Utilization of Western Hemlock and Western Firs for Poles and Piles

W. J. Ruppert
R. D. Graham

Research Paper 22
February 1974

Forest Research Laboratory
School of Forestry
Oregon State University
Corvallis, Oregon

Utilization of Western Hemlock and Western Firs For Poles and Piles

William J. Ruppert
Senior Student
Robert D. Graham
Associate Professor of Forest Products

Research Paper 22
February 1974

Forest Research Laboratory
School of Forestry
Oregon State University
Corvallis, Oregon 97331

CONTENTS

Utilization of Western Hemlock and Western Firs for Poles and Piles

William J. Ruppert
Robert D. Graham

INTRODUCTION

The steadily increasing costs of raw materials, of the treated products, and of their replacement in service, as well as the steadily shrinking supply of preferred species, prompted a forum at Oregon State University on May 15, 1973 "to encourage the use of western hemlock and western firs[1] for poles and piles by presenting information on their availability and characteristics and discussing its implications for their utilization." The forum was attended by 27 representatives from wood preserving plants, utilities, and raw material suppliers, and research personnel from western United States and Canada.

This survey of relevant information, prepared for the forum, consists of an annotated bibliography of published and unpublished literature, plus an appendix, which contains a bark key, number of trees of pole and piling size by diameter classes, sapwood depth and bark thickness of selected species by diameter classes, and stress values for poles. The index, which lists the information by subject matter, served as the agenda for the forum.

The available quantity of pole- and piling-size trees of western hemlock and western firs (Table 1) shows that these nondurable species are an important potential source of supply. Bark-thickness values indicate that peeling residues will be lower with hemlock than with most of the firs (Table 2). These species are permitted for poles in Standard 05.1 1972, American National Standards Institute (Table 3), and for piles in Standard D25-70, American Society for Testing and Materials. No standards exist, however, for their preservative treatment by pressure processes.

All have deep sapwood (Table 2), which should make them especially well suited for piles and for distribution poles and the smaller transmission pole sizes in which they are available in greatest quantity. As the bark characteristics do not appear to be sufficiently different to provide a basis for segregating western hemlock and fir logs, and the wood of hemlock is difficult to distinguish from that of the firs without a microscope, standards for poles may have to be revised to include a hem-fir group with the fiber stress value for the firs.

Full-length incising appears necessary to insure uniform penetration of preservative in the sapwood of western hemlock and should prove equally desirable for the firs. Deep end-penetration and correspondingly high retentions of preservative could result in excessive treatment of short members.

[1] Western firs include California red, grand, noble, Pacific silver, and white fir.

Table 1. Millions of Pole- and Piling-Size Trees of Western Hemlock, True Firs, and Douglas-Fir in Western United States, 1970.[1]

Diameter class	Douglas-fir	True fir	Western hemlock
In.			
Douglas-fir region			
10	153.7	42.2	109.1
12	113.4	26.9	73.1
14	85.6	19.3	52.3
16	64.4	14.8	37.8
18	47.9	10.8	27.3
20	35.5	8.1	20.1
Ponderosa pine region			
10	68.4	52.4	4.4
12	44.1	34.9	2.4
14	28.4	23.5	2.3
16	19.7	16.6	1.8
18	13.6	11.2	1.2
20	10.0	8.6	0.9
California			
10	39.6	56.0	--
12	26.6	35.4	--
14	18.9	22.7	--
16	14.7	16.4	--
18	11.2	11.7	--
20	8.6	8.9	--
Coastal Alaska			
10	--	--	50.7
12	--	--	40.7
14	--	--	34.9
16	--	--	28.6
18	--	--	25.5
20	--	--	19.5
Northern Rocky Mountains			
10	153.2	92.0	11.2
12	98.2	49.2	6.6
14	66.8	31.4	3.9
16	42.8	18.3	2.5
18	27.6	10.7	1.7
20	18.4	6.8	1.1
Southern Rocky Mountains			
10	22.5	36.9	--
12	14.8	19.8	--
14	11.2	11.3	--
16	8.2	6.8	--
18	5.5	4.3	--
20	3.8	2.3	--

[1]Compiled by Forest Survey, Pacific N.W. Forest and Range Expt. Sta., Forest Service, Portland, Oregon. April 16, 1973.

A SURVEY OF RELEVANT INFORMATION

1. ABNER, T. L. "Dry West Coast Hemlock and Douglas Fir 1½ Inch Dimension to the New Moisture Specification with a Minimum of Degrade." IN: Proc., 17th Annual Meeting, Western Dry Kiln Clubs, Corvallis. P. 4-7. 1965.

Kiln schedules were developed for drying hemlock dimension lumber to 15 percent moisture content with less than 5 percent of the pieces above 19 percent.

2. ALEXANDER, J. B. "Wood Piles—Specifications and Mechanics." J. For. Prod. Res. Soc. 3(27):62-64. 1953.

The function of a pile is defined, and current specifications and their differences are reviewed. Relative strengths and stiffnesses in static bending of different piling species, and their supporting strengths when acting as columns, are discussed. Types of loading static and impact, which may be vertical or lateral, are explained. Bending, tensile, and compression stresses imposed are described. The types of support required from wood piles are discussed, as well as the effect of preservative treatment upon mechanical strength.

3. AMERICAN NATIONAL STANDARDS INSTITUTE. American National Standard Specifications and Dimensions for Wood Poles. ANSI 05.1-1972. 20 p. 1972.

Species and fiber stress values are listed.

Table 2. Sapwood Depth and Bark Thickness of Western Hemlock and Western Fir Trees.[1]

Tree diameter	Pacific silver fir	Grand fir	White fir	Noble fir	California red fir	Western hemlock
In.						
			SAPWOOD DEPTH, *inches*			
6	1.1	1.4	1.3	1.4	1.7	1.4
8	1.3	1.6	1.8	1.9	2.3	1.8
10	1.5	1.9	2.3	2.4	2.8	2.2
12	1.6	2.2	2.8	2.9	3.4	2.6
14	1.8	2.4	3.3	3.4	3.9	3.0
16	2.0	2.7	3.6	3.9	4.5	3.2
18	2.2	2.9	3.9	4.4	5.1	3.4
20	2.4	3.2	4.0	5.0	5.6	3.5
			BARK THICKNESS, *inches*			
6	0.20	0.15	0.35	0.35	0.45	0.20
8	0.25	0.25	0.50	0.45	0.60	0.30
10	0.30	0.35	0.65	0.55	0.80	0.35
12	0.35	0.45	0.80	0.60	0.95	0.40
14	0.45	0.55	0.95	0.70	1.10	0.45
16	0.50	0.70	1.10	0.80	1.30	0.50
18	0.55	0.80	1.25	0.90	1.45	0.60
20	0.65	0.90	1.40	1.00	1.65	0.65
			NUMBER OF TREES			
All	188	585	1,159	66	311	425

[1]Approximate values derived from preliminary data supplied by the U.S. Forests Products Laboratory from wood-density survey.

Table 3. Fiber Stress Values of Selected Western Woods.[1]

Treatment group	Fiber stress
	Psi
A. AIR SEASONED	
Cedar, northern white (eastern)	4,000
Spruce, Engelmann[2]	5,600
Cedar, western red-	6,000
Pine, ponderosa	6,000
Fir, western (true fir)	6,600
California red[2]	---
Grand[2]	---
Noble[2]	---
Pacific silver[2]	---
White[2]	---
Pine, lodgepole	6,600
Redwood[2]	6,600
Spruce, Sitka[2]	6,600
Cedar, Alaska yellow-	7,400
Hemlock, western[2]	7,400
Douglas fir, interior north	8,000
B. BOULTON DRYING	
Douglas fir, coast	8,000
Larch, western	8,400
C. STEAM CONDITIONED	
Pine, southern	8,000
D. KILN DRYING	
Cedar, western red-	6,000
Douglas fir, interior north	8,000
Douglas fir, coastal	8,000
Larch, western	8,400
Pine, lodgepole	6,600
Pine, ponderosa	6,000

[1]From American National Standard 05-1, 1972.
[2]Not in common use, according to Wood Preservation Statistics, Forest Service, U.S. Department of Agriculture, 1961.

4. ARGANBRIGHT. D. G. and W. W. WILCOX. "Comparison of Parameters for Predicting Permeability of White Fir." IN: Proc., Amer. Wood-Preservers' Assoc. 65:57-61. 1969.

Variations in the treatability of white fir, as expressed by retention and treatability index, were compared with the parameters of transverse nitrogen permeability, transverse diffusion coefficient, and specific gravity. Treatability could not be predicted accurately by any of these parameters. Within-tree variations in diffusion coefficient and specific gravity could be used to explain some of the variations observed in the drying of white fir. Unlike most species, the heartwood of white fir had both higher treatability index and retention values than the sapwood.

5. BARTON, G. M. "Chemical Color Tests for Canadian Woods." Canadian Forest Industries 93(2):57-62. February 1973.

Tests are described for differentiating Douglas fir from other western softwoods, pine from spruce, *amabilis* fir from alpine fir, and sapwood from heartwood of western hemlock, and for detecting iron on wood, as well as the length of splits in shear-cut logs.

To distinguish between sapwood and heartwood of western hemlock, streak a smooth surface, using an eyedropper with a solution that contains 40 ml of glycerin, 30 ml of methyl alcohol, and 60 ml of concentrated hydrochloric acid. After 10 minutes, heartwood turns green, and sapwood becomes pink or mauve. The color changes take longer on seasoned than on green wood.

6. BARTON, G. M. and J. A. F. GARDNER. Brown Stain Formation and the Phenolic Extractives of Western Hemlock. Dept. of Forestry. Publ. 1147. Canada. 20 p. 1966.

Hemlock brown stain, which occurs only on the surface of hemlock sapwood, is an innocuous brown pigment chemically indistinguishable from tannin. Good evidence that this pigment is formed from catechin, a normal phenolic constituent of sound hemlock sapwood, was obtained by simulating brown stain formation in the laboratory. It is postulated that catechin is transported with moisture to the surface of the lumber during drying and, accumulating there with evaporation of the water, reacts with air in the presence of an enzyme to form a brown polymerized pigment. The cross-sectional and seasonal variation of catechin and other naturally occurring phenolic constituents of hemlock sapwood and heartwood, such as matairesinol, hydroxymatairesinol, phenolic glucosides, and monomeric and polymeric leucoanthocyanidins, is presented also.

Although many chemicals were effective in inhibiting brown colorations in laboratory screening tests, none showed more than a short initial improvement in field tests, which emphasized the great difficulty in maintaining an effectively high concentration of control chemical on the surface of green hemlock lumber during yard seasoning.

The author emphasizes the need for strict controls on the use of alkaline sapstain control chemicals. He cautions, "Until an acidic sapstain and mould preventive solution is developed, the incorporation of a control chemical in a dip or spray treatment of the type currently in use would not appear promising."

7. BEEBE, C. W., J. S. ROGERS, F. P. LUVISI, and W. H. KOEPP. "Sodium Arsenite Causes Serious Loss of Tannin in Hemlock Bark." For. Prod. J. 6(1):38-40. 1956.

Sodium arsenite, as a debarking agent for hemlock trees, causes a loss of about 30 percent of tannin in the bark. The effect is not localized, but is distributed throughout the height of the tree. Results of the study indicate a need to investigate other debarking chemicals and methods of application.

8. BLEW, J. O. and H. L. DAVIDSON. "Preservative Retentions and Penetration in the Treatment of White Fir." IN: Proc., Amer. Wood-Preservers' Assoc. 67:204-221. 1971.

Six species of true fir, usually grouped as "white fir" for commercial purposes, were pressure treated with creosote and acid copper chromate to obtain information on preservative retention and penetration. Some of the species accepted preservative treatment moderately. The results show sufficient variability both within and between species to indicate a need for incising before treatment with the types of preservatives used here.

9. BRAMHALL, G. and W. M. CONNERS. "Vapor Pressures in Western Hemlock Heartwood During Boiling Under Vacuum." For. Prod. J. 5(4):267. 1955.

Data show that the vapor pressure, or vacuum required to initiate boiling, depends on temperature and moisture content of the wood. Apparatus was designed to indicate minimum vacuum at which a specimen of known moisture content and temperature starts to boil. Vapor pressures in wood below fiber saturation point were calculated and curves plotted for temperatures from 120 to 210 F.

10. BRAMHALL, G. and P. A. COOPER. "Suitability of Commercial Hem-Fir for Preservative-Treated Lumber and Glued-Laminated Beams." For. Prod. J. 22(2):33-37. 1972.

The marketing together of western hemlock and *amabilis* fir as "hem-fir" raises the possibility that for specific applications, for example, in preservative-treated products and glued-laminated beams, the properties of the two species may be sufficiently different to introduce problems. Others showed that machine-stress-rated hem-fir may, by a proper selection criterion, be as strong as Douglas fir for glued-laminated beams. Thus, low strength need not be a problem source. Incised western hemlock is accepted by national bodies for preservative-treated lumber products. The comparative treatability of western hemlock and *amabilis* fir was determined in this study. It showed, where significant differences occurred between the two species, *amabilis* fir received the better treatment, and when incised, *amabilis* fir completely passed requirements for penetration and retention.

11. CHANG, K. Bark Structure of North American Conifers. U.S. Dept. of Agric., Forest Serv., Tech. Bull. 1094. 86 p. 1954.

This paper presents a brief description of micro- and macroanatomy of bark of North American conifers.

12. CONNERS, M. S. Steaming and Impregnation of Round Western Hemlock. Dept. of Forestry, Ottawa, Canada. Publ. 1122. 25 p. 1965.

Round western hemlock specimens of various moisture contents, and of sizes ordinarily used for poles and piling, were placed in a closed retort filled with saturated steam that ranged in temperature from 200 to 280 F, and subsequently was evacuated to 28 inches of mercury and impregnated under pressure with creosote. From the results, a semitheoretical formula was derived that sets out the effect that the size of a specimen, its density, and the duration of the pressure exerts on the amount of preservative injected and the depth of penetration. Possibly, with this formula, one could determine the effect that steam and vacuum, applied before impregnation, exert on dissimilar specimens, and compare this with the effect of steam and vacuum applied after impregnation and with the effect of vacuum only.

A short treatise on the technique for steaming in wood preservation is included as an appendix to this publication.

13. CONNERS, W. M. Effect of Steam and Vacuum on the Weight of Round Western Hemlock. For. Prod. Res. Lab., Vancouver, British Columbia. Inform. Rept. VP-X-1. 12 p. 1965.

A method is described whereby logs may be weighed in a closed retort during steaming and vacuum. Results of experimental steam and vacuum treatments of round western hemlock logs indicate that, during steaming, the gain of weight of the specimen varies directly as the steam temperature and inversely as the green density. The loss in weight during vacuum varies directly as both temperature and density, and the net gain or loss is independent of temperature and tends to bring the specimen to a moisture content of about 45 percent.

14. CONNERS, W. M. and G. BRAMHALL. "An Evaluation of the Factors Affecting the Rate of Drying of Round Western Hemlock During the Boiling Under Vacuum Process." For. Prod. J. 7(6):205. 1957.

A series of experiments was conducted to establish a mathematical relation between factors that cause the removal of moisture from wood and the moisture removed or condensate collected. This article shows that the equation derived is an approximation and that additional experiments may necessitate modification.

15. CONNERS, W. M. and G. BRAMHALL. "Boiling and Impregnation in the Preservation of Round Western Hemlock." IN: Proc., Amer. Wood-Preservers' Assoc. 56:36-44. 1960.

Satisfactory penetration and retention of creosote was obtained in single round western hemlock poles at pressures of 80 pounds per square inch (psi) maintained for about 12 hours. A formula was devised, with which possibly one might estimate, within the range and limitations of these tests, the retention of creosote, which can be injected into round western hemlock poles after they have been boiled under vacuum and impregnated under pressure.

16. CORE, H. A., W. A. COTE, Jr., and A. C. DAY. "Characteristics of Compression Wood in Some Native Conifers." For. Prod. J. 11(8):356-362. 1961.

The authors present electron microscopic evidence of the nature of spiral checking in the secondary cell walls of compression-wood tracheids in this study. Emphasis is placed on the importance of recognizing compression wood in softwoods as well as the frequency of occurrence of this type of reaction wood.

17. DOOLITTLE, F. B. and R. F. TOWNSEND. Characteristics of 100 Western Hemlock Crossarms. Southern California Edison Co., Los Angeles, California. 25 p. 1956.

Results of this investigation of 100 sample western hemlock crossarms support the following conclusions.

Western hemlock crossarms of the quality tested have adequate strength for universal application in standard construction of the Southern California Edison Company, which is based on exceeding minimum strength requirements when using crossarms with a modulus of rupture of 6,300 psi. Interpretation of the strength test results indicates that 7,188 psi would be an appropriate modulus of rupture for western hemlock crossarms of the quality tested when used on lines located where the climate is like that of Southern California.

On air drying, western hemlock crossarms, compared to Douglas fir crossarms, appear less likely to develop checks, splits, and shakes. For this reason, western hemlock may be preferable to Douglas fir for crossarms in locations with hot, dry climates.

Western hemlock crossarms accept preservative treatment with ease and, in this respect, are preferable to Douglas fir.

18. DUNDAS, K. B. and R. R. WHITE. "The Development of a Treating Procedure for Western Hemlock Poles." IN: Proc., Amer. Wood-Preservers' Assoc. 68:169-173. 1972.

During the investigation of a satisfactory oil-borne preservative treatment for round western hemlock, several methods were tested to overcome the problems of artificial seasoning and radial penetration of the sapwood. Steam conditioning caused excessive checking, and Boulton-drying techniques were abandoned because of failure. The more favorable permeability characteristics of the species were exploited by full-length incising of poles. This technique, in combination with controlled air-seasoning practices, resulted in a treatment that is considered to be satisfactory. A treating standard for western hemlock poles is proposed, which we hope will be accepted by the industry after some commercial evaluation.

19. EADES, H. W. "Differentiation of Sapwood and Heartwood in Western Hemlock by Color Tests." For. Prod. J. 8(3):104. 1958.

Perchloric acid, iron salts, and ammonium bichromate were of value in differentiating sapwood and heartwood in western hemlock. Other indicators found effective on other softwood species are listed. Sapwood 5 inches thick may be found in western hemlock trees 20 inches in diameter.

20. ESPENAS, L. D. "Shrinkage of Douglas-Fir, Western Hemlock, and Red Alder as Affected by Drying Conditions." For. Prod. J. 21(6):44-46. 1971.

Moisture content and shrinkage were determined on specimens equilibrated at two conditions for equilibrium moisture content at room temperature after having been dried under a variety of constant temperatures with conditions for constant EMC. Moisture content at room-temperature equilibrium was less for specimens dried at high temperature than for those dried at low temperature, and effect was about the same on the three species. Shrinkage was greater on specimens dried at high temperature, more than can be accounted for by lower moisture content. Douglas fir was the least affected and with red alder, the most affected, shrinkage doubled sometimes. Effect of temperature on both moisture content and shrinkage was more pronounced above 150 F.

21. FOUNTAIN, W. C. and F. W. GUERNSEY. "Variables Affecting Shrinkage of Western Hemlock." For. Prod. J. 6(4):148. 1956.

The shrinkage of western hemlock was studied with a dimensional recorder, which gave a continuous record of shrinkage during drying. The instrument showed that, with hig h-moisture-content boards at elevated temperatures, rate of shrinkage was rapid at the beginning of the drying period. It also showed that the amount of shrinkage that occurs above the fiber saturation point varies with initial moisture content. Accelerated shrinkage apparently does not cause an abnormal amount of degrade in the form of excessive checking.

22. GERHARDS, C. C. Strength and Related Properties of White Fir. U.S. Dept. of Agric., Forest Serv., Res. Paper FPL 14. 12 p. 1964.

Strength and related properties of white fir (*Abies concolor*) were reevaluated by combining previous data with that developed from recent samples obtained from Jackson and Lake Counties, Oregon, and Calaveras and Plumas Counties, California. New average strength values compared favorably to the previous averages for the species, although new averages for air-dry wood were slightly higher. Slight increases in species stiffness of green and air-dry wood and notable increases in shear strength of air-dry wood were of most significance.

23. GERHARDS, C. C. Strength and Related Properties of Western Hemlock. U.S. Dept. of Agric., Forest Serv., For. Prod. Lab., Madison, Wisconsin, Res. Paper FPL 28. 8 p. 1965.

Western hemlock trees grown in the United States were sampled for reevaluation of physical and mechanical properties of the species. The new property estimates were about equal to or higher than the previous estimates, except that for air-dry wood, work to proportional limit in static bending, height of drop in impact bending, and stress at proportional limit in compression parallel to the grain were lower.

24. GRAHAM, R. D. "Air Seasoning and Preservative of Crossties from Eight Oregon Conifers." IN: Proc., Amer. Wood-Preservers' Assoc. 50:175. 1954.

Data are presented on the change in weight and grade of ties during air seasoning and the penetration and retentions obtained in this material at a commercial plant. The data indicate that all of the species can be air seasoned in less than 1 year without the development of serious defects and that most can be treated with good results.

25. GRAHAM, R. D. "Preservative Treatment of Eight Oregon Conifers by Pressure Processes." IN: Proc., Amer. Wood-Preservers' Assoc. 52:117-138. 1959.

Air-dried incense cedar, coast-type Douglas fir, Shasta red fir, white fir, mountain hemlock, west coast hemlock, lodgepole pine, and Sitka spruce crosstie sections, about 3.5 by 4.5 by 48 inches and incised on two surfaces, were pressure treated with a creosote petroleum solution. The full-cell, Lowry, and Rueping processes were used. Four additional charges of each species were treated with various maximum pressures and pressing times. Recommendations for treating each species were made.

26. GRAHAM, R. D. and D. J. MILLER. "Kiln Drying and Pressure Treatment of Round West Coast Hemlock." IN: Proc., Amer. Wood-Preservers' Assoc. 54:215-221. 1958.

Round west coast hemlock specimens were kiln dried and treated with creosote by full-cell and empty-cell processes. Drying to average moisture contents below 30 percent was found necessary to obtain adequate penetrations and retentions. Material at an initial moisture content of 80 percent was dried at 200 F and conditions for equilibrium moisture content of 5 percent to a final moisture content of 30 percent in about 4 days. Surface checks were numerous, generally small, and uniformly scattered. Large checks were infrequent.

Round hemlock was more difficult to penetrate than coast Douglas fir treated in previous studies. Retention varied inversely with moisture content and initial air pressure. Penetration varied inversely as moisture content, but was independent of initial air pressure. A maximum pressure of 95 psi reduced internal checking that occurred at 125 psi and higher.

A final period of steaming and vacuum was found necessary to reduce or prevent bleeding.

Separate specifications apparently will be required for treatment of round west coast hemlock if it is to be included in the manual of recommended practices of the American Wood-Preservers' Association.

27. GRAHAM, R. D. and D. J. MILLER. "Service of Crossties from Oregon Woods." IN: Proc., Amer. Wood-Preservers' Assoc. 60:27-31. 1964.

The condition of 12,249 crossties from 10 Oregon woods is reported after service that ranged from 7 to 15 years in 17 test tracks in main lines of the Southern Pacific Company in Arizona, California, Nevada, and Oregon. Because no more than 9 percent of the ties of any one species were removed from track, no attempt was made to estimate service life.

Results indicate the desirability of inspecting test ties removed from track.

28. GUERNSEY, F. W. "High Temperature Drying of British Columbia Softwoods." For. Prod. J. 7(10):368-371. 1957.

Speed and less space are among the advantages of high-temperature drying. Little is known of the effect on the wood itself, however. Wood tends to darken slightly, but nothing conclusive is known about strength values (western hemlock, Douglas fir, and western redcedar).

29. HARKIN, J. M. and J. W. ROWE. Bark and Its Possible Uses. U.S. Dept. of Agric., Forest Serv., Res. Note FPL 091. 57 p. 1971.

The complexity of bark and extreme variation in chemical and physical properties between barks of different species are discussed. Present methods of upgrading bark for increased utilization information are presented. A table of bark specific gravities for many woods is included.

30. HUBERT, E. F. "Non-Pressure Preservative Treatment of Poles with Pentachlorophenol in the Northwestern States." IN: Proc., Amer. Wood-Preservers' Assoc. 43:126-141. 1947.

White fir and western hemlock were recommended for pressure treatment only.

31. HUNT, D. L. Seasoning and Surfacing Degrade in Kiln-Drying Western Hemlock in Western Washington. U.S. Dept. of Agric., Forest Serv., Pac. N.W. For. and Range Expt. Sta., Res. Note PNW 6. 6 p. 1963.

In 1962, this study of more than 175,000 board feet of lumber was made on the Olympic Peninsula in Washington to determine the degrade (loss in volume and value) of western hemlock cut, kiln dried, and surfaced in accordance with usual industry practices. The degrade measured included the reduction in grade because of seasoning, surfacing, and manufacturing defects and the loss in volume because of culling and trimming of surfaced dry lumber. Degrade is expressed both as a percentage of the rough-green lumber input and as a loss in value per thousand board feet of lumber.

32. JAHN, E. C. "Chemical Debarking of Trees." Pulpwood Annual, American Pulpwood Assoc. 3 p. 1953.

The method of application and effects of sodium arsenite as a chemical debarking agent are discussed. Sodium arsenite may be a safe and effective method of debarking eastern hemlock and Pacific silver fir.

33. JOHNSON, J. W. "Relationships Among Moduli of Elasticity and Rupture: Seasoned and Unseasoned Coast-Type Douglas Fir and Seasoned Western Hemlock." IN: Non-Destructive Testing of Wood. Symposium Proc.Spokane, Washington. P. 419-459. 1965.

Six samples of 2- by 6-inch unseasoned coast-type Douglas fir and three of seasoned western hemlock, each including 80 pieces that represented large populations of select structural, construction, and utility grades of lumber, were matched by strength ratio and modulus of elasticity flatwise. Then three samples of the Douglas fir were seasoned. Specimens were tested for elasticity, flatwise and edgewise, and for modulus of rupture. One sample from each species-moisture group was tested to failure flatwise; two were broken edgewise, one each with the strongest and weakest edges in tension. Lines of regression, relating moduli of elasticity and rupture, were developed. Differences in these relations were shown among the unseasoned and seasoned Douglas fir, the seasoned hemlock, and the three positions of testing to failure. Regression lines were obtained, which related elasticity of unseasoned Douglas fir to elasticity and rupture of seasoned lumber. Best results were obtained from lumber tested flatwise; worst results were from material tested on edge with the weakest edge in tension. At similar positions of test, stiffness of unseasoned and seasoned Douglas fir differed little, but the ability of lumber to withstand breaking loads was improved more than 20 percent by drying to 10 percent moisture content.

34. JOHNSON, J. W. "Efficient Fabrication of Glued-Laminated Timbers." Amer. Society of Civil Engineers, J. of Structural Division 99(3):431-442. 1973.

Glued-laminated beams with predictable values for modulus of elasticity can be designed with lumber that has the modulus of elasticity determined.

Glued-laminated beams of several species, or combinations of species, can be constructed of nondestructively tested lumber to give satisfactory values for modulus of rupture. Additional visual grading is required, however, for material used in highly stressed areas. Also, joints are needed that conform to requirements of Commercial Standard CS253-63.

Grading the lumber by modulus of elasticity successfully replaced the requirements for rate of growth and recommendations of density of the American Institute for Timber Construction for tension laminations.

Lumber with adequate modulus of elasticity and with sizes of knots up to those permitted in Douglas fir L3 or southern pine No. 3 grades was used in the compression zone without reducing the minimum values for modulus of rupture below the desired level.

35. JOHNSON, J. W. Flexural Tests of Large Glued-Laminated Beams Made from Visually Graded Hem-Fir Lumber. For. Res. Lab., Oregon State Univ. Corvallis. Res. Paper 18. 11 p. 1973.

Fifteen large glued-laminated beams made from visually graded hem-fir lumber were designed, fabricated, and tested to failure in static bending. When tested, the beams had an average moisture content of 7.5 percent. The beams were 40 feet long, 5 1/8 inches wide and 24 inches deep. Before laminating, individual pieces of lumber were graded by specifications similar to those for the L-grades and the recommendations of the American Institute for Timber Construction for face laminations for Douglas fir. Three combinations (designs) were included, with 5 beams in each.

Performances of the beams during testing are tabulated and graphed. Guidelines were established for the grades and locations of material needed for different levels of modulus of elasticity and modulus of rupture. Least values of modulus of elasticity and rupture obtained from beams of each design were: combination one, 1,788,000 and 5,350 psi; combination two, 1,660,000 and 4,580 psi; and combination three, 1,724,000 and 3,950 psi. Results of the tests will provide a basis for the development of industry laminating specifications for visually graded hem-fir lumber.

36. KENNEDY, E. I. Strength and Related Properties of Wood Grown in Canada. Dept. of Forestry, Ottawa Lab. Canada. Publ. 1104. 51 p. 1965.

This publication lists the strength values and main physical properties of most of the woods grown in Canada. The data were obtained by the systematic sampling and testing of tens of thousands of clear wood specimens with standard procedures. Statistics are provided to inform the reader of the average values and the degree of variability of the properties. Summary tables of the most frequently used averages are presented in both English and metric units.

37. KOZLIK, C. J. Kiln Schedules for Douglas Fir and Western Hemlock Dimension Lumber. For. Res. Lab., Oregon State Univ., Corvallis. Rept. D 7. 20 p. 1963.

A more efficient kiln schedule was desired for drying 2- by 10-inch dimension lumber from Douglas fir and western hemlock to an average moisture content of 19 percent. Unseasoned lumber from several different areas in Oregon was segregated into three classes: fine-grain Douglas fir, coarse-grain Douglas fir, and western hemlock. Effects of 3 dry-bulb temperatures (130, 150, and 180 F), conditions for three equilibrium moisture contents (9, 12, and 15 percent) and 3 air velocities (150-200, 450, and 600 feet a minute) were studied to determine the most satisfactory kiln schedule. Evaluation of individual charges was based on time in kiln and amount of checking that occurred during drying.

Conclusions of the study indicate that an initial dry-bulb temperature of 180 F can be tolerated by both Douglas fir and western hemlock without increased degrade. Initial conditions for equilibrium moisture content of 9 percent can be followed by conditions for 6 percent for western hemlock after average moisture content of the wood has reached 22 percent.

38. KOZLIK, C. J. Effect of Kiln Conditions on the Strength of Douglas Fir and Western Hemlock. For. Res. Lab., Oregon State Univ., Corvallis. Rept. D 9. 32 p. 1967.

To test the effects of kiln drying on strength properties of Douglas fir and western hemlock, temperatures to 230 F, conditions for equilibrium moisture contents of 6 percent and 12 percent, and prolonged heating were investigated.

Prolonged heating and choice of conditions for 6- or 12-percent equilibrium moisture content had little effect on most strength properties.

Temperature was important. The higher the temperatures, the greater was the reduction in strength. Toughness was affected most, shear almost as much, modulus of rupture and fiber stress at the proportional limit somewhat less, and modulus of elasticity was affected least.

39. KOZLIK, C. J. Effect of Kiln Temperatures on Strength of Douglas Fir and Western Hemlock Dimension Lumber. For. Res. Lab., Oregon State Univ., Corvallis. Rept. D 11. 20 p. 1968.

To test the effects of kiln temperatures on the bending strength of 2- by 6-inch Douglas fir and western hemlock dimension lumber, temperatures applied included 70 (control), 170, 200, and 230 F.

Modulus of elasticity was affected least by increasing temperature. Modulus of rupture in Douglas fir was affected most. The higher the temperature, the greater the reduction in the modulus of rupture. Reduction as high as 23 percent took place on Douglas-fir wood dried at 230 F. Modulus of rupture was reduced by 10 to 18 percent in western hemlock dried at 230 F.

Split and crook were the most common forms of seasoning degrade.

40. KOZLIK, C. J. "Problems of Drying Western Hemlock Heartwood to a Uniform Final Moisture Content." IN: Proc., 21st Annual Meeting of Western Dry Kiln Clubs. P. 55-61. 1970.

Many softwood species contain wet pockets or streaks in the heartwood that defy any means of drying them to an acceptable moisture content after a reasonable time in the kiln. Species included in this group are the true firs, western hemlock, sugar pine, western or Idaho white pine, redwood, and western redcedar.

Segments of several studies of the slow movement of moisture in western hemlock sinker heartwood and possible means of easing moisture problems at individual mills are discussed. Processing of western hemlock lumber includes two difficult problems, the wide variation in moisture content after kiln drying and large losses in degrade from shake.

The problems arise in the heartwood, which includes portions of wood that have been termed wetwood or sinker or heavy wood. Sinker heartwood has a distinctive odor and darker color or wetter appearance than normal heartwood. Properties of sinker heartwood include higher initial moisture content, greater specific gravity, higher percentage of extractives, and lower drying rates than adjacent heartwood. Shake commonly is associated with sinker heartwood.

Some of the physical and chemical properties of sinker heartwood and normal heartwood are compared. Revised kiln schedules with temperatures above 212 F did not affect materially the nonuniformity of final moisture, but did reduce total kiln time. Degrade loss from shake is an unavoidable problem because shake occurs in the living tree. It can only be eliminated by proper trimming at the sawmill.

41. KOZLIK, C. J. "Electrical Moisture Meter Readings on Western Hemlock Dimension Lumber." For. Prod. J. 21(6):34-35. 1971.

Fifty pieces of 2-inch western hemlock dimension lumber were measured for moisture content with a radio-frequency power-loss meter and a resistance meter, and then by ovendrying. The average moisture content determined by ovendrying was generally lower than readings with the power-loss meter, but higher than resistance-meter readings. Wet pockets in the wood influenced measurements of average moisture content by all methods. Density affected readings with the power-loss meter.

42. KOZLIK, C. J. and L. W. HAMLIN. "Variability in Final Moisture Content of Kiln-Dried Western Hemlock Lumber." For. Prod. J. 22(7):24-31. 1972.

This study investigated presteaming of western hemlock lumber to minimize the nonuniformity of final moisture content. Presteaming from 4 to 24 hours and drying with conventional or high-temperature (above 212 F) schedules did not promote uniform drying. Schedules were developed for high-temperature (above 212 F) drying of 2-inch dimension lumber in 4-, 6-, and 8-inch widths. Total kiln time was reduced from 0 to 19 percent in drying 2- by 8-inch lumber, from 19 to 39 percent for 2- by 4-inch lumber, and 50 percent on 4- by 4-inch vertical-grain shop lumber when compared to commercial schedules. Degrade was not increased and, generally, final moisture contents were more uniform with high-temperature drying. Lack of uniformity of final moisture contents is attributed directly to wet pockets or streaks in the heartwood. Segregation of sinker or heavy stock on the green chain can be accomplished with a high degree of accuracy (about 98 percent). Through good segregation practices, the uniformity of final moisture contents would be improved and total kiln time would be reduced, because sinker stock represents a low percentage of the lumber production in a given mill.

43. KRAHMER, R. L. "Variation of Specific Gravity in Western Hemlock Trees." Tappi 49(5):227-229. 1966.

Information on variation of specific gravity in trees, correlated with possible causes of variation, is effective for estimating wood quality in existing timber stands and helpful in tree-improvement programs. Considerable literature is available on research that concerns the influence of various factors on specific gravity of wood for many species of trees, but few data are available on variation of specific gravity in western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Results from a study of variations of specific gravity in trees of this species are presented here.

44. KRAHMER, R. L. and W. A. COTE, Jr. "Changes in Coniferous Wood Cells Associated with Heartwood Formation." Tappi 46(1):42-49. 1963.

In applied areas such as preservative treatment, pulping, and drying of wood, the anatomical structures involved in the movement of materials through wood are important. In this study, the rate of intertracheid fluid movement in the sapwood and heartwood of four coniferous species was related to the condition of the bordered pit pairs. The bordered pit membrane in Douglas fir consists of fibrillar strands, which radiate from a rough-surfaced torus to the outer margin of the pit cavity; in hemlock, the membrane has torus extensions in addition to fine strands that radiate from a torus; and in western redcedar, the membrane does not possess a torus, but consists of numerous, closely packed strands. The air-permeability ratio of early sapwood to late heartwood for the three species tested was: Douglas fir, 34; western hemlock, 10; and western redcedar, 6.5. Solvent extraction of the heartwood samples with hot water, ethanol, and ethanol-benzene improved the permeability. The mechanism for pit closure in the heartwood was attributed to bordered pit aspiration and to deposition of heartwood extractives and ligninlike substances in the fine openings of the bordered pit pairs.

45. KRAHMER, R. L., R. W. HEMINGWAY, and W. E. HILLIS. "Cellular Distribution of Lignins in *Tsuga heterophylla* Wood." Wood Science and Tech. 4(27):122-139. 1970.

Western hemlock heartwood contains patches of tracheids with large amounts of cellular inclusions. Microscopic and chemical examination of the wood showed several types of deposits, which contained the lignins matairesinol, hydroxymatairesinol, and conidendrin. The deposits, which were often almost pure individual lignins, frequently assumed different physical forms and chemical composition. A check in the wood contained three distinct forms of deposits, each of which was a different lignin. Rays contained deposits physically similar to those in adjacent tracheids. Although lignins were present in the tracheids, they were not detected in the rays. Lignins lined tracheid walls as surface films and often encrusted the bordered pits. The amount of lignins in the wood was not related to wetwood zones, although surface films and pit encrustations should have an influence on physical properties. The location and physical nature of lignin deposits in western hemlock heartwood indicates their biosynthesis probably has taken place at the heartwood periphery in the vicinity of the half-bordered pit.

46. KRAHMER, R. L. and J. D. SNODGRASS. "Strength of Western Hemlock Compared for Two Areas." For. Prod. J. 17(8):36-38. 1967.

The statistical analysis in this study was made to determine whether differences occurred in basic strength properties of western hemlock wood (*Tsuga heterophylla*) sampled randomly from two separated areas in Oregon.

47. LAIRD, P. P. The Influence of Pre-Harvest Killing of Western Hemlock on Subsequent Stump Invasion by *Fomes annosus*. Ph.D. thesis, Oregon State Univ., Corvallis. 117 p. 1971.

The results clearly show that little stump infection by *F. annosus* occurs in western hemlock killed by monosodium methylarsonate. At the same time, the trees dry quickly on the stump, and bark is removed easily. Disadvantageously, wood deterioration and breakage increase. Breakage problems can be reduced by careful felling, but the deterioration cannot be so easily prevented. The type of deterioration encountered is tolerable in pulpwood operations, however, and in stands managed for pulp, treatments such as these probably could be beneficial economically as well as pathologically. The immediate question is: Do harvest and thinning operations upset this balance to favor *F. annosus* and possibly other disease-causing organisms?

This thesis concludes that epidemiology of *F. annosus* in commercial thinnings of western hemlock is subject to deliberate prophylactic treatment by preharvest killing with monosodium methylarsonate. The utility or necessity for such treatment on an economic and long-term basis is beyond the scope of this paper, but appears encouraging.

48. LIN, R. T. and C. J. KOZLIK. "Permeability and Drying Behavior of Western Hemlock." IN: Proc., 22nd Annual Meeting, Western Dry Kiln Club. Portland, Oregon. P. 44-48. November 1971.

Longitudinal permeability to water and air of western hemlock cannot be used to estimate the drying characteristics of the wood above the fiber saturation point. Extracting wood with acetone or steaming improved the longitudinal permeability to air. Compressive treatment perpendicular to the grain by 10 percent of original dimensions neither improved the permeability to water nor the water diffusion coefficient of western hemlock. Compressive treatment by 33 percent of original dimension improved permeability to water of heartwood, but degraded permeability of sapwood.

49. McGOWAN, W. M. The Strength of Western Hemlock Power and Communication Poles. Dept. of Forestry, Ottawa, Canada. Tech. Note 27. 15 p. 1962.

Within the limitations of this investigation, observations can be made about the strength of treated and untreated 25-foot western hemlock poles. When adequately treated with preservative, western hemlock is a suitable species for the support of power and transmission lines. The average moduli of rupture of treated and untreated poles were 6,432 and 6,135 psi. The combined average modulus of rupture was 6,280 psi. Standard pressure treatment with creosote had no apparent effect on the strength of these poles. The variation in strength was slightly higher in treated poles than in untreated poles. The average strength of a consignment of poles may be reasonably estimated by: $M = 18{,}992\ G^{1.22}$, where M is modulus of rupture in psi and G is specific gravity (volume at test, weight ovendry). The regression of the strength of small clear specimens upon the strength of poles was highly significant for both treated and untreated groups.

50. McLEAN, J. D. "Factors That Have an Important Bearing on the Preservative Treatment of Round Timbers." IN: Proc., Amer. Wood-Preservers' Assoc. 46:162-171. 1950.

Important factors that should be considered in preparing specifications for the treatment and in the treatment of round timbers are: treating conditions; service conditions; cost; relation of diameter, sapwood resistance, and sapwood depth to penetration and retention; sapwood-penetration requirements; treatment of different size timbers in the same charge; and relation of retention and penetration in timbers of different species.

51. MILLER, D. J. Pressure Treatment of Western Hemlock at Various Moisture Contents. For. Res. Lab., Oregon State Univ. Corvallis. File Rept., Project 50C-9. Unpubl. 3 p. 1955.

Western hemlock boards (1 by 8 by 70 inches long), pressure treated by a full-cell process at 110 pounds per square inch for 3-4 hours with a copper sulfate solution had the retentions shown in Table 4.

Penetration was virtually complete.

52. MILLER, D. J. Creosote Treatability of Western Hemlock from Oregon Coast and Cascade Sources. For. Res. Lab., Oregon State Univ., Corvallis. File Rept., Project 26C-15. Unpublished. 17 p. 1963.

Western hemlock lumber from the coast was more treatable than that from the Cascade Mountains (Table 5). Within each area, longitudinal penetration, which was much greater than radial or tangential penetration, was similar in both sapwood and heartwood.

53. MILLER, D. J. Treatability of White Fir. For. Res. Lab., Oregon State Univ., Corvallis. File Rept., Project 26C-15. Unpubl. 11 p. 1963.

Longitudinal penetration of creosote was determined on 6-inch long specimens. Radial and tangential penetration were measured from a hole through the center of 2-inch-square by ¾-inch-long blocks that had been completely coated with an epoxy resin. Preservative retention and longitudinal penetration were high in both sapwood and heartwood; radial and tangential penetration varied greatly, with frequent minimum values of zero (Table 6).

54. MILLER, D. J. and R. D. GRAHAM. Service Life of Treated and Untreated Fence Posts. For. Res. Lab., Oregon State Univ., Corvallis. Progress Rept. 14. 18 p. 1971.

Most Oregon woods untreated and many woods treated with preservatives have been or are being tested for serviceability. Eight series of untreated posts (including 5 series of steel), 22 series of nonpressure-treated posts, and 13 series of pressure-treated posts remain in test. Series in which all posts have failed now number 36 for untreated and 29 for non-

Table 4. Pressure Treatment of Western Hemlock at Various Moisture Contents (51).

Number of boards	Moisture content	Retention
	Percent	*Lb/cu ft*
6	10-13	34
2	19	32
3	30-37	26

Table 5. Treatability of Western Hemlock from Oregon (52).[1]

Direction of penetration and source	Specimens	Moisture content	Retention		Penetration	
			Sapwood	Heartwood	Sapwood	Heartwood
		Percent	*Lb/cu ft*	*Lb/cu ft*	*In.*	*In.*
Radial						
Cascade Mt.	15	0	2.2	0.7	0.09	0.02
Coast	18	0	4.2	2.5	0.22	0.16
Tangential						
Cascade Mt.	11	0	2.3	2.3	0.09	0.11
Coast	7	0	5.4	3.9	0.30	0.29
Longitudinal					Rating[3]	
Cascade Mt.[2]	16, 12	0	14	13	4.1	3.6
Coast[2]	18, 7	0	22	22	5.3	5.5
Cascade Mt.	22	0	9		4.1	3.7
Coast	16	0	19		5.5	5.3
Cascade Mt.	22	12	8		4.0	3.4
Coast	16	12	18		5.5	4.7

[1]Source--Cascade Mountains (Mt. Hood) and coast (Clatsop County).
Impregnation--Creosote at 120 F and 100 psi for ½ hour (longitudinal) or 4½ hours (radial and tangential).
Size--1.5 inches in radial and tangential directions and 6 inches in longitudinal direction.
Sapwood--identified with 40 percent perchloric acid solution.
[2]Specimens 4.5 inch long, 50:50::sapwood:heartwood.
[3]Penetration rating scale from 1 (none) to 6 (complete).

pressure-treated. Causes of failures since 1949 were: fungi, 75 percent of failures; fungi and termites, 16 percent; fungi and insects other than termites, 6 percent; and termites, 2 percent.

Preservative treatment of the entire post is needed for longest service of nondurable woods at this test site in western Oregon. Untreated Douglas fir, grand fir, and western hemlock have an average service life of from 4 to 9 years.

Posts of hemlock and Douglas fir, pressure treated with effective water-borne and oil-type preservatives, have estimated service lives of from 39 to over 50 years.

Table 6. Treatability of White Fir from Oregon and California (53)[1].

Source and type of wood	Specimens	6-inch-long specimens Retention	6-inch-long specimens Penetration	2-inch squares penetration Radial	2-inch squares penetration Tangential
		Lb/cu ft	*Rating*[2]	*In.*	*In.*
Lake County, Oregon					
Sapwood	2	25	5.5	0.35	0.18
Sapwood, heartwood	11	16	3.7	.10	.15
Heartwood	9	17	3.7	.03	.18
Jackson County, Oregon					
Sapwood	2	26	6.0	.44	.53
Sapwood, heartwood	6	25	5.7	.29	.43
Heartwood	4	24	4.9	.33	.43
Calaveras County, California					
Sapwood	2	25	4.5	.54	.66
Sapwood, heartwood	12	25	4.9	.23	.59
Heartwood	4	24	5.2	.13	.33
Plumas County, California					
Sapwood	0	--	--	--	--
Sapwood, heartwood	11	22	5.1	.40	.36
Heartwood	5	24	5.5	.09	.26

[1]Material obtained from U.S. Forest Products Laboratory, Madison, Wisconsin, and treated with a pentachlorophenol-heavy petroleum solution for 4 hours at 100 psi. As sapwood could not be distinguished from heartwood, wood in the outer 2 inches of tree was considered sapwood, between 2 and 4 inches was considered sapwood-heartwood, and more than 4 inches inside was considered heartwood.
[2]Based on ratings from 1 (none) to 6 (complete).

55. MILLER, D. J. and R. D. GRAHAM. "Report of 1966-68 Inspection of Ties in Main Lines of Southern Pacific Transportation Company." IN: Proc., Amer. Wood-Preservers' Assoc. 69:180-183. 1973.

This report describes the condition and, where sufficient ties have been replaced, estimates the service life of different Oregon woods represented by 11,433 ties that have been in main-line tracks of the Southern Pacific Transportation Company at 15 sites in Arizona, California, Nevada, and Oregon for 11 to 19 years. The species include incense cedar, Douglas fir, Shasta fir, white fir, mountain hemlock, western hemlock, lodgepole pine, ponderosa pine, Sitka spruce, and tanoak.

Checking, splitting, and twisting, much of which occurred during air seasoning before preservative treatment, continued to be the most common defects. Platecutting has occurred in about 80 percent of the 16- to 19-year-old ties of most species in Arizona and California. It has not exceeded 20 percent in the 12- to 14-year-old ties in Nevada or 7 percent of ties of similar age at 3 sites in Oregon. At Fields, Oregon, almost all ties of the two species in test were platecut.

Where renewals have been highest at sites in California and Arizona, the estimated service life of different species ranges from 18 to 29 years. Because most Oregon woods are performing about as well as or better than Douglas fir, their utilization should be considered to increase the supply of ties.

56. MOECK, H. A. "Surfaced Hemlock-Balsam Lumber Sorting on the Basis of Bark-Maggot Damage." British Columbia Lumberman. 3 p. April 1968. (Table 7).

57. OBERG, J. C. "Schedules for Kiln-Drying White Fir and Hemlock to the Proposed New Standard." For. Prod. J. 14(1):10. 1964.

Kiln schedules were developed for drying western hemlock and white fir lumber to 15 percent moisture-content average with less than 5 percent of the pieces above 19 percent moisture content.

58. OKKONEN, E. A., H. Z. WAHLGREN, and R. R. MAEGLIN. "Relationship of Specific Gravity to Tree Height in Commercially Important Species." For. Prod. J. 22(7):37. 1972.

The relations of wood specific gravity to height in a tree were investigated for 28 commercially important timber species. The resulting trends were the following: in 17 species, specific gravity decreased with increase in height; in 5 species, specific gravity increased with increase in height; in 3 species, specific gravity initially decreased with increase in height, but was followed by an increase in specific gravity as height increased; and in 3 species, no significant change was observed. Users of upper logs interested in information on strength or pulp yield should find this report of value.

59. ROSS, J. D. "Chemical Resistance of Western Woods." For. Prod. J. 6(1):34-37. 1956.

The resistance of different wood species to chemical solutions is an important factor in selecting wood for storage tanks. Thirteen western woods and two southern woods were exposed to solutions of several common acids, bases, and salts at room and boiling temperatures to measure their relative chemical resistance. Extent of deterioration was determined by comparing final average breaking load for each species with average breaking load for untreated pieces.

60. SALAMON, M. "Effect of High Temperature Drying on Quality and Strength of Western Hemlock." For. Prod. J. 15(3):122. 1965.

The study shows that the strength properties of kiln-dried western hemlock are unaffected by temperatures ranging up to 230 F when applied as in the kiln schedules presented here. It also shows that the strength properties of lumber dried under the low-high temperature schedule are not reduced below those of lumber dried under a conventional schedule, even when the drying times for the two different schedules are equal.

61. SALAMON, M. and C. F. McBRIDE. "A Comparison of Western Hemlock and Balsam Fir Dried at High and Conventional Temperatures." IN: Proc., 17th Annual Meeting, Western Dry Kiln Clubs, Corvallis. P. 50-57. 1965.

This is an economic study of the effect of higher drying temperatures on degrade of 1¾-inch western hemlock and Pacific silver fir.

Table 7. Sorting 2- by 6-Inch Hemlock-Balsam Lumber for Bark-Maggot Damage (56).

Measurement	Sample			
	1	2	3	All
Board length, *ft*	12	10	10	
Pieces	120	120	120	360
Balsam, *percent*	25.8	52.5	35.7	38.4
Hemlock, *percent*	74.2	47.5	63.3	61.6
Pieces with black check, *percent*	90.8	80.0	80.8	83.9
Pieces with black check correctly identified, *percent*	8.16	83.3	88.7	84.5

62. SCHROEDER, H. A. and C. J. KOZLIK. "The Characterization of Wetwood in Western Hemlock." Wood Sci. and Tech. 6:85-94. 1972.

One problem in the kiln drying of western hemlock lumber is the wide variation in final moisture content of the wood. This variation in moisture content occurs because of the presence of sinker or wetwood in the heartwood. The features of wetwood that differentiate it from the normal heartwood include higher specific gravity, higher extractives content, and lower permeability. The apparent higher specific gravity can be fully accounted for by the higher content of extractives. The principal extractive is α-conidendrin. The wetwood in western hemlock often occurs together with ring shake and, under these circumstances, the white deposit on the shake surfaces is also α-conidendrin and not matairesinol, the substance usually associated with ring shake in western hemlock.

A viewpoint is presented on the origin of wetwood as the end product of a reaction by the tree to injury, such as ring shake, in which additional extractives are deposited. The extractives result in a greatly lowered permeability, which prevents loss of moisture during heartwood formation and thereby results in wetwood. Bacteria usually found in wetwood and re sponsible for many of the symptoms associated with wetwood are a result of the high moisture content, which favors bacterial growth in wood. Presumably, the two primary sources of loss in kiln drying western hemlock, shake and wetwood, often are associated intimately.

63. SMITH, J. H. G. and A. KOZAK. "Thickness, Moisture Content, and Specific Gravity of Inner and Outer Bark of Some Pacific Northwest Trees." For. Prod. J. 21(2):38. 1971.

Improved methods, including bark thickness and percentages and corrections for volumes lost in voids, are discussed. Tabulated averages and measures of variation in thickness, moisture, and specific gravity provide new data about both inner and outer bark for 19 common tree species of the Pacific Northwest, 13 conifers, and 6 hardwoods.

Selected data on bark thickness are summarized in Table 8.

Table 8. Bark Thickness of Selected Western Woods (63, 64).

	Trees		Thickness			Outer bark	
Species	Number	Dbh	Outer	Total	Volume	Moisture content	Specific gravity
		In.	*In.*	*In.*	*Percent*	*Percent*	
Douglas fir	98	15	0.39	0.63	--	80	.43
Coastal	97	--	--	1.60	32	--	--
Interior	78	--	--	1.50	35	--	--
Hemlock	29	10	0.12	0.25	--	65	.56
Coastal	81	--	--	0.50	18	--	--
Interior	61	--	--	0.55	21	--	--
Grand fir	2	11	0.10	0.34	--	51	.70
Silver fir	10	8	0.07	0.20	--	40	.58
Lodgepole pine	22	11	0.19	0.27	--	42	.51
	454	--	--	0.25	11	--	--
Western larch	3	11	0.47	0.59	--	44	.35
Ponderosa pine	11	10	0.57	0.65	--	21	.34
	100	--	--	1.20	32	--	--
Englemann spruce	3	12	0.11	0.27	--	61	.50

64. SMITH, J. H. G. and J. KURUEZ. "Amounts of Bark Potentially Available from Some Commercial Trees of British Columbia." Proc., N.W. Scientific Assoc. Cheney, Washington. P. 1-8. 1969.

Some factors that determine distribution of thickness and precentage of bark were analyzed for the commercial tree species of British Columbia. Methods were developed for estimation of specific gravity of bark and were used primarily in simulation of forest fuel weights for Douglas fir, western hemlock, and western redcedar. Data obtained will have applications in biomass studies and in estimation of bark available for various commercial purposes.

Selected data on bark thickness are summarized in Table 8.

65. SWAN, E. P. "Chemical Methods of Differentiating the Wood of Several Western Conifers." For. Prod. J. 16(1):51-54. 1966.

Identification of the species of lumber by microscopic techniques is laborious. Modern methods of chemical analysis were applied to this problem in an attempt to develop simple chemical tests to differentiate the species. Heartwoods from several Canadian pines, namely, *Pinus banksiana, P. contorta* var. *latifolia, P. banksiana* x *contorta* and *P. contorta*, are differentiated by a gas-liquid chromatographic analysis of the terpenes. A more difficult and important separation is a method to distinguish between western hemlock (*Tsuga heterophylla*) and balsam (*Abies amabilis*). The status of existing chemical methods of differentiation between these two woods is discussed. The application of the following methods of analysis is shown. Paper chromatography was used to study the phenolic heartwood extractives; gas-liquid chromatography was used in a study of the terpenes and other volatile material; and thin-layer chromatography was used to study the lipophilic extractives. The possibility of finding a suitable chemical differentiation test from each of these chromatographic examinations is discussed. Tentative methods of differentiation are described.

66. TOWNSEND, R. F. "Western Hemlock Poles: Preliminary Report, Committee T-3." IN: Proc., Amer. Wood-Preservers' Assoc. 60:72-73. 1964.

Data are given on 111 Class 5, 40-foot poles.

After air drying, average moisture content of 1-inch cores equalled 23 percent, and of 2-inch cores equalled 27 percent by resistance-type meter. The appearance was good, with small uniform checks and no large checks.

After treatment with creosote[2], average moisture content of 2-inch-long cores equalled 19 percent. Retention by gauge was 8.80 pounds per cubic foot. Retention by assay was 4.14 pounds per cubic foot on total volume, and 6.6 pounds per cubic foot in the outer 2 inches. Tops and butts were loaded excessively with preservative. Penetration averaged 0.85 inch or 42 percent into the sapwood, which was 2.04 inches deep.

67. U.S. DEPARTMENT OF AGRICULTURE. Weights of Various Woods Grown in the U.S. U.S. Dept. of Agric., Forest Serv., For. Prod. Lab., Madison, Wisconsin. 8 p. 1949.

Tables of average specific gravity and moisture content of common commercial species grown in the United States are provided to approximate weights of green sawed and round timbers.

68. U.S. DEPARTMENT OF AGRICULTURE. Wood Handbook. U.S. Dept. of Agric., Forest Serv., For. Prod. Lab., Madison, Wisconsin. Handbook 72. 528 p. 1955.

Average strength values of selected western woods are summarized in Table 9.

[2] Boulton-dried 10 hours at 190 F, 35 psi initial air pressure, impregnation at 92 psi for 13 hours, expansion bath of 3 hours, final steam for 3 hours at 240 F, and final vacuum for 2 hours.

Table 9. Average Strength Properties of Selected Western Woods at 12-Percent Moisture Content (68).[1]

Species	Specific gravity	Static Bending			Compression parallel to grain		Compression perpendicular to grain
		Fiber stress at PL[2]	Modulus of Rupture	Modulus of Elasticity	Fiber stress at PL[2]	Max. crushing strength	Fiber stress at PL[2]
		Psi	*Psi*	*1000 Psi*	*Psi*	*Psi*	*Psi*
Douglas fir							
Coast type	0.48	7,800	12,200	1,950	5,850	7,430	1,160
Intermediate type	.44	7,400	11,200	1,640	5,540	6,720	920
Rocky Mt. type	.43	6,300	9,600	1,400	4,660	6,060	820
Fir							
California red	.39	6,300	10,800	1,540	4,220	5,650	650
Grand	.40	5,800	9,300	1,630	4,420	5,430	620
Noble	.38	6,600	10,000	1,580	4,960	5,550	640
Pacific Silver	.38	6,200	9,400	1,530	4,660	5,550	490
White	.37	6,500	9,300	1,380	3,590	5,350	600
Hemlock							
Eastern	.40	6,100	8,900	1,200	4,020	5,410	800
Western	.42	6,800	10,100	1,490	5.340	6,210	680
Pine							
Lodgepole	.41	6,700	9,400	1,340	4,310	5,370	750
Ponderosa	.40	6,300	9,200	1,260	4,060	5,270	740
Spruce							
Englemann	.34	5,500	8,700	1,280	3,580	4,770	540

[1]Wood Handbook, U.S. Dept. of Agric., Handbook 72, 1955.
[2]Proportional limit.

69. U.S. DEPARTMENT OF AGRICULTURE. Derivation of Fiber Stresses from Strength Values of Wood Poles. U.S. Dept. of Agric., Forest Serv., For. Prod. Lab., Madison Wisconsin. Res. Paper FPL-39. 8 p. 1965.

Factors of variability, round form, moisture content, and effect of preservative treatment that influence fiber stress values for wood poles are discussed. The report is based on the authors' studies of these factors for Sectional Committee 05 on Wood Poles of the American Standards Association. Tables of strength values from three sources of data are compared with the values adopted by the American Standards Association, now the American National Standards Institute.

70. U.S. DEPARTMENT OF AGRICULTURE. Western Wood Density Survey, Report No. 1. U.S. Dept. of Agric., Forest Serv., For. Prod. Lab., Madison, Wisconsin. 58 p. 1965.

Mean specific gravities by forest survey units are presented for nine species of the 23 sampled by the Western Wood Density Survey. Environmental relations and strength-property relations with specific gravity are discussed.

71. WALTERS, J. The Branch Arrangement of Western Hemlock. Faculty of Forestry, Univ. of British Columbia, Vancouver. Res. Note 29. 3 p. 1960.

Height, age, diameter at breast height, and crown class exerted no apparent influence on the pattern of branching described here. The detection, however, of annual stages of growth of western hemlock by recognition of subnodal branches is simple only in juvenile growth such as that of seedlings and of the upper crowns of larger trees.

In summary, the data presented graphically in this paper indicate that termination of annual leader growth in western hemlock is marked usually by an extra long branch produced immediately below the annual node. This branch is called the "subnodal" branch. Other branches tend to be concentrated along the upper portion of the annual internode below the subnodal branch.

72. WELLWOOD, R. W. "Specific Gravity and Tracheid Length Variations in Second-Growth Western Hemlock." J. Forestry 58(3):361-368. 1960.

Data from specific gravity determinations showed maximum values at the base and minimum values at the top section. Percentage of summerwood in the growth ring, as determined by macroscopic methods, had no significant effect on specific gravity, but rate of growth had a highly significant effect. A regression equation for specific gravity and rate of growth checked closely with other published data.

73. WILCOX, W. W. "Some Physical and Mechanical Properties of Wetwood in White Fir." For. Prod. J. 18(12):27-31. 1968.

Some physical and mechanical properties of white fir were tested to compare wetwood of fir with that of other species. The presence or absence of wetwood had little effect on wood properties other than moisture content, but distance aboveground in the tree had a significant effect. Specific gravity and toughness were considerably higher at the butt than further up the stem. Shrinkage of both wetwood and sapwood was similar to other results reported for the species.

74. WILCOX, W. W. and W. Y. PONG. "The eEffects of Height, Radial Position and Wetwood on White Fir Wood Properties." Wood and Fiber 3(1):47-55. 1971.

Critical measurements and location of externally detectable defects were determined for 20 white fir [*Abies concolor*(Gord. and Glend.) Lindl.] trees. Boards sawed from these trees were identified with regard to tree, height aboveground, and radial position within the stem.

Size and location of defects and grade and drying sort of each board also were recorded. Moisture content, specific gravity, toughness, shrinkage, and liquid absorption were determined on samples taken at three heights and three radial positions from eight of the trees. The data indicated that the sinker sort (the one requiring the longest drying time) came primarily from the center portion of the lowest two 16-foot logs, but the corky (the one requiring the shortest drying time) and sap sorts were from the center and outer portions of logs above the second 16-foot log. About 43 percent of the board volume came from the lowest 32 feet of stem. The highest values of moisture content, specific gravity, tangential and radial toughness, and tangential and radial shrinkage generally occurred in the butt log, which decreased with height, and in the outer third of radial position, decreasing with approach toward the pith. Longitudinal shrinkage was lowest at the butt and increased with height. Because most typical wetwood symptoms occurred in the center of butt logs, the conclusion was that, except for the association with drying time, wetwood has little or no detrimental effect on those white fir wood properties investigated.

75. WILCOX, W. W. and C. G. R. SCHLINK. "Absorptivity and Pit Structure as Related to Wetwood in White Fir." Wood and Fiber 2(4):373-379. 1971.

White fir wetwood and sapwood and white fir wood, artificially inoculated with the bacterium isolated from white fir wetwood, were observed by light and electron microscopy. No alterations in wood structure, such as decomposition of ray parenchyma cell walls or bordered pit tori, were observed in any of the samples. The capacity of wood samples incubated in a nutrient medium to absorb liquid was the same even when the medium had been inoculated with the wetwood bacterium. Apparently, the bacterium present in white fir wetwood does not alter wood structure in the same manner as other bacteria known to be wood attackers.

76. WILLISTON, E. M. "Proposal: New Stress Values for the Coast White Woods." For. Prod. J. 10(12):621. 1960.

A comparison of existing data on strength properties of the coast white woods, with new data obtained in a wide sampling, indicated current stress values may be too conservative. To improve the economic utilization of these species, the author recommends an interim grouping of hemlock and the coast true firs at a higher level of stress values, until a proposed industry-government study of the problem is completed.

77. WOOD, L. W., E. C. O. ERICKSON, and A. W. DOHR. "Strength and Related Properties of Wood Poles." Amer. Soc. for Testing Materials, Philadelphia, Pennsylvania. Final Rept. September 1960.

Some of the important findings from the Wood Pole Research Program of the American Society for Testing Materials and related research were as follows:

Strength of a pole is related to specific gravity of the wood. Stiffness of a pole can be represented by the compression modulus of elasticity of the wood in it. Modulus of rupture is less in large than in small poles. Southern pine poles of rapid growth and low specific gravity for the species are below average in strength.

Significant correlation exists between the strength of untreated poles and that of untreated small clear specimens, and between treated poles and treated small clear specimens.

Natural characteristics such as knots or spiral grain as limited in specifications of the American Standards Association are not important factors in controlling the strength of poles as they are most commonly used.

Preservative treatment has no consistent effect on the surface hardness of a pole. The bending strength of southern pine test poles is reduced 20 to 40 percent by steam conditioning and treatment within the limits of the American Standards Association. The reduction of strength from conditioning and treatment of southern pine poles is greater in the poles than in small clear specimens of wood from the poles. A supplementary series of strength tests on treated longleaf pine showed that shortening the period and lowering the temperature of steam conditioning gives strength values closer to those of untreated poles. Treating-plant experiments with reduced steam-conditioning schedules showed that steaming temperatures of 240 and 245 F may be used successfully on southern pine poles. The bending strength of Douglas-fir and western larch test poles is reduced about 10 percent by Boultonizing and treatment within limits permitted by standards of 1960 of the American Wood-Preservers' Association. Lodgepole pine and western redcedar poles show no significant change in strength after air seasoning and treatment in accordance with standards of 1960 of the American Wood-Preservers' Association. Reintroduction of moisture into poles that are treated after air seasoning is difficult.

The two standard test methods gave essentially similar strength values, except for the 55-foot poles.

An accurate field-test method for specific gravity, applicable for poles, was developed. Variability of the pole samples tested compared closely with the variability of the species from which they were taken. Standard volume computations closely approached the true volumes of most of the test poles. The reduction in circumference because of shrinkage of lodgepole pine, Douglas-fir, and western hemlock poles that dried to 20 percent moisture content is generally on the order of 1 percent. Moisture contents at 6 inches and at 4 feet above ground line of poles in service in the northern and western states are predominantly in the approximate range of 10 to 15 percent. The twisting of poles in service is related to spiral grain and to change of moisture content.

Research needed on wood poles is: effects on strength from machine shaving compared to hand peeling; the effects from butt soaking compared to full-length soaking of test poles; the effects of incising on strength; specification of poles by specific gravity; and moisture content of poles in service and effect of drying on strength.

The whole broad field of conditioning and preservative treatment needs more study. A good start has been made on the effect of the temperature and duration of heating of wood in various media on strength. Does seasoning or preservative treatment modify the water-holding properties of wood, and is that modification permanent? Some indication is that the moisture content at fiber saturation is changed and makes possible an actual gain in strength in poles treated after seasoning. Seasoning before treatment introduces other problems, which include protection from decay in the warmer climates and the tendency toward bleeding after treatment. Where seasoning in air at normal outdoor temperatures is unsatisfactory, more study should be given to the drying of poles at higher temperatures, as in a kiln. A great amount of research could be done in the field of moisture content in relation to conditioning and preservative treatment. These unanswered questions, however, do not belittle the knowledge of poles already gained. The natural wood pole, like the trunk of its parent tree, is an efficient structural member. Wood preservation has proved to be the key to long life and economical service of poles.

APPENDIX

BARK KEY FOR DOUGLAS FIR, HEMLOCKS, AND TRUE FIRS IN WESTERN UNITED STATES[3]

A. White or light yellow corky plate lines in outer bark . . . . B

A. No white or light yellow corky plate lines in outer bark C

B. Wood color on sawcut shows white or light-colored sapwood and pink or reddish heartwood; smooth sawcut. Usually pitch on end of log. Mature bark usually deeply fissured. Inner bark seldom over 20 percent of total bark thickness. Mature old-growth bark usually over 4 inches thick and may be as thick as 24 inches; second growth often over 2 inches thick . . . . **Douglas fir**

B. Wood color on sawcut white or grayish white for both sap and heartwood; rough sawcut. No pitch on sawcut. Inner bark usually about 40 percent of total bark thickness; no gel formation when injured. Mature bark usually 1½ to 2½ inches thick, but may be 4½ to 6 inches thick . . . . **White Fir**

C. Purple plate lines in outer bark thin and distinct, overlapping slightly at the tips causing a dish-shaped pattern. Bark seldom over 2 inches thick with narrow ridges. Inner bark often yellow colored, less than 35 percent of total bark thickness, not slick or sticky when moistened. Wood often has wavy annual rings . . . . D

C. Purple plate lines in outer bark broad and distinct or may blend into adjacent bark . . E

D. Mature surface bark usually dominated by brown colors, brown to gray brown. Narrow ridges flattened and overhang fissures (described as platy); fissures deep and tend to parallel length of log. Dry bark flakes or powders when rubbed between the fingers. Young surface dark gray to gray brown, with narrow ridges that curl at the edge and tend to scale off . . . . **Western hemlock**

D. Mature surface bark dull purplish brown to dark reddish brown, at a distance may have blue-gray tinge. (Color to dark, not clearly brown.) Narrow ridges rounded or flattened; fissures deep and narrow (more of a ridge and groove structure than western hemlock with the grooves intertwining). Young surface bark light brown, rough, and scaly . . . . **Mountain hemlock**

E. Mature surface bark dark (reddish brown or almost black when wet in pond, dark gray in standing tree) and has deep and fairly straight fissures that form long, high crowning ridges, but young silver bark has deep fissures that separate flat ridges. Mature bark usually from 2 to 3 inches thick, occasionally from 4 to 6 inches thick. Outer bark rich red or purplish color with broad purple parallel plate lines that tend to blend into adjacent bark. Inner bark from 20 to 35 percent of the total bark thickness; secretes sticky gel when injured . . . . **California red fir and Shasta fir**

E. Mature surface bark not dark, but gray to gray brown with fissures that form flattened ridges, but young silver bark has few, if any, shallow fissures . . . . F

F. Mature surface bark divided by shallow and irregular fissures into broad plates. Outer bark has few, irregular purplish plate lines. Inner bark may extend to surface of bark; usually 60 percent or more of total bark thickness . . . . G

F. Mature surface bark has many fissures with the outer bark plate lines always evident. Mature bark is usually over 1 inch thick . . . . H

[3] Developed by Louis Powell, formerly with American Plywood Association, with the help of several individuals from public and private organizations and industries, especially George Bryon, of Douglas Veneer Company. Unpublished.

G. Mature surface bark silvery gray, may be cinnamon red on furrowed old trees. Bark contains scattered shot-size resin pockets. Mature bark from 1 to 1½ inches thick. Scattered resin pockets begin to show up in young bark . . . . .Subalpine fir

G. Mature surface bark silvery gray with chalky white splotches. Bark shows numerous large resin blisters. Inner bark not slick or sticky when moistened. Mature bark seldom over 1 inch thick . . . . Pacific silver fir

H. Mature surface bark gray to dull gray brown with fissures that separate bark ridges into oblong, depressed plates. Outer bark plate lines purplish, broad, distinct, and wavy; oblong yellow pockets scattered throughout outer bark. Inner bark often over 50 percent total bark thickness; secretes gel when injured. Mature bark from 3 to 4 inches thick at base of trees at higher elevations, rarely over 1¾ inches thick at lower elevations . . . . Grand fir

H. Mature surface bark grayish brown, gray black, or purplish with shallow, irregular fissures that break the bark into squarish plates, which may be depressed. Outer bark plate lines purplish, broad, distinct, and sharply curving to give a cupped pattern. Inner bark usually from 35 to 40 percent of the total bark thickness, though occasionally 50 percent; secretes sticky gel when injured. Mature bark from 1¼ to 1¾ inches thick . . . . Noble fir

INDEX