FOCUS ARTICLE

PERFORMANCE AND DURABILITY OF FINISHES ON PREVIOUSLY COATED CCA-TREATED WOOD

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ABSTRACT

Wood treated with chromated copper arsenate (CCA) preservative is used extensively in many architectural applications. In this study, untreated and CCA-treated southern pine and hem-fir boards that had been finished with several finishes and then weathered for 2 years at 45 degrees facing south were cleaned, refinished, and exposed to the weather again. After exposure for an additional 2 years at 45 degrees Facing south in Wisconsin and Mississippi, the durability of the finishes on weathered and refinished specimens was similar to that of the initial finish durability. The CCA treatment was shown to have a positive effect on the perfomlance and durability of many finishes in the study. Little difference in finish durability was noted between 0.25 and 0.40 pcf CCA retention levels. Coating perfommance was generally better on CCA-treated hem-fir than on treated southern pine, regardless of CCA treatment levels. Finish failures occurred more rapidly in Mississippi than in Wisconsin, particularly surface discoloration. Within the coating groups, the overall durability and appearance were reflected by the following order: fully pigmented (film-forming paints and stains) > lightly pigmented (semitransparent stains) > unpigmented (transparent water repellents and water-repellent preservatives). This study demonstrated that CCA-treated wood is compatible with a variety of surface finishes and that the effects of the treatment enhance the performance life of those finishes, even after cleaning and refinishing.

The objective of the work reported here was to evaluate the performance of a variety of surface finishes applied over previously finished and exposed wood that was either untreated or treated with chromated copper arsenate (CCA). This information is important because wood pressure treated with CCA is widely used in architectural projects, such as decks, walk ways, gazebos, marine structures, and retaining walls. This wood is subjected to the damaging effects of weathering (ultraviolet (UV) light and water wetting), and most preservative-treated-wood manufacturers recommend to end users that CCA-treated wood be protected with surface finishes.

Until the first paper in this series (13) and a second paper on the practical aspects of surface finishes and treatments for CCA-treated wood (12) were written, little published information was available on the performance and durability of surface finishes on CCA-treated wood. No information was available on the refinishing or maintenance of CCA-treated wood. This lack of information led to some confusion among preservative-treated-wood manufacturers, coating manufacturers, painters, carpenters, architects, builders, and consumers. This confusion also led to a number of misconceptions about the effects of CCA treatment on coating performance, and many erroneous recommendations were made concerning the coating and protecting of CCA-treated wood.

In previous laboratory studies, it's been shown that the application ofaqueous solutions of hexavalent chromium (e.g., chromium trioxide) to wood surfaces had an inhibiting effect on the outdoor weathering process and enhanced the life of surface finishes applied over the treated wood (2,6,7,14). Studies have demonstrated that reactions between hexavalent chromium and wood lead to enhanced surface stability find protection against weathering and UV light (5,8). Because the widely used preservative treatment CCA-Type C consists of approximately 47 percent chromium trioxide (11), similar resistance to weathering and UV light degradation was proposed as a result of the chromium-wood reactions in CCA-treated lumber (9). This thesis was confirmed when we demonstrated the improved perfomlance of many finishes applied over CCA-treated wood (13). In this study, several commercially avail-

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TABLE 1. — SI conversion factors.

English unit	Conversion factor	SI unit
Foot (ft.)	*0.3048*	meter (m)
Inch (in.)	*25.4*	millimeter (mm)
Pound per cubic foot (pcf) (weight)	1.6	kilogram per cubic meter (kg/m^3)

TABLE 3. — Finishes for CCA refinishing study.

Finish number	Description
1	Control (no finish)
2	Commercial water repellent for wood containing petroleum distillates
3	Commercial water repellent oil stabilizer for CCA pressure-treated wood containing petroleum distillates
4	Commercial water-repellent wood preservative; active ingredient, 3-iodo- 2-propynyl butyl carbamate 0.5 percent
5	Commercial waterborne water-repellent wood preservative for treated and untreated wood
6	Commercial waterborne water repellent for stabilizing new exterior wood
7	Commercial semitransparent oil-based natural stain finish; manufactured according to reference (3)
8	Commercial waterborne deck stain for treated wood
9	Commercial semitransparent linseed oil-based stain and wood preservative; active ingredients: Bis(tributyltin) Oxide 0.50 percent. N-[(trichloromethyl)thio] phthalimide 0.50 percent
10	Commercial semitransparent alkyd resin (oil-based) stain for pressure-treated wood containing a water repellent and a mildewcide
11	Commercial semitransparent waterborne wood stain specially formulated for pressure-treated wood with 4.5 percent pigment and a water repellent
12	Commercial translucent varnish stain containing petroleum distillate solvents, transparent iron oxides, and 0.50 percent bis(tributyltin) oxide
13	Commercial semitransparent waterborne desk stain for treated wood with water repellent
14	Commercial heavy bodied (solid-color) acrylic latex exterior stain with 20.5 percent pigment
15	Commercial acrylic latex flat house and trim paint
16	Commercial acrylic latex flat house and trim paint

able transparent, translucent, and pigmented coatings products were applied to untreated and CCA- treated boards of two wood species. These finished boards were then exposed to exterior weathering at sites in Wisconsin and Mississippi and evaluated for durability and appearance. In general, finish performance on CCA-treated wood was better or equal to that on untreated wood of the same species.

MATERIALS AND METHODS

Residual specimens from the first study (13) were cleaned, refinished, exposed outdoors for an additional 2 years, and then evaluated. Details of the original exposure study and the finishes used are summarized in the first report of this work. The finished test boards from the first study had been exposed at a 45-degree angle facing south for 2 years before being cleaned and refinished. Exposure sites were at Madison, Wis., and Saucier, Miss.

WOOD SPECIES AND TREATMENT LEVELS

The two woods used in this study were flat-grained S4S southern pine and hem-fir sapwood. These species are commonly treated with CCA and often utilized for outdoor architectural projects. The southen pine was clear and the hem-fir had a minimum number of tight knots. Commercially treated boards (nominally l-in. by 6-in. by 8-ft.) with specified CCA treatment levels of 0.25 and 0.40 pcf were obtained (Table

TABLE 2. — Characteristics of finishes and pretreatments used for refinishing CCA-treated wood.

Finish number	Finish type or pretreatment	Color	Nonvolatile content	Weight	Original finish	Finish condition	original finish remaining
			(%)	(lb./gal.)[a]			(%)
1	None (control)	--	--	--	None (control)	--	--
2	Water repellent	Transparent	8.8	8.4	Water repellent	Poor	0
3	Water repellent	Transparent	14.0	7.0	Water repellent	Poor	0
4	Water-repellent preservative	Transparent	96.1	7.1	Water-repellent preservative	Poor	0
5	Water-repellent preservative	Transparent	8.5	8.4	Water-repellent preservative	Poor	0
6	Water repellent	Transparent	4.0	8.4	Water repellent	Poor	0
7	Semitransparent oil-based stain	Brown	76.4	7.7	Semitransparent oil-based stain	Good	65
8	Waterborne deck stain, semitransparent	Brown	24.6	8.9	Solid-color oil-based stain	Good	75
9	Semitransparent oil-based stain	Red-brown	26.2	8.8	Semitransparent oil-based stain	Poor	20
10	Semitransparent oil-based stain	Brown	26.2	7.4	Semitransparent oil-based stain	Good	60
11	Waterborne deck stain, semitransparent	Red-brown	22.3	8.7	Waterborne deck stain, semitransparent	Fair	40
12	Varnish stain	Transparent	41.9	7.4	Varnish stain	Good	80
13	Waterborne deck stain, semitransparent	Gray	18.1	8.6	Semitransparent oil-based stain	Fair	40
14	Solid-color acrylic latex stain	Tan	38.7	10.0	Solid-color acrylic latex stain	Good	80
15	Acrylic latex topcoat paint	White	51.2	9.7	Acrylic latex topcoat paint	Very good	95
16	Acrylic latex topcoat paint	White	59.5	12.2	Acrylic latex topcoat paint	Very good	95

[a] 1 lb./gal. = 1.2 kg/m^3.

TABLE 4. — Spreading rates for finishes applied to CCA-treated wood.

Finish number	Spreading rate (ft.²/gal.)[a]					
	Southern pine			Hem-fir		
	0	0.25	0.40	0	0.25	0.40
2	210	240	315	225	300	415
3	200	210	285	235	355	380
4	135	170	195	230	240	385
5	250	305	285	285	365	450
6	175	185	210	265	250	300
7	260	395	350	310	480	535
8	265	375	325	325	320	265
9	210	240	245	220	260	280
10	210	280	240	335	330	355
11	205	320	280	290	260	275
12	1,270	1,405	1,270	1,270	1,405	1,230
13	215	245	265	310	210	225
14	225	280	250	305	245	265
15	1,425	1,350	1,005	1,385	1,195	1,425
16	1,085	890	970	1,065	765	985

[a] All finishes were field-applied as one coat. 1 ft.² = 0.0929 m²; 1 gal. = 3.785 l; values are for 0, 0.25, and 0.40 pcf CCA-treatment levels.

TABLE 5. — Geographic and climatic data comparison.

	Madison, Wis.	Saucier, Miss.
Latitude, (degrees north)	43	30
Elevation above sea level (m)	265	69
Average daytime temperature (°C)		
In winter	-8.2	10.1
In summer	21.5	27.4
Yearly average temperature (°C)	7.4	19.6
Yearly precipitation (mm)	780	1803
Duration of sunshine (hr./yr.)	2,100	3,900

TABLE 6. — Evaluation methods and inspection criteria.

Evaluation	Method[a]
Nonvolatile content	ASTM D 2369-87
Finish	
Flaking	ASTM D 772-86
Cracking	ASTM D 661-86
Erosion	ASTM D 662-86
Discoloration	Subjective visual assessment similar to ASTM D 3274-86 (mildew)
Substrate	
Cracking	Similar to ASTM D 661-86
Checking	Similar to ASTM D 66-87
General appearance	Subjective visual assessment
Water repellency	Subjective visual assessment after water was splashed on the surface

[a] All evaluations used a 10 (perfect) to 1 (total failure) scale. A value of 5 indicates the need for refinishing without major surface preparation.

1 shows metric conversions). Untreated wood was used as a control for comparison purposes.

FINISHES

Commercially available finishes for refinishing CCA-treated boards were chosen to represent products commonly used to coat previously coated untreated wood and preservative-treated wood. Finish physical properties are summarized in Table 2 along with information on the previous finishes used and the condition of the test panels before refinishing. A general description of finish composition is given in Table 3. Some finishes were identical to those used in the first exposure study, while others represented newer finishes that were of the same type as the original finish but formulated to comply with volatile organic compound (VOC) requirements (10). The refinishing systems used included clear water repellents, water-repellent preservatives, semitransparent stains, and film-forming solid-color stains and paints. Coatings were both waterborne and solvent borne. All coatings were applied as one coat over the previously finished, weathered, and cleaned surfaces.

SAMPLE PREPARATION

The original l-inch by 6-inch by 8-foot boards had been cut into two 4-foot lengths. One 4-foot section from each board was tested In Wisconsin and the other in Mississippi. Each 4-foot board had been divided into 8-inch sections by applying strips of aluminum pigmented varnish so that each board had five 8-inch sections with 4 inches on each end. The back, sides, and 4-inch end sections of each board were left unfinished. The original finishes had been applied by brush to the front and edge faces of the boards following manufacturer's recommendations under ambient laboratory conditions while the boards were in a horizontal position. After 2 years of exposure, all surfaces were cleaned with a commercial wood clearer containing sodium peroxydicarbonatc, rinsed with water, allowed to dry, and refinished. Cleaning and refinishing were done outdoors on warm, sunny days. The surface coverage, or spreading rate for each product, was calculated by weighing the amount of finish applied to the surface (Table 4). All finishes were applied as one coat over the old cleaned surface.

EXPOSURE CONDITIONS

Exposure of the test boards was continued at 45 degrees facing south to ensure maximum sun exposure. This accelerates the weathering process compared with that of a typical vertical exposure by a time factor from 1-1/2 to 2-1/2 (4). Both test series consisted of an uncoated control plus 15 finishes on 2 wood species at 3 retention levels of CCA: 0 (i.e., untreated). 0.25, and 0.40 pcf. Geographic and climatic data for the two exposure sites arc given in Table 5.

FINISH PERFORMANCE RATINGS

Several criteria were used to determine the performance ratings of the various pretreatment/finish systems on the wood specimens (Table 6). Most evaluation methods were based on American Society for Testing and Materials (ASTM) standards (1). These standards use pictorial standards of coating defects compiled by the Federation of Societies for Coatings Tcchnol-

TABLE 7. — Performance of transparent water repellents and water-repellent preservatives on CCA-treated wood after 6 months of outdoor exposure at 45 degrees south.

Finish number	Rating[a]											
	Discoloration			Substrate checking/cracking			Water repellency			General appearance		
	0	0.25	0.40	0	0.25	0.40	0	0.25	0.40	0	0.25	0.40
Southern pine (Wisconsin)												
2	4.7	5.3	4.3	4.0	4.7	5.7	6.0	7.0	7.0	4.7	5.3	4.3
3	3.3	4.0	4.0	4.7	5.0	5.3	10.0	10.0	10.0	3.3	4.0	4.0
4	4.7	6.0	5.0	5.0	4.3	5.7	8.7	7.7	8.0	4.7	5.7	5.0
5	5.3	4.3	4.3	5.0	5.3	5.0	9.3	10.0	10.0	5.3	4.3	4.3
6	2.7	4.7	4.0	4.0	5.3	3.7	1.0	1.0	1.0	2.7	4.7	4.0
Southern pine (Mississippi)												
2	1.7	7.3	7.7	4.3	6.0	4.7	1.0	5.0	5.0	1.7	7.3	7.7
3	3.3	4.7	5.7	4.0	6.0	4.3	10.0	10.0	10.0	3.3	4.7	5.7
4	5.7	8.0	8.0	3.0	6.3	4.7	8.0	8.0	8.0	5.7	8.0	8.0
5	4.0	7.3	6.0	3.7	5.7	3.7	10.0	10.0	10.0	4.0	7.3	6.0
6	1.0	5.7	8.0	3.0	4.7	4.0	1.0	1.0	1.0	1.0	5.7	8.0
Hem-fir (Wisconsin)												
2	3.3	5.3	5.0	2.7	4.0	4.7	8.7	10.0	10.0	3.3	5.3	5.0
3	2.3	5.7	5.7	2.7	4.0	5.3	10.0	10.0	10.0	2.3	5.7	5.7
4	2.0	4.3	5.7	3.0	4.0	5.3	10.0	10.0	10.0	2.0	4.3	5.7
5	2.3	4.0	4.7	3.0	3.7	5.3	10.0	1.0	10.0	2.3	4.0	4.7
6	2.7	4.3	4.0	2.7	2.3	4.0	1.0	3.7	1.0	2.7	3.7	4.0
Hem-fir (Mississippi)												
2	4.3	7.7	7.0	3.7	4.0	2.3	1.0	5.0	5.0	4.3	7.7	7.0
3	4.0	6.3	6.3	3.7	3.7	2.3	10.0	10.0	10.0	4.0	6.3	6.3
4	6.0	8.0	7.3	3.7	4.0	2.3	8.0	8.7	8.0	6.0	8.0	7.3
5	3.0	7.0	6.3	3.7	3.7	2.3	10.0	10.0	10.0	3.0	7.0	6.3
6	1.0	7.7	7.3	3.7	3.0	2.3	1.0	1.0	1.0	1.0	7.7	7.3

[a] The rating used a scale of 10 (perfect) to 1 (complete failure). A value of 5 indicates the need for refinishing without major surface preparation. 0, 0.25, and 0.40 pcf are CCA treatment levels.

ogy. The evaluations were based on finish performance and appearance. The 10 to 1 rating scale was used for mildew and general appearance of transparent finishes; erosion and general appearance of semitransparent finishes; and flaking, cracking, and general appearance of solid-color stains and paints. A 10 value represents the original condition of the finish; a 1 value represents total failure (i.e., surface is covered with mildew; finish is completely eroded; paint is completely cracked); a 5 value represents the overall condition at which refinishing would be required but without extensive preparation of the substrate or finish surface.

Because of the visual effect, mildew and discoloration are good indicators of clear finish performance. Solid-color stain and paint performance are best evaluated for flaking and cracking because these properties reflect the most damaging visual effect to performance. A general appearance rating (subjective visual assessment) was also used as a final overall criterion for all finishes. The general rating of the finish system is often a good indicator of overall finish durability because this rating is based on an average of the various elements of mildew, finish performance, and general appearance of the system.

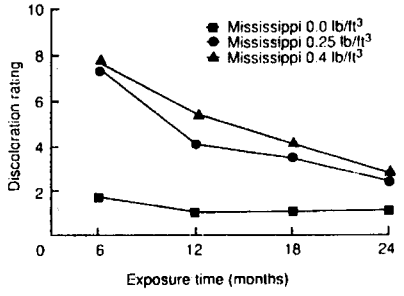

Figure 1. — Discoloration rating for transparent water repellent (finish 2) on southern pine in Mississippi during 24 months of exposure.

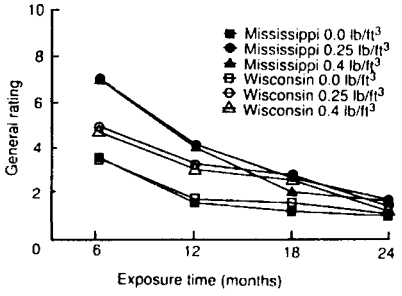

Figure 2.— Average general rating for all transparent finishes (finishes 2 to 6) on southern pine and hem-fir (average) at two exposure sites during 24 months of exposure.

Completely objective rating observations are difficult. For consistency, observations were made by the same person on each occasion, and color transparencies were used to compare results from year to year.

RESULTS AND DISCUSSION

The following results from outdoor exposure studies illustrate the performance of a range of commercially available and laboratory-prepared pretreatments and finishes on previously finished and weathered CCA-treated southern pine and hem-fir boards. All test specimens were evaluated at the two exposure sites at 6-month intervals for 2 years. For evaluation purposes, the coatings were grouped into three categories: 1) transparent water repellents and water-repellent preservatives; 2) semitransparent stains; and 3) film-forming finishes (solid-color stains and paints).

TRANSPARENT FINISHES

Transparent finishes (finishes 2 to 6) were applied to specimens previously coated with similar finishes. In all cases, the old finishes had completely weathered away and there was no finish remaining after cleaning and before refinishing **(Table 2).** After refinishing, transparent finish performance declined fairly quickly after 6 months of exposure **(Table 7).** These transparent water repellents and water-repellent preservatives generally do not have effective, long-lasting UV-blocking pigments; they had the lowest durability of the three finish groups. These transparent finishes became discolored fairly quickly. This discoloration increase is illustrated for the water repellent finish in Mississippi in **Figure 1** (finish 2). Even with the decline in the discoloration rating with time, transparent finish performance on the treated wood was better than on the untreated wood.

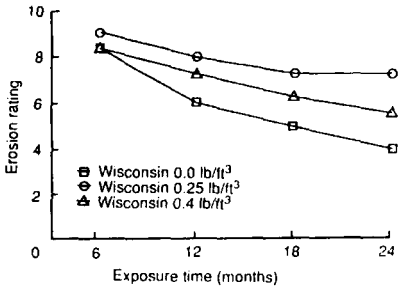

Figure 3. — Erosion rating for waterborne deck stain (finish 8) on southern pine in Wisconsin during 24 months of exposure.

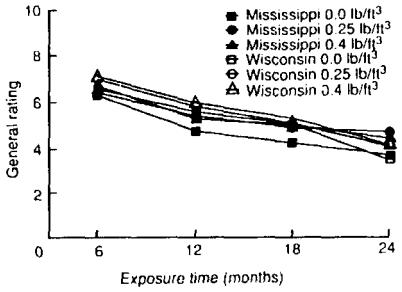

Figure 4. — Average general rating for all semitransparent finishes (finishes 7 to 11, and 13) on southern pine and hem-fir (average) at two exposure sites during 24 months of exposure.

This same trend was observed when the general rating results of five transparent finishes (finishes 2 to 6) were grouped and averaged **(Fig. 2).** The general rating for transparent finishes is primarily influenced by discoloration, most often by mildew growth. Mildew growth was far more pronounced on the coatings applied to the untreated wood than to the treated wood. After 2 years, all transparent products had failed on the untreated wood and most were close to failure even on CCA-treated boards. Some finishes still exhibited surface water repellency after 2 years of exposure in Mississippi. Transparent finish performance was worse in Wisconsin than in Mississippi. The primary reason for this is the greater amount of sunlight the finishes receive in Wisconsin compared with Mississippi. The UV light in sunlight can photochemically degrade

TABLE 8. — Performance of semitransparent stains on CCA-treated wood after 6 months of outdoor exposure at 45 degrees south.

Finish number	Rating[a]											
	Discoloration			Substrate checking/cracking			Finish erosion			General appearance		
	0	0.25	0.40	0	0.25	0.40	0	0.25	0.40	0	0.25	0.40
Southern pine (Wisconsin)												
7	8.0	8.0	8.7	4.3	7.7	6.3	8.0	8.0	8.7	7.3	8.0	8.0
8	5.3	8.0	8.0	4.0	7.0	5.0	8.3	9.0	8.3	4.7	7.7	7.3
9	6.0	5.3	6.0	4.3	6.7	5.0	7.0	8.0	7.3	5.3	5.3	5.7
10	4.0	5.3	5.7	4.7	6.3	6.0	4.3	5.0	6.0	4.0	5.3	5.7
11	8.0	7.0	7.7	3.7	6.0	5.0	8.0	8.0	7.7	6.7	7.0	7.7
13	7.0	6.7	6.7	5.0	7.0	5.0	8.0	7.3	7.3	6.0	7.3	6.3
Southern pine (Mississippi)												
7	7.0	8.0	7.7	3.3	6.3	3.7	7.3	8.3	7.7	6.7	8.0	7.3
8	7.0	8.3	8.0	3.7	5.3	3.3	7.3	8.3	8.0	7.0	8.3	7.0
9	3.0	2.7	2.3	3.7	4.3	3.3	3.7	2.7	2.0	3.0	2.7	2.3
10	7.3	8.0	7.3	3.3	4.7	3.0	7.7	8.0	7.3	7.3	8.0	7.3
11	6.0	5.3	7.0	3.7	4.7	3.0	7.3	5.7	6.7	6.0	5.3	6.7
13	7.7	8.3	8.7	4.0	5.3	4.7	8.3	8.0	8.3	7.7	8.0	8.3
Hem-fir (Wisconsin)												
7	7.0	9.0	9.0	6.3	6.0	5.3	8.7	9.0	9.0	7.0	9.0	8.3
8	7.3	7.0	7.0	6.3	3.7	4.0	9.3	9.0	9.0	7.3	6.0	7.0
9	3.7	4.0	5.0	5.3	4.0	5.3	5.3	8.0	7.0	4.0	5.7	5.0
10	6.3	7.3	7.0	6.0	3.7	4.7	6.7	7.3	6.7	6.3	7.3	7.0
11	7.3	9.0	8.7	5.3	3.7	4.0	8.3	9.0	8.7	7.3	7.7	8.0
13	7.7	4.0	4.7	7.3	4.7	5.0	7.7	4.7	5.7	7.7	4.0	4.7
Hem-fir (Mississippi)												
7	5.0	5.0	6.3	4.0	4.0	3.0	6.0	6.0	7.3	5.0	5.0	6.0
8	5.7	5.7	6.3	4.7	4.7	2.7	8.3	8.3	7.7	5.7	5.7	6.3
9	3.3	3.3	3.7	3.7	3.7	2.3	5.0	5.0	4.3	3.3	3.3	3.7
10	7.3	7.3	8.0	4.3	4.3	2.3	8.0	8.0	8.0	7.3	7.3	7.0
11	7.0	7.0	8.0	3.7	3.7	2.3	8.0	8.0	7.7	7.0	7.0	7.0
13	7.3	7.0	8.0	6.7	4.7	4.3	8.3	7.3	8.0	7.3	6.7	7.3

[a] The rating used a scale of 10 (perfect) to 1 (complete failure). A value of 5 indicates the need for refinishing without major surface preparation. 0, 0.25, and 0.40 pcf are CCA treatment levels.

TABLE 9. — Performance of semitransparent stains on CCA-treated wood after 18 months of outdoor exposure at 45 degrees south.

Finish number	Rating[a]											
	Discoloration			Substrate checking/cracking			Finish erosion			General appearance		
	0	0.25	0.40	0	0.25	0.40	0	0.25	0.40	0	0.25	0.40
Southern pine (Wisconsin)												
7	5.0	7.3	6.7	4.3	7.3	5.3	6.0	7.3	6.7	5.0	7.3	6.3
8	3.7	5.0	5.0	3.7	5.7	4.7	5.0	7.3	6.3	3.7	5.0	5.0
9	3.0	4.0	3.7	3.3	5.3	4.0	3.3	4.0	3.7	3.0	4.0	3.7
10	2.7	3.3	4.0	4.3	5.0	5.3	3.7	4.3	4.0	2.7	3.3	4.0
11	4.3	5.0	5.7	3.3	4.7	4.3	5.3	6.0	5.7	4.3	5.0	5.7
13	5.0	5.3	4.7	4.0	5.3	4.0	6.0	5.3	5.0	5.0	5.3	4.7
Southern pine (Mississippi)												
7	3.0	6.3	5.7	3.3	5.7	3.0	5.0	7.3	6.0	3.0	6.3	5.3
8	4.3	7.3	6.3	3.3	4.3	2.3	4.7	7.3	6.0	4.3	7.0	5.3
9	2.0	1.7	1.7	3.0	3.0	2.3	2.0	1.7	1.7	2.0	1.7	1.7
10	5.0	6.0	6.0	2.7	3.3	2.3	5.3	6.3	5.7	4.7	5.3	5.0
11	3.7	4.3	5.0	3.3	3.3	2.0	4.3	4.7	4.7	3.7	3.7	4.3
13	4.0	7.0	7.0	3.7	5.0	3.7	5.0	7.3	6.3	4.0	6.7	6.3
Hem-fir (Wisconsin)												
7	6.3	7.3	6.7	5.7	5.7	4.7	6.3	7.3	7.0	6.0	7.0	6.7
8	6.0	5.0	5.3	5.7	3.0	3.0	7.3	7.0	6.0	6.0	4.3	5.0
9	3.3	3.3	3.0	5.0	3.0	3.7	3.7	4.3	3.0	3.7	3.3	3.0
10	4.0	4.3	3.7	5.7	3.0	3.0	4.0	4.7	3.7	4.0	4.0	3.7
11	4.7	5.0	7.0	4.3	2.7	3.7	5.0	5.0	6.0	4.3	4.0	6.0
13	6.3	2.7	3.7	7.0	4.0	4.0	6.7	2.7	3.7	6.3	2.7	3.7
Hem-fir (Mississippi)												
7	3.3	3.3	5.0	3.3	3.3	2.3	4.3	4.3	5.7	3.3	3.3	4.3
8	4.7	4.7	5.7	3.7	3.7	2.0	6.0	6.0	6.3	4.7	4.7	4.7
9	2.3	2.3	2.0	2.7	2.7	1.7	3.3	3.3	2.0	2.3	2.3	2.0
10	5.3	5.3	6.3	3.3	3.3	1.7	5.7	5.7	6.7	5.3	5.3	5.3
11	4.7	4.7	5.7	3.0	3.0	1.7	5.0	5.0	5.7	4.3	4.3	4.7
13	5.0	5.7	7.0	6.0	3.3	4.0	7.0	5.7	6.7	5.7	5.0	6.0

[a] The rating used a scale of 10 (perfect) to 1 (complete failure). A value of 5 indicates the need for refinishing without major surface preparation. 0, 0.25, and 0.40 pcf are CCA treatment levels.

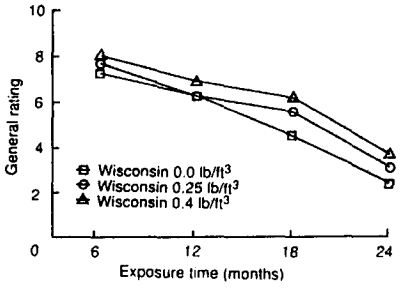

Figure 5. — General rating for translucent varnish stain (finish 12) on southern pine in Wisconsin during 24 months of exposure.

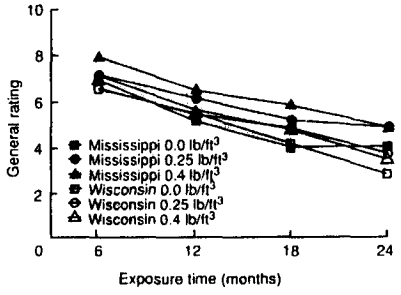

Figure6.— Average general rating for solid-color acrylic latex stain (finish 14) on southern pine and hem-fir (average) at two exposure sites during 24 months of exposure.

mildewcides present in the finish and allow mildew growth to proceed faster.

SEMITRANSPARENT STAINS

The original performance of the semitransparent stain finishes (7 to 11 and 13) ranged from poor (finish 9) to fair (finish 11 and 13) to good (finishes 7, 8, and 10) **(Table 2).** After cleaning, most of the old finish had been removed. After refinishing, most semitransparent finishes performed considerably better than the transparent finishes after 6 months of exposure **(Table 8).** Even after 18 months **(Table 9),** several of these pigmented, nonfilm- forming finishes were performing quite well. **Figure 3** demonstrates the performance of the waterborne deck stain (finish 8) on southern pine in Wisconsin during the 24 months of the study. With this penetrating deck stain finish, as with several similar finishes, the CCA treatment improved coating performance. This improvement was greater for coatings on the treated southern pine than on the treated hem-fir boards.

The trend toward improvement of semitransparent stain performance on CCA-treated wood compared with that of untreated wood was observed when the general rating results of six semitransparent finishes were grouped and averaged **(Fig. 4).** The general rating for semitransparent finishes is primarily influenced by erosion of the stain and somewhat by mildew growth. After 2 years, all semitransparent stains had general ratings in the 4 to 5 range, indicating that these finishes would need refinishing. As previously mentioned, 24 months at 45 degrees facing south equates to 40 to 54 months of exposure if the samples were installed vertically (90 degrees) facing south.

Overall, semitransparent stain finish performance was slightly better in Wisconsin than in Mississippi up to 18 months of exposure. Although the specimens received more sunlight in

TABLE 10. — Performance of film-forming coatings on CCA-treated wood after 18 months of outdoor exposure at 45 degrees south.

Finish number	Rating[a]											
	Discoloration			Substrate checking/cracking			Finish checking/cracking			General appearance		
	0	0.25	0.40	0	0.25	0.40	0	0.25	0.40	0	0.25	0.40
Southern pine (Wisconsin)												
12	4.7	5.7	6.3	5.0	6.3	6.0	4.7	5.7	7.0	4.7	5.7	6.3
14	4.3	5.0	5.0	4.0	4.7	3.3	4.3	5.0	5.0	4.3	5.0	4.7
15	7.3	9.0	8.7	8.7	9.0	8.7	9.0	9.0	8.7	7.3	9.0	8.7
16	7.3	9.0	8.7	8.0	9.0	8.7	8.0	9.0	8.7	7.3	9.0	8.7
Southern pine (Mississippi)												
12	2.7	4.0	6.3	4.0	5.7	6.3	3.7	4.0	6.0	2.7	4.0	6.0
14	3.3	4.0	6.3	3.3	4.7	3.7	4.0	5.0	6.3	3.3	4.0	5.3
15	5.7	7.3	8.0	6.0	9.0	8.3	7.7	9.0	8.3	5.7	7.7	8.0
16	5.3	6.3	7.0	5.3	9.0	8.3	5.7	8.0	8.3	4.7	6.3	7.0
Hem-fir (Wisconsin)												
12	8.0	7.0	6.7	8.7	6.7	7.7	8.3	7.0	7.3	8.0	7.0	6.7
14	4.0	5.7	5.7	5.3	3.3	4.0	4.3	5.0	5.7	4.0	4.7	5.0
15	7.7	8.0	8.0	9.0	8.7	9.0	9.0	9.0	9.0	7.7	8.0	8.0
16	8.7	8.0	8.3	8.7	7.7	9.0	9.0	8.3	9.0	8.7	8.0	8.3
Hem-fir (Mississippi)												
12	6.3	5.7	6.0	7.3	5.0	5.0	6.7	5.7	6.0	6.3	5.7	5.3
14	4.7	7.0	7.0	5.0	4.7	4.3	5.7	6.3	6.7	4.7	6.3	6.3
15	4.3	7.7	8.0	7.7	8.7	8.3	7.0	8.7	8.7	4.7	7.7	8.0
16	4.3	5.7	6.0	8.7	7.7	7.7	8.7	8.3	8.3	5.3	6.0	6.0

[a] The rating used a scale of 10 (perfect) to 1 (complete failure). A value of 5 indicates the need for refinishing without major surface preparation. 0, 0.25, and 0.40 pcf are CCA treatment levels.

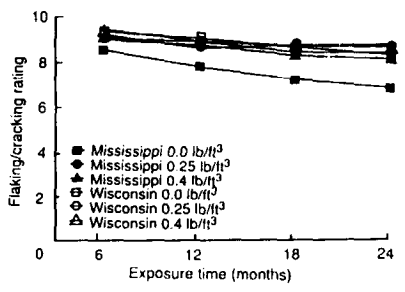

Figure 7. — Average flaking/cracking rating for acrylic latex topcoat paint finishes (finishes 15 and 16) on southern pine and hem-fir (average) at two exposure sites during 24 months of exposure.

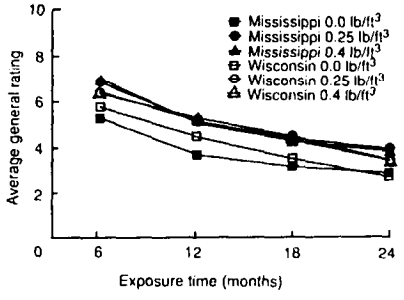

Figure 8.— Average general rating for all finishes on southern pine and hem-fir (average) at two exposure sites during 24 months of exposure.

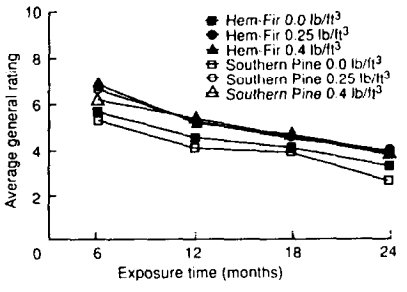

Figure 9.— Average general rating for all finishes at two exposure sites (average) on southern pine and hem-fir during 24 months of exposure.

Wisconsin than in Mississippi, the tendency for mildew to be more predominant on finishes in Mississippi, caused by more moisture and humidity, led to lower general ratings. After 24 months, the increased amount of sunlight in Wisconsin with subsequent erosion of the semitransparent stain was a more predominant factor in the general rating, resulting in lower general appearance ratings than the specimens in Mississippi.

OPAQUE FINISHES

The more opaque a finish is to UV light, the better it is in preventing erosion of the wood surface and providing longer protection (11). Fully opaque film-forming coatings Iike solid-color stains and paints completely block UV light. The translucent varnish stains represent a special form of wood finish, standing part way between semitransparent stains and solid-color stains in their ability to partially block UV light.

The original performance of the opaque finishes (translucent varnish stains, solid-color stains, and paints) (finishes 12 and [4 to 16) were good or very good **(Table 2).** After cleaning, most of the old finish remained. After 18 months, the refinished film-forming finishes gave mixed performance results that appeared to be directly related to their ability to block UV light **(Table 10).** The specialty translucent varnish stain (finish 12) contained transparent iron oxide pigments. These pigments, while partially effective, are not as effective at blocking UV light as the opaque pigments in solid-color stains and paints. However, this finish system was originally applied as a three-coat system and the subsequent build-up of film resulted in a fairly good performance, somewhat better than the fully

opaque one-coat solid-color stain. After 24 months **(Fig. 5),** this finish had general ratings less than 5 for all three CCA treatment levels in the study.

The one-coat solid-color acrylic latex stain (finish 14) had the poorest performance of the film-forming finishes atler 18 months of exposure **(Table 10).** This finish system offered minimal protection to the wood surface because of the thinness of the one coat used (the original finish was also applied as one coat). Average values of the performance of this finish on both wood species during 24 months of exposure arc shown in **Figure 6.**

The paint systems (finish 15 and 16) were both performing very well after 18 months **(Table 10)** and had generally high evaluations. These finishes were applied as one coat over the original two-coat system. Ultimately, the problem with these finishes is their mode of failure. Most paints, being film-forming coatings, fail by cracking, blistering, and peeling. However, even after 24 months, the flaking and cracking ratings of these two paint systems were very good **(Fig. 7)** and refinishing was still not required.

EFFECTS OF CCA TREATMENT, SPECIES TYPE, AND EXPOSURE SITE ON FINISH PERFORMANCE

The overall durability and performance of many finishes were improved when applied over previously finished and weathered CCA-treated wood. This can best be seen by taking an average of the general ratings for all 15 coatings on both wood species after 24 months of outdoor exposure **(Fig. 8).** At each exposure site, there is a clear trend toward improved coating performance of the CCA-treated specimens compared with the performance of untreated wood. There does not appear to be a dramatic difference in refinish performance between the 0.25 and 0.40 pcf levels of CCA treatment. From **Figure 8,** it can also be seen that average general ratings for all coatings were better in Wisconsin than in Mississippi for untreated wood, but initially were somewhat better in Mississippi for the treated specimens. Little difference in the average general ratings was found for the treated wood specimens after 12 months of exposure.

From **Figure 9,** it can be seen that average general ratings for all coatings at both exposure sites were slightly higher for the hem-fir untreated specimens compared to the southern pine untreated specimens. Little difference was observed between the two species of the CCA-treated specimens.

CONCLUSIONS

The CCA treatment of southern pine and hem-fir was shown to have a positive effect on the performance of many finishes applied over previously finished and weathered wood in this study. Little difference in refinish coating durability was noted between the 0.25 and 0.40 pcf CCA retention levels. Failure of the new finishes occurred more rapidly in Mississippi than in Wisconsin, particularly with regard to surface discoloration. The difference in finish degradation was less pronounced between the two exposure locations. Within the coating groups, the overall durability and appearance were reflected by the following order: fully pigmented (film-forming paints and stains) > lightly pigmented (semitransparent stains) > unpigmented (transparent water repellents and water-repellent preservatives).

This study demonstrates that CCA-treated wood is not only compatible with a variety of surface finishes, but the effects of the treatment enhance the performance life of some finishes, especially the semitransparent stains. The finished and weathered wood can be refinished using conventional techniques, and special surface preparation techniques are not needed other than those cleaning methods usually used for recoating wood outdoors. As with all exterior wood finishing, proper surface preparation (surface must be clean and dry) and application techniques are essential for good coating and recoating performance.

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