DURABILITY OF LOW-DENSITY CORE MATERIALS AND SANDWICH PANELS OF THE AIRCRAFT TYPE AS DETERMINED BY LABORATORY TESTS AND EXPOSURE TO THE WEATHER

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DURABILITY OF LOW–DENSITY CORE MATERIALS AND SANDWICH PANELS OF THE AIRCRAFT TYPE AS DETERMINED BY LABORATORY TESTS AND EXPOSURE TO THE WEATHER[1]

Part I

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Introduction

The purpose of these studies was to obtain information on the durability Of low–density core materials and sandwich constructions of the aircraft type. A need for this information exists because of the probability of widespread application of sandwick-type construction in high–speed aircraft. The work was done at the Forest Products Laboratory under the joint direction of the Army Air Forces, the Bureau of Aeronautics, Navy Department, and the Civil Aeronautics Authority.

The results of various tests on three core materials; balsa, cellular cellulose acetate, and cellular hard rubber, and the nine combinations Of these three cores with three face materials; aluminum, glass cloth-resin, and plywood, are presented in this report. Specimens of the same core and face materials, but involving different adhesives, are at present undergoing test. Additional core materials, of the honeycomb type, are currently being prepared for test. Results of tests now in progress will be reported in future supplements to this report.

This report is divided into two sections: A - Tests an Core Materials, and B - Tests on Sandwich Panels. The three core materials were subjected to the following exposures:

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[1]This is one of a series of progress reports prepared by the Forest Products Laboratory relating to the use of wood in aircraft. Results here reported are preliminary and may be revised as additional data become available.

1. Water immersion
2. High humidity
3. High temperature
4. Alternate high–low temperature combined with alternate high–low humidity
5. Conditions favoring decay
6. Flame
7. Aircraft liquids

The nine sandwich combinations were subjected to the following exposures:

1. Water immersion
2. High humidity
3. High temperature
4. Alternate high–low temperature combined with alternate high–low humidity
5. Outdoor weathering

SECTION A - TESTS ON CORE MATERIALS

Summary

End-grain balsa wood, cellular hard rubber, and cellular cellulose acetate specimens were conditioned to equilibrium at a relative humidity of 65 percent and a temperature of 75° F. and then subjected to the following treatments: (1) immersion in running tap water for (a) 24 hours, (b) 40 days, (c) 40 days and reconditioned at 75° F. and 65 percent relative humidity; (2) (a) conditioned to equilibrium at a relative humidity of 97 percent and a temperature of 80° F., (b) treatment 2a followed by reconditioning at 75° F. and 65 percent relative humidity, (3) (a) heated for 240 hours at a temperature of 2000 F., (b) treatment 3a followed by reconditioning at 75° F. and 65 percent relative humidity, (4) exposed to (a) one, (b) five, and (c) 10 cycles of high–low temperatures, each cycle consisting of 24 hours at a temperature of 175° F, and 75 percent relative humidity, 24 hours at a temperature of -20° F. , 24 hours at 175° F. dry heat, and 24 hours at –20° F. At the end of the last cycle the specimens were reconditioned at 75° F. and 65. percent relative humidity.

One group of specimens of each core material was tested after the initial conditioning to provide a basis of comparison with test values obtained from the specimens exposed to the different conditions. Ten other groups of specimens were provided, one for each of the exposures in the preceding list, and tested after each particular exposure had been accomplished.

The data obtained from the tests included ultimate strength in compression, stress at the proportional limit, modulus of elasticity, yield at 0.7 percent strain as obtained from compression, ultimate strength in tension, modulus of rigidity and specific gravity. Measurements were taken for the determination of changes in specimen dimensions and weight.

The results of the tests showed that of the three materials, balsa had the poorest weight and dimensional stability when immersed in water, heated for long periods, or subjected to high humidities. It retained its compressive strength at high temperatures but lost considerable strength when immersed in water or subjected to high humidities. The elastic properties followed the strength properties, increasing slightly when dry and decreasing when wet. The results thus follow the general strength-moisture relations as found for native wood species.[2]

Of the three materials, the cellular hard rubber when immersed in water had good dimensional and weight stability and retained its compressive strength better than the other two materials, but it was permanently weakened. The balsa and cellular cellulose acetate had better recovery characteristics than the cellular hard rubber when reconditioned at 75° F, and 65-percent relative humidity after immersion, The cellular hard rubber had very poor strength properties when heated to 200° F. for 240 hours, retaining only one-third of the original values, and it did not recover well when reconditioned. It was likewise most affected by the cyclic exposures, decreasing in all properties except modulus of rigidity. The loss in strength might have been due to the high-temperature portion of the cyclic exposure.

In general, the cellular cellulose acetate had the best properties of the three materials. Although it was inferior to the other materiels in a few Individual exposures, it had the best weight and dimensional stability under a majority of them. It was the least affected by the cyclic exposures and maintained a better portion of its tensile strength under dry heat. While the material was reduced considerably in strength when immersed in water or subjected to high humidities, its strength recovery after it was reconditioned was very good.

Rated on a specific gravity basis, the balsa had much higher strength and elastic properties than either the rubber or acetate: the unsatisfactory characteristic of balsa was its very great change in weight when equilibrium moisture conditions were varied. Even with its increase in weight when wet, however, the balsa had greater strength and stiffness than the other two materials on a strength-weight ratio.

The cellular cellulose acetate had approximately the same strength-weight properties as the cellular hard rubber and appeared to be a good material under severe exposures. The rubber had good properties when wet, but lost considorable strength when subjected to the high temperatures that may be encountered in aircraft structures.[3]

In bottle decay tests, untreated balsa was severely decayed (as measured by percentage loss in weight) when exposed to _Poria microspora_ (No. 106), _Poria incrassata_ (No. 563), and _Polyporus versicolor_ (No. 72074.) for periods

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[2]"Moisture Content - Strength Adjustments for Wood." Forest Products Laboratory Report No. 1313, December 1941.

[3]A Study of Temperatures Attained in a Dummy Aircraft Wing During the Summer at Madison, Wisconsin." Forest Products Laboratory Report No. 1343 - B, January 1943,

of 1, 2, and 3 months, and when exposed in soil. Under the same conditions. cellulose acetate and cellular hard rubber sustained no weight losses. Treatment of the balsa with 2.0 percent pentachlorophenol in acetone was required to prevent decay.

Flame tests made in accordance with Method No. 2021 of L–P–406a "Federal Specification for Plastics, Organic: General Specifications, Test Methods" gave an average rate of burning, in inches per minute, of 34 for cellular hard rubber, 30 for balsa and 10 for cellular cellulose acetate.

The same three core materials were immersed in the following aircraft liquids: iso–propyl alcohol, ethylene glycol, 3680 oleo fluid, 3586 oleo fluid, 100 octane gasoline, used crankcase oil, and distilled water. None of the core material8 was greatly affected by the 7–day immersion, except balsa, which materially increased in weight and dimensions when immersed in water, ethylene glycol, 3586 oleo fluid, and alcohol. After reconditioning for 39 days most test specimens returned essentially to their original weight and dimensions; however, an appreciable weight increase was retained by specimens immersed in 3580 and 3586 oleo fluids and used crankcase oil, particularly by the balsa specimens, A slight amount of permanent shrinkage in dimensions was noted after reconditioning acetate and rubber cores, while balsa, notably the specimens exposed to ethylene glycol, retained a small amount of permanent swelling.

Description of Materials

Balsa

Balsa passing the following specifications was obtained from a commercial source: balsa lumber, surfaced two sides, weight 6 to 9 pounds per cubic foot, kiln–dried, random widths (3 inches minimum), random lengths (6 feet minimum). Thickness, 1–1/2 inches or 2–1/2 inches with not less than 50 percent of the material 2–1/2 inches in thickness, with ± 1/8 inch allowable tolerance.

Cellular Hard Rubber[4]

The cellular hard rubber was an expanded, hard, black, synthetic sponge rubber of the butadiene–acrylonitrile type, hereafter referred to in this report as cellular hard rubber, or merely as rubber. It was received in the form of slabs, approximately 1–1/2 by 20 by 36 inches, from a commercial source. The density, after removing the outer hard skin and adjacent high–density material, varied between 6.2 and 7.2 pounds per cubic foot. A cross section view of a slab is shown in figure 1.

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[4]Appendix I, note 1.

Cellular Cellulose Acetate[5]

The cellular cellulose acetate was manufactured commercially in a pilot plant from cellulose acetate and approximately 3 percent of chopped-glass fibers by an extrusion process employing heat and pressure.

The material was received in the form of extruded bars, white in color, 5/8 by 2-5/8 inches in cross section and from 4 to 10 feet in length. The outer surface of the bar was composed of a dense firm skin, which was subsequently removed. After removal of the outer skin, the density ranged between 6.0 and 6.8 pounds per cubic foot.

A view of the material is shown In figure 2.

Preparation of Materials

Balsa

Balsa pieces as received were kiln dried to a moisture content (5 to 7 percent) corresponding approximately to the relative humidity of the atmosphere in the work rooms.

The pieces were accurately jointed and planed to rectangular shapes, which were sawed into end-grain slabs 1/2 inch in thickness, or flat-sawn boards 1/2 inch thick, by ordinary woodworking machinery. Despite the care used in sawing the balsa slabs, the end-grain surfaces were occasionally slightly wavy because the higher density summerwood produced ridges and the lower density springwood formed valleys. A view of the saw set-up for cutting end-grain slabs is shown in figure 3.

Cellular Hard Rubber

The slabs of cellular hard rubber were jointed to remove the tough outer skin and adjacent layer of high-density material and subsequently cut on a band saw and planed to form sheets approximately 1/2 inch thick. In general, ordinary woodworking machinery and procedures were employed.

Cellular Cellulose Acetate

The bars of cellular cellulose acetate were cut into lengths approximately 48 inches or less for ease in handling. The outer skin of one side and of both edges of each bar was removed by jointing, after. which the bar was reduced to 1/2-inch thickness by the use of a wood-cutting band saw running at a rate of 4,000 feet per minute and having five teeth per inch. The surface produced by the band saw compared favorably with surfaces produced by the jointer. The band saw set-up is shown in figure 4.

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[5]Appendix I, note 2.

Preparation—of Test Specimens

In general, the specimens for strength tests conformed to the specifications given in the Forest Products Laboratory Report No. 1555.[6]

Compression Flatwise

Compression specimens 2 inches square by 1/2 inch thick were carefully cut from a number of prepared pieces of each of the three core materials. The 1/2–inch thickness was selected because it was the maximum that could be Obtained from the cellular cellulose acetate. The 2–inch dimensions represented an arbitrary and convenient test size. It appeared advisable to have the specimen size common to all three materials in order that the effects Of subsequent exposures would be more nearly comparable for each of the materials.

Plate Shear

Plate shear specimens, 16 inches square by 1/2 inch thick, were prepared by gluing together a sufficient number of smaller pieces, properly oriented, to obtain the modulus of rigidity associated with shear distortion in the length–thickness plane of the material when used as the core in a sandwich construction.

Balsa. specimens were prepared by edge gluing three pieces of flat–sawn boards.

Strips Of cellular hard rubber, 5/8 inch wide by 1 inch thick by 17 inches long were cut and glued together to form plates 5/8 inch thick by approximately 17 inches square. The length and thickness of the strips were parallel to the length and thickness dimensions of the slabs as received. The plates were jointed and planed to a uniform 1/2 inch thickness and trimmed to dimension in directions parallel and perpendicular to the glue lines.

The procedure used in preparing plate shear specimens from cellular cellulose acetate was identical to that described for rubber specimens except that the thickness of the strips was 1/2 inch.

Tension

Tensile specimens were prepared by bonding 1–inch aluminum cubes to the faces Of 1/2 inch thick strips of end–grain balsa, and plywood blocks to similar strips Of cellular hard rubber and cellular cellulose acetate. The specimens were then cut to the desired contour and 1 inch square cross section by normal woodworking methods. A view of the bonded assemblies and finished specimens is shown in figure 5.

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[6] "Tentative Methods of Test for Determining Strength Properties of Core Materials for Sandwich Construction." February 1946.

Decay Specimens

Balsa.--All balsa used in the decay tests was selected from material with a density of 6 to 9 pounds per cubic foot at 75° F. and 65 percent relative humidity. The test specimens were 2-1/2 by 1 by 1/2 inch with the shortest dimension, or thickness, parallel with the direction of the grain. In addition to the untreated or control specimens, flat-sawed, conditioned specimens approximately 2 by 1 by 3/8 inch in size were also treated with 0.1, 1.0, and 2.0 percent acetone solutions of commercial grade pentachlorophenol applied under a vacuum.

Cellular cellulose acetate.--Cores 1/2 inch thick, from which the 2-1/2- by 1- by 1/2-inch specimens were cut, were prepared from the original thicker sections of cellular cellulose acetate.

Cellular hard rubber.--The skin on the cellular hard rubber was removed, and 1/2-inch cores were prepared from which the 2-1/2- by 1- by 1/2-inch specimens were cut.

Fungi.--The fungi used were: *Poria microspora* (No. 106) and *Poria incrassata* (No. 563), both brown-rot fungi; and *Polyporus versicolor* (No. 72074), a white-rot fungus. The fungi grew on a. substrate of 25 cc. malt agar (Trommer's malt extract, 25 grams; bacto-agar, 20 grams; 2nd distilled water, 1000 cc.) slanted in 6-ounce French-square bottles. The test specimens were held away from direct contact with the substrate by means of two glass rods about 0.14 inch in diameter. Specimens were also placed in uninoculated moistened soil[7] in soil bins.

The distribution of the test specimens among the various exposure conditions of this test are given in table 6.

Flame Test Specimens

The specimens for flame tests were 1/2 by 1/2 by 5 inches cut from the respective core materials after removal of the outer skin.

Aircraft Liquid Exposure Specimens

Twenty-one pieces, 1/2 by 1 by 3 inches in size, were cut from each core material. The balsa selected was within the range of 6 to 9 pounds per cubic foot when in equilibrium with air at 65 percent relative humidity and 80° F. It was cut with the grain parallel to the 1/2-inch dimension.

The chemical test liquids used were iso-propyl alcohol: ethylene glycol; 3580 oleo fluid, hydraulic (light petroleum base) Specification No. 3580-c; 3585 oleo fluid, hydraulic (castor oil base) Specification No. 3586-c Grade A - heavy; 100 octane gasoline; used crankcase oil; and distilled water.

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[7] The average soil moisture, oven-dry basis, was 21.6 percent; 1/16-inch birch heartwood veneer buried in it 24 hours attained an average moisture content of 42.5 percent. The pH of the soil varied from 5.73 to 6.1.

Treatment of Specimens

All specimens were conditioned to approximate weight equilibrium in a room maintained at 75° F. and 65 percent relative humidity. The control specimens were then teated and the remaining specimens subjected to treatments described in the following discussion.

Water Immersion

The specimens were placed on small wire racks to prevent floating and contact with each other, and immersed in a tank of running water. The tank was 18 inches wide by 34 inches long by 16 inches, high and provided with an overflow opening. Continuously running water was supplied by a small hose connection to the drinking water supply of the Laboratory, Temperature data taken by a recording thermometer indicated that the water temperature was approximately 60° F. The immersion periods were 1 day and 40 days.

High Humidity

Specimens were placed in a room in which a temperature of 80° F. and a relative humidity of 97 percent were automatically maintained, The specimens remained in this atmosphere until weight observations indicated that they had reached approximate equilibrium.

When weight equilibrium was reached, one–half of the specimens were tested immediately. The remainder were placed in a room maintained at 75° F, and 65 percent relative humidity until weight equilibrium was attained, after which they were tested.

High Temperature

Specimens were exposed continuously for 240 hours to dry heat at 200° ± 10° F. in an insulated box equipped with steam pipe radiators and a circulating fan. At the conclusion of the heating period, one-half of the specimens were tested immediately at a temperature of 200° F., while the remainder were reconditioned to equilibrium with 75° F. and 65 percent relative humidity and then tested.

Cyclic Exposures to Alternate High and Low Temperatures Combined with High and Low Humidities

Specimens were exposed in a manner conforming essentially to Method No. 6011 described in Federal Specificat ion LP–406a, Plastics, Organic; General Specifications, Test Methods, "Accelerated Service Tests (Temperature and Humidity Extremes)". An exposure cycle was composed of the following treatments:

(a) 24 hours In a small kiln automatically operated at 175° F. and 75 percent relative humidity

(b) 24 hours in a mechanically refrigerated room maintained at −20 + 5° F.

(c) 24 hours in the small kiln, mentioned in (a) at 175° F, without humidity control

(d) 24 hours as described in (b)

The cycle was continuously repeated, except that every sixth day the 24-hour period in the refrigerator was increased to 48 hours.

It may be noted that the 24-hour period between treatments (a) and (c) permitted the kiln to dry out.

Specimens were exposed for 1, 5, and 10 cycles respectively. At the end of the respective cycles one-third of the specimens were reconditioned to approximate weight equilibrium with 75° F. and 65 percent relative humidity and tested.

Description of Test Procedures

In general, the test methods conformed to, or were similar to, those described in Forest Products Laboratory Report No. 1555 "Tentative Methods of Test for Determining Strength Properties of Core Material for Sandwich Construction," February 1946.

Compression Flatwise

Compression tests were conducted by applying loads in the direction parallel to the thickness of the specimen by means of a universal testing machine equipped with a hydraulic capsule and load indicator. When end-grain balsa specimens were tested, the capsule and load indicator were omitted became the capacity of these instruments was exceeded and the applied loads were high enough to be easily and accurately read on the weighing scale of the testing machine. In general, the rate of head motion under no load was 0.0038 inch per minute.

Deformations to 0.00001 inch were observed by means of a 1/4-inch gage length compressometer attached to two opposite faces of the specimen and to 0.0001 inch by two dial indicators, which measured the total deformation of the specimen. Load deformation data were observed to maximum load. A typical test arrangement and the device for alining the small brads used in attaching the gages are shown in figure 6.

Plate Shear

Plate shear tests for the determination of the modulus of rigidity conformed to the testing procedure described in Forest Products Laboratory Report No. 1555. This testing procedure is also described in and is a part of American Society of Testing Materials Specification D805-45T, "Tentative Methods of Testing Plywood, Veneer, and Other Wood and Wood-Base Materials." A view of the test arrangement is shown in figure '7.

Tension Flatwise

Tension flatwise tests were conducted in the manner described in Forest Products Laboratory Report No. 1555, except that the rate of head travel of the testing machine was 0.05 inch per minute.

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All tests, except those which required a temperature of 200° F., were conducted in a room in which the temperature and humidity were controlled at 75° F. and 65 percent, respectively. Dimensions and widths of all specimens were taken immediately before test. Normal testing techniques or practices were supplemented with the following variations:

Specimens that were immersed for 1 and 40 days were blotted to remove the surface or free water, weighed, measured, and tested wet immediately,

The specimens exposed to high humidity (97 percent) and not reconditioned were kept in a closed container (a few at a time) to prevent a change in their moisture level during the interval of time required for weighing, measuring, and awaiting test .

A large and a small insulated plywood box, each housing the specimen and necessary apparatus, were used to conduct tests at 200° F. The large box permitted plate shear and tension tests and the small box, compression tests. Each box was equipped with a doubled glazed door and windows (to permit observations), hand holes for apparatus adjustments, a thermometer, several heating coils, a thermostat, and a fan or means of circulating the air. Views of the boxes are shown in figures 8, 9, and 10.

Decay

(1) All test specimens were conditioned at 80° F. and 65 percent relative humidity for about 3 weeks until approximate equilibrium weights were reached, and the weights recorded.

(2) The balsa specimens designated for preservative treatment were removed and treated. They were then reconditioned as before for about 5 weeks and weighed, as were the untreated specimens.

(3) The test specimens (except acetate and rubber, which received no treatment) were surface disinfected by autoclaving for 30 minutes at atmospheric pressure.

(4) The test specimens were placed in test bottles or soil, as recorded in table 6, and incubated at room temperature (about 82° F.).

(5) The specimens were removed from the test conditions at the end of 1, 2, and 3 months, They were cleaned of mycelium or soil and weighed.

(6) The test specimens were returned to conditions of 80° F. and 65 percent relative humidity for a minimum period of about 6 months, until they were in approximate equilibrium, and weighed.

(7) The percentage change in weight, based on the approximate equilibrium weights at 80° F. and 65 percent relative humidity before and after exposure, were computed as follows:

$$\frac{\text{Weight at step 2 - weight at step 6}}{\text{Weight at step 2}} \times 100$$

Flame

Flame tests were in accordance with Method No. 2021 of L-P-406a, "Federal Specifications, Test Methods."

Aircraft Liquids

The core specimens were first conditioned for 7 days in a room maintained at 75° F. and 50 percent relative humidity, They were then weighed to the nearest milligram on an analytical balance kept in the same room under the same conditions, and their length, width, and thickness dimensions were measured with a micrometer caliper to the nearest 0.001 inch. Two measurements were made of both width and thickness, one on each end of the specimen, and the average was recorded. Of the 21 specimens of each core material, three were selected at random for immersion in each of the seven liquids.

The specimens were placed in quart cans in layers, three layers per can, each layer composed of three specimens of a single core material laid edgewise upon wire screen of 1/4-inch mesh. The cans were filled with enough liquid to cover all specimens completely. A maple block 1 inch thick was placed upon the top layer in each can to insure that the specimens would remain submerged, and the can was closed with a lid.

The core materials were allowed to soak for 7 days in a room maintained at approximately 75° F. Each day the liquids were agitated by shaking each can gently, At the end of the 7-day soaking period, the specimens were removed from the containers, one specimen at a time, wiped with a dry cloth, weighed in a closed weighing bottle, and measured as before in each dimension to the nearest 0.001 inch.

Because of the possibility that soluble constituents might be removed from the core materials by the liquid, all specimens were dried for 7 days in the conditioning atmosphere (75° F. and 50 percent relative humidity), and then reweighed. As a final check, all specimens were conditioned for 32 days more and then weighed and measured again.

Results and Discussion

Physical Appearance of Specimens During Various Treatments

The physical appearance of the specimens during immersion in water conformed generally to expectations, except for one unusual phenomenon. At about the midpoint of the immersion period, a nearly colorless, slimy or gelatinous film, which could not be positively identified, appeared on the specimens. The cause or source of the film was not known, although it was thought that the extractives in the wooden strips around the wire trays might be contributing to a chemical reaction involving the zinc coating on the wire.

Very little distortion in the shape of the specimens appeared during the reconditioning period following Immersion.

During the 40 days of immersion, the cellular rubber and acetate reached approximate weight equilibrium, while the end-grain balsa attained about 80 percent of its estimated weight equilibrium.

Specimens exposed to 80° F. and 97 percent relative humidity displayed no unusual behavior. Although extensive weight observations were not made during the exposure period, the data taken indicate that approximately 70 to 80 days were required for the specimens to reach approximate weight equilibrium.

Cellular hard rubber plate-shear specimens showed some distort ion when exposed for 240 hours to dry heat at 200° F. Some embrittlement of the surface texture was also noted. Balsa and cellular cellulose acetate exhibited no apparent change,

Cyclic exposurea to high and low temperatures and humidities affected. the cellular hard rubber plate shear specimens much the same as did the exposure to dry heat at 200° F. Several additional specimens from which the outer dense layer was not completely removed had considerably more surface distortion, Small surface irregularities were observed in the balsa and cellular cellulose acetate.

Water Immersion

Table 1 is a compilation of the results of the tests on balsa, cellular hard rubber, and cellular cellulose acetate after immersion in water at 60° F. for (a) 24 hours and (b) 40 days, and (c) reconditioning after (b) to equilibrium with 75° F. and 65 percent relative humidity,

(a) Specimens immersed for 24 hours.—Of the three materials, the balsa specimens had the least dimensional stability and after 24 hours immersion had increased approximately 1-1/2 times their original weights. The acetate specimens increased approximately 45 percent and the rubber specimens approximately 30 percent of their original weights. The bond between the tension blocks and the balsa was not sufficient to withstand the high tensile stresses developed, and failure took place largely in the bond. The strength of bond developed in the rubber and acetate specimens was sufficient to cause these materials to fail in tension. The results of the tension tests showed that the immersion lowered the tensile strength of the acetate and rubber approximately 50 percent. The balsa tensile specimens maintained their strengths after immersion. The modulus of rigidity of the rubber specimens did not appear to be materially affected by immersion, but the values for balsa and acetate were reduced by about 25 percent.

The data obtained from the flatwise compression tests showed that the balsa had a greater ultimate strength and modulus of elasticity after treatment than the other materials, The rubber which lost approximately 25 percent of its original strength, showed less change after immersion than either the balsa or acetate, which lost approximately 50 percent. The yields at 0.7 percent strain for the three materials were reduced in general, approximately the same amounts as their respective ultimate strengths. in modulus of elasticity, the rubber lost about 18 percent compared with the control value; the balsa and acetate, about 35 percent.

(b) Specimens immersed for 40 days.--The balsa wood specimens continued to gain in weight and increase in dimensions during the 40-day immersion period. The acetate and rubber changed to a lesser degree after the first 24 hours. The strength values for the three materials were not appreciably changed by the increase in immersion time. The modulus of elasticity of the materials appeared to change to a lesser degree than after immersion for 24 hours, the rubber showing no decrease and the balsa and acetate losing approximately 20 percent of their original values.

(c) Specimens immersed for 40 days and reconditioned. --The specimens of balsa that were subjected to 40 days immersion in water and then reconditioned to equilibrium with 75° F. and 65 percent relative humidity before testing, showed an overall return to approximately 85 percent of the values obtained from the control specimens. The rubber specimens returned to approximately 90 percent of the control values. After reconditioning, balsa did not return completely to original dimensions, but for both the rubber and acetate the final dimensions were less than the originals, It also appeared that the acetate retained its compressive and tensile strengths after immersion and. reconditioning better than the rubber and the balsa, since the specimens were able to withstand 99 and 91 percent of the control. stress against 82 and 88 percent for balsa and 72 and 79 percent for rubber, respectively.

Exposure to High Humidity

Table 2 is a compilation of the results of tests on the same materials when conditioned to equilibrium with 80° F. and 97 percent relative humidity, and also after reconditioning at 75° F. and 65 percent relative humidity.

Again the balsa specimens increased considerably more in weight and in dimensions than the other two materials. The rubber retained a better proportion of its compressive strength and shear modulus. All three materials lost about one–third of their tensile strength after exposure. Except in tensile strength, the test values obtained after reconditioning were approximately equal to the control values.

Exposure to High Temperature

Table 3 is a compilation of the results of teste on the specimens that we— heated to 200° F., dry heat, for 240 hours and also when reconditioned at 75° F. and 65 percent relative humidity. Except in thickness, the balsa showed the greatest decrease in weight and dimensions and the rubber the least when weighed and measured at 200° F. Although the tensile strength Of the rubber was reduced approximately 65 percent, it was reduced only about 35 and 15 percent for balsa and acetate, respectively. After reconditioning, the tensile strengths of the rubber and acetate showed permanent weakening due to the heat, testing approximately 60 percent and 75 percent, respectively, of their control strengths, This was not due to a weakness in the glue bonds. In compression, the rubber lost approximately 65 percent of ita original strength but, after reconditioning, the ultimate compressive strength was about 85 percent of the control value. The compressive strength values obtained from the balsa specimens tested after reconditioning were also about 85 percent Of the control values. The shear modulus of the materials was not permanently changed by the high temperature exposure.

Exposure to Cycles of High and Low Temperatures Combined with High and, Low Humidities

Table 4 gives the results of the tests on specimens subjected to 1, 5, and 10 cycles of high and low temperatures combined with high and low humidities. One cycle consisted of 24 hours at 175° F. and 75 percent relative humidity, 24 hours at —20° F., 24 hours at 175° F. dry heat, and 24 hours at —20° F. All specimens were conditioned to equilibrium at 75° F. and 65 percent relative humidity after cyclic exposure prior to testing. In general, the three materials stood up well under the heating and freezing cycle. The rubber specimens were the most affected, losing up to 20 percent in compressive and 25 percent in tensile strength after exposure. The acetate specimens were the least affected, for they retained their compressive strength for all cycles and lost approximately 20 percent io tensile strength. The balsa specimens dropped approximately 10 percent in compressive strength and 17 percent in tensile strength after 10 cycles of exposure. All three materials maintained their modulus of rigidity throughout the exposures,

Table 5 is a condensation of tables 1 through 4 listing the results as ratios for all tests of the final strength or property after exposure to the control value from tests of specimens conditioned to equilibrium with 75° F, and 65 percent relative humidity.

Decay Resistance

Results for the balsa specimens (excluding those treated with 2 percent preservative) are reported individually in table 7 in order that the density, preservative retention, and amount of decay of these specimens may be compared. A summary for these specimens, as well as the remaining ones in test, is given in table 6.

Growth of all the fungi over the balsa control specimens in bottles was good and a considerable amount of weight loss was sustained; there was also a considerable amount of weight loss for the specimens buried in soil, In general, the weight losses were greater as the length of exposure increased. Specimens attacked by Poria incrassata were brown, shrunken, and curved. The cross-sect ion surface resisted somewhat indentation by the thumb nail. Specimens attacked by Polyporus versicolor were yellowed, only slightly shrunken or distorted, and very light in weight, The cross section offered but slight resistance to pressure of the thumb nail.

The response of the fungi to the balsa specimens containing preservative was varied. Poria microspora was very susceptible to the preservative during the first 2 months of exposure. The effect of the preservative in concentrations at and below 1.0 percent, however, seemed to diminish with time in the case of all the fungi.

The 2.0 percent concentration of the preservative was sufficient to suppress all the fungi in the test bottles. At the end of the test re-isolations were attempted from 18 bottles, and in two-thirds of the cases the results were negative. If this type of test is considered acceptable, a concentration Of 2.0 percent pentachlorophenol is shown to be adequate to protect the balsa specimens against the fungi tried, It should also be noted, in support of this type of test, that the specimens treated with 2.0 percent pentachlorophenol exposed to soil sustained no losses.

Neither cellular cellulose acetate nor cellular hard rubber sustained any significant weight losses. The growth of the fungi over these specimens varied, although most of the cultures appeared normal. The rubber specimens were well covered by Poria microspora and the acetate specimens by Poria incrassata, Polyporus versicolor did not achieve good growth in either case. The acetate specimens were somewhat stained by contact with the fungi, while no change was apparent in the rubber. Slight contamination by Penicillium and Aspergillus spp. was observed in many of these tests.

It was planned to make a more careful analysis of the weight changes of the specimens based on the behavior of the reference specimens. However, when the density of the various balsa specimens, as well as the retention of the preservative, was found to vary so widely this was abandoned. Therefore, the change in weight of each specimen was based on a conditioned weight after the preservative had been added and again after exposure to test, The weight of preservative was thus included in all computations, and the results were subject to any changes in weight of the preservative, While these values were small as far as any consequential decay loss was concerned, they undoubtedly accounted for variations that did occur. The results indicated that the effect of the preservative diminished with time of exposure: presumably some of the preservative was volatilized during this time. An idea of the behavior of the reference samples may be obtained from table 7, where changes in weight after exposure to sterile agar (simulating exposure to test) and to 65 percent relative humidity are shown. A technique that might be employed to advantage in future tests would be to expose all specimens to a high humidity under sterile conditions for a time before they are conditioned for the test at a lower humidity. This would allow the application of a desorbing gradient in obtaining equilibrium weights before the test, as well as afterward,

In computing the density of the specimens, the weight of each at 65 percent relative humidity and 80° F. before preservative was added was used. The volume used was the average of 35 reference specimens held under the same conditions.

There seemed to be no relationship between the density of the specimens, retention of preservative, and the weight loss, At retentions of 0.0950 pound per cubic foot or more, however, there were only two or three cases of consequential weight loss. It was observed that most control specimens were more or less uniformly decayed, while in many of the treated specimens the decay was likely to occur in pockets or at one end. This seemed to indicate failure of this method of treatment to disperse the preservative completely.

Flame Tests

Flame tests were made on end-grain balsa, cellular hard rubber, and cellular cellulose acetate core materials, A summary of the results is given in table 8.

Aircraft Liquids

Table 9 shows the average changes in weight of the specimens of balsa, rubber, and cellular cellulose acetate after ? days of immersion in aircraft liquids, after immersion followed by 7 days of conditioning, and after immersion followed by 39 days of conditioning. Also shown in the table are the average changes in thickness, width, and length after 7 days of immersion and after immersion plus 39 days of conditioning. The changes are expressed as percentages based upon the weight and dimension of the specimens after the initial conditioning.

The percentage increase in weight of balsa, after 7 days of immersion in the liquids, was higher than that for the other core materials. Water was absorbed by balsa to a greater extent than were the other liquids. The core materials appeared to have lost no solid matter while in the solutions, except perhaps the rubber in the alcohol and gasoline,

The rubber showed only slight dimensional change in any of the seven liquids tested.

The balsa specimens showed but slight dimensional change in the petroleum oleo fluid, gasoline, or crankcase oil. They did show appreciable changes, however, in width and length in the alcohol, glycol, castor oil oleo fluid, and water, and in these cases the percentage change in width was greater than the percentage change in length, The greatest expansion was in water and amounted to about 4.0 percent in width. The longitudinal change of balsa (thickness of specimen) was usually slight.

The cellular cellulose acetate showed only slight dimensional change in the petroleum oleo fluid, gasoline, and crankcase oil. There was appreciable change in the alcohol, castor oil oleo fluid, glycol, and water.

The general appearance of the core materials used in this test did not seem to have been altered by the 7-day immersion in any way, except in color. The balsa and cellular cellulose acetate were colored by crankcase oil and the oleo fluids. Rubber was not perceptibly colored, Other physical characteristics of the materials appeared to remain unchanged.

SECTION B - TESTS ON SANDWICH PANELS

Summary

Nine sandwich constructions (made by combining three face materials: aluminum, glass cloth-resin, and plywood, with the three core materials described in Section A; balsa, cellular hard rubber, and cellular cellulose acetate) were conditioned to equilibrium at a relative humidity of 65 percent and a temperature of 75° F. and then subjected to the following exposures: water immersion, high humidity, high temperature, alternate high-low temperature and humidity, and weathering to determine, by tension tests, weight and dimensional measurements, and observation, the relative durability of each construction. The details of these exposure conditions were the same as those described in Section A.

All test panels were nominally 1/2 by 6 by 6 inches, and four panels were prepared for each exposure condition, two with unprotected edges and two with well-painted edges. Eight tension specimens, of the type described in Section A, were prepared for each exposure, except weathering.

The test results, in general, presented considerable variation. It is difficult therefore to present clearly and concisely the effect of the different exposure conditions on the nine sandwich combinations. Certain fairly well established effects, however, can be summarized.

In water immersion, the weight gain of each sandwich construction was controlled partly by the characteristics of the core and face material and partly by the quality of the edge seal. Unsealed balsa-glass cloth panels gained about 92 percent, whereas, edge-coated rubber-aluminum panels gained about 2.5 percent, The glass cloth faces were poorer vapor barriers than the 1/16-inch birch plywood faces but absorbed less moisture.

Tensile strengths were generally lower in the soaked conditions than at room conditions but regained most of this loss upon reconditioning.

Transverse dimensional. changes under all exposures reflected the properties Of the faces only and those for plywood were usually two to three times those for either glass cloth or aluminum. Changes in thickness followed the same trends exhibited by the respective core materials in the tests described in Section A.

The effects of exposure to high humidity resembled, on a reduced scale, those of immersion in water,

All sandwich combinations lost weight in the exposure to high temperature. The unprotected acetate–plywood specimens lost the most (about 9 percent); the rubber-glass cloth, the least (about 1.5 percent). A retained loss in weight in some combinations (glued with resorcinol glue) upon being recon–ditioned was attributed to a loss of retained solvent in the glue lines. Dimensionally the acetate–glass cloth panels were the most stable in this exposure.

Ten cycles of high and low temperatures and humidities had relatively little effect on the weight, dimensions, or tensile strengths of the nine sandwich combinations.

An exposure of 1 year to the weather with inspection after 4, 8, and 12 months' exposure produced little detertoration on edge–protected sandwich panels other than fading of the glass cloth faces, checking of the unpro-tected plywood, and slight corrosion of the aluminum. Panels with unpro-tected edges exhibited some delamination between the faces and the cores. Unprotected cellular cellulose acetate edges shrank considerably and were in poorer condition than either the balsa or cellular hard rubber.

Description of Materials

The three core materials, balsa, cellular hard rubber, and cellular cellu–lose acetate previously described in Section A of this report, were each faced with three face materials to produce nine different constructions of sandwich panels for test specimens. Descriptions of the three face materi–als follow:

Plywood

Plywood faces conforming to Army–Navy Aeronautic Specification AN-NN-P-511b were 0.070 inch, three–ply, birch plywood glued with a phenolic–type sheet glue.

Aluminum

All aluminum faces were 24 ST Alclad 0.020 inch thick conforming to Army—Navy Aeronautic Specification AN—A—13. The material was inspected to eliminate all dented, wrinkled, and contaminated sheets that might produce weak or questionable panels.

Glass Cloth[8] Resin[9]

Heat-treated glass cloth 0.003 inch thick with a basket weave was impregnated with one of the exceptionally viscous, contact pressure, laminating resins to a resin content of approximately 43 percent, based on total treated weight, to form glass cloth-resin face material, hereafter referred to as glass cloth faces.

Preparation of Panels

Plywood-balsa.--Panels with end-grain balsa cores and plywood faces were glued with an intermediate-temperature-setting melamine resin glue.[10] The glue was spread on the plywood by brush. Twenty-four grams of wet glue were spread per square foot. After an open assembly period of 1 to 7 days the panels were assembled and bag molded on a flat plate glass or aluminum mold. The curing cycle was 15 minutes at a pressure of 50 pounds per square inch and a temperature of 300° F.

Aluminum-balsa.--The Air Forces requested that a specific two-step bonding process[11] be used on all aluminum combinations. The primed and cured aluminum faces, therefore, were bonded to the balsa cores with a room-temperature-setting resorcinol resin glue.[12]

Glass cloth-balsa.--Panels with glass cloth faces and balsa cores were assembled and cured in one operation with no additional adhesive between the faces and the core. This procedure was commonly known as "wet laminating."

The normal procedure was to cover the flat caul with a parting film of cellophane. The impregnated glass cloth for one face (8 sheets) was then laid, one sheet at a time, cross laminated, on the cellophane-covered caul. This procedure was repeated for the other face on the matching caul or a piece of cellophane taped to a flat surface. The balsa core was then laid on one of the cauls and covered with the lay-up for the opposite face. This procedure, rather than laying the glass cloth directly on the core, was found necessary to avoid blisters and wrinkles.

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[8] Appendix I, note 3.

[9] Appendix I, note 4.

[10] Appendix I, note 5.

[11] Appendix I, note 6.

[12] Appendix I, note 7.

Due to the slight waviness of the balsa–core surfaces, fluid pressure or its equivalent was necessary to assure intimate contact between the glass cloth and the core.

The panels were cured at a temperature of 220° F. and a pressure of 13 pounds per square inch for 1-1/2 hours and were then removed from the press while hot.

Plywood–cellulose acetate.––These panels were made by brushing a room–temperature–setting resorcinol glue (35 grams per square foot) on the plywood faces Only, and pressing the panels in a vacuum bag at room temperature for a minimum period of 4 hours.

Aluminum–cellulose acetate.–-The normal technique for producing these panels was the same as that used on the aluminum-balsa durability panels.

Glass cloth–cellulose acetate.––This combination was fabricated by the same technique as that used on the glass cloth–balsa combination.

Plywood–cellular rubber.--This combination was made by the same process that was used on the plywood–cellulose acetate combination.

Aluminum–cellular rubber.--The same process was used on this combination as on aluminum-cellulose acetate.

Glass cloth–cellular rubber.-—Cellular rubber inhibits the cure of the contact–pressure laminating resin when the two are in intimate contact during the curing cycle. Therefore, the normal wet–laminating process, as used on balsa and cellulose acetate cores, could not be used. If, however, a suspension (about 15 percent concentration) of the catalyst (benzoyl peroxide) in water was sprayed or brushed on the cellular rubber and allowed to dry, the normal laminating process could be used with fair results.

Preparation of Test Specimens

Two types of specimens were prepared for this part of the study: a square panel nominally 1/2 by 6 by 6 inches in dimensions used to determine weight and dimensional changes, and a tension specimen similar to that described in Section A of this report.

Four Of the square panels were prepared for each exposure, two with unprotected edges, and two with well-painted edges. The edge coating consisted of one coat of lead primer (1,000 parts white lead paste, 97 parts raw oil, and 9.4 parts drier), which was allowed to dry for 24 hours at room temperature, followed by two separate coats of aluminized varnish (1-1/2 pounds of aluminum paste, fine aircraft–use grade, to 1 gallon of phenolic resin varnish conforming to specificat ion AN-TT-V-116) with an 8–hour drying interval between coat a.

Eight tension specimens were prepared far each exposure condition, except the weathering exposure.

Treatment of Specimens

All specimens were first conditioned to approximate weight equilibrium at 75° F. and 65 percent relative humidity and then divided into groups and exposed to water immersion, high humidity, high temperature, and alternate high-low temperature combined with alternate high-low humidity under the conditions described in Section A for tests on core materials. An additional group of 1/2- by 6- by 6-inch specimens was prepared and exposed to the weather for 1 year as described later.

The specimens were inspected for glue joint integrity, stability, completeness of end coating, and general appearance. They were then brought to approximate equilibrium with 75° F. and 65 percent relative humidity and carefully weighed and measured prior to exposure. The specimens were placed on racks after they had been fastened at three points with a brass spring beneath each point and a screw hook above as shown in figure 11. This arrangement allowed for free movement and easy removal of the panels.

On April 6, 1945, the exposure was started by facing the panels south at an angle of 45° to the horizon, The specimens were inspected, weighed, and measured at the end of three 4-month intervals.

Discussion

Water immersion tests.--The effects of water immersion on the weight, dimensions, and tensile strength of the nine sandwich constructions are summarized in table 10. Most panels with painted edges gained less weight than those with unpainted edges. The average gain in weight for each construction was largely controlled by the face and core material but was also apparently affected by the effectiveness of the seal provided by the edge coating. The unsealed balsa-glass cloth panels gained the most weight in immersion to approximate equilibrium (92.42 percent) and the edge-sealed rubber-aluminum panels, the least (2.44 percent).

The respective weight gains of panels with various cores fell in the same order as that for the core alone as shown in Section A, the order was rubber least, acetate intermediate, and balsa highest. The order of weight gain, according to face material, was not consistent and apparently depended largely on the absorbing properties of the core. Glass cloth faces appeared to be a poorer moisture barrier than 1/16-inch birch plywood as shown by weight gains of the panels having balsa cores. The plywood faces, however, absorbed more water than the glass cloth faces as shown by results On rubber cores.

Transverse dimensional changes as reported in table 10 reflect only the dimensional stability of the face material, as the measurements were made on the faces, For all three face materials the changes were small but net changes in the plywood were consistently greater than the changes for either glass cloth or aluminum faces, The changes in thickness were greater than the changes in transverse dimensions and were effected by the face materials, The increase in thickness of panels with plywood faces amounted to 1 to 2 percent when thoroughly water soaked. Panels with aluminum or glass-cloth faces changed very little in thickness when soaked and dried. Some of them, notably the rubber-aluminum combination, actually shrank slightly (about 0.6 percent) when soaked.

Upon reconditioning most of the combinations returned very nearly to their original dimensions, except those with acetate cores. All of these shrank slightly in thickness; the retained shrinkage varied from 0.46 to 1.89 percent of the original thickness,

The tension values obtained before and after immersion to weight equilibrium and after reconditioning were somewhat erratic but revealed in general a reduced tensile strength when thoroughly soaked. The acetate-aluminum specimens were markedly weakened. The combinations of rubber-aluminum and rubber-plywood had higher tensile strengths when soaked than the matched specimens before soaking.

Some reconditioned specimens tested higher in tensile strength and some lower than the corresponding control specimens. Those combinations testing higher after exposure and reconditioning than the controls were the balsa-aluminum, rubber-plywood, rubber-glass cloth, acetate-plywood and acetate aluminum.

High-humidity tests.--The data from the high-humidity tests are summarized in table 11. The effect of high humidity on the weight, dimensional stability, and tensile strength of sandwich panels displayed the same general trend as that obtained from water immersion tests. The magnitude of the weight and dimensional changes produced by the high-humidity exposure, however, was considerably less than that produced by water immersion. The decrease in tensile strength in high humidity vas generally less than the decrease upon immersion in water, except for the acetate-aluminum and acetate-glass cloth specimens, which were reduced in tensile strength, about 75 percent by the exposure to high relative humidity. The tensile strength of the reconditioned tensile specimens was less than the controls in all cases, the reduction varying from about 5 percent for acetate-plywood to 40 percent for rubber-aluminum specimens.

High temperature tests.---Table 12 summarizes the effects of exposure for 240 hours to 200° F. on the weight, dimensions, and tensile strength of these sandwich constructions. All combinations lost weight during the exposure; the relation between face materials was consistent for all three cores. Plywood showed the greatest loss; aluminum, intermediate; and glass cloth, least. The greatest weight loss was recorded for the acetate-plywood specimens with upainted edges (8.96 percent) and the least for rubber-glass cloth specimens with unpainted edges (1.44 percent).

An examination of the weights after reconditioning indicated. permanent loss in weight for certain combinations, notably the aluminum-faced panels. A room-temperature-setting resorcinol glue (which was liquid at the time of pressing) was used in the fabrication of these panels. The original conditioning period may have been insufficient to evaporate completely the entrapped liquid. (partly alcohol and partly water). This liquid, therefore, may nave been vaporized and lost during the exposure to 200° F., and the loss would then appear as a permanent reduction in weight.

Changes in length and width were again small but consistent in magnitude and direction. Thickness measurements, however, revealed considerable change following the 200° F. exposure and also after reconditioning. Panels with balsa cores shrank slightly in thickness during the exposure but returned approximately to their original dimensions after reconditioning. When exposed to high temperature most panels with rubber cores increased in thickness and the increase was retained after reconditioning, with the rubber-aluminum combination swelling the most (about 6 percent), The panels with acetate cores, all shrank in thickness when exposed, those with plywood and aluminum faces shrinking the most (about 2-1/2 percent). About half of this shrinkage was retained after reconditioning. The acetate-glass cloth panels were the most stable, shrinking less than 1 percent during exposure and returning upon reconditioning approximately to their original dimensions.

Tensile strengths again revealed considerable variation, with both increases and decreases resulting from the exposure to high temperature. In general, the rubber specimens were weakened considerably by the exposure, the acetate specimens were weakend slightly, and the balsa specimens revealed tensile strength values both lower and higher than the controls, possibly depending more on the type of balsa rather than on the effect of the exposure.

<u>High- and low-temperature tests.</u>--Table 13 summarizes the effect on sandwich specimens of exposure to alternate high and low temperatures for 1, 5, and 10 cycles of exposure, following the same procedures as in Section A.

In general, the specimens progressively lost weight when weighed after exposure to 1, 5, and 10 cycles. Weight losses, however, were confined to a narrow range, with a maximum recorded loss of 2.90 percent for the rubber-aluminum specimens with painted edges. The acetate-glass cloth specimens changed the least in weight after 10 cycles of exposure.

Dimensional changes were confined to a range of less than ± 3 percent except those for the thickness of the rubber-aluminum and rubber-glass cloth panels, which increased 1 to 9 percent after Exposure to 10 cycles. The specimens with acetate cores rather consistently shrank, while those with balsa cores remained practically constant in thickness.

The tensile strength values revealed no consistent trend toward a decrease or increase in strength as a result of this cyclic exposure except for the balsa-plywood specimens in which a consistent decrease to a final Value Of about 55 percent of the control value was evidenced. It is doubtful, however, whether this decrease was significant because the tensile strength of' the balsa (density range 6 to 9 pounds per cubic foot) varied greatly. All aluminum-faced specimens developed tensile strengths after 10 cycles that were greater than the controls, but in most cases the values obtained after 1 and 5 cycles were slightly lower than the controls. It seemed probable that this apparent increase resulted from an insufficient number of specimens rather than from possible beneficial effects of exposure. It seemed unlikely, however, that the exposure had a weakening effect. A11 other combinations, involving plywood or glass cloth faces, produced tensile strength values after 1, 5, and 10 cycles lower than the control values

Weathering Tests

The changes in weight and dimension were converted to percentages and are presented in table 14. In general the panels sustained a weight and dimensional loss at 4 months (August), a slight gain at 8 months (December) and a loss at 12 months (April); these changes were apparently related to the seasonal moisture changes. On a percentage basis, the specimens with m-Painted edges lost or gained more in weight and dimensions than the specimens with painted edges.

The final inspection of these panels for glue joint integrity, completeness of end coating, and general appearance is summarized in table 15. The balsa core combinations withstood the weather very well, tile rubber core combinations were slightly deteriorated, and the acetate core combinations had a considerable amount of deterioration.

The balsa core, plywood-faced panels with and without end coating were in good condition after a year's exposure, as shown in figure 12A. Both the untreated plywood faces and the unpainted balsa cores checked. The balsa core, aluminum-faced panels were in good condition; the aluminum discolored slightly, and the unpainted balsa cores checked as shown in figure 12B. The panels with glass-cloth faces and balsa cores shown in figure 12C were in good condition, but again the balsa core checked when unpainted, and the glass-cloth faces faded from a rich brown color to a whitish gray.

The cellular hard rubber core construction made with the three face materials as shown in figure 13 was in good condition after a year's exposure and the face materials were in the same condition as those on balsa cores. The panels with unpainted edges showed signs of weathering and a slight amount of plastic deformation, especially at the points of contact with the rack. There was also a slight amount of peeling on the edges of the core material. Due to its cellular nature, the rubber core did not take the edge coating well, and it might have been advisable to add an extra coat of primer to this material.

The constructions with cellular cellulose acetate cores were in poor condition after a year's exposure to weather, especially the panels with unpainted edges, The three face materials were in much the same condition as those used on the other two core materials. The acetate cores had a considerable amount of shrinkage, plastic deformation, checking, and honeycombing as may be noted in figure 14. The glue joints in the core were separated and the glue joints between the core and face were broken at several corners. The panels with painted edges were in fair condition with tho exception of those with glass cloth faces where some plastic deformation was noted. The cellular nature of this core material made it difficult to obtain a complete edge coating,

Appendix

Note 1 CELLULAR HARD RUBBER - A synthetic rubber core material, black in color, 8 pounds per cubic foot density (including skin).

Note 2 CELLULAR CELLULOSE ACETATE - An extruded, unoriented, multicellular form of cellulose acetate containing a small percentage of glass fiber as a filler, 7-8 pounds per cubic foot density (including skin) e

Note 3 HEAT TREATED GLASS CLOTH - A plain weave cloth, 0.003 inches thick, 2.09 ounces per square yard, having a straw color.

Note 4 A high-temperature-setting, high-viscosity, contact-pressure, laminating resin of the polyester type.

Note 5 A high-temperature-setting, melamine resin adhesive.

Bote 6 A high-temperature-setting, thermoplastic resin with thermosetting resin and pigment.

Note 7 A room-temperature-setting resorcinol resin adhesive.

Table 1.--Some properties[1] of low density core materials for sandwich type constructions at 75° F. and 65 percent relative humidity, after immersion in water at 60° F., and after reconditioning at 75° F. and 65 percent relative humidity following immersion

Material	Treatment[2] of specimens before test	Range of values	Compression (Flatwise)[3]: Specific gravity[1]	Compression: Ultimate strength	Compression: Proportional limit: 1/4" strain gage length	Compression: Proportional limit: Dials between heads	Compression: Modulus of elasticity: 1/4" strain gage length	Compression: Modulus of elasticity: Dials between heads	Compression: Yield at 0.7 percent strain: 1/4" strain gage length	Compression: Yield at 0.7 percent strain: Dials between heads	Shear: Modulus of rigidity[4]	Tension (Flatwise)[5]: Specific gravity[1]	Tension: Ultimate strength	Tension: Failure area: Core	Tension: Failure area: Bond	Dimensional stability: Change based on original observations made at 75° F. - 65 percent R. H.: Length	Dimensional stability: Width	Dimensional stability: Thickness	Dimensional stability: Weight
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
				Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.		Lb. per sq. in.	Percent	Percent	Percent	Percent	Percent	Percent
Balsa (end grain)	Conditioned to equilibrium with 75° F. - 65 percent relative humidity (Controls)	Minimum	0.104	851	223	447	378,220	36,596	794	249	17,632	0.100	1,040						
		Average	.113	935	406	485	415,115	46,080	895	317	19,308	.104	1,455	36	64	0	0	0	0
		Maximum	.120	990	474	571	531,190	55,876	969	384	21,412	.116	1,891						
	Immersed in running tap water for 24 hours and tested immediately	Minimum	.093	313	113	205	65,266	15,143	244	103	10,371	.100	1,372			+2.16	+1.20	+0.19	+120.2
		Average	.118	466	234	291	270,500	22,506	405	155	12,486	.104	1,673	37	63	+2.54	+1.72	+.43	+153.5
		Maximum	.145	663	300	362	427,600	30,527	506	208	13,594	.116	1,988			+2.95	+2.05	+.60	+275.7
	Immersed in running tap water for 40 days and tested immediately	Minimum	.097	444	120	189	166,168	18,759	308	130	12,065	.090	1,069			+2.49	+1.25	+.59	+278.2
		Average	.133	546	189	303	364,527	26,221	406	180	14,149	.103	1,570	41	59	+3.37	+1.98	+.79	+327.1
		Maximum	.163	641	249	409	499,000	39,797	476	277	15,620	.116	1,995			+3.89	+2.65	+.99	+395.8
	Immersed in running tap water for 40 days and conditioned to equilibrium with 75° F. - 65 percent relative humidity	Minimum	.095	598	296	423	282,960	22,535	580	157	16,079	.090	1,031			+.20	+.10	0	+1.0
		Average	.110	769	361	522	344,894	30,478	725	211	17,289	.103	1,280	3	37	+.39	+.30	+.32	+1.4
		Maximum	.126	992	522	646	452,056	39,465	948	276	19,196	.116	1,773			+.60	+.65	+.59	+1.6
Cellular hard rubber (expanded type)	Conditioned to equilibrium with 75° F. - 65 percent relative humidity (Controls)	Minimum	.102	151	65	80	11,049	7,227	77	48	3,330		305						
		Average	.111	199	89	127	22,445	7,345	134	50	3,379	.115	331	100	0	0	0	0	0
		Maximum	.115	224	121	156	28,186	7,534	152	52	3,424		358						
	Immersed in running tap water for 24 hours and tested immediately	Minimum	.101	126	65	80	15,523	5,772	101	39	3,210		157			-.05	-.10	-.78	+21.1
		Average	.105	157	80	100	18,509	6,726	114	46	3,390	.109	167	100	0	-.13	-.11	-1.17	+28.4
		Maximum	.109	184	95	118	28,595	8,170	149	56	3,533		208			-.20	-.15	-1.94	+33.2
	Immersed in running tap water for 40 days and tested immediately	Minimum	.103	122	50	90	13,810	6,403	90	44	3,124		149			+.10	+.05	-.39	+38.0
		Average	.108	148	78	104	25,441	7,282	124	50	3,282	.106	187	100	0	+.13	+.11	-.66	+44.1
		Maximum	.113	177	116	131	50,226	8,174	140	55	3,387		208			+.20	+.15	-.98	+50.4
	Immersed in running tap water for 40 days and conditioned to equilibrium with 75° F. - 65 percent relative humidity	Minimum	.091	96	55	68	11,514	4,788	77	33	2,855		244			-.05	0	-1.34	+.4
		Average	.104	144	94	98	15,602	6,799	104	46	3,004	.105	262	100	0	-.15	-.05	-1.71	+.6
		Maximum	.114	184	174	133	19,741	8,323	124	58	3,248		275			-.30	-.10	-2.33	+.8
Cellular cellulose acetate (extruded type)	Conditioned to equilibrium with 75° F. - 65 percent relative humidity (Controls)	Minimum	.096	138	94	64	21,075	5,317	126	35	4,274	.096	274						
		Average	.099	164	79	105	30,805	6,461	152	44	4,394	.098	316	100	0	0	0	0	0
		Maximum	.105	201	130	118	38,502	9,639	187	68	4,481	.101	358						
	Immersed in running tap water for 24 hours and tested immediately	Minimum	.096	74	20	50	9,976	1,937	58	13	2,683	.096	147			+1.14	+.40	0	+40.2
		Average	.102	88	44	56	19,485	3,015	77	20	2,879	.098	184	100	0	+1.40	+.47	+.19	+43.6
		Maximum	.108	94	62	59	36,670	3,592	94	24	3,261	.101	210			+1.63	+.55	+.39	+56.1
	Immersed in running tap water for 40 days and tested immediately	Minimum	.098	70	20	44	15,594	2,626	70	18	3,454	.097	140			+1.44	+.60	+.39	+64.4
		Average	.103	83	43	53	23,702	3,385	80	23	3,544	.098	149	94	6	+1.65	+.72	+.62	+77.1
		Maximum	.109	88	69	59	36,670	3,838	84	26	3,716	.100	162			+1.89	+.80	+1.36	+99.2
	Immersed in running tap water for 40 days and conditioned to equilibrium with 75° F. - 65 percent relative humidity	Minimum	.095	140	32	77	22,472	5,022	131	34	3,367	.097	216			-.74	-.60	-.97	+.2
		Average	.102	162	74	104	38,382	6,857	144	46	4,096	.098	287	100	0	-.95	-.82	-1.39	-.1
		Maximum	.106	173	101	128	71,506	8,146	156	55	4,474	.100	348			-1.04	-1.00	-1.56	-.4

[1] Based on dimensions and weights when in equilibrium with 75° F. - 65 percent relative humidity prior to immersion in water.

[2] All immersed specimens were conditioned to equilibrium with 75° F. - 65 percent relative humidity prior to immersion treatment.

[3] Average of five tests, specimen size 2 inches square by 1/2 inch long, load applied parallel to 1/2-inch dimension.

[4] Modulus associated with shear distortion in planes parallel to the length-thickness plane of the original material (lengthwise-radial or tangential plane for balsa). See FPL Report No. 1301 for plate shear test method. Average of three tests. Specimen 16 by 16 by 1/2 inches.

[5] Average of six tests, specimen size 1 inch square by 1/2 inch thick. Aluminum loading blocks were bonded to balsa and plywood loading blocks were bonded to cellular hard rubber and cellular cellulose acetate core materials. Load applied parallel to 1/2-inch dimension.

Table 2.--Some properties[1] of low-density core materials for sandwich-type constructions at 75° F. - 65 percent relative humidity, at 80° F. - 97 percent relative humidity, and after conditioning at 75° F. - 65 percent relative humidity following exposure to 80° F. - 97 percent relative humidity

Material	Treatment[2] of specimens before test	Range of values	Compression (Flatwise)[3]: Specific gravity[1]	Compression (Flatwise)[3]: Ultimate strength	Compression: Proportional limit: 1/4" strain gage length	Compression: Proportional limit: Dials between heads	Compression: Modulus of elasticity: 1/4" strain gage length	Compression: Modulus of elasticity: Dials between heads	Compression: Yield at 0.7 percent strain: 1/4" strain gage length	Compression: Yield at 0.7 percent strain: Dials between heads	Shear: Modulus of rigidity[4]	Tension (Flatwise)[5]: Specific gravity[1]	Tension (Flatwise)[5]: Ultimate strength	Tension: Failure area: Core	Tension: Failure area: Bond	Dimensional stability[6]: Change based on original observations made at 75° F. - 65% relative humidity: Length	Dimensional stability[6]: Width	Dimensional stability[6]: Thickness	Dimensional stability[6]: Weight
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
				Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.		Lb. per sq. in.	Percent	Percent	Percent	Percent	Percent	Percent
Balsa (end grain)	Conditioned to equilibrium with 75° F. - 65 percent relative humidity (Controls)	Minimum	0.104	851	223	447	328,220	36,556	794	249	17,340	0.100	1,040						
		Average	.113	935	404	485	415,115	46,080	895	317	17,977	.104	1,459	36	64	0	0	0	0
		Maximum	.120	990	474	521	531,190	55,876	969	384	19,151	.116	1,891						
	Conditioned to equilibrium with 80° F. - 97 percent relative humidity	Minimum	.105	383	254	274	145,464	18,281	380	127	12,969	.090	747			+2.14	+1.34	+1.77	+14.14
		Average	.149	629	283	441	239,949	28,521	577	197	13,663	.100	1,038	51	49	+2.78	+1.57	+1.90	+14.58
		Maximum	209	930	312	662	372,575	44,218	884	303	14,615	.111	1,368			+3.30	+2.15	+2.00	+14.98
	Conditioned to equilibrium with 80° F. - 97 percent relative humidity followed by conditioning to equilibrium with 75° F. - 65 percent relative humidity	Minimum	.097	476	261	324	114,432	29,285		202	16,971	.090	660			+.10	+.20	+.98	-1.14
		Average	.133	890	286	457	357,296	47,352	1,033	326	17,772	.100	856	33	67	+.27	+.33	+1.30	-1.57
		Maximum	.189	1,551	311	745	642,162	67,318		463	19,081	.116	1,156			+.40	+.55	+1.78	-1.75
Cellular hard rubber (expanded type)	Conditioned to equilibrium with 75° F. - 65 percent relative humidity (Controls)	Minimum	.102	151	65	80	11,049	7,227	77	48	2,862		305						
		Average	.111	199	89	127	22,445	7,345	134	50	3,029	.115	331	100	0	0	0	0	0
		Maximum	.115	224	121	156	28,186	7,534	152	52	3,321		358						
	Conditioned to equilibrium with 80° F. - 97 percent relative humidity	Minimum	.108	106	33	80	10,749	6,396	76	36	2,757		171			+.25	+.20	-.19	+4.29
		Average	.112	155	82	100	17,755	7,420	106	47	2,914	.111	210	100	0	+.37	+.26	-.29	+4.58
		Maximum	.116	196	146	123	26,288	7,984	125	55	3,023		242			+.60	+.30	-.39	+5.17
	Conditioned to equilibrium with 80° F. - 97 percent relative humidity followed by conditioning to equilibrium with 75° F. - 65 percent relative humidity	Minimum	.104	154	35	105	15,955	6,721	111	46	3,630		257			0	0	-.57	+.89
		Average	.110	188	90	130	39,482	7,914	149	54	3,716	.116	288	100	0	+.04	+.04	-.66	+.93
		Maximum	.114	198	146	141	62,751	9,001	188	62	3,838		330			+.05	+.10	-.78	+.99
Cellular cellulose acetate (extruded type)	Conditioned to equilibrium with 75° F. - 65 percent relative humidity (Controls)	Minimum	.096	138	54	64	21,075	5,317	126	35	4,117	.096	274						
		Average	.099	164	79	105	30,605	6,461	152	44	4,228	.098	316	100	0	0	0	0	0
		Maximum	.105	201	130	118	38,502	9,639	187	68	4,404	.101	358						
	Conditioned to equilibrium with 80° F. - 97 percent relative humidity	Minimum	.094	100	44	64	16,280	4,065	88	28	2,557	.099	177			+.99	+.40	+.39	+7.21
		Average	.099	114	59	71	23,515	4,555	98	31	2,799	.106	218	91	9	+1.32	+.55	+.62	+7.96
		Maximum	.107	127	72	84	40,242	5,293	124	36	3,025	.110	257			+1.54	+.64	+1.17	+8.78
	Conditioned to equilibrium with 80° F. - 97 percent relative humidity followed by conditioning to equilibrium with 75° F. - 65 percent relative humidity	Minimum	.097	148	59	96	21,573	5,625	130	39	3,671	.099	238			-.40	-.30	0	-.51
		Average	.102	167	85	113	34,064	6,639	137	46	4,038	.104	274	98	2	-.53	-.42	-.24	-.89
		Maximum	.108	180	103	139	63,134	7,989	143	55	4,392	.110	340			-.75	-.55	-.79	-1.14

[1]Based on dimensions and weights when in equilibrium with 75° F. - 65 percent relative humidity prior to exposure to 80° F. - 97 percent relative humidity.

[2]All specimens were initially conditioned to equilibrium with 75° F. - 65 percent relative humidity.

[3]Average of five tests, specimen size 2 inches square by 1/2 inch long, load applied parallel to 1/2-inch dimension (parallel to grain for balsa).

[4]Modulus associated with shear distortion in planes parallel to the length-thickness plane of the original material (lengthwise-radial or tangential plane for balsa). See FPL Report No. 1555 for plate shear test method. Average of three tests, specimen size 16 inches square by 1/2 inch thick.

[5]Average of five to eight tests, specimen size 1 inch square by 1/2 inch thick. Aluminum loading blocks were bonded to balsa, and plywood loading blocks were bonded to cellular hard rubber and cellular cellulose acetate core materials. Load applied parallel to 1/2-inch dimension.

[6]Data obtained from compression specimens prior to test.

Table 3.--Some properties[1] of low-density core materials for sandwich type constructions at normal and elevated temperatures

Material	Temperature at time of test	Treatment of specimens before test[2]	Range of values	Compression (flatwise)[3]: Specific gravity[6]	Compression (flatwise)[3]: Ultimate strength	Compression: Proportional limit: 1/4-inch strain gage length	Compression: Proportional limit: Dials between heads	Compression: Modulus of elasticity: 1/4-inch strain gage length	Compression: Modulus of elasticity: Dials between heads	Compression: Yield at 0.7 percent strain: 1/4-inch strain gage length	Compression: Yield at 0.7 percent strain: Dials between heads	Shear: Modulus of rigidity[4]	Tension (flatwise)[5]: Specific gravity	Tension (flatwise)[5]: Ultimate strength	Tension: Failure area: Core	Tension: Failure area: Bond	Dimensional stability[6]: Change based on original observations made at 75° F.-65% relative humidity: Length	Width	Thickness	Weight
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
	°F.				Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.		Lb. per sq. in.	Percent	Percent	Percent	Percent	Percent	Percent
Balsa (end grain)	75	Conditioned to equilibrium with 75° F. - 65 percent relative humidity (controls)	Minimum	0.104	851	223	447	328,220	36,156	794	249	14,459	0.100	1,040						
			Average	.113	935	404	485	415,115	46,350	895	317	16,133	.104	1,455	36	64	0	0	0	0
			Maximum	.120	990	474	521	531,190	55,875	969	384	17,947	.116	1,891						
	200	Heated continuously for 240 hours at 200° F. dry heat	Minimum	.114	999	322	520	301,416	46,726	1,047	323	13,397	.090	596			-1.05	-0.94	-0.19	-9.72
			Average	.124	1,148	463	599	448,157	52,116	1,109	358	14,227	.094	982	34	66	-1.19	-1.03	-.20	-9.87
			Maximum	.129	1,270	893	743	627,115	58,150	1,171	395	15,821	.103	1,342			-1.29	-1.24	-.20	-9.93
	75	Heated continuously for 240 hours at 200° F. dry heat and conditioned to equilibrium with 75° F. - 65 percent relative humidity	Minimum	.095	666	299	447	320,175	30,647	664	212	14,200	.091	1,141			0	.05	.20	-1.12
			Average	.102	766	348	504	387,118	36,455	716	251	15,496	.100	1,717	21	79	-.08	.07	.34	-1.19
			Maximum	.110	874	397	635	525,328	44,122	771	305	17,560	.111	2,208			-.10	.10	.39	-1.29
Cellular hard rubber (expanded type)	75	Conditioned to equilibrium with 75° F. - 65 percent relative humidity (controls)	Minimum	.102	151	65	80	11,049	7,227	77	48	3,132		305						
			Average	.111	199	89	127	22,445	7,345	134	50	3,300	.115	331	100	0	0	0	0	0
			Maximum	.115	224	121	156	28,186	7,534	192	52	3,406		358						
	200	Heated continuously for 240 hours at 200° F. dry heat	Minimum	.102	59	11	25	11,764	1,990	39	14	1,187		95			.70	0	0	-3.00
			Average	.108	68	24	46	15,037	2,290	48	16	1,250	.106	102	100	0	1.47	-.12	-1.57	-3.26
			Maximum	.116	84	42	66	21,754	2,681	65	18	1,312		112			2.36	-.20	-2.36	-3.45
	75	Heated continuously for 240 hours at 200° F. dry heat and conditioned to equilibrium with 75° F. - 65 percent relative humidity	Minimum	.096	120	55	98	23,139	4,610	104	34	3,287		180			1.10	-.05	-.56	-1.43
			Average	.108	171	92	123	27,947	6,348	124	44	3,495	.114	196	100	0	1.49	-.23	-.98	-1.57
			Maximum	.114	211	129	166	36,648	7,474	156	52	3,681		214			1.76	-.65	-1.79	-1.67
Cellular cellulose acetate (extruded type)	75	Conditioned to equilibrium with 75° F. - 65 percent relative humidity (controls)	Minimum	.096	138	54	64	21,075	5,317	126	35	4,329	.096	274						
			Average	.099	164	79	105	30,605	6,461	152	44	4,353	.098	316	100	0	0	0	0	0
			Maximum	.105	201	130	118	38,502	9,639	187	68	4,391	.101	358						
	200	Heated continuously for 240 hours at 200° F. dry heat	Minimum	.096	135	29	89	14,649	4,940	102	34	4,153	.099	235			-.69	-.30	-.39	-5.18
			Average	.101	160	73	110	28,613	5,830	130	40	4,246	.104	266	99	1	-1.00	-.62	-.70	-6.06
			Maximum	.108	173	149	139	61,757	6,623	158	46	4,432	.108	329			-1.24	-.90	-1.17	-6.97
	75	Heated continuously for 240 hours at 200° F. dry heat and conditioned to equilibrium with 75° F. - 65 percent relative humidity	Minimum	.095	143	94	79	20,525	6,321	132	43	4,606	.099	178			0	0	0	-.43
			Average	.102	166	106	111	30,981	7,290	154	50	4,823	.104	232	99	1	-.17	-.07	+.16	-.94
			Maximum	.109	177	117	139	37,865	8,013	171	54	5,091	.108	285			-.30	-.25	+.20	-1.19

[1] Based on dimensions and weights when in equilibrium with 75° F. - 65 percent relative humidity prior to heating at 200° F.

[2] Specimens which were subsequently heated for 240 hours were first conditioned to equilibrium with 75° F. - 65 percent relative humidity.

[3] Specimen size 2 inches square by 1/2 inch long, load applied parallel to 1/2-inch dimension, average of 4 to 9 tests.

[4] Modulus associated with shear distortion in planes parallel to the length-thickness plane of the original material (lengthwise-radial or tangential plane for balsa). See FPL Report No. 1301 for plate shear test method. Specimen size 16 inches square by 1/2 inch thick. Average results from three specimens.

[5] Average of six tests, specimen size 1 inch square by 1/2 inch thick. Aluminum loading blocks were bonded to balsa and plywood loading blocks were bonded to cellular hard rubber and cellular cellulose acetate core materials. Load applied parallel to 1/2-inch dimension.

[6] Data obtained from compression specimens prior to test.

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Table 4.—The effect of 1, 5, and 10 cycles[1] of exposure to high and low temperatures and humidities on several properties[2] of low-density core materials for sandwich-type constructions

Material	Treatment[3] of specimens before test	Range of values	Compression (flatwise)[4]: Specific gravity[2]	Compression: Ultimate strength	Compression: Proportional limit: 1/4" strain gage length	Compression: Proportional limit: Dials between heads	Compression: Modulus of elasticity: 1/4" strain gage length	Compression: Modulus of elasticity: Dials between heads	Compression: Yield at 0.7% strain: 1/4" strain gage length	Compression: Yield at 0.7% strain: Dials between heads	Shear: Modulus of rigidity[5]	Tension (flatwise)[6]: Specific gravity[2]	Tension: Ultimate strength	Tension: Failure area: Core	Tension: Failure area: Bond	Dimensional stability[7]: Change based on original observations made at 75°F.-65% R.H.: Length	Width	Thickness	Weight
				P.s.i.	P.s.i.		P.s.i.		P.s.i.		P.s.i.		P.s.i.	Percent	Percent	Percent	Percent	Percent	Percent
Balsa (end grain)	Conditioned to equilibrium	Min.	0.104	851	223	447	328,220	36,556	794	249	16,849	0.100	1,040						
	with 75° F.-65% R.H.	Av.	.113	935	404	485	415,115	46,080	895	317	18,834	.104	1,455	36	64	0	0	0	0
	(controls)	Max.	.120	990	474	521	531,190	55,876	969	384	22,641	.116	1,891						
	Exposed to 1 cycle	Min.	0.100	724	309	395	181,909	31,729	663	215	---	0.090	1,240	---	---	-0.20	0	+0.19	-0.91
	followed by conditioning	Av.	.110	876	404	552	307,428	38,348	833	260	24,042	.100	1,632	59	41	-0.28	-0.11	+0.24	-1.06
	to equilibrium with 75° F.-65% R.H.	Max.	.130	1,089	507	643	532,469	44,482	1,003	302	---	.116	1,954	---	---	-0.40	-0.25	+0.38	-1.14
	Exposed to 5 cycles	Min.	0.105	918	444	396	447,649	35,952	904	243	---	0.091	1,013			-0.25	-0.05	-0.39	-1.97
	followed by conditioning	Av.	.123	1,097	569	495	718,134	76,953	1,062	445	18,349	.098	1,384	73	27	-0.32	-0.13	0	-2.01
	to equilibrium with 75° F. - 65% R.H.	Max.	.145	1,203	767	598	949,554	156,428	1,147	663	---	.101	2,000			-0.40	-0.20	+0.20	-2.05
	Exposed to 10 cycles	Min.	0.095	695	309	421	113,881	26,180	662	179	---	0.091	866			-0.35	-0.20	-0.98	-2.09
	followed by conditioning	Av.	.105	852	523	572	390,075	39,129	819	268	16,548	.097	1,205	77	23	-0.63	-0.33	-1.21	-1.34
	to equilibrium with 75° F. - 65% R.H.	Max.	.120	1,068	793	694	784,072	46,310	979	316	---	.103	1,571			-0.79	-0.45	-1.56	+0.89
Cellular hard rubber (expanded type)	Conditioned to equilibrium	Min.	0.102	151	65	80	11,049	7,227	77	48	3,125	---	305						
	with 75° F. - 65% R.H.	Av.	.111	199	89	127	22,445	7,345	134	50	3,845	0.115	331	100	0	0	0	0	0
	(controls)	Max.	.115	224	121	156	28,186	7,534	152	52	4,416	---	358						
	Exposed to 1 cycle	Min.	0.106	1,581	73	108	---	5,233	133	36	3,405	---	248			0.55	0.20	-0.98	-0.77
	followed by conditioning	Av.	.111	179	83	131	---	6,487	156	45	3,801	0.118	273	100	0	2.29	1.68	-0.48	-0.94
	to equilibrium with 75° F. - 65% R.H.	Max.	.116	201	95	149	---	7,380	173	51	4,197	---	296			3.71	3.46	+0.57	-1.17
	Exposed to 5 cycles	Min.	0.108	147	75	93	22,534	5,802	124	39	3,443	---	227			0.25	-0.10	-0.19	-1.67
	followed by conditioning	Av.	.111	176	77	123	28,148	7,010	146	48	4,190	0.119	250	100	0	1.55	1.93	-0.78	-1.79
	to equilibrium with 75° F. - 65% R.H.	Max.	.115	205	78	143	33,763	8,920	158	62	4,571	---	275			3.35	3.46	-1.16	-1.97
	Exposed to 10 cycles	Min.	0.103	136	118	105	11,035	6,215	110	43	3,296	---	261			-0.10	-0.20	-0.99	-1.77
	followed by conditioning	Av.	.106	161	126	128	20,788	6,889	142	48	4,027	0.119	302	100	0	1.22	0.96	-2.01	-2.07
	to equilibrium with 75° F. - 65% R.H.	Max.	.112	196	135	148	34,490	7,509	172	52	4,617	---	337			2.55	2.90	-2.94	-2.40
Cellular cellulose acetate (extruded type)	Conditioned to equilibrium	Min.	0.096	138	54	64	21,075	5,317	126	35	4,003	0.096	274						
	with 75° F. - 65% R.H.	Av.	.099	164	79	105	30,605	6,461	152	44	4,225	.098	316	100	0	0	0	0	0
	(controls)	Max.	.105	201	130	118	38,502	9,639	187	68	4,368	.101	358						
	Exposed to 1 cycle	Min.	0.094	143	47	86	15,983	6,289	115	43	---	0.098	254			-0.25	-0.15	-0.19	0
	followed by conditioning	Av.	.100	164	113	113	24,021	7,201	136	49	4,687	.103	284	100	0	-0.10	-0.27	-0.45	-0.50
	to equilibrium with 75° F. - 65% R.H.	Max.	.106	181	144	136	30,818	8,593	164	61	---	.108	316			+0.05	-0.45	-0.77	-1.01
	Exposed to 5 cycles	Min.	0.095	149	42	79	16,700	6,355	113	43	---	0.098	208			-0.30	-0.05	0	-1.24
	followed by conditioning	Av.	.101	165	89	111	44,446	7,823	142	54	4,470	.103	251	100	0	-0.13	-0.16	-0.16	-0.47
	to equilibrium with 75° F. - 65% R.H.	Max.	.106	174	117	130	90,050	9,786	173	61	---	.108	308			+0.05	-0.20	-0.39	+0.54
	Exposed to 10 cycles	Min.	0.095	150	70	99	12,821	6,389	90	43	---	0.090	232			0.65	-0.64	-1.16	-0.29
	followed by conditioning	Av.	.102	169	105	124	40,389	7,068	145	48	4,652	.095	259	97	3	-0.28	-0.31	-1.58	-0.84
	to equilibrium with 75° F. - 65% R.H.	Max.	.106	180	133	138	75,417	8,142	175	55	---	.099	291			+0.75	+0.60	-1.76	-1.20

[1] One cycle consisted of the following consecutive treatments: 24 hours at 175° F. - 75% R.H., 24 hours at -20° F., 24 hours at 175° F., and 24 hours at -20° F.

[2] Based on dimensions and weights when in equilibrium with 75° F. - 65% R.H. prior to cyclic exposures.

[3] All specimens were initially conditioned to equilibrium with 75° F. - 65% R.H.

[4] Average of five tests, specimen size 2 inches square by 1/2 inch long, load applied parallel to 1/2 inch dimension (parallel to grain for balsa).

[5] Modulus associated with shear distortion in planes parallel to length-thickness plane of the original material (lengthwise-radial or tangential plane for balsa). See Forest Products Laboratory mimeograph 1555 for plate shear method. Average of 1-3 tests, specimen size 16 inches square by 1/2 inch thick.

[6] Average 5-8 tests, specimen size 1 inch square by 1/2 inch thick. Aluminum loading blocks were bonded to balsa, and plywood loading blocks were bonded to cellular hard rubber and cellular cellulose acetate core materials. Load was applied parallel to 1/2-inch dimension.

[7] Data obtained from compression specimens prior to test.

Table 5.—Some properties[1] of low-density core materials for sandwich constructions after various exposures[2]

Treatment of specimens	Material	Compression (flatwise): Specific gravity[1]	Compression: Ultimate strength	Proportional limit: 1/4" strain gage length	Proportional limit: Dials between heads	Modulus of elasticity: 1/4" strain gage length	Modulus of elasticity: Dials between heads	Yield at 0.7 percent strain: 1/4" strain gage length	Yield at 0.7 percent strain: Dials between heads	Shear modulus of rigidity	Tension (flatwise): Specific gravity[1]	Tension (flatwise): Ultimate strength	Dimensional stability: Average of length, width, and thickness	Weight
Immersed in running tap water for 24 hours	Balsa	1.044	0.502	0.578	0.600	0.652	0.48[illegible]	0.453	0.488	0.645	1.000	1.150	1.015	7.535
	C.H.R.[3]	.946	.788	.899	.788	.825	.915	.851	.920	1.002	.948	.565	.995	1.284
	C.C.A.[4]	1.030	.536	.557	.533	.636	.466	.507	.455	.538	1.000	.582	1.007	1.436
Immersed in running tap water for 40 days	Balsa	1.177	.585	.467	.625	.869	.570	.454	.568	.733	.991	1.078	1.020	4.271
	C.H.R.[3]	.973	.743	.876	.819	1.134	.991	.926	1.000	.972	.922	.565	1.001	1.441
	C.C.A.[4]	1.040	.506	.544	.505	.775	.524	.527	.522	.719	1.000	.472	1.010	1.771
Immersed in running tap water for 40 days and reconditioned[5]	Balsa	.973	.821	.893	1.077	.830	.661	.810	.666	.694	.991	.880	1.003	1.014
	C.H.R.[3]	.937	.723	1.057	.772	.695	.925	.776	.920	.890	.913	.792	.994	1.006
	C.C.A.[4]	1.030	.988	.937	.991	1.252	1.061	.948	1.045	.829	1.000	.909	.989	.999
Conditioned to equilibrium with 80° F. - 97% R.H.	Balsa	1.319	.673	.700	.910	.576	.617	.645	.621	.770	.962	.714	1.021	1.146
	C.H.R.[3]	1.009	.780	.922	.788	.790	1.010	.791	.940	.962	.965	.635	1.001	1.046
	C.C.A.[4]	1.000	.695	.747	.676	.767	.705	.645	.705	.662	1.081	.688	1.008	1.080
Conditioned to equilibrium with 80° F. - 97% R.H. and reconditioned[5]	Balsa	1.177	.952	.708	.943	.885	1.026	1.155	1.029	.986	.962	.589	1.006	.985
	C.H.R.[3]	.991	.945	1.012	1.022	1.760	1.079	1.111	1.080	1.225	1.009	.871	.998	1.009
	C.C.A.[4]	1.030	1.018	1.076	1.075	1.115	1.027	.902	1.045	.995	1.061	.865	.996	.991
Heated for 240 hours at 200° F. dry heat	Balsa	1.097	1.230	1.195	1.235	1.320	1.135	1.239	1.130	.882	.903	.675	.992	.902
	C.H.R.[3]	.973	.342	.270	.355	.669	.312	.358	.320	.379	.870	.302	.999	.967
	C.C.A.[4]	1.020	.975	.924	1.047	.935	.903	.855	.909	.974	1.061	.842	.992	.939
Heated for 240 hours at 200° F. dry heat and reconditioned[5]	Balsa	.903	.820	.862	1.040	.932	.791	.800	.792	.959	.962	1.180	1.001	.988
	C.H.R.[3]	.973	.860	1.023	.968	1.243	.864	.926	.880	1.058	.992	.592	1.001	.984
	C.C.A.[4]	1.030	1.012	1.342	1.056	1.010	1.130	1.013	1.136	1.107	1.061	.735	1.000	.991
Exposed to one cycle of temperatures and humidities[6]	Balsa	.973	.936	1.000	1.138	.739	.832	.930	.820	1.279	.962	1.121	.999	.989
	C.H.R.[3]	1.000	.900	.933	1.031		.883	1.163	.900	.989	1.026	.825	1.012	.991
	C.C.A.[4]	1.010	1.000	1.430	1.077	.786	1.116	.894	1.113	1.102	1.051	.899	.997	.995
Exposed to five cycles of temperatures and humidities[6]	Balsa	1.088	1.130	1.410	1.021	1.730	1.670	1.187	1.404	.975	.942	.951	.998	.980
	C.H.R.[3]	1.000	.884	.865	.968	1.252	.955	1.090	.960	1.089	1.035	.755	1.009	.982
	C.C.A.[4]	1.020	1.005	1.127	1.058	1.451	1.211	.934	1.227	1.051	1.051	.794	.998	.995
Exposed to ten cycles of temperatures and humidities[6]	Balsa	.929	.911	1.295	1.180	.940	.848	.915	.845	.878	.932	.828	.993	.987
	C.H.R.[3]	.955	.808	1.417	1.008	.924	.937	1.060	.960	1.047	1.035	.912	1.001	.979
	C.C.A.[4]	1.030	1.030	1.330	1.181	1.318	1.093	.954	1.091	1.088	.969	.820	.993	.992

[1]Based on dimensions and weights when in equilibrium with 75° F. - 65 percent relative humidity prior to exposure.

[2]All figures are ratios of the average test values after exposure to the average control values prior to exposure.

[3]Cellular hard rubber - (expanded butadiene-acrylonitrile type).

[4]Cellular cellulose acetate - (extruded type).

[5]Reconditioned to equilibrium with 75° F. - 65 percent relative humidity.

[6]One cycle consisted of the following consecutive treatments: 24 hours at 175° F. - 75 percent relative humidity, 24 hours at -20° F., 24 hours at 175° F., and 24 hours at -20° F.

Note: See tables 1 to 4 for detailed results.

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Table 6.--Change in weight[1] of low-density core materials for sandwich type constructions when tested for resistance to decay

Material	Exposures					
	No. 106 Poria microspora	No. 563 Poria incrassata	No. 72074 Polyporus versicolor	Soil	Sterile agar[2]	65% relative humidity[3]
	Percent	Percent	Percent	Percent	Percent	Percent
One month's exposure						
Balsa - no preservative	-23.4	-15.5	-21.3	-5.4	+0.68	-0.53
Balsa - 0.1% pentachlorophenol	- 1.21	- 8.4	- 8.8	- .12	- .2	-1.0
Balsa - 1.0% pentachlorophenol	+ .03	- 4.3	- 1.6	- .15	- .1	-1.3
Balsa - 2.0% pentachlorophenol	- .44	- .46	- .72	+ .19	- .37	-1.7
Cellular cellulose acetate	+ .64	+ .66	+ .34	+1.30	+ .4	- .6
Cellular hard rubber	+ 1.3	+ 1.1	+ .54	+2.7	+ .5	+ .15
Two months' exposure						
Balsa - no preservative	-22.6	-28.7	-34.9	-10.3	- .18	- .66
Balsa - 0.1% pentachlorophenol	- 1.0	-24.3	-30.1	- 3.1	- .70	-1.30
Balsa - 1.0% pentachlorophenol	- .8	- 8.2	-14.7	- .71	- .6	-1.40
Balsa - 2.0% pentachlorophenol	- .88	- 1.4	- 1.1	+ .56	- .97	-1.10
Cellular cellulose acetate	+ .56	+ 1.2	+ .04	+ 2.60	+ .20	- .45
Cellular hard rubber	+ 1.0	+ .94	+ .60	+ 4.9	+ .6	+ .35
Three months' exposure						
Balsa - no preservative	-32.5	-34.8	-43.4	-19.8	+ .05	- .35
Balsa - 0.1% pentachlorophenol	-13.8	-33.9	-41.0	-12.0	- .77	-1.10
Balsa - 1.0% pentachlorophenol	- .7	-16.9	-16.9	- 5.8	- .70	-1.10
Balsa - 2.0% pentachlorophenol	- .92	- 1.0	- .84	+ 4.4	- .43	-1.30
Cellular cellulose acetate	+ .13	+ 1.1	- .36	+ 7.7	+ .27	- .20
Cellular hard rubber	+ 1.1	+ 1.1	+ .52	+10.7	+ .4	+ .55

[1] Based on conditioned weights at 65% relative humidity and 80° F. before and after exposure. Weight of preservative included where present. Average of 5 specimens except where otherwise stated. Minus sign indicates loss in weight, plus sign a gain in weight.

[2] Average of 3 specimens.

[3] Average of 2 specimens.

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Table 8.--Flammability tests on core materials

Core material	Average rate of burning	Remarks
	Inches per minute	
Balsa	30	Odor and flame characteristics of dry wood.
Cellular hard rubber	34	Burned with smoky, sputtering flame. Shrank but did not melt. Odor of burning rubber. Specimen remained intact after burning.
Cellular cellulose acetate	10	Burned with clean, sputtering flame. Shrank, melted, charred, and dripped. Very slight odor similar to burnt sugar. Specimen entirely consumed.

Table 7.--Density, preservative retention, and change in weight of balsa control specimens and those with 0.1 and 1.0 percent preservative

ONE MONTH'S EXPOSURE

Balsa control specimens

No.	Density	Specimen exposed to:	Fungus growth Coverage	Fungus growth Type[1]	Amount of visible decay	Change in weight[2]
	Lb. per cu. ft.		Percent			Percent
1R-1	6.79	Ster. agar	--	--	--	+0.83
1R-2	6.51	...do...	--	--	--	+.32
1R-3	7.28	...do.	--	--	--	+.89
1R-4	6.29	65% R.H.	--	--	--	-.56
1R-5	7.23	...do...	--	--	--	-.49
1	9.87	No. 106	100	L-M	Decayed in	-15.4
2	12.34	...do.	100	M	order	-21.9
3	12.50	...do.	100	M	of	-26.0
4	12.19	...do...	100	H	weight	-26.3
5	10.63	...do.	100	H	loss	-27.5
6	12.10	No. 563	100	L	Decayed	-17.1
7	12.72	...do...	100	L	...do...	-16.6
8	9.33	...do...	100	L	...do...	-12.9
9	12.25	...do...	100	L	...do...	-15.5
10	12.24	...do...	100	L	...do...	-25.2
11	10.26	No. 72074	100	L-M	Decayed	-20.2
12	12.54	...do...	100	L-M	...do...	-21.0
13	10.26	...do...	100	M	...do...	-22.1
14	12.43	...do...	100	M	...do...	-22.1
15	12.16	...do...	100	M	...do...	-20.9
16	6.56	Soil	--	--	Decay	-2.4
17	9.63	...do...	--	--	Most decay	-7.8
18	10.99	...do...	--	--	Decay	-4.2
19	13.05	...do.	--	--	...do...	-6.5
20	10.20	...do...	--	--	...do...	-5.9

Balsa specimens treated with 0.1 percent pentachlorophenol in acetone

No.	Density	Preservative retention	Specimen exposed to:	Fungus growth Coverage	Fungus growth Type	Amount of visible decay	Change in weight
	Lb. per cu. ft.	Lb. per cu. ft.		Percent			Percent
1R-6	6.87	0.0974	Ster. agar	--	--	--	-0.3
1R-7	6.58	.1151	...do...	--	--	--	-.7
1R-8	11.95	.1210	...do.	--	--	--	+.2
1R-9	9.18	.1062	65% R.H.	--	--	--	-.9
1R-10	10.65	.0620	...do...	--	--	--	-1.1
21	10.97	.0354	No. 106	5	L	None	-.03
22	9.27	.0856	...do...	5	L	None	+.3
23	11.24	.0354	...do...	5	L	1/4 in. pocket	-1.0
24	11.56	.0561	...do...	5	L	None	-.4
25	10.68	.0531	...do...	5-10	L	3 pockets	-4.9
26	9.33	.0856	No. 563	50	H	Decay	-5.9
27	12.21	.0649	...do...	80	H	pockets	-9.4
28	12.92	.0649	...do...	95	H	in	-11.9
29	11.80	.0708	...do...	60	H	all	-7.2
30	12.89	.0738	...do...	70	H		-7.6
31	13.60	.0767	No. 72074	65	H	Decay pockets	-12.8
32	13.04	.07[illegible]	...do...	40	H	...do...	-5.0
33	12.95	.0885	...do...	95	H	...do...	-14.8
34	9.24	.0679	...do...	0	--	None	-.13
35	9.03	.0856	...do...	60	H	Decay	-11.3
36	9.03	.0561	Soil	--	--	None	+.3
37	9.09	.0561	...do...	--	--	None	+.7
38	12.29	.0620	...do...	--	--	Soft spot	-1.1
39	13.17	.0767	...do...	--	--	None	-.4
40	12.95	.0856	...do...	--	--	None	-.09

Balsa specimens treated with 1.0 percent pentachlorophenol in acetone

No.	Density	Preservative retention	Specimen exposed to:	Fungus growth Coverage	Fungus growth Type	Amount of visible decay	Change in weight
	Lb. per cu. ft.	Lb. per cu. ft.		Percent			Percent
1R-11	7.46	0.0915	Ster. agar	--	--	--	0
1R-12	6.25	.1151	...do...	--	--	--	-0.3
1R-13	10.32	.1180	...do...	--	--	--	0
1R-14	6.90	.1180	65% R.H.	--	--	--	-1.3
1R-15	6.00	.1121	...do...	--	--	--	-1.4
41	12.45	.0856	No. 106	0	S	None	+.1
42	13.43	.0974	...do...	Trace	S	...do...	+.2
43	9.30	.1151	...do...	0	S	...do...	0
44	12.21	.1210	...do...	0	A	...do...	-.2
45	12.20	.1033	...do...	Trace	S	...do...	+.05
46	13.68	.0915	No. 563	5	H(A)	Small pockets	-3.0
47	10.62	.0325	...do...	3-5	[illegible]	...do...	-3.[illegible]
48	12.77	.0856	...do...	25	[illegible]	...do...	-4.0
49	10.80	.0502	...do...	40	H(A)	...do...	-4.8
50	10.58	.0236	...do...	35	H(A)	...do...	-6.5
51	12.30	.0944	No. 72074	Trace	L	Tiny pockets	-1.2
52	12.21	[illegible]	...do...	Trace	L	...do...	-1.3
53	14.68	[illegible]	...do...	0	--	...do...	+.06
54	13.07	[illegible]	...do...	10-15	H	...do...	-4.4
55	13.12	.0767	...do...	Trace	L	...do...	-1.0
56	12.32	.0649	Soil	--	--	None	+.02
57	10.62	.0502	...do...	--	--	...do...	-.7
58	12.88	.0915	...do...	--	--	...do...	+.02
59	10.74	.0354	...do.	--	--	...do...	-.08
60	13.42	.1003	...do.	--	--	...do...	+.02

TWO MONTHS' EXPOSURE

Balsa control specimens

No.	Density	Specimen exposed to:	Fungus growth Coverage	Fungus growth Type[1]	Amount of visible decay	Change in weight[2]
2R-1	7.05	Ster. agar	--	--	--	+0.33
2R-2	6.17	...do...	--	--	--	-.09
2R-3	6.82	...do...	--	--	--	+.13
2R-4	6.62	65% R.H.	--	--	--	-.96
2R-5	12.62	...do...	--	--	--	-1.06
121	12.91	No. 106	100	H	Decay	-24.7
122	11.86	...do...	100	H	...do...	-25.9
123	10.26	...do...	100	H	On 1 corner	-3.8
124	10.51	...do...	100	H	Decay	-31.1
125	14.84	...do...	100	H	Decay	-34.0
126	12.99	No. 563	100	H	Decayed	-24.9
127	9.33	...do...	100	H	...do...	-26.2
128	9.30	...do...	100	H	...do...	-24.1
129	12.68	...do...	100	H	...do...	-28.2
130	12.32	...do...	100	H	...do...	-29.5
131	12.57	No. 72074	100	H	Decayed	-34.7
132	12.96	...do...	100	H	...do...	-33.0
133	10.71	...do...	100	H	...do...	-35.4
134	12.24	...do...	100	H	...do...	-32.2
135	12.92	...do...	100	H	...do...	-36.2
136	9.32	Soil	--	--	Decayed	-11.5
137	8.95	...do...	--	--	...do...	-11.0
138	12.12	...do...	--	--	...do...	-10.1
139	10.65	...do...	--	--	...do...	-10.8
140	10.74	...do...	--	--	...do...	-7.8

Balsa specimens treated with 0.1 percent pentachlorophenol in acetone

No.	Density	Preservative retention	Specimen exposed to:	Fungus growth Coverage	Fungus growth Type	Amount of visible decay	Change in weight
2R-6	7.55	0.1003	Ster. agar	--	--	--	-0.9
2R-7	6.54	.0915	...do...	--	--	--	-.9
2R-8	11.01	.0885	...do...	--	--	--	-.5
2R-9	5.57	.0679	65% R.H.	--	--	--	+1.3
2R-10	6.93	.0649	...do...	--	--	--	-1.3
141	10.16	.0708	No. 106	2-3	H	None	-.6
142	9.03	.0620	...do...	Trace	H	...do...	-.4
143	8.93	.0738	...do...	10	H	...do...	-.7
144	10.78	.0620	...do...	2-3	H	...do...	-2.2
145	10.95	.0561	...do...	2-3	H	...do...	-1.0
146	10.72	.0561	No. 563	100	H	Decayed	-29.2
147	10.77	.0561	...do...	100	H	...do...	-30.3
148	11.80	.0613	...do...	100	H	...do...	-21.5
149	12.49	.0797	...do...	100	H	...do...	-27.9
150	10.67	[illegible]	...do...	100	H	...do...	-12.5
151	12.33	.0620	No. 72074	100	H	Decayed	-34.1
152	7.35	.0531	...do...	100	H	...do...	-33.6
153	14.37	.0649	...do...	100	H	...do...	-35.1
154	10.83	.0531	...do...	100	H	...do...	-40.0
155	9.33	.0767	...do...	40	H	Pockets	-6.8
156	12.60	[illegible]	Soil	--	--	Soft spots	-4.3
157	13.28	[illegible]	...do...	--	--	...do...	-6.0
158	12.54	[illegible]	...do...	--	--	...do...	-3.4
159	8.77	[illegible]	...do...	--	--	None	-.07
160	12.22	[illegible]	...do...	--	--	Soft spots	-2.7

Balsa specimens treated with 1.0 percent pentachlorophenol in acetone

No.	Density	Preservative retention	Specimen exposed to:	Fungus growth Coverage	Fungus growth Type	Amount of visible decay	Change in weight
2R-11	10.62	0.[illegible]	Ster. agar	--	--	--	-0.6
2R-12	[illegible]	.1151	...do...	--	--	--	-.8
2R-13	6.88	.0656	...do...	--	--	--	+.5
2R-14	7.02	.1180	65% R.H.	--	--	--	-1.3
2R-15	7.49	.1239	...do...	--	--	--	-1.5
161	13.37	.0665	No. 106	Trace	H	Many	-.7
162	12.96	.1062	...do...	Trace	H	...do...	-.7
163	10.87	[illegible]	...do...	Trace	H	...do...	-.8
164	[illegible]	.0590	...do...	Trace	H	...do...	-.8
165	12.46	.1062	...do...	Trace	H	...do...	-.9
166	11.24	.0620	No. 563	Trace	S	1 tiny pocket	-.9
167	14.66	.1269	...do...	Trace	S	1 corner soft	-1.1
168	12.90	.0665	...do...	30	A	Decayed	-8.9
169	10.70	.0561	...do...	60	S	...do...	-18.3
170	12.56	[illegible]	...do...	40	A	...do...	-21.9
171	11.90	[illegible]	No. 72074	0	S	None	-.7
172	12.32	[illegible]	...do...	10	L	Pockets	-11.2
173	13.31	.0649	...do...	100	H	Decayed	-32.7
174	9.02	.0974	...do...	0	A	None	-.8
175	12.95	.0856	...do...	70	H	Decayed	-28.0
176	10.57	.0472	Soil	--	--	None	-.6
177	12.31	.0620	...do...	--	--	1 corner soft	-1.4
178	11.81	.1326	...do...	--	--	None	+.07
179	13.31	.1151	...do...	--	--	...do...	-.5
180	14.42	.1534	...do...	--	--	...do...	-.9

THREE MONTHS' EXPOSURE

Balsa control specimens

No.	Density	Specimen exposed to:	Fungus growth Coverage	Fungus growth Type[1]	Amount of visible decay	Change in weight[2]
3R-1	7.53	Ster. agar	--	--	--	+.31
3R-2	12.57	...do...	--	--	--	-.36
3R-3	6.61	...do...	--	--	--	+.09
3R-4	6.83	65% R.H.	--	--	--	-.36
3R-5	12.21	...do...	--	--	--	-.44
241	13.35	No. 106	100	H	Decayed	-29.7
242	11.55	...do...	100	H	...do...	-31.8
243	13.16	...do...	100	H	...do...	-29.3
244	13.01	...do...	100	H	...do...	-35.4
245	12.35	...do...	100	H	...do...	-30.7
246	10.61	No. 563	100	H	Decayed	-32.5
247	12.69	...do...	100	H	...do...	-33.6
248	9.92	...do...	100	H	...do...	-42.0
249	12.28	...do...	100	H	...do...	-33.9
250	12.72	...do...	100	H	...do...	-33.1
251	11.10	No. 72074	98	L-M	Decayed	-43.9
252	9.12	...do...	100	L	...do...	-35.8
253	13.27	...do...	100	L	...do...	-44.6
254	9.50	...do...	100	M	...do...	-44.1
255	12.68	...do...	100	M	...do...	-44.8
256	11.69	Soil	--	--	Decayed	-24.9
257	12.60	...do...	--	--	...do...	-21.5
258	10.24	...do...	--	--	...do...	-17.9
259	10.39	...do...	--	--	...do...	-17.6
260	11.45	...do...	--	--	...do...	-15.7

Balsa specimens treated with 0.1 percent pentachlorophenol in acetone

No.	Density	Preservative retention	Specimen exposed to:	Fungus growth Coverage	Fungus growth Type	Amount of visible decay	Change in weight
3R-6	6.58	.0856	Ster. agar	--	--	--	-.9
3R-7	12.83	.0885	...do...	--	--	--	-.8
3R-8	10.51	.0590	...do...	--	--	--	-.6
3R-9	6.63	.0885	65% R.H.	--	--	--	-1.2
3R-10	9.57	.0885	...do...	--	--	--	-1.0
261	9.00	.0590	No. 106	2-3	H	None	+.7
262	14.60	.0649	...do...	98	H	Decay	-21.8
263	12.69	.0797	...do...	2-3	H	None	-1.8
264	11.98	.0826	...do...	2-3	H	None	-1.2
265	12.60	.0620	...do...	100	H	Decay	-43.6
266	10.65	.0354	No. 563	100	H-S	Decayed	-34.2
267	13.99	.0620	...do...	100	H-M	...do...	-33.3
268	11.89	.0915	...do...	100	H-M	...do...	-35.3
269	9.56	.0620	...do...	80	L-M	...do...	-31.7
270	10.15	.0295	...do...	80	L-M	...do...	-34.2
271	13.63	.0620	No. 72074	100	H	Decayed	-45.5
272	10.80	.0472	...do...	100	H	...do...	-42.7
273	10.80	.0325	...do...	90	H	...do...	-35.1
274	12.24	.0590	...do...	80	H	...do...	-40.5
275	13.66	.0708	...do...	80	H	...do...	-41.4
276	9.26	.0649	Soil	--	--	Decayed	-6.4
277	12.27	.0649	...do...	--	--	...do...	-17.3
278	8.91	.0620	...do...	--	--	...do...	-18.9
279	10.52	.0325	...do...	--	--	...do...	-20.4
280	9.29	.0649	...do...	--	--	...do...	-3.2

Balsa specimens treated with 1.0 percent pentachlorophenol in acetone

No.	Density	Preservative retention	Specimen exposed to:	Fungus growth Coverage	Fungus growth Type	Amount of visible decay	Change in weight
3R-11	6.32	.1416	Ster. agar	--	--	--	-1.0
3R-12	11.98	.1629	...do...	--	--	--	-.8
3R-13	6.09	.0856	...do...	--	--	--	-.3
3R-14	7.44	.1446	65% R.H.	--	--	--	-1.5
3R-15	12.55	.1121	...do...	--	--	--	-.5
281	11.89	.1770	No. 106	0	S	None	-.8
282	8.98	.1062	...do...	0	S	...do...	-.3
283	12.03	.1180	...do...	0	S	...do...	-.7
284	10.27	.0885	...do...	0	S	...do...	-.9
285	12.95	.0708	...do...	0	S	...do...	-.7
286	11.09	.0915	No. 563	50	H(A)	Decay	-22.7
287	11.12	.0944	...do...	60	H(A)	...do...	-45.9
288	6.92	.1326	...do...	Trace	S	None	-.6
289	10.23	.0649	...do...	30	H(A)	Decay	-17.2
290	10.36	.0797	...do...	30	H(A)	...do...	-18.3
291	13.13	.1239	No. 72074	2-3	H	None	-9.0
292	8.97	.1180	...do...	0	--	...do...	-.7
293	9.68	.1121	...do...	0	--	...do...	-.9
294	12.86	.0915	...do...	75	H	Decay	-30.7
295	12.99	.0708	...do...	75	H	...do...	-42.9
296	12.34	.1357	Soil	--	--	Decay	-1.4
297	10.61	.0502	...do...	--	--	...do...	-10.6
298	12.92	.0944	...do...	--	--	...do...	-40.5
299	11.99	.0767	...do...	--	--	...do...	-6.1
300	12.32	.1003	...do...	--	--	...do...	-.6

[1] L = light
M = medium
H = heavy
S = suppressed
A = atypical

[2] Based on conditioned weights at 65 percent relative humidity and 80° F. before and after exposure. Weight of preservative included where present. Minus sign indicates loss in weight, plus sign a gain in weight.

Z M 72596 F

Table 9.—Weight and dimensional changes of core materials exposed to various aircraft liquids

Core material[1]	Liquid	Average gain in weight[2]: After soaking for 7 days	Average gain in weight[2]: After soaking 7 days and conditioning for 7 days	Average gain in weight[2]: After soaking 7 days and conditioning for 39 days	Average gain in thickness[3]: After soaking for 7 days	Average gain in thickness[3]: After soaking 7 days and conditioning for 39 days	Average gain in width[3]: After soaking for 7 days	Average gain in width[3]: After soaking 7 days and conditioning for 39 days	Average gain in length[3]: After soaking for 7 days	Average gain in length[3]: After soaking 7 days and conditioning for 39 days
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Cellular hard rubber	Iso-propyl alcohol	29.45	0.22	0.15	0.14	-0.37	-0.17	-0.28	-0.03	-0.03
Balsa		181.96	2.01	2.00	0.13	-0.20	1.62	0.08	0.79	0.01
Cellular cellulose acetate		45.66	2.52	1.86	1.20	-0.33	0.53	-0.18	1.03	-0.54
Cellular hard rubber	Ethylene glycol	10.95	0.27	0.22	-0.34	-0.47	-0.21	-0.33	-0.06	-0.02
Balsa		219.20	125.11	14.30	0.39	0.23	3.34	1.79	2.15	1.14
Cellular cellulose acetate		54.34	5.22	3.31	0.86	-0.53	0.56	-0.48	1.00	-0.48
Cellular hard rubber	3580-Oleo fluid (petroleum base)	37.08	10.91	7.57	0.14	-0.17	-0.17	-0.03	-0.07	-0.09
Balsa		117.26	75.11	62.68	0.46	0.16	0.33	0.13	0.30	0.06
Cellular cellulose acetate		38.52	14.52	9.72	0.13	-0.36	0.03	-0.21	0.11	0.02
Cellular hard rubber	3586-Oleo fluid (castor-oil base)	45.22	18.42	17.46	-0.20	-0.27	-0.17	-0.09	-0.03	-0.02
Balsa		148.05	69.29	62.73	0.34	0.33	1.85	1.22	1.18	0.73
Cellular cellulose acetate		63.91	26.75	24.34	0.19	-0.36	0.46	-0.48	0.55	-0.54
Cellular hard rubber	100-octane gasoline	25.68	-0.09	-0.05	-0.07	0.00	-0.21	-0.17	0.02	-0.04
Balsa		159.98	0.00	0.48	-0.39	-0.29	-0.13	-0.15	-0.06	-0.06
Cellular cellulose acetate		28.92	0.17	0.40	0.26	-0.13	0.00	0.10	-0.18	-0.09
Cellular hard rubber	Used crankcase oil	28.62	22.93	19.47	-0.41	-0.68	-0.14	-0.23	-0.03	-0.06
Balsa		92.48	84.26	82.83	0.07	-0.26	0.00	-0.43	0.11	-0.03
Cellular cellulose acetate		34.48	28.50	23.55	-0.07	-0.40	0.13	-0.16	0.00	-0.01
Cellular hard rubber	Water	21.35	0.67	0.67	0.07	-0.58	0.07	-0.28	0.21	-0.01
Balsa		536.55	0.96	0.78	0.07	0.00	4.00	0.61	2.44	0.31
Cellular cellulose acetate		65.30	0.84	0.79	0.60	-0.73	0.89	-0.80	1.79	-0.67

[1] Dimensions of test specimens - thickness 1/2-inch, width 1 inch, length 3 inches. Balsa 1/2-inch dimension in grain direction (thickness).

[2] Based on weight of specimens, conditioned to equilibrium at 75° F., 50 percent relative humidity before immersion. Each value is the average for 3 specimens.

[3] Based on dimension of specimens, conditioned to equilibrium at 75° F., 50 percent relative humidity before immersion. Each value is the average for 3 specimens.

[4] Cellular cellulose acetate.

Z M 72597 F

Table 10.--Effect of water immersion on the weight, dimensions, and tensile strength of glue sandwich constructions

Sandwich construction: Core	Sandwich construction: Face	Edge condition	Conditioned to equilibrium with 75° F. and 65 percent relative humidity (controls): Tension: Strength	Tension: Material failure	Tension: Glue failure[2]	Immersed in water for 24 hours and tested immediately: Dimensional change[1]: Weight	Dimensional change[1]: Average of length and width	Dimensional change[1]: Thickness	Tension: Strength	Tension: Material failure	Tension: Glue failure[2]	Immersed in water for 40 days and tested immediately: Dimensional change[1]: Weight	Dimensional change[1]: Average of length and width	Dimensional change[1]: Thickness	Tension: Strength	Tension: Material failure	Tension: Glue failure[2]	Immersed in water for 40 days and conditioned to equilibrium with 75° F. and 65 percent relative humidity: Dimensional change[1]: Weight	Dimensional change[1]: Average of length and width	Dimensional change[1]: Thickness	Tension: Strength	Tension: Material failure	Tension: Glue failure[2]
			P.s.i.	Percent	Percent	Percent	Percent	Percent	P.s.i.	Percent	Percent	Percent	Percent	Percent	P.s.i.	Percent	Percent	Percent	Percent	Percent	P.s.i.	Percent	Percent
Balsa	Plywood	Unpainted	753.2	15	85	20.90	0.20	1.42	388.4	5.7	94.3	67.28	0.25	1.74	428.3	0	100	2.32	0.02	0.95	664.2	6.8	93.2
		Painted				12.63	.90	1.58				41.69	.23	1.82				3.00	.02	1.26			
Balsa	Aluminum	Unpainted	425.6	4.2	95.8	7.02	.14	.28	366.5	0	100	29.46	.17	-.10	457.2	0	100	-.64	.05	.28	521.1	0	100
		Painted				1.40	-.02	.00				5.52	.02	-.18				.84	.00	.37			
Balsa	Glass cloth	Unpainted	626.6	3.6	96.4	22.30	.10	.28	278.4	0	100	92.42	.10	-.10	132.5	0	100	.76	-.07	.28	312.8	0	100
		Painted				20.54	.07	-.10				76.60	.08	-.37				.36	-.10	.00			
Rubber	Plywood	Unpainted	256.5	100	0	16.05	.16	1.16	233.2	100	0	40.73	.22	1.54	261.6	100	0	.80	.01	.46	278.0	100	0
		Painted				12.38	.07	.70				40.94	.19	1.16				1.55	.01	.08			
Rubber	Aluminum	Unpainted	166.6	100	0	2.08	.00	-.46	164.4	100	0	5.74	.03	-.82	179.9	98.4	1.6	-.67	.06	-.18	162.2	81.3	18.7
		Painted				.51	-.02	-.28				2.44	.04	-.46				-.03	.04	.19			
Rubber	Glass cloth	Unpainted	174.2	90	10	1.68	.01	-.09	135.7	83.3	16.7	5.66	.06	-.18	113.0	15	85	-.40	-.05	.36	220.7	87.5	12.5
		Painted				.31	.00	.00				5.10	.07	-.18				.00	.06	.37			
Acetate	Plywood	Unpainted	253.9	98	2	19.14	.23	1.16	177.7	99.3	.7	54.26	.31	1.78	175.4	99.2	.8	-.19	-.01	-.70	281.1	100	0
		Painted				15.76	.17	1.56				53.82	.32	2.04				1.52	.03	-.46			
Acetate	Aluminum	Unpainted	240.2	37.5	62.5	3.07	.10	-.18	203.3	64.1	35.8	16.00	.14	-.36	95.3	26.3	73.7	-.66	.02	-1.39	259.0	69.2	30.8
		Painted				2.56	.04	-.18				18.02	.10	.19				-.15	-.03	-1.12			
Acetate	Glass cloth	Unpainted	242.5	96.4	3.6	4.78	.15	-.28	180.8	13.8	86.2	17.92	.14	.00	103.1	0	100	.31	-.10	-1.19	283.1	34.1	65.9
		Painted				3.82	.05	.29				16.00	.11	.20				.40	-.02	-.76			

[1] Based on dimensions and weights when in equilibrium with 75° F. and 65 percent relative humidity prior to exposure.

[2] No attempt was made to classify the type of glue line failure; that is, adhesive, cohesive, or failure between primary and secondary adhesive. Miscellaneous types of failures, such as failures between face and grip, were not recorded. Delamination in glass cloth faces was classified as glue line failure.

Z M 72544 F

Table 11.--Effect of high humidity on the weight, dimensions, and tensile strength of nine sandwich constructions

Sandwich construction: Core	Sandwich construction: Face	Edge condition	Conditioned to equilibrium with 75° F. and 65 percent relative humidity (controls): Tension: Strength	Material failure	Glue failure[2]	Conditioned to equilibrium with 80° F and 97 percent relative humidity: Dimensional change[1]: Weight	Average of length and width	Thickness	Tension: Strength	Material failure	Glue failure[2]	Conditioned to equilibrium with 80° F. and 97 percent relative humidity followed by conditioning to equilibrium with 75° F. and 65 percent relative humidity: Dimensional change[1]: Weight	Average of length and width	Thickness	Tension: Strength	Material failure	Glue failure[2]
			P.s.i.	Percent	Percent	Percent	Percent	Percent	P.s.i.	Percent	Percent	Percent	Percent	Percent	P.s.i.	Percent	Percent
Balsa	Plywood	Unpainted	753.2	15	85	11.50	0.15	1.67	633.4	0	100	0.72	-0.02	0.47	589.6	18.5	81.5
		Painted				17.42	.22	1.59				2.44	.07	.55			
Balsa	Aluminum	Unpainted	425.6	4.2	95.8	3.47	.16	-.09	355.2	20	80	-.39	.04	.27	387.2	25	75
		Painted				2.99	.01	.19				.37	.02	.46			
Balsa	Glass cloth	Unpainted	626.6	3.6	96.4	---	---	---	210.6	0	100	-.99	-.03	.27	446.8	0	100
		Painted				---	---	---				.27	-.02	.37			
Rubber	Plywood	Unpainted	256.5	100	0	9.30	.18	1.54	284.8	100	0	.80	-.01	.46	216.0	0	100
		Painted				9.16	.20	1.86				1.29	.03	1.31			
Rubber	Aluminum	Unpainted	166.6	100	0	.80	.05	-.28	154.6	98.3	1.7	.25	-.01	-.18	97.2	100	0
		Painted				.19	.10	.00				-.34	.05	.47			
Rubber	Glass cloth	Unpainted	174.2	90	10	3.11	.05	.66	101.7	23.4	76.6	.80	.01	.75	152.2	77	23
		Painted				2.21	.09	.55				.29	.20	.36			
Acetate	Plywood	Unpainted	253.9	98	2	10.10	.22	1.16	226.9	98	2	-.35	-.04	-.39	245.1	100	0
		Painted				11.40	.21	2.03				1.04	-.02	-.08			
Acetate	Aluminum	Unpainted	240.2	37.5	62.5	2.32	.06	-.81	50.7	10	90	-1.02	-.01	-1.89	147.2	0	100
		Painted				2.15	.09	.85				.40	.03	-.56			
Acetate	Glass cloth	Unpainted	242.5	96.4	3.6	3.41	.06	.47	67.3	5	95	.50	-.05	-.19	202.9	19.3	80.7
		Painted				3.39	.08	.92				.46	-.01	.18			

[1] Based on dimensions and weights when in equilibrium with 75° F. and 65 percent relative humidity prior to exposure.

[2] No attempt was made to classify the type of glue line failure; that is, adhesive, cohesive, or failure between primary and secondary adhesive. 100 percent - (percent core + percent glue line failure) = miscellaneous types of failures, such as failures between face and grip or delamination of face.

Z M 72045 F

Table 12.--Effect of high temperature (200° F.) on the weight, dimensions, and tensile strength of nine sandwich constructions

Sandwich construction		Edge condition	Conditioned to equilibrium with 75° F. and 65 percent relative humidity (controls)			Heated continuously for 240 hours at 200° F. dry heat						Heated continuously for 240 hours at 200° F. dry heat and conditioned to equilibrium with 75° F. and 65 percent relative humidity					
			Tension			Dimensional change[1]			Tension			Dimensional change[1]			Tension		
Core	Face		Strength	Material failure	Glue failure[2]	Weight	Average of length and width	Thickness	Strength	Material failure	Glue failure[2]	Weight	Average of length and width	Thickness	Strength	Material failure	Glue failure[2]
			P.s.i.	Percent	Percent	Percent	Percent	Percent	P.s.i.	Percent	Percent	Percent	Percent	Percent	P.s.i.	Percent	Percent
Balsa	Plywood	Unpainted	753.2	15	85	-7.08	-0.25	-1.33	332.7	14	86	0.43	0.01	-0.32	479.4	10.8	89.2
		Painted				-5.98	-.18	-1.10				.82	-.37	.16			
Balsa	Aluminum	Unpainted	425.6	4.2	95.8	-5.11	.03	-.76	996.7	0	100	-1.87	.04	-.66	791.2	2.5	97.5
		Painted				-4.24	.07	-1.22				-2.40	.06	-.10			
Balsa	Glass cloth	Unpainted	626.6	3.6	96.4	-3.69	-.13	-.28	267.3	1.2	98.8	.30	-.02	.09	514.2	0	100
		Painted				—	.09	-.18				.00	-.01	.37			
Rubber	Plywood	Unpainted	256.5	100	0	-6.92	-.15	.77	93.8	92.1	7.9	-.93	.15	2.08	187.8	100	0
		Painted				-6.16	.11	2.01				-.22	.26	3.16			
Rubber	Aluminum	Unpainted	166.6	100	0	-4.02	.08	4.86	127.2	96.6	3.4	-3.00	.04	5.51	257.4	96.6	3.4
		Painted				-3.32	.30	6.14				-2.68	.22	7.72			
Rubber	Glass cloth	Unpainted	174.2	90	10	-1.44	-.03	2.16	93.0	58.3	41.7	.08	.02	1.69	146.3	49.1	50.9
		Painted				-2.00	.34	-.45				-.37	.34	-.36			
Acetate	Plywood	Unpainted	253.9	98	2	-8.96	-.29	-2.80	218.2	100	0	-1.68	-.02	-.86	207.5	100	0
		Painted				-7.14	-.25	-2.66				-.10	.02	-.78			
Acetate	Aluminum	Unpainted	240.2	37.5	62.5	-3.16	.05	-2.64	260.4	67.5	32.5	-.69	.03	-1.55	257.7	100	0
		Painted				-3.89	.07	-2.11				-1.19	.09	-1.19			
Acetate	Glass cloth	Unpainted	242.5	96.4	3.6	-2.68	-.08	-.86	142.0	15	85	.22	-.05	-.47	132.1	41.4	58.6
		Painted				-3.19	-.01	-.92				-.13	.05	.00			

[1] Based on dimensions and weights when in equilibrium with 75° F. and 65 percent relative humidity prior to exposure.

[2] No attempt was made to classify the type of glue line failure, that is, adhesive, cohesive, or failure between primary and secondary adhesive. 100 percent - (percent core failure + percent glue line failure) = miscellaneous types of failures such as failure between face and grip, or delamination of face.

Z M 72546 F

Table 13.--Effect of 1, 5, and 10 cycles[1] of exposure to high and low temperatures and humidities on the weight, dimensions, and tensile strength of nine sandwich constructions

Sandwich construction		Edge condition	Conditioned to equilibrium with 75° F. and 65 percent relative humidity (controls)			After 1 cycle followed by conditioning to equilibrium with 75° F. and 65 percent relative humidity						After 5 cycles followed by conditioning to equilibrium with 75° F. and 65 percent relative humidity						After 10 cycles followed by conditioning to equilibrium with 75° F. and 65 percent relative humidity					
			Tension			Dimensional change[2]			Tension			Dimensional change[2]			Tension			Dimensional change[2]			Tension		
Core	Face		Strength	Material failure	Glue failure[3]	Weight	Average of length and width	Thickness	Strength	Material failure	Glue failure[3]	Weight	Average of length and width	Thickness	Strength	Material failure	Glue failure[3]	Weight	Average of length and width	Thickness	Strength	Material failure	Glue failure[3]
			P.s.i.	Percent	Percent	Percent	Percent	Percent	P.s.i.	Percent	Percent	Percent	Percent	Percent	P.s.i.	Percent	Percent	Percent	Percent	Percent	P.s.i.	Percent	Percent
Balsa	Plywood	Unpainted	753.9	15	85	0.76	0.03	0.08	675.0	27.8	72.2	0.13	-0.02	0.00	450.2	95.2	3.8	0.22	-0.02	0.16	413.5	4.5	94.5
		Painted				1.52	.04	.48				.40	.04	.16				.30	.02	.24			
Balsa	Aluminum	Unpainted	425.6	4.2	95.8	-1.39	.02	-.28	596.3	20	80	-2.06	-.01	-.10	563.4	5	95	-2.20	.05	-.10	871.2	33.1	66.9
		Painted				-.74	.03	.18				-1.59	.02	-.18				-2.12	.07	.19			
Balsa	Glass cloth	Unpainted	626.6	3.6	96.4	.34	-.03	.10	465.2	3.3	96.7	-.36	-.02	.18	456.8	4.1	95.9	-1.18	.03	.10	424.8	27.2	72.8
		Painted				-.07	-.02	.18				-.60	.01	-.09				-1.64	.04	-.18			
Rubber	Plywood	Unpainted	256.5	100	0	-.26	.17	3.32	147.0	92.8	7.2	-1.26	.09	3.41	121.2	54.2	45.8	-1.60	-.01	1.56	210.2	100	0
		Painted				.48	.23	3.26				-.70	.30	1.16				-.75	.19	2.86			
Rubber	Aluminum	Unpainted	166.6	100	0	-.52	.28	11.60	116.5	83.3	16.7	-2.40	.03	4.06	209.4	100	0	-2.80	.04	8.25	238.1	100	0
		Painted				-.60	.21	3.19				-2.63	.48	4.94				-2.90	.34	3.46			
Rubber	Glass cloth	Unpainted	174.2	90	10	.75	.04	1.69	147.5	60.8	39.2	.57	.08	2.76	46.2	2.5	97.5	.06	.13	1.10	106.8	7.5	92.5
		Painted				.30	.21	.64				-.10	.34	2.58				-.88	.32	9.19			
Acetate	Plywood	Unpainted	253.9	98	2	-1.08	-.05	-.08	243.4	100	0	-2.36	-.07	-.96	225.3	97.1	2.9	-2.63	-.10	-1.01	239.1	96.7	3.3
		Painted				-.14	.04	.08				-.92	-.01	-.62				-1.36	-.08	-.70			
Acetate	Aluminum	Unpainted	240.2	37.5	62.5	-.83	.01	-1.46	204.3	71.6	28.4	-1.73	.01	-2.47	226.9	100	0	-1.58	.04	-2.22	288.7	100	0
		Painted				-.77	.04	-.28				-.90	-.01	-.46				-.93	.04	-.46			
Acetate	Glass cloth	Unpainted	242.5	96.4	3.6	.24	-.01	-.10	233.5	52.1	47.9	.27	-.01	-.36	82.7	2.8	97.2	.04	.04	.10	115.9	2	98
		Painted				.24	.05	.09				.08	.07	.00				-.18	.18	-.08			

[1] One cycle consisted of the following consecutive treatments: 24 hours at 175° F. and 75 percent relative humidity, 24 hours at -20° F., 24 hours at 175° F., and 24 hours at -20° F.

[2] Based on dimensions and weights when in equilibrium with 75° F. and 65 percent relative humidity prior to exposure.

[3] No attempt was made to classify the type of glue line failure; that is, adhesive, cohesive, or failure between primary and secondary adhesive. 100 percent (percent core failure + percent glue line failure) = miscellaneous types of failures, such as failure between face and grip or delamination of face.

Table 14.--Effect of weathering on the weight and dimensions of nine sandwich constructions

Sandwich construction		Edge condition	After 4 months			After 8 months			After 12 months		
			Dimensional change[1]			Dimensional change[1]			Dimensional change[1]		
Core	Face		Weight	Average of length and width	Thickness	Weight	Average of length and width	Thickness	Weight	Average of length and width	Thickness
			Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Balsa	Plywood	Unpainted	-3.54	-0.31	-0.56	3.82	0.04	0.56	-4.38	-0.15	-0.48
		Painted	-2.61	-.15	-.56	3.74	.08	.48	-3.48	-.07	-.40
Balsa	Aluminum	Unpainted	-1.16	-.23	-.28	1.40	.00	.09	-1.50	-.09	.27
		Painted	-.40	-.01	-.18	.12	.04	.28	-.05	-.03	.65
Balsa	Glass cloth	Unpainted	-.45	-.30	-.56	4.26	-.12	-.18	-.66	-.23	.00
		Painted	-7.00	-.12	-.18	6.14	.02	.18	-.02	-.10	.21
Rubber	Plywood	Unpainted	-4.04	-.19	-.93	1.56	.04	.00	-4.80	-.13	-.70
		Painted	-2.70	-.13	-.46	1.64	.16	.39	-3.30	.01	.08
Rubber	Aluminum	Unpainted	-.50	-.06	-.09	-.58	.01	.28	-.32	.07	.56
		Painted	-.74	-.02	-.18	-.71	.03	.28	-.33	.07	.37
Rubber	Glass cloth	Unpainted	-.28	-.13	-.28	.17	.01	.00	-.11	-.04	.38
		Painted	-.65	-.05	-.09	-.09	.11	.18	2.30	.10	.55
Acetate	Plywood	Unpainted	-8.14	-.46	-1.16	1.48	-.02	.00	-6.32	-.32	-1.16
		Painted	-3.34	-.21	-1.01	2.56	.07	.08	-4.38	-.18	-.97
Acetate	Aluminum	Unpainted	-1.14	-.28	-1.22	3.28	.02	-.56	.40	-.06	-1.88
		Painted	-.78	-.15	-.18	.89	-.02	.28	-.42	-.10	-.37
Acetate	Glass cloth	Unpainted	-.63	-.32	-.64	1.02	-.04	-.18	.99	-.12	-.28
		Painted	-.92	-.10	-.46	1.00	.12	-.09	-.87	.05	-.09

[1] Based on dimensions and weights when in equilibrium with 75° F. and 65 percent relative humidity prior to exposure.

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Table 15.--The condition of nine sandwich constructions after weathering

Sandwich construction		Edge condition	After 4 months			After 8 months			After 12 months		
Core	Faces		End coat condition	Glue joint integrity	General appearance	End coat condition	Glue joint integrity	General appearance	End coat condition	Glue joint integrity	General appearance
Balsa	Plywood	Unpainted	--	Good	Good	--	Good	Plywood checked	--	Good	Plywood checked
		Painted	Good	Good	Good	Good	Good	Plywood checked	Good	Good	Plywood checked
Balsa	Aluminum	Unpainted	--	Good	Good	--	Good	Good	--	Good	Good
		Painted	Good	Good	Good	Good	Good	Good	Good	Good	Good
Balsa	Glass cloth	Unpainted	--	Good	Good	--	Good	Glass cloth faded	--	Fair	Glass cloth faded, core checked
		Painted	Good	Good	Good	Good	Good	Glass cloth faded	Good	Fair	Glass cloth faded
Rubber	Plywood	Unpainted	--	Good	Good	--	Good	Good	--	Good	Plywood checked, plastic deformation
		Painted	Fair	Good	Good	Fair	Good	Good	Fair	Good	Plywood checked
Rubber	Aluminum	Unpainted	--	Good	Good	--	Good	Good	--	Good	Good
		Painted	Fair	Good	Good	Fair	Good	Good	Fair	Good	Good
Rubber	Glass cloth	Unpainted	--	Good	Plastic deformation	--	Good	Glass cloth faded	--	Fair	Glass cloth faded, plastic deformation
		Painted	Fair	Good	Good	Fair	Good	Glass cloth faded	Fair	Good	Glass cloth faded, plastic deformation
Acetate	Plywood	Unpainted	--	Good	Plastic deformation	--	Good	Plywood checked	--	Good	Plywood checked, plastic deformation, core shrinkage
		Painted	Fair	Good	Good	Fair	Good	Plywood checked	Fair	Good	Plywood checked
Acetate	Aluminum	Unpainted	--	Good	Good	--	Fair	Good	--	Fair	Plastic deformation, core shrinkage
		Painted	Fair	Good	Good	Fair	Good		Fair	Good	Good
Acetate	Glass cloth	Unpainted	--	Good	Plastic deformation	--	Good	Plastic deformation	--	Good	Plastic deformation, glass cloth faded
		Painted	Fair	Good	Good	Fair	Good	Plastic deformation	Fair	Good	Plastic deformation, glass cloth faded

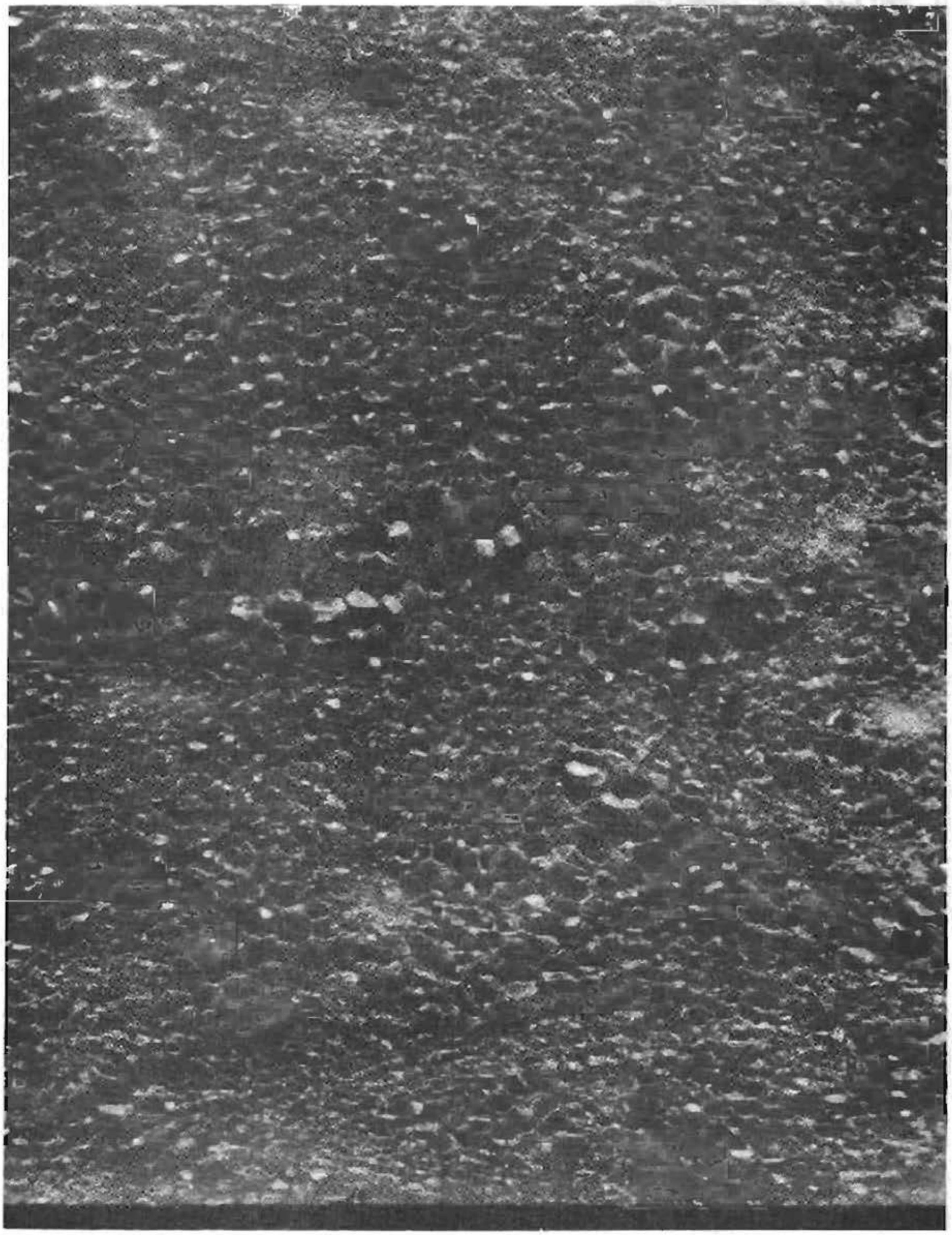

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Figure 3.--Table saw set-up for cutting end-grain balsa core stock.

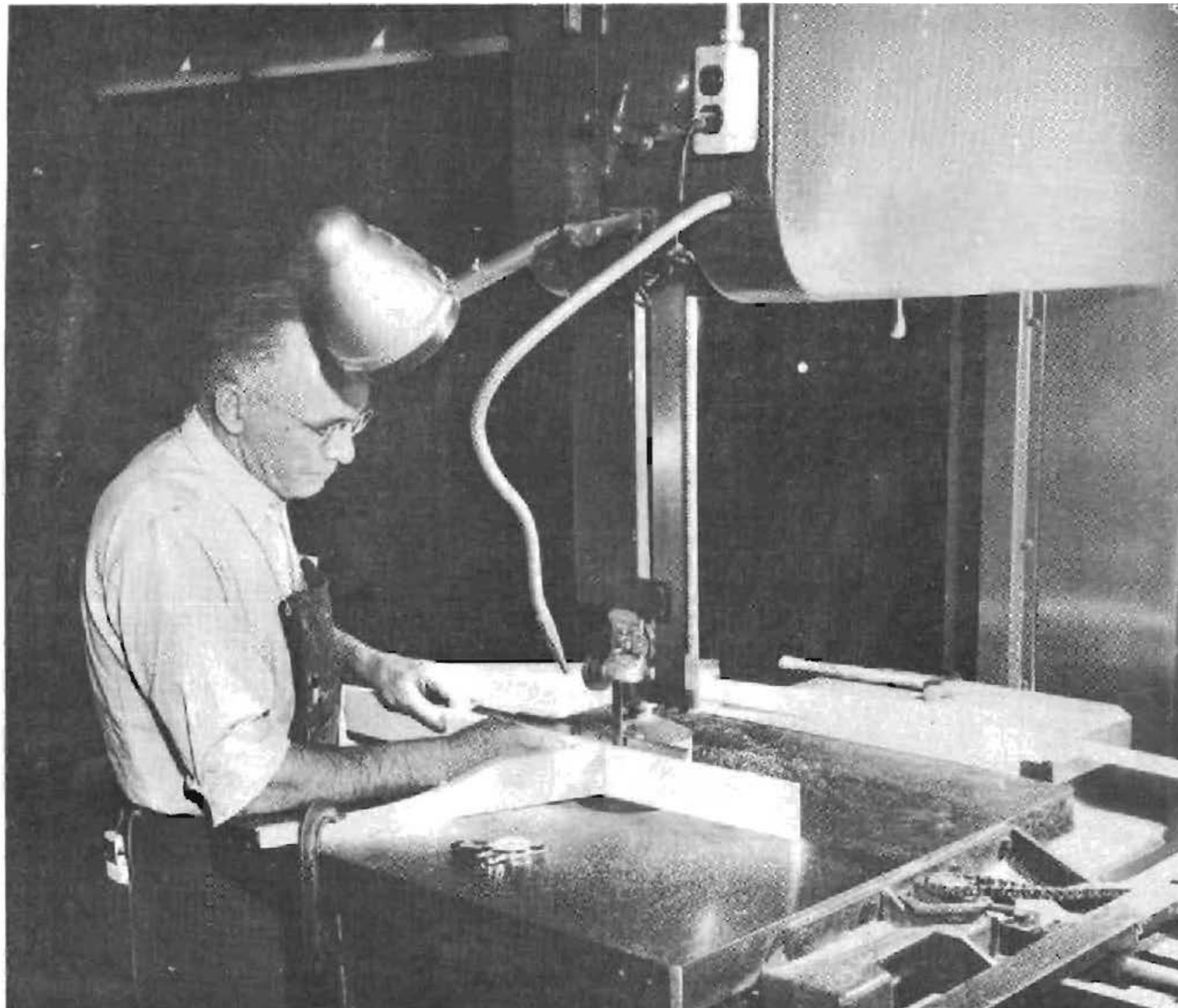

Figure 4.--Band saw set-up for cutting cellular cellulose acetate to proper thickness after skin is removed.

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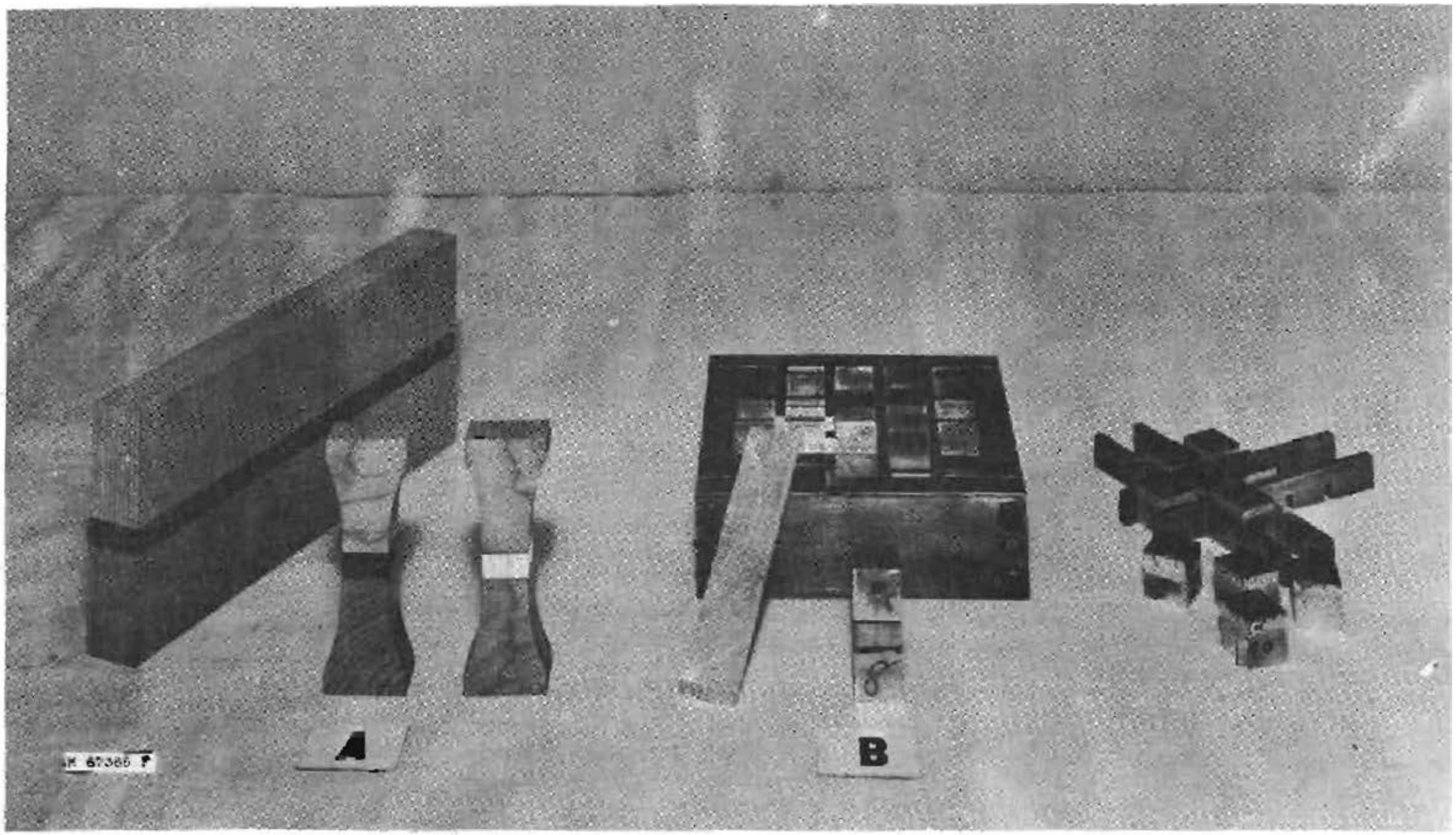

Figure 5.——A Tension test specimens used in tests on cellular hard rubber (black) and cellular cellulose acetate (white).

B - Tension test specimen used in tests on end–grain balsa and jig for preparing specimens.

Z M 73494 F

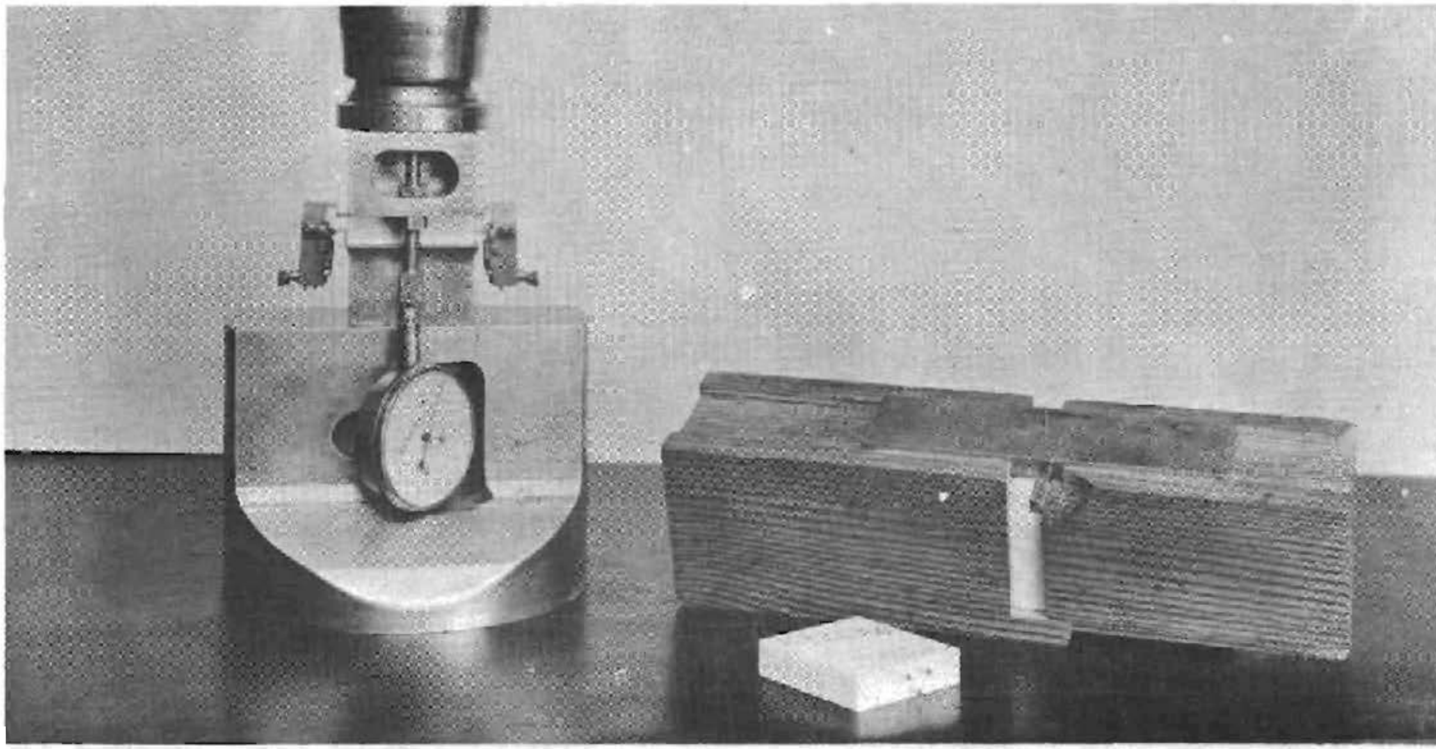

Figure 6.--Typical test arrangement for compression flatwise tests and device for alining the brads for the gages.

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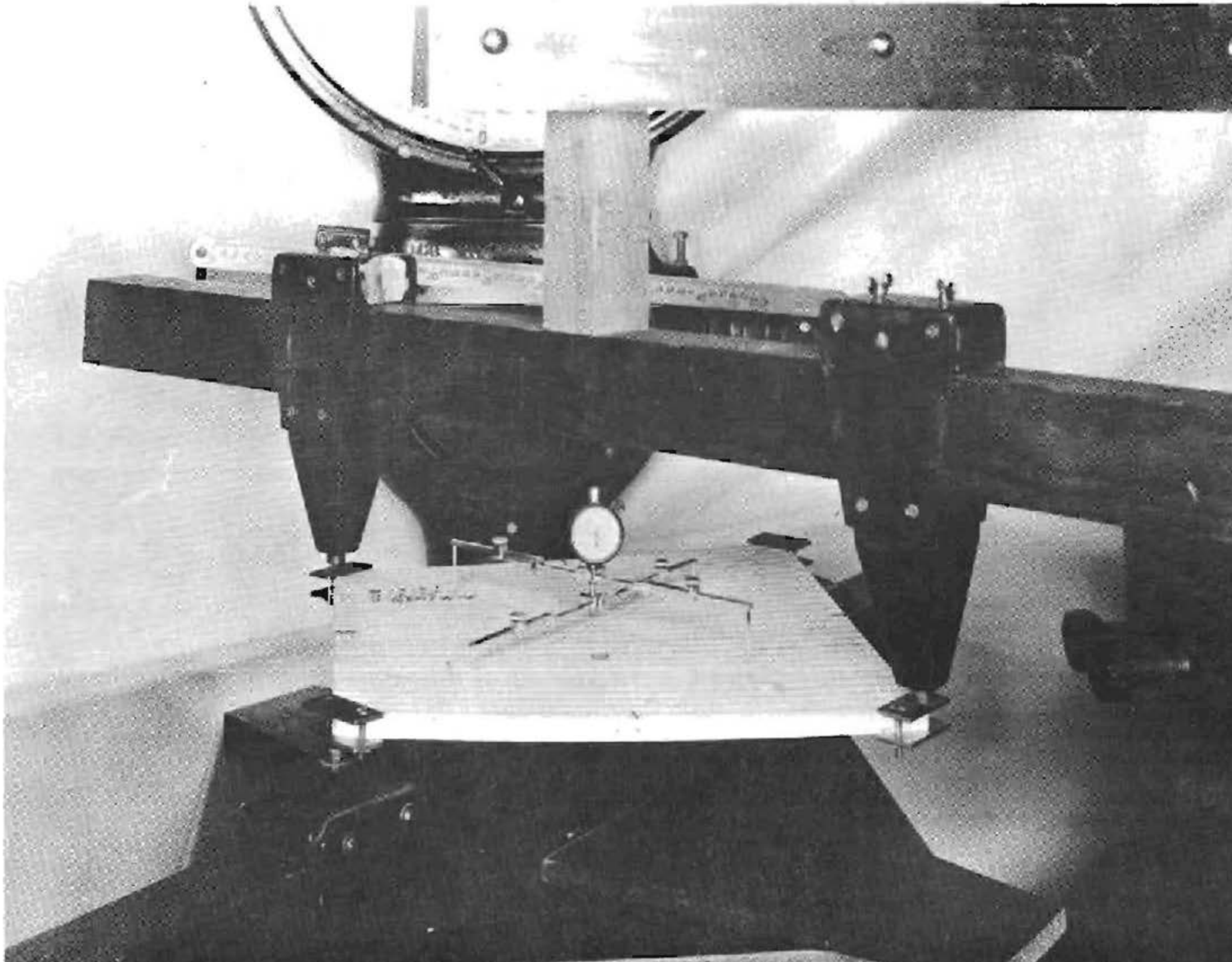

Z M 73496 F Figure 7.--General view of plate shear test specimen assembled for test.

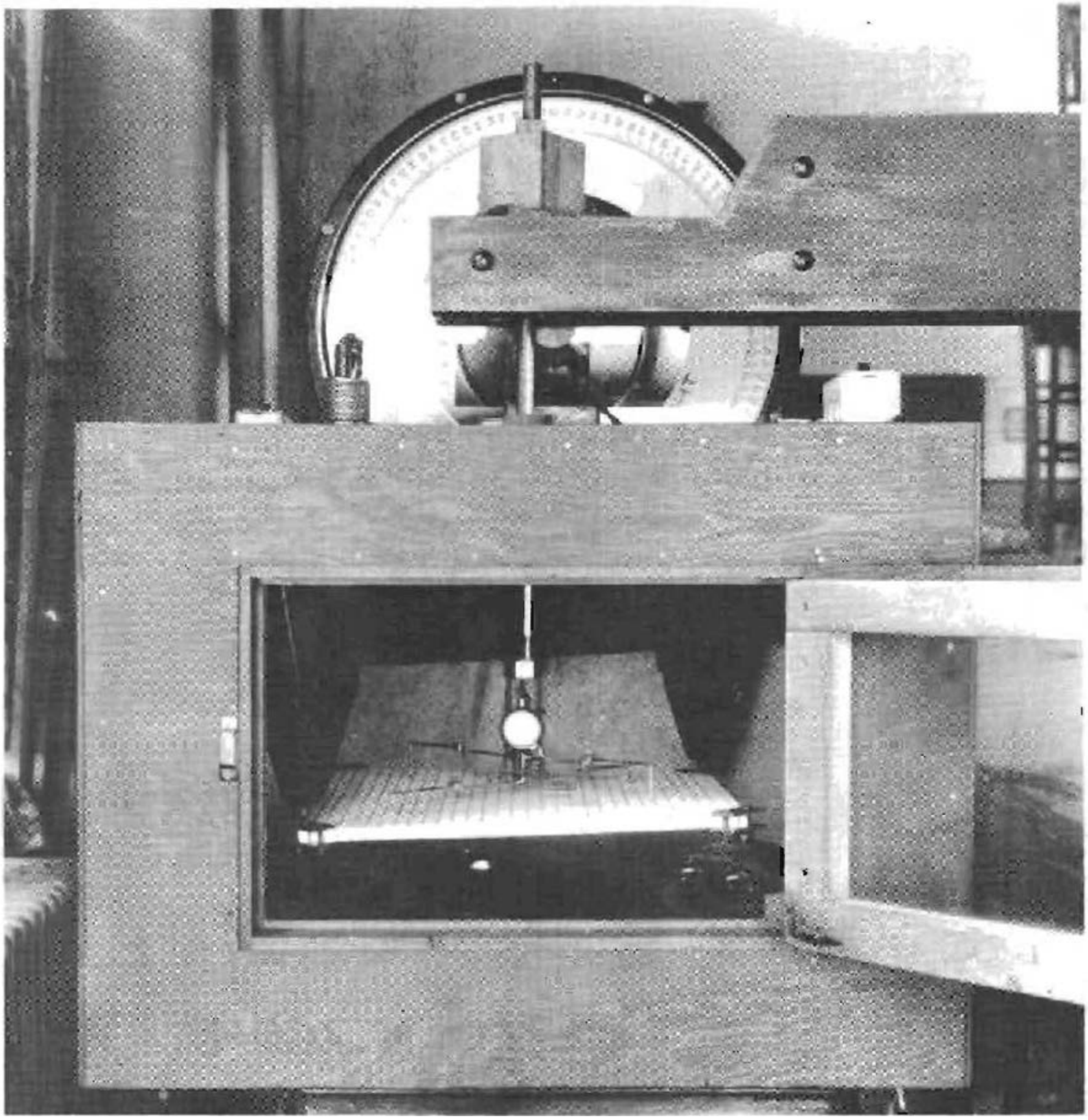

Figure 8.--Large insulated, heated box used in making tests at high temperature. Plate shear specimen assembled in place.

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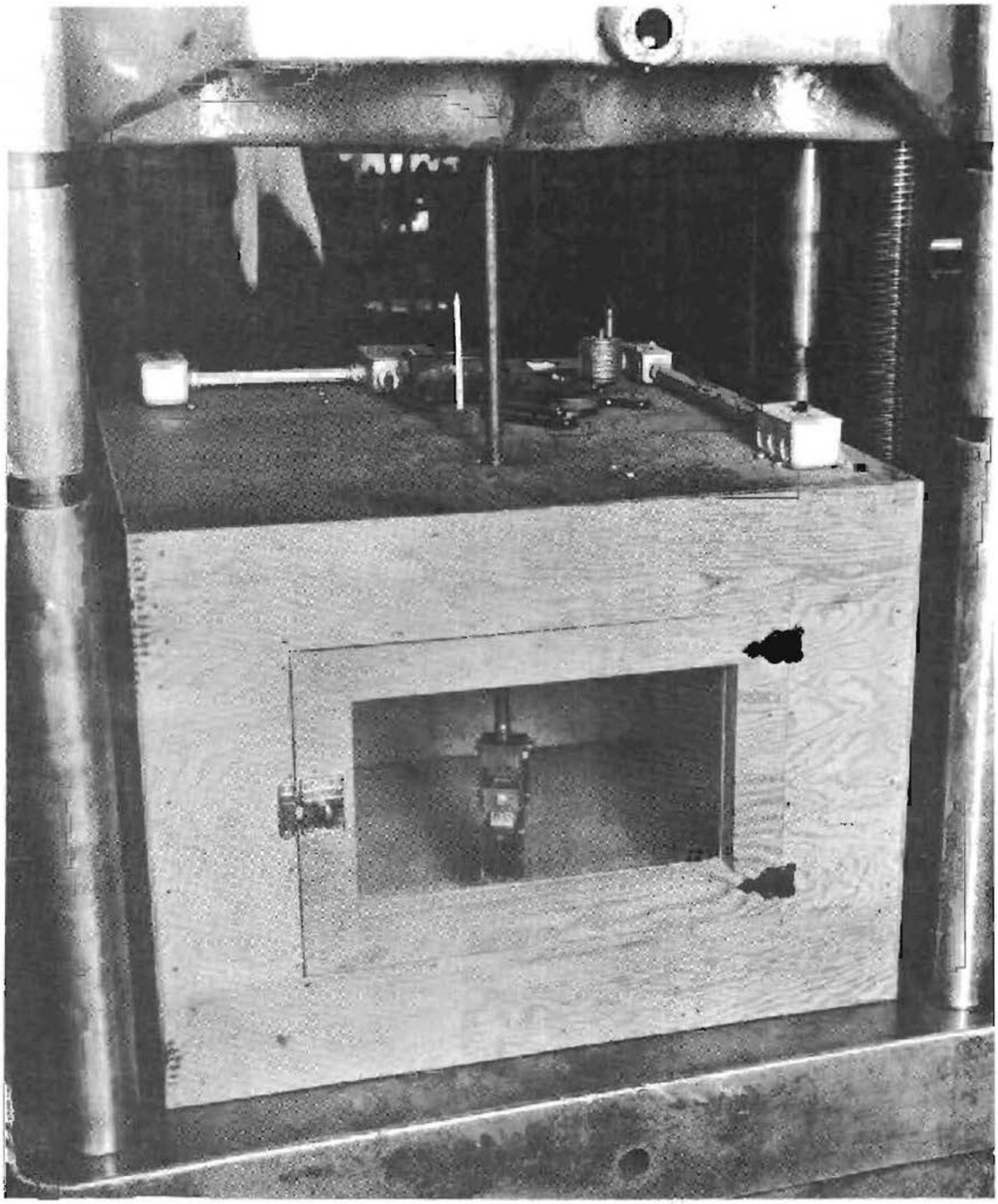

Figure 9.--Large insulated, heated box used in making tests at high temperature. Balsa tension specimen shown in place.

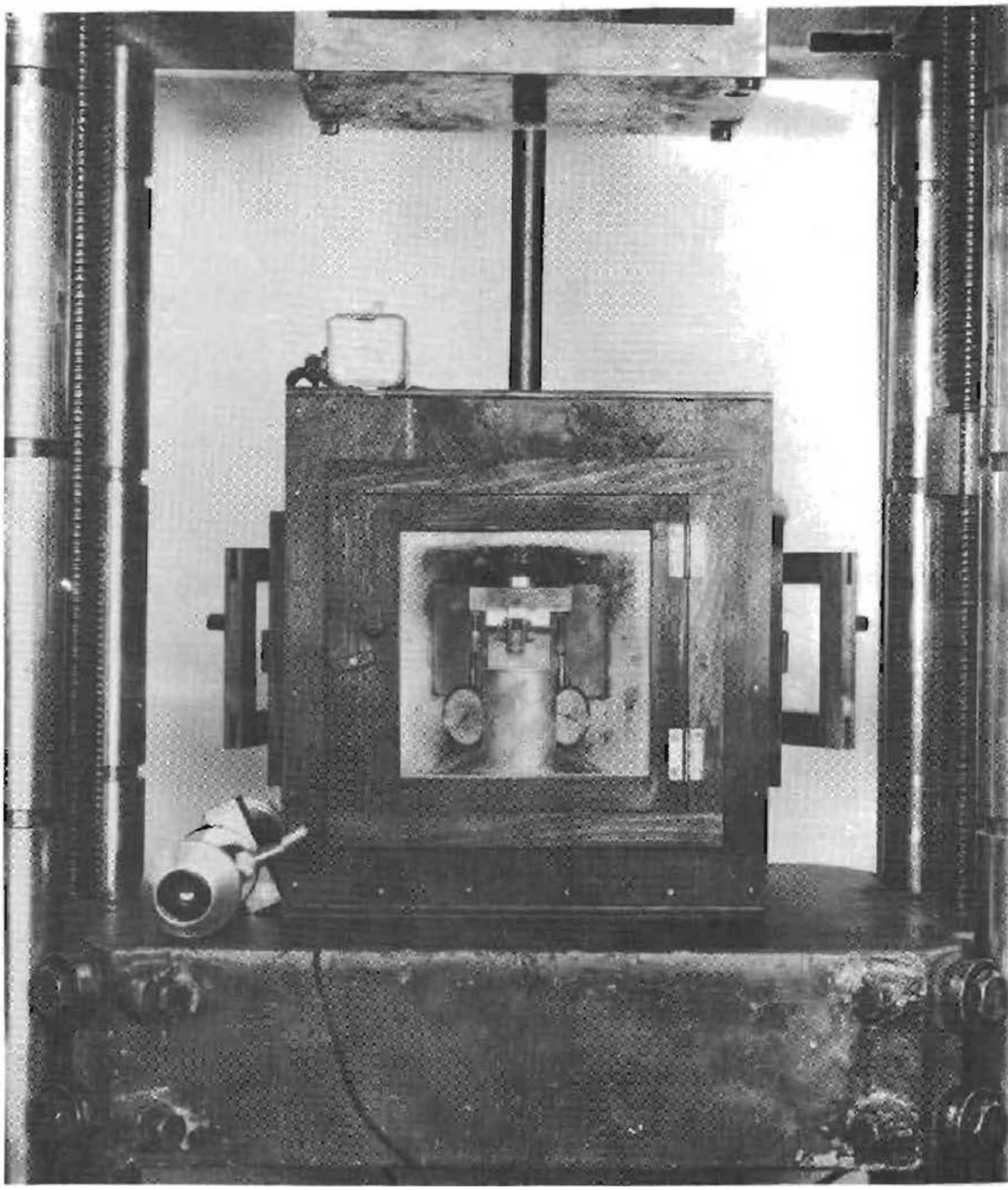

Figure 10.--Small insulated, heated box used in compression tests at elevated temperature.

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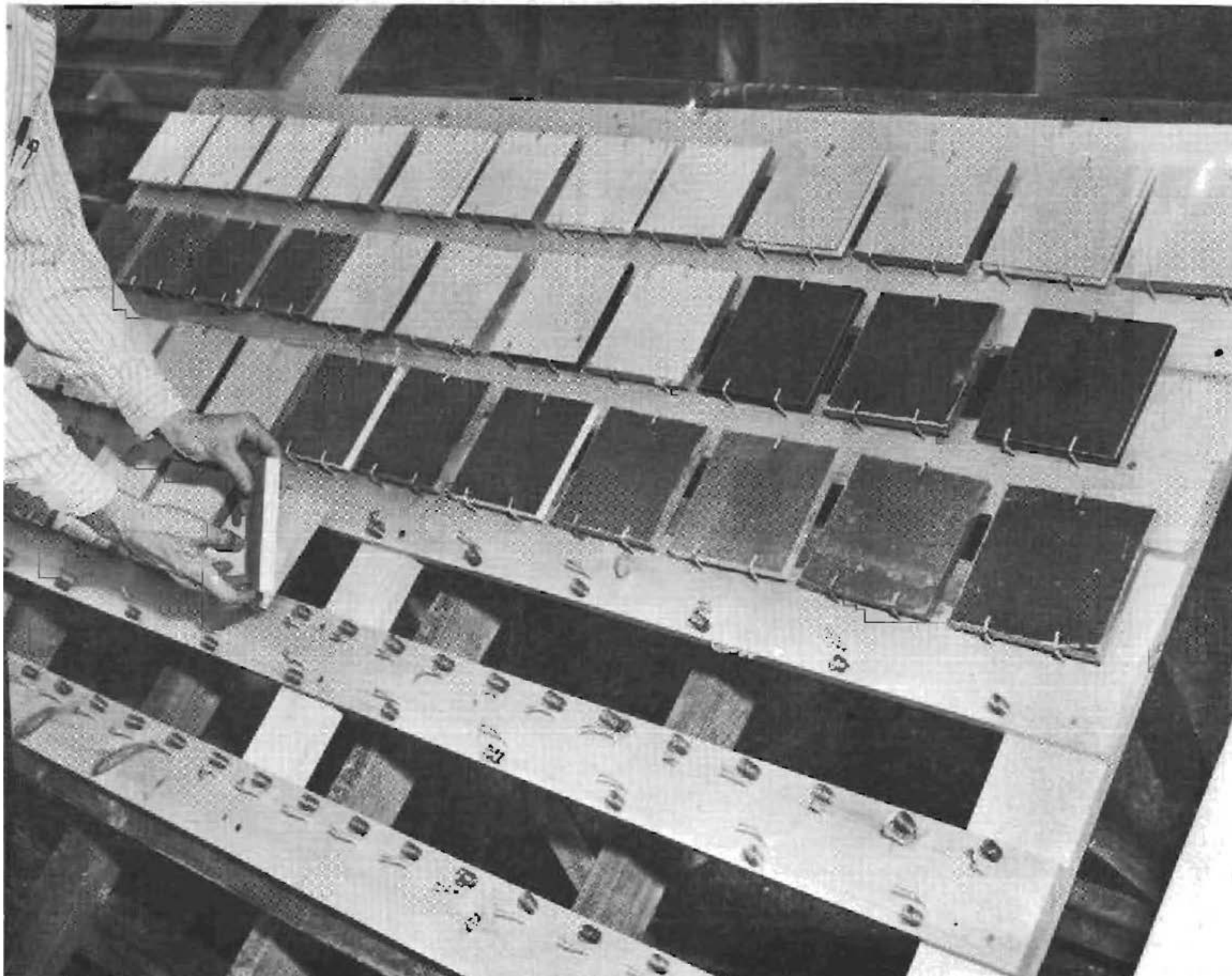

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Figure 11.--Racks used for mounting sandwich panels for exposure to weather showing the method of attaching specimens.

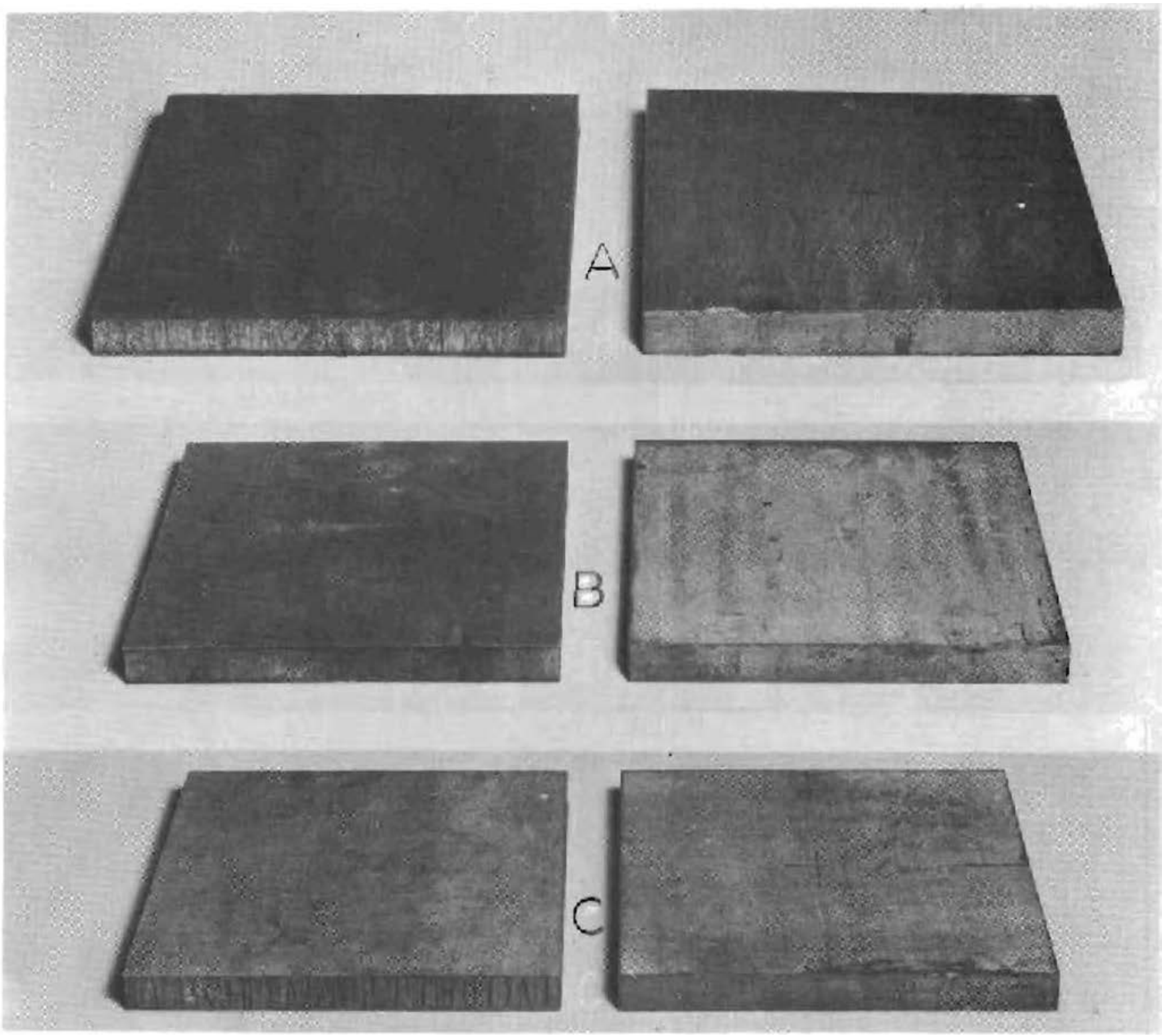

Figure 12.--Effect of 1 year's exposure to the weather on sandwich panels having balsa cores. Panels on left show weathered faces and unpainted edges, and those on right show unexposed faces (bottom) and painted edges.

A. Panels with birch plywood faces.

B. Panels with aluminum faces.

C. Panels with glass cloth faces.

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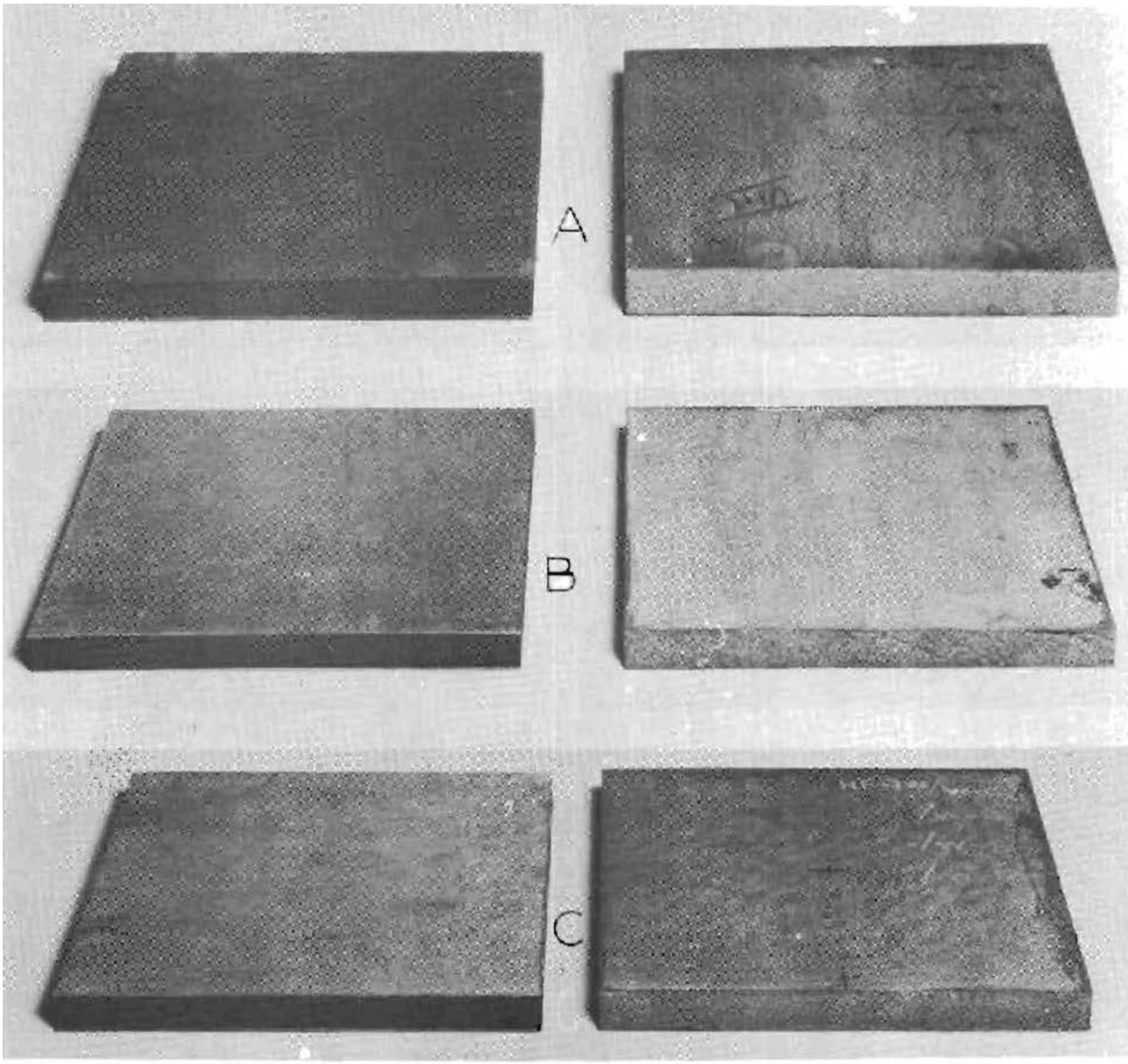

Figure 13.--Effect of 1 year's exposure to the weather on sandwich panels having cellular hard rubber cores. Panels on left show weathered faces and unpainted edges, and those on right show unexposed faces (bottom) and painted edges.

A. Panels with birch plywood faces.
B. Panels with Alclad faces.
ZM 73502 F C. Panels with glass cloth faces.

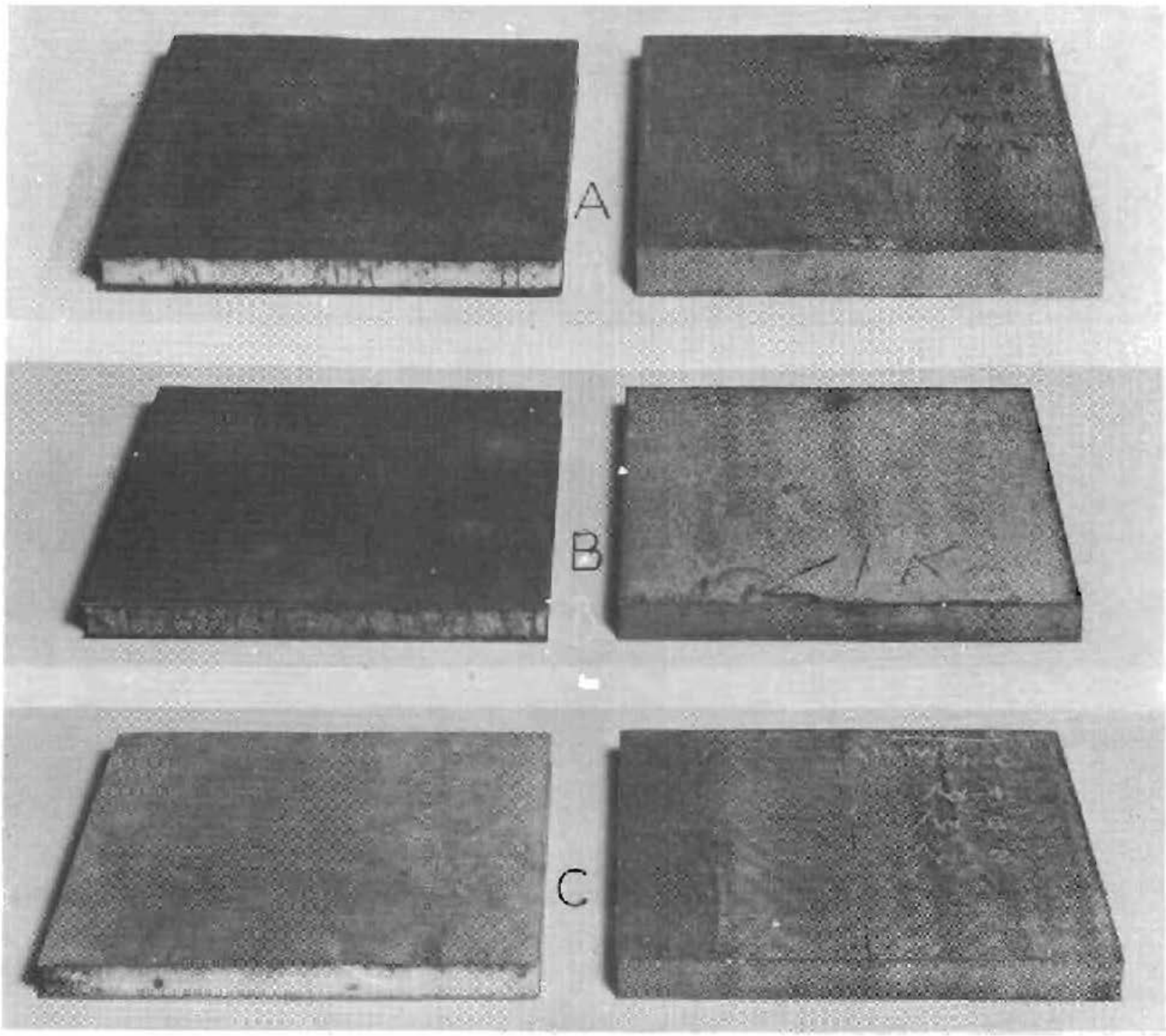

Figure 14.--Effect of 1 year's exposure to the weather on sandwich panels with acetate cores. Panels on left show weathered faces and unpainted edges, and those on right showing unexposed faces (bottom) and painted edges.

A. Panels with birch plywood faces.
B. Panels with Alclad faces.
C. Panels with glass cloth faces.

Z M 73503 F