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# FINISHING PROPERTIES OF CANADIAN SPECIES FOR EXTERIOR APPLICATIONS

By

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## Summary

Over 96 million square metres of wood and wood panel products are used as exterior siding annually in Canada and the U.S. To better understand how finishes perform on Canadian wood in exterior applications, accelerated, artificial weathering and natural exposure tests were carried-out on eight species and nine finish combinations. Additional substrate variables investigated were substrate texture (planed vs saw-texture), heartwood versus sapwood, grain orientation and old growth versus 2$^{nd}$ growth. Weather-Ometers® and environmental chambers were used for the accelerated, artificial weathering tests. For the exterior exposure study, south facing test fences were set-up with profiled, bevel siding samples in Vancouver, Sainte-Foy (Quebec) and Gulfport, Mississippi.

After 18 months exposure, the dominant factors affecting finish performance were finish type, climate, surface orientation and substrate texture. The best performing finishes were the paint combinations including the acrylic primer + topcoat, the water repellent preservative (WRP) + latex primer + topcoat and the two-coat, acrylic latex factory finish. A factory-applied, acrylic latex finish stood out, showing little or no finish deterioration. The semi-transparent and clear finishes all performed poorly with most showing serious deterioration, especially at the Vancouver and Mississippi test sites. These performance results were also reflected in the artificial weathering tests.

Samples in Quebec deteriorated at approximately 1/3$^{rd}$ the rate of those in Vancouver and 1/6$^{th}$ the rate of those in Mississippi. Finish/species combinations on the 45 degree fence in Mississippi showed deterioration at a rate approximately twice that of the samples on the vertical test fence. Finishes on saw-textured samples consistently and substantially out-performed the planed texture samples. For example, the saw-textured samples from Vancouver deteriorated at about half the rate compared to the planed samples.

Species was not a major factor affecting finish performance compared to finish type and weathering exposure. However, in Vancouver and Mississippi, there were trends beginning to develop after 18 months exposure showing a hierarchy between the species with the western red cedar ranked highest and the aspen and poplar ranked lowest. Substrate grain orientation (vertical/flat) and heartwood/sapwood ratio also did not significantly affect finish performance and, in most cases, there were no significant differences in finish performance between old growth and 2$^{nd}$ growth red cedar.

# 1 Introduction

Sun and moisture act together to deteriorate unfinished wood products used outdoors, substantially reducing their serviceable life. To protect wood surfaces from the effects of exterior exposure, surface finishes are applied. A variety of finishes can be used to retard degradation including clear finishes, stains and paints. Clear finishes allow the natural colour and texture of the wood to show through. Stains partially block the wood's natural appearance while paints totally obscure the wood colour and figure. Currently, the selection of finishes is based on manufacturers' recommendations, with little attention paid to the variability of wood as a substrate. Research has shown that the performance of finished wood depends on several factors, most notably the physical and chemical characteristics of the finish, the natural characteristics of the wood and the climate conditions. Wood characteristics linked to finish performance including density, texture, extractives, resins and oils, earlywood/latewood, heartwood/sapwood content, knots, grain orientation and manufacturing characteristics [1]. Many of these relationships are not taken into consideration when finishing different species. This can account for a high percentage of failure, such as flaking, blistering, and chipping.

It is also important to consider the changes to traditional woods and finishing materials which pose new challenges for finished, exterior products. For example, more second and even third growth wood is displacing the traditional, old growth wood supply. Compared to old growth, these woods have more knots, more flat grain and lower density and dimensional stability; all factors known to adversely affect finish performance. The changes to wood supply have also challenged us to look at different species, traditionally not considered for exterior purposes. These include western hemlock, Pacific silver fir and aspen. Along with the changes to wood supply, there have been changes to finish formulations and preservatives, for example the trend from solvent-borne to water-based formulations.

The North American market for exterior wood products is large. Currently, exterior products are used extensively for residential millwork (siding, fascia, ornamental trim and doors), decking and fencing. For example, over 96 million square metres of wood and wood based panel products are used as exterior siding annually in Canada and the U.S [2]. Market research also shows that extended service life, low maintenance and, where possible, preserving the natural look of wood are increasingly demanded by customers. There is added pressure from competitive non-wood alternatives including plastics, metal and fibre cement which often mimic wood’s appearance and promise long term durability.

The purpose of this paper is to present and discuss the results of a recently completed study which examined the performance of surface finishes on Canadian species. Extensive experimental testing was done to study the accelerated and natural exposure weathering of various species/finish combinations on exterior bevel siding. This involved the use of Forintek's and Université Laval's Weather-Ometers® and environmental chambers for artificial weathering tests and three test fence sites located in Vancouver, Mississippi and Quebec to study natural weathering in different climates.

## 2 Experimental

To investigate the performance of various finishes on selected wood species, both accelerated, artificial weathering and long-term natural exposure tests were planned. Exterior exposure tests were set up using bevel siding, with the intention that the results could be extended to help predict the finish performance of other exterior finished wood products which share similar weathering conditions. These include doors, facia, ornamental trim and fencing.

In the 1999/2000 year, work focussed on setting up the natural exposure test sites. At six-month intervals, test fence samples were rated for finish and substrate performance. In 2000/2001, research also involved accelerated, artificial weathering tests of finishes on different wood species. The accelerated testing was carried out to determine the relative failure rates of various finishes on different species in a short time under controlled conditions. In this study, a Weather-Ometer® instrument was used to subject small, finished wood samples to heat, humidity and UV exposure cycles. A separate environmental chamber was also used to expose samples with various forms of wood staining fungi. Together, these instruments challenge samples with the main known causes of finish deterioration.

### 2.1 Natural Exposure Tests

To investigate performance natural weathering of all finishes and wood species was tested at three sites (Table 1) in different Canadian and U.S climates. At the three sites, vertical test fences were constructed for mounting samples with southern exposure. At the Mississippi site only, samples were also mounted on a south facing, 45 degree test fence. Samples were prepared and finished at Forintek for set-up on each of the outdoor test fences.

**Table 1: Exterior test fence sites**

| Test Site | Climate | Test Fence Orientation |
|---|---|---|
| Vancouver – Forintek Western lab | Mediterranean | 90°, south facing |
| Ste-Foy, Quebec - Forintek Eastern lab | Humid Continental | 90°, south facing |
| Gulfport, Mississippi, USDA Site | Humid Subtropical | 90° & 45° south facing |

### 2.1.1 Wood Sample Preparation

Wood from each species was sourced and collected as kiln dried, dimension 2" x 6" and 1" x 6" lumber prior to being cut into profiled siding samples. The red cedar, western hemlock and Pacific silver fir were from the lower mainland/ Vancouver Island region and the hybrid poplar was from Vernon, B.C. The aspen, spruce, balsam fir and jack pine were from Quebec.

Next, several species were sorted into subgroups in preparation for studying the finish performance of the following substrates:

1. Flat versus vertical grain with planed heartwood – western red cedar, western hemlock, white spruce, jack pine
2. Roughsawn versus planed surface texture with flat grain heartwood – all species
3. Heartwood versus sapwood with flat grain, planed surface texture– Pacific silver fir, western hemlock, jack pine
4. Old growth versus second growth with flat grain, planed heartwood – western red cedar

All lumber was then milled into bevelled siding samples measuring 6"x 5/8" (butt thickness) x 72" with one side planed and the other with sawn texture. In total, 516 pieces of siding were cut. Shallow (1/16") saw kerfs were then made at 8" intervals along each piece of siding for separating the different finishes.

### 2.1.2 Finish Combinations

The finish combinations selected in this study are:

F1 *acrylic latex primer (stain blocking) + latex topcoat*
F2 *aqueous, 2-part, semi-transparent stain*
F3 *acrylic latex solid colour stain**
F4 *alkyd, semi-transparent stain*
F5 *clear film**
F6 *water repellent preservative (WRP) + acrylic latex primer + acrylic latex topcoat*
F7 *CCA dip treatment + alkyd, semi-transparent stain*
F8 *CCA dip treatment (3 minute dip in 5% CCA solution)***
F9 *acrylic latex factory finish**

* - indicates two coats applied
** - intended to simulate the surface of pressure-treated wood

Specific finish details are described in Table2.

**Table 2: Finish description and spread rates**

| Finish | | Colour | Specific Gravity | Spread Rates (m²/l) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Planed Surface | | Saw Texture Surface | |
| | | | | 1st coat | 2nd coat | 1st coat | 2nd coat |
| Primer – stain blocking, latex | | White | 1.2 | 13.1 | - | 5.3 | - |
| Paint – latex topcoat | | White | 1.3 | 19.7 | - | 10.2 | - |
| Water Repellent Preservative | | Clear | 0.8 | 15.7 | - | 5.4 | - |
| Stain – semi-transparent Aqueous | part a | Brown | 1.0 | 16.1 | - | 6.4 | - |
| | part b | Clear | 1.0 | 15.2 | - | 5.6 | - |
| Clear film | | Clear | 1.0 | 14.3 | 25.8 | 5.1 | 9.5 |
| Stain– semi-transparent, alkyd | | Brown | 0.9 | 25.8 | - | 5.5 | - |
| Stain – solid colour, latex | | White | 1.3 | 15.2 | 16.8 | 5.4 | 8.6 |
| Factory finish – latex | | Grey | 1.3 | N/a | N/a | - | - |

### 2.1.3 Finish Application

Finishes #F1-F7 were brush applied in the Vancouver laboratory, according to manufacturers instructions, on the siding locations shown in Figure 1. Shallow saw kerfs separated the finishes. Finish combinations F7 and F8 were pre-treated with CCA (3 minute dip into 5% CCA solution). Prior to applying the finishes, digital photographs were taken of all the species to record surface wood features including surface texture, colour and knots. For the vertical test fence at all three test sites, there were six replicates prepared for each F1-F8 finish combination on each species substrate type. On the Mississippi 45-degree fence, only three replicates were made per finish per substrate. Table 2 shows the sample matrix for laboratory applied finishes #F1-#F8.

| C | F1 | F2 | F3 | F4 | F5 | F6 | C | F7 | F8 |
|---|---|---|---|---|---|---|---|---|---|
| 4” | 8” | 8” | 8” | 8” | 8” | 8” | 4” | 8” | 8” |

**Figure 1: Finish sample location on siding (C=Control)**

With each finish from F1-F8, application rates were determined by using a balance to measure the weight of finish material applied to the sample areas (5.5 x 8-inches). From this, spread rates were calculated and are shown in Table 2.

Finish #9 was factory applied by flow coating and machine brushing at Maibec Industries with one coat full length on the siding backside and two coats full length on the exterior facing side. At all three test sites, 3 siding replicates per species, except hybrid poplar, were prepared with finish F9 with only the planed, flat grain, heartwood substrates.

**Table 3: Sample matrix for laboratory finished samples**

| Species | Samples Sections Prepared | Sample Replicates/Finish #F1-#F8 | | | |
|---|---|---|---|---|---|
| | | Van | Que | Miss | |
| | | | | 45° | 90° |
| Pacific Silver Fir (*Abies amabilis*) | Heart/flat grain/planed | 6 | 6 | 3 | 6 |
| | Heart/flat grain/rough | 6 | 6 | 0 | 0 |
| | Sap/flat grain/rough | 6 | 6 | 0 | 0 |
| Western Red Cedar (*Thuja plicata*) | Heart/old growth/flat/planed | 6 | 6 | 3 | 6 |
| | Heart/old growth/vertical/planed | 6 | 6 | 0 | 0 |
| | Heart/2$^{nd}$ growth/flat/planed | 6 | 6 | 0 | 6 |
| | Heart/2$^{nd}$ growth/flat/rough | 6 | 6 | 0 | 0 |
| Western Hemlock (*Tsuga heterophylla*) | Heart/flat grain/planed | 6 | 6 | 3 | 6 |
| | Heart/flat grain/rough | 6 | 6 | 0 | 0 |
| | Heart & sap mix/vertical/planed | 6 | 6 | 0 | 0 |
| | Heart & sap mix/flat/planed | 6 | 6 | 0 | 0 |
| Hybrid Poplar (*Populus trichocarpa* x *P.deltoides*) | Heart & sap mix/flat/planed | 6 | 6 | 0 | 0 |
| | Heart & sap mix/flat/rough | 6 | 6 | 0 | 0 |
| Trembling Aspen (*Populus tremuloides*) | Heart/flat grain/planed | 6 | 6 | 3 | 6 |
| | Heart/flat grain/rough | 6 | 6 | 0 | 0 |
| White Spruce (Picea glauca) | Heart/flat grain/rough | 6 | 6 | 0 | 0 |
| | Heart/vertical grain/planed | 6 | 6 | 0 | 0 |
| | Heart/flat/planed | 6 | 6 | 3 | 6 |
| | Heart/flat/rough | 6 | 6 | 0 | 0 |
| Balsam Fir (Abies balsamea) | Heart/flat/planed | 0 | 6 | 3 | 6 |
| | Heart/flat/rough | 0 | 6 | 0 | 0 |
| Jack Pine (*Pinus banksiana*) | Heart/flat/planed | 6 | 6 | 3 | 6 |
| | Heart/flat/rough | 6 | 6 | 0 | 0 |
| | Sap/flat/planed | 6 | 6 | 0 | 0 |
| | Heart and sap mix/vertical /planed | 6 | 6 | 0 | 0 |

### 2.1.4 Set-Up of Samples

At all three test sites, the bevel siding samples were fastened horizontally to south facing, vertical test fences as depicted in Figure 2. Figure 3 shows the test fence in Ste-Foy, Quebec. Additional samples were mounted on south facing, 45-degree fences, only in Mississippi.

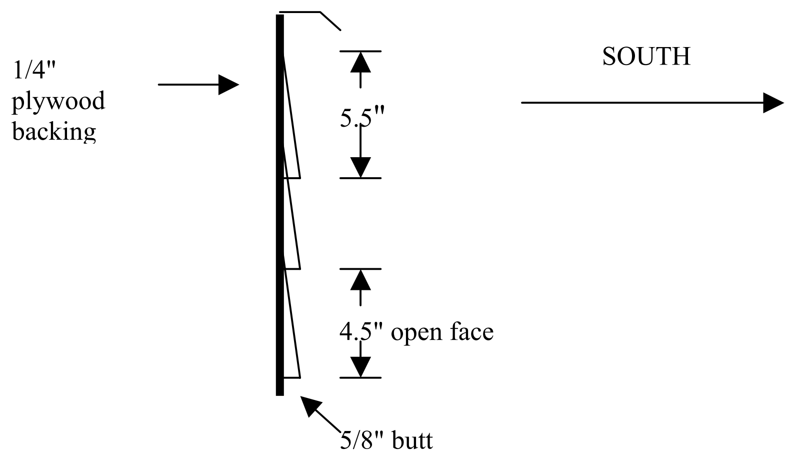



**Figure 2: Sample set-up**

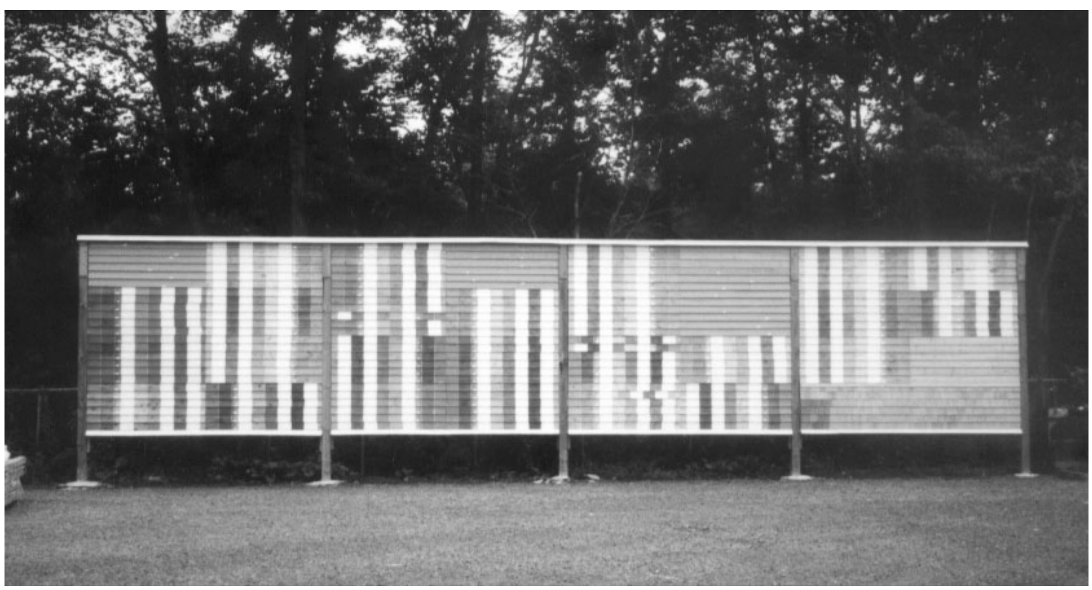


**Figure 3: Test fence, Ste-Foy, Quebec**

### 2.1.5 Weather Data Collection

At all three test sites, data loggers were set-up to record ambient temperature, relative humidity (RH) and finish surface temperature (Figure 4). Ambient temperature and RH were recorded inside a solar-shielded, vented enclosure. Surface temperatures were recorded with a white-surface mounted thermocouple. Data was recorded for the period March-November, 2001 for all three-test sites.

Additional weather data on annual rainfall and days with measured rainfall were obtained from Environment Canada and the U.S. National Weather Service.


**Figure 4: Weather station set-up**

### 2.1.6 Sample Rating

Samples were visually assessed with the same rating system used by the Forest Products Laboratory (FPL) to inspect for discolouration, mildew, finish flaking, erosion and cracking and substrate condition (Table 4). Discolouration, mildew and finish evaluations were each based on ASTM methods [3,4,5,6] and were rated on a scale from 1 (complete failure) – 10 (perfect). In addition, the substrate was also rated (using the same scale) for signs of surface checking, warping and defects (e.g. knots). An overall general rating was assigned as the average rating of the evaluation group.

A performance rating of 10 indicates no change from the original unweathered condition; 5 indicates that refinishing would normally be required but without extensive preparation; and 1 represents a total failure (Figure 5). The time required for the finish to reach a level of 5 serves as a convenient measure of durability.

**Table 4: Evaluation methods**

| Evaluation | | Method |
|---|---|---|
| Discolouration | | Subjective visual assessment similar to ASTM D 3274-82 |
| Mildew | | ASTM D 3274-83 |
| Finish | Flaking | ASTM D 772-86 |
| | Erosion | ASTM D 662-93 |
| | Cracking | ASTM D 661-93 |
| Substrate Condition | | Subjective visual assessment |
| General Rating | | Average rating from evaluation group |

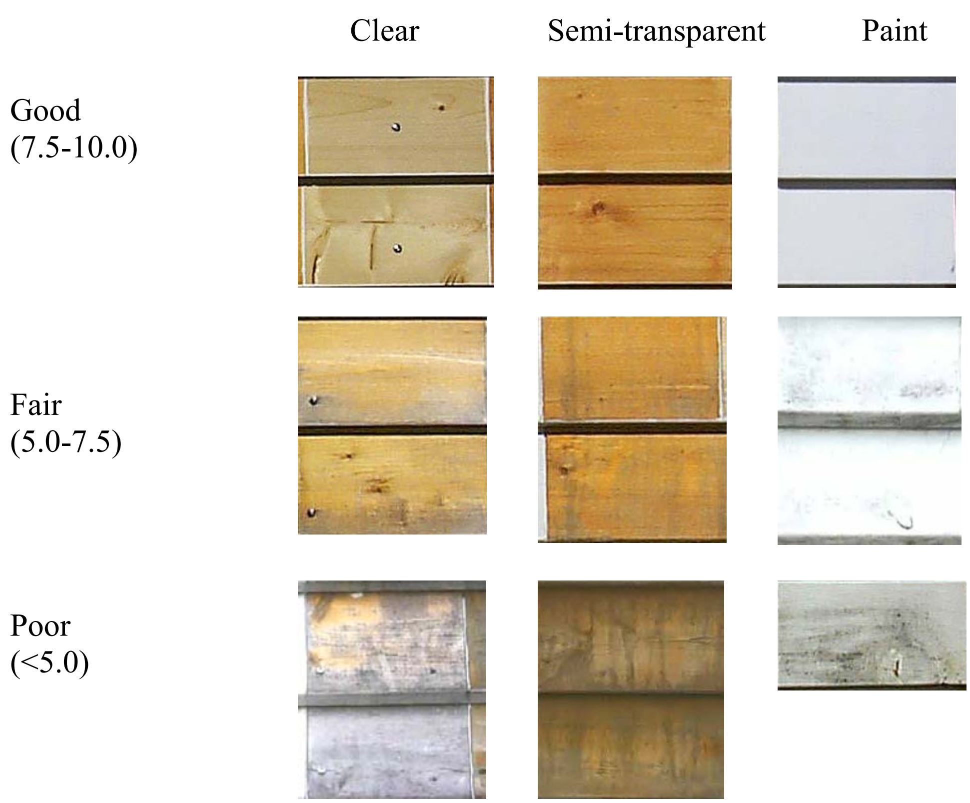



**Figure 5: Sample rating examples**

## 2.2 Artificial Weathering

### 2.2.1 Test Methodology

In many non-wood applications, testing with the Weather-Ometer® alone is sufficient for accelerating weather conditions involving UV, heat and moisture cycling. However, when testing finishes on wood, the use of the Weather-Ometer® alone can give misleading results because one of the important factors linked to finish failure is missing. This is the affect of biological activity from fungi that can penetrate finishes and cause black stain and even wood decay underneath the finish. The damage caused by the staining fungi increase water penetration of the finish causing UV damage. The Weather-Ometer® cannot replicate these conditions because the high intensity of UV radiation in the weathering cycle inhibits fungal growth.

To compensate for this, an extra step was added to the accelerated weathering process to allow fungal growth. This involves inoculating the samples with different staining fungi that are then placed into a environment chamber for 4 weeks to allow growth. From start to finish the entire accelerated test procedure includes the following stages:

1) 1000 hours continuous Weather-Ometer® operation
2) sample rating
3) 4 weeks in environment chamber and inoculated with stain and mold fungi
4) sample rating
5) 1000 hours continuous Weather-Ometer® operation.
6) sample rating

### 2.2.2 Wood Species

The following species were tested:

1) *White spruce*
2) *Pacific silver fir*
3) *Trembling aspen*
4) *Hybrid poplar*
5) *Balsam fir*
6) *Western hemlock*

### 2.2.3 Finishes & Application Methods

The following finishes were tested in addition to control samples:

*F1) latex primer + latex topcoat*
*F4) alkyd, semi-transparent stain*
*F5) clear, film forming finish*

*F7) CCA dip treatment (3 minute dip in 5% CCA solution)*

### 2.2.4 Sample Preparation

Wood from each species was supplied to Forintek as dry lumber (<20% moisture content). The wood was then cut and planed into fifteen, 2”x8”x1/2” samples per species to mount on the sample holding rack inside the Weather-Ometer® .

Next the finishes were applied. The test matrix consisted of five finishes applied to each of five species producing 25 different combinations (Table 5). For each of these combinations, three replicates were produced, bringing the total number of samples per test to 75 (5 finishes x 5 species x 3 replicates).

**Table 5: Sample Matrix**

| Finish | Replicates/Species | | | | | |
|---|---|---|---|---|---|---|
| | W. Spruce | W. Hemlock | P.S. fir | B. Poplar | T. Aspen | B. fir |
| Control | 3 | 3 | 3 | 3 | 3 | 3 |
| Primer + Paint (F1) | 3 | 3 | 3 | 3 | 3 | 3 |
| Semi-transparent Stain (F4) | 3 | 3 | 3 | 3 | 3 | 3 |
| Clear Film (F5) | 3 | 3 | 3 | 3 | 3 | 3 |
| CCA Dip (F7) | 3 | 3 | 3 | 3 | 3 | 3 |

### 2.2.5 Weather-Ometer® Operation

Accelerated weathering was done using an Atlas Weather-Ometer® (model Ci65 A) equipped with a 6500 watt, Xenon arc UV lamp and borosilicate inner and outer filters. This light source irradiates samples with near equal sunlight exposure with a lower UV wavelength cut-off at between 275 and 380 nanometres.

The 24-hour weathering cycle consists of three phases (Figure 6): 8 hours of light only, followed by a combined light/water spray for 10 hours and ending with 6 hours of water spray only (no light).

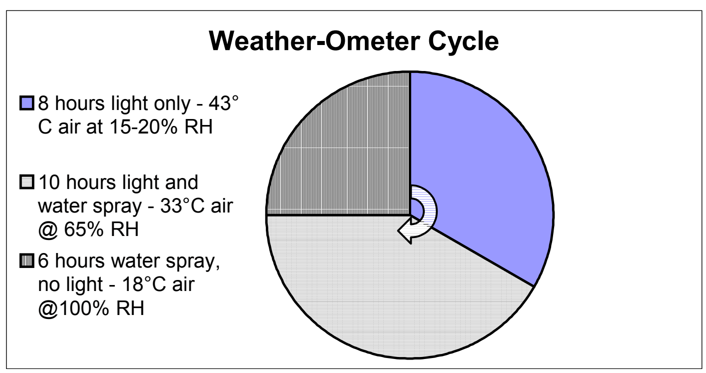



**Figure 6: Weather-Ometer® Cycle**

### 2.2.6 Inoculum

The following cultures were inoculated onto 1.5% malt extract, 2% agar (Difco) Petri plates and incubated for 18 days at 32.5EC to produce inoculum for the test chamber:

1) *Epicoccum purpurascens*
2) *Sclerophoma pithyophila*
3) *Alternaria tenuis*
4) *Aureobasidium pullulans*

An inoculation suspension was prepared by scraping spores and mycelium from the surface of the incubated plates and mixing in a blender with water for 15 seconds. The suspension volume was adjusted with water to about 1 litre. A 50 ml pipette was used to distribute the inoculum evenly over the soil surfaces in the four chambers. The chamber was operated at test conditions for at least one week before the inoculum was introduced, and for at least four weeks after inoculation before the test samples were installed in the chamber. This allowed the fungi to become established in the soil and to produce airborne spores for dispersal to the sample surfaces.

### 2.2.7 Environment Chamber Operation

For the middle phase of the accelerating weathering test, samples were inoculated with various strains of staining fungi and then placed inside small environment chambers operating at 100% RH and 20C. These conditions are ideal for fungal growth. The samples are then removed after four weeks exposure for rating.

Each chamber (Figure 7) consists of a rectangular 114 litre (61 x 46 x 46 cm) heavy-duty polyethylene tank fitted with a pitched-roof cover made of 6.4 mm thick clear acrylic. The pitch allows condensation to run down the inside surface of the cover instead of dripping on the samples suspended inside the tank.

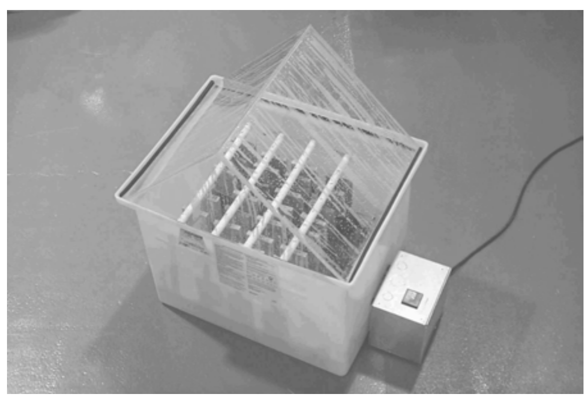


**Figure 7: Environment Chamber**

The bottom of the tank contains about eight cm of water. A tray with a bottom of stainless steel coarse wire mesh covered with plastic sunscreen fabric supports an 80 mm thick layer of non-sterilized commercial potting soil about 30 mm above the surface of the water. Approximately 50 mm is left between the side of the tray and the tank wall to permit air movement within the tank. A 100 mm diameter fan (Muffin, model MU2A1) positioned at one end of the soil tray circulates air within the chamber over the surface of the soil to aid in the distribution of spores.

Samples are suspended with the long dimension vertically, evenly spaced, using eye hooks, on one of four plastic support bars spanning the width of the tank. The samples are suspended parallel to each other with the faces perpendicular to the fan airflow. The lower ends of the samples are about 130 mm above the soil surface.

Each chamber is heated by an immersion heater (Ogden, 300 watt, 120 volt) installed horizontally in the water through one end of the chamber. It is controlled by a solid-state electronic temperature controller (Ogden) to maintain a temperature of 25.0EC ∀ 1.0EC in proximity of the samples, as measured by a thermocouple located amongst the samples. To even heat distribution, water within the tank is constantly stirred by an aquarium circulating pump (Aqua-pump-1, variable flow) set at maximum flow. Lack of chamber ventilation results in a constant RH at, or near, 100% inside the chamber.

# 3 Results

## 3.1 Exterior Exposure Test Results

### 3.1.1 Effect of Heartwood versus Sapwood on Finish Performance

In both Vancouver and Quebec, samples of planed, flat grain heartwood and sapwood were compared for Pacific silver fir, western hemlock and jack pine.Table 6 shows the average general ratings for each species/finish combination for both test sites. There were few cases of significant difference between the heartwood and sapwood samples and there were also no observable trends between the two sample groups as shown in Figure 8.

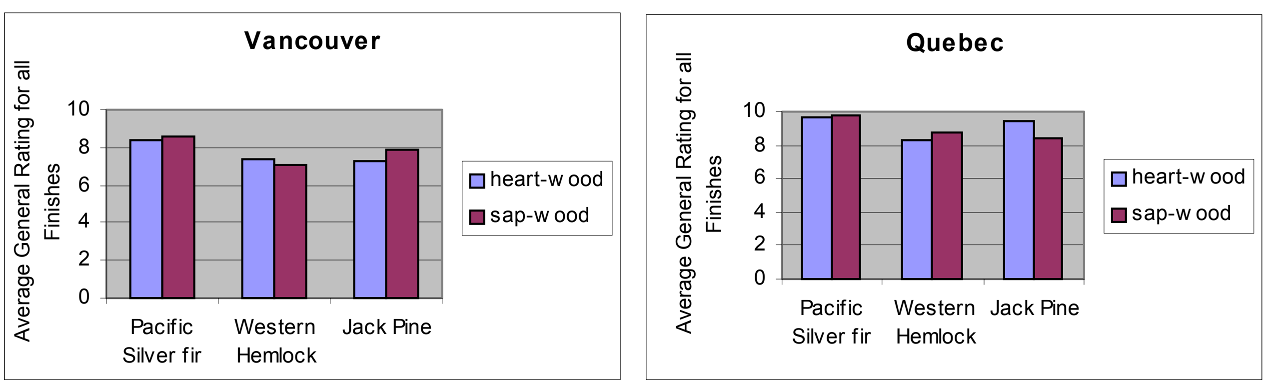



**Figure 8: Finish rating comparison between heartwood and sapwood samples**

**Table 6: Finish ratings for heartwood and sapwood samples in Vancouver and Quebec**

| Location & Finish type | | Average general ratings for species heartwood and sapwood combinations | | | | | |
|---|---|---|---|---|---|---|---|
| | | Pacific Silver Fir | | Hemlock | | Pine | |
| | | heart | Sap | heart | sap | heart | sap |
| Vancouver | F1 | 9.5 | 10.0 | 9.7 | 9.7 | 8.8 | **9.7** |
| | F2 | 10.0 | 10.0 | 8.5 | 8.2 | 8.8 | 9.2 |
| | F3 | 10.0 | 10.0 | 8.8 | 9.3 | 9.7 | 9.3 |
| | F4 | 8.7 | 8.3 | 4.5 | 4.3 | 4.3 | **5.5** |
| | F5 | 5.8 | 5.2 | **4.8** | 3.3 | 7.3 | 7.3 |
| | F6 | 9.5 | 10.0 | 9.3 | 9.3 | 9.0 | 9.7 |
| | F7 | 8.7 | 8.5 | 6.5 | 6.0 | 5.7 | **7.2** |
| | F8 | 5.2 | 6.8 | 7.3 | 6.3 | 4.8 | 5.5 |
| Quebec | F1 | 10.0 | 10.0 | 9.3 | 9.0 | 9.8 | 9.8 |
| | F2 | 10.0 | 10.0 | 8.5 | 9.3 | 9.8 | 9.5 |
| | F3 | 9.8 | 10.0 | 9.3 | 9.7 | 9.3 | 9.8 |
| | F4 | 9.3 | 9.7 | 6.2 | **8.0** | **8.2** | 4.5 |
| | F5 | 9.3 | 9.0 | 6.8 | 7.0 | **9.2** | 8.3 |
| | F6 | 10.0 | 10.0 | **10.0** | 9.5 | 10.0 | 10.0 |
| | F7 | 9.5 | 9.3 | 8.7 | 9.0 | **9.7** | 7.2 |
| | F8 | 10.0 | 10.0 | 7.8 | **9.0** | 8.8 | 8.3 |

***bold font*** *= significantly higher in pairing between heart and sap values (t-test at 0.05 level)*

### 3.1.2 Effect of Vertical Grain versus Flat Grain on Finish Performance

In both Vancouver and Quebec, after 12 months test fence exposure at 90 degrees inclination, samples of flat-grain and vertical-grain were compared for western red cedar, western hemlock, jack pine and white spruce. All samples were comprised planed heartwood.

Table 7 shows the average general ratings for each species/finish combination for both sites. There were few significant differences between the flat-grain and vertical-grain samples and no observable trends between the two sample groups as shown in Figure 9.

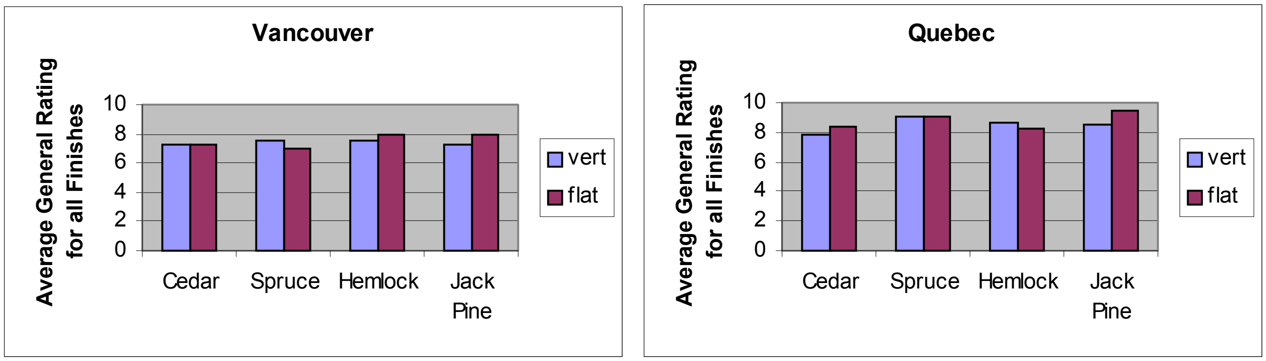



**Figure 9:** **Finish rating comparison between flat-grain and vertical-grain samples**

**Table 7:** **Finish ratings for flat-grain and vertical-grain samples in Vancouver and Quebec test sites**

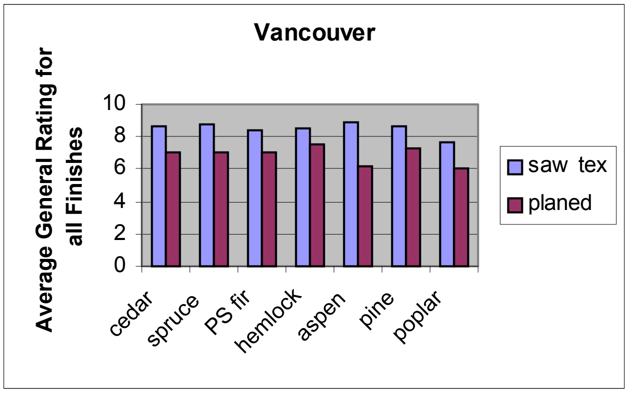
| Location & Finish type | | Average general ratings for species/grain combinations | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cedar | | Spruce | | Pine | | Hemlock | |
| | | vertical | flat | vertical | flat | vertical | flat | vertical | Flat |
| Vancouver | F1 | 8.7 | 8.7 | 9.2 | 9.0 | 9.5 | 8.8 | 9.8 | 9.7 |
| | F2 | 7.7 | 8.5 | 8.7 | 7.8 | 9.0 | 8.8 | 8.0 | 8.5 |
| | F3 | 8.8 | 9.3 | 9.8 | 9.8 | 10.0 | 9.7 | 9.8 | 8.8 |
| | F4 | 5.5 | 4.5 | 5.5 | 4.7 | 4.7 | 4.3 | 5.5 | 4.5 |
| | F5 | 6.0 | 5.5 | 5.5 | 4.7 | 7.3 | 7.3 | 3.7 | 4.8 |
| | F6 | 9.7 | 9.8 | 9.5 | 8.7 | 10.0 | 9.0 | 10.0 | 9.3 |
| | F7 | 6.0 | 6.5 | 7.2 | 5.7 | 5.8 | 5.7 | 7.3 | 6.5 |
| | F8 | 4.8 | 5.3 | 4.8 | 5.5 | 6.8 | 4.8 | 6.8 | 7.3 |
| Quebec | F1 | 8.5 | 8.5 | 10.0 | 10.0 | 8.8 | **9.8** | **10.0** | 9.3 |
| | F2 | 8.6 | 9.0 | 9.5 | 9.2 | 10.0 | 9.8 | 9.0 | 8.5 |
| | F3 | 8.3 | **9.8** | **10.0** | 9.5 | 7.8 | **9.3** | 10.0 | 9.3 |
| | F4 | 5.8 | **8.8** | 7.8 | 7.8 | 5.0 | **8.0** | **7.2** | 6.2 |
| | F5 | 5.8 | 5.8 | 6.2 | 8.0 | 9.3 | 9.2 | 6.0 | 6.8 |
| | F6 | 8.5 | 8.2 | **10.0** | 8.8 | 9.8 | 10.0 | 10.0 | 10.0 |
| | F7 | 8.3 | 8.3 | 9.5 | 9.5 | 9.5 | 9.7 | 9.0 | 8.7 |
| | F8 | 8.7 | 8.7 | 8.8 | 9.5 | 7.8 | 8.8 | 7.8 | 7.8 |

***bold font*** *= significantly higher in pairing (t-test at 0.05 level)*

### 3.1.3 Effect of Surface Texture on Finish Performance

In both Vancouver and Quebec, planed and saw-texture samples were compared for western red cedar, white spruce, jack pine, western hemlock, Pacific silver fir, balsam fir, hybrid poplar and trembling aspen. All samples were comprised of flat-grained heart-wood.

Table 8 shows the average general ratings for each species/finish combination for both sites. Results show finishes on saw-textured samples significantly out-performed those on planed samples in both Vancouver and Quebec on all species (Figure 10).



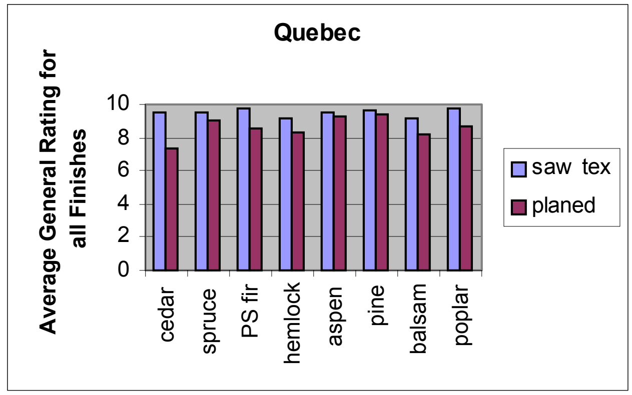




**Figure 10: Comparison of finish ratings for saw-texture and planed samples**

**Table 8: Finish Ratings for Planed and Saw-Texture Samples in Vancouver and Quebec**

| Location & Finish type | | Average general ratings for species/texture combinations (S=Saw Texture, P=Planed) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cedar | | Spruce | | Pine | | Hemlock | | P.S. Fir | | B. Fir | | Poplar | | Aspen | |
| | | S | P | S | P | S | P | S | P | S | P | S | P | S | P | S | P |
| Vancouver | F1 | 9.7 | 8.8 | 9.8 | 9.0 | **9.5** | 8.8 | 9.8 | 9.7 | 9.5 | 9.2 | - | - | 9.3 | 8.8 | **9.8** | 7.7 |
| | F2 | **10.0** | 7.8 | **10.** | 7.8 | 9.3 | 8.8 | 9.2 | 8.5 | 10. | 7.7 | - | - | **9.7** | 7.2 | **10.0** | 7.3 |
| | F3 | **10.0** | 9.2 | 10. | 9.8 | 9.8 | 9.7 | **9.5** | 8.8 | 10. | 9.7 | - | - | **9.3** | 7.7 | 9.7 | 9.0 |
| | F4 | **8.3** | 4.2 | **8.8** | 4.7 | **8.3** | 4.3 | **8.5** | 4.5 | **8.7** | 5.3 | - | - | 7.3 | 3.7 | **9.0** | 4.2 |
| | F5 | 6.2 | 5.2 | **7.3** | 4.7 | 7.7 | 7.3 | 4.8 | 4.8 | 5.8 | 4.7 | - | - | 4.7 | 4.0 | **6.5** | 3.8 |
| | F6 | 9.7 | 9.7 | **10.** | 8.7 | **9.5** | 9.0 | 9.8 | 9.3 | 9.5 | 9.5 | - | - | 9.2 | **10.0** | 9.7 | 8.5 |
| | F7 | 8.8 | 6.5 | **9.0** | 5.7 | **9.0** | 5.7 | **9.2** | 6.5 | 8.7 | 8.3 | - | - | **8.6** | 4.2 | **8.8** | 6.0 |
| | F8 | **6.3** | 4.8 | 5.7 | 5.5 | **6.7** | 4.8 | 7.3 | 7.0 | 5.2 | 4.7 | - | - | 3.4 | 3.0 | **7.3** | 3.3 |
| Quebec | F1 | **9.0** | 9.0 | 10. | 10. | 10. | 9.8 | 9.7 | 9.3 | **10.** | 9.3 | 6.8 | **10.** | 10. | 9.7 | 9.8 | 10. |
| | F2 | **10.0** | 7.8 | **10.** | 9.2 | 10. | 9.8 | **10.** | 8.5 | **10.** | 8.0 | 10. | 9.3 | **10.** | 8.2 | 10.0 | 9.7 |
| | F3 | 8.8 | 8.8 | **10.** | 9.5 | **10.** | 9.3 | 9.5 | 9.3 | 9.8 | 9.8 | 10. | 10. | **10.** | 9.0 | 8.7 | **9.7** |
| | F4 | **10.0** | 3.3 | **9.0** | 7.8 | **9.5** | 8.2 | **8.8** | 6.2 | **9.3** | 6.8 | **9.5** | 5.5 | **10.** | 8.0 | 9.5 | 8.5 |
| | F5 | **8.8** | 6.2 | 8.8 | 8.0 | 9.2 | 9.2 | **7.8** | 6.8 | **9.3** | 7.3 | **8.7** | 5.2 | **9.0** | 8.5 | **10.0** | 8.2 |
| | F6 | **10.0** | 8.8 | **10.** | 8.8 | 10. | 10. | 9.5 | **10.** | **10.** | 9.5 | 9.7 | 9.2 | **10.** | 9.5 | 10.0 | 9.0 |
| | F7 | **9.8** | 7.5 | 9.3 | 9.5 | 9.2 | 9.7 | 9.3 | 8.7 | 9.5 | 8.3 | **10.** | 8.0 | **10.** | 8.7 | 10.0 | 10. |
| | F8 | **9.5** | 7.3 | 8.8 | 9.5 | 9.0 | 8.8 | **9.2** | 7.8 | 10. | 8.7 | 9.0 | 8.5 | 8.2 | 8.0 | 7.8 | **9.2** |

***bold font*** *= significantly higher in pairing (t-test at 0.05 level)*

### 3.1.4 Old Growth vs Second Growth Red Cedar

In both Vancouver and Quebec, finished samples of old-growth and second-growth western red cedar samples were compared. All samples were comprised of flat-grained, planed, heart-wood. Table 9 shows the average general ratings for samples in Vancouver, Quebec and Mississippi. Results show only a few signs of the old-growth outperforming the 2nd growth in Mississippi and Quebec. In both these locations, ratings for the old-growth were significantly higher for the finishes F3 (solid colour stain), F4 (semi transparent, alkyd stain) and F8 (CCA dip treatment + alkyd semi-transparent stain.). In Vancouver, there were no significant differences observed.

**Table 9: Finish ratings for old growth versus 2nd growth western red cedar**

| Finish | Mississippi 18 months | | Vancouver 12 months | | Quebec 12 months | |
|---|---|---|---|---|---|---|
| | old gr. | 2nd gr. | old gr. | 2nd gr. | old gr. | 2nd gr. |
| F1 | 9.0 | 8.8 | 8.7 | 8.8 | 8.5 | 9.0 |
| F2 | 4.5 | 5.7 | 8.5 | 7.8 | **9.0** | 7.8 |
| F3 | **7.7** | 3.8 | 9.3 | 9.2 | **9.8** | 8.8 |
| F4 | **3.3** | 2.2 | 4.5 | 4.2 | **8.8** | 3.3 |
| F5 | 4.5 | 2.5 | 5.5 | 5.2 | 5.8 | 6.2 |
| F6 | 8.8 | 8.7 | 9.8 | 9.7 | 8.2 | 8.8 |
| F7 | 3.8 | 4.3 | 6.5 | 6.5 | 8.3 | 7.5 |
| F8 | **4.2** | 3.2 | 5.3 | 4.8 | **8.7** | 7.3 |

***bold font*** *= significantly higher in pairing (t-test at 0.05 level)*

### 3.1.5 Finish Performance with Different Species

Tables 10, 11 and 12 show the average general ratings for finish/species combinations with planed surface texture after 6, 12, and 18 months exposure respectively. Within each table the data cells are shaded to show relative finish deterioration, which is described as follows:

- [white box] = 7.5-10.0 (little or no deterioration)
- [light grey box] = 5.0- 7.5 (noticeable deterioration)
- [dark box] = 1.0- 5.0 (refinishing required)

For the sixth month evaluation, samples were rated in Vancouver and Mississippi only. At twelve months, all three test sites were evaluated and at eighteen months only the Mississippi site was rated.

### 3.1.5.1 6-Month Test Fence Data

After 6 months exposure (Table10), many trends emerged. Finishes F4 (semi-transparent stain), F5 (clear film), F7 (CCA+semi-transparent stain) and F8 (CCA) have clearly started to fail. F8 showed only discolouration and mildew growth while F4, F5 and F7 show additional cracking, flaking and erosion. The factory finish (F9), rated only at the Mississippi test, protected all species from significant deterioration with an average of 9.9. It is also evident that most samples on the Mississippi test site were deteriorating, on average, at a faster rate than those in Vancouver. Samples on the Mississippi fence at 45 degrees had the lowest average rating at 5.6 compared to the next lowest for the Mississippi fence at 90 degrees at 6.9, and the best average for the Vancouver site at 90 degrees with an average rating of 8.4. All species show similar trends with each finish and test fence location, with no outstanding species. The dominant factors were the type of finish, the test site location and the sample orientation.

**Table 10: Six-month data**

| Test Site | Inclination | Species | Average General Rating | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Control | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | Sub-strate |
| Vancouver | 90 | Cedar 2nd | 7.0 | 8.7 | 8.7 | 9.2 | 6.3 | 7.3 | 9.2 | 7.5 | 9.0 | n/a | 9.5 |
| | | Cedar Old | 8.3 | 8.3 | 9.3 | 9.7 | 7.3 | 6.5 | 9.0 | 7.8 | 8.7 | n/a | 9.2 |
| | | Spruce | 5.3 | 9.0 | 9.5 | 9.8 | 7.3 | 7.2 | 9.5 | 9.2 | 7.7 | n/a | 9.6 |
| | | Amabilis Fir | 7.5 | 9.2 | 8.3 | 10.0 | 8.0 | 7.3 | 10.0 | 9.0 | 7.8 | n/a | 9.6 |
| | | Hemlock | 3.8 | 9.5 | 9.8 | 9.7 | 7.0 | 7.5 | 9.4 | 8.8 | 7.0 | n/a | 9.6 |
| | | Aspen | 4.2 | 7.7 | 8.3 | 9.8 | 6.7 | 6.7 | 10.0 | 7.5 | 6.8 | n/a | 9.7 |
| | | Jack Pine | 7.3 | 9.3 | 9.8 | 9.8 | 7.5 | 8.5 | 10.0 | 8.2 | 9.0 | n/a | 9.9 |
| | | Poplar | 3.3 | 9.8 | 7.0 | 9.3 | 6.5 | 6.3 | 10.0 | 7.3 | 6.5 | n/a | 10.0 |
| Mississippi | 90 | Cedar 2nd | 6.0 | 8.3 | 8.8 | 8.8 | 5.8 | 6.7 | 8.5 | 8.3 | 8.5 | 10.0 | 10 |
| | | Cedar Old | 8.2 | 7.8 | 8.8 | 9.0 | 7.2 | 7.5 | 7.8 | 6.8 | 7.3 | n/a | 10 |
| | | Spruce | 4.2 | 8.5 | 8.3 | 7.8 | 3.7 | 7.0 | 8.2 | 6.2 | 7.8 | 9.3 | 9.4 |
| | | Amabilis Fir | 3.8 | 8.3 | 7.5 | 7.8 | 4.8 | 5.3 | 8.2 | 6.3 | 8.0 | 10.0 | 9.1 |
| | | Hemlock | 4.8 | 7.2 | 8.0 | 7.2 | 4.0 | 6.3 | 7.8 | 6.0 | 7.5 | 10.0 | 8.7 |
| | | Aspen | 2.3 | 6.2 | 5.7 | 7.8 | 2.8 | 2.3 | 7.7 | 4.3 | 2.8 | 10.0 | 9.6 |
| | | Jack Pine | 4.2 | 8.0 | 8.3 | 8.7 | 5.0 | 6.3 | 7.8 | 5.2 | 6.0 | 10.0 | 9.5 |
| | | Balsam Fir | 3.7 | 8.2 | 7.2 | 7.8 | 4.2 | 4.0 | 8.3 | 5.7 | 7.8 | 10.0 | 9.2 |
| Mississippi | 45 | Cedar Old | 5.7 | 7.3 | 7.3 | 5.0 | 5.3 | 5.3 | 7.3 | 5.7 | 5.3 | n/a | 9.2 |
| | | Spruce | 2.7 | 7.3 | 7.3 | 6.3 | 4.3 | 2.7 | 8.7 | 4.3 | 4.7 | n/a | 9.3 |
| | | Amabilis Fir | 3.7 | 7.7 | 6.0 | 8.0 | 5.0 | 2.0 | 8.3 | 5.3 | 5.3 | n/a | 9.6 |
| | | Hemlock | 4.0 | 7.7 | 8.3 | 5.0 | 3.3 | 3.3 | 8.3 | 4.3 | 4.7 | n/a | 9.3 |
| | | Aspen | 2.3 | 7.3 | 6.3 | 6.3 | 2.3 | 1.3 | 6.7 | 2.3 | 3.3 | n/a | 9.3 |
| | | Jack Pine | 4.0 | 8.0 | 8.3 | 5.8 | 4.5 | 5.8 | 7.0 | 3.8 | 6.0 | n/a | 9.4 |
| | | Balsam Fir | 3.0 | 7.0 | 8.0 | 6.5 | 4.5 | 3.0 | 6.5 | 5.0 | 4.0 | n/a | 9.3 |

### 3.1.5.2 12-Month Test Fence Data

After 12 months exposure (Table 11), finishes at the Quebec site showed surprisingly little deterioration with an average rating of 8.6. The Vancouver site average rating fell from to 7.0 from 8.4 from the 6-month evaluation, due mainly to deterioration of finishes F4, F5, F7 and F8. The Mississippi average ratings also fell significantly for both the 90 degree, from 6.9 to 5.6, and for the 45-degree fences, from 6.0 to 4.3. Again the factory finish (F9) performed the best with an average rating of 9.4.

**Table 11: Twelve-month data**

| Location | Inclination. | Species | Average General Rating | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Control | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | Sub-strate |
| Quebec | 90 | Cedar 2nd | 5.7 | 9.0 | 7.8 | 8.8 | 3.3 | 6.2 | 8.8 | 7.5 | 7.3 | n/a | 9.2 |
| | | Cedar Old | 6.3 | 8.5 | 9.0 | 9.8 | 8.8 | 5.8 | 8.2 | 8.3 | 8.7 | n/a | 7.7 |
| | | Spruce | 9.5 | 10.0 | 9.2 | 9.5 | 7.8 | 8 | 8.8 | 9.5 | 9.5 | n/a | 9.7 |
| | | Amabilis Fir | 9.0 | 9.3 | 8.0 | 9.8 | 6.8 | 7.3 | 9.5 | 8.3 | 8.7 | n/a | 9.1 |
| | | Hemlock | 8.3 | 9.3 | 8.5 | 9.3 | 6.2 | 6.8 | 10.0 | 8.7 | 7.8 | n/a | 9.3 |
| | | Aspen | 8.5 | 10.0 | 9.7 | 9.7 | 8.5 | 8.2 | 9.0 | 10.0 | 9.2 | n/a | 9.6 |
| | | Jack Pine | 9.0 | 9.8 | 9.8 | 9.3 | 8.2 | 9.2 | 10.0 | 9.7 | 8.8 | n/a | 9.9 |
| | | Poplar | 7.3 | 9.7 | 8.2 | 9.0 | 8.0 | 8.5 | 9.5 | 8.7 | 8.0 | n/a | 9.3 |
| | | Balsam Fir | 8.0 | 10.0 | 9.3 | 10.0 | 5.5 | 5.2 | 9.2 | 8.0 | 8.5 | n/a | 9.2 |
| Vancouver | 90 | Cedar 2nd | 4.3 | 8.8 | 7.8 | 9.2 | 4.2 | 5.2 | 9.7 | 6.5 | 4.8 | n/a | 9.1 |
| | | Cedar Old | 4.7 | 8.7 | 8.5 | 9.3 | 4.5 | 5.5 | 9.8 | 6.5 | 5.3 | n/a | 8.5 |
| | | Spruce | 3.3 | 9.0 | 7.8 | 9.8 | 4.7 | 4.7 | 8.7 | 5.7 | 5.5 | n/a | 9.3 |
| | | Amabilis Fir | 3.3 | 9.2 | 7.7 | 9.7 | 5.3 | 4.7 | 9.5 | 8.3 | 4.7 | n/a | 9.0 |
| | | Hemlock | 2.0 | 9.7 | 8.5 | 8.8 | 4.5 | 4.8 | 9.3 | 6.5 | 7.3 | n/a | 9.2 |
| | | Aspen | 2.3 | 7.7 | 7.3 | 9.0 | 4.2 | 3.8 | 8.5 | 6.0 | 3.3 | n/a | 9.3 |
| | | Jack Pine | 4.8 | 8.8 | 8.8 | 9.7 | 4.3 | 7.3 | 9.0 | 5.7 | 4.8 | n/a | 9.6 |
| | | Poplar | 2.0 | 8.8 | 7.2 | 7.7 | 3.7 | 4.0 | 10.0 | 4.2 | 3.0 | n/a | 9.6 |
| Mississippi | 90 | Cedar 2nd | 2.3 | 8.3 | 7.5 | 6.0 | 3.3 | 4.8 | 7.7 | 4.7 | 7.0 | 9.7 | 9.5 |
| | | Cedar Old | 5.0 | 7.7 | 7.2 | 7.5 | 5.7 | 6.2 | 7.7 | 5.7 | 6.0 | n/a | 9.7 |
| | | Spruce | 3.5 | 8.2 | 8.0 | 6.7 | 3.2 | 5.5 | 7.7 | 3.5 | 7.2 | 9.7 | 9.4 |
| | | Amabilis Fir | 3.2 | 7.7 | 6.7 | 7.5 | 4.2 | 3.3 | 7.7 | 4.7 | 7.7 | 9.0 | 9.2 |
| | | Hemlock | 3.7 | 7.2 | 7.5 | 5.7 | 2.8 | 4.5 | 8.3 | 4.0 | 7.7 | 9.7 | 8.5 |
| | | Aspen | 1.2 | 6.3 | 5.2 | 5.3 | 2 | 2.3 | 7.7 | 3.0 | 2 | 9.3 | 9.2 |
| | | Jack Pine | 3.3 | 6.3 | 8.7 | 6.7 | 3.7 | 7.0 | 7.8 | 4.0 | 4.5 | 8.3 | 9.4 |
| | | Balsam Fir | 2.5 | 8.0 | 6.5 | 7.7 | 4.2 | 3.0 | 7.8 | 4.2 | 7.2 | 10.0 | 8.9 |
| Mississippi | 45 | Cedar Old | 3.7 | 6.7 | 6.3 | 3.0 | 4.7 | 3.7 | 6.7 | 4.3 | 4.3 | n/a | 7.3 |
| | | Spruce | 1.0 | 6.3 | 4.0 | 3.3 | 3.0 | 2.0 | 7.7 | 4.3 | 3.0 | n/a | 8.0 |
| | | Amabilis Fir | 1.0 | 7.7 | 4.0 | 4.3 | 3.0 | 2.0 | 8.3 | 4.0 | 3.7 | n/a | 8.5 |
| | | Hemlock | 1.0 | 7.7 | 4.3 | 3.0 | 2.0 | 3.0 | 8.3 | 4.3 | 2.6 | n/a | 8.0 |
| | | Aspen | 2.3 | 5.3 | 3.0 | 2.3 | 2.0 | 1.0 | 5.7 | 2.0 | 2.0 | n/a | 7.5 |
| | | Jack Pine | 1.8 | 7.8 | 5.0 | 3.0 | 2.3 | 3.0 | 7.3 | 3.3 | 3.8 | n/a | 8.0 |
| | | Balsam Fir | 1.0 | 7.0 | 4.5 | 3.5 | 2.5 | 2.5 | 7.0 | 4.0 | 3.0 | n/a | 8.3 |

### 3.1.5.3 18-Month Test Fence Data

At eighteen months, only results from the Mississippi site are available (Table 12) which shows that most of the finish/species combinations, except for the paints, require refinishing (<5 rating). The best performing is the factory finish (F9) which shows little or no degradation for all species except jack pine which dropped to a 6.3 rating. The lab-applied paint finishes (F1, F6) also did not decline in rating with the main problem being mildew growth; other finishes suffered more wide-spread, severe deterioration by flaking, cracking and erosion.

In this evaluation, finish performance and sample orientation again appear to be the major determinants of performance. All species were performing similarly although for both test fences the old growth redcedar had the highest average finish ratings while aspen had the lowest.

**Table 12: Eighteen-month test fence data**

| Test Site | Inclination | Species | Average General Rating | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Control | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | Substrate |
| Mississippi | 90 | Cedar 2nd | 1.0 | 8.8 | 5.2 | 3.8 | 2.2 | 2.5 | 8.7 | 4.3 | 3.2 | 10.0 | 8.9 |
| | | Cedar Old | 4.0 | 9.0 | 4.5 | 7.7 | 3.3 | 4.5 | 8.8 | 3.8 | 4.2 | n/a | 9.5 |
| | | Spruce | 1.0 | 8.7 | 6.7 | 3.3 | 1.8 | 3.0 | 7.8 | 2.2 | 3.3 | 9.3 | 8.6 |
| | | Amabilis Fir | 1.0 | 8.2 | 4.5 | 4.3 | 1.8 | 1.7 | 8.0 | 3.0 | 3.2 | 9.3 | 8.7 |
| | | Hemlock | 1.0 | 7.8 | 4.7 | 3.0 | 1.3 | 2.3 | 7.8 | 2.2 | 3.2 | 10.0 | 7.9 |
| | | Aspen | 1.0 | 7.0 | 4.2 | 3.2 | 1.0 | 1.2 | 7.7 | 2.2 | 2.0 | 9.3 | 9.0 |
| | | Jack Pine | 1.0 | 8.0 | 7.5 | 3.8 | 1.0 | 2.5 | 7.8 | 2.2 | 2.5 | 6.3 | 8.9 |
| | | Balsam Fir | 1.0 | 8.2 | 4.7 | 4.0 | 2.0 | 3.0 | 8.0 | 2.3 | 3.0 | 10.0 | 8.5 |
| Mississippi | 45 | Cedar Old | 2.3 | 5.3 | 3.7 | 2.7 | 3.3 | 2.3 | 6.3 | 3.3 | 3.0 | n/a | 5.3 |
| | | Spruce | 1.0 | 5.3 | 4.3 | 3.0 | 1.3 | 1.0 | 6.7 | 2.3 | 1.0 | n/a | 6.3 |
| | | Amabilis Fir | 1.0 | 7.7 | 4.0 | 3.0 | 2.0 | 1.0 | 8.0 | 2.3 | 1.0 | n/a | 7.3 |
| | | Hemlock | 1.0 | 7.3 | 4.3 | 3.0 | 1.0 | 1.0 | 7.7 | 2.3 | 1.0 | n/a | 6.9 |
| | | Aspen | 1.0 | 3.0 | 2.3 | 2.3 | 1.7 | 1.0 | 5.0 | 2.0 | 1.0 | n/a | 6.3 |
| | | Jack Pine | 1.0 | 7.5 | 2.3 | 3.0 | 1.0 | 1.5 | 7.0 | 1.0 | 1.0 | n/a | 6.4 |
| | | Balsam Fir | 1.0 | 7.0 | 5.0 | 3.0 | 1.5 | 1.0 | 6.0 | 2.0 | 1.0 | n/a | 7.3 |

### 3.1.6 Test Site Weather Conditions

Weather conditions for the three test sites are shown in Table 13. Notable differences between the three sites include the ambient temperature, rainfall and frequency of 100% relative humidity (RH). The recorded average RH were similar for all three-test sites.

The maximum surface temperature was similar in both Quebec and Vancouver and was higher in Mississippi.

**Table 13: Test Site weather conditions**

| Weather Conditions | | Quebec | Vancouver | Mississippi |
|---|---|---|---|---|
| Normal annual ambient temperature | | 4.0 | 9.9 | 19.9 |
| Normal annual rainfall (mm) | | 881 | 1234 | 1593 |
| Days with measurable rainfall | | 117 | 168 | N/A |
| On-Site Measurements from April-November,2001 (2 ½ hr intervals) | average RH (%) | 73 | 72 | 85 |
| | maximum surface temperature (C) | 44 | 44 | 49 |
| | frequency of 100% RH (%) | 19 | 6 | 49 |

### 3.2 Artificial Weathering Test Results

The results from the artificial weathering tests are shown in Table 14. The paint finish (F1) on all species performed the best with a high average rating of 9.0. The finishes F4, F5 and F8 all performed poorly with low ratings averaging less than 5 for all species.

**Table 14: Artificial weathering results**

| Test Site | Inclination | Species | Average General Rating | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Control | F1 | F4 | F5 | F8 | Substrate |
| Vancouver | 90 | Spruce | 2.0 | 8.8 | 2.0 | 2.7 | 2.3 | 7.5 |
| | | Amabilis Fir | 2.0 | 9.0 | 2.0 | 5 | 3.7 | 6.0 |
| | | Hemlock | 2.0 | 9.0 | 2.0 | 2.3 | 3.3 | 5.8 |
| | | Aspen | 1.0 | 9.0 | 2.7 | 2.7 | 1.3 | 6.5 |
| | | Poplar | 1.0 | 9.0 | 2.0 | 1.0 | 1.0 | 6.6 |
| | | Balsam Fir | 2.0 | 9.0 | 2.0 | 2.7 | 2.3 | 5.5 |

## 4 Discussion

Significant differences were observed between many of the finish/species groups from both natural exposure and accelerated, artificial weathering tests. Several finish/species combinations were monitored from new condition to failure while with others only the early stages of finish deterioration were evident.

### 4.1 Species Type

In this study, wood species was not a major factor affecting finish performance compared to finish type and weathering exposure. However, after 12-18 months exposure in Vancouver and Mississippi trends are beginning to develop showing a hierarchy between the species. The average finish ratings were consistently the lowest for aspen and poplar while western red cedar ranked the highest. There was no consistent ranking order between the other species. Even though the finish averages were lower for aspen and poplar, these species generally performed as well as the other species when finished with either the WRP+Primer+Topcoat paint finish combination or the factory finish.

As exterior exposure continues, the differences in finish performance between species may become more apparent due to fungal attack. It is well documented that red cedar has superior natural resistance to fungal deterioration while other species including aspen and poplar are especially vulnerable.

### 4.2 Dominant Factors Affecting Finish Performance

Results from the short-term exterior exposure and Weather-Ometer® tests show that the dominant factors affecting finish performance were:

1) Finish type
2) Substrate texture
3) Surface inclination (i.e. 45°, 90°)
4) Climate

#### 4.2.1 Finish Type

This section compares finish performance on samples with planed-surface, heartwood and flat grain. In this study, finish performance was considerably variable. However, from inspecting both the exterior exposure and Weather-Ometer® evaluation data, trends were detected between finish types for all types of exposure.

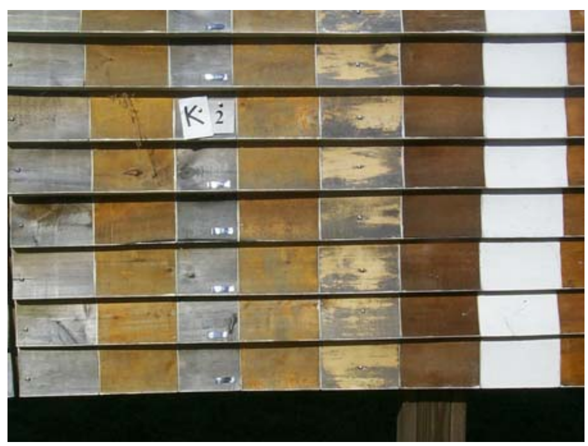



**Figure 11: Section of test fence after 18 months exposure in Mississippi**

At the 6-month evaluation of exterior samples several finishes were deteriorating faster than others, especially the semi-transparent and clear finish types in Vancouver and Mississippi (Figure 11).

By 12 months, most of the samples, irrespective of wood species, finished with F4 (semi-transparent, alkyd stain), F5 (clear film), F7 (CCA dip pretreatment + semi-transparent, alkyd stain) and F8 (CCA dip pre-treatment) in Vancouver and Mississippi required refinishing or showed significant signs of degradation. In Quebec, while most finish combinations showed much less deterioration, the F4 and F5 finishes were still observed to be trending lower. The Weather-Ometer® data also showed that the semi-transparent and clear finishes F4, F5 and F8 had deteriorated substantially for all species tested.

The best performing finishes were opaque including F1 (primer+paint), F3 (solid colour stain), F6 (water repellent preservative+ primer+paint) and F9 (factory finish). Finish F9 showed the overall best performance with no significant deterioration observed for any of the species except for jack pine which showed significant discolouration from resin exuding at knots (Figure 12). This was observed only after 18 months exposure on the Mississippi, vertical test fence. The paint finishes F1 and F6 gave similar results for all locations with high average ratings which remained relatively constant from 6 months-18 months on the Vancouver and Mississippi vertical test fences. Mildew was the main reason for the lower ratings. However, on the 45-degree fence in Mississippi, these finishes were beginning to show signs of cracking and flaking after one year's exposure. It was observed that the deterioration of the finish F1 was more pronounced on aspen compared to the other species. The Weather-Ometer® test results were consistent with the field test data with paints outperforming the clear and semi-transparent finishes and no significant differences between the species tested. Overall finish/species ratings were similar to the Mississippi vertical test fence results after 18-months exposure.

**Figure 12: Knot discolouration on jack pine**

Finish F2 (semi-transparent, 2-part aqueous stain) performed similarly to the paint finishes F1 and F6 on the vertical fences at all test sites, while on the 45 degree fence in Mississippi, deterioration of finish F2 was more accelerated with significant advancement of flaking, creaking and erosion.

### 4.2.2 Climate

This study has clearly shown that climate is an important factor affecting the finish performance on wood products. In Mississippi, finishes/species combinations on the vertical test fences showed the fastest average decline followed by those in Vancouver and then Quebec as shown by the graph of Figure 13. In this graph, trendlines of the form $y=cx^b$ (power equation type- c, b are constants) fit well with the observed data for 6, 12 and 18 months. These trendlines show that samples at 90 degree inclination in Quebec are deteriorating at a rate approximately 1/3 that of samples in Vancouver and 1/6 that of those in Mississippi.

### 4.2.3 Surface Orientation

Surface orientation is also important. The samples mounted at 45 degrees in Mississippi showed a significantly faster deterioration rate than those mounted at 90 degrees at the same test site. As Figure 13 shows, the rate of decline is approximately 2x that of the 90 degree samples in Mississippi. This accelerated deterioration is probably due to a combination of the increased ultra-violet intensity, surface wetness and temperature.

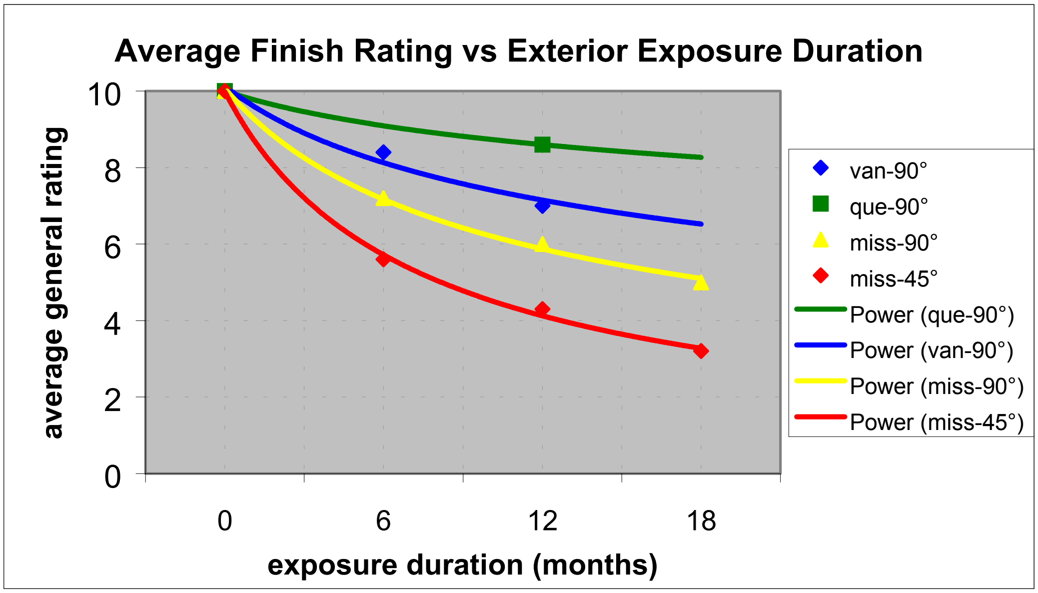



**Figure 13: Average finish rating in Vancouver, Quebec and Mississippi at 0 6, 12,and 18 month intervals**

### 4.2.4 Substrate Texture

From the Vancouver and Quebec test fence data, finishes on the saw-texture samples consistently and substantially outperformed the planed texture samples. For example, the saw-textured samples from Vancouver deteriorated at about half the rate of the planed samples. It is also important to point out that the spread rates on the saw-textured samples were 2-3 times greater than those on the planed samples for all finishes.

### 4.3 Artificial, Weather-Ometer® Testing

As discussed earlier, Weather-Ometer® testing provided useful accelerated results for a few species/finish combinations in 2 ½ months. The accelerated results corroborated the exterior finish deterioration trends being similar to those found in Mississippi after 6 months exposure on the 45 degree fence, or after 18 months exposure on the 90 degree fence. Natural exposure tests have the advantage of providing extended term data which is especially relevant for long lasting finishes. Also, Weather-Ometer® testing is limited to small-sized, flat samples which do not always behave the same way as actual size, wood products with different surface profiles.

## 5 Conclusions

1. Finish type, wood substrate texture and weathering exposure, including climate and finished surface orientation, were the dominant factors affecting finish performance. At this stage wood species was not an important determinant of performance.

2. In general, finish ratings were good to excellent for paints and fair to poor for semi-transparent and clear finishes.

3. The factory applied, acrylic latex finish formulation gave the best performance with very little deterioration observed even after 18 months exterior exposure in Mississippi.

4. Finished, saw-textured samples of all species deteriorated at approximately half the rate of planed samples.

5. Finished samples (vertical/planed) in Quebec deteriorated at approximately 1/3 the rate of those in Vancouver and 1/6 the rate of those in Mississippi.

6. Substrate grain orientation (vertical/flat) and heartwood/sapwood ratio did not significantly affect finish performance.

7. In most cases, there were no significant differences in finish performance between old growth and 2$^{nd}$ growth western red cedar.

8. Although not statistically significant, average finish ratings on aspen and poplar were generally lower than on other species. A notable exception was aspen finished with the factory finish which performed very well with only minor deterioration after 18 months exposure in Mississippi.

9. Accelerated, artificial weathering which combined Weather-Ometer® exposure and incubation of inoculated samples in an environment chamber, showed finish deterioration that was similar to finished samples receiving 6 months exposure on a 45 degree, test fence in Mississippi.

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