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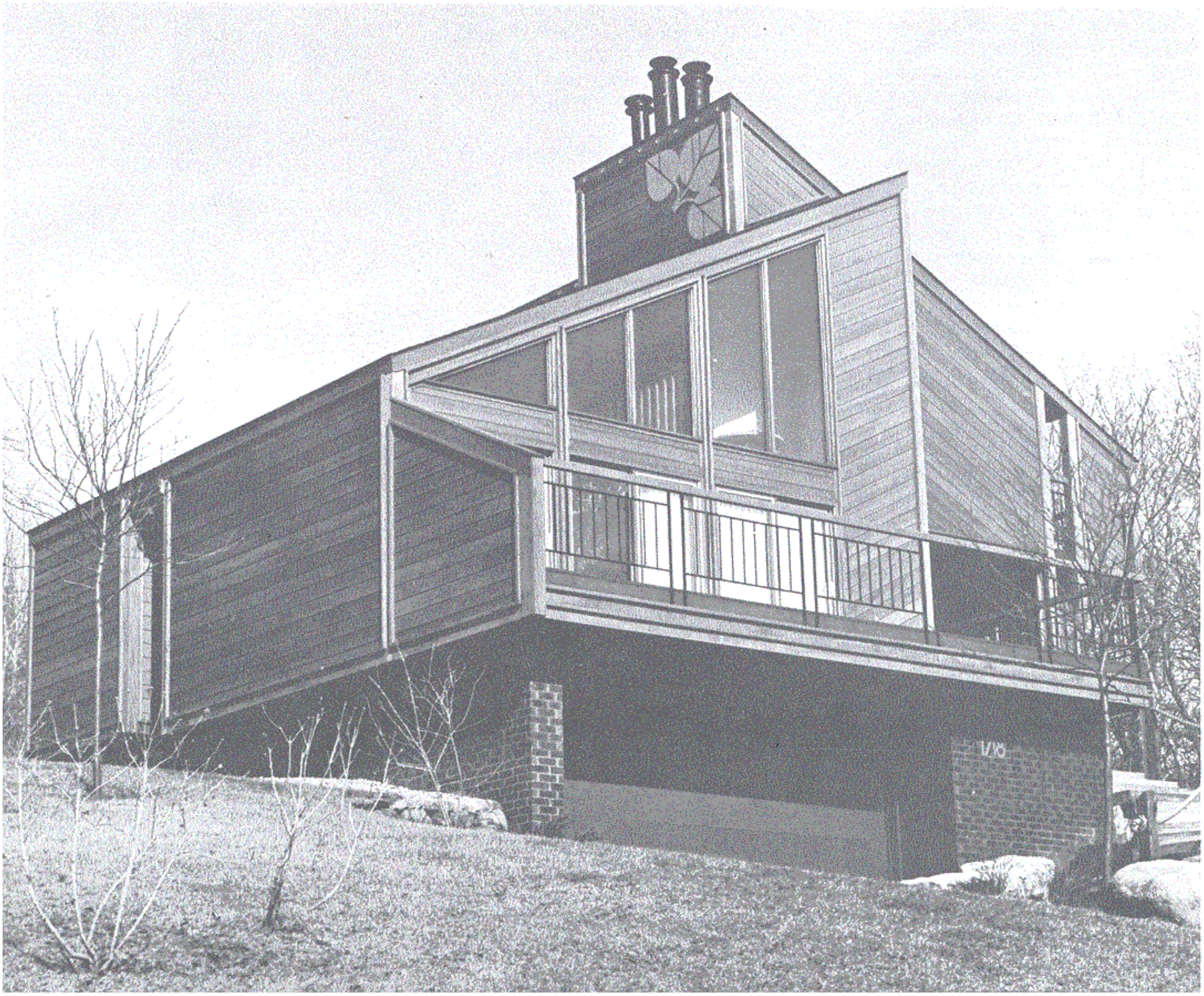
Durability of Exterior Natural Wood Finishes in the Pacific Northwest



ABSTRACT

There is a growing demand for natural exterior wood finishes that retain the original attractive appearance of wood with the least change in color and masking of grain. A number of experimental finishes are being evaluated for their performance in the cool, moist climate of Olympia, Wash. This study, started in 1966, has included observations on the weathering performance of 48 experimental finishes, both transparent and pigmented. Of these, 36 are still on exposure and inspected annually. Generally, water-repellent preservatives are the least durable of the natural finishes. Pentachlorophenol was the most effective mildewcide used in these finishes. Semitransparent, penetrating stains provide greater durability as compared to the transparent water-repellent preservatives. Stains containing only 20 percent binder provided excellent protection even after 8 years' exposure. Latex stains containing copper chromate were excellent durable natural finishes Simple water solutions of chromium-containing chemicals acted as durable "natural" finishes and were especially effective after one refinishing. These exposure results indicate that natural finishes for wood can be used successfully in climates where mildew growth is a problem and service lives of at least 6 years could be expected.

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By
WILLIAM C. FEIST, Chemist
EDWARD A. MRAZ, Technician

NATURAL WOOD FINISHES

In many locations throughout the United States, there is a continuing and growing trend toward the use of more natural colors and finishes to protect wood siding on the exterior of structures. Architects, builders, and owners are increasingly interested in the "natural look" for their homes, apartments, churches, and commercial buildings. A truly successful and ideal natural exterior wood finish is one which will retain the original, attractive appearance of wood siding with the least change in color and the least masking of wood grain and surface texture. The most natural appearance for wood would be achieved without a protective finish. Unfortunately, unprotected wood exposed outdoors is soon changed in appearance by the adverse effects of light, moisture, and the growth of micro-organisms on the surface (*4,9*).[2]

In outdoor weathering of smooth wood, original surfaces become rough as grain raises and the wood checks, and the checks sometimes grow into large cracks; grain may loosen, boards may cup and warp. and pull away from fasteners. The roughened surface changes color rapidly, gathers dirt and often mildews, and may become unsightly; the wood loses its surface coherence and becomes friable. Where salt in the atmosphere may inhibit excessive mildew growth, natural weathering may create a changed but desirable silvery appearance to the exposed wood. In dry climates (or cold), a rustic. brown-to-gray patina may result. In many humid locations, however, weathering is often accompanied by a surface growth of dark gray, blotchy mildew, which may remain unsightly until the wood has weathered for many years.

An ideal natural finish, therefore, should inhibit the growth of mildew micro-organisms, protect against moisture and sunlight, and not change surface appearance or color of the wood.

Types

Natural wood finishes fall into two broad classifications-film-forming and penetrating.

Film-forming

Varnishes are the primary transparent film-forming materials used for natural wood finishes, and their use greatly enhances the natural beauty and figure of wood. They lack exterior permanence unless protected from direct exposure to sunlight, and varnish finishes on wood exposed outdoors will generally require refinishing every 1 to 2 years.

Penetrating

The penetrating finishes are the second broad classification of natural wood finishes. These finishes do not form a film on the wood surface and are further divided into (1) transparent or clear systems and, (2) pigmented or semitransparent systems.

Transparent.– Water-repellent preservatives (WRP) (5) are the most important of the transparent penetrating systems. It has been found that treating wood surfaces with WRP will protect wood exposed outdoors with little change in appearance. A clean, golden-tan color can be achieved with most wood species. The treatment reduces warping and cracking, and prevents water staining at edges and ends of wood siding, and helps to control mildew growth. The first application of WRP may protect exposed wood surfaces for only 1 to 2 years, but subsequent reapplications may last 2 to 4 years. depending on exposure.

Semitransparent.– The semitransparent stains (*2*) are the second of the penetrating natural wood finishes. These stain finishes provide a less natural appearance because they contain pigment and mask the original grain and color of the wood. They are

[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
[2]Italicized numbers in parenthesis refer to literature cited at end of report.

generally much more durable then are varnishes or WRP's and provide more protection against weathering. With these stain systems, weathering is slowed by retarding the alternate wetting and drying of wood end the presence of pigments on the wood surface minimizes the degrading effects of sunlight. The amount of pigment in the semitransparent steins varies considerably, and different degrees of protection against ultraviolet degradation end masking of the appearance of the original wood surface can be achieved.

Latex stains are also described as semitransparent. These pigmented "natural" finishes are generally nonpenetrating but do retain the surface texture of the wood. Several pigmented semitransparent latex steins are included in this study.

Waterborne salts.–Waterborne inorganic salts (3) are a special group of penetrating finishes. These surface treatments which result in a natural finish are related to the semitransparent penetrating finishes, since they change the color of the wood end leave a surface deposit of material similar to the pigment found in the semitransparent steins.

Opaque Stains

Solid-color or opaque steins are another classification of finishes sometimes described as natural wood finishes. These finishes are high in pigment content end completely mask the color and figure of the wood. Surface texture is retained end these generally nonpenetrating finishes yield a flat appearance. They do protect wood against ultraviolet degradation, but tend to perform more like paints in that they do not penetrate the wood surface to any degree. The remainder of this publication will be concerned with the performance of the penetrating finish systems, both clear end semitransparent. No opaque or solid-color systems were investigated.

Advantages of Penetrating Stains

Penetrating exterior wood finishes offer many advantages for protecting exposed wood. They (1) provide a natural appearance; (2) do not peel or blister since they do not form a surface film or coating; (3) are especially durable and well suited for rough-textured surfaces, severely exposed horizontal wood surfaces (decks, railings, end steps), and perform well on knotty, flat-grained surfaces; (4) often contain water repellents which inhibit the rapid pickup of rein end dew; (5) do not trap moisture in wood which may encourage decay; end (6) are easily applied and renewed.

FPL Research

The Forest Products Laboratory (FPL) has a long history of research on finishes end surface treatments that enable wood to provide greater serviceability end more user satisfaction (23.6). An outdoor exposure site in the Pacific Northwest at Olympia, Wash.. is used to study the performance of natural finishes in that cool, moist climate. Such climate often results in excessive mildew growth end special challenge to the performance of natural finishes. Previous publications in this study initiated in 1966 describe exposure results up to 1975 (*7,8*). This report summarizes exposure results of a number of finishes applied in 1974 as well as continuing exposure results on finishes applied in 1966, 1970, 1972, and 1973, some of which were subsequently refinished.

The objective of this research is to evaluate the weathering performance of "natural" exterior finishes that protect the wood surface from the deteriorating effects of sunlight, moisture, and the growth of mildew. Systems included are (a) water solutions of inorganic salts (*3*) that absorb ultraviolet light and protect surface wood fibers from photodegradation, (b) pigmented oil or latex stains which retard the penetration of ultraviolet light, and(c) transparent WRP finishes (*5*). These lest are included because of their ability to retard mildew growth and control water penetration.

TEST PROCEDURES, MATERIALS, METHODS

Exposure Panels

Three species of wood siding with both rough end smooth surfaces. installed vertically end horizontally on a test panel, were exposed on a test fence et 90° facing south at Olympia, Wash.

Table 1.–*Water-repellent preservative formulation*

Finish No.	Composition (weight percent)									
	Boiled linseed oil	Exterior varnish[1]	Silicone resin[2]	Penta-chloro-phenol	Mercury[3]	TBTO[4]	Zinc[5]	Cobalt[5]	Paraffin wax	Volatiles[6]
2	10.0	—	—	5.0	—	—	—	—	0.5	84.5
3a	—	10.0	—	—	—	—	1.5	1.5	.5	86.5
4	—	—	—	—	—	—	1.5	1.5	.5	96.5
13a	—	10.0	5.5	8.0	—	—	—	—	.5	76.0
17	—	—	—	5.0	—	—	1.5	1.5	.5	91.5
18	10.0	—	—	9.5	0.5	—	—	—	.5	79.5
19a	—	10.0	—	5.0	—	—	1.5	1.5	.5	81.5
20	—	20.0	—	9.5	.5	—	—	—	.5	69.5
25a	10.0	—	—	—	—	2.0	—	—	.5	87.5
31	—	10.0	5.5	—	—	2.0	—	—	.5	82.0
35	—	10.0	—	—	—	2.0	1.5	1.5	.5	84.5
36	—	20.0	—	—	—	2.0	—	—	.5	77.5
37	—	20.0	—	8.0	—	—	—	—	.5	71.5

[1]Mautz Paint Company exterior Polyurethane, 50 percent solids.
[2]Dow Sylgard 184.
[3]Metasol 57 (Phenyl mercury propionate).
[4]Bis (tri-n-butyltin) oxide.
[5]Metallic zinc or colbalt as naphthenate.
[6]Solvents, primarily mineral spirits.

Table 2.–*Semitransparent penetrating stain and latex stain formulations*

Finish No.	Composition (weight percent)											
	Boiled linseed oil	Alkyd varnish[1]	Urethane varnish[2]	Acrylic resin[3]	Vinyl resin[4]	Penta-chloro-phenol	Paraffin wax	Pigment[5]	Copper chromate	Water	Volatiles[6]	Pigment volume concen-tration[7]
7a	—	—	—	14.8	—	—	—	5.8	—	79.4	—	5
8a	—	—	—	10.8	—	—	—	10.3	—	78.9	—	10
9a	—	—	—	7.5	—	—	—	13.7	—	78.8	—	15
10a	—	—	—	5.0	—	—	—	16.7	—	78.3	—	20
11a	—	—	—	2.8	—	—	—	18.9	—	78.3	—	25
12a	—	—	—	.7	—	—	—	21.4	—	77.9	—	30
21	20.0	—	—	—	—	10.0	1.0	10.0	—	—	59.0	—
22	20.0	—	—	—	—	5.0	1.0	10.0	—	—	64.0	—
23	—	25.0	—	—	—	10.0	1.0	10.0	—	—	54.0	—
24	—	—	25.0	—	—	10.0	1.0	10.0	—	—	54.0	—
28	—	—	—	—	10.0	—	—	10.0	8.7	71.3	—	—
29	—	—	—	10.0	—	—	—	10.0	10.0	70.0	—	—
32	—	—	—	—	10.0	—	—	10.0	—	80.0	—	—

[1]Mautz Exterior, V 103, 50 percent solids.
[2]Cargill 1210, 50 percent solids.
[3]Rohm and Haas AC-388.
[4]Elmer's Glue-All.
[5]Universal colors, 50 percent solids.
[6]Solvents, primarily mineral spirits.
[7]Determined by dividing the volume of pigments alone by the combined volume of resin plus pigments and multiplying by 100.

All specimens with a given finish were grouped in one composite panel on the test fence as shown in figure 1. Construction details were described earlier (8). The three wood species used were Douglas-fir plywood (*Pseudotsuga menziesii* (Mirb.) Franco); redwood (*Sequoia sempervirens* (D. Don) Endl.); and western redcedar (*Thuja plicata Donn*).

Wood Finishes

All natural finishes included in this study were prepared at the Forest Products Laboratory. Three general types were included: (1) WRP'S; (2) stains, both semitransparent penetrating (solventborne) and latex (waterborne); and (3) water solutions of inorganic salts. Compositions of the finishes evaluated are shown in tables 1 through 3. Each finish is identified by a number for convenience. Subsequent reference to any finish will be by the use of its identification number. Identification numbers are identical to those used in the last report on this subject (*7*). Numbers with an "a" suffix represent finishes which replaced those described earlier (7.8). These "a" finishes were applied over new panels of the three wood species. All finishes were applied by brush, using spreading rates of 200 to 250 square feet per gallon.

Several finishes investigated included surface pretreatment and finishing. Finish No. 30 was a combined treatment. The panel was first treated with a water solution containing copper sulfate and sodium dichromate. (Referred to for convenience as copper chromate.) After a 24-hour drying period, the surface-treated panel was finished by brush application of two coats of an aqueous suspension containing acrylic latex resin (Rohm and Haas Co., AC-388, 62 grams) and boiled linseed oil (33 g) (48 hours of drying between coats). A wood surface pretreatment was also included in the latex stain finish evaluations (7a to 12a). One-half of each portion of the vertical and horizontal boards on the test panels was brush-treated with a water solution of copper chromate (9.9 g of $CuSO_4 \cdot 5 H_2O$, 5.9 g of $Na_2Cr_2O_7 \cdot 2 H_2O$, and 84.2 g of H_2O). The treated surface was allowed to dry for 48 hours and the latex stain then applied.

Table 3.–*Waterborne inorganic salt composition*

Component	Finish number										
	5a	6	14	15	16-1[1]	16-2	26	27	30[2]	33	34
	Percent by weight										
As_2O_5	—	—	—	2.3	—	—	2.4	—	—	—	—
Citric acid	—	0.2	—	—	—	—	—	—	—	—	—
CrO_3	—	—	5.0	5.0	—	—	—	—	—	—	—
$CuCl_2$	—	—	—	—	—	4.2	—	—	—	—	—
$CuSO_4 \cdot 5H_2O$	15.5	6.0	12.7	4.0	—	—	10.5	10.5	14.0	14.0	14.0
$Na_2Cr_2O_7 \cdot 2H_2O$	—	6.0	—	—	—	—	2.1	—	5.0	5.0	5.0
$Na_2CrO_4 \cdot 4H_2O$	4.9	—	—	—	—	—	—	3.3	—	—	—
$Na_2HAsO_4 \cdot 7H_2O$	—	—	—	—	—	—	—	6.6	—	—	—
NH_4OH (30 pct NH_3)	31.0	0.2	20.7	15.4	2.9	7.8	—	21.0	—	—	—
Resorcinol	—	—	—	—	—	—	—	—	—	5.0	10.0
Sodium penta[3]	—	—	—	—	4.5	—	—	—	—	—	—
Water	48.6	87.6	61.6	73.3	92.6	88.0	85.0	58.6	81.0	76.0	71.0

[1]Finish 16-1 applied, allowed to air dry, and finish 16-2 then applied.
[2]Clear finish consisting of 2 coats of acrylic resin (62 g) and linseed oil (33 g) applied after treatment with inorganic salt.
[3]Sodium salt of pentachlorophenol.

Evaluation of Finishes

All test panels are inspected annually. The WRP-finished panels were evaluated by assigning a rating to each species on the panel based on the amount of graying (mildew growth) and surface roughening observed. Separate values were assigned to rough and smooth boards. The rating system used was based on a descending scale from 10 to 0; 10 represents no graying and 0 represents a totally grayed panel with heavy mildew growth. A photographic representation of each of the values from 10 to 0 was used for reference similar to those used for the American Society for Testing and Materials (ASTM) tests for chalking (D 659-74). checking (D 660-44), cracking (D 661-

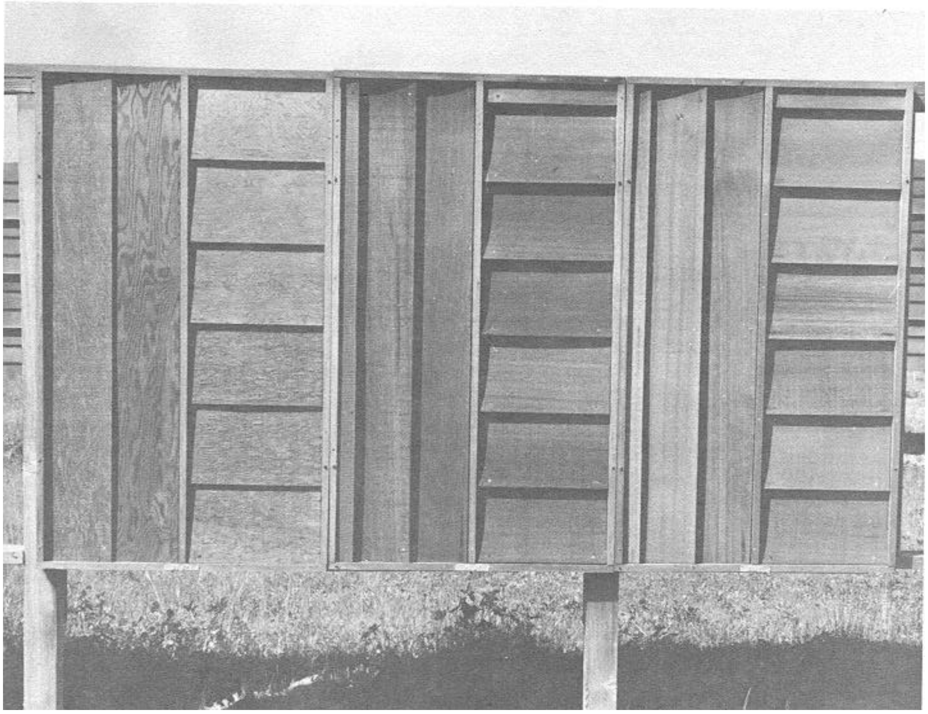

Figure 1.–Typical test panel on exposure fence. Left one-third, Douglas-fir plywood; center one-third, redwood; right one-third, western redcedar. (Panel dimension: 4 feet 6 inches high; 8 feet wide.)
(M 147 122-20)

Table 4.–*Finish performance ratings*

Numerical rating	Mildew growth[1]	General appearance rating
	Pct of surface area	
10	0	Excellent (E)
9	10	Excellent (E)
8	20	Very good (VG)
7	30	Very good (VG)
6	40	Good (G)
5	50	Good (G)
4	60	Fair (F)
3	70	Fair (F)
2	80	Poor (P)
1	90	Poor (P)
0	100	Poor (P)

[1]Similar values assigned to samples to evaluate erosion were based on photographic representations for each value (1).

44), erosion (D 662-44), blistering (D 714-56). and flaking (D 772-47) (*1*). The mildew-growth rating values for rough/ smooth boards and for each of the three species were totalled end values compared between panels. For convenience, these combined 10 to 0 scale ratings were converted to an overall general appearance scale of excellent, very good, good, fair, end poor (table 4). Semitransparent stains, latex steins, and inorganic-salt finishes were evaluated by the degree of erosion of the finish (weathering) es well es by surface mildew growth. As with the WRP, values from 10 to 0 were assigned, depending on panel condition. Values were combined end compared with other panels. Excellent to poor overall ratings were assigned for convenience in discussing results. Evaluations since the start of the study are shown in tables 5 and 6.

RESULTS AND DISCUSSION

Water-Repellent Preservatives

Water-repellent preservatives are unpigmented and rely on a preservative or mildewcide to prevent growth of mildew and subsequent graying of wood. The water repellent (often paraffin wax) in the finish reduces penetration of water, particularly into the end grain, minimizing staining end reducing decay (*5*). The WRP usually contains a small amount of resin or binder (drying oil) which helps to hold the fungicide and wax in the wood and retards finish degradation on the wood surface. All WRP's currently in test were formulated using 0.5 percent paraffin wax and mineral spirits as solvent (table 1).

Finish No. 2 contains 5 percent pentachlorophenol and 10 percent boiled linseed oil. This formulation was used to represent a typical WRP (*5*) for comparison with other WRP's evaluated. As seen in table 5, the overall perfomance of this WRP is judged fair in resistance to mildew growth after 12 years of exposure end three refinishings. The test panel has retained **a** somewhat uneven brown appearance even though 4 years have elapsed since the last refinishing (table 6).

Finish No. 4. formulated with zinc and cobalt naphthenetes, was reasonably effective in performance. A fair performance rating has been maintained in the 4 years since the third refinishing. This simple treatment results in a soft, bleached appearance versus the uneven brown of the standard WRP, No. 2. Addition of 5 percent pentechlorophenol to the zinc and cobalt naphthenate finish (No. 17) greatly improved mildew resistance and resulted in a panel with attractive brown color even with 4 years of exposure since the last refinishing (table 6). Other modifications of the zinc and cobalt naphthenete-containing finishes, No. 3a with added exterior varnish and No. 19a with both exterior varnish end 5 percent pentachlorophenol, have been exposed for 6 years. The improved performance of the zinc and cobalt naphthenete with added pentechlorophenol indicates that this letter mildewcide is probably necessary for effective resistance to mildew growth end graying in the Pacific Northwest.

A WRP containing 8 percent pentachlorophenol (No. 37) performed similar to No. 2, which contained 5 percent. This WRP finish was more effective then finish No. 2 in preventing graying and after 4 years of exposure and no refinishing, it still rated fair in overall appearance and has a somewhat uneven brown color with about 30 percent graying. Replacement of part of the varnish resin with a silicone (No. 13a) resulted in improved performance compared to No. 37; a more even, very soft brown appearance resulted with about 20 percent graying apparent. The silicone addition probably resulted in greater water repellency and reduced mildew growth.

Light additions of mercury-containing mildewcide (0.5 pct phenyl mercury propionate by weight) were used in combination with 9.5 percent pentachlorophenol (Nos. 18, 20). Both finishes, using boiled linseed oil or exterior varnish as binder, are rated es very good 4 years after the last refinishing. Test panels have a slightly uneven soft brown appearance. No additional experiments are planned with mercury-containing mildewcides since these materials are no longer permitted in solvent-based finishes.

The remaining four WRP's under evaluation contained 2 percent bis (tri-n-butyltin) oxide (TBTO). Performance after 1 year of exposure was very good but mildew growth became quite rapid after that (finish Nos. 25a, 31, 35, 36). Mildew growth after 3 years of exposure was very heavy for all but finish No. 31 which contained a silicone. All four finishes were rated poor after 4 years of exposure. While the TBTO-containing WRP's were effective after 1 year of exposure, mildew growth became very rapid thereafter and the test panels were much darker and more uneven than untreated controls of the panels with finish No. 2, which contained 5 percent pentachlorophenol.

The best of the WRP's evaluated-Nos. 17, 18, 19a, and 20–maintained a clean, relatively natural appearance, free of mildew growth, on all boards in the test panels for 4 years after refinishing. Performance was best on Douglas-fir. followed closely by western redcedar and finally by redwood (table 6). The pentachlorophenol-containing finishes (Nos. 18 and 20) gave all three test species a slight golden-brown cast; addition of zinc and cobalt naphthenate to the pentachlorophenol gave a light, bleached effect. Generally, several years of weathering were required to achieve the fully developed patina of the WRP-type natural finish.

Semitransparent Penetrating Stains

The performance of the proven FPL natural finish (*2*) on exposure in Olympia, Wash., was described earlier (*7*). This high-solids stain (linseed oil) had excellent ratings after 7 years of exposure. Four finishes currently being evaluated (Nos. 21 to 24) are variations of the FPL natural finish. These were formulated with reduced linseed oil content as well as replacement binders to evaluate if the changes would enhance performance and reduce mildew growth (table 2). After 9 years' exposure, finish No. 21, formulated with 20 percent linseed oil and 10 percent pentechlorophenol, is rated excellent in performance followed closely by No. 22, which contains 5 percent pentachlorophenol, and No. 23, which had the linseed oil totally replaced by 25 percent alkyd varnish (the varnish contained 50 percent solids, so in reality only 12.5 percent varnish resin is in No. 23). Formulation No. 24 contained 25 Percent of a polyurethane varnish (12.5 pct resin) and did not perform quite es well as the other three semitransparent penetrating stains. Generally, performance of these four finishes corresponds very well to the Performance of the FPL natural finish even after 6 years of exposure since the first refinish was applied (*7*).

Differences in performance of the four modifications of the FPL natural finish were most pronounced, particularly on smooth wood surfaces, after the first 3 years of weathering (table 5). Smooth wood surfaces are less absorptive than are rough sawed

Table 5.–*Condition of test panels*[1]

Finish No.	Years of exposure											
	1	2	3	4	5	6	7	8	9	10	11	12
					WATER-REPELLENT PRESERVATIVES							
2	E	P[2]	F	F	F	F[2]	F	F[2]	F	F	F	F
3a	E	F[2]	G	G	F	F	—	—	—	—	—	—
4	VG	G	F[2]	F	F	F[2]	G	P[2]	F	F	F	F
13a	E	VG	VG	G	—	—	—	—	—	—	—	—
17	E	VG	G[2]	VG	VG[2]	VG	VG	VG	VG	—	—	—
18	E	VG	VG[2]	VG	VG[2]	VG	VG	VG	VG	—	—	—
19a	E	VG[2]	E	E	VG	VG	—	—	—	—	—	—
20	E	VG	VG[2]	VG	VG[2]	VG	VG	VG	VG	—	—	—
25a	VG	F	P	P	—	—	—	—	—	—	—	—
31	VG	G	F	P	—	—	—	—	—	—	—	—
35	VG	F	P	P	—	—	—	—	—	—	—	—
36	VG	F	P	P	—	—	—	—	—	—	—	—
37	E	VG	VG	F	—	—	—	—	—	—	—	—
					SEMITRANSPARENT PENETRATING STAINS							
21	E	E	VG[2]	E	E	E	E	E	E	—	—	—
22	E	VG	P[2]	E	E	VG	VG	E	VG	—	—	—
23	E	VG	P[2]	E	E	E	E	VG	VG	—	—	—
24	E	E	G[2]	E	E	E	VG	G	G	—	—	—
					LATEX STAINS[3]							
7a	E/E	E/VG	E/G	VG/F	VG/F	—	—	—	—	—	—	—
8a	E/E	E/VG	E/G	VG/F	VG/F	—	—	—	—	—	—	—
9a	E/E	E/VG	E/G	VG/G	VG/G	—	—	—	—	—	—	—
10a	E/E	E/E	E/G	VG/G	VG/G	—	—	—	—	—	—	—
11a	E/E	E/E	E/G	VG/G	VG/G	—	—	—	—	—	—	—
12a	E/E	E/E	E/G	VG/G	VG/G	—	—	—	—	—	—	—
28	E	E	VG	VG	—	—	—	—	—	—	—	—
29	E	E	E	E	—	—	—	—	—	—	—	—
32	E	E	VG	G	—	—	—	—	—	—	—	—
					WATER SOLUTIONS—INORGANIC SALTS							
5a	E	E	VG	G	G	F	—	—	—	—	—	—
6	VG	G[2]	VG	VG	VG	VG[2]	VG	VG	VG	VG	VG	VG
14	VG	VG	G[2]	G	VG	VG	VG	G	G	—	—	—
15	G	G	F[2]	E	E	VG	E	VG	VG	—	—	—
16	VG	G	G[2]	VG	E	VG	G	G	G	—	—	—
26	G	F	P[2]	VG	G	VG	E	VG	E	—	—	—
27	VG	VG	VG[2]	VG	VG	VG	E	VG	E	—	—	—
30[4]	E	E	E	E	—	—	—	—	—	—	—	—
33	E	VG	G	F	—	—	—	—	—	—	—	—
34	E	E	VG	G	—	—	—	—	—	—	—	—

[1]Overall appearance of panel as affected by mildew and erosion. E = excellent; VG = very good; G = good; F = fair; P = poor.
[2]Refinished.
[3]Rating on left was performance over pretreated wood; on right, over untreated wood.
[4]Surface-treated panel was finished with clear, acrylic resin.

Table 6.—*Finish performance on three wood species*

Finish No.	Total years of exposure	Number of finish coats or refinishes applied	Years of exposure since last finish	Condition of test panel[1]			
				Douglas-fir	Redwood	Western redcedar	Overall
				WATER-REPELLENT PRESERVATIVES			
2	12	4	4	F	F	F	F
3a	6	2	4	VG	F	F	F
4	12	4	4	G	F	F	F
13a	4	1	4	E	F	P	G
17	9	3	4	E	G	VG	VG
18	9	3	4	VG	G	VG	VG
19a	6	2	4	E	VG	VG	VG
20	9	3	4	E	G	VG	VG
25a	4	1	4	F	P	P	P
31	4	1	4	F	P	P	P
35	4	1	4	F	P	P	P
36	4	1	4	F	P	P	P
37	4	1	4	G	F	F	F
				SEMITRANSPARENT PENETRATING STAINS			
21	9	2	6	E	E	E	E
22	9	2	6	E	VG	G	VG
23	9	2	6	G	VG	VG	VG
24	9	2	6	F	G	G	G
				LATEX STAINS[2]			
7a	5	1	5	VG/F	VG/G	G/F	VG/F
8a	5	1	5	VG/F	VG/G	G/F	VG/F
9a	5	1	5	E/G	VG/G	G/F	VG/G
10a	5	1	5	E/G	VG/VG	VG/G	VG/G
11a	5	1	5	E/VG	VG/VG	VG/G	VG/G
12a	5	1	5	VG/VG	VG/VG	G/G	VG/G
28	4	1	4	VG	VG	G	VG
29	4	1	4	E	E	E	E
32	4	1	4	F	VG	G	G
				WATER SOLUTIONS—INORGANIC SALTS			
5a	6	1	6	E	F	G	G
6	12	3	6	E	VG	VG	VG
14	9	2	6	VG	F	G	G
15	9	2	6	E	G	VG	VG
16	9	2	6	VG	F	G	G
26	9	2	6	E	E	E	E
27	9	2	6	E	E	E	E
30	4	1	4	E	E	E	E
33	4	1	4	VG	F	P	F
34	4	1	4	VG	F	G	G

[1]Overall appearance of panel as affected by mildew and erosion: E = excellent; VG = very good; G = good; F = fair; P = poor.
[2]Rating on left was performance over pretreated wood; on right, over untreated wood.

and show earlier failure of the initial stain finish. In refinishing, surfaces initially smooth but roughened by weathering are more absorptive and stains performed much the same on all surfaces. Six years after refinishing, all the modified FPL stains compare favorably with the FPL natural finish. In general, these oil- or varnish-base semitransparent stains have provided at least twice the service life of the transparent WRP finishes. The pigmented stains, however, obscure part of the wood grain and do not provide as natural a finish as do the WRP's.

Latex Stains

Finish Nos. 7a to 12a were formulated from acrylic latex resin and pigment to cover pigment volume concentration (PVC) of 5 to 30 percent (table 2) (*6*). In addition to evaluating the effect of PVC on stain performance, these stains were applied over both copper chromate-treated wood (*3*) and untreated wood. The copper chromate pretreatment has been shown to be highly effective in extending the life of applied finishes (*3,6*). All six of these latex stains performed well over both treated and untreated wood for 2 years (table 5). After that, performance on untreated and particularly untreated smooth wood declined. After 5 years. however, stain performance on the treated portion of all six test panels is still rated very good, indicating the effectiveness of the copper chromate surface pretreatment.

When copper chromate was added directly to a latex stain formulated from a polyvinyl acetate latex (No. 28) or an acrylic latex (No. 29), a very durable finish resulted. After 4 years of exposure. panels finished with these two modified stains are rated very good to excellent. By comparison, a simple polyvinyl acetate latex-stain system without added copper chromate has fallen to a rating of good after 4 years of exposure.

Water Solutions–Inorganic Salts

Increased use of waterborne preservatives for treatment of structural wood has created an awareness of the attractiveness of some treatments. In addition, the efficacy of copper as a fungicide and chromium in protecting wood surfaces against degradation by ultraviolet light, makes waterborne preservatives containing these metals of particular interest. The water-soluble salt finishes currently being evaluated at the Olympia, Wash., exposure site include several formulations containing copper and chromium (copper chromate).

The copper chromates have been shown to impart some exceptional protection to exposed wood in other studies conducted by FPL (*3,6*). Finish formulations based on these earlier studies were prepared for evaluation in the study reported here. Finishes evaluated include three copper chromate formulations, three chromated copper arsenate, one copper pentachlorophenate, one copper chromate covered with a clear linseed oil-modified acrylic latex, and two copper chromates modified with resorcinol (table 3).

Although copper chromate treatments impart beneficial mildewcide and weathering protection properties when used as exterior wood finishes, there are some problems due to the nonuniform appearance of the wood treated with some solutions. Solutions containing ammonia are very nonuniform on redwood, although less so on western redcedar and Douglas-fir, particularly during early weathering months after initial application. Appearance improves with age. Acid copper chromate (no added ammonia) finishes are generally uniform and attractive initially but are somewhat less durable than the corresponding ammoniacal copper chromate finishes. Performance of all finishes improves markedly on refinishing.

Of 10 waterborne salt finishes being evaluated (table 3). those that offer the best appearance and durability are:

(1) Acid copper chromate (No. 6) formulated with equal weights of copper sulfate and sodium dichromate. This finish is rated very good 6 years after its second refinishing (table 5). The son green-brown panels are very uniform with slight mildew growth. This finish was first applied in 1966.

(2) Chromated copper arsenate (No. 15) in ammoniacal solution. This finish has produced an even, son, green-brown appearance.

(3) Chromated copper arsenates (Nos. 26 and 27) with a high copper ratio (compared to No. 15). These finishes have excellent ratings and have developed an even green-brown to brown appearance. Their general appearance has improved with exposure and No. 27 has essentially lost its early nonuniform appearance (*7*). The copper chromate and chromated copper arsenate formulations are similar to standard wood preservatives with established performance records. With these finishes, erosion of the wood surface is slight compared with that of other classes of experimental finishes on exposure.

The ammoniacal copper chromate with high copper content (No. 5a) performed very well for the first 5 years of exposure (table 5). This rating has fallen to fair with some mildew growth apparent; panel color is uniform. however. Performance on Douglas-fir is still excellent in the sixth year (table 6). Finish No. 14, also an ammoniacal copper chromate, has slight mildew growth but an even green-brown color. Panels were refinished 6 years ago and performance is rated as good. Like the semitransparent stains. the copper chromate treatments have increased durability when applied to rough, weathered wood as compared to smooth wood, and service lives of at least 6 years are possible.

Addition of resorcinol to a copper chromate (Nos. 33 and 34) was investigated in an attempt to improve the overall color and evenness of the finishes. Performance after 4 years of exposure is rated only fair to good. Mildew growth is apparent and panels are an uneven. somewhat unpleasant brown. A clear. oil-modified acrylic latex applied over a copper chromate treatment (without resorcinol) resulted in an excellent finish rating (No. 30). Unfortunately, the panel is a dark green-brown with little of the original wood color remaining. The treatment was very effective in protecting against ultraviolet degradation as was found earlier (3).

The only finish not containing chromium was the two-component copper-pentachlorophenate (No. 16). After 8 years and one refinishing, this finish shows some blotchiness and mildew growth. This finish initially provided a more uniform, natural tan appearance than did either the copper chromate or chromated copper arsenate finishes. Best performance was on Douglas-fir plywood. Nail staining and mildew growth detracted from the performance on redwood.

FINISH PERFORMANCE ON DIFFERENT SPECIES

The evaluation of natural finishes at the Olympia, Wash., exposure site was conducted on three representative exterior cladding-grade wood siding materials: Douglas-fir plywood, redwood board, and western redcedar board. In general, Douglas-fir plywood panels used in this study provided the best substrate for the performance of the natural finish WRP's (table 6). Redwood and western redcedar boards selected for the study were consistently more prone to mildew growth. Performance of the Douglas-fir plywoods finished with water solutions of inorganic salts was also better than for the boards of the other species. Finish performance with pigmented stains was essentially consistent for all three siding materials evaluated. Finishes on vertically oriented boards performed better than on horizontal ones. As indicated earlier, all finishes performed better when applied to rough-textured (either rough-sawed or weathered) surfaces than on smooth surfaces.

CONCLUSIONS

Three classes of natural wood finishes with several variations are undergoing exposure, on three wood species, to the mild, moist climate of the Pacific Northwest at Olympia, Wash. Transparent water-repellent preservatives (WRP) preserve the natural color and grain of exposed wood. Initial treatments last only 2 to 3 years in this climate, but durability and performance increase to 3 to 5 years after refinishing. Mildew growth and unsightly graying are controlled by the preservative in the formulation. Of those preservatives examined, pentachlorophenol was the most effective. Pentachlorophenol-based finishes tend to add a golden-brown cast to the wood surface, while zinc and cobalt naphthenate-base finishes tend to slightly bleach the original color of Douglas-fir. redwood, and western redcedar.

The second of the natural finish systems, semitransparent penetrating stains, offer greater protection to exposed wood against degradation by sunlight. These oil-base pigmented stains promise excellent serviceability. They change the original color of the wood to some extent but provide better durability than do WRP's.

Increasing the pentachlorophenol fungicide content from 5 to 10 percent and decreasing the binder content (linseed oil or exterior varnish) in oil-base stains from 60 to 20 percent did not significantly alter performance. These semitransparent stains have provided an excellent finish for 6 years since being refinished. Latex stains, related to the semitransparent oil-base stains, do not penetrate wood substance to any degree but have performed well, particularly over surfaces treated with copper chromate or when copper chromate was added directly to the formulation.

Water-soluble salts of chromium and copper (copper chromate) as well as chromated copper arsenate wood preservative are excellent natural finishes and provide outstanding resistance to mildew attack and to degradation by sunlight comparable to the semitransparent stains. They do change the wood color and initial finishes may tend to be uneven in appearance. Appearance improves with time (especially after refinishing) as the chemical residue on the wood surface weathers away. Of the experimental water-soluble salt finishes exposed at Olympia, a copper chromate and chromated copper arsenate finish were found to be the most durable and attractive. Overall performance ratings of very good to excellent have been observed with these water-soluble finishes 6 years after refinishing.

Except for the latex-based finishes, all the natural finishes described are penetrating systems ideally suited for use on wood siding, particularly if the siding is rough and/or weathered. The solvent-based finishes are excellent on exposed horizontal wood surfaces such as decks, stairways, and railings. These penetrating finishes are particularly attractive and durable on rough-sawed or weathered wood surfaces, including plywood. They do not offer the same degree of protection from surface checking as do film-forming impervious finishes (paints), but they do not blister or peel even in severe moisture conditions and are easily refinished. In all systems evaluated, performance and durability were increased on refinishing the weathered wood surfaces.

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