INVESTIGATION OF MULTI PLATES TESTED AS COLUMNS

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Richard Porter Gillespie

1950

This is to certify that the

thesis entitled

INVESTIGATION OF MULTI PLATES
TESTED AS COLUMNS

presented by

Richard Porter Gillespie

has been accepted towards fulfillment of the requirements for

M.S. **degree in** Civil Engineering

C. A. Miller

Major professor

Date 3-10-'50

O-169

INVESTIGATION OF MULTI PLATES TESTED AS COLUMNS

by

Richard Porter Gillespie

A THESIS

Submitted to the graduate school of Michigan State College of Agriculture and Applied Science in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

Department of Civil Engineering

1950

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ACKNOWLEDGMENT

I wish to thank Professor C. A. Miller for his helpful comments and guidance in the preparation of this thesis. I want to express my thanks to the Bridge Division of the Michigan State Highway Department and the Research Division of the Michigan State Highway Department for the use of their material, time and equipment.

INVESTIGATION OF MULTI PLATES TESTED AS COLUMNS

Introduction

The practical success attained by corrugated pipe under a wide variety of conditions— its resistance to cracking and disjointing under unfavorable loading and foundation conditions, its immunity to damage by frost, fire, and by termites and other borers, its comparatively light weight, ease of handling, hauling and installation, its freedom from maintenance, and its adaptability to extension and re-use— led to its employment in larger sizes than were first contemplated.

Natural Limits of Standard Corrugated Pipe

The qualities that made corrugated pipe so much in demand for small openings were also in demand for waterways of from 50 to 60 square feet in cross section. Many small bridges have been replaced by Standard Corrugated Pipe of from 8' to 9' in diameter, but because of shipping difficulties, larger diameter pipe can not be used in this form.

Development of Multi Plate

In 1931 plates of larger corrugations, 6 inches wide by $1\frac{1}{2}$ inches deep, made from metal ranging up to No. 1 gauge, $\frac{9}{32}$ inch thickness, as compared with the former limit of No. 8 gauge, $\frac{11}{64}$ inch thickness, were developed. These

plates are corrugated, curved and galvanized at the factory, and shipped in knock down form for bolted assembly in the field, in pipe or arch form. These multi plates have been widely employed on highways, railways and in cities, and they have in many cities taken the place of bridges and sewers of much more expensive construction.

In 1944 the multi plate corrugation was improved by making it 6 inches wide by $1\frac{3}{4}$ inches deep and of an entirely different shape. This new type corrugation proved to be more efficient and increased the strength approximately 40 per cent with the use of only 10 per cent more metal in any given gauge.

Description of Plates

Improved multi plate sections made by Armco Company are structural units of corrugated metal with corrugations 6 inches wide and $1\frac{3}{4}$ inches deep, running at right angles to the length of the sheet. They are available in No. 1 gauge ($\frac{9"}{32}$), No. 3 ($\frac{1}{4}"$), No. 5 ($\frac{7"}{32}$), No. 7 ($\frac{3"}{16}$), No. 8 ($\frac{11"}{69}$), No. 10 ($\frac{9"}{64}$), and No. 12 ($\frac{7"}{64}$) gauge. Plates are made in three widths, 9 pi, 15 pi, and 21 pi. The covering width of each sheet is designated by its number of pi; that is, 9 pi is 9 x 3.14 inches wide. These improved plates are made in two lengths, 6 feet and 8 feet. They are punched along each edge and end.

Plates are furnished flat or curved to any radius of 30 inches or longer.

Standard and Special Punching

The standard multi plate is punched with one bolt hole in each crest and valley in staggered rows 2 inches apart on each longitudinal edge of the plate. There are also additional holes along each end, corrugation punched at 3 pi inch intervals.

For special cases such as extremely high fills over a multi plate structure, it is possible to obtain the plates with additional bolt holes along each edge of the plate, thus making six or eight instead of four bolts per foot.

It is also possible to obtain the plates with bolt holes in only the inside valleys, thus eliminating nuts or bolt heads projecting inside of the inside crest where that is objectionable.

Additional holes in the end corrugations may be obtained for watertight construction or other special purposes.

Specially punched plates are not carried in stock and may cause some delay as compared with standard plates.

Comparison of Three Manufacturer's Plates

The three leading manufacturers of multi plates, are Armco Products Company of Middletown, Ohio; Republic Steel Corporation of Cleveland, Ohio; and United Steel Fabricators Inc. of Wooster, Ohio. The Armco Products Company will here-

after be referred to as Armco or A. on graphs and pictures to avoid crowding of material. The Republic Steel Corporation will be referred to as Republic or R. hereafter, and the United Steel Fabricators Inc. will be referred to as United or U. hereafter.

Difference of Pitch and Depth of Corrugation

Armco uses a 6 inch pitch and a $1\frac{3}{4}$ inch depth of corrugation. Republic uses a 6 inch pitch and a 2 inch depth of corrugation. United uses a 6 inch pitch and a 2 inch depth of corrugation.

Difference of Type of Corrugation

Armco uses a sine wave type of corrugation. Republic uses a sine wave type of corrugation. United uses a box type of corrugation.

Difference of Jointing (Butt or lap)

Armco uses a lap type of joint. Republic uses a lap type of joint. United uses a butt type of joint.

Report

The Michigan State Highway Department and The Public Roads Administration in conjunction with Armco, Republic and United Companies, furnished the material and place

where these tests could be run. The tests were run at the Michigan State Highway's Testing and Research Laboratory at Michigan State College in East Lansing, Michigan. The multi plates were furnished by Armco, Republic and United Companies.

These tests were run to see if a standard type plate as to gauge, pitch and depth of corrugation could be put out by all three of the multi plate companies. The Michigan State Highway Department and The Public Roads Administration also want to find out if a standard type of joint can be used (either butt or lap).

REPORT ON COLUMN TEST NO. 3

For the column test on 150" radius plates, each manufacturer sent 3 plates which are lettered X, Y, and Z. Two of the plates, (X and Y), will be used to find an average value of load and displacement, and the third plate, (Z), will be used in case a mistake was made in testing either plate X or Y. If the tests X and Y compare favorably, then test Z may be used to find additional information on what ever kind of test you care to run.

The multi plates from each manufacturer are cut to a length of $52\frac{3}{4}$ inches and a width of 22 inches, for this test. The bolted columns are of the same dimensions, and the bolted section is in the middle of the test plate.

The guages used in this test are No. 1, o.2690 inches

thick; No. 7, 0.1793 inches thick; and No. 12, 0.1046 inches thick. The total number of plates for this test is 3 tests x 6 plates x 3 manufacturers, or 54 plates to test. In this report only 18 graphs were drawn, one from each test.

A short form type of designation will be used on these tests for ease in drawing graphs for each type of multi plate.

Example: A3Y7P stands for Armco Manufacturer test No. 3, plate Y of X, Y, Z, and P stands for unbolted plate. An S will be used in place of a P for the bolted plates in the designation numbers.

DESIGN OF TEST PRESS

The testing of multi plates of 150" radius presented the problem of designing a press of 150,000# capacity. We had on hand a Dake hydraulic testing jack with a capacity of 120,000#, and we built our press to conform to this load. The loading head was mounted between two reinforced angles, see Fig. 1, and the sides were made of 7 inch channels. The base was made like a ribbed box and this box was filled with concrete (see Fig. 2). The frame was jacked in place from the ceiling and shims were put in so that the machine would be tight under load. A steel plate was put on the bottom of the machine for bearing load, and a raised platform was built so that the 52¾" plate would fit in the machine and leave enough room for a 6 inch travel of the piston in the hydraulic pump. The top and bottom of the multi plate is fitted with adjustable angles which have half rounds welded on to them, see Fig. 3. These rounds fit into flat pieces of metal which are grooved out. One piece is fastened at the base, see Fig. 5, and the other piece is fastened to the loading head, (see Fig. 4). The loading head is built up with flat stock, and four edges are smoothed off for rollers to be put on to take care of side thrust (see Fig. 4), which would otherwise bend the piston of the hydraulic pump when the load is applied. A dynometer ring, called K-1 which is calibrated to 50,000# see Fig. 6, and a dynometer ring M-1, which is calibrated to 150,000#, (see Fig. 7), are used in these tests. They

have a hole in the bottom of their base plates, which fits over a ball which is set in a moveable plate on the loading head, see Fig. 4. The rollers move on flat plates which are recessed in two 9 inch channels (see Fig. 5).

Straps are placed on each side of the rollers and finger tightened for light guage plates and wrench tightened for heavy guage plates. This is to keep the channels from spreading. The head has a tendency to turn and follow the curve of the plate, therefore, the straps are needed (see Fig. 5). For raising and lowering the loading head, hooks were placed on each end of the loading head, and a pulley system was used to raise and lower the head. The vertical displacement was measured by two 3 inch displacement dials, and the horizontal displacement was measured by two 1 inch displacement dials, which were reset for each inch displacement, see (Fig. 5). The concrete blocks were from another test, but they were left as guards in case something happened during a test.

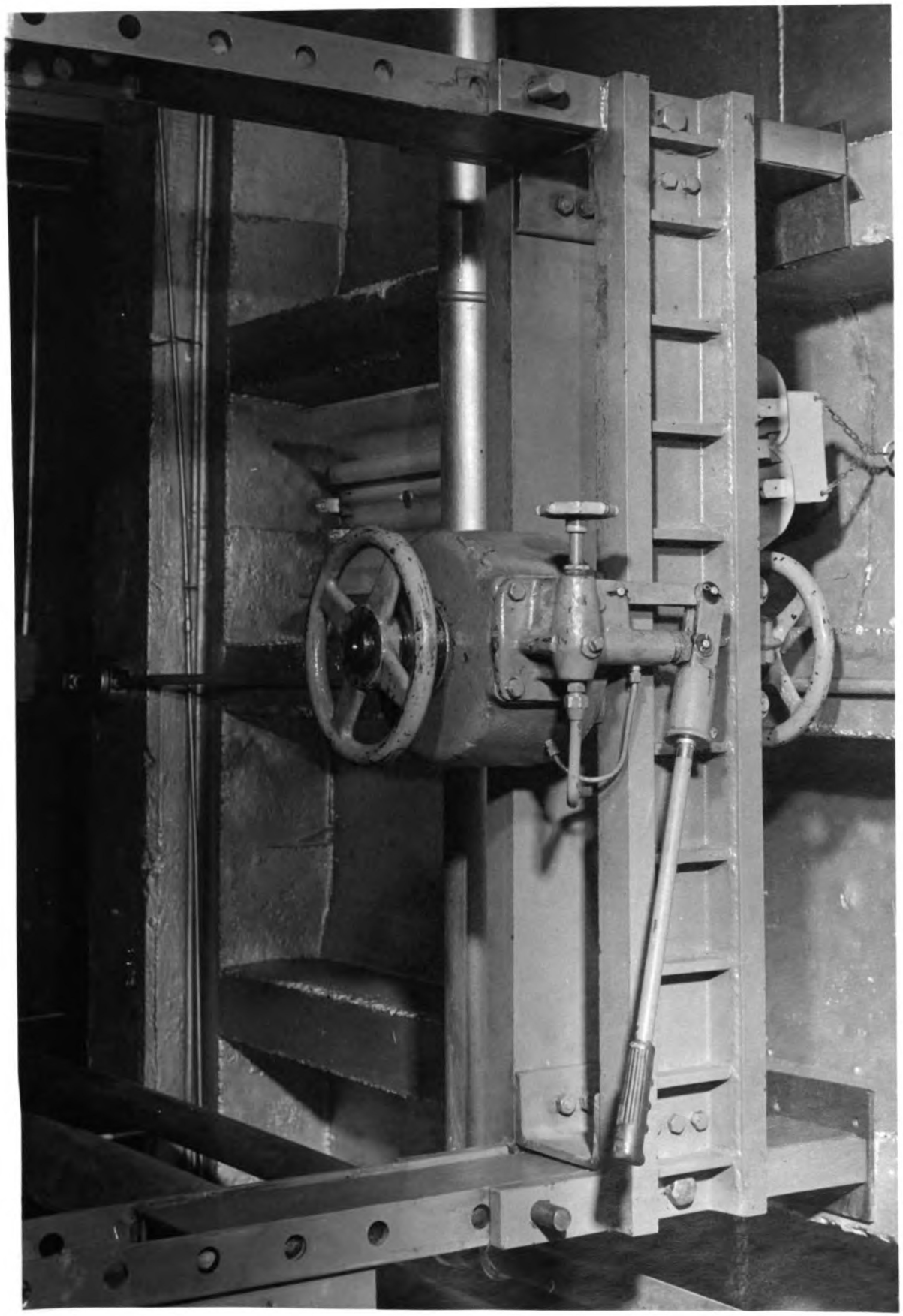

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

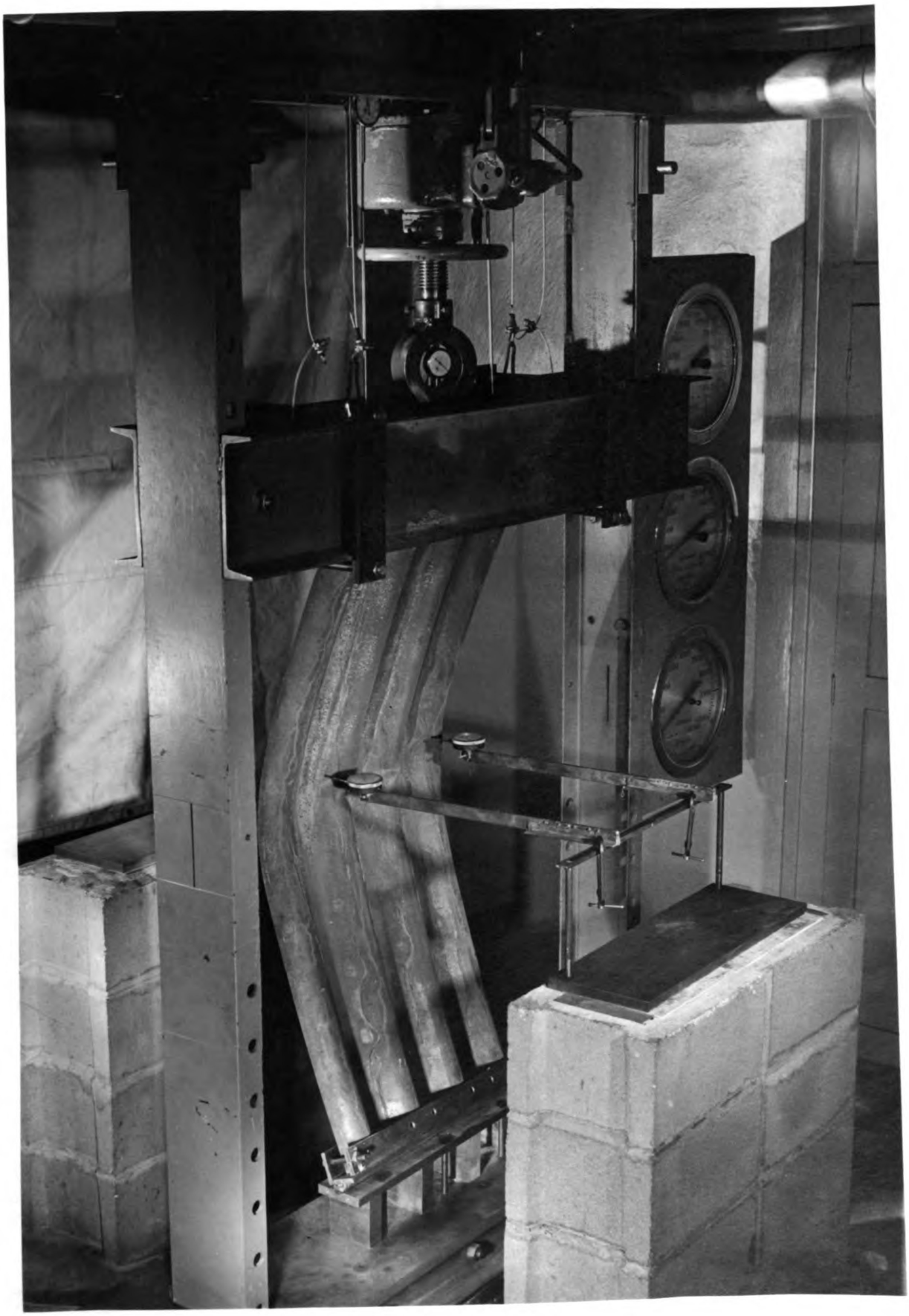

Fig. 5.

DYNOMETER RINGS K-1 AND M-1

Two dynometer rings, K-1 and M-1, were calibrated for use in this test of multi plates, used as columns.

For the ring K-1, an initial load of 2,000# was put on the ring to take out any slack in the machine, and then it was loaded to 50,000# in equal loads of 1,000#. The initial curve was then changed to the corrected curve, which was used to change dial readings to load in pounds readings. See Fig. 6 page 16

For the ring M-1, an initial load of 10,000# was put on the ring to take out any slack in the machine, and then it was loaded to 150,000# in equal loads of 5,000#. The initial curve was then changed to the corrected curve, which was used to change dial readings to load in pounds readings, see Fig. 7 page 17

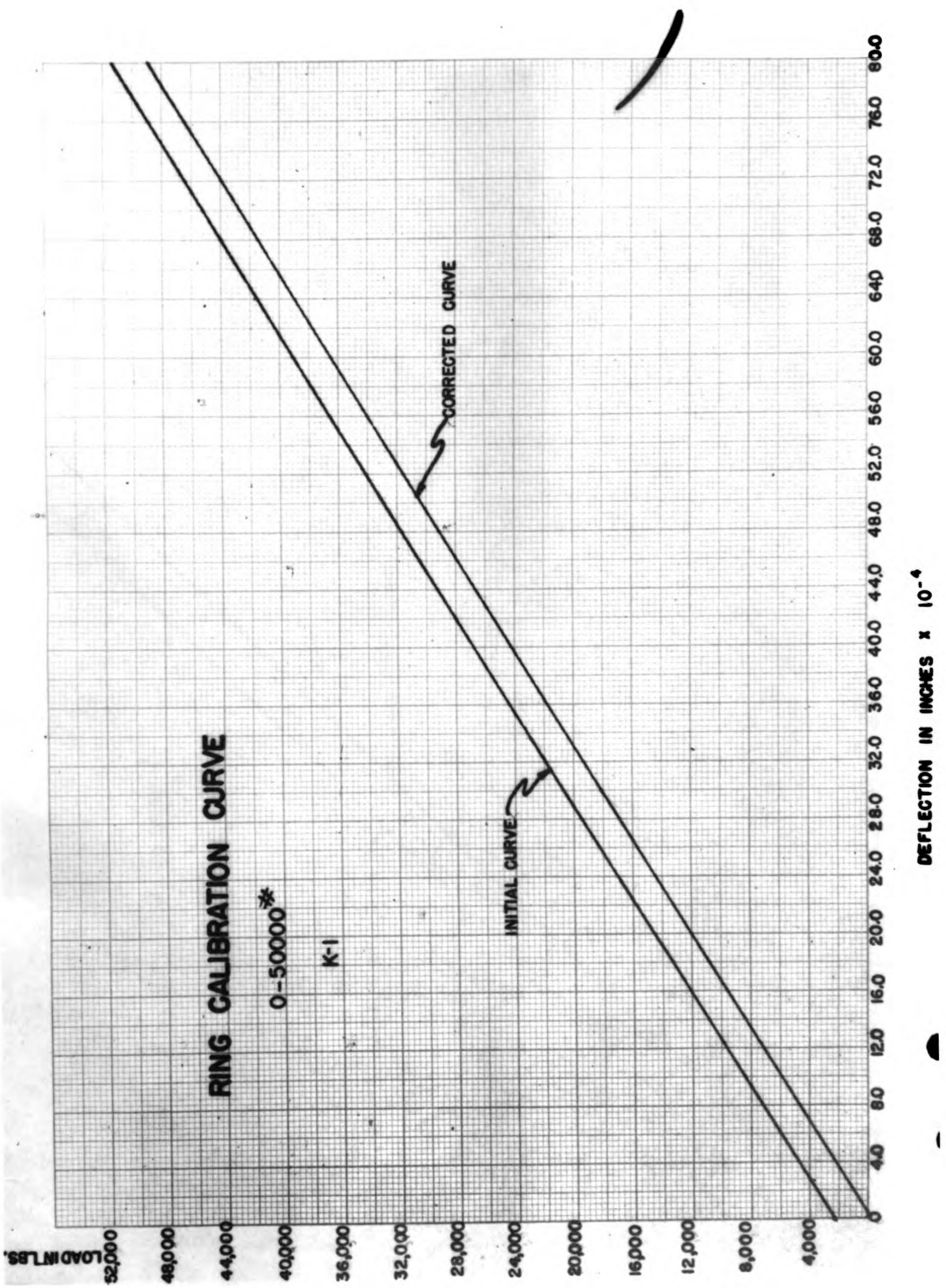
RING CALIBRATION CURVE
0-50000*
K-1
INITIAL CURVE
CORRECTED CURVE
LOAD IN LBS.
52,000
48,000
44,000
40,000
36,000
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000
0
4.0
8.0
12.0
16.0
20.0
24.0
28.0
32.0
36.0
40.0
44.0
48.0
52.0
56.0
60.0
64.0
68.0
72.0
76.0
80.0
DEFLECTION IN INCHES x 10⁻⁴

Fig. 6.

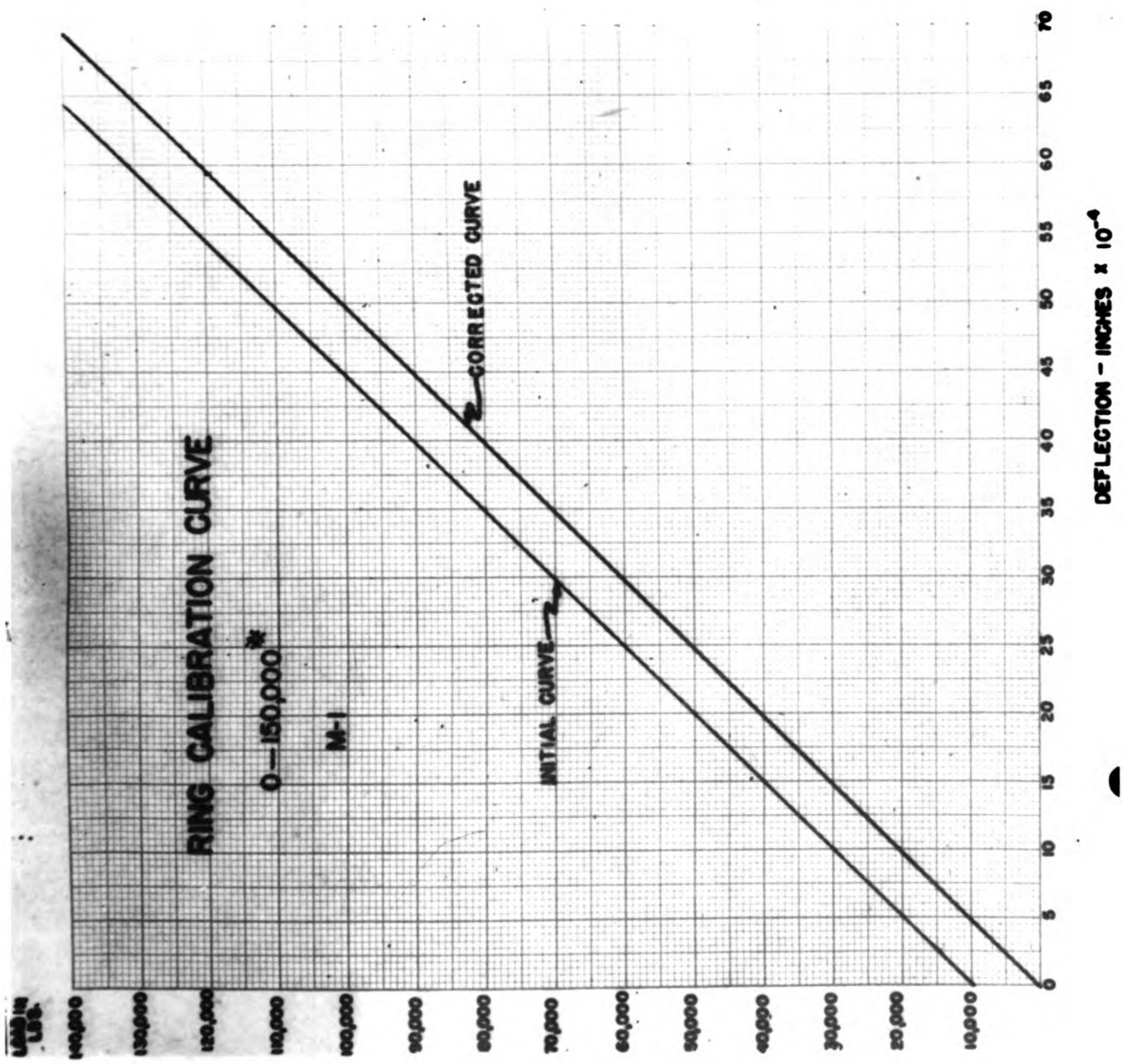
RING CALIBRATION CURVE
0—150,000#
M-1
CORRECTED CURVE
INITIAL CURVE
LOAD in LBS.
DEFLECTION - INCHES x 10⁻⁴

Fig. 7.

The following are the factors to be considered in this report to check on the use of a standard type multi plate:

1. Size and type of corrugation.
2. Gauge of metal.
3. Method of jointing (butt or lap).
4. Tensile stresses in bolts.
5. Torque resistance of bolts.
6. Single versus double bolted joints.

Presentation of data:

1. Size and type of corrugations: A series of 18 graphs are used in this report to show the displacement plotted against load for the vertical and horizontal direction. Six cross graphs are used to show the difference between the different manufacturers plain and bolted plates for the No. 1 guage, No. 7 guage, and No. 12 guage plates.

2. Guage of metal: A series of 6 graphs will be used to compare the different guages of each manufacturer. Three graphs will be used for the plain plates and 3 graphs will be used for the bolted plates. The graphs will be used to compare the No. 1 guage, No. 7 guage, and the No. 12 guage plates of the same manufacturer with each other.

3. Method of jointing (butt or lap): This data has already been shown graphically in presenting items (1.) and (2.). The method of presentation would be in tabular form, showing the % efficiency of each type of bolted joint as compared with a plain specimen of the same thickness.

4. Tensile stresses in bolts: In direct tension where the pull is applied to the head of the bolt and to the nut, the average tensile strength per bolt is approximately 27,000#.

5. Torque resistance of bolts: A torque of 200 ft. lbs. has been used during this test to insure a tight fit of the joints. The overall test was primarily run to test the plates and not the joints. Under actual field conditions it will be found that different men of different strength will be tightening the bolts, and it is assumed that the bolt tightness will vary between 100 ft. lbs. torque to 200 ft. lbs. torque.

A torque wrench of special design rated up to 1200 ft. lbs. torque was used to check the tightness of the bolts in this test. A test was run on Armco, Republic and United bolts to see at what ft. # torque they would fail. At a torque of 700 ft. # none of the bolts failed, so the tests were discontinued and the bolts passed as adequate.

6. Single versus double bolted joints: Failure was found to occur outside of the limits of the joint. When the bolts are strong enough to hold the joint together it doesn't matter if the plates are double bolted or if the plates are drilled for double bolting and no extra bolts put in the holes. The load at failure will be approximately the same as for single bolting. This test was run on Armco and Republic lap joints. United's butt joint could not be tested for double bolting.

Data sheet for Armco plain and bolted 12 gauge plates with picture of the two plates taken after failure has occurred:

Elastic Limit at 15,000# for plain 12 gauge plate, (see Fig. 8).

Elastic Limit at 15,200# for bolted 12 gauge plate, (see Fig. 10).

% efficiency of bolted specimen compared with plain specimen taken as the standard:

$$\frac{15,200}{15,000} \times 100 = 1.013\ \%$$

Failure of plain (see Fig. 9) and bolted plates (see Fig. 11).

Spreading, crimping and buckling at the center for plain 12 gauge plate.

Spreading, failure of the plate below the bolted joint for bolted 12 gauge plates.

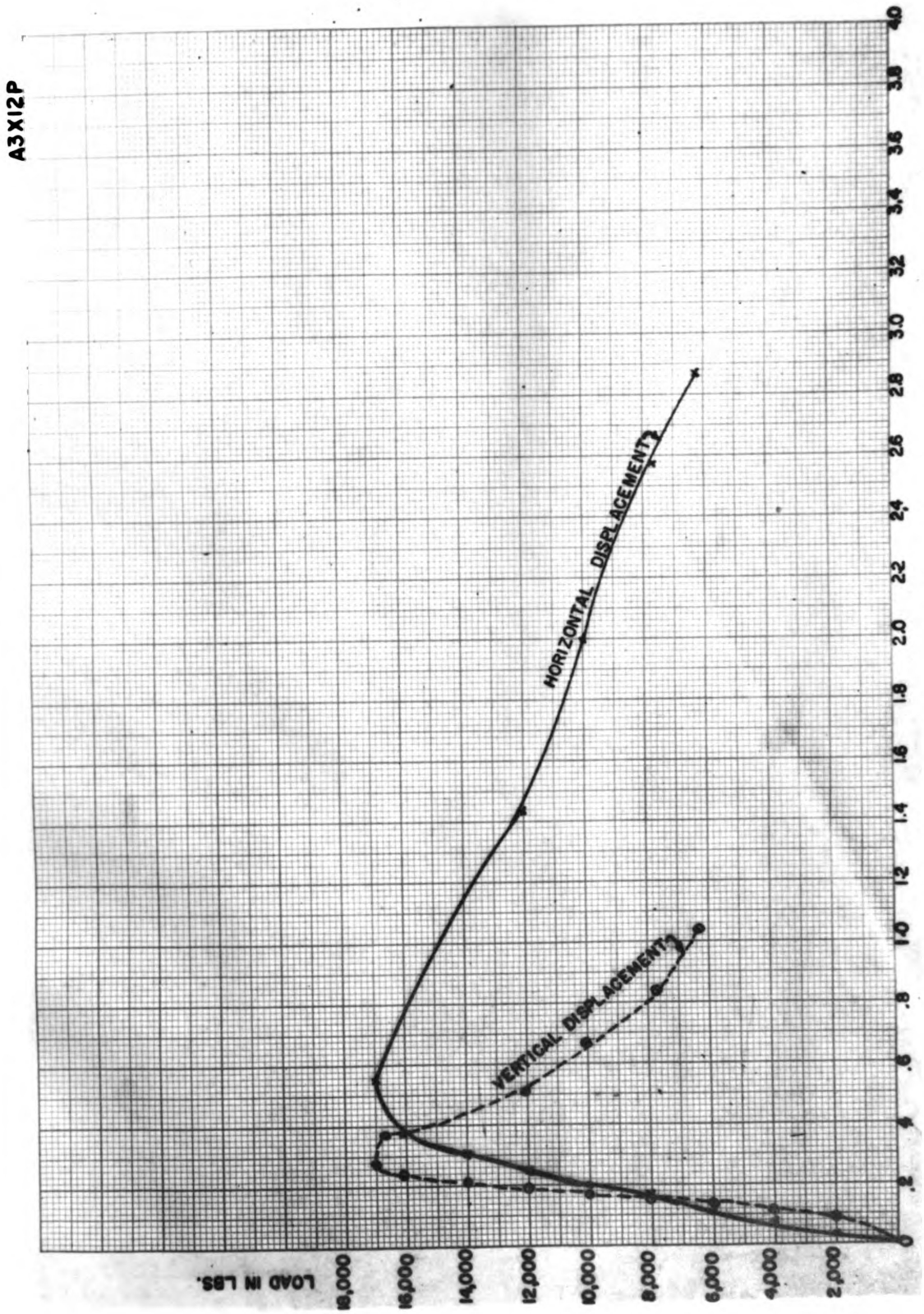
A3X12P
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT
LOAD IN LBS.
DEFLECTION IN INCHES
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0

Fig. 8.

Fig. 9.

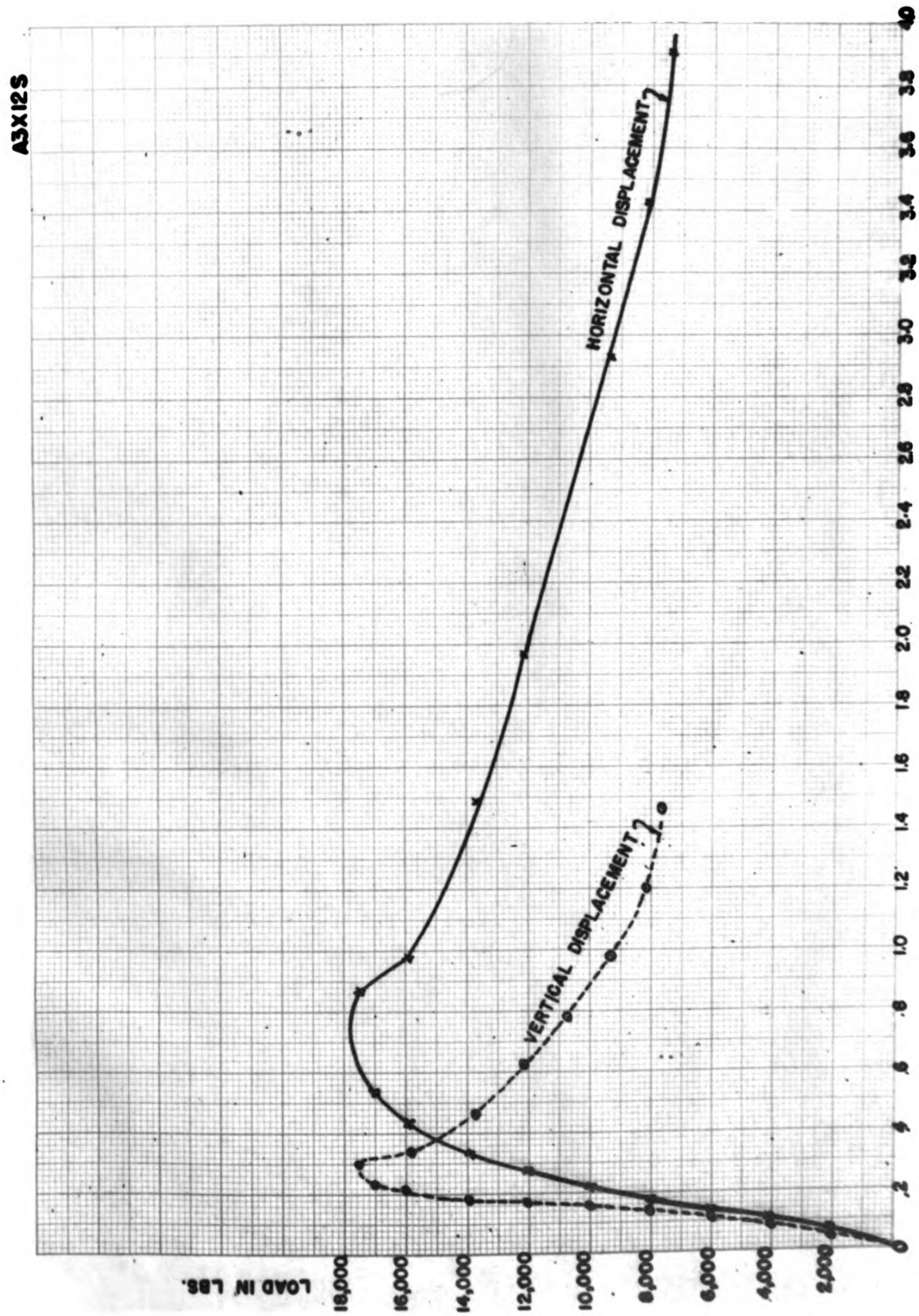
A3X12S
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT
LOAD IN LBS.
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
DISPLACEMENT IN INCHES

Fig. 10.

Fig. 11.

Data sheet for Armco plain and bolted 7 gauge plates with pictures of the two plates taken after failure has occurred.

Elastic Limit at 37,000# for plain 7 gauge plate, (see Fig. 12).

Elastic Limit at 29,000# for bolted 7 gauge plate, (see Fig. 14).

% efficiency of bolted specimen compared with plain specimen taken as the standard:

$$\frac{29,000}{37,000} \times 100 = 78.4\ \%$$

Failure of plain (see Fig. 13) and bolted plates (see Fig. 15).

Spreading at the center for plain 7 gauge plates.

Spreading at the center for bolted 7 gauge plates.

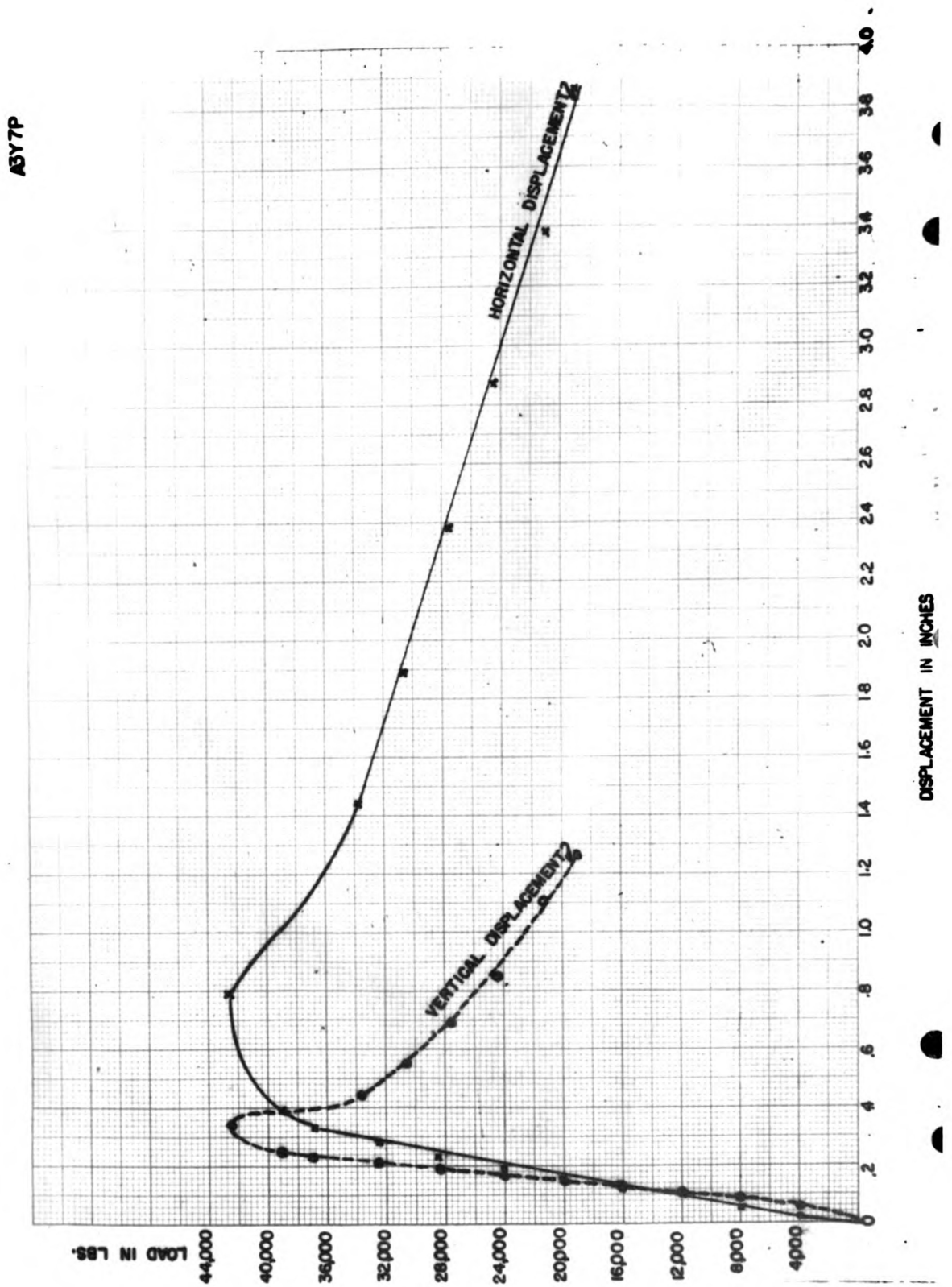
ASY7P
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT
LOAD IN LBS.
44,000
40,000
36,000
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
DISPLACEMENT IN INCHES

Fig. 12.

Fig. 13.

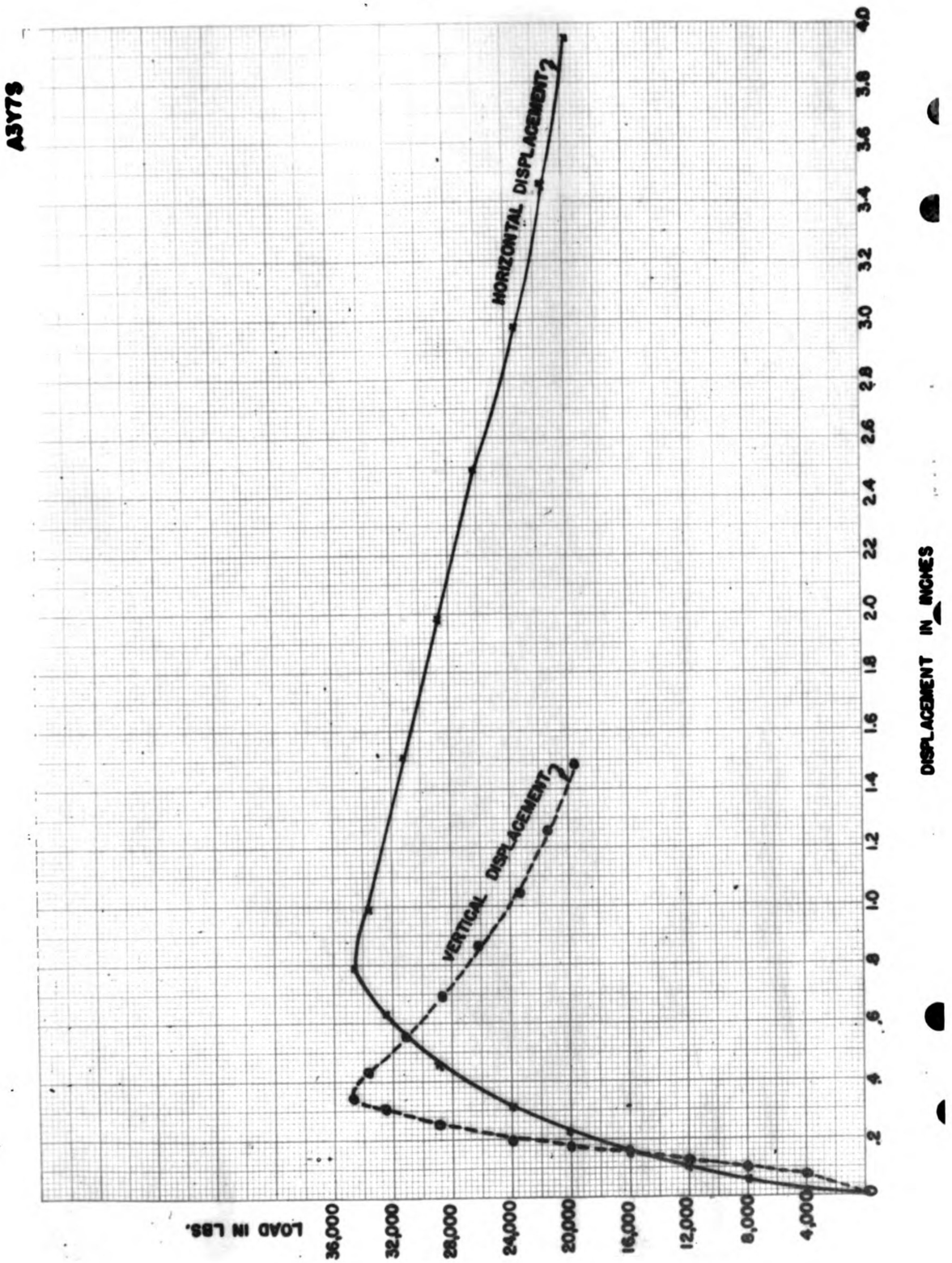
A3Y73
LOAD IN LBS.
36,000
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
DISPLACEMENT IN INCHES
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT

Fig. 14.

Fig. 15.

Data sheet for Armco plain and bolted 1 gauge plates with pictures of the two plates taken after failure has occurred:

Elastic Limit at 45,000# for plain 1 gauge plate, (see Fig. 16).

Elastic Limit at 35,000# for bolted 1 gauge plate, (see Fig. 18).

% efficiency of bolted specimen compared with plain specimen taken as the standard:

$$\frac{35,000}{45,000} \times 100 = 77.9\ \%$$

Failure of plain (see Fig. 17) and bolted plates (see Fig. 19).

Slight spreading at the center for plain 1 gauge plate.

Slight spreading at the center for bolted 1 gauge plate.

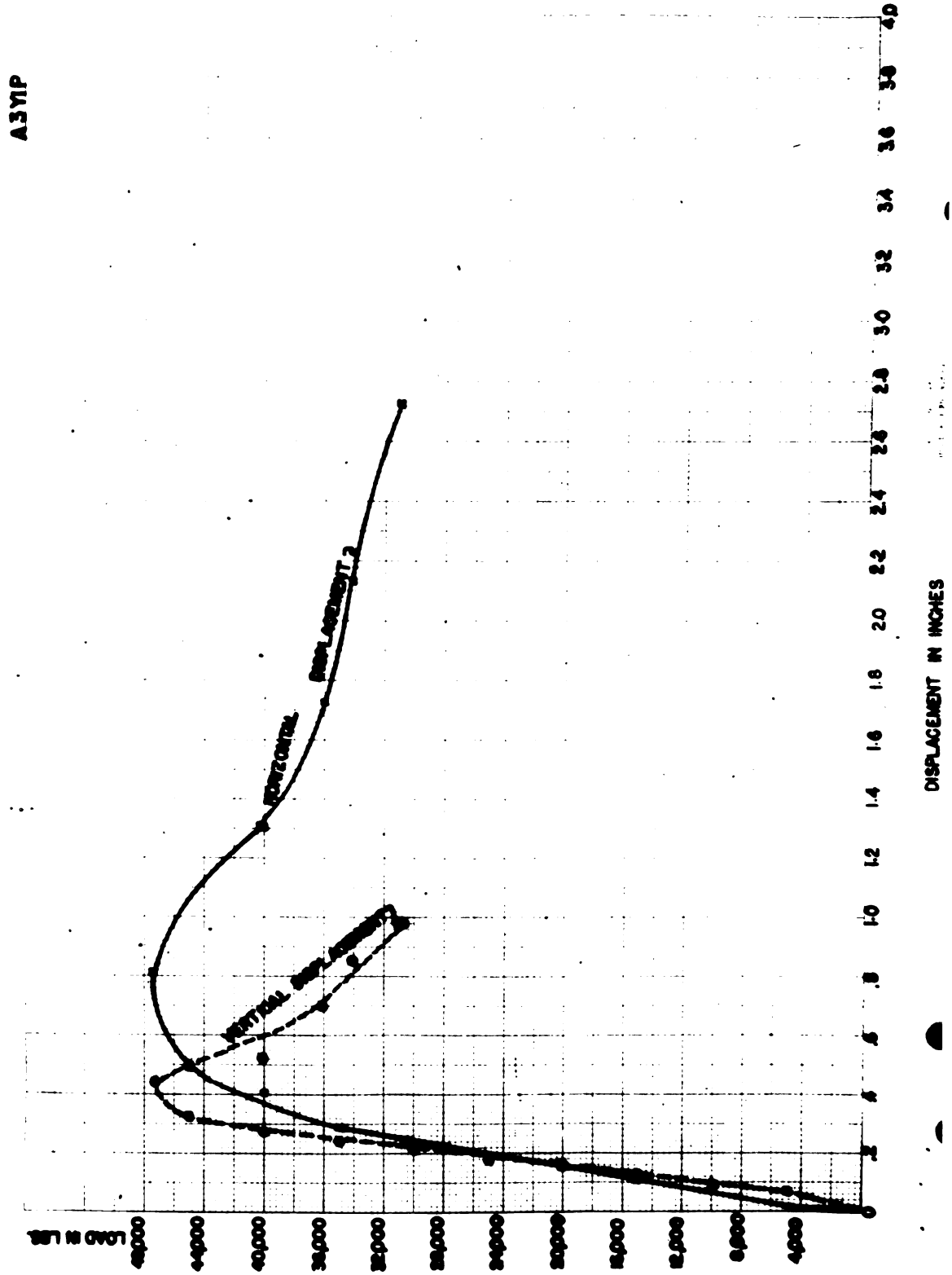
A3YP
DISPLACEMENT IN INCHES
HORIZONTAL DISPLACEMENT 2
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
40000
36000
32000
28000
24000
20000
16000
12000
8000
4000

Fig. 16.

Fig. 17.

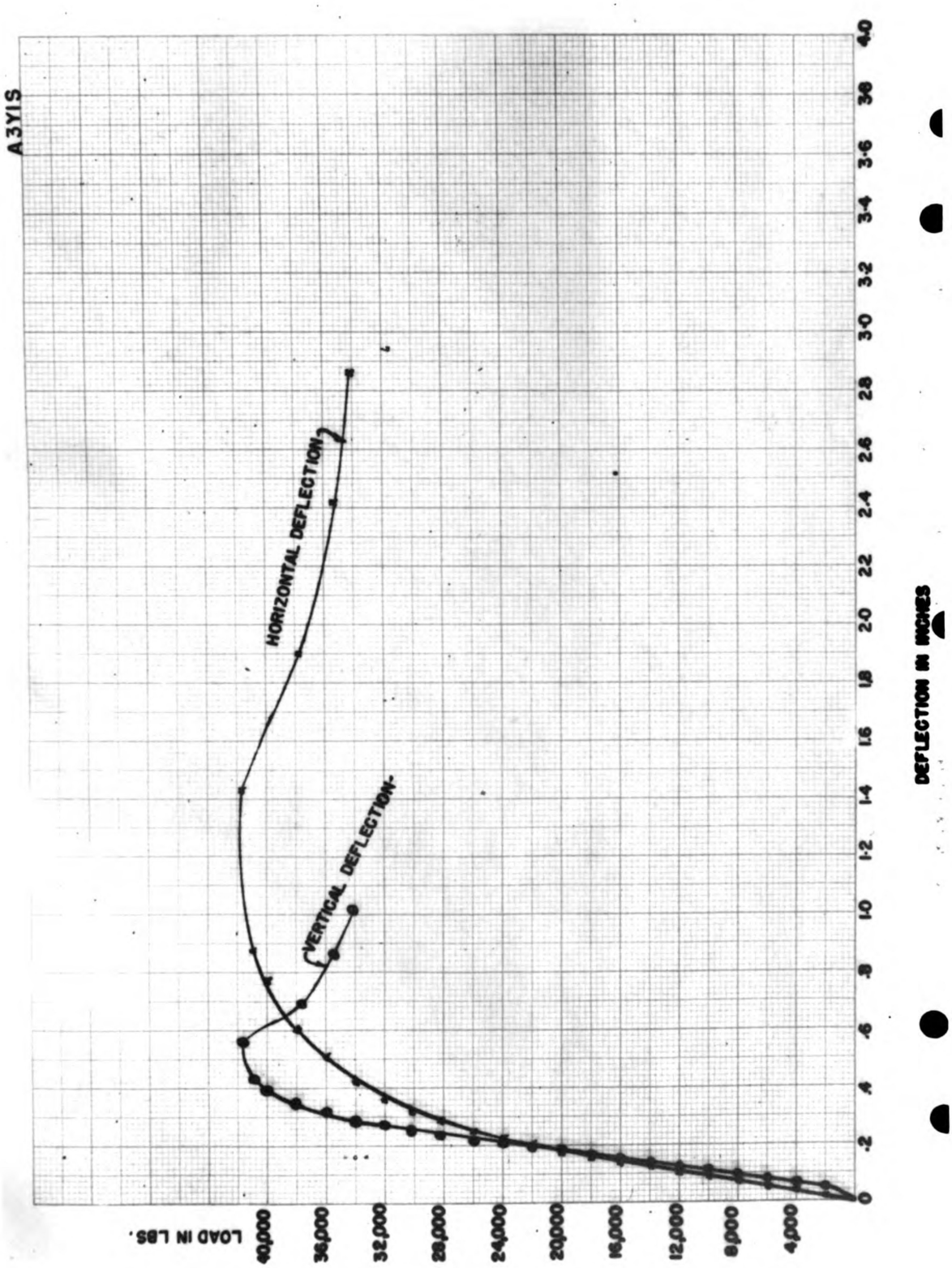
A3YIS
LOAD IN LBS.
40,000
36,000
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
DEFLECTION IN INCHES
HORIZONTAL DEFLECTION
VERTICAL DEFLECTION

Fig. 18.

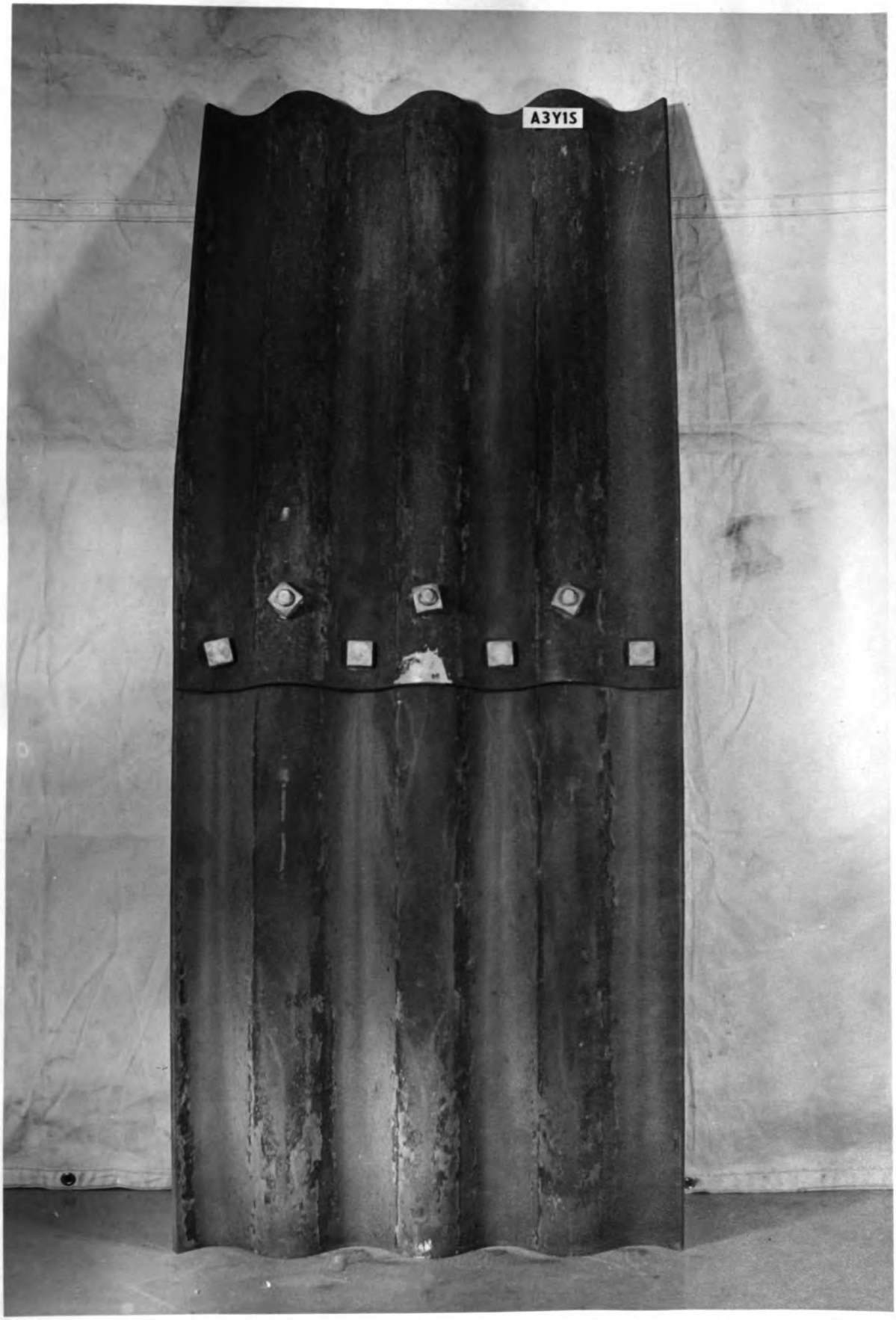

Fig. 19.

Data sheet for Republic plain and bolted 12 gauge plates with pictures of the two plates taken after failure has occurred:

Elastic Limit at 27,000# for plain 12 gauge plate, (see Fig. 20).

Elastic Limit at 23,000# for bolted 12 gauge plate, (see Fig. 22).

% efficiency of bolted specimen compared with plain specimen taken as the standard:

$$\frac{23,000}{27,000} \times 100 = 85.3\ \%$$

Failure of plain (see Fig. 21) and bolted plates (see Fig. 23).

Spreading and buckling at the center of the 12 gauge plain plate.

Spreading, buckling, and tearing of the plate through the bolt holes in the 12 gauge bolted plate.

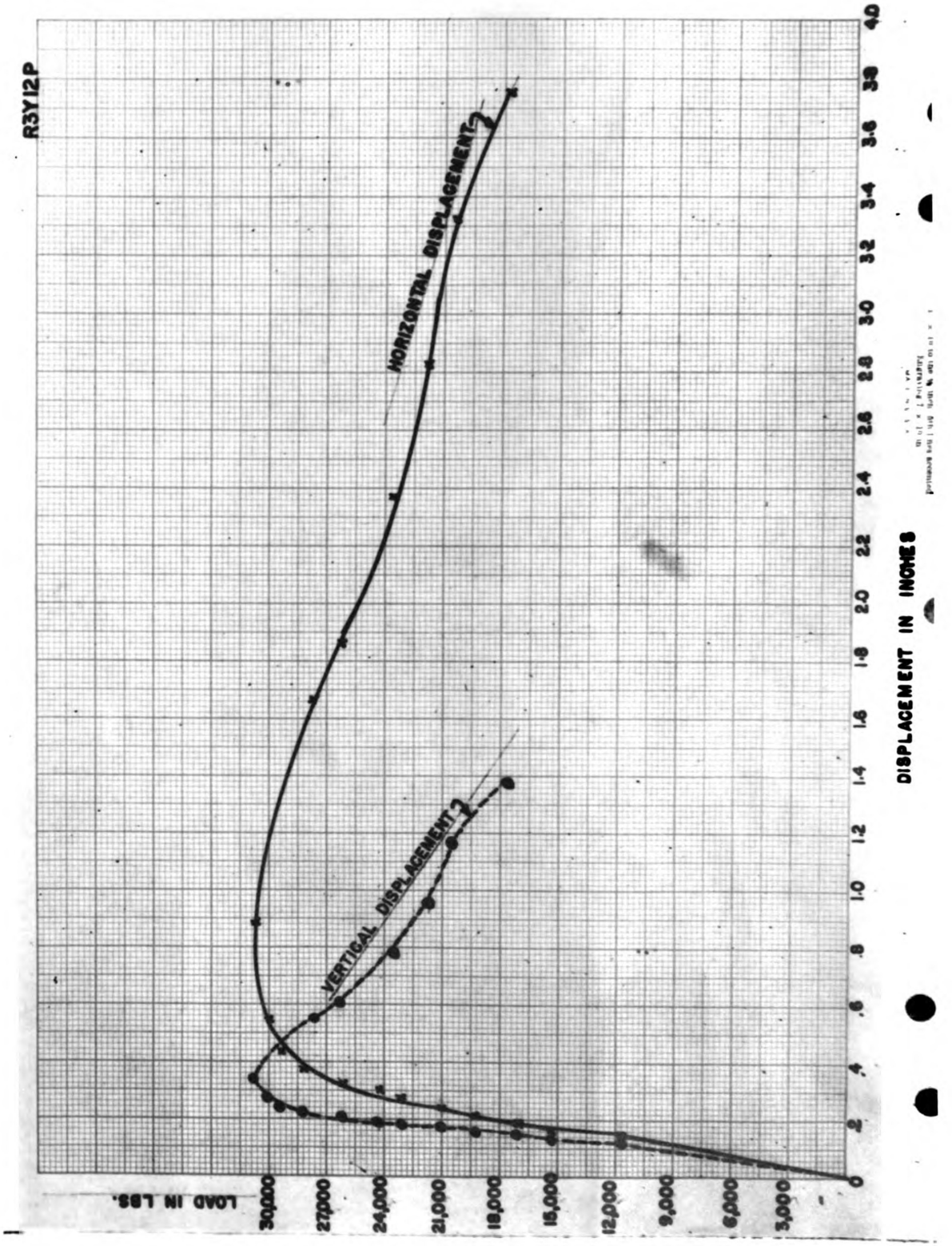
R3Y12P
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT
LOAD IN LBS.
30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
DISPLACEMENT IN INCHES
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0

Fig. 20.

Fig. 21.

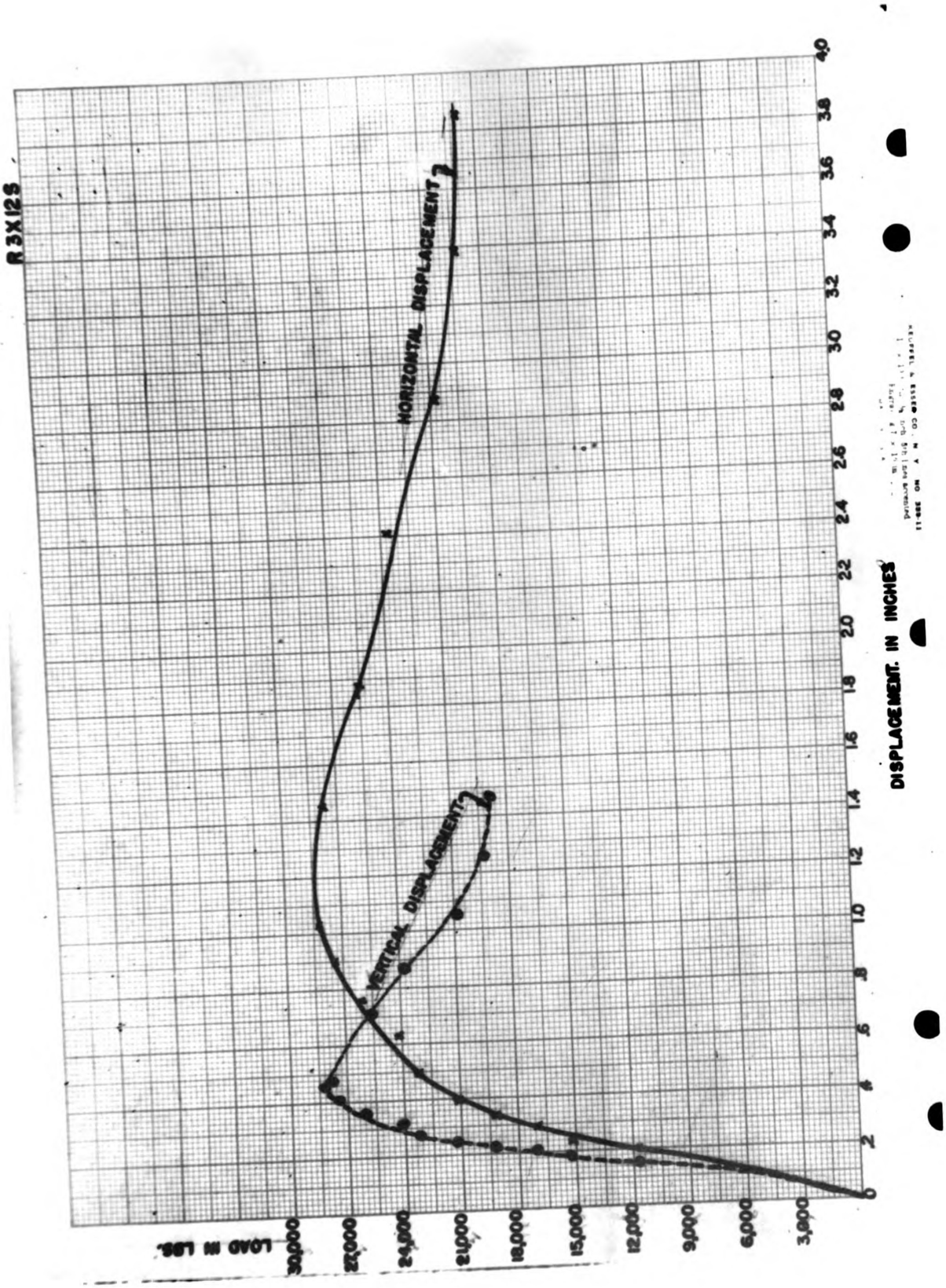
R3X12S
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT
DISPLACEMENT IN INCHES
LOAD IN LBS.
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
3,000
6,000
9,000
12,000
15,000
18,000
21,000
24,000
27,000
30,000

Fig. 22.

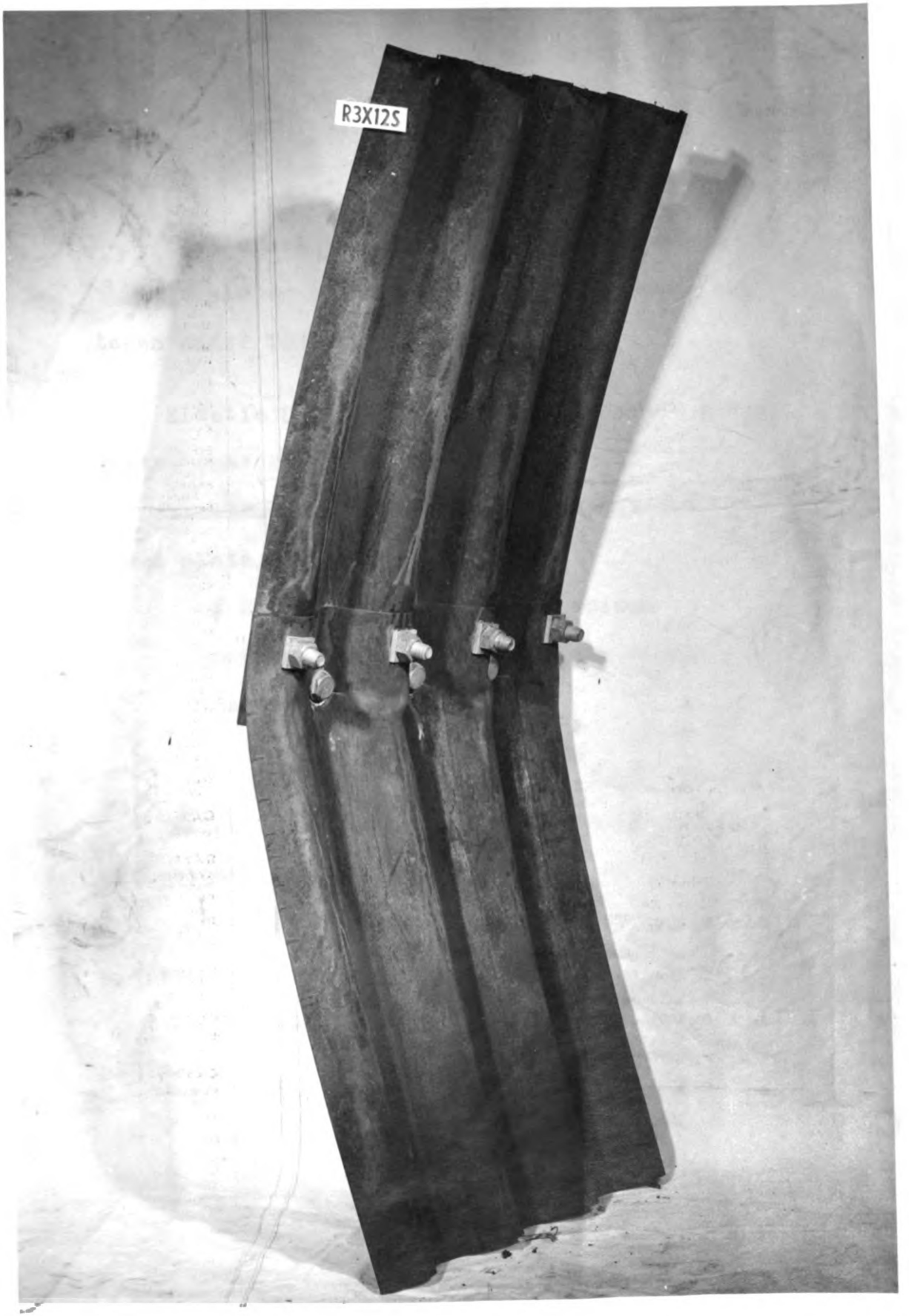

Fig. 23.

Data sheet for Republic plain and bolted 7 gauge plates with pictures of the two plates taken after failure has occurred:

Elastic Limit at 48,000# for plain 7 gauge plate, (see Fig. 24).

Elastic Limit at 34,000# for bolted 7 gauge plate, (see Fig. 26).

% efficiency of bolted specimen compared with plain specimen taken as the standard:

$$\frac{34,000}{48,000} \times 100 = 70.8\ \%$$

Failure of plain (see Fig. 25) and bolted plates (see Fig. 27).

Spreading at the center of the 7 gauge plain plate.

Spreading at the center of the 7 gauge bolted plate.

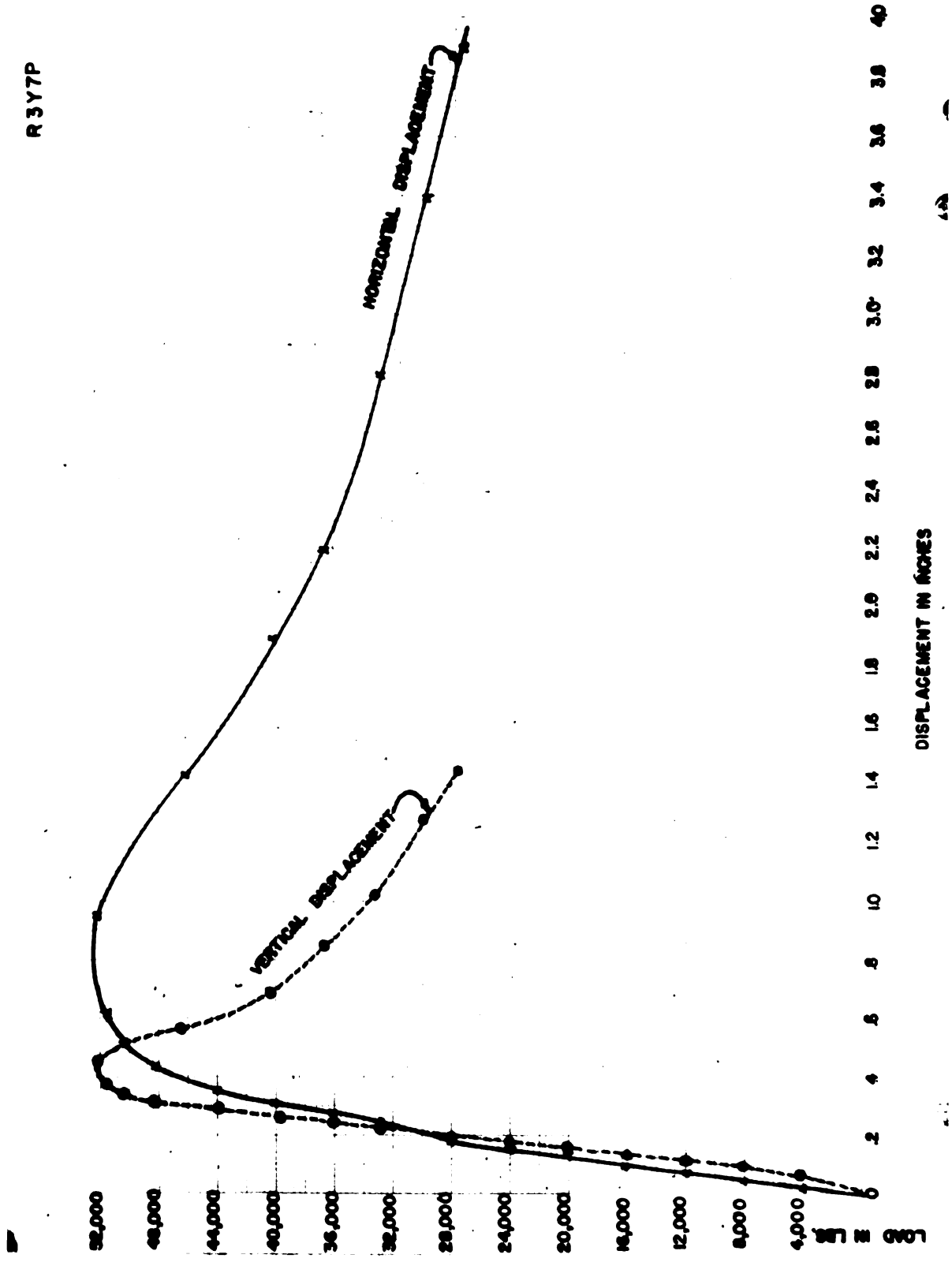
R3Y7P
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT
DISPLACEMENT IN INCHES
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
52,000
48,000
44,000
40,000
36,000
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000

Fig. 24.

Fig. 25.

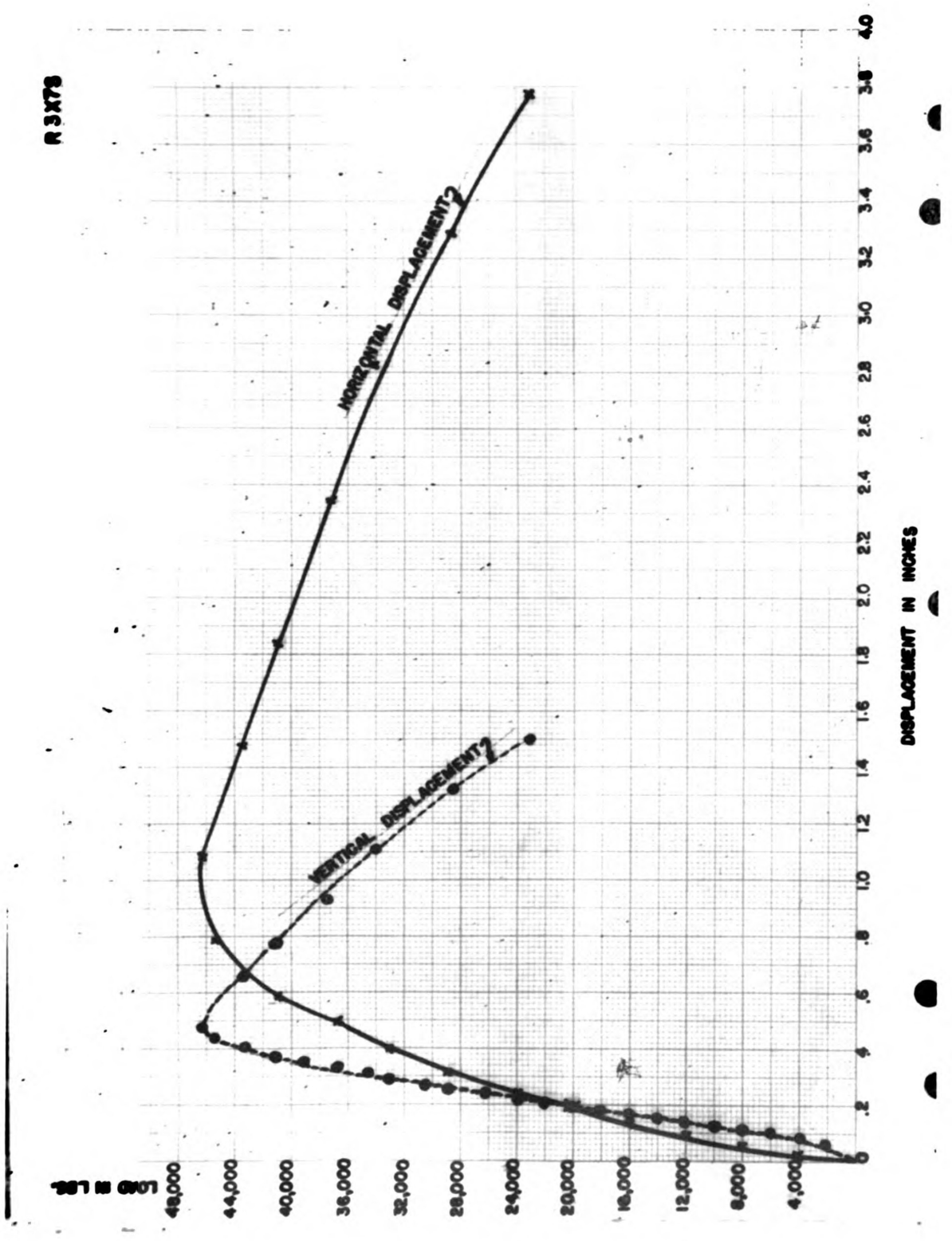
HORIZONTAL DISPLACEMENT?
VERTICAL DISPLACEMENT?
DISPLACEMENT IN INCHES
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
48,000
44,000
40,000
36,000
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000

Fig. 26.

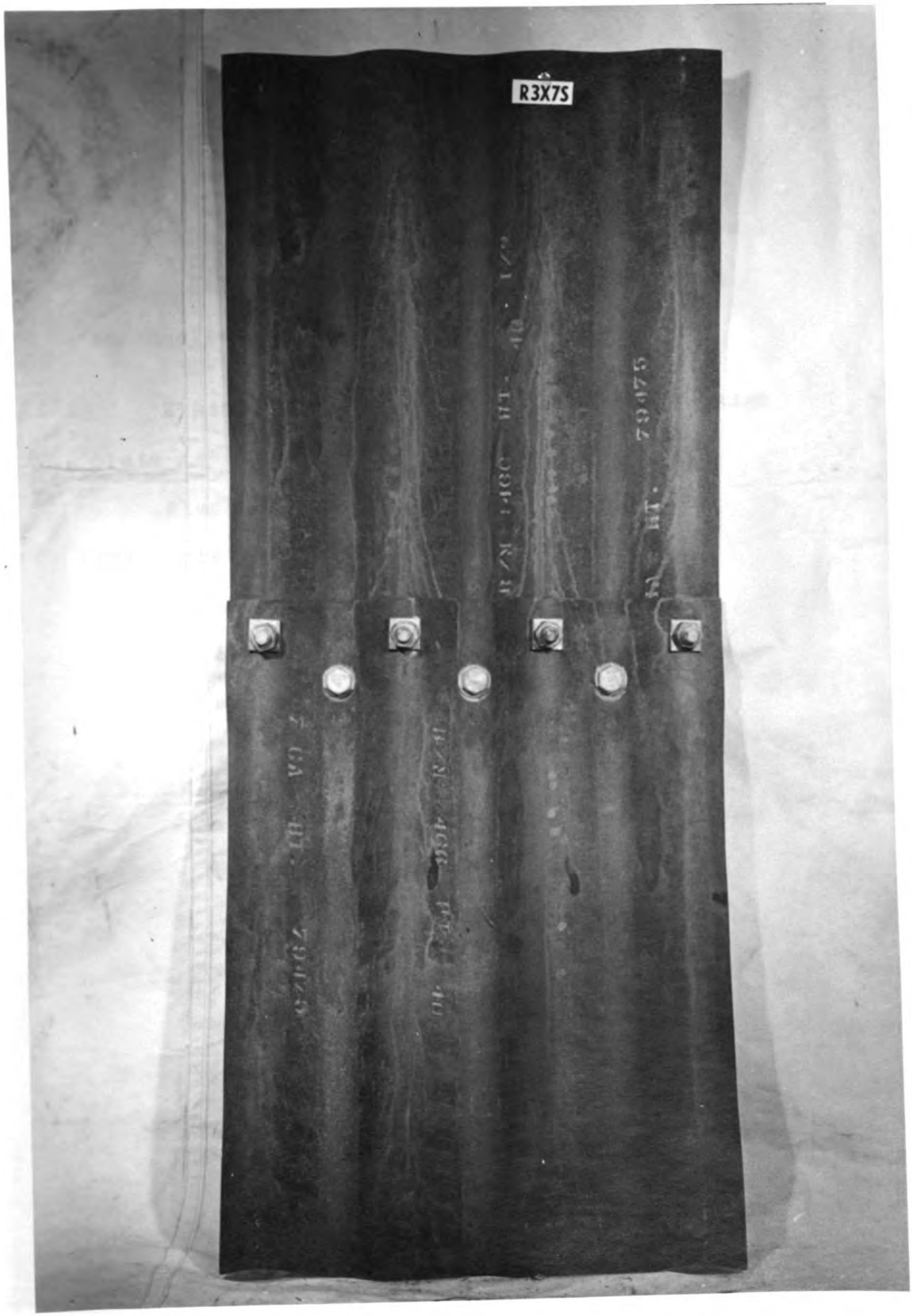

Fig.27.

Data sheet for Republic plain and bolted 1 gauge plates with pictures of the two plates taken after failure has occurred.

Elastic Limit at 73,000# for plain 1 gauge plate (see Fig. 28).

Elastic Limit at 42,000# for bolted 1 gauge plate (see Fig. 30).

% efficiency of bolted specimen compared with plain specimen taken as the standard:

$$\frac{42,000\#}{73,000\#} \times 100 = 57.5\ \%$$

Failure of plain (see Fig. 29) and bolted plates (see Fig. 31).

Slight spreading at the center of the 1 gauge plain plate.

Slight spreading at the center of the 1 gauge bolted plate.

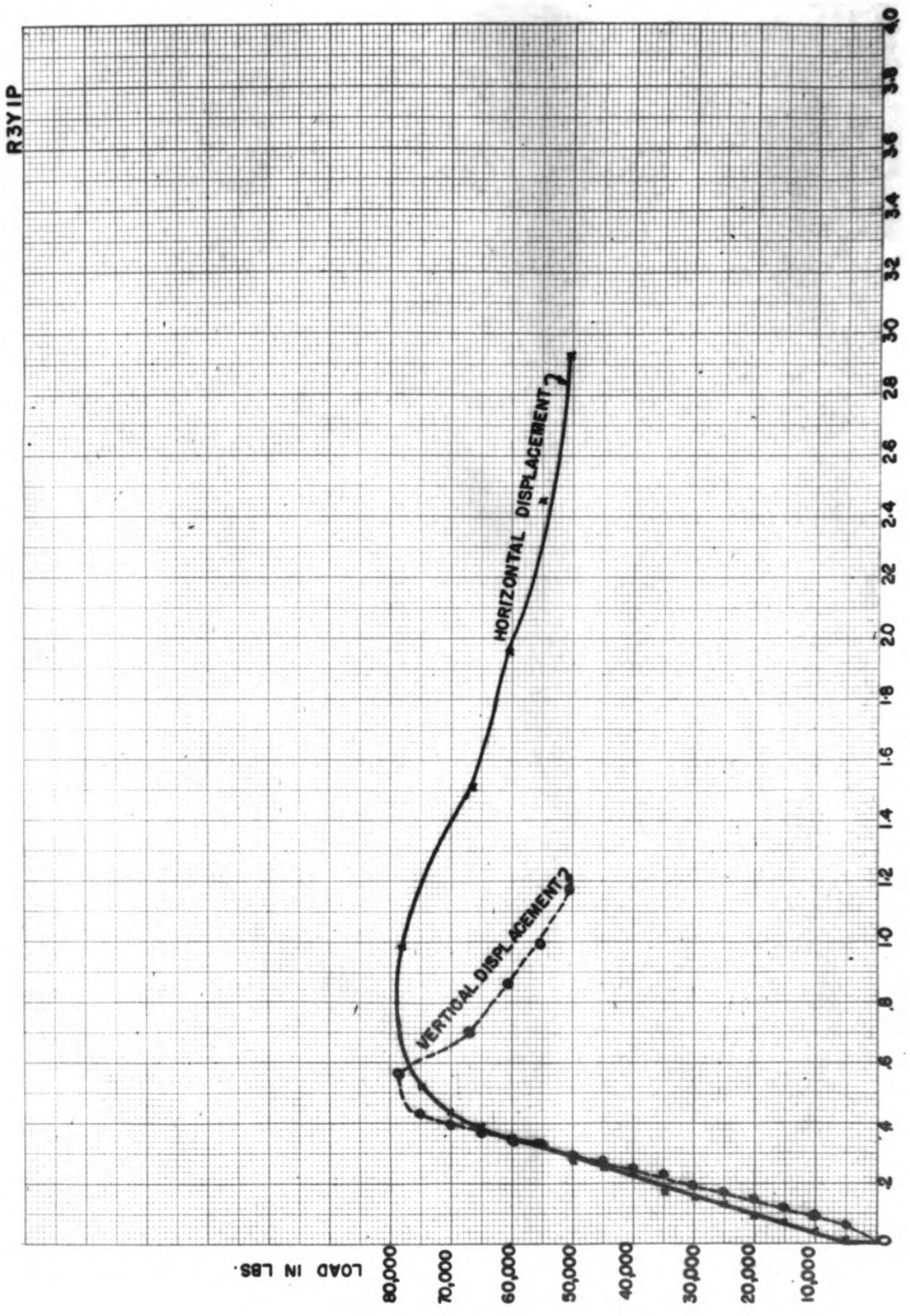
R3Y1P
LOAD IN LBS.
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
DISPLACEMENT IN INCHES
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT

Fig. 28.

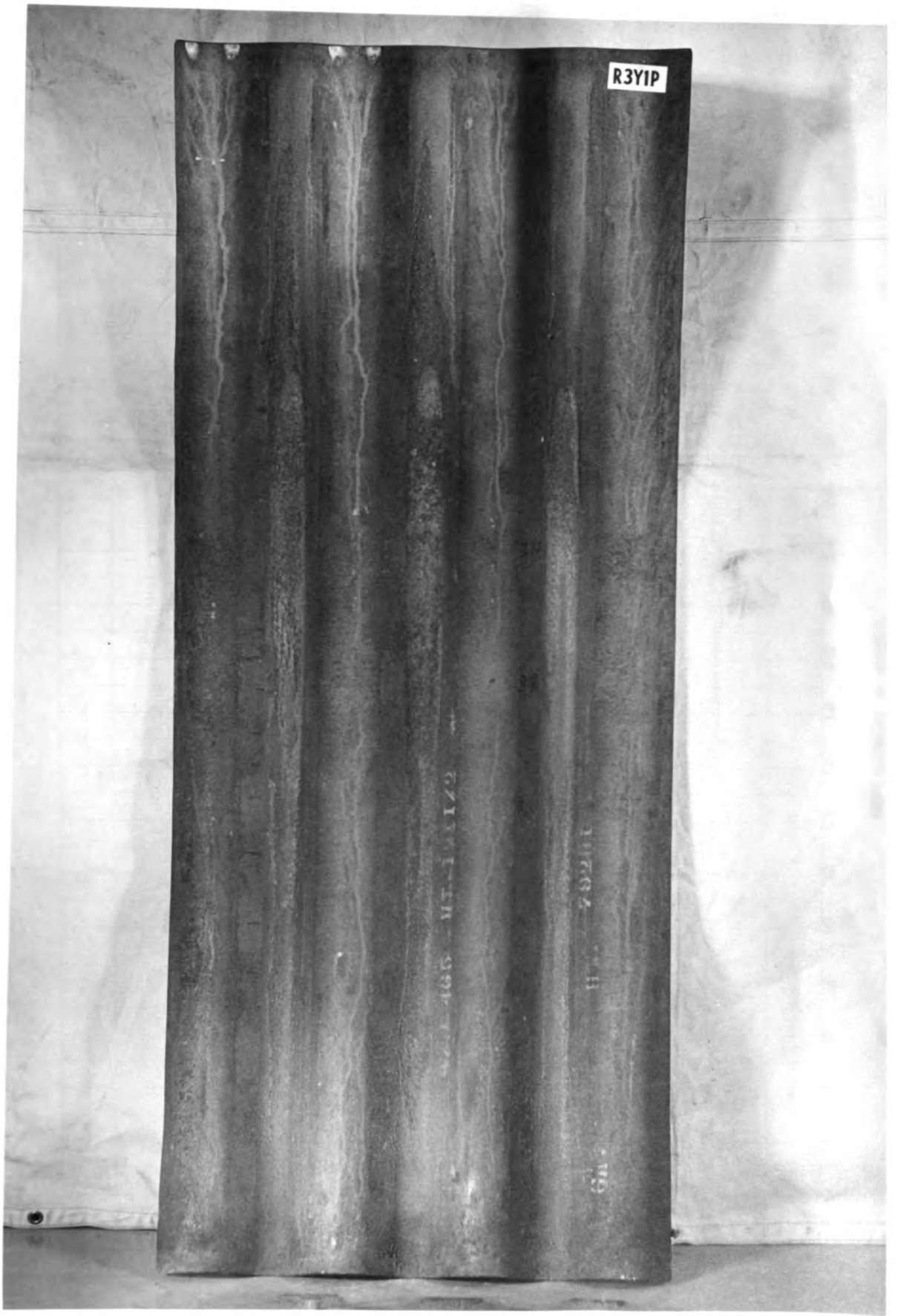

Fig. 29.

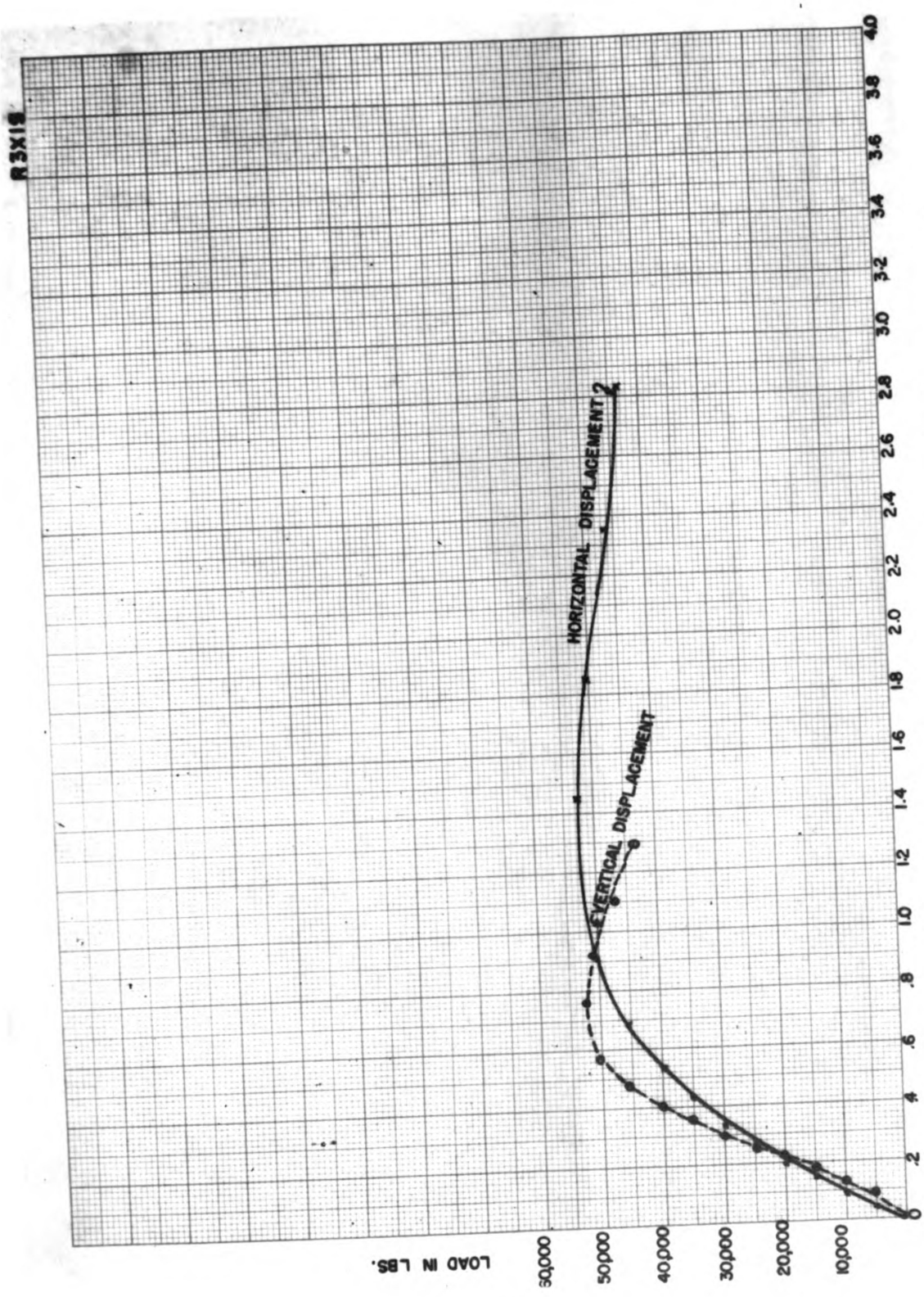
R3X18
LOAD IN LBS.
50,000
40,000
30,000
20,000
10,000
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
DISPLACEMENT IN INCHES
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT

Fig. 30.

Fig. 31.

Data sheet for United plain and bolted 12 guage plates with pictures of the two plates taken after failure has occurred:

Elastic Limit at 35,000# for plain 12 gauge plate, (see Fig. 32).

Elastic Limit at 23,000# for bolted 12 gauge plate (see Fig. 34).

% efficiency of bolted specimen compared with plain specimen taken as the standard:

$$\frac{23,000}{35,000} \times 100 = 65.8\ \%$$

Failure of plain (see Fig. 33) and bolted plates (see Fig. 35).

Spreading and crimping at the center of the 12 gauge plain plate.

Slight butt joint failure, crimping and buckling of the plate below the joint for the bolted 12 gauge plate.

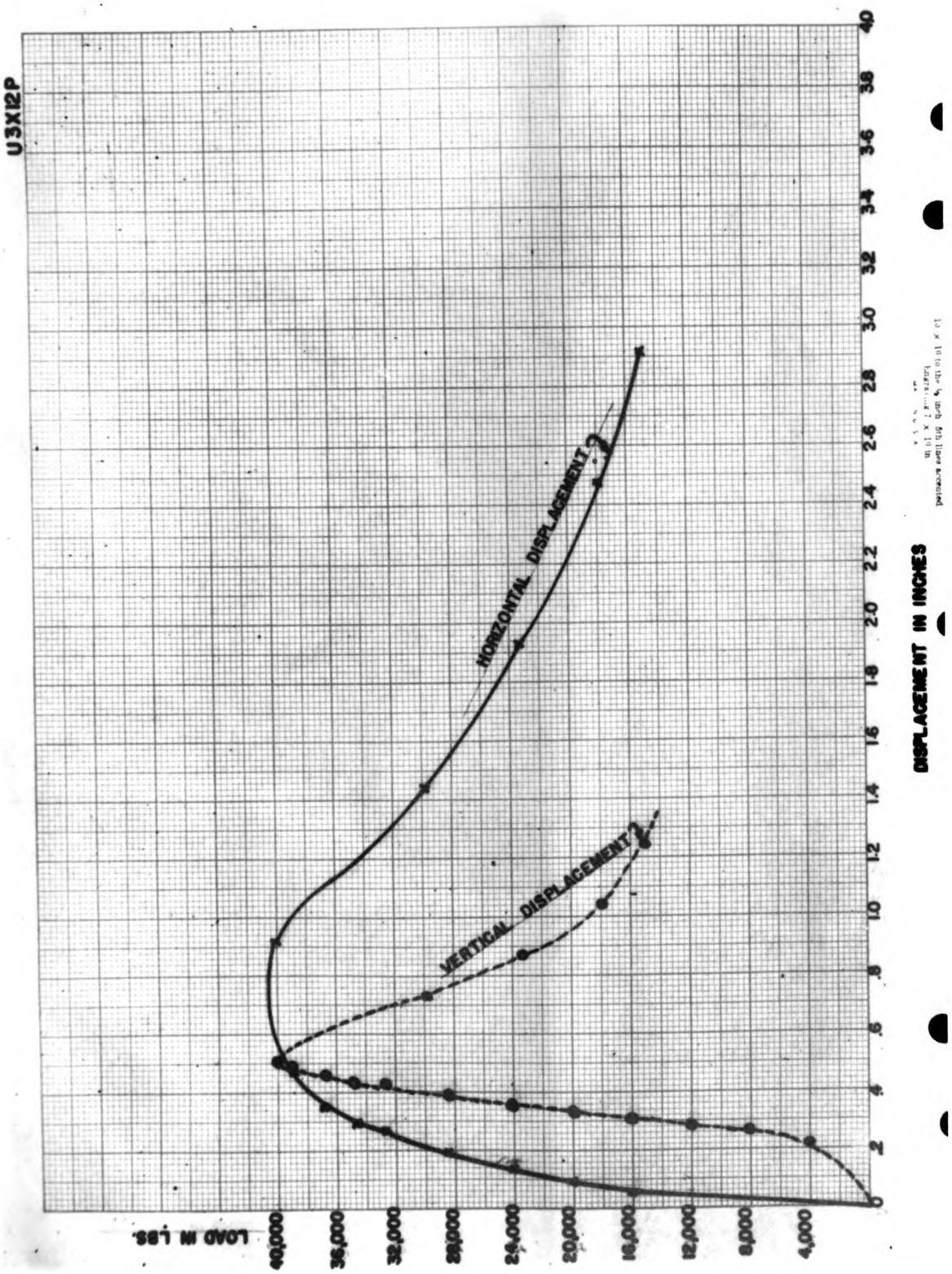
U3X12P
LOAD IN lbs
DISPLACEMENT IN INCHES
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT
40,000
36,000
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40

Fig. 32.

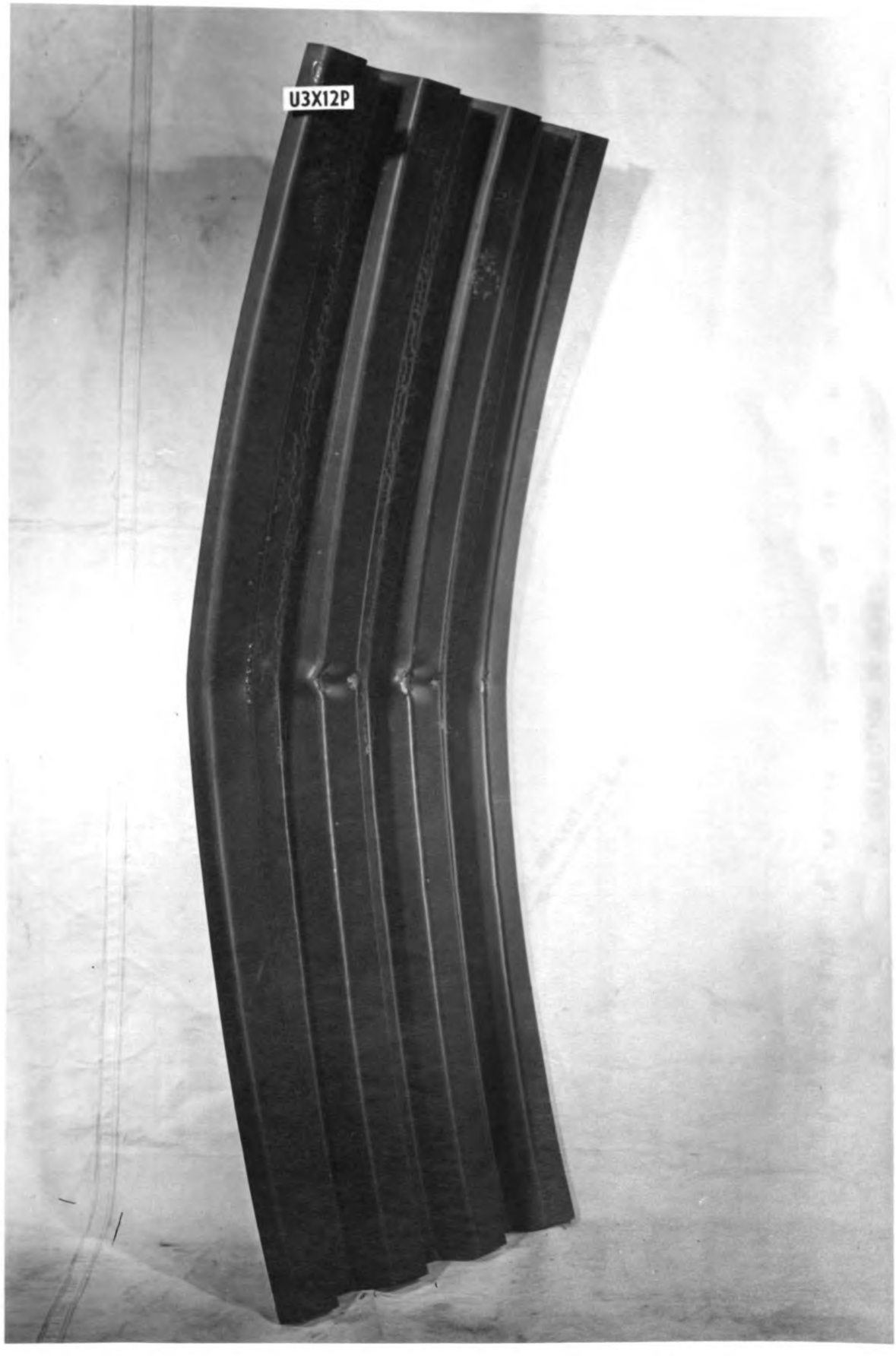

Fig. 33.

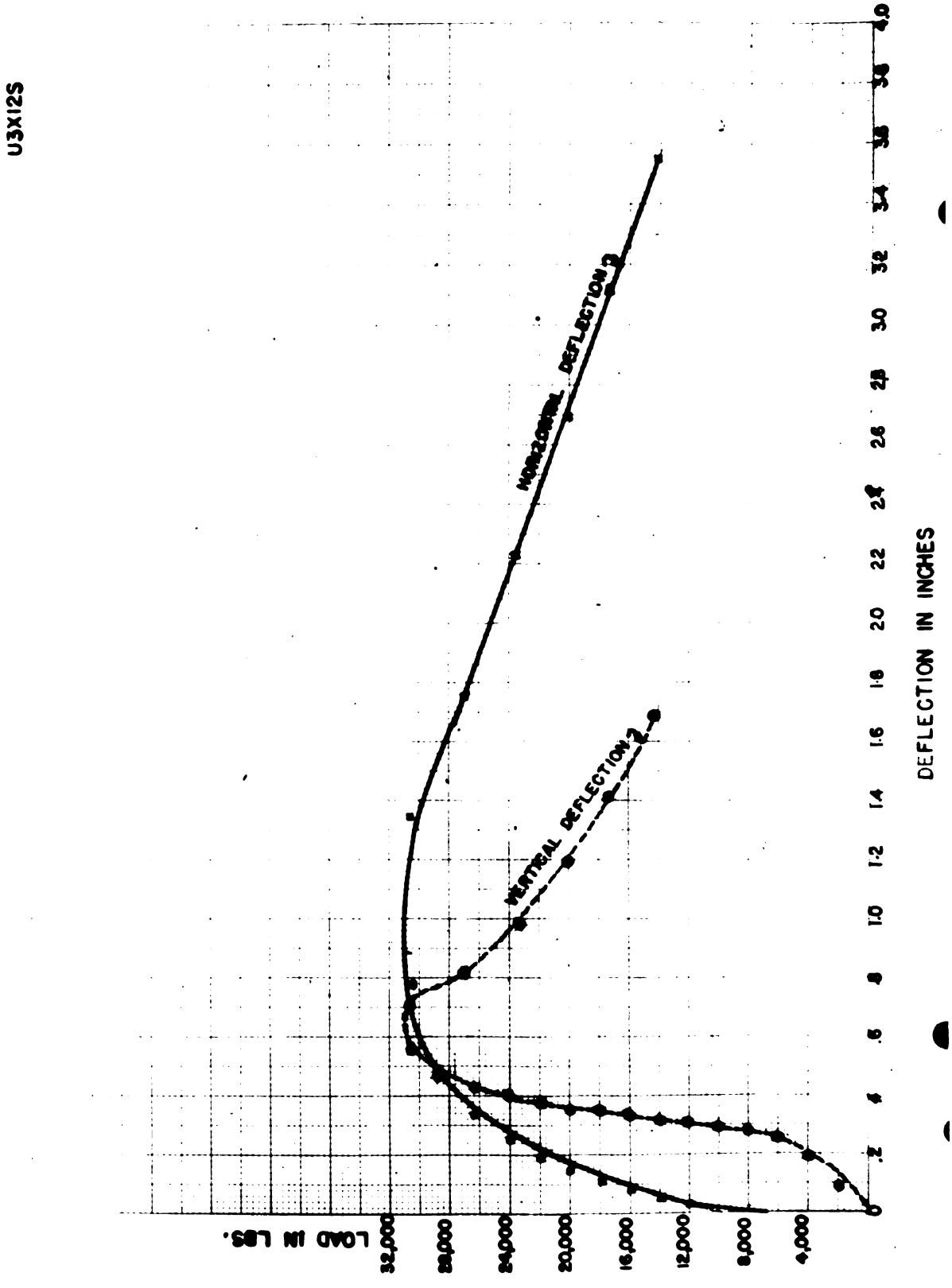
U3X12S
LOAD IN LBS.
32,000
28,000
24,000
20,000
16,000
12,000
8,000
4,000
0
.2
.6
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
4.0
DEFLECTION IN INCHES
HORIZONTAL DEFLECTION 2
VERTICAL DEFLECTION 2

Fig. 34.

Fig. 35.

Data sheet for United plain and bolted 7 gauge plates with pictures of the two plates taken after failure has occurred:

Elastic Limit at 66,000# for plain 7 gauge plate, (see Fig. 36).

Elastic Limit at 36,000# for bolted 7 gauge plate (see Fig. 38).

% efficiency of bolted specimen compared with plain specimen taken as the standard:

$$\frac{36,000}{66,000} \times 100 = 54.6\ \%$$

Failure of plain (see Fig. 37) and bolted plates (see Fig. 39 and 39(a).

Slight rippling of inner corrugation for 7 gauge plain plate.

Failure of butt joint plates also failure of weld on the edges.

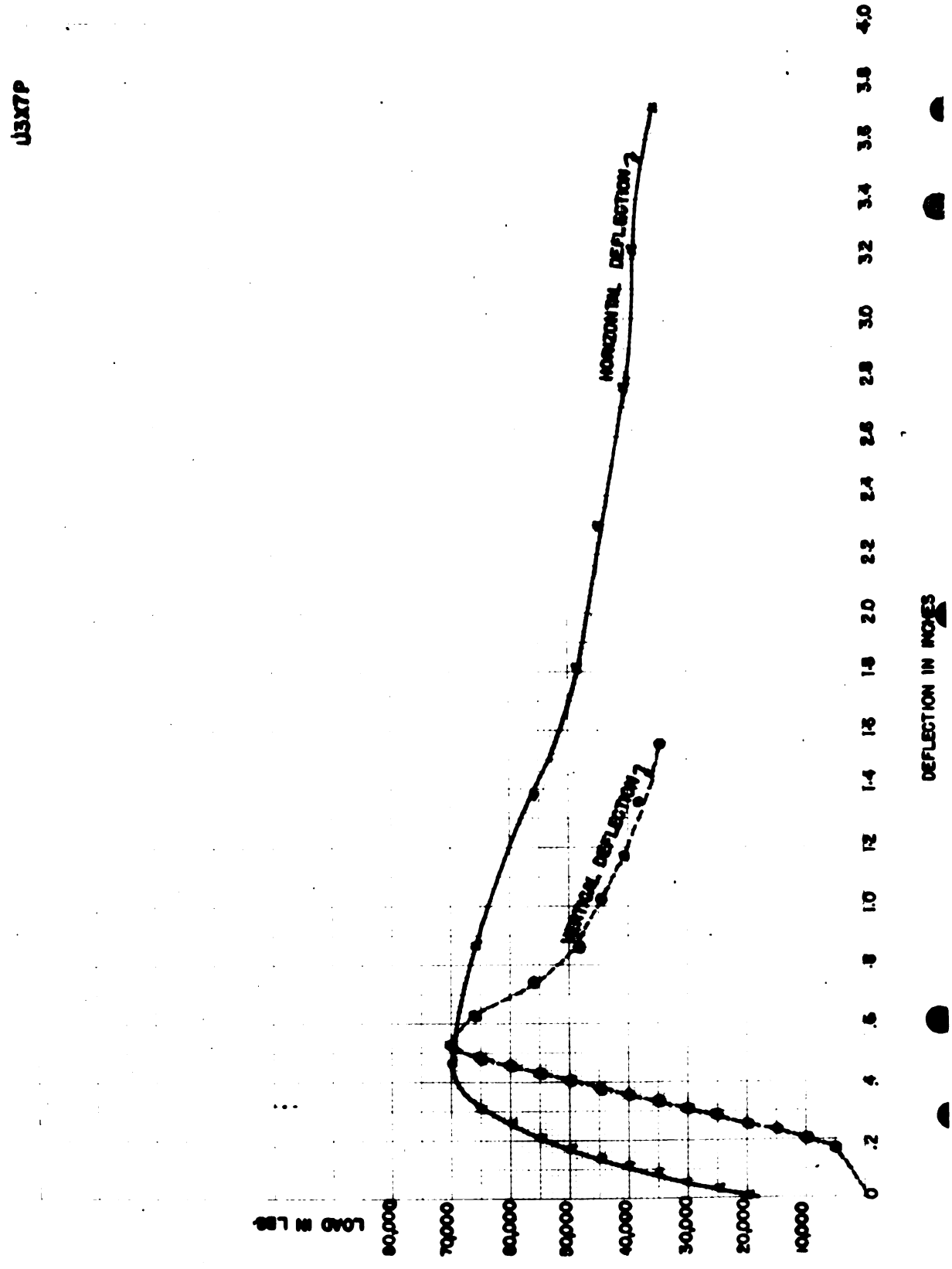
13X7P
LOAD IN LBS.
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
DEFLECTION IN INCHES
HORIZONTAL DEFLECTION 2
VERTICAL DEFLECTION 2

Fig. 36.

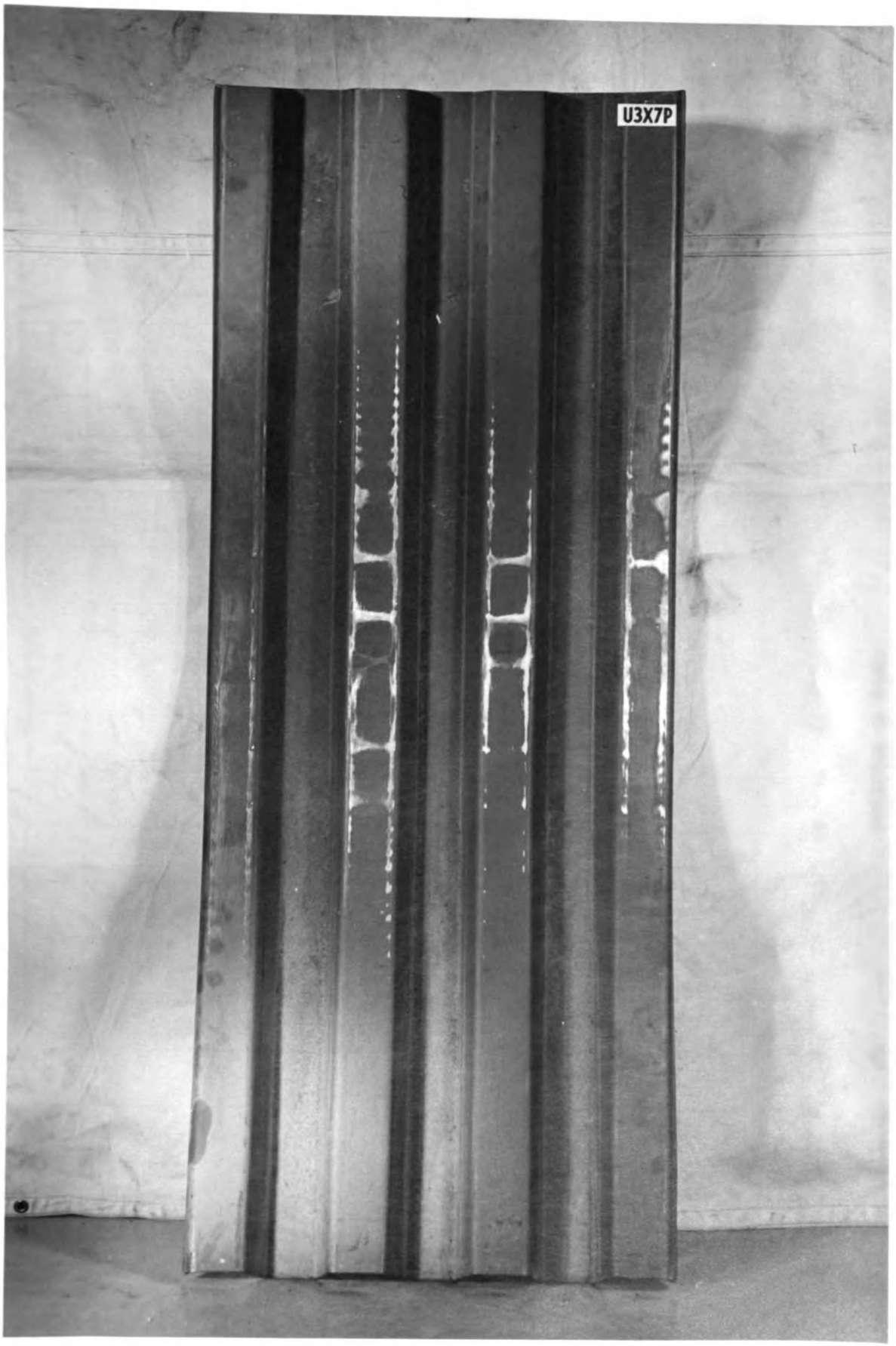

Fig. 37.

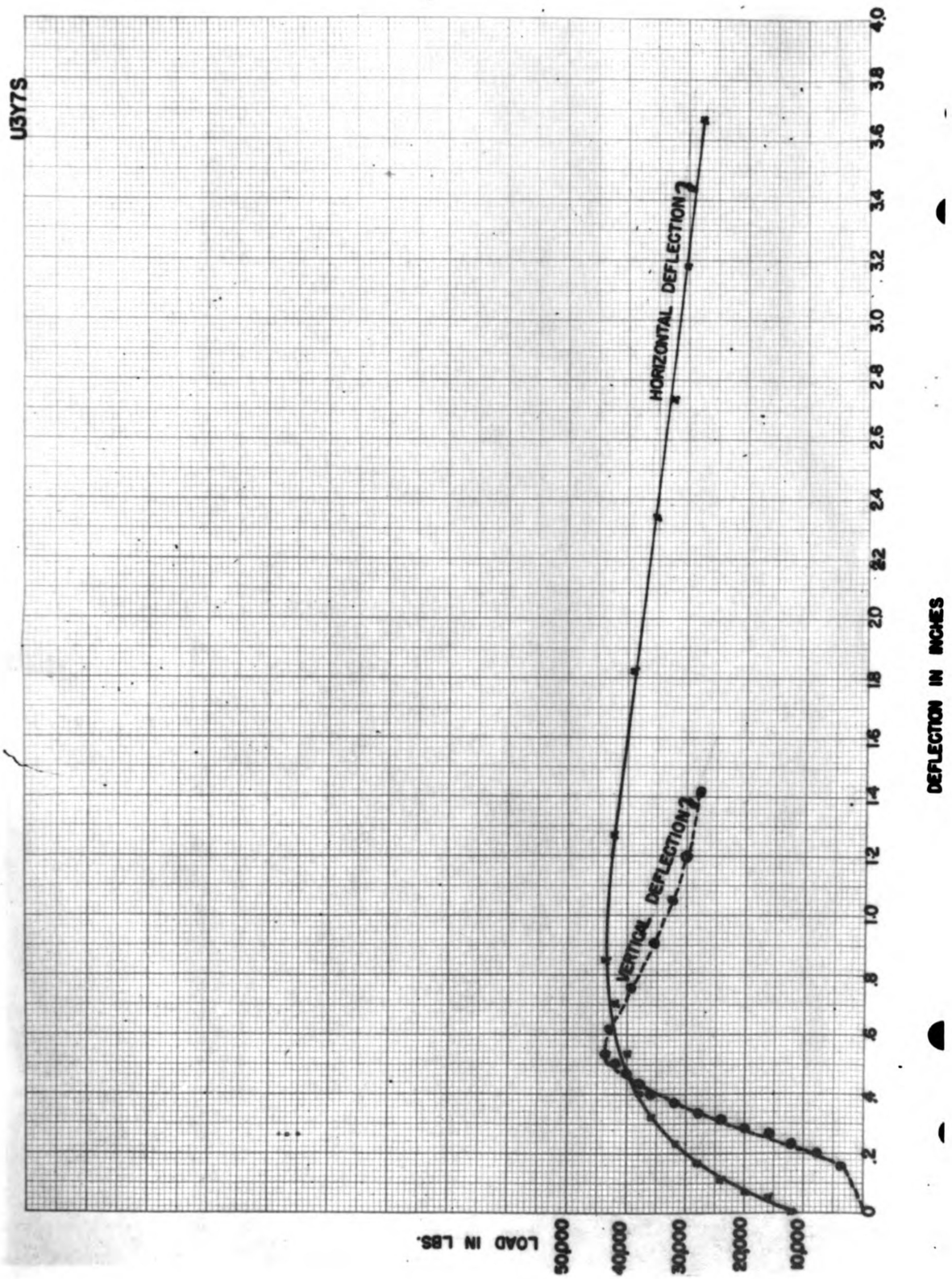
U3Y7S
HORIZONTAL DEFLECTION
VERTICAL DEFLECTION
LOAD IN LBS.
50000
40000
30000
20000
10000
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
DEFLECTION IN INCHES

Fig. 38.

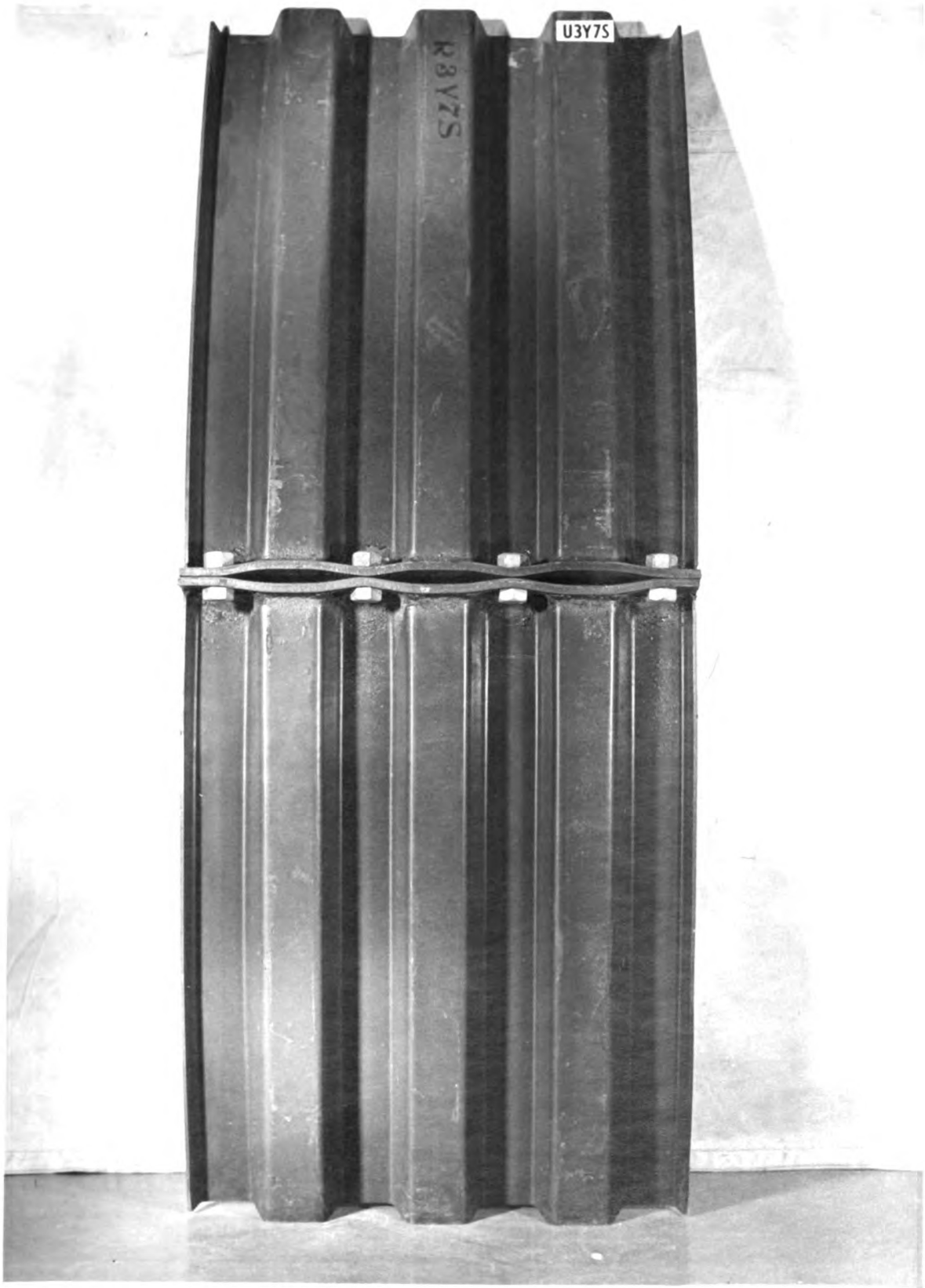

Fig. 39.

Fig. 39a.

Data sheet for United plain and bolted 1 gauge plates with pictures of the two plates taken after failure has occurred:

Elastic Limit at 120,000# for plain 1 gauge plate (see Fig. 40).

Elastic Limit at 61,000# for bolted 1 gauge plate (see Fig. 42).

% efficiency of bolted specimen compared with plain specimen taken as the standard:

$$\frac{61,000}{120,000} \times 100 = 50.8\ \%$$

Failure of plain (see Fig. 41) and bolted plates (see Fig. 43).

Small change in radius of curvation for plain 1 gauge plate.

Weld failure and butt joint failure for bolted 1 gauge plate.

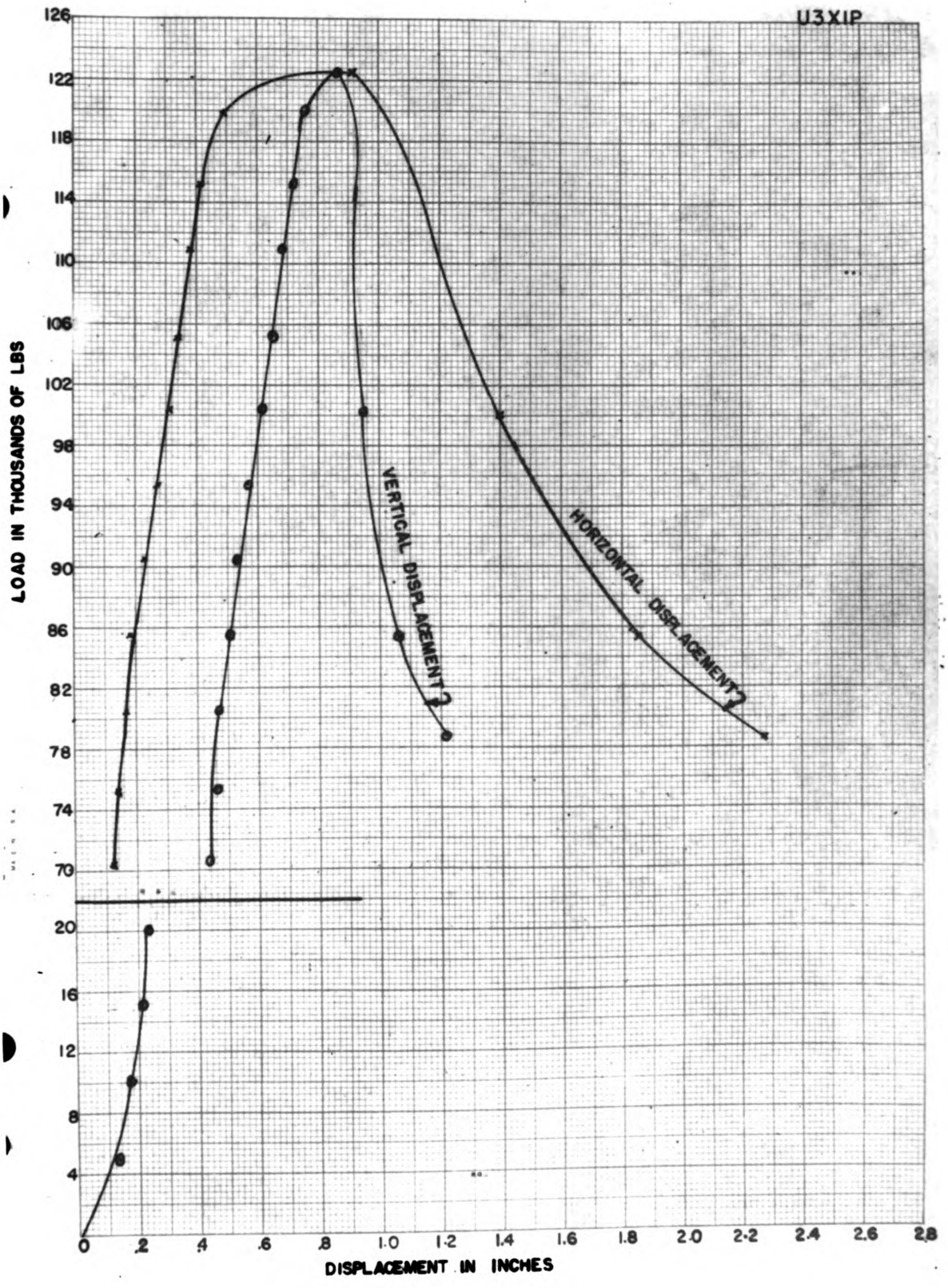
U3X1P
LOAD IN THOUSANDS OF LBS
126
122
118
114
110
106
102
98
94
90
86
82
78
74
70
20
16
12
8
4
VERTICAL DISPLACEMENT
HORIZONTAL DISPLACEMENT
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
DISPLACEMENT IN INCHES

Fig. 40.

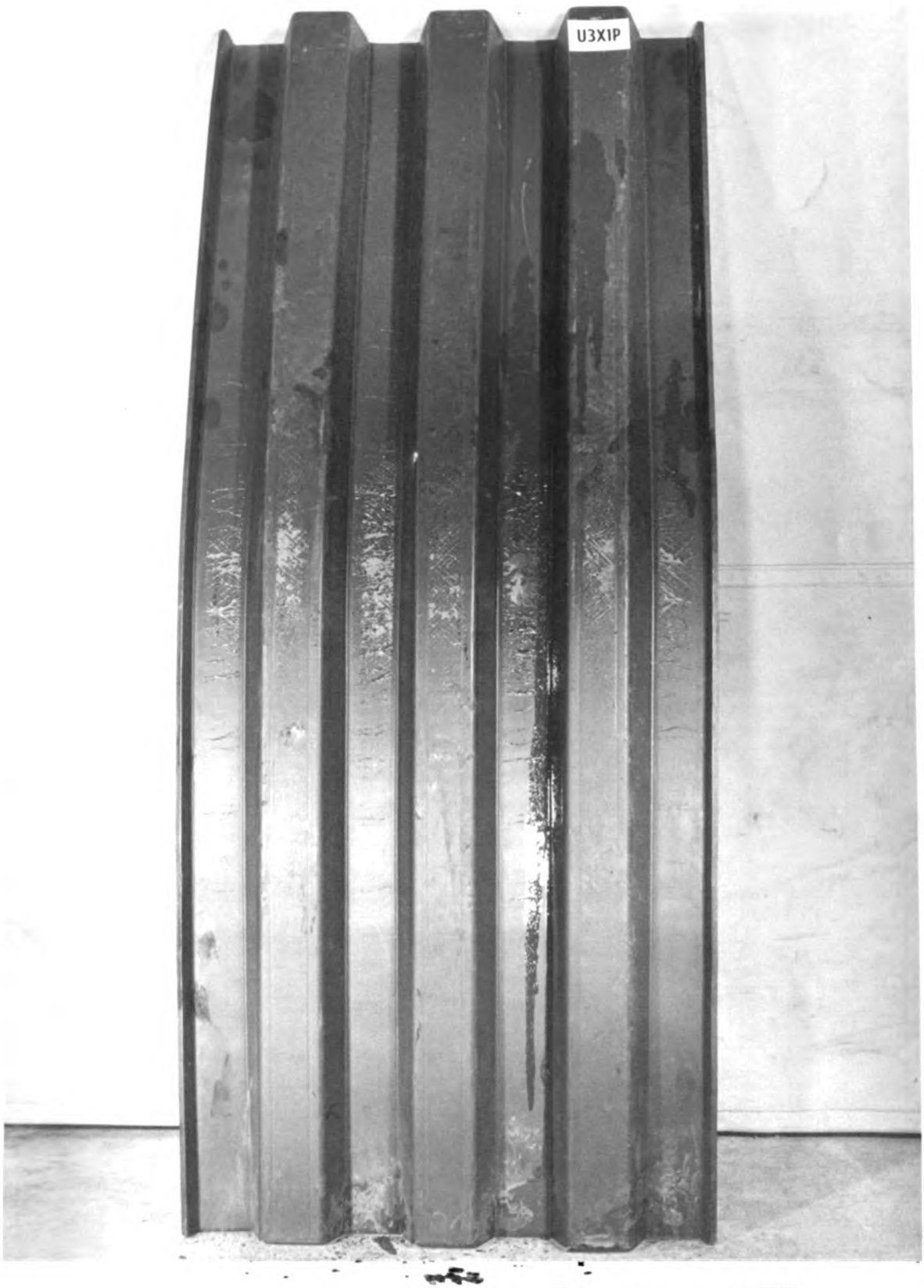

Fig. 41.

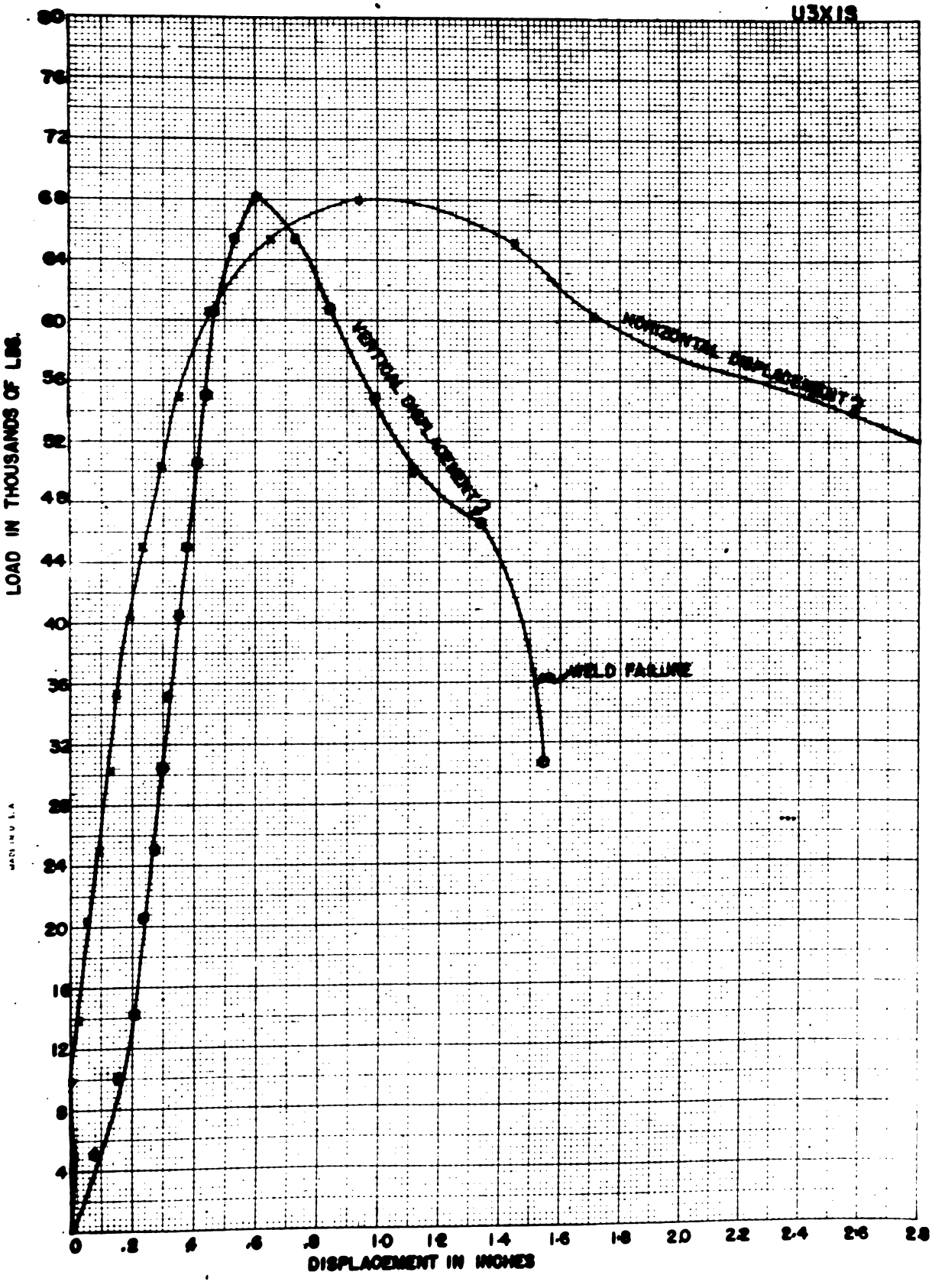
U3X19
LOAD IN THOUSANDS OF LBS.
DISPLACEMENT IN INCHES
HORIZONTAL DISPLACEMENT
VERTICAL DISPLACEMENT
WELD FAILURE
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80

Fig. 42.

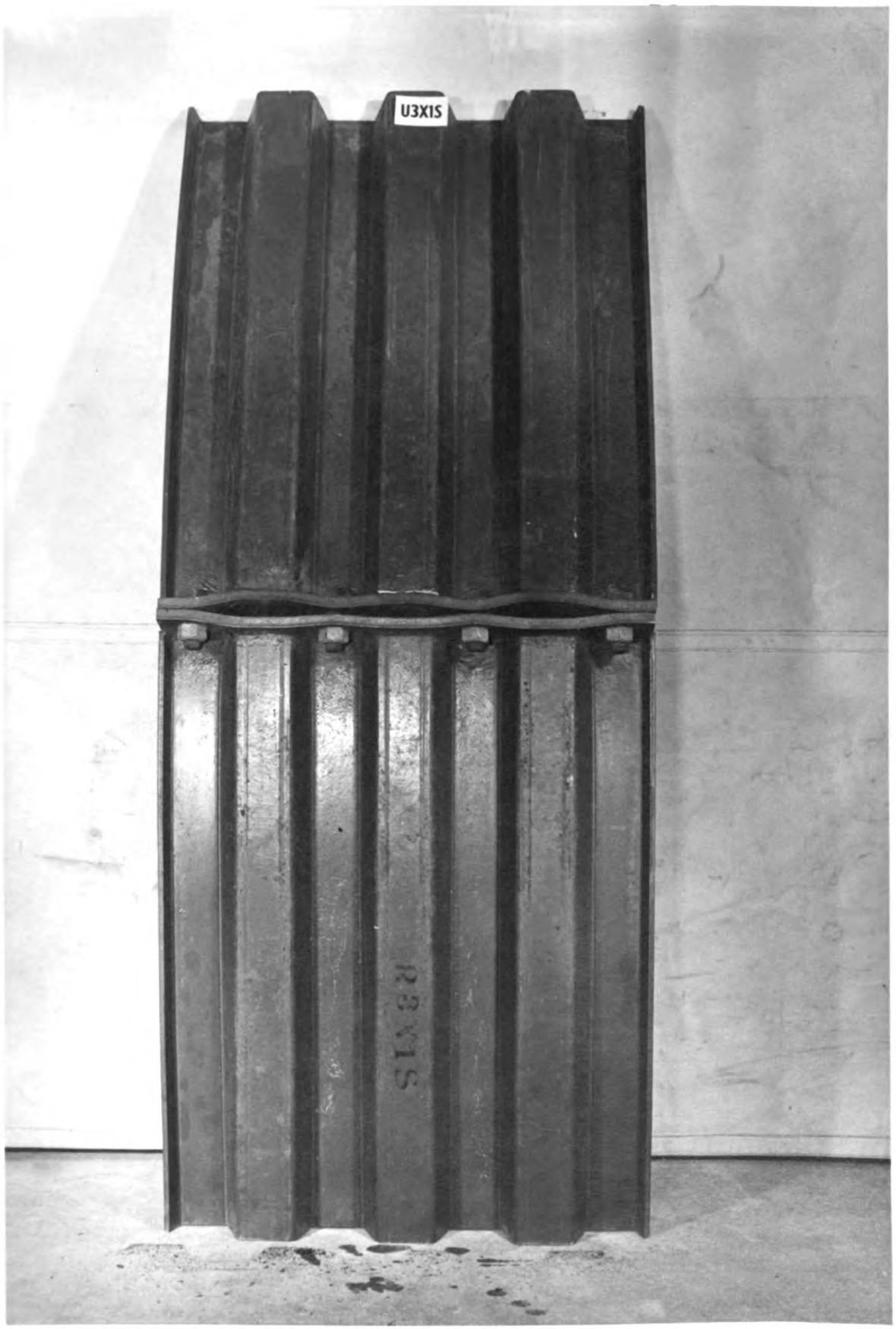

Fig. 43.

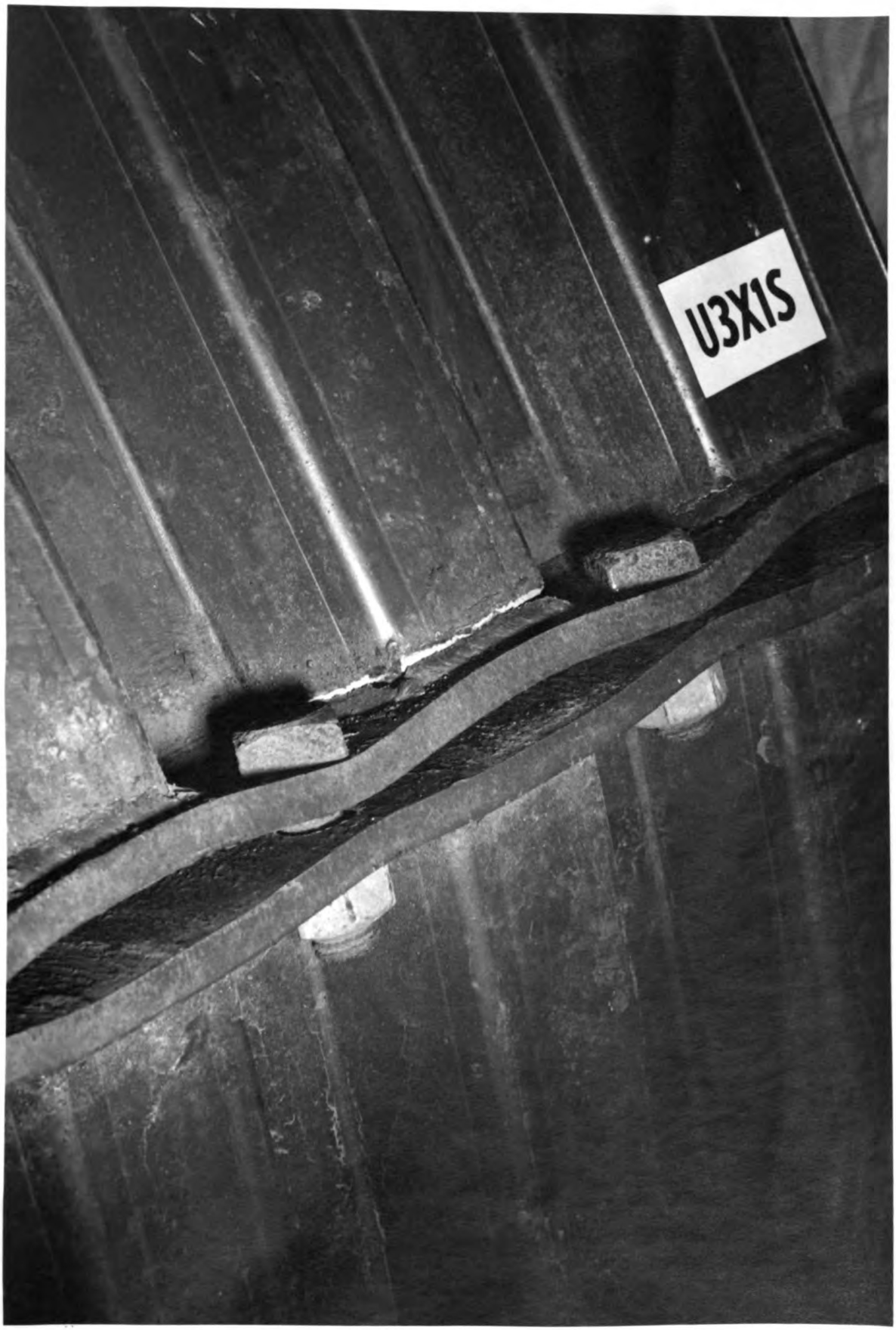

Fig. 43a.

SIZE AND TYPE OF CORRUGATION

The following 6 graphs compare the plain and bolted specimens of the same gauge of metal with one another:

DATA SHOWING ELASTIC LIMITS

	ARMCO	REPUBLIC	UNITED
12 gauge plain plate See Fig. 44	14,700#	28,300#	37,000#
12 gauge bolted plate See Fig. 45	15,000#	22,000#	26,300#
% efficiency of bolted specimen compared with plain specimen taken as a standard	$\frac{15,000}{14,700}$=102%	$\frac{22,000}{28,000}$=78.6%	$\frac{26,300}{37,000}$=71.3%
7 gauge plain plate See Fig. 46	39,400#	49,000#	65,000#
7 gauge bolted plate See Fig. 47	28,500#	43,000#	36,000#
% efficiency of bolted specimen compared with plain specimen taken as a standard	$\frac{28,500}{39,400}$=72.3%	$\frac{43,000}{49,000}$=87.8%	$\frac{36,000}{65,000}$=55.5%
1 gauge plain plate See Fig. 48	44,000#	73,000#	120,000#
1 gauge bolted plate See Fig. 49	36,000#	44,800#	61,000#
% efficiency of bolted specimen compared with plain specimen taken as a standard	$\frac{36,000}{44,000}$ 81.8%	$\frac{44,800}{73,000}$=61.4%	$\frac{61,000}{120,000}$=50.8%

Analysis of data:

The Armco Company uses a $1\frac{3}{4}$" depth of corrugation and 6" pitch, which develops a good efficiency ratio between

the bolted and unbolted specimens, but the overall loads that can be withstood by these plates is less than the Republic and United plates.

The Republic Company uses a 2" depth of corrugation and a 6" pitch which develops from good to fair efficiency ratio between the bolted and unbolted specimens. The overall loads that can be withstood by these plates are in all cases better than the Armco Company's and in one case (No. 7 gauge) they are better than the United Company's plates.

The United Company uses a 2" box type corrugation with a 6" pitch. The plain specimens of the United plates are in all cases better than the Armco or Republic Company's plates but the butt type joint fails on the bolted plates and does not let the bolted specimen take a high load. The overall efficiency of this plate is poor but this is due not to type of corrugation, but to the butt type joint used by the United Company.

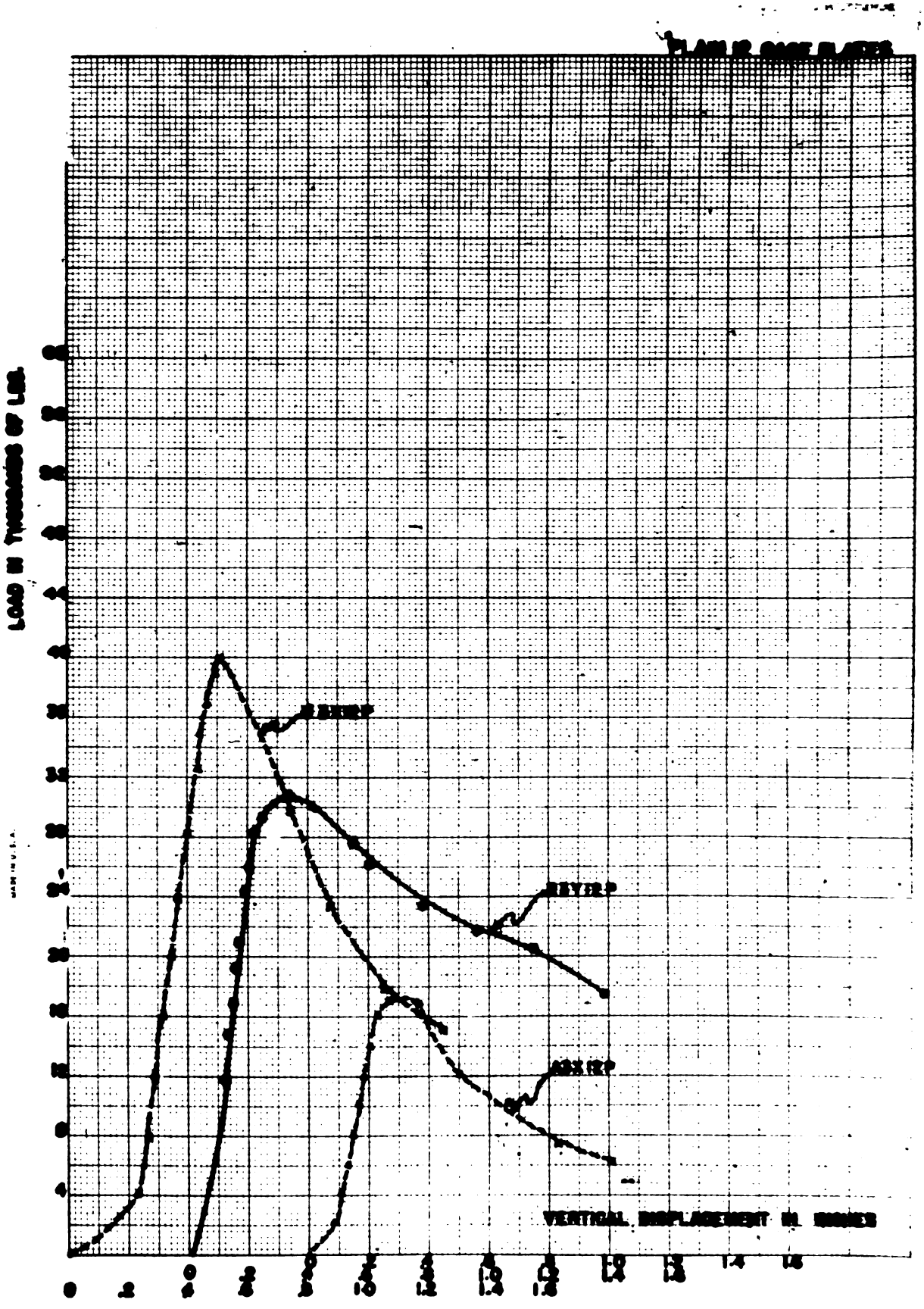

Fig. 44.

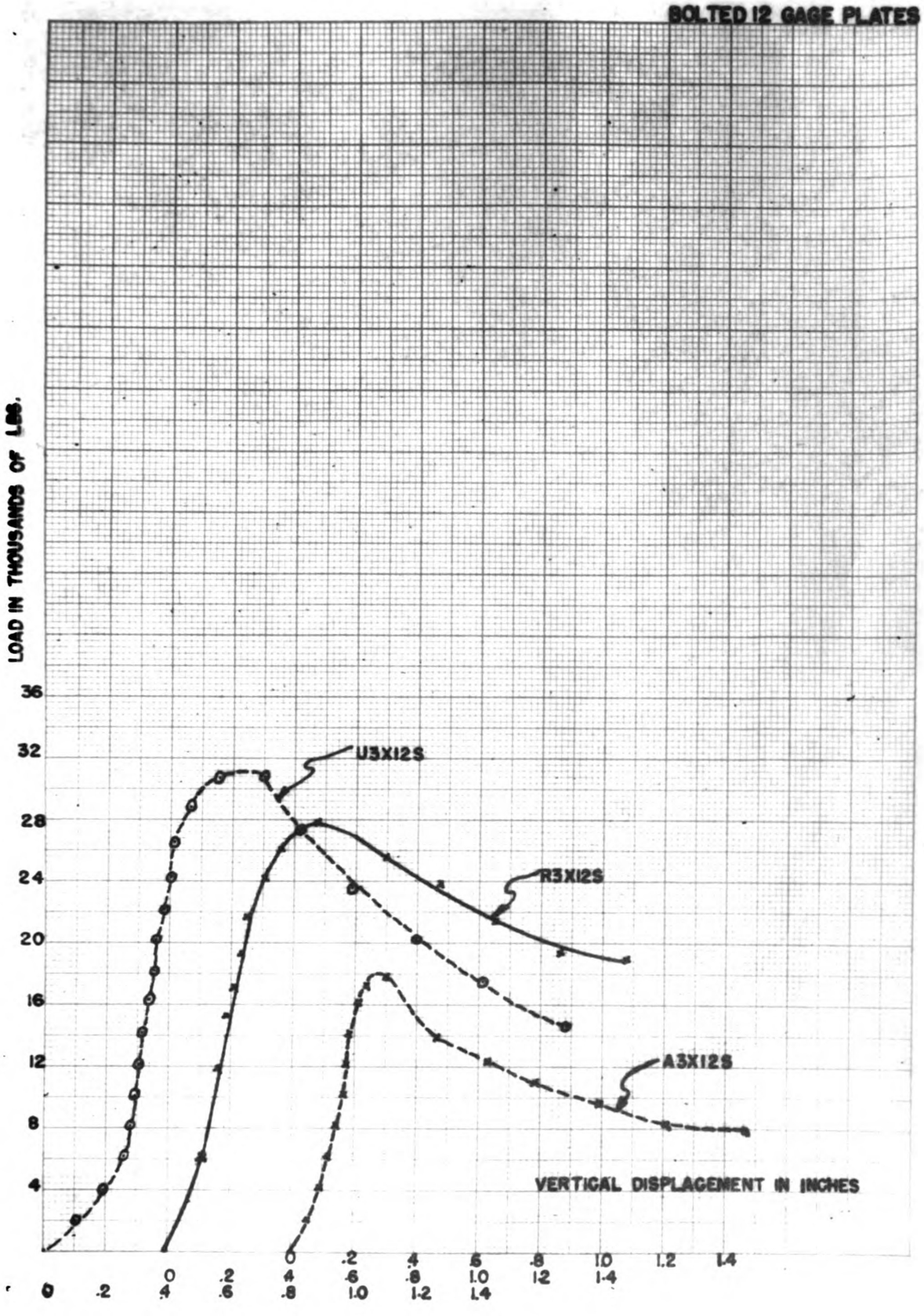
BOLTED 12 GAGE PLATES
LOAD IN THOUSANDS OF LBS.
36
32
28
24
20
16
12
8
4
U3X12S
R3X12S
A3X12S
VERTICAL DISPLACEMENT IN INCHES
0 .2 .4 .6 .8 1.0 1.2 1.4

Fig. 45.

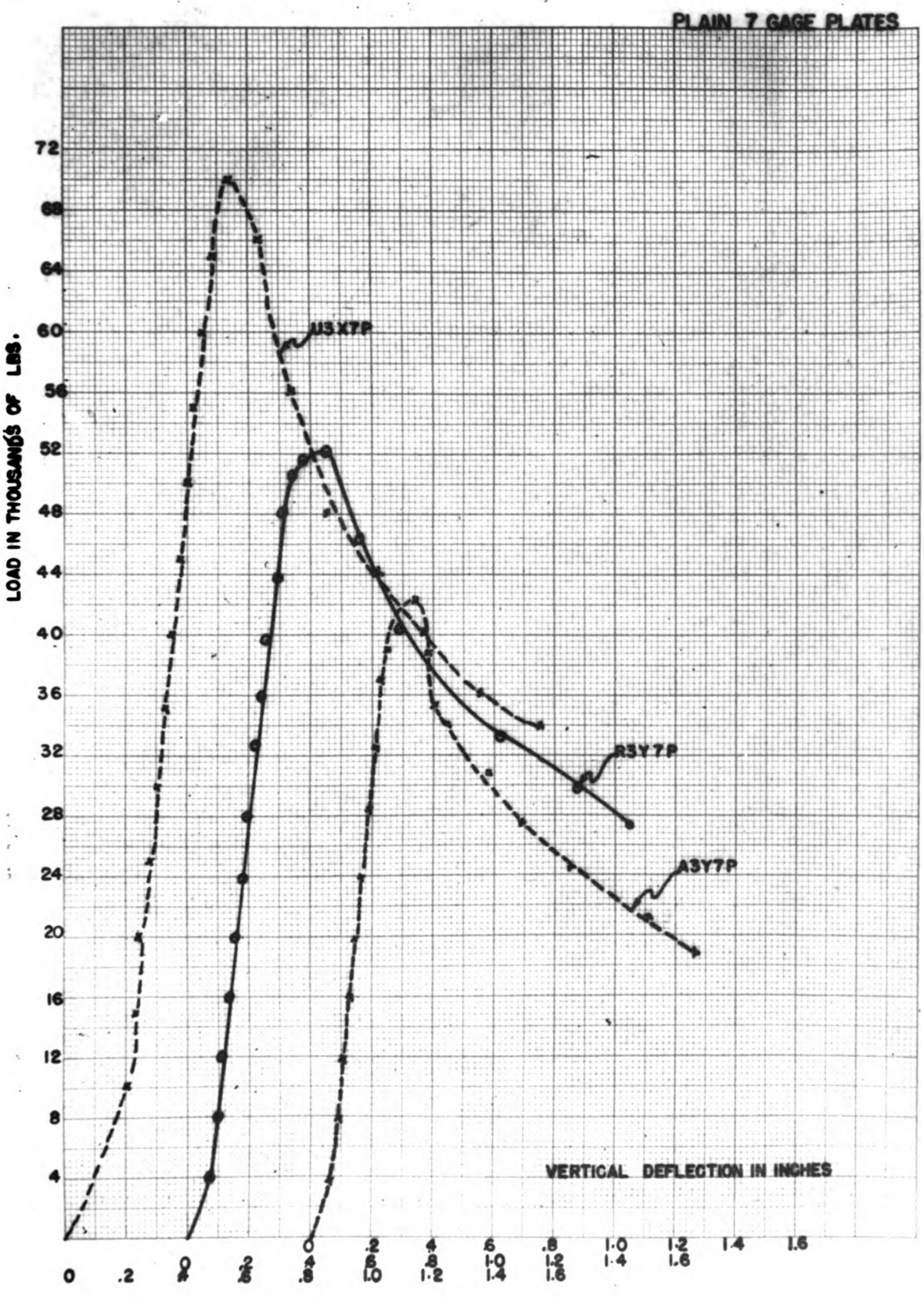
PLAIN 7 GAGE PLATES
LOAD IN THOUSANDS OF LBS.
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
U3X7P
R3Y7P
A3Y7P
VERTICAL DEFLECTION IN INCHES
0
.2
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
0
.4
.8
1.2
1.6
2.0
2.4
2.8
3.2

Fig. 46.

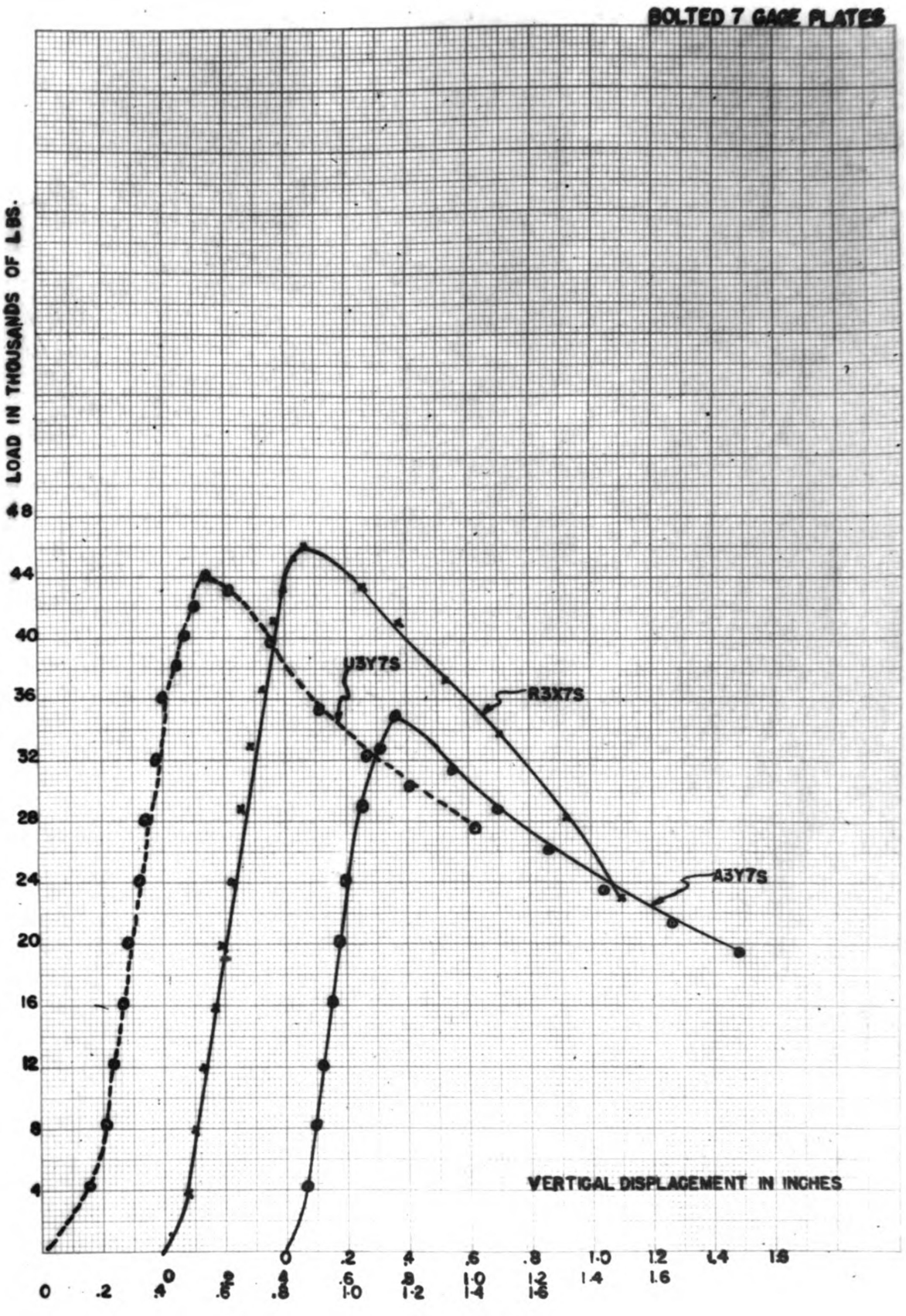
BOLTED 7 GAGE PLATES
LOAD IN THOUSANDS OF LBS.
48
44
40
36
32
28
24
20
16
12
8
4
U3Y7S
R3X7S
A3Y7S
VERTICAL DISPLACEMENT IN INCHES
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6

Fig. 47.

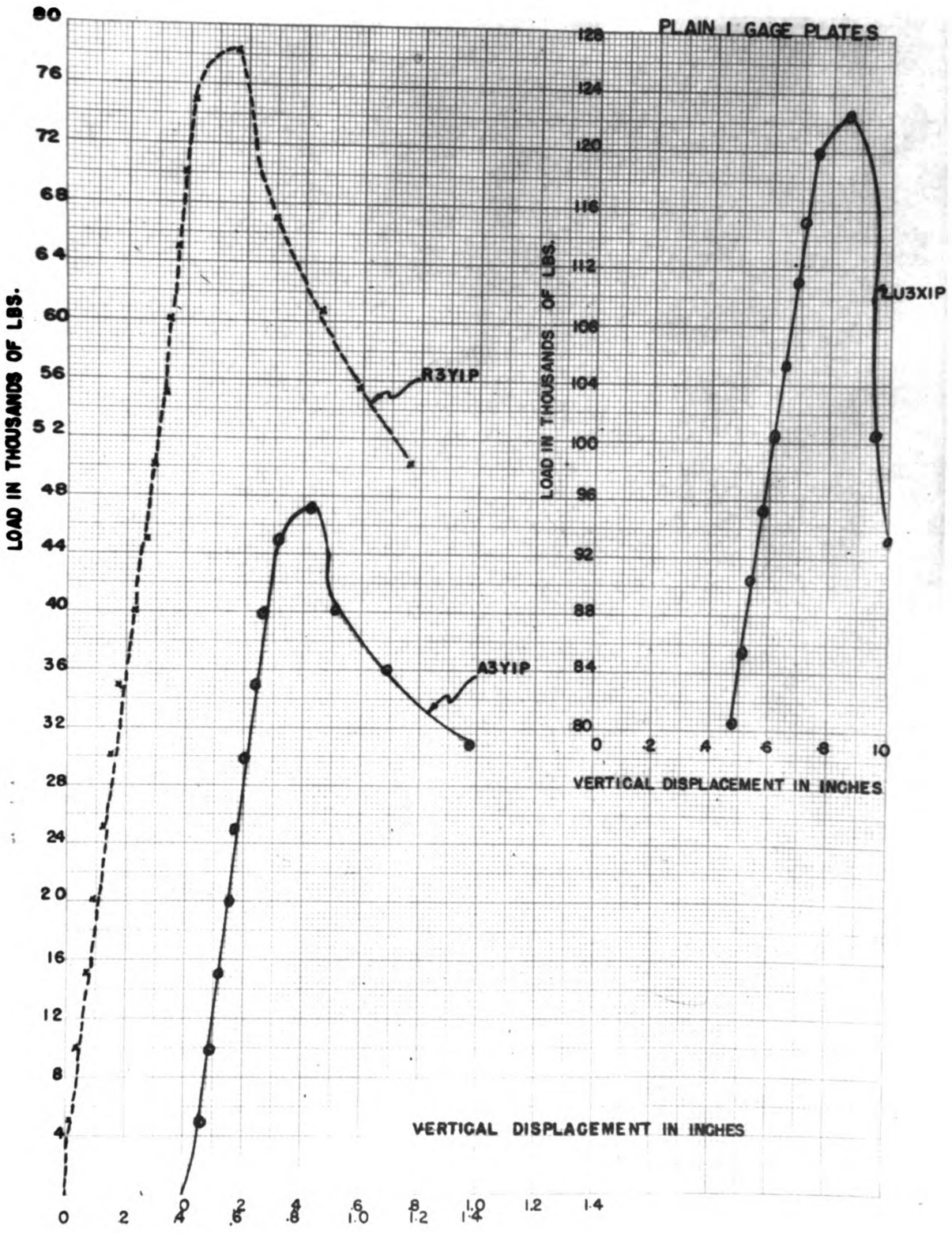
PLAIN I GAGE PLATES
LOAD IN THOUSANDS OF LBS.
R3YIP
A3YIP
U3XIP
VERTICAL DISPLACEMENT IN INCHES
VERTICAL DISPLACEMENT IN INCHES

Fig. 48.

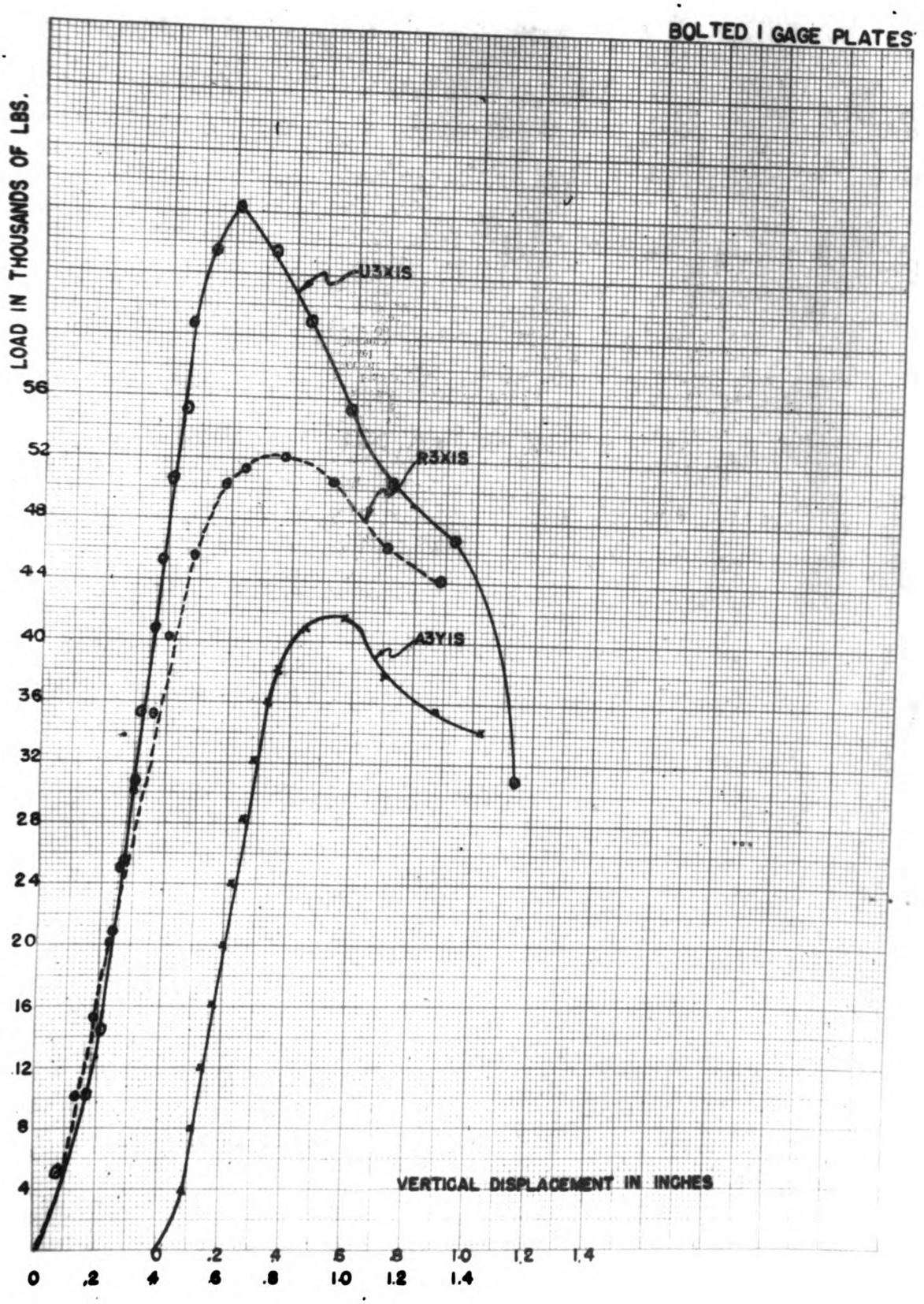
BOLTED I GAGE PLATES
LOAD IN THOUSANDS OF LBS.
U3XIS
R3XIS
A3YIS
VERTICAL DISPLACEMENT IN INCHES
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
.2
.4
.6
.8
1.0
1.2
1.4

Fig. 49.

GAUGE OF METAL

The following 6 sheets of graphs compare the plain and bolted specimens of each manufacturer for the No. 12 gauge, No. 7 gauge, and No. 1 gauge plates.

An ideal series of multi plates would show that the bolted and plain plates would both have the same elastic limit for the same gauge plate. Also the difference between the elastic limits of the different plates (No.12, No. 7, and No. 1 gauge plates for the same manufacturer) is in proportion to the section modulus of the different plates in an ideal series of multi plates.

The analysis of data will be run on the plain plates to test the section modulus against gauge for the various plates. If we were to use the bolted plates we would be studying the joints instead of the gauge of metal.

Comparison of the ratio of the section modulus to the ratio of the elastic limits for the various gauge plates to see if there is a definite relationship between section modulus and elastic limit for these plates, is made. I used Armco plates as a standard for elastic limit and section modulus.

Z = .0786 in , 12 gauge United 37,000# at Elastic Limit
Z = .0585 in , 12 gauge Republic 28,300# at Elastic Limit
Z = .0520 in , 12 gauge Armco 14,700# at Elastic Limit

Ratio	Armco	Republic	United
Section Modulus 12 gauge plain plates	1 :	1.125 :	1.513

Ratio	Armco	Republic	United
Elastic Limit 12 gauge plain plates	1 :	1.925 :	2.520

Z = .1298 in , 7 gauge United 65,000# at Elastic Limit
Z = .0984 in , 7 gauge Republic 44,000# at Elastic Limit
Z = .0865 in , 7 gauge Armco 37,000# at Elastic Limit

Ratio	Armco	Republic	United
Section Modulus 7 gauge plain plates	1 :	1.135 :	1.501

Ratio	Armco	Republic	United
Elastic Limit 7 gauge plain plates	1 :	1.32 :	1.76

Z = .1945 in , 1 gauge United 120,000# at Elastic Limit
Z = .1450 in , 1 gauge Republic 73,000# at Elastic Limit
Z = .1280 in , 1 gauge Armco 44,000# at Elastic Limit

Ratio	Armco	Republic	United
Section Modulus 1 gauge plain plate	1 :	1.132 :	1.52

Ratio	Armco	Republic	United
Elastic Limit 1 gauge plain plates	1 :	1.66 :	2.73

Results of comparison of the ratio of Elastic Limit to the ratio of Section Modulus.

For the plates tested as columns there seems to be no definite relationship for a basis of comparison of Elastic Limit to Section Modulus except that for all gauge plates tested the ratio of Elastic Limit is higher than the ratio for Section Modulus.

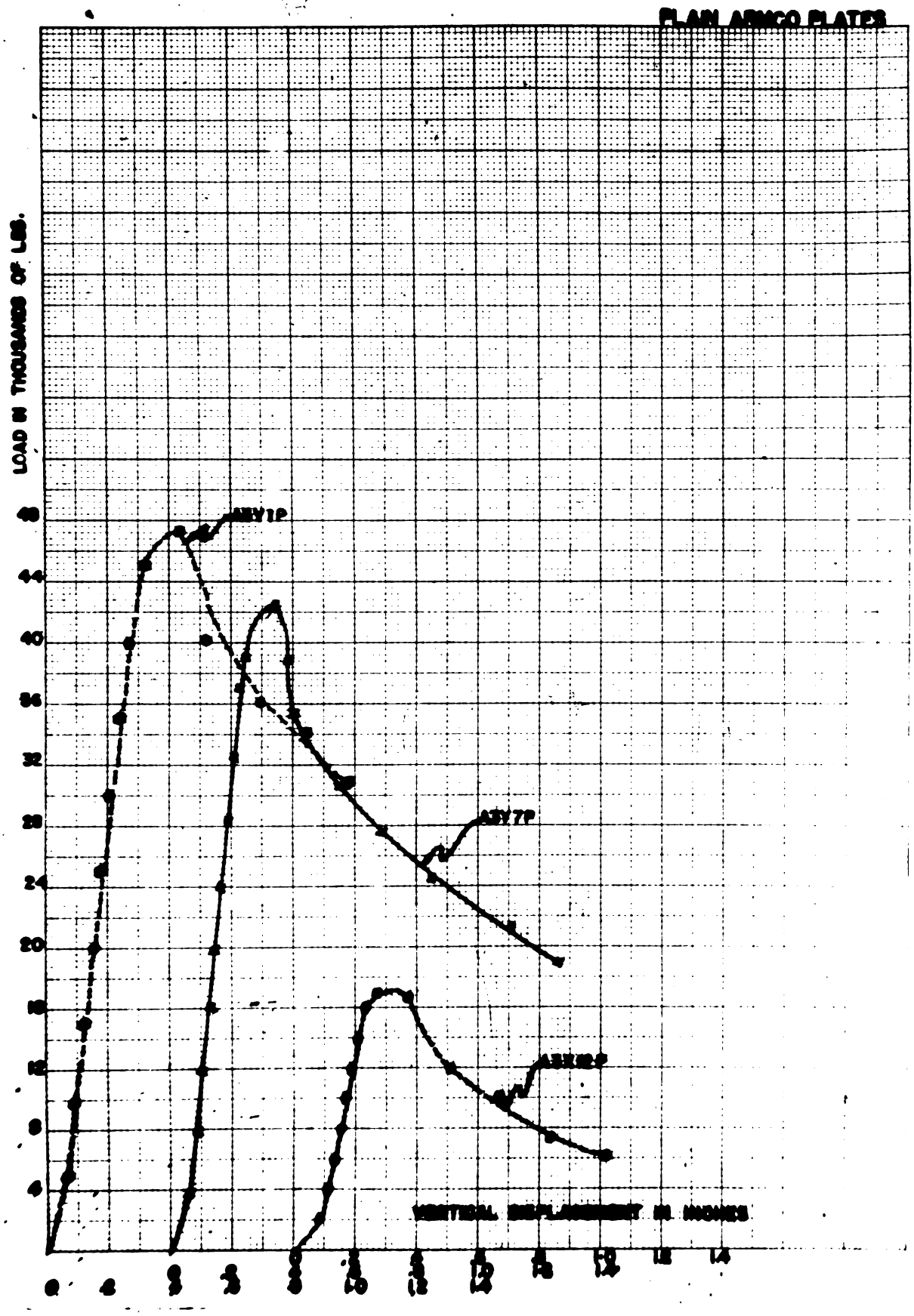
PLAIN ARMCO PLATES
LOAD IN THOUSANDS OF LBS.
A3Y1P
A3Y7P
A3X1P
VERTICAL DISPLACEMENT IN INCHES

Fig. 50.

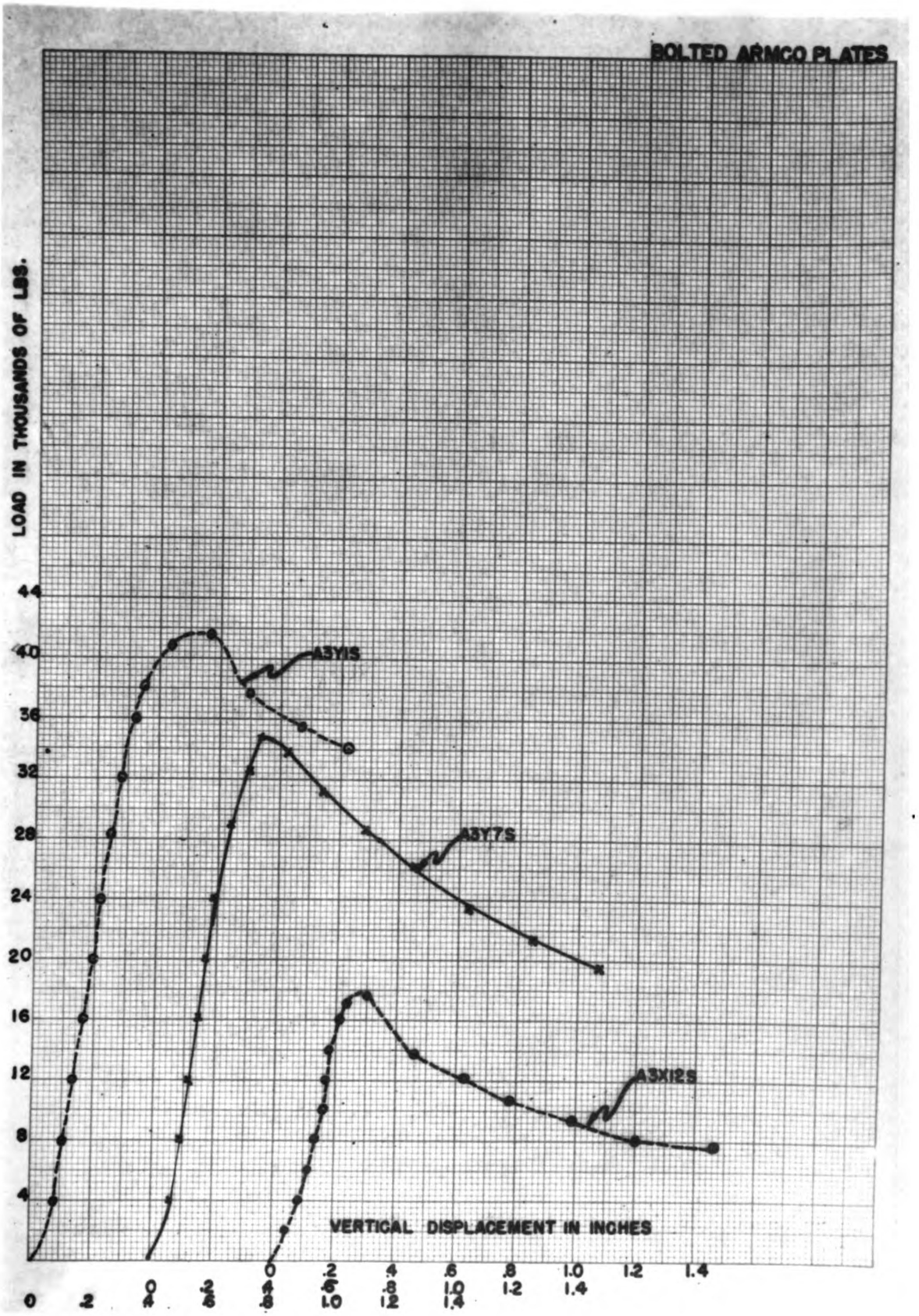
BOLTED ARMCO PLATES
LOAD IN THOUSANDS OF LBS.
44
40
36
32
28
24
20
16
12
8
4
A3Y1S
A3Y7S
A3X12S
VERTICAL DISPLACEMENT IN INCHES
0 .2 .4 .6 .8 1.0 1.2 1.4

Fig. 51.

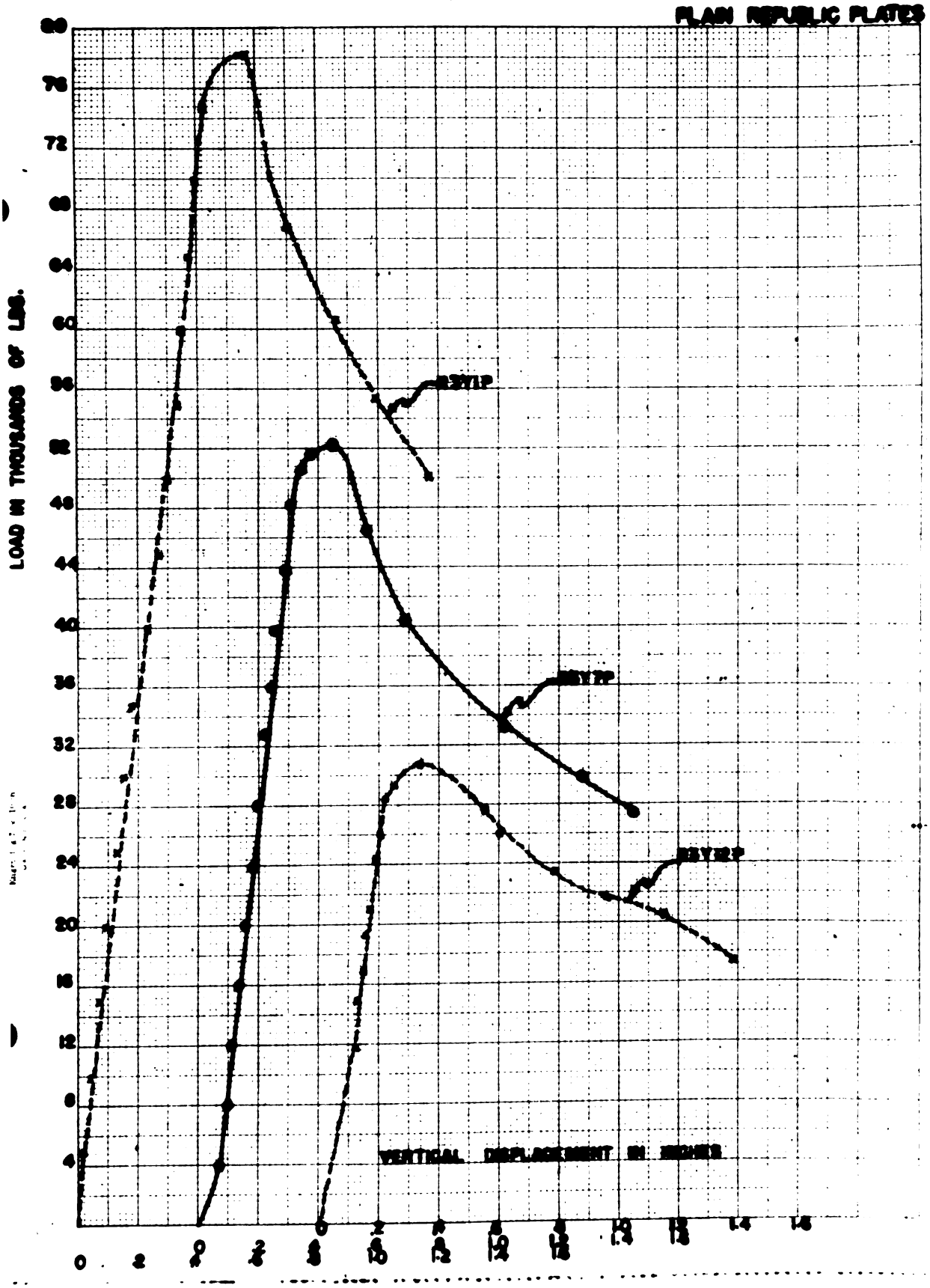
PLAIN REPUBLIC PLATES
LOAD IN THOUSANDS OF LBS.
80
76
72
68
64
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
2
4
6
8
10
12
14
16
1.4
1.6

Fig. 52.

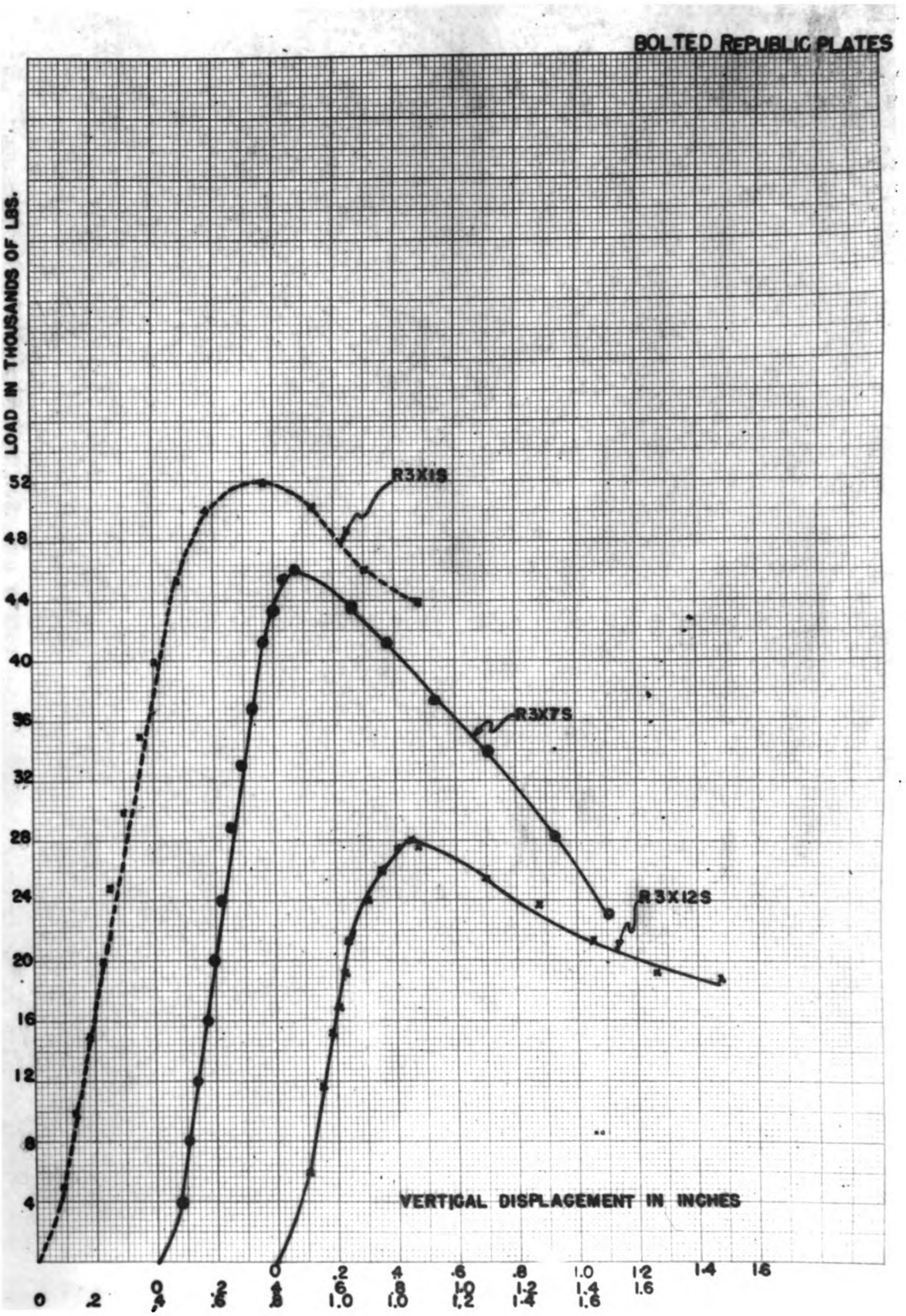
BOLTED REPUBLIC PLATES
LOAD IN THOUSANDS OF LBS.
52
48
44
40
36
32
28
24
20
16
12
8
4
R3X18
R3X7S
R3X12S
VERTICAL DISPLACEMENT IN INCHES
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6

Fig. 53.

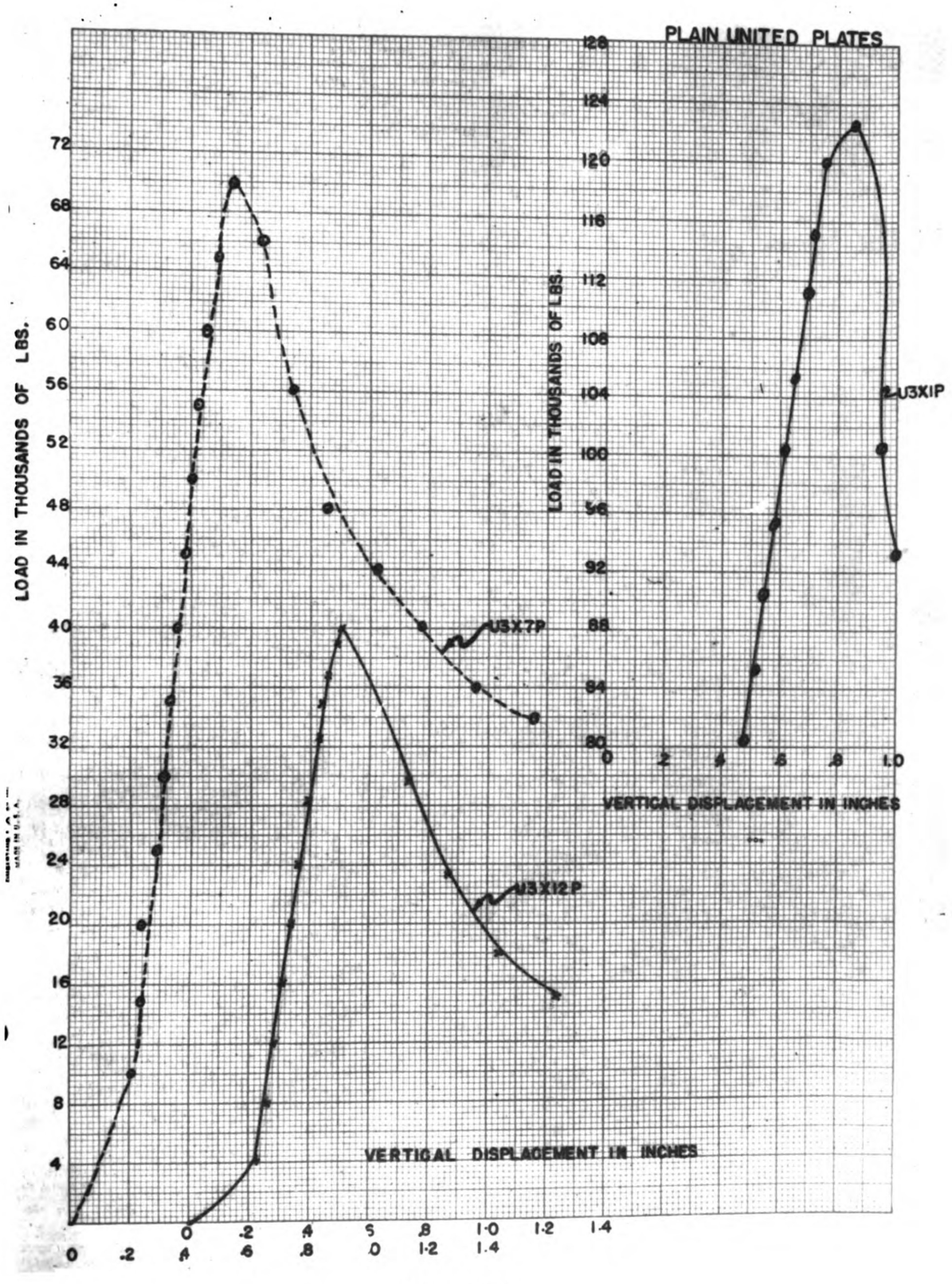
PLAIN UNITED PLATES
LOAD IN THOUSANDS OF LBS.
VERTICAL DISPLACEMENT IN INCHES
U3X7P
U3X12P
U3X1P

Fig. 54.

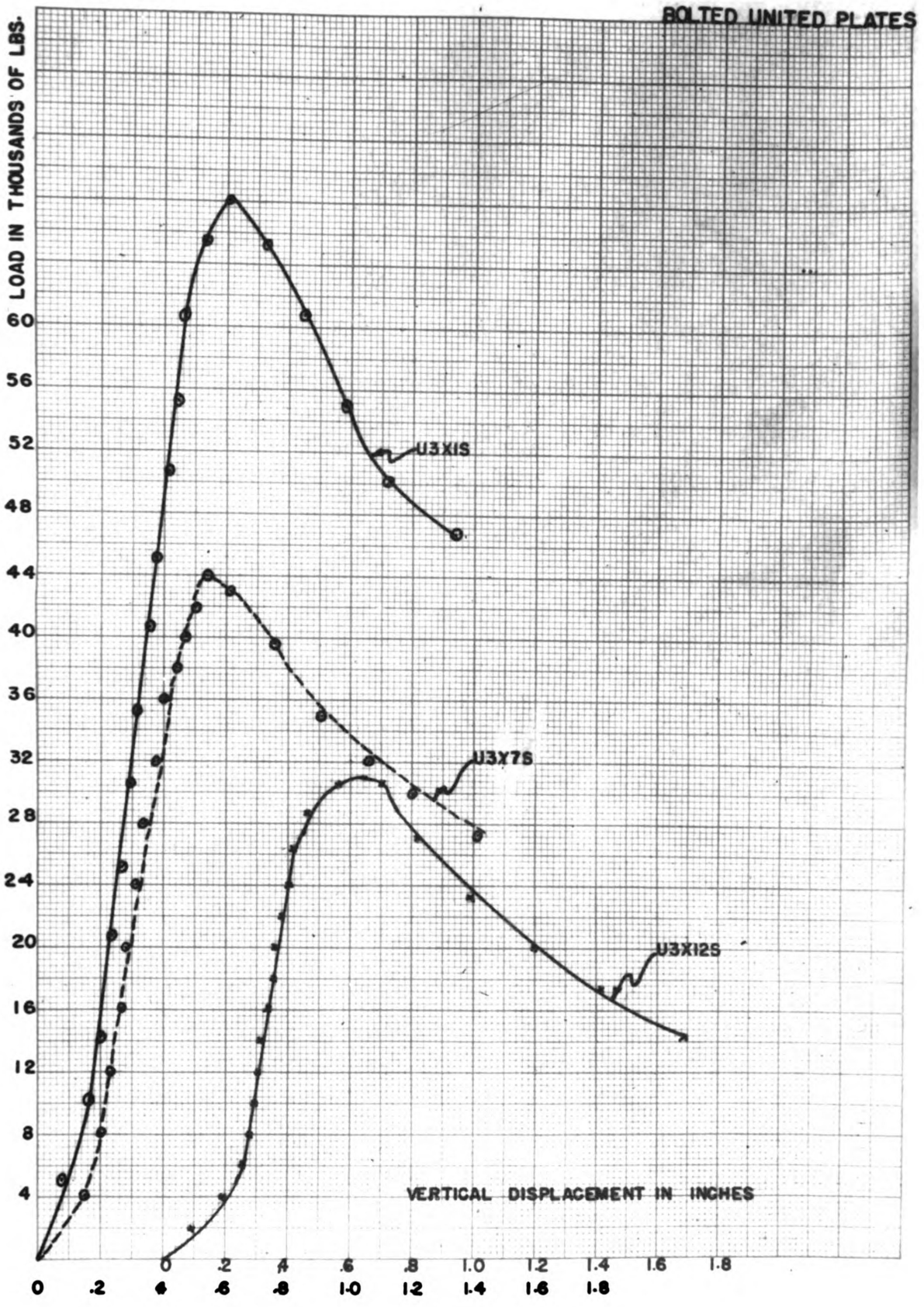
BOLTED UNITED PLATES
LOAD IN THOUSANDS OF LBS.
60
56
52
48
44
40
36
32
28
24
20
16
12
8
4
U3X1S
U3X7S
U3X12S
VERTICAL DISPLACEMENT IN INCHES
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8

Fig. 55.

CONCLUSION

This test on multi plate sections was run to see if the 2" depth of corrugation was superior to the $1\frac{3}{4}$" depth of corrugation, also to find out if the box type of corrugation was superior to the sine wave type of corrugation, and to see if the lap joint was superior to the butt joint for joining the multi plate sections together.

The Armco Company uses a $1\frac{3}{4}$" depth of corrugation with a sine wave type of corrugation and a lap joint.

The United Company uses a 2" depth of corrugation with a box type of corrugation and a butt joint.

The Republic Company uses a 2" depth of corrugation with a sine wave type of corrugation and a lap joint.

Results:

The test results show that the 2" depth of corrugation is superior to the $1\frac{3}{4}$" depth of corrugation and that the box type of corrugation is superior to the sine wave type of corrugation (see Page 67 for computations).

The test results also show that the lap joint is superior to the butt joint (see page 67 for computations).

RESEARCH DATA

The following data sheets are the ones from which the data for the graphs for this report were taken. The data sheets follow the same order in this report as the graphs do in the front part of this report. All of the data sheets have an identifying marking on them which is the same as the graph and picture marking. For example on the first data sheet opposite Spec. Designation, the marking A3 x 12P appears, which means it is the data sheet of the Armco Company's test 3, plate x, and it is also a 12 gauge plain plate.

In the first column the dynometer readings are placed, the second column is used for load in lbs., the third and fifth columns are used for the vertical displacement (see Fig. 5) in inches, the fourth and sixth columns are used for the displacement in inches per increment of load used. The seventh and ninth columns are used for the horizontal displacement (see Fig. 5) in inches, and the eighth and tenth columns are used for the displacement in inches per increment of load used.

In addition the thickness of each plate is given and the radius to the neutral axis is given.

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date *Jan. 5, 1950*
Machine *Highway [illegible]*
Ring No. *AK1*
Observers *[illegible]*
Sheet No *1*

Source of Material *Armco* Spec. Designation *A 3 X 12 P*
Type Corrugations *A* Test No. *3* Spec. No. *X* Gage *12*
Plain *P* Bolted ____ Thickness *.106* Length ____ Radius *150"*
Pictures *A 3 X 12 P 1 pic*

TEST RESULTS

Dial, Load	Load #	Dial 1	Δ1	Dial 2	Δ2	Dial 3	Δ3	Dial 4	Δ4
0		6.651		7.071		6.991		6.984	
3.5	2,000	6.559	.092	6.984	.087	6.943	.048	6.966	.018
7.0	4,000	6.534	.117	6.961	.116	6.904	.087	6.930	.054
10.5	6,000	6.512	.139	6.942	.139	6.863	.128	6.889	.095
13.8	8,000	6.490	.161	6.922	.149	6.814	.177	6.890	.144
17.2	10,000	6.472	.179	6.906	.165	6.772	.219	6.796	.188
20.4	12,000	6.456	.195	6.891	.180	6.732	.259	6.756	.228
23.5	14,000	6.434	.217	6.870	.201	6.672	.319	6.696	.288
27.0	16,177	6.410	.241	6.849	.222	6.595	.396	6.625	.359
28.4	17,000	6.371	.280	6.812	.259	6.425	.566	6.466	.518
24.0	16,590	6.273	.378	6.716	.355	6.000	.991	6.056	.828
24.0	16,590	6.273	.378	6.716	.355	5.992	.991	5.996	.828
20.5	12,063	6.131	.520	6.577	.494	5.465	1.518	5.490	1.334
17.0	9,885	5.977	.674	6.427	.644	5.000	1.983	5.026	1.798
17.0	9,885	5.977	.674	6.427	.644	4.975	1.983	4.994	1.798
13.2	7,620	5.796	.855	6.247	.824	4.495	2.463	4.517	2.225
11.0	6,300	5.577	1.074	[illegible]	1.041	4.000	2.958	4.011	2.781

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date Jan. 2, 1960
Machine [illegible]
Ring No. K-1
Observers [illegible]
Sheet No. 1

Source of Material Uemco
Spec. Designation A3X125
Type Corrugations B
Test No. 3
Spec. No. X
Gage 12
Plain
Bolted 5
Thickness .103
Length
Radius 180°
Pictures A3X125 1 pic

TEST RESULTS

Dial Load	Load #	Dial 1	Δ 1	Dial 2	Δ 2	Dial 3	Δ 3	Dial 4	Δ 4
0		6.899		6.421		6.984		6.983	
3.5	2,000	6.848	.051	6.358	.063	6.947	.037	6.942	.041
7.0	4,000	6.821	.078	6.329	.092	6.911	.073	6.902	.081
10.5	6,000	6.801	.098	6.307	.114	6.876	.108	6.860	.123
13.8	8,000	6.783	.116	6.288	.113	6.836	.148	6.814	.169
17.2	10,000	6.764	.135	6.268	.153	6.787	.197	6.757	.226
20.4	12,000	6.749	.150	6.251	.170	6.743	.241	6.704	.279
23.5	14,000	6.728	.171	6.229	.192	6.678	.306	6.627	.356
26.6	16,000	6.707	.192	6.205	.216	6.601	.383	6.537	.446
28.4	17,000	6.679	.220	6.173	.248	6.482	.502	6.402	.581
29.2	17,472	6.614	.285	6.101	.320	6.166	.818	6.079	.904
26.5	15,882	6.579	.320	6.067	.354	6.011	.973	6.000	.983
26.5	15,882	6.579	.320	6.067	.354	5.991	.973	6.000	.983
23.0	13,660	6.454	.445	5.939	.482	5.488	1.476	5.512	1.471
20.5	12,063	6.312	.587	5.793	.628	5.000	1.964	5.039	1.945
20.5	12,063	6.312	.587	5.763	.628	4.992	1.964	5.000	1.945
18.5	10,780	6.145	.754	5.621	.800	4.495	2.461	4.524	2.421
16.0	9,300	5.953	.946	5.425	.996	4.000	2.956	4.144	2.901
16.0	9,300	5.953	.946	5.425	.996	3.992	2.956	4.000	2.901
14.0	8,120	5.731	1.168	5.195	1.226	3.495	3.453	3.510	3.391
13.0	7,500	5.455	1.414	4.950	1.471	3.000	3.948	3.030	3.871

Form 579 (8-49)

MULTI-PLATE INVESTIGATION

RESEARCH DATA

Date Jan 4, 1950
Machine [illegible]
Ring No. [illegible]
Observers [illegible]
Sheet No. 1

Source of Material Gemco Spec. Designation A347P
Type Corrugations A Test No. 3 Spec. No. 4 Gage 7
Plain P Bolted Thickness .183 Length Radius 150"
Pictures A347P 1 pic.

TEST RESULTS

Dial, Load	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
0		6.059		6.431		7.000		6.986	
3.5	2,000	6.023	.036	6.388	.043	6.991	.009	6.979	.007
7.0	4,000	6.004	.055	6.364	.067	6.978	.022	6.961	.025
10.5	6,000	5.989	.070	6.346	.085	6.962	.038	6.944	.042
13.8	8,000	5.976	.083	6.332	.099	6.946	.054	6.929	.062
17.2	10,000	5.967	.092	6.321	.110	6.931	.069	6.907	.079
20.4	12,000	5.959	.100	6.312	.119	6.919	.081	6.892	.094
23.5	14,000	5.949	.110	6.302	.129	6.903	.097	6.873	.113
26.6	16,000	5.941	.118	6.293	.138	6.889	.111	6.858	.128
30.5	18,528	5.931	.128	6.282	.149	6.871	.139	6.837	.149
33.2	20,000	5.921	.138	6.272	.159	6.856	.144	6.818	.168
36.2	22,000	5.912	.147	6.263	.168	6.841	.159	6.800	.186
39.4	24,000	5.904	.155	6.254	.177	6.826	.174	6.780	.206
42.9	26354	5.893	.166	6.243	.188	6.807	.193	6.757	.229
46.4	28,472	5.881	.178	6.230	.201	6.786	.214	6.734	.252
49.9	30,567	5.873	.186	6.221	.210	6.769	.231	6.714	.272
53.4	32,693	5.859	.200	6.206	.225	6.742	.258	6.683	.303
56.9	34,767	5.849	.210	6.195	.236	6.718	.282	6.655	.331
60.4	36,882	5.837	.222	6.182	.249	6.684	.316	6.615	.371
63.9	39,059	5.822	.237	6.166	.265	6.638	.362	6.559	.427
67.4	41,189	5.806	.253	6.149	.282	6.575	.425	6.486	.500
69.5	42,504	5.736	.323	6.065	.366	6.160	.840	6.035	.951
69.5	42,504	5.736	.323	6.065	.366	5.999	.840	5.979	.951
55.0	33,640	5.638	.421	5.957	.474	5.458	1.381	5.438	1.492
50.0	30,630	5.534	.525	5.849	.582	5.000	1.839	5.000	1.930
50.0	30,630	5.534	.525	6.849	.582	5.000	1.839	4.989	1.930
44.8	27,504	5.396	.663	5.708	.723	4.494	2.345	4.501	2.418
40.0	24432	5.238	.821	5.547	.884	4.000	2.839	4.019	2.900

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

Date Jan 6 1950
Machine Hydraulic 50 ton
Ring No. K1
Observers Gil. Yocke
Sheet No. 2

RESEARCH DATA

Source of Material Gemco Spec. Designation A347P
Type Corrugations G Test No. 3 Spec. No. 4 Gage 17
Plain P Bolted _____ Thickness .183 Length 4 Radius 1.70"
Pictures A347P 1 pic

TEST RESULTS

Dial / Load	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
40.0	24432	5.238	.821	5.547	.884	4.000	2.839	3.992	3.900
35.0	21191	4.939	1.120	5.347	1.084	3.492	3.347	3.492	3.400
31.5	18928	4.828	1.231	5.136	1.295	3.000	3.839	3.009	3.883

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date ____
Machine Highway 50 Ton
Ring No. B-1
Observers Gid. Yask
Sheet No. 1

Source of Material Armco   Spec. Designation A3475
Type Corrugations A   Test No. 3   Spec. No. 4   Gage 7
Plain ____   Bolted 5   Thickness .183   Length ____   Radius 150"
Pictures A3475 Spec.

TEST RESULTS

Load Read	Load #	Dial 1	Δ 1	Dial 2	Δ 2	Dial 3	Δ 3	Dial 4	Δ 4
0		6.884		6.183		6.999		6.993	
3.5	2000	6.832	.052	6.130	.053	6.999	.000	6.992	.001
7.0	4000	6.813	.071	6.105	.078	6.981	.018	6.978	.015
10.5	6000	6.800	.084	6.089	.094	6.960	.039	6.955	.038
13.8	8,000	6.786	.098	6.076	.107	6.940	.059	6.937	.056
17.2	10,000	6.774	.110	6.063	.120	6.914	.085	6.911	.082
20.4	12,000	6.765	.119	6.054	.129	6.897	.102	6.893	.100
23.5	14,000	6.753	.121	6.042	.141	6.872	.127	6.869	.124
26.6	16,000	6.743	.141	6.032	.151	6.848	.151	6.844	.149
30.1	18,000	6.729	.155	6.018	.165	6.816	.183	6.811	.182
33.2	20,000	6.714	.170	6.003	.180	6.777	.222	6.772	.221
36.2	22,000	6.704	.180	5.988	.195	6.729	.270	6.730	.263
39.4	24,000	6.684	.190	5.973	.210	6.688	.311	6.687	.306
42.9	26,354	6.665	.219	5.954	.229	6.628	.371	6.631	.362
47.0	28,826	6.636	.248	5.925	.258	6.537	.462	6.542	.451
49.9	30,567	6.620	.264	5.907	.276	6.485	.574	6.492	.501
53.4	32,693	6.586	.298	5.873	.310	6.358	.641	6.372	.621
56.9	34,767	6.545	.339	5.834	.349	6.194	.805	6.211	.782
55.0	33,640	6.463	.421	5.752	.431	6.000	.999	6.000	.993
55.0	33,640	6.463	.421	5.752	.431	6.000	.999	5.992	.993
51.0	31,236	6.331	.553	5.622	.561	5.479	1.510	5.485	1.500
46.5	28.531	6.194	.690	5.483	.700	5.000	1.989	5.000	1.985
46.5	28,531	6.194	.690	5.483	.700	4.995	1.989	4.992	1.985
42.5	26,118	6.026	.858	5.312	.861	4.484	2.500	4.495	2.482
38.3	23,354	5.848	1.036	5.133	1.050	4.000	2.984	4.021	2.956
38.3	23,354	5.848	1.036	5.133	1.050	3.986	2.984	3.992	2.956
35.1	21,258	5.636	1.248	4.919	1.264	3.487	3.483	3.505	3.443

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date Jan 12, 1950
Machine Riehle [illegible]
Ring No. M-1
Observers [illegible]
Sheet No. 1

Source of Material Armco Spec. Designation A3Y1P
Type Corrugations P Test No. 3 Spec. No. 4 Gage 01
Plain P Bolted Thickness .274 Length 0 Radius 1.50
Pictures A3Y1P [illegible]

TEST RESULTS

Dial Load	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
0		6.925		6.564		6.945		6.936	
2.5	5,000	6.859	.066	6.499	.065	6.908	.037	6.903	.033
4.9	10,000	6.827	.098	6.465	.099	6.870	.075	6.869	.067
7.4	15,000	6.799	.126	6.439	.125	6.829	.116	6.795	.141
9.8	20,000	6.772	.153	6.412	.152	6.787	.158	6.799	.137
12.3	25,000	6.743	.182	6.385	.179	6.741	.204	6.759	.177
14.9	30,200	6.713	.212	6.354	.210	6.693	.252	6.716	.220
17.4	35,200	6.686	.239	6.324	.240	6.644	.301	6.665	.271
20.0	40,000	6.651	.274	6.292	.272	6.572	.373	6.600	.336
22.5	45,400	6.600	.325	6.247	.317	6.428	.517	6.467	.469
23.6	47,600	6.518	.407	6.174	.390	6.091	.854	6.153	.783
23.6	47,600	6.518	.407	6.174	.390	5.985	.854	5.962	.783
20.0	40,000	6.390	.535	6.[illegible]	.570	5.487	1.352	5.485	1.260
18.0	36,000	6.257	.668	5.926	.638	5.019	1.820	5.032	1.713
18.0	36,000	6.257	.668	5.926	.638	4.965	1.820	4.972	1.713
17.0	34,400	6.099	.826	5.775	.789	4.496	2.289	4.495	2.160
15.8	32,000	5.916	1.009	5.598	.966	4.008	2.777	4.009	2.676

Form 579 (8-49)

MULTI-PLATE INVESTIGATION

Date ______
Machine [illegible]
Ring No. [illegible]
Observers [illegible]
Sheet No. 10

RESEARCH DATA

Source of Material Uemco Spec. Designation A 3415
Type Corrugations ______ Test No. 9 Spec. No. 4 Gage 1
Plain ______ Bolted 5 Thickness ______ Length ______ Radius 150"
Pictures A3415 1 pic

TEST RESULTS

Dial Load	Load #	Dial 1	Δ 1	Dial 2	Δ 2	Dial 3	Δ 3	Dial 4	Δ 4
0		6.782		6.414		6.922		6.925	
3.5	2,000	6.728	.054	6.347	.067	6.906	.016	6.910	.015
7.0	4,000	6.705	.077	6.323	.091	6.887	.035	6.892	.033
10.5	6,000	6.690	.092	6.308	.106	6.872	.050	6.874	.051
13.8	8,000	6.667	.115	6.295	.119	6.853	.069	6.857	.068
17.2	10,000	6.664	.118	6.283	.131	6.837	.085	6.828	.097
20.4	12,000	6.652	.130	6.272	.142	6.820	.102	6.820	.105
23.5	14,000	6.640	.142	6.261	.153	6.802	.120	6.801	.124
26.7	16,000	6.629	.153	6.251	.163	6.785	.137	6.783	.142
30.1	18,000	6.618	.164	6.241	.173	6.763	.159	6.764	.161
33.2	20,000	6.607	.175	6.229	.185	6.745	.177	6.744	.181
36.2	22,000	6.594	.188	6.216	.198	6.723	.199	6.721	.204
39.4	24,000	6.582	.200	6.204	.210	6.700	.222	6.698	.227
42.3	26,000	6.571	.211	6.193	.221	6.678	.244	6.675	.250
46.0	28,236	6.555	.227	6.176	.238	6.643	.279	6.638	.287
49.4	30,252	6.540	.242	6.160	.254	6.609	.313	6.598	.327
52.3	32,000	6.525	.257	6.144	.270	6.571	.351	6.557	.368
55.8	34,118	6.504	.278	6.121	.293	6.512	.410	6.495	.430
59.0	36,000	6.473	.309	6.089	.325	6.425	.497	6.403	.522
62.2	38,000	6.445	.337	6.058	.356	6.342	.570	6.306	.619
65.5	40,000	6.397	.385	6.005	.409	6.182	.740	6.128	.797
67.1	41,000	6.372	.410	5.976	.438	6.090	.832	6.025	.900
67.1	41,000	6.372	.410	5.976	.438	5.982	.832	5.977	.900
68.3	41,756	6.241	.541	5.838	.576	5.482	1.440	5.454	1.423
61.8	37,756	6.110	.672	5.702	.712	5.006	1.916	5.000	1.877
61.8	37,756	6.110	.672	5.702	.712	4.999	1.916	4.980	1.877
58.0	35,463	5.948	.834	5.530	.884	4.485	2.430	4.453	2.444
56.0	34,236	5.802	.980	5.365	1.049	4.044	2.871	4.004	2.853

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

Date Dec 27, 1949
Machine Highway Testing
Ring No. B-6
Observers Gill, Yorke
Sheet No. 1

RESEARCH DATA

Source of Material Republic
Type Corrugations R Test No. 3 Spec. No. 4 Spec. Designation R3Y12P
Plain P Bolted Thickness .116 Length 4 Gage 12
Pictures R3Y12P 4pic. Radius 150"

TEST RESULTS

Dial Rad	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
		6.157		6.876		6.909		6.951	
20.0	11,720	6.040	.117	6.756	.120	6.783	.126	6.819	.132
25.5	15,252	6.023	.134	6.742	.134	6.754	.155	6.784	.167
28.5	17,057	6.008	.149	6.729	.147	6.727	.182	6.753	.198
32.0	19,252	5.996	.161	6.718	.158	6.702	.202	6.725	.226
25.0	21,191	5.986	.171	6.708	.168	6.681	.228	6.700	.251
38.0	23,177	5.971	.186	6.694	.182	6.649	.260	6.665	.286
39.8	24,288	5.958	.199	6.682	.194	6.621	.288	6.630	.321
42.5	26,118	5.948	.209	6.672	.204	6.599	.310	6.604	.347
46.0	28,226	5.933	.224	6.657	.219	6.559	.350	6.554	.397
47.9	29,345	5.912	.245	6.636	.240	6.500	.490	6.480	.471
49.0	30,000	5.887	.270	6.608	.268	6.406	.503	6.363	.588
50.1	30,693	5.814	.343	6.529	.347	6.096	.813	6.000	.951
50.1	30,693	5.814	.343	6.529	.347	5.985	.813	6.000	.951
45.0	27,630	5.618	.539	6.325	.551	5.221	1.577	5.194	1.757
42.9	26,354	5.560	.597	6.265	.611	5.026	1.772	5.000	1.951
42.9	26,354	5.560	.597	6.265	.611	4.932	1.772	5.000	1.951
38.6	23,531	5.384	.773	6.086	.790	4.440	2.290	4.485	2.466
35.9	21,794	5.215	.942	5.913	.963	4.001	2.730	4.026	2.925
35.9	21,794	5.215	.992	5.913	.963	3.979	2.730	3.950	2.925
34.0	20,526	5.005	1.152	5.701	1.175	3.491	3.218	3.439	3.436
29.5	17,649	4.798	1.359	5.491	1.385	3.072	3.637	3.000	3.875

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

Date Sept. 28, 1949
Machine Riehle 60,000
Ring No. 1461
Observers Gid. Upade
Sheet No. 1

RESEARCH DATA

Source of Material Republic Spec. Designation R3X12.5
Type Corrugations R Test No. 2 Spec. No. X Gage 12
Plain Bolted S Thickness .113 Length Radius 6.27"
Pictures R3X12.5 1 pic.

TEST RESULTS

Dial Read	Load #	Dial 1	Δ 1	Dial 2	Δ 2	Dial 3	Δ 3	Dial 4	Δ 4
0		6.024		6.528		6.993		6.961	
20.0	14,720	5.877	.147	6.367	.161	6.847	.196	6.759	.202
25.5	15,252	5.852	.172	6.338	.190	6.791	.202	6.689	.272
28.5	17,059	5.835	.189	6.317	.211	6.747	.246	6.636	.326
32.0	19,262	5.818	.206	6.297	.231	6.702	.291	6.585	.376
35.0	21,191	5.799	.225	6.276	.252	6.649	.344	6.524	.437
38.0	23,177	5.765	.259	6.239	.289	6.549	.444	6.412	.549
39.8	24,288	5.720	.304	6.190	.338	6.416	.577	6.265	.696
42.5	26,118	5.683	.341	6.150	.378	6.300	.693	6.140	.821
44.8	27,504	5.640	.384	6.104	.424	6.162	.831	6.000	.961
44.8	27,504	5.640	.384	6.104	.424	5.981	.831	6.000	.961
46.0	28,236	5.600	.424	6.064	.464	5.857	.955	5.871	1.090
45.1	27,693	5.479	.445	5.936	.592	5.436	1.376	5.432	1.529
41.7	25,593	5.347	.677	5.800	.728	5.000	1.812	5.000	1.961
41.7	25,593	5.347	.677	5.800	.728	4.985	1.812	4.995	1.961
38.9	23,708	5.184	.840	5.634	.894	4.470	2.327	4.482	2.474
34.5	20,861	5.011	1.013	5.451	1.077	4.000	2.797	4.010	2.946
34.5	20,861	5.011	1.013	5.451	1.077	3.992	2.797	3.981	2.946
32.0	19,252	4.812	1.212	5.238	1.290	3.450	3.299	3.479	3.460
31.5	18,928	4.610	1.414	5.021	1.507	2.000	3.789	3.000	4.929

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

Date
Machine Hydraulic 50
Ring No. K-1
Observers Gill, York
Sheet No. 1

RESEARCH DATA

Source of Material Republic Spec. Designation R3Y7P
Type Corrugations R Test No. 3 Spec. No. Y Gage 7
Plain P Bolted Thickness .183 Length Radius 150"
Pictures R3Y7P 1 pic.

TEST RESULTS

0		6.223		6.683		6.997		6.993	
1.7	1,000	6.197	.026	6.661	.022	6.992	.005	6.993	.000
3.5	2,000	6.179	.048	6.641	.042	6.989	.008	6.993	.000
5.3	3,000	6.164	.059	6.631	.052	6.988	.009	6.992	.001
7.0	4,000	6.156	.067	6.622	.061	6.981	.016	6.985	.008
8.8	5,000	6.148	.075	6.615	.068	6.973	.024	6.978	.015
10.6	6,000	6.141	.082	6.607	.076	6.966	.031	6.969	.024
12.1	7,000	6.134	.089	6.600	.083	6.958	.039	6.959	.034
13.8	8,000	6.127	.096	6.594	.089	6.950	.047	6.951	.042
15.6	9,000	6.121	.102	6.588	.095	6.943	.054	6.944	.049
17.2	10,000	6.115	.108	6.582	.101	6.935	.062	6.936	.057
18.9	11,000	6.111	.112	6.578	.105	6.931	.066	6.930	.063
20.4	12,000	6.106	.117	6.574	.109	6.925	.072	6.924	.069
22.0	13,000	6.101	.122	6.569	.114	6.919	.078	6.916	.077
23.5	14,000	6.096	.127	6.563	.120	6.912	.085	6.909	.084
25.1	15,000	6.090	.133	6.558	.125	6.906	.091	6.901	.092
26.6	16,000	6.089	.134	6.554	.129	6.900	.097	6.896	.097
28.8	17,000	6.081	.142	6.549	.134	6.893	.104	6.889	.106
30.1	18,000	6.076	.147	6.543	.140	6.885	.112	6.879	.114
31.6	19,000	6.072	.151	6.540	.143	6.879	.118	6.874	.119
33.2	20,000	6.065	.158	6.533	.150	6.870	.127	6.864	.129
34.8	21,000	6.060	.163	6.528	.155	6.862	.135	6.857	.136
36.2	22,000	6.055	.168	6.523	.160	6.856	.141	6.849	.144
37.7	23,000	6.051	.172	6.519	.164	6.850	.147	6.844	.149
39.8	24,000	6.044	.179	6.513	.170	6.840	.157	6.834	.159
41.8	25,000	6.040	.183	6.509	.174	6.835	.162	6.828	.165
42.5	26,118	6.033	.190	6.503	.180	6.825	.172	6.819	.174
44.5	27,315	6.025	.198	6.495	.188	6.819	.183	6.809	.185
45.9	28,177	6.021	.202	6.492	.191	6.805	.189	6.801	.192
47.6	29,177	6.015	.208	6.486	.197	6.798	.199	6.792	.201

Form 579 (8-49)

MULTI-PLATE INVESTIGATION

RESEARCH DATA

Date______
Machine Highway Autoclave
Ring No. Rod
Observers G.H. York
Sheet No. 2

Source of Material Republic Spec. Designation R3Y7P
Type Corrugations R Test No. 3 Spec. No. 4 Gage 7
Plain P Bolted______ Thickness .188 Length______ Radius 150"
Pictures R3Y7P 1 pic

TEST RESULTS

Load Read	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
49.5	30,315	6.009	.214	6.480	.203	6.788	.209	6.783	.210
51.2	31,354	6.003	.220	6.474	.209	6.778	.220	6.772	.221
52.9	32,378	5.996	.227	6.469	.214	6.768	.229	6.763	.230
54.6	33,413	5.990	.233	6.463	.220	6.758	.239	6.755	.240
56.5	34,531	5.983	.240	6.457	.226	6.747	.250	6.742	.251
59.0	36,000	5.975	.248	6.449	.234	6.732	.265	6.728	.265
59.9	36,315	5.973	.250	6.496	.237	6.727	.270	6.723	.270
61.6	37,630	5.967	.256	6.441	.242	6.719	.278	6.714	.279
63.3	38,693	5.960	.263	6.435	.248	6.705	.292	6.701	.292
65.0	39,708	5.955	.268	6.430	.253	6.690	.307	6.683	.310
67.0	40,945	5.948	.275	6.423	.260	6.678	.319	6.672	.321
68.4	41,815	5.943	.280	6.418	.265	6.668	.329	6.661	.332
70.1	42,882	5.938	.285	6.413	.270	6.657	.340	6.651	.342
71.8	43,885	5.930	.293	6.406	.277	6.641	.356	6.634	.359
73.5	44,885	5.921	.302	6.398	.285	6.621	.376	6.614	.379
75.5	46,126	5.913	.310	6.391	.292	6.605	.392	6.596	.397
77.0	47,000	5.907	.316	6.385	.298	6.591	.406	6.580	.413
78.9	48,189	5.898	.325	6.376	.307	6.565	.432	6.555	.438
80.6	49,252	5.888	.335	6.361	.316	6.539	.458	6.526	.467
82.5	50,441	5.872	.351	6.352	.331	6.487	.510	6.470	.523
84.2	51,504	5.848	.375	6.328	.355	6.399	.598	6.371	.622
85.4	52,252	5.769	.454	6.246	.437	6.052	.945	6.000	.993
85.4	52,252	5.769	.454	6.296	.437	6.000	.994	5.992	.993
76.0	46,378	5.652	.571	6.128	.555	5.528	1.466	5.479	1.406
65.9	40,259	5.528	.695	6.002	.681	5.070	1.924	5.000	1.885
65.9	40,252	5.528	.695	6.002	.681	5.000	1.924	4.992	1.885
59.8	36,504	5.369	.854	5.842	.841	4.513	2.411	4.486	2.391
54.0	33,059	5.197	1.026	5.667	1.016	4.032	2.892	4.000	2.877

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date________
Machine *Highway 50?*
Ring No. *R-1*
Observers *Gill, Harter*
Sheet No. *3*

Source of Material *Republic* Spec. Designation *R3Y7P*
Type Corrugations *R* Test No. *3* Spec. No. *Y* Gage *7*
Plain *P* Bolted____ Thickness *.183* Length____ Radius *150"*
Pictures *R3Y7P 1pic*

TEST RESULTS

54.0	33059	5.197	1.026	5.667	1.016	4.032	2.892	4.000	2.877
54.0	33,059	5.101	1.122	5.567	1.116	4.000	2.924	3.992	2.885
49.0	30,000	4.990	1.333	5.456	1.227	3.505	3.419	3.489	3.888
45.0	27,630	4.768	1.455	5.231	1.452	3.020	3.904	3.000	3.877

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date Jan 9, 1950
Machine Hydraulic Testing Machine
Ring No. K10
Observers Gil, Yerke
Sheet No. 1

Source of Material Republic
Type Corrugations R Test No. 3 Spec. Designation R 9 x 7.5
Plain Bolted 5 Thickness .188 Spec. No. X Length Gage 7 Radius 1.50"
Pictures R 9 x 7.5 1 pic

TEST RESULTS

Dial / Load	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
0		6.650		6.596		7.000		6.992	
3.5	2000	6.593	.057	6.535	.060	7.000	.000	6.978	.014
7.0	4,000	6.571	.079	6.508	.087	6.986	.014	6.959	.033
10.5	6,000	6.556	.094	6.486	.109	6.969	.031	6.940	.052
13.8	8,000	6.544	.106	6.470	.125	6.951	.049	6.918	.074
17.2	10,000	6.531	.119	6.457	.138	6.932	.068	6.896	.096
20.4	12,000	6.521	.129	6.445	.150	6.917	.083	6.876	.116
23.5	14,000	6.508	.142	6.432	.163	6.897	.103	6.852	.140
26.6	16,000	6.496	.154	6.420	.175	6.877	.123	6.828	.164
30.1	18,000	6.482	.168	6.406	.189	6.855	.145	6.800	.192
33.2	20,000	6.469	.181	6.393	.202	6.835	.165	6.773	.219
36.2	22,000	6.456	.194	6.380	.215	6.814	.186	6.746	.246
39.4	24,000	6.442	.208	6.367	.228	6.791	.209	6.716	.276
42.9	26,354	6.425	.225	6.351	.244	6.762	.238	6.681	.311
47.0	28,826	6.405	.245	6.332	.263	6.725	.275	6.632	.360
49.9	30,567	6.392	.258	6.317	.278	6.697	.303	6.599	.393
54.2	33,177	6.367	.283	6.289	.304	6.643	.357	6.533	.459
56.9	34,767	6.353	.297	6.278	.317	6.612	.388	6.497	.495
60.4	36,882	6.332	.318	6.256	.339	6.562	.438	6.442	.550
63.9	39,059	6.310	.340	6.234	.361	6.514	.486	6.385	.607
67.4	41,189	6.289	.361	6.212	.383	6.466	.534	6.325	.667
70.9	43,354	6.264	.386	6.183	.412	6.400	.600	6.242	.750
74.4	45,413	6.227	.423	6.142	.453	6.306	.694	6.113	.879
76.0	46,378	6.195	.455	6.105	.490	6.225	.775	6.000	.992
76.0	46,378	6.195	.455	6.105	.490	6.000	.775	5.992	.992
71.0	43,413	6.032	.618	5.911	.684	5.455	1.320	5.360	1.632
67.0	40,945	5.927	.723	5.795	.800	5.040	1.695	5.000	1.984
67.0	40,945	5.927	.723	5.795	.800	5.000	1.695	4.963	1.984

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date Jan 4, 1950
Machine [illegible]
Fing No. 3/1
Observers [illegible]
Sheet No. 2

Source of Material Republic Spec. Designation R 9 X 7 5
Type Corrugations R Test No. 9 Spec. No. X Gage 7
Plain ______ Bolted 5 Thickness .188 Length ______ Radius 150"
Pictures R 9 X 7 5 [illegible]

TEST RESULTS

Dial Load	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
67.0	40,945	5.927	.723	5.798	.800	6.000	1.690	4.903	1.884
61.0	37,252	5.759	.891	5.617	.978	4.480	2.215	4.495	2.482
55.5	33,944	5.587	1.063	5.436	1.159	3.999	2.690	3.997	2.902
46.0	28,236	5.383	1.267	5.220	1.375	3.489	3.105	3.488	3.166
38.0	23,177	5.158	1.492	4.994	1.601	3.000	3.594	3.000	3.854

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date *Jan 19, 1950*
Machine [illegible]
Ping No. [illegible]
Observers [illegible]
Sheet No *1*

Source of Material *Republic* Spec. Designation *R3Y1P*
Type Corrugations *R* Test No. *3* Spec. No. *Y* Gage *1*
Plain *P* Bolted ____ Thickness *.304* Length *Y* Radius *150°*
Pictures *R3Y1P 1pic*

TEST RESULTS

Dial Load	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
0		6.155		6.872		6.995		6.991	
2.5	5,000	6.101	.054	6.804	.068	6.978	.017	6.977	.014
4.9	10,000	6.071	.084	6.772	.100	6.949	.046	6.954	.037
7.4	15,000	6.045	.110	6.745	.127	6.922	.073	6.927	.064
9.8	20,000	6.019	.136	6.719	.153	6.892	.103	6.901	.090
12.3	25,000	5.993	.162	6.691	.181	6.863	.132	6.872	.119
14.8	30,000	5.972	.183	6.668	.204	6.838	.157	6.847	.144
17.3	35,000	5.948	.207	6.644	.228	6.811	.184	6.818	.173
20.0	40,000	5.919	.236	6.615	.257	6.775	.220	6.782	.209
22.3	45,000	5.893	.262	6.589	.283	6.742	.253	6.748	.243
24.9	50,000	5.874	.281	6.569	.303	6.716	.279	6.721	.270
27.3	55,000	5.842	.313	6.537	.335	6.669	.326	6.674	.317
29.8	60,000	5.827	.328	6.521	.351	6.647	.348	6.652	.339
32.2	65,000	5.799	.356	6.494	.378	6.604	.391	6.609	.382
34.7	70,000	5.774	.381	6.470	.402	6.559	.436	6.562	.429
37.2	75,000	5.736	.419	6.430	.442	6.476	.519	6.471	.520
38.8	78,300	5.608	.547	6.293	.579	6.003	.992	6.000	.991
38.8	78,300	5.608	.547	6.293	.579	6.000	.992	6.978	.991
33.0	66,600	5.469	.686	6.158	.714	5.485	1.507	5.458	1.511
30.2	60,400	5.339	.816	6.030	.842	5.036	1.956	5.008	1.961
30.2	60,400	5.339	.816	6.030	.842	4.999	1.956	4.978	1.961
27.3	55,200	5.174	.981	5.869	1.003	4.506	2.449	4.485	[illegible]
25.1	50,100	4.993	1.162	5.690	1.182	4.022	2.933	4.001	2.938

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

Date Jan. 17, 1950
Machine [illegible]
Ring No. [illegible]
Observers [illegible]
Sheet No. 1

RESEARCH DATA

Source of Material Republic

Spec. Designation R 3 X 15

Type Corrugations R Test No. 2 Spec. No. 8 Gage 1

Plain ___ Bolted 5 Thickness .294 Length ___ Radius 120″

Pictures R 3 X 15 1 pic.

TEST RESULTS

Dial Load	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
0		6.803		7.014		6.987		6.998	
2.5	5,000	6.689	.114	6.934	.080	6.943	.044	6.993	.055
4.9	10,000	6.640	.163	6.907	.107	6.901	.086	6.895	.103
7.4	15,000	6.585	.218	6.873	.141	6.846	.141	6.830	.168
9.8	20,000	6.542	.261	6.844	.170	6.797	.190	6.770	.228
12.3	25,000	6.495	.308	6.810	.204	6.730	.257	6.716	.282
14.8	30,000	6.456	.347	6.774	.240	6.668	.319	6.645	.353
17.3	35,000	6.389	.414	6.731	.283	6.579	.408	6.557	.441
14.8	39,600	6.328	.475	6.684	.330	6.475	.512	6.449	.549
22.3	45,000	6.255	.548	6.620	.394	6.328	.659	6.296	.702
24.8	49,800	6.158	.645	6.531	.483	6.089	.898	6.070	.928
24.8	49,800	6.158	.645	6.531	.483	5.992	.898	5.998	.928
26.3	53,000	5.953	.850	6.350	.664	5.437	1.453	5.488	1.438
24.9	50,000	5.803	1.000	6.203	.811	5.022	1.868	5.085	1.841
24.9	50,000	5.813	1.000	6.203	.811	4.992	1.868	4.993	1.841
23.2	46,800	5.606	1.197	6.009	1.005	4.486	2.374	4.491	2.343
21.7	41,400	5.415	1.388	5.821	1.193	4.007	2.980	4.022	2.812

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

Date 9a-9.1950
Machine Upham 60 Ton
Ring No. 1 K-1
Observers Gill & Yeebs
Sheet No. 1

RESEARCH DATA

Source of Material United
Type Corrugations U Test No. 8 Spec. No. X Gage 12
Plain P Bolted Thickness .106 Length Radius 150"
Pictures U 3 X 12 P 1pic

Spec. Designation U 3 X 12 P

TEST RESULTS

Dial Read	Load #	Dial 1	Δ 1	Dial 2	Δ 2	Dial 3	Δ 3	Dial 4	Δ 4
0		6.881		6.330		6.992		6.992	
7.0	4,000	6.658	.223	6.199	.221	6.999	-.007	6.992	.000
13.8	8,000	6.616	.265	6.078	.252	6.999	-.007	6.992	.000
20.4	12,000	6.589	.292	6.054	.276	6.982	-.010	6.967	.025
26.9	16,000	6.564	.317	6.031	.299	6.948	.044	6.931	.061
33.2	20,000	6.539	.342	6.006	.324	6.906	.086	6.892	.100
39.9	24,000	6.513	.368	5.983	.347	6.862	.130	6.853	.139
46.4	28,472	6.482	.399	5.954	.376	6.809	.183	6.797	.195
53.4	32,693	6.447	.434	5.923	.407	6.733	.259	6.724	.268
56.9	34,767	6.431	.450	5.907	.423	6.698	.294	6.690	.302
60.4	36,882	6.407	.474	5.886	.444	6.639	.353	6.630	.362
63.9	39,059	6.370	.511	5.850	.480	6.516	.476	6.509	.483
65.5	40,000	6.262	.619	5.748	.582	6.064	.928	6.083	.909
65.5	40,000	6.262	.619	5.748	.582	5.998	.928	5.992	.909
48.8	29,885	6.129	.752	5.620	.710	5.470	1.456	5.478	1.423
38.0	23,177	5.988	.893	5.479	.851	5.000	1.926	5.000	1.901
38.0	23,177	5.988	.893	5.479	.851	4.957	1.926	4.992	1.901
30.0	17,944	5.819	1.062	5.310	1.020	4.489	2.494	4.530	2.462
25.0	14,945	5.615	1.266	5.108	1.222	4.000	2.993	4.045	2.847

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date Jan. 9, 1950
Machine [illegible]
Fing No. 1 K-1
Observers Gill & [illegible]
Sheet No. 1

Source of Material [illegible] Spec. Designation U 9X12 P
Type Corrugations U Test No. 9 Spec. No. K Gage 12
Plain P Bolted Thickness .106 Length Radius 150"
Pictures U 9X12 P [illegible]

TEST RESULTS

Dial Read	Load #	Dial 1	Δ 1	Dial 2	Δ 2	Dial 3	Δ 3	Dial 4	Δ 4
0		6.881		6.330		6.992		6.992	
7.0	4,000	6.658	.223	6.199	.221	6.999	-.007	6.992	.000
13.8	8,000	6.616	.265	6.078	.252	6.999	-.007	6.992	.000
20.4	12,000	6.589	.292	6.054	.276	6.882	-.010	6.967	.025
26.9	16,000	6.564	.317	6.031	.299	6.948	.044	6.931	.061
33.2	20,000	6.539	.342	6.006	.324	6.906	.086	6.892	.100
39.9	24,000	6.513	.368	5.983	.347	6.802	.130	6.853	.139
46.4	28,472	6.482	.399	5.954	.376	6.809	.183	6.797	.195
53.4	32,693	6.447	.434	5.923	.407	6.733	.259	6.724	.268
56.9	34,767	6.431	.450	5.907	.423	6.698	.294	6.690	.302
60.4	36,882	6.407	.474	5.886	.444	6.639	.353	6.630	.362
63.9	39,059	6.370	.511	5.850	.480	6.516	.476	6.509	.483
65.5	40,000	6.262	.619	5.748	.582	6.064	.928	6.083	.909
65.5	40,000	6.262	.619	5.748	.582	5.998	.928	5.992	.909
48.8	29,885	6.129	.752	5.620	.710	5.470	1.456	5.478	1.423
38.0	23,177	5.988	.893	5.479	.851	5.000	1.926	5.000	1.901
38.0	23,177	5.988	.893	5.479	.851	4.957	1.926	4.992	1.901
30.0	17,944	5.819	1.062	5.310	1.020	4.489	2.444	4.530	2.462
25.0	14,945	5.615	1.266	5.108	1.222	4.000	2.923	4.045	2.847

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date Jan 10, 1960
Machine [illegible] 60 ton
Ping No. [illegible]
Observers [illegible]
Sheet No. 1

Source of Material United Spec. Designation U 3 X 12 S
Type Corrugations U Test No. 3 Spec. No. X Gage 12
Plain ____ Bolted S Thickness .107 Length ____ Radius 1.504
Pictures U 3 X 12 S [illegible]

TEST RESULTS

Dial Read	Load #	Dial 1	Δ 1	Dial 2	Δ 2	Dial 3	Δ 3	Dial 4	Δ 4
.0		6.939		7.395		6.984		6.958	
3.5	2000	6.850	.089	7.304	.091	6.991	-.007	6.968	-.010
7.0	4000	6.749	.190	7.199	.196	6.992	-.008	7.000	-.042
10.5	6000	6.697	.242	7.126	.269	6.988	-.004	7.000	-.042
13.8	8000	6.679	.260	7.107	.288	6.984	.000	6.999	-.041
17.2	10000	6.664	.275	7.091	.304	6.968	.016	6.980	-.022
20.4	12000	6.649	.290	7.076	.319	6.945	.039	6.949	-.009
23.5	14000	6.637	.302	7.064	.331	6.925	.059	6.922	.036
26.6	16000	6.622	.317	7.048	.347	6.899	.085	6.884	.074
30.1	18000	6.606	.333	7.032	.363	6.872	.112	6.842	.116
33.2	20000	6.592	.347	7.016	.379	6.847	.137	6.799	.159
36.2	22000	6.575	.364	6.997	.398	6.813	.171	6.744	.214
39.4	24000	6.556	.383	6.976	.419	6.764	.220	6.674	.284
42.9	26,384	6.530	.409	6.949	.446	6.691	.293	6.579	.379
46.4	28,767	6.489	.450	6.904	.491	6.550	.434	6.414	.544
49.9	30,567	6.404	.535	6.813	.582	6.227	.757	6.050	.908
49.9	30,567	6.404	.535	6.813	.582	5.948	.757	5.960	.908
50.0	30,630	6.265	.674	6.667	.728	5.421	1.274	5.419	1.449
44.0	27,000	6.147	.792	6.544	.851	5.031	1.674	5.009	1.859
44.0	27000	6.147	.792	6.544	.851	4.971	1.674	4.962	1.859
38.5	23,472	5.983	.956	6.375	1.020	4.519	2.126	4.487	2.334
33.5	20,191	5.784	1.155	6.175	1.220	4.069	2.576	4.001	2.820
33.5	20,191	5.784	1.155	6.175	1.220	3.941	2.576	3.952	2.820
29.0	17,557	5.562	1.377	5.954	1.441	3.530	2.987	3.497	3.275
24.1	14,378	5.289	1.650	5.682	1.713	3.078	3.439	3.012	3.760

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date Jan 17-1950
Machine [illegible]
Fing No. K-1
Observers [illegible]
Sheet No. 1

Source of Material United
Type Corrugations U — Test No. 9 — Spec. No. X — Spec. Designation U 9X7 P
Plain P — Bolted — Thickness .183 — Length — Gage 7
Pictures U 9X7P 4 pic — Radius 100"

TEST RESULTS

Dial, Load	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
0		7.055		6.689		6.919		6.897	
2.5	5,000	6.896	.159	6.502	.187	6.992	-.073	6.969	-.072
4.9	10,000	6.862	.193	6.465	.224	6.981	-.062	6.951	-.054
17.4	15,000	6.831	.224	6.433	.256	6.949	-.030	6.912	-.015
9.8	20,000	6.806	.249	6.409	.280	6.922	-.003	6.883	.014
12.3	25,000	6.783	.272	6.385	.304	6.896	.023	6.855	.042
14.8	30,000	6.760	.295	6.362	.327	6.871	.048	6.829	.068
17.3	35,000	6.733	.322	6.335	.354	6.841	.078	6.795	.102
19.8	39,600	6.709	.346	6.312	.377	6.816	.103	6.767	.130
22.3	45,000	6.688	.367	6.291	.398	6.791	.128	6.739	.158
24.8	49,800	6.662	.393	6.261	.428	6.758	.161	6.703	.194
27.3	55,000	6.638	.417	6.241	.448	6.723	.196	6.662	.236
29.8	60,000	6.610	.445	6.213	.476	6.680	.239	6.612	.285
32.2	65,000	6.586	.469	6.187	.502	6.634	.285	6.560	.337
34.7	70,000	6.539	.516	6.132	.557	6.495	.424	6.388	.509
32.8	66,200	6.451	.604	6.030	.659	6.079	.840	6.000	.897
32.8	66,200	6.451	.604	6.030	.659	5.982	.840	5.981	.897
27.6	55,600	6.342	.713	5.909	.780	5.457	1.365	5.477	1.401
24.2	48,600	6.228	.827	5.788	.901	5.023	1.799	5.053	1.825
24.2	48,600	6.228	.827	5.788	.901	4.979	1.799	4.984	1.825
22.2	44,800	6.078	.977	5.633	1.056	4.475	2.303	4.499	2.310
20.2	40,400	5.923	1.132	5.472	1.217	4.004	2.774	4.046	2.763
20.2	40,400	5.923	1.132	5.472	1.217	3.975	2.774	3.958	2.763
18.6	38,200	5.750	1.305	5.281	1.408	3.513	3.246	3.491	3.230
17.0	34,400	5.549	1.506	5.078	1.611	3.022	3.727	3.031	3.690

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date
Machine Highway 50 ton
Ring No. Nil
Observers Gill, Yoshe
Sheet No. 1

Source of Material United Spec. Designation TL 3 475
Type Corrugations TL Test No. 3 Spec. No. 4 Gage 07
Plain Bolted 5 Thickness .083 Length 1 Radius 150"
Pictures TL 3 475 4 in

TEST RESULTS

Dial Load	Load #	Dial 1	Δ 1	Dial 2	Δ 2	Dial 3	Δ 3	Dial 4	Δ 4
0		7.103		6.860		6.913		6.915	
7.0	4,000	6.933	.170	6.733	.127	6.900	.013	6.930	-.015
12.8	8,000	6.893	.210	6.654	.206	6.911	.001	6.944	-.029
20.4	12,000	6.866	.237	6.615	.245	6.883	.030	6.919	-.004
26.9	16,000	6.844	.259	6.587	.273	6.850	.063	6.889	.026
33.2	20,000	6.820	.283	6.564	.296	6.817	.096	6.854	.061
39.4	24,000	6.795	.308	6.540	.320	6.784	.129	6.814	.101
45.6	28,000	6.766	.337	6.514	.346	6.732	.181	6.765	.150
52.3	32,000	6.750	.353	6.486	.374	6.662	.251	6.705	.210
59.0	36,000	6.730	.373	6.453	.407	6.538	.375	6.606	.309
62.2	38,000	6.707	.396	6.433	.427	6.473	.440	6.532	.383
65.5	40,000	6.672	.431	6.400	.460	6.331	.582	6.401	.514
68.7	42,000	6.632	.471	6.364	.496	6.162	.751	6.251	.664
71.0	43,413	6.591	.512	6.327	.533	6.000	.913	6.089	.826
71.0	43,413	6.591	.512	6.927	.533	5.972	.913	5.980	.826
70.0	42,889	6.493	.610	6.238	.622	5.548	1.337	5.592	1.214
64.5	39,413	6.345	.758	6.100	.760	5.000	1.885	5.045	1.761
64.5	39,413	6.345	.758	6.100	.760	4.948	1.885	4.977	1.761
57.5	35,118	6.188	.915	5.952	.908	4.432	2.401	4.462	2.276
54.0	33,057	6.054	1.049	5.819	1.041	4.031	2.802	4.058	2.680
54.0	33,054	6.054	1.049	5.819	1.041	3.931	2.802	3.974	2.680
49.0	30,000	5.884	1.219	5.653	1.207	3.492	3.241	3.535	3.119
44.5	27,314	5.672	1.431	5.447	1.413	3.006	3.727	3.049	3.605

MULTI-PLATE INVESTIGATION

Form 579 (8-49)

RESEARCH DATA

Date ___ 1950
Machine Highway [illegible]
Ring No. VMG
Observers Gill, Kassner
Sheet No. 1

Source of Material United
Spec. Designation U 3 X 1 P
Type Corrugations U Test No. 3 Spec. No. X Gage 1
Plain P Bolted ___ Thickness .225 Length 52" Radius 120"
Pictures U 3 X 1 P 1 pic

TEST RESULTS

Dial Lead	Load #	Dial 1	Δ_1	Dial 2	Δ_2	Dial 3	Δ_3	Dial 4	Δ_4
0		6.908		6.266		6.912		6.913	
2.5	5,000	6.765	.143	6.132	.134	6.970	-.058	6.982	-.069
5.0	10,000	6.717	.191	6.081	.185	6.970	-.058	6.982	-.069
7.5	15,200	6.693	.215	6.057	.209	6.958	-.046	6.969	-.056
10.0	20,600	6.670	.238	6.034	.232	6.942	-.030	6.956	-.043
12.5	25,500	6.646	.262	6.009	.257	6.927	-.015	6.942	-.029
15.0	30,500	6.626	.282	5.990	.276	6.915	-.003	6.931	-.018
17.5	35,500	6.602	.306	5.966	.300	6.900	-.012	6.915	-.002
20.0	40,500	6.578	.330	5.943	.323	6.883	+.029	6.900	-.013
22.5	45,500	6.561	.347	5.926	.340	6.871	+.041	6.887	+.026
25.0	50,500	6.541	.367	5.904	.362	6.855	+.057	6.869	+.044
27.5	55,500	6.523	.385	5.887	.379	6.841	+.071	6.854	+.059
30.0	60,500	6.503	.405	5.867	.399	6.822	+.090	6.836	+.077
32.5	65,500	6.481	.427	5.846	.420	6.802	+.110	6.816	+.097
35.0	70,500	6.463	.445	5.827	.439	6.786	+.126	6.798	+.115
37.5	75,500	6.443	.465	5.806	.460	6.767	+.145	6.778	+.135
40.0	80,500	6.420	.488	5.784	.482	6.745	+.167	6.753	+.160
42.5	85,500	6.400	.508	5.765	.501	6.723	+.189	6.732	+.181
45.0	90,500	6.374	.534	5.741	.525	6.693	+.219	6.701	+.212
47.5	95,500	6.328	.580	5.699	.567	6.637	+.275	6.648	+.265
50.0	100,500	6.282	.626	5.667	.599	6.592	+.320	6.621	+.292
52.5	105,500	6.250	.658	5.637	.629	6.554	+.358	6.591	+.322
55.3	111,000	6.203	.705	5.597	.669	6.512	+.400	6.557	+.356
57.5	115,500	6.168	.740	5.567	.699	6.473	+.439	6.524	+.389
60.0	120,500	6.120	.788	5.525	.741	6.389	+.523	6.454	+.459
61.0	122,600	6.011	.897	5.431	.835	6.000	+.912	6.100	+.913
61.0	122,600	6.011	.897	5.431	.835	5.950	+.912	5.992	+.913
49.7	100,100	5.922	.986	5.343	.923	5.480	1.432	5.542	1.362
42.8	85,500	5.815	1.093	5.235	1.031	5.020	1.892	5.084	1.821

MULTI-PLATE INVESTIGATION

Form 579 (6-49)

RESEARCH DATA

Date Feb 24th 1950
Machine Highway - 50 ton
Ring No. O-M-1
Observers Gill, [illegible]
Sheet No. 1

Source of Material United Spec.Designation U 3 X 1 P
Type Corrugations U Test No. 3 Spec.No. X Gage 1
Plain P Bolted ____ Thickness .225 Length 52" Radius 150"
Pictures U 3 X 1 P 1 pic

TEST RESULTS

Dial Load	Load	Dial 1	Δ 1	Dial 2	Δ 2	Dial 3	Δ 3	Dial 4	Δ 4
42.8	85,500	5.815	1.093	5.235	1.031	5.120	1.892	5.084	1.821
42.8	85,500	5.815	1.093	5.235	1.031	4.918	1.892	4.941	1.821
38.3	78,800	5.699	1.309	5.118	1.148	4.487	2.323	4.575	2.247
34.1	68,600	5.546	1.463	4.962	1.464	4.025	2.785	4.008	2.204

MULTI-PLATE INVESTIGATION

Form 579 (6-49)

RESEARCH DATA

Date [illegible]
Machine [illegible]
Ring No. [illegible]
Observers [illegible]
Sheet No. 1

Source of Material United ______ Spec. Designation U3X15
Type Corrugations S Test No. 3 Spec. No. 1 Gage 1
Plain ______ Bolted S Thickness .278 Length ______ Radius [illegible]
Pictures U3X15 2 pic.

TEST RESULTS

Dial Read	Load #	Dial 1	Δ 1	Dial 2	Δ 2	Dial 3	Δ 3	Dial 4	Δ 4
0		6.912		6.319		6.960		6.945	
2.5	5,000	6.838	.072	6.253	.066	6.945	.015	6.939	.006
5.0	10,000	6.739	.161	6.174	.145	6.960	.000	6.943	.002
7.5	15,200	6.693	.207	6.128	.191	6.938	.022	6.920	.025
10.0	20,600	6.668	.242	6.093	.226	6.906	.054	6.884	.061
12.5	25,500	6.628	.272	6.065	.254	6.869	.091	6.854	.091
15.0	30,500	6.598	.301	6.037	.282	6.833	.127	6.821	.124
17.5	35,500	6.570	.330	6.011	.308	6.801	.159	6.791	.154
20.0	40,500	6.539	.361	5.981	.338	6.762	.198	6.753	.192
22.5	45,500	6.512	.388	5.957	.362	6.722	.238	6.712	.233
25.0	50,500	6.484	.416	5.930	.389	6.671	.289	6.658	.287
27.5	55,500	6.455	.445	5.899	.420	6.610	.350	6.594	.351
30.0	60,500	6.414	.468	5.858	.461	6.504	.456	6.483	.462
32.5	65,500	6.357	.543	5.799	.520	6.306	.654	6.283	.662
34.0	68,200	6.288	.612	5.727	.592	6.025	.935	6.000	.945
34.0	68,200	6.288	.612	5.727	.592	5.981	.935	5.922	.945
32.5	65,100	6.167	.733	5.601	.718	5.422	1.444	5.467	1.460
30.1	60,800	6.048	.852	5.477	.842	5.004	1.912	5.010	1.917
30.1	60,800	6.048	.852	5.477	.842	4.984	1.912	4.932	1.917
27.3	53,800	5.904	.996	5.332	.987	4.490	2.406	4.463	2.486
24.9	50,300	5.745	1.165	5.165	1.154	4.000	2.896	4.000	2.919
24.9	47,300	5.745	1.155	5.165	1.154	3.943	2.896	3.921	2.949
23.0	46,600	5.566	1.334	4.984	1.335	3.490	3.349	3.483	3.396
15.0	30,500	5.347	1.553	4.781	1.538	3.000	3.889	3.000	3.870
Weld failed									

BIBLIOGRAPHY

1. "Handbook of Culvert and Drainage Practice"
Armco Drainage and Metal Products, Inc.

2. Toncan Sectional Plate
Republic Steel Company.

3. Folders from United Steel Fabricators Inc.

4. Interview with Mr. Jerry Evans "Armco representative for Michigan."

5. Interview with Mr. Shaffer, Research Engineer for Armco.

Nov 21 '50