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WEATHERING OF GLASS-FABRIC-BASE PLASTIC LAMINATES

FRED WERREN

AND

B. G. HEEBINK

FOREST PRODUCTS LABORATORY, FOREST SERVICE

U. S. DEPARTMENT OF AGRICULTURE

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FOREWORD

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This report covers period of work from July 1954 to September 1955.

ABSTRACT

Eleven different glass-fabric-base plastic laminates, made with 9 different laminating resins, were subjected to outdoor weathering at 5 sites having entirely different weather conditions. After completion of the exposure cycles, the laminated panels were tested in tension, compression, and flexure at the U. S. Forest Products Laboratory. Data on the effect of exposure on the mechanical properties and the appearance of the laminates after exposure periods of 3 months and 12 months are presented in this report.

Another series of panels is still undergoing exposure at all sites, and this series will be tested after 3 years' exposure. Upon completion of tests of these panels, all data will be compiled in a final report.

Data obtained from the tests made to date show that the effect of outdoor exposure varies with the type of laminate and condition of exposure. The laminate materials showed no severe reductions of strength after outdoor exposure for one year. Most of the materials showed average reductions of from 5 to 10 percent. However, one type of material, that being the heat-resistant polyester resin laminates, showed reduction in strength averaging about 20 percent.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

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INTRODUCTION

Considerable data are available on the mechanical properties of glass-cloth reinforced plastic laminates after normal or wet exposure. Few tests have been made, however, on material that has been subjected to outdoor weathering for extended periods of time. Many different factors are expected to affect the ability of laminates to resist outdoor weathering. These factors include such variables as (1) site and conditions of exposure, (2) type of glass-cloth reinforcement, (3) finish on fabric, (4) type of resin, (5) method of curing resin including catalysts, accelerators, and temperature, and (6) resin content. Extended weathering tests require so much time that it is difficult to isolate and determine the effect of all of the factors affecting the weathering characteristics of laminates.

It is the purpose of this study to determine the effect of outdoor weathering on several types of glass-cloth laminates at 5 different exposure sites for periods up to 3 years. The exposure sites and conditions of exposure are (1) Alaska (arctic), (2) Panama (jungle), (3) Florida (salt air), (4) New Mexico (arid), and (5) Wisconsin (temperate). Tests of the laminates after various exposure periods will indicate the relative resistance to outdoor weathering of the particular laminates included in the study.

The results of tension, compression, and flexural tests of laminates subjected to exposure periods of 3 months and 12 months are presented in this interim report. The laminates to be exposed for 3 years will be removed from the exposure racks in August 1956, and a final report will be written after completion of all tests.

I. DESCRIPTION OF MATERIAL

All of the panels were parallel laminated of 181 glass fabric and were approximately 1/8 inch thick. The number of plies of fabric varied with the fabrication techniques and the type of resin. The fabric finish used with each resin also varied so that fabric finish and resin were compatible. Two panels, about 1/8 by 36 by 36 inches, were fabricated for most of the laminates. For three of the laminates, however, panels of a smaller size were made because of the process, technique, or limitations of the equipment used in fabrication. Most of the laminates were fabricated at the U. S. Forest Products Laboratory. A few, however, were made by other laminators.

All panels were cured in a press with the exception of panels 336 through 341, which were cured at room temperature. These panels were cured in a vacuum bag at room temperature and were free of bubbles or voids.

The fabrication details for each laminate follow.

Panels Nos. 301 and 302

Fabricated at Forest Products Laboratory.

Size: 36 by 36 inches.

Resin: Selectron 5003 (Pittsburgh Plate Glass Co.). **(Polyester)**

Catalyst: 0.8 percent benzoyl peroxide.

Cloth: 181-Garan RS-49 finish.

Number of plies: 12.

Method of impregnation: Hand pouring and spreading.

Initial resin impregnation: 55 percent.

Diffusion period: 2 hours.

Curing time and temperature: 20 minutes at 220° F. followed by 70 minutes at 250° F.

Pressure in press: 14 pounds per square inch.

Parting film in press: 600 PC cellophane on both sides of laminate between 1/4-inch aluminum cauls.

Cushion in press: 2 sheets of 0.027-inch chipboard on both sides between cauls and platens.

Removal from press: Hot.

Comments: Panels were uniform in color and translucency. They were essentially void-free, but certain areas had slight concentrations of small bubbles.

Panels Nos. 303 and 304

Fabricated at Forest Products Laboratory.

Size: 36 by 36 inches.

Resin: Plaskon 911-11 (Libbey-Owens-Ford Glass Co.). (Polyester)

Catalyst: 4 percent paste made of equal parts of benzoyl peroxide and tricresyl phosphate.

Cloth: 181-Garan RS-49 finish.

Number of plies: 12.

Method of impregnation: Hand spreading with squeegee.

Initial resin impregnation: 41 to 43 percent.

Diffusion period: Rolled up 16 to 20 hours.

Curing time and temperature: 90 minutes at 220° F. platen temperature.

Pressure: 14 pounds per square inch.

Parting film in press: 600 PC cellophane on both sides of laminate between 1/4-inch aluminum cauls.

Cushion in press: 2 sheets of 0.027-inch chipboard on both sides between cauls and platens.

Removal from press: Hot.

Comments: Because of the high viscosity of the resin, it was difficult to fabricate the panels and to obtain uniform resin impregnation. Panels were spotty with regard to translucency and number of voids. Voids were substantially larger than in any of the other panels fabricated for this study.

Panels Nos. 309 and 310

Fabricated at Forest Products Laboratory.

Size: 36 by 36 inches.

Resin: PDL-7-669 (American Cyanamid Co). (Heat Resistant Polyester)

Catalyst: 0.5 percent benzoyl peroxide.

Cloth: 181-Garan RS-49 finish.

Number of plies: 12.

Method of impregnation: Hand pouring and spreading.

Initial resin impregnation: 58 percent.

Diffusion period: 2 hours.

Curing time and temperature: 40 minutes at 220° F. platen temperature.

Pressure: 14 pounds per square inch.

Parting film in press: 600 PC cellophane on both sides of laminate between 1/4-inch aluminum cauls.

Cushion in press: 2 sheets of 0.027-inch chipboard on both sides between cauls and platens.

Removal from press: Hot.

Postcure: 500° F. for 3 hours.

Comments: After postcuring, the panels were light brown in color.

Panels Nos. 313 and 314

Fabricated at Forest Products Laboratory under direction of a representative of Naugatuck Chemical Co.

Size: 36 by 36 inches.

Resin: Vibrin X-1047 (Naugatuck Chemical Co.). (Heat Resistant Polyester)

Catalyst: 2.0 percent benzoyl peroxide.

Cloth: 181-Garan RS-49 finish.

Number of plies: 13.

Method of impregnation: Built dam around caul and poured in about 70 percent resin by straining through cheesecloth. Then placed the assembly of 13 plies of cloth on the resin and let the resin diffuse through the cloth from below.

Diffusion period: 16 to 20 hours.

Prepressing operation: Removed voids and much of the excess resin from laminate with wooden squeegee.

Curing time and temperature: 200° F. for 15 minutes followed by 250° F. for 2 hours 15 minutes.

Pressure: Contact for 10 seconds, and then 40 pounds per square inch for remaining time in press.

Parting film in press: 600 PC cellophane on both sides of laminate between 1/16-inch aluminum cauls.

Cushion in press: 10 sheets of 0.027-inch chipboard on both sides between caul and platen.

Removal from press: Turned off steam and cooled slowly under pressure.

Postcure: 400° F. for 24 hours.

Comments: After postcuring, the panels were light brown in color.

Panels Nos. 319 and 320

Fabricated by Shell Development Co.

Size: 36 by 36 inches.

Resin: Epon 1001 (Shell Chemical Co.). (Epoxy)

Catalyst: 4 percent dicyandiamide.

Cloth: 181-Volan A finish.

Number of plies: 12.

Initial resin content: Not divulged.

Parting film: Dow Corning Release Agent XEC 135A.

Cushion in press: 2 plies of 0.060-inch alpha-cellulose on each side under 16-gage stainless steel cauls.

Pressure and temperature in press: Contact pressure for 15 minutes, followed by 25 pounds per square inch for 25 minutes, all at 174° C. (345° F.) platen temperatures.

Removal from press: Cooled under pressure.

Comments: Panels were a greenish-gray color and appeared to be essentially void-free except at the edges. The outer 1 or 2 inches at the edges were lighter in color apparently due to the voids. The surfaces were somewhat rough probably due to the parting agent.

Panels Nos. 321 and 322

Fabricated at Forest Products Laboratory.

Size: 36 by 36 inches.

Resin: Dryply 81 (Flexifirm Products). (Polyester)

Catalyst: None added at time of fabrication.

Cloth: 181-Garan RS-49 finish.

Number of plies: 11.

Method of impregnation: Impregnated by Flexifirm Products before receipt at U. S. Forest Products Laboratory.

Curing time and temperature: 270° F. for 33 minutes.

Pressure: 50 pounds per square inch.

Parting film in press: 600 PC cellophane on both sides of laminate between 1/4-inch aluminum cauls.

Cushion in press: 2 sheets of 0.027-inch chipboard on both sides between caul and platen.

Removal from press: Cooled under pressure.

Comments: Panels were very light tan in color.

Panels Nos. 326 and 327

Fabricated by Shell Development Co.

Size: 36 by 36 inches.

Resin: Epon 828 (Shell Chemical Co.). (Epoxy)

Catalyst: 13 percent Curing Agent D.

Cloth: 181-Volan A finish.

Number of plies: 12.

Initial resin content: Not divulged.

Parting film in press: 600 PC cellophane.

Cushion in press: 2 sheets 0.060-inch alpha-cellulose on each side of laminate between 16-gage stainless steel cauls and platens.

Pressure and temperature in press: Contact pressure for 5 minutes, followed by 25 pounds per square inch for 25 minutes, all at 115° C. (239° F.) platen temperature.

Removal from press: Cooled under pressure.

Comments: Panels were light olive in color, uniform in translucency, and essentially void-free.

Panels Nos. 331 and 332

Fabricated at Forest Products Laboratory.

Size: 36 by 36 inches.

Resin: DC 2104 Silicone (Dow Corning Corp.). (Silicone)

Catalyst: None added at time of fabrication.

Cloth: 181 heat cleaned; no finish.

Number of plies: 12.

Method of impregnation: Impregnated by Polymeric Co. before receipt at Forest Products Laboratory.

Curing time and temperature: 340° F. for 45 seconds. Press then opened and closed to full pressure within 15 seconds. Full pressure at 340° F. for 17 minutes.

Pressure: 45 pounds per square inch.

Parting film in press: 600 PC cellophane on both sides of laminate between 1/16-inch aluminum cauls.

Cushion in press: None.

Removal from press: Cooled under pressure.

Postcure: 16 hours at 195° F., 1 hour at 260° F., 1 hour at 300° F., 1 hour at 350° F., 1 hour at 420° F., and 140 hours at 480° F.

Comments: Panels were white in color.

Panels Nos. 336, 337, 338, 339, 340, and 341

Fabricated at Forest Products Laboratory.

Size: Nos. 336, 337, and 338 were 18 by 25 inches; Nos. 339, 340, and 341 were 12 by 27 inches.

Resin: Selectron 5003 (Pittsburgh Plate Glass Co.). (Polyester)

Catalyst: 0.5 percent tertiary butyl hydroperoxide.

Promoter: 0.5 percent Nuodex cobalt (6 percent solution).

Cloth: 181-Garan RS-49 finish.

Number of plies: 12.

Method of impregnation: Hand pouring and spreading.

Initial resin impregnation: 60 percent.

Description of general fabrication procedure: A 1/4-inch-thick flat aluminum caul, several inches larger than the laminate to be fabricated, was covered with 600 PC cellophane. The correct dimension of the laminate was drawn on the cellophane. A rope of breather cloth was placed about 1-1/2 inches from and surrounding the dimensions of the laminate before the lay-up of the laminate was made. The assembly was covered with polyvinyl alcohol film, and a vacuum connection was fastened to the film above the breather cloth. The film was sealed to the cellophane-covered caul with aircraft putty, and a low vacuum (5 to 7 inches mercury) was applied.

Diffusion period: 10 to 15 minutes.

Removing voids and excess resin: Voids and excess resin were removed with a wooden squeegee. The thickness of the laminate was checked periodically, and the process of working out resin continued until the approximate thickness was attained.

Curing time and temperature: Laminate jelled in 1 to 2 hours at room temperature (70° to 80° F.), but it was maintained at room temperature for about 16 hours before removal from the vacuum bag.

Pressure: Vacuum pressure (5 to 7 inches mercury).

Comments: Panels were uniform in color and translucency and were void-free. Color was a very light gray. These panels were more translucent than any of the other panels fabricated for this study.

Panels Nos. 342 and 343

Fabricated by Naugatuck Chemical Co.

Size: 22 by 22 inches.

Resin: Vibrin X-1047 (Naugatuck Chemical Co.). (**Heat Resistant Polyester**)

Catalyst: 2.0 percent benzoyl peroxide.

Cloth: 181 with OC-301 finish.

Number of plies: 14.

Method of impregnation: All 14 plies of cloth were laid in a pool of resin and allowed to soak overnight. The cloth and resin were then sealed in a cellophane bag and squeezed to remove excess resin and air.

Pressure in press: 10 pounds per square inch.

Temperature and time in press: 1/2 hour at 160° F., 10 to 20 minutes to reach 250° F., followed by 2 hours at 250° F.

Removal from press: Hot.

Postcure: 24 hours at 400° F.

Comments: After postcuring, the panels were light brown in color. Color and translucency were about the same as Panels 313 and 314, which were fabricated at the Forest Products Laboratory.

Panels Nos. 346, 347, 348, and 349

Fabricated by Bakelite Co.

Size: 28 by 35 inches.

Resin: Bakelite BV 17085 (Bakelite Co.). (**Heat Resistant Phenolic**)

Catalyst: None.

Cloth: 181-Volan A finish.

Number of plies: 13.

Method of impregnation: Laminating treater.

Initial resin content: 40 percent.

Precure: Dried at 285° F. to a volatile content of 2.9 percent.

Curing cycle: 40 minutes at 300° F. and 45 pounds per square inch.

Removal from press: Cooled under pressure.

Postcure: 15 hours at 250° F., 4 hours at 300° F., 4 hours at 340° F.

Comments: After postcuring, the panels varied considerably in color from a light to a dark brown. All panels had a slightly reddish hue. The center area of the panel was usually appreciably darker than the area at the edges with an abrupt transition from the dark to the light colored areas. There appeared to be a greater dissimilarity between these panels than between those of the other laminates in this study. The panels were also the least translucent of the laminates.

General

All of the panels were translucent in that they permitted the transmission of some light. The degree of translucency, however, varied greatly. An illustration of a specimen from each of the control subpanels, photographed with transmitted light, is shown in figure 1.

After the resin was cured, each laminated panel was trimmed, measured, and weighed, and Barcol hardness readings were taken. The specific gravity and resin content of the trimmed panel were then determined. The approximate percentage of resin content was computed from:

$$\frac{\text{Weight of laminated panel - weight of fabric in panel}}{\text{Weight of laminated panel}} \times 100$$

General information on each of the panels is given in table 1.

When additional postcure of a particular laminate was required, the panels were cut to a maximum size of 18 by 24 inches so that they would fit in the high temperature oven available. Postcuring was then completed as described for individual laminates.

II. MARKING AND EXPOSURE OF PANELS

Each laminated panel was cut up into 9- by 12-inch subpanels as shown in figures 2 to 5. Each subpanel was numbered at one edge as shown in the figures with the original panel number followed by a letter of the alphabet. By this method, it is possible to determine the location of each subpanel in the original laminated panel. Those with certain letter designations were assigned to specific exposures. For example, all of the subpanels designated by the letters F or R were used for control tests, those with the letter A were sent to Alaska for 3 months' outdoor weathering, those with the letter K went to Panama for 12 months' outdoor weathering, and so on.

In marking each laminated panel made at the Forest Products Laboratory and in numbering each subpanel, the top of the panel as laminated was the face upon which numbers were placed. This procedure was not particularly important in this study since all panels were parallel laminated of 181 glass fabric, but it follows the general marking procedure used at the Laboratory. In panels received from other sources, the side that had the identification markings was assumed to be the top ply of the panel as laminated.

The subpanels for control tests, designated by the letters F and R, were stored in a normal atmosphere maintained at 73° F. and 50 percent relative humidity until they were cut into test specimens.

In subsequent discussion, these panels will be referred to as the control panels.

The 9- by 12-inch subpanels designated for exposure will hereafter in this report be called exposure panels. After at least 2 weeks' conditioning at a temperature of 73° F. and a relative humidity of 50 percent, 10 Barcol hardness readings were made of each face of each exposure panel. The panels designated for outdoor weathering were then mounted on 1- by 4-inch boards with 5 or 6 panels on each board. Each panel was fastened to the board with 2 screws and kept from contact with the board by small wood blocks about 1/2 inch thick. All the mounted panels except those designated for exposure at Madison, Wis., were then crated and shipped to the appropriate exposure site.

The mail addresses and exposure conditions of the five outdoor exposure sites were:

(1) University of Alaska
Geophysical Institute
College, Alaska
(Arctic conditions)

(2) Naval Research Laboratory
Tropical Exposure Station
Coco Solo, Canal Zone
(Jungle conditions)

(3) New Mexico College of Agriculture
and Mechanic Arts
School of Engineering
State College, N. Mex.
(Arid conditions)

(4) South Florida Test Service
4201 Northwest Seventh Street
Miami 34, Fla.
(Salt air exposure)

(5) U. S. Forest Products Laboratory
Madison 5, Wis.
(Temperate conditions)

The exposure panels were placed outdoors at each of the 5 sites on or about August 15, 1953. The panels were mounted on racks, so that the face to be exposed was facing south and was tilted upwards at an angle of 45 degrees from the horizontal. The exposed face was the bottom side of the panel as laminated, and thus the panel numbers were on the sheltered face. A photograph of panels on exposure racks at the Florida site is shown in figure 6.

In addition to the exposure panels for outdoor weathering, 9- by 12-inch panels of each type of laminate were subjected to continuous normal conditioning. These panels were stored in vertical racks at the U. S. Forest Products Laboratory in an atmosphere maintained at 73° F. and at a relative humidity of 50 percent.

Ten different laminates were subjected to all of the exposure conditions described. The eleventh laminate, made with Vibrin X-1047 resin by the Naugatuck Chemical Co., was subjected only to the exposure conditions at Madison, Wis. Control tests were made of all laminates.

After outdoor exposure periods of 3 months and 12 months, the panels were removed from the exposure racks and returned to the Forest Products Laboratory while still mounted on the boards. The 12-month panels at Alaska were inadvertently exposed about 14 months. The exposure panels were then removed from the mounting boards and conditioned for at least 1 week at 73° F. and 50 percent relative humidity. Then Barcol hardness readings were made of both the exposed and sheltered faces. The panels were then ready to be cut into test specimens.

Exposure panels to be tested after 3 years outdoor weathering or normal conditioning will be removed from the racks in August 1956.

III. METHODS OF TEST

Both the control panels and the exposure panels were cut into tension, compression, and flexural specimens as shown in figure 7. The longer dimension of each specimen was parallel to the warp direction. In all panels, the tensile specimens were cut from the end of the panel opposite the panel number, so that it is possible to determine from approximately what area of the original laminate each specimen was taken.

From each subpanel, 5 each of tension, compression, and flexural specimens were tested after normal conditioning, and 5 flexural specimens were tested after wet conditioning. Normal conditioning means that specimens were conditioned for at least 2 weeks at 73° F. and 50 percent relative humidity before testing. Wet conditioning refers to conditioning at 100° F. and near 100 percent relative humidity until approximate weight equilibrium is reached. The wet specimens were first normally conditioned for at least 2 weeks, measured and weighed, and wet conditioned for about 4 months longer. The specimens were then remeasured, reweighed, and tested.

In addition to the normal and wet tests, 4 flexural tests were made of each control and exposure panel from laminates made with a high-temperature-resistant resin. These resins were PDL-7-669, Vibrin X-1047, DC 2104 Silicone, and Bakelite BV 17085. The flexural specimens were subjected to normal conditioning for at least 2 weeks and tested at 500° F. after 1/2 hour at that temperature. The modulus of rupture for each specimen was determined.

Tensile specimens were 3/4 inch wide and 9 inches long, and their configuration corresponded to the type 2 specimen described under Method 1011 of Federal Specification L-P-406b, "Plastics, Organic: General Specifications, Test Methods," dated September 27, 1951. The specimens were tested using Templin tension grips at a testing machine-head speed of 0.2 inch per minute. Maximum load only was determined.

Compression specimens were 1/2 inch wide and 3-1/16 inches long and were restrained from buckling by means of a supporting jig similar to that described in Method 1021.1 of Federal Specification L-P-406b, dated September 25, 1952. The ends of the specimens were machined parallel to each other and perpendicular to the adjacent faces. Load was applied at a testing machine-head speed of 0.05 inch per minute, and the maximum load was determined. Since the compression specimens were cut from an area near the center of each subpanel, the specific gravity of each specimen was determined from its linear measurements and weight after normal conditioning. The average specific gravity is thus representative of the specific gravity for the particular subpanel.

Flexural specimens were 1/2 inch wide and 4 inches long and were tested flatwise by center loading over a span of 2 inches. The numbered face of the specimen corresponding to the top of the original laminate was faced upward during testing. Under these conditions, the weathered or exposed faces of the panels that had been subjected to weathering were on the bottom, and they were thus subjected to tensile stresses during test. Load was applied at a testing machine-head speed of 0.025 inch per minute. Load-deflection data were obtained for most of the specimens, but only the maximum load was determined for the others.

IV. PRESENTATION OF DATA

Results of tests of control and exposure subpanels of the 11 different laminates are presented in tables 2 through 6. The headings of all tables are the same except that results of flexural tests at 500° F. are given for laminates made with heat-resistant resins in tables 5 and 6.

Columns 1 and 2 indicate the exposure condition and the length of exposure of each subpanel. The number of each 9- by 12-inch panel in column 3 makes possible the orientation of each subpanel with respect to its location in the original laminate (figs. 2 to 5). Barcol hardness readings of the exposure panels both before and after exposure are given in columns 4 through 7.

The average tensile strength of each panel after normal conditioning of the specimens is given in column 8. Data obtained from compression specimens include average thickness, specific gravity, and compressive strength after normal conditioning, which are listed in columns 9, 10, and 11. Since compression specimens were cut from near the center of each 9- by 12-inch panel, the thickness and specific gravity are reasonably representative of that particular panel. This is of interest in analyzing specific test data, since there may be a difference in mechanical properties throughout the original laminate simply because the thickness and subsequent resin content and specific gravity may vary appreciably. Data obtained from tests of flexural specimens are given in columns 12 through 16. Column 17 contains additional data for the laminates made with the heat-resistant resins. Average values of proportional limit stress, modulus of rupture, and modulus of elasticity after normal conditioning are given in columns 12, 13, and 14. The modulus of rupture values after wet conditioning the specimens for about 4 months at 100° F. and a relative humidity of about 100 percent are given in column 15. Each wet flexural specimen was first weighed after a period of normal conditioning and again after wet conditioning. The average weight increase in percent of the dry weight is shown in column 16. For the heat-resistant laminates, the modulus of rupture at 500° F. after 1/2-hour exposure to that temperature is given in column 17.

V. DISCUSSION OF RESULTS

General

Because of the nature of the weathering study and the amount of material involved, it was impracticable to match materials to the extent desired. A practicable procedure was followed. The subpanels of each type of laminate were cut as far as possible from two 36- by 36-inch laminates which were fabricated from the same roll of fabric, the same batch of resin, and under the same fabrication conditions. In general, the laminates of each type were closely matched with respect to average thickness, specific gravity, resin content, and Barcol hardness. However, the first three properties may have varied considerably in different parts of the laminate, and the properties of subpanels from different locations must be expected to vary somewhat in mechanical properties. In reviewing the test data, these factors should be considered, and the thickness and specific gravity values given in tables 2 through 6 may be helpful in analyzing the test results.

The panels that are undergoing exposure for a 3-year period will not be removed from the exposure racks until August 1956. Several additional months will then be needed to return the panels to the Laboratory, prepare, condition, and test specimens, and then analyze data and prepare a final report on this study. This interim report on the results of tests after exposure periods of 3 months and 12 months will serve as a basis to indicate expected resistance of several types of laminates to various exposure conditions.

In the following discussion, the appearance of the exposure panels after weathering 1 year is briefly described. There was no concrete way of comparing the appearance of the exposure panels after normal conditioning to their appearance before conditioning, but they seemed to be practically unchanged on the basis of a few available notes and a general recollection of their appearance. The effect of exposure on the physical and mechanical properties is also discussed later in a general way. Detailed comparisons between different properties under different exposure conditions may be made by the reader by referring to tables 2 through 6. Since this is an interim report, no conclusions are given at this time.

Appearance of 1-Year Exposure Panels

There was considerable variation in the appearance of the exposure panels after weathering at the different sites. The exposed faces generally showed some wearing away of the surface resin which resulted in exposure of the glass fibers on the face of the laminate. Many of the panels exposed at Panama showed a marked discoloration of the exposed face, which was probably due to the action of fungi. This discoloration was most evident on the lighter colored panels, but it also occurred on the darker colored laminates. The discoloration occurred only on the exposed face and was simply a surface condition which probably had no effect on the mechanical properties of the laminate.

Many of the laminates changed in color, and usually the darker panels turned somewhat lighter. The amount of color change varied with the exposure site.

Viewing the exposed laminates with a 10-power hand lens showed that the resin of some laminates was cracked throughout the laminate. Since these cracks were also evident in material which had been stored in a normal atmosphere, the cracking of the resin could not be attributed entirely to outdoor weathering. Possibly these cracks were formed during the cooling of the laminate after fabrication, but the panels were not inspected for cracks at that time. The presence of cracks in the resin, however, seemed to result in poorer weathering resistance. In one case, the presence of cracks was observed only on the exposed face of the panel weathered at Florida, while no cracks were evident on the other panels of the same type of material.

The amount of wearing away, or erosion, of the surface resin after 1 year's exposure was estimated for each laminate, based on the percentage of fibers exposed. For example, if the exposed surface appeared to be about 25 percent fibers and 75 percent resin when viewed with a 10-power hand lens, the erosion was arbitrarily called minor erosion. However, the face of one panel was eroded until practically all traces of resin had disappeared from the surface, and this situation was called much erosion. The terminology used to describe the degree of erosion in terms of the percentages of exposed fibers was:

Much	-- Over 80 percent
Considerable	-- 60 to 80 percent
Moderate	-- 40 to 60 percent
Minor	-- 20 to 40 percent
Slight	-- Under 20 percent

A brief description of the changes in appearance of the exposure panels weathered for 1 year follows:

(1) 181 Garan fabric and Selectron 5003.--Exposed faces of panels weathered in Alaska, New Mexico, Florida, and Wisconsin showed moderate erosion. The Florida panel showed the greatest erosion. Slight yellowing appeared on all panels except that from Panama.

(2) 181 Garan fabric and Selectron 5003 (room-temperature setting).--Exposed face of the Florida panel showed moderate erosion, and the face of the New Mexico panel showed slight erosion. Negligible erosion occurred on the other panels, although the exposed face of the Panama panel was discolored.

(3) 181 Garan fabric and Plaskon 911-11.--Considerable erosion occurred on the exposed face of the Florida panel. The exposed face of the Panama panel showed loss of lustre.

(4) 181 Garan fabric and Dryply 81.--Moderate erosion occurred on the exposed face of the Florida panel, and minor erosion occurred

on the other panels except the Panama panel which showed no noticeable erosion. The exposed face of the Panama panel was discolored. Noticeable cracks in resin were evident on the exposed face of the Florida panel when viewed with a 10-power glass.

(5) 181 Volan A fabric and Epon 1001.--Considerable erosion occurred on the exposed face of the Florida panel, and moderate erosion on the panels from Panama, New Mexico, and Wisconsin. There was no noticeable erosion of the Alaska panel.

(6) 181 Volan A fabric and Epon 828.--Moderate erosion occurred on the exposed face of the Florida panel, and some minor erosion on the panels from Alaska, New Mexico, and Wisconsin. All panels except that from Panama changed from a light olive color to a slightly darker hue.

(7) 181 Garan fabric and PDL-7-669.--All panels faded, but the least fading occurred on the Panama panel. Much erosion occurred on the exposed faces of the panels from Florida and Wisconsin. The Florida panel, with practically all resin eroded from its surface, showed the most severe erosion. The appearance of the Florida panel was gray because of the exposed fabric. Moderate erosion occurred on the panels from Alaska and New Mexico, and minor erosion on the Panama panel. All panels, including that exposed normally, showed noticeable cracks in resin when viewed with a 10-power glass.

(8) 181 Garan fabric and Vibrin X-1047.--All panels faded, but the Panama panel faded the least. Much erosion occurred on the exposed face of the Florida panel, and moderate erosion occurred on the other

panels except the Panama panel which showed only minor erosion. The appearance was similar to the PDL-7-669 except that erosion was not quite as severe. Noticeable cracks in resin of all panels, including that exposed normally, were evident when viewed with a 10-power glass.

(9) 181 OC-301 fabric and Vibrin X-1047.--Outdoor exposure was made in Wisconsin only. Moderate erosion occurred on the exposed face. The exposed face changed greatly in color from a light brown to a dull gray. Some fading appeared on the sheltered face. Noticeable cracks in resin of panels, including the normally exposed panel, were evident when viewed with a 10-power glass.

(10) 181 heat cleaned fabric and DC 2104.--No noticeable erosion appeared on the exposed faces. The exposed face of the Panama panel had a discolored and mottled appearance, but this was only a surface condition.

(11) 181 Volan A fabric and Bakelite BV 17085.--All panels were warped and slightly faded. Minor erosion occurred on the exposed face of the Florida panel, slight erosion on the panels from Alaska and New Mexico, and only a perceptible erosion on the Wisconsin panel.

Florida with salt air exposure was consistently the most severe outdoor exposure condition with respect to erosion of resin and change in color of the laminate. The jungle exposure at Panama showed the smallest effect on erosion and change of color of all the panels except the Epon 1001 laminate for which the Alaska exposure was least severe. The exposed surfaces of the panels from Panama were generally discolored by what appeared to be mold.

Photographs of extra compression specimens cut from near the center of each subpanel (specimen No. 6 of figure 7) are shown in figures 8 through 12. The specimens at the left of each of the two exposure groups were cut from the original control panel, and the view is from the top surface as laminated. The specimens at the center and right were cut from a panel after exposure periods of 3 months or 12 months, and the view is from the bottom surface as laminated or from the exposed face for those panels subjected to outdoor weathering. Since the specimens from the control panel and from the normally conditioned panel were continuously kept in a normal atmosphere, these specimens serve as a basis of comparison between weathered and nonweathered material.

Barcol Hardness

Ten Barcol hardness readings were made on the faces of the exposure panels both before exposure and after exposure. In general, the hardness readings were about the same or increased slightly with exposure. However, the hardness of both faces of the DC 2104 laminate and of the exposed (bottom) faces of the PDL-7-669 and Vibrin X-1047 laminates generally decreased after outdoor exposure. After substantial erosion of the resin on the exposed faces and the exposure of the bare fabric, changes in hardness readings are to be expected.

Strength of Panels after Normal Exposure

The tensile strength of panels exposed under normal conditions for 3 months was about the same or slightly higher than the tensile strength of the control panels. The strength values of panels exposed for 12 months were slightly lower than those of panels exposed for 3 months.

All of the panels that were exposed to normal conditions for 3 months had higher compressive strength than the control panels. After 12 months of exposure, the strength values varied somewhat and were higher for some laminates and lower for others than the 3-month test values.

The normal, wet, and high temperature flexural strengths of exposed panels were generally about the same as those of the control panels, but the normal and wet flexural strengths of the Dryply panels were somewhat higher.

Strength of Panels after Outdoor Exposure

Tensile strength values after 3 months of weathering were generally about the same or slightly higher than the control values with the largest increase in the Dryply laminates. Tensile strength values after 12 months of exposure were generally somewhat lower than the 3-month values. As might be expected, the most severe reductions appeared to be associated with panels having the greatest amount of resin erosion of the exposed faces.

There was sometimes considerable variation in the compressive strength values obtained from the 5 specimens of each subpanel. Although each specimen was carefully set up prior to loading, there was no way of knowing whether or not the compressive stress distribution was uniform during testing. Therefore the average compressive strength values given in the tables are not considered to be as reliable as the tensile and flexural test values. In general, compressive strength appeared to increase after weathering. In the 2 Selectron 5003 laminates, compressive strength increased with longer outdoor exposure. In some laminates, the compressive strength after exposure periods of 3 months and 12 months was about the same, and in other laminates, increased exposure time resulted in lower compressive strength probably because of resin erosion of the exposed faces.

There was a great deal of difference in the results of the flexural tests due to the different types of laminate and conditions of exposure. The Dryply panels became stronger at all exposure sites with longer periods of outdoor exposure. The greatest increased occurred at the Alaska, New Mexico, Florida, and Wisconsin sites. On the other hand, the PDL-7-669 laminates decreased in normal and wet flexural strengths with increased periods of weathering. For this laminate, the available data indicate that the jungle exposure at Panama was the least detrimental weathering site. On the other hand, the Panama site was the least favorable for the Dryply laminate. The normal and wet flexural strengths of the DC 2104 laminate did not appear to be appreciably affected by the exposure site. All values of this laminate were about the same as the original control strength values.

Considering the tension, compression, and flexural strengths of all laminates as a group, the most detrimental weathering effects occurred at the Florida site and the least detrimental effects at the Panama site.

Increase in Weight

Values of weight increase of wet flexural specimens given in column 16 of tables 2 through 6 indicate percentage increase in weight due to conditioning at 100° F. and about 100 percent relative humidity for about 4 months. In general, the increase in weight was greater for specimens that had been exposed for 12 months than for those that had been exposed only 3 months.

Table 1.--General information on parallel-laminated panels of 181 glass fabric used in outdoor weathering study

Fabric finish	Resin	Fabrication: Impregnation by --	Fabrication: Lay-up and cure at --	Fabrication: Number of plies	Panel No.	Thickness: Minimum	Thickness: Maximum	Thickness: Average	Specific gravity	Resin content	Barcol hardness
						Inch	Inch	Inch		Percent	
Garan RS-49	Selectron 5003	FPL	FPL	12	301	0.110	0.127	0.122	1.82	35.8	67
					302	.110	.128	.124	1.81	36.5	64
Garan RS-49	Plaskon 911-11	FPL	FPL	12	303	.111	.132	.125	1.86	38.7	75
					304	.114	.141	.135	1.81	41.6	76
Garan RS-49	PDL-7-669	FPL	FPL	12	309	.112	.125	.121	1.88	37.4	74
					310	.114	.127	.122	1.88	37.8	73
Garan RS-49	Vibrin X-1047	FPL	FPL	13	313	.109	.125	.118	1.93	31.9	76
					314	.107	.120	.114	1.94	30.3	75
Volan A	Epon 1001	Shell Dev. Co.	Shell Dev. Co.	12	319	.111	.128	.122	1.80	35.2	60
					320	.112	.128	.122	1.81	35.3	62
Garan RS-49	Dryply 81	Flexifirm Prod.	FPL	11	321	.112	.129	.122	1.79	40.1	61
					322	.113	.129	.123	1.79	40.4	63
Volan A	Epon 828	Shell Dev. Co.	Shell Dev. Co.	12	326	.111	.138	.127	1.77	36.6	59
					327	.110	.130	.121	1.82	35.2	62
Heat cleaned	DC 2104 silicone	Polymeric Co.	FPL	12	331	.126	.133	.130	1.73	36.4	42
					332	.124	.133	.130	1.74	36.9	39
Garan RS-49	Selectron 5003 (room-temperature setting)	FPL	FPL	12	336	.123	.137	.131	1.77	38.3	51
					337	.126	.137	.132	1.76	38.6	50
					338	.127	.141	.133	1.76	39.0	55
					339	.117	.132	.125	1.80	36.6	56
					340	.118	.132	.127	1.78	36.8	53
					341	.124	.139	.131	1.76	38.1	58
OC-301	Vibrin X-1047	Naugatuck Chem.Co.	Naugatuck Chem.Co.	14	342	.124	.152	.136	1.87	34.4	71
					343	.123	.151	.136	1.89	35.2	74
Volan A	Bakelite BV 17085	Bakelite Co.	Bakelite Co.	13	346	.130	.146	.137	1.79	37.0	69
					347	.124	.142	.133	1.80	35.5	68
					348	.119	.135	.127	1.84	33.9	69
					349	.118	.135	.126	1.86	34.1	69

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Table 2--Properties of Selectron 5003 Laminates of 181 Glass Fabric After Various Exposure Conditions

Exposure	Length of exposure	Panel No.	Barcol hardness: Before exposure: Top	Barcol hardness: Before exposure: Bottom	Barcol hardness: After exposure: Top	Barcol hardness: After exposure: Bottom	Tensile strength (normal)	Compression (normal): Thickness	Compression (normal): Specific gravity	Compression (normal): Strength	Flexure: Normal: Proportional limit	Flexure: Normal: Modulus of rupture	Flexure: Normal: Modulus of elasticity	Flexure: Wet: Modulus of rupture	Flexure: Wet: Increase in weight
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Months						P.s.i.	Inch		P.s.i.	P.s.i.	P.s.i.	1,000 p.s.i.	P.s.i.	Percent
GARAN FINISHED FABRIC AND SELECTRON 5003 RESIN															
Control		301-F					45,300	0.126	1.78	33,700	35,300	59,000	2,850	53,300	0.60
		302-R					46,700	.128	1.77	37,900	36,300	56,400	2,800	53,200	.60
Alaska	3	301-A	66	65	66	65	48,900	.122	1.81	38,300	28,200	59,400	3,150	55,300	.58
	12	301-L	66	66	69	68	47,800	.124	1.81	48,400		64,400		57,400	.69
Panama	3	301-B	65	65	65	63	50,600	.124	1.80	38,700	27,000	58,200	3,140	55,300	.51
	12	301-K	65	64	69	67	48,500	.125	1.81	47,000		65,800		56,400	.62
New Mexico	3	301-C	64	64	67	66	49,400	.123	1.80	44,800	24,400	61,400	3,260	57,200	.62
	12	301-J	66	64	72	71	44,700	.121	1.85	49,400		61,600		53,800	.77
Florida	3	301-D	64	63	65	64	52,300	.122	1.80	42,200	25,800	61,900	3,220	57,100	.50
	12	301-I	66	66	68	65	46,800	.123	1.82	50,600		61,700		50,900	.82
Wisconsin	3	301-H	66	64	66	65	49,400	.124	1.80	41,500	26,700	59,600	3,140	58,200	.56
	12	301-E	66	65	70	69	47,700	.124	1.81	45,700		64,400		56,900	.66
Normal	3	302-Q	64		68		47,400	.126	1.80	40,100	31,200	55,600	2,930	53,100	.57
	12	302-U	64		67		46,400	.124	1.82	43,000		55,400		54,400	.75
GARAN FINISHED FABRIC AND SELECTRON 5003 RESIN (ROOM TEMPERATURE SETTING)															
Control		336-F					43,900	.132	1.74	38,100	26,600	54,700	3,010	56,000	.69
		338-F					45,000	.135	1.74	36,100	31,700	52,800	2,930	55,400	.70
		340-F					43,000	.132	1.74	31,100	31,600	55,300	3,030	57,700	.66
Alaska	3	336-A	60	63	63	63	45,500	.128	1.79	49,200	29,200	57,400	3,200	52,900	.76
	12	336-L	63	63	66	66	43,200	.130	1.78	53,800		58,400		49,400	.79
Panama	3	337-B	61	62	63	60	48,200	.135	1.75	48,700	29,600	60,400	3,110	52,100	.61
	12	337-K	62	61	66	61	49,100	.132	1.77	52,100		63,000		50,900	.70
New Mexico	3	338-C	64	62	65	65	45,600	.133	1.76	51,000	30,600	56,300	3,170	49,100	.73
	12	338-J	62	62	69	68	42,600	.134	1.78	55,100		53,900		44,200	.84
Florida	3	339-D	62	63	65	63	48,000	.130	1.78	53,800	34,900	60,400	3,190	51,800	.60
	12	339-I	63	61	69	67	46,600	.123	1.81	56,300		56,200		45,200	.77
Wisconsin	3	341-H	61	62	65	63	44,200	.131	1.76	50,000	31,100	57,500	3,180	51,200	.70
	12	341-E	63	60	70	66	43,200	.133	1.76	55,900		58,500		49,700	.79
Normal	3	337-Q	63		63		43,900	.132	1.75	42,700	26,200	55,100	3,170	54,800	.69
	12	340-U	62		67		41,800	.130	1.78	44,800		56,100		51,600	.80

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Table 3--Properties of Plaskon 911-11 and Dryply 81 Laminates of 181 Glass Fabric After Various Exposure Conditions

Exposure	Length of exposure	Panel No.	Barcol hardness: Before exposure: Top	Barcol hardness: Before exposure: Bottom	Barcol hardness: After exposure: Top	Barcol hardness: After exposure: Bottom	Tensile strength (normal)	Compression (normal): Thickness	Compression (normal): Specific gravity	Compression (normal): Strength	Flexure: Normal: Proportional limit	Flexure: Normal: Modulus of rupture	Flexure: Normal: Modulus of elasticity	Flexure: Wet: Modulus of rupture	Flexure: Wet: Increase in weight
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Months						P.s.i.	Inch		P.s.i.	P.s.i.	P.s.i.	1,000 p.s.i.	P.s.i.	Percent
							GARAN FINISHED FABRIC AND PLASKON 911-11 RESIN								
Control	...	303-F	...	...	...	...	48,100	0.130	1.82	44,700	28,100	61,500	2,970	59,600	0.95
	...	304-R	...	...	...	...	43,600	.141	1.78	43,200	24,600	56,800	2,850	53,700	1.03
Alaska	3	303-A	72	71	72	71	49,200	.126	1.86	52,000	26,100	61,900	3,160	59,100	.93
	12	303-L	70	68	74	75	48,700	.122	1.88	51,000	...	63,600	...	57,700	1.01
Panama	3	303-B	71	68	69	65	50,100	.127	1.84	47,800	22,100	60,400	3,150	58,000	.76
	12	303-K	69	69	72	71	47,800	.126	1.86	51,800	...	60,900	...	56,500	.85
New Mexico	3	303-C	72	65	70	69	49,600	.125	1.85	52,300	25,300	61,200	3,250	57,200	1.05
	12	303-J	68	68	76	78	43,800	.129	1.87	52,900	...	54,600	...	48,500	1.19
Florida	3	303-D	73	72	73	70	52,100	.123	1.87	54,600	26,100	64,400	3,310	60,000	.78
	12	303-I	66	66	73	70	42,800	.128	1.87	53,300	...	53,800	...	48,000	1.13
Wisconsin	3	303-H	74	73	69	72	49,800	.124	1.85	53,700	26,100	63,000	3,280	61,300	.90
	12	303-E	68	65	75	75	46,000	.128	1.86	52,200	...	56,300	...	52,500	.98
Normal	3	304-Q	62	...	68	...	43,500	.141	1.78	48,000	24,100	56,500	2,900	54,900	1.00
	12	304-U	66	...	68	...	42,600	.137	1.77	45,500	...	54,000	...	53,900	1.21
							GARAN FINISHED FABRIC AND DRYPLY 81								
Control	...	321-F	...	...	...	...	37,500	.128	1.74	32,800	29,200	49,300	2,450	33,700	1.51
	...	322-R	...	...	...	...	38,200	.129	1.74	33,500	27,300	49,600	2,440	32,800	1.57
Alaska	3	321-A	61	60	58	60	47,200	.119	1.79	45,200	28,500	57,000	2,750	37,100	1.43
	12	321-L	59	59	66	68	44,000	.121	1.78	48,100	...	64,700	...	48,100	1.42
Panama	3	321-B	59	59	57	57	51,000	.123	1.77	39,000	25,600	52,200	2,550	34,300	1.36
	12	321-K	59	59	59	61	46,200	.125	1.76	36,900	...	57,800	...	36,400	1.10
New Mexico	3	321-C	59	59	64	66	44,500	.124	1.78	49,600	31,600	56,200	2,680	45,200	1.49
	12	321-J	60	59	70	71	42,100	.124	1.78	47,300	...	63,000	...	51,700	1.44
Florida	3	321-D	60	61	69	63	47,000	.121	1.78	48,400	31,700	59,200	2,710	45,900	1.37
	12	321-I	59	60	68	64	44,900	.121	1.78	47,400	...	64,800	...	47,300	1.54
Wisconsin	3	321-H	59	59	59	65	43,300	.125	1.77	48,600	31,100	54,800	2,700	44,400	1.34
	12	321-E	60	59	67	69	43,400	.123	1.77	46,400	...	63,600	...	48,700	1.47
Normal	3	322-Q	57	...	59	...	42,400	.124	1.78	40,700	29,300	54,800	2,600	36,800	1.51
	12	322-U	58	...	61	...	41,800	.119	1.80	36,800	...	57,900	...	39,400	1.36

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Table 4--Properties of Epon 1001 and Epon 828 Laminate of 181 Glass Fabric After Various Exposure Conditions

Exposure	Length of exposure	Panel No.	Barcol hardness: Before exposure: Top	Barcol hardness: Before exposure: Bottom	Barcol hardness: After exposure: Top	Barcol hardness: After exposure: Bottom	Tensile strength (normal)	Compression (normal): Thickness	Compression (normal): Specific gravity	Compression (normal): Strength	Flexure: Normal: Proportional limit	Flexure: Normal: Modulus of rupture	Flexure: Normal: Modulus of elasticity	Flexure: Wet: Modulus of rupture	Flexure: Wet: Increase in weight
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Months						P.s.i.	Inch		P.s.i.	P.s.i.	P.s.i.	1,000 p.s.i.	P.s.i.	Percent
VOLAN A FINISHED FABRIC AND EPON 1001 RESIN															
Control		319-F					57,700	0.126	1.78	51,000	38,700	71,300	3,170	59,100	0.88
		320-R					58,500	.125	1.79	53,400	34,400	70,500	3,200	62,500	.87
Alaska	3	319-A	53	57	59	57	53,600	.123	1.77	58,800	31,300	68,600	3,160	56,900	.94
	12	319-L	56	57	61	62	53,100	.120	1.82	61,700		71,000		56,700	.96
Panama	3	319-B	58	56	60	53	55,300	.123	1.80	60,900	32,100	67,500	3,180	61,800	.76
	12	319-K	58	58	58	57	51,000	.125	1.79	57,500		67,300		55,700	.71
New Mexico	3	319-C	56	59	61	62	56,800	.121	1.81	62,000	34,500	68,900	3,220	60,100	.89
	12	319-J	59	59	63	63	52,400	.124	1.79	61,900		66,900		52,200	1.04
Florida	3	319-D	53	57	58	57	57,400	.118	1.81	61,000	32,300	71,200	3,230	58,700	.89
	12	319-I	55	53	56	56	52,200	.124	1.79	58,200		65,300		50,900	1.02
Wisconsin	3	319-H	58	56	58	60	59,100	.122	1.81	63,400	34,100	71,600	3,220	60,200	.90
	12	319-E	56	55	58	59	56,300	.126	1.79	60,900		67,300		52,400	1.11
Normal	3	320-Q	56		60		59,800	.121	1.80	60,100	35,500	70,600	3,190	62,000	.86
	12	320-U	56		56		55,400	.122	1.79	56,400		66,800		56,900	.96
VOLAN A FINISHED FABRIC AND EPON 828 RESIN															
Control		326-F					47,700	.133	1.72	48,400	29,700	56,800	2,740	38,100	.95
		327-R					48,300	.128	1.74	44,100	34,000	63,300	3,120	40,500	.89
Alaska	3	326-A	56	58	54	54	47,100	.133	1.73	48,500	26,900	55,700	2,840	37,900	1.05
	12	326-L	60	58	62	61	50,600	.125	1.76	49,400		63,400		44,800	.69
Panama	3	326-B	58	56	53	52	45,200	.134	1.73	49,000	25,700	52,900	2,890	37,700	.95
	12	326-K	60	57	56	55	38,000	.130	1.74	48,100		50,000		39,000	.78
New Mexico	3	326-C	58	57	58	57	49,400	.128	1.75	42,900	27,200	56,600	2,970	43,500	.94
	12	326-J	57	56	61	62	47,300	.136	1.72	49,100		55,500		43,200	.79
Florida	3	326-D	60	57	56	57	52,500	.121	1.78	51,600	30,900	60,300	3,060	45,700	.77
	12	326-I	58	54	59	56	46,100	.135	1.74	48,000		55,600		41,800	.70
Wisconsin	3	326-H	60	58	58	58	52,600	.124	1.77	49,600	30,100	62,100	3,070	45,000	.88
	12	326-E	58	57	59	58	47,300	.132	1.75	47,800		61,800		41,300	.79
Normal	3	327-Q	59		57		50,900	.119	1.80	50,600	34,200	65,300	3,280	45,400	.96
	12	327-U	59		60		48,900	.125	1.77	49,700		58,600		36,100	1.02

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Table 5--Properties of PDL-7-669 and Vibrin X-1047 Laminates of 181 Glass Fabric After Various Exposure Conditions

Exposure	Length of exposure	Panel No.	Barcol hardness: Before exposure: Top	Barcol hardness: Before exposure: Bottom	Barcol hardness: After exposure: Top	Barcol hardness: After exposure: Bottom	Tensile strength (normal)	Compression (normal): Thickness	Compression (normal): Specific gravity	Compression (normal): Strength	Flexure: Normal: Proportional limit	Flexure: Normal: Modulus of rupture	Flexure: Normal: Modulus of elasticity	Flexure: Wet: Modulus of rupture	Flexure: Wet: Increase in weight	Flexure: Wet: Modulus of rupture at 500° F.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
	Months						P.s.i.	Inch		P.s.i.	P.s.i.	P.s.i.	1,000 p.s.i.	P.s.i.	Percent	P.s.i.
							GARAN FINISHED FABRIC AND PDL-7-669 RESIN									
Control		309-F					34,700	0.123	1.86	30,800	33,700	46,500	2,970	40,600	2.07	29,500
		310-R					34,700	.124	1.86	35,700	34,300	44,800	2,950	39,700	2.02	28,400
Alaska	3	309-A	69	73	69	69	35,600	.121	1.87	38,300	30,100	42,900	3,000	34,500	1.41	29,400
	12	309-L	67	70	71	68	30,200	.124	1.86	31,700		34,500		28,700	2.65	26,300
Panama	3	309-B	69	71	68	68	36,000	.122	1.88	41,700	32,100	44,900	2,850	36,800	1.29	29,700
	12	309-K	68	69	69	67	32,600	.123	1.88	36,900		42,300		33,800	2.22	29,800
New Mexico	3	309-C	68	71	70	72	34,500	.123	1.87	39,200	31,900	41,600	2,920	33,300	1.79	28,900
	12	309-J	70	72	72	70	27,000	.122	1.89	33,200		32,800		28,600	2.45	28,100
Florida	3	309-D	68	70	70	68	33,500	.123	1.85	37,700	30,900	37,400	2,830	31,400	1.99	26,400
	12	309-I	70	73	69	58	26,500	.119	1.88	28,800		30,800		28,500	3.08	24,300
Wisconsin	3	309-H	68	70	68	70	34,400	.124	1.85	39,400	28,600	37,000	2,840	31,200	1.75	28,900
	12	309-E	70	72	72	67	29,200	.121	1.88	31,100		34,600		28,400	2.44	28,900
Normal	3	310-Q	66		68		35,400	.124	1.87	38,600	31,700	44,800	2,910	38,400	2.16	29,600
	12	310-U	67		69		30,200	.121	1.87	35,900		41,200		35,000	3.27	32,800
							GARAN FINISHED FABRIC AND VIBRIN X-1047 RESIN									
Control		313-F					40,800	.122	1.90	29,800	29,000	50,200	3,220	46,400	1.42	21,400
		314-R					40,500	.120	1.91	25,900	30,000	53,500	3,380	48,000	1.41	23,000
Alaska	3	313-A	73	76	72	71	39,700	.114	1.96	33,800	29,200	47,100	3,270	41,900	1.27	23,200
	12	313-L	73	73	72	70	33,500	.121	1.92	32,900		40,400		34,900	1.76	22,200
Panama	3	313-B	73	72	70	70	41,600	.119	1.94	33,300	24,200	46,200	3,190	43,900	1.21	21,500
	12	313-K	70	71	72	70	38,200	.122	1.92	36,100		48,400		41,600	1.54	22,600
New Mexico	3	313-C	70	73	74	73	40,500	.120	1.93	34,100	25,000	46,800	3,180	41,000	1.56	21,800
	12	313-J	73	71	76	71	32,200	.120	1.93	31,900		37,200		31,600	1.76	19,600
Florida	3	313-D	72	74	72	69	36,400	.120	1.93	31,800	29,200	42,500	3,070	37,100	1.75	22,600
	12	313-I	72	71	72	62	28,700	.115	1.95	26,900		34,200		28,400	2.36	19,550
Wisconsin	3	313-H	72	69	71	71	40,900	.122	1.91	32,800	27,000	45,800	3,110	40,900	1.64	22,900
	12	313-E	73	76	76	72	32,000	.116	1.94	32,500		37,800		31,800	1.83	20,000
Normal	3	314-Q	72		74		42,500	.114	1.94	37,100	27,700	50,700	3,370	47,800	1.76	23,200
	12	314-U	72		75		42,200	.113	1.95	38,600		52,800		45,000	1.81	23,100
							OWENS CORNING 301 FINISHED FABRIC AND VIBRIN X-1047 RESIN									
Control	3	342-F					41,100	.128	1.91	35,100	29,000	53,600	3,030	50,700	1.80	23,500
	12	343-F					44,500	.140	1.87	34,600	28,100	54,900	2,920	53,900	1.72	22,600
Wisconsin	3	343-H	74	73	72	72	42,600	.128	1.92	42,200	31,800	50,400	3,340	46,000	1.40	26,300
	12	343-E	72	70	75	72	33,800	.137	1.90	41,400		40,800		36,600	1.56	22,900
Normal	3	342-Q	67		68		40,100	.138	1.88	38,700	28,700	51,900	3,000	48,600	2.05	24,100
	12	342-U	68		71		39,700	.132	1.90	39,100		52,700		49,800	2.08	22,600

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Table 6--Properties of DC 2104 and Bakelite BV 17085 Laminates of 181 Glass Fabric After Various Exposure Conditions

Exposure	Length of exposure	Panel No.	Barcol hardness: Before exposure: Top	Barcol hardness: Before exposure: Bottom	Barcol hardness: After exposure: Top	Barcol hardness: After exposure: Bottom	Tensile strength (normal)	Compression (normal): Thickness	Compression (normal): Specific gravity	Compression (normal): Strength	Flexure: Normal: Proportional limit	Flexure: Normal: Modulus of rupture	Flexure: Normal: Modulus of elasticity	Flexure: Wet: Modulus of rupture	Flexure: Wet: Increase in weight	Flexure: Wet: Modulus of rupture at 500° F.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
	Months						P.s.i.	Inch		P.s.i.	P.s.i.	P.s.i.	1,000 p.s.i.	P.s.i.	Percent	P.s.i.
							HEAT-CLEANED FABRIC AND DC 2104 SILICONE RESIN									
Control		331-F					38,000	0.132	1.70	15,500	18,300	28,800	2,310	27,500	0.67	11,850
		332-R					34,600	.134	1.68	14,200	18,200	27,300	2,210	26,200	.73	11,100
Alaska	3	331-A	37	36	32	30	30,200	.134	1.66	16,700	17,900	28,400	2,190	28,600	1.61	12,400
	12	331-L	40	38	40	35	34,100	.129	1.71	15,600		28,600		26,700	2.90	13,600
Panama	3	331-B	44	46	37	38	31,000	.133	1.68	19,000	18,800	28,600	2,250	28,600	1.34	11,800
	12	331-K	46	44	45	40	34,600	.129	1.72	19,200		28,600		27,400	1.97	13,700
New Mexico	3	331-C	43	44	37	40	29,800	.134	1.68	18,300	17,500	27,900	2,190	27,800	1.76	11,900
	12	331-J	47	44	45	44	34,000	.129	1.72	18,600		27,200		27,000	2.25	11,550
Florida	3	331-D	38	38	30	34	30,800	.133	1.67	17,200	17,900	27,600	2,190	27,500	2.22	11,850
	12	331-I	34	37	35	31	32,600	.131	1.69	17,400		27,600		26,600	3.94	10,400
Wisconsin	3	331-H	41	42	36	30	37,000	.133	1.68	18,200	16,300	27,900	2,250	28,200	1.06	11,800
	12	331-E	41	42	40	39	34,600	.133	1.68	18,700		27,700		27,400	3.03	11,100
Normal	3	332-Q	38		36		34,900	.134	1.65	16,800	16,300	26,300	2,120	26,100	.89	11,500
	12	332-U	34		36		34,300	.131	1.69	17,800		28,200		26,900	2.85	10,400
							VOLAN A FINISHED FABRIC AND BAKELITE BV 17085 RESIN									
Control		346-F					28,800	.135	1.83	47,600	41,600	55,900	3,250	52,900	1.48	12,250
		347-F					27,400	.131	1.83	47,600	32,900	51,300	3,370	48,700	1.58	9,950
		348-F					33,300	.126	1.87	44,900	38,300	57,500	3,370	51,800	1.21	11,150
		349-F					34,900	.125	1.88	51,000	37,600	60,700	3,380	53,800	1.18	12,850
Alaska	3	346-A	71	73	70	70	29,600	.134	1.83	49,800	29,200	53,800	3,470	54,200	1.33	14,050
	12	347-L	72	75	75	74	28,200	.130	1.84	46,400		51,900		49,400	1.42	9,850
Panama	3	346-B	69	72	66	67	28,200	.135	1.82	50,700	30,000	54,700	3,450	55,000	1.01	13,950
	12	347-K	72	70	74	72	27,200	.128	1.84	49,400		56,300		50,100	1.09	10,000
New Mexico	3	346-C	69	72	68	71	29,300	.132	1.84	50,600	31,500	53,800	3,540	52,300	1.50	14,000
	12	347-J	71	75	78	78	30,900	.129	1.84	46,200		55,100		50,800	1.53	10,600
Florida	3	346-D	70	74	70	70	28,900	.133	1.84	50,300	33,900	52,000	3,440	51,200	1.29	15,050
	12	347-I	71	70	74	74	27,800	.132	1.83	48,000		53,400		45,500	1.36	10,500
Wisconsin	3	346-H	68	73	69	70	30,000	.132	1.84	49,700	35,600	53,800	3,460	54,100	1.43	13,700
	12	347-E	70	71	76	76	27,500	.130	1.85	50,200		51,400		49,200	1.32	10,100
Normal	3	349-Q	71		70		38,000	.125	1.87	52,200	31,200	58,500	3,500	54,700	1.04	12,900
	12	349-U	71		75		35,400	.122	1.90	56,000		62,100		55,500	.95	12,400

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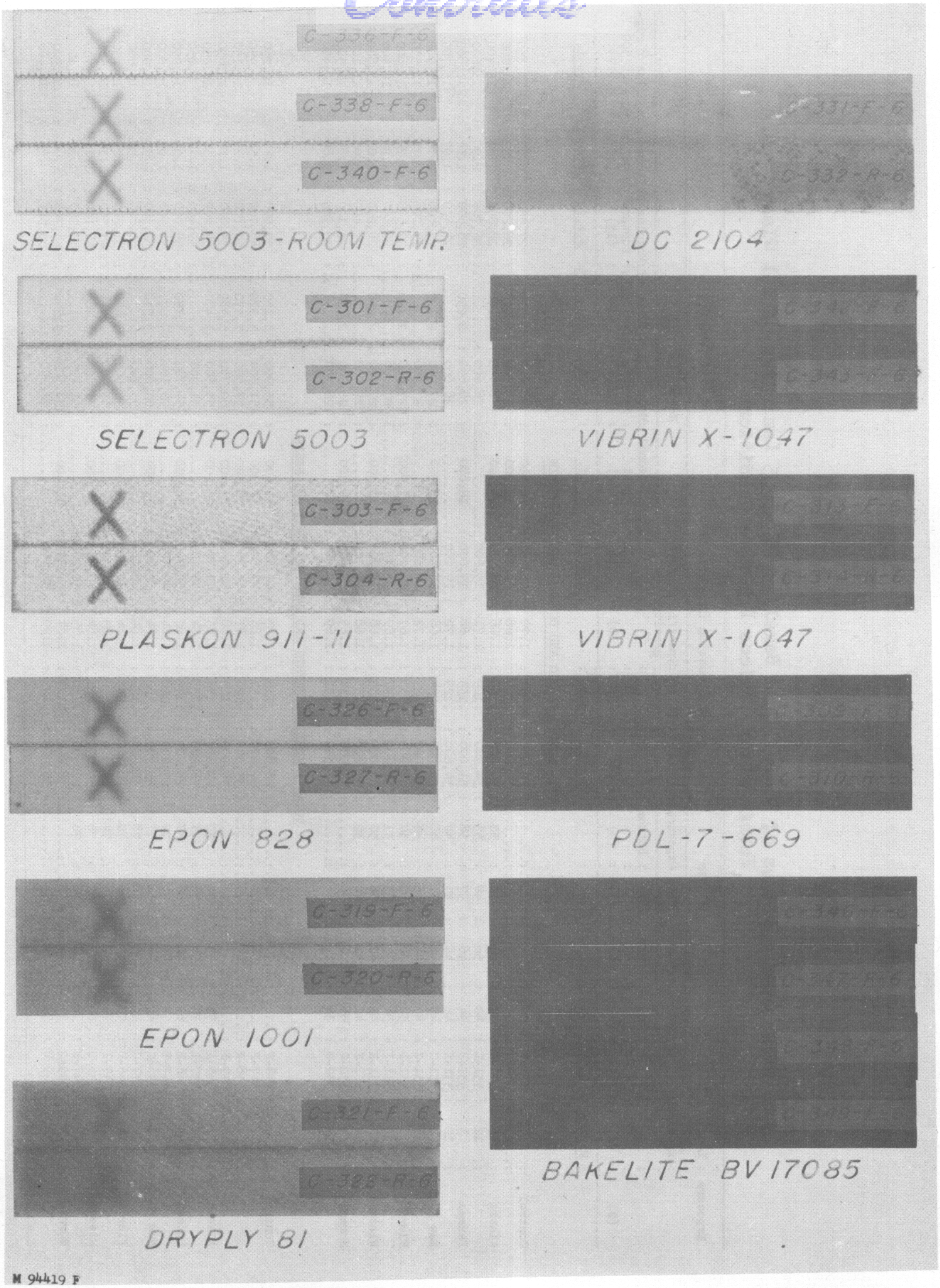


Figure 1--Translucency of specimens from different laminates with transmitted light. One specimen was taken from each 9- by 12- inch control panel.

Alaska 3 months 301-A	Panama 3 months 301-B	New Mexico 3 months 301-C	Florida 3 months 301-D
Wisconsin 1 year 301-E	Control 301-F	Extra 301-G	Wisconsin 3 months 301-H
Florida 1 year 301-I	New Mexico 1 year 301-J	Panama 1 year 301-K	Alaska 1 year 301-L

Panel No. 301

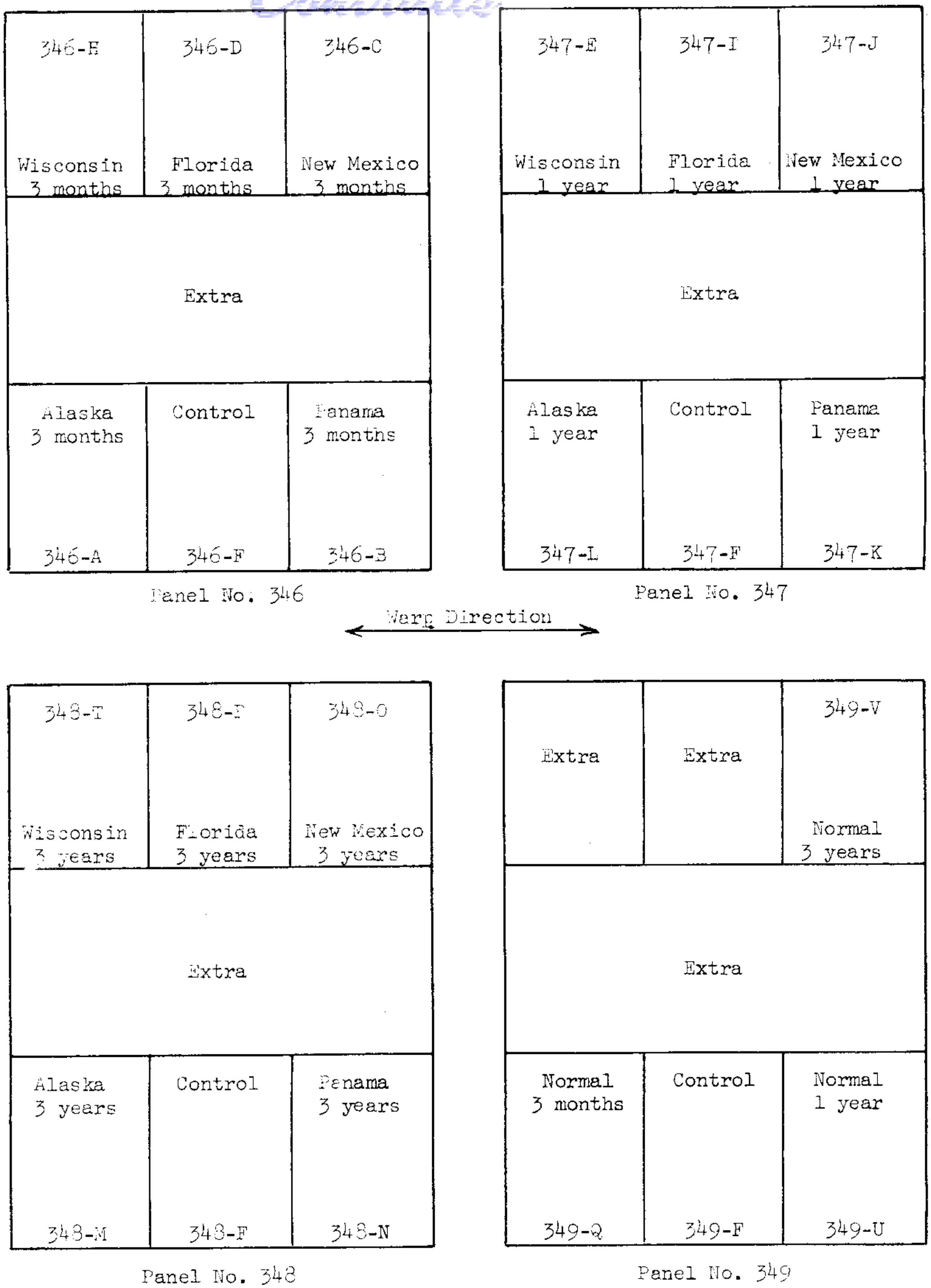
← Warp Direction →

Alaska 3 years 302-M	Panama 3 years 302-N	New Mexico 3 years 302-O	Florida 3 years 302-P
Normal 3 months 302-Q	Control 302-R	Extra 302-S	Wisconsin 3 years 302-T
Normal 1 year 302-U	Normal 3 years 302-V	Extra 302-W	Extra 302-X

Panel No. 302

M 106 733

Figure 2--Method of sectioning each pair of 36- by 36- inch laminates into subpanels for exposure.



M 106 736

Figure 3--Method of sectioning 28- by 35- inch Bakelite BV 17085 laminates into subpanels for exposure.

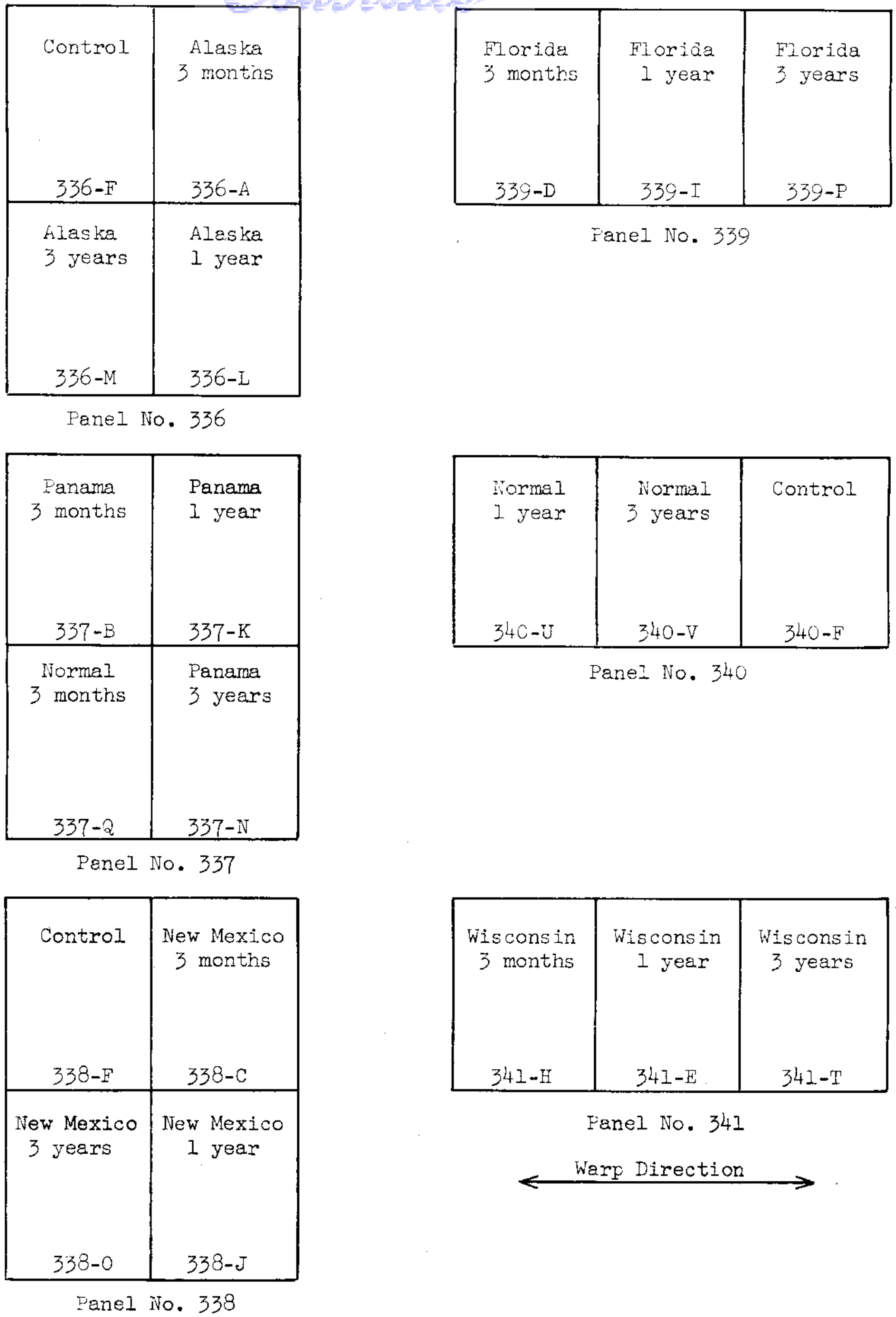
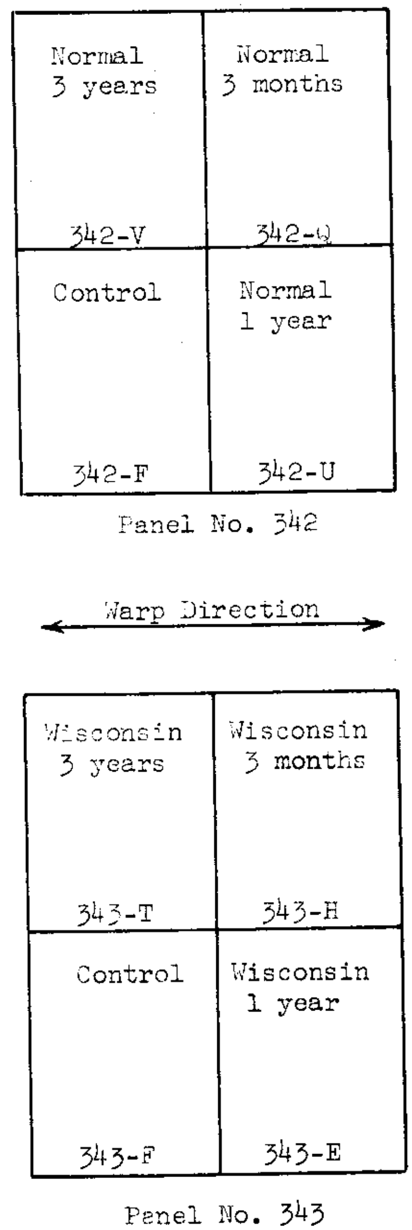


Figure 4--Method of sectioning of room-temperature-setting Selectron 5003 laminates into subpanels for exposure.



M 106 734

Figure 5--Method of sectioning 2 small Vibrin X-1047 laminates, reinforced with OC-301 finished glass fabric, into subpanels for exposure.

Figure 6--Method of mounting subpanels on boards and exposure racks. Photograph shown is of the salt air exposure site in Florida.

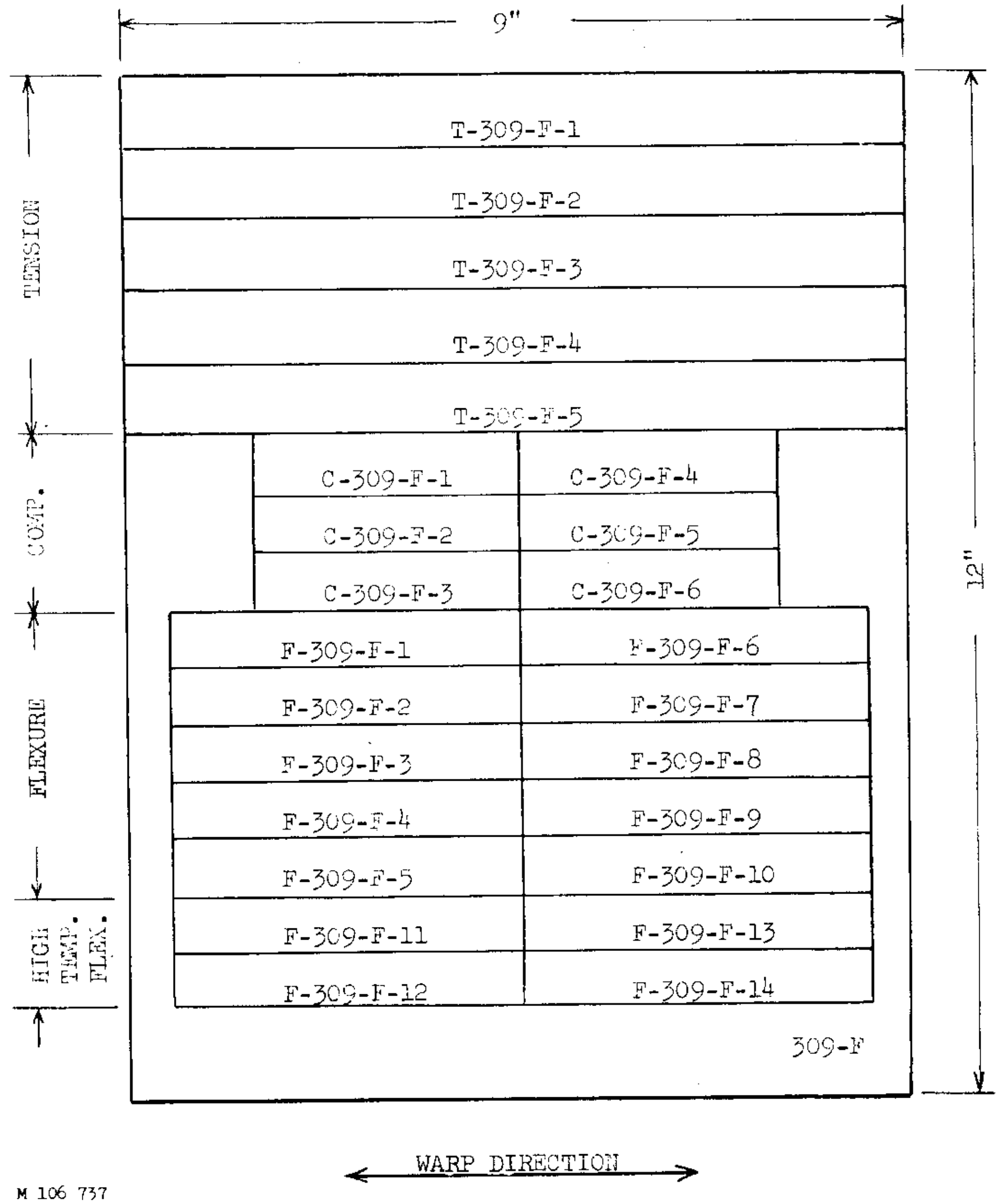


Figure 7 -- Diagram for cutting each 9- by 12- inch subpanel to obtain tension compression, and flexural specimens. Flexural specimens 11 through 14 are for high-temperature-resistant laminates only.

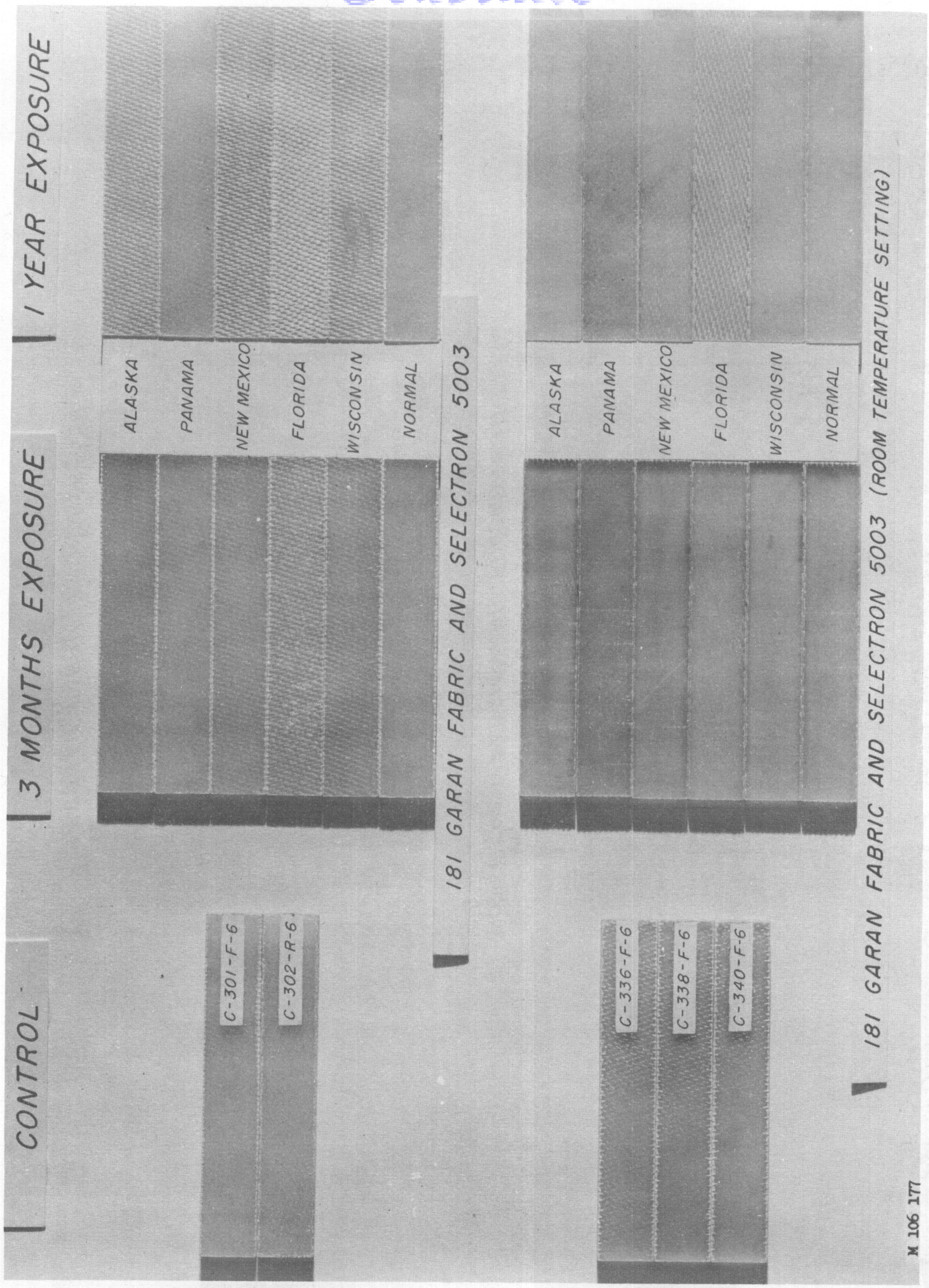


Figure 8--Specimens from Selectron 5003 laminates after various exposure conditions.

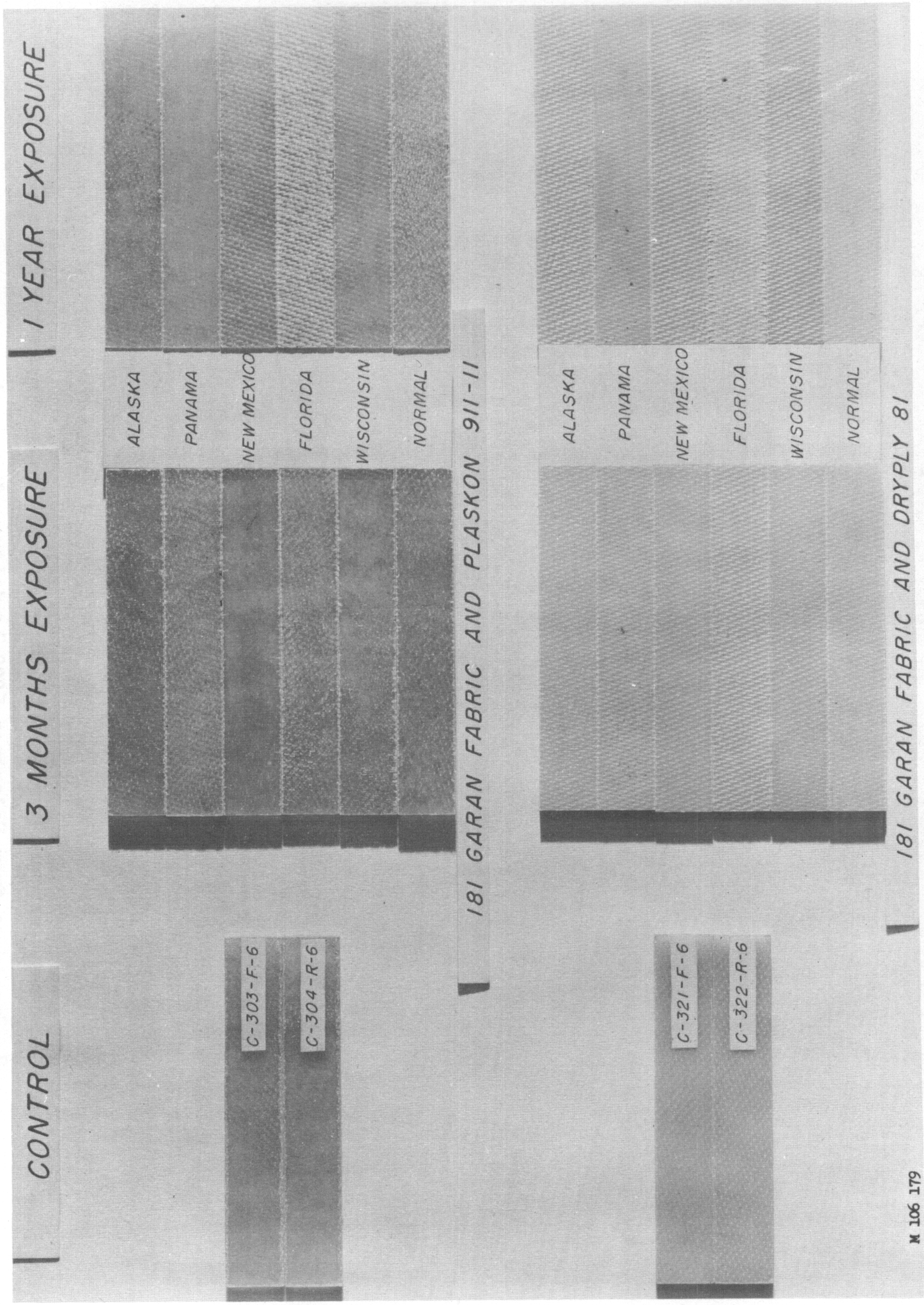


Figure 9--Specimens from Plaskon 911-11 and Dryply 81 laminates after various exposure conditions.

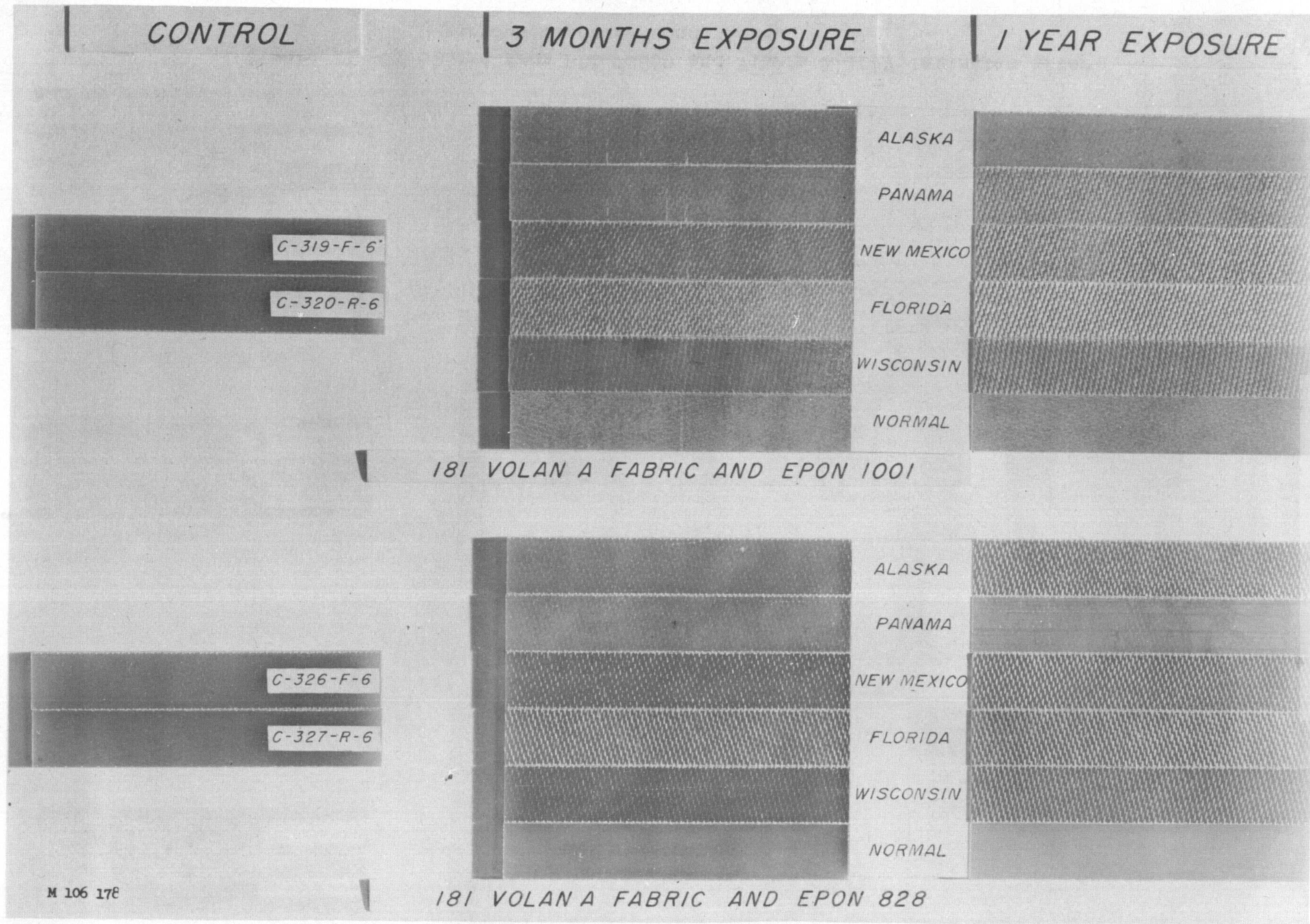


Figure 10--Specimens from Epon 1001 and Epon 828 laminates after various exposure conditions.

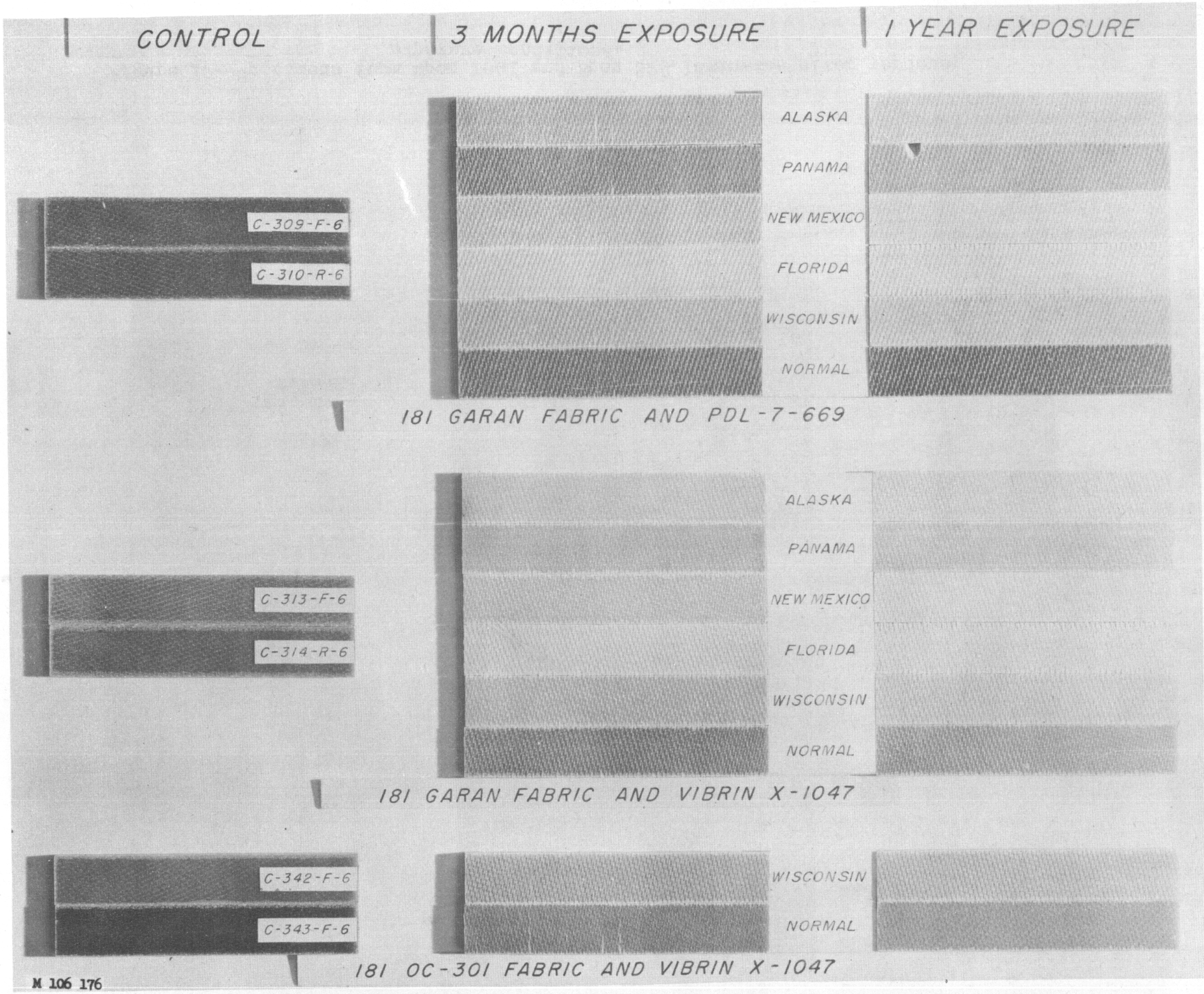


Figure 11--Specimens from PDL-7-669 and Vibrin X-1047 laminates after various exposure conditions.

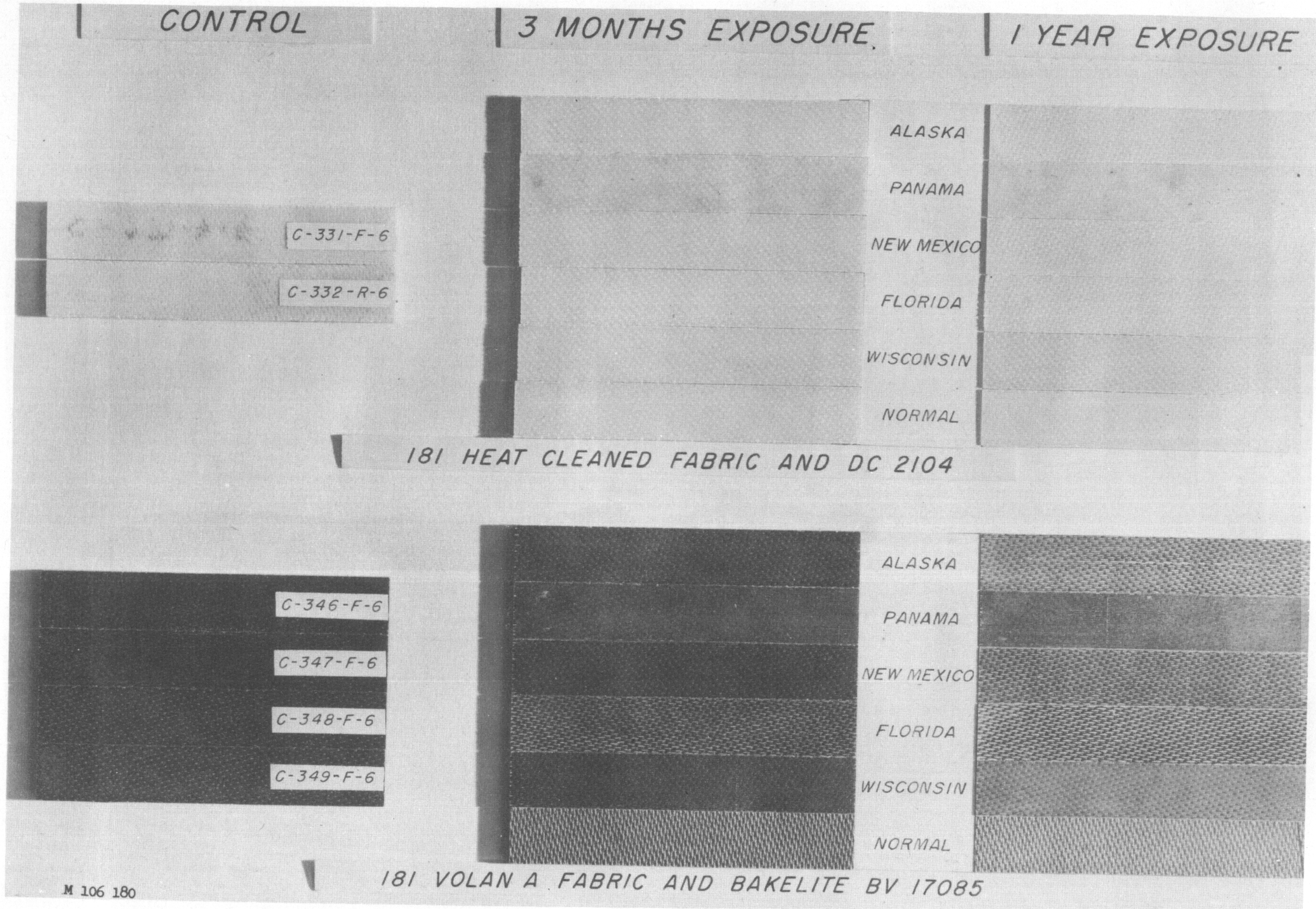


Figure 12--Specimens from DC 2104 and Bakelite BV 17085 laminates after various exposure conditions.