METHODS FOR CONDUCTING MECHANICAL TESTS OF SANDWICH CONSTRUCTION AT NORMAL TEMPERATURES

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METHODS FOR CONDUCTING MECHANICAL TESTS OF SANDWICH CONSTRUCTIONS AT NORMAL TEMPERATURE[1]

Introduction

Foreword

1. Sandwich construction as here considered is comprised of a construction consisting of thin faces of a relatively high-strength material bonded to a core of a lighter-weight material or materials.

Experience in the testing of sandwich constructions has been extensive enough to establish procedures generally applicable to all possible combinations of materials and covering all details. The procedures presented herein have been followed in the tests of a large number of specimens and have given satisfactory results.

General information is included on gluing procedures that have been found satisfactory, as well as descriptions of fabrication methods and jigs that may be helpful to the user of this report in the preparation of specimens.

Scope

2. These methods cover procedures for testing sandwich constructions in compression, tension, bending, and shear at normal temperatures.

Number of Tests

3. The number of test specimens to be chosen and the method of their selection depend on the purpose of the particular tests under consideration, so that no general rule can be given to cover all cases. However, if specimens are to be used for acceptance tests, not less than five specimens of a type shall be tested.

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[1] This progress report is one of a series prepared and distributed by the Forest Products Laboratory under U. S. Navy, Bureau of Aeronautics No. NBA-PO-NAer 00619, Amendment No. 1, and U. S. Air Force No. USAF-PO-(33-038)48-41E. Results here reported are preliminary and may be revised as additional data become available.

Control of Moisture Content

4. Where the physical properties of the component materials are affected by moisture, the test specimens shall be brought to constant weight before testing, preferably in a conditioning room with temperature and humidity control. The tests shall preferably be made in a room under the same conditions. This would provide specimens having a uniform moisture content, and changes in moisture content would not occur during test. A temperature of 75° F. and a relative humidity of 64 percent or a temperature of 75° F. and a relative humidity of 50 percent are recommended.

Adhesive Processes and Alining Jigs for Use in Fabrication of Tension and Shear Specimens

5. The adhesive process to be used in bonding tension cubes or shear plates to the sandwich specimen will depend on the properties of the core, adhesive, and facing of the sandwich panel. When a metal-faced sandwich panel is being tested, it is recommended that a hot-setting adhesive of the type formulated for bonding metal to metal be used, providing the use of the required heat does not interfere with the proper evaluation of the properties of the sandwich panel. If it be desirable that lower temperatures be used in bonding the metal cubes or plates to the facings, it will be necessary to apply and cure a heat-curing priming adhesive on the exterior side of the sandwich facings prior to the fabrication of the sandwich panel. An acid-catalyzed intermediate-temperature-setting phenol-resin or room-temperature-setting resorcinol-resin adhesive can then be used to bond this primed surface to the primed surface of metal cubes or plates at curing temperatures ranging from room temperatures to 220° F., depending on the type of glue used, the amount of catalyst added, and the pressing time that can be allowed. If it is not possible either to prime the sandwich facing prior to the fabrication or to apply heat to the panel, low-strength joints between the sandwich and fixtures can be obtained by the use of adhesives such as casein-rubber latex, solvent drying of rubber and thermoplastic cements, and specially formulated room-temperature-setting metal-to-metal adhesives.

When glass-fabric-faced sandwich panels are being tested, primed metal cubes or plates can be bonded to the facings by use of acid-catalyzed intermediate-temperature-setting phenol-resin adhesives. If it is necessary that this gluing be done at room temperatures, room-temperature-setting resorcinol-resin adhesives can be used in the same manner.

Plywood-faced sandwich panels can be bonded to adhesive-primed cubes or plates by room-temperature-setting resorcinol-resin adhesives, or if shorter pressing periods are desirable, by the intermediate-temperature-setting phenol-resin adhesives.

The particular gluing conditions to be used with these adhesives will vary considerably with the type used, so that the recommendation of the adhesive manufacturer should be followed as closely as possible. It is recommended that the adhesives always be applied to both surfaces of the glue joint. Maximum allowable pressure (15 p.s.i. has been used with a number of commercial-aircraft core materials and as high as 100 p.s.i. with end-grain balsa) that will not damage the core material, shall be used. To obtain proper curing of the adhesive, sufficient time should be allowed for the heat to penetrate any alining jig and the metal cubes or plates, and to cure the glue joint.

It is necessary to remove any surface contamination from the sandwich facings and the metal cubes or plates prior to the bonding. A recommended procedure for use with aluminum cubes is first to remove as much contamination as possible with an acetone-soaked cloth, and then to immerse them for 10 minutes at 140° to 160° F. in a solution of 10 parts by weight of concentrated sulfuric acid, 1 part by weight of sodium dichromate, and 30 parts by weight of water, followed by washing in hot water and air-drying. Steel plates have been cleaned by abrading with No. 1/2 emery cloth, washing off particles with hot water and steam, and then quickly air-drying. Glass-fabric laminate, plywood, aluminum alloy, and primed metal surfaces should be lightly and sufficiently abraded with sandpaper or emery cloth to remove the glossy surface and any irregularities.

Aluminum cubes can be reused by sanding off adhesive and core materials and resurfacing them to a uniform thickness on a metal-milling machine. In some instances adhesives have been removed from the cubes by the use of solvent chemicals or hot molten salts. Cubes shall not be reused when more than 0.100 inch has been removed during reuse. Steel plates can be reused by scraping off as much adhesive and core material as possible, with application of some heat if necessary, and then by sanding the remainder off with emery cloth.

As alinement is an important factor in tension- and shear-test specimens, it is recommended that alinement jigs be used during the fabrication of specimens. Alinement jigs that have been used for preparing tension- and shear-test specimens are shown in figures 1 and 2. The tension jig will prepare up to 25 test specimens on a single section of panel. The procedure in assembling specimens in this jig is to place the cubes with glue spread on their upper face in the alining holes, lay the sandwich panel with glue applied on both surfaces in place on top of the cubes, insert the upper alining bars on top of the panel, and then place the cubes with glue on their lower faces in the upper holes of the jig. The assembly is then pressed under the proper curing conditions. Following this curing, the jig is disassembled and the glued assembly removed. Individual specimens are cut from this assembly with the use of a bandsaw.

The shear-specimen (flatwise) jig shown in figure 2 has a number of adjustments to allow it to be used with several thicknesses and lengths of plates. The procedure in assembling specimens in this jig is to put the lower plate in place with the loading end against the movable end of the jig and with the adhesive-spread surface up, to place the sandwich panel with glue spread on both faces on top of the plate, and then to lay the top plate on the panel with its loading end against the fixed end of the jig and with its adhesive-spread surface down. The movable end of the jig is then tightened until the distance between the upper stops is equal to the length of the plate. With a properly designed jig the distance between the middle stops will then be equal to the length of the sandwich panel, and the sandwich specimen will be in the proper position between the two plates. The assembly is then pressed and cured, and the finished specimen is removed from the jig.

Report

6. The report of each test shall include a complete description of the material -- the thicknesses of the core and facings, the materials in each, the direction of grains, fibers, or warp, if any, the glue used to bond the facings to the core, and the bonding pressure and temperature. For component materials affected by moisture, the moisture content shall be determined. The report shall also include a complete description of the type of failure.

The formulas are correct for any consistent system of units. If units of pounds and inches are used the stress and moduli of elasticity and rigidity will be obtained in pounds per square inch. Average stresses are equal to the total load divided by the total cross section.

Compression Edgewise

Scope

7. Compression edgewise shall be defined as compression in a direction parallel to the plane of the sheet.

Test Specimen

8. The test specimen shall be rectangular in cross section. The unclamped length (dimension parallel to the direction of applied load) of the specimen shall not be greater than four times the total thickness of the specimen. The width of the specimen shall be at least 2 inches, but not less than twice the total thickness. The width and thickness shall be measured to the nearest 0.001 inch and the length to the nearest 0.01 inch. Care shall be taken in preparing the test specimens to insure smooth end surfaces free of burs. The ends shall be parallel to each other and at right angles to the length of the specimens.

Lateral Support at Ends of Specimen

9. All specimens shall be laterally supported adjacent to the loaded ends on the facings of the sandwich by means of clamps, which shall be tightened to the extent that no appreciable force shall be required to remove the specimen from the clamps. Each of the two clamps shall be made of two rectangular steel bars fastened together so as to clamp the specimen between them. The cross-sectional dimensions of these bars shall not be less than the total thickness of the specimen. The clamps will provide support for the

facings and prevent an early buckling failure due to separation of the facing from the core at the point of contact with the loading plates. They shall be placed on contact with the loading plates to approximate fixed end conditions of the specimen.

One type of apparatus used in this test is shown in figure 3. A more satisfactory test procedure to insure a fixed end condition at the bearing edge of each facing through the utilization of cast-disk end supports is illustrated in figure 4. To obtain uniform stress distribution across the width of the facings, the bearing edges of the facings shall be ground so as to be smooth and parallel to each other and at right angles to the specimen length. A portion of the core material, equal to one-half the thickness of the cast disks, shall be removed from each end of the specimen, and the ends of the specimen shall then be so cast in a suitable molding material (plaster of Paris or cast resin) that the bearing ends will be flush with the exterior surfaces of the disk support.

Loading Procedure

10. The load shall be applied through a spherical bearing block of the suspended, self-alining type, properly centered on the specimen to distribute the load uniformly on each facing. The load may be considered to be uniformly distributed if the strains measured on opposite sides of the specimen are within 10 percent of each other in the early stages of loading. The load shall be applied by continuous motion of the movable head of the testing machine. The rate of load application shall be such that the unit rate of strain shall be equal to 0.003 inch per inch of total length of specimen per minute, within a permissible variation of ± 25 percent.

Load-deformation Data

11. Data for load-deformation curves may be taken to determine the effective modulus of elasticity, proportional-limit stress, yield stress, compressive strength, the approximate strain at failure, and the distribution of strain in each face. Increments of load shall be so chosen that approximately 12 readings of load and deformation will be taken to the proportional limit. Deformations shall be read to the nearest 0.001 inch by means of a suitable gage-length compressometer attached over the central portion of the length of the specimen. The gage length shall not be greater than two-thirds of the unclamped length of the specimen, nor shall the points of attachment be closer than 1/4 inch, and preferably not closer than 1/2 inch, to the ends of the unsupported length. The gages shall be attached to the facings.

Compression Flatwise

Scope

12. Compression flatwise shall be defined as compression normal to the plane of the sheet.

Test Specimen

13. The nominal size of the test specimen shall be 2 inches square by the thickness of the material.[2] The cut edges shall be smooth and free of burs. All dimensions shall be measured to the nearest 0.001 inch.

Loading Procedure

14. The load shall be applied through a spherical bearing block of the suspended, self-alining type. The load shall be applied by continuous motion of the movable head of the testing machine. The rate of load application shall be such that the unit rate of strain is equal to 0.003 inch per inch of core thickness per minute, within a permissible variation of ± 25 percent.

Deformation Data

15. Data for load-deformation curves may be taken to determine the effective modulus of elasticity and the apparent proportional-limit stress. Increments of load shall be so chosen that approximately 12 readings of load and deformation are taken to the proportional limit. Deformations shall be read to the nearest 0.0001 inch by means of a compressometer having a gage length not greater than two-thirds the thickness of the core material of the sandwich and whose weight will have no effect on strain measurement. The compressometer shall be attached over the central portion of the thickness of the specimen and, if of the lever type, shall have adequate support to permit free motion of the knife edges. Excessive penetration of the knife edges into the soft core material may be eliminated by placing a protective material under each knife edge on the surface of the core. Deformations may also be taken between the heads of the testing machine. These deformations shall be read to the nearest 0.0001 inch. Figure 5 shows a satisfactory arrangement of apparatus using 1/4-inch Tuckerman strain gages to measure core deformations and 0.0001-inch dial indicators to measure total deformation. In this illustration, the Tuckerman gages rest upon the heads of nails driven into the soft core material.

Tension Flatwise

Scope

16. Tension flatwise shall be defined as tension normal to the plane of the sandwich.

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[2] This method of test is applicable only to material 3/8 inch or greater in thickness.

Test Specimen

17. The specimen shall be a 1-inch square section of the sandwich panel. One-inch cubes of wood or metal (17ST aluminum alloy is recommended for use with high-strength cores, but hard-maple cubes bonded to the side-grain surface will test most core materials having tensile strengths to 350 pounds per square inch) shall be bonded to both facings of the sandwich specimen. One hole 1/4 inch in diameter shall be drilled in each cube. The axis of the hole shall be parallel to the bonding face, (with wood cubes the holes shall be drilled into the side grain) 0.375 ± 0.02 inches from the face opposite the bonding face, and equidistant (tolerance ± 0.02 inch) between the adjacent sides. The specimen shall be assembled so that the holes in the two cubes on opposite sides of the sandwich specimen will be oriented at 90° to each other, and the sides of the two cubes be in alinement (maximum offset tolerance 0.015 inch). The dimensions of the cross section shall be measured to the nearest 0.001 inch. The completed specimen and fittings that apply the load are shown in figure 6. In panels having cellular-type core materials with cell opening in excess of 3/8 inch, the section of sandwich panel shall be increased to 2 by 2 inches and corresponding changes be made in the test specimen.

Loading Procedure

18. The specimen shall be tested to failure in the fittings shown in figures 6, 7, and 8. The load shall be applied by continuous motion of the movable head of the testing machine. The rate of load application shall be such that the rate of total deformation is 0.035 inch per minute, within a permissible variation of ± 25 percent.

Test Data

19. The tensile strength of the weakest plane shall be determined from the ultimate load and the cross-sectional area. The type and location of failure shall be noted and identified as core, core-to-facing bond, or face delamination. The percentage estimate of failure of each type shall be given. Failures occurring in the bond between the sandwich and test fixture shall be considered unsatisfactory.

Bending Flatwise

Scope

20. Bending flatwise shall be defined as bending so that the applied moments produce curvature of the plane of the sheet.

Test Specimen

21. The test specimen shall be rectangular in cross section. The depth of the specimen shall be equal to the thickness of the sandwich construction, and the width shall be not less than twice the total thickness nor greater than 1/2 the span. The specimen length shall be equal to the span length plus 2 inches. The span length shall be determined in accordance with the information desired, and the span-depth ratios shall be as follows: (a) maximum shear load with resulting shear failure of core or core-to-facing bond, 6 to 1 - 16 to 1; (b) shear modulus determination, and failure occurring in tension or compression in the facings, 16 to 1 - 60 to 1; (c) stiffness determination with minimum of shear deformation, greater than 60 to 1. The actual width and depth shall be measured to the nearest 0.001 inch, and the specimen and span lengths shall be measured to the nearest 0.01 inch.

Loading Procedure

22. Center loading shall be used. A 1-inch overhang shall be allowed at each support. Round-nosed knife edges or roller-bearing supports may be used. In both instances the supports shall be adjustable laterally to compensate for slight twist or warp in the specimen. The construction of this apparatus is shown in detail in figure 9, and the test set-up is shown in figure 10. A loading block having a radius of curvature of one and one-half times the depth of test specimen for a chord length of not less than twice the depth of the specimen shall be used. In cases where excessive local deformation may occur, suitable bearing plates shall be used at the load and support points. The load shall be applied with a continuous motion of the movable head throughout the test. The rate of load application shall be such that the unit rate of fiber strain is equal to 0.0015 inch per inch of outer-fiber length per minute, within a permissible variation of ± 25 percent. The rate of motion of the movable head may be calculated as follows:

$$N = \frac{z L^2}{6d}$$

where N = rate of motion of moving head, in inches per minute
L = span, in inches
d = depth of beam, in inches
z = unit rate of fiber strain, in inches per inch of outer-fiber length per minute (0.0015)

Test Data

23. Data for load-deflection curves may be taken to determine the modulus of elasticity, proportional limit, work to proportional limit, work to maximum load, and total work as shown in figure 10, and readings shall be taken to the nearest 0.001 inch. Increments of load shall be so chosen that not less than 12, and preferably 15 or more, readings of load and deflection will be taken to the proportional limit.

Calculations

24. The average shear stress across the thickness of a sandwich specimen is:

$$p_s = \frac{P}{2hb}$$

If the facings are thin with respect to the core the shear stress in the core is given by

$$p_s = \frac{P}{b(h+c)}$$

where p_s = shear stress, in pounds per square inch
P = load on specimen, in pounds
h = total depth of specimen, in inches
b = width of specimen, in inches
c = thickness of core, in inches.

The approximate shearing modulus of the core associated with shear distortion in planes perpendicular to the facings and parallel to the length of the specimen, is computed as follows:

$$G_c = \frac{P l c}{2\Delta h(h+c)b\left[1 - \frac{Pl^3}{48\Delta D}\right]}$$

in which D is the computed stiffness of the sandwich beam without considering the deflection due to shear in pounds inches squared and is:

$$D = \frac{bf_1f_2(h+c)^2}{4(h-c)} \frac{E_f}{\lambda}$$

and G_c = modulus of rigidity of the core associated with shear strains in planes normal to the facings and parallel to the length of the beam.
P = central load on the beam, in pounds
Δ = measured central deflection associated with P, in inches
l = span of beam, in inches
h = thickness of sandwich = depth of beam, in inches
c = thickness of core, in inches
f_1 = thickness of upper facing of sandwich beam, in inches
f_2 = thickness of lower facing of sandwich beam, in inches
λ = approximately 0.91 for isotropic facings and 1 for most orthotropic facings
b = width of beam, in inches
E_f = modulus of elasticity of the facing in a direction parallel to the span length, in pounds per square inch.

The formula for G_c can be applied successfully only if the following limitation is placed on the span:

$$\frac{P l^3}{48 \Delta D} < 0.60$$

The tensile or compressive stress at the outer surface of the facings depending on which way the beam is bent may be computed as follows:

For the upper facing

$$p_f = \frac{P l}{b} \; \frac{(h-c)^2 + 2f_2 c}{2f_1 f_2 \, (h+c)^2}$$

For the lower facing:

$$p_f = \frac{P l}{b} \; \frac{(h-c)^2 + 2f_1 c}{2f_1 f_2 \, (h+c)^2}$$

The average tensile or compressive stress in the facings depending on which way the beam is bent may be computed as follows:

For the upper facing:

$$p_f = \frac{P\, l}{2f_1 (h+c) b}$$

For the lower facing:

$$p_f = \frac{P\, l}{2f_2 (h+c) b}$$

where p_f = tensile or compressive stress, in pounds per square inch.

Shear Test for the Determination of the Modulus of Rigidity

The test procedure for the determination of the modulus of rigidity of sandwich constructions shall be in accordance with the method described in "Methods of Test for Determining Strength Properties of Core Material for Sandwich Construction," Forest Products Laboratory Report No. 1555, Revised, articles 24 to 29, inclusive. It shall be noted that when a sandwich specimen is tested according to this method, the modulus determined from the equation in article 28 is that of the sandwich construction as a unit and not that of any individual part. The relationship of this modulus of the sandwich construction, G, to the modulus of the facings, G_f, and of the core, G_c, if theoretically expressed as follows:

$$G = G_f \frac{(h^3 - c^3)}{h^3} + G_c \frac{c^3}{h^3}$$

where - The modulus of rigidity measured is that which enters the equations for elastic instability of flat plates.

The respective moduli are those associated with shearing strains in the plane of the sandwich plate, the magnitude of which vary directly with the distance from the neutral plane of the sandwich.

h = total thickness of sandwich specimen, in inches

c = thickness of core, in inches.

Shear Strength -- Flatwise Plane

Scope

25. Shear strength in the flatwise plane of a sandwich shall be defined as the shear strength parallel to the plane of the sandwich. The modulus of rigidity of the sandwich obtained by this test procedure is the modulus associated with the strains in a plane normal to the facing of the sandwich and parallel to the direction of the applied forces.

Test Specimen

26. The test specimen shall be 2 inches in width, with a thickness equal to the thickness of the sandwich, and shall be 12 times the thickness in length. The thickness shall be measured to the nearest 0.001 inch, and the length and width to the nearest 0.01 inch. The test specimen shall be rigidly supported by means of steel plates bonded to the facings as shown in figure 11. The thickness of the plates may be varied in accordance with the strength of the sandwich, but the plate dimensions shall be such that the line of action of the direct tensile or compressive force shall pass through the diagonally opposite corners of the sandwich as shown in figure 11.

Loading Procedure

27. The load shall be applied to the edge of the rigid plates in compression or tension through a spherical bearing block or universal joint so as to distribute the load uniformly across the width of the specimen. The load shall be applied by a continuous motion of the movable head of the testing machine at a rate of application of 0.005 inch per inch of length of specimen diagonal per minute, within a permissible variation of ± 25 percent.

Deformation Data

28. Data for load-deformation curves may be taken to determine the modulus of rigidity of the sandwich. Increments of load shall be taken to obtain approximately 12 readings of load and deformation below the proportional limit. Deformations shall be read to the nearest 0.0001 inch by means of an optical-lever system, dial gage, or any other suitable means. Figure 12 shows a shear-test set-up, using a dial gage for measuring deformations.

Calculations

29. The shear stress shall be computed in accordance with the following formula:

$$p_s = \frac{P}{Lb}$$

where p_s = shear stress, in pounds per square inch

P = load on specimen, in pounds

L = length of specimen, in inches

b = width of specimen, in inches.

The maximum shear strength is obtained by this formula when P equals the maximum load. If the failure at maximum load occurs in the bond between the facings of the sandwich and the face plates, the test shall be considered unsatisfactory.

The shear strains shall be computed as the angular movement of one face plate of the test jig with respect to the other about an axis located on the inside face of one plate and perpendicular to the length-thickness plane. This shear strain is computed by the following equation

$$\theta = \frac{r}{t}$$

where θ = angular strain in radians

r = dial reading or movement of one face plate of test jig with respect to another, in inches

t = distance between plates in inches.

The modulus of rigidity of the sandwich as a unit shall be obtained by computing the slope of the initial straight line portion of the stress-strain curve. It should be noted that the modulus obtained by this method is that of a combination of all of the material between face plates acting as a unit. The theoretical relationship of this modulus, G, to the modulus of the facings, G_f, and of the core, G_c, is expressed as follows:

$$\frac{1}{G} = \frac{h - c}{G_f h} + \frac{c}{G_c h}$$

where; the respective moduli are those associated with shearing strains in a plane normal to the facing and parallel to the direction of the applied forces.

h = total thickness of sandwich, in inches

c = thickness of core, in inches.

The modulus of rigidity of the facings G_f may readily be so large with respect to that of the core G_c that the first term of the right hand member of this equation may be neglected.

Shear Strength -- Edgewise Plane[3]

Scope

30. Shear strength in the edgewise plane of a sandwich shall be defined as the shear strength in a plane normal to the facings of the sandwich. The modulus of rigidity obtained by this procedure is the modulus associated with strains in the plane parallel to the sandwich facings.

Test Specimen

31. The effective specimen shall be square in shape and equal in thickness to the thickness of the sandwich. The specimen shall have projections along each side of the square that are bonded to the loading frame. The length of the sides of the specimen will depend on the strength and stiffness of the sandwich and shall be of such length that the unsupported specimen will not buckle as a unit. The width of the projections will depend on the shear strength and bending stiffness of the sandwich and shall provide sufficient area in shear bond to transmit the applied loads. The thickness of the specimen shall be measured to the nearest 0.001 inch, and the length of the sides to the nearest 0.01 inch. The projections on the specimen shall be bonded to portions of the eight-piece reinforcing and loading frame as shown in figure 13. Details of the loading frame are shown in figure 14.

Loading Procedure

32. The load shall be transmitted to the specimen through the loading frame and shall be applied to the rollers and pins that are a part of this frame as shown in figure 15, or as shown in figure 13 by means of a suitable linkage the load may be applied in tension. The axis of the pins shall be located at the edge of the test panel at the center of the length of the edge. The load shall be applied through a loading block so that the lines of action of the applied force are parallel to the edges of the panel. The load shall be applied continuously throughout the test with a uniform motion of the movable head at a rate of 0.005 inch per inch of length of specimen diagonal per minute, within a permissible variation of ± 25 percent. Figures 13 and 15 show tests being made using this shear apparatus.

Load-deformation Data

33. Data for load-deformation curves may be taken to determine the modulus of rigidity of the sandwich. Strain gages capable of being read to

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[3]This test has proven entirely satisfactory for evaluation of plywood, and preliminary tests indicate its suitability for testing sandwich constructions, but more intensive testing is needed to be certain of its satisfactory use over a wide range of materials.

the nearest 0.0001 inch shall be attached to the central portion of the loaded diagonal on opposite sides of the specimen. Figures 13 and 15 show the use of metalectric strain gages and Huggenberger Tensometers that have been found satisfactory for this purpose. Increments of load shall be so chosen that approximately 12 readings of load and deformation will be obtained below the proportional limit.

Calculations

34. The shear stress of the sandwich is equal to the following:

$$p_s = \frac{.707P}{yh}$$

where p_s = shear stress of the sandwich specimen, in pounds per square inch
P = total load on a square specimen, in pounds
h = total thickness of sandwich specimen, in inches
y = length of a side of the specimen, in inches.

The maximum shear strength is obtained by this formula when P equals the maximum load. If the failure at maximum load occurs in the bond between the facing of the sandwich and the loading plate of the test jig, the test shall be considered unsatisfactory.

The shear strains of this specimen are equal to twice the pure tensile or compressive strain, in inches per inch (average of strains measured on opposite facings at the center of the specimen).

The modulus of rigidity or the shearing modulus of the sandwich as a unit shall be obtained by computing the slope of the initial straight line portion of the stress strain curve. It should be noted that the modulus obtained by this method is that of a combination of the materials within the square test panel acting as a unit. The theoretical relationship of this modulus, G, to the modulus of the facings, G_f, and of the core, G_c, is expressed as follows:

$$G = G_f \left(\frac{h - c}{h}\right) + G_c \frac{c}{h}$$

where; the respective moduli are those associated with shearing strains in the plane parallel to the plane of the sandwich.
h = total thickness of sandwich in inches
c = thickness of core in inches.

Strip Test

Scope

35. The strip test shall determine the energy required to peel or tear off one face of a sandwich specimen.

Test Specimen

36. The test specimen shall be fabricated from a rectangle 3 inches by 4 inches in size and of a thickness equal to that of the sandwich panel. Grooves parallel to the 4-inch dimension shall be cut through one face and the core of the sandwich specimen to the glue line of the opposite face so as to leave a test strip 1.00 inch wide at the center of the specimen as shown in figure 16, and a supporting strip along each edge. A groove parallel to the 3-inch dimension and 1 inch from the end of the specimen shall be cut through from the opposite face to the same depth, and the material thus separated from the specimen shall be removed to leave a 1- by 1-inch projecting tab on the test strip. A 5/16-inch-diameter hole centered 1/2 inch from the tab end shall be drilled in the tab for attachment of the loading device. This drilling shall be done with caution so as not to damage the test specimen.

Test Apparatus

37. The test specimen, (fig. 16) shall be rigidly held, to permit unrestricted removal of the test strip, in an apparatus similar to that shown in figure 17. The apparatus shall be firmly mounted on the specimen platform of a Forest Products Laboratory-type toughness machine[4] or equivalent. The specimen shall be inclined toward the loading arm so that the force applied to remove the test strip will make an angle of 60° to the specimen face and the strip shall be removed in a single continuous application of force.

Loading Procedure

38. The load shall be applied to the specimen through a loading arm attached to the test strip and to a chain attached to the drum of the toughness machine. This drum will be centered around the axis of rotation of the pendulum. The load linkage shall be adjusted so that the load will be applied when the pendulum is 55 degrees below the horizontal on the downward swing. The initial angle of the pendulum shall be at 45 degrees with the horizontal, and the weight shall be in position 5 to supply sufficient energy to test most sandwich materials. Figure 18 shows the test apparatus after completion of a test, and figure 19 gives a diagrammatic sketch of the test set-up.

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[4]Forest Products Laboratory Toughness Testing Machine. FPL Report No. 1308.

Test Data

39. The initial and final angle shall be read to the nearest 0.1° by means of the vernier. The energy absorbed shall be calculated as follows:

$$T = wL\ (\cos A_2 - \cos A_1)$$

where T = toughness or energy absorbed, in inch pounds

w = weight of pendulum, in pounds

L = distance from center of supporting axis to center of gravity of the pendulum, in inches

A_1 = initial angle (45° since friction is compensated for in machine adjustment)

A_2 = final angle the pendulum makes with the vertical after failure of test specimen, in degrees.

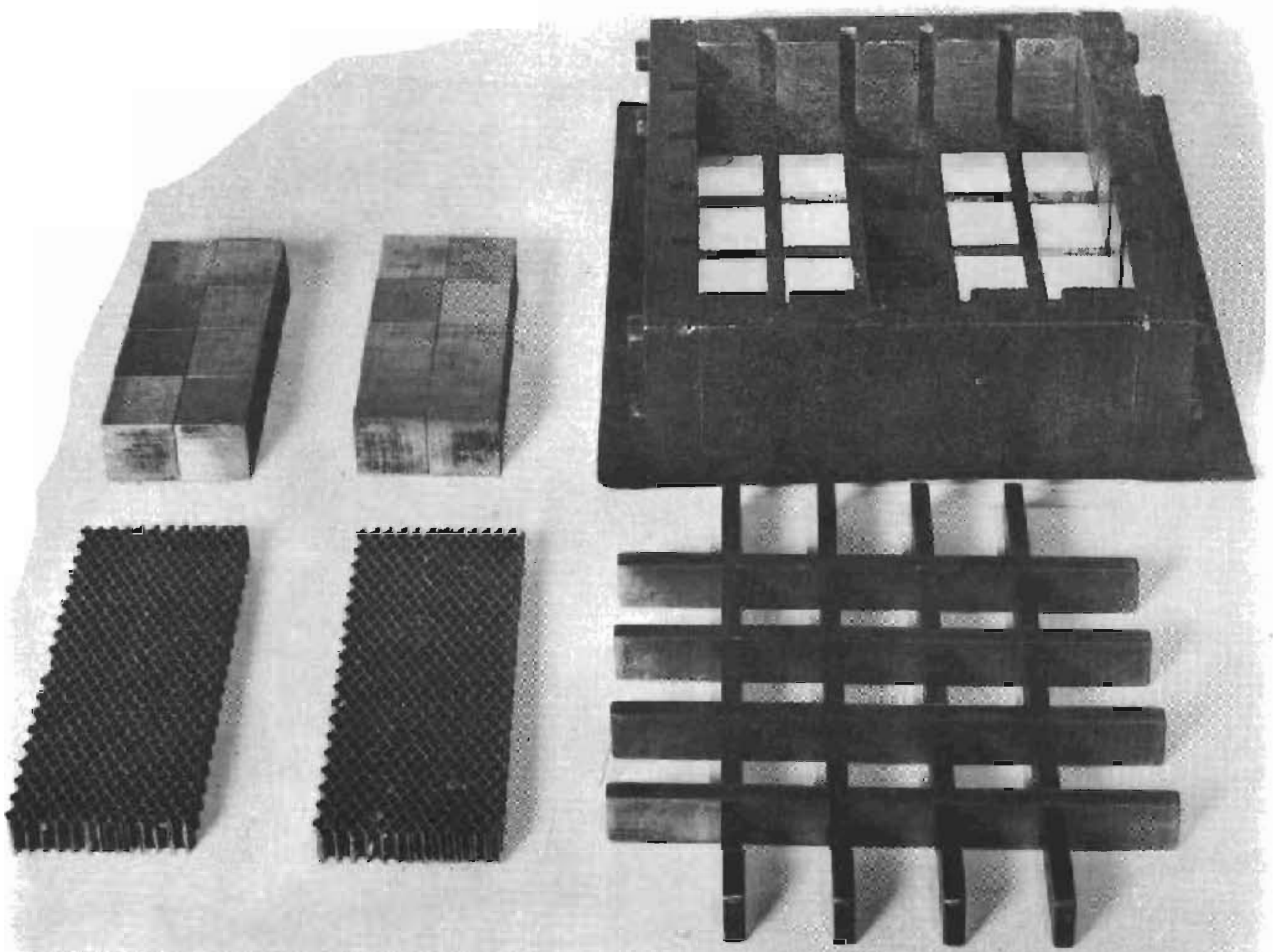

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Figure 1.--Alinement jig used in the fabrication of 25 or less tension-edgewise specimens. In making specimens from sandwich materials the honeycomb core shown in the figure would be replaced by the desired sandwich construction.

ZM 78953 F

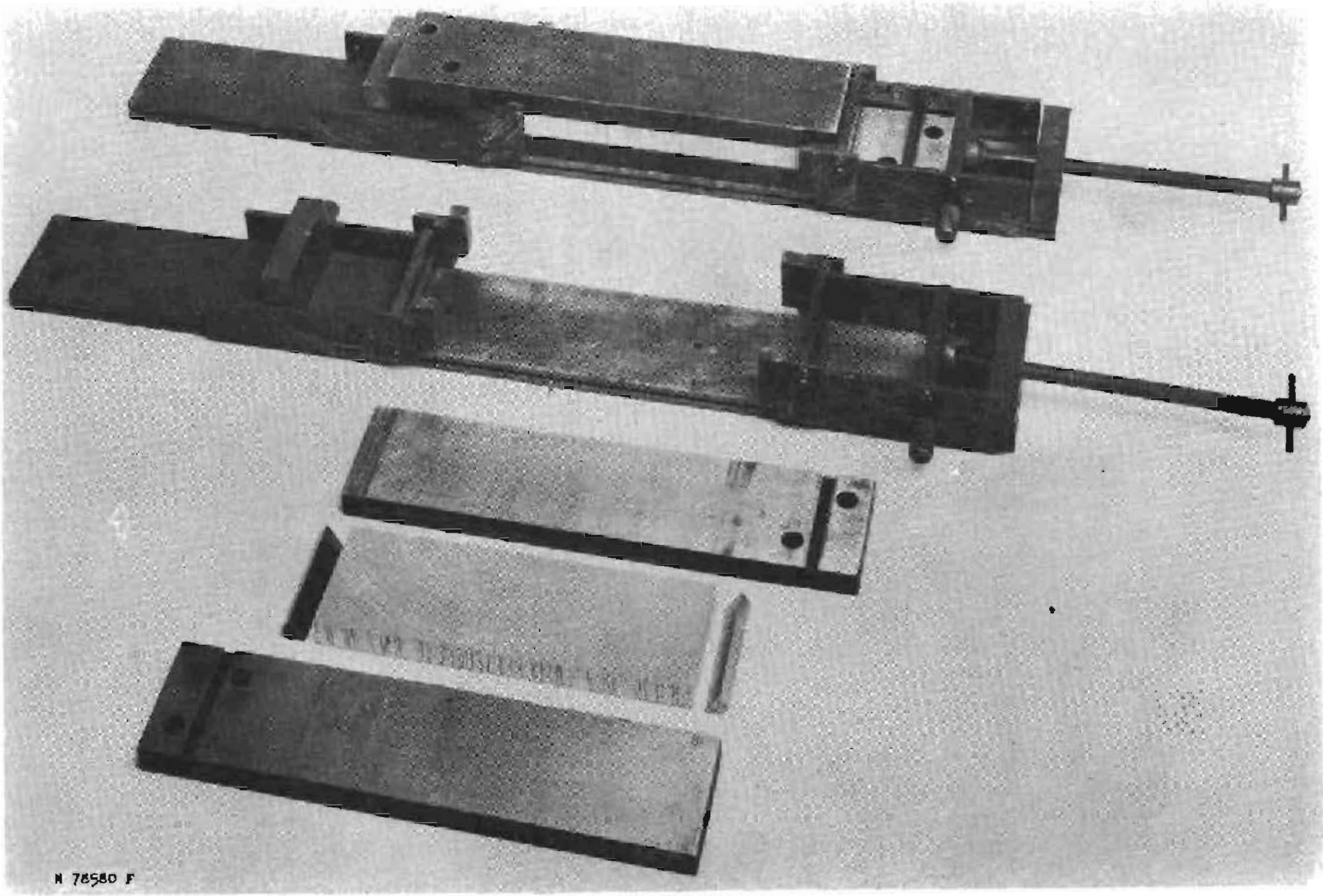


Figure 2.--Alinement jig for fabrication of shear-test specimens of sandwich or sandwich-core materials. Component parts and a complete assembly are shown.

zM 78954 F

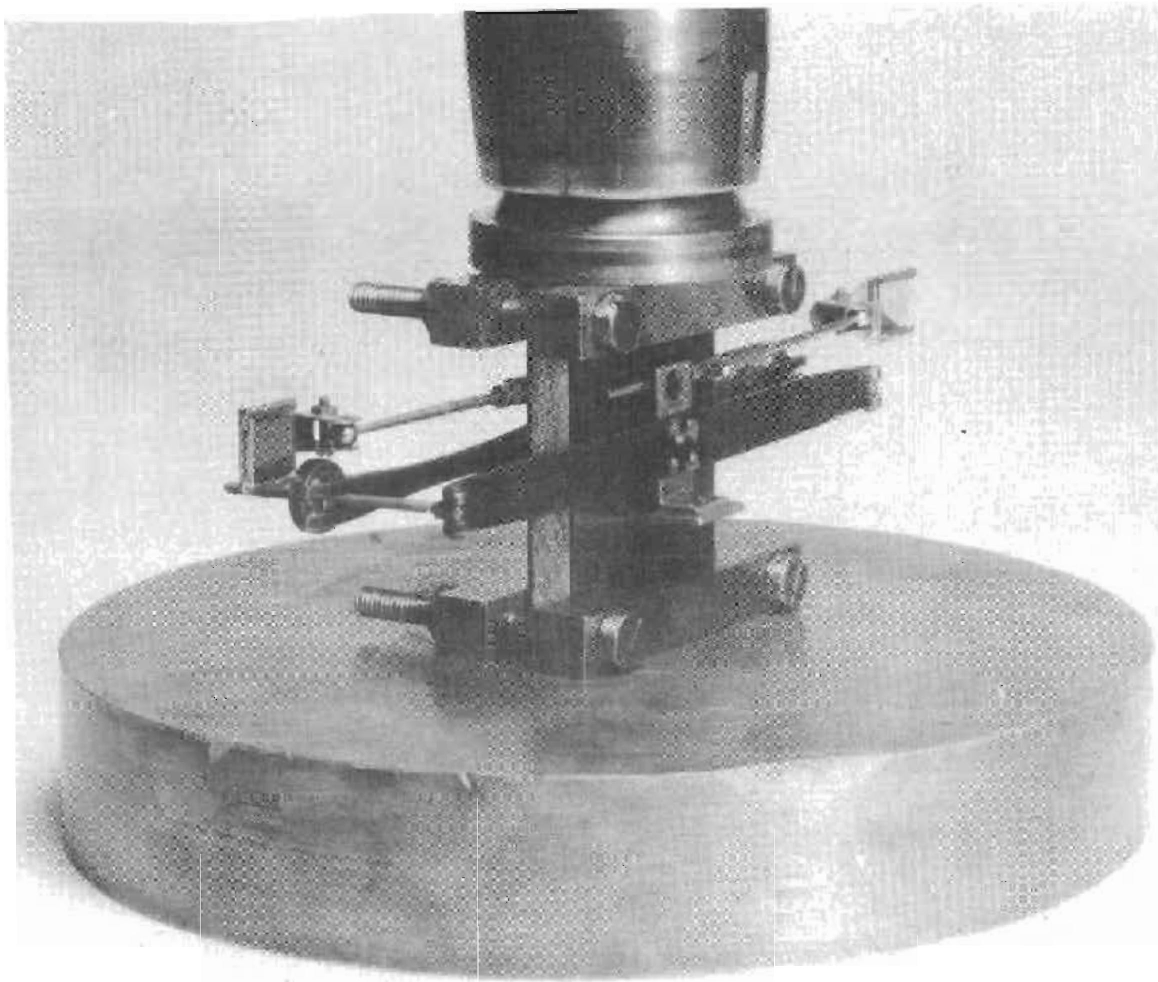


Figure 3.--Short column compression edgewise of sandwich specimen (1/2 inch thick) with restrained ends.

Z M 67028 F

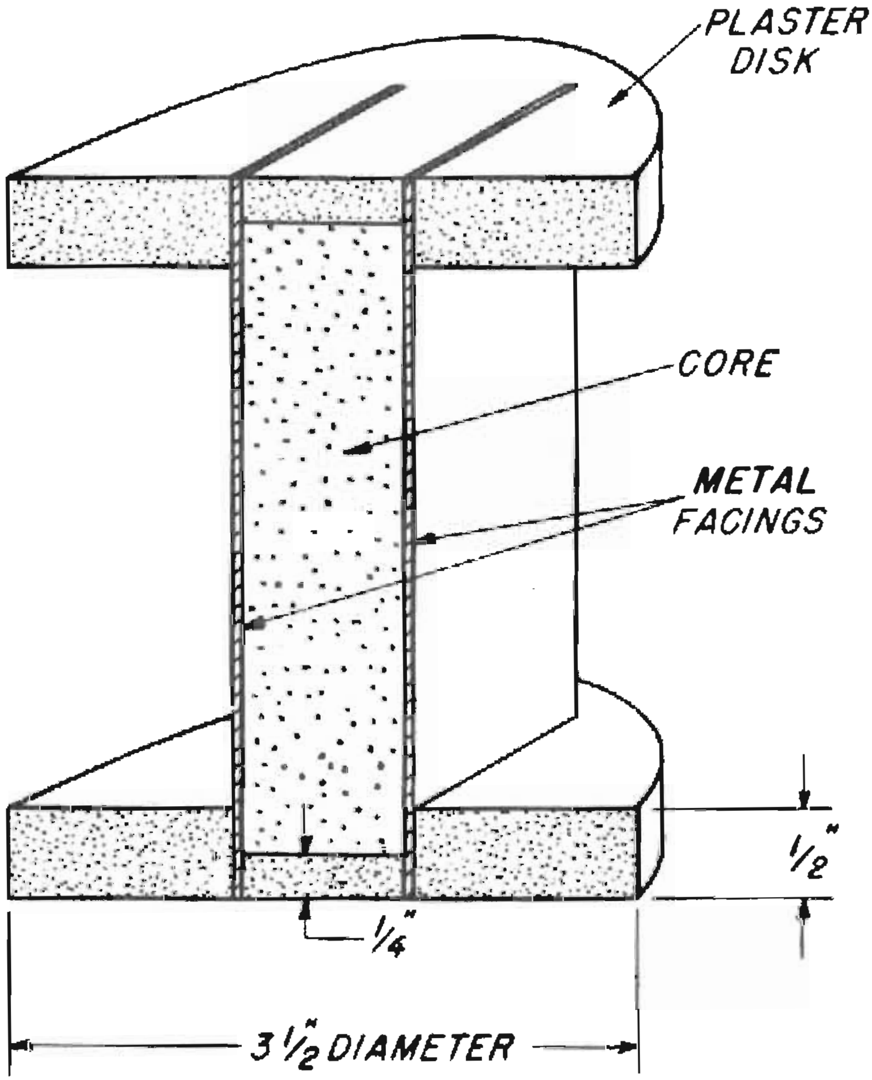


Figure 4.--Cross section of compression-edgewise specimen of sandwich plate with plaster disks at the bearing ends.

Z M 72645 F

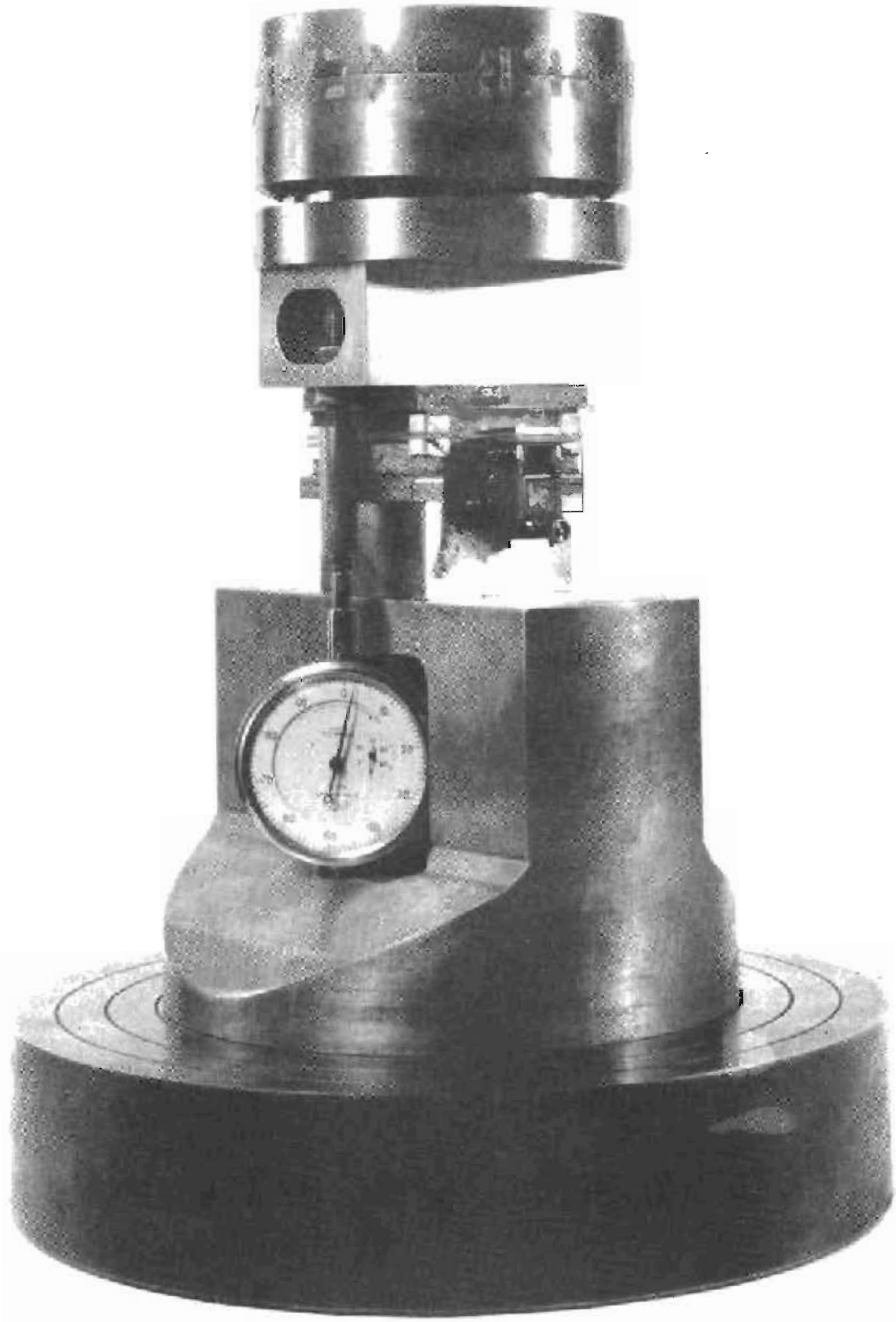


Figure 5.--Compression flatwise of sandwich specimen with 1/4-inch Tuckerman strain gage and dials between heads.

Z M 67030 F

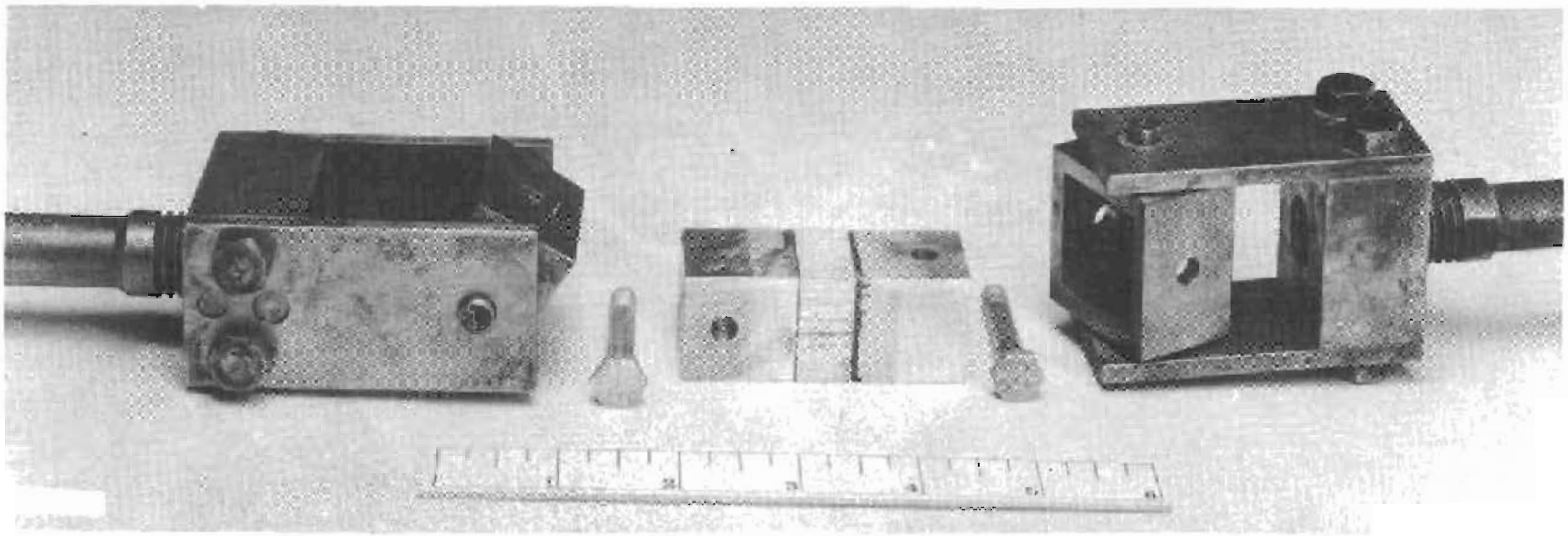


Figure 6.--Specimen and fittings for applying load for tension flatwise test.

Z M 67036 F

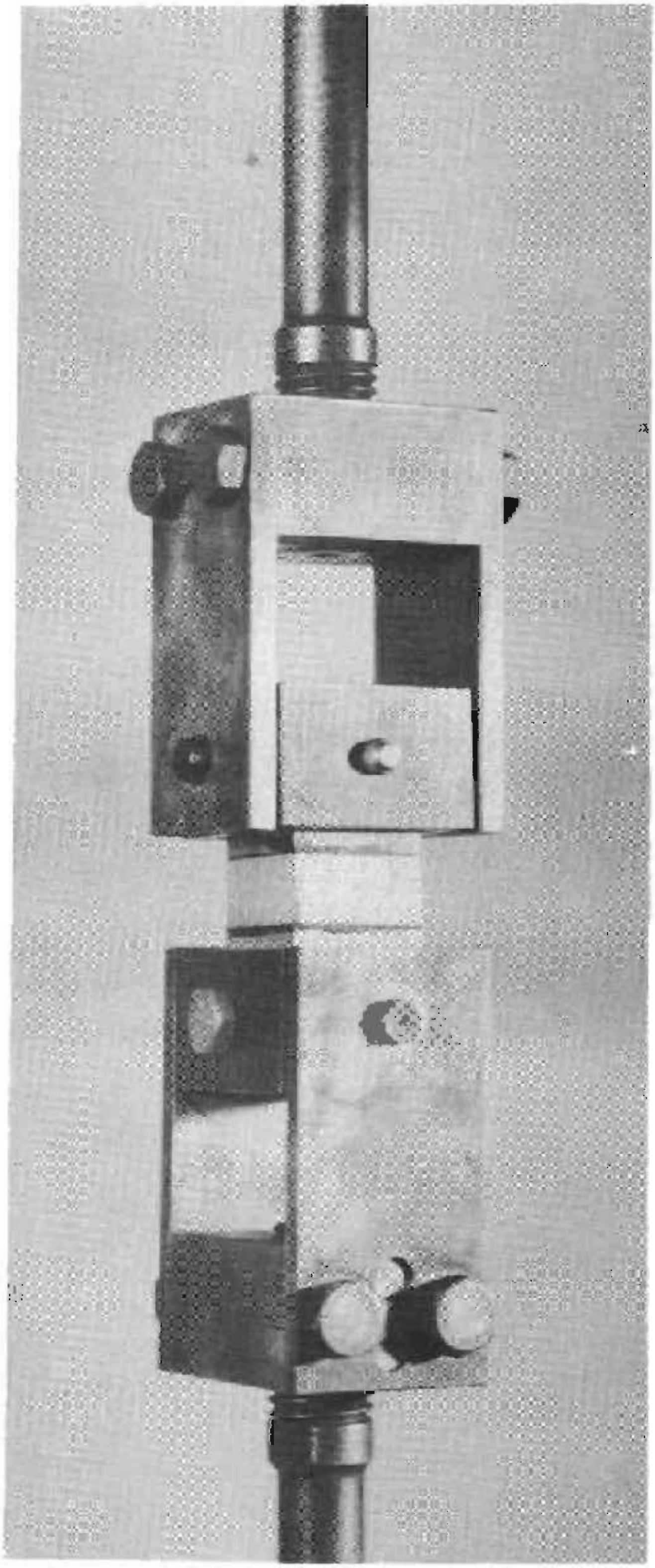


Figure 7.--Test set-up for tension flatwise test for sandwich constructions showing specimen and fitting for applying load.

Z M 67039 F

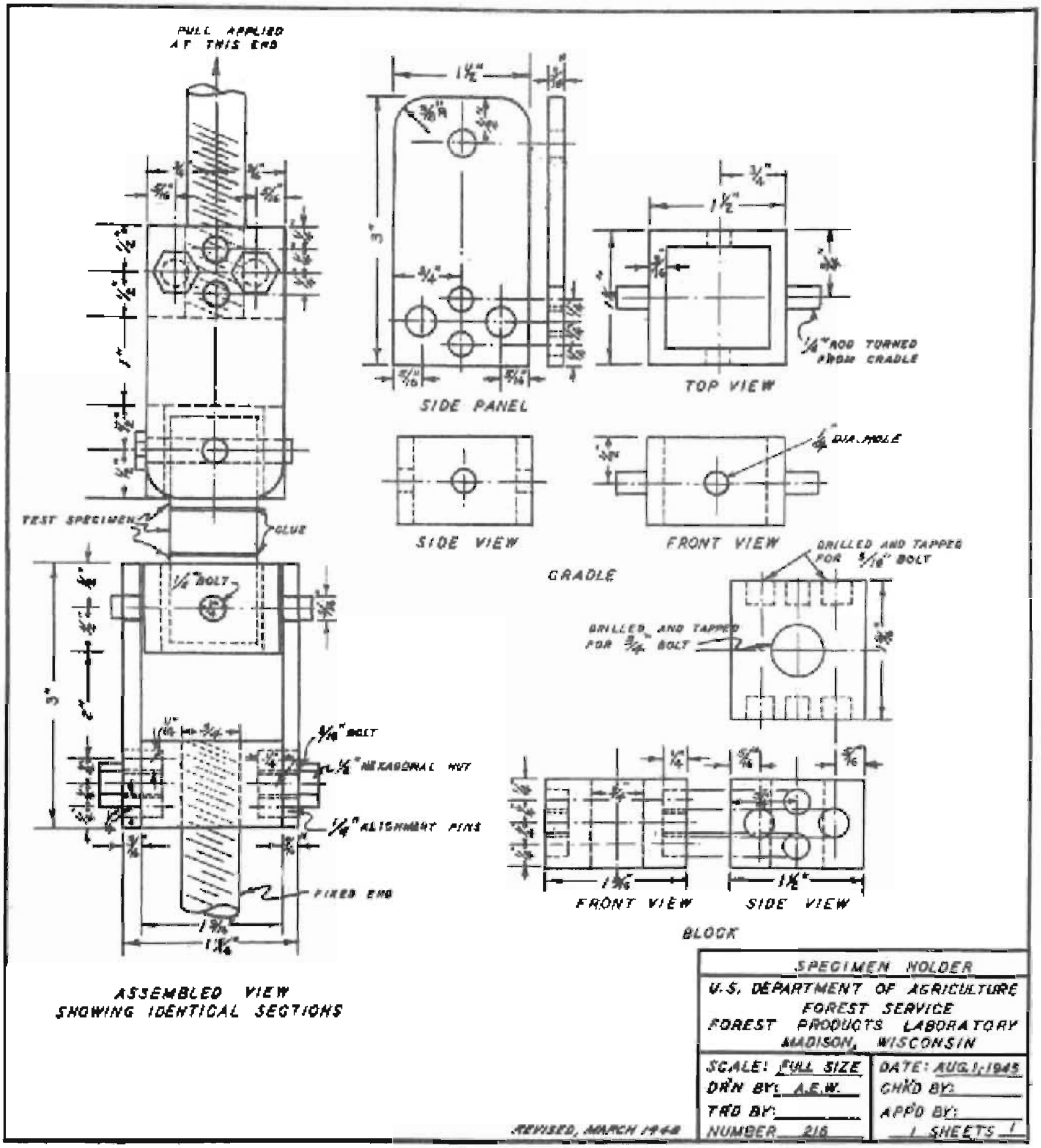


Figure 8.--Details of construction of the fittings for tension flatwise tests of sandwich constructions.

Z M 64941 F

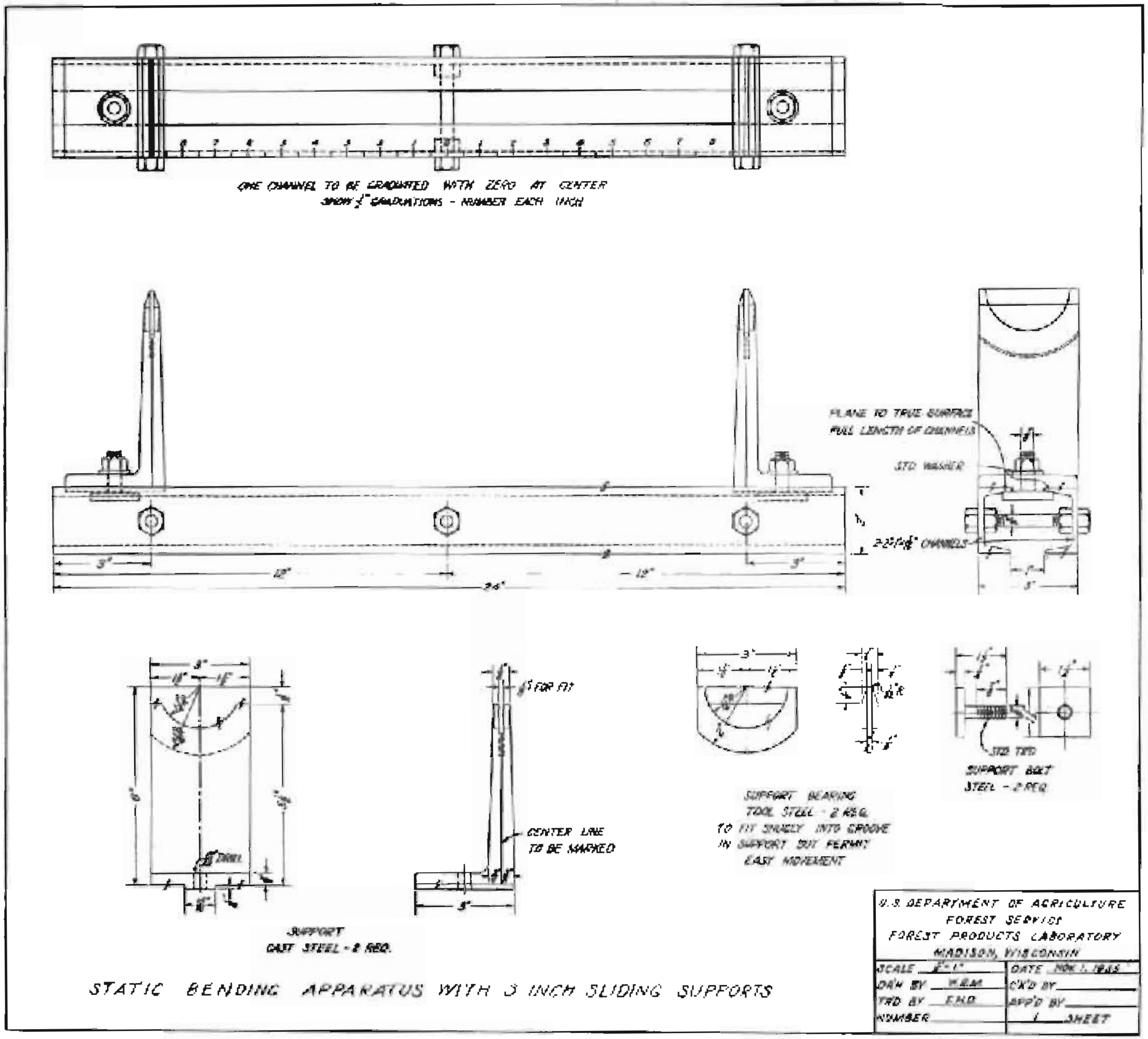


Figure 9.--Apparatus for static bending test showing details of laterally adjustable supports.

Z M 54377 F

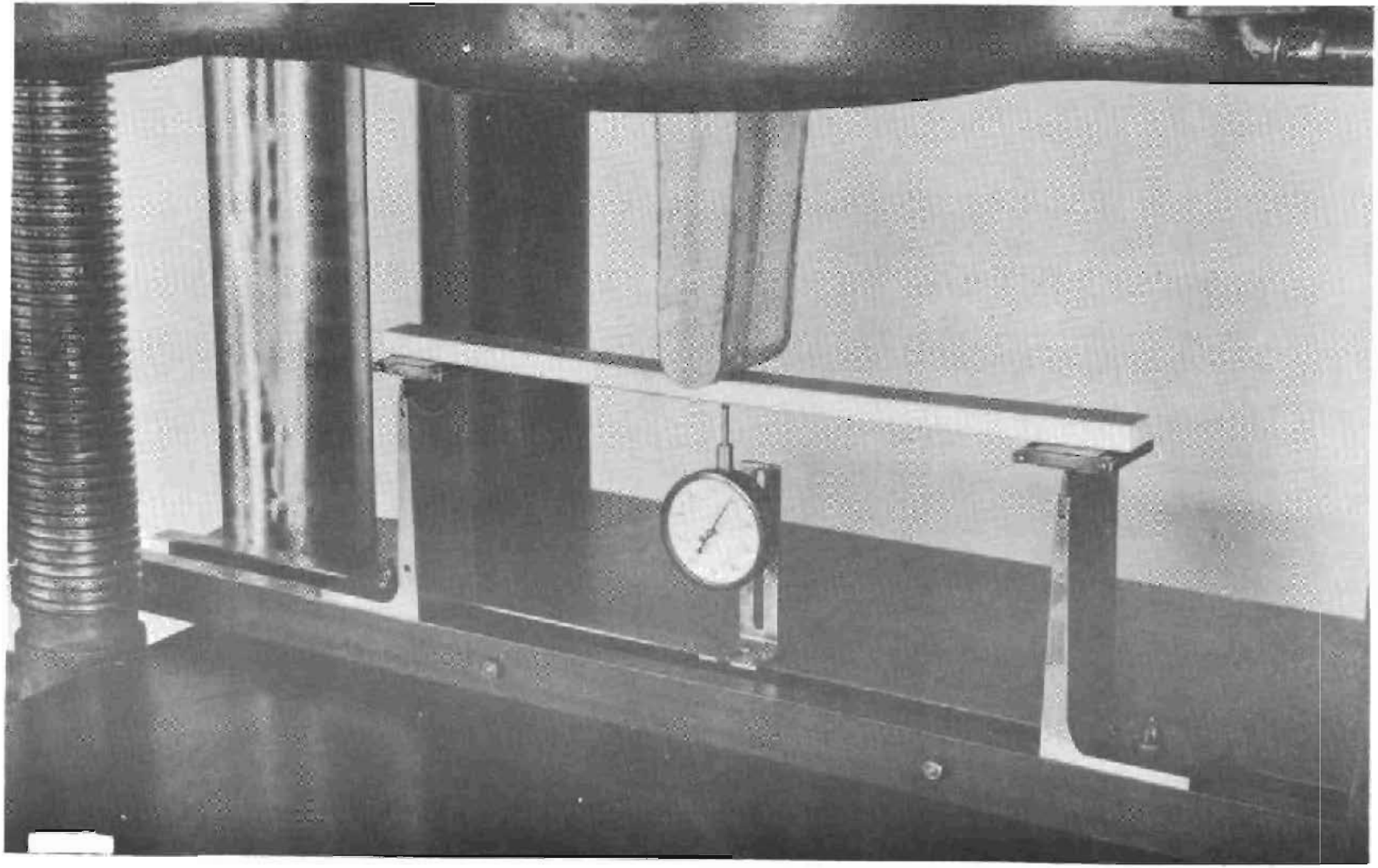


Figure 10.--Static bending test showing adjustable supports and method of measuring deflection.

Z M 77106 F

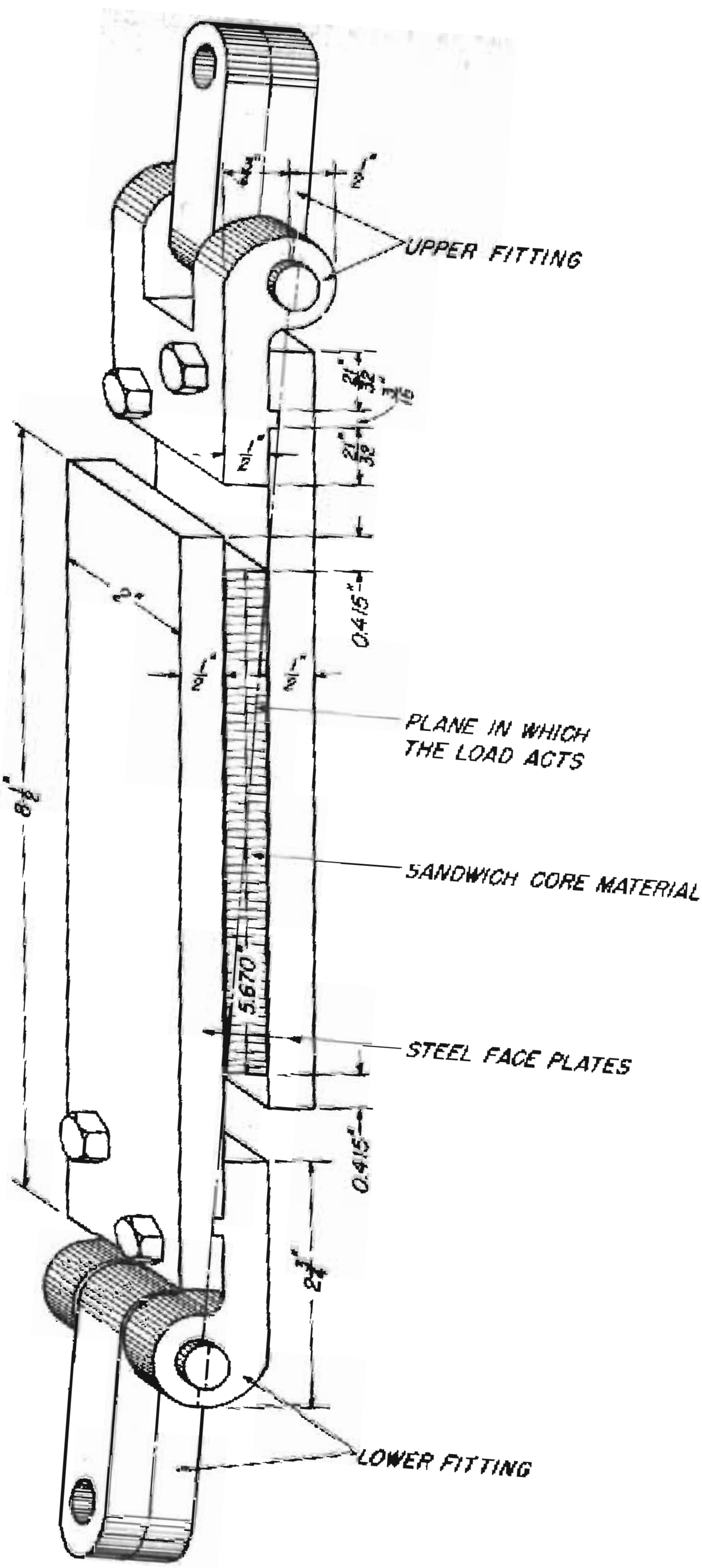


Figure 11.--Shear test for sandwich material.

Z M 84123 F

Figure 12.--Apparatus for shear test showing steel plates, specimen, and dial arrangement for measuring deformations between plates.

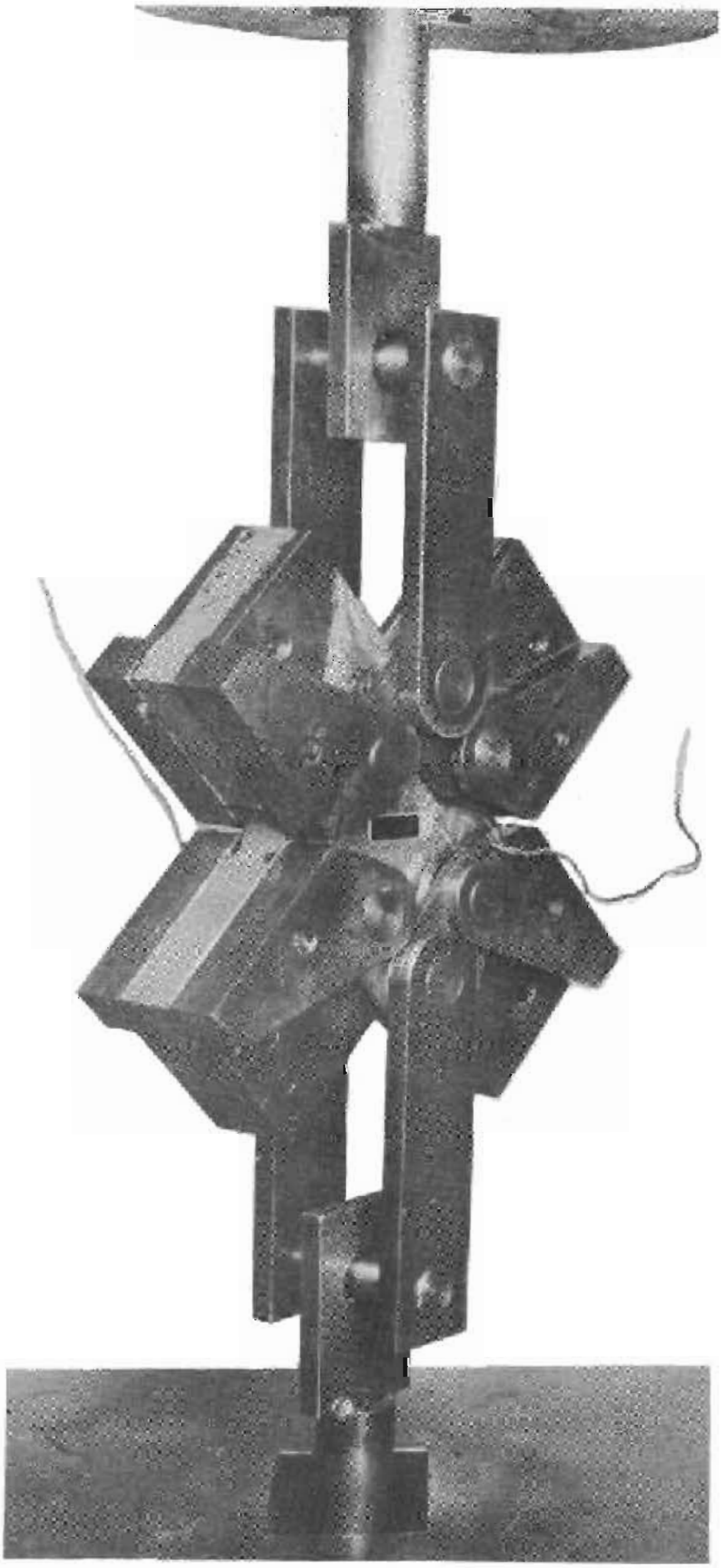
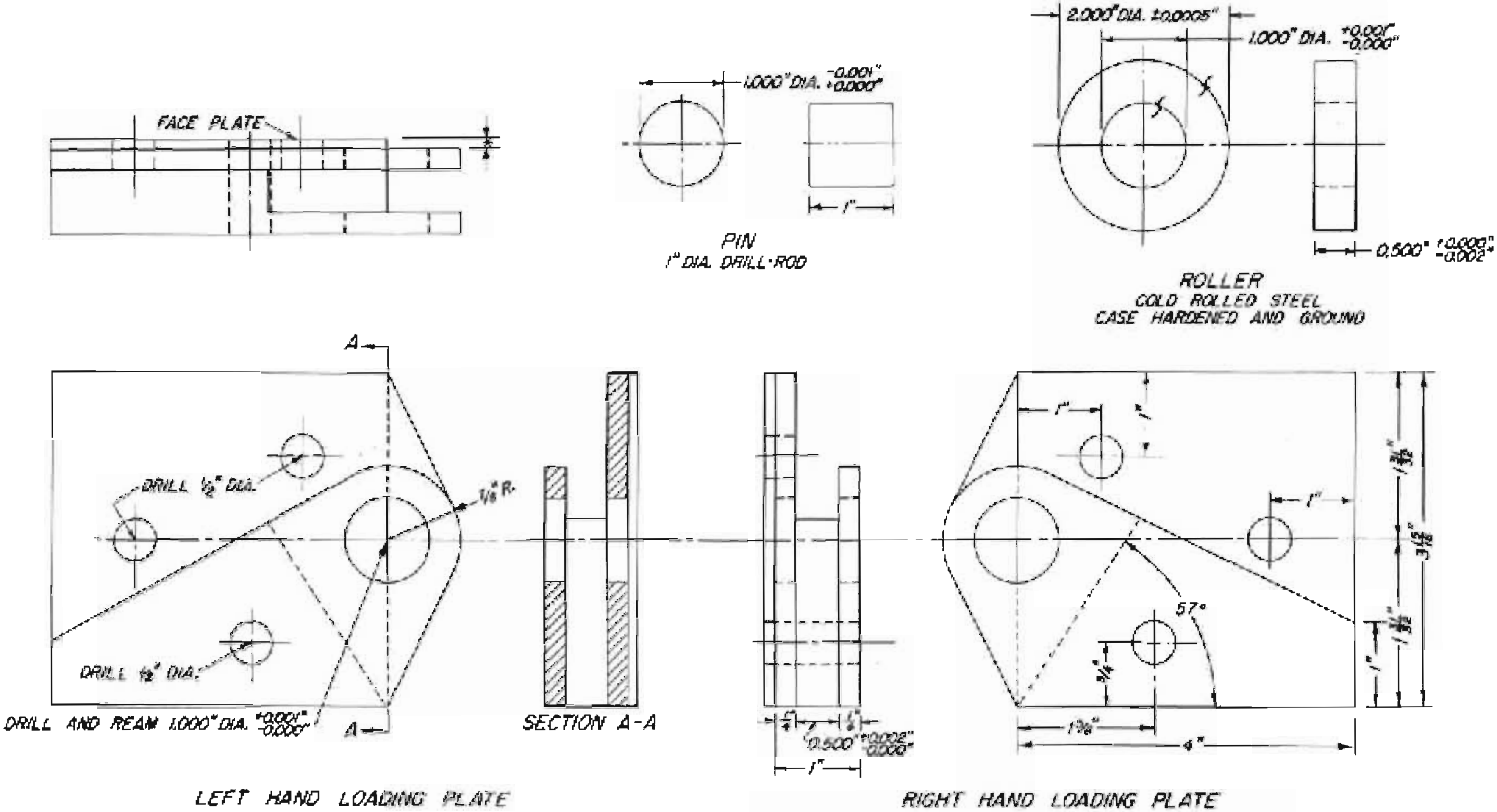


Figure 13.--Shear test showing method of loading used and method of obtaining measurement of deformations by means of a metalectric gage.

Z M 84124 F



NOTE: 1. FOUR PAIRS OF COLD ROLLED STEEL LOADING PLATES WITH NECESSARY ROLLERS AND PINS ARE REQUIRED FOR COMPLETE SHEAR FRAME.

2. IN ASSEMBLY OF APPARATUS, 3 - 1/2" DIAMETER STEEL ALINEMENT PINS CONNECT EACH PAIR OF PLATES, AND 1" PIN HOLES ARE THEN IN EXACT ALINEMENT.

3. FACE PLATE MAY BE OF ANY SUITABLE MATERIAL BETWEEN 1/64" AND 3/16" THICK.

Z M 76900 F

Figure 14.--Details of design of shear test apparatus.

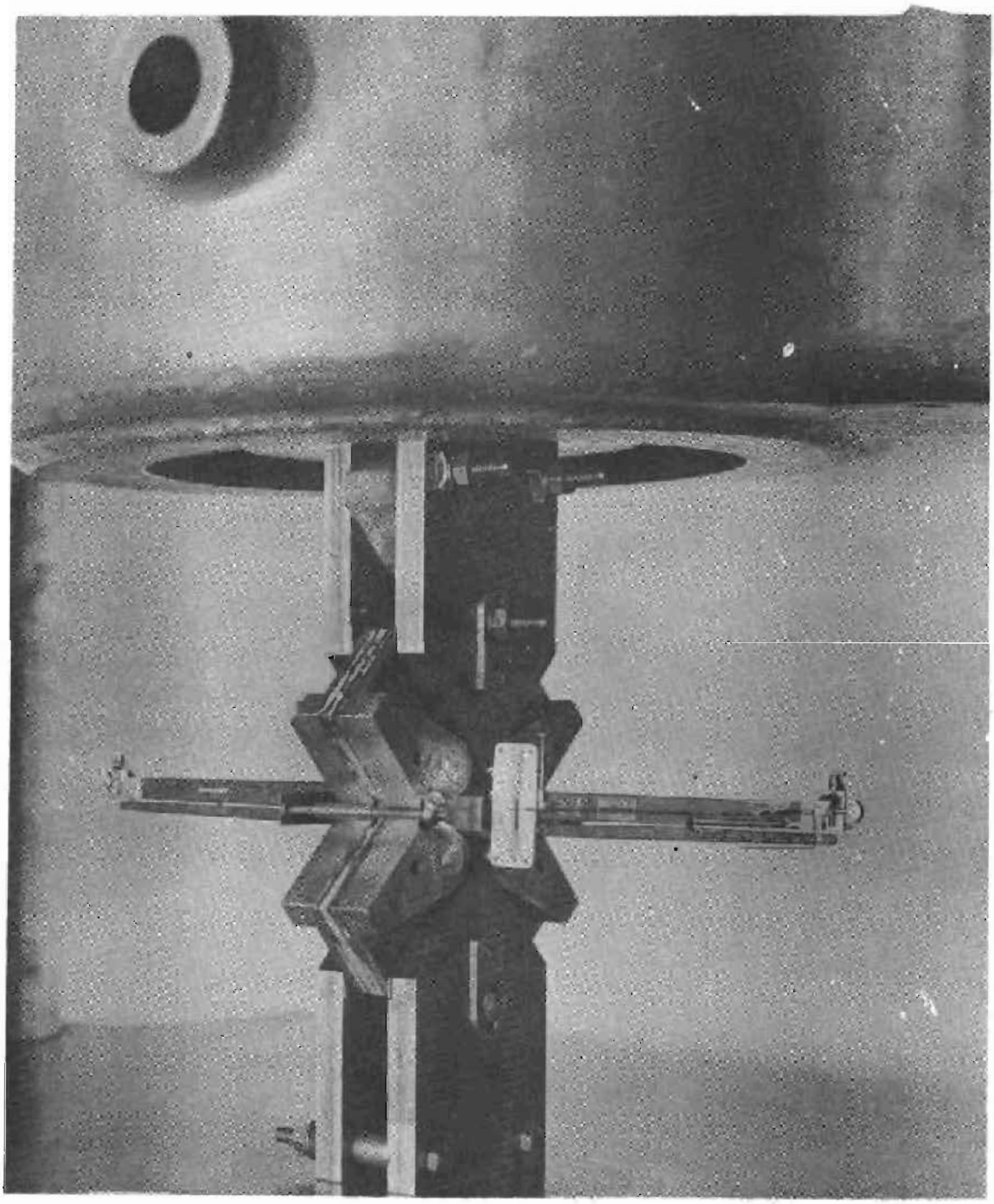
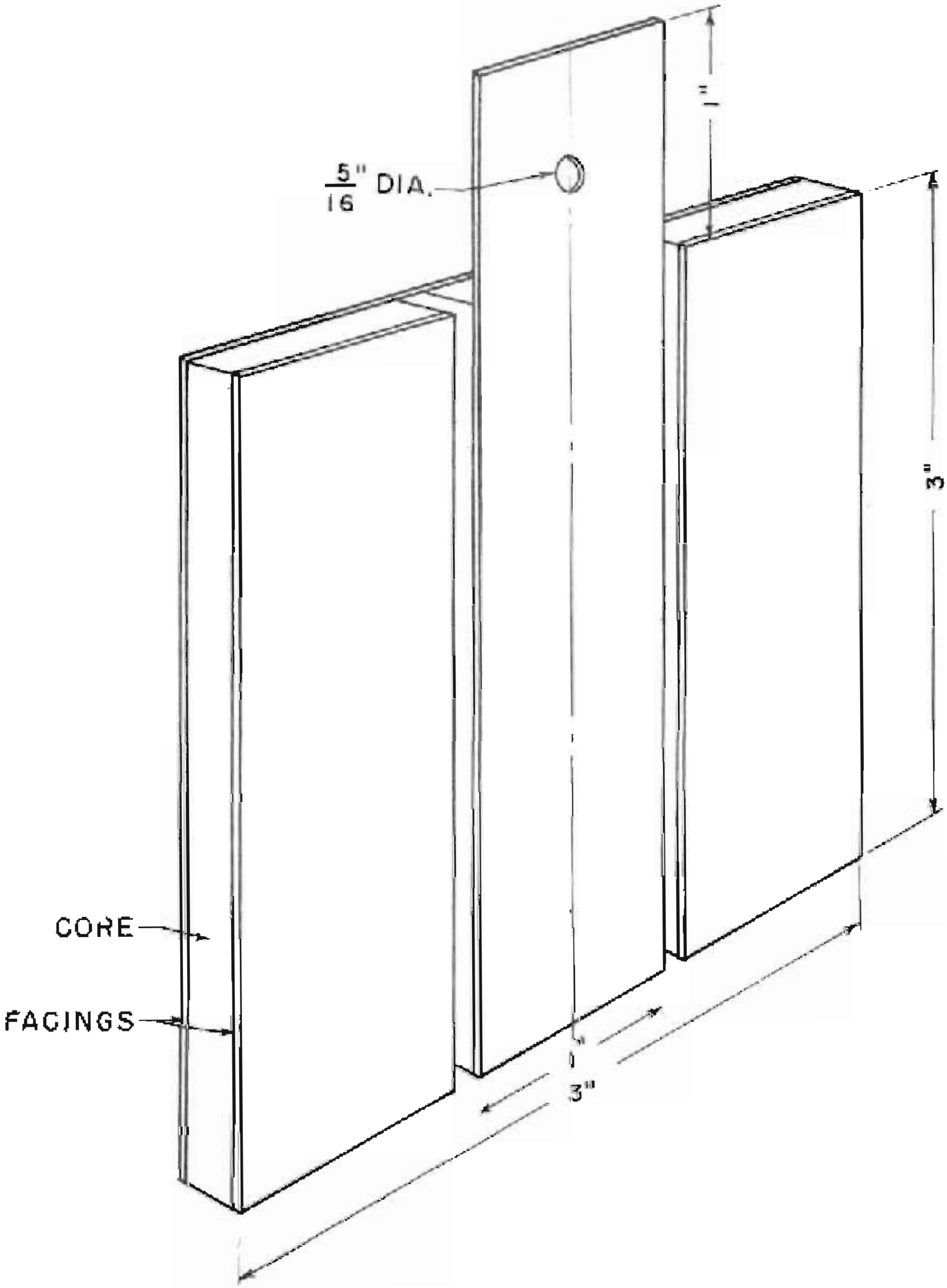


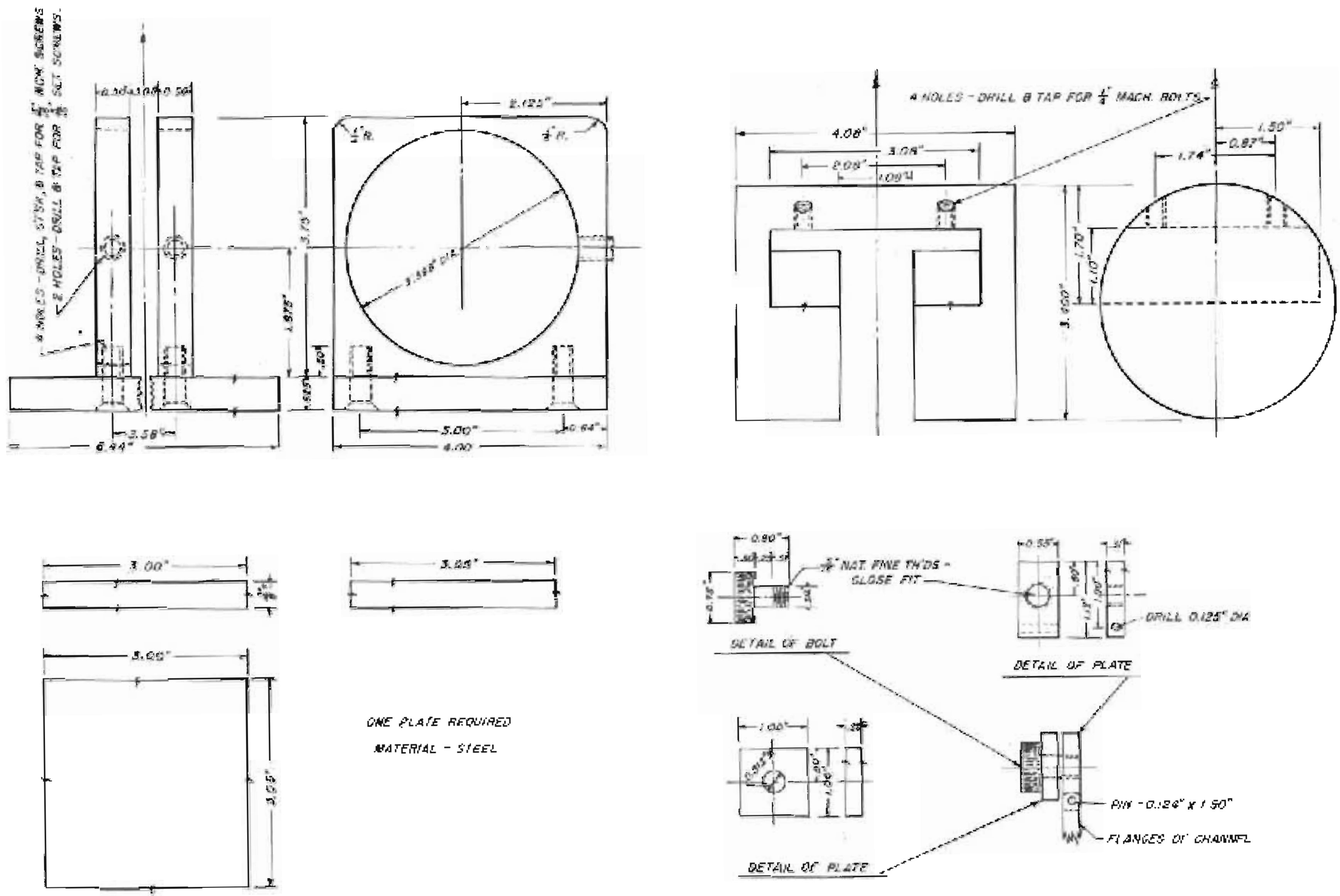
Figure 15.--Shear test showing method of loading and method of attachment of Huggenberger Tensometer for measurement of deformation.

Z M 77108 F



SPECIMEN FOR STRIP TEST

Z M 76899 F Figure 16.--Details of sandwich strip test specimen.



DETAILS OF SANDWICH STRIP TEST APPARATUS

Z M 76901 F

Figure 17.--Details of the specimen holder and loading arm for sandwich strip test specimen.

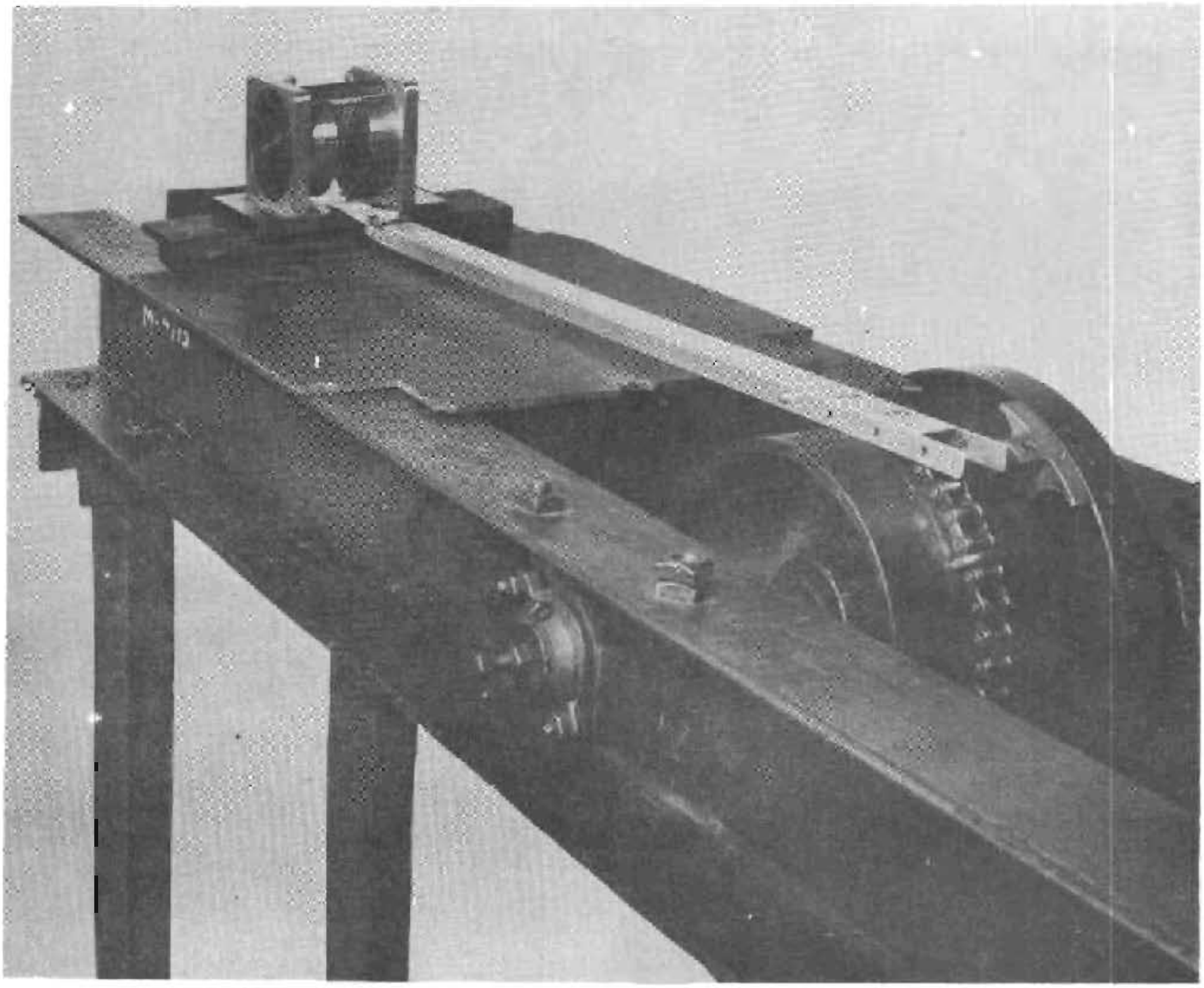
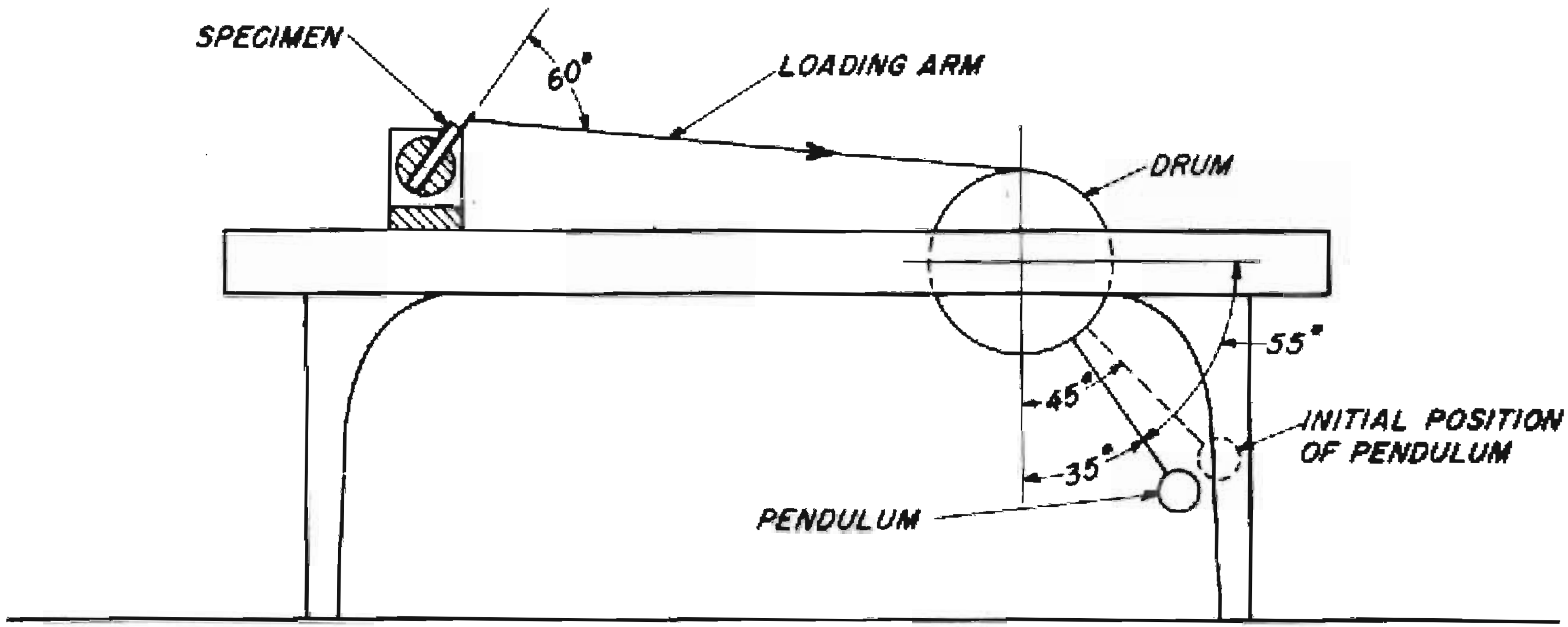


Figure 18.--Strip test specimen and testing apparatus after specimen has failed. Specimen holder and method of loading specimen are evident.

Z M 77109 F



ZM 78440 F

Figure 19.--Diagrammatic sketch showing method of making strip test for sandwich materials.