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ULTIMATE STRENGTH OF AIRCRAFT CARRIER FLIGHT DECKS

by
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and
N. M. Newmark

Final Report
for the
BUREAU OF SHIPS, U. S. NAVY
Contract NObs 55507
Index No. NS-731-040

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

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Department of Civil Engineering

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I. INTRODUCTION

1.1 General

In present day construction there is a large amount of plate-beam construction especially in the field of ship building. Unfortunately, however, there is not available a great deal of information on the actual strength of this type of structure. Current design procedures are approximate and based on previous experience. Normally design stresses are kept well within the elastic range, actually considerably below the elastic limit, so that the resulting designs are conservative and possibly not efficient. With more information available on the behavior of these structures, improved design procedures could make greater use of the available strength.

1.2 Object and Scope

The purpose of this investigation was to conduct laboratory tests and observe the behavior in the elastic and plastic range of simply-supported specimens composed of a flat plate stiffened on the underside by a series of parallel, longitudinal beams. These specimens were approximately half-scale models of parts of some of the more common aircraft carrier flight deck structures and were fabricated in a manner similar to actual practice. Under these circumstances it was felt that the results obtained would be representative of the behavior that might occur in the prototype structure and that they could provide suitable information with which design procedures could be compared or developed.

In particular, tests were made on specimens stiffened by a series of parallel, equally-spaced longitudinal T-beams welded to one side of a flat plate. (Phase I). Because of the almost complete lack of data available on the behavior of this type of structure when beams in a transverse direction are added, a large portion of this laboratory investigation (Phase II) was concerned with extensive tests of specimens, basically similar to one selected from Phase I, to which one, two and three transverse beams of various stiffnesses were added. These transverse beams were clamped beneath the longitudinal beams of a specimen so that they could be moved or changed readily. This permitted one stiffened plate specimen to be used in combination with several different transverse beam arrangements and thus provide a number of different tests. From these data the combination of stiffness and number of transverse beams that appeared to be most effective was selected and used in the preparation of Phase III specimens which were fabricated with a transverse beam welded intercostally between the longitudinal beams.

The specimens were subjected to a concentrated load which was statically applied over a scaled tire area. The positions of the load varied for the tests of the different specimens. In general, a concentrated load creating only elastic strains throughout the specimens was applied at several locations on the specimens tested in each of the three phases. Additional increments of load which produced plastic strains in the specimens were applied at the location considered to be most severe for specimens in Phases I and III.

1.3 Acknowledgment

The work described in this report constituted an investigation resulting from a cooperative agreement between the Engineering Experiment Station of the University of Illinois and the Bureau of Ships, Department of the Navy, Contract NObs 55507, Project NS-731-040. This program was under the general supervision of N. M. Newmark, Professor and Head of the Civil Engineering Department and the immediate direction of R. J. Mosborg, Associate Professor of Civil Engineering.

The analytical work and the correlation of the analytical and experimental work of Phase I was done by H. L. Cox, formerly Research Assistant in Civil Engineering. The computational work for this analytical phase of the program was done on the Electronic Digital Computer at the University of Illinois and the coding of certain equations for the analysis was done by A. J. Carlson, formerly Research Associate in Civil Engineering. The experimental work of Phases II and III was done by J. M. Farley, formerly Research Assistant in Civil Engineering. In addition, the care and attention given to the preparation of the specimens by the Civil Engineering Shop personnel is acknowledged.

II. DESCRIPTION OF TEST PROGRAM

2.1 Materials and Specimen Details

Generally, in actual flight deck construction, the deck plate is supported by a series of I- or inverted T-beams (made of HTS material) whose top flange or web is welded to the underside of a deck plate (made of STS material). The Bureau of Ships, Navy Department, provided typical HTS and STS stock for this investigation so that similar materials could be used in the fabrication of laboratory test specimens. The longitudinal T-beams were cut from either 12 x 4 @ 16.5 lb or 8 x 4 @ 13 lb HTS I-beams and the deck plates were taken from 3/8 x 90 x 124-in. STS plate material.

The average mechanical properties from tests of standard flat rectangular coupons with a 2-in. gage length, a 3/4-in. width and a thickness equal to that of the material from which they were taken were summarized for certain specimens. (4)* Representative values of the mechanical properties for the plate and beam material used in this investigation are:

Property	STS Plate	HTS Beams
Yield Point, ksi	104	62
Ultimate Strength, ksi	115	78
Percent Elongation	21	30
Percent Reduction of Area	68	68

The test specimens were fabricated by welding a series of equally-spaced, parallel, inverted T-beams to the underside of a 3/8-in. plate. Since only 6 or 7 longitudinal T-beams were used in fabricating each specimen, a channel beam section was welded horizontally in a longitudinal direction

*Numbers in parentheses refer to references in the bibliography along both sides of the 3/8-in. deck plate in order to represent the additional lateral stiffness that would exist in an actual structure composed of relatively large and continuous deck plates welded to several more longitudinal beams. The welding sequence used throughout the fabrication of all specimens was chosen so as to introduce a minimum amount of distortion and locked-in stress.

Diaphragm plates were welded to the bottom of the deck plate and the webs of the longitudinal beams across both ends of the specimens above the reaction line. Except for the outermost beams, the various longitudinal supporting beams were simply-supported on rollers at each end. The exterior longitudinal beams were fastened to roller supports at each end to prevent uncontrollable and undesirable uplift at the corners. All specimens had a longitudinal span length of 60 in. and, as in the prototype, the direction of rolling of the plate material was parallel to the span length.

The first four specimens (I, II, III, IV) consisted of a deck plate stiffened with either 6 or 7 longitudinal beams. Tests on these specimens comprised Phase I of this investigation. In Phase II, Specimens V-1, V-2, and V-3 contained transverse beams (varying in number and stiffness) which were bolted across the bottoms of the longitudinal beams of a specimen similar to Specimen II. Phase III specimens (V-F and VI) contained only one transverse beam welded intercostally between the longitudinal beams at midspan.

From limited information on actual aircraft carrier steel flight decks, an aspect ratio (ratio of longitudinal beam spacing to span length) of 0.2 and an H value (the relative stiffness of the specimen) of 90 to 100 seemed typical and suitable for these laboratory specimens. From this information and the data available in the Final Report on Contract NObs 47294 (1), a reasonable range in value for the aspect ratio is from 0.15 to 0.30 and a low value for H seems to be about 35. Specimens tested in this program were fabricated with the foregoing data in mind and their characteristics are summarized in Table 2.1.1.

2.2 Testing Apparatus and Machines

For applied loads up to 200,000 lb. the specimens were supported on concrete abutments and the load was supplied by a hydraulic jack supported from a loading frame which was erected over the test specimen and bolted to the test floor. A calibrated dynamometer, located between the hydraulic jack and the specimen, provided an accurate measure of the applied load and, in addition, an estimate of the load was available from the pressure reading in the hydraulic system. Placing the specimens on top of concrete abutments provided access to the underside of the specimen and permitted deflection measurements immediately under the load. The load was applied to the specimen through a 5- x 12-in. hard rubber loading pad which simulated an aircraft tire load and was centered over the desired point of loading.

After subjected to a 200,000-lb. load (the capacity of the loading frame and the hydraulic jack), the test specimen was transferred to a 3,000,000-lb. hydraulic testing machine and supported on railroad rails which acted as rocker supports. Additional load was applied to the structure until the ultimate load-carrying capacity of the specimen was reached and collapse of the structure occurred.

2.3 Testing Procedure and Measurements

In general, regular increments of loads were applied to the specimens. After the application of each load increment, deflections and strains were measured throughout the structure. After yielding in the specimen started, the applied load was periodically reduced to zero so that the accumulated permanent deflection and strain could be measured. Deflection measurements were made with direct reading 0.001-in. Ames dials located, in general, at midspan, 6 in. from midspan, and at the quarter points of the test specimen. Usually these measurements were made along each of the longitudinal beams and midway between them. Except for the deflections along the loaded beam, all deflections were measured with dials mounted on a movable bridge which spanned the specimen and was moved along the top of the concrete abutments. Deflections along the loaded beam and directly beneath the applied load were measured with dials mounted on a movable bridge beneath the specimen. A number of SR-4 strain gages (in general, 1/2-in. gage length -- Type A-5 or AX-5) were mounted on each specimen. These gages were mounted primarily on the longitudinal beams and the deck plate in the vicinity of the applied load and provided information on the elastic and slightly inelastic strain distribution throughout the specimen as successive increments of load were applied.

The locations of the strain gages throughout Specimens V-1, V-2, V-3, V-F and VI are shown in Figs. 2.3.1, 2.3.2, and 2.3.3. In these figures, where two numbers refer to the same location, the upper number designates the near side and the lower number the far side of the specimen.

2.4 Nomenclature

The following terms are used commonly throughout the text and will be defined here for convenience.

a = simple span length of the longitudinal beams

b = spacing of the longitudinal beams

aspect ratio = ratio of $\frac{b}{a}$

$$\beta_n = \left(\frac{H_n b^3}{a^3}\right)^{1/6}$$

$\beta_o = \left(\frac{H_o b^3}{a^3}\right)^{1/6}$

E = modulus of elasticity of steel

$H = \frac{EI_b}{aN} = \frac{10.95\ I_b}{ah^3}$ = dimensionless coefficient which is a measure of the stiffness of the beam relative to that of the plate

H_o = original value of H without effect of transverse members

H_n = revised value of H to include added stiffness of transverse members

h = thickness of deck plate

I_b = moment of inertia of cross section of a longitudinal composite T-beam

$I_p = \frac{h^3}{12}$ = moment of inertia of unit width of plate

I_t = moment of inertia of cross section of a transverse beam

$K = \frac{E_t I_t L^3}{EI_b b^3}$ = relative stiffness of transverse and longitudinal beams

load position = location of the center of the applied 5- by 12-in. rectangular load (load position 10 is the geometric center, all others are measured from the center)

longitudinal beams = those beams welded to the underside of the deck plate in the direction of the span length

loaded beam = that longitudinal beam which is directly under the applied load (for 7-beam specimens this is longitudinal Beam 4)

first adjacent beam = the first longitudinal beam on either side of the loaded beam (for 7-beam specimens this is longitudinal Beam 3 or 5)

second adjacent beam = the second longitudinal beam on either side of the loaded beam (for 7-beam specimens this is longitudinal Beam 2 or 6) transverse member or beam = a beam placed across the specimen and clamped below or welded between the longitudinal beams

M_t = maximum moment in transverse member

$N = \frac{EI_p}{1-\mu^2} = \frac{Eh^3}{10.95}$ = stiffness of plate element

n = number of transverse beams

P = total load applied to structure

r_n = proportion of concentrated or distributed load for moment, n transverses of equal stiffness, load over transverse at or near center. When n = o, $r_n = r_o$.

2.5 Outline of Test Program

Phase I specimens, fabricated without transverse members, were tested to failure with the load applied either over the center longitudinal beam (for 7-beam specimens) or midway between the center longitudinal beams (for 6-beam specimens). The results from the tests of these specimens (I, II, III, and IV) have been reported previously (4).

An H value of 91.5 and an aspect ratio of 0.2 (similar to Specimen II of Phase I) were then selected for the specimen to which one or more transverse beams would be clamped. Clamping transverse beams across the bottom of the longitudinal beams permitted the testing of specimens with 1, 2, or 3 transverse members of varying moments of inertia (I_t) which could be located at the center, third points, and quarter points, respectively, of the span lengths. These specimens (V-1, V-2, and V-3) are summarized in Table 2.5.1.

The results of the preceding tests were then used to determine the most desirable transverse detail for the specimen in which the transverse member would be welded intercostally between the longitudinal beams. The influence of added transverse members on the total weight of the structure and the distribution of the load throughout the structure were considered. On the foregoing basis, two specimens (V-F and VI) were fabricated with a transverse beam welded at midspan. (See Table 2.5.1) These specimens were similar to Specimens II and IV respectively, which had no transverse member. In addition the moment of inertia of the welded transverse beam in Specimen V-F was the same as one of the values used in the series of tests on Specimen V-1 with clamped transverses, thus providing a comparison of the behavior of specimens with welded and clamped transverse beams.

In the tables and figures included in this report, strains are reported in microinches per inch (microin./in.) and deflections are reported in inches. Unless otherwise noted, all reported strains are positive, indicating tension, and all deflections are positive, indicating downward deflections. The double entries of data, recorded in many cases for adjacent beams, represent data obtained from each adjacent beam.

III. TESTS OF SPECIMENS WITHOUT TRANSVERSE MEMBERS -- WORK REPORTED PREVIOUSLY

The specimens tested as part of Phase I of this investigation consisted of a plate stiffened on the underside with a series of longitudinal supporting beams and no transverse members. Four specimens (I, II, III and IV) were tested in this phase of the program. The results of these tests together with an appropriate analysis have already been reported completely (4) and will be briefly summarized here for convenience.

3.1 Load Applied Between Longitudinal Beams -- Specimens I and III

Specimens I and III -- with six longitudinal beams, relative stiffness (H_o) of 91.5, and beam spacings of 12 and 18 in. respectively (b/a of 0.2 and 0.3) -- were loaded to failure at midspan midway between the center longitudinal beams. Both specimens failed by buckling of the deck plate over the end support at maximum loads of 376 and 359 kips, respectively.

In the tests on these specimens, the deck-plate bottom strain in a transverse direction directly under the applied load was 3500 microin./in. (the yield point of the material) in Specimens I and III at applied loads of about 33 and 24 kips, respectively. In both specimens these maximum plate strains increased to approximately three to four times this yield point value under applied loads of 120 and 200 kips, respectively, indicating that, once yielded, the plate material did not develop strains proportional to the applied loads, and that the longitudinal beams were the primary supporting elements in this type of structure.

Yield point strains were developed at midspan in the longitudinal beams on each side of the geometric center of Specimens I and III under applied loads of about 60 and 55 kips, respectively. In Specimen I the next adjacent beams yielded first at their centers at a load of 160 kips; the outermost longitudinal beams did not yield but were strained to about 90 percent of yield at a load of 360 kips. In Specimen III the next adjacent beams yielded first at their centers when the applied load was 220 kips and the outermost longitudinal beams were strained to about 30 percent of yield at a load of 320 kips. In both specimens the quarter points of the two longitudinal beams nearest the center had not yielded at maximum load. It was evident that the wider spacing of the beams (larger aspect ratio) reduced the stiffness in the transverse direction so that the load was not as effectively transferred to the outer beams in Specimen III.

The midspan deflections of the center longitudinal beams were somewhat larger for Specimen III than for Specimen I. However, the deflections of the next adjacent beams were considerably less in Specimen III -- further indication of the reduced outward distribution of the load as the aspect ratio increased.

As yield point strain in the deck plate was reached, the deflection beneath the load was about 0.30 in. for Specimen I and 0.45 in. for Specimen III. When the center longitudinal beams began to yield (at a load of about 60 kips) the deck-plate deflections became 0.5 and 0.8 in. for Specimens I and III, respectively, whereas the midspan deflections of the center longitudinal beams were about 0.2 in. It was apparent that the plate deflection rapidly became an important factor for this position of the load, particularly as the beam spacing was increased.

3.2 Load Applied Over Longitudinal Beams -- Specimens II and IV

Specimens II and IV -- with 7 longitudinal beams at 12-in. spacing ($b/a = 0.2$) and relative stiffnesses (H_o) of 91.5 and 36, respectively -- were loaded to failure at midspan directly over the center longitudinal beam. Both specimens failed by buckling of the plate over the end supports at maximum loads of 385 and 280 kips, respectively.

In the tests on these specimens, yield point strains were developed at the center of the longitudinal beam directly under the load (Beam 4) of Specimens II and IV at loads of about 40 and 30 kips, respectively. (See Tables 3.2.1 and 3.2.2.) The first adjacent beams (3 and 5) yielded at their centers at a load of almost 100 kips in Specimen II and 65 kips in Specimen IV; the second adjacent beams (2 and 6) yielded at 240 kips in Specimen II but at 150 kips in Specimen IV, demonstrating the decrease in load-carrying capacity that can be expected as H_o is reduced from 91.5 to 36.

The plate strain developed most rapidly on the underside of the deck in the region beneath the load. Transverse strains of 3500 microin./in. were measured on the bottom of the deck in Specimens II and IV at a load of about 70 kips. At a load of 120 kips this was still the only gage location showing inelastic strain. With the load applied over a longitudinal beam, yield point strains were not developed in the plate material until after one or more longitudinal beams had yielded. In contrast to the results from Specimens I and III, the deck strains did not become extremely large and the beam strains were of primary importance in Specimens II and IV where the load was applied over a longitudinal beam.

The maximum elastic deflection at the midspan of the loaded longitudinal beam was approximately 0.20 in. for Specimen II (at a load of 38 kips) and 0.29 for Specimen IV (at a load of 30 kips). For a given applied load, the deflections were generally larger for Specimen IV than for Specimen II. (See Figs. 3.2.1 and 3.2.2.)

IV. TESTS OF SPECIMENS WITH CLAMPED TRANSVERSE MEMBERS

4.1 General

The tests of the four previously described specimens where no transverse members were included completed the series of tests in Phase I of this program. Next the influence of transverse members on the elastic behavior of this type of specimen was studied. Since only limited information seemed to be available, different numbers and stiffnesses of transverse beams were investigated in order to provide as much information as possible on the effect of various transverse members on the specimen behavior. For these tests (Phase II), a specimen similar to Specimen II (aspect ratio of 0.2, H_o of 91.5 and I_b of 26.5 in.^{4}) was fabricated. It was then fitted with one, two, or three transverse members of various stiffnesses which were clamped across the bottoms of the seven longitudinal beams. A series of tests was conducted on this specimen with one transverse member clamped at midspan (designated Specimen V-1), two transverses clamped at the third points (designated Specimen V-2), and three transverses clamped at the quarter points (designated Specimen V-3). By subsequently removing material from the bottom of a transverse beam, successively smaller values of I_t were obtained from one rolled section for each series of tests. A 12 x 4 WF at 16.5 lb., milled to the depths shown in Fig. 4.5.3.1, provided the transverse beams for the tests on Specimen V-1. The transverse beams for Specimens V-2 and V-3 came from 8 x 4 WF at 13 lb. beams cut to the sizes indicated in Figs. 4.5.3.2 and 4.5.3.3. A bottom view of Specimen V-3 showing transverse members clamped at the quarter points of the longitudinal beams is shown in Fig. 4.1.1.

For the tests on Specimen V-1 the moment of inertia of the transverse beam (I_t) was varied from 26.5 to 3.33 in.^{4} or from a stiffness equal to that of the composite I of the longitudinal T-beam section to 1/8 of this value. For each value of I_t considered, the load was applied to the specimen at two positions -- the geometric center of the specimen directly over the transverse beam (load position 10), and along the center longitudinal (Beam 4) at the location that produced the maximum elastic flexural strain in the loaded longitudinal beam for a particular value of I_t. This latter position was determined from exploratory tests where a constant load of 25 kips was applied at several locations along the length of longitudinal Beam 4. As the load was moved along this beam, strain measurements were taken along the bottom flange of the beam (including a point directly beneath the load). From these data the position of the load providing maximum longitudinal beam strain was determined for each value of I_t and these positions are summarized in Table 2.5.1. For example, for the greatest value of I_t considered (26.5 $in.^4$) in Specimen V-1, this position was 2 in. from the quarter point (load position 4). As the moment of inertia of the transverse beam was reduced, this position moved toward the center and was 5 in. from midspan (load position 8) when I_t = 3.33 $in.^4$.

For the tests on Specimen V-2 the moment of inertia of the transverse located at each of the third points of the longitudinal beams varied from 26.5 to 3.33 $in.^4$ also. For each stiffness of transverse member, the specimen was loaded elastically at the geometric center (load position 10) and at a point directly over the intersection of the center longitudinal beam and one transverse beam -- 10 in. from the geometric center (load position 5A).

For the tests on Specimen V-3 the moment of inertia of the transverse located at each of the quarter points varied from 13.3 to 3.33 $in.^4$ or from 1/2 to 1/8 of the moment of inertia of the composite longitudinal beam. Each of these specimens was loaded elastically at the geometric center of the specimen over the middle transverse (load position 10) and at a point over the center longitudinal beam midway between the middle and adjacent transverse beams -- 7 1/2 in. from the geometric center of the specimen (load position 6A).

Because of the scarcity of data on the behavior of stiffened plate specimens which also contain one or more beams in a transverse direction, extensive measurements of strain and deflection were made on the specimens tested in this series. Consequently, these strain and deflection data have been reported fairly completely in the tables and figures referred to in the sections which follow.

In Table 2.5.1 are summarized the various moments of inertia of the transverse members (I_t) used in the series of tests on Specimens V-1, V-2, and V-3 together with the position of the load which produced the maximum strain in the loaded longitudinal beam for each case.

4.2 Transverse Member at Midspan -- Specimen V-1

Specimen V-1 refers to the specimen with a transverse beam clamped at midspan to the underside of the longitudinal beams. Actually, a specimen with five different transverse beam stiffnesses comprised this series of tests and the load was applied, in each case, at the two positions previously described.

In Table 4.2.1 are summarized the flexural strains (in microin./in.) measured at and near the center of the loaded and adjacent longitudinal beams (both sides of the center) when the load was applied at the geometric center (position 10). In this case the transverse member was directly under the load and in the best position to effectively distribute the applied load to the adjacent beams. When the specimen was loaded at the geometric center, the greatest strain in both loaded and adjacent beams occurred at or near midspan. As the stiffness of the transverse member was decreased from 26.5 to 3.33 $in.^4$, more of the load was supported by the loaded and first adjacent longitudinal beams. This can be seen in Fig. 4.2.1 where the longitudinal beam strains at midspan and 3 in. from midspan are plotted for an applied load of 40 kips. In particular, the largest strain in the loaded longitudinal beam increased from 1170 to 1490 microin./in. The largest average strain in the first adjacent beam increased from 480 to 530 microin./in., but the largest average strain in the second adjacent beam decreased from 260 to 140 microin./in.

Table 4.2.2 gives the strains around midspan for the loaded and adjacent longitudinal beams when the load was applied at the position which produced the largest strain in the loaded longitudinal beam. As can be seen in Table 2.5.1 this location of load moved from position 4 (13 in. from the centerline of the 60-in. span) to position 8 (5 in. from the centerline of the 60-in. span) as the stiffness of the transverse varied from 26.5 to 3.33 in.^{4} The variation of longitudinal beam strain at the centerline and 3 in. from the centerline is shown in Fig. 4.2.2 for various values of I_t when a 40-kip load was applied at the proper position to produce maximum longitudinal strain in Beam 4. In this case, however, the maximum strain developed in the loaded longitudinal beam did not exist at either of the plotted locations but occurred under the applied load as can be seen in Table 4.2.2. When $I_t = 26.5$ in.^{4}, this maximum strain is more than three times the strain value at midspan but this difference decreases substantially as I_t is reduced. Under a load of 40 kips this maximum strain increased slightly (from 1400 to 1470 microin./in.) as I_t decreased from 26.5 to 6.67 in.^{4} but increased abruptly to 1620 microin./in. as I_t decreased to 3.33 in.^{4}

For a particular value of I_t, the strains developed in the adjacent longitudinal beams were as much as 50 percent larger when the load was applied directly over the transverse beam (position 10) than when the load was positioned to give the maximum loaded beam strain. At the same time, the largest strains developed in the loaded longitudinal beam when load was applied at position 10 were as much as 15 percent less than the maximum value obtained when the load was applied at the other position considered.

The deflections (in inches) measured in the center region of Specimen V-1 are summarized in Table 4.2.3 for load applied at position 10 and at the position which gave maximum strain in the loaded longitudinal beams. For a given transverse stiffness the maximum measured deflection occurred 6 in. from midspan and was not affected significantly by the variation in load position. As would be expected, the midspan deflections of the loaded and adjacent beams were larger when the load was placed directly over the transverse member (position 10). For a given load, the maximum loaded beam deflection increased almost 50 percent as the transverse beam stiffness decreased from 26.5 to 3.33 $in.^4$

4.3 Transverse Member at Each of the Third Points -- Specimen V-2

Specimen V-2 refers to a specimen with transverse beams clamped at the third points of the longitudinal beam span. Actually, specimens with four different transverse beam stiffnesses constituted this series of tests.

The longitudinal beam strains measured in the region between midspan and the location of the applied load are summarized in Table 4.3.1 when the load was applied at one of the third points of the longitudinal beam span over a transverse member (position 5A). The variation of longitudinal beam strain across a transverse section of the specimen at the centerline and 3 in. from the centerline is shown in Fig. 4.3.1, for a 40-kip load at position 5A. In this case the largest strain developed in the adjacent beams occurred at or near midspan. However, the midspan strain in the loaded beam was only about

60 percent of the largest strain measured in that beam (the largest strain in Beam 4 occurred at a point about 7 in. from the centerline of the specimen).

The longitudinal beam strains in this specimen when the load was applied at the geometric center of the specimen, midway between the two transverse members (position 10), are summarized in Table 4.3.2. As can be seen in the table, when load was applied at this position, the largest strain in each longitudinal beam almost always occurred at the center. Under an applied load of 40 kips the midspan loaded beam strain increased from 1230 to 1520 microin./in. as the stiffness of the transverse beams decreased from 26.5 to 3.33 $in.^4$ This can be seen in Fig. 4.3.2 where the variation of longitudinal beam strain across a transverse section of the specimen is shown when the load is applied at position 10.

In comparing the data for these two load positions, load at position 10 produced somewhat greater strains in the adjacent beams. With the load applied at position 5A the largest strain in longitudinal Beam 4 occurred directly beneath the load. However, this strain was about 15 percent less than the maximum strain that developed in Beam 4 when the load was applied at position 10.

Table 4.3.3 summarizes the deflections measured in the tests on Specimen V-2 for load applied at positions 5A and 10. In each case the largest deflection of loaded and adjacent longitudinal beams was measured at midspan. For the same transverse beam stiffness, load applied at position 10 (the geometric center of the specimen) produced larger midspan deflection of the loaded beam. However, midspan deflections of adjacent beams were not greatly different for the two positions of load.

4.4 Transverse Member at Each of the Quarter Points -- Specimen V-3

Specimen V-3 refers to a specimen with transverse beams clamped at the quarter- and midpoints of the longitudinal beam span. Actually, specimens with three different transverse beam stiffnesses made up this series of tests.

The strains at and near the center of the loaded and adjacent longitudinal beams are summarized in Table 4.4.1 when the load was applied at the geometric center, over the middle transverse beam (position 10), and in Table 4.4.2 when the load was applied midway between the center and the quarter point of the longitudinal beam span (position 6A). Shown in Figs. 4.4.1 and 4.4.2 is the variation of longitudinal beam strain across a transverse section of the specimen at the centerline and 3 in. from the centerline for a 40-kip load located at positions 10 and 6A, respectively. When the load was applied at position 10 the largest strain measured in the loaded longitudinal beam occurred at one of these sections. This strain was only about five percent less than the maximum value measured in Beam 4 when the load was applied at position 6A.

With load applied at position 6A, the centerline strains were substantially less than those measured 3 in. away (see Fig. 4.4.2) in Beam 4. Load applied at this position developed the maximum strain measured in the loaded longitudinal beam. For a 40-kip load this strain increased from 1140 to 1380 microin./in. as I_t decreased from 13.3 to 3.33 in.^{4} These data indicate that, in a specimen of this type with three transverse beams, the maximum strain that may occur in the loaded or adjacent longitudinal beams is about the same for these two positions of load.

The deflections in the center region of the specimen are given in Table 4.4.3 for the tests of Specimen V-3 with load applied at positions 10 and 6A. The maximum deflection measured in the loaded beam occurred at a point 6 in. from midspan and for a given load was almost the same for both load positions. In the tests where the load was applied at position 10 and I_t was 6.67 or 3.33 $in.^4$ (the more flexible specimensin the group) the midspan deflection of the loaded beam was about equal to that measured 6 in. from midspan.

4.5 Comparison of Specimens with One, Two and Three Transverse Members

In the previous sections the experimental data obtained from tests of specimens with one, two, or three transverse members of varying stiffness have been presented. These data will now be compared so that their relative effectiveness may be determined.

4.5.1 Strains in Longitudinal Beams. Under an applied load of 40 kips the largest beam strains (in microin./in.) measured in the loaded longitudinal beam when the load was applied over the transverse beam were as follows:

SPECIMEN	LOAD POSITION	MOMENT OF INERTIA OF EACH TRANSVERSE BEAM, $in.^4$				
		26.5	19.6	13.3	6.67	3.33
V-1	10	+1170	+1220	+1240	+1330	+1490
V-2	5A	+1020	---	+1130	+1180	+1330
V-3	10	---	---	+1080	+1220	+1310

Under the same load, positioned to produce the maximum possible strain in the loaded longitudinal beam, the following strains were obtained in longitudinal Beam 4:

SPECIMEN	LOAD POSITION	MOMENT OF INERTIA OF EACH TRANSVERSE BEAM, $in.^4$				
		26.5	19.6	13.3	6.67	3.33
V-1	Varied	+1400	+1420	+1470	+1470	+1620
V-2	10	+1230	---	+1320	+1400	+1520
V-3	6A	---	---	+1140	+1290	+1380

From the data in the preceding tables it is evident that the largest strain occurring in the loaded longitudinal beam when the load is applied over the transverse member may be as much as 20 percent less than the absolute maximum strain that can be developed in the loaded longitudinal beam by the most severe load position. However, this difference is only about 5 percent for the case where three transverse members are present.

In the above tables the moments of inertia are the values for each individual transverse beam strip. Therefore, if specimens with approximately equal values of total transverse moment of inertia are compared, Specimen V-3, with three transverse members of 6.67 $in.^4$ each, would compare with Specimen V-1 with one transverse member of 19.6 $in.^4$ and Specimen V-2, with two transverse members of 6.67 $in.^4$ each, would compare with Specimen V-1 with one transverse member of 13.3 $in.^4$. When compared in this manner the difference in maximum strains obtained in the tests of the various specimens is reduced considerably.

At the same load (40 kips), the maximum strain measured in the first adjacent longitudinal beam occurred with the applied load at position 10, the geometric center. The average values measured in the first adjacent beams are summarized below:

SPECIMEN	MOMENT OF INERTIA OF EACH TRANSVERSE BEAM, $in.^4$				
	26.5	19.6	13.3	6.67	3.33
V-1	480	490	490	510	530
V-2	410	---	440	490	530
V-3	---	---	360	480	520

It can be seen that varying the number of transverses has a negligible effect on this maximum strain for low values of I_t (3.33 and 6.67 $in.^4$). However, for a given number of transverse beams, the strain in the first adjacent beam is reduced as I_t is increased.

In the above table, moments of inertia are again given for each individual transverse beam strip. Therefore, if specimens with approximately equal values of total moment of inertia are compared, Specimen V-3, $I_t = 6.67$ in.^{4}, would compare with Specimen V-1, $I_t = 19.6$ in.^{4}, and Specimen V-2, $I_t = 6.67$ in.^{4}, would compare with Specimen V-1, $I_t = 13.3$ in.^{4}. If this comparison is made there is almost no difference in the results obtained from the various tests.

The maximum strain in the second adjacent beam usually occurred at midspan. However, where available for comparison, there was little variation evident in the strain measured at the center, 3 in. from the center, and 7 in. from the center of the beam. The two load positions used for each specimen produced similar strains in the second adjacent beams. Load at position 10 usually gave a slightly higher strain which varied from approximately 140 to 250 microin/in. under a 40-kip load for the variation in number and stiffness of transverse beams considered. These data indicate that the strain in the second adjacent beams is not greatly affected by variations in number or stiffness of transverse members or position of applied load.

4.5.2 Deflections of Longitudinal Beams. In order to compare the results from the elastic tests of specimens with one, two and three transverse members, the maximum deflections measured in the loaded longitudinal beam are summarized below. With a 40-kip load applied over a transverse at or near midspan, the largest deflections (in inches) of the loaded longitudinal beam were:

SPECIMEN	LOAD POSITION	MOMENT OF INERTIA OF EACH TRANSVERSE BEAM, in.^{4}				
		26.5	19.6	13.3	6.67	3.33
V-1	10	.091	.100	.104	.110	.127
V-2	5A	.075	---	.096	.099	.113
V-3	10	---	---	.106	.105	.118

With a 40-kip load applied to produce maximum strain in the loaded longitudinal beam, the largest measured deflections (in inches) in longitudinal Beam 4 were:

SPECIMEN	LOAD POSITION	MOMENT OF INERTIA OF EACH TRANSVERSE BEAM, in.^{4}				
		26.5	19.6	13.3	6.67	3.33
V-1	Varied	.090	.098	.102	.116	.135
V-2	10	.101	---	.116	.123	.134
V-3	6A	---	---	.106	.108	.120

In general, except for Specimen V-2, the measured deflections, summarized in the two tables above, are very similar regardless of the position of the load. In the case of specimens with two transverse beams, load applied at the geometric center resulted in loaded beam deflections that were as much as 35 percent greater than those for load at position 5A. This is not surprising since the transverse beam is generally more effective when directly beneath the load.

While there was not a great deal of difference in some cases, load at position 10 usually produced larger midspan deflections in the first adjacent beams. These midspan deflections (in inches) are summarized below for a load of 40 kips at position 10. The values given are the average of the two available measurements which were usually in good agreement.

SPECIMEN	LOAD POSITION	MOMENT OF INERTIA OF EACH TRANSVERSE BEAM, $in.^4$				
		26.5	19.6	13.3	6.67	3.33
V-1	10	.056	.066	.056	.054	.056
V-2	10	.054	---	.041	.048	.060
V-3	10	---	---	.046	.046	.047

These deflections are 40 to 50 percent of the value for the loaded beam, thus indicating the beneficial effect of the transverse beam in distributing load to adjacent beams. Variation in I_t did not seem to affect greatly the first adjacent beam deflections.

In most cases slightly greater midspan deflections were obtained in the second adjacent beam with the load applied at position 10. Under a load of 40 kips these average deflections (in inches) were:

SPECIMEN	LOAD POSITION	MOMENT OF INERTIA OF EACH TRANSVERSE BEAM, $in.^4$				
		26.5	19.6	13.3	6.67	3.33
V-1	10	.028	.034	.027	.022	.018
V-2	10	.037	---	.020	.022	.018
V-3	10	---	---	.030	.023	.020

In these tests, a variation in the number of transverse beams had little effect on the midspan deflection of the second adjacent beams for small values of I_t. The midspan deflection in the second adjacent beam was influenced somewhat by a variation in I_t.

4.5.3 Strains in Transverse Beams. As pointed out previously specimens V-1, V-2 and V-3 were each subjected to a series of tests wherein the moment of inertia of the transverse beam was varied. In the series of tests on Specimen

V-1 the same transverse beam was used throughout and successively smaller values of transverse beam stiffness (I_t) were obtained by removing the proper amount of material from the bottom flange of the transverse beam each time. In this manner the stiffness of the transverse beam was varied from 26.5 to 3.33 in.^{4}. By successively removing the required amount from each of the transverse beams in Specimen V-2, the transverse beam stiffness was varied from 26.5 to 3.33 in.^{4} in the tests on that specimen. Using the same procedure, the stiffness of each of the transverse beams in the tests of Specimen V-3 was varied from 13.3 to 3.33 in.^{4}.

Strains were measured at the center of the transverse beam (that is, directly under the intersection of the transverse beam and longitudinal Beam 4). In general, strain gages were mounted at several locations across the depth of the transverse in Specimen V-1 as indicated by the gage numbers shown in Fig. 4.5.3.1. For Specimens V-2 and V-3, only one strain gage was mounted on each of the transverse beams and it was located 0.5 in. from the bottom of the beam as shown in Figs. 4.5.3.2 and 4.5.3.3.

The strains that were measured at the center of the transverse beam of Specimen V-1 under loads of 20, 30 and 40 kips are summarized in Table 4.5.3.1 for the various values of I_t considered. In these tests the strains developed in the transverse beam were somewhat larger when the load was applied at position 10. This difference was more pronounced for the tests in which I_t was large and decreased to less than five percent when I_t = 3.33 in.^{4}.

The strains measured at the center of each of the transverse beams in Specimen V-2 are summarized in Table 4.5.3.2. As would be expected, both transverse beams experienced approximately equal strains when the load was applied at the geometric center, position 10. When the load was applied directly over one of the two transverse beams (position 5A), the strain in the transverse beam under the load was approximately 70 percent more than the strain measured in the other transverse beam and as much as 20 percent greater than the average strain developed in the transverse beams when the load was applied at position 10.

Table 4.5.3.3 summarizes the strains measured at the center of each transverse beam for Specimen V-3, when the load was applied at positions 10 and 6A. Of these positions load at position 10 created the larger transverse beam strain. This strain occurred in the transverse beam directly under the applied load and was around 15 percent greater than the largest strain developed when the load was applied at position 6A.

Variation of the strains measured at the center of the transverse beams in Specimens V-1, V-2 and V-3 is shown in Figs. 4.5.3.1, 4.5.3.2 and 4.5.3.3 for an applied load of 30 kips. With the exception of strain gage 92, in Specimen V-1, the strain distribution seems to be fairly uniform throughout the depth of the transverse beams. Although no measurements were made on the top flange, it appears that the top flange strains would be substantially smaller than might have been expected, indicating that the neutral axis may have been raised because of some composite action between the transverse and longitudinal beams. The strain gages were mounted on the transverse along a line directly beneath the longitudinal beam. In fabricating the specimen each edge of the top flange of the transverse beam was clamped to both sides of the bottom flange of each longitudinal beam. It is possible that the normal flexure of the top flange of the transverse beam could be restrained and the strains therefore reduced.

4.5.4 Deck-Plate Strains. SR-4 strain gages were mounted on the top and bottom surfaces of the 3/8-in. deck-plate at selected locations as shown in Fig. 2.3.1. Measurements from these gages provided information on the strains developed in the longitudinal and transverse directions of the STS plate material during the tests of Specimens V-1, V-2 and V-3. The largest and second largest strains measured in these specimens have been summarized in Table 4.5.4.1 for various positions of the 40-kip load. Values for tensile and compressive strain on both surfaces of the plate are given. It is evident that, at a load of 40 kips, the maximum measured plate strain in specimens with clamped transverse beams was generally less than 600 microin/in., considerably below this material's yield strain of approximately 3500 microin/in.

At this same load maximum strains ranging between 1100 and 1600 microin/in. occurred in the loaded longitudinal beams (made of HTS material with a yield strain of approximately 2200 microin/in.). It was apparent that the maximum strains in the deck-plate were approximately half of those existing in the loaded beam. When the yield strength was considered, it was evident that the plate strains were of secondary importance in the behavior of this type of structure. This is in agreement with the results of the Phase I tests where, for specimens without transverse beams, the longitudinal beams were found to be the primary supporting elements (4).

V. TESTS OF SPECIMENS WITH WELDED TRANSVERSE MEMBERS

5.1 General

Described in the previous section were the elastic tests on Specimens V-1, V-2 and V-3 (Phase II) where 1, 2 and 3 transverse beams respectively were clamped across the bottoms of the longitudinal beams of the specimen. In these tests, the moment of inertia of the transverse beam varied from a value equal to the stiffness of the composite longitudinal T-beam (26.5 $in.^4$) to approximately 1/8 of that value (3.33 $in.^4$). These elastic tests showed that for a given load, the presence of one or more transverse members considerably increased the distribution of applied load to adjacent longitudinal beams.

The results of these elastic tests with clamped transverse members were used to help determine the details of the specimens wherein the transverse beam or beams would be welded intercostally between the longitudinal supporting beams (Phase III). Providing a transverse beam in this fashion would not increase the overall depth of the structure and would be more typical of the detail that might be used in actual practice.

From the results of the tests on Specimens V-1, V-2 and V-3 it appeared that the addition of one transverse at midspan was very beneficial in distributing the applied load throughout the supporting structure. However, the addition of two or three transverses did not provide a significantly greater improvement in load distribution in the cases considered.

On the basis of the maximum elastic strain developed in the loaded longitudinal beam for specimens with one transverse member clamped at midspan (Table 4.2.2), it appeared that, for the weight of the material added, a transverse beam with a stiffness of 6.67 $in.^4$ (1/4 that of the composite longitudinal T-beam) was the most effective and should be used in subsequent test specimens. This transverse beam was also of such a size that it could be conveniently provided in an actual structure.

Accordingly, two specimens (V-F and VI) were fabricated with a transverse beam (a specially fabricated H-beam cut from a 6 x 4 WF @ 12 lb) that was coped and welded to the flanges and webs of the longitudinal beams at midspan. These two specimens constituted Phase III of the program. Specimen V-F with a welded transverse having an I_t of 6.67 in.^{4} (depth of 3.60 in. and flange widths of 4.60 in.) was similar to Specimen V-1 with a clamped transverse of the same stiffness. Without this transverse member, Specimen V-F was a duplicate of Specimen II (7 longitudinal beams, $\frac{b}{a}$ = 0.2, H_o = 91.5). Figures 5.1.1 and 5.1.2 provide an underside view of Specimen V-F showing the transverse beam welded intercostally between the longitudinals. Specimen VI was fabricated with a transverse beam whose stiffness was 2.60 in.^{4} (depth of 2.96 in. and flange widths of 1.50 and 4.00 in. Without this transverse member, Specimen VI was a duplicate of Specimen IV (7 longitudinal beams, $\frac{b}{a}$ = 0.2, H_o = 36).

Specimens V-F and VI were tested in the elastic range with the loads applied over the intersection of the center longitudinal beam and the transverse beam (position 10). They were then tested to failure with the load at the position along the center longitudinal beam which produced the maximum elastic strain in the loaded longitudinal beam. The selection of the load position for the test-to-failure was made by applying a load of 25 kips at a series of positions along the loaded beam as described in Section 4.1 for tests on Specimen V-1 with one clamped transverse beam. The results of these exploratory tests showed that position 6 (9 in. from midspan) for Specimen V-F and position 4 (13 in. from midspan) for Specimen VI were the ones that should be used. It should be noted that the position for Specimen V-F is the same as that determined for Specimen V-1 with a clamped transverse of the same stiffness.

5.2 Specimen V-F

Two tests were conducted on this specimen. In one test, load increments to 60 kips, applied at the geometric center, created only elastic strains throughout the entire structure. In the second test on this specimen, the load was applied at a point 9 in. from midspan and was increased until failure of the specimen occurred.

Under a load of about 130 kips one of the welds between the bottom flanges of the transverse beam and longitudinal Beam 4 cracked as shown in Fig. 5.2.1. The test was stopped so that the weld could be chipped out and the beams could be rewelded. The test was then resumed until, at a maximum load of 320 kips, the center beam showed considerable rotation over the support. The specimen failed by simultaneous buckling of the plate between longitudinal Beams 4 and 5 and of the diaphragm between the ends of longitudinal Beams 5 and 6 as shown in Fig. 5.2.2.

The longitudinal beam strains in the center region of Specimen V-F are summarized in Table 5.2.1 for load applied at positions 10 and 6. When measured by the maximum strain developed in the loaded longitudinal beam, a load applied at position 6 is more severe than the same load located at position 10. The greatest strain always occurred under and close to the center of the applied load, i.e., 3 in. from midspan with the load at position 10 and approximately 9 in. from midspan with the load at position 6. The strain at the midspan of the loaded longitudinal beam is less than this value, particularly for the case where the load is applied at position 6. Probably the biaxial tensile strains, to which longitudinal Beam 4 was subjected by the intercostally welded transverse beam, helped to reduce the midspan strain in the loaded longitudinal beam.

With a 60-kip load at position 6, the loaded longitudinal beam was beginning to experience plastic strain. Beams 3 and 5 yielded first at their centers when the applied load was about 90 kips while Beams 2 and 6 yielded first at their centers when the applied load was approximately 160 kips. At the ultimate load of 320 kips the strains in Beams 1 and 7 were of negligible magnitude. After yielding initially under the load, the extent of the yielding spread rapidly along the bottom fibers of the loaded beam. With increasing loads, yielding in adjacent beams also spread. Points 7 in. from the center of Beams 3 and 5 yielded at a load of 140 kips; points 7 in. from the center of Beams 2 and 6 yielded at a load of 280 kips. Yielding was impending at the quarter points of Beams 3 and 5 at the ultimate load. The maximum recorded beam strain at a load of 200 kips was 0.076 in. per in. for Beam 4 at a point 7 in. from the center.

Load at position 10 produced the greater midspan strain in the first and second adjacent beams. The measured strain in the adjacent beams peaked abruptly at midspan and was 30 to 50 percent less at a point only 3 in. from midspan for loads up to 80 kips. Apparently the presence of an intercostally welded transverse beam created a significant strain gradient at the midspan of the adjacent beams.

The deflections near midspan are given in Table 5.2.2 for load at positions 10 and 6 of Specimen V-F. With the load at position 10, only deflections for the loaded beam are available and the maximum measured deflection was directly beneath the applied load. The largest deflections of the loaded beam were slightly less when the load was applied at position 6 and they occurred 6 in. from midspan.

For this same position of load, the maximum measured deflection of the adjacent beams was at midspan. This midspan deflection, for the first adjacent beam, was almost one-half and, for the second adjacent beam, about one-sixth of the value for the loaded longitudinal beam. Fig. 5.2.3 shows, for a transverse section at the centerline of the specimen, the deflections under load and residual deflections for various load increments up to 200 kips. The improved outward distribution of load was evidenced by the substantial deflection of adjacent beams at higher loads.

5.3 Specimen VI

Specimen VI was subjected to loads applied at two different positions. Load increments to 30 kips, producing only elastic strains throughout the structure, were applied at the geometric center. The specimen was loaded to failure with the load applied at position 4, 13 in. from midspan.

Under an applied load of about 130 kips one of the welds between the bottom flanges of the center longitudinal beam and the transverse beam failed as shown in Fig. 5.3.1. After this weld had been chipped out and rewelded, the test was resumed. In the last stages of the test, buckling of the plate between longitudinal Beams 3 and 4 became apparent. At an applied load of 280 kips the weld between the bottom flanges of the transverse beam and the center longitudinal beam cracked again and the specimen failed. The specimen is shown in Fig. 5.3.2 at ultimate load.

The longitudinal beam strains in the center region of Specimen VI are summarized in Table 5.3.1 for load applied at positions 10 and 4. It is evident that load applied at position 4 produced greater strains in the loaded longitudinal beam than did load applied at the geometric center. In both cases, the midspan strain was considerably smaller than the maximum strain measured in the loaded longitudinal beam (similar to the behavior of Specimen V-F). With the load at position 4 the midspan strain was negative, probably because of the restraint of the transverse beam.

Yield point strain in longitudinal Beam 4 occurred under a load of about 40 kips. Beams 3 and 5 yielded first at their centers when the applied load was approximately 65 kips and Beams 2 and 6 yielded in a similar manner at about 130 kips. At the near-maximum load of 240 kips, the midspan bottom fibers of the exterior beams had experienced only slightly more than half of the yield point strain.

As in Specimen V-F, the adjacent beams of Specimens VI exhibited the greatest strain at midspan and a rapid drop-off along the length of the beam since strains 3 in. from midspan were only 50 to 70 percent of the midspan value for loads up to 60 kips. However, above this load, the strain 3 in. from midspan in the first adjacent beam developed at a much more rapid rate and quickly exceeded the strains measured at midspan. As indicated by the larger strains developed in the adjacent beams, load located at position 10 (over the transverse) is distributed more completely to the supporting beams.

The deflections in the center region of Specimen VI are summarized in Table 5.3.2 for load applied at positions 10 and 4. Comparing the results for these two positions, load applied at position 10 produced somewhat greater deflection in the loaded longitudinal and also at the midspan of the first and second adjacent longitudinal beams.

When loaded at position 4 (13 in. from midspan), the maximum measured deflection of the loaded beam occurred at a point 6 in. from midspan when the applied loads were small. As larger loads were applied, the deflection measured at a point 16 in. from midspan (3 in. from the centerline of the applied load) became the largest.

In Fig. 5.3.3 the deflections under load and residual deflections for various load increments up to 200 kips are shown for a transverse section at the midspan of the specimen. It is evident, with first and second adjacent beams exhibiting deflections that are approximately one-half and one-fifth of the loaded beam deflection, that the transverse beam has improved the distribution of the applied load to adjacent beams.

VI. COMPARISON OF SPECIMENS WITH CLAMPED AND WELDED TRANSVERSE MEMBERS

As pointed out in Section V, Specimen V-F (with a welded transverse beam) was similar to Specimen V-1 (with a clamped transverse beam). Both transverse beams had an I_t of 6.67 $in.^4$. The only difference in these specimens was the cross-sectional shape of the transverse beam and its position relative to the longitudinals. In Specimen V-1 the transverse member (a T-section) was fastened at each edge to both sides of the bottom flange of each longitudinal beam while in Specimen V-F the transverse member (a fabricated I-section) was welded intercostally between the longitudinal beams. In this section the behavior of these two specimens in the elastic range will be compared.

6.1 Strains in Longitudinal Beams

In the exploratory tests on Specimens V-1 and V-F, the position of the load producing maximum strain in the loaded longitudinal beam was found to be position 6. Each of these specimens was loaded in the elastic range at this position and also at position 10.

The distribution of strain measured along the loaded longitudinal beam of Specimen V-F and V-1 is shown in Fig. 6.1.1 for a load of 40 kips applied at positions 10 and 6. With load at position 6, the more critical position, there was excellent agreement between the strains measured in the two specimens except for the point at midspan where the different elevation and method of connection of the transverse beam apparently had a local effect. With load at position 10 there is generally good agreement between the two specimens except near midspan.

The increments of strain measured in longitudinal Beams 1, 2, 3 and 4 of Specimens V-1 and V-F are compared in Figs. 6.1.2 and 6.1.3 for loads up to 40 kips applied at positions 10 and 6. While not all corresponding adjacent beams were in good agreement, it can be seen that the maximum strain developed in the loaded beam was about the same in each specimen for a given load position.

The longitudinal beam strains across a transverse section at midspan and 3 in. from midspan are summarized in Table 6.1.1 for Specimens V-1 and V-F when subjected to a load of 40 kips at positions 10 and 6. Regardless of the position of load, the strain at the centerline was always larger in the loaded beam and usually smaller in the adjacent beams of Specimen V-1 (where the transverse member was clamped in place) than it was in the longitudinal beams of Specimen V-F. The difference in midspan strain for the loaded beam was quite large, but need not be given serious consideration since the maximum strain in longitudinal Beam 4 did not occur at midspan. Across a transverse section 3 in. from midspan the agreement between the two specimens was very good for both positions of the load, indicating that the sizeable differences noted previously existed primarily at midspan.

6.2 Deflections of Longitudinal Beams

Referring to Figs. 6.1.2 and 6.1.3 where the deflections for longitudinal Beams 1, 2, 3 and 4 of Specimens V-1 and V-F are summarized, there is generally good agreement between the deflections of corresponding locations in the two specimens. The variation in cross section and elevation of the transverse beam in these two specimens did not influence the deflections of the loaded or adjacent longitudinal beams for the range of load considered.

6.3 Deck-Plate Strains

Strains were measured in a longitudinal and transverse direction on both the top and bottom of the deck-plate of Specimen V-F at selected locations as shown in Fig. 2.3.2. A summary of the maximum tensile and compressive strains measured on Specimen V-F under a load of 40 kips applied at positions 10 and 6 is given in Table 4.5.4.1. In general, the maximum and next largest measured strains are less than 500 microin/in. for this applied load. Considering that the deck plating is STS material with a yield point of approximately 100,000 psi, the measured plate strains are relatively low under a 40 kip load.

Specimen V-1 ($I_t = 6.67$ in.^{4}) was comparable to Specimen V-F. In most cases the results were in very good agreement, indicating that neither the different methods of fastening the transverse member to the longitudinal beams nor the marked difference in location of the transverse beam (beneath vs. between the longitudinal beams) significantly affected the maximum strains measured in the deck-plate of the specimens investigated.

VII. COMPARISON OF SPECIMENS WITH AND WITHOUT TRANSVERSE MEMBERS

As pointed out in Section VI, Specimens V-1 and V-F are identical except for the elevation, cross section and method of connection of the transverse beam located at midspan. Without the transverse member, these specimens were exactly the same as Specimen II (i.e., 7 longitudinal beams, b/a = 0.2, $H_o = 91.5$). Specimen VI without a transverse member was exactly the same as Specimen IV (7 longitudinal beams b/a = 0.2, $H_o = 36$). In this section the behavior of these specimens with and without transverse members, will be compared.

7.1 Strains in Longitudinal Beams

The strains in the longitudinal beams of Specimens II, V-1, and V-F have been summarized in Tables 3.2.1, 4.2.1, 4.2.2 and 5.2.1. Compared in Table 7.1.1 are the longitudinal beam strains at various locations in these specimens for a load of 40 kips applied at positions 10 and 6. It is evident that the maximum strain in the loaded longitudinal beam for specimens with a transverse member was developed when the load was applied at position 6 (9 in. from midspan). For a specimen without a transverse member the maximum strain in the loaded longitudinal occurred with a 40-kip load applied at position 10 and was 2370 microin/in.

The introduction of a transverse member with a moment of inertia of 6.67 in.^{4} at midspan reduced the maximum strain in the loaded beam to 1290 microin/in. (average value measured in Specimens V-1 and V-F) when a 40-kip load was applied at the geometric center. Application of the same load at position 6 developed the maximum possible strain in the loaded beam, an average of 1475 microin/in. in Specimens V-1 and V-F. This is approximately 65 percent of the maximum strain (2370 microin/in.) measured in the loaded beam of Specimen II where no transverse beam was present.

Under a 40-kip load the average midspan strains in the adjacent beams were substantially greater for the specimens with the transverse member, indicating the beneficial influence of the transverse beam in improving the lateral distribution of the applied load to the adjacent beams. This was particularly true for the second adjacent beam which in Specimen II made no contribution of positive moment capacity when a load of 40 kips was applied to the specimen.

In Fig. 7.1.1 strains in the loaded and adjacent beams of specimens II and V-F are plotted for applied loads up to 200 kips. It is evident in Specimen II that inelastic action began first in the bottom fibers of the center beam when the applied load was 40 kips. As the test was continued, only one beam was strained inelastically for loads between 40 and 100 kips, 3 beams were inelastically strained for loads between 100 and 240 kips, and 5 beams were inelastically strained for loads between 240 kips and failure. In Specimen V-F, inelastic action first occurred in Beam 4 under an applied load of about 65 kips (about 50 percent higher than the corresponding load for Specimen II). After initial yielding in this beam, plastic deformation spread more rapidly than in Specimen II. One beam in Specimen V-F was strained in the plastic range for loads between 65 and 90 kips, 3 beams for loads between 90 and 160 kips, and 5 beams for loads between 160 kips and failure. The transverse beam definitely improved the distribution of the applied load and enabled adjacent beams to contribute earlier to the support of the applied load.

The strains in the longitudinal beams of Specimens IV and VI have been summarized previously in Tables 3.2.2 and 5.3.1. Selected strains are summarized in Table 7.1.2 for a load of 30 kips applied at positions 10 and 4. It is evident that the maximum strain developed in the loaded beam of the specimen without a transverse member (Specimen IV) occurred when the load was applied at the geometric center (position 10). This maximum strain was 2470 microin/in. under a load of 30 kips.

When the same load was applied to Specimen VI (containing a transverse member with a moment of inertia of 2.60 in.^{4}) the largest strain in the loaded beam was 1440 microin/in. (for load at position 10) and 1790 microin/in. (for load position 4). It can be seen that the maximum possible strain in the loaded beam was reduced approximately 25 percent when the transverse beam was present at midspan. The distributing effect of the transverse member was quite apparent when the midspan strains of adjacent beams were compared. The second adjacent beam, in particular, exhibited a substantial positive-moment contribution when the transverse member was present.

Figure 7.1.2 presents the strains in longitudinal Beams 1, 2, 3 and 4 of Specimens IV and VI for loads up to 200 kips. In the figure the more rapid development of strain in the loaded beam of the specimen without a transverse beam is evident. The apparent "leveling off" of midspan strain in Beam 3 of Specimen VI occurred because inelastic strain actually developed more rapidly 3 in. from midspan (see Table 5.3.1).

In the test of Specimen IV, inelastic action began first in the bottom fibers of the center beam when the applied load was about 30 kips. Until the applied load reached 65 kips, only the center longitudinal beam was strained in the inelastic range; then three beams were inelastically strained until this load reached 150 kips, and five beams were inelastically strained until this load reached 260 kips. In Specimen VI, however, inelastic action first occurred at an applied load of about 40 kips. After initial yielding in this specimen, inelastic deformation spread more rapidly than in Specimen IV. One beam in Specimen VI was plastic until the applied load reached 65 kips, three beams were plastic until this load reached 130 kips, and five beams were plastic until failure. Again the transverse beam improved the distribution of the applied load to adjacent beams.

7.2 Deflections of Longitudinal Beams

Presented in Tables 7.2.1 and 7.2.2 are the deflections of the longitudinal beams of Specimens II, V-1 and V-F for a load of 40 kips and of Specimens IV and VI for a load of 30 kips.

Referring to Table 7.2.1, the maximum deflection of Specimen II was 0.215 in. under a 40-kip load. The maximum measured deflection was approximately 50 percent less in the case of identical specimens where a transverse member (I_t = 6.67 in.^{4}) had been clamped or welded to the structure at midspan. This maximum deflection was about the same for both positions of the load in Specimens V-1 and V-F. A transverse member located at midspan appears to have little effect on the midspan deflection of the first adjacent beam but a profound effect on the midspan deflection of the second adjacent beam at this load.

Comparisons can be seen more easily in Fig. 7.2.1 where the deflections of the longitudinal beams of Specimens II and V-F are shown. At a load of 200 kips, the maximum deflection of Beam 4 was 2.8 in. for Specimen II and 1.6 for Specimen V-F.

In Table 7.2.2 the presence of a transverse beam welded intercostally at midspan reduced the maximum measured deflection in Specimen VI to approximately 65 percent of the 0.291-in. deflection measured in Specimen IV at a load of 30 kips. The reduction in maximum deflection of the loaded beam was again accompanied by little change in the average midspan deflection of the first adjacent beams but a substantial increase in average midspan deflection of the second adjacent beams.

The longitudinal beam deflections of these specimens are shown in Fig. 7.2.2 for load to 200 kips. At a load of 160 kips, the maximum deflection of longitudinal Beam 4 was 2.2 in. for Specimen IV and 1.7 in. for Specimen VI.

7.3 Deck-Plate Strains

It was found previously (Section 3.2) that yield point strains were developed in the deck-plating of specimens without transverse members (Specimens II and IV) under an applied load of about 70 kips. When similar specimens were outfitted with welded transverse beams, (Specimen V-F and VI), the deck-plate strains throughout the specimen were generally less than one-half the yield point of the material for an applied load of 120 kips. When the applied load was 200 kips, a few gages indicated yield point strains in the deck-plate of both Specimens V-F and VI. Thus it is evident that deck-plate strains increased at a relatively slow rate in the specimens with transverse beams and were not nearly as important as the strains which developed at a much more rapid rate in the longitudinal beams.

VIII. ANALYSIS AND DISCUSSION OF THE EFFECT OF TRANSVERSE MEMBERS

8.1 General Concept

Stiffened plate specimens, by virtue of the stiffness of both the deck and the longitudinal supporting beams, distribute applied load laterally so that the surrounding regions of a structure may contribute to the support of the load. This lateral distribution can be augmented by the addition of one or more members which are placed in a transverse direction and connected to the longitudinal supporting beams. The effectiveness of such transverse members depends upon several factors, including the stiffness of the transverse relative to the longitudinal beams and, more particularly, relative to the deck.

A transverse member functions most effectively in laterally distributing an applied load when the position of the load is directly over the transverse. Under these conditions, the maximum moment in the loaded beam is considerably reduced and the moments in adjacent beams are correspondingly increased when compared with the moments which would exist in the same structure without a transverse member. Unfortunately, however, such a position is not the critical location of the load for producing maximum moment in the loaded beam. Hence, this apparent improvement is not as beneficial as it would appear to be at first glance, since the maximum moment in the loaded beam is usually of primary concern.

When the same load is located at some position which is not directly over the transverse, the effectiveness of the transverse member as a distributor of the load is reduced. Under these conditions the maximum moment in the loaded longitudinal beam may be considerably larger than the moment in the loaded longitudinal when the load is placed directly over the transverse member.

It has been found previously (3) that the relative stiffness of a transverse member may be measured by the quantity K where

$$K = E_t I_t a^3 / E I_b b^3$$

Each transverse in the structure can be compared in effectiveness with a width of decking of a/n+1. When the stiffness of the transverse is added to such a width of decking, a revised value of H_o, referred to as H_n, can be computed in the following manner for a structure with n transverse members of finite stiffness:

$$\frac{1}{H_n} = \frac{1}{H_o} + (n+1)\frac{E_t I_t}{EI}$$

where H_o is the original value when no transverse member is present.

Then,

$$\frac{1}{\beta_n^6} = \frac{1}{\beta_o^6} + (n+1)K$$

where

$$\beta_n = \left(\frac{H_n b^3}{a^3}\right)^{\frac{1}{6}}$$

With the value of β_o known for the structure and various values of K available, corresponding values of β_n can be computed from the above relationship and used to determine the proportion of load or the necessary coefficients for the calculation of moments or deflections in the various longitudinal beams.

In the investigation described herein, a specimen with seven longitudinal supporting beams (b/a = 0.2, H_o = 91.5) was tested with transverse members of varying stiffness clamped across the bottoms of the longitudinal beams at the center, third points, and quarter points (Specimens V-1, V-2 and V-3 respectively). In each of these cases, the stiffnesses of the added transverse members were combined in the manner previously described to provide a calculated value of H_n for the structure with transverse members. This value of H_n was then converted to the parameter β_n for the structure, and these calculations are summarized in Table 8.1.1. The same procedure was used to determine the values of H_n and β_n for Specimens V-F and VI which contained a transverse beam welded intercostally to the longitudinal beams at midspan. These data are given in Table 8.1.1 also.

8.2 Strains in Longitudinal Beams

The coefficients to be used in the calculation of the moments in the longitudinal beams of certain simply-supported deck structures (acting as a one-way slab) are given in Tables E-4 and E-18 of Reference (2) for a concentrated load. The values for the loaded beam, first and second adjacent beams have been plotted in Fig. 8.2.1 in terms of the parameter β. From these plots the necessary coefficients for the various specimens (now expressed in terms of β_n) were obtained and used to compute the theoretical strains (and moments) for the specimens tested.

The longitudinal beam strains computed in this fashion as well as the largest strains measured when the load was located over the transverse member at or near the center are summarized in Tables 8.2.1, 8.2.2 and 8.2.3 for Specimens V-1, V-2 and V-3 respectively under applied loads of 20, 30, 40 and 50 kips. Referring to these tables, it can be seen that the computed strains are usually somewhat greater than the measured strains for all of the beams considered. This difference is most pronounced for the first adjacent beam. For the loaded beam, which is of greatest interest, there is generally good agreement between the measured and computed strains for large values of I_t. For small values of I_t, however, the computed strain is always greater than the measured strain shown in these tables. In the cases where I_t was 3.33 or 6.67 in.^{4}, the computed value of strain actually agrees quite well with the maximum possible strain that was measured in the loaded longitudinal beam when the load was applied at the other more critical position.

8.3 Deflections of Longitudinal Beams

The coefficients to be used for the calculation of deflections of the longitudinal beams of certain simply-supported deck structures acting as a one-way slab are given in Tables E-3 and E-17 of Reference (2) for a concentrated load applied at the center. These are plotted in terms of the parameter β in Fig. 8.3.1 for the loaded, first and second adjacent beams. From these data the coefficients, applicable to the various specimens tested, were obtained and used to calculate the theoretical deflections of the longitudinal beams.

These computed deflections, together with the largest deflections measured in Specimens V-1, V-2 and V-3 when the load was applied over the transverse member at or near the center are summarized in Tables 8.3.1, 8.3.2 and 8.3.3 respectively. In general, the calculated deflections are less than the measured deflections. Why this occurred is not clear since the calculations were made on the assumption of a concentrated load and actually the load was distributed. The calculations for deflection neglected any shear deflection. However, since the shear deflection would be approximately 0.001 in. for a load increment of 10 kips, this reduction was extremely small and would have little effect on the comparison between calculated and measured values.

8.4 Strains in Transverse Beams

In previous flight deck analyses (3), it was found that the maximum moment in a transverse beam could be approximated by the relationship

$$\frac{M_t}{Pb} = 0.115K^{\frac{1}{4}}\left(1 - \frac{r_n^6}{r_o^6}\right)$$

from which

$$\epsilon = \frac{M_t \cdot C \cdot 1000}{30 \cdot I_t}$$

The values of r_n and r_o for these specimens were obtained from Fig. 8.2.1. These values were then used in the above equation to calculate a value for moment in the transverse beam (M_t). This value of moment was then converted to strain for two locations--the extreme bottom fiber of the transverse beam and a point coinciding with the location of the strain gage closest to the bottom fiber. In most cases this second location (providing the largest tensile strain measurement) was within 0.5 in. of the bottom edge of the beam.

These calculated transverse beam strains are shown in Table 8.4.1 for loads of 20, 30, 40 and 50 kips for Specimens V-1, V-2 and V-3. These calculated strains have been compared with the measured transverse beam strains under a load of 30 kips in Figs. 4.5.3.1, 4.5.3.2 and 4.5.3.3.

It is evident, when referring to the figures mentioned above, that there is very good agreement between the calculated and measured strains in the transverse beam for Specimen V-1 (when loaded at position 10) for all values of I_t considered. For Specimens V-2 and V-3 there is fairly good agreement between calculated and measured transverse beam strains for the large values of I_t. However, when I_t is 3.33 or 6.67 in.^{4} in Specimen V-2 or V-3 the calculated strain is greater than the measured value. This method does not seem to predict transverse beam strains accurately in specimens where 2 or 3 relatively flexible transverse beams are clamped across the bottoms of the longitudinal beams. However, this method seems to be quite satisfactory for specimens containing one transverse beam of varying stiffness or several relatively stiff ($I_t \geq \frac{1}{2} I_b$) transverse beams.

IX. SUMMARY

From the work done on this project the following observations are made:

1. The presence of one or more transverse members usually contributed materially to the distribution of the applied load. As a result, specimens with a transverse member developed peak strains and deflections at a much slower rate than did specimens without a transverse. In specimens with a transverse (where I_t is one-fourth of I_b), an increase of about 50 percent in the applied load was necessary for the two types of specimen to develop similar maximum strain in the loaded beam. When equal maximum strains were developed in the loaded beam of each of these types of specimens, the accompanying maximum deflection of the specimen with a transverse member was about 25 percent less than the maximum deflection of the specimen without a transverse. Associated with this reduction in maximum deflection of the loaded beam was an increase in the deflection of adjacent beams of the specimen with a transverse member.

2. For specimens with one transverse member (varying in stiffness from 3.33 to 26.5 in.^{4}) the maximum possible moment in the loaded beam was not greatly affected by a reduction in I_t from 26.5 to 6.67 in.^{4}.

3. The maximum strain developed in the loaded longitudinal beam when two transverses were present at the third points was 5 to 10 percent less than the maximum strain developed under the same load when only one such transverse was located at midspan. Providing three transverses (one at each of the quarter points) reduced the maximum longitudinal beam strain about 15 percent from that obtained under the same load when only one such transverse was located at midspan.

4. When the total transverse beam stiffness (the sum of the stiffnesses of the individual transverse beams) was approximately equal for different specimens,

there was little difference in the maximum elastic strains developed in the loaded or first adjacent beams of the various specimens.

5. In specimens containing transverse members, a pronounced strain gradient was present in the longitudinal beams in the region near the transverse beam. This condition was particularly noticeable in the loaded longitudinal beam of specimens with welded transverse beams.

6. As indicated by the excellent agreement of strains and deflections, the elastic behavior of specimens with clamped or welded transverse beams was essentially the same. This agreement indicated that the difference in fabrication had little influence on the test results and that the technique of clamping transverse beams across the bottoms of the longitudinal beams was a satisfactory method for investigating the effect of different number and stiffnesses of transverse beams on the behavior of this type of specimen.

7. The analysis used for specimens with transverse members gave good agreement with the measured strains but only fair agreement with the measured deflections in the elastic tests of these specimens with one or more transverse members.

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4. Cox, H. L., "Behavior of Plate-Beam Construction Beyond the Elastic Range," University of Illinois Structural Research Series Report No. 60, August 1953.

TABLE 2.1.1 SUMMARY OF ALL SPECIMENS TESTED IN PROGRAM

PHASE	SPECIMEN	H_o	$\frac{b^*}{a}$	LONGITUDINAL BEAMS		TRANSVERSE BEAMS	
				No.	I_b	No.	Location
I	I	91.5	0.2	6	26.5	None	
	II	91.5	0.2	7	26.5	None	
	III	91.5	0.3	6	26.5	None	
	IV	36	0.2	7	10.35	None	
II	V-1	91.5	0.2	7	26.5	1	Clamped at midspan beneath longitudinal beams
	V-2	91.5	0.2	7	26.5	2	One clamped at each of third points of longitudinal beams
	V-3	91.5	0.2	7	26.5	3	One clamped at each of quarter points of longitudinal beams
III	V-F	91.5	0.2	7	26.5	1	Welded at midspan between longitudinal beams
	VI	36	0.2	7	10.35	1	Welded at midspan between longitudinal beams

* All specimens have span length (a) of 60 in.

TABLE 2.5.1 SUMMARY OF TESTS OF SPECIMENS WITH TRANSVERSE MEMBERS

SPECIMEN	TRANSVERSE MEMBER Location	I_t	LOAD POSITION FOR MAXIMUM STRAIN IN BEAM 4
	TRANSVERSE BEAMS CLAMPED ACROSS BOTTOMS OF LONGITUDINAL BEAMS		
V-1	Midspan	26.5	Load position 4, 13 in. from midspan
		19.6	" " 5, 11 " " "
		13.3	" " 5, 11 " " "
		6.67	" " 6, 9 " " "
		3.33	" " 8, 5 " " "
V-2	Third Points	26.5	Load position 10, at midspan
		13.3	" " 10, " "
		6.67	" " 10, " "
		3.33	" " 10, " "
V-3	Quarter Points	13.3	Load position 6A, 7 1/2 in. from midspan
		6.67	" " 6A, " " " " "
		3.33	" " 6A, " " " " "
	TRANSVERSE BEAM WELDED INTERCOSTALLY BETWEEN LONGITUDINAL BEAMS		
V-F	Midspan	6.67	Load position 6, 9 in. from midspan
VI	Midspan	2.60	Load position 4, 13 in. from midspan

TABLE 3.2.1 SUMMARY OF EXTREME FIBER STRAINS MEASURED NEAR MIDSPAN

FOR LONGITUDINAL BEAMS OF SPECIMEN II

	LOADED BEAM			FIRST ADJACENT BEAM			SECOND ADJACENT BEAM		THIRD ADJACENT BEAM
Load, kips	Center	7 in. from Center	15 in. from Center	Center	7 in. from Center	15 in. from Center	Center	15 in. from Center	Center
20	+1110	+940	+570	+160 +170	+150	+110	-30	-10	+20
30	+1630	+1390	+830	+220 +240	+210	+150	-40	-30	-10
40	+2370	+1820	+1090	+300 +310	+280	+200	-60	-40	+10
60	-	+3290	+1220	+810 +790	+740	+520	-100	-80	+10
0	-	+750	-210	+310 +310	+280	+200	-70	-50	+10
80	-	+3290	+1230	+1380 +1360	+1250	+870	-110	-90	+10
0	-	+280	-560	+600 +600	+540	+380	-110	-80	+10
100	-	+3290	+1260	+2280 +1920	+1730	+1200	-70	-70	0
0	-	-110	-770	+1220 +860	+720	+500	-130	-100	+10
120	-	+3540	+1280	+5040 +3730	+4310	+1460	+20	-10	-10
0	-	-150	-910	+3700 +2380	+3070	+540	-100	-80	0

TABLE 3.2.2 SUMMARY OF EXTREME FIBER STRAINS MEASURED NEAR MIDSPAN FOR LONGITUDINAL BEAMS OF SPECIMEN IV

Load, kips	LOADED BEAM			FIRST ADJACENT BEAM			SECOND ADJACENT BEAM		THIRD ADJACENT BEAM	
	Center	7 in. from Center	15 in. from Center	Center	7 in. from Center	15 in. from Center	Center	15 in. from Center	Center	15 in. from Center
18	+1630	+1430	---	+340 +300	---	+180 +210	-50 -80	--- -30	-10	-10
25	+2230	+1570	+870	+460 +430	+200	+130 +290	-60 -60	-40 -40	-10	-10
30	+2470	+1930	+1110	+560 +520	+330	+240 +350	-60 -70	+10 -40	-10	-10
40	---	+1980	+1120	+1050 +1030	+820	+590 +670	-80 -70	+40 -50	-30	-30
0	---	-460	-370	+290 +290	+180	+90 +180	-70 -60	-30 -40	-10	-10
60	---	+2530	+1560	+1900 +1880	+1970	+1510 +1210	+20 +40	+80 +20	-50	-50
0	---	-560	-380	+670 +670	+850	+630 +420	-100 -80	-30 -60	-20	-20
80	---	+2330	+1340	+2780 +3540	+2290	+1670 +1640	+200 +220	+120 +130	-70	-60
0	---	-1100	-870	+1190 +3020	+740	+500 +540	-90 -60	-90 -50	-30	-30
100	---	+2330	+1320	+14430	+2340	+1750	+660	+330 +440	-80	-60
0	---	-1080	-820	--- ---	+670	+540 +440	+150 +190	+200 +110	-70	-50

TABLE 4.2.1 SUMMARY OF EXTREME FIBER STRAINS MEASURED NEAR MIDSPAN FOR

LONGITUDINAL BEAMS OF SPECIMEN V-1, LOAD POSITION 10

Load, Kips	I_t	LOADED BEAM			FIRST ADJACENT BEAM			SECOND ADJACENT BEAM			THIRD ADJACENT BEAM	
		Center	3 in. from Center	7 in. from Center	Center	3 in. from Center	7 in. from Center	Center	3 in. from Center	7 in. from Center	Center	3 in. from Center
						LOAD POSITION 10						
30	26.5	840	910	670	370	360	330	170	190	170	50	50
					350	350	320	220	200	190	60	50
	19.6	910	950	740	370	380	350	160	170	160	40	40
					380	370	340	210	200	190	30	30
	13.3	930	960	730	370	380	340	130	150	140	10	10
					360	370	340	200	180	160	--	0
	6.67	1020	1040	800	400	400	360	120	150	140	-20	-20
					390	390	350	160	160	140	-30	-20
	3.33	1110	1110	870	400	400	370	100	110	100	-20	-30
					410	400	360	120	120	110	--	-20
40	26.5	1080	1170	870	490	480	430	230	250	230	70	70
					460	460	410	280	260	240	80	60
	19.6	1120	1220	940	490	490	460	220	220	210	50	50
					490	480	440	270	250	240	40	40
	13.3	1160	1240	940	500	500	450	170	180	170	0	0
					480	480	430	250	230	210	--	--
	6.67	1270	1330	1020	510	510	460	160	190	180	-40	-30
					510	510	460	200	190	170	-30	-20
	3.33	1490	1460	1160	520	-520	---	120	140	---	-40	-40
					540	540	---	150	160	---	--	-10

TABLE 4.2.2 SUMMARY OF EXTREME FIBER STRAIN MEASURED NEAR MIDSPAN FOR

LONGITUDINAL BEAMS OF SPECIMEN V-1, LOAD POSITION VARIED

Load, kips	I_t	LOADED BEAM Center	LOADED BEAM 3 in. from Center	LOADED BEAM 7 in. from Center	LOADED BEAM Max.	FIRST ADJACENT BEAM Center	FIRST ADJACENT BEAM 3 in. from Center	FIRST ADJACENT BEAM 7 in. from Center	SECOND ADJACENT BEAM Center	SECOND ADJACENT BEAM 3 in. from Center	SECOND ADJACENT BEAM 7 in. from Center	THIRD ADJACENT BEAM Center	THIRD ADJACENT BEAM 3 in. from Center
					LOAD POSITION VARIED								
30	26.5	330	520	790	1080(4)*	270	280	270	130	130	130	40	20
						260	270	250	160	150	130	40	40
	19.6	450	680	960	1090(5)	280	310	300	130	120	110	30	30
						280	300	270	160	160	150	20	20
	13.3	420	650	930	1060(5)	260	280	260	60	80	70	-30	-30
						250	260	230	120	100	90	--	-60
	6.67	630	900	1120	1190(6)	340	360	340	110	130	110	-20	-10
						340	350	320	140	130	130	-40	-10
	3.33	970	1170	1170	1240(8)	380	390	360	90	100	100	-30	-30
						400	400	350	120	130	120	--	-10
40	26.5	410	670	1030	1400(4)	340	370	350	170	170	160	50	30
						330	340	320	200	200	170	40	50
	19.6	560	880	1240	1420(5)	370	390	370	150	160	140	30	30
						360	380	350	200	190	170	0	10
	13.3	590	910	1290	1470(5)	390	420	410	140	160	140	10	10
						390	390	370	210	200	180	--	0
	6.67	790	1140	1410	1470(5,6)	430	460	420	150	150	140	-40	-40
						420	440	410	160	170	140	-40	-40
	3.33	1290	1540	1540	1620(8)	480	520	---	120	120	---	-30	-40
						520	520	---	160	180	---	--	-20

*() Gage position of measured strain

TABLE 4.2.3 SUMMARY OF DEFLECTIONS MEASURED NEAR MIDSPAN FOR

LONGITUDINAL BEAMS OF SPECIMEN V-1

Load, kips	I_t	LOADED BEAM Center	LOADED BEAM 6 in. from Center	LOADED BEAM 16 in. from Center	FIRST ADJACENT BEAM Center	SECOND ADJACENT BEAM Center
			LOAD POSITION 10			
30	26.5	.063	.073	.053	.043	.018
					.047	.024
	19.6	.068	.077	.055	.040	.028
					.039	.020
	13.3	.071	.081	.056	.043	.021
					.042	.024
	6.67	.079	.085	.060	.044	.016
					.043	.017
	3.33	.093	.098	.069	.044	.013
					.044	.014
40	26.5	.082	.091	.068	.056	.023
					.057	.033
	19.6	.089	.100	.070	.067	.030
					.066	.037
	13.3	.092	.104	.072	.057	.024
					.054	.030
	6.67	.104	.110	.078	.054	.022
					.054	.023
	3.33	.122	.127	.089	.057	.017
					.056	.019
			LOAD POSITION VARIED			
30	26.5	.048	.070	.066	.023	.007
					.035	.013
	19.6	.055	.076	.068	.031	.014
					.032	.015
	13.3	.058	.080	.069	.023	.014
					.037	.017
	6.67	.071	.090	.074	.038	.014
					.008	.044
	3.33	.090	.102	.076	.042	.007
					.042	.015
40	26.5	.062	.090	.086	.031	.009
					.044	.017
	19.6	.071	.098	.086	.041	.019
					.044	.020
	13.3	.076	.102	.089	.042	.020
					.044	.023
	6.67	.094	.116	.095	.049	.018
					.045	.025
	3.33	.120	.135	.100	---	---
					---	---

TABLE 4.3.1 SUMMARY OF EXTREME FIBER STRAINS MEASURED NEAR MIDSPAN FOR

LONGITUDINAL BEAMS OF SPECIMEN V-2, LOAD POSITION 5A

Load, kips	I_t	LOADED BEAM			FIRST ADJACENT BEAM			SECOND ADJACENT BEAM		
		Center	3 in. from Center	7 in. from Center	Center	3 in. from Center	7 in. from Center	Center	3 in. from Center	7 in. from Center
					LOAD POSITION 5A					
30	26.5	440	580	760	250	260	270	150	160	150
					240	260	270	190	200	200
	13.3	540	690	860	280	270	280	150	150	140
					---	330	320	190	190	180
	6.67	570	720	890	310	330	330	140	230	110
					---	330	340	160	160	150
	3.33	680	830	1010	350	370	360	110	120	100
					350	370	380	150	150	150
40	26.5	600	790	1020	340	360	380	210	220	210
					330	350	370	250	260	260
	13.3	700	900	1130	370	380	390	200	200	190
					---	420	420	240	250	240
	6.67	760	950	1180	420	450	450	180	180	160
					---	450	460	210	210	200
	3.33	890	1090	1330	460	480	480	150	150	140
					450	480	500	180	190	180
50	26.5	---	---	---	---	---	---	---	---	---
					---	---	---	---	---	---
	13.3	890	1140	1470	480	490	500	250	260	250
					---	520	510	300	310	300
	6.67	950	1180	1460	530	560	560	220	230	200
					---	550	560	250	260	240
	3.33	---	---	---	---	---	---	---	---	---
					---	---	---	---	---	---

TABLE 4.3.2 SUMMARY OF EXTREME FIBER STRAINS MEASURED NEAR MIDSPAN FOR LONGITUDINAL BEAMS OF SPECIMEN V-2, LOAD POSITION 10

Load, kips	I_t	LOADED BEAM Center	LOADED BEAM 3 in. from Center	LOADED BEAM 7 in. from Center	FIRST ADJACENT BEAM Center	FIRST ADJACENT BEAM 3 in. from Center	FIRST ADJACENT BEAM 7 in. from Center	SECOND ADJACENT BEAM Center	SECOND ADJACENT BEAM 3 in. from Center	SECOND ADJACENT BEAM 7 in. from Center
					LOAD POSITION 10					
30	26.5	930	860	570	320	310	280	190	170	170
					310	300	290	230	240	180
	13.3	1010	940	660	330	310	300	160	150	140
					---	370	340	210	210	200
	6.67	1060	1000	700	370	360	330	140	150	120
					---	370	340	180	170	170
	3.33	1140	1070	760	400	390	360	130	120	110
					400	400	390	160	160	140
40	26.5	1230	1140	770	410	400	370	250	240	220
					410	410	390	290	290	290
	13.3	1320	1240	860	440	430	400	220	210	190
					---	480	450	270	280	250
	6.67	1400	1320	930	480	480	450	190	200	170
					---	490	460	220	220	220
	3.33	1520	1420	1020	530	520	490	160	160	140
					530	530	520	190	200	190
50	26.5	1540	1430	980	520	510	470	310	290	280
					510	510	480	350	350	350
	13.3	1630	1540	1070	560	540	510	270	260	240
					---	590	550	320	330	300
	6.67	1750	1650	1170	620	600	560	240	250	220
					---	610	580	270	280	260
	3.33	1890	1770	1270	650	640	600	210	200	170
					650	650	640	240	240	220

TABLE 4.3.3 SUMMARY OF DEFLECTIONS MEASURED NEAR MIDSPAN FOR

LONGITUDINAL BEAMS OF SPECIMEN V-2

		LOADED BEAM			FIRST ADJACENT BEAM		SECOND ADJACENT BEAM
Load, kips	I_t	Center	10 in. from Center	16 in. from Center	Center	10 in. from Center	Center
				LOAD POSITION 5A			
30	26.5	----	----	----	----	----	----
					----	----	----
	13.3	.077	.070	.068	.028	.027	.015
					.033	.029	.019
	6.67	.078	.072	.068	.035	.032	.013
					.033	.033	.015
	3.33	.089	.084	.076	.053	.037	.014
					.038	.034	.014
40	26.5	.075	.071	.065	.035	.036	.024
					.037	.034	.026
	13.3	.096	.087	.085	.034	.038	.021
					.044	.038	.025
	6.67	.099	.092	.085	.052	.043	.019
					.045	.043	.021
	3.33	.113	.105	.096	.061	.037	.017
					.048	.044	.018
50	26.5	.093	.088	.081	----	----	----
					----	----	----
	13.3	.116	.105	.102	.049	.048	.026
					.053	.048	.032
	6.67	.120	.111	.103	.057	.051	.025
					.060	.053	.028
	3.33	----	----	----	.069	.047	.020
					.058	.054	.022
				LOAD POSITION 10			
30	26.5	.079	.057	.053	.043	.028	.020
					.032	.019	.024
	13.3	.094	.068	.062	.029	.029	.014
					.033	.031	.018
	6.67	.096	.073	.062	.037	.032	.016
					.038	.036	.018
	3.33	.105	.081	.067	.052	.036	.013
					.040	.034	.015
40	26.5	.101	.071	.065	.058	.050	.035
					.051	.038	.039
	13.3	.116	.084	.076	.040	.040	.019
					.042	.042	.020
	6.67	.123	.092	.078	.048	.042	.021
					.049	.047	.022
	3.33	.134	.103	.086	.067	.048	.017
					.052	.048	.019
50	26.5	.123	.084	.076	.064	.055	.040
					.057	.047	.047
	13.3	.140	.101	.090	.048	.050	.023
					.051	.051	.026
	6.67	.149	.111	.093	.072	.057	.024
					.063	.061	.028
	3.33	.162	.125	.103	.074	.059	.024
					.060	.060	.015

TABLE 4.4.1 SUMMARY OF EXTREME FIBER STRAINS MEASURED NEAR **MIDSPAN FOR**

LONGITUDINAL BEAMS OF SPECIMEN V-3, LOAD POSITION 10

Load, kips	I_t	LOADED BEAM Center	LOADED BEAM 3 in. from Center	LOADED BEAM 7 in. from Center	FIRST ADJACENT BEAM Center	FIRST ADJACENT BEAM 3 in. from Center	FIRST ADJACENT BEAM 7 in. from Center	SECOND ADJACENT BEAM Center	SECOND ADJACENT BEAM 3in. from Center	SECOND ADJACENT BEAM 7 in. from Center	THIRD ADJACENT BEAM Center	THIRD ADJACENT BEAM 3 in. from Center
						LOAD POSITION 10						
30	13.3	730	810	550	160	250	220	120	140	130	80	90
					330	330	310	230	230	220	30	20
	6.67	890	920	670	370	360	340	120	140	130	10	10
					360	360	330	200	200	200	10	10
	3.33	990	990	720	390	370	350	130	140	140	10	0
					400	390	370	170	180	180	--	-10
40	13.3	980	1080	750	270	360	320	190	200	190	90	100
					450	440	410	290	290	280	40	40
	6.67	1160	1220	890	490	480	450	180	190	190	10	20
					480	490	450	250	260	250	0	20
	3.33	1300	1310	960	520	500	470	170	190	180	0	0
					530	520	480	220	220	220	--	-10
50	13.3	1230	1360	960	490	470	430	250	260	240	300	120
					570	550	530	360	360	350	60	60
	6.67	1420	1510	1100	610	600	560	230	240	240	20	20
					610	600	560	310	310	300	10	20
	3.33	---	---	---	---	---	---	---	---	---	--	-
					---	---	---	---	---	---	--	--

TABLE 4.4.2 SUMMARY OF EXTREME FIBER STRAINS MEASURED NEAR MIDSPAN FOR

LONGITUDINAL BEAMS OF SPECIMEN V-3, LOAD POSITION 6A

Load, kips	I_t	LOADED BEAM Center	LOADED BEAM 3 in. from Center	LOADED BEAM 7 in. from Center	LOADED BEAM Max.	FIRST ADJACENT BEAM Center	FIRST ADJACENT BEAM 3 in. from Center	FIRST ADJACENT BEAM 7 in. from Center	SECOND ADJACENT BEAM Center	SECOND ADJACENT BEAM 3 in. from Center	SECOND ADJACENT BEAM 7 in. from Center	THIRD ADJACENT BEAM Center	THIRD ADJACENT BEAM 3 in. from Center
						LOAD POSITION 6A							
30	13.3	480	750	830	850(8)*	250	---	---	150	---	---	100	---
						330	---	---	220	---	---	---	---
	6.67	610	860	950	970(8)	320	---	340	---	---	130	---	---
						---	---	350	---	---	190	---	---
	3.33	680	900	1000	1020(8)	330	350	340	120	120	130	0	0
						340	360	370	150	160	160	---	-10
40	13.3	630	1110	1110	1140(8)	350	350	370	190	210	210	110	120
						440	460	450	280	300	310	60	60
	6.67	800	1140	1260	1290(8)	440	460	460	180	190	190	30	30
						450	480	470	240	250	250	20	20
	3.33	920	1210	1350	1380(8)	460	480	480	160	170	180	0	0
						460	490	490	200	210	210	--	-10
50	13.3	770	1260	1400	1440(8)	450	---	---	250	---	---	120	---
						540	---	---	340	---	---	---	---
	6.67	980	1420	1560	1620(8)	550	570	570	220	230	230	30	30
						560	590	580	290	300	300	20	20
	3.33	1110	1490	1660	1710(8)	570	590	580	190	210	220	-10	-10
						570	600	600	230	240	240	--	-30

*() Gage position of measured strain

TABLE 4.4.3 SUMMARY OF DEFLECTIONS MEASURED NEAR MIDSPAN

FOR LONGITUDINAL BEAMS OF SPECIMEN V-3

		LOADED BEAM			FIRST ADJACENT BEAM		SECOND ADJACENT BEAM	
Load, kips	I_t	Center	6 in. from Center	16 in. from Center	Center	16 in. from Center	Center	16 in. from Center
				LOAD POSITION 10				
30	13.3	.077	.085	.064	.030	.027	.019	.013
					.036	.027	.026	.017
	6.67	.081	.083	.059	.041	.029	.018	.014
					.042	.030	.023	.023
	3.33	.092	.095	.060	.034	.030	.017	.013
					.036	.029	.014	.010
40	13.3	.095	.106	.077	.042	.032	.025	.018
					.051	.036	.034	.024
	6.67	.104	.105	.073	.042	.038	.022	.017
					.050	.039	.024	.024
	3.33	.117	.118	.085	.045	.040	.017	.016
					.049	.038	.022	.015
50	13.3	.114	.127	.089	.052	.040	.031	.022
					.063	.045	.040	.029
	6.67	.126	.127	.087	.060	.047	.026	.021
					.063	.045	.032	.032
	3.33	---	---	---	---	---	---	---
					---	---	---	---
				LOAD POSITION 6A				
30	13.3	.069	.085	.068	---		---	
					---		---	
	6.67	.075	.085	.065	---		---	
					---		---	
	3.33	.084	.094	.074	.023		.023	
					.049		.031	
40	13.3	.086	.106	.082	.040		.022	
					.047		.035	
	6.67	.095	.108	.081	.049		.021	
					.049		.026	
	3.33	.106	.120	.091	.041		.033	
					.063		.036	
50	13.3	.102	.127	.096	---		---	
					---		---	
	6.67	.116	.132	.098	.062		.028	
					.065		---	
	3.33	.128	.144	.109	.055		.037	
					.075		.041	

TABLE 4.5.3.1 SUMMARY OF STRAINS MEASURED AT CENTER OF TRANSVERSE BEAMS FOR SPECIMEN V-1

		LOAD POSITION 10 STRAIN GAGE NO.				LOAD POSITION VARIED STRAIN GAGE NO.			
Load, kips	I_t	91	92	93	94	91	92	93	94
20	26.5	720	540	300	210	540	400	230	170
	19.6	---	710	390	290	---	600	330	260
	13.3	---	---	540	410	---	---	460	350
	6.67	---	---	970	770	---	---	950	700
	3.33	---	---	---	1380	---	---	---	1340
30	26.5	1070	800	450	320	800	600	340	250
	19.6	---	1070	590	450	---	880	490	380
	13.3	---	---	820	620	---	---	640	480
	6.67	---	---	1520	1170	---	---	1390	1040
	3.33	---	---	---	2060	---	---	---	1990
40	26.5	1420	1070	580	410	1040	780	440	330
	19.6	---	1400	780	590	---	1250	620	480
	13.3	---	---	1050	790	---	---	870	680
	6.67	---	---	2010	1560	---	---	1760	1380
	3.33	---	---	---	---	---	---	---	---

TABLE 4.5.3.2 SUMMARY OF STRAINS MEASURED AT CENTER

OF TRANSVERSE BEAMS FOR SPECIMEN V-2

Load, Kips	I_t	LOAD POSITION 10 STRAIN GAGE NO. 101	LOAD POSITION 10 STRAIN GAGE NO. 102	LOAD POSITION 5A STRAIN GAGE NO. 101	LOAD POSITION 5A STRAIN GAGE NO. 102
20	26.5	400	460	490	250
	13.3	630	680	730	440
	6.67	760	810	830	510
	3.33	870	850	1030	590
30	26.5	600	650	710	360
	13.3	910	980	1070	650
	6.67	1100	1170	1210	740
	3.33	1300	1250	1500	850
40	26.5	750	810	930	470
	13.3	1160	1250	1360	820
	6.67	1410	1500	1600	950
	3.33	1700	1630	1940	1090
50	26.5	940	990	---	---
	13.3	1430	1530	1670	1010
	6.67	1730	1830	1980	1150
	3.33	2220	2020	---	---

TABLE 4.5.3.3 SUMMARY OF STRAINS MEASURED AT CENTER OF TRANSVERSE BEAM FOR SPECIMEN V-3

Load, kips	I_t	LOAD POSITION 10 STRAIN GAGE NO.			LOAD POSITION 6A STRAIN GAGE NO.		
		103	104	105	103	104	105
20	13.3	540	740	450	620	670	340
	6.67	520	770	520	670	680	390
	3.33	620	940	580	770	810	430
30	13.3	740	1100	640	890	950	470
	6.67	750	1160	750	980	1030	570
	3.33	890	1400	830	1110	1200	620
40	13.3	890	1390	770	1100	1220	570
	6.67	960	1520	950	1250	1330	710
	3.33	1110	1800	1070	1420	1560	790
50	13.3	1050	1710	970	1320	1490	690
	6.67	1160	1870	1160	1520	1630	780
	3.33	---	---	---	1730	1930	950

TABLE 4.5.4.1 SUMMARY OF PLATE STRAINS MEASURED UNDER 40-KIP LOAD

FOR SPECIMENS V-1, V-2, V-3, V-F and VI

(a) MAXIMUM STRAIN

SPEC.	I_t	LOAD POS.	TOP OF PLATE Positive	TOP OF PLATE Negative	BOTTOM OF PLATE Positive	BOTTOM OF PLATE Negative	Load Pos.	TOP OF PLATE Positive	TOP OF PLATE Negative	BOTTOM OF PLATE Positive	BOTTOM OF PLATE Negative
V-1	26.5	10	+180(74)*	-320(80)	+510(56)	-220(54,55)	4	+170(86)	-310(83)	+250(60)	-160(51,53)
	19.9	10	+180(74)	-350(80)	+540(56)	-240(55)	5	+130(86)	-380(81)	+240(58)	-190(53)
	13.3	10	+170(74)	-350(80)	+520(56)	-260(55)	5	+130(86)	-390(81)	+250(58)	-190(53)
	6.67	10	+200(74)	-390(80)	+590(56)	-250(55)	6	+130(86,87)	-400(81)	+340(56)	-260(53)
	3.33	10	+200(76)	-360(77)	+520(56)	-320(55)	8	+200(76)	-480(79)	+240(58)	-640(56)
V-2	26.5	5A	+70(74)	-330(81)	+210(58)	-180(55)	10	+140(74)	-330(79)	+490(56)	-190(55)
	13.3	5A	+90(74)	-330(81)	+220(56)	-190(55)	10	+140(74)	-350(79)	+470(56)	-240(55)
	6.67	5A	+90(74)	-360(81)	+220(56,58)	-200(55)	10	+150(74)	-400(79)	+530(56)	-250(55)
	3.33	5A	+100(76)	-360(81)	+280(56)	-200(55)	10	+170(74)	-420(79)	+610(56)	-240(55)
V-3	13.3	10	+130(73)	-300(76)	+500(56)	-230(55)	6A	+90(74)	-310(81)	+310(56)	-210(55)
	6.67	10	+140(74)	-340(77,79)	+540(56)	-300(57)	6A	+100(74,76)	-330(81)	+300(56)	-220(55)
	3.33	10	+130(76)	-360(79)	+570(56)	-240(55)	6A	+110(74,76)	-370(81)	+300(56)	-240(55)
V-F	6.67	10	+180(76)	-400(80)	+540(56)	-240(55)	6	+160(76)	-390(81)	+270(56)	-230(55)
VI	2.60	10	+260(67)	-460(64.65)	+450(42)	-360(46)	4	+230(67)	-450(58)	+320(50)	-280(46)

*() Gage position of measured strain

TABLE 4.5.4.1 (Continued)

(b) SECOND LARGEST STRAIN

SPEC.	I_t	LOAD POS.	TOP OF PLATE Positive	TOP OF PLATE Negative	BOTTOM OF PLATE Positive	BOTTOM OF PLATE Negative	Load Pos.	TOP OF PLATE Positive	TOP OF PLATE Negative	BOTTOM OF PLATE Positive	BOTTOM OF PLATE Negative
V-1	26.5	10	+140(76)*	-300(77)	+140(64)	-180(57)	4	+90(74)	-290(81)	+220(58)	-120(51,53)
	19.6	10	+150(76)	-320(77)	+220(54)	-180(57)	5	+110(74)	-290(83)	+21[illegible]	-170(51,55)
	13.3	10	+150(76)	-330(77)	+220(54)	-200(57)	6	+110(74)	-250(83)	+220(56)	-180(51)
	6.67	10	+180(76)	-340(77)	+240(54)	-200(57)	6	+120(76)	-280(73)	+300(58)	-230(55)
	3.33	10	+170(74)	-310(73)	+220(54)	-240(57)	8	+180(74)	-400(77,80)	+220(54)	-180(57)
V-2	26.5	5A	+60(76,86)	-210(83)	+190(56)	-160(63)	10	+110(76)	-300(77)	+320(54)	-180(57)
	13.3	5A	+80(76)	-220(83)	+210(58)	-160(53)	10	+110(76)	-330(77)	+200(54)	-180(57)
	6.67	5A	+70(76)	-250(83)	+150(60)	-180(53)	10	+130(76)	-360(77)	+220(54)	-200(57)
	3.33	5A	+90(74)	-240(83)	+230(58)	-170(53)	10	+160(76)	-380(77)	+270(54)	-210(57)
V-3	13.3	10	+110(75)	-280(78)	+210(54)	-170(57)	6A	+80(76)	-190(77)	+200(58)	-160(59)
	6.67	10	+130(76)	-270(73,75)	+220(54)	-240(55)	6A	+40(86)	-220(73,75)	+200(58)	-210(57)
	3.33	10	+30(72)	-350(77)	+240(54)	-190(57)	6A	+70(88)	-240(77)	+210(58)	-190(59)
V-F	6.67	10	+140(70)	-350(73)	+190(54)	-200(57)	6	+140(70)	-290(73)	+240(58)	-220(51,53)
VI	2.60	10	-----	-380(62)	+340(53)	-240(45)	4	+30(37)	-430(60)	+310(42)	-220(45)

*() Gage position of measured strain

TABLE 5.2.1 SUMMARY OF EXTREME FIBER STRAINS MEASURED NEAR

MIDSPAN FOR LONGITUDINAL BEAMS OF SPECIMEN V-F

Load, kips	LOADED BEAM				FIRST ADJACENT BEAM			SECOND ADJACENT BEAM		
	Center	3 in. from Center	7 in. from Center	Max.	Center	3 in. from Center	7 in. from Center	Center	3 in. from Center	7 in. from Center
					LOAD POSITION 10					
20	210	620	610	620(9)*	380	270	240	150	80	80
					370	280	250	140	80	80
40	580	1250	1230	1250(9)	810	530	470	300	150	160
					760	560	500	300	160	160
60	1380	2000	1990	2000(9)	1280	780	710	460	210	220
					1180	820	740	460	230	230
					LOAD POSITION 6					
20	30	570	690	750(5,6)	320	240	230	130	60	70
					310	240	230	120	80	70
40	140	1130	1370	1480(5,6)	660	480	460	260	130	140
					630	490	460	250	150	130
60	470	1700	2630	2630(8)	1000	720	680	400	200	200
					940	430	680	380	220	190
80	590	2010	8460	8740(5)	1630	1100	1040	590	280	280
					1460	1100	1040	570	310	270
0	450	-100	5910	6200(5)	230	150	250	70	---	---
					---	---	---	---	---	---
100	600	2530	13120	---	3220	1690	1570	840	350	350
					2680	1640	1555	810	390	380
0	-510	20	9650	---	1630	490	430	180	20	10
					1190	430	420	180	30	50
120	-20	4220	15980	---	6820	2300	2050	1150	460	450
					4500	2090	1950	1070	500	530
0	-1060	890	11690	---	4870	810	620	340	50	40
					1700	630	580	290	60	120

*() Gage position of measured strain

TABLE 5.2.2 SUMMARY OF DEFLECTIONS MEASURED NEAR MIDSPAN

FOR LONGITUDINAL BEAMS OF SPECIMEN V-F

Load, kips	LOADED BEAM Center	LOADED BEAM 6 in. from Center	LOADED BEAM 16 in. from Center	FIRST ADJACENT BEAM Center	FIRST ADJACENT BEAM 6 in. from Center	FIRST ADJACENT BEAM 16 in. from Center	SECOND ADJACENT BEAM Center	SECOND ADJACENT BEAM 16 in. from Center
				LOAD POSITION 10				
20	.060	.056	.040					
40	.115	.110	.076					
60	.173	.165	.115					
				LOAD POSITION 6				
20	.048	.051	.042	.021	.020	.018	.008	.004
				.022	.021	.013	.008	.005
40	.100	.111	.088	.048	.045	.036	.018	.010
				.049	.046	.029	.017	.010
60	.148	.165	.129	.080	.072	.053	.026	.015
				.072	.068	.044	.025	.014
80	.230	.286	.218	.115	.105	.079	.044	.027
				.110	.105	.073	.041	.026
0	.042	.080	.048	---	---	---	---	---
				---	---	---	---	---
100	.405	.536	.412	.167	.154	.116	.056	.034
				.160	.156	.110	.052	.036
0	.173	.279	.203	.050	.043	.037	.007	.008
				.036	.039	.032	.008	.011

TABLE 5.3.1 SUMMARY OF EXTREME FIBER STRAINS MEASURED NEAR

MIDSPAN FOR LONGITUDINAL BEAMS OF SPECIMEN VI

Load, kips	LOADED BEAM Center	3 in. from Center	7 in. from Center	Max.	FIRST ADJACENT BEAM Center	3 in. from Center	7 in. from Center	SECOND ADJACENT BEAM Center	3 in. from Center	7 in. from Center
					LOAD POSITION 10					
20	140	930	790	930(9)*	590 670	420	390	250 300	160	150
30	370	1440	1210	1440(9)	940 1030	640	600	390 450	230	230
					LOAD POSITION 4					
20	-190	550	900	1180(4)	410 470	320	320	180 240	120	110
30	-270	820	1340	1790(4)	650 700	500	500	290 350	180	170
40	-470	1050	1650	2780(3)	890 950	680	680	400 460	250	220
50	-1840	1000	1550	8350(3)	1370 1440	990	1010	610 680	---	---
60	-3520	800	1690	----	2070 2050	1300	1390	850 930	410	380
0	-3060	-720	-770	----	820 730	310	390	230 250	---	---
80	-6050	960	2000	----	3610 3350	4920	1940	1160 1380	520	530
0	-5580	-880	-930	----	2030 1720	3720	570	340 470	20	50
100	-7000	1250	2140	----	4240 3670	11690	1840	1540 1670	710	780
120	-7060	1870	4820	----	4040 3490	----	3390	1840 2300	990	1110
0	-6490	-430	870	----	1820 1350	----	1530	710 1110	220	350

*() Gage position of measured strain

TABLE 5.3.2 SUMMARY OF DEFLECTIONS MEASURED NEAR **MIDSPAN**

FOR LONGITUDINAL BEAMS OF SPECIMEN VI

Load, kips	LOADED BEAM Center	LOADED BEAM 6 in. from Center	LOADED BEAM 16 in. from Center	FIRST ADJACENT BEAM Center	FIRST ADJACENT BEAM 6 in. from Center	FIRST ADJACENT BEAM 16 in. from Center	SECOND ADJACENT BEAM Center	SECOND ADJACENT BEAM 16 in. from Center
				LOAD POSITION 10				
20	.125	.121	.086	.063	---	---	.036	---
				.071	---	---	.035	---
30	.185	.179	.127	.096	---	---	.049	---
				.102	---	---	.049	---
				LOAD POSITION 4				
20	.100	.111	.102	.045	---	---	.025	---
				.051	---	---	.023	---
30	.145	.162	.149	.069	.068	.048	.028	.018
				.079	.076	.053	.032	.020
40	.193	.211	.200	.095	.095	.068	.039	.035
				.102	.086	.068	.042	.027
50	.275	.318	.318	---	---	---	---	---
				---	---	---	---	---
60	.374	.457	.478	.188	.190	.139	.071	.043
				.197	.176	.145	.072	.047
0	.109	.160	.202	.047	.049	.036	.008	---
				.048	.022	.040	.007	---
80	.591	.749	.792	.300	.305	.225	.103	.066
				.316	.264	.224	.104	.070
0	.242	.358	.425	.108	.112	.080	.014	.007
				.111	.094	.082	.014	.010

TABLE 6.1.1 COMPARISON OF LONGITUDINAL BEAM STRAINS MEASURED

IN SPECIMENS V-1 and V-F UNDER 40-KIP LOAD

SPECIMEN	STRAIN AT MIDSPAN OF LONGITUDINAL BEAM							STRAIN 3 in. FROM MIDSPAN OF LONGITUDINAL BEAM						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
							LOAD POSITION 10							
V-1	-40	160	510	1270	510	200	-30	-30	190	510	1330	510	190	-20
V-F	-30	300	81C	580	760	300	-20	-10	150	530	1250	560	160	-10
							LOAD POSITION 6							
V-1	-40	150	430	790	420	160	-40	-40	150	460	1140	440	170	-40
V-F	-30	260	660	130	630	250	-10	-10	130	480	1130	490	150	0

TABLE 7.1.1 COMPARISON OF LONGITUDINAL BEAM STRAINS MEASURED IN SPECIMENS II, V-1 AND V-F UNDER 40-KIP LOAD

SPECIMEN	TRANSVERSE	LOAD POSITION	LOADED BEAM			FIRST ADJACENT BEAM		SECOND ADJACENT BEAM	
			Center	3 in. from Center	Maximum	Center	3 in. from Center	Center	3 in. from Center
II	None	10	2370	---	2370	300	---	-20	---
V-1	Clamped	10	1270	1330	1330	510	510	180	190
	(I_t = 6.67 in.^{4})	6	790	1140	1470	420	450	160	160
V-F	Welded	10	580	1250	1250	780	540	300	160
	(I_t = 6.67 in.^{4})	6	140	1130	1480	640	480	260	140

TABLE 7.1.2 COMPARISON OF LONGITUDINAL BEAM STRAINS MEASURED IN SPECIMENS IV AND VI UNDER 30-KIP LOAD

SPECIMEN	TRANSVERSE	LOAD POSITION	LOADED BEAM			FIRST ADJACENT BEAM		SECOND ADJACENT BEAM	
			Center	3 in. from Center	Maximum	Center	3 in. from Center	Center	3 in. from Center
IV	None	10	2470	---	2470	540	---	-60	---
VI	Welded	10	370	1440	1440	990	640	420	230
	(I_t = 2.60 in.^{4})	4	-270	820	1790	680	500	320	180

TABLE 7.2.1 COMPARISON OF DEFLECTIONS OF LONGITUDINAL BEAMS MEASURED

IN SPECIMENS II, V-1 AND V-F UNDER 40-KIP LOAD

SPECIMEN	TRANSVERSE	LOAD POSITION	LOADED BEAM Center	LOADED BEAM 6 in. from Center	LOADED BEAM 16 in. from Center	FIRST ADJACENT BEAM Center	FIRST ADJACENT BEAM 6 in. from Center	FIRST ADJACENT BEAM 16 in. from Center	SECOND ADJACENT BEAM Center	SECOND ADJACENT BEAM 16 in. from Center
II	None	10	.215	.200	.142	.048	.036	.025	.002	0
V-1	Clamped	10	.104	.110	.078	.054	---	---	.022	---
	(I_t = 6.67 in.^{4})	6	.094	.116	.095	.047	---	---	.022	---
V-F	Welded	10	.115	.110	.076	---	---	---	---	---
	(I_t = 6.67 in.^{4})	6	.100	.111	.088	.048	.046	.032	.018	.010

TABLE 7.2.2 COMPARISON OF DEFLECTIONS OF LONGITUDINAL BEAMS

MEASURED IN SPECIMEN IV AND VI UNDER 30-KIP LOAD

SPECIMEN	TRANSVERSE	LOAD POSITION	LOADED BEAM Center	LOADED BEAM 6 in. from Center	LOADED BEAM 6 in. from Center	FIRST ADJACENT BEAM Center	FIRST ADJACENT BEAM 6 in. from Center	FIRST ADJACENT BEAM 16 in. from Center	SECOND ADJACENT BEAM Center	SECOND ADJACENT BEAM 16 in. from Center
IV	None	10	.291	.270	.156	.096	.089	.062	.002	---
VI	Welded	10	.185	.179	.127	.099	---	---	.049	---
	(I_t = 2.60 in.^{4})	5	.145	.162	.149	.074	.072	.050	.030	.019

TABLE 8.1.1 CALCULATION OF H_n AND β_n FOR SPECIMENS V-1, V-2, V-3, V-F and VI

SPECIMEN	H_o	I_b	I_t	n	$(n+1)\frac{I_t}{I_b}$	$\frac{1}{H_o}$	$\frac{1}{H_n}$	H_n	$\frac{b^3}{a^3}$	$\frac{H_n b^3}{a^3}$	β_n
V-1	91.5	26.5	26.5	1	2	0.0109	2.0109	0.4973	0.008	0.0040	0.3984
V-2	91.5	26.5	26.5	2	3	0.0109	3.0109	0.3321	0.008	0.0026	0.3708
V-1	91.5	26.5	19.6	1	1.4792	0.0109	1.4901	0.6711	0.008	0.0054	0.4189
V-1	91.5	26.5	13.3	1	1.0038	0.0109	1.0147	0.9855	0.008	0.0079	0.4463
V-2	91.5	26.5	13.3	2	1.5057	0.0109	1.5166	0.6594	0.008	0.0053	0.4176
V-3	91.5	26.5	13.3	3	2.0076	0.0109	2.0185	0.4954	0.008	0.0040	0.4013
V-1	91.5	26.5	6.67	1	0.5034	0.0109	0.5143	1.9444	0.008	0.0156	0.4999
V-2	91.5	26.5	6.67	2	0.7551	0.0109	0.7660	1.3055	0.008	0.0104	0.4672
V-3	91.5	26.5	6.67	3	1.0068	0.0109	1.0177	0.9826	0.008	0.0079	0.4463
V-1	91.5	26.5	3.33	1	0.2514	0.0109	0.2623	3.8124	0.008	0.0305	0.5590
V-2	91.5	26.5	3.33	2	0.3771	0.0109	0.3880	2.5773	0.008	0.0206	0.5236
V-3	91.5	26.5	3.33	3	0.5028	0.0109	0.5137	1.9467	0.008	0.0156	0.4999
V-F	91.5	26.5	6.67	1	0.5034	0.0109	0.5143	1.9444	0.008	0.0156	0.4999
VI	36.0	10.35	2.60	1	0.5024	0.0278	0.5302	1.8861	0.008	0.0151	0.4972

TABLE 8.2.1 COMPARISON OF CALCULATED AND MAXIMUM MEASURED STRAINS IN LONGITUDINAL BEAMS OF SPECIMEN V-1 LOAD POSITION 10

Load, kips	I_t, in.^{4}	LOADED BEAM*		FIRST ADJACENT BEAM		SECOND ADJACENT BEAM	
		Theory	Test	Theory	Test	Theory	Test
20	26.5	580	600	280	230	140	120
	19.6	610	620	290	220	140	110
	13.3	660	630	300	240	120	110
	6.67	740	680	320	250	100	90
	3.33	830	730	320	260	60	60
30	26.5	870	910	420	360	210	200
	19.6	920	950	440	380	210	180
	13.3	990	960	460	360	190	160
	6.67	1110	1040	470	400	140	140
	3.33	1250	1110	470	400	90	110
40	26.5	1160	1170	570	480	290	260
	19.6	1230	1220	580	490	270	240
	13.3	1320	1240	610	490	250	210
	6.67	1480	1330	630	510	190	180
	3.33	1660	1490	630	530	120	140
50	26.5	1450	---	710	---	360	---
	19.6	1540	1490	730	600	340	340
	13.3	1650	1540	760	620	310	270
	6.67	1850	---	790	---	240	---
	3.33	2080	---	790	---	150	---

* Generally measured 3 in. from center

TABLE 8.2.2 COMPARISON OF CALCULATED AND MAXIMUM MEASURED STRAINS IN LONGITUDINAL BEAMS OF SPECIMEN V-2, LOAD POSITION 5A

Load, kips	I_t	LOADED BEAM Theory	LOADED BEAM Test*	FIRST ADJACENT BEAM Theory	FIRST ADJACENT BEAM Test	SECOND ADJACENT BEAM Theory	SECOND ADJACENT BEAM Test
20	26.5	540	500	270	160	150	120
	13.3	610	560	290	170	140	120
	6.67	690	570	310	200	120	100
	3.33	780	660	320	230	80	90
30	26.5	810	---	410	240	220	170
	13.3	920	860	440	280	210	170
	6.67	1040	890	470	310	170	150
	3.33	1160	1010	480	350	120	130
40	26.5	1070	1020	540	340	300	230
	13.3	1230	1130	580	370	270	220
	6.67	1380	1180	630	420	230	200
	3.33	1550	1330	640	460	160	160
50	26.5	1340	---	680	---	370	---
	13.3	1530	1470	730	480	340	280
	6.67	1730	1460	780	530	290	240
	3.33	1940	---	800	---	200	---

* Generally measured 7 in. from center

TABLE 8.2.3 COMPARISON OF CALCULATED AND MAXIMUM MEASURED STRAINS IN LONGITUDINAL BEAMS OF SPECIMEN V-3, LOAD POSITION 10

Load, kips	I_t	LOADED BEAM* Theory	LOADED BEAM* Test	FIRST ADJACENT BEAM Theory	FIRST ADJACENT BEAM Test	SECOND ADJACENT BEAM Theory	SECOND ADJACENT BEAM Test
20	13.3	580	500	280	180	140	120
	6.67	660	590	300	230	120	100
	3.33	740	640	320	260	100	100
30	13.3	870	810	420	300	210	180
	6.67	990	920	460	360	190	160
	3.33	1110	990	470	400	140	150
40	13.3	1160	1080	570	360	290	240
	6.67	1320	1220	610	480	250	220
	3.33	1480	1310	630	520	190	200
50	13.3	1450	1360	710	540	360	300
	6.67	1650	1510	760	610	310	270
	3.33	1850	1640	790	660	240	250

* Generally measured 3 in. from center

TABLE 8.3.1 COMPARISON OF CALCULATED AND MAXIMUM MEASURED DEFLECTIONS

IN LONGITUDINAL BEAMS OF SPECIMEN V-1, LOAD POSITION 10

Load, kips	I_t	LOADED BEAM Theory	LOADED BEAM Test*	FIRST ADJACENT BEAM Theory	FIRST ADJACENT BEAM Test	SECOND ADJACENT BEAM Theory	SECOND ADJACENT BEAM Test
30	26.5	.048	.073	.037	.045	.020	.021
	19.6	.052	.077	.038	.040	.020	.024
	13.3	.057	.081	.040	.043	.018	.023
	6.67	.067	.085	.042	.044	.013	.017
	3.33	.079	.098	.043	.044	.008	.014
40	26.5	.065	.091	.049	.056	.027	.028
	19.6	.070	.100	.051	.066	.026	.034
	13.3	.076	.104	.054	.056	.023	.027
	6.67	.090	.110	.056	.054	.017	.022
	3.33	.105	.127	.057	.056	.011	.018
50	26.5	.081	---	.061	---	.034	---
	19.6	.087	.123	.064	.073	.033	.043
	13.3	.094	.128	.067	.068	.029	.032
	6.67	.112	---	.071	---	.022	---
	3.33	.131	---	.071	---	.014	---

* Measured 6 in. from center

TABLE 8.3.2 COMPARISON OF CALCULATED AND MAXIMUM MEASURED DEFLECTIONS IN

LONGITUDINAL BEAMS OF SPECIMEN V-2, LOAD POSITION 5A

Load, kips	I_t	LOADED BEAM		FIRST ADJACENT BEAM		SECOND ADJACENT BEAM	
		Theory	Test	Theory	Test	Theory	Test
20	26.5	.030	.038	.023	.018	.014	.012
	13.3	.034	.054	.026	.022	.013	.012
	6.67	.041	.054	.028	.020	.011	.008
	3.33	.048	.063	.028	.030	.007	.009
30	26.5	.044	---	.035	---	.021	---
	13.3	.052	.077	.038	.030	.020	.017
	6.67	.061	.078	.042	.034	.016	.014
	3.33	.072	.089	.043	.046	.011	.014
40	26.5	.059	.075	.046	.036	.028	.025
	13.3	.069	.096	.051	.039	.026	.023
	6.67	.082	.099	.055	.048	.021	.020
	3.33	.096	.113	.057	.054	.015	.018
50	26.5	.074	.093	.058	.045	.035	.031
	13.3	.086	.116	.064	.051	.033	.029
	6.67	.102	.120	.069	.059	.026	.027
	3.33	.120	---	.071	---	.018	---

TABLE 8.3.3 COMPARISON OF CALCULATED AND MAXIMUM MEASURED DEFLECTIONS IN

LONGITUDINAL BEAMS OF SPECIMEN V-3, LOAD POSITION 10

Load, kips	I_t	LOADED BEAM		FIRST ADJACENT BEAM		SECOND ADJACENT BEAM	
		Theory	Test*	Theory	Test	Theory	Test
20	13.3	.032	.062	.024	.022	.014	.015
	6.67	.038	.058	.027	.026	.012	.013
	3.33	.045	.066	.028	.023	.009	.013
30	13.3	.048	.085	.037	.034	.020	.023
	6.67	.057	.083	.040	.041	.018	.020
	3.33	.067	.095	.042	.035	.013	.016
40	13.3	.065	.106	.049	.046	.027	.030
	6.67	.076	.105	.054	.046	.023	.023
	3.33	.090	.120	.056	.045	.017	.020
50	13.3	.081	.127	.061	.058	.034	.036
	6.67	.094	.127	.067	.056	.029	.029
	3.33	.112	---	.071	---	.022	---

* Measured 6 in. from center

TABLE 8.4.1 CALCULATED STRAINS AT CENTER OF TRANSVERSE BEAMS FOR SPECIMENS V-1, V-2 AND V-3

Load, kips	I_t	SPECIMEN V-1 Extreme Fiber	SPECIMEN V-1 Nearest Gage*	SPECIMEN V-2 Extreme Fiber	SPECIMEN V-2 Nearest Gage*	SPECIMEN V-3 Extreme Fiber	SPECIMEN V-3 Nearest Gage*
20	26.5	690	640	700	630	---	---
	19.6	780	490	---	---	---	---
	13.3	940	570	940	840	940	850
	6.67	1240	1110	1260	1090	1260	1100
	3.33	1580	1340	1600	1360	1630	1380
30	26.5	1040	960	1050	940	---	---
	19.6	1170	740	---	---	---	---
	13.3	1410	860	1420	1270	1420	1270
	6.67	1860	1670	1880	1640	1890	1650
	3.33	2360	2020	2410	2020	2440	2060
40	26.5	1390	1270	1400	1250	---	---
	19.6	1550	980	---	---	---	---
	13.3	1880	1150	1880	1690	1890	1690
	6.67	2480	2220	2510	2190	2520	2200
	3.33	3150	2680	3210	2720	3260	2760
50	26.5	1740	1590	1750	1560	---	---
	19.6	1940	1230	---	---	---	---
	13.3	2350	1430	2360	2110	2360	2120
	6.67	3100	2780	3140	2740	3150	2740
	3.33	3940	3360	4010	3400	4070	3440

* Location of SR-4 strain gage nearest the extreme bottom fiber

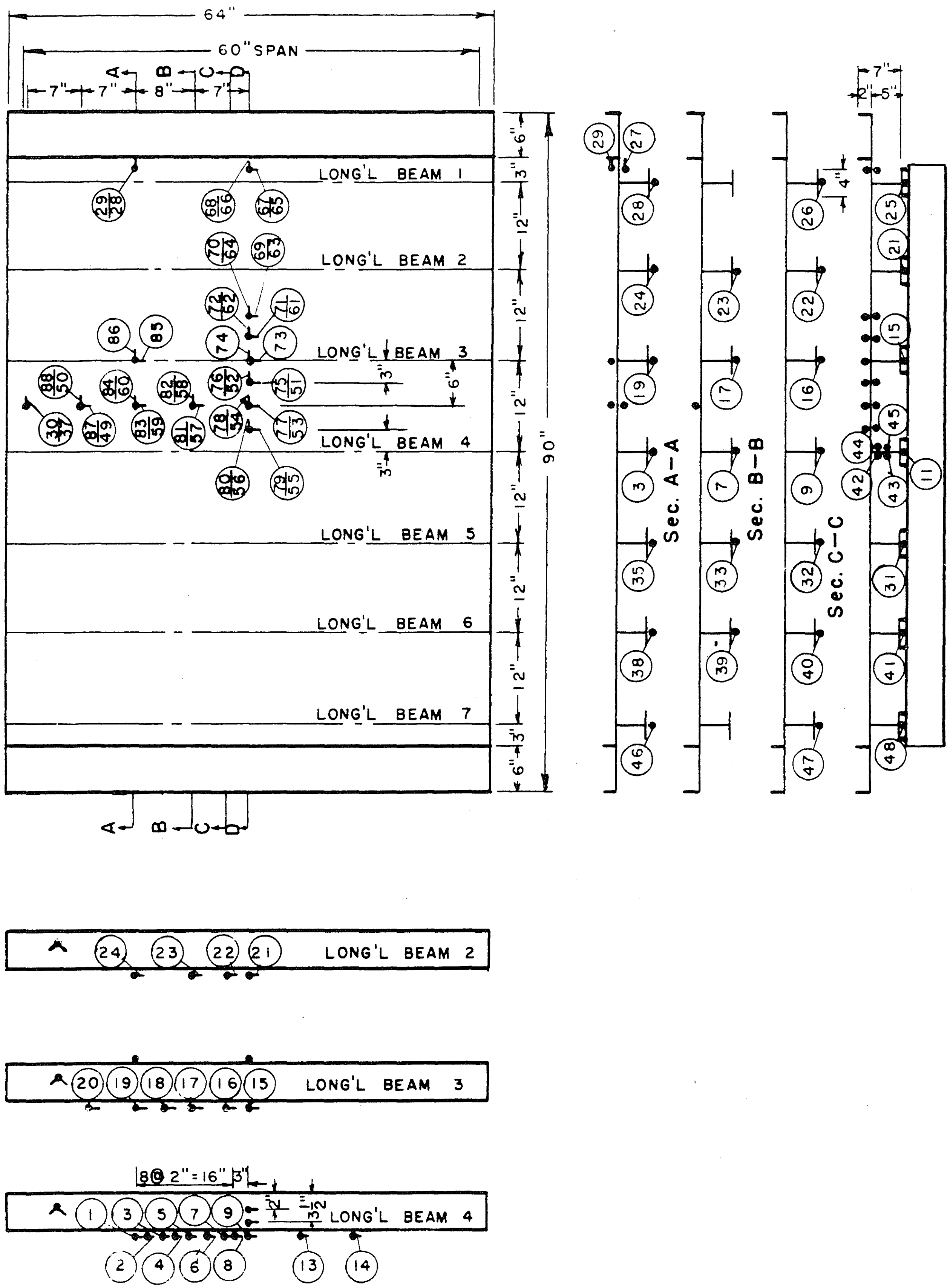

FIG. 2.3.1 DETAILS OF SPECIMENS V-1, V-2 AND V-3

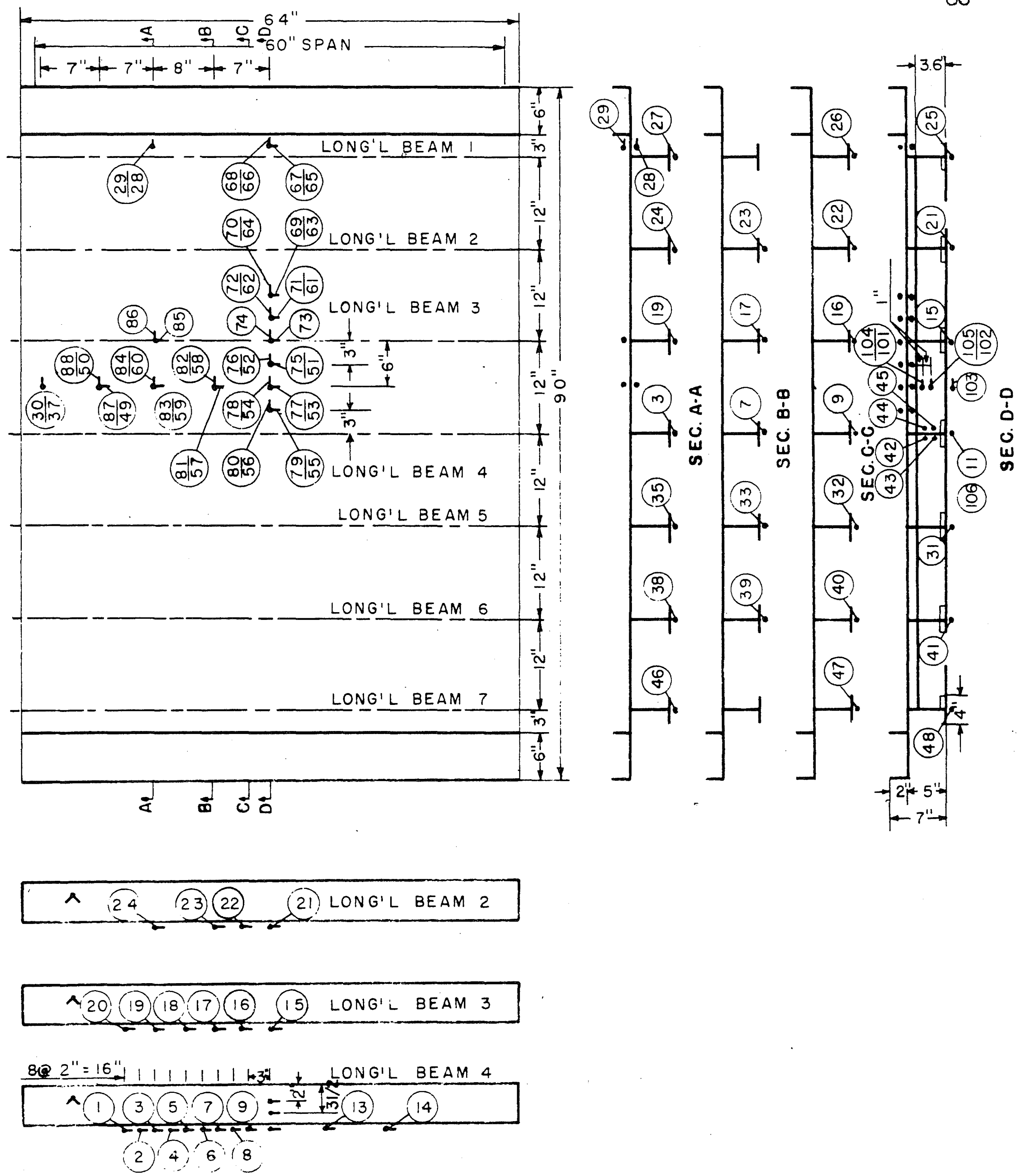

FIG. 2.3.2 DETAILS OF SPECIMEN V-F

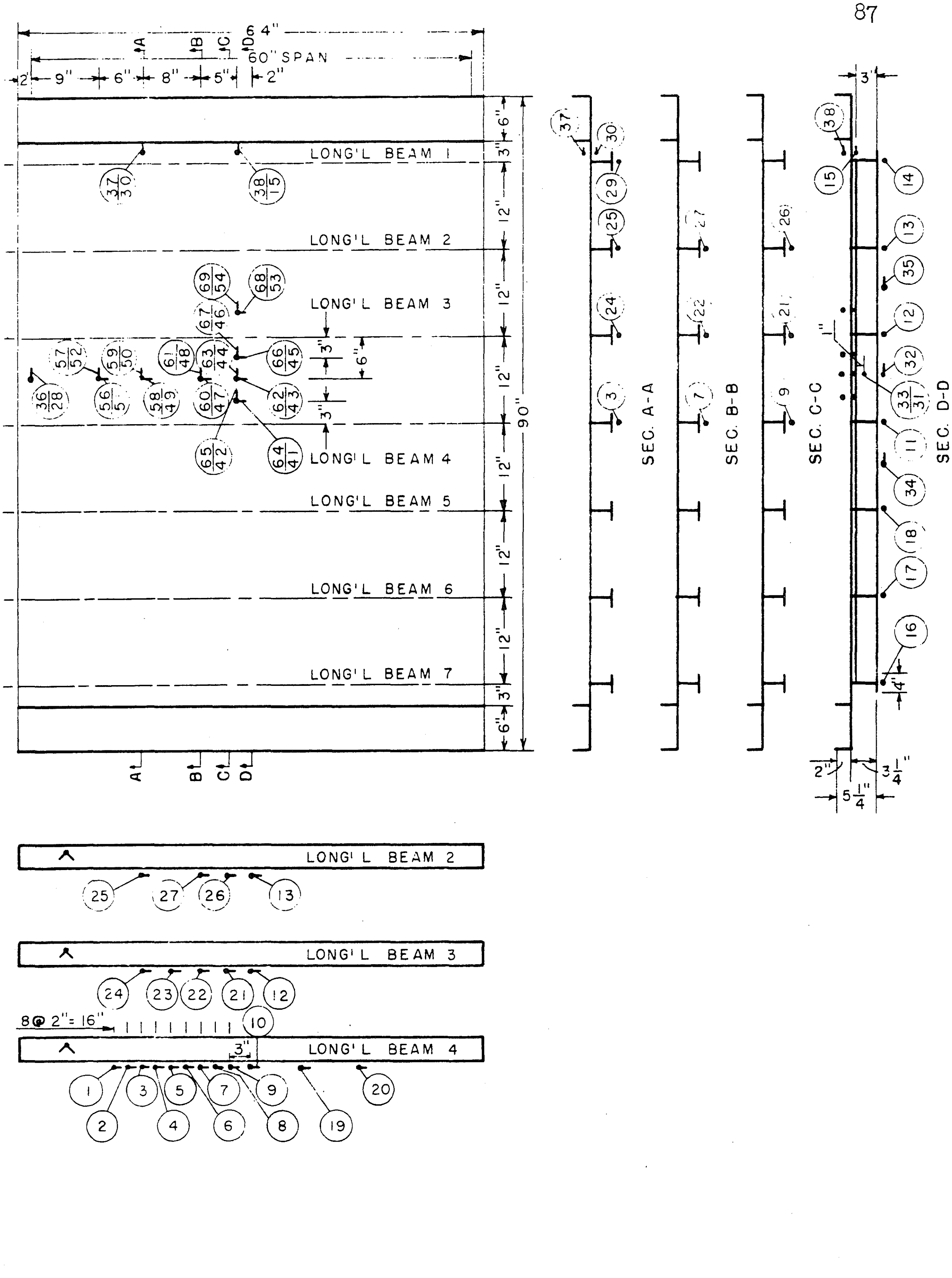

FIG. 2.3.3 DETAILS OF SPECIMEN VI

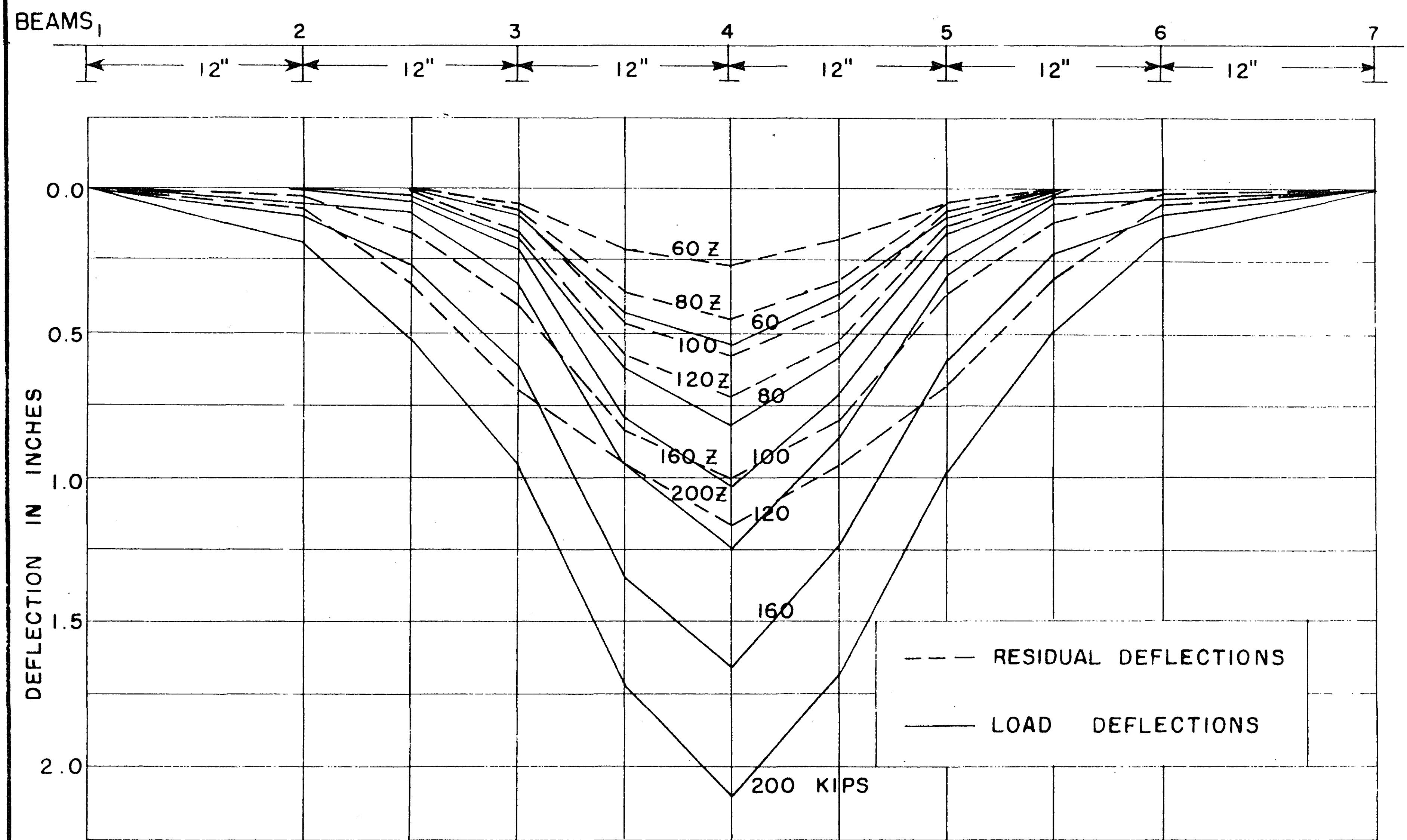

FIG. 3.2.1 DEFLECTIONS UNDER LOAD AND RESIDUAL DEFLECTIONS OF TRANSVERSE SECTION AT CENTERLINE OF SPECIMEN II

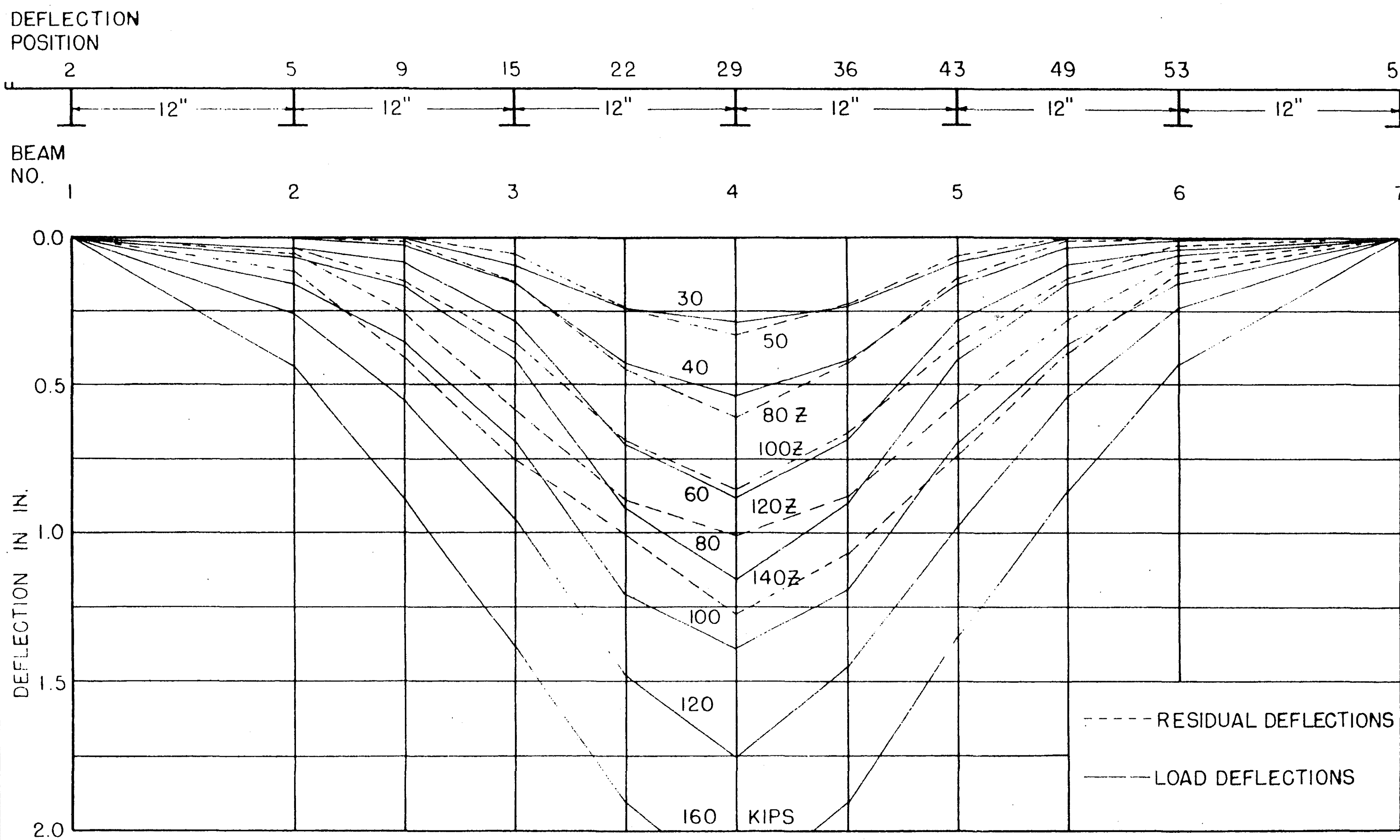

FIG. 3.2.2 DEFLECTIONS UNDER LOAD AND RESIDUAL DEFLECTIONS OF TRANSVERSE SECTION AT CENTERLINE OF SPECIMEN IV

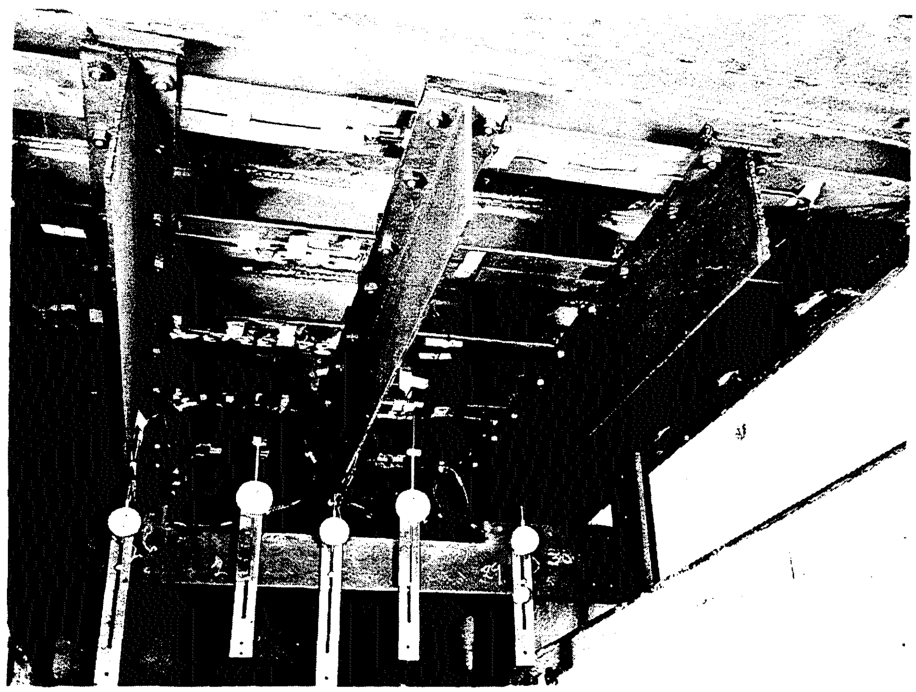

FIG. 4.1.1 BOTTOM VIEW OF SPECIMEN V-3 SHOWING TRANSVERSE BEAMS CLAMPED AT QUARTER POINTS

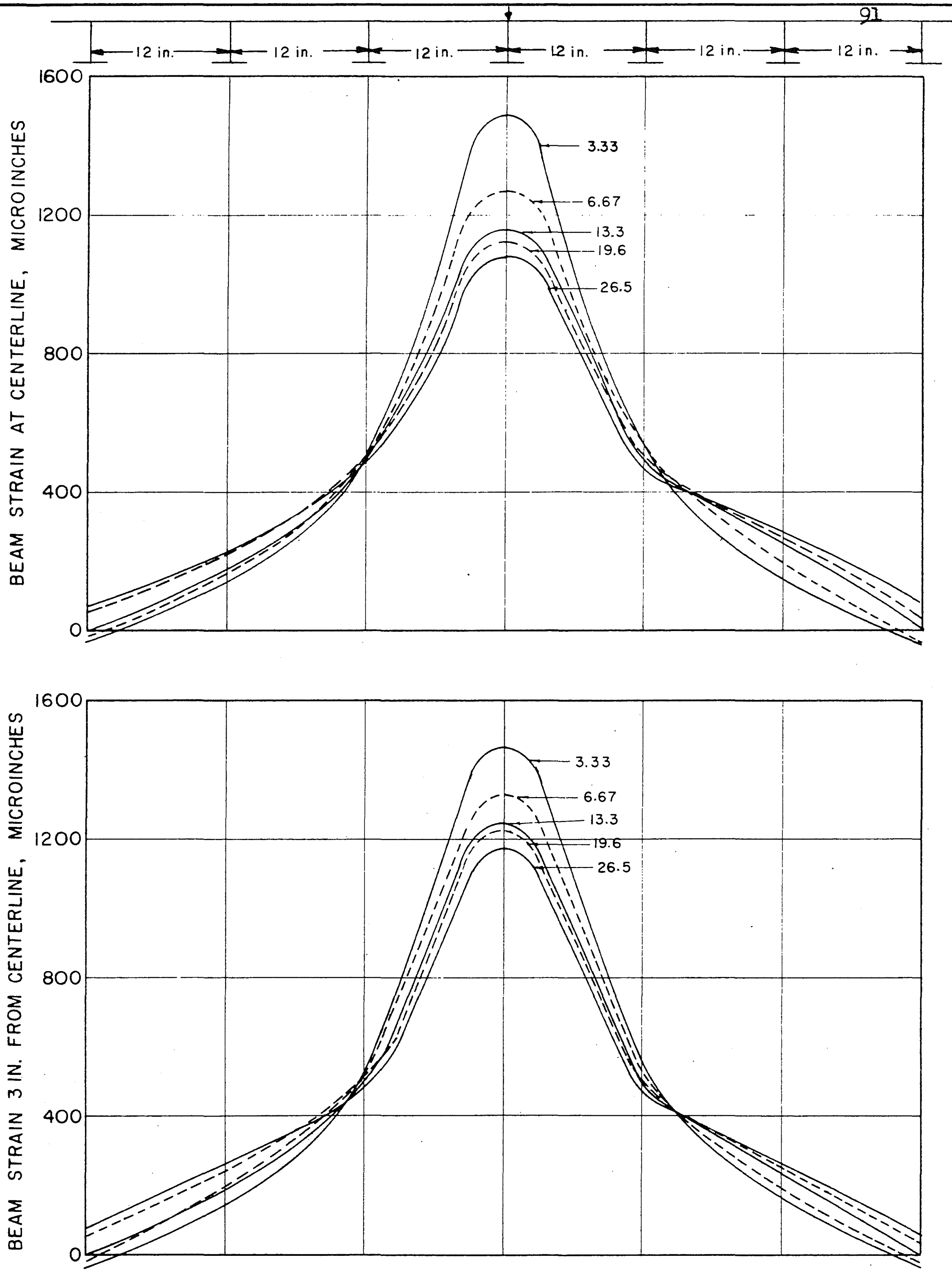

FIG. 4.2.1 VARIATION OF LONGITUDINAL BEAM BOTTOM FIBER STRAIN WITH VARIOUS VALUES OF I_t FOR SPECIMEN V-1 WITH 40-KIP LOAD AT POSITION 10

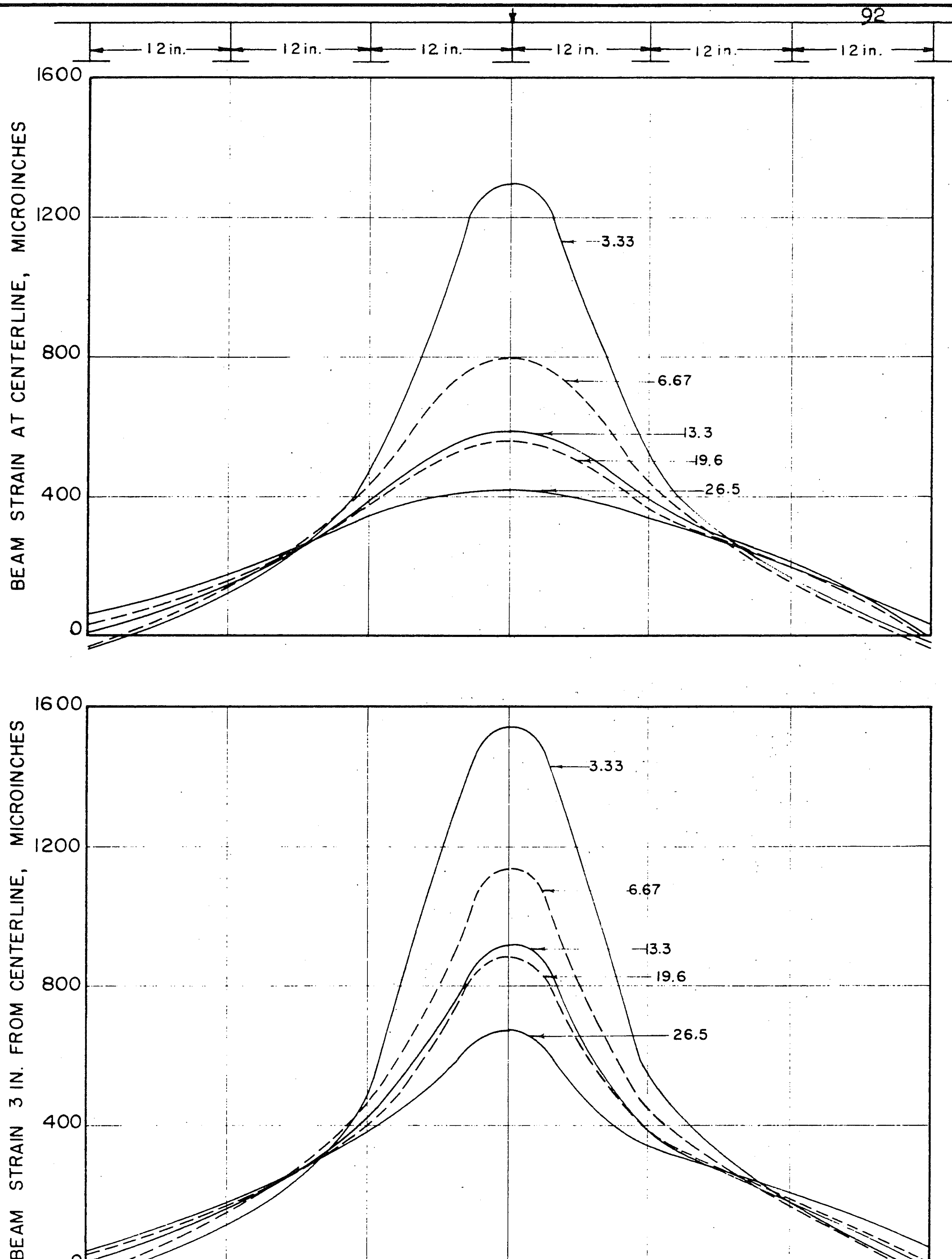

FIG. 4.2.2 VARIATION OF LONGITUDINAL BEAM BOTTOM FIBER STRAIN WITH VARIOUS VALUES OF I_t FOR SPECIMEN V-1 WITH 40-KIP LOAD AT POSITION PRODUCING MAXIMUM STRAIN IN LONGITUDINAL BEAM 4

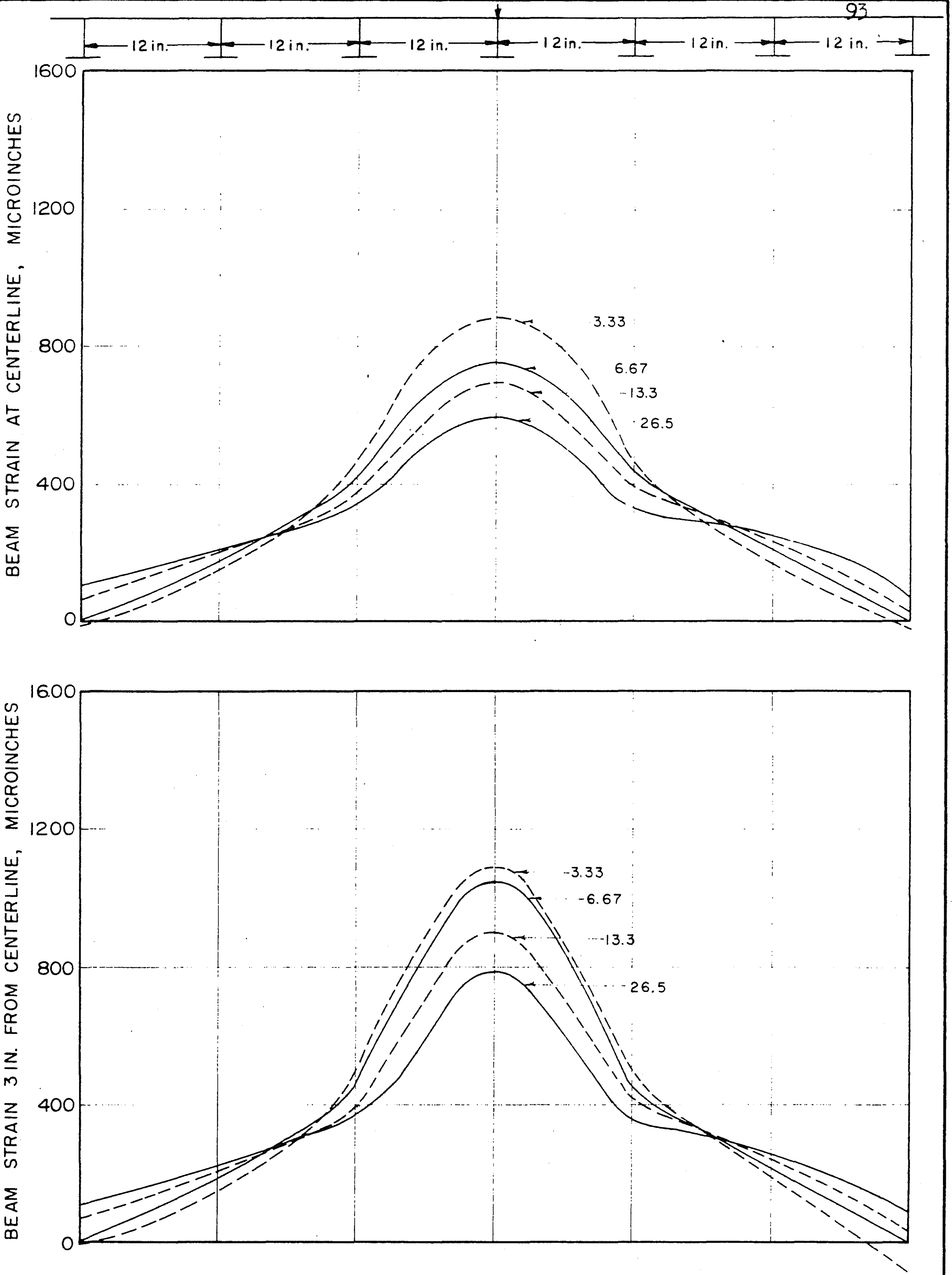

FIG. 4.3.1 VARIATION OF LONGITUDINAL BEAM BOTTOM FIBER STRAIN WITH VARIOUS VALUES OF I_t FOR SPECIMEN V-2 WITH 40-KIP LOAD AT POSITION 5A

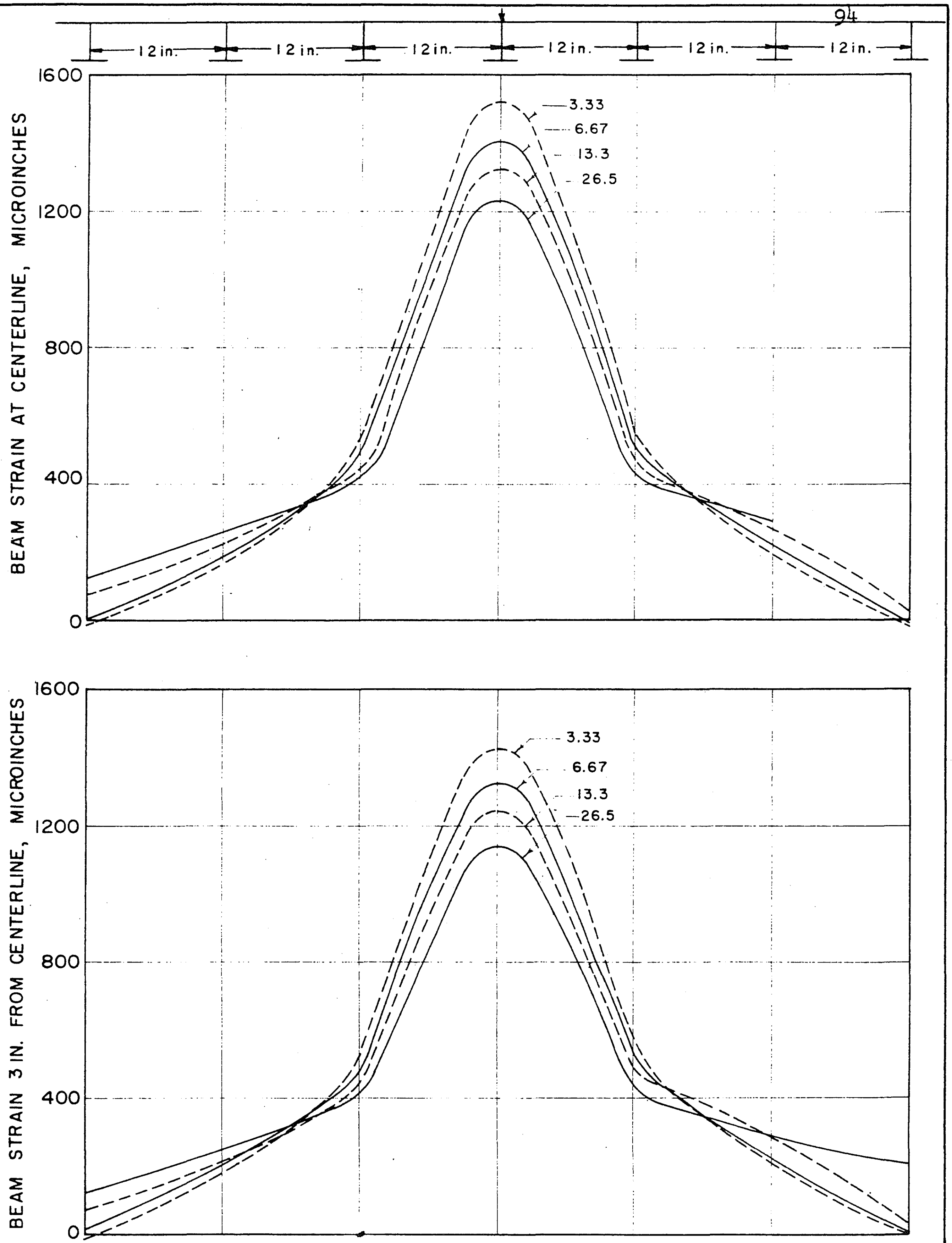

FIG. 4.3.2 VARIATION OF LONGITUDINAL BEAM BOTTOM FIBER STRAIN WITH VARIOUS VALUES OF I_t FOR SPECIMEN V-2 WITH 40-KIP LOAD AT POSITION 10

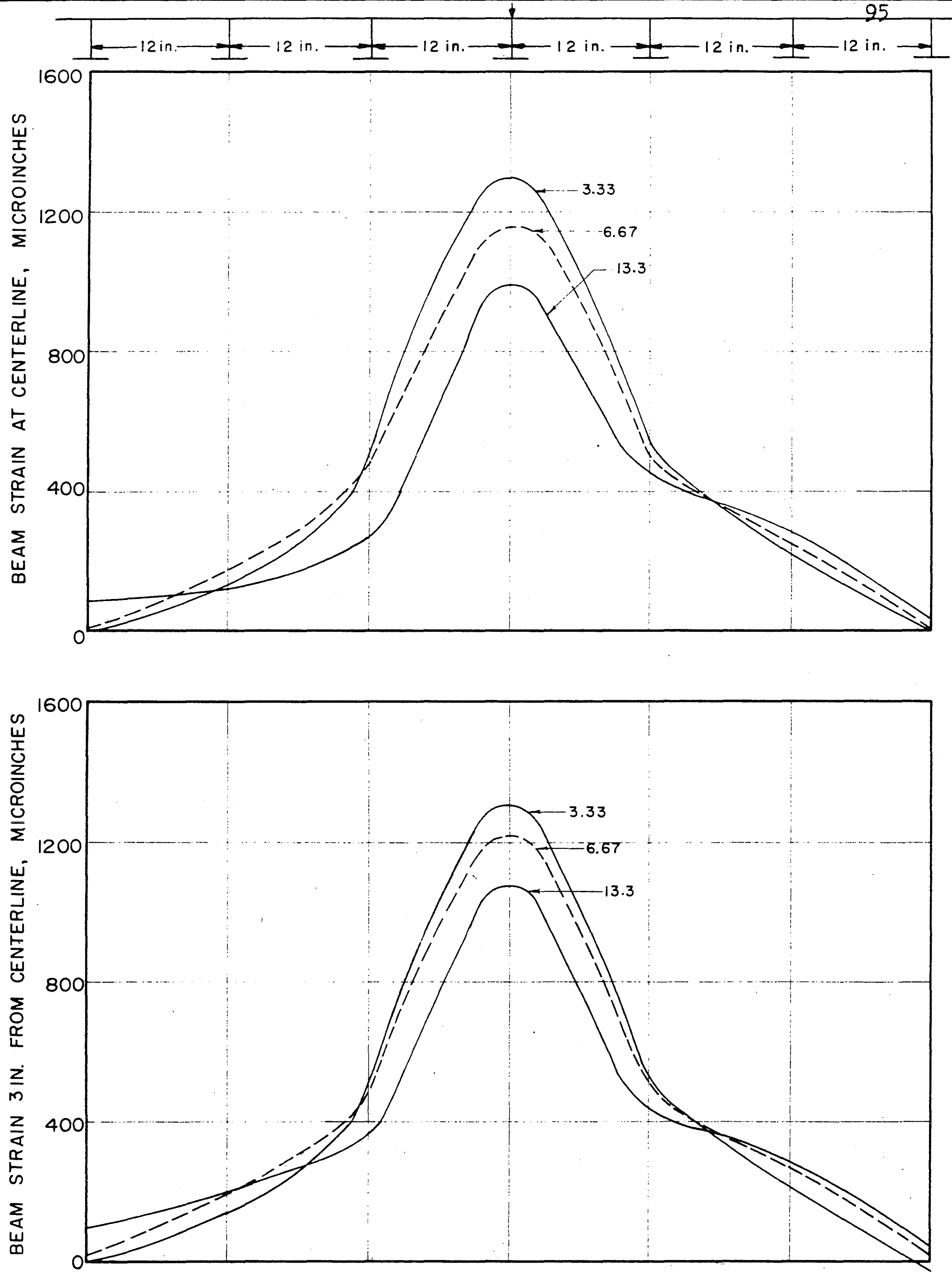

FIG. 4.4.1 VARIATION OF LONGITUDINAL BEAM BOTTOM FIBER STRAIN WITH VARIOUS VALUES OF I_t FOR SPECIMEN V-3 WITH 40-KIP LOAD AT POSITION 10

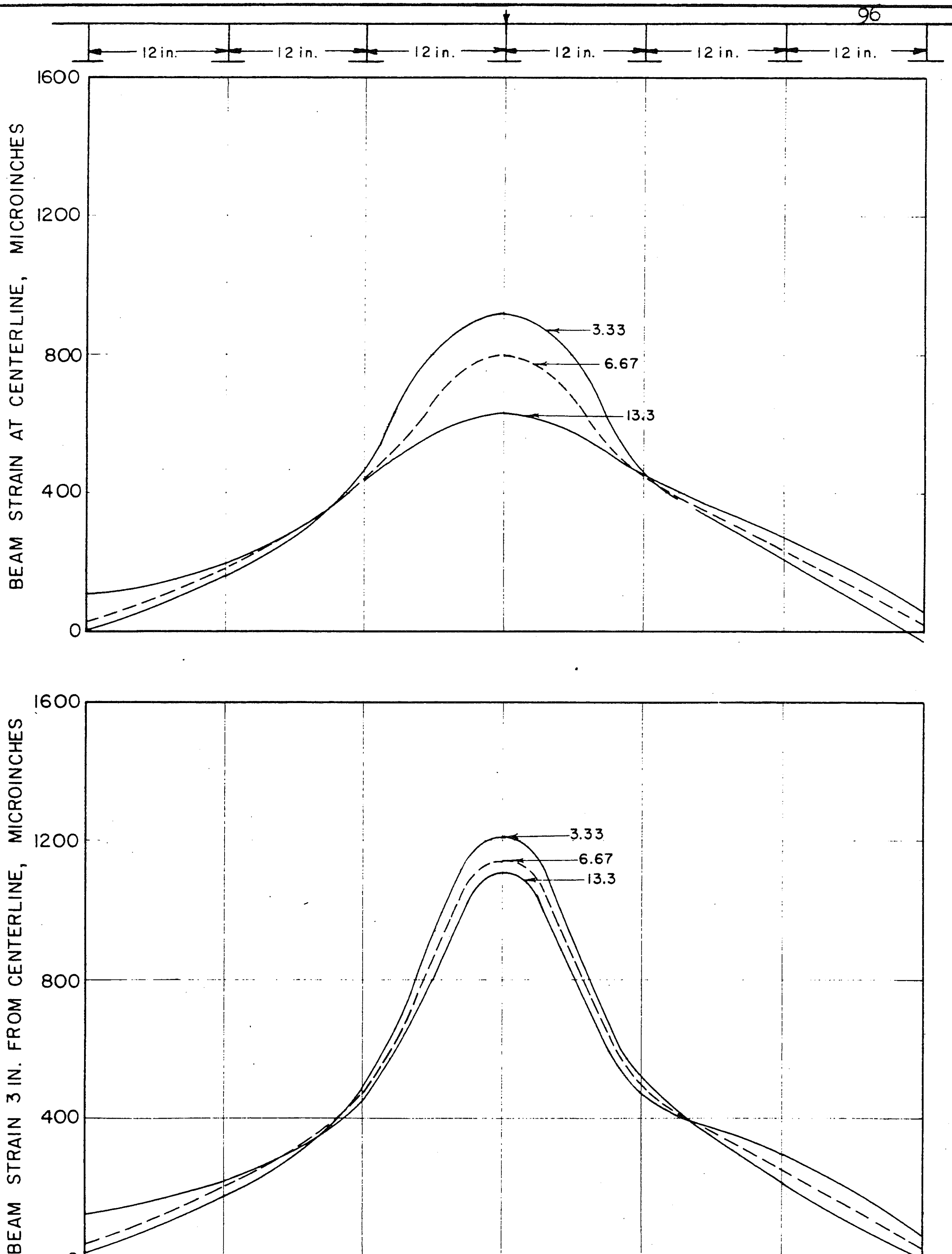

FIG. 4.4.2 VARIATION OF LONGITUDINAL BEAM BOTTOM FIBER STRAIN WITH VARIOUS VALUES OF I_t FOR SPECIMEN V-3 WITH 40-KIP LOAD AT POSITION 6A

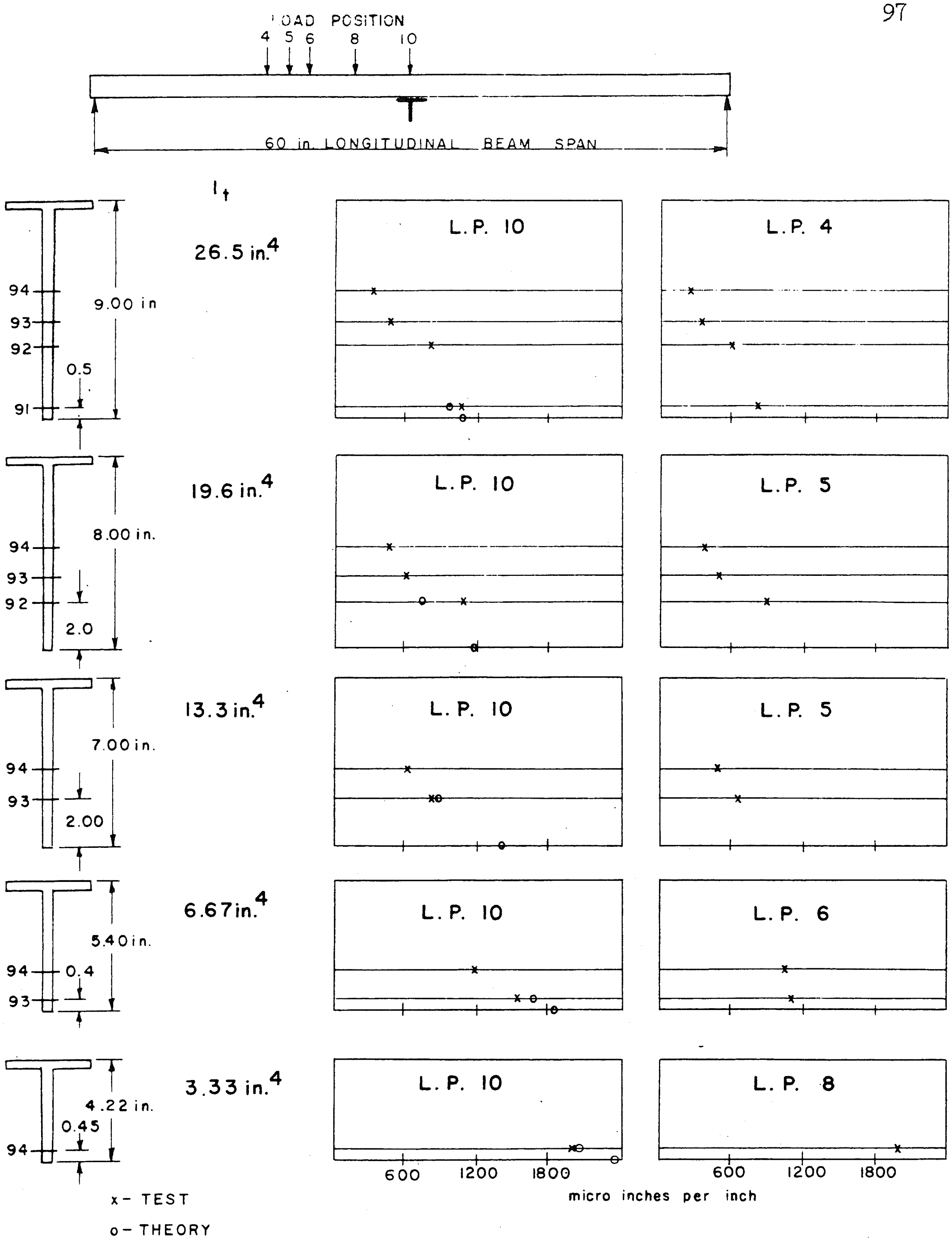

FIG. 4.5.3.1 VARIATION OF COMPUTED AND MEASURED STRAINS AT CENTER OF TRANSVERSE BEAM OF SPECIMEN V-1 UNDER 30-KIP LOAD

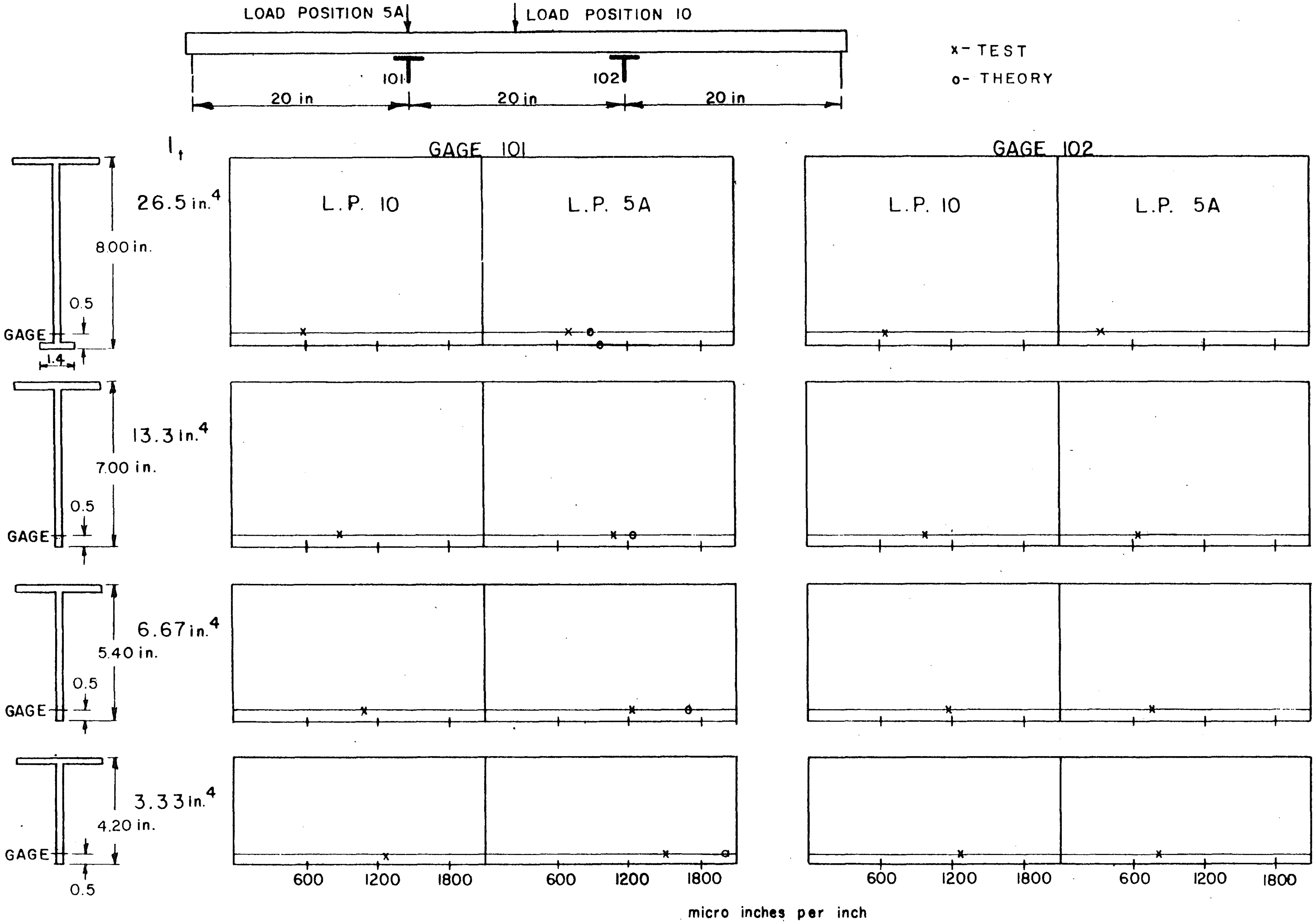

FIG. 4.5.3.2 VARIATION OF COMPUTED AND MEASURED STRAINS AT CENTER OF TRANSVERSE BEAMS OF SPECIMEN V-2 UNDER 30-KIP LOAD

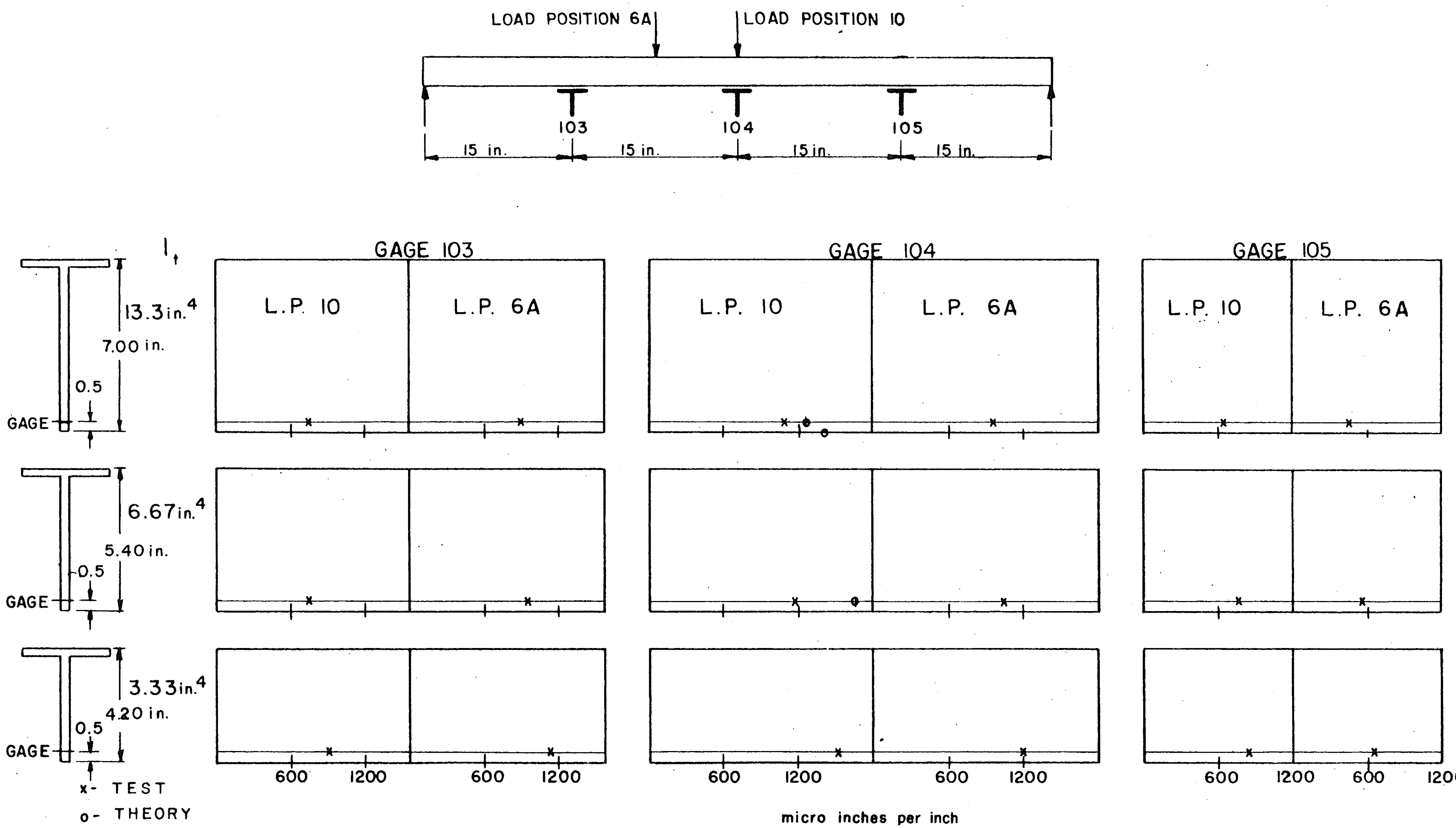

FIG. 4.5.3.3 VARIATION OF COMPUTED AND MEASURED STRAINS AT CENTER OF TRANSVERSE BEAMS OF SPECIMEN V-3 UNDER 30-KIP LOAD

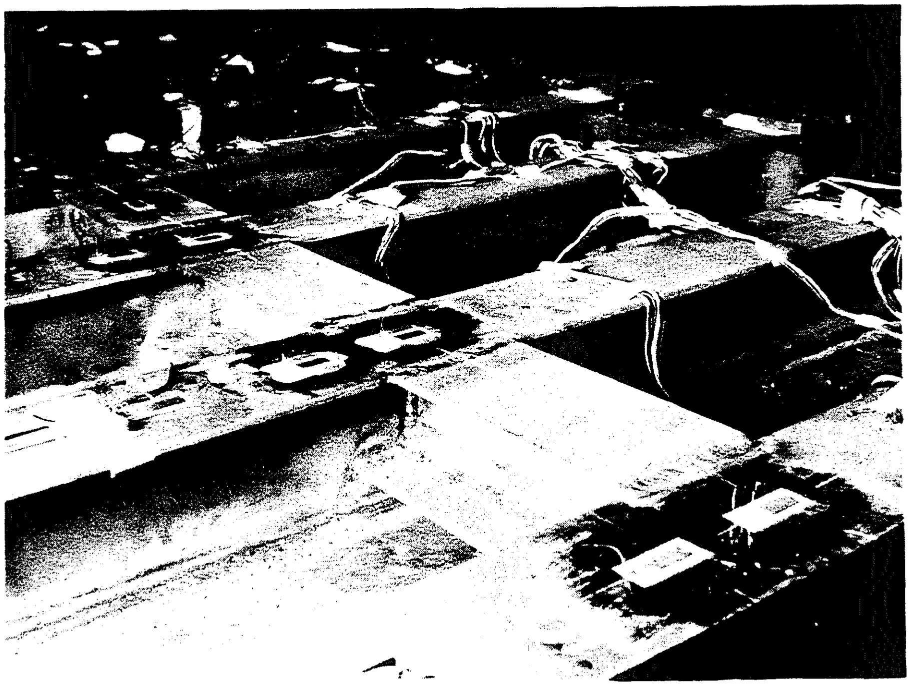

FIG. 5.1.1 CLOSEUP OF INTERCOSTALLY WELDED TRANSVERSE BEAM, SPECIMEN V-F

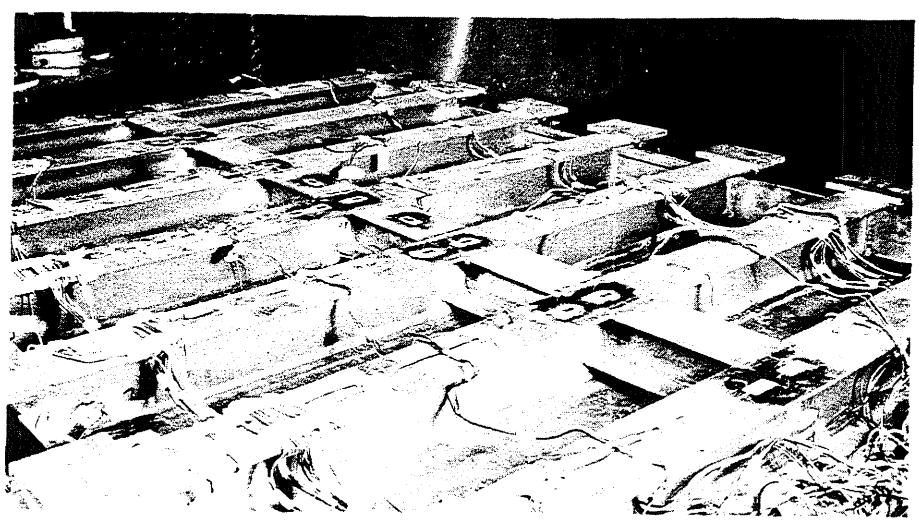

FIG. 5.1.2 UNDERSIDE OF SPECIMEN V-F SHOWING TRANSVERSE INTERCOSTALLY WELDED TO LONGITUDINALS

FIG. 5.2.1 FAILURE OF WELD BETWEEN LONGITUDINAL AND TRANSVERSE BEAMS IN SPECIMEN V-F, ~130-KIP LOAD

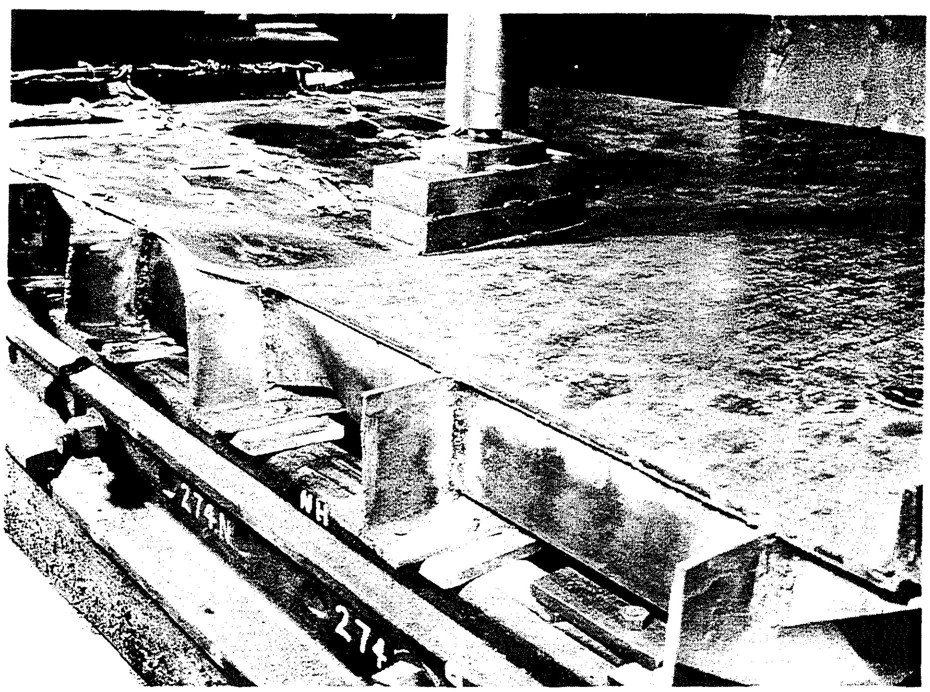

FIG. 5.2.2 END VIEW OF SPECIMEN V-F AT ULTIMATE LOAD

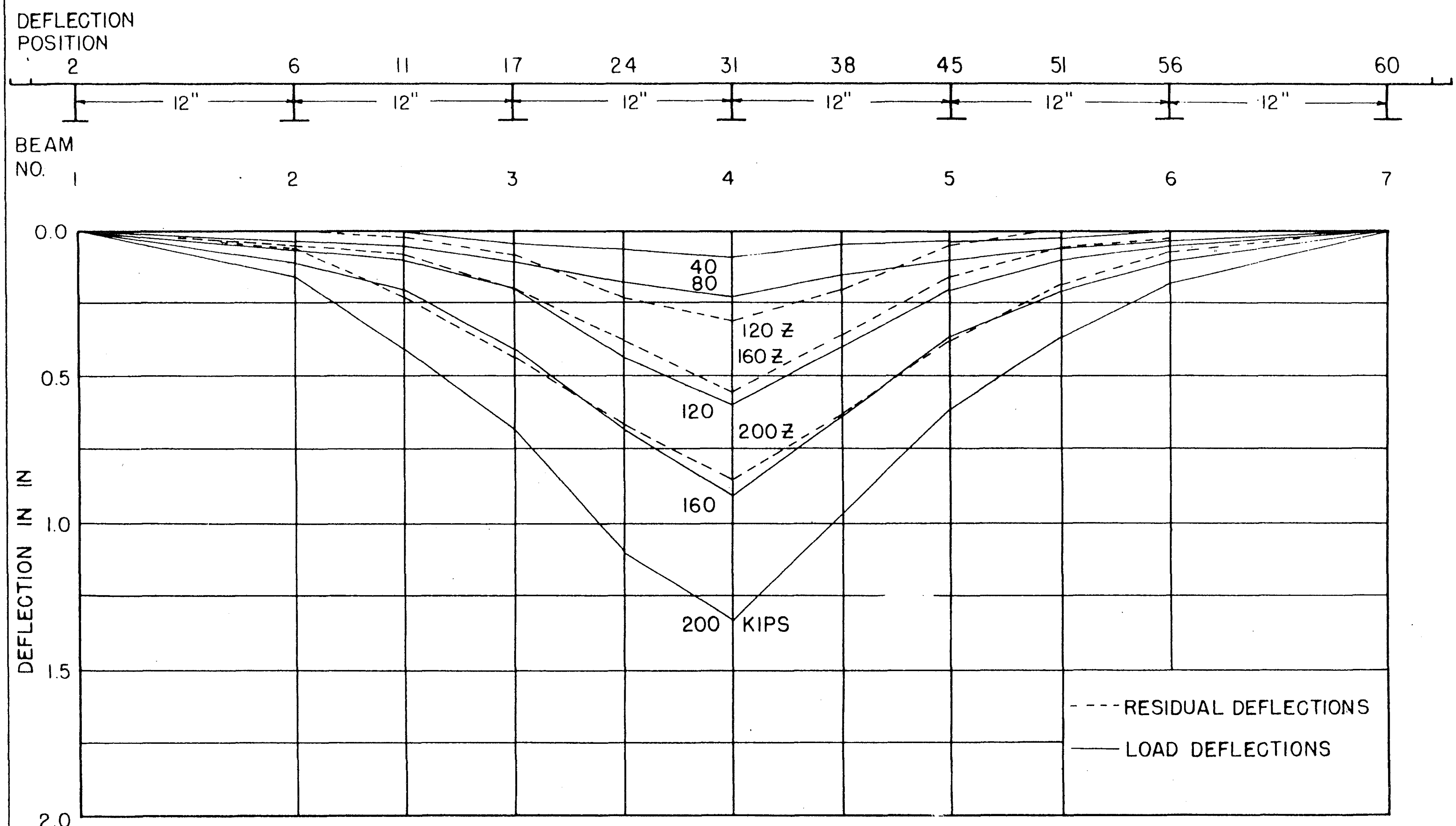

FIG. 5.2.3 DEFLECTIONS UNDER LOAD AND RESIDUAL DEFLECTIONS OF TRANSVERSE SECTION AT CENTERLINE OF SPECIMEN V-F

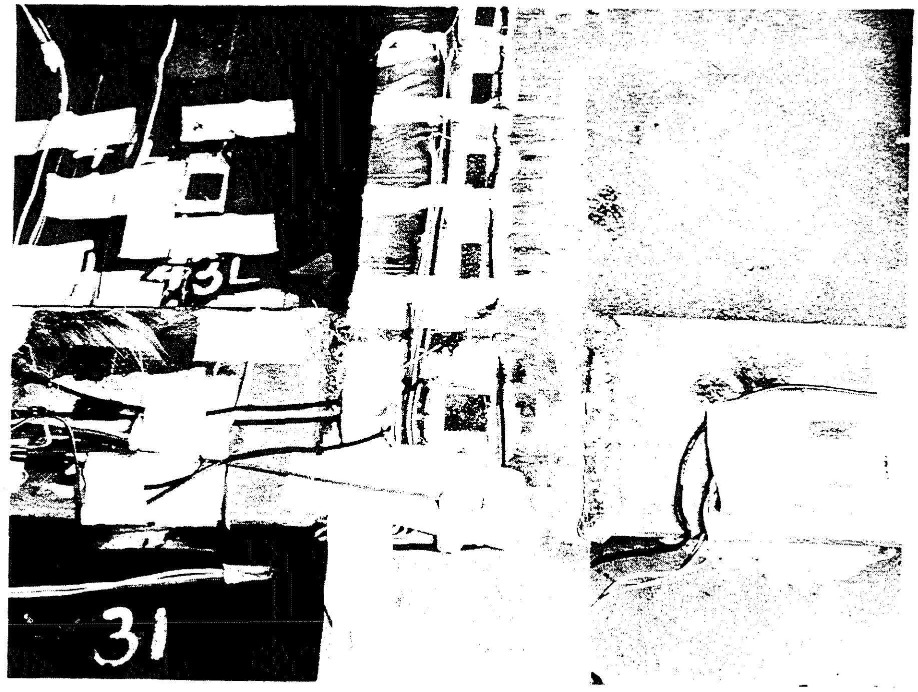

FIG. 5.3.1 FAILURE OF WELD BETWEEN LONGITUDINAL AND TRANSVERSE BEAMS IN SPECIMEN VI~130-KIP LOAD

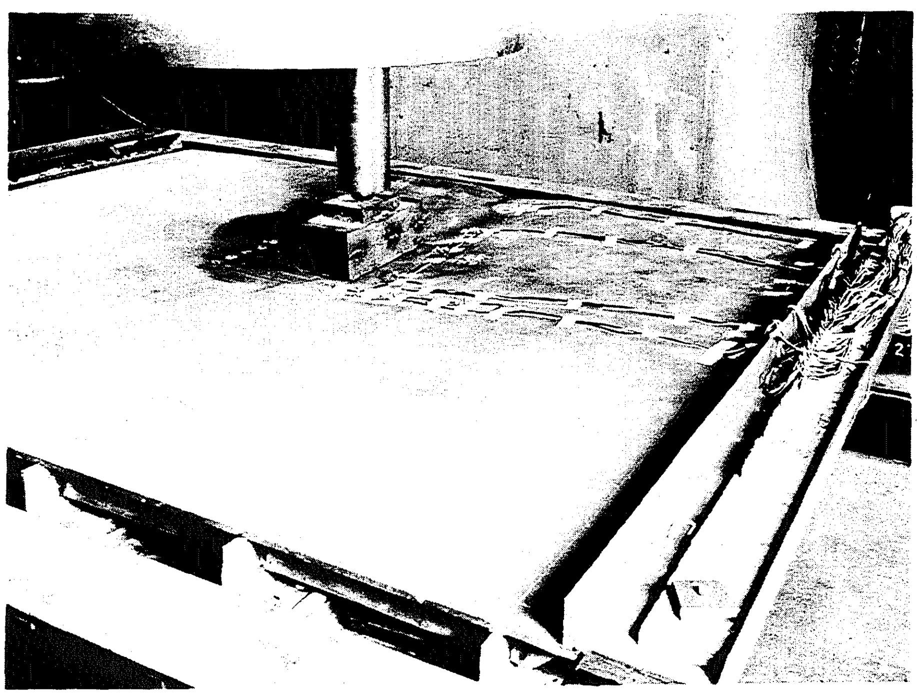

FIG. 5.3.2 GENERAL VIEW OF SPECIMEN VI AT ULTIMATE LOAD

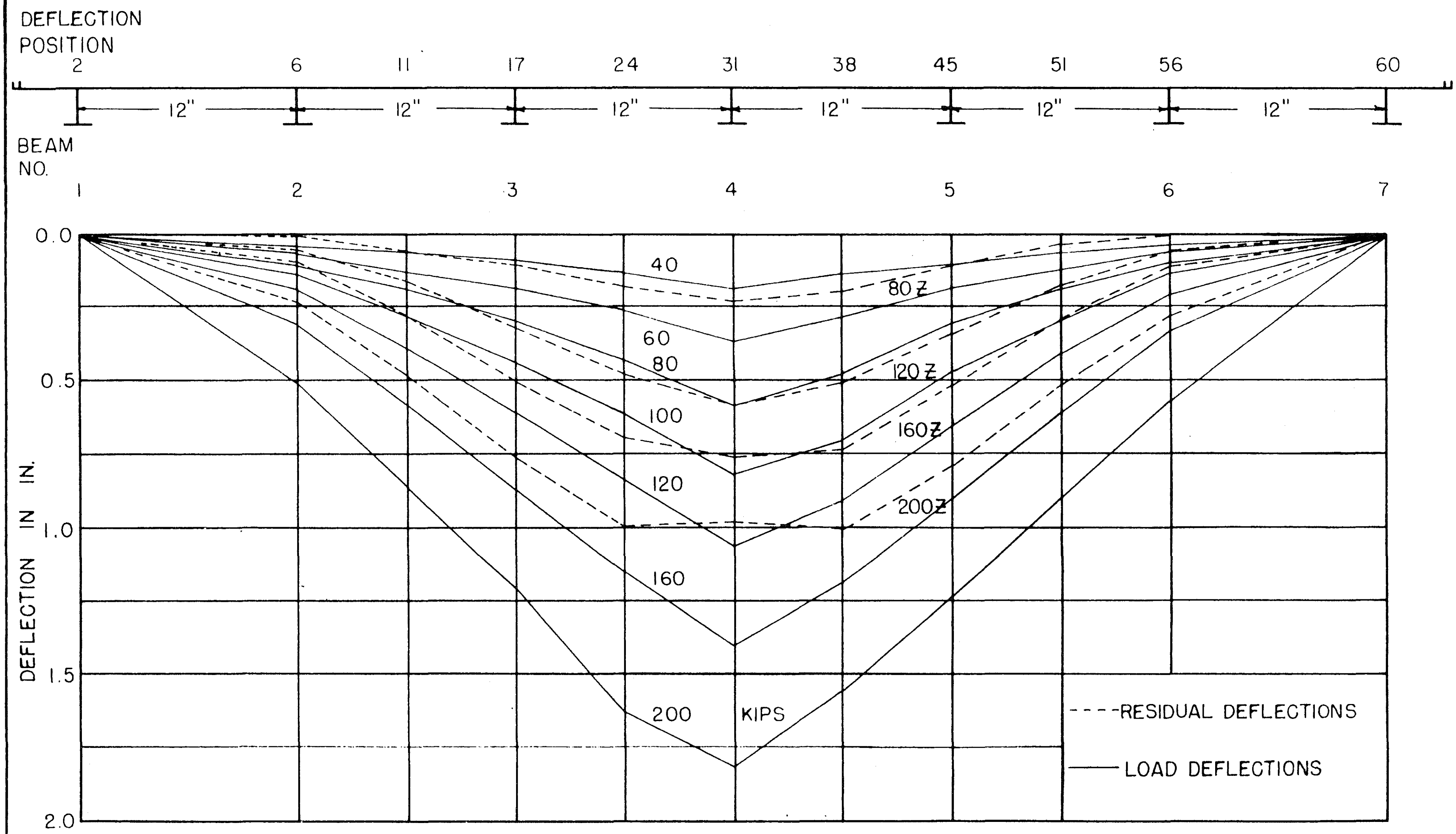

FIG. 5.3.3 DEFLECTIONS UNDER LOAD AND RESIDUAL DEFLECTIONS OF TRANSVERSE SECTION AT CENTERLINE OF SPECIMEN VI

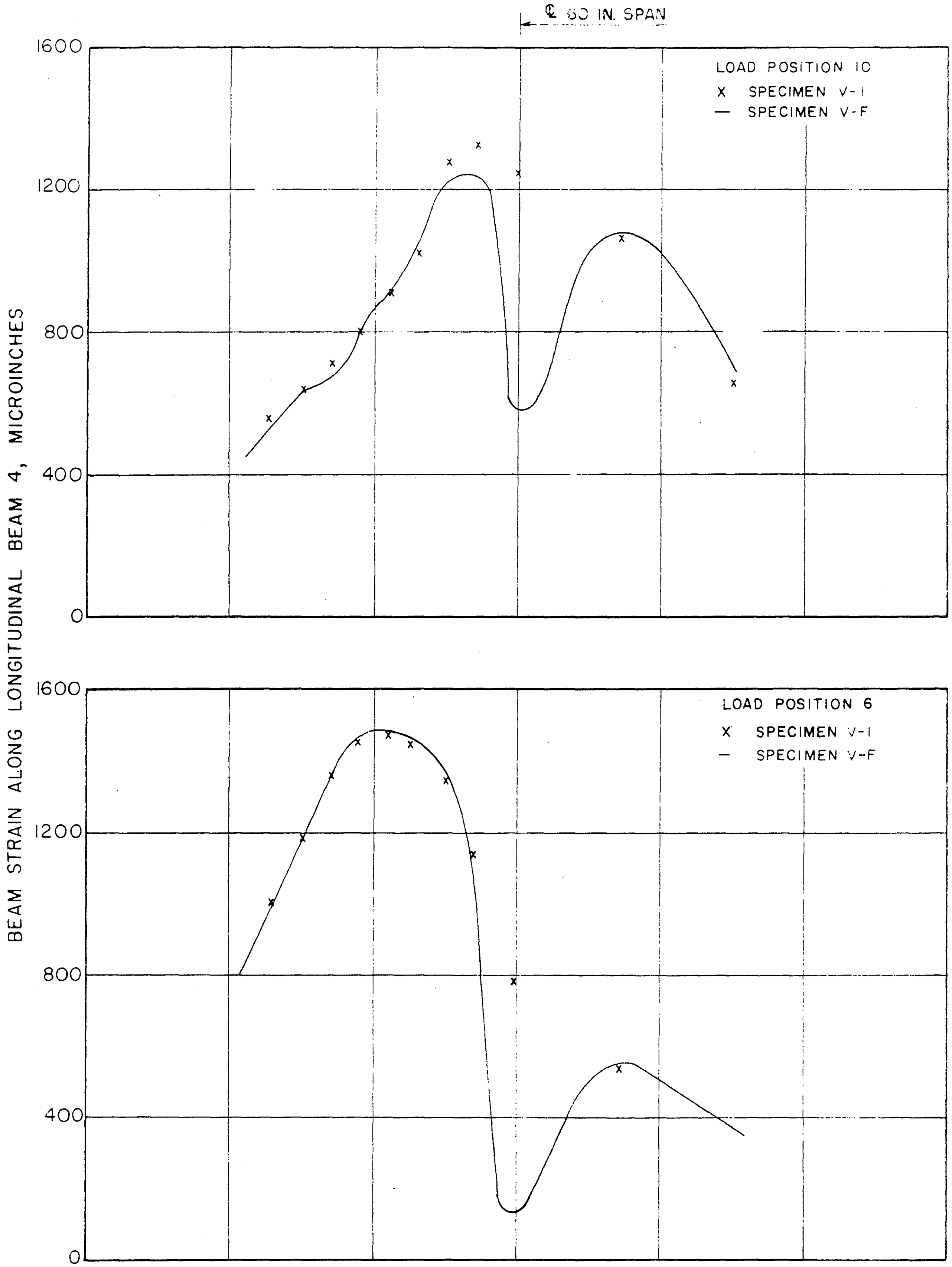

FIG. 6.1.1 VARIATION OF BOTTOM FIBER STRAIN ALONG LONGITUDINAL BEAM 4 OF SPECIMENS V-1 AND V-F WITH 40-KIP LOAD AT POSITIONS 10 AND 6

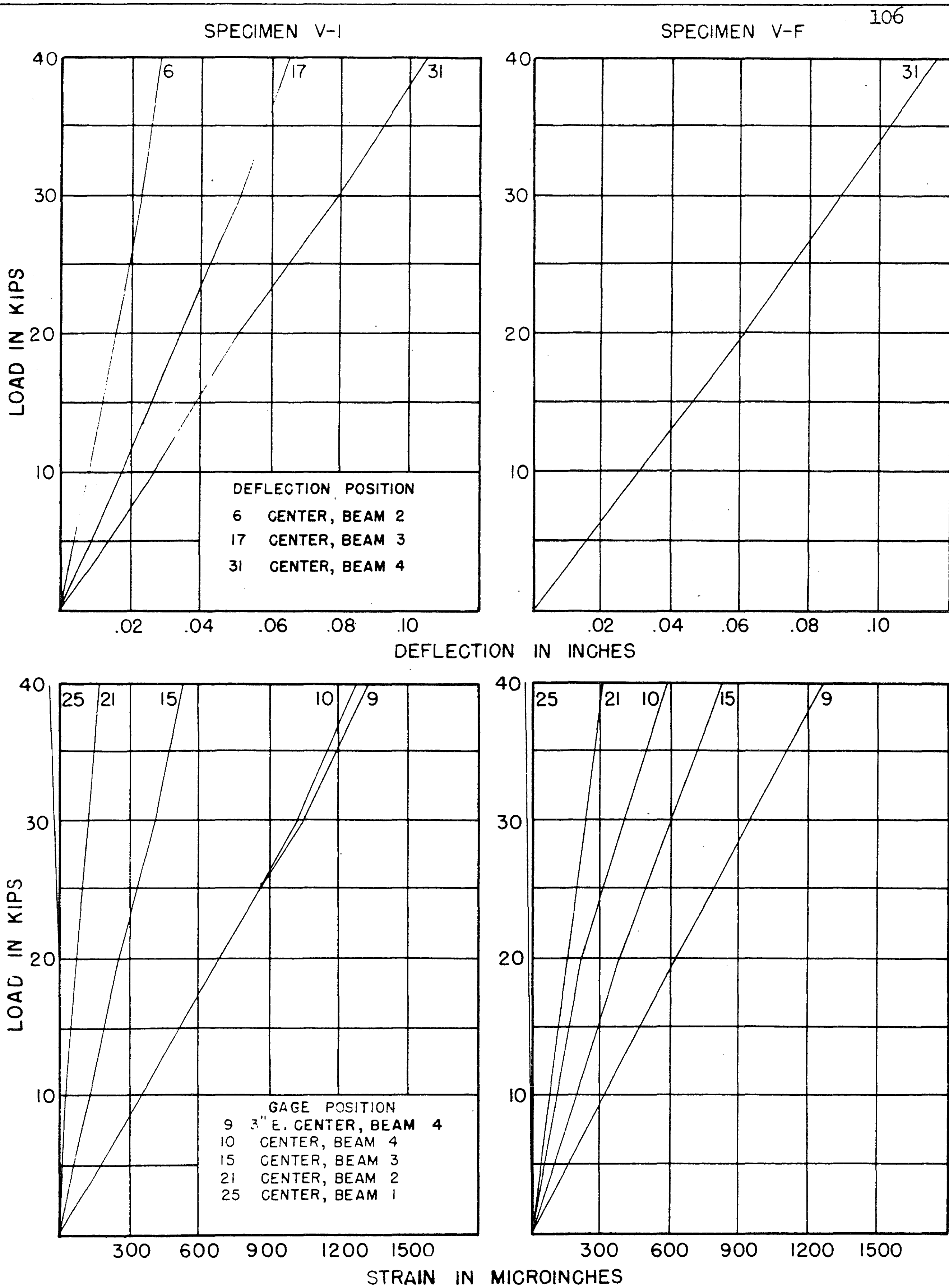

FIG. 6.1.2 COMPARISONS OF STRAINS AND DEFLECTIONS IN THE ELASTIC RANGE FOR SPECIMENS V-1 AND V-F WHEN LOADED AT POSITION 10

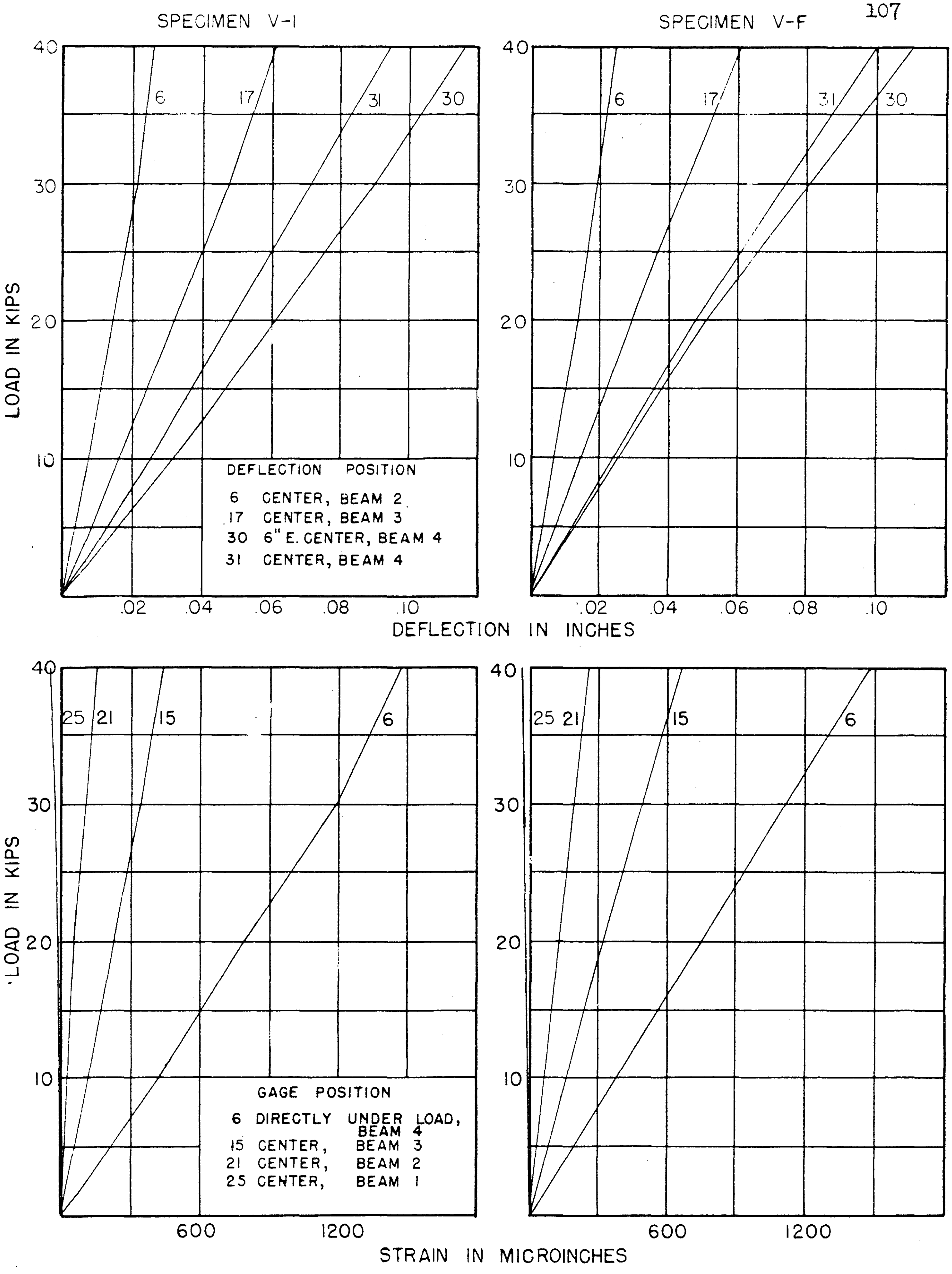

FIG. 6.1.3 COMPARISONS OF STRAINS AND DEFLECTIONS IN THE ELASTIC RANGE FOR SPECIMENS V-1 AND V-F WHEN LOADED AT POSITION 6

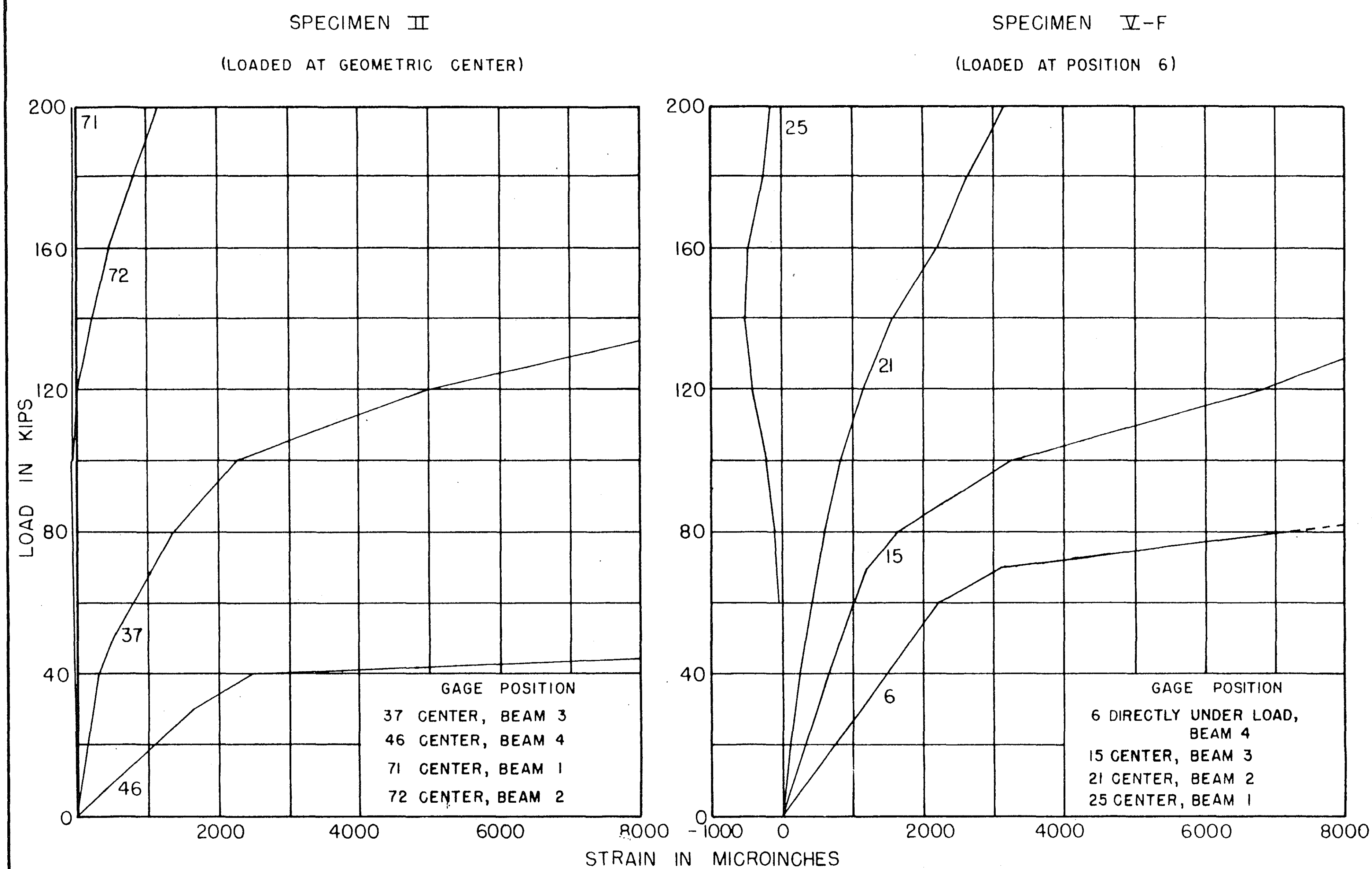

FIG. 7.1.1 COMPARISON OF EXTREME FIBER STRAINS IN LONGITUDINAL BEAMS OF SPECIMENS II AND V-F DURING LOAD-TO-FAILURE TESTS

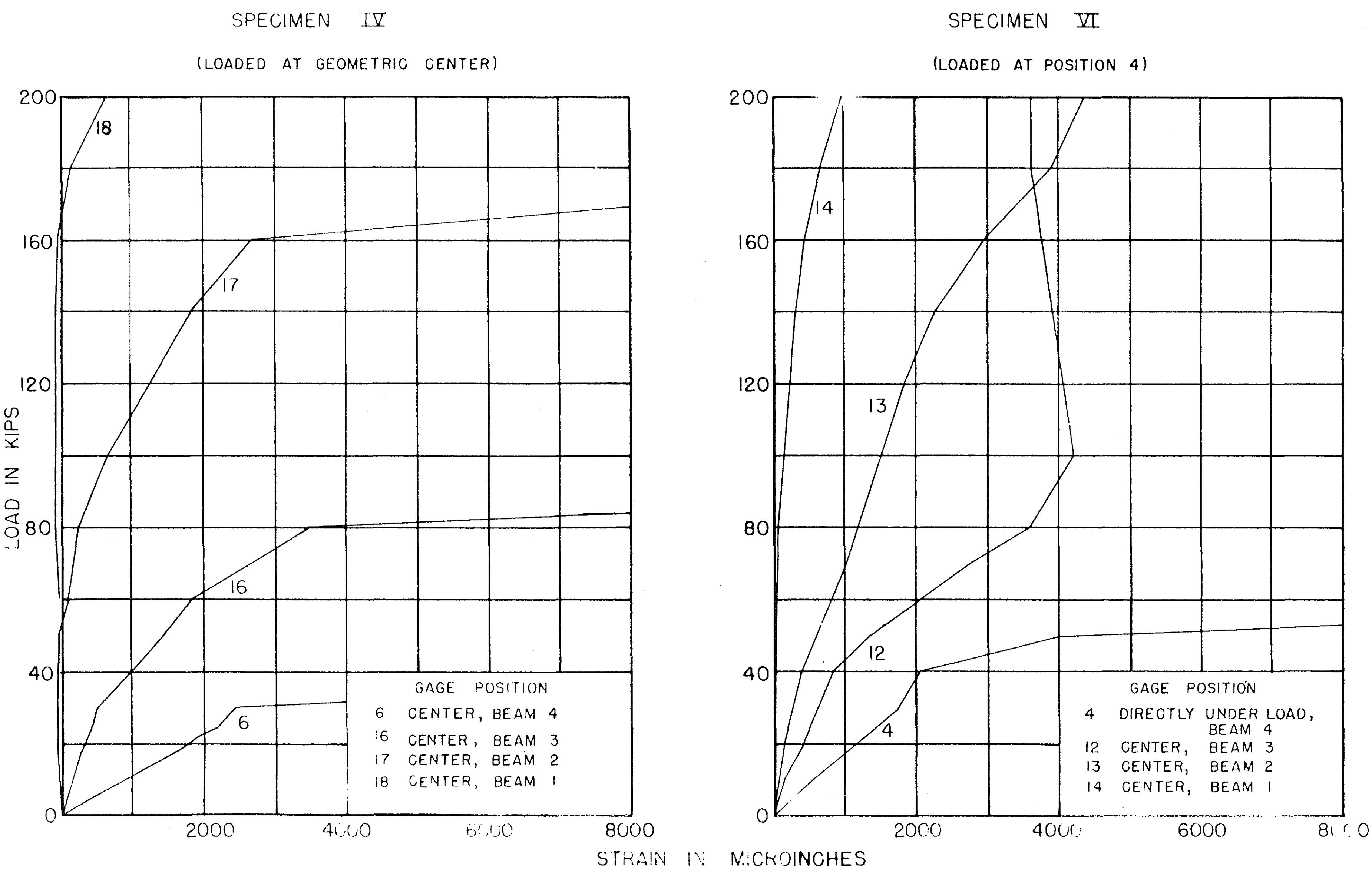

FIG. 7.1.2 COMPARISON OF EXTREME FIBER STRAINS IN LONGITUDINAL BEAMS OF SPECIMENS IV AND VI DURING LOAD-TO-FAILURE TESTS

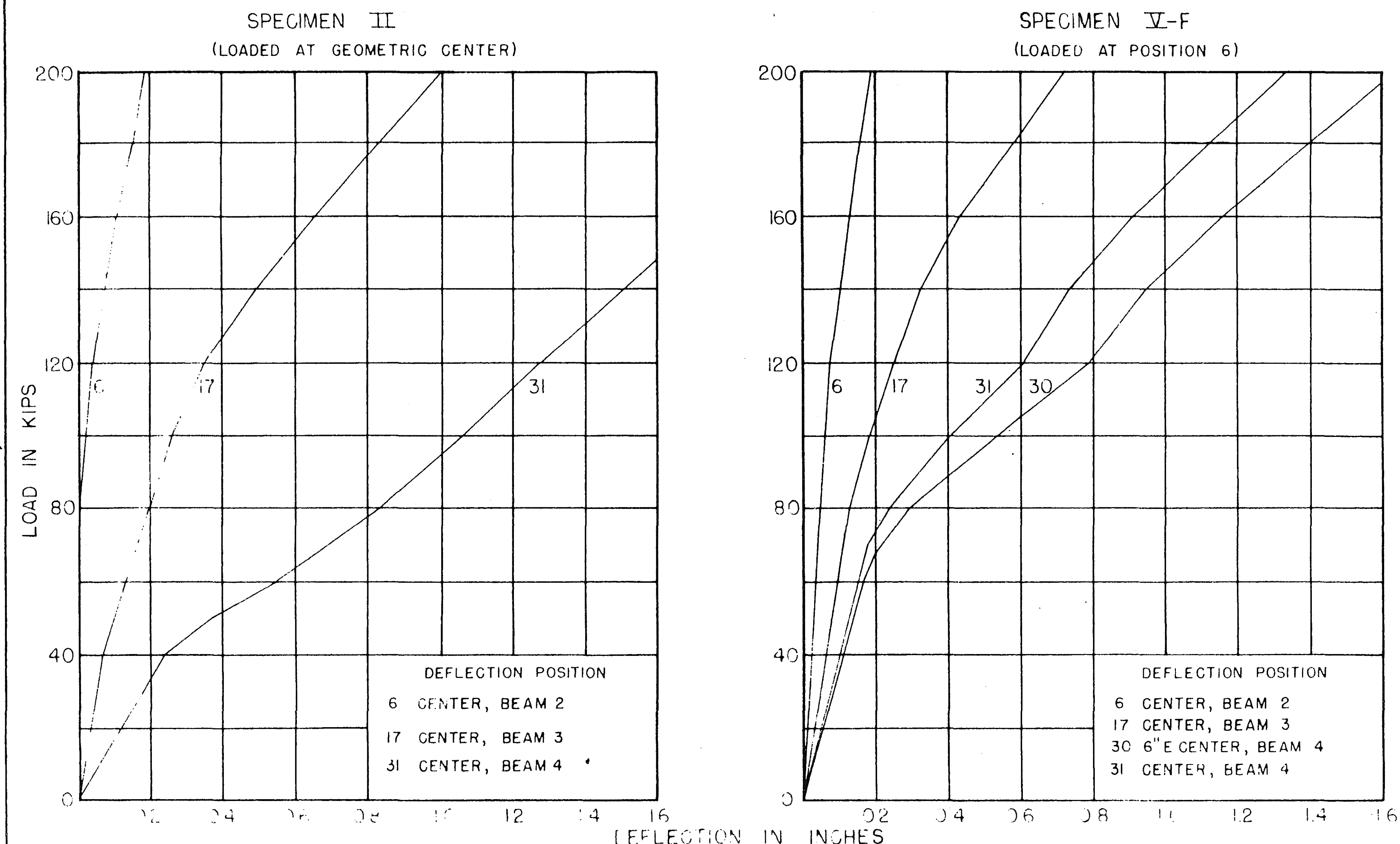

FIG. 7.2.1 COMPARISON OF LONGITUDINAL BEAM DEFLECTIONS OF

SPECIMENS II AND V-F DURING LOAD-TO-FAILURE TESTS

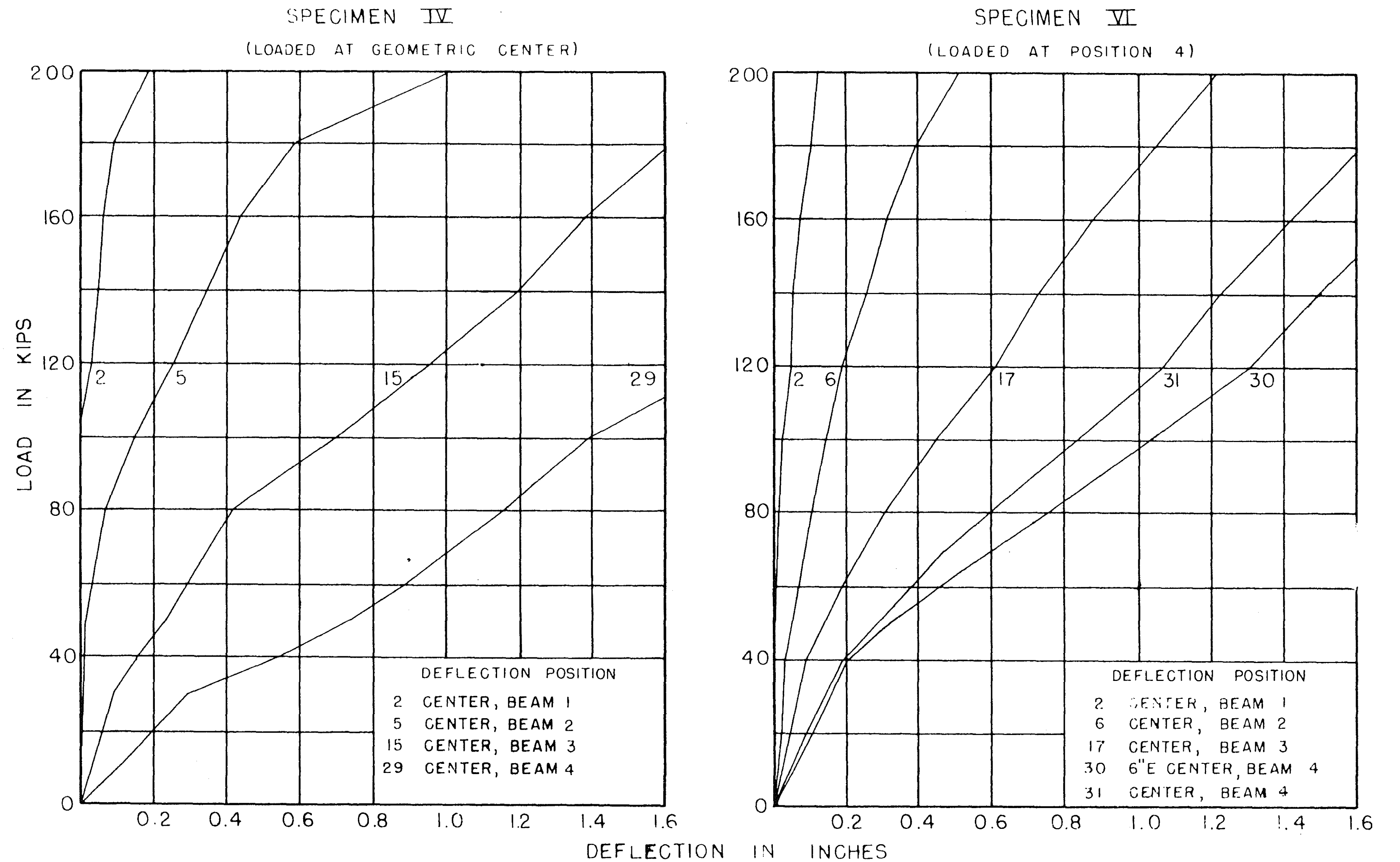

FIG. 7.2.2 COMPARISON OF LONGITUDINAL BEAM DEFLECTIONS OF SPECIMENS IV AND VI DURING LOAD-TO-FAILURE TESTS

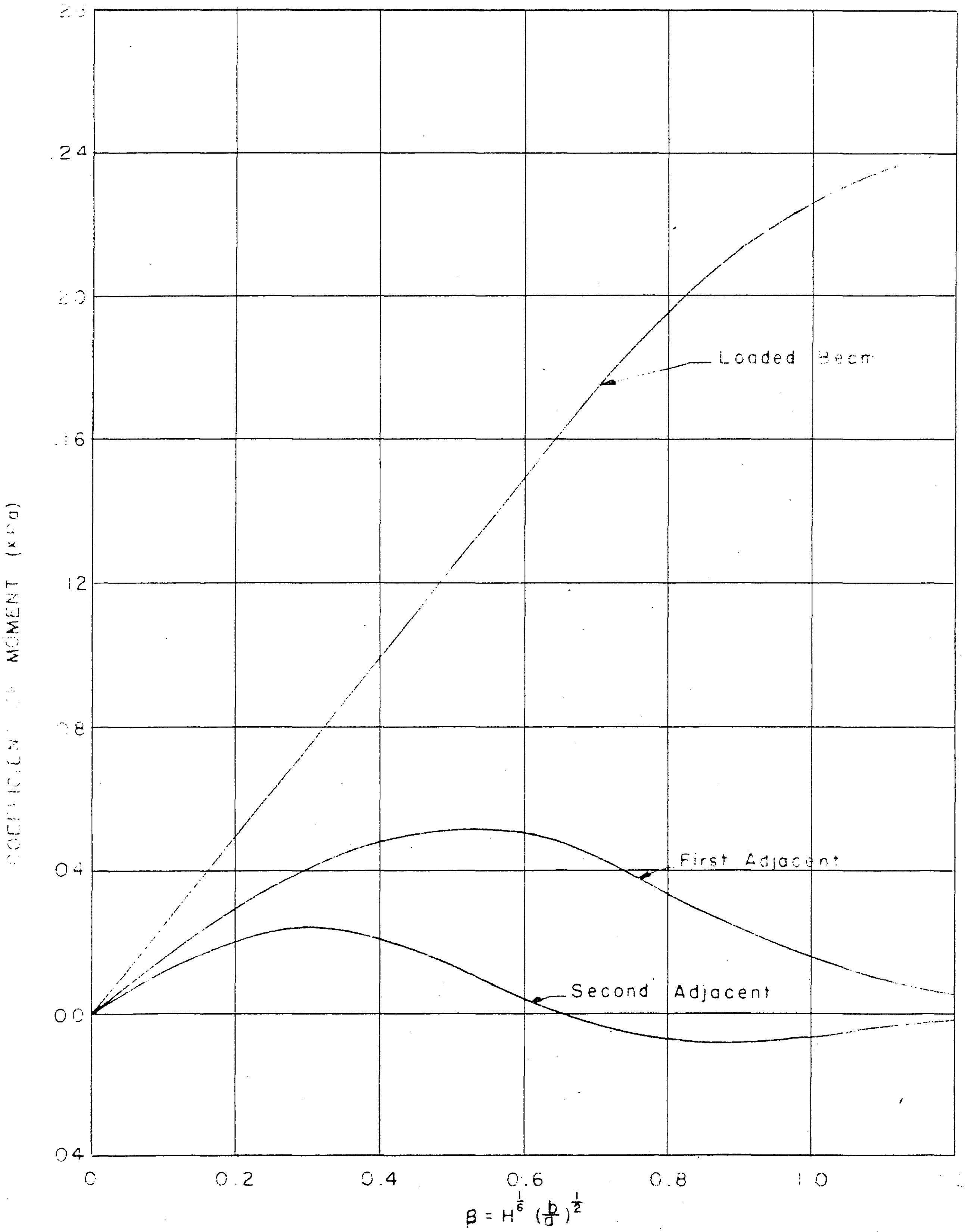

FIG. 8.2.1 INFLUENCE COEFFICIENTS FOR MIDSPAN MOMENTS IN LONGITUDINAL BEAMS OF A SIMPLY-SUPPORTED DECK UNDER CONCENTRATED LOAD

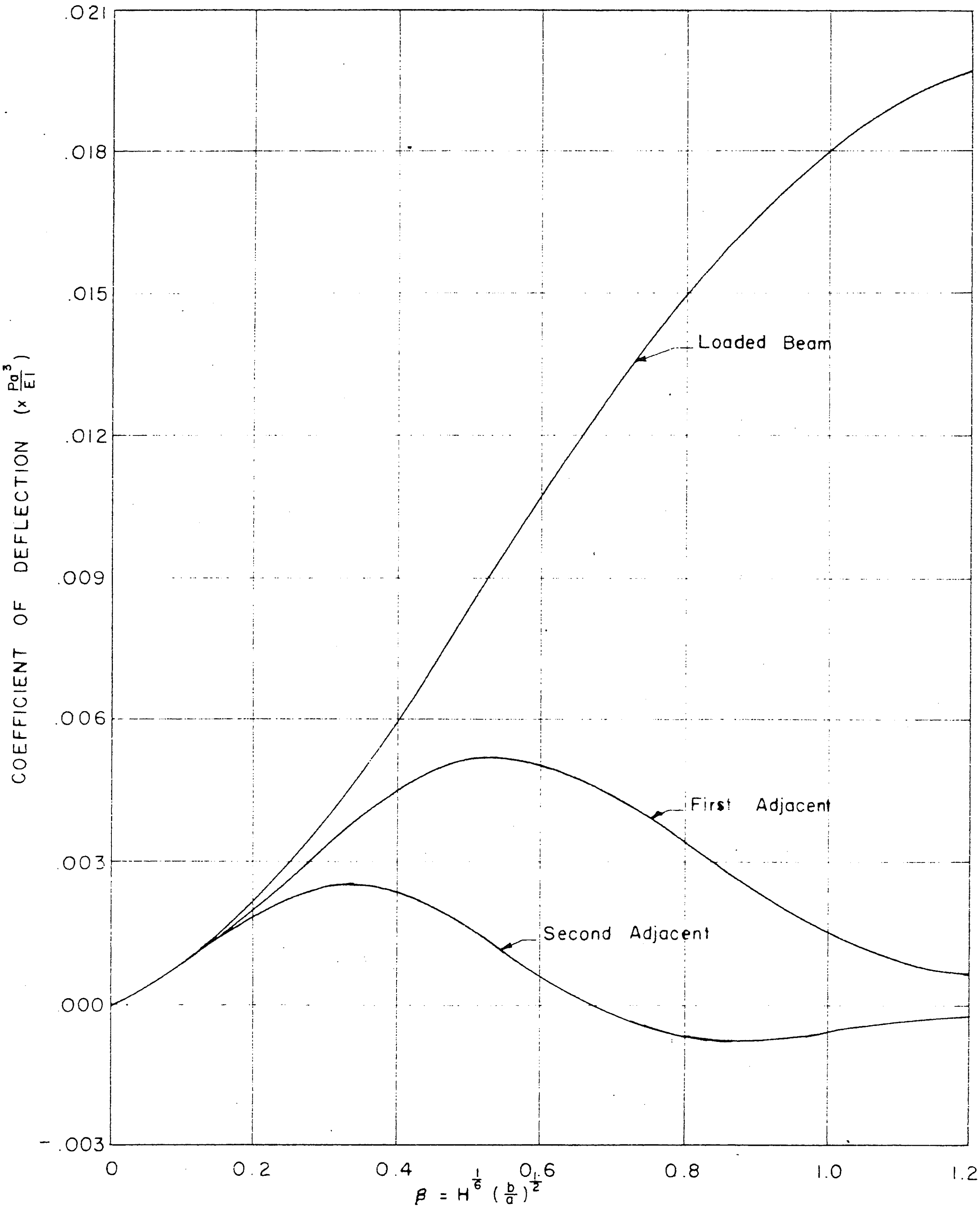

FIG. 8.3.1 INFLUENCE COEFFICIENTS FOR MIDSPAN DEFLECTIONS IN LONGITUDINAL BEAMS OF A SIMPLY-SUPPORTED DECK UNDER CONCENTRATED LOAD