FACTORS AFFECTING THE STRENGTH OF PAPREG

EFFECT OF REPEATED CYCLES OF FREEZING AND THAWING ON CERTAIN STRENGTH PROPERTIES OF PAPREG

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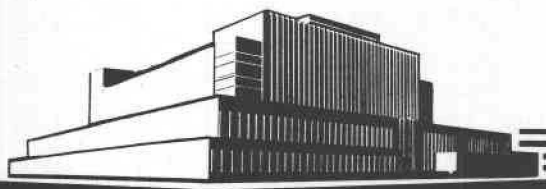

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

FACTORS AFFECTING THE STRENGTH OF PAPREG[1, 2]

Effect of Repeated Cycles of Freezing and Thawing[3] on Certain Strength Properties of Papreg

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Summary

This report presents the results of approximately 800 strength tests to determine the effect of repeated cycles of freezing and thawing on the tensile, compressive, bending, and bearing properties of papreg.

The tests included cyclic changes in temperature of approximately 110° F. on relatively dry, normal, and wet papreg. The number and type of cycles varied from a few cycles consisting of a short freezing period and a long thawing period to a large number of cycles of short, equal periods of freezing and thawing.

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[1] This is one of a series of progress reports prepared by the Forest Products Laboratory relating to the use of wood in aircraft issued in cooperation with the Army-Navy-Civil Committee on Aircraft Design Criteria. Original report published January 1945.

[2] A laminated paper plastic made by Forest Products Laboratory (Improved Standard -- June 1943).

[3] This report is the fourth of a series presenting the effect of aircraft service conditions on certain strength properties of papreg.

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

The results of the tests indicated that the freezing and thawing action had a negligible effect upon the strength properties of papreg covered in this investigation.

Introduction

Previous investigations[5] designed to simulate certain aircraft service conditions have indicated the level of certain strength properties of papreg over a wide range of temperature and humidity. Moisture effects and temperature effects at a specific level of moisture content were each determined by separate studies involving only the single variable, moisture or temperature.

This investigation was designed to simulate, in part, the combined effect of moisture and temperature as produced by rapid and repeated exposures of aircraft materials to conditions that varied from hot, humid atmospheres at ground level to frigid, dry air at high altitudes.

Since all such possible conditions could not readily be experimentally produced, the effects of the following two freezing and thawing conditions on papreg were investigated: (1) cyclic changes from normal to subzero temperatures, on relatively dry papreg; and (2) similar cyclic changes in temperature on relatively wet papreg, to determine whether the repeated expansion and contraction associated with the alternate freezing and thawing of the moisture particles in the wet papreg would decrease certain strength properties beyond that attributable to moisture alone.

Test Material

The test material, which is identified as Improved Standard -- June 1943, was manufactured by the Forest Products Laboratory from a commercial

[5] Forest Products Laboratory Rept. No. 1521. Factors Affecting the Strength of Papreg. Some Strength Properties at Elevated and Subnormal Temperatures.
Forest Products Laboratory Rept. No. 1521-A. Factors Affecting the Strength of Papreg. Effect of Accelerated Weathering on Certain Strength Properties of Papreg.
Forest Products Laboratory Rept. No. 1521-B. Factors Affecting the Strength of Papreg. Effect of Moisture on Certain Strength Properties of Papreg.

Mitscherlich type black spruce sulfite pulp. The preparation of the papreg was identical to that described in Forest Products Laboratory Rept. No. 1521.[6] The test material consisted of both parallel- and cross-laminated flat panels, approximately 12 inches square and 1/8 inch in thickness.

Selection and Preparation of Test Panels

As in previous related investigations, the papreg panels were selected from groups I and II (parallel- and cross-laminated material, respectively) which are described in the aforementioned Rept. No. 1521. Twelve panels were taken from group I and six from group II.

These panels were divided into three lots numbered 1, 2, and 3. Each lot consisted of four panels from group I and two panels from group II.

The panels were trimmed to provide clean-cut edges, which were then sealed with two coats of aluminum paint to retard the movement of moisture through these edges. In addition, all panels were weighed and measured before and after conditioning and at the conclusion of the last freezing cycle. Subsequent weight and dimensional changes are based on data taken before conditioning.

Conditioning of Panels

The various lots were conditioned as follows:

Lot 1 -- 80° F. and 30 percent relative humidity.
Lot 2 -- 75° F. and 50 percent relative humidity.
Lot 3 -- 80° F. and 97 percent relative humidity.

One-half of the panels from each lot were conditioned for approximately 100 days and the remainder for approximately 130 days. The 30-day interval permitted a preliminary evaluation of test data to determine the course of further testing.

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[6] Factors Affecting the Strength of Papreg. Some Strength Properties at Elevated and Subnormal Temperatures.

All conditioning was done in large rooms in which temperature and humidity were automatically controlled.

Freezing-thawing Cycles

The freezing-thawing cycle consisted of 1 hour of freezing followed by 1 hour of thawing. The freezing was done by placing the conditioned panels in air in a mechanically refrigerated chamber in which the temperature varied between -20° F. and -30° F. At the end of the freezing period, the panels were thawed in air by returning them immediately to their respective conditioning chambers.

These procedures were repeated 36 times on those panels conditioned for approximately 100 days and 95 times on those panels conditioned for approximately 130 days.

Preparation of Specimens

At the conclusion of the 36 and 95 cycles of freezing-thawing, all panels were cut into specimens as shown in figure 1. Six lengthwise and four crosswise specimens of parallel-laminated material and five specimens, lengthwise and crosswise of the cross-laminated material were provided for each of the following tests: tension, compression (edgewise), static bending, and bearing.

The type, dimensions, and cutting of the specimens conformed to Federal Specification for Plastics, Organic; General Specifications (Methods of Tests) L-P-406, December 9, 1942, and were identical to those described in Forest Products Laboratory Rept. No. 1521-B.[7]

Conditioning of Specimens

The preparation of test specimens was performed in a relatively dry atmosphere. In order to insure a uniform and specific moisture content,

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[7] Factors Affecting the Strength of Papreg. Effect of Moisture on Certain Strength Properties of Papreg.

each specimen, following preparation, was reconditioned for at least 24 hours prior to test in the previous conditioning atmosphere of the respective panel from which it was taken.

Except for the few minutes required for the weighing and measuring operations, the specimens were not exposed to test room atmospheres until placed in a testing machine.

Testing Procedures

All tests were conducted at normal test room temperatures and humidities according to procedures specified in Federal Specification L-P-406. Test details were identical with those described in the appendix of Forest Products Laboratory Rept. No. 1521-A.[8]

Test Results

The results of tests to determine the effect of repeated cycles of freezing-thawing on various strength properties of papreg are presented graphically in figures 2 and 3 by means of comparison with identical papreg similarly conditioned but not subjected to freezing and thawing action. The solid-line curves[9] in figures 2 and 3 show the relationship between moisture and several strength properties of papreg, while the plotted points represent the average results of 4 to 6 tests at specific moisture levels after 36 and 95 cycles, respectively, of freezing and thawing action. Hence, the difference between the points and the curves (beyond the variability of the papreg) reflects the effect of repeated cycles of freezing-thawing.

The plotted points do not depart greatly from the curves at specific moisture levels. In fact, the magnitude of the departures is largely within the limits of variability indicated in Forest Products Laboratory Rept. No. 1319.[10] An exception to this behavior occurred in the modulus of elasticity

[8] Factors Affecting the Strength of Papreg. Effect of Accelerated Weathering on Certain Strength Properties of Papreg.

[9] Reproduced from Forest Products Laboratory Rept. No. 1521-B.

[10] Strength and Related Properties of Forest Products Laboratory Laminated Paper Plastics (Papreg) at Normal Temperatures.

in tension for both parallel- and cross-laminated materials after 95 repetitions of freezing-thawing. The departures in these instances amounted to a reduction of 23 and 19 percent, which is beyond the limits of variability. In general, however, the effect of repeated cycles of freezing-thawing is not significant.

An inspection of the plotted data reveals that the increase in the number of repeated cycles (open versus solid symbols) did not produce a trend in the values of any specific strength property. That is, increasing the number of repeated cycles from 36 to 95 did not bring about a significant change in strength properties.

Figure 4 shows the change in the interior temperature of the papreg during a freezing-thawing cycle. Observations were obtained by means of a thermocouple inserted in the edge of a panel at midthickness to a depth of about 2 inches. It may be noted that the length of time required to lower the temperature of the papreg to 32° F. was relatively short -- only about 7 percent of the total time in the cold chamber. At the beginning of the thawing period, a similar length of time was required to raise the temperature of the papreg to 32° F. From these facts, it is evident that the time element of the cycle was of sufficient length to freeze and thaw the papreg.

Freezing and thawing produced no visible change in the surface condition of the papreg. Likewise, the type of failures appeared no different than normal.

Conclusions

The study indicated that the several strength properties of papreg covered in this investigation are not appreciably affected by alternate freezing and thawing. These properties included tension, compression, bending, and bearing.

APPENDIX

Exploratory freezing-thawing tests were conducted on a group of specimens immersed in water at room temperature for periods of 2, 4, and 8 days, respectively, for which the objective, the test material, preparation, conditioning, and testing were identical to those described in the appendix of Forest Products Laboratory Rept. No. 1521-B.[7]

The specimens selected constituted the majority of those referred to in the report as "used in tests of other service conditions."

Freezing-thawing Cycles

The freezing-thawing cycle consisted of 6 hours of freezing followed by 18 hours of thawing. The freezing was done in a mechanically refrigerated chamber in which the temperature varied between -25° F. and -30° F. The thawing was done in a room maintained at 40° F. and 95 percent relative humidity.

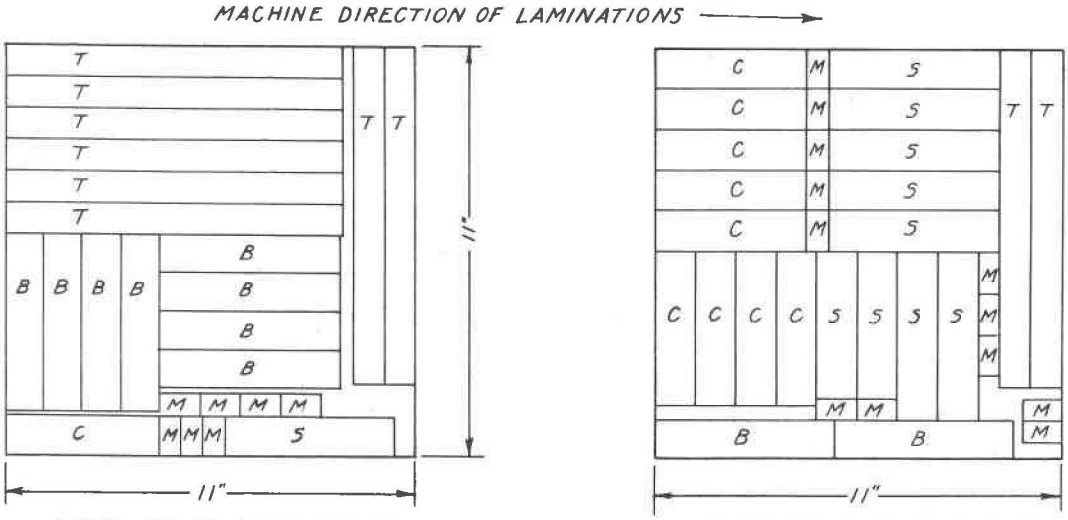
All specimens, with the exception of half of those conditioned by immersion in water for 8 days, were subjected to six consecutive cycles of freezing-thawing immediately following their respective conditioning period. The remaining specimens were subjected to 12 cycles.

Testing

Tension, compression, and static bending tests were conducted at normal room temperatures and humidities at the conclusion of the designated number of freezing-thawing cycles according to the procedures outlined in Federal Specification L-P-406.

Test Results

The results of these exploratory tests showed no significant changes in the stress at ultimate, proportional limit, modulus of elasticity, and modulus of rupture for the tensile, compressive, and static bending properties when compared with like papreg not subjected to freezing and thawing action. In addition, it was also found that increasing the number of cycles from 6 to 12 did not change the strength properties.

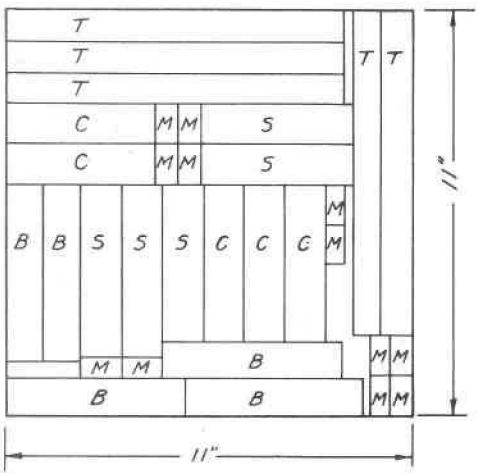


PANEL NOS. 39, 41, 45, 47, 53, 55

PANEL NOS. 40, 42, 46, 48, 54, 56

LOT NOS. 1, 2, 3

CUTTING DIAGRAMS FOR PARALLEL-LAMINATED (GROUP I) PANELS



LEGEND:-

T:-TENSION SPECIMENS $\frac{3}{4}$-BY 9-INCHES (BEFORE SHAPING)

M:-COMPRESSION SPECIMENS $\frac{1}{2}$-BY 1-INCH (FOR ULTIMATE STRENGTH ONLY)

C:-COMPRESSION SPECIMENS 1-BY 4-INCHES (FOR OTHER STRENGTH PROPERTIES)

S:-STATIC BENDING SPECIMENS 1-BY $4\frac{1}{2}$-INCHES.

B:-BEARING SPECIMENS $\frac{15}{16}$-BY $4\frac{3}{4}$-INCHES.

NOTE:-IN ALL BEARING SPECIMENS THE DISTANCE FROM THE EDGE OF THE HOLE TO THE END OF THE SPECIMEN IS 2.5 HOLE DIAMETERS

PANEL NOS. 28, 29, 33, 34, 40, 41

LOT NOS. 1, 2, 3

CUTTING DIAGRAM FOR CROSS-LAMINATED (GROUP II) PANELS

Figure 1.--Cutting diagrams for specimens taken from 1/8-inch papreg panels after exposure to repeated cycles of freezing and thawing.

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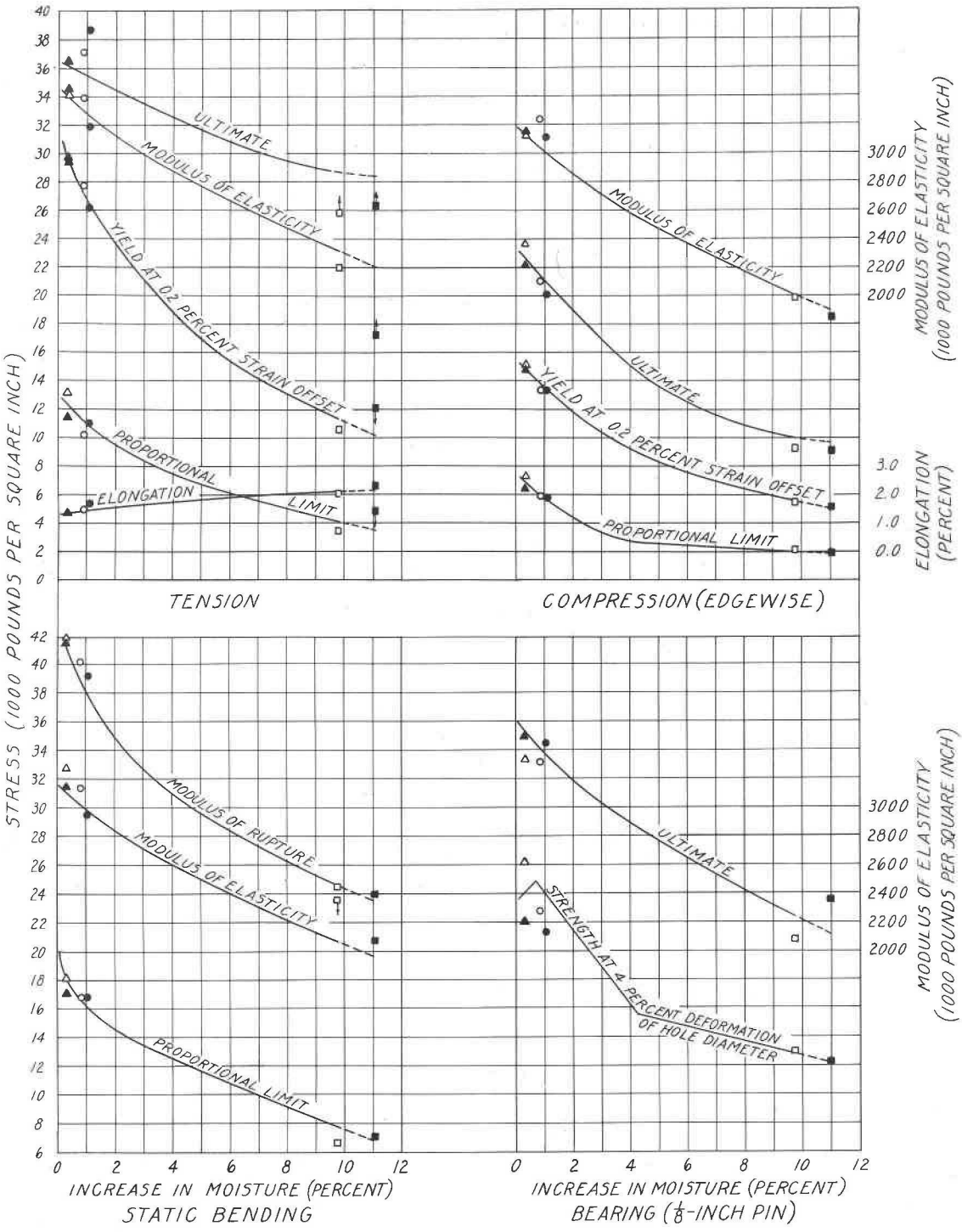


LEGEND:-

——— MOISTURE-STRENGTH RELATIONSHIP (HUMIDITY CONDITIONS ONLY) REPRODUCED FROM MIMEO. 1521-B

– – – – ARBITRARY EXTENSION OF THE MOISTURE-STRENGTH RELATIONSHIP

△-36 CYCLES OF FREEZING-THAWING AFTER 100 DAYS CONDITIONING AT 80°F.-30 PERCENT RELATIVE HUMIDITY

▲-95 CYCLES OF FREEZING-THAWING AFTER 130 DAYS CONDITIONING AT 80°F.-30 PERCENT RELATIVE HUMIDITY

○-36 CYCLES OF FREEZING-THAWING AFTER 100 DAYS CONDITIONING AT 75°F.-50 PERCENT RELATIVE HUMIDITY

●-95 CYCLES OF FREEZING-THAWING AFTER 130 DAYS CONDITIONING AT 75°F.-50 PERCENT RELATIVE HUMIDITY

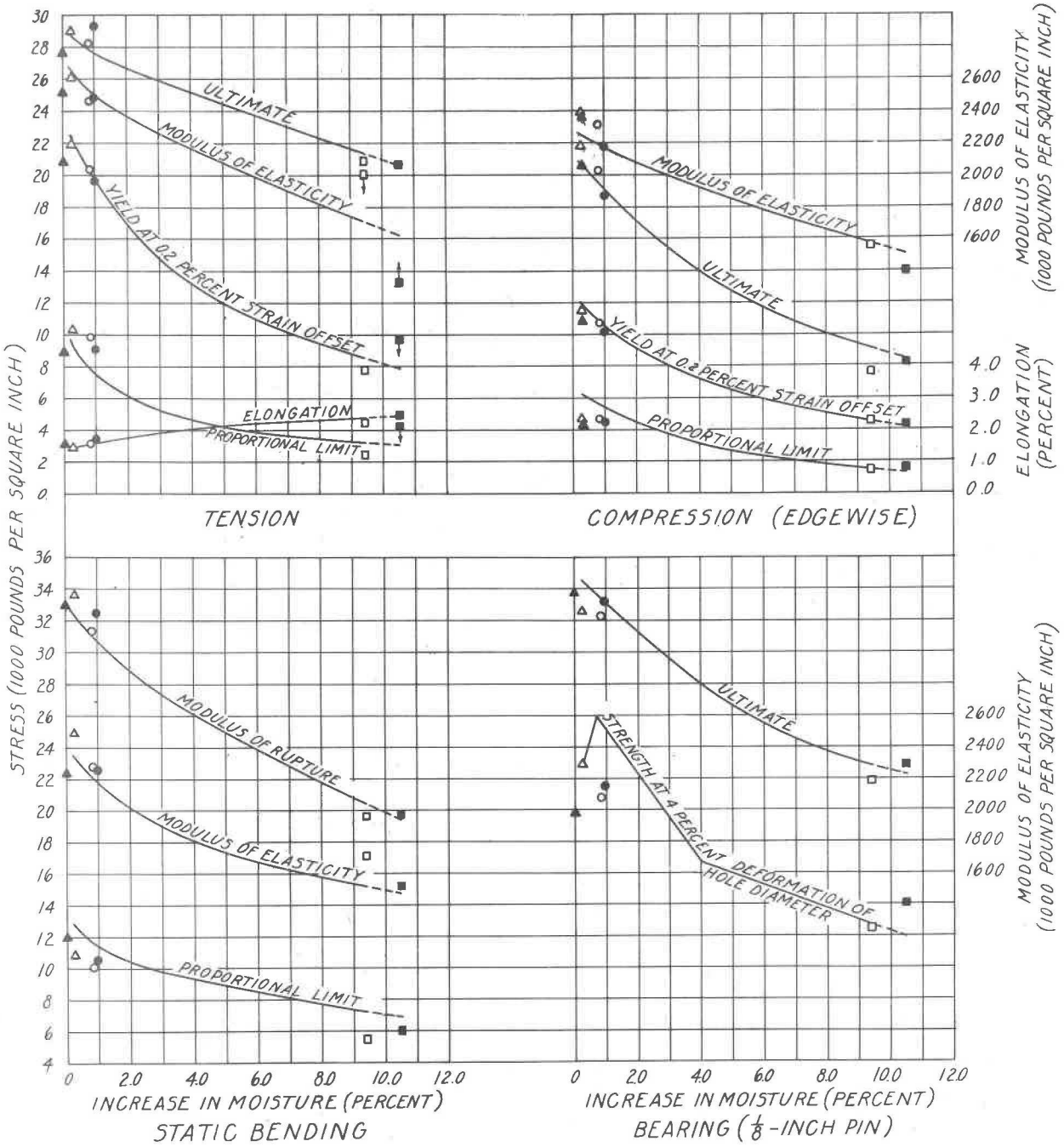
□-36 CYCLES OF FREEZING-THAWING AFTER 100 DAYS CONDITIONING AT 80°F.-97 PERCENT RELATIVE HUMIDITY

■ 95 CYCLES OF FREEZING-THAWING AFTER 130 DAYS CONDITIONING AT 80°F.-97 PERCENT RELATIVE HUMIDITY

NOTE:-A FREEZING-THAWING CYCLE CONSISTED OF 1 HOUR OF FREEZING FOLLOWED BY 1 HOUR OF THAWING IN THE CONDITIONING MEDIA.

EACH POINT REPRESENTS THE AVERAGE OF 6 TESTS.

Figure 2.--Comparison between the freezing and thawing-strength relations and the moisture-strength relationship of parallel-laminated papreg (Improved Standard - June 1943) tested lengthwise.



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○–36 CYCLES OF FREEZING-THAWING AFTER 100 DAYS CONDITIONING AT 75°F.-50 PERCENT RELATIVE HUMIDITY
●–95 CYCLES OF FREEZING-THAWING AFTER 130 DAYS CONDITIONING AT 75°F.-50 PERCENT RELATIVE HUMIDITY
□–36 CYCLES OF FREEZING-THAWING AFTER 100 DAYS CONDITIONING AT 80°F-97 PERCENT RELATIVE HUMIDITY
■–95 CYCLES OF FREEZING-THAWING AFTER 130 DAYS CONDITIONING AT 80°F-97 PERCENT RELATIVE HUMIDITY

NOTE: A FREEZING-THAWING CYCLE CONSISTED OF 1 HOUR OF FREEZING FOLLOWED BY 1 HOUR OF THAWING IN THE CONDITIONING MEDIA.
EACH POINT REPRESENTS THE AVERAGE OF 5 TESTS.

Figure 3.--Comparison between the freezing and thawing-strength relations and moisture-strength relationship of cross-laminated papreg (Improved Standard - June 1943).

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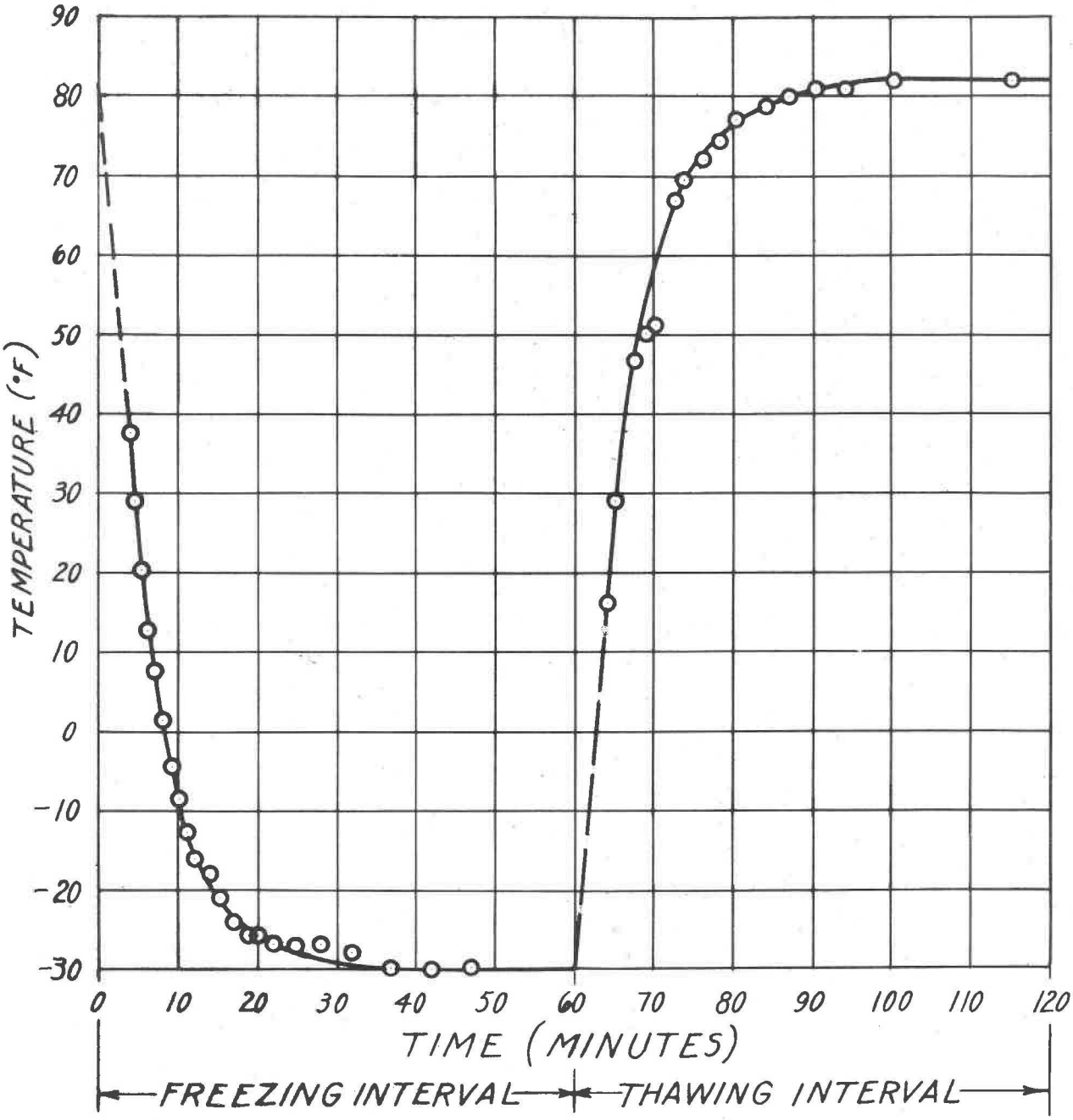

Figure 4.--Temperature change at center of a 1/8-inch papreg panel, conditioned at 80° F. and 30 percent relative humidity, during a freezing and thawing cycle of 60 minutes at -30° F. followed by 60 minutes at 82° F.

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