Understanding the Relationship Between Humidity and Wood

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Much of what I have included in this article was taken from Bruce Hoadley's book Understanding Wood published in 1980 by Taunton Press, and is used with permission. The remainder is from my own experience.

Wood expands and contracts and water is usually the cause. Changes in moisture content result in dimensional changes that can be manifested by distortion (twist, cup, bow, crook, kink, diamond, crack, split) and/or failed joinery. Wood on the stump contains water that we choose to divide into two categories – free and bound. **Free** water is that liquid that fills the otherwise empty cells within the wood. Once the tree is cut and its free water is removed from the cells, that which remains is water that has taken up residence within the cell walls, and is referred to as **bound** water. When the tree is cut, harvested wood begins immediately to give up its free water. This can happen relatively quickly in a kiln, or at a much slower pace if allowed to "air dry". All of the free water must be driven out of the wood before any of the bound water can be removed. At the point when all the free water has departed and all the bound water remains, the wood is said to be at its fiber saturation point **FSP**. At this point, your moisture meter should read 100%. In a kiln or dry atmosphere this piece of wood will continue to give up moisture and in doing so the wood will shrink and harden. If the wood is small enough and you place it in your kitchen oven long enough to drive out all the bound water, your moisture meter should give a reading of 0% moisture. We woodworkers are concerned with what is happening between 0% and 100% moisture content, and that subject cannot be understood in the absence of a working knowledge of water vapor in the air around us - - aka humidity.

A cubic foot of air at 70^0 F is capable of holding approximately 8 grains of water in the form of vapor. (A grain is a unit of weight equal to 1/7000 pounds.) Suppose that you are able to capture 1 ft^3 of air, test it, and you determine that there are 6 grains of water contained in your sample. By definition, the absolute humidity of that sample is 6 grains. In contrast to absolute humidity, relative humidity (that's the humidity you hear about daily from the TV/radio weatherman) is a ratio of the amount of moisture in the air (its absolute humidity) and its capacity to hold moisture, in this case 8 grains. Thus, your sample's relative humidity is 6/8 or 75%. If that air sample were taken in Atlanta during the summer months, you would likely find it contained 7.5 or so grains of water vapor and thus its relative humidity would be 7.5/8 or slightly less than 94% - - uncomfortably humid.

Relative humidity is seldom static. If you don't like the weather, wait a few minutes and it will change. With one exception, at any given time wood is in the process of absorbing or giving up moisture - - moving toward a point of equilibrium with moisture in the atmosphere. Generally, wood will absorb moisture and expand in summer (humid) months and desorb moisture and contract in winter (dry) months. Central heating and cooling can alter this cycle. The exception occurs when relative humidity remains constant for a sufficiently long period of time that moisture in the wood is in balance with moisture in the air. At this point wood reaches its equilibrium moisture content (EMC). Hoadley devoted a significant portion of his book to this subject. Hoadley states that:

- Relative humidity held constant at 0% (analogous to oven dry) results in an EMC of 0%.
- Relative humidity held constant at 25% results in an EMC of 5%
- Relative humidity held constant at 50% results in an EMC of 9%
- Relative humidity held constant at 75% results in an EMC of 14%
- Relative humidity held constant at 100% (analogous to totally saturated) results in an EMC of 30%

Graphically, these numbers appear in Figure 1 below, and although they are for white spruce at 70^0 F, they represent a good rule-of-thumb for woodworkers. In fact, Hoadley states that it (the graph) "is the most important item" in his book, and that you should "reproduce this graph in poster size, hang it on your shop wall, and look at it every day. It's that important."

Now lets turn our attention to the wood itself and some facts that you need to know before beginning any project.

1. Practically speaking, the wood you use to make a table or turn a bowl contains moisture - - the concept of oven dry wood occurs only in a laboratory. The moisture content will change in response to changes in relative humidity. You can slow this change, but you cannot stop it. It is somewhat like your house; insulation in walls and attics will slow heat transfer, but given enough time, outside and inside temperatures will equalize.
2. Cross grain movement (in response to moisture) varies from species to species, and average coefficients are available for almost any wood you choose. According to Hoadley, black cherry shrinks 7.1 % tangentially and 3.7 % radially from its green dimension to oven-dry dimension. Comparable numbers for walnut are 7.8 % tangentially and 5.5 % radially, and for mahogany the numbers are 5.1 % and 3.7 % respectively. Expansion and contraction along the grain is so inconsequential that it can be ignored in most instances.
3. Determine how is your wood milled (quarter sawn, flat sawn, etc.)
4. As best as you can, consider where and how will your finished piece will be used? At the very minimum you should ascertain whether it will be indoors or outdoors.
5. Consider where your wood has been stored and check its moisture content. Relative humidity in the vicinity of your wood while stored, may be different from that in your shop, and different again from humidity where the completed piece will be used.

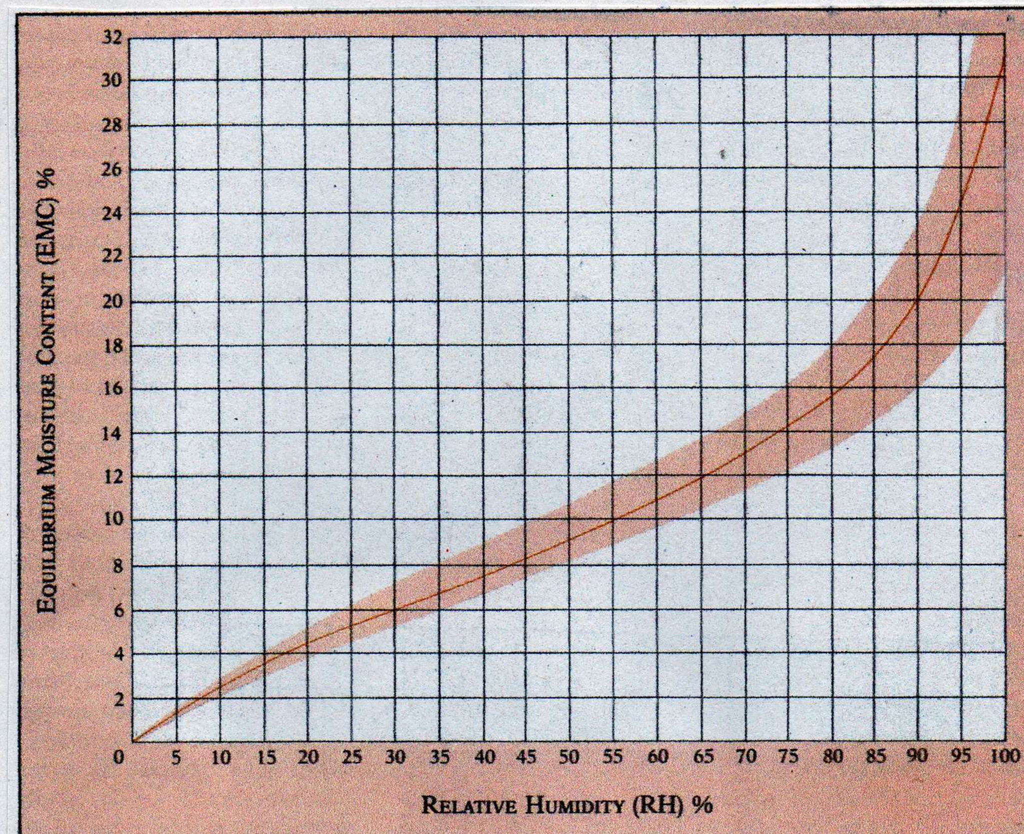
Understanding the interaction of moisture and wood is of no value to us unless we have a strategy. What do we do with all this information? According to Hoadley there are five distinct approaches to dealing with wood's propensity to change dimensions in response to changes in humidity. These are listed below with my comments:

1. Preshrinking prior to use - - Drying in a kiln or open air will result in shrinking.
2. Controlling humidity - - Placing your finished piece in an air conditioned space.
3. Chemical stabilization - - Thermally modified wood and the use of PEG are modern day examples.
4. Mechanical Restraint - - You cannot totally restrain wood's movement. Mechanical restraint can fall under the umbrella of design. For example, adding breadboard ends to a tabletop is a design element, but it is also a mechanical restraint. On the other hand, using buttons to hold a table top down tightly against the apron is a stand alone mechanical restraint.
5. Design - - Use joinery that allows the wood to have its way season after season without damaging the piece.

The bottom line: Is the wood I am now using going to swell or shrink and how much? If wood is stored in a non-conditioned space (such as a garage) and you move it into a conditioned shop, it will begin immediately giving up moisture. Depending on its thickness and how it is cut from the log (quarter sawn, flat sawn, etc.) it may take weeks or even months to adapt to the shop's conditions. So, when fitting a drawer, for example, it would be beneficial to know where your wood lies on the expansion/contraction cycle. By using a moisture meter you can determine the moisture content today, but what you need to know is what was its moisture content yesterday or last month, and what will it likely be two months hence.

To that end, allow me to suggest that you make a "humidity stick". Employing the wood species most often used in your projects, cut and glue together pieces of wood resulting in a single piece approximately 2' to 3' wide x 2" long x 2" thick. No, a 2" x 2" x 3' long piece of wood will not suffice. The 3' dimension must show end grain on two sides. See Figure 2. With the "humidity stick" stored in your shop, measure its width (the 3' dimension) at least once a month and record it on the stick itself. To minimize any errors, use the same ruler for all measurements. Depending on species of wood, width may vary as much as $^3/_8$" over the span of a year. Using this "humidity stick" you should be able to determine whether you wood is expanding or contracting at any given time. Let me know if it works for you.

Jim Milam



1—The amount of bound water in wood is determined by the relative humidity (RH) of the surrounding atmosphere; the amount of bound water changes (albeit slowly) as the relative humidity changes. The moisture content of wood, when a balance is established at a given relative humidity, is its equilibrium moisture content (EMC). The solid line represents the curve for white spruce, a typical species with fiber saturation point (FSP) around 30% EMC. For species with a high extractive content, such as mahogany, FSP is around 24%, and for those with low extractive content, such as birch, FSP may be as high as 35%. Although a precise curve cannot be drawn for each species, most will fall within the color band.

FIGURE 1

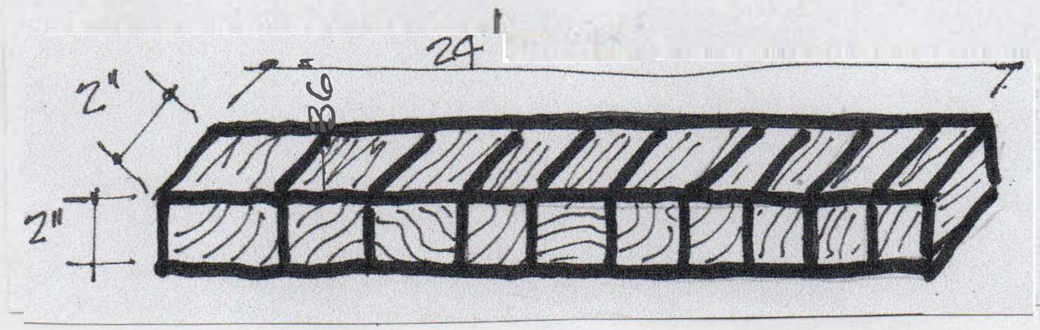


FIGURE 2