2.0 THEORY

2.1 Relationship between penetration and deterioration

While rot formation varies widely between wood species and physical circumstances, there are certain characteristics that follow similar patterns. One is that rot producing micro-organisms thrive when free water is readily available, i. e. when the wood is moist or wet. If the wood is completely saturated then fungi do not flourish but there are varieties of bacteria that do, and they feed on the wood, with their activity limited by available oxygen. When the wood becomes dry (below about fifteen percent water) both bacteria and the more common fungi lack the moisture necessary to support normal growth. The "Brown Rot" is active with less water but is slower to develop. It is a truism that water is required to support rot growth. If one can identify water pathways in infested wood, it is possible to identify existing and future rot progression. This is because fungal attack changes the nature of the wood.

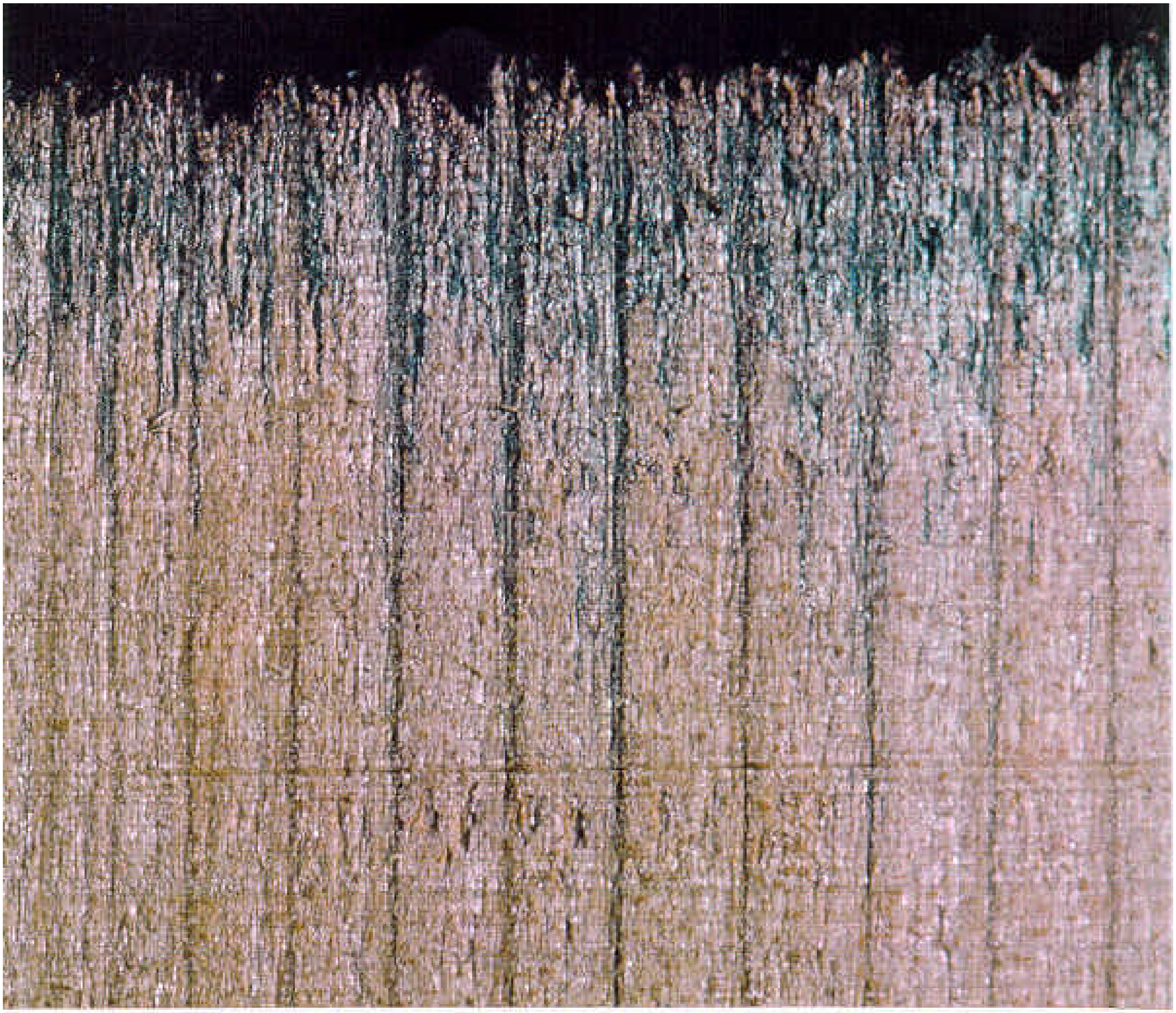
Water enters wood in many ways, but there are several common patterns. One is a close association with the ground or another moist surface (concrete, stone, etc.). Another is from building leaks and a third from penetration through unprotected surfaces. Common to all is insufficient air circulation to dry the wood before rot has a chance to develop. There tends to be a "rot growing season" when a combination of warmth, free moisture and inadequate air drying provide optimum conditions for rot growth.

Water can readily penetrate wood parallel to the grain, adjacent to the same cellular pump and valve systems of the live tree (Those pump and valve systems are largely closed after the tree dies). The adjacent pathways are microscopic, twisting and in some species blocked after short distances by cross cellulose patterns. This should limit the rate of water penetration. Wood sustains enough air to float for a long time, for example, but water is still absorbed considerable distances through end grain before natural barriers slow down the process. Access is much reduced through side grain, but water is often able to penetrate through knots, checks and cracks in the side grain to find end grain openings. This is plausible for sound wood but does not apply once the fungi have eaten away enough cellulose to provide open porosity for water to penetrate and promote further rot from that porosity extending further into the wood. The porosity patterns for slightly deteriorated wood are different, as these pictures, made with blue-dyed liquids, show. The porosity pattern is also different for hardwoods such as Radiata Pine, which rot rapidly due to cross-grain porosity. This may be seen in the following photographs as the water wicking into each summer growth ring, perpendicular to the grain direction.

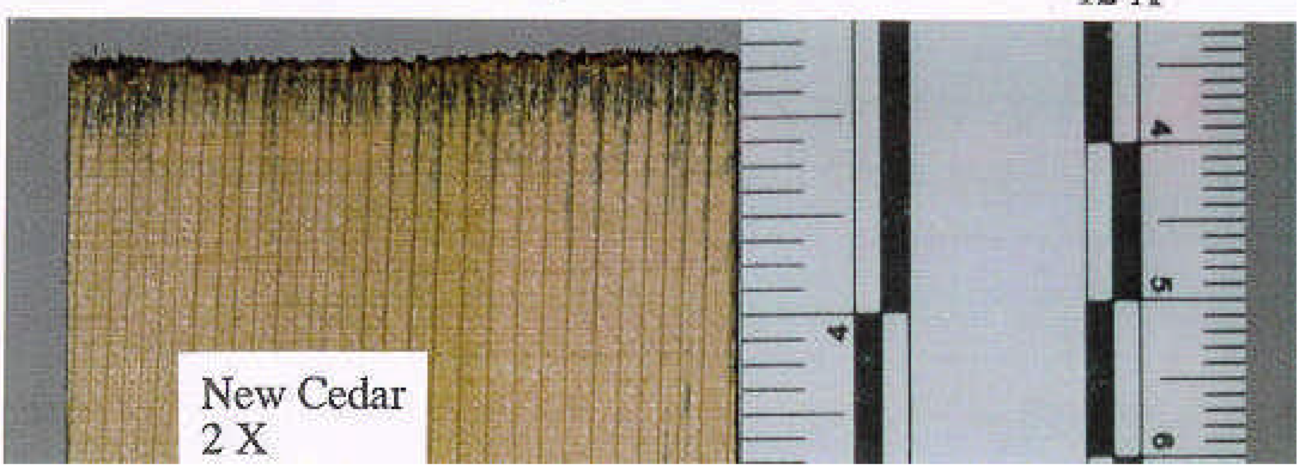
The physical relationship between the entering resin/solvent impregnating compound and the microscopic channels is relatively simple where the microorganisms have opened access channels. There, the pictures following Section 2.2 show the impregnant penetrating rapidly and preferentially. It follows that ***a properly formulated impregnant such as the Smith & Co. Professional Version Clear Penetrating Epoxy Sealer can follow almost all channels produced by micro-organisms.***

The potential to impregnate damaged wood with resins to microscopic levels suggests that wood can be said to have been restored if the rot channels are fully impregnated and if the mechanical properties of the treated wood are similar to those of natural wood. This is the basic connection between the penetration and the mechanical tests.

On the following pages are a series of progressively magnified photographs of Cedar and slightly deteriorated Fir, both impregnated with the Smith & Co. impregnant to which a blue dye was added. These show the penetration of the impregnant into these materials. The randomity of penetration depth in the Cedar without deterioration may be seen to be similar to that of Fir after some fungal deterioration. Compare the cedar at 12X with the Fir at 16X.



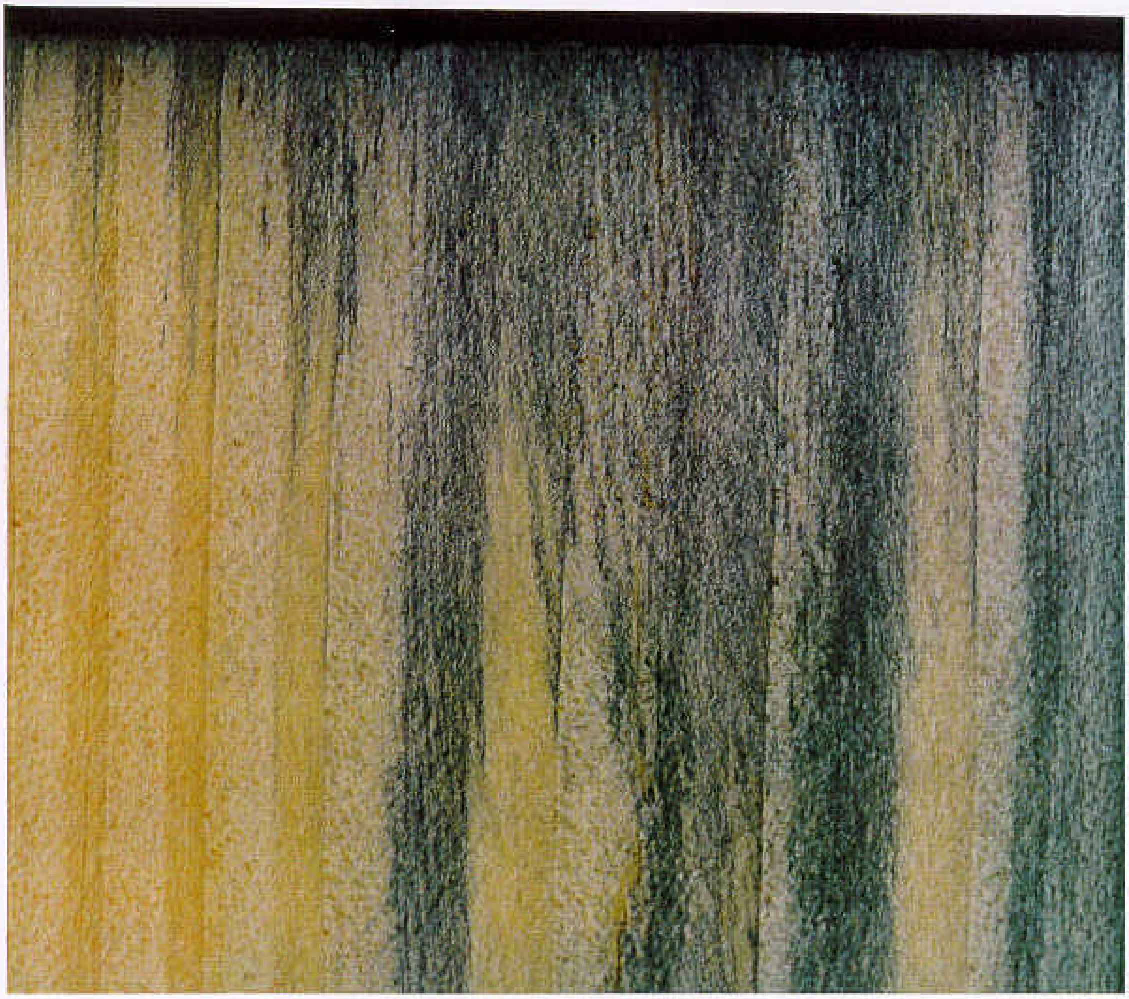
New Cedar
12 X



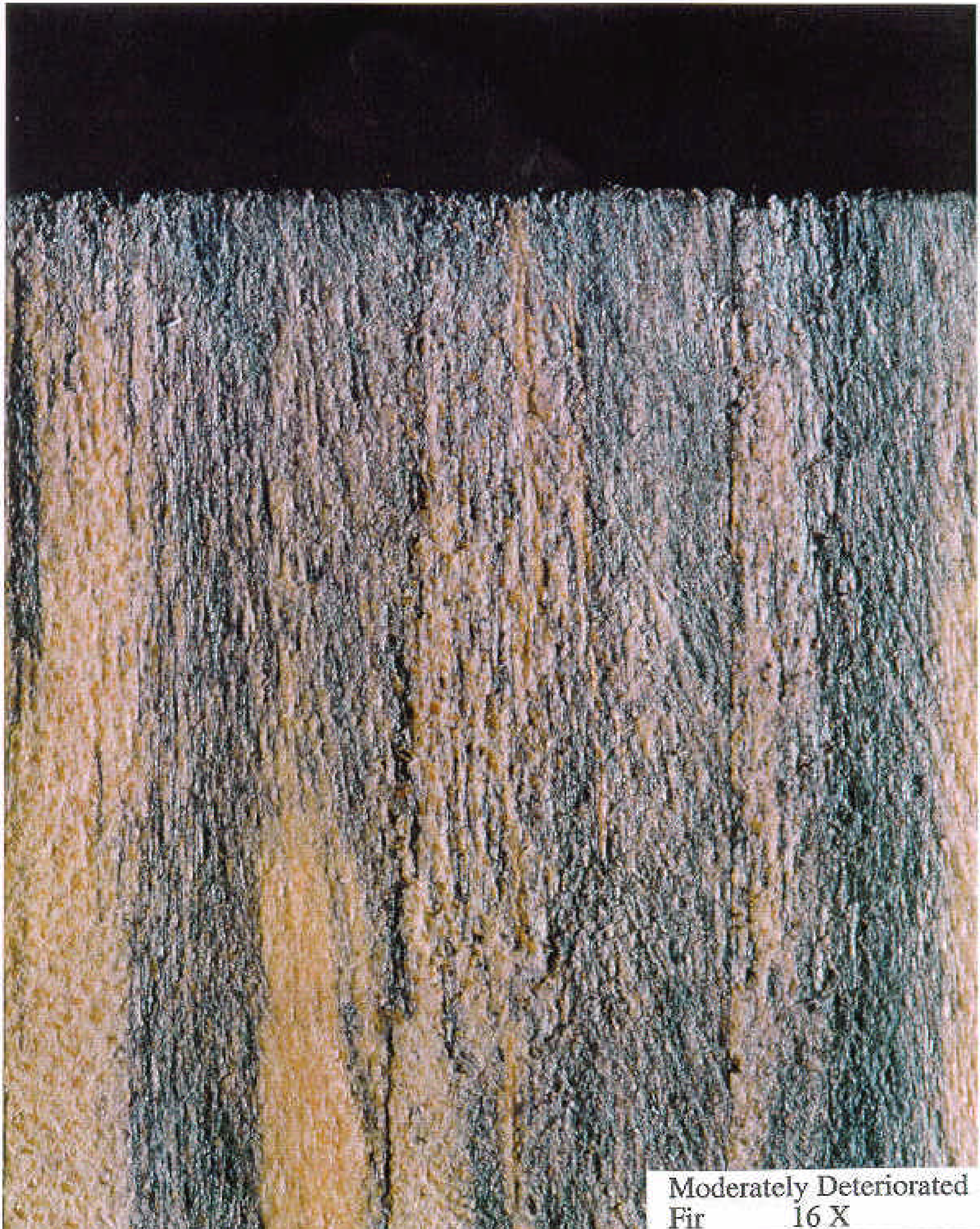
New Cedar
2 X

Moderately Deteriorated
Fir 4 X

Moderately Deteriorated
Fir 2 X



Moderately Deteriorated
Fir 8 X

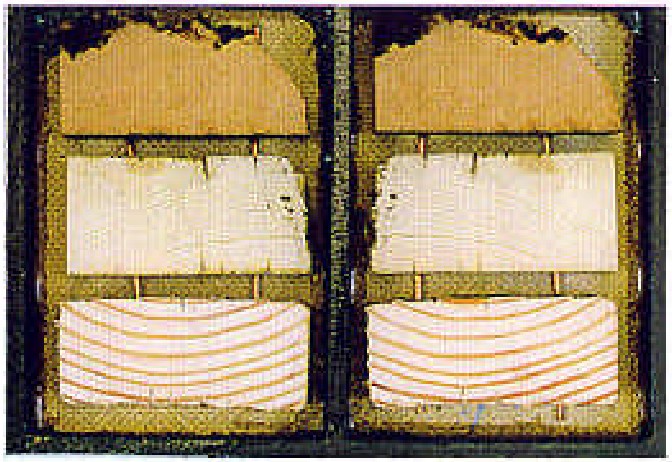


Moderately Deteriorated
Fir 16 X

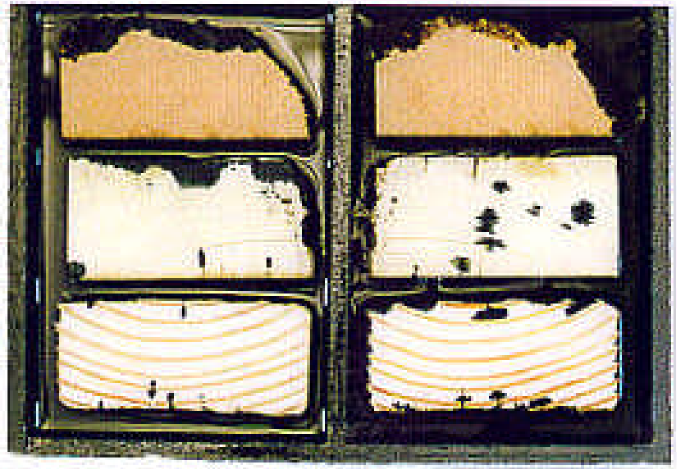
Moderately Deteriorated
Fir 30 X

2.2 Penetration tests

The primary object of the penetration tests is to verify that the resin-solvent blend of the impregnating compound developed by Smith & Co. will impregnate channels in damaged wood to produce an effective resin-cellulose bond and that there is an effective bond between restored areas and undamaged wood. The tests must also verify that the penetration process is practical; that the resin-solvent blend is able to enter microscopic channels easily and rapidly. A test of types of wood cut together (i, e., one after the other) from the same pieces of deteriorated fir and redwood, and from a sound 2 x 4 of Radiata Pine, was done to compare the penetration ability of the new Smith & Co. impregnating product with water. A timed series of photographs was done, and the results are shown on the following page. This demonstrates an unusual property of the Smith & Co. impregnant compared to water: ***The impregnant prefers to penetrate deteriorated wood while water prefers to penetrate sound wood.*** A possible explanation is: (a) the largely closed valves in the dead cells open when the cellulosic portion of wood absorbs water, (b) the cellulosic portion of wood is readily wetted by water, and (c) after the fungi have eaten away the some of the cellulose from the cellulosic portion, the natural oils and resins which are hydrophobic but readily wetted by solvents remain as much of the structure of the deteriorated region . That may or may not be the full explanation, but the evidence clearly shows that ***the Professional Version of Smith & Co. Clear Penetrating Epoxy Sealer Seeks out deteriorated wood, recognizes it and preferentially impregnates it. Thus, its absorption by wood is an accurate indicator of the extent of deterioration of the wood.***

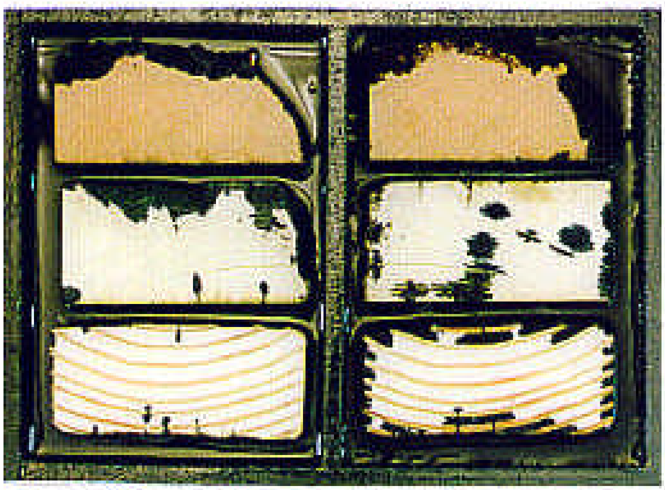


Starting Appearance



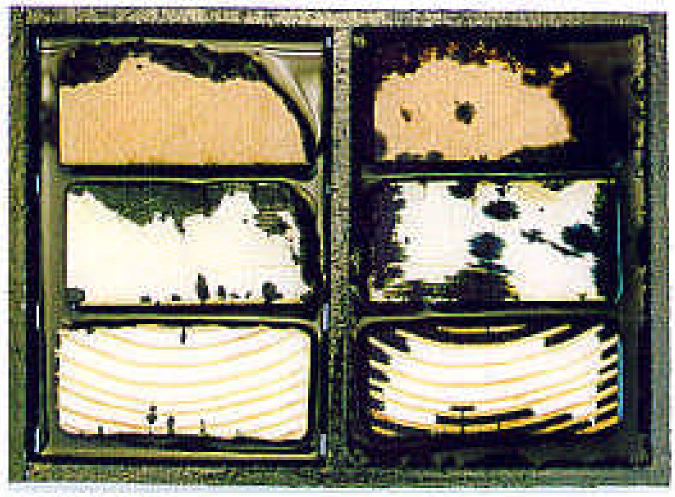
Smith & Co.
Professional Version
C.P.E.S.

Water
20 Seconds



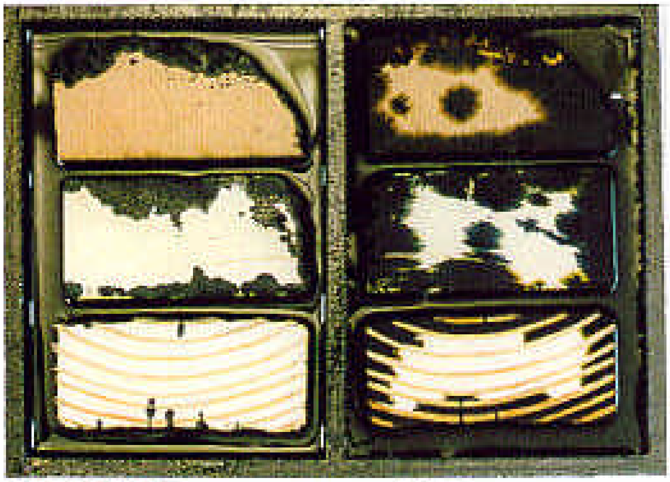
Smith & Co.
Professional Version
C.P.E.S.

Water
40 Seconds



Smith & Co.
Professional Version
C.P.E.S.

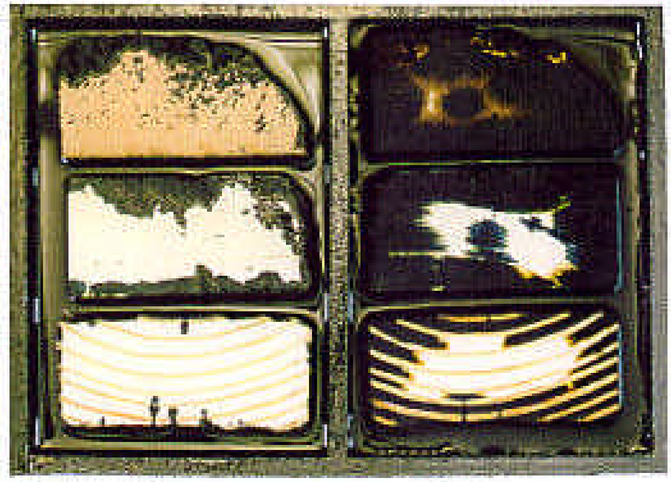
Water
1 Minute



Smith & Co.
Professional Version
C.P.E.S

Water

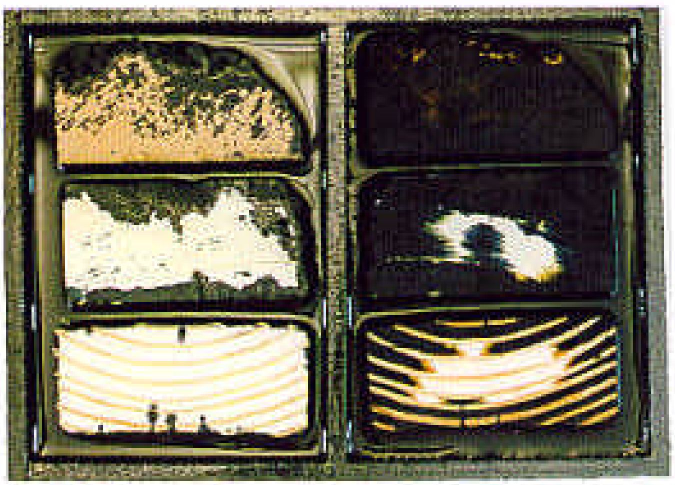
2 Minutes



Smith & Co.
Professional Version
C.P.E.S.

Water

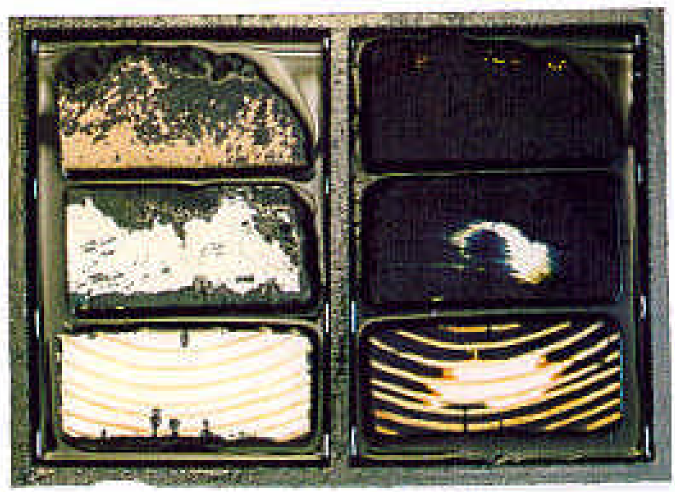
4 Minutes



Smith & Co.
Professional Version
C.P.E.S.

Water

8 Minutes



Smith & Co.
Professional Version
C.P.E.S.

Water

16 Minutes

3.0 Porosity of treated wood

The first question that arises when one opens the subject of "epoxy impregnation of wood" is - ***what does that do to the wood?*** There are many epoxy or other products that have been used in the past for this purpose. It is common for rot to start up again behind fillers in wood, or in the vicinity of such treatment. Since fungi flourish in the presence of higher humidity levels (over 25%) than the natural humidity level of wood (typically 7-15%) it is logical to conclude that conventional repair technology does not allow excess water in wood to freely diffuse through the wood and evaporate out through its entry means. ***The reason for this is that conventional saturation of wood with liquid epoxy resins destroys the porosity of the wood, while leaving active fungal infestations in the untreated regions.*** Due to the variability of decayed wood, water can easily migrate to these decayed, porous regions behind the "repair" and accumulate there, promoting further decay. The technology of wood treatment with the Clear Penetrating Epoxy Sealer is utterly different, in that ***wood porosity remains even after the impregnation.*** Since the impregnating resin system is hydrophobic, the water absorption of the wood is reduced, while the impregnation process adds mechanical strength to the wood. This destroys the ability of the wood to hold enough water to promote rapid fungal activity, while allowing some water to diffuse in and out of the wood, so that excessive dehydration does not result in brittle wood, nor excess transient moisture be retained such as to promote decay. It is in this manner that treatment with the Clear Penetrating Epoxy Sealer improves the ability of the wood to resist further deterioration such as might be caused by fungi, bacteria, etc.

Porosity Test Procedure and Results

A piece of old Douglas fir, about 1 1/2" square X 6" long with severe decay at one end, and four cedar shingle strips 1.7" wide (the same size as the test specimens used later in this paper) were treated in the following procedure:

1) Let dry 1 month at 20°C, 40% R.H. in a closed room on a dry concrete floor.
2) Weigh and record as Initial weight #1
3) Fully immerse in tap water (15°C) for 24 hours.
4) Weigh and record as Weight saturated with water.
5) Let dry as in #1 for 1 month.
6) Weigh and record as Initial weight #2.
7) Impregnate for 60 minutes by full immersion in a 1000 mL laboratory graduate. Drain, let dry and cure as in #1.
8) Weigh and record as Impregnated weight.
9) Immerse in tap water (15°C) for 24 hours.
10) Weigh and record as Impregnated weight after water soak.

The initial weights #1 and #2 were essentially identical, and so the data results table shows simply Initial weight.

Data Results

	Douglas Fir
Initial weight	165 g
Weight saturated with water	279 g
Water taken up	114 g
Percent water absorbed	**69 %**
Impregnated weight	212 g
Impregnated weight after water soak	245 g
Water taken up	33 g
Percent water absorbed	**16%**

	Four pieces Cedar Shingle
Initial weight	182 g
Weight saturated with water	253 g
Water taken up	71 g
Percent water absorbed	**39 %**
Impregnated weight	191 g
Impregnated weight after water soak	201 g
Water taken up	10 g
Percent water absorbed	**5%**

The results of this simple test have the most profound implications in the development and evaluation of this technology.

The observable fact is that the treated wood has some porosity remaining after treatment with the Smith & Co. Professional Version Clear Penetrating Epoxy Sealer . This explains why this technology has been so effective, in all its incarnations since 1972. It explains the tendency of rot not to start up again in a treated area. The amount of water absorbed by the untreated cedar shingle, comparable to moderately rotted wood (the fir had severe rot on one end, with about two cubic inches entirely eaten away), is a clear indication that ***a natural cedar shingle is an acceptable surrogate standard for deteriorated wood.*** Cedar shingles (as we will see in the experimental section) turn out to be surprisingly consistent in their properties, and thus viable candidates for mechanical tests.