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Revised January 1959

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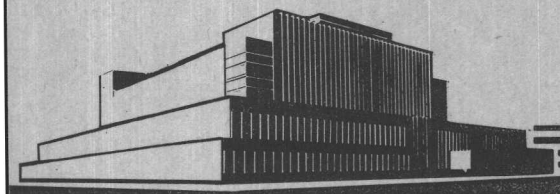

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

THE SAP OR MOISTURE IN WOOD[1]

By

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Meaning of "Sap"

By "sap" is meant the moisture in wood and all material it holds in solution. The amount and kind of materials dissolved in the water of the sap vary with the species, part of tree, and time of year, but constitute only a small amount of the sap.

In drying lumber it is principally the moisture that evaporates, leaving the soluble materials behind, although some acid and volatile oils also pass off in the form of vapor. In pine, Douglas-fir, and some cedars the volatile oils constitute an appreciable part of the evaporated materials.

The soluble materials in the sapwood are mostly sugar and a very small amount of mineral matter, while in the heartwood they are tannins, resin, dyestuffs, and other materials. To what extent these materials affect the utilization of wood is not definitely known, and, if they do affect it there is no practical means of removing them.[3] It has been said that logs that have been in water for a year or more dry more easily and shrink less, but definite proof is lacking.

Kiln drying and steaming do not remove the starches, sugars, albuminous material, and the like to any appreciable extent, as it has been sometimes claimed. If they are removed, the wood would not become stronger, nor more decay resistant. Heartwood might be less decay resistant because such materials as the tannins help it to resist decay. Sapwood is not naturally decay resistant, and the removal of materials would not improve its resistance.

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[1]Report originally published August 1953.

[2]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3]Ponderosa pine has been seasoned by treatment with a solvent liquid, which does remove resin and other materials, but the process is apparently limited in its application.

In kiln drying, operators speak of the moisture content of the wood and ignore the soluble materials in the sap.

How the Amount of Moisture in Wood is Expressed

It is customary to express the amount of moisture in wood in terms of percent of the weight of the dry wood substance. For example, if a piece of wood weighing 120 grams contained 100 grams of wood and 20 grams of water, its moisture content expressed in the usual terms would be 20 percent. This term is relative and does not give a measure of the absolute amount of moisture unless the density of the wood is taken into consideration. A piece of oak at 20 percent moisture content contains more moisture than a piece of pine of the same dimension at the same moisture content.

Fiber-Saturation Point

The moisture in green or wet wood is held in two ways: (1) within the cell cavities, and (2) within the cell walls. When wood dries, the cell cavities become empty before the cell walls begin to give off moisture. When dry wood takes up moisture, the cell walls become saturated before the cell cavities fill up. The condition in which the cells are empty but the cell walls are saturated, is known as the "fiber saturation point." It is generally considered to be about 30 percent moisture content.

In drying wood, parts of it may be below the fiber saturation point and shrink, or attempt to shrink, while other parts may be above the fiber saturation point and do not shrink. As a consequence, severe stresses are set up within the wood.

Variation in Moisture Content

In Green Wood

The moisture content of green wood varies from about 30 to about 250 percent, as shown in table 1. Figure 1 at the end of this report shows the maximum possible moisture content values based on the specific gravity of the wood.

Sapwood usually contains more moisture than heartwood, but the heartwood of some hardwoods and of cypress is also very wet.

Butt logs usually contain more water than top logs.

There is practically no difference in the moisture content of wood cut in different seasons of the year, as shown in table 2.

In Air-Dry Wood

The variation in moisture content in air-dry wood is due to differences in climatic conditions (table 3), length of time in the pile, position in the pile, and kind of stock.

The following tabulation of moisture content of small blocks of wood thoroughly air dried at New Haven, Conn., indicates that wood reaches about the same moisture content regardless of species.

Species	Moisture Percent
Ash, black	14.9
Ash, white	14.4
Chestnut	13.8
Douglas-fir	14.1
Maple, hard	14.9
Pine, loblolly	14.7
Pine, longleaf	13.3
Pine, white	13.4
Spruce, red	15.0
Sweetgum	14.9
Average.....	14.3

Some southern yellow pine 8- by 16-inch timbers were found to contain 22 percent moisture in the core and 17 percent in layers from the surface to one-half of the distance to the center after 21 months of air drying under cover. Redwood timbers 8 by 16 inches contained 17 percent moisture in the outer layers and 33 percent in the core after 20 months of air drying.

In Kiln-Dried Wood

Variations in the moisture content of kiln-dried wood are caused by mechanical inefficiency of the kiln, insufficient length of time in the kiln, and inherent differences in the drying characteristics of individual pieces.

Some years ago the Laboratory collected considerable data on the moisture content of kiln-dried softwood lumber at the time of shipment from the sawmills. The following tabulation gives some of these data on the average moisture content and ranges for all the principal softwoods.

	Moisture content	
	Average	Range of 80 percent of the stock
	Percent	Percent
Uppers.....	11	5 - 16
Common.....	16	8 - 22

Hardwoods are usually first air dried and then kiln dried at the point of consumption. When a charge of hardwood lumber is put into a dry kiln, the moisture content is lower and the difference between individual boards is less. For these reasons, and because the drying time in the kiln is usually longer, the range in moisture content among the hardwood boards at the time of discharge is generally less than in softwoods.

In Storage

Lumber in storage usually becomes more uniform in moisture content; that is, the boards of higher moisture content lose moisture while those of lower moisture content take on moisture. Whether the average moisture content becomes lower or higher depends upon the average moisture content when placed in storage and the conditions in the shed. Lumber in storage is usually solid piled so that only a small area comes in contact with the atmosphere of the shed. Consequently, where dry lumber is stored under relatively moist conditions, both the average and the variations in moisture content among the individual boards are increased.

A monorail package of Douglas-fir lumber that was in a storage shed for 2-1/2 years, illustrates the change in moisture content during storage. The initial average moisture content was 6 percent and the final average was 11 percent, brought about by a gradual pickup of moisture during the period of storage.

In Service

Wood in actual service will be found to possess variations in moisture content brought about by the changing conditions to which it is exposed. A study of the moisture content of woodwork within dwelling houses indicates what these variations are for this class of material. The chief determining factors are climate, season, and position in the dwelling. Tables 4 and 5 illustrate the variations in moisture content due to some of these causes.

Table 1. --Average moisture content of green wood

Species	Moisture content[1]		
	Heartwood	Sapwood	Mixed heartwood and sapwood
	Percent	Percent	Percent
SOFTWOODS			
Baldcypress	121	171	
Cedar:			
Alaska-	32	166	
Eastern redcedar	33		
Incense-	40	213	
Northern white-			55
Port-Orford-	50	98	
Atlantic white-			35
Western redcedar	58	249	
Douglas-fir:			
Coast type	37	115	
Intermediate type	34	154	
Rocky Mountain type	30	112	
Fir:			
Alpine			47
Balsam			117
California red			108
Grand	91	136	
Noble	34	115	
Pacific silver	55	164	
White	98	160	
Hemlock:			
Eastern	97	119	
Western	85	170	
Larch, western	54	119	
Pine:			
Eastern white			68
Lodgepole	41	120	
Ponderosa	40	148	

Table 1. --Average moisture content of green wood (continued)

Species	Moisture content[1]		
	Heartwood	Sapwood	Mixed heartwood and sapwood
	Percent	Percent	Percent
SOFTWOODS (continued)			
Pine (continued):			
Red	32	134	
Southern yellow:			
Loblolly	33	110	
Longleaf	31	106	
Shortleaf	32	122	
Sugar	98	219	
Western white	62	148	
Redwood:			
Second-growth			127
Old-growth	86	210	
Spruce:			
Eastern	34	128	
Engelmann	51	173	
Sitka	41	142	
Tamarack	49		
HARDWOODS			
Alder, red		97	
Apple	81	74	
Ash:			
Black	95		
Green		58	
White	46	44	
Aspen (quaking and bigtooth)	95	113	
Basswood	81	133	
Beech	55	72	

Table 1. --Average moisture content of green wood (continued)

Species	Moisture content[1]		
	Heartwood	Sapwood	Mixed heartwood and sapwood
	Percent	Percent	Percent
HARDWOODS (continued)			
Birch:			
Paper	89	72	
Sweet	75	70	
Yellow	74	72	
Buckeye, yellow			141
Butternut			104
California-laurel			65
Cherry, black	58		
Chestnut	120		
Chinquapin			134
Cottonwood, black	162	146	
Dogwood, flowering			62
Elm:			
American	95	92	
Cedar	66	61	
Rock	44	57	
Hackberry	61	65	
Hickory:			
Bitternut	80	54	
Mockernut	70	52	
Pignut	71	49	
Red	69	52	
Sand	68	50	
Water	97	62	

Table 1. --Average moisture content of green wood (continued)

Species	Moisture content[1]		
	Heartwood	Sapwood	Mixed heartwood and sapwood
	Percent	Percent	Percent
HARDWOODS (continued)			
Holly, American			82
Hophornbeam, eastern			52
Locust, black			40
Madrone, Pacific			81
Magnolia	80	104	
Maple:			
Silver (soft)	58	97	
Sugar (hard)	65	72	
Oak:			
California black	76	75	
Live			50
Northern red	80	69	
Southern red	83	75	
Southern swamp	79	66	
Tan			89
White	64	78	
Osage-orange			31
Persimmon, common			58
Sweetgum	79	137	
Sycamore, American	114	130	
Tupelo:			
Black	87	115	
Swamp	101	108	
Water	150	116	

Table 1.--Average moisture content of green wood (continued)

Species	Moisture content[1]		
	Heartwood	Sapwood	Mixed heartwood and sapwood
	Percent	Percent	Percent
HARDWOODS (continued)			
Walnut, black	90	73	
Willow, black			139
Yellow-poplar	83	106	

[1]Based on weight when oven-dried.

Table 2.--Percent of moisture in green wood cut during different seasons

Month	Arbor-vitae	Doug-las-fir	Average of 24 European hardwoods	Average of 5 European conifers	Chest-nut	Loblolly pine	
						Sapwood	Heartwood
Jan.	--	40	47	60)	91	Winter 109	59
Feb.	--	47	48	58)			
Mar.	--	49	44	59)	89	Spring 107	48
Apr.	82	38	43	54)			
May	74	40	43	60)			
June	84	33	41	61)	89	Summer 107	57
July	84	28	45	60)			
Aug.	77	39	--	--)			
Sept.	71	--	43	58)	88	Autumn 100	47
Oct.	87	34	--	--)			
Nov.	80	42	40	58)			
Dec.	90	39	--	--	--	--	--

Table 3.--Approximate moisture content of thoroughly air-dry stock by months for different regions[1]

Forest region	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
California pine	20	18	16	14	12	10	9	9	10	12	16	18
Redwood	24	25	22	20	18	16	15	15	16	17	19	21
Inland Empire[2]	20	20	18	15	14	14	12.5	13	14	15	20	20
Oregon and Washington	26	24	22	18	16	15	12	13	15	16	22	26
Southern pine	20	--	--	13	--	--	14	14	14	16	17	20

[1] In the arid Southwest during the driest portion of the year air-dry lumber dries down to between 5 and 10 percent moisture content.

[2] Northwestern Montana, Idaho north of the Salmon River, Washington east of the Cascade Mountains, and the northeastern tip of Oregon.

Table 4.--Variations in percentage of moisture content of wood in dwelling houses due to geographic location and season

City	Moisture content		
	High	Low	Range
New Orleans, La.	13.4	11.6	1.8
San Francisco, Calif.	10.9	9.2	1.7
Portland, Oreg.	9.6	8.2	1.4
Washington, D. C.	11.9	8.2	3.7
Madison, Wis.	10.2	6.4	3.8
Alburquerque, N. M.	8.6	5.4	3.2

Table 5.--Variations in percentage of moisture content of wood in dwelling houses due to position in the house[1]

Location	Moisture content		
	Summer	Winter	Range
Cellar (over heating plant)	13.1	5.1	8.0
Cellar (other parts)	13.8	8.0	5.8
Living room, kitchen, bedroom, and bathroom	10.2	6.4	3.8
Hall	11.0	7.5	3.5
Attic	7.3	9.2	1.9

[1]Houses in Madison, Wis.

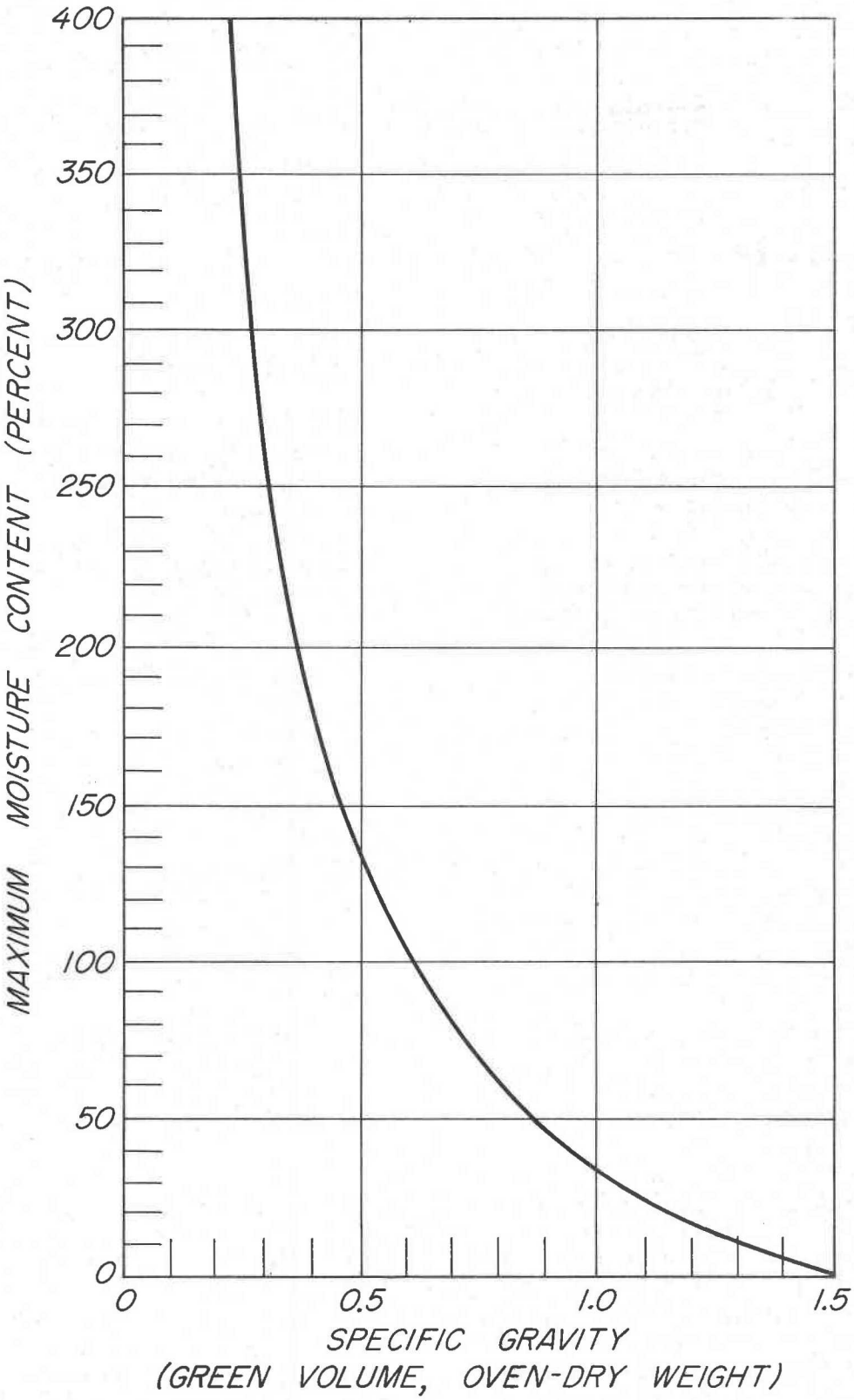

Figure 1. --Moisture content limits of wood of various specific gravities.

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