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THE EFFECT OF PRIMING-COAT REDUCTION AND SPECIAL PRIMERS UPON PAINT SERVICE ON DIFFERENT WOODS

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In 1924 the Forest Products Laboratory started an extensive series of exposure tests of painted wood, the object of which was to compare the behavior of coatings of typical house paints on wood surfaces of different kinds under normal conditions of exterior exposure (*1*).[2] Many technologists have been of the opinion (*8*, *16*) that such comparisons between woods are fair only if the primer is mixed with linseed oil and thinner, that is, reduced, in proportions determined by the characteristics of the wood. The theory underlying this opinion is that some woods require a larger proportion of thinner in the priming coat than others in order to obtain maximum durability of the coating. Inquiry, however, revealed the fact that, although reasonable agreement exists among technologists about good practice in reducing white-lead paste paint or lead and zinc prepared paint for new exterior woodwork in general, there is no agreement either about the woods that require modification of this general practice or what that modification should be for specific woods. It was therefore decided to begin the 1924 tests with the same reduction of the primer, which this paper will call the standard reduction, for all woods and then to start a second series of tests in 1925, using the woods on which less satisfactory paint service was expected, to see whether the durability of the coatings would be affected by changing the standard reduction of the primer or by using some of the special

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[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
[2]Reference is made by number (italic) to "Literature Cited," given at the end of this article.

priming paints that have been suggested for such woods. Results of the 1924 tests are being published elsewhere (4, 5). This paper presents the outcome of the 1925 tests.

WOODS SELECTED FOR THE 1925 TESTS

The woods for the 1925 tests were selected partly on the basis of observations after the first year of exposure of the 1924 series, partly on the basis of opinions about the painting characteristics of woods expressed in the technical literature, and partly with consideration of the commercial importance of the woods.

By the end of the first year's exposure of the 1924 tests (2, 3), the type of defect in paint coatings that the writer has called "slits" began to appear. Slits are breaks in the coating, parallel to the grain of the wood, at the edges of which the coating curls away, leaving the wood bare. They nearly always occur first over summerwood, and they look much like cuts in the coating made with a knife over areas where the bond with the wood is not very firm. It was surmised that they were centers from which disintegration of the coating would develop; if so, they are roughly indicative of the order in which failure may be expected on the different woods. Subsequent developments proved this surmise to be true when the order of failure of coatings of the same paint on different woods was under comparison, but not at all true for comparison of the coatings of different kinds of paint. Slits were observed after the year's exposure in some of the coatings on southern yellow pine, western larch, Douglas fir, and western yellow pine, and more rarely in coatings on white fir, western hemlock, sugar pine, and northern white pine.

Only a few woods were used in the comparative tests recorded in the technical literature prior to 1925. On southern yellow pine and Norway pine, coatings are reported to fail sooner than on white pine or western red cedar (8, 10, 16, 19). On southern cypress coatings are said to have failed very early in some tests (10, 19), while very satisfactory results are reported in others (7, 9). Good results are reported on redwood (7, 9).

The woods selected for the 1925 tests were: Southern cypress, eastern hemlock, western hemlock, western yellow pine, Douglas fir, western larch, and southern yellow pine. This list may be compared with Table 1 in which the woods are classified for painting characteristics on the basis of the 1924 tests (4, 5). The distribution of the total cut of softwood lumber in the United States in 1927 among the woods is also given in the table.

The western yellow pine, western hemlock, and Douglas fir lumber was taken from the supplies of those species furnished by the regional lumber associations for the 1924 tests. The western larch was obtained from the mill that provided the larch for the 1924 study. The southern cypress, eastern hemlock, and southern yellow pine lumber was purchased from stocks in retail lumber yards in Madison, Wis.

PAINTS FOR THE 1925 TESTS

Except for the variations in the treatment of the priming coat, the paints and painting practices of the 1925 tests were the same as those of the 1924 tests. Trade practice with paste paint was represented by the use of basic carbonate white lead paint, which was reduced for application as follows:

	Standard primer	Second coat	Third coat
Paste white lead (92 per cent pigment)	100 lbs.	100 lbs.	100 lbs.
Raw linseed oil	4 gals.	1-1/2 gals.	3-1/2 gals.
Turpentine	2 gals.	1-1/2 gals.	1 pint
Liquid drier	1 pint	1 pint	1 pint

Trade practice with prepared paint was represented by the use of a paint having the composition:

Pigment....64 per cent by weight,	composed of....
basic carbonate white lead	60 per cent by weight
zinc oxide	30 per cent by weight
asbestine	10 per cent by weight
Vehicle....36 per cent by weight,	composed of....
raw linseed oil	90 per cent by weight
turpentine	5 per cent by weight
liquid drier	5 per cent by weight

The standard reduction of the primer for the prepared paint was 1-1/4 pints of raw linseed oil and 2 pints of turpentine per gallon of paint. The reduction for the second coat was 2-1/2 pints of turpentine per gallon of paint.

Table 1.--Classification of woods for painting characteristics and their annual production of these woods as lumber

Classification using U. S. Forest Service common names and the botanical names		Percentage of all softwood lumber cut in 1927
Group I -- Woods on which coatings served longest, both in integrity and in protection		
Cedar, Alaska	(Chamaecyparis nootkatensis)	1 (Cedar, Alaska; Cedar, Port Orford; Cedar, western red)
Cedar, Port Orford	(Chamaecyparis lawsoniana)	
Cedar, western red	(Thuja plicata)	
*Cypress, southern	(Taxodium distichum)	2
Redwood	(Sequoia sempervirens)	2
Group II -- Woods on which coatings failed in protection sooner than on woods of Group I		
Pine, northern white	(Pinus strobus)	5 (Pine, northern white; Pine, western white)
Pine, western white	(Pinus monticola)	
Pine, sugar	(Pinus lambertiana)	1
Group III -- Woods on which coatings failed in both integrity and protection sooner than on woods of Group I		
Fir, white	(Abies concolor)	1
*Hemlock, eastern	(Tsuga canadensis)	7 (*Hemlock, eastern; *Hemlock, western)
*Hemlock, western	(Tsuga heterophylla)	
*Pine, western yellow	(Pinus ponderosa)	10
Spruce, eastern	(Picea spp.)	2 (Spruce, eastern; Spruce, Sitka)
Spruce, Sitka	(Picea sitchensis)	
Group IV -- Woods on which coatings failed soonest, especially in integrity		
*Douglas fir	(Pseudotsuga taxifolia)	30
*Larch, western	(Larix occidentalis)	1
*Pine, southern yellow	(Pinus spp.)	38

*Selected for the 1925 primer tests.

Note: This classification of woods by species is necessarily an approximation because there is much variation within species. Thus in lumber of species placed in the lower groups, edge-grain boards of relatively light weight and even texture may give better paint service than relatively heavy and coarse-textured, flat-grain boards of species placed in a higher group. For details, see references 4 and 5 in "Literature Cited."

PROCEDURE FOR THE 1925 TESTS

The test panels were 5/8 by 15-1/2 by 36 inches in size, made up of three boards each, as shown in the accompanying illustrations. They were exposed in a vertical position, facing south, by nailing the panels on open framework fences (except at Sayville, N. Y., where the framework was covered with lumber sheathing before the panels were attached). The backs of the boards were protected with one coat of lampblack paint and the ends with aluminum paint.

Each panel was divided by a vertical line into two equal areas each 15-1/2 by 18 inches. The left-hand half was designated A and the right-hand B. In general, the A half was used as a control and received the standard primer, while the primer with a varied reduction or the special primer to be studied was applied to B. Through comparison of the new procedure and the standard procedure on adjoining parts of the same boards differences in coating behavior were revealed that would otherwise have escaped notice.

All painting was done at Madison before the panels were shipped to the exposure stations, the procedure differing in this respect from that followed in 1924, when the painting was done in the field after the panels had been nailed in position. The priming and the second-coat paints were applied out of doors with the panels placed where they would receive sunlight when it was available. About one week was allowed between coats for drying. The third-coat paints were applied indoors.

THE EXPOSURE STATIONS

The 296 test panels were distributed among 11 testing stations, representing widely varying climates, as indicated in the following list, in which the names of the cooperators maintaining the stations are also given:

Madison, Wis. (University of Wisconsin)

Southern yellow pine	12	panels
Western larch	8	"
Douglas fir	12	"
Eastern hemlock	8	"
Western hemlock	8	"
Western yellow pine	12	"
Southern cypress	12	"

Milwaukee, Wis. (Pittsburgh Plate Glass Company)
Southern yellow pine 12 panels
Southern cypress 12 "

Sayville, N. Y. (National Lead Company)
Southern yellow pine 12 panels
Douglas fir 12 "

Palmerton, Pa. (New Jersey Zinc Company)
Southern yellow pine 12 panels
Southern cypress 12 "

Washington, D. C. (U. S. Bureau of Standards)
Southern yellow pine 12 panels
Eastern hemlock 8 "

Gainesville, Fla. (University of Florida and Gregg Memorial Laboratory)
Southern yellow pine 12 panels
Southern cypress 12 "

Fargo, N. Dak. (North Dakota Agricultural College)
Western yellow pine 12 panels
Western hemlock 8 "

Seattle, Wash. (University of Washington)
Western yellow pine 12 panels
Douglas fir 12 "

Fresno, Calif. (W. P. Fuller Company)
Western yellow pine 12 panels
Western hemlock 8 "

Tucson, Ariz. (Southern Pacific Company)
Western yellow pine 12 panels
Douglas fir 8 "
Western larch 4 "

Grand Junction, Colo. (Denver and Rio Grande Western Railroad)
Western yellow pine 12 panels
Western larch 8 "

The writer has inspected the panels at all stations once each year. The panels at Madison have been inspected more frequently. The methods used by the staff of the Forest Products Laboratory for inspecting and evaluating paint tests on wood are being published in detail elsewhere (6). Briefly, at each inspection ratings (good, fair, poor, or bad) are assigned to the coating in three indexes of serviceableness, the appearance, which depends chiefly upon the color, cleanliness, and uniformity in color of the coating, the integrity, which is a matter of its remaining in place and covering all parts of the wood, and the protection, which is judged by the success in preventing checking or cupping of the wood. The supplementary observations also recorded concern changes in such qualities of the coating as gloss and opacity, or the development of defects such as chalking, checking, cracking, and flaking. The durability of the coating with respect to integrity only is taken as the time elapsed until the integrity is first rated poor. It is taken for granted that protection ceases where the coating fails to remain intact, but often signs of wood weathering are seen where the coating is still sound. An estimate is therefore made of the total durability of the coating, taking account of both integrity and protection.

RESULTS

This investigation falls naturally into three major divisions. The results, therefore, are presented here under three principal heads, each of which begins with a brief introductory review of the considerations most pertinent to that particular part. The three divisions follow:

PART 1.--VARIATION IN REDUCTION OF PRIMING COAT

Introduction

An experimental study of the effect of reduction of the primer on the durability of paint coatings was included in the 1915-16 (17) and again in the 1921 tests (18) at North Dakota Agricultural College. Northern white pine was the only wood used there. White-lead paint and several paints containing white lead, zinc oxide, and inert pigments were applied. With each paint eight different reductions of the priming coat, varying from 1-3/4 pints of turpentine and no linseed oil to 3 pints of linseed oil and no turpentine per gallon of paint, were tried. The experimenters report that "it was found to be impossible to draw any conclusions" because the differences in behavior with the various reductions were too slight.

The theories usually advanced in support of varying reductions of the primer for different woods are unconvincing. If the penetration theory were correct, woods like southern yellow pine, which have conspicuous bands of dense, horny summerwood, would require much thinner to make the priming coat penetrate. The facts are, however, that paint pigments are too large to pass beyond the cavities in the wood tracheids immediately at the surface and, further, paint liquids, like other liquids (20), actually penetrate more deeply into the summerwood than they do into the lighter springwood. The deepest penetration of paint liquids, therefore, occurs where paint coatings fail soonest. According to the resin-solvent theory the cavities of summerwood are plugged with resin, which must be dissolved by the paint thinner to permit entrance of the paint oil. In general, however, the cavities in summerwood are not filled with resin. Furthermore, failure of coatings takes place first over summerwood whether the wood is a resinous kind or not.

Discussion

Priming coat reductions containing more thinner than the standard primer were mixed with paste paint as follows:

	For all woods except the hemlocks	For eastern and western hemlock
White-lead paste (92 per cent pigment)	100 lbs.	100 lbs.
Raw linseed oil	2 gals.	3 gals.
Turpentine	4 gals.	3 gals.
Liquid drier	1 pint	1 pint

With prepared paint 5 pints of turpentine was added to a gallon of paint for all woods except the hemlocks, and 3 pints per gallon for the hemlocks. The turpentine-rich primer was always applied to the B half of a test panel of which the A half received the standard primer.

A reduction different from that for the other woods studied was used for the hemlocks because these species are relatively nonresinous woods and are noticeably less absorptive, in the painter's sense, than the other woods tested, with the possible exception of southern cypress. It therefore seemed desirable to use an intermediate reduction for the hemlocks, but for cypress, which contains characteristic extractives of an oily nature, the reduction containing most turpentine was used.

Reduction of the primer might have been made in many other proportions also, but it is not necessary to test a large number of formulas to learn whether material improvement in paint service can be brought about by changing this reduction. The formulas chosen differ significantly from the standard practice and yet they lie well within the range of reductions commonly suggested by painters and paint technologists. Thus the official textbook of the master painters' association (21), referring to the reduction of white-lead paste, advises for woods like southern yellow pine that "the mixing formula for such lumber is about right when it reads one-fourth pure raw linseed oil and three-fourths turpentine." If reduction of the primer exerts a marked effect on the durability of the coating the fact should be clearly revealed by a significant difference in the behavior of the coatings on the A and the B halves of these test panels.

Table 2, which summarizes the results of the tests, shows that the marked alteration in reduction of the primer had very little effect on the behavior of the coatings.

The turpentine-rich reduction of white lead paste paint was applied to most woods at a slightly higher spreading rate, corresponding to a somewhat thinner coating, than the standard primer. The turpentine-rich reduction of prepared paint was applied at a slightly lower spreading rate than the standard reduction. On adding thinner to paint the spreading rate is usually decreased up to a certain point beyond which the spreading rate increases again. It may therefore be concluded that in these experiments the thinning of the paste paint was carried somewhat farther than that of the prepared paint.

The durability of the coatings proved nearly the same on both the A and the B halves of the panels, whether durability was determined from consideration of coating integrity alone or from consideration of protection as well as integrity. On 34 out of 54 panels careful comparison failed to reveal any difference between A and B at any time during the exposure. On 18 panels B, the side having the turpentine-rich primer, seemed to be inferior to A, but only very slightly inferior. On 2 panels B seemed slightly better than A.

In Figure 1 panel 207 received the standard primer on A and the turpentine-rich primer on B. No choice can be made between them. Much the same can be said of Figure 2, panel 237. Figure 1 shows also the advantage gained by

Table 2.--Results of changing the reduction of the primer*

Species of wood and kind of paint	Number of panels tested	Spreading rate of primer in square feet per gallon		Average durability of coating in months considering -- Integrity only		Average durability of coating in months considering -- Integrity and protection		Number of panels on which B was -- Better than A	Worse than A	Same as A
		A	B	A	B	A	B			
Southern cypress										
Paste paint	4	740	790	49	49	43	43	--	--	4
Prepared paint	4	810	770	49	49	39	39	--	--	4
Western yellow pine										
Paste paint	6	620	660	45	44	30	29	--	4	2
Prepared paint	6	860	770	38	37	34	34	--	2	4
Eastern hemlock										
Paste paint	2	570	640	44	43	35	35	--	1	1
Prepared paint	2	740	710	47	47	33	33	--	--	2
Western hemlock										
Paste paint	3	640	610	44	44	36	38	--	--	3
Prepared paint	3	780	720	42	41	33	33	--	1	2
Douglas fir										
Paste paint	4	550	560	42	39	32	31	1	2	1
Prepared paint	4	750	660	45	42	41	38	--	3	1
Western larch										
Paste paint	2	720	680	35	32	27	25	--	1	1
Prepared paint	2	640	590	34	43	32	41	1	--	1
Southern yellow pine										
Paste paint	6	660	680	36	36	26	26	--	2	4
Prepared paint	6	710	700	39	37	33	33	--	2	4

*A primer of standard reduction was applied to the A half of each panel and the primer richer in turpentine to the B half.

Note: The figures for durability should be used only for comparing A with B; they should not be used for comparing the species because the different woods were not tested at the same stations.

placing painting procedures to be compared side by side on the same boards. Part A of panel 208 was painted in exactly the same way as part A of panel 207, but the three boards in panel 208 seem to contain less summerwood than those in panel 207 and therefore held paint longer. Comparison of part B of 208 with part A of 208 leaves no doubt that the primer used on 208-B was deleterious, but if 208-B were compared with 207-A no such conclusion could be drawn.

The results presented in Table 2 point unmistakably to the conclusion that variation in the reduction of the priming coat exerts but a trifling influence on the durability of the coating. Addition of more thinner to the priming coat than that called for in the standard reduction gives poorer rather than better results on woods containing much summerwood, which are the woods for which primers rich in thinner are commonly recommended. As far as the durability of the coating is concerned, there is at present no good reason why the painter should not adopt the convenient practice of using the standard reduction for the priming-coat paint for all softwoods. As a rule, however, woods of light weight tend to consume slightly more priming paint than heavy woods and if the painter wishes he may obtain a greater spreading rate on the light woods by mixing the priming coat with more linseed oil and correspondingly less turpentine.

PART 2.--THINNERS OTHER THAN TURPENTINE

Introduction

According to the solvent theory of thinning the priming coat for resinous woods, the best volatile thinner is the one that dissolves the resin most easily. On this basis benzol has often been recommended in preference to turpentine for the priming coat for southern cypress and other woods because certain extractives in these woods are said to be more readily soluble in benzol (14).

Discussion

In the 1925 tests primer thinned with benzol was tested on southern cypress but not on the other woods. White lead paste paint was reduced with 2 gallons of linseed oil, 4 gallons of benzol, and 1 pint of drier per 100 pounds of paste to make the priming coat for the B half of the panels. The primer for A was the same except that turpentine replaced the benzol. Similarly, prepared paint was reduced with 5 pints of benzol per gallon of paint for priming B and with 5 pints of turpentine for priming A. The results of the tests as summarized in Table 3 indicate that the benzol-thinned primer was if anything slightly inferior to the turpentine-thinned primer.

Similar results were obtained in an earlier test of different paint thinners conducted at Madison only. A prepared paint, the pigment of which consisted of equal parts by weight of basic carbonate white lead and zinc oxide, was applied to panels of southern yellow pine, southern cypress, and eastern hemlock. The cypress boards contained an unusually large amount of the oily extractive characteristic of the wood. Eight volatile thinners were tested, including gum turpentine, destructively distilled turpentine, benzol, four petroleum distillates ranging in volatility from gasoline to kerosene, and tetralin (tetrahydronaphthalene). The thinner used has no observable effect on the durability of the coatings on any of the three woods. (Figure 3.)

A more elaborate study of volatile thinners was started in 1927. The wood was dense southern yellow pine; the paints were white lead paste paint and a prepared paint the pigment of which consisted of 45 per cent by weight basic carbonate white lead, 45 per cent American-process zinc oxide, and 10 per cent asbestine; and exposures were made at Madison, Wis., Pittsburgh, Pa., Washington, D. C., Gainesville, Fla., and Fresno, Calif. The thinners included four types of turpentine, five petroleum distillates, and solvent naphtha. The results will be reported in detail in a later publication, but it may be said here that none of the thinners have exhibited any advantage over the turpentines on the score of durability of the coating.

PART 3.--SPECIAL PRIMING PAINTS

Introduction

Special paints for priming wood before applying top coats of ordinary house paints have been used to a certain extent for many years. Often economy is the motive for the practice, in which event the primer may be made from

Table 3.--Benzol instead of turpentine as thinner in the priming coat on southern cypress*

Kind of paint	Number of panels tested	Average durability of coating in months considering-- Integrity only		Integrity and protection		Number of panels on which B was-- Better than A	Worse than A	Same as A
		A	B	A	B			
Paste paint	4	48	48	40	38	--	2	2
Prepared paint	4	49	47	43	41	--	2	2

*The primer on A was thinned with turpentine, and that on B with benzol.

odds and ends of paint accumulated in the painter's shop or from a cheap pigment, such as yellow ochre. The first is obviously an uncertain procedure and the second is commonly considered bad practice. However, special primers have also been suggested in the belief that they obtain better paint service on woods containing much summerwood and thereby reduce the variability in paint behavior on different woods.

The suggestion to use special primers has often been based largely upon certain theories of paint behavior. The moisture proofing theory (11) attributes the flaking of coatings from summerwood to swelling and shrinking of the wood in response to changes in moisture content and therefore postulates that primers of high effectiveness in retarding moisture movement improve the durability of coatings. The antioxidant theory (15) assumes that components of paint that retard oxidation of linoxyn keep the coating next the wood more flexible and more adherent and therefore capable of withstanding stresses without cracking and flaking. The opacity theory (12) states that similar results are achieved by the use of very opaque pigments, particularly pigments opaque to ultraviolet light, because the pigments then shield the linoxyn next the wood from light and thus retard its photochemical oxidation. Very opaque pigments are likely to be colored pigments.

Five special primers were tested in the 1925 experiments. The results follow.

Red Lead In The Primer

Coatings of red lead rank high among oil paints in resistance to the passage of moisture. Red-lead primer for wood is said to be used by painters to a certain extent. In a few tests, good results were reported over red-lead primer but control panels were not included for comparison with standard practice (9). The color of red lead is somewhat difficult to conceal with two top coats of white paint and therefore the National Lead Company in a former edition of its "Handbook on Painting" recommended a primer containing a mixture of red lead and white lead (the latest edition of this handbook omits entirely the recommendation of red lead as a primer for wood under other paints).

The primer containing red lead for use under paste paint was mixed as follows:

	For all woods except the hemlocks	For eastern and western hemlock
Paste white lead	60 lbs.	60 lbs.
Paste red lead	40 lbs.	40 lbs.
Raw linseed oil	1-3/4 gals.	4 gals.
Turpentine	1-3/4 gals.	2 gals.
Drier	1 pint	1 pint

The primer containing red lead, for use under prepared paint, had the following composition:

Pigment....64.6 per cent by weight, composed of....	
red lead	40 per cent by weight
white lead	20 per cent by weight
zinc oxide	30 per cent by weight
asbestine	10 per cent by weight
Vehicle....35.4 per cent by weight, composed of....	
raw linseed oil	59.3 per cent by weight
turpentine	38.0 per cent by weight
drier	2.7 per cent by weight

The primer containing red lead was always applied to the B half of the test panel with the standard primer on A.

Table 4 shows that the incorporation of red lead in the priming coat was decidedly disadvantageous. Almost without exception coatings proved less durable on B than on A. The difference appears most striking when the coating is judged on the basis of integrity alone because, although the primer containing red lead apparently did not affect the protective power of the coating, it did lead to earlier flaking from the summerwood, as illustrated in Figure 2.

The poor results obtained in these experiments on adding red lead to the primer do not mean that red-lead paint itself is not a durable coating for wood where its appearance is satisfactory. Neither should it be understood that red lead is unsuitable as a component of the priming coat under all circumstances. The experiments do show, however, that the addition of red lead to the priming coat can not be recommended as a general practice in painting wood with ordinary house paints and that it does not overcome the variable behavior of coatings on different woods.

Table 4.--Red lead as a component of the primer*

Species of wood and kind of paint	Number of panels tested	Average durability of coating in months considering -- Integrity only A	Integrity only B	Integrity and protection A	Integrity and protection B	Number of panels on which B was -- Better than A	Worse than A	Same as A
Southern cypress								
White-lead paint	4	49	43	36	35	--	4	--
Lead-zinc paint	4	49	43	40	40	--	2	2
Western yellow pine								
White-lead paint	6	43	28	33	27	--	6	--
Lead-zinc paint	6	34	29	31	29	--	5	1
Eastern hemlock								
White-lead paint	2	39	31	28	28	--	2	--
Western hemlock								
White-lead paint	3	47	35	31	31	--	3	--
Douglas fir								
White-lead paint	4	42	30	30	27	--	4	--
Lead-zinc paint	3	52	44	49	43	--	3	--
Western larch								
White-lead paint	2	30	20	23	17	--	2	--
Lead-zinc paint	1	24	24	22	22	--	1	--
Southern yellow pine								
White-lead paint	6	42	30	31	26	--	6	--
Lead-zinc paint	6	38	31	32	29	--	5	1

*A standard primer was applied to the A half of each panel and the special primer containing red lead to the B half.

Note: The figures for durability may be used only for comparing A with B; they may not be used for comparing the species because the different woods were not tested at the same stations.

Zinc-dust and Zinc-oxide Primer

A special paint made with metallic zinc dust and zinc oxide as the pigment has been proposed for priming woods containing much summerwood (15). While this paint is kept in the liquid condition hydrogen is slowly evolved from reaction between metallic zinc and the free acids of the linseed oil. It has been suggested that the hydrogen acts as an antioxidant for linseed oil, keeping the linoxyn flexible and adherent. It is also possible that the neutralization of free acids in the linoxyn may be beneficial.

The special primer tested had the composition:

Zinc-oxide paste (82 per cent pigment)	100 lbs.
Raw linseed oil	15-3/4 gals.
Turpentine	4 gals.
Drier	1 gal.
Zinc dust	328 lbs.

The zinc dust was stirred into the rest of the paint immediately before use.

The results of the experiments are presented in Table 5 and a typical test panel at the end of the exposure is shown in Figure 1. Under top coats of white-lead paint the zinc-dust and zinc-oxide primer invariably gave rise to earlier flaking of the coating from summerwood. The special primer gave somewhat better experience under top coats of lead and zinc paint, for 12 panels revealed no difference in behavior between A and B, 7 panels held paint better on B than on A, and 8 failed sooner on B than on A. The average durability in integrity of the coatings of lead and zinc paint proved a trifle longer on some woods when the special primer was used, but it was always materially shorter for coatings of white-lead paint over the special primer.

There was a notable tendency for the coatings of both paints over the zinc-dust and zinc-oxide primer to remain cleaner than they did when applied in standard practice. This was most marked at Gainesville, Fla., where many paint coatings became badly discolored with lichen and sooty mold within a year or so after they had been exposed. No lichen and no mold colonies were observed on coatings over primers containing zinc dust although the corresponding A halves of the panels were always more or less discolored. At other stations where lichen and mold

Table 5.--Zinc-dust and zinc-oxide paint as a special priming paint*

Species of wood and kind of paint	Number of panels tested	Average durability of coating in months considering -- Integrity only A	Integrity only B	Integrity and protection A	Integrity and protection B	Number of panels on which B was -- Better than A	Worse than A	Same as A
Southern cypress								
White-lead paint	4	49	41	41	38	--	4	--
Lead-zinc paint	4	50	50	43	43	--	---	4
Western yellow pine								
White-lead paint	6	42	26	31	24	--	6	--
Lead-zinc paint	6	36	35	35	33	1	3	2
Eastern hemlock								
Lead-zinc paint	2	44	42	29	29	1	1	--
Western hemlock								
Lead-zinc paint	3	44	45	39	40	1	--	2
Douglas fir								
White-lead paint	4	37	27	36	26	--	4	--
Lead-zinc paint	4	46	48	42	45	2	--	2
Western larch								
Lead-zinc paint	2	27	35	24	24	1	--	1
Southern yellow pine								
White-lead paint	6	39	24	27	23	--	6	--
Lead-zinc paint	6	36	38	34	33	2	4	--

*A standard primer was applied to the A half of each panel, and the zinc-dust and zinc-oxide primer to the B half.

Note: The figures for durability should be used only for comparing A with B; they should not be used for comparing the species because the different woods were not tested at the same stations.

are not supposed to play an important part in the discoloration of coatings, cleaner surfaces were often maintained over primers containing zinc dust.

Zinc-dust and zinc-oxide paint can not be recommended for general practice as a primer under all sorts of house paints, although it is entirely possible that it may be useful under paints of some compositions. It does not overcome the variable behavior of coatings on different woods. Zinc-dust and zinc-oxide paint, when used both as primer and top coats, makes a durable paint for wood where its grey color is satisfactory.

Zinc Dust Added To The Standard Primer

Zinc dust was stirred into the standard primer just before application. For white-lead paste paint, 40 pounds of zinc dust was added to 100 pounds of the standard priming paint; for the lead and zinc prepared paint, 50 pounds of zinc dust was added to 100 pounds of standard priming paint.

Table 6 indicates that the addition of zinc dust to the primer was distinctly harmful with white lead paste paint, leading to earlier flaking of the coating from the summerwood. With lead and zinc paint the addition of zinc dust had no significant effect on the durability of the coating, for the coating behaved alike on the A and B halves of most panels and on the remaining panels B was sometimes slightly better and sometimes slightly worse than A.

Aluminum Powder Added To The Standard Primer

The addition of metallic aluminum powder to paint primers has been proposed (12) in the belief that the aluminum shields the oil next the wood from ultraviolet light. To the standard primer resulting from the reduction of 100 pounds of white-lead paste, 2 pounds of aluminum powder was added just before application; to each gallon of the standard reduction of lead and zinc prepared paint, 0.3 pound of aluminum powder was added before use.

Table 7 reveals only unimportant differences in the behavior of coatings of either kind of paint on the A and B halves of the panels. What slight differences there

Table 6.--Zinc dust as a component of the primer*

Species of wood and kind of paint	Number of panels tested	Average durability of coating in months considering -- Integrity only A	Integrity only B	Integrity and protection A	Integrity and protection B	Number of panels on which B was -- Better than A	Worse than A	Same as A
Southern cypress								
White-lead paint	4	49	45	42	43	--	2	2
Lead-zinc paint	4	50	49	41	47	1	--	3
Western yellow pine								
White-lead paint	6	46	34	31	28	--	6	--
Lead-zinc paint	6	38	39	37	38	1	2	3
Douglas fir								
White-lead paint	4	41	37	34	30	--	3	1
Lead-zinc paint	4	43	44	41	42	3	--	1
Southern yellow pine								
White-lead paint	6	41	32	34	30	--	6	--
Lead-zinc paint	6	37	34	31	31	--	2	4

*A standard primer was applied to the A half of each panel, and zinc dust was added to the standard primer on B.

Note: The figures for durability should be used only for comparing A with B; they should not be used for comparing the species because the different woods were not tested at the same stations.

Table 7.--Aluminum powder as a component of the primer*

Species of wood and kind of paint	Number of panels tested	Average durability of coating in months considering -- Integrity only A	Integrity only B	Integrity and protection A	Integrity and protection B	Number of panels on which B was -- Better than A	Worse than A	Same as A
Southern cypress								
White-lead paint	4	49	49	43	43	--	--	4
Lead-zinc paint	4	50	49	41	47	1	--	3
Western yellow pine								
White-lead paint	6	43	44	27	27	2	1	3
Lead-zinc paint	6	37	41	35	35	2	--	4
Eastern hemlock								
White-lead paint	2	40	40	27	27	--	--	2
Lead-zinc paint	2	44	38	37	29	--	1	1
Western hemlock								
White-lead paint	3	51	51	45	45	--	1	2
Lead-zinc paint	3	45	45	37	37	1	--	2
Douglas fir								
White-lead paint	4	41	44	33	34	3	--	1
Lead-zinc paint	3	48	46	43	41	2	--	1
Western larch								
White-lead paint	2	35	35	23	23	--	--	2
Lead-zinc paint	3	38	39	23	24	1	--	2
Southern yellow pine								
White-lead paint	6	39	37	31	31	2	1	3
Lead-zinc paint	6	37	36	36	40	1	1	4

*A standard primer was applied to the A half of each panel, and aluminum powder was added to the standard primer on B.

Note: The figures for durability should be used only for comparing A with B; they should not be used for comparing the species because the different woods were not tested at the same stations.

were usually indicated a beneficial effect from the aluminum, but the differences were never great enough to make the procedure worth while.

Aluminum Paint As Primer

There is already substantial published evidence that paint coatings last longer and protect wood better when applied over a priming coat of aluminum paint than when applied over the standard primer(7). The aluminum paint used as a primer in the Forest Products Laboratory's 1925 series of experiments consisted of:

Aluminum powder	25 lbs.
Boiled linseed oil	6.5 gals.
turpentine	3.8 gals.

At the time these tests were started there was much difference of opinion among paint technologists about the best vehicle for aluminum paint. Boiled oil has the practical advantage of being readily available in the retail paint trade, but it is now known to be less suitable for aluminum paint than kettle-bodied linseed oil or long oil spar varnish. Two further mistakes were made in formulating the aluminum paint; it contained too much aluminum powder and no paint drier was incorporated. The amount of aluminum powder should have been from 15 to 20 pounds instead of 25. Drier was omitted because the maker of the boiled oil advised that, for general paint purposes, addition of more drier than that already incorporated was harmful. However, aluminum powder apparently retards the drying of boiled linseed oil, for the aluminum primer was by no means dry 18 hours after application, as most paints using the oil would have been.

As a result of these errors in formulating the aluminum paint, the top coats of white paint developed an objectionable checking that marred the appearance of the surfaces. The checking occurred in the patterns characteristic of the two white paints -- reticulate with white-lead paint and parallel with lead and zinc paint -- but the checks were of wider mesh than usual and the aluminum showed through them, so that the white coatings seemed to be a mottled grey when viewed from a little distance. The experience of other workers (7) and later experiments of the Forest Products Laboratory prove that the unsightly checking in these tests is easily avoided by following a more suitable formula for mixing the aluminum paint. When that is done the top coats of white lead or of lead and zinc paint behave with respect to checking just as they do when applied over their standard primers.

In spite of the coarse checking, however, Table 8 shows that the paint coatings were more durable, whether judged for integrity only or for protection as well as integrity, when applied over the aluminum primer than when applied over the standard primers. On 45 of the 54 panels tested the durability of the coatings was improved by the aluminum primer, while on the remaining 9 panels no difference in durability was observed between the A and B halves. Figure 4 shows a typical test panel on which the aluminum primer greatly retarded the flaking of paint from summerwood.

Aluminum paint as a primer under ordinary house paints constitutes a significant improvement over the standard painting practice by keeping the coating intact longer and by maintaining more adequately its protection against the weathering of the wood. The improvement is especially marked on woods containing much summerwood, and for that reason the variation in paint behavior on light wood having narrow annual growth rings and on heavy wood with wide rings is probably reduced materially when aluminum primer is used. However, failure by flaking from summerwood is merely delayed, it is not prevented by using aluminum primer. For that reason the writer does not consider it a completely satisfactory solution of the problem of variability in the painting characteristics of woods.

Other Primers

The special primers included in these tests do not exhaust the list of those that have been proposed and it is entirely possible that some of those not included may possess substantial merit. Among the suggestions that invite more careful study are a special primer containing red lead, zinc dust, and aluminum powder (11), and modification of the standard primer by adding such strongly colored pigments as lampblack, venetian red, and basic lead chromate (13).

Table 8.--Aluminum paint as a special primer*

Species of wood and kind of paint	Number of panels tested	Average durability of coating in months considering -- Integrity only A	Integrity only B	Integrity and protection A	Integrity and protection B	Number of panels on which B was -- Better than A	Worse than A	Same as A
Southern cypress								
White-lead paint	4	48	50	47	49	1	--	3
Lead-zinc paint	4	50	50	41	49	2	--	2
Western yellow pine								
White-lead paint	6	49	51	35	45	5	--	1
Lead-zinc paint	6	35	50	34	45	6	--	--
Eastern hemlock								
White-lead paint	2	44	49	27	30	2	--	--
Lead-zinc paint	2	49	52	28	30	2	--	--
Western hemlock								
White-lead paint	3	46	50	40	49	3	--	--
Lead-zinc paint	3	44	50	38	49	2	--	1
Douglas fir								
White-lead paint	4	46	52	45	48	3	--	1
Lead-zinc paint	3	47	51	37	47	3	--	--
Western larch								
White-lead paint	2	35	37	25	25	1	--	1
Lead-zinc paint	3	35	45	31	42	3	--	--
Southern yellow pine								
White-lead paint	6	44	49	33	44	6	--	--
Lead-zinc paint	6	39	49	34	45	6	--	--

*A standard primer was applied to the A half of each panel, and the special aluminum primer to the B half.

Note: The figures for durability should be used only for comparing A with B; they should not be used for comparing the species because the different woods were not tested at the same stations.

CONCLUSIONS

An experimental study of the effect of methods of priming on the durability of paint coatings on seven species of softwoods, tested in widely differing climates, indicated that:

(1) A marked variation in the proportions of linseed oil and of turpentine in the priming coat failed to alter appreciable the durability of coatings on any of the seven woods. As far as durability is concerned, the painter may as well use the standard reduction of the primer for all softwoods.

(2) The classification of the important softwoods for painting characteristics made by the Forest Products Laboratory on the basis of the 1924 series of tests would not have been altered by any practicable variation in the reduction of the primer for the different woods.

(3) The durability of paint coatings on southern cypress was not improved by replacing turpentine with benzol in the reduction of the priming coat.

(4) The incorporation of red lead in priming paints hastened the flaking of the coatings from summerwood. A special priming paint containing zinc dust and zinc oxide decreased the durability of white-lead paint and failed to increase that of lead and zinc paint, although it improved the appearance of both paints by keeping the surfaces freer from dirt, especially from molds. The addition of zinc dust to the standard primer caused effects similar to those of the zinc-dust and zinc-oxide primer. The addition of a small amount of aluminum powder to primers was practically without effect. Aluminum paint as a primer under top coats of white-lead and of lead and zinc paint increased the durability of the coatings markedly by retarding flaking from summerwood and maintaining better protection against the weathering of the wood, although the coatings failed ultimately through flaking from the summerwood.

(5) It is clear that the flaking of coatings from summerwood, which is the principal reason for variation in painting characteristics between woods, can not be prevented by altering the reduction of the primer or by choice of volatile thinners and probably such flaking can not be overcome by changing the pigment composition of the priming paint. The problem of obtaining permanent adhesion to summerwood challenges a more thorough probing of the fundamental principles of the behavior of paint on wood.

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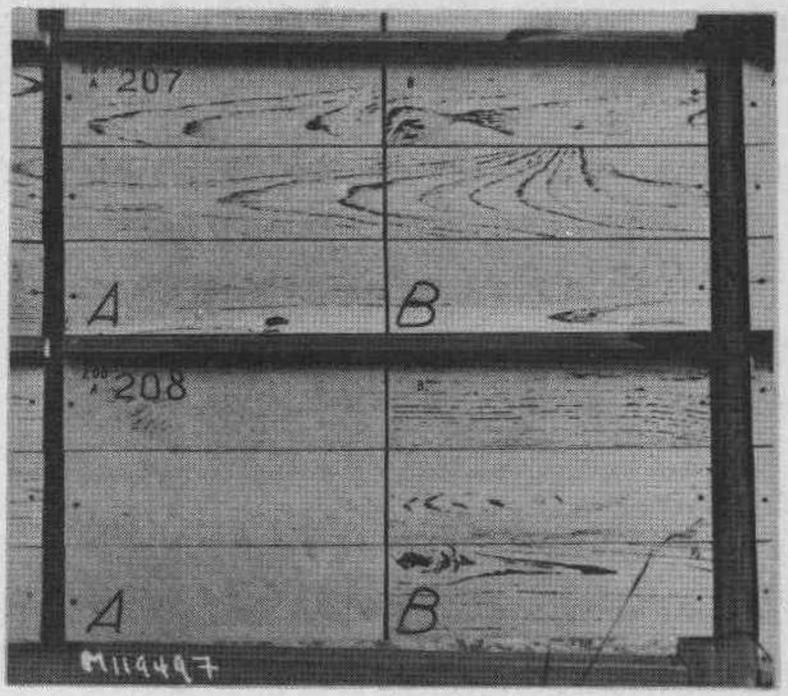

Figure 1.--The negligible effect of changing the reduction of the primer and the bad effect of zinc-dust and zinc-oxide primer on the integrity of paint coatings. The A halves of both panels received a primer that had had a standard reduction, the B half of panel 207 received a primer rich in turpentine, and the B half of panel 208 received a primer made of zinc-dust and zinc-oxide. The paint was a lead and zinc prepared paint, and the wood was southern yellow pine

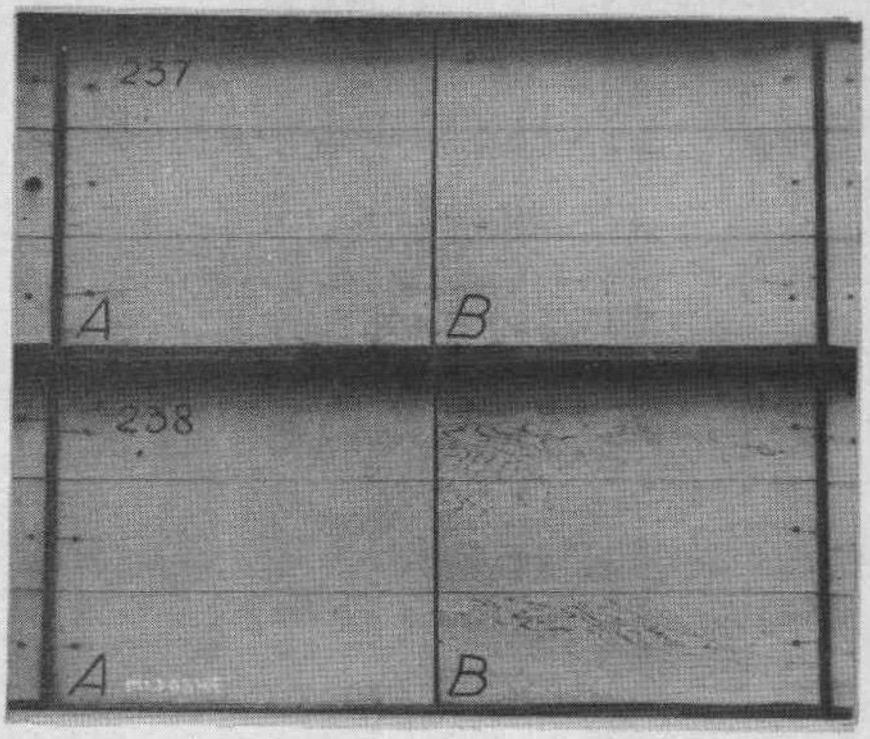

Figure 2.--The negligible effect of changing the reduction of the primer and the bad effect of adding red lead to the priming paint. The A halves of both panels received a primer that had had a standard reduction, the B half of panel 237 received a primer rich in turpentine, and the B half of panel 238 received a primer containing red lead. The paint was a white lead paste paint and the wood was Douglas fir

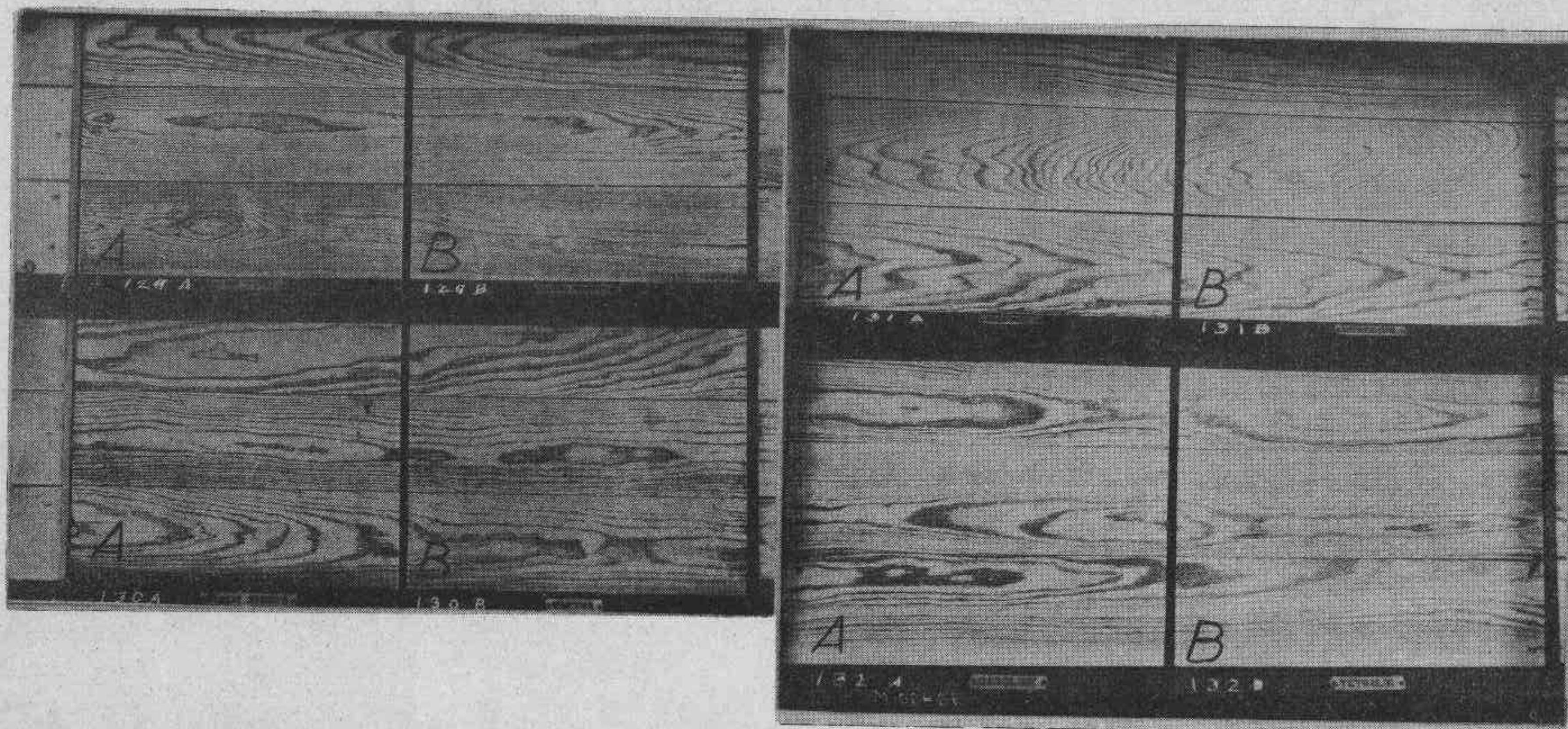

Figure 3.--The small effect, upon the durability of the coating, of the kind of volatile thinner used in paint. All panels were southern yellow pine, coated with paint that was the same except for the thinners, which were as follows: For panel 129-A, gum turpentine; 129-B, destructively distilled turpentine; 130-A, oleum spirits; 130-B, painters' naphtha; 131-A, benzol; 131-B, kerosene; 132-A, gasoline; and 132-B, tetralin

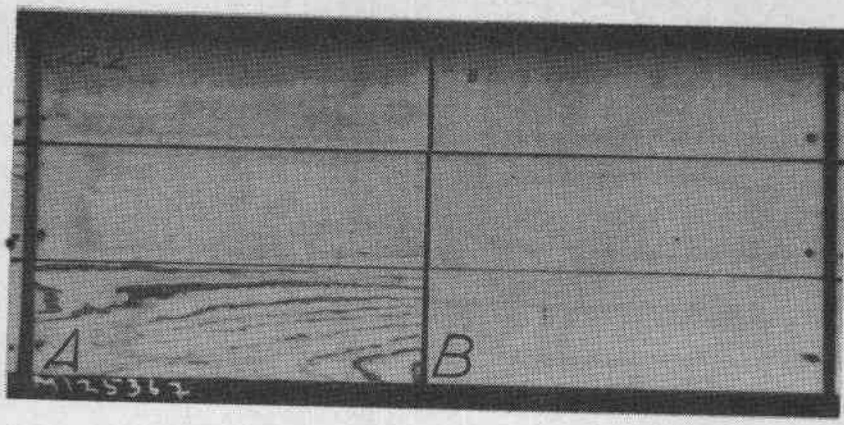

Figure 4.--The beneficial effect of aluminum primer on the integrity of paint coatings. The A half of panel 222 received the standard primer, while the B half was primed with aluminum priming paint. The paint was lead and zinc prepared paint, and the wood was western yellow pine.