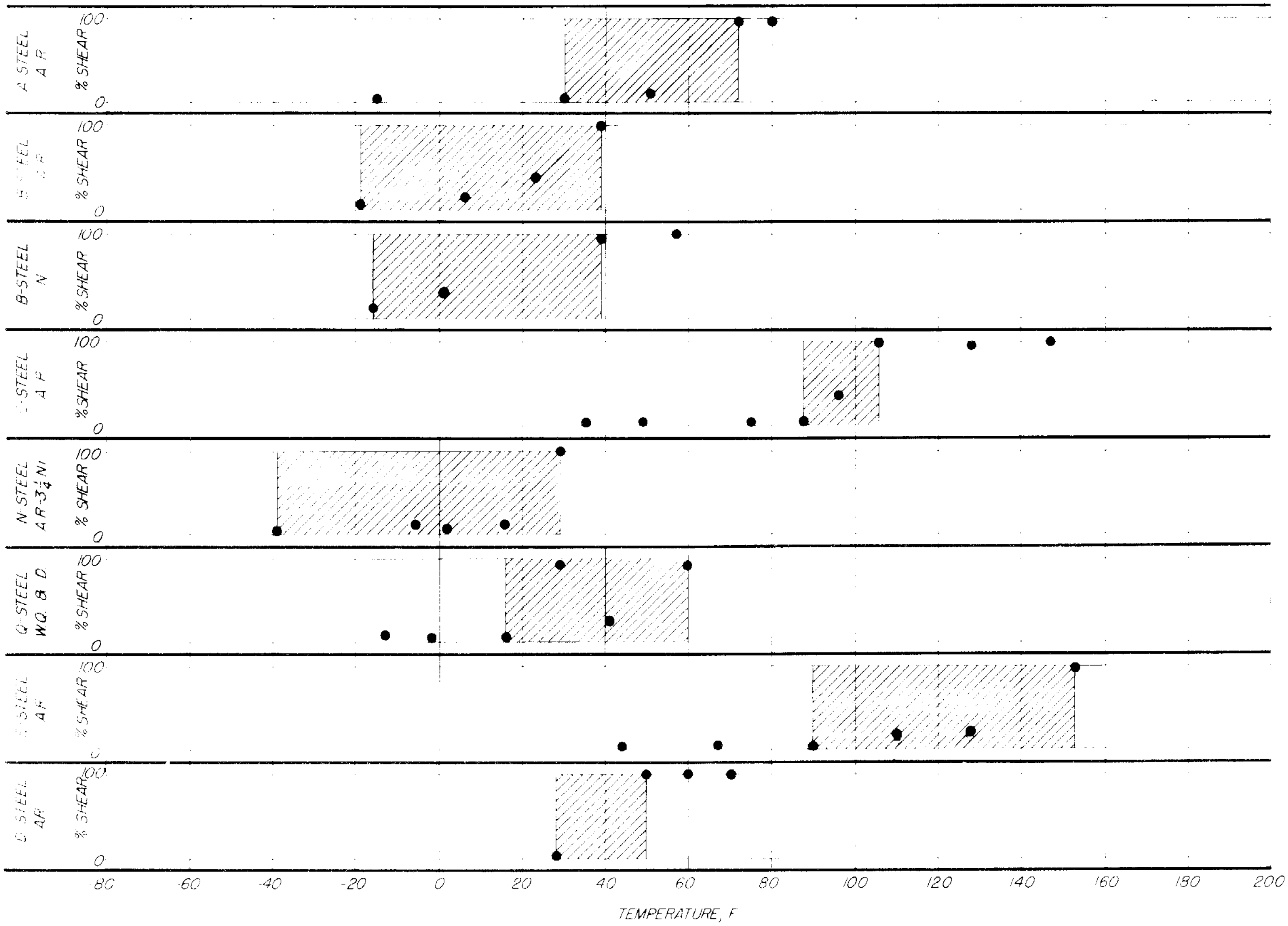


FIG. 55 - TRANSITION TEMPERATURE RANGE 3-INCH WIDE NOTCHED SPECIMENS
$\frac{3}{4}$-INCH THICK, "C" STEEL

FIG 55

44E163

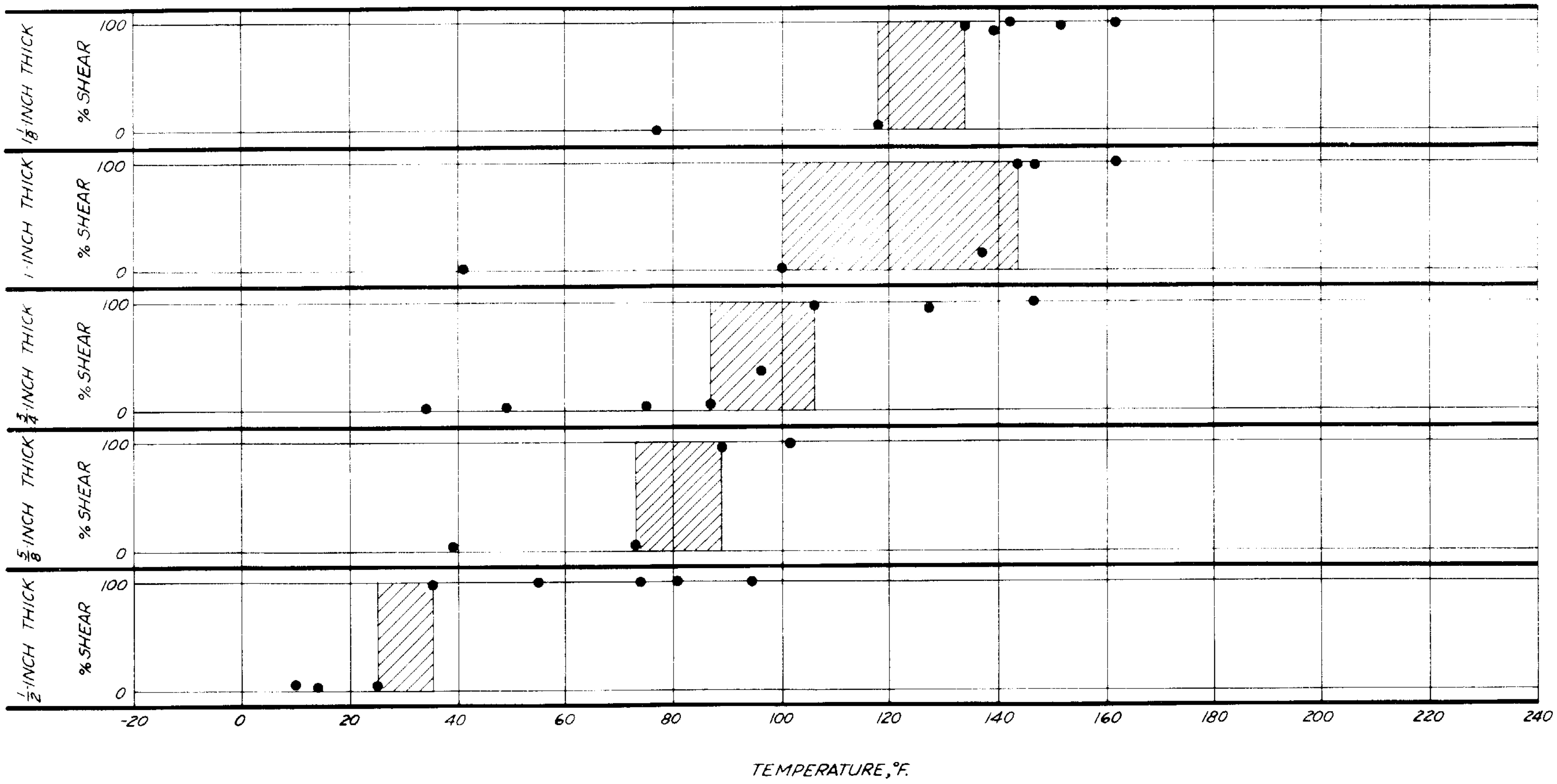
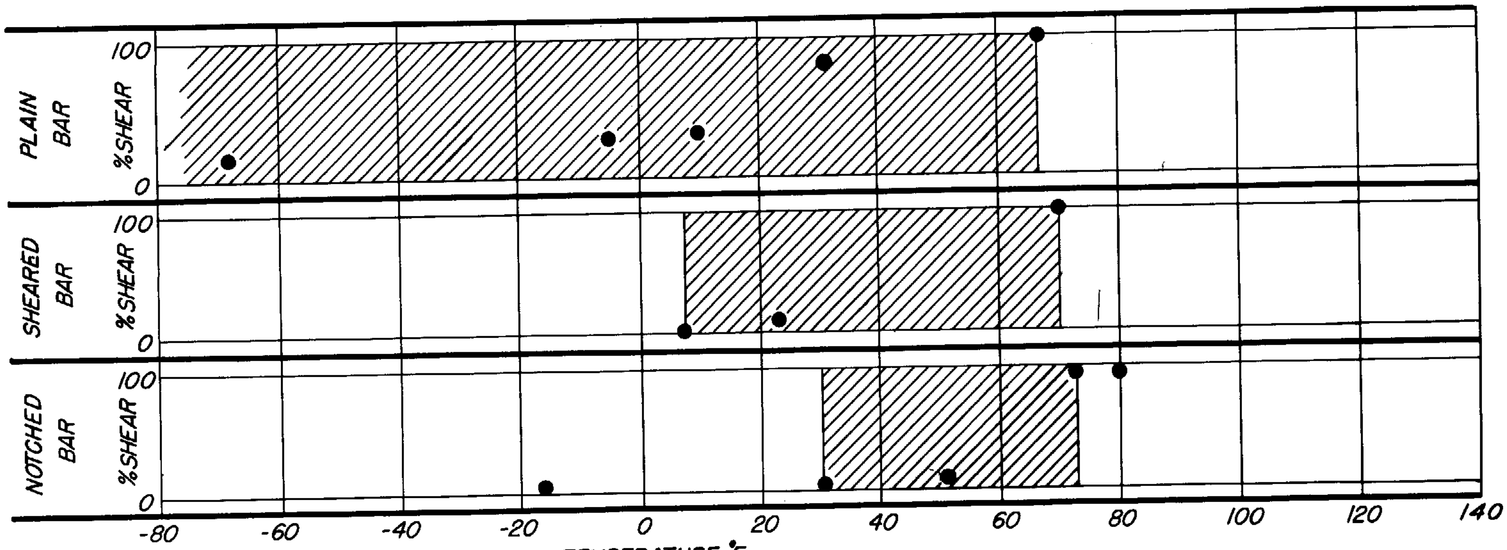


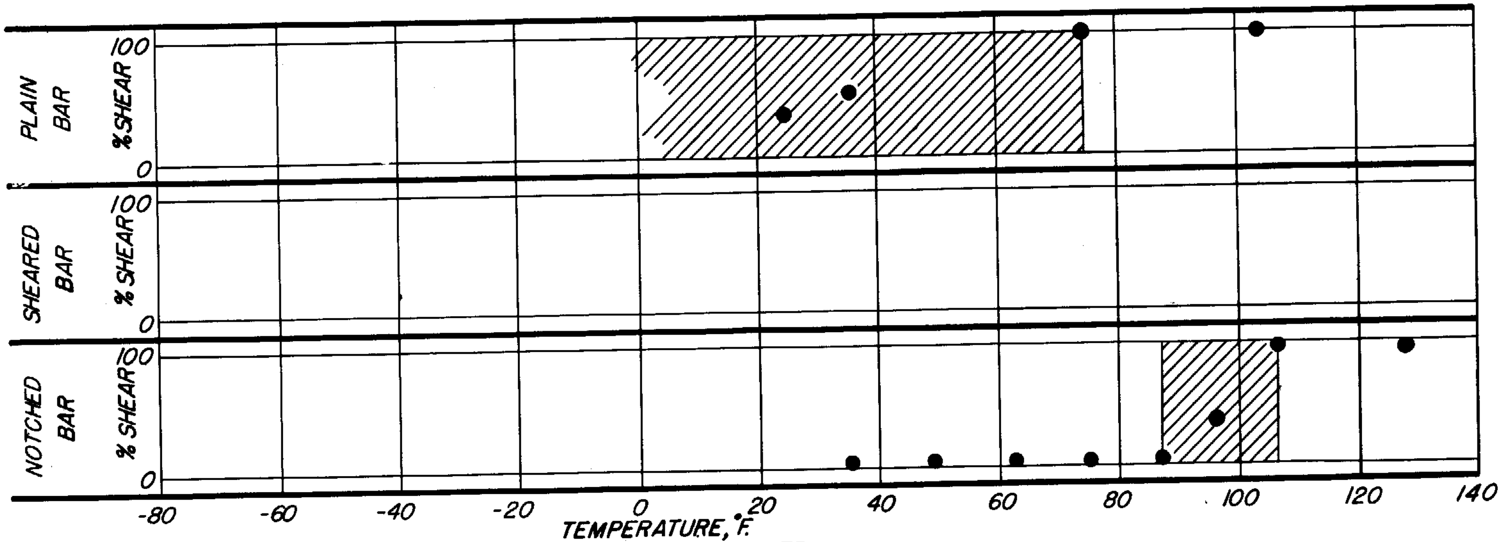
FIG. 56 - TRANSITION TEMPERATURE RANGE, 3-INCH WIDE EDGE NOTCHED SPECIMENS, C-STEEL, FROM PLATES OF VARIOUS THICKNESSES

FIG. 56

44E73



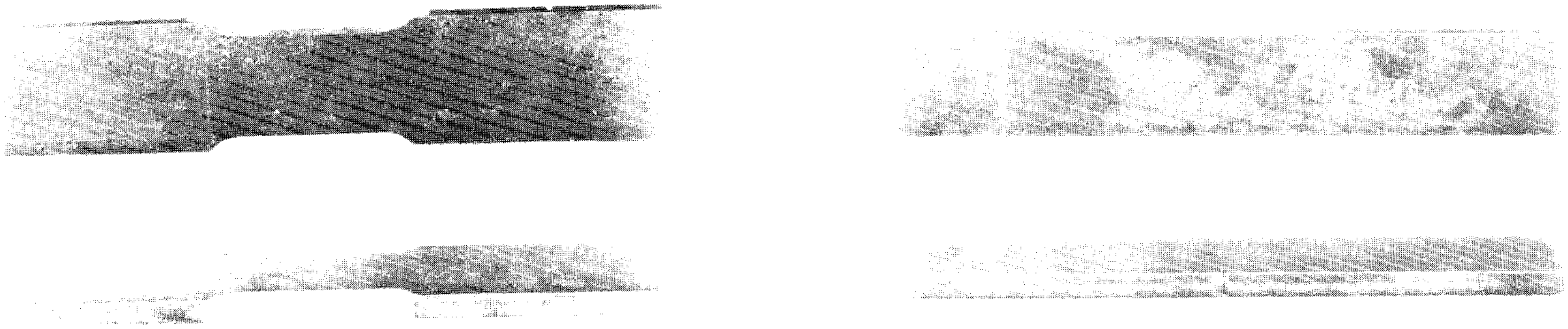
TEMPERATURE, °F.
A-STEEL AS ROLLED



TEMPERATURE, °F.
C-STEEL AS ROLLED

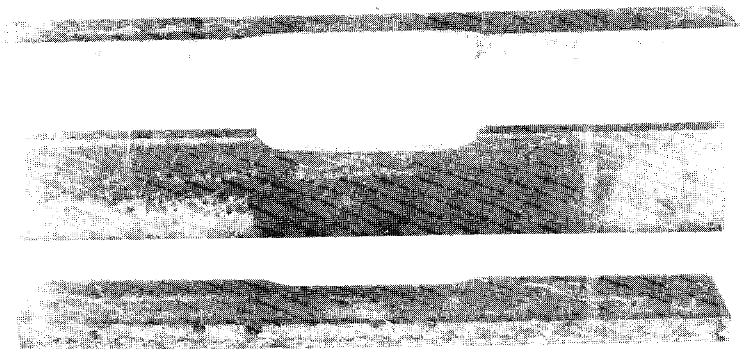
FIG. 57 - TRANSITION TEMPERATURE RANGE, 3-INCH WIDE TENSILE SPECIMENS

FIG. 57
44E71



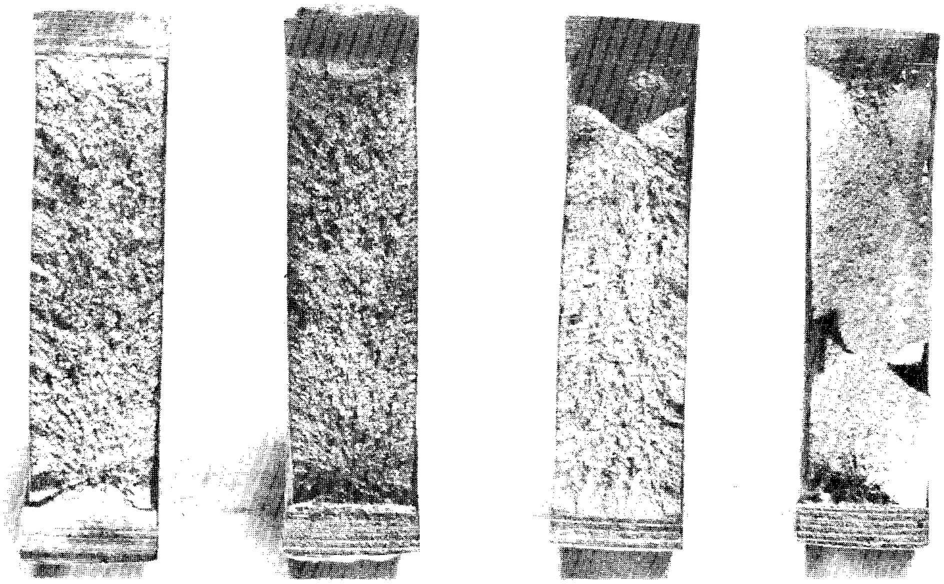
PLAIN BAR

EDGE NOTCHED BAR



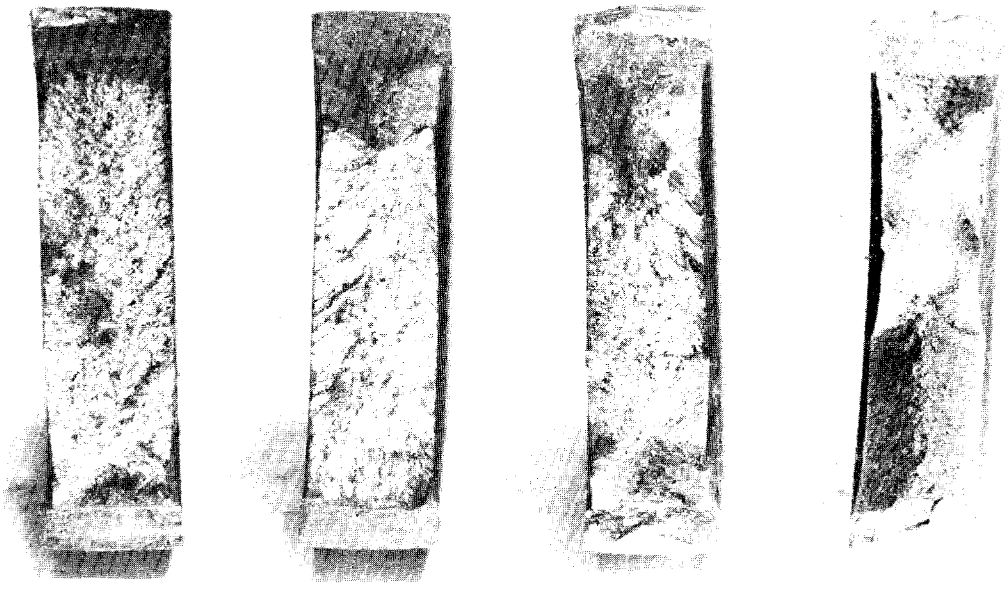
SHEARED EDGE BAR

FIG **58** EDGE NOTCHED SPECIMENS, 3-INCH WIDE, SHOWING THE THREE TYPES OF BARS USED IN TESTS



TEMPERATURE,°F	-15°	30°	51°	72°
% SHEAR	3%	2%	10%	97%

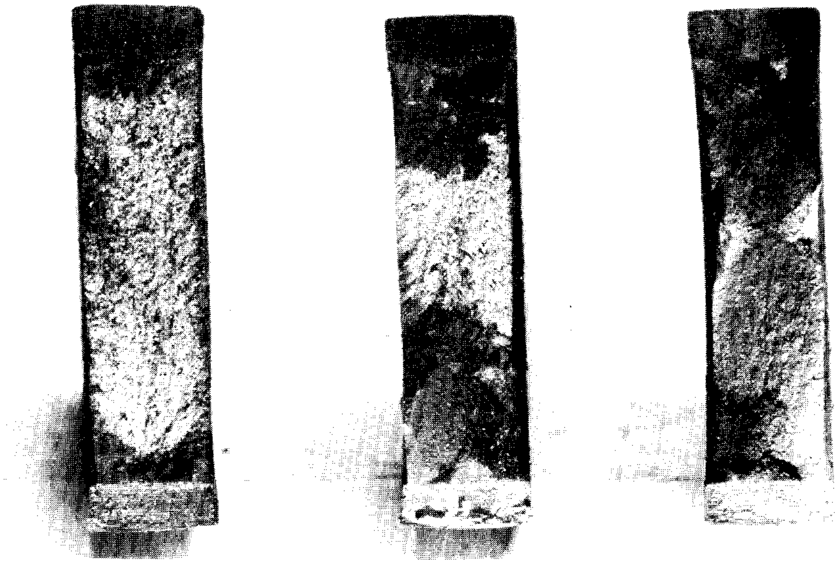
A-STEEL



TEMPERATURE,°F	-19°	6°	22°	39°
% SHEAR	6%	16%	39%	100%

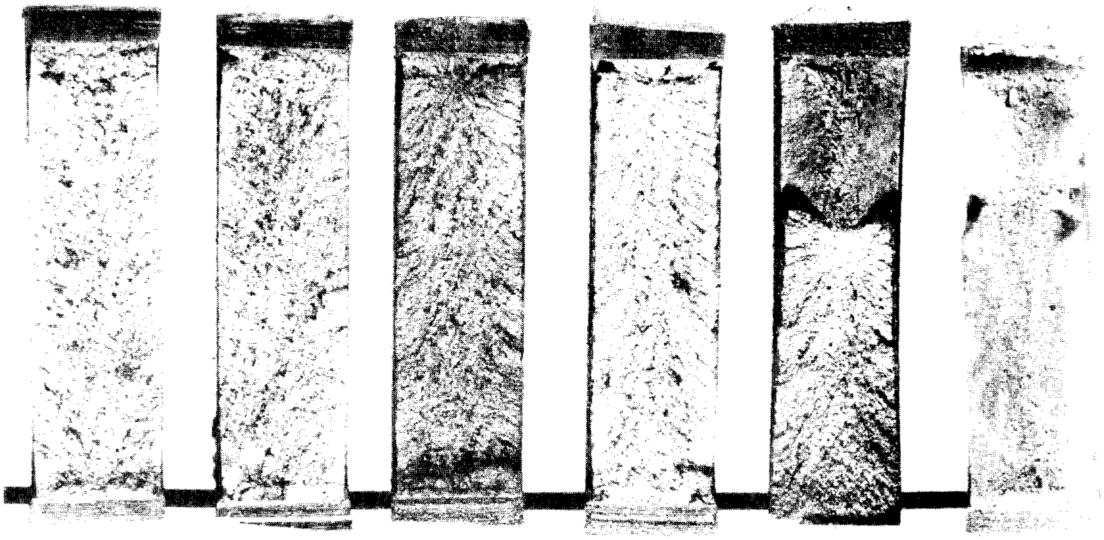
Bor-STEEL

FIG.59 EDGE NOTCHED SPECIMENS, 3-INCH WIDE, $\frac{3}{4}$-INCH THICK, SHOWING EFFECT OF TEMPERATURE ON TYPE OF FRACTURE



TEMPERATURE, °F	−16°	−1°	40°
% SHEAR	13%	31%	94%

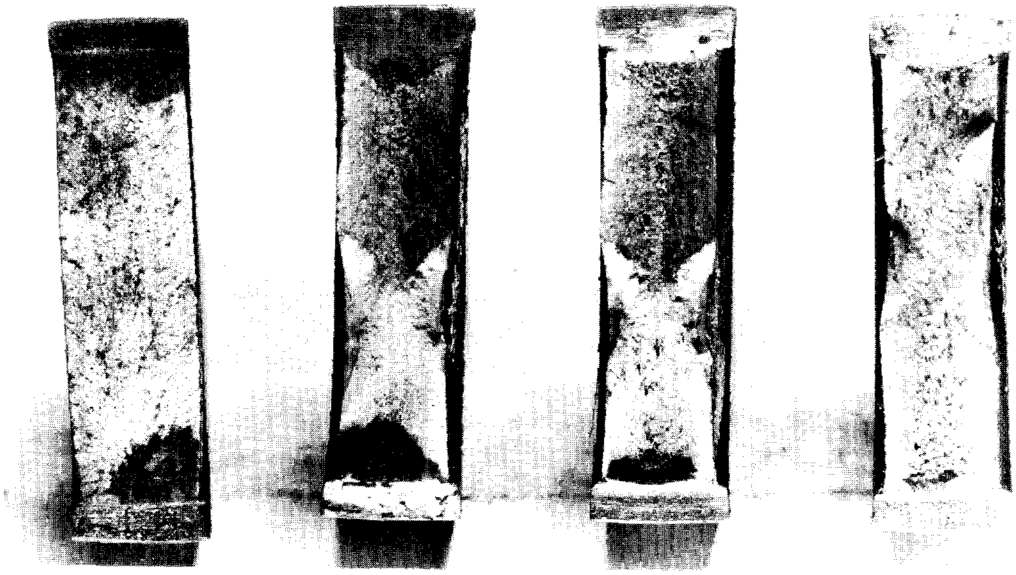
Bn-STEEL



TEMPERATURE, °F	34°	49°	75°	87°	96°	106°
% SHEAR	2%	3%	4%	6%	36%	98%

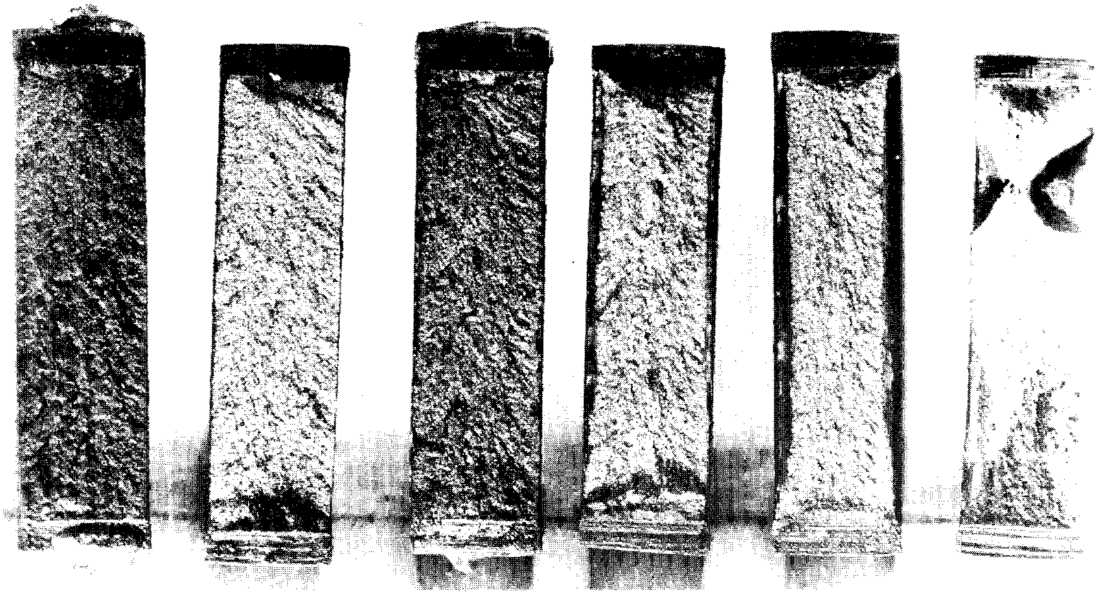
C-STEEL

FIG. 60 EDGE NOTCHED SPECIMENS, 3-INCH WIDE, $\frac{3}{4}$-INCH THICK SHOWING EFFECT OF TEMPERATURE ON TYPE OF FRACTURE



TEMPERATURE, °F	28°	51°	60°	70°
% SHEAR	3%	100%	100%	100%

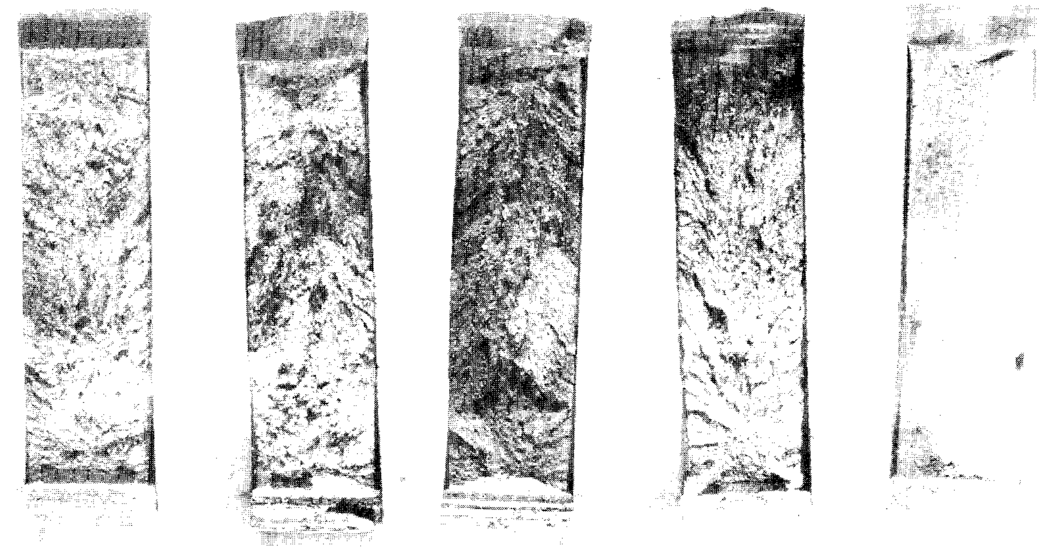
D–STEEL



TEMPERATURE, °F	44°	67°	90°	110°	128°	154°
% SHEAR	3%	5%	3%	17%	20%	98%

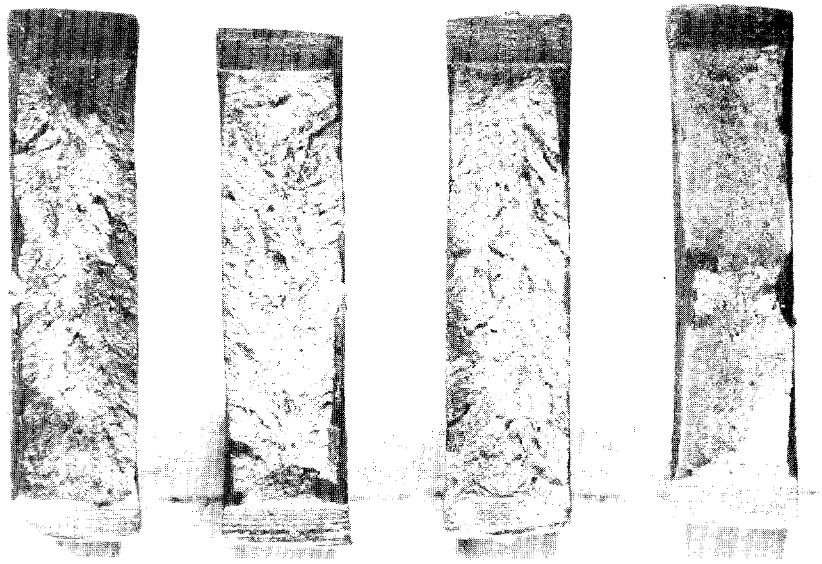
E–STEEL

FIG. 61 EDGE NOTCHED SPECIMENS, 3-INCH WIDE, $\frac{3}{4}$-INCH THICK SHOWING EFFECT OF TEMPERATURE ON TYPE OF FRACTURE



TEMPERATURE, °F	−39°	−6°	1°	15°	29°
% SHEAR	5%	11%	4%	12%	98%

N-STEEL



TEMPERATURE, °F	−13°	−2°	16°	29°
% SHEAR	8%	5%	6%	93%

Q-STEEL

FIG. 62 EDGE NOTCHED SPECIMEN, 3-INCH WIDE, $\frac{3}{4}$-INCH THICK, SHOWING EFFECT OF TEMPERATURE ON TYPE OF FRACTURE

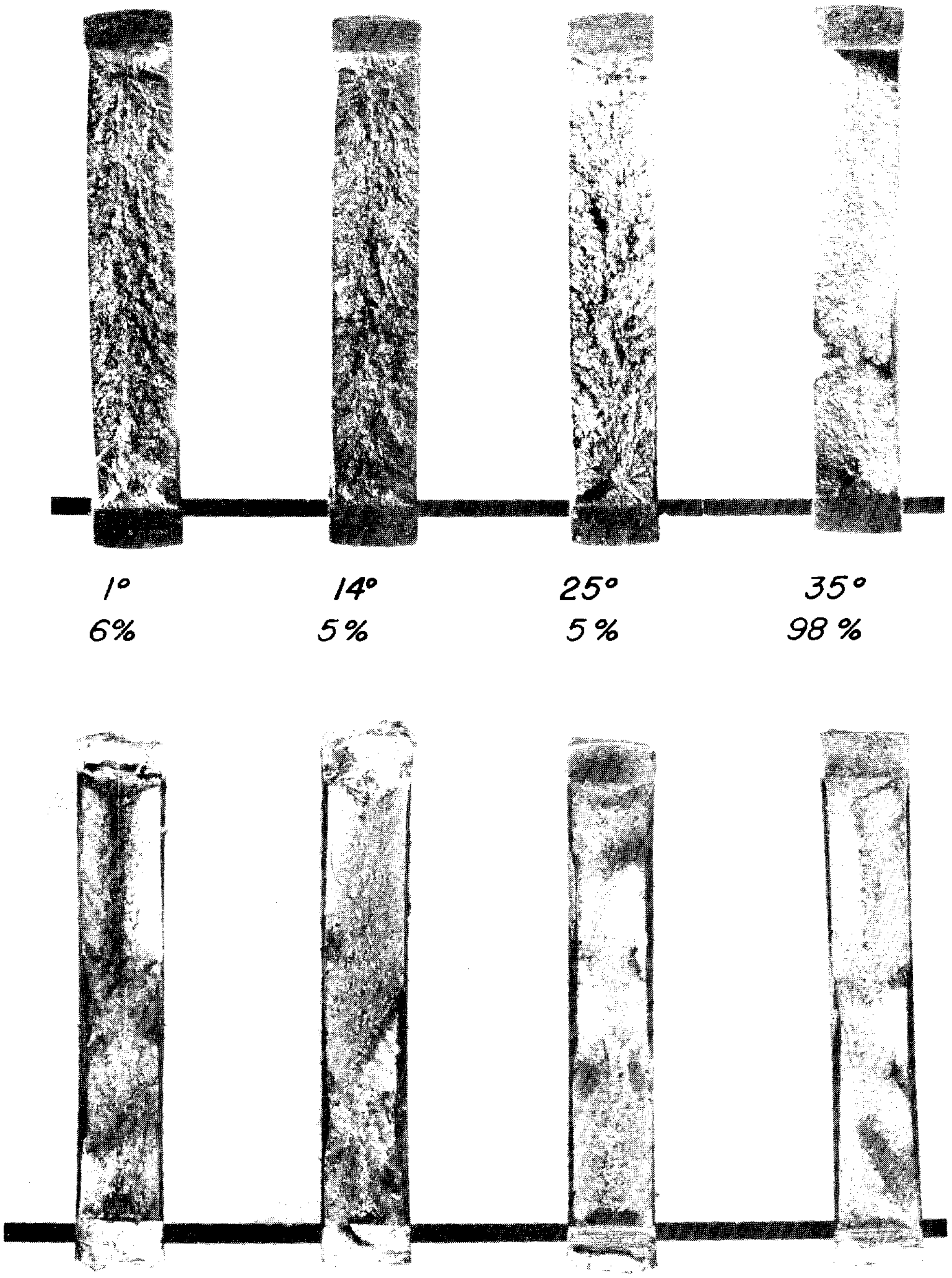
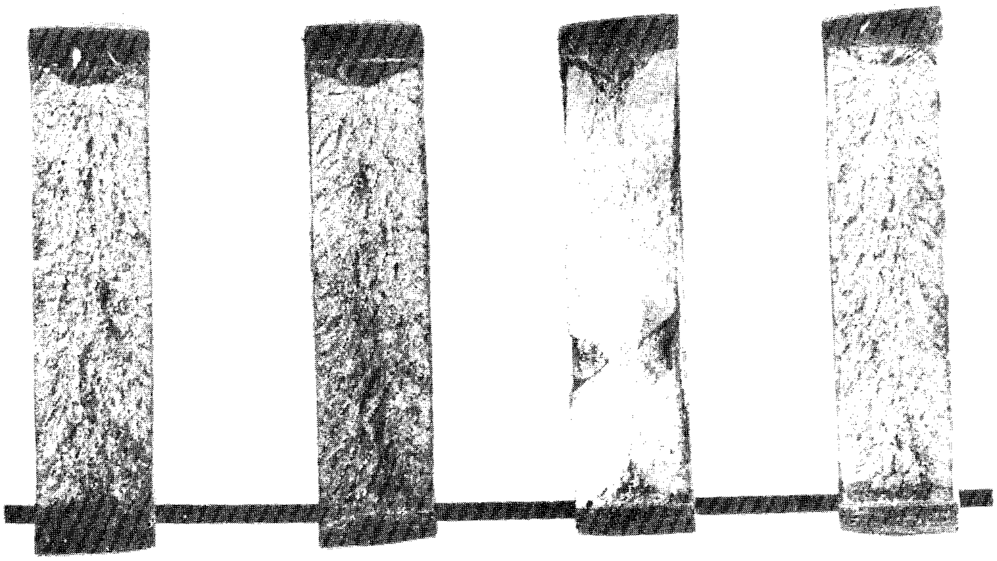
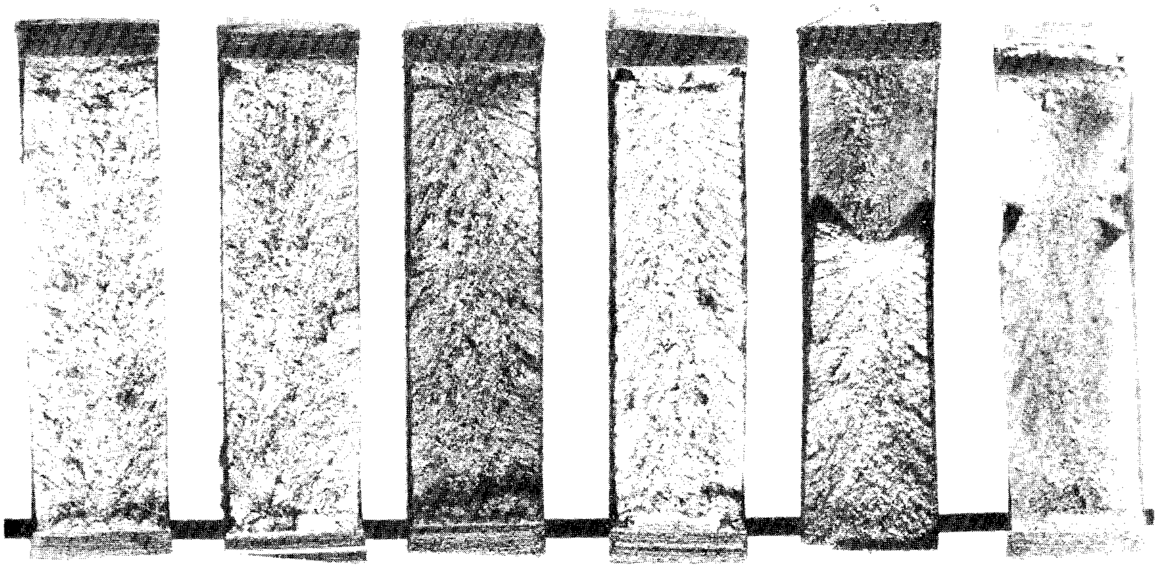


FIG. **63** EDGE NOTCHED SPECIMENS, 3-INCH WIDE, $\frac{1}{2}$-INCH THICK SHOWING EFFECT OF TEMPERATURE ON TYPE OF FRACTURE



TEMPERATURE, °F	39°	73°	89°	100°
% SHEAR	4%	4%	96%	10%

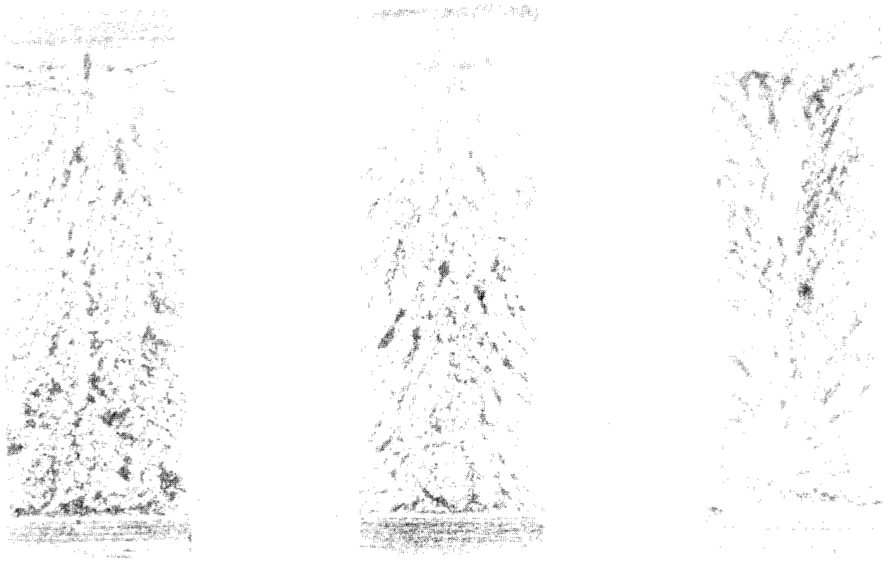
$\frac{5}{8}$-INCH THICK



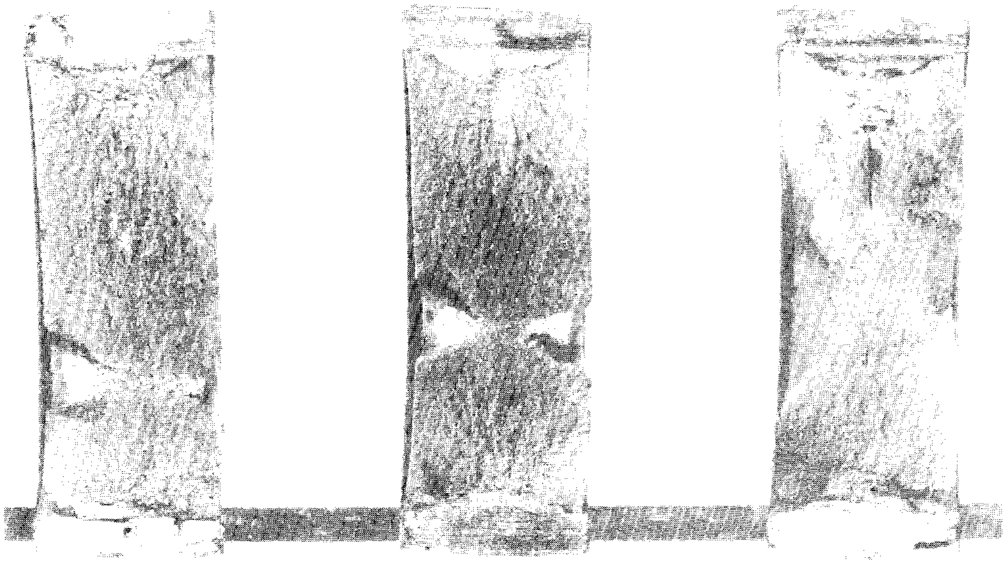
TEMPERATURE, °F	34°	49°	75°	87°	96°	106°
% SHEAR	2%	3%	4%	6%	36%	98%

$\frac{3}{4}$-INCH THICK

FIG. 64 EDGE NOTCHED SPECIMENS, 3-INCH WIDE, $\frac{3}{4}$-INCH THICK AND $\frac{5}{8}$-INCH THICK, SHOWING EFFECT OF TEMPERATURE ON TYPE OF FRACTURE

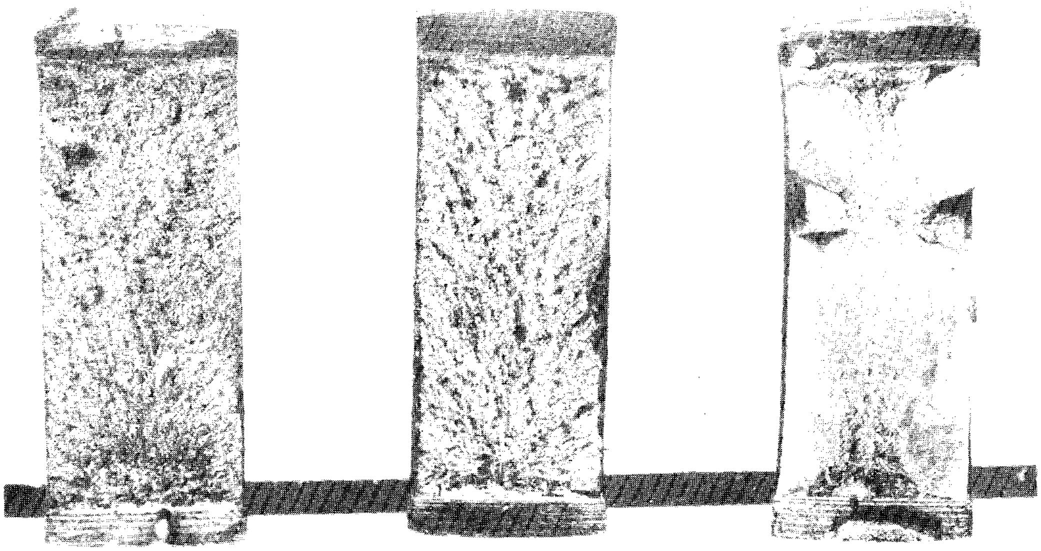


TEMPERATURE, °F	41°	100°	137°
% SHEAR	2%	2%	18%

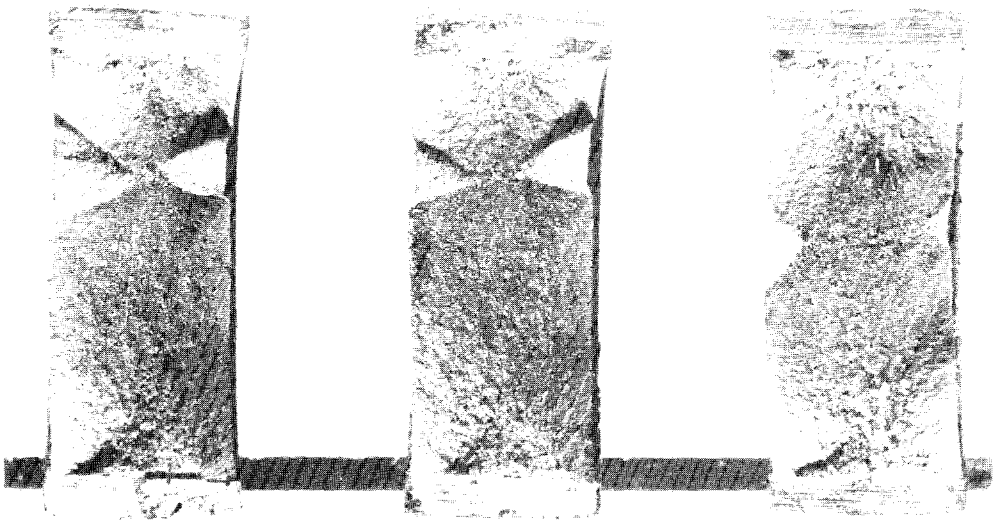


TEMPERATURE, °F	144°	147°	161°
% SHEAR	97%	97%	100%

FIG. 65 EDGE NOTCHED SPECIMENS, 3-INCH WIDE, 1-INCH THICK SHOWING EFFECT OF TEMPERATURE ON TYPE OF FRACTURE



TEMPERATURE, °F	77°	118°	134°
% SHEAR	0%	4%	96 %



TEMPERATURE, °F	139°	152°	162°
% SHEAR	94 %	97%	100%

FIG. 66 EDGE NOTCHED SPECIMENS, 3-INCH WIDE, $1\frac{1}{8}$-INCH THICK SHOWING EFFECT OF TEMPERATURE ON TYPE OF FRACTURE

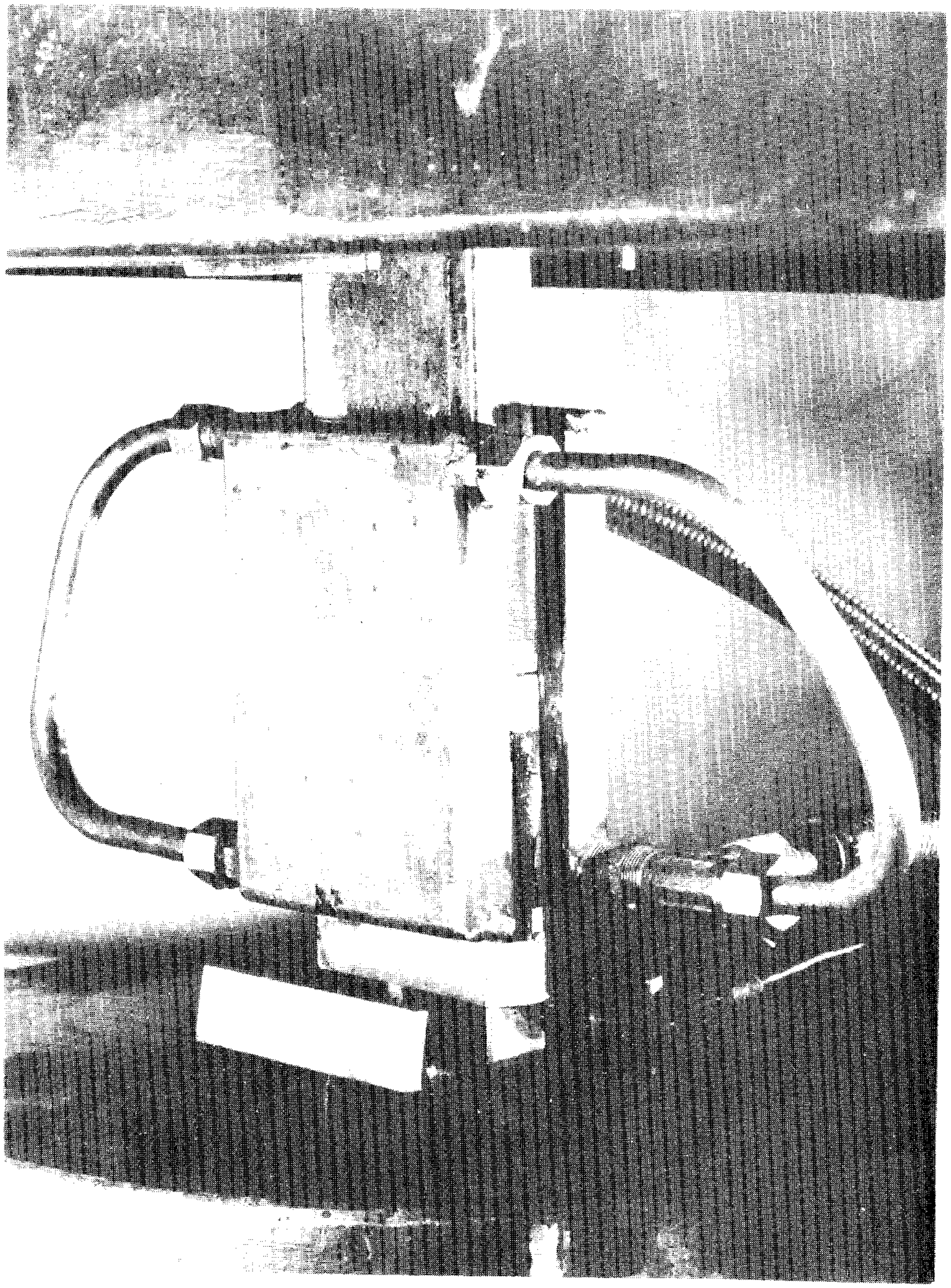


FIG. 67 EDGE NOTCH SPECIMEN, VIEW OF COOLING JACKET AROUND A 3-INCH EDGE NOTCHED BAR

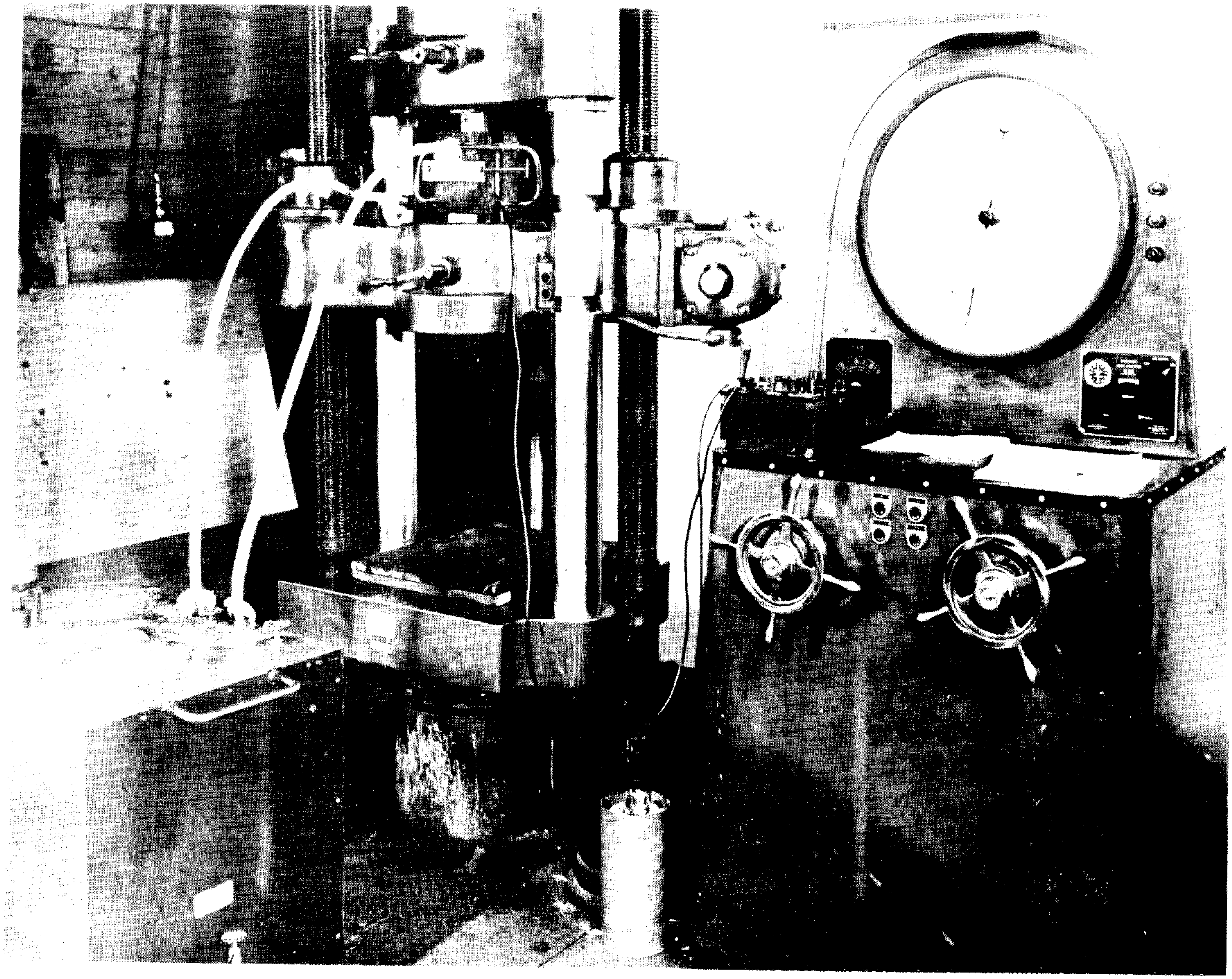


FIG. 68 GENERAL VIEW OF 3-INCH BAR TEST STATION

NOTE: TEMPERATURE CONTROL APPARATUS IN FOREGROUND

APPENDIX A

Residual Strain Distribution in Notched Flat Plate after Fracture

A system of rectangular grids shown in Fig. 5 was applied to one face of all the wide notched flat plates that were tested. Readings reproducable to ±0.002 in. were taken by means of a special strain gage prior to loading and after the fracture; percent elongations were calculated and are presented in Figs. A-1 through A-67. Lines of fracture are also shown in all of the figures. It is to be noted that the values shown in the figures do not include the elastic elongations or the plate separation at fracture. Also, since the residual elongations were measured on one face only, the effect of distortion of plate during fracture may be included in the values shown, although in most cases this distortion was fairly small.

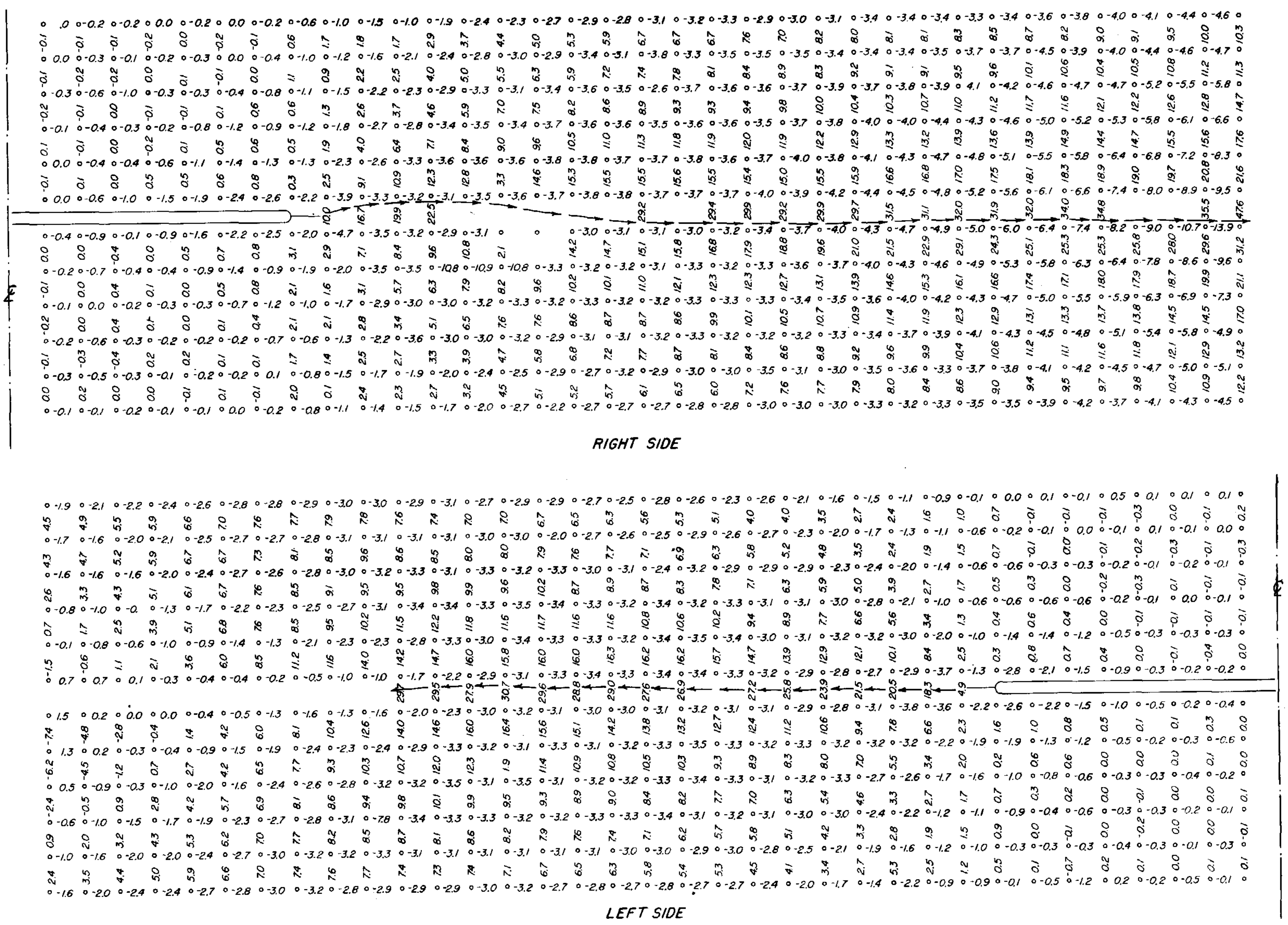


FIG. A-1 PERCENT ELONGATION PLATE A-1A (1-IN. GRID)

"A" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH - 38.5 KSI

TEMPERATURE 75°F 100% SHEAR

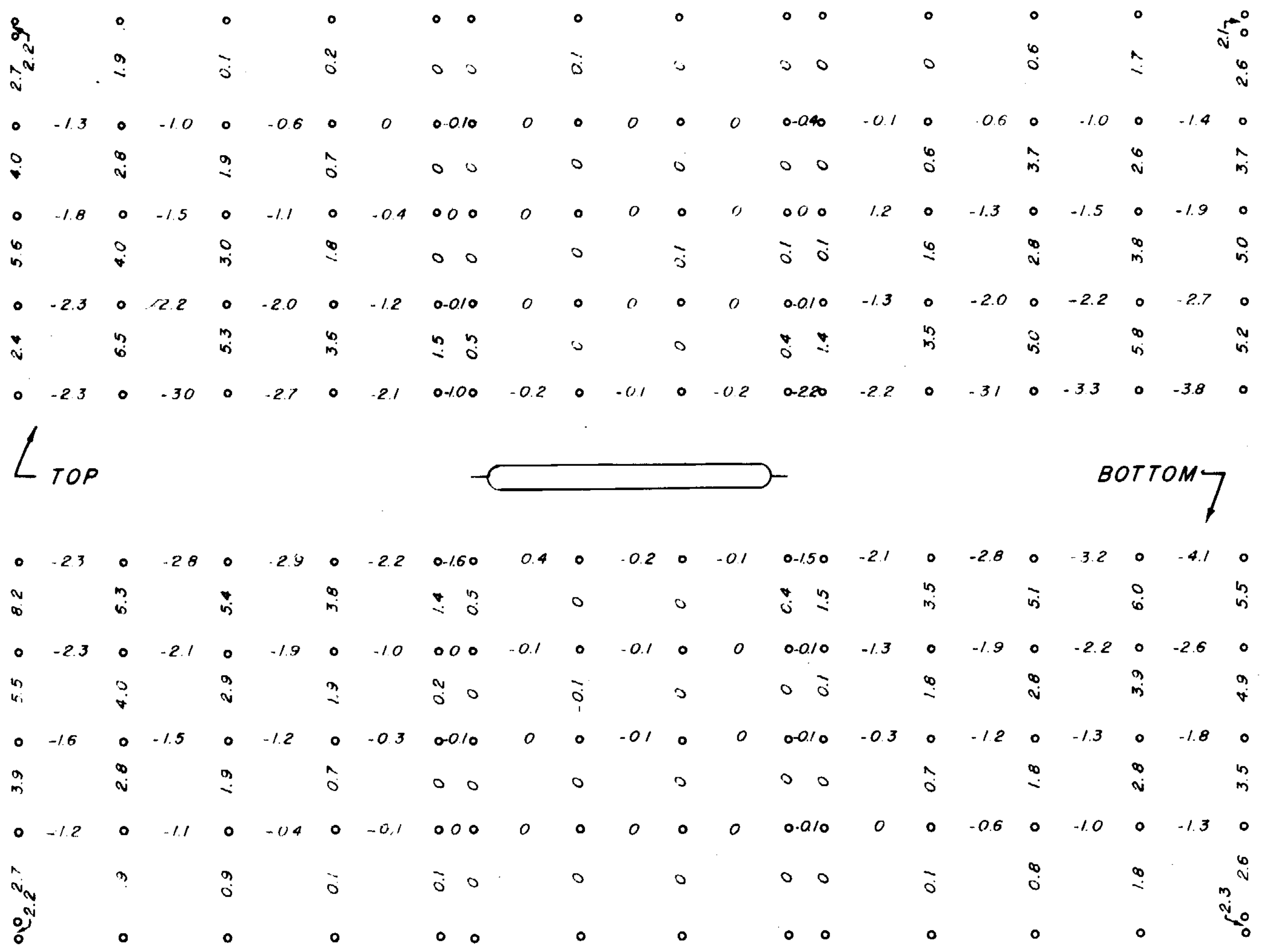


FIG A-2 PERCENT ELONGATION PLATE A-IA (5 INCH GRID)

"A" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 38.5 KSI
TEMPERATURE 75°F 79.9 % SHEAR

DWG 44E 85

FIG. A-2

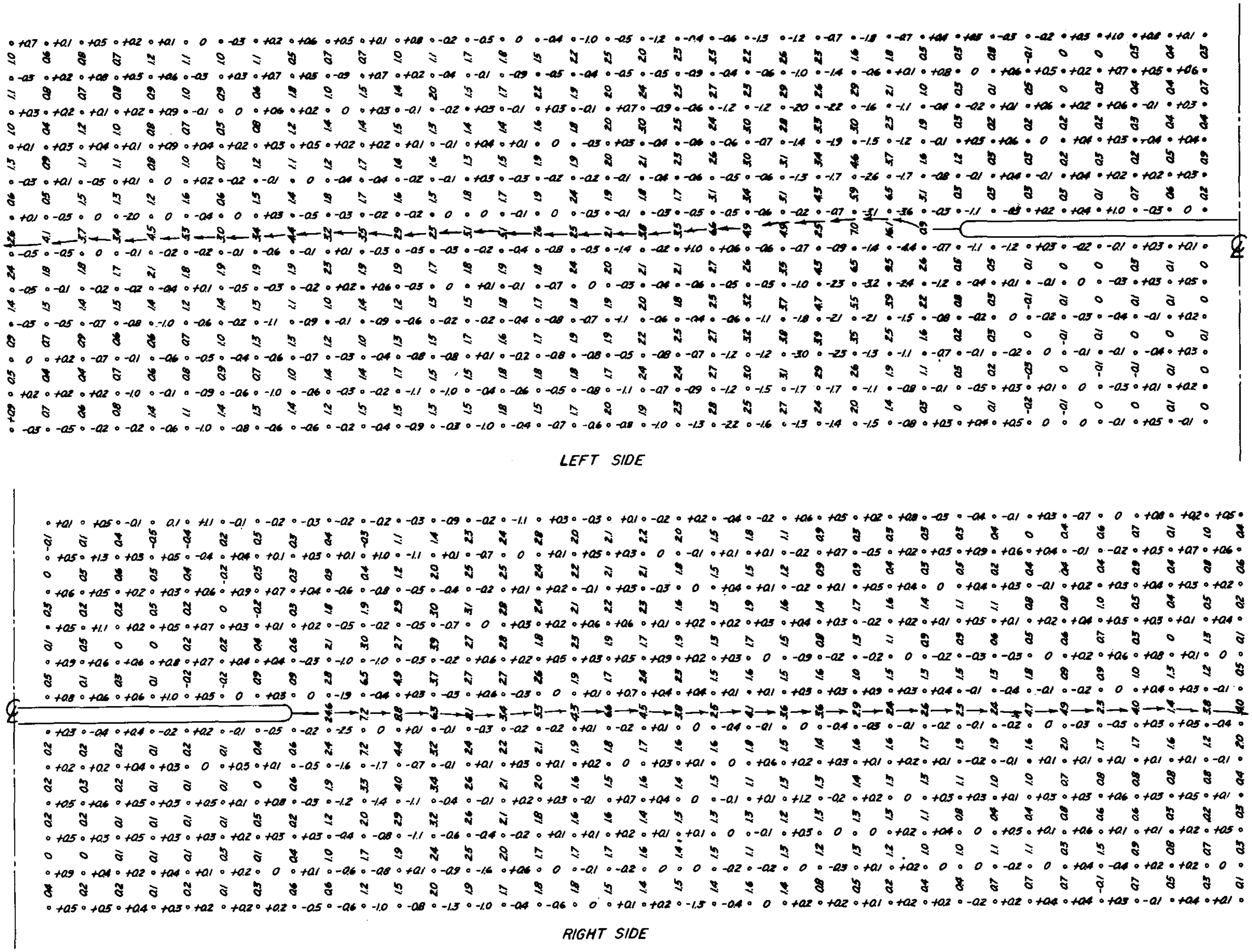


FIG. A-3 PERCENT ELONGATION PLATE A-2A (1-INCH GRID)

"A" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 38.5 KSI
TEMPERATURE: 30-35°F. 2.0% SHEAR

44E133

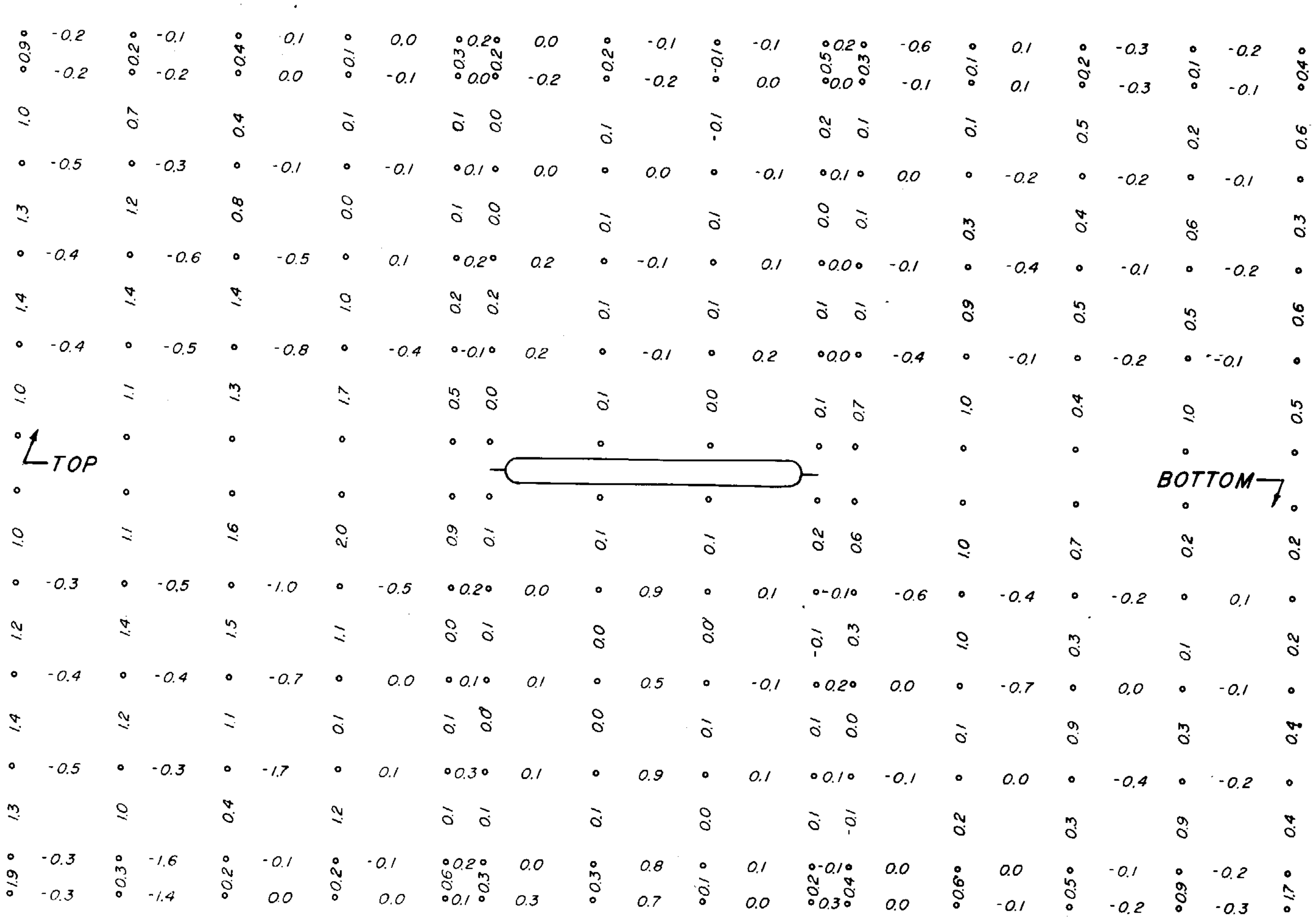


FIG. A-4 PERCENT ELONGATION PLATE A-2A (5 INCH GRID)

"A" STEEL, 72 INCH WIDE PLATE
TEMPERATURE 30—35°F

NOMINAL STRENGTH 38.5 KSI
2% SHEAR

DWG. 44 E 86

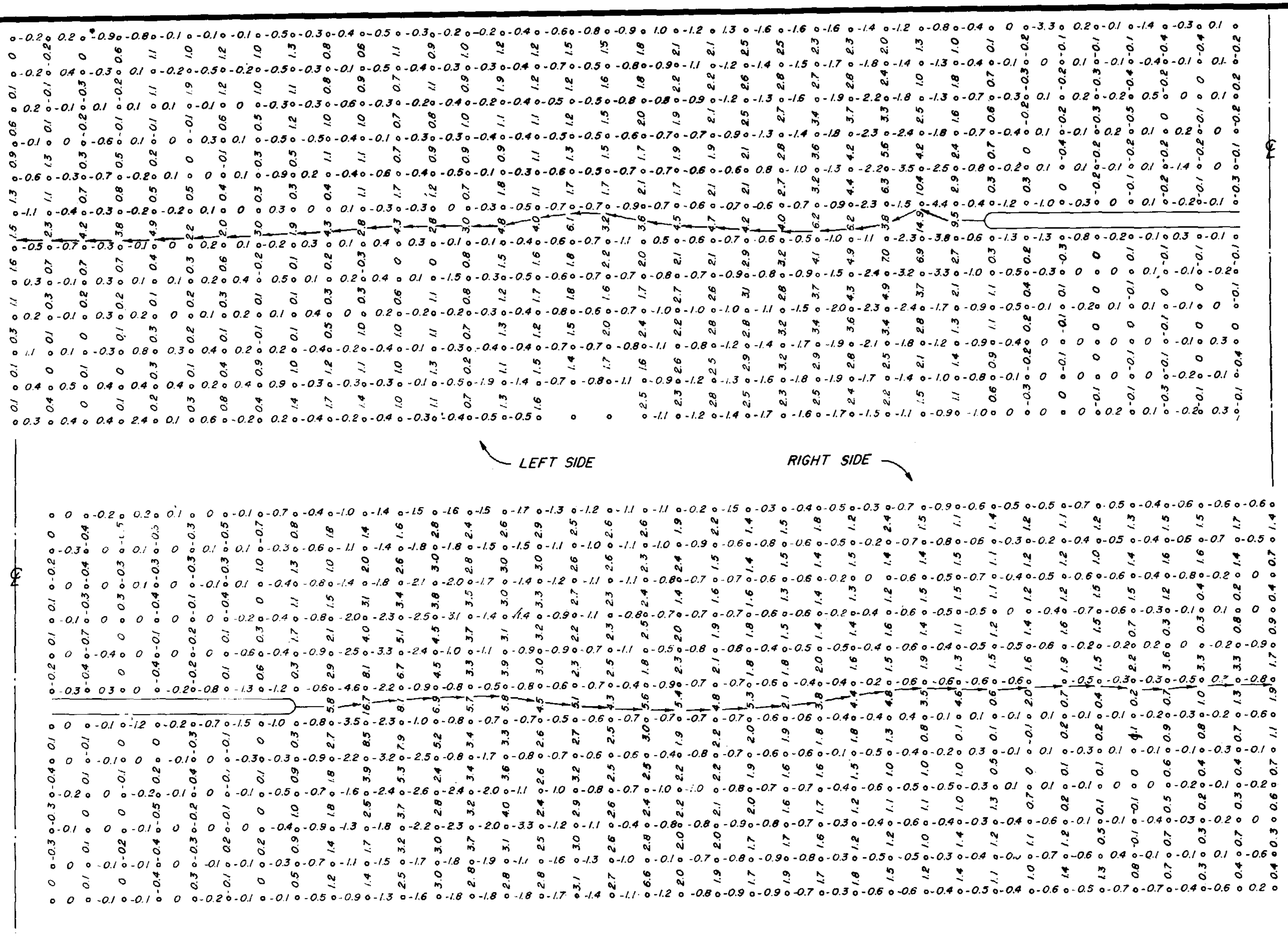


FIG. A-5 PERCENT ELONGATION PLATE B-1A' (1-INCH GRID)

"Bor" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 38.5 KSI

TEMPERATURE 30 - 35° F. 3 % SHEAR

DWG. 44E164

FIG.A-5

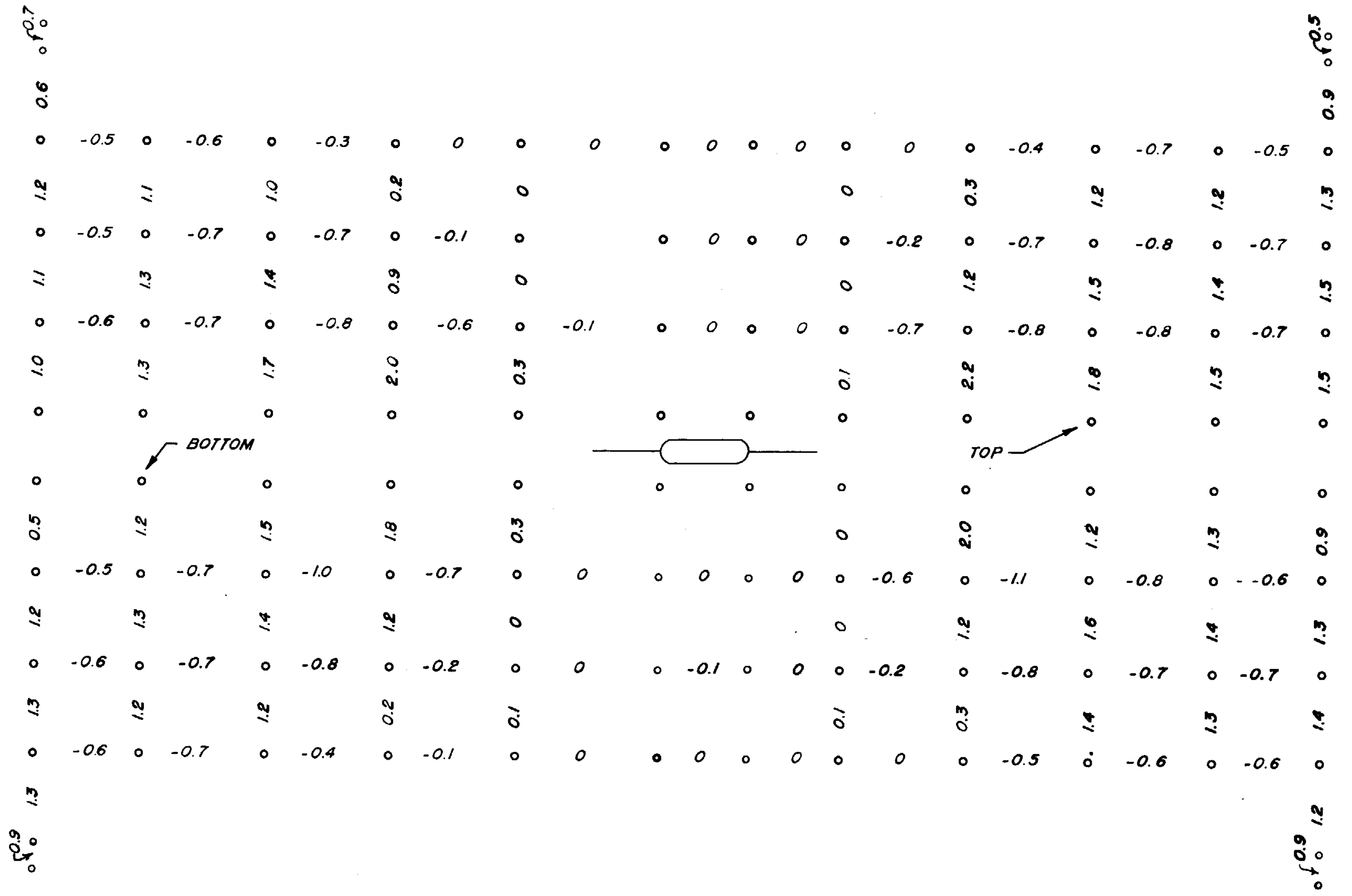


FIG. A-6 PERCENT ELONGATION PLATE B-1A (5-INCH GRID)

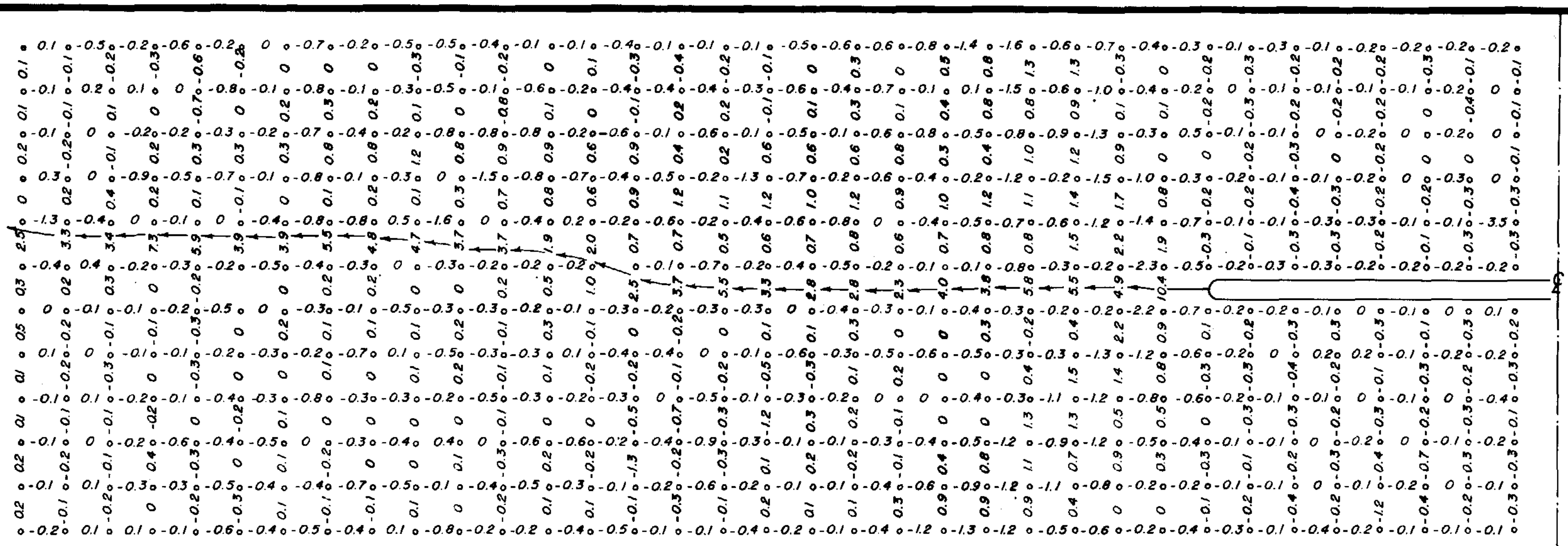
"Bar" STEEL, 72 INCH WIDE PLATE

TEMPERATURE 30–35° F

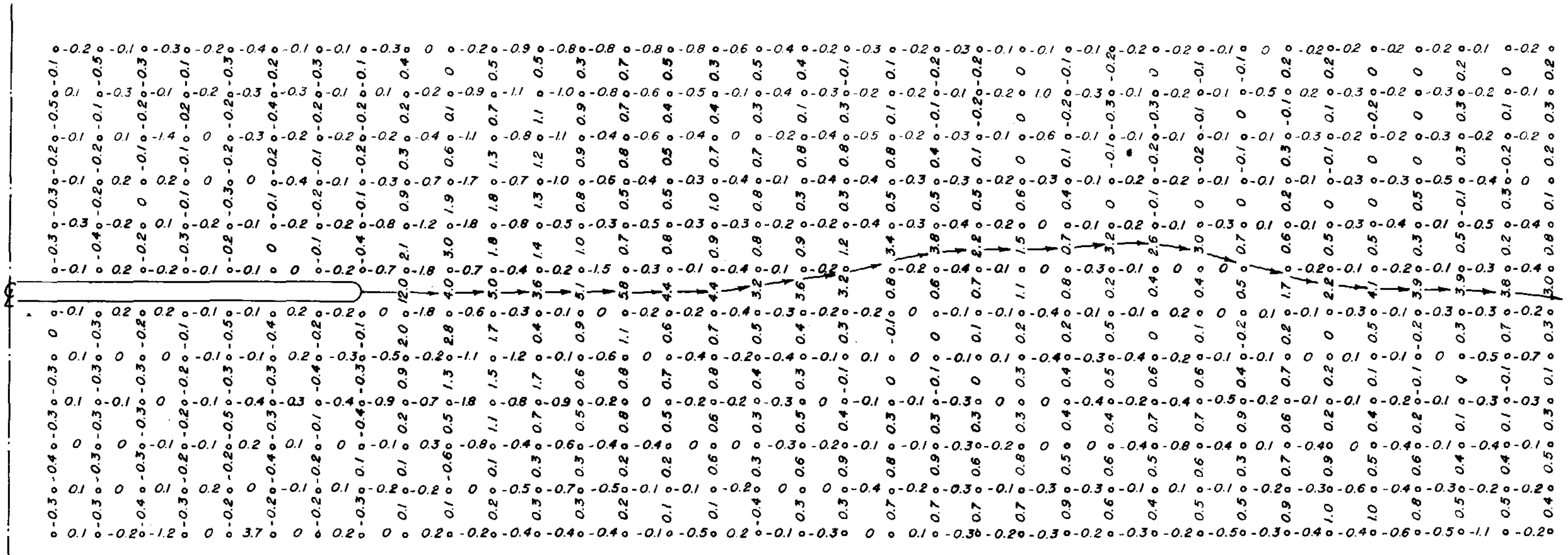
NOMINAL STRENGTH 38.5 KSI

3% SHEAR

44E87



LEFT SIDE



RIGHT SIDE

FIG. A-7 PERCENT ELONGATION PLATE B-2A (1-INCH GRID)

"Bn" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 33.2KSI

TEMPERATURE 29-32°F. 0% SHEAR

44E154

FIG. A-7

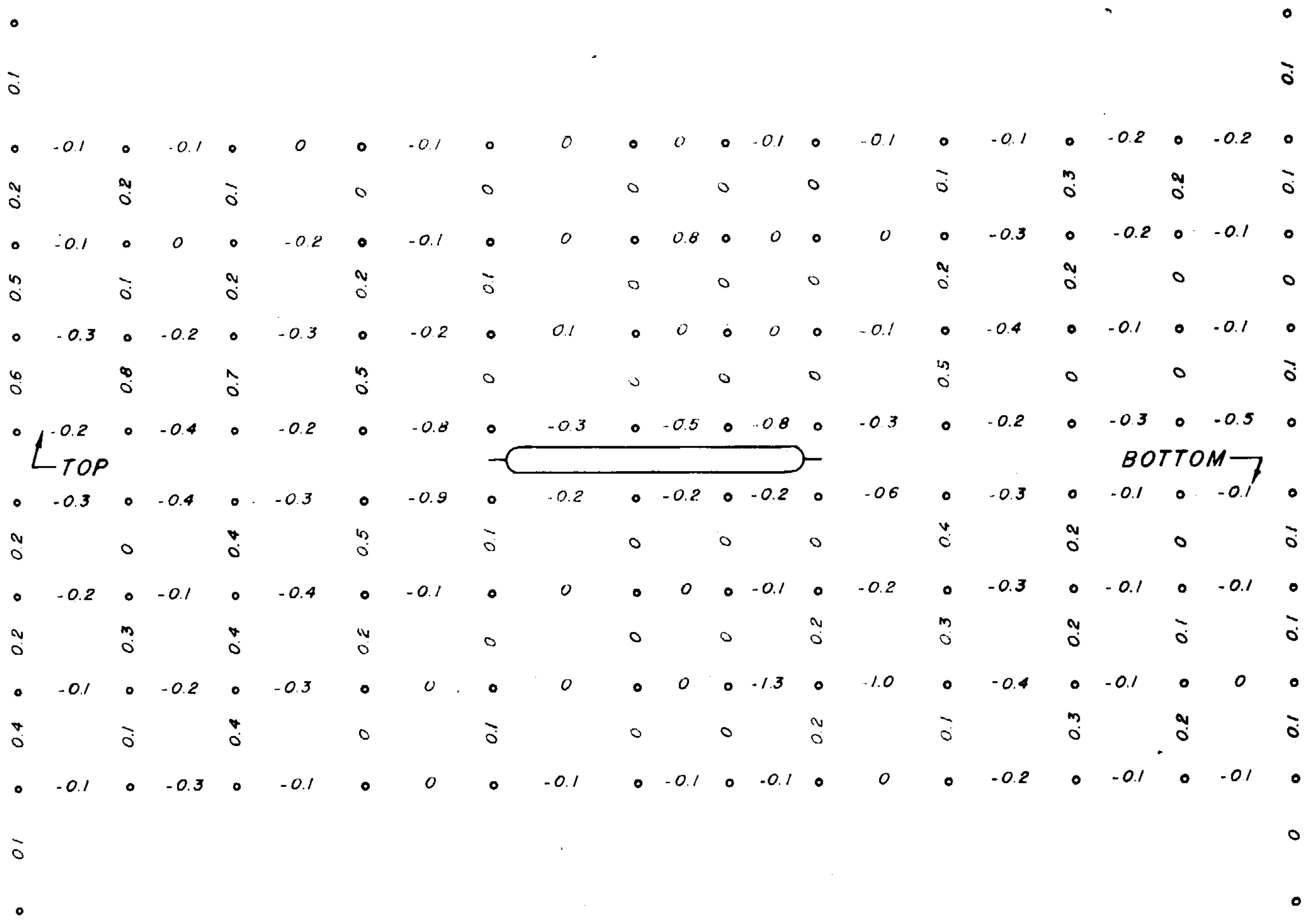


FIG. A-8 PERCENT ELONGATION PLATE B-2A (5 INCH GRID)

"B" STEEL, 72 INCH WIDE NOMINAL STRENGTH 33.2 KSI
TEMPERATURE 29-32°F 0% SHEAR

DWG. 44E88

FIG. A-8

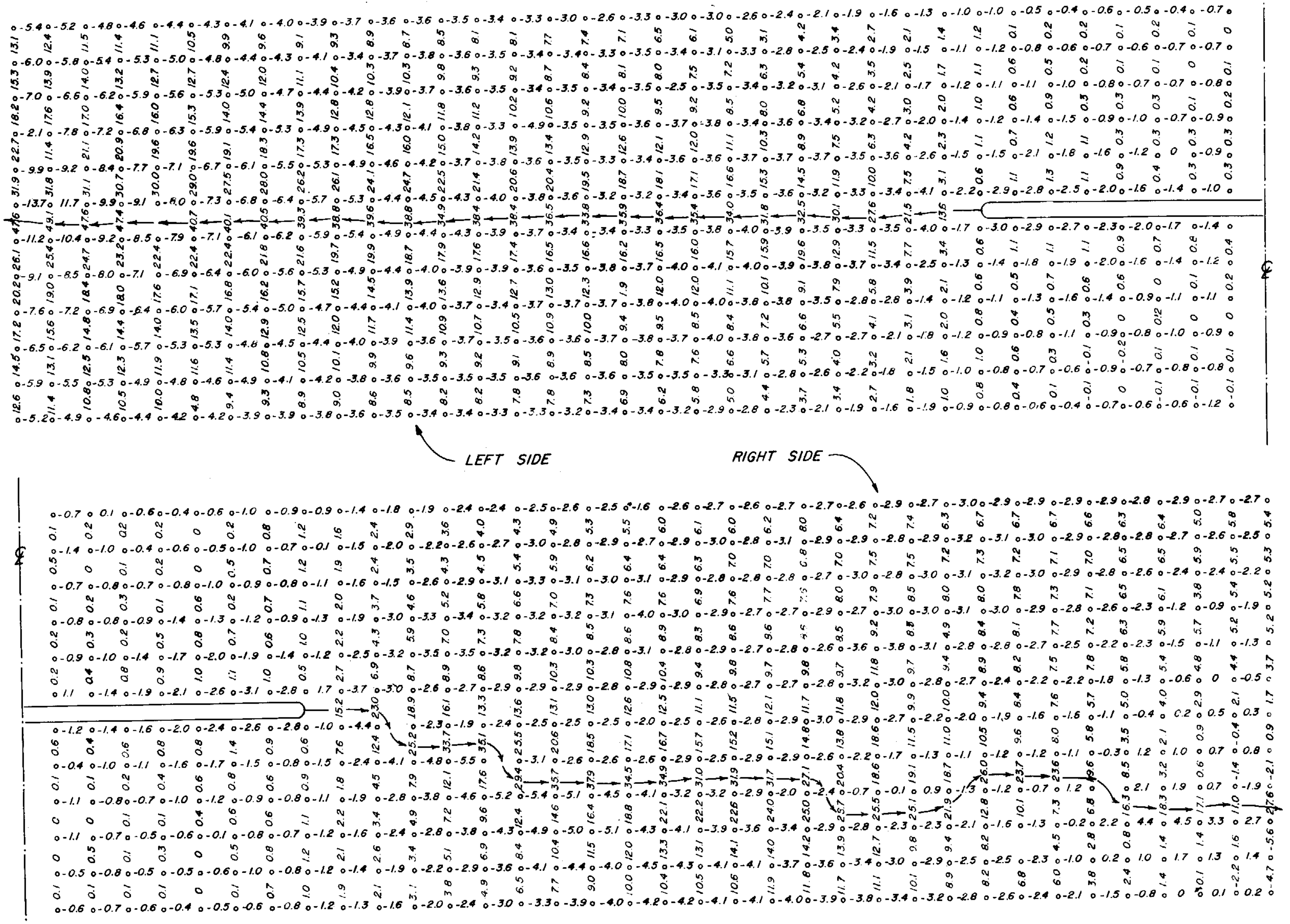


FIG. A-9 PERCENT ELONGATION PLATE B-3A (1-INCH GRID)

"Bar" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 40.0KSI

TEMPERATURE 72° F. 74% SHEAR

44E135

FIG. A-9

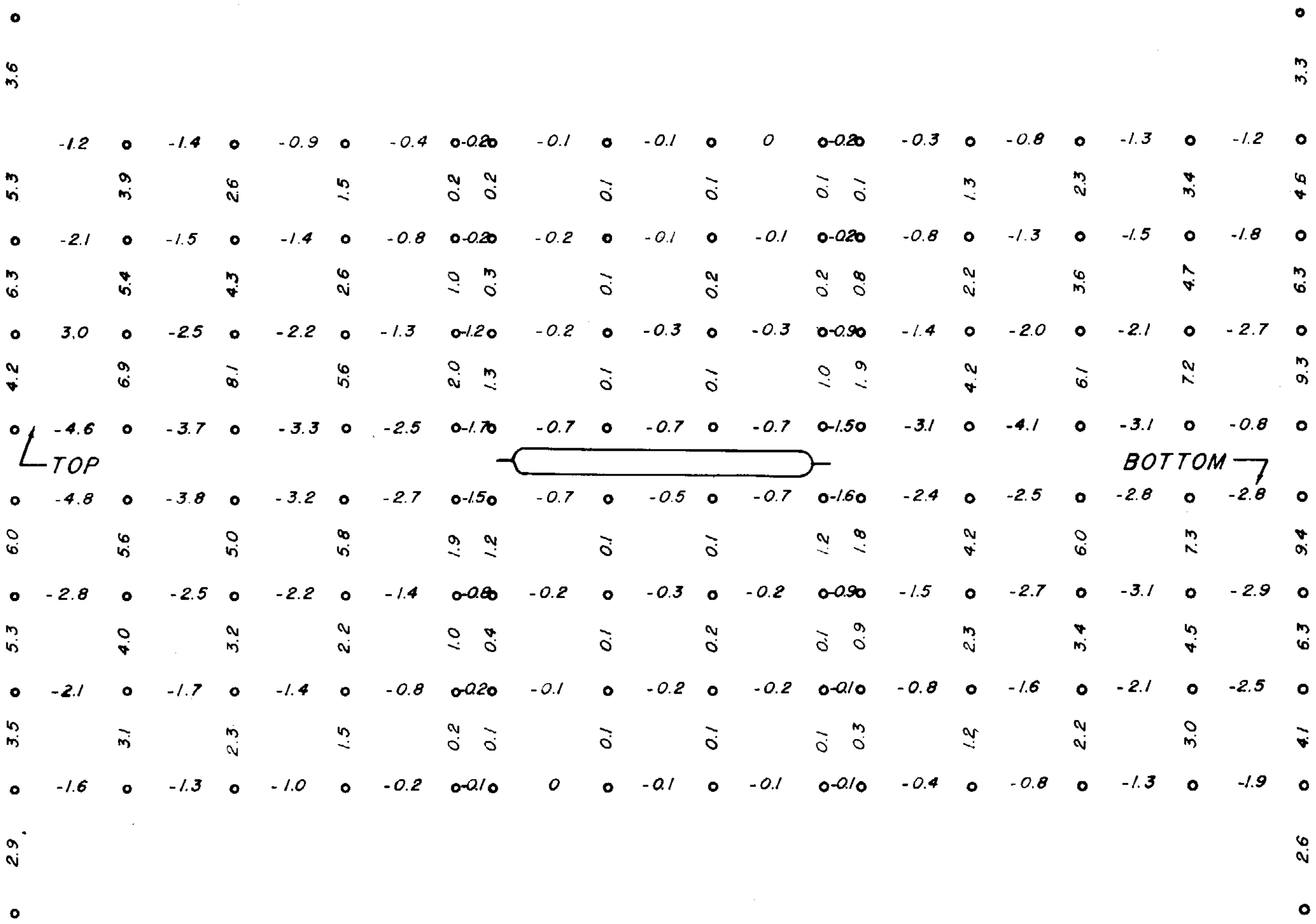


FIG. A-10 PERCENT ELONGATION PLATE B-3A (5 INCH GRID)

"B" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 40.0 KSI
TEMPERATURE 72-74° F 74% SHEAR

DWG. 44E 89

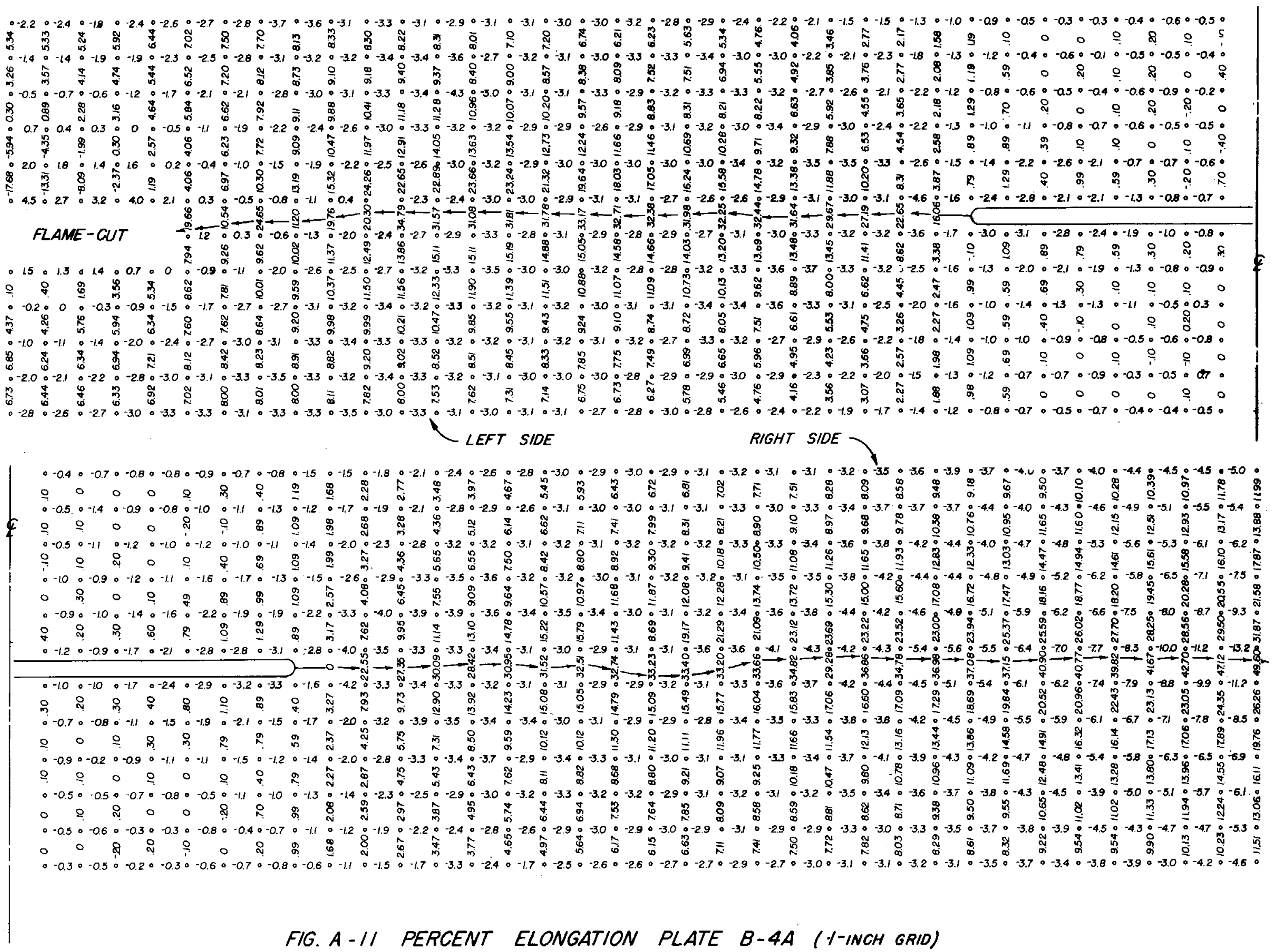


FIG. A-11 PERCENT ELONGATION PLATE B-4A (1-INCH GRID)

"Bn" STEEL 72 INCH WIDE PLATE NOMINAL STRENGTH 37.9 KSI

TEMPERATURE 72° F. 100% SHEAR

FIG. A-11

44E136

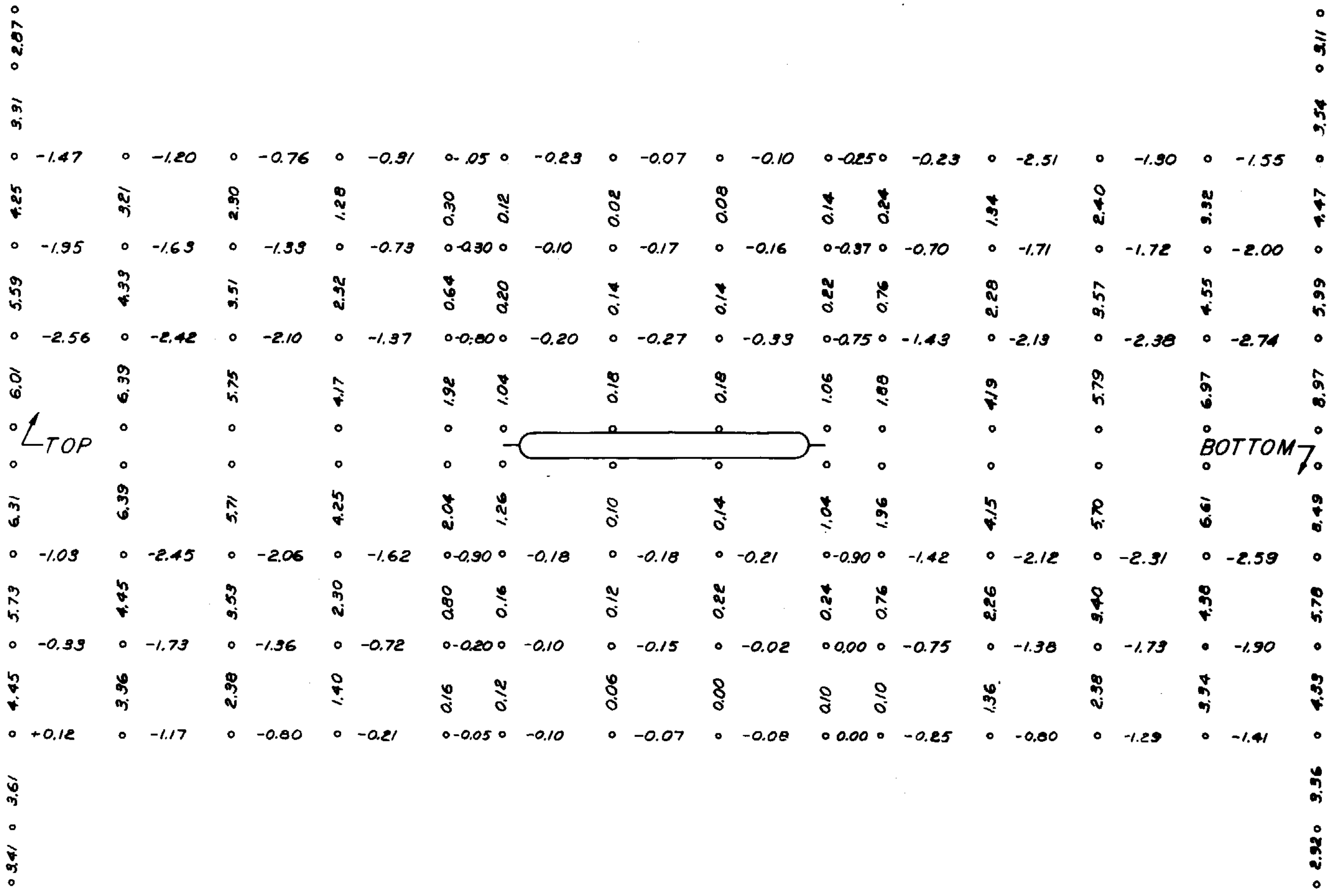


FIG. A-12 PERCENT ELONGATION PLATE B-4A (5 INCH GRID)

"B" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 37.9 KSI
TEMPERATURE 72°F 91 % SHEAR

DWG. 44E90

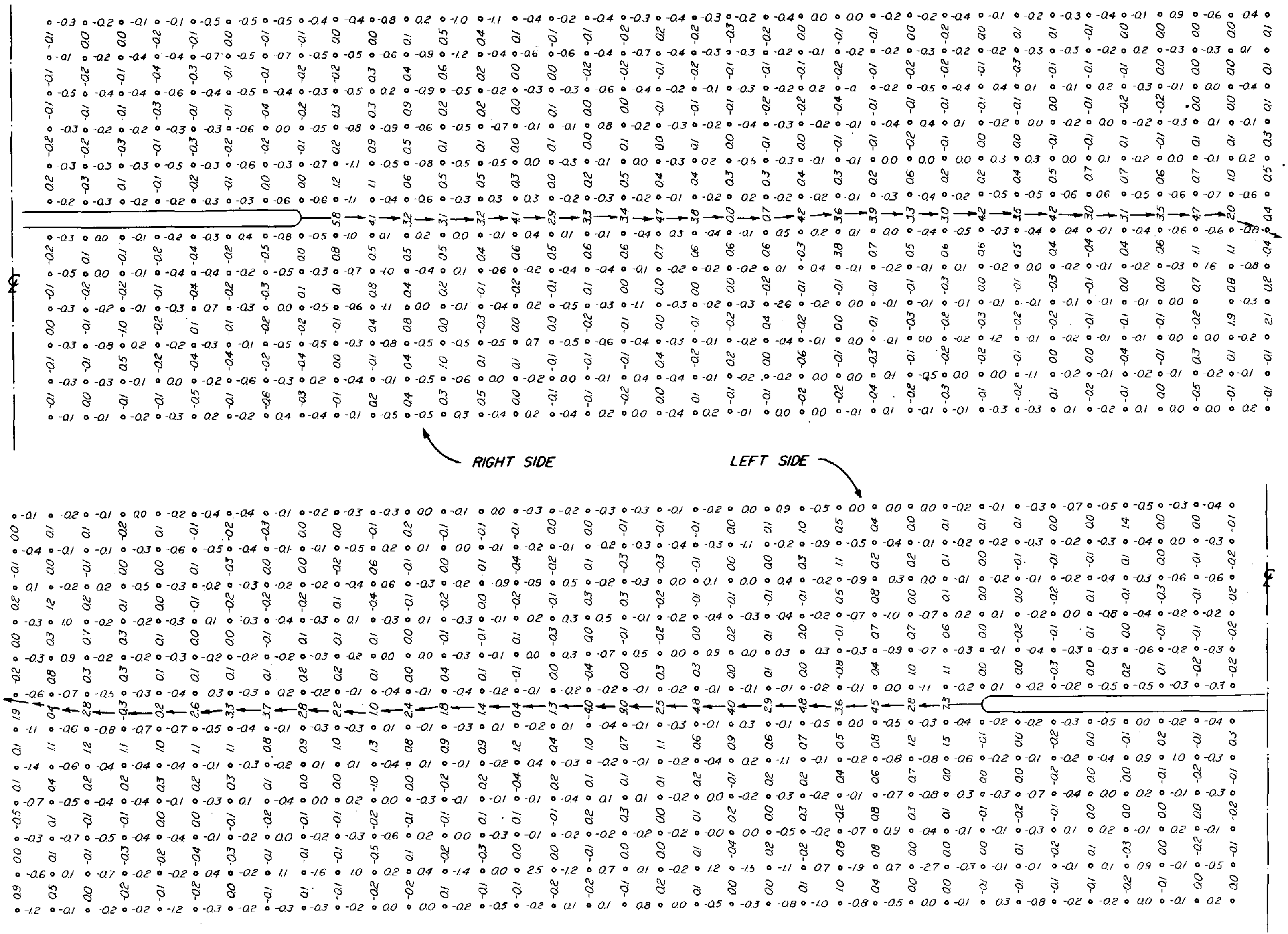


FIG. A-13 PERCENT ELONGATION PLATE C-1A (1-INCH GRID)

"C" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 37.0 KSI

TEMPERATURE 30-34° F. 0% SHEAR

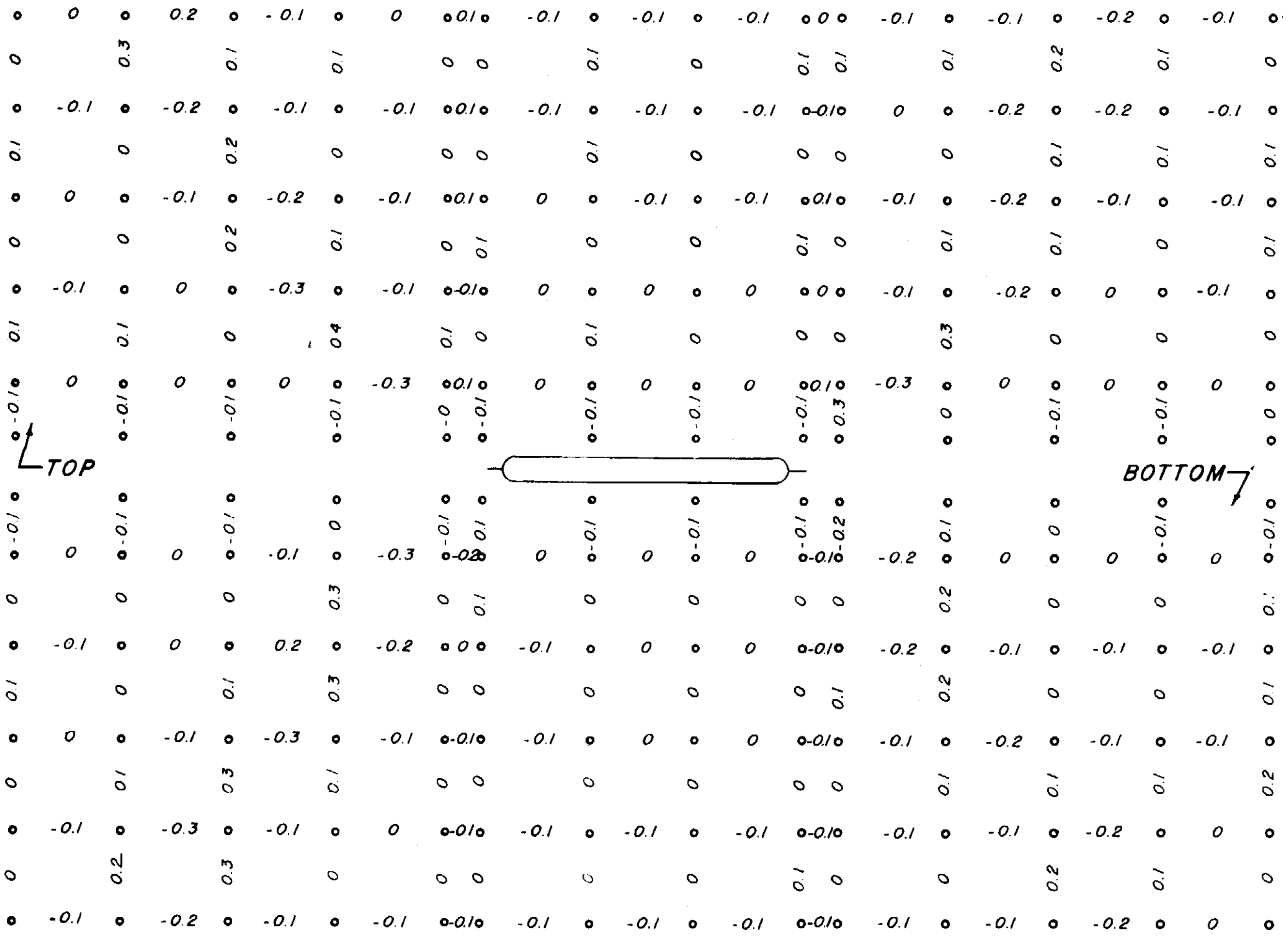


FIG. A-14 PERCENT ELONGATION PLATE C-1A (5 INCH GRID)

"C" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 37.0 KSI

TEMPERATURE 30–34°F 0% SHEAR

DWG. 44E91

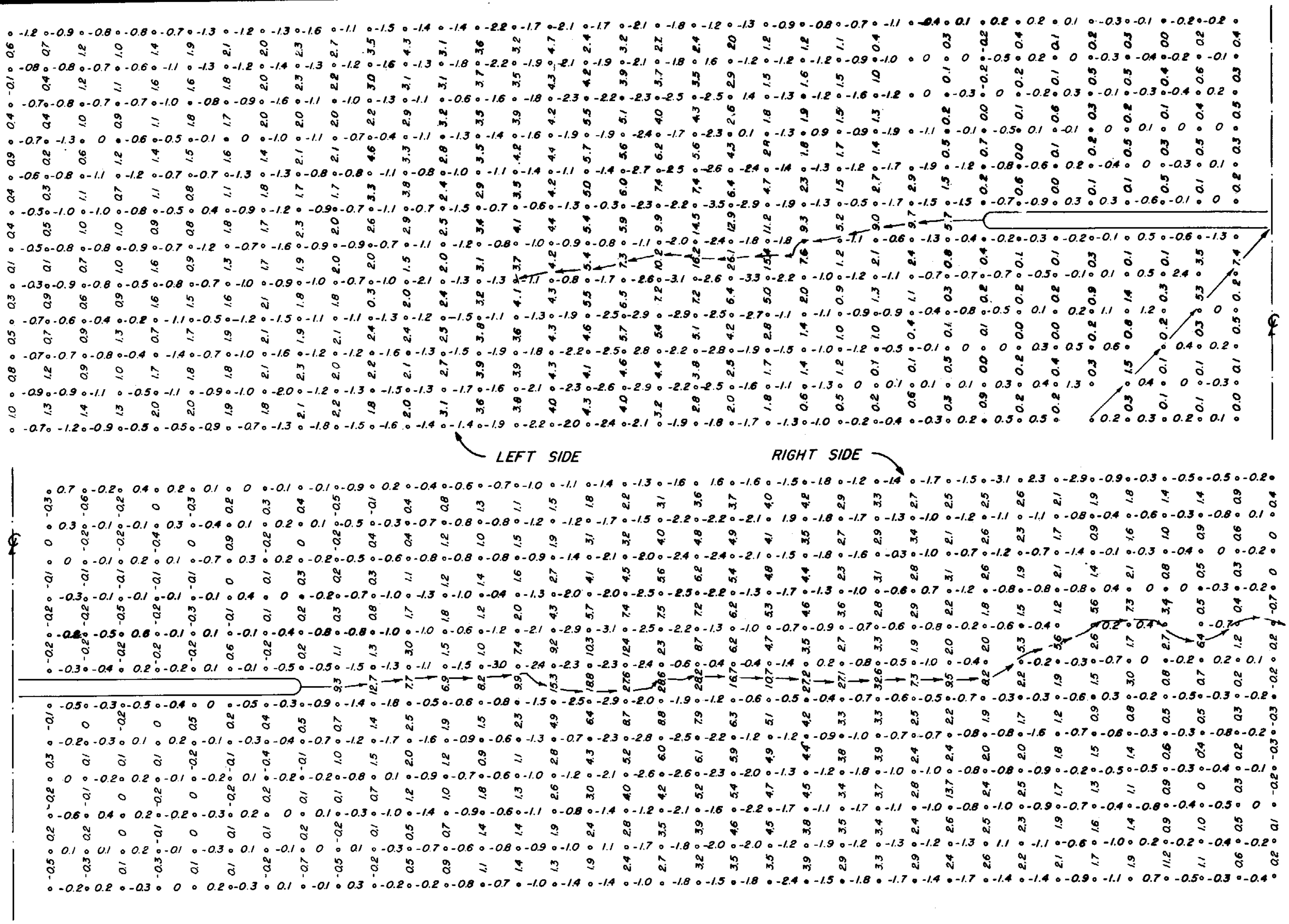


FIG. A-15 PERCENT ELONGATION PLATE C-2A (1-INCH GRID)

"C" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 37.8 KSI

TEMPERATURE 75-78° F. 9% SHEAR

44E138

FIG. A 15

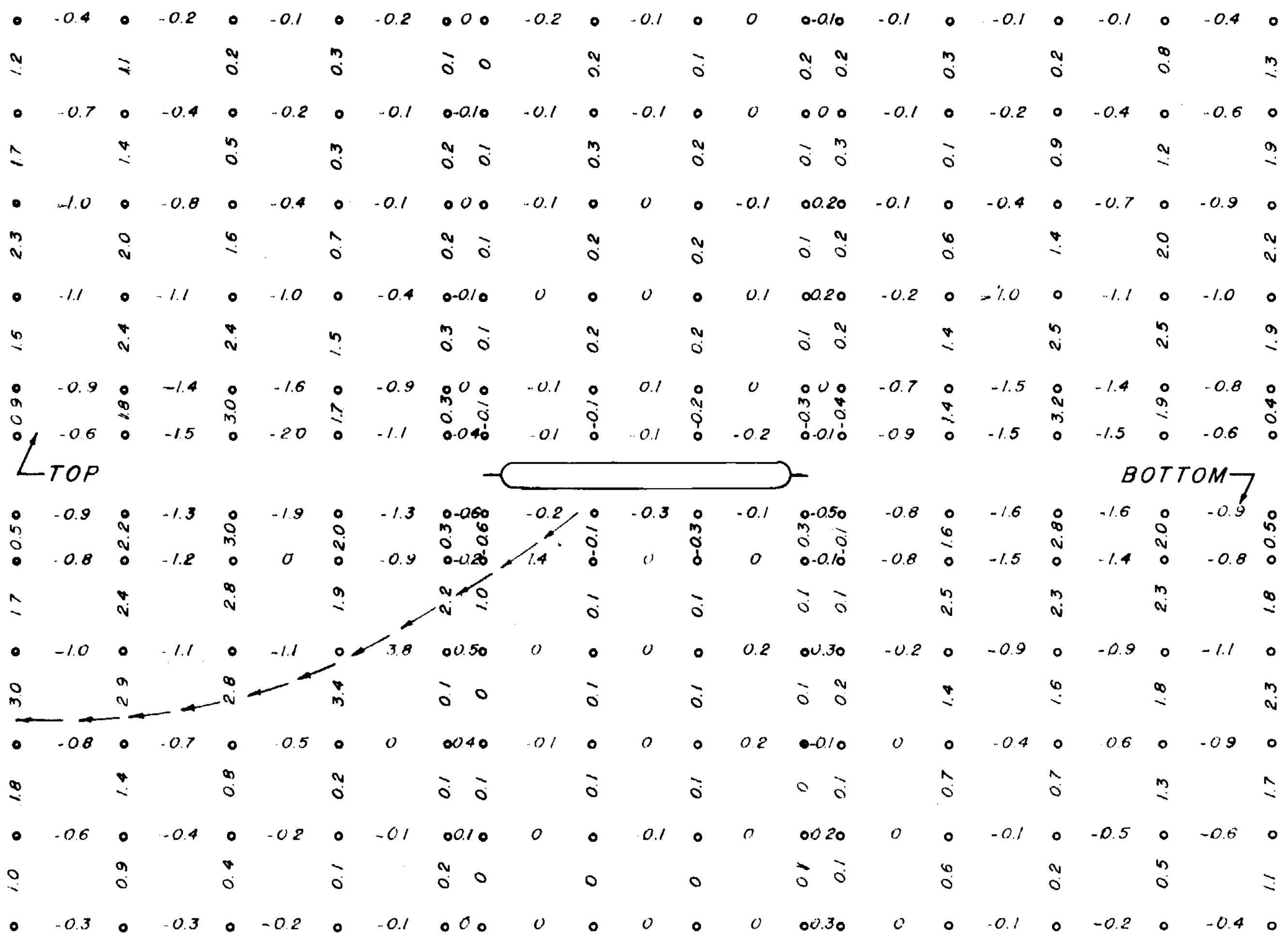


FIG A-16 PERCENT ELONGATION PLATE C-2A (5 INCH GRID)

"C" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 37.8 KSI
TEMPERATURE 75–78°F 9% SHEAR

DWG. 44E92

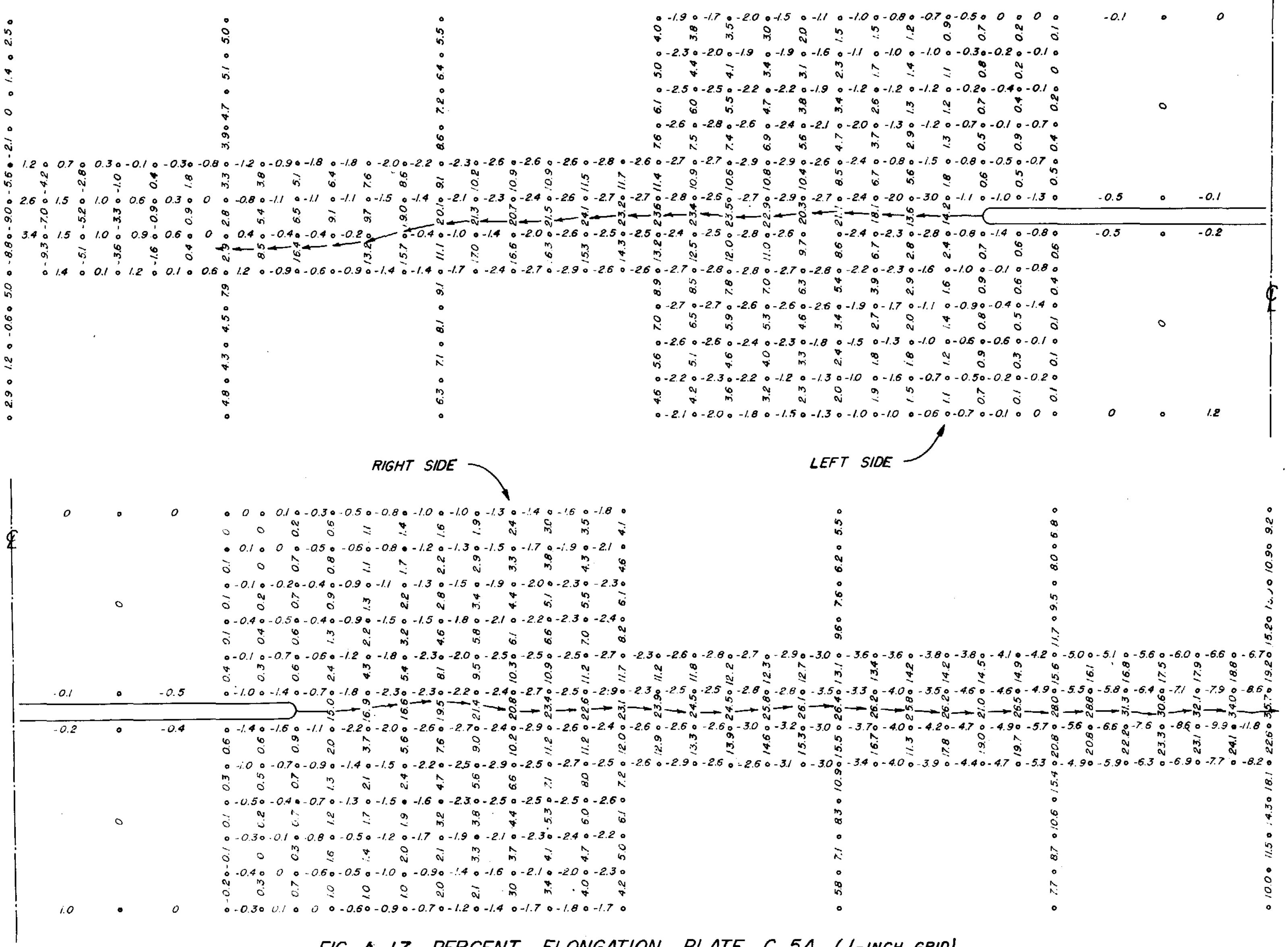


FIG. A-17 PERCENT ELONGATION PLATE C-5A (1-INCH GRID)

"C" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 43.0 KSI

TEMPERATURE 146-153° F. 98% SHEAR

FIG A-17

44E139

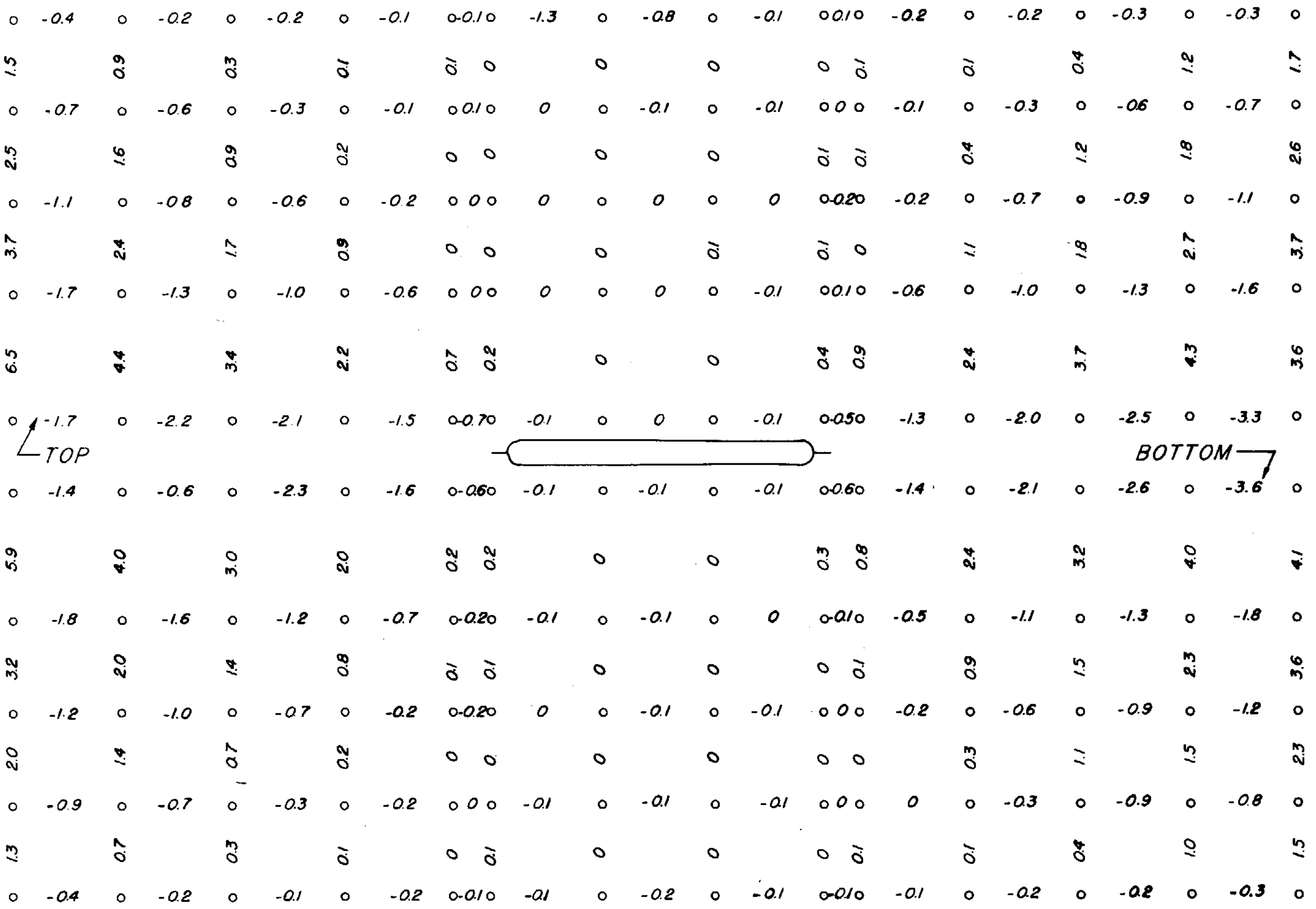


FIG. A-18 PERCENT ELONGATION PLATE C-5A (5 INCH GRID)

"C" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 43.0 KSI
TEMPERATURE 146—153°F 98% SHEAR

DWG. 44E93

FIG. A-18

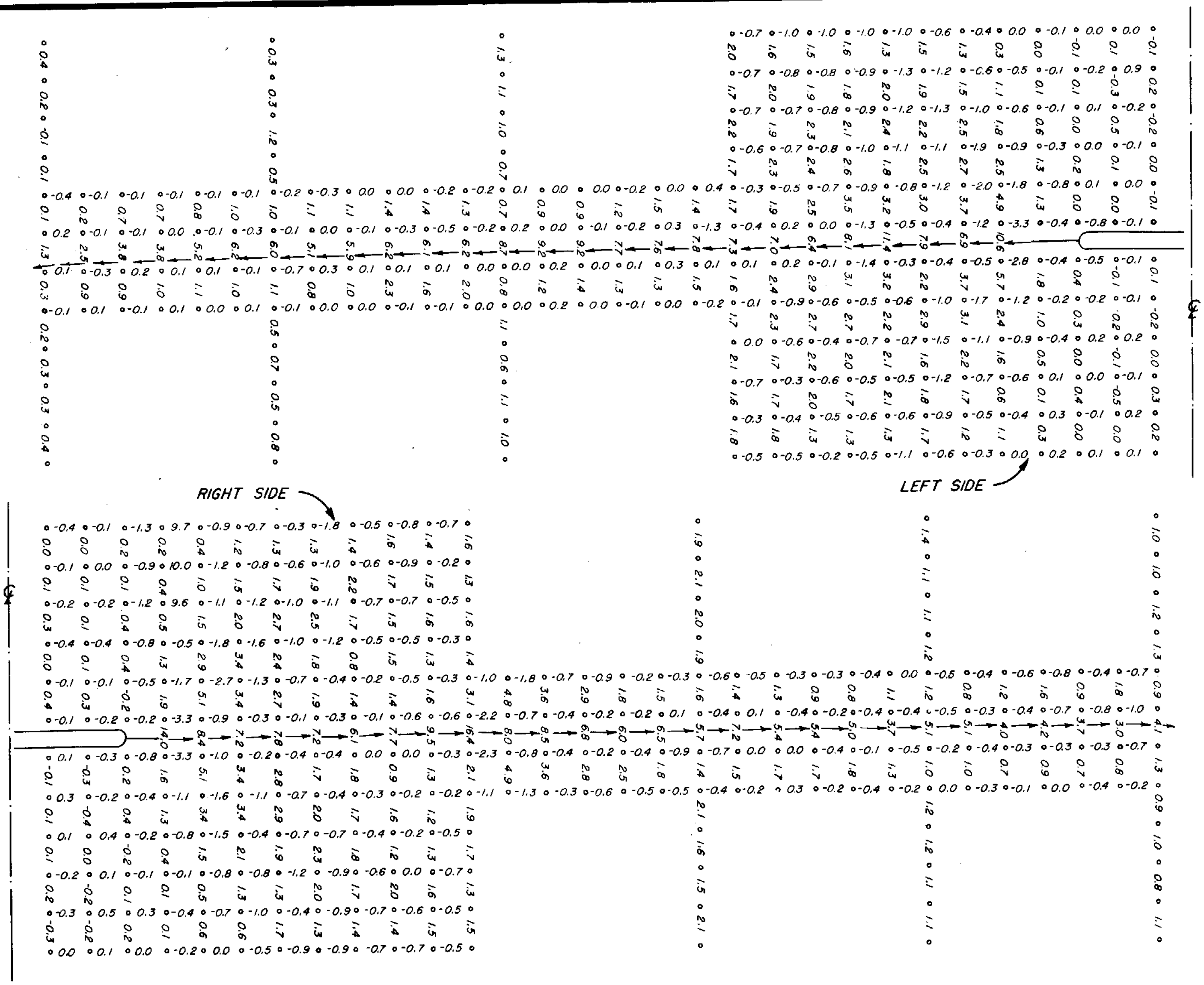


FIG A-19 PERCENT ELONGATION PLATE D-1A (1-INCH GRID)

"D" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 39.0KSI

TEMPERATURE 33-35° F 0% SHEAR

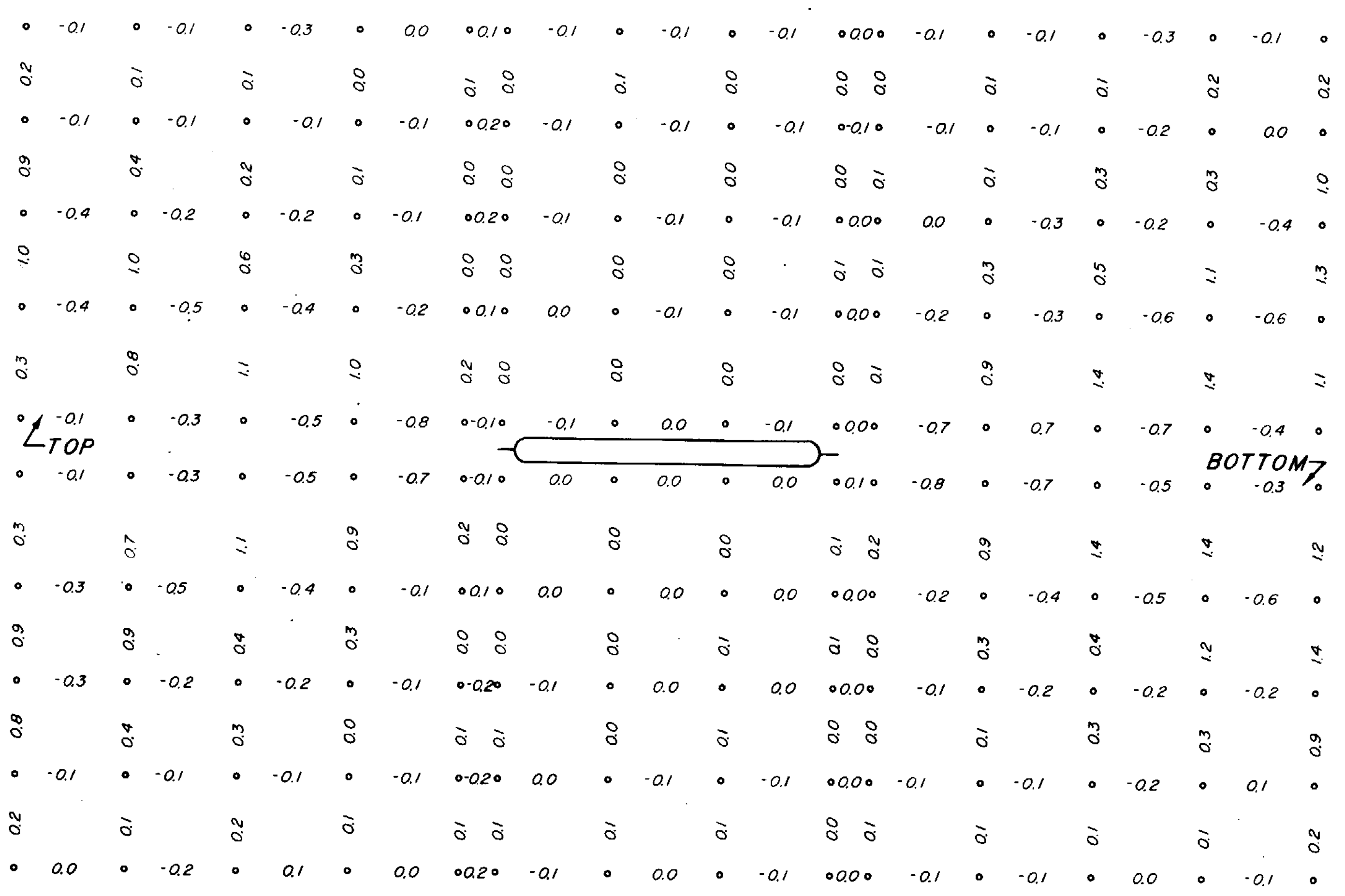


FIG. A-20 PERCENT ELONGATION PLATE D-1A (5 INCH GRID)

"D" STEEL, 72 INCH WIDE PLATE NOMINAL STRENGTH 39.0 KSI
TEMPERATURE 33–35°F 0% SHEAR

DWG. 44E94

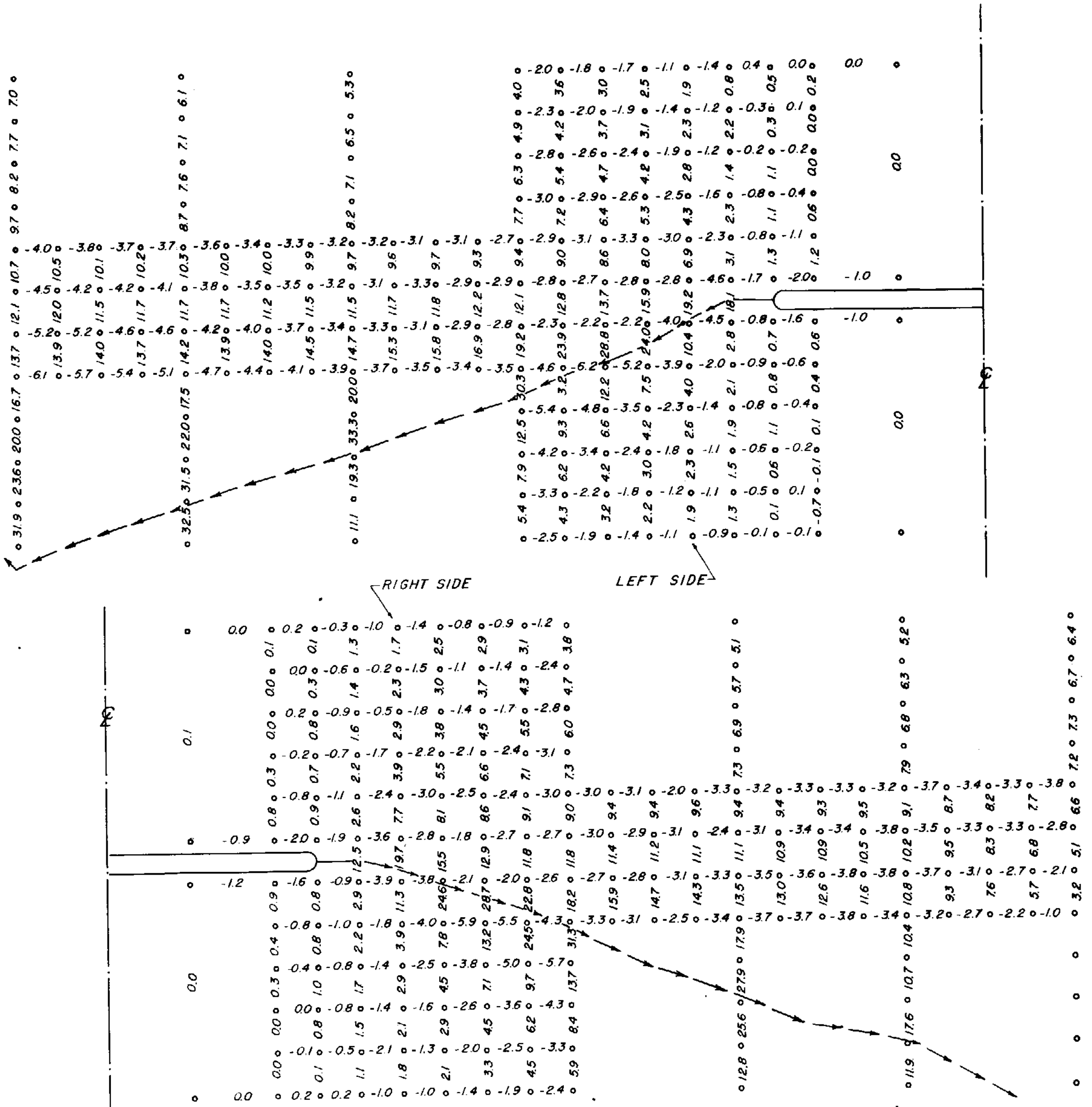


FIG. A-21 PERCENT ELONGATION PLATE A-1B (1-INCH GRID)

"A" STEEL, 48 INCH WIDE PLATE NOMINAL STRENGTH 40.7 KSI

TEMPERATURE 67-68° F 90% SHEAR

FIG. A 21

44E141

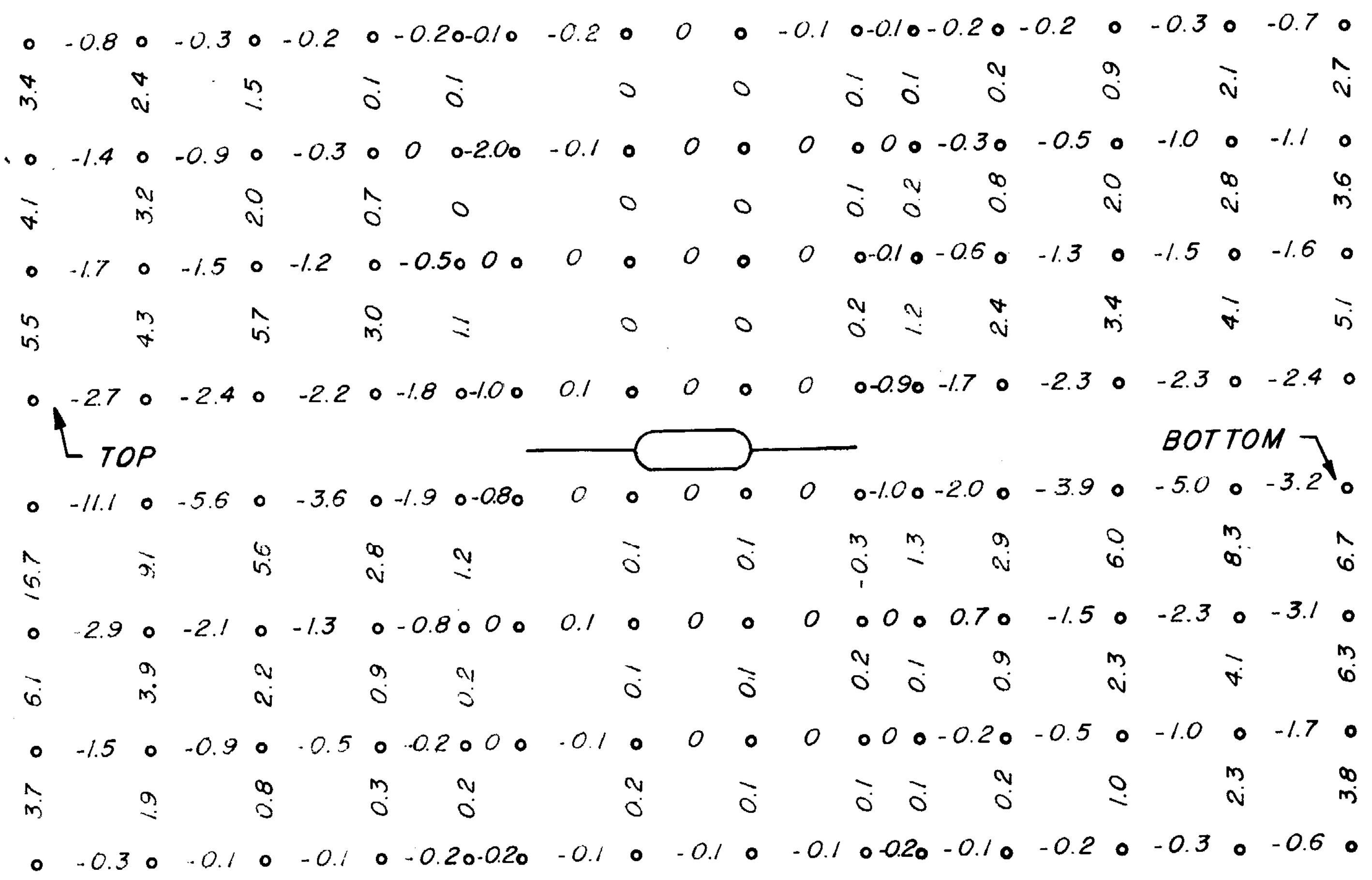


FIG. A-22 PERCENT ELONGATION PLATE A-1B (4-INCH GRID)

"A" STEEL, 48 INCH WIDE PLATE NOMINAL STRENGTH 40.7 KSI

TEMPERATURE 67-68°F 90% SHEAR

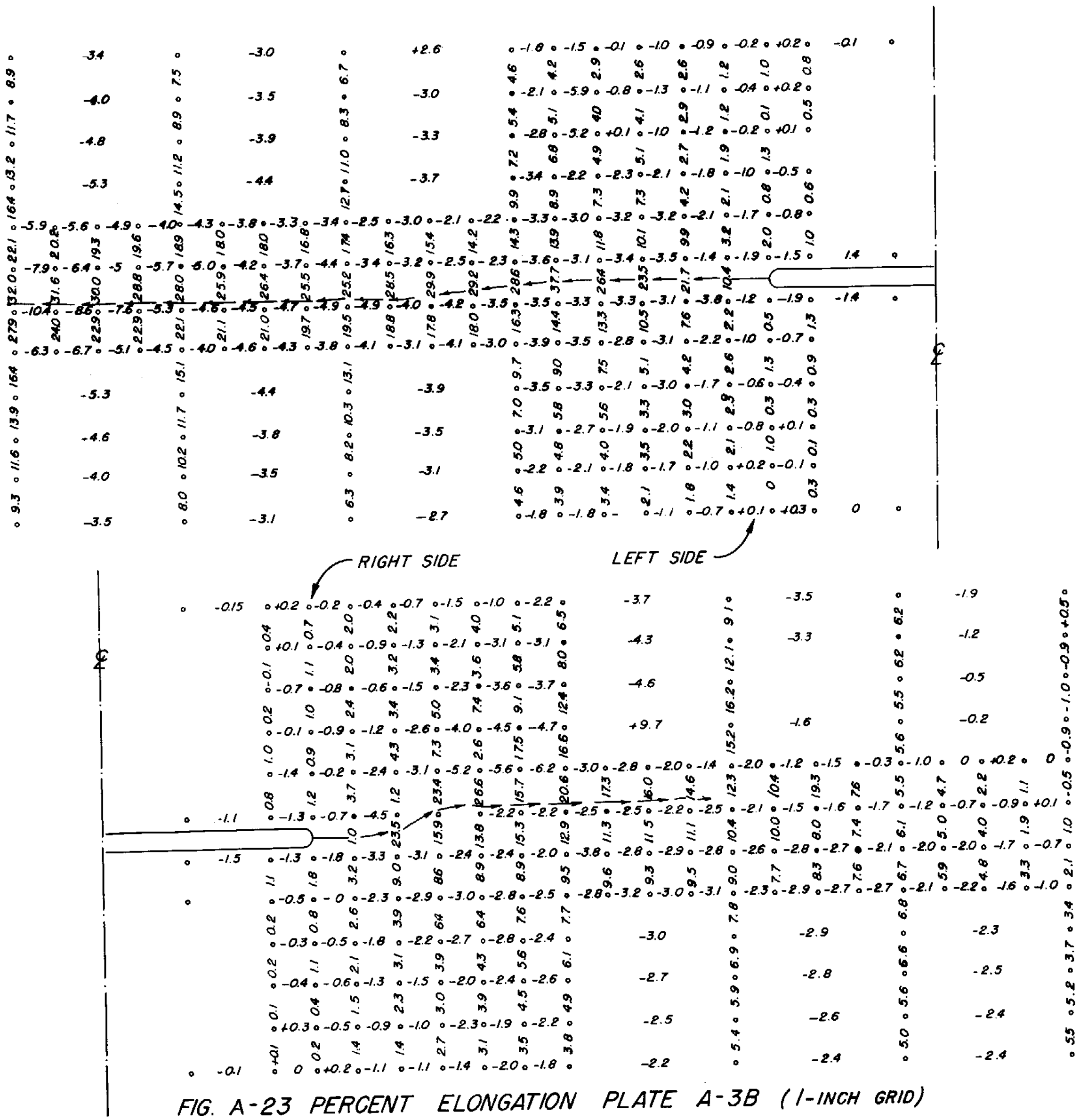


FIG. A-23 PERCENT ELONGATION PLATE A-3B (1-INCH GRID)

"A" STEEL 48 INCH WIDE PLATE NOMINAL STRENGTH 41.1 KSI

TEMPERATURE 48-50° F. 76 % SHEAR

44E14c

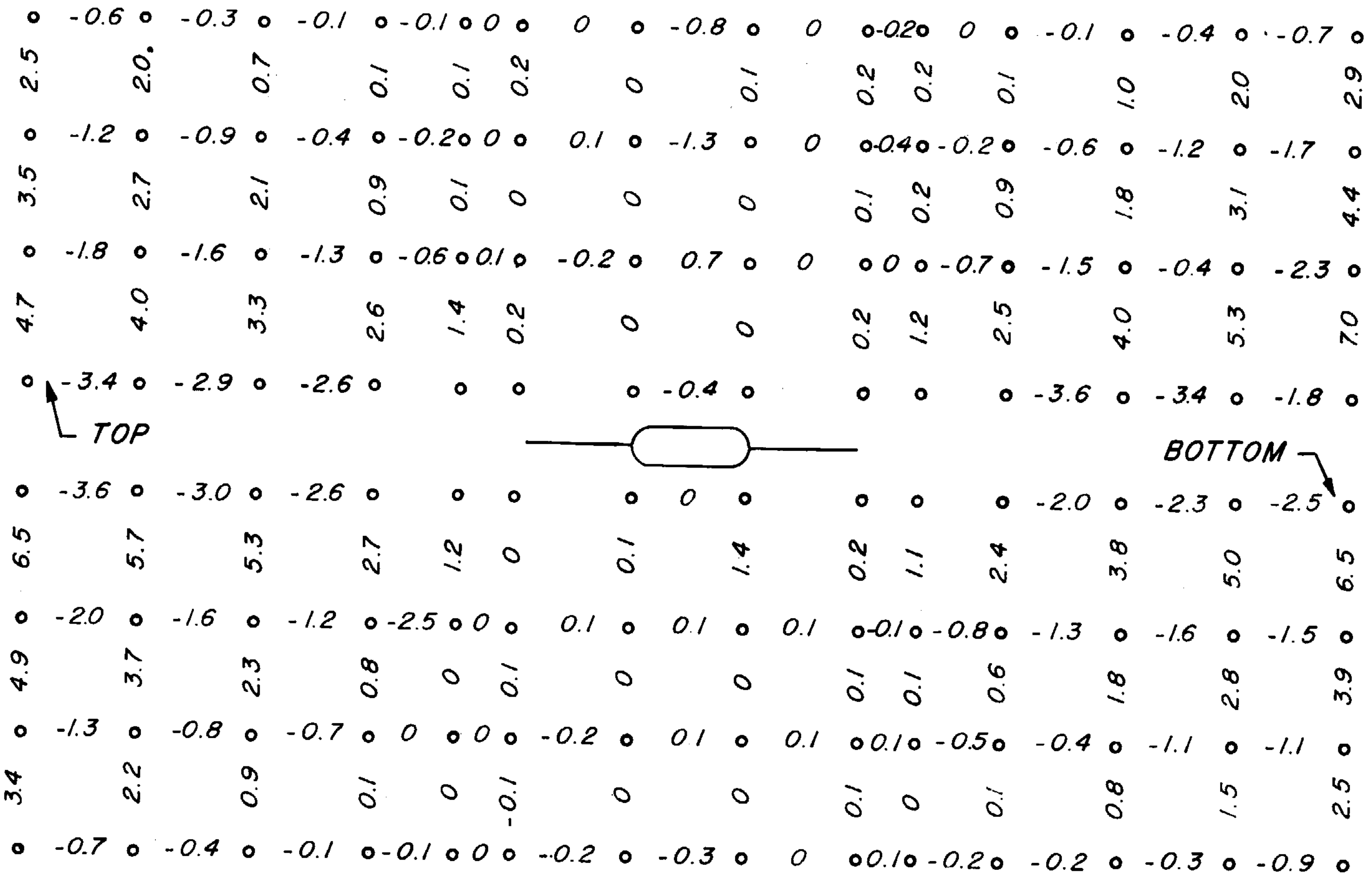


FIG. A-24 PERCENT ELONGATION PLATE A-3B (4-INCH GRID)

"A" STEEL, 48 INCH WIDE PLATE NOMINAL STRENGTH 41.1 KSI

TEMPERATURE 48-50°F 76% SHEAR

44 E147

FIG. A-24

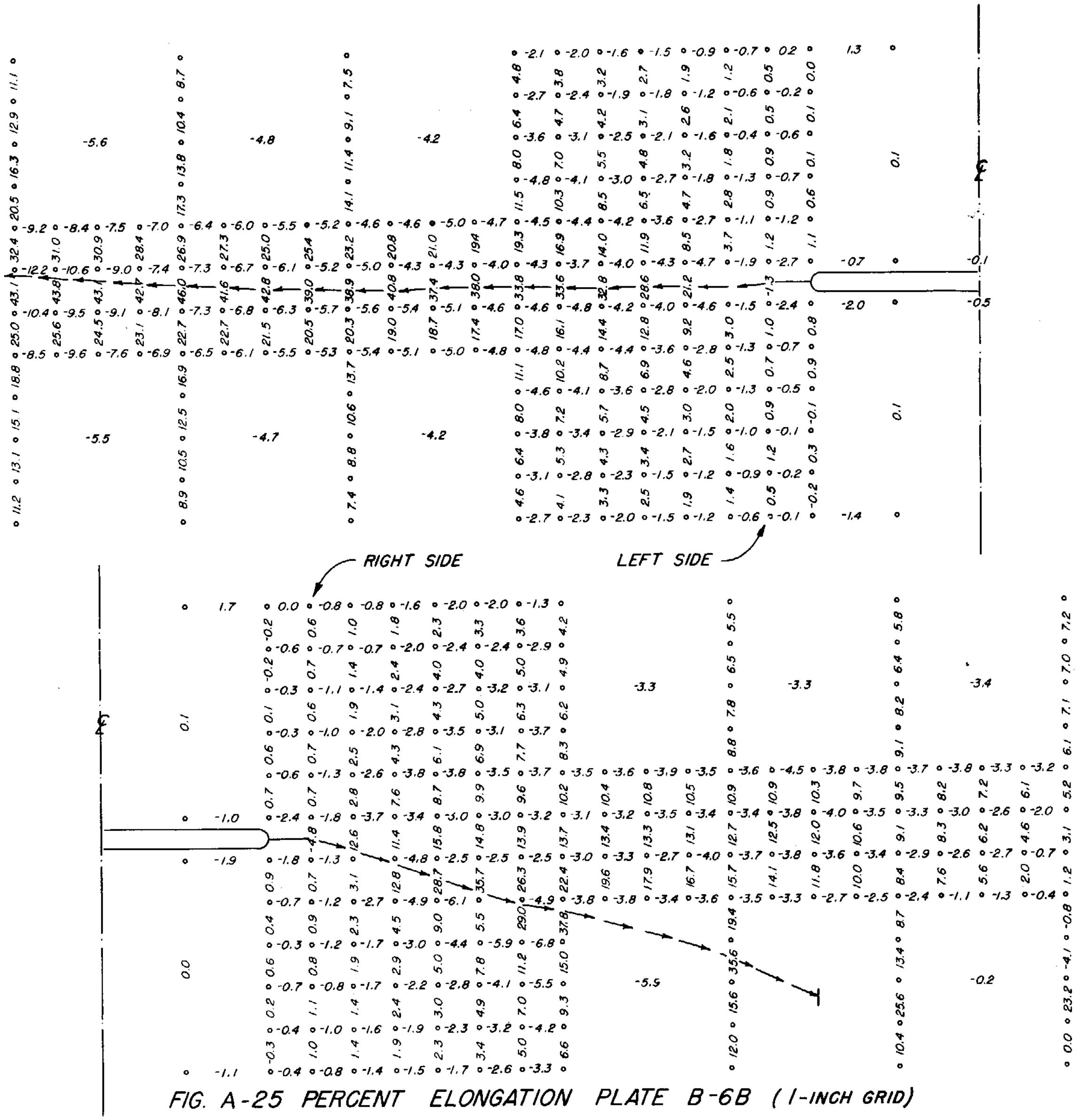


FIG. A-25 PERCENT ELONGATION PLATE B-6B (1-INCH GRID)

"B" STEEL, 48 INCH WIDE PLATE NOMINAL STRENGTH 42.6KSI

TEMPERATURE 49-50 °F. 83% SHEAR

44E143

44 E 148

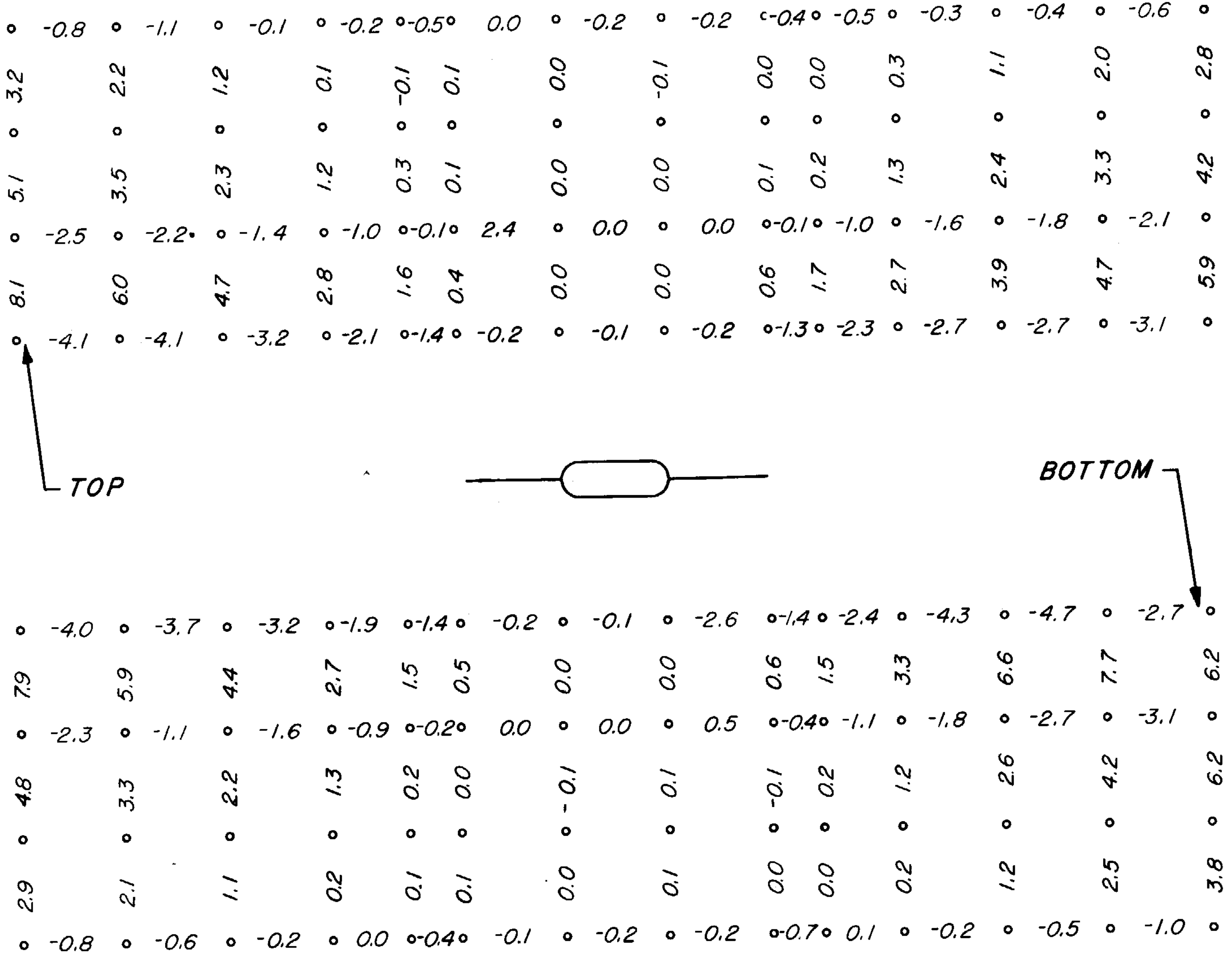


FIG. A-26 PERCENT ELONGATION PLATE B-6B (4-INCH GRID)

"B" STEEL, 48 INCH WIDE PLATE NOMINAL STRENGTH 42.6KSI

TEMPERATURE 49-50° F 83% SHEAR

FIG. A 26

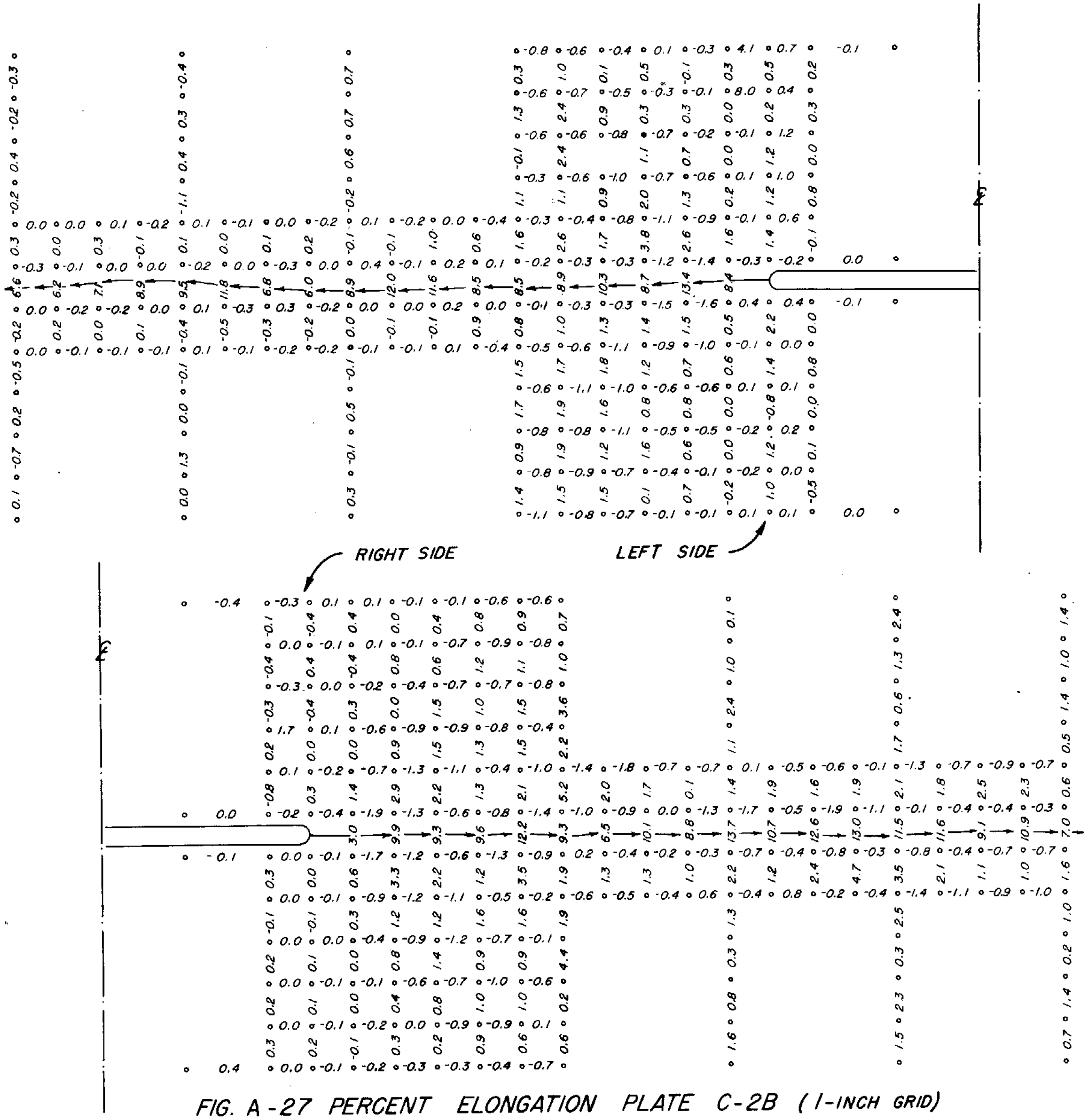


FIG. A-27 PERCENT ELONGATION PLATE C-2B (1-INCH GRID)

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

TEMPERATURE 80° F. 0 % SHEAR

44E144

FIG.A-27

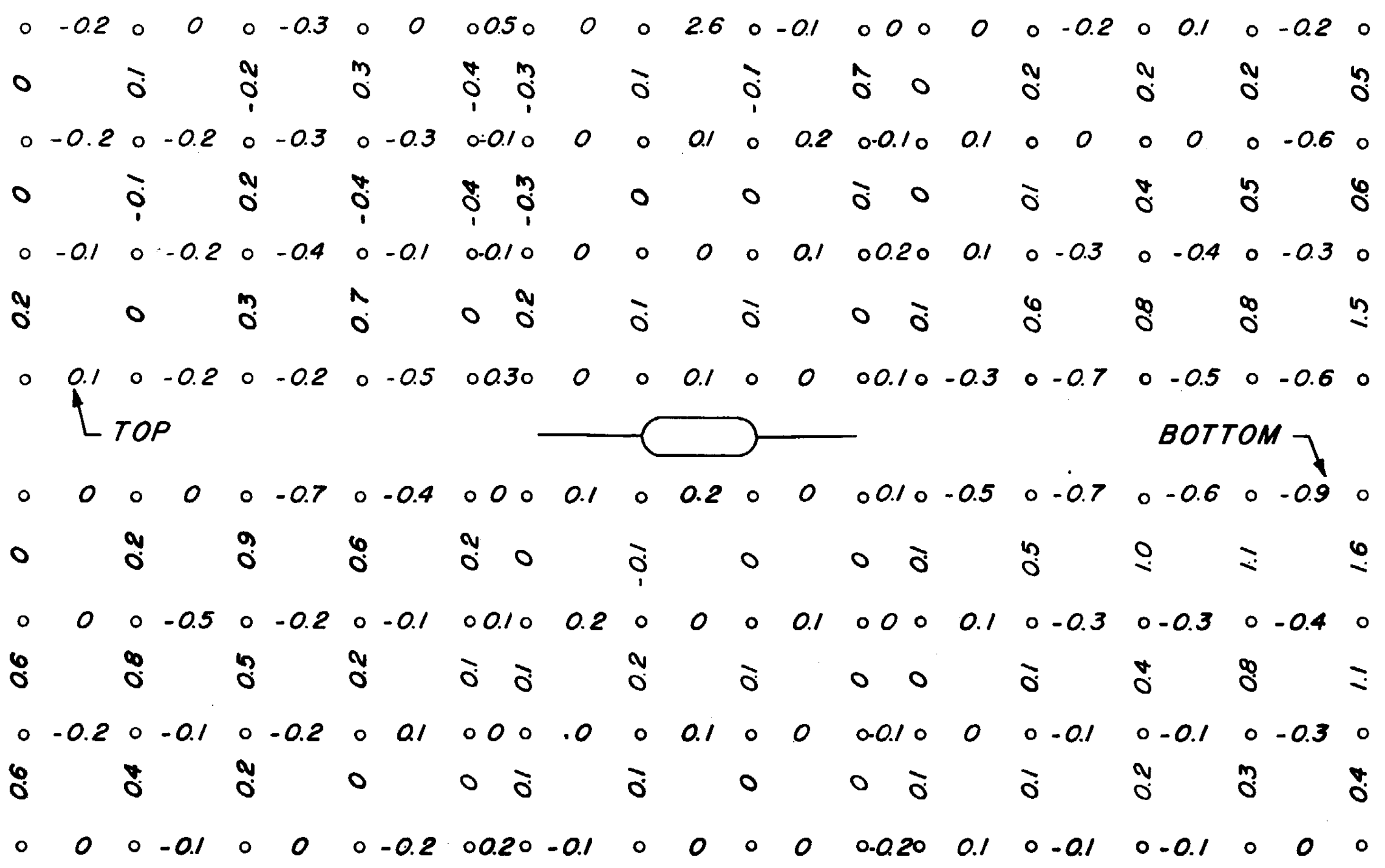


FIG. A-28 PERCENT ELONGATION PLATE C-2B (4-INCH GRID)

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

TEMPERATURE 80° F. 0 % SHEAR

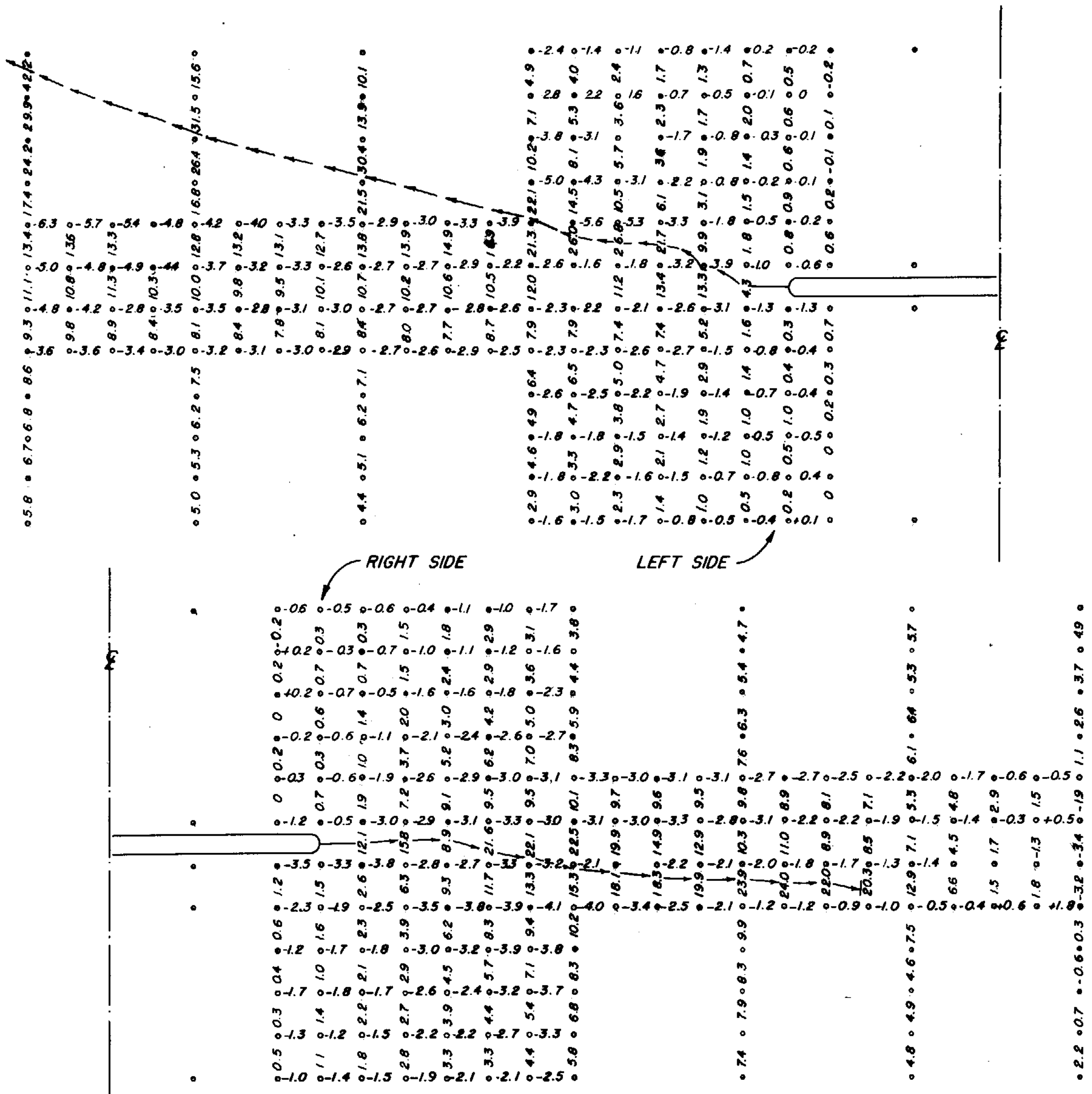


FIG. A-29 PERCENT ELONGATION PLATE C-3B (1-INCH GRID)

"C" STEEL 48 INCH WIDE PLATE NOMINAL STRENGTH 44.9 KSI

TEMPERATURE 100-104° F. 98% SHEAR

FIG. A-29

44E145

44 E 150

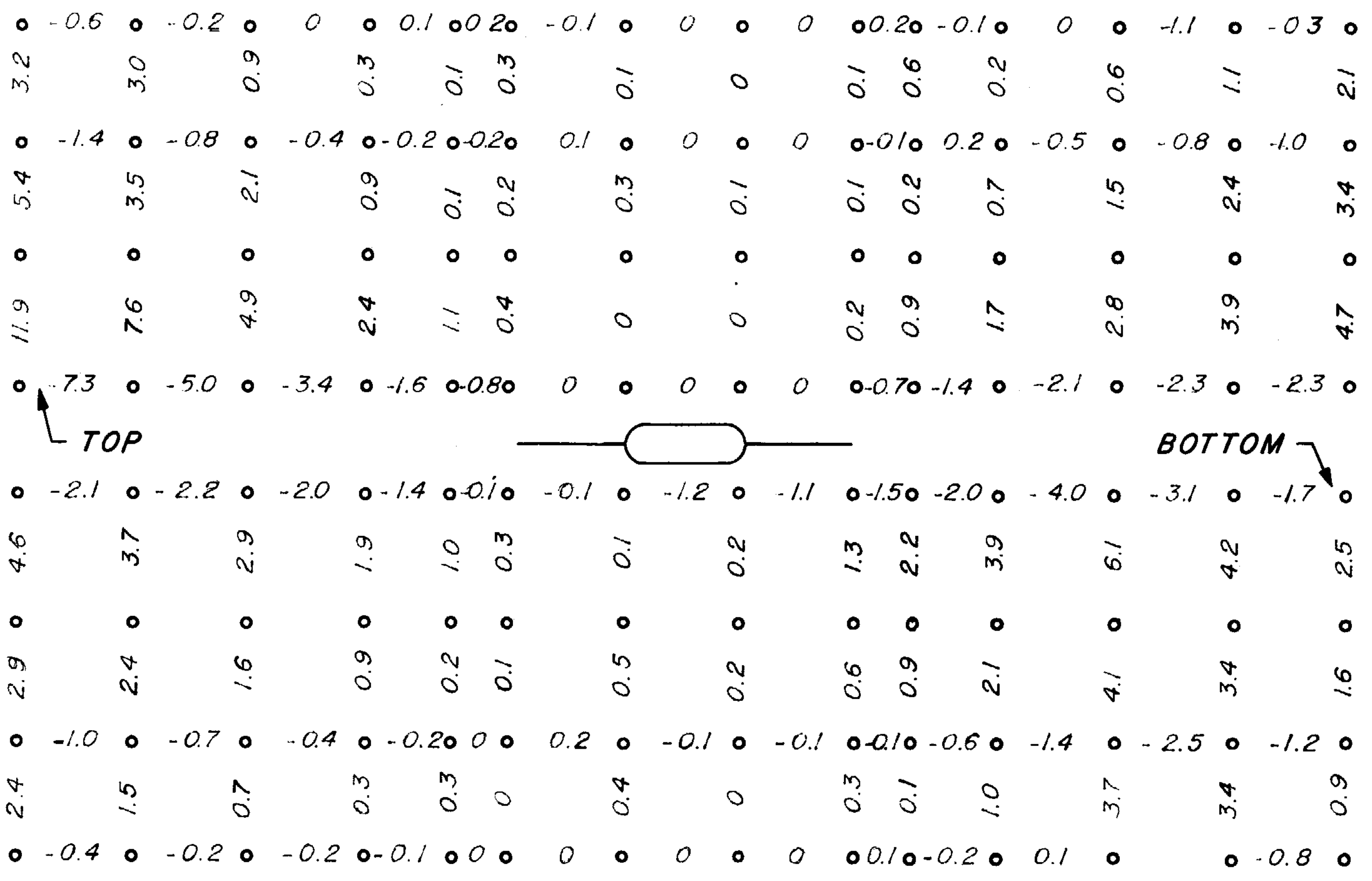


FIG. A-30 PERCENT ELONGATION PLATE C-3B (4-INCH GRID)

"C" STEEL, 48 INCH WIDE PLATE NOMINAL STRENGTH 44.9KSI

TEMPERATURE 100-104°F 98% SHEAR

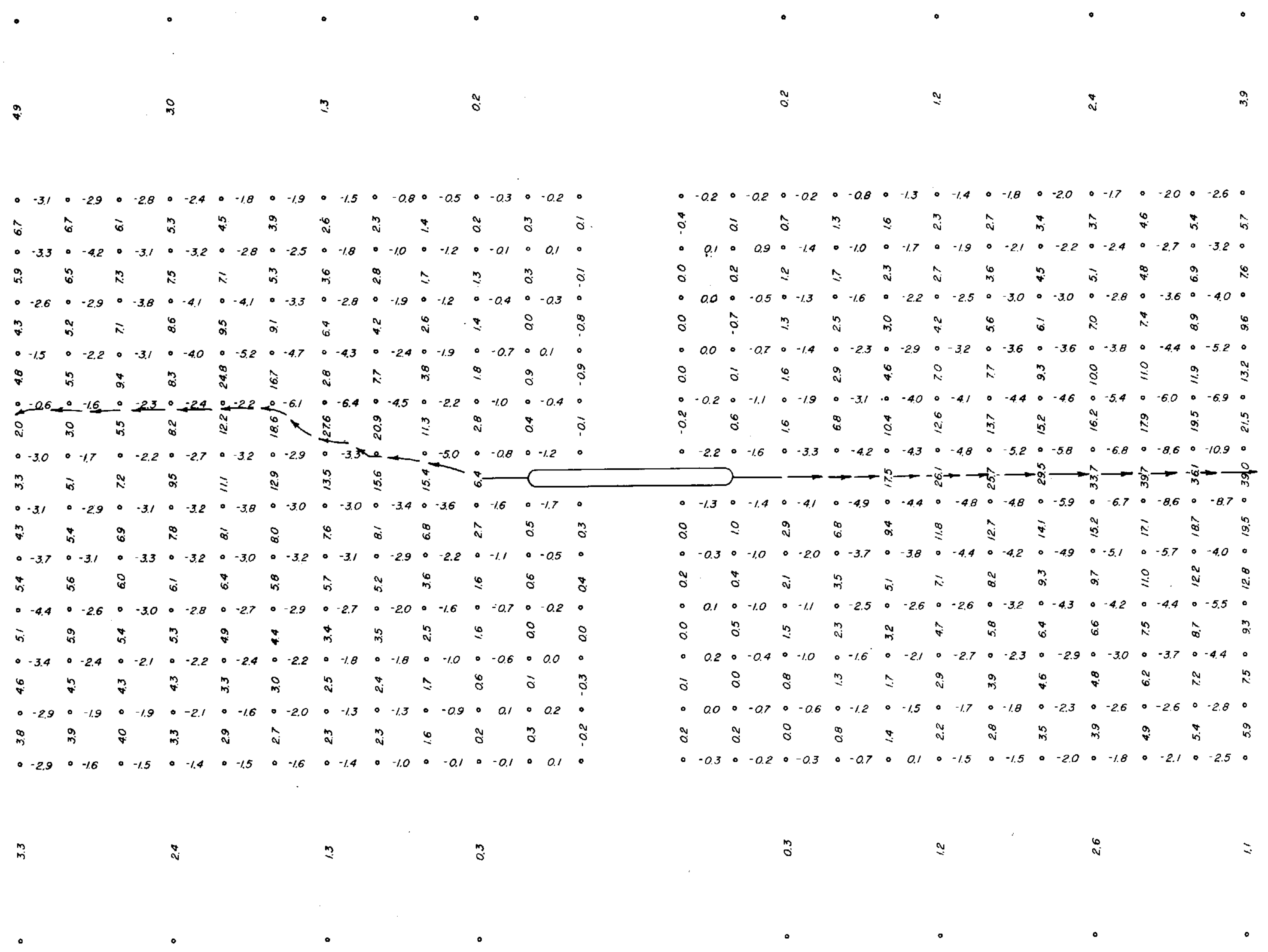


FIG. A-31 PERCENT ELONGATION PLATE A-1C (1-INCH & 3 INCH GRIDS)

"A" STEEL, 24 INCH WIDE PLATE

TEMPERATURE 30 - 37°F

NOMINAL STRENGTH 43.6 KSI

72% SHEAR

DWG. 44E95

FIG. A-31

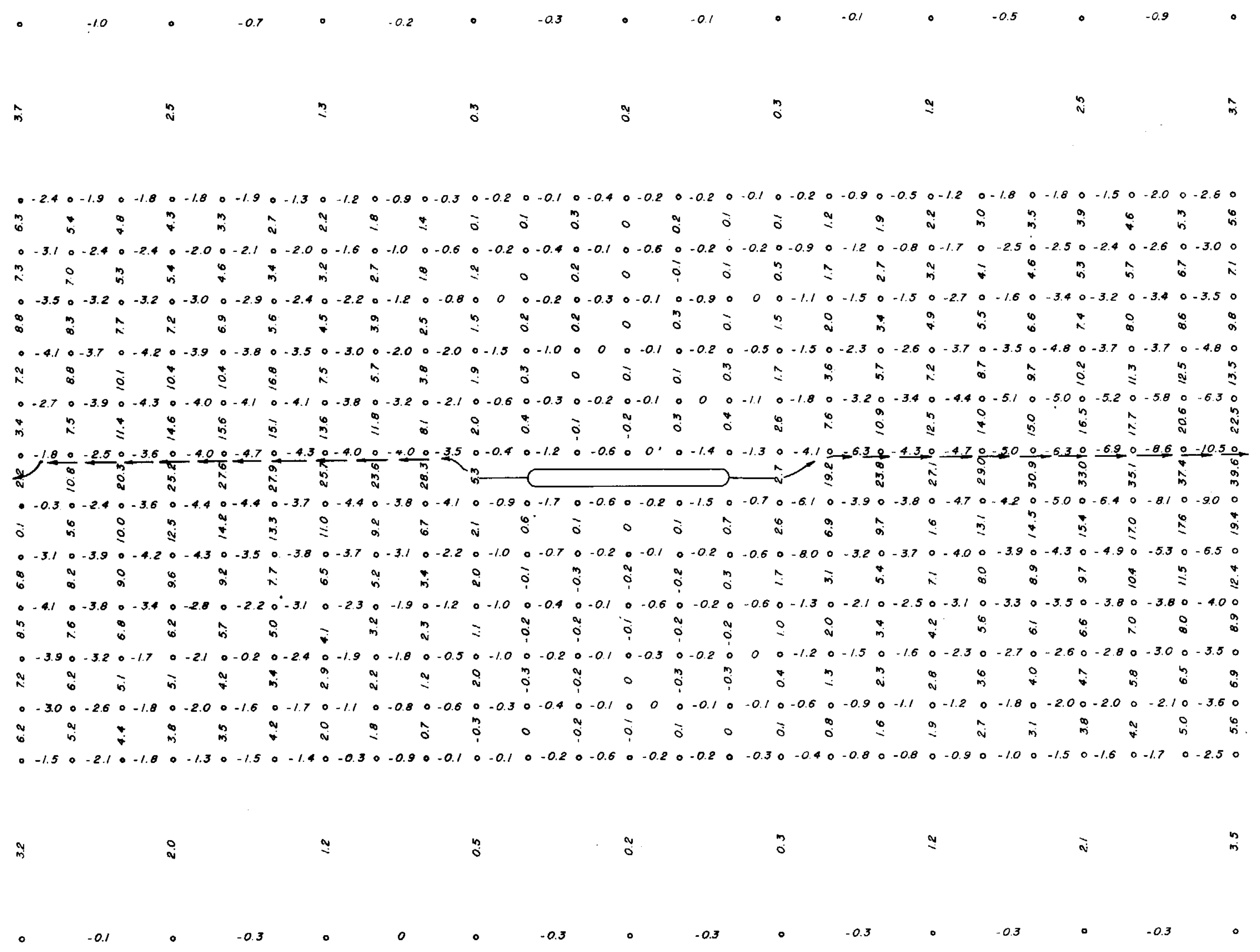


FIG. A-32 PERCENT ELONGATION PLATE A-2C (1-INCH & 3 INCH GRIDS)

"A" STEEL, 24 INCH WIDE PLATE

NOMINAL STRENGTH 42.6 KSI

TEMPERATURE 74 - 80°F.

100% SHEAR

DWG. 44E96

FIG. A-32

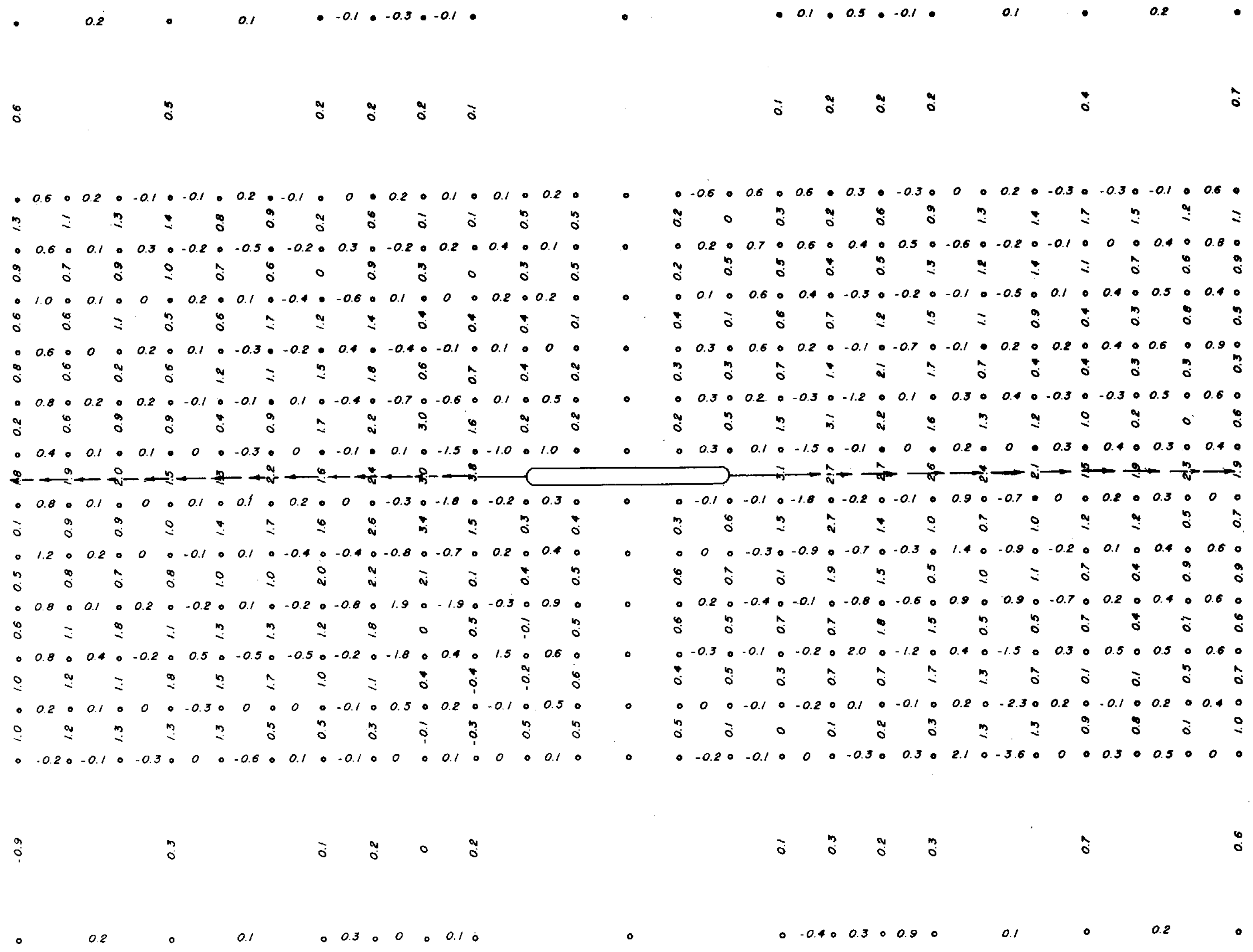


FIG. A-33 PERCENT ELONGATION PLATE A-3C (1-INCH & 3INCH GRIDS)

"A" STEEL, 24 INCH WIDE PLATE NOMINAL STRENGTH 38.1 KSI

TEMPERATURE (-8)-(-5) °F 0 % SHEAR

DWG. 44E97

FIG. A-33

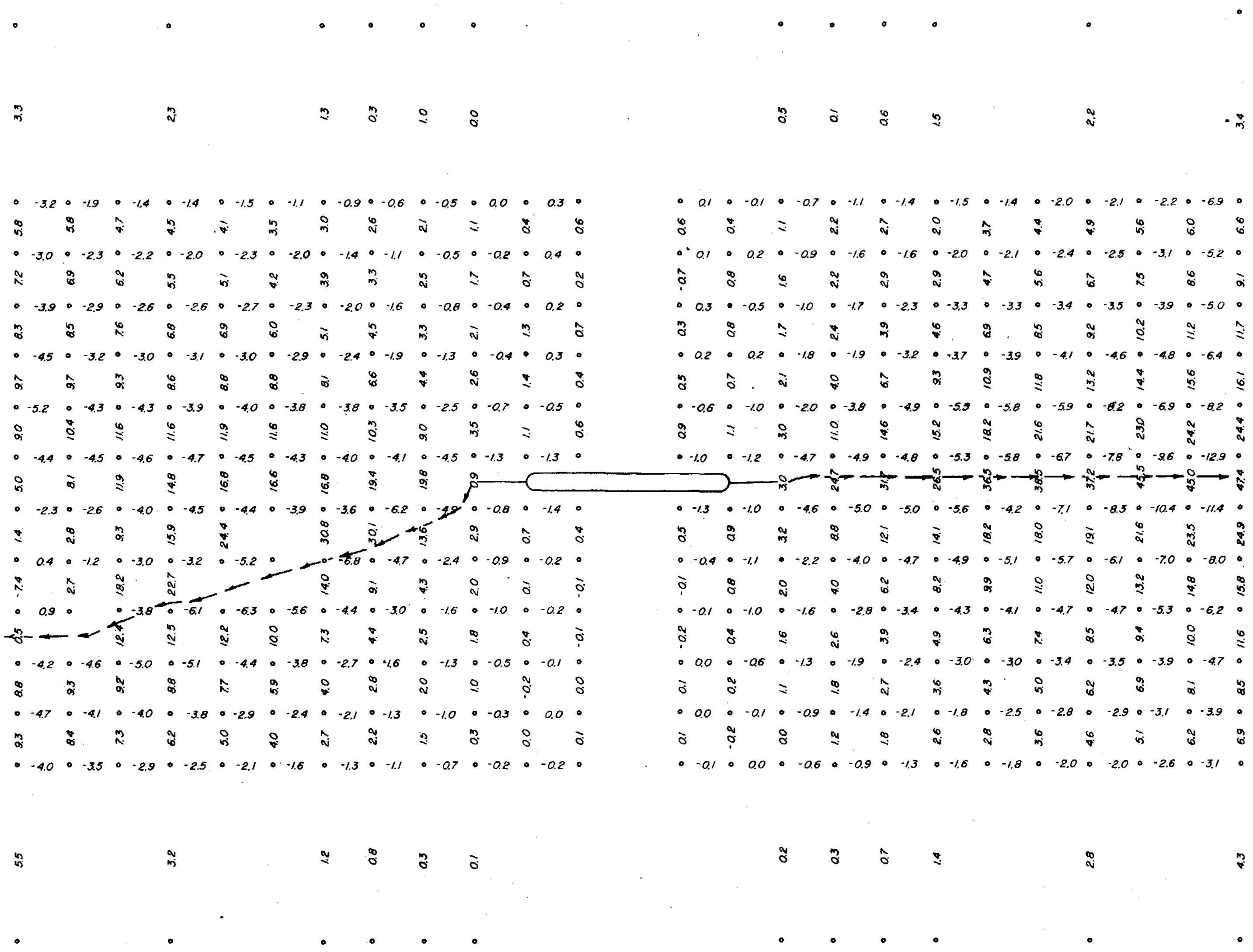


FIG. A-34 PERCENT ELONGATION PLATE B-IC (1-INCH & 3 INCH GRIDS)

"B" STEEL, 24 INCH WIDE PLATE
TEMPERATURE 31 - 33°F

NOMINAL STRENGTH 46.3 KSI
100 % SHEAR

DWG. 44E98

FIG. A-34

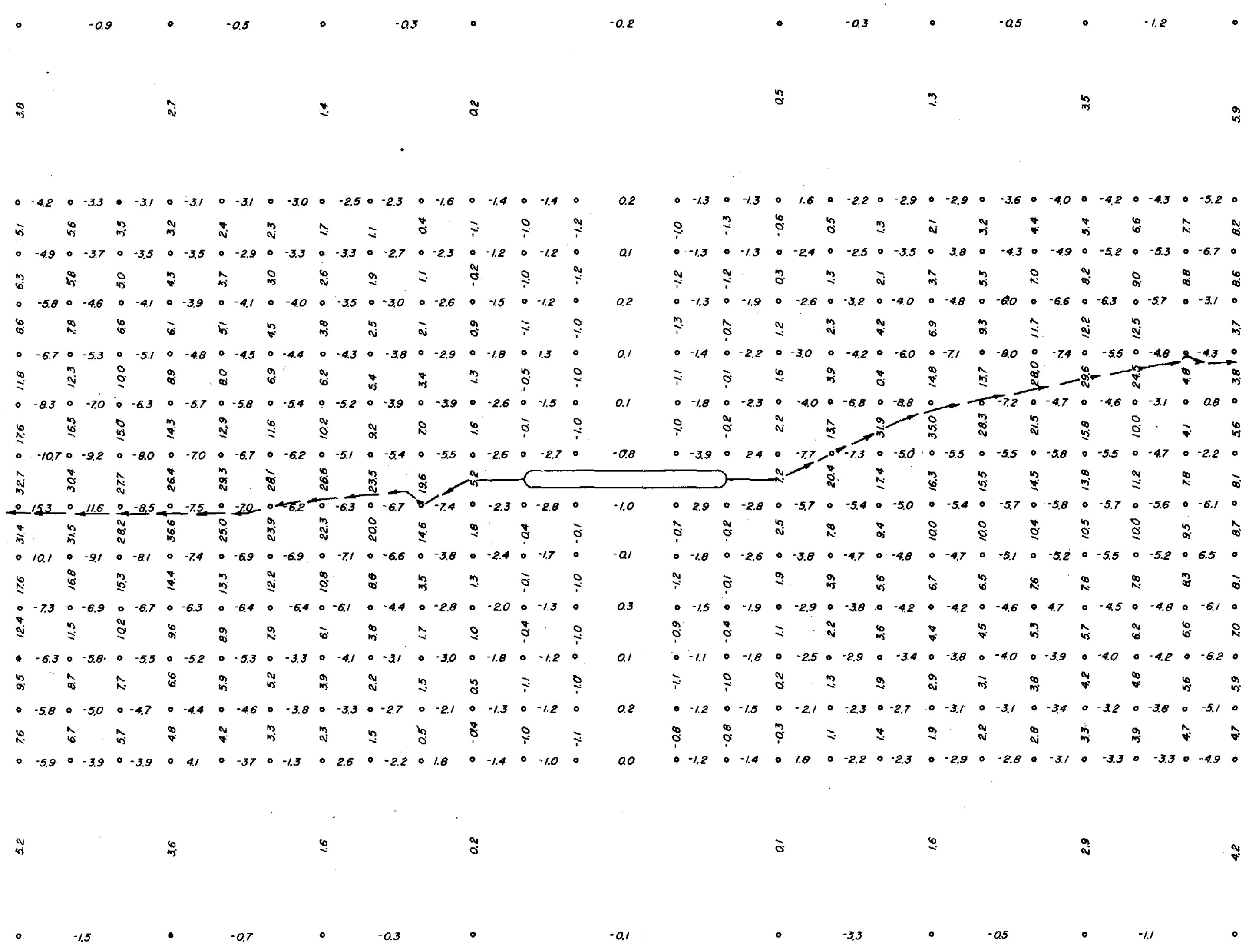


FIG. A-35 PERCENT ELONGATION PLATE B-2C (1-INCH & 3 INCH GRIDS)

"B" STEEL, 24 INCH WIDE PLATE　　NOMINAL STRENGTH 46.3 KSI

TEMPERATURE 30-33°F.　　90 % SHEAR

DWG. 44E99

FIG. A-35

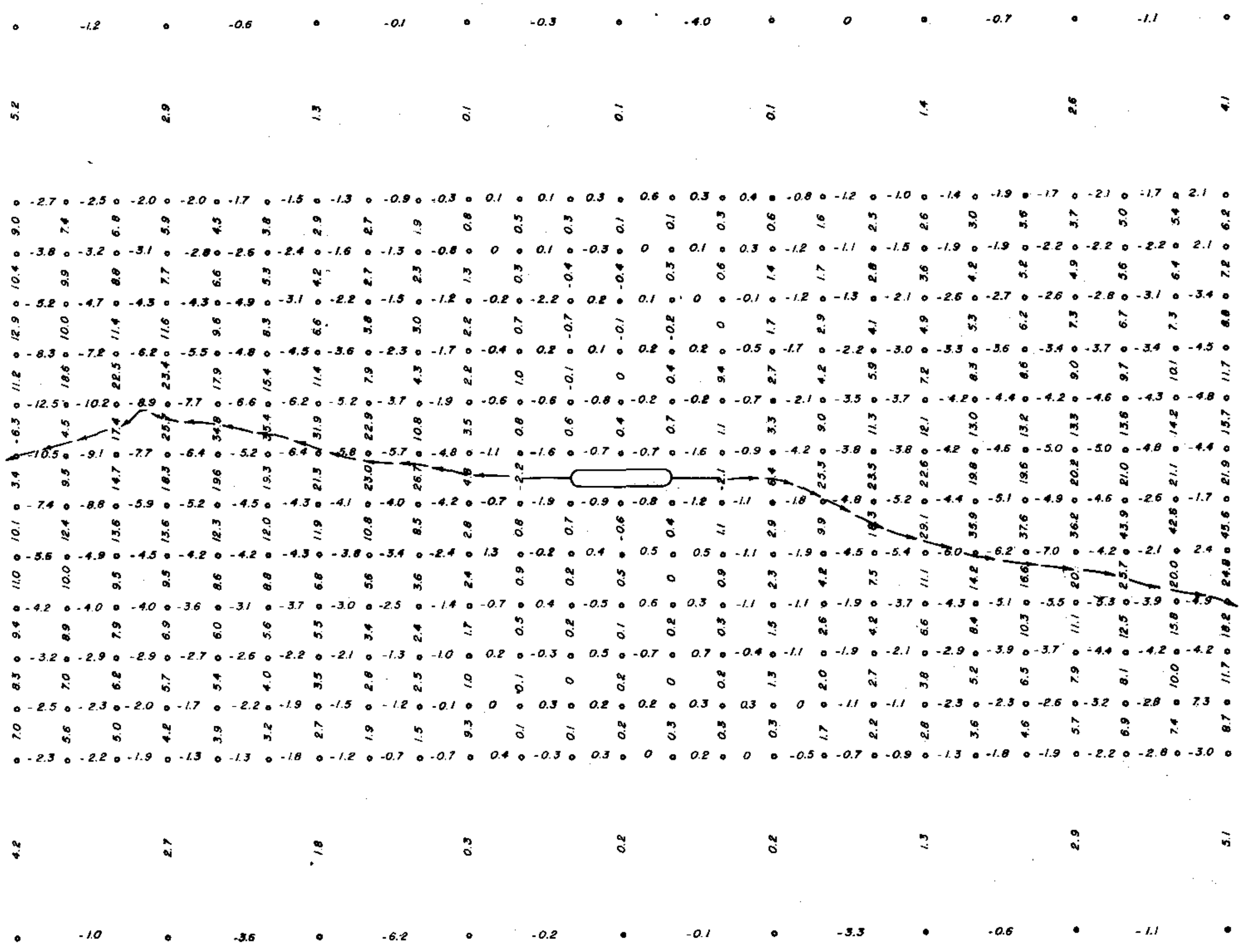


FIG A-36 PERCENT ELONGATION PLATE B-3C (1-INCH & 3INCH GRIDS)

"B" STEEL, 24 INCH WIDE PLATE NOMINAL STRENGTH 43.3 KSI

TEMPERATURE 72 ° F. 100% SHEAR

DWG 44E 100

FIG A-36

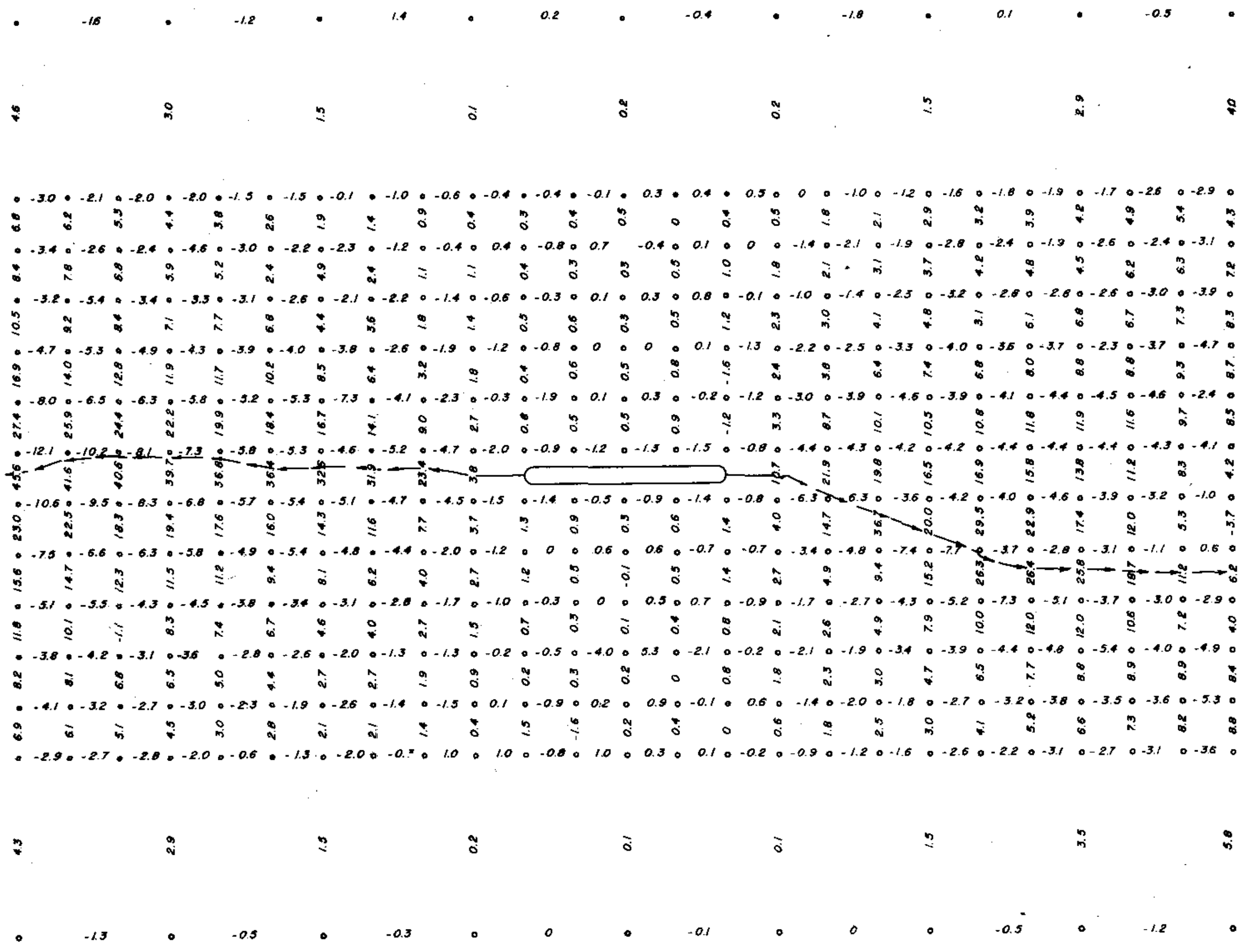


FIG. A-37 PERCENT ELONGATION PLATE B-4C (1-INCH & 3 INCH GRIDS)

"B" STEEL, 24 INCH WIDE PLATE

TEMPERATURE 75-97 °F

NOMINAL STRENGTH 41.5 KSI

100% SHEAR

DWG. 44 E 101

FIG. A-37

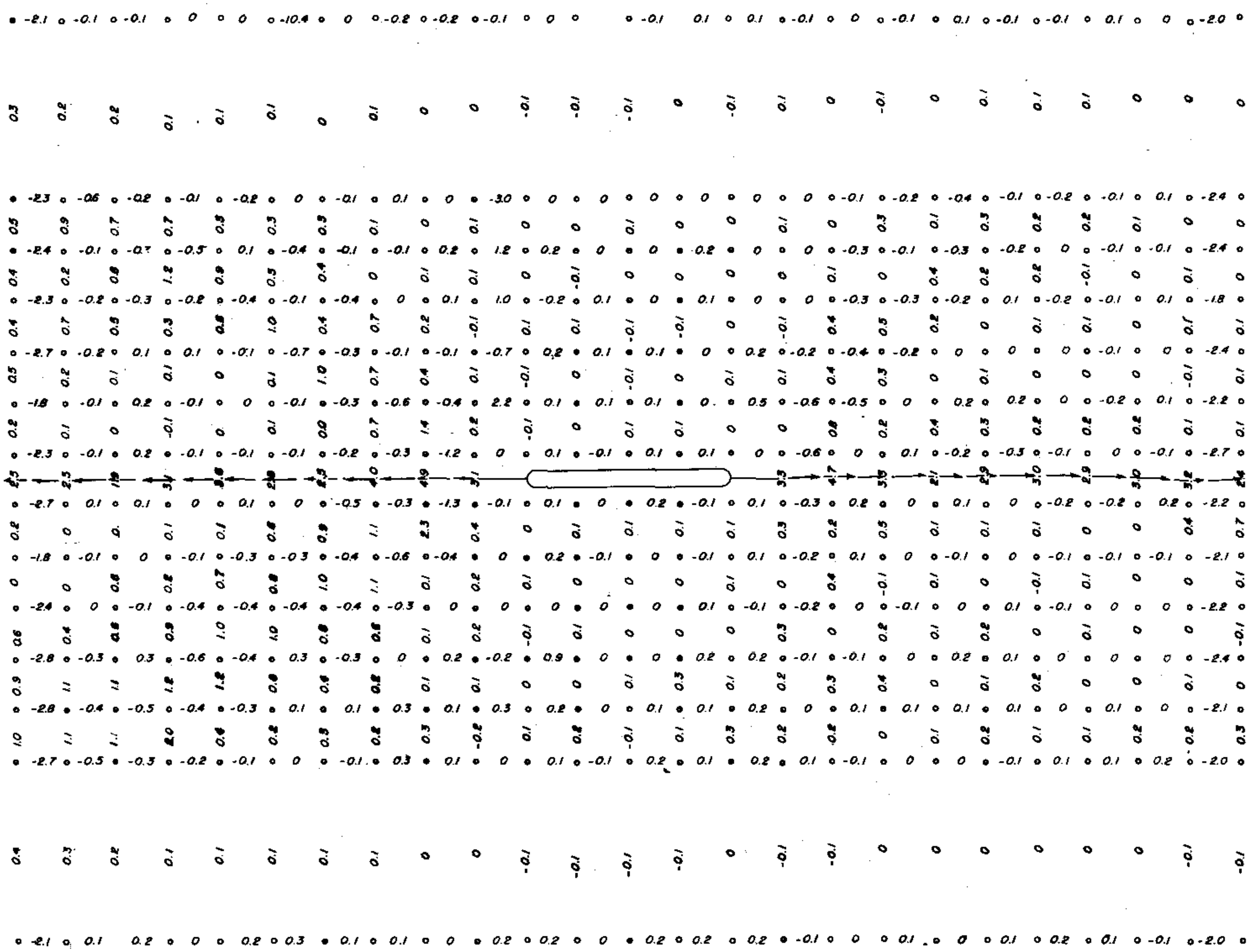


FIG. A-38 PERCENT ELONGATION PLATE C-1C (1-INCH & 3INCH GRIDS)

"C" STEEL, 24 INCH WIDE PLATE NOMINAL STRENGTH-37.0 KSI

TEMPERATURE 27-31°F. 0% SHEAR

DWG. 44 E 102

FIG. A-38

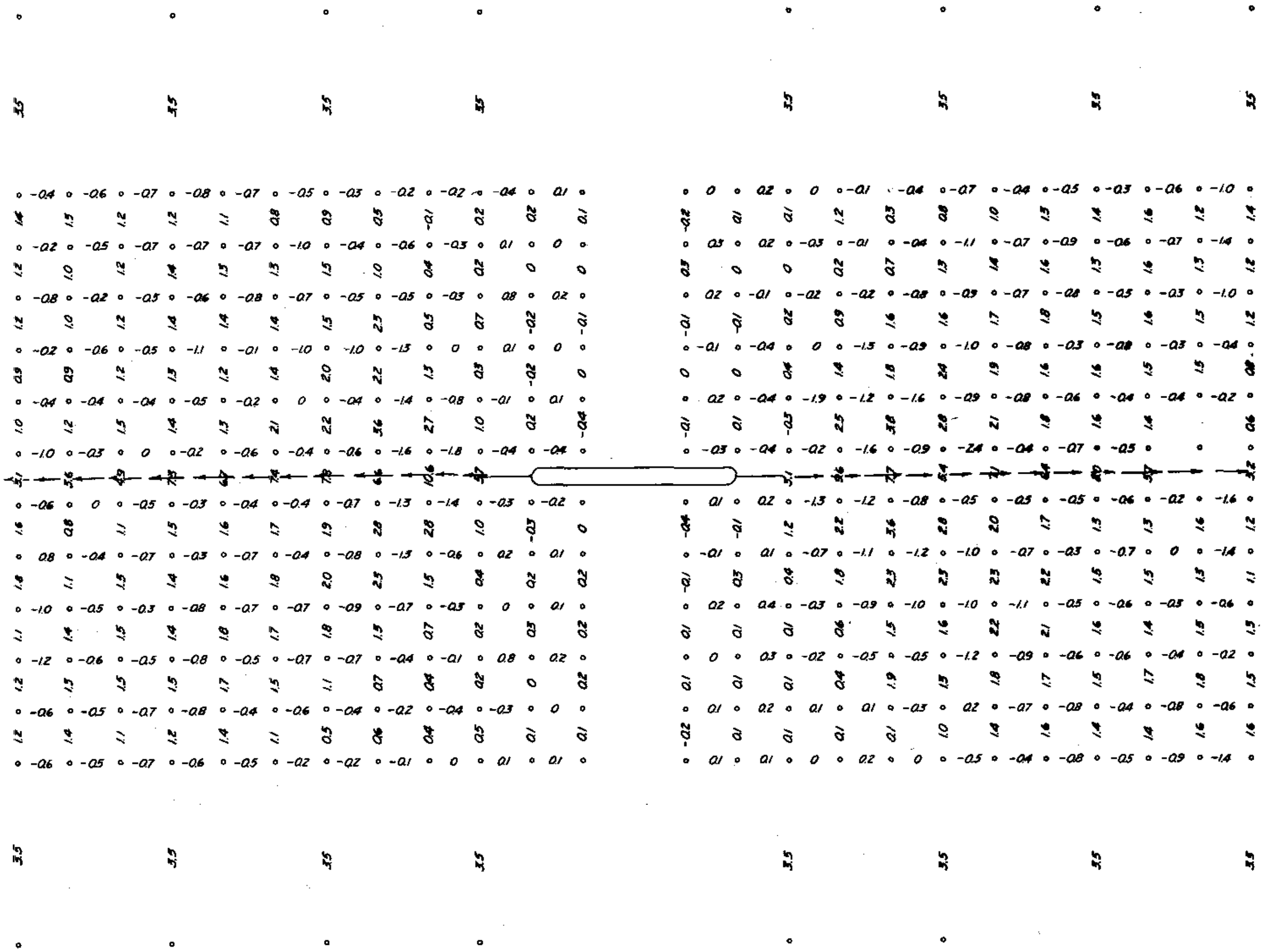
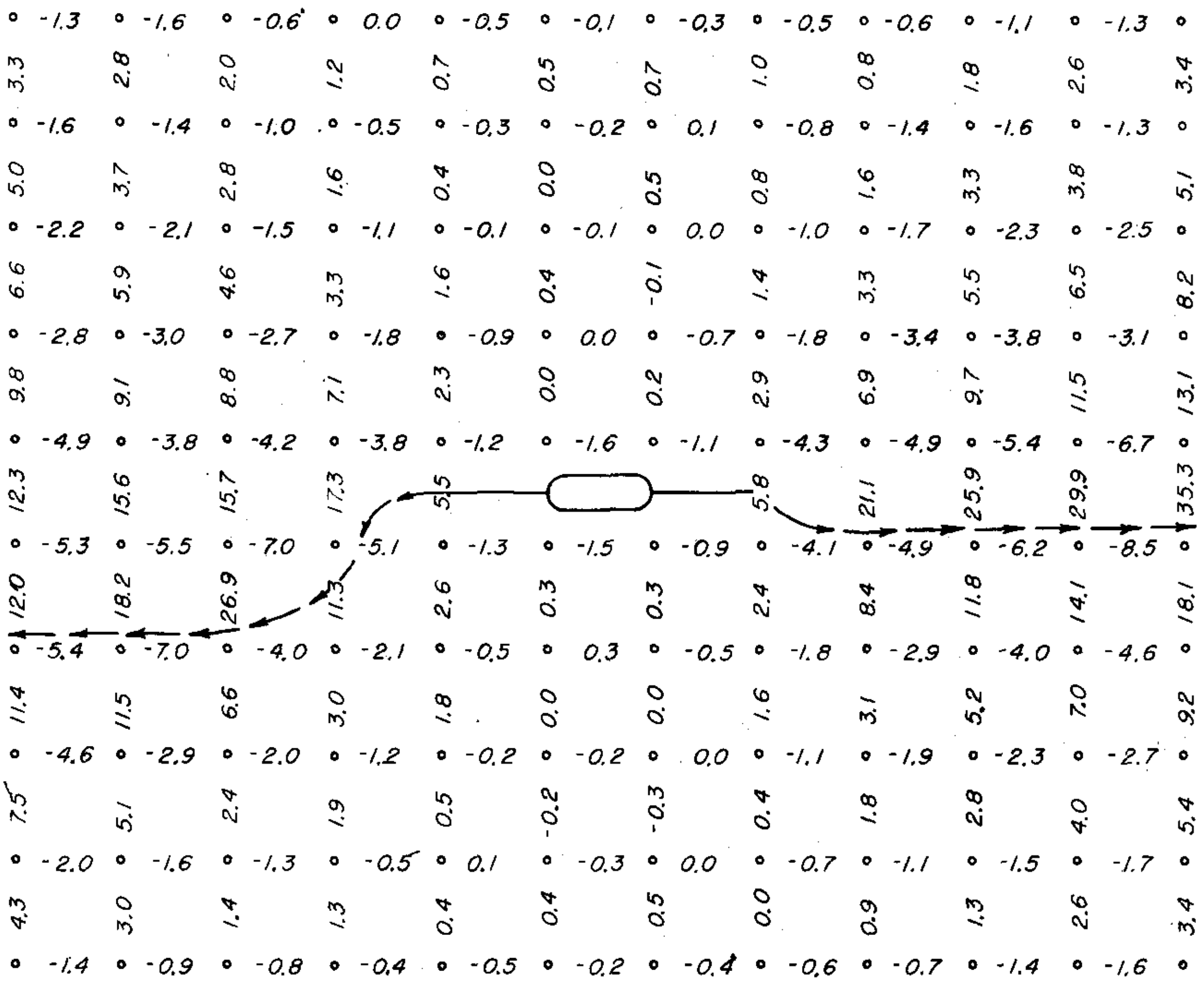


FIG. A-39 PERCENT ELONGATION PLATE C-2C (1-INCH & 3 INCH GRIDS)

"C" STEEL, 24 INCH WIDE PLATE
TEMPERATURE 80-88°F.

NOMINAL STRENGTH 40.4 KSI
1 % SHEAR



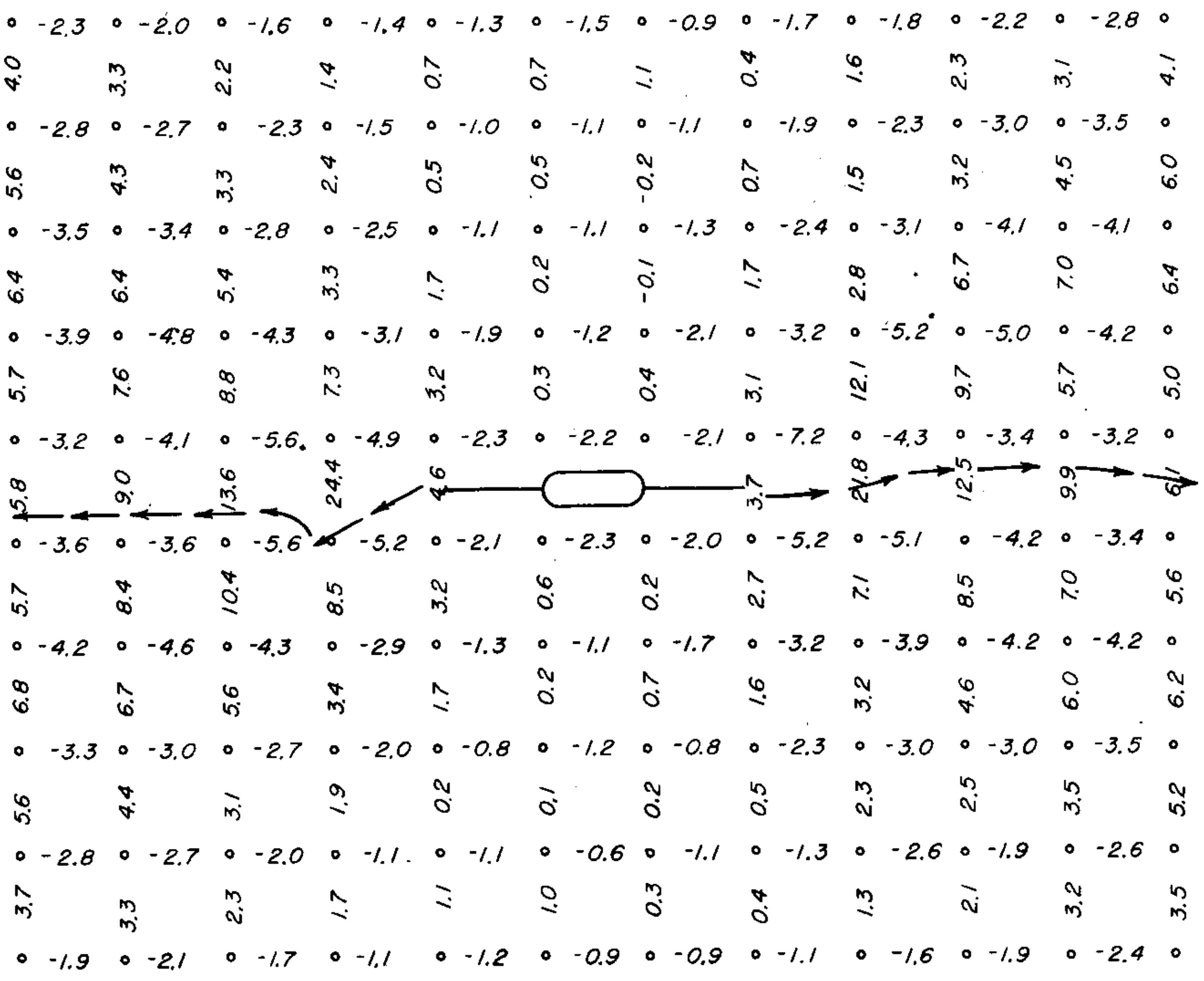
○	-1.3	○	-1.6	○	-0.6	○	0.0	○	-0.5	○	-0.1	○	-0.3	○	-0.5	○	-0.6	○	-1.1	○	-1.3	○
3.3		2.8		2.0		1.2		0.7		0.5		0.7		1.0		0.8		1.8		2.6		3.4
○	-1.6	○	-1.4	○	-1.0	○	-0.5	○	-0.3	○	-0.2	○	0.1	○	-0.8	○	-1.4	○	-1.6	○	-1.3	○
5.0		3.7		2.8		1.6		0.4		0.0		0.5		0.8		1.6		3.3		3.8		5.1
○	-2.2	○	-2.1	○	-1.5	○	-1.1	○	-0.1	○	-0.1	○	0.0	○	-1.0	○	-1.7	○	-2.3	○	-2.5	○
6.6		5.9		4.6		3.3		1.6		0.4		-0.1		1.4		3.3		5.5		6.5		8.2
○	-2.8	○	-3.0	○	-2.7	○	-1.8	○	-0.9	○	0.0	○	-0.7	○	-1.8	○	-3.4	○	-3.8	○	-3.1	○
9.8		9.1		8.8		7.1		2.3		0.0		0.2		2.9		6.9		9.7		11.5		13.1
○	-4.9	○	-3.8	○	-4.2	○	-3.8	○	-1.2	○	-1.6	○	-1.1	○	-4.3	○	-4.9	○	-5.4	○	-6.7	○
12.3		15.6		15.7		17.3		5.5						5.8		21.1		25.9		29.9		35.3
○	-5.3	○	-5.5	○	-7.0	○	-5.1	○	-1.3	○	-1.5	○	-0.9	○	-4.1	○	-4.9	○	-6.2	○	-8.5	○
12.0		18.2		26.9		11.3		2.6		0.3		0.3		2.4		8.4		11.8		14.1		18.1
○	-5.4	○	-7.0	○	-4.0	○	-2.1	○	-0.5	○	0.3	○	-0.5	○	-1.8	○	-2.9	○	-4.0	○	-4.6	○
11.4		11.5		6.6		3.0		1.8		0.0		0.0		1.6		3.1		5.2		7.0		9.2
○	-4.6	○	-2.9	○	-2.0	○	-1.2	○	-0.2	○	-0.2	○	0.0	○	-1.1	○	-1.9	○	-2.3	○	-2.7	○
7.5		5.1		2.4		1.9		0.5		-0.2		-0.3		0.4		1.8		2.8		4.0		5.4
○	-2.0	○	-1.6	○	-1.3	○	-0.5	○	0.1	○	-0.3	○	0.0	○	-0.7	○	-1.1	○	-1.5	○	-1.7	○
4.3		3.0		1.4		1.3		0.4		0.4		0.5		0.0		0.9		1.3		2.6		3.4
○	-1.4	○	-0.9	○	-0.8	○	-0.4	○	-0.5	○	-0.2	○	-0.4	○	-0.6	○	-0.7	○	-1.4	○	-1.6	○

FIG. A-40 PERCENT ELONGATION PLATE A-ID (1 INCH GRID)

"A" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 46.5 KSI

TEMPERATURE 78-86° F 77% SHEAR

DWG. 44E104

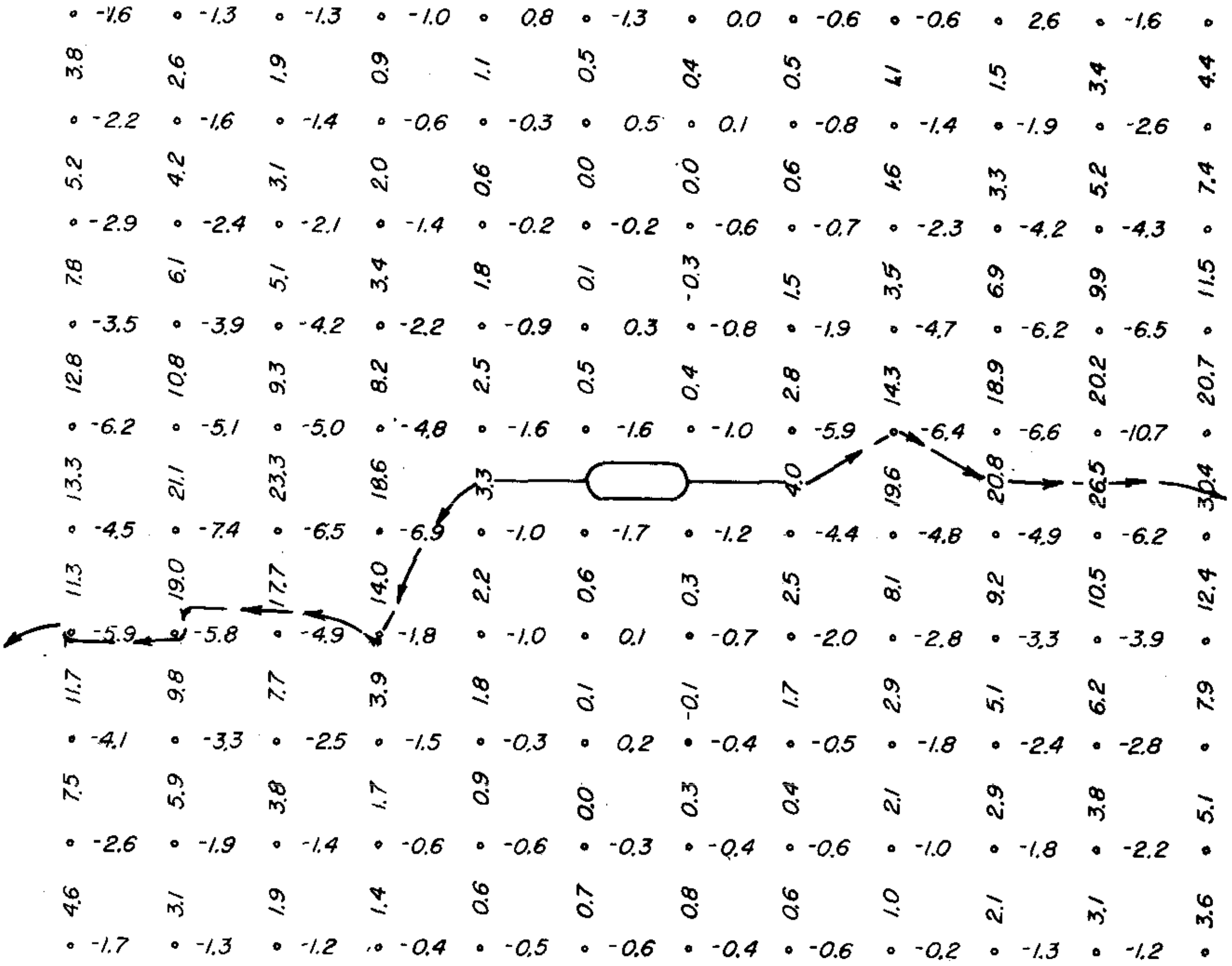


-2.3 -2.0 -1.6 -1.4 -1.3 -1.5 -0.9 -1.7 -1.8 -2.2 -2.8
4.0 3.3 2.2 1.4 0.7 0.7 1.1 0.4 1.6 2.3 3.1 4.1
-2.8 -2.7 -2.3 -1.5 -1.0 -1.1 -1.1 -1.9 -2.3 -3.0 -3.5
5.6 4.3 3.3 2.4 0.5 0.5 -0.2 0.7 1.5 3.2 4.5 6.0
-3.5 -3.4 -2.8 -2.5 -1.1 -1.1 -1.3 -2.4 -3.1 -4.1 -4.1
6.4 6.4 5.4 3.3 1.7 0.2 -0.1 1.7 2.8 6.7 7.0 6.4
-3.9 -4.8 -4.3 -3.1 -1.9 -1.2 -2.1 -3.2 -5.2 -5.0 -4.2
5.7 7.6 8.8 7.3 3.2 0.3 0.4 3.1 12.1 9.7 5.7 5.0
-3.2 -4.1 -5.6 -4.9 -2.3 -2.2 -2.1 -7.2 -4.3 -3.4 -3.2
5.8 9.0 13.6 24.4 4.6 3.7 21.8 12.5 9.9 6.1
-3.6 -3.6 -5.6 -5.2 -2.1 -2.3 -2.0 -5.2 -5.1 -4.2 -3.4
5.7 8.4 10.4 8.5 3.2 0.6 0.2 2.7 7.1 8.5 7.0 5.6
-4.2 -4.6 -4.3 -2.9 -1.3 -1.1 -1.7 -3.2 -3.9 -4.2 -4.2
6.8 6.7 5.6 3.4 1.7 0.2 0.7 1.6 3.2 4.6 6.0 6.2
-3.3 -3.0 -2.7 -2.0 -0.8 -1.2 -0.8 -2.3 -3.0 -3.0 -3.5
5.6 4.4 3.1 1.9 0.2 0.1 0.2 0.5 2.3 2.5 3.5 5.2
-2.8 -2.7 -2.0 -1.1 -1.1 -0.6 -1.1 -1.3 -2.6 -1.9 -2.6
3.7 3.3 2.3 1.7 1.1 1.0 0.3 0.4 1.3 2.1 3.2 3.5
-1.9 -2.1 -1.7 -1.1 -1.2 -0.9 -0.9 -1.1 -1.6 -1.9 -2.4

FIG. A-41 PERCENT ELONGATION PLATE A-2D (1-INCH GRID)

"A" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 48.1 KSI

TEMPERATURE 31-33°F 25.5% SHEAR



-1.6	-1.3	-1.3	-1.0	0.8	-1.3	0.0	-0.6	-0.6	2.6	-1.6	
3.8	2.6	1.9	0.9	1.1	0.5	0.4	0.5	4.1	1.5	3.4	4.4
-2.2	-1.6	-1.4	-0.6	-0.3	0.5	0.1	-0.8	-1.4	-1.9	-2.6	
5.2	4.2	3.1	2.0	0.6	0.0	0.0	0.6	1.6	3.3	5.2	7.4
-2.9	-2.4	-2.1	-1.4	-0.2	-0.2	-0.6	-0.7	-2.3	-4.2	-4.3	
7.8	6.1	5.1	3.4	1.8	0.1	-0.3	1.5	3.5	6.9	9.9	11.5
-3.5	-3.9	-4.2	-2.2	-0.9	0.3	-0.8	-1.9	-4.7	-6.2	-6.5	
12.8	10.8	9.3	8.2	2.5	0.5	0.4	2.8	14.3	18.9	20.2	20.7
-6.2	-5.1	-5.0	-4.8	-1.6	-1.6	-1.0	-5.9	-6.4	-6.6	-10.7	
13.3	21.1	23.3	18.6	3.3			4.0	19.6	20.8	26.5	30.4
-4.5	-7.4	-6.5	-6.9	-1.0	-1.7	-1.2	-4.4	-4.8	-4.9	-6.2	
11.3	19.0	17.7	14.0	2.2	0.6	0.3	2.5	8.1	9.2	10.5	12.4
-5.9	-5.8	-4.9	-1.8	-1.0	0.1	-0.7	-2.0	-2.8	-3.3	-3.9	
11.7	9.8	7.7	3.9	1.8	0.1	-0.1	1.7	2.9	5.1	6.2	7.9
-4.1	-3.3	-2.5	-1.5	-0.3	0.2	-0.4	-0.5	-1.8	-2.4	-2.8	
7.5	5.9	3.8	1.7	0.9	0.0	0.3	0.4	2.1	2.9	3.8	5.1
-2.6	-1.9	-1.4	-0.6	-0.6	-0.3	-0.4	-0.6	-1.0	-1.8	-2.2	
4.6	3.1	1.9	1.4	0.6	0.7	0.8	0.6	1.0	2.1	3.1	3.6
-1.7	-1.3	-1.2	-0.4	-0.5	-0.6	-0.4	-0.6	-0.2	-1.3	-1.2	

FIG. A - 42 PERCENT ELONGATION PLATE A-3D (1-INCH GRID)

"A" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 48.1 KSI

TEMPERATURE 50°F 100 % SHEAR

DWG. 44E106

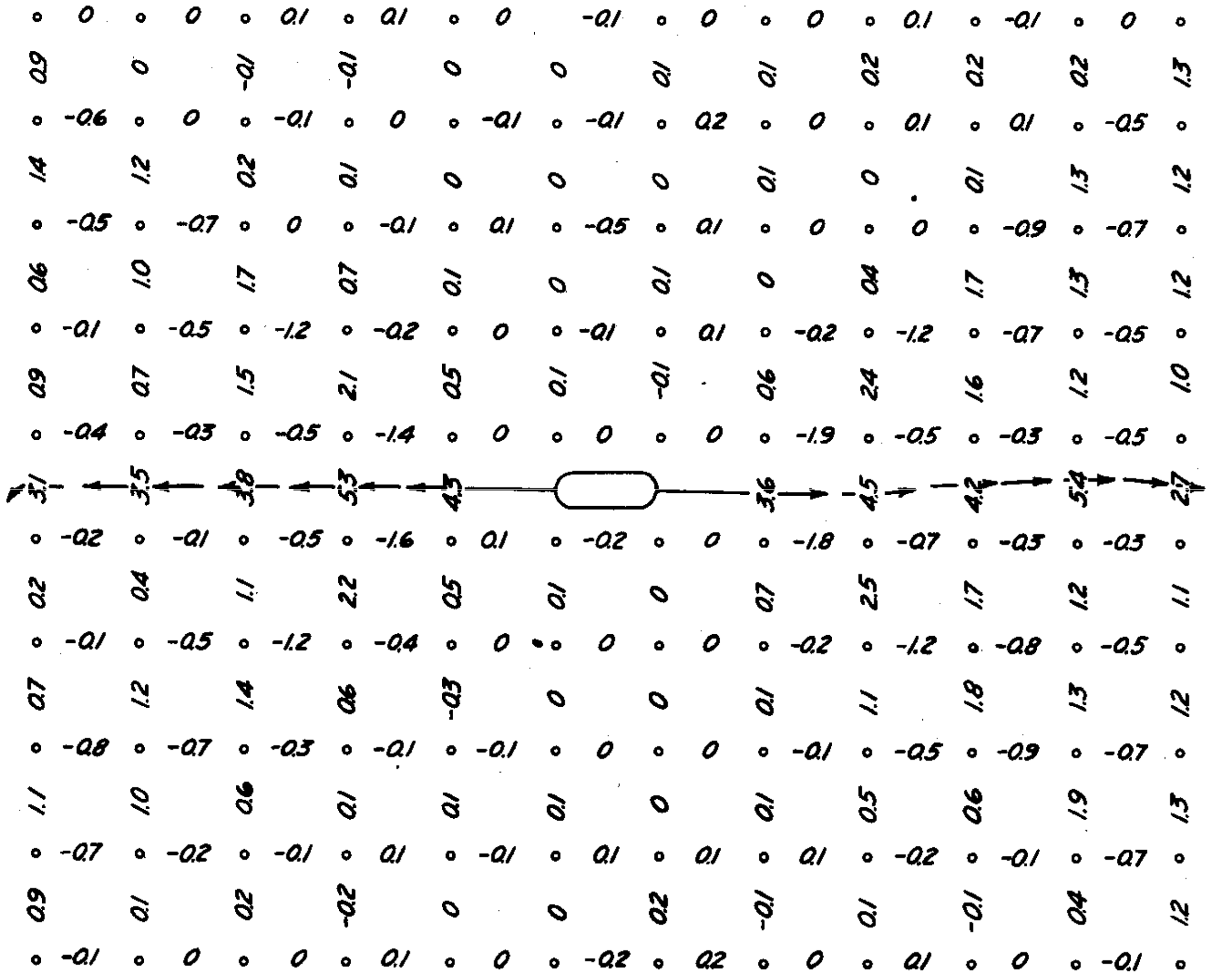


FIG. A-43 PERCENT ELONGATION PLATE A-4D (1 INCH GRID)

"A" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 39.3 KSI

TEMPERATURE 10°F 0 % SHEAR

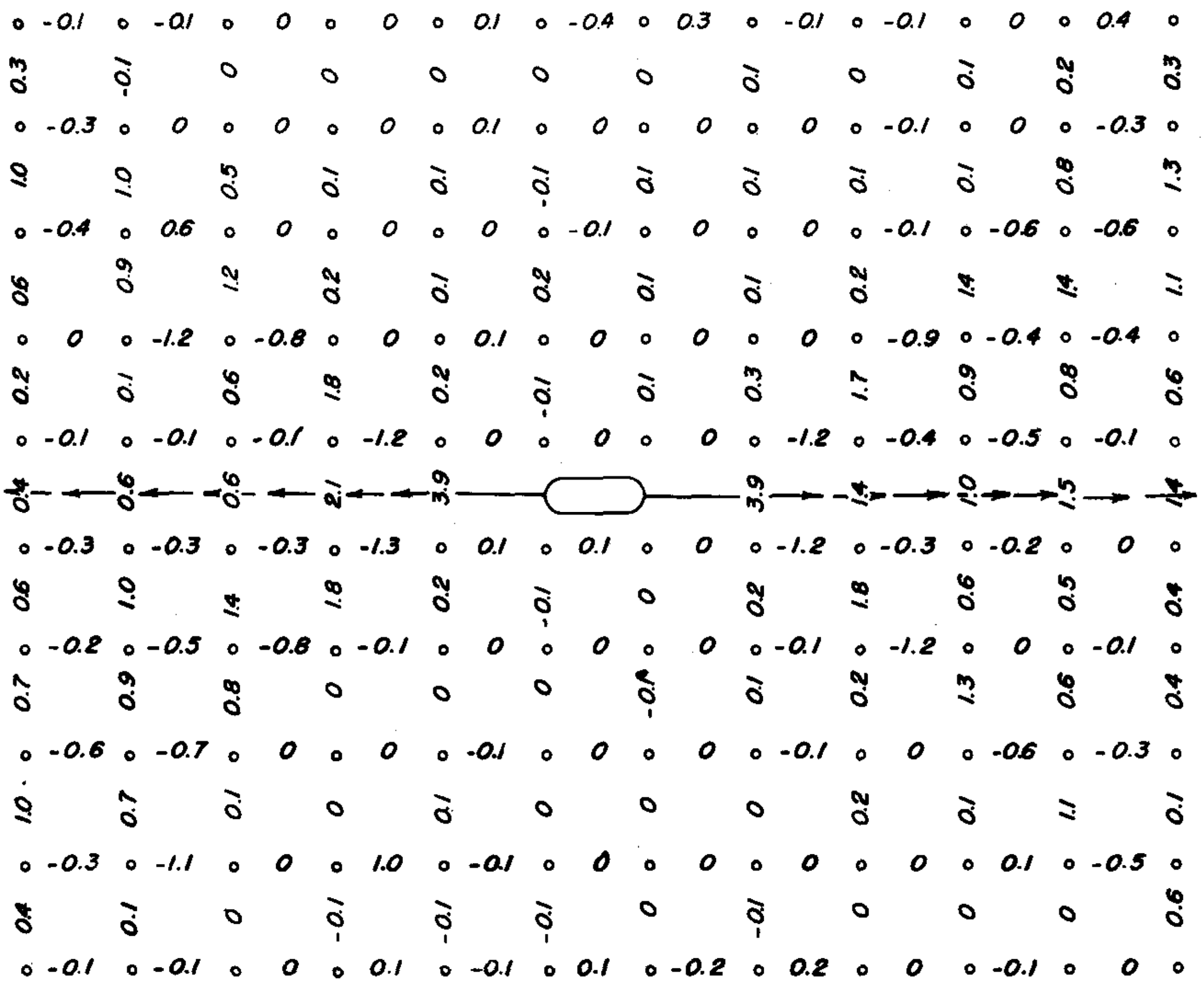
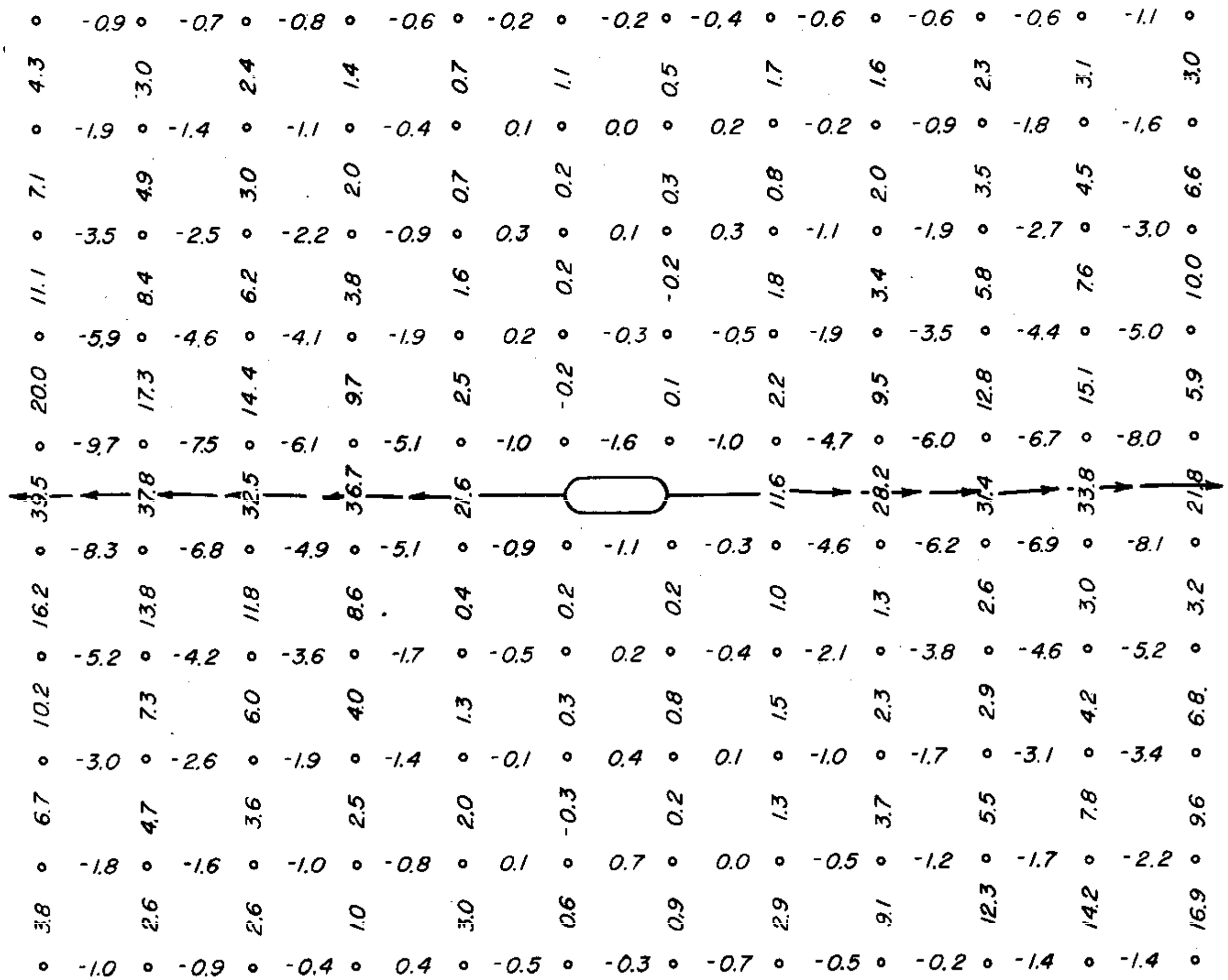


FIG A-44 PERCENT ELONGATION PLATE A-5D (1-INCH GRID)

TEMPERATURE (-8) - (-7)°F 0% SHEAR

"A" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 39.9 KSI

DWG. 44E108



○	-0.9	○	-0.7	○	-0.8	○	-0.6	○	-0.2	○	-0.2	○	-0.4	○	-0.6	○	-0.6	○	-0.6	○	-1.1	○
4.3		3.0		2.4		1.4		0.7		1.1		0.5		1.7		1.6		2.3		3.1		3.0
○	-1.9	○	-1.4	○	-1.1	○	-0.4	○	0.1	○	0.0	○	0.2	○	-0.2	○	-0.9	○	-1.8	○	-1.6	○
7.1		4.9		3.0		2.0		0.7		0.2		0.3		0.8		2.0		3.5		4.5		6.6
○	-3.5	○	-2.5	○	-2.2	○	-0.9	○	0.3	○	0.1	○	0.3	○	-1.1	○	-1.9	○	-2.7	○	-3.0	○
11.1		8.4		6.2		3.8		1.6		0.2		-0.2		1.8		3.4		5.8		7.6		10.0
○	-5.9	○	-4.6	○	-4.1	○	-1.9	○	0.2	○	-0.3	○	-0.5	○	-1.9	○	-3.5	○	-4.4	○	-5.0	○
20.0		17.3		14.4		9.7		2.5		-0.2		0.1		2.2		9.5		12.8		15.1		5.9
○	-9.7	○	-7.5	○	-6.1	○	-5.1	○	-1.0	○	-1.6	○	-1.0	○	-4.7	○	-6.0	○	-6.7	○	-8.0	○
39.5		37.8		32.5		36.7		21.6						11.6		28.2		31.4		33.8		21.8
○	-8.3	○	-6.8	○	-4.9	○	-5.1	○	-0.9	○	-1.1	○	-0.3	○	-4.6	○	-6.2	○	-6.9	○	-8.1	○
16.2		13.8		11.8		8.6		0.4		0.2		0.2		1.0		1.3		2.6		3.0		3.2
○	-5.2	○	-4.2	○	-3.6	○	-1.7	○	-0.5	○	0.2	○	-0.4	○	-2.1	○	-3.8	○	-4.6	○	-5.2	○
10.2		7.3		6.0		4.0		1.3		0.3		0.8		1.5		2.3		2.9		4.2		6.8
○	-3.0	○	-2.6	○	-1.9	○	-1.4	○	-0.1	○	0.4	○	0.1	○	-1.0	○	-1.7	○	-3.1	○	-3.4	○
6.7		4.7		3.6		2.5		2.0		-0.3		0.2		1.3		3.7		5.5		7.8		9.6
○	-1.8	○	-1.6	○	-1.0	○	-0.8	○	0.1	○	0.7	○	0.0	○	-0.5	○	-1.2	○	-1.7	○	-2.2	○
3.8		2.6		2.6		1.0		3.0		0.6		0.9		2.9		9.1		12.3		14.2		16.9
○	-1.0	○	-0.9	○	-0.4	○	0.4	○	-0.5	○	-0.3	○	-0.7	○	-0.5	○	-0.2	○	-1.4	○	-1.4	○

FIG A-45 PERCENT ELONGATION PLATE B-1D (1-INCH GRID)

"B" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 48.9 KSI

TEMPERATURE 31-32°F 82 % SHEAR

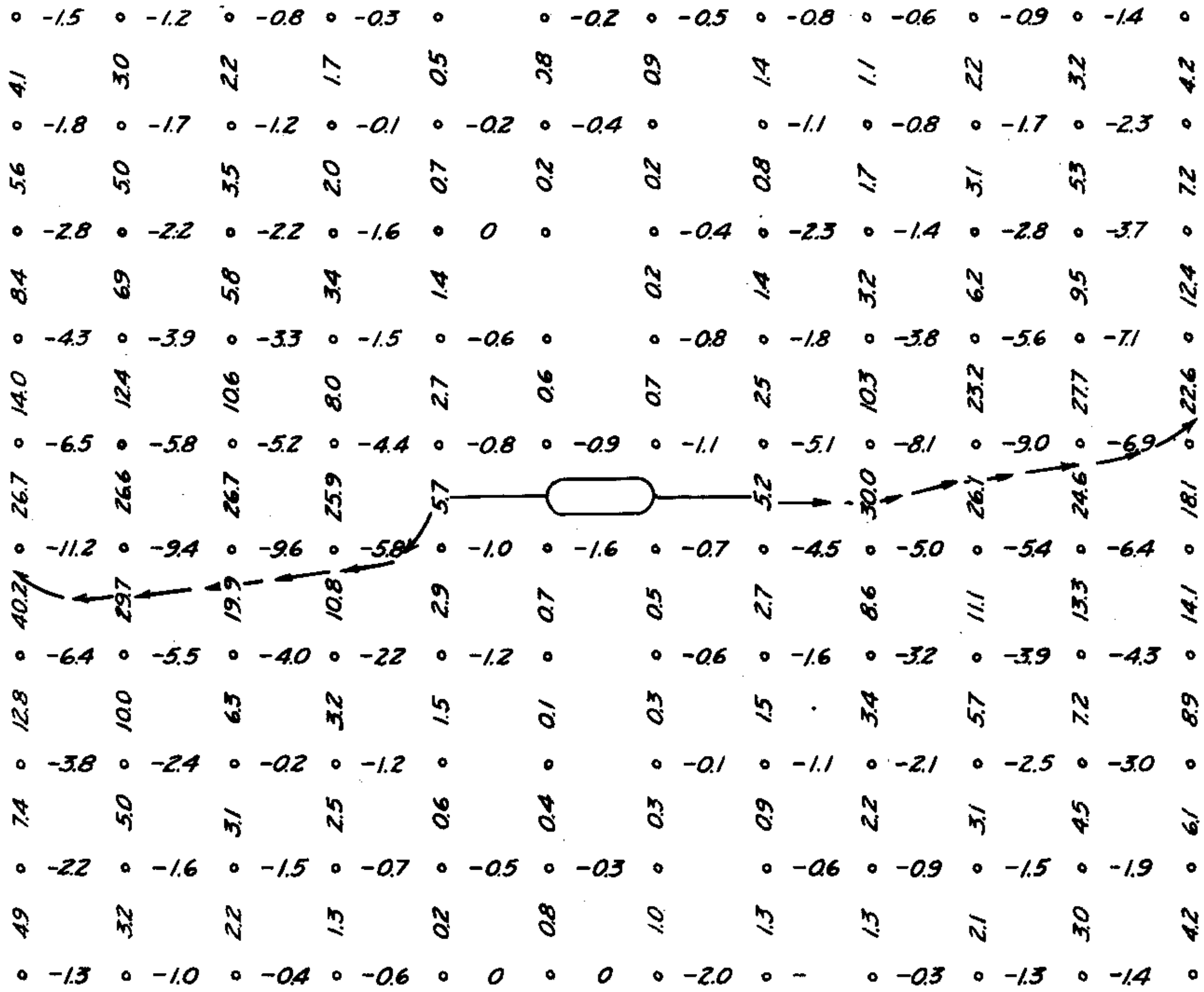


FIG A-46 PERCENT ELONGATION PLATE B-3D (1-INCH GRID)

"B" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 46.1 KSI

TEMPERATURE 70-73°F 94% SHEAR

DWG. 44E110

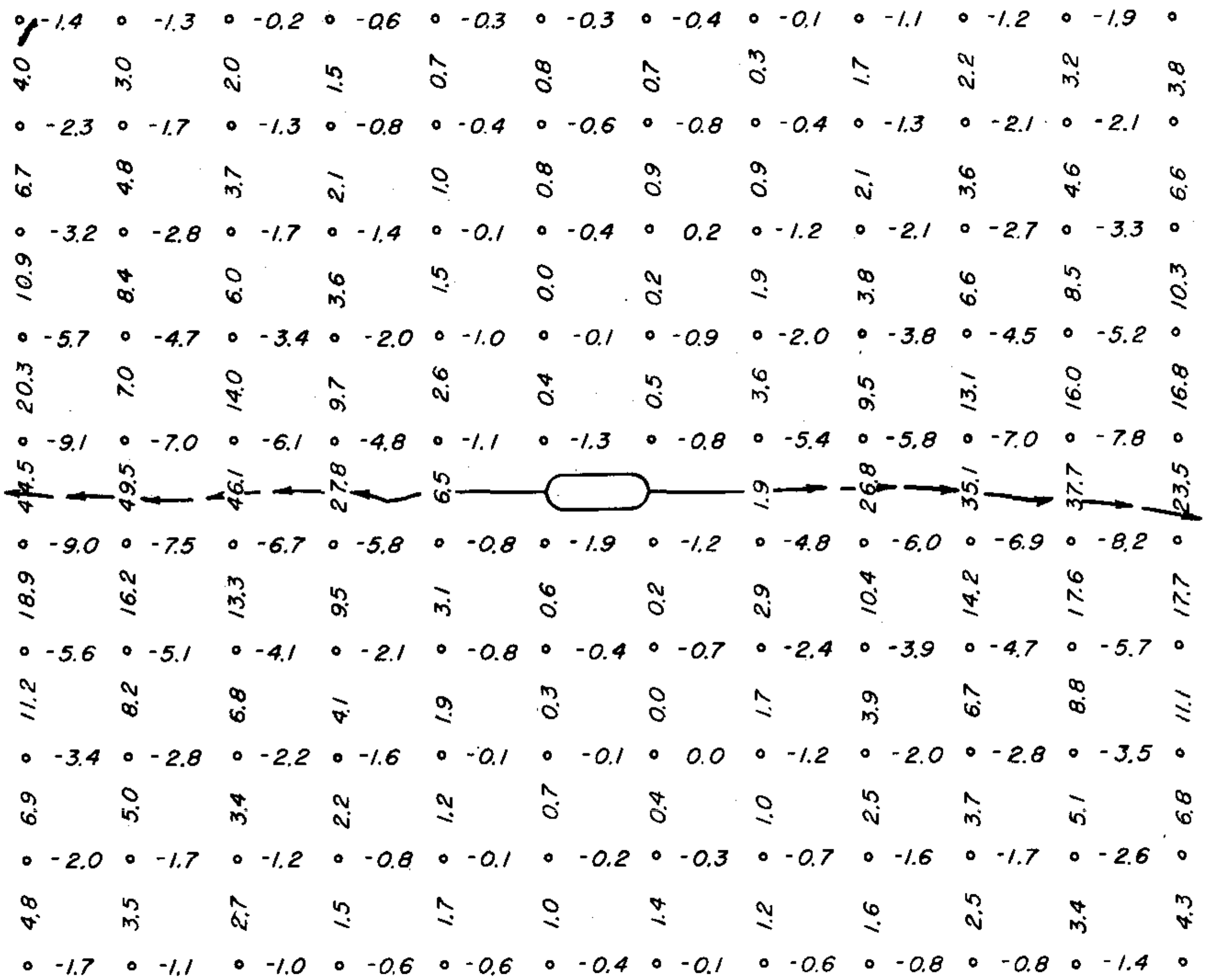


FIG. A-47 PERCENT ELONGATION PLATE B-6D(1-INCH GRID)

"B" STEEL 12 INCH WIDE PLATE NOMINAL STRENGTH 49.3KSI

TEMPERATURE 50-51°F 100% SHEAR

DWG. 44E111

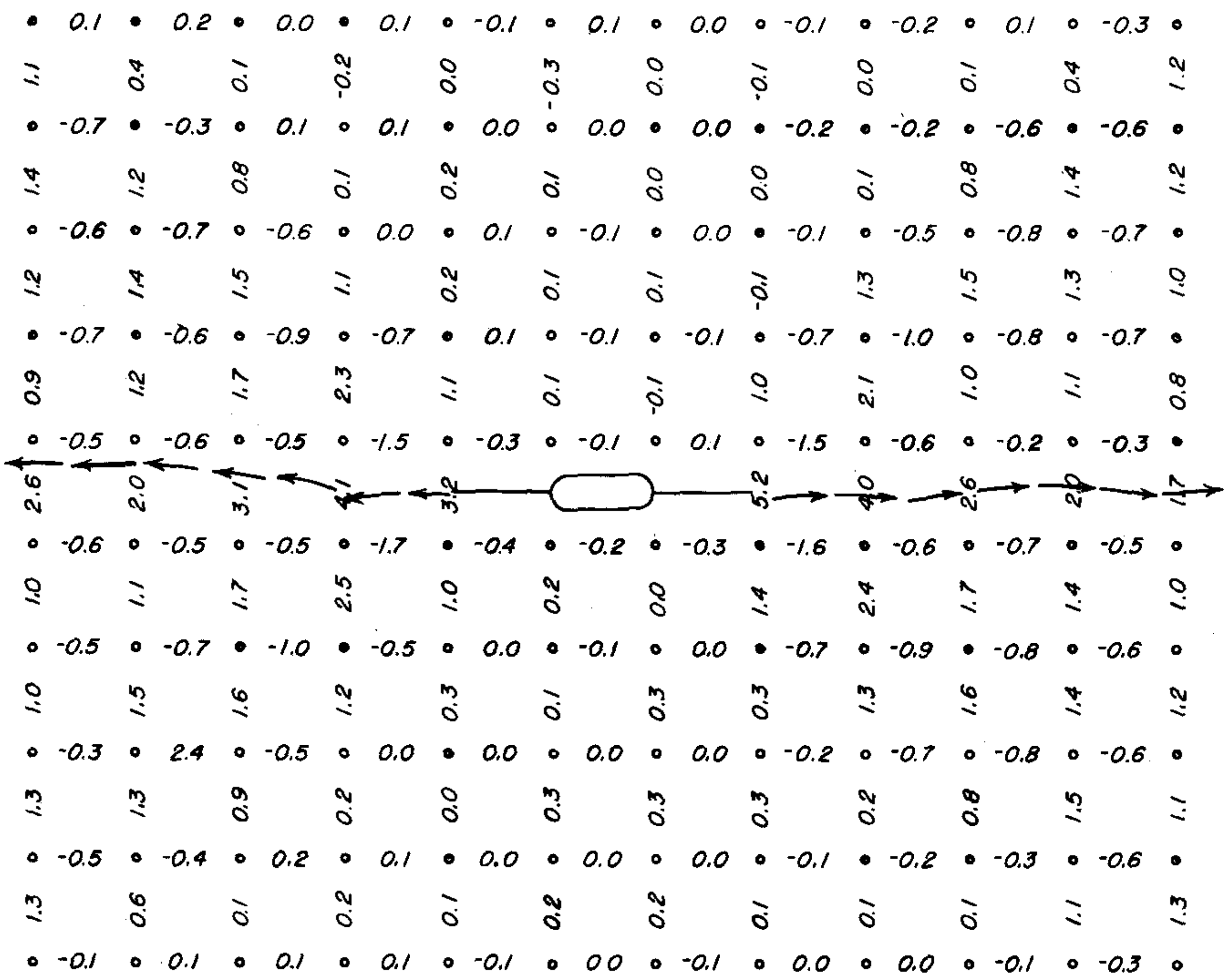


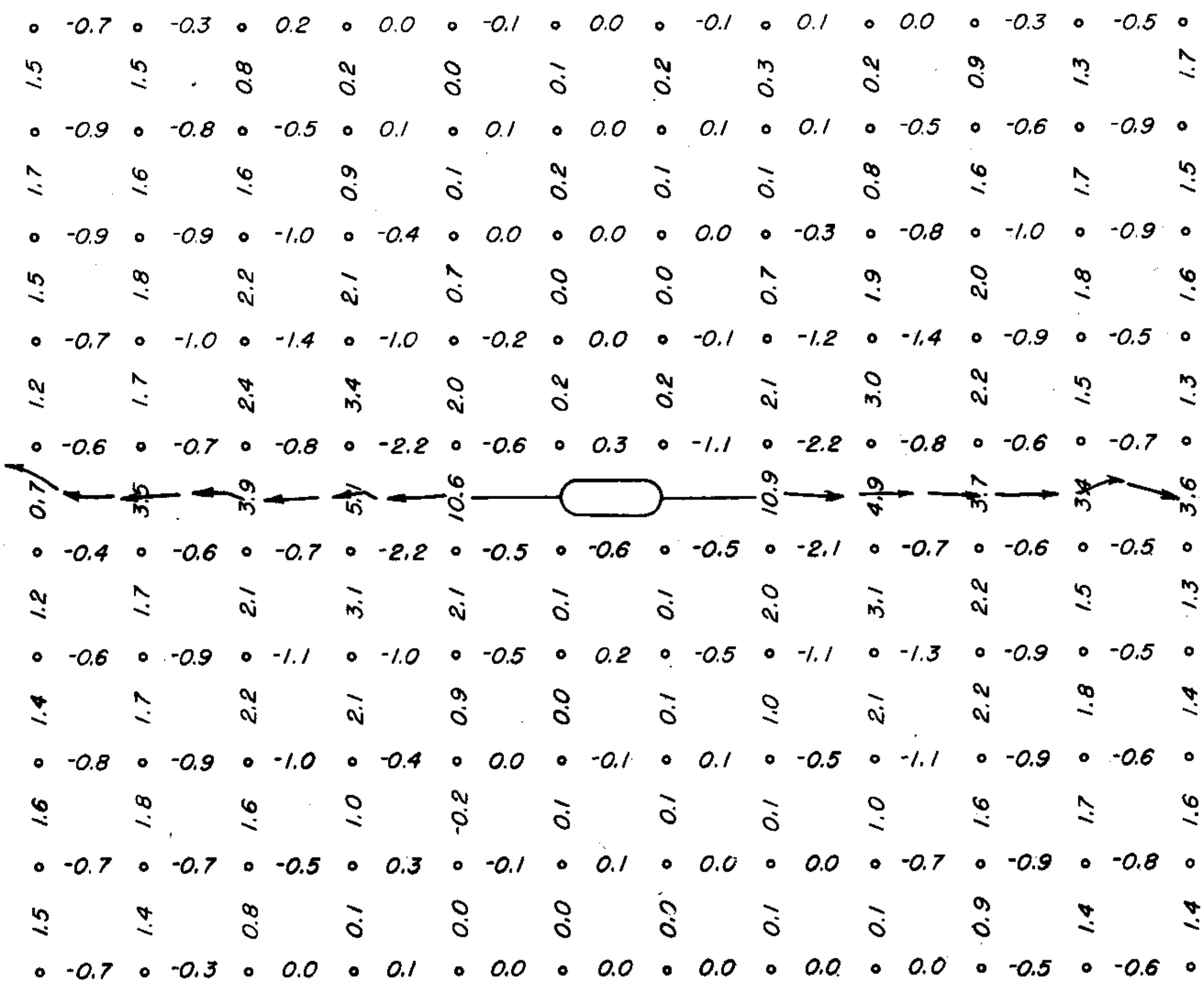
FIG. A-48 PERCENT ELONGATION PLATE B-7D (1-INCH GRID)

"B" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 40.0 KSI

TEMPERATURE (-36)-(-33)°F 0 % SHEAR

DWG. 44E112

FIG. A-48



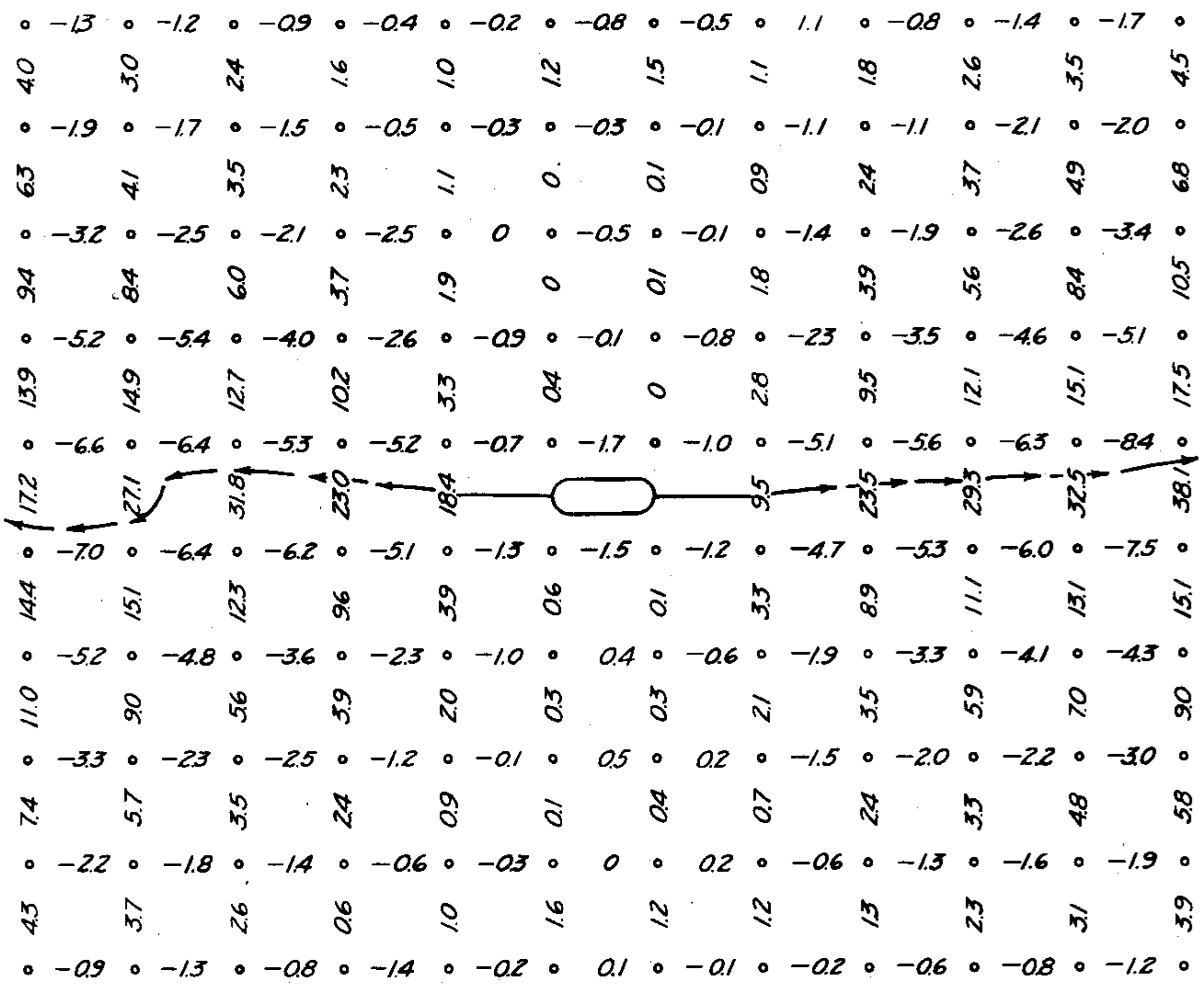
-0.7 -0.3 0.2 0.0 -0.1 0.0 -0.1 0.1 0.0 -0.3 -0.5
1.5 1.5 0.8 0.2 0.0 0.1 0.2 0.3 0.2 0.9 1.3 1.7
-0.9 -0.8 -0.5 0.1 0.1 0.0 0.1 0.1 -0.5 -0.6 -0.9
1.7 1.6 1.6 0.9 0.1 0.2 0.1 0.1 0.8 1.6 1.7 1.5
-0.9 -0.9 -1.0 -0.4 0.0 0.0 0.0 -0.3 -0.8 -1.0 -0.9
1.5 1.8 2.2 2.1 0.7 0.0 0.0 0.7 1.9 2.0 1.8 1.6
-0.7 -1.0 -1.4 -1.0 -0.2 0.0 -0.1 -1.2 -1.4 -0.9 -0.5
1.2 1.7 2.4 3.4 2.0 0.2 0.2 2.1 3.0 2.2 1.5 1.3
-0.6 -0.7 -0.8 -2.2 -0.6 0.3 -1.1 -2.2 -0.8 -0.6 -0.7
0.7 3.5 3.9 5.1 10.6 10.9 4.9 3.7 3.4 3.6
-0.4 -0.6 -0.7 -2.2 -0.5 -0.6 -0.5 -2.1 -0.7 -0.6 -0.5
1.2 1.7 2.1 3.1 2.1 0.1 0.1 2.0 3.1 2.2 1.5 1.3
-0.6 -0.9 -1.1 -1.0 -0.5 0.2 -0.5 -1.1 -1.3 -0.9 -0.5
1.4 1.7 2.2 2.1 0.9 0.0 0.1 1.0 2.1 2.2 1.8 1.4
-0.8 -0.9 -1.0 -0.4 0.0 -0.1 0.1 -0.5 -1.1 -0.9 -0.6
1.6 1.8 1.6 1.0 -0.2 0.1 0.1 0.1 1.0 1.6 1.7 1.6
-0.7 -0.7 -0.5 0.3 -0.1 0.1 0.0 0.0 -0.7 -0.9 -0.8
1.5 1.4 0.8 0.1 0.0 0.0 0.0 0.1 0.1 0.9 1.4 1.4
-0.7 -0.3 0.0 0.1 0.0 0.0 0.0 0.0 0.0 -0.5 -0.6

FIG. A-49 PERCENT ELONGATION PLATE B-9D (1-INCH GRID)

"B" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 41.8 KSI

TEMPERATURE (-6)-(-5)° F 0% SHEAR

DWG. 44E113



○	-1.3	○	-1.2	○	-0.9	○	-0.4	○	-0.2	○	-0.8	○	-0.5	○	1.1	○	-0.8	○	-1.4	○	-1.7	○
4.0		3.0		2.4		1.6		1.0		1.2		1.5		1.1		1.8		2.6		3.5		4.5
○	-1.9	○	-1.7	○	-1.5	○	-0.5	○	-0.3	○	-0.3	○	-0.1	○	-1.1	○	-1.1	○	-2.1	○	-2.0	○
6.3		4.1		3.5		2.3		1.1		0.		0.1		0.9		2.4		3.7		4.9		6.8
○	-3.2	○	-2.5	○	-2.1	○	-2.5	○	0	○	-0.5	○	-0.1	○	-1.4	○	-1.9	○	-2.6	○	-3.4	○
9.4		8.4		6.0		3.7		1.9		0		0.1		1.8		3.9		5.6		8.4		10.5
○	-5.2	○	-5.4	○	-4.0	○	-2.6	○	-0.9	○	-0.1	○	-0.8	○	-2.3	○	-3.5	○	-4.6	○	-5.1	○
13.9		14.9		12.7		10.2		3.3		0.4		0		2.8		9.5		12.1		15.1		17.5
○	-6.6	○	-6.4	○	-5.3	○	-5.2	○	-0.7	○	-1.7	○	-1.0	○	-5.1	○	-5.6	○	-6.3	○	-8.4	○
17.2		27.1		31.8		23.0		18.4						9.5		23.5		29.5		32.5		38.1
○	-7.0	○	-6.4	○	-6.2	○	-5.1	○	-1.3	○	-1.5	○	-1.2	○	-4.7	○	-5.3	○	-6.0	○	-7.5	○
14.4		15.1		12.3		9.6		3.9		0.6		0.1		3.3		8.9		11.1		13.1		15.1
○	-5.2	○	-4.8	○	-3.6	○	-2.3	○	-1.0	○	0.4	○	-0.6	○	-1.9	○	-3.3	○	-4.1	○	-4.3	○
11.0		9.0		5.6		3.9		2.0		0.3		0.3		2.1		3.5		5.9		7.0		9.0
○	-3.3	○	-2.3	○	-2.5	○	-1.2	○	-0.1	○	0.5	○	0.2	○	-1.5	○	-2.0	○	-2.2	○	-3.0	○
7.4		5.7		3.5		2.4		0.9		0.1		0.4		0.7		2.4		3.3		4.8		5.8
○	-2.2	○	-1.8	○	-1.4	○	-0.6	○	-0.3	○	0	○	0.2	○	-0.6	○	-1.3	○	-1.6	○	-1.9	○
4.3		3.7		2.6		0.6		1.0		1.6		1.2		1.2		1.3		2.3		3.1		3.9
○	-0.9	○	-1.3	○	-0.8	○	-1.4	○	-0.2	○	0.1	○	-0.1	○	-0.2	○	-0.6	○	-0.8	○	-1.2	○

FIG. A-50 PERCENT ELONGATION PLATE B-2D (1-INCH GRID)

"B" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 48.1 KSI

TEMPERATURE 32-36°F 80% SHEAR

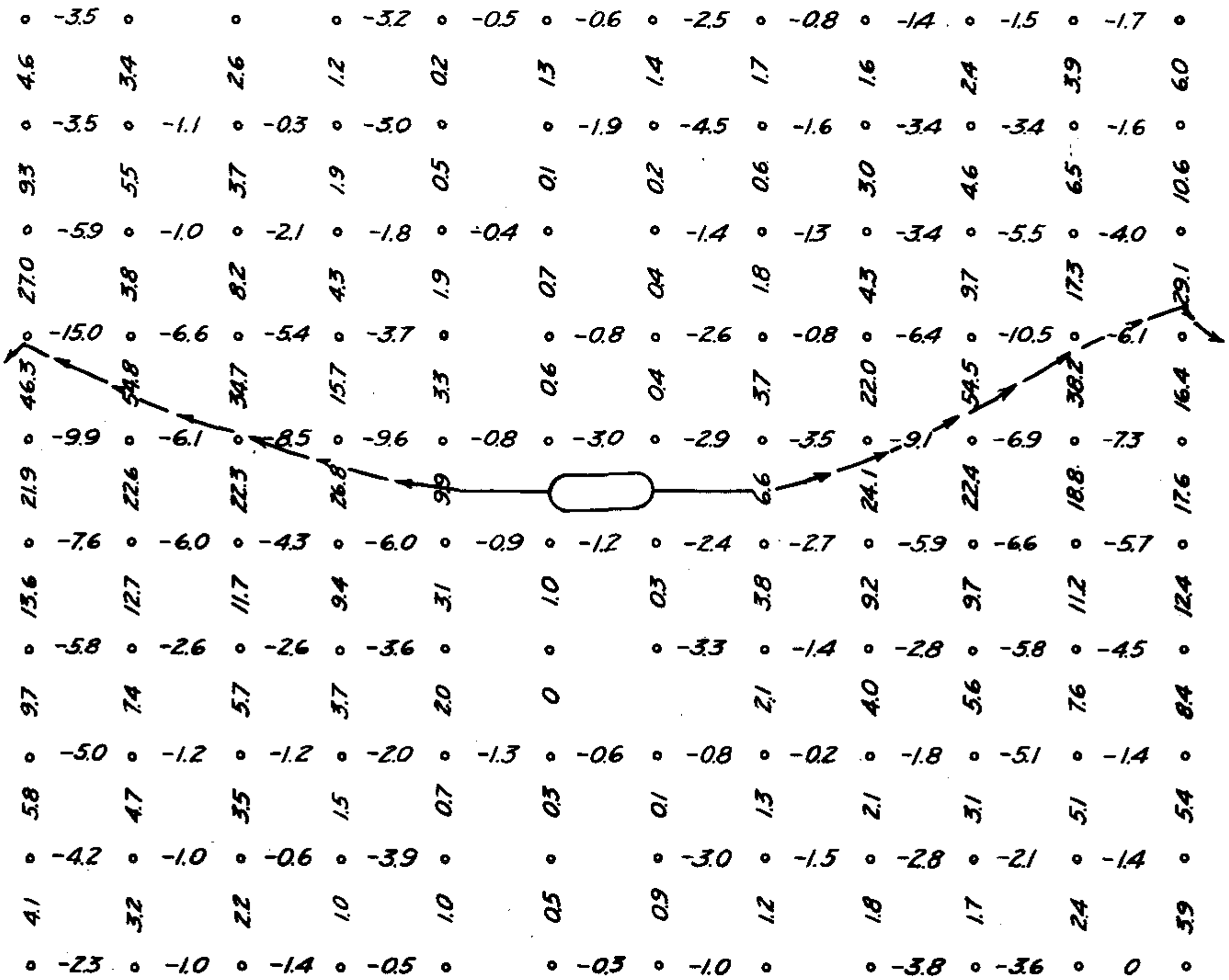


FIG. A-51 PERCENT ELONGATION PLATE B-4D (1-INCH GRID)

"B" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 45.6 KSI

TEMPERATURE 73–89°F 94% SHEAR

DWG. 44E115

FIG. A-51

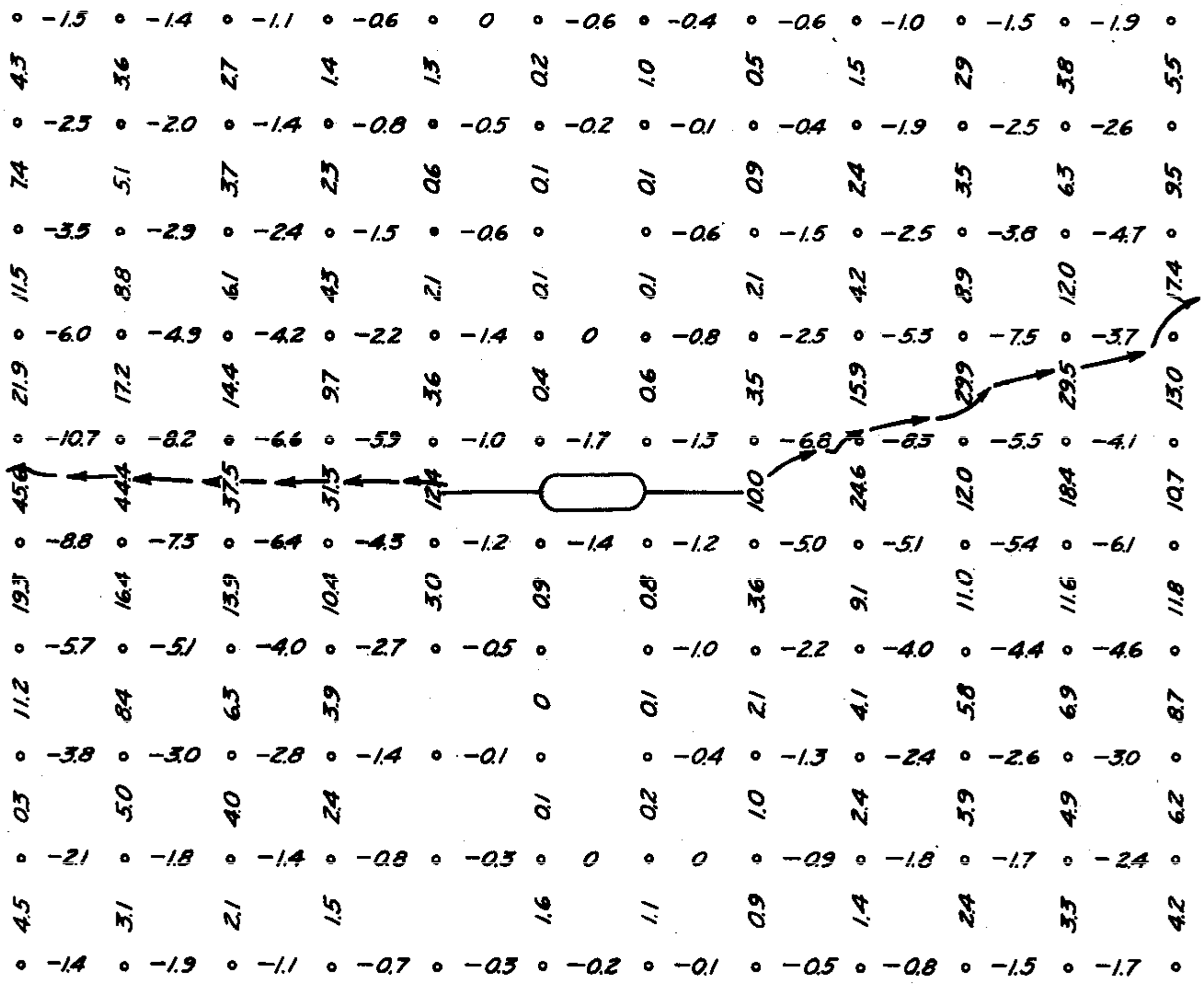


FIG. A -52 PERCENT ELONGATION PLATE B-5D (1-INCH GRID)

"B" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 45.9 KSI

TEMPERATURE 48-51°F 100% SHEAR

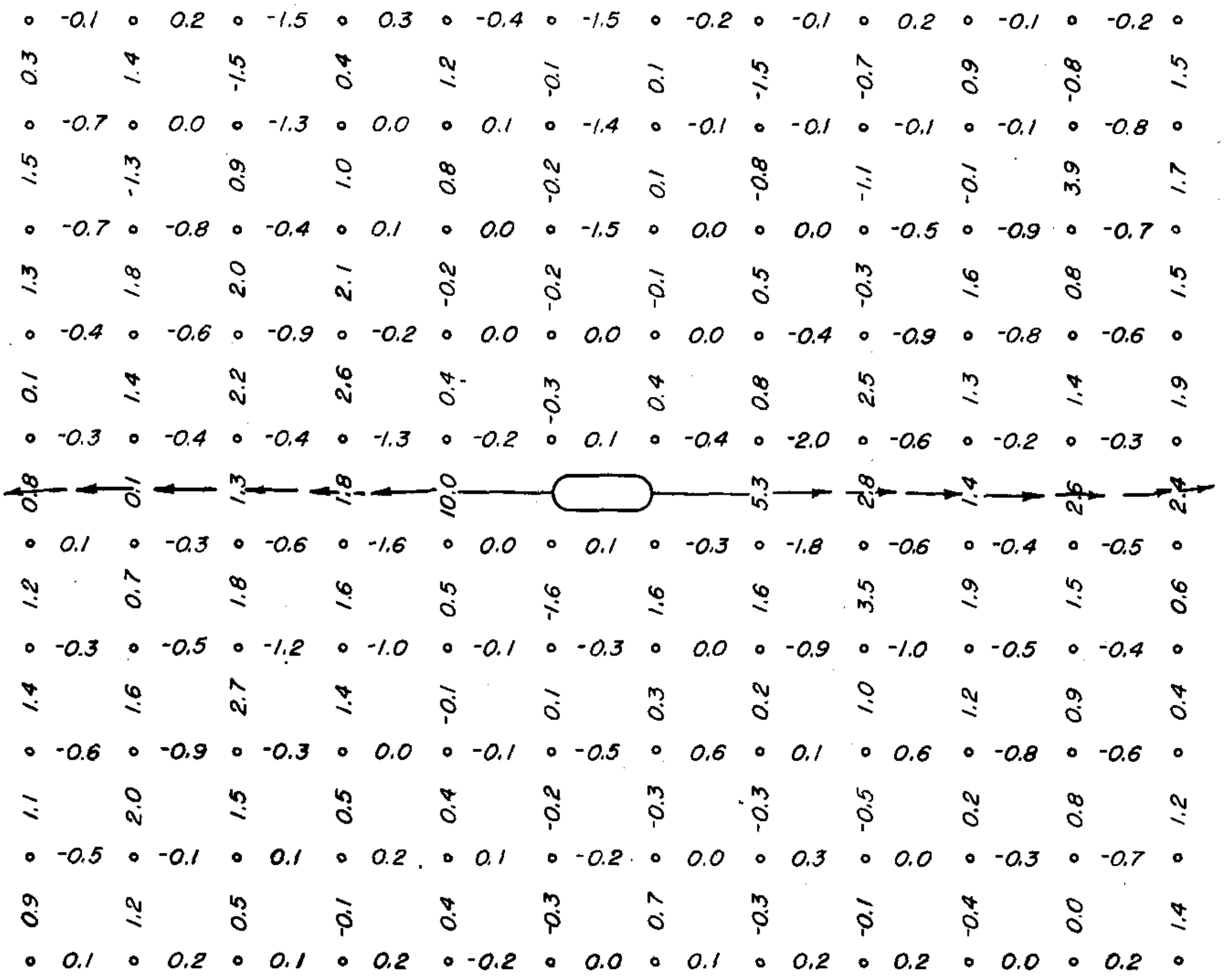


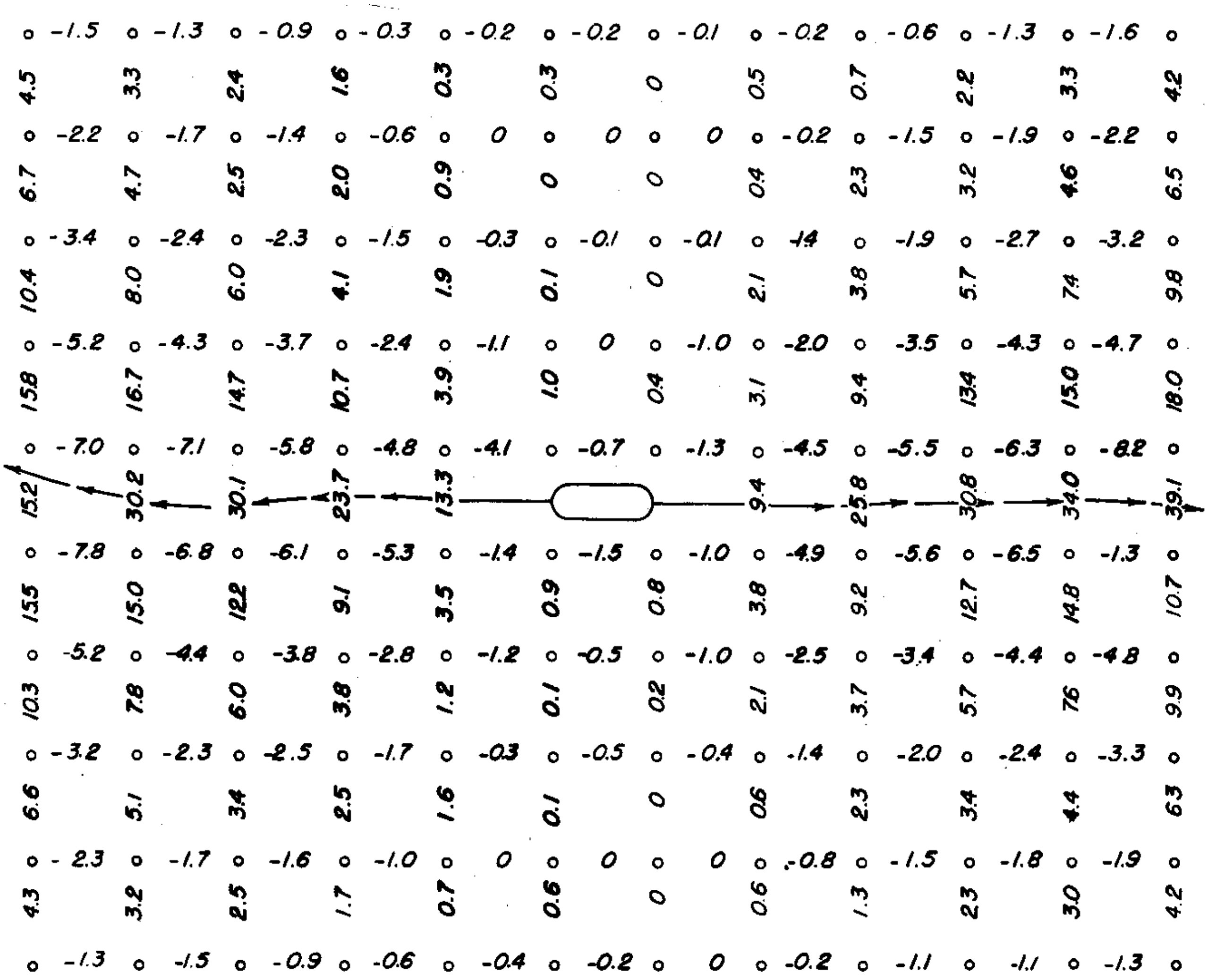
FIG. A-53 PERCENT ELONGATION PLATE B-8D (1-INCH GRID)

"B" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 38.5 KSI

TEMPERATURE (-10)-(-13)°F 0% SHEAR

DWG. 44E117

FIG. A-53



	-1.5		-1.3		-0.9		-0.3		-0.2		-0.2		-0.1		-0.2		-0.6		-1.3		-1.6	
4.5		3.3		2.4		1.6		0.3		0.3		0		0.5		0.7		2.2		3.3		4.2
	-2.2		-1.7		-1.4		-0.6		0		0		0		-0.2		-1.5		-1.9		-2.2	
6.7		4.7		2.5		2.0		0.9		0		0		0.4		2.3		3.2		4.6		6.5
	-3.4		-2.4		-2.3		-1.5		-0.3		-0.1		-0.1		-1.4		-1.9		-2.7		-3.2	
10.4		8.0		6.0		4.1		1.9		0.1		0		2.1		3.8		5.7		7.4		9.8
	-5.2		-4.3		-3.7		-2.4		-1.1		0		-1.0		-2.0		-3.5		-4.3		-4.7	
15.8		16.7		14.7		10.7		3.9		1.0		0.4		3.1		9.4		13.4		15.0		18.0
	-7.0		-7.1		-5.8		-4.8		-4.1		-0.7		-1.3		-4.5		-5.5		-6.3		-8.2	
15.2		30.2		30.1		23.7		13.3						9.4		25.8		30.8		34.0		39.1
	-7.8		-6.8		-6.1		-5.3		-1.4		-1.5		-1.0		-4.9		-5.6		-6.5		-1.3	
15.5		15.0		12.2		9.1		3.5		0.9		0.8		3.8		9.2		12.7		14.8		10.7
	-5.2		-4.4		-3.8		-2.8		-1.2		-0.5		-1.0		-2.5		-3.4		-4.4		-4.8	
10.3		7.8		6.0		3.8		1.2		0.1		0.2		2.1		3.7		5.7		7.6		9.9
	-3.2		-2.3		-2.5		-1.7		-0.3		-0.5		-0.4		-1.4		-2.0		-2.4		-3.3	
6.6		5.1		3.4		2.5		1.6		0.1		0		0.6		2.3		3.4		4.4		6.3
	-2.3		-1.7		-1.6		-1.0		0		0		0		-0.8		-1.5		-1.8		-1.9	
4.3		3.2		2.5		1.7		0.7		0.6		0		0.6		1.3		2.3		3.0		4.2
	-1.3		-1.5		-0.9		-0.6		-0.4		-0.2		0		-0.2		-1.1		-1.1		-1.3	

FIG. A-54 PERCENT ELONGATION PLATE B-10D (1-INCH GRID)

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

TEMPERATURE 10–17° F 86.5% SHEAR

DWG. 44E118

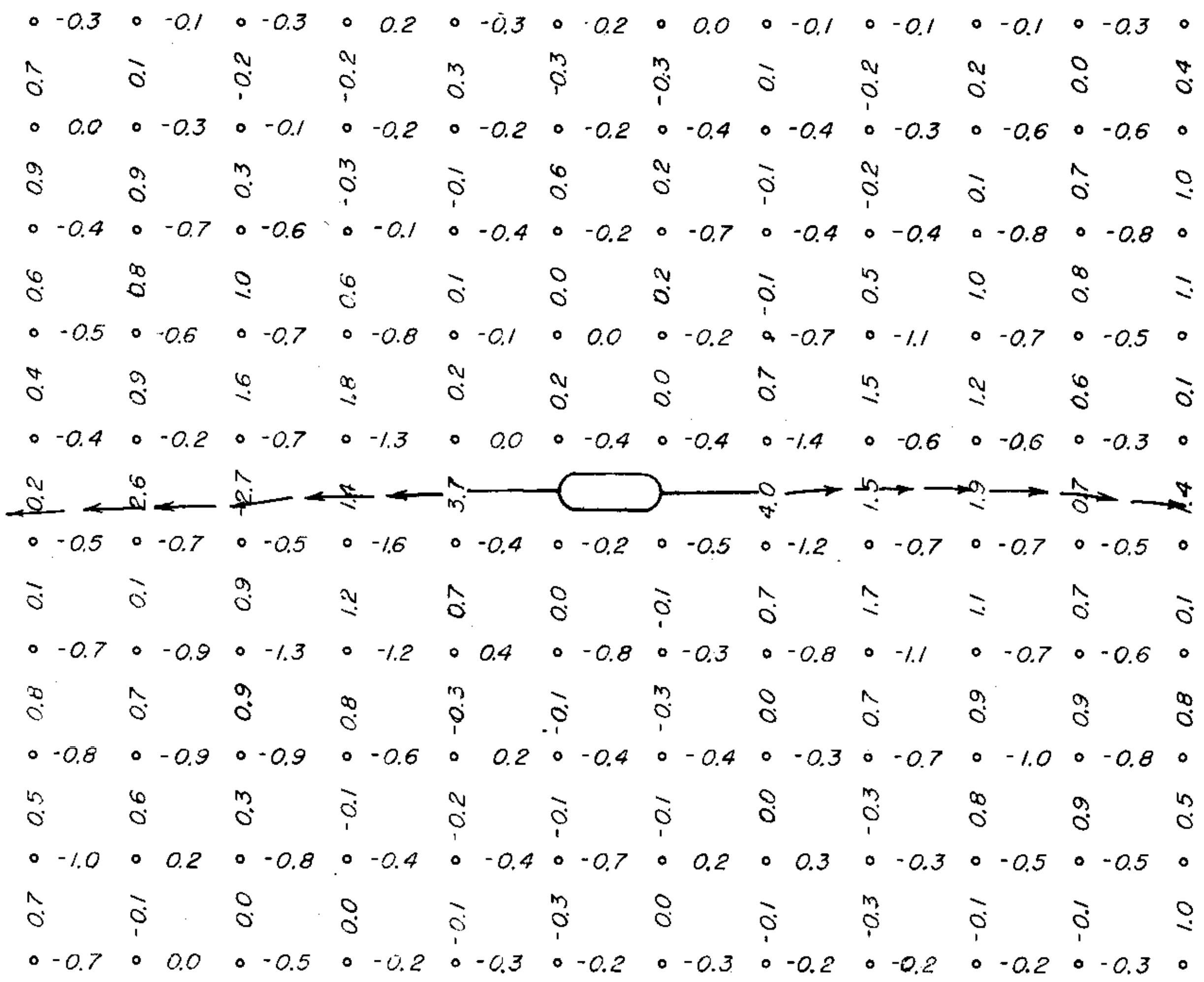


FIG. A-55 PERCENT ELONGATION PLATE C-ID (1-INCH GRID)

"C" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 40.0 KSI

TEMPERATURE 32—33° F 0 % SHEAR

DWG 44E119

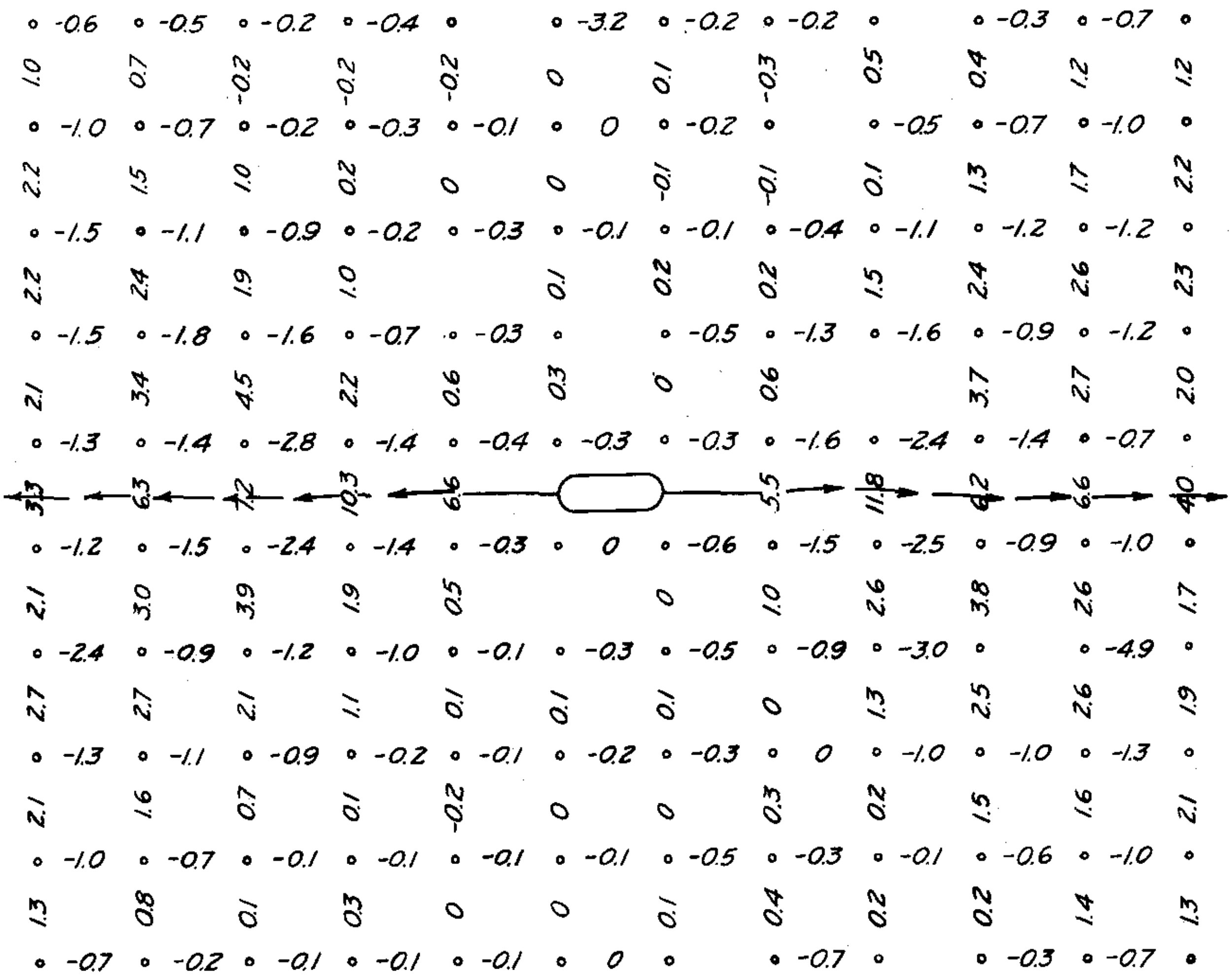
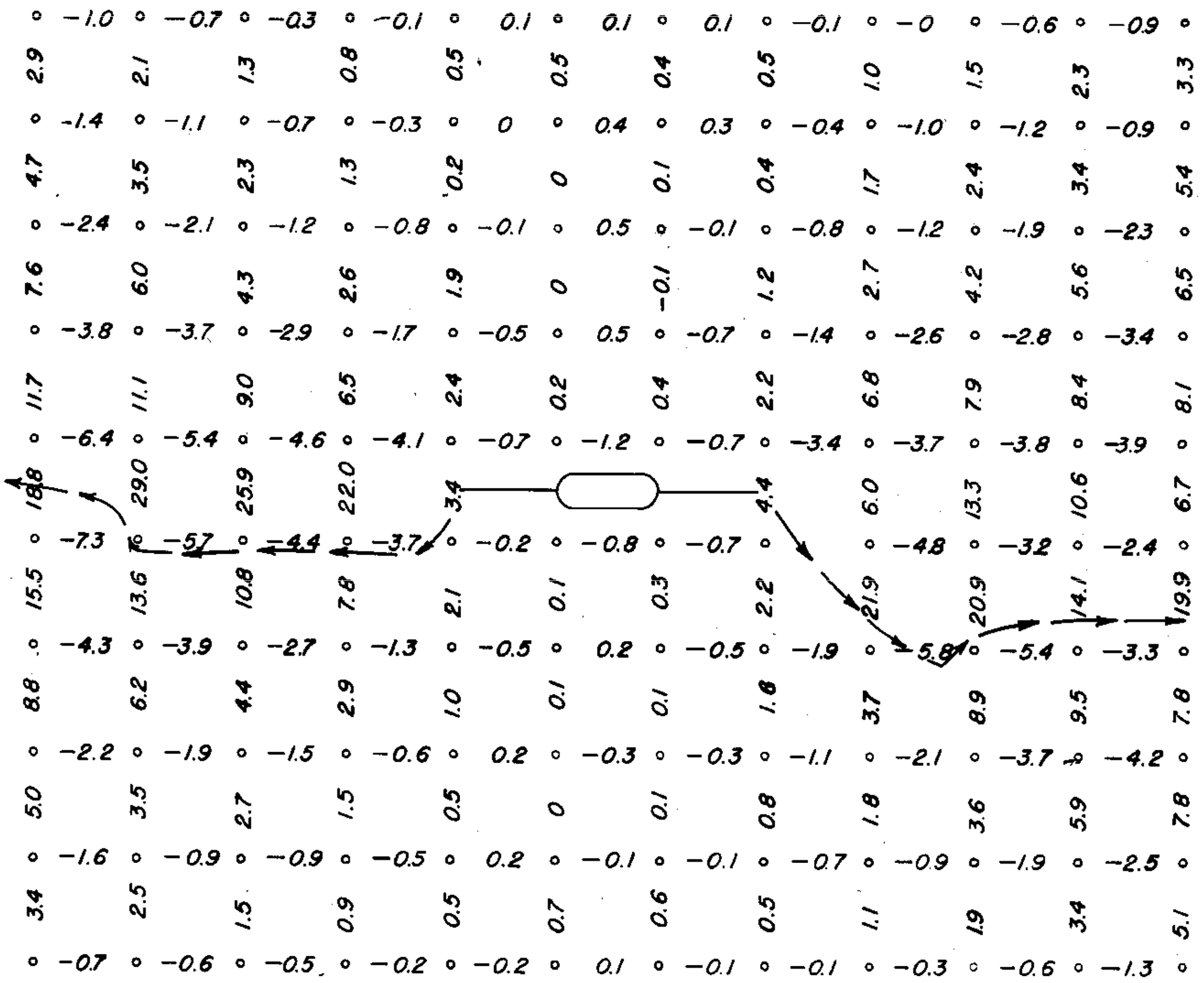


FIG. A-56 PERCENT ELONGATION PLATE C-2D (1 INCH GRID)

"C". STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 42.8 KSI

TEMPERATURE 80°F 3 % SHEAR

DWG. 44E120



−1.0 −0.7 −0.3 −0.1 0.1 0.1 0.1 −0.1 −0 −0.6 −0.9

2.9 2.1 1.3 0.8 0.5 0.5 0.4 0.5 1.0 1.5 2.3 3.3

−1.4 −1.1 −0.7 −0.3 0 0.4 0.3 −0.4 −1.0 −1.2 −0.9

4.7 3.5 2.3 1.3 0.2 0 0.1 0.4 1.7 2.4 3.4 5.4

−2.4 −2.1 −1.2 −0.8 −0.1 0.5 −0.1 −0.8 −1.2 −1.9 −2.3

7.6 6.0 4.3 2.6 1.9 0 −0.1 1.2 2.7 4.2 5.6 6.5

−3.8 −3.7 −2.9 −1.7 −0.5 0.5 −0.7 −1.4 −2.6 −2.8 −3.4

11.7 11.1 9.0 6.5 2.4 0.2 0.4 2.2 6.8 7.9 8.4 8.1

−6.4 −5.4 −4.6 −4.1 −0.7 −1.2 −0.7 −3.4 −3.7 −3.8 −3.9

18.8 29.0 25.9 22.0 3.4 4.4 6.0 13.3 10.6 6.7

−7.3 −5.7 −4.4 −3.7 −0.2 −0.8 −0.7 −4.8 −3.2 −2.4

15.5 13.6 10.8 7.8 2.1 0.1 0.3 2.2 21.9 20.9 14.1 19.9

−4.3 −3.9 −2.7 −1.3 −0.5 0.2 −0.5 −1.9 5.8 −5.4 −3.3

8.8 6.2 4.4 2.9 1.0 0.1 0.1 1.6 3.7 8.9 9.5 7.8

−2.2 −1.9 −1.5 −0.6 0.2 −0.3 −0.3 −1.1 −2.1 −3.7 −4.2

5.0 3.5 2.7 1.5 0.5 0 0.1 0.8 1.8 3.6 5.9 7.8

−1.6 −0.9 −0.9 −0.5 0.2 −0.1 −0.1 −0.7 −0.9 −1.9 −2.5

3.4 2.5 1.5 0.9 0.5 0.7 0.6 0.5 1.1 1.9 3.4 5.1

−0.7 −0.6 −0.5 −0.2 −0.2 0.1 −0.1 −0.1 −0.3 −0.6 −1.3

FIG. A-57 PERCENT ELONGATION PLATE C-3D (1 INCH GRID)

"C" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 51.1 KSI

TEMPERATURE 99-104° F 51% SHEAR

DWG. 44E121

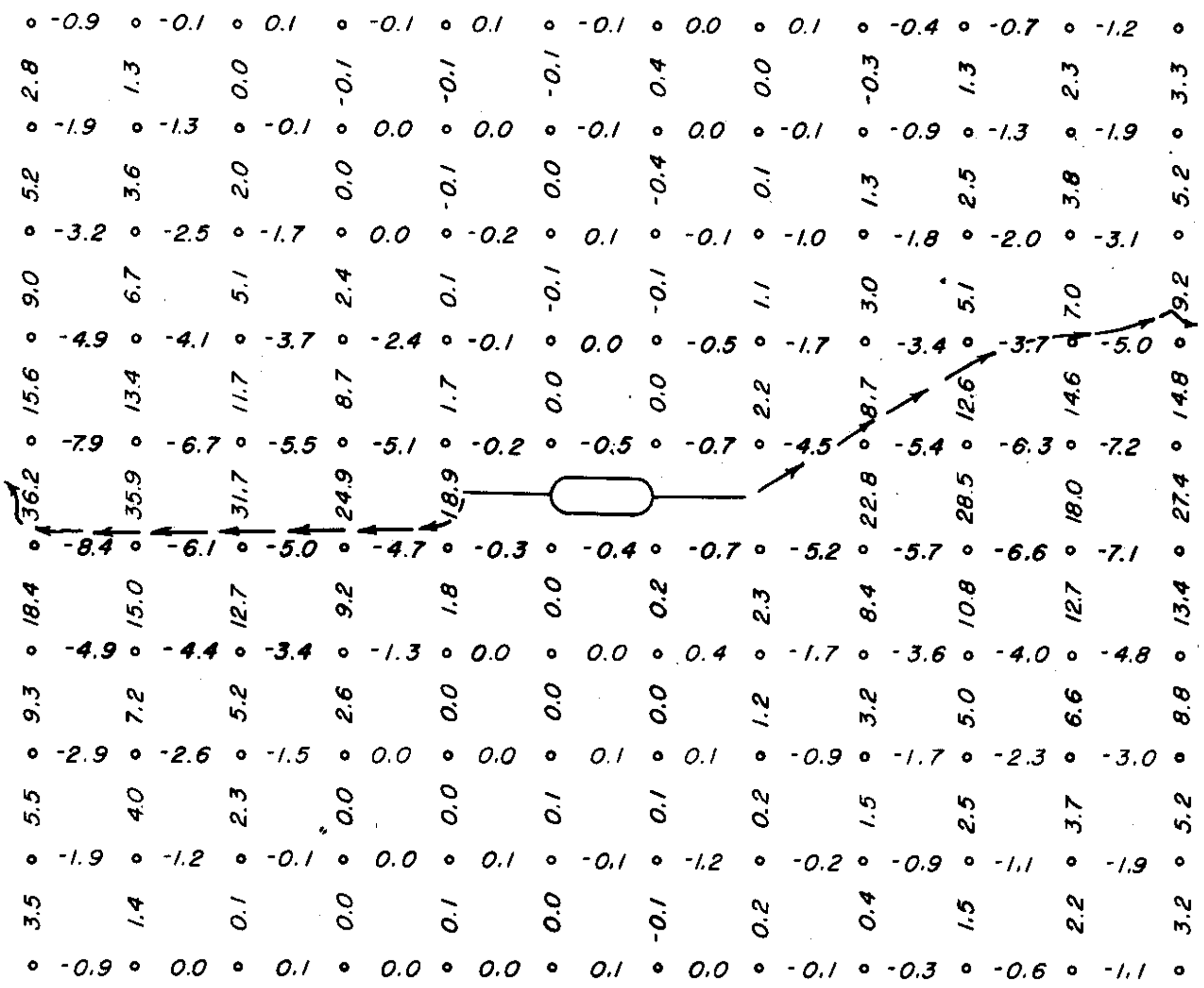
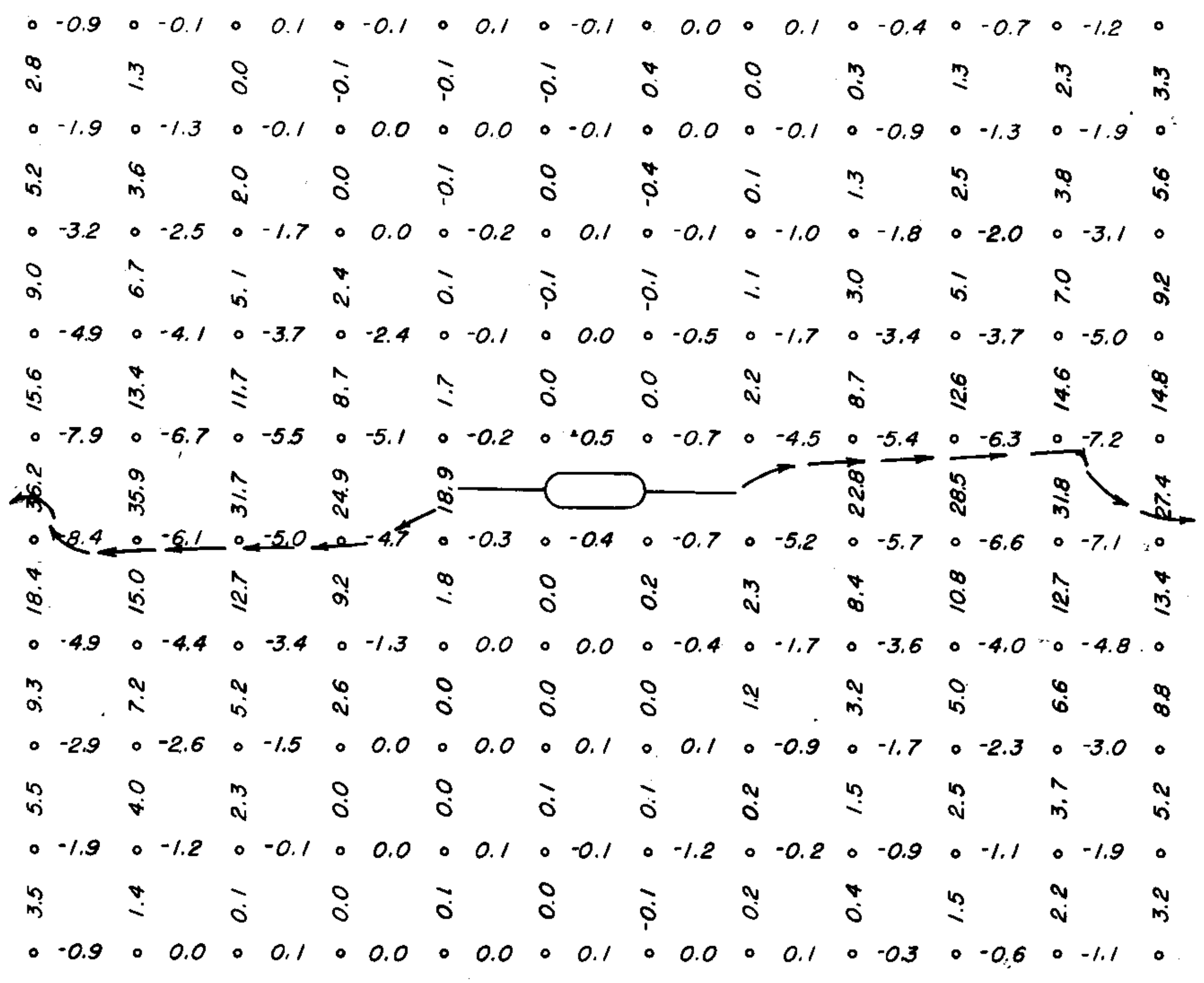


FIG. A-58 PERCENT ELONGATION PLATE C-5D (1 INCH GRID)

"C" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 54.7 KSI

TEMPERATURE 141-148°F 91% SHEAR

DWG. 44E122



○	-0.9	○	-0.1	○	0.1	○	-0.1	○	0.1	○	-0.1	○	0.0	○	0.1	○	-0.4	○	-0.7	○	-1.2	○
2.8		1.3		0.0		-0.1		-0.1		-0.1		0.4		0.0		0.3		1.3		2.3		3.3
○	-1.9	○	-1.3	○	-0.1	○	0.0	○	0.0	○	-0.1	○	0.0	○	-0.1	○	-0.9	○	-1.3	○	-1.9	○
5.2		3.6		2.0		0.0		-0.1		0.0		-0.4		0.1		1.3		2.5		3.8		5.6
○	-3.2	○	-2.5	○	-1.7	○	0.0	○	-0.2	○	0.1	○	-0.1	○	-1.0	○	-1.8	○	-2.0	○	-3.1	○
9.0		6.7		5.1		2.4		0.1		-0.1		-0.1		1.1		3.0		5.1		7.0		9.2
○	-4.9	○	-4.1	○	-3.7	○	-2.4	○	-0.1	○	0.0	○	-0.5	○	-1.7	○	-3.4	○	-3.7	○	-5.0	○
15.6		13.4		11.7		8.7		1.7		0.0		0.0		2.2		8.7		12.6		14.6		14.8
○	-7.9	○	-6.7	○	-5.5	○	-5.1	○	-0.2	○	-0.5	○	-0.7	○	-4.5	○	-5.4	○	-6.3	○	-7.2	○
36.2		35.9		31.7		24.9		18.9								22.8		28.5		31.8		27.4
○	-8.4	○	-6.1	○	-5.0	○	-4.7	○	-0.3	○	-0.4	○	-0.7	○	-5.2	○	-5.7	○	-6.6	○	-7.1	○
18.4		15.0		12.7		9.2		1.8		0.0		0.2		2.3		8.4		10.8		12.7		13.4
○	-4.9	○	-4.4	○	-3.4	○	-1.3	○	0.0	○	0.0	○	-0.4	○	-1.7	○	-3.6	○	-4.0	○	-4.8	○
9.3		7.2		5.2		2.6		0.0		0.0		0.0		1.2		3.2		5.0		6.6		8.8
○	-2.9	○	-2.6	○	-1.5	○	0.0	○	0.0	○	0.1	○	0.1	○	-0.9	○	-1.7	○	-2.3	○	-3.0	○
5.5		4.0		2.3		0.0		0.0		0.1		0.1		0.2		1.5		2.5		3.7		5.2
○	-1.9	○	-1.2	○	-0.1	○	0.0	○	0.1	○	-0.1	○	-1.2	○	-0.2	○	-0.9	○	-1.1	○	-1.9	○
3.5		1.4		0.1		0.0		0.1		0.0		-0.1		0.2		0.4		1.5		2.2		3.2
○	-0.9	○	0.0	○	0.1	○	0.0	○	0.0	○	0.1	○	0.0	○	0.1	○	-0.3	○	-0.6	○	-1.1	○

FIG. A-59 PERCENT ELONGATION PLATE N-ID (1-INCH GRID)

"N" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 69.3 K.S.I.

TEMPERATURE (-29)-(-30)°F 84 % SHEAR

DWG. 44E123

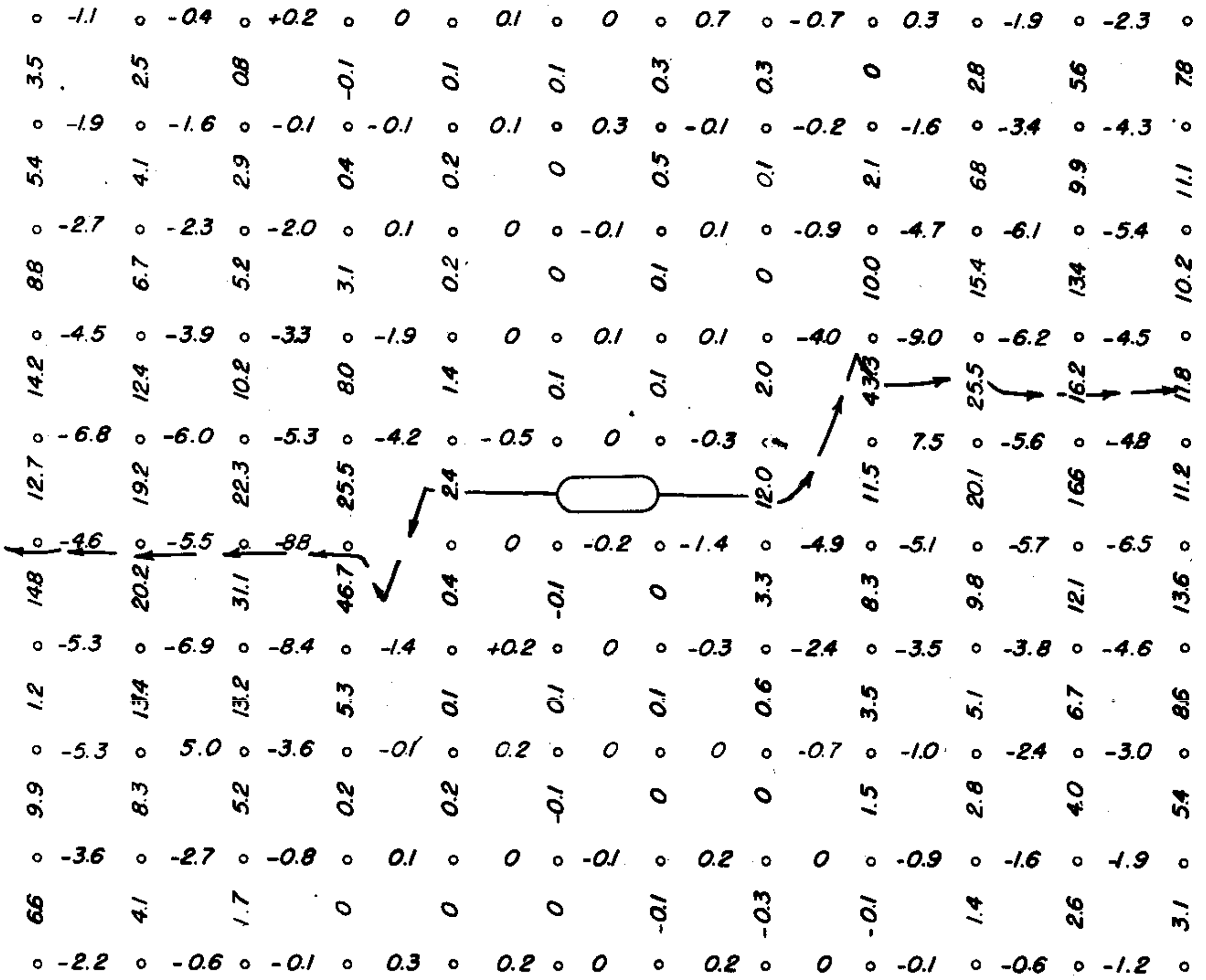


FIG. A-60 PERCENT ELONGATION PLATE N-2D (1 INCH GRID)

"N" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 75.9 KSI

TEMPERATURE (-65)-(-61)° F 6 % SHEAR

DWG. 44E124

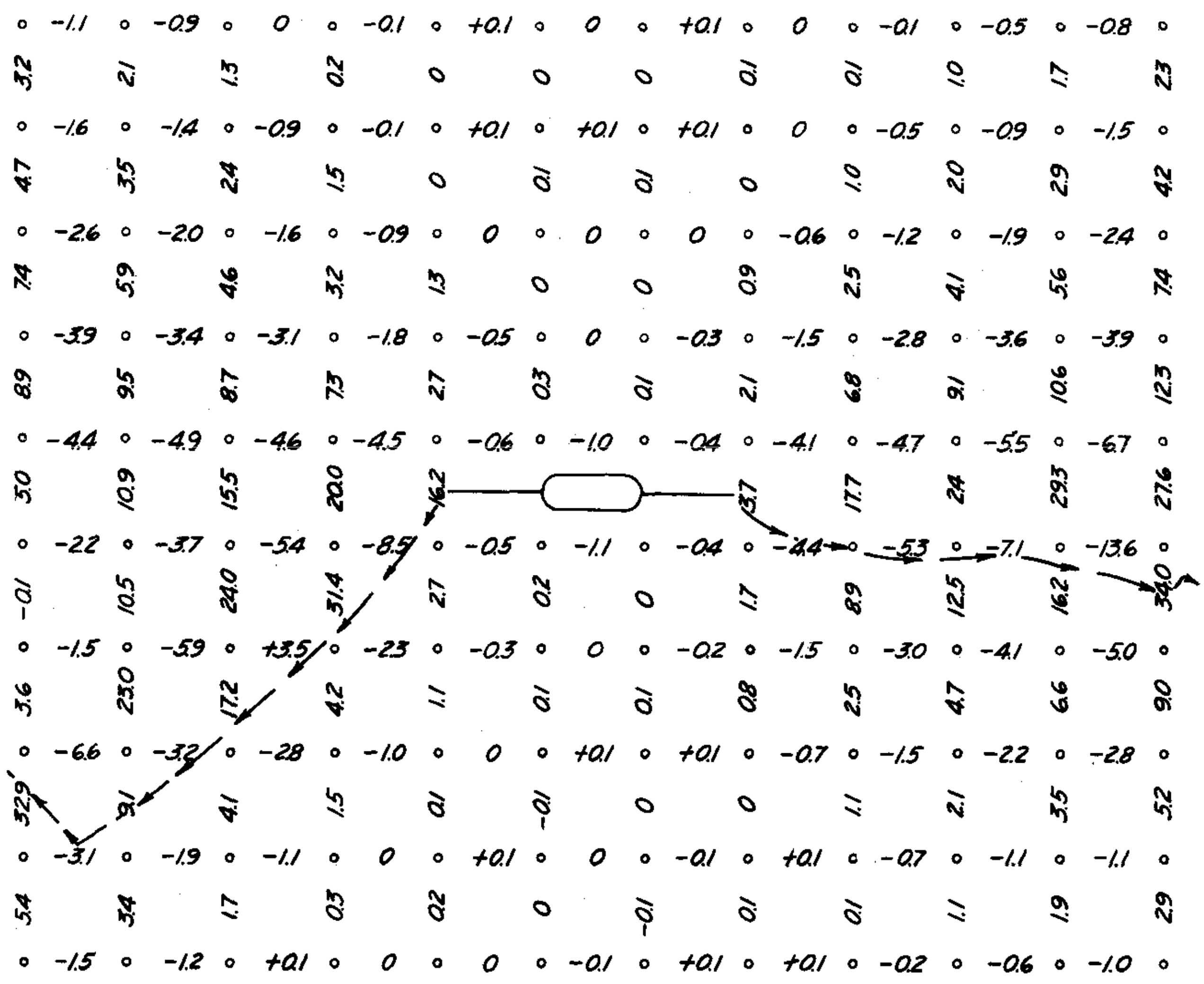


FIG. A-61 PERCENT ELONGATION PLATE N-3D (1-INCH GRID)

"N" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 66.4 KSI

TEMPERATURE 72–73° F 100% SHEAR

DWG. 44E125

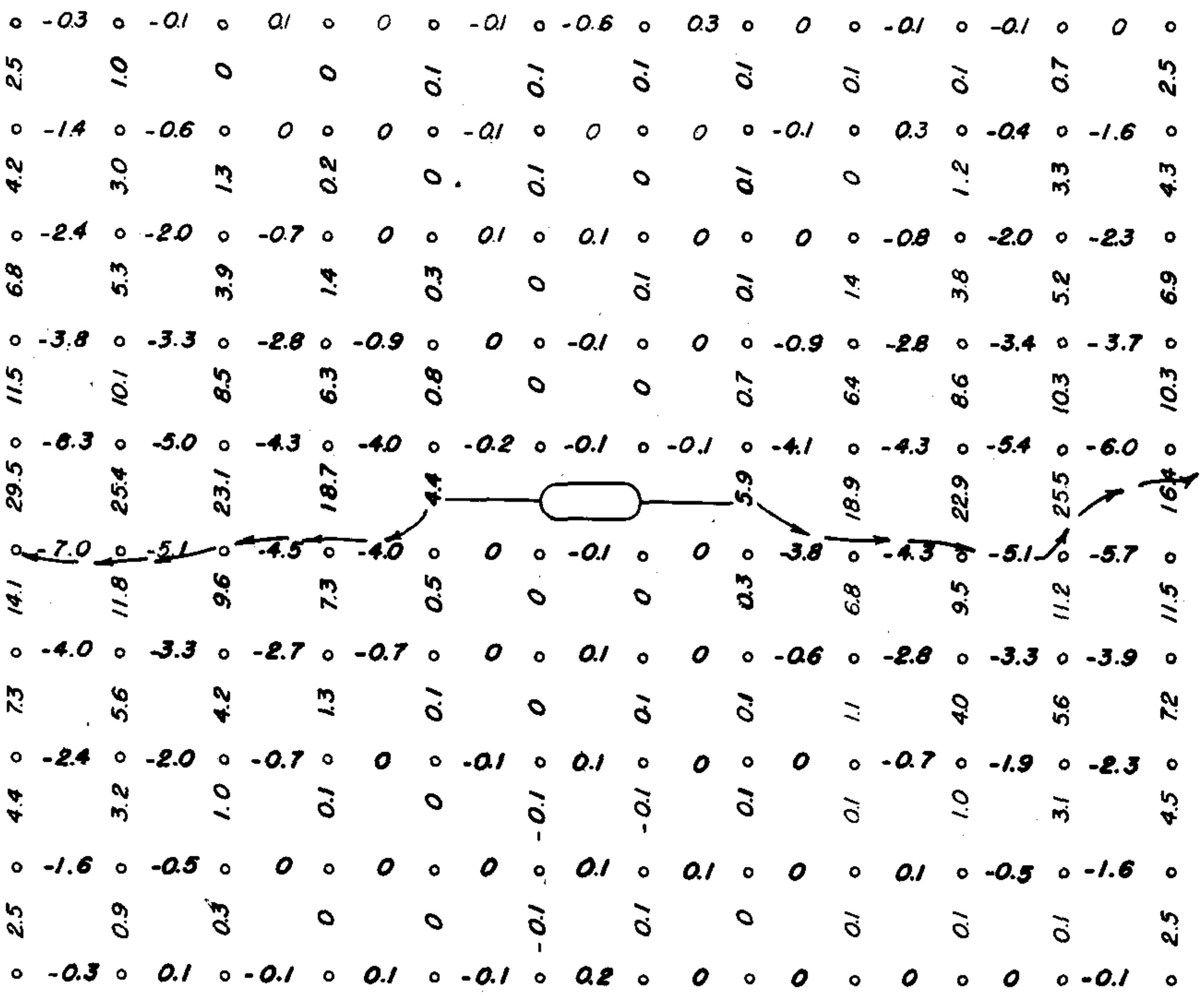


FIG. A-62 PERCENT ELONGATION PLATE N-4D (1-INCH GRID)

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

TEMPERATURE (-37)-(-32)°F 100% SHEAR

DWG. 44E126

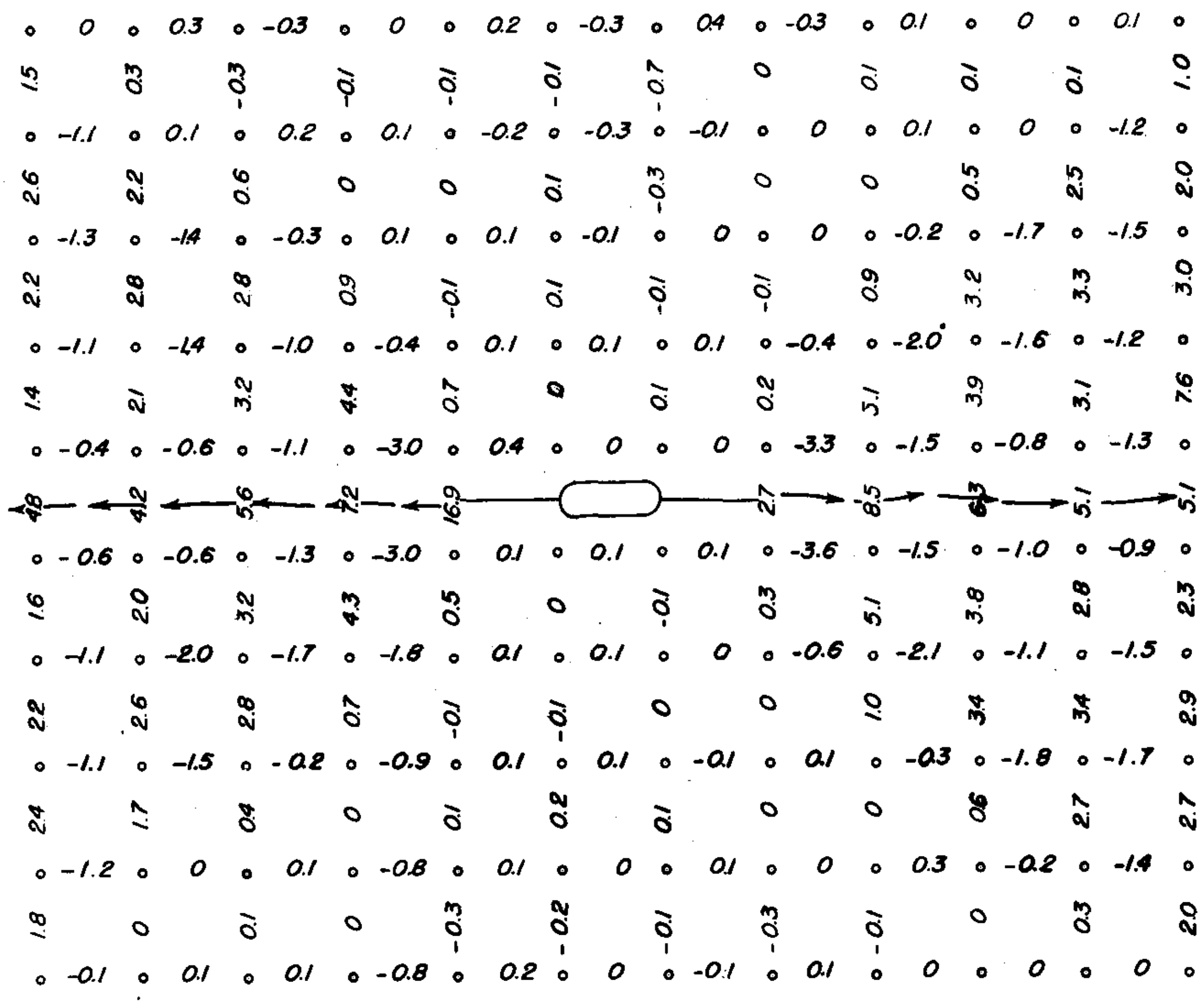


FIG. A-63 PERCENT ELONGATION PLATE N-4XD (1-INCH GRID)

"N" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 68.9KSI

TEMPERATURE -79°F 0% SHEAR

DWG. 44E127

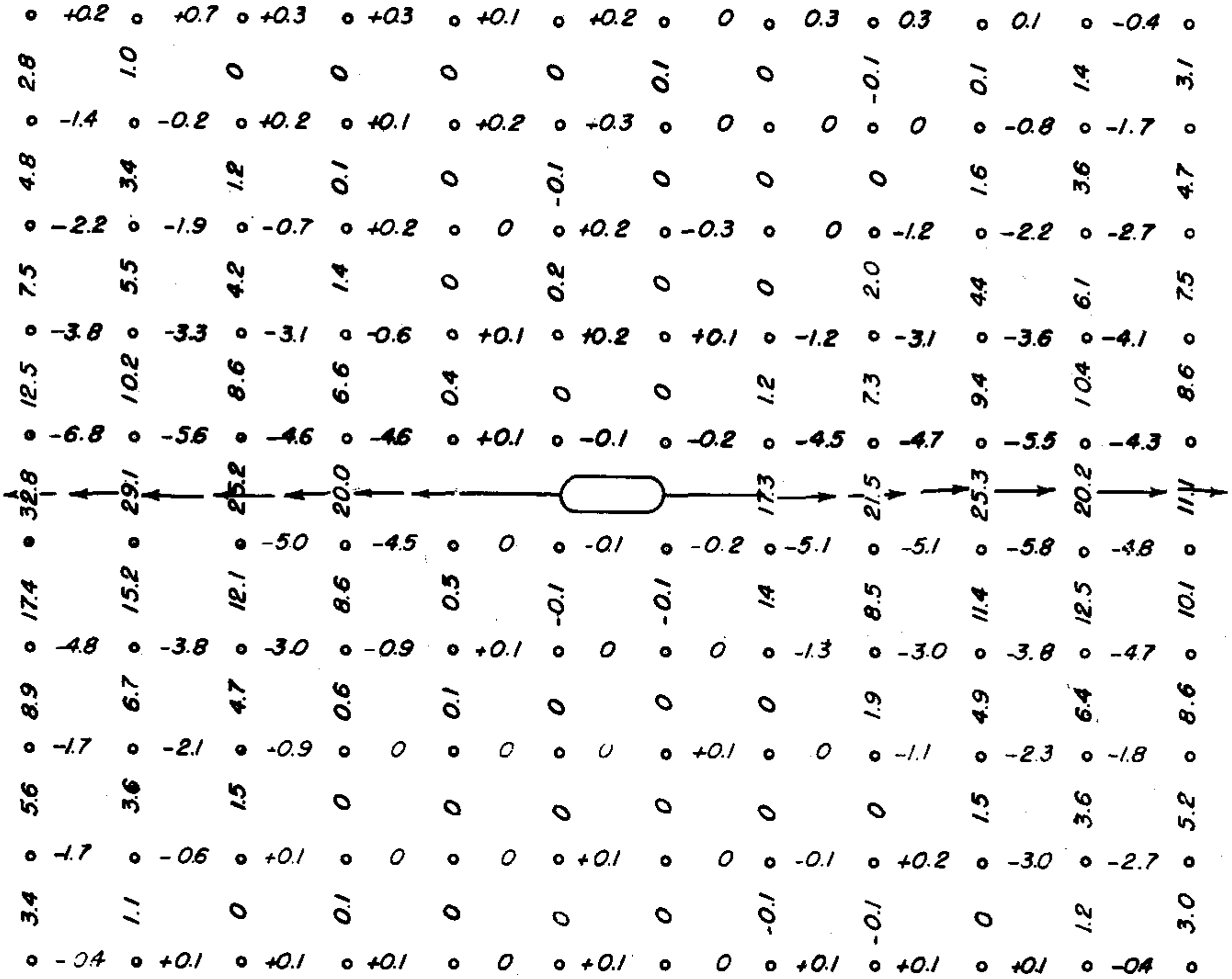


FIG. A-64 PERCENT ELONGATION PLATE N41XD (1-INCH GRID)

"N" STEEL, 12-INCH WIDE PLATE NOMINAL STRENGTH 69.9 KSI

TEMPERATURE (49)-(44)°F 80% SHEAR

DWG. 44E128

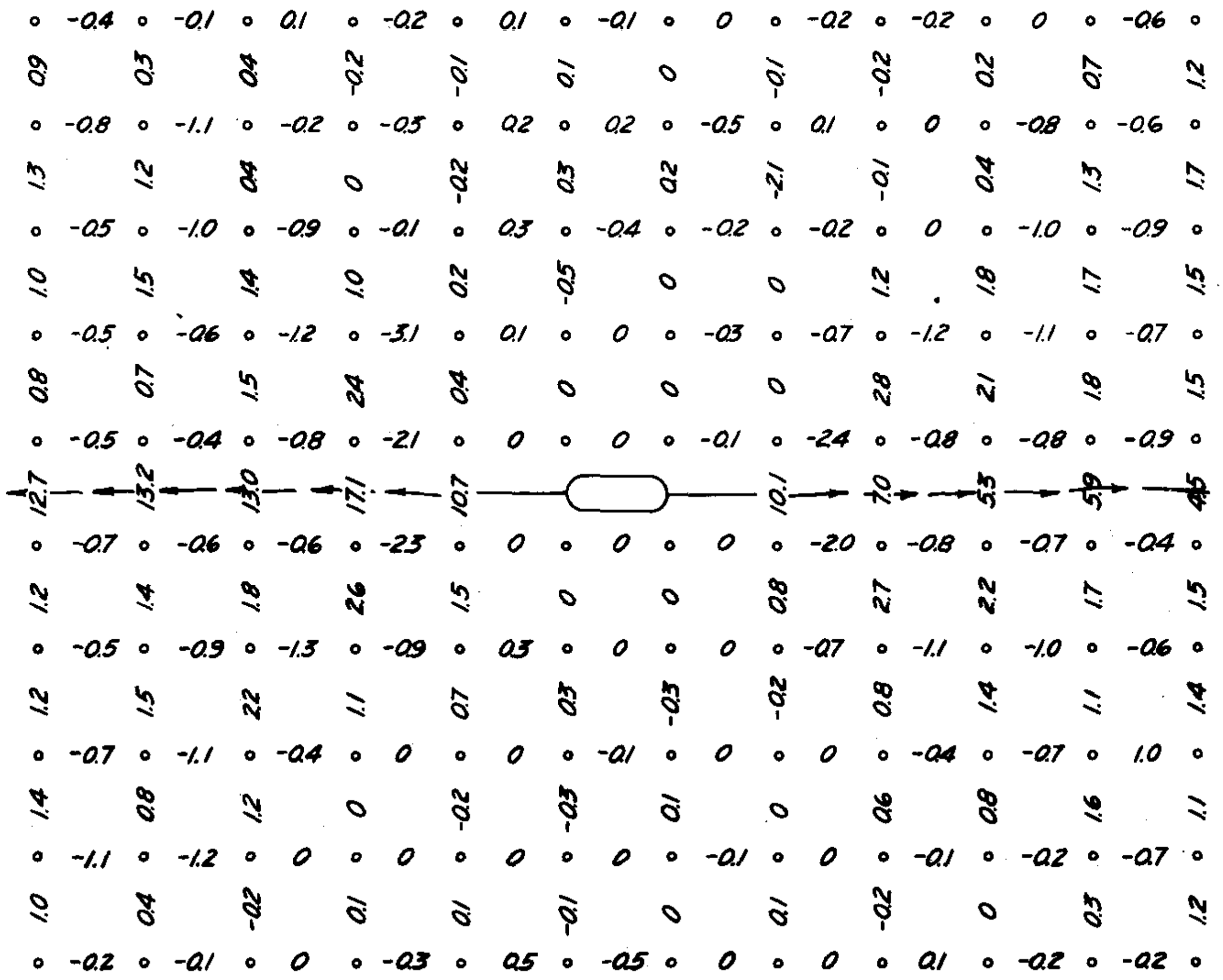
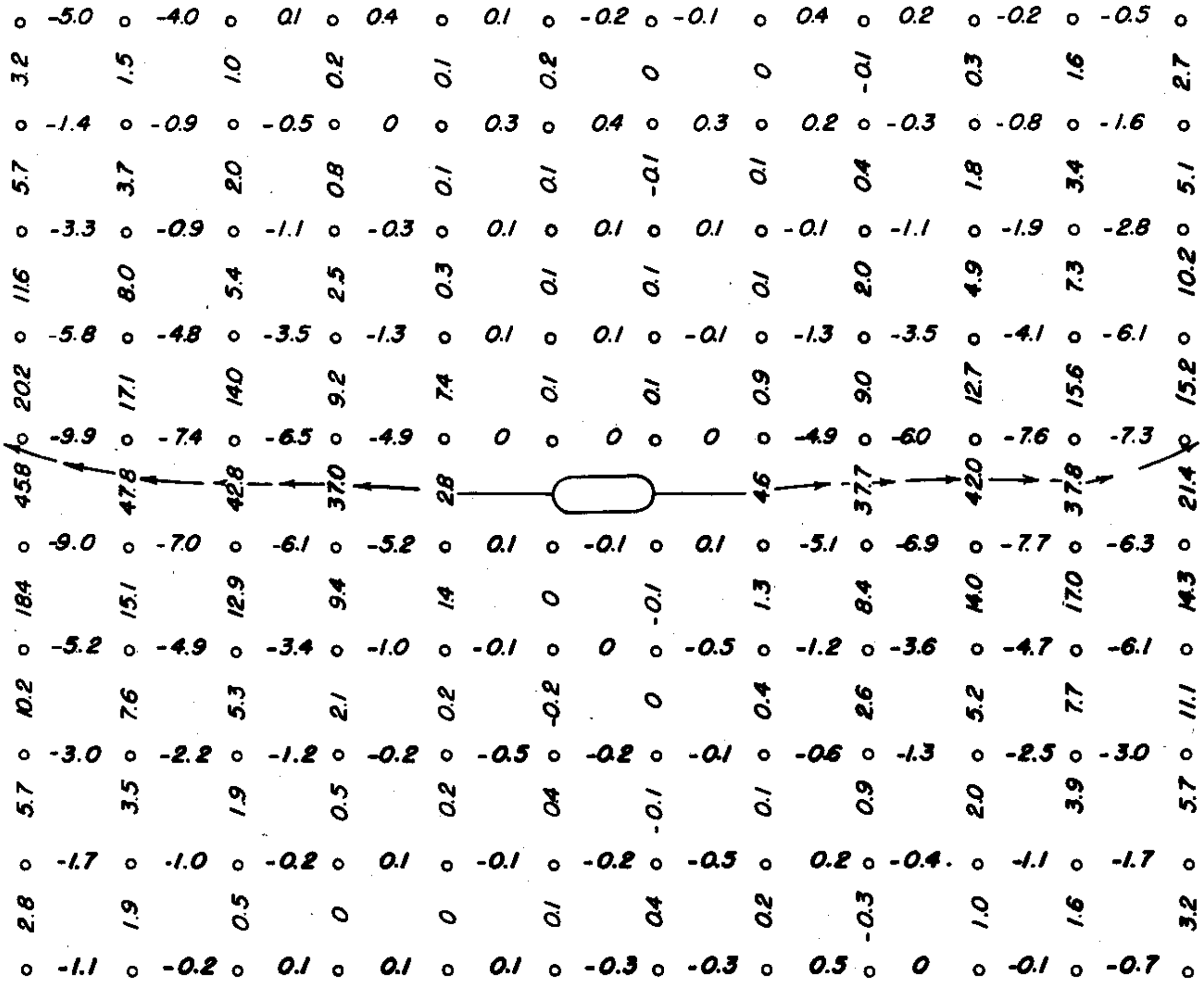


FIG. A-65 PERCENT ELONGATION PLATE Q-1D (1- INCH GRID)

"Q" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 57.3 KSI

TEMPERATURE 70-71° F 0 % SHEAR



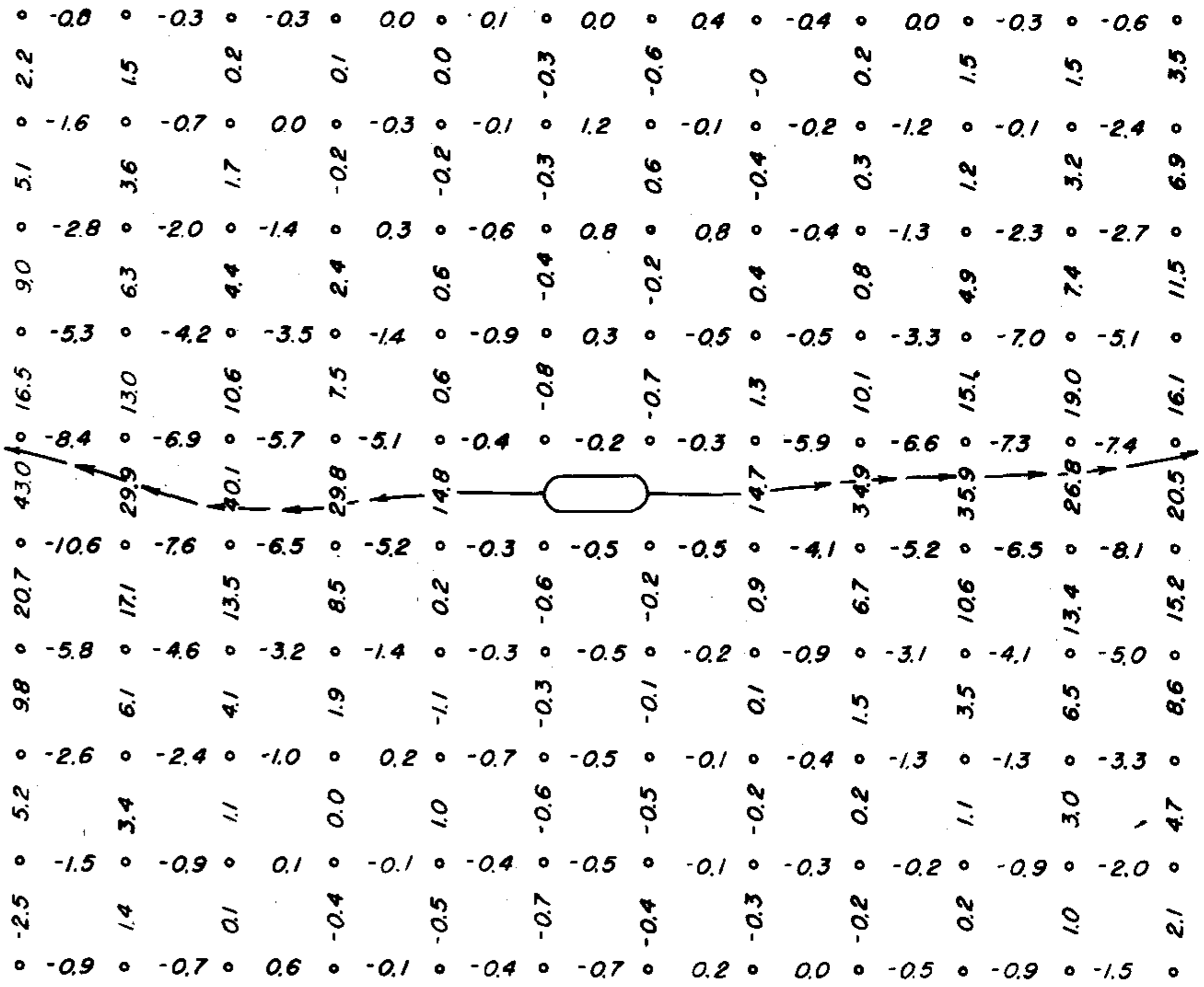
o	-5.0	o	-4.0	o	0.1	o	0.4	o	0.1	o	-0.2	o	-0.1	o	0.4	o	0.2	o	-0.2	o	-0.5	o
3.2		1.5		1.0		0.2		0.1		0.2		0		0		-0.1		0.3		1.6		2.7
o	-1.4	o	-0.9	o	-0.5	o	0	o	0.3	o	0.4	o	0.3	o	0.2	o	-0.3	o	-0.8	o	-1.6	o
5.7		3.7		2.0		0.8		0.1		0.1		-0.1		0.1		0.4		1.8		3.4		5.1
o	-3.3	o	-0.9	o	-1.1	o	-0.3	o	0.1	o	0.1	o	0.1	o	-0.1	o	-1.1	o	-1.9	o	-2.8	o
11.6		8.0		5.4		2.5		0.3		0.1		0.1		0.1		2.0		4.9		7.3		10.2
o	-5.8	o	-4.8	o	-3.5	o	-1.3	o	0.1	o	0.1	o	-0.1	o	-1.3	o	-3.5	o	-4.1	o	-6.1	o
20.2		17.1		14.0		9.2		7.4		0.1		0.1		0.9		9.0		12.7		15.6		15.2
o	-9.9	o	-7.4	o	-6.5	o	-4.9	o	0	o	0	o	0	o	-4.9	o	-6.0	o	-7.6	o	-7.3	o
45.8		47.8		42.8		37.0		2.8						4.6		37.7		42.0		37.8		21.4
o	-9.0	o	-7.0	o	-6.1	o	-5.2	o	0.1	o	-0.1	o	0.1	o	-5.1	o	-6.9	o	-7.7	o	-6.3	o
18.4		15.1		12.9		9.4		1.4		0		-0.1		1.3		8.4		14.0		17.0		14.3
o	-5.2	o	-4.9	o	-3.4	o	-1.0	o	-0.1	o	0	o	-0.5	o	-1.2	o	-3.6	o	-4.7	o	-6.1	o
10.2		7.6		5.3		2.1		0.2		-0.2		0		0.4		2.6		5.2		7.7		11.1
o	-3.0	o	-2.2	o	-1.2	o	-0.2	o	-0.5	o	-0.2	o	-0.1	o	-0.6	o	-1.3	o	-2.5	o	-3.0	o
5.7		3.5		1.9		0.5		0.2		0.4		-0.1		0.1		0.9		2.0		3.9		5.7
o	-1.7	o	-1.0	o	-0.2	o	0.1	o	-0.1	o	-0.2	o	-0.5	o	0.2	o	-0.4	o	-1.1	o	-1.7	o
2.8		1.9		0.5		0		0		0.1		0.4		0.2		-0.3		1.0		1.6		3.2
o	-1.1	o	-0.2	o	0.1	o	0.1	o	0.1	o	-0.3	o	-0.3	o	0.5	o	0	o	-0.1	o	-0.7	o

FIG. A-66 PERCENT ELONGATION PLATE Q-2D(I-INCH GRID)

"Q" STEEL, 12 INCH WIDE PLATE NOMINAL STRENGTH 61.0 KSI

TEMPERATURE 134-154°F 100% SHEAR

DWG. 44F130



∘	-0.8	∘	-0.3	∘	-0.3	∘	0.0	∘	0.1	∘	0.0	∘	0.4	∘	-0.4	∘	0.0	∘	-0.3	∘	-0.6	∘
2.2		1.5		0.2		0.1		0.0		-0.3		-0.6		-0		0.2		1.5		1.5		3.5
∘	-1.6	∘	-0.7	∘	0.0	∘	-0.3	∘	-0.1	∘	1.2	∘	-0.1	∘	-0.2	∘	-1.2	∘	-0.1	∘	-2.4	∘
5.1		3.6		1.7		-0.2		-0.2		-0.3		0.6		-0.4		0.3		1.2		3.2		6.9
∘	-2.8	∘	-2.0	∘	-1.4	∘	0.3	∘	-0.6	∘	0.8	∘	0.8	∘	-0.4	∘	-1.3	∘	-2.3	∘	-2.7	∘
9.0		6.3		4.4		2.4		0.6		-0.4		-0.2		0.4		0.8		4.9		7.4		11.5
∘	-5.3	∘	-4.2	∘	-3.5	∘	-1.4	∘	-0.9	∘	0.3	∘	-0.5	∘	-0.5	∘	-3.3	∘	-7.0	∘	-5.1	∘
16.5		13.0		10.6		7.5		0.6		-0.8		-0.7		1.3		10.1		15.1		19.0		16.1
∘	-8.4	∘	-6.9	∘	-5.7	∘	-5.1	∘	-0.4	∘	-0.2	∘	-0.3	∘	-5.9	∘	-6.6	∘	-7.3	∘	-7.4	∘
43.0		29.9		30.1		29.8		14.8						14.7		34.9		35.9		26.8		20.5
∘	-10.6	∘	-7.6	∘	-6.5	∘	-5.2	∘	-0.3	∘	-0.5	∘	-0.5	∘	-4.1	∘	-5.2	∘	-6.5	∘	-8.1	∘
20.7		17.1		13.5		8.5		0.2		-0.6		-0.2		0.9		6.7		10.6		13.4		15.2
∘	-5.8	∘	-4.6	∘	-3.2	∘	-1.4	∘	-0.3	∘	-0.5	∘	-0.2	∘	-0.9	∘	-3.1	∘	-4.1	∘	-5.0	∘
9.8		6.1		4.1		1.9		-1.1		-0.3		-0.1		0.1		1.5		3.5		6.5		8.6
∘	-2.6	∘	-2.4	∘	-1.0	∘	0.2	∘	-0.7	∘	-0.5	∘	-0.1	∘	-0.4	∘	-1.3	∘	-1.3	∘	-3.3	∘
5.2		3.4		1.1		0.0		1.0		-0.6		-0.5		-0.2		0.2		1.1		3.0		4.7
∘	-1.5	∘	-0.9	∘	0.1	∘	-0.1	∘	-0.4	∘	-0.5	∘	-0.1	∘	-0.3	∘	-0.2	∘	-0.9	∘	-2.0	∘
-2.5		1.4		0.1		-0.4		-0.5		-0.7		-0.4		-0.3		-0.2		0.2		1.0		2.1
∘	-0.9	∘	-0.7	∘	0.6	∘	-0.1	∘	-0.4	∘	-0.7	∘	0.2	∘	0.0	∘	-0.5	∘	-0.9	∘	-1.5	∘

FIG. A-67 PERCENT ELONGATION PLATE Q-12XD (1-INCH GRID)

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

TEMPERATURE 56-59°F 100% SHEAR

DWG 44E131