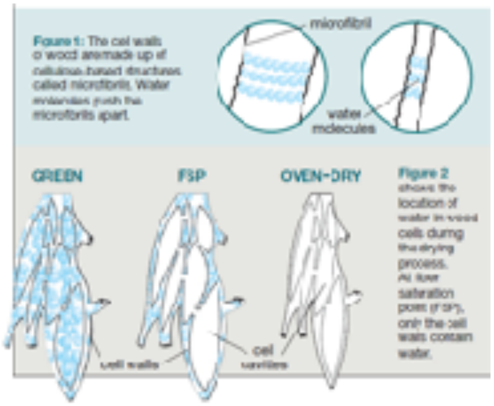
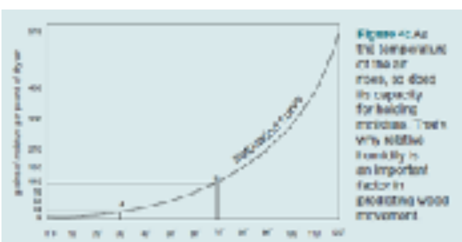
Wood Movement

Why does wood move? Because of water! The science behind shrinkage is simple, and might just come in handy for forecasting the future of your furniture.
By Udo Schmidt



PREDICTING WOOD MOVEMENT
Why do hardwood floors have wider cracks in winter than in summer? Why do solid-wood drawer boxes run smoothly in moderate seasons but act more and more stubborn as the temperature rises?
The tendency of wood to expand and contract, simply called wood movement, can frustrate even the most experienced woodworker. Problems range from minor nuisance to full-scale disaster. Fortunately, there are tools and knowledge at our disposal to help us predict wood movement and avoid its negative consequences.



Wood movement is caused by a nearly unavoidable, natural tendency of moisture to enter and exit wood cells from the surrounding environment. Through photosynthesis, trees produce the sugar glucose; long chains of glucose form cellulose. Cell walls are composed of bundles of cellulose chains, called microfibrils.
Wood is a network of cells, and as part of a living tree, the cell cavities are filled with water. But water also exists in the cell walls, trapped between microfibrils.
When it comes to drying green wood, the water in the cell cavities is called free water. Free water dries first and can be thought of as water poured out of a container; it does not cause wood movement. On the other hand, the loss of bound water in cell walls causes wood to shrink – its microfibrils move closer together **(Fig. 1)**.
The cells in fresh wood are saturated with water. The weight of the water contained in green lumber can actually exceed the weight of the wood itself. Moisture content of wood is its percentage of water weight to dry wood weight, and can range from 40% to 200% in fresh wood. (At 200%, there would be twice as much water as dry wood in a piece of lumber, by weight.) Usually softwoods have a higher moisture content than hardwoods, and sapwood has a higher moisture content than heartwood.
When the cell cavities are empty but the cell walls are still saturated **(Fig. 2)**, the wood is at its fiber saturation point (FSP). For most species, the FSP is reached at a moisture content of 27% to 30%. It is only when the moisture content dips below the FSP that wood begins to shrink. Much of the lumber used in woodshops falls somewhere between oven-dry (0% moisture) and its FSP.

Finding a Balance
To avoid wood movement as much as possible, the moisture content of wood should be near to equilibrium with the humidity of the environment. Equilibrium moisture content (EMC) is the point at which the moisture in the air is in balance with the moisture in the wood, and the wood will neither lose nor gain water molecules.

EMC is measured according to relative, not absolute, humidity. Absolute humidity is the total amount of moisture in the air, regardless of air temperature. But as air warms up, its capacity for holding moisture increases. Therefore relative humidity – a percentage of how much moisture the air is actually capable of holding at a given temperature – is a much more heavy useful measurement for targeting the EMC of wood than absolute humidity.

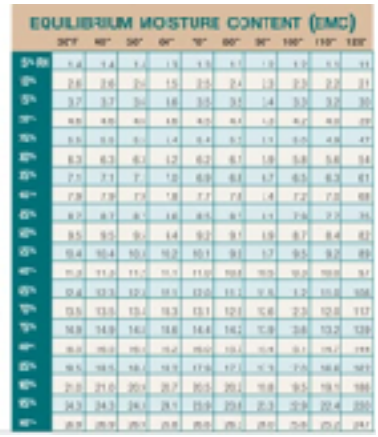
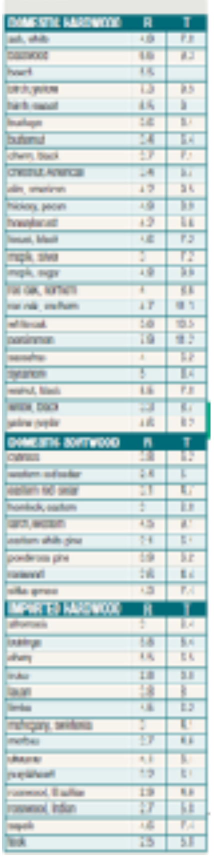


Figure 3: When wood has reached its equilibrium moisture content, the moisture it contains is in balance with the surrounding air. Wood reaches its greatest structural stability at this point, since it can be expected to neither gain nor lose moisture.

Fig. 3 shows EMC values in relation to temperature and relative humidity. If, for instance, the temperature is 70° and the relative humidity is 60%, then the EMC under these conditions is 11. The wood equalizes to a moisture content of 11%. If the relative humidity is 80%, then the EMC will also go up to 15.7. As temperature and relative humidity change by the day, if not by the hour, so does wood's EMC change. Fortunately, it takes a long time for wood to reach a given EMC, and therefore dimensional changes in wood happen much more slowly than temperature and relative humidity changes. Under normal conditions, wood movement is noticeable only with the changing seasons. But even if the results are imperceptible, wood is always trying to reach its EMC.

Figure 5: Shrinkage values of the radial and tangential dimensions for some common hardwoods and softwoods



Water in the air is measured in grains, with one pound equaling 7000 grains. At a temperature of 70°, air can hold 110 grains of water. If there are 55 grains of water in the air, the relative humidity is 50%. The curve of the graph in Fig. 4 shows why wood dimensions can change according to whether it is stored indoors or outdoors. At point A, the outside air at a temperature of 30° and relative humidity of 100% can hold 24 grains of water. The same air indoors is heated to a temperature of 70 F., a point at which the air can hold 110 grains of water. So, if the inside air is 70°. and has 24 grains of water, then its relative humidity has dropped to about 22%. Looking back to figure 3, we see that in this scenario, the wood has an EMC of 26.9 outdoors, but only 4.5 indoors.

The changes in EMC are usually not all that dramatic between summer and winter for wood kept indoors. An average summer day with temperatures of 70-80 and relative humidity of 60% to 80% produces an EMC of 12 to 13. In the winter, there is an average EMC of 4 to 6 indoors. So generally speaking, wood kept indoors will have a seasonal change in EMC of 6 to 8.

Why Wood Moves

Remember, shrinkage and movement only occur below the fiber saturation point (FSP), which varies by wood species. The manner in which lumber is cut from a log also influences its shrinkage character, since the MC can vary greatly between heartwood and sapwood, softwood and hardwood. Green lumber will dry relatively quickly to its FSP, that is, when cell cavities are empty but water is retained in the cell walls. No shrinkage occurs during this time.

Before we can calculate the dimensional changes to expect as a piece of wood dries below its FSP, we need to know its shrinkage value. Fig. 5 shows the shrinkage values for some common species. The values are given for the radial (R) and the tangential (T) shrinkage of a species from FSP to oven-dry. For instance, if northern red oak has a shrinkage value of 8.6% in the tangential plane, then a board will shrink 8.6% from FSP to oven-dry. Nobody uses wood at 30% moisture content or oven dry, but these values are the basis for calculating the movement of wood between two different moisture contents.

Fig. 6 shows which one of the shrinkage values applies (R or T) to a board cut from a log. If the lumber is flat-sawn (A), then the tangential shrinkage applies to the width of the board and the radial shrinkage to the thickness. If the board is quartersawn (B), the opposite is true.

Based on the assumption that wood shrinks below FSP and that this point is at about 30% moisture content, then the movement between two moisture content values is a fraction of the shrinkage value. That means that a change of 1% in moisture content is about 1⁄30 of the total shrinkage value of a piece of wood. If a spe cies has a shrinkage value from green to oven dry of 9%, then a 1% change in moisture content equals 1⁄30 of 9%. If the change in moisture content is 5%, then the change in dimensions is 5⁄30 of 9% or 1.5%.

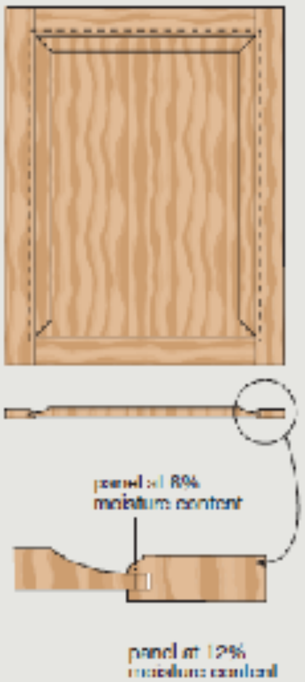


Figure 7: Raised-panel construction helps combat the detrimental effects of seasonal wood movement by allowing sufficient space for expansion and contraction. In this example, the wood reaches an EMC of 6% in winter and 12% in summer, resulting in a width difference of less than 1/4".

Fig. 7 shows a raised-panel cabinet door with an overall width of 21¾" and a height of 28". The opening for the raised panel is 18" wide and 24¼" high. Since the longitudinal shrinkage (parallel to the grain) in most species is less then 0.2% from green to oven dry, we will ignore the dimensional changes of the raised panel height. The width of the panel, however, can vary greatly between summer and winter. If the panel is made out of northern red oak and has an initial moisture content of 12% (summertime), then under typical winter conditions this panel will have a moisture content of 6%. To calculate the resulting changes in the dimensions of this panel, we take the total shrinkage value of northern red oak from Fig. 5. The total shrinkage for northern red oak across the tangential plane is 8.6%. Now, the two different EMC values are 12% in the summer and 6% in the winter, or a difference of 6%.We can calculate now that the panel movement will be: 18*8.6%*6/30 =0.31 or just about 5⁄16".

Now, let's assume the door is built of lumber containing 8% moisture content, a measurement that can be obtained with a good moisture meter. The shrinkage in winter will be 18*8.6%*2/30=0.10 or just a little more than 3⁄32". When the panel swells in the summer, it will gain 18*8.6*4/30=0.20 or a little more than 3⁄16".

Figure 6: In flat-sawn lumber (A), tangential shrinkage occurs across the width of the board and radial shrinkage across the thickness. The opposite is true of quartersawn lumber (B).