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[2]

Part III

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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 increasing application of sandwich-type construction in high-speed aircraft, The work was done at the Forest Products Laboratory under the joint direction of the Air Materiel Command, U. S. Air Force; the Bureau of Aeronautics, Navy Department; and the Civil Aeronautics Authority.

The results of various tests on four honeycomb core materials constructed of paper, cotton cloth, glass cloth, and aluminum foil, and combinations of these four cores with three facing materials, aluminum, resin-treated glass cloth, and plywood, are presented in this report. Results of similar tests on three core materials, balsa, cellular cellulose acetate,

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[1]This progress report is one of a series prepared and distributed by the Forest Products Laboratory under U. S. Navy, Bureau of Aeronautics No. NBA-PO-NAer 00619, Amendment No. 2, and U. S. Air Force No. USAF–PO–(33-038) 49-4696E. Results here reported are preliminary and may be revised as additional data become available.

[2]This report covers the third part of a continuing study, the first and second parts of which were covered in Forest Products Laboratory Reports Nos. 1573 and 1573-A of the same title.

[3]Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.

and cellular hard rubber, and the nine combinations of these three cores with the above three facing materials, are presented in Part I (Report No. 1573). Specimens of the same core and facing materials as in Part I, but involving different adhesives and resins, were tested and reported in Part II (Report No. 1573-A).

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

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

The sandwich combinations were subjected to the following exposures:

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

SECTION A - TESTS ON CORE MATERIALS

Summary

Resin-impregnated paper, glass-cloth, and cotton-cloth honeycomb and, at a later date, aluminum foil honeycomb cores, 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) (E) conditioned to equilibrium at a relative humidity of 97 percent and a temperature of 80° F., and (b) treatment 2a followed by reconditioning at 75° F. and 65 percent relative humidity; (3) (a) heated for 240 hours at a temperature of 200° F., and (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); (5) exposures favoring decay; (6) flame tests; and (7) aircraft liquids.

The compressive strength of nominal 2- by 2- by 6-inch specimens of all four core materials, when loaded in the direction of the axis of the cells, was adversely affected by the water and high humidity treatment. The paper-honeycomb-core specimens retained less than half' their control strength following these exposures and exhibited the least resistance to moisture of any of tho cores tested. The strength of the-glass cloth, cotton-cloth, and aluminum honeycomb core specimens was reduced approximately 25, 15, and 15 percent respectively. All the core materials except the cotton cloth were reduced in strength when exposed to and tested at 200° F.; all exceeded their control strength however, when reconditioned to 65 percent relative humidity and 75° F. The high-low temperature and humidity exposure cycles did not appear to materially affect the strength of any of the core materials.

In general the modulus values showed the same trends as the strength values.

Exposure to conditions favoring decay for periods up to 3 months resulted in insignificant weight losses in glass-cloth honeycomb. Paper and cotton-cloth honeycomb specimens progressively lost weight, the greatest loss (about 7 percent) being with paper honeycomb exposed to the fungus *Poria incrassata* for 3 months.

Flame tests indicated that paper honeycomb had the most rapid burning rate of the cores tested, but the test method employed is thought to be inadequate.

In exposure to typical aircraft liquids, glass cloth honeycomb exhibited the least gain in weight. Changes in thickness for all specimens were confined to a range of +2.63 to -1.31 percent of original thickness.

Description of Materials

Paper Honeycomb

All the paper honeycomb material[4] used in this study was made at the Forest Products Laboratory. The material was produced by impregnating 4.5-mil kraft paper of 12-inch width with about 10 percent of a high-temperature-setting phenolic resin, designated T[5] thinned with alcohol and water. This preliminary treatment was given by passing the paper around a roller partly submerged in the resin, and then through a drier about 12 feet long, heated at 140° C., at a speed of about 3 feet per minute. The phenolic-treated paper was then put through a "B-flute" corrugating machine, cut to 40-inch lengths, and nested with other sheets. These nested sheets were cured in an oven at 125° C. for 5 to 6 hours.

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[4]Developent of this paper honeycomb core material was made in cooperation with the National Advisory Committee for Aeronautics.

[5]Appendix I Note 11.

The individual corrugated sheets were impregnated with a high-temperature-setting, low-viscosity laminating resin B[6] to a 55 percent resin content by laying the sheets on a piece of plate glass covered with a uniform film of the resin. The sheets were then placed on e jig that had heating elements on the side to cure the resin partially and thus reduce slippage when the corrugated sheets were placed with the antinodes of one sheet centered on the antinodes of the next sheet. It also prevented the resin from running to one side and thereby producing a block of nonuniform density. A sufficient number of sheets were laid together to produce a block 2-1/2 to 2-3/4 inches thick, The use of blocks of greater thickness resulted in greater thickness variations than desired when cut into thin sections, and the thicker blocks could not be cut with a circular saw. The approximate dimensions of the blocks were 2-1/2 by 12 by 40 inches, with the axes of the cells parallel to the 12-inch direction. In this form, the block6 were given a final cure in an oven provided with forced-air circulation at 120° to 125° C. for 2-1/2 hours.

Glass-cloth Honeycomb

The glass-cloth honeycomb was received from the manufacturer in blocks measuring 3-1/2 by 17 by 18 inches, with a cell size of 3/16 inch in the 17-inch direction. Their density varied from 7 to 10 pounds per cubic foot. Their resin content, approximately 60 percent as received, was determined by heating small samples to 1,000° F. for about one-half hour, or to constant weight, in an electric furnace.

Cotton-cloth Honeycomb

The cotton-cloth honeycomb material was received from the manufacturer in blocks measuring about 8 by 9 by 125 inches, with the axes of the 7/16-inch hexagon cells parallel to the 9-inch direction. Since most of the material was to be made into panels 1/2 by 36 by 36 inches in size, the blocks were cut into 38-inch lengths, These individual blocks were measured and weighed and found to have a density of about 3.65 pounds per cubic foot. Due to the unavailability of the 4-ounce cotton duck, another cotton cloth of similar quality used by the manufacturer in some of the blocks reduced their density to approximately 3.25 pounds per cubic foot.

Aluminum Honeycomb

The aluminum-foil, honeycomb-core material was received in blocks approximately 6 by 7 by 32 inches in size, with the axis of the cells parallel to the 7-inch dimension. The 3/8-inch hexagonal cells were made by bonding together formed sheets of 0.003-inch, 2SH, aluminum foil. A high-temperature-setting metal-to-metal adhesive, J[7] was used as the bond between the sheets. The blocks of core material had a density of approximately 4.5 pounds per cubic foot.

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[6] Appendix I Note 2.

[7] Appendix I Note 7.

Preparation of Materials

Paper Honeycomb

The paper-honeycomb blocks were trimmed, measured, and weighed and the density of each block was determined. The average density was approximately 6 pounds per cubic foot. Two methods were used for sawing the blocks into 1/2-inch thick core stock strips; (1) a band saw with four teeth per inch running at a speed of 4,000 feet per minute; and (2) a circular saw with 4-1/2 teeth per inch turning at 1,770 revolutions per minute. The method used depended upon the availability of the saw.

After the strips were cut and checked for thickness, they were bonded together with a phenolic-resin, adhesive N[8] on a high-frequency edge-gluing machine to make finished cores for the nominal 36- by 36-inch sandwich panels. The corrugations of one strip were nested into the corrugations of the next, so that a strong glue bond would be obtained and thus make the finished core easier to handle. After assembly, the cores were sanded with fine sandpaper on a wood block to remove glue squeeze-out and other minor surface imperfections. Figure 1 shows a typical piece of paper-honeycomb core. No attempts were made to make matched cores, since the density variation in any one block was often as great as the density variation between different blocks,

Glass-cloth Honeycomb

From several cutting trials, the best method found to cut glass-cloth honeycomb with the equipment available was to use a 14- or 24-tooth metal–cutting band saw mounted so that the teeth traveled backwards at a speed of 3,500 feet per minute. Other saws with larger teeth or teeth running in the forward, or normal, direction caused varying degrees of breakage. The normal thickness used was one-half inch and was not difficult to saw. All sections were measured and held within the tolerances of ±0.005 inch of the desired thickness. The fuzzy character of the surface produced by the saw is shown in figure 2.

The cut sections were bonded together with a phenolic resin, adhesive N, in a high-frequency edge-gluing machine by nesting the corrugations of the adjoining pieces, Cores made of glass-cloth honeycomb required more delicate handling than paper-honeycomb cores, probably because of the shorter pieces used and the nature of the material. The cores were lightly sanded to remove glue squeeze-out.

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[8] Appendix I Note 10.

Cotton-cloth Honeycomb

The cotton-cloth honeycomb was cut into sections of 1/2-inch thickness Kith a four-tooth band saw running at 3,500 feet per minute. Because of the thickness of the blocks and the flexibility of this type of structure, considerable material was wasted in cutting, with the greater percentage of rejections occurring toward the end of the block. A tolerance of ±0.005 inch was permitted in the thickness of the cut sections. The nature of the surface formed by the band saw is shown in figure 3.

Due to the hexagonal shape of the cells and large areas for contact, the sections of cotton-cloth honeycomb were bonded together, antinode to antinode, Kith a phenolic resin, adhesive N, using the high-frequency edge-gluing machine. The cores were sanded to remove excess squeeze-out of the adhesive and other nonuniformities.

Aluminum Honeycomb

This core material was cut using the same procedures employed for cutting glass-cloth honeycomb. Tension and shear specimens were obtained from sandwich panels of nominal 1/2-inch thickness supplied by the manufacturer. It was therefore necessary to cut only compression specimens from the core material received,

Preparation of Test Specimens

Compression Test for Core Materid

In general, the specimens for compression strength tests of core materials after exposures (1), (2), (3), and (4) conformed to the specifications given in Forest Products Laboratory Report No. 1555.[9] The specimens were cut from large blocks of the core material and were approximately 6 inches long and 2 by 2 inches in cross section. It was necessary, however, to reduce these dimensions in some cases, as the amount of material available or the size of a block received prevented the cutting of a sufficient number of full-sized specimens. The compression specimens were divided into two equal groups, of which one group was to be tested as cut and the other group tested with the ends of the specimens cast in plaster of Paris to a depth of approximately one-half inch as an additional support of the bearing surfaces, as shown in figure 4.

Decay Test for Core Material

The test specimens used for the decay tests of cores Were 2-1/2 by 1 by 1/2 inches in size, with the axes of the cells in the 1/2-inch direction.

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[9]"Methods of Test for Determining Strength Properties of Core Materials for Sandwich Construction at Normal Temperatures." Revised October 1948.

Flame Test for Core Material

The specimens for flame tests were 1/2 by 1/2 by 5 inches, with the axes of the cells in the 1/2-inch direction.

Aircraft Liquid Exposure for Core Material

Test specimens were 1/2 by 1 by 3 inches, Kith the axe6 of the cells in the 1/2-inch direction.

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

Test Procedures

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 tested 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 15 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 55° F. The immersion periods were 1 day and 40 days.

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 to a temperature of 200° F., while the remainder were reconditioned to equilibrium with 75° F. and 65 percent relative humidity and then tested.

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.

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 Specification LP-406a, Plastics, Organic; General Specifications, Test Methods, "Accelerated Service Tests (Temperaature 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, and10 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.

Decay

All test specimens were conditioned at 80° F. and 65 percent relative humidity for about 2-1/2 months until an approximate equilibrium weight was reached, and the weights recorded.

The test specimens were surface disinfected by placing them in cellophane bags and holding them in an oven at 80° C. for about 24 hours.

The fungi used were: Poria monticola (Madison 698) and P. incrassata (Madison 563), both brown-rot fungi; and Polyporus versicolor (Madison 697 a white-rot fungus. The fungi were grown on a substrate of 25 cubic centimeter malt agar (Trommer's malt extract, 25 grams; bacto-agar, 20 grams; and distilled water, 1,000 cubic centimeters) in 6-ounce French-square bottles placed horizontally. The test specimens were held away from direct contact with the substrate by means of two L-shaped glass rods about 0.14 inch in diameter.

The specimens were placed in test bottles and incubated et 28° C. for 1, 2, or 3 months, They were then cleaned of mycelium and weighed.

The test specimens were returned to conditions of 80° F. and 65 percent relative humidity for a period of about 2-1/2 months, until they were in approximate equilibrium, and then weighed.

The percentage change in weight, based on the approximate equilibrium weight at 80° F, and 65 percent relative humidity before and after exposure, was computed as follows:

$$\frac{\text{weight after original conditioning period minus weight after reconditioning}}{\text{weight after original conditioning period}} \times 100$$

In a few cases where the behavior of the reference specimens over sterile agar indicated the need, adjustments were made.

The cultures were examined from time to time during the test to ascertain the presence of any contaminants. Observations on the growth of the test fungi were also recorded. At the end of each exposure period isolations were made from a number of the cultures to determine if they were still viable. Observations on the condition of the test specimens, such as amount of visible decay, color, staining, corrosion, and separation, were also made.

Flame

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

Aircraft Liquids

After being conditioned, the specimens were weighed to the nearest milligram on an analytical balance kept in the same room under the same conditions, and their length, width, and thickness were measured with a Vernier 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.

Compression Tests

The compression tests of all honeycomb-core specimens were similar to those described in Forest Products Laboratory Report No. 1555.[9] Tests were made in a hydraulic testing machine, with the load applied to the specimens through a spherical, self-aligning type of block at a uniform rate of head travel of 0.018 inch per minute. Data for load-deformation curves for the determination of modulus of elasticity were obtained by means of a Marten's mirror compressometer of 2-inch gage length.

General

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 weights 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 free water, weighed, measured, and tested immediately while wet.

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.

An insulated plywood box, housing the necessary apparatus, was used to conduct compression tests at 200° F. The 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.

Results and Discussion

The results of the compression tests of the four honeycomb–core materials, (paper, glass cloth, cotton cloth, and aluminum foil) in the direction of the axes of the cells following the various simulated exposure conditions are listed in table 1.

In general, the specimens of all the core materials having plaster of Paris ends had higher strength values than the specimens having unsupported ends. Those having unsupported ends usually failed by a "rolling" of the ends of the cell walls that were in contact with the head of the testing machine, while those of the plaster type usually failed in the body of the specimen between the supported ends. It is believed that the supported type is the more indicative of the performance of a core as it is used in a completed sandwich structure.

Water Immersion

The paper–honeycomb core material had the highest compressive strength of the four materials tested under the original or control. conditions of 65 percent relative humidity and 75° F., on either an actual or specific strength basis. The strength of the material was reduced, however, approximately 50 percent after immersion in water for 24 hours, and still further reduced after a soaking period of 40 days.

The glass–cloth honeycomb core material lost approximately 20 percent of its control strength after 24 hours in water, and approximately 30 percent after 40 days' immersion, The cotton–cloth honeycomb core specimens also were reduced approximately 20 percent in strength after 24 hours immersion, but did not appear to be further reduced when the period was increased to 40 days.

The aluminum–foil honeycomb core material, as might be expected, was affected least of any by the water treatment. The compressive strength following 24 hours' immersion was approximately 85 percent of the control strength, and there was only a slight additional loss in strength by increasing tho immersion tine to 40 days.

When the specimens were reconditioned to 65 percent relative humidity and 75° F., the strength of all the materials approached the control values, with the paper and aluminum cores showing a permanent loss in strength of 15 and 10 percent respectively.

The compressive strength of a honeycomb core structure, in the direction of the axes of the cells, is directly proportional to the modulus of elasticity[10] of the material. The proportionality of the values obtained from tho tests of tho specimens having plaster ends was in general more consistent than that of tho values obtained from the tests of the f rue-end specimens.

Exposure to High Temperature

The cotton-cloth honeycomb core was the only material that was not reduced in strength when exposed to 200° F., for 10 days and tested at the same temperature. The results of the tests showed a slight increase in strength, but there was a alight decrease in the modulus of elasticity values, which would perhaps indicate that these differences in averages were within the experimental scatter obtained from the data.

The paper and glass-cloth core materials on the other hand were considerably reduced in strength, approximately 45 and 55 percent, respectively, by this exposure when tested hot; but upon reconditioning, the specimens that were tested exceeded the control strengths by approximately 20 percent. It is possible that the exposure plasticized the resin in these cores, lowering the modulus of elasticity and strengths at the 200° F. temperature; but that it also affected an additional cure of the resin, thus increasing the above properties when reconditioned.

Tho aluminum-foil honeycomb-core material was reduced in strength approximately 15 percent when tested at 200° F., and seemed to be permanently weakened, as it did not regain appreciably upon reconditioning.

On a percentage basis, the high temperature had a more serious effect on tho glass-cloth and aluminum-foil honeycomb-core materials than did any of tho other exposures to which these materials were subjected.

Exposure to High Humidity

The compressive strength and modulus of elasticity of the core materials, following exposure to 97 percent relative humidity until approximate weight equilibrium had been reached, were approximately the same as found after immersion in water for 24 hours. The specimens exposed to the high humidity conditions and then reconditioned. generally showed better strength recovery than did the specimens soaked in water for 40 days and reconditioned. Again the data obtained from specimens having plaster ends wore the more uniform.

It would appear from tho data presented, that for the core materials tested, tho high humidity exposure would be similar to the 24-hour water-immersion exposure, but less severe than the 40-day soaking tests.

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[10] Norris, C. B., "An analysis of the compressive strength of honeycomb cores for sandwich constructions." N.A.C.A. Technical Note No. 1251, April 1947.

Exposure to Cycles of High and Low Temperature Combined with High and Low Humidity

The high–low temperature and humidity exposure, while seemingly quite rigorous, had the least effect on the strength properties of the core materials. This may partially be explained by the sequence of the humidities and temperatures in the cycles. One cycle consisted of 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. Since the high temperatures and humidities, which would tend to weaken some of the materials, are at the beginning of the cycle, the effect on tost results was probably not so serious as if these exposures had been at the end of the cycle. The paper–honeycomb core was stronger following the cyclic exposure, due possibly to the additional curing of the resin during the high–temperature portion of the cycle, The same was true for the glass–cloth material after 1 and 5 cycles, but it was slightly reduced in strength after 10 cycles of exposure.

Tho cotton–cloth honeycomb material was reduced in strength by successive cycles, until after 10 cycles the material had lost approximately 10 percent of its control strength. The aluminum–foil core was not materi—ally affected by the cyclic exposure.

Decay Resistance

The changes in might sustained by the specimens during tho course of tho tost are shown in table 2.

The papor–honeycomb specimens showed appreciable weight loss after 1–month exposure to _Polyporus versicolor_ and, at the end of 3 months, at least some deterioration was caused by all three fungi. The growth of all test fungi was vigorous and the specimens wore well–covered except by _P. versicolor_. Tho results appeared to be uncomplicated by the presence of contaminants. Isolations of the tost fungi at the end of each exposure period were successful. At tho end of the first month of exposure when tho specimens were examined as removed from tho bottles (in a moist condi—tion) the excess glue seemed soft. When the sheets were separated there also appeared to be less fiber failure in the test specimens than in the reference specimens maintained over sterile agar. A number of the paper–honeycomb specimens were definitely changed in appearance when reconditioned aftor the test. They were lighter in color and mottled, and the sheen was lacking, as if some deterioration had changed the refraction.

The glass–cloth–honeycomb tost specimens showed very insignificant weight losses, and furthermore those were of the order of samples main–tained over sterile agar. The growth of all test fungi concerned was vigorous and normal in appearance, but it was noted that none made much growth over the specimens themselves. Only a few instances of contaminated cultures were observed. Isolations of tho test fungi at the end of each exposure period were successful. At the end of the 3–month exposure period, a number of tho specimens were appreciably darkened, The cotton-cloth-honeycomb test specimens exposed to Polyporus versicolor developed a trend toward weight loss at the end of 1-month exposure which became appreciable with the extension of the test. The growth of all test fungi was vigorous and, except for P. versicolor, which does not normally produce an extensive aerial or "fluffy" mycelium, all grew well over the specimens. The presence of contaminants may have influenced slightly the results of the 1- and 2-month exposure groups; none were observed in the 3-month group. Isolations of the test fungi at the end of each test period were successful.

No decay-resistance tests were made on aluminum honeycomb.

In spite of an exploratory test, it was apparent that the surface-disinfection treatment used was not adequate in all cases. Fortunately, the distribution of the contaminated cultures was such that allowances could bo made in most instances.

The failure of the test fungi to grow over the glass-cloth specimens may be due to the low moisture content of the glass cloth as compared with the other materials. Average moisture content values, oven-dry basis, of a few specimens maintained over sterile agar for 3 months were: glass-cloth honeycomb, 11.5 percent; cotton-cloth honeycomb, 27.9 percent; and paper-honeycomb, 40.1 percent.

The average weight losses for all the honeycomb materials tested would indicate a considerable resistance to decay. Interpretation of these weight losses in terms of impaired strength of the materials must await the development of satisfactory physical tests.

Flame Tests

In flame tests, made in accordance with method No. 2021 Of Specification L-P-406a, "Federal Specifications, Test Methods," paper-honeycomb exhibited the most rapid rate of burning, followed by glass-cloth honeycomb. Tho cotton-honeycomb specimens could not be made to burn for the 3 inches required by the test method for establishing a burning. No tests were made on aluminum honeycomb.

A summary of the flame-test results is presented in table 3.

This test, meant for solid plastic specimens, is unsuitable for honeycomb-core specimens, and therefore tho results are not thought to be indicative of tho burning characteristics of these materials in actual service.

Aircraft Liquids

Table 4 shows tho average changes in weight of paper, glass-cloth, and cotton-cloth honeycomb-core specimens after 7 days of immersion in aircraft liquids and after immersion followed by 39 days of conditioning. Also shown in the table are tho 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 tho weight and dimension of tho specimens after the initial conditioning.

Tho percentage increase in weight of glass-cloth honeycomb, after 7 days of immersion in the liquids, was smaller than that for the other core materials tested. The core materials appeared to have lost no solid matter while in the solutions, except perhaps tho paper honeycomb immersed in gasoline, (the reconditioned weight of which was 2.5 percent less than the original weight).

Thickness measurements on all core-fluid combinations after soaking and after reconditioning varied within the rather narrow range of +2.63 and -1.31 percent of their original thickness. No significant trend was apparent for any of the combinations, except for a possible retained increase in thickness of about 2 percent for glass-cloth honeycomb upon being reconditioned after soaking in gasoline, oil, and water. Most fluids seemed to produce a slight permanent Increase in thickness, varying from 0 for the paper-honeycomb - oil combination to a maximum of 2.25 percent for the glass-cloth - water combination.

Accurate width and length measurements wore difficult to obtain because of the flexible nature of the honeycomb core specimens, but it is doubtful if any significant changes occur from soaking of these honeycomb cores in any of the fluids. Changes in width and length of a core material due to exposure are of little consequence after the facings are attached by means of a high-quality permanent adhesive; however, if significant width and length changes had appeared due to these soaking tests, it would have been an indication that the core material itself was being affected by tho fluid.

SECTION B - TESTS ON SANDWICH PANELS

Summary

Nine sandwich constructions (made by combining one of the three facing materials; aluminum, resin-treated glass cloth, and plywood, with one of the three core materials described in Section A; paper, glass-cloth, and cotton-cloth honeycomb bonded with various adhesives) were conditioned to equilibrium at a relative humidity of 65 percent and a temperature of 75° F. They were then subjected to the following exposures: water immersion, high temperature, high humidity, 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 those exposure conditions were the same as those described in Section A. Later sandwich panels having aluminum facings on an alminum-foil honeycomb core were exposed and tested in a similar manner.

Considerable variation was noted in the results of individual tests of these materials, which was also evident in the data obtained from the tests of other sandwich constructions, previously presented in Forest Products Laboratory Reports Nos. 1573 and 1573-A (Parts I and II of this study). It is difficult, therefore, to present clearly the effect of the different exposure conditions, although certain trends and apparent effects can be summarized.

The paper-honeycomb material had the highest compressive strength of the four cores reported in section A. Of the specimens tested in the form of sandwich construction, however, the glass-cloth honeycomb had the highest tonsilo strength in the direction of the axes of the cells. The ultimate strength of the glass fibers was not reached, as the specimens failed in the adhesive bond between the cores and the facings. The tensile strength of the paper, glass-cloth, and cotton-cloth honeycomb specimens was most adversely affected by the 40-day water-immersion exposure, being reduced by one-half for most of the adhesives used in this series of tests. The other exposures generally reduced the tensile strength of the materials, and in the order of severity were: 24-hour immersion in water, 97 percent relative humidity, 200° F. for 10 days (specimens tested at 200° F.), and the cyclic tests. The tensile strength of the aluminum-foil sandwich specimens varied considerably, but appeared to be most seriously affected by the cyclic exposures. The variation in the strength properties of the aluminum honeycomb may be caused in part by the fact that the core material had been crushed during fabrication over some portions of the sandwich plates, rolling over the ends of the cell walls as a result of which some of the adhesive may have been wiped from the facings and both the bond and the core weakened thereby.

The tensile specimens cut from the sandwich panels subjected to one year of exposure to the weather did not show any definite trend with respect to possible deterioration of core material, but rather an indication of the relative merit of the various adhesives used in making the sandwich combinations.

Determinations were made of the edgewise compression strength of the sandwich constructions following exposure, to show a comparison of the effectiveness of the adhesives in bonding the several core and facing combinations. The ultimate control strength of any combination depended largely upon the facing matorial but was also affected by the core material of the sandwich. The specimens having glass-cloth facings and glass-cloth honeycomb cores wore stronger than the same facings with paper or cotton-cloth honeycomb cores. The aluminum facing materials, however, had higher strength when combined with the paper-honeycomb core material. The specinens having birch plywood facings had approximately equal strength for all three core materials.

The exposures affected the edgewise compression strength of the specimen in approximately the same order as they affected the tension specimens; water immersion being the most severe, followed by high humidity, high temperature, and cyclic exposures. There were individual. combinations, however, that reacted differently; some for example, were most affected by the high–temperature exposure. All the materials had good resistance to the weathering exposure.

Very little difference was noted in strength between the weathering panels having edges sealed and those having unprotected edges.

The effect of the exposures on the weight and dimensional stability of the sandwich materials was not serious except for some of the materials having glass–cloth or plywood facings. The panels having the plywood facings exhibited severe cupping and twisting when exposed to the weather, and in addition considorable increase in weight and thickness when exposed to high humidity or water. Some of the glass–cloth facing material was sufficiently porous to permit some of the honeycomb cells of the cores to fill with water when the sandwich specimens were submerged in water. The panels having glass-cloth facings also had more tendency to cup and twist than the panels having aluminum facings, when oxposed to the weather. The largo panels that had aluminum facings, however, had a tendency to cup when a temperature differ–ential developed between the two facings; such as would occur when one face was exposed to bright sunshine on a cold day, with the other face in the shade. Upon equalizing the face temperatures, the panels would return quickly to normal flatness.

Description of Materials

Each of the three core materials described in section A of this report was faced with three materials, to produce nine different constructions of sandwich panels for test specinens. A tenth combination of aluminum facings on aluminum-foil honeycomb was added later. Descriptions of the three facing materials follow:

Plywood

Plywood facings conforming to specification AN–P–69 were 0.070 inch, three–ply, birch plywood bonded with a phenolic–type sheet adhesive.

Aluminum

All aluminum facings were 24 ST clad and 0.020 inch thick, conforming to specification AN-A-13. The material was inspected to eliminate all dented, wrinkled, and contaminated sheets that might produce weak or questionable panels.

Resin-treated Glass Cloth

The glass–cloth facings were fabricated from a basket–weave, heat-cleaned, 0.003–inch–thick fabric, No. 112–114. the cloth was impregnated with one of several contact-pressure laminating resins to a rosin content of 40 to 45 percent, based on total treated weight. "Wet laminating" procedures were used in assembling the sandwich panels,

Preparation of Panels

Two panels, approximately 1/2 inch thick and 36 inches square, were fabricated for each combination of core, facing, and resin (table 5). These panels were cut into individual test specimens for exposure as shown in figures 5 and 6. One panel, cut as shown in figure 5, was designated as panel type A and the specimens were used for weathering exposure tests. A similar panel, cut as shown in figure 6, was designated as panel type B, and the specimens were subjected to all exposures other than weathering.

Glass-Cloth Facings on Paper, Glass-Cloth, and Cotton-Cloth Honeycomb Cores

Panels having resin-impregnated glass-cloth facings and honeycomb cores were assembled and cured in one operation. The impregnated glass cloth for one facing was laid on a cellophane-covered mold, one sheet at a time, cross-laminated. This procedure was repeated for the other facing but it was laid on a cellophane-covered caul of 0.020-inch aluminum. The honeycomb core was roller coated on both sides with the same resin that was used to impregnate the glass-cloth facings, a spread of 10 grams per square foot being applied on each side. The honeycomb core was then laid on one facing and covered with the other.

The panel, mold, and caul wore inserted in a rubber vacuum bag, covered with a bleeder cloth, and cured in a circulating-air oven at a pressure of about 13 pounds per square inch. Oven temperatures and curing times were varied depending upon the type of resin used.

Method 1.--A high-viscosity laminating resin of the polyester type, resin A[11] was applied to the glass cloth by an adaptor for a glue spreader. This resin has a solids content of approximately 100 percent, and was applied to the glass cloth at the rate of approximately 45 percent of the total coated weight. The panels were molded at a temperature of 225°F. for 1-1/2 hours.

Method 2.--A low-viscosity laminating resin B[12] of the polyester type was coated on the glass cloth to a wet resin content of about 50 percent. This resin has a nonvolatile content of approximately 70 percent, which made it necessary to use the coated glass cloth within 2 or 3 hours after spreading.

The panels were molded at a temperature of 250° F, for 1-1/2 hours.

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[11] Appendix I Note 1.

[12] Appendix I Note 2.

Method 3.--A high-viscosity laminating resin of the polyester type, resin C[13] very similar to resin A, was applied by the same method used for resin A, and cured at a temperature of 240° F. for 1-1/2 hours.

Method 4.--This resin was a high-temperature-setting, low-viscosity polyester type, resin D[14] the application and cure being identical to method 2.

Aluminum Facings on Paper, Glass-Cloth, and Cotton-Cloth Honeycomb Cores

Panels made with paper and glass-cloth honeycomb cores were fabricated with 30 pounds of pressure per square inch, but for those having cotton-cloth honeycomb, the pressure was reduced to 20 pounds per square inch for pressing, or vacuum pressure if the panels were made by a bag molding. The following five methods were employed in fabricating panels of these types.

Method 1.--The etched aluminum facings were coated with adhesive G[15] a combination of a thermosetting liquid and a thermoplastic powder. A liquid spread of 35 grams per square foot was used on the facings and dusted with the powder. In addition, 10 grams per square foot of the liquid were applied to each side of the honeycomb core with a roller. The facings and cores were air dried for a minimum of 16 hours. The panels with paper and glass-cloth honeycomb cores were assembled on a 1/4-inch flat aluminum mold and cured. in an autoclave at 275° F. for 1 hour, The panels with the cotton cloth honeycomb core were assembled and cured in a hot press at 275° F. for 1 hour.

Method 2.-—Ahigh-temperature-setting modified thermosetting resin, adhesive F[16] was thinned with a mixture of ethyl acetate and ethyl alcohol and brush spread on the etched aluminum surface. Several coats were required to obtain a dry film of approximately 14 grams per square foot. A drying period of one–half hour was allowed between coats, and a 16 hour minimum drying period after the final coat. The core was given two roller coats, resulting in a dry spread of 3 grams per square foot on each side. The panels were assembled on a 1/4-inch aluminum mold, placed in a rubber bag, and cured at 275° F. for 1 hour.

Method 3.--Adhesive L[17] a combination of high-temperature thermosetting resin and synthetic rubber, was thinned with acetone and applied directly to the etched aluminum by brush in an air-dry spread of 15 grams per square foot. Several coats were applied, allowing 0.5 hour between coats and at least 16 hours after the final coat for drying. By roller application, a dry spread

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[13] Appendix I Note 3.

[14] Appendix I Note 4.

[15] Appendix I Note 6.

[16] Appendix I Note 5.

[17] Appendix I Note 8.

of 5 grams per square foot was applied to each side of the cores. The panels were assembled on a flat aluminum mold, placed in a rubber bag, and cured at 260° F. for 1 hour.

Method 4.--Adhesive J[18], a high-temperature-setting mixture of thermoplastic and thermosetting resins, was also applied directly to the etched aluminum surface by brush application. The adhesive was thinned with a special thinner to 30 percent by volume. About four brush coats were required to build up a dry film thickness of 0.006 to 0.010 inch, or about 20 grams per square foot. One-half hour or longer of drying was allowed between coats and a minimum of 16 hours after the final coat. A dry spread of 10 grams per square foot was applied to the cores with a rubber roller. The panels with papor and glass-cloth honeycomb cores were cured on a flat aluminum mold in a rubber bag et 275° F. for 1-3/4 hours, and the panels with the cotton-cloth honeycomb core were cured in a hot press at 275° F. for 1-3/4 hours.

Method 5.--Adhesive M[19], a high-temperature-setting, modified, thermosetting resin, was sprayed on the etched aluminum sheets in six coats to a film thickness of approximately 0.003 inch. After drying over night the sprayed shoats were cured in a press without pressure at 325° F. for 30 minutes. Prior to applying the secondary adhesive, N[20], a high-temperature-setting phenolic rein, the cured primary adhesive M was sanded and wiped with a clean cloth moistened in methyl alcohol. A wet spread of 20 grams per square foot of the secondary adhesive N was applied with a rubber roller and dried for 1 to 24 hours before assembling. The honeycomb cores were coated with a wet spread of 5 grams of adhesive N per square foot on each side with a roller and dried for the same period. The panels were then assombled on a flat aluminum mold and bag molded at 230° F. for 1 hour.

Plywood Facings on Paper, Glass-cloth, and Cotton-cloth Honeycomb Cores

Panels with birch plywood facings and honeycomb coros were glued with adhesive N. A wet spread of 20 grams per square foot was applied to the facings and 5 grams per square foot to each side of the cores with a rubber roller, and both dried for 1 to 24 hours before assembling. The panels were assembled on a flat aluminum mold and bag molded at 230° F. for 1 hour.

Aluminum to Aluminum Honoycomb

Two panels of this combination 1/2 by 36 by 36 inches, were fabricated by the manufacturer. The adhesive used to bond the facings to the honeycomb core was adhesive J, but the details of spreads and cure are not known.

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[18] Appendix I Note 7.

[19] Appendix I Note 9.

[20] Appendix I Note 10.

Preparation of Test Specimens

From each combination, four types of specimens were prepared for this study; small panels each about 5-1/2 by 6 inches; large weathering panels each approximately 16 by 25 inches; tension specimens; and short-column, edgewise-compression specimens each about 2 by 3 inches.

Two of the 5–1/2–by 6-inch panels were prepared for each exposure with unprotected edges.

Eight to ten tension specimens were prepared for each exposure condition, excluding the weathering exposure.

Two panels of each combination, approximately 16 by 25 inches, were used for determining the effect of weathering on distortion, such as cupping and twisting. One was exposed with unprotected edges, while the other had three of the four edges sealed with waterproof fabric tape and two coats of aluminized varnish (1-1/2 pounds of aluminum paste, fine aircraft-use grade, to 1 gallon of phenolic-resin varnish conforming to Specification AN-V–26). Those weathering panels were mounted on the exposure racks with the unprotected edge of the panel downward. Provisions were made for tension specimens to be cut out of each panel after exposure by applying (and curing) a metal priming cement, adhesive M, to a strip about 1-1/2 inches wide across the center of each aluminum facing before the panels were assembled.

Specimens for the determination of the compressive strength of the sandwich materials in the direction parallel to the plane of the sheets were cut from the central portion of the large weathering panels. The specimens were nominally 2 inches wide and 3 inches long. Tho control edgewise-compression specimens were cut and tested prior to exposure, while the final specimens wore cut and tested following exposure of the panel. The 5-1/2- by 6-inch specimens were also cut into four nominal 2- by 3-inch edgewise-compression specimens following exposure to determino the effect of the weathering on the exposed edges of these small specimens.

Treatment of Specimens

All indoor exposure specimens were first conditioned to approximate weight equilibrium at 75° F. and 65 percent relative humidity and then divided into groups for the following exposures.[21]

(1) Water immersion.
- (a) Immersion in running tap water, approximately 55° F., for 24 hours.
- (b) Immersion in running tap water for 40 days.
- (c) Immersion in running tap water for 40 days followed by reconditioning to approximate weight equilibrium at 75° F. and 65 percent relative humidity.

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[21]For a more complete discussion of the exposure, see section A of Forest Products Laboratory Report No. 1573.

(2) High temperature.

(a) Placed for 240 hours in an insulated box maintained at 200° F. dry heat, tested hot.

(b) Maintained at 200° F. for 240 hours, followed by reconditioning to 75° F. and 65 percent relative humidity.

(3) High humidity.

(a) Placed in a room maintained at a temperature of 80° F. and 97 percent relative humidity until approximate weight equilibrium has been reached.

(b) Brought to equilibrium at 80° F. and 97 percent relative humidity, followed by reconditioning to 75° F. and 65 percent relative humidity.

(4) Cyclic exposure, one cycle consisting of tho following:

(a) 24 hours at 175° F. and 75 percent relative humidity.

(b) 24 hours at —20° F.

(c) 24 hours at 175° F. dry heat.

(d) 24 hours at —20°F.

(5) Weathering

The small outdoor weathering specimens were inspected for glue-joint integrity 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 by attachment at three points with a brass spring beneath each point and a screw hook above. This arrangement allowed free movement and easy removal of specimens.

The large weathering panels were conditioned and inspected in a similar manner and, in addition, were measured for flatness. This was done by means of a special measuring bar having a dial indicator calibrated in 0.001-inch increments mounted in the center. Six readings were taken on the numbered side; one near each edge and two from diagonal corners. This measuring device is shown in figure 7. The panels wore then mounted by a 3-point support, similar to the small panels.

On July 1, 1947, the exposure was started by facing the panels south at an angle of 45° from the vertical position. The numbered side was placed away from the sun, so that the identification was protected from the weather. The specimens were inspected, weighed, and measured at the end of 3, 6, 9, and 12 months of exposure. The exposure of the aluminum facings on aluminum honeycomb-core panels were started on April 1, 1948.

Description of Test Procedures

In general, the test methods conformed to, or were similar to, those described in Forest Products Laboratory Report No. 1556, "Methods for Conducting Mechanical Tests of Sandwich Construction at Normal Temperatures," revised October 1948.

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

(A) Specimens that were immersed for 1 and 40 days were blotted to remove surface or free water, weighed, measured, and tested immediately.

(B) A small insulated plywood box housing the specimen and necessary apparatus was used to conduct the tests at 200° F. The box was equipped with a double-glazed door and windows, heating coils, thermostat, and a fan for air circulation.

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

The large weathering panels were measured for warping immediately after removal from the test racks on the Laboratory roof. During the winter months any snow or ice on a panel was removed with a hand scraper prior to measuring it. These measurements were taken on the numbered side of each panel with a special measuring bar and dial gage shown in figure 7. The gage was placed on the panel in six different positions supported at the corners, and the measurement to the face of the panel, at the center of each span, was recorded. Measurements with the numbered face in the concave position were given a positive value; those with the face in the convex position were given a negative value. The amount of cupping was determined from the average change in deformation along the edges of the four sides of each panel. The amount of twist was determined from the difference in change in deformation across the two diagonals of each panel.

Weights and measurements of thickness were obtained from both the large and small weathering panels after they had been brought inside the building .

Initial and final tension specimens were obtained from strips cut from both type-A and type-B panels. Initial and final edgewise compression specinens were obtained from each type-A panel but only final specimens were obtainable from each of the type-B panels.

The specimens were selected for each individual indoor exposure by a sampling method, representing as many different portions of each panel as possible. This was done to determine the average properties of each panel, and to reduce the effect of a possible variation within any one panel.

Presentation of Data

The weight and dimensional stability measurements recorded following the indoor exposures of the type-B panels are listed in table 6. The change in weight, in percent, and the change in thickness, in inches, are given for each sandwich construction. The values in the table are the average of the measurements of four specimens following each exposure and the average of measurements for the two specimens that have been reconditioned at 65 percent relative humidity and 75° F.

Table 7 is a similar presentation of the tensile strength values obtained from specimens that were subjected to the indoor series of exposures. Average strength and the average amount of core failure are given for each construction. The control values are the average of nine individual tests and values following each of the exposures are the average of six tests.

Tho edgewise compressive strength data are shown in table 8 for both the outdoor weathering and indoor exposures. The control values are the average strength of 14 test specimens cut from the type-A panels; no control specimens were available for test from the type-B panels. The strength of each construction following tho exposures is the average of eight tests except that, for the large plates exposed to the weather, the average is of four tests.

Table 9 presents the data obtained from the weathering test on the type-A panels of sandwich construction after 3, 6, 9, and 12 months of exposure. Information tabulated included the change in weight, in percent, change in thickness, in inches, and the amount of cupping and twist, in inches, for each exposure period.

The tensile strength of the various sandwich constructions before and after exposure to the weather for 1 year are listed in table 1Q. The specimens tested were all cut from the type-A panels, as shown in figure 5. The values in the table represent an average of approximately 10 tests, with additional columns to show the high and low value within each group, Tensile strength values were determined from both the panels having sealed and unsealed edges. In addition, the average percentage of core failure is given as an indication of whether the adhesive or the core material limited the tensile strength of tho sandwich tested.

A summary of the weather conditions during the period of exposure, July 1947 to April 1949, is presented in table 11.

Results and Discussion

Effect on Weight and Dimensions

In general, the sandwich constructions included in this series of tests had good weight and dimensional stability (see table 6). As was indicated in Forest Products Laboratory Report No. 1573-A, the combinations having plywood facings or balsa cores were subject to the greatest changes in weight and dimensions, The 5-1/2-. by 6-inch specimens in this series of tests were not edge sealed as were some of the solid-core sandwich constructions reported on earlier. In water immersion, the honeycomb-core sandwich constructions did not seriously increase in weight except for those having plywood facings and those having porous glass-cloth facings that permitted water to fill the cells of the core. Absorption of water through the faces could be minimized in actual practice, of course, by using void-free laminate facings or by sealing the surfaces with a suitable coating.

Water Immersion

Most of the sandwich constructions tested were adversely affected by the water immersion exposure, being reduced in tensile and edgewise compressive strength more than by any of the other exposures. The results of the tensile strength tests illustrated this fact more clearly, perhaps, than did the edgewise compression tests, as the losses in strength were of greater magnitude under the tensile forces. Various data in tables 7 and 8 indicate that the strength of some of the constructions increased as a result of water immersion. This, however, is not considered to be the case, but rather indicates that the control values did not accurately present the strength of the whole sandwich panel. Variations within any one panel were considerable even though specimens had been selected at random from various portions of the original panels. Tables 7 and 8 give detailed data on the ability of various combinations to withstand water immersion.

High-temperature Exposure

The specimens of all sandwich constructions were heated to 200° F. and hold at that temperature for 240 hours prior to test. The results of these tests were similar to those reported in part A for the core materials. In most cases, the resin-impregnated honeycomb-core materials appeared to become somewhat softened at the 200° F. temperature, reducing the strength of the sandwich in both tension and edgewise compression. Upon reconditioning these specimens to approximate weight equilibrium with 65 percent relative humidity and 75° F. the resin in the paper-honeycomb-core specimens seemed to have been given an additional cure with corresponding higher strength properties.

High-humidity Exposure

The results obtained from the tests of specimens following this exposure were very similar to those of the 24-hour immersion in water. In some cases the high humidity did not reduce the strength of the materials so seriously as did immersion. In general, the tensile strength of specimens having glass-cloth honeycomb cores, however, was more affected by the high humidity than by water immersion in all but three combinations. The recovery following exposure was again similar to the immersion tests.

Cyclic Exposures

The specimens in this group were subjected to 1, 5 or 10 cycles of alternate high and low temperatures combined with high and low relative humidities. It might be expected that this exposure would be more severe than some of the others, but this is not indicated in the results of the tests. The order in which tho specimens were exposed to the humidities and temperatures may, in part, explain the apparently minor effect of the exposure on these sandwich materials. The high temperatures and humidities were applied at the early part of the cycle, followed by low temperature and humidity, a sequence that in effect produced a final specimen that had been dried and cooled prior to test. If the order of exposure had been reversed, considerable reduction in strength might have been noted. There was a slight indication that additional cycles of exposure may slightly reduce the strength properties of the materials.

Weathering exposure

The type-A panels were exposed to the weather for 12 months, being removed from the racks at the end of each 3-month interval for observation. A summary of the weather conditions during this period is presented in table 11.

Visual Observation.--Very little effect was observed from visual examination of the test panels. In most cases no delamination between the facings and cores was noticeable, but the actual effect of weathering on the strength of tho glue bond had to bo determined by other methods. Warp was tho most predominant change in the sandwich panels and this was very noticeable in panels with plywood facings. Differences between panels having protected and unprotected edges could not be distinguished visibly.

The results of the strength tests following the 12-month exposure (tables 8 and 10) were quite variable, and it is difficult to present conclusive effects from the data available. There was no definite indication that the strength properties of specimens cut from panels having protected edges were better than those of specimens cut from panels having unprotected edges.

The panels having plywood facings were seriously affected by the weather, being badly cupped and twisted after three months of exposure (table 9). The panels having glass-cloth facings were more subject to deformation after exposure than were the aluminum panels. The latter, however, were more responsive to temperature differentials between the two facings of the sandwich.

The only constructions having poor weight stability were the panels having plywood facings and the sandwich construction of balsa core and glass-cloth facings. The glass-cloth facings, in this case, did not prevent moisture from reaching the balsa, and consequently the specimens were highly responsive to moisture conditions by gaining or losing considerable weight. Sealing tho edges of the type-A panels with moisture-resistant tape and paint did not appear to affect the weight or dimensional stability of the honeycomb-core sandwich materials.

APPENDIX I

Description of Resins and Adhesives

Note 1. Resin A. A high–temperature–setting, high–viscosity, contact–pressure, laminating resin of the polyester type.

Note 2. Resin B. A high–temperature–setting, low–viscosity, laminating resin of the styrene monomer, polyester type.

Note 3. Resin C. A high–temperature–setting, high–viscosity, contact–pressure, laminating resin of the polyestor type.

Note 4. Resin D. A high–temperature–setting, low–viscosity, contact–pressure, laminating resin of the polyester type.

Note 5. Adhesive F. A high–temperature–setting, modified thermoplastic metal–to–metal adhesive.

Note 6. Adhesive G. A high–temperature–setting, two–component resin with a thermosetting liquid and thermoplastic powder.

Note 7. Adhesive J. A high–temperature–setting mixture of thermoplastic and thermosetting resins.

Note 8. Adhesive L. A high–temperature–setting mixture of a thermosetting resin and synthetic rubber.

Note 9. Adhesive M. A high–temperature–setting mixture of the thermosetting resin and synthetic rubber.

Note 10. Adhesive N. A high–temperature–setting acid–catalyzed, phenolic resin.

Note 11. Adhesive T. A high–temperature–setting phenolic resin adhesive.

Table 1.--Compressive strength and modulus of elasticity of four honeycomb core materials subjected to four controlled exposure conditions[1]

Exposure conditions	Compressive strength-free ends (3 tests)	Compressive strength-plastered ends (3 tests)	Average compressive strength (6 tests)	Modulus of elasticity-free ends (3 tests)	Modulus of elasticity-plastered ends (3 tests)	Average modulus of elasticity (6 tests)
	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.
A.--Paper honeycomb -- Apparent specific gravity = 0.104						
Controls	559	692	626	70,670	80,670	75,670
24-hour water immersion	232	382	307	24,200	45,170	34,685
40-day water immersion	230	210	220	29,170	25,500	27,335
40-day water immersion and reconditioned	527	525	526	77,930	70,970	74,450
200° F. for 10 days	311	369	340	53,270	50,530	51,900
200° F. for 10 days and reconditioned	789	833	811	96,270	88,230	92,250
Equilibrium at 97 percent relative humidity	311	306	308	30,630	38,930	34,775
Equilibrium at 97 percent relative humidity and reconditioned	548	585	566	73,130	67,030	70,080
One cycle[2]	643	811	727	84,370	96,070	90,220
Five cycles[2]	617	746	682	84,130	87,230	85,680
Ten cycles[2]	604	793	698	80,100	85,270	82,685
Ten cycles and reconditioned[2]	620	669	644	79,830	72,930	76,380
B.--Glass cloth honeycomb -- Apparent specific gravity = 0.118						
Controls	247	497	372	81,600	93,130	87,365
24-hour water immersion	182	406	294	70,800	82,430	76,615
40-day water immersion	156	354	255	85,130	77,570	81,350
40-day water immersion and reconditioned	330	487	408	93,650	94,500	94,075
200° F. for 10 days	102	224	163	71,970	62,790	67,380
200° F. for 10 days and reconditioned	347	568	458	110,970	95,200	103,085
Equilibrium at 97 percent relative humidity	163	402	282	72,930	79,750	76,340
Equilibrium at 97 percent relative humidity and reconditioned	303	519	411	112,330	98,500	105,415
One cycle[2]	229	519	374	94,430	101,270	97,850
Five cycles[2]	261	519	390	92,450	93,520	92,985
Ten cycles[2]	203	412	308	90,630	76,170	83,400
Ten cycles and reconditioned[2]	249	366	308	86,670	74,600	80,635

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Table 1.--compressive strength and modulus of elasticity of four honeycomb core materials subjected to four controlled exposure conditions[1] (continued)

Exposure conditions	Compressive strength-free ends (3 tests)	Compressive strength-plastered ends (3 tests)	Average compressive strength (6 tests)	Modulus of elasticity-free ends (3 tests)	Modulus of elasticity plastered ends (3 tests)	Average modulus of elasticity (6 tests)
	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.
C.--Cotton cloth honeycomb -- Apparent specific gravity = 0.084						
Controls	305	316	311	29,900	29,100	29,500
24-hour water immersion	236	254	245	19,800	23,000	21,400
40-day water immersion	256	254	255	23,400	23,100	23,300
40-day water immersion and reconditioned	292	309	301	28,900	29,700	29,300
200° F. for 10 days	370	327	349	28,400	28,800	28,600
200° F. for 10 days and reconditioned	306	390	348	29,300	29,800	29,600
Equilibrium at 97 percent relative humidity	268	265	267	20,000	19,200	19,600
Equilibrium at 97 percent relative humidity and reconditioned	248	326	287	25,200	27,800	26,500
One cycle[2]	279	317	298	25,900	30,100	28,000
Five cycles[2]	260	314	287	27,100	30,800	29,000
Ten cycles[2]	230	326	278	24,300	23,500	23,900
Ten cycles and reconditioned[2]	262	338	300	26,500	25,900	26,200
D.--Aluminum foil honeycomb -- Apparent specific gravity = 0.071						
Controls	195	312	262	25,600	28,000	26,900
24-hour water immersion	174	274	224	25,300	25,100	25,200
40-day water immersion	179	249	214	23,900	22,100	23,500
40-day water immersion and reconditioned	179	275	227	21,300	24,900	23,100
200° F. for 10 days	150	247	198	21,400	21,100	21,300
200° F. for 10 days and reconditioned	175	262	218	24,400	22,900	23,600
Equilibrium at 97 percent relative humidity	166	283	224	22,000	23,300	22,500
Equilibrium at 97 percent relative humidity and reconditioned	155	277	216	24,100	21,100	22,600
One cycle[2]	174	306	240	24,600	21,800	23,200
Five cycles[2]	226	330	278	28,800	23,500	26,200
Ten cycles[2]	202	316	259	22,900	21,100	22,000
Ten cycles and reconditioned[2]	176	328	252	27,600	21,000	24,300

[1] All specimens initially in equilibrium with 75° F. and 65 percent relative humidity.

[2] One cycle consists 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.

Table 2.-—Change in weight of honeycomb core specimens exposed to various fungi[1]

Exposure period and material	Weight change when exposed to				
	Poria monticola	*Poria incrassata*	*Polyporus versicolor*	65 percent relative humidity	Sterile agar
	Percent	Percent	Percent	Percent	Percent
1-Month Exposure:					
Paper honeycomb	[2]+0.26	[2]-0.11	[2]-3.35	+0.02	[3]+0.73
Glass-cloth honeycomb	+ .29	+ .74	+ .09	+ .04	+ .07
Cotton-cloth honeycomb	+1.37	+2.45	- .80	+ .02	+ .53
2-Month Exposure:					
Paper honeycomb	[2]- .61	[2]-2.97	[2]-2.93	+ .05	[3]+ .25
Glass-cloth honeycomb	- .21	- .29	- .55	+ .04	- .31
Cotton-cloth honeycomb	[2]+ .57	[2]+1.00	[2]-3.95	+ .11	+ .93
3-Month Exposure:					
Paper honeycomb	-1.96	-6.86	-4.57	- .51	+ .06
Glass-cloth honeycomb	[2]- .43	[2]- .41	[2]- .72	- .30	- .35
Cotton-cloth honeycomb	[2]- .15	[2]- .05	[2]-4.43	- .14	+1.05

[1]Based on conditioned weight at 65 percent relative humidity and 80° F. before and after exposure. Average of 5 specimens except where otherwise noted. Minus sign indicates loss in weight, plus sign a gain in weight.

[2]Adjusted change in weight.

[3]Average of four specimens.

Table 3.--Results of flammability tests on three honeycomb-core materials[1]

Type of material	Axis of cells	Time for flame to travel 3 inches	Rate of burning	Comments
		Minutes	Inches per minute	
Paper-honeycomb core - 3/16-inch cell size	Horizontal	0.16		Considerable black smoke during burning. Specimens reduced to ash.
	...do.....	.16		
	...do.....	.09		
		Av. .14	21	
	Vertical	.13		
	...do.....	.11		
	...do.....	.13		
		Av. .12	25	
Glass-cloth honeycomb core - 3/16-inch cell size	Horizontal	.67		Considerable black smoke during burning. Specimens intact after test, only resin burned off.
	...do.....	.48		
	...do.....	.64		
		Av. .60	5	
	Vertical	(2)		(2-1/2-inch flame spread)
	...do.....	.68		
	...do.....	.85		
		Av. .76	4	
Cotton-cloth honeycomb core - 7/16-inch cell size	Horizontal	.59		
	...do.....	(3)		(2-inch flame spread)
	...do.....	(3)		(2-1/2-inch flame spread)
		Av. ---		
	Vertical	(3)		(2-inch flame spread)
	...do.....	(3)		(1-inch flame spread)
	...do.....	(3)		(1-inch flame spread)
		Av. ---		Small amount of black smoke during burning Burned section reduced to ash.

[1]Specimens were 1/2 by 1/2 by 6 inches with the axis of the cells in the 1/2-inch direction. Tested in accordance with method No. 2021 of L-P-406a, "Federal Specifications, Test Methods."

[2]Flame did not travel 3 inches during first exposure to flame. During second exposure, no ignition occurred due to resin having been consumed by fire at fire end of specimen.

[3]Flame did not travel 3 inches during first exposure. No second test was made because specimen had bent to such an extent that free end could not be located in flame under requirements of specification.

Table 4.--Weight and dimensional changes of three honeycomb-core materials exposed to various liquids

Core material[1]	Liquid	Average gain in weight[2]		Average gain in thickness[3]		Average gain in width[3]		Average gain in length[3]	
		After soaking for 7 days	After soaking 7 days and conditioning for 39 days	After soaking for 7 days	After soaking 7 days and conditioning for 39 days	After soaking for 7 days	After soaking 7 days and conditioning for 39 days	After soaking for 7 days	After soaking 7 days and conditioning for 39 days
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Paper honeycomb	Iso-propyl alcohol	+18.2	-0.9	+0.81	+1.01	+0.29	+0.39	-0.17	+0.23
Glass-cloth honeycomb		+18.1	-0.4	+1.12	+0.37	+0.29	+0.19	+0.23	+0.07
Cotton-cloth honeycomb		+31.8	+0.1	-1.31	+0.38	-1.14	-0.09	+1.13	+0.20
Paper honeycomb	Ethylene glycol	+51.9	+0.8	+1.21	+0.20	-0.39	+0.10	+0.73	+0.10
Glass-cloth honeycomb		+32.4	-0.5	-0.37	+0.56	-0.68	+0.39	-0.07	+0.07
Cotton-cloth honeycomb		+57.9	+0.7	+1.49	+0.74	-2.86	+0.36	+0.30	-1.02
Paper honeycomb	3580-Oleo fluid (petroleum base)	+40.9	+16.3	+0.40	+0.20	+0.10	+0.39	+0.07	+0.03
Glass-cloth honeycomb		+19.0	+ 0.7	-0.74	+0.19	0.0	0.0	+0.10	+0.10
Cotton-cloth honeycomb		+35.8	+ 9.3	+0.76	+0.95	+0.09	+0.26	-0.36	+0.03
Paper honeycomb	3586-Oleo fluid (castor-oil base)	+62.2	+3.5	+0.60	+1.01	-0.29	+0.29	+0.43	+0.33
Glass-cloth honeycomb		+37.1	+3.0	+0.74	+0.19	-0.20	+0.40	+0.40	+0.20
Cotton-cloth honeycomb		+56.0	+15.9	+0.56	+1.12	-1.71	-0.68	+0.26	+0.03
Paper honeycomb	100-octane gasoline	+ 9.3	- 2.5	+0.20	+1.01	-0.10	+0.29	+0.10	+0.17
Glass-cloth honeycomb		+ 7.9	- 0.03	+2.26	+2.07	0.0	+0.10	+0.10	+0.17
Cotton-cloth honeycomb		+21.7	+0.16	+0.19	+1.14	+0.26	+0.52	+0.33	+0.30
Paper honeycomb	Used crankcase oil	+123.9	+5.7	0.0	0.0	+0.19	+0.19	+0.16	+0.10
Glass-cloth honeycomb		+ 89.9	+2.8	+1.88	+2.07	+0.29	+1.27	+0.10	+0.30
Cotton-cloth honeycomb		+105.6	+17.0	-0.38	+1.12	0.0	+0.18	+0.07	+0.20
Paper honeycomb	Water	+ 54.8	-1.0	+2.02	+0.81	-3.33	+0.39	+2.97	+0.33
Glass-cloth honeycomb		+ 22.1	-0.3	+2.63	+2.25	+1.46	+0.19	-0.03	+0.23
Cotton-cloth honeycomb		+ 49.4	+0.1	+1.33	+1.90	+2.99	+0.18	-1.10	-0.23

[1]Dimensions of test specimens - thickness 1/2 inch, width 1 inch, length 3 inches.

[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.

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Table 5.—Description of durability-test panels

Panel number	Facing construction	Type of core	Adhesive or resin[1]
P1A and P1B	8 plies glass cloth[2]	Paper honeycomb	Resin A
P2A and P2B	do.	do.	Resin B
P3A and P3B	do.	do.	Resin C
P4A and P4B	(Omitted)		
P5A and P5B	8 plies glass cloth	do.	Resin D
P6A and P6B	0.020-inch aluminum	do.	Adhesive G
P7A and P7B	do.	do.	Adhesive F
P8A and P8B	do.	do.	Adhesive L
P9A and P9B	do.	do.	Adhesive J
P10A and P10B	do.	do.	Adhesive M+N
P11 and P11B	0.070-inch birch plywood	do.	Adhesive N
F1A and F1B	8 plies glass cloth	Glass cloth honeycomb	Resin A
F2A and F2B	do.	do.	Resin B
F3A and F3B	do.	do.	Resin C
F4A and F4B	(Omitted)		
F5A and F5B	8 plies glass cloth	do.	Resin D
F6A and F6B	0.020-inch aluminum	do.	Adhesive G
F7A and F7B	do.	do.	Adhesive F
F8A and F8B	do.	do.	Adhesive L
F9A and F9B	do.	do.	Adhesive J
F10A and F10B	do.	do.	Adhesive M+N
F11A and F11B	0.070-inch birch plywood	do.	Adhesive N
CH1A and CH1B	8 plies glass cloth	Cotton honeycomb	Resin A
CH2A and CH2B	do.	do.	Resin B
CH3A and CH3B	do.	do.	Resin C
CH4A and CH4B	(Omitted)		
CH5A and CH5B	8 plies glass cloth	do.	Resin D
CH6A and CH6B	0.020-inch aluminum	do.	Adhesive G
CH7A and CH7B	do.	do.	Adhesive F
CH8A and CH8B	do.	do.	Adhesive L
CH9A and CH9B	do.	do.	Adhesive J
CH10A and CH10B	do.	do.	Adhesive M+N
CH11A and CH11B	0.070-inch birch plywood	do.	Adhesive N

[1]See Appendix I.

[2]Glass cloth No. 112-114.

Table 6.--Weight and thickness changes of various sandwich constructions subjected to four controlled exposure conditions

Sandwich construction: Facings	Sandwich construction: Core	Bond symbol[1]	24-hour water immersion: Change in weight	24-hour water immersion: Change in thickness	40-day water immersion: Change in weight	40-day water immersion: Change in thickness	40-day water immersion and reconditioned: Change in weight	40-day water immersion and reconditioned: Change in thickness	200° F. for 10 days: Change in weight	200° F. for 10 days: Change in thickness	Equilibrium at 97 percent relative humidity: Change in weight	Equilibrium at 97 percent relative humidity: Change in thickness	97 percent relative humidity and reconditioned: Change in weight	97 percent relative humidity and reconditioned: Change in thickness	One cycle[3]: Change in weight	One cycle[3]: Change in thickness	Five cycles[3]: Change in weight	Five cycles[3]: Change in thickness	Ten cycles[3]: Change in weight	Ten cycles[3]: Change in thickness	Ten cycles[3] and reconditioned: Change in weight	Ten cycles[3] and reconditioned: Change in thickness
			Percent	In.	Percent	In.	Percent	In.	Percent	In.	Percent	In.	Percent	In.	Percent	In.	Percent	In.	Percent	In.	Percent	In.
Eight-ply glass cloth	Paper honeycomb	A	9.30	0.002	15.22	0.004	0.52	0.000	-2.21	0.000	1.93	0.001	0.43	-0.002	-0.49	-0.002	-0.79	-0.002	-0.72	0.000	+0.14	+0.001
Do.	do.	B	17.20	.000	42.38	.003	.52	-.001	-2.08	.000	2.37	.005	.50	.000	-.40	-.001	-.82	-.001	-.79	.000	+.04	-.002
Do.	do.	C	9.72	.002	26.08	.006	.36	.000	-2.14	-.002	2.60	.004	.45	.000	-.74	-.003	-1.21	-.005	-1.21	-.002	+.16	-.001
Do.	do.	D	11.02	.000	21.20	.005	.17	.000	-2.38	-.002	3.23	.004	.26	.000	-.81	-.002	-1.24	-.003	-1.46	.000	+.01	.000
0.020-inch aluminum	do.	G	6.92	.000	11.65	.001	.38	.002	-2.04	.000	2.78	.002	.62	.000	-.26	-.002	-.88	-.003	-1.10	.000	-.42	-.002
Do.	do.	F	46.08	.002	44.15	.002	.42	.000	-1.41	.000	1.38	.003	.38	.000	-.16	-.001	-.48	-.002	-.63	-.001	+.03	-.001
Do.	do.	L	16.08	.001	21.22	.004	.56	.004	-1.25	.000	1.53	.006	.37	.001	-.04	.000	-.33	.000	-.42	.000	+.06	.001
Do.	do.	J	56.60	.002	81.55	.003	1.06	.001	-1.91	.001	1.42	.006	-.01	.001	-.59	.000	-1.00	-.001	-1.20	.000	+.28	.000
Do.	do.	M+N	43.22	.001	54.08	.003	3.18	.002	-2.06	.000	1.95	.006	.28	.002	-.60	-.002	-1.05	-.001	-1.02	-.001	-.05	-.001
0.070-inch birch plywood	do.	N	43.62	.007	74.32	.016	.98	.005	-5.77	-.006	10.96	.016	1.75	.014	-2.94	.000	-3.83	-.002	-3.28	+.001	+.16	.000
Eight-ply glass cloth	Glass-cloth honeycomb	A	81.28	.002	87.40	.003	.40	.001	-1.60	-.001	2.04	.004	.42	.000	-.44	.000	-.78	-.003	-.79	-.003	.26	.001
Do.	do.	B	93.02	.002	95.98	.005	.42	.000	-1.49	.000	1.54	.002	.38	.001	-.36	.002	-.65	.000	-.69	-.001	.18	.000
Do.	do.	C	62.62	-.002	68.62	.000	.36	-.004	-1.62	-.001	2.37	.002	.42	.000	-.54	.004	-.85	.000	-.80	.000	.15	.002
Do.	do.	D	70.65	.002	75.18	.002	-.37	.000	-2.08	-.001	3.62	.001	-.92	.002	-.52	.002	-1.18	.000	-1.70	-.001	-.48	-.001
0.020-inch aluminum	do.	G	34.58	.002	44.72	.003	1.76	.002	-1.41	-.001	3.31	.002	.75	.001	-.68	.000	-.92	-.002	-.86	-.001	.01	-.001
Do.	do.	F	82.82	.002	98.90	.002	2.45	.000	-.88	.000	1.28	.002	.46	.000	-.24	.000	-.51	-.001	-.70	.000	-.10	.000
Do.	do.	L	54.68	.000	71.38	.002	.45	-.001	-.92	.001	1.33	.002	.30	.000	-.12	.000	-.27	-.002	-.22	.000	.36	.000
Do.	do.	J	53.15	.001	67.25	.002	4.44	.000	-1.26	.000	1.45	.000	.29	-.001	-.73	.000	-.98	-.002	-1.13	.000	-.30	.000
Do.	do.	M+N	62.00	.001	71.30	.004	.42	.002	-1.31	.000	2.34	.003	.42	.000	.60	-.001	-.94	-.001	-.99	.000	-.04	.000
0.070-inch birch plywood	do.	N	88.15	.011	92.18	.017	.46	.004	-5.23	-.005	10.02	.014	1.64	.006	-2.49	-.002	-3.53	-.003	-3.44	-.002	.04	.000
Eight-ply glass cloth	Cotton-cloth honeycomb	A	60.65	.0015	103.35	.003	-.16	.0005	-1.96	-.002	1.40	.005	.26	.002	-.56	.002	-.8[illegible]	-.002	-.72	-.002	+.24	.001
Do.	do.	B	120.45	.002	178.80	.004	.64	.001	-1.65	-.001	1.44	.004	.30	.001	-.41	.002	-.75	-.002	-.46	.000	+.20	.000
Do.	do.	C	107.35	.002	81.90	.004	.37	.001	-2.16	-.002	1.35	.004	.12	.002	-.27	.003	-.97	-.002	-.57	.002	+.14	.000
Do.	do.	D	90.42	.002	125.48	.005	-.85	-.001	-2.38	-.003	1.34	.004	.06	.002	-.33	.003	-1.42	-.001	-1.80	-.001	-.76	.001
0.020-inch aluminum	do.	G	95.30	.002	108.50	.005	.42	.002	-1.41	-.002	2.23	.004	.60	.002	-.09	.001	-.47	-.004	-.32	-.003	+.49	-.003
Do.	do.	F	93.62	.002	71.88	.004	.25	.002	-1.24	-.002	.56	.006	.11	.004	+.16	.004	-.11	-.001	-.10	.000	+.24	+.001
Do.	do.	L	133.92	.005	111.65	.006	.28	.001	-1.14	-.002	.62	.004	.02	.006	+.06	.004	-.20	-.002	-.14	-.001	+.22	.000
Do.	do.	J	104.55	.003	114.12	.007	.38	.001	-1.40	-.002	.97	.004	.32	.001	-.35	.004	-.63	-.002	-.66	.000	+.005	.000
Do.	do.	M+N	73.96	.003	65.95	.005	.37	.001	-1.66	-.003	1.85	.004	.12	.002	-.31	.000	-.74	-.003	-.82	-.003	+.18	.000
0.070-inch birch plywood	do.	N	128.08	.018	144.58	.020	1.12	.008	-6.78	-.006	11.91	.017	1.84	.004	-2.60	.001	-4.32	-.002	-3.86	-.001	+.16	+.005
0.020-inch aluminum	Aluminum honeycomb	J	4.84	.000	9.66	-.001	2.54	.000	-.23	.001	.12	.001	-.26	.000	.34	.000	-.30	.001	.13	.000	-.05	.001

[1]See Appendix I.

[2]All specimens originally conditioned to 75° F., 65 percent relative humidity.

[3]One cycle consisted of 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.

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Table 7.--Tensile strength of various sandwich constructions subjected to four controlled exposure conditions[1]

Sandwich construction: Facings	Core	Bond symbol[2]	Controls: Average strength	Controls: Core failure	24-hour water immersion: Percent of control strength	24-hour water immersion: Core failure	40-day water immersion: Percent of control strength	40-day water immersion: Core failure	40-day water immersion, reconditioned[1]: Percent of control strength	40-day water immersion, reconditioned[1]: Core failure	200° F. for 10 days: Percent of control strength	200° F. for 10 days: Core failure	200° F. for 10 days, reconditioned[1]: Percent of control strength	200° F. for 10 days, reconditioned[1]: Core failure	Equilibrium at 97 percent relative humidity: Percent of control strength	Equilibrium at 97 percent relative humidity: Core failure	97 percent relative humidity, reconditioned[1]: Percent of control strength	97 percent relative humidity, reconditioned[1]: Core failure	One cycle[3]: Percent of control strength	One cycle[3]: Core failure	Five cycles[3]: Percent of control strength	Five cycles[3]: Core failure	Ten cycles[3]: Percent of control strength	Ten cycles[3]: Core failure	Ten cycles[3], reconditioned[1]: Percent of control strength	Ten cycles[3], reconditioned[1]: Core failure
			P.s.i.	Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent		Percent
Eight-ply glass cloth	Paper honeycomb	A	319	49	96	61	61	0	77	3	77	43	82	64	64	1	72	24	114	61	103	60	95	83	78	60
Do.	do.	B	292	0	54	0	24	0	56	0	50	4	65	2	29	0	55	0	46	0	53	1	59	16	36	2
Do.	do.	C	272	5	61	1	30	0	86	0	56	0	94	46	55	0	77	2	109	0	83	0	73	1	51	2
Do.	do.	D	154	0	73	0	31	0	116	0	58	0	81	0	51	0	121	2	128	6	103	0	53	0	34	1
0.020-inch aluminum	do.	G	391	78	94	90	71	33	105	82	78	100	93	100	79	83	107	67	110	100	92	98	92	100	76	100
Do.	do.	F	278	32	96	29	48	31	126	30	25	1	116	86	73	27	82	30	80	30	92	50	82	58	75	68
Do.	do.	L	49	0	122	0	112	0	184	18	137	0	292	7	131	1	167	3	267	3	304	15	239	4	192	11
Do.	do.	H+N	131	24	99	13	148	38	176	25	145	11	188	63	80	7	147	12	149	28	167	48	179	59	121	46
0.070-inch birch plywood	do.	N	402	49	64	38	59	45	84	40	65	68	79	90	65	67	94	42	81	59	67	72	43	90	51	78
Eight-ply glass cloth	Glass-cloth honeycomb	A	549	0	71	0	62	0	86	0	79	0	84	0	58	0	69	0	83	0	69	0	66	0	60	0
Do.	do.	B	568	0	85	0	51	0	83	0	64	0	98	0	48	0	76	0	102	0	91	0	82	0	64	0
Do.	do.	C	441	0	96	0	53	0	102	0	86	0	120	0	56	0	74	0	102	0	91	0	75	0	64	0
Do.	do.	D	274	0	60	0	54	0	142	2	88	33	177	0	42	0	105	0	184	0	133	0	105	0	66	0
0.020-inch aluminum	do.	G	624	1	73	0	87	12	98	17	83	0	100	15	82	6	86	5	98	3	84	7	82	8	77	8
Do.	do.	F	327	1	83	0	73	5	96	15	46	0	98	34	70	22	101	36	92	12	107	23	108	10	101	17
Do.	do.	L	109	2	136	0	120	0	197	0	191	0	304	5	108	3	163	0	196	7	362	18	206	7	207	8
Do.	do.	J	390	1	89	0	96	0	117	7	106	0	121	7	75	2	84	0	111	0	147	2	128	10	102	6
Do.	do.	H+N	163	0	37	1	50	4	64	2	110	0	100	5	77	8	89	2	85	3	91	3	94	12	94	8
0.070-inch birch plywood	do.	N	367	0	35	0	40	15	78	9	76	0	89	0	63	10	78	5	79	0	58	2	46	11	44	10
Eight-ply glass cloth	Cotton-cloth honeycomb	A	212	1	105	0	56	0	77	0	70	0	87	27	62	0	73	0	88	0	79	0	64	1	54	2
Do.	do.	B	147	0	116	0	67	0	138	0	100	1	127	0	46	0	95	0	112	0	80	0	76	1	59	0
Do.	do.	C	97	1	67	0	55	0	125	2	89	2	106	3	79	2	74	0	71	0	80	1	66	2	61	5
Do.	do.	D	107	0	53	0	37	0	150	2	70	0	125	5	49	0	102	0	120	0	79	0	77	9	71	23
0.020-inch aluminum	do.	G	149	28	67	0	83	8	97	17	105	48	106	50	81	0	74	0	87	25	93	40	60	0	85	47
Do.	do.	F	102	3	71	1	52	32	114	37	76	2	74	38	84	42	83	20	103	52	85	30	89	48	49	37
Do.	do.	L	63	0	83	8	33	3	143	3	100	4	164	35	95	19	137	11	121	25	145	35	122	38	142	23
Do.	do.	J	84	16	88	0	39	8	132	8	86	3	99	16	95	13	64	0	117	57	101	38	95	12	101	33
Do.	do.	H+N	88	2	106	1	39	0	80	0	99	9	97	6	105	2	130	3	141	6	97	10	77	18	83	23
0.070-inch birch plywood	do.	N	161	14	88	0	....	2	115	15	85	52	93	43	76	7	106	14	94	23	98	23	82	59	104	45
0.020-inch aluminum	Aluminum honeycomb	J	175	7	114	13	97	8	101	0	149	19	132	13	103	2	90	0	85	7	91	7	82	13	....	.....

[1]Each figure represents the average results of six to nine individual tests. All specimens initially in equilibrium with 75° F. and 65 percent relative humidity.

[2]See Appendix I for description of resins and adhesives.

[3]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.

Table 8.--Edgewise compressive strength of various sandwich construcitons subjected to four controlled exposures and to weathering

Sandwich construction: Facing	Sandwich construction: Core	Bond symbol[1]	Controls: High	Controls: Low	Controls: Average of tests	Water immersion for 40 days	Water immersion for 40 days, reconditioned	200° F. for 10 days	200° F. for 10 days, reconditioned	97 percent relative humidity	97 percent relative humidity, reconditioned	Ten cycles[2]	Ten cycles,[2] reconditioned	Weathered for 12 months, reconditioned--small plates	Weathered for 12 months, reconditioned--large plates edges sealed	Weathered for 12 months, reconditioned--large plates edges unsealed
			Lb. per in. of width	Lb. per in. of width	Lb. per in. of width	Percent of control strength	Percent of control strength	Percent of control strength	Percent of control strength	Percent of control strength	Percent of control strength	Percent of control strength	Percent of control strength	Percent of control strength	Percent of control strength	Percent of control strength
Eight-ply glass cloth	Paper honeycomb	A	892	717	791	57	92	72	98	75	81	86	82	76	117	119
Do.	do.	B	1,007	847	916	57	86	52	83	66	82	70	62	87	103	105
Do.	do.	C	994	505	711	43	79	53	95	42	72	80	57	94	113	98
Do.	do.	D	386	259	328	71	158	85	143	52	125	136	86	148	147	171
0.020-inch aluminum	do.	G	2,278	1,620	2,014	105	108	86	116	110	[illegible]	94	116	105	106	108
Do.	do.	F	1,935	294	1,410	92	98	80	112	108	107	91	95	107	79	123
Do.	do.	L	1,475	752	1,206	55	71	30	87	74	59	82	76	109	127	102
Do.	do.	J	2,110	1,013	1,518	67	60	84	47	90	67	42	88	98	127	134
Do.	do.	M+N	2,106	609	1,624	85	73	69	62	87	87	76	82	69	126	128
0.070-inch birch plywood	do.	N	1,056	988	1,024	39	78	91	83	47	75	101	82	83	93	91
Eight-ply glass cloth	Glass cloth honeycomb	A	1,155	843	982	70	96	86	94	83	79	92	72	81	107	114
Do.	do.	B	1,324	863	1,105	65	87	41	94	70	79	67	61	80	88	83
Do.	do.	C	900	686	820	64	90	57	107	62	77	66	67	100	101	110
Do.	do.	D	511	337	437	44	111	59	108	26	72	76	44	155	140	153
0.020-inch aluminum	do.	G	1,886	1,138	1,529	148	160	119	168	145	158	164	156	155	131	112
Do.	do.	F	1,741	850	1,223	140	162	59	184	148	163	142	160	139	121	120
Do.	do.	L	1,471	513	1,158	105	120	61	....	109	113	140	129	124	94	92
Do.	do.	J	1,598	955	1,319	148	148	117	184	152	146	140	160	136	131	131
Do.	do.	M+N	1,736	917	1,346	91	99	80	98	83	91	84	100	120	115	127
0.070-inch birch plywood	do.	N	1,278	1,014	1,145	35	71	84	71	42	68	90	69	74	104	99
Eight-ply glass cloth	Cotton-cloth honeycomb	A	906	497	744	66	87	70	102	61	77	95	90	88	92	86
Do.	do.	B	840	590	712	73	99	46	105	77	86	93	68	90	89	104
Do.	do.	C	670	525	590	58	84	87	99	71	89	105	83	89	106	106
Do.	do.	D	464	365	420	47	95	68	134	33	85	105	51	135	178	123
0.020-inch aluminum	do.	G	841	444	662	171	204	136	215	180	197	215	202	218	134	135
Do.	do.	F	820	509	676	138	136	83	135	137	156	162	136	178	120	116
Do.	do.	L	641	391	495	113	148	106	201	130	128	170	152	166	123	103
Do.	do.	J	1,007	506	846	136	145	92	....	153	150	155	147	162	119	118
Do.	do.	M+N	927	524	779	120	139	95	155	132	161	150	157	182	112	117
0.070-inch birch plywood	do.	N	1,074	950	1,027	36	64	81	82	41	62	79	74	59	89	90
0.020-inch aluminum	Aluminum honeycomb	J	1,854	934	1,436	....	119	....	128	....	125	....	124	113	83	91

[1] See Appendix I.

[2] One cycle consisted of the following treatment: 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.

Table 9.--Effect of exposure to weather on weight, thickness and flatness of various sandwich constructions

Sandwich construction: Facing	Sandwich construction: Core	Bond symbol[1]	Change after 3 months: Weight	Change after 3 months: Thickness	Change after 3 months: Amount of warp: Cupping[2]	Change after 3 months: Amount of warp: Twist[3]	Change after 6 months: Weight	Change after 6 months: Thickness	Change after 6 months: Amount of warp: Cupping[2]	Change after 6 months: Amount of warp: Twist[3]	Change after 9 months: Weight	Change after 9 months: Thickness	Change after 9 months: Amount of warp: Cupping[2]	Change after 9 months: Amount of warp: Twist[3]	Change after 12 months: Weight	Change after 12 months: Thickness	Change after 12 months: Amount of warp: Cupping[2]	Change after 12 months: Amount of warp: Twist[3]	Change after 12 months and reconditioning to 75° F., and 65 percent relative humidity: Weight	Change after 12 months and reconditioning: Thickness	Change after 12 months and reconditioning: Amount of warp: Cupping[2]	Change after 12 months and reconditioning: Amount of warp: Twist[3]
			Percent	In.	In.	In.	Percent	In.	In.	In.	Percent	In.	In.	In.	Percent	In.	In.	In.	Percent	In.	In.	In.
Glass cloth	Paper honeycomb	A	0.3	0.000	0.029	0.011	0.7	-0.001	0.038	0.017	0.6	0.002	0.028	0.017	0.5	0.001	0.012	0.014	0.1	0.000	0.032	0.011
Do.	do.	B	.2	-.003	-.003	.107	.6	-.005	.006	.117	.7	-.002	-.006	.097	.8	-.003	-.011	.095	.4	-.004	.004	.012
Do.	do.	C	.3	-.002	-.010	.073	1.1	-.004	.004	.084	.6	-.001	-.007	.050	.9	-.002	-.016	.028	.2	-.003	.004	.021
Do.	do.	D	-.2	-.002	-.030	.016	.4	-.001	-.021	.034	-.1	.000	-.032	.001	.0	-.004	-.028	.008	.0	.002	-.013	.017
Aluminum	do.	G	.7	-.005	-.001	.009	.7	-.006	-.001	.010	.8	-.004	.007	.010	1.1	-.006	.023	.014	.7	-.001	.006	.004
Do.	do.	F	.2	.000	-.004	.023	.3	.000	.000	.002	.5	.000	.003	.002	.4	.000	.016	.003	.3	.000	.002	.004
Do.	do.	L	.0	-.002	.004	.008	.1	-.001	.004	.006	.3	.000	.012	.009	.1	-.001	.023	.003	.2	-.001	.006	.005
Do.	do.	J	.8	-.001	.008	.003	1.1	.001	.003	.004	1.2	.002	.010	.008	1.3	.002	.030	.007	.8	.003	.006	.002
Do.	do.	K+N	1.6	.000	.002	.002	1.4	.000	.001	.002	1.4	.001	.004	.001	1.0	.000	.024	.000	.5	.000	.006	.003
Plywood	do.	N	.3	-.001	-.072	.219	2.6	.004	-.078	.198	-1.2	-.001	-.153	.322	-3.1	-.004	-1.89	.428	-1.8	-.004	.094	.199
Glass cloth	Glass-cloth honeycomb	A	2.1	-.002	-.000	.018	3.4	-.001	.008	.014	3.0	-.001	.001	.009	.9	-.002	-.006	.016	.2	-.001	.008	.003
Do.	do.	B	1.3	-.002	-.003	.022	1.2	-.003	.007	.027	.6	-.002	.003	.025	.4	-.004	-.001	.022	.1	-.004	.002	.014
Do.	do.	C	-.1	-.002	-.012	.044	.4	-.001	-.004	.042	.2	-.002	-.008	.031	.3	-.003	-.014	.042	.2	-.002	-.006	.011
Do.	do.	D	-.4	-.002	-.000	.021	-.2	-.001	.004	.044	-.3	-.003	-.002	.038	.2	-.002	-.001	.032	-.2	-.002	.006	.049
Aluminum	do.	G	.3	-.004	.009	.004	.5	-.003	.002	.002	1.3	-.001	.017	.005	.6	-.003	.021	.003	.4	-.003	.006	.004
Do.	do.	F	.3	-.001	.007	.013	3.2	.000	.003	.008	1.9	.002	.019	.013	.2	.000	.024	.015	2.5	.000	.004	.008
Do.	do.	L	-.1	-.002	.010	.003	-.1	-.002	.006	.006	.0	.000	.024	.001	-.1	-.003	.026	.003	.1	-.002	.006	.016
Do.	do.	J	-.1	-.001	.006	.003	.0	-.002	.002	.004	.2	-.001	.025	.005	-.1	-.003	.022	.006	-1.3	-.001	.007	.002
Do.	do.	M+N	3.2	-.003	.005	.001	2.3	.000	.003	.001	2.5	.002	.026	.006	-.2	-.002	.024	.006	.1	.000	.006	.000
Plywood	do.	N	2.2	.003	-.046	.007	2.2	.005	-.041	.024	-1.6	-.001	-.082	.036	-2.2	-.001	-.098	.049	-1.6	-.001	-.050	.035
Glass cloth	Cotton-cloth honeycomb	A	.0	-.002	-.004	.009	.7	-.002	.013	.004	.5	-.000	-.006	.002	.5	-.001	-.008	.011	.6	-.001	.011	.006
Do.	do.	B	.1	-.002	-.008	.055	2.4	-.003	.000	.064	.6	.000	-.006	.054	1.0	-.001	-.008	.066	.5	-.002	.000	.032
Do.	do.	C	-.2	-.006	-.012	.104	1.5	-.005	-.010	.101	.3	-.003	-.021	.096	.1	-.006	-.024	.123	.2	-.006	-.006	.012
Do.	do.	D	-.6	-.003	-.014	.043	1.7	-.001	-.006	.020	-.1	.000	-.018	.019	-.2	-.003	-.017	.012	-.2	-.003	-.010	.001
Aluminum	do.	G	.2	-.003	+.005	.001	.6	-.003	.002	.001	1.5	-.002	.020	.008	.1	-.005	.007	.004	.6	-.002	.005	.002
Do.	do.	F	.2	-.002	.005	.004	.4	-.002	.002	.002	.5	-.004	.016	.001	-.1	-.005	.018	.002	.4	-.005	.005	.008
Do.	do.	L	-.1	-.002	-.001	.025	-.1	-.001	-.000	.023	.1	.003	.008	.025	-.1	-.002	-.004	.026	.2	-.001	.000	.017
Do.	do.	J	3.7	-.002	.002	.010	1.2	-.002	.000	.009	1.2	.002	.004	.010	1.1	-.004	.012	.013	1.4	-.002	.004	.001
Do.	do.	M+N	-.2	-.002	.005	.005	.3	-.001	.002	.005	-.1	-.001	.012	.002	-.3	-.004	-.007	.003	.0	-.003	.003	.002
Plywood	do.	N	-1.2	-.005	-.022	.081	1.1	-.001	-.024	.041	-2.5	-.006	-.066	.072	-4.3	-.009	-.068	.108	-2.4	-.007	-.008	.049
Aluminum	Aluminum honeycomb	J	.0	.001	-.002	.006	.1	.000	-.001	.005	.2	.002	-.002	.000	.2	.002	.003	.002	.2	.002	-.001	.002

[1] See Appendix I.

[2] Average of four edge measurements. Minus sign indicates concave upward.

[3] Difference between two diagonal measurements.

Table 10--Tensile strength of various sandwich constructions subjected to 1 year of exposure tot he weather

Sandwich construction: Facings	Sandwich construction: Core	Bond symbol[1]	Tensile strength (control tests): Low	Tensile strength (control tests): High	Tensile strength (control tests): Average of 10 tests	Tensile strength (control tests): Average core failure	Tensile strength (final tests): Low	Tensile strength (final tests): High	Tensile strength (final tests): Edges not sealed (average of 5 tests)	Tensile strength (final tests): Edges sealed (average of 5 tests)	Tensile strength (final tests): Grand average (of 10 tests)	Tensile strength (final tests): Average core failure	Tensile strength (final tests): Percent of control strength
			P.s.i.	P.s.i.	P.s.i.	Percent	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	Percent	
Eight-ply glass cloth	Paper honeycomb	A	300	447	360	61	180	398	340	232	286	68	79
Do	do	B	277	366	333	15	272	394	291	315	303	14	91
Do	do	C	170	260	211	1	76	164	105	127	116	1	55
Do	do	D	100	152	119	1							
0.020-inch aluminum	do	G	10	530	396	100	88	436	376	272	324	40	82
Do	do	F	100	242	[2]179	1	102	288	171	205	188	1	105
Do	do	L	72	132	102	8	124	192	147	162	154	9	151
Do	do	J	50	397	[2]157	42	58	376	157	266	212	128	135
Do	do	M + N	50	490	245	43	15	352	18	231	[2]124	55	51
0.070-inch birch plywood	do	N	300	415	362	41	324	380	340	356	348	38	96
Eight-ply glass cloth	Glass-cloth honeycomb	A	110	600	503	1	424	542	486	464	475	0	94
Do	do	B	395	575	469	0	204	548	350	387	368	0	78
Do	do	C	540	657	591	0	360	572	388	476	432	0	73
Do	do	D	170	235	208	1	212	264	235	227	231	0	111
0.020-inch aluminum	do	G	405	912	711	16	2	516	140	158	149	0	21
Do	do	F	170	315	253	26	88	320	246	139	[2]192	0	76
Do	do	L	75	125	114	4	160	210	185	180	182	0	160
Do	do	J	300	565	401	2	108	296	160	234	197	0	49
Do	do	M + N	181	355	[2]279	4	82	232	169	162	[2]166	1	60
0.070-inch birch plywood	do	N	280	409	341	6	20	348	284	240	262	0	77
Eight-ply glass cloth	Cotton honeycomb	A	170	262	214	2	10	190	127	153	[2]140	0	65
Do	do	B	83	175	[2]111	0	46	180	84	104	94	0	85
Do	do	C	138	188	159	6	22	136	96	103	100	0	63
Do	do	D	93	120	104	0	10	68	10	47	[2]28	0	27
0.020-inch aluminum	do	G	117	189	151	25	20	168	113	136	124	14	82
Do	do	F	71	123	99	47	70	126	98	106	102	6	103
Do	do	L	50	70	61	11	76	98	90	85	88	0	144
Do	do	J	33	124	98	36	16	144	106	102	104	48	106
Do	do	M + N	35	187	106	13	44	136	85	67	76	0	72
0.070-inch birch plywood	do	N	108	170	139	5	72	136	118	128	123	0	89
0.020-inch aluminum	Aluminum honeycomb	J	100	268	[3]175	7	108	210	[4]123	[4]159	[5]141	5	81

[1]See appendix I.

[2]Average of less than 10 tests; specimens broken while handling prior to test not included.

[3]Average of 15 test specimens.

[4]Average of 10 test specimens.

[5]Average of 20 test specimens.

Z M 83950 F

Table 11.--Summary of weather conditions for the period of July 1, 1947 to April 1, 1949[1]

Month and year	Temperature				Average relative humidity	Precipitation		Average daily sunshine[2]	
	Maximum	Minimum	Mean	Normal mean		Total	Normal	Mean	Normal
	°F.	°F.	°F.	°F.	Percent	Inches	Inches	Percent	Percent
July 1947	94	42	70.4	72.1	67	2.81	3.88	78	70
August	101	47	77.8	69.8	70	2.58	3.21	79	64
September	94	28	64.3	61.4	72	3.92	3.72	68	57
October	85	29	59.8	49.3	75	1.36	2.43	60	51
November	62	-11	30.6	34.2	80	2.53	1.78	33	31
December	42	2	24.2	22.4	83	1.37	1.63	33	36
January 1948	39	-17	13.2	16.7	73	.49	1.38	53	43
February	51	-17	19.5	19.1	75	2.13	1.56	51	43
March	70	- 9	30.3	30.6	77	2.86	2.07	66	51
April	82	24	50.9	45.4	66	2.97	2.77	65	53
May	84	30	55.2	57.6	65	2.90	3.85	64	57
June	91	43	66.8	67.2	68	2.55	3.76	60	63
July	97	45	73.8	72.1	64	2.55	3.88	75	70
August	98	46	72.4	69.5	66	.70	3.21	75	64
September	93	38	65.6	61.4	70	1.87	3.72	70	57
October	72	18	48.2	49.3	71	1.29	2.43	63	52
November	69	18	39.5	34.2	80	3.56	1.78	23	39
December	54	- 5	24.8	22.4	77	1.75	1.63	53	36
January 1949	51	-19	20.8	16.7	76	1.97	1.38	38	43
February	43	-16	19.9	19.1	73	1.26	1.50	54	48
March	64	5	32.8	30.6	70	2.35	2.07	47	51

[1] Data from official U. S. Weather Bureau records.

[2] Percentage of total possible.

Report No. 1573-B

(Z M 74065 F)

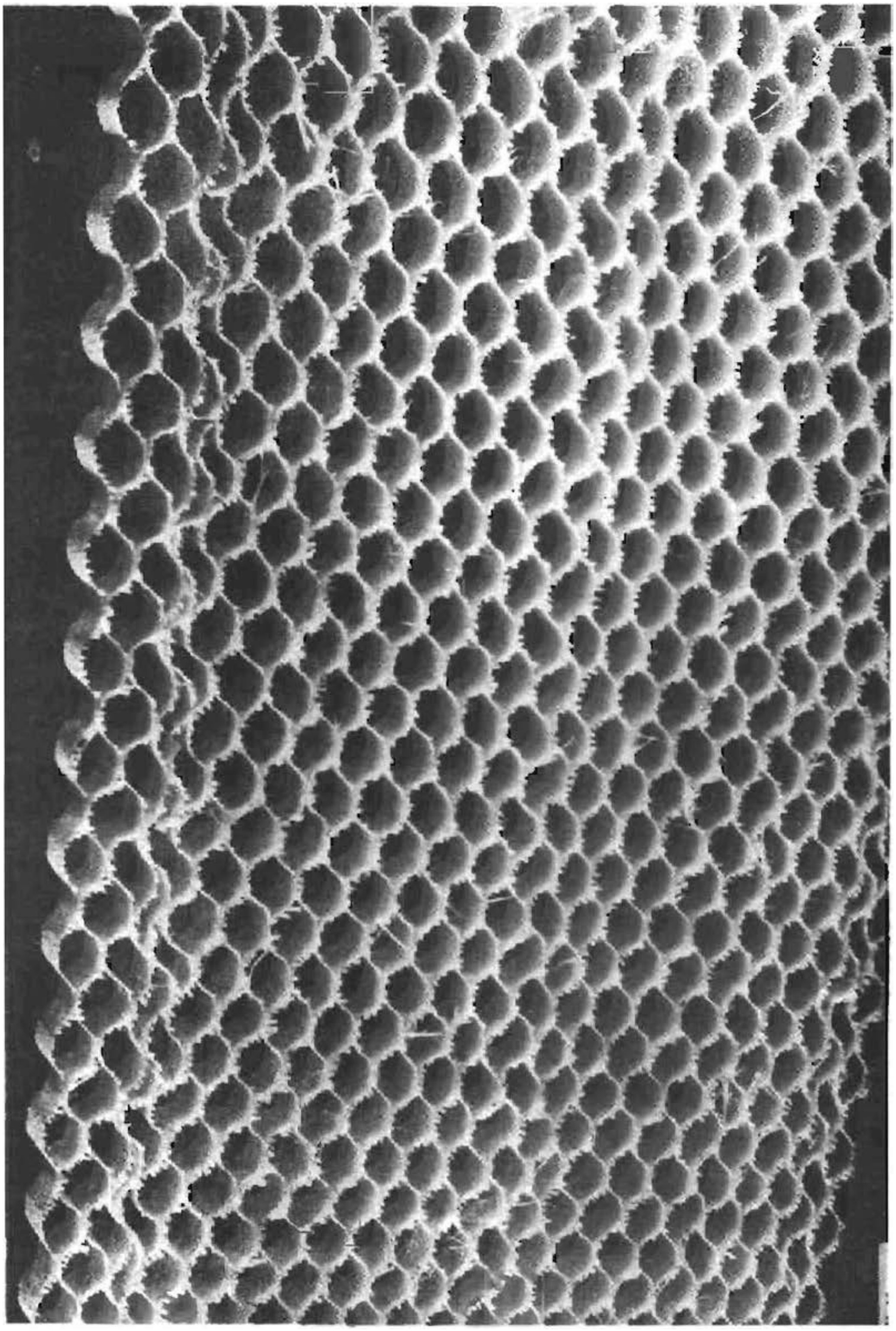
Figure 1.—Paper honeycomb core showing the surface obtained by cutting with a circular saw.

Z N 74065

(ZM 74067F)

Report No. 1573-B

Figure 2.--Glass-cloth honeycomb showing the fuzzy surface caused by a band saw.



Z M 74067 F

Report No. 1573-B

(ZM 74069 F)

Figure 3.--Cotton-cloth honeycomb showing the character of the surface produced by a 14-tooth band saw.

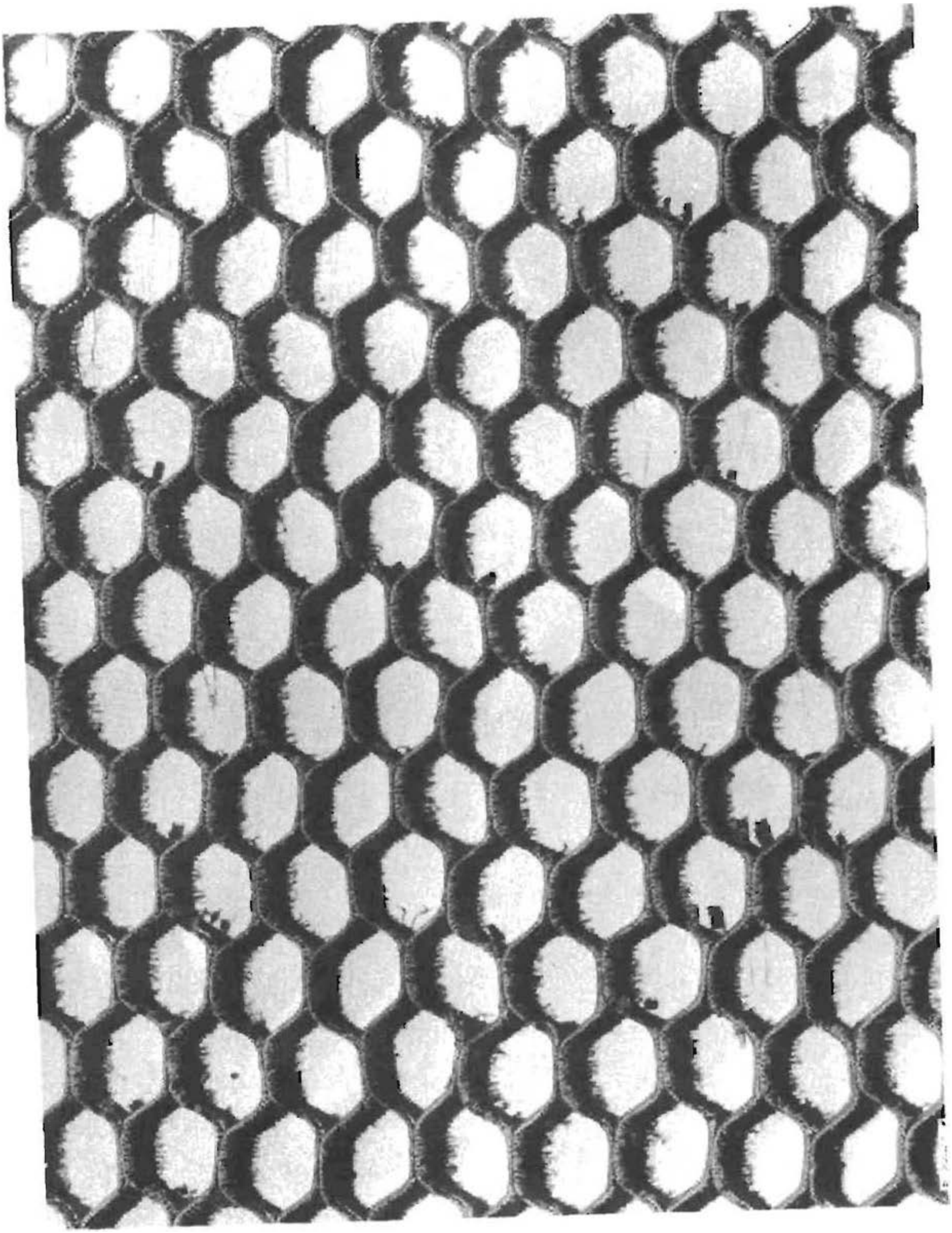
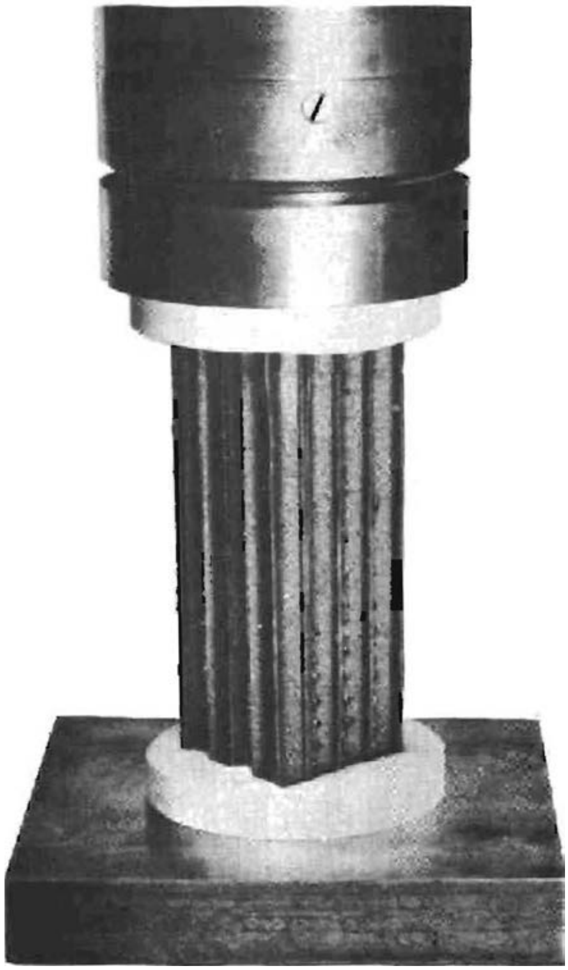


Figure 4.--Honeycomb type of compression specimen showing plaster of Paris end supports.

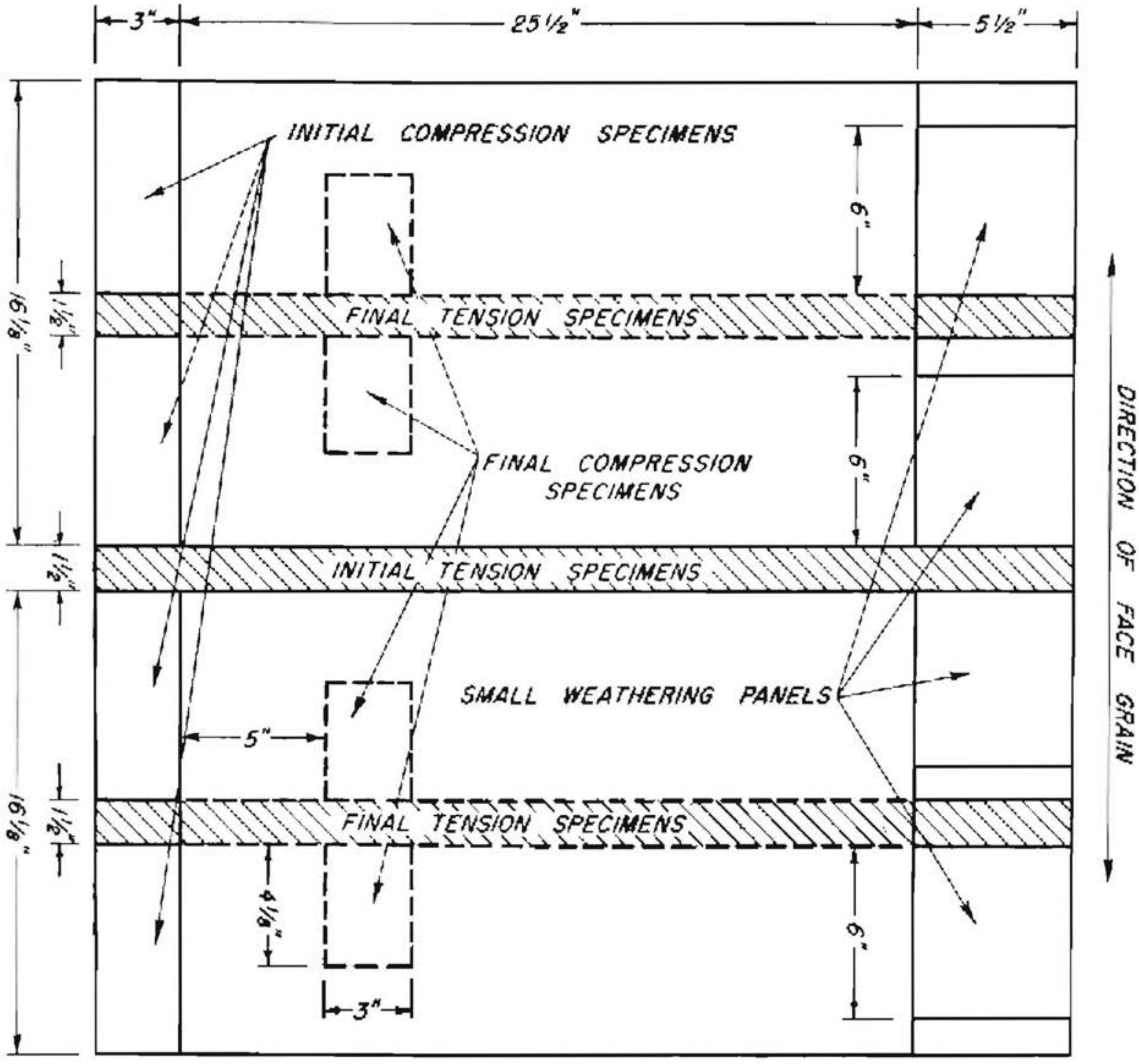
(ZM 76613 F)



ZM76613F

Figure 5.--Type A panels. The direction of the face grain (if any) in the facings was the same as the direction of the corrugated strips in the core. The shaded areas on the aluminum-faced panels were coated with a metal priming cement that was cured before assembly of the panels. The two 16-1/8- by 25-1/2-inch weathering panels were cut on the dotted lines after exposure.

(ZM 81260 F)

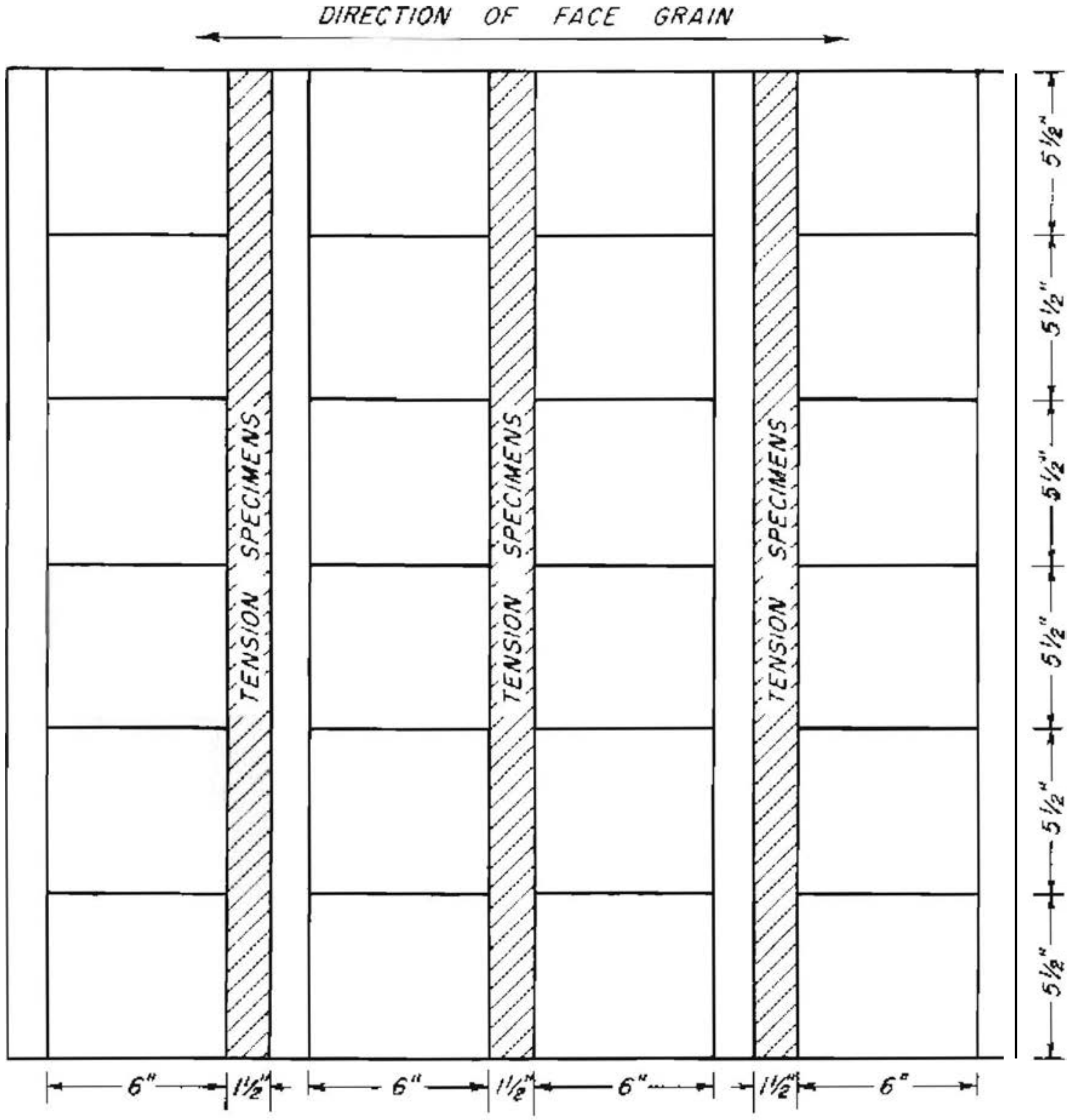


3"
25 1/2"
5 1/2"
INITIAL COMPRESSION SPECIMENS
FINAL TENSION SPECIMENS
FINAL COMPRESSION SPECIMENS
INITIAL TENSION SPECIMENS
SMALL WEATHERING PANELS
FINAL TENSION SPECIMENS
DIRECTION OF FACE GRAIN
16 1/8"
16 1/8"
1 1/2"
1 1/2"
1 1/2"
9"
9"
9"
5"
4 1/8"
3"

ZM81260F

Figure 6.--Type B panels. The direction of the face grain (if any) in the facings was the same as the direction of the corrugated strips in the core. The shaded areas on the aluminum-faced panels were coated with a metal priming cement that was cured before assembly of the panels.

(ZM 81261 F)


DIRECTION OF FACE GRAIN
TENSION SPECIMENS
TENSION SPECIMENS
TENSION SPECIMENS
5½"
5½"
5½"
5½"
5½"
5½"
6"
1½"
6"
1½"
6"
1½"
6"

ZM81261F

(ZM 80271F)
Report No. 1573-B

Figure 7.--Warp-measuring device shown in position on the long side of a weathering panel.