



United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

General Technical Report
PNW-GTR-782
March 2009



House Log Drying Rates in Southeast Alaska for Covered and Uncovered Softwood Logs

David Nicholls and Allen Brackley



The Forest Service of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, 1400 Independence Avenue, SW, Washington, DC 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Authors

David Nicholls is a forest products technologist and **Allen Brackley** is a research forester, Alaska Wood Utilization Research and Development Center, 204 Siginaka Way, Sitka, AK 99835.

Abstract

Nicholls, David; Brackley, Allen. 2008. House log drying rates in southeast Alaska for covered and uncovered softwood logs. Gen. Tech. Rep. PNW-GTR-782. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

Log moisture content has an important impact on many aspects of log home construction, including log processing, transportation costs, and dimensional stability in use. Air-drying times for house logs from freshly harvested trees can depend on numerous factors including initial moisture content, log diameter, bark condition, and environmental conditions during drying. In this study, we evaluated air-drying properties of young-growth Sitka spruce (*Picea sitchensis* (Bong.) Carr) and of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) from logs harvested in southeast Alaska. For each species, we considered inside storage in a warehouse vs. outside storage, as well as debarked logs vs. logs with bark remaining, resulting in four experimental treatments. We considered moisture losses after 8 and 12 months of air drying. There was considerable moisture loss for Sitka spruce logs, and much of the drying occurred during the first 8 months. Fastest drying rates for both species were for peeled logs with inside storage. Western hemlock logs showed higher moisture content and greater moisture content variation (vs. Sitka spruce), and in most cases would require additional drying beyond the 12-month study period to produce satisfactory house logs. Results of this study are significant because they can help entrepreneurs determine appropriate levels of capital investment (e.g., land, covered storage, debarking equipment), as well as whether to dry and process logs in southeast Alaska vs. some other location. This study found that a leading option for local producers would be to peel Sitka spruce logs, then air dry indoors for between 8 and 12 months. Another effective strategy would be to peel western hemlock logs, then air dry indoors for 12 months.

Keywords: Sitka spruce, western hemlock, moisture content, air drying.

Introduction

Large acreages of second-growth timber in southeast Alaska, originally harvested during the pulp mill era (approximately from the 1950s through the 1990s), are now reaching commercial size. Thinned stands can result in greater forest productivity and enhanced wildlife benefits and provide economic value from wood products, including sawn lumber, round wood, and biomass. Thinning can be an important means of influencing stand development while increasing the volume, size, and quality of wood produced from forests. Thinning can also help develop stand structures and characteristics for other values, such as wildlife or aesthetics (Duncan 2002). Within mixed stands of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr), as found in southeast Alaska, the ratio of western hemlock to other species can be an important factor determining tree response to thinnings (Graham et al. 1985).

In many cases, thinnings can yield some merchantable material, but not generate product revenues sufficient to cover harvesting costs (Fight et al. 2004). Precommercial thinnings can be conducted to redistribute growth to remaining stems and assist crown development of crop trees early in rotations. This can allow mixed stands of western hemlock and Sitka spruce to reach commercial size in as little as 25 to 30 years (Greene and Emmingham 1986). In southeast Alaska, important timber management goals are to enhance wildlife habitat in second-growth softwood stands while also improving stand quality. During fiscal years 2004 through 2007, an average of 5,449 acres per year were precommercially thinned in the Tongass National Forest.¹

Timber production in southeast Alaska will likely encompass a range of products types, including round logs and rough sawn green lumber for both domestic and export markets (Brackley et al. 2006). Log home construction is one potentially important use of round logs from thinned second-growth stands. An important distinction between round logs for export markets vs. round logs for log home construction is the potential for some degree of value-added processing with the latter. This could include log drying, bark removal, pre-assembly operations (such as cutting notches), log turning, or complete assembly of log home kits, all or part of which could take place within Alaska.

Log moisture content (MC) has an important impact on transportation costs and the in-service performance and durability of log homes (including dimensional stability). Therefore, it is worth exploring the feasibility of drying logs

Log moisture content has an important impact on transportation costs and the in-service performance and durability of log homes.

¹ Spores, S. 2008. Personal communication. Forest silviculturist, Tongass National Forest, 648 Mission Street, Ketchikan, AK 99901.

shortly after harvest. Air-drying times for house logs from freshly harvested trees can depend on numerous factors:

- Initial and final MC
- Species
- Wood specific gravity
- Log diameter
- Presence of defects (including knots) in logs
- Drying season (summer vs. winter)
- Other weather-related variables (including local wind direction, windspeed, and log orientation with respect to prevailing wind and rain)
- Debarked logs vs. bark remaining
- Stacking arrangement of logs
- Covered or uncovered logs.

Timbers can be dried by a number of different methods including conventional dry kilns, predryers, fan sheds, or air drying. Often, a tradeoff exists between capital investment and drying time. For example, a capital-intensive dry kiln could be used to dry logs quickly, whereas an air-drying yard (requiring little or no capital investment) would dry logs less quickly. When drying house logs and cants in conventional dry kilns (Gorman and Steinhagen 1992) and in radio frequency/vacuum kilns (Kang et al. 2004), a concern is the development of visible checks and v-cracks that could diminish the appearance of the finished product. Thus, an objective of the current study is to determine whether satisfactory air-drying rates can be obtained in southeast Alaska without the need for any dry kiln equipment purchases, while still maintaining satisfactory log appearances.

In this study, we evaluate outdoor air-drying conditions and rate of moisture loss of Sitka spruce and western hemlock logs in open air conditions vs. covered conditions, over a period of about 12 months in Ketchikan, Alaska. Knowledge gained could allow economic use of softwood logs from second-growth stands within the Tongass National Forest. Accurate information regarding log drying rates could assist wood products managers in deciding whether to:

- Invest in dry kilns, predryers, and/or heated buildings
- Dry logs in the debarked condition (vs. bark remaining)
- Ship logs to export destinations in the green condition vs. air-dried condition
- Consider additional value-added processing of logs within Alaska (such as log home kits).

Background and Literature Review

Wood exchanges moisture with the surrounding air. If stored in a specific location, the moisture content of the wood material will come into equilibrium with the climatic conditions to which it is exposed. This condition is called equilibrium moisture content (EMC) and it can either be determined by referencing published tables in wood science texts and research papers, or by calculations based on the relative humidity and temperature of the location (Simpson 1998, USDA FS 1999). For example, an EMC of 12 percent (ovendry basis) is obtained by constant exposure to climatic conditions of 65 °F and a relative humidity of 65 percent. At 65 °F, a relative humidity above 65 percent will result in an EMC greater than 12 percent, and at relative humidity levels below 65 percent, the EMC will be lower. Likewise, if relative humidity is constant at 65 percent, temperatures above 65 °F will result in equilibrium at lower moisture contents, whereas temperatures below 65 °F will result in higher EMCs.

The potential for drying wood in outdoor locations in southeast Alaska is limited by a climate that is characterized by high rainfall and humidity, when compared to other regions of the country. The EMC of wood in Juneau, Alaska (about 150 miles north of Ketchikan, Alaska), varies seasonally from about 13.5 percent to more than 18 percent. During this study, the calculated monthly average EMC at Ketchikan Airport was even higher, ranging from 17.2 to 22.5 percent (table 1).

Table 1—Equilibrium moisture content of wood, exposed to outdoor atmosphere, Juneau and Ketchikan, Alaska

Month	Equilibrium moisture content	
	Juneau	Ketchikan
January	16.5	22.5
February	16.0	21.0
March	15.1	20.8
April	13.9	19.7
May	13.6	17.2
June	13.9	17.6
July	15.1	18.3
August	16.5	19.8
September	18.1	22.1
October	18.0	21.9
November	17.7	18.3
December	18.1	22.0

Source of Juneau data: Simpson 1998 (year of data collection not reported).

Source of Ketchikan data: Weather-warehouse 2007 (calculated by using 2006 and 2007 weather data in the procedures published in Simpson 1998).

Wood “chunks” have been found to dry relatively quickly during as little as 60 days of outdoor exposure in northern Michigan (Sturos 1984). Aspen (*Populus* spp.) chunks dried from more than 50 percent MC (green basis) to less than 20 percent MC (green basis). Moisture loss for sugar maple (*Acer saccharum* Marsh.) chunk drying was not as pronounced.

Small-diameter logs from ponderosa pine (*Pinus ponderosa* Dougl. ex Laws) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), air-dried in Hayfork, California, also showed the greatest moisture loss during the first 60 days of drying (Simpson and Wang 2004). When small-diameter ponderosa pine logs were air dried during summer months, MC decreased from about 130 percent to about 20 percent (ovendry basis) in only 20 days. During winter air-drying, approximately the same moisture loss was realized in about 4.5 months (Simpson and Wang 2004). Similar trends were noted for Douglas-fir logs (i.e., air-drying periods were considerably longer during winter months, when drying started in October). The Hayfork study used multiple linear regression to fit experimental data to drying curves. Faster drying conditions would be expected in the Hayfork study (vs. Ketchikan) owing to the relatively dryer climate and use of smaller diameter, debarked logs.

Similar air-drying studies have also been completed in New Mexico and Arizona (USDA FS 2000). Primary results from this series of air-drying tests on small-diameter logs in arid locations include:

- On average, peeled logs lost roughly 2.5 percent MC per day (at moistures above fiber saturation)
- Moisture content loss below fiber saturation content was much slower (dropping from about 35 percent to 15 percent MC over a 2-month period)
- Unpeeled logs dried at only one-tenth the rate of peeled logs (i.e., no bark remaining).

For short-term air-drying studies, the starting date can be an important consideration. Simpson and Hart (2000) indicated air drying times for thick lumber ranging from less than 2 months to greater than 9 months, depending on whether drying starting during summer or autumn. Here, final MC was 20 percent. In the current study, we avoid seasonal drying variations by considering a 12-month study period.

The importance of bark in influencing drying times was also demonstrated with aspen logs (Defo and Brunette 2006). Here, a simulated log drying model predicted one-third the drying time when all the bark was removed from the logs (vs. all bark remaining).

Green MC (i.e., the MC of freshly cut wood) can differ considerably by species. Of the two primary softwoods on Prince of Wales Island in Alaska, western hemlock had higher average green MC than Sitka spruce (table 2). An evaluation of nine western hemlock logs from three trees harvested near Sitka, Alaska, found that local MC ranged from about 31 percent to about 150 percent MC (ovendry basis) (Nicholls and Brackley 2003). There were no significant differences in average MC between sample heights (i.e., height above ground) for the trees evaluated in this study. However, average MCs at 9 inches from the pith were almost twice that at the pith (Nicholls and Brackley 2003).

Western hemlock had higher average green moisture content than Sitka spruce.

Table 2—Average moisture content of green wood for western hemlock and Sitka spruce

Species	Average moisture content	
	Heartwood	Sapwood
	<i>Percent (ovendry basis)</i>	
Western hemlock	85	170
Sitka spruce	41	142

Source: USDA FS 1999.

Table 2 indicates the importance of sapwood content in influencing MC for both western hemlock and Sitka spruce. This factor can be especially important for smaller diameter second-growth stems having relatively high proportions of sapwood.

Procedures

Log Harvesting and Transportation

Our research material for air-drying consisted of a total of 80 bucked logs, all 16 feet in length (40 logs of Sitka spruce and 40 logs of western hemlock). This material was derived from a total of 40 full-length logs (20 logs of Sitka spruce and 20 logs of western hemlock), all having in-woods lengths of 34 feet. Logs were obtained from trees harvested within the Maybeso Experimental Forest, Tongass National Forest, Alaska. The harvest site was within about 2 miles of the community of Hollis, Alaska, on Prince of Wales Island (about 20 miles east of Craig, Alaska). The harvest site was on flat terrain, at an elevation of about 200 to 300 feet above sea level. Stand age was about 50 to 60 years old, and the forest type was even-aged Sitka spruce and western hemlock.²

²Lawton, G. 2008. Personal communication. Supervisory forester, Tongass National Forest, Craig Ranger District, P.O. Box 500, Craig, AK 99921.

Logs were cut to an 8-inch small-end diameter, and large-end diameter varied depending on natural stem taper. Large-end, inside bark log diameters ranged from 10.1 inches to 18.3 inches, with the largest concentration between 12 and 13 inches (fig. 1). Log ends were coated with a commercial wax and water emulsion end sealer immediately after harvest to minimize moisture losses during transit. Logs were then barged to Ketchikan, Alaska, where they were transported by truck to the air-drying yard. The initial MCs and log weights were taken about 3 weeks after harvest. This amount of time was needed for ground transportation on Prince of Wales Island, followed by barging to Ketchikan.

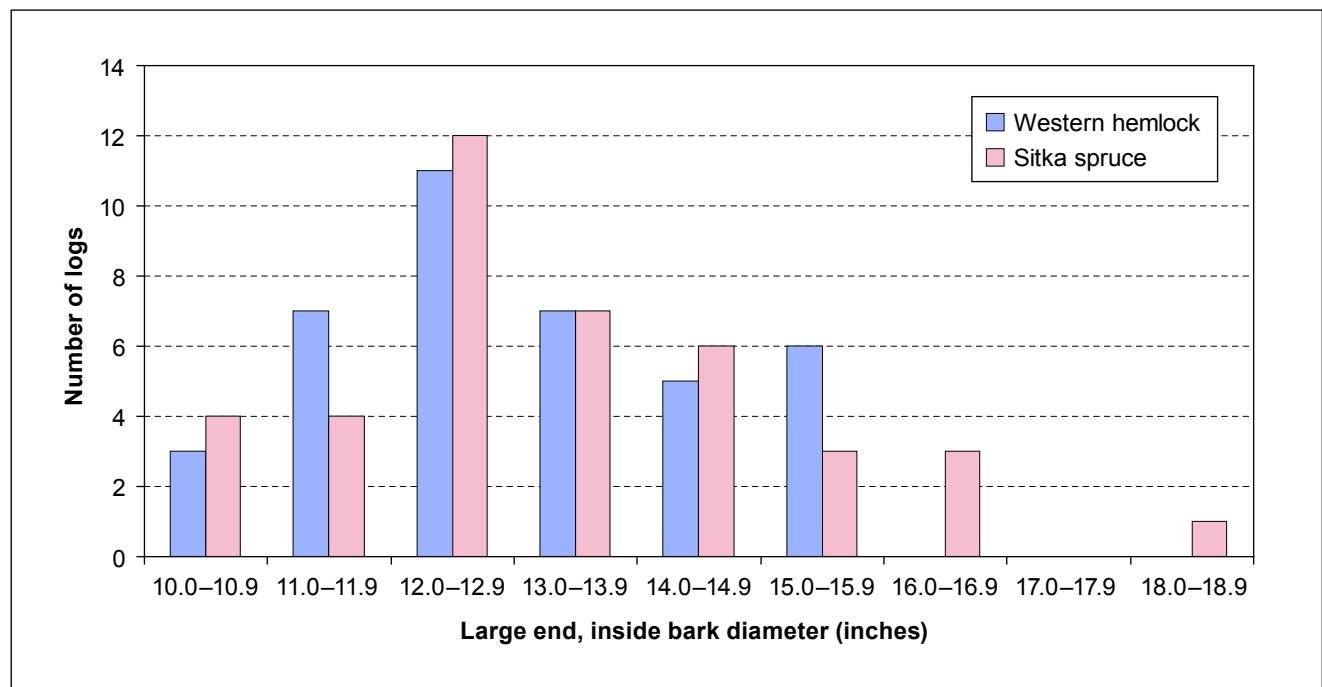


Figure 1—Distribution of log diameters for western hemlock and Sitka spruce house logs.

Log Preparation

Log weighing and air drying took place at the Ketchikan Wood Technology Center, located at Ward Cove, Alaska (near Ketchikan). A total of 20 logs for each species and drying condition were evaluated. Half of these logs were debarked and half were left with bark remaining.

The air drying conditions we evaluated were:

- Covered storage (bark remaining)
- Covered storage (debarked)
- Uncovered storage (bark remaining)
- Uncovered storage (debarked).

The covered logs were stored indoors within a large storeroom, and therefore there was no exposure to direct rainfall, mist (or any liquid precipitation), or direct sunlight during the storage period. Individual logs were weighed using a forklift and a crane scale.

The initial weighing occurred in early July 2006, the second weighing in early March 2007 (9 months after the initial weighing), and the third and final weighing occurred in late June 2007 (about 12 months after the initial weighing). Weights were recorded using a digital crane scale (a shackle-type dynamometer having a 3-ton capacity), mounted between a cable assembly and a fork lift. This assembly was then used to suspend each log above ground. Weather records were obtained for conditions at Ketchikan International Airport, less than 5 miles away from the study site. These records were used to estimate EMC conditions at the air-drying site (table 1). No other measurements of temperature or relative humidity were taken during the drying period; therefore, the Ketchikan International Airport records were used for discussions related to both indoor and outdoor exposures.

Log Storage Conditions

Outdoor log storage areas were well-drained, level, and free of vegetation. Logs were stored above ground level, similar to what is shown in figure 2. Logs were numbered and labeled, indicating species, tree number, and log number. Indoor logs were stored on two bunks, each housing two to three rows of logs, which were strapped in place (fig. 3). Indoor storage was in a dry, enclosed warehouse where temperatures ranged from about 50 to 60 degrees Fahrenheit throughout the year. Past research has indicated that wood products in long-term storage in this same warehouse equilibrated at between 10 and 17 percent EMC (Bannister et al. 2007).



David Nicholls

Figure 2—Debarked logs, outdoor storage. Identification tags are attached to the log ends.



Figure 3—Logs in indoor storage. Identification tags are attached to the log ends.

Therefore, in our study we estimate the EMC for indoor log storage to be at least 12 percent. No attempt was made to alter or monitor the temperature or relative humidity within the warehouse during the 12-month storage period.

Initial Log Weighings and Moisture Determinations

Initial MCs were determined by removing “cookies” (i.e., cross sections approximately 1 inch thick) from close to each log end and from the center. Next, cookies were manually debarked, and then oven-dried (see the appendix for more information). Next, half of the 16-foot logs (40 in number) were debarked before initial log weighing. Logs were debarked manually using small scribes and chisels. After debarking, logs were once again weighed (to determine weight without bark). Bark content is an important property that shows variation between species, and therefore we wanted to quantify this aspect of the study.

Once we determined cookie moisture content, the estimated dry weight for each log was calculated (see the appendix for details). At the completion of the study, it was noted that the actual weights of two logs were less than the estimated dry log weights which had been calculated. The possible reasons for this include (a) end drying could have occurred between harvest and initial log weighing (about 3 weeks), even though the ends were sealed, and (b) the average cookie MC from the ends of each log did not provide a sufficiently accurate estimate of log MC. Regardless, log MC and the weight derived from the driest samples are a function of the EMC of the storage areas. Given this fact, we developed a process to adjust all log MCs (by increasing the initial, estimated green log weights) so that the driest logs were based on the equilibrium condition. This process is described in the appendix. The amount of adjustment was based on EMCs historically obtained within the covered storage areas in Ketchikan. The adjustments we used ensured that none of the final MCs, calculated using estimated dry log weight, would be less than those resulting from the prevailing EMC conditions in the storage area. If logs had dried to less than the EMC conditions, end checks and surface cracks should have resulted (which did not occur, suggesting that the calculations needed adjustments). We report log MC values based both on estimated dry log weight and adjusted, estimated dry log weight.

Results

Moisture Content Variations Among Species and Storage Conditions

Western hemlock logs had overall higher MC versus Sitka spruce logs (figs. 4 and 5). Initial MCs were typically at least 10 percent higher for western hemlock. Sitka spruce logs dried more quickly than western hemlock during the initial 8 months, especially for inside storage conditions. For outside storage, unpeeled logs dried very slowly, with final (12 month) MCs ranging between about 80 and 100 percent (ovendry basis) for both species. Average MC for western hemlock logs (unpeeled, outside) even increased during the first 8 months of storage. For outside storage of peeled logs, each species exhibited good drying characteristics, finishing the 12-month period with average MCs of close to 40 percent, and relatively little difference between 8-month MCs (figs. 4 and 5, table 3). One limitation of this study is that after the final weighing, logs were not inspected for end checking, discoloration, or other weathering.

Western hemlock logs had overall higher moisture content versus Sitka spruce logs.

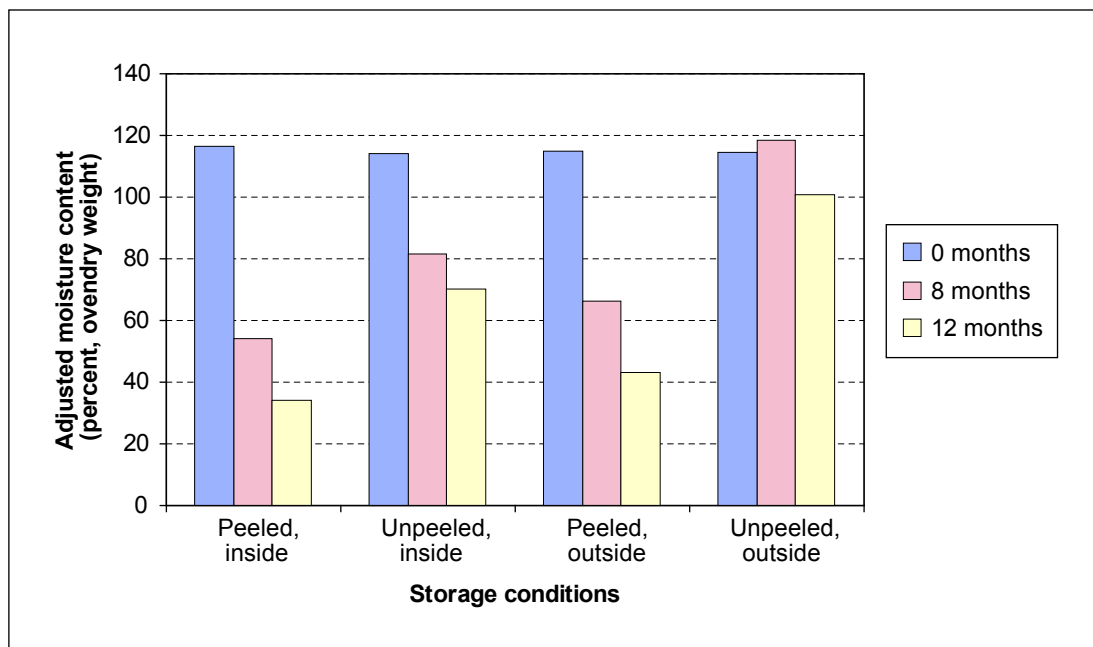


Figure 4—Average adjusted moisture content for western hemlock logs air dried in Ketchikan, Alaska, under four storage conditions.

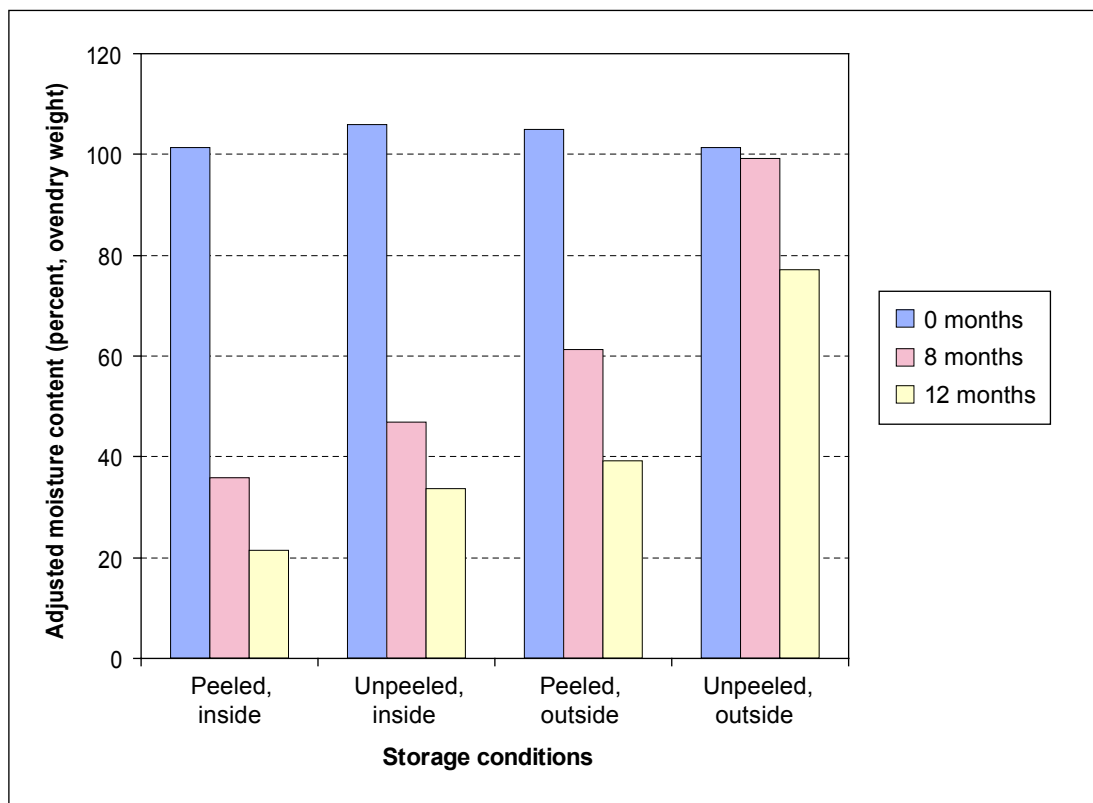


Figure 5—Average adjusted moisture content for Sitka spruce logs air dried in Ketchikan, Alaska, under four storage conditions.

Table 3—Average moisture content of western hemlock and Sitka spruce house logs during approximately 12 months of air drying in Ketchikan, Alaska

Species	Bark condition	Storage location	Number of logs	Green log weight ^a	Mean moisture content		
					0 months	8 months	12 months
Percent (ovendry basis)							
Western hemlock	Unpeeled	Inside	10	Estimated	98.2	67.8	57.3
				Adjusted	114.1	81.4	70.2
Sitka spruce	Unpeeled	Inside	10	Estimated	89.5	35.0	23.0
				Adjusted	105.8	46.8	33.6
Western hemlock	Unpeeled	Outside	10	Estimated	100.6	104.1	87.9
				Adjusted	114.6	118.2	100.7
Sitka spruce	Unpeeled	Outside	10	Estimated	86.3	84.3	63.8
				Adjusted	101.3	99.7	77.0
Western hemlock	Peeled	Inside	10	Estimated	102.2	43.9	25.2
				Adjusted	116.5	54.0	34.1
Sitka spruce	Peeled	Inside	10	Estimated	87.6	26.5	13.1
				Adjusted	101.2	35.8	21.4
Western hemlock	Peeled	Outside	10	Estimated	101.3	55.7	34.3
				Adjusted	114.8	66.3	43.3
Sitka spruce	Peeled	Outside	10	Estimated	89.7	49.2	28.7
				Adjusted	104.8	61.1	39.0

^aThis table includes moisture contents based on the initial estimates of green log weights and also adjustments that were made to the estimated weights once it was determined that the final moisture contents were not accurate (less than the equilibrium moisture content of the storage location). The adjustment to the green log weights was an increase by 17 percent.

The overall greatest moisture losses (i.e., fastest drying) occurred in peeled logs, stored inside. The overall least moisture losses (i.e., slowest drying) occurred in unpeeled logs, stored outside. Log home producers would be most interested in identifying the point at which drying could be stopped and still produce a good-quality house log (i.e., one with minimal shrinking). All of the final MCs were greater than the recommended acceptable MC of 15 percent for house logs (Gorman and Steinhagen 1992). Another important consideration would be for logs to be oriented so that the largest cracks are facing down, and therefore do not collect water. Sometimes house logs are “kerfed” before drying to facilitate development of primary checks at a specific location.

For Sitka spruce logs, the effect of peeling (vs. leaving bark on) was to reduce MC by about 10 to 15 percent for inside storage (fig. 5). For outside storage (Sitka spruce) the effect of peeling on MC was more pronounced, with peeled logs generally about 40 percent MC dryer than unpeeled logs (for both 8 and 12 months of storage). For western hemlock logs, the effect of peeling (vs. leaving bark on) was somewhat more pronounced (fig. 4), especially for outside storage.

It should be noted that all 40 of the logs for this study were debarked manually in about 3 hours (by a crew of six workers), suggesting that it could be a relatively quick process under certain production scenarios. Automated debarking equipment

The overall greatest moisture losses occurred in peeled logs, stored inside.

could also be considered when higher production volumes are needed. All of the trees used in this study were harvested in late spring, resulting in potentially easier bark removal than if harvests had occurred during other seasons.

Another factor that potentially influences MC determinations is wet pockets, zones of unusually high moisture sometimes found in western hemlock (Nicholls and Brackley 2003). If any of the MC “cookies” that were used to estimate initial log MC had been selected from a wet pocket, artificially high MC could result. Because the location of MC cookies within the original logs was fixed, we had no way to control for wet pockets. Nor did we attempt to determine if a given “cookie” was entirely or partially within a wet pocket zone.

Discussion and Conclusions

Second-growth timber from southeast Alaska could be used for house logs under a number of different scenarios:

- Ship logs “as is” shortly after harvesting to a log home production facility in the continental United States (here logs could be either air-dried or kiln-dried).
- Air dry logs in Alaska, then ship to a production facility in the continental United States.
- Air dry logs in Alaska, followed by production of log homes or log home kits (also in Alaska).
- Dry logs under accelerated conditions, such as predryers or conventional dry kilns, before further processing (either in Alaska or a continental United States location).

Most log home producers do not kiln-dry their logs nor do they attempt to reduce moisture to construction-grade levels (typically 19 percent MC or less), although some producers use exclusively kiln-dried material. Other producers practice air-drying, or they utilize low-moisture content material salvaged from fires (Lazarus Log Homes 2008). Still other producers use material from insect attacks (Satterwhite Log Homes 2008).

In other cases, log homes are built with green logs, and shrinkage and settling is accounted for by engineering and design. For example, in full-scribe methods, long logs can be debarked by hand and then built up row by row to create the final shell (Husky Logwork 2008). Other techniques might require more careful control of MC; for example, log home kits in which processed logs are in close contact with windows, exterior doors, and other components that have likely been kiln-dried. Many other variations of log home production are possible including turned logs (Rocky Mountain Log Homes 2008) and glulam members (Glu-lam-log 2008).

Our current study of air-drying house logs in Ketchikan, Alaska, has shown that a leading option for local producers would be to peel Sitka spruce logs, then air-dry indoors for between 8 and 12 months. Doing so should allow sufficient reductions in shipping weight and would minimize shrinkage as logs dry to their final MC in-service. Another very good option would be to peel western hemlock logs, then air-dry indoors for 12 months. If outdoor storage is the only option for air-drying, our study strongly suggests using only peeled logs. Unpeeled logs should not be air-dried outside in environments similar to Ketchikan, given the very low drying potential during the first 8 months (and relatively little drying during 12 months).

These results might be different for outside storage if rainfall were considerably different from that experienced in this study. However, Ketchikan is one of the highest rainfall locations in southeast Alaska, and EMC conditions for logs often exceed 20 percent (see table 1). Further, the logs dried in this study were “short” logs, approximately 16 feet long. Log home producers using longer logs (or full-length logs) could experience considerably different results under similar air-drying conditions. A limitation of this study was that the log-drying period started and ended during summer months. It is not known how this would compare to a similar (12 month) air-drying study that was started and ended during other seasons.

The above discussion illustrates that there are many important variables influencing log-drying rates in uncontrolled, outdoor conditions. Therefore, these drying results must be considered on a case-by-case basis, according to the log resources and production processes of individual manufacturers.

Significance for Log Home Production

Whether logs are used for custom home construction, for log home kits, or for other uses could influence strategies for air drying as well as required final MCs. For log home producers considering air drying house logs from southeast Alaska, several capital investment decisions could be relevant. Some of these investment decisions could include:

- Whether to debark logs (by using either manual labor for scribing, or by using a mechanical debarker)
- Whether to dedicate land for use as an air-drying yard (vs. potentially higher value uses)
- Whether to dedicate building or warehouse space for air drying (vs. potentially higher value uses)
- Whether to air-dry for 8 months, 12 months, or some other period

Peeling logs, then air-drying indoors for between 8 and 12 months, should allow sufficient reductions in shipping weight

- Whether to invest in predrying shed, dry kiln, or other structure having controlled heat and air flow for accelerated drying
- Whether to invest in an open, covered storage structure (i.e., a “T” shed), that could protect the peeled logs from periodic rewetting, while allowing air flow to aid in drying (note that this option would be less expensive than building enclosed, controlled-environment structures).

Acknowledgments

This research was conducted under the terms of Joint Venture PNW-06-JV-11261975-287, between the USDA Forest Service, Pacific Northwest Research Station, Alaska Wood Utilization and Research Development Center in Sitka, Alaska, and the Ketchikan Wood Technology Center in Ketchikan, Alaska. We recognize the contributions of Dr. Kevin Curtis and Michael Hannan of the Ketchikan Wood Technology Center.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.54	Centimeters
Feet	.3048	Meters
Miles	1.609	Kilometers
Acres	.405	Hectares
Pounds	454	Grams
Degrees Fahrenheit	.56(°F - 32)	Degrees Celsius

Literature Cited

- Bannister, J.; Curtis, K.; Barber, V.; Miller T. 2007.** A mechanical evaluation of Alaska yellow-cedar. *Forest Products Journal*. 57(6): 19–22.
- Brackley, A.M.; Rojas, T.D.; Haynes, R.W. 2006.** Timber products output and timber harvests in Alaska: projections for 2005-25. Gen. Tech. Rep. PNW-GTR-677. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 33 p.
- Defo, M.; Brunette, G. 2006.** A log drying model and its application to the simulation of the impact of bark loss. *Forest Products Journal*. 56(5): 71–77.
- Duncan, S. 2002.** Volume, value, and thinning: logs for the future. *Science Findings* 48. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 5 p.

Fight, R.D.; Barbour, R.J.; Christensen, G.A.; Pinjuv, G.L.; Nagubadi, R.V.

2004. Thinning and prescribed fire and projected trends in wood product potential, financial return, and fire hazard in New Mexico. Gen. Tech. Rep. PNW-GTR-605. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 48 p.

Glu-lam-log. 2008. Glu-lam-log, Inc. homepage. <http://www.glulamlog.com>. (28 January 2008).

Gorman, T.M.; Steinhagen, H.P. 1992. Kiln-drying of 9- by 9-inch cants for log home manufacturers. Forest Products Journal. 42(5): 43–46.

Graham, J.N.; Bell, J.F.; Herman, F.R. 1985. Response of Sitka spruce and western hemlock to commercial thinning. Res. Pap. PNW-334. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 17 p.

Greene, S.E.; Emmingham, W.H. 1986. Early lessons from commercial thinning in a 30-year-old Sitka spruce-western hemlock forest. Res. Note PNW-RN-448. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 p.

Husky Logwork. 2008. Husky Logwork: quality handcrafted log homes. <http://huskylogwork.com>. (28 January 2008).

Kang, W.; Lee, N.H.; Choi, J.H. 2004. A radial distribution of moistures and tangential strains within a larch log cross section during radio-frequency/vacuum drying. Holz Roh und Werkstoff. 62(1): 59–63.

Lazarus Log Homes. 2008. Lazarus Log Homes homepage. <http://www.customlogkits.com>. (28 January 2008).

Nicholls, D.L.; Brackley, A.M. 2003. Moisture distributions in western hemlock lumber from trees harvested near Sitka, Alaska. Res. Note PNW-RN-530. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 8 p.

Rocky Mountain Log Homes. 2008. Rocky Mountain Log Homes homepage. www.rmlh.com. (28 January 2008).

Satterwhite Log Homes. 2008. Satterwhite Log Homes homepage. <http://www.satterwhite-log-homes.com>. (28 January 2008).

- Simpson, W.T. 1998.** Equilibrium moisture content of wood in outdoor locations in the United States and worldwide. Res. Note FPL-RN-0268. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 11 p.
- Simpson, W.T.; Hart, C.A. 2000.** Estimates of air drying times for several hardwoods and softwoods. Gen. Tech. Rep. FPL-GTR-121. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 70 p.
- Simpson, W.T.; Wang, X. 2004.** Estimating air-drying times of small-diameter ponderosa pine and Douglas-fir logs. Forest Products Journal. 54(12): 24–28.
- Sturos, J.B. 1984.** Characterizations and air drying of chunkwood and chips. Res. Note NC-308. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.
- U.S. Department of Agriculture, Forest Service [USDA FS]. 1999.** Wood handbook- wood as an engineering material. Gen. Tech. Rep. FPL-GTR-113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 463 p.
- U.S. Department of Agriculture, Forest Service [USDA FS]. 2000.** Forest products laboratory research program on small-diameter material. Gen. Tech. Rep. FPL-GTR-110. Rev. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 31 p.
- Weather-warehouse. 2007.** Weather source. <http://weather-warehouse.com>. (25 March 2007).

Appendix

Sitka Spruce and Western Hemlock House Log Air-Drying Study Moisture Content Adjustment Procedures

1. The basic formula used to calculate moisture content (USDA FS 1999) is:

$$MC = [(W_G - W_{OD})/W_{OD}] \times 100$$

where:

MC = moisture content (percent),

W_G = initial green weight, and

W_{OD} = oven-dry weight (stabilized condition when dried at $100\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$).

Because the entire log cannot be used to measure oven-dry weight (that would prevent leaving any drying material to be measured), samples are cut from the log and used to determine MC. The cutting of samples for MC determination is a destructive process and the samples must be collected so that the integrity of the log is maintained during the period of drying.

2. In this study, MC was calculated by cutting samples (“cookies”) from the ends and midpoints of the 35-foot house logs. The initial green weight (W_G) and oven-dry weight (W_{OD}) of the cookies were measured and used in the formula above to calculate MC. Log MC was considered as the average of the butt and top disk from each 16-foot section. Given the average green MC from the cookies, the projected dry log weight was calculated by using algebra to solve for W_{OD} in the formula presented in step 1. In this example that follows, log 1B was a 16-foot Sitka spruce with an initial green weight of 442 pounds. The initial MC from the cookies was 95.9 percent. Given these values, the estimated dry weight of the log was calculated using the following formula:

$$W_{OD} = W_G / [(1.0 + (MC/100))]$$

The estimated oven-dry weight of the above log would be calculated as:

$$W_{OD} = 442 \text{ lbs} / [1.0 + (95.9/100)]$$

$$W_{OD} = 442 \text{ lbs} / 1.959$$

$$W_{OD} = 226 \text{ pounds}$$

3. When the final log weight measurements were obtained, it was determined that some of the dry weights (two logs exposed to the most severe drying conditions) were lower than the initially estimated dry weights, as calculated in step 2 above. This result may have been due to drying of the logs (and sampled portions) prior to initial measurements. It is noted that the logs were harvested in late May and

delivered to Ketchikan in June, and this period was during some of the best drying days during the summer of 2006. Another possibility is the use of samples, although precise, may not provide accurate estimates of log MC. Regardless, the final weights lower than the predicted dry log weights indicated that the original green weights needed to be adjusted upward.

4. A check of the conditions of log storage indicate that for the drying period the logs that were stored under cover were in a building that historically had a year-round temperature of 65 °F and a relative humidity of 60 percent. These conditions are similar to a system that would have a wood equilibrium moisture content of 12 percent. Given these facts, it was assumed that the best approach to adjusting MC was to increase green log weights, until the final equilibrium minimum MC of peeled Sitka spruce logs was equal to 12 percent.

5. The minimum final MC of the logs stored in the inside location were therefore adjusted to be no lower than 12 percent. All logs inside and outside were adjusted to reflect a uniform rate of drying in all logs, prior to the weighing in Ketchikan. The factor required to create the above relationship was a 17-percent increase in initial green weights. The green MC (MC of freshly cut wood) calculated by using either the estimated green log weight or the adjusted green log weight, both create average values that are well within the reported range of green MC for these two species. The relative change in log weights is the same regardless of the estimated basis of green material that is used to calculate change in moisture content over the period of the study.

Pacific Northwest Research Station

Web site	http://www.fs.fed.us/pnw/
Telephone	(503) 808-2592
Publication requests	(503) 808-2138
FAX	(503) 808-2130
E-mail	pnw_pnwpubs@fs.fed.us
Mailing address	Publications Distribution Pacific Northwest Research Station P.O. Box 3890 Portland, OR 97208-3890

U.S. Department of Agriculture
Pacific Northwest Research Station
333 SW First Avenue
P.O. Box 3890
Portland, OR 97208-3890

Official Business
Penalty for Private Use, \$300