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DEVELOPMENT OF STRENGTH IN YELLOW BIRCH LAP JOINTS GLUED WITH SIX RESORCINOL-RESIN GLUES AT TEMPERATURES FROM 40 °TO 80° F.

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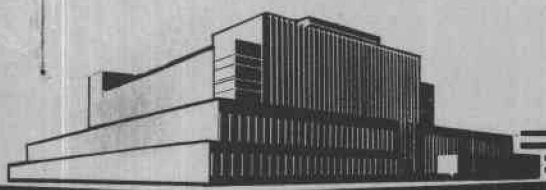

FOREST PRODUCTS LABORATORY
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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

DEVELOPMENT OF STRENGTH IN YELLOW BIRCH LAP JOINTS GLUED WITH SIX RESORCINOL-RESIN GLUES AT TEMPERATURES FROM 40° to 80° F.[1]

By

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Introduction

Glue manufacturers generally recommend the joints of wood-to-wood made with resorcinol-resin glues be cured at 70° F. or higher. Such temperatures are not always easy to attain, particularly in repair work. The following questions are often raised:

(1) Can resorcinol-resin glues be satisfactorily used for bonding wood at curing temperatures below 70° F.?

(2) If such temperatures are used initially, can higher strengths be developed if the joints are later heated to temperatures such as 140° F.?

To answer these questions tests were made at the Forest Products Laboratory in which yellow birch veneers were glued with several resorcinol resins and cured for periods up to approximately 2 weeks at several temperatures from 40° to 80° F. and also for 24 hours at 140° F. after 2 weeks at each of these temperatures.

Procedures

Four commercial resorcinol resins were used. These are designated as A, B, C, and D in this report. The formulations of all glue mixtures are given

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[1] This is one of a series of progress reports prepared by the Forest Products Laboratory relating to the use of wood in aircraft. Results here reported are preliminary and may be revised as additional data become available. Original report issued December 1947

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

in Table 1. Glues A and B were resorcinol-resin glues formulated for use with paraformaldehyde as the hardening agent. Glue C was a resorcinol-resin glue using formaldehyde in aqueous solution for the hardener. Glue D was a resorcinol-resin glue said to contain a significant percentage of phenol resin and using paraformaldehyde as the hardener. Glues A, B, C, and D were prepared for use as recommended by the manufacturer with the prescribed amount of the regular hardener for each glue. Glues B and D were also used with aqueous formaldehyde solution (37 percent by weight) as the hardener, and as such were designated as glues BF and DF, respectively. In these mixtures an amount of formaldehyde solution was so chosen that it contained approximately the same amount of formaldehyde as the paraformaldehyde content of the recommended amount of the standard hardener as furnished by the manufacturer. Walnut-shell flour was also added to bring the consistency of the mixtures to that of the glue when used with the normal hardener. Glues BF and DF, consequently, were not commercial formulations, but were included in this study to provide more information on those differences in the curing rate of a given resin that might be due to the availability or reactivity of the formaldehyde in the hardener.

The rate of strength development was determined at temperatures of 40°, 50°, 60°, 70°, and 80° F. by preparing lap joints with slips of yellow birch veneer in a special jig, and testing the joints after certain elapsed periods under pressure.

Clear, straight-grained, 1/16-inch, yellow birch veneer was selected and conditioned to a moisture content of about 12 percent. This veneer was cut into slips 1 by 2-1/8 inches is size with the grain running parallel with the longer dimension. In order to insure uniform pressure on all joints only those slips measuring 0.061 to 0.063 inch in thickness were used in this study.

In all tests, the veneers and the ingredients of the glues were brought to the curing temperatures indicated. The glue was then mixed and allowed to stand 20 to 30 minutes at this temperature. The birch veneer slips were clamped in a jig so that the glue could be applied rapidly and evenly in a normal thickness by brushing. The slips were then laid together in pairs, with a 1-inch overlap, in a special metal jig (fig. 1). After 15 minutes of closed assembly at the indicated curing temperature, a rubber caul was laid over the jig and a pressure of 150 pounds per square inch applied to the glue areas. At selected intervals of time the pressure was momentarily released and five specimens glued with each glue were removed from the jig and tested immediately by applying a load in tension in a plywood-testing machine at a rate of 600 to 1,000 pounds per minute. Pressure was immediately applied to the ramaining specimens. The specimen was placed in the jaws of the machine so that the glue joint was subjected, as nearly as possible, to pure shearing stresses (fig. 2). In addition, 10 specimens, glued with each glue at each temperature, were removed from the jig after 2 weeks under pressure, 5 of them were tested immediately and 5 of them were placed under moderate pressure in a C-clamp assembly, and heated in a chamber at 140° F. for 24 hours before testing in order to ascertain the possible benfits of such elevated curing temperature after preliminary curing at lower temperatures.

Results

The average results of the dry shear tests, when made immediately after the curing periods shown, were plotted in the form of smooth curves in figures 3 through 8. In some cases, particularly at the lower temperatures, the joints did not reach the ultimate strength of the wood in 300 hours. When the joints did achieve this level of strength, the curing periods that were necessary are given in table 2. The notation of "over 300" in table 2 indicates that the strength of the joints did not reach 850 pounds per square inch within the 300 hours that the tests were in progress. The results of dry shear tests, made on specimens cured at 140° F. after curing for 2 weeks at lower temperatures, are given in table 3.

The yellow birch veneer used in this study was of sufficiently high quality to sustain a load of approximately 850 pounds per square inch in the lap-type specimens used. A strength value of this magnitude does not necessarily indicate that the glue was fully cured, but it does indicate a strength sufficient to cause failure in the wood when the joint was tested to destruction.

None of the glues reached this level of performance when cured at 40° or 50° F. for 300 hours. Glues A, B, and C reached this level at 60° F. after 215, 220, and 240 hours, respectively. All but glues D and DF cured to this level at 70° F., and these latter two glues were also slowest in developing strength at 80° F., but did reach the strength of the wood after approximately 165 and 170 hours, respectively.

Glues B (fig. 4) and BF (fig. 5) developed strength most rapidly of all the glues at 40° and 50° F., with the rate of development being somewhat more rapid with BF. Glues A and C were somewhat slower to develop strength at these lower temperatures. It is possible that joints made with some of the glues would have increased in strength to the level of 850 pounds per square inch at these lower temperatures if the tests had been continued longer.[3]

At 70° and 80° F., glue B cured most rapidly and glues A and C at approximately equal rates. Glues D and DF were the slowest of the glues to develop strength as previously noted.

The resorcinol-resin glues cured more rapidly at temperatures of 70° F. or below than did the resorcinol resin modified with phenol resin (glue D).

Figures 4, 5, 7, and 8 indicate a slight but probably unimportant advantage in rate of strength development of the use of formaldehyde solution as hardener in place of the paraformaldehyde in glues B and D. This advantage was more apparent during the early stages of curing than in the strength developed in 300 hours and was more important at 40° to 60° F., than at 70° and 80° F.

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[3] Forest Products Laboratory Report No. R1629, "Curing of Resorcinol-Resin Glues at Temperatures from 40° to 80° F."

There was no significant and consistent differences in results with glues A and C, two similar resorcinol-resin glues, one used with a paraformaldehyde hardener and one with formaldehyde solution as a hardener. There was only a very slight advantage in the rate of original strength development of glue C over glue A 40° and 50° F., which was reversed to a similar extent at the higher temperatures. There did seem to be an advantage of glue C over A at 40° F. when the joints were subsequently cured at 140° F.

When joints were cured initially for 2 weeks at lower temperatures and subsequently cured at 140° F. improvements in strength over specimens cured only at 40° to 70° F. for 2 weeks were noted at all of the lower temperatures (table 3). Joints made with glue D were improved when cured at 140° F. after initial cure, but did not reach the strength of the wood, except when the initial curing temperature was 70° F. Joints made with glue A and cured initially at 40° F. were improved by subsequent heating to 140° F., but did not reach the level of 850 pounds per square inch. All other joints in these tests reached the approximate strength of the wood after the additional curing period at 140° F. following initial cure at temperatures from 40° to 70° F.

Summary

It appears feasible to use such resorcinol glues as A, B, and C at temperatures as low as 60° F. for the gluing of some wood aircraft parts if the stock is required to remain under pressure for about 24 hours. If the joints could be subsequently heated under moderate pressure to 140°F., glues typified by A, B and C could be used at temperatures as low as 50° F., and those typified by B and C possibly as low as 40° F. At 40° and 50° F resorcinol-resin glues with aqueous formaldehyde solution as the hardening agent appeared to be somewhat more capable of curing to higher strengths than those in which paraformaldehyde was used as the hardener, although the glues developed strength at the same rate at 70° and 80° F.

Resorcinol-resin glues that contained substantial amounts of phenol resin cured more slowly than those that contained little or no phenol resin.

Table 1.--Formulations of the glues used in this study[1]

Glue symbol	Ingredients in parts by weight			
	Resin[2]	Paraformaldehyde walnut-shell flour hardener	Formaldehyde hardener	Walnut-shell flour
A	100	20[3]	.....	.....
B	100	15[3]	.....	.....
BF	100	.....	23[4]	23[5]
C	100	.....	25[6]	(7)
D	100	20[3]	.....	.....
DF	100	.....	28[4]	18[5]

[1] All ingredients were brought to and all mixing was done at the temperatures used in the curing process.

[2] Used as received from the manufacturer.

[3] These proportions are the amounts of the specific hardeners recommended by the manufacturer of the resin. The proportions of the paraformaldehyde and walnut-shell flour were not known.

[4] Commercial aqueous formaldehyde solution, 37 percent by weight, used as received.

[5] Walnut-shell flour was added to bring the consistency of the mixture to that of the normal mixture with the recommended amount of the regular hardener.

[6] An aqueous solution of formaldehyde, used as received from the glue manufacturer. The amount of formaldehyde in the solution was not known.

[7] Walnut-shell flour was present in the resin as furnished by the manufacturer and none was added.

Table 2.--Approximate length of time for glue joints in yellow birch lap-type specimens to reach a strength of 850 pounds per square inch when cured at temperatures from 40° to 80° F.

Glue	Minimum time to reach a joint strength of 850 pounds per square inch at temperature of				
	40° F.	50° F.	60° F.	70° F.	80° F.
	Hours	Hours	Hours	Hours	Hours
A	Over[1] 300	Over 300	215	80	35
B	Over 300	Over 300	220	70	20
BF	Over 300	Over 300	Over 300	120	55
C	Over 300	Over 300	240	85	40
D	Over 300	Over 300	Over 300	Over 300	165
DF	Over 300	Over 300	Over 300	Over 300	170

[1] The notation "over 300" indicates that the strength of the joints did not reach 850 pounds per square inch within the 300 hours that the tests were in progress.

Table 3.--Average results of dry shear tests of yellow birch lap joint specimens showing effect of heating joints under pressure for 24 hours at 140° F. after initial cure for 2 weeks at temperatures from 40° to 70° F.

Glue	Average results[1] when lap joint specimens were cured for 2 weeks at temperatures indicated and then tested immediately				Average results[1] when lap joint specimens were tested after heating for 24 hours at 140° F. following initial cure for 2 weeks at temperatures indicated			
	40° F.	50° F.	60° F.	70° F	40° F.	50° F.	60° F.	70° F
A	554-2	655-20	(2)	(2)	766-66	855-94	(2)	(2)
B	738-5	748-22	(2)	(2)	811-91	855-100	(2)	(2)
BF	761-33	762-50	770-83	(2)	838-99	835-98	827-100	(2)
C	568-4	585-4	(2)	(2)	826-100	825-95	(2)	(2)
D	380-0	455-2	651-20	785-67	640-32	712-61	740-73	870-100
DF	466-1	493-1	550-10	695-86	818-93	811-91	838-92	842-100

[1] The value before the dash is the average shear strength in pounds per square inch; the value after the dash is the average estimated wood failure in percent. Each value is the average for 5 specimens.

[2] Joints attained full strength in less than 2 weeks (see table 2) and tests were terminated at that time.

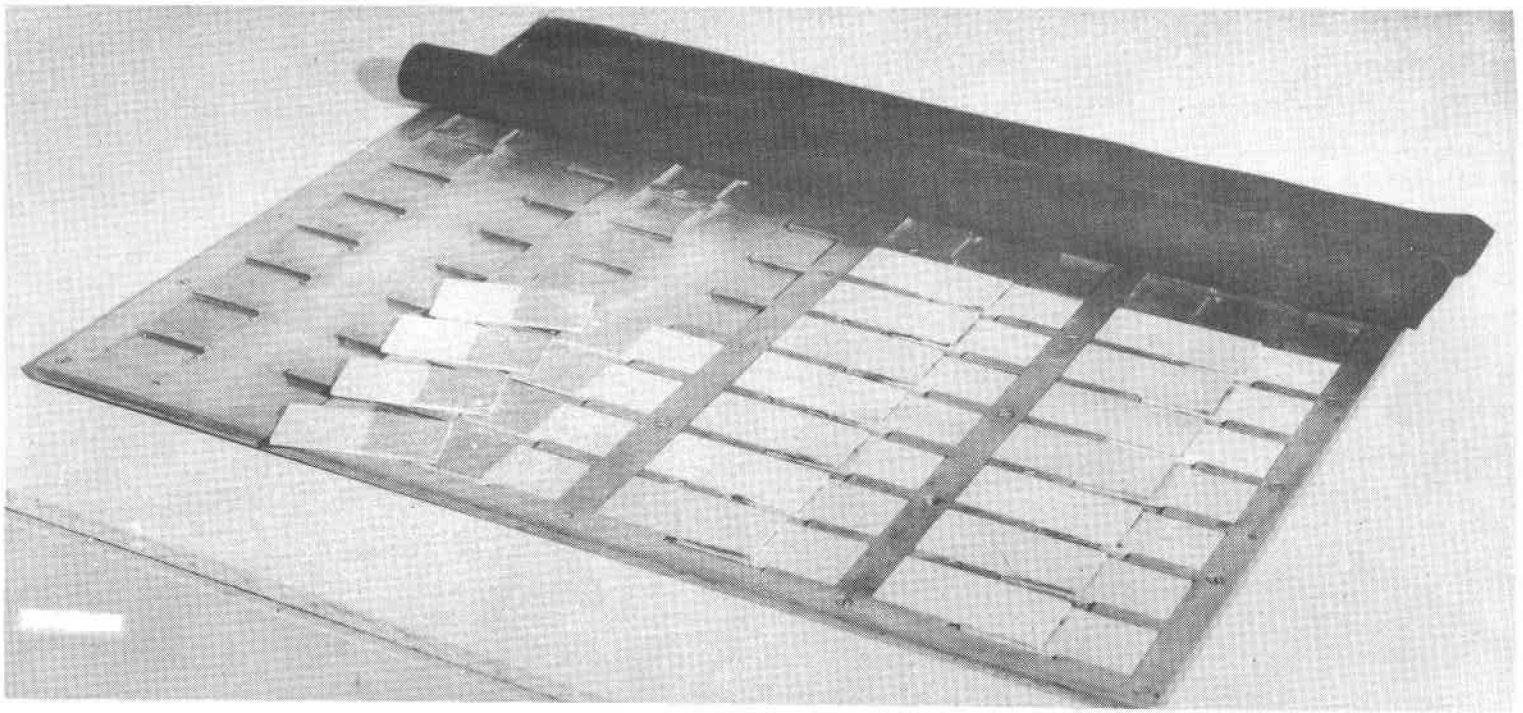

Figure 1.--Metal jig, with rubber caul, in which lap-joint specimens were prepared.

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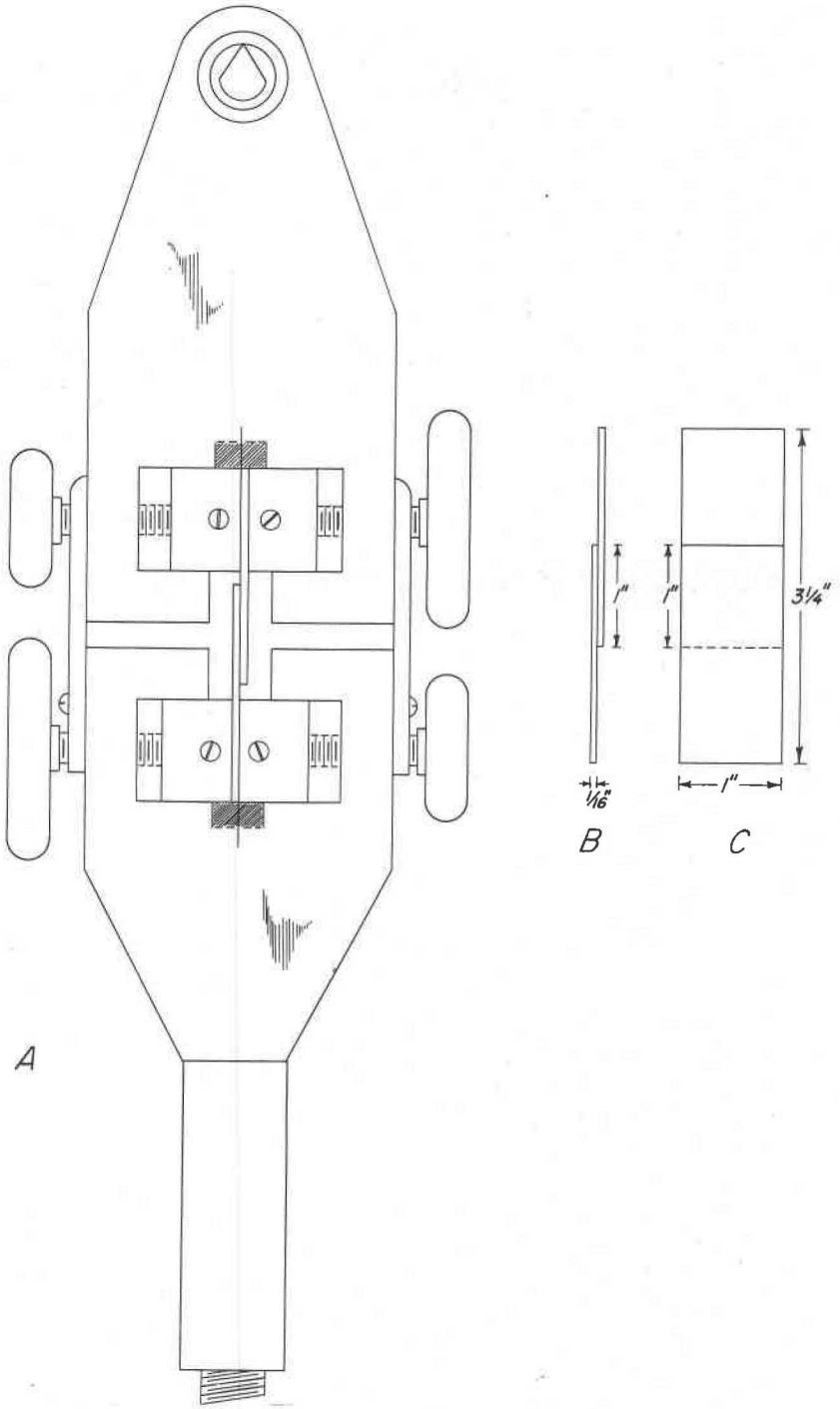

Figure 2.--The jaws (A) of plywood-testing machine showing alinement of specimen for testing, and two views (B and C) of the specimen used.

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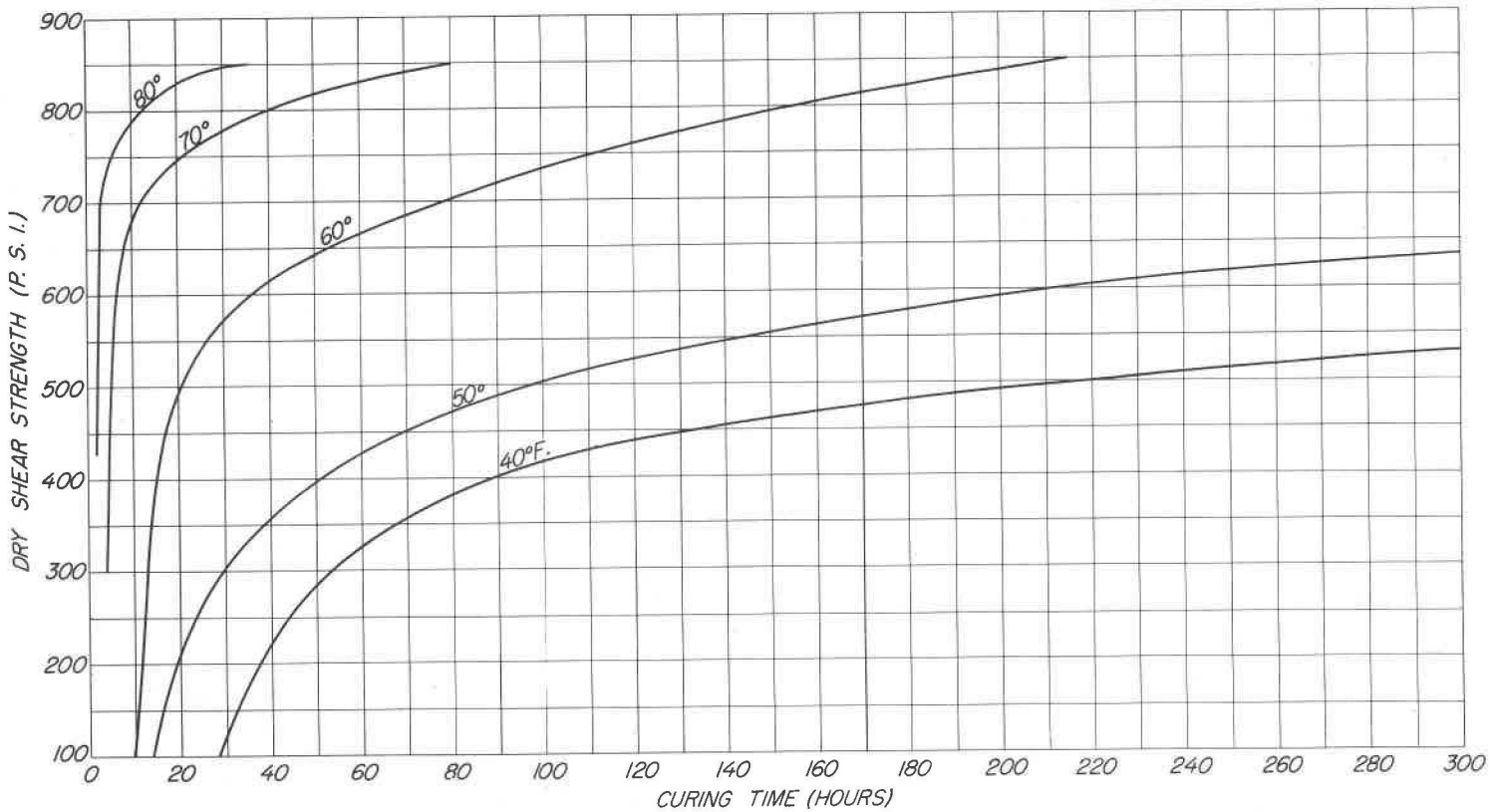

Figure 3.--Rate of development of dry shear strength at 40° to 80° F. in a lap-type specimen of yellow birch glued with glue A, a resorcinol resin with regular paraformaldehyde hardener.

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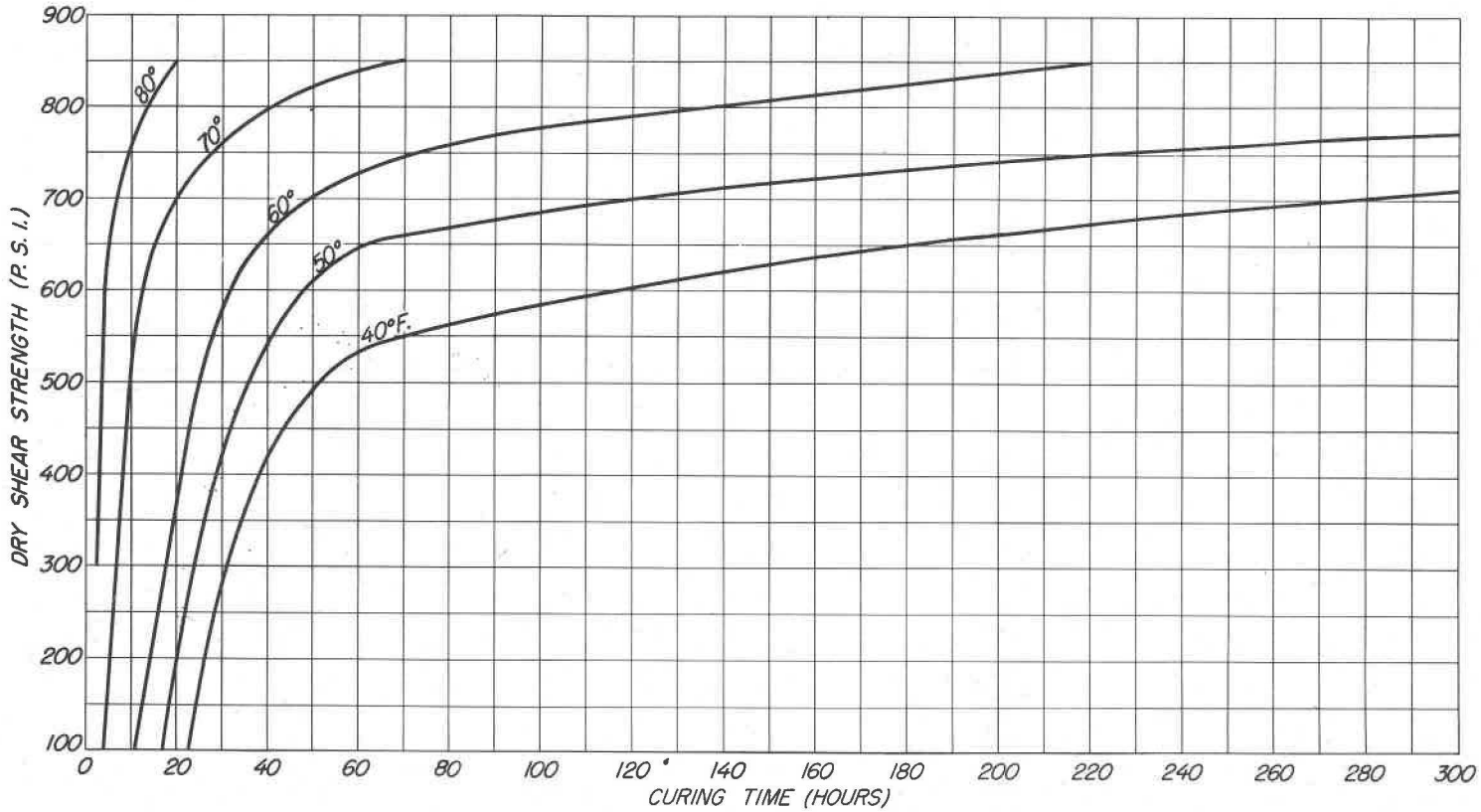

Figure 4.--Rate of development of dry shear strength at 40° to 80° F. in a lap-type specimen of yellow birch glued with glue B, a resorcinol resin with regular paraformaldehyde hardener.

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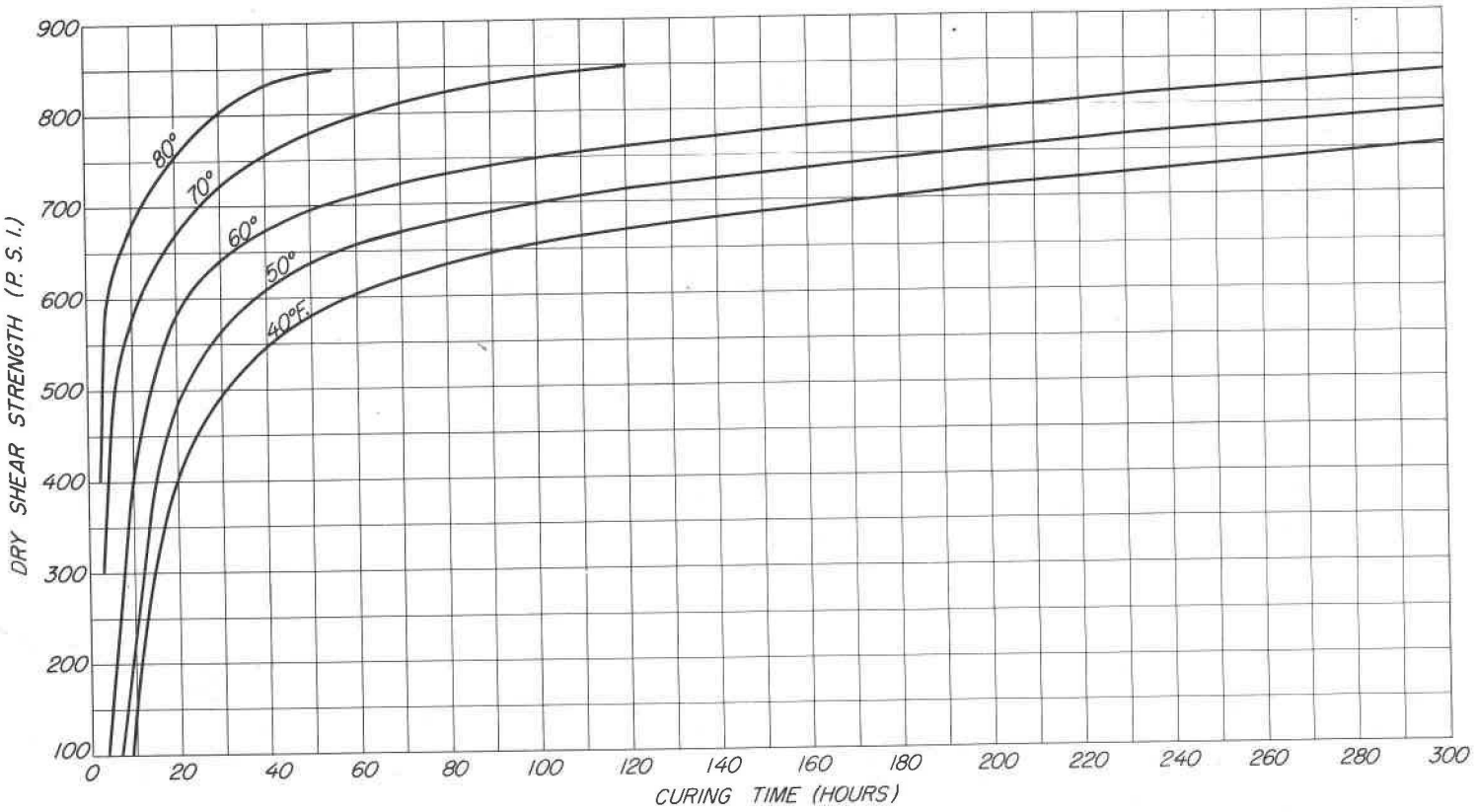

Figure 5.--Rate of development of dry shear strength at 40° to 80° F. in a lap-type specimen of yellow birch glued with glue BF, a resorcinol resin to which aqueous formaldehyde solution was added as an experimental hardener.

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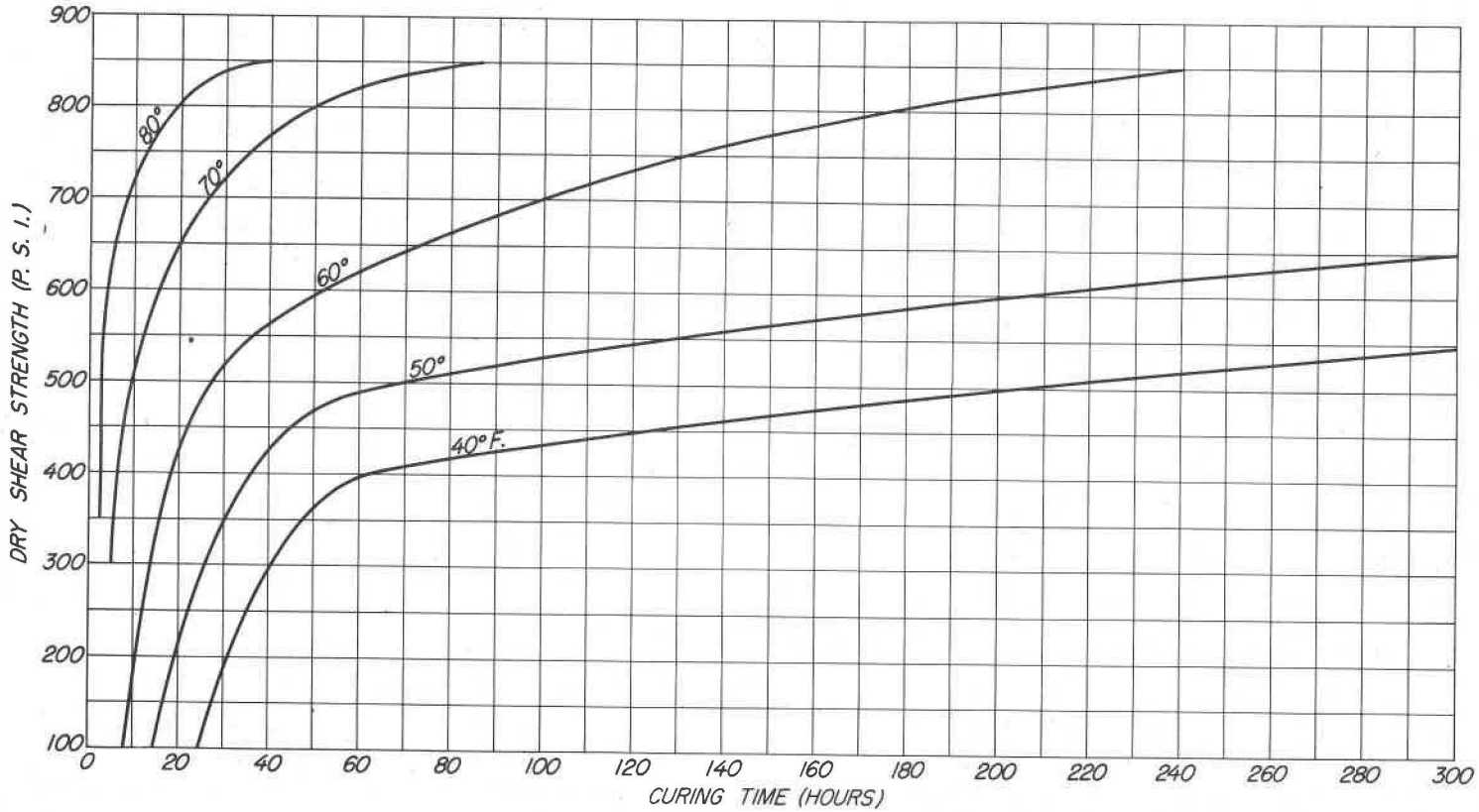

Figure 6.--Rate of development of dry shear strength at 40° to 80° F. in a lap-type specimen of yellow birch glued with glue C, a resorcinol resin with regular aqueous formaldehyde solution hardener.

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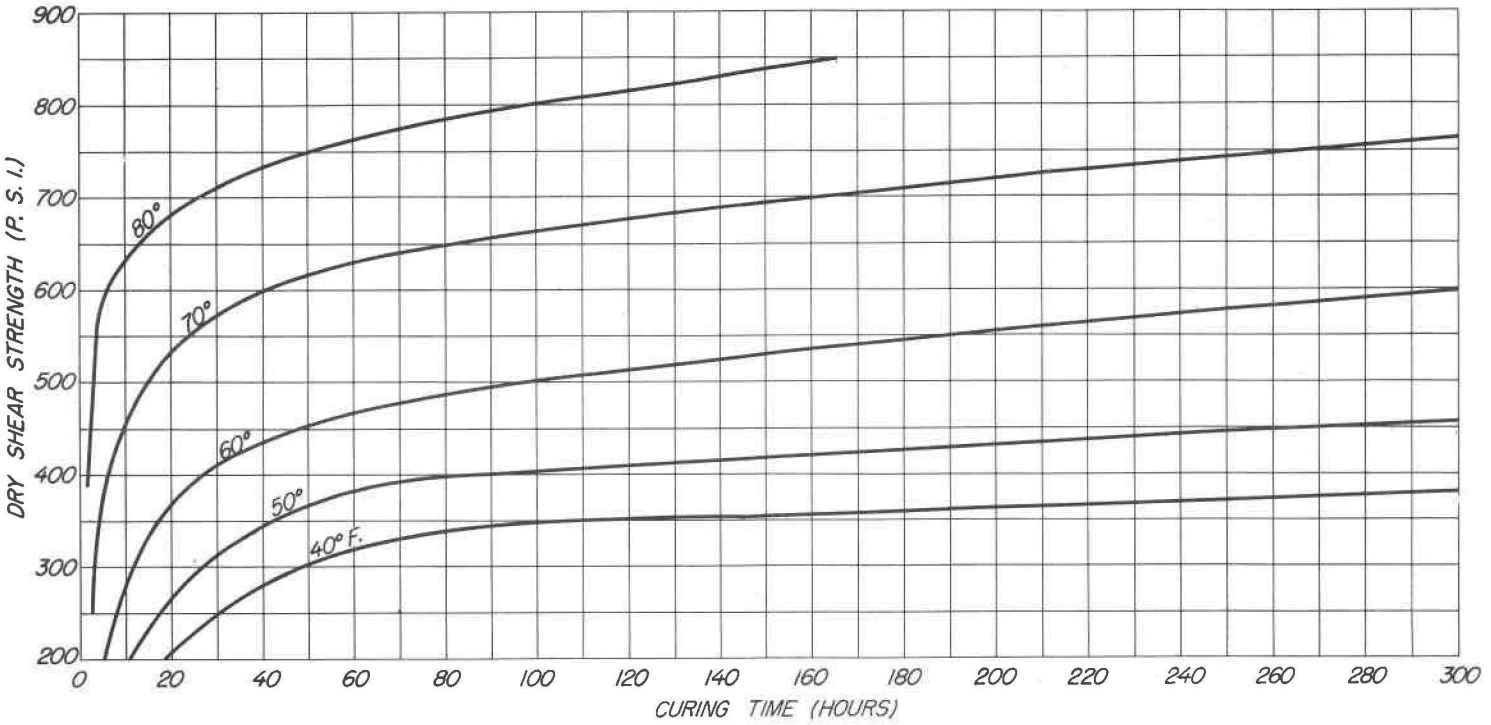

Figure 7.--Rate of development of dry shear strength at 40° to 80° F. in a lap-type specimen of yellow birch glued with glue D, a resorcinol-phenol resin with regular paraformaldehyde hardener.

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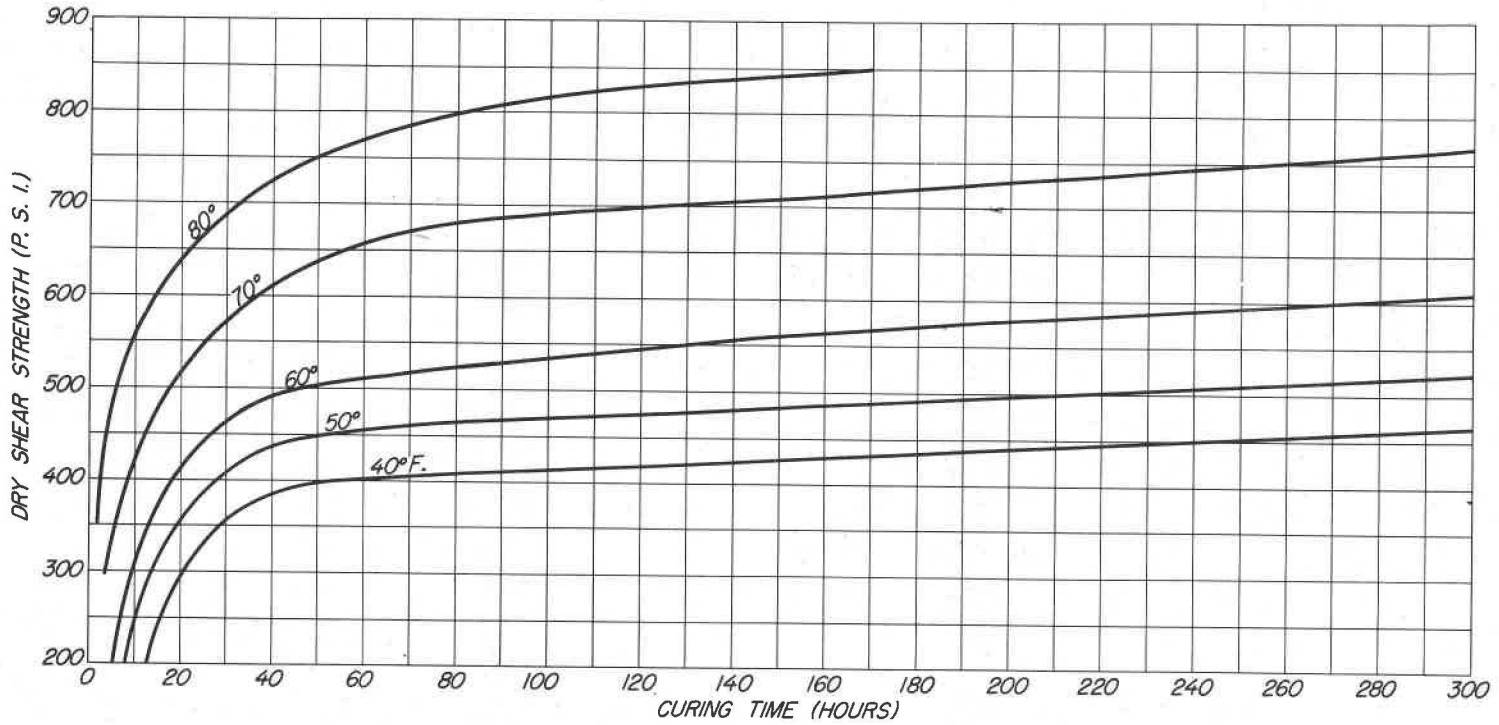

Figure 8.--Rate of development of dry shear strength at 40° to 80° F. in a lap-type specimen of yellow birch glued with glue DF, a resorcinol-phenol resin to which aqueous formaldehyde solution was added as an experimental hardener.

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