

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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**UNITED STATES DEPARTMENT OF AGRICULTURE
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In Cooperation with the University of Wisconsin**

DURABILITY OF LOW-DENSITY CORE MATERIALS AND
SANDWICH PANELS OF THE AIRCRAFT TYPE AS DETERMINED
BY LABORATORY TESTS AND EXPOSURE TO THE WEATHER^{1 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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²This 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.

³Maintained 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) (a) 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 the 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 material⁴ 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 T2 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.

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

⁵Appendix I Note 11.

The individual corrugated sheets were impregnated with a high-temperature-setting, low-viscosity laminating resin B⁶ 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 a 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 blocks 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-1 was used as the bond between the sheets. The blocks of core material had a density of approximately 4.5 pounds per cubic foot.

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^o 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.

Cotton-cloth Honeycomb

The cotton-cloth honeycomb was cut into sections of 1/2-inch thickness with 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, with 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 Material

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. 1555.² 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.

²"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, with the axes 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 (Temperature and Humidity Extremes)". An exposure cycle was composed of the following treatments:

- (a) 24 hours in a small kiln automatically operated at 175° F. and 75 percent relative humidity
- (b) 24 hours in a mechanically refrigerated room maintained at $-20 \pm 5^{\circ}$ F.
- (c) 24 hours in the small kiln, mentioned in (a) at 175° F. without humidity control
- (d) 24 hours as described in (b)

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

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

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

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 at 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:

$$\frac{\text{Weight after original conditioning period} - \text{Weight after reconditioning}}{\text{Weight after original conditioning period}} \times 100$$

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. 1555.² 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 the immersion time 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 elasticity¹⁰ of the material. The proportionality of the values obtained from the tests of the specimens having plaster ends was in general more consistent than that of the values obtained from the tests of the free-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 slight 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.

The 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 the glass-cloth and aluminum-foil honeycomb-core materials than did any of the 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 were the more uniform.

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

¹⁰Norris, 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 test 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.

The 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 materially affected by the cyclic exposure.

Decay Resistance

The changes in weight sustained by the specimens during the course of the test are shown in table 2.

The paper-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 were well-covered except by P. versicolor. The results appeared to be uncomplicated by the presence of contaminants. Isolations of the test fungi at the end of each exposure period were successful. At the end of the first month of exposure when the specimens were examined as removed from the bottles (in a moist condition) 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 after 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 test specimens showed very insignificant weight losses, and furthermore these were of the order of samples maintained 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 the test fungi at the end of each exposure period were successful. At the end of the 3-month exposure period, a number of the 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 be 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. The 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 the results are not thought to be indicative of the burning characteristics of these materials in actual service.

Aircraft Liquids

Table 4 shows the 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 the average changes in thickness, width, and length after 7 days of immersion and after immersion plus 39 days of conditioning. The changes are expressed as percentages based upon the weight and dimension of the specimens after the initial conditioning.

The percentage increase in weight of 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 the 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 were 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 the 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 these exposure conditions were the same as those described in Section A. Later sandwich panels having aluminum facings on an aluminum-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 tensile 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 material but was also affected by the core material of the sandwich. The specimens having glass-cloth facings and glass-cloth honeycomb cores were 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 specimens 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 considerable 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 exposed to the weather. The large panels that had aluminum facings, however, had a tendency to cup when a temperature differential 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 specimens. 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 resin 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 were 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 A¹¹ 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 B¹² 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.

¹¹Appendix I Note 1.

¹²Appendix I Note 2.

Method 3.--A high-viscosity laminating resin of the polyester type, resin C¹³ 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 D¹⁴ 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 G¹⁵ 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.--A high-temperature-setting modified thermosetting resin, adhesive F¹⁶ 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 I¹⁷ 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

¹³Appendix I Note 3.

¹⁴Appendix I Note 4.

¹⁵Appendix I Note 6.

¹⁶Appendix I Note 5.

¹⁷Appendix 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 J¹⁸, 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 paper and glass-cloth honeycomb cores were cured on a flat aluminum mold in a rubber bag at 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 M¹⁹, 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 sheets were cured in a press without pressure at 325° F. for 30 minutes. Prior to applying the secondary adhesive, N²⁰, a high-temperature-setting phenolic resin, 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 assembled 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 cores 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 Honeycomb

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.

¹⁸Appendix I Note 7.

¹⁹Appendix I Note 9.

²⁰Appendix 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). These 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. The control edgewise-compression specimens were cut and tested prior to exposure, while the final specimens were 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 determine 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.

²¹For 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 the 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 were 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 specimens 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.

The 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 the 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 10. 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 the 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 held 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 the 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 the glue bond had to be determined by other methods. Warp was the 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 the 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 polyester 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

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

Table 1.--Compressive strength and modulus of elasticity of four honeycomb core materials subjected to four controlled exposure conditions¹ (continued)

Exposure conditions	Compressive strength-free ends (3 tests)			Compressive strength-plastered ends (3 tests)			Average compressive strength: free ends (3 tests)			Modulus of elasticity: free ends (3 tests)			Modulus of elasticity: plastered ends (3 tests)			Average modulus of elasticity: plastered ends (6 tests)		
	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	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																		
24-hour water immersion	305			316			311			29,900			29,100					29,500
40-day water immersion	236			254			245			19,800			23,000					21,400
40-day water immersion and reconditioned	256			254			255			23,400			23,100					23,300
200° F. for 10 days	292			309			301			28,900			29,700					29,300
200° F. for 10 days and reconditioned	370			327			349			28,400			28,800					28,600
Equilibrium at 97 percent relative humidity	306			390			348			29,300			29,800					29,600
Equilibrium at 97 percent relative humidity and reconditioned	268			265			267			20,000			19,200					19,600
One cycle ²	248			326			287			25,200			27,800					26,500
Five cycles ²	279			317			298			25,900			30,100					28,000
Ten cycles ²	260			314			287			27,100			30,800					29,000
Ten cycles and reconditioned ²	230			326			278			24,300			23,500					23,900
	262			338			300			26,500			25,900					26,200
D.--Aluminum foil honeycomb -- Apparent specific gravity = 0.071																		
Controls																		
24-hour water immersion	195			312			262			25,600			28,000					26,900
40-day water immersion	174			274			224			25,300			25,100					25,200
40-day water immersion and reconditioned	179			249			214			23,900			22,100					23,500
200° F. for 10 days	150			275			227			21,300			24,900					23,100
200° F. for 10 days and reconditioned	175			247			198			21,400			21,100					21,300
Equilibrium at 97 percent relative humidity	166			262			218			24,400			22,900					23,600
Equilibrium at 97 percent relative humidity and reconditioned	155			283			224			22,000			23,300					22,500
One cycle ²	174			277			216			24,100			21,100					22,600
Five cycles ²	226			306			240			24,600			21,800					23,200
Ten cycles ²	202			330			278			28,800			23,500					26,200
Ten cycles and reconditioned ²	176			316			259			22,900			21,100					22,000
				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 fungi¹

Exposure period : and material :	Weight change when exposed to				
	<u>Poria</u>	<u>Poria</u>	<u>Polyporus</u>	65	Sterile
	<u>monticola</u>	<u>incras-</u>	<u>versi-</u>	percent	agar
		<u>sata</u>	<u>color</u>	relative:	
				humidity:	
	<u>Percent</u>	<u>Percent</u>	<u>Percent</u>	<u>Percent</u>	<u>Percent</u>
<u>1-Month Exposure:</u>					
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
<u>2-Month Exposure:</u>					
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
<u>3-Month Exposure:</u>					
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

¹Based 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.

²Adjusted change in weight.

³Average of four specimens.

Table 3.—Results of flammability tests on three honeycomb-core materials¹

Type of material	: Axis of cells	: Time for flame to travel 3 inches	: Rate of burning	: Comments
		: <u>Minutes</u>	: <u>Inches</u>	
			: <u>per</u>	
			: <u>minute</u>	
Paper-honeycomb core - 3/16-inch cell size	: Horizontal:	: 0.16	:	: Considerable black smoke
	:do.....	: .16	:	: during burning. Specimens reduced to ash.
	: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
	:do.....	: .48	:	: smoke during burning.
	:do.....	: .64	:	: Specimens intact after
	: : Av.	: .60	: 5	: test, only resin burned
	: Vertical :	: (2)	:	: off.
	:do.....	: .68	:	: (2-1/2-inch flame spread)
	: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.

¹Specimens 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."

²Flame 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.

³Flame 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 ²		Average gain in width ²		Average gain in length ²	
		After soaking for 7 days and conditioning for 39 days		After soaking for 7 days and conditioning for 39 days		After soaking for 7 days and conditioning for 39 days		After soaking for 7 days and conditioning for 39 days	
		Percent	Value	Percent	Value	Percent	Value	Percent	Value
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

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

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

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

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

¹See Appendix I.²Glass cloth No. 112-114.

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

Sandwich construction		Bond symbol	Change in weight and thickness by exposure ² to																			
Facing	Core		24-hour water immersion		40-day water immersion		40-day water immersion and reconditioned		200° F. for 10 days		Equilibrium at 97 percent relative humidity and reconditioned		One cycle ³		Five cycles ³		Ten cycles ³		Ten cycles ³ and reconditioned			
			Change in weight in lb.	Change in thickness in in.	Change in weight in lb.	Change in thickness in in.	Change in weight in lb.	Change in thickness in in.	Change in weight in lb.	Change in thickness in in.	Change in weight in lb.	Change in thickness in in.	Change in weight in lb.	Change in thickness in in.	Change in weight in lb.	Change in thickness in in.	Change in weight in lb.	Change in thickness in in.	Change in weight in lb.	Change in thickness in 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	0.53	-0.002	-0.49	-0.002	-0.72	0.000	+0.14	+0.001		
	Do	B	9.72	0.000	12.98	0.003	0.52	0.001	-2.05	0.000	2.37	0.005	0.59	0.000	-0.40	-0.001	-0.01	-0.79	0.000	+0.04	+0.002	
	Do	C	11.02	0.000	26.20	0.005	0.17	0.000	-5.59	0.002	3.23	0.004	0.28	0.000	-0.61	-0.002	-1.26	0.000	+0.16	+0.001		
	Do	D	5.92	0.000	11.65	0.001	0.39	0.002	-2.04	0.000	2.79	0.002	0.62	0.000	-0.26	-0.002	-1.88	0.003	-1.10	0.000	+0.42	+0.002
0.020-inch aluminum	Do	E	46.09	0.002	44.15	0.002	0.42	0.000	-1.41	0.000	1.29	0.003	0.38	0.000	-0.16	-0.001	-0.48	0.002	-0.63	0.001	+0.03	+0.001
	Do	F	56.60	0.002	54.55	0.003	0.26	0.001	-1.03	0.000	1.75	0.006	0.27	0.001	-0.04	0.000	-0.73	0.000	-1.82	0.000	+0.06	+0.001
	Do	G	56.60	0.002	54.55	0.003	0.26	0.001	-1.03	0.000	1.75	0.006	0.27	0.001	-0.04	0.000	-0.73	0.000	-1.82	0.000	+0.06	+0.001
	Do	H+N	43.22	0.001	54.68	0.003	0.18	0.002	-2.06	0.000	1.95	0.006	-0.28	0.002	-0.60	0.002	-1.05	0.001	-1.62	0.000	+0.05	+0.001
0.070-inch birch plywood	Do	I	43.62	0.007	74.32	0.016	0.99	0.005	-5.77	0.006	10.36	0.016	1.75	0.014	-2.94	0.000	-3.83	0.002	-3.28	0.001	+0.15	+0.000
	Do	J	81.28	0.002	89.40	0.003	0.40	0.001	-1.60	0.001	2.60	0.004	0.42	0.000	-0.44	0.000	-0.78	0.000	-0.79	0.000	+0.26	+0.001
	Do	K	93.02	0.002	95.98	0.005	0.42	0.001	-1.69	0.000	2.60	0.004	0.42	0.000	-0.44	0.000	-0.78	0.000	-0.79	0.000	+0.26	+0.001
	Do	L	62.62	0.002	68.62	0.000	0.26	0.004	-1.62	0.001	2.37	0.002	0.78	0.000	-0.54	0.004	-0.95	0.000	-0.80	0.000	+0.15	+0.002
0.020-inch aluminum	Do	M	70.65	0.002	75.19	0.002	0.37	0.000	-2.09	0.001	3.62	0.001	-0.92	0.002	-0.52	0.004	-1.18	0.000	-1.70	0.000	+0.48	+0.001
	Do	N	34.58	0.002	44.72	0.003	1.76	0.002	-1.44	0.001	3.21	0.002	0.75	0.001	-0.68	0.000	-0.92	0.000	-0.86	0.001	+0.01	+0.001
	Do	O	54.68	0.000	70.29	0.002	2.45	0.001	-0.97	0.001	1.93	0.002	0.30	0.000	-0.72	0.000	-1.11	0.000	-1.70	0.000	+0.10	+0.000
	Do	P	53.15	0.001	67.25	0.002	4.44	0.003	-1.66	0.001	1.65	0.000	0.29	0.001	-0.73	0.000	-0.98	0.000	-1.13	0.000	+0.30	+0.000
0.070-inch birch plywood	Do	Q	62.00	0.001	71.30	0.004	0.42	0.002	-2.31	0.000	2.34	0.003	0.42	0.000	-0.60	0.001	-0.94	0.001	-0.99	0.000	+0.04	+0.000
	Do	R	88.15	0.011	92.18	0.017	0.46	0.004	-5.23	0.005	10.02	0.014	1.64	0.006	-2.49	0.002	-3.63	0.003	-3.44	0.002	+0.04	+0.000
	Do	S	60.65	0.0015	103.25	0.0056	0.16	0.0008	-1.96	0.002	1.40	0.005	0.26	0.002	-0.56	0.002	-0.89	0.002	-0.72	0.002	+0.24	+0.001
	Do	T	120.45	0.002	178.80	0.004	0.64	0.001	-1.65	0.001	1.44	0.004	0.30	0.001	-0.41	0.002	-0.75	0.002	-0.46	0.000	+0.20	+0.000
Eight-ply glass cloth	Cotton-cloth honeycomb	A	107.25	0.002	81.90	0.004	0.37	0.001	-2.16	0.002	1.35	0.004	0.12	0.002	-0.27	0.003	-0.97	0.002	-0.57	0.002	+0.14	+0.000
	Do	B	90.42	0.002	125.48	0.005	0.85	0.001	-2.38	0.003	1.34	0.004	0.06	0.002	-0.23	0.003	-1.42	0.001	-1.80	0.001	+0.76	+0.001
	Do	C	95.30	0.002	108.50	0.005	0.42	0.002	-1.91	0.002	2.23	0.004	0.60	0.002	-0.09	0.001	-0.47	0.004	-0.22	0.003	+0.39	+0.003
	Do	D	93.62	0.002	71.88	0.004	0.25	0.002	-1.28	0.002	2.66	0.006	0.11	0.004	+0.16	0.004	-0.11	0.001	-0.16	0.001	+0.24	+0.001
0.020-inch aluminum	Do	E	133.82	0.005	111.65	0.006	0.28	0.001	-1.14	0.002	0.62	0.004	0.02	0.006	+0.06	0.004	-0.20	0.002	-0.14	0.001	+0.22	+0.000
	Do	F	104.55	0.003	113.12	0.007	0.39	0.001	-1.40	0.002	0.97	0.004	0.32	0.001	-0.35	0.004	-0.74	0.002	-0.66	0.000	+0.05	+0.000
	Do	G	73.96	0.003	65.95	0.005	0.37	0.001	-1.66	0.003	1.85	0.004	0.12	0.002	-0.31	0.000	-0.74	0.003	-0.82	0.003	+0.18	+0.000
	Do	H+N	128.08	0.018	114.58	0.020	1.12	0.008	-6.78	0.006	11.91	0.017	1.84	0.004	-2.60	0.001	-4.62	0.002	-3.86	0.001	+0.16	+0.005
0.070-inch birch plywood	Do	I	4.84	0.000	9.66	0.001	2.54	0.000	-0.23	0.001	0.12	0.001	-0.26	0.000	-0.34	0.000	-0.30	0.001	0.13	0.000	+0.05	+0.001
	Aluminum honeycomb	J																				

See Appendix I.

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

³One cycle consisted of following consecutive treatments: 24 hours at 175° F., and 24 hours at 175° F., 24 hours at 175° F., and 24 hours at -20° F.

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Table 7.—Tensile strength of various manila construction subjected to FHF controlled exposure conditions¹

Sample construction	Bond	Controls	Effect on strength of exposure to—													Ten original	Ten original	Ten original						
			200° F. for 10 days																					
			24-hour water immersion	40-day water immersion	40-day water immersion	40-day water immersion	40-day water immersion	40-day water immersion	40-day water immersion	40-day water immersion	40-day water immersion	40-day water immersion	40-day water immersion	40-day water immersion										
P.S.A.	Per- cent	Per- cent	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control	Percent of failure of control								
			strength	strength	strength	strength	strength	strength	strength	strength	strength	strength	strength	strength	strength	strength	strength	strength						
Eight-ply glass cloth	A	319	49	96	61	0	77	3	77	43	82	64	1	72	24	114	61	103	60	95	83	78	60	
	B	292	0	54	0	56	0	50	0	55	2	39	0	55	0	46	0	53	1	59	16	36	2	
	C	272	5	61	1	86	0	58	0	94	46	53	0	75	2	128	0	103	0	73	1	51	2	
	D	194	0	73	0	116	0	58	0	81	0	51	0	121	0	103	0	103	0	53	0	34	1	
0.020-inch aluminum	G	391	78	94	90	71	33	105	82	78	100	93	100	79	107	67	110	100	92	98	92	100	76	100
	H	278	32	96	48	31	126	30	25	1	116	86	73	87	30	80	30	92	90	82	58	95	68	
	I	149	0	122	0	112	0	126	127	77	131	7	167	12	149	12	149	23	167	143	79	111	111	
	J	131	24	99	13	148	38	176	25	145	11	188	63	7	147	12	149	23	167	143	79	111	111	
0.070-inch birch plywood	K	402	49	64	38	59	45	84	40	65	68	79	90	65	67	94	42	81	59	67	92	43	90	51
	L	549	0	71	0	62	0	86	0	79	0	84	0	58	0	69	0	69	0	66	0	60	0	0
	M	268	0	85	0	51	0	83	0	64	0	98	0	48	0	76	0	102	0	91	0	82	0	0
	N	441	0	96	0	53	0	102	0	86	0	120	0	56	0	74	0	102	0	91	0	75	0	0
0.020-inch aluminum	O	624	1	73	0	87	12	98	17	83	0	100	15	82	6	86	5	98	1	84	7	82	8	8
	P	327	1	83	0	73	5	96	13	46	0	98	34	70	22	101	30	92	12	107	23	108	10	
	Q	109	2	126	0	120	0	197	0	191	0	104	5	108	3	167	196	7	362	118	205	7	207	
	R	183	0	99	1	96	4	84	2	110	0	121	7	75	2	89	1	111	0	147	2	128	10	
0.070-inch birch plywood	S	367	0	35	0	40	15	78	9	76	0	89	0	63	10	78	5	79	0	58	2	46	11	44
	T	212	1	105	0	56	0	77	0	70	0	87	27	62	0	73	0	88	0	79	0	64	1	54
	U	147	0	116	0	67	0	138	0	120	0	177	0	46	0	96	0	112	0	80	0	76	2	0
	V	107	1	67	0	55	0	135	2	88	2	106	3	78	2	96	0	80	0	80	0	76	2	0
0.020-inch aluminum	W	149	28	67	0	83	8	97	17	105	48	106	50	81	0	74	0	87	25	93	40	60	1	85
	X	102	3	71	1	52	12	114	37	76	2	74	38	84	45	83	20	103	52	95	30	89	48	49
	Y	61	0	83	8	33	1	163	3	100	2	164	3	95	19	127	11	123	22	101	30	89	48	49
	Z	84	16	88	0	39	8	132	8	95	3	99	16	95	13	132	3	117	57	101	30	89	48	49
0.070-inch birch plywood	AA	88	2	106	1	39	0	80	0	99	6	97	6	105	2	130	0	117	57	101	30	89	48	49
	AB	161	14	88	0	88	0	115	15	85	52	93	43	76	7	106	14	94	23	98	23	82	59	104
	AC	175	7	114	13	97	8	101	0	149	19	132	13	103	2	90	0	85	7	91	7	82	13	13
	AD																							

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

²See Appendix I for description of resins and adhesives.

One cycle consisted of the following consecutive treatments: 24 hours at 175° F. and 75 percent relative humidity, 24 hours at -20° F. and 65 percent relative humidity, 24 hours at 175° F. and 75 percent relative humidity, 24 hours at -20° F. and 65 percent relative humidity.

Table 8.--Edge-wise compressive strength of various sandwich constructions subjected to four controlled exposures and to weathering

Facing	Sandwich construction	Bond: Type	Controls		Effect on strength of exposure to----									
					200° F.: 200° F. 197 per- cent		200° F.: 200° F. 197 per- cent		200° F.: 200° F. 197 per- cent		200° F.: 200° F. 197 per- cent		200° F.: 200° F. 197 per- cent	
			High	Low	Immersion: Water	Percent of control	Immersion: Water	Percent of control	Immersion: Water	Percent of control	Immersion: Water	Percent of control	Immersion: Water	Percent of control
			in. of width	in. of width	for 40 days	strength	for 40 days	strength	for 40 days	strength	for 40 days	strength	for 40 days	strength
					tests	of width	tests	of width	tests	of width	tests	of width	tests	of width
Eight-ply glass cloth	Paper	A	892	717	791	57	92	72	98	75	81	86	76	117
Do.	honeycomb	B	1,007	847	916	57	86	52	83	66	82	70	62	87
Do.	do.	C	994	505	711	43	79	53	95	42	82	80	57	94
Do.	do.	D	386	259	328	71	158	83	163	52	125	136	148	147
0.020-inch aluminum	do.	G	2,278	1,620	2,014	105	108	86	116	110	107	94	105	106
Do.	do.	F	1,935	294	1,410	92	98	80	112	108	107	91	95	107
Do.	do.	L	1,475	752	1,206	55	71	30	87	74	59	82	76	108
Do.	do.	J	2,110	1,013	1,218	67	60	47	90	67	67	42	88	127
Do.	do.	M+N	2,105	609	1,624	85	73	69	62	87	87	76	82	126
0.070-inch birch plywood	do.	N	1,056	988	1,024	39	78	91	83	47	75	101	82	93
Eight-ply glass cloth	do.	A	1,155	843	982	70	96	86	94	83	79	92	81	107
Do.	honeycomb	B	1,224	863	1,105	65	87	41	94	70	79	67	80	88
Do.	do.	C	900	686	820	64	90	57	107	62	77	66	100	101
Do.	do.	D	511	337	437	44	111	59	108	26	72	76	155	140
0.020-inch aluminum	do.	G	1,886	1,138	1,529	148	160	119	168	145	158	164	156	155
Do.	do.	F	1,761	850	1,223	140	162	59	184	148	163	142	160	139
Do.	do.	L	1,471	517	1,158	105	158	51	161	109	113	140	129	124
Do.	do.	J	1,598	935	1,319	148	148	117	184	152	146	140	160	136
Do.	do.	M+N	1,736	917	1,346	91	99	80	98	89	91	94	100	120
0.070-inch birch plywood	do.	N	1,278	1,014	1,145	35	71	84	71	42	68	90	69	74
Eight-ply glass cloth	Cotton-cloth	A	906	497	744	66	87	70	102	61	77	95	90	88
Do.	honeycomb	B	840	590	712	73	99	46	105	77	86	93	68	90
Do.	do.	C	670	525	590	58	84	87	99	71	89	105	89	88
Do.	do.	D	464	365	420	47	95	68	134	33	85	105	51	135
0.020-inch aluminum	do.	G	841	444	662	171	204	136	215	180	197	215	202	218
Do.	do.	F	820	509	676	138	196	83	135	137	156	162	136	193
Do.	do.	L	641	391	495	113	148	106	201	130	128	170	152	166
Do.	do.	J	1,007	506	846	136	145	92	.....	153	150	147	147	162
Do.	do.	M+N	927	524	779	120	139	95	135	132	161	150	157	182
0.070-inch birch plywood	do.	N	1,074	950	1,027	36	64	81	82	41	62	79	74	59
0.020-inch aluminum	Aluminum	J	1,854	934	1,436	.....	119	.....	128	.....	125	.....	124	113
Do.	honeycomb					.....							

See Appendix I.

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 flashpoint of various asphaltic constructions

Sandwich construction	Bond layer	Change after 3 months				Change after 6 months				Change after 9 months				Change after 12 months				Change after 12 months and seconding to 75° F., and 65 percent relative humidity
		Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp			
Facing	Core	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	Flak-Weight	Flak-Amount of warp	
																		Flak-Weight
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
		B	2	0.003	0.003	0.073	1.6	0.005	0.006	0.137	6	0.001	0.006	0.077	5	0.003	0.011	0.095
		C	3	0.002	0.010	0.073	1.1	0.004	0.004	0.084	0.064	0.001	0.001	0.084	0.001	0.004	0.012	0.095
		D	2	0.002	0.010	0.073	1.4	0.001	0.021	0.034	1.1	0.001	0.032	0.001	0	0.004	0.028	0.088
Aluminum	Aluminum	G	7	0.005	0.001	0.009	7	0.006	0.001	0.010	6	0.004	0.007	0.010	1.1	0.001	0.023	0.014
		H	2	0.001	0.004	0.023	3	0.000	0.000	0.028	5	0.003	0.003	0.002	4	0.001	0.016	0.003
		I	2	0.001	0.004	0.023	1.1	0.001	0.004	0.006	3	0.003	0.012	0.009	1	0.001	0.023	0.003
		J	8	0.001	0.004	0.023	1.4	0.001	0.003	0.004	1.2	0.002	0.010	0.008	1.3	0.002	0.007	0.003
Plywood	Plywood	K	1.6	0.000	0.002	0.002	1.4	0.000	0.001	0.002	1.4	0.001	0.004	0.001	1.0	0.000	0.024	0.006
		L	3	0.001	0.072	0.219	2.6	0.004	0.078	0.198	1.2	0.001	0.153	0.322	3.1	0.004	1.29	0.428
		M	2.1	0.002	0.000	0.018	3.4	0.001	0.008	0.014	3.0	0.001	0.001	0.009	9	0.002	0.006	0.016
		N	1.3	0.002	0.000	0.022	1.2	0.003	0.007	0.027	1.6	0.002	0.003	0.025	0.9	0.004	0.004	0.021
Glass cloth	Glass-cloth honeycomb	A	0	0.002	0.012	0.044	4	0.001	0.004	0.042	2	0.002	0.008	0.038	2	0.003	0.014	0.021
		B	4	0.002	0.012	0.044	2	0.001	0.004	0.042	2	0.003	0.002	0.038	2	0.002	0.001	0.021
		C	4	0.002	0.012	0.044	2	0.001	0.004	0.042	2	0.003	0.002	0.038	2	0.002	0.001	0.021
		D	4	0.002	0.012	0.044	2	0.001	0.004	0.042	2	0.003	0.002	0.038	2	0.002	0.001	0.021
Aluminum	Aluminum	G	3	0.004	0.009	0.004	3	0.003	0.002	0.002	1.3	0.001	0.017	0.005	6	0.003	0.021	0.003
		H	3	0.004	0.009	0.004	3	0.003	0.002	0.002	1.3	0.001	0.017	0.005	6	0.003	0.021	0.003
		I	3	0.004	0.009	0.004	3	0.003	0.002	0.002	1.3	0.001	0.017	0.005	6	0.003	0.021	0.003
		J	3	0.004	0.009	0.004	3	0.003	0.002	0.002	1.3	0.001	0.017	0.005	6	0.003	0.021	0.003
Plywood	Plywood	K	3.2	0.003	0.005	0.011	2.3	0.003	0.003	0.003	2.5	0.002	0.026	0.006	2	0.002	0.024	0.006
		L	2.2	0.003	0.046	0.091	2.2	0.005	0.041	0.024	1.6	0.001	0.082	0.361	2.2	0.001	0.098	0.449
		M	2.2	0.003	0.046	0.091	2.2	0.005	0.041	0.024	1.6	0.001	0.082	0.361	2.2	0.001	0.098	0.449
		N	2.2	0.003	0.046	0.091	2.2	0.005	0.041	0.024	1.6	0.001	0.082	0.361	2.2	0.001	0.098	0.449
Glass cloth	Cotton-cloth honeycomb	A	0	0.002	0.004	0.009	7	0.002	0.013	0.004	5	0.000	0.006	0.021	5	0.001	0.008	0.011
		B	1	0.002	0.008	0.051	2.4	0.003	0.000	0.064	6	0.000	0.006	0.054	1	0.001	0.008	0.066
		C	2	0.006	0.012	0.104	1.5	0.005	0.010	0.101	3	0.003	0.021	0.094	1	0.006	0.028	0.271
		D	6	0.003	0.014	0.043	1.7	0.001	0.006	0.020	1.1	0.000	0.018	0.019	2	0.003	0.017	0.012
Aluminum	Aluminum	G	2	0.002	0.005	0.001	6	0.003	0.002	0.001	1.5	0.002	0.020	0.008	1	0.005	0.007	0.004
		H	2	0.002	0.005	0.004	4	0.002	0.002	0.002	1.5	0.004	0.016	0.001	1	0.005	0.018	0.021
		I	2	0.002	0.005	0.004	1.2	0.001	0.000	0.023	1.1	0.003	0.008	0.023	1	0.002	0.004	0.026
		J	3.7	0.002	0.002	0.010	1.2	0.001	0.000	0.023	1.1	0.003	0.008	0.023	1	0.002	0.004	0.026
Plywood	Plywood	K	2	0.002	0.005	0.005	3	0.001	0.002	0.003	1.1	0.001	0.004	0.010	1.1	0.004	0.012	0.013
		L	1.2	0.005	0.022	0.081	1.1	0.001	0.024	0.041	2.5	0.006	0.066	0.072	4.3	0.009	0.068	1.081
		M	1.2	0.005	0.022	0.081	1.1	0.001	0.024	0.041	2.5	0.006	0.066	0.072	4.3	0.009	0.068	1.081
		N	1.2	0.005	0.022	0.081	1.1	0.001	0.024	0.041	2.5	0.006	0.066	0.072	4.3	0.009	0.068	1.081
Aluminum	Aluminum honeycomb	A	0	0.001	0.002	0.006	1.1	0.003	0.001	0.005	2	0.002	0.002	0.000	2	0.002	0.003	0.002
		B	0	0.001	0.002	0.006	1.1	0.003	0.001	0.005	2	0.002	0.002	0.000	2	0.002	0.003	0.002
		C	0	0.001	0.002	0.006	1.1	0.003	0.001	0.005	2	0.002	0.002	0.000	2	0.002	0.003	0.002
		D	0	0.001	0.002	0.006	1.1	0.003	0.001	0.005	2	0.002	0.002	0.000	2	0.002	0.003	0.002

1-See Appendix I.

²Average of four edge measurements. Minus sign indicates constant upward.

3. Difference between two diagonal measurements.

Table 10.—Tensile strength of various sandwich constructions subjected to 1 year of exposure to the weather

Sandwich construction		Bond symbol	Tensile strength (control tests)				Tensile strength (final tests)			
Facing	Core		Low	High	Average of 10 tests	Percent core failure	Low	High	Average of 10 tests	Percent core failure
			P.S.I.	P.S.I.	P.S.I.	Percent	P.S.I.	P.S.I.	P.S.I.	Percent
Eight-ply glass cloth		A	300	447	360	61	180	398	232	286
Do.	Paper honeycomb	B	277	366	333	15	272	394	315	303
Do.	do.	C	170	260	211	1	76	164	127	116
Do.	do.	D	100	152	119	1				
0.020-inch aluminum		G	10	530	396	100	88	436	272	324
Do.	do.	F	100	242	2179	1	102	288	171	188
Do.	do.	L	72	132	102	8	124	192	147	154
Do.	do.	J	50	397	2157	42	58	376	157	266
Do.	do.	M + N	50	490	245	43	15	352	18	231
0.070-inch birch plywood		N	300	415	362	41	324	380	356	348
Eight-ply glass cloth		A	110	600	503	1	424	542	486	475
Do.	Glass-cloth honeycomb	B	395	575	469	0	204	548	350	387
Do.	do.	C	540	657	591	0	360	572	388	476
Do.	do.	D	170	235	208	1	212	264	235	227
0.020-inch aluminum		G	405	912	711	16	2	516	140	158
Do.	do.	F	170	315	253	26	88	320	246	139
Do.	do.	L	75	125	114	4	160	210	185	180
Do.	do.	J	300	565	401	2	108	296	160	234
Do.	do.	M + N	181	355	2279	4	82	232	169	162
0.070-inch birch plywood		N	280	409	341	6	20	348	284	262
Eight-ply glass cloth		A	170	262	214	2	10	190	127	153
Do.	Cotton honeycomb	B	83	175	211	0	46	180	84	104
Do.	do.	C	138	188	159	6	22	136	96	103
Do.	do.	D	93	120	104	0	10	68	10	47
0.020-inch aluminum		G	117	189	151	25	20	168	113	136
Do.	do.	F	71	123	99	47	70	126	98	106
Do.	do.	L	50	70	61	11	76	98	90	85
Do.	do.	J	33	124	98	36	16	144	106	102
Do.	do.	M + N	35	187	106	13	44	136	85	67
0.070-inch birch plywood		N	108	170	139	5	72	136	118	128
0.020-inch aluminum		J	100	268	2175	7	108	210	4123	4159

See appendix I.

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

Average of 15 test specimens.

Average of 10 test specimens.

Average of 20 test specimens.

Table 11.--Summary of weather conditions for the period of July 1, 1947 to April 1, 1949¹

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

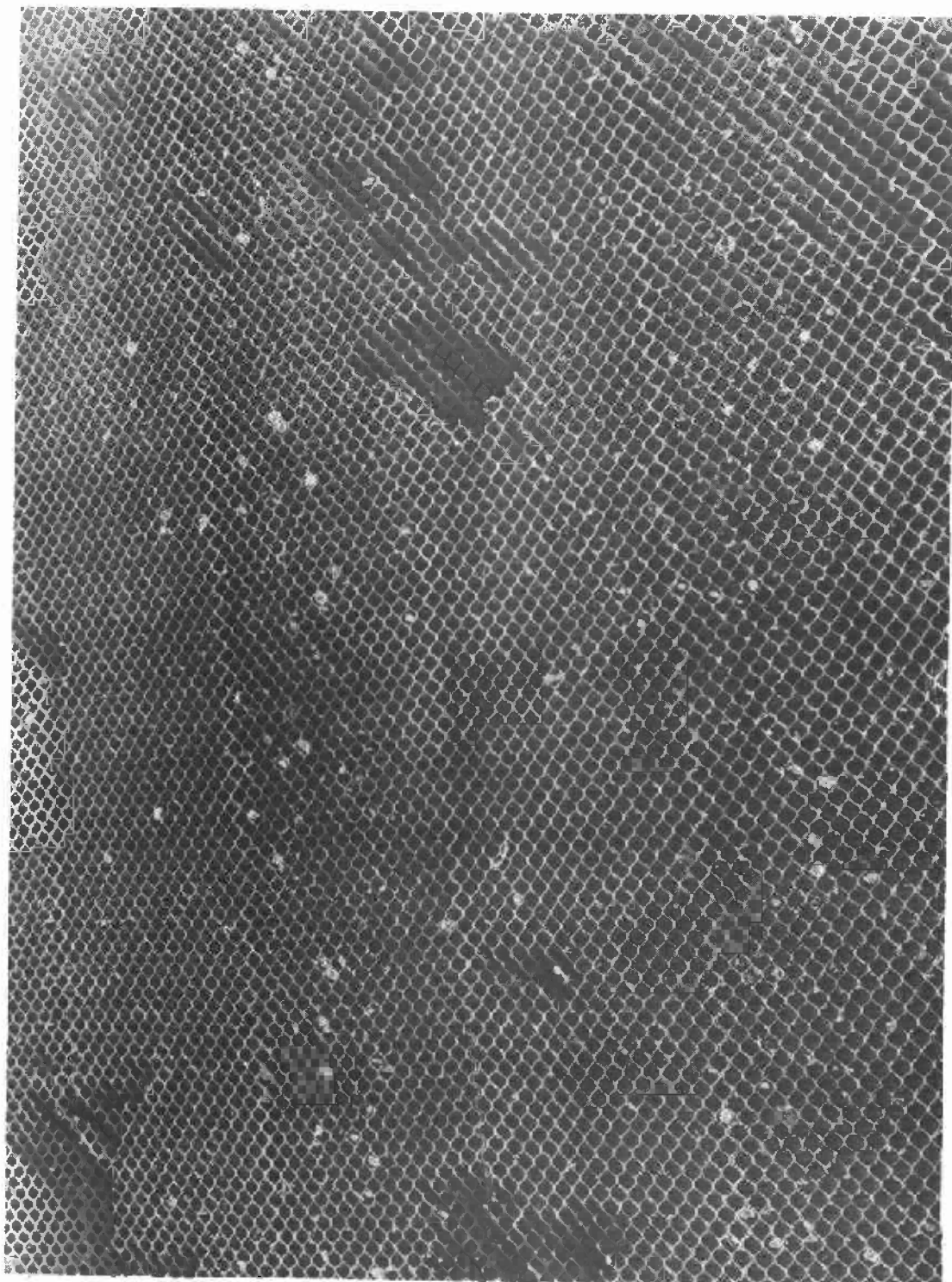
¹Data from official U. S. Weather Bureau records.

²Percentage of total possible.

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

(Z M 74065 F)

Report No. 1573-B

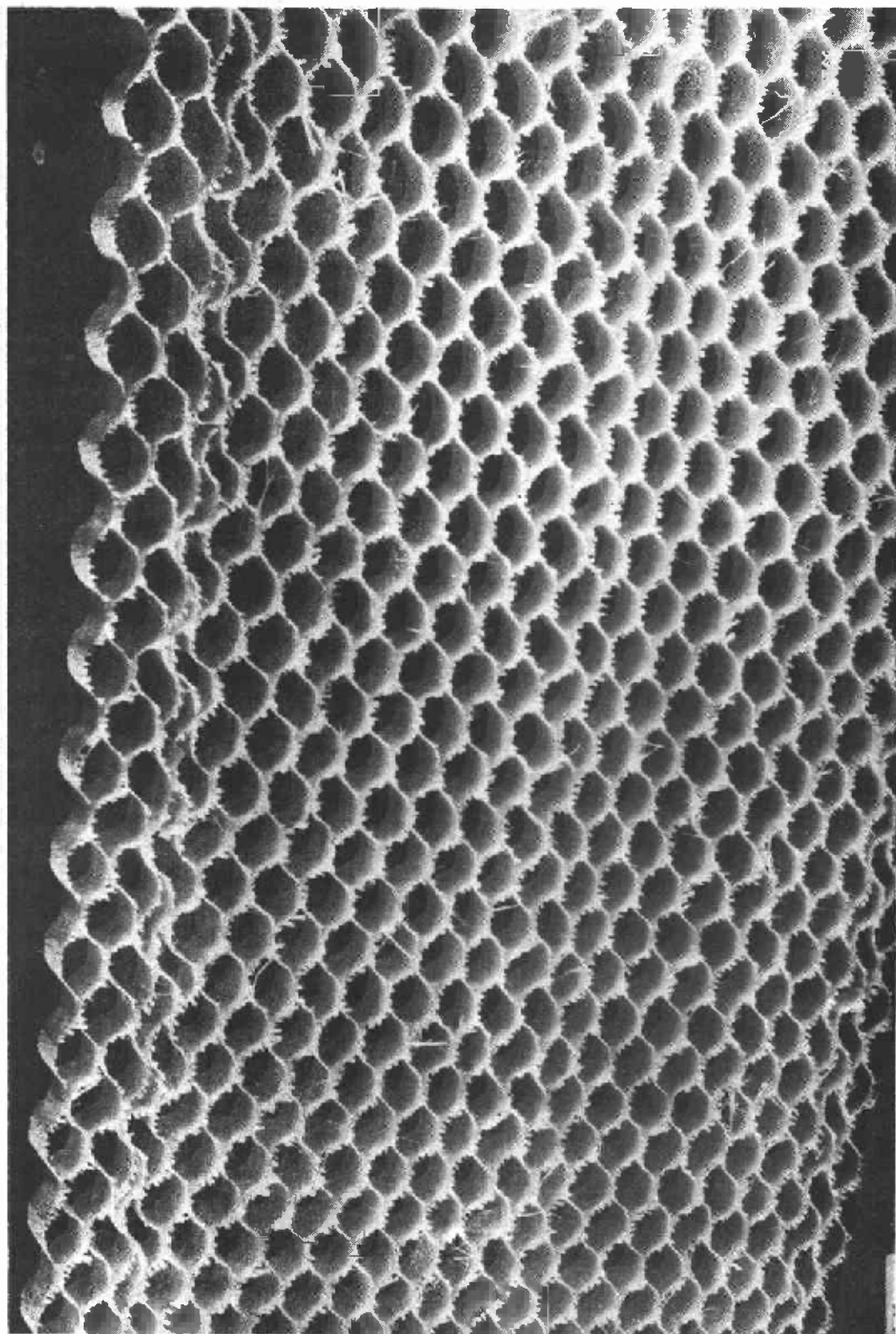


Z M 74065 P

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

(ZM 74067F)

Report No. 1573-B



Z M 74087 F

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

(ZM 74069 F)

Report No. 1573-B

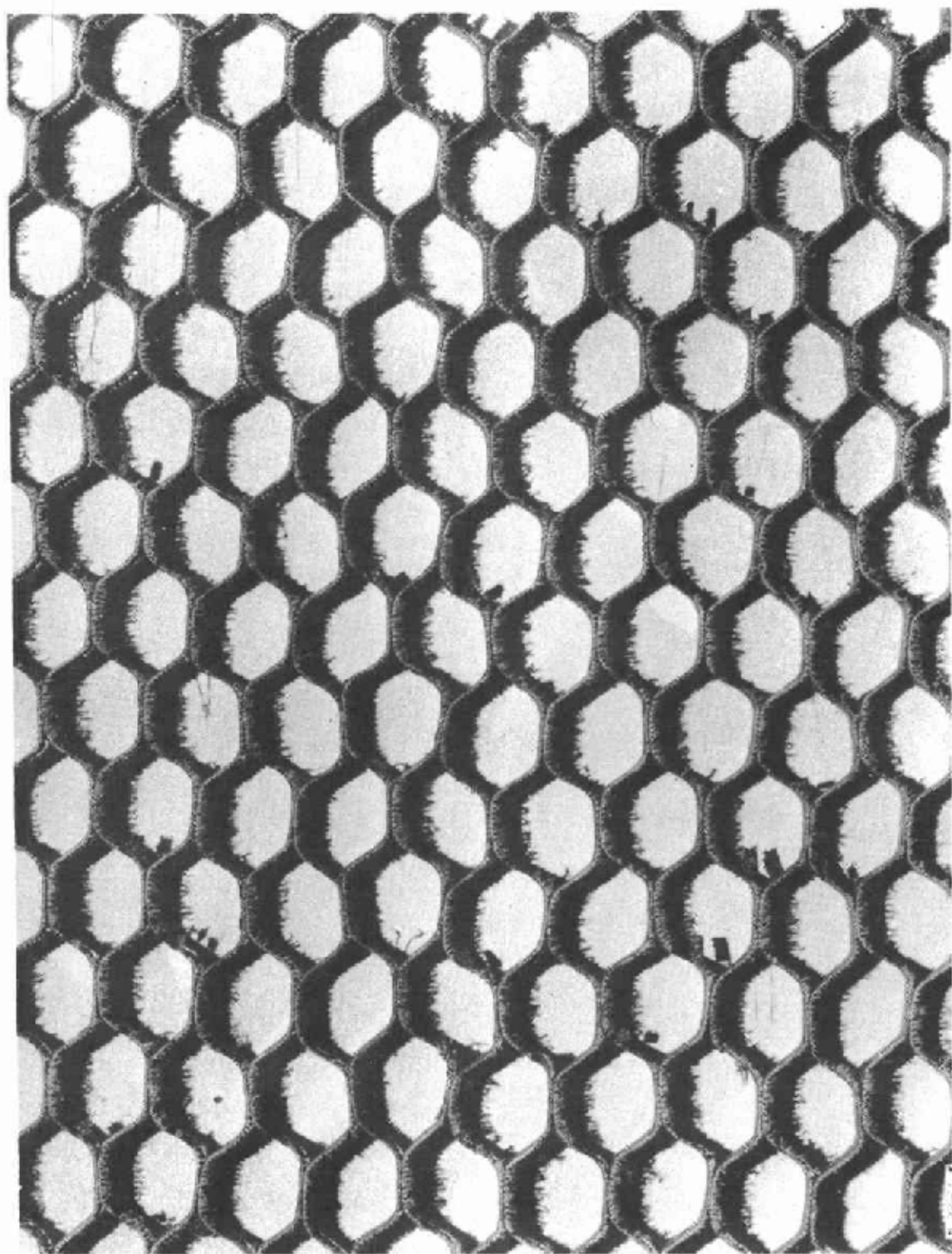
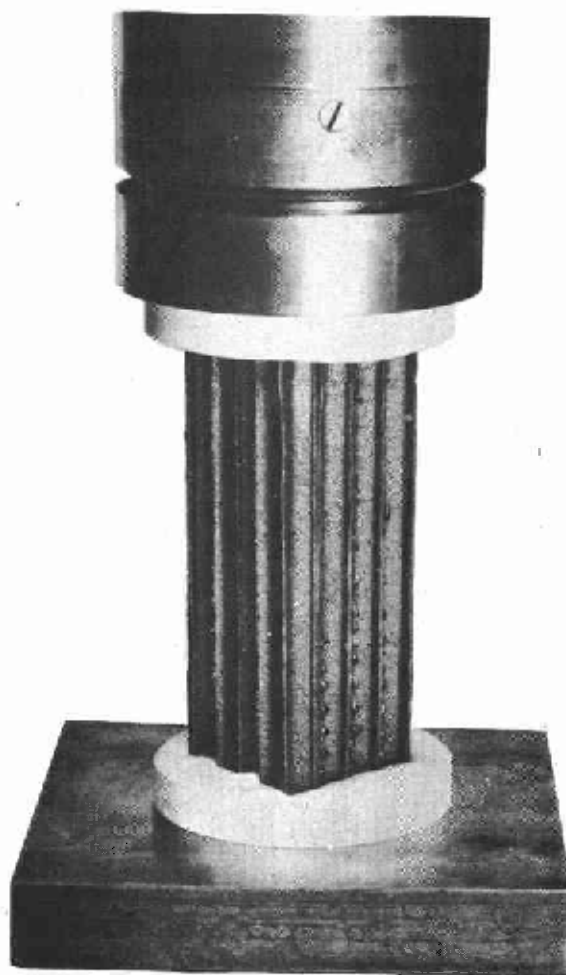


Figure 4.--Honeycomb type of compression specimen
showing plaster of Paris end supports.

(ZM 76613 F)

Report No. 1573-B

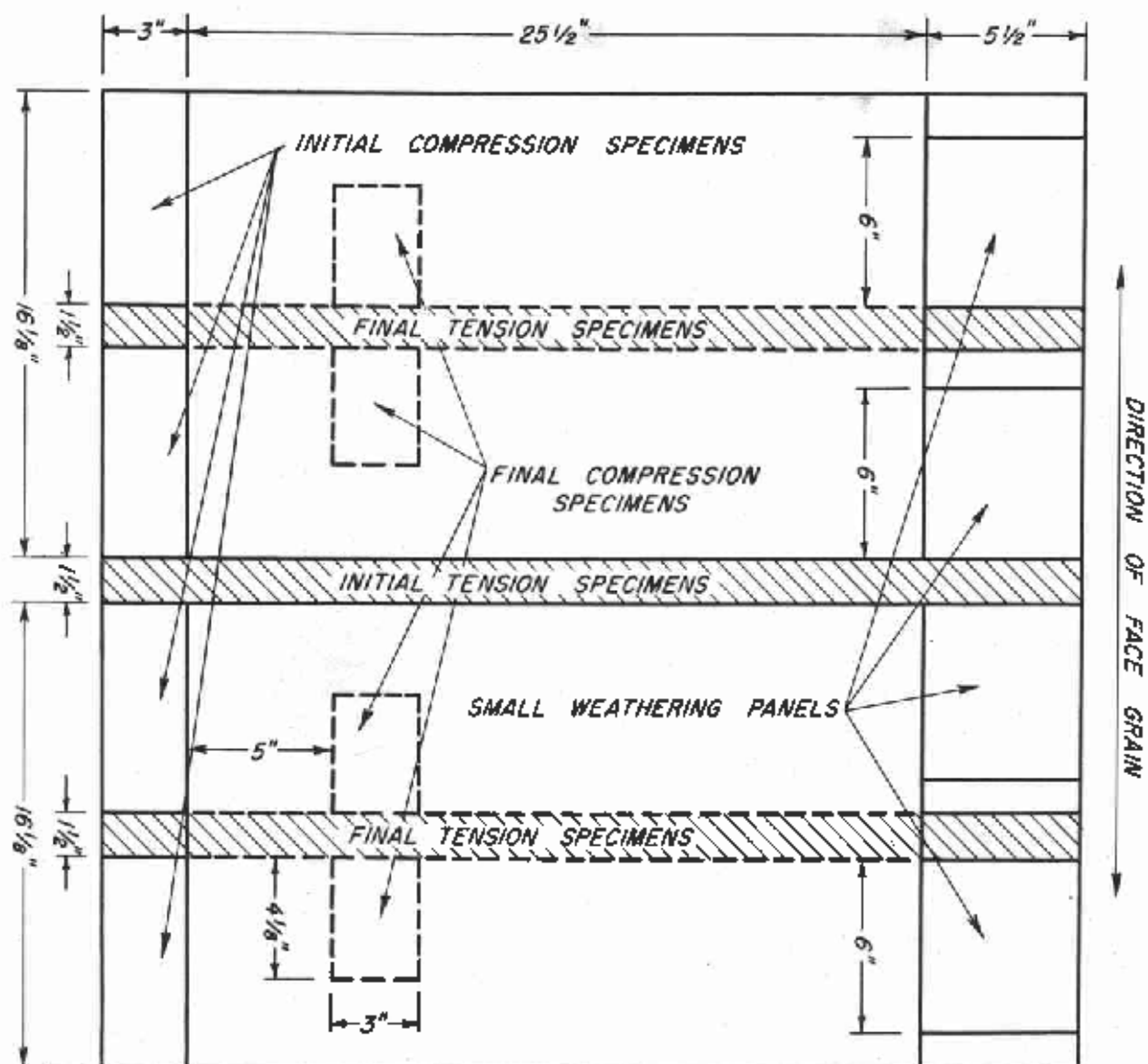


Z M76613F

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)

Report No. 1573-B

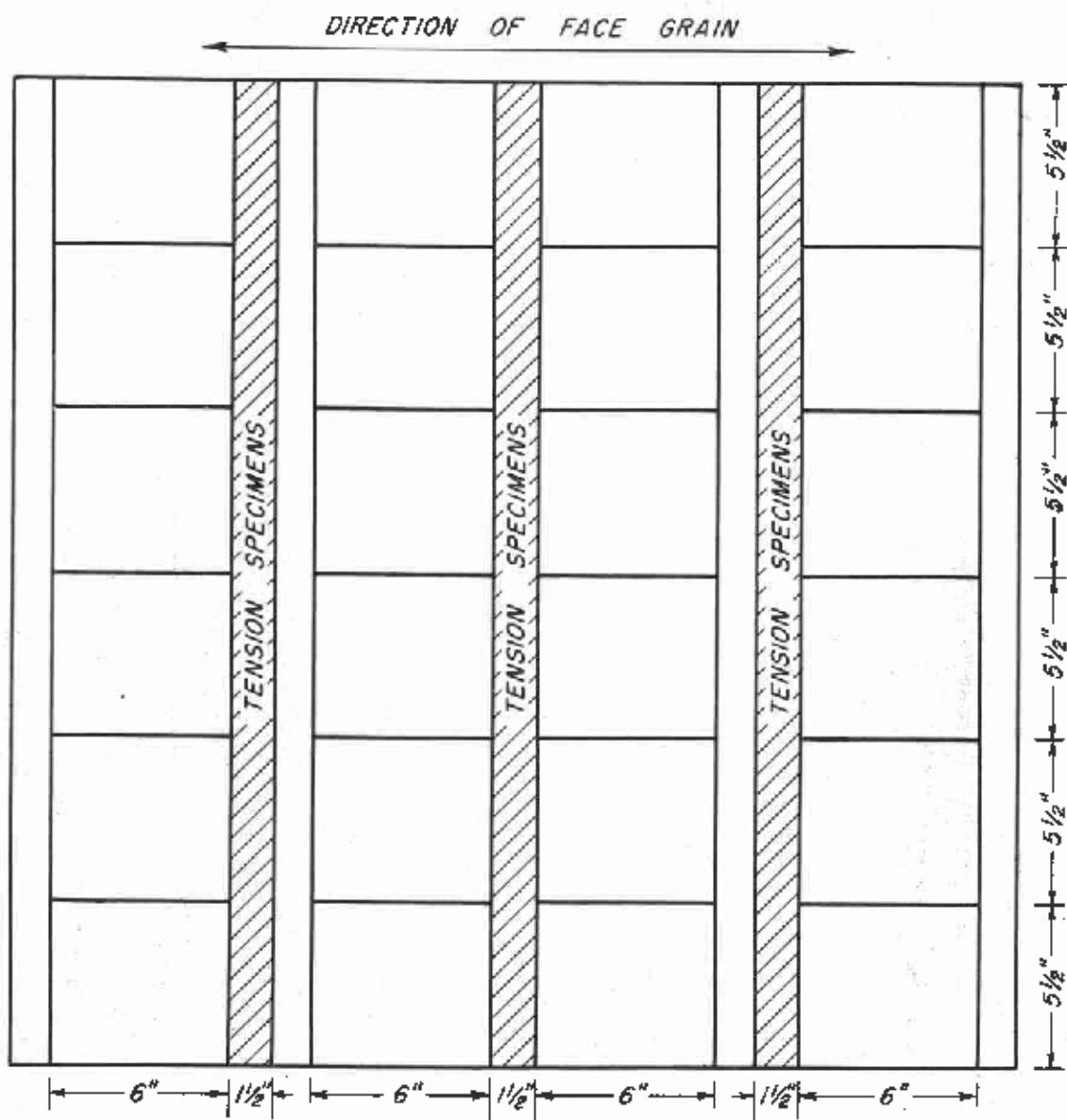


ZM81260F

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)

Report No. 1573-B

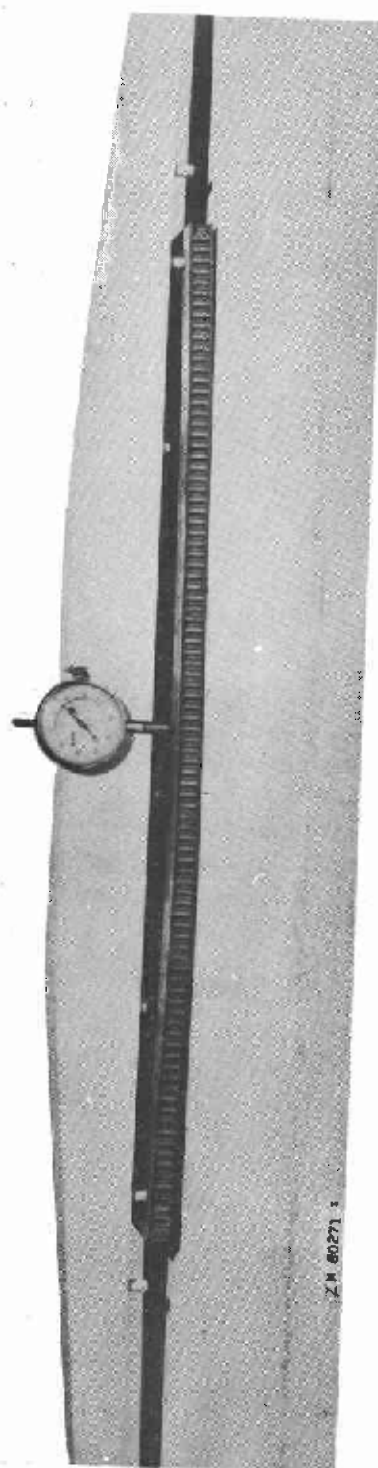


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Figure 7.--Warp-measuring device shown in position on
the long side of a weathering panel.

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