

# Weathering performance of finished aspen siding

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## Abstract

Roughsawn and smooth-planed aspen (*Populus tremuloides*) siding was finished with several finishes and exposed outdoors on vertical test fences facing south in southern Wisconsin, southern Mississippi, and the Olympic Peninsula of Washington. Transparent, penetrating finishes protected roughsawn surfaces for up to 36 months in Wisconsin and 24 months in Washington, but only 7 months in Mississippi. A semitransparent oil-based stain gave better performance than the transparent finishes; two coats of stain protected roughsawn aspen surfaces for up to 10 years. Accelerated weathering studies on unfinished aspen predicted that transparent and semitransparent finishes would have good performance. Solid-color stains also protected roughsawn wood surfaces for up to 10 years at all three locations; smooth surfaces were protected for 5 years. The best finishes for aspen were acrylic latex paints. Even after 10 years of exposure at the three locations, two coats of acrylic latex paint over an acrylic latex or oil-based primer provided very good protection and appearance to both roughsawn and smooth-planed wood. All finishes evaluated always performed better over roughsawn surfaces than over smooth. Except for a solid-color oil-based stain, two coats of finish were always better than one, and three were better than two. The results show that aspen has finishing and weathering characteristics similar to those of softwoods like ponderosa pine, fir, hemlock, and spruce. Good construction and finishing practices are required to ensure good finish performance and protection against decay.

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The primary objective of this study was to obtain information on the outdoor weathering performance and durability of different finishing systems on quaking aspen (*Populus tremuloides*). The finishes included in this study were both commercially available and laboratory prepared. The effects of primer/finish/substrate interactions were emphasized.

Redwood (*Sequoia sempervirens*) and western red-

cedar (*Thuja plicata*) have been very popular solid wood siding materials for decades in the United States, and ponderosa pine (*Pinus ponderosa*) has been the species of choice for millwork (13). These popular species have become more difficult to obtain in sufficient quantities to meet the demands for solid wood siding and millwork products and several alternative species have been sought (9, 10).

Aspen is a low- to medium-density, diffuse porous hardwood with moderate resistance to weathering that could make it an attractive wood for outdoor applications (13). The wood is generally straight grained, comparatively uniform in texture, and easily worked. Aspen is low in strength, moderately stiff, moderately low in resistance to shock, and has moderately high shrinkage. It is not difficult to season unless it contains wet wood. It resists warping in place reasonably well after seasoning, even though it exhibits moderately large shrinkage when dried from a green condition. Aspen weathers to a light gray color with moderate sheen and weather checks are usually small and relatively inconspicuous.

When going from green to oven-dry, aspen has a fairly low shrinkage: 3.5 percent radial, 6.7 percent tangential, and 11.5 percent volumetric (13). The large tangential-to-radial shrinkage ratio of 1.8 means aspen will be subject to cupping and diamonding when moisture content changes occur in drying (unless

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The author is a Research Chemist, USDA Forest Serv., Forest Prod. Lab., One Gifford Pinchot Dr., Madison, WI 53705-2398. The author gratefully acknowledges the laboratory and field assistance, and technical suggestions of Peter G. Sotos and Edward A. Mraz (retired), and the computer assistance of Tracey Duch. Fungal identification was by Harold H. Burdsall, Jr. This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate state and/or federal agencies before they can be recommended. Pentachlorophenol is a restricted pesticide. This paper was received for publication in January 1994.

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Forest Prod. J. 44(6):15-23.

TABLE 1. — Characteristics of finishes and pretreatments used for aspen siding.

| Finish or pretreatment                                     | Source     | Color       | Nonvolatile content |  | Weight<br>(lb./gal.) <sup>a</sup> |
|--|------------|-------------|---------------------|--|-----------------------------------|
|  |            |             | (%)                 |  |                                   |
| Water-repellent preservative <sup>b</sup> (paintable) (12) | Laboratory | Transparent | 16                  |  | 6.99                              |
| Water-repellent preservative-1 <sup>b</sup> (12)           | Laboratory | Transparent | 18                  |  | 6.99                              |
| Water-repellent preservative-2 <sup>c</sup>                | Commercial | Green-brown | 51                  |  | 6.97                              |
| Semitransparent oil-based stain <sup>b</sup> (2)           | Laboratory | Brown       | 76                  |  | 7.95                              |
| Solid-color oil-based stain                                | Commercial | Brown       | 60                  |  | 9.42                              |
| Solid-color latex stain                                    | Commercial | Brown       | 45                  |  | 10.45                             |
| Latex primer paint   | Commercial | White       | 52                  |  | 9.76                              |
| Acrylic latex house paint-A                                | Commercial | White       | 53                  |  | 10.93                             |
| Alkyd primer paint   | Commercial | White       | 78                  |  | 11.41                             |
| Acrylic latex house paint-B                                | Commercial | White       | 52                  |  | 11.27                             |

<sup>a</sup> 1 lb./gal. = 1.2 kg/m<sup>3</sup>.<sup>b</sup> Contained 5 percent pentachlorophenol.<sup>c</sup> Contained 0.675 percent copper-8-quinolinate.

TABLE 2. — Average spreading rates for finishes applied to aspen wood.

| Finish or pretreatment          | Spreading rate                        |                 |          |     |          |    |                   |    |          |    |          |    |
|---------------------------------|---------------------------------------|-----------------|----------|-----|----------|----|-------------------|----|----------|----|----------|----|
|                                 | Smooth surface                        |                 |          |     |          |    | Roughsawn surface |    |          |    |          |    |
|                                 | 1st coat                              | SD <sup>b</sup> | 2nd coat | SD  | 3rd coat | SD | 1st coat          | SD | 2nd coat | SD | 3rd coat | SD |
|                                 | (ft. <sup>2</sup> /gal.) <sup>a</sup> |                 |          |     |          |    |                   |    |          |    |          |    |
| Water-repellent preservative-1  | 329                                   | 23              | 612      | 103 |          |    | 181               | 18 | 376      | 25 |          |    |
| Semitransparent oil-based stain | 461                                   | 44              | 686      | 58  |          |    | 239               | 12 | 463      | 33 |          |    |
| Water-repellent preservative-2  | 406                                   | 44              | 401      | 27  |          |    | 210               | 12 | 302      | 49 |          |    |
| Solid-color oil-based stain     | 438                                   | 22              | 551      | 30  |          |    | 244               | 21 | 484      | 47 |          |    |
| Solid-color latex stain         | 422                                   | 15              | 433      | 59  |          |    | 226               | 17 | 383      | 30 |          |    |
| Latex primer + latex topcoat    | 298                                   | 25              | 472      | 11  | 413      | 22 | 203               | 4  | 406      | 32 | 348      | 19 |
| Alkyd primer + latex topcoat    | 402                                   | 34              | 342      | 18  | 364      | 19 | 252               | 7  | 245      | 6  | 302      | 13 |

<sup>a</sup> 1 ft.<sup>2</sup> = 0.0929 m<sup>2</sup>; 1 gal. = 3.785 L.<sup>b</sup> SD = standard deviation.

restrained) (18). In addition, aspen often has abnormal amounts of tension wood, and longitudinal shrinkage can be significant: 0.16 to 0.72 percent from green to oven-dry. This longitudinal shrinkage means aspen lumber and siding will be subjected to both bowing and crooking in drying, and veneer will be subject to buckling when moisture content changes occur in drying and use (18).

Before 1875, hardwoods like aspen were sometimes used in the Midwest as construction woods (6). When softwood lumber became readily available, the use of hardwoods diminished. The declining use of hardwoods was due mainly to difficulties in nailing, seasoning, and painting hardwoods compared with softwoods. Today, relatively small amounts of hardwood are used for construction or siding even where supplies are readily available. Newer nailing techniques, improved seasoning techniques, and new finishes could eliminate the difficulties encountered in using hardwoods. In addition, some hardwoods have good weathering properties (14,17).

Other than brief notations that aspen has the paint-holding characteristics of softwoods like ponderosa pine, hemlock, spruce, fir, and several hardwoods (5,13), little information has been published on exterior finishing and performance characteristics of aspen. There are no reports describing the performance of modern coating materials on aspen. The painting and performance characteristics of aspen waferboard have been described (3,4). One review describes the general finishing of hardwoods for exte-

rior use (8). The weathering and finishing properties of yellow-poplar (*Liriodendron tulipifera*) were recently described (9). Other reports describe basic physical and chemical properties associated with the weathering of hardwoods (1,7,14).

## Materials and methods

### Exposure panels

The aspen wood for these exterior exposure studies was cut into boards from 10- to 14-inch- (25.4- to 35.6-cm) diameter logs and kiln-dried. Surfaces were both smooth planed and roughsawn. Boards were cut into bevel siding (0.5 by 5 by 13-3/4 in. (1.3 by 12.7 by 34.9 cm)). The wood was a mixture of sapwood and heartwood and was almost entirely flat grain with some small, tight knots. Three randomly selected pieces of bevel siding were assembled onto exposure panels consisting of 16-inch-wide by 13.5-inch-long (40.6-cm-wide by 34.3-cm-long) frames made from 0.25-inch (0.6-cm) exterior-grade plywood with 0.5-inch-wide by 1-inch-deep (1.3-cm-wide by 2.5-cm-deep) side rails. The frames of these exposure panels were dip-treated with a water-repellent preservative (WRP) and edge-coated with latex paint before the bevel siding pieces were attached with stainless steel nails. The exposure panels were hung on vertical fences with southern exposure at Madison, Wis.; Olympia, Wash; and Saucier, Miss. Panels were randomly installed in groups of four horizontal rows of four (9).

TABLE 3. — Ratio of spreading rates for finishes applied to smooth and roughsawn aspen.

| Finish or pretreatment          | Ratio, smooth to roughsawn |          |          |
|---------------------------------|----------------------------|----------|----------|
|                                 | 1st coat                   | 2nd coat | 3rd coat |
| Water-repellent preservative-1  | 1.8                        | 1.6      | --       |
| Semitransparent oil-based stain | 1.9                        | 1.5      | --       |
| Water-repellent preservative-2  | 1.9                        | 1.3      | --       |
| Solid-color oil-based stain     | 1.8                        | 1.1      | --       |
| Solid-color latex stain         | 1.9                        | 1.1      | --       |
| Latex primer + latex topcoat    | 1.5                        | 1.2      | 1.2      |
| Alkyd primer + latex topcoat    | 1.6                        | 1.4      | 1.2      |

TABLE 4. — Evaluation methods and inspection criteria.

| Evaluation          | Method                       |
|---------------------|------------------------------|
| Nonvolatile content | ASTM <sup>a</sup> D 2369-87  |
| Finish              |                              |
| Flaking             | ASTM D 772-86                |
| Cracking            | ASTM D 661-86                |
| Erosion             | ASTM D 662-86                |
| Mildew              | ASTM D 3274-86               |
| Discoloration       | Subjective visual assessment |
| Substrate           |                              |
| Cracking            | Similar to ASTM D 661-86     |
| Checking            | Similar to ASTM D 660-87     |
| General appearance  | Subjective visual assessment |

<sup>a</sup> American Society for Testing and Materials.

## Finishes and pretreatments

Commercially available and laboratory-prepared finishes and pretreatments were selected for the outdoor exposure studies (Table 1). Finish systems comprised of combinations of the individual finishes or pretreatments or both were used as well as individual materials. The materials selected represented finishes currently available (or recommended) for application on wood used in outdoor exposures and were finishes that would be expected to perform well based on past experience or research or both.

An oil-based, semitransparent stain containing linseed oil, paraffin wax (a water repellent (WR)), pentachlorophenol (a mildewcide), pigment, and mineral spirits solvent was prepared in the laboratory (2). Two solid-color stains (oil-based and latex) and two acrylic latex paints were applied to aspen wood siding. The solid-color stains were applied as one and two coats (self-priming); the paints were applied as two coats (one primer and one topcoat) and three coats (one primer and two topcoats). Both oil-based primer and latex primer were used. A WRP pretreatment was used for the oil-based primer/latex topcoat system. The WRP pretreatments have been shown to be very beneficial in improving the performance of paints on softwoods (9,12,13).

All finishes and pretreatments were brushed on the clean and unweathered surface of the wood substrate under ideal laboratory conditions and following all the recommendations provided by the manufacturers, where applicable. The wood was conditioned for 2 weeks at 65 percent relative humidity and 80°F (26.7°C) before finishing. All finishes were applied to the wood surfaces with the panels horizontal. Top, side, and bottom edges of all exposure panels were

sealed as completely as possible with the finish or pretreatment itself. Spreading rates (Tables 2 and 3) were those usually recommended for good finishing practices (5,13) and were determined by direct weighing. All substrate surfaces were wiped with a soft cloth before finishing and between coats. No other special surface preparation was used. Drying time between coats was 48 hours for the WRP pretreatment, natural finishes, semitransparent stain, and solid-color stain. Drying time between paint coats was 24 hours. The finished exposure panels were stored indoors at 60 percent relative humidity and 70°F (21.1°C) for 1 week before being installed on the vertical exposure fences. The panels were installed on the test fences in May 1981, in Mississippi, and in June 1981, in Wisconsin and Washington.

## Finish performance ratings

Different criteria were used to determine the performance ratings of the various pretreatment/finish systems on aspen (Table 4). Most evaluation methods were based on American Society for Testing and Materials (ASTM) standards. These standards use pictorial standards of coatings defects compiled by the Federation of Societies for Coatings Technology (1979). The evaluations are based on finish performance and appearance. The 10 to 1 rating scales were used for mildew and general appearance of transparent finishes, erosion and general appearance of semitransparent finish, and flaking and cracking performance and general appearance for solid-color stains and paints. A 10 value represents the original condition of the finish; a 1 value represents total failure (i.e., the paint is completely cracked; the surface is covered with mildew; the finish is completely eroded); a 5 value represents the overall condition at which refinishing would be required but without extensive preparation of the substrate or finish surface.

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

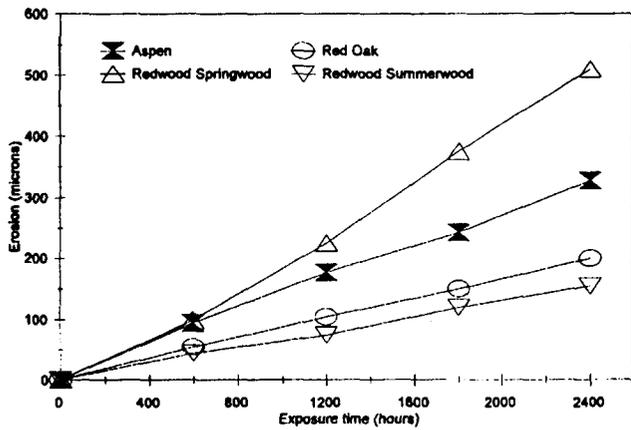


Figure 1. — Accelerated weathering of woods.

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

### Accelerated weathering

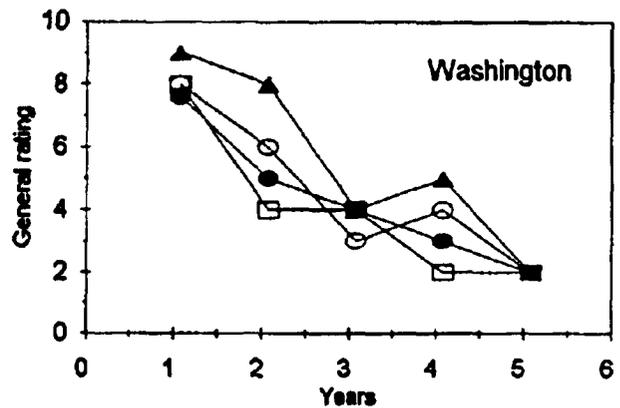
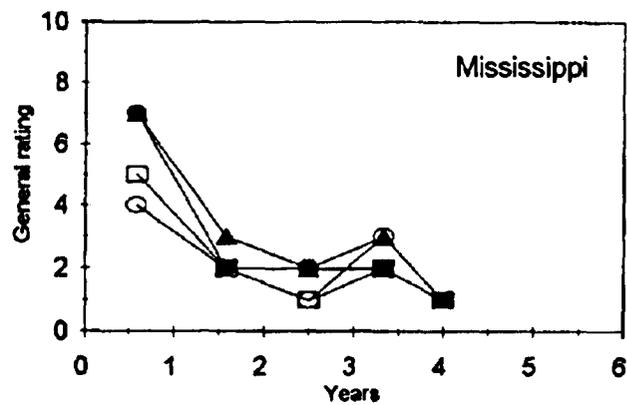
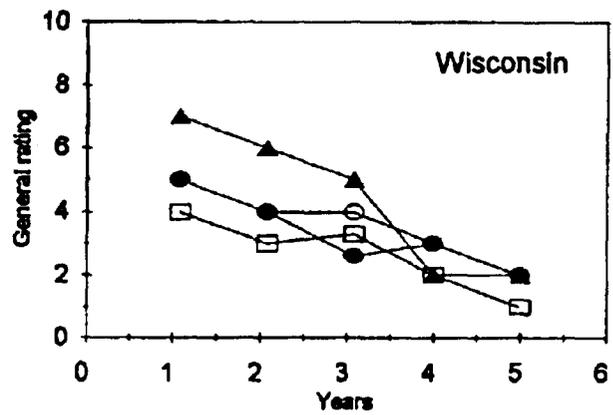
Accelerated weathering can be correlated with exterior natural weathering to give an estimate of weathering resistance (16). An accelerated weathering study was done on unfinished aspen using a commercial Xenon arc weathering chamber. Exposure consisted of high-intensity Xenon arc light exposure for 24 hours per day for 100 days. Each day the aspen was sprayed with distilled water for 4 hours. Chamber conditions were  $113^{\circ}\text{F} \pm 3.6^{\circ}\text{F}$  ( $45^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ) and  $50 \pm 2$  percent relative humidity.

### Results and discussion

The following results from outdoor exposure studies illustrate the performance of a range of commercially available and laboratory-prepared pretreatment and finishes on aspen wood siding. The finish systems were chosen for their recognized durability (particularly on softwoods) and were expected to protect wood surfaces for 1 to 3 years (transparent finishes), 4 to 6 years (semitransparent stains), and 6 to 10 years (opaque solid-color stains and paints) (5,13). In most cases, only the overall general performance ratings are shown to reflect the performance; however, different performance factors (discoloration, flaking, cracking, erosion, and mildew) affected the general ratings. Specific modes of finish failure are illustrated where appropriate.

### Accelerated weathering

Weathering of the wood substrate is very important in predicting how transparent and semitransparent finishes will perform. An accelerated weathering study using a Xenon arc weathering chamber and accelerated weathering conditions identical to those described earlier (16) showed that aspen erodes similarly to other woods at a rate consistent with its density (Fig.



○ 1 Coat rough    ▲ 2 Coats rough  
 □ 1 Coat smooth    ● 2 Coats smooth

Figure 2. — General performance rating of a laboratory-prepared water-repellent preservative finish.

1). Aspen, like all other hardwoods, has uniform erosion across the annual rings (14). Because of this and because erosion of aspen is consistent with its low density, transparent and semitransparent finishes would be expected to perform normally and compare favorably with woods of similar density.

### Natural weathering

One exposure panel at each exposure site contained bevel siding specimens that were not finished. The natural weathering process caused the usual graying and roughening of the aspen surface (14). Generally, a pleasing gray color developed within a few months. Some slight checking and cracking was found. Mildew growth was heavier in Mississippi than in Wisconsin and Washington. Lichen was found on unfinished wood in Washington.

### Transparent finishes

Transparent finishes are sometimes called natural or clear finishes. Water repellents and WRP are often used as penetrating transparent finishes for wood (5,12,13). These finishes are also very useful as pre-treatments for other finishes. A successful transparent finish will control the growth of staining fungi (commonly called mildew) on the wood surface and provide a good general appearance. Generally, discoloration and mildew are the most important factors affecting finish durability and appearance. Two coats of a laboratory-prepared WRP containing 5 percent pentachlorophenol provided good protection and appearance to roughsawn aspen surfaces for 36 months in Wisconsin and 24 months in Washington, but only 7 months in Mississippi where the warm, moist climate was very conducive to mildew growth (Fig. 2). A commercial WRP containing 0.675 percent copper-8-quinolinolate had considerably poorer performance than did the laboratory-prepared WRP at the exposure sites in Wisconsin and Mississippi but provided a reasonable appearance for 36 months in Washington where the climate was cool and moist (Fig. 3).

At all three sites, performance of transparent finishes was poorer on smooth surfaces than on roughsawn surfaces. This is a common observation (10) explained in part by the fact that more finish can be applied to the roughsawn surface than to the smooth (Table 2). The roughsawn surface accepted more finish (i.e., had a lower spreading rate) than did the planed smooth surface. The ratio of spreading rates for the WRP finishes (Table 3) shows that 1.8 to 1.9 times as much finish material was applied as a first coat to roughsawn compared with smooth surfaces. We also found that two coats of transparent finish always gave considerably better performance than one coat. This is also a common observation in finishing studies on wood exposed outdoors.

These results of the performance of transparent finishes on aspen are similar to those observed for softwoods and to those observed for yellow-poplar (9). The results illustrate the need for a combination of sealing, water repellency, and preservative action (against staining fungi) for a successful transparent

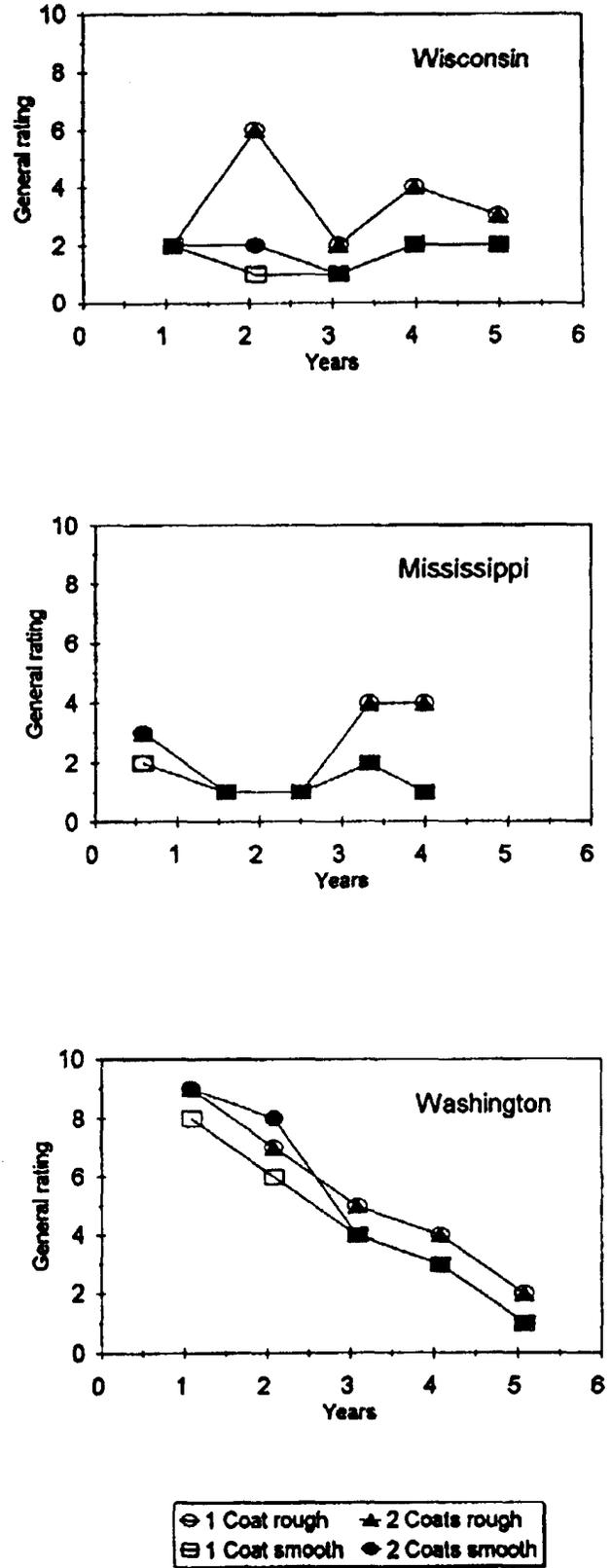


Figure 3. — General performance rating of a commercial water-repellent preservative finish.

wood finish (5). A good WR will minimize checking, cracking, and deformation, and a good preservative (mildewcide) will control mildew and other staining organisms, the primary cause of wood surface discoloration in transparent finishes (5,13). The results also

illustrate the relatively short life of the transparent finishes for wood compared with the pigmented semi-transparent finishes described in the following sections.

### Semitransparent stains

Semitransparent penetrating stains are popular wood finishes especially for flat-grain wood with roughsawn or weathered surfaces (2,13). Unlike paints, these stains do not leave a surface film when properly applied and, thus, should not fail from blistering, cracking, or peeling. The normal failure mechanism of semitransparent stains is one of slow erosion of the finish from the wood surface during weathering. These stains should be useful exterior finishes for hardwoods such as aspen, especially when they contain a WR to minimize the shrinking and swelling of wood and mildewcides to help control staining fungi (mildew).

The semitransparent stain was evaluated over time by estimating the amount of erosion of the stain from the wood surface (Fig. 4). The stain performed well for the 10 years of this study when applied as two coats on roughsawn surfaces. Best overall performance was observed in Wisconsin. Performance for one-coat application was considerably poorer than for two coats, and performance over smooth surfaces was considerably less than on roughsawn surfaces. The spreading rates in Table 2 and the comparison ratios between rough and smooth surfaces in Table 3 show that nearly twice as much stain is applied to the roughsawn surface compared with the smooth. Thus, stain erosion rate (Fig. 4) is nearly identical for two coats of stain on smooth wood and one coat of stain on roughsawn wood because both surfaces have essentially the same amount of finish on them. Also, the roughsawn surface allows a second coat to be applied without any film formation. Film formation with penetrating semitransparent stains changes the mode of failure from erosion to flaking and peeling, a much more destructive form of coating failure. These results show that aspen can be successfully finished with a penetrating semitransparent stain and good performance can be expected, especially on roughsawn surfaces.

### Opaque finishes (paints and solid-color stains)

Solid-color stains and paints are film-forming coatings usually opaque to visible and ultraviolet light; some also resist the penetration of liquid water and water vapor. These coatings, especially paints, generally provide the most protection against the weather for wood exposed outdoors above ground (5).

*Solid-color stains.* — The overall general performance of the solid-color stains after exposure in Wisconsin is illustrated in Figure 5. Similar general performance trends were observed at the other two exposure sites. Good performance was found with the solid-color stains, particularly when they were applied to roughsawn wood. Surprisingly, the general performance of two coats of solid-color stain was poorer than for one coat; the difference was greater for the oil-

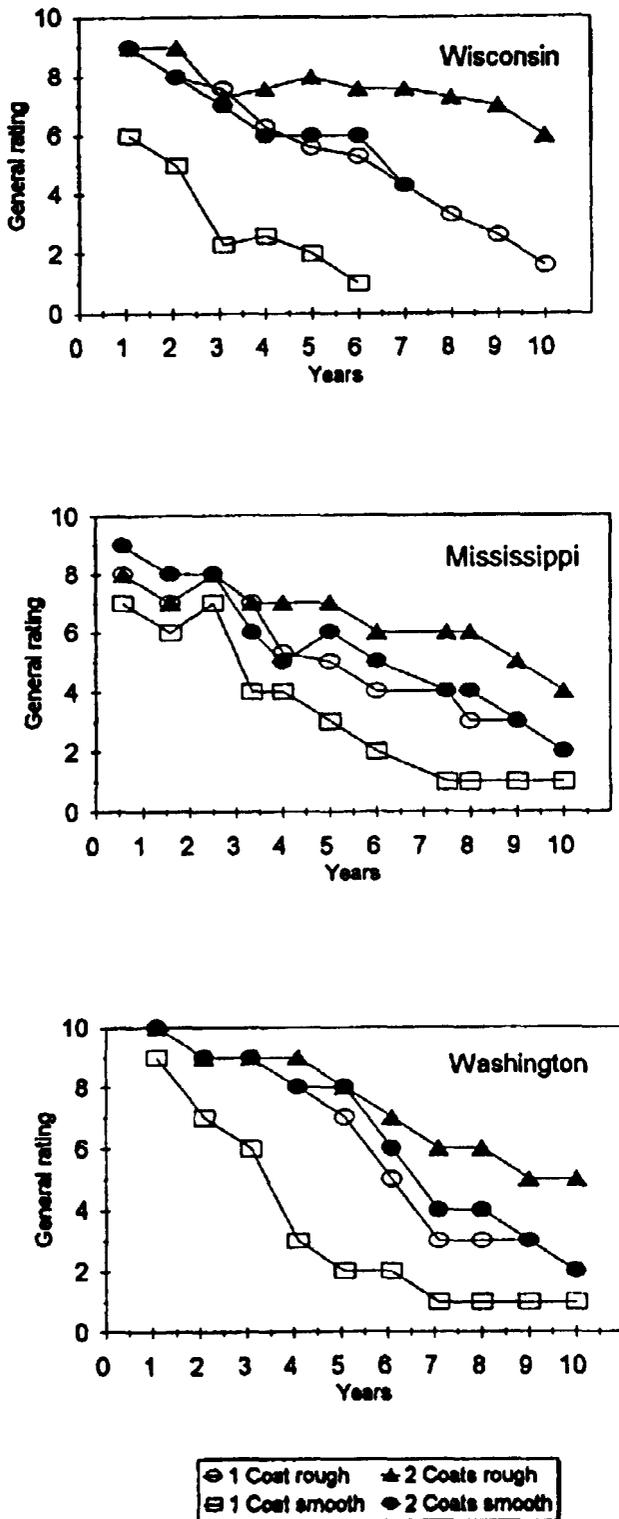


Figure 4.— General performance of a semitransparent oil-based stain finish.

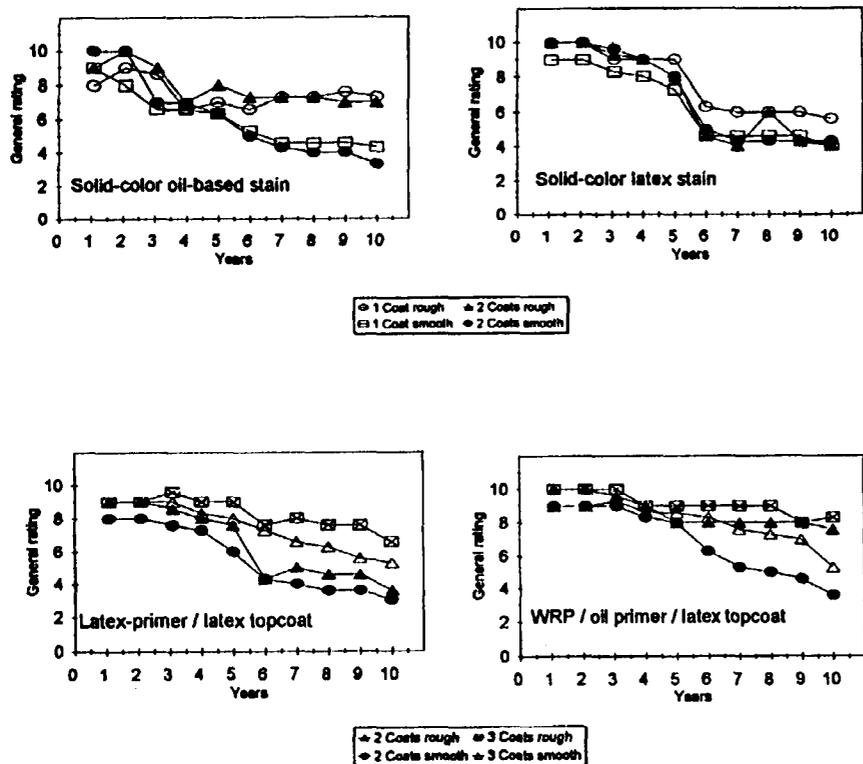


Figure 5. — General performance of film-forming finishes in Wisconsin.

TABLE 5. — Performance of film-forming finishes after 10 years on smooth and roughsawn aspen siding (average of cracking and flaking evaluations).<sup>a</sup>

| Finish  | Wisconsin |         |           |         | Mississippi |         |           |         | Washington |         |           |         |         |
|---|-----------|---------|-----------|---------|-------------|---------|-----------|---------|------------|---------|-----------|---------|---------|
|   | Smooth    |         | Roughsawn |         | Smooth      |         | Roughsawn |         | Smooth     |         | Roughsawn |         |         |
|   | 1 coat    | 2 coats | 1 coat    | 2 coats | 1 coat      | 2 coats | 1 coat    | 2 coats | 1 coat     | 2 coats | 1 coat    | 2 coats |         |
| Solid-color oil-based stain                         | 4.6       | 3.8     | 8.5       | 8.5     | 7.0         | 5.0     | 8.5       | 9.0     | 5.0        | 2.5     | 9.0       | 9.0     |         |
| Solid-color latex stain                             | 5.1       | 8.0     | 8.3       | 9.5     | 7.0         | 9.0     | 8.5       | 8.5     | 5.5        | 7.5     | 9.5       | 9.5     |         |
| Latex primer + latex topcoat                        |           | 2 coats | 3 coats   | 2 coats | 3 coats     | 2 coats | 3 coats   | 2 coats | 3 coats    | 2 coats | 3 coats   | 2 coats | 3 coats |
| WRP <sup>b</sup> + oil-based primer + latex topcoat | 8.3       | 8.8     | 9.8       | 10.0    | 8.5         | 9.0     | 9.5       | 9.5     | 7.0        | 9.0     | 9.0       | 9.5     |         |

<sup>a</sup> The rating used a scale of 10 (perfect) to 1 (complete failure). A value of 5 indicates the need for refinishing without major surface preparation.

<sup>b</sup> WRP = water-repellent preservative.

based stain than for the latex stain.

This difference in one- and two-coat performance is illustrated more clearly in the average values for cracking and flaking at the three sites after 10 years of exposure (Table 5). Flaking (i.e., peeling of a film-forming finish exposing bare wood) and cracking are generally convenient and reliable indicators of film-forming coating performance. The two-coat oil-based stain on smooth wood had much more cracking and flaking than did one coat. The latex stain did not show this difference, and cracking/flaking was worse for one coat of finish than for two coats with the latex stains.

This observation for the cracking and flaking of two coats of oil-based stain may be explained by the brittle nature of the relatively thin oil-based coating. The greater thickness of the two-coat oil-based solid-color stain compared with the one coat could lead to brittleness, which leads to cracking and peeling. This ten-

dency would not be as great for the thinner one-coat finish. Miniutti (15) discusses in detail the importance of this mode of film failure. The brittle failure and cracking allow water absorption under the film, leading to swelling (and shrinking after drying) stresses that can accelerate film failure with the more brittle oil-based stain. The solid-color latex stain, like all latex products, is a more flexible coating than the oil-based finishes. This flexibility results in a better durability of the two-coat latex system compared with the one-coat latex, and in better finish performance.

**Paints.** — The acrylic latex house paints in this study showed excellent performance on roughsawn aspen siding after 10 years of exposure at all three sites (Table 5). As expected, the best performance was found for the three-coat application (one primer coat and two topcoats). The WRP/oil-based primer/latex topcoat system was considerably better in performance compared to the latex primer/latex topcoat sys-

tern, especially when one primer and one topcoat were applied to smooth wood. There was less difference when a second topcoat was applied, essentially because neither finish system showed any substantial deterioration after 10 years of exposure (the lowest cracking/flaking value observed was only 8). This enhanced finish durability observation is consistent with earlier observations on the enhanced performance of paints when applied over WRP pretreatment (11,12) compared to when applied over untreated wood. Such performance enhancement is found with both latex and oil-based paint systems. Thus, if the all-latex primer and one-topcoat paint system had been applied over a WRP-pretreated wood surface, it would probably have had performance and durability equivalent to the oil primer/latex topcoat system.

Paint performance was considerably better on roughsawn compared with smooth surfaces. For film-forming finishes, a lower spreading rate on roughsawn surfaces equates to greater film buildup and possibly greater absorption of the binder into the surface. These performance results reflect the excellent durability of modern latex topcoat paints and demonstrate that acrylic latex paints perform as well on hardwoods as they do on softwoods. Similar results with latex paints were observed for yellow-poplar (5).

These laboratory and field exposure studies indicate that hardwoods such as aspen can be finished with modern acrylic latex paint systems and excellent performance can be expected. This, of course, would be true only if good construction and painting practices are followed (13).

**Decay.** — Aspen is a wood species described as slightly or nonresistant to decay (16). This means there would always be the possibility of decay occurring if the moisture content of the wood was sufficiently high. The design of our outdoor exposure panels was such that the vertical edges of the test specimens were butted against a wood strip, and completely sealing the end grain was not normally possible. Also, water could enter at the top of the test specimen and could move between the specimen and plywood backing on the exposure panel. This design increased the possibility for decay because water is easily trapped and retained.

In Wisconsin, a white-rot fungus, *Coriolus hirsutus*, was found growing through small defects on painted aspen surfaces of the exposure panels painted with the latex primer/latex topcoat paint system after 8 years of outdoor exposure. No other decay was observed for the Wisconsin panels. In Mississippi, decay fungi, (*Schizophyllum commune*) were found after only 6 months on the panel painted with the latex primer/latex topcoat paint system. Decay was found on one siding piece on the exposure panel painted with the oil-based primer/latex topcoat paint system after 2 years. After 4 years, decay fungi were found on the bottom board of the panel coated with the semitransparent stain. No decay fungi were observed on any panels in Washington, but lichen growth was fairly common on the finished surfaces.

Other than the usual surface-staining fungi often described as mildew, there was no sign of decay fungi on any aspen panels that were unfinished or finished with transparent or semitransparent finishes or solid-color stains, except for the one board with the semitransparent finish, as noted previously. The penetrating finishes are not film-forming and do not restrict the movement of water vapor. Thus, wood wetted from rain or dew can dry more quickly than when painted with two coats of paint. Latex paints are generally noted for permeability to water vapor but the water loss is so slow that the wood stays wet long enough for decay to occur. Solid-color stains are also noted for permeability to water vapor. Southern Wisconsin does not have a climate conducive to decay (13), and only a small amount of decay was observed on painted aspen panels. The climate of southern Mississippi is much more conducive to decay, and many more decay problems were apparent on the panels.

These field results illustrate the potential problems when using a hardwood like aspen as exterior siding. Poor construction practices could result in water being trapped and decay occurring. A similar result was found for waferboard siding made from aspen (3,4) and for yellow-poplar solid-wood siding (9). If the wood siding is pretreated with a WR or WRP, the potential for decay should be greatly reduced. However, even with pretreatment, decay could still occur, especially when poor construction practices are used. A WRP pretreatment should be better than a WR in protecting the painted wood siding from decay and for improving paint performance (11,12,13).

### Concluding remarks

These outdoor exposure studies of the performance of various laboratory-prepared and commercially available finish systems on aspen siding clearly illustrate the benefit of using acrylic latex paints for the best protection and longest durability. The study also demonstrates the benefit of finishing roughsawn rather than smooth wood surfaces for long-term protection. Roughsawn surfaces always gave better finish performance than did smooth surfaces. Semitransparent finishes performed very well on roughsawn aspen and transparent finishes gave moderate protection against outdoor weathering. Exposures in Wisconsin were generally the most severe with regard to finish degradation from sunlight. Mississippi exposures usually resulted in more failure problems related to mold and mildew discoloration. In Washington, finish performance was usually intermediate between Wisconsin and Mississippi.

There were some problems with the development of decay when the aspen was painted. White-rot decay fungi were found under latex-painted test panels exposed in Wisconsin and Mississippi; decay was more extensive in Mississippi. The decay was probably a direct result of water entrapment from the exposure panel design used, but the results do show that all precautions must be addressed when wood nonresistant to decay is used in exterior above-ground appli-

cations. Decay may be enhanced when the wood is painted because of water entrapment. There are steps that can be taken to minimize the decay problem. Given good construction practices, any pretreatment like a WR, a WRP, or similar material, should be very beneficial in protecting painted wood from decay and for improving the overall performance of the wood and the finish.

These outdoor durability results show that aspen wood siding has finishing characteristics similar to softwoods like fir, pine, hemlock, and spruce. The finish performance and durability results generally reflect the performance that would be expected for finished aspen siding when exposed to climates similar to those found in Wisconsin, Washington, and Mississippi. These finishing results do not take into account any problems that might arise from the warping of aspen after wetting and drying, and its inherent dimensional instability. Most importantly, however, the results are those that would be expected only when the wood was handled and finished under the most ideal conditions and only when proper construction and installation procedures were used.

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