

DURABILITY OF ROOM-TEMPERATURE- SETTING AND INTERMEDIATE-TEMPERATURE- SETTING RESIN GLUES CURED TO DIFFERENT DEGREES IN YELLOW BIRCH PLYWOOD

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DURABILITY OF ROOM-TEMPERATURE-SETTING AND INTERMEDIATE-
TEMPERATURE-SETTING RESIN GLUES CURED TO DIFFERENT
DEGREES IN YELLOW BIRCH PLYWOOD¹

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Introduction

When used in gluing heavy constructions of dense woods, the more completely that phenol- and resorcinol-resin glues are cured the greater is the durability of the joints made with them. This is particularly true of the resistance of the joints to delamination due to the severe mechanical stresses set up by the swelling and shrinking of the wood when the moisture content changes. In lighter constructions, such as plywood, members laminated with species of lower density, and structural aircraft joints involving such species as spruce and mahogany, an exceptionally high degree of cure may not be required. The minimum degree of cure, however, that is required to impart sufficient durability to glue joints in these lighter constructions is not known. As one step toward the determination of such data, the study herein reported was performed at the Forest Products Laboratory to determine the minimum degree of cure that will provide satisfactory durability in yellow birch plywood joints.

The study was begun with two alkaline-catalyzed, intermediate-temperature-setting, phenol-resin glues, A and C, one acid-catalyzed, intermediate-temperature-setting phenol-resin glue, B, and one nearly neutral, resorcinol-resin glue, D. At later periods a melamine-resin glue, E, and a fortified urea-resin glue, F, and two additional resorcinol-resin glues, G and H, were added. The work consisted in gluing three-ply, 3/16-inch yellow birch plywood with these glues, curing the glue to different degrees of cure, subjecting specimens of this plywood to four different conditions of exposure, and periodically testing exposed specimens to ascertain the strength of the joints.

This is the final report on this study. It presents durability data obtained over a period of 36 months for glues A to F inclusive and 30 months for glues G and H.

¹This is one of a series of progress reports prepared by the Forest Products Laboratory relating to the use of wood in aircraft.

Procedures

Preparation of Specimens

The glues were mixed in accordance with the manufacturer's instructions.

Yellow birch veneer, 1/16 inch thick and 26 inches square, of about 11 percent moisture content, selected for straightness of grain and freedom from defects, was glued with approximately 20 grams of wet glue per square foot applied to the core ply. These were assembled into three-ply panels, which, after a closed assembly period of 10 minutes, were pressed under a pressure of 150 pounds per square inch.

The glues were cured in a room at 75° F. or between hot-press platens heated by hot water or steam. For glues A to F inclusive, temperatures and periods of heating were selected to give various degrees of cure from 30 to 100 percent estimated on the solubility in water of films of the glues cured under the same conditions.² For glues G and H the curing temperatures and periods were selected to result in dry shear strengths of three magnitudes, about 150, 350, and over 450 pounds per square inch. Wet strength values corresponding to these dry strength values were often considerably higher because of further curing that occurred during the 48-hour immersion in water. The actual curing times and temperatures are given in table 1.

Immediately after removal from the press, the panels were chilled in a room at -20° F., then cut into shear test specimens that were kept at -20° F. to inhibit further curing until put to exposure. With each glue, over 300 specimens from 3 panels were prepared for each degree of cure. The specimens were selected at random for distribution to the various exposure conditions.

Exposure Conditions

Groups of the specimens were exposed to the following conditions:

1. Continuous 80° F. and 65 percent relative humidity.
2. Continuous 158° F. and 20 percent relative humidity.
3. Continuous soaking in water at room temperature.
4. A repeating cycle of 2 days' soaking in water at room temperature followed by 12 days' drying at 80° F. and 30 percent relative humidity.

²The procedure for the determination of water solubility of glue film is described in Forest Products Laboratory Report No. 1352.

Test Procedure

For each glue and each degree of cure 20 specimens were tested before exposure, as controls. Ten of these specimens were tested dry and 10 after 48 hours of immersion in water at room temperatures. After each exposure period (except for exposure 3), for each glue and each degree of cure, 5 specimens were tested dry and 5 after this same water immersion to obtain average values for each variable. Specimens from exposure 3 were tested wet immediately upon removal from the soaking tank. The specimens were tested in shear in a standard plywood testing machine loaded at a rate of about 750 pounds per minute.

Results

The average results of the shear test made after the several periods of exposure are given in tables 2 through 12.

On the basis that approximately 90 percent or more of wood failure in both the dry and wet tests was necessary to insure bonds of satisfactory initial quality, the degrees of cure required by the different glues are shown in column 2 of table 13.

Exposed Continuously at 80° F. and 65 Percent Relative Humidity

In tables 2, 3, and 9 are presented the average results of the shear tests of the specimens after aging under the mild condition of 80° F. and 65 percent relative humidity.

Joints that were undercured often appeared to improve in quality, indicating a further curing of the glue during the exposure period. In no case did the test values at the end of 36 months appear to be significantly lower than those of the corresponding controls with the possible exception of joints made with glue B.

Damage to the wood by glue B, the acid-catalyzed phenol resin, was indicated by the trend, which was particularly evident in the wet test values as the exposure period lengthened, toward decreasing shear strength values accompanied by consistently high wood failure values.

With the criterion of the retention of approximately 90 percent or more wood failure applied to the results obtained after 30 to 36 months in this exposure, the degree of cure required by the different glues is shown in column 3 of table 13.

Exposed Continuously at 158° F. and
20 Percent Relative Humidity

The data obtained for this exposure are given in tables 4, 5, and 10. If the glue was originally cured to a low degree the test values obtained at the end of the early periods of exposure were often higher in strength or in wood failure than the initial or control test values, indicating that the glue joints continued to cure during the first few weeks of exposure. Except for glue H, the decreases in joint quality as the exposure progressed appeared to depend more upon the characteristics of the glue and the resistance of the wood to heat than upon the initial degree of cure of the glue bond. Undercured joints of glue H appeared to decrease in strength more rapidly than those more highly cured but the effect of undercuring on the rate of decrease in joint strength was less marked than its effect on initial strength.

As the exposure continued, all of the well-cured joints decreased in strength but the wood failure of those joints made with phenol, resorcinol, and melamine glues remained high, indicating that the strength of the wood was decreasing at least as rapidly as the strength of the glue.

The well-cured joints made with glue B decreased in strength more rapidly (while the wood failures remained higher than the well-cured joints made with the alkaline phenol, resorcinol, or melamine joints) indicating that the acid catalyst of glue B affected the strength of the wood.

Both the strength and the wood failure of joints made with the fortified urea-resin glue F showed continuous and marked decrease during the exposure period, indicating that the glue itself was distinctly weakened by the exposure. Based on the quality of the joints after 30 to 36 months of exposure to 158° F. and 20 percent relative humidity, an estimate of the approximate degree of cure required by the different glues to maintain a level of wood failure values of approximately 90 percent or more is given in column 4 of table 13.

Soaked Continuously in Water

Average results of tests on specimens soaked continuously in water at room temperature are given in tables 6 and 11.

In general, most glues showed a high order of water resistance throughout these tests. In some cases, incompletely cured joints increased in strength and wood failure, indicating continuation of cure during the soaking period. In other cases, the strength test values of incompletely cured joints remained nearly constant or decreased slightly while wood failure values increased. The strength values of well-cured joints decreased gradually while the wood failure values remained high, indicating that the strength of the wood decreased.

The strength of completely cured joints made with glue B fell to lower values than those of the well-cured joints of other glues, indicating further the probability of acid damage to the wood.

The melamine-resin glue E showed an inconsistent decrease in water resistance when cured to the 70 percent level. These joints were cured to an estimated 70 percent level by heating for 3 hours at 135° F., while those cured to an estimated 60 percent level were heated for 60 minutes at 160° F., and the estimated 80 percent level was reached by heating 4 hours at 180° F. From these results it appeared that, contrary to solubility tests, the melamine resin glue line heated at 135° F. for 3 hours was not so well cured as the glue lines heated to higher temperatures.

Based on the assumption that 90 percent of wood failure should be retained after 30 to 36 months of soaking, the degree of cure estimated to be required by the different glues is shown in column 5 of table 13.

Exposed to Alternate Soaking and Drying

In tables 7, 8, and 12 are presented the average results of tests on specimens subjected to a repeating cycle of soaking in water for 2 days at room temperature and then drying for 12 days in air at 80° F. and 30 percent relative humidity.

While some evidence of curing beyond the initial test period was apparent, the results of the soaking-drying test cycles showed a more definite correlation between degree of cure and durability of joints than the results from other exposure cycles included in these tests.

In general, adequate durability resulted only when the glues were subjected to the higher degrees of cure.

As in other exposure cycles, glue B gave evidence of acid damage to the wood.

The melamine resin showed an inconsistent decrease when cured to the 70 percent level, indicating again that a temperature of 135° F. is not adequate for this glue when high strengths and durability are required.

From the test results obtained after 30 to 36 months of soaking and drying the specimens, an estimate of the degree of cure required by the different glues to retain an average of 90 percent wood failure is given in column 6 of table 13.

Conclusions

1. In general, undercuring the glues used in these experiments appeared to have more effect on initial dry strength and wood failure and upon durability in soaking-drying exposures than upon the durability of joints when exposed continuously to 158° F. and 20 percent relative humidity, to continuous soaking in water, or to 80° F. and 65 percent relative humidity.

2. If species of high density are to be glued for use in aircraft the degrees of cure indicated in column 2 of table 13 for the different glues are recommended.

3. Curing temperatures as low as 135° F. were inadequate for melamine glue E.

4. The fortified urea-resin glue F appeared to lack permanence when exposed continuously to 158° F. and 20 percent relative humidity.

5. The acid-catalyzed phenol-resin glue B appeared to decrease the strength of the wood under the exposure conditions used.

Table 1.—Times and temperatures used to cure the glues to various degrees in the preparation of the driven plywood.

Degree of cure		Glue designation and type									
		A	B	C	D	E	F	G	H	I	J
Estimated film in- solubility ¹	Approximate dry joint strength (P.s.i.) ²	Alkaline phenol	Acid phenol	Alkaline phenol	Resorcinol	Melamine	Fortified urea	Resorcinol	Resorcinol	Resorcinol	Resorcinol
		Time of cure : temp- ture	Time of cure : temp- ture	Time of cure : temp- ture	Time of cure : temp- ture	Time of cure : temp- ture	Time of cure : temp- ture	Time of cure : temp- ture	Time of cure : temp- ture	Time of cure : temp- ture	Time of cure : temp- ture
Percent		Hr. : Min. : °F.	Hr. : Min. : °F.	Hr. : Min. : °F.	Hr. : Min. : °F.	Hr. : Min. : °F.	Hr. : Min. : °F.	Hr. : Min. : °F.	Hr. : Min. : °F.	Hr. : Min. : °F.	Hr. : Min. : °F.
30		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
40		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
50		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
60		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
70		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
80		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
90		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
95		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
100		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
150 (A) ³		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
150 (B)		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
340 (A)		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
350 (B)		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160
Over 450 (B)		30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160	30 : 160

¹Method described in Forest Products Laboratory Report No. 1359.

²The panels were removed from the press when the joints had reached approximately these values.

³A and B refer to separate series of panels in which two different curing temperatures were used to produce the same approximate original dry strength.

Table 2.--Average results of dry¹ shear tests of three-ply, 3/16-inch yellow birch plywood, made with glues cured to various degrees, and exposed to 80° F. and 65 percent relative humidity²

Glue		Period of exposure	Estimated degree of cure of glue in percent								
Designation	Type		30	40	50	60	70	80	90	95	100
		Months									
A	Alkaline phenol	0			421-28	453-41	467-61	480-64	541-78	536-98	534-74
		2			428-34	465-70	520-50	510-65	582-94	550-88	544-84
		4			528-46	510-73	495-90	543-67	513-64	540-93	608-91
		6			430-63	434-87	525-100	538-85	523-69	532-100	629-93
		12			434-93	497-85	496-100	521-82	488-80	531-100	575-90
		18			456-60	438-92	466-84	471-85	466-92	463-100	511-93
		24			436-77	474-93	472-79	444-84	506-94	459-100	572-66
		30			452-88	460-78	509-92	486-87	452-99	493-97	545-82
		36			419-100	461-100	455-100	457-85	414-98	440-92	513-98
B	Acid phenol	0					229-0	204-0	449-4	489-77	308-100
		2					502-86	458-94	445-24	479-75	336-98
		4					468-73	463-72	517-46	494-83	361-100
		6					417-82	430-95	499-57	463-85	341-100
		12					422-96	432-100	509-69	470-83	383-100
		18					405-95	401-95	438-78	377-100	288-100
		24					435-80	374-94	474-83	355-96	370-90
		30					431-100	378-100	451-99	342-100	297-100
		36				396-100	340-100	397-100	368-100	288-100	
C	Alkaline phenol	0			358-2	437-11	561-91	547-93	543-99	513-100	530-100
		2			439-49	516-68	551-83	556-94	592-98	562-98	530-100
		4			468-60	572-63	566-100	558-91	573-100	557-100	575-100
		6			436-84	498-81	662-94	662-97	633-100	638-99	628-100
		12			485-81	543-86	584-95	545-92	562-100	563-100	523-99
		18			439-97	504-70	505-84	511-95	506-100	470-97	459-100
		24			498-100	509-81	559-75	514-79	524-92	505-98	532-99
		30			444-94	478-78	523-81	496-77	532-88	523-95	522-95
		36			426-94	432-77	493-82	494-84	519-100	458-99	480-98
D	Resorcinol	0			341-7	373-8	422-33	583-99	571-97	595-100	535-89
		2			495-88	540-82	620-100	643-98	589-100	576-97	540-100
		4			503-83	572-100	576-98	581-99	606-100	633-98	548-100
		6			522-93	507-93	579-100	562-100	596-100	585-100	559-94
		12			529-97	537-94	572-98	606-100	602-99	613-98	589-95
		18			447-80	468-81	535-100	534-100	522-99	550-95	480-100
		24			417-100	463-97	514-96	548-94	551-93	549-92	566-88
		30			443-82	461-94	519-91	516-89	576-94	562-92	511-94
		36			454-99	478-97	520-92	521-97	463-100	531-88	489-100
E	Melamine	0	414-38	594-100	398-26	435-45	338-13	548-100	564-97	537-94	570-98
		2	496-100	502-99	502-97	479-100	500-76	502-100	480-98	519-100	570-100
		4	416-97	428-98	577-98	607-100	459-72	499-100	500-92	509-100	584-100
		6	458-100	450-95	517-97	459-100	546-100	538-100	528-100	578-98	588-98
		12	528-100	509-98	617-99	524-96	528-100	543-100	507-100	510-94	603-99
		18	475-82	556-83	469-100	488-100	503-100	497-94	499-100	479-99	529-100
		24	459-99	468-89	518-96	482-98	464-99	450-99	498-98	454-97	517-95
		30	361-95	359-100	487-100	452-100	420-100	412-100	433-96	434-88	466-99
		36	444-99	378-100	462-100	488-100	409-93	449-98	410-98	422-82	482-99
F	Fortified urea	0					478-99	529-100	512-98	521-100	569-100
		2					470-100	483-100	478-100	493-100	498-100
		4					498-86	466-100	492-100	479-100	513-100
		6					534-98	531-100	532-97	540-98	568-99
		12					545-96	527-100	513-100	552-96	568-98
		18					478-97	468-100	456-95	511-100	507-98
		24					499-87	499-96	474-87	502-99	524-94
		30					438-81	406-90	393-88	439-99	480-100
		36				420-95	452-98	476-100	422-93	421-97	

¹The specimens were at a moisture content of about 11 percent when tested.

²The value before the dash is average shear strength in pounds per square inch; the value after the dash is average wood failure in percent. Control values are the averages of 10 specimens; other values the averages of 5.

Table 3.—Average results of wet¹ shear tests of three-ply, 3/16-inch yellow birch plywood, made with glues cured to various degrees, and exposed to 80° F. and 65 percent relative humidity²

Designation:	Glue Type	Period of exposure:	Estimated degree of cure of glue in percent								
			30	40	50	60	70	80	90	95	100
		Months									
A	Alkaline phenol	0			369-7	425-6	490-28	608-63	618-96	626-87	676-100
		2			423-13	462-9	595-44	588-49	578-97	583-98	670-100
		4			496-8	518-44	550-51	607-66	578-99	573-98	620-98
		6			488-49	477-65	527-65	588-64	567-100	588-100	561-100
		12			552-76	510-81	627-88	571-80	586-96	607-94	600-97
		18			598-81	535-96	580-95	561-93	575-97	583-98	649-97
		24			477-99	408-93	596-100	605-96	598-99	596-98	585-100
		30			492-95	547-90	539-90	563-96	540-97	552-97	573-97
B	Acid phenol	36			543-98	566-99	600-99	629-93	638-100	531-100	574-98
		0					134-0	84-0	579-29	583-94	332-100
		2					564-100	542-98	610-88	503-100	374-100
		4					538-100	541-98	532-100	489-98	297-100
		6					450-98	487-100	529-100	447-92	316-100
		12					443-97	467-97	507-99	448-97	310-100
		18					418-100	438-100	454-100	372-100	320-100
		24					394-98	392-100	374-90	471-100	302-100
C	Alkaline phenol	30					391-99	358-100	408-100	344-99	275-100
		36					350-100	294-100	438-100	335-100	274-100
		0			309-0	389-8	574-97	559-95	598-100	596-100	726-100
		2			484-94	458-98	608-100	589-98	600-98	584-100	631-100
		4			557-86	508-100	571-100	564-100	564-100	593-100	687-100
		6			541-86	516-94	564-100	554-100	536-100	529-100	618-100
		12			535-99	511-93	599-97	574-98	574-99	601-98	610-100
		18			525-98	502-99	544-100	597-97	546-98	541-100	657-100
D	Resorcinol	24			503-98	517-97	572-98	576-99	562-100	550-100	671-100
		30			472-99	469-95	519-99	520-97	515-100	513-99	559-100
		36			518-99	508-98	574-100	585-100	566-100	554-100	699-100
		0			315-4	346-18	558-88	580-99	559-98	619-96	533-93
		2			553-98	497-99	555-100	625-100	551-99	590-100	574-98
		4			623-100	575-100	575-86	580-98	592-99	623-100	555-100
		6			549-100	462-100	593-100	567-100	559-100	579-100	623-100
		12			564-94	518-100	587-98	583-99	571-98	576-98	620-97
E	Melamine	18			582-99	604-100	599-100	563-100	538-99	583-99	564-97
		24			489-99	477-93	550-93	590-96	551-95	575-99	615-98
		30			500-97	480-98	552-96	556-100	517-99	536-100	577-99
		36			612-100	543-97	547-96	610-100	562-97	584-100	583-96
		0	475-83	588-100	504-47	502-88	431-34	599-95	609-99	631-100	524-96
		2	456-100	542-100	558-100	519-100	474-100	498-100	474-100	533-100	442-100
		4	558-100	504-100	574-100	537-100	524-100	578-100	542-100	568-100	435-100
		6	575-100	563-99	533-95	512-98	567-100	542-100	591-100	592-100	494-100
F	Fortified urea	12	520-100	583-99	578-100	528-100	581-100	570-98	607-100	637-100	506-100
		18	593-100	531-100	570-100	520-96	517-100	587-100	579-100	623-98	579-95
		24	532-99	525-100	464-100	422-100	517-100	571-100	567-100	548-100	531-100
		30	510-99	507-100	512-99	436-100	472-100	521-100	518-100	582-98	458-100
		36	516-100	511-100	547-100	482-100	476-100	501-100	526-100	514-100	486-100
		0					521-98	556-100	564-99	581-99	588-100
		2					462-100	472-100	481-100	458-100	523-100
		4					513-100	494-100	544-100	524-100	544-100
		6					531-100	533-99	523-100	534-100	562-100
		12					540-100	545-100	526-100	559-100	557-100
		18					592-100	501-96	566-97	575-98	562-98
		24					542-100	535-100	492-100	490-100	524-100
		30					489-98	470-99	457-100	494-100	541-99
		36					482-100	489-100	501-100	511-100	510-100

¹Specimens tested wet after soaking 2 days in water at room temperature.

²The value before the dash is average shear strength; the value after the dash is average estimated percentage wood failure. Control values are the averages of 10 specimens; other values the averages of 5.

Table 4.—Average results of dry¹ shear tests of three-ply, 3/16-inch yellow birch plywood, made with glues cured to various degrees, and exposed to 158° F. and 20 percent relative humidity²

Glue		Period of exposure	Estimated degree of cure of glue in percent								
Designation	Type		30	40	50	60	70	80	90	95	100
		Months									
A	Alkaline phenol	0			421-28	453-41	467-61	480-64	541-78	536-98	534-74
		2			378-100	365-100	371-97	431-100	422-92	349-100	470-74
		4			445-100	449-100	386-99	341-100	364-99	318-100	431-75
		6			403-99	374-100	339-98	415-98	416-100	344-100	502-92
		12			399-97	358-100	349-87	365-98	375-98	344-100	476-98
		18			379-98	346-97	340-100	325-100	360-100	277-100	416-82
		24			316-100	356-98	339-98	312-100	346-90	267-100	375-91
		30			338-98	314-99	232-100	296-100	320-95	289-100	339-96
		36			338-93	216-100	247-100	272-98	268-100	252-100	333-94
B	Acid phenol	0					229-0	204-0	449-4	489-77	308-100
		2					242-88	242-99	290-97	244-100	243-100
		4					287-100	270-100	285-45	216-96	298-100
		6					232-94	228-100	255-98	202-100	282-99
		12					254-98	220-100	260-98	224-100	198-100
		18					236-100	198-100	231-100	209-100	221-97
		24					218-98	167-100	229-97	202-97	216-100
		30					173-95	206-100	194-96	156-100	166-100
		36					216-100	155-90	166-90	128-100	178-100
C	Alkaline phenol	0			358-2	437-11	561-91	547-93	543-99	513-100	530-100
		2			387-100	417-97	454-98	400-97	410-94	409-98	390-92
		4			457-100	509-99	461-93	414-100	431-100	364-99	451-100
		6			435-100	455-96	444-100	428-85	406-100	354-100	402-100
		12			356-100	423-98	444-100	409-100	458-100	404-100	433-100
		18			355-99	415-88	402-100	375-94	407-100	347-100	360-100
		24			324-100	330-100	361-97	334-100	358-98	323-99	422-98
		30			329-98	389-91	331-100	291-100	334-100	295-100	298-100
		36			305-98	383-97	318-100	297-100	292-100	299-100	243-100
D	Resorcinol	0			341-7	373-8	422-33	583-99	571-97	595-100	535-89
		2			355-80	417-99	461-96	458-97	465-94	456-78	427-93
		4			492-100	473-100	398-98	427-98	444-100	483-94	403-97
		6			402-78	398-98	439-100	428-99	440-100	452-94	430-98
		12			388-88	409-97	418-99	419-97	435-98	439-96	394-82
		18			344-62	380-84	368-98	392-90	396-95	409-100	373-84
		24			308-100	325-74	326-74	317-46	349-70	325-40	352-69
		30			310-80	330-81	286-80	304-62	310-72	319-65	283-83
		36			298-79	311-60	282-92	223-58	264-51	277-65	307-82
E	Melamine	0	414-38	594-100	398-26	435-45	338-13	548-100	564-97	537-94	570-98
		2	385-76	290-96	425-96	423-99	419-87	382-100	403-100	406-94	454-100
		4	485-95	474-97	495-100	570-85	405-81	398-86	426-100	398-70	447-95
		6	440-90	475-99	471-86	448-94	509-70	462-100	475-98	491-100	503-98
		12	433-91	511-97	440-85	450-88	411-98	400-80	402-86	404-62	444-98
		18	381-100	434-81	423-91	441-94	359-52	343-98	430-100	419-82	427-100
		24	335-87	348-95	418-89	401-81	322-78	345-99	341-100	419-96	377-95
		30	449-100	450-100	410-84	389-90	322-100	281-92	295-98	294-90	346-100
		36	304-83	338-100	387-89	413-100	301-86	327-100	302-100	300-90	346-95
F	Fortified urea	0					478-99	529-100	512-98	521-100	569-100
		2					405-80	419-100	429-93	389-90	422-97
		4					401-84	365-89	379-81	355-69	404-84
		6					457-87	463-97	424-92	454-89	512-91
		12					356-52	345-31	336-59	327-16	393-47
		18					290-6	295-39	279-42	268-7	306-8
		24					241-3	271-39	257-37	238-3	280-20
		30					185-0	178-2	218-0	220-0	210-6
		36					175-1	188-0	176-1	174-2	194-5

¹The specimens were at a moisture content of about 11 percent when tested.

²The value before the dash is average shear strength; the value after the dash is average estimated percentage wood failure. Control values are the averages of 10 specimens; other values the averages of 5.

Table 5.--Average results of wet¹ shear tests of three-ply, 3/16-inch yellow birch plywood, made with glues cured to various degrees, and exposed to 158° F. and 20 percent relative humidity²

Glue		Period of exposure	Estimated degree of cure of glue in percent									
Designation:	Type		30	40	50	60	70	80	90	95	100	
		Months										
A	Alkaline phenol	0			369- 7	425- 6	490- 28	608- 63	618- 96	626- 87	676-100	
		2			616-100	574- 99	578-100	607-100	683-100	556-100	549- 98	
		4			574-100	587-100	447-100	572-100	604-100	467-100	543- 98	
		6			509- 99	549-100	542-100	564- 98	597-100	509-100	536-100	
		12			506-100	522-100	534-100	529-100	534- 99	461-100	585-100	
		18			584-100	558-100	458-100	520-100	484-100	399-100	439-100	
		24			541-100	517-100	421-100	422-100	476-100	425-100	455-100	
		30			446-100	429-100	340-100	351-100	364-100	334-100	387-100	
	36			456-100	467-100	290-100	336-100	339-100	293-100	332-100		
B	Acid phenol	0					134- 0	84- 0	579- 29	583- 94	332-100	
		2					305- 98	252-100	322- 94	271-100	290-100	
		4					256-100	249-100	244-100	183-100	198-100	
		6					257-100	254-100	285-100	226-100	255-100	
		12					254- 99	230-100	233- 97	199-100	195-100	
		18					216-100	236- 99	217-100	183-100	180-100	
		24					199-100	187- 99	206-100	166-100	122- 80	
		30					180-100	167-100	155-100	114-100	114-100	
	36					134-100	146-100	159-100	94-100	142-100		
C	Alkaline phenol	0			309- 0	389- 8	574- 97	559- 95	598-100	596-100	726-100	
		2			544-100	482-100	590- 99	607-100	605-100	573-100	613-100	
		4			558-100	535-100	507-100	533-100	521-100	492-100	531-100	
		6			511-100	481-100	487-100	547-100	485-100	499-100	587-100	
		12			474-100	441- 98	459-100	477-100	468-100	470-100	460-100	
		18			487-100	474-100	410-100	481-100	413-100	364-100	408-100	
		24			413-100	422-100	455-100	426-100	442-100	412-100	397-100	
		30			413-100	438-100	325-100	530-100	296-100	272-100	295-100	
	36			425-100	455-100	321-100	318-100	328-100	279-100	301-100		
D	Resorcinol	0			315- 4	346- 18	558- 88	580- 99	559- 98	619- 96	533- 93	
		2			532-100	525- 98	552-100	591-100	613-100	647-100	544-100	
		4			592-100	568-100	498- 96	573-100	580-100	554-100	433-100	
		6			511-100	539- 99	493-100	537-100	568-100	582-100	527-100	
		12			479-100	460- 98	455-100	448-100	474-100	468-100	400-100	
		18			494-100	460-100	374-100	356-100	396-100	433-100	375-100	
		24			396- 99	341- 98	345-100	334-100	387-100	377- 98	334-100	
		30			396-100	339-100	278-100	268-100	297-100	284-98	258-100	
	36			390-100	380-100	237-100	217-100	267-100	281-100	222-100		
E	Melamine	0	475- 83	588-100	504- 47	502- 88	431- 34	599- 95	609- 99	631-100	524- 96	
		2	486-100	576-100	505-100	441- 98	477-100	550-100	506-100	549-100	441-100	
		4	455-100	525-100	569-100	468-100	479-100	476-100	494-100	560-100	466-100	
		6	521-100	540-100	468- 98	397-100	422- 88	552-100	481- 99	569-100	441- 99	
		12	414-100	511-100	511-100	434-100	456- 98	460-100	469- 98	530-100	491-100	
		18	439-100	473-100	515-100	419-100	450-100	520-100	500-100	534- 99	429-100	
		24	415-100	438-100	508-100	384-100	359-100	386-100	370-100	422-100	362-100	
		30	430-100	425-100	380-100	369-100	319-100	347-100	334-100	371-100	288-100	
	36	398-100	367-100	491-100	385-100	283-100	316-100	313-100	346-100	301-100		
F	Fortified urea	0						521- 98	556-100	564- 99	581- 99	588-100
		2						508-100	533-100	527-100	496-100	512-100
		4						504-100	452-100	482-100	500-100	537-100
		6						474-100	497- 99	481-100	448-100	495- 99
		12						461- 92	467-100	429- 97	425- 80	514-100
		18						367- 79	465- 92	393- 93	320- 65	469- 98
		24						314-100	340- 71	348- 95	303- 36	381-100
		30						231-62	262-74	278-51	221-24	285-75
	36						227-6	227-27	227-58	213-4	233-71	

¹Specimens tested wet after soaking 2 days in water at room temperature.

²The value before the dash is average shear strength; the value after the dash is average estimated percentage wood failure. Control values are the averages of 10 specimens; other values the averages of 5.

Table 6.--Average results of wet¹ shear tests of three-ply, 3/16-inch yellow birch plywood, made with glues cured to various degrees, after continuous soaking in water at room temperature²

Glue		Period of	Estimated degree of cure of glue in percent									
Designation:	Type	exposure:	30	40	50	60	70	80	90	95	100	
		Months										
A	Alkaline phenol	0			369- 7	425- 6	490- 28	608- 63	618- 96	626- 87	676-100	
		2			381- 4	378- 1	470- 27	518- 36	547- 86	589- 94	545- 96	
		4			447- 20	492- 0	453- 16	547- 47	570- 94	568- 98	569-100	
		6			417- 26	464- 5	435- 56	505- 47	500-100	529-100	577-100	
		12			411- 24	405- 54	496- 96	541- 65	527-100	537- 98	533- 99	
		18			434- 63	462- 27	480- 77	535- 91	509- 99	466- 98	563-100	
		24			397- 45	416- 39	473- 70	526- 95	512- 98	509-100	542-100	
B	Acid phenol	30			387-74	383-57	454-95	464- 93	449- 97	452- 98	474-100	
		36			409- 75	397- 72	437- 96	465- 97	379-100	428- 99	451-100	
		0					134- 0	84- 0	579- 29	583- 94	332-100	
		2					175- 0	90- 0	543- 76	514- 98	313-100	
		4					206- 0	116- 0	529- 48	517- 98	333-100	
		6					237- 0	155- 0	531- 38	516-100	303-100	
		12					268- 0	190- 0	543- 77	504- 96	280-100	
C	Alkaline phenol	18					264- 0	185- 0	513- 88	476- 95	272-100	
		24					280- 0	197- 0	535- 76	435-100	272-100	
		30					151- 0	146- 0	467-100	430-100	225-100	
		36					286- 3	163- 0	446-100	415- 99	200-100	
		0			309- 0	389- 8	574- 97	559- 95	598-100	596-100	726-100	
		2			326- 0	447- 76	533- 98	527- 99	538-100	521-100	585-100	
		4			391- 7	509- 96	545- 92	515-100	571- 99	520- 96	638-100	
D	Resorcinol	6			382- 35	460- 89	528-100	508-100	526-100	500-100	588-100	
		12			378- 35	466- 90	529- 99	537-100	533-100	511- 98	624-100	
		18			402- 71	449- 97	511-100	489-100	504-100	501-100	568-100	
		24			360- 71	405- 97	497-100	464- 97	496-100	483-100	542-100	
		30			360- 62	406- 95	460-100	433- 98	456-99	437-100	541-100	
		36			395- 76	411- 99	399-100	371-100	460-100	456-100	556-100	
		E	Melamine	0			315- 4	346- 18	558- 88	580- 99	559- 98	619- 96
2					463- 96	434- 98	530- 98	542-100	518- 98	557- 97	581- 94	
4					518-100	525- 94	535-100	525-100	537-100	552-100	575-100	
6					487- 97	471- 95	505-100	498-100	465-100	531-100	492-100	
12					497- 83	469- 94	484-100	531-100	482- 96	529- 98	543- 96	
18					493- 95	433- 91	495-100	464-100	449-100	506-100	501- 97	
24					425- 86	412-100	487- 99	508- 99	434- 97	478- 96	515- 99	
F	Fortified urea	30			389- 98	399- 86	437- 99	450-100	438- 95	473- 99	466- 92	
		36			411-98	376-100	408-100	438-100	424-100	426-100	448- 98	
		0			475- 83	588-100	504- 47	502- 88	431- 34	599- 95	609- 99	631-100
		2			483-100	539-100	525-100	466-100	489- 98	514-100	533-100	551-100
		4			487-100	486-100	577-100	490- 93	450- 70	526-100	487-100	561-100
		6			534-100	483-100	518- 82	479- 99	426- 26	472-100	490-100	564-100
		12			446-100	517-100	484- 74	457- 93	371- 4	500-100	492- 99	495-100
		18			449- 82	476- 92	453- 55	401- 34	363- 7	430-100	484-100	554-100
		24			448- 80	454- 84	406- 38	330- 64	344- 19	463-100	485- 95	511-100
		30			429-70	444-95	394- 45	326- 56	289- 6	412- 93	453-100	440- 97
		36			364-76	378-100	386- 96	344- 80	197- 0	385-100	395-100	426-100
		0					521- 98	556-100	564- 99	581- 99	588-100	
		2					533-100	483-100	495-100	482-100	486-100	
		4					543-100	446-100	509-100	514-100	534-100	
		6					502-100	486-100	495-100	490-100	530-100	
		12					528-100	449- 98	504-100	506-100	469-100	
		18					458-100	498- 95	501-100	532-100	473-100	
		24					460-100	328-100	467-100	462-100	475-100	
		30					406-100	379-100	460-100	450-100	453-100	
36					348-100	344-100	394-100	429-100	440-100			

¹Specimens tested wet upon removal from the soaking tank.

²The value before the dash is average shear strength; the value after the dash is average estimated percentage wood failure. Control values are the averages of 10 specimens; other values the averages of 5.

³No specimens remained for further tests.

Table 7.—Average results of dry¹ shear tests of three-ply, 3/16-inch yellow birch plywood, made with glues cured to various degrees, and alternately soaked in water at room temperature for 2 days and dried for 12 days at 80° F. and 30 percent relative humidity²

Designation	Glue Type	Period to exposure, Months	Estimated degree of cure of glue in percent							
			30	40	50	60	70	80	90	100
A	Alkaline phenol	0			421-28	453-41	467-61	480-64	541-78	536-98
		2			326-1	396-17	446-16	398-33	413-92	420-84
		4			358-4	359-18	460-76	448-61	461-80	466-98
		6			321-4	393-25	447-68	432-65	489-88	458-100
		12			342-8	332-19	491-71	525-93	533-97	534-98
		18			339-13	366-57	407-75	440-55	457-84	432-99
		24			312-6	343-17	368-80	409-90	401-87	377-98
		30			305-12	338-37	418-100	445-99	429-91	467-100
B	Acid phenol	0			319-25	320-92	366-90	411-100	406-88	427-100
		2					229-0	204-0	449-4	489-77
		4					0-0	0-0	368-4	426-52
		6					0-0	0-0	391-3	420-34
		12					0-0	0-0	404-8	421-43
		18					0-0	0-0	457-41	440-60
		24					0-0	0-0	385-2	383-44
		30					0-0	0-0	339-0	390-36
C	Alkaline phenol	0					0-0	0-0	366-0	427-82
		2					0-0	0-0	328-5	358-72
		4								
		6								
		12								
		18								
		24								
		30								
D	Resorcinol	0								
		2								
		4								
		6								
		12								
		18								
		24								
		30								
E	Melamine	0								
		2								
		4								
		6								
		12								
		18								
		24								
		30								
F	Fortified urea	0								
		2								
		4								
		6								
		12								
		18								
		24								
		30								

¹Specimens were at a moisture content of about 7 percent when tested.

²The value before the dash is average shear strength; the value after the dash is average estimated percentage wood failure. Control values are the averages of 10 specimens; other values the averages of 5.

³No specimens remained for further tests.

Table 8.—Average results of wet¹ shear tests of three-ply, 3/16-inch yellow birch plywood, made with glues cured to various degrees, and alternately soaked in water at room temperature for 2 days and dried for 12 days at 80° F. and 30 percent relative humidity².

Glue		Period to exposure:	Estimated degree of cure of glue in percent								
Designation:	Type		30	40	50	60	70	80	90	95	100
		Months									
A	Alkaline phenol	0			369-7	425-6	490-28	608-63	618-96	626-87	676-100
		2			355-1	435-2	453-46	486-42	524-99	548-93	558-100
		4			391-19	448-15	456-70	533-56	564-82	566-79	521-100
		6			397-28	429-17	508-73	539-75	550-98	556-100	579-100
		12			396-12	438-20	459-94	498-94	526-97	513-98	536-99
		18			351-6	420-32	452-83	457-99	491-96	491-100	497-100
		24			324-5	380-26	470-78	488-96	503-99	475-100	500-100
		30			344-5	357-36	417-97	412-100	462-97	436-100	393-99
		36			389-26	355-17	386-100	433-100	467-100	386-100	438-100
B	Acid phenol	0					134-0	84-0	579-29	583-94	332-100
		2					0-0	0-0	505-34	538-82	332-100
		4					0-0	0-0	544-42	512-70	271-100
		6					0-0	0-0	510-33	509-82	321-100
		12					0-0	0-0	471-46	466-96	284-100
		18					0-0	0-0	465-72	468-98	263-100
		24					0-0	0-0	415-32	423-100	244-100
		30					0-0	0-0	370-58	338-100	225-100
		36					0-0	0-0	346-60	389-100	241-100
C	Alkaline phenol	0			309-0	389-8	574-97	559-95	598-100	596-100	726-100
		2			260-0	425-39	550-97	533-100	507-99	532-100	476-96
		4			321-0	437-41	533-99	520-98	476-100	512-100	536-100
		6			323-7	435-28	543-100	532-100	508-100	521-100	534-100
		12			344-17	418-53	517-99	515-100	487-100	497-100	464-100
		18			328-24	406-61	450-100	468-100	434-100	431-100	413-100
		24			334-37	373-84	472-100	454-99	461-100	441-100	388-100
		30			315-45	360-88	407-100	407-99	361-100	368-100	384-100
		36			329-54	367-90	421-100	413-100	430-100	453-100	393-100
D	Resorcinol	0			315-4	346-18	558-88	580-99	559-98	619-96	533-93
		2			474-93	498-97	504-99	540-99	510-96	511-99	549-100
		4			480-86	462-98	561-100	536-100	526-98	529-100	548-100
		6			503-99	486-95	496-100	516-100	482-100	517-100	528-100
		12			505-100	485-94	474-99	497-100	511-100	448-100	480-100
		18			406-98	467-97	450-100	481-100	427-100	427-100	401-100
		24			413-100	371-96	501-100	494-100	468-100	465-98	412-100
		30			380-100	384-100	401-100	426-100	397-100	432-100	383-100
		36			375-100	359-100	406-100	455-100	386-100	360-100	365-100
E	Melamine	0	475-83	588-100	504-47	502-88	431-34	599-95	609-99	631-100	524-96
		2	485-100	462-100	512-100	509-100	325-62	529-100	457-100	544-100	469-100
		4	527-100	545-100	520-100	445-100	299-42	469-100	468-100	550-100	453-100
		6	533-100	554-100	498-97	465-99	436-85	515-94	497-100	567-100	468-100
		12	415-100	486-100	447-91	458-100	381-43	484-98	500-100	501-100	444-97
		18	466-98	536-100	436-70	398-100	375-68	520-100	501-100	536-100	410-98
		24	406-100	417-100	401-90	354-100	334-70	420-100	352-100	474-100	374-100
		30	427-96	440-88	361-73	326-84	252-36	420-100	402-100	426-100	389-100
		36	384-86	372-99	361-94	301-98	253-48	383-100	377-100	411-96	370-97
F	Fortified urea	0					521-98	556-100	564-99	581-99	588-100
		2					495-100	483-100	506-100	494-100	478-100
		4					495-100	487-100	468-100	495-100	498-100
		6					470-100	489-100	502-100	499-100	516-100
		12					463-98	472-96	467-97	485-100	502-100
		18					419-100	494-100	481-100	451-100	433-100
		24					374-100	393-100	414-100	401-100	429-100
		30					368-100	370-97	401-98	397-100	399-99
		36					344-100	372-100	344-100	335-100	383-100

¹Specimens tested wet after soaking 2 days in water at room temperature.

²The value before the dash is average shear strength; the value after the dash is average estimated percentage wood failure. Control values are the averages of 10 specimens; other values the averages of 5.

Table 9.--Average results of shear tests of three-ply 3/16-inch yellow birch plywood, made with room-temperature-setting resorcinol glues cured to various degrees and exposed to 80° F. and 65 percent relative humidity¹

Glue Designation	Period of exposure Months	Approximate initial dry shear strength - pounds per square inch										over 450
		2150	2150	2350	2350	2150	2150	2350	2350	2150	2350	
Tested Dry ²												
G : Resorcinol	0	208-0	156-0	344-1	367-1	541-86	495-94	484-79	479-65	516-91	568-98	
	2	479-66	455-61	535-94	528-65	583-90	602-96	532-88	467-78	568-98	614-98	
	4	519-55	495-49	470-47	524-88	574-94	568-97	446-95	422-71	481-97	573-99	
	6	483-77	524-63	461-51	489-50	581-98	576-93	500-82	440-79	522-84	544-87	
	12	530-70	564-61	434-32	538-59	532-89	595-90	538-88	497-90	566-89	576-100	
	18	448-45	431-44	455-70	445-66	553-97	529-93	491-95	454-95	470-93	621-97	
	24	463-86	395-47	389-71	465-61	624-97	605-95	495-92	461-96	502-89	596-98	
	30	462-50	450-30	415-52	432-61	484-79	545-88	478-82	462-86	454-87	590-98	
	Tested Wet ³											
H : Resorcinol	0	159-0	164-1	353-3	450-45	555-94	177-5	229-4	447-48	477-89	468-93	
	2	376-38	506-49	459-77	499-84	576-78	353-51	375-65	421-76	488-93	474-95	
	4	447-44	431-63	571-92	513-96	572-87	339-47	405-53	485-97	448-95	493-92	
	6	390-45	437-51	518-77	490-99	522-83	360-68	430-83	483-98	461-97	428-89	
	12	477-40	430-37	545-82	471-97	531-57	373-53	423-77	517-97	457-98	459-84	
	18	377-38	412-29	459-77	455-99	500-73	338-72	399-69	456-97	436-99	432-90	
	24	332-8	370-4	414-84	415-91	477-99	338-83	408-52	469-100	469-98	441-80	
	30	320-0	406-43	460-87	433-96	453-76	362-67	425-56	470-94	497-95	459-87	

¹The value before the dash is average shear strength in pounds per square inch; the value after the dash is average wood failure in percent. Control values are averages of 10 specimens; other values the averages of five.

²Cured at 75° F.

³Cured at 120° F.

⁴Cured at 140° F.

⁵The specimens were at a moisture content of about 11 percent when tested.

⁶Specimens tested wet after soaking 2 days in water at room temperature.

Table 10.--Average results of shear tests of three-ply, 3/16-inch yellow birch plywood made with room-temperature-setting resorcinol glue cured to various degrees, and exposed to 158° F. and 20 percent relative humidity.

Glue		Period of exposure	Approximate initial dry shear strength - pounds per square inch									
Designation:	Type		2150	2150	2350	2350	over 4450	2150	2150	2350	2350	over 4450
		Months	Tested Dry 5									
G	Resorcinol:	0	208-0	156-0	344-1	367-1	541-86	495-94	484-79	479-65	516-91	568-98
		2	402-53	409-64	467-93	484-91	402-100	544-99	497-86	488-81	548-95	561-100
		4	488-92	460-79	421-81	488-72	436-99	552-97	478-94	444-83	494-96	595-99
		6	455-44	443-65	456-55	464-24	425-99	409-93	445-92	429-80	461-95	520-100
		12	443-59	393-25	379-18	457-79	303-97	468-94	414-87	385-91	462-92	512-100
		18	334-72	300-30	306-19	325-29	363-81	428-98	393-96	355-79	392-98	357-100
		24	319-54	335-7	266-29	319-0	297-91	380-100	382-95	334-71	391-97	464-99
		30	296-30	294-3	253-7	305-13	277-23	374-99	387-94	342-74	371-100	354-100
H	Resorcinol:	0	159-0	164-1	353-3	450-45	555-94	177-5	229-4	447-48	477-89	468-93
		2	298-45	428-39	344-76	429-92	477-100	337-39	410-20	491-97	547-96	462-94
		4	448-57	345-27	455-88	447-90	468-81	265-38	406-60	475-99	459-100	445-88
		6	311-12	357-16	409-59	418-93	444-92	254-24	344-55	469-84	444-94	488-72
		12	316-7	321-5	429-52	421-58	382-82	292-51	300-37	420-93	423-97	440-56
		18	241-7	235-19	273-49	329-93	284-88	254-34	299-57	295-99	296-94	343-89
		24	165-4	214-10	361-75	297-82	387-76	221-52	317-72	375-95	376-100	394-80
		30	187-2	205-10	288-51	302-51	286-72	277-33	370-50	374-98	391-100	406-83

Tested Dry²

Tested Wet⁶

¹The value before the dash is average shear strength in pounds per square inch; the value after the dash is average wood failure in percent. Control values are averages of 10 specimens; other values the average of five.

²Cured at 75° F.

³Cured at 120° F.

⁴Cured at 140° F.

⁵The specimens were at a moisture content of about 11 percent when tested.

⁶Specimens tested wet after soaking 2 days in water at room temperature.

Table 11.--Average results of wet¹ shear tests of three-ply, 3/16-inch yellow birch plywood, made with room-temperature-setting resorcinol glues cured to various degrees and soaked continuously in water at room temperature

Designation:	Glue Type	Period of exposure:	Approximate initial dry shear strength - pounds per square inch				
			² 150	³ 150	² 350	³ 350	⁴ over 450
		Months					
G	Resorcinol:	0	⁵ 495-94	⁵ 484-79	⁵ 479-65	⁵ 516-91	⁵ 568-98
		2	605-92	471-74	458-79	480-93	556-100
		4	485-89	461-89	425-84	462-83	598-100
		6	519-83	444-87	458-89	484-95	530-99
		12	466-85	486-90	454-97	478-87	497-100
		18	469-78	461-95	412-93	429-94	514-90
		24	421-78	432-95	392-96	390-100	491-98
		30	436-97	380-100	354-100	398-95	460-98
H	Resorcinol:	0	177-5	229-4	447-48	477-89	468-93
		2	227-24	401-56	418-84	437-97	456-93
		4	252-29	357-25	424-85	450-88	447-98
		6	220-21	351-17	431-67	384-83	457-81
		12	187-34	367-34	411-71	462-93	375-64
		18	282-46	268-41	420-99	383-97	404-88
		24	194-63	301-70	373-100	363-100	390-88
		30	185-55	273-66	375-98	351-98	333-100

¹Specimens were tested wet upon removal from the soaking tank.

²Cured at 75° F.

³Cured at 120° F.

⁴Cured at 140° F.

⁵The value before the dash is average shear strength in pounds per square inch; the value after the dash is average wood failure in percent. Control values are averages of 10 specimens; other values the averages of five.

Table 12.--Average results of shear tests of three-ply, 3/16-inch yellow birch plywood, made with room-temperature-setting resorcinol glues cured to various degrees, and alternately soaked in water at room temperature for 2 days and dried at 80° F. and 30 percent relative humidity for 12 days¹.

Designation	Glue	Period of exposure	Approximate initial dry shear strength - pounds per square inch									
			2150	2350	2350	2150	2150	2350	2350	2350	2350	Over 2450
		Months										
G	Resorcinol	0	208-0	156-0	344-1	367-1	495-94	484-79	479-65	516-91	568-98	
		2	549-96	577-74	539-55	595-85	559-95	507-95	464-74	518-95	519-100	
		4	573-95	571-85	500-52	557-73	553-90	479-74	438-81	498-93	582-100	
		6	530-95	513-57	427-44	481-56	477-90	439-87	434-72	461-98	521-100	
		12	528-79	533-63	416-36	486-63	519-98	477-94	414-82	470-95	559-90	
		18	332-63	414-52	354-36	419-78	486-96	435-96	431-95	390-97	472-100	
		24	366-61	463-69	380-35	442-67	477-99	468-91	396-92	424-100	460-100	
		30	328-47	357-38	351-21	381-42	478-99	453-91	379-90	445-96	460-99	
H	Resorcinol	0	159-0	164-1	353-3	450-45	177-5	229-4	447-48	447-89	468-93	
		2	197-3	308-31	384-74	554-97	243-24	355-25	426-94	463-93	408-95	
		4	308-15	316-5	484-97	474-93	201-44	332-15	435-96	413-72	432-92	
		6	262-5	400-30	467-75	488-83	255-25	356-29	416-100	421-94	420-95	
		12	311-14	360-44	431-71	454-81	335-73	382-67	447-99	437-92	478-72	
		18	318-30	372-33	368-85	418-90	300-66	352-62	420-94	416-99	498-96	
		24	276-23	366-19	427-76	367-90	273-46	243-61	356-100	361-94	374-82	
		30	214-11	219-8	336-74	349-85	240-41	299-55	409-93	375-93	377-65	

¹The value before the dash is average shear strength in pounds per square inch; the value after the dash is average wood failure in percent. Control values are averages of 10 specimens; other values the averages of five.

²Cured at 75° F.

³Cured at 120° F.

⁴Cured at 140° F.

⁵The specimens were at a moisture content of about 7 percent when tested.

⁶Specimens tested wet after soaking 2 days in water at room temperature.

Table 13.--Approximate degrees of cure estimated to be required by the different
glues to insure adequate joints in yellow birch plywood under con-
ditions shown¹

	Initial strength	Continuous exposure to: 80° F. and 65 percent relative humidity	Continuous exposure to: 158° F. and 20 percent relative humidity	Continuous soaking in water	Alternate soaking and drying
A	90 to 95 percent	50 percent	50 percent	70 percent	70 percent
B	95 to 100 percent	70 percent	70 percent	90 percent	95 to 100 percent
C	70 to 80 percent	50 percent	50 percent	60 percent	80 percent
D	70 to 80 percent	50 percent	70 percent	50 percent	70 percent
E	70 to 80 percent	30 percent	30 percent	40 percent	80 percent
F	70 to 80 percent	70 percent	----- ²	70 percent	80 percent
G	350 to 450 p.s.i.	450 p.s.i.	450 p.s.i.	150 p.s.i.	450 p.s.i.
H	350 to 450 p.s.i.	350 p.s.i.	450 p.s.i.	350 p.s.i.	450 p.s.i.

¹Percentages below indicate the minimum percentages of cure, based on solubility of glue films in water, or initial dry strengths required to produce joints which retain approximately 90 percent wood failure on yellow birch plywood specimens after 30 to 36 months of exposure under the conditions indicated.

²This glue was not sufficiently durable at any degree of cure in this exposure.