AMERICAN WOOD-PRESERVERS' ASSOCIATION

Effect of Water Repellent Preservatives and Other Wood Treatments on Restoration and Durability of Millwork

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ABSTRACT: This report describes the long-term performance of painted window units that were placed outdoors near Madison, Wisconsin, in 1956. Covered in this report are the effects of the initial water repellent preservative (WRP) treatment during the first 6 years of exposure, a comparison of the water repellent effectiveness (WRE) ofthe WRP with the condition ofthe windows after 32 years, restoration ofthe windows after 32 years, paint performance after the restoration, and the final evaluation for decay after 45 years. There was no correlation between the WRE of the treating solutions as measured by the swellometer test and the condition of the windows after 32 years. However, those windows treated with a WRP that was formulated to have a WRE above the industry standard of 60% performed best. The WRP-treated windows were free of decay after 32 years in service but were badly weathered. The severely weathered window units were used to test several restoration methods and wood treatments, henceforth called pretreatments. The restoration involved pretreatments for both the window sash (stiles and rails) and the sills below the window sashes. The window sashes and sills were severely cracked and weathered, and pretreatment consisted of sanding and applying consolidants or WRPs. The use of consolidants as pretreatments was, in most cases, detrimental to the finish, and these pretreatments generally caused increased flaking and cracking of the paint compared with the untreated controls. However, sanding the surface and applying a copper-naphthenate-containing WRP prior to painting greatly improved the service life of the subsequently applied paint system. Pretreating the windows with a WRP after 32 years in service was critical to their continued durability. Windows that did not receive the WRP treatment at 32 years decayed within 10 years after the restoration.
KEY WORDS: wood durability, paints, service life, windows

INTRODUCTION

~~For more than 50~~ years, wooden doors and windows have been dipped in WRP solutions during manufacture to extend their service life (Banks 1971, Borgin 1965, Bravery and Miller 1980, Verrall 1965). Until about 1980, these WRP formulations were composed of about 1% to 3% water repellent (WR), such as paraffin wax, 5% preservative (pentachlorophenol), 10% sealer (linseed oil or alkyd resin), and solvent (mineral spirits or turpentine) (Feist and Mraz 1978b). Although pentachlorophenol was replaced by other preservatives in the early 1980s, many solvent-borne formulations used today are similar to those developed 50 years ago. In addition to solvent-borne formulations, waterborne formulations are now available. Solvent- and waterborne formulations continue to protect wooden doors, windows, and other millwork. If premature decay of wooden windows and doors occurs that is not due to poor installation or leaking building envelopes, the cause is often insufficient treatment with a WRP (Miller and Boxall 1984, Pearce 1983, Purslow 1975,1982). Quantifying the benefit of such treatments, particularly the effect of WR, has been elusive because the effect of water repellency on durability is often obscured by the inclusion of preservatives in these formulations (Borgin and Corbett 1961, Purslow and Williams 1978). Scheffer and Eslyn (1978) evaluated the effectiveness of pentachlorophenol after 22 years with WRs included with the pentachlorophenol, but it was not possible to determine the effect of the WR on durability without the preservative. The effects of WRs were not clear in other studies of preservatives with and without WRs (Scheffer and others 1963, Verrall 1961). Scheffer and Eslyn (1982) did show that formulation of pentachlorophenol with heavy oil gave better efficacy than with light oil or mineral spirits. The heavy oil probably improved water repellency.

It is well known that WR treatments do not last very long on lateral surfaces exposed to the weather. Voulgaridis and Banks (198 1) exposed WR-treated Scots pine *(Pinus sylvestris)* and European beech *(Fagus sylvatica)* outdoors for 1 year near Bangor, Wales. They used scanning electron microscopy (SEM) to evaluate the surface degradation, and they reported that the loss of surface water repellency was caused to a large degree by the degradation of the wood. Loss of wood from the surface essentially destroyed the structural support for the WR. The loss of water repellency matched that of wood surface degradation. Voulgaridis and Banks (1983) also evaluated the performance of WRs using long wood specimens from Scots pine and European beech. For Scots pine, they showed that the WRE of two solvent-borne WRs decreased with depth from the end-grain. Water absorption ranged from 15% at 10 mm from the end to about 55% at 70 mm from the end (controls absorbed about 70%). As the specimens were weathered with a 24-h wet-dry cycle for 40 cycles, the WRE decreased more rapidly at the end-grain surface than 20 to

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30 mm from the end of the specimen; little change occurred 40 to 50 mm from the end. Although European beech showed quite different water absorption rates than did Scots pine, the general trend in the change in water repellency with cyclic wetting and drying was the same for both species. Savory and others (1977) showed a decrease in water repellency during a 4-year outdoor exposure of window joinery.

This report contains the final evaluations of window sashes exposed outdoors for 45 years in AWPA Deterioration Zone 2 (AWPA 2000) and compares their performance to evaluations that were conducted after 4, 20, 32, and 37 years of exposure and reported earlier (Feist and Mraz 1978a, Miniutti and others 1961). This study offers a unique opportunity to link initial measurements of water repellency with long-term durability and to evaluate the effect of maintenance of severely weathered windows after 32 years of exposure. Severely weathered window units (sills, sashes, and casings) can be difficult to refinish. Film-forming finishes such as paint adhere poorly to weathered surfaces. The cracked and uneven surface of severely weathered window units appears rough even after the application of several coats of paint. Moreover, it is difficult to obtain a good seal with the paint system because the stile–rail joints of weathered window sashes are often separated. Exposure of windowsills, particularly those of south-facing windows, to direct and reflected solar radiation shortens the service of life of paint. The restoration done after 32 years of exposure involved sanding, surface treatment, field application of WRPs, and painting.

OBJECTIVES

The objectives were to evaluate the usefulness of the swellometer test as specified in 1956 in predicting the efficacy of the WRP formulations and to evaluate the effects of (1) the original WRP treatment on the condition of the windows after 32 years, (2) the paint performance after restoration treatments of the 32-year-old windows, and (3) the restoration treatments on durability of windows after 45 years.

BACKGROUND

In 1956, Miniutti and others (1961) began a study of the effect of various solvent-borne WRP dip treatments on the water repellency and service life of window sashes. Three WRP manufacturers supplied three different WRPs each, which totaled nine industry formulations. These WRPs included three formulations that met the industry standard at that time of 60% WRE, three formulations that were above the 60% industry standard, and three that were below the 60% standard. Dip treatments also included a preservative (5.2% pentachlorophenol) without a WR and a WR (1.5% paraffin wax) without a preservative, totaling 11 treatments plus a control. Window sashes of ponderosa pine sapwood were dip-treated in these solutions for 3 min. There were five replicates for each treatment solution and five controls. The window sashes were glazed, varnished on the interior side, painted on the exterior side with a primer and topcoat, and placed outdoors near Madison, Wisconsin, with the exterior side facing south. The windows were installed in casings typical of those found in normal construction and had a roof cap and plywood backing (Fig. 1). The casings received the same preservative, WR, or WRP treatment as the sashes, and these treatments were brush-applied before installing the sashes. The casings were primed prior to installing .the sashes and topcoated following installation of the sashes. There was minimal overhang of the roof cap. Except for removal from the casings periodically to determine swelling during the first 6 years, the window units (casings, sills, and sashes) were left to weather without maintenance until 1988 (a total of 32 years of exposure).

The first report on these windows after 4 years of field exposure included an evaluation of several methods for determining the WRE of the WRP formulations (Miniutti and others 1961). The laboratory methods were the swellograph, the swellometer, flowing water, water spray, cupping, weight gain at 30% to 80% relative humidity (RH), weight gain at 65% to 97% RH, and a field method that compared the dimensional change of the WRP-treated and untreated windows. The results of this interim evaluation showed good correlation between the swelling of the window units and the laboratory methods. The 3-min dip in solutions that contained 60% or greater WRE gave good protection during the early years.

Premature paint failure (after 4 years) was observed in window casings that were not pretreated with a WRP (Fig. 2). Miniutti and others (1961) showed that painted window sashes without a WRP absorbed water, which caused moisture contents above the fiber saturation point at the joint at the bottom of the sash. Water entered the end grain of the wood through cracks in the paint and moved into the interior of the wood.

Feist and Mraz (1978a) evaluated these same window units again after 20 years of exposure. They reported that the windows treated with a WR without the preservative were generally in the same condition as those treated with the WRP. Another evaluation was done after 32 years (Williams 1999). This evaluation showed that the WR alone was not sufficient to protect the windows. Windows that had not received the preservative treatment were badly decayed. The badly decayed windows were not included with those restored after 32 years (Williams and Knaebe 2000).

Previous reports (Arnold and others 1992, Evans and others 1996, Williams and Feist 1994, Williams and others 1987, 1990) have shown that several weeks of weathering of wood prior to painting caused decreased paint adhesion and decreased service life when the wood was subsequently painted. The deleterious effects of many months of weathering have also been reported (Boxall 1977, Bravery and Miller 1980, Desai 1967, Kleive 1986, Miller 1981, Shurr 1969, Underhaug and others 1983). Access to these window sashes and their support structure (windowsills and sashes) that had been exposed for 32 years near Madison, Wisconsin, gave us the opportunity to expand this previous research to include severely weathered wood and to determine the effect of restoration techniques on the continued performance ofthe windows.

MATERIALS

Initial Installation

The windows (45 treated with industry-supplied WRPs, 5 treated with solvent-borne 5% pentachlorophenol, 5 treated with solvent-borne wax WR, and 10 untreated controls) were placed in test 15 km west of Madison, Wisconsin (AWPA Deterioration Zone 2) in 1956 (Miniutti and others 1961). The untreated controls (both painted and unpainted) decayed and fell off the fence within 10 years.

Restoration

In 1988, the sashes from the 55 intact window units were evaluated and 36 sashes were selected foradditional study. All the sashes were free of obvious decay but severely weathered, with deep cracks and extensive surface checks (Fig. 3). The windowsills were also severely weathered but free of decay.

Restoration involved sanding the weathered surface, applying pretreatments, and painting. Pretreatments included consolidants that filled the surface cracks and WRPs that absorbed into the weathered surface but did not fill the cracks. Pretreatments for sills included three commercial consolidants and four WRPs (Table 1), and pretreatments for sashes included one consolidant and four WRPs (Table 2). Only the modified waterborne acrylic resin consolidant pretreatment was common to both sills and sashes. Sills were painted with a commercial oil-alkyd primer and topcoat or a commercial oil-alkvd primer and latex topcoat. Sashes were painted with a commercial oil-alkyd primer and topcoat or a commercial latex primer and topcoat. The same oil-based primer and oil-based topcoat were used for both sills and sashes.

METHODS

Initial Installation

The methods used in the original determination of water repellency, dimensional change, and WRE were reported by Miniutti and others (1961) and included the swellometer test. This method involved submerging treated and matched untreated specimens in water and measuring the tangential swelling after 30 min. The percentage WRE was calculated by subtracting the swelling ofthe treated specimens from the swelling ofthe controls divided by the swelling ofthe controls times 100 in accordance with the then current Federal specification for water repellency (USDA Forest Service 1952). The specification is the forerunner ofstandards adopted by the National Woodwork Manufacturers Association swellometer test (NWMA 1981). This standard has recently been revised (WDMA 1999) The water repellency ofthe window sashes during the first 6 years ofexposure was determined by comparing the swelling of the treated window sashes (measured at the rail close to the mortise and tenon joint) with that of the untreated window sashes. Calculation ofthe WRE was done in the same way as with the swellometer test.

Restoration

After 32 years, the windows were removed from the casings and rated for decay on a scale of 0, 2, 4, 6, 8, or 10 (Table 3) on the basis of soundness of the wood (10 being most sound and 0 being unusable). The 36 window units selected for restoration had ratings of at least 6, and most had ratings of 8 or 10. The wood pieces (rails and stiles) at the mortise and tenon joints on the lower sash were the most susceptible to degradation, and therefore the windows were inspected most closely at that location. Inspection involved visual examination and probing with a sharp pick. Surface cracking was of secondary importance because all windows were fairly similar with regard to weathering (Fig. 3).

The restoration of the windows after 32 years of exposure included hand sanding, machine sanding, WR and WRP treatment, and surface treatments, which included consolidants (Williams and Knaebe 2000). Consolidants are commercial products that are designed to solidify deteriorated wood.

Window units were evaluated annually for 5 years according to American Society for Testing and Materials standards for paint cracking (ASTM 1991a) and paint flaking (ASTM 1991b). Three window units were used for each pretreatment to give three observations for each experimental condition. For the sills, each pretreatment was applied at random to three locations on the sills. Each half of the window sashes and each section of the windowsills was rated annually for paint flaking, paint cracking, general appearance, mildew growth, and wood cracking during a 5-year period. A rating of 10 was used to indicate no observable degradation and a rating of 1 to indicate complete failure of the unit. A rating of 5 indicates sufficient degradation to warrant normal refinishing if the coating system were in use on a structure.

Final Evaluation, 45 Years

After a total of 45 years on the test fence, the restored windows were evaluated for decay. The areas of the windows near the mortise and tenon joints were probed using a sharp ice-pick and rated on a scale of 10 to 1 (10 = excellent and 1 = massive decay). A rating of 5 indicates that the window was no longer serviceable.

RESULTS AND DISCUSSION

Initial Installation

After 32 years of exposure in Deterioration Zone 2, the windows were evaluated for decay. Of the 65 window units placed in test in 1956, the 32-year evaluation included only the treated windows (55 window units) because the untreated controls had decayed and fallen off the fence (Table 3). The treating solutions that gave the highest average decay rating for the five replicates were the WRP solutions with high water repellency (HWR), with average values of 9.6 8.8, and 8.8. The variability in these specimens was considerably less than in most of the other treatments. Those specimens treated with only the WR had the lowest average value (2.4). Windows treated with either the industry standard or the below industry standard (<60% WRE) formulations were inconsistent with ratings that varied from a low of 4.8 to a high of 7.6.

Table 3 lists the original WRE for the WRPs used to treat these windows (Miniutti and others 1961). The WRE was determined in accordance with National Wood Window and Door Association TM-2 (USDA Forest Service 1952). The correlation between the WRE of the WRPs and the final decay evaluation of the windows is poor. For example, treatment 1 had a WRE value of 6%, and the decay ratings of the windows after 32 years were 2, 4, 6, 8, and 10 for the five replicate windows to give an average rating after 32 years of 6.0. Treatment 7 had a WRE of 77%, and the 32-year window ratings were 2, 4, 4, 8, and 10 to give an average rating of 5.6. The water repellency measured for the HWR solutions ranged from 61% to 83%, and the average window decay ratings after 32 years of exposure ranged from 8.8 to 9.6. The rating of treatment 5 with a water repellency of 83% was the same as that of treatment 6 with water repellency of 67%. Treatment 3, which was formulated to be below the industry standard of 60% WRE, had a measured WRE of 61%, and window units treated with this formulation had a higher average decay rating than those window units treated with the industry standard. This is shown in Table 3 by comparing treatment 3 (average rating 7.6) with treatments 7, 8, and 9 (average ratings 5.6, 6.4, and 7.2). The variability among the WRE determinations was high even within the same types of formulations. For example, the three WRPs formulated to be less than 60% WRE had measured WRE values of 6%, 28%, and 61% (Table 3). It is unknown whether they were intentionally formulated to have such a wide range of water repellency.

Miniutti and others (1961) suggested that dimensional changes in the windows should give a realistic appraisal of the WR effectiveness. To calculate WRs, they used the average maximum deviations from the original dimensions during the first 4 years of exposure for windows having various treatments. They noted a fairly good correlation during the early years of exposure between these values and the WRE (Table 4). A correlation coefficient of 0.922 was reported for the average maximum WRE during the 4th year of exposure and the WRE. But there was little correlation between the dimensional changes reported by Miniutti after 4 years and the condition of the windows after 32 years. (Williams 1999). For example, Treatment 11 showed good effectiveness in 1960 (WRE = 76%; Table 4), but its long-term durability was poor (average decay rating 2.4; Table 3). However, the interim 20-year report indicated that WRs without preservatives were as effective as those with preservatives (Feist and Mraz 1978b). Apparently. WRE was about at its limit at 20 years, and substantial degradation took place following the 20-year evaluation.

Information in Miniutti's original laboratory notebooks showed considerable variation in shrinking and swelling during any year caused by seasonal changes in RH and differences in rainfall. However, the general trend appeared to be increasing swelling during wet periods with exposure time. The maximum swelling during periods of high rainfall tended to be fairly consistent among the five replicates as shown for treatment 7 (Fig. 4). The other WR and WRP treatments responded similarly to treatment 7.

Based on window dimensional changes during 6 years of outdoor exposure, WRE loss was plotted and fit with a linear least square. Extrapolation of the slope to 0 WRE gave an approximate "years to zero WRE" (Table 5). The correlations between the swellometer WRE values and the other columns in Table 5 were determined (between swellometer WRE and calculated WRE, slope, years to zero WRE, or 32-year rating). The best correlation with the swellometer WRE column was with the years to zero WRE (0.64). Miniutti and others (1961) reported a correlation coefficient of 0.922 between swellometer values and the maximum swelling during only the 4th year of exposure. The correlation coefficient of 0.64 may better approximate the value of the test because it was calculated from a number of WRE observations during 6 years.

Restoration

Following 32 years of weathering, 36 of the original 65 windows were selected for restoration. This restoration involved the windowsills and sashes. Although all windowsills and sashes were treated and placed into test at the same time, the focus of study was different for sashes and sills (Tables 1 and 2). Windowsill pretreatments focused on the use of consolidants to restore the surface prior to painting. Three commercial consolidants were used on the sills, whereas only one consolidant was used for sash pretreatments. Four WRP treatments were used on the sills and sashes. Sills were sanded either lightly or moderately by hand, whereas sashes were power sanded or not sanded. Thus, the surfaces of sills and sashes were distinct.

Windowsills: Windowsills were restored because they provided surfaces that were badly cracked and were ideal for evaluating consolidant treatments. Flaking provided the best measure of the effect of sanding and pretreatment on paint performance (Fig. 5). Average flaking ratings for oil-alkyd and latex topcoats for the two different types of sanding are shown along with the distribution of ratings for one of the treatments. The graph for the lightly sanded sills finished with the oil-alkyd primer and topcoat (upper left) is duplicated in the lower right graph to show the distribution of ratings for each pretreatment. Each mean value is shown along with its standard deviation. The standard deviations are staggered at each time point to reveal the spread in the data. In most cases, the mean is bracketed by ±1 evaluation unit. Means that do not differ by at least 1 evaluation unit are probably not different. The distribution of the data in the flaking plot is typical of the data in the plots for paint cracking on the sills (Fig. 6) and the data on the sashes (Figs. 7 and 8).

The flaking ratings for windowsills were different for various pretreatments after 5 years of outdoor exposure following restoration. Pretreatment with copper naphthenate WRP or tung oil improved the performance of both paint systems regardless of the amount of sanding. Zinc naphthenate WRP also improved paint performance but not to the extent of the copper naphthenate WRP. The other pretreatments gave mixed results, depending on the paint system and the amount of sanding. For example, the epoxide consolidant performed better with the oil primer–latextopcoat system than with the oil primer-oil topcoat (Fig. 5). For several pretreatments, the paint was in worse condition after 5 years compared with the untreated control regardless of finish system or amount of sanding (Fig. 5). For example, solvent-borne consolidant (EC) and modified acrylic consolidant (resin) performance was worse than performance of controls for both lightly and moderately sanded units finished with oil primer-oil topcoat and oil primer–latextopcoat systems. These types of consolidants probably lack the flexibility to move with the wood as it changes dimension through daily and seasonal changes in moisture content, particularly when the consolidant is used with an oil-based primer.

In evaluating the sills, it was difficult to separate substrate cracking from paint cracking (Fig. 6). The type of sanding apparently had little influence on cracking of the wood with either paint system, probably because of the oil primer. Neither system performed very well, although copper naphthenate seemed to help improve paint performance in all cases. None of the consolidant treatments improved the paint performance.

Window sashes: The window sashes were also evaluated for paint flaking and cracking (Figs. 7 and 8). The flaking evaluation gave the best indication of paint service life, and these results are reported in more detail than the cracking evaluation. Flaking performance was most affected by sanding (Fig. 7). Little overall difference could be attributed to type of paint. As was shown in previous research, adhesion of both oil- and latex-based paints is badly compromised by weathered wood (Williams and others 1987). Sanding improved flaking performance of all sashes, even the untreated controls. All pretreatments improved flaking performance of sashes finished with the latex-based system. This was not the case for sashes finished with the oil-based system. For example, pretreatment with the modified acrylic resin consolidant improved flaking performance of sashes finished with the latex paint system but not that of sashes finished with the oil-based system (Fig. 7). This acrylic is apparently compatible with the latex primer but not with the oil-based primer.

The evaluations for paint cracking are similar to flaking, but cracking generally occurs prior to flaking (Fig. 8). After 1 year, many oil-alkyd paint systems had failed and there was not much improvement with any pretreatments. For the latex paint systems, the pretreatment improved the paint performance, particularly for the unsanded portion of the sashes. The sanded portions performed much better than the unsanded portions. As with the flaking evaluations, the modified acrylic resin consolidant used in conjunction with the latex paint improved the finish service life.

In summary, pretreatments varied in their long-term effect on sashes, and sanding was beneficial in all cases. Pretreatment with WRP plus sanding gave the best performance. Results of this study are from windows exposed on an unheated test fence located in AWPA Deterioration Zone 2. They do not necessarily predict decay rates in windows installed in heated structures in other AWPA Deterioration Zones.

Final Evaluation, 45 years

After 45 years, evaluation of the window sashes for decay showed that the WRP treatment during the restoration was critical to continued performance of the windows. The windows were examined using a sharp probe (ice pick) to determine the soundness of the wood surrounding the mortise and tenon joints on each window sash (Table 6). As mentioned, a rating of 5 indicated that the window was too decayed for continued service. If either location on the window received a 5 or lower, the window was considered unusable. Although Table 6 contains the average evaluations for each restoration method, the most meaningful information is number of windows in useable condition. Windows treated with the solvent-borne WRP gave the best service life. Treatment with linseed oil did not improve the performance of the windows. The type of paint used for the restoration had little effect on the condition of the windows. If fact, most of the paint had failed.

It is difficult to quantify the effect of the original window treatments on the final evaluation. However, of the window sashes that were still in serviceable condition after 45 years (10 sashes), eight were treated with a WRP that met the industry standard in 1956.

CONCLUSIONS

The WRE determined according to the swellometer standard in 1956 does not appear to be correlated with the condition of windows after 32 years of outdoor exposure in AWPA Deterioration Zone 2. The long-term performance of WRPs formulated to have water repellency greater than the 60% WRE that also contained a wood preservative HWR was better than that for the other formulations, but the swellometer test failed to show this. The swellometer test was not sensitive enough to distinguish amongst the good WRs or to predict long-term performance of formulations that had a preservative.

In restoring severely weathered window units, sanding is beneficial in most cases. The pretreatment that contained copper naphthenate greatly improved paint performance by stabilizing the wood surface. In most cases, the consolidants did not improve performance of window units finished with the oil-alkyd based system. For the consolidants used in this study, the best performance was obtained from modified acrylic resin consolidant in combination with the acrylic-latex finish. Thus, care should be taken to match the consolidant to the type of paint system used. Incompatibility of the consolidant with the wood and paint can cause premature paint failure.

The critical factor in a long service life of windows is WRP treatment during manufacture and continued maintenance with WRP. In restoring severely weathered windows after 32 years of exposure, pretreatment with solvent-borne WRP was critical to preventing decay during the 13 years following restoration.

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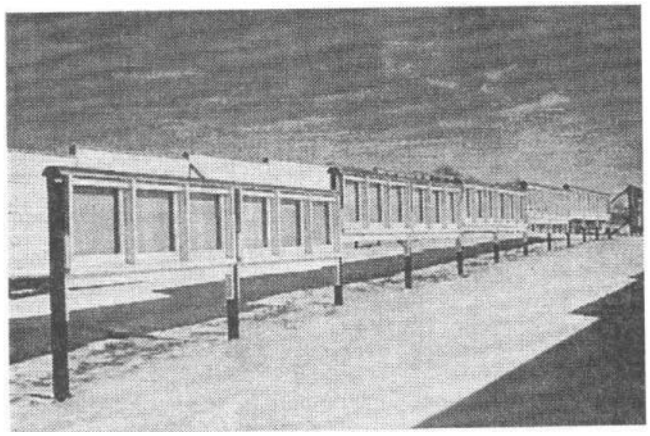

Figure 1. Window units as orginally installed by Miniutti and others (1961) in 1956.

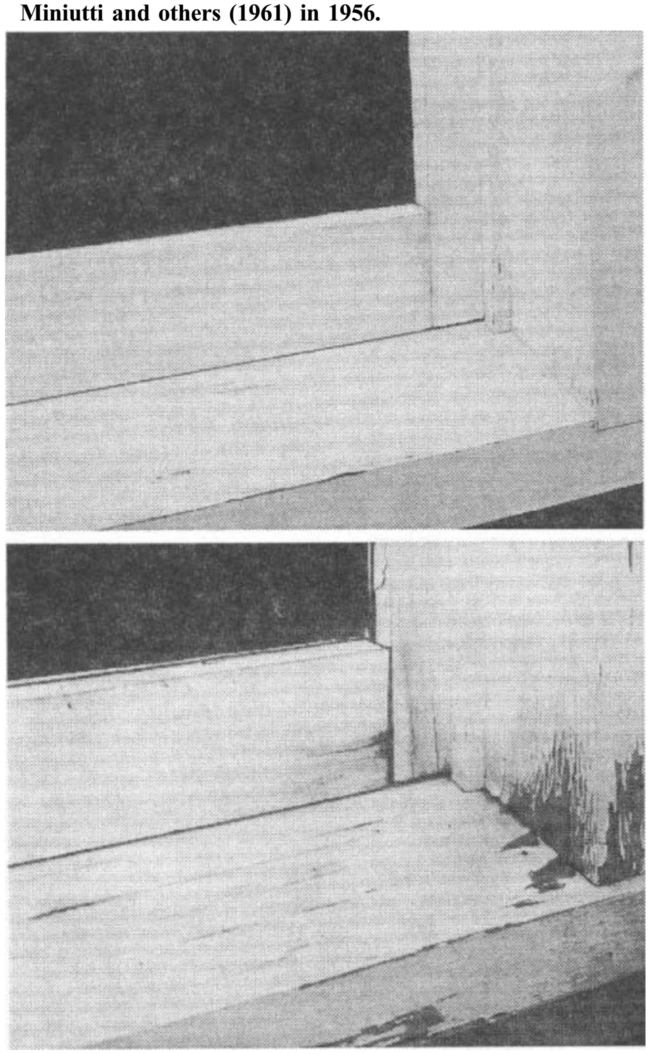

Figure 2. Effect of water repellent preservative (WRP) on service life of window unit: (top) window unit pretreated with WRP prior to painting; (bottom) untreated window unit. Paint degradation caused by water absorption into end grain.

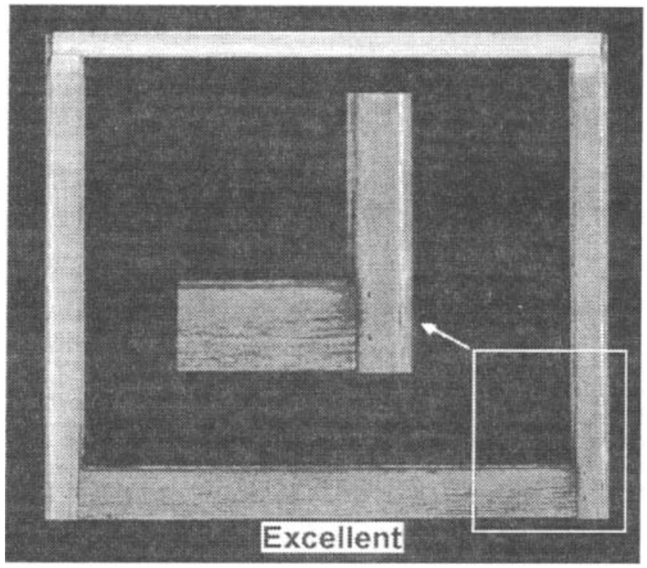

Figure 3. Pretreatment of window sash prior to painting; right half of sash has been sanded.

Table 1. Pretreatments, surface preparation, and finishes for windowsills from test units that had been exposed in AWPA Deterioration Zone 2 for 32 years[a]

Variable	Abbreviation[b]
Pretreatment:	
Control	Control
Zinc naphthenate WRP	Zn
Solvent-borne epoxide consolidant	EC
Modified waterborne acrylic resin consolidant	resin
Copper napthenate WRP	Cu
Solvent-borne consolidant	SC
Tung oil	tung
50% polyurethane varnish in mineral spirits	poly
Surface prep:	
Light sanding by hand	light sand
Moderate sanding by hand	moderate sand

[a]WRP, water repellent preservative.

[b]Abbreviations used in figures.

Table 2. Pretreatments, surface preparation, and finishes for window sashes from test units that had been exposed in AWPA Deterioration Zone 2 for 32 years[a]

Variable	Abbreviation[b]
Pretreatment:	
Control	Control
Solvent-borne WRP	SWRP
Solvent-borne water repellent	WR
50% linseed oil in mineral spirits	linseed
Waterborne WRP	WWRP
Modified waterborne acrylic resin consolidant	resin
Surface prep:	
Washed with bristle brush	
Power sanded	
Paint system:	
Oil-alkyd primer and topcoat	
Acrylic-latex primer and topcoat	

[a]WRP, water repellent preservative.

[b]Abbreviations used in figures.

Table 3. Evaluation of windows after 32 years of outdoor exposure in AWPA Deterioration Zone 2

		Number of windows in each visual rating category at 32-year exposure[a]								
Treatment type	Treatmen t number	10	8	6	4	2	0	Average rating[b]	Std. dev.	Swellometer[c] WRE (%)
WRP, <60% WRE[d]	1	1	1	1	1	1		6.0	3.2	6
	2		1	1	2	1		4.8	2.3	28
	3	1	3		1			7.6	2.2	61
WRP, HWR[e]	4	4	1					9.6	1.4	61
	5	2	3					8.8	1.1	83
	6	2	3					8.8	1.1	67
WRP, industry standard[f]	7	1	1		2	1		5.6	3.3	77
	8	1	1	2		1		6.4	3.0	53
	9		3	2				7.2	1.1	82
Preservative only	10		1	2	2			5.6	1.7	4
Water repellent only	11				1	4		2.4	1.4	77

[a]The rating of 10 is the most sound, and 0 is unusable.

[b]Average rating of five window units after 32 years of outdoor exposure near Madison, Wisconsin.

[c]The WRE of the industry-supplied water repellent preservative (WRP) was determined using the swellometer test and reported by Miniutti and others (1961).

[d]WRE, water repellent effectiveness. Commercially formulated to be below the industry standard of 60% WRE.

[e]HWR, high water repellency. Commercially formulated to be above the industry standard of 60% WRE.

[f]Standard industry WR formulation to meet 60% WRE.

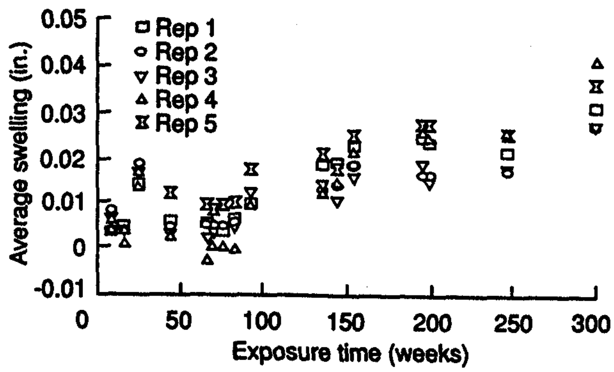

Figure 4. Average swelling of five replicate windows treated with WRP Treatment 7. Each data point is an average of two measurements. The shrinkage during dry periods is not shown (1 in. = 25.4 mm).

Table 4. Water repellency values based on dimensions during the first 4 years of weathering of treated and painted window sashes[a]

Treatment type	Treatment number	Water repellency by dimension change[b] (%)				Swellometer WRE (%)
		1957	1958	1959	1960	
WRP, <60% WRE[c]	1	21	37	23	28	6
	2	80	83	65	62	28
	3	78	86	70	66	61
WRP, HWR[d]	4	77	85	73	71	61
	5	82	90	78	80	83
	6	86	89	74	71	67
WRP, industry standard[e]	7	82	88	76	77	77
	8	80	81	55	52	53
	9	82	85	72	71	82
Preservative only	10	−1	37	30	37	4
Water repellent only	11	83	90	77	76	77

[a]Reproduced from Miniutti and others (1961).
[b]Water repellency calculated from the swelling of the sash rails near the mortise and tenon joint.
[c]WRP, water repellent preservative; WRE, water repellent effectiveness.
[d]HWR, high water repellency. Formulated to be above the industry standard.
[e]Standard industry water repellent formulation to meet 60% WRE.

Table 5. Least squares fit of the decrease in water repellent effectiveness (WRE) with time for windows exposed in AWPA Deterioration Zone 2 for 32 years[a]

Treatment type	Treatment number	Calculated WRE (%)[b]	Slope	Years to zero WRE[c]	R^2 (%)	Swellometer WRE (%)[d]	32-year rating
WRP[e], <60% WRE	1	43	–4.8	8	28	6	6.0
	2	94	–8.0	12	80	28	4.8
	3	95	–7.1	16	76	61	7.6
WRP, HWR[f]	4	93	–5.8	16	71	61	9.6
	5	94	–4.0	23	60	83	8.8
	6	99	–7.1	14	83	67	8.8
WRP, industry standard[g]	7	95	–4.9	19	70	77	5.6
	8	93	–11.0	8	85	53	6.4
	9	94	–5.6	17	79	82	7.2
Preservative only	10	47	–3.1	15	19	4	5.6
Water repellent only	11	97	–5.7	17	74	77	2.4

[a]The ratings for each individual replicate are shown for each treatment.

[b]Calculated WRE from they intercept of least squares fit of the 6-year data.

[c]Years to zero WRE values were obtained by extrapolating the linear fit of the WRE of the data for the first 6 years.

[d]Initial WRE obtained from swellometer measurement of the industry-supplied WRPs, preservative only, and the water repellent only from Miniutti and others (1 96 1).

[e]WRP, water repellent preservative.

[f]HWR, high water repellency, Formulated to be above the industry standard.

[g]Standard industry water repellent formulation to meet 60% WRE.

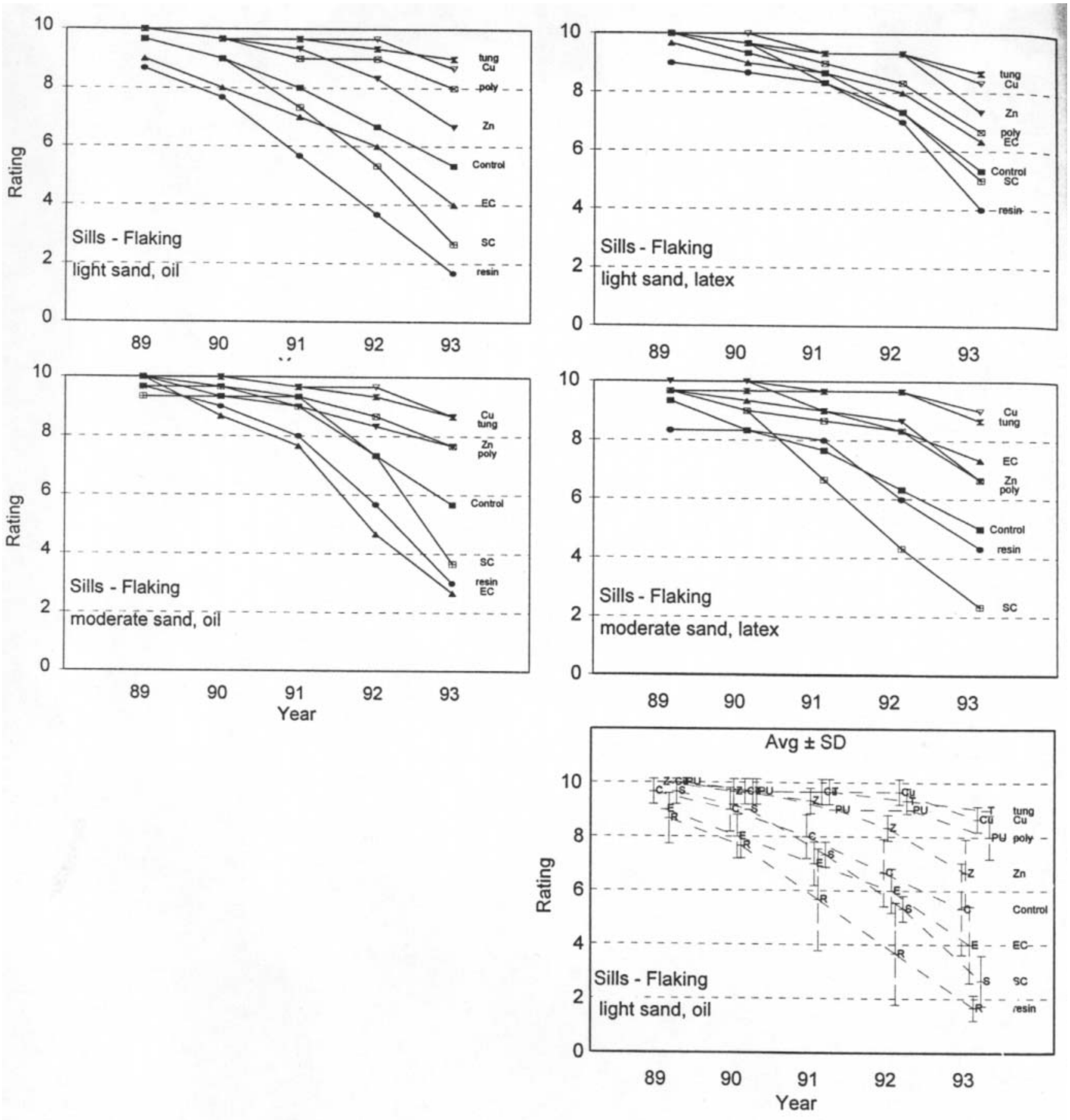

Figure 5. Mean ratings for flaking of windowsill paint after 5 years of outdoor exposure (10 means no observable degradation, and 1 means complete failure of the unit). All sills were prepared with oil-alkyd primer. *Oil* designates oil topcoat; *latex,* acrylic-latex topcoat. Lower right graph shows distribution of ratings for each pretreatment (Zn, zinc naphthenate WRP; EC, epoxide consolidant; resin, acrylic resin consolidant; Cu, copper naphthenate; SC, solvent-borne consolidant; tung, tung oil; poly, polyurethane varnish).

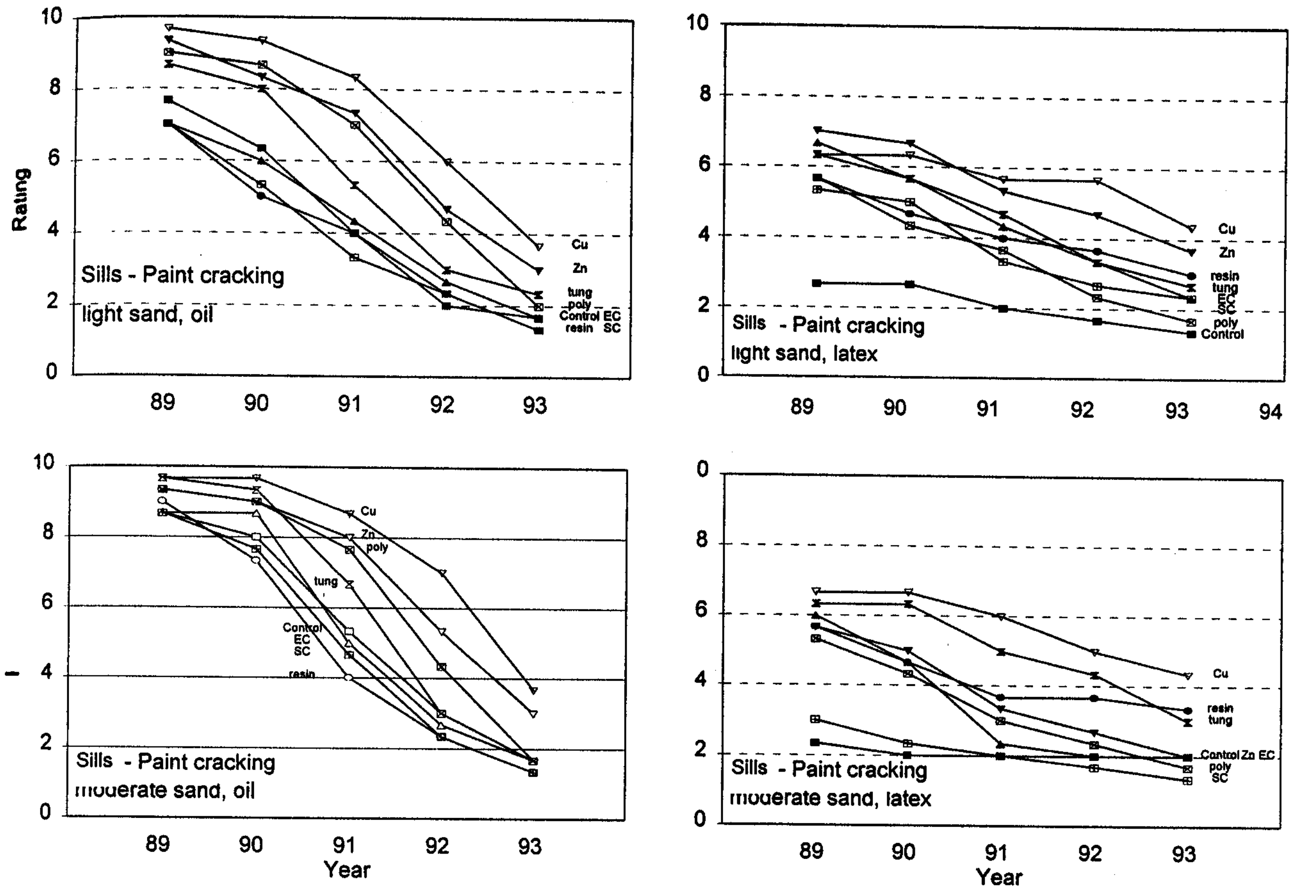

Figure 6. Mean ratings for cracking of windowsill paint after 5 years of outdoor exposure (10 means no observable degradation, and 1 means complete failure of the unit). All sills prepared with oil-alkyd primer. *Oil* designates oil topcoat; *latex,* acrylic-latex topcoat (Zn, zinc naphthenate WRP; EC, epoxide consolidant; resin, acrylic resin consolidant; Cu, copper naphthenate; SC, solvent-borne consolidant; tung, tung oil; poly, polyurethane varnish).

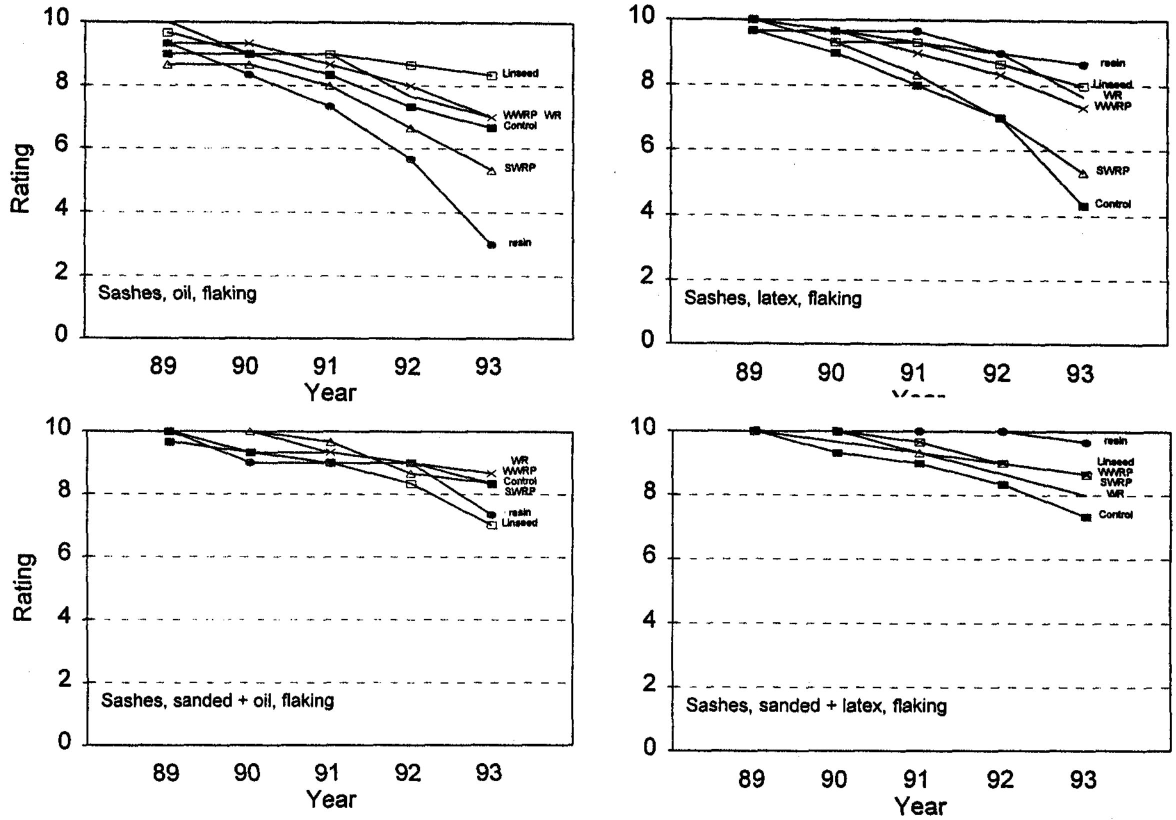

Figure 7. Mean ratings for flaking of window sash paint after 5 years of outdoor exposure (10 means no observable degradation, and 1 means complete failure of the unit). ***Oil*** **designates oil-alkyd primer and topcoat;** ***latex,*** **acrylic-latex primer and topcoat (SWRP, solvent-borne WRP; WR, water repellent; Linseed, linseed oil; WWRP, waterborne WRP; resin, acrylic resin).**

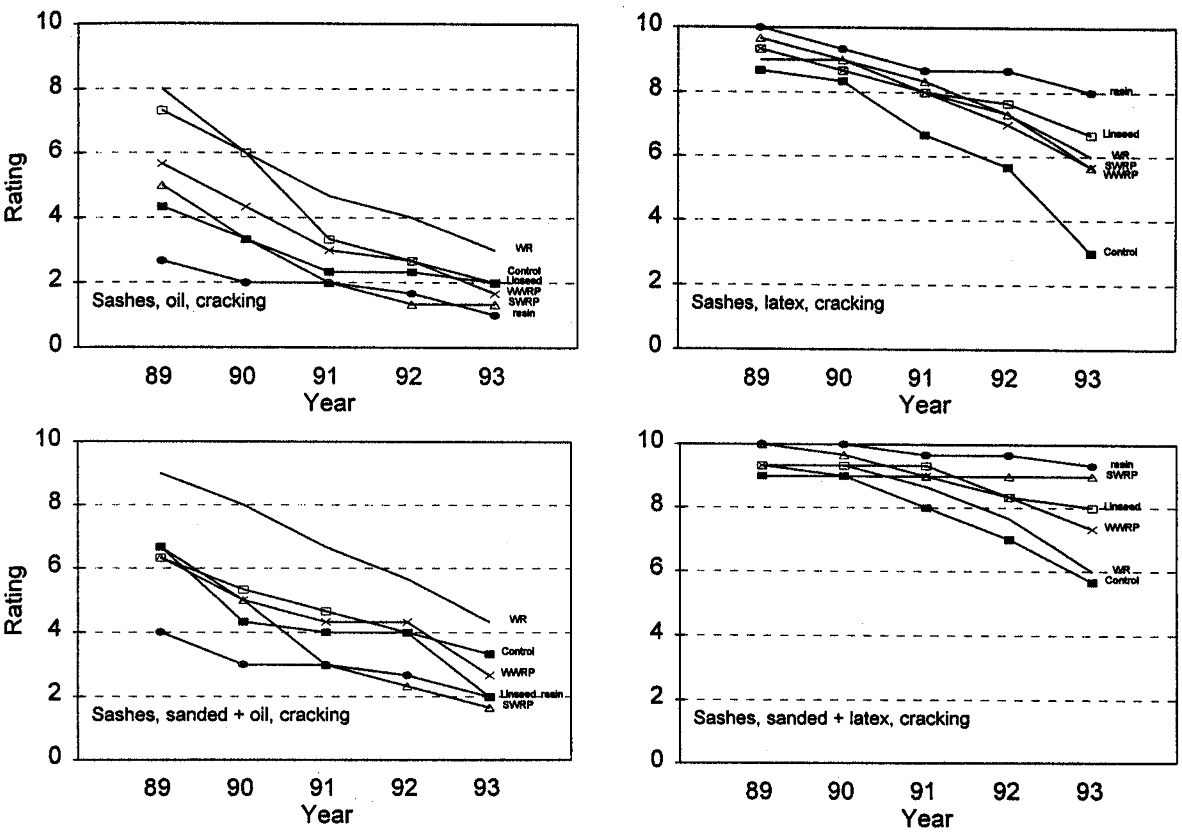

Figure 8. Mean ratings for cracking of window sash paint after 5 years of outdoor exposure (10 means no observable degradation, and 1 means complete failure of the unit). *Oil* designates oil-alkyd primer and topcoat; *latex,* acrylic-latex primer and topcoat (SWRP, solvent-borne WRP; WR, water repellent; Linseed, linseed oil; WWRP, waterborne WRP; resin, acrylic resin).

Table 6. Evaluation of the windows in service after 45 years of exposure in AWPA Deterioration Zone 2

Original treatment	Condition at 32 years	Treatment at 32 years (pretreatment/paint)[a]	After 45 years in service		
			Evaluation[b]	Average 6 units	Usable yes/no
High WRP	10	none/oil	7, 7		yes
Standard WRP	10	none/latex	1, 2		no
Standard WRP	8	none/oil	7, 7		yes
Standard WRP	8	none/latex	1, 1		no
Low WRP	6	none/oil	6, 5		no
Standard WRP	10	none/latex	1, 1	4 ± 2.7	no
					Total usable: 2
High WRP	10	S, WRP/oil	6, 7		yes
High WRP	10	S, WRP/latex	7, 8		yes
High WRP	8	S, WRP/oil	8, 8		yes
Low WRP	8	S, WRP/latex	7, 6		yes
Preservative only	6	S, WRP/oil	5, 5		no
Low WRP	6	S, WRP/latex	7, 5	7 ± 1.1	no
					Total usable: 4
High WRP	10	S, WR/oil	7, 8		yes
High WRP	10	S, WR/latex	7, 7		yes
Standard WRP	8	S, WR/oil	5, 5		no
High WRP	8	S, WR/latex	5, 2		no
Standard WRP	6	S, WR/oil	2, 7		no
Standard WRP	6	S, WR/latex	5, 3	5 ± 2.0	no
					Total usable: 2
Standard WRP	10	S, LO/oil	1, 1		no
Low WRP	10	S, LO/latex	5, 4		no
Low WRP	8	S, LO/oil	8, 7		yes
High WRP	8	S, LO/latex	1, 1		no
Low WRP	8	S, LO/oil	1, 1		no
Standard WRP	8	S, LO/latex	1, 1	3 ± 2.5	no
					Total usable: 1
High WRP	10	W, WRP/oil	5, 6		no
Standard WRP	8	W, WRP/oil	5, 5		no
Standard WRP	8	W, WRP/latex	1, 1		no
High WRP	8	W, WRP/oil	5, 7		no
Preservative only	8	W, WRP/latex	2, 2	3 ± 2.2	no
					Total usable: 0
Low WRP	10	Consolidant/oil	6, 6		yes
High WRP	10	Consolidant/latex	7, 4		no
Low WRP	8	Consolidant/oil	5, 7		no
Low WRP	8	Consolidant/latex	4, 6		no
High WRP	8	Consolidant/oil	7, 5		no
Standard WRP	6	Consolidant/latex	4, 4	5 ± 1.2	no
					Total usable: 1

[a]S, solvent-borne; WRP, water repellent preservative; WR, water repellant; LO, linseed oil; W, waterborne.
[b]Both lower comers of the window were evaluated. If either location of the window received an evaluation of 5 or lower, the window was considered unusable.

PROCEEDINGS

Ninety-Seventh Annual Meeting

of the

AMERICAN WOOD-PRESERVERS' ASSOCIATION

Minneapolis Marriott City Center
Minneapolis, Minnesota
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