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PROGRESS REPORT

ON

PART I - TWELVE INCH FLAT PLATE TESTS
PART II - ASPECT RATIO PROGRAM

BY

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SWARTHMORE COLLEGE
Under Bureau of Ships Contract NObs-45521

Transmitted through
NATIONAL RESEARCH COUNCIL'S

COMMITTEE ON SHIP STEEL
Advisory to

SHIP STRUCTURE COMMITTEE
under

Bureau of Ships, Navy Department
Contract NObs-50148

Division of Engineering and Industrial Research
National Research Council
Washington, D. C.
December 15, 1949

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2101 CONSTITUTION AVENUE, WASHINGTON 25, D. C.

COMMITTEE ON SHIP STEEL
OF THE
DIVISION OF ENGINEERING AND INDUSTRIAL RESEARCH

December 15, 1949

Chief, Bureau of Ships
Code 343
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Washington 25, D. C.

Dear Sir:

Attached is Report Serial No. SSC-35 entitled "Twelve Inch Flat Plate Tests." This report has been submitted by the contractor as a Progress Report of the work done on Research Project SR-98 under Contract NObs-45521 between the Bureau of Ships, Navy Department and Swarthmore College.

The report has been reviewed and acceptance recommended by representatives of the Committee on Ship Steel, 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,

Robert F. Mehl

R. F. Mehl, Chairman
Committee on Ship Steel

RFM:mh

PREFACE

The Navy Department through the Bureau of Ships is distributing this report for the SHIP STRUCTURE COMMITTEE to those agencies and individuals who were actively associated with the research work. This report represents results of part of the research program conducted under the Ship Structure Committee's directive "to investigate the design and methods of construction of welded steel merchant vessels."

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PROGRESS REPORT

NAVY BUSHIPS CONTRACT NOBS-45521

PROJECT SR-98

PART I

TWELVE INCH FLAT PLATE TESTS

PART II

ASPECT RATIO PROGRAM

FROM: DIVISION OF ENGINEERING
SWARTHMORE COLLEGE
SWARTHMORE, PA.

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TABLE OF CONTENTS

ABSTRACT

Part I of this report states the test results for the following steels: "W", S-9, S-12, and S-22. The tests of Part I are tension tests run at various temperatures on specimens 24" long, 12" wide and 3/4" thick, having a central internal notch one-quarter of the width of the plate with ends of the notch 0.010 inch wide made by a jeweler's hack-saw. The load was applied in the direction of rolling. The report contains tables giving the load at first visible crack, at maximum load, and at the failure load, together with the energies computed to these loads. Load elongation curves for each specimen tested are included, together with diagrams showing maximum load, vs. temperature and diagrams showing energy to maximum load vs. temperature. The character of the fracture as determined by the percentage of shear failure is also given.

The transition temperature zones of these steels on the basis of both energy considerations and the mode of the fracture are reported.

Part II of this report describes the aspect ratio program now under way to determine the effect of plate width and thickness on transition temperature.

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

Appendix A (Load Elongation Curves)

PROGRESS REPORT

on

Tension Tests of Flat Internally-Notched Plates

PART I

TWELVE INCH FLAT PLATE TESTS

The results presented in Part I represent a continuation of the investigation of 12" wide full-thickness specimens of steel plate tested with temperature as a variable. Each specimen contained a centrally located internal notch 3" wide terminating with a jeweler's hack-saw cut 1/8" long and 0.010" wide. (See Fig. 1). All tests were made with tension loading applied in the direction of rolling. The techniques employed in carrying out these tests have been reported in a previous paper[1]*.

The physical behavior of the steels with respect to maximum loads, strain energy and mode of fracture was investigated with the principal purpose of establishing transition temperatures based upon 24" long and 12" wide by 3/4" thick specimens.

The steels tested and reported are designated as "W", "S-9", "S-12" and "S-22".

The chemical analysis of these steels is as follows:

Chemical Analysis[2]

Code	C	Mn	Si	Al.	N.	Practice
W	.21	.52	.23	.006	.005	Fully-killed
S-9	.18	.50	.07	.002	.004	Semi-killed
S-12	.19	.77	.07	.04	.004	Semi-killed, fine grained
S-22	.19	.77	.09	.006	.004	" " coarse "

*Numerals refer to reference in Bibliography

S-9 is an A.S.T.M.-A7-46 steel. It is to be noted that S-12 and S-22 which are nominally ABS Class B steels are from the same heat.

Results of tensile tests of these steels are as follows:

Tensile Tests[2]

Code	Yield Point (P.S.I.)	Ultimate P.S.I.	% Elongation in 8"
W	37,230	62,540	30.3
S-9	32,600	57,900	34.5
S-12	34,700	64,100	28.0
S-22	35,000	63,800	32.0

Specimen Identification

The locations of the specimens in the plate are shown on the figures giving load and energy data for each steel. The specimen marked S-12-8 identifies specimen No. 8 from the plate of S-12 steel. A similar notation is used for the S-9 and S-22 steels.

The notation for the specimens of "W" steel is similar except that W-32-8 identifies specimen No. 8, from plate No. 32 of "W" steel.

INSTRUMENTATION

Elongation Measurement: To determine strain energy it was necessary to measure the elongation of the test specimens. The gage length was established as three-quarters of the width of the plate, or 9", with the ends of the gage length 4½" above and below the notch. The instrument developed permitted a determination of the elongations of the plate in both the elastic and plastic range. Bakelite SR-4 gages are used in these instruments. The elongations were measured over twelve separate gage lines. Five of the gage lines were on each of the 12" faces of the plate and two of the gage lines were on the edges. The five gage lines on the face of the plate were located as follows: one at the longitudinal centerline of plate, two 1½" either side of the centerline, and two 3 3/4" either side of the centerline. The elongation for each gage line was determined separately.

Preparation of Notch: Careful attention was given to the preparation of the notch. The accepted procedure at all laboratories where wide full-thickness plate tests have been made has been to use a jeweler's hack-saw to establish the acuity of the notch. To provide uniform acuity, the width of the last 1/8 of an inch of the notch on both sides of the internal notch was specified to be 0.010 inch. A jig-saw was utilized to make the jeweler's hack-saw cut.

Temperature Control Chamber: The temperature control chamber was made of Plexiglas, so that the specimen and instruments would be visible at all stages of the test. Strip heaters were installed to give temperatures above that of the laboratory. Cooling was obtained by blowing air over dry ice and conducting this cool air to the Plexiglas box by insulated ducts.

Measurement of Temperature: The temperature was determined by the use of thermocouples. Three thermocouples are mounted on each specimen, one in the 3/4" drill hole in the center of the plate, one 5½" above the notch in the center of the plate, and the third one located 1/8" from the end of the notch immediately above the junction of the standard and jeweler's hack-saw cuts. A fourth thermocouple determined the ambient temperature within the box.

The temperature at the 3/4" drill hole has been used in interpreting all tests.

LOAD ELONGATION CURVES

The load elongation curves for each specimen are shown in Appendix "A".

The elongation used is the average of all twelve gages over the established nine inch gage length.

The areas under the load elongation curve represent total strain energy. The strain energy absorbed by the specimen to the first visible crack is designated as "E". The strain energy to maximum load and to failure are designated as E_1 and E_2 respectively. E_2-E_1 represents the strain energy necessary to propagate the fracture after the maximum load.

RESULTS

"W" Steel

Fig. 2 shows the fracture surfaces for all specimens of the "W" steel. Table I gives the load, at and the energy in inch pounds to, the first visible crack, maximum load, and failure. It also gives the temperature and type of failure in terms of the percentage of shear failure within the 9" net width. Fig. 3 shows the maximum load plotted as ordinates with temperature as abscissas. In Fig. 4 the energy to maximum load is plotted as the ordinate with temperature as the abscissa, and Fig. 5 is a plot of the percentage of shear failure in the various specimens of "W" steel.

The transition temperature based upon the energy to maximum load lies in a temperature zone between 40 and 60°F. Based upon the appearance of the fracture, the transition temperature would lie close to 50°F.

S-9 Steel

The fracture surfaces of the specimens of S-9 steel are shown in Fig. 6. Table II records the energy in inch pounds to the first visible crack, to maximum load, and to failure. It also gives the type of fracture in terms of percent of shear. Fig. 7 is a plot of maximum load vs. temperature. Fig. 8 represents energy to maximum load vs. temperature, and Fig. 9 is a plot of percent shear vs. temperature.

The maximum loads observed for cleavage specimens are on an average about 50,000 pounds less than for a ductile specimen. A consideration of the energy to maximum load would place the transition temperature in a zone of from 50 to 75°F. The character of the fracture as determined by the percent of shear indicates the same transition temperature zone.

S-12 Steel

The fracture surfaces of the S-12 specimens are shown in Fig. 10. Table III, which gives the load at, and energy in inch pounds to, the first visible crack, maximum load, and failure, also gives the type of failure in terms of the percent of shear. Fig. 11 shows the maximum loads as ordinates with temperature as abscissa. Fig. 12 is a plot of the energy to maximum load vs. temperature. Fig. 13 represents the plot of the percent of shear failure vs. temperature.

It is to be noted that with the exception of specimen No. 7, the maximum load is quite uniform throughout the entire temperature range. Fig. 12 showing energy to maximum load vs. temperature does not provide a good criterion for the establishment of the transition temperature zone, since the energy level for cleavage specimens remains nearly as high as for a completely ductile specimen. It is to be noted that of all the specimens tested, only specimen No. 7 represented a complete cleavage failure. Insufficient specimens prevented the temperature range being lowered to procure a number of specimens in complete cleavage. A consideration of energy to maximum load does not permit a positive statement regarding the transition temperature. The transition temperature as determined from the appearance of the fracture is fairly definite and indicates that the transition temperature may be between 10 and 30°F. The total energy to failure would indicate the transition temperature as being between 10 and 20°F.

The cleavage fractures for the S-12 steels are extremely rough and ragged, showing a pronounced chevron pattern. This is a departure from the general cleavage surface noted for other steels tested in this laboratory. The ductile specimens show a trace of fissuring at mid-thickness. Hence, the S-12 steel shows two essential departures from the norm, namely, that the energy to maximum load for either the ductile or cleavage failures is essentially the same, and that the cleavage surface is more irregular.

The S-12 steel and the S-22 steel reported subsequently may be compared. The difference between S-12 steel and the S-22 steel, which are from the same heat, is one of fine and coarse grained practice, the S-12 being of the fine grained practice.

In passing, it should be stated that the energy to maximum load for the S-22 steel is discretionary and that the appearance of the brittle cleavage fracture represents the normal appearance noted for other steels.

S-22 Steel

The fractures of the S-22 steel are shown in Fig. 14. Table IV gives the load at, and energy in inch pounds to, the first visible crack, maximum load, and failure. It also gives the type of fracture in terms of percentage of shear failure. Fig. 15 shows the maximum loads as ordinates with temperature as abscissas. Fig. 16 represents energy to maximum load vs. temperature. Fig. 17 represents a plot of the percent of shear failure vs. temperature.

The transition temperature zone as determined from energy to maximum load appears to be quite sharply defined and lies between 55 and 60°F. The appearance of the fractures would indicate the transition temperature at about 60°F. These statements concerning transition temperature are based upon a limited number of tests, and must be considered as tentative only.

The maximum load for specimens failing completely in cleavage was about 50,000 lbs. lower than for specimens failing completely in shear.

SUMMARY OF TRANSITION TEMPERATURES

Code	Based on Energy to Max. Load	Based on appearance of fracture as defined by % of shear
W	40 to 60°F	50°F
S-9	50 to 75°F	50 to 75°F
S-12	indefinite	10 to 30°F
S-22	55 to 60°F	60°F

PART II

ASPECT RATIO PROGRAM

The aspect ratio program is a study of the effects of width and thickness, using centrally notched tensile specimens, on energy absorption and transition temperature. The thickness of any specimens is the as-rolled thickness and thicknesses to be investigated are 1/2", 3/4", 1" and 1½". The steel is a semi-killed steel and all thicknesses are rolled from the same heat.

The aspect ratio (AR) is defined as the width of the specimen divided by the thickness of the plate. Fig. 18, showing a typical specimen, explicitly defines this term. In Fig. 18 the notch layout is shown, and it should be particularly noted that the notch terminates with a drill hole instead of a jeweler's hack-saw cut. The diameter of the drill hole is directly proportional to the thickness of the plate and the diameters for particular thicknesses are shown.

Preliminary considerations indicated that geometric similitude should be adhered to in planning the aspect ratio program, and that similitude would necessitate a varying notch radius. Laboratory tests indicated that a drill hole of 3/64" diameter in a plate 3/4" thick would provide a notch acuity sufficiently sharp to give transition temperatures near those already found by using specimens having notches terminating with a jeweler's hack-saw cut.

Specimens with equal aspect ratios are geometrically similar in all respects. They may be dissimilar only in the metallurgical constituancy of the as-rolled plate. To investigate the effect of width of plate with a given as-rolled thickness, the aspect ratio studies extend over a range of from an AR of 4 to an AR of 20.

TENTATIVE PROGRAM

Fig. 19 indicates the scope of the tentative program. Not all of the specimens shown on Fig. 19 are to be tested at this time. An exploratory program consists of the following aspect ratios in the various thicknesses.

Thickness	Aspect Ratios
1/2"	4, 8, 16, 20
3/4"	4, 8, 12, 16
1"	4, 8
1½"	4, 6

In order to utilize a limited amount of steel and to secure information relative to changes due to position of the specimens within the plate, the available steel plates have been laid out as shown on Figs. 20, 21, 22, and 23.

Our testing program at this time has not been in effect long enough to present the results of this program. It is anticipated that in an early Progress Report some of the results of this program can be reported.

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The work has been under the general supervision of S. T. Carpenter, Chairman of the Division of Engineering.

Captain W. P. Roop, USN, (Ret) has acted in the capacity of consultant.

BIBLIOGRAPHY

1. Progress Report on "Twelve Inch Flat Plate Tests", by S. T. Carpenter, W. P. Roop, N. Barr, E. Kasten, and A. Zell. Bureau of Ships Contract NObs-45521, Serial No. SSC-21, April 15, 1949.

2. Unpublished report by Noah A. Kahn and Emil A. Imbembo, "Further Study of Navy Tear Test", (Paper delivered at A.W.S. meeting in Cleveland, October 1949 , to be published in the Welding Journal).

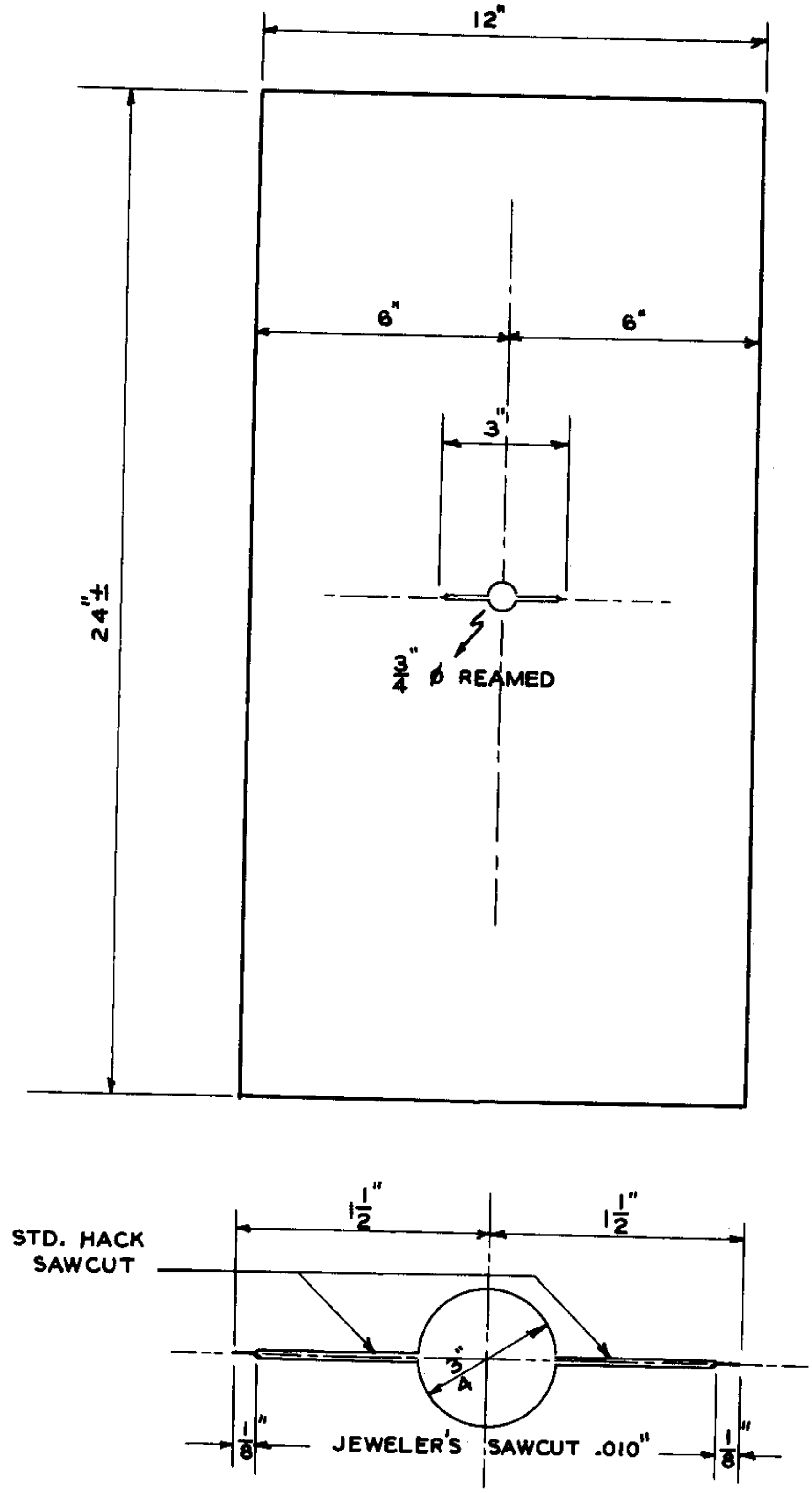


FIG. I
NOTCH LAYOUT
SWARTHMORE COLLEGE

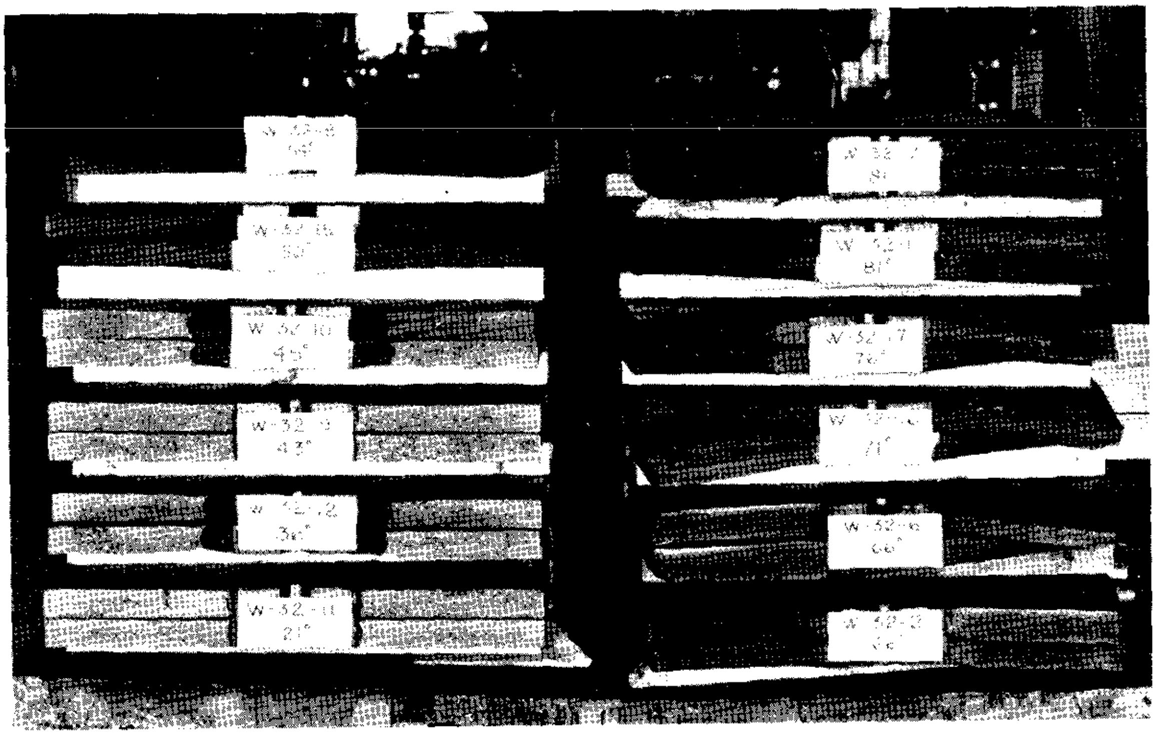


FIG. 2 "W" STEEL

PHOTOGRAPH OF FRACTURE SURFACES

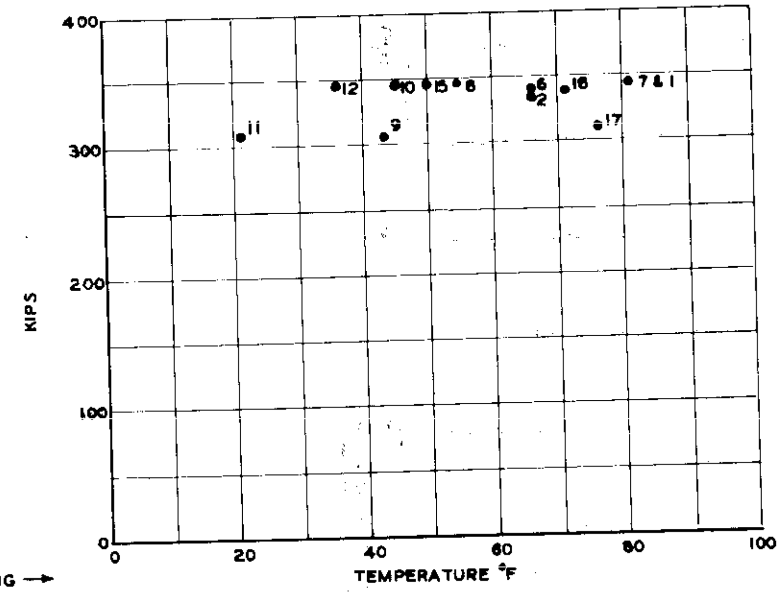
TABLE I

"W" Steel

Test Specimens 12" wide x 3/4" thick, with standard notch

The notch is 3" wide and has at its extremities a cut 1/8" long and 0.010" wide made with a jeweler's hac

Spec. No.	Deg. F	First Visible Energy E in. lbs.	First Crack Load lbs.	To Maximum Load Energy E_1 in. lbs.	To Maximum Load Load lbs.	To Failure Energy E_2 in. lbs.	To Failure Load lbs.	Energy $E_2 - E_1$ in. lbs.	% Shear
W-32-11	21	4,000	257,800	48,000	309,300	48,000	309,300	0	0
W-32-12	36	3,500	253,000	67,500	346,000	71,000	340,600	3,500	22
W-32-9	43	5,300	250,800	40,000	306,000	40,000	306,000	0	0
W-32-10	45	8,700	256,000	120,000	345,700	158,000	330,000	38,000	30
W-32-15	50	5,000	253,600	125,500	345,500	300,200	22,000	174,700	100
W-32-8	54	4,500	257,000	107,500	346,800	292,300	30,500	184,800	100
W-32-2	66	not obtained		93,000	335,000	253,000	150,000	160,000	100
W-32-6	66	3,500	228,300	142,600	340,700	not obtained		---	100
W-33-16	71	25,100	276,500	129,700	338,500	317,000	126,000	187,300	100
W-32-17	76	19,700	260,000	109,700	310,000	244,800	61,000	135,100	100
W-32-1	81	not obtained		102,700	345,000	263,600	71,500	160,900	100
W-32-7	81	8,000	250,000	110,000	342,100	282,500	55,000	172,500	100



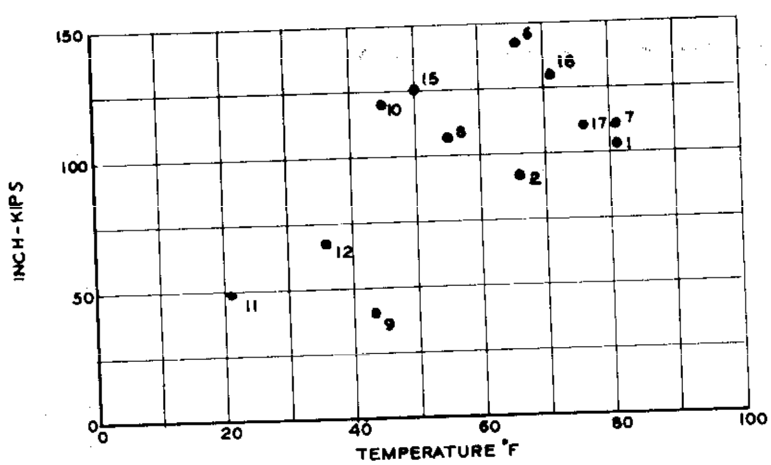
← DIRECTION OF ROLLING →

	1	2	3	4	
	5	6	7	8	
	9	10	11	12	
	13	14	15	16	
	17	18	19	20	

FIG. 3

MAX. LOAD
VS
TEMPERATURE

W-32 STEEL
SWARTHMORE COLLEGE
9-30-49



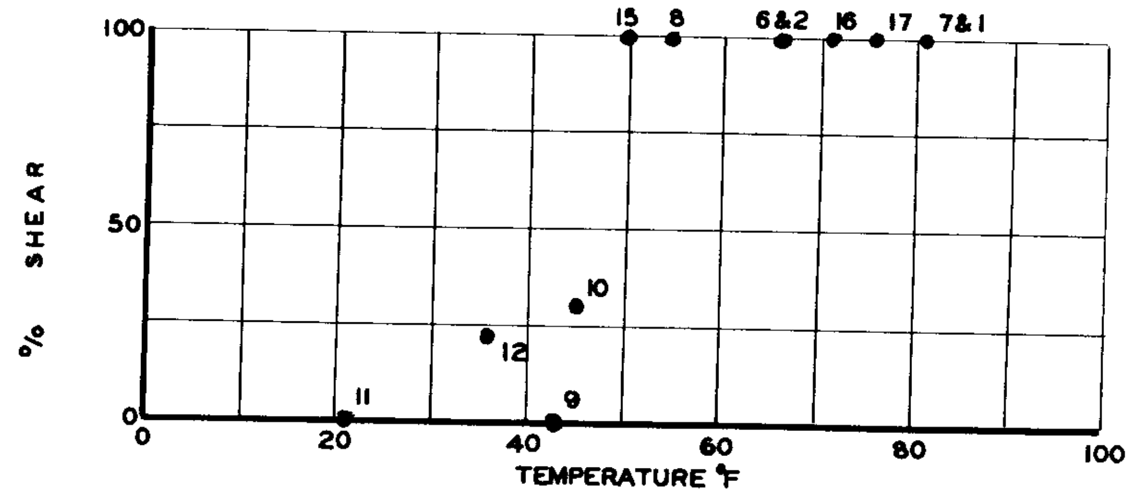
	1	2	3	4	
	5	6	7	8	
	9	10	11	12	
	13	14	15	16	
	17	18	19	20	

← DIRECTION OF ROLLING →

FIG. 4

ENERGY TO
MAX. LOAD
VS
TEMPERATURE

W-32 STEEL
SWARTHMORE COLLEGE
9-30-49



	1	2	3	4	
	5	6	7	8	
	9	10	11	12	
	13	14	15	16	
	17	18	19	20	

← DIRECTION OF ROLLING →

FIG. 5

PERCENTAGE SHEAR VS TEMPERATURE

W-32 STEEL

SWARTHMORE COLLEGE
10-1-49

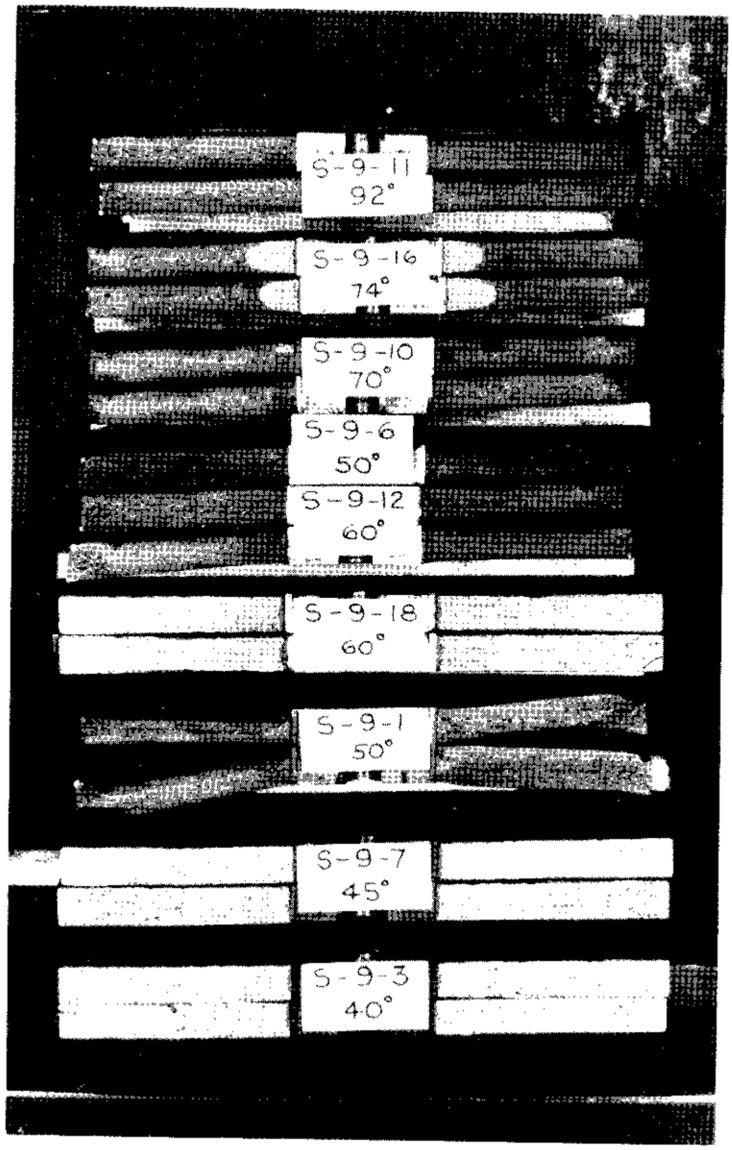


FIG. 6 "S-9" STEEL

PHOTOGRAPH OF FRACTURE SURFACES

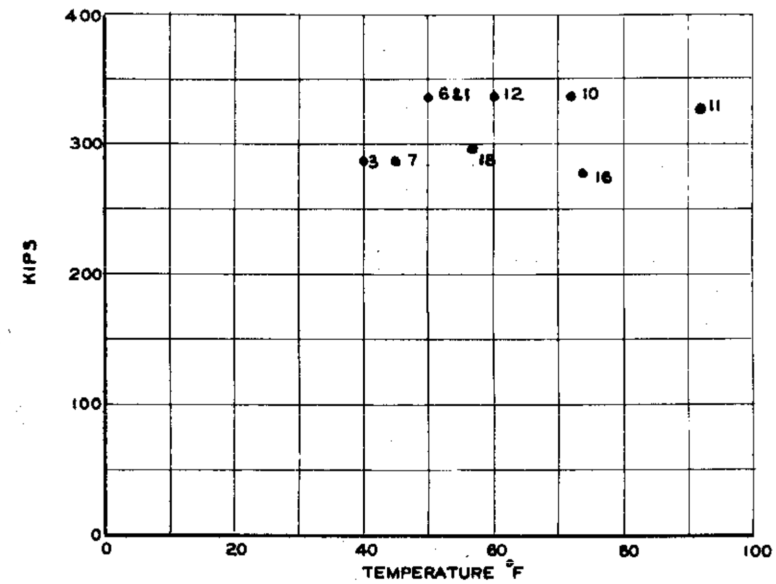
TABLE II

Code S-9 (A.S.T.M. Steel)

Test specimens 12" wide x 3/4" thick, with standard notch

The notch is 3" wide and has at its extremities a cut 1/8" deep made with a .010" Jeweler's hack-saw

Spec. No.	Deg. F	First To Visible Crack Energy E in. lbs.	First To Visible Crack Load lbs.	To Maximum Load Energy E_1 in. lbs.	To Maximum Load Load lbs.	To Failure Energy E_2 in. lbs.	To Failure Load lbs.	Energy $E_2 - E_1$ in. lbs.	% Shear
11	92	13,600	229,600	118,200	326,600	310,100	20,000	191,900	100
16	74	9,800	229,600	105,800	278,000	256,500	19,500	150,700	75
10	70	12,000	231,800	151,800	338,500	311,100	30,000	159,300	100
12	60	12,000	233,000	130,900	336,500	333,600	51,000	202,700	100
18	60	11,500	229,000	54,200	295,600	54,200	295,600	0	0
1	50	12,500	236,000	121,400	334,000	309,000	70,000	187,600	100
6	50	9,500	227,500	125,000	336,300	325,000	49,000	200,000	100
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



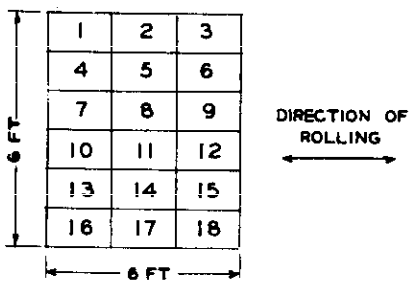
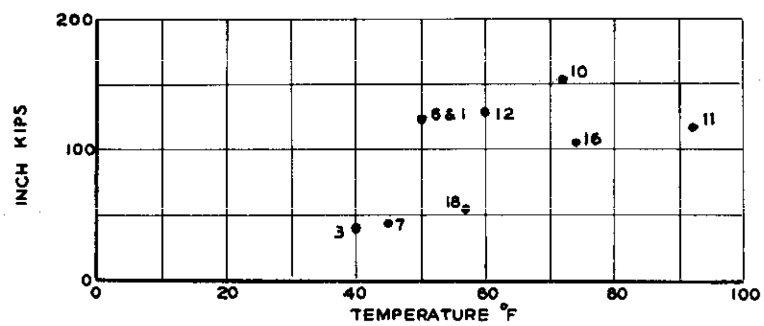


FIG. 7

MAX. LOAD
VS.
TEMPERATURE

S-9 STEEL
SWARTHMORE COLLEGE
10-11-49



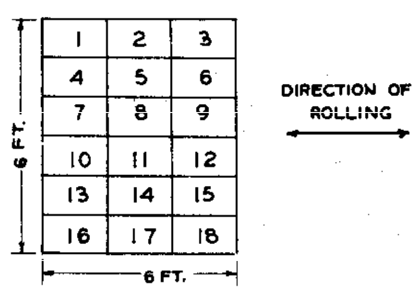
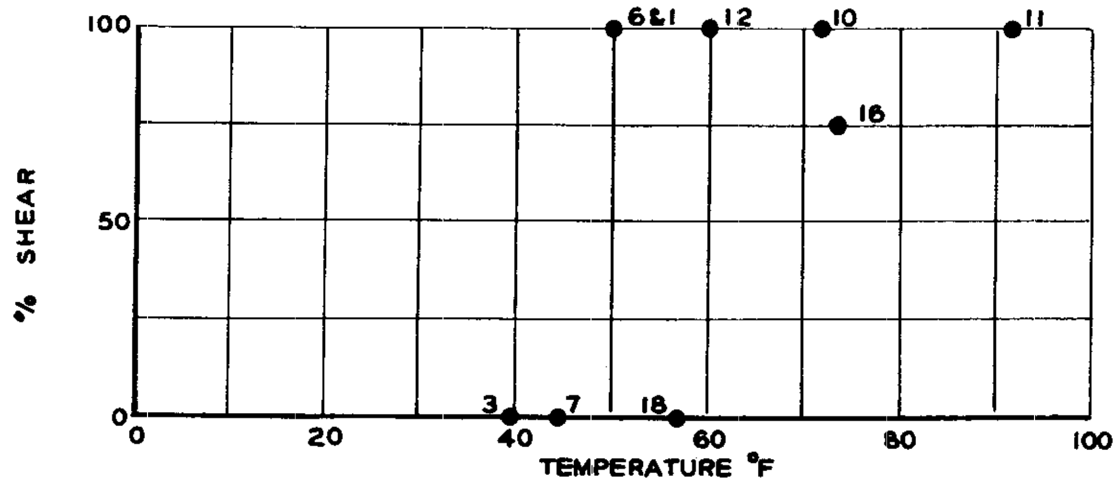


FIG 8

ENERGY TO
MAX. LOAD
VS
TEMPERATURE

S-9 STEEL
SWARTHMORE COLLEGE
10-11-49



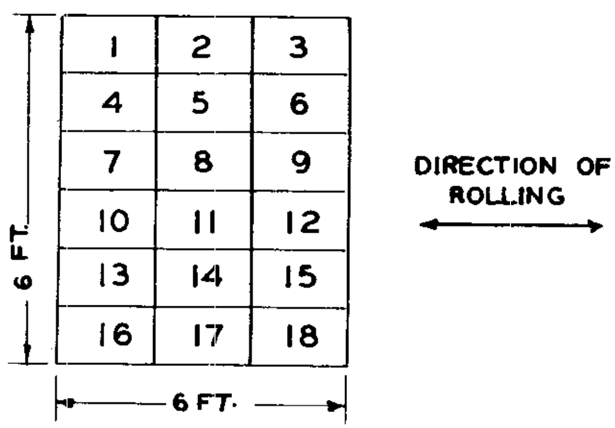


FIG. 9

PERCENT
SHEAR
VS.
TEMPERATURE
S-9 STEEL
SWARTHMORE COLLEGE
10-12-49

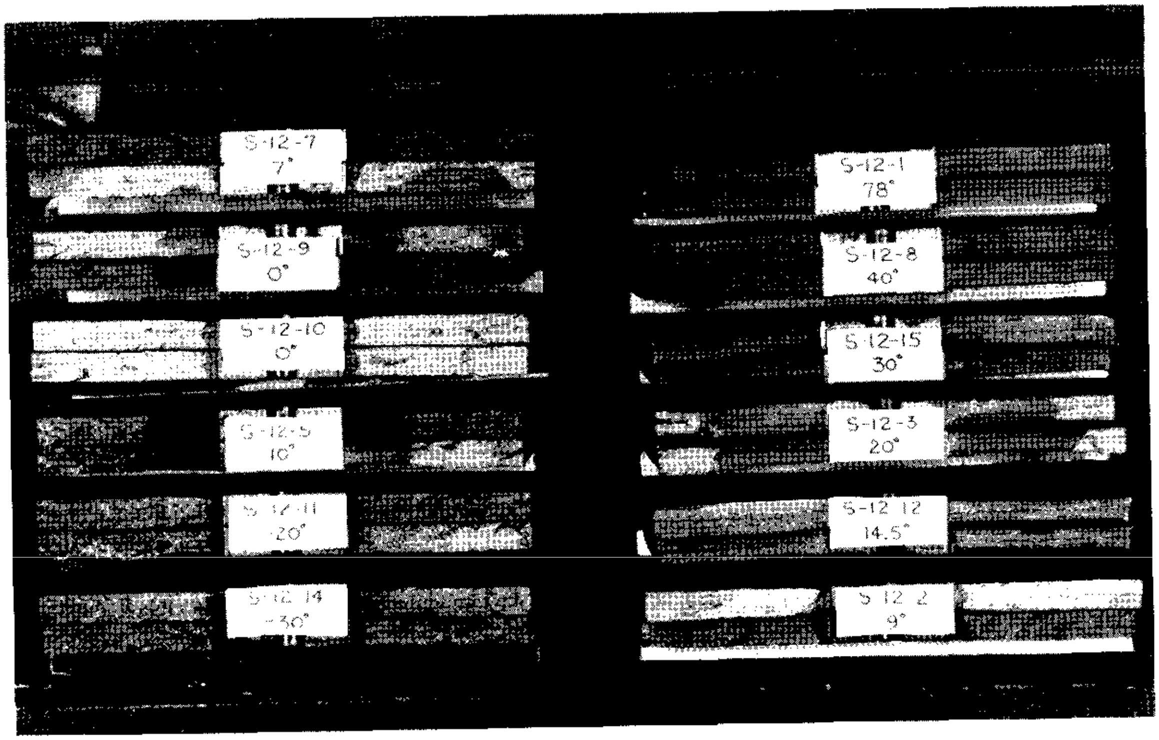


FIG. 10 "S-12" STEEL

PHOTOGRAPH OF FRACTURE SURFACES

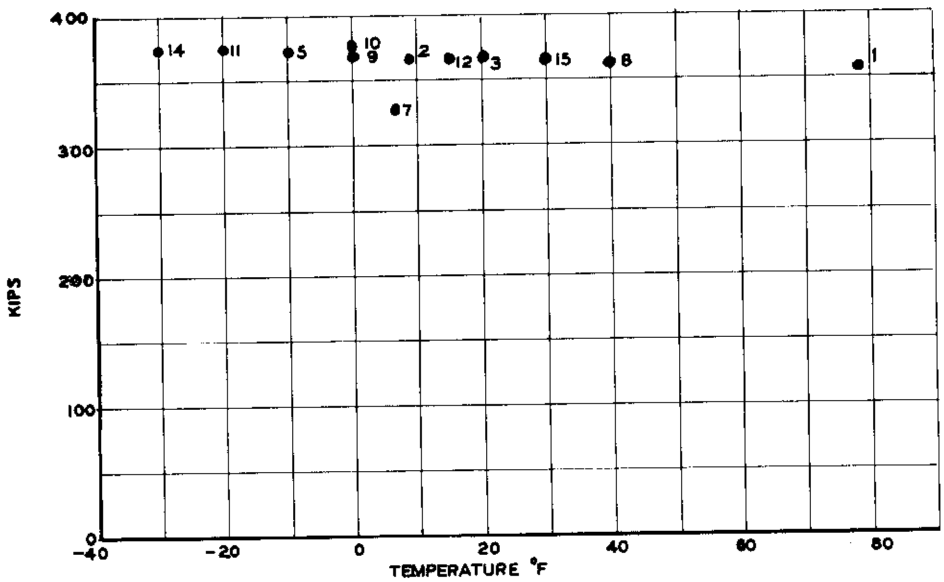
TABLE III

Code S-12 Fine Grain

Test specimens 12" wide x 3/4" thick, with standard notch

The notch is 3" wide and has at its extremities a cut 1/8" deep made with a .010" Jeweler's hack-saw

Spec. No.	Deg. F.	First To Visible Crack Energy E in.lbs.	First To Visible Crack Load lbs.	To Maximum Load Energy E_1 in.lbs.	To Maximum Load Load lbs.	To Failure Energy E_2 in.lbs.	To Failure Load lbs.	Energy E_2-E_1 in.lbs.	% Shear
1	78	10,000	250,000	114,000	356,000	294,000	45,000	180,000	100
8	40	8,000	258,200	110,000	363,000	290,000	55,000	180,000	100
15	30	5,000	235,500	128,000	366,400	300,000	77,000	172,000	100
3	20	10,000	254,400	111,000	365,800	286,500	150,000	175,500	70
12	15	4,000	248,000	102,000	366,700	296,000	45,000	194,000	100
2	9	7,000	253,000	97,000	366,500	97,000	366,500	0	10
7	7	7,000	267,000	39,000	326,000	39,000	326,000	0	0
9	0	6,300	243,000	112,000	371,000	214,000	320,000	102,000	30
10	0	2,500	250,000	98,500	378,000	98,500	378,000	0	5
5	-10	9,000	268,500	108,000	375,000	220,000	305,000	112,000	30
11	-20	5,000	259,000	90,200	375,600	90,200	375,600	0	8
14	-30	7,200	263,500	86,900	376,300	86,900	376,300	0	8



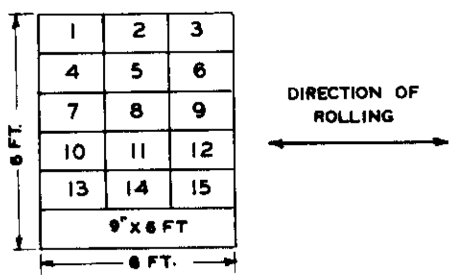
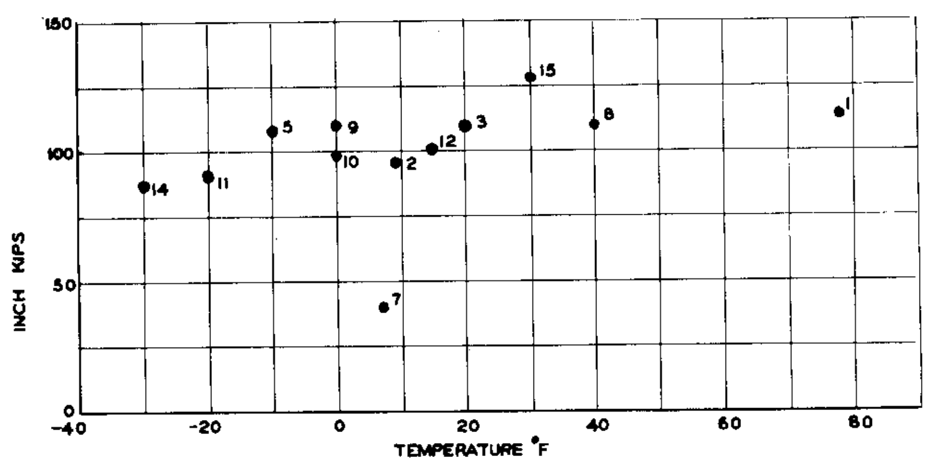


FIG. 11

MAX. LOAD
VS.
TEMPERATURE
S-12 STEEL
SWARTHMORE COLLEGE
9-22-49



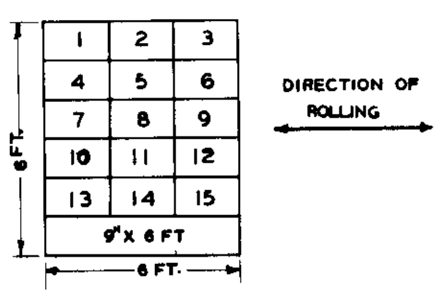
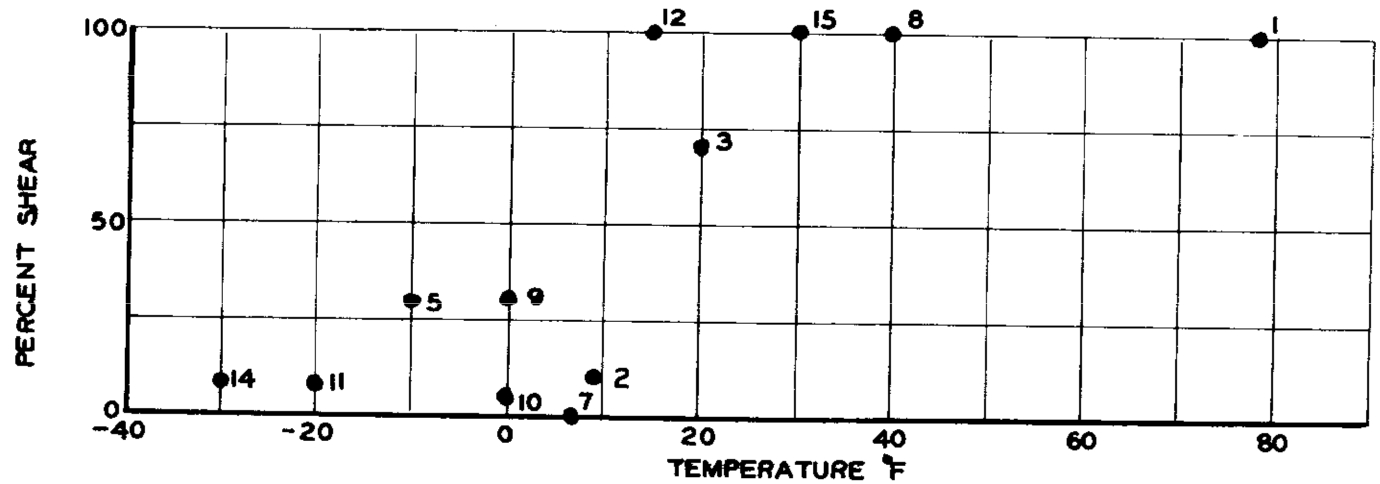


FIG 12

ENERGY TO
MAX. LOAD
VS.
TEMPERATURE
S-12 STEEL
SWARTHMORE COLLEGE
9-21-49



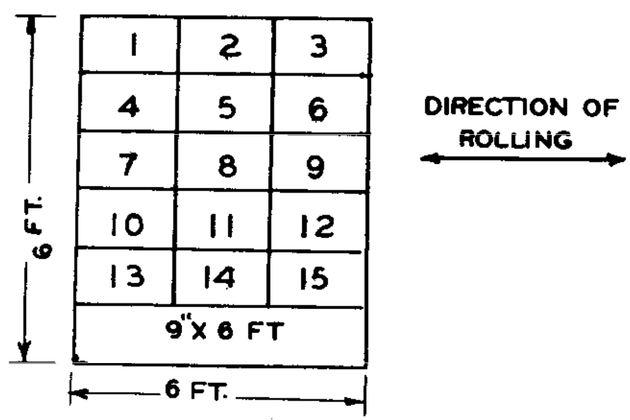


FIG 13
PERCENTAGE SHEAR
VS.
TEMPERATURE
S-12 STEEL
SWARTHMORE COLLEGE
9-21-49

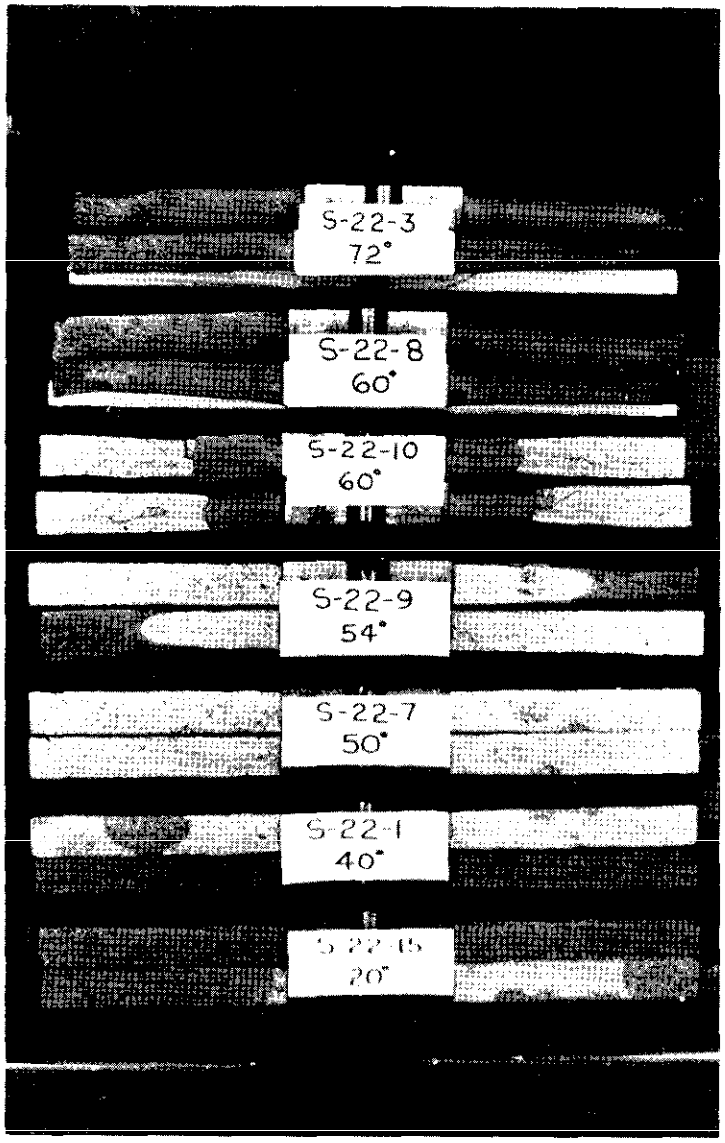


FIG. 14 "S-22" STEEL

PHOTOGRAPH OF FRACTURE SURFACES

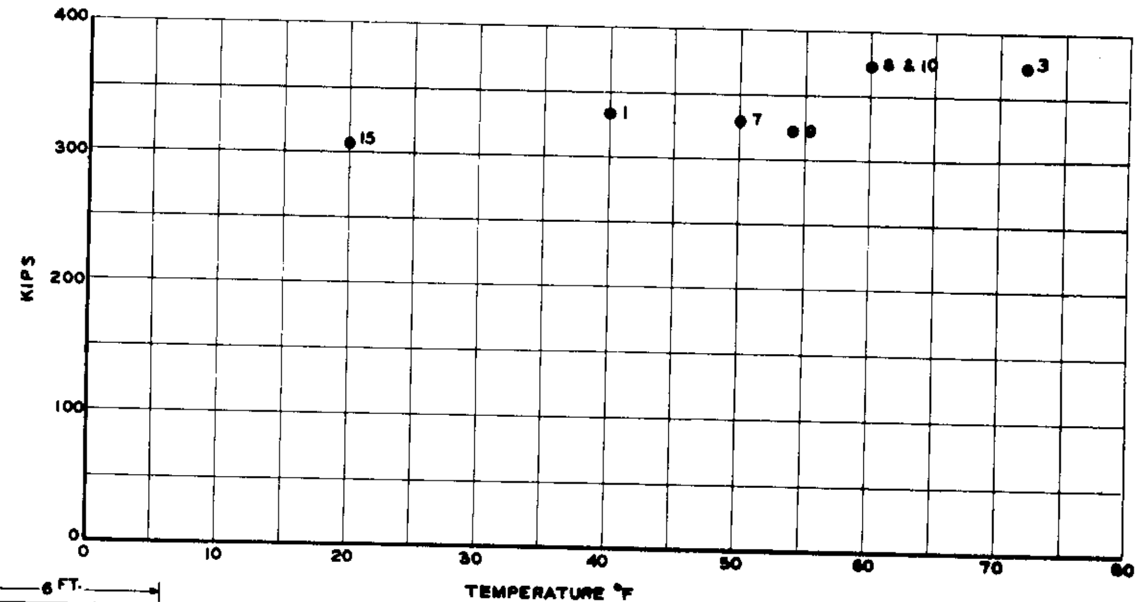
TABLE IV

Code S-22 (Coarse grain)

Test specimens 12" wide x 3/4" thick, with standard notch

The notch is 3" wide and has at its extremities a cut 1/8" deep made with a .010" Jeweler's hack-saw

Spec. No.	Deg. F	First To Visible Crack Energy E in. lbs.	First To Visible Crack Load lbs.	To Maximum Load Energy E_1 in. lbs.	To Maximum Load Load lbs.	To Failure Energy E_2 in. lbs.	To Failure Load lbs.	Energy $E_2 - E_1$ in. lbs.	% Shear
3	70	5,600	247,800	127,900	375,000	330,000	53,000	202,100	100
8	60	2,500	234,000	104,800	376,500	334,000	40,000	229,200	100
10	60	7,500	253,500	130,500	375,900	212,000	320,000	81,500	35
9	54	7,500	261,000	35,000	312,000	210,000	312,000	175,000	22
7	50	5,400	252,200	35,600	330,000	35,600	330,000	0	0
1	40	5,300	242,500	43,800	332,000	43,800	332,000	0	0
15	20	12,700	265,000	29,000	308,500	29,000	308,500	0	5



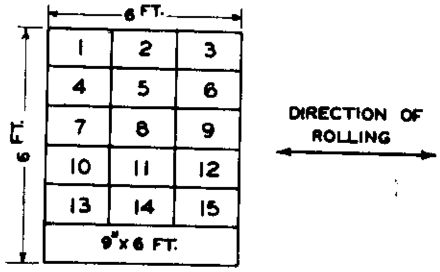
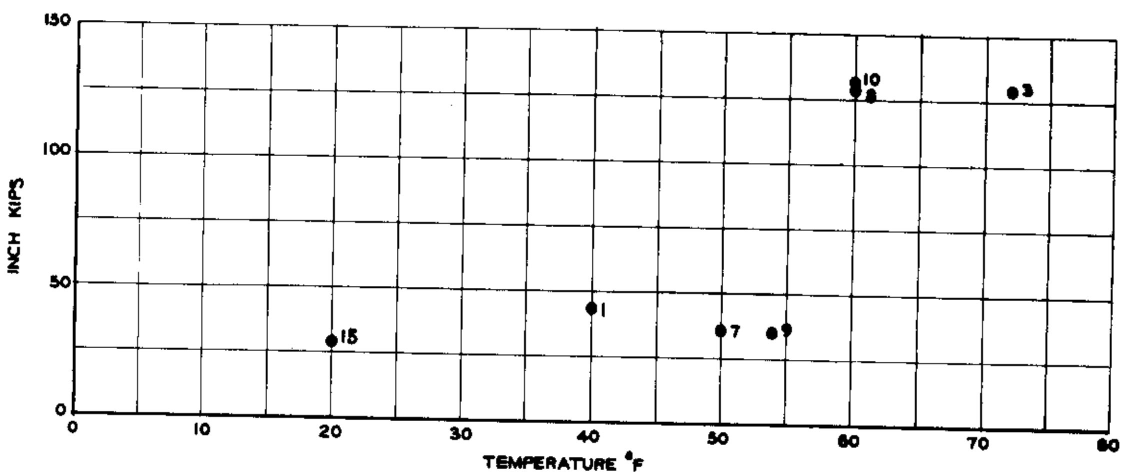


FIG. 15

MAX. LOAD
VS.
TEMPERATURE
S-22 STEEL
SWARTHMORE COLLEGE
9-21-49



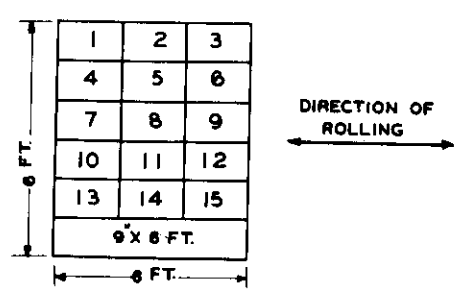


FIG. 16

ENERGY TO
MAX. LOAD
VS.
TEMPERATURE
S-22 STEEL
SWARTHMORE COLLEGE
9-21-49

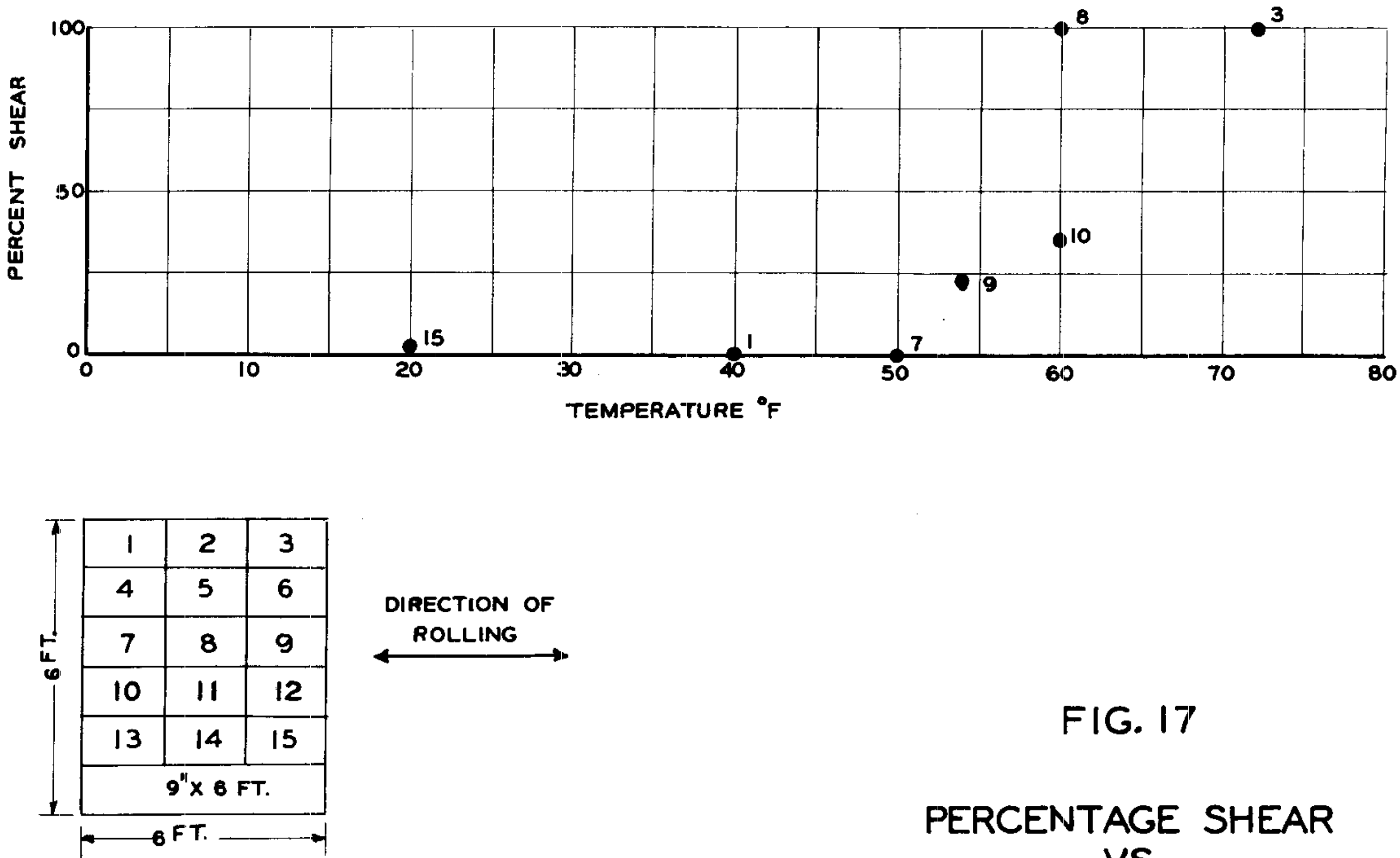
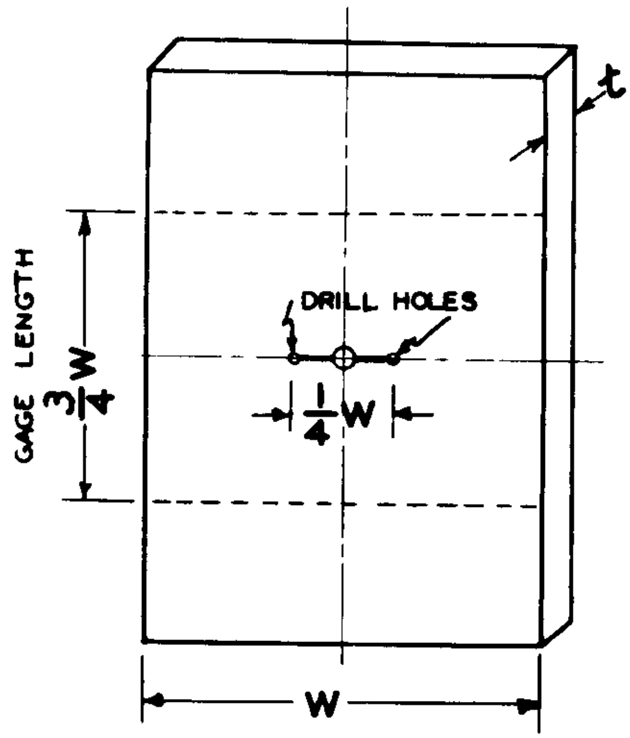


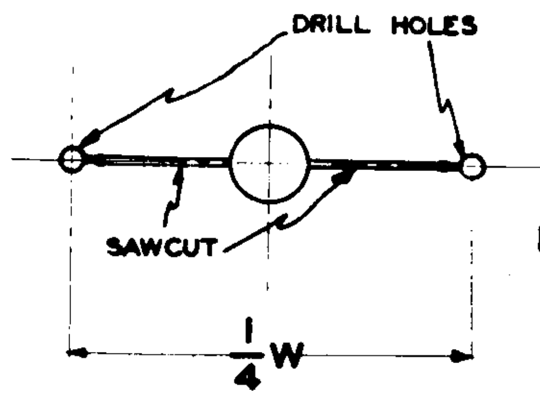
FIG. 17

PERCENTAGE SHEAR
VS.
TEMPERATURE
S-22 STEEL
SWARTHMORE COLLEGE
9-21-49



ASPECT RATIO = $\frac{W}{t}$

t	DIA. OF DRILL HOLES
$\frac{1}{2}$"	$\frac{1}{32}$"
$\frac{3}{4}$"	$\frac{3}{64}$"
1"	$\frac{1}{16}$"
$1\frac{1}{2}$"	$\frac{3}{32}$"



ENLARGED VIEW

FIG. 18

TYPICAL SPECIMEN

SWARTHMORE COLLEGE

9-6-49

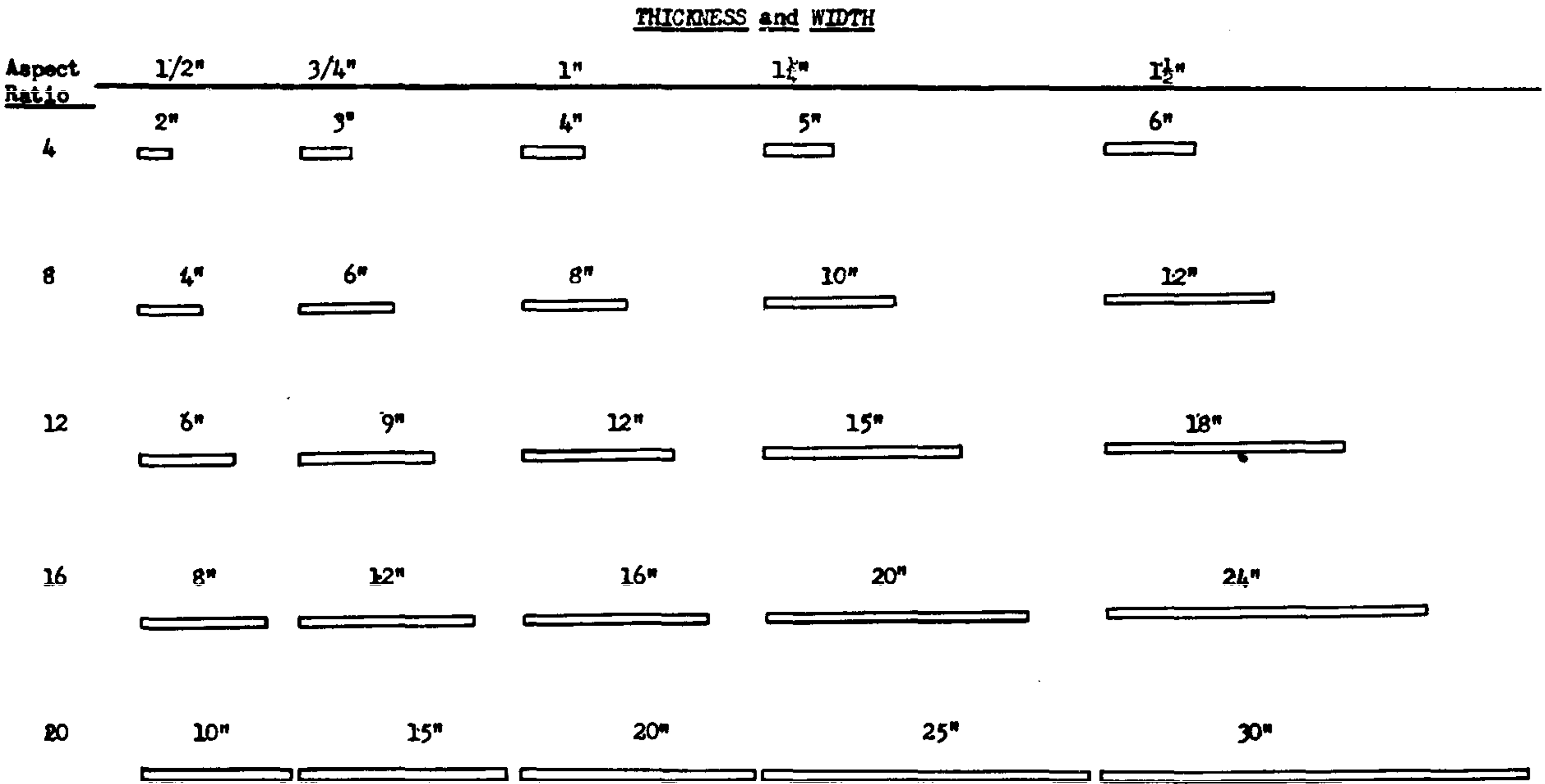
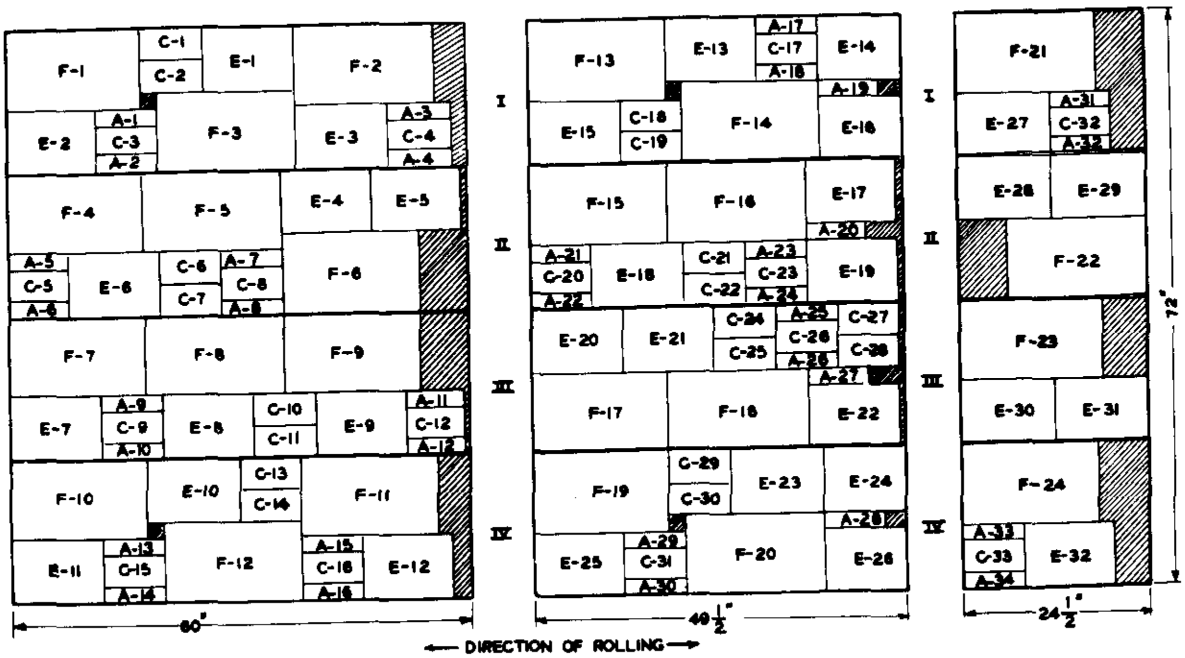


FIG. 19
ASPECT RATIO PROGRAM
SWARTHMORE COLLEGE
9-6-49

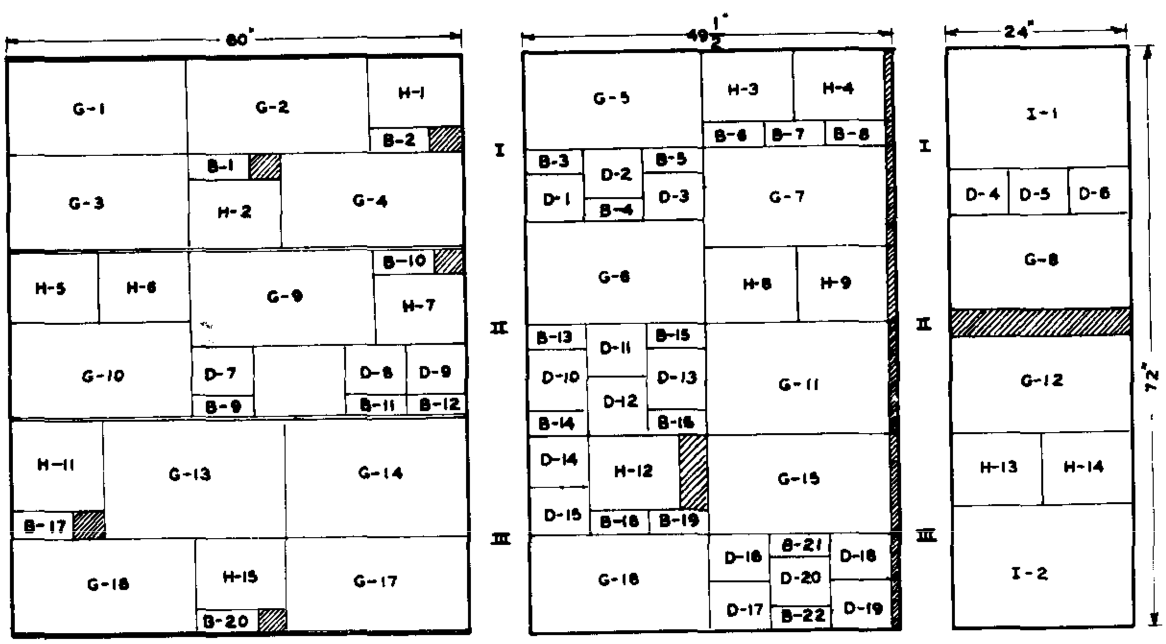


A - 2" x 8"
C - 4" x 8"
E - 8" x 12"
F - 9½" x 18"

SCALE - 0.5" = 8"

FIG. 20

1/2" PLATE LAYOUT
SWARTHMORE COLLEGE
9-7-49

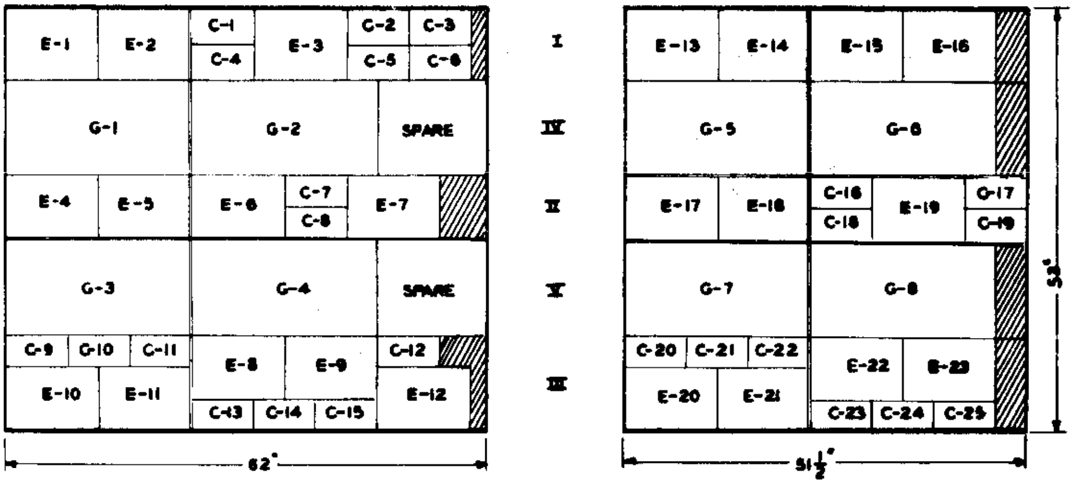


B - 3" x 8"
D - 6" x 8"
H - 9" x 12"
G - 12" x 24"
I - 15" x 24"

SCALE - 0.5" = 8"

FIG. 21

3/4" PLATE LAYOUT
SWARTHMORE COLLEGE
9-7-49

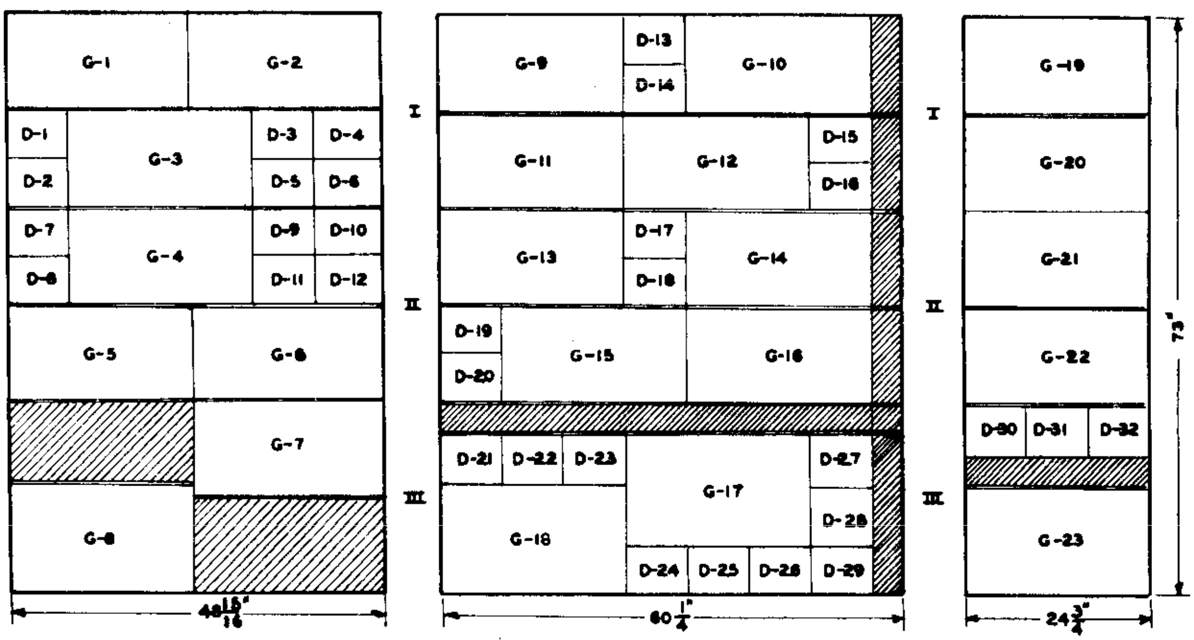


C- 4" X 8"
E- 8" X 12"
G- 11 1/2" X 24"

SCALE- 0.5" = 8"

FIG. 22

1" PLATE LAYOUT
SWARTHMORE COLLEGE
9-6-49



D- 6" X 8"
G- 12" X 24"

← DIRECTION OF ROLLING →

FIG. 23

1 1/2" PLATE LAYOUT
SWARTHMORE COLLEGE
9-7-49

SCALE — 0.5" = 8"

APPENDIX A

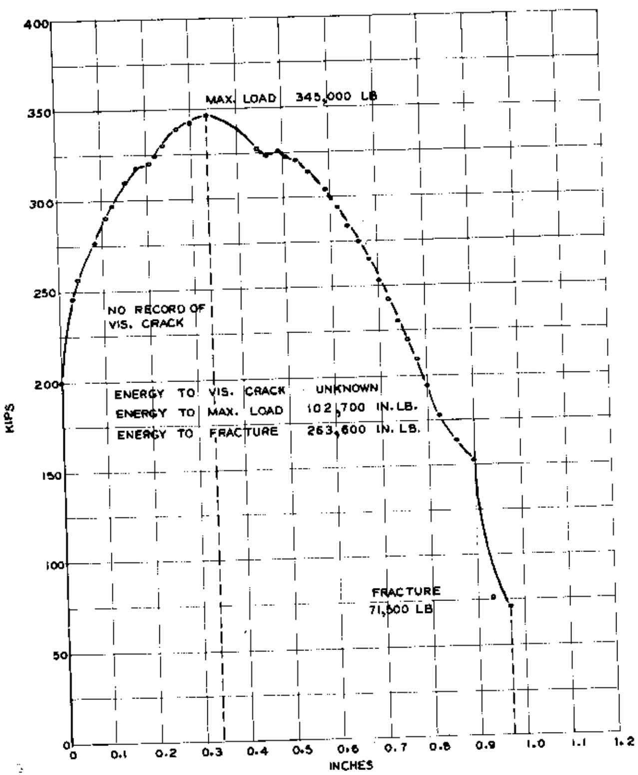


FIG. 1-W

LOAD vs ELONGATION

W-32-1

TEMP. 81°F 100% SHEAR
SWARTHMORE COLLEGE
10-7-49

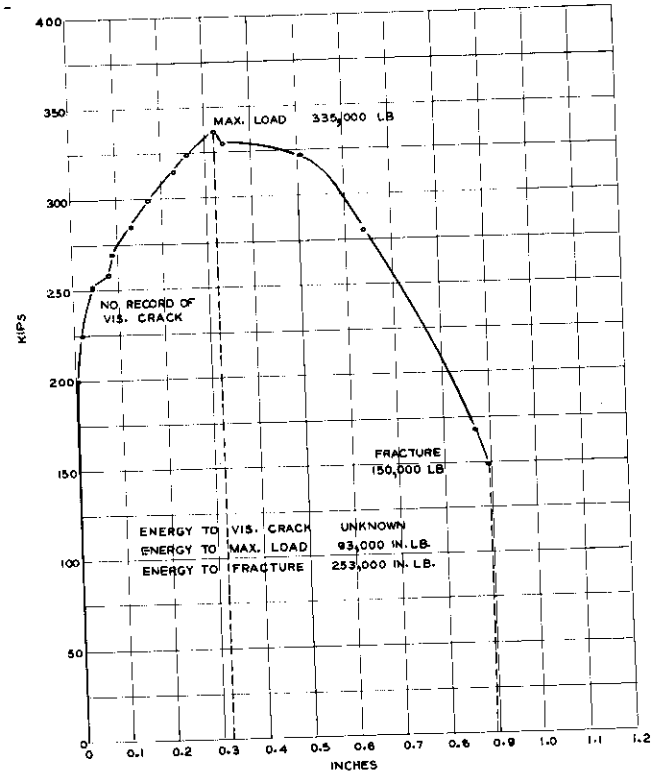


FIG. 2-W

LOAD vs ELONGATION

W-32-2

TEMP. 66°F 100% SHEAR
SWARTHMORE COLLEGE
10-7-49

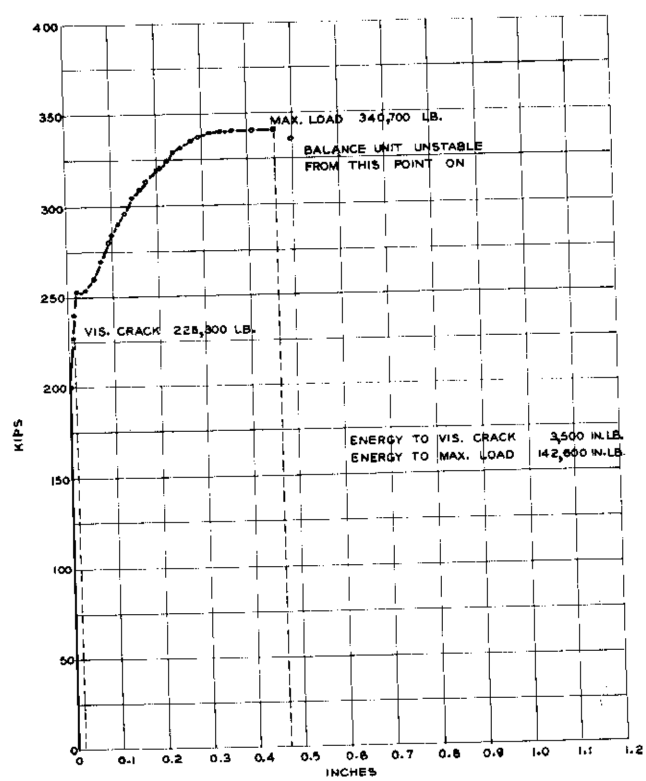


FIG. 3-W

LOAD vs ELONGATION

W-32-6

TEMP. 66°F 100% SHEAR
SWARTHMORE COLLEGE
10-10-49

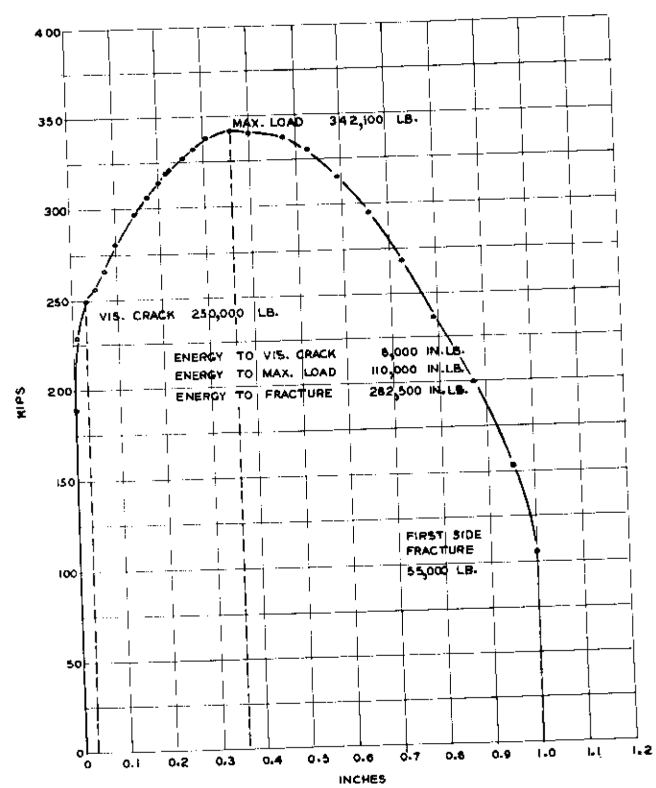


FIG. 4-W

LOAD vs ELONGATION

W-32-7

TEMP. 81°F 100% SHEAR
SWARTHMORE COLLEGE
10-7-49

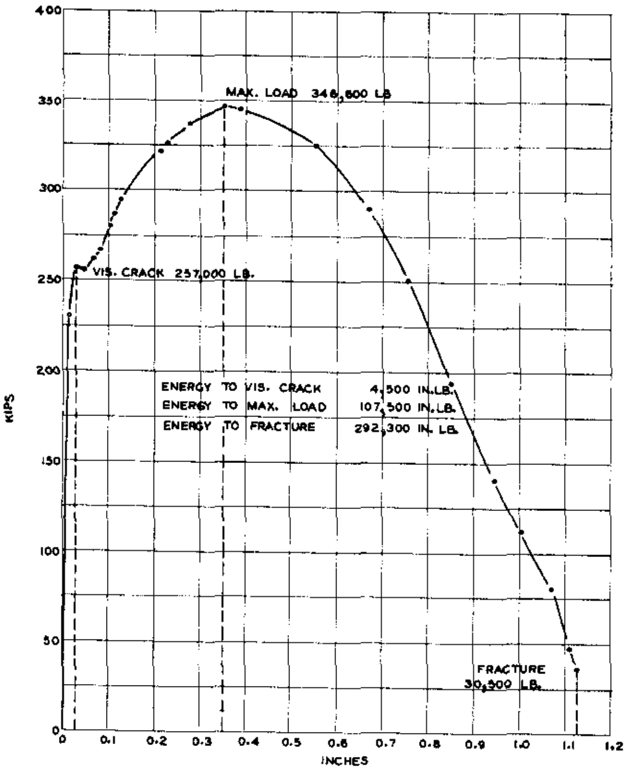


FIG. 5-W

LOAD vs ELONGATION

W-32-8

TEMP. 54.5°F 100% SHEAR

SWARTHMORE COLLEGE

10-6-49

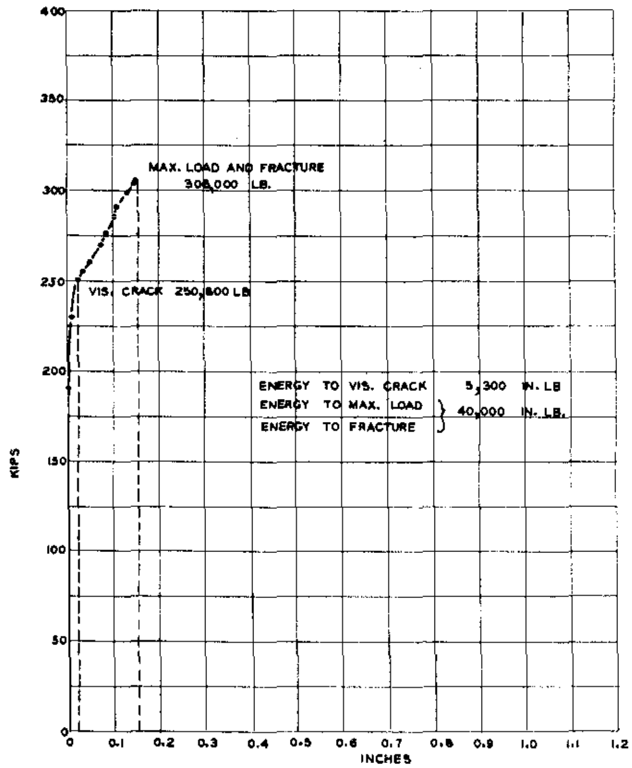


FIG. 6W

LOAD vs ELONGATION

W-32-9

TEMP. 43°F 0% SHEAR

SWARTHMORE COLLEGE

10-6-49

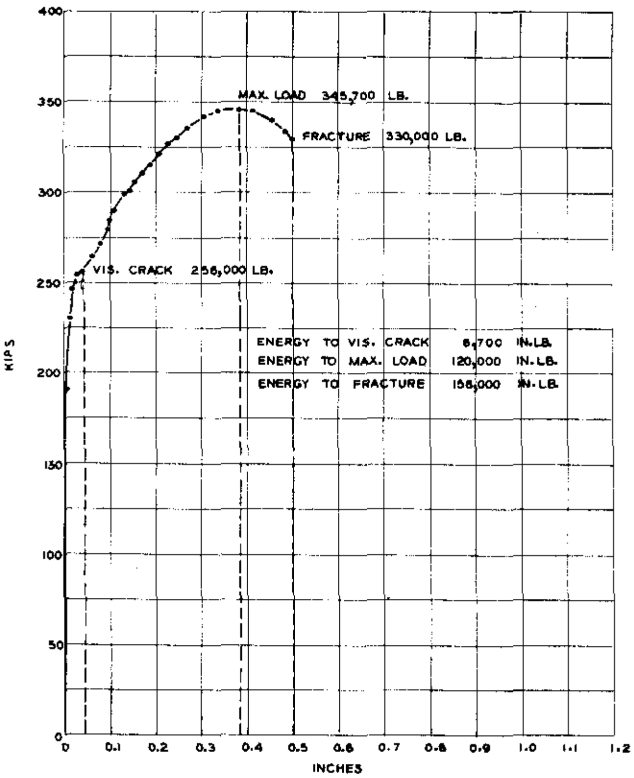


FIG. 7-W

LOAD vs ELONGATION

W-32-10

TEMP. 45°F 30% SHEAR

SWARTHMORE COLLEGE

10-6-49

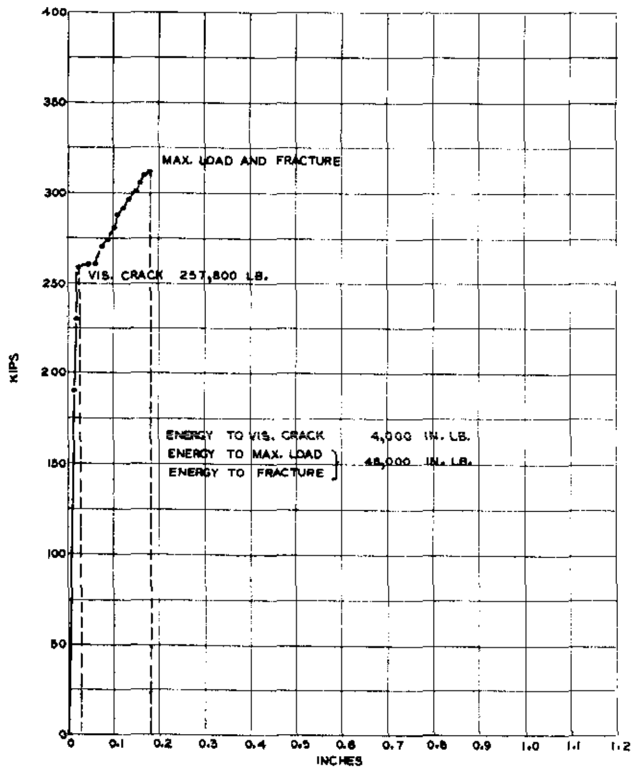


FIG. 8-W

LOAD vs ELONGATION

W-32-11

TEMP. 21°F 0% SHEAR

SWARTHMORE COLLEGE

10-4-49

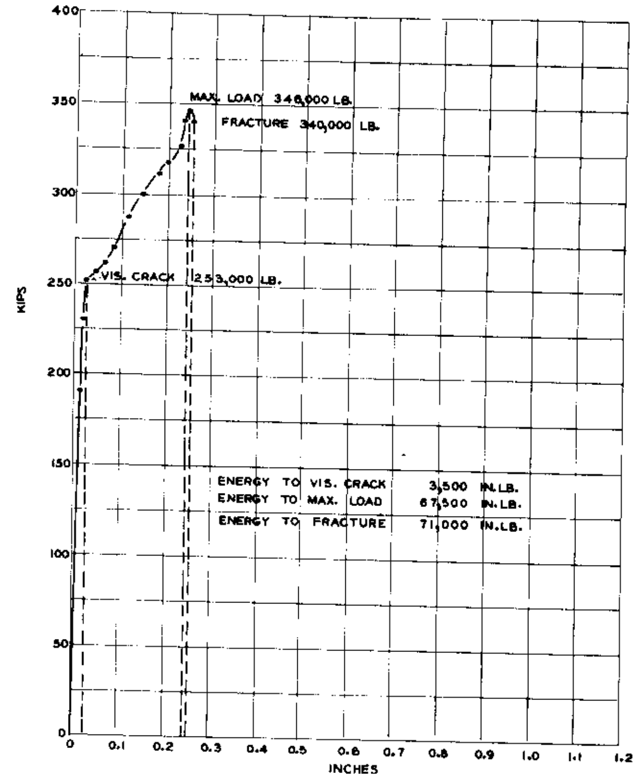


FIG. 9-W

LOAD vs. ELONGATION
W-32-12
TEMP. 36 F 22% SHEAR
SWARTHMORE COLLEGE
10-4-49

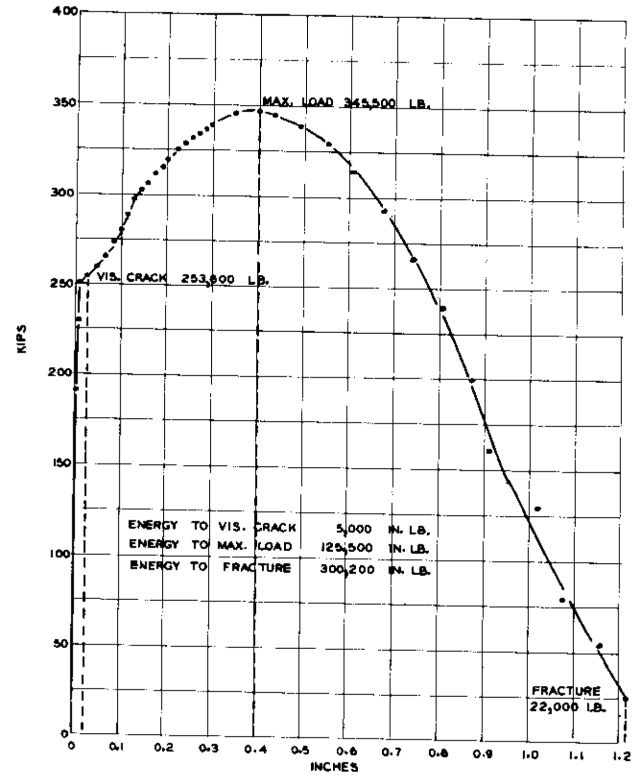


FIG. 10-W
LOAD vs ELONGATION
W-32-15
TEMP. 50F 100% SHEAR
SWARTHMORE COLLEGE
10-1-49

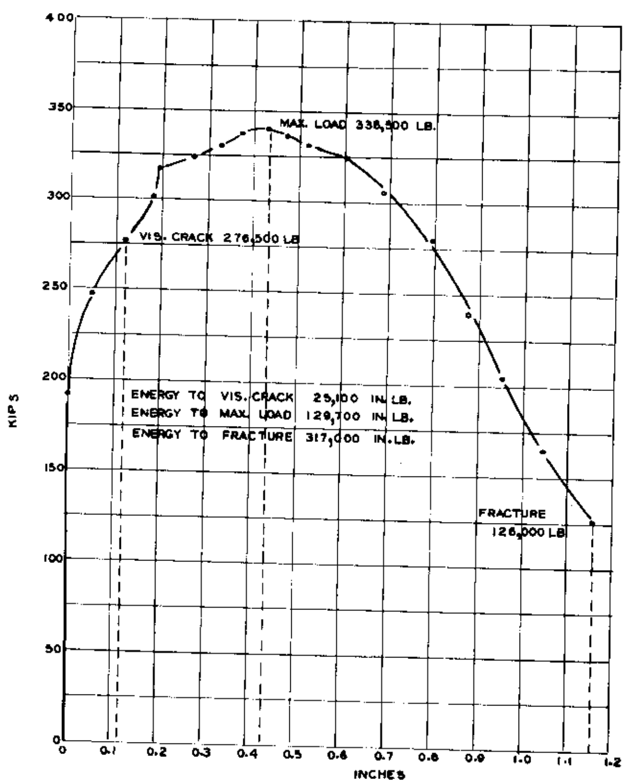


FIG 11-W

LOAD vs ELONGATION
W-32-16
TEMP. 71°F 100% SHEAR
SWARTHMORE COLLEGE
10-1-49

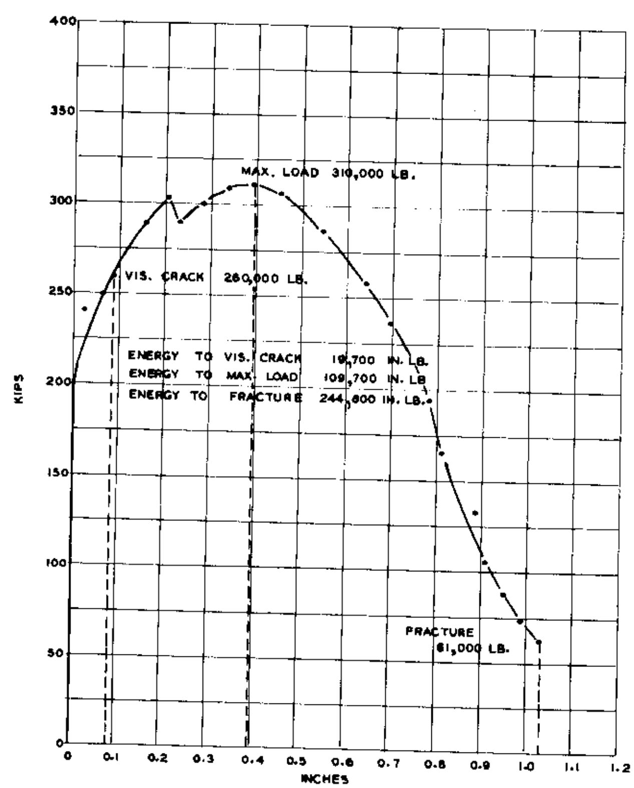


FIG. 12-W
LOAD vs ELONGATION
W-32-17
TEMP. 76°F 100% SHEAR
SWARTHMORE COLLEGE
10-10-49

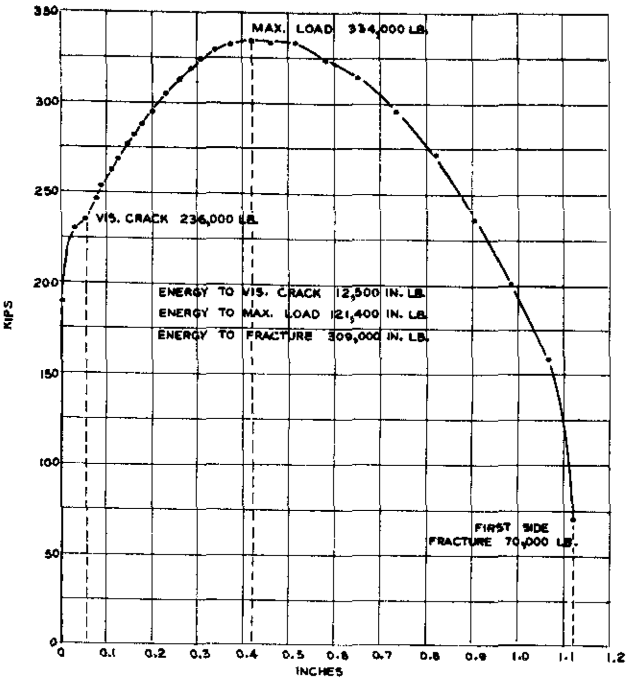


FIG. 1-S9

LOAD vs ELONGATION

S-9-1

TEMP. 50F 100% SHEAR
SWARTHMORE COLLEGE
10-17-49

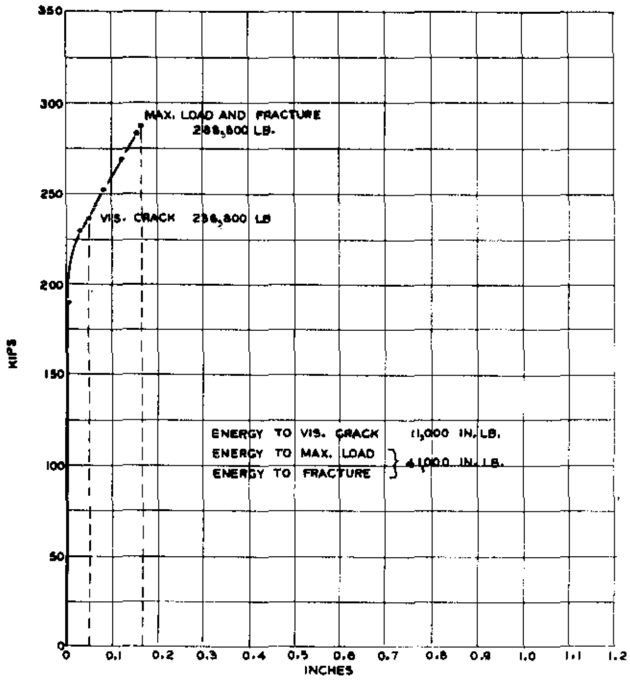


FIG. 2-S9

LOAD vs ELONGATION

S-9-3

TEMP. 40F 0% SHEAR
SWARTHMORE COLLEGE
10-14-49

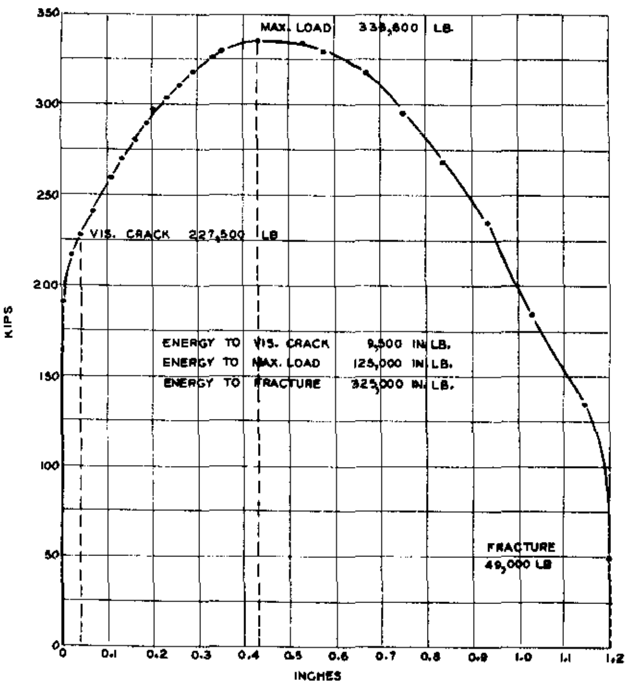


FIG. 3-S9

LOAD vs ELONGATION

S-9-6

TEMP. 50F 100% SHEAR
SWARTHMORE COLLEGE
10-17-49

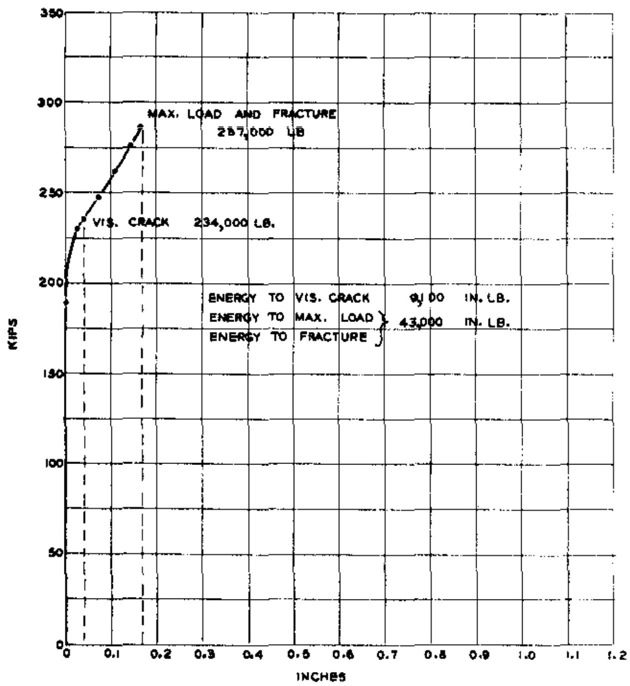


FIG. 4-S9

LOAD vs ELONGATION

S-9-7

TEMP 45F 0% SHEAR
SWARTHMORE COLLEGE
10-13-49

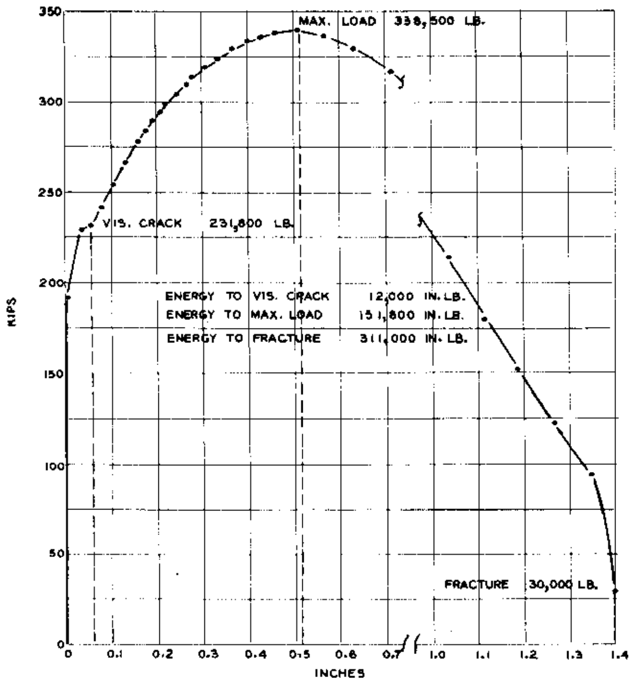


FIG. 5-S9

LOAD vs ELONGATION

S-9-10

TEMP. 72°F 100% SHEAR
SWARTHMORE COLLEGE
10-17-49

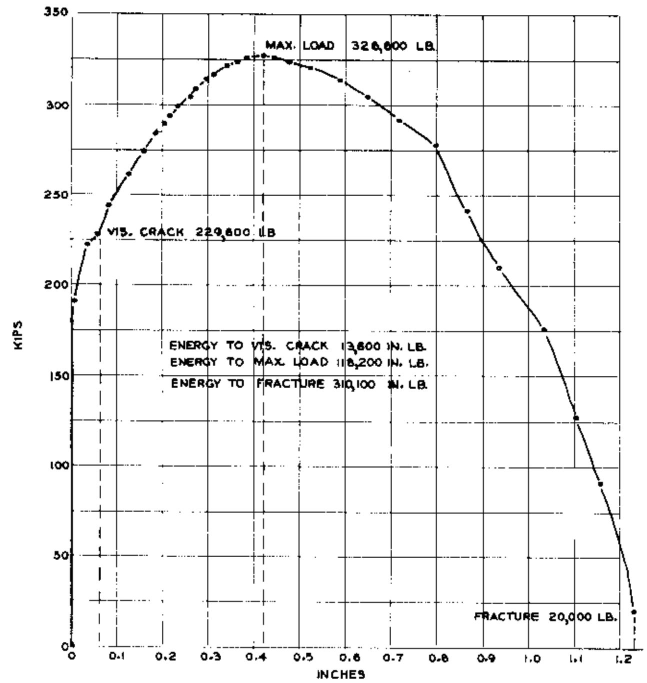


FIG. 6-S9

LOAD vs ELONGATION

S-9-11

TEMP. 92°F 100% SHEAR
SWARTHMORE COLLEGE
10-17-49

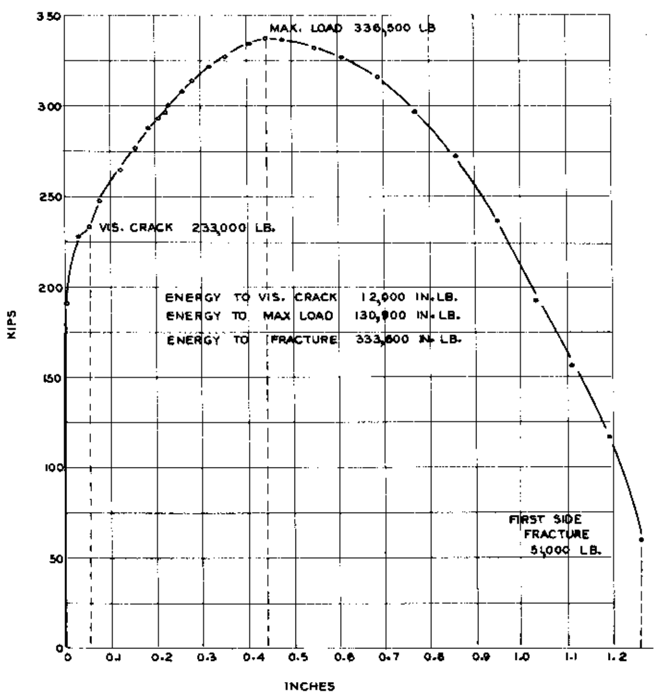


FIG. 7-S9

LOAD vs ELONGATION

S-9-12

TEMP. 60°F 100% SHEAR
SWARTHMORE COLLEGE
10-13-49

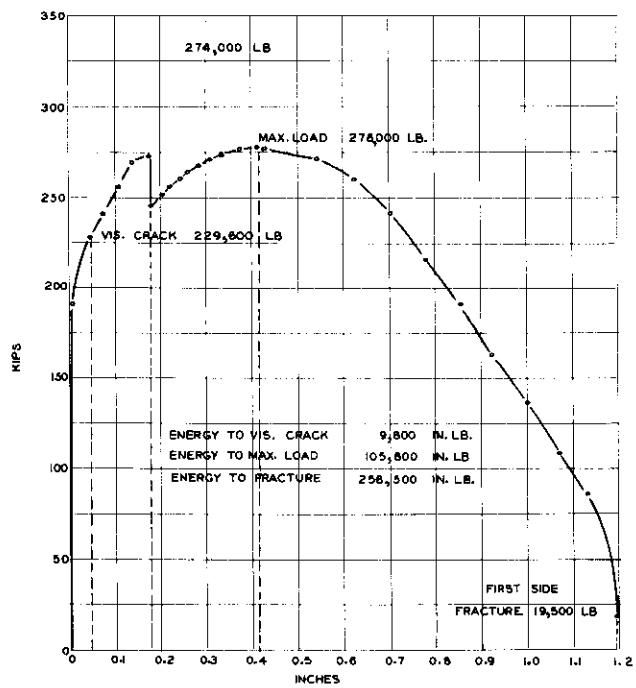


FIG. 8-S9

LOAD vs ELONGATION

S-9-16

TEMP. 74°F 75% SHEAR
SWARTHMORE COLLEGE
10-15-49

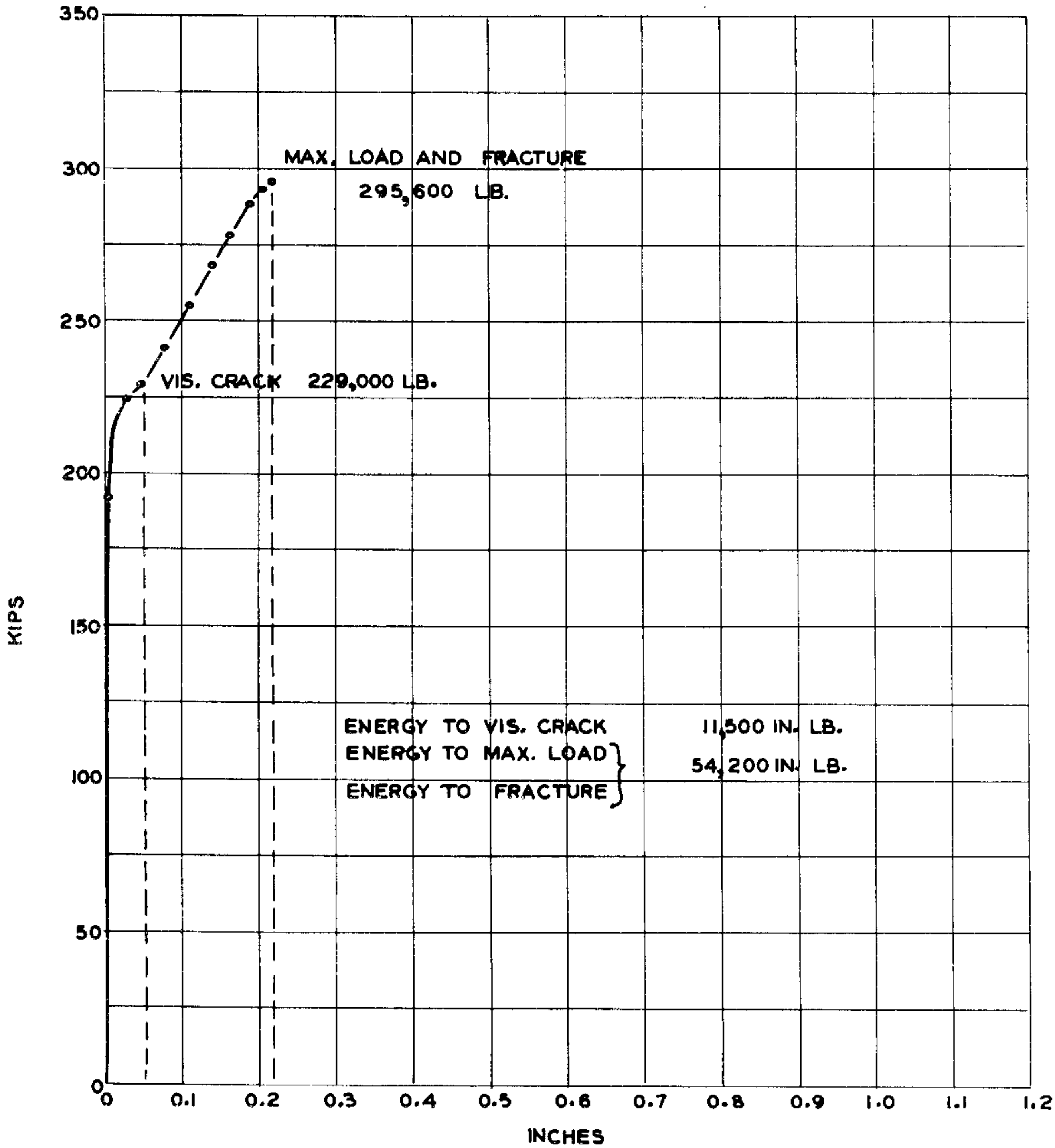


FIG. 9-S9

LOAD vs ELONGATION

S-9-18

TEMP. 57°F 0% SHEAR

SWARTHMORE COLLEGE

10-15-49

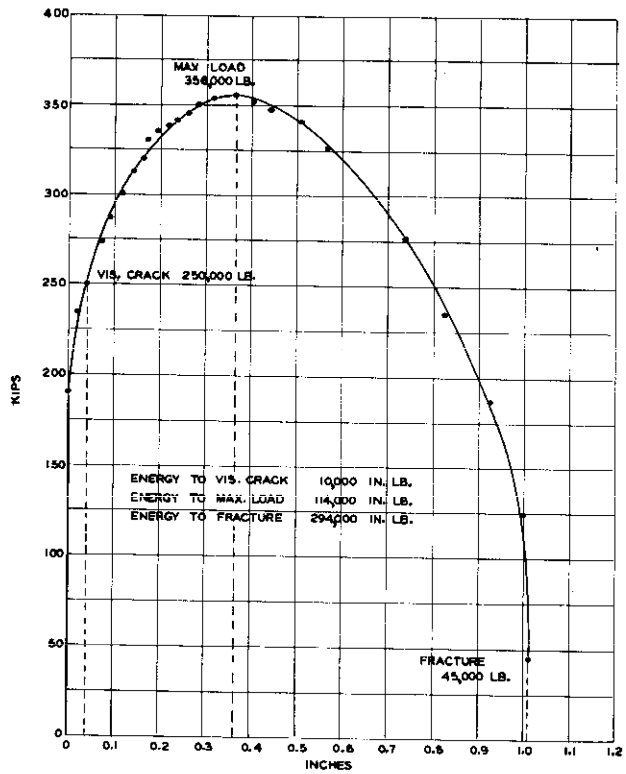


FIG. 1-S12

LOAD vs ELONGATION

S-12-1

TEMP. 78°F 100% SHEAR

SWARTHMORE COLLEGE

9-23-49

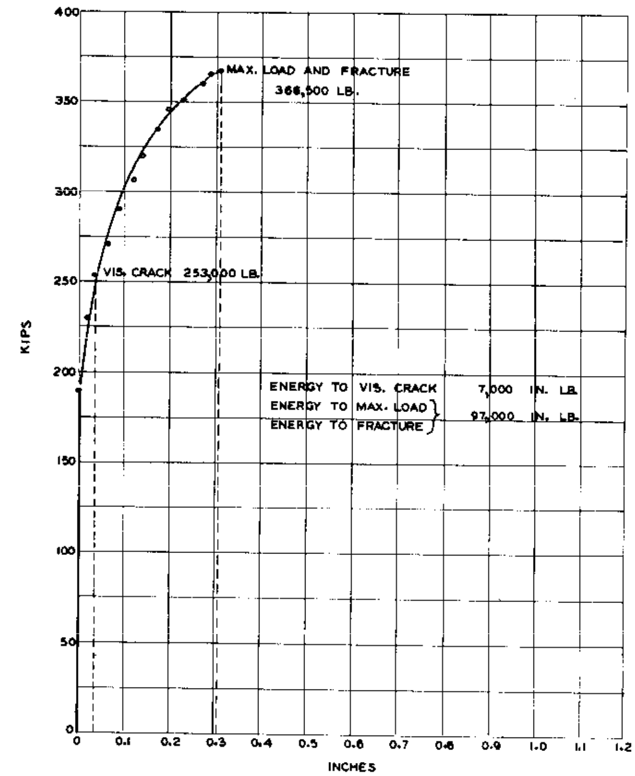


FIG. 2-S12

LOAD vs ELONGATION

S-12-2

TEMP. 9°F 10% SHEAR

SWARTHMORE COLLEGE

9-23-49

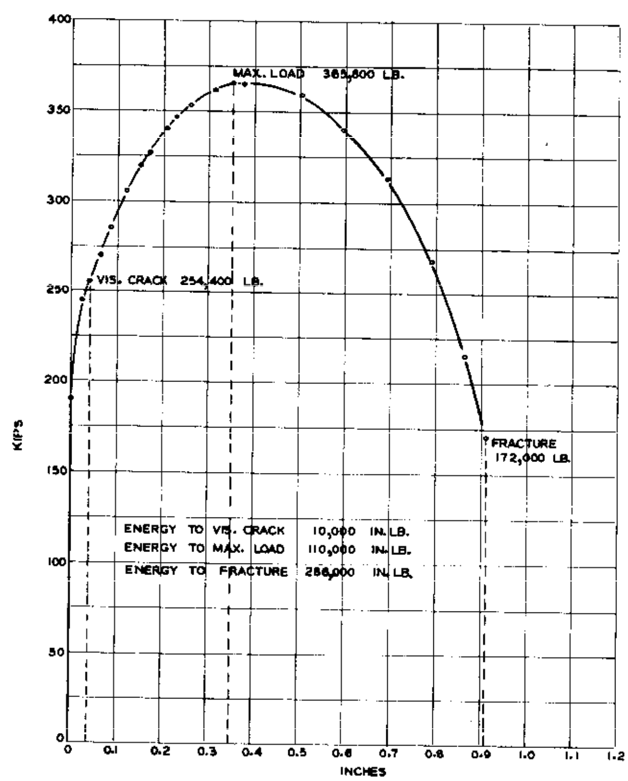


FIG. 3-S12

LOAD vs ELONGATION

S-12-3

TEMP. 20°F 70% SHEAR

SWARTHMORE COLLEGE

9-23-49

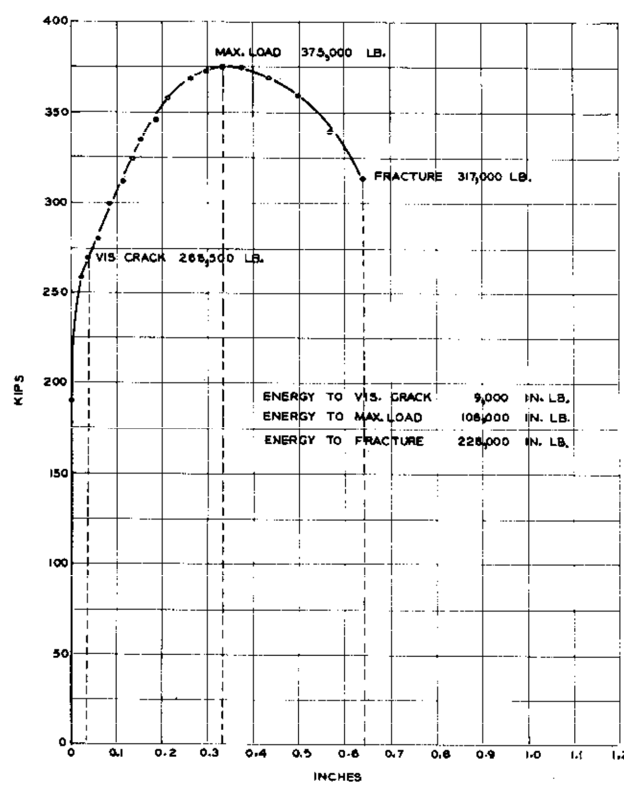


FIG. 4-S12

LOAD vs ELONGATION

S-12-5

TEMP. -10°F 30% SHEAR

SWARTHMORE COLLEGE

9-23-49

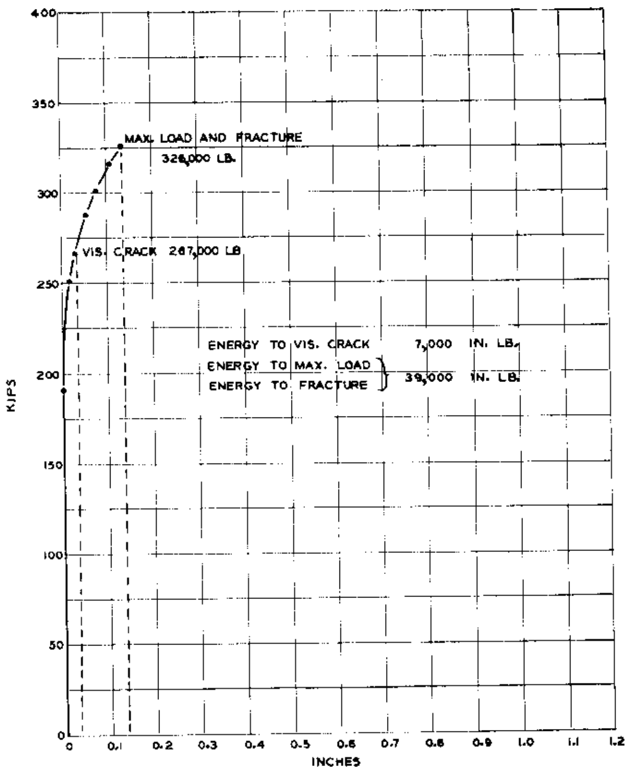


FIG. 5-S12
LOAD VS ELONGATION
S-12-7
TEMP. 7°F 0% SHEAR
SWARTHMORE COLLEGE
9-23-49

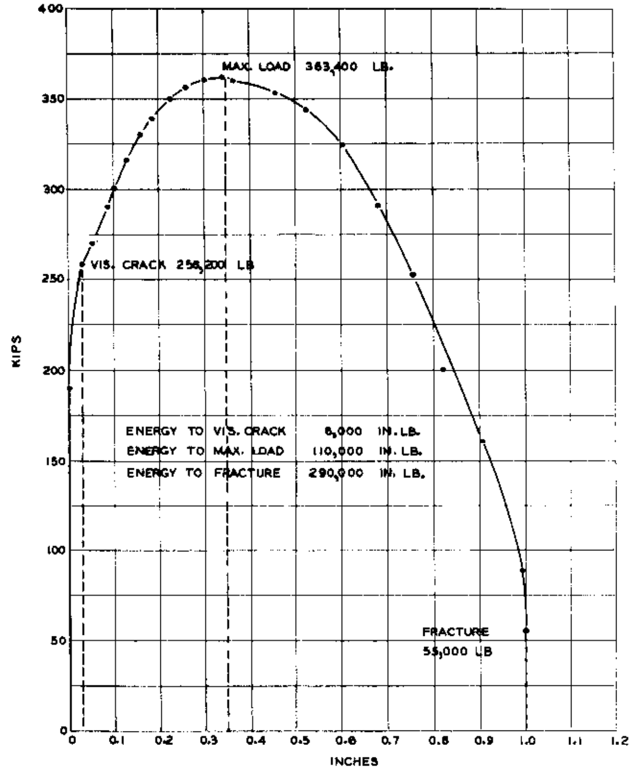


FIG. 6-S12
LOAD VS ELONGATION
S-12-8
TEMP. 40°F 100% SHEAR
SWARTHMORE COLLEGE
9-23-49

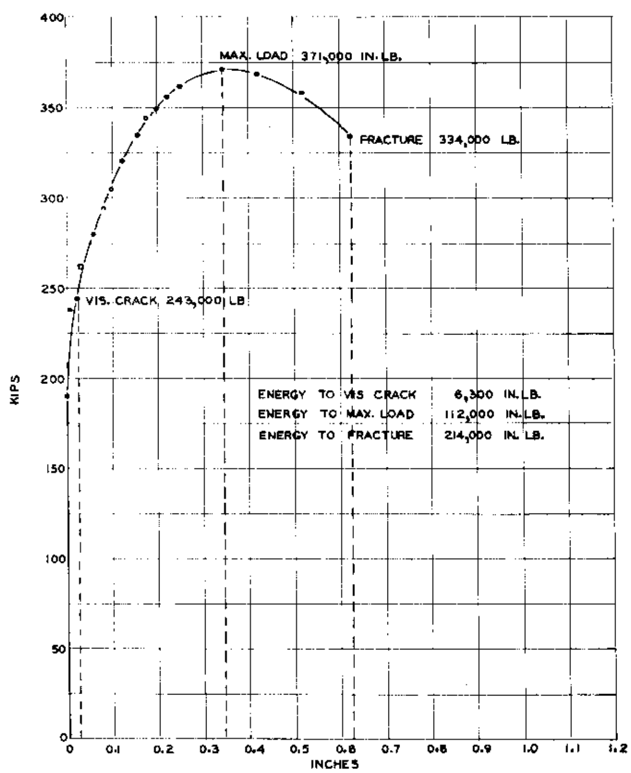


FIG. 7-S12
LOAD VS ELONGATION
S-12-9
TEMP. 0°F 30% SHEAR
SWARTHMORE COLLEGE
9-28-49

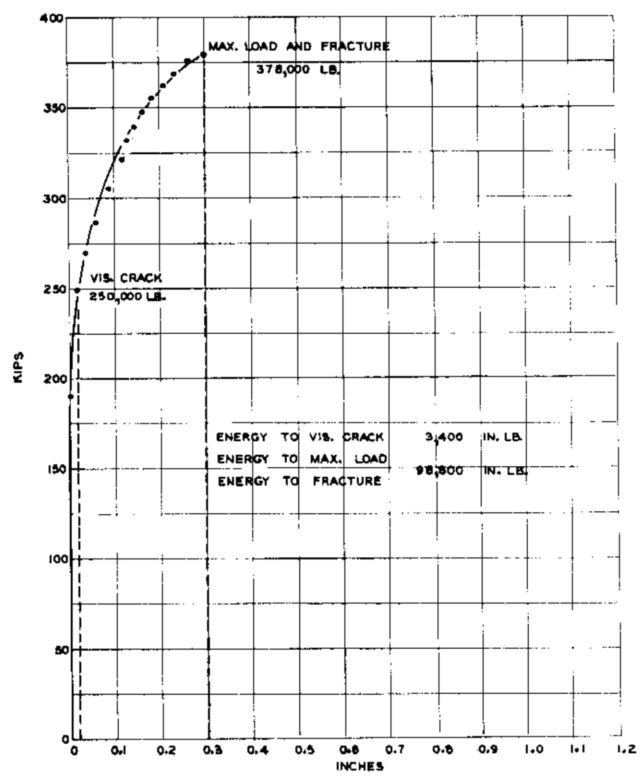


FIG. 8-S12
LOAD VS ELONGATION
S-12-10
TEMP. 0°F 5% SHEAR
SWARTHMORE COLLEGE
9-27-49

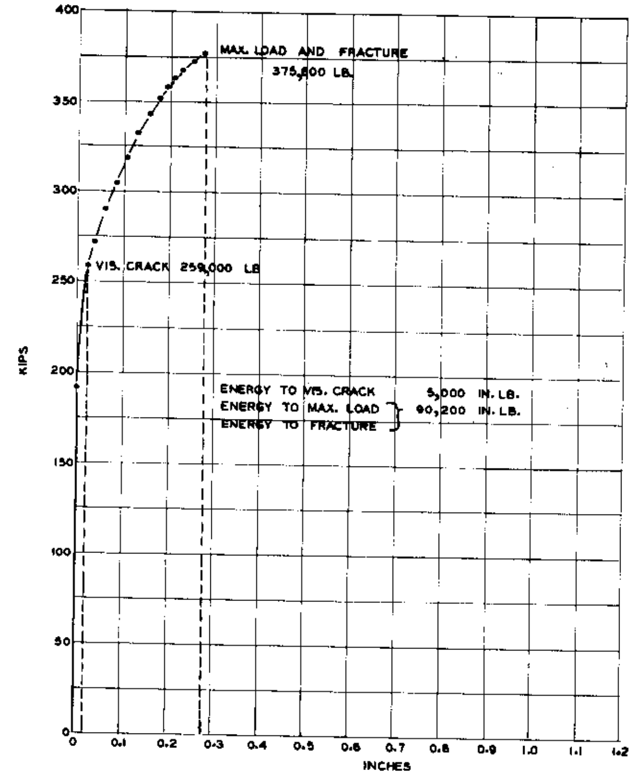


FIG. 9-S12

LOAD vs ELONGATION

S-12-11

TEMP. -20°F 8% SHEAR

SWARTHMORE COLLEGE

9-27-49

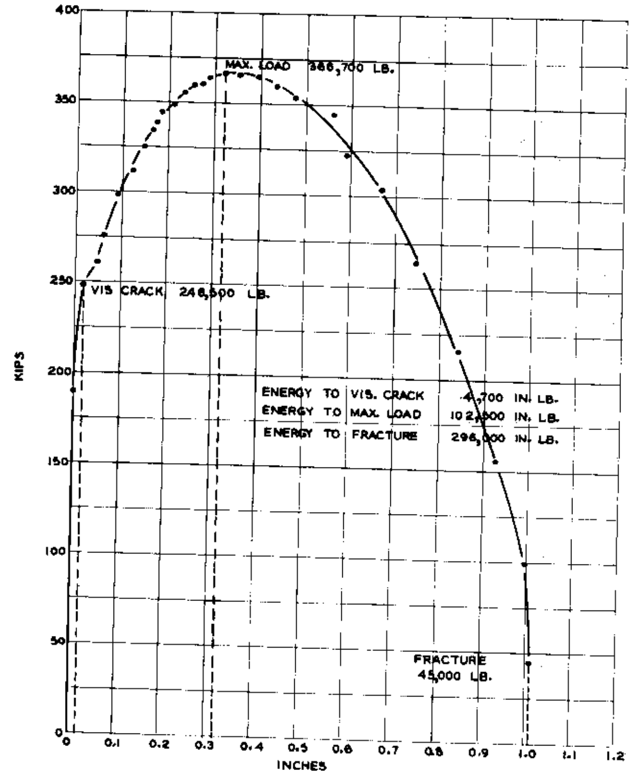


FIG. 10-S12

LOAD vs ELONGATION

S-12-12

TEMP. 14.5 F 100% SHEAR

SWARTHMORE COLLEGE

9-27-49

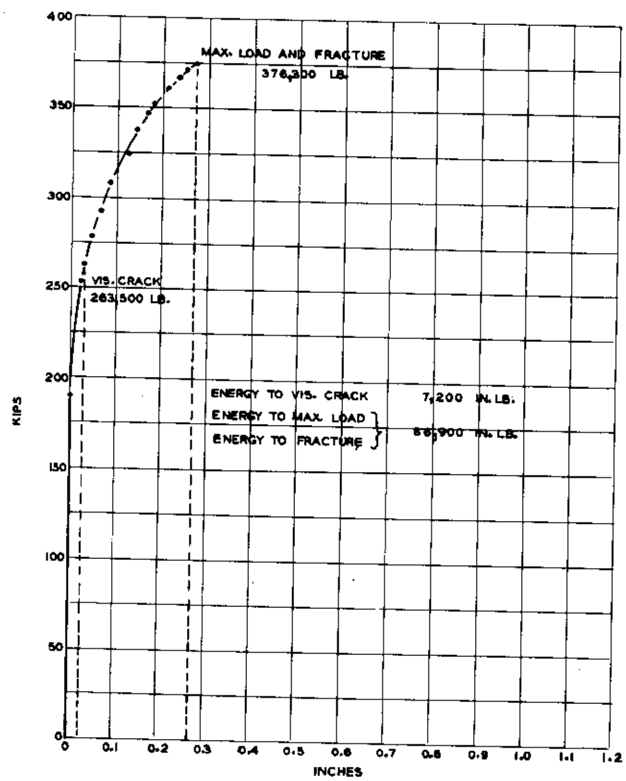


FIG. 11-S12

LOAD vs ELONGATION

S-12-14

TEMP. -30°F 8% SHEAR

SWARTHMORE COLLEGE

9-27-49

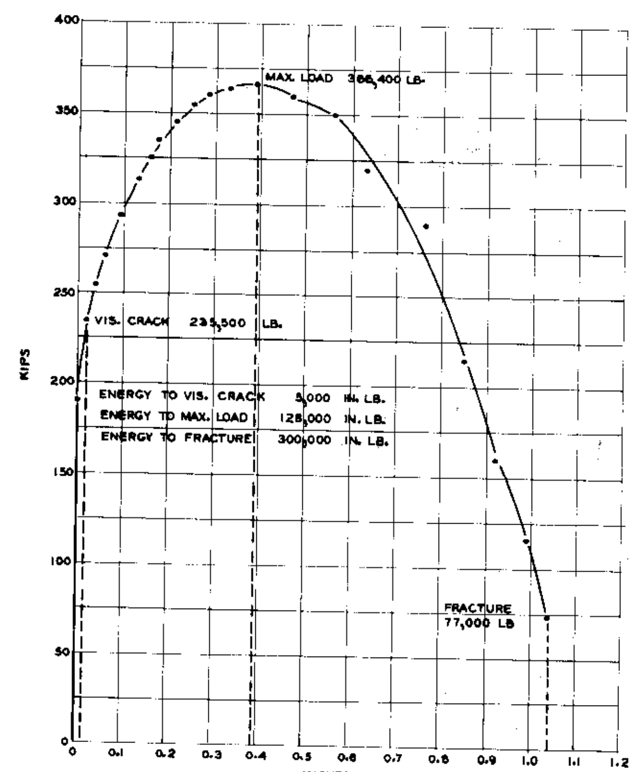


FIG. 12-S12

LOAD vs ELONGATION

S-12-15

TEMP. 30°F 100% SHEAR

SWARTHMORE COLLEGE

9-27-49

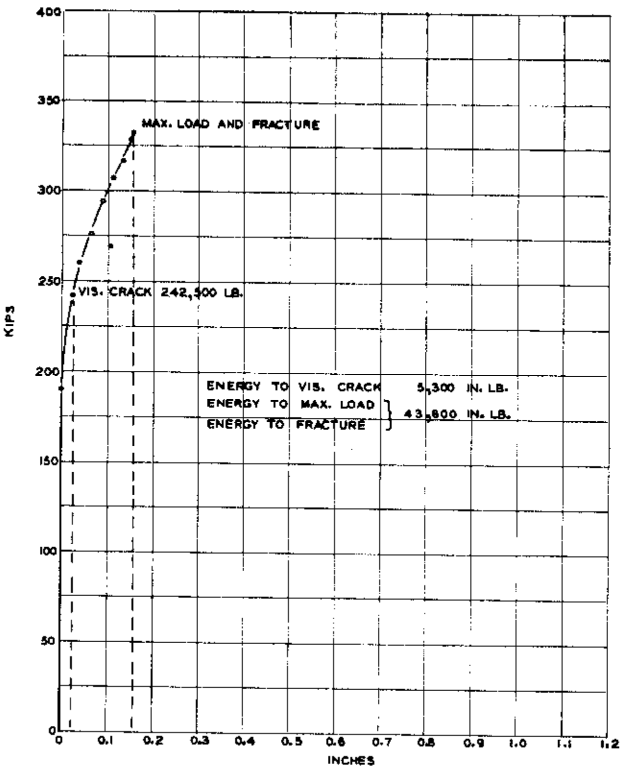


FIG. 1-S22

LOAD vs ELONGATION

S-22-1

TEMP. 40°F 0% SHEAR

SWARTHMORE COLLEGE

9-27-49

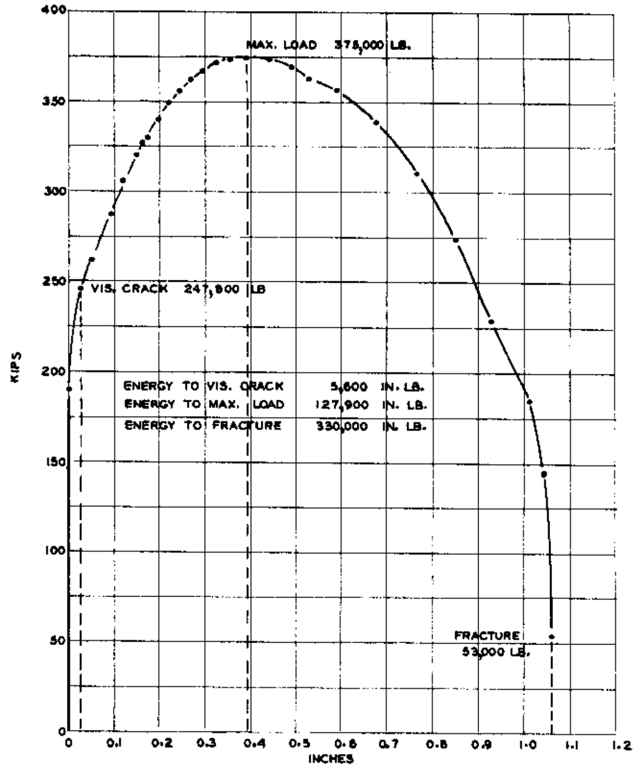


FIG. 2-S22

LOAD vs ELONGATION

S-22-3

TEMP. 72°F 100% SHEAR

SWARTHMORE COLLEGE

9-28-49

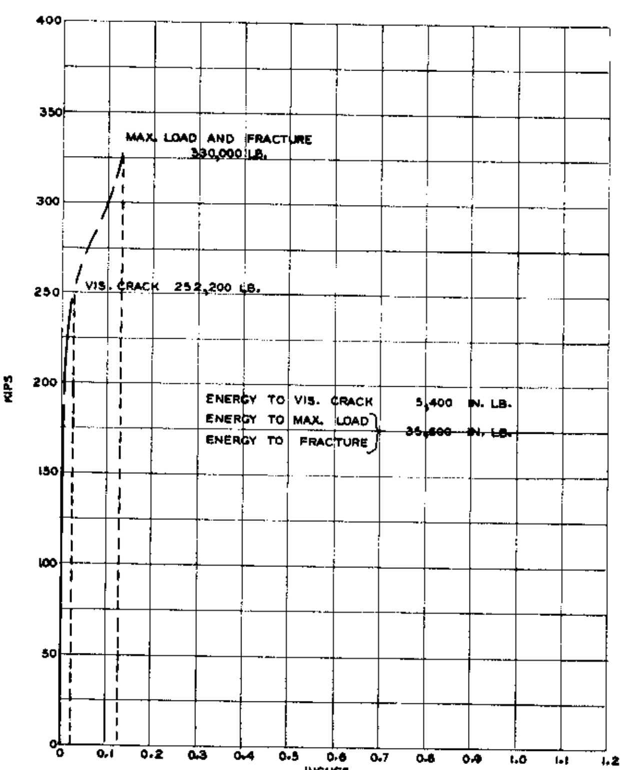


FIG. 3-S22

LOAD vs ELONGATION

S-22-7

TEMP. 50°F 0% SHEAR

SWARTHMORE COLLEGE

9-28-49

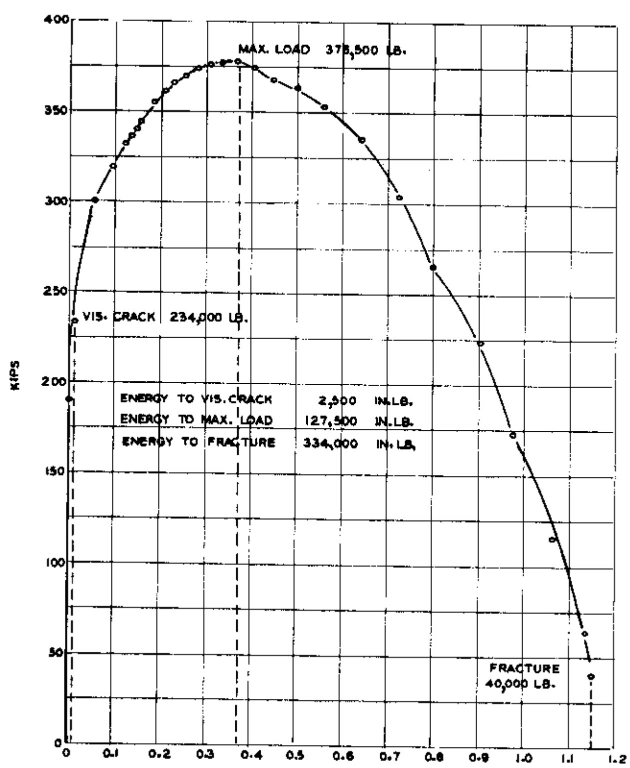


FIG. 4-S22

LOAD vs ELONGATION

S-22-8

TEMP. 60°F 100% SHEAR

SWARTHMORE COLLEGE

9-28-49

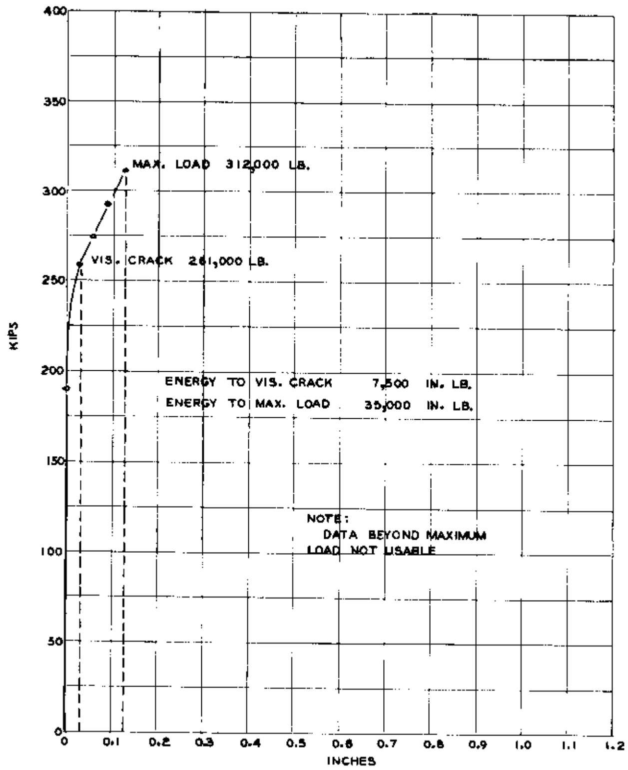


FIG.5–S22

LOAD vs ELONGATION

S-22-9

TEMP. 54°F 22% SHEAR
SWARTHMORE COLLEGE
9-28-49

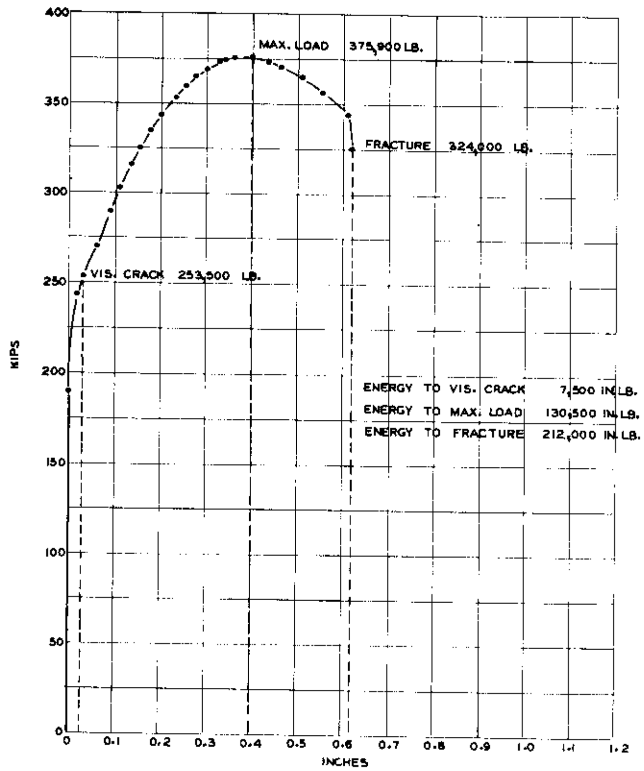


FIG. 6–S22

LOAD vs ELONGATION

S-22-10

TEMP. 60°F 35% SHEAR
SWARTHMORE COLLEGE
9-29-49

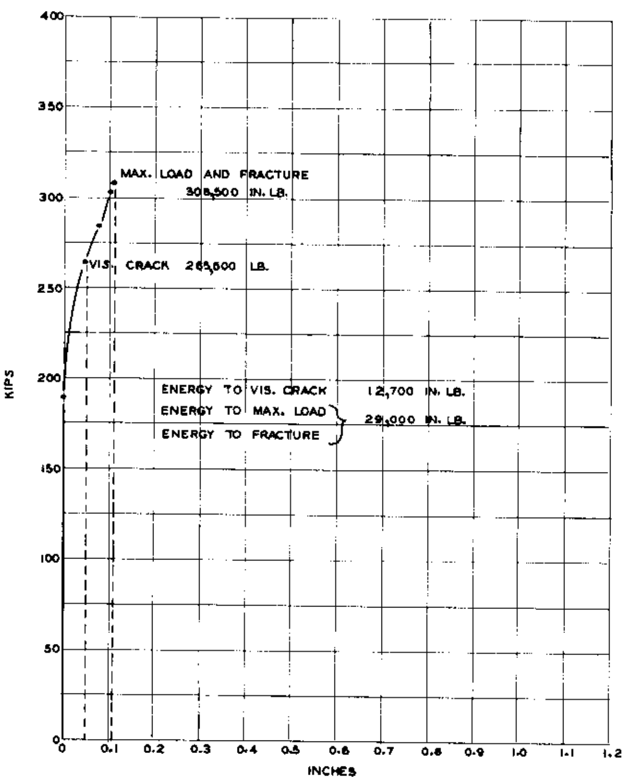


FIG 7–S22

LOAD vs ELONGATION

S-22-15

TEMP. 20 F 5% SHEAR
SWARTHMORE COLLEGE
9-29-49