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# Welded plate girders. Intermediate report

Konrad Basler

Bruno Thurlimann

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LEHIGH UNIVERSITY
BETHLEHEM, PENNSYLVANIA

DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY

File: 251✓
December 19, 1958

To: Members of the Welded Plate Girders Project Committee

Messrs:
E. L. Erickson
A. Amirikian
Karl de Vries
F. H. Dill
LaMotte Grover
T. R. Higgins
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G. W. Lamb
W. B. McLean
W. H. Munse
E. J. Ruble
J. E. South
W. Spraragen
R. M. Stuchell
G. Winter

Gentlemen:

Enclosed is the Proposal for the Welded Plate Girders for 1959 and the Intermediate Report 251-4, which will be discussed at the forthcoming meeting of the AISC, January 9, 1959.

Sincerely yours,

Bruno Thürlimann
Project Director

BT:lk

Enclosure

FRITZ ENGINEERING
LABORATORY LIBRARY

# Welded Plate Girders

Intermediate Report
No. 251-4

Konrad Basler

Bruno Thürlimann

Intermediate Report

Submitted to the

Welded Plate Girder Project Committee

by

Konrad Basler

Bruno Thürlimann

January 1959

Fritz Engineering Laboratory
Department of Civil Engineering
Lehigh University
Bethlehem, Pennsylvania

# INTRODUCTION

On January 10, 1958, at a meeting held in New York, the Project Committee accepted a proposal for large scale tests on plate girders. Summarizing the main points of the meeting it was resolved that:

The Objective of the tests was to be an investigation of the stability of the web (web buckling) and the load carrying capacity of plate girders. Applied to the design of such members, a tolerable slenderness of the web (1), an admissible spacing of the stiffeners (2), and a proper shape of the compression flange (3) should be developed for various loading conditions (4).

The Test Program, therefore, was to consist of tests on seven girders in order to investigate all the above mentioned parameters, (1) to (4). Of these girders, five (G1 to G5), would be tested in bending and two (G6 and G7) primarily in shear.

The Design was to conform to the data listed in Table 1 which includes the parameters under investigation and the properties of the test girders. These properties are applicable to the so-called "test section" in which failure was to occur. (Fig. 1).

## WORK COMPLETED

Following is a brief summary of the work completed since this meeting.

Design and Preliminary Testing:

In accordance with the summarized resolutions of the committee the girders were designed by the investigators, submitted to the committee on March 11, 1958 for approval, and finally ordered from the Bethlehem Steel Company.

Prior to testing, a great deal of effort was spent in obtaining the actual sizes of the girder elements. In Table 2 the ordered sizes are listed; in Table 3 the actual sizes of those elements which affect the computation of section moduli are included for comparison.

Since the physical properties of the material are essential for an interpretation of the test results, a comprehensive coupon testing program was conducted. A typical stress-strain curve as recorded by a Tinius-Olsen machine is presented in Fig. 2. Table 4 lists the results obtained at Fritz Engineering Laboratory and compares them with values taken from mill reports. The static yield stress of the compression flange coupon is considered to be the significant yield level for the bending girders. The yield stress of the web coupons, fortunately the same in both directions, is the essential yield level for the shear girders. Using these selected values the following are obtained:

| Girder No: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| $\sigma_{y,st}$(ksi): | 35.4 | 38.6 | 35.5 | 37.6 | 35.5 | 36.7 | 36.7 |

The efforts of the Bethlehem Steel Company, and in particular Mr. Karl de Vries, in procuring materials with a substantially uniform yield stress are gratefully acknowledged.

In the design of the test rig a special effort was made to avoid overall instability (lateral buckling) without introducing forces acting in the plane of the girder. This was achieved by using 10 ft. long lateral bracing pipes pin-connected to the stiffeners near the compression flange and a lateral bracing beam. The arrangement of this test rig is illustrated in Fig. 3.

### Testing:

From July through October, 1958, a total of fifteen ultimate load tests were completed on the seven plate girders. The results are summarized in Table 5. In addition to the ultimate load, $P_u$, reached in each test, the buckling load, $P_{cr}$, according to the linear buckling theory and the yield load, $P_y$, based on ordinary beam theory, are listed. The testing of each girder began by applying equal increments of load until the ultimate load was believed to be almost reached. Then, after unloading the girder, this load was repeated ten times. This was to prove that no "cumulative damage" would occur, barring fatigue considerations. Next, the girder was loaded to ultimate load and failure. After reinforcing the damaged portion, it was reloaded until a second ultimate load was obtained. A more detailed explanation of this procedure is included in the Appendix A.

The testing reaped a harvest of some 30,000 observations. AMES-dial readings account for more than half of them. The enclosed Figs. 7 and 8 are two samples of web deflection measured by means of AMES-dials. The figures are explained in Appendix B.

The design of the test girders and the testing rig was fully proven by the performance during testing. No complications developed and failure of the girders took place within the pre-selected test sections. The procedure of reinforcing a girder after ultimate load and forcing failure in another location was fully successful. On the basis of the results it is believed that these later tests are as significant as the ones obtained on the new girders.

## Tentative Conclusions:

It should be understood that the theoretical study combined with a careful analysis of the tests will lead to quantitative results useful for design purposes. Nevertheless, it is felt that the following qualitative conclusions are of sufficient importance to be given.

Girders in Pure Bending

1. The carrying capacity of a plate girder in pure bending is governed essentially by the stability of the compression flange.

2. Failure of the compression flange occurs by either local, lateral or vertical (pushing into the web) buckling.

3. With the exception of the tests on girder No. 1 which failed by elastic flange buckling as intended (slenderness ratio of flange $b/_t = 48.4$), all girders reached loads in the vicinity of the yield load prior to failure.

4. The theoretical web buckling load $P_{cr}$ based on the linear buckling theory has no significance concerning ultimate load. Not even a sudden increase of transverse web deflections is observed after this load is exceeded.

Girders in Shear

5. The carrying capacity of shear girders is governed by (1) the stability of the stiffening frame, i.e., flanges and vertical stiffeners, (2) the spacing of the vertical stiffeners and (3) the thickness of the web.

6. The ultimate load can not be predicted on the basis of the web buckling load $P_{cr}$ according to the linear buckling theory.

Girders in General

7. Even considerable initial web deflections have no influence on the carrying capacity.

8. The fact that the vertical stiffeners did not bear on the tension flange (gap of 1/4 inch) caused no detrimental effects even in the case of the shear girders.

9. No weld failures occurred. The sum of the throat dimensions of both fillet welds was chosen equal to the thickness of the web.

10. The tests have demonstrated that the linear buckling theory on which all present specifications are based can not be applied in determining the carrying capacity of plate girders. A new approach is hence needed.

## FUTURE WORK

The reduction of test data is now under way. It is contemplated to present the experimental results in a rather extensive manner. Samples are given in Figs. 4 to 8. The experiments have shown unmistakably that a new theoretical approach is needed to predict the carrying capacity of plate girders. Such a study will be undertaken in order to propose appropriate design recommendations.

# APPENDIX

## Explanation of Figures*

### A) LOAD-DEFLECTION CURVES - FIGS. 4, 5 and 6.

Figure 4 represents the load-deflection curve for girder No. 2. Plotted as abscissa is the center line deflection ($v_{\mathrm{c\!\!\!L}}$) as observed by an Engineer's level. The applied jack load (P) is plotted as the ordinate. A second ordinate - a stress scale ($\sigma$) - is added. The stress, as computed by $\sigma = M/S_a$, corresponds to the extreme fiber stress of the top flange. If, for instance, the yield load ($P_y$) is read from the graph as 148 kips, then the yield stress is known to be 38.6 ksi. Hence, the yield load ($P_y$) is the jack load for which nominal yielding at the extreme top fiber first occurs; the plastic load ($P_p$) is the jack load which produces full plastic moment; and the critical load ($P_{cr}$) is the jack load at which web buckling is predicted according to the linear buckling theory. The circles in the graph mark the observed test data and the characters next to them indicate the load numbers. For example, load No. 6, whose ordinate is 90 kips jack load, causes a deflection of about one inch at the center line of the girder. All test points (circles) are connected with straight lines except in the vicinity of the ultimate

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* For symbols not explained in the following, reference is made to the list of Nomenclature.

load where a more complete curve is plotted. The predicted load deflection lines for each test are indicated by the lines labeled $v_{th}$.

By following the load numbers it is quite simple to retrace the testing procedure from the graph. Starting with load No. 1 (zero kips), the girder was loaded up to load No. 8 (127 kips) then unloaded to load No. 9 (zero kips). After repeating a load of 126 kips ten times, it was reloaded, starting with load No. 10 (zero kips) and proceeding to load No. 19 (127 kips). The next deflection data was recorded for load No. 23. During the following load increment the ultimate load was reached. The girder was then stabilized at load No. 24. It was unloaded to load No. 25 (zero kips) and Test No. 1 (T1) was complete.

In preparing the girder for Test No. 2 the damaged section was reinforced. In doing so, the girder acquired an added permanent deflection due to the welding. The difference in deflection between loads No. 25 and 28 represents this permanent addition. Test No. 2 began at load No. 28 and the reinforced girder was loaded to load No. 37. In proceeding from load No. 37 to No. 38, the maximum load for T2 was reached, load No. 38 representing the point at which the girder could be stabilized. Since it was scheduled for no further testing, deflections were increased until load No. 51 was reached in order to obtain the unloading curve. The girder was unloaded after load No. 43 to readjust the loading jacks. The second test (T2) was completed when the girder was unloaded from load No. 51 to load No. 53 (zero kips).

Using the explanations given for Fig. 4, Figs. 5 and 6 can readily be understood.

## B) WEB DEFLECTIONS - FIGS. 7 and 8

### Upper Portion Fig. 7:

The thin lines in the upper portion of the figure show a side view of the test section of Girder No. 2. As defined in the list of nomenclature, the coordinate system has its origin in the center of the test section. Giving the X-coordinate (abscissa) for any point clearly defines the position of a cross section. The units of all coordinates are inches. Using this system, the test section extends from X = -75 to X = +75 and contains three panels: X = -75 to X = -37.5, X = -37.5 to X = 0, and X = 0 to X = +75. For a girder with a symmetrical cross section, the X-axis coincides with the neutral axis and the Y-coordinates are distances from the neutral axis. Since the depth of the web is 50 in., the inside of the upper and lower flanges have Y-distances of +25 and -25 respectively.

Lateral deflections were observed in the cross sections at the third points in the shorter panels (X = -62.5, -50, -25 and -12.5) and in the fifth points of the longer panel (X = +12.5, +25, +37.5, +50 and +62.5). At each section deflections were noted at $Y = -15$, 0, +9, +15 and +21. On two stiffeners, at $X = -37.5$ and $X = 0$, deflections were also measured.

The purpose of this graph is to represent pictorially the deflections as they occurred for a number of loads. By plotting web deflections (w) in the direction of the X-axis to a scale 12 times that in which the girder is shown, the distorted cross sections can be visualized. It should be remembered that all distortions are shown at their respective locations in the test section. They are given for three different loads:

1) Load No. 1, $P = 0$ kips for initial web distortions
2) Load No. 5, $P = 72$ kips for deflection at about $P_{cr}$
3) Load No. 8, $P = 126$ kips for deflection at about $0.9\ P_u$

All dots, representing individual measurements, are connected by straight lines in order to depict the distorted web. For clarity, it was also necessary to show the distortion of the flanges due to welding in the exaggerated 12:1 scale.

Thus, by consulting the graph one can see the following:

- all initial distortions fell to the same side of the girder (the far side).
- the additional web deflections up to $P_u$ are of the same order of magnitude as the initial ones.

- the stiffeners had initial distortions but the additional deflections were so small that they coincided with the initial ones. The same is true of the flange distortions.

- the web deflections in the longer panel reversed, starting with the left side of the panel.

<u>Lower Portion Fig. 7</u>:

Since the upper portion of the graph contains deflections for a limited number of loads only, the lower portion was added to show the complete load-web deflection curves for three selected stations. Taking for instance station $X = -50$, $Y = +15$, for load No. 1, zero kips, the initial deflection was about 0.05 inches to the far side of the girder, i.e., in the negative direction of Z and W. As loading increased and exceeded the buckling load $P_{cr} = 74$ kips, the deflection did not exhibit a sudden increase as may be expected on the basis of the linear buckling theory. Upon unloading from load No. 8 to load No. 9, practically all the deflection caused by load was recovered. Then the girder was loaded 10 times between loads No. 9 and 10 causing no additional deflections. Loading again, loads No. 23 and 24 occurred before and after the ultimate load was reached. When unloaded to load No. 25, the deflection recovered to 0.1 inches - twice as much as the initial distortion. After the damaged top flange had been reinforced, a second ultimate load test was conducted (loads No. 28 to No. 39). Since the panel could sustain a load as high as the first ultimate load, one concludes that the magnitude of initial distortions in the web has no influence on the ultimate load.

# NOMENCLATURE

$a$ : Distance of transverse stiffeners

$b$ : Depth of girder

$t$ : Thickness of web

$u,v,w$ : Displacements in X,Y,Z direction

$I$ : Moment of inertia

$M$ : Bending moment

$P$ : Jack load

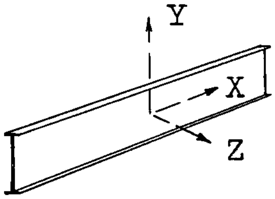
$Q$ : Static moment of area

$S$ : Section modulus

$T$ : Test - used with a number

$V$ : Shear force

$X,Y,Z$ : Cartesian coordinates having their origin in the middle of the girder



$\alpha = a/b$ : Panel length to panel depth

$\beta = b/t$ : Web depth to web thickness

$\epsilon$ : Strain

$\sigma$ : Normal stress

$\tau$ : Shear stress

$\xi = \tau/\sigma$ : Ratio shear to normal stress

Nomenclature (cont.)

<u>Numbers</u>: used to designate proper girder and test.
G1 - T2 refers to the second test on the first girder.

Meaning of letters if used as indexes.

a : above, e.g. $S_a$ : Section modulus used for stress in top fiber

b : below, e.g. $y_b$ : Distance between bottom fiber and neutral axis

cr : critical, e.g. $\sigma_{cr}$ : Buckling stress

e : end, e.g. $I_e$ : Moment of inertia of the end sections

m : middle, e.g. $I_m$ : Moment of inertia of the middle section (Test Section)

p : plastic, e.g. $M_p$ : Plastic moment

th : theoretical, e.g. $v_{th}$ : Theoretical (=computed) deflection

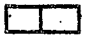
u : ultimate, e.g. $P_u$ : Ultimate load

y : yielding, e.g. $\sigma_y$ : Yield stress

# List of Tables and Figures

# TABLE 1

Summary of Girder Properties

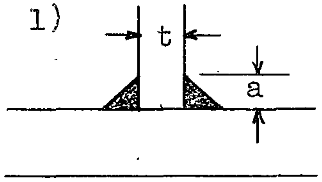
| | Girder | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|
| Parameters | 1. $\beta = b/t$ | actual | 185 | 185 | 185 | 388 | 388 | 259 | 255 |
| | | proposed | 200 | 200 | 200 | 400 | 400 | 267 | 267 |
| | 2. $\xi = \tau/\sigma$ | | 0 | 0 | 0 | 0 | 0 | 1.5 | 1.1 |
| | 3. $\alpha = a/b$ | | 1.5<br>0.75 | 1.5<br>0.75 | 1.5<br>0.75 | 1.5<br>0.75 | 1.5<br>0.75 | 1.5 | 1.0 |
| | 4. Restraint | | Negligible | Heavy | Fixed | Heavy | Fixed | Heavy | Heavy |
| | Type of Cross-Section | | I | II | III | II | III | II | II |
| | Stiffener Arrangement | |  |  |  |  |  |  |  |
| | Material | | All Specimens A-373 | | | | | | |

# TABLE 2

## Summary of Ordered Plate and Weld Dimensions

| | Girder | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Dimensions of: Cross Sections | Top Flange | 20 1/2 x 7/16 | 12 x 3/4 | Pipe 2) | 12 x 3/4 | Pipe 2) | 12 x 3/4 | 12 x 3/4 |
| | Bottom Flange | 12 x 3/4 | 12 x 3/4 | 12 x 3/4 | 12 x 3/4 | 12 x 3/4 | 12 x 3/4 | 12 x 3/4 |
| | Cover Plates | --- | --- | --- | --- | --- | 11 x 1/2 | 11 x 1/2 |
| | Web at Test Section | 1/4 | 1/4 | 1/4 | 1/8 | 1/8 | 3/16 | 3/16 |
| | Web at Ends | 3/8 | 1/2 | 1/2 | 3/8 | 3/8 | 3/8 | 3/8 |
| | Intermediate Stiffeners | 1/4 x 4 | 1/4 x 4 | 1/4 x 4 | 1/4 x 4 | 1/4 x 4 | 1/4 x 4 | 1/4 x 4 |
| | Stiffeners under Loading | Out of 12 x 8 WF 50 | | | | | | |
| Welds 1) | Web to Flange: Test Section | 3/16 | 3/16 | 3/16 | 3/32 | 3/32 | 1/8 | 1/8 |
| | Web to Flange: End Section | 1/4 | 1/4 | 1/4 | 1/4 | 1/4 | 1/4 | 1/4 |
| | Intermed. Stiffener to Web: Test Section | 3/16 | 3/16 | 3/16 | 3/32 | 3/32 | 1/8 | 1/8 |
| | Intermed. Stiffener to Web: End Section | 3/16 | 3/16 | 3/16 | 3/16 | 3/16 | 3/16 | 3/16 |
| | Loaded Stiffeners to Web | 1/4 | 1/4 | 1/4 | 1/4 | 1/4 | 1/4 | 1/4 |

1)



a = size listed

a ≦ 3/4 t

2) 8" Std. Pipe

0.322" Wall Th.

All dimensions in inches

## TABLE 3

Summary of Measured Plate Dimensions

| Girder | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Top Flange | Width | 20.65 | 12.19 | 8.62* | 12.16 | 8.62* | 12.13 | 12.19 |
| | Thickness | 0.427 | 0.769 | 0.329 | 0.774 | 0.327 | 0.778 | 0.769 |
| Bottom Flange | Width | 12.25 | 12.19 | 12.19 | 12.19 | 12.25 | 12.13 | 12.19 |
| | Thickness | 0.760 | 0.774 | 0.770 | 0.765 | 0.767 | 0.778 | 0.766 |
| Cover Plates | Width | --- | --- | --- | --- | --- | 11.19 | 11.19 |
| | Thickness | | | | Top plates | | 0.511 | 0.509 |
| | | --- | --- | --- | Bottom plates | | 0.509 | 0.511 |
| Web Thickness at Test Section | | 0.270 | 0.270 | 0.270 | 0.129 | 0.129 | 0.193 | 0.196 |
| Web Thickness at End Section | | 0.382 | 0.507 | 0.492 | 0.392 | 0.392 | 0.369 | 0.381 |

All dimensions in inches.

*Pipe - Outside Diameter

# TABLE 4

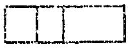
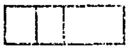
## Summary of Material Properties

| Designation | | | | | | | Chemical Analysis | | | | Mill Tests | | | Test at Fritz Lab. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Location | Thickness | Coupon | Specification | Heat No./Slab No. | C | MN | P | S | $\sigma_y$ (ksi) | $\sigma_{ult}$ (ksi) | Elong % | $\sigma_{yst}$ (ksi) | $\sigma_{ult}$ (ksi) | Elong % |
| Flange-Material | | Bottom G1 | 3/4" | CP 9 | ASTM A 373-56T (Modified, aimed at 40.0 ksi Y.P.) | Heat No. 86K271<br>40572 | .17 | .70 | .016 | .026 | 40.2 | 65.8 | 30.0 | 35.8 | 61.8 | 33.5 |
| | | Top G2 | | CP 17 | | 40569 | | | | | 42.0 | 66.4 | 29.0 | 38.6 | 63.7 | 27.1 |
| | | Top G4 | | CP 27 | | 40511 | | | | | 40.5 | 66.4 | 30.0 | 37.6 | 63.8 | 31.5 |
| | | Bottom G3 | | CP 40 | | 40569 | | | | | 42.0 | 66.4 | 29.0 | 38.1 | 63.7 | 32.1 |
| | | Bottom G5 | | CP 51 | | 40570 | | | | | 40.4 | 65.1 | 30.0 | 37.0 | 63.0 | 32.6 |
| | | Top G6 | | CP 54 | | 40567 | | | | | 41.9 | 66.0 | 30.0 | 37.9 | 63.8 | 31.4 |
| | | Top G7 | | CP 62 | | 40568 | | | | | 41.7 | 65.8 | 29.0 | 37.6 | 63.1 | 31.6 |
| | | Top G1 | 7/16" | CP 7 | | 87K270/40833 | .22 | .59 | .011 | .029 | 40.8 | 66.5 | 29.0 | 35.2 | 64.5 | 28.2 |
| | | Top G1 | | CP 8 | | | | | | | | | | 35.5 | 62.2 | 30.0 |
| | | Top G6 | 1/2" | CP 53 | | 87K254/(40859) | .22 | .59 | .008 | .023 | 38.1 | 63.2 | 29.0 | 33.6 | 60.8 | 29.3 |
| | | Top G7 | | CP 63 | | | | | | | | | | 33.3 | 60.1 | 31.8 |
| Web-Material | End-Section | G2 | 1/2" | CP 12 | | 87K270/40671 | .22 | .59 | .011 | .029 | 40.5 | 66.3 | 29.0 | 35.4 | 63.2 | 29.9 |
| | | G2 | | CP 12-A | | | | | | | | | | 34.3 | 62.7 | 24.0 |
| | | G3 | | CP 35 | | 87K270/41200 | | | | | 40.2 | 67.8 | 26.0 | 37.3 | 67.4 | 28.7 |
| | | G1 | 3/8" | CP 2 | | 87K270/39809 | | | | | 40.9 | 67.7 | 28.0 | 41 | 69.2 | 24.9 |
| | | G1 | | CP 2-A | | | | | | | | | | 42.4 | 68.4 | 21.8 |
| | | G4 | | CP 22 | | 87K270/39808 | | | | | 42.0 | 67.6 | 29.0 | 40.0 | 67.0 | 28.2 |
| | Test-Section | G1 | 1/4" | CP 3 | | 84K241/53268 | .13 | .49 | .009 | .026 | 39.1 | 60.9 | 28.0 | 32.9 | 55.8 | 35.1 |
| | | G1 | | CP 3-A | | | | | | | | | | 33.0 | 54.4 | 34.6 |
| | | G2 | | CP 13 | | | | | | | | | | 35.3 | 60.0 | 31.1 |
| | | G6 | 3/16" | CP 57 | | | | | | | | | | -- | 62.4 | 28.6 |
| | | G6 | | CP 57-A | | 59K346/83483 | .22 | .50 | .008 | .020 | 40.7 | 64.5 | 23.5 | 36.8 | 63.3 | 30.0 |
| | | G7 | | CP 66 | | | | | | | 40.8 | 66.3 | 24.5 | 36.6 | 64.2 | 28.4 |
| | | | 1/8" | CP 23B | ASTM-A 245-57T | | | | | | | | | 43.2 | 60.9 | 25.4 |
| | | G4 | | CP 23 | | 95K198/? | | | | | 40.6 | 62.9 | 28.5 | 43.5 | 60.7 | 28.4 |
| | | | | CP 47B | | 95K198/? | .18 | .82 | .010 | .022 | | | | 44.8 | 63.5 | 24.2 |
| | | G5 | | CP 47 | | | | | | | 40.2 | 62.3 | 26.0 | 46.6 | 62.8 | 27.1 |
| | | 8" Pipe G3 | 0.322" | CP 31 | A-53 Grade A | ---- | | | .017 | | 40.2 | 60.4 | 42.5 | 35.5 | (51.5) | |

Note: A refers to coupon taken transverely to the direction of rolling.
B refers to additional coupon taken next to the original one, e.g., CP 23 and CP 23B.

## TABLE 5

Summary of Test Loads

| Girder | Test No. | Condition | $P_u$ (Kips) | $P_{cr}$ (Kips) | $P_y$ (Kips) |
|---|---|---|---|---|---|
| 1 | T1 | Width of Top Fl.=20 9/16" | 81 | 70.1 | 130.9 |
| | T2 | Width of Top Fl.=13 9/16" | 72 | 41.9 | 100.8 |
| 2 | T1 |  | 135 | 74.1 | 148.8 |
| | T2 |  | 144 | | |
| 3 | T1 |  | 130 | 18.7 | 115.6 |
| | T2 |  | 136 | | |
| 4 | T1 |  | 118 | 15.3 | 130.1 |
| | T2 |  | 125 | | |
| 5 | T1 |  | 110 | 17.0 | 104.9 |
| | T2 |  | 124 | | |
| 6 | T1 |  | 116 | 25.9 | 193.3 |
| | T2 |  | 150 | 49.1 | |
| | T3 |  | 177 | 92.2 | |
| 7 | T1 |  | 140 | 35.5 | 196.0 |
| | T2 |  | | | |

▨ - reinforced panel

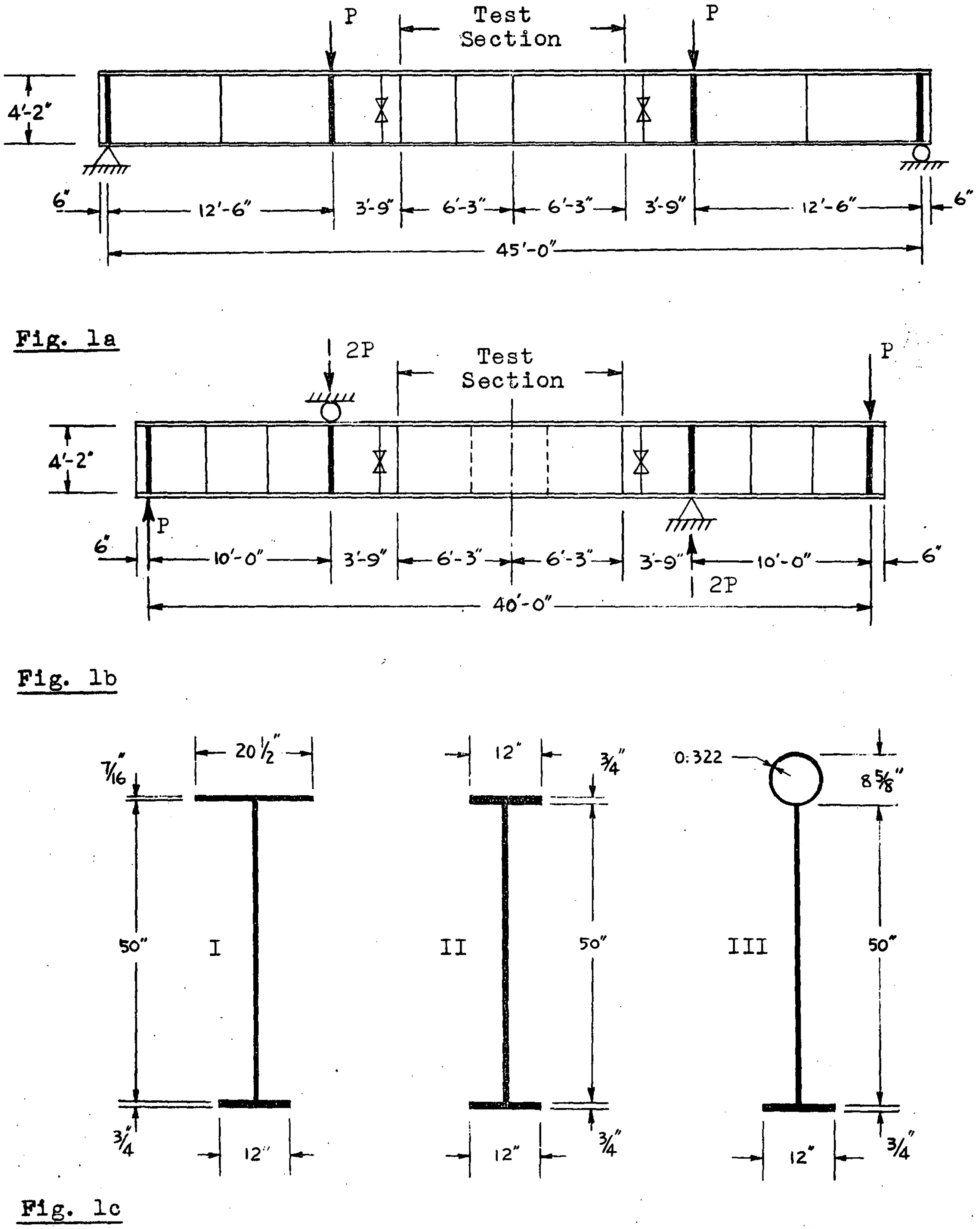


Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1 - Test Girders and Cross-Sections

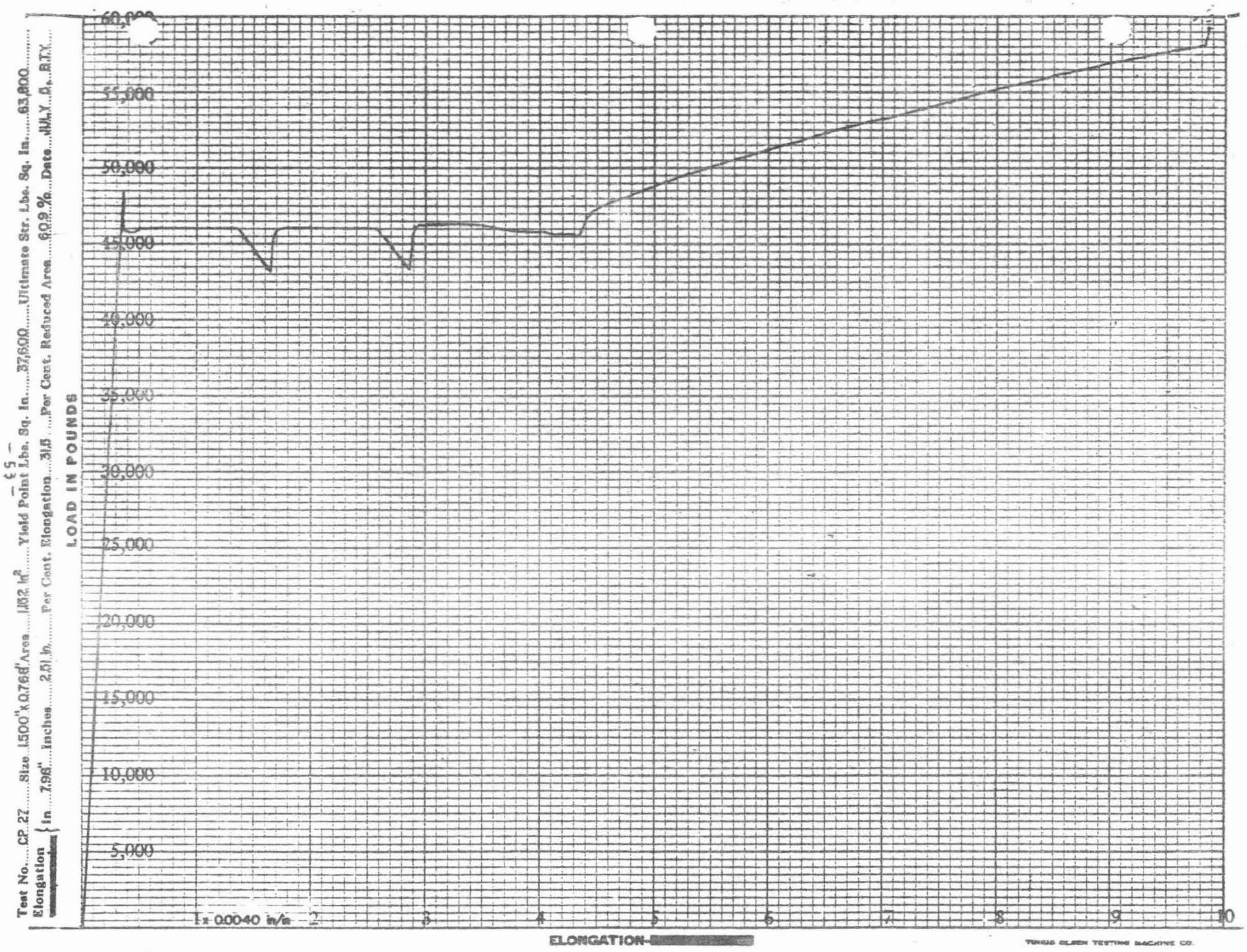


FIG. 2 - Typical Stress-Strain Diagram

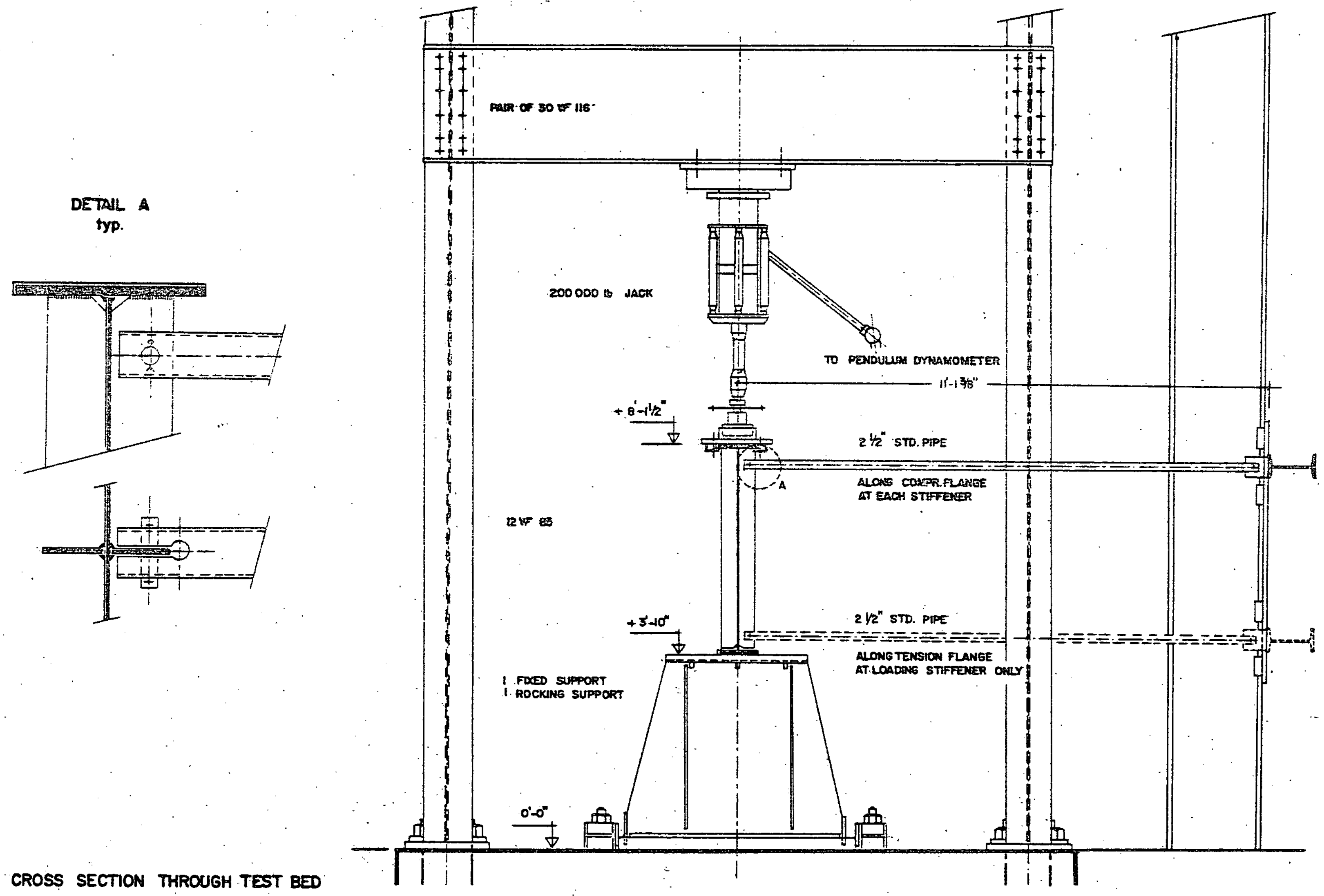


FIG. 3 - Cross Section through Test Bed

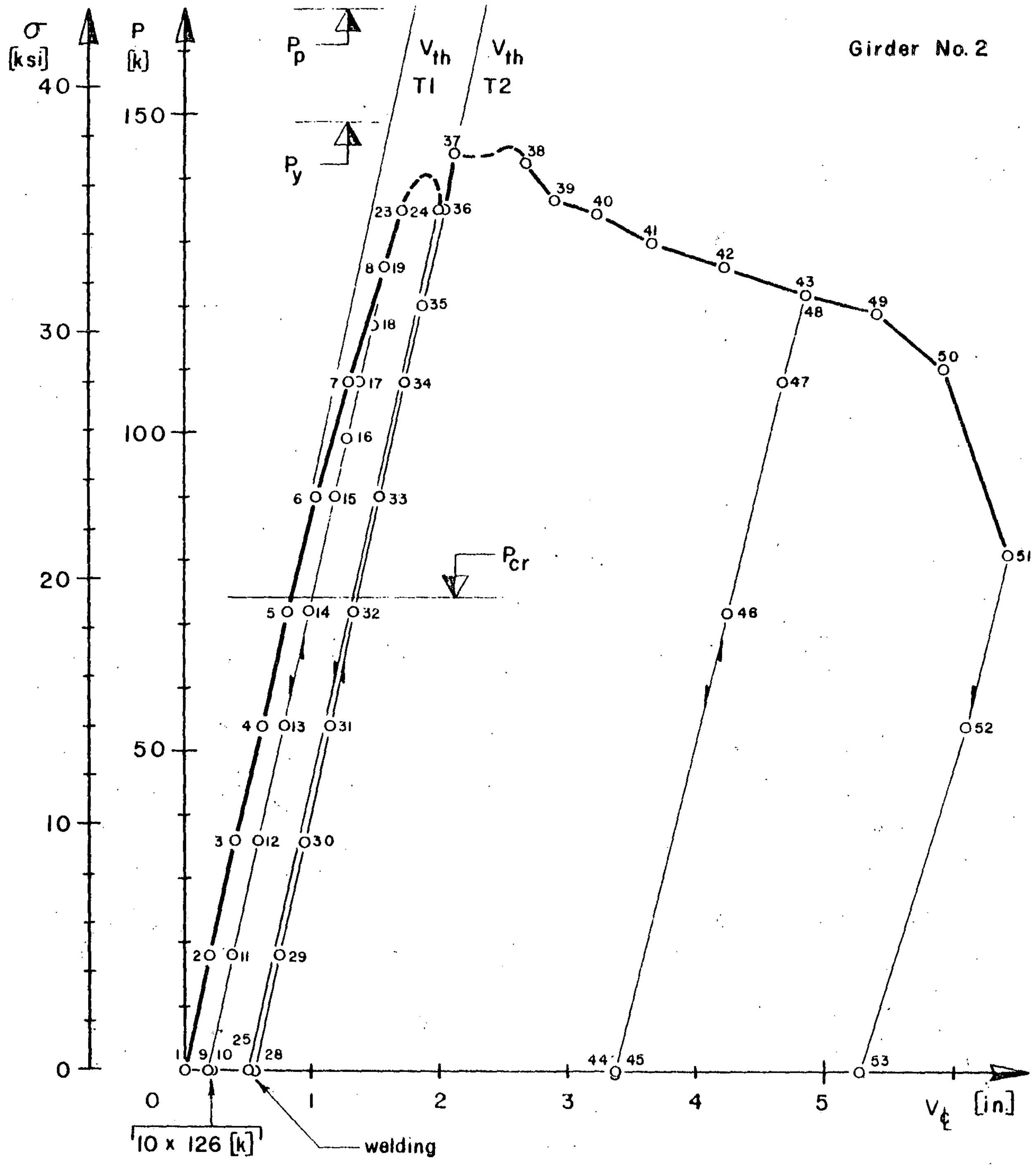


FIG. 4 - Load Deflection Curve of Girder No. 2

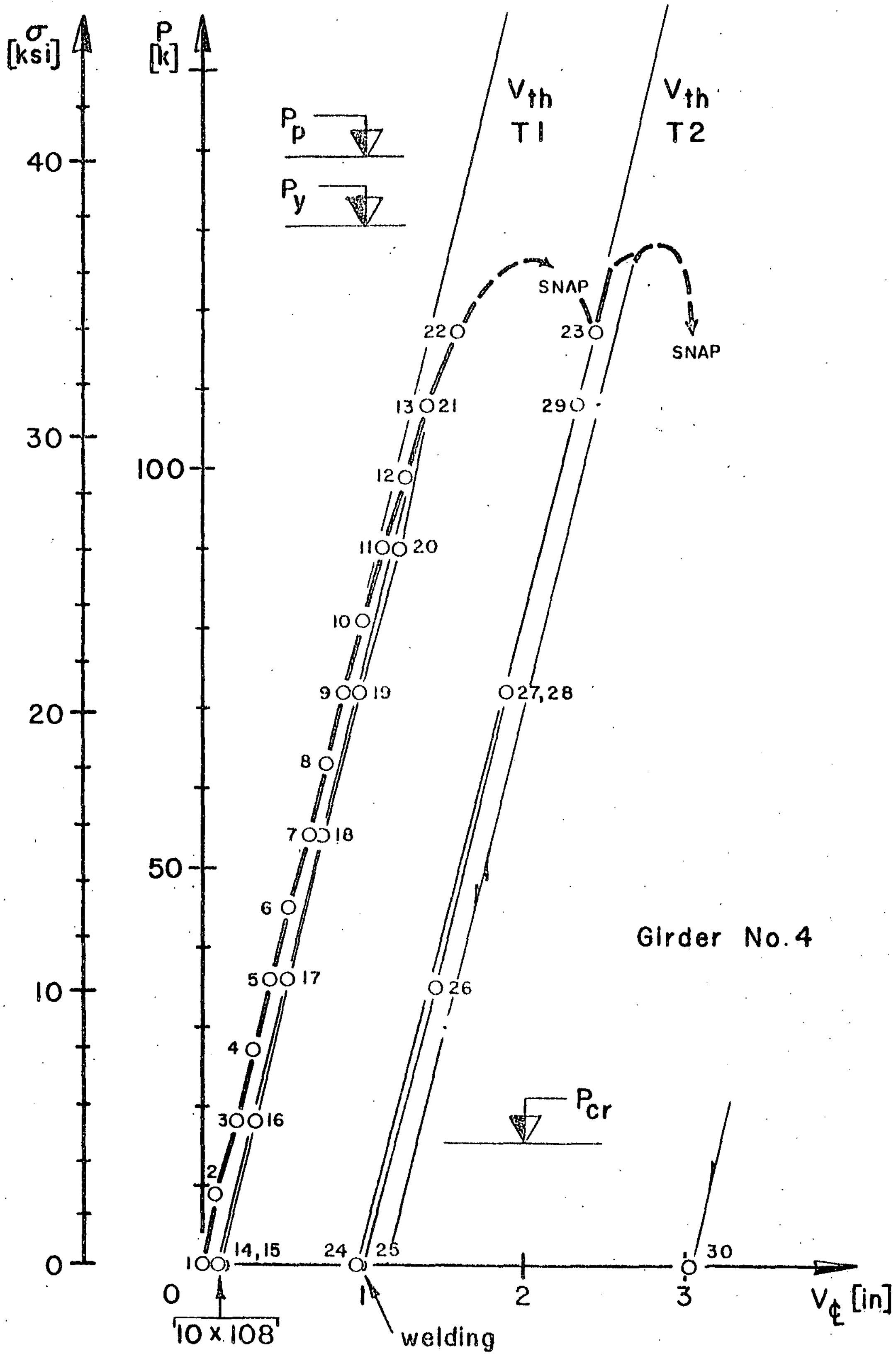


FIG. 5 - Load Deflection Curve of Girder No. 4

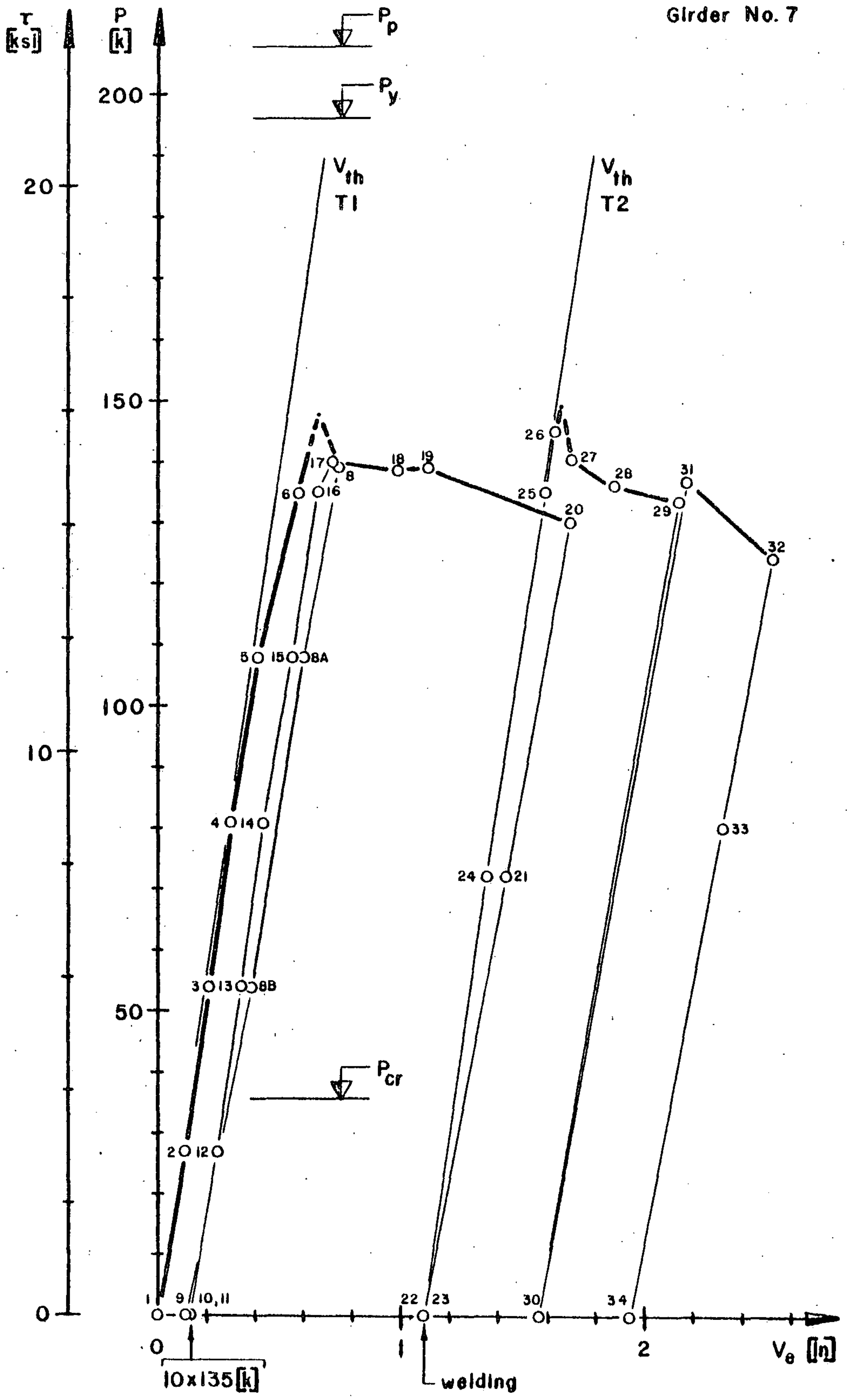


FIG. 6 - Load Deflection Curve of Girder No. 7

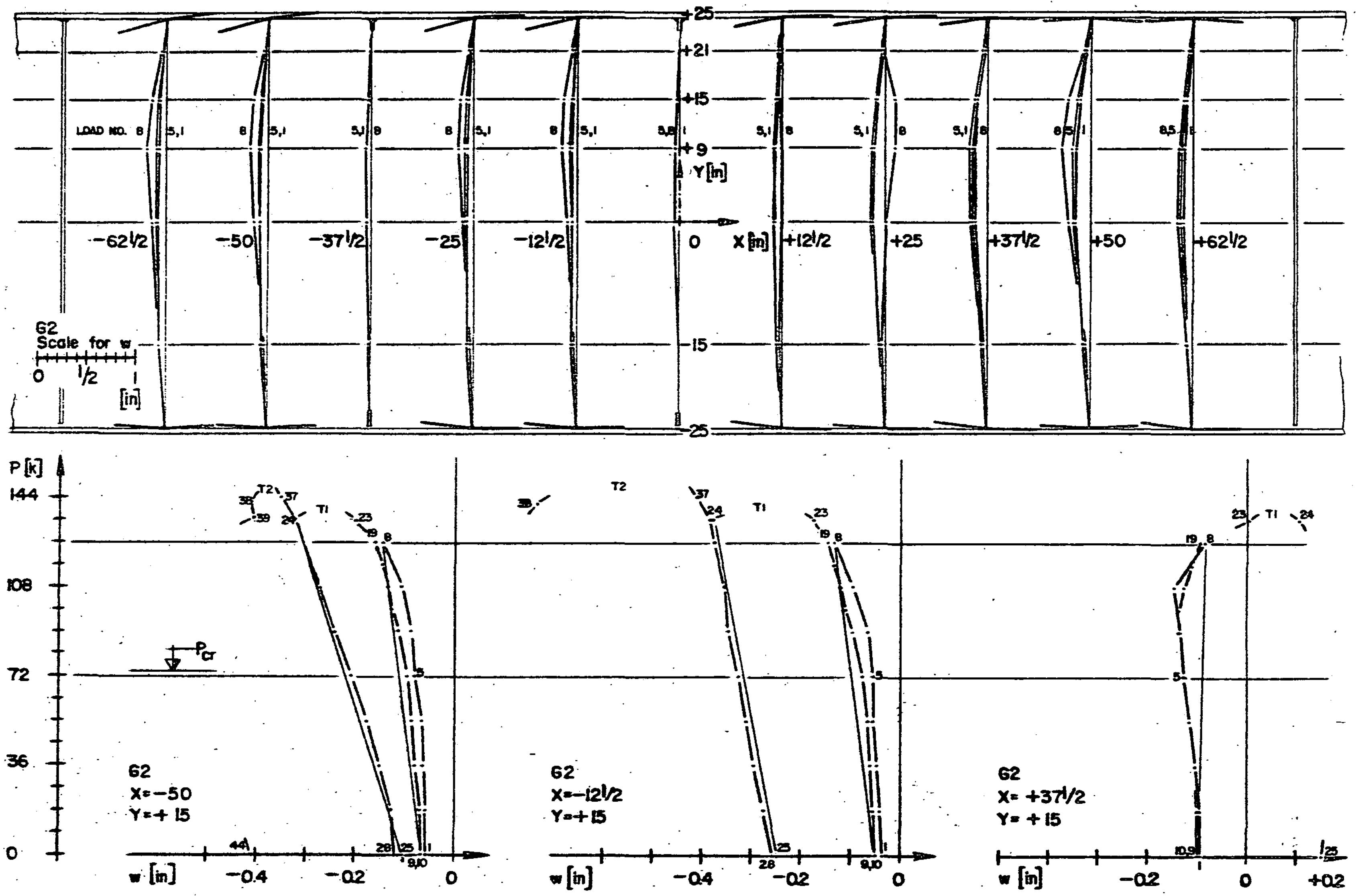


FIG. 7 - Web Deflections of Girder No. 2

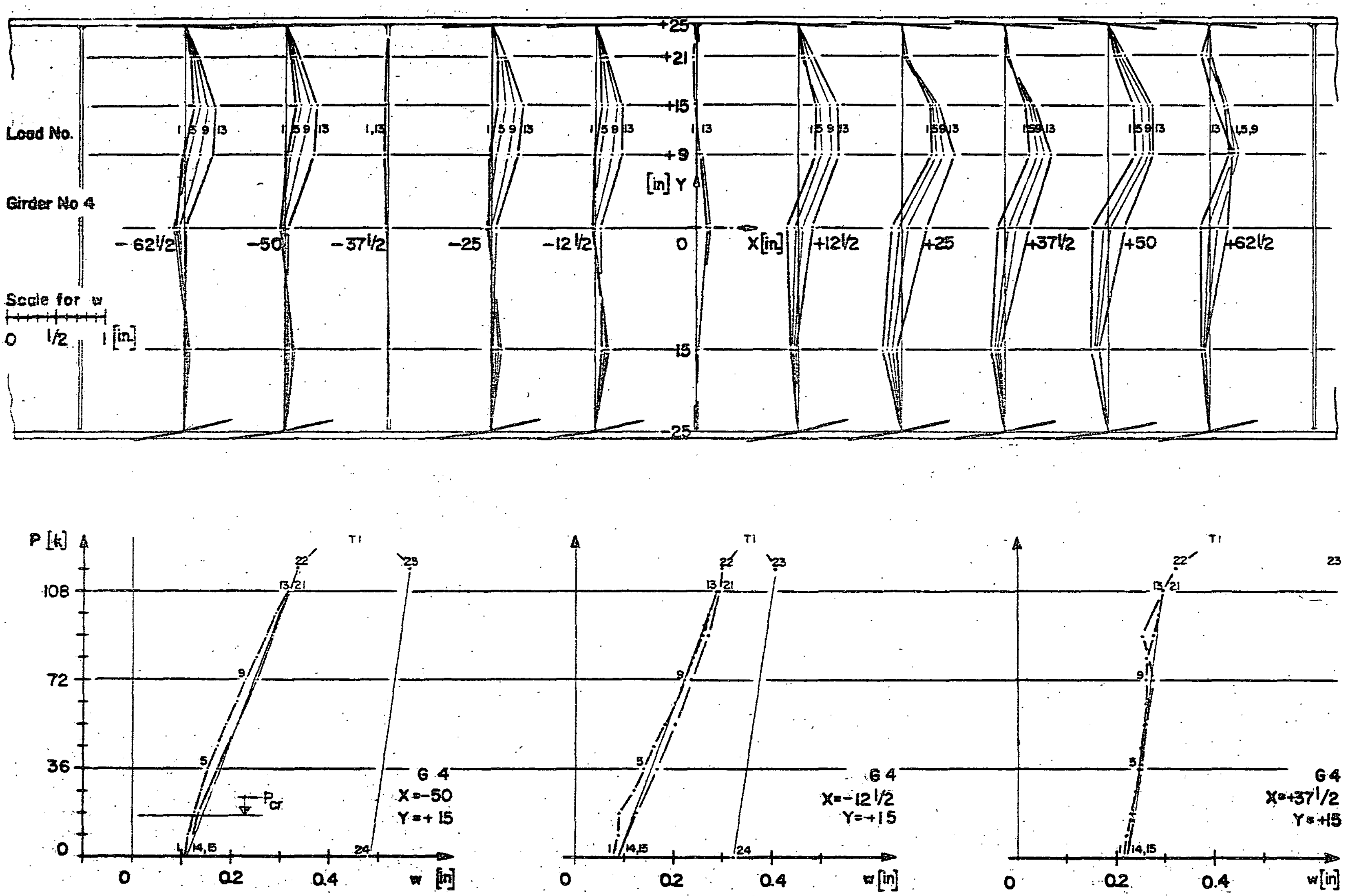


FIG. 8 - Web Deflections of Girder No. 4