FORGOTTEN RESULTS IN HEMLOCK DRYING

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INTRODUCTION

My lecture is entitled "Forgotten Results in Hemlock Drying". I chose this topic for two reasons:

1) To raise the awareness of researchers who are conducting wood drying investigations;

2) To indicate where ideas and practices can be expanded and improved.

I will briefly cover a few areas which are of great interest to researchers and kiln operators, and which were thoroughly explored and investigated by Charles Kozlik, Marion Salamon, Tom L. Abner, and others. These areas are:

a) Sinker heartwood and its effect on moisture content and drying rates;

b) Wide range of initial moisture content and its effect on overdrying and underdrying;

c) The occurrence of compression wood and its effect on degrade;

d) The effect of different types of kiln schedule on lumber quality.

I. Sinker Heartwood (Characteristics)

Kozlik and Ward investigated the characteristics of sinker heartwood in western hemlock; its occurrence, moisture content and chemical constituents as well as kiln drying properties. Figure (1) shows the location of sinker heartwood in a 105 year old tree. This type of wood contains anaerobic bacteria, has a higher extractive content, higher specific gravity, dries at a slower rate than normal sapwood and heartwood. Lumber containing sinker heartwood develops shake when kiln dried and retains wet pockets areas.

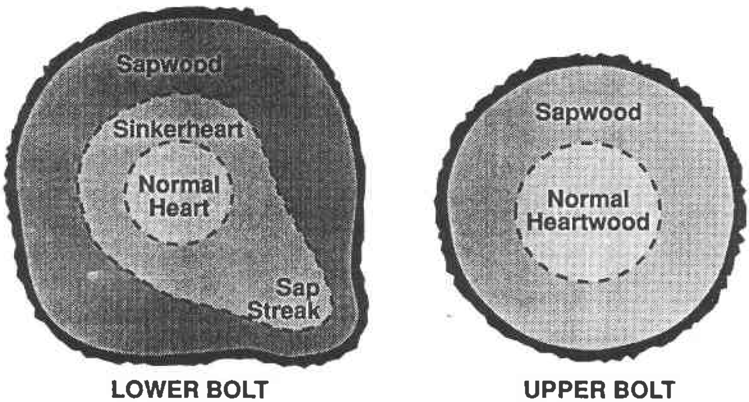


Figure 1. Sinker Heartwood Characteristics. Schematic of end sections of 2-foot-long bolts cut from a 105-year-old western hemlock tree. Lower bolt was cut at 18-inches above ground line and upper bolt at 52-feet. Sinker heartwood was infected with anaerobic bacteria. The sap streak was infected with both bacteria and fungi, and could be traced to a mechanical root injury. Normal heart and sapwood was non-infected. (Kozlik)

Sinker heartwood is found in young growth as well as old growth and can be divided into two categories:

a) lighter (easy to dry) occurring in young growth; and,

b) heavy (hard to dry) occurring in old growth.

Table (1) compares the drying rates of sinker heartwood, sapwood and heartwood in young growth as well as old. The percentage of sinker wood was estimated for sapwood and heartwood and were examined for bacteria infection. The relationship between drying rates and length of time of the infection were correlated.

Improvement in drying rates was attempted by removing the extractive with acetone and ethanol and then pre-steaming. The results of this work can be summarized as the following:

a) Sinker heartwood seem to occur in trees which were subjected to injury;

b) Moisture content, specific gravity and chemical extractives are higher than that of normal sapwood or heartwood;

c) "Wet spots" persist after kiln drying;

d) Drying rates are slower than that of normal sapwood or heartwood;

e) Improvements in drying rates can be obtained by acetone and ethanol treatment and then pre-steaming.

One proposed solution for dealing with the "wet spots" issue is to subject lumber to radiofrequency for a short period after the material has been kiln dried. This area requires research because a number of parameters need to be investigated.

II. Occurrence of Compression Wood in Western Hemlock

Earlier studies have shown that most of the kiln drying degrade of western hemlock is associated with differences in shrinkage rate during drying. The presence of compression wood results in an uneven shrinkage pattern causing twist in 2x4, cup in 2x8, 2x10 and 2x12. One possible explanation for the occurrence of compression wood streaks was given by Kellogg and Warren (1978). The observation was made while they were investigating the effect of drying temperature on the colour and strength of western hemlock. The findings were:

a) Compression wood streaks introduced variability in both of these parameters;

b) Less severe and slower kiln schedules minimized degrade and gave a much better final moisture uniformity;

c) Compression wood affects the strength of the lumber.

Many kiln operators are regularly asked to correct the problem of twist, cup and splits by applying better kiln schedules without realizing that the degrade may be occurring due to the presence of compression wood. Understanding the physical characteristics such as sinker heartwood, wet spots, compression wood, are critical factors in seasoning western hemlock.

III. Sorting for Kiln Drying

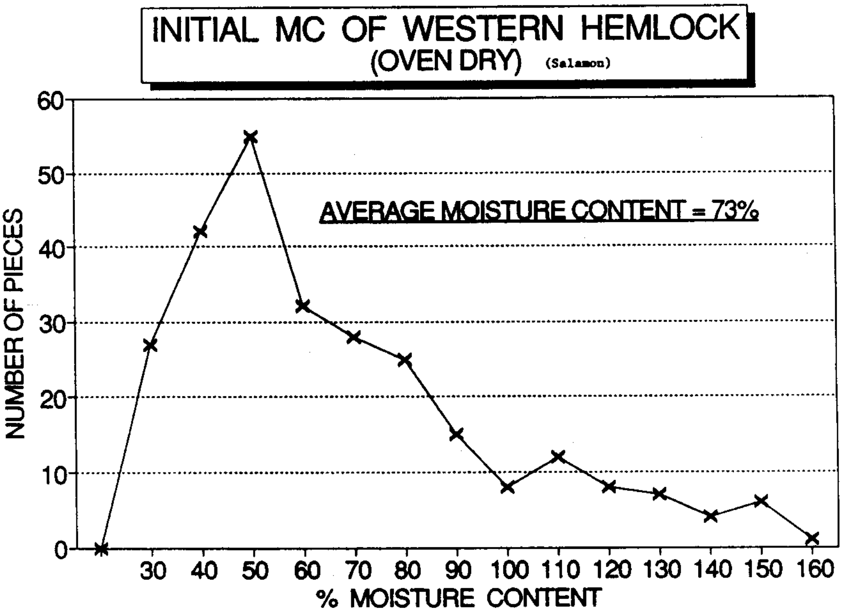
Marion Salamon in 1965 presented some interesting results in his paper entitled "Four-Day Drying of Western Hemlock". These results show the relation of initial moisture content to specific gravity, calculates the drying rates using different air velocities, and describes the development of kiln schedules. Specific gravity calculations revealed that western hemlock can be sorted into moisture

TABLE 1

Moisture content of normal and microbially infected wood from young and old-growth western Hemlock at various stages of drying. (Kozlik)

TYPE OF WOOD	Associated Micro-Organisms	Number of Samples	Average Board Moisture Content % Initial	51 hr	74 hr	98 hr	144 hr	227 hr
	YOUNG GROWTH							
Lower Stem								
Sapwood 100%	None	10	131	35	19	13	8	7
Sap 65%, Sapstreak 35%	Mixed [1]	4	95	27	16	11	8	6
Sap 60%, Sinker 40%	Bacteria	5	100	34	22	16	10	7
Sinker 60%, Heart 40%	Bacteria	5	107	38	27	19	11	7
Upper Stem								
Sapwood 100%	None	7	153	31	16	10	7	6
Heartwood 100%	None	2	53	16	11	9	7	7
Sap 50%, Heart 50%	None	4	97	22	14	11	9	8
	OLD GROWTH							
Sapwood 100%	None	3	185	43	19	10	7	6
Heartwood 100%	None	2	55	17	12	9	7	6
Sap 60%, Sapstreak 40%	None	1	69	25	16	11	8	7
Sap 70%, Sinker 30%	Bacteria	2	105	30	20	14	9	7
Heart 50%, Sinker 50%	Bacteria	2	100	29	20	14	9	7
Sinker - Light [2]	Bacteria	4	146	45	28	17	10	7
Sinker - Heavy [3]	Bacteria	3	155	63	47	33	18	9
	TOTAL	54						

[1] Mixed population of bacteria and fungi. Sapstreak originating from root injury.
[2] Apparently early stage of sinker formation, generally easy to dry.
[3] Older or more advanced stage of sinker formation, generally harder to dry.



classes based on weight before kilning. This method eliminated overdrying and underdrying. Figure (2) shows a typical initial moisture distribution. The average is 73% whereas the range is 30% to 160%. There is also a large variation in specific gravity .30 to .50; due to the presence of sinker heartwood.

Table (2) presents data from Tom Abner's work "Drying West Coast Hemlock and Douglas Fir to the New Moisture Specification with Minimum Degrade". Hemlock lumber was sorted into 2 groups by weight "heavy" and "light". After kiln drying the charges with similar schedules, it was found that 2/3 of the wet pieces were in the heaviest 30% by green weight.

Kozlik and Hamlin (1971) noted the ease of visual segregation of sinker heartwood on the green chain, while his later work (Kozlik and Ward, 1981) noted the variability of sinker heartwood specific gravity.

Ward and Kozlik (1975) indicated the particular importance of sorting by electric resistance to segregate sinker heartwood in young growth Western hemlock to prevent shake.

Other methods employed in sorting for kiln drying are:

a) Segregating sapwood from heartwood;

b) Sorting by initial moisture content.

Moisture sorting of "SPF" is being done by several mills in the interior of British Columbia and one mill on the coast. The Novax moisture sensor is used to perform this task. Data on the economics derived from sorting can be obtained from their brochure.

IV. Drying Schedules

As noted above, much work has been done by Abner, Kozlik, Lin, Salamon and others on schedules to successfully dry western hemlock despite the unusual difficulties of sinker heartwood and compression wood. An excellent resume of these results are given in Tables (3,4,5,6,7).

Salamon showed in 1965 that it was possible to dry common dimension lumber with combined conventional/high temperature schedule, using air circulation rate of 450-850 ft/min.

Subsequent work by Kozlik (1971, 1981) and Kozlik and Hamlin (1971), documents the improvement in drying quality and time with higher kiln temperatures. The later work clearly indicates the differences between heartwood, sapwood, and sinker heartwood. Kozlik (1975) also warns of the loss of strength in western hemlock due to high temperature drying. Salamon (1965) had earlier developed schedules (low-high temperature) to minimize the loss of strength.

CONCLUSION

As coastal mills in British Columbia consider major investments in drying facilities for western hemlock, it is essential that we be familiar with the work carried out since the early times on the particular problems of this species and the solutions offered by sorting and special drying schedules. This will be invaluable in specifying equipment and quantifying economic benefits, but is also necessary as a foundation to further research, by avoiding blind alleys and focusing on the key problem areas that remain.

Suggested areas of future research are (1) selective treatment of residual "wet spots" by the use of radio-frequency drying, (2) development of improved sorting technique for segregating "sinker heartwood" and compression wood, (3) drying schedules for sorted lumber as well as schedules for lumber containing "wet spots" and compression wood.

BIBLIOGRAPHY

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Summary: West coast hemlock 1½-inch dimension can be dried to the new moisture specifications with a minimum of drying degrade and moisture non-uniformity with the schedules discussed in the paper. Fast, severe schedules increase the drying degrade and result in poor moisture uniformity.

Barton, G.M. 1963. Conidendrin in floccosoids of western hemlock. Forest Prod. J. 13(7):304. 1968. Significance of western hemlock phenolic extractives in pulping and lumber. Forest Prod. J. 18(5):76-80.

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Espenas, Leif D. 1974. Longitudinal Shrinkage of Western Red Cedar, Western

TABLE 2

Proportion of Pieces Over 19% Dry Moisture Content in Green Weight Classes (Abner)

	Heavy			Light						
Pieces Over 19% Moisture	10	9	8	7	6	5	4	3	2	1
# Pieces	41	41	51	23	20	13	10	9	4	1
% in Each Class	19.3	19.3	23.8	10.8	9.4	6.1	4.7	4.2	1.9	0.5
Cumulative %	19.3	38.6	62.4	73.2	82.6	88.7	93.4	97.6	99.5	100.0

About 2/3 of "wet" pieces are in the heaviest 30% by green weight (10% in each class).
Total number of pieces in each "green" weight class is approximately 100.

TABLE 3

Typical High Temperature-Large Wet Bulb Depression Schedule Used for Drying Western Hemlock Dimension (Abner)

Hours	Dry Bulb (° F.)	Wet Bulb (° F.)
0 - 18	200	180
18 - 30	200	170
30 - 48	200	160
48 - 72	200	150
72 - 96	200	175

TABLE 4

Constant Depression Schedule (ABNER)

Hours	Dry Bulb (° F.)	Wet Bulb (° F.)
0 - 98	174	154
98 - 104	vents closed	spray on

TABLE 5

Equalization Schedule for Drying Western Hemlock Dimension (ABNER)

Hours	Dry Bulb (° F.)	Wet Bulb (° F.)
0 - 12	180	170
12 - 24	180	165
24 - 48	175	155
48 - 72	175	145
72 - 96	165	145
96 - 115	155 - 160	145

TABLE 6

Degrade vs. Dry Moisture Content (ABNER)

	Classes of Dry Moisture Content				
	-7 - 11%	12 - 13%	14 - 16%	17 - 20%	21 - 25+%
No. of Pieces (2 x 8" x 16')	225	191	234	175	179
No. of Pieces Degrading	58	45	34	26	34
% of Pieces in MC Class that Degraded	25.8	23.6	14.5	14.9	19.0
Cost of Degrade in $/MBF	$5.20	$4.41	$2.63	$2.39	$3.94

TABLE 7

Proportion of Pieces Over 19% Dry Moisture Content in Green Weight Classes (ABNER)

	Heavy			Light						
Pieces Over 19% Moisture	10	9	8	7	6	5	4	3	2	1
# Pieces	41	41	51	23	20	13	10	9	4	1
% in Each Class	19.3	19.3	23.8	10.8	9.4	6.1	4.7	4.2	1.9	0.5
Cumulative %	19.3	38.6	62.4	73.2	82.6	88.7	93.4	97.6	99.5	100.0

About 2/3 of "wet" pieces are in the heaviest 30% by green weight (10% in each class).
Total number of pieces in each "green" weight class is approximately 100.

Hemlock, and True Fir. For. Prod. J. 24(10):46-47.
Abstract: Average longitudinal shrinkage of western red cedar, western hemlock, and true fir from green to OD ranged from about 0.2 to 0.3 percent. Most of the shrinkage occurred between about 12 and 0 percent moisture content. Estimates of maximum shrinkage and movement are given for exterior and interior exposure conditions.

Gerhards, C.C. 1965. Strength and Related Properties of Western Hemlock. U.S. Forest Service Research Paper FPL 28, May 1965.

Horton, Robert K., Resch, H. 1976. Kiln Stick Thickness Effect on Drying 2-inch Western Hemlock Lumber. For. Prod. J. 26(3) 35-39.
Abstract: Increased kiln capacity in lumber dry kilns may be achieved by separating lumber courses with sticks thinner than is customary. Thin sticks may be made by impregnating multi-layers of kraft paper with phenolic compounds or by laminating solid wood. Established advantages of such kiln sticks are longer stick life and increased stacking efficiency. In this study, criteria for evaluation were air velocity between courses of lumber and drying degrade with the corresponding moisture content distribution. Good drying conditions were obtained using kiln sticks as thin as 7/16-inch. Further reduction in stick thickness, however, decreased both velocity and the uniformity of air flow. In a commercial run, no significant differences in degrade were observed between 3/4-inch wood sticks and 1/2-inch phenolic sticks.

Kellogg, R.M., Warren, Sita R. 1979. The Occurrence of Compression Wood Streaks in Western Hemlock. Forest Sci. 25(1):129-131.
Abstract: Streaks of compression wood were observed in western hemlock lumber. These streaks were not associated with leaning stems, but they were observed to initiate at knots and to extend downwards for as much as 4 meters. This observation suggests that transportable auxin may play a role in compression wood induction. Forest Sci. 25:129-131.

Kozlik, C.J. 1976. Kiln Temperature Effect on Tensile Strength of Douglas Fir and Western Hemlock. For. Prod. J. 26(10):30-34.
Abstract: Unseasoned 2-inch by 6-inch Douglas fir [Pseudotsuga menziesii (Mirb.)] and western hemlock (Tsuga heterophylla (Raf.) Sarg.) dimension lumber was kiln dried to an average of 8 to 10 percent moisture content at 170°F, 200°F, and 230°F, and tested in tension parallel to the grain. Two edge-knot classes, from 3/4 to 1-inch and from 1¼ to 1½-inches, were included for each species at the three test temperatures. For both species, an increase in temperature resulted in a decrease in tensile strength. Douglas fir lumber with small knots dried at 230°F was 11 percent lower in tensile strength than that dried at 170°F. The corresponding reduction for Douglas fir with large knots was 22 percent; corresponding reductions for western hemlock with small knots were 21 percent and 2 percent. One or a combination of several physical properties measured to predict tensile strength provided low estimates; the correlation coefficients ranged from 0.22 to 0.41. In four of six combinations of temperature and knot size, the tensile strength of hemlock was 3 to 4 percent greater than that of Douglas fir.

Kozlik, C.J., Hamlin, L.W. 1972. Reducing variability in Final Moisture Content of Kiln Dried Western Hemlock Lumber. For. Prod. J. 22(7):24-31.
Abstract: This study investigated pre-steaming of western hemlock lumber to minimize the non-uniformity of final moisture content. Pre-steaming 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 37 percent for 2 by 6-inch lumber, from 14 to 39 percent for 2 by 4-inch lumber, and 50 percent on 4/4 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.

Kozlik, C.J., Kramer, R.L., Lin, R.T. 1962. Drying and Other Related Properties of Western Hemlock Sinker Heartwood. Wood and Fibre. 4(2):99-111.
Abstract: Sinker heartwood dries more slowly than normal heartwood of western hemlock. Extraction with ethanol or acetone and pre-steaming improved the rate of drying of sinker heartwood. Electron microscopy was used to examine bordered pits in normal and sinker heartwood and extracted specimens of sinker heartwood. Parallel capacitance was lowest in sapwood, higher in normal heartwood, and highest in sinker heartwood. The range in capacitance was related to total extractive content at similar moisture contents.

Kozlik, C.J. 1963. Kiln schedules for Douglas fir and western hemlock dimension lumber. School of Forestry, Oregon State University, Corvallis, Oregon. Report D-7.

Kozlik, C.J., Ward, J.C. 1981. Properties and Kiln Drying Characteristics of Young-Growth Western Hemlock Dimension Lumber. For. Prod. J., 31(6):45-52.
Abstract: Sinker heartwood occurs in both old-growth and young-growth trees. Two classifications of sinker were found and characterized as heavy, with floccosoids, and light, without floccosoids. Green moisture content of sapwood and sinker heartwood averaged above 140 percent while normal heartwood averaged about 80 percent. However, the range in moisture content for sinker heartwood varied from 80 to more than 200 percent. Specific gravity of sinker may or may not be higher than normal heartwood depending on growth rate and extractive content. During kiln drying, normal heartwood reached fiber saturation point in one-half the time of sapwood and sinker heartwood. Total drying time to 15 percent moisture content for normal heartwood was about 30 percent less with a conventional schedule (180°F) and 40 percent less with a high-temperature schedule (230°F) than for sinker heartwood and sapwood. High-temperature drying reduced kiln time from conventional drying by 50 percent or more for the four board types.

Kozlik, C.J. 1981. Shrinkage of Western Hemlock Heartwood after Conventional and High-Temperature Kiln Drying. For. Prod. J. 31(12):45-50.
Abstract: Two groups of end-matched specimens of unseasoned 2-inch by 6-inch western hemlock [Tsuga heterophylla (Raf.) Sarg.] dimension lumber and vertical-grain 2-inch by 6-inch clear lumber containing varying amounts of sinker heartwood were kiln dried and equilibrated to 11, 6, and zero percent moisture content. Conventional (186°F) and high-temperature (230°F) schedules were used. Before

kiln drying, each specimen was surfaced on four sides to 1.7 by 6-inches, cut to 20-inch lengths, measured for width and thickness, and weighed. The measurement areas were given four classifications: normal (no sinker heartwood), streak, band, and sinker. Measurements and weights were recorded again after kiln drying and equalizing. Specimens with normal heartwood shrank similarly with both schedules. High-temperature drying of streak, band, and sinker heartwood specimens produced greater shrinkage than conventional drying of matched specimens. Sinker specimens shrank least after kiln-drying, followed by band, streak, and normal specimens. Total shrinkage was nearly equal for the four heartwood classifications. Adjustment of measurements of shrinkage of the vertical-grain specimens to a 90°F ring angle did not indicate any differences in total shrinkage except in 4 of 12 comparisons in the tangential plane.

Lin, R.T., Lancaster, E.P., Kramer, R.L. 1973. Longitudinal Water Permeability of Western Hemlock. 1. Steady State Permeability. Wood and Fiber. 4(4):278-289.

Abstract: Average initial permeability to water of sapwood was found to be 9.6 x 10^{-10} cm^2, that of wetwood from heartwood was 6.64 x 10^{-10} cm^2, and that of normal heartwood was 4.4 x 10^{-12} cm^2. All the specimens were never-dried, approximately 0.95 cm in diameter and 2 cm long, and were embedded in a lucite tube using epoxy resin as binder.

Using polyethylene glycol 1000 as an embedding agent, 23% of sapwood pits, 42% of pits in wetwood from heartwood, and 84% of pits in normal heartwood were found to be aspirated. Scanning electron microscopy revealed that the normal heartwood of freeze-dried heartwood was heavily incrusted, but that of wetwood was relatively free of encrustation. High water permeability of wet heartwood was attributed to a low level of pit aspiration and freedom from encrustation.

Both sapwood and wetwood exhibited deterioration of permeability with time. In sapwood the cause was considered to be time-dependent pit aspiration because of hydro-static pressure differentials during testing, but in wetwood the deterioration was attributed to extractives transported by water and deposited on pit membranes to form an impermeable coat of film.

A further proposal is that formation of wet pockets during drying of western hemlock lumber is caused by formation of an impermeable zone from the encrustation of pits by extractives during the migration of water, which traps the moisture in lumber.

Additional Keywords: Tsuga heterophylla, sapwood, heartwood, wetwood, pit aspiration, transmission electron microscopy, scanning electron microscopy.

Lin, R.T., Lancaster, E.P. 1973. Longitudinal Water Permeability of Western Hemlock. 1. Unsteady-State Permeability. Wood and Fibre. 4(4):290-297.

Abstract: A mathematical model was developed and used as the basis for constructing two experimental apparatus to investigate the permeability of western hemlock to water. When unsteady-state and steady-state permeability were compared, the unsteady-state permeability of both sapwood and normal heartwood was found to be higher than the steady-state permeability, but that of wetwood was generally lower than the initial steady-state permeability and was of the order of the final steady-state permeability. The permeability of western hemlock to water, regardless of whether it is measured by steady-state or unsteady-state techniques, is the highest for sapwood, followed by wetwood and normal heartwood.

Under unsteady-state conditions, sapwood permeability is time-independent, but wetwood exhibits time-dependent behaviour, probably caused by blocking of the openings on pit membranes by movable extractives when water flows through the cell lumen. Storing western hemlock wetwood in water at room temperature reduces its water permeability. Wet pockets that form when wetwood of western hemlock is subjected to kiln drying have lower permeability than the dried portion of the lumber.

Additional Keywords: Tsuga heterophylla, sapwood, heartwood, kiln drying, wet pockets.

Lexford, R.F., Wood, L.W., Gerry, E. 1943. "Black Streak" in Western Hemlock: Its Characteristics and Influence on Strength. U.S.D.A., Forest. Serv., Forest Products Laboratory, Madison, Wis. Rept. 1500 16 pp.

Moeck, H.A. 1968. Surfaced Hemlock-Balsam Lumber Sorting on the Basis of Bark-Maggot Damage. B.C. Lumberman.
Abstract: In British Columbia, western hemlock and balsam fir lumber is sold mixed together as "Western Canada Hemlock" or "Hembal". However, demand is growing for the separation of the two types of lumber. The frequently appearing black check of both types of lumber, caused by bark maggots (Cheilosia sp.), can be used to sort the lumber. Of 360 pieces examined (38.4% balsam), 83.9% had black check. Of these, 84.5% was correctly sorted on this basis alone.

Oberg, J.C. 1964. Schedules for Kiln Drying White Fir and Hemlock to the Proposed New Standards. For. Prod. J. 14(1):10-12.

Salamon, M. 1965. Four-Day Drying of Western Hemlock. Proceed. Kiln Drying Seminars, Vancouver, B.C.

Conclusion: Four-day drying of western hemlock and balsam fir common dimension was carried out successfully by the use of a combined schedule of conventional temperatures and high- temperatures in a kiln capable of working with air circulation rates of 450 and 850 f.p.m.

For industrial operations which are unable to raise both the temperature and the air circulation rate, it might be possible to raise one or the other. Upon the basis of preliminary experiments it is expected that an increase of air circulation rate will reduce the drying time as well as lower the range of final moisture content.

Salamon, M. 1965. Effect of High-Temperature Drying on Quality Strength of Western Hemlock. For. Prod. J. 15(3):122-126.
Abstract: Western hemlock dimension lumber was kiln dried under special schedules and then compared to matched samples dried under conventional schedules. One schedule was conventional until the fiber saturation point was reached, and then temperatures above 212°F were used. In the other schedule a constantly high-temperature of 220°F was used from the start. The degrade was greatest in the conventionally dried lumber and least in the lumber dried at the low-high temperature schedule. The range in the distribution of final moisture content decreased with increasing time of exposure at temperatures above 212°F. The saving in drying time compared to the conventional schedules was about 33 percent for the constant high-temperature schedule and up to 10 percent for the low-high temperature schedule.

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.

Salamon, M., McBride, C.F. 1965. A comparison of western hemlock and balsam fir dried at high and conventional temperatures. Proc. 17th Annual Meeting, Western Dry Kiln Clubs, West Coast Dry Kiln Association, Portland, Oregon.

Schroeder, H.A., Kozlik, C.J. 1972. The Characterization of Wetwood in Western Hemlock. Wood Sci, and Tech. Vol. 6: 85-94.
Summary: One of the problem areas in the kiln drying of western hemlock lumber is the wide variation in final moisture content of the wood. This variation in moisture content is due to the presence of sinker or wetwood in the heartwood. The features of wetwood which 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 extractives content. The principal extractive is 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 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, i.e., 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 resulting in wetwood. Bacteria usually found in wetwood and responsible for many of the symptoms associated with wetwood are a result of the high moisture content which favours bacterial growth in wood. Presumably, the two primary sources of loss in kiln drying of western hemlock, shake and wetwood, are often intimately associated.