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Moisture Distributions in Western Hemlock Lumber From Trees Harvested Near Sitka, Alaska

David L. Nicholls, Allen M. Brackley, and Travis Allen[1 2]

Abstract

Western hemlock *(Tsuga heterophylla)* can be characterized by localized regions of high-moisture-content wood, often referred to as wet pockets, and uneven drying conditions may occur when lumber of higher and lower moisture content is mixed together in a dry kiln. The primary objective of this preliminary study was to characterize the frequency and extent of wet pockets (wetwood) in western hemlock lumber sawn from trees harvested near Sitka, Alaska. Nine western hemlock logs were sampled from three trees, ranging in diameter from approximately 10 to 18 inches. Forty-five boards were processed, yielding 225 samples.

Sample moisture content ranged from 31.4 percent to 149.7 percent (as a percentage of oven-dry wood weight), with a standard deviation of 30.6 percent. There was no significant moisture variation among sample heights for the three western hemlock trees included in this study. Average moisture content at a given height ranged from about 70 to 85 percent. Moisture contents of approximately 50 percent were not uncommon for pith-centered samples, whereas most samples more than 5 inches from the pith were typically at least 100-percent moisture content. There was considerable variation in overall moisture content among trees, ranging from about 69 to more than 85 percent. Moisture content variation among butt logs was also considerable, ranging from about 58 to 95 percent.

Keywords:Western hemlock, *Tsuga heterophylla*, lumber, drying, sawmill, moisture content, Alaska.

Introduction and Research Objectives

Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) is a primary commercial softwood in southeast Alaska, accounting for close to 60 percent of the region's timber (Alaska Department of Community and Economic Development, n.d.). Western hemlock can be characterized by localized regions of high-moisture-content wood, often referred to as wet pockets, or wetwood. Wetwood develops in living trees as a result of bacterial infections and causes boards to have higher initial moisture content, be slower drying, and be more susceptible to drying defects (Ward and Pong 1980).

[1] **David L. Nicholls** is a forest products technologist and **Travis Allen** was a forest products technologist, USDA Forest Service, Pacific Northwest Research Station, Alaska Wood Utilization Research and Development Center, 204 Siginaka Way, Sitka, AK 99835-7316; **Allen M. Brackley** is a coordinator, Forest Products Applied Research, Extension, and Education Program, University of Alaska Southeast-Sitka, 1332 Seward Avenue, Sitka, AK 99835. Travis Allen is currently an undergraduate student, Wood Science and Technology, College of Natural Sciences, Forestry, and Agriculture, University of Maine, Orono, ME 04469.

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Considerable variations in moisture content may also be found between normal heartwood and sapwood in western hemlock and other species (Forest Products Laboratory 1999). Uneven drying conditions may occur when lumber of higher and lower moisture content is mixed together in a dry kiln, or when an individual board has significant moisture content variation from end to end. The result can be warping, checking, and other degrade that can reduce lumber value.

This research project is viewed as a first step in developing kiln drying schedules for western hemlock in southeast Alaska. Lumber that is grouped together according to green moisture content can reduce the likelihood of defects resulting from uneven drying. Alternatively, separate drying schedules could be developed for lumber having uniformly high moisture content that would not require sorting prior to drying.

The primary objective of this preliminary study was to characterize the frequency and extent of wet pockets in western hemlock lumber sawn from trees harvested near Sitka, Alaska. It is recognized that as a small sample was obtained from a limited geographic area, these study results should not be used to make inferences about western hemlock from larger geographic areas.

Background and Literature Review

Schroeder and Kozlik (1972) characterized wetwood in western hemlock and found that it can differ from normal heartwood by its higher specific gravity, higher extractives content, and lower permeability. The viewpoint was presented that wetwood originates from a physical injury that in turn leads to additional extractives being deposited. All of these factors point to property differences of wetwood that could lead to difficulties when kiln drying lumber. Lumber drying times, rates, and final moisture content can also be influenced by the presence of wetwood (Ward 1986).

Wetwood regions in the heartwood of fir trees in Greece were measured and evaluated for a number of properties, including color, moisture content, and rate of drying (Passialis and Tsoumis 1984). Wetwood was found in young fir trees, starting at age 10 to 15 years. Schneider and Zhou (1989) evaluated balsam fir (*Abies balsamea* (L.) Mill.) wetwood from four trees. Moisture content of wetwood was generally comparable to sapwood and was higher than that of normal heartwood. The extractives content of wetwood was found to be intermediate between sapwood and normal heartwood.

A moisture content evaluation of softwoods from Maine indicated significant moisture differences between butt, midpoint, and top sections of balsam fir and eastern spruce logs (Shottafer and Brackley 1982). High-moisture regions have been identified in old-growth and young-growth western hemlock, often referred to as sinker heartwood, and can have moisture contents up to 200 percent (as a percentage of oven-dry wood weight), requiring 30 to 40 percent additional drying time compared with normal wood (Kozlik and Ward 1981).

Wetwood also can be found in young-growth or precommercially thinned stands of western hemlock (Shaw et al. 1995). In this study in coastal Washington, study trees ranged in age from 17 to 35 years and had been thinned 5 to 17 years previously. Wetwood was present in more than 50 percent of the 1,215 trees examined, and in some stands was found in 80 percent of the trees studied.

Wetwood can differ from normal wood in its fiber saturation point and electrical resistance (Ward 1984). An important contributing factor is the presence of bacteria in wetwood. Fiber saturation point differences between wetwood and normal wood point to a need for accurate moisture content measurements during kiln drying. Wetwood also can influence lumber manufacturing and processing operations (Pong and Ward 1979). Ring shake, frost cracks, lumber checking, and collapse were all identified as characteristics of wetwood that could contribute to losses in product volume and value.

Several research studies have explored the benefits of sorting softwood lumber prior to drying, including southern pine lumber (Taylor and So 1990), grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.) lumber (Wagner et al. 1996), and white fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.) lumber (Ward and Shedd 1981). Moisture uniformity of grand fir boards could be improved by presorting boards based upon weight, while also reducing drying times for lower moisture boards. For white fir lumber, it was recommended that boards be sorted into three groups: sapwood, heartwood, and wetwood (Ward and Shedd 1981). One drawback of presorting was identified—boards would need to be examined on both faces (top and bottom), and this would be difficult to accomplish under high production mill conditions. Another method of identifying wetwood—resistance to pulsed electric current—also was explored in this study.

Procedures

Experimental Design

Nine western hemlock logs were sampled from three trees that had been harvested near Sitka, Alaska, in November 2001. The logs were stored outside until being sawn into lumber in June 2002. Log diameter ranged from approximately 10 to 18 inches (small end, inside bark).

Logs were either 12 feet in length (butt logs) or 10 feet (second- and third-position logs), resulting in moisture-content information to a height of 32 feet above the cut stump. Forty-five boards were processed at a sawmill site in Sitka, Alaska. For each board, moisture-content samples were sawn at 2-foot intervals, resulting in 5 samples per board, for a total of 225 samples.

All logs were sawn on a portable sawmill that consisted of two horizontal blades and one vertical blade. Board width was determined by the distance setting between horizontal blades (and ranged from 4 to 10 inches). Board thickness was determined by the distance advanced by the vertical sawblade between each cut (target of 1.5 inches for all boards). With this type of sawmill, logs are clamped in place before being sawn and remain stationary until sawing is completed.

Four to six boards were sampled from each log, based primarily on log diameter (table 1). For each log we tried to obtain at least one board near or encompassing the pith and at least one board close to the bark. Radial distance from the pith was estimated visually for each board as the distance from the center of the board to the pith. No attempt was made to classify boards as being sawn from heartwood versus sapwood regions.

Sample Preparation and Oven Drying

Moisture-content samples were cut from boards within 1 hour of sawing. Most samples were about 5 to 6 inches long (representing the distance along the grain), and the sample width varied according to board width, from 4 to 10 inches. Samples were placed into plastic bags and sealed immediately after sawing, and green sample weights were taken 1 to 2 days later.

All samples were dried at approximately 103 °C for close to 5 days in forced air convection ovens, in accordance with method B, ASTM standard D4442-92 (American Society for Testing and Materials 2001). This oven-drying period had been verified as adequate during trial runs, even for the widest (i.e., heaviest) samples to stabilize at

Table 1—Experimental design for moisture content evaluation of samples obtained from three western hemlock trees harvested near Sitka, Alaska

	Log 1 (butt log)		Log 2 (middle)		Log 3 (upper)	
	Number of boards	Number of MC[a] samples	Number of boards	Number of MC[a] samples	Number of boards	Number of MC[a] samples
Tree 1	5	25	5	25	4	20
Tree 2	6	30	5	25	5	25
Tree 3	5	25	5	25	5	25

[a] Moisture-content samples.

oven-dry weight. Since oven-drying space was a limiting factor, many samples experienced some air drying (up to 1 month) while waiting to be oven dried. The 5-day oven-drying period was maintained throughout the study even though it was likely that the air-dried samples would have reached oven-dry conditions more quickly.

Statistical Evaluations

Single-factor Analysis of Variance (ANOVA) tests were performed to determine differences in sample means between trees (trees 1, 2, 3) and also between logs (butt log, middle log, top log). Single-factor ANOVA also was used to evaluate moisture-content differences with height. T-tests for two samples, assuming equal variances, were performed to identify any significantly different sample means.

Results and Discussion

Overall Moisture Content

The overall moisture content of all samples (approximately 78 percent) was close to the values identified in the Forest Products Laboratory's Wood Handbook (1999) for western hemlock heartwood (85 percent moisture content) (table 2). Given the relatively small log diameters and the presence of sapwood (which is expected to have considerably higher moisture content than heartwood), it was surprising that the overall moisture levels were not higher.

Maximum moisture content in lumber is important because of its influence in controlling kiln-drying schedules. From a practical standpoint, when determining kiln schedules, the largest number of moisture samples should be selected from the slowest drying material (Simpson 1991). The highest moisture content in our sample (approximately 150 percent) was still less than the reference value for western hemlock sapwood (170 percent). It is possible that the 7-month period between harvest and sawing contributed to the relatively low moisture content.

Moisture Content Variations With Height Above Ground

There was no significant moisture variation among sample heights for the three western hemlock trees sampled. Average moisture content at a given height varied within a fairly narrow range (from about 70 to 85 percent), up to the highest position of 32 feet above the base of the butt log (fig. 1). There was no statistically significant difference in average moisture content among heights. The standard deviation of moisture content remained fairly uniform at different heights (fig. 1).

Moisture Content Variations With Distance From Pith

Moisture content tended to increase as distance from the pith increased. This would be expected as the sapwood regions of high moisture are located farthest from the pith. In western hemlock, sapwood moisture content is typically about twice that of heartwood (table 2).

Table 2—Overall moisture content of 225 samples from three western hemlock trees harvested near Sitka, Alaska

	Percent
Average moisture content:	78.4
Minimum	31.4
Maximum	149.7
Standard deviation	30.6
Reference value for moisture content:	
Western hemlock sapwood	170
Western hemlock heartwood	85

Source: Forest Products Laboratory 1999.

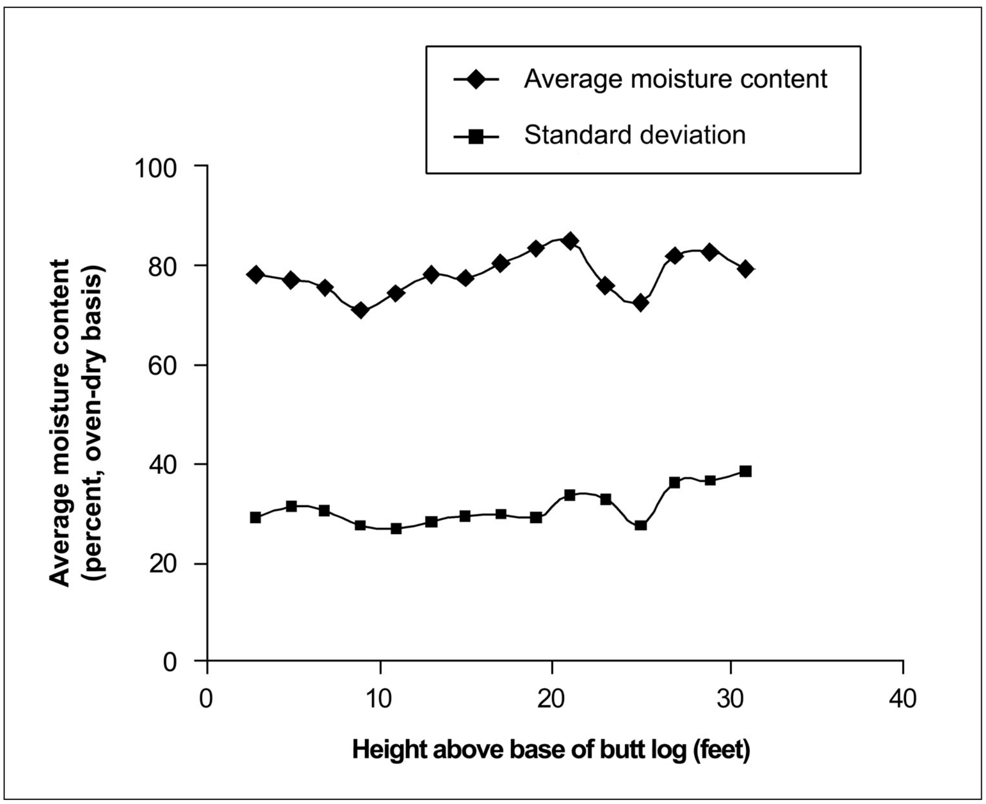

Figure 1—Moisture content versus height above base of butt log for lumber samples from three western hemlock trees harvested near Sitka, Alaska.

In this study, moisture contents of approximately 50 percent (oven-dry basis) were not uncommon for pith-centered samples, whereas most samples more than 5 inches from the pith were typically at least 100-percent moisture content (fig. 2). Because log diameter ranged from about 10 to 18 inches, samples obtained at a given distance from the pith could have been either heartwood or sapwood, depending on log size.

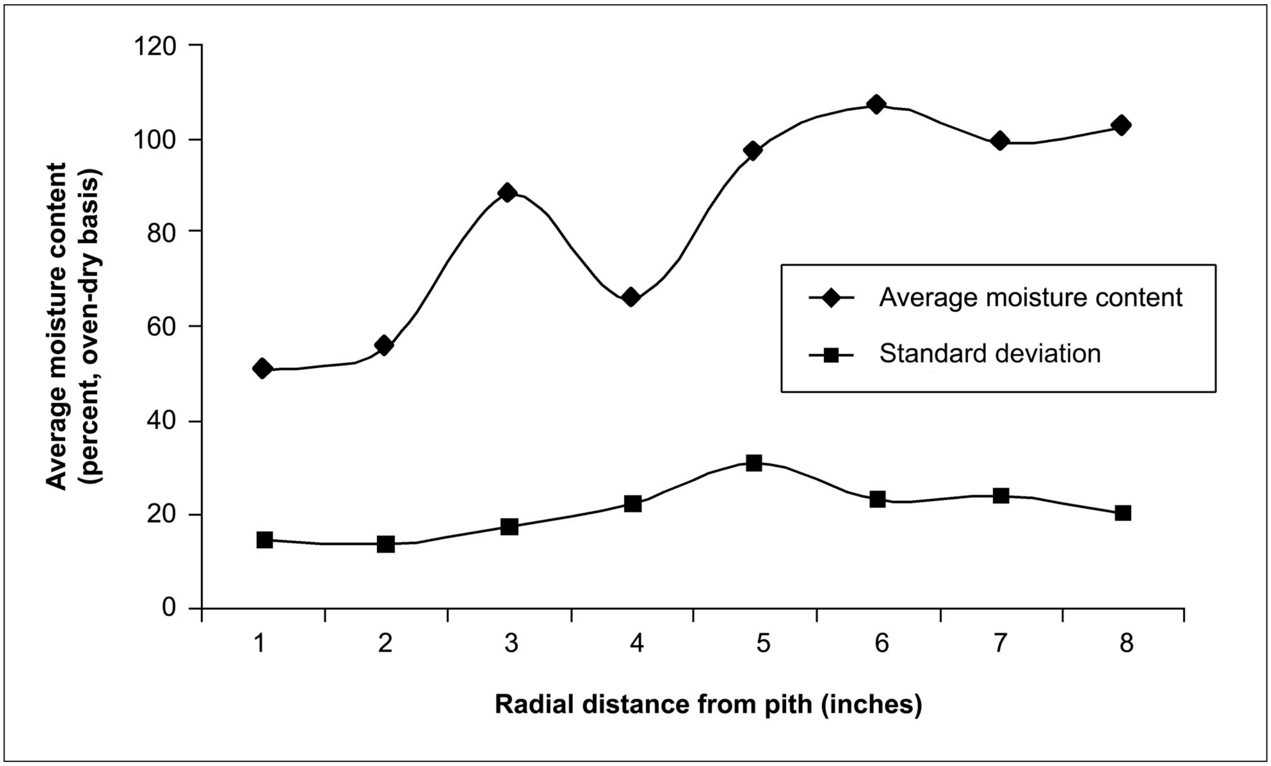

Figure 2—Average moisture content versus radial distance from pith for lumber samples from three western hemlock trees harvested near Sitka, Alaska.

Mean moisture content was considerably less for pith-centered samples than for most outer locations (fig. 2). The number of samples obtained 2 and 3 inches from the pith was considerably lower than from other radial positions (table 3). This small sample size could have influenced the general trends observed in average moisture content within the first 4 inches of the pith (fig 2). The general trends observed were consistent with published moisture content values for western hemlock sapwood and heartwood (table 2), although overall values of our samples were somewhat lower. The standard deviation of moisture content remained fairly uniform at different distances from the pith (fig. 2).

Moisture Content Variations Between Trees and Between Logs

There was considerable variation in moisture content among trees, ranging from about 69 percent to more than 85 percent (table 4). The overall moisture content for tree 1 was lower, and was statistically different from trees 2 and 3. Moisture content variation among butt logs was also considerable, with average values ranging from about 58 to 95 percent. There was relatively little moisture content variation between logs in the second and third positions (i.e., logs cut from higher portions of the stem). There was no statistically significant difference in average moisture content between log positions (table 4).

Conclusions

Overall moisture content from this limited sample of western hemlock logs was somewhat lower than reference values for western hemlock heartwood and sapwood. Differences in butt log moisture content between trees 1 and 2 led to statistically

Table 3—Moisture content for pith-centered lumber samples versus other lumber samples from three western hemlock trees harvested near Sitka, Alaska

	Distance from pith (inches)							
	0	2	3	4	5	6	7	9
Average moisture content (percent, oven-dry basis)	50.4	55.6	87.9	65.9	97.2	106.7	99.1	102.3
Number of samples	45	15	15	55	40	30	10	14

Table 4—Average moisture content (oven-dry basis), by tree and by log, for samples obtained from three western hemlock trees harvested near Sitka, Alaska

	Log 1 (butt)	Log 2 (middle)	Log 3 (upper)	Average[a]
		Percent		
Tree 1	57.80	75.07	75.08	68.91 (a)
Tree 2	94.82	81.71	78.80	85.60 (b)
Tree 3	70.48	86.77	81.59	79.61 (b)
Average[b]	75.40 (a)	81.19 (a)	78.73 (a)	78.38

[a] Tree averages having different letters are significantly different at the 0.05 significance level.
[b] Log averages having different letters are significantly different at the 0.05 significance level.

significant differences in average moisture content between these trees. Because the butt logs showed considerable between-log moisture variations (whereas higher logs generally did not), this study suggests that most attention should be given to lumber sawn from butt logs. This could be important when considering strategies for sorting lumber by moisture content or when developing specialized kiln schedules.

No significant moisture-content differences were observed among logs at a given position (butt log, middle log, upper log). Sapwood moisture content was considerably higher than heartwood moisture, as expected, and maximum moisture contents generally were reached at about 5 inches from the pith.

These results would suggest that moisture-content variations associated with wet pockets were not an important factor in this sample; accurately determining the size of wet-pocket regions, however, was not within the scope of this study. Factors likely to warrant greater attention for lumber manufacturing and drying facilities would be radial position from pith and properties of butt logs.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	.3048	Meters

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Pacific Northwest Research Station
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