THE SEASONAL VARIATION IN PERMEABILITY OF SOFTWOOD

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For several years, the permeability of wood has challenged researchers in the field of wood science. This property influences treating and is generally believed to be important in drying, so it has merited the effort that has gone into the research. Only recently, however, techniques for measuring liquid permeability have reached the point that they can be applied extensively to the solution of practical problems.

The first logical step after developing measuring procedures was to study some of the fundamental variables related to permeability. This paper discusses the results of a study designed to determine if green and dry permeability change from one time of the year to another. The study was conducted to answer such questions as: Is there an optimum time to fell a difficult-to-treat softwood species in order to achieve the best preservative treatment or to maximize the drying rate? Is there a seasonal variation influence that must be considered in planning future research?

Specifically, the study determined how longitudinal permeability of three Rocky Mountain species, lodgepole pine, Engelmann spruce, and Douglas-fir, varied throughout the year.

Procedures

Specimen Selection

The trees to be sampled were selected by personnel at the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. Two sets of five trees were selected for each of the three species. Set I of each species was sampled during June, July, August, and September 1967 and June, July, and August 1968. Set 2 was sampled during July and October 1967 and January, June, and August 1968.

Five evenly spaced sampling locations on the circumference of each tree were marked at both the 3-ft and 5-ft levels above the ground. The sampling locations at both the upper and lower levels of a tree were randomly assigned a particular sampling month. Station personnel bored four cores, two at the upper and two at the lower assigned location, from each tree with a 1/2-inch increment borer during the particular sampling month. The cores were bored to a depth approaching the pith.

Two of the cores, one bored at 3 feet and the other at 5 feet, were sent to the Forest Products Laboratory at Madison for permeability measurement. Each core intended for permeability measurements was sealed immediately in a glass vial filled with distilled water and shipped by airmail. The other two cores were used by Station personnel to determine green moisture content.[1]

Mechanical Preparation of Permeability Samples

Upon arrival at the Forest Products Laboratory, the vials were placed in a refrigerator at 38° F. and green permeability measurements were made within a period of 1 to 2 weeks.

Permeability specimens were cut from the increment cores with an automatic cork and stopper borer. Four permeability test plugs--outer sapwood, inner sapwood, outer heartwood, and inner heartwood--each approximately 0.250 inch in diameter and 0.35 inch in the fiber direction, were taken from a core (fig. 1).

A record was kept of the distance from the cambium to the center of the sample plug, since it has been established that permeability decreases with increased distance from the cambium (1).[2] Because of damage to the original increment core (by splitting and for various other reasons), there were 15 percent fewer permeability specimens than were originally planned. However, this does not materially affect the overall results, because of the large number of samples (over 1,000) and because the missing samples were randomly distributed throughout the study. The liquid permeability of each specimen was measured in the green condition, then the specimen was conditioned to approximately zero moisture content and the permeability to nitrogen (gas permeability) was determined.

Permeability Measurement

The general equipment and procedures used to measure gas and liquid permeability have been previously described (1, 2).

The specimen holder used for the cylindrical cores is shown in figure 2. A rubber stopper, drilled out in the center to hold the specimen, was placed in a tapered chamber. The chamber was tapered at the sides to conform to the angular bevel of the stopper. A plunger designed to apply pressure was placed on top of the stopper. When the cap for the holder was tightened, the plunger was forced against the rubber stopper. This in

[1] The moisture content information will be reported by the Rocky Mountain Station in a later paper along with a more detailed analysis of permeability variation.

[2] Underlined numbers in parentheses refer to literature cited at the end of this report.

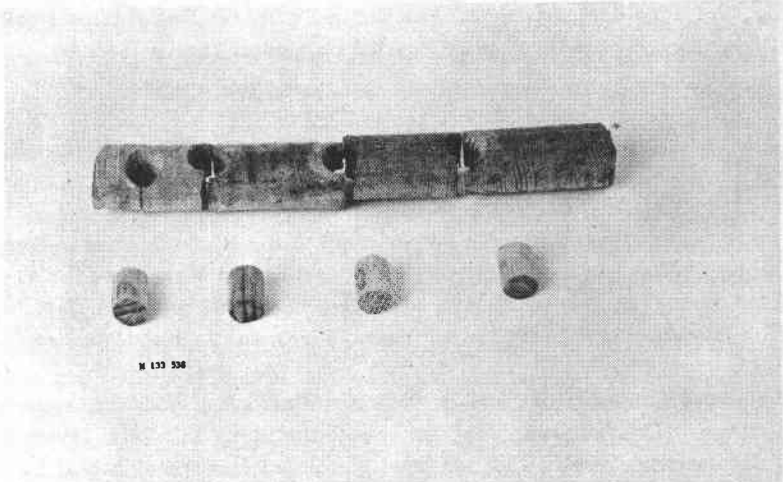
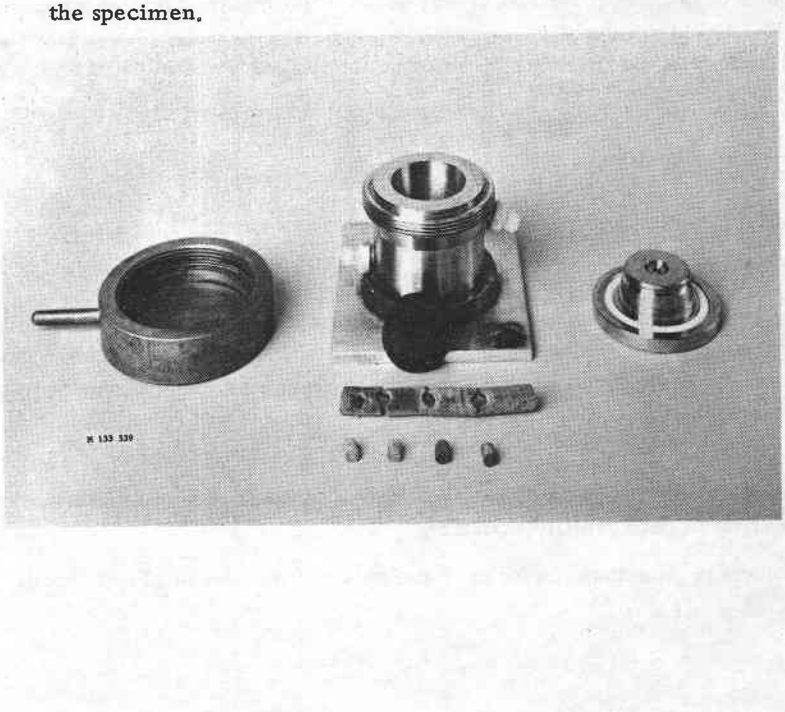


Figure 1. An increment core collected for this study and the four permeability specimens that were cut from the core.

Figure 2. Specimen holder used in this study. The specimen is placed in the hole in the rubber stopper (center), the stopper is placed in the tapered housing (upper center), the plunger (right) is placed on top of the stopper, and finally, the cap (left) is tightened on the housing to force the plunger against the stopper, thus sealing the stopper tightly around the specimen.



turn forced the stopper further down in the tapered chamber. The compression of the stopper effectively sealed the specimen so that flow was only through the wood structure, not along the sides of the specimen. Water permeability was determined over a 3-minute time interval to insure that the apparatus was working properly and that contamination of the permeating water was not a factor in the results.

A hydrostatic head was used to maintain flow through sapwood permeability plugs. A tube of plexiglass, providing a maximum head of approximately 80 centimeters of water, was used. After the liquid passed through the test cell, the flow rate was measured on a Brooks rotometer to an accuracy of ±1 percent. A calibration of the temperature effect for the flow of water in the rotometer was made at 1° C. temperature intervals to bracket the working temperature of the room.

The flow rate through heartwood was more difficult to determine because of its relatively low permeability as compared to sapwood. Consequently a graduated pipette was used in place of the rotometer. Pressure was applied to the water in the storage tanks, using nitrogen. Pressure was regulated with a standard pressure regulator on the nitrogen tank and recorded on a Bourdon gage in pounds per square inch. Flow was established by recording the time of advance of a liquid interface into the empty graduated pipette.

After the liquid permeability was measured, the specimens were dried and nitrogen gas permeability was measured. Details of the method are described by Comstock (1). The general makeup of the apparatus consisted of four parts: A nitrogen tank, a pressure measuring and regulating system, the specimen holder (fig. 2), and a series of rotometers. Gas permeability was measured at atmospheric pressure on the downstream side while maintaining a pressure drop through the specimen of approximately 40 centimeters of mercury. The gas permeability values were not corrected for slip flow. Slip flow increases gas permeability slightly (2) but this effect is not of sufficient magnitude to be of importance in this study.

Results

Tables 1 and 2 and figures 3 through 8, summarize the results. Table 1 compares the average gas permeability of the three species in the outer and inner sapwood and the heartwood over the 2-year period. Outer and inner heartwood were combined because there was no apparent difference in the two locations. Table 2 makes the same comparison for liquid permeability results. Figures 3, 4, and 5 show the gas permeability of sapwood and heartwood for the three species at various times. Figures 6, 7, and 8 show the liquid permeability of inner and outer sapwood as a function of time. The liquid permeability of heartwood is not plotted because the measured values were so low that no seasonal trend (if it did exist) could be detected.

Discussion and Conclusion

From a practical point of view, the major result of this study is that there was no significant seasonal variation in the liquid or gas permeability of the three species during the 2 years of the study. Certainly there is considerable variation, but time of year does not appear to be a factor. For these species, at least, it appears that the reports of seasonal variations in drying and treating properties must result from some other cause.

A possible cause is indicated by the large difference between the liquid and gas permeability of the sapwood, tables 1 and 2. The liquid permeability is a measure of the permeability of undried material. The gas permeability is a measure of permeability of dry wood. The permeability of the sapwood of softwoods decreases greatly when dried below the fiber saturation point (ref. 3 and tables 1 and 2). Therefore, if logs are stored during a certain season of the year so that a part of the sapwood dries below the fiber-saturation point, a producer might logically conclude that seasonal variation in permeability caused poor treating. However, partial drying of the sapwood and the subsequent reduction in permeability could have caused the poor treating.

References

1. Comstock, G. L. 1965. Longitudinal permeability of green eastern hemlock. Forest Prod. J. 15(10): 441-449.

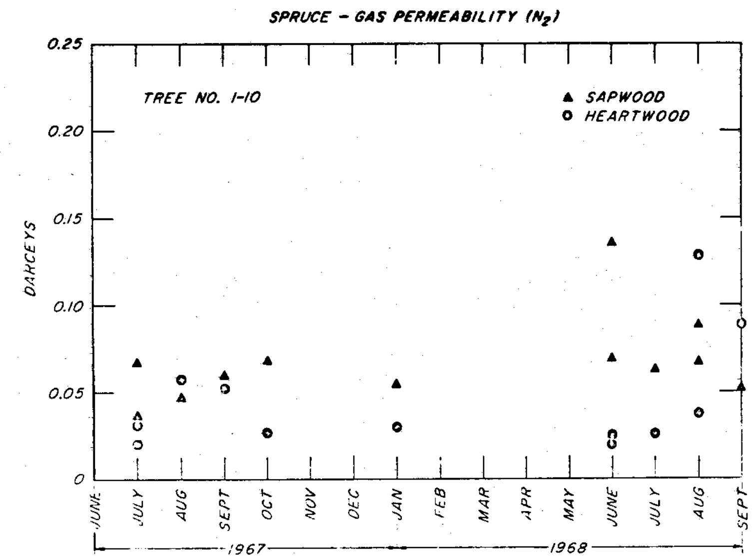


Figure 3. The longitudinal permeability of Englemann spruce. Each point represents 20 samples (less broken specimens). Data from both sets of trees are shown. Trees 1-5 are set 1 and trees 6-10 are set 2.

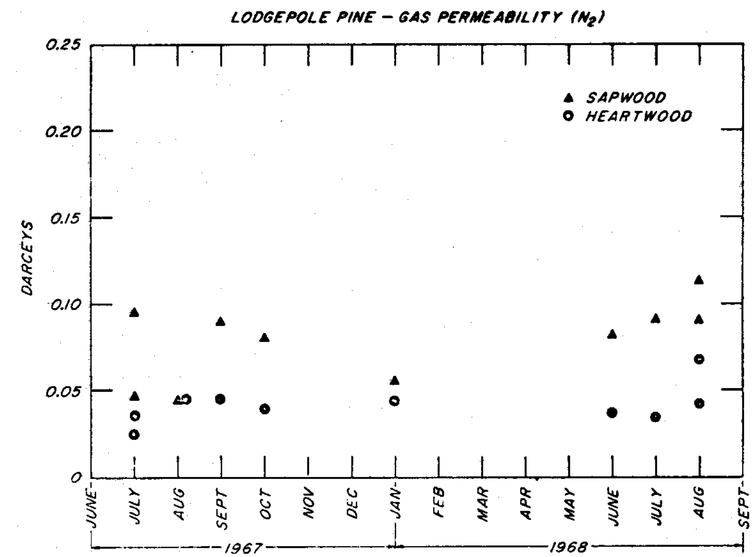


Figure 4. The longitudinal gas permeability of lodgepole pine. Each point represents 20 samples (less broken specimens). Data from both sets of trees are shown. Trees 1-5 are set 1 and trees 6-10 are set 2.

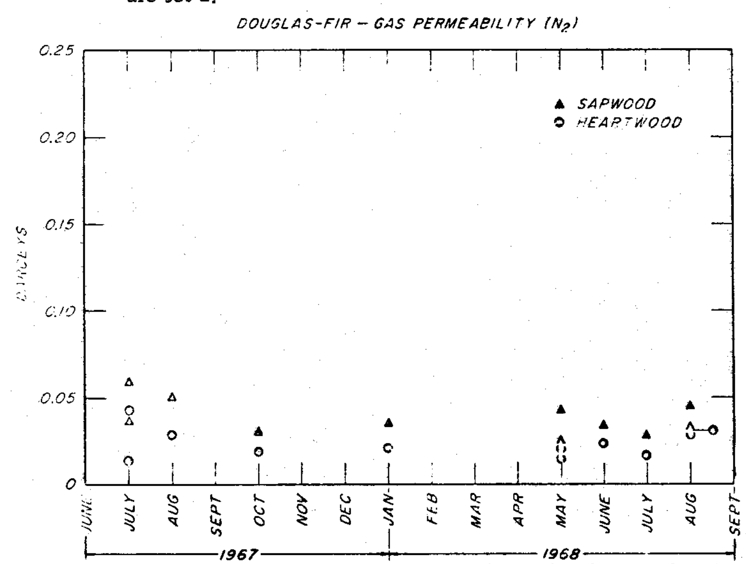


Figure 5. The longitudinal gas permeability of Douglas-fir. Each point represents 20 samples (less broken specimens). Data from both sets of trees are shown. Trees 1-5 are set 1 and trees 6-10 are set 2.

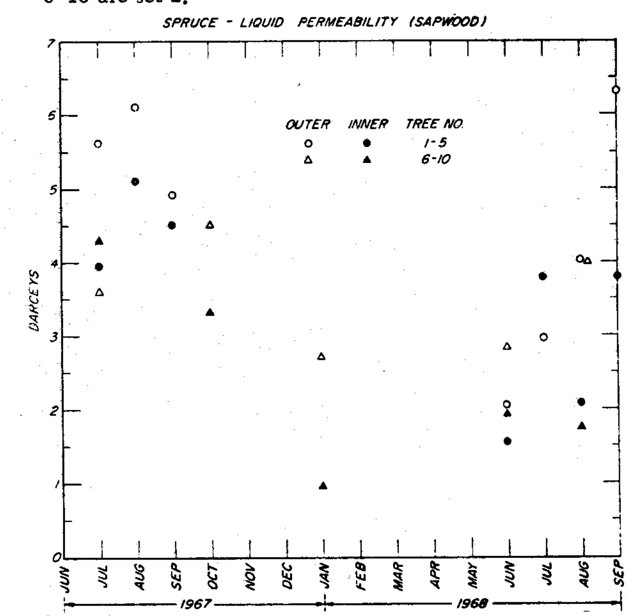


Figure 6. The longitudinal liquid permeability of Englemann spruce sapwood. Each point represents 10 samples (less broken specimens). Data from both sets of trees are shown.

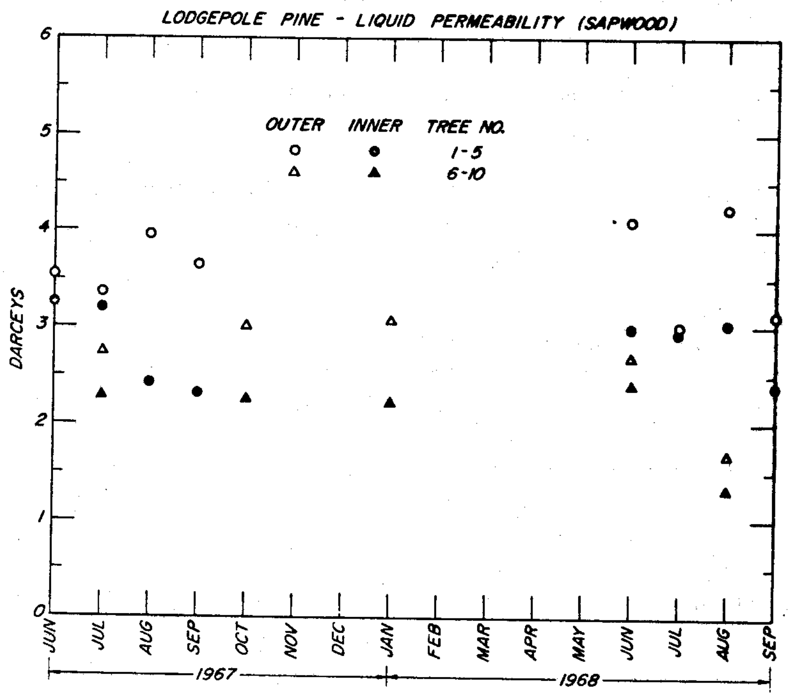


Figure 7. The longitudinal liquid permeability of lodgepole pine sapwood. Each point represents 10 samples (less broken specimens). Data from both sets of trees are shown.

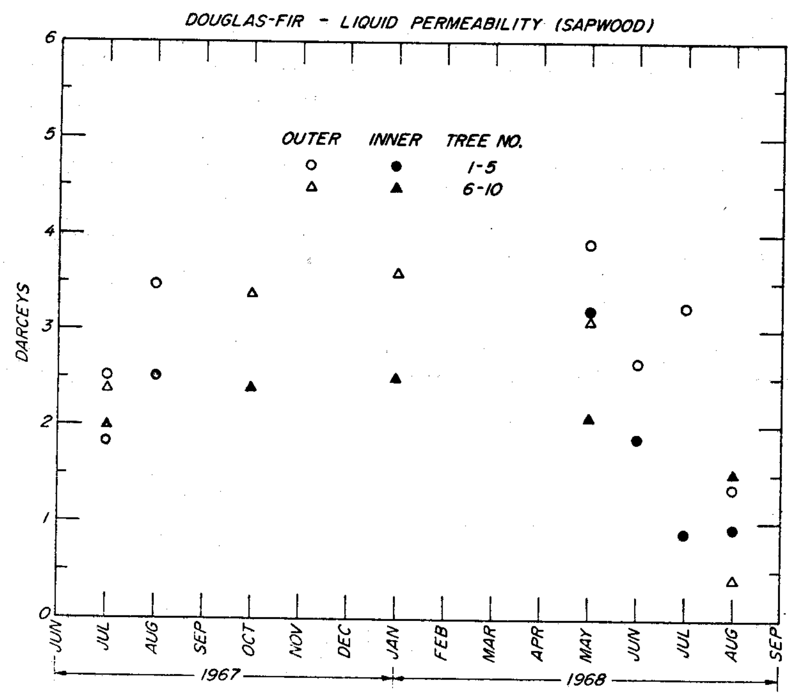


Figure 8. The longitudinal liquid permeability of Douglas-fir sapwood. Each point represents 10 samples (less broken specimens). Data from both sets of trees are shown.

2. ______________ 1967. Longitudinal permeability of wood to gases and nonswelling liquid. Forest Prod. J. 17(10): 41-46. Oct.

3. ______________ 1968. Relationship between permeability of green and dry eastern hemlock. Forest Prod. J. 18(8): 20-23. Aug.

4. ______________, and Côté, W. A., Jr. 1968. Factors affecting permeability and pit aspiration in coniferous sapwood. Wood Sci. and Tech. Vol. 2, pp. 279-291.

Table 1. Gas permeability (dry condition)

Portion	Lodgepole pine	Douglas-fir	Spruce
	Darceys*	Darceys	Darceys
Sapwood, outer	0.086	0.046	0.070
Sapwood, inner	.066	.040	.048
Heartwood	.040	.024	.041

* Darcey is a measure of liquid or gas permeability of a material, such as wood.

Table 2. Summary--liquid permeability (green condition)

Portion	Lodgepole pine	Douglas-fir	Spruce
	Darceys	Darceys	Darceys
Sapwood, outer	3.121	2.637	3.862
Sapwood, inner	2.838	1.992	2.850
Heartwood	.002	.006	.023