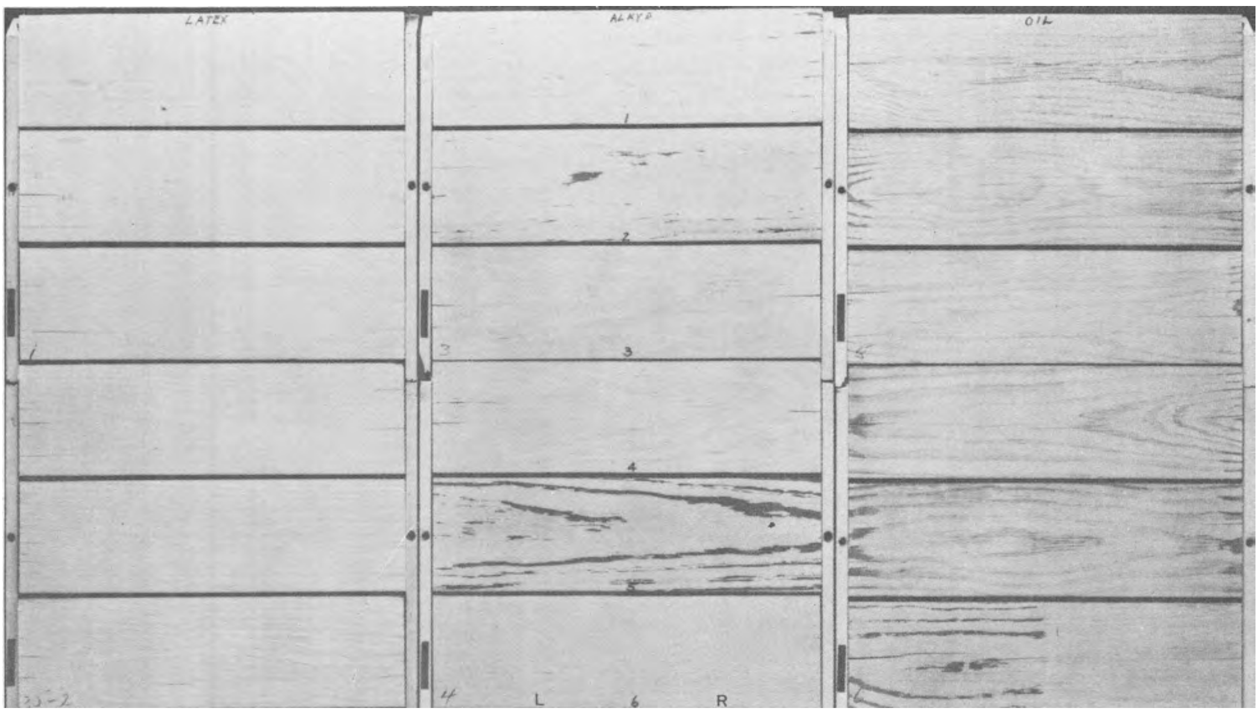
IMPROVING PAINT PERFORMANCE ON SOUTHERN PINE BY RELIEF OF MACHINING STRESSES AND CHROMIC ACID TREATMENT



USDA Forest Service
Research Paper
FPL 271
1976

U.S. Department of Agriculture
Forest Service
Forest Products Laboratory
Madison, Wis.

ABSTRACT

Relieving surface machining stresses by wetting with steam on both pith-out and bark-out surfaces of southern pine improved the durability of an alkyd and a linseed-oil base paint.

An acrylic latex paint, superior in performance to both the alkyd and the oil paints, was not benefited by stress-relief treatment before painting indicative that the water in a latex paint serves as a stress-relief agent.

Treating the wood surface after steaming with a brush coat of 10 percent chromic acid significantly improved the adhesion of alkyd and oil-type paints to summerwood, reduced peeling and erosion, and retarded the formation of mildew. A two-coat paint system of a long-oil alkyd did not need refinishing on flat-grain southern pine treated with chromic acid after 9 years' exposure to weather.

IMPROVING PAINT PERFORMANCE ON SOUTHERN PINE BY RELIEF OF MACHINING STRESSES AND CHROMIC ACID TREATMENT

By
JOHN M. BLACK, Chemist,
and
EDWARD A. MRAZ, Technician
Forest Products Laboratory,[1] Forest Service
U.S. Department of Agriculture

Evidence *(1-3)*[2] indicates paint performance is largely dependent on the stability of the wood substrate, that is, little shrinking and swelling with moisture. For this reason, vertical grain or quartersawed surfaces of all species are far superior to flat-grain surfaces for painting because radial swelling is only about half that of tangential. Water-soluble extractives in species such as redwood and western redcedar and in uniform grain or low-density species such as ponderosa pine further reduce swelling and improve paint performance.

Stresses in coatings presumably are related to the moisture content of wood at the time of painting. Wood with a relatively high moisture content (15-20 pct) is considered better for painting than is very dry wood *(1)*. This indicates that when dry wood is painted, subsequent adsorption of water causes the wood to swell, putting the coating in tension; this leads to checking and cracking failures in the coating. If lumber is painted at a high moisture content, a small desorption of moisture will produce shrinkage, and compressive stresses in coatings will form. Coatings are not generally known to fail by compression.

Swelling stresses in wood, especially flat-grain boards, can be concentrated in transition zones where abrupt changes in cell wall thickness and wood density occur. These zones, such as the transition of summerwood to springwood, are also common sites of machining stresses near the surface *(1-3)*. Pressure of cutting knives in the planing operation compresses the weak cells of springwood. Subsequent relief of these compressive stresses by wetting will raise the grain at the surface. When grain raising occurs under coatings, high tensile stressing of the coating can occur that can lead to premature separation and cracking failure.

Compressive stresses can occur also in surfaces of plywood, particleboard, and hardboard if surface fibers are compressed by pressure during fabrication. Likewise sanding operations can compress surface fibers that lead to grain raising and stressing of paint coatings. Because the recovery of surface compressive stresses and raise in grain after painting can be contributing factors to early paint failure, a treatment of the surface to relieve the surface of compressive stresses should improve paint performance.

The purpose of this study was to examine how wetting the surface with steam, sanding, and applying acid solutions or water-repellent preservatives might contribute to service life of paint applied to flat-grain boards of southern pine.

---

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Underlined number in parentheses refer to literature cited at end of this report.

PROCEDURE

Specimens

Six end-matched specimens, 15 inches in length, one for each treatment, were cut from a single 3/4- by 4-1/2-inch by 8-foot board of southern pine. A total of 18 boards was employed. Six surface treatments were applied to two different flat-grain surfaces (pith-in and pith-out) with three finishes and three replicas, which made a total of 108 specimens.

Treatments

The 15-inch specimens were conditioned to 80°F and 65 percent relative humidity (RH) and given the following six treatments:

1. Surfaced with a dull planer, steamed for 1 minute over boiling water, reconditioned to 80° F and 60 percent RH, and brush-treated with a water-repell en t preservative.

2. Surfaced with a sharp planer.

3. Surfaced with a dull planer, steamed for 1 minute over boiling water, reconditioned to 80°F and 65 percent RH, and sanded with two passes through a drum sander with 2-0 paper.

4. Surfaced with a dull planer, steamed for 1 minute over boiling water, and reconditioned to 80°F and 65 percent RH (fig. 1).

5. Surfaced with a dull planer.

6L and 6R. Surfaced with a dull planer, steamed for 1 minute over boiling water, and dried. The left half (6L) of the specimen was brush-treated with one coat of a 5 percent phosphoric acid solution and the right half (6R) with a 10 percent solution of chromic acid. Specimens were then reconditioned to 80°F and 65 percent RH before painting.

Paint

After treating and conditioning to 80°F and 65 percent RH, the specimens were painted with two coats of the following systems:

1. Acrylic latex house paint.

2. Alkyd long-oil house paint.

3. One coat of oil primer and one top-coat Of house paint.

The acrylic latex paint (No. 1) was applied to a thickness of about 2 mils; the oil-base and alkyd paint, to a thickness of about 3.5 mils.

The painted specimens were exposed vertically facing south at Madison, Wis., and evaluated annually for resistance to mildew and paint performance.

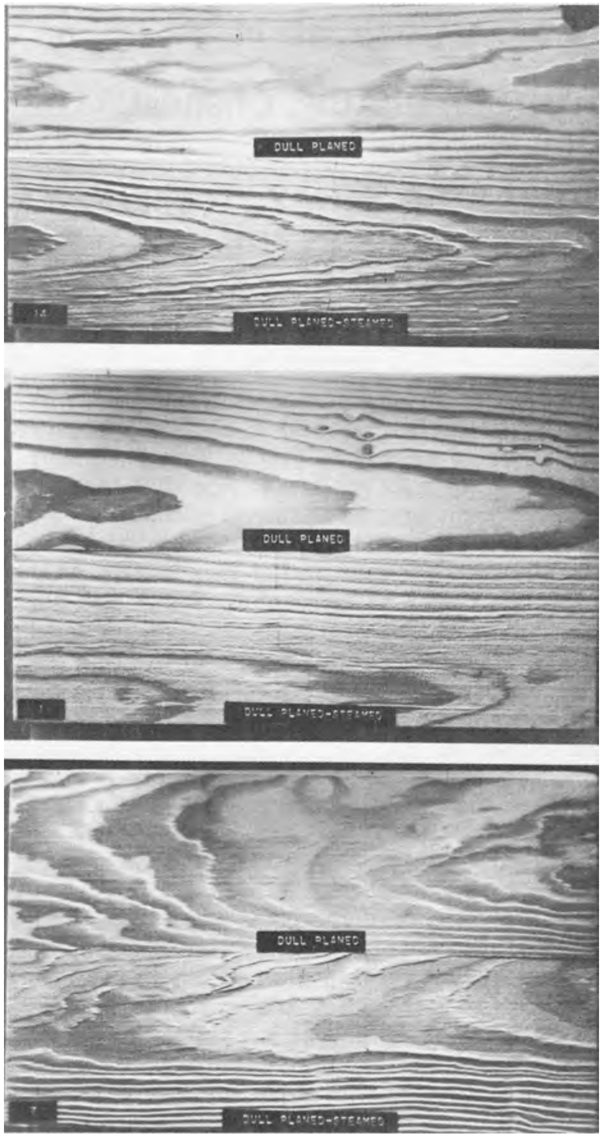


Figure 1.—Boards 14, 1, and 7 of southern pine, illustrate stress-relief (grain raising) by steaming. (M 143 621)

RESULTS AND DISCUSSION

Ratings on paint performance and mildew resistance are presented in tables I and 2, respectively. Because there was no observable difference in paint performance on bark-out and pith-out surfaces, data for the two substrates were grouped together. The appearance of the test panels after 6 and 9 years of exposure is shown in figures 2-3.

Except on surfaces treated with chromic acid (6R) the acrylic latex paint performed better than the alkyd or the oil-base paint. The acrylic paint remained free of cracking and peeling, and did not need refinishing on any of the surfaces for at least 6 years. The long-oil alkyd paint failed after 6 years, primarily by separating from summerwood bands, whereas the oil-base paint with a white lead primer showed better adhesion to summerwood than the alkyd but failed by uniform erosion from both springwood and summerwood.

The advantage of surface treatments to relieve compressive machining stresses was most pronounced on the alkyd paint. The 6 and 9 year exposure data show the flat-grain pine surfaces prepared for finishing with a dull planer, treatment 5 (without stress relief), had the most advanced degree of paint failure. The second most advanced paint failure occurred over treatment 2 (sharp planing) indicating that even with planing practices, assumed to be good, the need for relief of machining stresses is not eliminated. All of the other surface treatments (1, 3, 4, and 6L), which involved dull planing and stress relief by steaming, produced improved paint performance with alkyd paint.

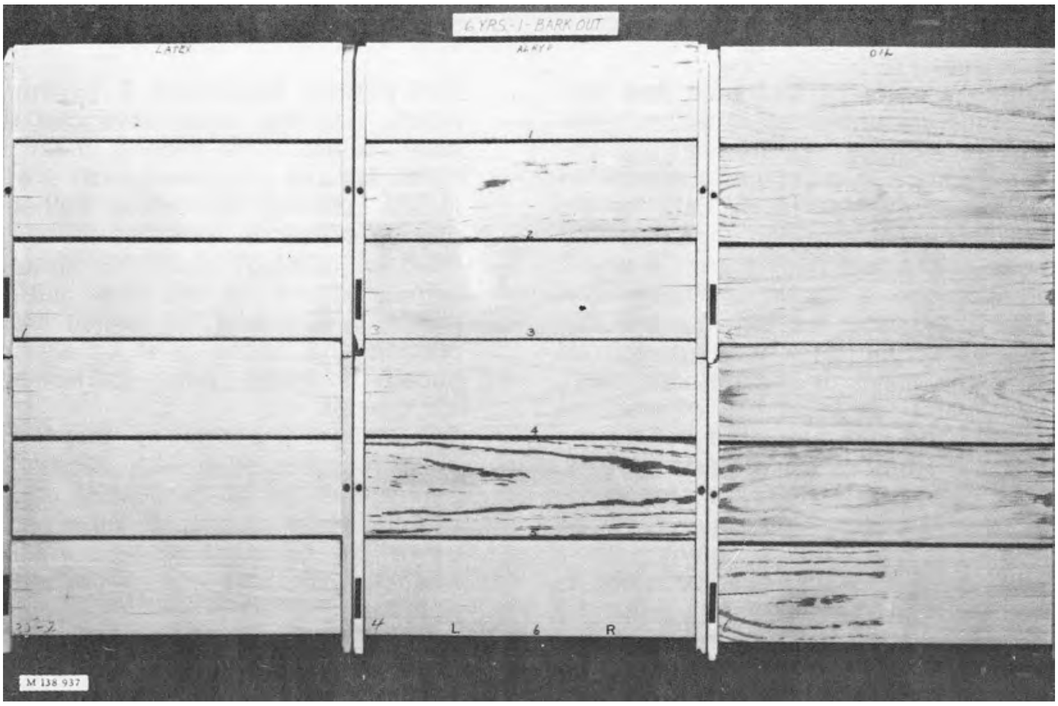
A slight improvement in paint performance by stress relief with steaming was apparent with the oil-base paint after 6 years. After 9 years' exposure, however, the failure of the oil paint on all surfaces, except treatment 6R, was one of uniform chalking or erosion.

The outstanding performance of acrylic latex paint on all of the surface treatments indicates that stress relief in steaming was not needed for latex paint as much as for the alkyd or oil paint. A probable explanation for this observation is the water in the latex paint had the same beneficial effect as steaming by

Table 1.—Ratings for paint failure on fiat-grain southern pine treated for stress-relief after 3, 6, and 9 years' exposure to weather

Wood treatment prior to painting	Treatment number	Paint failure rating[1] after exposure, by years: Acrylic			Alkyd			Oil		
		3	6	9	3	6	9	3	6	9
Sharp planed	2	0.0	2.0	3.0 D	1.0	4.5	8.0	2.6	4.3	8.4
Dull planed	5	0.0	2.7	4.7 D	2.0	6.0	9.2	3.0	5.0	8.3
Dull planed, steamed	4	0.0	2.7	4.0 D	0.0	3.2	4.9	1.3	4.0	7.4
Dull planed, steamed, sanded	3	0.0	2.0	3.0 D	0.0	3.0	3.5	0.0	3.5	7.3
Dull planed, steamed, water-repellent preservative	1	0.0	2.1	4.0	0.2	3.0	6.0	0.4	4.4	7.7
Dull planed, steamed, phosphoric acid	6L	0.0	2.7	3.7 D	0.0	2.9	3.7	0.5	3.9	8.7
Dull planed, steamed chromic acid	6R	0.0	1.5	3.0	0.0	1.5	2.2	0.2	1.5	3.7

[1]Each rating is average of 6 specimens. 0.0, No failure; 3.0, a need to refinish; ratings above 3.0, advanced degree of failure by paint cracking, peeling, or erosion; and D, decay in wood substrate.



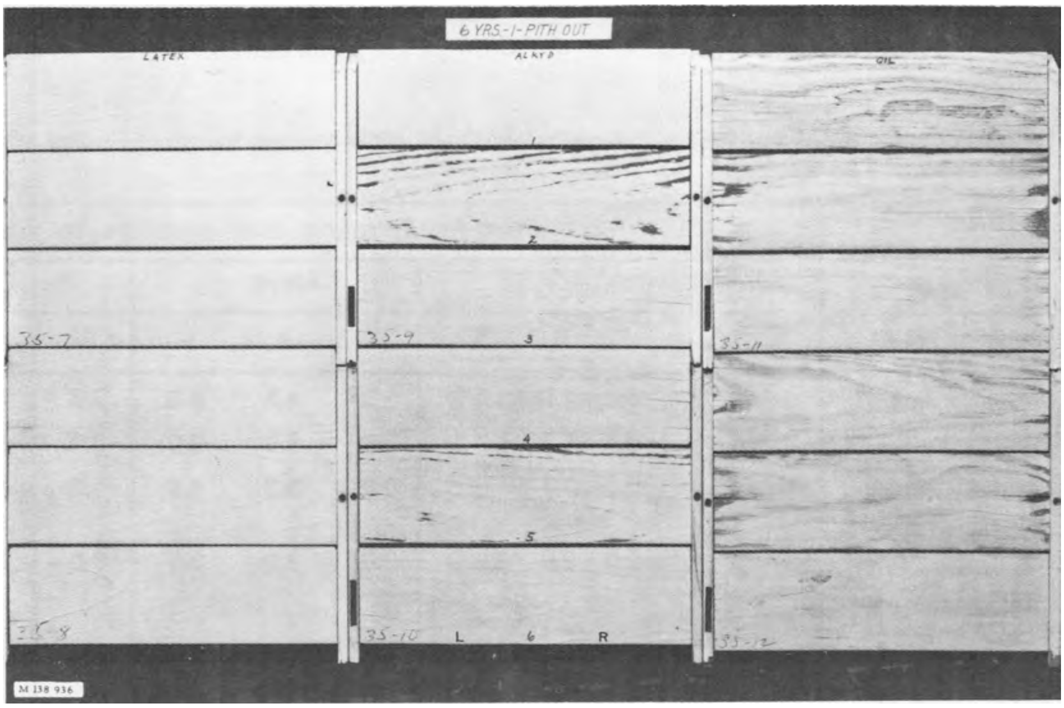
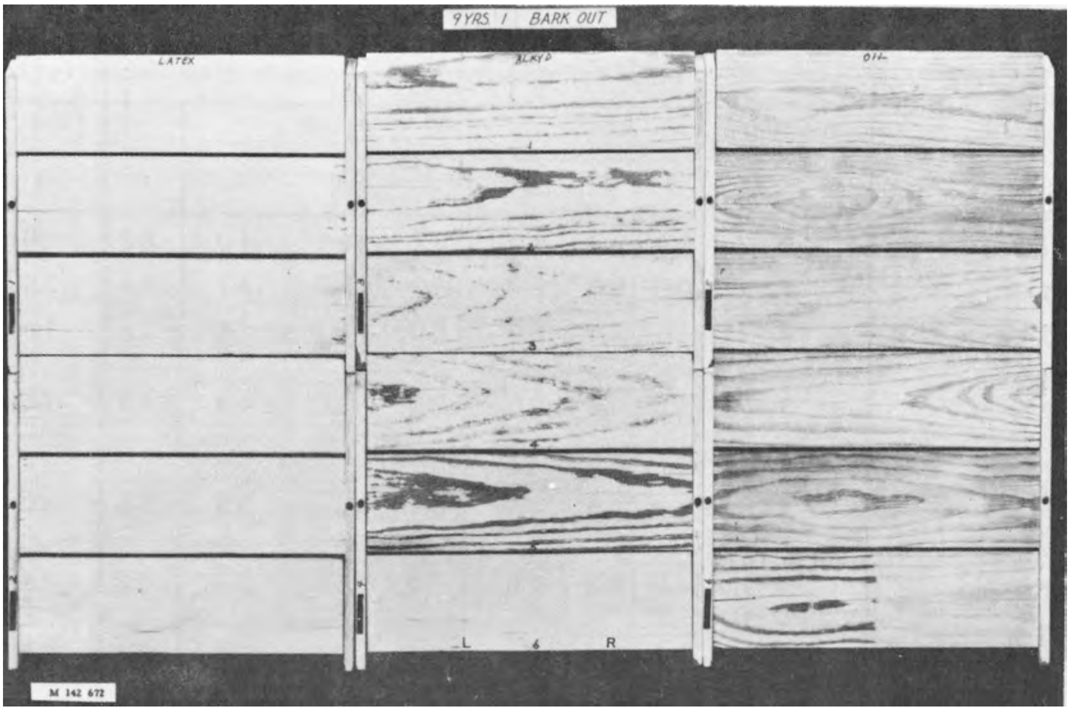


Figure 2.—Latex, alkyd, and oil-based paints after 6 years' exposure to weather. Treatment numbers are indicated on alkyd panels (first replica). Note advanced peeling failure of alkyd paint from summerwood bands on boards surfaced with sharp planer (treatment 2) and with dull planer (treatment 5). Note improved performance of oil paint over chromic acid-treated surface (treatment 6R). The performance shown here was typical of three replicas. (M 138 937) (M 138 936)



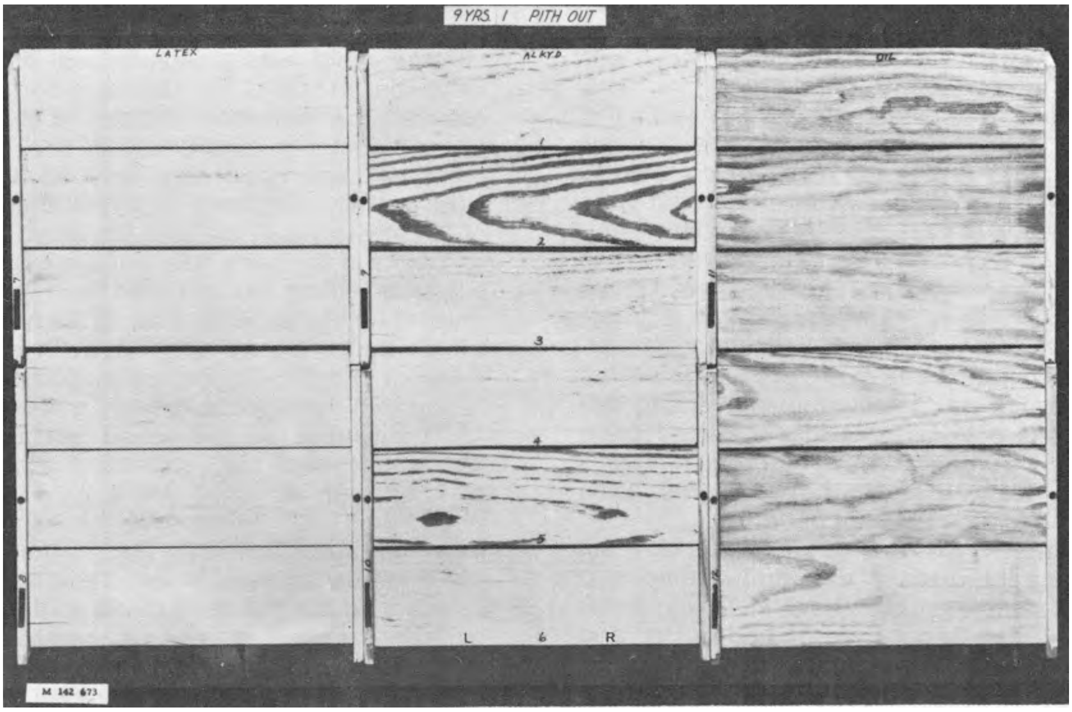


Figure 3.—Latex, alkyd, and oil-based paints after 9 years' exposure. Treatment numbers are indicated on alkyd panels (first replica). Note superior performance of acrylic latex paint and improved performance of both alkyd and oil paints over chromic acid-treated surface (6R). The performance shown here was typical of three replicas. (M 142 672) (M 142 673)

Table 2.-Ratings for mildew growth on acrylic, alkyd, and oil painted surfaces after 3, 6, and 9 years' exposure to weather

Wood treatment prior to painting	Treatment number	Paint ratings[1] for mildew growth after exposure, by years: Acrylic			Alkyd			Oil		
		3	6	9	3	6	9	3	6	9
Sharp planed	2	0.5	2.9	5.9	8.7	9.4	4.0	2.2	1.9	6.0
Dull planed	5	0.0	3.4	5.7	9.2	9.0	4.7	1.4	2.5	6.0
Dull planed, steamed	4	0.0	3.4	6.0	8.9	8.2	4.5	1.4	1.4	6.0
Dull planed, steamed, sanded	3	1.0	3.4	6.0	8.9	9.0	4.4	1.8	1.5	6.0
Dull planed, steamed, water-repellent preservative	1	0.0	2.0	4.5	8.4	4.5	3.3	0.5	1.2	6.0
Dull planed, steamed, phosphoric acid	6L	1.9	3.2	5.5	7.5	8.7	3.5	6.2	8.4	6.0
Dull planed, steamed, chromic acid	6R	0.2	2.5	5.0	2.7	3.5	2.5	0.4	0.2	3.8

[1]Each rating is average of 6 specimens; 0.0 indicates no mildew.

reducing surface stresses produced by machining. This performance suggests also that applying water to exterior wood surfaces will improve the surface for painting.

A most interesting observation was the high incidence of decay in boards painted with the latex-type paint. Four of six boards showed decay. The decay developed between 6 and 9 years of exposure (table 1). No decay was observed in boards treated with either alkyd or oil-base paint after 9 years. Decay was not observed with latex paint if treatments 1 and 6 were used, indicating a brush coat of water-repellent preservative or chromic acid was effective in preventing decay. These data suggest that the latex paint coating is porous and allows more moisture (rain and dew) to enter the wood than does either the alkyd or the oil paint.

Treatment 6R, a brush coat of chromic acid after the surface was dull planed and steamed, demonstrated several unusual advantages. The service life of both alkyd and oil-base paints, for example, was greatly increased. The alkyd paint if used without the chromic acid treatment needed refinishing after 6 years' exposure but with the treatment did not need refinishing after 9 years' exposure. The need for refinishing was delayed for about 3 years with oil-base paint, also.

The better performance of the alkyd and the oil-base paints over surfaces treated with chromic acid was characterized by better adhesion of paint to summerwood, which reduced the tendency of paint to peel. The rate of chalking or erosion of the oil-base paint was also noticeably reduced. Chromic acid further effectively retarded the growth of mildew (table 2) on both the alkyd and the oil paints in the early years of exposure. This suggests either the chromic acid could be preventing the outward flow of sapwood nutrients that enhance fungal growth or molecules of fungistatic chromium could be diffusing into the paint to prevent mildewing.

Treatment of the wood surface with phosphoric acid (6L) enhanced the growth of fungus on oil paint (table 2). The phosphoric acid did not improve the adhesion of paint to summerwood. This difference in performance between chromic acid and phosphoric acid suggested chromic acid, a strong oxidizing agent, may have improved the chemical bonding of paint to wood by creating reactive sites or by crosslinking the paint to wood. Further study of the action of chromic acid or possibly of other oxidizing agents to improve paint performance by reducing peeling, chalking, and mildew and improving adhesion to summerwood is warranted.

SUMMARY AND CONCLUSIONS

The life of alkyd and oil-based paints on flat-grain boards of southern pine was improved by wetting the wood surface with steam to relieve compressive stresses produced by planing. Planing with well sharpened knives did not eliminate the need to relieve surface stresses. There was no difference in paint performance on pith-out and bark-out surfaces.

Surface-wetting techniques may not be necessary with latex paints, indicating that the water in latex paint systems wets the wood and relieves surfaces of stresses before the film formation is completed. Porous paint systems such as latex, however, contribute to the tendency of southern pine siding to decay unless brush-treated with either a water-repellent preservative or a solution of chromic acid. In this study, with exposure only in Wisconsin, the decay in southern pine was not apparent under an acrylic latex paint for more than 6 years.

Treating a steamed surface with a dilute solution of phosphoric acid before painting did not improve paint performance; it increased the tendency for oil-base paint to mildew.

Treating steamed surfaces with a solution of chromic acid, however, significantly improved adhesion of paint to summerwood, greatly minimized peeling failure, and noticeably reduced the chalking rate of an oil-base primer and topcoat. The best performance of a two-coat paint system on flat-grain southern pine ever observed at the Forest Products Laboratory was achieved with two coats of a long-oil alkyd paint over a chromic acid treated surface. This system did not need refinishing after 9 years of exposure to weather.

LITERATURE CITED

1. Browne, F. L.
   1947. Wood properties and paint durability. U.S. Dept. Agric. Misc. Publ. 629, Washington, D.C.

2. Miniutti, V. P.
   1963. Properties of softwoods that affect the performance of exterior paints. J. Paint Tech. 35(460):451-471.

3. U.S. Forest Products Laboratory
   1965. Raised, loosened, torn, chipped, and fuzzy grain in lumber. U.S. Dept. Agric. For. Serv. Res. Note FPL-099, For. Prod. Lab., Madison, Wis.

U.S. GOVERNMENT PRINTING OFFICE 1976-650-517/49