METHODS OF CONDUCTING BUCKLING TESTS OF PLYWOOD PANELS IN COMPRESSION

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FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison, Wisconsin
In Cooperation with the University of Wisconsin

NOTE

The methods here reported are based on techniques developed at the Forest Products Laboratory in connection with the research program of the Army-Navy-Civil Committee on Aircraft Design Criteria and are published as a report of the ANC Technical Subcommittee on Wood Aircraft Structures.

The NACA Subcommittee on Wood and Plastics for Aircraft has also approved these procedures for publication.

METHODS OF CONDUCTING BUCKLING TESTS OF PLYWOOD PANELS IN COMPRESSION[1]

Foreword

1. (a) The testing of plywood panels in compression presents a number of special problems and in order to simulate the various edge conditions found in practice, requires the use of special apparatus and techniques.

(b) The methods of test herein covered are the result of progressive development and have been found satisfactory for the specific investigations for which they were used. The principles of operation and the basic design of equipment are believed suitable and readily adaptable to other studies of this type. Changes in detailed procedure may be made when necessary to meet new requirements or different conditions.

Scope

2. Test methods are presented (1) for unstiffened flat plywood panels with the direction of applied load at various angles to the face grain and (2) for stiffened panels with direction of applied load at 0° or 90° to the face grain. The equipment used in the tests of stiffened panels is a modification of that for unstiffened panels.

Testing Apparatus

3. (a) The conditions that are assumed in the theory of the compression buckling of plywood plates and which shall be approximated in tests are:

(1) The plywood is initially flat.

(2) All four edges of the panel remain in the same plane as the applied load during test.

(3) The edges are simply supported.

(4) The displacement of the loaded edges with respect to each other is uniform across the specimen.

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[1] The theoretical treatment and experimental verification of buckling of plywood panels in compression is presented in Forest Products Laboratory Reports Nos. 1316, 1316-A, 1316-B, 1316-C, 1316-D, 1316-E, and 1316-G.

The testing apparatus provides essentially for the last three of these conditions. Drawings and photographs of the test frame developed to satisfy these conditions are provided in figures 1 to 12.

(b) Essentially the apparatus shall consist of a channel iron base which can be firmly attached to the lower head of the testing machine and to which are bolted the two fixed vertical posts, made of channels and angles, at positions determined by the width of the test panel. The faces of the outstanding legs of angles shall be machined flat and the angles positioned to allow 0.002-inch clearance between the angles and the stem of the T-shaped movable posts. The movable posts shall be supported on rollers or springs to permit lateral adjustment. The springs, in addition, reduce the transmission of load from the movable posts to the base of the frame. Two adjustable guide rails on the head of each T-shaped movable post provide the desired lateral support for the unloaded edges of the panel as shown in figure 8, 10, and 11. The guides shall be flexible so as to permit adjustment to compensate for any initial curvature and irregularities of the test specimen. This adjustment is discussed in the section on tests of unstiffened panels.

(c) The loaded edges of the specimen shall be fitted into solid or segmented cylindrical steel loading rods to provide an approximation of simply-supported end conditions. Shims shall be used, when necessary, to produce a snug fit. The solid loading rod shall have small rectangular tips which fit between the guide rails to position the loaded edges. The segmented rods shall be maintained in position by the loading head shown in figure 9.

(d) The unloaded edges of the specimen shall be positioned by the guide rails as shown in figure 11, or tension springs shall be attached to the edges as shown in figure 10. The use of the springs has the added advantage of reducing possible friction on the edges of the panel when the panel begins to distort, since the springs will distort if any friction exists.

(e) The load shall be transmitted from the head of the testing machine to the specimen either through a spherically-seated loading head, fixed so that it can rotate only about a single axis perpendicular to the plane of the test panel, as is shown in figure 13, or by means of knife edges, bearing on a loading plate, which are free to rotate about this same axis, figure 15. The load shall be transmitted through rollers to the loading rods, as shown in figures 1 and 13, or through the more elaborate loading head shown in figure 9.

(f) Figures 1 to 5 show the different parts of the testing apparatus photographically while figures 6 to 12 are drawings of the different parts of the apparatus.

Compression Buckling Tests of Unstiffened Flat Plywood Panels

Direction of Grain

4. The plywood specimens shall be constructed with the grain of adjacent plies at right angles to each other and with the direction of the

grain of the face plies at any angle to the direction of the applied load (note).

Note: Tests have been made with the direction of the grain of the face plies at 0°, 15°, 30°, 45°, 60°, 75°, and 90° to the direction of the applied load.

Specimen

5. (a) The size of specimen shall be determined by the object and scope of the investigation (note). The actual thickness of the panel shall be measured to the nearest 0.001 inch and the length and width to the nearest 0.01 inch.

Note 1: The minimum critical buckling load for a given construction of test panel occurs when the panel length is equal to one-half the theoretical wave length of the buckled surface or a multiple thereof.

Note 2: In determining the conformance of buckling test results with theory, it is desirable that the panel size be such that it will buckle in a single half-wave; otherwise inequalities of the panel tend to distort the neutral plane enough so that buckling loads are often lower than indicated by theory. The apparatus and test method described herein, however, may be used for testing panels of any length, when it is desired to determine how and when a certain panel will buckle under compressive loading.

Note 3: It has not been possible to test all possible sizes and combinations of plywood. Nominal dimensions of the panels tested varied from 1/16 to 5/16 inch in thickness, 6 to 14-1/2 inches in length (parallel to the unloaded edge), and 7-1/2 to 12 inches in width (parallel to the loaded edge).

(b) The plywood specimens shall not be noticeably warped and all four edges shall be in a plane. The specimens shall be carefully prepared with the loaded edges parallel to each other and perpendicular to the faces.

Loading Procedure

6. Prior to test the loaded edges of the specimen shall be fitted snugly into the rectangular slots in the solid cylindrical loading rods; when necessary, shims shall be used to obtain this fit. The supporting frame shall be centered on and attached to the lower head of the testing machine, after which the two guide rails for one face of the specimen shall be adjusted until vertical and in a plane. The specimen support and rollers shall be set in place and arranged to bring the center of the specimen at the same level as the center adjusting screws on the movable posts. Next the specimen shall be placed in the frame so that about 1/8 inch of the unloaded edges

projects between the guide rails with a 0.002-inch clearance provided between the specimen and the rails. The ends of the loading rods shall be held similarly to insure that all edges of the specimens remain in a plane. End and edge conditions of a specimen at the time of test are illustrated in figures 11 and 12. The load shall be applied, through a loading head free to rotate only about an axis perpendicular to the plane of the plywood, at a rate of motion of the movable head of the testing machine of 0.003 inch per inch of specimen length per minute, with a permissible variation of ±25 percent. A test set-up with the specimen and apparatus is shown in figure 13.

Load-deformation Data

7. (a) Load-lateral deformation data shall be taken to determine the critical buckling load. Readings of lateral deformation shall be taken to the nearest 0.001 inch (note).

Note: Compressive strain measurements should be taken on all test panels, particularly on those in which the computed buckling stress exceeds 75 percent of the stress at proportional limit as an aid to securing the buckling load. Strain measurements shall be taken to the nearest 0.0001 inch at the center of the test panel and plotted against the corresponding load. The rate of average strain at this location decreases at and above the buckling load. The point on the curve at which the rate of strain decreases rapidly shall be used to indicate the buckle load.

(b) When testing specimens where the computed buckling stress does not exceed 75 percent of the proportional limit stress, simultaneous readings of load and lateral deformation shall be taken until the lateral deformation becomes approximately 0.03 inch. Then the load shall be removed and the center guide rail adjusting screws adjusted to an edge curvature in the direction opposite to that of the deflection. This procedure shall be repeated until lateral deflection, as the panel is loaded, occurs abruptly rather than progressively. The load which causes this abrupt deflection shall be considered the critical buckling load.

(c) Tests have shown that panels with a computed buckling stress that exceeds 75 percent of the stress at proportional limit shall not be manipulated in the manner described in the previous paragraph. The loading shall be continuous and simultaneous readings of load and lateral deflection shall be taken until an abrupt change in lateral deflection occurs. The load at which this abrupt deflection occurs shall be taken as the critical buckling load. Occasionally, when the lateral deflection does not occur in an abrupt manner, the load-compressive strain curve can be used to obtain the critical buckling load.

Moisture and Specific Gravity

8. (a) Immediately after test, a coupon shall be cut from the panel, weighed, measured, and used to determine the moisture content and specific gravity. The thickness of the sample shall be measured to the nearest 0.001 inch and the length and width to at least the nearest 0.01 inch (depending on the size of the sample). The sample shall be dried in an oven at 100° C. until approximately constant weight is attained. After drying, the sample shall be weighed immediately. The weight of the moisture and specific gravity sample shall be determined to an accuracy of not less than 0.2 percent.

(b) The moisture content shall be calculated as follows:

$$M = \frac{W - F}{F} \times 100$$

where

M = moisture content, in percent

W = initial weight, and

F = final weight when oven dry.

(c) The specific gravity shall be calculated as follows:

$$\text{Specific gravity} = \frac{F \times 0.061}{L \times w \times t}$$

where

F = final weight when oven dry, in grams

L = length of moisture specimen, in inches

w = width of moisture specimen, in inches, and

t = thickness of moisture specimen, in inches.

It may be advantageous sometimes to use the original measurements of the panel for determining specific gravity. Then the formula becomes:

$$\text{Specific gravity} = \frac{W_i \times 0.061}{\left(1 + \frac{M}{100}\right) \times L \times w \times t}$$

where

W_i = initial weight of the panel, in grams

M = moisture content at time of test

L = length of panel, inches

w = width of panel, in inches, and

t = thickness of panel in inches.

Note 1: The moisture content and specific gravity as determined above are the average values for the entire specimen. When the plywood is made up of thin veneers, the glue may constitute a significant part of the total weight and as a result the calculated specific gravities and moisture contents may vary substantially from the true values for the veneers. In some instances it may be desirable to correct for the weight of the glue.

Note 2: The specific gravity determined as outlined above is based on volume at test and weight when oven dry. If desired, the specific gravity may be obtained on a weight-and-volume-when-oven-dry basis, by using the procedure described in the Standards Methods of Testing Small Clear Specimens of Timber[2].

Compression Buckling Tests of Flat Plywood Panels with a Single Stiffener Perpendicular to the Direction of Applied Load

Direction of Grain

9. The plywood specimens shall be constructed with the grain of adjacent plies at right angles to each other and with the direction of the grain of the face plies parallel or perpendicular to the direction of applied load.

Specimen

10. (a) The size of specimen shall be determined by the object and scope of the investigation (note). The actual thickness of the panel shall be measured to the nearest 0.001 inch and the length and width to the nearest 0.01 inch.

Note 1: In determining the conformance of test results with theory, it is desirable that the panel size be such that it will buckle as a complete wave if it is stiffened sufficiently, and as a half-wave if insufficiently stiffened; otherwise inequalities of the panel tend to distort the neutral plane so that test results are often lower than indicated by theory. The apparatus and test method described herein may be used for testing panels which

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[2] American Society for Testing Materials, Designation D143, 1944 Book of Standards, Part II.

buckle more complexly when it is desired to determine how and when a certain panel will buckle under compressive loading.

Note 2: It has not been feasible to test all sizes of panels. Nominal dimensions of the panels tested varied from 3/16 to 1/4 inch in thickness, 6 to 20 inches in length (parallel to the unloaded edge) and 8 to 14 inches in width (parallel to the loaded edge).

(b) The transverse wood stiffener shall be glued to one face of the panel along the horizontal centerline. The clear distances from the ends of the stiffeners to the edges of the panels shall be 5/8 inch. Actual width and thickness of the stiffener shall be measured to the nearest 0.001 inch and the length to the nearest 0.01 inch.

Note: The widths of stiffeners, parallel to the face of the panel, varied from 1/8 to 3/8 inch and the depth, perpendicular to the face, varied from 1 inch to zero on one series of panels tested under this procedure.

(c) The plywood specimens shall not be noticeably warped and all four edges shall be in a plane. The specimens shall be carefully prepared with the loaded edges parallel to each other and perpendicular to the faces.

Loading Procedure

11. (a) Prior to test the loaded edges of the specimen shall be fitted snugly into the rectangular slots in the segmented cylindrical steel loading rods; when necessary, shims shall be used to obtain this fit. A separation of approximately 1/16 inch shall be allowed between segments. Tension springs, approximately 0.9 of the length of the unloaded edges, shall be attached to screws, in the loading rods, located 3/16 inch from the unloaded edges of the specimen. The ends of the stiffener shall be restrained to avoid separation of the stiffener from the plywood. A prepared specimen is shown in figure 14.

(b) The supporting frame shall be centered on and attached to the lower head of the testing machine, after which the two guide rails for one face of the specimen shall be adjusted until vertical and in a plane. The lower and the upper loading heads (of identical construction) shall be set in place next. The specimen shall be placed in the frame so that about 1/4 inch of the unloaded edges projects between the guide rails, with 0.002 inch clearance between the rails and the tension springs on the faces of the specimen. Edge conditions required at the time of test are illustrated in figure 10. The loaded edges of the panel are held in place by the rollers in the loading heads, figure 9, so that all edges of the panel are held in a plane and are approximately simply supported. The load shall be applied to the loading heads by means of knife edges which are free to rotate about an axis perpendicular to the plane of the plywood, at a rate of motion of the movable head of the testing machine of 0.003 inch per inch of specimen length per minute, with a permissible variation of ±25 percent. A stiffened panel ready for test in the apparatus is shown in figure 15.

Load-deformation Data

12. Data for load-strain curves shall be taken to determine the critical buckling load and increments in load shall be chosen so as to clearly define the initial portion of the curve as well as the buckling point. Compressive strain measurements (to the nearest 0.00001 inch) shall be made at points at the center of the width of the panel just below the stiffener. Readings obtained from opposite faces shall be averaged and plotted against corresponding loads. The critical buckling load is the point where the slope of the load-strain curve is vertical, or at the point where the stress increases without any change in strain.

Moisture and Specific Gravity

13. Immediately after test, a coupon shall be cut from the panel, weighed, measured, and used to determine moisture content and specific gravity as specified in section 8.

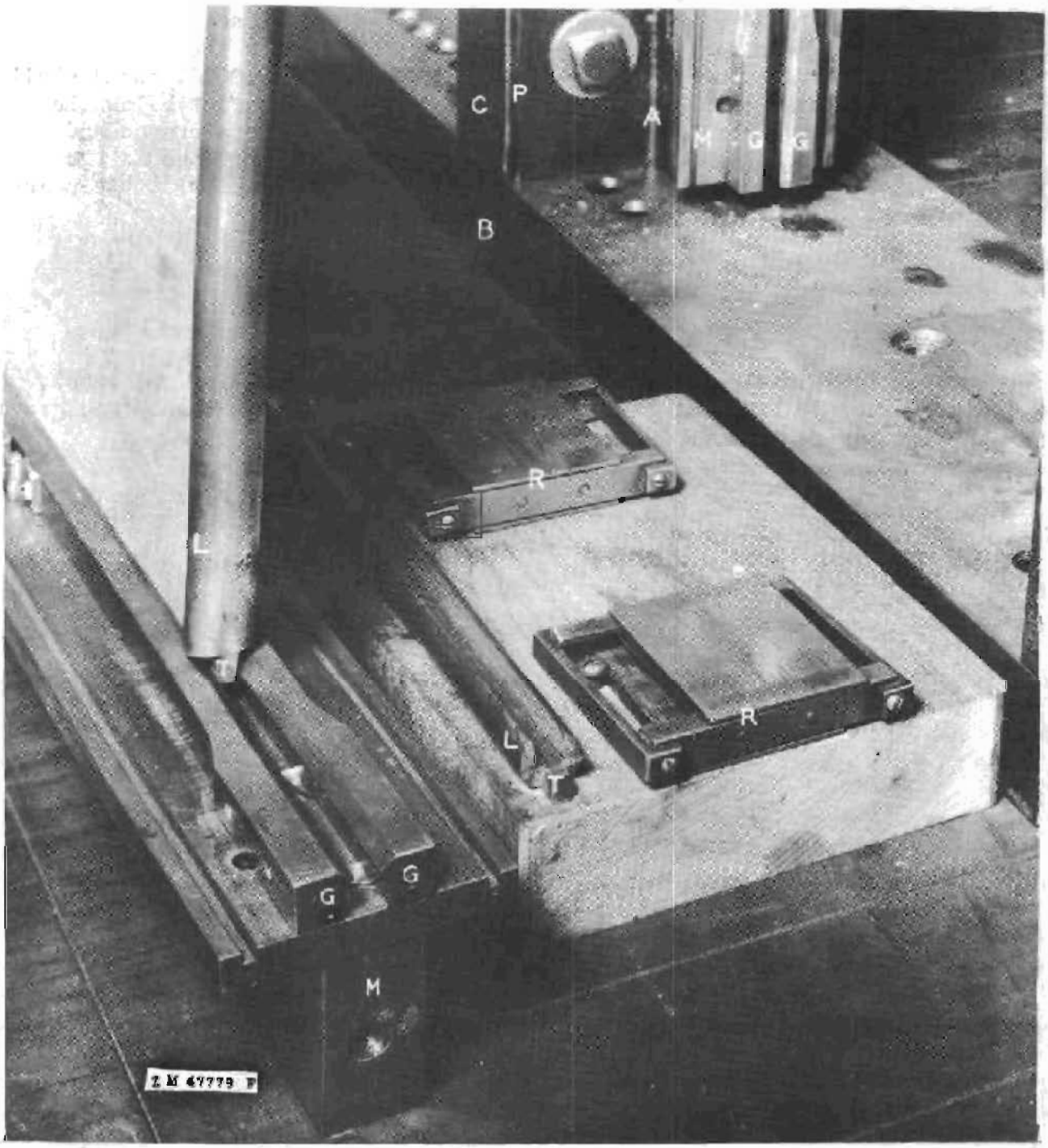

Figure 1.--Details of apparatus used in the buckling test of unstiffened plywood panels in compression: A, angle iron on fixed post; B, channel iron base; C, channel iron portion of fixed post; G, guide rails on movable post; L, solid loading rods; M, movable posts; P, fixed post; R, rollers; T, rectangular tip of solid loading rod to aid in alinement of specimen.

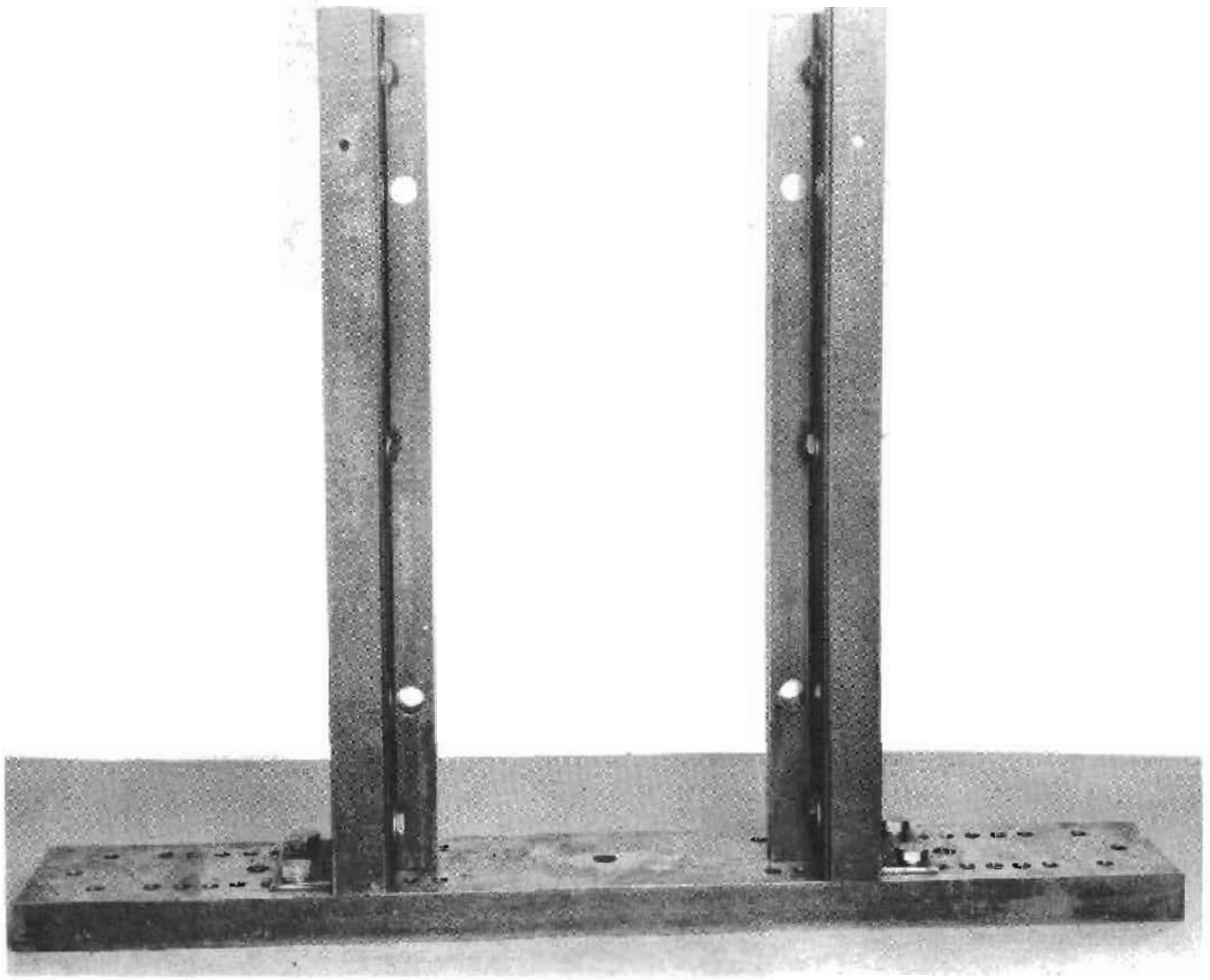

Figure 2.--Front view of panel buckling apparatus showing details of base and fixed posts.

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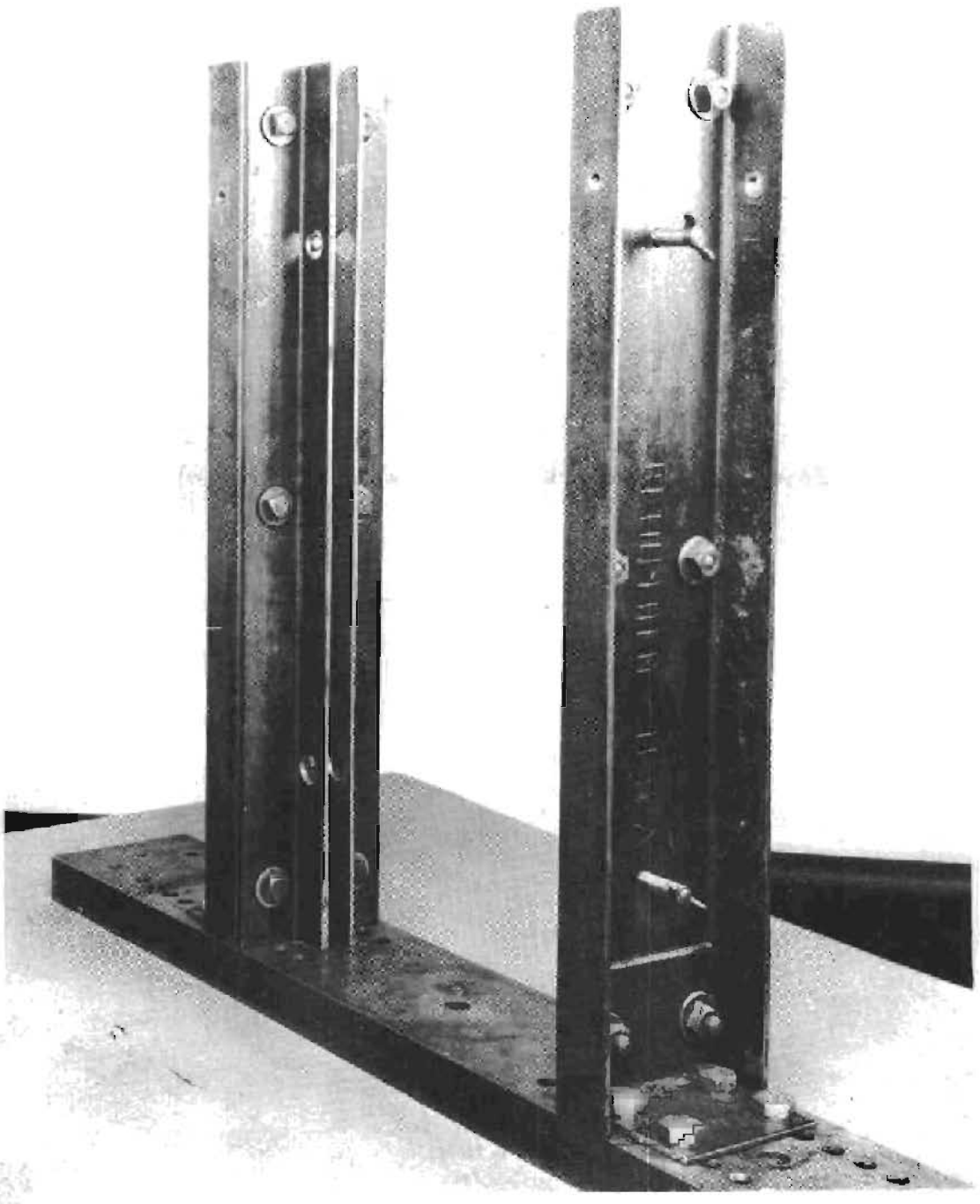

Figure 3.--Side view of panel buckling apparatus showing details of base and fixed posts.

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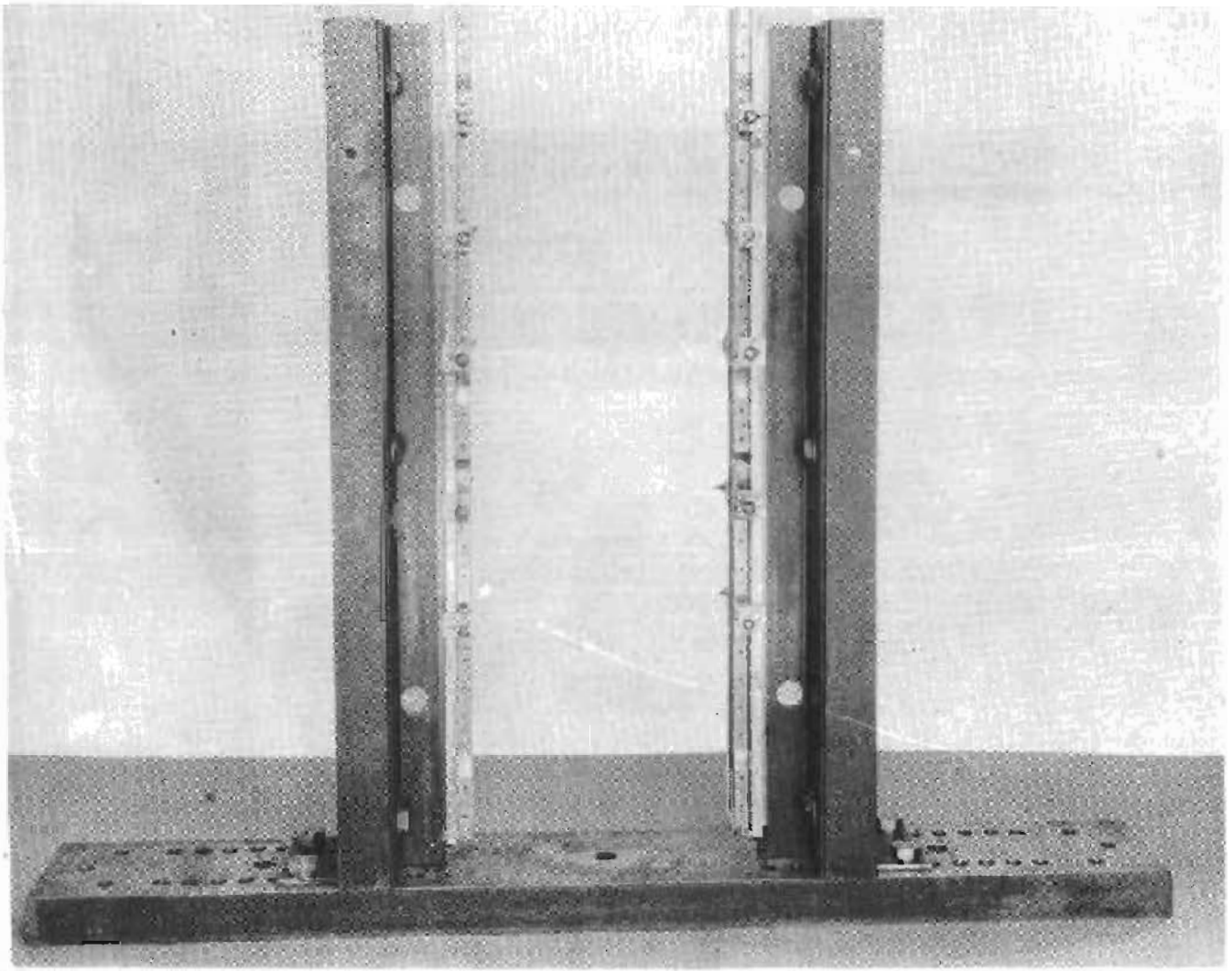

Figure 4.--Front view of panel buckling apparatus showing movable posts in place.

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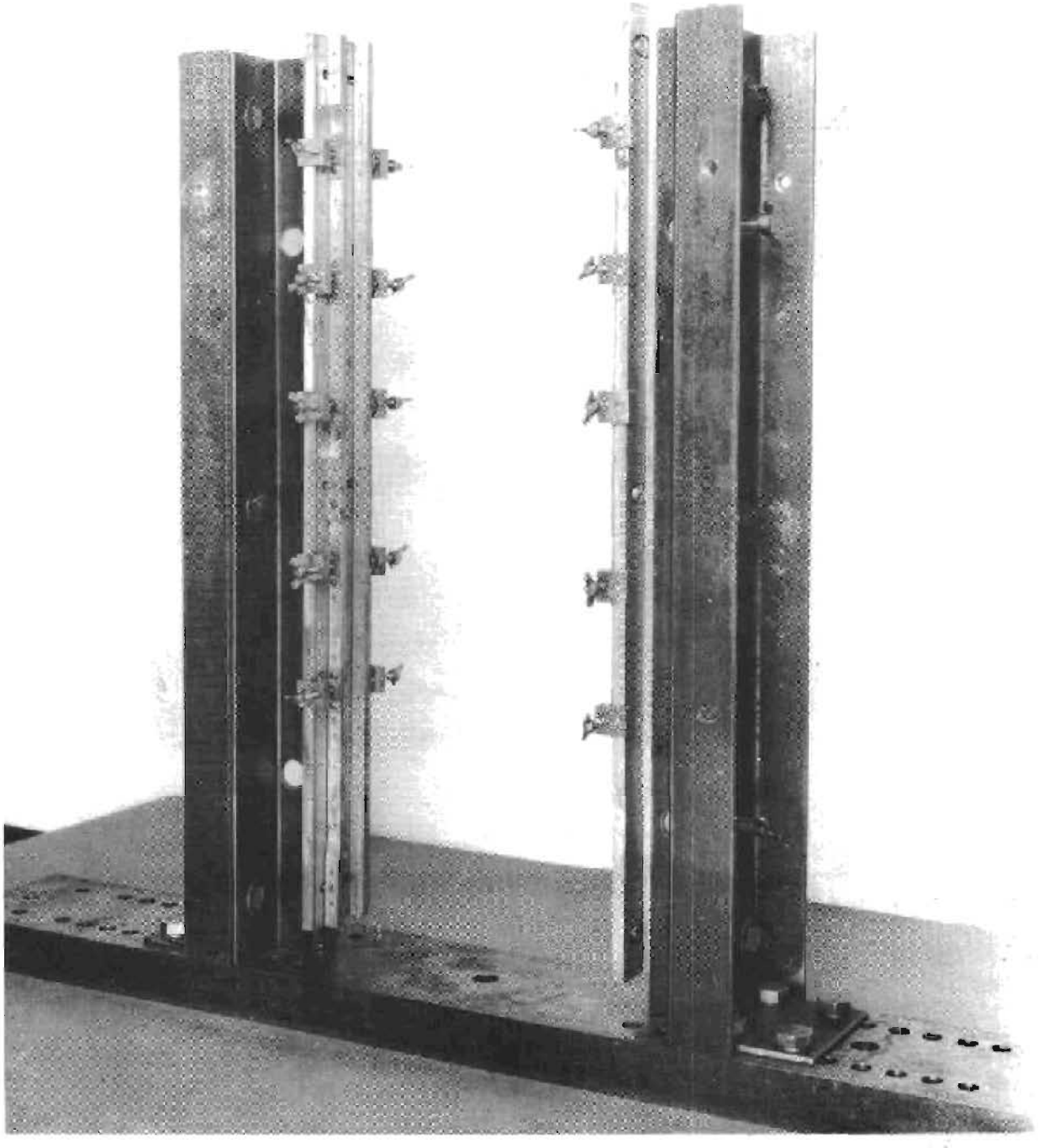

Figure 5.--Side view of panel buckling apparatus showing movable posts in place.

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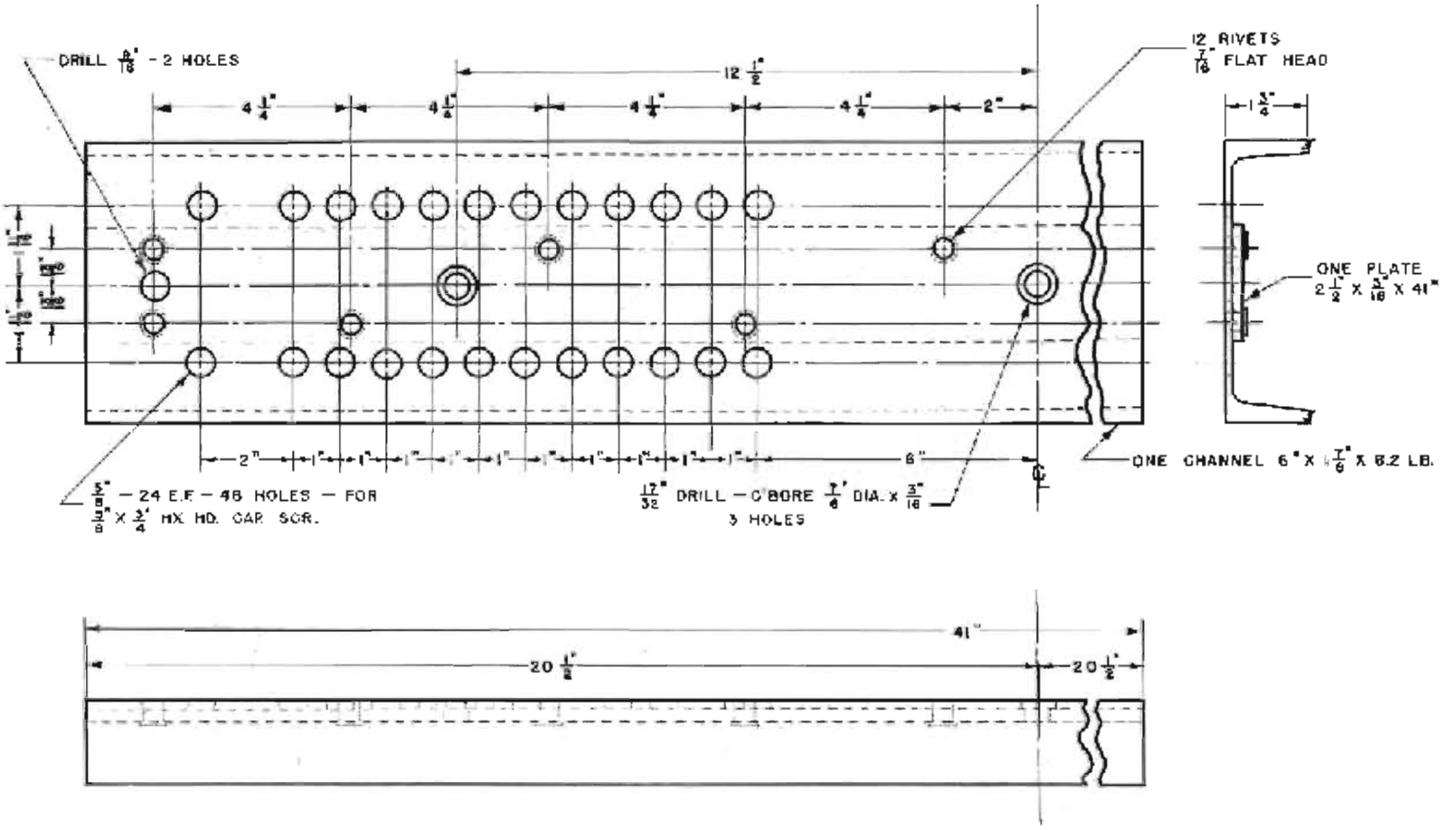

CHANNEL IRON BASE ASSEMBLY FOR PANEL BUCKLING TEST

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN

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Figure 8.--Design details of channel iron base for panel buckling apparatus.

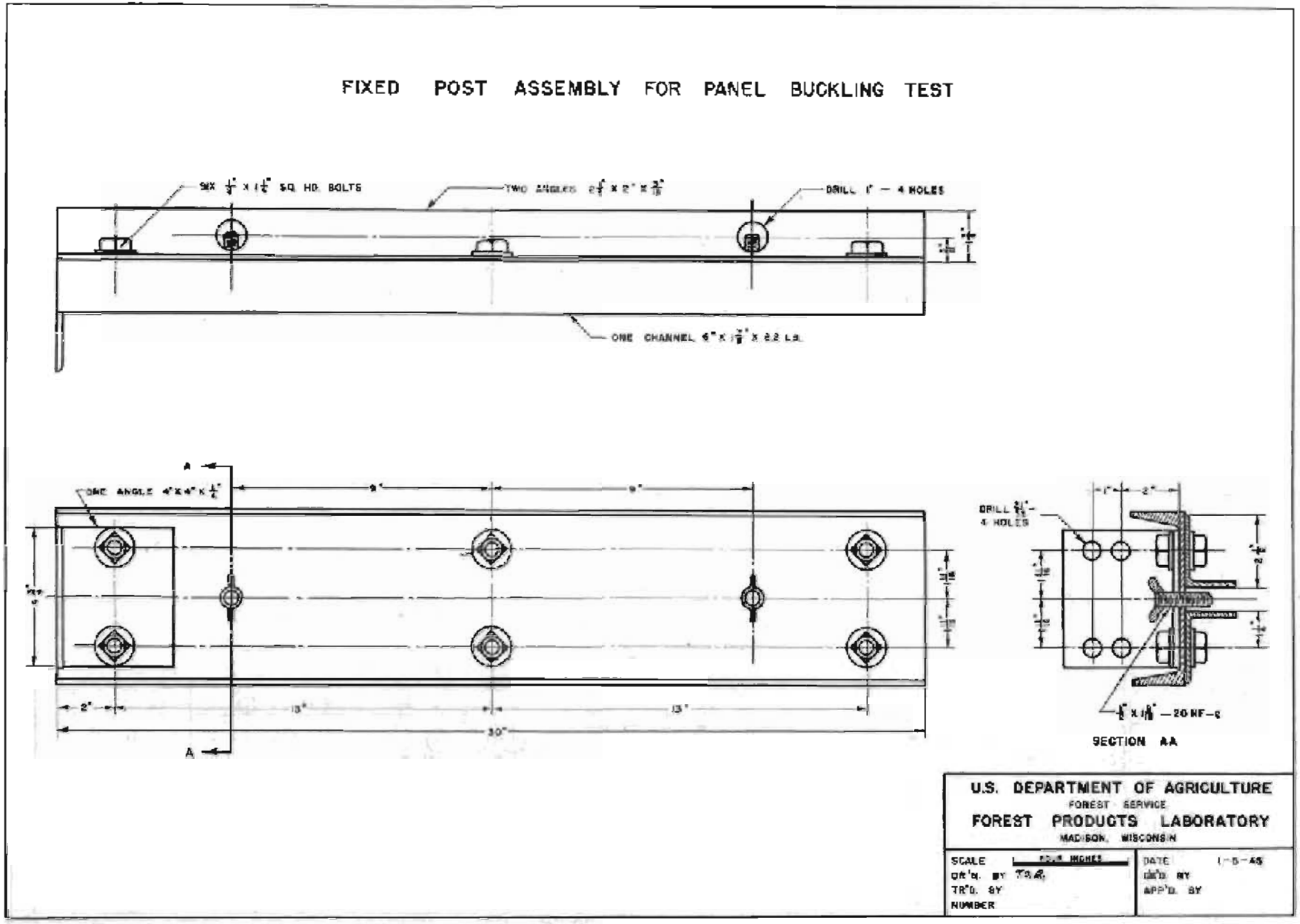


Figure 7.--Design details of fixed posts of panel buckling apparatus built of channel and angle iron sections.

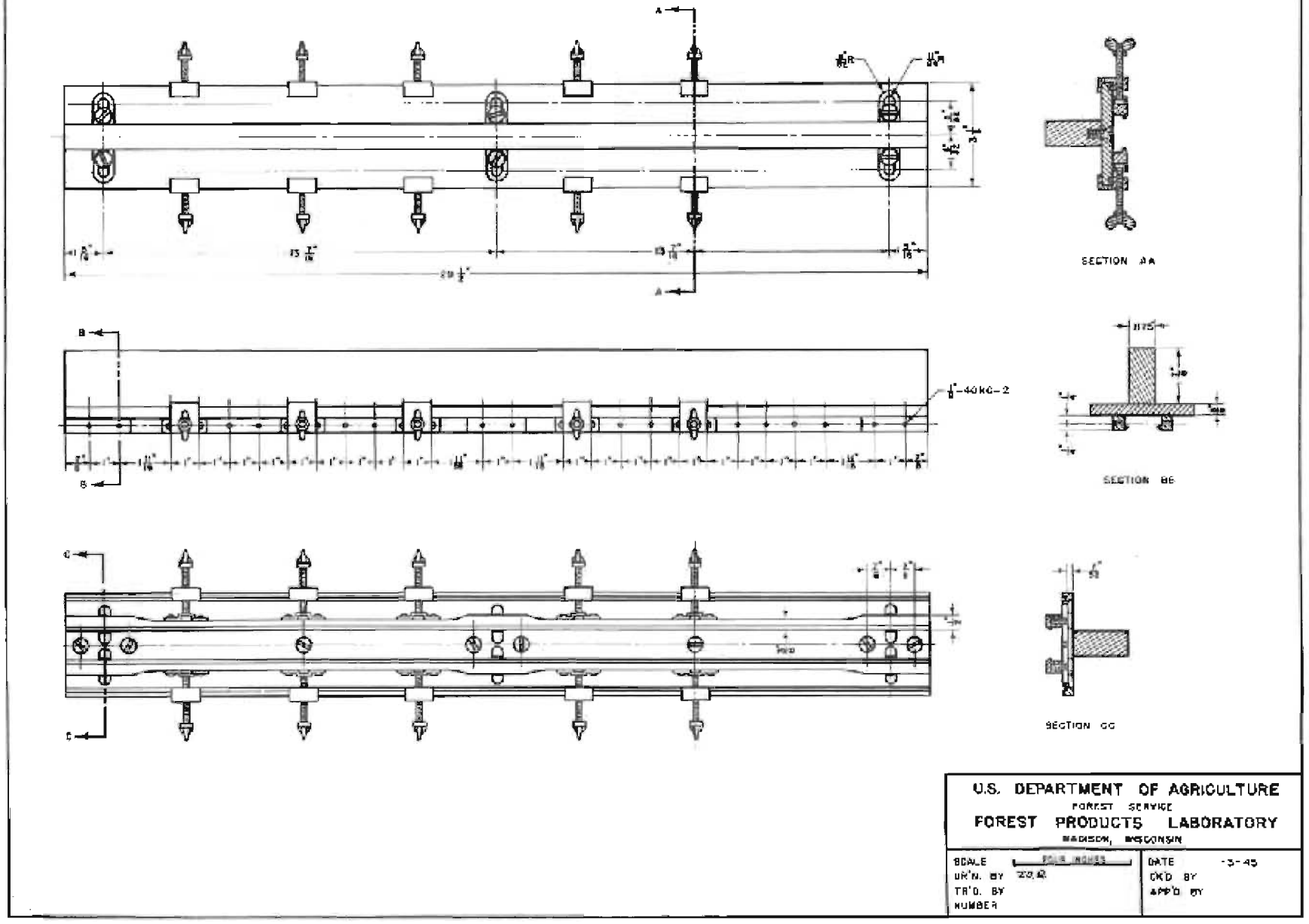
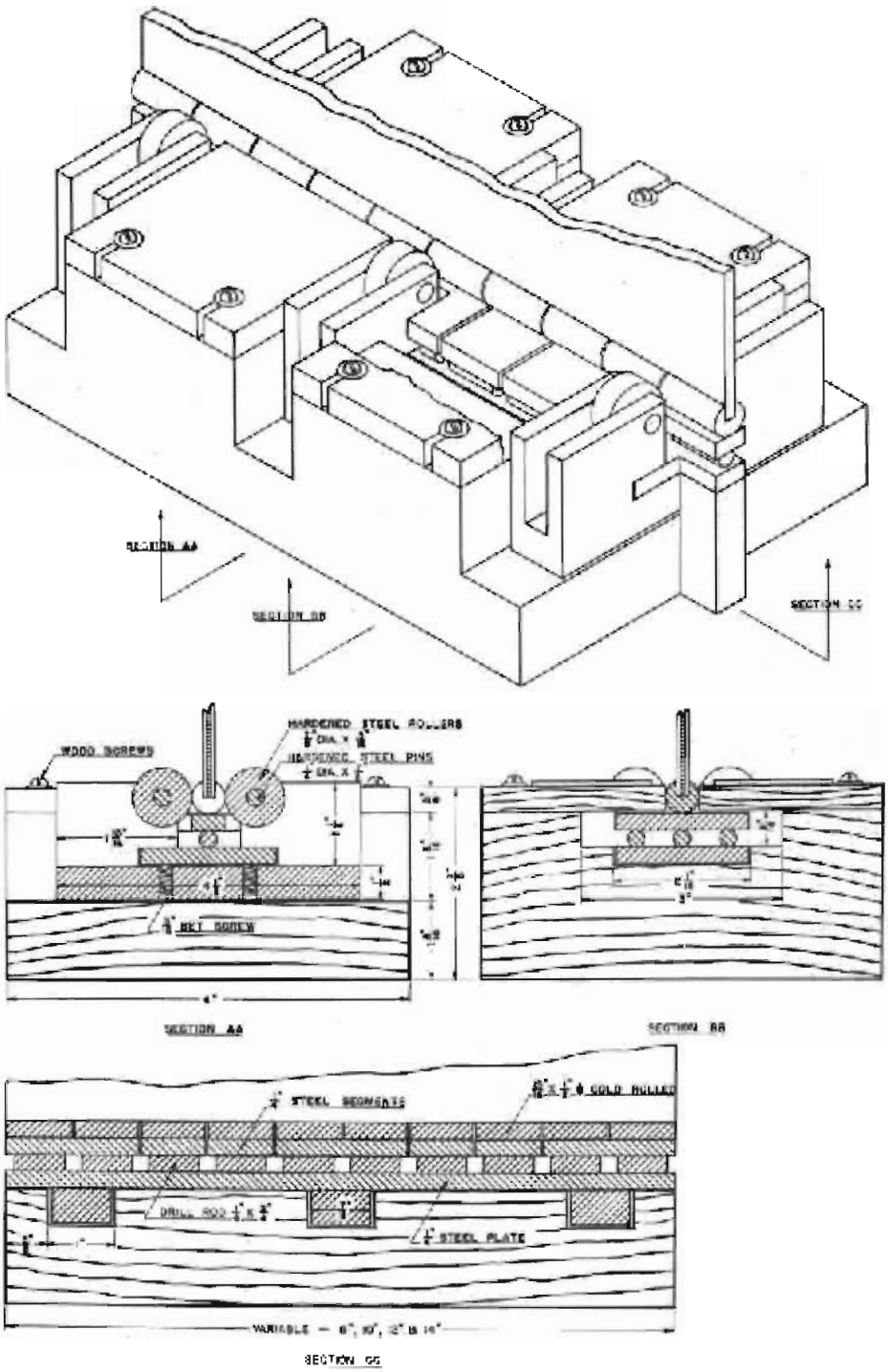


Figure 8.--Design details of movable posts of panel buckling apparatus.



LOADING HEAD
FOR
PANEL BUCKLING TEST
(SIMPLY-SUPPORTED EDGES)

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN

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Figure 9.--Design details of loading head used in tests of stiffened flat panels.

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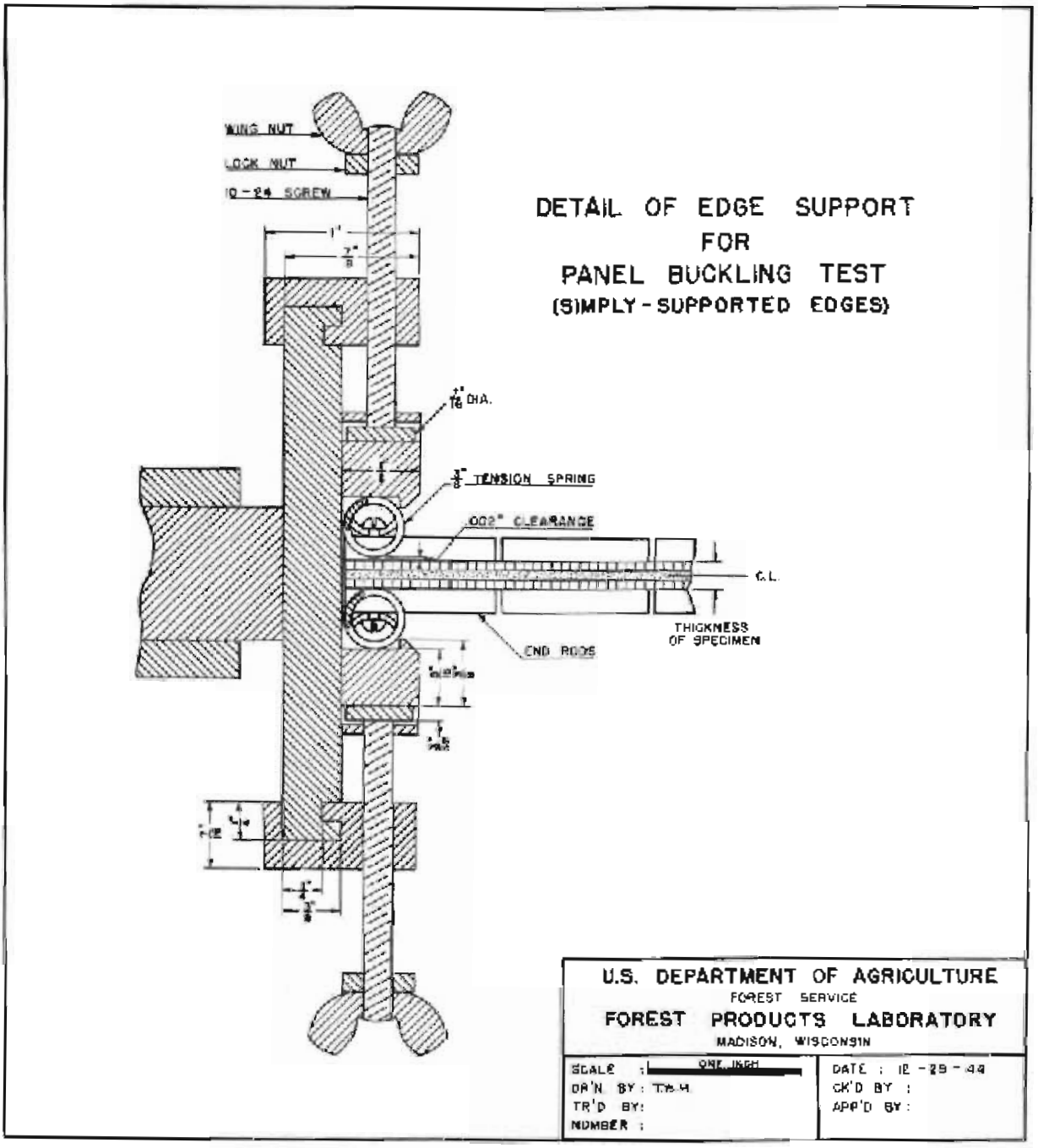

Figure 10.--Detail of edge support for panel buckling test of stiffened panels.

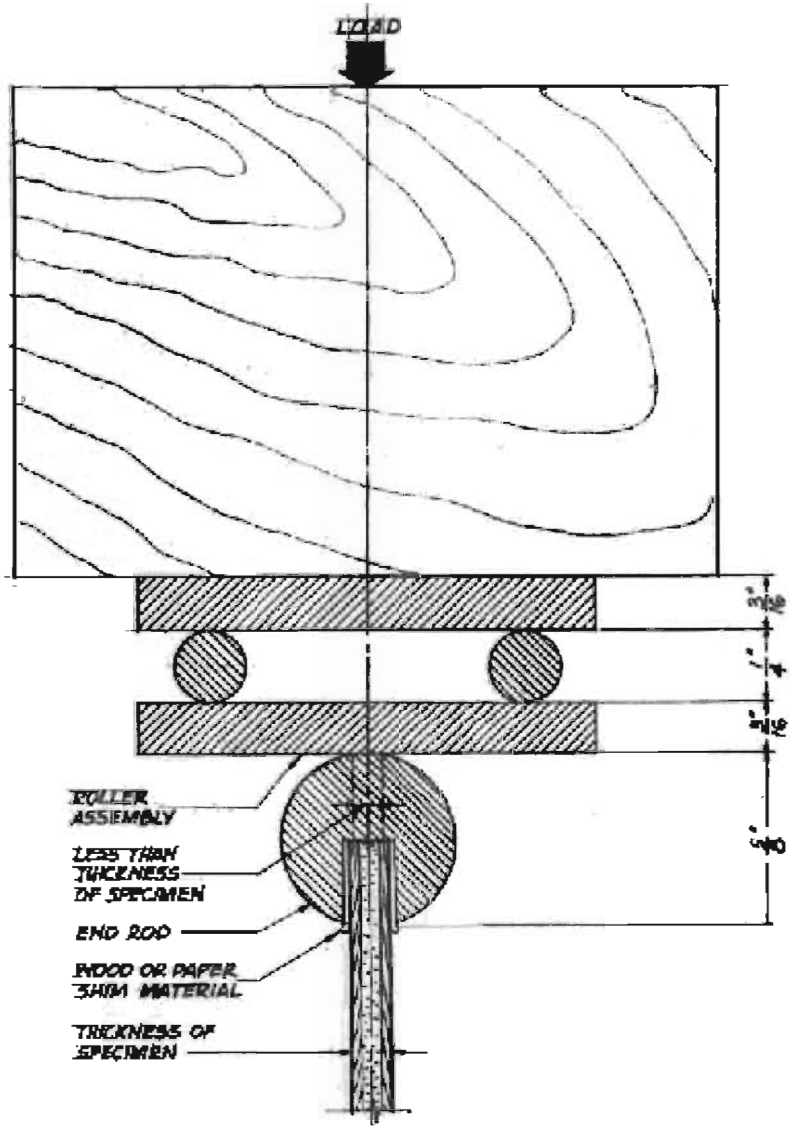

Figure 11.--Edge assembly for unstiffened panels during test as shown by a section through guide rail. Section is symmetrical about centerline.

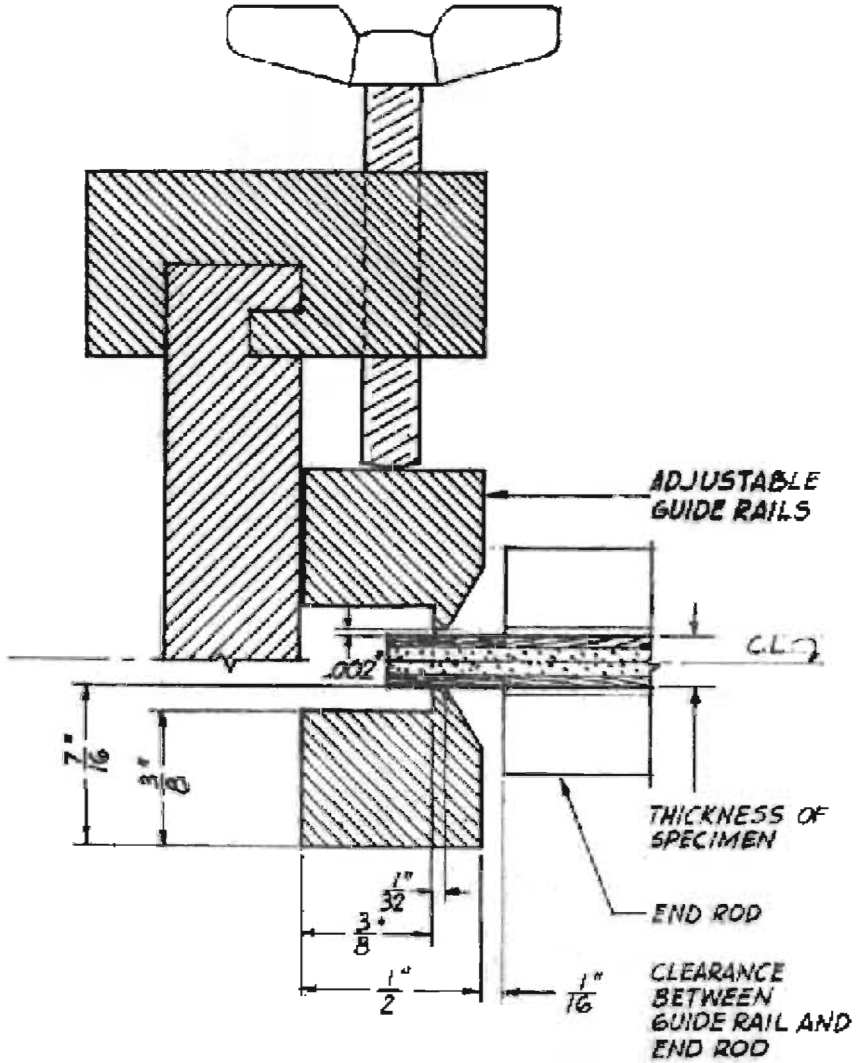

Figure 12.--End assembly of unstiffened panels during test as shown by a transverse section through the top of specimen. Bottom assembly is identical.

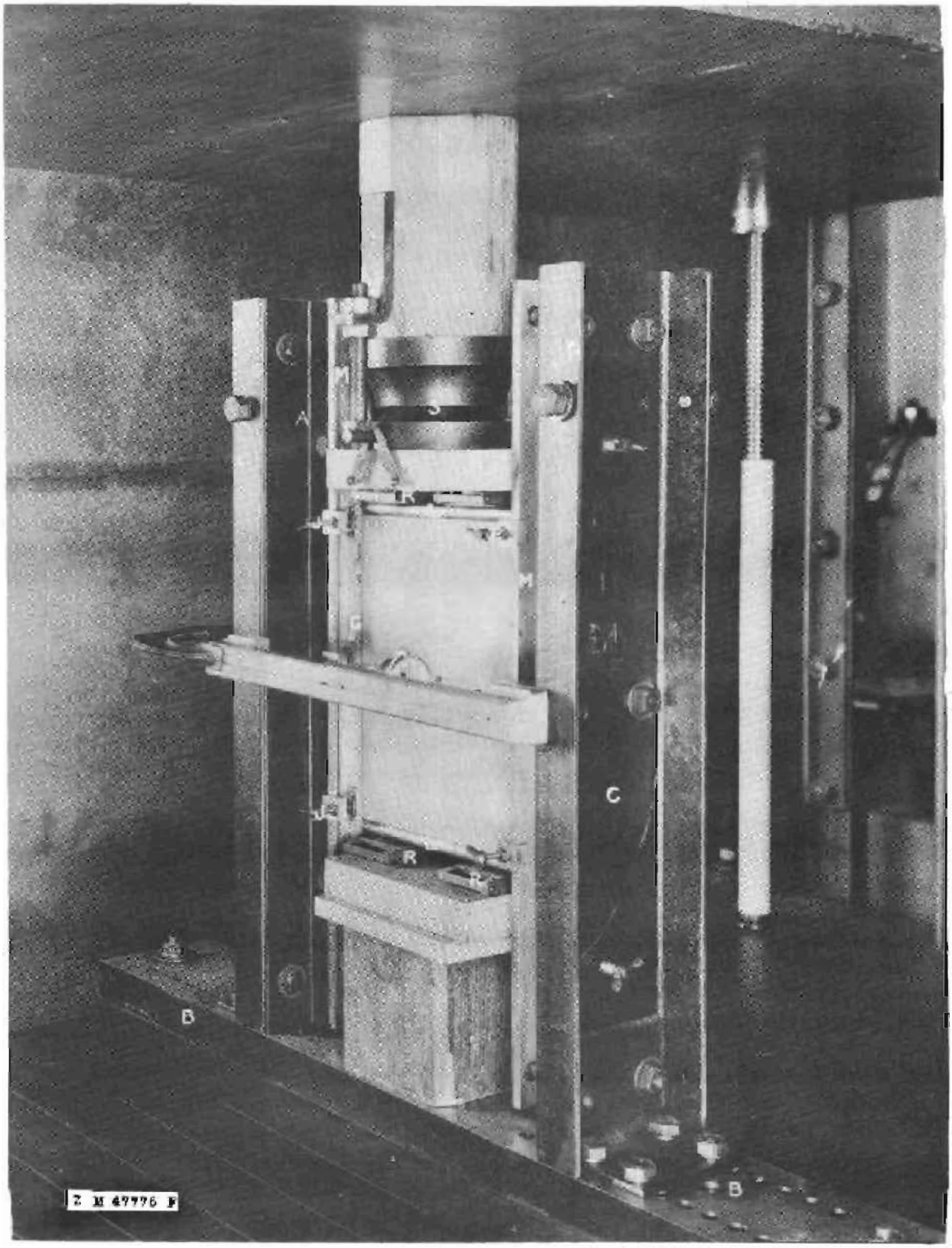

Figure 13.--Unstiffened test panel ready for test in the buckling test apparatus. The lettering refers to the same parts identified in figure 4. In addition, J indicates adjusting screws and S the spherical head (note provision for motion of head in one plane only).

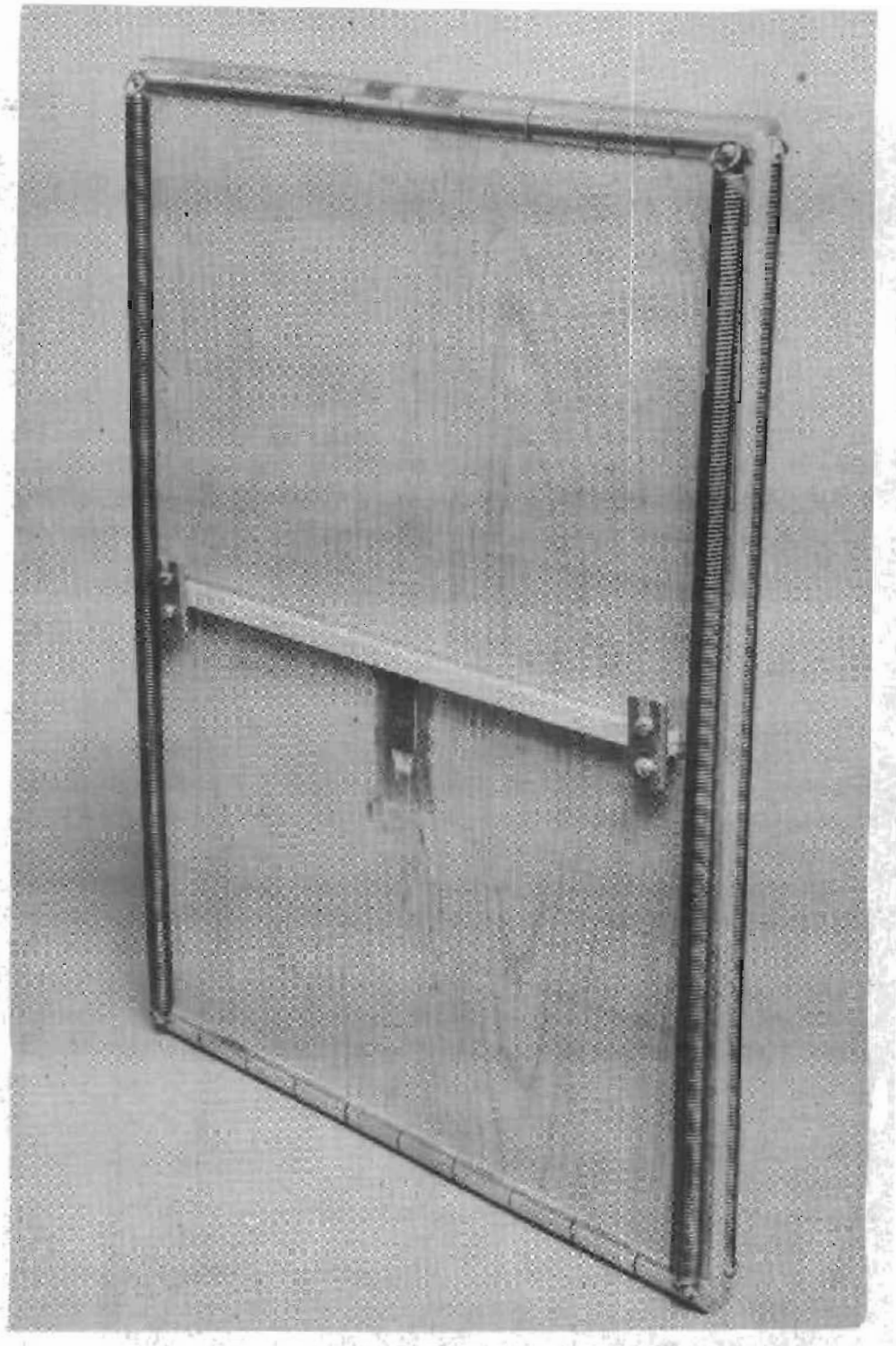

Figure 14.--Stiffened test panel mounted in segmented cylindrical steel loading rods prior to test. The method of restraining the ends of the stiffener to prevent separation at the ends, the metalectric strain gage for measuring deformation, and the attachment of coil springs at the panel edges to reduce frictional restraint during test can clearly be seen.

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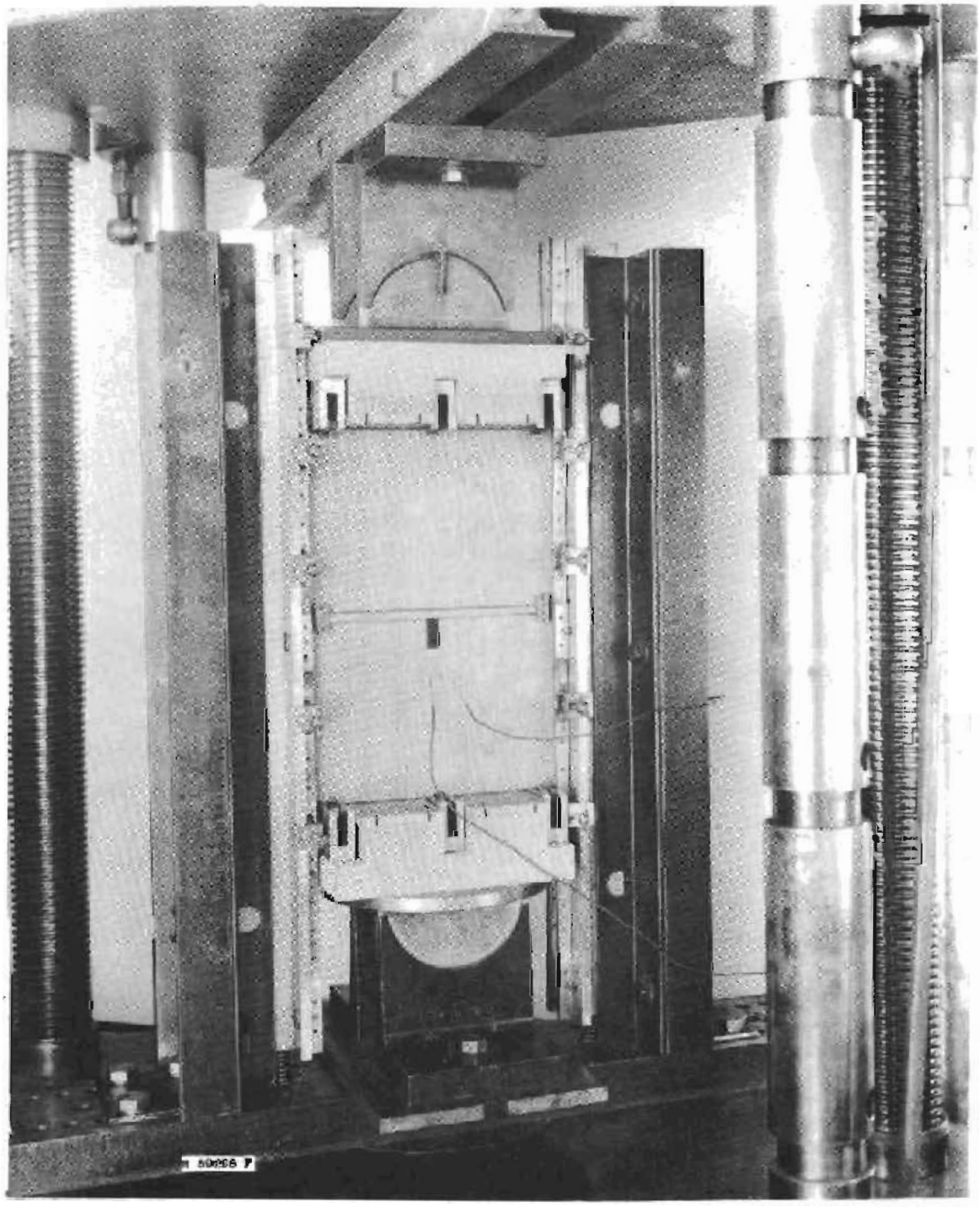

Figure 15.--Stiffened test panel ready for test. Metalectric strain gage mounted below horizontal stiffener is used in measuring deformations in the specimen.

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