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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 BEAMS OF COLD FORMED STEEL

FOR THE AMERICAN IRON AND STEEL INSTITUTE.

FOURTH PROGRESS REPORT, JUNE 8, 1939.

I. OBJECT OF THIS REPORT.

Buckling tests have been carried out on the remaining three beams of the 22 gage series, i.e. B-22-812a, B-22-816a and B-22-820a. A stress survey has been made on the bottom flange of beam B--22-812b. A new series of 22 gage specimens has been designed for the further study of the bottom flange stresses and of the top flange buckling.

II. METHOD OF TESTS.

The same methods of testing were used as described in the previous report. It was found however that the pres ent method of mounting the Huggenberger strain gages results in serious difficulties on these thin sheet beams due to the great flexibility of the flange. Another method of applying the gages will be developed for further investigation.

III. GRAPHICAL REPRESENTATION OF THE RESULTS.

The results of the buckling tests are given in three of the accompanying graphs. The results of the stress survey of B-22-812b are not included in this report for reasons given below. The suggested dimensions of the new series of specimens will be found on the last t sheets.

Sheets 26, 27, 28 give the load deflection curves of the beams B-22-812a, B-22-816a and B-22-820a respectively.

Sheets 29 and 30 give the design and dimensions of the new specimens considered for investigation.

IV. BUCKLING OBSERVATIONS.

1)B-22-812a.

This beam failed at about 2550 lb., which corresponds to a computed stress of 12650 p.s.i. in the flanges. The buckling was detected by the break in the load deflection curve; at this load a slight local short wave appeared at part "a" near midspan on one side of the flange. (Part "a" see sheet 21). No dropping of the load occured. At a further increase of the load to 2700 lb. a sudden buckling wave formed directly at one of the load points and the load rapidly dropped. Inspection revealed that the two sheets of part "b" had buckled separately, the buckling waves being shifted with respect to one another about 2" and the top sheet having bentup, the bottom sheet down. At this place the spacing of the spot welds is 4", whereas on the rest of the beam it is 2". This explains the separate action of the two sheets.

2) B-22-816a and B-22820a.

B-22-816a buckled at 2580 lb. (10100 p.s.i.), B-22-820a buckled at 2450 lb. (7900 p.s.i.). The buckling processes of these two beams were very much alike, although in beam B-22-820a the deformation of the top flange before buckling took place, was much greater than in B-22-816a. The top flanges of both beams as received had slight waves. These waves increased in amplitude under load until, especially on beam B-22-820a the entire top flange appeared heavily twisted. These were not short but long waves, the length of one half wave being about 3 ft. Buckling, which resulted in dropping of the load, occurred on both beams when a very slight short local wave formed at part "a". On beam B-22-820a the depth of part "a" at one side was 3/4", at the other 1/2";

buckling took place at the 1/2" side. This beam was further bent after failure in order to check the simultaneous work of both sheets of the top flange. These sheets deformed uniformly and apparently no failure of the spot welds andno separate buckling of the sheets in the spaces between the spot welds took place, despite the large deformation.

V. ANALYTICAL INVESTIGATION OF BUCKLING

In the following table the actual and the theoretical buckling stresses are recorded for all five beams of this series. The theoretical critical stresses have been computed the same way as in the previous report. Thus plate "type 1" means a long plate under longitudinal compression, simply supported at one of the long edges and unsupported at the other; "type 2" means a similar plate, unsupported at one edge, but completely restrained at the other. (See section V. of third progress report)

Table I.

Buckling stresses and type of failure

Beam	Computed critical stress of part "a" type 1	part "a" type 2	part "b" type 1	part "b" type 2	Actual failure at	Failed first in part
B-22-84a	51000	134000	15200	14900	14500	b
B-22-88a	12750	33000	16700	43800	12725	a
B-22-812a	12750	33000	6500	17200	12650	a
B-22-816a	51000	134000	3550	9300	10100	b
B-22-820a	51000	134000	2850	7400	7900	b

As a first approximation it seems therefore established, that part "a" of the flange fails at a stress corresponding to the critical stress of a "type 1" plate, while the horizontal part "b", stiffened by part "a", fails at the critical stress of a "type 2 " plate. These results were taken into account in designing the proposed new specimens.

The deflections of the beams of this series under loads less than the buckling load do not show the same regularity as in the series A-14. A marked deviation from the straight line is seen especially on the load deflection curves of B-22-816a and B-22-820 and a comparison of the actual and the computed deflection reveals the following facts:

Table II.

Comparison of theoretical and actual deflection below buckling load (load increment P = 1200 lb.)

Beam	deflection d_{act}	d_{theor}	$d_{act}/d_{theor.}$
Series A-14	-	-	1.0
B-22-84a	.290	.268	1.08
B-22-88a	.200	.165	1.21
B-22-812a	.155	.119	1.30
B-22-816a	.150	.095	1.75
B-22-820a	.160	.078	2.06

It thus appears that with increasing width (flexibility) of the top flange the rigidity of the beam as a whole rapidly decreases; this takes place not only near the buckling load but throughout the entire load range.

VI. STRAIN OBSERVATIONS ON B-22-812a.

Strain measurements were carried out on six points on the bottom flange of this beam in the usual way. Since the results appeared remarkably irregular, repeated readings with resetting of the gages were taken similar to those reported on in section IV. of the second progress report. It was observed, that the readings varied in a systematic way depending upon the manner of mounting the gages, i.e. different readings ere obtained when the mounting rod was applied from one side of the gage or from the other side. The deviations were too large (± 30%) to provide any reliable data by averaging. It can only be said in the most general way, that no marked change in the magnitude of the longitudinal stresses over the width of the flange takes place. The observed irregularities obviously result from the following fact: The mounting device used is similar to that designed by Beggs & Timby (Eng. News-Record, March 17, 1938) except that the hammerhead of this design is replaced by a calibrated spring support. It is easily seen that a relative motion of the point, where this support rests, will be transmitted through the mounting rod to the gage and thus will affect the reading. Obviously s uch motion occurs in the flexible light gage flanges, resulting in a certain twisting of the flange. This is especially likely in the beam under consideration, since the top flange of this beam as received was not at right angles to the web andhence the beam was bound to twist under load. It therefore appears necessary to develop a new mounting device for the gages, especially for the light gage beams, in such a way that the gage is not connected with a remote point of the flange.

As predicted in the previous report, no strain observations could be carried out on beams B-22-816 and B-22-820, since buckling occuredat such low stresses, that no sufficient load range for stress determinations is available.

VII. CONCLUSIONS.

1) The buckling of the top flange on all five beams tested occured in a regular manner guided by the formulas given in section VIII.

2) The beams under consideration showed a marked decrease in rigidity with increasing flange width. This fact resulted in heavy twisting of the

top flange under loads much below the ultimate buckling load. For this reason the load deflection curves of these beams show a clear departure from the straight line, especially for the wide beams, and an actual deflection much greater than the one computed for a rigid cross section.
3) Further tests are necessary to investigate both of these problems.

VIII. DESIGN OF THE NEXT SERIES OF SPECIMENS.

In order to complete the stress survey on the bottom flanges of the 22 gage beams it appears necessary to have another series of these beams with increased rigidity of the top flange. The results mentioned in section V. of this report were used to design the new specimens on the basis of a supposed buckling stress of 40000 p.s.i. In designing these beams the same formulae were used which served to determine the theoretical buckling stresses of table I, namely:

$$\sigma_{crit} = 1330\ (100\ \frac{h}{b})^2$$

for the part of the flange were a "type 1" failure is to be expected and

$$\sigma_{crit} = 3500\ (100\ \frac{h}{b})^2$$

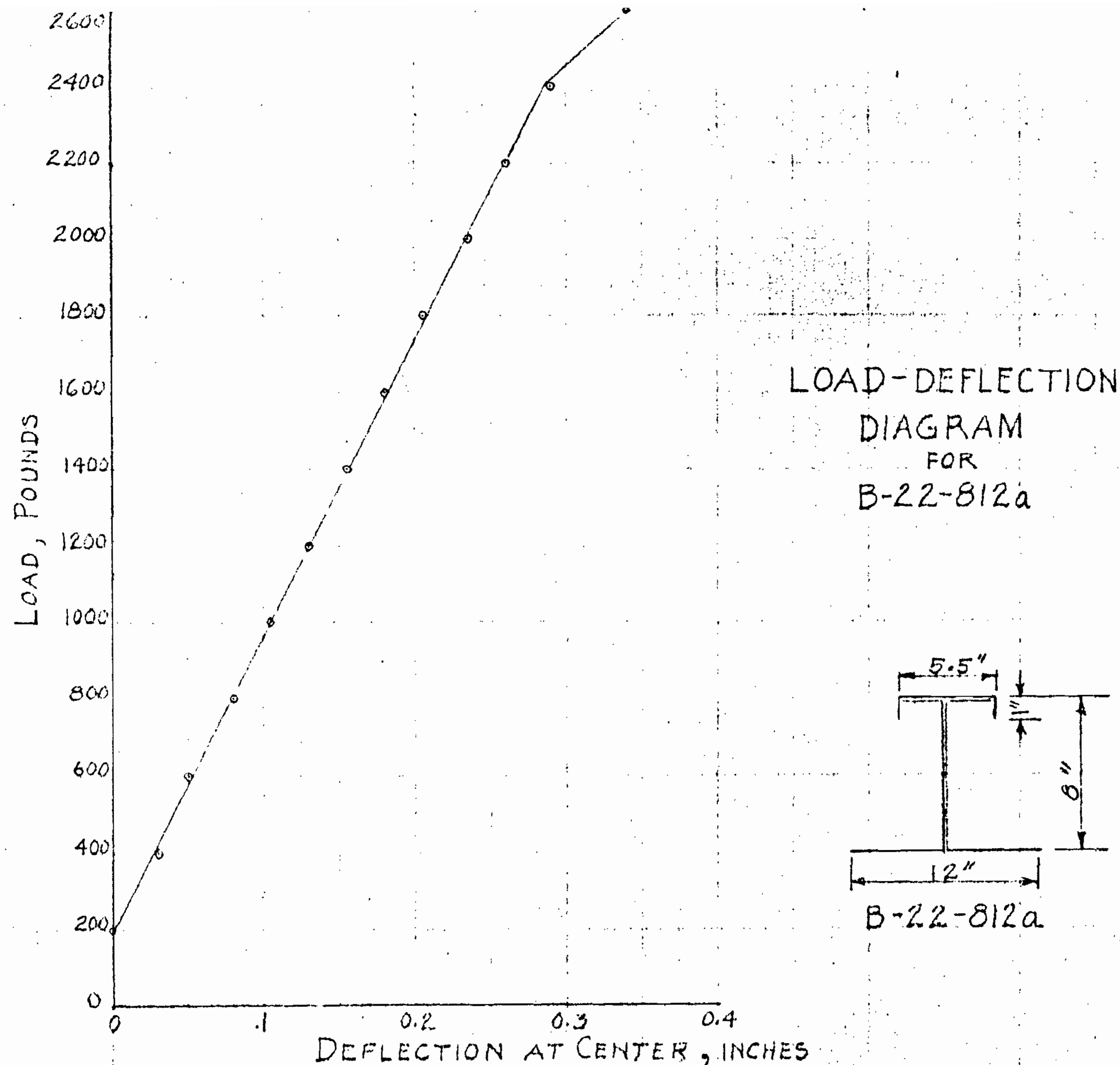
for the part of the flange of a "type 2" failure.

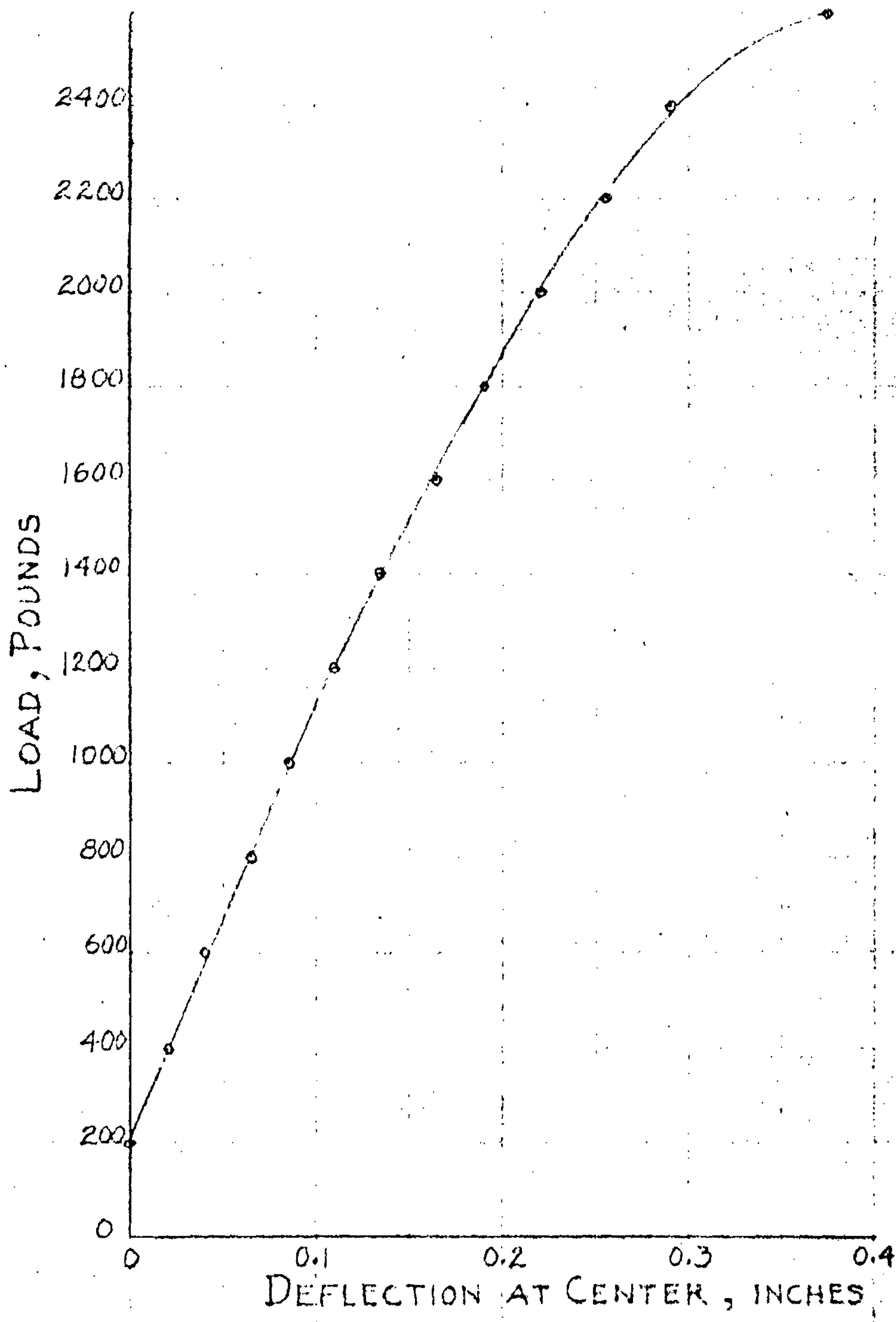
h = thickness of the part of the flange under consideration

b = free width " " " " " .

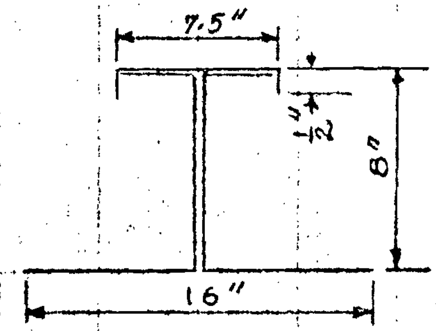
It is expected that these beams will not only serve for the stress survey of the bottom flanges but, if tested to failure, will cast more light on the buckling problem and on the observed decrease in rigidity with increasing flexibility of the top flange.

In order to exclude twisting of the top flange additional stiffeners as shown on the accompanying drawings should be provided. These stiffeners are designed only to fix the flange without affecting the web. It is expected to carry out the stress survey and the tests to failure on the first specimens with these stiffeners. Probably the twin beams of this series will be tested to failure with these stiffeners cut off in order to discern pure buckling and twisting action which obviously took place in the beams failed hitherto.

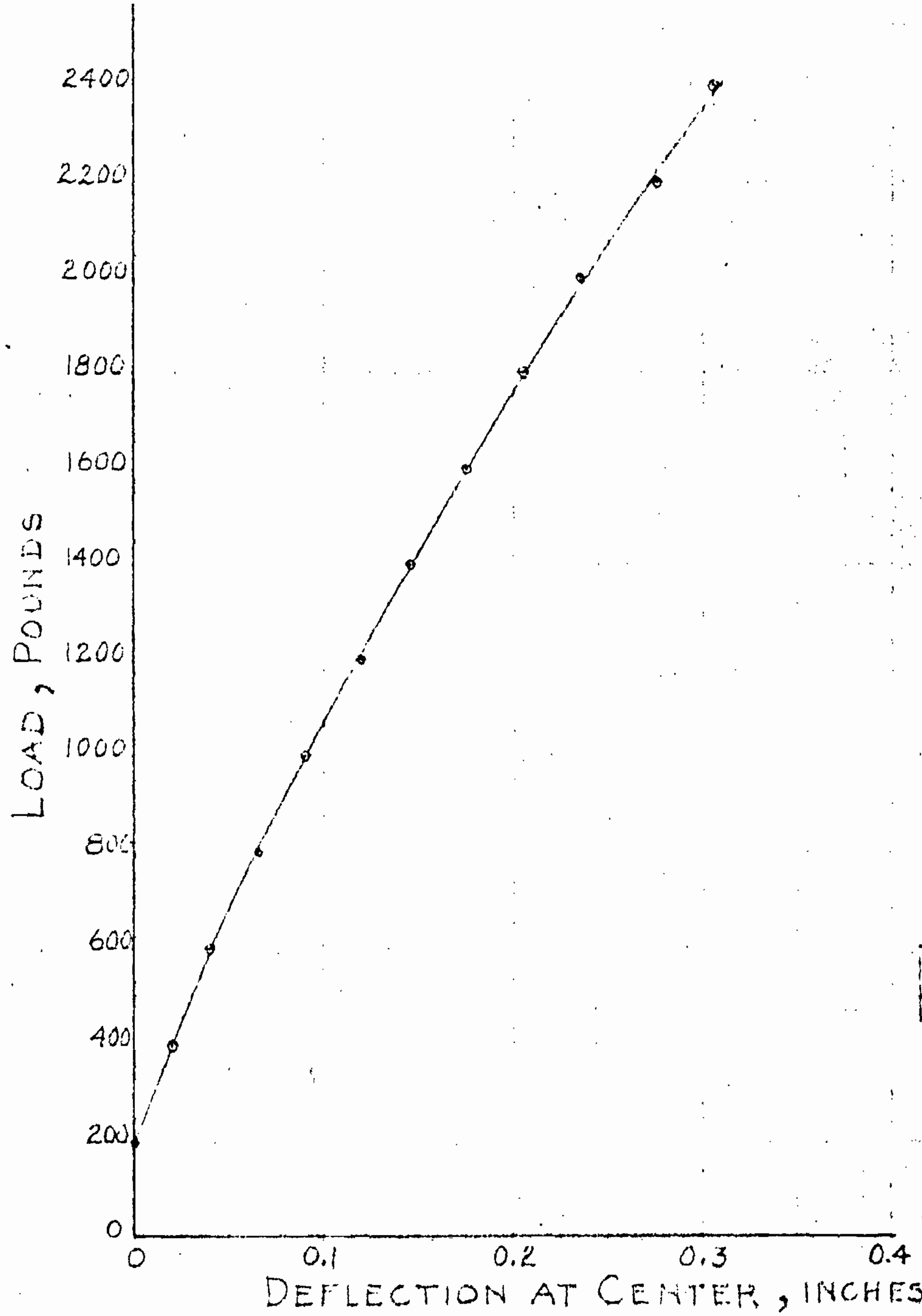

LOAD-DEFLECTION
DIAGRAM
FOR
B-22-812a
LOAD, POUNDS
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
.1
0.2
0.3
0.4
DEFLECTION AT CENTER, INCHES
5.5"
8"
12"
B-22-812a



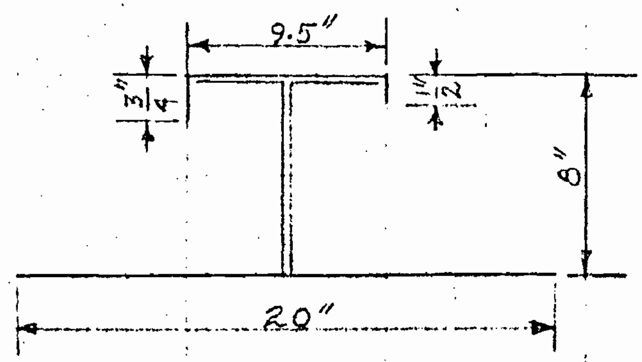
LOAD-DEFLECTION
DIAGRAM
FOR
B-22-816a



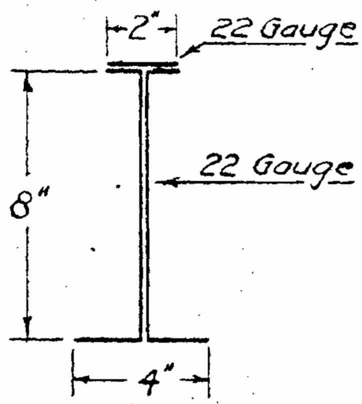
B-22-816a

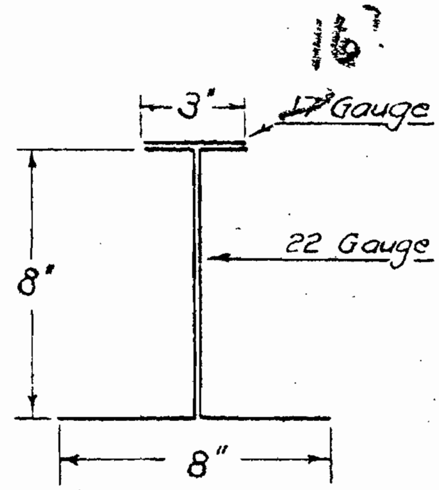


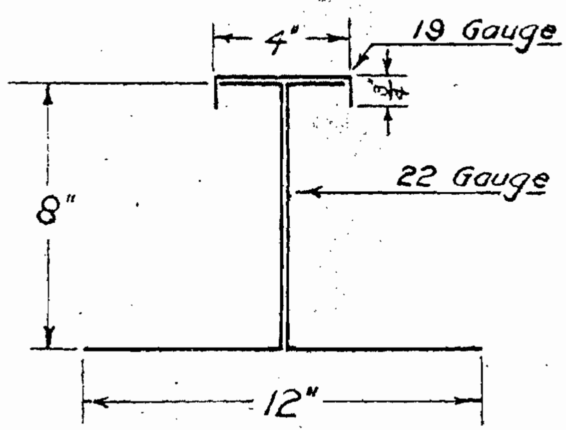
LOAD-DEFLECTION DIAGRAM FOR B-22-820a

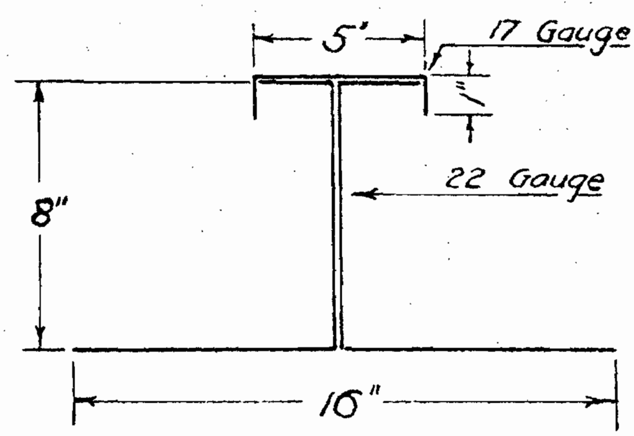


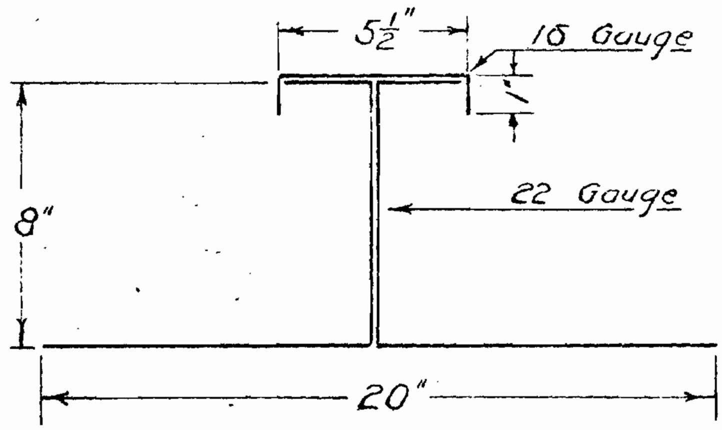
B-22-820a



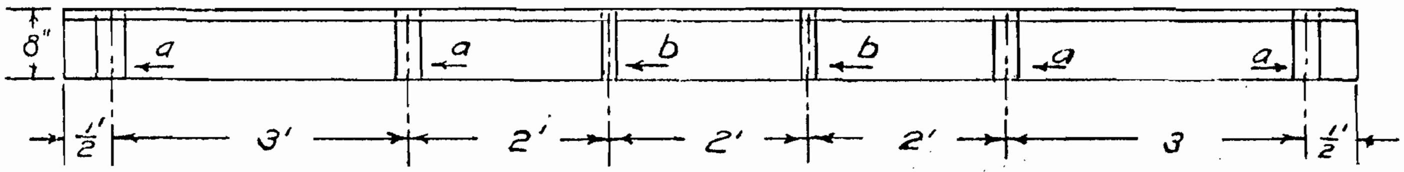




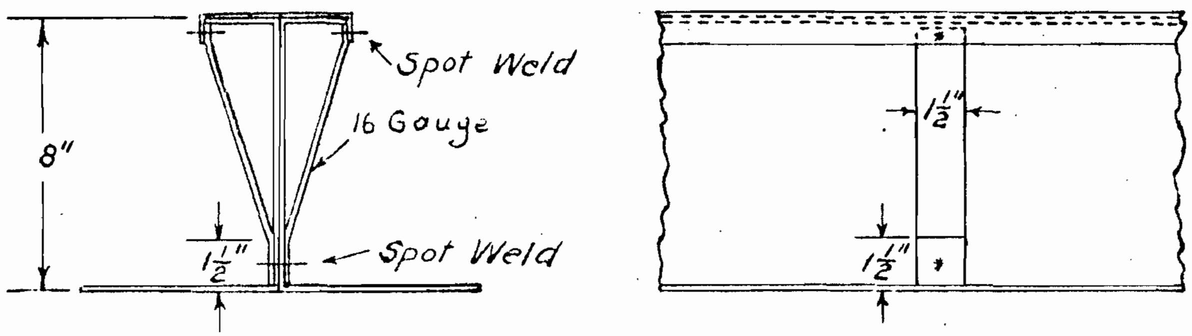




Make Two of Each Cross Section



Beam Elevation



Section Elevation

Stiffeners Type "b"

Stiffeners Type "a":

Same as in previous 22 gauge series of specimens. Make stiffeners type "b" only on specimens with 12", 16", 20" width of bottom flange.

Specimens for Investigation of Cold Formed Light Gauge Steel Beams