Considerations in Drying Hardwood Lumber

For centuries, freshly cut lumber has been allowed to dry in response to the temperature and humidity of the surrounding air, also known as the ambient conditions. The result was air-dried or air-seasoned lumber, which in Missouri typically has a moisture content (MC) between 12 and 14 percent.

Moisture content is defined as:

$$\text{MC percent} = \frac{\text{Green weight - ovendry weight}}{\text{Ovendry weight}} \times 100$$

The green or wet weight is the as-is weight. The ovendry weight is determined by drying at 212 degrees F until constant weight is reached.

Then, two major changes occurred that largely eliminated the use of air-dry lumber for many uses. The first was the development of ways to control the ambient temperature and humidity of the air surrounding the lumber. This development resulted in kiln-drying, speeding up the drying process. Faster drying reduced the amount of time the lumber was sitting, occupying valuable land.

The second change was the widespread use of air conditioning in buildings. Most air-conditioning systems produce air that has a lower humidity than the outside air. The moisture content of wood used in interior applications typically ranges from 6 to 10 percent in Missouri. This means that air-dried lumber brought into this environment continues to dry, resulting in greater lumber shrinkage. This placed greater stress on matching proper drying techniques to the desired product end use.

This publication presents some important points to remember when considering hardwood lumber drying. You may obtain more detailed information on this subject from the publications listed under *For more information*.

How wood dries

Three elements are necessary for lumber to dry:

- An atmosphere capable of receiving water vapor
- Energy to drive water from the wood
- Air movement around the lumber

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More simply stated, dry air, heat and wind are needed. In the summer, low ambient humidity, prevailing winds, and the sun provide the necessary three ingredients to dry 1-inch red oak boards to 20 percent MC in two to three months. Remember, however, that humidity levels in air-conditioned residential or commercial buildings will result in wood moisture contents of 6 to 10 percent or lower in the winter months.

When green or wet lumber starts to dry, the water that is first removed is called free water. The energy required to evaporate this water is the same required to boil water. When all the free water has been removed, the wood has reached the fiber saturation point (FSP). The FSP varies between 25 and 30 percent MC, depending on wood species.

The water that remains in the wood below the FSP is called bound water and requires considerably higher energy levels to break its bonds with the wood. In fact, as the moisture content drops, the energy required to dry the wood increases sharply.

Eventually, the wood will reach a moisture content that is in equilibrium with the surrounding ambient air and humidity. While a 1-inch red oak board may take two to three months to air-dry, a 2-inch board may take six to eight months, and even thicker lumber may take years.

Frequently, eastern hardwood lumber, such as red oak, is air-dried to 25 to 30 percent MC and then placed in a dry kiln, an environment where the rate of drying can be increased and controlled. The time and costs associated with this practice must be considered by potential users before investing in drying facilities. However, the rewards can be significant. For many uses, dry lumber is preferred or even required.

Accelerated air-drying

Air-drying can be accelerated by stacking the lumber in a chamber or shed that provides protection from the elements, and using fans to force air through the lumber.

The facilities are commonly called predryers. The structures range from very simple pole-type buildings with temporary exterior walls to commercially designed low-temperature dry kilns. Capacities will range from a few hundred board feet (BF) to over 1 million board feet.

Many of these air-drying facilities have no supplemental heat. When heat is included, the air temperature usually will not exceed 120 degrees F. The supplemental heat can be provided several ways, including solar heat.

In more-permanent structures, some means of humidity control may be used to ensure dry air, as well. It is possible for 1-inch red oak lumber to be dried to 20 percent MC in less than 30 days in a predryer.

Proper stacking of the lumber is necessary to achieve optimal drying conditions for any species in any situation.

Conventional kiln drying

More than 75 percent of the existing hardwood dry kilns in the United States are steam heated, are humidity controlled and have reversible fans inside the kiln.

These kilns will typically hold several thousand board foot of lumber. Temperatures inside the kiln range from 120 to 190 degrees F, depending on the stage of drying. Although there are kilns in which temperatures reach up to 240 degrees F, they are usually limited to softwoods that dry very easily and low-value hardwoods.

Both temperature and humidity are controlled by either fully automated or semi-automated systems. These systems contain devices that monitor conditions in the kiln and lumber, and adjust interior conditions accordingly.

The rate at which the lumber dries is controlled to minimize or eliminate defects caused by drying. Defects include discoloration, warping, cracking, splitting, and surface checking (small openings on the faces of the boards). In extreme cases, drying causes honeycomb (internal splits that cannot be seen on the surface) or collapse.

Other forms of heat include direct-fired hot air, electricity, solar, and hot water or oil. Direct-fired hot air kilns usually are limited to softwoods and relatively low-value hardwoods because precise humidity control is difficult — if not impossible — to obtain in the kilns.

Usually, electric heat is limited to either dehumidification kilns or to one of the vacuum-drying processes. Solar heat can be used as supplemental heat in some areas. Some successful designs of solar kilns intended for hobby use are available at 500 to 1,000 board foot capacity. Usually, commercial solar kilns are restricted to tropical areas, to areas where conventional energy sources are not available, or to small, home-based businesses. Neither hot water nor hot oil systems find much use in commercial kilns because of low heat-transfer efficiency.

Air movement in the kiln is controlled by reversible fans and baffles. Air movement is necessary to carry moist air away from the surface of the boards, and heat to the boards. The air flow is periodically reversed automatically to ensure even drying across the width of the kiln.

Baffles are used to force the air through the lumber packages across the surface of the boards. Place baffles at the top, bottom and ends of the kiln. Adjust the baffles to accommodate size variations in lumber packages in the kiln and to account for the lumber shrinkage that occurs during the drying process.

Specific details on humidity and temperature control systems are beyond the scope of this publication, but most systems rely on measuring the dry-bulb and wet-bulb temperatures in one or more places inside the kiln.

Use a standard thermometer to measure the dry-bulb temperature. Measure the wet-bulb temperature by placing a wet cotton wick over a conventional thermometer. Water evaporating from the cotton wick cools the thermometer.

The wet-bulb temperature will always be lower than the dry-bulb temperature. The difference between these readings is called wet-bulb depression. It is a measure of the drying force applied to the lumber.

The relative humidity inside the kiln — or anywhere — is calculated using these two measurements and a conversion chart. Accurate humidity control in the kiln is mandatory for properly drying hardwood lumber.

Periodically sampling the actual moisture content of the lumber in the kiln ensures that changes in temperature and humidity settings keep the lumber drying at the maximum safe rate schedule. The U.S. Department of Agriculture (USDA) report *Dry Kiln Schedules for Commercial Woods* contain several typical schedules for various species and thicknesses of lumber.

Measurement can be done either by weighing predetermined sample boards or by using a hand-held, battery-powered moisture meter. In either case, several measurements must be taken throughout the kiln to get reliable readings.

Special drying methods

Dehumidification kilns

A dehumidification kiln captures the energy needed to dry wood from the water in the wood itself. Warm, dry air is circulated through the lumber package and absorbs the water from the lumber. The warm, humid air passes over condenser coils in a dehumidifier. The process of condensing water vapor into liquid allows the recovery of the energy required to evaporate the water from the wood in the first place. The process is essentially identical to an air conditioner.

Typically, this kiln is more energy efficient. Also, the construction costs are somewhat lower, since conventional well-insulated, wood-framed buildings can be used for the structure.

The disadvantages include the cost of power. Usually, the kiln is electrically powered. Also, the maximum temperature is somewhat lower and the water condensate may contain unwanted chemicals. Generally, this process takes longer to dry lumber than does a conventional kiln.

Predryers

Essentially, predryers are large, low-temperature (below 120 degrees F) drying sheds used instead of conventional air-drying to get the initial MC of the wood to 25 percent or less. Limited temperature, humidity and air movement controls are used in the building.

The use of the sheds reduces the amount of land area needed for air-drying. Originally, predryers were used in areas where the normal air-drying season was fairly short, but their use has spread to other areas of the country. Predryers reduce air-drying defects, discoloration, and inventory costs.

Solar kilns

Solar kilns became popular in the mid-1970s, when energy prices started to rise. The main advantage of the solar kiln is the simplicity with which it can be constructed and operated. A solar kiln can provide enough well-dried lumber for a small operation. The major drawback is that a solar kiln takes a relatively long time to dry lumber to 6 to 8 percent MC.

Virginia Cooperative Extension has an excellent publication on the design and operation of a solar-heated dry kiln. This solar kiln can hold up to 1,000 board feet of 1-inch-thick lumber per charge, or load, and can dry a load in about one month of moderately sunny weather in the mid-latitudes of the United States.

Vacuum-drying

Vacuum-drying has been used off and on since the early 1900s. Because of costs involved, this method did not receive much commercial attention until the 1970s. Placing a partial vacuum on a closed chamber lowers the boiling point of water below 212 degrees F. This lower boiling point reduces the amount of energy needed to dry the lumber.

Vacuum-drying is useful in drying thick, high-value pieces of wood, such as large turning stock or dimension parts. Dense woods, which are difficult to dry because of excessive shrinkage, can also be successfully dried in a vacuum system.

Other drying methods

Other unconventional drying methods have found use, usually on a limited case-by-case scale. These include press drying, solvent or exchange seasoning, high-frequency or microwave drying, and vapor drying. Vapor drying is frequently used for drying large timber, such as crossties or poles before preservative treating the lumber.

For more information

U.S. Department of Agriculture (USDA), General Technical Report FPL-GTR-57, *Dry Kiln Schedules for Commercial Woods: Temperate and Tropical*, ***https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr57.pdf***.

Virginia Cooperative Extension, *Design and Operation of a Solar-Heated Dry Kiln*: ***https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/420/420-030/420-030_pdf.pdf***.

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