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Effectiveness of Fire-Retardant Treatments for Shingles After 10 Years of Outdoor Weathering

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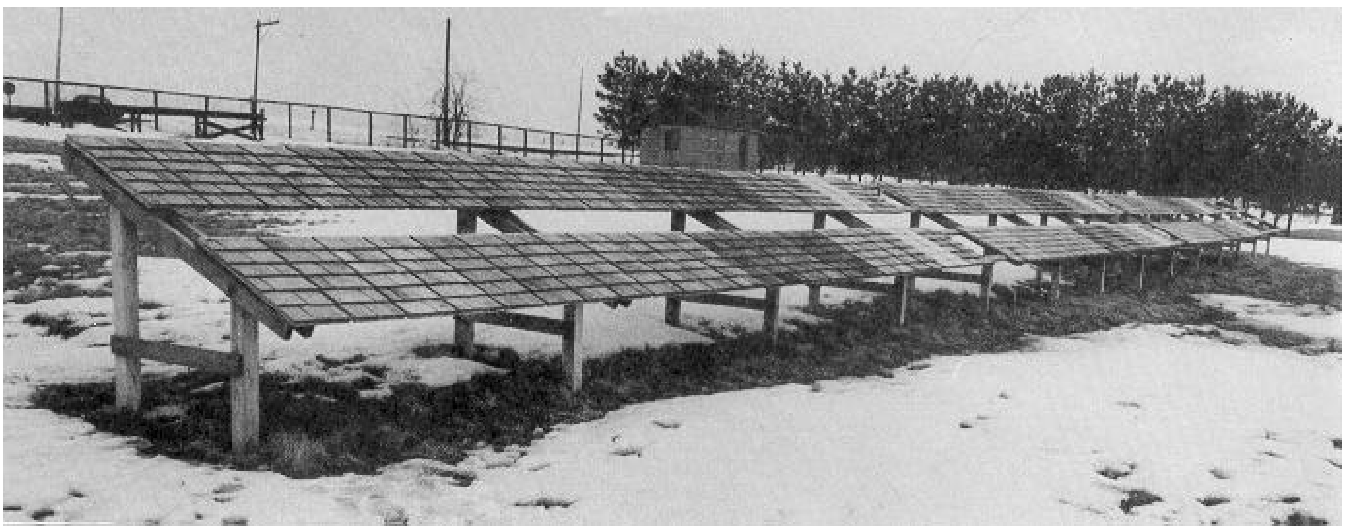

Abstract

Some building codes require wood shingles to be fire-retardant treated. Because exterior fire-retardant treatments are subjected to weathering, treatment durability and leach resistance are critical for insuring adequate fire protection. We examined the effectiveness of various fire-retardant treatments on wood after 0, 2, 5, and 10 years of outdoor exposure.

We used a Class C burning-brand test (ASTM E 108) and a Schlyter flamespread test to evaluate effectiveness. Most shingle treatments evaluated were either pressure impregnated or coated at the Forest Products Laboratory; however, a commercial treatment was used as a control. After 10 years of exposure, most treatments passed the Class C burning-brand test, but lost considerable effectiveness in the Schlyter test method. The commercial treatment was the most effective after 10 years of weathering.

Keywords: Exterior fire-retardant treatments, wood shingles, weathering, leach resistance, Class C burning-brand, Schlyter test.

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Effectiveness of Fire-Retardant Treatments for Shingles After 10 Years of Outdoor Weathering

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Introduction

Wood shingles and shakes are esthetically desirable and durable, and they are being used in both commercial and residential construction in a variety of ways. Because building codes in some localities require wood shingles to be fire-retardant treated, the Forest Products Laboratory (FPL) undertook a study both to examine the effectiveness of potential treatments and to evaluate the durability of these treatments after outdoor weathering. This paper discusses the effectiveness of various treatments after 10 years of outdoor weathering.

In prior research at FPL we evaluated the performance of various fire-retardant treatments using three methods: the 8-foot tunnel furnace (American Society for Testing and Materials Designation E 288-89) (ASTM 1984); the modified Schlyter test (Forest Service 1959); and a Class C burning-brand test (ASTM Designation E 108-83) (ASTM 1984). Treatment systems that displayed fire-retardant effectiveness were then evaluated for durability.

In the earlier work we used two accelerated weathering procedures to evaluate durability. In the first procedure, panels were placed outdoors for 28 days and sprayed daily with water. The daily water spray, plus any additional rainfall, totaled 30 inches of rain, the average annual precipitation for Madison, Wisconsin. In the second procedure, panels were given a 1,000-hour ultraviolet (UV) light-plus-water spray exposure in an accelerated weathering apparatus developed to simulate outdoor weathering, ASTM D 2898-81 (ASTM 1982, Holmes 1973).

After both weathering procedures, specimens were conditioned to constant weight at 80°F and 30 percent relative humidity (RH) and then tested. Treatments that demonstrated the most promise in fire tests after accelerated weathering (table 1) were then evaluated for durability after outdoor exposure. A previous paper (Holmes and Knispel 1981) reported the results after 2 and 5 years of exposure. This paper is the final report on the same treatments after 10 years of outdoor exposure.

[1]Now retired.

Table 1 .—Description of treating solution

Panel number	Treatment[1]	Loading	Method	Treating solution	Percent	Drying schedule
1A	THPC-1	4.1 lb/ft^3	Pressure impregnation	Tetrakis (hydroxymethyl) phosphonium chloride (80 pct in water) Sodium hydroxide (50 pct in water) Urea A liquid melamine Water	 12.55 2.16 2.05 4.35 78.89	Kiln dried using kiln schedule not exceeding 130 °F dry bulb to 6 pct moisture content
1B	THPC-1	6.2 lb/ft^3	do.	do.		Do.
2A	THPC-2	8.4 lb/ft^3	do.	Tetrakis (hydroxymethyl) phosphonium chloride (80 pct in water) sodium hydroxide (50 pct in water) Urea A liquid melamine Water	 18.66 3.24 2.98 6.47 68.65	Do.
2B	THPC-2	11.9 lb/ft^3	do.	do.		Do.
3A	DPF-1	7.3 lb/ft^3	do.	Dicyandiamide Phosphoric acid (85 pct) Formaldehyde (37 pct) Water Solution prereacted.	8.64 11.83 0.83 78.7	Kiln dried using kiln schedule not exceeding 130 °F dry bulb to 6 pct moisture content. Temperature slowly raised to 185 °F. Shingles cured at 185 °F for 24 hours.
3B	DPF-1	8.2 lb/ft^3	do.	do.		Do.
4A	DPF-2	9.5 lb/ft^3	do.	Dicyandiamide Phosphoric acid (85 pct) Formaldehyde (37 pct) Water Solution prereacted.	10.90 14.95 1.05 73.10	Do.
4B	DPF-2	8.4 lb/ft^3	do.	do.		Do.
5A	DP-1	6.2 lb/ft^3	do.	Dicyandiamide Phosphoric acid (85 pct) Water	6.98 9.45 83.57	Same as DPF-1 and DPF-2 except cured for 5 hours.
5B	DP-1	6.3 lb/ft^3	do.	do.		Do.
6A	DP-2	7.7 lb/ft^3	do.	Dicyandiamide Phosphoric acid (85 pct) Water	9.3 12.6 78.1	Do.
6B	DP-2	7.2 lb/ft^3	do.	do.		Do.
7A	Pyresote-1	7.1 lb/ft^3	do.	Zinc chloride Ammonium sulfate Boric acid Sodium dichromate Water	7.92 7.92 5.65 1.13 77.38	Same as THPC-1 and THPC-2.

Table 1.—Description of treating solution-continued

Panel number	Treatment[1]	Loading	Method	Treating solution	Percent	Drying schedule
7B	Pyresote-2	4.5 lb/ft^3	Pressure impregnation and brush coating	Same as pyresote-1 Two applications of a solution consisting of 80 pct sealer A and 20 pct tricresyl phosphate. Sealer A is a mineral spirits solution containing a water repellent, pentachlorophenol, and other chlorophenols; it meets Federal Specification TT-W-572 Type II. Additional coating reapplied after 5 years.		After pressure impregnation, shingles kiln-dried using kiln schedule not exceeding 130 °F, dry to 6 pct moisture content. Coating allowed to air-dry between coats.
8B	Pyresote-3	5.0 lb/ft^3	Pressure impregnation	Zinc chloride Ammonium sulfate Boric acid Sodium dichromate Water	5.95 5.95 4.25 0.85 83.0	Same as THPC-1 and THPC-2.
8A	Pyresote-4	4.7 lb/ft^3	Pressure impregnation and brush coating	Same as pyresote-3. Two applications of a solution consisting of 80 pct sealer A and 20 pct tricresyl phosphate. Additional coating reapplied after 5 years.		Same as pyresote-2.
9A	Pyresote-5	3.8 lb/ft^3	do.	Same as pyresote-2. Four applications of a solution consisting of 80 pct sealer A and 20 pct tricresyl phosphate.		Do.
9B	Pyresote-5	4.0 lb/ft^3	do.	do.		Do.
10A	UDFP-1	7.1 lb/ft^3	Pressure impregnation	Urea Dicyandiamide Formaldehyde (37 pct) Phosphoric acid Water	1.08 4.54 4.32 7.06 83.0	Same as THPC-1 and THPC-2.
10B	UDFP-1	7.4 lb/ft^3	do.	do.		Do.
11A	UDFP-2	10.3 lb/ft^3	do.	Urea Dicyandiamide Formaldehyde (37 pct) Phosphoric acid Water	1.44 6.03 5.75 9.38 77.4	Do.
11B	UDFP-2	7.7 lb/ft^3	do.	do.		Do.

Table 1 .—Description of treating solution-continued

Panel number	Treatment[1]	Loading	Method	Treating solution	Percent	Drying schedule
12A	Epoxy paint	77.6 ft^2/gal	Brush coating	Manufactured commercially in accordance with Military Specification MIL-C-46081.		Allowed to air-dry between two coats.
12B	Epoxy paint	75.8 ft^2/gal	do.	do.		Do.
13A	Untreated	——	– –	– –		– –
13B	Untreated	– –	– –	– –		– –
14A	NCX	– –	Pressure impregnation	Commercial treatment, class C labeled by Underwriters' Laboratories, Inc.		– –
14B	NCX	– –	do.	do.		– –
16A	FR coating	66.0 ft^2/gal	Brush coating	Clear fire-retardant coating.		Allowed to air-dry.
16B	FR coating	77.8 ft^2/gal	do.	do.		Do.

'See text for explanation of treatment abbreviations.

Procedures

Materials

Shingles used in this study were western redcedar (*Thuja plicata* Donn) conforming to the grading rules of commercial standard CS-31-52 (U.S. Department of Commerce 1952) as No. 1 Grade: 16 inches long and 2 inches across the butts of five shingles. These random-width sawn shingles were edge grain and 100 percent clear heartwood. Shingles were purchased from a local lumber dealer and treated at FPL (except for the commercially treated ones). We obtained commercial shingles labeled as Underwriters Laboratory (UL) Class C to provide some data by which to judge the severity of the test procedures.

Six chemical formulations were used in the treatments:
1. Tetrakis (hydroxymethyl) phosphorium chloride (THPC).
2. Dicyandiamide-phosphoric acid-formaldehyde (DPF).
3. Dicyandiamide-phosphoric acid (DP).
4. Pyresote.
5. Urea-dicyandiamide-formaldehyde-phosphoric acid (UDFP).
6. Kopper's NCX[2] (NCX).

These formulations and their application are described in table 1.

The pyresote formulation, a leachable interior inorganic soluble salt, was included for two reasons: First, to serve as a reference for leach-resistance treatments; second, to determine if a water-repellent sealer coating could be used effectively with this type of treatment to provide leach resistance.

Preparation of Specimens

The impregnation treatments were made by the full-cell, vacuum-pressure process. The sealed treatment cylinder was first evacuated to 27-1/2 inches of mercury, and this vacuum was held for 15 to 30 minutes. The treating solution was then drawn into the cylinder, and a pressure of 75 to 90 pounds per square inch (lb/in^2) was maintained for 1-1/2 to 2 hours. Solution temperature depended on type and solubility of chemical. The dry chemical retention in pounds per cubic foot (lb/ft^3) of wood was calculated for each bundle using the solution concentration (table 1). The treated shingles were either air dried or kiln dried. Special drying conditions for some of the treatments are included in the description (table 1). See Holmes (1971) for further description of the treating process.

[2]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

For coating treatments we followed the manufacturer's recommended procedure for application technique and loading levels. Coating treatments by brush or spray were applied to the shingles only after they had been conditioned to constant weight at 80 °F and 30 percent RH. After treatment, shingles were reconditioned for at least 30 days to insure evaporation of the solvent.

For each treatment system and retention level, eight Schlyter specimen panels and eight burning brand-specimen panels were made up. All specimen panels were conditioned to constant weight at 80 °F and 30 percent RH. Two Schlyter panels and two burning-brand panels were fire tested without any outdoor exposure (0 yr); the remaining panels were placed outside in the Madison, Wisconsin, area on racks facing south at a slope of 22.6° from horizontal (fig. 1) for 2-, 5-, and 10-year exposure periods. At the end of each period, two panels for Schlyter tests and two panels for burning-brand tests of each treatment and retention level were removed from the outside weathering rack, conditioned at 80 °F and 30 percent RH, weighed, and fire tested.

Construction of Test Panels

Each test panel consisted of the treated shingles on a decking or backing used to provide support. Shingles were applied to the decks following the recommendations of the Red Cedar Shingle and Handsplit Shake Bureau (Grondal 1963). Holmes (1971) describes the construction of the panels in more detail. Four panels of each treatment at each treatment level were constructed. For the burning-brand test, the decking was made of western white pine boards, 3-1/2 inches wide by 1-inch nominal thickness, laid across the shorter dimension of the deck and spaced 1-1/2 inches apart. For the modified Schlyter test, the decking of each panel was 3/8-inch-thick Douglas-fir plywood, 11-7/8 inches wide by 31 inches long.

Fire Test Methods

Class C burning-brand test. —We followed ASTM E 108-83 standard methods of fire tests of roof coverings for the Class C burning-brand test. The ASTM E 108 standard includes five separate tests to evaluate the fire-retardant characteristics of roof coverings as follows:
1. Intermittent flame exposure test
2. Spread of flame test
3. Burning-brand test
4. Flying-brand test
5. Rain test.

However, evaluations in this study were limited to the Class C burning-brand test, which measures the resistance of the treated shingles to fire penetration. In the Class C burning-brand method, the roof-section assembly consisted of a 40- by 52-inch section of a shingled roof, with a simulated eave and cornice (fig. 2). The roof sloped 22.6° from the horizontal. A previous publication details the construction of the test structure (Holmes 1971).

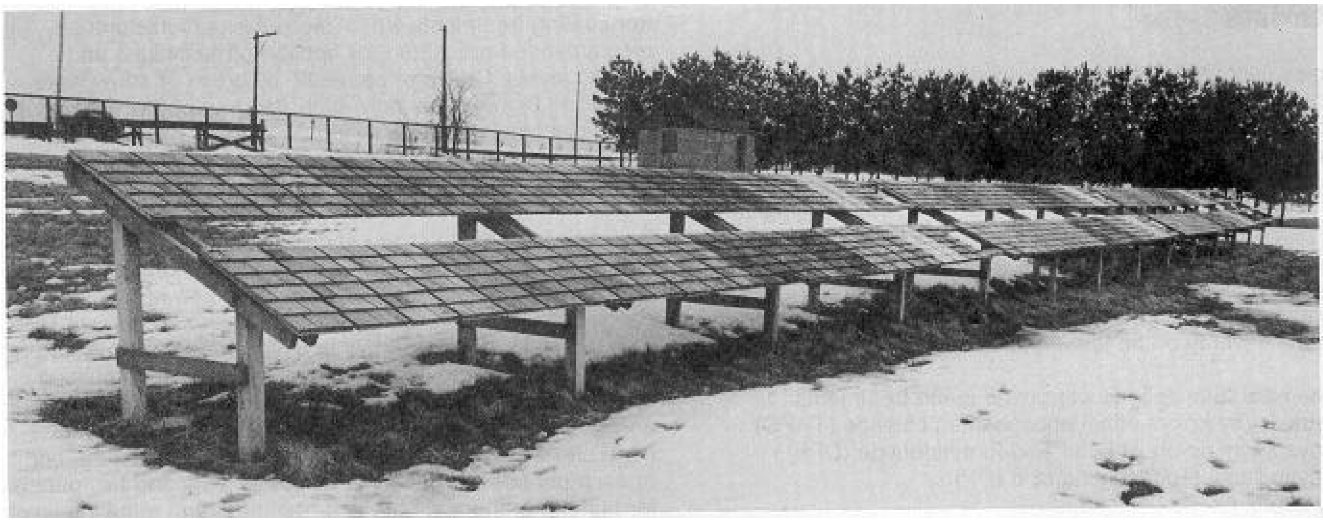

Figure 1.—Outside weathering test fence located in Madison, WI. Panels placed outside in January 1974. (M141 902-13)

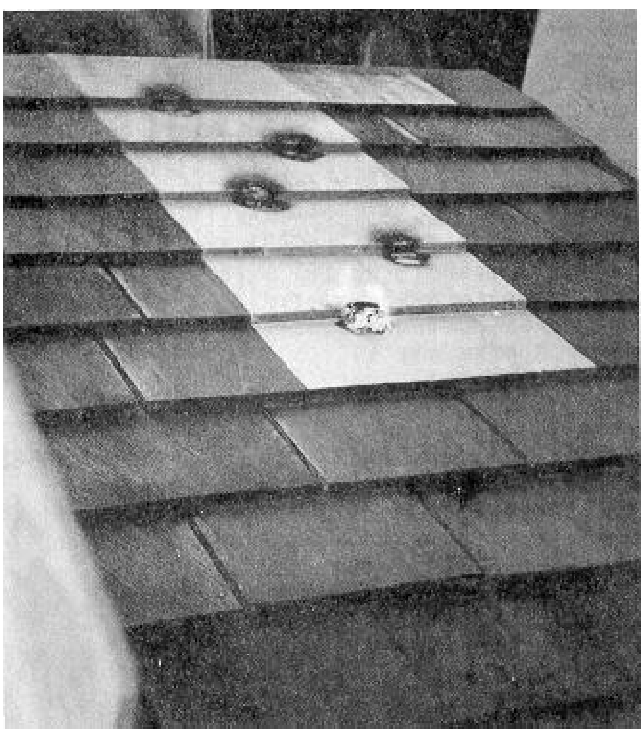

Figure 2.—Class C burning-brand test. (M127 768)

A large fan placed 60 inches from the front edge of the deck was positioned so that it generated a 12-mile-per-hour (mi/h) wind over the surface of the structure when air velocity was measured midway up the slope of the specimen panel at its center and edges. A Class C brand was ignited and centered over the joint between two shingles in the same course and just below the butt edge of a shingle in the course above. The number of brands that could be used on a specimen panel was limited by the number and location of these joints. All our panels had eight such joints. The test was continued for each brand until it was consumed and all evidence of flame, glowing, and smoke disappeared, or until failure (as shown by sustained flaming on the underside of the deck).

Modified Schlyler test.—We used the Schlyter test to measure the vertical flamespread property of the material (fig. 3). Two matched specimen panels were held parallel in vertical position, with the test surfaces facing each other 2 inches apart. The bottom of one panel was supported 4 inches higher than the bottom of the other. Behind the testing rack was a ruler for recording flame height. The arrangement of the panels gives a chimney effect to promote combustion, since each panel radiates heat to the other.

In this test we used 6 cubic feet per hour (ft^3/h) of natural gas flowing through a wing-top Bunsen burner as the ignition source. At the start of the test, the burner was placed between the panels and the gas ignited. The initial height of the gas flame was recorded immediately and at every 15 seconds thereafter. At the end of 3 minutes of exposure, the gas flame was shut off. The times until all flaming stops and afterglowing is no longer visible are recorded. If flaming or glowing does not self-extinguish in 5 minutes, the operator extinguishes it with water.

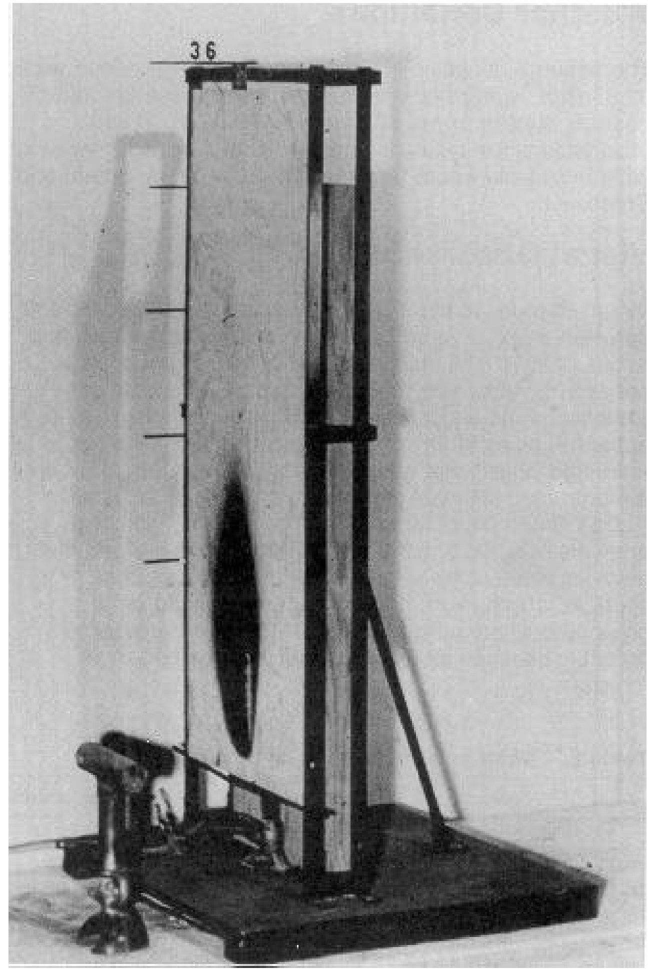

Figure 3.—Modified Schlyter test. (M85 0412)

Results and Discussion

Weather Conditions

The average rainfall in Madison for the 10-year period was 32.3 inches water equivalents, and the average amount of possible sunshine was 52.8 percent (table 2). These observations are typical of interior North America; however, different results would be expected in the West, South, and Southeast.

Visual Observations

Visual changes in the shingles between 0 and 2 years and between 2 and 5 years have been described (Holmes and Knispel 1981). The shingles showed little visual change between 5 years and 10 years (table 3). All specimens exhibited some checks, splits, and cracks. There was no apparent decay in any of the specimens, including the untreated. Significant quantities of mold were apparent on the untreated shingles (fig. 4) and on the THPC shingles (fig. 5). Since the other shingles showed no significant amounts of surface mold, the fire-retardant treatment must have imparted some degree of mold resistance. For specimens with mold, it was more pronounced on plywood-backed panels than on decking-backed panels, probably because the plywood backing retained more moisture.

Table 2.—Weather conditions during 10-year period

	Year	Water equivalents	Possible sunshine
		In	*Pct*
	1973	35.53	49
	1974	36.06	51
	1975	34.53	51
	1976	21.08	63
	1977	32.53	56
	1978	36.44	56
	1979	28.12	52
	1980	34.38	52
	1981	32.10	53
	1982	31.58	50
	1983	31.67	46
	1984	33.72	54
Mean		32.31	52.75
Median		33.12	52.00
SD		4.24	4.29
SE mean		1.22	1.24
Maximum		36.44	63.00
Minimum		21.08	46.00

The THPC and DPF specimens exhibited some cupping, more so with the plywood-backed specimens than with the decking-backed specimens.

The untreated specimens were dark gray after 10 years (fig. 4), while most of the other shingles were medium gray. The graying is due to accumulation of fungal spores and mycelium on the surface (Black and Mraz 1974, Feist and Mraz 1978). The commercial NCX treatment specimens (fig. 6) were medium gray, with a slight reddish hue. The commercial treatment must have imparted a small fungicidal effect to the shingles. The pyresote specimens (fig. 7) showed only a moderate amount of graying. The epoxy paint did not hold up well after 3 years of weathering, as indicated in figure 8.

Burning-Brand Test

Specimens from all except the pyresote treatments retained the level of flame retardancy (less than 20 pct failures) needed to pass the burning-brand test (table 4). The pyresote treatment in which two coats of sealer were reapplied after 5 years also retained effectiveness in the burning-brand test. Because pyresote is water soluble, degradation of the sealer coating is the primary reason for loss of flame retardants.

The epoxy paint retained some of its flame retardancy, even though 80 percent of it had flaked off. This was probably because paint remained in the cracks between the butt joints (fig. 8).

Before weathering, the transparent coating (panel No. 16) passed the burning-brand test but did not withstand a 3-year outdoor exposure. Buchanan[3] has found this coating to pass the burning-brand test after accelerated weathering in the laboratory. The lack of durability under actual outdoor weathering conditions suggests that the coating gives limited protection against UV light and biological degradation.

[3]Buchanan, Brian. Personal communication. Texas Forest Products Laboratory, Lufkin, TX. 1984.

Table 3.—Visual observation after 1, 2, 5, and 10 years of weathering

Treatment[1]	1 year	2 years	5 years	10 years
THPC (1 and 2)	Medium gray in color, shingles cupped slightly.	Light gray in color, slight cupping.	Medium gray in color, with slight cupping.	Dark gray in color with black specks. Lots of moss which gives green color to shingles. Lots of checking and splitting. Plywood backed panels support more mildew growth. Lots of cupping. Surface mildew can be scraped off. No apparent decay.
DPF (3 and 4)	Light tan to light gray in color.	Light gray in color.	Medium gray. Cupping on two of the panels but other panels were flat.	Lots of checking; more checking on plywood-backed panels. Some discoloration around bottom of shingles (yellow green in color) probably due to chemicals. No apparent decay.
DP (5 and 6)	Light tan to light gray in color.	Light gray in color.	Medium gray, slight cupping on panels.	Lots of discoloration. Yellow green in color. Cupping on these panels with lots of checks. Mildew and moss present. Plywood-backed panels have more mildew. No apparent decay.
Pyresote-2, 3, 5 with sealer (7B,8A, 9A and B)	Greenish tan in color with some spots of gray.	Light gray in color with some small tan areas.	Medium gray with some small tan areas.	Specimen looks good, 9 looks better than 8, 10, 11, or 15. Very little checking even on plywood-backed panels. No apparent decay.
Pyresote-1, 4 without sealer (7A 8B)	Medium gray in color.	Light gray in color.	Medium gray in color.	Dark gray in color with lots of mildew. Lots of checks and splits which were very deep. No apparent decay.
UDFP (10 and 11)	Light tan to almost gray in color, 6 checks average per shingle.	Light tan to light gray in color, 6 checks average per shingle.	Light reddish brown, 6 checks average per shingle.	Dark gray color. Lots of checks and splits, mostly emanating from the edges. No apparent decay.

Table 3.—Visual observations after 1, 2, 5, and 10 years of weathering-continued

Treatment[1]	1 year	2 years	5 years	10 years
Epoxy paint (12)	Blueish white color, no checking.	Lot of paint worn off especially near bottom of panel, no checking.	Approximately 50 percent of paint worn off, no checking.	Eighty percent of paint peeled off, lots of mold, especially where the paint was peeling. No apparent decay.
Untreated (13)	Dark gray.	Medium gray in color.	Deep gray in color.	Lots of mold, several splits, lots of checking. Mold and mildew growth especially on grooves between shingles. No apparent decay.
NCX (14)	Light tan color, slight checking.	Light tan to almost gray color, light checking.	Medium gray color with a slight red tone, slight checking.	Some discoloration light and dark gray mixture. Little streaking of brown. Looks pretty good compared to others but not as good as 8 and 9. No apparent decay.

[1]See text for explanation of abbreviations.

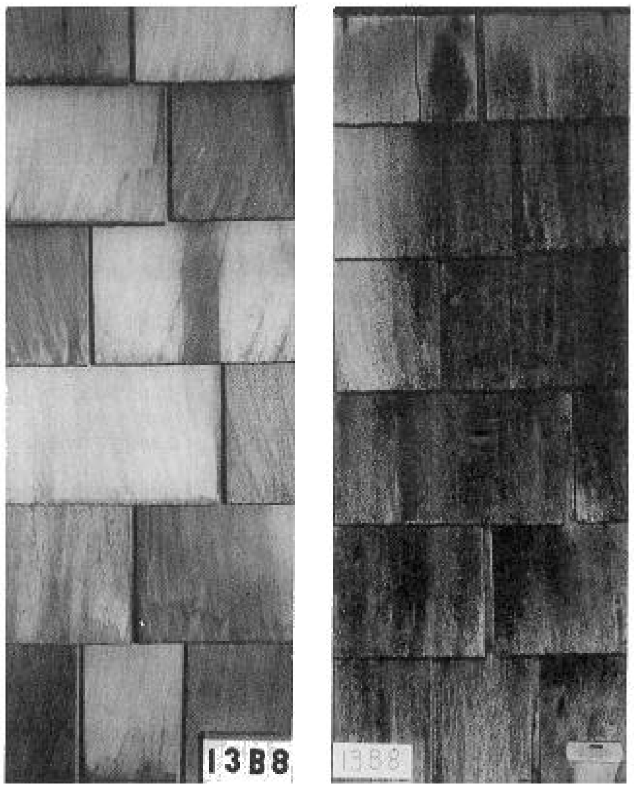

Figure 4.—Appearance of panel 13B8 before exposure (left) and after 10 years (right) of exposure. (M141 757, M84 0195)

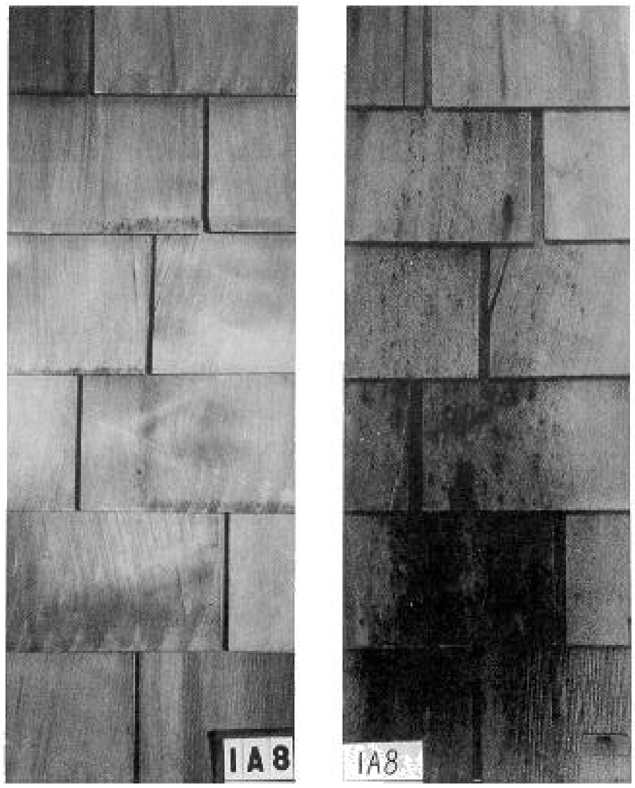

*Figure 5.—Appearance of panel 1A8 before exposure (left) and after 10 years (right) of exposure. (M141 **753, M84 0213)***

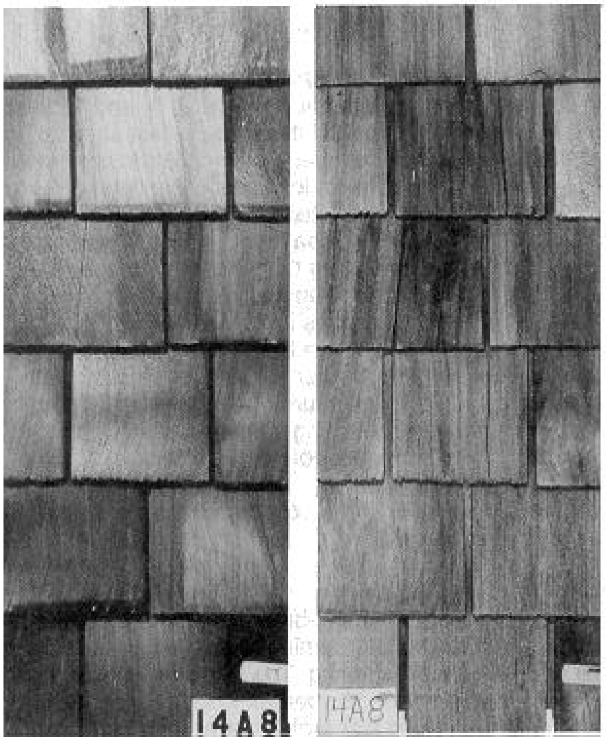

Figure 6.—Appearance of panel 14A8 before exposure (left) and after 10 years (right) of exposure. (M142 250, M84 0192)

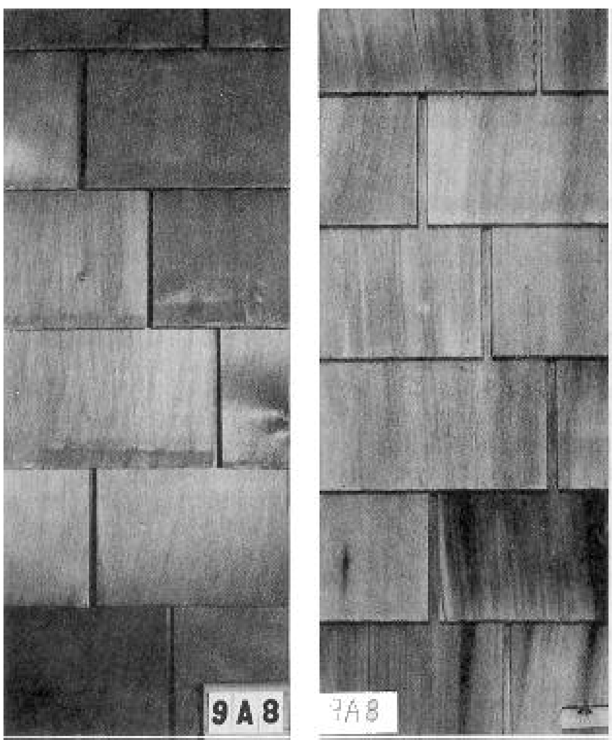

Figure 7. —Appearance of panel 9A8 before exposure (left) and after 10 years (right) of exposure. (M141 748, M84 0197)

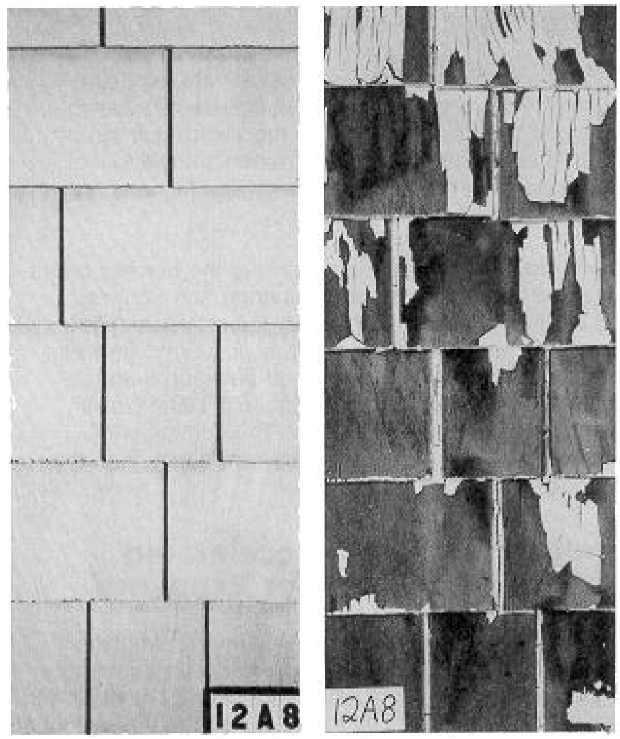

Figure 8.—Appearance of panel 12A8 before exposure (left) and after 10 years (right) of exposure. (M141 754, M84 0190)

Schlyter Test Results

The Schlyter test presents a very severe fire exposure because of the chimney effect and because reradiation between the two panels promotes the vertical spread of flame. In this test, the ability of a treated shingle to self-extinguish after removal of the igniting flame is an important indication of fire retardancy.

Although most of the treatments passed the burning-brand test after 10 years of outdoor weathering, the Schlyter results indicate considerable loss of fire retardancy (table 4). The biggest changes in fire retardancy occurred between 0 and 2 years; retardancy leveled off between 5 and 10 years, with most of the treatments exhibiting similar flamespread values after 10 years. The commercially treated shingles retained greater fire retardancy than the other specimens.

Correlation Between Accelerated Weathering and Outdoor Exposure

To estimate how well accelerated weathering simulates natural outdoor weathering, we compared Schlyter results for 1,000 hours in the accelerated weathering chamber with outdoor results (table 5). The levels of treatment were not all the same between accelerated weathering and outdoor weathering so all treatments are not represented. For the DPF and DP formulations, the epoxy paint and the commercial treatment, the 1,000 hours of accelerated weathering simulates about 2 years of actual outdoor weathering. These results are similar to those reported by Feist and Mraz (1978) and Black and Mraz (1974) which show that 24 weeks (4,632 h) in the Weatherometer corresponds to between 5 and 6 years of outdoor exposure.

Although 1,000 hours of accelerated weathering simulates the equivalent of 34 years of average rainfall, the accelerated weathering may not properly simulate the UV light degradation and biodegradation which occurs in outdoor weathering. These factors may be just as important in the permanency of fire-retardant treatments as leach resistance. To improve exterior fire-retardant formulations, UV light inhibitors and preservatives will have to be incorporated into the treatment.

Chemical Treatments

Tetrakis (hydroxymethyl) phosphorium chloride.— THPC had no burning-brand failures after 2, 5, and 10 years of outdoor exposure. However, the Schlyter test showed high flamespread values, comparable to those in untreated panels. Postweathering weight loss was only slightly greater in THPC panels than in untreated panels, indicating some leach resistance. Our THPC treatment had lower amounts of nitrogen-containing compounds than those of commercial manufacturers. Commercial manufacturers use an excess of nitrogen-containing components in the formulation to produce a flame-retardant finish that is completely crosslinked and durable to water leaching or washing with detergent at elevated temperatures (Stephenson[4]). The use of insufficient nitrogen-containing components may lead to the formation of mainly linear polymers of lower molecular weight. These may be more susceptible to hydrolytic and photolytic decomposition than crosslinked polymers of a higher molecular weight.

Dicyandiamide-phosphoric acid-formaldehyde.— The DPF formulation had 6 burning-brand failures out of 32 after 10 years of weathering. No burning-brand failures occurred after 2 or 5 years of weathering. The Schlyter test results for the DPF formulation after 10 years of weathering were poor, with flamespread values just slightly lower than untreated. The postweathering weight loss for DPF-treated shingles after 10 years was about twice as great as for untreated shingles.

Dicyandiamide-phosphoric acid.— Like the DPF formulation, the DP formulation had four burning-brand failures after 10 years of weathering. No burning-brand failures occurred after 2 or 5 years. The Schlyter test results were poor, with values comparable to the untreated. The weight loss for DP shingles after 10 years' weathering was twice as great as the weight loss for the untreated specimens. The durability of this formulation is questionable.

Pyresote.—The results of burning brand for 7A and the Schlyter test for 8B (no sealer coatings) indicate very little fire retardancy after 2 years of weathering, giving values comparable to the untreated specimens. The pyresote-5 formulation with four coats of sealer applied before weathering retained considerable fire retardancy after 2 and 5 years of weathering. After 10 years, however, the fire-retardant effectiveness was reduced considerably, although it still provided some protection. The pyresote-2 and pyresote-4 formulation (in which a second coat of sealer was applied after 5 yr) did not retain fire retardancy as well as pyresote-5, in which four coats of sealer were initially applied to the specimens. Again, some degree of effectiveness remained after 10 years' weathering, although retardancy was reduced.

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[4]Stephenson, J. E. Personal communication. Albright and Wilson LTD, West Midlands, Great Britain. 1984.

Table 4.—Burning-brand and modified Schlyter results after 0, 2, 5, and 10 years' weathering

Panel number	Treatment[1]	Loading	Weight loss		Burning brand: Number of failures per 16 brands				Schlyter: Flamespread in inches			
			5 years	10 years	0 year	2 years	5 years	10 years	0 year	2 years	5 years	10 years
		Lb/ft[3]	*------ Pct ------*									
1A	THPC	4.1	2.9	8.0	—	—	—	—	42	41	39	[2]44
1B	THPC	6.2	4.0	7.0	0	0	0	0	—	—	—	—
2A	THPC	8.4	4.5	8.6	—	—	—	—	36	29	36	[2]39
2B	THPC	11.9	5.5	9.8	0	0	0	0	—	—	—	—
3A	DPF	7.3	6.9	10.6	—	—	—	—	10	18	29	37
3B	DPF	8.2	6.9	8.5	0	0	0	3	—	—	—	—
4A	DPF	9.5	10.1	14.0	0	0	0	3	—	—	—	—
4B	DPF	8.4	9.8	14.4	—	—	—	—	10	22	32	40
5A	DP	6.2	9.8	14.5	—	—	—	—	10	24	35	44
5B	DP	6.3	8.7	13.6	0	0	0	2	—	—	—	—
6A	DP	7.7	10.2	14.1	0	0	0	2	—	—	—	—
6B	DP	7.2	10.7	16.6	—	—	—	—	10	23	36	44
7A	Pyresote-1	7.1	12.8	15.7	0	15	16	16	—	—	—	—
7B	Pyresote-2	4.5	6.2	11.4	—	—	—	—	7	39	45	44
8A	Pyresote-4	4.7	6.4	9.2	0	0	4	3	—	—	—	—
8B	Pyresote-3	5.0	10.5	16.3	—	—	—	—	28	41	43	45
9A	Pyresote-5	3.8	5.5	11.8	—	—	—	—	26	34	39	47
9B	Pyresote-5	4.0	4.7	9.7	0	1	3	8	—	—	—	—
10A	UDFP	7.1	6.9	11.9	—	—	—	—	10	20	29	38
10B	UDFP	7.4	7.1	11.6	0	0	0	0	—	—	—	—
11A	UDFP	10.3	7.0	10.8	0	0	3	0	—	—	—	—
11B	UDFP	7.7	6.5	11.7	—	—	—	—	11	19	32	36
12A	Epoxy paint	—	3.5	3.9	—	—	—	—	27	38	44	44
12B	Epoxy paint	—	2.8	2.1	0	0	3	3	—	—	—	—
13A	Untreated	—	3.7	6.4	15	14	16	16	—	—	—	—
13B	Untreated	—	3.2	7.2	—	—	—	—	48	47	44	44
14A	NCX	—	3.2	6.9	0	0	0	0	—	—	—	—
14B	NCX	—	3.6	7.2	—	—	—	—	11	12	25	[3]29
16A	Clear coating	—	—	—	—	—	—	—	45	[4]46		
16B	Clear coating	—	—	—	2	[4]10	—	—	—	—	—	—

[1]See text for explanation of abbreviations.

[2]Heavy smoke, considerable glowing.

[3]Self-extinguished.

[4]Evaluated after 3 years.

Table 5.—Comparison of natural outdoor exposure with accelerated results for Schlyter test

Treatment[1]	Loading	Exposure: Natural				Exposure: Accelerated	
		0 year	2 years	5 years	10 years	28 days	1,000 hours in chamber
DPF	7.3	10	18	29	37	—	21
DP	7.7	10	23	36	44	10	25
Epoxy paint	—	27	38	44	44	—	36
Untreated	—	48	47	44	44	46	46
NCX	—	11	12	25	29	12	13

[1]See text for explanation of abbreviations.

Heavy applications of water-repellent sealers appear to aid in retaining fire retardancy for treated wood, but periodic reapplication of the sealer is necessary. Resistance to biodegradation and improved appearance of the shingles are additional advantages. However, more work is necessary to determine the best interior treatment, the initial application level to insure best retention, the reapplication schedule to insure continued fire retardancy, and the effect on exterior fire-retardant durability.

Urea-dicyandiamide-formaldehyde-phosphoric acid.—The UDFP formulation had no burning-brand failures after 2, 5, or 10 years of weathering. The Schlyter test indicates considerable loss of fire-retardant effectiveness after 10 years, although the performance was better than for untreated shingles. The shingles used in this study were treated at FPL and may not have had the same treatment level as those produced commercially. Also, the treated shingles were not heat cured as is done commercially; this influences the extent of leach resistance.

Kopper's NCX.—After 10 years of weathering the two commercially treated specimens had no burning-brand failures, had a flamespread of 29 inches, and self-extinguished. of all treatments evaluated after 10 years, only the NCX-treated specimens self-extinguished in the Schlyter test, indicating a high degree of leach resistance. The NCX specimens had a postweathering weight loss of only 7 percent, equivalent to the weight loss of the untreated specimens after 10 years of weathering. The increase in flamespread from 11 inches at the outset (no weathering) to 29 inches after 10 years' weathering could result from photodegradation and defiberization of the surface wood cells by UV light; fire-retardant chemicals are probably lost along with the degraded wood fibers.

Summary

Of all the treatments evaluated, the commercial treatment NCX performed best in fire tests after 10 years of outdoor weathering. Other treatments, such as the UDPF and the DP, performed well in the burning-brand test but unacceptably in the modified Schlyter test for flamespread.

The accelerated weathering test of 1,000 hours light coupled with water spray corresponds to about 2 years of outdoor exposure. Although the equivalent of 34 years of average rainfall is used in the 1,000-hour accelerated weathering test, there is probably not enough UV light exposure. Photodegradation by UV light and biological degradation is just as important in maintaining retardancy in treated shingles as is leach resistance.

The use of copious amounts of water-repellent sealer coatings over interior-type fire retardant showed some promise in providing a degree of leach resistance. However, several sealer coatings must be applied initially and then reapplied periodically. More research is necessary to determine the proper reapplication schedule to insure continued fire protection. Such treatments should also be useful in extending the life of exterior fire-retardant treatments.

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