Exterior exposure study of stains and clear finishes

Ashton, H. E.

Internal Report (National Research Council of Canada. Division of Building Research), 1973-07-01

NATIONAL RESEARCH COUNCIL OF CANADA
DIVISION OF BUILDING RESEARCH

EXTERIOR EXPOSURE STUDY OF STAINS AND CLEAR FINISHES

by

H. E. Ashton

Internal Report No. 404

of the
Division of Building Research

OTTAWA
July 1973

EXTERIOR EXPOSURE STUDY OF STAINS AND CLEAR FINISHES

by

H. E. Ashton

PREFACE

Clear finishes for exterior wood have been a perennial problem in most countries. Because of the steady interest in their use in Canada, the Division has continued studies aimed at establishing whether improved durability of these finishes might be obtained. Stains have also been investigated because, in general, dark coloured stains have been much more durable than clear finishes. It is of interest to determine whether lighter colours could be effective. This report contains the results of exterior exposures begun in 1967 and terminated in 1972.

OTTAWA
July 1973

N. B. Hutcheon
Director

EXTERIOR EXPOSURE STUDY OF STAINS AND CLEAR FINISHES

by
H. E. Ashton

The Building Materials Section of the Division of Building Research has received a large number of inquiries regarding the use of clear finishes and stains on exterior wood. Advice to users has been based on the results of exposure tests initiated in 1955 and 1960 and, to a limited extent, on accelerated weathering studies. The composition of the test coatings and the exposure results of the first series were given in DBR Report No. 295. The complete exposure results and the outcome of some re-finishing studies have been reported in the literature. [1]

Because so few clear finishes have performed adequately, additional exposure tests were carried out to discover whether durability could be enhanced. Most attention was devoted to the use of ultra-violet absorbers and the number of coats required for improved performance. Accelerated weathering studies had shown that UV absorbers gave improved durability provided they were added to coatings in quantities at least 10 times greater than the 0.5 per cent used in the 1960 studies. The effect of pigmentation on the U.S. Forest Products Laboratory stain formula was also investigated because of enquiries about changing the original dark colour. This report describes the materials tested and the results of additional exposure studies.

As before, coatings were exposed at Ottawa although some workers have questioned whether there is sufficient sunlight at Ottawa to cause much degradation of clear coatings. It should be noted that Ottawa's latitude is the same as that of Venice, Italy. Although latitude is not the only variable, the test results should be applicable to most of Europe as well as to Canada and the northern United States.

MATERIALS AND METHODS

The phenolic varnish and alkyd resin solution that had best durability in their classes in the 1960 series of tests were selected for the present study. A new batch of varnish was cooked as before and a new lot of alkyd resin obtained from the manufacturer. Urethane coatings had previously performed rather poorly but a few were included to determine whether UV

absorbers would upgrade their performance. The most successful acrylics in an accelerated weathering study were added to the exterior program. The U.S. Forest Products Laboratory stain formula was made in the same colour as the 1-GP-145 alkyd so that direct comparison could be made. The level and type of pigmentation in the USFPL stain were also varied to see whether light colours would perform satisfactorily. The composition of the coatings is given in Appendix A.

The materials were applied in the laboratory to Western red cedar panels. For increased confidence in the results four panels were coated with each material, except for the stains where two additional white pine panels were included. Panels coated with phenolic and alkyd finishes were exposed on the test fence on 15 July 1967 and the remaining materials on 20 September 1967.

Although it is known that a longer life is obtained if clear coatings are maintained at yearly intervals, the panels were allowed to weather without touch-up. They were removed from the test fence in May 1972 after almost five years of exposure. Any clear finish still in good condition after four summers can be considered to have very good durability since most fail after two summers.

The panels were moved to the laboratory so that thorough examinations and comparative assessments could more easily be made. Two observers first rated the panels independently, and then compared their ratings to resolve differences. The correlation coefficient between the independent ratings of the clear finishes was 0.927, showing excellent agreement between the observers. For the stains, the coefficient was lower at 0.81, but this was still significant at the 99.9 per cent confidence level. The lower coefficient resulted because one observer tended to rate the stains above 4 while the other gave lower ratings.

The final combined ratings of the two observers are given in Appendix B, with the descriptions of the appearance of the panels at the end of the exposure test. The average ratings shown are based on both the median and the mean. The difference

between them was usually small, but the latter frequently resulted in figures with two decimal places, an unrealistic situation when visual ratings are being used.

RESULTS

The first objective of the study was to determine whether additional coats of phenolic varnish or a combination of alkyd and varnish films would improve durability. The results after 4 years 10 months of exposure are summarized in Table I. It may be seen that an additional coat of phenolic did improve performance markedly. The combination of the two types of clear finish did not perform so well as expected from the accelerated weathering test. Performance was poor because the alkyd tended to delaminate from the varnish film, in some cases trapping dirt, although this did not happen in the accelerated test.

It is also evident from the results that the durability of the combination is chiefly due to the phenolic varnish. Two coats of alkyd and one of varnish had a lower rating than three coats of varnish; two coats of alkyd and two of varnish rated lower than four coats of varnish. Anomalously, two coats of varnish and one of alkyd rated higher than three coats of varnish. Three coats of alkyd alone had the lowest rating in this group. The durability of three coats of phenolic was comparable to that in the previous series when NRP 893 had a rating of 4 after 3-1/2 years of weathering[1].

The effectiveness of ultraviolet absorbers in improving the performance of phenolic and alkyd clear finishes is illustrated in Table II. The absorber was more effective in the alkyd than in the phenolic, probably because alkyds are transparent to lower wavelengths of UV light. The paraphenyl-phenolic resin used in these varnishes tends to act as an UV absorber because of the two benzene rings coupled together in the resin molecule. Hence there is a smaller possibility that the additive will improve the varnish performance. This is shown by the fact that an extra coat of varnish was considerably more effective than 7.5 per cent UV absorber in three coats of varnish.

The UV absorber improved the performance of the alkyd to a certain level and additional absorber seemed to be without effect.

Table III illustrates the addition of UV absorber to the combined alkyd-phenolic system. Addition to only one coat of a three-coat system had no effect, but when two coats of a three or four-coat system contained UV absorber the performance was improved markedly. Whether the absorber was added to the phenolic or to the alkyd did not change the result. When the absorber was present in all four coats the performance was excellent, with one individual panel rating 9 after almost five years of exposure.

When urethanes were first introduced, it was hoped that they would solve the problem of clear finishes for exterior wood. Unfortunately, this has not been the case, as is shown in this and the previous study. In Table IV it may be seen that two urethanes without UV absorber were slightly poorer than the alkyd and the other slightly better. Addition of 5 per cent absorber did not improve durability sufficiently to warrant the extra cost. There was no essential difference between the different types of urethanes exposed. Clear aliphatic urethanes should not be expected to be an improvement over the aromatic urethanes tested here since they transmit more UV radiation than do the aromatics.

Two acrylic finishes were also exposed. In an accelerated test they had performed the best of several acrylics, although not so well as the standard phenolic. The results are given in Table V. It is evident that the UV absorber markedly improved the performance of the acrylic lacquer to the point where it was the second best clear finish. Addition of absorber to the acrylic emulsion was not attempted because most absorbers are solvent soluble.

The effect of pigment in enhancing exterior durability of stains may be readily observed in Table VI. The unpigmented vehicle failed completely in four years eight months; for the samples containing the normal quantity of pigment the lowest

average rating was 2.75. With the sample in which the amount of pigment was reduced by 50 per cent the rating also decreased to about half. Similarly, two coats of USFPL stain were considerably more durable than one coat. This confirms the findings of the 1960 test. White stain was inferior to iron oxide containing stains in the USFPL vehicle. On cedar, two coats of the original pigmentation were more durable than the stain containing yellow and red iron oxide, but on pine the reverse occurred. This may be due to difference in wood, since only two pine panels of each sample were exposed. In most cases the performance of stains was better on cedar than on pine.

CONCLUSIONS

To obtain fairly long-term performance from clear finishes it is necessary to use four coats of a material containing at least 5 per cent of an effective UV absorber. In this study the best durability was obtained from a system of two coats of a tung oil - paraphenylphenolic varnish and two coats of a medium oil alkyd resin, both materials containing 5 per cent of 2, 2' - dihydroxy 4 - methoxy benzophenone. Four coats of a UV-stabilized acrylic lacquer and two coats of the U.S. Forest Products Laboratory stain formula were almost as durable as the phenolic-alkyd combination. UV absorbers have been shown to be quite specific,[2] and the performance of the above clears might be improved or reduced if other types of absorber were used. An additional coat of phenolic varnish without absorber improved durability considerably over the performance of a standard three-coat system. Four coats of varnish containing absorber may have performed as well as or better than the phenolic-alkyd system because without absorber the varnish was superior to the varnish-alkyd system. The combination tended to fail by delamination of the alkyd from the varnish in a manner unfavourable to appearance.

The reason for the great improvement in the performance of the acrylic with UV absorber may be due to the transparency of acrylics to UV light. Because the resin itself is not degraded, the UV absorber only has to protect the underlying wood. If this hypothesis is correct the best approach to durable clears is to

use a material highly transparent to UV, but with sufficient absorber to protect the wood substrate and enough flexibility to withstand wood movements caused by moisture changes. The acrylic lacquer was formulated with n-butyl methacrylate, which has the highest elongation of the acrylic resins made by the resin supplier. Where the vehicle itself absorbs UV to protect the wood, it eventually becomes degraded, as is the case with phenolic varnish.

Aromatic-type urethanes performed about the same as alkyd without UV absorber and not so well as alkyd when both were stabilized against UV.

Changing the pigmentation of the USFPL stain to white or a lighter colour tends to reduce durability. Where such colours are desired more frequent maintenance will be required. The alkyd stain was again less durable than the fortified oil stain, possibly because of the much lower solids content which results in a thinner film. The performance of the alkyd might be improved by adding the water repellants, paraffin wax and zinc stearate, used in the USFPL formula.

ACKNOWLEDGEMENTS

The varnish and the test panels were prepared by G.A. O'Doherty who also made the first evaluation of the exposed panels.

REFERENCES

[1] Ashton, H.E., Clear Finishes for Exterior Wood: Field Exposure Tests. J. Paint Tech., 39, 507, p. 212, 1967.

[2] Philadelphia Society for Paint Technology, Ultraviolet Light Absorbers in Clear Coatings for Wood, J. Paint Tech., 39, 515, p. 736, 1967.

TABLE I

PHENOLIC AND ALKYD DURABILITY

Sample No.	Code No.	Description	No. of Coats	Avg. Rating
1	893	Phenolic Varnish	3	2
2	893	Phenolic Varnish	4	5.5
5	893 914	Phenolic Varnish Alkyd	2 1	2.75
7	893 914	Phenolic Varnish Alkyd	1 2	1.5
9	914	Alkyd	3	0.5
12	893 914	Phenolic Varnish Alkyd	2 2	2.75

TABLE II

ULTRA VIOLET ABSORBER IN PHENOLIC AND ALKYD FINISHES

Sample No.	Code No.	Description	No. of Coats	% UV Absorber	Avg. Rating
1	893	Phenolic Varnish	3	0	2
3	893	Phenolic Varnish	3	5	2.5
4	893	Phenolic Varnish	3	7.5	3.5
9	914	Alkyd	3	0	0.5
10	914	Alkyd	3	5	4.75
11	914	Alkyd	3	7.5	4.5

TABLE III

UV ABSORBER IN PHENOLIC-ALKYD COMBINATIONS

Sample No.	Code No.	Description	No. of Coats	% UV Absorber	Avg. Rating
5	893	Phenolic	2	0	2.75
	914	Alkyd	1	0	
6	893	Phenolic	2	0	2.5
	914	Alkyd	1	5	
7	893	Phenolic	1	0	1.5
	914	Alkyd	2	0	
8	893	Phenolic	1	0	5.5
	914	Alkyd	2	5	
12	893	Phenolic	2	0	2.75
	914	Alkyd	2	0	
13	893	Phenolic	2	5	6.25
	914	Alkyd	2	0	
14	893	Phenolic	2	0	6.25
	914	Alkyd	2	5	
15	893	Phenolic	2	5	7.75
	914	Alkyd	2	5	

TABLE IV

UV ABSORBER IN URETHANES

Sample No.	Code No.	Description	No. of Coats	% UV Absorber	Avg. Rating
16	850	Urethane Prepolymer-Modified Castor Oil	3	0	1.25
17	850	" " " "	3	5	2.75
18	1042	" " - Castor Oil	3	0	0
19	1042	" " - " "	3	5	2.5
20	1043	Urethane Polymer-Catalyst (ASTM)	3	0	0.25
21	1043	" " " (Type 4)	3	5	2.5

TABLE V

DURABILITY OF CLEAR ACRYLICS

Sample No.	Code No.	Description	No. of Coats	% UV Absorber	Avg. Rating
22	1005	Acrylic Lacquer	4	0	1.25
23	1005	Acrylic Lacquer	4	5	7.5
24	Rhoplex (R) WN-80	Acrylic Emulsion	4	0	0

R - Registered Trade Mark

TABLE VI

DURABILITY OF STAINS AND STAIN VEHICLE

Sample No.	Description	Average Rating	
		Cedar	Pine
29	Original USFPL Burnt Sienna-Raw Umber Pigment,		
	2 coats	7.5	3.75
	1 coat	3	-
26	Ferrite Yellow and Red Pigment, USFPL type	5.75	4.25
27	Reduced Ferrite Yellow and Red Pigment, USFPL type	2.5	2.25
30	White Pigment, USFPL type	4.25	2.5
25	Clear U.S. Forest Products Vehicle	0.25	-
28	Alkyd Stain, 1-GP-145	2.75	3
31		2.5	-

APPENDIX A

COMPOSITION OF COATINGS

(All formulae in pounds per 100 gallons)

NRP No. Type	893 Phenolic Varnish	914 Alkyd Resin
Ingredients		
Bakelite BR 254	150.0	-
Tung oil	300.0	-
Mineral spirits	300.0	-
Xylene	75.0	154.0
Hi-flash naphtha	75.0	-
24% lead naphthenate	3.7	7.7
6% cobalt naphthenate	1.5	3.1
Anti- skinning agent	2.7	1.5
Glyptal G 2475	-	770.0
Up heat time, min	17.0	-
Cooking temp., °C	233.0	-
Holding time, min	23.0	-
Viscosity, Gardner-Holdt	C	E
% solids	50.0	50.0
% oil on solids	66.7	56.0

URETHANE COATINGS

NRP No. Type	850 Polyisocyanate and Modified Castor Oil	1042 Polyisocyanate and Castor Oil	1043 Prepolymer and Amine Catalyst
Ingredients			
Spenkel P23-75S	343.0	234.0	-
Spenkel P93-80X	-	-	620.0
Castor 1066	238.0	-	-
D-I castor oil	-	303.0	-
Spenkel catalyst C87-100	-	-	10.0
Amyl acetate	204.0	212.0	-
Hi-flash naphtha	204.0	212.0	-
Methyl cellosolve acetate	-	-	387.0
% solids	50.1	49.8	49.8

NRP No.	1005	-
Type	Acrylic Lacquer	Acrylic Emulsion
Ingredients		
Lucite 2044	330.0	
Xylene	204.0	
95% Ethanol	204.0	
2-Nitropropane	204.0	
Rhoplex WN-80	-	100%
% Solids	35.0	45%

For samples containing UV absorber, Cyasorb UV 24 was dissolved in toluene or amyl acetate and the appropriate amount of solution added to the finish. In spite of the extra solvent it was noted that coatings containing the absorber were slightly more viscous and set to touch faster than the corresponding material without absorber.

STAINS

Sample No.	29	26	27	28
NRP No.	848	-	-	870
Ingredients				
Refined linseed oil	570.0	600.0	600.0	128.0
Mineral spirits	162.0	162.0	162.0	516.0
Paraffin wax	25.0	25.0	25.0	-
Zinc stearate	3.2	3.2	3.2	-
50% pentachlorophenol	118.0	118.0	118.0	-
6% manganese naphthenate	2.0	2.0	2.0	-
6% cobalt naphthenate	1.0	1.0	1.0	1.5
Burnt sienna in oil	40.0	-	-	-
Raw umber in oil	40.0	-	-	-
Ferrite yellow #310	-	36.0	18.0	36.0
Ferrite red #403	-	10.0	5.0	10.0
Lampblack	-	1.5	0.75	1.5
Glyptal G2504-70	-	-	-	132.0
Micro mica C-3000	-	-	-	40.0
UV absorber (33% solution)				13.5
% solids	76.9	76.9	76.2	35.7

WHITE STAIN AND STAIN VEHICLE

Sample No.	30	25
Ingredients		
Refined linseed oil	600.0	600.0
Mineral spirits	167.0	162.0
Paraffin wax	25.0	25.0
Zinc stearate	3.2	3.2
50% pentachlorophenol	118.0	118.0
6% manganese naphthenate	2.0	2.0
6% cobalt naphthenate	1.0	1.0
Titanium dioxide	75.0	-
% solids	77.0	75.5

APPENDIX B

DESCRIPTION AND RATING OF PANELS AT END OF EXPOSURE

Sample No.	Panel No.	Description	Panel Rating	Average Rating
1	1	No large patches of bare wood, but peeled off narrow spring wood bands, most with dark grey colour. About one-third area with intact film and good colour.	1.5	
	2	About 60% panel satisfactory. One small patch of bare wood and remainder peeled off narrow spring wood bands with dark grey colour. Semi-gloss except flat immediately below lap. No fading of wood colour.	2	
	3	About 50% panel satisfactory. Two small patches with film removed, remainder small cracks with wood exposed or whitening of film. Breaks with darkening along most of bottom.	2	2
	4	About 60% panel satisfactory. 20% cracking and curling with medium to dark grey wood; 20% fine cracking with whitening. Crack with dark grey along all of bottom. Low gloss below lap.	2.5	
2	1	2-by 2-in. and 1-by 2-in. areas cracked film with dark grey wood. Numerous small breaks with whitening, some cracked, some with greying. 8-in. crack at bottom with dark grey wood. Gloss low especially below lap.	4	
	2	Two areas small cracks with whitening. One area small breaks with dark grey. Several small breaks with whitening, several cracked with greying. Two 1-in. cracks at bottom with dark grey.	5.5	
	3	Several small breaks with whitening. Three small individual cracks and one area small cracks with dark grey wood. Bottom corners 6-in. cracks with 1/8-in. greying. Low gloss especially below lap.	5.5	5.5

Sample No.	Panel No.	Description	Panel Rating	Average Rating
	4	Ten medium and eight medium-small streaks. Three cracks on lower half, one with blackening. Gloss low especially just below lap.	6	
3	1	About 40% film satisfactory. Five areas film removed, three with grey wood. Strips of small cracks with whitening, some starting to lift. Cracks with greying about half of bottom edge.	2.5	
	2	Film cracked and eroded away 1-by 2-in. patch one end. Fine cracks and whitening same end, 15% of panel. Numerous small breaks with dark centre spot, whitening and staining. Break with greying 75% of bottom edge. Gloss low below lap.	3	
	3	About 20% film removed, bare wood medium grey with dark grey centres. Cracking and curling about half of remainder.	1.5	2.5
	4	About 50% film satisfactory, most failures below lap and at one end. Patches of fine cracks leaving grey wood. Band of fine cracks with whitening across panel. Several small cracks with whitening across panel. Cracks at bottom edge with medium-grey. Wood colour good.	2.5	
4	1	Most of panel in good condition but large patch in centre and smaller one at end fine cracks with whitening. One deep 1-in. crack with dark wood. 1-by 2-in. patch at other end film starting to erode. Gloss fairly good except at patches and 1-in. strip below lap.	4	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
	2	Most of panel in good condition. 2-by 3-in. area film eroded with light grey wood surrounded by fine cracks with whitening. One medium long streak with greying. Fairly numerous small breaks with whitening and slight staining. One deep 1/2-in. crack with dark wood. Four short cracks at bottom with greying. Gloss good except 1-1/2 in. below lap.	4	3.5
	3	One strip 1/4-by 2-in. film removed with light grey wood. Two large patches cracking with whitening, starting to grey in centre. Numerous small breaks with whitening and staining. 8-in. cracks at bottom with greying. Gloss low below lap.	3	
	4	About 35% panel satisfactory. 2-1/2-by 1-1/2-in. area film removed with dark grey wood at one end. At bottom 1/2-by 10-in. film removed with medium grey wood, remainder cracked with greying. Band of cracking with whitening below lap. Several small breaks with whitening and staining on lower half of panel. Dark brown wood colour faded.	2	
5	1	Colour of wood good over 50% of panel. Clear topcoat removed except 3 in. below lap where looks whitish and ragged. Film removed bottom edge 3/8 in. with medium-grey wood most of bottom, cracked remainder. 1/2-by 1-1/2-in. area film removed with medium grey wood. Fine cracks with dark grey wood at ends. Breaks with whitening over remainder failed area.	2.5	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
5	2	Clear topcoat delaminating over most of panel except below lap. Some dirt trapped near bottom. Most of varnish in good condition. 2-by 4-in. patch bottom corner cracked and partly eroded with dark grey wood. Fairly numerous small breaks with whitening. Cracking with medium grey most of bottom edge.	3	
	3	Clear topcoat delaminating from most of lower half of panel. Three patches near ends, varnish film cracked and mostly peeled with medium to dark grey wood. Fairly numerous small breaks with dark centres, whitening and stains. 8-in. cracks with greying at bottom.	3	2.75
	4	Clear topcoat only left in 1-in. strip below lap. About 20% varnish film removed. Breaks with grey centre spots, whitening and stains scattered over remainder. Three strips peeled back with medium grey wood. End area and half bottom shredding with dark wood. Half bottom edge peeled with grey wood.	2	
6	1	Poor appearance because clear topcoat lifting, trapping dirt and looking whitish over 65% of panel. Three small areas film removed with grey-brown wood, four larger areas film removed with light brown wood. Small breaks with whitening and moisture stains. 8-in. cracks with greying at bottom. Dark brown wood colour faded.	2	
	2	Most of panel good except film removed 1 by 10 in. at bottom, one end with medium grey wood. Two small areas film removed with grey-brown wood. Patches of cracking with grey at both ends.		

Sample No.	Panel No.	Description	Panel Rating	Average Rating
		Cracking with lifting and greying half of bottom. Small areas of clear topcoat delamination starting from ends. Gloss good. Dark brown wood colour faded.	2.5	
6 cont.	3	Clear topcoat delamination with trapped dirt and looking whitish. Two patches 1-by 2-in. and 1/4-by 1/2-in. film cracked and removed leaving dark grey wood. Three small breaks with dark grey wood. Half bottom cracked with dark or medium-grey wood. Numerous small breaks with small whitened areas. Gloss good.	3	2.5
	4	Clear topcoat delaminating, trapping dirt and looking whitish on end quarters and one patch in centre. Varnish film removed 2 by 3 in. at one end with dark grey wood. Three 1-in. strips and two 3in. strips film removed at bottom 1/4 in. wide with medium greying. 8-in. cracks with greying. Whitening from small breaks. Gloss good where topcoat left. Dark brown wood colour faded.	2.5	
7	1	50% film removed. Flaking and peeling both coatings on much of remainder. Bare wood light brown where recently lost, some areas yellowish from traces of varnish. Few dark grey streaks at bottom and where film first lost.	1	
	2	30% film removed. Flaking or delamination on about half of remainder. Bare wood light brown, medium-grey where first lost with some yellowish from varnish. 1/4 in. grey at bottom. Wood colour maintained where film retained.	1.5	
	3	50% film removed. Flaking or delamination on about half remainder. Bare wood light brown where recently lost, medium-dark grey where first removed. Several streaks with film lost across grain. Dark brown wood colour faded.	1	1.5

Sample No.	Panel No.	Description	Panel Rating	Average Rating
7	4	30% film removed and topcoat delaminating about 20%. Some breaks with dark spots and whitening on remainder. Bare wood yellowish where film recently lost, grey in other areas. 1/2-in. dark grey strip on bottom.	2.5	
8	1	Fairly numerous medium small and several medium streaks with grey centres, whitening and moisture stains across centre of panel. Several small cracks at bottom leading to greying. Gloss good.	5.5	
	2	Ten medium long streaks with whitening and stains. Two areas of whitening. Crack along 75% of bottom with grey wood. Gloss good.	5.5	
	3	Twelve very small breaks with whitening. One break with blackening. One sq in. small breaks and whitening. Three breaks along bottom with greying. Gloss good.	6.5	5.5
	4	Most film in good condition but dark brown wood colour faded badly. At one end patch of cracking with whitening and grey wood. Numerous small breaks with whitening and staining; five larger breaks with greying. Small breaks on half of bottom with greying. Gloss good.	3.5	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
9	1	Film 75% removed and delaminating from most of remainder. Colour maintained under film. Bare wood light brown, dark grey at one end.	0.5	
	2	Film almost completely flaked off except near lap and one small area. Wood light brown except black near bottom where peeling first started.	0.5	0.5
	3	Film 75% removed and delaminating from most of remainder. Wood colour faded most of panel; medium-grey at one end, dark grey bottom 1 in.	0.5	
	4	Film 75% removed and delaminating from most of remainder. Bare wood medium grey. Colour maintained under film.	0.5	
10	1	Numerous small breaks with grey spots, medium and small whitening streaks and moisture stains. 1 by 1/2 in. lifted with blackening. Most of bottom cracked with slight lifting and greying of wood. Wood colour faded. Gloss good.	5	
	2	Numerous small breaks with grey spots, medium small to small whitening streaks and moisture stains. 1 by 1/2 in. peeled off with dark brown wood. Most of bottom cracked with peeling to 1/4 in. and grey wood. Gloss good.	4.5	4.75
	3	Numerous small breaks with whitening and moisture staining; five larger breaks with greying. Patch at one end of cracking with whitening and grey wood. Half of bottom small breaks with greying. Dark brown wood colour faded badly. Gloss good.	4	
	4	Fairly numerous small breaks with whitening and moisture stains. Eight small cracks with greying. Most of bottom cracked, one-third with 1/8-in. grey wood. Gloss good.	5.5	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
11	1	Numerous small breaks with grey spots, medium whitening streaks and moisture stains. One patch film breaks with whitening and grey wood at centre. 1/4-in. strip at bottom starting to lift with greying. Gloss good except 1/2 in. below lap. Dark brown wood colour faded badly.	3.5	
	2	Numerous small breaks with grey spots and small whitening streaks. Two small cracks with dark grey. Most of bottom cracked with grey wood 1/8 in. Gloss good.	6	4.5
	3	Fairly numerous small breaks most with grey spots, medium-small whitening streaks and moisture stains. 75% bottom breaks with grey wood. Dark brown wood colour faded badly. Gloss good.	4.5	
	4	Numerous small breaks, most with grey spots, medium-small and medium whitening streaks and moisture stains. 1/4 by 1/2 in. flaked off with grey-brown wood. Two-thirds bottom cracks with 1/4 in. whitening and greying. Brown wood colour faded badly. Gloss good.	4.5	
12	1	Film completely removed 1-1/2 by 15 in. at bottom, lower 3/4 in. of bare wood dark grey. Clear topcoat delaminating at ends. Four 1-in. cracks with peeling and several breaks starting to peel. Patch of cracks with greying at one end. Gloss good except 1/2 in. below lap.	3	
	2	Clear topcoat delaminating and whitening of varnish from film breaks. Two large patches and many small spots of cracking with grey wood at one end. One-third bottom cracks with light grey wood. Dark brown wood colour faded badly. Gloss good.	2.5	2.75

Sample No.	Panel No.	Description	Panel Rating	Average Rating
12 cont.	3	Triangular strip 12 in. wide by 2 in. high removed at bottom. 1/2 in. wood grey and 1 to 1-1/2 in. wood brown where recently removed. 1-by 2-in. patch at one end film cracked with dark grey wood. Several small breaks with dark spots but little whitening and no staining. Gloss good.	3.5	
	4	Clear topcoat delaminating at both ends with cracking of varnish and dark grey wood at one end. About half of remainder whitened from small breaks. Film removed 1/4 to 3/4 in. from most of bottom with medium-grey wood. Wood colour good where film intact. Gloss good.	2.5	
13	1	Nine very small breaks with lightening. One 5-in. break bottom corner with 1/8-in. greying. Gloss good.	7.5	
	2	Numerous medium-long and long streaks of whitening with grey spots and moisture staining. Two small cracks at bottom.	5	
	3	Four medium-small and 12 medium streaks of whitening with moisture stains. Two cracks at bottom with greying.	6.5	6.25
	4	Seven small and 10 medium-small streaks of whitening with moisture stains. 8 by 1/4-in. strip peeled from bottom corner with grey wood.	6	
14	1	Eight breaks with medium streaks of whitening and moderate moisture staining. Three small cracks at lower edge.	7	
	2	Fourteen breaks, eight with very small, six with small streaks of whitening. Slight moisture stains. Two breaks at lower edge with greying.	7	
	3	Twenty breaks with grey centres, medium streaks of whitening and moisture stains, 40% of bottom cracks with greying wood.	5.5	6.25
	4	Numerous breaks with grey centres, few medium most medium-long streaks of whitening and moisture stains. No breaks at lower edge.	5	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
15	1	Three very small, two small breaks with whitening. One small break with greying. Three small cracks at lower edge.	8	
	2	Two 3-in. breaks with greying at lower edge.	9	
	3	Twelve breaks, half with grey centres, eight small, four medium-small whitening streaks with moderate moisture stains. Cracks on one quarter of lower edge with blackening.	6	7.75
	4	Fifteen breaks with small streaks of whitening, slight moisture stains. Four small cracks with greying at lower edge.	7.5	
16	1	About one-third film removed but cracking and curling on much of remainder. Colour retained on about 1/4 of panel; bare wood mostly medium grey.	1	
	2	About one quarter film removed but cracking or shredding on most of remainder. Film breaks and dark grey wood along half lower edge. Colour maintained on 75% of panel, bare wood light to dark grey.	1.5	1.25
	3	Two thirds of film removed and remainder shredding. Bare wood mostly dark grey with some erosion of spring wood.	0	
	4	About one-third panel fairly good - more failure on top half of panel. Peeling from spring wood in tiny strips. Cracking with whitening in some areas. One strip and one patch of exposed grey-brown wood. Colour good where film retained.	3	
17	1	About two-thirds of panel fairly good. Patch at one end 1-1/2-by 2-in. film cracked and partly eroded with medium grey wood. Patch 2-1/2 by 5 in. at other end film cracked and partly peeling with light grey wood. Patch in centre 3 by 3 in., film cracked on grain lines with whitening. Two small areas film removed with greying. Few cracks near bottom edge. Wood colour well retained.	3.5	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
17 cont.	2	No large patches of bare wood but lifting or poor adhesion to spring wood bands on much of panel. Wood greying except where film recently detached. About 15 % film and wood colour fairly good.	1.5	2.75
	3	About half panel fairly good. Several patches film shredding with grey wood, remainder film whitened from fine cracks. Few breaks at lower edge. Wood colour good.	2.5	
	4	Top half of panel fairly good except low gloss below lap. One area film removed with medium grey wood. Two patches cracking with grey wood. About 25% cracking along grain lines with whitening and some staining. Wood colour quite good.	3	
18	1	Film 80% removed, shredding (curling between summer wood lines) on remainder. Bare wood dark grey to black with some erosion of spring wood.	0	
	2	Film 75% removed, shredding on remainder. Bare wood light grey with erosion of spring wood.	0	0
	3	Film 80% removed, peeling or shredding on half of remainder. Bare wood medium grey with some erosion of spring wood.	0.5	
	4	Film 85% removed, shredding and peeling on remainder. Bare wood medium grey with erosion of spring wood.	0	
19	1	About one-third of panel fairly good. Cracking and lifting on much of remainder with streaks of bare wood showing. Bare wood light brown to light grey.	1.5	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
19 cont.	2	Upper half quite good except low gloss below lap. Three-quarters of bottom half cracking and lifting leaving dark-grey to black wood. Most cracks are at summer wood line. No cracks lower edge.	3	2.5
	3	2-by 3-in. patch cracking over spring wood with dark grey wood. Eight very small breaks with whitening. Most of lower edge cracked with 1/8 in. lifting and blackening.	5	
	4	No large patches of bare wood but shredding over half panel and whitening on one-third. Exposed wood light brown to light grey.	1.5	
20	1	Film 80% removed. Peeling at edges of retained area and some fine cracking of film. Bare wood medium grey except light brown where recently peeled. Spring wood eroding.	0.5	
	2	Film 90% removed, shredding on remainder. Bare wood medium to dark grey. Spring wood eroding.	0	0.25
	3	Film 85% removed, remainder shredding. Bare wood medium to dark grey. Spring wood eroding.	0	
	4	Film 80% removed. Peeling at edges of retained areas and cracking of film. Bare wood mostly dark grey. Spring wood eroding.	0.5	
21	1	Most of panel quite good. 2-by 1/4-in. break with medium greying. Several cracks starting to peel and expose wood. Only two small cracks at lower edge. Gloss good.	4	
	2	About one-third film removed with cracking and curling on half of remainder. One 2-in. break at lower edge. Bare wood brown to medium-grey.	2	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
	3	About 50% film removed. Curling and cracking on half of remainder. Colour retained about one-quarter of panel. Bare wood light to medium grey with one patch dark grey. Dark brown wood colour faded.	1.5	2.5
	4	About half panel fairly good. Three short strips film removed with medium greying. Four patches film cracked with greying. 40% cracked and starting to lift. 1-in. crack at lower edge. Gloss low below lap.	3	
22	1	Film completely removed except 1/2 in. below lap where delaminated and white. Bare wood light brown except streaks of light grey where film first lifted. Spring wood eroding.	1	
	2	Film completely removed except narrow band still delaminating below lap. Bare wood light brown with fine grey streaks where film first lifted. Spring wood eroding.	1.5	1.25
	3	Film removed except 1 in. still delaminating near lap. Bare wood light brown near top with several grey streaks, medium-dark grey at bottom corners. Spring wood eroding.	1	
	4	Film removed except 1/2 in. below lap. Bare wood not in bad condition - light brown except four narrow streaks where film first lifted. Spring wood eroding.	1.5	
23	1	Five breaks with medium grey streaks. Wood colour quite good.	7.5	7.5
	2	Nine breaks with moisture stains, six medium and three medium-small whitening streaks.	7	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
23 cont.	3	One break with grey centre, moisture staining and small whitening, streak. Dark brown wood colour faded.	9	
	4	Ten breaks with moisture stains, six long, four medium whitening streaks. Brown wood colour faded.	6.5	
24	1	Film 50% removed but remainder deteriorated into fine pinholes near top and black shreds on lower portion. Bare wood light brown top half, dark grey bottom half. Spring wood eroded.	0	
	2	Film almost completely removed except few black shreds. Bare wood dark grey and spring wood eroded.	0	
	3	Traces of film with mildew spots near lap. Black shreds clinging to panel. Bare wood grey brown and narrow spring wood bands eroded.	0.5	0
	4	Film half removed but remainder whitened near lap and white shreds clinging to summer wood. Bare wood dark grey to black. Spring wood eroded.	0	
25	1	Film mostly removed but slight yellowish colour on half of panel, dark grey on other half. Spring wood eroded.	0	
	2	Film degraded to tiny flakes. 2-in. yellowish stain near lap. Bare wood medium-grey on lower half. Spring wood eroded.	0	
	3	Film eroded but yellowish colour on 75% of panel, grey area one end and light brown near middle. Spring wood eroded where bare. Dark brown wood colour faded.	1	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
25 cont.	4	Three-quarters of film disintegrated. 2-in. yellowish stain near lap and one third lower portion. Remainder of bare wood medium-grey. Spring wood eroded.	0.5	
26	1	Yellowing and whitening of colour. 2-by 4-in. area with spring wood eroded giving a poorer appearance. One area of slight film erosion.	4.5	
	2	Three areas 5 by 1 in., 3 by 10 in. and 4 by 6 in. where wood looks porous due to cracks in spring wood and subsequent erosion.	4	5.75
	3	Moderate chalking with yellowing. Slight erosion near lower edge.	7	
	4	Yellowing and whitening with slight chalking. Slight film erosion over summer wood near lower edge.	7	
	1-Pine	Cracks in wood - small and narrow near top, considerably wider and longer near lower edge. Several summer wood bands curled, exposing greyed wood. Stain moderately yellowed.	3.5	
	2-Pine	Small narrow cracks in wood over most of panel. Stain moderately yellowed.	5	4.25
27	1	Film removed from one third of panel with erosion of spring wood, thin on remainder with cracks in spring wood. Remaining stain lighter in colour than original.	2	
	2	Film partially eroded from 80% of panel. Colour lighter. Dark brown streaks at one end and near lower edge.	3	2.5
	3	No patches of bare wood but uniform erosion of film over spring wood with wood showing through. Colour lighter.	3	
	4	Film completely removed 50% of panel. Remaining colour lighter and yellower. Bare wood light brown with spring wood checked.	1.5	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
27 cont.	1-Pine	Panel cupped. Slight moderate erosion of film with grey wood showing through 25% of panel. Narrow cracks in wood over most of panel with summer wood curling near top. Colour darker and yellower.	2	
	2-Pine	Slight cupping of panel. Erosion of film with grey wood across most of bottom. Cracks in wood - narrow in centre, wider near bottom. Few bands of summer wood curling. Stain colour yellower on top half darker on lower half.	2.5	2.25
28	1	Slight cupping of panel. Cracking in spring wood with fissures on almost all panel. Dark strip below lap but remainder whiter than original.	2.5	
	2	Fine checking in spring wood giving porous appearance over all panel. Colour slightly lighter than original except few reddish streaks.	3.5	2.75
	3	Small fissures in spring wood over all panel with porous appearance	3	
	4	Cracking and fissures in spring wood over all panel. Dark strip below lap.	2.5	
	1-Pine	Slight cupping of panel. Narrow and wide wood cracks over all panel. Slight grain raising of summer wood. Slight whitening of stain.	3	
	2-Pine	Slight cupping of panel. Some erosion lower 1 in. of panel with slight greying wood. Narrow wood cracks, quite small at bottom, long near lap. Stain whitened and yellowed.	3	3

Sample No.	Panel No.	Description	Panel No.	Average Rating
29 1 coat	1	Erosion over all panel but not much bare wood exposed.	3	
	2	Erosion of most of spring wood but little bare wood exposed. Several dark streaks.	2.5	3
	3	Moderate erosion of spring wood over all panel.	3	
	4	Uniform fissures in spring wood leading to porous appearance but no bare wood visible.	3.5	
29 2 coats	1	Trace whitening	9	
	2	Slight moderate whitening. Very tiny cracks in some spring wood bands	8	
	3	Slight moderate whitening. Slight erosion of film in two areas.	7	7.5
	4	Slight moderate whitening. Erosion of spring wood in 1-in. band with bare wood showing.	6	
	1-Pine	Slight cupping of panel. Erosion with grey wood 1/4-in. band 1 in. below lap and few small spots at centre near lower edge. Short and long wood cracks scattered over panel. Stain colour brown compared to cedar panels.	3.5	3.75
	2-Pine	Wide medium length cracks most of panel. Slight erosion near lower edge. Colour slightly lighter and yellower.	4	
30	1	Fine cracks at summer-spring wood boundary making summer wood more visible and giving eroded appearance. Coating fairly well retained.	4	
	2	1-by 3-in. area film removed. 1-in. band of dense fine cracks in spring wood at bottom. Most of remainder yellow-brown stain.	4.5	

Sample No.	Panel No.	Description	Panel Rating	Average Rating
30	3	Cracks in spring wood over 80% of panel. Checks with greying at bottom 1/2 in.	2.5	4.25
	4	Yellowish colour over most of panel. Summer wood most bands more visible than spring wood. Tiny cracks in spring wood, medium dense over all panel except dense in bottom 1/2 in.	6	
	1-Pine	Moderate cupping of panel. Over-all appearance silver-grey, darker on bottom half, possibly due to erosion. Small narrow cracks near top becoming wider and longer near bottom. Several edges of summer wood curled exposing dark grey wood.	2.5	2.5
	2-Pine	Slight cupping of panel. Over-all colour silver grey, slightly darker on bottom half. Small cracks near top becoming longer near bottom. Few edges of summer wood curled exposing dark grey wood. Dirt collected below lap.	2.5	
31	1	1-1/2-in. strip below lap with no failure; remainder whitened from tiny cracks some with slight lifting. One patch cracking with grey wood at one end. Two cracks with dark grey wood on panel. Film lifted with 1/4-in. dark grey wood half of lower edge, cracked with greying other half.	2.5	
	2	85% of panel tiny cracks with whitening except 1 in. below lap. Several 1-by 1/2-in. areas film lifted with grey to dark grey wood. Film cracked with lifting and greying wood several areas and most of lower edge.	2	2.5
	3	1-in. strip below lap with no failures then band of small breaks with dark spots. Lower portion whitened from tiny cracks some with lifting. Three areas film removed with dark grey wood. Film cracked		

Sample No.	Panel No.	Description	Panel Rating	Average Rating
		with lifting one third of lower edge.	2	
	4	1-1/2-in. light coloured strip below lap with no defects; remainder with tiny cracks. Four minor breaks and three 1/2 sq.-in. breaks, two with dark grey centres. Film 1/4 in. peeled with medium grey wood most of lower edge. Gloss good.	3.5	