VARIATIONS IN LONGITUDINAL PERMEABILITY OF COASTAL WESTERN HEMLOCK[1]

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ABSTRACT

The air permeability of western hemlock from coastal forests in western Oregon was assessed. Permeability varied widely among trees, as well as by position within individual trees. Permeability tended to decrease with distance inward from the bark, a trend implying that this species produces a heartwood zone. These variations may help to explain the treatability differences observed in lumber of this species.

Keywords: Western hemlock, gas permeability, heartwood.

INTRODUCTION

Western hemlock (*Tsuga heterophylla* (Raf.) Sarg) is an important component of the coastal forests of Oregon and Washington. For many years, the commercial value of this species was overshadowed by the more valuable Douglas-fir. Changes in purchasing preferences, however, have led to western hemlock gaining in value, particularly in Asian export markets.

An important attribute of western hemlock is the ease with which it can be pressure impregnated with wood preservatives. Douglas-fir has a well-deserved reputation as a difficult-to-treat species with a high percentage of virtually untreatable heartwood (AWPA 1999; Miller and Graham 1963; Kumar and Morrell 1989). Conversely, western hemlock can gen-

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TABLE 1. *Average permeability of plugs cut from selected heights and relative radial positions of western hemlock trees.*

	Mean permeability (μm^2)[a]		
Distance above ground	Outer zone	Middle zone	Inner zone
Breast height	3.5 (1.5)	1.7 (1.3)	1.0 (1.2)
30% of total height	4.7 (0.6)	2.2 (1.2)	0.4 (0.3)
50% of total height	4.6 (2.5)	0.8 (0.7)	0.3 (0.2)
Base of live crown	4.3 (2.1)	3.7 (1.8)	1.2 (1.7)

[a] Values represent means, while those in parentheses represent one standard deviation.

erally be treated to current industry standards (AWPA 1999). Yet despite its reputation for treatability, western hemlock still varies quite widely in its receptivity to treatment (Cooper 1973; Kumar and Morrell 1989). The reasons for this variability remain unclear, although studies with other refractory species suggest that treatability can vary with site, elevation, and a host of other variables (Miller and Graham 1963). It is also possible that this species produces heartwood without a distinguishable color change. Eades (1958) suggested that western hemlock heartwood could be distinguished by various indicators, but there are few other reports describing the possibility of heartwood in this species. Decreased permeability as a result of heartwood formation and associated aspiration of pit membranes could account for treatment variation. There is little information on the relative differences in permeability within western hemlock, despite its importance as a treatable species (Cooper et al. 1974; Erickson and Crawford 1959). In this report, we describe the results of a survey of permeability of western hemlock trees from the North Coast of Oregon as a means for assessing relative treatability and the possible presence of heartwood.

MATERIALS AND METHODS

Sixty-one western hemlock trees in stands growing in the North Coast Range of Oregon were selected for study. The trees were selected randomly from within pure 30- to 60-year-old western hemlock stands. A series of

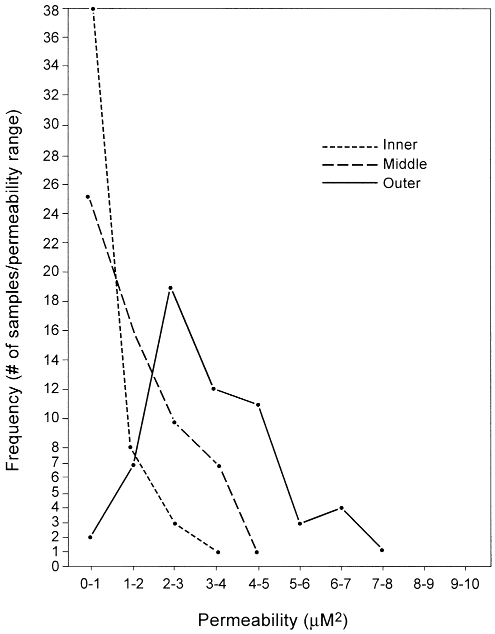

FIG. 1. Distribution of permeability by distance inward from the outer bark at the breast height of western hemlock.

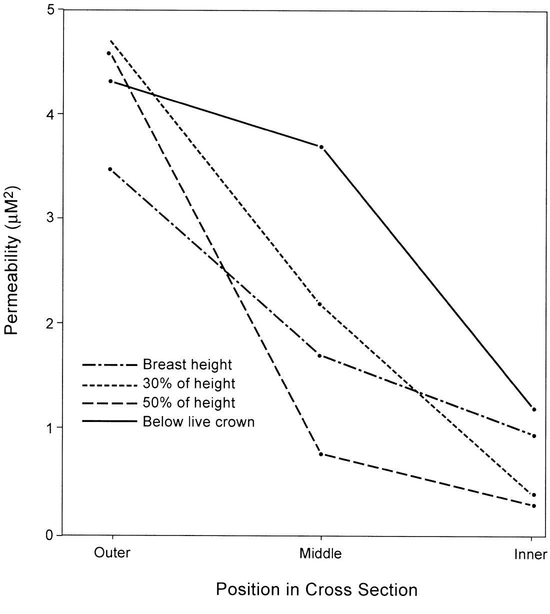

FIG. 2. Permeability of plugs removed from selected distances inward from the bark at four locations along the bole of western hemlock trees.

discs were cut from each tree at locations corresponding to 50% and 70% of the original tree height, as well as at breast height and at the base of the live crown. These discs were returned to the laboratory, where they were stored at 5°C until they could be processed. A series of 12.7-mm-diameter plugs, 50 mm long were then cut on the transverse face from xylem locations corresponding to the area immediately adjacent to the inner bark (outer zone), a zone near the pith (inner zone), and at the mid-point between these two sites (middle zone). Two plugs were removed from the inner zone, four were removed from the outer zone, and two were taken from the middle zone of each cross section. The plugs were dehydrated through a graded series of increasing ethanol concentrations, then were stored in absolute ethanol in screw-cap vials for 3 weeks prior to testing. The caps were removed from the vials to allow the ethanol to slowly evaporate under a fume hood. The cores were then heated at 105°C for 24 h to drive off any residual ethanol, then stored in sealed containers in a dessicator until needed. Prior tests indicated that these procedures did not adversely affect permeability (Milota personal communication). Dry cores were used instead of wood at moisture contents closer to the range that is typically treated (20% to 40%) because of concerns about the ability to reliably condition the wood to higher moisture regimes.

The length and diameter of each core were measured to the nearest 0.0254 mm; then the dry cores were embedded in a rubber stopper that had been drilled along its longitudinal axis to the diameter of the core. The cores tended to have some roughness on the sides. To overcome this roughness, the zone between the core and the stopper was sealed with a two-part epoxy. The cores were stored for 24 h to allow the epoxy to cure, then placed in a test apparatus so that flow could occur only parallel to the long axis of the core (Comstock 1967). The apparatus slightly compressed the rubber stopper to seal the cylindrical surfaces of the core. Nitrogen gas was reduced to a pressure of approximately 0.138 MPa and applied to the upstream side of the sample. A flow meter was used to measure the flow on the downstream side of the sample at atmospheric pressure. Pressure drop across the sample was measured with a transducer.

Permeability was calculated using previously described procedures (Comstock 1967):

$$K_g = \frac{Q}{A} \times \eta \times \frac{L}{\Delta P} \times \frac{p}{p'} \times 10^{-2}$$

where

K_g = gas permeability
A = specimen area, cm^2
L = specimen length, cm
Q = gas flow rate, cm^3/sec
η = gas viscosity, Pa-sec
P = pressure drop, MPa
p = pressure at rotameter, MPa
p' = pressure in sample, MPa

RESULTS AND DISCUSSION

Permeability measurements varied widely among trees, as well as by position within individual trees, reflecting the inherent variability of wood. Permeabilities ranged from 0.511 to 22.24 μm^2, a range that is consistent with those of other wood species (Lihre et al. 2000; Milota et al. 1995). Most of the values fell between 0.1 and 9 μm^2, suggesting that samples were relatively similar in their gas permeabilities.

Although there was wide variation between individual data, some trends were evident. Permeabilities tended to be higher just below the live crown than at breast height at each of the three cross-section positions sampled (Table 1). Permeability also tended to decrease with distance from the outer bark, a finding that implies some degree of pit occlusion associated with heartwood formation, despite the absence of a visible sapwood/heartwood interface in this species (Fig. 1). It may also be possible that the effect closer to the pith is related to the presence of juvenile wood, since juvenile wood tends to have shorter, narrower tracheids. The differences are clearly shown when the frequencies of various permeability categories are plotted by distance from the pith for samples removed at breast height (Fig. 2). Permeability distributions tended to be more skewed to the lower end in the pith and middle sections. This shift was greatest at breast height, but was evident at the base of the live crown as well. Clearly, gas permeability declines with distance inward, suggesting that, despite the absence of visible heartwood, the ability of fluids to move through western hemlock declines as the wood ages. The implications of this potentially reduced conductance are unknown.

Detecting western hemlock heartwood is difficult (Eades 1958), yet the current standards for treatment of this species are predicated on the ability to treat sapwood. We attempted to use the indicators proposed by Eades (1958), but found little difference in response across the cross section (data not shown). The American Wood Preservers' Association Standards for treatment of western hemlock lumber require a minimum penetration of 10 mm, but also require treatment of 90% of the sapwood (AWPA 1999). Our results clearly suggest that the permeability of western hemlock wood declines with distance from the surface. Although difficult to detect visually, this wood has lower permeability that could affect its ability to be acceptably treated. These results may help to explain inconsistent treatment results obtained with this species.

CONCLUSIONS

Longitudinal permeability variations with distance from the pith imply that older western hemlock wood develops heartwood-like properties that might account for variations in treatability.

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