Wood Surface Treatments to Prevent Extractive Staining of Paints

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Abstract

A number of water-soluble chemicals including stannous chloride, zinc oxide-ammonia complex, copper chromate, and simple chromium compounds were used to pretreat the surfaces of redwood and western redcedar. Each of these chemical treatments was successful to a degree in preventing the staining, by water-soluble wood extractives, of subsequently applied water-base latex paints. A number of different treating variables were evaluated.

CAUTION: Latex or other water-base primers are NOT FOR USE over bare redwood, cedar, or cypress, since these primers will not resist the natural bleeding of water-soluble stains (extractives) in these woods.

This warning, or one very similar to it, appears on paint cans and in many descriptive books and pamphlets on painting. The reason for it is that water-soluble extractives from certain wood species can produce an unsightly red-to-brown discoloration on paint coatings, particularly on porous paints, whenever moisture has access to the wood substrate (10).

Proposed solutions to the problem of extractive staining have been described in early (9) and recent literature (4,7). The recent studies were on lead-free compounds since Public Law 91-965, "Lead Paint Poisoning Prevention Act," January 13, 1971, banned the use of lead-containing compounds in those paints with which children could come into contact. The extractive staining of latex paints had generally been controlled by reactive lead silicate pigments. The staining was also controlled by the use of an oleoresinous primer coat (2,10,11).

Pretreatment of redwood and cedar surfaces with certain inorganic chemicals, notably copper chromate and related compounds, is effective in fixing complexing the water-soluble extractives in redwood and cedar (and other wood species of high extractives content) and thus minimizing paint staining (1) Recent work describes pretreatments with zinc salt complexes (5,6). The chemical nature of these extractives and some proposed mechanisms of fixation have also recently been reviewed (8).

The objective of the present work was to investigate methods of fixing water-soluble wood extractives to prevent them from subsequently discoloring paint, and permit the application of primarily water base latex painting systems directly to wood without special primers. This would greatly simplify the wood painting process and might also enhance the life of the exterior coating as reported previously (1).

Wood Samples

Samples of redwood *(Sequoia sempervirens)* and western redcedar *(Thuja plicata),* measuring 4-1/2

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Table 1. — **COMPOSITION OF COPPER CHROMATE SOLUTIONS.**

Components	Quantity (g)					
$CuSO_4 \cdot 5\ H_2O$	15.5	10.8	5.8	15.5	10.8	5.8
$Na_2Cr_2O_7 \cdot 2\ H_2O$	3.1	6.5	10.2	3.1	6.5	10.2
NH_4OH (30% NH)	30.8	21.6	11.5	–	–	–
H_2O	150.6	161.1	172.5	181.4	182.7	184.0
Molar ratio, Cu/Cr	3/1	1/1	1/3	3/1	1/1	1/3

inches by 3/8 inch by 15 inches longitudinally, were cut from large boards. Each sample was divided into five equal longitudinal parts by urethane varnish stripes. Thus, different concentrations of treating chemical could be examined on the same sample as well as be compared to an untreated wood area. The samples were stored at 30 percent relative humidity (RH and 26.7°C prior to treatment.

Chemicals Tested

Copper Chromate

Earlier work at the Forest Products Laboratory indicated the effectiveness of copper chromate ($CuCrO_4$) compounds in fixing wood extractives (1). This work was continued with an examination of the effect of treating variables on the efficacy of the treatment. Variables investigated included: concentration of chemical, ratio of copper to chromium, effect of time after treatment and before subsequent painting, and effect of heating the surface-treated wood before painting. The chemicals used in this portion of the study are shown in Table 1.

Each solution had a total copper and chromium content (referred to hereafter as total metals) of 2.5 percent. Additional dilutions tested were 1.25 and 0.63 percent total metals.

Stannous Chloride

Oxides of tin are amphoteric and a number of complex ions can be formed in solution by adding acid or alkali (3). Four stannous chloride ($SnCl_2$) solutions were freshly prepared using either hydrochloric acid or odium hydroxide in three of them. Three concentrations of stannous ion (tin metal) were examined–2.5, 1.25, and 0.63 percent. Compositions of the treating solutions are shown in Table 2. A solution containing 5 percent tin was used in a later comparative study (9.5% stannous chloride).

Zinc Oxide

Zinc oxide (ZnO) complexed with ammonia was evaluated for comparative purposes since it had been reported to prevent staining of paint over wood (5,6).

Table 2 — **COMPOSITION OF STANNOUS CHLORIDE SOLUTIONS.**

Components	Quantity (g)			
$SnCl_2 \cdot 2H_2O$	9.5	9.5	9.5	9.5
H_2O	190.5	170.5	177.8	181.2
acidic hydrochloric acid (HCl),	–	20.0	–	–
Sodium hydroxide (NaOH)	–	–	12.7	9.3

The 4 percent zinc metal solution was prepared by dissolving 10 grams zinc oxide and 12 grams ammonium carbonate in 178 milliliters of 6 percent ammonium hydroxide. Additional dilutions evaluated were 2 and 1 percent zinc metal.

Chromate Salts

Three chromate compounds were examined in addition to copper chromate. A solution of chromium trioxide (CrO_3, chromic acid) was prepared by dissolving 10 grams of the chemical in 190 milliliters of water to give a solution with 2.5 percent chromium metal. Dilutions of 1.25 and 0.63 percent chromium were examined. The other chromates were ammonium chromate (14.6 g in 185.4 ml water) and sodium dichromate (14.3 g of sodium dichromate dihydrate in 184.7 ml water).

General Procedure

The treating chemical was applied by brush to each wood sample at an approximate rate of 15 grams of solution per 1,000 square centimeters. The end portions of each wood sample were left untreated and the center portions treated with one of each of the three dilutions of chemical. After any conditioning or post treatment, the samples were wiped with a cloth to remove any excess surface chemicals. Then two coats of a standard, laboratory-prepared, white acrylic latex paint were applied with a 5-hour interval between coats. After 24 hours at room temperature, the samples were placed on open-back racks at 26.7°C and 90 percent RH for periods of 1 to 3 months.

Three end-matched wood samples were used to study either the effect of heating after treatment, or conditioning time after treatment and before painting. The heat-study boards were treated and wrapped tightly in aluminum foil to prevent drying, and placed in a forced-draft oven at 60° or 80°C for 1 or 2 hours. The samples were unwrapped and allowed to stand at room temperatures for 24 hours before painting. The boards used to study conditioning time were treated and placed in 80 percent RH and 26.7°C for 1, 3, or 7 days before painting.

Brightness Measurement

The amount of extractive staining through the white latex paint was determined visually by comparing the treated areas to untreated areas and by the use of a tristimulus colorimeter. With the colorimeter, the brightness of the white painted surface was measured using a standard paper test, TAPPI Method T 217, M-48. The method gives a number indicative of the brightness or reflectance of the sample. The standard used was three coats of the acrylic latex paint on an aluminum plate, which gave a brightness value of 90.

Chemical Treatments vs. Commercial Primers

Several promising chemical pretreatments were compared to three commercial primer paints for effectiveness in preventing extractive staining through a latex paint. Two primers were oil-base alkyd paints recommended for use over new redwood and cedar. The third commercial primer was a latex paint

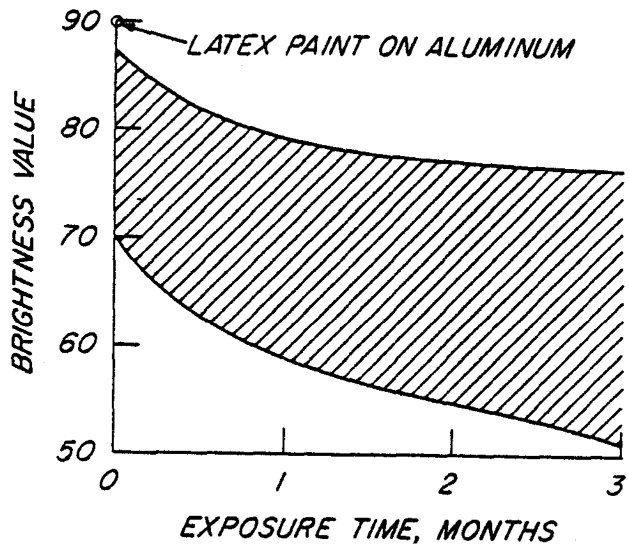

Figure 1. — Range of brightness values for latex paints on untreated redwood exposed to 90 percent RH and 26.7°C.

not recommended for use over "staining-type wood." The chemicals were stannous chloride, chromium trioxide, zinc oxide, acid copper chromate, and ammoniacal copper chromate. The concentration of the stannous chloride was doubled for this experiment (5% metal). The acid and ammoniacal copper chromates were prepared at a Cu/Cr ratio of 1/1.

Four redwood and two cedar boards were randomly selected for each chemical or primer. Each sample was divided into five equal longitudinal parts by a urethane varnish stripe for the chemical pretreatments or into two equal parts for the primer application.

The chemical pretreatments were brush-applied at three different concentrations. After 24 hours at room temperature, two coats of the standard acrylic latex paint were applied with a 5-hour interval between coats.

For the boards with commercial primers, the primer coat was applied on one-half of the board and allowed to dry 24 hours under ambient conditions. One coat of acrylic latex paint was then applied to the unprimed half of the sample. After 5 hours, a second coat of latex paint was applied over the entire sample. In this way, only two total coats of paint were on each sample, the same as for the chemically treated samples.

All samples stood for an additional 24 hours, brightness values were measured, and the samples placed at 90 percent RH and 26.7°C on open-back frames. Brightness values were measured at 1, 2, and 3 months.

Effect of RH

Preconditioning redwood and cedar samples at different RHs may influence the subsequent effectiveness of extractive fixation by chemical pretreatments. This influence was evaluated for five chemicals and three RHs.

Three end-matched samples were used for each chemical tested and each wood- The wood samples were preconditioned for 7 days at 30, 65, or 90 percent, RH and 26.7°C. The samples were then treated with three concentrations of each of the five chemicals and allowed to stand 24 hours at ambient conditions. Two coats of the standard acrylic latex paint were then applied with 5 hours between coats. After 24 hours of drying at room temperature, the samples were stored on open-back racks at 90 percent RH and 26.7°C. Brightness values were determined at 1, 2, and 3 months.

Results and Discussion

Paint, especially porous paints of the latex house paint type, can be severely discolored by the water soluble extractives from the heartwood of redwood and western redcedar whenever water (rain, dew, or vapor) has ready access to the wood substrate. The concentration of the extractives varies within a particular piece of wood as well as from piece to piece, and the uneven staining results in an unsightly appearance. This variability in extractives content and subsequent staining is illustrated (Fig. 1) where the brightness values for the painted, untreated redwood and cedar boards are shown as a function of exposure time to 90 percent RH. This variability made assessment of each individual chemical treatment difficult, especially when comparing treating variables. Using end-matched samples or averaging results over several replicates reduced this problem- In addition, every attempt was made to select uniformly dark boards

This study involved a large number of treatment variables and observations of brightness values representing extractive staining. Rather than attempt to cover all the aspects and observations, only the most encouraging results will be summarized here.

The brightness values (Table 3) for paint over treated redwood and cedar after 3 months' exposure to 90 percent RH, show that stannous chloride, chromium trioxide, zinc oxide-ammonia complex, and copper chromates effectively prevented staining by wood extractives. These treatments compared favorably to the recommended practice for preventing paint staining, namely, use of an oil-base primer under the latex paint topcoat.

The copper- or chromium-containing chemicals were all effective even at low concentrations of 0.63 percent metal, but these are colored chemicals and a slight green color would sometimes migrate through the paint. This was most-noticeable at the 25 percent metal concentration.

The stannous chloride treatment was an effective treatment, particularly at 5 percent tin concentration, although other experiments indicated that boards with exceptionally high extractives content would sometimes stain unevenly through the paint film. In all the experiments performed, no one chemical treatment was totally effective in fixing extractives and preventing the subsequent staining of paint.

Generally, extractive staining was more prevalent in untreated redwood than in untreated cedar boards

Table 3. — BRIGHTNESS VALUES FOR TREATED AND PAINTED REDWOOD AND CEDAR BOARDS BEFORE AND AFTER 3 MONTHS' EXPOSURE TO 90 PERCENT RH AND 26.7°C. STANDARD PAINT ON ALUMINUM = 90.

Treatment	Redwood[1]		Cedar[2]	
	Before	After	Before	After
Stannous chloride				
Untreated	81	66	82	73
5% tin	90	87	90	87
2.5% tin	90	85	90	87
1.25% tin	89	83	90	86
Chromium trioxide				
Untreated	81	65	80	73
2.5% chromium	87	83	85	85
1.25% chromium	87	84	86	85
0.63% chromium	87	83	88	85
Zinc oxide-ammonia				
Untreated	77	68	82	74
4 % zinc	88	81	87	84
2 % zinc	88	78	87	82
1 % zinc	88	76	87	82
Ammoniacal copper chromate				
Untreated	82	70	81	73
2.5% metals[3]	88	86	87	85
1.25% metals	88	85	88	85
0.63% metals	88	83	88	84
Acid copper chromate				
Untreated	75	62	82	74
2.5% metals[3]	87	82	88	85
1.25% metals	88	79	89	86
0.63% metals	86	77	89	85
Oil-base Primer-1				
Unprimed	82	67	82	76
Primed	90	82	89	85
Oil-base Primer-2				
Unprimed	76	67	82	74
Primed	90	84	90	86
Latex base Primer				
Unprimed	77	63	83	74
Primed	76	61	84	74

[1]Each value ix an average of 4.
Each value ix au average of 2.
[1]Copper and chromium.

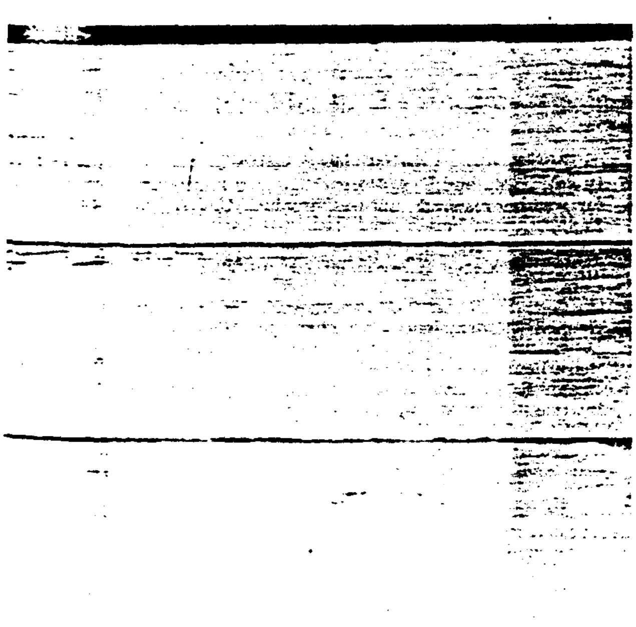

Figure 2. — Typical test panel (painted redwood boards, pretreated with stannous chloride) after 3 months' exposure to 90 percent RH and 26.7°C.

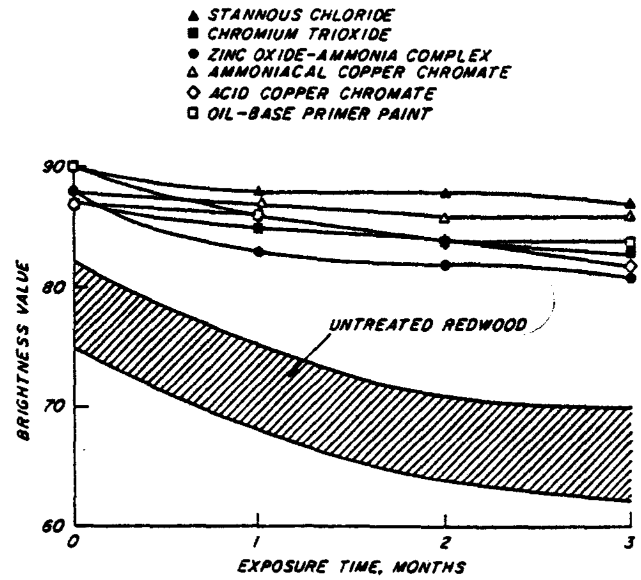

Figure 3. — Brightness values for latex paint over treated and untreated redwood as a function of time of exposure to 90 percent RH and 26.7°C.

Most chemical treatments were more effective on cedar than on redwood except for cedar with apparent high extractives content on the wood surface, which caused dark, uneven streaking through the applied paint

Figure 2 shows a typical test panel after 3 months' exposure to 90 percent RH. The end portions of each board were untreated. The center portions were treated with each of the three chemical concentrations. Each board was either randomly selected or end-matched, depending on the purpose of the experiment. In the panel in Figure 2, the three boards were end-matched to evaluate the effect of preconditioning the boards at three different RHs before chemical treatment. This is discussed later.

Development of Staining

Staining of paint over redwood or cedar increases with exposure to high humidity. In Figure 3, brightness values for the chemically treated samples are compared with untreated painted wood and oil-base primed, painted wood. The effectiveness of the various chemicals investigated is apparent; staining continues through exposure, although differences between 2 and 3 months are generally less than those between 1 and 2 months. Stannous chloride and chromium trioxide gave slightly better results than did the other chemicals investigated, with the zinc oxide-ammonium treatment being least effective. The variability in the staining of untreated wood is again obvious (Fig. 3).

Reconditioning at Three RHs

The end-matched samples of redwood and cedar preconditioned to 30, 60, or 90 percent RH were evaluated after 3 months' exposure to 90 percent RH (Table 4). Generally, the chemical treatment was slightly more effective on wood which had been preconditioned at 30 percent RH rather than at 60 or 90 percent; that is, drier wood can be treated more

Table 4. —BRIGHTNESS VALUES FOR PAINTRD REDWOOD AND CEDAR TREATED AFTER CONDITIONING TO 30, 65. AND 90 PERCENT RH AND SUBSEQUENTLY EXPOSED TO 90 PERCENT RH AND 26.7°C FOR 3 MONTHS. STANDARD PAINT ON ALUMINUM = 90.

Treatment	Redwood at RH of			Cedar at RH of		
	30	65	90	30	65	90
Stannous chloride						
Untreated	68	66	65	72	74	76
5% tin	82	81	80	84	84	84
2.5% tin	81	79	80	84	84	85
1.25% tin	78	77	78	86	85	86
Chromium trioxide						
Untreated	67	66	67	75	71	75
2.5% chromium	83	81	81	84	82	83
1.25% chromium	83	81	82	86	83	84
0.63% chromium	82	80	81	86	84	84
Zinc oxide-ammonia						
Untreated	77	75	75	76	76	77
4% zinc	86	85	83	84	84	84
2% zinc	86	83	81	83	84	84
1% zinc	83	81	79	85	84	84
Ammoniacal copper chromate						
	72	70	71	76	74	75
2.5% metals[1]	86	85	84	87	87	87
1.25% metals	86	84	84	87	87	87
0.63% metals	83	83	81	86	86	86
Acid copper chromate						
Untreated	71	68	70	75	74	77
2.5% metals[1]	81	82	80	86	86	87
1.25% metals	83	83	80	86	87	87
0.63% metals	81	80	79	86	86	87

[1]Copper and chromium.

readily. The differences observed were relatively small for redwood and very small for cedar. Concentration effects are also apparent.

Other Treatment Variables

A variety of treating times, chemical ratios, concentrations, and heat treatments was investigated to determine their effects on extractive fixation and subsequent staining of applied latex paint. The copper chromate chemicals were investigated to the greatest extent. Conditioning time after treatment, ratio of copper to chromium, concentration, heat treatment after chemical treatment, and related variables were examined. In these experiments, little difference was noted through a wide range of variables.

The most important factors that affected the results were the variability of the extractives in the wood, and the concentration and nature of chemical.

Stannous chloride treatments were performed on redwood and cedar (Table 2) with either hydrochloric acid or sodium hydroxide added to change the pH and the composition of the stannous ion in solution (complex ion formation). Little difference was observed in the four treatments investigated.

Chemical Treatments And Durability

All paint panels were installed on a test fence in Madison, Wisconsin. The panels face south and were installed at 90°. These panels will remain in test and be inspected annually so that the durability and any staining of the standard paint over the treated wood surfaces can be evaluated. These results will be reported in the future.

Conclusions

A numher of water-soluble chemicals, ranging from stannous chloride and zinc oxide-ammonia complex to chromate compounds and chromium. trioxide, were evaluated for their ability to fix the water-soluble extractives of redwood and western redcedar. All compounds investigated were successful **to a** degree in fixing the extractives and minimizing the staining of water-base latex paints applied over the treated wood.

No chemical treatment was more effective than the generally recommended practice of priming extractive-rich woods with oil-base primer paints to prevent or control extractive staining. Many treatments were as effective, however, particularly stannous chloride, chromium trioxide, and ammoniacal copper chromate. The compounds containing colored chromium caused some chemical staining through the applied white latex paint.

A number of treatment variables were investigated including concentration, temperature, preconditioning to different RHs, conditioning time after treatment, and ratios of chemicals. Only chemical concentration had any marked effect. A 9.5 percent stannous chloride treatment (5% tin) was consistently effective and, because of its colorless solutions, did not develop color in the applied paint.

None of the chemical solutions gave completely consistent results. When the treatments were used on very dark redwood or cedar samples, indicative of high concentrations of extractives on the surface, some uneven staining was observed through the white paint even at the highest chemical concentrations examined.

Chemical pretreatment of extractive-rich wood surfaces can be an effective tool in preventing the staining of applied water-base latex paints cawed by migration of the water-soluble extractives.

Literature Cited

1. Black, J. M., and E. A. Mraz. 1974. Inorganic surface treatments for weather-resistant natural finishes. USDA Forest Serv. Res. Pap. FPL 232. Forest Prod. Lab., Madison, Wis. 40 pp.
2. California Redwood Association. (n.d.) Data Sheet 4B1-3. "Painting exterior redwood." 617 Montgomery St., San Francisco, Calif.
3. Cotton, F. A., and G. Wilkinson. 1962. Advanced inorganic chemistry. Interscience Publishers. pp. 364-370.
4. Davidson, S. L. 1975. A new versatile lead-free pigment. J. Oil Col. Chem. Assoc. 58:435-441.
5. Desai, R. L., and M. R. Clarke. 1972. Simple wood surface treatment combats weathering and fungi. Canad. For. Indust. 92(12):47-49.
6. ———. A. J. Dolenko, and M. R. Clarke. 1974. Promising primer-sealer for wood is water-based. Canad. For. Indust. 94(2):39-40.
7. Gallagher, J. E. 1972. Acrylic polymer additive. Paint and Varnish Prod. 62(5):35-40.
8. Huff, R. H. 1974. Painting: from earliest time to unfathomable future. J. Paint Tech. 46(588):62-71.
9. Timberman. 1929. Paint stain overcome. 30:33.
10. U.S. Forest Products Laboratory. 1972. Wood finishing: Discoloration of house paints by water-soluble extractives. USDA Forest Serv. Res. Note FPL-0132, Forest Prod. Lab., Madison, Wis. 4 pp.
11. ———. 1973. Wood siding. Installing, finishing, maintaining. USDA Home and Garden Bull. No. 203. 13 pp.