EFFECT OF CLOSED ASSEMBLY TIME ON JOINT STRENGTH IN GLUING WITH LOW-TEMPERATURE-SETTING PHENOL, RESORCINOL, AND MELAMINE GLUES

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EFFECT OF CLOSED ASSEMBLY TIME ON JOINT STRENGTH IN GLUING WITH LOW-TEMPERATURE-SETTING PHENOL, RESORCINOL, AND MELAMINE GLUES[1]

By

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Introduction

This report is part of an investigation being made at the Forest Products Laboratory to find suitable gluing techniques for low-temperature-setting phenol, resorcinol, and melamine glues. It covers work done to determine how various lengths of closed assembly time might affect the strength of joints between blocks when the temperatures at which the assembly is laid up and the pressures used in clamping the assembly are varied. The permissible assembly time may be considered as the period, between spreading the glue and applying the pressure, with which acceptable glue joints can be produced. Both minimum and maximum limits of assembly time affect joint strength. This experiment, however, was not set up to determine the maximum possible closed assembly time for each glue, but rather to determine whether the properties of the glue would permit assembly times as short as 3 minutes and as long as 2 hours, thus covering the range that is customarily required in practical gluing operations.

Twelve glues of the phenol, melamine, and resorcinol types were employed in this study and are listed in table 1.

The effect of assembly time varies with several factors other than the nature of the glue, including species of wood, moisture content of the wood, temperature of assembly, temperature of cure, and gluing pressure, but these variables were not all explored in this study.

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[1] This report is one of a series of progress reports prepared by the Forest Products Laboratory to aid the Nation's war program. Results here reported are preliminary and may be revised as additional data become available. This study was made with funds provided in part by the Army-Navy-Civil Committee on Aircraft Design Criteria and in part by the Bureau of Ships of the United States Navy.

Procedures

One species, hard maple, selected to be within the specific gravity range of 0.63 to 0.69 based on oven-dry weight and volume, was used.

Blocks were glued at approximately 12 percent moisture content. This moisture content is employed in many gluing operations and is within the range commonly used in aircraft assembly gluing.

Assembly temperatures of 70° and 90° F. were used with nine glues, and a temperature of 75° F. with three.

The curing time and temperature used for each glue were those found by other tests to effect a high degree of cure.

A pressure of 200 pounds per square inch was used with all 12 glues, and also a relatively low pressure of 50 pounds per square inch with 9 of them.

Hard maple boards were conditioned to approximately 12 percent moisture content, then sawed and surfaced to 3/4 by 2-1/2 by 12 inches, and glued together in stacks of 6 laminations. The glues were mixed in the proportions given in table 1. The gluing and assembling was done in a room held at 70°, 75°, or 90° F.

Glue was applied to the upper surface of the first lamination and to the under surface of the second lamination. The two spread surfaces immediately were laid in contact. After a measured time interval, glue was spread on the upper surface of the second lamination and on the under surface of a third lamination, and the two spread surfaces laid together as before. This procedure was followed until 6 laminations were assembled, then pressure was applied. Each glue line thus had a different assembly time, from a long period for the first glue line, to a short period for the last.

When an assembly temperature of 90° F. was employed, the glue was maintained at about 70° F. by a water jacket to prolong the working life, since it is probable that some of the glues would have been unusable after 120 minutes had the glue been allowed to reach 90° F. in the glue pot.

Pressure was applied to the assembly by pressure-equalizing-head clamps tightened to either 50 or 200 pounds per square inch pressure with a calibrated torque wrench. The clamped assembly was immediately placed in a temperature- and humidity-controlled kiln. After removal from the kiln, the blocks were conditioned 1 to 2 weeks. Moisture content was maintained at 10 to 12 percent throughout the curing and conditioning periods. Gluing details are included in table 2.

After conditioning, 4 step-type, block-joint specimens were cut from each block and, as 3 blocks were prepared at each assembly temperature for each pressure, 12 joint tests resulted for each assembly time, assembly temperature, and pressure condition. The specimens were tested by shearing to failure in a universal testing machine with the shearing head moving about 0.015 inch per minute.

Discussion of Results

Results of the shear tests are given in table 2. They are also plotted in figures 1, 2, 3, and 4 to show graphically the variations in strength and wood failure throughout the assembly-time range. Brief conclusions were drawn from the data on the effect of closed-assembly time on the performance of each of the several glues. In judging the effect of the variables of assembly time, assembly temperature, and pressure, both the shear strengths and the wood failures were considered. A combination of a decrease in strength and a reduction in wood failure were considered particularly significant in indicating an undesirable effect on joint quality.

Uniform and satisfactory results were obtained from 3- to 120-minute assembly times, inclusive, with Amberlite PR-75B, Cascophen LT-67, and Resinox 230[2] under the conditions of pressure and assembly temperature used in these tests. The variations shown by the data are probably due to nonuniformity of the wood.

With Durez 12533-34B, long assembly time appeared detrimental at the higher assembly temperature, particularly at the lower pressure.

Durez 12688 produced joints of good quality under all conditions up to and including 90-minute closed assembly, but the strengths fell off after an assembly period of 90 minutes.

Penacolite G-1131 gave reasonably strong joints over a wide range of conditions, but the strengths were inclined to be low at an assembly time of 3 minutes.

With Lauxite 252 an assembly time of 120 minutes was found to be too long and the experiment was repeated using shorter assembly intervals up to a maximum of 90 minutes. About 65 minutes was the longest closed-assembly time, under all the conditions of pressure and temperature employed, at which the joints met the 2,800-pound-per-square-inch requirement of current government specifications for maple block-shear strength.

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[2] This glue is no longer being marketed.

With Melmac 401, acceptable joint strengths were obtained at all assembly times when 200 pounds pressure was used, but joint strengths were lower than required by current specifications at 120-minute assembly time when 50 pounds pressure was used.

Using Resinox 840[2] at 3- to 90-minute assembly times, joints were obtained within the range of 2800 to 3300 pounds per square inch, but at 120-minute assembly time and 90° F. temperature the joints fell below specification standards although wood failures were fairly high throughout the assembly-time range.

A closed assembly time of 3 minutes at 75° F. gave unsatisfactory joints with Amberlite PR-245, but assembly times from 30 to 120 minutes produced joints meeting the specification requirement of 2800 pounds per square inch.

Cascophen RS-216 produced joints slightly below 2,800 pounds per square inch in strength with a closed assembly period of 3 minutes at 75° F. but joint strengths were higher than 2800 pounds per square inch with assembly times of 30 to 120 minutes.

Assembly times ranging from 3 to 90 minutes at 75° F. gave good results with Lauxite PF-90C, but the data indicate a decrease in joint quality if the assembly time is as long as 120 minutes under the conditions used.

Table 1.--Glues and proportions of ingredients used

Glue		Hardener	Ingredients in parts by weight			
Designation	Type		Resin	Hardener	Water	Miscellaneous
Amberlite PR-75B	Phenol	P-79	90	13.5		10, alcohol
Amberlite PR-245	Phenol	Q-108	100	3.5	152	
Cascophen LT-67	Phenol	M-18	100	8		
Cascophen RS-216	Resorcinol	FM-60	100	15		
Durez 12533-34B	Phenol	(Incorporated)	50(12533) 50(12534B)			10, walnut shell flour
Durez 12688	Resorcinol	12689	100	20		
Lauxite PF-900	Resorcinol	PF-90	100	17.5		
Lauxite 252	Melamine	252	100	12.5	55	
Melmac 401	Melamine	(Incorporated)	100		50	
Penacolite G-1131	Resorcinol	G-11313	100	20		
Resinox 230[1]	Phenol	230B	100	18		
Resinox 840[1]	Melamine	(Incorporated)	70		30	

[1]This glue is no longer being marketed.

Table 2.--Shear strength of hard maple step-type block-joint specimens as affected by assembly time, pressure, and temperature of assembly

Glue	Curing cycle	Gluing conditions				Shear test results	
		Assembly room temperature	Spread[1]	Assembly time closed	Pressure	Average shear strength[2]	Average wood failure[2]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		° F.	Gr. per sq. ft.	Minutes	Lb. per sq. in.	Lb. per sq. in.	Percent
Amberlite PR-75B (phenol)	180° F. for 24 hours	70	26	3	50	2,851	69
				30		2,930	45
				60		2,861	82
				90		2,992	73
				120		3,074	59
		70	29	3	200	2,817	80
				30		2,962	70
				60		2,783	57
				90		2,856	73
				120		2,861	42
		90	33	3	50	3,255	52
				30		3,341	55
				60		3,069	61
				90		3,065	45
				120		3,056	68
		90	34	3	200	3,253	59
				30		3,221	63
				60		3,298	75
				90		3,092	78
				120		3,171	73
Amberlite PR-245 (phenol)	180° F. for 24 hours	75	39	3	200	1,677	5
				30		2,857	84
				60		2,899	64
				90		2,935	84
				120		2,803	75
Cascophen LC-67 (phenol)	180° F. for 24 hours	70	32	3	50	2,942	47
				30		2,815	59
				60		2,888	43
				90		2,768	72
				120		2,702	74

(Continued)

Table 2.--Shear strength of hard maple step-type block-joint specimens as affected by assembly time, pressure, and temperature of assembly (continued)

Glue	Curing cycle	Gluing conditions				Shear test results	
		Assembly room temperature	Spread[1]	Assembly time closed	Pressure	Average shear strength[2]	Average wood failure[2]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		° F.	Gr. per sq. ft.	Minutes	Lb. per sq. in.	Lb. per sq. in.	Percent
Cascophen LF-67 (phenol)(Cont.)	180° F. for 24 hours	70	34	3	200	2,921	69
				30		2,890	50
				60		2,994	67
				90		3,068	58
				120		2,938	61
		90	30	3	50	2,984	68
				30		3,046	58
				60		3,118	76
				90		2,960	61
				120		3,128	77
		90	28	3	200	3,184	84
				30		3,105	82
				60		2,933	88
				90		2,925	81
				120		2,898	70
Cascophen RS-216 (resorcinol)	140° F. for 24 hours	75	33	3	200	2,729	48
				30		3,025	90
				60		2,970	86
				90		3,076	93
				120		3,141	88
Durez 12533-34B (phenol)	180° F. for 24 hours	70	44	3	50	3,177	56
				30		3,128	66
				60		3,054	65
				90		3,132	85
				120		2,788	71
		70	46	3	200	3,549	66
				30		3,251	88
				60		2,985	83
				90		2,968	79
				120		3,010	92

(Continued)

Table 2.--Shear strength of hard maple step-type block-joint specimens as affected by assembly time, pressure, and temperature of assembly (continued)

Glue	Curing cycle	Gluing conditions: Assembly room temperature	Gluing conditions: Spread[1]	Gluing conditions: Assembly time closed	Gluing conditions: Pressure	Shear test results: Average shear strength[2]	Shear test results: Average wood failure[2]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		° F.	Gr. per sq. ft.	Minutes	Lb. per sq. in.	Lb. per sq. in.	Percent
Durez 12533-34B (phenol)(cont.)	180° F. for 24 hours	90	46	3	50	3,190	57
				30		3,024	48
				60		2,714	42
				90		2,446	36
				120		2,459	34
		90	45	3	200	3,285	91
				30		3,080	84
				60		3,025	81
				90		2,992	73
				120		2,850	48
Durez 12688 (resorcinol)	140° F. for 24 hours	70	37	3	50	3,196	64
				30		3,248	76
				60		3,399	72
				90		3,166	65
				120		2,675	79
		70	37	3	200	3,030	88
				30		3,375	75
				60		3,303	73
				90		3,287	62
				120		2,962	73
		90	39	3	50	3,162	55
				30		3,270	68
				60		2,903	81
				90		2,891	77
				120		2,591	65
		90	38	3	200	3,085	71
				30		3,192	77
				60		3,246	66
				90		3,105	72
				120		2,712	68

(Continued)

Table 2.--Shear strength of hard maple step-type block-joint specimens as affected by assembly time, pressure, and temperature of assembly (continued)

Glue	Curing cycle	Gluing conditions: Assembly room temperature	Gluing conditions: Spread[1]	Gluing conditions: Assembly time closed	Gluing conditions: Pressure	Shear test results: Average shear strength[2]	Shear test results: Average wood failure[2]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		° F.	Gr. per sq. ft.	Minutes	Lb. per sq. in.	Lb. per sq. in.	Percent
Lauxite PF-900 (resorcinol)	140° F. for 24 hours	75	39	3	200	2,840	75
				30		3,002	75
				60		2,939	84
				90		2,837	71
				120		2,704	63
Lauxite 252 (melamine)	140° F. for 24 hours	70	35	3	50	2,892	77
				25		2,910	65
				45		2,901	70
				65		2,833	65
				90		2,609	53
		70	35	3	200	3,105	63
				25		3,015	53
				45		3,006	59
				65		2,858	55
				90		2,670	61
		90	41	3	50	2,825	28
				25		2,995	36
				45		3,176	54
				65		2,951	47
				90		2,568	35
		90	43	3	200	3,033	95
				25		3,045	93
				45		3,176	82
				65		2,870	55
				90		2,795	59
Melmac 401 (melamine)	180° F. for 24 hours	70	43	3	50	2,975	61
				30		2,953	61
				60		2,798	65
				90		2,733	64
				120		2,526	61

(Continued)

Table 2.--Shear strength of hard maple step-type block-joint specimens as affected by assembly time, pressure, and temperature of assembly (continued)

Glue	Curing cycle	Gluing conditions: Assembly room temperature	Gluing conditions: Spread[1]	Gluing conditions: Assembly time closed	Gluing conditions: Pressure	Shear test results: Average shear strength[2]	Shear test results: Average wood failure[2]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		° F.	Gr. per sq. ft.	Minutes	Lb. per sq. in.	Lb. per sq. in.	Percent
Melmac 401 (melamine) (cont.)	180° F. for 24 hours	70	44	3	200	3,282	95
				30		3,226	92
				60		3,073	91
				90		3,171	89
				120		2,900	84
		90	39	3	50	2,927	38
				30		2,970	74
				60		3,088	73
				90		2,889	72
				120		2,678	66
		90	39	3	200	3,296	84
				30		3,122	87
				60		3,185	96
				90		3,180	96
				120		3,153	97
Penacolite G-1131 (resorcinol)	140° F. for 24 hours	70	28	3	50	3,117	62
				30		3,219	78
				60		3,345	69
				90		3,366	87
				120		3,231	67
		70	30	3	200	2,590	55
				30		3,148	57
				60		3,063	70
				90		3,056	67
				120		3,013	58
		90	34	3	50	2,812	57
				30		2,970	63
				60		2,986	62
				90		2,911	74
				120		2,907	55

(Continued)

Table 2.--Shear strength of hard maple step-type block-joint specimens as affected by assembly time, pressure, and temperature of assembly (continued)

Glue	Curing cycle	Gluing conditions: Assembly room temperature	Gluing conditions: Spread[1]	Gluing conditions: Assembly time closed	Gluing conditions: Pressure	Shear test results: Average shear strength[2]	Shear test results: Average wood failure[2]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		° F.	Gr. per sq. ft.	Minutes	Lb. per sq. in.	Lb. per sq. in.	Percent
Penacolite G-1131 (resorcinol) (continued)	140° F. for 24 hours	90	36	3	200	2,695	47
				30		3,240	85
				60		3,144	85
				90		2,813	61
				120		2,776	55
Resinox 230[3] (phenol)	180° F. for 24 hours	70	36	3	50	2,850	38
				30		3,199	65
				60		3,102	70
				90		2,972	60
				120		2,839	75
		70	35	3	200	2,951	77
				30		2,828	71
				60		2,952	67
				90		2,994	72
				120		3,150	89
		90	27	3	50	2,872	50
				30		2,845	71
				60		2,954	62
				90		3,126	30
				120		2,872	41
		90	26	3	200	2,887	89
				30		3,078	70
				60		3,081	86
				90		3,067	85
				120		3,086	85
Resinox 840[3] (melamine)	180° F. for 24 hours	70	34	3	50	3,101	79
				30		2,953	66
				60		3,045	79
				90		2,896	85
				120		2,842	85

(Continued)

Table 2.--Shear strength of hard maple step-type block-joint specimens as affected by assembly time, pressure, and temperature of assembly (continued)

Glue	Curing cycle	Gluing conditions: Assembly room temperature	Gluing conditions: Spread[1]	Gluing conditions: Assembly time closed	Gluing conditions: Pressure	Shear test results: Average shear strength[2]	Shear test results: Average wood failure[2]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		° F.	Gr. per sq. ft.	Minutes	Lb.per sq.in.	Lb. per sq. in.	Percent
Resinox 840[3] (melamine) (continued)	180° F. for 24 hours	70	35	3	200	3,178	85
				30		3,281	95
				60		3,173	60
				90		2,826	47
				120		2,912	74
		90	35	3	50	3,221	69
				30		3,017	60
			-	60		3,006	68
				90		2,972	86
				120		2,768	74
		90	31	3	200	3,086	71
				30		3,094	71
				60		2,916	44
				90		2,891	77
				120		2,648	66

[1]Number of grams of wet glue per square foot of single glue line.

[2]Each value represents the average of 12 shear tests.

[3]This glue is no longer being marketed.

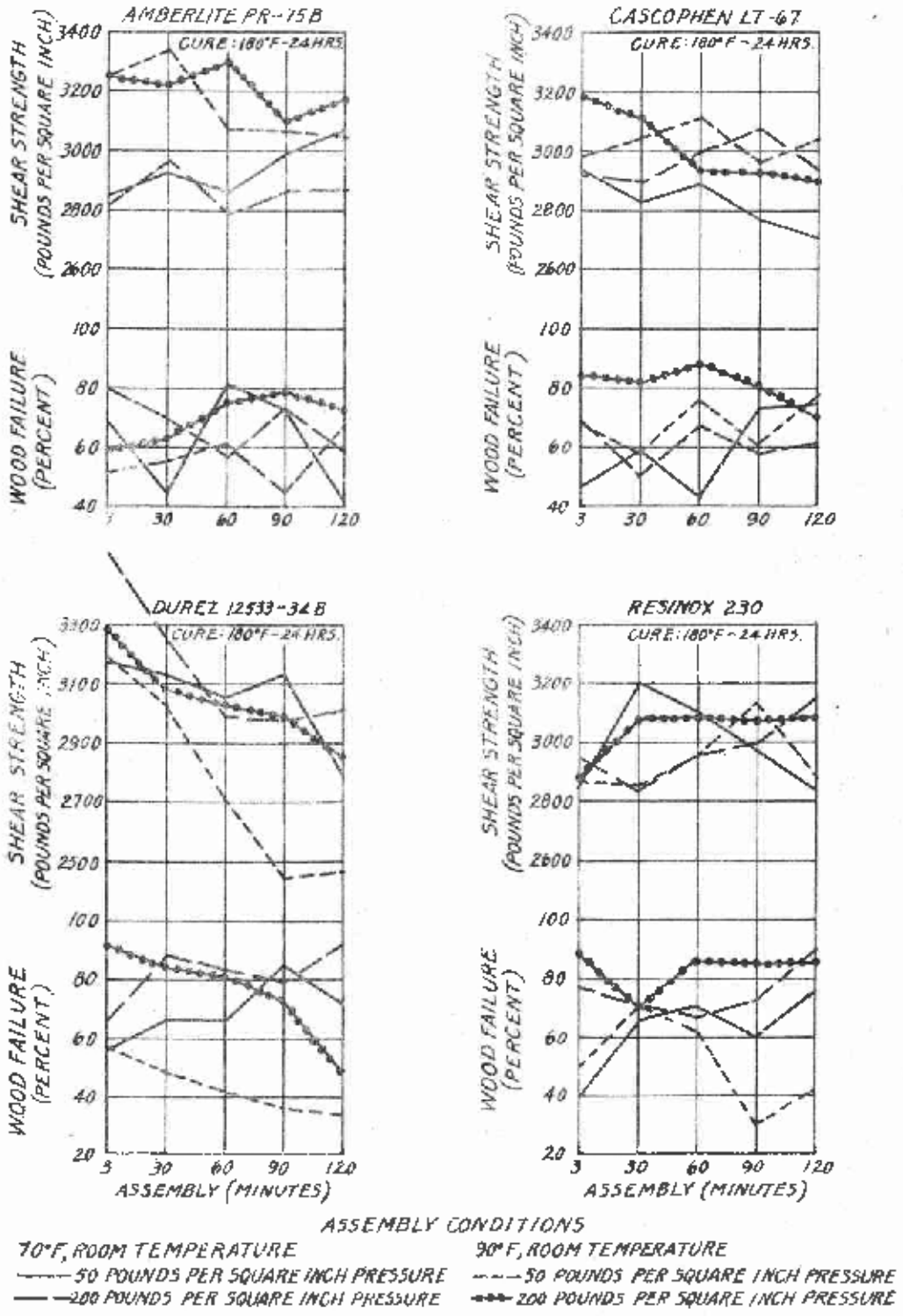

Figure 1.--Variation in average shear strengths and wood failure percentages obtained in hard maple block joints prepared with low-temperature phenolic glues at different closed assembly times.

Z M 55406 F

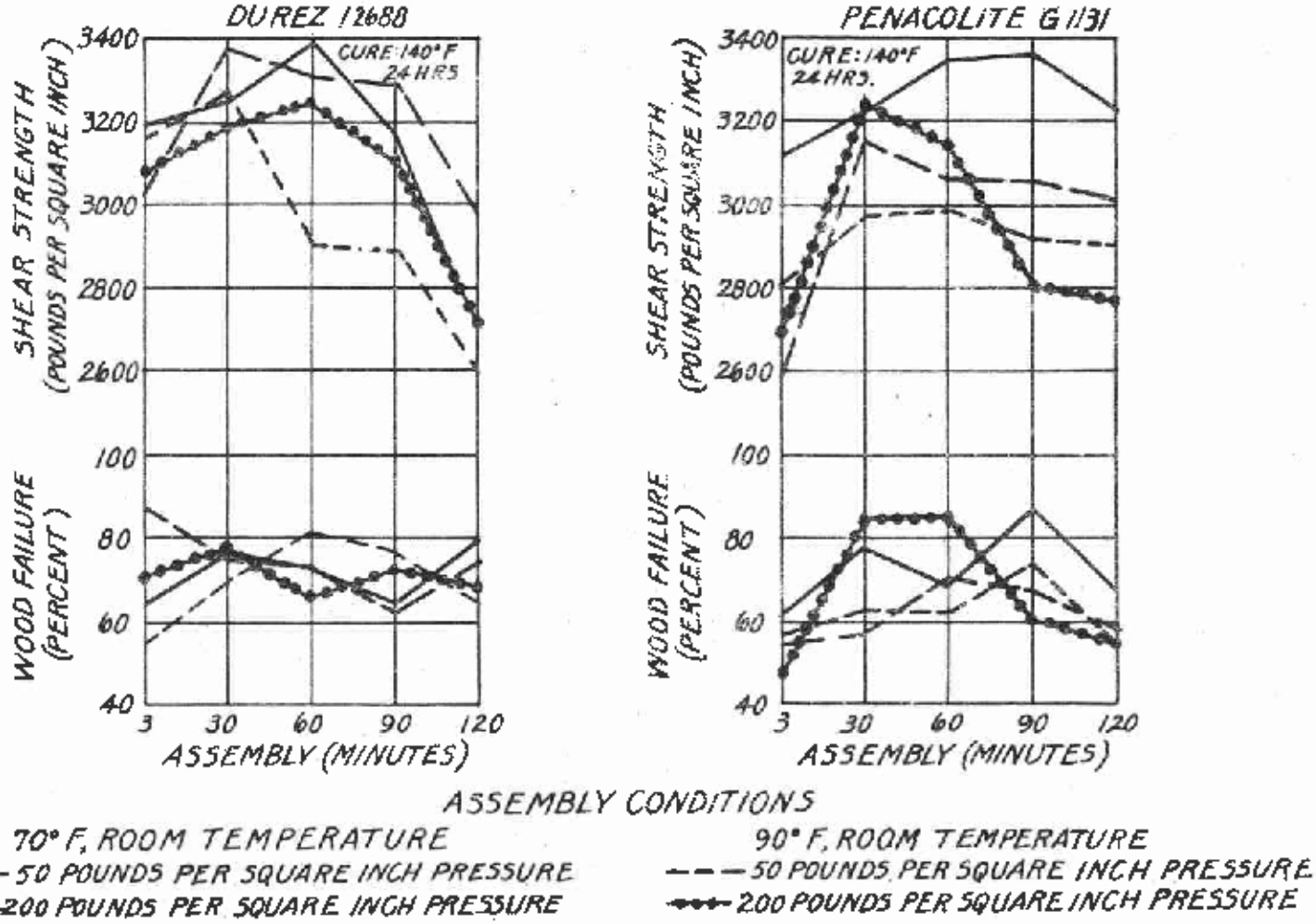

Figure 2.--Variations in average shear strengths and wood failure percentages obtained in hard maple block joints prepared with low-temperature resorcinol glues at different closed assembly times.

Z X 55406 F

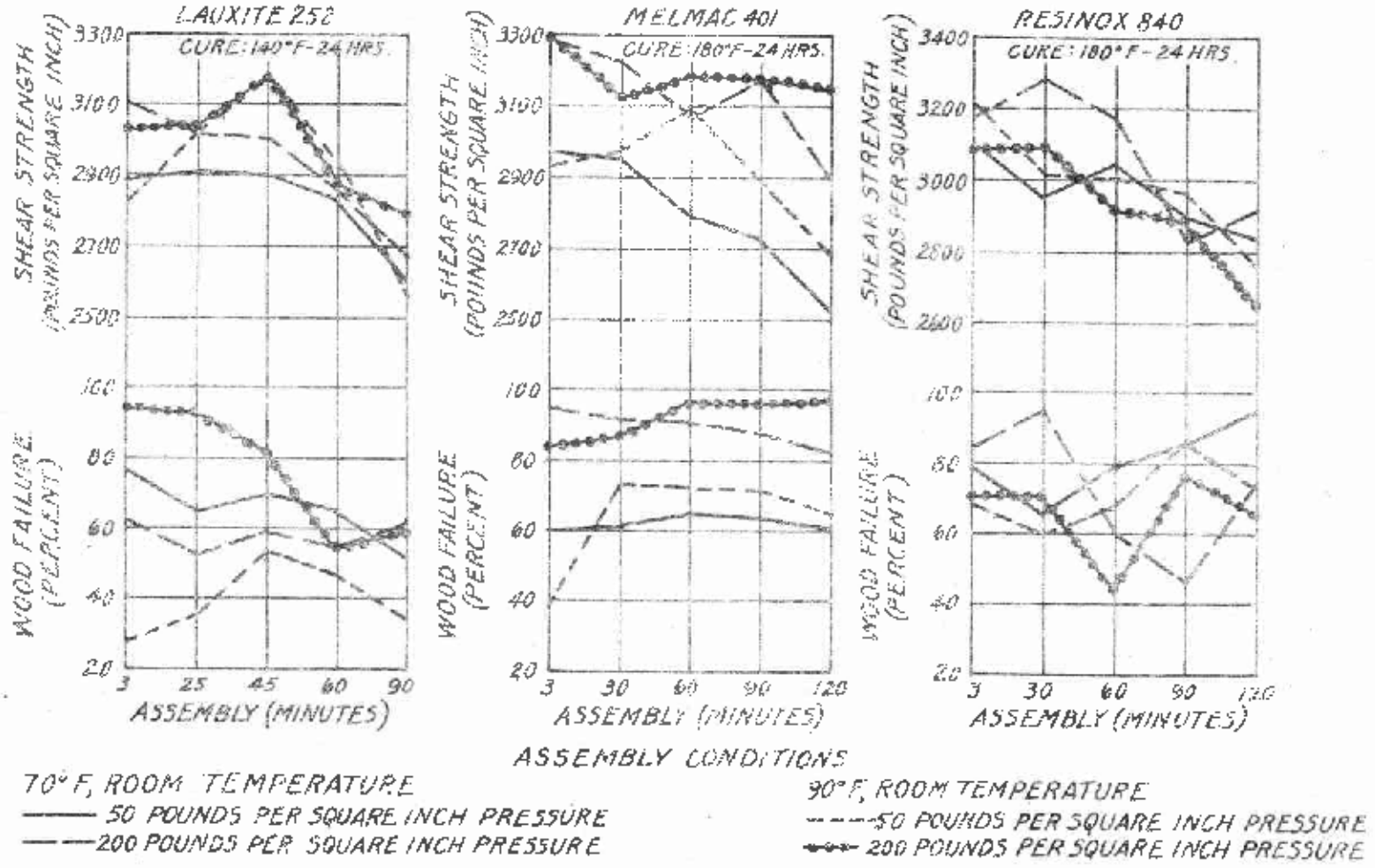

Figure 3.--Variations in average shear strengths and wood failure percentages obtained in hard maple block joints prepared with low-temperature melamine glues at different closed assembly times.

Z M 55151 F

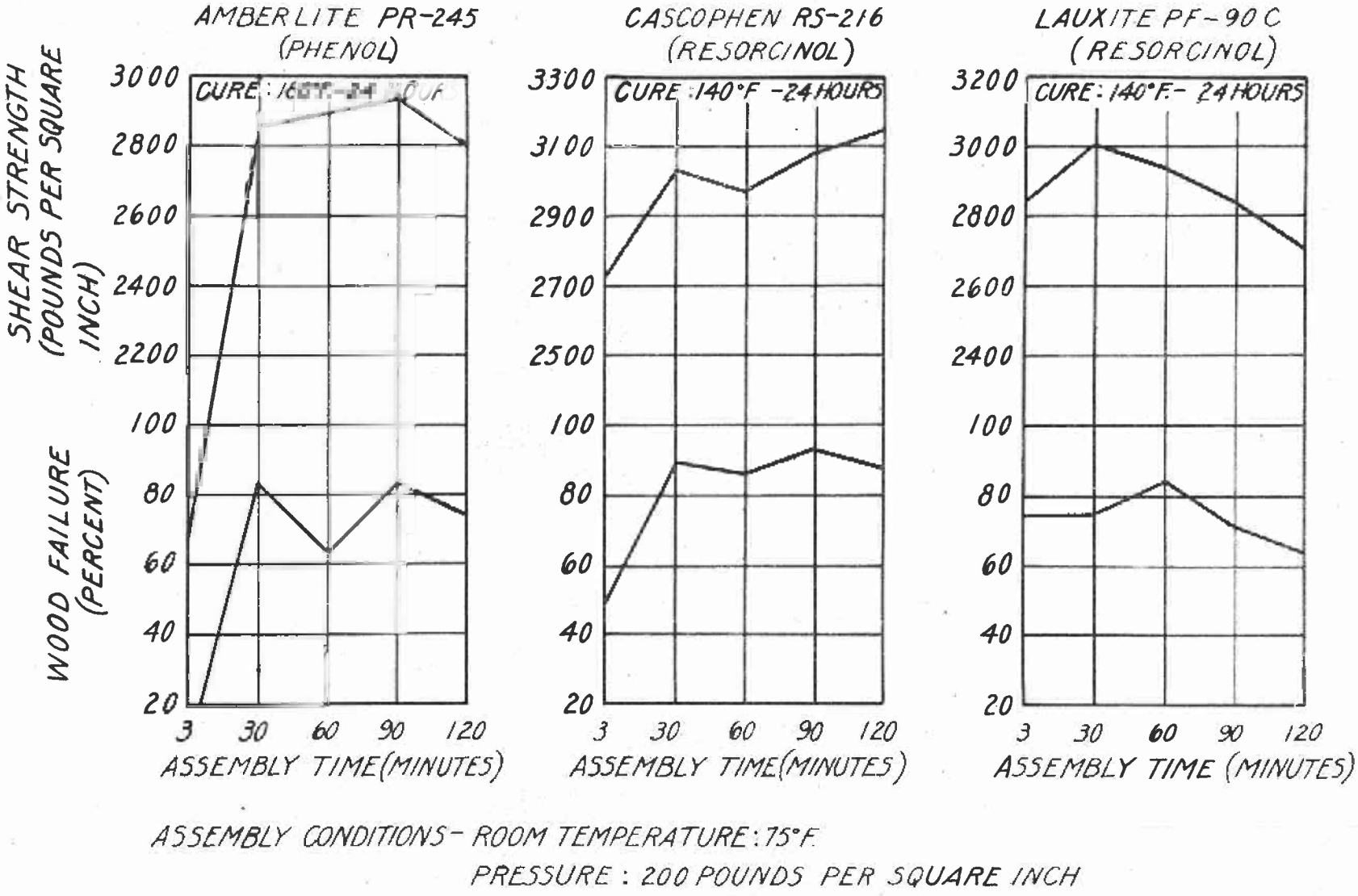

Figure 4.--Variations in average shear strengths and wood failure percentages obtained in hard maple block joints prepared with three low-temperature-setting glues at different closed assembly times.

Z M 61174 F