THE WETWOOD PROBLEM IN THE FOREST PRODUCTS INDUSTRY

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Introduction

The excessive accumulation of wood moisture in the bole of standing trees appropriately described as wetwood, is a phenomenon familiar to many of us in the timber industry. Less familiar are the causes or possible causes of wetwood, where it occurs in trees, its properties and the many problems associated directly or indirectly with its occurrence in trees and during conversion to solid wood products.

This paper will attempt to highlight some of the current knowledge on wetwood and try to relate this knowledge to some of the utilization and processing problems plaguing the forest products industry.

General Characteristics

For purposes of this report, wetwood will be defined as the wood in standing trees which has been internally infused with water. Wood infused with water from an external source (e.g., rain or storage ponds) does not fit this definition and will not be included in this discussion. Wetwood often has a water-soaked translucent appearance and is commonly designated as water core, sinker heart, wet core, wet heart, and black heart. In general, wetwood is consistently higher in moisture content than the adjacent normal heartwood, and in comparison to sapwood, it can be higher, lower or equal in moisture (see Table 1). Regardless of external appearance, wetwood differs from normal wood in physical and chemical properties and is generally more difficult to dry.

Causes of Wetwood

The formation of wetwood in trees has been attributed by researchers to a number of causes. These causes generally can be placed in one of three categories: microbial (bacterial), nonmicrobial (injury), and normal age-growth formation. In assessing the cause or causes of wetwood, associative relationships have been the basis of many of these evaluations; actual tests to confirm cause-and-effect relationships have met with little success.

Much of the current research on wetwood has been directed towards investigating the association of bacterial infection and the occurrence of wetwood in trees. That wetwood formation or initiation may be nonmicrobial in nature has been suggested by some investigators who suggest that bacteria are possibly part of an indigenous microflora of normal wood, living in a viable, but quiescent state until some change occurs in the wood to provide favorable substrate (wetwood) for bacterial growth.

Wetwood have been found to be associated with a number of physical-mechanical and biological injuries. Whether these injuries result in or initiate wetwood formation have not been substantiated. Investigations have shown that the column of wetwood in white fir deviated radially and longitudinally to regions of natural and silvicultural injuries. Similar deviations have been noted in conjunction with injuries apparently caused by insect attack. Wetwood also have been found to be associated with dwarf mistletoe and decay. The lack of a consistent association has lead some investigators to conclude that wetwood in the conifer is only a condition of excessive accumulation of moisture and is a normal age-growth formation.

Wetwood occurs in both conifers and hardwoods. Western hemlock and the true firs develop wetwood consistently; the white pines (both eastern and western), sugar pine, western larch, redwood and western redcedar have been reported to develop wetwood, but to a lesser extent. In the hardwoods, the occurrence of wetwood is most prevalent in the cottonwoods, aspen and willows, and to a lesser extent in the oaks, maples, and hickories. Though rarely found in Douglas-fir, it has been reported to occur in varying amounts in this species.

Because wetwood occurs less in young-growth trees has led some foresters to speculate the wetwood problem would be solved when the last old-growth timber is removed. Wetwood, however, has been reported in very young trees of white fir, hemlock, cottonwood, aspen, maple, and western redcedar. Site, soil moisture, soil type, aspect, and cultural practices all have been cited as contributing to wetwood formation in young trees.

Wetwood Types and Patterns Within the Trees

With few exceptions wetwood formation is restricted to the heartwood and heartwood-sapwood transition zones of living trees. Two types of wetwood can occur within the living tree, namely: 1) wetwood formed from inner aging of normal or injured sapwood, and 2) wetwood developing in previously formed heartwood.

Wetwood is generally not found in the outer sapwood of living trees. Where it does occur in the sapwood, however, it appears to be associated with attack, stem cankers, and wounds of various forms. In these instances, as previously stated, the wetwood zone deviates from the central core radially and longitudinally to the traumatized zone of the sapwood.

Although the spatial distribution of wetwood in standing trees will vary by factors such as point of origin, duration of formation, etc., there are essentially three general patterns. Most frequently encountered is the conical pattern which occurs in the central core of the lower bole with the wetwood base originating at the root collar and tapering to an apex in the upper bole. This pattern is commonly found in white fir, hemlock, western larch, northern red oak and eastern cottonwood.

A second pattern consists of streaks or columns of wetwood which can be traced to injuries or to dead branch stubs in the upper stem. The basal portion of these trees may or may not contain wetwood. Upper stem wetwood have been reported in white fir, hemlock, white pine, aspen, willow, and elms.

A third pattern contains both basal and upper stem wetwood formations which have extended and coalesce into a single massive wetwood formation.

Problems with Wetwood in Timber and Wood Products

Wetwood has distinctive physical and chemical properties which can cause utilization and processing problems. These problems can result in substantial economic losses when the affected timber is converted into logs, lumber, and veneer. Although wetwood is visibly sound it may be intrinsically weaker than sapwood and normal heartwood with respect to bonding strength between wood cells. This weakening in cell to cell bonding appears to be related to the production of pectin-degrading enzymes by anaerobic bacteria present in the wetwood. These enzymes attack the pectic substances in the middle lamella that hold together the wood cells. Consequently, wetwood is generally weaker in the cohesive bonding between cells.

Shake and Frost Cracks. This weaker bonding results in radial and ring shake and spangles in wetwood of living trees when the trees are subjected to stresses from wind, growth and freezing. Stem frost cracks, seen frequently on white fir and hemlock, are external forms of radial shake.

Losses in product volume and value associated with shake and frost cracks are especially important when one realizes that these defects are most prevalent in the lower two logs of trees and are invariably spiraled. In the true firs, for example, these logs not only have the potential for producing the highest quality boards, but also nearly half of the total usable lumber volume of the tree.

Lumber Checking and Collapse. The weaker intercellular bonding of wetwood manifests itself also in dried lumber as deep surface checks, collapse, honeycomb, and ring failure resulting from failure of the wood to withstand normally inocuous shrinkage stresses during drying. These "drying defects" have, in the past, been attributed to the drying operation. It has been recognized only recently that many of these so-called "drying defects" are initiated in the tree and become apparent only after the drying operation. These defects which develop from rupture under shrinkage stresses are usually, but not always, less frequent and severe in air dried lumber. Wetwood in studs and dimension lumber from hemlock, true firs, aspen and cottonwood seriously limits, and even precludes, the drying of these species under elevated and high temperature kiln schedules.

Monetary losses resulting from lumber degrade due to honeycomb and ring shake of softwood studs with wetwood have been reported to be $7 per thousand board feet in Canada. Losses of $38 to $40 per thousand board feet for hemlock-fir dimension lumber is possible in extreme cases of degrade resulting from wetwood associated drying defects.

Honeycomb and ring failure are also major defects in kiln drying of oak, our most important hardwood lumber species. Annual wood volume losses from wetwood associated drying defects in oak factory grade lumber produced in eastern United States are estimated to be at least three percent. It is not unusual, however, for 10 to 50 percent of the lumber from individual kiln charges to be lost because of honeycomb and ring failure; monetary losses range from $34 to $139 per thousand board feet.

Uneven Moisture Content or Wet Pockets. Because of the low permeability of green wetwood to internal moisture movement, boards containing wetwood will take longer to dry (see Table 2). This coupled with the higher moisture content found in wetwood, has become crucial for certain commercially important timber species such as hemlock, pine, redwood and the true firs with ever-increasing costs of energy. For most end product uses lumber and veneer must be dried. Boards with wetwood may require 50 percent or more kiln residence time to reach a desired moisture content. For white fir veneer with wetwood, residence time may increase as much as 20 percent or more. Even with this increase, veneer redry was seven percent or more.

When drying softwood dimension lumber, the kiln operator dries according to the time required to bring the majority of normal sapwood and heartwood boards below 19 percent average moisture content. A desired average moisture content for the charge should range from 12 to 16 percent. If wetwood boards are present they invariably will still exceed the maximum allowed moisture content of 19 percent. In sufficient numbers, these wetwood boards could result in the rejection of the charge or shipment as not meeting moisture specifications.

Where wetwood boards are occurring in a kiln charge of softwood lumber, the processor is confronted with five possible alternatives. Each alternative may result in losses in terms of wood, energy and higher manufacturing costs:

1) He can extend the kiln residence time until the wettest boards reach the required moisture content. This can cause overdrying of the non-wetwood stock which is then subject to costly degrade in subsequent machining operations.

2) He can dry, sort and redry the wet stock after a normal kiln run. This approach will increase his drying and handling costs for the wetwood lumber. In the case of white fir dimension lumber, redrying can result in an additional 40 percent in the kiln drying costs.

3) He can market lumber as surfaced green and receive less return for his product. In the case of hemlock-fir dimension lumber, this can amount to approximately $26 per thousand board feet.

Shipping weights and the resulting shipping costs of green lumber are important considerations here. In Table 3 are calculated weights for 1000 board feet of white fir at different moisture contents. Also included are the costs for shipping 1000 board feet of white fir at these different moisture contents to Los Angeles and Chicago from Portland, Oregon. It is quite obvious that the price differential of $26 between green and dry lumber barely offsets the shipping cost differential of dry lumber (15 percent) and green lumber (150 percent) when shipping to Los Angeles but not the differential when shipping to Chicago.

4) He can dry the lumber using a normal schedule and not sort for the wetstock and surface the lumber as is. This option, obviously, could be exceedingly costly should the lumber be found too wet. Not only must the surface lumber be resorted, regraded and metered for moisture, but the lumber found to exceed the maximum allowable moisture is now considered substandard surfaced green and graded accordingly. Losses in excess of $50 per thousand board feet are possible.

5) The fifth alternative would call for segregating the green lumber into uniform drying sorts and then drying these sorts using different kiln schedules or treatments. Such an approach would minimize the extremes in drying properties of the lumber in a given kiln charge.

With the energy crisis, it now becomes imperative that costs of energy used in drying and redrying wetwood must be given careful consideration, especially since 60 to 70 percent of the total energy used in manufacturing most wood products is consumed in drying. This approach would go far in minimizing energy costs.

Presorting green lumber for drying has been used with some success for California white fir where studies indicated that when hand sorted, nearly 45 percent of board volume of a tree falls into the wetwood or "sinker" category for drying. Of this amount more than 75 percent came from the lower two logs of the trees.

To be effective, however, each board must be examined on all sides during the segregation process. Under mill production conditions this is generally not possible, especially with the advent of tray and drop sorters which limits board-by-board examination. To date mechanical, electrical and optical means of detecting and sorting wetwood lumber have met with little success.

Even with segregation, studies on white fir have indicated that commercial drying sorts still lack uniformity because these sorts contain boards composed of material of more than one sort. These "mixture" boards of wetwood-sapwood-corky mix, which in white fir come mainly from the second log, were found to degrade more than boards of more uniform drying sort.

Because wetwood dries slower, boards containing wetwood may develop internal wet streaks even after reaching the desired moisture content. Though pencil thin in size, these streaks can be a problem during the electronic gluing operations in manufacturing doors and panels with aspen and hemlock cores. "Blows" in the manufacture of white fir plywood have been reported by industry to be wetwood related and the major portion of veneer redry for this species is closely tied to the occurrence of wetwood in the green veneer.

<u>Chemical Brown Stain</u>. Chemical brown stain associated with wetwood is an especially serious defect in lumber graded on the basis of appearance. The marketability of softwood dimension lumber is also affected somewhat because the stain imparts a "decay" appearance to the lumber. Data suggest that the presence of a phenyloxidizing bacteria is required in the microbial population of the wetwood for brown stain to develop. Processing problems

associated with chemical brown stain have been reported on a commercial scale in the white pines, ponderosa pine, the true firs, western hemlock, redwood, western redcedar and Sitka spruce.

Brown stain can develop in both air dried and kiln dried wetwood when initial drying conditions are warm and humid. Prolonged storage of wetwood logs in the yard or in a pond can result in the spread of the stain to lumber cut from wetwood-free sapwood. Subsurface staining in air dried lumber can also occur; its presence is unnoticed until after surfacing.

Reduction and prevention of chemical brown stain in coniferous lumber can be accomplished either by manipulating kiln drying schedules or by dipping green lumber in stain retarding solutions. Both methods, however, have drawbacks which are becoming increasingly important.

Because anti-stain dry kiln schedules require low initial temperatures and humidities with good circulation and venting, energy consumption is considerably greater using these schedules. To maintain low temperatures and humidities, venting may last three days to one week. Segregating wetwood into a separate drying sort, which was discussed earlier, would help minimize energy consumption by applying the anti-stain schedule only to the wetwood portion of the lumber.

Dipping lumber in the anti-stain solutions not only can prevent brown stain, but permits the use of higher initial kiln temperatures and humidities, which can result in a substantial reduction in drying costs. The highly toxic nature of the chemicals, however, has caused their use to be discontinued by many mills.

Kiln Corrosion. The pH, or the acidity of wetwood can be either higher or lower than normal wood depending on tree species. In the hardwoods, the pH of wetwood has frequently been reported to be above pH 7.0. In contrast, wetwood of conifers, in particular the true firs and western hemlock, have a pH as low as 3.5 and generally has a lower pH than its associated sapwood and normal heartwood. The low pH in hemlock is attributed to an elevated, easily volatile fatty acid content in the wood. Reports of accelerated kiln corrosion when drying western hemlock have been ascribed to the highly acid atmosphere in the kiln during the drying process. Not only are the metal fasteners attacked by this corrosive air mixture but unprotected concrete is also subjected to accelerated deterioration.

Closing Remarks

From the proceeding discussion, it is apparent that wetwood is responsible for substantial losses of wood, energy and production expenditures in the forest products industry. These losses result from a raw material anomaly which in the past, we have either failed to recognize or have innocently ignored. Though there is a definite need to assess more thoroughly these losses and to find ways of eliminating or minimizing them, there is also a definite need to examine the cause of these losses, i.e., wetwood. The fact that more and more utilization and processing problems are being recognized as related directly or indirectly to the occurrence of wetwood clearly demonstrates the importance of this phenomenon.

An effective program of research is needed to determine the extent wetwood is involved in these problems. This program should plan and provide for obtaining both short-term and long-term solutions to the overall problem. Because of increasing interest in wetwood, excellent opportunities now exist to initiate such a comprehensive research program.

There can be little doubt the effects of wetwood on the forest products industry are real and the impact is far-reaching. With dwindling timber supplies, increasing costs of available energy and a scarcity of low cost capital, the timber industry can no longer afford to ignore the problems associated with wetwood, for wetwood has an impact on all these issues.

It is time we examine, in depth, the detrimental effects of wetwood during all phases of timber production -- from the stump to the finished product. Wetwood related losses, which in the past were accepted as part of the package of doing business or thought to be the result of inadequate processing, can no longer be viewed in that context. A fuller understanding of the characteristics of wetwood whether in the tree, log or product, can and will provide timber managers and processors with the tools with which to handle the wetwood problem.

TABLE 1 -- Green moisture content of wetwood, sapwood and heartwood of selected wetwood tree species.

		Percent Moisture Content		
Species	Data source	Wetwood	Sapwood	Heartwood
Western hemlock	Ward and Kozlik	150	156	54
	Kozlik et al.	153	--	66
Eastern Hemlock	Ward	148	137	75
White Fir	Smith and Dittman	193	145	57
	Wilcox	182	164	74
	Wilcox and Pong	164-172	164-175	92-118
	Ward	155	170	66
Sugar Pine	Ward	194	204	51
Aspen	Cech, Huffman	170	140	--
	Ward	115-128	76-122	81-106
Cottonwood	Ward	144	131	--
Amer Elm	Ward	106	90	69
California Black Oak	Ward and Shedd	95	--	85
N. Red Oak	Ward	97	--	86

TABLE 2 -- Drying time of wetwood, sapwood, and heartwood of selected wetwood tree species

Species	Data source	Product[2] specs		Drying Time[1]		
		Thickness	Dried MC	Wetwood	Sapwood	Heartwood
Western hemlock	Ward & Kozlik	1 3/4	15	139	82	59
	Kozlik et al.	3/4	10	170	--	90
Eastern hemlock	Ward	1 3/4	15	185	95	96
White Fir	Smith & Dittman	1 7/8	20	158	84	42
	Pong & Wilcox	1-1 3/4	15-16	174	106	60
	Ward	1 3/4	15	150	105	73
	Bendix Corp.	1/8(V)	5	10 MIN.	8 MIN.	--
Sugar Pine	Ward	1 1/2	15	226	148	72
Aspen	Ward	1 3/4	15	179	90	115
American Elm	Ward	1 1/8	7	134	121	113
California Black Oak	Ward & Shedd	1 1/8	7	387	--	379
N. Red Oak	Ward	1 1/8	7	324	--	312

[1]In hours except where noted.

[2]Lumber except where noted for veneer (V).

TABLE 3 -- Shipping freight costs for White Fir lumber (FOB Portland)

Moisture content	Calculated weight/ 1000 BF	Shipping costs Per 1000 board feet: Los Angeles (Base rate - $1.27/100)[1]	Chicago (Base rate - $3.01/100)[1]
Percent	Pounds	Dollars	
0	1271	16.14	38.26
12	1423	18.07	42.83
15	1463	18.58	44.04
19	1513	19.22	45.54
25	1590	20.19	47.86
75	2226	28.27	67.00
100	2543	32.30	76.54
115	2734	34.72	82.29
150	3178	40.36	95.66

[1] Base rates are for shipments of 85,000 pounds or less (Western Wood Products Association)