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

Cornell University School of Civil Engineering

(Copied by Milton Male for transmission to the Building Codes Committee)

SCHOOL OF CIVIL ENGINEERING, CORNELL UNIVERSITY

# TESTS ON LIGHT BEAMS OF COLD FORMED STEEL FOR THE AMERICAN IRON AND STEEL INSTITUTE

SECOND PROGRESS REPORT, APRIL 25, 1939

## I. OBJECT OF THIS REPORT

After having obtained preliminary information from the abbreviated tests referred to in the previous report, a detailed survey of the stress distribution over the bottom flange at midspan has been carried out for the beams A-14-612b, A-14-612a and A-14-68a (in chronological order). Furthermore a special investigation has been made at the same section of beam A-14-612a for the purpose of determining the accuracy of the actual strain measurements.

## II. METHOD OF TESTS

In general the same method, as described in section VI of the previous report, was used for mounting and loading the beams, observing the deflections and mounting the strain gages. But whereas in the previous work only longitudinal strains were measured, longitudinal as well as transverse strains have been observed at all points in the present survey. Since, by symmetry, the directions of the principal stresses at midspan are bound to coincide with the longitudinal and transverse directions in which the strains were measured, these observations give direct information on the magnitude of the principal stresses in the bottom flange. These stresses were computed from the observed strains by means of the relation

$$\sigma_x = \frac{E}{1 - v^2} (e_x + ve_y)$$

$$\sigma_y = \frac{E}{1 - v^2} (e_y + ve_x)$$

where $\sigma_x$ is the principal stress in the longitudinal and $\sigma_y$ the principal stress in the transverse direction, $e_x$ and $e_y$ the observed strains in the longitudinal and transverse direction respectively, E the modulus of elasticity and v Poissons ratio

## III. GRAPHICAL REPRESENTATION OF THE RESULTS

The results of the tests referred to in both this report and the previous one are given on the accompanying 20 graphs.

Sheet 1 shows the load deflection curves of the beams A-14-612 a and b, A-14-68a and A-14-64a and the cross section dimensions at midspan.
Sheet 2 gives the strain magnitudes of the preliminary survey of beam A-14-612a.
Sheets 3, 4 show the longitudinal and transverse strains as measured on 8 points of beam A-14-612b.
Sheets 5-12 give the longitudinal and transverse strains at each of 12 points of each of the beams A-14-612a and A-14-68a. (It is to be noted that the longitudinal strains are elongations, the transverse contractions).
Sheets 13 and 14 show the results of special measurements taken to determine the accuracy of this investigation. (Explanation see section IV of this report).
Sheets 15, 17, 19 give the stress distribution over the top and bottom surfaces of the bottom flange of the beams A-14-612a and b and A-14-68a respectively.
Sheets 16, 18, 20 give the stress distribution in the middle plane of each of those beams and the transverse bending stresses corresponding to the upward bending of the flanges mentioned in section VIII a in the previous report. The stresses in the middle plane were determined as the mean of the stresses on top and bottom of the flange at each point; the bending stresses represent the difference between these middle plane stresses and the stresses on the top and bottom surface.

## IV. ACCURACY OF STRAIN MEASUREMENTS

Since the experimental points as recorded on sheets 2 to 14 fall on very smooth curves, the uniformity of the work of the strain gages over the given range is well established. However the stresses computed from these strains (sheets 15 - 20), although having very marked general trends, show appreciable irregularities in detail. These irregularities may be the result of a) instrumentation, the set up of the beam or other features of the test method resulting in erroneous measurements, or b) deviation of dimensions of the beams which consequently would result in irregularities in the stress distribution. Actually the following irregularities have been observed on the specimens: lack of symmetry and the presence of trays and bumps especially near the edges of the bottom flanges. Visual inspection showed that these trays and bumps straightened out under load and reoccurred after unloading.

In order to determine the reliability of the set up, the following procedure was chosen: The longitudinal strains at points a, g, f and m of beam A-14-612a (see sheets 13 and 14) were measured. The first readings were taken during the general survey of this beam. Then the beam was taken out of the testing machine. Some days later the beam was again set up in the machine and the strains were measured at the same points. Leaving the beam in the machine, the gages were then removed and replaced by other gages, simultaneously applying the mounting rods in the opposite direction to that for the previous determination. Thus three entirely independent measurements were obtained. The results of these tests are given in the following table:

| Point | Strains: First Set-Up | Second Set-Up | Third Set-Up | Mean Strain | Maximum Deviation From Mean |
|---|---|---|---|---|---|
| a | 5.32 | 5.55 | 5.55 | 5.48 | 3% |
| g | 3.95 | 4.15 | 3.65 | 3.92 | 7% |
| f | 4.56 | 4.85 | 4.65 | 4.68 | 4% |
| m | 5.20 | 4.90 | 5.35 | 5.15 | 5% |

Half inch gages were used for this test. The results show satisfactory accuracy and prove that the irregularities in the stress distribution curves are mainly due to irregularities of the specimens.

## V. DEFLECTION OF BEAM A-14-68a

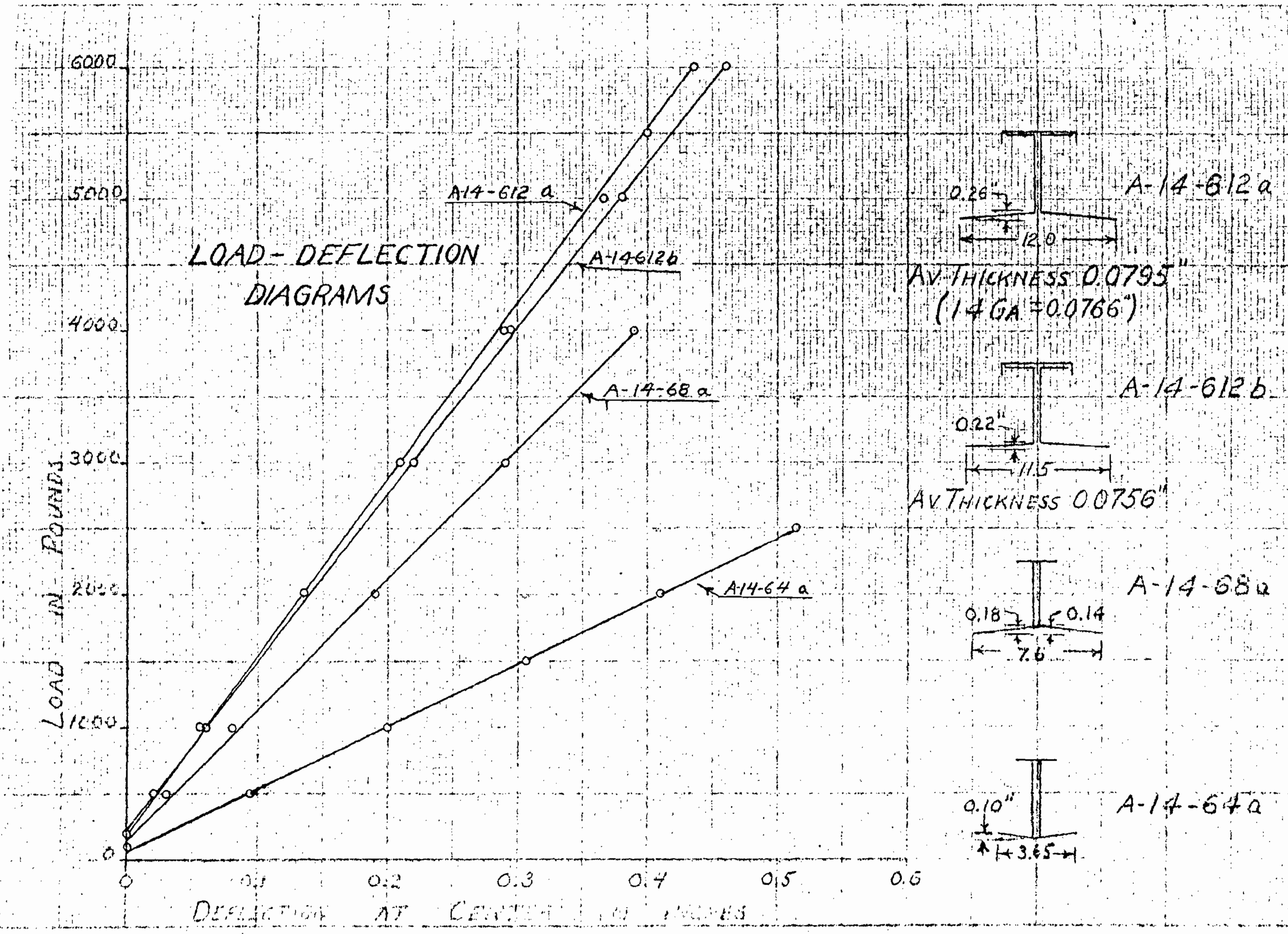
A comparison of the actual with the theoretical deflections of three of the four beams was given in Table II in the first report. At beam A-14-68a the deflection corresponding to a load increment of 3000 lb. was observed to be .310" as compared with the theoretical deflection of .324".

## VI. SPECIAL OBSERVATIONS

At higher loads several shot like sounds were heard accompanied by shocks to the beam sufficient to throw some of the gages out of position. These shocks undoubtedly originated in failures of spot welds. About half a dozen of such shocks were observed, mainly on the wide beams.

## VII. CONCLUSIONS

1) The exact linearity of the load deflection curves (sheet 1) proves that the compound sections investigated act as a monolithic unit. This is emphasized by the excellent coincidence of the actual and the theoretical deflections.
2) No decrease of the longitudinal stresses toward the edges of the bottom flanges has been observed. On the contrary, the stresses in all the beams which have been surveyed in detail show an increase toward the edges. This may be seen most clearly from the graphs of the longitudinal stresses in the middle planes (sheets 16, 18, 20 top). It is likely that this increase is due to the fact that the bottom flanges of all three beams are not plane but bent downward towards the edges, thus increasing the distances of the outer fibers from the neutral axis. However this effect will be studied in more detail in later tests when the flange will be cold bent more nearly perpendicular to the web.
3) In addition to these longitudinal stresses there exist much smaller transverse stresses in the middle plane (sheets 16, 18, 20 center) the regularity of distribution of which is best seen on the wide beams A-14-612 a and b.
4) Corresponding to the observed upward bending of the flanges (which in all three beams did not touch the stiffeners at the load points) there exist transverse bending stresses, especially near the web (sheets 16, 18, 20 bottom). These stresses increase with increasing flange width and attain considerable values (about 27% of the maximum longitudinal stresses for the 12" flanges). Due to the sizes of the strain gages strains could not be measured closer than .8" from the web. It is very likely that the magnitude of these [illegible]



LOAD - DEFLECTION DIAGRAMS
6000
5000
4000
3000
2000
1000
0
LOAD IN POUNDS
0
0.1
0.2
0.3
0.4
0.5
0.6
DEFLECTION AT CENTER IN INCHES
A14-612 a
A-14612b
A-14-68 a
A14-64 a
0.26"
12.0
A-14-612 a
AV. THICKNESS 0.0795"
(14 GA = 0.0766")
0.22"
11.5
A-14-612 b
AV. THICKNESS 0.0756"
0.18
0.14
7.6
A-14-68 a
0.10"
3.65
A-14-64 a

| Point | Strains First Set-Up | Second Set-Up | Third Set-Up | Mean Strain | Maximum Deviation From Mean |
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3) In addition to these longitudinal stresses there exist much smaller transverse stresses in the middle plane (sheets 16, 18, 20 center) the regularity of distribution of which is best seen on the wide beams A-14-612 a and b.
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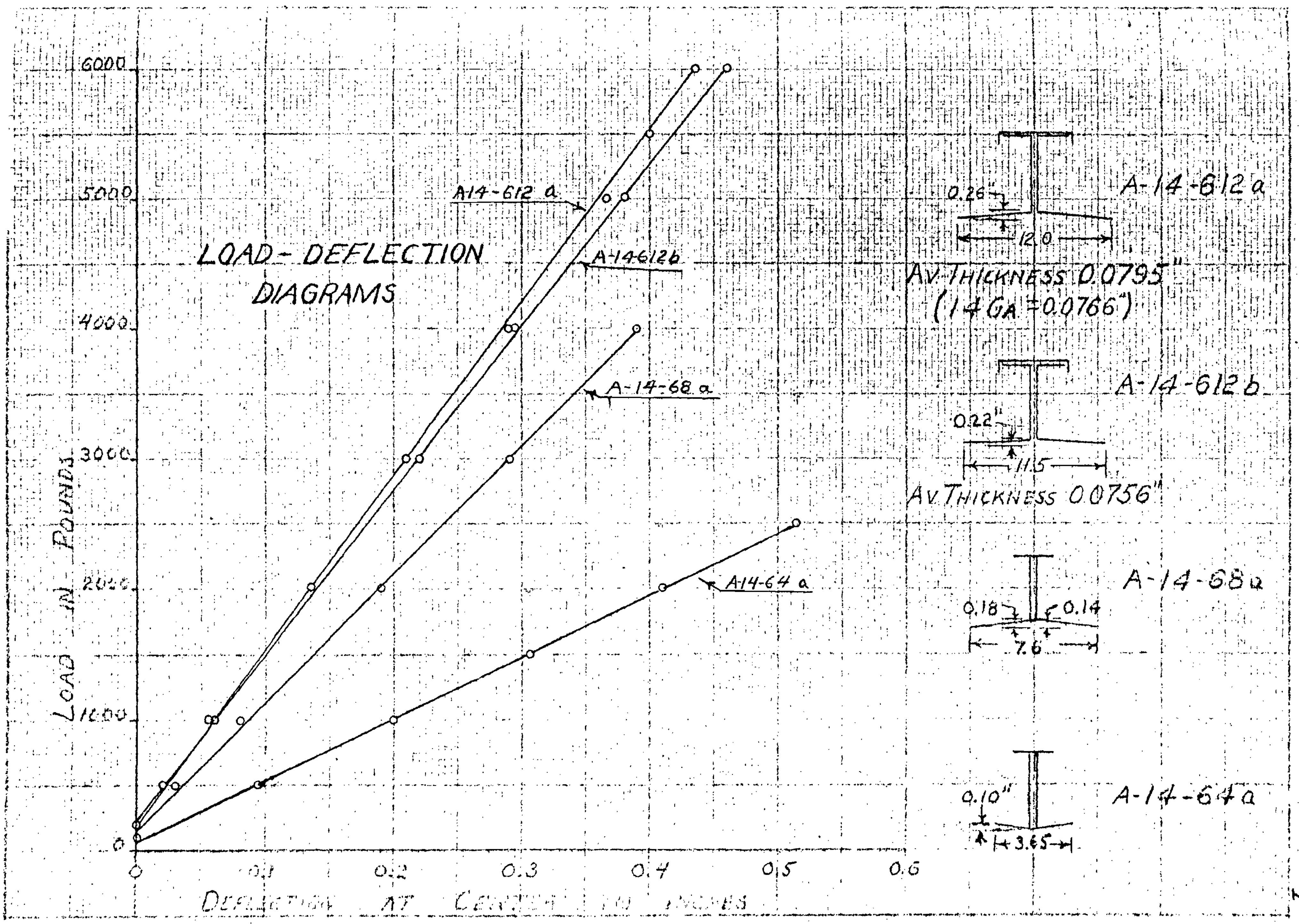
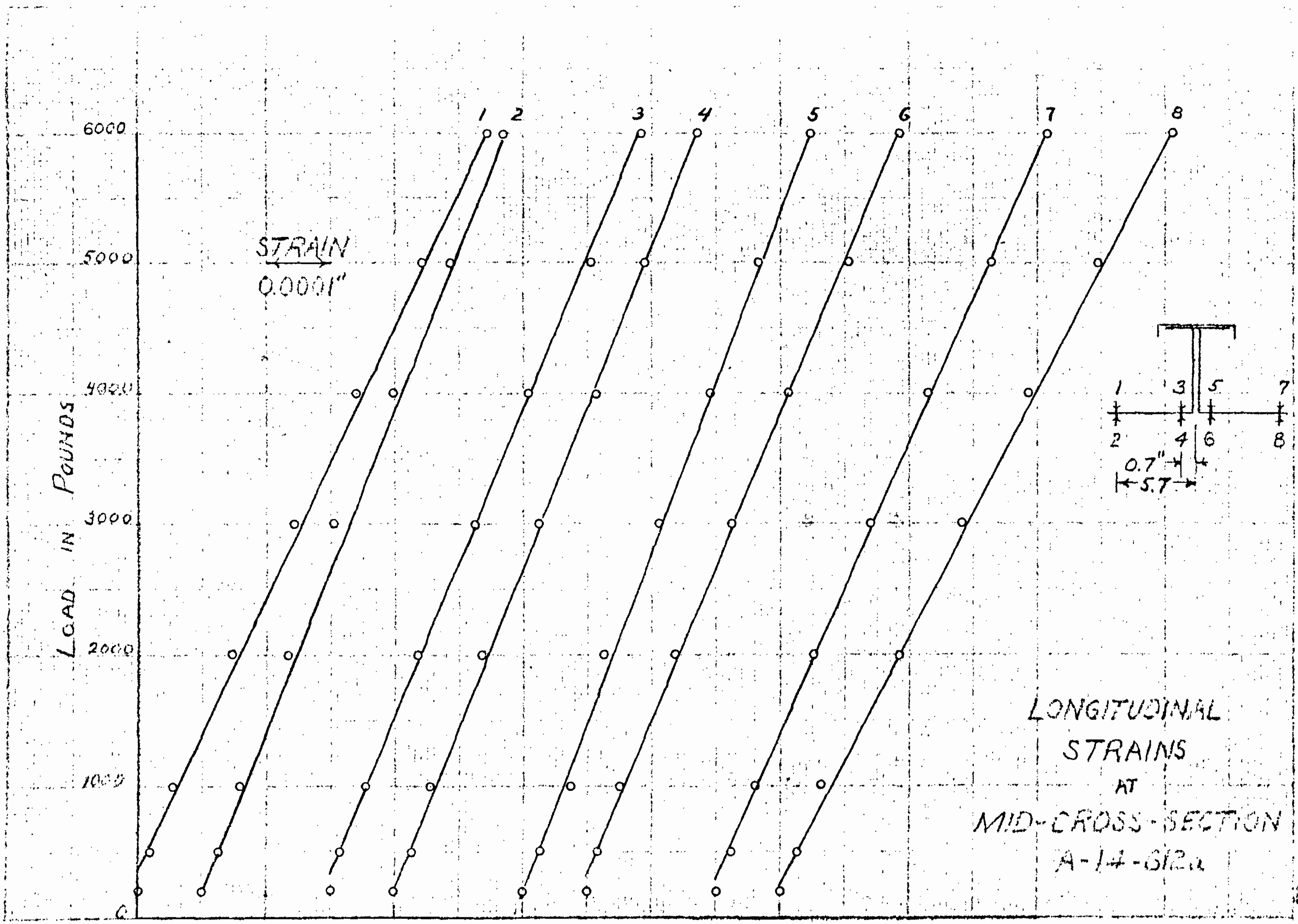
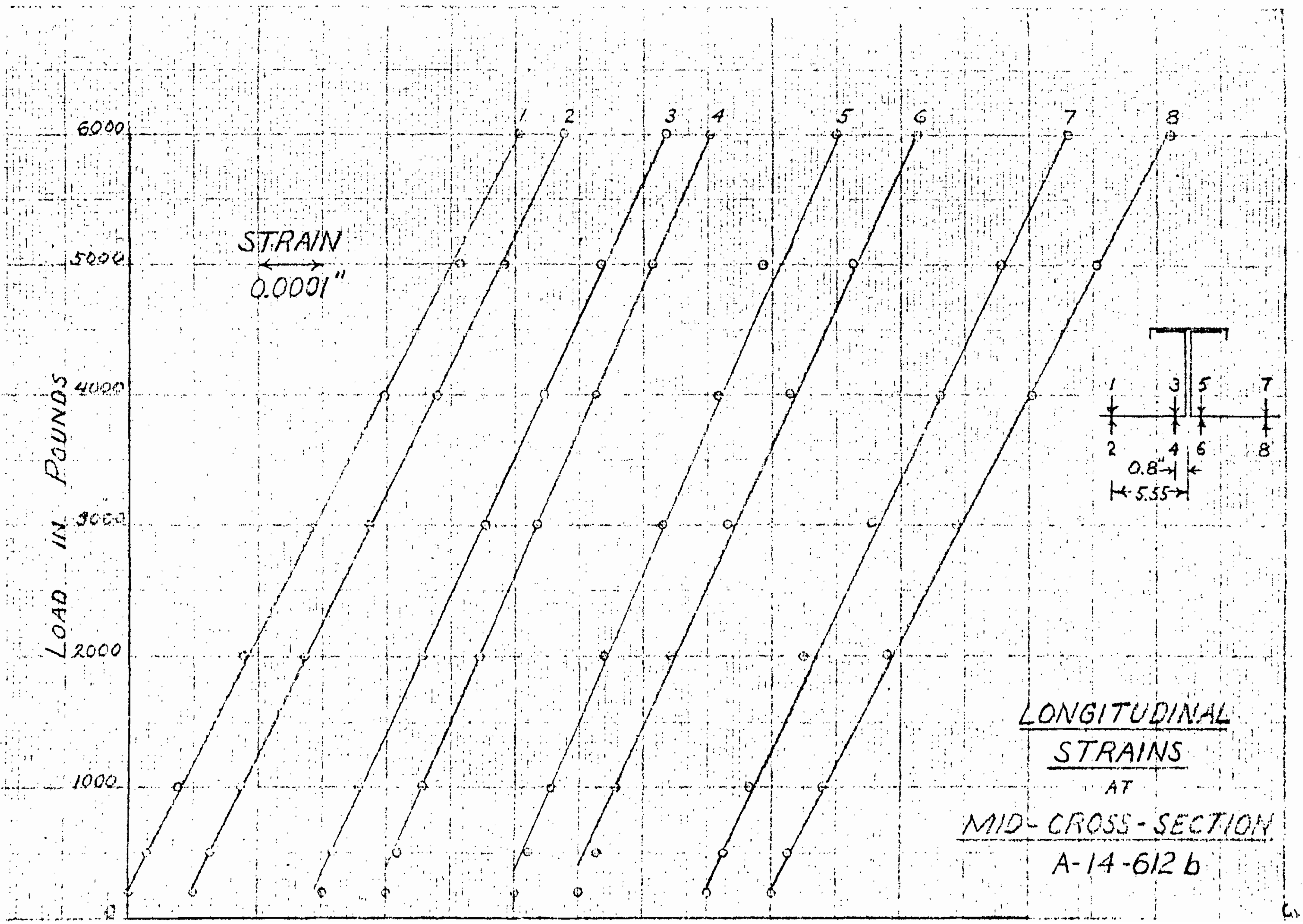
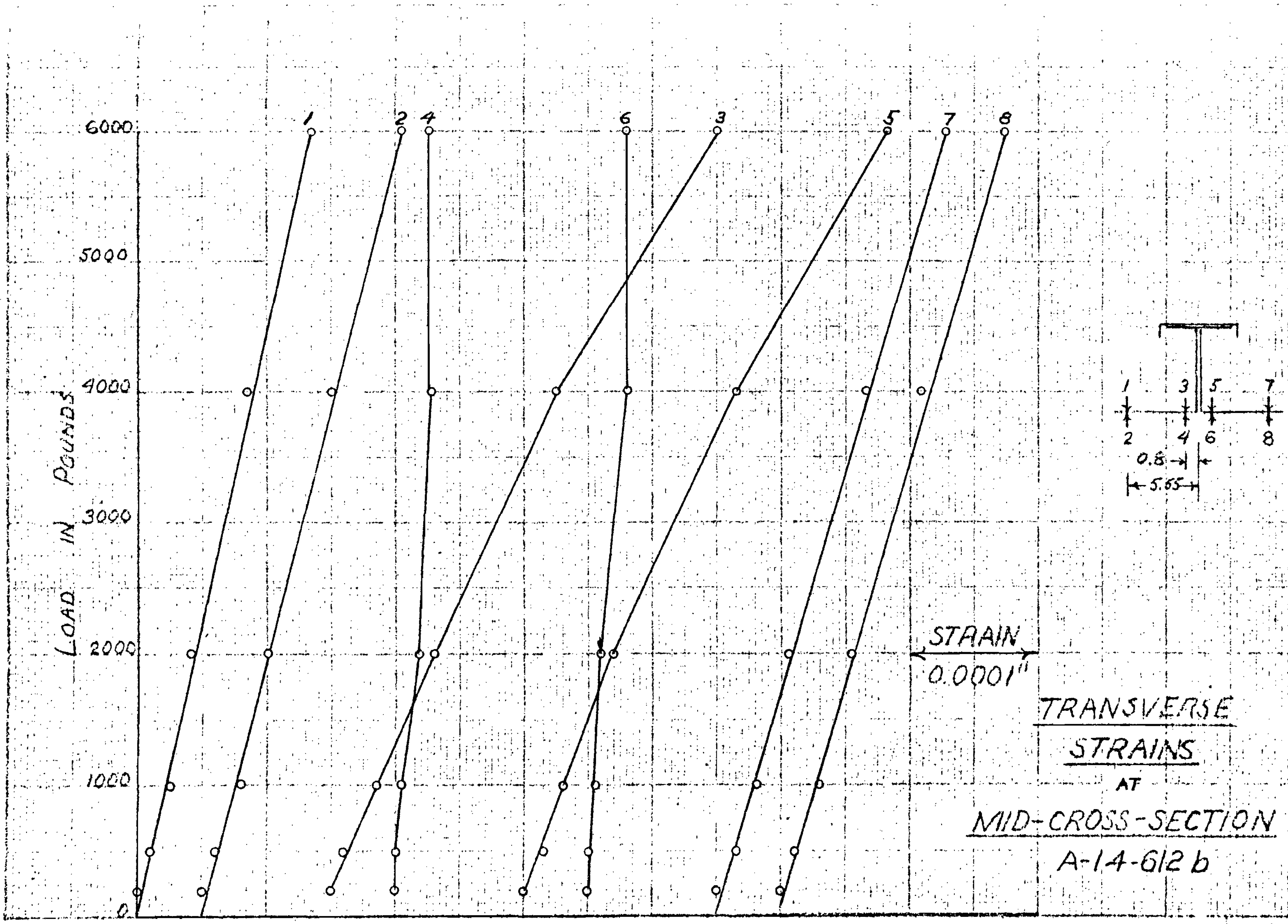


LOAD - DEFLECTION
DIAGRAMS
A14-612 a
A-146126
A-14-68 a
A14-64 a
6000
5000
4000
3000
2000
1000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
LOAD IN POUNDS
DEFLECTION AT CENTER IN INCHES
A-14-612 a
0.26"
12.0
AV. THICKNESS 0.0795"
(14 GA = 0.0766")
A-14-612 b
0.22"
11.5
AV. THICKNESS 0.0756"
A-14-68 a
0.18
0.14
7.6
A-14-64 a
0.10"
3.65

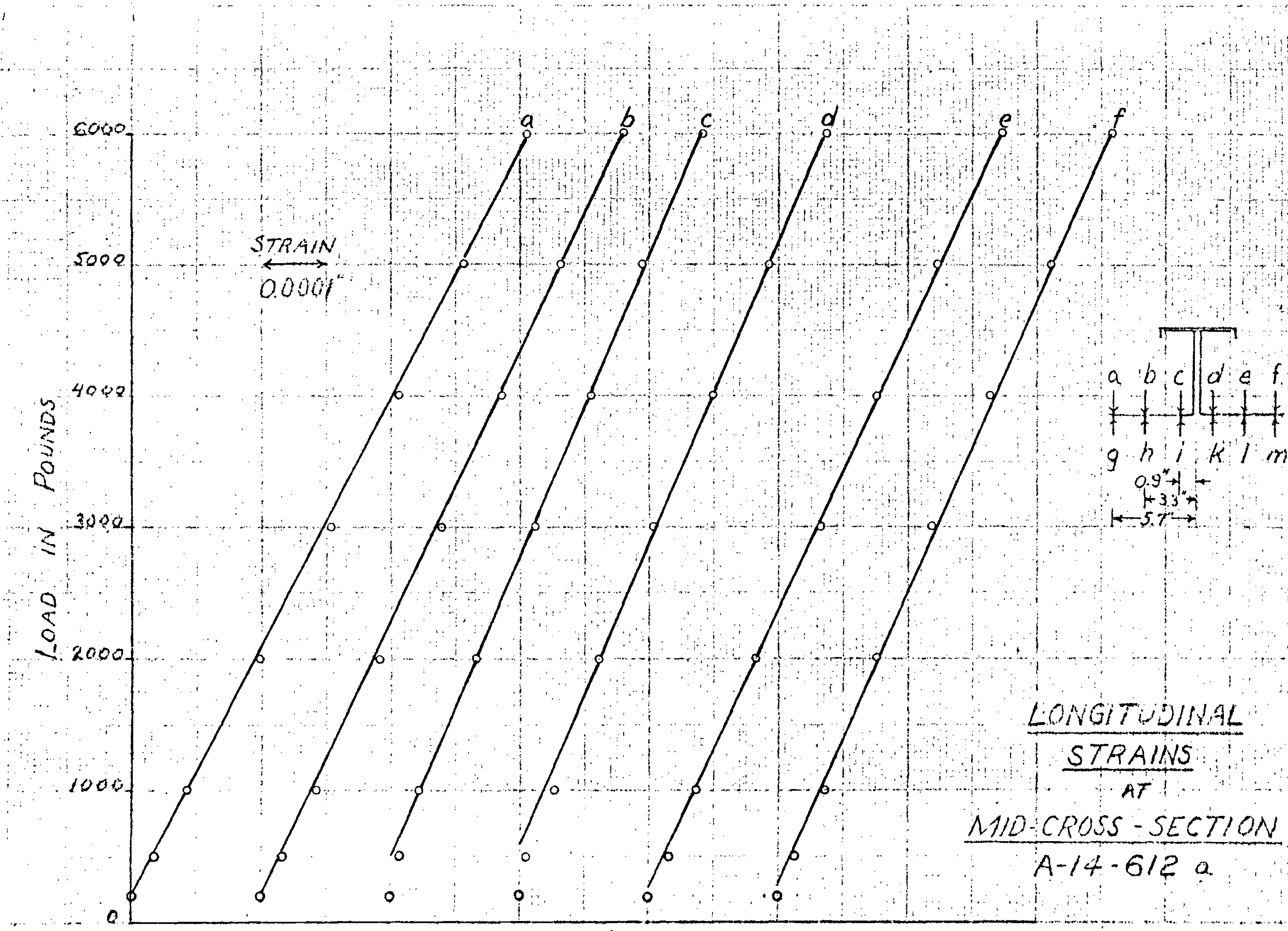


1
2
3
4
5
6
7
8
6000
5000
4000
3000
2000
1000
0
LOAD IN POUNDS
STRAIN
0.0001"
0.7"
5.7
LONGITUDINAL
STRAINS
AT
MID-CROSS-SECTION
A-14-612a

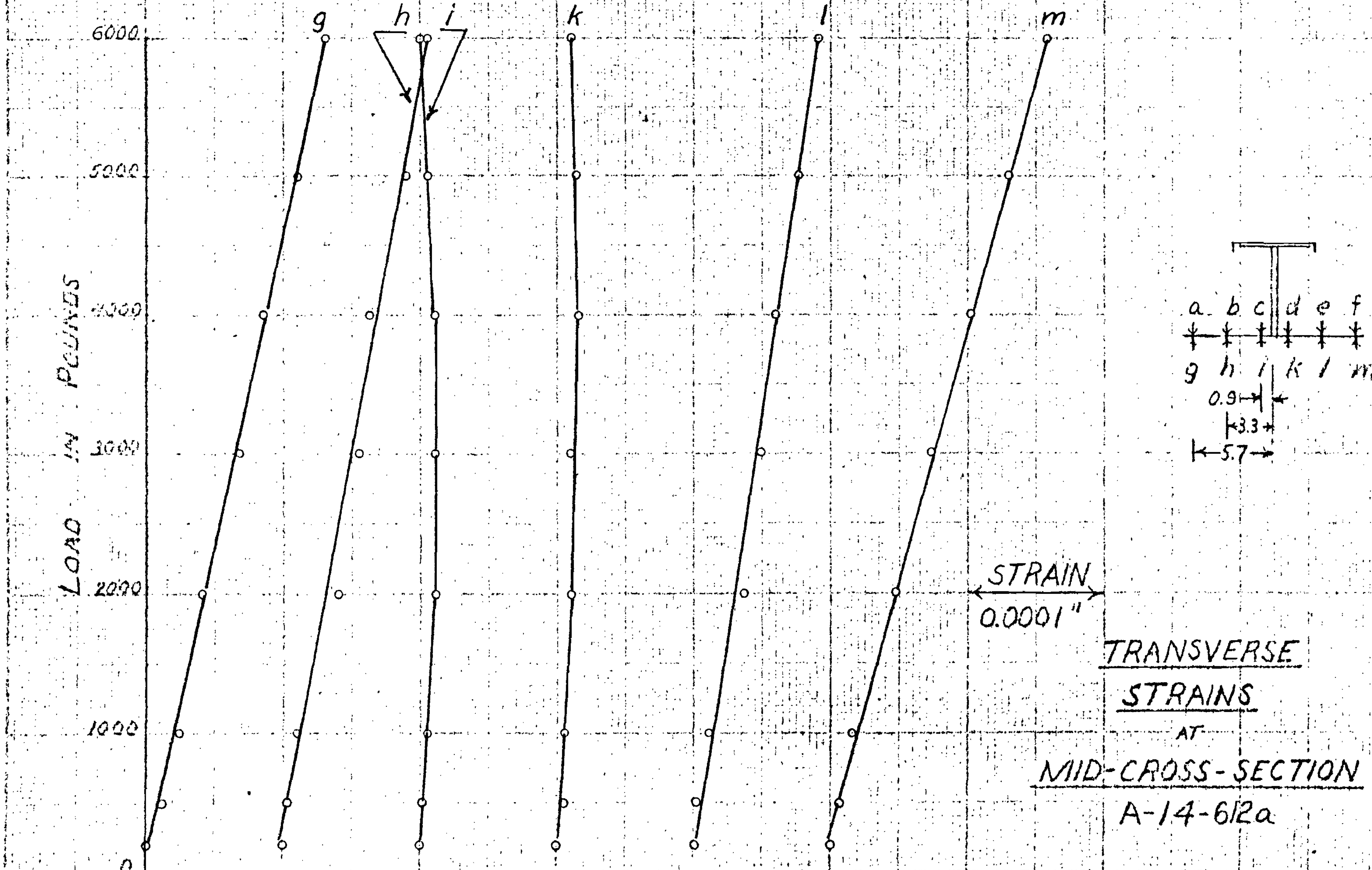

LONGITUDINAL
STRAINS
AT
MID-CROSS-SECTION
A-14-612 b
LOAD IN POUNDS
6000
5000
4000
3000
2000
1000
0
STRAIN
0.0001"
1
2
3
4
5
6
7
8
0.8"
5.55



6000
5000
4000
3000
2000
1000
0
LOAD IN POUNDS
1
2
4
6
3
5
7
8
STRAIN 0.0001"
0.8
5.65
TRANSVERSE STRAINS AT MID-CROSS-SECTION
A-14-612 b

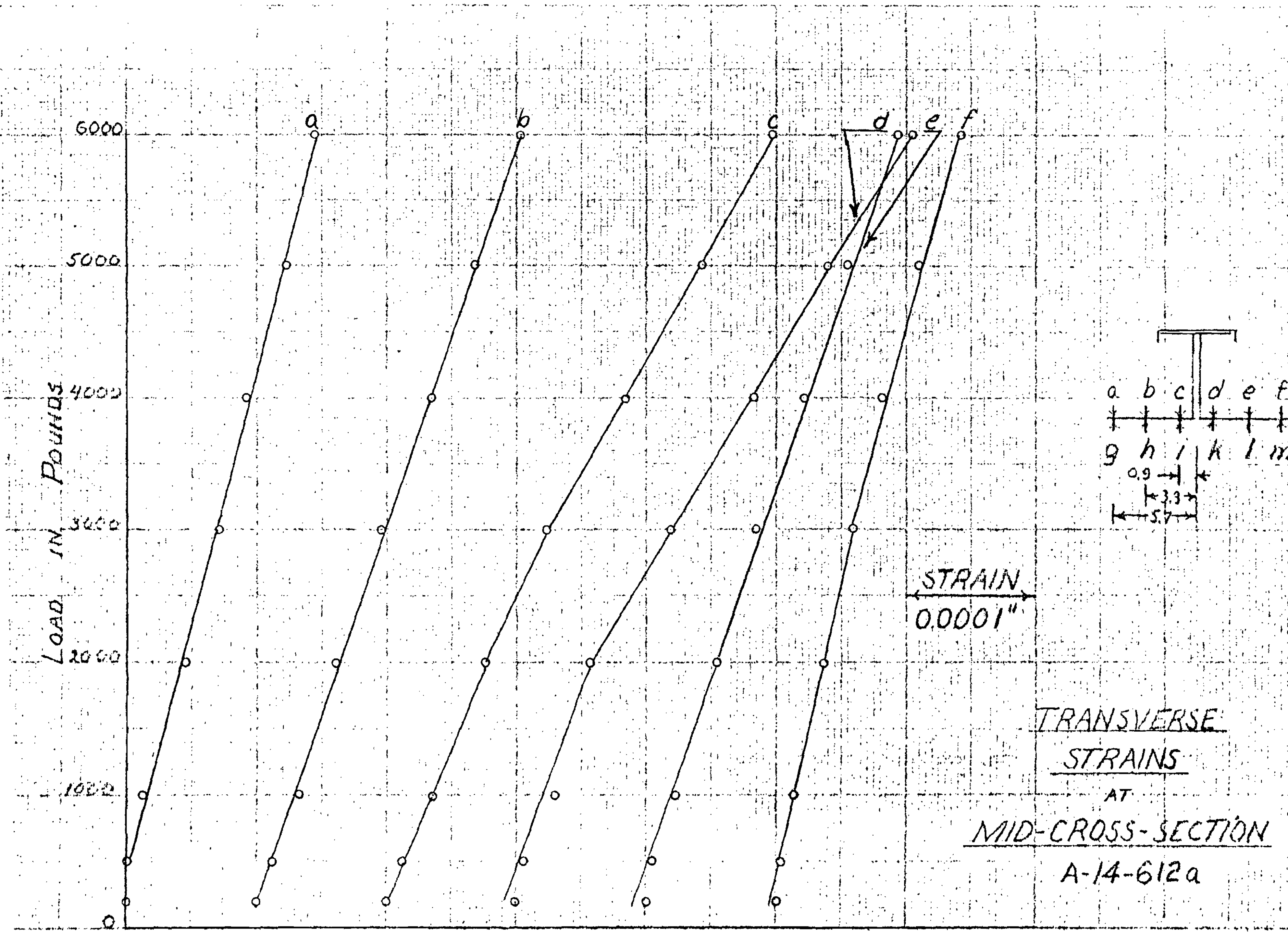


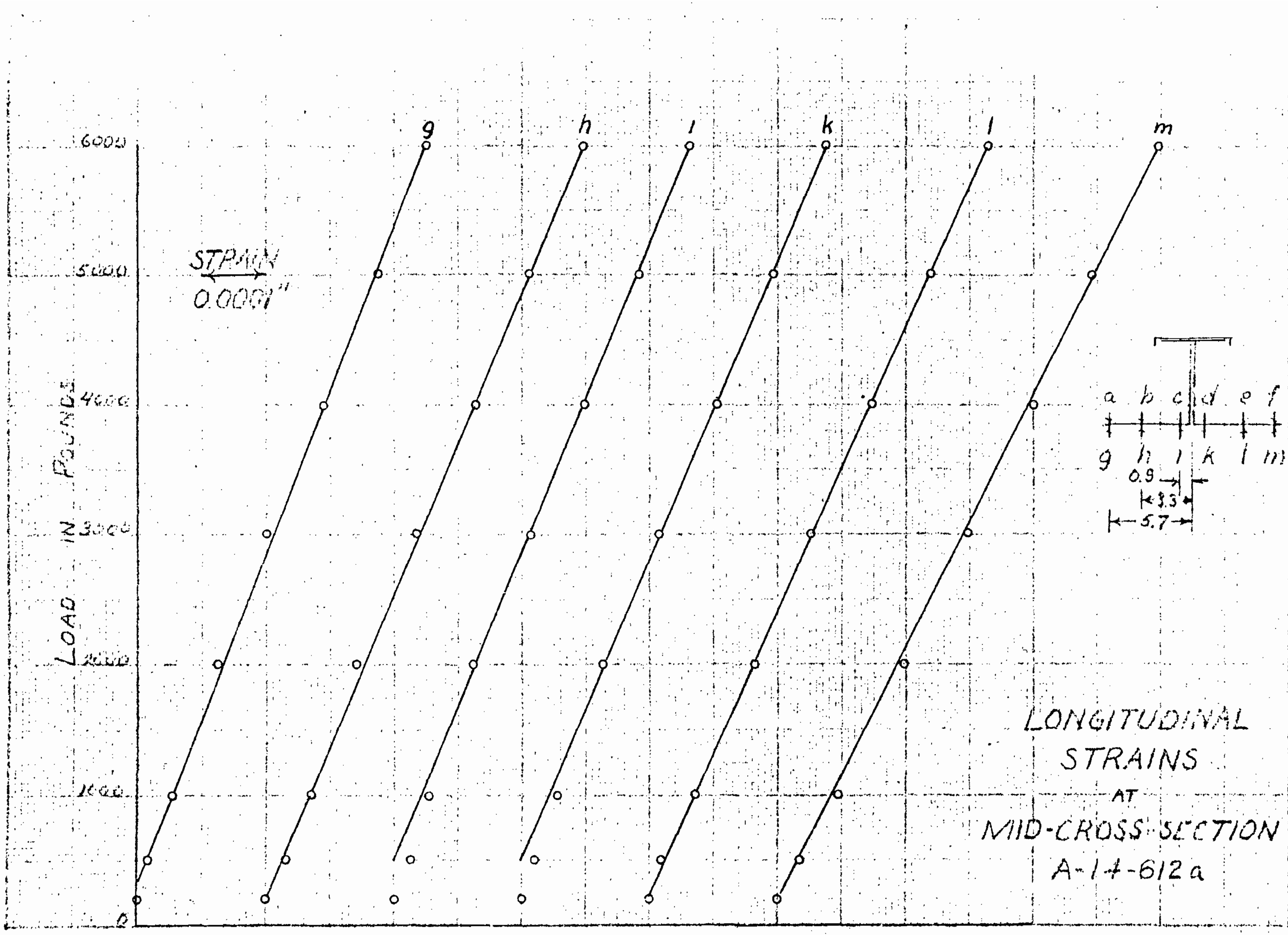

LONGITUDINAL STRAINS AT MID-CROSS-SECTION
A-14-612 a



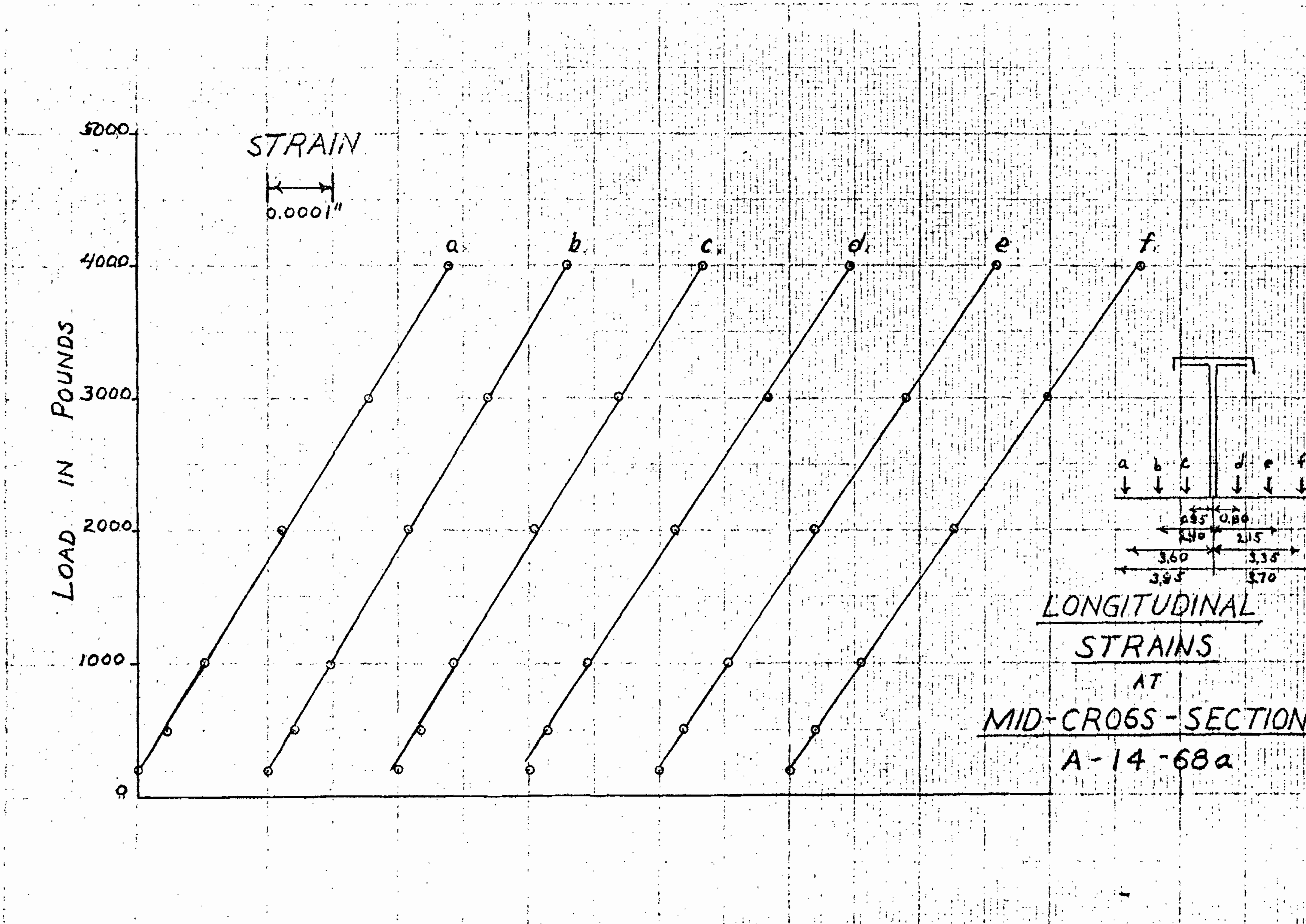

TRANSVERSE STRAINS AT MID-CROSS-SECTION

A-14-6l2a


TRANSVERSE
STRAINS
AT
MID-CROSS-SECTION
A-14-612a
STRAIN
0.0001"
LOAD IN POUNDS
6000
5000
4000
3000
2000
1000
0
a
b
c
d
e
f
g
h
i
k
l
m
0.9
3.3
5.7

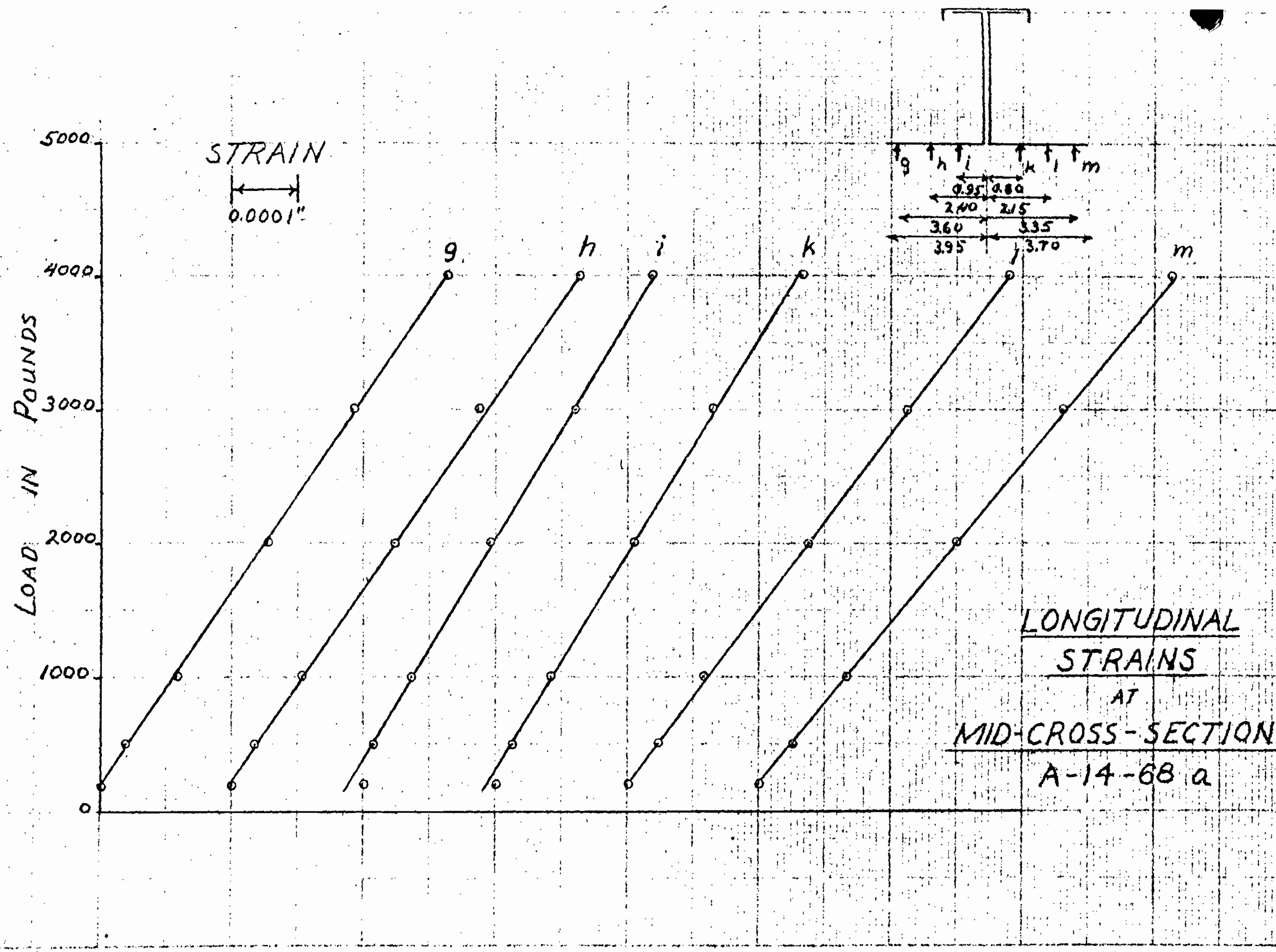


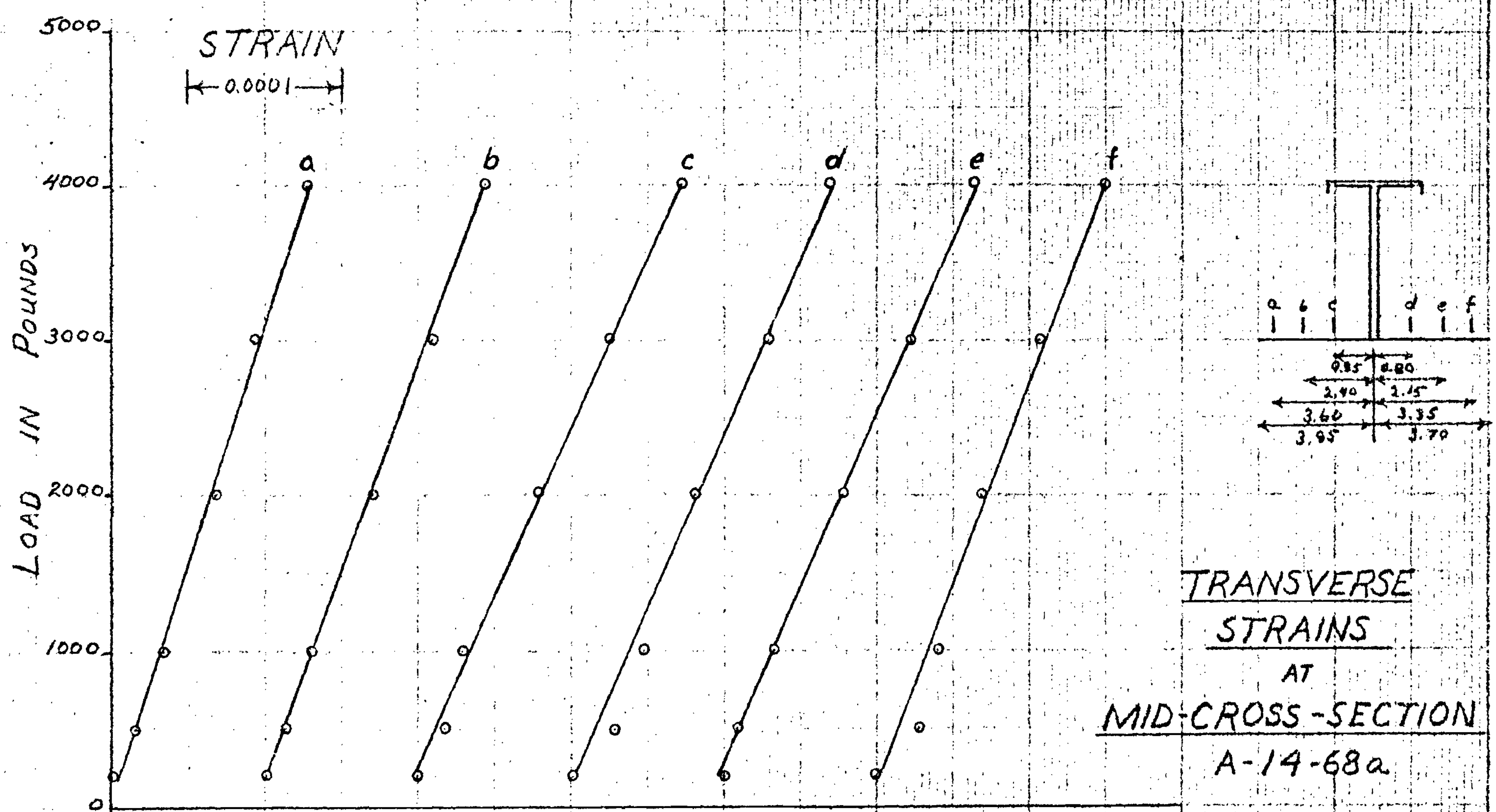
g
h
i
k
l
m
6000
5000
4000
3000
2000
1000
0
LOAD IN POUNDS
STRAIN
0.0001"
a b c d e f
g h i k l m
0.9
3.3
5.7
LONGITUDINAL
STRAINS
AT
MID-CROSS SECTION
A-14-612a



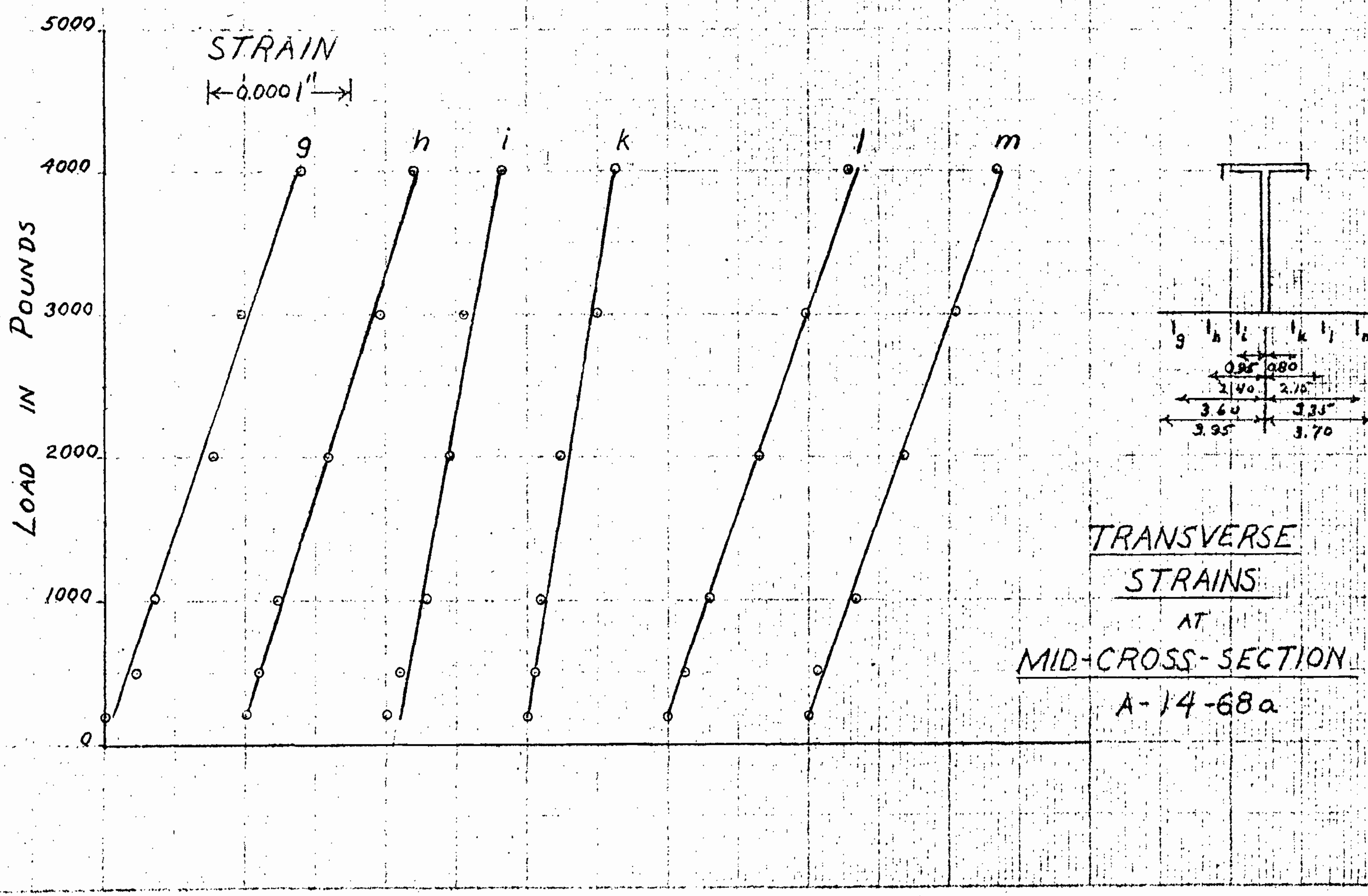

LONGITUDINAL STRAINS AT MID-CROSS-SECTION

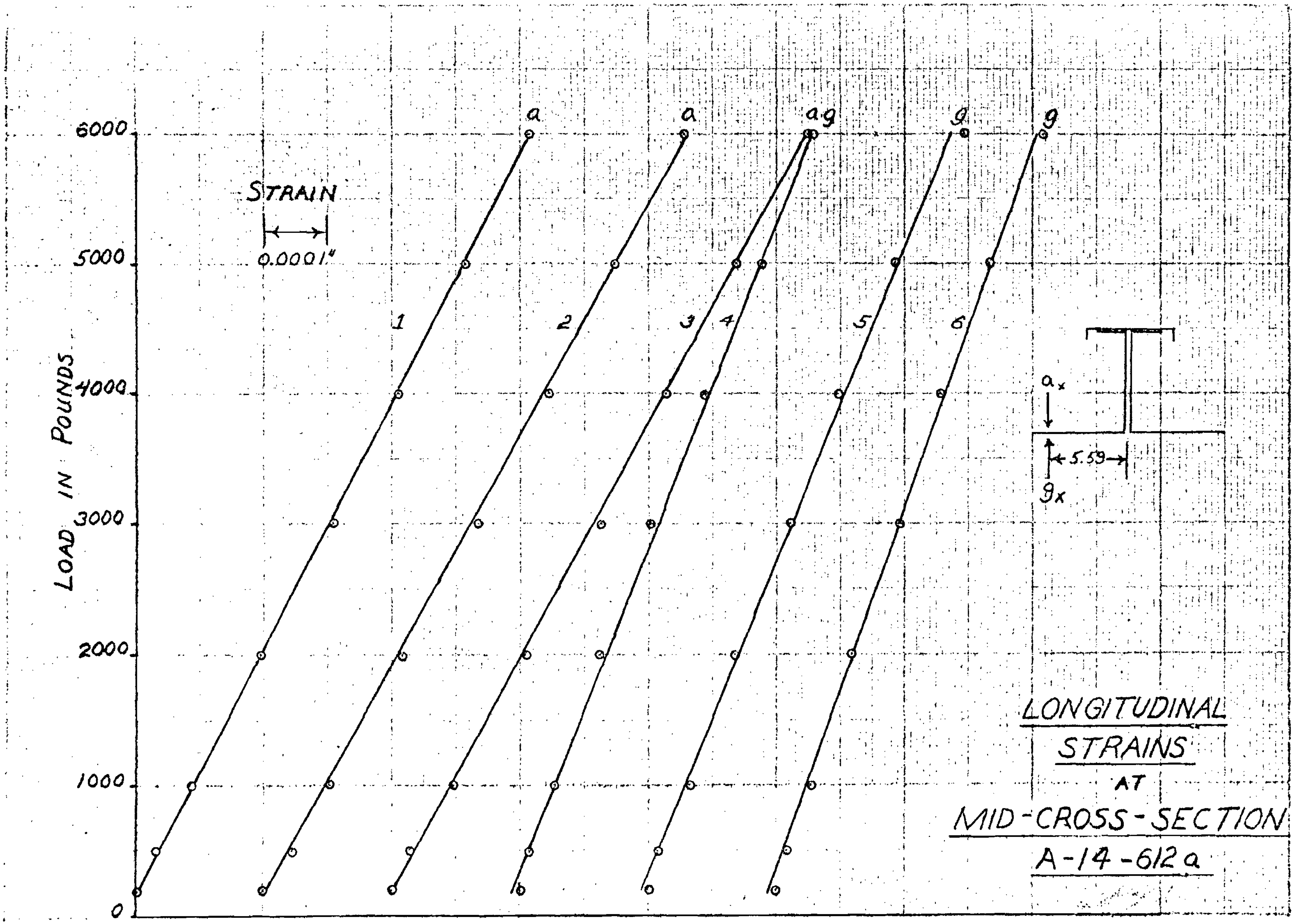
A-14-68a

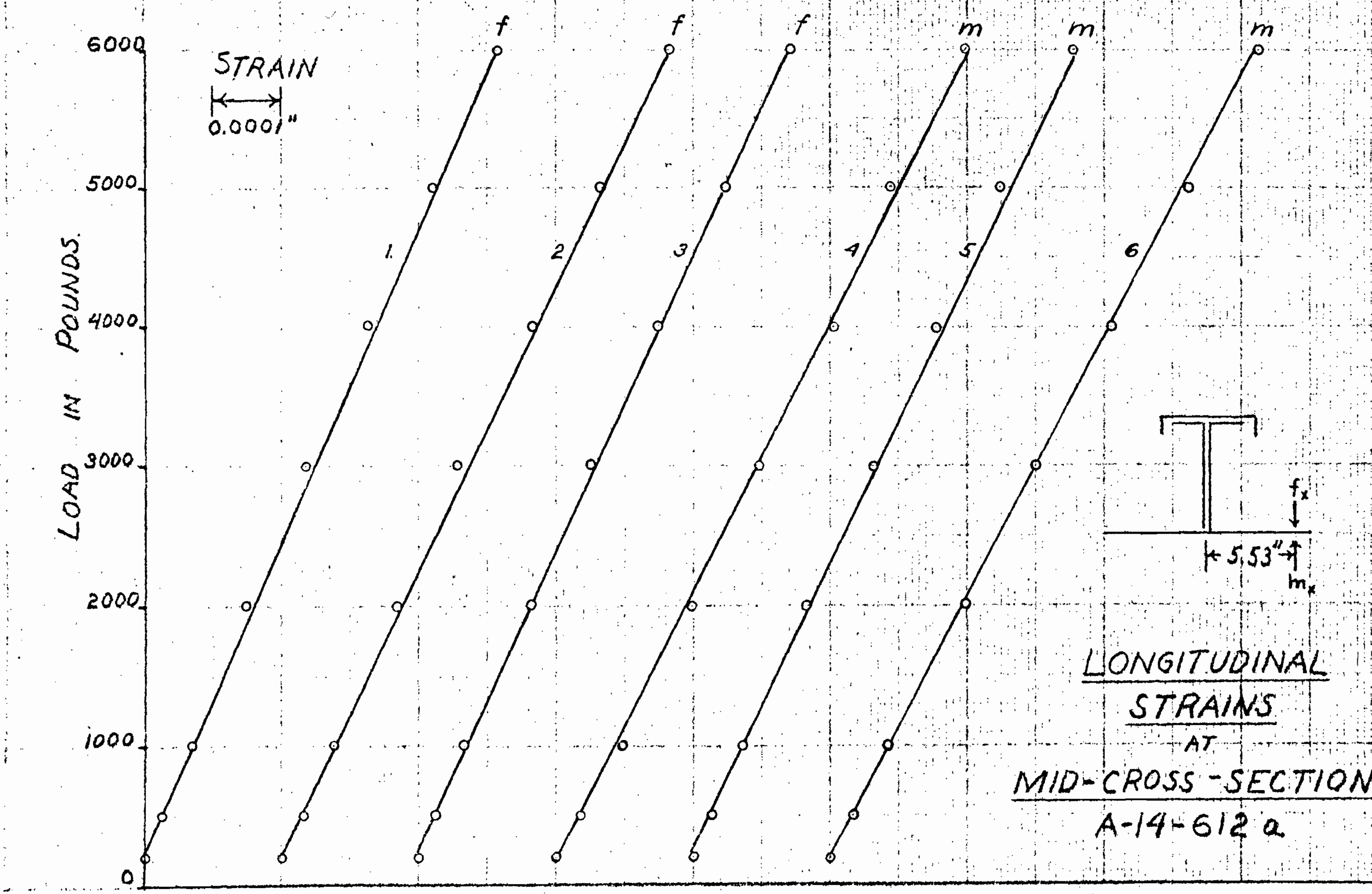

STRAIN
0.0001"
g h i k l m
0.95 0.80
2.40 2.15
3.60 3.35
3.95 3.70
5000
4000
3000
2000
1000
0
LOAD IN POUNDS
LONGITUDINAL
STRAINS
AT
MID-CROSS-SECTION
A-14-68 a



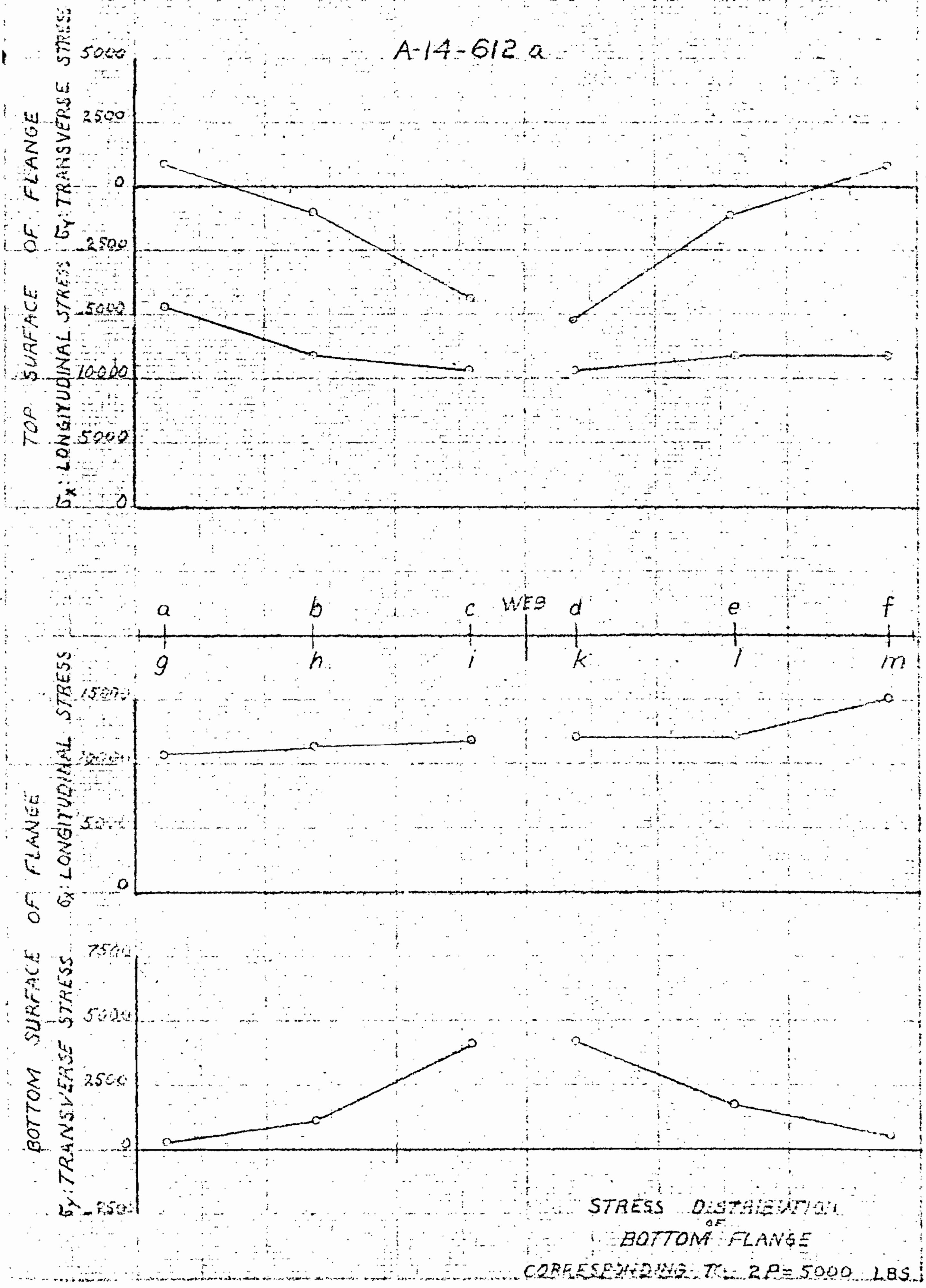

TRANSVERSE STRAINS AT MID-CROSS-SECTION A-14-68a

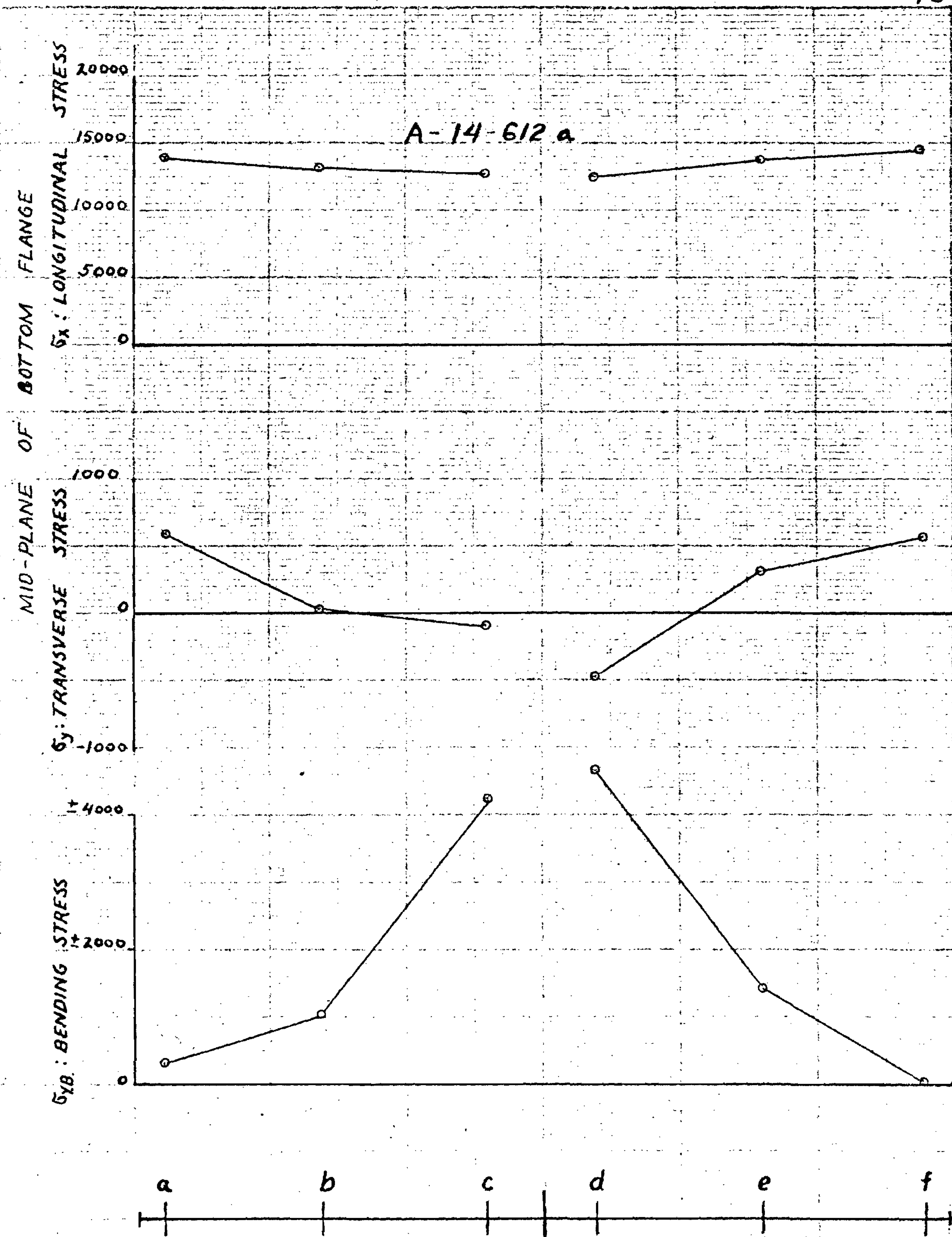

STRAIN
0.0001"
LOAD IN POUNDS
5000
4000
3000
2000
1000
0
g
h
i
k
l
m
0.95
0.80
2.40
2.10
3.60
3.35
3.95
3.70
TRANSVERSE
STRAINS
AT
MID-CROSS-SECTION
A-14-68a


LONGITUDINAL STRAINS AT MID-CROSS-SECTION
A-14-612a
LOAD IN POUNDS
6000
5000
4000
3000
2000
1000
0
STRAIN
0.0001"
1
2
3
4
5
6
a
a
a.g
g
g
$a_x$
$g_x$
5.59



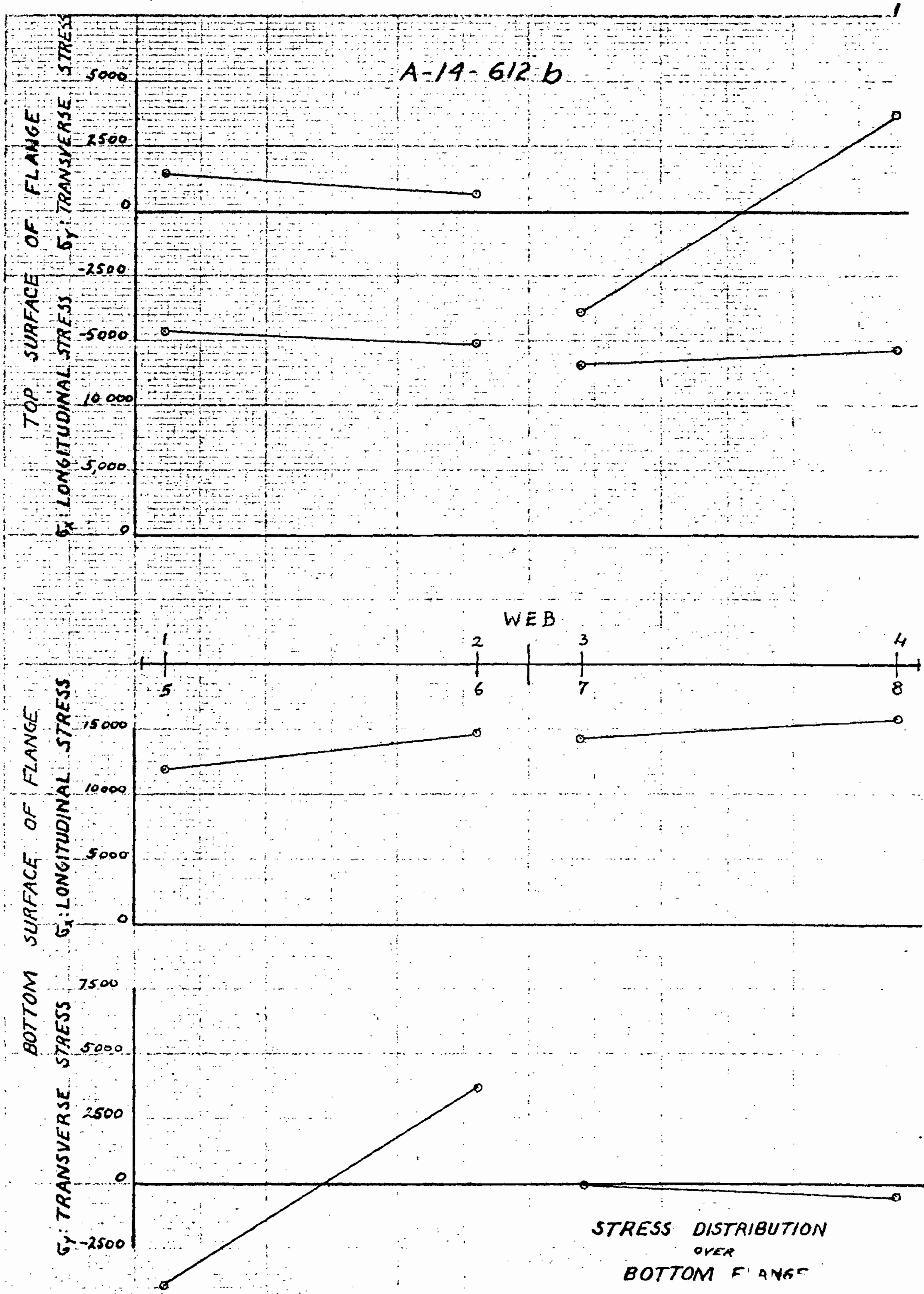

LONGITUDINAL STRAINS AT MID-CROSS-SECTION
A-14-612 a


A-14-612 a
TOP SURFACE OF FLANGE
$\sigma_y$: TRANSVERSE STRESS
$\sigma_x$: LONGITUDINAL STRESS
5000
2500
0
-2500
-5000
10000
5000
0
a
b
c
WEB
d
e
f
g
h
i
k
l
m
BOTTOM SURFACE OF FLANGE
$\sigma_x$: LONGITUDINAL STRESS
15000
10000
5000
0
$\sigma_y$: TRANSVERSE STRESS
7500
5000
2500
0
-2500
STRESS DISTRIBUTION OF BOTTOM FLANGE
CORRESPONDING TO 2P=5000 LBS.

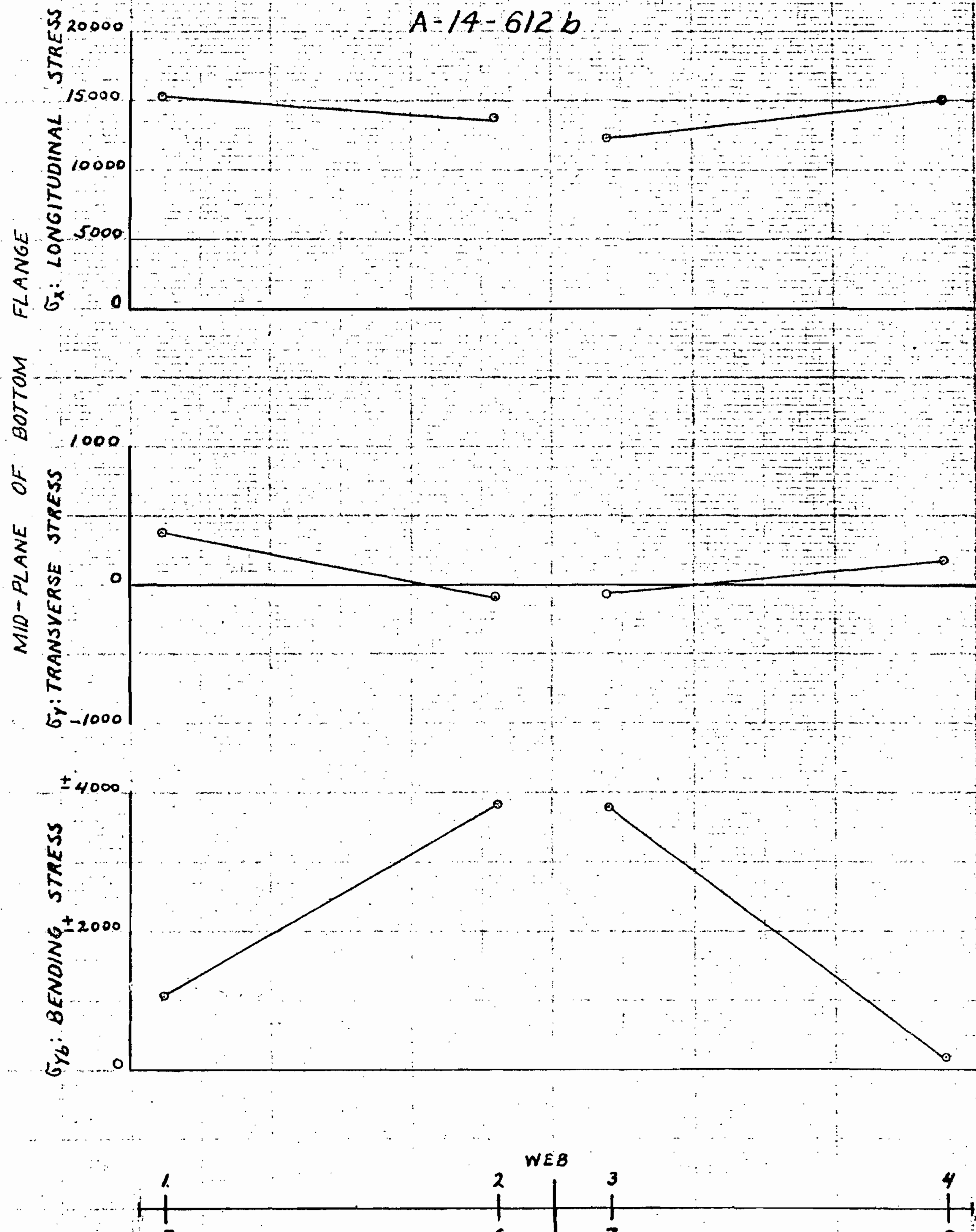



MID-PLANE AND BENDING STRESS DISTRIBUTION OVER THE BOTTOM FLANGE CORRESPONDING TO 2P = 5000 LBS

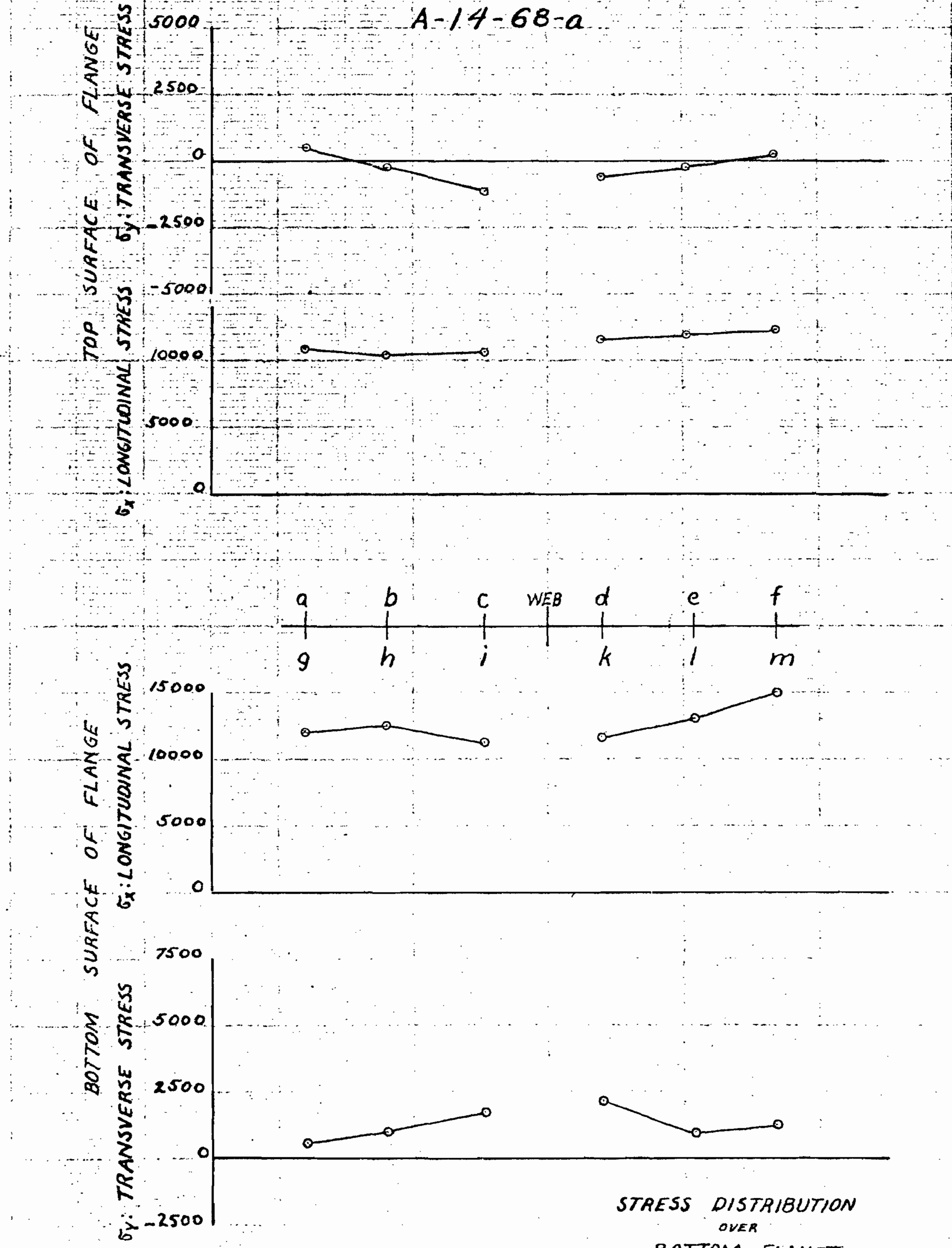
FORM C2




STRESS DISTRIBUTION
OVER
BOTTOM FLANGE

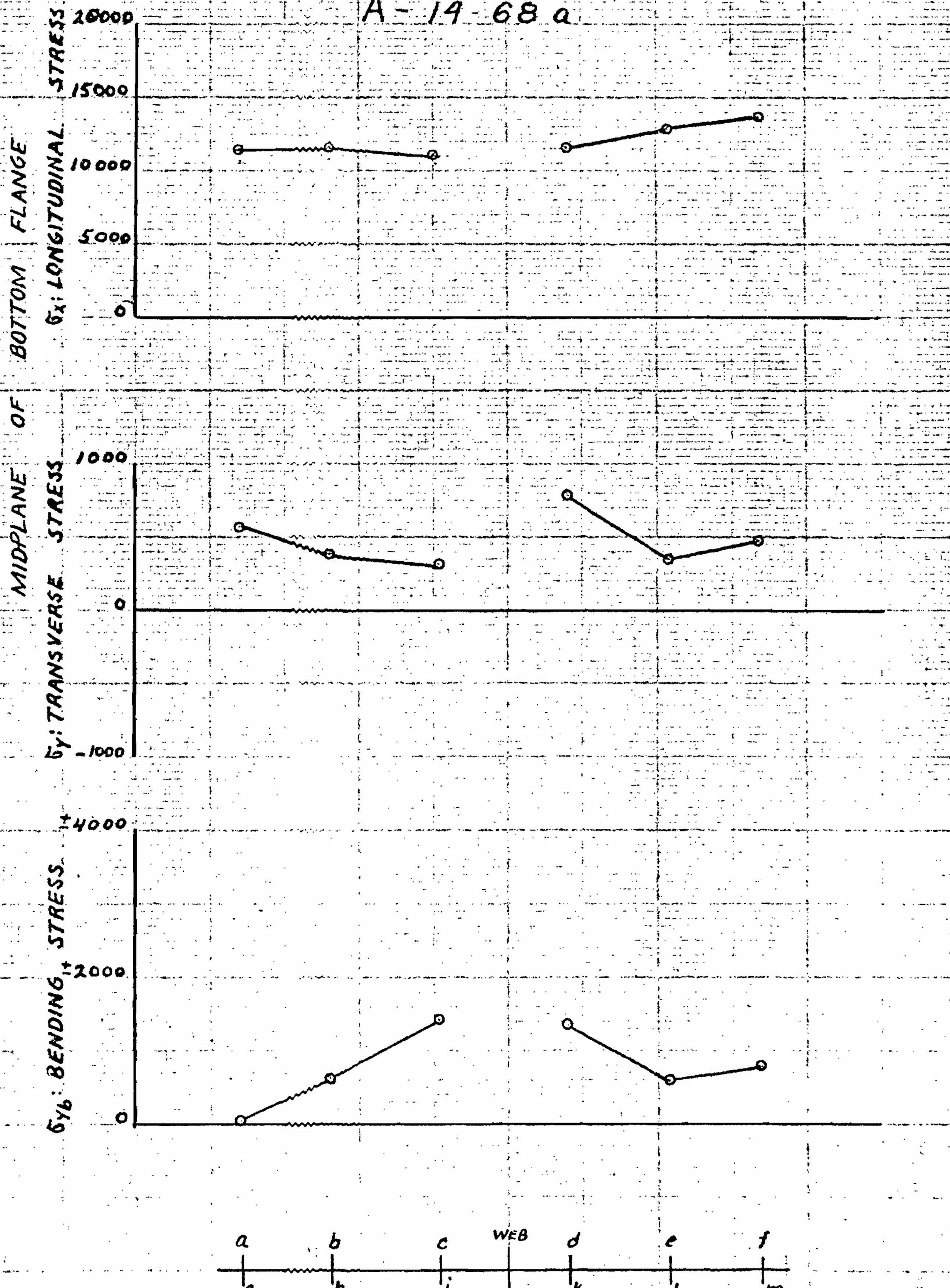



MID-PLANE AND BENDING STRESS DISTRIBUTION
OVER THE
BOTTOM FLANGE
CORRESPONDING TO 2 P = 5000 LBS




STRESS DISTRIBUTION
OVER
BOTTOM FLANGE
CORRESPONDING TO 2P = 3000 LBS

A-14-68 a




MIDPLANE AND BENDING STRESS DISTRIBUTION OVER THE BOTTOM FLANGE

CORRESPONDING TO 2 P = 3000 LBS