# SHRINKAGE OF WOOD

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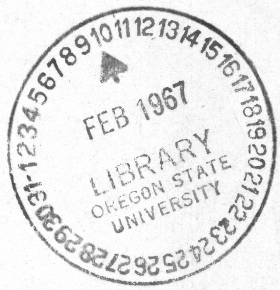


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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison, Wisconsin
In Cooperation with the University of Wisconsin

# SHRINKAGE OF WOOD[1]

Wood, like many other materials, shrinks as it loses moisture and swells as it absorbs moisture.

While wood in its green condition as it comes from the tree may contain water ranging in quantity from 30 to 250 percent, based on the weight of the oven-dry wood, the removal of only the last 25 or 30 percent of this moisture content has the effect of shrinking the wood on drying out; and since wood in service is never totally dry, the possible shrinkage effect falls within a relatively narrow range. Water is held in the wood in two distinct ways -- imbibed water in the walls of the wood cells, and free water in the cell cavities. When wood begins to dry the free water leaves first followed by the imbibed water. The fiber-saturation point is that condition in which all the free water has been removed but all the imbibed water remains; for most woods this point is between 25- and 30-percent moisture content.

Wood changes size with moisture content only below the fiber-saturation point. Since in seasoning green wood the surface dries more rapidly than the interior and reaches the fiber-saturation point first, shrinkage may start while the average moisture content is considerably above the fiber-saturation point. Wood shrinks most in the direction of the annual growth rings (tangentially), about one-half to two-thirds as much across these rings (radially), and very little, as a rule, along the grain (longitudinally). The joint effects of radial and tangential shrinkage on the shape of various sections in drying from the green condition are illustrated in figure 1. When a board is excessively cross-grained the lengthwise shrinkage is a combination of crosswise and longitudinal shrinkage, resulting in a greater shortening than would occur in a straight-grained piece. Shrinkage is usually expressed as a percentage of the green dimensions, which represent the natural size of the piece. Table 1 gives the range in shrinkage in different directions for most of the commercially important native species.

Table 1.--Range in average shrinkage of a number of native species of wood

| Direction of shrinkage | From green to oven-dry condition | From green to air-dry condition (12- to 15-percent moisture content) |
|---|---|---|
| | Percent of green size | Percent of green size |
| Tangential | 4.3 to 14 | 2.1 to 7 |
| Radial | 2 to 8.5 | 1 to 4.2 |
| Longitudinal | .1 to .2 | .05 to .1 |
| Volumetric | 7 to 21 | 3.5 to 10.5 |

[1]This mimeograph is one of a series of progress reports issued by the Forest Products Laboratory to aid the nation's defense effort.
Mimeo. No. 1363

Shrinkage in drying is proportional to the moisture lost below the fiber-saturation point. Approximately one-half the total shrinkage possible has occurred in wood seasoned to an air-dry condition (12- to 15-percent moisture content) and about three-fourths in lumber kiln dried to a moisture content of about 7 percent. Hence, if wood is properly seasoned, manufactured, and installed at a moisture content in accord with its service conditions, there is every prospect of satisfactory performance without serious changes in size or distortion of section.

In general, the heavier species of wood shrink more across the grain than the lighter ones. Heavier pieces also shrink more than lighter pieces of the same species. When shrinkage is more of a factor than hardness or strength a lightweight species should be chosen. When both hardness or strength and low shrinkage are very important then an exceptional species, such as black locust, should be chosen.

The average tangential, radial, and volumetric shrinkages for individual species dried to an air-dry, kiln-dry, or oven-dry condition are given in table 2.

Theoretically the normal moisture content-shrinkage relation may be considered a direct one, from zero shrinkage at the fiber-saturation point to maximum shrinkage at zero moisture content. Actually the relationship in lumber of commercial size is similar to the curves in figure 2, but for practical use a straight-line relation may be assumed without appreciable error. The curves represent average values, and the shrinkage of an individual board may, of course, be above or below the amount indicated.

Changes in moisture content in seasoned wood, such as those caused by seasonal variation in relative humidity, produce changes in dimension proportional to the moisture-content changes. For example, assume that a piece of flat-sawed southern yellow pine sheathing at 12 percent moisture content loses 5 percent of moisture. The shrinkage curve (marked "tangential") indicates that from the green condition to 7 percent moisture content the shrinkage in width would be 5 percent and to 12-percent moisture content would be 3-1/2 percent. The difference of 1-1/2 percent indicates the shrinkage in width of the board because of the 5 percent loss in moisture. These curves represent average values, and the shrinkage of an individual board may be below or above the indicated amount.

Table 2.---Shrinkage values for commercially important woods grown in the United States

| Species | Shrinkage (percent of dimension when green) from green to -- | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Air dried to 12- to 15-percent moisture[1] (estimated values) | | | Kiln dried to 6- to 7-percent moisture[2] (estimated values) | | | Oven dried to 0-percent moisture (test values) | | |
| | Radial | Tangential | Volumetric | Radial | Tangential | Volumetric | Radial | Tangential | Volumetric |
| | Percent | Percent | Percent | Percent | Percent | Percent | Percent | Percent | Percent |
| Ash: | | | | | | | | | |
| Black | 2.5 | 3.9 | 7.6 | 3.8 | 5.8 | 11.4 | 5.0 | 7.8 | 15.2 |
| Commercial white[3] | 2.3 | 3.8 | 6.4 | 3.4 | 5.6 | 9.6 | 4.6 | 7.5 | 12.8 |
| Oregon | 2.0 | 4.0 | 6.6 | 3.1 | 6.1 | 9.9 | 4.1 | 8.1 | 13.2 |
| Basswood | 3.3 | 4.6 | 7.9 | 5.0 | 7.0 | 11.8 | 6.6 | 9.3 | 15.8 |
| Beech | 2.6 | 5.5 | 8.2 | 3.8 | 8.2 | 12.2 | 5.1 | 11.0 | 16.3 |
| Birch[4] | 3.4 | 4.4 | 8.2 | 5.2 | 6.7 | 12.2 | 6.9 | 8.9 | 16.3 |
| Birch, paper | 3.2 | 4.3 | 8.1 | 4.7 | 6.4 | 12.2 | 6.3 | 8.6 | 16.2 |
| Butternut | 1.6 | 3.0 | 5.1 | 2.5 | 4.6 | 7.6 | 3.3 | 6.1 | 10.2 |
| Cedar: | | | | | | | | | |
| Alaska | 1.4 | 3.0 | 4.6 | 2.1 | 4.5 | 6.9 | 2.8 | 6.0 | 9.2 |
| Eastern red | 1.6 | 2.4 | 3.9 | 2.3 | 3.5 | 5.8 | 3.1 | 4.7 | 7.8 |
| Incense | 1.6 | 2.6 | 3.8 | 2.5 | 3.9 | 5.7 | 3.3 | 5.2 | 7.6 |
| Northern white | 1.0 | 2.4 | 3.5 | 1.6 | 3.5 | 5.2 | 2.1 | 4.7 | 7.0 |
| Port Orford | 2.3 | 3.4 | 5.0 | 3.4 | 5.2 | 7.6 | 4.6 | 6.9 | 10.1 |
| Southern white | 1.4 | 2.6 | 4.2 | 2.1 | 3.9 | 6.3 | 2.8 | 5.2 | 8.4 |
| Western red | 1.2 | 2.5 | 3.8 | 1.8 | 3.8 | 5.8 | 2.4 | 5.0 | 7.7 |
| Cherry, black | 1.8 | 3.8 | 5.8 | 2.8 | 5.3 | 8.6 | 3.7 | 7.1 | 11.5 |
| Chestnut | 1.7 | 3.4 | 5.8 | 2.6 | 5.0 | 8.7 | 3.4 | 6.7 | 11.6 |
| Cottonwood: | | | | | | | | | |
| Eastern | 2.0 | 4.6 | 7.0 | 2.9 | 6.9 | 10.6 | 3.9 | 9.2 | 14.1 |
| Northern black | 1.8 | 4.3 | 6.2 | 2.7 | 6.4 | 9.3 | 3.6 | 8.6 | 12.4 |
| Cypress, southern | 1.9 | 3.1 | 5.2 | 2.8 | 4.6 | 7.9 | 3.8 | 6.2 | 10.5 |
| Douglas fir: | | | | | | | | | |
| Coast region | 2.5 | 3.9 | 5.9 | 3.8 | 5.8 | 8.8 | 5.0 | 7.8 | 11.8 |
| "Inland Empire" region | 2.0 | 3.8 | 5.4 | 3.1 | 5.7 | 8.2 | 4.1 | 7.6 | 10.9 |
| Rocky Mountain region | 1.8 | 3.1 | 5.3 | 2.7 | 4.6 | 8.0 | 3.6 | 6.2 | 10.6 |
| Elm: | | | | | | | | | |
| American | 2.1 | 4.8 | 7.3 | 3.2 | 7.1 | 11.0 | 4.2 | 9.5 | 14.6 |
| Rock | 2.4 | 4.0 | 7.0 | 3.6 | 6.1 | 10.6 | 4.8 | 8.1 | 14.1 |
| Slippery | 2.4 | 4.4 | 6.9 | 3.7 | 6.7 | 10.4 | 4.9 | 8.9 | 13.8 |
| Fir: | | | | | | | | | |
| Balsam | 1.4 | 3.3 | 5.4 | 2.1 | 5.0 | 8.1 | 2.8 | 6.6 | 10.8 |
| Commercial white[5] | 1.6 | 3.6 | 4.9 | 2.4 | 5.3 | 7.4 | 3.2 | 7.1 | 9.8 |
| Noble | 2.2 | 4.1 | 6.2 | 3.4 | 6.2 | 9.4 | 4.5 | 8.3 | 12.5 |
| Gum: | | | | | | | | | |
| Black | 2.2 | 3.8 | 7.0 | 3.3 | 5.8 | 10.4 | 4.4 | 7.7 | 13.9 |
| Red | 2.6 | 5.0 | 7.5 | 3.9 | 7.4 | 11.2 | 5.2 | 9.9 | 15.0 |
| Tupelo | 2.1 | 3.8 | 6.2 | 3.2 | 5.7 | 9.4 | 4.2 | 7.6 | 12.5 |
| Hackberry | 2.4 | 4.4 | 6.9 | 3.6 | 6.7 | 10.4 | 4.8 | 8.9 | 13.8 |
| Hemlock: | | | | | | | | | |
| Eastern | 1.5 | 3.4 | 4.8 | 2.2 | 5.1 | 7.3 | 3.0 | 6.8 | 9.7 |
| Western | 2.2 | 4.0 | 6.0 | 3.2 | 5.9 | 8.9 | 4.3 | 7.9 | 11.9 |
| Hickory: | | | | | | | | | |
| Pecan[6] | 2.4 | 4.4 | 6.8 | 3.7 | 6.7 | 10.2 | 4.9 | 8.9 | 13.6 |
| True[7] | 3.6 | 5.7 | 9.0 | 5.5 | 8.6 | 13.4 | 7.3 | 11.4 | 17.9 |
| Honey Locust | 2.1 | 3.3 | 5.4 | 3.2 | 5.0 | 8.1 | 4.2 | 6.6 | 10.8 |
| Larch, western | 2.1 | 4.0 | 6.6 | 3.2 | 6.1 | 9.9 | 4.2 | 8.1 | 13.2 |
| Locust, black | 2.2 | 3.4 | 4.9 | 3.3 | 5.2 | 7.4 | 4.4 | 6.9 | 9.8 |
| Magnolia: | | | | | | | | | |
| Cucumber | 2.6 | 4.4 | 6.8 | 3.9 | 6.6 | 10.2 | 5.2 | 8.8 | 13.6 |
| Evergreen | 2.7 | 3.3 | 6.2 | 4.0 | 5.0 | 9.2 | 5.4 | 6.6 | 12.3 |
| Mahogany, true | 1.7 | 2.4 | 3.8 | 2.6 | 3.6 | 5.8 | 3.5 | 4.8 | 7.7 |
| Maple: | | | | | | | | | |
| Bigleaf | 1.8 | 3.6 | 5.8 | 2.8 | 5.3 | 8.7 | 3.7 | 7.1 | 11.6 |
| Black | 2.4 | 4.6 | 7.0 | 3.6 | 7.0 | 10.5 | 4.8 | 9.3 | 14.0 |
| Red | 2.0 | 4.1 | 6.6 | 3.0 | 6.2 | 9.8 | 4.0 | 8.2 | 13.1 |
| Silver | 1.5 | 3.6 | 6.0 | 2.2 | 5.4 | 9.0 | 3.0 | 7.2 | 12.0 |
| Sugar | 2.4 | 4.8 | 7.4 | 3.7 | 7.1 | 11.2 | 4.9 | 9.5 | 14.9 |
| Oak: | | | | | | | | | |
| Red[8] | 2.2 | 4.5 | 7.4 | 3.2 | 6.8 | 11.1 | 4.3 | 9.0 | 14.8 |
| White[9] | 2.7 | 4.6 | 8.0 | 4.0 | 7.0 | 12.0 | 5.4 | 9.3 | 16.0 |
| Pine: | | | | | | | | | |
| Loblolly | 2.4 | 3.7 | 6.2 | 3.6 | 5.6 | 9.2 | 4.8 | 7.4 | 12.3 |
| Lodgepole | 2.2 | 3.4 | 5.8 | 3.4 | 5.0 | 8.6 | 4.5 | 6.7 | 11.5 |
| Longleaf | 2.6 | 3.8 | 6.1 | 3.8 | 5.6 | 9.2 | 5.1 | 7.5 | 12.2 |
| Northern white | 1.2 | 3.0 | 4.1 | 1.7 | 4.5 | 6.2 | 2.3 | 6.0 | 8.2 |
| Norway | 2.3 | 3.6 | 5.8 | 3.4 | 5.4 | 8.6 | 4.6 | 7.2 | 11.5 |
| Ponderosa | 2.0 | 3.2 | 4.8 | 2.9 | 4.7 | 7.2 | 3.9 | 6.3 | 9.6 |
| Shortleaf | 2.2 | 3.8 | 6.2 | 3.3 | 5.8 | 9.2 | 4.4 | 7.7 | 12.3 |
| Sugar | 1.4 | 2.8 | 4.0 | 2.2 | 4.2 | 5.9 | 2.9 | 5.6 | 7.9 |
| Western white | 2.0 | 3.7 | 5.9 | 3.1 | 5.6 | 8.8 | 4.1 | 7.4 | 11.8 |
| Poplar, yellow | 2.0 | 3.6 | 6.2 | 3.0 | 5.3 | 9.2 | 4.0 | 7.1 | 12.3 |
| Redwood | 1.3 | 2.2 | 3.4 | 2.0 | 3.3 | 5.1 | 2.6 | 4.4 | 6.8 |
| Spruce: | | | | | | | | | |
| Eastern[10] | 2.2 | 3.8 | 6.3 | 3.2 | 5.8 | 9.4 | 4.3 | 7.7 | 12.6 |
| Engelmann | 1.7 | 3.3 | 5.2 | 2.6 | 5.0 | 7.8 | 3.4 | 6.6 | 10.4 |
| Sitka | 2.2 | 3.8 | 5.8 | 3.2 | 5.6 | 8.6 | 4.3 | 7.5 | 11.5 |
| Sycamore | 2.6 | 3.8 | 7.1 | 3.8 | 5.7 | 10.6 | 5.1 | 7.6 | 14.2 |
| Tamarack | 1.8 | 3.7 | 6.8 | 2.8 | 5.6 | 10.2 | 3.7 | 7.4 | 13.6 |
| Walnut, black | 2.6 | 3.6 | 5.6 | 3.9 | 5.3 | 8.5 | 5.2 | 7.1 | 11.3 |

[1] These shrinkage values have been taken as one-half the shrinkage to the oven-dry condition as given in the last three columns of this table.

[2] These shrinkage values have been taken as three-fourths the shrinkage to the oven-dry condition as given in the last three columns of this table.

[3] Average of Biltmore white ash, blue ash, green ash, and white ash.

[4] Average of sweet birch and yellow birch.

[5] Average of lowland white fir and white fir.

[6] Average of bitternut hickory, nutmeg hickory, water hickory, and pecan.

[7] Average of bigleaf shagbark hickory, mockernut hickory, pignut hickory, and shagbark hickory.

[8] Average of black oak, laurel oak, pin oak, red oak, scarlet oak, southern red oak, swamp red oak, water oak, and willow oak.

[9] Average of bur oak, chestnut oak, post oak, swamp chestnut oak, swamp white oak, and white oak.

[10] Average of black spruce, red spruce, and white spruce.

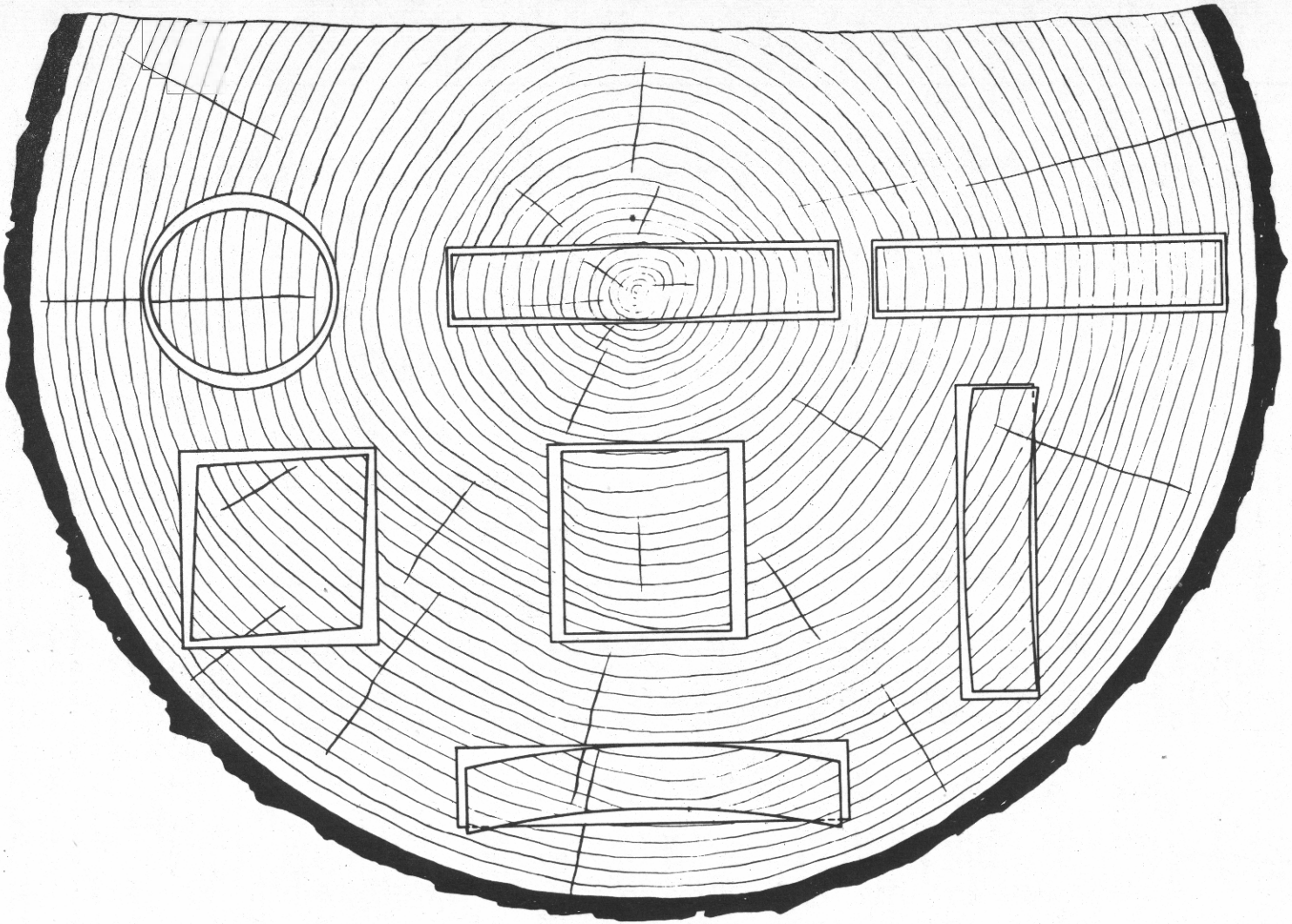

Fig. 1. Characteristic shrinkage and distortion of flats, squares, and rounds as affected by the direction of the annual rings. Tangential shrinkage is about twice as great as radial.

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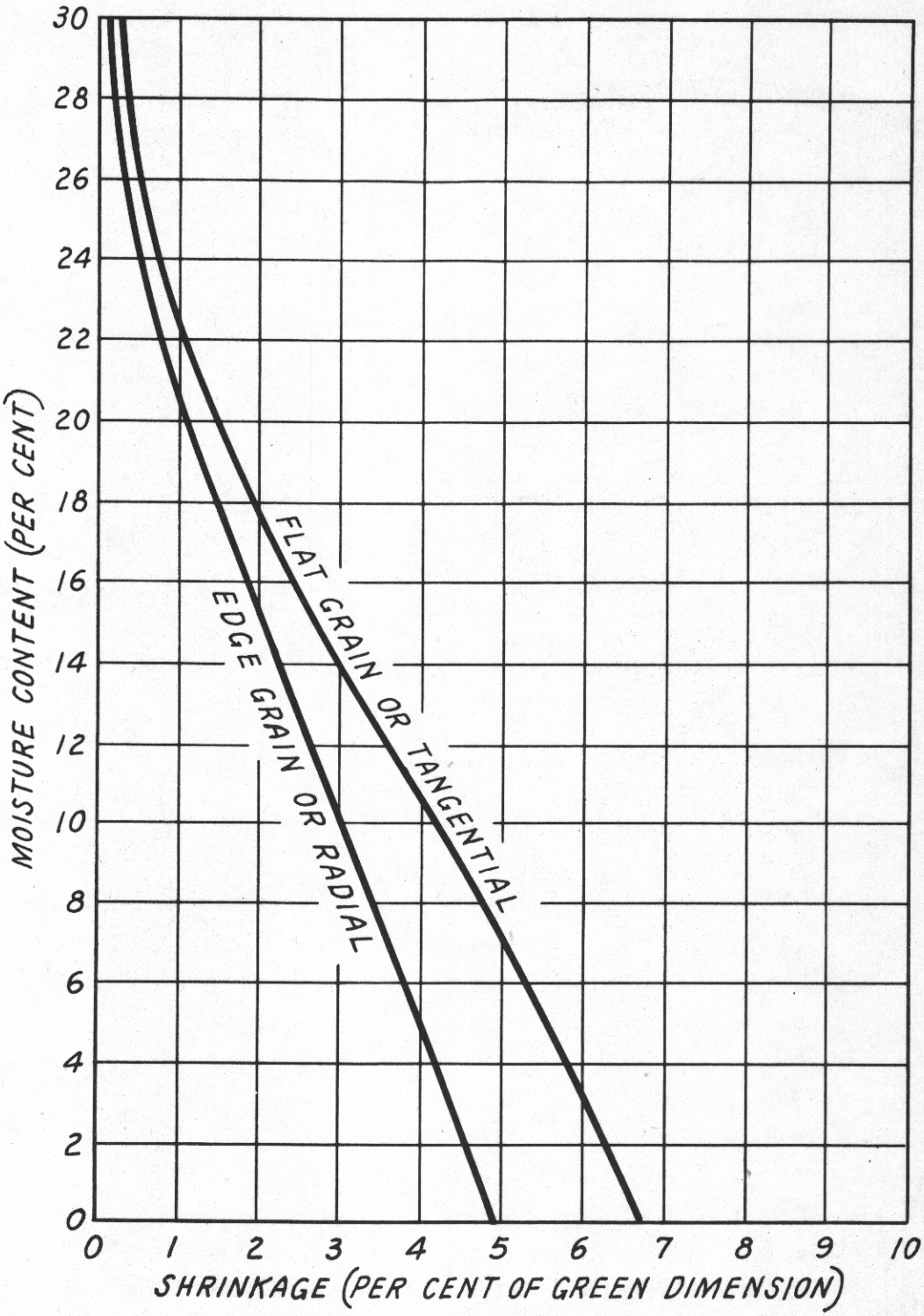


Fig. 2. Typical moisture-shrinkage curves. These curves are for Douglas-fir and southern yellow pine and may be used for estimating the amount of change in dimension that will take place with change in the moisture content of the wood.

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