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Cornell University School of Civil Engineering Tests on light beams of cold-formed steel

Cornell University School of Civil Engineering

SCHOOL OF CIVIL ENGINEERING, CORNELL UNIVERSITY
TESTS ON LIGHT BEAM OF COLD FORMED STEEL
FOR THE AMERICAN IRON AND STEEL INSTITUTE

SEVENTH PROGRESS REPORT, FEB. 28, 1940

I. OBJECT OF THIS REPORT

1. Investigation of the stress distribution in the bottom flange of beam A-14-612a after its reconstruction.

2. Investigation of the strain distribution in the bottom flange of beam D-18-12-816a.

3. Observations on beams E-18-12-816a and b.

II. GRAPHICAL REPRESENTATION OF RESULTS

The results of the stress and the strain investigations referred to in this report are given in the accompanying 7 graphs:

Drawings 70 and 71 show the stress distribution on both load points of A-14-612a after reconstruction.

Drawing 72 shows the way how this beam has been reconstructed, and the characteristics of beams E-18-12-816a and b.

Drawings 73, 74, 75 show load - strain curves for D-18-12-816a at different points of the bottom flange and at different spans and loadings.

Drawing 76 shows similar load strain curves of D-18-16-808a for purposes of comparison.

III. STRESS DISTRIBUTION IN BEAM A-14-612a.

It had been mentioned in the 6th Report (Section VII, 4) that the stress ratios of the beams of series A were all higher than those reported on in the 6th report. Furthermore it is seen from the Summary Report, section V, table 3 that among the four beams tested of series A beam A-14-612a has an excessively high stress ratio of 2.48 (cf.A-14-610a with 1.25 in that table). As mentioned in the 6th report cited above, it was believed that these high ratios are due to the fact that the welds in the web of series A are located 1 in. above the bottom flange. This provides for both halves of the flange a certain freedom to move sideways individually which, it was stated, increases the stress ratio. This effect was thought to be further increased in its influence on this particular beam A-14-612a since during the stress investigation on this beam several spot welds near the support had broken and the two parts of the beam spread apart about 1/4 in. Since from the point of view of manufacturing beams of maximum efficiency (i.e. with the minimum obtainable stress ratio) it is important to investigate the influence of the location of spot welds, beam A-14-612a was subjected to reconstruction. In order to eliminate as far as possible the possibility of sideway motion of the two parts of the flange, bolts were placed in the web along the bottom flange in a manner shown on drawing 72. Care was taken that the quadratic plates on both sides of the web actually fitted as closely as possible right into the corner of web and flange. It is believed that by this method horizontal motion of the flange parts is practically prevented.

Stress investigations were made at both load points, the results of which are given on drawings 70 and 71. If these graphs are compared with the corresponding ones without bolts (drawings 38 and 39 of 5th Report), the difference is immediately seen. It is remarkable that the stress concentration near the web is very marked in the original beam (no bolts, some spot welds failed) but that very little concentration was observed after reconstruction (cf. especially mid-plane stress graphs). This fact is still more evident from the following table of stress ratios:

TABLE 1

Ratio of stresses at joint of web and flange to stresses at outer edge of flange at load point. Beam A-14-612a,

Condition	Stress Ratio, Test	Stress Ratio, Theory	Difference
Spot welds (some failed)	2.48	1.15	100%
Bolts,			
load point A	1.125	1.15	- 2%
load point B	1.22	1.15	+ 6%

It is seen from this table that whereas before reconstruction the actual stress ratio is about twice as large as the theoretic stress ratio for the beam, after reconstruction these values are nearly equal. This proves the point predicted in the 6th report, namely, that in beams of present design the possibility of sideway motion is of great influence on the stress distribution.

(Considering this test only the thought may occur that the stress concentration may be due entirely to the fact that the beams tested have flanges consisting of two halves instead of being one piece and that in a beam with continuous flanges no stress concentration takes place. That this is not the case is shown not only by the analytical investigation but also by the tests made on rolled WF sections; cf. 6th Report, sections 5 and 6).

It is thus seen that in manufacturing such beams care has to be taken to see that the flange is designed in such a way that the minimum possible stress ratio, i.e. the maximum efficiency of the beam is actually obtained. This will always be the case in beams with one piece plane bottom flanges. It will be a matter of further tests to investigate how close this ideal condition can be approximated by beams of the present design.

Table 3 further emphasizes the fact that light gage beams are subject to considerable non-uniformities in their different parts. This is seen from the difference in the stress ratios at both load points of A-14-612a. Similar observations have been reported on previously (cf. 6th Report, table 2, D-18-16-808a and section VII,6).

IV. STRAIN OBSERVATIONS ON BEAM D-18-12-816a

This wide flange beam (flange width 16 in.) as received showed again very marked waves in the bottom flange. Such waves repeatedly have been referred to before. In order to more clearly demonstrate the nature of these waves, the accompanying series of photographs of this beam has been made. The photographs of the beam are made with 12 ft. span, loaded at the quarter-points. Pictures 1 and 2 are taken at a load of 2 P = 500 lb., pictures 3 and 4 at 2 P = 1,500 lbs. and pictures 5 and 6 at 2 P = 6,000 lbs. It is clearly seen that the waves are of greatest amplitude at the lowest load and gradually disappear with increasing load, i.e., as the flange stresses increase.

The influence of this fact on the behavior of this beam is clearly seen from the load-strain diagrams on drawings 73, 74, 75. These graphs show the complete absence of proportionality between load and strain. It is seen that at lower loads the strains measured near the outer edges of the flange (i.e., where the waves are greater) either increase very slowly or, in some cases are even negative (compression). With increasing load the strains at these points gradually increase, and, in case of compression, become tension. The strains measured near the web behave more regularly since the waves usually do not extend close to the web. But even there it is seen that there is no proportionality. With some exceptions the slope of these curves is smallest at lower load and increases with load increasing. This indicates that at lower loads (maximum waves) the outer parts of the flanges take little part in carrying the load and hence more stress is thrown on to the inner parts of the flange. With flattening of the waves the outer parts gradually come into play thus taking over an increasing part of the total tensile force. As a result the slope of the curves for the points near the web increases with increasing load.

It is evident that it would be futile to draw any quantitative conclusions (magnitude of stresses) from these observations since their numerical values obviously are entirely accidental. They depend largely on whether the point where the strains are measured is located on the crest or in a trough or at any other part of a wave.

For purposes of comparison similar graphs for D-18-16-808a are given on drawing 76. Here as well as on drawings 2 to 14 of the 2nd Report it is seen that beams not having such waves show a clear proportionality between load and strain over the entire load range.

(NOTES BY MILTON MALE)

As sent with the original copy of this report, this page contained six (6) photographs showing views of opposite sides of Beam D-18-12-816a. As explained in Section IV, these photographs indicated that at increasing loads the presence of waves in the lower flange of the I-Beam tended to disappear and at a load of 6,000 pounds the flange straightened almost completely.

The difficulty of clearly reproducing photographs by the processes usually available in these offices, and the fact that the behavior of the Beam in question could be almost as clearly visualized with the aid of the explanatory matter, prompted me to omit the photographs from the report. I assume that they will be included in the final report when ready for publication and that the omission of them from this progress report as submitted to Members of the Committee will not in any way detract from its usefulness.

The fact is remarkable that D-18-16-808a, having 18 gage material in the bottom flange (flange width 8 in.) shows practically no waves whereas D-18-12-816a (flange width 16 in.) having the same flange thickness, has very marked waves in the flange. The twin specimens of these two beams have exactly corresponding characteristics. It therefore seems, that with the given method of manufacturing and for beams without stiffeners at the outer edges of the flange, there is a definite maximum flange width beyond which it is not possible to produce beams with sufficiently plane flanges. It is clear that beams like D-18-12-816a cannot be used in construction since their properties and behavior are unpredictable.

V. OBSERVATIONS ON BEAMS E-18-12-816 a and b

About half of the stress investigation of E-18-12-816a had been completed when this beam suddenly failed in a very peculiar manner. Welds "b" failed with a rather mild crack over about 2/3 of the length of the beam and the two parts of the beam spread apart as shown on drawing 72. The welds failed only between the two parts of the web which separated about 3/8 in. whereas the spot welds fastening the flange to the web did not fail except in a few isolated places.

Visual inspection revealed that along the whole length where failure occurred, only 5 or 6 of the welds joining the webs together had fused whereas all the other welds had not formed at all. Moreover some of those welds were placed right on the edge of the bent down portion of the flange and some of the welds were missing altogether. Inspection further revealed that welds "a" also were made very irregularly, their distance from the flange varying from 3/8 in. to 3/4 in. Another irregularity in this beam is that the top flange is not plane but bent up as shown on drawing 72. This makes correct loading exceedingly difficult.

It had been intended to proceed with the investigation on the twin specimen of this beam. However on inspection this beam showed even worse characteristics. The spacing of welds "a" was just as bad and so was the bent up form of the top flange. Moreover over 3/4 of the length of this beam there was not a single spot weld "b" joining the two parts of the web. It was therefore necessary to reconstruct this beam before any testing could be done on it.

Since it was not possible to make in our mechanical shop spot welds of the present type, the two parts of the beam were joined together by placing tack welds 4 in. c.c. on the top surface of the top flange. The metal of these welds went well down into the joint thus connecting not only the two parts of the flange but also welding together both parts of the web. In addition bolts were placed in the web along the bottom flange in the same way as on beam A-14-612a. The work on this beam is not yet completed and will be reported in the next report.

The bottom flanges of these beams look rather straight without any waves. This is thought to be due to the presence of the bent up stiffeners on the outer edges of the flange. The strain observations taken so far, correspondingly, do not reveal the characteristics discussed above for D-18-12-816a. More details about these facts will be given after completion of the tests on this beam.

VI. CONCLUSIONS

1. Tests on beam A-14-612a after reconstruction again showed good coincidence of the stress distribution with that determined analytically.

2. Stress investigations made on both load points of this beam showed some difference due to varying properties of the beam.

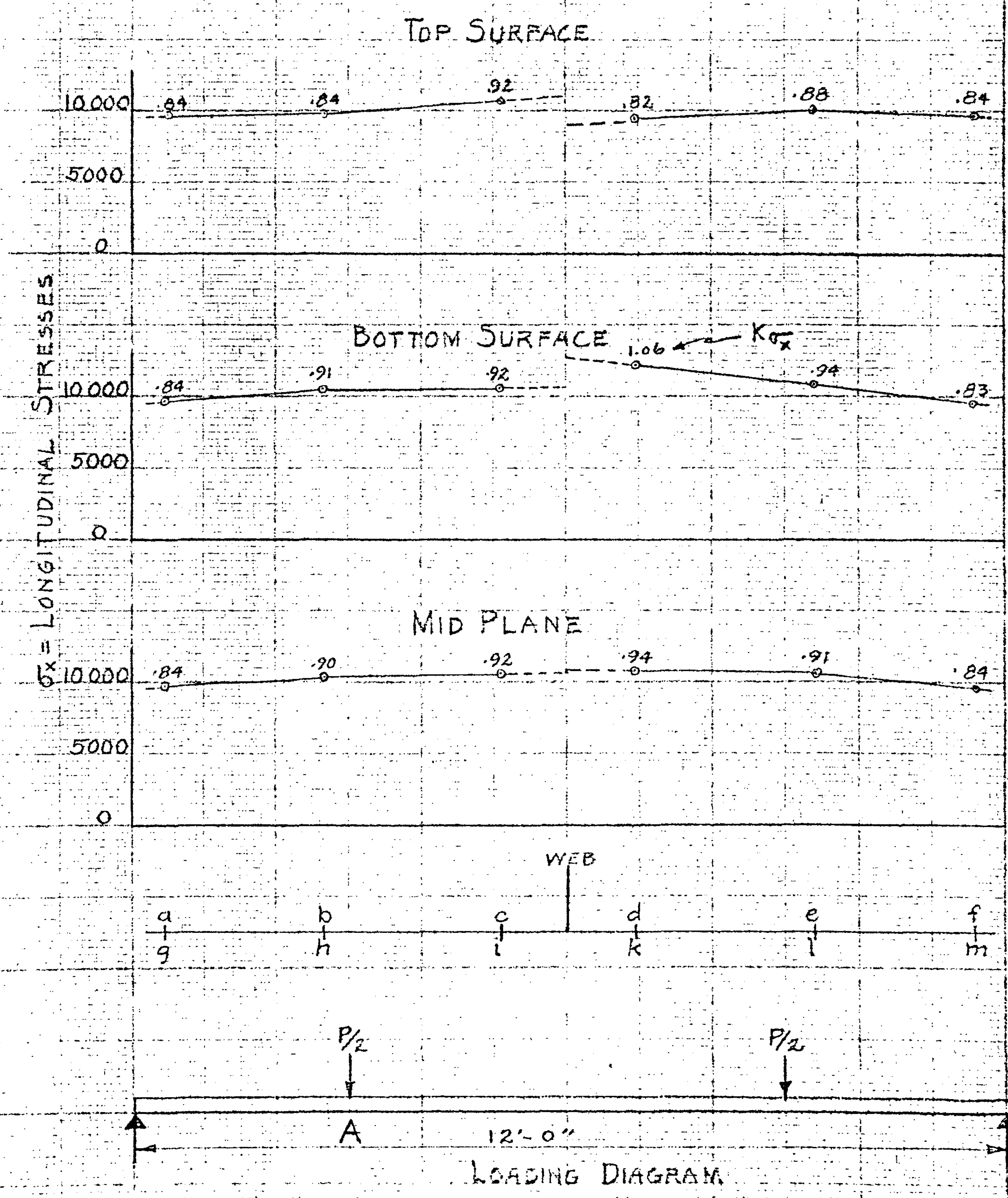
3. Comparison of the stress distribution of this beam before and after reconstruction reveals the importance of designing the beams in such a way that separate lateral motion of the halves of the flange is made impossible. If such motion takes place it greatly increases the stress concentration near the web and thus diminishes the efficiency of the beam; that is, the welds must be accurately made as well as placed in the most advantageous position.

4. Tests on D-18-12-816a revealed the significance of the presence of waves in the bottom flange. Waves of the magnitude of those of this beam make the stress distribution entirely uncertain. The outer parts of the flanges take little part in the work of the beam and consequently the inner parts are apt to be overstressed. Beams of that sort cannot be used in practice with any reasonable amount of certainty as to their behavior.

5. So far incomplete tests on D-18-12-916a and b seem to show that the formation of such waves is at least greatly reduced by the use of bent up stiffeners on the outer edges of the flange.

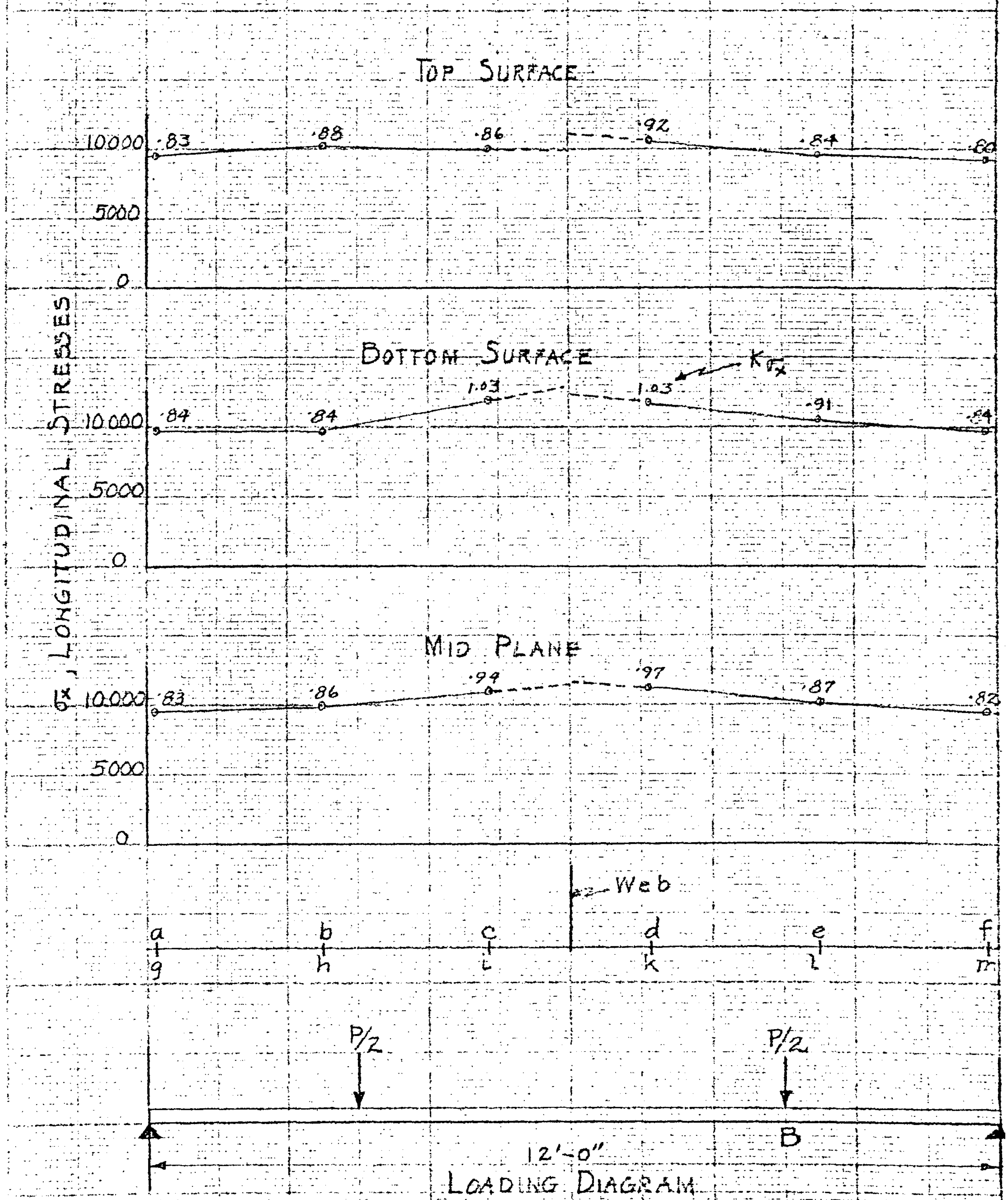
STRESS DISTRIBUTION IN BOTTOM FLANGE AT LOAD POINT "A"

A-14-612a



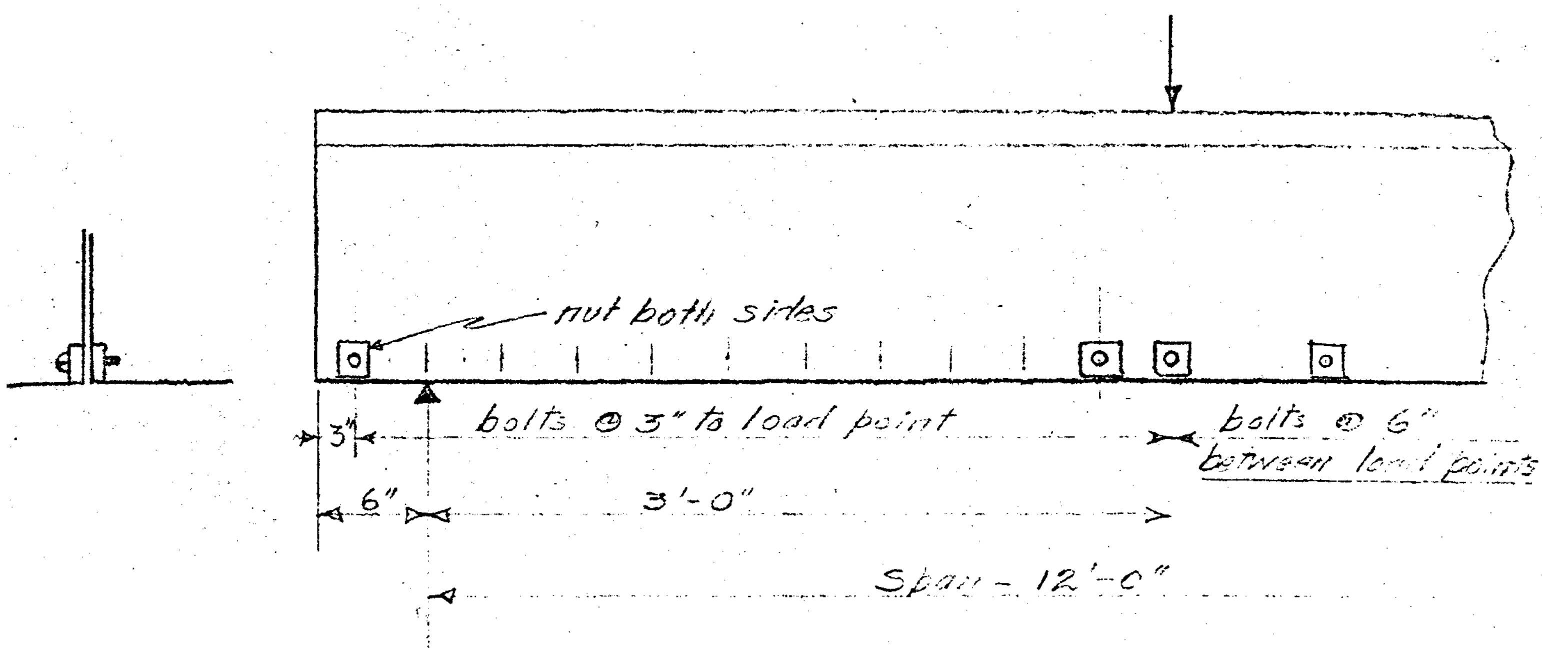
STRESS DISTRIBUTION IN BOTTOM FLANGE AT LOAD POINT "B"

A-14-612a

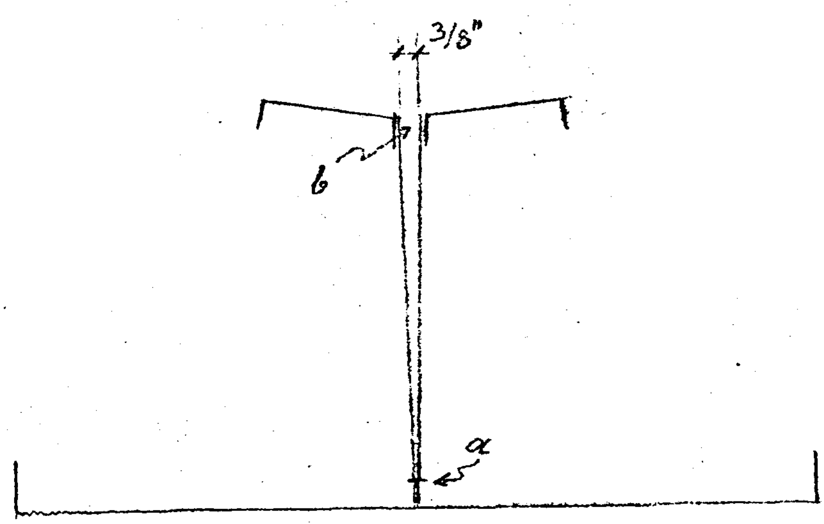


A-14-612 a

LOCATION OF BOLTS

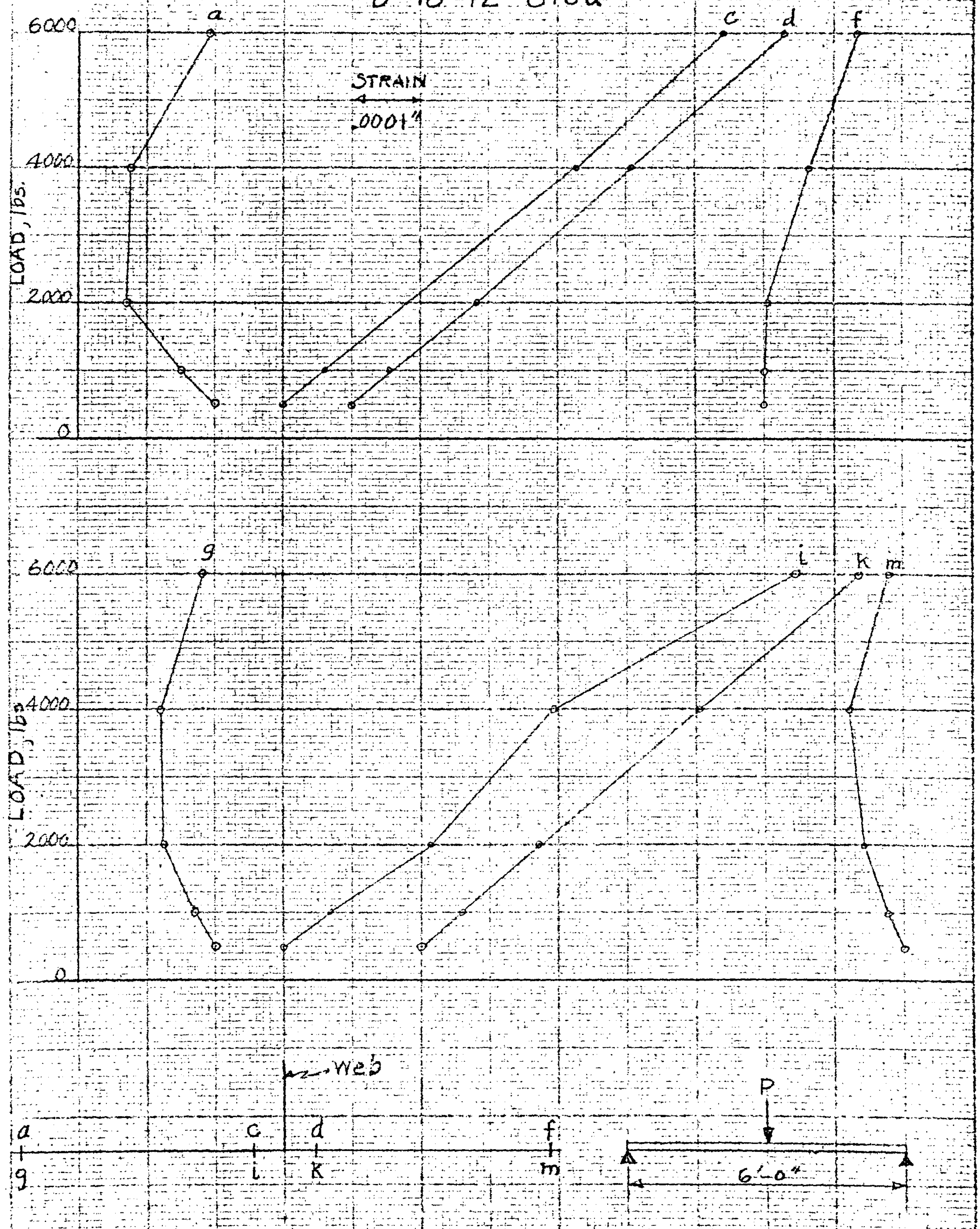


E-18-12-816



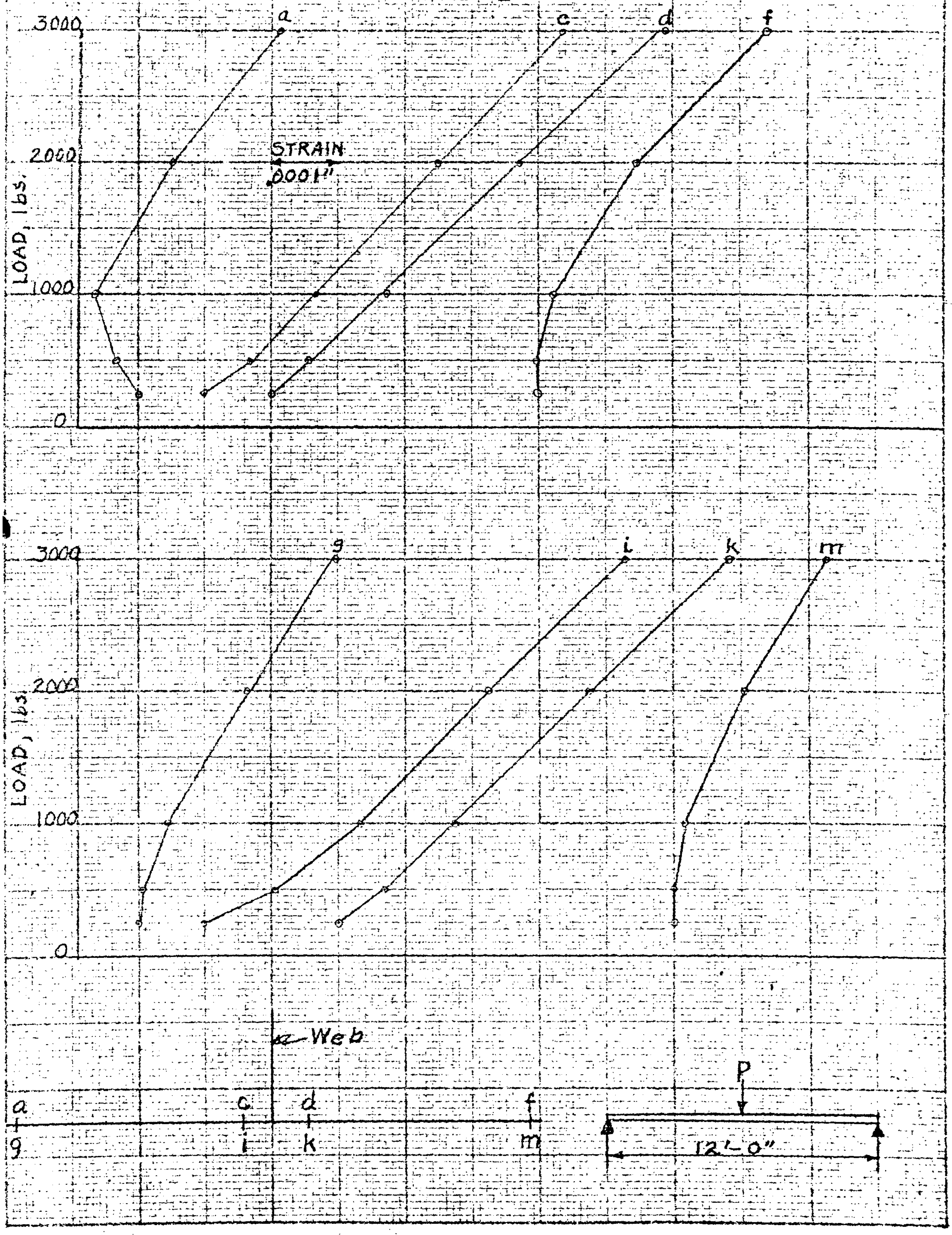
STRAIN DISTRIBUTION IN BOTTOM FLANGE AT LOAD POINT

D-18-12-816a

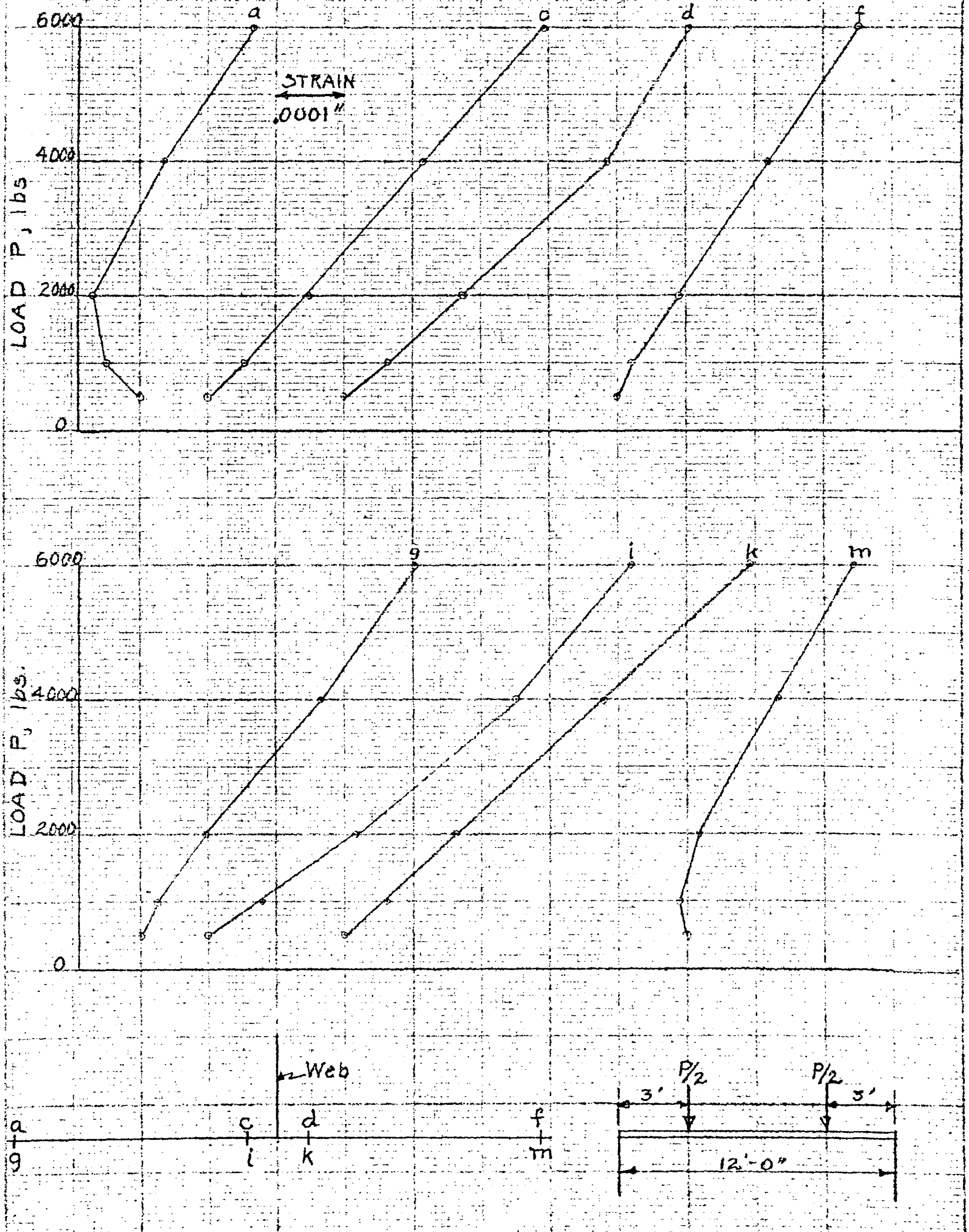


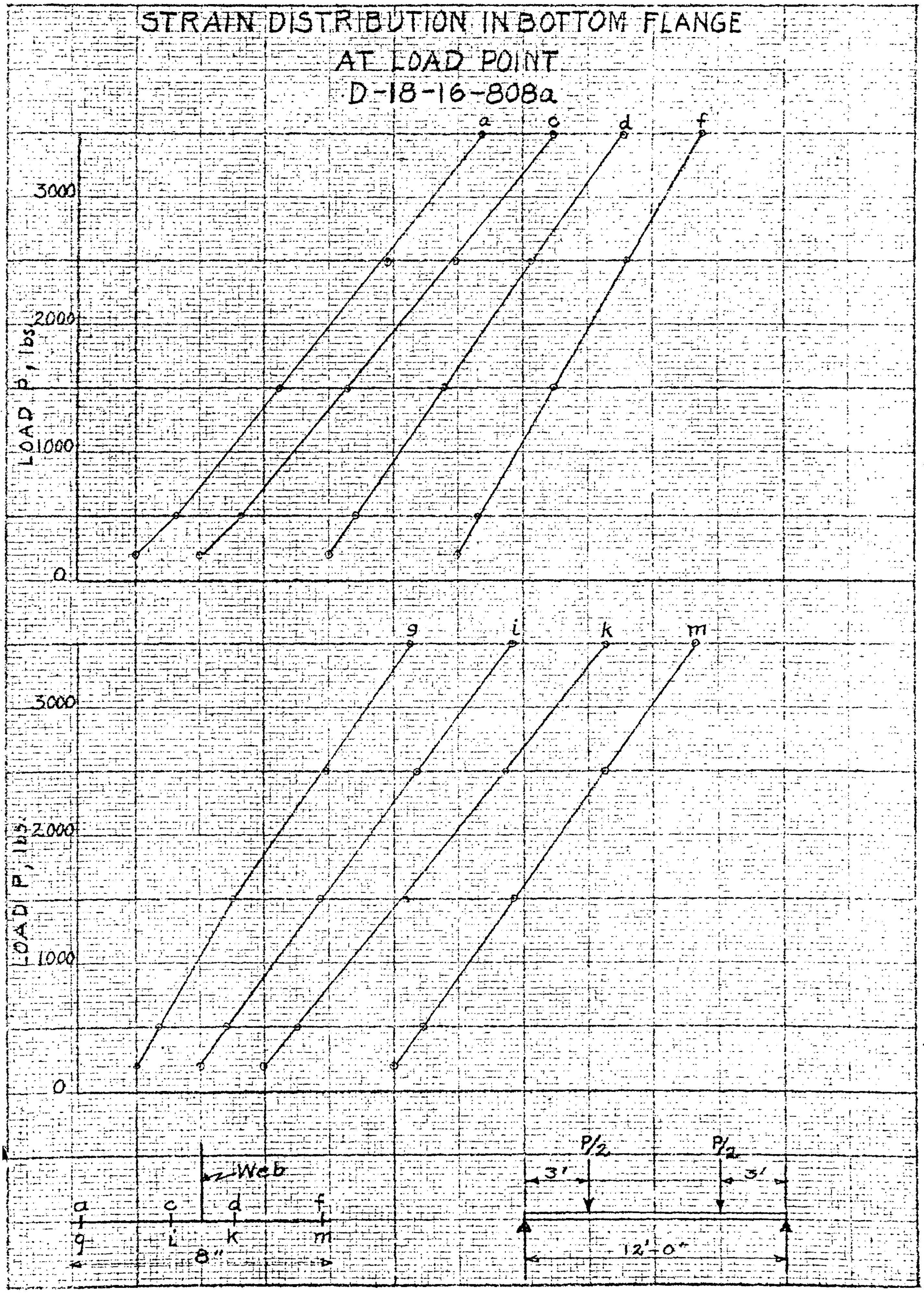
STRAIN DISTRIBUTION IN BOTTOM FLANGE AT LOAD POINT

D-18-12-816a



STRAIN DISTRIBUTION IN BOTTOM FLANGE AT LOAD POINT
D-18-12-816a




STRAIN DISTRIBUTION IN BOTTOM FLANGE
AT LOAD POINT
D-18-16-808a
a
c
d
f
LOAD P, lbs.
3000
2000
1000
0
g
i
k
m
LOAD P, lbs.
3000
2000
1000
0
Web
a
c
d
f
g
i
k
m
8"
P/2
P/2
3'
3'
12'-0"