TECHNICAL NOTE NUMBER 248

FOREST PRODUCTS LABORATORY UNITED STATES FOREST SERVICE

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COMPUTED THERMAL CONDUCTIVITY OF COMMON WOODS

The Forest Products Laboratory has made careful determinations of the thermal conductivity of wood at various moisture contents. These tests, which covered 32 species, have furnished sufficient data on the relationship between conductivity, specific gravity, and moisture content to make it possible to compute the approximate thermal conductivity for any wood for which the specific gravity is known and for which the moisture content can be determined or assumed. Such conductivities have many practical applications, such as in estimating the thermal resistance or insulating value of various woods; thermal resistance being the reciprocal or inverse value of conductivity.

It is common engineering practice to express heat conductivity, represented by K, as the amount of heat in British thermal units that will pass in 1 hour through 1 square foot of the material 1 inch thick per degree Fahrenheit temperature difference between the faces. Numerical values of K offered in this note are so expressed.

From the Forest Products Laboratory's wood conductivity tests the following formulas expressing the conductivity, specific gravity, moisture content relationship were derived:

For wood having a moisture content under 40 percent;

$$K = S\,(1.39 + 0.028M) + 0.165 \qquad (1)$$

For wood having a moisture content of 40 percent or more;

$$K = S\,(1.39 + 0.038M) + 0.165 \qquad (2)$$

In these expressions K is the conductivity, M is the average moisture content at time of test, and S is the average specific gravity based on volume at current moisture content and weight when oven dry.

A convenient application of formula (1) is found in the accompanying chart for finding the thermal conductivity of a given wood at a known or assumed moisture content. Since published average specific gravities are commonly based on volume when green, these specific gravities were used in the preparation of this chart. The specific gravity values for different degrees of seasoning down to the oven dry condition were computed from the specific gravity based on oven dry weight and volume when green, and these computed values of S were then substituted in formula (1) and the conductivity, K, was computed for the corresponding moisture content.

To use this chart: Read the average specific gravity for the wood under consideration from the accompanying table of specific gravity

values. On the chart follow a vertical line corresponding to the known or assumed moisture content of the wood upward until it intersects the sloping line corresponding to the specific gravity taken from the table. The reading on the vertical scale at the left for this intersection point is the desired thermal conductivity K (as previously defined), for the wood at the assumed moisture content.

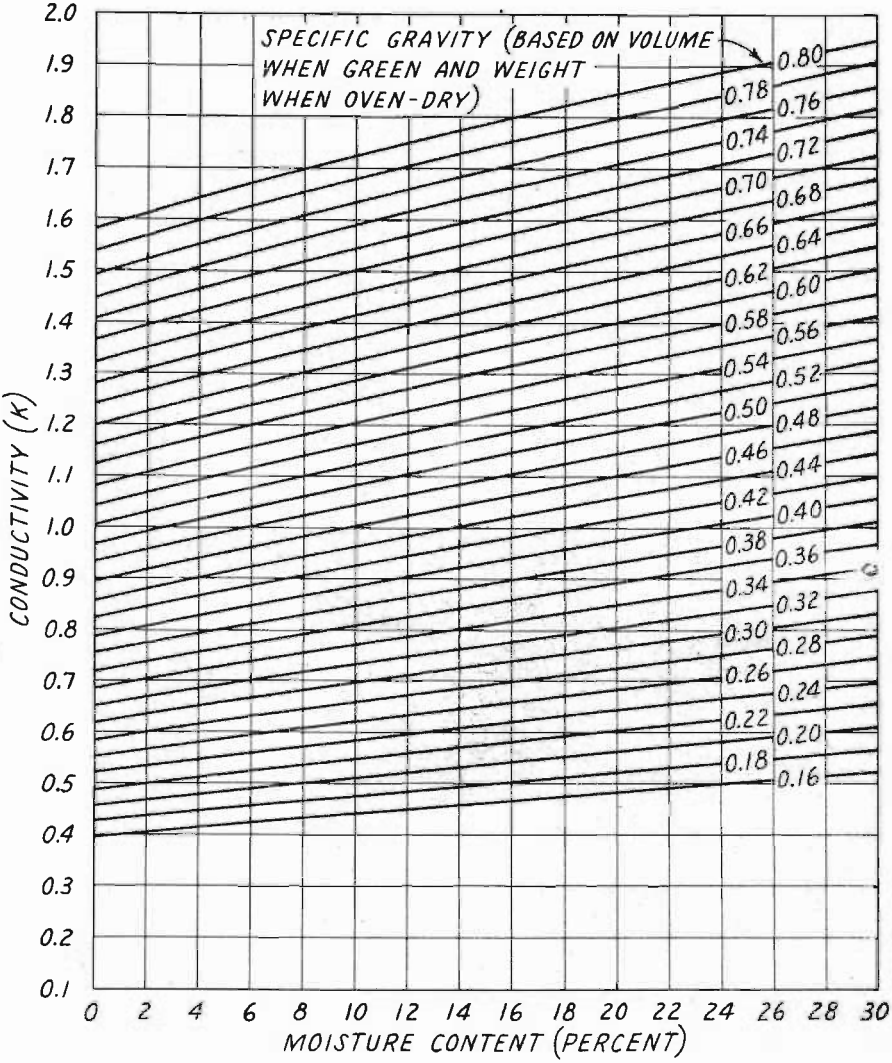
The following example will illustrate the use of the chart: Assume that it is desired to compare the average conductivity of loblolly pine at 15 percent moisture with that of yellow birch at the same moisture content. The table shows the average specific gravity of loblolly pine to be 0.47. By following the vertical line for 15 percent moisture to a point halfway between the lines for specific gravities of 0.46 and 0.48 the conductivity opposite this intersection point (on the left-hand scale) is shown to be 1.07. Yellow birch, reading from the table, has an indicated average specific gravity of 0.55. Applying this specific gravity and a moisture content of 15 percent on the chart, the average yellow birch wood at this moisture content is found to have a conductivity of about 1.24, so that nearly 16 percent more heat would flow through it than would flow through average loblolly pine at this moisture content.

The data of the table are average values for the species listed and there are, of course, appreciable variations in specific gravity between boards or shipments of the same species. The conductivities computed by means of the chart from the specific gravities given will be sufficiently correct for many purposes, but where greater accuracy is desired for a given lot of lumber or a single board, the actual specific gravity and moisture content should be determined and used in the formulas given.

Note: A comprehensive report discussing the data derived from the conductivity tests, derivation of the formulas, and the preparation of the accompanying and other charts, can be obtained on request from the Forest Products Laboratory, Madison, Wisconsin.

Average specific gravity of various species of softwoods and hardwoods.

Species	Average specific gravity (based on volume when green and weight when oven dry)
Hardwoods:	
Ash, white (Fraxinus americana)	0.55
Basswood, American (Tilia glabra)	.32
Beech, American (Fagus grandifolia)	.56
Birch, yellow (Betula lutea)	.55
Blackgum (Nyssa sylvatica)	.46
Chestnut, American (Castanea dentata)	.40
Elm, American (Ulmus americana)	.46
Elm, rock (Ulmus thomasii)	.57
Hackberry (Celtis occidentalis)	.49
Hickory, mockernut (Hicoria alba)	.64
Maple, silver (Acer saccharinum)	.44
Maple, sugar (Acer saccharum)	.56
Oak, red (commercial) (Quercus sp.)	.56
Oak, white (commercial) (Quercus sp.)	.59
Pecan (Hicoria pecan)	.60
Sweetgum (Liquidambar styraciflua)	.44
Sycamore, American (Platanus occidentalis)	.46
Tupelo, water (Nyssa aquatica)	.46
Walnut, black (Juglans nigra)	.51
Yellowpoplar (Liriodendron tulipifera)	.38
Softwoods:	
Baldcypress (Taxodium distichum)	.42
Douglas-fir, coast (Pseudotsuga taxifolia)	.45
Fir, white (Abies sp.)	.37
Hemlock, eastern (Tsuga canadensis)	.38
Hemlock, western (Tsuga heterophylla)	.38
Larch, western (Larix occidentalis)	.48
Pine, eastern white (Pinus strobus)	.34
Pine, jack (Pinus banksiana)	.39
Pine, loblolly (Pinus taeda)	.47
Pine, lodgepole (Pinus contorta)	.38
Pine, longleaf (Pinus palustris)	.54
Pine, ponderosa (Pinus ponderosa)	.38
Pine, red (Pinus resinosa)	.44
Pine, shortleaf (Pinus echinata)	.46
Pine, slash (Pinus caribaea)	.56
Pine, sugar (Pinus lambertiana)	.35
Pine, western white (Pinus monticola)	.36
Redcedar, eastern (Juniperus virginiana)	.44
Redcedar, western (Thuja plicata)	.31
Redwood (Sequoia sempervirens)	.38
Spruce, Engelmann (Picea engelmannii)	.31
Spruce, Sitka (Picea sitchensis)	.37
Spruce, white (Picea glauca)	.37
Tamarack (Larix laricina)	.49
White-cedar, northern (Thuja occidentalis)	.29


SPECIFIC GRAVITY (BASED ON VOLUME WHEN GREEN AND WEIGHT WHEN OVEN-DRY)
0.80
0.78
0.76
0.74
0.72
0.70
0.68
0.66
0.64
0.62
0.60
0.58
0.56
0.54
0.52
0.50
0.48
0.46
0.44
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
CONDUCTIVITY (K)
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
MOISTURE CONTENT (PERCENT)

A 36149 F