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Seasoning and Checking of Timbers Before and After Treatment

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Some of the more important factors that affect the shrinkage and checking of timbers while seasoning are the following: density of the wood; whether the timbers are from softwood or hardwood species; occurrence of collapse; differences in tensile or compressive strength perpendicular to the gram; rate of seasoning; resistance of the wood to moisture movement; depth and permeability of the sapwood; cross-sectional dimensions; presence of boxed heart and position of pith in sawed timbers; time of year the timber is cut and seasoned; humidity, temperature, and rainfall during the seasoning period; method of piling; whether timbers are exposed to winds that will tend to produce rapid seasoning; differences in the unit tangential and radial shrinkage; whether timbers are exposed to the direct sunshine; and whether the sun strikes them while they are seasoning in a horizontal or vertical position.

As far as practicable timbers that are in danger of checking and exposing untreated wood after treatment should be seasoned so that any checking that may occur after treatment or after the timbers are placed in service will not expose untreated wood to decay or insect attack.

While it is not possible to control all the variables that produce the undesirable checking that may occur when various types of timber are seasoned or treated, it is possible to use measures that will greatly reduce much unnecessary checking. These measures can be used more effectively when the more important causes of checking are understood.

Introduction

Objectionable checking often occurs when sawed and round timbers are seasoned prior to treatment or after they have been treated. This is of considerable concern both to treating plant operators and to the users of treated structural materials, such as crossarms, caps, stringers, ties, poles, posts, and piles.

A certain amount of checking is unavoidable and is a normal result of seasoning both round timbers and dimension stock. Checking through the treated wood on the outer portion of a timber may, however, expose the unpenetrated wood underneath to decay and insect attack after the timber is placed in service. Such checking after treatment may seriously reduce the life of otherwise well treated material.

An understanding of the more outstanding factors that affect checking is therefore important to avoid unnecessary checking either before or after treatment, and to obtain the maximum service life from timbers.

Some of the more important factors that affect the amount of shrinkage and checking that occurs in the different types of timber are: (1) species, density, and proportion of sapwood and heartwood, (2) size and shape of timbers, (3) whether the timbers are round or sawed, and (4) time of cutting, method of piling, yard site, and climatic conditions as influenced by latitude, temperature, humidity, and rainfall.

[1] Maintained at Madison, Wis., in co-operation with the University of Wisconsin.

Species, Density, and Proportion of Sapwood and Heartwood

The amount of shrinkage or swelling that occurs when the moisture content of wood changes will depend both on the density and on the original moisture content. Since the different species often vary widely in density, it is evident that species has an important effect on shrinkage. The denser woods normally shrink more than those of lower density. There are, however, a few exceptions. In certain species, stresses may be set up during seasoning that cause a variable amount of collapse of the cell walls. This collapse will naturally increase the total amount of shrinkage, and collapse is often associated with ring shakes and checking. Basswood is an example of a species in which collapse commonly occurs. In seasoning from the green to the ovendry condition, this wood has an average volumetric shrinkage that is over 80 percent greater than the normal shrinkage of most species of similar density. On the other hand, some species contain extractives in the cell walls that reduce the amount of shrinkage that would occur if these extractives were not present. For example, extractives in the heartwood of black locust reduce the volumetric shrinkage to about 55 percent of that which normally occurs in woods similar in density.

In studies made at the Forest Products Laboratory, it has been found that for most of the softwoods and many of the hardwoods, the volumetric Shrinkage is about proportional to the change in moisture content

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that takes place in seasoning below the fiber saturation point. That is, in the case of a large proportion of the different species, when the specific gravity of their green wood is about the same, the shrinkage differences between such woods are usually small for the same reduction in moisture content, although there are some exceptions for the reasons mentioned.

The principal exceptions among the more commonly used commercial species are American basswood, cottonwood, pecan, honeylocust, black locust, eastern red cedar, sweetgum, redwood, Engelmann spruce, and black walnut. In this group, the pecan, honeylocust, black locust, eastern red cedar, redwood, and black walnut shrink less and the others shrink more than would be expected for their respective specific gravity values based on volume of the green wood.

Some species have a tendency to check much more than others under the same conditions of seasoning. In general, hardwood timbers are more likely to develop objectionable checks than similar softwood timbers. Some woods also seem to check more because of lower tensile or compressive strength perpendicular to the grain. It has been noted that round timbers with spiral grain seem to have a tendency to check more than those with straight grain.

Since the heartwood of many species is more resistant to moisture movement than is the sapwood, round timbers with thin sapwood may season fairly rapidly on the surface while the moisture content of the heartwood remains high and close to that of the green wood. This naturally produces a steep moisture gradient that favors checking. Some species, such as the spruces and true firs, have sapwood that is about as resistant to moisture movement as the heartwood. These woods also will have a steep moisture gradient while seasoning that will increase checking. When the heartwood is surrounded by fairly deep, permeable sapwood, as in some of the pines, the lower resistance of the sapwood to moisture movement apparently allows the timber to season with less checking compared with woods that have resistant or thin sapwood. The sapwood of the conifers, however, generally has a very much higher moisture content than the heartwood. There is usually much less difference between the moisture content of the green heartwood and sapwood of the hardwood species, as may be noted from the data in Table 1.

Side-cut timbers (those that do not contain the pith) usually give much less trouble from checking as a result of seasoning than do those that have boxed heart. When the pith is at or near the center of some of the larger boxed-heart timbers subjected to bending loads, such as bridge stringers, for example, checking may be an important problem from the standpoint of strength because of its effect on the shear stress. Crossarms that contain boxed heart sometimes develop checks that allow the insulator pins to become loose. Variations in the relative amount of shrinkage of the crossarms and pins also may tend to make loose pins.

Table 1.—Average Moisture Content and Specific Gravity of Green Timbers

Species	Moisture content, Percent: Heartwood	Moisture content, Percent: Sapwood	Average specific gravity[1]
Softwoods:			
Baldcypress	121	171	0.42
Douglas fir, coast type	37	115	.45
Fir, grand	91	136	.37
Fir, white	98	160	.35
Hemlock, eastern	97	119	.38
Hemlock, western	85	170	.38
Larch, western	54	119	.51
Pine, lodgepole	41	120	.38
Pine, ponderosa	40	148	.38
Pine, eastern white	68[2]	---	.34
Pine, western white	62	148	.36
Pine, red	32	134	.41
Pine, southern yellow			
Loblolly	33	110	.47
Longleaf	31	106	.54
Shortleaf	32	122	.46
Pine, sugar	98	219	.35
Red cedar, western	58	249	.31
Redwood (old-growth)	86	210	.38
Spruce, Engelmann	51	173	.32
Spruce, Sitka	41	142	.37
Hardwoods:			
Ash, green	---	58	.53
Ash, white	46	44	.55
Beech	55	72	.56
Birch, sweet	75	70	.60
Birch, yellow	74	72	.55
Chestnut	120	---	.40
Elm, American	95	92	.46
Elm, cedar	66	61	.60
Hickory, water	97	62	.61
Maple, silver	58	97	.44
Maple, sugar	65	72	.56
Oak, black	76	75	.56
Oak, northern red	80	69	.56
Oak, southern red	83	75	.52
Oak, swamp red	79	66	.61
Oak, water	81	81	.56
Oak, white	64	78	.60
Oak, willow	82	74	.56
Sweetgum	79	137	.44
Sycamore, American	114	130	.46
Tupelo, black	87	115	.46
Tupelo, water	158	---	.46
Yellow poplar	83	106	.38

[1] Based on weight when oven dry and volume when green.
[2] Mixed heartwood and sapwood.

Ties and caps commonly have boxed heart and often develop considerable end as well as side checking. This is quite common in ties of hardwoods such as oak, beech, birch, and maple. When the pith is near a corner, or is close to or on one of the side surfaces of sawed material, checking is usually less severe than when the pith is in the central portion. The minimum distance from the pith to the last uncut annual ring has an important bearing on the width and depth of checks.

Size of Timbers

The size of the timber has a very important influence on the rate of seasoning, which also affects the amount of checking. Size also limits the final moisture content to which it is practical to season the timber before it is treated or placed in service. Lumber and round timbers such as posts of small

diameter will, of course, season much faster and more uniformly than larger timbers, such as ties, stringers, caps, poles, and piles, since the ratio of surface area to volume is greater in the material that has the smaller cross section.

A point often overlooked when seasoning timbers is the fact that the rate of moisture loss is always greatest when the initial moisture content is high. As seasoning progresses, the time required to obtain a given percentage reduction in moisture content becomes increasingly longer. In this respect, the rate of seasoning is analogous to the rate of drop in temperature of a cooling object. As the moisture in the wood approaches the limiting equilibrium moisture content, the time required to reduce the remaining moisture a given amount increases rapidly in much the same way that the time required for each degree drop in temperature of a heated body increases rapidly as the body approaches its surrounding exterior temperature. Similarly, wood at a low moisture content will take up moisture more rapidly, just as wood or other materials will take up heat more rapidly at the start of a heating period. It is desirable, therefore, to protect seasoned material from heavy rains that may greatly increase the moisture content. This is particularly important if the wood is easily penetrated.

In the case of large-dimension timbers, especially when the wood is resistant to moisture movement, it may not be practical to attempt seasoning the timbers to an average moisture content close to the fiber saturation point, which ranges from about 25 to 35 percent. An average value for the fiber saturation point may be assumed to be about 30 percent.

Red oak crossties 7 by 9 inches in cross section and 8 feet long were seasoned from the green condition for 14.5 and 18 months, respectively, in Illinois and Ohio.[2] The data showed that the average moisture content for the two groups was approximately 41 and 39 percent, respectively, at the end of the seasoning periods. In this study it was found that the average moisture content of the wood within the first inch from the surface was from 13 to 14 percent below the average for the ties as a whole, and was from 31 to 34 percent below the average moisture content at the central portion. Similar average moisture content values, based on weights taken during the seasoning periods, have been found in seasoning oak ties in other localities.

The question might be asked whether ties of other species would season in about the same manner as the oak ties, and also whether most of the seasoning would occur at least within a year. Some woods will season faster than red oak, while other more resistant woods, which may also have a high moisture content when green, will season slower. Coast Douglas fir heartwood timbers 12 by 12 inches in cross section and 24 feet long have been seasoned to an average moisture content of about 22 to 23 percent in one year. It should be borne in mind, however, that the moisture content of the green heartwood of this species is low and averages around 36 to 38 percent. These timbers were seasoned at the Forest Products Laboratory.

Available data indicate that there is generally little to be gained in air seasoning timbers of tie size or even larger for more than 10 to 12 months, and in many cases only the spring and summer months need to be used for the seasoning period. Longer seasoning also might increase the decay hazard. Sawed ties of mountain-type Douglas fir, which were practically all heartwood, that had been seasoned in the relatively dry Rocky Mountain region for as long as two years were found to be wet in the central region when they were sawed transversely at the midlength. The outer portion was apparently well seasoned, however. The heartwood of mountain-type Douglas fir is very resistant to treatment, and is apparently resistant to moisture movement while it is being seasoned.

Weights were obtained for ties of the following woods, 6 by 8 inches in cross section and 8 feet long, after they had been seasoned in the Rocky Mountain region for about one year: mountain-type Douglas fir, coast Douglas fir, western larch, western hemlock, and lodgepole pine. Based on the average specific gravity values for the respective species, the weights of the ties indicated about the following average moisture content values after seasoning for a year: mountain-type Douglas fir, 35 percent; coast Douglas fir, 23 percent; western larch, 36 percent; lodgepole pine, 65 percent; and western hemlock, 70 percent.

Although the average moisture content of large timbers may seem somewhat high after seasoning for even a year or more, the moisture content of the outer portion that is normally treated is generally markedly lower than the average, and the well-seasoned wood in the outer portion may comprise a large part of the total volume. For example, consider the cross section of a 7- by 9-inch tie. In any rectangular section, if A represents the width, *B* the side thickness, and *t* the thickness of the walls of the outer enclosing section under consideration, the cross-sectional area of this outer portion will be $2t\ (A + B - 2t)$. In a tie with a cross-sectional area of 7 by 9 inches, the first inch, measured from each of the 4 surfaces, will then have an area of $2(7 + 9 - 2) = 28$ square inches. The first 2

[2] Mathewson. J S., Morton, C. S., and Bescher, R. H. 1949. Air seasoning of red oak crossties. AWPA Proceedings 45:216-230.

inches will have an area of (2) (2) (7 + 9 - 4) or 48 square inches. The area of the second inch will then be 48 - 28 or 20 square inches. If the distance measured from each surface is 3 inches, the enclosing section will have an area of (2) (3) (7 + 9 - 6) or 60 square inches, and the area of the third inch from the surfaces will be 12 square inches. The remaining central section, which is 1 by 3 inches in size, will, of course, have an area of only 3 square inches, On a percentage basis, the first inch will therefore have 44.5 percent of the total area, the second inch 31.7 percent, the third inch 19 percent, and the core or remainder only 4.8 percent of the total cross-sectional area of 63 square inches.

Even when the average moisture content within the first inch of the surface is not much below the fiber saturation point, the wood at or close to the surface may have a moisture content of around 15 to 18 percent. The shrinkage of this outer portion causes drying stresses and starts checking. Information published on drying stresses and the resultant sets[3,4] has not been applied to the seasoning of timbers, and the computations in this paper have, therefore, been set up without such complicating factors. In side-cut material, checks tend to close when the average moisture content gets down to 15 percent. In boxed heart and round timbers, the checks commonly remain open because the tangential shrinkage is greater than the radial shrinkage.

Partially dried material can be considered a special case where the smaller radial shrinkage is reduced by the higher moisture content in the core. The diameter of round timbers has an important effect on both the width of checks and the extent of checking. Large-diameter timbers usually develop wider and deeper checks. The effect of unequal tangential and radial shrinkage. on size of residual checks, if drying were fully completed, is shown by the following relationships: Longitudinal shrinkage is so small in normal wood that its effect can be disregarded. For this reason, only changes in the cross-sectional area will be considered as factors that affect the checking and changes in volume that occur as a result of seasoning. If tangential shrinkage only is considered in the case of a round timber, and the effect of checking on the resultant dimension is disregarded, the diameter D_s after seasoning would be computed as $\pi D_s = \pi D_o \left(1 - \frac{P_t}{100}\right)$ or $D_s = D_o\left(1 - \frac{P_t}{100}\right)$ where D_o is the original diameter and P_t is the unit percent tangential shrinkage. If, on the other hand, only radial shrinkage were considered, the diameter D_s after shrinkage would be computed as $D_o\left(1 - \frac{P_r}{100}\right)$ where P_r is the unit percent radial shrinkage.

Both radial and tangential shrinkage, however, are involved whenever wood is seasoned, regardless of the site and shape of the timber or whether it does or does not contain the pith. Since the unit tangential shrinkage P_t is greater than the unit radial shrinkage P_r, the diameter $D_o\left(1 - \frac{P_t}{100}\right)$ is less than $D_o\left(1 - \frac{P_r}{100}\right)$. Then $D_o\left[\left(1 - \frac{P_r}{100}\right) - \left(1 - \frac{P_t}{100}\right)\right] = D_o\left(\frac{P_t - P_r}{100}\right)$. The difference between P_t and P_r sets up a stress that tends to cause checking. If the values of P_t and P_r are known, the difference in the original diameter D_o and that after shrinkage D, would be computed as $D_o\left(\frac{P_t - P_r}{100}\right)$. The theoretical width of checks after shrinking, because of the difference of radial and tangential shrinkage, would then be computed as $\pi D_o\left(\frac{P_t - P_r}{100}\right)$.

In some cases where shrinkage may affect the classification of poles, it is of interest to know the maximum shrinkage that might occur in the pole diameter. For most purposes it should be sufficiently accurate to assume that the maximum shrinkage would not exceed that based on tangential shrinkage only. The diameter after shrinkage would then be $D_o\left(1 - \frac{P_t}{100}\right)$ where D_o is the diameter before seasoning and P_t is the unit percent tangential shrinkage over the moisture range under consideration. Values of P_r and P_t are shown in the second and third columns respectively of Table 2.

If one considers the large proportion of the total volume that is included within even a thin ring or band of thickness *t* on the outer portion of a timber, it is not difficult to understand why checking can develop when this outer portion is seasoned well below the moisture content of wood nearer the center. To illustrate, the total cross-sectional area of a round timber with an average radius R would be πR^2, and the area of a ring on the outer surface with a thickness $t = 0.1R$ would then be computed as $\pi R^2 [1 - (0.9)^2]$ or 19 percent of the total area; a ring with a thickness of $t = 0.2R$ would have 36 percent of the total area, and so on.

Figure 1 shows the percentage of the total area of each ring 0.1R thick measured from the circumference to the center, and the total area of the consecutive rings measured from the surface to the center.

[3] McMillen, J. M. February 1955. Drying stresses in red oak. Forest Products Journal, pp. 71–76.

[4] ———. August 1955. Drying stresses in red oak: Effect of temperature. Forest Products Journal, pp. 230–241.

Table 2.—Average Radial, Tangential, and Volumetric Shrinkage of Various Commercial Species Grown in the United States

(Data show average shrinkage from the green to the oven-dry condition)

Species	Shrinkage from green to oven-dry condition (percent of dimensions when green)			Specific gravity based on weight when oven dry and volume when green = S[4]
	Radial	Tangential	Volumetric	
Softwoods:				
Baldcypress	3.8	6.0	10.5	0.42
Douglas fir, coast type	5.0	7.8	11.8	.45
Douglas fir, intermountain type	4.1	7.6	10.9	.41
Douglas fir, Rocky Mountain type	3.6	6.2	10.6	.40
Fir, balsam	2.9	6.9	11.2	.34
Fir, commercial white[1]	3.3	7.3	10.4	.36
Hemlock, eastern	3.0	6.8	9.7	.38
Hemlock, western	4.3	7.9	11.9	.38
Larch, western	4.2	8.1	13.2	.51
Pine, lodgepole	4.5	6.7	11.5	.38
Pine, eastern white	2.3	6.0	8.2	.34
Pine, red	4.6	7.2	11.5	.41
Pine, ponderosa	3.9	6.3	9.6	.38
Pine, southern yellow				
Loblolly	4.8	7.4	12.3	.47
Longleaf	5.1	7.5	12.2	.54
Shortleaf	4.4	7.7	12.3	.46
Slash	5.5	7.8	12.2	.56
Pine, sugar	2.9	5.6	7.9	.35
Pine, western white	4.1	7.4	11.8	.36
Redcedar, eastern	3.1	4.7	7.8	.44
Redcedar, western	2.4	5.0	6.8	.31
Redwood (old-growth)	2.6	4.4	6.8	.38
Spruce, eastern[2]	4.2	7.8	12.6	.38
Spruce, Engelmann	3.4	6.6	10.4	.32
Spruce, Sitka	4.3	7.5	11.5	.37
Tamarack	3.7	7.4	13.6	.49
White cedar, northern	2.2	4.9	7.2	.29
Hardwoods:				
Ash, commerical white[3]	4.4	7.1	12.6	.54
Aspen, quaking	3.5	6.7	11.5	.35
Basswood, American	6.6	9.3	15.8	.32
Beech	5.1	11.0	16.3	.56
Birch, yellow	7.2	9.2	16.7	.55
Cherry, black	3.7	7.1	11.5	.47
Chestnut	3.4	6.7	11.6	.40
Cottonwood, eastern	3.9	9.2	14.1	.37
Cottonwood, northern black	3.6	8.6	12.4	.32
Elm, American	4.2	9.5	14.6	.46
Elm, rock	4.8	8.1	14.1	.57
Elm, slippery	4.9	8.9	13.8	.48
Hackberry	4.8	8.9	16.9	.49
Hickory, pecan[4]	4.9	8.9	13.6	.59
Hickory, true[5]	7.4	11.3	17.9	.65
Honeylocust	4.2	6.6	10.8	.60
Locust, black	4.6	7.2	10.2	.66
Maple, bigleaf	3.7	7.1	11.6	.44
Maple, black	4.8	9.2	14.0	.52
Maple, red	4.0	8.2	13.1	.49
Maple, silver	3.0	7.2	12.0	.44
Maple, sugar	4.9	9.5	14.9	.56
Oak, red[6]	4.4	9.3	15.8	.56
Oak, white[7]	5.2	9.8	15.9	.59
Sugarberry	5.0	7.3	12.7	.47
Sweetgum	5.2	9.9	15.0	.44
Sycamore, American	5.1	7.6	14.2	.46
Tupelo, black	4.4	7.7	13.9	.46
Tupelo, water	4.2	7.6	12.5	.46
Walnut, black	5.5	7.8	12.8	.51
Yellow poplar	4.0	7.1	12.3	.38

Note: To compute the shrinkage due to seasoning from green to any moisture content below fiber-saturation point multiply figure from Table 2 by $(1 - \frac{M}{30})$ where M is the moisture content (percent) to which wood is seasoned.

[1] Average of grand fir and white fir.
[2] Average of black spruce, red spruce, and white spruce.
[3] Average of Biltmore ash, blue ash, green ash, and white ash.
[4] Average of bitternut hickory, nutmeg hickory, water hickory, and pecan.
[5] Average of shellbark hickory, mockernut hickory, pignut hickory, and shagbark hickory.
[6] Average of black oak, laurel oak, pin oak, northern red oak, scarlet oak, southern red oak, water oak, and willow oak.
[7] Average of bur oak, chestnut oak, post oak, swamp chestnut oak, swamp white oak, and white oak.

It may be noted that the area of the first ring is 19 percent of the total, that of the next is 17 percent, and so on down to the central portion, each ring with 2 percent less area than the one preceding. This relation is easy to remember and will be found to be very convenient in making a quick estimate of the volume of wood (or percentage of sapwood based on the total volume) within any given distance from the surface, regardless of the region under consideration.

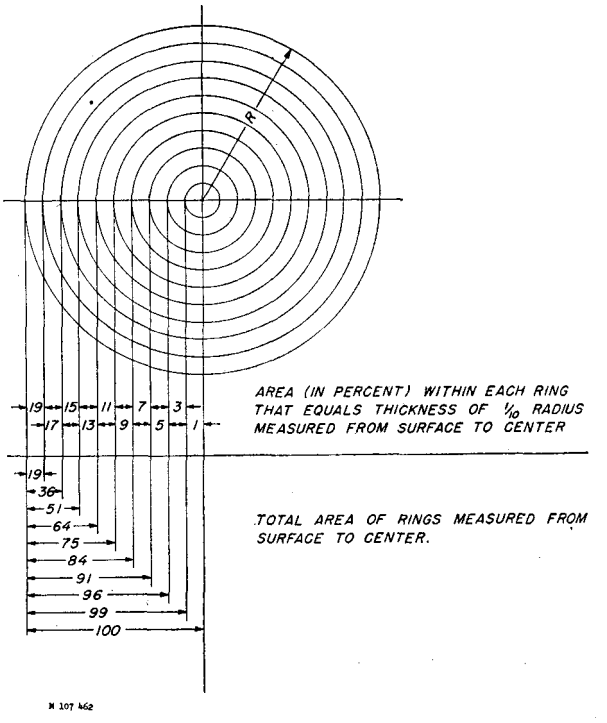

Figure 1.—Area of rings with a thickness of one tenth of the radius, measured from the circumference to the center.

For example, assume that a timber has an average diameter of 13 inches, and it is desired to make an estimate of the approximate volume in a ring 1.8 inches thick measured from the surface. Since the radius R is 6.5 inches, and 0.10 of this is 0.65, the distance 1.8 inches, expressed in units of 0.1R is 1.8/0.65 or about 2.8 times 0.1R. Then adding the percentages for the first two rings (19 + 17) gives 36 percent, and 0.8 of the area of the third ring is (0.8) (15) or 12 percent, for a total of about 48 percent of the original cross-sectional area. When there is a fractional part of the area in any one of the 10 divisions of the radius under consideration, it will be sufficient to simply multiply the ring area by the decimal fraction, as was done in the example (0.8) (15).

The same relation of area shown for each 0.1R also holds for a square section. Thus, if L is the distance from the center of a square to the midpoint of one side, then the outer hollow rectangular section with a thickness of 0.1L will contain 19 percent of the total cross-sectional area, 17 percent will be in the second section with the same thickness 0.1L, and

so on in the same manner as shown for the cylindrical section.

Flat-sawed material, such as lumber and timbers, usually checks less than sawed timbers with boxed heart. Timbers cut near the outer portion of the log will shrink more per unit width than per unit thickness, as a result of seasoning, than will those cut nearer the central portion of the log. The latter will shrink more per unit thickness. The reason for this is indicated by Figure 2. Flat-sawed material cut near the outer surface of the log will have less unit shrinkage on the narrow faces because of the smaller angle made by the annual rings with respect to a plane parallel to the width, while the reverse is true for sawed material cut nearer the center of the log.

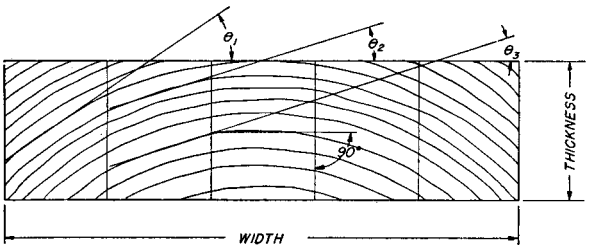

Figure 2.—Methodof finding the approximate slope of rings for the different portions of timbers.

A close determination of the relative amount of shrinkage in width and thickness for sawed material can be obtained by finding the average angle θ made by the rings at a few different places along the width, as indicated in Figure 2.

[6]**MacLean, J. D. 1945. Effect of growth rings on the relative amount of shrinkage in width and thickness of lumber and effect of radial and tangential shrinkage on dimensions of round timbers. U. S. Forest Products Laboratory Report No. 1473, 10 pp.**

It has been shown in a previous paper[5] that if H represents the average unit shrinkage in width, and T the average unit shrinkage in thickness, then:

$$H = \left[\left(\frac{P_t}{100}\right)\cos^2\theta + \left(\frac{P_r}{100}\right)\sin^2\theta\right] \qquad \text{(A)}$$

and

$$T = \left[\left(\frac{P_t}{100}\right)\sin^2\theta + \left(\frac{P_r}{100}\right)\cos^2\theta\right] \qquad \text{(B)}$$

Figure 3 shows plotted values of $\sin^2\theta$ and $\cos^2\theta$.

If W is the total width before shrinkage, W_s is the total width after shrinkage, V is the total thickness before shrinkage, and V_s is the total thickness after shrinkage, then the width W_s after shrinkage would be computed as $W(1 - H)$ and the thickness V, after shrinkage would be computed as $V(1 - T)$.

Time of Cutting, Method of Piling, Yard Site, and Exposure to Direct Sunshine in Different Latitudes

In the Northern States, most of the seasoning takes place between the months of April and October. Even green wood will season very slowly during the winter months. In the Southern States, seasoning conditions last somewhat longer than in the Northern States, but the summer months are still the more important period for seasoning. While the Southern States have higher average temperatures during the year, they usually have more rainfall and a higher average humidity than States in the northern latitudes. The greater amount of rainfall and higher humidity naturally tend to retard the rate of seasoning.

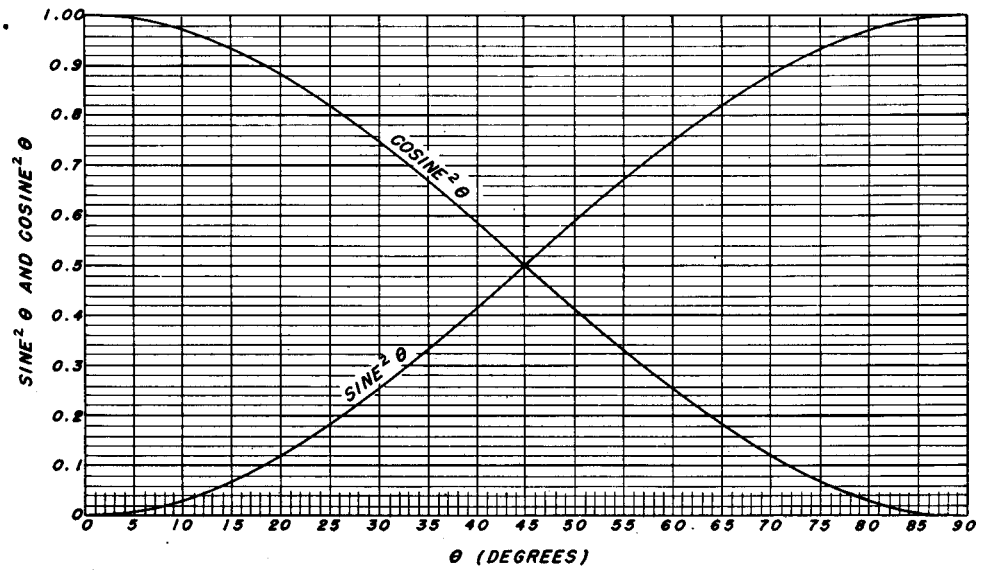

Figure 3-Curves of $\sin^2\theta$ and $\cos^2\theta$.

Another factor that affects the rate of seasoning is the time of year at which the maximum amount of precipitation occurs. In the Pacific Coast region, the heavier rainfall usually occurs in the fall and winter, while in the Southern and in most of the Northern States there is generally a greater amount of rain in the spring and summer months. High summertime precipitation often makes it difficult to season species that have low durability and that have a large amount of sapwood and consequently a low resistance to decay.

The yard site and method of piling will naturally have an important bearing on the results obtained in seasoning. The yard site may of necessity be more or less unfavorable for the best seasoning conditions. In some cases it may be necessary to season timbers in an arid region where hot dry winds and direct sunshine increase trouble from end checking or may cause rapid seasoning that will aggravate general surface checking.

On the other hand, it may be necessary to have the yard site located where temperature and humidity conditions are high and favorable for decay, or where the timbers cannot be air seasoned to a moisture content that is low enough to prevent future checking because of additional seasoning that will occur if the material is placed in service in a relatively dry region.

Proper attention to the method of piling, however, can help in overcoming some of the disadvantages that may exist because of the unfavorable location of the seasoning yard site. In some cases, close piling may be necessary when the yard is located in an arid region or where winds promote checking and too rapid seasoning.[6] At the other extreme, open piling with ample space for air circulation may be necessary to hasten seasoning and reduce the danger of injury from decay.

Not infrequently, round timbers are close-piled or scattered on the ground or on supports where they are exposed on one side to the sun. This method of piling is often used while the timbers are awaiting treatment, or they may be piled in this way after treatment until they can be loaded for shipment. In the case of poles, the user may leave them unpiled for several months, or may distribute them for installation at some convenient time later in the year.

When either round or sawed timbers are in a horizontal position and exposed to the sunshine for a considerable period in the summer months, they are more likely to develop deep checks than when they are in service in the vertical position or when they are piled and protected from the sun. In the horizontal position, they are exposed to a greater intensity of sunshine, especially during the long days of summer, and the surface wood on the side exposed to the sun may season to a moisture content considerably lower than that of the wood on the opposite surface. This wide difference in the moisture distribution will tend to develop deep checking on the upper surface because of the lower moisture content in this region. Timbers that season after they are set in the ground will tend to develop a larger number of smaller and shallower checks around the circumference. This has been noted when comparing treated poles set in line soon after treatment with poles piled on the ground and exposed to the sun and rain. Alternate wetting and drying of the wood within the checks also may tend to increase the depth of checks.

Bleeding of treated material shortly after treatment is often greater if the timbers are exposed to the sun when they are in the horizontal position.

The amount of direct sunshine to which timbers are exposed on clear days while lying on the ground will be proportional to the sine of the angle at which the sun's rays strike the horizontal plane. In the vertical position it will be proportional to the cosine of this angle. From sunrise to near midmorning, and after the middle of the afternoon until sunset, the component of sunshine at right angles to the vertical plane will be larger than the component at right angles to the horizontal plane. The sunshine component at right angles to the vertical plane, however, will pass through a deeper layer of air than will that at right angles to the ground. The maximum temperature will usually occur from about' midmorning to the middle of the afternoon, and it is during this period that the amount of direct sunshine on the horizontal plane is a maximum. Figure 4 shows the percentage of direct sunshine that may occur on this plane at midday for the approximate range of latitudes in the United States. These curves show the computed data for different days and months in the year. Figure 5 shows similar data for the amount of direct sunshine on the vertical plane. Direct sunshine on timbers while seasoning in any position will promote checking, but those exposed in the horizontal plane will be under the more severe seasoning conditions.

It may be noted from Figures 4 and 5 that the percentage of direct sunshine on the horizontal plane would be maximum at midday during the summer months, while the amount of direct sunshine on the vertical plane would be minimum at midday during this period. The middle latitude of the United States is about 37°, and Figure 4 shows that at this latitude there is about 95 percent direct sunshine on the horizontal plane during June and most of July. Even at the more northern latitude of 45°, over 90 percent of the sunshine beams directly on the horizontal

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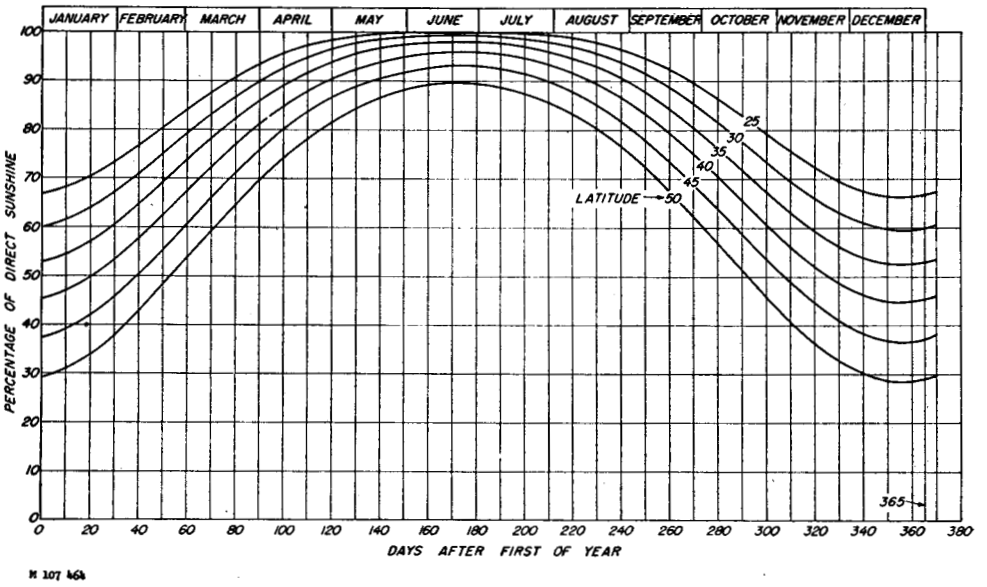

Figure 4.—Percentage of direct sunshine on the horizontal plane at midday for different latitudes.

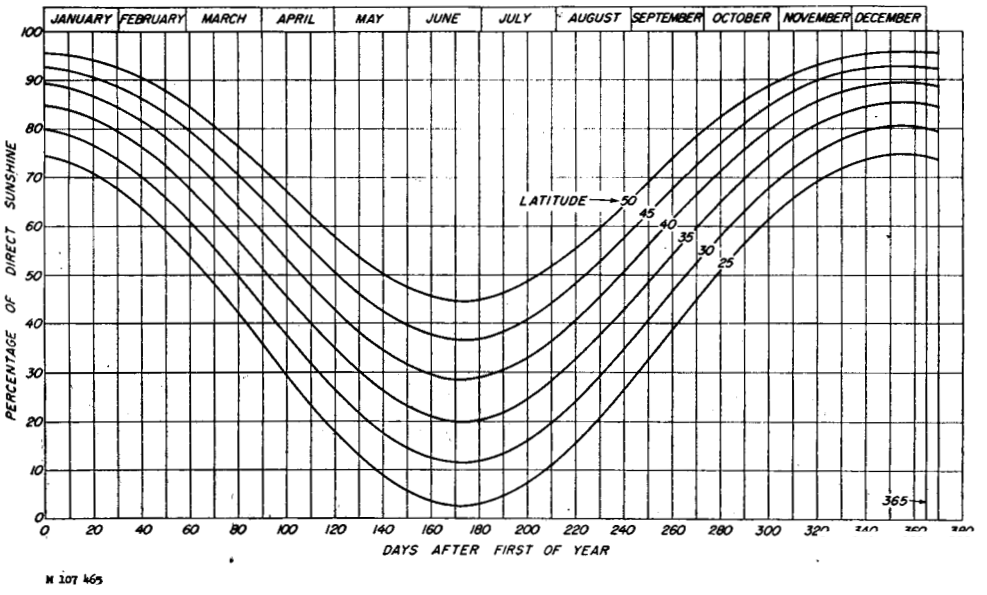

Figure 5.—Percentage of direct sunshine on the vertical plane at midday for different latitudes.

plane at midday for more than 2 months. For the same period and latitude, Figure 5 shows that the percentage of direct sunshine at midday on the vertical plane ranges from about 39 to 44 percent.

Figure 6 was prepared to show variations in the angle that the sun's rays make at midday with the horizontal and vertical planes at different latitudes and at four different periods of the year. Figure 6*A* shows the angles made at the periods of the equinox, which occur in March and September, when the length of day and night are equal and the sun's declination is zero. Figure 6*B* shows the maximum angle the sun's rays make at the summer solstice in June when the sun is highest and furthest north, and Figure 6*C* shows the angle the sun's rays make at the time of the winter solstice when the sun is lowest and furthest south.

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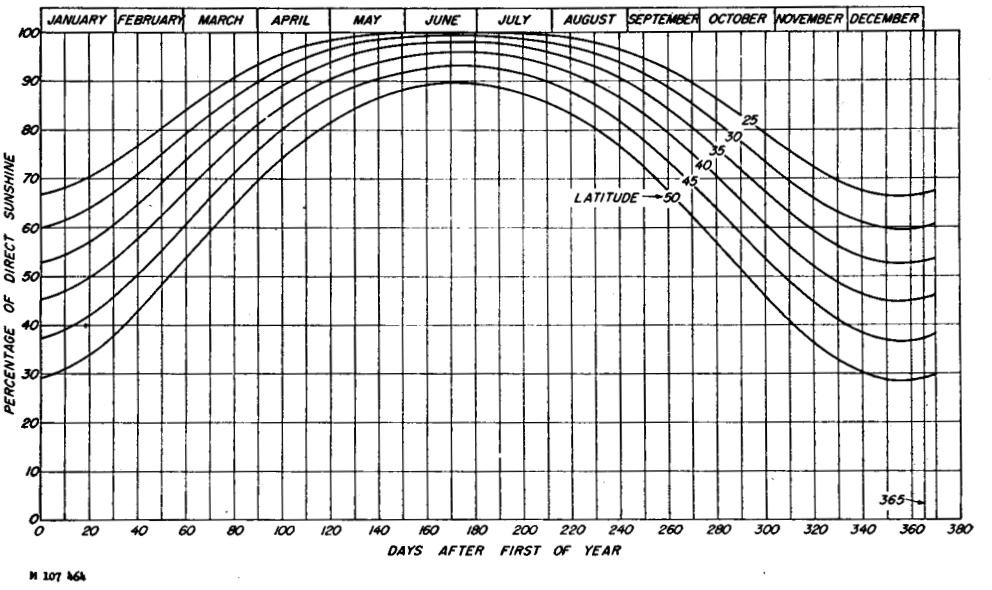
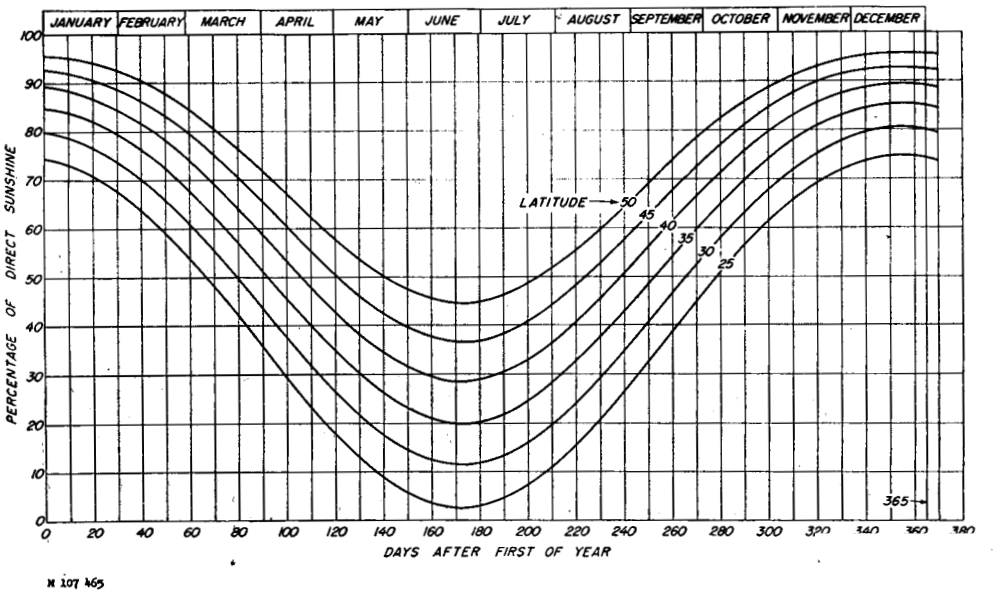


Figure 4.—Percentage of direct sunshine on the horizontal plane at midday for different latitudes.



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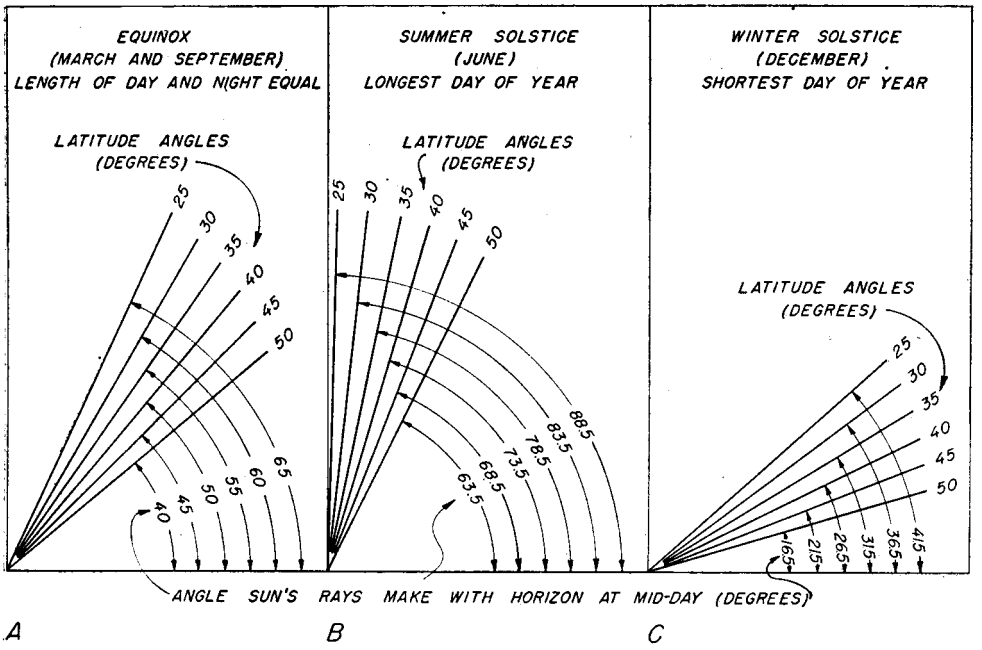

Figure 6.—Angle sun's rays make with horizon at different latitudes at vernal and autumnal equinox and summer and winter solstice.

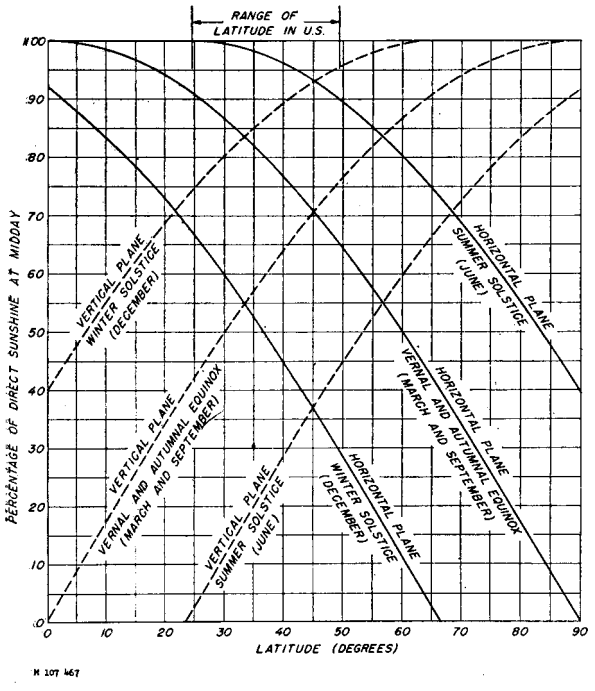

Figure 7.—Percentage of direct sunshine at midday at different latitudes at vernal and autumnal equinox and summer and winter solstice.

the United States with that in other countries, the data were computed and plotted for all latitudes in the Northern Hemisphere from the equator to the pole. The approximate latitudes within the United States are indicated on the figure.

From Figure 7 it may be noted that, in the United States at the time of the equinoxes, the amount of direct sunshine at midday on a horizontal plane ranges from about 66 percent on the northern boundary to about 91 percent on the southern boundary, while on the vertical plane it ranges from about 76 percent in the North to about 42 percent in the South. The summer months are, of course, within the period between the spring equinox in March and the autumnal equinox in September.

At the summer solstice at midday, the amount of direct sunshine ranges from about 90 percent in the North to about 100 percent in the South for the horizontal plane, while on the vertical plane it ranges from about 44 percent in the North to about two percent in the South.

At the winter solstice, the amount of direct sunshine at midday on the horizontal plane ranges from about 30 percent in the North to about 66 percent in the South. The corresponding direct sunshine on the vertical plane ranges from about 96 percent in the North to about 74 percent in the South. Since this is in the winter period and the sun is at its lowest point in the South, the higher percentage of sunshine on the vertical plane is of little importance compared with the high percentage of direct sunshine on the horizontal plane in the summer.

To obtain some preliminary data on the effect of sunshine on checking when poles are exposed in the horizontal and vertical positions, two southern pine and two larch poles were sawed into two sections

about eight feet long. These poles were peeled by machine, and had been soaked in a tank of water for several weeks in preparation for bending tests, which were made before the poles were used for this study. Poles of these two species were the only woods available when these preliminary tests on checking were started.

The four half-length sections of the two larch poles were marked T92-1, T92-2, T93-1, and T93-2, and the four sections of the southern pine poles were marked 16-S-1, 16-S-2, 66-S-1, and 66-S-2. Pieces marked T92-1, T93-2, 16-S-1, and 66-S-2 were given a light pressure treatment with coal tar creosote, while the others were left untreated.

The untreated larch section T93-1 and the treated section T93-2, with the untreated and treated southern pine sections 16-S-2 and 16-S-1, were set in the ground in the vertical position. The other four sections were placed on supports in the horizontal position. All these sections were placed in test in July 1954 and were removed a year later. Before the specimens were removed, moisture determinations were made with a moisture meter[7] at distances of ½ 1, and 1½ inches from the surface on both the north and south sides of the sections set in the ground, and in the top and bottom surfaces of the sections placed in the horizontal position. The data on these moisture determinations are shown in Tables 3 and 4. Since moisture meter readings are not very reliable for wet wood, when the meter readings showed moisture content values of about 35 to 40 percent or more, the data in Tables 3 and 4 show only that the readings were made in wet wood.

After the sections were removed at the end of the year, disks were sawed from the midlength of each piece, and the average moisture content was determined as closely as practicable. These data are shown in Tables 5 and 6.

[7] Mathewson, J. S. 1952. Air seasoning of lodgepole pine poles. Forest Products Laboratory Report R1922.

Table 3.—Moisture Content of Vertically Seasoned Pole Sections, as Determined by Moisture Meter

Species	Average diameter In.	Distance from surface In.	Moisture content, Percent: South side	Moisture content, Percent: North side
Larch				
T93-1 (untreated)	14.0	0.5	10.8	11.5
		1.0	15.2	15.4
		1.5	19.0	19.0
T93-2 (treated)	13.5	.5	12.1	14.0
		1.0	16.0	18.2
		1.5	19.3	21.8
Southern pine				
16-S-2 (untreated)	13.0	.5	15.0	17.0
		1.0	30.0	27.0
		1.5	Wood wet	Wood wet
16-S-1 (treated)	15.5	.5	14.4	23.8
		1.0	22.0	Wood wet
		1.5	Wood wet	Wood wet

Table 4.—Moisture Content of Horizontally Seasoned Pole Sections, as Determined by Moisture Meter

Species	Average diameter In.	Distance from surface In.	Moisture content, Percent: Top surface	Moisture content, Percent: Bottom surface
Larch				
T92-2 (untreated)	12.5	0.5	9.9	13.2
		1.0	16.3	18.3
		1.5	22.5	23.0
T92-1 (treated)	13.0	.5	10.8	18.0
		1.0	16.0	22.0
		1.5	21.0	24.5
Southern pine				
66-S-1 (untreated)	14.5	.5	10.5	18.4
		1.0	18.5	26.0
		1.5	25.5	Wood wet
66-S-2 (treated)	13.5	.5	11.7	21.5
		1.0	20.0	30.0
		1.5	29.0	Wood wet

There was very little penetration of preservative in the thin sapwood of the larch sections, but, even with the light treatment, penetration in the pine sapwood ranged from about 0.5 to 2.5 inches. For this reason, average moisture determinations made by ovendrying the pine specimens are more or less uncertain.

Table 5.—Moisture Content of Vertically Seasoned Pole Sections, as Determined by Ovendrying Method

Specimen No.	Average depth of sapwood In.	Average moisture content of pole section disk, Percent: South side, Sapwood	South side, Heartwood	North side, Sapwood	North side, Heartwood
Larch					
T93-1 (untreated)	0.4	(1)	25	--	38
T93-2 (treated)[2]	.6	(1)	13	--	12
Southern pine					
16-S-2 (untreated)[3]	5.25	72	(4)	95	--
16-S-1 (treated)[5]	5.50	About 21	--	About 52	--

[1]Sapwood very thin and variable in thickness.
[2]Very little preservative penetration in sapwood.
[3]Considerable sapwood decay at groundline.
[4]Heartwood comprised only a small proportion of total volume of pine section.
[5]Sapwood penetrated about ½ to 2 inches by preservative.

Table 6.—Moisture Content of Horizontally Seasoned Pole Sections, as Determined by Ovendrying Method

Specimen No.	Average depth of sapwood In.	Average moisture content of pole section disk, Percent: From top surface, Sapwood	From top surface, Heartwood	From bottom surface, Sapwood	From bottom surface, Heartwood
Larch					
T92-2 (untreated)	0.6	(1)	39	--	60
T92-1 (treated)[2]	.9	(1)	25	--	50
Southern pine					
66-S-1 (untreated)	3.9	29.5	(3)	50	--
66-S-2 (treated)[4]	3.5	About 24	(3)	Not determined	

[1]Sapwood very thin and variable in thickness.
[2]Very little preservative penetration in sapwood.
[3]Heartwood comprised only a small proportion of total volume of pine section.
[4]Sapwood penetrated about 1 to 2.5 inches by preservative.

No decay was found in any of the treated sections, but there was a considerable amount of decay at the groundline in untreated pine section 16-S-2.

It may be noted from the data in Tables 3 and 4 that, in general, there was a distinctly greater difference between the moisture content values of the upper and lower surfaces of the pole sections placed in the horizontal position than between the values for the wood on the north and south sides of the sections set in the ground.

Figures 8, 9, 10, and 11 show the untreated and treated larch and southern pine sections set in the ground, and Figure 12 shows the sections placed in a horizontal position. The ends of the pieces shown in Figure 12 were facing west. Photographs that show the vertical sections (Figures 8, 9, 10 and 11) were taken from the south.

The figures show that there was much more checking in the larch than in the pine sections in both the horizontal and vertical positions. Examination showed that the checks were more conspicuous on the upper surface and also deeper in the larch sections placed horizontally than in those set in the ground. There was no deep checking in any of the southern pine sections, although the upper surface of the horizontal sections showed a greater number of small checks on the top surfaces of the horizontal pieces than in any part of the surface of those set in the ground. Since much of the sapwood of the pine was still wet when the test period was ended, it is possible that somewhat more checking might have occurred in the pine pieces if they had been more thoroughly seasoned. The deep, permeable sapwood of the pine, however, would probably help reduce the possibility of severe checking in the pine sections.

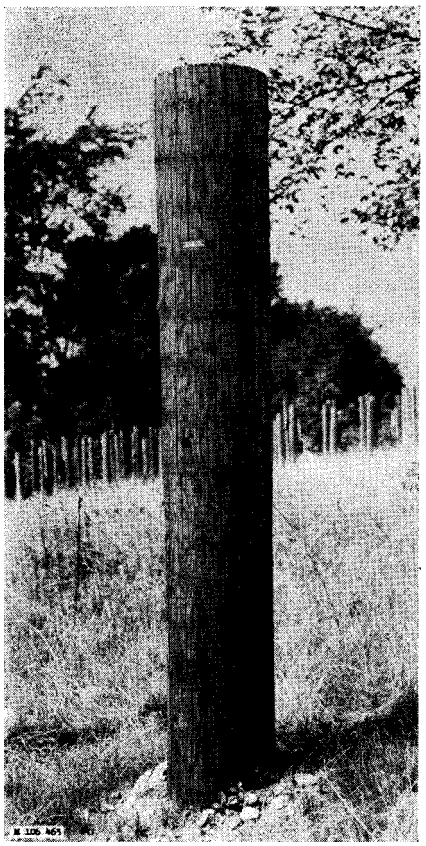

Figure 8.—Viewof the south side of untreated larch section No. T93-1 seasoned in the vertical position.

Figure 9.—Viewof the south side of larch section No. T93-2, with a light creosote treatment, seasoned in the vertical position.

These tests were necessarily very limited, but the results substantiate observations made on poles and piles of different species seasoned in different parts of the country and exposed to the heat of the sun in both the horizontal and vertical positions. If poles or piles had a fairly high moisture content after treatment, there would be less opportunity for severe checking to develop if the timbers were placed in service as soon as possible after treatment, instead of

Figure 10.—Viewof the south side of untreated southern pine section No. 16-S-2, seasoned in the vertical position.

leaving them to season on the ground without protection from the sun. It is not always practical to do this, of course.

Checking does not have an important affect on the bending strength of round timbers, since their diameter is usually small compared with the length. But, as previously mentioned, checking of load-bearing structural timbers, such as bridge stringers, may seriously reduce their shear strength. If, however, checks expose untreated wood in either round or sawed material, they may provide an entrance for decay and insect attack. In any case, it would be desirable either to season timbers before treatment, so that checking below the depth of penetration will not occur as a result of subsequent checking, or the penetration should be deep enough to protect the wood even if additional checking does occur after treatment.

Species that have fairly deep and permeable sapwood, such as the southern pines, ponderosa pine, and red pine, can be penetrated to nearly the full depth of the sapwood, and seasoning before treatment is not so important for these woods. Most of the Rocky Mountain and western species, however, have more shallow sapwood, or sapwood that is relatively resistant to treatment. It is therefore desirable to season timbers of these species before treatment, so that later seasoning will not expose untreated wood.

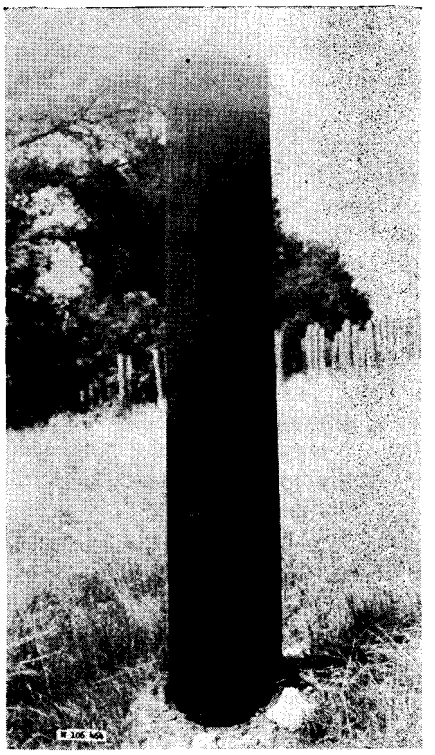

Figure 11.—Viewof the south side of southern pine section No. 16-S-1, with a light creosote treatment, seasoned in the vertical position.

Checking as a Result of Treatment

In addition to the checking that occurs when wood is air seasoned, excessively severe treating conditions

Figure 12.—Viewfrom west end of test sections seasoned in horizontal position. From left: Southern pine section No. 66-S-2 with light treatment; larch section No. T92-1 with light treatment; larch section No. T92-2, untreated; southern pine section No. 66-S-1, untreated.

also are responsible for a considerable amount of checking that could be avoided by the use of milder treating conditions. Unnecessarily long steaming periods and too high steam temperatures when wood is steam conditioned, or the use of very long boiling periods when wood is conditioned by the Boulton process, may weaken the wood so that severe burst checks or side checking will occur when pressure is applied. The use of excessively high preservative pressure during treatment is a common cause of severe burst checks, collapse, ring shakes, and surface checking.

Information Needed

Experiments are needed to determine how commercial timbers of different species for such uses as poles, piles, ties, caps, and stringers can be piled to best advantage under different climatic conditions to reduce objectionable checking as much as possible.

Very little is known about the possible advantage of using some type of roof over timbers piled for seasoning. Such roofs would help protect the timbers against exposure to direct sunshine and rain.

In some parts of the South, it is difficult to air season timbers that contain a large amount of sapwood, or to season timbers of species in which both the sapwood and heartwood are low in resistance to decay. This difficulty arises because the heavy rains usually come in the summer months, when the temperature and humidity are high and conditions are most favorable for decay of the wood. Roofs over the timbers piled for seasoning might be found to be economical under such conditions, since they would help reduce the danger of decay and would keep the rain from retarding the rate of seasoning. In arid regions, roofs would help protect the timbers against too rapid seasoning due to exposure to the sun and winds.

Information is needed also on the moisture distribution in timbers of different kinds seasoned or in service under different climatic conditions. Such information would be helpful in determining what moisture reduction can be expected when the timbers are seasoned in different localities, and whether serious checking may occur after the timbers are in service.

AMERICAN WOOD-PRESERVERS' ASSOCIATION, 839 Seventeenth Street, N. W., Washington 6, D. C. PREPARED FOR THE annual meeting of April 23, 24, 25, 1956, the Jung Hotel New Orleans, Louisiana. THIS ASSOCIATION is not responsible for any statement made or opinion expressed in its publications.