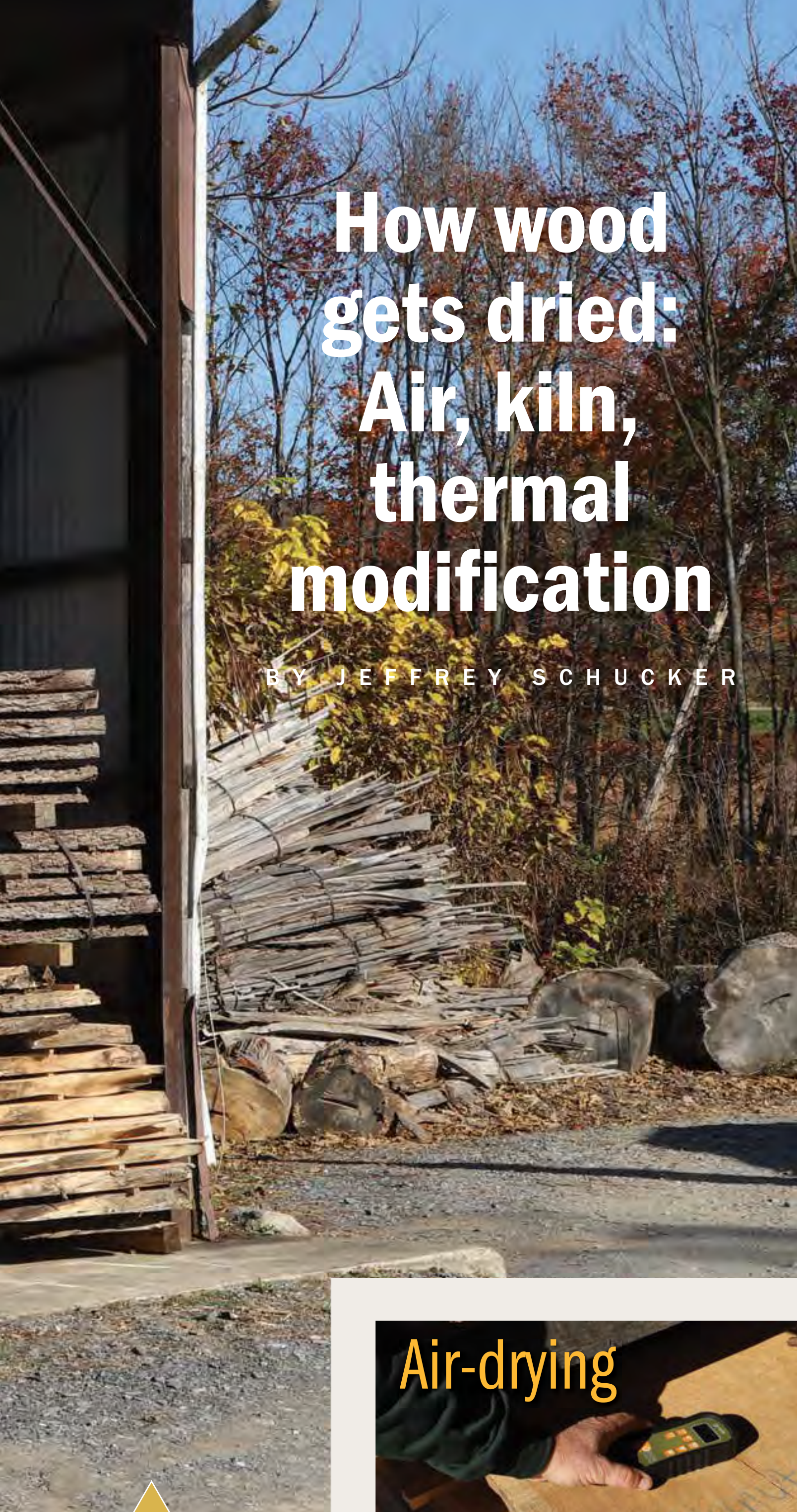
a closer look

All wood contains moisture in its cellular structure, and much of that moisture needs to be removed before the wood is ready for use. The wood's application will determine the amount of moisture that needs to be removed from the cells. The goal is to reach a level of moisture in the cells equal to the relative humidity where the wood will be used. When a tree is felled and the green log is cut into planks, the wood's moisture content (MC) can range from roughly 40% to 160% depending on the species. For use in framing a house or building outdoor furniture, the MC needs to be lowered to 20% or below. For furniture and other indoor use, the MC target is closer to 6% to 8%. Here I'll describe the two primary methods for drying wood to these moisture levels—air-drying and kiln-drying.

I run a wood business that's been in my family for four generations. We saw logs into planks and then air-dry and/or kiln-dry the lumber. In recent years we've also begun selling wood that, after being kiln-dried, gets thermally modified. This brief, high-heat process, which involves no chemicals, makes wood far more rot resistant and also less hygroscopic—greatly reducing its tendency to expand and contract. I'll discuss thermal modification as well.

Photos: Jonathan Binzen



How wood gets dried: Air, kiln, thermal modification

BY JEFFREY SCHUCKER

It all starts outside. *Air-drying is a reliable, if slow, method for reducing the moisture in wood so it can be worked. Even lumber that will later be dried in a kiln will often first be air-dried for a time.*

Air-drying

The first method of removing moisture from the wood is simply to stack the lumber on drying sticks—stickers—so air can pass over and around the surface of each board. Nearly all lumber drying starts with some air-drying. This allows "free water" contained inside the wood's cells to migrate to the surface of the lumber and evaporate. It will occur naturally, and will stop when the lumber's MC is equal to the relative humidity of its surroundings. In the northeastern U.S., where I live, most air-dried lumber will eventually reach a moisture content of somewhere between 12% and 16%.

Depending on the species of wood, and the thickness of the planks, this process can take several months to several years. The thicker the lumber, the longer it takes for the moisture in the center of the wood to be removed. The rule of thumb is to expect the drying to take a year per inch of thickness. Even lumber that will be kiln-dried is generally air-dried first for a while to begin the drying process.

Air-drying doesn't cost a lot to do, and given time, good results can be achieved. If the wood is going to be used for an exterior application, once it has reached equilibrium with the environment, it is ready for use.

Kiln-drying

For indoor use, however, wood needs to be dried to a lower moisture content than can be achieved by air-drying alone (unless the air is extremely arid, as in the desert Southwest). In order to do that, the wood needs to be subjected to heat, and a dry kiln is the vehicle that makes that happen. There are many types of kilns (see "A diversity of dry kilns" on p. 78), including solar, dehumidification, microwave, vacuum, and conventional. The kilns I use are the conventional type, which are the most widely used for commercial seasoning of lumber.

Air-drying

Check the content. *Given enough time, air-drying stickered lumber outdoors can bring wood's moisture content (MC) to about 15%—dry enough for outdoor woodwork. Bringing the MC down into the 6% to 8% range suitable for furniture making usually requires kiln-drying.*

Air-drying suits thick stock. *The author often dries very thick planks and cookies outdoors. Conventional kilns, like those he uses, struggle to dry very thick stock without causing cracks and other drying defects.*

Rolling load of lumber. *Schucker pushes a stickered stack of planks into one of his conventional kilns. The walnut in this load, previously air-dried outside under cover for several weeks, goes in at about 30% MC and will emerge two weeks later at 6% to 8% MC.*

Kiln-drying

Stoking the steamer. *A sawyer of logs and a millworker as well as a drier of lumber, the author uses sawmill and shop waste to feed the boiler that produces the hot water that heats his kilns.*

In a conventional kiln the lumber is stacked and stickered in an enclosed chamber where fans circulate heated air across and through the load of wood, and excess moisture is vented out of the chamber. The MC of the wood and the relative humidity of the air in the kiln are carefully monitored and adjusted to keep the wood drying evenly, steadily, and not too quickly. Depending on the species of wood being dried, in a conventional kiln the process takes roughly several weeks.

Through kiln-drying, the wood fibers will reach equilibrium with the relative humidity in your home. In the Northeast that moisture content is 6% to 8%, depending on the season. Winter is when the relative humidity is at its lowest, because the air, in colder temperatures, isn't able to carry as much moisture.

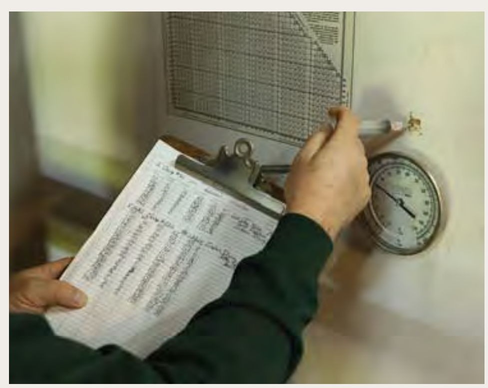
Near the end of the conventional kiln-drying cycle, an important process called conditioning takes place. As the wood dries in these kilns, the moisture content of the fibers in the center of a plank is always a few percentage points higher than those on the surface where evaporation occurs. Conditioning introduces steam to the kiln to regulate the final stage of drying. When the fibers in the center have reached the 6% to 8% range, the steam is introduced, raising the moisture content of the surface fibers. When conditioning is done correctly, the MC of the wood will be the same from the center to the surface.

If you have sawn up improperly conditioned wood, you'll know it—the workpiece will either bind on the sawblade or split apart as the blade cuts through. The severity of these reactions relates directly to the amount of drying stress that remained in the wood, which could have been relieved with proper conditioning.

Even when lumber has been properly kiln-dried and conditioned, it is important to bring the material into the shop for several days or even a week before beginning to work on it. This allows the wood to adjust to its new environment. During the winter, if wood is stored at a colder temperature, it is even more important to allow it to acclimate to your shop.

Stacked right. *Conventional kilns, which rely on surface evaporation to extract moisture from wood, require green planks to be stacked on stickers, creating airways between layers of lumber. Schucker mills specially shaped stickers that reduce the chance of sticker stain.*

It's windy inside. *In conventional kilns like this one, fans circulate the heated air, driving it around and through the lumber stack.*



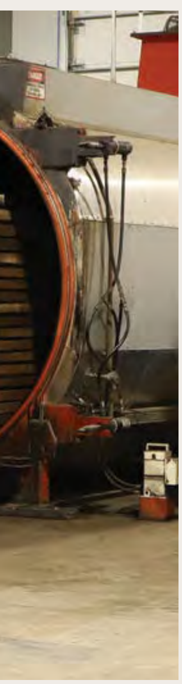
Moisture metering. *The author uses wet bulb and dry bulb readings to track the relative humidity in his kilns and adjusts the temperature and venting schedule accordingly. He follows tables that prescribe humidity and temperature levels for a wide range of wood species.*

Into the chamber. Bingaman Lumber, in Kreamer, Pa., is one of a number of companies now producing thermally modified lumber. After their modification chambers are loaded and sealed, a vacuum is drawn, and the heat within rises to 420°F.

Thermal modification

The difference is day and night. After treatment in a thermal modification chamber, during which the sugars in its cells are "carmelized," kiln-dried lumber radically changes character—becoming resistant to rot, less prone to movement, and darker in color.

After the treatment. Two days after going in, a load of oak rolls out of the chamber. The vacuum drawn in the chamber, by removing oxygen, prevents the wood from igniting at high temperatures.



Color shift. *Bingaman thermally modifies mostly oak and poplar. Both species turn a rich dark brown from the treatment. A lighter brown can be achieved with moderated time and temperatures in the kiln.*

Thermally modified

In the last decade or so, thermally modified wood—also known as toasted, torrified, or carmelized—has entered the market. Thermally modified wood takes kiln-dried wood one step further. After being briefly air-dried, then properly kiln-dried, the wood is put in a special vacuum chamber and subjected to high temperatures. In a conventional kiln, the air is typically heated to 140°F to 160°F. In a thermal modification chamber, the temperature is raised to between 300°F and 460°F. Before the chamber is heated, a vacuum is pulled, removing oxygen and preventing the wood from igniting at high temperatures. The treatment typically lasts from one to two days.

Thermal modification makes wood rot-resistant without applying any chemical treatment. Wood, like other plants, contains sugars and starches in the cellular makeup of its fibers. And wood decays when mold and fungus consume the sugars and starches. Thermal modification, by virtue of the high level of heat, carmelizes the sugars and starches, modifying them into a substance that mold and fungus can no longer break down. Hence the term thermal modification.

Another boon for the woodworker is that the wood's cellular walls are crystallized in the process, making the wood fibers far less able to absorb moisture. As a result, there is roughly 85% less seasonal movement in thermally modified wood than in air-dried wood. Modification also alters the color of wood. Depending on time and temperature in the chamber, the wood can be turned anywhere from caramel to a deep, rich chocolate brown. The color change, like the other benefits of the modification treatment, affects every fiber in the wood.

Because of its rot-resistance, thermally modified wood is frequently chosen for decking, siding, and other outdoor uses. And because of its rich colors and reduced seasonal movement, it is also seeing use in furniture and other indoor woodwork.

This process may be relatively new to the market on a commercial scale, but it isn't a new idea. Vikings were fire charring the hulls of ships hundreds of years ago to prevent barnacles from growing and causing rot. Native Americans used fire to harden and cure arrows and other tools. And Japanese woodworkers have long been scorching wood to preserve it.

One downside of thermally modified wood is that the heating process makes it more brittle. The wood fibers become more rigid and a lot less willing to bend as compared to kiln-dried wood, and even more so compared to air-dried wood. Also, as thermal modification crystallizes the wood's cell walls, they become less able to absorb moisture. If you are coating thermally modified wood, use an oil-based primer, and avoid use of any waterborne finishes, because they will not bond properly. Additionally, when gluing thermally modified wood, it is recommended that you increase the clamp time over kiln-dried wood, particularly with water-based glues.

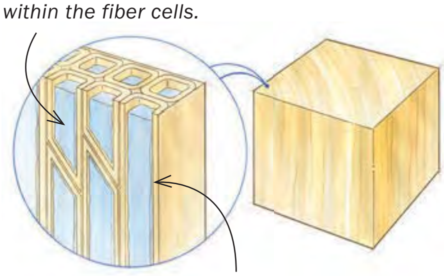
Jeffrey Schucker cuts, dries, mills, and sells wood at Bailey Wood Products in Kempton, Pa.

What happens when wood dries?

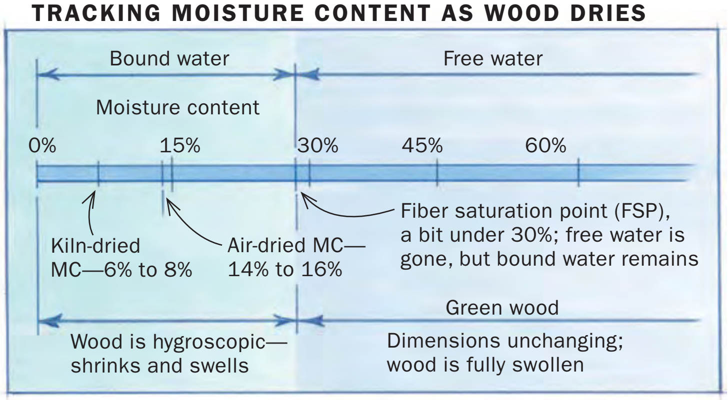
Once a tree is cut and begins to dry, moisture in the wood's cell cavities, known as free water, evaporates first. When that water is gone the cells are empty, but the cell walls are still fully saturated, and the wood has reached "fiber saturation point," or FSP. The moisture that remains, known as bound water, is what air-drying and kiln-drying are designed to remove. The cell walls are at their weakest when they are saturated; the strength of the wood increases as the bound water is removed. And it is only after the bound water has begun to evaporate that wood will swell and shrink with changes in relative humidity.

WHERE THE WATER IS

Wood has "free water" within its cells but also "bound water" in its cell walls. As wood dries, first the free water evaporates, then the bound water.

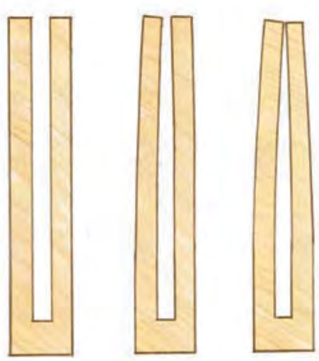


TRACKING MOISTURE CONTENT AS WOOD DRIES



THE PRONG TEST FOR CASE HARDENING

In kiln-drying, failure to even out wood's MC creates stresses that are exposed when the wood is worked. If a dried plank's core is wetter than its outer shell, it is "case hardened." The fibers in the center want to expand but are constrained by shell fibers that want to contract. Kiln operators use a prong test—cutting a slice of wood from near the end of a plank, then sawing a notch in it—to assess how evenly a load of wood has dried.



kilns

A diversity of dry kilns

All wood kilns generate heat to evaporate moisture from the wood, but they differ widely in the ways they produce the heat and in how they deliver it. In a field with a long history, there has been a fair amount of recent innovation; here's a brief taxonomy of the major types of wood kilns. *—Jonathan Binzen*

CONVENTIONAL KILNS

Long the standard of the lumber industry, conventional kilns typically use steam or hot water in pipes to radiate heat in the kiln chamber. Fans blow the heated air around and through the pile of lumber, inducing surface evaporation of the water in the wood. Each layer of planks is laid on stickers, separating it from the layers above and below so the air flows across all surfaces. Moisture drawn from the wood exits the kiln as humid air via vents. The steam or hot water is typically generated by burning wood, oil, or gas, or using electricity.

SOLAR KILNS

These operate just like conventional kilns, but using heat from the sun in place of steam or hot water. Hot air is circulated by fans through a stickered stack of planks to produce surface evaporation, and the resultant moist air is vented from the kiln. If the fans are powered by batteries or solar panels, the solar kiln can be operated completely off the grid. Placement of a solar kiln is key to capture the amount of sunlight required to dry wood; these kilns tend to operate more slowly, if at all, in winter months.

Drawings: Dan Thornton