

Service Life of Finishes on Smooth-Planed and Saw-Textured Western Redcedar Bevel Siding

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The performance of 35 finishes (clear water-repellent Preservatives; lightly pigmented, water-repellent preservatives; semitransparent stains; solid-color stains; and paints) applied to newly planed vertical-grained; factory-planed, flat-grained; or saw-textured, vertical-grained western redcedar bevel siding was evaluated for cracking, erosion, and general appearance over 14 years of outdoor exposure at two sites (Madison, WI, and Gulfport, MS). Service life was dependent on the wood surface and increased in the following order: clear water-repellent preservatives; lightly pigmented, water-repellent preservatives; semitransparent stains; solid-color stains; and paints. The performance was about the same for both the flat-grained and vertical-grained smooth-planed bevel siding but was greatly improved for almost all finish systems on the saw-textured western redcedar bevel siding.

INTRODUCTION

Previous information on the service life of finishes on western redcedar was obtained from studies of vertical-grained lumber from old-growth forests using finishes that are no longer available. From previous studies at the USDA Forest Products Laboratory (Madison, WI), the performance of finishes formulated prior to 1990 on saw-textured and planed western redcedar (*Thuja plicata*), redwood (*Sequoia sempervirens*), Southern Pine (*Pinus sp.*),^{1,2} and aspen (*Populus tremuloides*)³ were reported. Others have compared the performance of paint systems on smooth and saw-textured plywood.⁴⁻⁶

All architectural finishes for use in the United States were reformulated in the early 1990s to lower their volatile organic compound (VOC) content to meet air quality legislation. At the time this study was started, little information was available on the long-term performance of these low-VOC finishes. Nor had any work been done to compare the performance of these new low-

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Table 1—Description of Finishes Used in Study 4-92 VOC

		Product	Description	Pigment	Lb/Gal	Grams/cc	Solids %	Volatile %	Water %	VOC %
A	1	Thompson Water Seal	Clear solventborne WR	Clear	6.66	0.798	14.6	85.4	0.1	85.3
	2	Thompson Wd. Prot.	Clear mineral oil WRP	Clear	7.10	0.851	95.8	4.2	0.1	4.1
	3	X-100	Clear natural oil-based WRP	Clear	7.16	0.858	92.6	7.4	0.1	7.3
	4	Carver Tripp S Poly	Clear 30% solids WB WRP	Clear	8.64	1.035	30.4	69.6	49.6	41.2
	5	Lifetime Sealant	Clear 5% solids WB WRP	Clear	10.58	1.268	4.8	95.2	0.1	56.7
	6	Masterguard Wd. Sealer	Clear 20% solids WB WRP	Clear	8.44	1.011	19.5	80.5	80.4	0.5
	7	Wolman WRP (New WRPs used May/96)	Clear 67% solids oil-based SB WRP	Clear	7.25	0.869	66.8	33.2	2.9	31.1
A	8	Woodlife VOC Waterborne	Clear 4% solids WB WRP	Clear	8.38	1.004	3.5	96.5	96.4	0.5
	9	Thompson Wd. Prot.	Clear mineral oil WRP	Clear	7.10	0.851	95.8	4.2	0.1	4.1
	10	X-100 Cedartone	Tinted 45% solids WB WRP	Cedar	7.99	0.957	44.6	55.4	46	<10
	11	Amteco TWP 100 Clear	Clear 14% solids SB WRP	Clear	6.85	0.821	13.8	86.2	0.6	6.1
	12	Cuprinol CWP	Clear 10% solids WB WRP	Clear	8.33	0.998	10.5	89.5	86.4	3.2
	13	Cuprinol Copper Naphth.	Tinted 55% solids SB WRP	Green	7.12	0.853	55.4	44.6	0.1	44.3
	14	Wolman WRP	Clear 67% solids oil-based SB WRP	Clear	7.25	0.869	66.8	33.2	2.9	31.1
B	1	Oly. Marathon Alk./Lat.	Redwood 24% solids alkyd mod. acrylic WB STS	Redwood	9.09	1.089	23.6	76.4	75.6	4.6
	2	Oly. Marathon Acrylic Lat.	Redwood 27% solids acrylic latex WB STS	Redwood	8.98	1.076	27.1	72.9	61.0	34.8
	3	Lindsey ST Oil Stain	Cedar 76% solids oil-based SB STS	Cedar Br.	7.63	0.914	75.9	24.1	0.2	23.9
	4	Duckback Oil ST Stain	Cedar 60% solids oil-based SB STS	Cedar	7.17	0.859	56.9	43.1	0.1	43.0
	5	Pratt+Lam. ST Lat. Stain	Pigmented 27% solids WB STS	Rustic	8.66	1.038	26.8	73.2	59.3	36.3
	6	Oly. WR ST Lat. Stain	Cedar 27% solids WB STS	Cedar	9.02	1.081	28.6	71.4	65.5	20.4
	7	Lifetime ST Oil Stain	Cedar 6% solids SB STS	Cedar	10.63	1.274	6.4	93.6	0.1	56.7
C	1	Pratt+Lam. SC Alkyd Stain	White 78% solids oil-based SB SCS	White	12.29	1.473	77.8	22.2	0.2	22.1
	2	Pratt+Lam. SC Latex Stain	White 45% solids acrylic-based WB SCS	White	10.43	1.250	44.9	55.1	51.4	10.4
	3	Mautz SC Oil Stain	Tan 54% solids oil-based SB SCS	Tan	9.27	1.111	54.5	45.5	0.6	45.2
	4	Mautz SC Latex Stain	Tan 39% solids acrylic-based WB SCS	Tan	10.01	1.199	38.7	61.3	56.5	15.0
	5	Oly. SC Oil Stain	Red 55% solids oil-based SB SCS	Red	8.66	1.038	55.4	44.6	0.1	44.5
	6	Oly. SC Latex Stain	Red 38% solids acrylic-based WB SCS	Red	10.03	1.202	37.6	62.4	56.3	19.0
	7	Oly. SC Oil+ SC Lat. Stain	Red 55% solids oil-primer + 38% solids acrylic SCS	Red	8.7/10	1.04/1.2	55/38	45/62	0.1/56.3	45/19
D	1	Oly. SC Oil Stain (2 cts.)	Red 55% solids oil-based SCS (2 coats)	Red	8.7/8.7	1.04/1.04	55.4/55.4	44.6/44.6	0.1/0.1	44.5/44.5
	2	Pratt+Lam. SC Oil/+SC Lat.	White 78% solids oil-based SCS + 45% solids acrylic SCS	White	12.3/10.4	1.47/1.25	78/45	22/55	0.2/51.4	22.1/10.4
	3	Pratt+Lam. Oil pr.+Oil Top.	White 80% solids alkyd primer + 71% solids alkyd TC	White	11.8/9.7	1.42/1.16	80.5/71.2	19.5/28.8	0.4/0.1	19.2/28.7
	4	Pratt+Lam. Lat.pr.+Lat.Top.	White 38% solids latex primer + 46% solids latex TC	White	9.76/9.93	1.17/1.19	38.3/46.1	61.7/53.9	42.1/22.1	38.8/43.2
	5	Lucite Lat.pr.+ Lat.Topcoat	White 48% solids acrylic primer + 57% solids acrylic TC	White	10.0/11.0	1.20/1.31	48.3/57.0	51.7/43.0	50.9/40.4	2.0/5.6
	6	Lucite Oil.pr.+ Lat.Topcoat	White 77% solids alkyd primer + 57% solids acrylic TC	White	11.6/11.0	1.39/1.31	77.1/57.0	22.9/43.0	0.2/40.4	22.7/5.6
	7	S/W A-100 Oil pr.+Lat.Top.	White 74% solids alkyd primer + 53% solids acrylic TC	White	11.0/11.1	1.32/1.33	74.5/52.8	25.5/47.2	0.3/45.2	25.3/5.1
E		Woodlife Wood Preserv. +		Clear	6.65	0.797	6.4	93.6	0.1	93.6
	1	Pratt+Lam. SC Alkyd Stain	SB WRP + White 78% solids oil-based SB SCS	White	12.29	1.473	77.8	22.2	0.2	22.1
	2	Pratt+Lam. SC Latex Stain	SB WRP + White 45% solids acrylic-based WB SCS	White	10.43	1.250	44.9	55.1	51.4	10.4
	3	Mautz SC Oil Stain	SB WRP + Tan 54% solids oil-based SB SCS	Tan	9.27	1.111	54.5	45.5	0.6	45.2
	4	Mautz SC Latex Stain	SB WRP + Tan 39% solids acrylic-based WB SCS	Tan	10.01	1.199	38.7	61.3	56.5	15.0
	5	Oly. SC Oil Stain	SB WRP + Red 55% solids oil-based SB SCS	Red	8.66	1.038	55.4	44.6	0.1	44.5
	6	Oly. SC Latex Stain	SB WRP + Red 38% solids acrylic-based WB SCS	Red	10.03	1.202	37.6	62.4	56.3	19.0
	7	Oly. SC Oil+ SC Lat. Stain	SB WRP + Red 55% solids oil-primer + 38% solids acrylic SCS	Red	8.7/10	1.04/1.2	55/38	45/62	0.1/56.3	45/19
F		WRP+								
	1	Oly. SC Oil Stain (2 cts.)	SB WRP + Red 55% solids oil-based SCS (2 coats)	Red	8.7/8.7	1.04/1.04	55.4/55.4	44.6/44.6	0.1/0.1	44.5/44.5
	2	Pratt+Lam. SC Oil/+SC Lat.	SB WRP + White 78% solids oil-based SCS + 45% solids acrylic SCS	White	12.3/10.4	1.47/1.25	78/45	22/55	0.2/51.4	22.1/10.4
	3	Pratt+Lam. Oil pr.+Oil Top.	SB WRP + White 80% solids alkyd primer + 71% solids alkyd TC	White	11.8/9.7	1.42/1.16	80.5/71.2	19.5/28.8	0.4/0.1	19.2/28.7
	4	Pratt+Lam. Lat.pr.+Lat.Top.	SB WRP + White 38% solids latex primer + 46% solids latex TC	White	9.76/9.93	1.17/1.19	38.3/46.1	61.7/53.9	42.1/22.1	38.8/43.2
	5	Lucite Lat.pr.+ Lat.Topcoat	SB WRP + White 48% solids acrylic primer + 57% solids acrylic TC	White	10.0/11.0	1.20/1.31	48.3/57.0	51.7/43.0	50.9/40.4	2.0/5.6
	6	Lucite Oil.pr.+ Lat.Topcoat	SB WRP + White 77% solids alkyd primer + 57% solids acrylic TC	White	11.6/11.0	1.39/1.31	77.1/57.0	22.9/43.0	0.2/40.4	22.7/5.6
	7	S/W A-100 Oil pr.+Lat.Top.	SB WRP + White 74% solids alkyd primer + 53% solids acrylic TC	White	11.0/11.1	1.32/1.33	74.5/52.8	25.5/47.2	0.3/45.2	25.3/5.1

Table 2—Spreading Rates of Applied Finishes in Square Feet Per Gallon [Sq ft/gal (m²/l)]

Madison							Gulfport						
		NP VG	NP VG	ST VG	ST VG	FP FG		NP VG	NP VG	ST VG	ST VG	FP FG	FP FG
		Sq ft/gal	m ² /l	Sq ft/gal	m ² /l	Sq ft/gal	m ² /l	Sq ft/gal	m ² /l	Sq ft/gal	m ² /l	Sq ft/gal	m ² /l
A	1	530	13.0	210	5.1	550	13.5	635	15.6	260	6.4	505	12.4
	2	440	10.8	185	4.5	510	12.5	480	11.8	240	5.9	450	11.0
	3	545	13.4	185	4.5	505	12.4	525	12.9	225	5.5	445	10.9
	4	395	9.7	195	4.8	355	8.7	390	9.6	210	5.1	375	9.2
	5	310	7.6	155	3.8	315	7.7	325	8.0	160	3.9	285	7.0
	6	370	9.1	175	4.3	355	8.7	345	8.5	185	4.5	345	8.5
	7	510	12.5	225	5.5	490	12.0	550	13.5	205	5.0	465	11.4
B	1	500	12.3	225	5.5	470	11.5	445	10.9	175	4.3	440	10.8
	2	485	11.9	195	4.8	550	13.5	465	11.4	190	4.7	555	13.6
	3	490	12.0	190	4.7	500	12.3	515	12.6	205	5.0	555	13.6
	4	470	11.5	200	4.9	450	11.0	405	9.9	205	5.0	475	11.6
	5	475	11.6	185	4.5	510	12.5	450	11.0	195	4.8	410	10.0
	6	455	11.2	165	4.0	535	13.1	450	11.0	205	5.0	435	10.7
	7	270	6.6	120	2.9	245	6.0	235	5.8	125	3.1	255	6.3
C	1	460	11.3	250	6.1	460	11.3	435	10.7	230	5.6	430	10.5
	2	395	9.7	230	5.6	485	11.9	420	10.3	230	5.6	460	11.3
	3	480	11.8	220	5.4	465	11.4	515	12.6	240	5.9	480	11.8
	4	420	10.3	215	5.3	445	10.9	395	9.7	215	5.3	465	11.4
	5	520	12.7	215	5.3	520	12.7	610	14.9	240	5.9	450	11.0
	6	395	9.7	175	4.3	415	10.2	360	8.8	205	5.0	375	9.2
	7	575	14.1	250	6.1	620	15.2	630	15.4	280	6.9	700	17.2
D		635	15.6	390	9.6	665	16.3	680	16.7	395	9.7	730	17.9
	1	425	10.4	225	5.5	410	10.0	460	11.3	200	4.9	435	10.7
		660	16.2	595	14.6	660	16.2	645	15.8	595	14.6	585	14.3
	2	410	10.0	235	5.8	465	11.4	460	11.3	230	5.6	430	10.5
		760	18.6	645	15.8	825	20.2	845	20.7	645	15.8	745	20.7
	3	445	10.9	240	5.9	470	11.5	455	11.1	240	5.9	425	10.4
		625	15.3	370	9.1	610	14.9	565	13.8	405	9.9	580	14.2
	4	380	9.3	180	4.4	370	9.1	360	8.8	185	4.5	365	8.9
		840	20.6	445	10.9	1025	25.1	950	23.3	450	11.0	950	23.3
	5	375	9.2	200	4.9	450	11.0	405	9.9	205	5.0	425	10.4
		715	17.5	465	11.4	730	17.9	705	17.3	500	12.3	650	15.9
	6	415	10.2	195	4.8	370	9.1	355	8.7	205	5.0	345	8.5
		800	19.6	515	12.6	740	18.1	850	20.8	525	12.9	715	17.5
	7	425	10.4	225	5.5	395	9.7	430	10.5	230	5.6	390	9.6
		475	11.6	335	8.2	490	12.0	510	12.5	340	8.3	465	11.4

Table 2 continued on next page.

Table 2—cont'd

SB		Madison				Gulfport			
		NP VG Sq ft/gal	NP VG m ² /l	ST VG Sq ft/gal	ST VG m ² /l	FP FG Sq ft/gal	FP FG m ² /l	NP VG Sq ft/gal	NP VG m ² /l
WRP E	1	130	3.2	65	1.6	125	3.1	145	3.6
	2	460	11.3	250	6.1	500	12.3	435	10.7
	3	595	14.6	340	8.3	570	14.0	580	14.2
	4	595	14.6	315	7.7	605	14.8	565	13.8
	5	550	13.5	320	7.8	555	13.6	540	13.2
	6	660	16.2	280	6.9	645	15.8	660	16.2
	7	490	12.0	290	7.1	510	12.5	500	12.3
WRP F	1	950	23.3	335	8.2	870	21.3	850	20.8
	2	720	17.6	460	11.3	745	18.3	690	16.9
	3	85	2.1	50	1.2	105	2.6	100	2.5
	4	535	13.1	270	6.6	595	14.6	520	12.7
	5	685	16.8	585	14.3	700	17.2	660	16.2
	6	520	12.7	300	7.4	580	14.2	545	13.4
	7	705	17.3	595	14.6	745	18.3	720	17.6
	1	480	11.8	295	7.2	500	12.3	430	10.5
	2	465	11.4	435	10.7	510	12.5	510	12.5
	3	420	10.3	265	6.5	420	10.3	400	9.8
	4	950	23.3	605	14.8	1055	25.8	925	22.7
	5	535	13.1	290	7.1	465	11.4	435	10.7
	6	670	16.4	660	16.2	650	15.9	740	18.1
	7	420	10.3	240	5.9	400	9.8	370	9.1
	1	770	18.9	590	14.5	755	18.5	770	18.9
	2	465	11.4	250	6.1	430	10.5	435	10.7
	3	465	11.4	340	8.3	460	11.3	525	12.9

VOC finishes on flat-grained bevel siding from second- and third-growth forests.

We report here the performance of 35 finishes used in 49 finish systems on newly planed vertical-grained factory-planed flat-grained; or saw-textured vertical-grained western redcedar bevel siding. Finishes included clear water-repellent preservatives, lightly pigmented water-repellent preservatives, semitransparent stains, solid-color stains (also called full-bodied stains or opaque stains), and acrylic and alkyd paints. All finishes were readily available commercial finishes and were applied under laboratory conditions. It is not the intent of the study to compare the performance of the various brands of finish, but rather to obtain general performance information for various types of finish on the different substrates (for example, to determine the expected service life of a typical semitransparent stain on saw-textured and smooth-planed bevel siding). The effect of a water-repellent preservative (WRP) pretreatment on the performance of several paint and solid-color stains is also evaluated.

EXPERIMENTAL

Materials

Western redcedar bevel siding was obtained from lumber dealers in Madison, WI. Bevel siding was nominal 6 in. (150 mm) and was obtained in 12-ft (3.66 m) lengths. The vertical-grained siding was an all-heartwood clear grade having growth rates in the range of 26–28 growth rings per inch (10–11 per cm). As received, the siding had one side smooth-planed and one side saw-textured. The factory-planed surface was planed again in our laboratory several days prior to finishing and stored in one of our controlled-humidity rooms (65% relative humidity (RH) and 27 °C) until it was finished. Approximately 1 mm was removed from the surface. The flat-grained

Figure 1—Paints and two-coat solid-color stains (Group D) after 10 years outdoor exposure near Gulfport, MS.

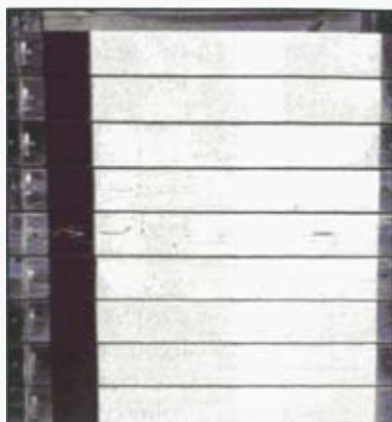


Figure 2—General appearance evaluations for a red 55% solids oil-based solid-color stain (SCS, C-5, Table 1) exposed near Madison, WI (NP VG: newly planed vertical-grained; FP FG: factory-planed flat-grained; ST VG: saw-textured vertical-grained).

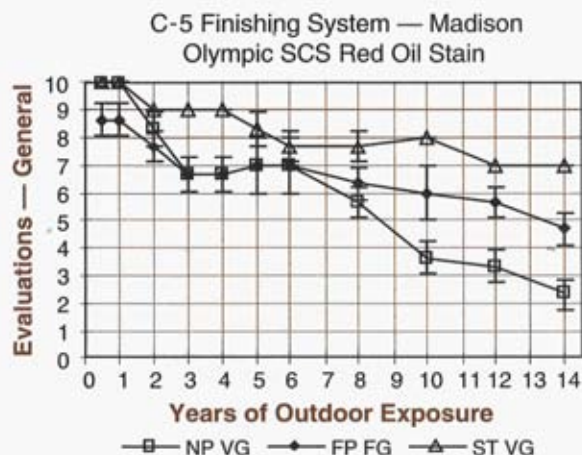
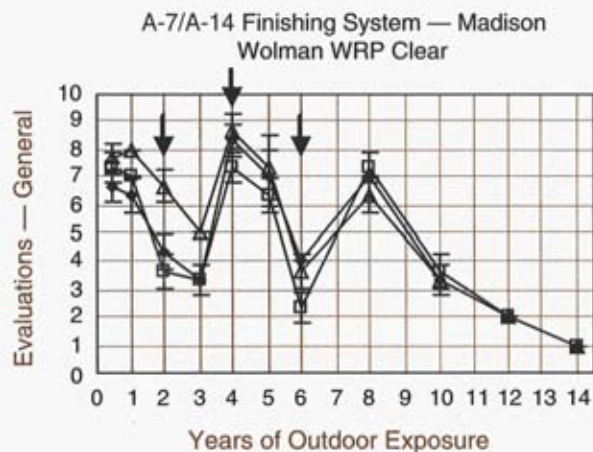


Figure 3—General appearance evaluations for a clear 67% solids repellent-preservative (WRP, A-7, Table 1) exposed near Madison (NP VG, newly planed vertical-grained; FP FG: factory-planed flat-grained; ST VG: saw-textured vertical-grained). Boards were refinished after 2, 4, and 6 years (arrows).



bevel siding was all heartwood select-knotty grade with small tight knots having approximately two to three growth rings per cm. This siding was also stored in our controlled-humidity room prior to being finished. Siding was cut to 47.75 in. (1.21 m) lengths (henceforth referred to as 4-ft boards) and each board was marked with a pencil with seven 6-in. (150 mm) sections for the various finishes, with approximately 3 in. (76 mm) on each end to remain unfinished.

All finishes were purchased from paint stores in Madison, WI. Their description and general characteristics are given in Table 1. The description includes the type of color, binder, solids content, volatile content, water content, VOCs, and preservatives/mildewcides. Solids content was determined using the ASTM D 2832-83 procedure. Finishes are grouped in six general categories: clear and lightly pigmented water-repellent preservatives (Group A), semitransparent stains (Group B), solid-color stains (Group C), paints (Group D), solid-color stains with a WRP pretreatment (Group E), and paints with a WRP pretreatment (Group F). Within each group are seven finishes except in Group A, which has 14 finishes. Hereafter, when the finish groups are mentioned, the reader can refer to Table 1. Seven Group A (1 to 7) finishes were laboratory-applied at the beginning of the study. These finishes lasted less than two years and were subsequently reapplied in the field (first refinish). Note that finish A-2 is the same as A-9 and A-7 is the same as A-14. For all other Group A finishes (A1, A3, A4, A5, and A6), a different finish was used in subsequent years for the second and third refinish. Some of the original seven finishes were no longer manufactured.

Figure 4—General appearance ratings for a redwood color 24% solids alkyd-modified acrylic waterborne semitransparent stain (STS, B-1, Table 1) exposed near Madison (NP VG: newly planed, vertical-grained; FP FG: factory-planed flat-grained; ST VG: saw-textured vertical-grained).

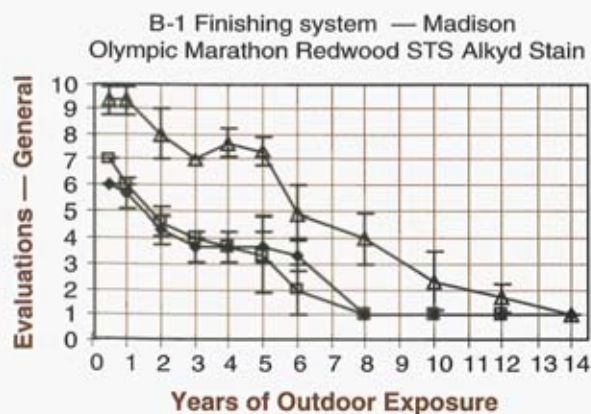
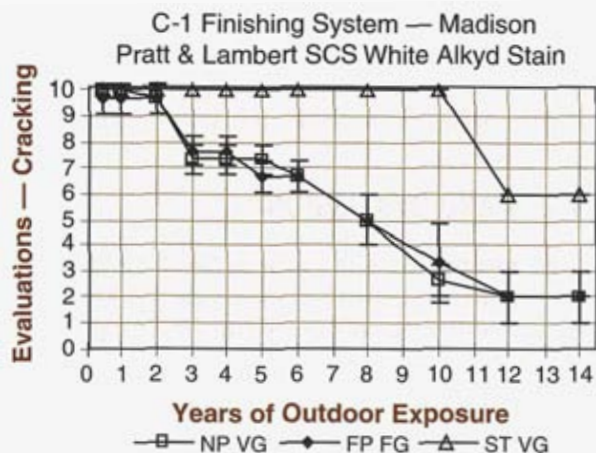


Figure 5—Finishing tracking ratings for a white 78% solids oil-based, solventborne solid-colorstain (SCS, C-1, Table 1) exposed near Madison (NP VG: newly planed vertical-grained; FP FG: factory-planed flat-grained; ST VG saw-textured vertical-grained),



Cleaning solution was one part household bleach (5% sodium hypochlorite), three parts water, and a small amount of powdered detergent.

Methods

FINISHING—Within each type of bevel siding (factory-planed flat-grained; newly planed vertical-grained; and saw-textured vertical-grained), the 4-ft boards were randomized, and three boards were used for each finish system. Six general categories of finish were applied to each of these three-board sets. Each category of finish had seven finishes—one for each section within each of the 4-ft boards. This gave a total of 54 4-ft boards for each outdoor exposure site. One site is located approximately 5 km west of Madison, WI, and the other site is located approximately 15 km north of Gulfport, MS. These sites have distinctly different climates. The Madison site has four seasons with rather severe winters, and the Gulfport site is a maritime climate with hot humid summers and mild winters.

All 4-ft boards were initially finished under ambient laboratory conditions; the spread rates are given in Table 2. Finishes in Group A were reapplied in the field and field-applied spread rates were not determined. Prior to field application (refinishing) of the boards in Group A, the boards were cleaned with a mild household bleach and detergent mixture. Bleach solution was applied using a soft-bristle brush and thoroughly rinsed with water after 15 min. Boards were refinished after they dried, usually the next day. All other finishes (Groups B to F) were applied only once at the beginning of the study. All finishes were brush applied.

The 4-ft boards were attached to a vertical test fence facing south with a single screw at each end and there

was a ¼-in. (6 mm) gap between each board. Nine boards were placed in each section of the fence (Figure 1).

EVALUATION—With the exception of Group A each of the finish systems was evaluated once a year over 12 to 14 years. The finishes in Group A were evaluated more often (approximately every six months). The service life of the clear and lightly pigmented finishes (Group A) was determined from the general appearance evaluations (listed as "General" in the tables and figures). Semitransparent stains were evaluated for "erosion," and the solid-color stains and paints were evaluated for "cracking" and "general appearance." Evaluations for erosion, cracking, and general appearance were in accordance with ASTM D 662-93, D 661-93, and D 3274-88, respectively. A rating of "10" indicates no degradation, and "1" indicates total failure of the coating system. A rating of "5" indicates a condition at which the coating should be refinished without having to do excessive surface preparation (in other words, the approximate service life).

DATA REDUCTION—The data for each of the finish systems were plotted to show performance over the 14-year exposure on each of the three different surfaces (newly planed vertical-grained (NP VG); factory-planed flat grained (FP FG); and saw-textured vertical-grained (ST VG)). The plots showed the average and standard deviation of the three observations for each of the finish systems on each of the surfaces. For example, the general-appearance ratings over 14 years for a red 55% solids oil-based solid-color stain (Group C, finish C5) exposed near Madison is shown in Figure 2. The standard deviations are the bars at each average point in the plots.

Most finishes had four plots ("General Appearance" and "Cracking" for Madison and Gulfport), which to-

Figure 6—Paint tracking ratings for a white 77% solids alkyd primer and 57% solids acrylic topcoat (D-6) exposed near Madison (NP VG: newly planed vertical-grained; FP FG: factory-planed flat-grained; ST VG: saw-textured vertical-grained).

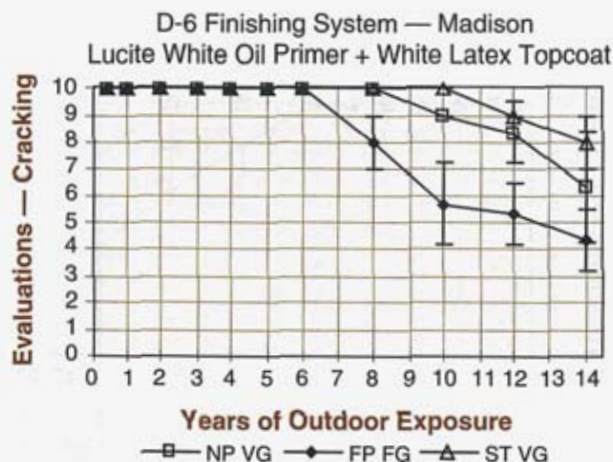
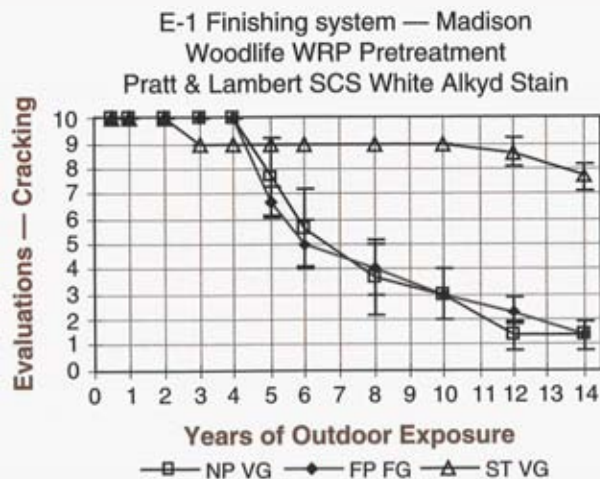
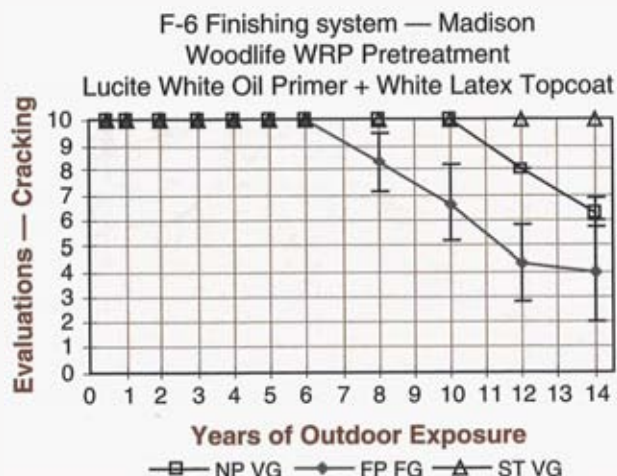


Figure 7 — Painttacking ratings for white 78% solids oil-based solid-color stain (E-1) with a solventborne water-repellent preservative (WRP) pretreatment exposed near Madison (NP VG: newly planed vertical-grained; FP FG: (factory-planed flat-grained); ST VG: saw-textured vertical-grained).



talled almost 200 plots for all the finish wood combinations. Only a few representative plots are included. The service life was determined as the time it took for the average rating to reach "5" on the evaluation scale. The service life (time on the abscissa) of each finish is the intersection of the performance line with the five-year line (ordinate). For example, the service life of finish C-5 (solid-color oil stain, Figure 2) was about nine years on newly planed vertical-grained, 13 years on factory-planed flat-grained boards, and more than 14

Figure 8 — Painttacking ratings for a white 77% solids alkyd primer and 57% solids acrylic topcoat (F-6) with a solventborne water-repellent preservative (WRP) pretreatment exposed near Madison (NP VG: newly planed vertical-grained; FP FG: factory-planed flat-grained; ST VG: saw-textured vertical-grained).



years on saw-textured vertical-grained lumber. The service life for each finish is tabulated in the various tables. The performance line often intersected the five-year line between years. The closest year was listed in the tables: clear penetrating finishes (Table 3A,B), semitransparent finishes (Table 4), solid-color stains (Table 5 and 7), and paints (Table 15 and 8). Tables include the service life for both the Madison and Gulfport field sites.

RESULTS AND DISCUSSION

The performance of the various finish systems on the three different substrates varied greatly. Many of the clear and lightly pigmented finishes (Group A) lasted less than six months, whereas some of the solid color stains and paints were in excellent condition after 14 years. The most important factor in determining the service life was the type of finish. In general, the ranking in decreasing order of service life was as follows: paints, solid color-stains, oil-based semitransparent stains, water-based semitransparent stains, lightly pigmented WRPs, and clear WRPs.

After the type of finish, next in importance is the wood surface. In general, each of the finish systems had longer service life on the saw-textured vertical-grained bevel siding. The vertical grain surface is primarily comprised of early wood, which absorbs the finish better than latewood. The saw-textured surface has no planer-induced surface stresses, which can place stress on subsequently applied coatings.⁸ The saw-textured surface accepts more finish, which gives a greater film thickness than smooth-planed surfaces. In general, we found little difference between the newly planed vertical-grained surface and the factory-planed flat-grained surface with some exceptions noted in the following subsections. The service lives for finishes within each of the six finish systems (Group A to F) are given in the following subsections.

Clear and Lightly Pigmented WRPs (Group A)

General appearance ratings for finish system A-7 (A-14) show considerable difference over the 14 years (Figure 3). The initial finish application lasted less than 18 months, and the boards were refinished after two, four, and six years. The finish was not evaluated after refinishing at two years. Not evaluating the finish systems immediately after they were refinished was an oversight because in many cases the ratings fell below "5" within six months of refinishing. To compare the ratings among the various finish systems, the information on the various plots (such as shown in Figure 3) is tabulated for each of the finishes on each of the substrates. The times (years) that it took for the rating to drop below "5" are tabulated (Table 3A (Madison) and

Table 3A—Service Life (Years) of Water-Repellent Preservatives (WRP) Exposed Near Madison, WI^a

Finish Group and Number ^{b,c}	Initial Finish			First Refinish			Finish Group and Number ^d	Second Refinish			Third Refinish		
	FP	NP	ST	FP	NP	ST		FP	NP	ST	FP	NP	ST
A-1—Clear SB WR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	A-8—Clear 4% S WB WRP	<0.5	0.5	0.7	1	1	1
A-2—Clear mineral oil WRP	1.5	1.5	1.5	<0.5	<0.5	<0.5	A-9—Clear mineral oil WRP	2	1.5	2	1.5	1.5	1.5
A-3—Clear natural oil-based WRP	1.5	1.5	1.5	<0.5	<0.5	<0.5	A-10—Tinted 45% S WB WRP	1.5	1.5	1.5	1.5	1.5	1.5
A-4—Clear 30% S WB WRP	0.5	0.5	0.5	<0.5	<0.5	<0.5	A-11—Clear 14% S SB WRP	1.2	1.5	1.5	3.5	3	2
A-5—Clear 5% S WB WRP	1	1	1	<0.5	<0.5	<0.5	A-12—Clear 10% S WB WRP	<0.5	0.5	<0.5	3	3.5	3
A-6—Clear 20% S WB WRP	1.5	1.5	2	0.5	0.5	0.5	A-13—Tinted 55% S SB WRP	0.5	0.5	0.5	2.5	3	2
A-7—Clear 67% S oil-based SB WRP	1.5	1.5	2[7] ^e	<0.5	<0.5	<1	A-14—Clear 67% S oil-based SB WRP	1	1	1	3	3.5	2.5

Table 3B—Service Life (Years) of Water-Repellent Preservatives (WRP) Exposed Near Gulfport, MS

Finish Number	Initial Refinish			First Refinish			Finish Number	Second Refinish			Third Refinish		
	FP	NP	ST	FP	NP	ST		FP	NP	ST	FP	NP	ST
A-1—Clear SB WR	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	A-8	<0.5	<0.5	<0.5	1	1.5	1.5
A-2—Clear mineral oil WRP	1.5	1.5	1.5	<0.5	2[7] ^e	<0.5	A-9	1.2	1.2	1.2	1.4	1.4	1.4
A-3—Clear natural oil-based WRP	1	1.5	1.5	<0.5	<0.5	<0.5	A-10	0.5	1	0.5	1	1	1
A-4—Clear 30% S WB WRP	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	A-11	<0.5	<0.5	<0.5	3.5	2	1.5
A-5—Clear 5% S WB WRP	0.5	1.5	2	<0.5	<0.5	<0.5	A-12	<0.5	<0.5	<0.5	1.5	2	1.4
A-6—Clear 20% S WB WRP	<0.5	0.5	1	<0.5	<0.5	<0.5	A-13	<0.5	<0.5	<0.5	2.5	3	2.5
A-7—Clear 67% S oil-based SB WRP	2	1	2	<0.5	<0.5	<0.5	A-14	<0.5	0.5	0.5	15	15	15

(a) Service life was determined on the basis of the average evaluations of general appearance.

(b) Each of the A-1 to A-7 finishes were applied to sections of three replicate boards.

(c) SB: solventborne; WB: waterborne; WR: water repellent; S: solids; STS: semitransparent stain; WRP: water-repellent preservatives; SCS: solid-color stain; TC: topcoat; FP: factory-planed flat-grained; NP: newly planed vertical-grained; ST: saw-textured.

(d) The second and third refinish was done using finishes A-8 to A-14.

(e) Value in brackets indicates that the rating was "7" after 2 years.

Table 4—Service Life (Years) of Semitransparent Stains Exposed Near Madison or Gulfport^a

Finish Number and Description ^b	Madison						Gulfport					
	Erosion			General			Erosion			General		
	FP	NP	ST	FP	NP	ST	FP	NP	ST	FP	NP	ST
B-1—Redwood 24% S ^c alkyd mod. acrylic WB STS	3	4	6	<1.5	<1.5	6	3	2	10	3	<1	8
B-2—Redwood 27% S acrylic latex WB STS	2	2	6	0.5	<1.5	6	0.5	2	7	<0.5	<0.5	6
B-3—Cedar 76% S oil-based SB STS	6	6	12	6	6	11	4	4	11	2	1	9 ^d
B-4—Cedar 60% S oil-based SB STS	1	1.5	2	0.5	1	5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
B-5—Pigmented 27% S WB STS	3	3	10	2	3	10	6	3	10	5	3	10
B-6—Cedar 27% S WB STS	5	5	9	0.5	0.5	7	3	0.5	10	<0.5	<0.5	8
B-7—Cedar 6% S SB STS	6	2.5	7	3	2	7	6	2	9	<0.5	0.5	7

(a) Service life was determined on the basis of the average evaluations of erosion and general appearance.

(b) Each of the B-1 to B-7 finishes were applied to sections of three replicate boards.

(c) SB: solventborne; WB: waterborne; WR: water repellent; S: solids; STS: semitransparent stain; SCS: solid-color stain; TC: topcoat; FP: factory-planned flat-grained; NP: newly planed vertical-grained; ST: saw-textured.

(d) The rating was below "5" early in the exposure, then above "5." The value in the table is for the final drop below a rating of "5."

3B (Gulfport)). The values extracted from *Figure 3* are shown in bold type in *Table 3A*. These tables are not the raw data from the evaluations; they contain the finished analysis of data taken from numerous evaluations over many years. The values in the tables are the service life determined from the "General Appearance" evaluation.

The general appearance rating for the clear and lightly pigmented finishes (Group A-1 to A-7) varied from less than half a year to two years during the first two years of exposure in both Madison and Gulfport (*Tables 3A* and *3B*). The "2[7]" for A-7 on the saw-textured bevel siding (ST VG) indicates that the rating was "7" after two years, the time at which it was refinished. Surprisingly, we observed little difference between the smooth-planed and saw-textured bevel siding. After two years, the siding was cleaned with dilute household bleach and detergent solution, allowed to dry, and refinished with Group A-1 to A-7. The ratings over the next two years (years 2–4, *Tables 3A* and *3B*) were lower than for the first two years. *Figure 3* is typical of other figures for these finishes. It appears from the plot that the boards were refinished only twice (prior to year 4 and year 8). The boards were refinished after two years using finishes 1–7, but the appearance of the refinished boards was not improved as shown by the evaluation at two years. The general performance ratings during the first four years were low because of considerable

mildew growth. Mildew is also the reason that we saw little apparent difference for the different types of bevel siding. Almost all finishes failed within six months. *Table 1* lists the ingredients for the various finishes that we could determine from the product labels and data sheets and gives minimal data on formulation. Note, however, that some of the finishes in Group A apparently did not contain a mildewcide. Those finishes that contained a mildewcide seemed to perform better than those that did not (1.5–2 years service versus 0.5 years) after the initial finish application. Performance was about the same for all finishes after the first refinish (about 0.5 years).

Four years after the study started (two years after first refinish), the bevel siding was cleaned again and refinished (Group A-8 to A-14). This group of finishes gave much better service life on all three types of bevel siding for years four to six and after refinishing in year 6 (years 6 to 14). We attribute this improved performance to the efforts by the finishing industry to obtain longer service life for these clear and lightly pigmented finishes. All finishes in this group contained mildewcides. The performance of finishes A-8 to A-14 were vastly superior to A-1 to A-7. This better performance can be attributed to several factors: in general, the solids content of the finishes were higher; the board surfaces became more porous and thus absorbed more finish as they weathered; and the weather was likely

Table 5—Service Life (Years) of Solid-Color Stains Exposed Near Madison or Gulfport^a

Finish Number and Description ^{b,c}	Madison						Gulfport					
	Cracking			General			Cracking			General		
	FP	NP	ST	FP	NP	ST	FP	NP	ST	FP	NP	ST
C-1-White 78% S oil-based SB SCS	8	8	14 [6] ^d	8	9	14 [6]	10	9	12	5	5	10
C-2-White 45% S acrylic-based WB SCS	9	8	12	8	8	13	11	10	12	3.5	3.5	9
C-3-Tan 54% S oil-based SB SCS	10	10	13	10	9	14	11	10	14 [9]	7	6	10
C-4-Tan 39% S acrylic-based WB SCS	8	7	12	8	6	10	7	7	14 [9]	4.5	3	9
C-5-Red 55% S oil-based SB SCS	13	9	14 [7]	12 [6]	9	12 [7]	12	10	14 [9]	11	9	12 [8]
C-6-Red 38% S acrylic-based WB SCS	9	7	14 [7]	10	10	12 [7]	12	11	14 [8]	11	11	12 [7]
C-7-Red 55% S oil-primer + 38% S acrylic SCS	14 [6]	14 [6]	14 [8]	12 [7]	12	12 [7]	12	11	14 [9]	12 [6]	12	12 [7]

(a) Service life was determined on the basis of the average evaluations of cracking and general appearance.

(b) SB: solventborne; WB: waterborne; WR: water repellent; S: solids; STS: semitransparent stain; SCS: solid-color stain; TC: topcoat; FP: factory-planed flat-grained; NP: newly planed vertical-grained; ST: saw-textured.

(c) Each of the C-1 to C-7 finishes were applied to sections of three replicate boards.

(d) Value in brackets indicates that the rating was "6" after 14 years.

Table 6—Service Life (Years) of Paints Exposed Near Madison or Gulfport^a

Finish Number and Description ^{b,c}	Madison						Gulfport					
	Cracking			General			Cracking			General		
	FP	NP	ST	FP	NP	ST	FP	NP	ST	FP	NP	ST
D-1-Red 55% S oil-based SCS (2 coats)	14	14 [9]	14 [10]	14 [7]	14 [7]	14 [8]	14 [7]	14 [9]	14 [8]	14 ^d [6]	14 ^d [7]	14 ^d [8]
D-2-White 78% S oil-based SCS + 45% S acrylic SCS	12	14 [7]	14 [8]	10	12	14	14	14	14 [8]	8	8	10 ^d
D-3-White 80% S alkyd primer + 71% S alkyd TC	13	6	13	12	10	12	13	7	14 [8]	4 ^d	7	10
D-4-White 38% S latex primer + 46% S latex TC	12	7	14 [8]	10	10	10	13	9	14 [8]	5	4	10
D-5-White 48% S acrylic primer + 57% S acrylic TC	14 [6]	14 [9]	14 [9]	13	14 [7]	14 [8]	14	14 [7]	14 [8]	10	10	14 [6]
D-6-White 77% S alkyd primer + 57% S acrylic TC	13	14 [6]	14 [8]	9	12	12	14	14	14 [8]	7 ^d	7	10
D-7-White 74% S alkyd primer + 53% S acrylic TC	14 [7]	14 [9]	14 [9]	14 [7]	14 [7]	14 [7]	14 [7]	14 [9]	14 [8]	10	10	14

(a) Service life was determined on the basis of the average evaluations of general appearance.

(b) SB: solventborne; WB: waterborne; WR: water repellent; S: solids; STS: semitransparent stain; SC: solid-color stain; TC: topcoat; FP: factory-planed flat-grained; NP: newly planed vertical-grained; ST: saw-textured.

(c) Each of the D-1 to D-7 finishes were applied to sections of three replicate boards.

(d) The rating was below "5" early in the exposure, then above "5." The value in the table is for the final drop below a rating of "5."

Table 7—Service Life (Years) of Solid-Color Stain (SCS) with a Water Repellent Preservative (WRP) Pretreatment Exposed Near Madison or Gulfport^a

Finish Number and Description ^{b,c}	Madison						Gulfport					
	Cracking			General			Cracking			General		
	FP	NP	ST	FP	NP	ST	FP	NP	ST	FP	NP	ST
E-1—White 78% S oil-based SB SCS	6	7	14 [8] ^d	6	7	14 [7]	7	7	12	1	3	9
E-2—White 45% S acrylic-based WB SCS	5	5	11	2	1	8	7	7	11	3	1	8
E-3—Tan 54% S oil-based SB SCS	6	6	12	8	8	11	7	7	12	1	1	9
E-4—Tan 39% S acrylic-based WB SCS	5	5	12	6	6	9	7	7	12	3	3	8
E-5—Red 55% S oil-based SB SCS	9	8	7	5	5	14 [8]	10	10	12 [9]	1	1	12 [7]
E-6—Red 38% S acrylic-based WB SCS	8	7	14 [6]	9	9	13	8	8	12 [7]	9	9	12
E-7—Red 55% S oil-primer + 38% S acrylic SCS	12	12	14 [9]	14 [6]	14 [6]	14 [8]	12 [6]	12 [6]	12 [9]	12 [6]	12 [6]	12 [7]

(a) Service life was determined on the basis of the average evaluations of general appearance.

(b) SB: solventborne; WB: waterborne; WR: water repellent; S: solids; STS: semitransparent stain; SCS: solid-color stain; TC: topcoat; FP: factory-planed flat-grained; NP: newly planed vertical-grained; ST: saw-textured.

(c) Each of the E-1 to E-7 finishes were applied to sections of three replicate boards.

(d) Value in brackets indicates that the rating was "B" after 14 years.

different and possibly less conducive to mildew growth—the major factor causing decrease in appearance evaluations. Some of the lightly pigmented finishes performed well for more than three years. Note, however, that the ratings were lower for the Gulfport site because of more mildew growth in the warm, moist climate. One of the finishes (A-11) showed poorer performance on the saw-textured bevel siding. However, in general, the type of surface (smooth-planed or saw-textured, vertical-grained or flat-grained) had little overall effect on the general appearance ratings of these finishes (Group A-1 to A-14), primarily because of mildew growth. It was difficult to differentiate among the various finish-substrate combinations because many of the finishes failed within one year.

Semitransparent Stains (Group B)

A typical example of the plots of finish general appearance ratings compared with time for the three types of substrate is shown in Figure 4. The bars indicate the standard deviation for the three replicates for each type of substrate. As with the Group A finishes, the service life was extracted from these plots and tabulated (Table 4). For example, values extracted from Figure 4 are shown in bold type in Table 4. Twenty-seven additional plots were used to obtain performance data on these seven finishes and are summarized in Table 4. Erosion and general appearance are shown in Table 4. It is inter-

esting that finish B-3 (oil-based solventborne semitransparent stain having 76% solids) had excellent performance for both erosion and general appearance in Madison, but performed poorly in Gulfport because of mildew growth.

All finishes performed better on the saw-textured bevel siding. Some of the finishes lasted more than 10 years (Table 4). The general appearance ratings were generally lower for the Gulfport site, particularly for two of the oil-based formulations (B-3 and B-4). In some cases, finishes on the factory-planed flat-grained siding gave better performance than on the newly planed vertical-grained siding, but this was not universal. No general trends were apparent other than the superior performance of all finishes on the saw-textured surfaces. In evaluating finish performance (Table 4) on the basis of formulation (Table 1), several observations can be made. These finishes perform poorly on smooth wood. They generally fail in appearance because of mildew growth prior to failing by erosion. There seems to be no correlation between the solids content and performance.

Solid-Color Stains, No WRP Pretreatment (Group C)

A typical example of the plots (Figure 5) and the service life (Table 5) for this group of finishes shows that the performance is excellent on the saw-textured

bevel siding. Many of the finishes lasted more than 12 years at both sites. The cracking ratings were "8" to "9" for many of the finishes. The general appearance ratings were also high for the Madison site (ratings of "5" to "7" after 12 years), but were slightly lower for some of the finishes (C-1, C-2, C-3, and C-4) at Gulfport because of mildew. Those finishes with red iron oxide pigments (C-5, C-6, and C-7) had higher ratings than the white-pigmented finishes. In general, the service life was slightly less on the newly planed bevel siding. The two-coat oil/latex finish system (C-7) gave excellent performance on all substrates at both sites. Finishes C5, C-6, and C-7 containing red pigment had higher appearance ratings at the Gulfport site, even on the smooth-planed siding. The dark color may have obscured the mildew growth.

Paints, No WRP Pretreatment (Group D)

Although Group D is labelled paints, D-1 and D-2 were solid-color stains. They were two-coat systems and thus had application rates similar to the paint systems (D-4–D-6) (Table 2). Figure 6 shows the paint cracking

ratings for an alkyd primer/acrylic topcoat paint system exposed near Madison. Almost all finishes lasted more than 14 years on all substrates at both sites (Table 6). However, the ratings were higher for finishes on the saw-textured bevel siding. Note that three ratings are marked with a superscript "d" [general appearance ratings for saw-textured surface for D-1, D-2, D-3, and D-6 exposed near Gulfport (Table 6)]. For these finish systems, the rating dropped below "5" during the first few years, then was above "5" for several years until the finish failed. The service life was determined from the second drop below "5." This type of inconsistent performance was caused by mildew. The mildew growth was severe during the early exposure period, probably because of the weather. As with the other finish systems, the general appearance ratings were less for the Gulfport site. The "cracking" evaluations for finishes D-3 and D-4 were rather surprising. Note that the service life was higher at Gulfport and Madison for the factory-planed flat-grained siding than for the newly planed vertical-grained siding. We have no explanation for this result and it is not consistent with the evaluation of the other five finish systems.

Table 8—Service Life (Years) of Paint with a Water Repellent Preservative (WRP) Pretreatment Exposed Near Madison or Gulfport^a

Finish Number and Description ^{b,c}	Madison						Gulfport					
	Cracking			General			Cracking			General		
	FP	NP	ST	FP	NP	ST	FP	NP	ST	FP	NP	ST
F-1-Red 55% S oil-based SCS (2 coats)	14 [7] ^d	14 [9]	14 [10]	14 [7]	14 [7]	14 [8]	14 [7]	14 [9]	14 [9]	14 [6] ^e	14 [6] ^e	14 [7] ^e
F-2-White 78% S oil-based SCS + 45% S acrylic SCS	11	13	14 [9]	10	9	14 [7]	13	8	12	10	9	10 ^e
F-3-White 80% S alkyd primer + 71% S alkyd TC	9	9	7	11	8	11	10	8	7	9 ^e	7 ^e	10 ^e
F-4-White 38% S latex primer + 46% S latex TC	14 [6]	14 [7]	14 [7]	11	14 [6]	24	8	8	8	9	9	10
F-5-White 48% S acrylic primer + 57% S acrylic TC	14 [9]	14 [9]	14 [10]	14 [7]	14 [9]	14 [8]	14 [9]	14 [6]	14 [6]	10 ^e	10 ^e	14 ^e
F-6-White 77% S alkyd primer + 57% S acrylic TC	11	14 [6]	14 [10]	10	14 [6]	14 [6]	14	10	10	8	8	10
F-7-White 74% S alkyd primer + 53% S acrylic TC	14 [9]	14 [9]	14 [10]	14 [7]	14 [7]	14 [7]	14 [9]	10	14 [6]	9	9	13

(a) Service life was determined on the basis of the average evaluations of general appearance.

(b) SB: solventborne; WB: waterborne; WR: water repellent; S: solids; STS: semitransparent stain; SCS: solid-color stain; TC: topcoat; FP: factory-planed flat-grained; NP: newly planed vertical-grained; ST: saw-textured.

(c) Each of the F-1 to F-7 finishes were applied to sections of three replicate boards.

(d) Value in brackets indicates that the rating was "7" after 14 years.

(e) The rating was below "5" early in the exposure, then above "5." The value in the table is for the final drop below a rating of "5."

Solid-Color Stains, with WRP Pretreatment (Group E)

The solid-color stains used in Group E were the same as those used in Group C, except that a WRP was applied to all 4-ft boards prior to applying the solid-color stain. For example, the performance of an oil-based solventborne solid-color stain with the WRP pretreatment (E-1, *Figure 7*) can be compared with the same solid-color stain without the pretreatment (C-1, *Figure 5*). The service life for all finish systems obtained from the "cracking" and "general appearance" ratings show that the performance of all finishes on the saw-textured bevel siding was about the same for Group C (no WRP, *Table 5*) and Group E (with WRP, *Table 7*). The results for the smooth-planed siding were quite different. In general, the service life was less for the Group E finish systems than for the Group C finish systems. This was quite surprising, as we expected better performance with the WRP pretreatment. The only explanation we can offer is that the amount of finish accepted by the planed surface following the WRP pretreatment was considerably less for many of the solid-color stains (*Table 2*). Little apparent difference was evident between the WRP-treated and untreated for the newly planed vertical-grained siding and the factory-planed flat-grained siding.

Paints, with WRP Pretreatment (Group F)

The finishes used in Group F were the same as those used in Group D, except that a WRP was applied to all 4-ft boards prior to applying the finishes. This is illustrated by comparing the WRP/alkyd primer/acrylic topcoat (F-6, *Figure 8*) with the same primer and topcoat without the WRP (D-6, *Figure 6*). In general, the performance of all finishes on all substrates was about the same for those 4-ft boards treated with the WRP pretreatment (Group F, *Table 8*) and those without the WRP pretreatment (Group D, *Table 6*) for both sites. This is in agreement with a previous study that showed little benefit from a WRP pretreatment on western redcedar, but did show considerable benefit for difficult-to-paint species, such as southern pine.⁹

CONCLUSIONS

In general, the performance of finish systems was far superior on the saw-textured bevel siding than on the smooth-planed siding. The exception to this was the

multi-coat solid-color stains and paint systems. These paint systems performed well on all substrates. There was little difference between the factory-planed flat-grained siding and the newly planed vertical-grained siding after 14 years of outdoor exposure near Madison and Gulfport. The dear and lightly pigmented water repellent preservatives used to refinish the bevel siding the second and third times performed better than the original formulations. It appears that those more modern formulations (those developed after 1995) were better than those developed in the late 1980s. On the basis of data obtained from this study, it appears that the WRP had no positive effect on the performance of finishes on the three different western redcedar substrates.

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